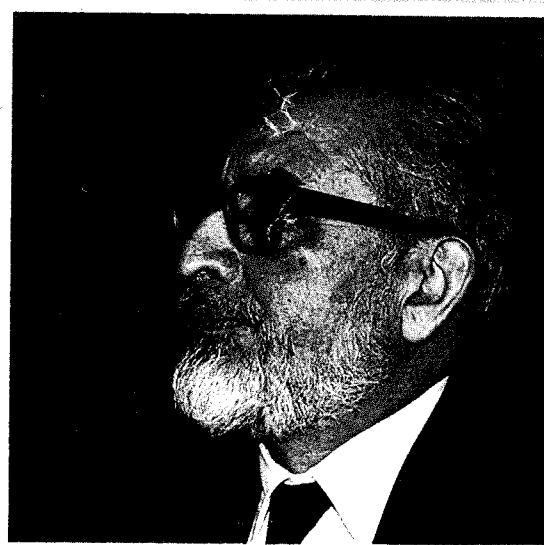


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NUCLEAR TECHNOLOGY IS SAFE



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Dr. M.R. Srinivasan
Chairman
Atomic Energy Commission

NUCLEAR TECHNOLOGY IS SAFE

Ladies & Gentlemen,

I thank the Andhra Pradesh Academy of Sciences for inviting me to deliver the "Second Prof. Y. Nayudamma Memorial Lecture". As many of you would be aware, Prof. Nayudamma took keen interest in the application of science and technology to the country's developmental activities. It is a fitting tribute to him that the Academy, of which the late Prof. Nayudamma was the President, has instituted this series of lectures in his memory.

In today's talk I propose to discuss certain safety related issues of nuclear technology, which have of late been exercising public's mind. However, prior to considering nuclear technology in particular, I would like to address a much broader question: How does one view and evaluate the risks and hazards of modern technology vis-a-vis its tremendous benefits to mankind?

Importance of balanced approach whilst assessing risks and hazards

Probably very few facets of our present life—rural or urban—have not been affected by technology. To varying degrees, the use of plastics, fertilisers, cooking gas, energy, pharmaceuticals, automobiles, aircrafts, medical techniques, to name some, have improved the quality of life, and all of us will agree that these benefits should not be confined to only those who are now availing them. Improving the quality of life has been the driving force for mankind to push ahead with the use of modern technology—though sometimes indiscriminately. That these

benefits carry along with them some risks, has been known for sometime. It is gratifying that this awareness is now growing not only amongst technologists, but also amongst all sections of society. It is the society at large which should ultimately decide what it is willing to pay for the fruits of modern technology. So public debates on how technology should be managed are a welcome development. It is, of course, very important that such issues are discussed in a rational manner.

All technologies involve some risks

Many technologists do scoff at the fears of laymen who do not understand technology. Putting across a proper perspective, being honest, and educating the public, are essential for discussing any issue of public interest in modern society. One has to recognise that there is nothing like an absolutely safe technological product—be it the automobile, aircraft, chemical industry, spacecraft, or for that matter the nuclear reactor. If mankind had decided to take a "zero risk approach", we would not have undertaken space exploration, developed chemical technology or exploited nuclear energy, and there would not have occurred the tragedies of "Challenger", "Bhopal" or "Chernobyl". But then we also would not have had the tremendous spin-offs of space technology (in areas of microelectronics, computers, satellites and communication, optics, medical technology, etc.); there would have been no fertilisers and pesticides which have been primarily responsible for quantum leaps in food production that feed our growing populations, and we would also have burnt more coal and oil, resulting in additional acid rain, environmental pollution, scarce oil, and in many instances, costlier electricity. With this in the background, let us examine issues of safety as regards nuclear technology.

