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KARACHI NUCLEAR POWER PLANT — A REVIEW OF PERFORMANCE, PROBLEMS AND UPGRADES

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Abstract

The Karachi Nuclear Power Plant (KANUPP), a 137 MWe CANDU Unit is located 30 Km west of the city of Karachi, Pakistan. It is the first commercial CANDU PHWR, built on turn-key basis by the Canadian General Electric Company for the Pakistan Atomic Energy Commission. It was declared in-service on 4 October 1972 and since then operated with a life time average availability factor of 55.9%.

KANUPP during its 23 years of operation has experienced multiple challenges in keeping the plant operating and supplying safe and economical power to the Karachi grid. The biggest challenge was faced in 1976, when the original vendor imposed unilateral embargo leading to the stoppage of supplies of essential spare-parts, nuclear fuel, heavy water and technical support. This forced KANUPP to a new way of operating the plant which necessarily had to be based on indigenous support.

Obsolescence of C&I components became evident soon after plant went into commercial operation because of explosive development and advancement in the electronic and computer technology. KANUPP was, however, able to cope with the normal maintenance and improvement of its process, mechanical and electrical equipment till 80's. However, many of the critical components are now reaching the end of their designed life and developing chronic problems due to ageing. The only technically suitable and commercially viable alternative is the complete replacement of CC&I components. KANUPP has already undertaken this job alongwith other related work under "Technological Upgradation Project".

In order to manage ageing related degradation and carry out full scale assessment of the health of reactor fuel channels KANUPP prepared an "Integrated Safety Master Action Plan" and submitted it to IAEA for arranging international assistance. After intense negotiations and with the IAEA's cooperation in May 1990, Canadian policy towards KANUPP was revised allowing it to provide assistance for Safe Operation of KANUPP (SOK) through the IAEA and only for the IAEA suggested remedial actions. Work under SOK is being carried out to

- Combat ageing and obsolescence problems
- Modernize Operational Safety practices
- Improve safety systems design

This paper describes KANUPP's efforts in overcoming different problems mentioned above.

1. Introduction

The Karachi Nuclear Power Plant (KANUPP) consists of a single CANDU PHWR unit with a total gross generation capacity of 137,000 kilowatts. It is a natural Uranium, Heavy Water cooled and Moderated Nuclear generating station located at Paradise Point on the arid Arabian Sea Coast, about 15 miles to the west of Karachi. It is the oldest operating CANDU-PHWR.

Civil construction began in September 1965, following a turn-key contract with the Canadian General Electric Company (CGE). The reactor attained criticality on 1 August 1971 and subsequent full power operation, on 4 October 1972. The Plant is now operating as integral part of Karachi Electric Supply Corporation (KESC) system, contributing approximately 10% of the total demand of power in Karachi. During its two decades of operation, the plant has generated about 7.9 billion units of electricity with an average life time availability factor of 55.9%. KANUPP which has a design life of 30 years has now completed nearly 23 years of its successful commercial operation.

2.0 Plant Main Features

• Location	Paradise Point, Karachi
• Owner	Pakistan Atomic Energy Commission
• Prime Contractor and Designer	Canadian General Electric Company
• Civil Consultant	Montreal Engineering Company
• Reactor Type	CANadian Deuterium Uranium (CANDU) Pressurized Heavy Water (PHWR)
• Fuel	Natural Uranium
• Moderator	Heavy Water
• Coolant	Heavy Water
• Thermal Output	432.8 MWth
• Electrical Output Gross	137 MWe
• Electrical Output Net	125 MWe

3.0 Operation Objectives

The operation of KANUPP is optimized to meet the following two prime objectives.

- Public, plant workers and environmental safety shall be ensured.
- Continuous efforts shall be made to produce economic and reliable electricity.

The management ensures that the designed features, the procedures and the workers are developed to the best possible standards and that the necessary environment is created and maintained to achieve the above objectives. The safety features of the plant to achieve these objectives are

- Defence-in-Depth
  A defence-in-depth concept, in the form of several successive barriers preventing the release of radioactive material to the environment, has been implemented.

- Automatic Safety System
  Automatic systems safely shut down the reactor and maintain it in a safe and cooled state.

- Normal and Emergency Heat Removal
  Heat transport systems are designed for reliable and efficient heat removal in normal and abnormal operation. Provision is also made for alternative means to restore and maintain fuel cooling under accident conditions.

- Conduct of Operation
  The Plant is operated by well qualified, trained and licensed personnel.

