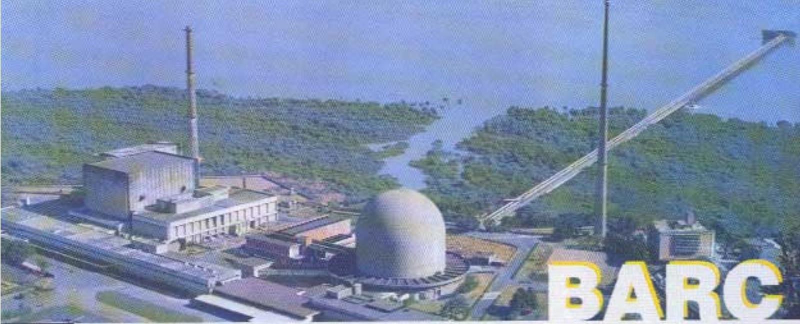

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RELIABILITY ASSURANCE THROUGH ASSESSMENT AND UPGRADATION

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Introduction

The terms 'reliable' and 'reliability' have originated from 'rely' which means "to depend on with full trust". How much to rely, whom to rely upon and what should be the rational basis of reliance are the moot questions any body would like to ask in any given situation. If you ask a question about an instrument like this: Is it reliable? The answer will be either 'yes' or 'no'. This answer is qualitative in nature and does not specify in quantitative terms how good or how bad the instrument is. For a long time, scientists were in search of a quantitative answer to the question of reliability so that reliabilities of two or more similar instruments can be compared, graded, upgraded and standardised. After a lot of thinking and discussion, they have come out with a probabilistic concept which can answer the above question in quantitative terms. According to this concept, an instrument is found in either of the two states at any give time :

(1) Working or ready to work as and when demanded.

(2) Non-working/failed.

These states are also called success and failure states respectively. Since success and failure are mutually exclusive events and there is a probability of unity that either of them must occur. The sum of these probabilities also must be unity. Reliability is the probability of success in a given time and unreliability is the probability of failure during the same time interval. If R(t) and Q(t) are the reliability and unreliability during time t respectively, then

$$R(t) + Q(t) = 1 \quad \text{.......... (1)}$$

The measure of reliability of an instrument is the frequency at which failures occur in time. Thus, failure rate is an index of reliability. Failure rate is denoted by λ and is defined by the following equation :

$$\lambda = r/(N.t) \quad \text{.......... (2)}$$

where r is the number of failures in time t out of N number of instruments under consideration. The relationship between reliability and failure rate is expressed by the following equation :

$$R(t) = \exp(-\lambda t) \quad \text{.......... (3)}$$

From equation (3) it is quite obvious that R(t) = 1 if t = 0. R(t) decreases exponentially with increase in time and becomes zero when t approaches infinity. Also, for a specified time, R(t) will be high if λ can be reduced. It is not possible to reduce failures completely. What is possible is to reduce failure rate by design, manufacturing, quality control, reduction of environmental and operational stresses, and maintenance efforts.

In equation (3), it is assumed that λ is constant, failures occur randomly and there is no ageing effect. A random or chance failure is one about which no advance information is available regarding its time of occurrence; it occurs all of a sudden. The other category of failures are ageing failures which are time dependent. In general, electronic instruments and components fail randomly, while electric cables and elastomeric components (gaskets, hoses, O-rings, diaphragms, etc.) fail due to ageing. The efforts of reliability engineers are directed towards minimising failure rates and maximising life-spans. This is possible by close collaboration amongst manufacturers, users and reliability experts.

It is important to understand the difference between quality and reliability. Quality is the backbone of reliability; we cannot think about reliability without quality. However, higher quality need not necessarily mean higher reliability; reliability depends upon how quality degrades with time. The index of quality is initial performance (judged by performance parameters); that is, quality does not have time dimension. If an instrument works satisfactorily initially, there is no guarantee about its satisfactory performance with passage of time. Time dependence of performance comes under the purview of reliability and is defined as the probability that it will perform its function satisfactorily for a specified period of time under specified conditions. As mentioned earlier, probabilistic concept of reliability is useful only for small mission periods. However, a generalised concept of reliability takes into account short-term performance, long-term performance and performance under adverse conditions such as a Loss Of Coolant Accident (LOCA) in a nuclear power plant, and it is necessary to test engineering hardware under these environments over a period of time to gain confidence.

Reliability Assessment

Reliability is assured by assessment and upgradation. Assessment is carried out by the following two methods:

Field performance data collection : A systematic survey is carried out regarding past performance history of identical instruments in use since last 5 to 10 years. The survey should cover a large number of users and instruments so that the data generated is statistically significant and reliable. The data should contain the following points:

- Total number of instruments covered under the survey and length of usage of each instrument.
- Total number of failures reported along with date of failure of each instrument.
- The number of times an instrument has failed over a specified time.
- List of components that fail frequently.
- Environmental and operating conditions of each instrument.
- Nature of failure, that is, catastrophic or drift in performance parameters with time.
- Probable cause of failure.
- Acceptance/rejection criteria set by users.

The above survey will provide fairly accurate and reliable data regarding long-term performance of instruments based on which users can take decisions in respect of procurement. However, the above data is not easily available because performance history cards are not adequately maintained by users. Also, if the manufacturer is new, the question of past performance history does not arise. In such situations, users have no other option except going for accelerated testing.

