CHAPTER II: DEPARTMENT OF ATOMIC ENERGY

2.1 Delays in setting up of a Nuclear Desalination Plant

Bhabha Atomic Research Centre took up a demonstration project for setting up a nuclear desalination plant which was to provide potable water to the water scarce coastal areas of the country and had potential of earning foreign exchange through export of such plants. The project remained incomplete despite cost overrun of Rs.35.79 crore and time overrun of more than six years due to inadequate pre-project feasibility study and poor implementation of the project.

2.1.1 Introduction

Bhabha Atomic Research Centre (BARC) is a premier multi-disciplinary nuclear research centre of India under Department of Atomic Energy (DAE). BARC has expertise in various thermal desalination technologies including setting up and operating a Multi Stage Flash (MSF) desalination[1] plant with a capacity of 425 m^3 of purified water per day. Based on this experience, BARC proposed, in April 1997, to set up a Nuclear Desalination Demonstration Plant in conjunction with Madras Atomic Power Station (MAPS) at Kalpakkam using steam and power from MAPS. DAE obtained approval for the project from the Atomic Energy Commission (AEC), an apex body of DAE, in September 1997 with a firm commitment that if sufficient funds were made available, the project would be completed in 48 months. Accordingly, DAE sanctioned the project in November 1997 at a cost of Rs.30.97 crore with scheduled date of completion by November 2001.

2.1.2 Objective of the project

The objective of the project was to achieve indigenous capability to design, fabricate and operate a MSF plant and a Reverse Osmosis[2] (RO) sea water desalination plant at a nuclear power station. Keeping this objective in view it was planned that:

- The plant would produce 6300 m^3 of purified water per day (4500 m^3 per day through MSF desalination plant and 1800 m^3 per day sea water through RO plant) in conjunction with MAPS Kalpakkam using steam and power from MAPS.

[1] Multi-stage flash is a desalination process that distills sea water by flashing a portion of the water into steam in multiple stages of what are essentially regenerative heat exchangers.
[2] Reverse Osmosis is a separation process that uses pressure to force a solvent through a membrane that retains the solute on one side and allows the pure solvent to pass to the other side.

- A portion of the processed high purity water would meet the total water requirement of MAPS and other facilities at Kalpakkam and the remaining water would augment the drinking water resources of the township and nearby areas.

- The nuclear desalination demonstration project would pave the way for setting up of large-scale desalination plants for providing water in coastal water-scarce areas of the country.

- It was envisaged that the operational experience of this plant would be made available to the member states of International Atomic Energy Agency (IAEA) interested in adoption of large scale nuclear desalination technology and a significant potential for earning of foreign exchange through export of desalination plants to Middle East and North African countries was also projected.

2.1.3 Audit findings

2.1.3.1 Deficient project planning

As per the project proposal, the nuclear desalination plant was planned to be constructed inside MAPS campus. Availability of space for setting up an "Additional Upgrading Facility (AGF)" for the power plant and the nuclear desalination plant at MAPS was jointly decided by BARC and MAPS in August 1996, i.e. prior to sanctioning of the project. However, considering the technical requirement of having an AGF in proximity to MAPS, BARC, in August 2000, proposed shifting the location of the desalination plant outside the campus of MAPS. Shifting the location entailed major changes in electrical system, steam supply and seawater intake system which led to significant upward revision of costs.

Further, as per the initial proposal, 40 persons for operations of the desalination plant were to be deployed from MAPS and Kalpakkam Fuel Reprocessing Plant. However, since this did not seem feasible in view of the change in location, the creation of 79 additional posts at an expenditure of Rs.71 lakh and requirement of Rs.5.54 crore for construction of 79 residential quarters was also projected.

The above facts indicated that the pre-project feasibility was inadequate necessitating a change in location of the plant causing delay and cost overrun as discussed in paragraphs 2.1.3.2 and 2.1.3.3 below.

2.1.3.2 Delay in project implementation

BARC could only commission the RO desalination plant of 1800 m^3 per day capacity in August 2002. The MSF plant encountered problems with fabricators of evaporation modules. The MSF desalination plant consisted of 10 number of large rectangular MSF evaporator modules. These modules were the core equipment of the plant. M/s Artson, the firm on which the order was placed for fabrication and installation of the MSF modules, could only complete the mock up module and 22 *per cent* of the module fabrication till September 2002, which was the revised date of completion of the project. Though there were financial and technical problems with the firm seriously affecting the progress of work, the order was kept alive till June 2004. Finally, the pending work was re-tendered in July 2004 and the work could only be awarded in April 2006. Poor contract management and delay in re-tendering resulted in further delays and cost escalations. The pending work of fabrication and installation of MSF modules was yet to be completed as of September 2007.

While accepting the delay in project completion, DAE stated in December 2007 that the project was the first of its kind and the largest nuclear desalination demonstration plant based on hybrid MSF-RO technology in the world and the fabrication of the MSF modules gave rise to problems which were unanticipated. It further stated that scarcity of skilled manpower had also impacted completion of MSF fabrication. The reply has to be viewed in light of DAE's claim that it had embarked upon the project based on earlier experience and adequate pre-feasibility studies.

2.1.3.3 Time and cost overrun

In order to accommodate the additional cost due to shifting of location, DAE with the approval of AEC, revised the cost of the project from Rs.30.97 crore to Rs.41.96 crore in September 2000 and rescheduled the date of completion to March 2002.