- Training
  Standard programmes are followed for training and re-training of operating personnel. Training is particularly intensive for control room staff.

- Emergency Operating Procedures
  Emergency Operating Procedure have been established, documented and approved to provide a basis for suitable operator response to any abnormal event.

- Maintenance, Testing and Inspection
  Safety related structures, components, and system are subjected to regular preventive maintenance, inspection and testing to ensure that they meet their design intent.

- Quality Assurance in Operation
  An Operation Quality Assurance Programme (OQAP) provides for ensuring satisfactory performance of all plant activities related to safety.

- Containment of Radioactive Material
  The Plant is capable of retaining the bulk of radioactive material that could be released from the fuel during accident conditions.

- Emergency Preparedness
  A "Karachi Emergency Relief Plan (KERP)" for radiological hazards has been chalked out outlining procedures for protection of public and plant personnel in the event of accident.

4.0 Organization

Pakistan Atomic Energy Commission (PAEC) exerts full responsibilities for the safe operation of the plant through a strong organizational structure as defined in Figure-1 under the line authority of General Manager (KANUPP). The General Manager ensures that all elements for safe plant operation are in place, including an adequate number of qualified and experienced personnel. Consequent to the challenges of embargoes and commitment to self-reliance, the following divisions and units were either established or upgraded:

- Computer Development Division (CDD) : For long term solution of real time Computer Control and other related problems.
- Mechanical Design & Development Division (D&D) : For local design and Manufacture of precision and custom made mechanical components.
- Technical Division (TD) : For providing effective technical support in the field of design changes, modifications, plant chemistry, operating experience feedback, planning and nuclear material control
- Quality Assurance Division (QAD) : For ensuring effective establishment and execution of quality assurance programme in accordance with international standards and guidelines.
- Karachi Nuclear Power Training Centre (KNPTC) : For imparting specific training to engineers and technicians in basic nuclear technology.
- In-Plant Training Centre (IPTC) : For providing advanced training to engineers & technicians leading to operating license for KANUPP.
- In-Service Inspection (ISI) & NDT Laboratory : For non-destructive testing, evaluation and inspection of plant components.
- Control & Instrumentation Application Laboratory (CIAL) : For long term solutions of C&I problem including in-house static calibration and dynamic verification of pressure, temperature, flow and level instruments under plant operating conditions.
- Health Physics Division (HPD) : For ensuring effective implementation and control of radiological protection measures and for minimizing personnel radiation dose.
- Maintenance Division : For safe and efficient conductance of preventive and predictive maintenance on plant systems and equipments.