Public perception of safety of nuclear technology

During the past 45 years, nuclear technology has come a long way since Fermi's first atomic pile went critical in Chicago in 1942. This was the event that demonstrated that nuclear energy could be used for production of explosive material and for generation of heat. Since then, the world has seen nuclear technology being applied primarily to two areas—weapons development and generation of electricity. There are no doubt other areas also like—cancer therapy, medical and industrial x-ray imaging, food irradiation, radiopharmaceuticals, tracer techniques, to name some, where it plays a role. All these involve the fundamental question of how safe the nuclear technology is.

While conventional safety issues applicable to any technology are equally applicable to this field too, only one aspect,—that is, "radiation", has been predominant in the public's perception of nuclear technology. The principal cause for this is the fact that human senses do not react to radiation—one cannot see, hear, smell, taste or feel it. While with almost every other human activity we can make a reasonable judgement based on common sense and without much of external advice, as to how safe it is, with radiation it is not so. One can only measure it and that does not tell much to a layman as to what it is all about. Understandably, this is also the reason why the public at large has several misconceptions, and indeed fears, about radiation.

International mechanisms for ensuring safety from radiation

Fortunately, nuclear technologists have always been aware of this, and "safety" has always predominated all areas of nuclear technology. In all stages of nuclear technology, evaluation of a particular activity includes quantitative assessment of

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the possible deleterious effects in all possible scenarios so that sufficient safety features are incorporated during the stages of design, construction, operation and maintenance. In areas where adequate data or information is not available, implementation of safety measures is carried out on the principle of "*erring on the safe side*", and by adopting the methodology of mitigating the consequences of hypothetical situations which include severe accident conditions, that would be hazardous to man and damaging to the environment.

The effects of radiation have been exhaustively studied, researched and documented. There is an enormous amount of literature about this subject, probably as much if not more than any other harmful agent. There is also a powerful network of international and national organisations for its supervision and control. This network, which cuts across all geographical and political boundaries, is unique, for no similar mechanism exists in the world for any other potentially harmful agent. To begin with, the International Commission on Radiological Protection (ICRP), recommends the limits for exposure to radiation. The extreme caution with which radiation is treated by nuclear technology is evident from the fact that these limits are based on the assumption, although not yet fully substantiated scientifically, that exposure to ionising radiation at any level is injurious to man. But it is also well known that the effects at low levels are insignificant. The radiation safety policy is concerned with the protection of individuals, their progeny and mankind as a whole, while still allowing necessary activities, from which radiation exposure might result. Radiation exposure limits, recommended by ICRP, follow the basic guiding principle that no practice involving ionizing radiation shall be adopted unless its introduction produces a positive net benefit. The International Atomic Energy Agency (IAEA) prepares Basic Safety Standards related to ICRP recommendations in consultation

with the World Health Organisation (WHO), the International Labour Organisation (ILO), and other bodies. These Basic Safety Standards form the basis for individual countries to draw up their own regulatory mechanisms to ensure safe usage of nuclear technology.

It would be appropriate at this stage to elaborate on some aspects of Radiation Safety Policy adopted in India.

Radiation Safety Policy in India

All regulatory and safety functions for installations within the Department of Atomic Energy (DAE), as well as outside, are carried out by the Atomic Energy Regulatory Board (AERB). There also functions a Safety Review Committee (SRC) which evaluates and enforces radiological safety in all units of DAE and directly assists AERB in carrying out its functions. These in turn, are assisted by various safety committees (at the local and unit level and by expert teams) as well as the Health Physics Division of Bhabha Atomic Research Centre (BARC). All nuclear facilities are required to seek and obtain authorisation from AERB for construction, commissioning and operation, prior to commencement of these activities. The licensing policy is based on stringent requirements for shielding against penetrating radiation and to severely restrict releases of radioactive substance into the environment.

The primary objectives of our radiation safety policy are that :

- There is no interference with the usage of environmental resources by various sections of society.
- There is no unplanned, haphazard growth of human activity in the immediate neighbourhood.
- There are no deleterious effects, either of an acute short term or chronic long term nature, to the environment, and the ecological balance is not disturbed.