Accelerated testing : In accelerated testing, the magnitudes of environmental and operating stresses are higher than those existing under normal use conditions. The purpose of accelerated testing is to obtain reliability data in 3 to 6 months which will correspond to 30 - 40 years of ageing. One of the most important constraints in accelerated testing is that failure mechanisms should be same under accelerated and natural ageing. This puts a limitation on the magnitude of accelerated stress. Once reliability data is generated under accelerated conditions, failure rate or life-span is extrapolated under normal working conditions with the help of empirical mathematical equations. Arrhenius and Eyring equations describe 'performance' as a function of temperature and combined environment respectively. Arrhenius equation is described as follows:

$$\lambda = A \exp(-E_A/kT) \quad \ldots\ldots\ldots\ldots \quad (4)$$

where k is Boltzmann' s constant, T is temperature in ºK, A and E_A (activation energy) are the characteristic constants of the test item under consideration. Using equations (2) and (4), we get,

$$t = C \exp(E_A/kT) \quad \ldots\ldots\ldots\ldots \quad (5)$$

where $C = r / (NA)$

In equation (5), t is life-span. It is to be noted that temperature dependence of failure rate and life-span are represented by Arrhenius equation.

Failure rate under combined environments of temperature and any other stress is represented by Eyring equation as given below:

$$\lambda = A \exp(-E_A/kT).\ \exp(D\,s).\ \exp(Es/kT) \quad \ldots\ldots \quad (6)$$

where A, E_A, D and E are characteristic constants of the item under consideration. In equation (6), the first, second and third exponential terms represent, temperature dependent, stress dependent and their interaction effect related degradations respectively.

Stress, s, is represented as the ratio of operating to rated stress.

It is to be noted that there are 2 and 4 characteristic constants associated with Arrhenius and Eyring equations respectively. To determine their values, one will have to conduct accelerated tests at least at 2 accelerated temperatures in case of Arrhenius equation, and at 4 combinations of temperatures and stresses in case of Eyring equation. This job is quite difficult and needs appropriate design of experiments. Here it is worth mentioning that estimation of λ needs large sample size. On the other hand, estimation of life-span needs relatively small sample size because all the specimens degrade almost identically and fail in a narrow time interval. That is why estimation of λ and life-span are generally done by the method of field failure data collection and laboratory accelerated testing respectively.

Reliability assessment of the following items is being described as illustrations:

(1) *Relays :* About 8000 relays were exposed to smoke and water spray in the fire incident at Narora Atomic Power Station (NAPS) in March 1993. Chlorine gas generated from burning PVC cables reacted chemically with water, which was used to quench fire and improve visibility, to form hydrochloric acid. Metallic body and screws of the relays were corroded due to this acid. Reactor Safety Division (RSD), BARC, took the responsibility of assessing the reliability of these affected relays. Six representative relays were tested at 80°C for 180 days. Performance was checked periodically at room ambient. Usage of all the fire affected relays was recommended after cleaning/replacing corroded metallic parts. All the relays are working satisfactorily.

(2) *O-rings :* Seven types of O-rings are lying in the stores of NAPS for 2-18 years, storage temperature being 25-45°C. It is a well known fact that O-rings age irrespective of whether they are in stores or in use; higher the storage/use temperature, higher will be the rate of degradation. Representative specimens of O-rings have been tested at l00°C for 115 days. Estimated residual life-span have been found to be 2-20 years at 40°C. This study has helped NAPS to take appropriate decision regarding usage and timely replacement.

(3) *Pressure transmitters :* Frequent failures of pressure transmitters manufactured by M/s Odin, Germany, were reported from Kaiga Atomic Power Project. RSD studied in detail the characteristics, capabilities and limitations of one transmitter and found that it is highly sensitive to excessive input voltage. Over-voltage protection and keeping the power supply unit under lock and key were suggested so that tampering by operators could be avoided. This solved the problem.

Reliability Upgradation

If an instrument is found reliable either by its performance history in actual use environment or by accelerated testing in the laboratory, then there is no need for reliability upgradation. However, if it is found to be unreliable, then it is possible to upgrade its reliability by the following techniques:

- Identification of critical components and materials. This is possible by field failure data collection as well as accelerated testing in the laboratory.
- Selection of reliable components and materials.
- Reliability screening of components to weed out potential defectives.

- Derating thermal, electrical and mechanical stresses.
- Using redundancy techniques
- Failure analysis and corrective action.

An equipment may not be reliable for all environments. Hence, it is essential to specify operating and environmental conditions. For example, if a safety - related electrical/electronic instrument is required to function in LOCA environment, it has to be specifically designed, manufactured and tested for its worthiness before its installation.

Reliability upgradation of the following items is being described as illustrations:

(1) *Indicating Alarm Meters (IAMs)* : About 508 IAMs manufactured by M/s Lectrolab Equipment Company, Mumbai, have been installed at Madras Atomic Power Station (MAPS). Their performance was found to be erratic above 30°C; there was no alarm when it was needed, or alarm was delayed or there was alarm when it was not needed. After detailed investigation, weak/substandard/critical components were identified. Accordingly, the photocell was replaced by photodiode, and the carbon film resistors by metal film resistors. Modified version of IAMs were tested upto 90°C for many days and the performance was found to be satisfactory. MAPS has upgraded almost all the IAMs and their performance has been found to be satisfactory. This exercise has resulted in the reliability improvement of the entire production lot. Rajasthan Atomic Power Station Unit 2 has got the benefit of using upgraded version of IAMs.

(2) *Solenoid valves for liquid poison injection systems* : Nuclear Power Corporation has given the responsibility of developing a special type of solenoid valve to M/s Rotex Manufactures & Engineers Pvt. Ltd., Vadodara. This valve consists of a permanent magnet and 4 reed switches attached to the plunger so that the status of the valve is known in the control room by indicating lamps. Even though the valve worked satisfactorily during thermal and radiation ageing tests and during simulated Loss of Coolant Accident (LOCA) condition, it failed to reveal the status. Detailed investigation at RSD revealed that there was nothing wrong with the reed switches but their alignment was not proper. This fact was brought to the notice of the manufacturer and corrective action was taken. Upgraded version of valve was tested again and performance was found to be satisfactory. The upgraded valves have been installed at Kaiga and RAPP and their performance has been found to be satisfactory. This valve has been developed as an import substitution.

