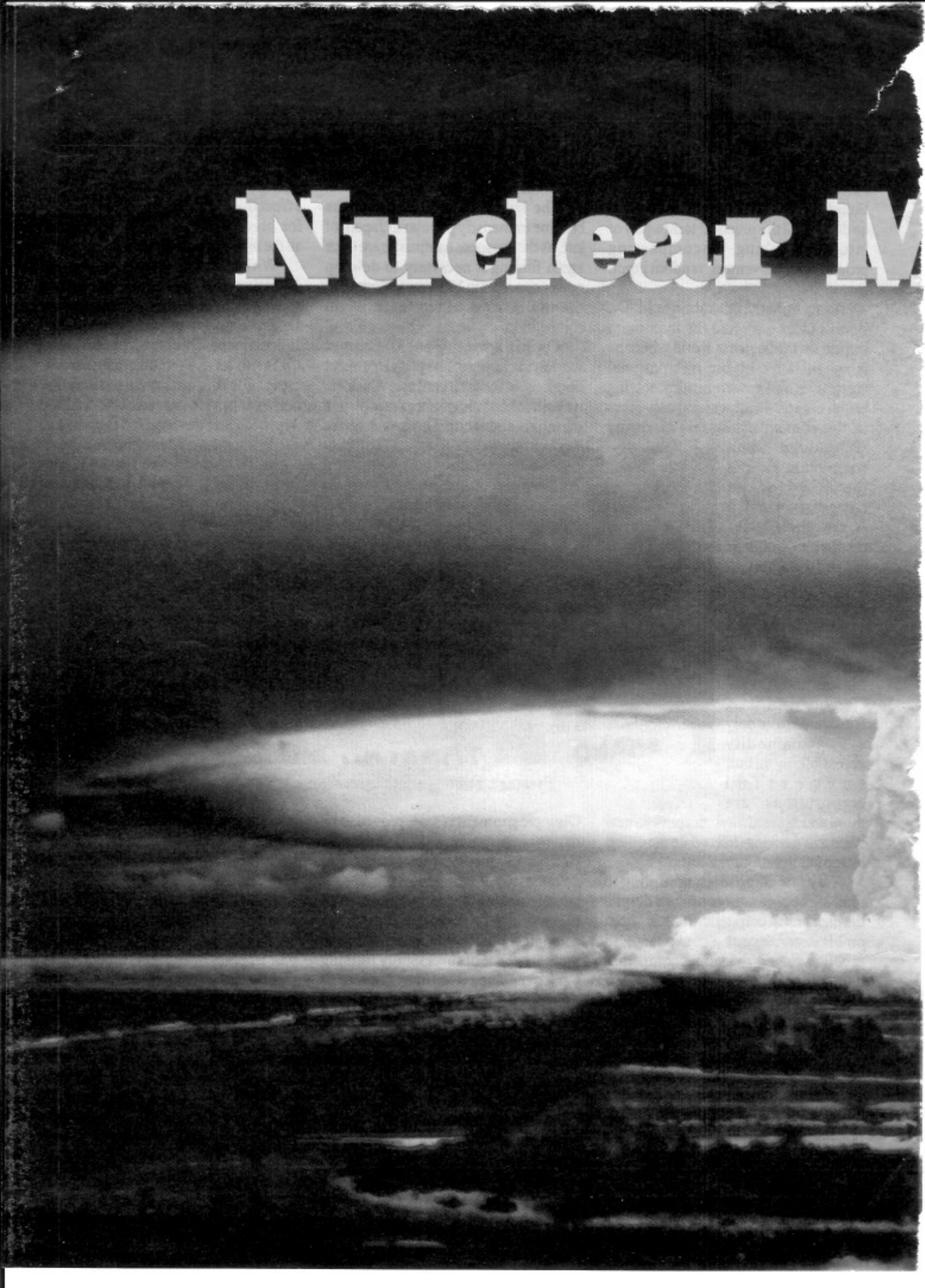
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