# CHAPTER-1

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# NUCLEAR POWER PROGRAMME - STAGE 1 : PRESSURISED HEAVY WATER REACTOR

*Department of Atomic Energy has achieved comprehensive capability in the design, construction and operation of pressurised heavy water reactor (PHWR). The design of 220 MWe PHWR has been standardised and scaled up to 540 MWe capacity. Strides have also been taken towards the development 700 MWe PHWR.*

*The self reliant programmes relating to Nuclear Power and the Nuclear Fuel Cycle have been built based on the results from the multidisciplinary R&D infrastructure of DAE.*

## NUCLEAR POWER

### Nuclear Power Generation

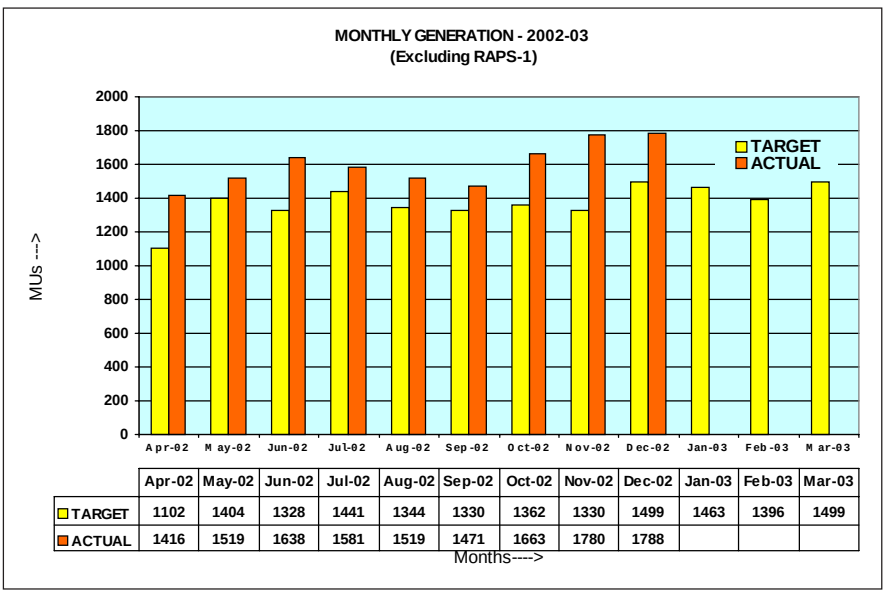
There are fourteen (14) operating nuclear power reactors in the country with a total installed capacity of 2720 MWe. These include RAPS-1 (100 MWe), which is being managed by the Nuclear Power Corporation of India Ltd. (NPCIL) on behalf of the Government of India.

The total electric power generation by all the nuclear power stations, since they commenced commercial operation, up to end December 2002, was about 1,97,085 million units (MUs) including RAPS-1. NPCIL has demonstrated an excellent improvement in the capacity factors[$] of its operating reactors. Its overall capacity factor has gone up from about 71% in 1997-98 to nearly 85% in 2001-02. The company has improved this further by achieving about 89% in 2002-03 (up to December 2002). NPCIL's reactors generated about 19,199 million units (MUs) during 2001-02 and had generated 14,375 MUs during 2002-03 (up to December 2002). The current year's performance of NPCIl viz-a-viz the monthly power generation targets is shown in the graph below:

*Operational Highlights*

Nine (9) out of fourteen (14) operating nuclear power reactors have registered capacity factors above 90 % during the calendar year 2002.

Unit-1 of the Kakrapar Atomic Power Station (KAPS) achieved the highest ever annual capacity factor of 98% during the year. Its annual record performance (1.10.2001 to 30.9.2002) moved it into first place in the world ranking of PHWR type reactors at the end of September 2002. Other notable achievements during the year were the completion of "Refuelling Outage" at Unit-2 of Tarapur Atomic Power Station in a record time of 27 days and completion of Annual Maintenance Shutdown (ASD) at Unit-2 of KAPS in a record time of 18 days. The international standards of safe commercial operations of NPCIL's operating reactors was demonstrated through the peer reviews of




| | Apr-02 | May-02 | Jun-02 | Jul-02 | Aug-02 | Sep-02 | Oct-02 | Nov-02 | Dec-02 | Jan-03 | Feb-03 | Mar-03 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TARGET | 1102 | 1404 | 1328 | 1441 | 1344 | 1330 | 1362 | 1330 | 1499 | 1463 | 1396 | 1499 |
| ACTUAL | 1416 | 1519 | 1638 | 1581 | 1519 | 1471 | 1663 | 1780 | 1788 | | | |

[$] *Capacity factor exclude RAPS-1 and units under renovation and modernisation in RAPS-2 from 01.08.1994 to 06.06.1998 and MAPS-2 from 09.01.2002 onwards.*

**Station Wise Power Generation Performance**

| | | Calendar Year 2002 | | Financial Year 2002-03 upto Dec. 2002 | |
|---|---|---|---|---|---|
| **STATION** | **CAPACITY (MWe)** | **Generation (MUs)** | **Capacity Factor (%)** | **Generation (MUs)** | **Capacity Factor (%)** |
| TAPS | 2 X 160 =320 | 2573 | 92 | 1900 | 90 |
| RAPS-2 | 1 X 200 =200 | 1568 | 89 | 1145 | 87 |
| MAPS | 2 X 170 =340 | 1048 | 69 | 705 | 63 |
| NAPS | 2 X 220 =440 | 3613 | 94 | 2653 | 91 |
| KAPS | 2 X 220 =440 | 3660 | 95 | 2752 | 95 |
| KGS-1&2 | 2 X 220 =440 | 3457 | 90 | 2704 | 93 |
| RAPS-3&4 | 2 X 220 =440 | 3344 | 87 | 2516 | 87 |

*Legends*
*TAPS - Tarapur Atomic Power Station, RAPS - Rajasthan Atomic Power Station, MAPS - Madras Atomic Power Station.*
*NAPS - Narora Atomic Power Station, KAPS - Kakrapar Atomic Power Station, KGS - Kaiga Generating Station.*

*Notes:*
*RAPS-1 generated 293 MUs & 116 MUs during the calendar year 2002 and upto December 2002 in financial year 2002-03 respectively. This Unit is under shutdown since May 2002 for in-service-inspection of coolant channels and system upgradation jobs.*

*MAPS-2 was taken out of service in January 2002 for enmassed coolant channel replacement and other safety upgradation jobs which are in advanced stage of completion.*

the World Association of Nuclear Operators (WANO). One such peer review was completed during January 2002 at the Kaiga Generating Station and a similar review of RAPS-3&4 is nearing completion.

The station wise generating performance is indicated in the Table above:

## Nuclear Power Projects under construction

### Pressurised Heavy Water Reactors

*Tarapur Atomic Power Project-3&4 (2x540 MWe)*

The project is located adjacent to existing two units at Tarapur, District Thane, Maharashtra and when completed, it will feed electrical power into the Western grid. The project comprises a twin unit station of the PHWR type, each with an installed capacity of 540 MWe.

*Tarapur Atomic Power Project-3&4 (2x540 MWe)*

The civil construction work for Unit-4 is nearing completion and that of Unit-3 progressed well. Installation of various critical equipment was in progress. The fabrication and erection of nuclear piping package is in full swing and other major packages for electrical system, common service piping and main plant control & instrumentation are being taken up at site.

The project had achieved an overall cumulastive physical progress of 62% by December 2002. The project was progressing as per schedule. The scheduled criticality dates of October 2005 and July 2006 for TAPP-4 and TAPP-3 respectively are expected to be met.

*Kaiga Atomic Power Project -3&4 (2x220 MWe)*

The project comprises a twin unit station of the PHWR type, each of 220 MWe installed capacity. It is

*Kaiga Atomic Power Project -3&4 (2x220 MWe)*

located at Kaiga in Uttar Kannada district of Karnataka. Adjacent to the existing two operating reactors, the station will supply electricity to the Southern grid. Subsequent to the initial project financial sanction, in May 2001, the project schedule was advanced, and the funding pattern was modified resulting in a significant reduction in the cost of the project.

The excavation of all the main plant buildings have been completed. The first pour of concrete for Unit-3 was done on March 30, 2002. Concreting of rafts of reactor buildings for both the units was completed. Other civil works were in progress. Procurement action was initiated for all the main packages such as nuclear piping package, main plant electrical package, Turbo-generator set and condenser.

The project had achieved an overall cumulative physical progress of about 20% by December 2002. The scheduled criticality dates of December 2006 for Unit-3 and June 2007 for Unit-4 are expected to be met.

*Rajasthan Atomic Power Project 5&6 (2 x 220 MWe)*

The project comprises a twin unit station of PHWR type, each reactor having an installed capacity of 220 MWe. It is located adjacent to the existing RAPS-1 to 4 stations at Rawatbhyata, Rajasthan and when completed will supply electricity to the Northern Grid. The financial savings effected in the Kaiga Atomic Power Project were used to fund this project in such a manner by ensuring that there were no additional budgetary support was required from the government for this project.