(3) *Neutron and Gamma Ionisation Chambers* : The performance of neutron ionisation chambers manufactured by M/s Electronics Corporation of India Ltd., Hyderabad, was checked before and after LOCA test. It was found to be satisfactory. However, usage of viton o-rings in place of neoprene o-rings, XLPE cables and heat shrinkable tubes at the junction of MI and soft cables has been recommended for long service life. This is also an import substitution.

Similarly, on-line performance of the gamma ionisation chamber was checked during LOCA, but the polyethylene cables of signal and EHT melted, resulting in the shorting of EHT of the monitor. Then polyethylene cables were replaced by kepton cables and the LOCA test was repeated. Performance has since been found to be satisfactory.

Test Facilities Available in BARC

In the above sections, emphasis has been given for quantification of qualitative statements as well as practising reliability engineering principles. This is essential for technology upgradation and confidence building in indigenous equipment. To achieve these objectives, the following test facilities, with on-line measurement of performance parameters, have been set-up in BARC:

Thermal ageing test facilities : Four temperature chambers are available, each with an internal dimension of about 40x40x40 cm^3 and temperature range from room ambient to 400°C. Two such chambers are shown in Fig. 1.

Fig. 1 Thermal ageing test facilities

Synergism simulator : This is a unique and versatile research facility for simulating combined environments prevailing inside the reactor containment building simultaneously to study their interaction effects. The combined environments are temperature, humidity, gamma radiation and electrical stresses. It is possible to vary the magnitudes of the above cited stresses as per the design of the experiment. Internal dimensions of the simulator are 84x84x 90 cm^3. Temperature and relative humidity can be varied from room ambient to 80°C, and 95 ± 5% respectively. It is also possible to use the simulator as a dry heat chamber with a maximum temperature of 150°C. Dose rates can be varied from 2 to 30 krad/hr with the help of three lead cylinders fixed on a rotary platform. Instrumentation, control and display panel of the simulator is located in the adjacent room. The facility is shown in Fig. 2.

Fig. 2 Synergism simulator

LOCA environment simulator : LOCA environment is steam bound under which safety related equipment, such as shutdown pump motors, must work. Steam is generated in the containment building as a result of rupture/break in the primary heat transport system. That is why it is extremely important to qualify all safety related equipment under LOCA environment. The simulator is a cylindrical vessel with internal diameter of 100 cm and length of 120 cm. Maximum temperature and pressure of steam achievable are 150°C and 50 psig respectively. The simulator is shown in Fig. 3.

Benefits from Reliability Research

- Standardisation (reduction in variety).
- Determination of critical and potential defective components, thereby upgrading reliability of instruments.

Fig. 3 Loss of Coolant Accident (LOCA) environment simulator

- Estimation of life and residual life-spans, thereby taking adequate decisions regarding procurement and replacement.
- Reduction in spare parts.
- Reduction in wastage of materials.
- Reduction in stores and maintenance personnel.
- Reduction in men-rem consumption.
- Technology upgradation.
- Enhancement in professionalism, performance, competence, confidence and profits.
- Import substitution and export promotion.

SYNTHETIC SEEDS : A NOVEL CONCEPT IN SEED BIOTECHNOLOGY

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Progress in biotechnological research during the last two decades has opened up unprecedented opportunities in many areas of basic and applied biological research. Plant tissue culture, which is an important component of plant biotechnology, presents new strategies for the improvement of cereals, legumes, forest trees, plantation crops and ornamental plants. Besides, plant cell cultures provide a good system for many basic studies in plant breeding, plant physiology, genetics and cell biology. Cell manipulations through the sophisticated methods of genetic engineering for plant quality and product improvement has to rely on plant tissue culture for the final goal. Micropropagation is an area of plant tissue culture which has received maximum attention of researchers for its potential commercial applications.

The regeneration of plants through the techniques of plant tissue culture and their subsequent acclimatization and delivery to the field poses many problems to make tissue culture technology a viable alternative proposition. The successful demonstration of encapsulation of tissue culture derived propagules in a nutrient gel has initiated a new line of research on synthetic seeds. Synthetic seeds are basically defined as, "encapsulated somatic embryos which functionally mimic seeds and can develop into seedlings under sterile conditions". In a broader sense, it would also refer to encapsulated buds or any other form of meristems which can develop into plants.

The main thrust idea is to prepare a simple, inexpensive delivery unit of tissue culture propagated plants and a method for direct sowing of encapsulated material in the field. The encapsulating matrix has the ability to incorporate nutrients, biofertlizers, pesticides, nitrogen - fixing bacteria, antibiotics or other essential additives. The direct delivery of encapsulated material will save many subcultures to obtain plants and also eliminate the difficult stage of acclimatization of *in vitro* plants. The uniform and simultaneous production of encapsulated propagules followed by uniform germination could possibly remove many drawbacks associated with natural seeds.

Many plant systems are known to produce abundant number of embryos in culture which share many properties similar to natural embryos including germination leading to plant production. To mimic the natural seeds, embryos from cultures are encapsulated in a nutrient gel containing essential organic/inorganic salts, carbon source, plant hormones and antimicrobial agents and coated completely to protect the embryos from mechanical damages during handling and to allow the development and germination to occur without any undesirable variations. Several agents have been attempted for encapsulation and sodium alginate complexing with calcium chloride is found to be the most suitable. By this method, two types of synthetic seeds are prepared: hydrated and desiccated. Hydrated synthetic seeds consist of embryos individually encapsulated in a hydrogel, whereas in desiccated type the coating mixture is allowed to dry for several hours in a sterile hood.

The Plant Cell Culture Technology Group of Nuclear Agriculture and Biotechnology Division had initiated research on synthetic seeds in the late 1980s working with sandalwood and mulberry. Eventually other crop systems such as banana, cardamom and rice have also been taken up for the production of synthetic seeds.