I will now discuss how this safety philosophy is actually implemented in some applications of nuclear

technology in India. As the prime objective of our country's nuclear programme is the generation of electricity to meet the exponential growth in demand for energy, one can begin with the design, construction and operation of nuclear power stations.

Siting of Nuclear Power Stations

To begin with, let us take the question of siting of nuclear power stations, about which you must have read a lot in recent times. Amongst various criteria that are examined before clearance is given to any site, are :

- The population densities in the neighbourhood.
- Location of human settlements
- Utilisation of the environment (both aquatic and terrestrial).
- Hydrological, Hydrogeological, and Meteorological conditions.

These criteria require the establishment of two zones—an exclusive zone and a sterilised zone. The exclusion zone is the area immediately around the plant that would be under the exclusive control of the station authorities and within which no public habitation is allowed. The sterilised zone extends from the boundary of the exclusion zone within which the overall expansion of public activities is controlled, with only natural growth being permitted. Even outside these zones, attention is paid to the distribution of population upto a 30 km radius surrounding the plant. The purpose of providing these zones is to minimise the impact of the station on the public and to ensure that in the unlikely event of a serious accident, effective emergency actions can be taken to protect the surrounding population.

There have been recent reports that the nuclear power project at Kaiga would need 3500 acres (or about 1416 hectares) of dense forest. The fact is that the actual area to be cleared for the plant would be only 60 hectares of degraded forest land. This would go up to 120 hectares in the event of a 2000 MWe power complex being set up at same location. Most of the other areas to

be cleared include land required for laying transmission lines to supply power to load centres which would be required whether a nuclear, thermal or hydro power plant were to be built. The remaining areas will be left intact if not improved upon over the coming years. A visit to any of our existing facilities will show the extreme care that is taken to preserve and improve the surrounding greenery. In most instances it has always been one of significant improvements over the conditions that prevailed there originally. There have also been some reports that safety norms are reported to have been violated whilst considering the location at Nagarjunasagar as a prospective site. Here again, the fact is that there is no township with a population exceeding 100,000 within a radius of 30 kms. from the prospective plant site. There are also frequent references to dangers from possible earthquakes to the Narora Plant. Our designers are aware of the seismic conditions prevailing not only at the Narora site, but all other sites. Seismic analysis is an integral part in the design of any nuclear facility. In this context, we may note the example of Japan. This country, which is only one that has actually faced the extreme horrors of radiation hazards from atomic bombs, having a high population density, and which is located in one of the most earthquake prone areas of the world, has consciously gone in for nuclear power in a big way. It has at present 34 operating nuclear power stations with an installed capacity of about 25,800 MWe that provide nearly a quarter of its total electric power requirements. Ten more reactors with a total capacity of about 7590 MWe are under construction.

Design, Construction & Operation of Nuclear Power Stations

In a nuclear power station all systems fall under two categories—either conventional or nuclear. The design of all nuclear systems is carried out by our departmental engineers who, prior to joining the department undergo an intensive

course that includes amongst others, radiation safety and health physics. During each of the design stages, appropriate analysis is carried out in areas such as radiation shielding, physics, thermal, seismic, material compatibility, accessibility during service for inspection, etc.. Prior to manufacturing, detailed reviews of the manufacturer's materials management system, facilities for fabricating and the system for establishing quality assurance, are carried out. As manufacturing proceeds, a comprehensive documentation is prepared which includes copies of all material test certificates, listing of all design deviations if any, inspection and QS reports, installation reports, manuals etc.

The principles of "diversity of systems" and "redundancy of equipment" are used to ensure safe operation of a nuclear reactor. All highly critical systems such as the reactor core cooling system, have several backup safety systems functioning on diverse principles and the non-availability of even one of these backup systems would lead to the shutting down of the reactor, where necessary, this is reinforced by incorporating redundancy in equipment too. To give an example, the electric power supply to a critical system like the reactor control system would be backed up by the grid supply, which in turn would be backed up by a diesel generator set, and which in turn would be backed up by storage batteries. The non-functioning of any one of these will result in the shutdown of the nuclear reactor. All critical nuclear systems are designed on the concept of "defence-in-depth" One other example of this design concept is that of the vapour suppression pool and double containment adopted in our reactors. The vapour suppression pool is designed to limit any pressure build up that could result from a possible loss of coolant accident. This is backed up by the primary containment which is a prestressed concrete building, which in turn is enveloped by a secondary contain-

ment of reinforced concrete.

