



M.S.S. MURTHY

The Case of the **Aging** **Nukes**

AFTER the nuclear weapon tests by India and Pakistan in 1998, no other country has conducted such tests except North Korea in recent years. Most of the nuclear weapon countries have declared “no first use” moratorium. They deploy nuclear weapons only as a deterrent. Under such circumstances, the reliability of the weapon has to be more than 100 per cent to ensure the desired deterrence and also provide national security. However, there is a problem. Some of these warheads are more than 30 years old. Like all engineered systems, nuclear weapons also age and this puts a question mark on their reliability.

No system is engineered to sit inactive for years or decades and still be able to spring into action at just a few moments’ notice. It cannot happen with a car, a TV or even a bicycle. However, that is what is expected of a nuclear weapon.

A thermonuclear weapon is a highly complex system consisting of approximately 6000 components including electrical, electronic, mechanical, chemical and nuclear packages. These various components grow old and eventually become nonfunctional. Though the aging process of many of these packages is reasonably well understood, what sets apart a nuclear weapon from other engineered systems is the aging of the nuclear package.

Nuclear Package

The nuclear package of a modern thermonuclear weapon is made up of two stages—one primary and the other secondary.

The primary stage consists of a core or a pit containing Plutonium-239 as the fissile material and a booster fusion gas—a mixture of tritium and deuterium. The secondary stage consists of another fissile material such as Uranium-235 and lithium deuteride as the fusion material. During a weapon operation, first a chemical explosive, which surrounds the primary stage, is triggered. The shockwaves produced by the exploding chemical compress the pit containing plutonium to such a density that a spontaneous nuclear fission chain reaction sets in resulting in instant explosion. The imploding plutonium also drives the booster gas to compress and undergo fusion.

The combined fission-fusion yield of the primary stage initiates further fission-fusion reactions in the secondary. It is the secondary stage that provides the bulk of the military yield.

Causes of Aging

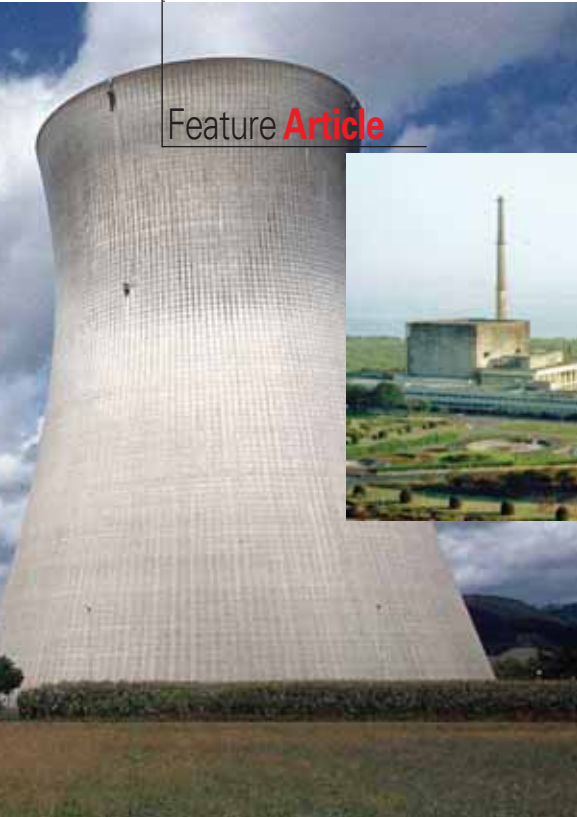
When deployed, a nuclear warhead is exposed to not only the harsh external environment, but also to several deteriorating factors from within. This is because plutonium, which is the heart of the nuclear trigger, is a highly corrosive metal. To reduce corrosiveness and improve mechanical

properties, plutonium is used in the form of an alloy with a small percentage of gallium. In addition, it is radioactive. As each plutonium atom decays, it breaks down into a uranium atom and helium nucleus (called alpha particle), both of which are highly energetic. The helium nuclei eventually combine with other helium nuclei to form helium gas bubbles inside the plutonium-gallium alloy matrix.

The uranium atoms continually knock out plutonium atoms from their positions in the matrix. It is estimated that every year about ten percent of the plutonium atoms are displaced. Though most of them come back to their original positions, some are permanently displaced. In the long-term, such changes may lead to deterioration of plutonium in the form of corrosion, warping and changes in its crystalline structure.