In general, the method used is as follows : The propagules (embryos / axillary buds / shoot tips) are carefully isolated from aseptic cultures and blot dried on filter paper, and are then mixed in sodium alginate prepared in nutrient medium. The propagules are then picked up manually by forceps and dropped into a solution of calcium chloride for 40 minutes. After the incubation period, the beads (synthetic seeds) are recovered by decanting the calcium chloride solution and washing them in sterile water 3 to 4 times before culturing on nutrient medium or on different substrates such as filter paper, cotton or soil for their growth and conversion to plants.

Results of the research on synthetic seeds in different plants are briefly described here and applications are highlighted in each case (Fig. 1).

Banana

Banana is an economically profitable crop with a large consumption in the country and a considerable export potential. Edible bananas are vegetatively propagated by suckers as viable seeds are generally not produced in these cultivars. New and effective means of propagating banana would be advantageous over conventional use of sucker material for germplasm maintenance, exchange and transportation. Shoot tips excised from the aseptically raised shoot cultures were excised and encapsulated to prepare synthetic seeds. High percent germination of these synthetic seeds was achieved on a very simple nutrient medium. Addition of the extract of blue green algae to the nutrient

Fig. I (1-3) : Synthetic seeds and plantlets in mulberry and banana. 1- synthetic seeds of mulberry planted in soil; 2- mulberry synthetic seeds germinating into plantlets in soil; 3-complete plantlets of banana obtained from synthetic seeds (arrow indicates portion of the synthetic seed still attached to the plantlet) matrix enhanced germination frequency. A cell mass (callus) initiated from male flower buds produced embryos which have been successfully encapsulated and germinated. Hence, a twin facility is available in banana to either encapsulate shoot apices or embryos.

Cardamom

Cardamom referred to as the queen of spices is an important plantation crop with considerable export earnings. It is generally propagated vegetatively as well as through seeds. Since cardamom is highly cross pollinated, seed derived plants exhibit considerable variation. Multiple shoot cultures from elite clones have been established aseptically for rapid micropropagation to generate a large number of plants. Shoot apices from aseptic cultures have been used for making synthetic seeds. Maximum germination of synthetic seeds was achieved and plants were grown successfully in soil.

Sandalwood

Sandalwood is a commercially valuable forest tree of India which, when propagated by seeds, shows variation. Culture of stem segments placed on an appropriate nutrient medium produced an undifferentiated callus which regenerated into a large number of embryos with the inherent potential to develop into a plant. Synthetic seeds were prepared by encapsulating embryos in a nutrient matrix of calcium alginate. Germination of these embryos into plants was possible. Addition of growth promoting substances to the matrix enhanced the germination frequency considerably.

Mulberry

Mulberry is an important plant whose leaves serve as chief source for feeding of silkworms and is therefore an important component of the silk industry. It is a perennial crop propagated by cuttings or by grafting. However, several cultivars of mulberry are difficult to root and this impedes the propagation. Axillary buds from aseptically growing plants were encapsulated to make individual synthetic seeds which look like pearl beads. Such beads could be stored for considerable time without loss of viability. In case of mulberry, only 30 –40 % cuttings survive the time period between pruning, transportation and final transplantation whereas synthetic seeds could be easily packed in bottles and transported, thus limiting space and ensuring increased viability and survival rate.

Rice

Rice is a major staple food crop of the world and has received considerable attention for investigations on genetic manipulations. Research on synthetic seeds can be useful for the large scale propagation of superior hybrids. Methods have been standardized for embryogenesis, and plant regeneration from indica rice cultivars has been achieved. Somatic embryos were singly encapsulated and were placed on nutrient medium and also on different substrates such as cotton, filter paper and macpeat. Encapsulated embryos developed into plants with varying frequencies. This technique has immense potential as it would permit multiplication of large scale propagation of elite hybrids.

Conclusion

The examples presented above suggest that, by employing synthetic seeds, the tissue culture raised plants can be regenerated on a simplified medium eliminating subcultures, thus reducing the cost of operation. Development of protocols for direct recovery of plants from synthetic seeds under non sterile conditions may have a greater impact.

Although large number of plants can be produced in tissue cultures through embryogenesis / multiple shoot cultures, their delivery is cumbersome. Embryos or shoots have to be separated singly and transferred for rooting to achieve root shoot balance, and the plants have to be hardened in the green house before field planting. Direct sowing of synthetic seeds in the soil does not need acclimatization often required for the tissue cultured plants. It thus provides an ideal delivery system enabling easy flexibility in handling and transport as compared to large parcels of seedlings or plants.

For large scale commercialization in synthetic seeds technology, enhanced production of propagules is necessary. Current tissue culture methods do not generate adequate propagules and are not sufficient to meet the demands of commercial exploitation of synthetic seeds technology. Standardization of methods for synchronization of developing propagules followed by automation of the whole process of sorting, harvesting, encapsulation and germination of the coated propagules can enhance the pace in the production of synthetic seeds.

(For further details, please contact the author.)

Acknowledgement

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INDIA'S ACHIEVEMENTS IN NUCLEAR ENERGY DEVELOPMENT

(Addressing the delegates of the 44th General Conference of the International Atomic Energy Agency (IAEA), Vienna, on September 20, 2000, Dr R. Chidambaram, Chairman, Atomic Energy Commission, highlighted the achievements of India in the development of nuclear energy for peaceful application in the areas of power, medicine, agriculture and industry, and simultaneously appealed to the world at large to shed unfounded fears about the safety of nuclear power generation and concerns over the management of long-lived radioactive wastes.

Following are the extracts from Dr Chidambaram's statement at the Conference.)

"Mr President,

"I have great pleasure in reading out a message from the Prime Minister of India, Mr Atal Bihari Vajpayee:

'We have emerged from the Millennium Summit of the United Nations with a redoubled resolve to work for balanced and sustainable socio-economic development for our people. The energy of the atom can be harnessed to further this agenda.