Both during commissioning and subsequent operations of a nuclear power station, a continuous track is kept of all "unusual occurrences". The term "unusual occurrence" may in isolation be misunderstood by a layman. It may conjure up an "unsafe occurrence" in the one's mind—in reality, it is rarely so. This is because in nuclear technology parlance, this term applies to anything and everything not in accordance with normal behaviour. To give an example, when a pump or diesel generator is started by pressing its push button and it does not start, the event is recorded as an "unusual occurrence", even if it does not have any implication on the safety of the reactor. All such "unusual occurrences", however insignificant, are recorded, reviewed, and analysed to find the cause, and corrective actions that may go right back to the design stage, are initiated to prevent its recurrence. This is an ongoing and continuous process which is unique to nuclear technology.

Why then the accidents at Three Mile Island and Chernobyl?

If despite all this, the accidents at Three Mile Island and Chernobyl did take place, why did they?

The Three Mile Island accident resulted mainly from operator's error which led to a partial meltdown of the reactor fuel. Despite this, the various backup safety systems functioned as designed. As the reactor was enclosed in a containment building, the release of radioactivity to the environment was negligible. Most important was the fact that there was no injury or loss to human life. At Chernobyl, the accident occurred whilst the operators were carrying out an unauthorised (from the safety aspect) experiment on the turbo-generator, and adopted improper procedures from the viewpoint of reactor safety. In the process, basic operating rules were violated and no less than six such specific violations took place. These included overriding of specific

safety mechanisms that would have otherwise shutdown the reactor. In addition, as the reactor design was of an earlier generation, more reliance was placed on manual intervention for ensuring reactor safety, than is customary with present day designs.

One of the most important lessons of Three Mile Island and Chernobyl was the need to inculcate a "culture of safety" at all levels in organisations that handle nuclear technology. I have already mentioned earlier how we ensure the growth of such a culture amongst our personnel through an appropriate training programme immediately after recruitment. In this context, one must state that right from the beginning we have deliberately adopted a policy of having specially trained graduate engineers in charge of the nuclear stations at all times.

Safety Procedures at some other facilities

There has been some concern expressed in recent years about possible radioactive hazards at the Indian Rare Earths (IRE) units in Kerala and at the Nuclear Fuel Complex (NFC) at Hyderabad.

The IRE plant site at Alwaye has for long had an independent and permanent Health Physics Group which periodically monitors its safety. Its observations and studies have revealed that so far nobody has received a dose higher than the permissible limits. The main radioactive solid wastes generated at the plant as a result of processing the naturally occurring monazite, are contained in reinforced concrete casks, sealed and then buried in reinforced concrete trenches. Radiation monitoring wells are provided all around these trenches and observations have not shown any seepage of radioactivity. The methods adopted are in accordance with international standards followed for solid wastes.

In addition, all liquid effluents generated in the plant are treated in the Effluent Treatment Plant and only the treated effluents which are

continuously monitored, are discharged to the river. These treated effluents conform to the standards stipulated by the Kerala State Water Pollution Control Board. In addition, regular environmental monitoring is carried out of the Periyar river itself. The level of Radium-228 observed at the point of discharge (around 10 pico-Curies per litre) is much less than the permissible concentrations of Radium-228 in normal drinking water (which is 30 pico-Curies per litre).