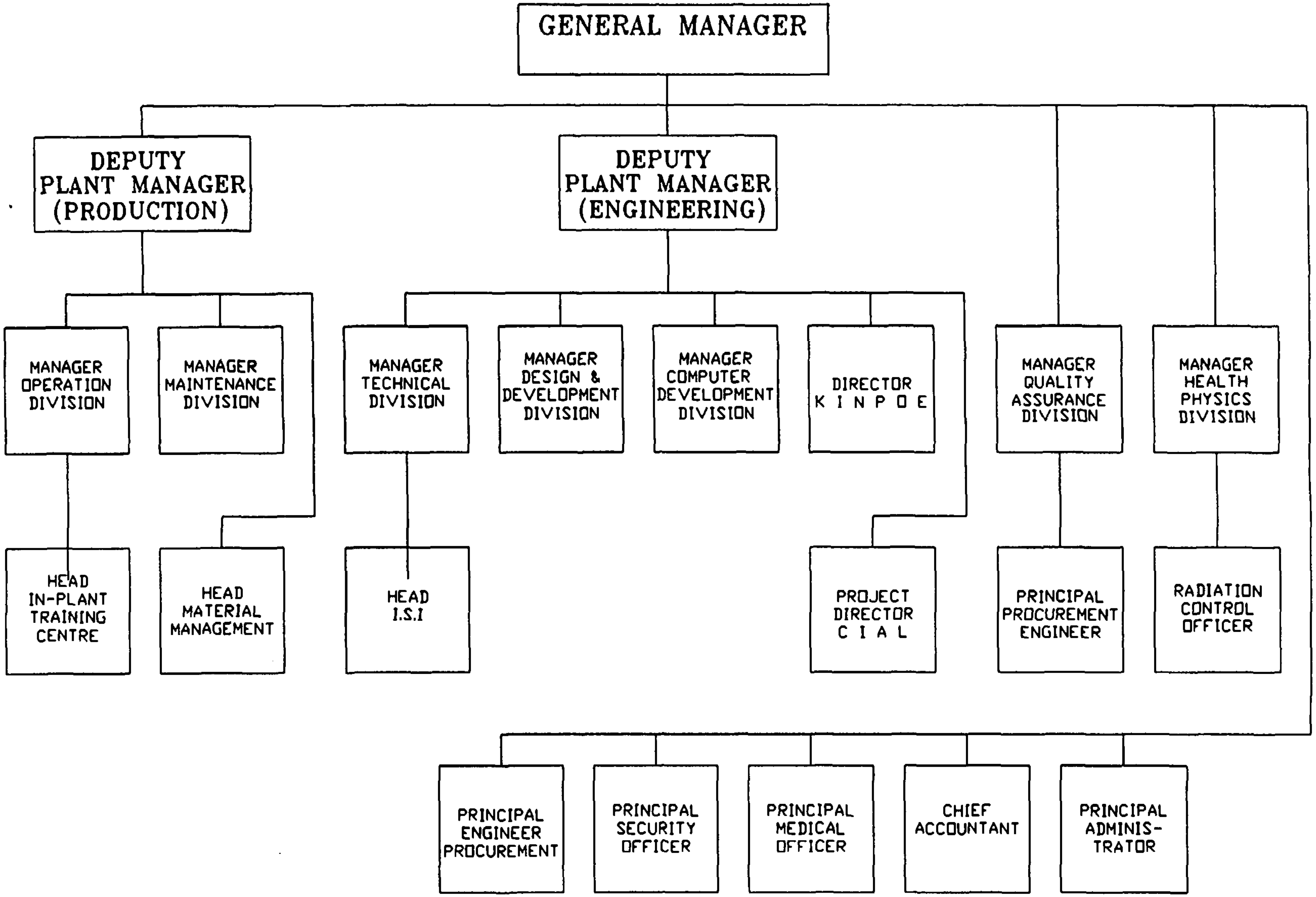

FIG. 1. KANUPP functional organization chart.

5.0 Interface with Regulatory Authority

Nuclear power is regulated in Pakistan by Directorate of Nuclear Safety and Radiation Protection (DNS&RP).

The distribution of responsibilities between regulatory body and KANUPP is such that:

- Primary responsibility for safe plant operation lies with KANUPP.
- Regulatory body sets achievable performance requirements and subsequently monitors these to ensure its compliance.
- Regulatory body has also the authority to accept or reject or modify any proposal submitted by KANUPP on system/equipment design changes, modifications and backfits.
- Regulatory body carries out annual performance review of the plant which includes quantitative measurement of safety and safety related system performance.
- Regulatory body is also responsible for arranging independent safety review of the plant after every five years in close co-operation with experts and consultants who have international experience in plant safety reviews, such as OSART.
- The regulatory body, whenever, finds its necessary and in consultation with KANUPP, provides an independent international assessment through IAEA ASSET missions for identifying areas which require potential improvements, so as to prevent incidents and also to attain an international standard of excellence.

KANUPP 'Operating Policies & Principle (OP&P)' is the key document which acts as an interface between KANUPP and DNS&RP. The OP&P clearly identifies and differentiates between actions where discretion may be applied by KANUPP and where jurisdictional authorization is required by DNS&RP.

On the basis of regulatory and operating policies and principles it is mandatory for KANUPP to report unusual events to DNS&RP within a specified time interval. These are

- Events with major safety significance are communicated promptly (within 24 hrs. of the recognition that event occurred).
- Events with lesser safety significance are communicated within a few days (usually 7 days) of the recognition that the event occurred.

6.0 Plant Performance

Since its connection with the KESC grid in 1972, plant has been operating as a base load Station. Inspite of the early post commissioning phase problems, KANUPP operated with relatively high availability factors upto the year 1977 with an annual average of about 70% (1973-1979). The plant achieved relatively low availability during the period 1978 to 1980 mainly due to non-availability of fuel and essential spare parts from the vendor country. In the wake of the Indian nuclear explosion on May 18, 1974, Canada cut off all technical assistance to Pakistan including operating and design information essential to the operation of KANUPP. The unilateral decision of imposing an embargo on the supplies of fuel, heavy water and spare parts for KANUPP resulted in the curtailment of power production and ultimate shutdown of the plant for most of the period in 1979.