In addition, weapon grade plutonium contains trace quantities of non-fissile isotopes of plutonium, the decay products of which also accumulate with time causing changes in the material properties of plutonium.

The organic polymers constituting the chemical explosives that surround the primary stage also deteriorate with time both on their own and due to irradiation from plutonium. Another important factor is the deterioration of the electronic components like chips, which control the fusing, triggering,



Though the weapon experts have observed certain number of age-related defects, they are of the opinion that many of them are not serious.



and detonation of the weapon, due to irradiation from plutonium. Though these components are radiation-hardened, their long-term efficacy cannot be predicted.

A crucial factor in the success of the weapon is the proper energy coupling between the primary and the secondary stages. A minimum amount of energy from the primary is required to trigger the secondary. Weapon designers generally provide, what they call, a performance margin, which is the difference between the minimum yield obtained from the primary and the yield required to drive the secondary. Subtle changes in the material properties can affect the primary stage implosion.

Hence, one of the major concerns about the aging is that plutonium deterioration due to self-irradiation and the deterioration of the chemical explosives surrounding it may affect the performance margin and the energy coupling between the primary and the secondary.

Though the non-nuclear components can be tested easily for deterioration, the nuclear package can be tested only by underground explosive tests. Since most countries have stopped explosive tests, they have adopted different approaches to ensure reliability of the arsenal without nuclear testing. One such adopted by

the United States is known as the Stockpile Stewardship Program. It is based on a strategy of surveillance, assessment and refurbishment.

The United States has more than 5200 active nuclear warheads belonging to a dozen types. Each year the engineers systematically inspect some twenty samples of each type. The inspection includes destructive testing of non-nuclear components such as chemical explosives and non-destructive testing of other components where they look for signs of aging like cracks, warps and corrosion. They also use supercomputer simulations to assess the possible impact of any such deterioration on the weapon's safety and reliability.

Though the weapon experts have observed certain number of age-related defects, they are of the opinion that many of them are not serious enough to compromise the reliability of the weapon itself. In this fashion, they have been able to certify each year, for the past two decades, the reliability of the country's nuclear arsenal. Other long-standing nuclear weapon countries have similar programs.

Accelerated Aging

Along with this, a variety of studies have been conducted to understand the process of aging using plutonium from dismantled weapons. These include X-

ray absorption fine structure analyses to study its crystalline structure, high-resolution transmission electron microscopy to observe the evolution of microstructures and accumulation of helium, and so on. Surprisingly, these experiments have revealed that majority of the defects caused by self-irradiation are annealed in due course and the plutonium samples approach ideal crystalline structure with aging. This suggests that plutonium may stay stable for several thousands of years.

However, plutonium is the most highly unpredictable of all the metals and some aging may appear suddenly after years of stable behavior. Hence, scientists are carrying out laboratory experiments to accelerate the plutonium aging process to predict its performance on a long-term basis.

Weapon grade plutonium is the isotope Plutonium-239 (Pu-239) with a half-life of about 24,000 years, which means it decays too slowly for studying long-term effects. The trick is to spike the weapon plutonium with another isotope, Plutonium-238, which decays 300 times faster. If Pu-239 were spiked with 7.5 per cent of Pu-238, it would age about 16 times faster than weapon plutonium.

After six years in to the experiment, which is equivalent of 60 to 90 years of aging, scientists at the Los Alamos Scientific Laboratory in USA found slight increase in volume, decrease in density and increase in strength of the plutonium alloy. Based on these results they are of the view that the plutonium pits may have credible lifetime of at least 85 years. However, because of the peculiar properties of plutonium and its strategic importance, the experiments on aging continue to discern the long-term effects of helium accumulation on its properties.

The results of such experiments will be very crucial in deciding how long to rely on the existing stockpile, when to go for newer ones and determine the fate of treaties like Comprehensive Test Ban Treaty and Fissile Material Cut-off Treaty.

Dr M.S.S. Murthy retired as Head, Radiological Physics Division, BARC, Mumbai and has attended IAEA meetings on matters of radiation safety. Address: B-104, Terrace Garden Apartments, 2nd Main Road, BSK IIIrd Stage, Bangalore- 560805