Again in January 2004, BARC sought second cost revision from Rs.41.96 crore to Rs.49.97 crore mainly due to local inflation, fluctuation in foreign exchange rate, inclusion of certain additional items of work under machinery and equipment, civil works and other capital equipment which was sanctioned by DAE in October 2004 and rescheduled the date of completion of the project to December 2004. At the instance of BARC and with the approval of AEC, DAE revised the cost of the project for the third time to Rs.66.76 crore in January 2007 as BARC encountered problems with fabricators of the MSF evaporation modules. This resulted in total cost escalation of Rs.35.79 crore, i.e. 116 *per cent* over and above the original sanctioned cost.

AEC, while approving third revision in cost to Rs.66.76 crore had observed that though it was a demonstration project, it had taken 10 years for its completion and desired that a report indicating lessons learnt on the implementation of the project be submitted to AEC. In this report of March 2007, BARC admitted that before embarking on similar projects, site selection and layout should be finalised and frozen in consultation with all parties. Further, financial capacity of the contractor should be one of the criteria for placing the purchase order. Incidentally, as per the General Financial Rules, these safeguards were anyway required to be ensured before embarking on projects and entering into contracts.

Thus, inefficient project planning and implementation led to increase in cost from Rs.30.97 crore to Rs.66.76 crore (116 *per cent*). Even though the project was to be completed by November 2001, DAE could not ensure its completion as of September 2007, by when an amount of Rs.44.24 crore was spent and completion date has been further extended to December 2007. Thus, the project has suffered from a time overrun of six years and a cost overrun of 116 *per cent* so far.

DAE replied in December 2007 that the decision to construct the AGF was taken subsequent to the selection of location of the desalination plant. DAE also claimed that unforeseen circumstances had led to cost and time overruns. The reply of the DAE was not tenable as decision on the location of the desalination and the AGF were taken in 1996 and the decision to shift the location of the desalination plant was taken subsequently in 2000, which led to the initial cost and time overruns. Moreover, the inclusion of the additional items and the consequent cost revision was also necessitated due to shifting of location, which was itself indicative of deficient project planning.

2.1.3.4 Inadequate utilisation of RO Plant

In October 2006, DAE appraised AEC that 1800 m^3 / day Reverse Osmosis section of the project was commissioned in August 2002 and since then this plant had been operating regularly and supplying potable water to Indira Gandhi Centre for Atomic Research (IGCAR) reservoir. However, Audit observed that the plant had produced only 2.26 lakh m^3 water from September 2002 to March 2007, representing 8.22 *per cent* of the total installed capacity. BARC stated that the installed capacity of such demonstration plants could be attained only in progressive manner.

DAE stated in December 2007 that the total quantity of desalinated water expected to be produced during September 2002 to March 2007 was 27.54 lakh $m^{3.}$ However, considering a single shift operation against three shift operations due to shortage of manpower, non operation of the plant due to maintenance shutdown of MAPS and tsunami disaster, expected production was 4.20 lakh m^3 and the actual production of potable water during September 2002 to March 2007 was 2.26 lakh m^3 with capacity utilisation of 53.84 *per cent*. DAE's reply was not tenable as actual production of purified water during the last nine months i.e. June 2006 to March 2007 was only 32,006 m^3 which was a meager 6.6 *per cent* of the installed capacity of the plant. Thus, the fact remains that even after five years of commissioning, utilisation of RO plant was highly unsatisfactory and the objective of providing purified water to meet the needs of MAPS and other facilities at Kalpakkam and augment drinking water resources of township and nearby areas remained unachieved.

2.1.4 Conclusion

The project on "Nuclear Desalination Demonstration Plant" which aimed at demonstrating the indigenous capability in design, fabrication and operation of a desalination plant on an industrial scale along with meeting the water requirement of various DAE facilities at Kalpakkam, was yet to be fully commissioned due to deficient planning and poor implementation even after ten years of its commencement and expenditure of Rs.44.24 crore. The delays have also resulted in repeated time and cost overruns which escalated the cost of the project and the project remained incomplete as of September 2007. As a result, not only did the objectives of providing water to water-scarce coastal areas of the country remained unachieved, the earning of foreign exchange through export of desalination plants to Middle East, North African countries and to IAEA member countries also remained unfulfilled.

Thus, DAE not only failed to complete the project on time, but also failed in its objective of harnessing the technology for providing water to water scarce coastal regions of the country and earning foreign exchange through the export of the desalination plant.

2.2 Non-installation of a Rapid Thermal Annealing System

Failure of the Institute of Physics, Bhubaneswar to procure a dry air compressor for installation of Rapid Thermal Annealing System resulted in an investment of Rs.28.48 lakh remaining blocked and the system remaining unutilised for more than two years.

Institute of Physics (IOP), Bhubaneswar, an autonomous institution under the Department of Atomic Energy (DAE), placed a Purchase Order in March 2005 on a foreign firm for procurement of Rapid Thermal Annealing[3] (RTA) System for thermal processing of various samples using programmed heat pulses for very short durations. As per the Purchase Order, the system was to remain under warranty for a period of one year from the date of shipment. A dry air compressor was required for installation of the system but no supply order was placed for the compressor, as the same was available with IOP.