The Pakistan Atomic Energy Commission started fabricating its own fuel in 1979 and since September 1980, KANUPP is operating on indigenously produced fuel. The plant availability started increasing in 1981 and it achieved the highest availability factor of 85.81% in 1994.

In 1982 the plant had to be shutdown for a period of nearly six months to carry out essential maintenance of the plant critical equipments. The major maintenance job undertaken during 1982 was the repair and overhaul of moderator system valves.

The plant was shutdown for a period of about 4 months in 1985 to carryout complete overhauling of turbine, modification on Main Generator, and maintenance jobs related to conventional, electrical, reactor, and protective system.

In 1993 the plant was shutdown for about three months to carryout the In-service inspection of reactor and to remove one sagged reactor fuel channels.

The Plant has so far generated over 7.9 billion units of electricity with an average life time availability factor of 55.9% and an average load factor of 28.4%. Its performance during the year 1994 was exceptionally good when it achieved the highest availability factor of 85.81%. On ten different occasions, the plant operated continuously for over two months including the longest continuous run of over 113 days in 1995. The performance of the plant over the last three years (1992-95) improved considerably when it produced on the average 530 million units of electricity per year with an availability factor of 74% and capacity factor of 44%.

Feeding a relatively small grid, KANUPP during its initial 15 years of operation was required to operate at lower than full power output mainly because of limitations of the load demand and stability of the Karachi grid. Load variations over a period of 24 hours were quite large and hence the utility could not apportion to KANUPP a larger base load. KANUPP is not in a position to load-follow as the excess reactivity available has not been designed to cater for such large load variations as are experienced in the Karachi grid. During the period of 1989 to 1993, the regulatory authority restricted the operation at about 60% capacity due to problems associated with one of its reactor fuel channels.

During the 23 years of its operation the plant had, therefore, to operate at an average of 60-70% of its net capacity. This resulted in relatively low load factors the maximum being 48.8%. The performance factors of KANUPP are shown in Figure-2 & 3.