Nuclear power provides an important and clean energy option for mitigating the energy shortfalls in the developing world. Last year, we in India commissioned two modern nuclear power reactors, built with indigenous technology and expertise. We have also succeeded in increasing the average capacity factor in our nuclear power plants to a figure of 80%. Scientific research has uncovered beneficial applications of radioisotopes and radiation in agriculture, medicine and industry.

'Together with ensuring safety and monitoring safeguards, we believe that the IAEA has an important role in promoting technological capabilitaies among its member states for these developmental goals. As a founder member of the Agency, India would extend its fullest support to these endeavours.

'I take this opportunity to wish the 44th General Conference of the IAEA all success in its deliberations.' "

"....I would like to emphasize that the IAEA was created with the main objective of accelerating and enlarging the contribution of atomic energy to peace, health and prosperity throughout the world. This is the central pillar on which the Agency should rest while giving due consideration to safeguards measures to prevent the use of Agency assistance for military proposes, and establish safety standards for protection of health and minimisation of danger to life and property. Safety and safeguards are, indeed, important and necessary supporting activities for enlarging and accelerating the contribution of nuclear energy for peaceful purposes. However, they cannot become activities of the IAEA overshadowing the peaceful uses of atomic energy. Primacy must be accorded to technology. This is the only way we can faithfully interpret the time-tested Statute of the Agency."

"Our delegation supports the priority assigned to the potential role of nuclear energy in sustainable development in the Medium Term Strategy which is in line with the recommendations of the Scientific Forum held during the last General Conference. In this regard, we would like to reiterate that IAEA, with its comprehensive in-house expertise, as well as its access to globally available expertise, would do well to pool all resources to facilitate the role of nuclear energy in sustainable development. This is the need of the hour and the Agency programme should include the Role of innovative Nuclear Reactors and Fuel Cycles for Sustainable Development...."

"Even in countries which are currently seeing a slowdown in their nuclear power development programme, it is likely that a reversal would occur due to two factors - firstly, due to a substantial increase in oil prices as is happening now, and, secondly, due to their commitment to the Kyoto Protocol. For a large country like India, with its need to increase its per capita electricity consumption substantially, rapid growth in nuclear electricity generation capacity is of vital importance."

".... the second unit of Rajasthan Atomic Power Station, where coolant channel replacement and upgradation works were successfully completed in 1998 based on indigenous technology and tools, have been operating exceedingly well since then. During the last GC, we had announced the commissioning of an indigenously designed and built 220 MW(e) Pressurised Heavy Water Reactor (PHWR) at Kaiga. Since then another PHWR has gone commercial at Rajasthan. Two more units of 220 MW(e) are expected to reach criticality soon. Construction work on the two indigenously designed 500 MW(e) PHWR units at Tarapur is in full swing. The preparation of the Detailed Project Report (DPR) for the construction of two 1000 MW(e) VVERs at Kudankulam in technical cooperation with Russia began in April 1999 and is expected to be completed next year. Site related activities have already commenced."

"Necessitated by our limited uranium resources and in order to ensure security, india has opted for a closed nuclear fuel cycle policy, involving a fast breeder reactor programme and thorium utilization and associated fuel reprocessing and refabrication plants. The capabilities for providing the technology resources for our programme have been mainly derived from our strong R & D programme. In the 15-year old Fast Breeder Test Reactor (FBTR) at Kalpakkam, the performance of the unique and indigenously developed mixed Uranium-Plutonium Carbide fuel has been extremely good and so far it has reached a maximum burn-up of 53,830 MWd/t without any fuel failure. Preparations for the commencement of construction of a 500 MWe Prototype Fast Breeder Reactor (PFBR) are underway. The U^{233} fuelled Kamini research reactor is also being operated successfully. A closed fuel cycle is also important for the safe management of the environment as it brings down the quantity of high level wastes to very low levels."

"At the Bhabha Atomic Research Centre (BARC), there is a strong emphasis on activities related to the design and development of the Advanced Heavy Water Reactor (AHWR), using plutonium and U^{233}. The reactor will have several advanced safety features, such as passive safety systems not requiring either external power or operator action for activation. Experimental programmes to validate the computer codes used for the design of the natural circulation based coolant system of the AHWR are now well under way. India's efforts in developing the AHWR, which will facilitate thorium utilization, is an effort towards developing innovative reactor and fuel cycle designs for sustainable development of nuclear energy. The growth in installed power generation capacity will, of course, continue with plants of state-of-the-art designs of thermal and fast reactors with emphasis on improved safety. In this context, we appreciate the initiative of President Putin announced in the recent UN Millennium Summit where he has recognised that the most rapid energy production growth will take place in the next century in the developing countries. He has also said that to diminish ecological degradation caused by greenhouse gases and to save global fossil reserves for non-electricity uses by the present and future generations, there is the need to develop new nuclear technologies which are also proliferation resistant. As already mentioned by me earlier, IAEA with its comprehensive membership covering almost the entire world and, more importantly, the developing Member States, has the collective responsibility to find technological solutions to such problems. India on its part, as always, strongly supports these efforts and will actively participate in such initiatives."

"We are also pursuing R&D in non-grid based electricity applications of nuclear energy such as desalination, process heat generation, production of non-fossil fuels and compact portable power packs. Since 1995, MOX fuel designed at BARC has been introduced in a limited fashion in the Boiling Water Reactors (BWRs) at Tarapur. The fuel has performed well and the discharged assemblies will now undergo post-irradiation examination. This programme is a forerunner to the introduction of MOX in a bigger way for the utilization of Pu in thermal reactors, in addition to the programme of using Pu in fast reactors. This experience in plutonium recycle is also of importance in the context of our long term interest in thorium which, incidentally, is also an excellent host for deep burning of fissile materials as compared to other alternatives and offers excellent characteristics needed for addressing issues related to large-scale deployment of nuclear power globally."