IOP received the system in July 2005. The Indian Agent of the foreign firm deputed the service engineer to IOP in August 2005 for installation of the system. During installation, the service engineer observed that the compressed air which was available from the present compressor contained moisture. He concluded that the presence of moisture in the compressed air would damage the lamps and the quartz window, if he started the calibration and

[3] Annealing is heat treatment that alters the microstructure of a material causing changes in properties such as strength and hardness.

recommended procurement of a high capacity dry air compressor for completing the installation. In September 2005, a requisition for procurement of dry air compressor was placed and quotation for the item was invited in October 2005. However, it was observed in audit that the specifications for the air dryer were not comprehensive. None of the two offers received by IOP were found suitable by the Evaluation Committee which felt that it was not clear whether the compressor unit being offered by the firm consisted of a single or dual compressor and, therefore, suggested invitation of fresh quotations, clearly stating the required specifications in detail. Thereafter, quotations were invited for the second time in May and for the third time in August 2006 but IOP could not place any Purchase Order. Meanwhile, the warranty of the system expired in June 2006 on completion of one year from the date of shipment of the equipment. Due to indecisiveness of IOP in finalising procurement of a small equipment like a dry air compressor costing around Rs.2 lakh resulted in Rapid Thermal Annealing System remaining uninstalled for more than two years from the date of its receipt.

Accepting the audit observations, DAE replied in November 2007 that there had been delay in procurement of new dry air compressor due to some technical problems and that the Purchase Order for a dry and oil free compressor has been placed in May 2007. It further stated that Indian agent and the supplier would be contacted on receipt of air compressor for necessary action. It also stated that it would request the supplier to commence the warranty from the date of the installation of the system at IOP. However, the fact remains that the warranty clause clearly stipulated that the equipment would be covered under warranty for one year from the date of shipment and therefore, the supplier was not legally bound to entertain IOP’s request.

Thus, failure of IOP to ensure availability of the required dry air compressor for installation of Rapid Thermal Annealing System resulted in an investment of Rs.28.48 lakh remaining blocked and the system lying unutilised for more than two years. IOP also lost the advantage of warranty as the calibration of the system is yet to be done. Moreover, due to non-installation of the equipment, the samples were being produced manually, affecting the research output.

2.3 Delay in commissioning of Incinerator System

Inadequate follow up with the supplier to commission the incinerator system purchased by Nuclear Fuel Complex, Hyderabad after spending Rs.52.81 lakh resulted in delay of nine years in commissioning of the equipment.

Nuclear Fuel Complex (NFC), Hyderabad a unit of Department of Atomic Energy placed an order for design, engineering, manufacture, fabrication, inspection, supply, erection and commissioning of LPG fired twin-chamber incinerator in May 1997 at an estimated cost of Rs.62.35 lakh on M/s Aireff deTox Inc., Thane. The incinerator was supplied in June 1998 and was commissioned with non-active waste in August 2000.

Audit examination of procurement and utilisation of the incinerator revealed that the incinerator was commissioned with active waste only in July 2007. NFC also did not take any action against the supplier for failure to commission the incinerator with active waste for nine years as discussed below:

According to the terms and conditions of the purchase order, 85 *per cent* of the order value was to be paid on pro-rata basis up to the receipt of the items and balance 15 *per cent* after erection, commissioning and satisfactory trial run of the system. The firm was also required to furnish a performance guarantee of Rs.6.54 lakh in the form of bank guarantee valid for a period of one year with a grace period of six months. Supply of the whole system/equipment and its commissioning was to be completed within a period of six months from the date of issue of Purchase Order, i.e. on or before 15 November 1997.

The firm furnished two bank guarantees for Rs.6 lakh each in May 1997 and supply of all the items was completed in June 1998. NFC released Rs.52.81 lakh to the firm during the period September 1997 to April 1998. The commissioning of the system with non-active waste was successfully completed in August 2000. The commissioning with active waste started in June 2001. However the incinerator could not be operated continuously due to various problems and the supplier was asked to rectify the shortcomings. Though the firm's engineers worked on the incinerator during April 2003 to September 2003 they could not commission the system till November 2003.

The firm agreed in January 2005 to commission the equipment in all respects by February 2005, failing which NFC could withhold the balance amount due to the firm and encash the bank guarantee. The firm, however, failed to commission the equipment as per its commitment. NFC did not encash the bank guarantee which was valid up to 31 May 2005 with a claim period up to 31 August 2005. Instead, NFC requested the supplier to extend the bank guarantee up to 31 August 2005 which the firm did not do. The bank guarantee lapsed. It was then decided by NFC to take up the commissioning work departmentally with the leftover amount of Rs.6.25 lakh.

DAE stated in November 2007 that the unit was made fully operational for all items including active waste (cellulose) departmentally. As regards not encashing the bank guarantee, NFC requested the supplier on 24 August 2005 to extend the bank guarantee up to 31 August 2005 which the firm did not and a final opportunity was offered to the supplier to complete the work and commission the unit on or before 21 March 2006.

The reply of DAE is not tenable as the action against the defaulting supplier should have been initiated as per terms and conditions of the contract and DAE should have explored possibilities of commissioning of the incinerator through other alternate sources without waiting for nine years. Considering that the normal expected life of the incinerator was only 15 years, inaction on the part of NFC has led to 60 *per cent* of the expected life of the incinerator lapsing even before its full commissioning.