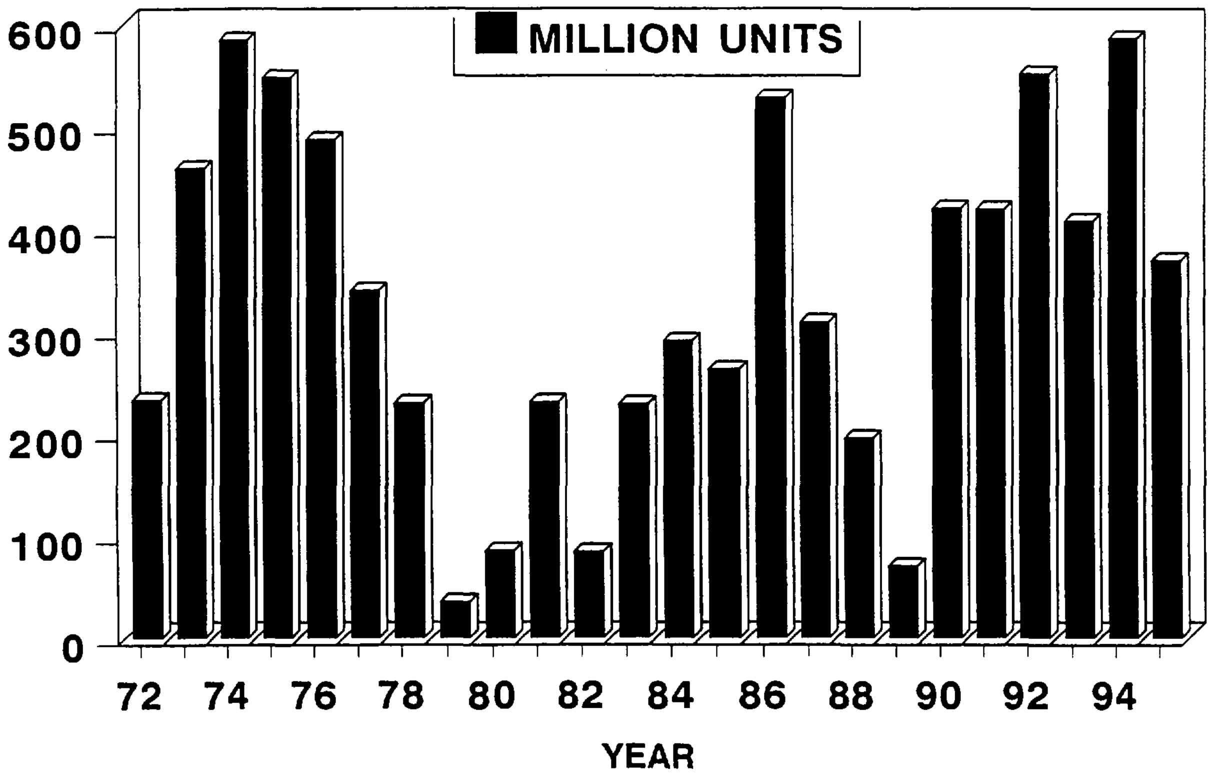

FIG. 2. Generation 1972-1995 (up to 19-09-1995).

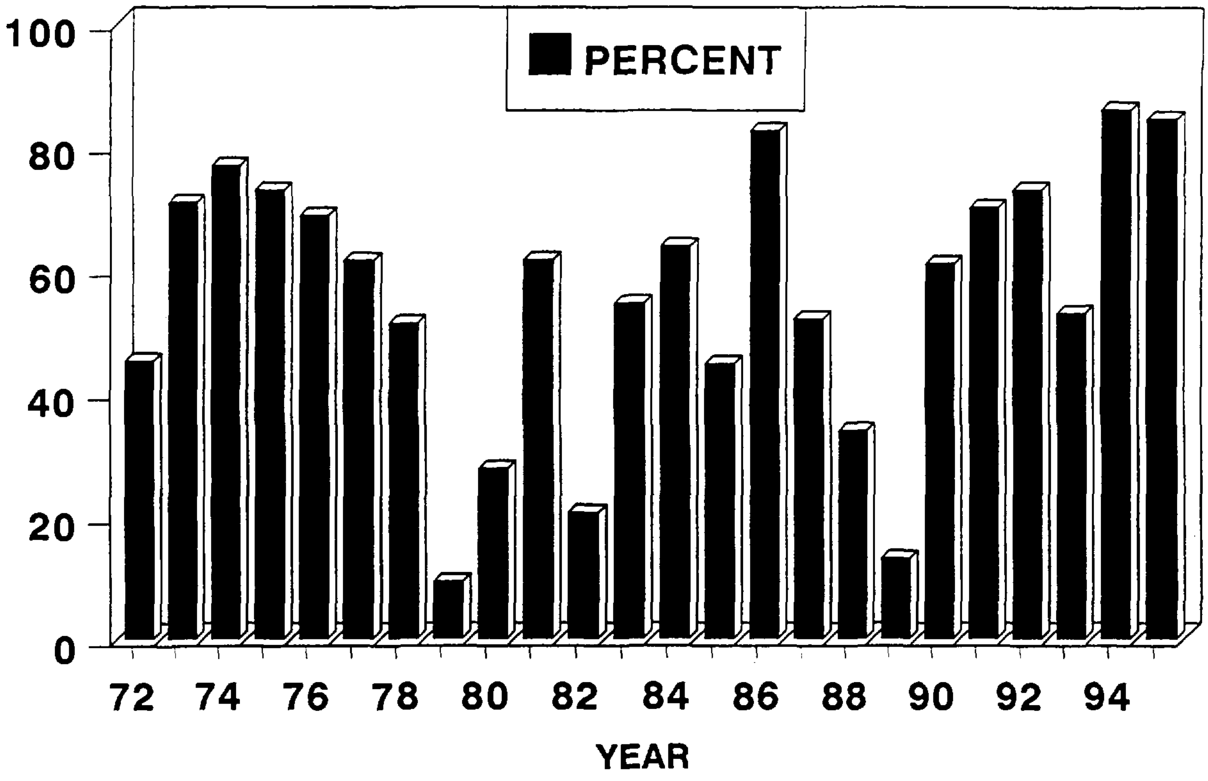

FIG. 3. Availability 1972 (up to 19-09-1995).

7.0 **Plant Outages**

Plant Outages during its 23 years of operation, have been high as compared to other Canadian plants. A total of 280 outages have been experienced, the average being 12 outages/year. The outage causes and their contributions have been classified as:

Outages Causes	Percentage Contribution
◆ Equipment	25.36
◆ Regulation	20.36
◆ Grid Transient.	12.86
◆ Human Error	7.86
◆ Forced	20.71
◆ Planned	7.5
◆ Safety	5.36

Operating KANUPP without vendor's support can be attributed as the major reason for such high outage rate. Many essential equipment and components which were supposed to be replaced on routine basis could not be attended in time causing unplanned plant outages. The other contributing reasons are

- Unstable Grid.
- Heavy Water Leaks (End Fitting, Valves & Pump Gland etc.)
- Fault in Controlling Computers.
- Sea Weed in rush.
- Condenser Tube leak etc.