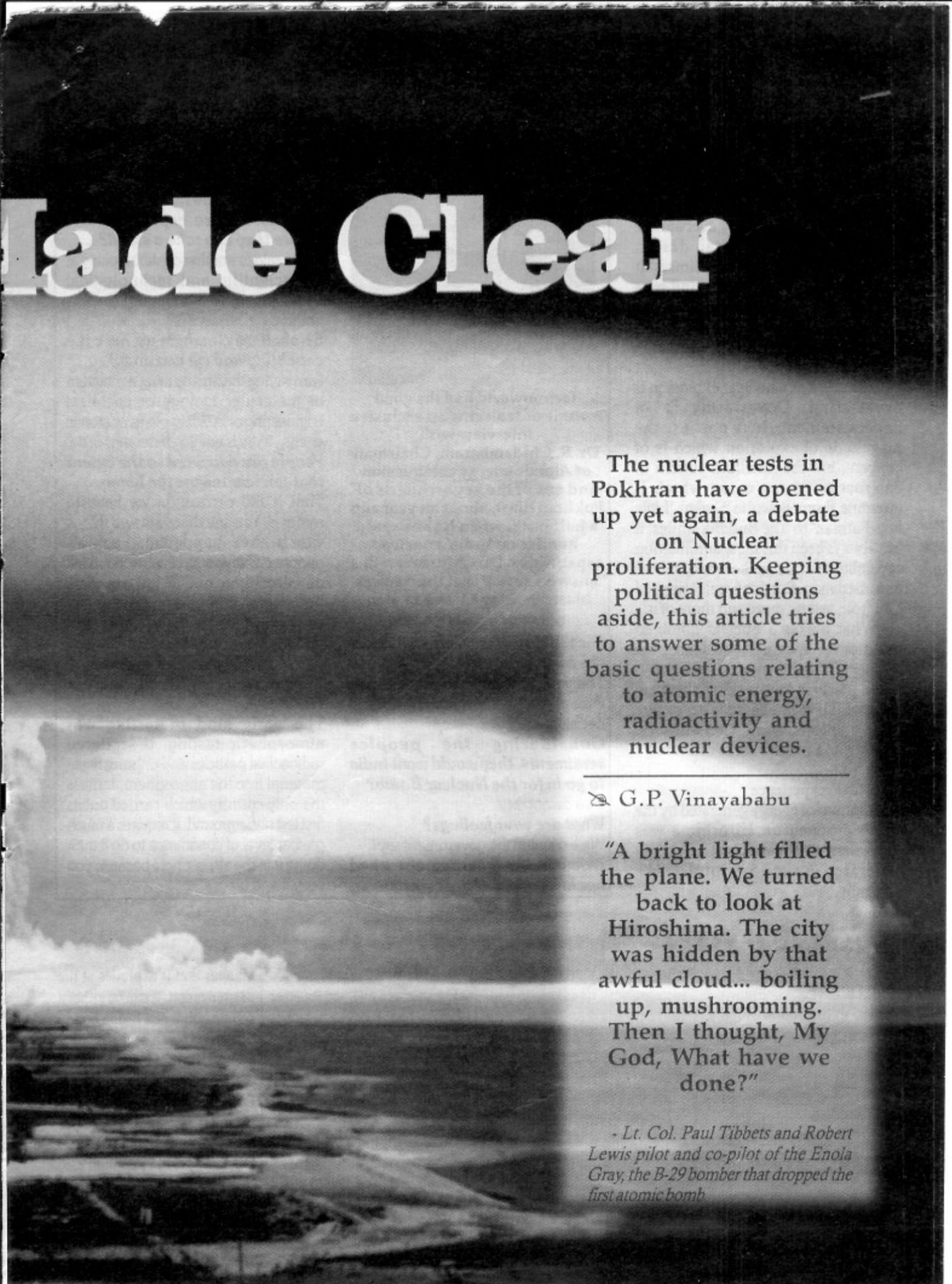