The excavation works of the reactor buildings and control building were completed and excavation in balance areas is nearing completion. The contract for the main plant civil works has been awarded. The first pour of concrete was completed during September 2002. Civil works in other buildings were in progress.

The project had achieved an overall physical progress of about 12%. The scheduled criticality dates of May 2007 for Unit-5 and November 2007 for unit-6 are expected to be met.

## Other Programmes and Projects relating to PHWR

*Coolant Channel Replacement and Upgradation*

The en-mass coolant channel replacement and systems upgradation jobs at Unit-2 of the Madras Atomic Power Station was taken up in January 2002. All the coolant channels were replaced. Several System Upgradation jobs were also carried out. Though this unit is scheduled to be re-commissioned by December 2003, efforts are being made to advance this date.

*New Projects (700 MWe PHWR)*

It is planned to scale up the power generation capacity of the present design of 540 MWe PHWR type units to 700 MWe unit size by permitting partial boiling in the coolant channels. This will enable setting up 700 MWe PHWR units in future. Significant work was done in this area with respect to in-depth understanding of design issues, areas

*Kudankulam Atomic Power Project (2x1000 MWe)*

requiring changes, modifications necessary in equipment capacities, thermal hydraulic studies, and issues relating to reactor control, thermal power studies, layout etc. Most areas, where changes are involved, have been identified. Detailed design has already started and preparation of PSAR is in progress.

Pre-project activities have been initiated for new projects, which are planned for commencement in the later part of X plan and construction during the XI plan. These include site selection works, site investigation, collection of site data for safety and environmental clearance etc.

### Light Water Reactor

*Kudankulam Atomic Power Project (2x1000 MWe)*

The Kudankulam Project is a twin unit, pressurised water reactor (PWR-VVER-1000) type, each reactor having a capacity of 1000 MWe. The project is being constructed at Kudankulam in Tamilnadu on a "Technical Co-operation" basis under the provisions of an Inter-Governmental Agreement (IGA) signed between the India and the Russian Federation. The power generated by this station would be fed to the Southern grid.

The project financial sanction was accorded by Government of India on November 3, 2001. Following this several follow-up actions were taken and various contracts were signed with Russian Federation, covering total commitments of US $1633 million.

Subsequent to the completion of infrastructure facilities and regulatory clearances, construction work on the project was initiated during March 2002. Several contracts for civil construction work and transportation of equipment were awarded. Manufacturing of major equipment such as Reactor Pressure Vessel (RPV) with internals, Steam Generator (SG), Pressurizer, Polar Crane, Reactor Coolant Pumps, Turbo Generator and Seawater pumps etc. commenced. The transportation of equipment also started and about 2500 MT are to be shipped before the end of the year.

The major milestones for the completion of the raft concreting for reactor building of both unit-1 and unit-2 were achieved in July and September 2002 respectively. The construction of raft for the Reactor Auxiliary Building for both the units was also completed. The construction of all the infrastructure buildings at Plant site was nearing completion. Other civil construction work is in full progress at the site. A number of public awareness campaigns, welfare activities, and greenery development projects were undertaken in and around the Kudankulam site.

The project had achieved an overall cumulative physical progress of 10% as of December 2002. The first and second units are expected to be completed by December 2007 and December 2008 respectively.

### Other Programmes and Projects relating to LWR

*Thermal Hydraulic Analysis:* TAPS-BWR recirculation line break analyses were carried out to evaluate the adequacy of the core spray system in conjunction with the auto relief system. A series of analyses were carried out covering break area ranging from 0.2 to 6 sq.ft

Safety evaluation of Kudankulam Reactors was also carried out for Loss of coolant accident, steam line break and pump seizure.

## FRONT -END FUEL CYCLE

### Heavy Water

The Heavy Water Board produces heavy water to meet the heavy water requirements of the Indian PHWRs which use heavy water as moderator and coolant. .

The performance and safety record of all the operating Heavy Water Plants during 2002-03 has been excellent. Heavy Water Board has also exported 10 MT of heavy water to South Korea in November 2002.

Stable and continuous operation of the plants, has resulted in the production surpassing the targets set so far. It is expected that the annual production for the year 2002-03 will also exceed the scheduled target, well within the allocated budget.

Continuous monitoring and increased awareness of the plant personnel with respect to energy conservation, has resulted in further

*Green-Tech Industrial Safety Award to Heavy Water Plant, Tuticorin*

overall reduction in specific energy consumption, leading to considerable reduction in the cost of production.

Heavy Water Board is continuing its programme of energy conservation, which is a major thrust area, in all its operating Heavy Water Plants in order to further reduce specific energy consumption per kilogramme of heavy water produced. The Board would be setting new bench marks on most of the performance indicators.

In order to intensify its interactive transactions with peer groups within the department and also with chemical process industry, professional bodies and association for the mutual growth and benefit, HWB organized a national symposium in June 2002 on Innovative Strategies for Cost Competitiveness in Indian Chemical Industry – ISCOCI 2002.

The plant at Nangal (Panjab), the first heavy water plant in the country, completed 40 years of operation in August 2002. Since the plant outlived its useful life, it was decided to dismantle the Plant.

*Plant-wise performance :*Performance of HWP (Manu-guru) was excellent during the reported period. The plant exceeded the targeted production with significant reduction in specific energy consumption. A reduction of 8.2% in specific energy consumption over the previous year could be achieved mainly due to implementation of waste heat recovery system.

Performance of HWP (Kota) was excellent during the period of the report and the plant exceeded the targeted production with significant reduction in specific energy consumption. A reduction of 7.7% in specific energy consumption over the previous year could be achieved mainly due to the increased feed processing rate by 2% over the previous year.

The plant is planning to implement certain capital schemes viz: replacement of 16" size control valves at gas boosters suction to 24" size, replacement of existing cation & anion ion exchange beds, having strong acid cation and strong base anion respectively, in water treatment plant with layered bed having weak and strong resin together in a single bed. It is planned to lay a steam line from RAPS 3&4 to Heavy Water Plant (Kota) to improve the reliability of steam supply and thereby increasing the production.

Performance and safety record of HWP(Hazira) was excellent during the period of the report and the plant would exceed the targeted production. Further reduction in specific energy consumption is expected during next financial year 2003-04, on account of implementation of modification schemes.

Performance of HWP (Thal) was excellent during the period of the report and the plant exceeded the targeted production with significant reduction in specific energy consumption. A reduction of 6.8% in specific energy consumption than the previous year could be achieved owing to various measures taken.

Performance of HWP (Tuticorin) during the report period was affected by frequent trips of the Ammonia plant of SPIC (the connected Fertiliser plant). However with sustained production picking up, the plant is expected to achieve a better capacity utilisation and also reduction in the specific energy consumption over the previous year.

In the field of safety, the HWP, Tuticorin crossed an all time high record of 10 years of continuous working as on Dec 02, 2002, without any reportable and disabling injury. This is equivalent to 12 million man hours. The trend was maintained and the plant completed 3680 days of safe operation without any disabling injury as on Dec31, 2002.

A modification scheme to utilise the surplus steam available in the plant by installing an Ammonia Absorption Refrigeration System (AARS) is under execution and with the commissioning of AARS the specific energy consumption is likely to come down further.

Operation of the Heavy Water Plant at Talcher remains suspended due to closure of operation of the connected fertilizer plant of the Fertilizer Corporation of India on which the plant depended for feed stock and other inputs.

*Other activities and modifications:* The HWP, Baroda revival project is being executed in two distinct phases viz. Modification to the Main Plant under Baroda Revival Project (BRP) Phase-I and Ammonia Water Front End under BRP Phase II. Mechanical completion of Phase-I is over and that of Phase II is expected by mid February 2003. Commissioning trials would start from end February 2003 onwards. Pre-production trial runs are expected to commence by April 2003.

The R&D pilot plant for production of Di-2-ethyl hexyl phosphoric acid (D2EHPA) at Talcher has been running satisfactorily and the cumulative production achieved so far has been 27.4 MT. The quality of the same meets the international standards and market acceptability has been established with sale of 16.5 MT of D2EHPA under the brand name of 'TOPS-99'. HWB has also taken up activity for development of another solvent viz. Tri-Butyl Phosphate (TBP), which has wide application in nuclear and non-nuclear fields. Mechanical completion for the 60 MT/annum capacity TBP plant at HWP, Talcher is expected by February 2003. Commissioning trial for the plant would be taken up thereafter. Regular production of TBP is expected to commence in the next financial year.

Flue gas conditioning technology developed by Heavy Water Board and transferred to M/s. Chemithon Engineers Ltd., is being put to commercial use. An order for ammonia flue gas conditioning was placed by GEB for their Ukai Power Station on M/s. Chemithon based on the HWB know-how & design. Heavy Water Board would get 10% of the contract value towards royalty for detailed engineering. Similarly HWB received a Work Order for a total cost of Rs.19.26 lakh (towards detailed engineering and royalty) from M/s. Chemithon Engineers Limited for conditioning of flue gases for Thermal Power Station of Panjab State Electricity Board, Bhatinda. The job on detailed engineering by HWB progressed satisfactorily.