8.0 Radiation Protection

Inspite of problems of sorts, KANUPP faithfully adhered to its original safety and public risk targets. The radiation control safety record has been extremely satisfactory as testified by regular testing and reliability analysis. Average personnel radiation exposure has been well within the prescribed limits of International Commission on Radiological Protection (ICRP). Refer Figure-4. Release of radioactive material through gaseous and liquid effluent has remained within 3 % of the Derived Release Limits. Refer Figure-5 & 6.

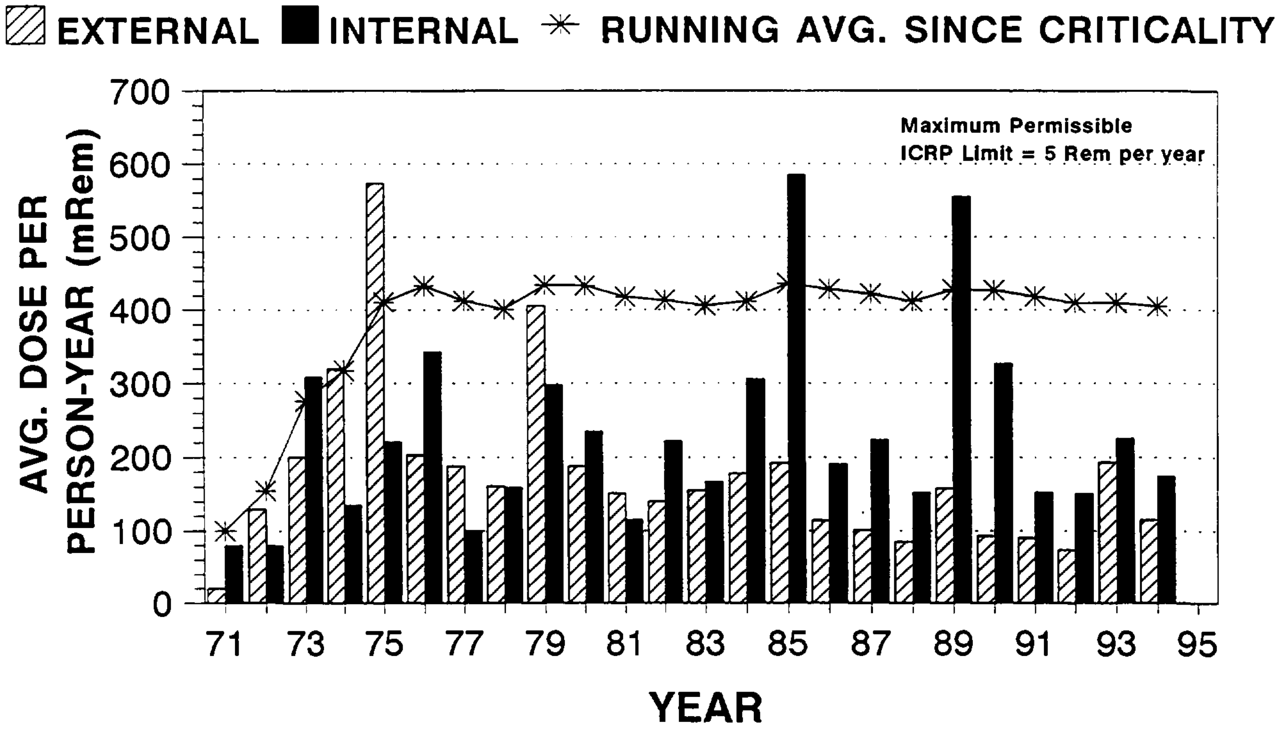

FIG. 4. Average dose per person and running average since criticality.