lade Clear

The nuclear tests in Pokhran have opened up yet again, a debate on Nuclear proliferation. Keeping political questions aside, this article tries to answer some of the basic questions relating to atomic energy, radioactivity and nuclear devices.

G.P. Vinayababu

"A bright light filled the plane. We turned back to look at Hiroshima. The city was hidden by that awful cloud... boiling up, mushrooming. Then I thought, My God, What have we done?"

- Lt. Col. Paul Tibbets and Robert Lewis pilot and co-pilot of the Enola Gray, the B-29 bomber that dropped the first atomic bomb

Just three weeks prior to the Hiroshima bomb explosion, i.e., on July 15, 1945, Robert Oppenheimer and his team of scientists in the US had successfully tested the first ever atomic bomb in the Nevada desert. Oppenheimer had then exclaimed "It was as if the light of a thousand suns were to blaze forth all at once in the sky ..." quoting from the Bhagavad Gita looking at the bright flash covering the sky.

The effect of a nuclear explosion is devastating. Devastating is an understatement. It is not just the magnitude of explosion which is of concern, but the manifold pattern of destruction it can cause which is awesome. From 'Bravo' to 'Shakti', 'Little boy-Fatman' to 'the Buddha smiles' it has always been this mass annihilation capability of a nuclear bomb which has terrorised man. But this has not stopped him from testing more and more of it.

What makes a nuclear bomb so destructive? Why is it considered the mother of all explosives?

A peep into the Hiroshima – Nagasaki blasts provides a better picture of the intensity of the diabolic destruction a nuclear bomb can cause.

Hiroshima experience

The amount of energy generated by the bomb dropped on Hiroshima was equivalent to the amount of energy generated by a 15-kiloton TNT explosion.

'There is nothing India cannot do'

Technoworld had the good fortune of featuring an exclusive interview with Dr. R. Chidambaram, Chairman of Atomic energy commission and one of the key architects of Pokhran blast, about an year and a half back, when he answered queries on India's nuclear capabilities. Dr. Chidambaram's answers reveal that the nuclear blasts on May 11 and 13 were not conducted in haste.

For the elusive answer, what about the nuclear bomb?

The government has said it's keeping the option open. The rest is a political decision.

Considering the peoples sentiments, they would want India to go in for the Nuclear Bomb?

It's a democracy.

What are your feelings?

We'll do what the government says.

Doesn't the government need backing from the scientists to take a stand? You have to tell them whether we are capable or not before they can take a stand?

I have said in another context looking at the scientific and technological development of this country, there is nothing we cannot do.

So shall we conclude we have the capability and we can do it?

I am saying that in any area, agriculture or molecular biology or chemical engineering or building plants or atomic energy, there is nothing India cannot do.

People are educated to the extent that nuclear means the bomb.

That is the correlation we have to remove. You see there are two things which have happened. People's opposition may come because they think of Hiroshima and Nagasaki. The beneficial aspects have to be emphasised. For eg. If i was not running the Trombay reactors, you wouldn't get your Cobalt 60 for cancer treatment.

Throw some light on nuclear testing.

The early kind of testing was atmospheric testing. It scattered radioactive particles and unburnt fissile material into the atmosphere. India is the only country which carried out its first test underground. It requires a much greater level of confidence to do it than doing it in the atmosphere because you bury it and blow it.

Nuclear FAQ

What is a nuclear device?

A nuclear device is one in which nuclear explosive material is configured in such a way that it will explode when the triggering mechanism is actuated. In a fission device, the explosive can be either Uranium 235 or Plutonium 239. The energy released is from a nuclear fission reaction. Once the reaction is triggered, the reaction rate will increase very rapidly so that all the energy is released within a fraction of a second. The yield is usually expressed in kilo tonnes equivalent of the conventional explosive TNT.

What are the different types of nuclear devices?

The 2 major types of nuclear devices are fission device in which Uranium 235 or Plutonium 239 is used as a fuel, and the other type is a fusion device which is often referred to as a thermo nuclear device.

What is a nuclear bomb? How different is it from Hydrogen bomb?

A nuclear bomb is a nuclear device which can be delivered by some or the other means in such a manner that it explodes at the desired target. It can be either a fission bomb or a fusion bomb. The fusion bomb is what is called a hydrogen bomb, or a thermonuclear bomb. Unlike the fission reaction which can be initiated by bringing together enough fissile material, i.e., Uranium 235 or Plutonium 239, the fusion reaction takes place

On the ground, beneath the explosion center(hypocenter), the temperature rose to approximately 7,000 degree F. On the stairway of the entrance to a bank, which was 1/8 mile from the explosion center, a man was sitting waiting for its opening. The surface of the stone stairway was changed by the immense heat. The part where the man was sitting remained unchanged because his body absorbed the heat.