2.4 Avoidable payment of penal interest and idle expenditure on vacant flats

Failure of Saha Institute of Nuclear Physics, Kolkata to ensure availability of funds from the Department of Atomic Energy for making timely payment to Kolkata Metropolitan Development Authority for acquisition of 64 ready built flats resulted in an avoidable expenditure of Rs.72.12 lakh towards payment of penal interest. In addition, 38 flats remained unoccupied resulting in idle expenditure of Rs.5.16 crore.

Saha Institute of Nuclear Physics (SINP), Kolkata, an autonomous body under the Department of Atomic Energy (DAE), requested Kolkata Metropolitan Development Authority (KMDA) in April 2002 to allot ready built flats for its staff. KMDA, in September 2002, agreed to sell 64 flats in eight buildings on the East Calcutta Township on Eastern Metropolitan Bye-pass at a cost of Rs.7.90 crore. SINP accepted the offer of KMDA in September 2002 and deposited Rs.30 lakh as earnest money in March 2003. KMDA informed SINP that the entire payment was to be made within nine months in three installments. They also stated that penal interest at the rate of 15 *per cent* per annum would be charged, if the payments were not made as per the said schedule.

Audit examination disclosed that though KMDA extended/revised the payment schedule time and again at the request of SINP, SINP/DAE could not ensure timely payment of installments to KMDA. This resulted in payment of penal interest of Rs.72.12 lakh on purchase of 64 flats costing Rs. 7.90 crore as detailed below:

(Rs. in crore)

Sl No.	Amount payable	Due date of payment	Amount paid	Actual date of payment	Penal interest
1	0.30	31 March 2003	0.30	30 March 2003	0.00
2	2.83	30 June 2003	2.83	1 December 2003	0.18
3	2.35	31 December 2003	1.77	23 December 2003	
			0.16	6 May 2004	
			0.42	25 May 2005	0.09
4	2.42	29 February 2004	2.42	25 May 2005	0.45
Total	**7.90**		**7.90**		**0.72**

SINP took possession of 56 flats in December 2005 and balance eight flats in March 2006 after payment of penal interest in January 2006.

It was also observed in Audit that of the 64 flats, only 10 flats were allotted to SINP employees while 16 were converted into guest house and students' hostel. The rest of the 38 flats purchased from KMDA remained unoccupied for about two years, pointing to excessive procurement resulting from improper assessment of requirement.

SINP stated in May 2007 that due to some technical difficulty at DAE level in getting the financial approval, release of funds were delayed.

DAE stated in December 2007 that payment of first and second installments were delayed due to administrative process involved. The payment for the third and final installment was delayed due to delay in construction and consequent delay in joint inspection of the flats. DAE also stated that 10 more flats were getting allotted shortly and the main reason for the flats lying vacant was that more and more employees were opting to purchase their own flats.

Thus, failure of DAE/SINP to ensure availability of funds for making timely payment of installments towards acquisition of 64 ready built flats for the staff resulted in an avoidable expenditure of Rs.72.12 lakh towards penal interest. Further 38 flats remained unoccupied due to improper assessment of requirement resulting in idle expenditure of Rs.5.16 crore.

2.5 Development and Application of Technologies in Raja Ramanna Centre for Advanced Technology

Raja Ramanna Centre for Advanced Technology could construct and commission only four out of six beamlines on SRS Indus-1 even after ten years of the scheduled completion of the project. The utilisation of beamlines of Indus-1 was only 39 *per cent* of the available days. Though SRS Indus-2 was to be commissioned by 1996-97, RRCAT was yet to commission it to designed energy levels as of March 2007 despite an expenditure of Rs.95.77 crore. The projects on "Accelerator for industrial and medical application" and "Accelerators for medical sterilisation and food irradiation" could not achieve the intended objectives, despite an expenditure of Rs.15.04 crore. Another project on "Laser photocathode RF Linac"to be completed by March 2002 could not be completed even after a delay of more than five years and an expenditure of Rs.3.58 crore. RRCAT also had to shut down a laser production unit constructed at a cost of Rs.6.80 crore as a result of which, expenditure was largely unfruitful.

2.5.1 Introduction

The Centre for Advanced Technology (CAT), Indore, a unit of the Department of Atomic Energy (DAE), was set up in March 1987 to undertake research and development in two frontline areas of science and technology, namely accelerators[4] and lasers[5] and their applications. The other scientific activities of CAT included production of high tech equipment and scientific/ technical infrastructure. CAT was renamed as the Raja Ramanna Centre for Advanced Technology (RRCAT) in February 2006. As of 31 March 2007, RRCAT had 1298 sanctioned posts of which 1056 posts were for scientific and technical work and the remaining 242 were for administrative and auxiliary work. Scientific and technical personnel in position were 1034, while the administrative and auxiliary complement comprised of 235 personnel. The total annual expenditure of RRCAT varied between Rs.75.25 crore to Rs.111.95 crore during 2001-07. The two major research and development programmes of RRCAT are:

- **Accelerator:** Building a 450 MeV[6] Synchrotron[7] Radiation Source (SRS) Indus-1 and then a 2.5 GeV[8] SRS Indus-2; setting up beamlines[9] to utilise Indus-1 and Indus-2 and developing industrial and medical accelerators.

- **Laser:** Taking up pilot scale manufacture of the equipment and supplying them to the users to establish technical and economic viability of the technology; making available lasers, laser related instrumentation etc. to universities, R&D Centres, hospitals and industries; and easing the need for import of lasers and dependence on foreign suppliers.