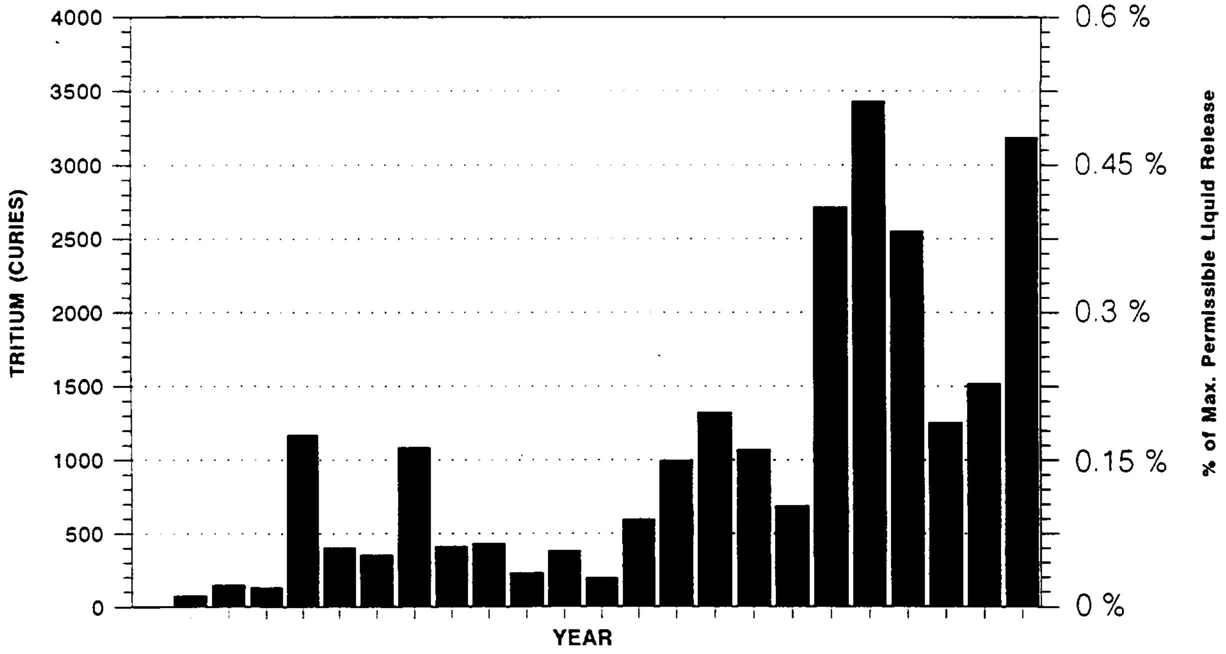

FIG. 5. Release of radioactivity to the environments via liquid effluent.