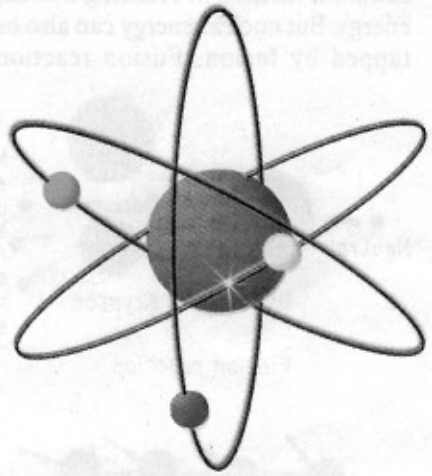
Roof (ceramic) tiles on houses within 1/3 mile radius from the explosion center melted, and gray stones which contained silicon particles became white. The clothes which people wore were burnt by the heat within 1 1/4 mile radius from the explosion center.

Bomb blast - An ultra high pressure was generated by the explosion. The wind velocity on the ground beneath the explosion center was 980 miles/hr, which is five times stronger than the wind generated by strong hurricanes. The pressure was 3.5 kg per square centimeter which is equivalent to 8,600 pound per square feet.

At a point that was 1/3 mile from the explosion center, the wind velocity was 620 miles/hr; the pressure was 4,600 pound per square feet. Most of concrete buildings inside this range were completely destroyed.

Even a mile from the explosion center, where the wind velocity was 190 miles/hr and the pressure was 1,180 pound per square feet, all brick buildings were completely destroyed.

Radiation - The explosion generated Alpha, Beta, Gamma and neutron rays. Alpha and Beta rays were absorbed by the air and did not reach the ground. Gamma and neutron rays were strong enough to reach the ground; thus it was these rays that affected people.



Neil Bohr's atomic model

Within 1/16 mile radius from the explosion center, most people died within a few hours (even in the case where they were not directly exposed to the heat or wind). Within a half mile radius, most people died within 30 days after the explosion.

The people who entered the area within a half mile radius from the explosion center in the first 100 hours after the explosion were also affected by the remaining radiation on the ground.

By the end of 1945 the estimated number of people who died as a direct result of the bomb was 140,000. It has been concluded that the number of people who died as a direct result of the bomb was approximately 200,000. The Hiroshima bomb was only a 15 KT yield bomb. The bombs which have been developed later on have all been of higher yield than this. Even the nuclear devices tested in Pokhran yielded 53 KT of energy. One device tested by the erstwhile USSR yielded 58 megatons of energy, a yield 1000 times more than that produced during the Hiroshima blast. This is an indiction of the amount of destruction a nuclear bomb can cause.

How is such an enormous amount of energy produced by a nuclear explosion? A little bit of elementary nuclear physics and radioactivity would help us to understand this better.

Atom was considered to be the smallest unit of matter for a very long time, almost till the end of the 19th century. It was thought to be indivisible and indestructible by many early scientists like Dalton, Ampere and Avagadro. But Joseph Thomson in 1897

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only at an extremely high temperature, of the order of a million degrees. That is why it is called a thermo nuclear reaction. In order to obtain the high temperature that is needed to initiate a fusion reaction, what is easily done is to have a fission bomb which will raise the temperature of the fuel in the fusion bomb to the required high level. The commonly used fuel in a fusion bomb is a mixture of deuterium and tritium. The fusion reaction takes place between deuterium and tritium, both of which are isotopes of hydrogen. Deuterium is available from water; tritium has to be artificially produced. In a thermonuclear device Lithium is used which will generate tritium when it absorbs neutron.

What is an underground testing? How is it done?

The testing of a nuclear device can be done either in the atmosphere or underground. Testing in the air has been banned by an international treaty for a number of years now. Atmospheric testing will result in radioactive materials being dispersed over a very wide area. To prevent such contamination, the nuclear device can be tested below ground level by drilling a hole of sufficient diameter so that the nuclear device along with its triggering mechanism can be placed below ground level. The depth at which the device is detonated is 100 to 200 meters, depending on the yield of the device. If it is done

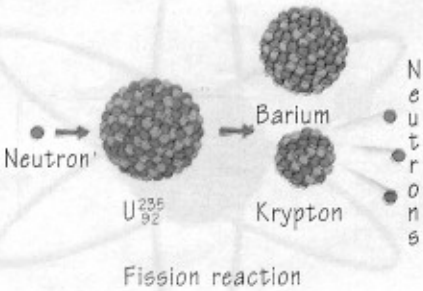
discovered the electron and Ernest Rutherford demonstrated that the positive charge of the atom is concentrated in a very small volume, the nucleus. Later Niels Bohr gave the now famous representation of the atom with the electron orbiting around a central nucleus. All these proved that atom was not the smallest unit of matter. It was discovered that the entire mass of an atom was concentrated in the nucleus. It was also found that the nucleus had an extremely high density of 10^{17} Kgm^{-3}.