A Memorandum of Understanding (MoU) was signed with a party for carrying out R&D work in the field of Ammonia Absorption Refrigeration system with a view to improve the coefficient of performance of the system. The Pilot Plant set up for the same was commissioned. The data at the various parametric conditions have been collected & evaluated and the results are excellent.

HWB has also initiated implementation of Total Productivity Maintenance (TPM) to minimize breakdown maintenance, improving performance, improving quality and environment aspects and economic production of heavy water. (TPM), a modern concept in plant operation and maintenance philosophy has a double goal of Zero breakdown & Zero defects to enhance the overall effectiveness of equipment and productivity.

BARC has developed and implemented a Real time fatigue monitoring system, a finite element based fatigue monitoring system and a software in HWP, Kota and HWP, Tuticorin, as a part of life-extension program of these plants.

## SURVEYS & EXPLORATION OF ATOMIC MINERALS

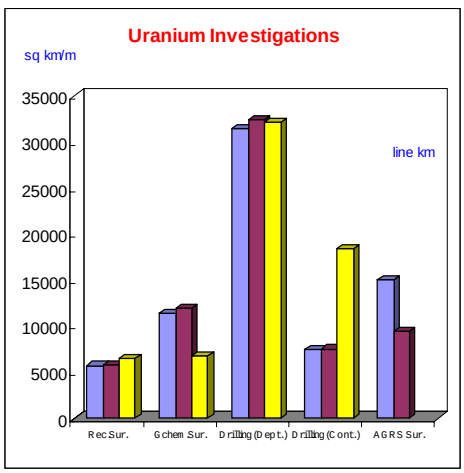
Atomic Minerals Directorate for Exploration and Research (AMD) of DAE carries out survey, prospecting and exploration for atomic minerals required for the Nuclear Power Programme of the country. The research and development oriented activities of the Directorate include assessment, evaluation, characterisation, and categorisation of atomic minerals, design and fabrication of instruments and development of ore extraction flow sheets. Following were the activities and achievements during 2002 - 2003:

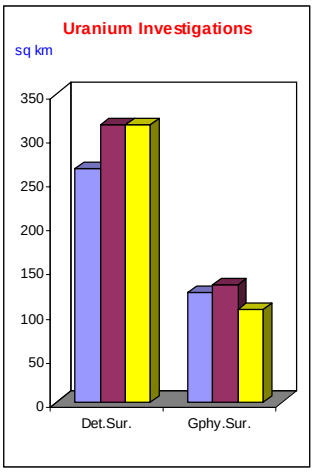
### Uranium Investigations

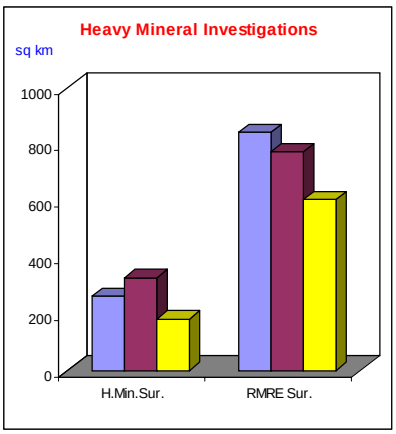
*Airborne Survey and Remote Sensing :* Airborne gamma-ray spectrometric and aeromagnetic surveys were carried out for over 9400 line km over Gwalior basin in parts of Madhya Pradesh.

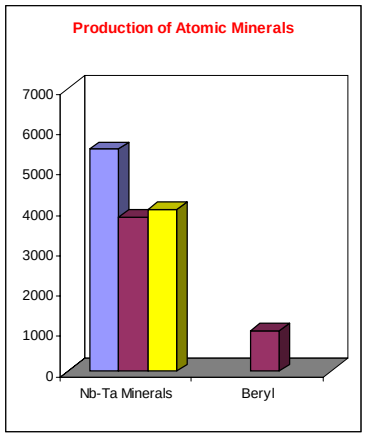
Integrated studies of Gwalior basin, Madhya Pradesh and environs of albitite line in Mahendragarh district, Haryana were carried out using AGRS, AM and remote sensing data. Ground checking of selected areas in Gwalior basin resulted in locating uranium anomalies associated with iron chert of Morar Formation at Dongrau, Gwalior district, Madhya Pradesh. WiFS based Atomic Min-

**PRINCIPLE ACTIVITIES OF AMD (TARGETS AND ACHIEVEMENTS)**




TARGETS 2002-2003 | ACHIEVEMENTS 2002-2003 | TARGETS 2003-2004

eral Information system for Lambapur uranium deposit was created.

*Ground Radiometric Survey* : Radiometric reconnaissance and detailed surveys were carried out in various geologically and structurally favourable areas over 5700 sq km and 314 sq km respectively. These have resulted in locating / delineating new uranium anomalies/extensions of known anomalies associated with :

i. Basement granite and overlying sandstone of Chhattisgarh Supergroup along the unconformity contact around Chitakhol, Renkhol, Bokardo and Kumharpahar, Korba district, Chhattisgarh.

ii. Basement granite unconformably overlying Banganapalli quartzite of Cuddapah Supergroup along Rallavagu Tanda-Damarcherla tract, Nalgonda district, Andhra Pradesh.

iii. Mahadek sandstone at Balphakram, South Garo Hills district, Meghalaya.

iv. Ferruginous/calcareous phyllite of Delhi Supergroup at Chirana and Kirori, Sikar and Jhunjhunu districts, Rajasthan.

v. Quartzto-feldspathic rock of Kunjar Group at Betjharan and Nuapali, Sambalpur district, Orissa.

vi.Fractured two-mica-granite along Laikera-Sarbahal tract, Sundergarh district, Orissa.

vii. Footwall/hangwall side of Cu-Pb-Zn lodes in Kolihan and Rajpura-Dariba mines, South Central Rajasthan.

*Ground Geophysical Survey :*Geophysical surveys comprising gravity, magnetic, electrical (IP), resistivity and electromagnetic (TURAM) methods were carried out which helped in deciphering:

i. Basement fracture zones in Cheetapurpara-Kakalgur area, Bastar district, Chhattisgarh.

ii. High chargeability and low resistivity zone in Mohariya area, Sidhi district, Madhya Pradesh.

iii. Major NNW-SSE trending structural displacements in Khatai-Ghogar-Maham tract, Madhya Pradesh.

*Geochemical Survey* : Hydrogeochemical surveys carried out over 11, 956 sq km in different parts of the country helped in narrowing down target areas. The significant hydro uranium anomalous zones were delineated over:

i. Gondwana sediments and their contact with Deccan Traps and Mahakoshals around Beohari, Shahdol district, Madhya Pradesh.

ii. Basement granite/gneiss and overlying Cuddapah Supergroup of rocks around Kurnool, Alampur, Yaparla and Peddapadu-Salkapuram tract in Kurnool and Mahaboobnagar districts, Andhra Pradesh.

iii. Alwar Group of rocks of Delhi Supergroup overlying the Banded Gneissic Complex along Andhi-Guda Katla-Reni tract and Kho-Dariba-Baldeogarh-Sarasamata-Saintal tract, Jaipur, Dausa and Alwar districts, Rajasthan.

iv. Basement granite and Srisailam Formation of Cuddapah Supergroup along Botalpalem-Jaggayapeta-Peddavaram-Ustapalle tract, Nalgonda and Krishna districts, Andhra Pradesh.

*Drilling* : To probe/delineate subsurface continuity of uranium mineralisation 32, 472 m of drilling was carried out in different promising sectors.

Significant mineralised intercepts were met in the boreholes drilled at Gogi (Karnataka), Rohil-Ghateshwar (Rajasthan), Koppunuru (Andhra Pradesh), Wahkyn (Meghalaya) and Yellapur-Peddagattu (Andhra Pradesh). The results have firmed up the already estimated reserves of uranium oxide in these areas.

Exploratory drilling have also resulted in establishing sub-surface continuity of uranium mineralisation at Tileli (Himachal Pradesh) and Dursendi (Madhya Pradesh).

To expedite the evaluation process and reduce the lead time in proving the new deposits contract drilling has been carried out in Koppunuru, Guntur district, Andhra Pradesh and in Gogi, Gulbarga district, Karnataka, where a total of over 7550 m of drilling was carried out.

## Rare Metal and Rare Earth Investigations

By detailed evaluation of known pegmatites, additional reserves of 3.7 tonnes of columbite-tantalite mineral in parts of Orissa, Bihar and Chhattisgarh were estimated. As a result of survey columbite-tantalite bearing new pegmatites were located in parts of Bastar district, Chhattisgarh; Bhandara district, Maharashtra and Jharsuguda & Sambalpur districts, Orissa.

Field recovery units in Chhattisgarh, and Orissa produced over 3.8 tonnes of columbite-tantalite, and 1tonne of beryl was recovered as a by-product.

## Beach Sand and Off-Shore Investigations

Assessment and evaluation of heavy mineral deposits along coastal tracts in Andhra Pradesh, Tamil Nadu and Kerala was continued.