"The power programme has been matched by good performance from its support base. The Nuclear Fuel Complex (NFC) has exceeded its target for the production of fuel and structural components for 1999-2000, while reducing the energy consumption per kilogramme of fuel fabrication. A few weeks back, it reached a major milestone by manufacturing the 2,00,000th bundle of PHWR fuel. The Heavy Water Board, by streamlining its manufacturing processes, ensured lower production costs while enhancing quality and productivity at the same time. The Electronics Corporation of India (ECIL) successfully tested and supplied microprocessor-based safety related systems for nuclear power plants at Kaiga and Rajasthan and installed successfully a man-machine interface (MMI) application package in the control instrumentation at Narora and Kakrapar."

"Our R&D programme has continued to lay emphasis in areas such as medicine, agriculture and industry. Tracer technology has been used successfully to detect leaks in petrochemical industries. A commercial facility for irradiation of spices upto 12,000 tonnes/year was commissioned early this year near Mumbai. A POTON irradiator, a demonstration plant for irradiation of 10 tonnes/hour of potatoes and onion is nearing completion. The Board for Radiation and Isotope Technology (BRIT) has developed and exported gamma chambers against orders received from the IAEA. It recently exported 50,000 curies of Cobalt-60 source along with irradiation flask and conveyor system to Bangladesh. Based on its R&D, the implantation of biocompatible metallic stents to help patients who have undergone angioplasty has been undertaken successfully.... "

"India continues to invest in fundamental research. For example, at the Institute for Plasma Research (IPR), work on the indigenous fabrication of the superconducting steady state tokamak SST 1 is in full swing and the commissioning of the tokamak is expected by end 2002. We would be happy to participate, on the basis of our experience, in international efforts towards development of fusion power."

"The Agency had placed before the Board of Governors a draft Memorandum of Understanding (MoU) between the IAEA and the OECD/NEA this year. The senior Experts Group, of which I was a member, did speak of enhancing synergies in the field of nuclear energy. But I wish to stress that synergies can be strengthened only in an atmosphere of transparency.... Our worry was that whatever co-operation was carried out under the auspices of the MoU should not be considered by the NEA to be confidential. Moreover, the purpose of the co-operation is lost when we are merely presented the results of the activities, without being privy to the scientific and technological effort by which the results were arrived at...."

"India has consistently supported the Technical Cooperation activities of the Agency. As in the past, India is pleased to pledge in full its share for the Technical Cooperation Fund 2001 and payment will be made on time as always. In addition, we are assisting, through expertise and equipment, two 'footnote-a' projects in Sri Lanka and have also offered our partnership in the establishment of a nuclear programme in that country...."

".....Although the contribution to the TC has been regarded as voluntary, it is based on the Resolution passed by the General Conference of the IAEA. To this extent, TC Funding should be regarded as morally obligatory if not mandatory. There is the need for the Agency to orient its TC programmes in such a way as to promote self-reliance among developing countries rather than reliance on developed countries. We had called on the Agency to identify centres of excellence for human resources development under the Technical Cooperation for Developing Countries (TCDC) programme and had offered our training facilities to scientists and engineers from developing countries. In this regard, in a signal event this year, the DAE signed a Memorandum of Understanding (MoU) with the IAEA for cooperation in connection with the Agency's regional and inter-regional training events, individual and group fellowships training programmes carried out as part of the Technical Cooperation activities of the IAEA. The MoU is an important milestone in our relationship with the IAEA and formalises our longstanding offer to make the Bhabha Atomic Research Centre (BARC) a "centre of excellence/Regional Resource Unit (RRU)" under the Agency's Technical Cooperation for Developing Countries (TCDC) programme."

"We reiterate our appreciation of the Agency's efforts in preventing illicit trafficking in nuclear materials. Yet, in our neighbourhood, clandestine acquisition of sensitive technology and materials is known to have occurred. Preventing this requires the commitment of Member States of the Agency. Both on the issue of physical protection measures and export controls, India follows a stringent law - based system which is borne out by its exemplary record."

"The stockpiles of weapons of mass destruction, in the custody of those who were the first to build up such deadly arsenals, remain at alarmingly high levels. Our own policy is based on responsibility and restraint, and we continue to press with undiminished commitment for universal, verifiable nuclear disarmament, even while safeguarding our strategic space and autonomy in decision-making. International peace cannot be divorced from the need for equal and legitimate security for all."

"Scientifically speaking, we move into the new millennium in 2001. The new century must cause us to pause, to rethink our strategies, and to examine our options. We need a fresh look at the importance of nuclear power. We need to shake off the fetters of prejudices and apprehensions that have led to public fears of this very important, indeed crucial technology. The concerns about nuclear power stem primarily from fears about safety of reactors, and concerns over management of long-lived radioactive wastes. These worries are exaggerated, since technological solutions are available for addressing both these issues. Let us pool our collective wisdom and scientific knowledge and work together to address the challenges of global development through deployment of nuclear technologies overcoming the barriers that come in the way."

"Thank you, Mr. President."

AUGMENTED URANIUM METAL PRODUCTION FACILITY INAUGURATED

Large-scale production of nuclear grade pure natural uranium metal is undertaken at the Uranium Metal Plant (UMP), BARC. UMP is in operation since 1959 and has been supplying metal fuel for research reactors, CIRUS and DHRUVA. Uranium metal ingots are produced by magnesiothermic reduction (MTR) of UF_4 (green salt) in a bomb type reactor vessel. The present batch size of metal ingot being produced at UMP is 200-250 kg. To meet the enhanced requirement of fuel for CIRUS and DHRUVA at their full power, it was decided to increase the production of uranium ingots by increasing the batch size of magnesiothermic reduction to 500 kg. Based on an in-depth analysis of various factors including upgradation of technology and safety of operation, it was proposed to construct a new facility exclusively for MTR operation. Accordingly, a new Augmentation of Uranium Metal Plant (AUMP) building has been erected by the side of old RCnD Shed at South Site.