These revealing features of an atom lead to the conclusion that the nucleus of an atom was a store house of abundant energy which could be tapped.

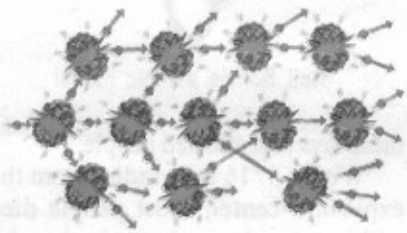
Neutron - the missile

The concept of an atom being indivisible was now rejected with conclusive evidence. The next step was to find a way in which the high-density nucleus is split to derive the abundant energy hidden in it. Neutron proved to be the missile capable of achieving this. Nuclear scientists discovered that nuclei with higher atomic number, due to an imbalance between the forces acting on the nucleus, emits radiations spontaneously to assume lower, more stable states. Uranium with an atomic number of 92 was found to be the most unstable element susceptible to neutron bombardment.

When Uranium 235 is bombarded with a neutron, the Uranium nucleus splits up into two fragments of comparable size, in the process liberating enormous amount of energy. This energy is manifested in the form of high temperature and pressure. Along with the release of energy, at least three neutrons are released in this reaction. This splitting of a radioactive nucleus into two fragments with the liberation of enormous amount of energy is called a fission reaction. This is the most common method of realising nuclear energy. But nuclear energy can also be tapped by fusion. Fusion reaction



Fission reaction



Chain reaction

combines two lighter nuclei to form a single heavy nucleus, in the process liberating energy. This reaction produces much more energy than the fission reaction.

Chain reaction

No doubt, enormous amount of energy is released in a fission reaction. But it is not enough if the reaction stops at splitting a single nucleus. If, by some means, these neutrons obtained at the end of a fission reaction are made to bombard other nuclei, then the reaction can yield lot more energy. For this to happen, the mass of the fissile material (material used in fission reaction) should be of critical size (the minimum size of the fuel sample to sustain chain reaction). This reaction goes on till all the atoms in the sample undergo fission. Such a reaction is known as a chain reaction. Chain reaction is also seen in case of a fusion reaction.

To induce fusion reaction, high temperatures of the order of 10^7deg.K. are required. Such temperatures are only seen in the burning core of the Sun.

It is impossible to achieve such high temperatures in the physical world. But there is a way to reach such high temperatures. A fission reaction can produce temperatures of this order. This is sufficient energy to combine two isotopes of hydrogen – Dueterium and Tritium to derive nuclear energy. This is exactly the principle used in the explosion of a thermonuclear bomb or a hydrogen bomb. This is the most powerful form of nuclear bomb. In the recent Pokhran series of

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properly, no radioactive material will escape to the environment. The energy release due to the explosion will crumble the ground above it, which may rise and later subside.

How is the radiation prevented from escaping into the atmosphere?

Since all the radioactivity is released underground and no activity is allowed to come out atmospheric pollution is prevented in an underground testing.

What are the other ways of testing a nuclear device? Can the test conditions be simulated using a supercomputer?

In theoretical simulation of a natural or man-induced phenomenon, the model used needs to be validated against properly conducted experiments. Once the theoretical model is validated by conducting experiment with an appropriate scaled down model the theoretical formalism can be used for simulating other experimental tests.

What is the effect of nuclear testing on ecology and environment?

Underground testing of nuclear devices has no effect on environment if the tests are conducted properly. But above surface testing causes a radiation disaster. Such tests are now banned. Tests are also conducted underwater and a separate mechanism is used to determine the effectiveness of the tests conducted.