Audit examined implementation of these programmes and applications and the findings are discussed below:

2.5.2 Accelerators

RRCAT is constructing a national facility for Synchrotron Radiation Source for research workers to satisfy the needs of a large number of users from all parts of the country to work in several branches of science and technology, besides providing valuable interaction between scientists from various disciplines.

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[4] A particle accelerator is a device that uses electric fields to propel electrically charged particles to high speeds and to contain them. An ordinary CRT television set is a simple form of accelerator. There are two basic types: linear (i.e. straight-line) accelerators and circular (i.e. circles) accelerators.

[5] A laser is a quantum-mechanical device that produces coherent radiation. The term "laser" is an acronym: Light Amplification by Stimulated Emission of Radiation.

[6] Mega electron Volt

[7] It is a type of cyclic particle accelerator.

[8] Giga electron volts

[9] In particle physics, a beamline is the line in a linear accelerator along which a beam of particles travels. It may also refer to the line of travel within a bending section such as a storage ring or cyclotron. In materials science, physics, chemistry, and molecular biology a beamline is the experimental end station utilising particle beams from a particle accelerator, synchrotron light obtained from a synchrotron.

The facility included construction of SRS Indus-1[10] and SRS Indus-2[11] in the Seventh Plan and Eighth Plan respectively. For utilisation of Indus-1, it was envisaged to construct nine beamlines. Out of these nine beamlines, two were to be constructed by the Inter University Consortium (IUC) established by the University Grant Commission and the remaining seven by RRCAT/Bhabha Atomic Research Centre (BARC).

In February 1992, DAE approved an Eighth Plan project “Utilisation of Indus-1 and Indus-2 Synchrotron Radiation Sources” at a total cost of Rs.17.25 crore to be completed by Eighth and Nine Plan respectively. The main objective of the project was to construct five beamlines[12] each for Indus-1 and Indus-2 by RRCAT. DAE revised the scope of the project to construct only five beam lines for Indus-1 by RRCAT and dropped the scope of construction of five beam lines for Indus-2. Accordingly, the project cost was revised to Rs.13.75 crore in June 1997 and again to Rs.14.15 crore in January 1998.

A review of construction and utilisation of SRS Indus-1 of SRS Indus-2 at RRCAT revealed the following:

2.5.2.1 SRS Indus-1

(i) Delay in construction of SRS Indus-1 Beamlines

Though all the beamlines for Indus-1 were targeted to be completed by the end of the Eighth Plan (1992-97), RRCAT could not commission any beamline by the end of the Eighth Plan. Even by the end of the Tenth Plan, SRS Indus-1 is not fully complete as one beamline is yet to be installed. Audit scrutiny revealed:

- RRCAT commissioned and made operational only one beamline by November 2000.
- IUC commissioned and made operational one beamline (out of the two envisaged) only by November 2000.
- BARC further commissioned and made operational the third and the fourth beamlines in December 2002 and March 2003 respectively.
- RRCAT stated in June 2006 that the fifth beamline was installed and commissioned “for a certain energy range” and the sixth beamline was ready to be installed.

[10] SRS Indus-1 is a Synchrotron Radiation Source consisting of a 20 Mev Microtron injector, a 700 MeV booster synchrotron, beam transfer lines and a 450 MeV storage ring.
[11] SRS Indus 2 is a Synchrotron Radiation Source consisting of an electron storage ring of 2.0 GeV electron energy dedicated primarily for production of soft x-rays.
[12] Due to the high cost of beamlines and limitation of funds, RRCAT/BARC proposed to construct only five beamlines on Indus-1 during the Eighth plan period and the remaining beamlines on Indus-1 and Indus-2 were to be constructed during the Ninth plan.

Thus, there was considerable delay in construction and commissioning of beamlines as only four out of six beamlines were fully operational ten years after the scheduled completion of the project.

DAE stated in June 2007 that one of the main causes for the delay was that it could not foresee in advance that the electric supply through 11KV power line was insufficient to operate the booster Synchrotron. This problem could be solved in 1994 when 132 KV power line was made available. It further stated that as Indus-I beamlines were being built for the first time, some delay was inevitable.

However the fact remains that failure on the part of RRCAT to take proactive measures in establishing basic facilities led to the delay in commissioning of beamlines.

(ii) Utilisation of SRS Indus-1 Beamlines

The beam availability and utilisation for the period November 2000 to April 2006 is summarised below:

Year	No. of days operated	Beam Availability (hours)	Number of beam lines	Available beam time (hours)	Actual utilisation of beam hours			Percentage utilisation
					In-house	External	Total	
2000[13]	39	287	2	574	290	Nil	290	50.5
2001	133	805	2	1610	293	42	335	20.8
2002	127	1089	2/3	2243	342	12	354	15.8
2003	174	1197	3/4	4497	921	539	1460	32.5
2004	137	1044	4	4176	451	360	811	19.4
2005	142	967	4	3868	450	192	642	16.6
2006[14]	31	189	4	756	80	12	92	12.2
Total	**783**	**5578**		**17724**	**2827**	**1157**	**3984**	**22.5**

Analysis of the above data and further audit scrutiny revealed gross under-utilisation of Indus-1 beamlines, as follows:

- Internationally, accelerators function round the clock. However, it was noticed in RRCAT that the accelerators were neither operated round the clock, nor on weekends or holidays. Between November 2000 and April 2006, the facility was operated only for 783 days i.e. 39.0 *per cent* of the available days. Even if Saturdays, Sundays and holidays are deducted over this period, the facility was utilised only for 58.6 *per cent* of days.