A similar independent Health Physics Group is also functioning at NFC. This group is responsible for the industrial hygiene and monitoring of the environment. Periodical environmental surveys are conducted as far as 25 Kms. from the plant. Further, a Safety Engineering Division has also been set up within NFC to ensure that all operations are performed under safe conditions. This division also advises the NFC management on all safety matters and has been empowered to place restrictions on operations considered by it to be unsafe. As regards effluent management, effective measures are in place to keep discharges to the environment well below permissible limits. Rigorous control of effluents is adopted to conform to standard norms which themselves are being progressively tightened. There were certain problems in the past, in that there were some leakage of nitrate effluents into the environment. By a variety of measures such as high density polythene lining of solar evaporation ponds and storm water drainage management, these leakages have been eliminated.

Safety of Food Irradiation Techniques

It would be appropriate to mention something about one of the not-so well known applications of nuclear energy—irradiation for food preservation. It has been known that poor storage facilities and adverse climatic conditions are responsible for large wastage of agricultural and marine food products. Despite adoption of conventional preservation

technologies such as canning, dehydration and salting, the wastage is still considerable. Needless to add, the consequences of this are severe for developing countries like India. Apart from altering the flavour, colour, texture and other highly desirable attributes of fresh food, some of the conventional techniques involve the use of several chemicals. Use of fumigants such as ethylene dibromide and ethylene oxide have been banned in several countries due to the hazards caused by toxic residues. Similarly, much concern has also been expressed that some of the food additives could be carcinogenic in nature.

In contrast, food preservation by irradiation does not have any of these drawbacks. As it induces virtually no temperature rise in the treated products, it is often termed as a "cold process". Some typical application of this technique are :

- Inhibition of the sprouting of vegetables (in potatoes, onions, garlic, yams)
- Shelf-life extension of fresh produce (such as fruits, fish, meats) by delaying ripening, or reducing the number of micro-organisms that spoil food.
- Control of pathogenic organisms and parasites found in food.
- Insect disinfection of food, and
- Microbial disinfection of spices and dry food ingredients.

Nuclear technologists have been working on this technique for several years. During the past fifteen years several processing policies and programmes have been developed both by a number of individual countries and through projects supported by the Food & Agricultural Organisation (FAO). International Atomic Energy Agency (IAEA) and World Health Organisation (WHO). On the basis of exhaustive data, the Joint FAO/IAEA/WHO Expert Committee on the wholesomeness of Irradiated Food (JECFI) was able to recommend in 1980 that food items irradiated upto an average dose of 10 kilo gray (kGy) be accepted as safe from the health angle and do not

present any toxicological hazards. One must appreciate that this is not the level above which irradiated foods become unsafe; rather it is the level at or below which safety has been established. The process does not, as many people mistakenly assume, make the treated food product radioactive. The safety of the technique has been established by thorough investigations involving multigeneration feeding trials, toxicological analysis, mutagenicity and carcinogenic testing that have been carried out for over two decades. At present, about thirty countries have given clearance to over forty items of irradiated food. These include countries such as USA, USSR, Japan, France, Canada, Bangladesh, Denmark, etc. Each country has provided for legislation to give conditional clearance for irradiation processing of one or more products depending on the local situation. Japan has been irradiating potatoes on a commercial scale since 1973. An industrial radiation disinfestation plant has been in operation since 1980 in the port of Odessa in USSR to treat imported grain before distribution in the country.

India has recently cleared this technique for preservation of frozen sea foods and spices. The Food Irradiation and Processing Laboratory of BARC is one of the foremost laboratories of its kind in the world. It has been conducting R&D work in this field for over two decades. It also possesses the entire technology for designing, constructing, commissioning and operating irradiation plants in accordance with safety standards prescribed by IAEA/ICRP.