'The whole process is antipeople'

Nagesh Hegde, Environmentalist

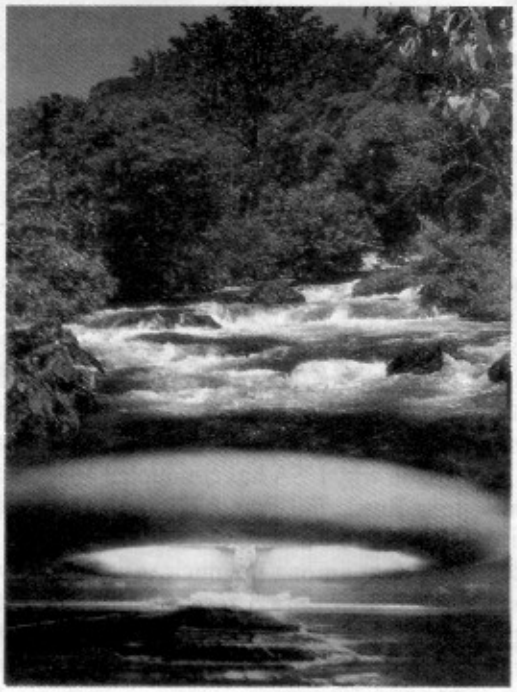
Right from the stage of extraction of raw material, to the stage when the nuclear waste is buried in the ground, a whole cycle of environmentally hazardous activities are involved. First the nuclear fuel has to be mined which is an activity of high environment risk. From there, it has to be taken elsewhere for processing, refining and enrichment to make it ready for use as a fuel. Then the fuel is used for power generation or to trigger a nuclear device (which is anyway hazardous). Then the spent fuel or the nuclear waste has to be buried and disposed off, which is again a source of radiation. In case of nuclear testing, radiation is let loose into our surroundings. Nuclear testing is carried out in basically three ways. Above ground testing, (which is now banned), under ocean testing and underground testing.

Above ground testing, which used to be the only way of nuclear testing earlier, has taken a heavy toll of flora and fauna surrounding the test areas. One island used by Americans for such tests has been completely destroyed with even the coconut water contaminated with radiation. Even third generation and fourth generation animals are suffering from the effects of radioactivity in this island.

Even underground nuclear testing is equally hazardous, if not more. But the effect is not readily evident. Particularly the animals are affected the most. They are born with congenital defects as seen in Pokhran. Radiation need not express as any one particular disease or deficiency. It affects the whole immune system.

Nuclear testing is the first part. Once the nuclear bomb is tested you can't keep quiet. By nuclear testing you trigger a much bigger, violent device race all over the world, especially among your neighbours. Neighbours will acquire or test their own devices. By doing so, they tend to stay equal in the arms race. To stay one step ahead, we need to device a missile. This leads to a series of violent activities.

Missile testing is also a hazardous thing. In Balassore range where rockets are tested in India, (or for that matter in any rocket testing range) there is a potential risk of environmental hazard. In the process of testing a huge missile, smaller devices are made and tested initially. Most of the missile shells explode during tests, while quite a number of them do not explode. The shells fall anywhere in the range of 2 to 30 kms away. Poor people living in the nearby villages, intending to make a quick buck, try to collect these bronze shells, when the unexploded shells explode causing injury and death. Quite a number of deaths happen this way. Once you develop a perfect missile after conducting a series of missile tests, it has to be located in all strategic areas. For this, one missile is not sufficient, so several missiles need to be built. Once you locate it in strategic areas, you have to protect them. Suppose you locate one in Thane in order to save Mumbai, you have to setup a missile silo (underground missile launcher) for counter attack. So this is a new kind of state funded terrorism which disturbs peace in civilian areas. The whole process is antipeople.



All these for what? To fuel the arms race. Military grows by fighting against each other. It is the same all over the world. The entire military exercise is antipeople. Nobody can ask how much is spent on defence. We are spending nearly 15-16% of our GNP on defence. The defence expenditure is passed without a debate in the parliament. Military always needs maximum money, best of educated youth and best of scientific talent. All this to destroy peace.

Now we may have to spend more money on science, technology, military and missiles in future which will definitely affect our internal resources and bring untold suffering to people. The same thing is happening to the hapless people in Pakistan. Winner is always the military and loser the people. Having a nuclear capability is like building a compound with bricks taken out from the house building. Acquiring nuclear bomb is not a big thing. Ukraine has 3000 bombs. It is a big problem for that country to protect these from terrorists.

The scientific community in India is one of the best. But ultimately science has to reach the common man. Look at the state of Indian roads, they are full of potholes. It is here that science and technology has to come to the common man's rescue.

blasts, one thermonuclear bomb was tested.