- The total beam availability was 5578 hours in 783 days of operation, which works out to 7.1 hours per operating day. By contrast, the Activity Report on Indus-1 indicated that the system generally operated on two shifts between 11 AM and 11 PM with 12 hours machine uptime.

[13] November – December 2000 only.
[14] Up to April 2006 only.

- Even out of the available 17724 beam hours, only 3984 hours (22.5 *per cent*) were utilised in-house as well as externally. The actual utilisation of beam hours gradually decreased from 50.5 *per cent* in 2000 to 12.2 *per cent* in 2006.

- The utilisation of beamlines by external users ranged between 12 and 539 hours, which indicated less attraction for the Indus-I facility. There were only 19 groups of users, who had utilised the Indus-1 beamlines.

DAE stated in June 2007 that the under-utilisation was due to the fact that at present the number of scientists in the country involved in VUV Spectroscopy is limited and the lower utilisation in the years 2005 and 2006 was due to diversion of injector beam for Indus-2 commissioning. DAE further stated that they have now intensified efforts to increase awareness of the facilities available with them.

The reply needs to be viewed in the light of the fact that RRCAT should have taken proactive measures for increasing awareness, both in-house as well as externally, so that the beamlines were efficiently utilised. Further, the fact remains that accelerators worldwide face intense user pressure and function round the clock but the accelerators in RRCAT were grossly underutilised.

(iii) SRS Indus-1 Beam Lifetime

The conceptual design report of Indus-1 indicated that the lifetime of the stored beam should be "a few hours" at the desired current so that the photon beam from the storage ring was available to the users for a sufficiently long time. The SRS Indus-1 beamline Handbook indicated the design parameter of beam life as 1.8 hours at greater than 100 mA[15]. However, the beam life achieved was only one hour at 100 mA. RRCAT attributed the huge shortfall to non-stabilisation of power supply, RF tripping problems, inadequate air-conditioning etc. It may be noted that RRCAT's efforts to solve the power supply problem by installation of a power conditioning system also did not yield the desired benefits, as the system could not be fully commissioned and made operational till January 2007, as brought in Para 2.5.2.1(iv) below.

DAE stated in June 2007 that world over beam life time improves over several years with the vacuum chamber of the accelerator getting conditioned. For improving the vacuum, RRCAT was commissioning a new RF cavity, which would give an order of magnitude, better vacuum and with this cavity, the life time was expected to improve further. It also stated that beam life time up to 80 minutes had been achieved in January 2004 as against the expected figure of 108 minutes.

The reply of DAE indicated that the beam lifetime had not improved over the years.

[15] Milli Ampere

(iv) Power Conditioning System

In order to provide stable input power to the accelerator systems of SRS Indus-1 and to maintain all subsystems in good working condition so that the source was operated optimally and synchrotron radiation was available uninterruptedly for a few hours to users and also to make necessary modifications in the source for providing a few more beam lines, DAE, in October 2000, approved a Ninth Plan project on "Up-gradation of sub-systems of Indus-1" at a total cost of Rs.4.96 crore to be completed by March 2003. This included Rs.2.30 crore towards a power conditioning system, which was to be installed and commissioned by March 2001.

In August 2000, RRCAT placed an order on a foreign firm for supply, installation and commissioning of two units of high performance power conditioning systems at a total cost of Rs.2.09 crore. The supply of the equipment was made between May 2001 and October 2002. It was observed in audit that the equipment could be made fully operational only in January 2007 i.e. after nearly six years of the targeted date of commissioning. The delay was attributable to the power conditioners not meeting the operational requirement and supplier was unable to rectify the defects.

RRCAT stated in September 2006 that the power conditioning systems were partially installed in May 2004 and the deficiencies noticed were brought to the notice of the manufacturer for modification. DAE stated in June 2007 that after persuasive interaction with manufacturer, the system had been made fully operational in January 2007.

However, the fact remained that poor contract management resulted in the defects in the system not getting rectified for over four years. Thus, the intended benefit of providing stable input power to the accelerator could be achieved only after six years.

2.5.2.2 SRS Indus-2

In February 1992, DAE approved an Eighth Plan project "SRS Indus-2" at a total cost of Rs.15.70 crore for completion by 1996-97. SRS Indus-2 was to be an electron storage ring of 2 GeV electron energy dedicated primarily for production of soft x-rays. Based on the recommendation of International Advisory Committee to increase the SRS energy from 2 GeV to 2.5 GeV and its acceptance by DAE, the construction work started in 1998. The project cost was revised four times during the period December 1996 (Rs.41.63 crore) to May 2006 (Rs.97.55 crore) due to unforeseen imports of material, escalation and devaluation of rupee etc. RRCAT spent Rs.95.77 crore up to 2006-07 on the project.

Audit examination of project records revealed that RRCAT had not yet commissioned SRS Indus-2 to the energy level of 2.5 GeV as of August 2006.

As against the designed energy level of 2.5 GeV at 300 mA with a lifetime of 24 hours, the actual energy level achieved as of August 2006 was 1.93 GeV at just 9.7 mA with a lifetime of about 40 minutes.