New areas of heavy mineral concentration were identified along coastal tract of Jagatsingpur district, Orissa and in the inland placers of Namakkal district, Tamil Nadu. Detailed evaluation of heavy mineral beach placer deposits of Kakinada, East Godavari district and Srikurmum and Koyyam, Srikakulam district, Andhra Pradesh have been completed.

Reports/executive summaries on different heavy mineral deposits

were prepared and supplied to IREL and private agencies.

Export consignment of 3,56,700 MT garnet sands and 1,28,300 MT ilmenite pertaining to private entrepreneurs and 93,200 MT ilmenite & 126 MT sillimanite pertaining to IREL were sampled for issuance of monazite test certificate.

### Other Activities

*Geotechnical Investigations* :Report/ note on the seismotect-onics of the areas around the existing/proposed nuclear power plants in Tamil Nadu, Maharashtra, Gujarat, Madhya Pradesh, Andhra Pradesh, Haryana and Punjab were submitted to NPCIL. Database on seismic events was updated and seismic event maps of the areas around various DAE installations were generated.

*Mining Plan approval:* Scrutiny of 20 mining plans in respect of atomic minerals / prescribed substances was carried out as per the provisions of Mines and Minerals (Development & Regulations) Act, 1957. Scrutiny of 20 applications received from DAE for issuing licences for handling prescribed substances (ilmenite, rutile, etc.) to private entrepreneurs was also carried out and observations / comments conveyed to DAE.

*Revenue Generation :*A sum of Rs. 1.64 crore was generated by providing professional and analytical services along with the sale of reports and Nb-Ta minerals to Nuclear Fuel Complex.

*Laboratory Investigations:*The laboratories of AMD gave research support to field investigations.

Gamma ray logging of boreholes (69,500m) radiometric analysis of samples (23,700), shielded probe logging of trenches/faces (1320 m) and radiometric assay of borehole core (4200 m) were carried out. 300 samples were studied for age dating.

Over 12,400 samples (1,10,363 estimations) of water, soil, stream sediment, rock, mineral, ore and beneficiation products were analysed and refinement of analytical techniques were continued. The analytical support was also extended to various outside organisations.

*Other activities included*

- Elemental analysis of the samples comprising ore minerals of uranium, thorium, rare metals and rare earths;
- Study of samples and identification of uranium, rare metal and rare earth bearing minerals, determination of unit cell parameter ;
- Petromineralogical studies on 2040 samples from various deposits / occurrences of atomic minerals;
- Analysis of 3000 samples and 900 samples & standards for different elements.
- Studies continued on hydrometallurgical characteristics of host rocks from different uranium deposits / occurrences, besides developing flow-sheets for the recovery of rare metals;
- Physical beneficiation and hydrometallurgical studies on uraniferous ore of Narwapahar and Yellapur-Peddagattu uranium deposits was carried out, and
- A Technology Demonstration Pilot Plant for development of process flow-sheet for uranium ores was set up at Jaduguda (Jharkhand).

### MINING OF URANIUM & PROCESSING

The Uranium Corporation of India Limited, a Public Sector Enterprise of DAE, is responsible for mining and processing uranium ores to produce uranium concentrates. The uranium concentrate is further processed at the Nuclear Fuel Complex (NFC), Hyderabad for production of nuclear fuel bundles for the nuclear power programme.

At present, the company is operating four underground mines at Jaduguda, Bhatin, Narwapahar and Turamdih and one Uranium Processing Plant at Jaduguda. UCIL also operates a uranium recovery plant at Mosabani to recover uranium concentrate from copper tailings. In addition magnetite present in the uranium ore is being recovered as a by-product in the uranium process plant.

Steps have been taken to monitor and control the cost of production and consultants were appointed by

*Mining operations at Narwapahar Mine (Jharkhand). The mine uses state-of-the art equipment.*

the company to study and suggest ways and means to enhance operational and production efficiency. Their recommendations are being implemented. The company is in the process of obtaining ISO-14001 certification in respect of Environmental Management System.

*Future Expansion Programmes :* Under the projected demand of the nuclear power programme, UCIL is planning the exploitation of uranium deposits at several locations in the country in Jharkhand, Andhra Pradesh and Meghalaya.

The financial performance of the company is given in the chapter on Public Sector Undertakings.

### R&D in Uranium Processing

The progress of the research and development done at Trombay in the field of ore processing and uranium metal production was as follows:

*Production of 450 kg uranium metal ingot in India:* An augmented uranium metal production facility (AUMP) for safe and secure production of 450 kg U-ingot was commissioned. This may be termed as an important milestone in the production of nuclear fuel.

*Production of high purity uranium metal powder in India:* High purity uranium metal powder is employed for the preparation of certain uranium alloy fuels, which are difficult to produce, by conventional melting and casting route. A new process was developed for the production of such high purity uranium metal powder.

*Uranium slag treatment plant (USTP):* Uranium slag treatment plant continued to operate and supply the slag material of specified quality for metal production.

*Development of large scale capacity pump-mix mixer-settler:* Recovery of uranium from dilute streams requires processing by solvent extraction as one of the unit operation. Pump-mix type mixer-settlers are suitable for efficient processing on large scale. A bench scale operation was carried out to study the various parameters of this system, which yielded encouraging results. Further developmental work has now been taken up under X plan.

At Trombay, an achievement was the development and demonstration on continuous plant scale, the process for rare element extraction from weak phosphoric acid and partially neutralized acid.

## FABRICATION OF FUEL AND STRUCTURAL COMPONENTS

Nuclear Fuel Complex (NFC) is responsible for manufacturing zirconium alloy-clad natural and enriched uranium oxide fuel assemblies for all the PHWRs and boiling water reactors respectively in the country and zirconium alloy structural components for these reactors, including calandria tubes, coolant tubes and reactivity & shut off mechanisms for PHWRs and square channels for BWRs. In addition, NFC produces seamless stainless steel tubes, hex cans and other structural for Fast Reactor Core Assemblies and special alloy tubes, all meeting international standards.

During the year 2002-2003, NFC could meet all the annual production targets set by the Board. Towards this, the production in Uranium Oxide Plant (UOP), Ceramic Fuel Fabrication Plant (CFFP), Enriched Fuel Fabrication Plant (EFFP), Zirconium Oxide Plant (ZOP), Zirconium Sponge Plant (ZSP), Zirconium Alloy Melt Shop, Zirconium Fabrication Plant (ZFP) and Special Tube Plant far exceeded the annual targets. There was significant improvement in the recovery and productivity in all these plants.

The monthly and annual fuel requirements for all the 12 operating PHWR units at RAPS. MAPS. NAPS, KAPS, & KAIGA and the 2 BWRs at TAPS were supplied on time. The entire core for MAPS 2, after retubi'ng, has ateo been manufactured along with the Thoria assemblies for neutron flux flattening. The requirement of zircaloy 4 square channels for the 2 BWRs (TAPS 1&2) and seamless zircaloy 4 calandria tubes & Zr-2.5% Nb coolant tubes for TAPP 4 were met on time and a few hitherto untried and complicated reactivity & shut off

*Chairman, AEC at Zr-2.5 % Coolant Tubes Fabrication Shop of Nuclear Fuel Complex*

mechanisms for TAPP 4 were also fabricated for the first time.

*On-going and New Projects:* Significant physical and financial progress was made in four of the five continuing schemes, namely, (i) 37 Element Fuel Bundle Fabrication Project for TAPP 3&4, (ii) Replacement and Augmentation of Zirconium Sponge Plant at Hyderabad, (iii) Advanced Materials Processing and Characterisation Facilities and (iv) Residential NFC-HWB Training School Complex at Hyderabad. For the New Zirconium Oxide Sponge Project (NZOSP) at Palayakayal, a detailed project report (DPR) has been redone and the Environmental Impact Assessment (EIA) is underway.

*Quality Assurance:* As a part of comprehensive quality assurance programme being implemented in NFC. the central-ised quality control laboratory has developed and stand-ardised a number of new analytical methods to meet the revised specifications of the products.

About 15 instrumental methods were developed replacing manual chemical methods, which resulted in improved productivity. A significant achievement had been the DAE Round Robin Test conducted on the NFC made homogenous U3O8 powder and adopting this as reference material in all DAE analytical laboratories. Surveillance audits were conducted by TUV CERT (India) for continued applicability of ISO 9002 certification for NFC.

At BARC, during the report period, metallic fuel assemblies, sub assemblies and other core components were fabricated and supplied to CIRUS & DHRUVA reactors. Control blades and channel fasteners were fabricated and supplied to TAPS.

In the field of NDT development programme, standardisation of hydrogen estimation methods, acoustic emission technique for monitoring the underground radioactive pipelines, standardisation of ultrasonic testing were taken up and accomplished. A new inspection head containing six UT probes and two ECT probes, for inspection of pressure tube sample was designed and developed. Eddy current coil and fixture were designed and developed for the measurement of actual gap between pressure tube and calandria tube and also to detect the location of garter spring in coolant tube of 540 MWe PHWR.

A super conductor wire 3 km long, was produced. Online testing facility was set up for checking the solder bond integrity during soldering process. Two soldered super conductor cables produced were tested.