Hydrogen bomb

In a hydrogen bomb, initially a fission chain reaction is triggered off in a plutonium sample. When the temperature reaches a level of 100 million degree kelvin, two light nuclei (say dueterium and tritium) are fused together. Once the fusion reaction is initiated between the two lighter nuclei, the process proceeds in a chain reaction culminating in a tremendous bomb blast.

Implosion bomb

The most commonly used bomb is an implosion bomb. The implosion bomb assembly is shown in the illustration.

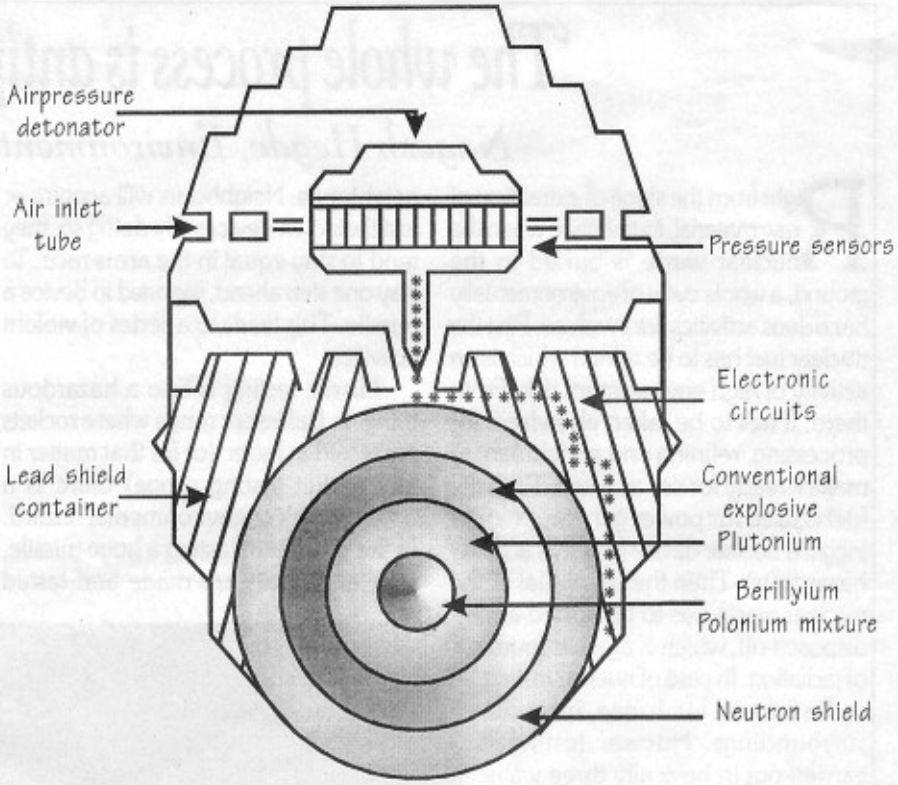
The conventional explosives stacked around the fissile material are triggered off to cause an implosion. The blast wave generated due to this travels inwards and increases the density of the fissile material to three times its original value. By this increase, the radioactive fuel (like Plutonium 239 or Uranium 235) reaches a critical mass.

Along with an increase in density, the temperature of the core material also rises to a high enough temperature for the fusion reaction to occur. At the centre of the core, solid LiD is placed which takes part in the fusion reaction.

A combination of both fusion and fission reaction increases efficiency. This kind of an arrangement can produce maximum yield. Fusion reaction produces neutrons with higher energy content which speeds up the chain reaction. When these ultra fast neutrons hit U^{235} nuclei at critical mass, chain reaction proceeds cataclysmically. The fusion reaction is essential to provide the necessary boost to improve neutron bombarding efficiency.

Why are nuclear tests required?

Unlike nuclear reactors which generate electricity under controlled conditions, nuclear bombs don't have a controlling mechanism. In fact, uncontrolled chain reaction is the main feature of a nuclear bomb. Implosion devices require precise machining and foolproof design to achieve highest order of efficiency. To ascertain these aspects, large number of tests need to be conducted. That's the reason why USA has conducted 1032 tests, Russia 750, France 210 and Britain 45 tests in the past 50 years. India is still an infant among the nuclear weapon states with only 5 tests of different capacities conducted so far.



Implosion bomb assembly

Source : MILNET

Nuclear weapons

It is not just enough if nuclear tests are conducted without building weapons systems for the delivery of nuclear devices.