Thus, SRS Indus-2 was not yet fully operational at the designed levels even after 10 years of the scheduled date of completion of the project.

DAE stated in June 2007 that the project was completed in eight years, reckoned from 1998 after the recommendations of International Advisory Committee were accepted by DAE, which was an achievement viewed in the light of the embargo from US and other countries. DAE, however stated that since microtron[16] and booster injector synchrotron were old having been installed in 1992 and 1995, they were not reliable as their performance deteriorated over time, thereby adversely affecting operation of SRS Indus-2 and efforts were on to improve them.

Reply of DAE is to be viewed in the light of the fact that microtron and booster injector synchrotron were installed in 1992 and 1995 respectively and had SRS Indus-2 also been completed in 1996-97, as per the original time schedule, these supporting systems would have provided satisfactory performance. By the time SRS Indus-2 was completed in March 2005 (at lower than 2.5GeV energy levels), the supporting systems had completed 10 to 13 years of service, thereby becoming unreliable with their performance and RRCAT was now finding ways and means for improving their efficiency.

2.5.2.3 Accelerator for industrial and medical applications

In October 1991, RRCAT proposed to take up the development and construction of accelerators for industrial and medical applications. In October 1992, DAE approved an Eighth Plan project on “Accelerator for industrial and medical applications” at a total cost of Rs.5.40 crore. The project cost was revised to Rs.7.94 crore in March 1997 and again to Rs.8.40 crore in September 1999. The project was completed in May 2003 at a total cost of Rs.8.39 crore[17].

Audit examination revealed that one of the envisaged objectives was to develop a 20 MeV microtron based radio therapy machine for treatment of cancer patients. RRCAT could only develop a 12 MeV microtron machine against the 20 MeV microtron machine as envisaged. This machine could not be used for treatment of cancer patients, as it did not meet the stipulated requirements of AERB/IEC[18]. Therefore, the machine was planned to be used for research and development purpose only.

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[16] A microtron is a cyclotron in which the kinetic energy of electrons is increased by a constant amount per field change.
[17] This included expenditure of Rs.3.04 crore for the Accelerator building with test bay for four accelerators.
[18] Atomic Energy Regulatory Board/ International Electrotechnical Commission

DAE did not furnish any reply to this observation.

2.5.2.4 Accelerators for medical sterilisation and food irradiation

Considering the importance of development of accelerator based units for sterilisation of medical products and food irradiation and the high cost of imported accelerators, DAE, in September 1997, approved a Ninth plan project "Accelerators for medical sterilisation and food irradiation" at a total cost of Rs.9.25 crore. The objective of the project was to develop accelerator based units for sterilisation of medical products and irradiation of food items.

DAE revised the project cost downward to Rs.7 crore in August 1998 with March 2002 as the revised date of completion. As per the project completion report of July 2006, the project commenced in August 1998 and was completed in November 2005 at a total cost of Rs.6.65 crore. Thus, there was a delay of over three years in the completion of the project. However, the envisaged two objectives of the project had not been fully achieved as detailed below:

Project	Status
Development of 10 MeV, 1 KW microtron for agricultural irradiation	After spending Rs.1.36 crore, RRCAT short-closed the project in July 2002 without the approval of DAE, as it was found that the microtron could not be made industrially robust.
Development of 10 MeV 10 KW electron Linac[19] for agricultural and medical sterilisation	RRCAT developed the 10MeV, 10KW electron Linac and installed it at IMA building. AERB had given the approval for trial operation in December 2004. However, RRCAT could not commence its regular operation as of August 2006, as it had not obtained the requisite license from AERB.

DAE stated in June 2007 that the project for development of 10 MeV, 1 KW microtron for agricultural irradiation was short-closed due to some insurmountable technical problems mostly connected with design of cooling system of microwave cavity which were integral part of any advanced Research and Development. The regular operation of 10 MeV/ 10 KW electron Linac was planned at a site located near vegetable market in Indore, where it could be conveniently used by the farmers of the region.

However, the fact remains that the ultimate aim of developing indigenous low cost accelerator based units for agricultural irradiation, agricultural and medical sterilisation remained unachieved so far.

[19] Linac, a linear particle accelerator, is an electrical device for the acceleration of subatomic particles.

2.5.2.5 Non-completion of project on laser photocathode RF Linac

RRCAT decided, in April 1997, to develop a laser photocathode RF Linac in order to establish its leadership in the field. DAE, in August 1997, approved a Ninth Plan project on "Laser photocathode RF Linac" to be completed by March 2003 at a total cost of Rs.5 crore which was revised to Rs.4.40 crore in December 1997 with revised date of completion as March 2002, due to reduction in the capital budget outlay.

RRCAT commenced the project in January 1998 and spent Rs.3.58 crore till March 2007. RRCAT stated in July 2006 that it had successfully built the Linac and used this to accelerate electrons to 3.5 MeV (as against the originally envisaged 50 MeV). DAE stated in June 2007 that the project involved highly sophisticated technology for which the learning curve was steeper than anticipated as it involved repetitive trials, some machining and brazing work. DAE also stated that project was now expected to be completed in about one year time.

Thus, the project, which was expected to be completed by March 2002, is still in the developmental stage even after nine years and an expenditure of Rs.3.58 crore as of March 2007.