While inaugurating the new AUMP facility on March 16, 2000, Dr. Anil Kakodkar, Director, BARC, termed the commissioning of AUMP as an important milestone in the production of nuclear fuel in the country. Dr. C.K. Gupta, Director, Materials Group, BARC, appreciated the excellent performance of UMP for meeting targeted production of uranium ingots in the last few years and for maintaining excellent safety records in the operation of the "highly exothermic" magnesiothermic reduction process.

The process flow sheet to be practised at AUMP is shown in Fig. 1. The major inputs to the plant are green salt (UF_4) of certified quality received from UMP in portable steel hoppers and magnesium chips received in steel drums. The requisite quantity of UF_4 and Mg chips are weighed on a weighing platform and added into a wobble blender for thorough mixing. The blender is also equipped with a jacketed heater and a vacuum system with argon purge for emergency use for expulsion of moisture and volatiles from reactants. Reaction vessels made of approved materials are lined with magnesium fluoride powder of specified quality. A vibrator or jolter is used for lining the reactor vessel with centrally placed mould.

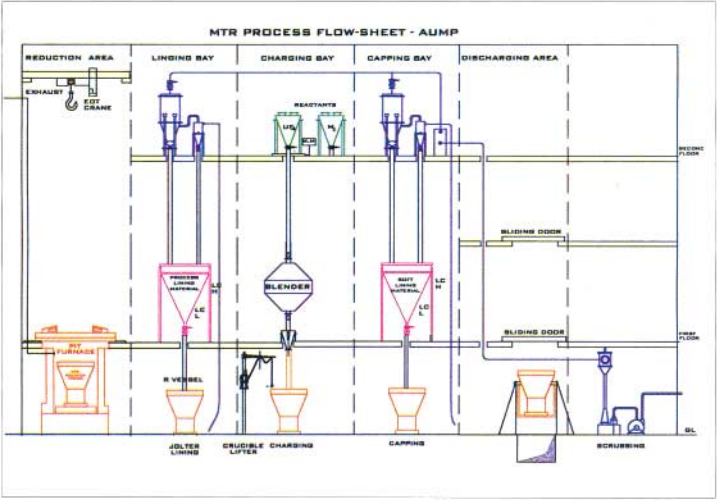

Fig. 1 MTR process flow-sheet - AUMP

Fig. 2 Pit furnace for reduction

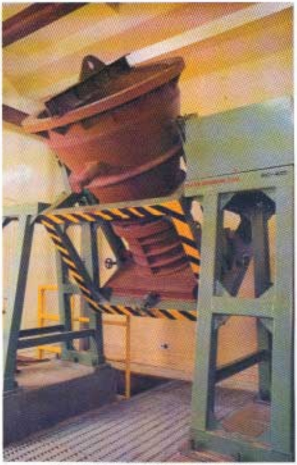

Fig. 3 Discharging stand for MTR reactor

The lined reactor is charged with Mg-UF_4 mixture from blender by gravity through a tube with internal baffles so that the mixture does not flow too fast to break the lining. After the charging of reactants with suitable compaction, the top is covered with a layer of soft lining material (SLM) and compacted to form a hard cap. The lid (top flange) is then placed in position to close the reactor vessel, inserting a thermocouple in a closed central cavity on the lid to monitor triggering of main reaction. After tightening the top flange with high strength fastener, the reactor vessel is lifted by overhead crane and placed into a top loading pit furnace (Fig. 2). A predetermined heating schedule is followed to raise the furnace temperature to over 630°C. Initiation of main reaction (firing) is indicated by a sudden rise in temperature of the core after setting the final temperature at >630°C. On ensuring the completion of reaction (firing), furnace heating is discontinued and the reactor is cooled to ~500°C inside the furnace and finally to room temperature with forced drought in a cooling chamber.

Fig. 4 Dr Anil Kakodkar, Director, BARC, inaugurating the Augmentation of Uranium Metal Plant facility (AUMP). Accompanying him are (left to right) Dr C.K. Gupta, Director, Materials Group, Dr D.K. Bose, Head, Uranium Extraction Division, and Mr A.M. Meghal (ex-Head, PPES, UED).

Fig. 5 Dr Anil Kakodkar, Director, BARC, delivering the inaugural address at metal reduction high bay area in AUMP.

The reactor is then removed from the furnace area and transferred to the discharge area equipped with facilities for controlling the air borne dust (Fig.3). The reactor lid is removed and slag is loosened by means of pneumatic chisel. The reactor vessel is finally inverted over a grizzly and struck by pneumatic hammer until the contents – the metal ingot, slag and lining material fall out. Cleanly separated ingot is removed from fused slag lumps, mechanically cleaned and stored for despatch to Atomic Fuels Division for fabrication of fuel elements. Slag lumps produced during reaction are separated and sent to Uranium Slag Treatment Facility (USTF) for grinding and recovery of residual uranium in slag. Fine slag that falls through the grater are recycled as Soft Lining Material (SLM) for lining and capping of reactor.

Magnesiothermic reduction of UF_4 as mentioned earlier is "highly exothermic" which raises the temperature at the core to >1400°C and generates impulsive pressures. Safe operation of such process needs very careful quality control of input materials, faultless design of reactor vessel and accurate heating schedule. Due to strategic nature of the work, no standard design data is available in open literature.

Design data generated in-house based on rich experience of the existing plant are utilized for equipment design, layout and safety aspects of the new plant. In all the unit operations in the plant, critical measures are taken to control dust and radioactivity by proper isolation and containment of the system, and by adopting mechanical transfer and remote control, wherever possible.

Fig. 6 Dr Anil Kakodkar, Director, BARC, inspecting the 500 kg(U) capacity MTR bomb reactor.

Some of the important safety features incorporated in AUMP are enlisted below :

(a) Strict quality control over input materials;(b) Furnace design incorporating heating of bottom portion of the reactor only, leaving top flanges and fasteners away from hot zone; (c) Use of fire-survival cables for connecting heating elements and thermocouples; (d) Primary containment of dusty operations like lining, charging and discharging of the reactor; (d) Remote operation with specialised instrumentation and control system; and (e) Provision of direct access to fire tenderer to furnace area in the event of any unusual occurrence.