*Technology Development in Fuel Fabrication* : The technology development activities carried out by Nuclear Fuel Complex were as follows:

-The PHWR fuel bundles, manufactured by employing innovative welding process for attaching appendages on fuel tubes prior to loading of the $UO_2$ pellets, were test-irradiated in MAPS and KAPS. The in-pile irradiation experience revealed excellent performance of these bundles and hence these were cleared for mass scale production, which is expected to commence during the period 2003-04.

-A novel method was developed to retrieve the sintered $UO_2$ pellets form the unaccepted PHWR fuel elements accumulated over the years and was put into large scale operation for the retrieval of sintered $UO_2$ pellets. Considerable quantity of such pellets was recycled for the production of PHWR fuel.

- manufacturing and supplying of more than 400 numbers of quadruple melted Zr-2.5% Nb coolant tubes of stringent hydrogen, chlorine and phosphorous specifications for TAPP-4 along with garter springs. NFC is the first manufacturer in the world to produce seamless zircaloy-4 calandria tubes for PHWRs.

-An important PHWR-540 core component namely, the prototype assembly of three compartment Liquid Zone Control units, was successfully fabricated, assembled and supplied to NPCIL. This unit is a 13.5-meter long assembly and involved integration of 88 individual components requiring about 300nos. of weld joints, which were carried out by electron beam/TIG/ resistant welding.

-An Automated Ultrasonic Fuel Tube Integrity Testing Station was developed and commissioned indigenously and was put into use.

-A novel Indigenous machine for resistance welding of bearing and spacer pads to zircaloy 4 cladding tube is in the final stage of completion and would be used for manufacturing 37-element fuel assemblies for PHWR 540.

-For the first time, NFC had manufactured and supplied 23 Meters long seamless 9 Cr-IMo (modified) heat exchanger tubes for PFBR, meeting stringent quality requirements with respect to dimensional, mechanical, eddy current and ultrasonic testing. Necessary dedicated facilities were developed to mass-produce and handle such long tubes.

## BACK-END FUEL CYCLE

The Back-end Nuclear Recycle activities comprise design, operation and R&D activities related to fuel reprocessing and waste management plants. Besides operating the existing reprocessing and waste management facilities, BARC is also engaged in major activities relating to the design and setting up of additional facilities to meet the extensive requirements of plutonium fuel for

the Indian Fast Breeder Reactor (FBR) programmes.

Fabrication of MOX fuel elements for irradiation in a PHWR was taken up by BARC. Production of MOX fuel pellets and welding for fuel elements is in progress.The MOX fuel assembly consists of 7 inner MOX elements and 12 outer Nat UO2 elements. It is proposed to load 50 bundles in one of the PHWRs.

A number of MOX fuel assemblies were under irradiation in TAPS reactors and fabrication of MOX fuel for TAPS reactor continued.

### Fuel Reprocessing

DAE has reprocessing facilities at Trombay, Tarapur and Kalpakkam. The Trombay plant processes spent fuel from research reactors while the other two plants process spent fuel from power reactors. Plutonium forms the base of second stage of the Indian Nuclear Programme. The performance of these plants was also steadily improving in terms of their throughputs, product quality and reduced waste volumes while maintaining the requisite safety standards.

*Research & Development:* The R&D activities covered the development of co-processing and co-conversion flowsheets for the MOX fuel fabrication. Flow sheet development was carried out for the reprocessing of the AHWR spent fuel bearing Th, U and Pu. A new plant-scale facility is being set up for the production of uranous nitrate by an alternate reduction process. Activities were continued for testing of the newer solvents for actinide separation. An automated, laser assisted fuel pin chopper unit was developed and is under trials for applications in the head-end operations in reprocessing plants. Novel sorbent and membrane based processes are being pursued for the removal of radionuclides from specific waste streams. Oxidative techniques for organic wastes and spent ion-exchange resins are in advanced stage of evaluation.

*Projects:*A number of projects were under various stages of execution to augment the availability of Plutonium for DAE's Fast Breeder Reactor (FBR) programme. These comprise additional facilities for reprocessing and waste management at Tarapur and Kalpakkam.

### Nuclear Waste Management

The waste management facilities at Trombay, Tarapur, Kalpakkam and Rawatbhata were operated safely to manage the waste from fuel fabrication, reactors, fuel reprocessing plant, research activities etc. At all sites, the discharge of radioactivity to the environment was well below the prescribed limits. The major achievement during the year was commissioning of Waste Immobilisation Plant at Trombay for vitrification of high level waste (HLW). The Plant was formally inaugurated by the Hon'ble Prime Minister on October 31, 2002.

At Tarapur, vitrification process was continued to immobilize HLW. Concentration process was also continued to reduce the volume of HLW

*Remote Welding of Vitrified Waste Canister at Waste Immobilisation Plant at Trombay*

for storage. On a campaign basis, intermediate level waste was immobilized in-situ in carbon steel lined RCC trenches.

A computer controlled mechanized facility was commissioned at Trombay. A waste assaying system to monitor the activity in waste drums was also commissioned. The technology developed in-house for spent organic solvent treatment was adopted for putting up a plant at Trombay. The plant was commissioned and the diluent is recovered for recycling.

*Research & Development:* A new system using activated impregnated charcoal was designed and commissioned for CIRUS in emergency exhaust system for the retention of airborne radioiodine. A facility for immobilisation of spent resin in polymer was commissioned at KAPS, Kakrapar with the active participation from NRG.

## RESEARCH AND TECHNOLOGY DEVELOPMENT RELATING TO PHWR

### Ageing Management Activities (PHWR)

*Wet Sliver sample Scraping Technology (WEST):* Technology for obtaining in-situ samples from a pressure tube of an operating PHWR to determine Hydrogen/Deuterium content for predicting life of the pressure tube, initially developed for dry tube, was further extended for wet channel operation through fuelling machine. This WEt Scraping Technology (WEST) helped in considerable reduction in radiation dose to the working personnel. This technology was successfully established through its large scale application at different Indian reactors.

*Garter Spring Repositioning:* Integrated Garter Spring Repositioning System (INGRES) including

associated software was developed in BARC for predicting and extending safe operating life of coolant channels of early generation Indian PHWRs.

## Engineering Development

*MAPS Sparger Channels:* To achieve full rated power operation of MAPS-2 reactor, three sparger channels with whirlers at the ends are to be installed in the calandria vessel to introduce moderator heavy water into the calandria vessel. The design was optimised and support for development and further installation of sparger channels at MAPS-2 were provided.

*Sludge Lancing Equipment for Steam Generators:* A Sludge Lancing Equipment for KAPS Steam Generators was developed by BARC as an import substitution. Periodic sludge lancing enhances steam generator life. Successful working of equipment was demonstrated on a steam generator mock up. Training to NPCIL officials from various power reactor sites on operation of

*Steam Generator Mock up*

this equipment was imparted.

*Fast Acting Valve:* Fast acting valves are needed to create certain test conditions in engineering experiments related to nuclear reactors. They are also used in nuclear power plants. A prototype fast acting valve was designed, manufactured and tested as part of import substitution drive.

*Development of Secondary Shut Down System (SDS-2) for 500 MWe*

*Test Setup for Fast Acting Valve*

*PHWR :* Experimental work on Liquid Poison Injection System was conducted. Poison Moderator Interface (PMI) Studies like effect of time and pipe bending angle on interface movement were carried out. High Pressure Online Conductivity Probes and their installation scheme were designed and developed for PMI monitoring in the U-bend region of poison system of TAPS 3 & 4 units. Non-intrusive Ultrasonic Ball Detection System (U-BDS) was developed to prevent the over pressurization of reactor vessel.

*Thermography Technique:* Inspection technique based on thermography technique are being developed. Using such technique, inspection of thermal insulation of primary system piping inside dry well area of TAPS-1 was carried out to assess the adequacy of the thermal insulation to reduce the heat loss. Thermography inspection of major electrical equipment, breaker panels and switchyard was also carried out to identify the presence of possible hot spots. Based on the inspection, the locations of the thermal insulation having concern from heat loss consideration were identified for rectification.

*Equivalent Hydrogen Analysis of RAPS-1 Pressure Tubes:* As a part of Life Management of RAPS-1 reactor sliver samples were retrieved from 87 pressure tubes. The samples were analysed to generate data on total equivalent hydrogen content of the pressure tubes. Data will be used for assessment of safety of pressure tubes in the reactors.

*Development of Universal Tensile Testing Machine:* Two 100 kN capacity screw driven universal tensile testing machines were developed in collaboration with two private parties.

The equipment were undergoing installation for remote operation in Hot Cells for testing irradiated reactor core structural materials.

*Oxide Layer Thickness Measurement by Eddy Current in Pressure Tube :* A non-destructive method based on eddy current technique is developed for the oxide layer thickness measurement of irradiated pressure tubes.

*Acoustic Emission (AE) Analysis System for Seal Plug Leak Sorting at NAPS-2:* The AE - leak-sorting experiments were performed at NAPS-2 after installing and commissioning AE-system. All 306-coolant channel positions were scanned using fueling machine with AE-tool for probable seal plug leaks.