Misconceptions about Radiation Hazards

I have detailed more on the subject of radiation safety to give you an idea of the considerable amount of research and development work that has gone into this aspect all over the world. You will also notice that it is not just nuclear technologists who are involved in setting up radiation safety standards, but a host of other international agencies such as IAEA, WHO, ILO, FAO, etc. Despite

this, there is considerable confusion and misinformation on the subject, and one hears statements like "food irradiation is unsafe and dangerous". Such opinions come about by lack of knowledge about radiation itself. To give an example of how the public can be misinformed about radiation, one may recall the recent scare in Bombay about the supply of imported Irish butter that was supposed to have been contaminated by radiation. When samples of this butter were tested by the Health Physics Division of BARC, in none of the imported product samples, the radioactivity level was anywhere close to the permissible limits. The levels detected were much lower than what one would detect in the normal milk we consume everyday.

A fact about radiation not often realised is that it is present everywhere, all the time. We receive radiation from the sky (from the stars and other bodies in the universe), from the sea, from the constituents of the earth and indeed even from living beings. Measurements of radiation have shown that the natural background levels in Bombay, Delhi and Bangalore are of the order of 480, 700 and 820 microgray per year. So if this leads to a headline like "Bangalore is the most radioactive city", it would be rather misleading. Development in the field of instrumentation have resulted in simple, cheap, and highly sensitive instruments which can measure very low levels of radiation, which by themselves are insignificant as far as health of human or animal life is concerned.

In this context, reference should be made to the measurements made in 1984 by the National Radiological Protection Board of UK to examine the composition of total radiation exposure of that country's population. These show that 87% of the total exposure comes from natural sources, 11.5% from medical applications, 0.5% from nuclear weapons fall out, and 0.4% from occupational sources. Only 0.1% comes from activities relating to nuclear power production. It should be borne in mind

that 24 nuclear power reactors with a total installed capacity of 12,900 MWe are operating at present in U.K., supplying around 18% of its total electric power requirements.

In Conclusion

In the course of today's talk, my attempt has been to present some aspects which illustrate how nuclear technology views the question of safety. Unlike most other technologies where the issue of "safety" acquired importance only after an accident or tragedy, nuclear technology is unique in that "safety" has been an area of major concern from the very beginning. This is what has made nuclear technology adequately safe, despite Three Mile Island and Chernobyl.

Electricity from nuclear power is of great relevance to India, given the energy resource base, its uneven distribution and the large population of the country. The early start the country made in this field has resulted in the availability of a large pool of trained engineers, scientists and technicians, and also a comprehensive industrial base for nuclear equipment. These endowments can now be put to use by a rapid expansion of the nuclear power programme. In some quarters there is a criticism that electricity is only used by the elite and not the masses. It is often not realised that our ability to feed our large population depends on providing electrical energy for irrigation and also for manufacturing pesticides and fertilizers. In addition, the growth of industry is a must for expanding job opportunities, and one does not have to labour the importance of electricity for this purpose. More generally, all advanced societies have managed to improve the quality of life for their citizens only through greater use of electricity. The role of non-conventional sources of energy is discussed often, sometimes with great hopes, but in the foreseeable future they are expected to play a very limited role so far as commercial electricity production is concerned.

Apart from electric power, applications of nuclear technology can be found in medicine, industry, and agriculture. Radioisotopes together with modern imaging devices and computers form one of the most sophisticated and powerful tools in present-day medical diagnosis. Radiation treatment for cancer therapy is currently a common practice. Radiotracers help in optimal utilisation of fertilisers. Groundnut and rice crops can be improved by mutation breeding. Gamma radiographic cameras, which are a common sight

in any modern industry, are used to detect flaws and defects during manufacturing and fabrication. Nuclear logging devices help in oil prospecting and medical products are sterilized using nuclear technology. In India, the usage of these technologies, in a safe manner, has already yielded significant benefits and they will continue to grow in the years to come.

I would like to conclude this lecture by stating that while nuclear technology is no doubt a demanding one, it can be used safely for the benefit of

this country with adequate assurance of safety to occupational workers, the general public and the environment. I also believe it is the task of scientists and technologists to educate the public so that their perceptions are based on sound rationale and they are not swayed by exaggerated fears and thus deny themselves the benefit of one of mankind's most important achievements, namely harnessing the energy of the nucleus for human well-being.