BARC SIGNS MoU WITH RAJASTHAN AGRICULTURAL UNIVERSITY

A Memorandum of Understanding (MoU) which envisages the development of collaborative resarch programmes and application of radiation and radioisotopes in the field of agriculture and veterinary sciences for uplifting agriculture and livestock potential in the western dry region in particular and in Rajasthan in general, was signed jointly by Dr Anil Kakodkar, Director, BARC, and Prof. C.P.S. Yadava, Vice Chancellor, Rajasthan Agricultural University, Bikaner, at Pant Krishi Bhavan, Jaipur, on July 13, 2000. Among the many dignitories from Rajasthan who witnessed the signing ceremony, were Mr Tayyab Hussain, Minister of Agriculture, Government of Rajasthan, Ms Bhatnagar, Principal Secretary, Ministry of Agriculture, Dr N.R. Bhasin, Principal Secretary, Higher Education, Dr V.S. Kavadia, Director of Research, RAU, Bikaner, Dr M.P. Sahu, Associate Director of Research, RAU, Director of Agriculture, Dept. of Agriculture, Government of Rajasthan and senior faculty members of the University. From BARC, Dr (Ms) A.M. Samuel, Director, Biomedical Group, Dr R.B. Grover, Secretary, BRNS, Dr R.K. Mitra, Head, NA&BTD, Dr S.E. Pawar and Dr T. Gopalakrishna participated in the function.

The vast desert region comprising the districts of Jaisalmer, Barmer, Bikaner and Jodhpur of Rajasthan is environmentally handicapped, and agricultural production remains unstable due to stresses like low rainfall and high temperature. Besides crop failure, which affects the economy of the region, drought also leads to wind erosion and subsequent creeping of sand dunes, which cover fertile agricultural lands. The application of nuclear techniques in agricultural research for these areas is highly relevant. A grant of Rs 1.26 crore has been provided under this MoU primarily to establish a Radiotracer laboratory at Agricultural Research Centre, Bikaner; for multilocation testing and multiplication of BARC crop varieties by RAU; and to implement collaborative research programmes in nuclear agriculture and post-harvest technology.

After signing of the MoU, Dr Anil Kakodkar, Director, BARC, and Prof. C.P.S. Yadava, Vice-Chancellor, RAU, display the documents. (From L to R) : Ms Krishna Bhatnagar, Dr A.M. Samuel, Mr Tayyab Hussain, Dr V.S. Kavadia, Dr R.K. Mitra, Dr Anil Kakodkar, Dr T. Gopalakrishna, Prof C.P.S. Yadava, Dr S.E. Pawar and Dr R.B. Grover.

Prof. Yadava thanked Dr Kakodkar for BARC's help in establishing a Radiotracer laboratory at Bikaner and hoped that the collaborative research envisaged under this MoU would bring about significant changes in the agricultural scenario in the western region of Rajasthan.

Dr Kakodkar, in his address, explained the need for establishing a meaningful synergy between BARC and State Agricultural Universities, especially to build up partnership in research efforts. He further explained how BARC could make significant contributions in agriculture in collaboration with the State Agricultural Universities. Dr Kakodkar gave assurance to RAU that BARC would help in radiation/radioisotope-based research in soils, fertilizers, plant breeding, biotechnology, water-shed management, sustainability of production system, post-harvest technology and other complementary research areas. Dr A.M. Samuel emphasised the need to integrate the recombinant DNA technology in traditional agricultural research. She also added that nuclear techniques can have a bigger impact in veterinary sciences. Dr Grover explained the idea behind establishing BRNS and how the Universities could take advantage from the agency for nuclear-related research programmes. The Hon'ble Minister of Agriculture, Mr Tayyab Hussain, acknowledged the help rendered by BARC and DAE to the causes of Rajasthan's development. He advised the University to take full advantage of this opportunity. Dr Mitra, Dr Pawar and Dr Gopalakrishna gave an account of the research work currently being pursued in BARC. Dr Kavadia outlined the major research programme of RAU. He also gave an account of the research collaborations with BARC.

BARC TRAINING SCHOOL GRADUATION FUNCTION

The Graduation Function of the 43rd OCES (Orientation Course for Engineering Graduates & Science Post Graduates) and 9th OCEP (Orientation Course for Engineering Post Graduates) was held on August 31, 2000 at the Central Complex Auditorium.

Prof. P. Rama Rao, Vice Chancellor, University of Hyderabad, gave away the Homi Bhabha Prizes and delivered the Chief Guest's address. Dr R. Chidambaram, Chairman, AEC and Secretary, DAE, and Dr Anil Kakodkar, Director, BARC, presided over the function.

Mr Partha Das of Instrumentation Engineering discipline who stood first among all 12 OCES43 disciplines receiving the Homi Bhabha Prize from the Chief Guest Prof. P. Rama Rao, Vice Chancellor, University of Hyderabad.

131 OCES43 and 16 OCEP9 Trainee Scientific Officers graduated and were inducted into the DAE family. The following is the list of Homi Bhabha Prize Awardees.

No	Discipline	Name
1.	Mechanical	Mr Imran Ali Khan
2.	Chemical	Mr Krishna Kumar Singh
3.	Metallurgy	Mr Arjit Laik
4.	Electrical	Ms Yachika Verma
5.	Instrumentation	Mr Partha Das
6.	Electronics	Mr Amit Chauhan
7.	Computer Science	Mr Pankaj Saksena
8.	Civil	Mr Dauji Saha
9.	Physics	Mr Jayanta Debnath
10.	Chemistry	Mr Rahul Tripathi
11.	BioScience	Ms Sheetal Uppal
12.	Env. Science	Mr Rajesh Kumar
13.	M. Tech	Mr Manish Sharma

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