*Repair of HP Turbine Shroud:* In-situ weld repair of cracked HP turbine shroud using type 410 consumable was carried out for MAPS, using technology already developed. Analysis of repeated premature failures of a spur gear in the DC generator of MAPS led to identifying the modifications necessary in the material and the manufacturing process for preventing such failures.

*In-reactor creep behaviour*: An irradiation experiment was designed and carried out in FBTR to determine the in-reactor creep behaviour of indigenously developed Zircaloy-2 and Zr-2.5%Nb alloy. The samples tested were in the form of pressurised

capsules with predetermined pressures to generate stresses in the tube walls that are similar to the stresses in the operating pressure tubes in PHWRs. The measured in-reactor creep rates for the alloys are comparable to those reported in literature. This has given confidence in the performance of the indigenously developed alloys.

*Electrical fire fighting with water:* In Nuclear Power Plant fire fighting with safety related electrical systems is required to be done keeping the supply on. Safe manual fire fighting distances when using water on live exposed electrical cables/ parts were evaluated at Trombay.

## Physical Protection Systems

*High Security Electronic Lock:* A digitally coded electronic lock, with advanced security features and which provides a tamper proof locking arrangement, was developed. A ruggedized version of the lock was also developed.

*Contact Less Smart Card Based Access Control System:* An Access Control System with contact-less Smart Card as the identification credential was developed. It provides all the features of advanced access control system.

## Monitoring Pressure Tube Health

*Special seal plug for BARCIS:* BARCIS was used for ISI of more than 600 channels in 220 MWe PHWRs. Based on experience a new design of special sealing plug (MK-IV) was developed which has many advance safety features

*Wet Scraping Tool:* Hydrogen concentration is an important parameter that must be assessed to evaluate the fitness for service of pressure tube. To obtain a small sample of material from the inside surface of the pressure tube, a wet scraping tool was developed.


*Coolant channel ID measurement:* A scheme for measuring coolant channel ID in water filled condition for 220 MWe PHWR was evolved jointly with NPC for resolving the anomaly of apparent ballooning of pressure tube in KAPS-2 channels.

*Leaky seal plug identification by using acoustic emission technique:* For monitoring heavy water leakage through seal plugs in operating PHWRs to keep a control on heavy water loss and associated raise in tritium activity, an acoustic emission based leakage monitoring system was developed.

*Wet integrated Garter spring repositioning system (Wet INGRES):* The special closure plug and Wet INGRES delivery equipment was developed to enable the garter spring repositioning in water filled channels. These equipment were manufactured, assembled and subjected to thorough qualification tests for use in reactor. Integral trials along with INGRES tool and drive systems were conducted successfully.

## Maintenance Tools

*Channel isolation plug:* The channel isolation plug is a standard tool for repair of damaged closure seal face of end fitting without draining the channel. Additional 4 nos. of plugs were manufactured assembled and tested for supplying to KAPS and RAPS-3 &4.

*End Fitting Blanking Assembly:* End fitting blanking assembly helps to block the heavy leakage from seal plug temporarily. This device was found to be very useful in all operating station. Five such assemblies were manufactured for supplying to KAPS and RAPS-3 & 4.

*Emergency Handling Tools:* A number of tools were developed for averting / handling emergencies in fuel handling system for operating PHWR.

*Engineering of Spent Fuel Transfer System for 540 MWe PHWRs:* Design work for spent fuel transfer system was completed. Detail design drawings and associated design documents were handed over to NPC for manufacturing.

*Remotely Operated Hydraulic Trolley along with Manipulator*

*Remotely Operated Hydraulic Trolley along with Manipulator (ROHYTAM):* ROHYTAM is a hydraulic mobile robot that was developed for handling emergencies in nuclear facilities and for mechanical dismantlement of radioactively contaminated structures.

## Tribology Lab

Major activities carried out were, Design & development of Indigenous Water Lubricated Bearings (WLB) & test set up; Tribological evaluation of Iron Aluminide in Dry & Water environment; Coatings for various applications; Tribological evaluation of wire brush material and carbon steel Pipe material for Instrumented Pipe Inspection Gauge, under crude oil environment; Design

of Calowear test setup for tribological evaluation of Multilayer coatings; Development of Condition monitoring technique for Testing of Water Lubricated Bearings.

### Water Lubricated Bearing Test Setup

A new set up "Water Lubricated Bearing test set up" with advanced condition monitoring technique that includes online monitoring of Frictional Torque, Dynamic variation in Coefficient of friction due to wear, Radial Internal Clearance, Applied load and Acoustic Emission was designed fabricated and commissioned for use in Fuelling Machine of PHWR.

### Controls & Instrumentation for PHWR

BARC has been providing R&D support to the Nuclear Power Programme in the areas of reactor control systems, remote handling and robotics and electronics and instrumentations etc. Following describes the activities of BARC in these areas during the year of report:

### Fuel Handling Control Systems

The computer base control system, commissioned for use in nuclear power plants at KGS-1&2 and RAPS-3&4, were upgraded by implementing improvements in software and hardware, to achieve 'zero manual intervention' during on power refueling operation on the reactor.

A new control system utilizing indigenous technology was developed to replace the old control system based on imported technology for on power refueling at NAPS-1. The project was undertaken under as an MoU between BARC & M/s ECIL and the system was fully commissioned.

Ram Assembly Test Facility (RATF) control system was designed, installed and commissioned for testing the fuelling machine Ram Assembly of 540 MWe PHWRs at BARC.

Fuelling Machine Test Facility (FMTF) control system for testing fuelling machine head of 540 Mwe PHWRs is being developed. The hardware was fully integrated and installed at BARC.

Fuel Handling System (FHS) training simulator was demonstrated and handed over to Nuclear Training Centre (NTC) Kaiga site.

The in-house code 3DFAST was parallelised on BARC's ANUPAM parallel system.A well known kinetics benchmark problem was analysed.

### Reactor Control Systems

*Control & Instrumentation Systems for TAPP 3&4:* A full-scale prototype of DPHS-PCS was designed, fabricated, installed and commissioned at Trombay.

*Real-Time Simulation of Core and RRS of 500 MWe PHWR:* A real-time simulator, an interconnection of three modules, namely, the core module, the reactivity devices module and the RRS module of the 500 MWe PHWR which was developed during the IX – plan period was commissioned.

*Test Set-up of LZCS of 500 MWe PHWR:* The facility for testing of Liquid Zone Control System (LZCS) of 500 MWe PHWR was successfully commissioned in December 2002. The commissioning experience and test data, acquired from the facility will be useful in commissioning of the 500 MWe PHWR units at Tarapur.

*Advanced Alarm Annunciation System for Nuclear Reactor Applications:* An advanced Alarm Annunciation System for nuclear reactor application was developed.

*Advanced Operator Information System (AOIS) for nuclear reactor applications*

*Advanced Operator Information System (AOIS) for Nuclear Reactor Applications:* Design and development of an Advanced Operator Information System (AOIS) for future Nuclear Plants was proposed under the tenth plan.

*An On-line Setpoint Servo System:* The system was designed for on-line calibration and checking of process instrumentation systems in power plants. The system enables faster calibration and is useful for applications in any process plant. The technology of this system was transferred to a private industry.

*Development of Gamma Scanners:* Gamma scanners for scanning of fuel pins and fuel bundles for an experimental Critical Facility are under development. Production of required numbers of these pin scanners will be taken up soon.

*System Reliability Analysis:* Reliability analysis of Programmable Digital Comparator System (PDCS), a

*Gamma scanner for fuel pin (above) and Miniature underwater radiation resistant closed circuit television (CCTV) Camera developed at BARC, for remotised inspection of coolant channels of PHWRs*

safety critical C&I system for Kaiga-1,2 and RAPS-3,4, was completed and the report was issued.

*Reactor and health Physics Instrumentation:* The amplifiers for processing the signals from the large numbers in-core detectors (self powered neutron detectors) used in 500MWe reactor were successfully tested at Kaiga. The know-how for production of these amplifiers were transferred to ECIL for fabrication and supply to TAPS-3&4. New type of Fission Ion-chamber and Boron-10 coated proportional counter for neutron detectors developed has about five times higher efficiency than the earlier detectors. These detectors will be used for all applications in reactors, accelerators and others.

*Multichannel Ultrasonic Imaging System:* A four channel ultrasonic Imaging system (ULTIMA 100 M4) was developed for volumetric ultrasonic inspection of SS403 billets for end fittings of coolant channels for 500 MWe PHWRs. The images are used for detection and sizing of flaws in the billets.

### Remote Handling and Robotics

The development of miniature underwater radiation resistant CCTV Camera for visual inspection of coolant channels of PHWRs was completed. The camera was used for in-situ examination of calandria tubes of MAPS-2 reactor during refurbishing of coolant channels.

An Automated Eddy Current Inspection system for Moderator Heat Exchanger was developed and supplied to NAPS.

The design and life-cycle testing of Prototype Drive Mechanisms for Adjuster Rods, Control Rods and Shut-off Rods of TAPP3&4 was completed.