Tactical nuclear weapons are those under a certain limit, let's say 1MT of explosive power. These weapons are intended to be "lobbed" over a mountain into a remote battlefield, thus eliminating a huge number of the enemy with one blow. Fortunately, they have never been used.

Strategic nuclear weapons are the really big ones. From 1MT to above 500MT fusion weapons, this class of nuclear weapon is intended to be used on vast areas, strategic targets such as whole cities or fortified launch sites, bunkers or other "hard targets".

There are three basic ways in which a nuclear device could be detonated at the desired site. The surface to surface ballistic missiles carry nuclear war heads to the desired location. These missiles have a range of upto 5000 kms.

The next is the water way option. Surface to surface ballistic missiles could be tracked down by surveillance systems. But if the missiles are positioned in a nuclear submarine, there is little chance of it being detected. The third and the most powerful option is the air bombers. The fighter bombers can carry nuclear devices and drop it at precise locations without much difficulty. The Indian government has claimed that the nuclear

weapons would act as a deterrent and may never be used to establish military supremacy against its neighbours.

All the nuclear weapon states have the same line of explanation for the posession of nuclear weapons. Infact, Americans claim that they have accumulated a huge stockpile of nuclear arms only to maintain peace in the world. This is misleading.

Nuclear weapons and peace can never go hand in hand. Hundreds and hundreds of nuclear weapons developed during the cold war are now posing the threat of triggering an unintentional war situation.

Several missile launchers with nuclear war heads both in Russia and America are always on high alert to counter attack. This may prove disastrous in the eventuality of an accidental missile release. The only way out is to destroy all nuclear stockpiles with a lead from the established nuclear weapon states.

Discovery of nuclear energy is further confirmation of man's exploitation of nature. If anything can destroy the entire humanity, it is the nuclear proliferation. The destructive qualities of nuclear power is far too threatening to even appreciate its goodies.

Nuclear armaments should be eliminated once and for all to set free this world of the constant threat of total destruction. ❑

Nuclear Chronology

Date/Year	Development
1932, February	Chadwick discovers the neutron.
1934	Artificial radioactivity discovered by Curie/ Joliot (bombardment with alpha particles) and by Fermi (bombardment with neutrons).
1942, December 2	First nuclear chain reaction at Chicago's Stagg Field by Fermi.
1945, July 16	U.S. explodes first atomic bomb, the Trinity test, at Alamogordo.
1945, August 6,9	Atomic bombs dropped on Hiroshima and Nagasaki.
1946, June 30	First subsurface detonation by U.S. at Bikini atoll.
1949, August 29	First Soviet detonation, in the Ustyurt desert.
1952, October 3	First British atomic detonation, Monte Bello Islands, Australia.
1957, September 19	First underground test, Rainier, 1.7 kilotons.
1960, February 13	First nuclear test by France, Sahara desert.
1961, October 31	U.S.S.R. explodes the largest nuclear bomb, with a yield of a 58 megatons.
1964, October 16	China (PRC) explodes first nuclear bomb.
1974, May 18	India sets off a low-yield device (10-15 kt) under Rajasthan desert.
1986, April	Chernobyl Nuclear Reactor meltdown
1995, September 5	France resumes nuclear testing.
1998, May 11	India tests three nuclear devices.
1998, May 13	India tests two more nuclear devices.
1998, May 28	Pakistan tests five nuclear devices.
1998, May 30	Pakistan tests one more nuclear device.

What is the impact of the explosion on life and property?
The immediate effect of a nuclear explosion is to release a tremendous amount of energy within a very short interval of time. This energy will be manifested as a propagating wave of high temperature and high pressure. The heat will burn all burnable substances until the temperature of the heat wave fall's to very low values. The high pressure wave, or shock wave as it is called, causes destruction to structures and buildings which will collapse. Later the radioactive materials released in the explosion will spread, exposing people and material not yet affected by the heat wave and the shock wave. Depending on the level of exposure, people will die or suffer the consequences of radiation sickness.

What are the different ways of triggering off a nuclear device?
Detailed information on the different ways of triggering a nuclear device is difficult to get. But the essential principle is to keep the fissile material in 2 or more parts which are below what is called critical mass and suddenly bring them together so that the formation is above critical mass. A chain reaction of fission starts spontaneously. In order to increase the efficacy, they can be compressed under high pressure by using appropriate techniques.

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