2.5.3 Laser

For boosting R&D activity in India in the field of lasers and their applications in basic research industries, medicine, surgery, defence, communication, entertainment, electronics etc, the Scientific Advisory Committee to the Prime Minister suggested the necessity of ensuring indigenous availability of important lasers, accessories and components. To achieve this objective, it had recommended the setting up of a laser production unit at RRCAT. It was envisaged that manufacturing of lasers indigenously at RRCAT would ease the need for import of lasers and dependence on foreign suppliers.

2.5.3.1 Laser Production Unit

DAE, in June 1992, sanctioned an Eighth Plan project for setting up a production unit for lasers and related instrumentation at RRCAT at a total cost of Rs.6.10 crore. DAE revised the project cost to Rs.6.84 crore in March 1998 and again to Rs.6.63 crore in February 1999.

The scope of the production unit was to make available lasers, laser related instrumentation and other high-tech equipment such as x-ray generators, crystal pullers etc, to universities, R&D centres, hospitals and industries. The scope of the production unit also included servicing and maintenance. Apart from laser-based equipment, the production unit was also required to produce medical and industrial accelerators, UHV system and cryogenics. The purpose of setting up the production unit of RRCAT was to take up and convert laboratory technology into production technology by carrying out proper engineering of various sub-systems of the items and to take up pilot scale manufacture of the equipment and supply them to the users to establish the technical and economic viability of the technology.

RRCAT commenced the project in June 1992 and completed it in March 1998 at a total cost of Rs.6.80 crore. However, work continued till July 2002 in order to fulfill the commitments of supply of lasers. RRCAT realised only Rs.2.72 crore from the sale of lasers and laser equipment during 1993-94 to 2002-03, as against the projected turnover of Rs.21.06 crore. RRCAT closed the activity of the production unit in 2002. However, it had not obtained the approval of DAE.

RRCAT stated that the production unit was closed due to inordinate delay in procurement of components and lack of sufficient skilled manpower. During the first six to seven years of operation, it was not possible to operate such a commercial venture because many Indian firms had already started manufacturing lasers with technology from abroad. Therefore, it had closed the production activities and instead took up the development of cutting edge technologies and concentrated only on research and development activities. RRCAT also stated that it would transfer the technology in case interested entrepreneurs came forward.

DAE stated in June 2007 that regarding the revenue generation, the activities and achievements of the unit may be viewed in terms of capacity building in the country and not in the form of a commercial technological venture.

Thus, the fact remains that due to deficient project management, RRCAT failed to establish production unit for lasers and laser related instruments in a timely manner. By the time RRCAT could develop and produce lasers and laser related instruments, the technology was already available in the market and its production was not commercially viable. Hence the expenditure of Rs.6.80 crore was largely unfruitful.

2.5.3.2 Manufacture of lasers for use in industry and medicine

DAE, in August 1998, approved a Ninth Plan project titled “Manufacture of lasers for use in industry and medicine” with a financial outlay of Rs.2.92 crore. The project was to be completed by March 2002. The main objectives of the project were to set up a unit at RRCAT for manufacture of lasers for use in industry and medicine in order to upgrade the technology before its transfer to interested entrepreneurs; to take up development and limited production of those lasers and laser based instruments that have low demand; and take up prototype engineering of lasers and laser based instruments, which were likely to have good projected market demand in the future.

The project report envisaged savings of foreign exchange and creation of an infrastructure of high tech ancillaries and high quality human resource development. During the execution of the project, several units of DAE requested development of laser systems on turnkey basis. In order to meet this request, DAE revised the project cost to Rs.5.94 crore in September 2000. At this stage, RRCAT envisaged revenue generation of Rs.1.50 crore from sales to DAE units, with the possibility of repeat orders as well as orders from other organisations.

The project completion report submitted in July 2006 indicated that RRCAT commenced the project in June 1998 and completed in March 2004 at a total cost of Rs.5.81 crore. Though RRCAT claimed that it had achieved the targets of developing the prototype laser models under the first objective of the project, it had yet to find a party to transfer the technology as of July 2006. Further, against the projected revenue generation of Rs.1.50 crore from sales to DAE units, RRCAT could generate revenue of Rs.79.50 lakh representing 53 *per cent* of the projected target.

DAE stated in June 2007 that to take the prototype stage to an industry level product, more work and substantial additional investment were needed and RRCAT had been exploring industrial partners who would carry such prototypes to the real market place.

Thus, the objectives of development of laser systems for internal use and its transfer for commercialisation with the ultimate aim of saving foreign exchange had not been fully achieved.

2.5.4 Conclusion

Thus, there was considerable delay in construction and commissioning of SRS Indus-1 beamlines as only four out of six beamlines were fully operational, ten years after the scheduled completion of the project. The cost of SRS Indus-1 increased from Rs.13.75 crore to Rs.14.37 crore. Even the operational beamlines were grossly under utilised.

SRS Indus-2 was not yet operational at the designed levels, even 10 years after the scheduled date of completion of the project. The cost of SRS Indus-2 increased from Rs.15.70 crore to Rs.95.77 crore.

The project for development of industrial and medical applications did not achieve the objectives of application of accelerators for radiotherapy for cancer treatment. Further the aim of developing low cost accelerator based units for sterilisation of medical products and food irradiation indigenously remained unachieved. The project on laser photocathode RF Linac had not been completed after a delay of more than five years.

The laser production unit set up by RRCAT could not generate projected revenue and RRCAT had to close down the unit and the lasers developed by RRCAT were yet to find a buyer in the market.