BARCIS was successfully deployed for inspection of large number of coolant channels of RAPS-1 and MAPS-1&2.

The development of laser based system for PHWR spent fuel dismantling was completed.

*Development of crown ether:* Work on development of Dibenzo 21 Crown 7 a crown ether continued and preparation of various intermediates was successfully completed. This crown ether, exhibits good selectivity for Cesium-137 in separation by solvent extraction.

*Fuel Chemistry:* U-232 is produced by neutron irradiation of its precursor element Pa-231 in a nuclear reactor. The isotope was successfully separated in pure form suitable for direct use in spectroscopic investigations involving LASERS. This is the first time such a technology was indigenously developed in the country, which has significance in Thorium fuel cycle.

The life of zircaloy coolant channel used in PHWRs, depends mainly on the extent of hydride formation. Therefore, it is necessary to determine accurately the hydrogen/deuterium pick up by the coolant channel. Detailed investigations have been carried out on PHWR coolant channel for deuterium pick up.

Burn-up determination of irradiated MOX fuel samples was carried out.

For the measurement of vapor pressure and thermodynamic properties of nuclear materials such as oxides and alloys, a quadrupole mass spectrometer system coupled to a Knudsen effusion cell was designed and tested.

## HEALTH, SAFETY AND ENVIRONMENT PROGRAMMES

### Atomic Power Station sites

The safety performance of the atomic power stations continued to

*Testing being done by the Health Physics Unit Laboratory of BARC, at Jaduguda*

*Radiation reading being taken at plant site, Jaduguda*

be excellent. The radioactive releases to the environment were much below the prescribed limits. The emergency preparedness systems in the nuclear power plants was updated and information on the same made available on the NPCIL website.

The Environmental Management System developed and implemented in line with International Standards ISO-14001 at most of the nuclear power stations. All the four units at Rawatbhata were certified during the year 2002 and with this, six stations viz. NAPS-1&2, KAPS-1&2, TAPS-1&2, MAPS 1&2, RAPS 1&2 and RAPS 3&4 have been certified as per ISO-14001. Most of these stations also won several safety awards for the year 2001. The new guidelines of AERB for the event reporting at the nuclear power plants to be classified as "significant event report" and "event report" have been adopted at all the plants.

### Uranium mines and mill sites

UCIL made concerted efforts towards the health, safety and environment conservation The company complied with all statutory environmental laws and works for conservation of environment. The Environmental Survey Laboratories (ESL)/ Health Physics Unit (HPU) of BARC functioning at Jaduguda and Narwapahar Mines, carried out routine radiological monitoring, and maintained surveillance on the environment in and around Jaduguda.

### ISO for Heavy Water Plants

Heavy Water Board has gone for international recognition through ISO certification of its heavy water plants for implementing Quality Management System (ISO-9001) and Environmental Management System (ISO-14001). The plants have started implementing Quality Management System and Environmental Management System and got ISO certifica-


*ISO certification ceremony at Heavy Water Plant, Kota*

tion at Manuguru, Tuticorin and Kota. Heavy Water Plant (Baroda) implemented quality management systems ISO:9001:2000 for manufacture and supply of Potassium Metal. The certificate has been awarded by TUV CERT (certification body of RWTUV systems Gmbh, Germany).

Activities related to implementation of ISO:9001 & ISO: 14001 were initiated simultaneously at HWP, Hazira since July 2002. After appointing the consultant, the employees of the plant werer given awareness training and Internal Auditors' Training. The precertificate audit was completed and the final certification is expected to be completed by February 2003.

## Reactor Safety

*Programme on material damage modelling:* Under the program being pursued at BARC to apply the advance knowledge of material damage to assess inherent safety margins in Indian nuclear reactor components, a finite element based code 'MADAM' was developed based on such advanced theory of damage. This code was tested and verified by participating in international benchmark exercises. The code was used to analyse Indian PHWR piping components to understand mechanism of ductile fracture in these materials and to assess maximum loads they can carry under accidental conditions.

*Multi-scale material modelling:* Multi-scale modelling help in generating many material data analytically, avoiding experimental uncertainties. Such analytical capability is also more relevant for our program to generate thermo-physical properties of thorium-based fuel under accidental conditions. The fracture properties of material at atomistic level and the variation of mechanical properties for MOX fuel having different ratios of thorium oxide and uranium oxide were generated as a part of this effort.

*Structural Integrity of Piping:* Primary coolant circuits in reactors are made using highly ductile and tough materials to ensure their integrity. To verify and validate the design philosophy a Comprehensive Component Integrity Test Program was launched.

Experiments were performed to understand the failure mode and to arrive at design criteria to avoid such failure by ratcheting. A computer code "BARC-RAS" (Reliability Assessment Software) was developed to perform reliability analysis of cracked piping components using a variety of probabilistic assessment techniques.

*Aircraft Impact Analysis:* A Transient dynamic analysis was performed to evaluate the extent of damage that could take place in the event of aircraft impact on reactor containment building.

*Ground Motion Studies:* Preliminary estimates were made for the peak ground acceleration for four sites in Madhya Pradesh and Punjab. A reappraisal was made for the seismotectonic status of the Kaiga site. Uniform hazard response spectra (UHRS) for Tarapur site were evaluated.

*Thermal Hydraulic Code Development:* For analyzing various phenomena encountered during safety evaluation, computer codes were modified and upgraded. Three-dimensional modeling of the thermal plume behaviour formed due to hot condenser water discharge from the Kaiga APP into the Kadra reservoir was carried out using CFD code STAR-CD

*Improvement in Plant Operations:* To prevent Emergency Core Cooling System (ECCS) line up with the reactor trip incidents, a proposal was analysed and found to be suitable. It was under adaptation in Narora Atomic Power Station and other PHWR Power Plants.

*Probabilistic Safety Assessment:* Core Damage Frequency was estimated based on reliability analysis of safety systems and initiating event frequency analysis. Symptom Based Diagnostic System (SBDS) was developed for Narora Atomic Power Station (NAPS), which can diagnose the reactor status from the set of reactor parameters taken from Control Room Computer System based on Neural Network. A preliminary version of this software was transferred to NAPS.

Fire Risk Analysis was carried out for Madras Atomic Power Station. Risk Based Inspection methodology was under study for piping systems in Indian NPPs. A computer program was developed to determine failure probability.

*Ageing Studies and LOCA qualification:* A number of studies related to ageing and LOCA qualification were carried.

*Human Reliability Assessment Studies:* Accident Sequence Evaluation Program (ASEP) methodology was analysed for use in HRA of Level-1 of probabilistic safety assessment of MAPS.

*Radiological Monitoring:* The Radiation workers at the Nuclear Power Stations and their plants were monitored every month for external radiation exposures. The TLD Badge Personal monitoring service was availed of by about 50,000 radiation workers, for routine monitoring.

*Internal Dosimetry:* BARC continued to provide the bioassay and

whole body counting internal monitoring services for various fission/ activation products and actinides, to the radiation workers.

Building of a Mobile Radiological Laboratory (MRL) was completed. This laboratory is equipped for rapid off-site deployment (public domain) to monitor the radiological and meteorological parameters in the event of a nuclear accident or nuclear weapon explosion.

A Shadow Shield Whole Body Radioactivity Monitor (SSWBRM), was upgraded for management of its operation, and data acquisition by a Micro-Controller based stand alone unit.

*Environmental Surveillance:* A radiochemical method for the separation of Neptunium and Plutonium (necessary for the preparation of Pu-236 tracer) was standardised.

## Radiation Protection

BARC provided radiological safety support to UCIL Facilities at Jaduguda, Bhatin, Narwapahar and NFC Facilities.

At the UCIL Facilities average radon and radiation levels were within the derived limits and the radioactivity levels in discharged effluents were within the prescribed limits.

At the NFC Facilities all the workers were monitored for Uranium lung burden and values observed were within the limits.

Health physics monitoring during preparation of Phosphorus-32, Phosphorus -33 labeled nuclides at Jonaki Laboratory of BRIT at Hyderabad was continued.

*Radioactivity Analysis:* Monitoring of natural and man made radionuclides in different types of samples were carried out. Samples of farm, dairy and meat products, bottled drinking water from export import consignments were analysed for man made radioactivity contamination and radioactivity test certification.

Pre-operational survey as a part of the baseline data around newly identified sites for uranium mining was conducted. Soil and water sample in and around these areas were collected and analysed for the natural radionuclides content.

*Environmental impact assessment in and around P II test site:* As a part of environmental impact assessment of Pokhran-II test site the activity level of natural and man made radionuclides were determined in the environmental samples collected within 20 km zone around Pokhran. The activity in different food products was found to be same as background level activity.

*Under the Indian Environmental Radiation Monitoring Network (IERMON):* Sixteen stations were upgraded during the year with data communication facility.

*Monazite Survey Project:* As a part of the continuing Monazite Survey Project, dosimetric surveys were being carried out.

*Gamma radiation monitoring:* Gamma radiation monitoring using TLDs in the environment around DAE facilities continued. Dating support was provided to the Centre for Marine Analytical Reference and Standards, Thiruvananthapuram, using Optically Stimulated Luminescence (OSL) techniques to date a soil sample from south Kerala, where an ancient human skeleton was found.

## Environmental Modeling Studies

*Atmospheric Dispersion Models:* Validation exercises of the Gaussian Plume Model, Equi-distant Puff Model (EDPUFF) and Particle Trajectory Model used for predicting atmospheric dispersion of pollutants were carried out. A mini-SODAR unit developed by SAMEER for profiling meteorological parameters was installed and its performance was compared with conventional instruments.

*Aquatic Dispersion Models:* The discharge rate limits of different groups of radionuclides were established for the Effluent Treatment Plant and the Uranium Metal Plant by coupling the aquatic dispersion model with the radiological model.

*Environmental monitoring of heated effluents:* As part of the environmental monitoring of heated effluent discharge into the sea, regular measurement of temperature around the MAPS outfall was carried out. Results showed that the water body as a whole is not getting warmed up significantly.

## Aerosol Studies

Experiments were carried out in the Nuclear Aerosol Test Facility (NATF) under quiescent and turbulent conditions. A model was developed by including inertial deposition, the predictions of which agree with the experimental observations.

Analysis of Trace and Toxic constituents in the Environment.

*Elemental Analysis using Nuclear Analytical Techniques:* Energy Dispersive X-ray Fluorescence (EDXRF) technique was standardized for the determination of sulphur at ppm levels in thorium samples. Study on the usefulness of moss collected from the high altitude area and at sea level was carried out to see its feasibility as bioindicator in Air pollution studies.

*Studies on Persistent Organic Pollutants (POPs) and Voltile Organic Compounds (VOCs):* Distribution of POPs, a group of compounds of known carcinogens and currently of

concern in Environmental Impact Assessment, was studied from coastal marine environment and non agricultural soil. In addition to this blood samples of general population from Mumbai were monitored for organochlorine pesticide residues.

Ambient air samples at traffic junctions were collected from six sites in Mumbai and analyzed for C6-C10 compounds. This study will help to estimate the occupational risk posed by VOCs to the traffic police.

*Trace and Ultra trace Analysis:* Trace and ultra trace constituents of heavy metals, organo-metallic compounds in different environmental matrices play significant role in the assessment of human exposure to them. The studies on these constituents is being continued. Methods for determination of organo-lead compounds and the estimation of nickel and cobalt in ppb levels using Differential Pulse Adsorptive Voltammetry were standardized.

*Effluent analysis at BARC utilities:* The quality of effluents generated from various BARC utilities was estimated.

## Radiation Safety Systems

*Instrumentation:* A plastic scintillator based highly sensitive Limb Monitor was developed, tested and was ready for installation. A truck monitor was installed near SECC, Mod Labs for monitoring the traces of radioactivity in trucks carrying inactive scraps. One more portal monitor is installed at RMD, BARC.

An Emergency Response Centre (ERC) was inaugurated in BARC. The ERC receives radiation level data from the early warning system; network of gate monitors commissioned recently, IRMON network and the SODAR working near FIPLY.

A fully automatic TLD Reader compatible with a new TLD Badge with machine–readable ID code in the form of an array of holes was developed.

1500 numbers of DIGIDOSE pocket dosimeters were fabricated and supplied to various users. In view of the wide spread demand for the low cost Digital Pocket dose-meter (DIGIDOSE), developed by BARC the Technology of the same was transferred to a Vishakhapatnam based company.

*Radiation safety surveillance and training:* Radiological safety coverage was provided for the nuclear fuel cycle facilities.

*Detection of orphaned radiation sources in Georgia:* BARC participated in an international effort under IAEA to search orphan radiation sources in Georgia. For this purpose, the device developed in BARC was loaned to IAEA. The system's performance and the contributions of the teams were applauded both by the IAEA and the Georgian authorities.

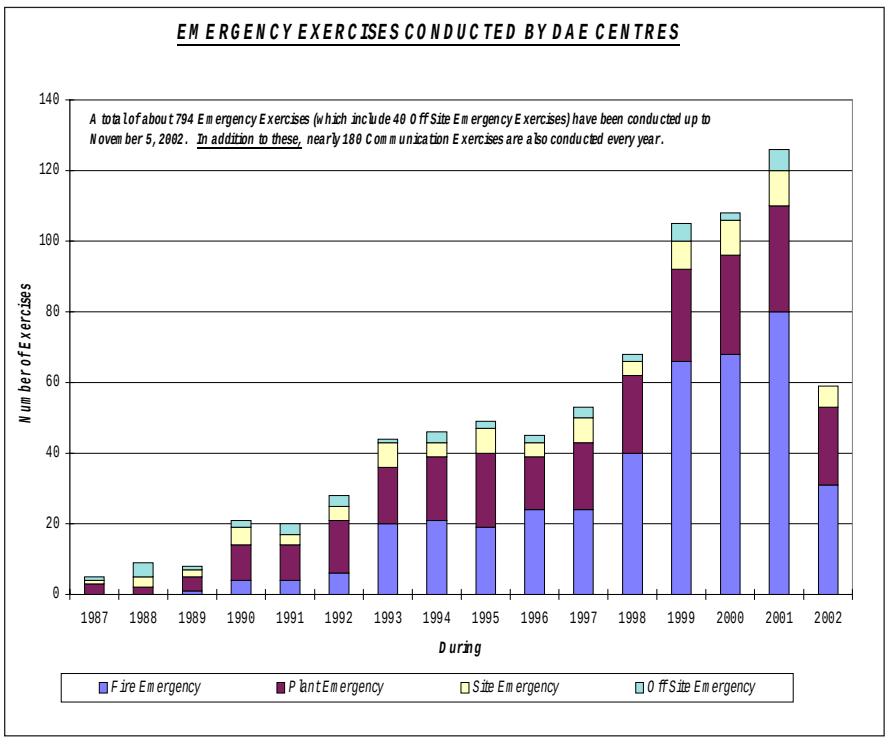
*Standardization facilities:* BARC maintains Primary and Secondary Standards of various parameters of radiation measurements. It is linked through various intercomparison programmes with the other International Organizations. It is the recognized Regional Secondary Standards Dosimetry Laboratory (SSDL) of IAEA/WHO.

Services such as calibration and testing of radiation detectors, monitors and dosimeters were provided besides distributing standard sources to the various users.

*Industrial Hygiene and safety:* Industrial hygiene and safety surveillance was continued for the various activities carried out at Trombay. Activities under the Accident Prevention program were continued. Investigation of accidents, analysis and database management of injury cases and industrial safety inspections and were carried out at all BARC facilities at Trombay, Tarapur and Kalpakkam.

## Crisis Management

The Crisis Management Group (CMG) is a standing committee of senior officials of DAE responsible for coordinating the Department's




*Training Programme of Emergency Preparedness for District Officials organized at Kakrapar, Gujarat*

response to a nuclear or radiological emergency in the public domain. Such an emergency could be due to events taking place within any nuclear facility, an accident involving the transport of nuclear material, events in other facilities handling radioactive materials such as hospitals or industries, or even due to any deliberate attempt to cause disruption in public activities, involving radioactive material. The possibility of any accident in a nuclear facility or during transport which could lead to a radiation emergency in the public domain is highly remote because of the multiple safety systems, defence-in-depth measures adopted in these areas. However, even to handle any unforeseen situations, formal emergency response systems are in place and are tested out to ensure that there is no radiological hazard to the public from these activities. All this is overseen by an independent regulatory authority, which ensures that all radiological safety issues are adequately addressed. Over and above this, a system is also in place to respond to even such situations, by mobilizing the expertise of the DAE in the field of radiation measurement and protection and medical treatment of radiation injuries and making it available at place in the country. The objective is to make these available to public officials who will be handling various types of disasters or emergencies.

To ensure that the emergency plans are in high state of readiness, major nuclear facilities like nuclear power stations periodically carry out a variety of emergency exercises. During the year 2002, the following exercises were carried out:

| | |
|---|---|
| -Communication Exercises | 170 |
| -Fire Emergency Exercises | 37 |
| -Plant Emergency Exercises | 28 |
| -Site Emergency Exercises | 10 |
| -Off Site Emergency Exercises | 2 |

The Off Site Emergency Exercises were carried out at Kakrapar, Gujarat and Manuguru, Andhra Pradesh. These Off Site Exercises are conducted by the concerned district officials (the District Magistrate or Collector is the Off Site Emergency Director) and information flows are established to the Crisis Management Group (CMG) as well as the National Crisis Management Committee of the Union Government.

The same system is also available to respond to a request from any public official in the event of the reported presence or suspected presence of radioactive material. For this purpose, guidelines were circulated to all the State Governments and Union Territories. Information about radiation emergency preparedness was posted on the DAE web site that also includes simple "Do's and Don'ts" during radiation emergencies. A significant component of the emergency response system of DAE is the availability of two emergency communications rooms at Mumbai, which are manned on a round the clock basis throughout the year. These have multiple modes of communication and are in constant contact with various nuclear facilities in the country as well as with the International Atomic Energy Agency (IAEA) in Vienna.

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