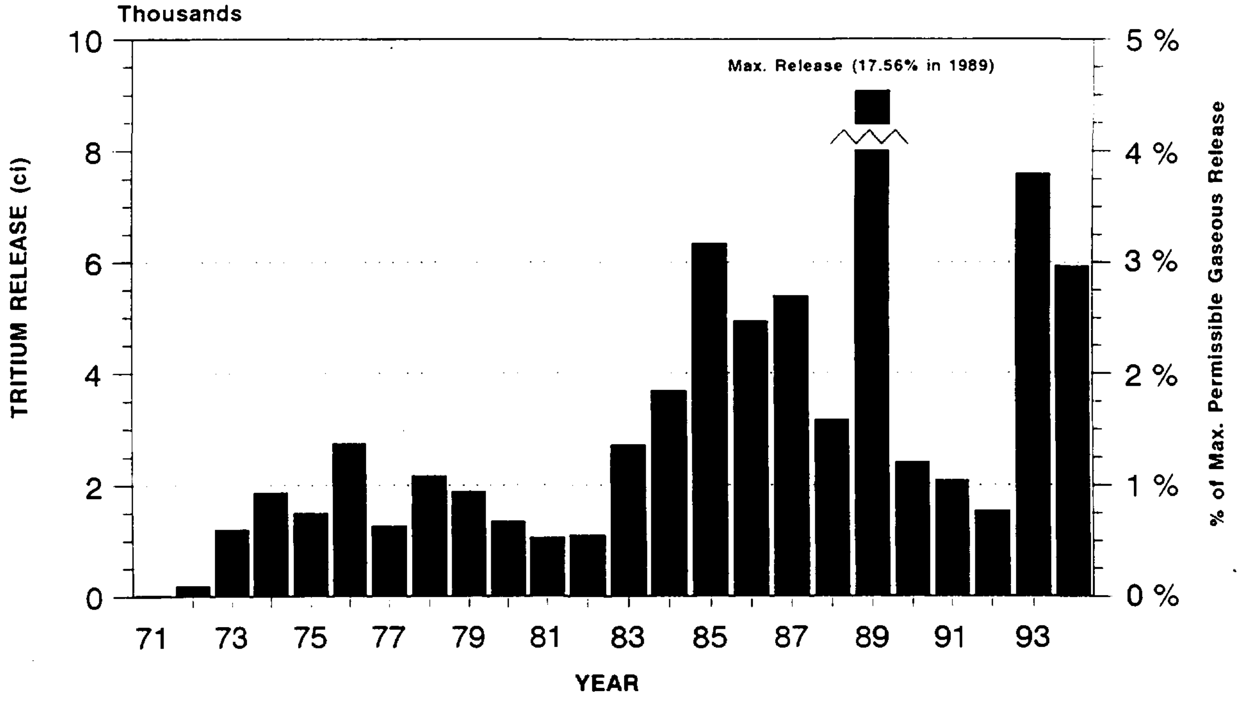

FIG. 6. Release of radioactivity to the environments via gaseou effluent.

9.0 Major Operating Problems and Remedial Actions

Some of the major operating problems experienced during its 23 years of operation and actions taken to resolve them are described below.

9.1 Problems Unique to KANUPP - Embargo and Commitment to Self-Reliance

Two decades of Plant operation since October 1971, when the first nuclear power unit was produced by KANUPP, have proved quite eventful. Following the explosion of a nuclear device by India in 1974, all sorts of nuclear assistance to KANUPP was suspended and a unilateral embargo was imposed by the vendor country on supply of technical assistance, spare parts and fuel in 1976.

Operating KANUPP in the environment of complete embargo was a difficult task, especially in the absence of technical infrastructure required to fulfill the station needs. However, a determined effort on the part of its owner, Pakistan Atomic Energy Commission (PAEC) in general and KANUPP in particular kept it operating safely.

The embargoes, however, proved a blessing in disguise. A self-reliance programme launched by Pakistan Atomic Energy Commission (PAEC) began to yield results. in 1980, PAEC successfully produced nuclear fuel for KANUPP while it made all-out efforts to create the technical infrastructures, Industrial resources and personnel expertise necessary to support station operation. The Design & Development Division (Mechanical), Computer Development Division, In-service Inspection Labs, Control and Instrumentation Application Laboratory and Quality Assurance Division were subsequently established at KANUPP. At about the same time, the Technical and Health Physics Divisions were strengthened to provide necessary backup for technical and radiation control support. The Karachi Nuclear Power Training Centre (KNPTC) and In-Plant Training Centre (IPTC) were established for imparting basic and advanced training in nuclear power technology to engineers and technicians engaged in the operation and maintenance of the plant.

Such technical support does not form part of nuclear power plant operation in developed countries but in the case of KANUPP, there was no other choice. Incidentally, KANUPP is the only nuclear power plant in the world which has been operating without an active technical and material support from the vendor which is vividly indicative of PAEC's commitment to self-reliance.

9.2 **Normal Operating Problems.**

9.2.1 **Nuclear Island**

9.2.1.1 **Standby Heat Exchangers**

Tubes of one of the two heavy water standby heat exchangers failed due to fretting caused by process water flow induced vibration only after three years of plant operation. All tubes of heat exchangers were checked by ECT and the tubes showing thinning in excess of acceptable limit were plugged. The tube bundles were also strengthened by installing more fasteners. Later inspections showed no or slight ageing effect. However, the tube bundles of one of the standby heavy water heat exchangers was fabricated locally and installed. It is planned to fabricate and replace the tube bundle of all the three remaining standby and charging heavy water heat exchangers.

9.2.1.2 **Moderator System valve Gasket**

As against the current practice of providing double gasket arrangement, valves in the Moderator System at KANUPP are provided with conventional single gasket arrangement using neoprene gasket at the bonnet. This neoprene gasket in one of the moderator pump discharge valves failed (ageing degradation due to embrittlement) and caused a large D_2O spill.

The frequency of inspection/replacement of the gasket of all such valves has been increased.

9.2.1.3 **Differential Pressure Transmitter Casing Bolts.**

A differential pressure transmitter between south outlet and north inlet-header failed due to breaking of two out of four chrome plated steel bolts used for joining the two metal casings enclosing the bellows assembly, resulting in D_2O leakage.

The bolts on all such transmitters have been replaced.

9.2.1.4 **Steam Generators**

KANUPP has six steam generators with Monel 400 tubes. Tube failure with ageing is a well known and expected phenomenon. In fact the performance of KANUPP has been better than expected in this area.

Steam Generator # 3 developed a small leak in 1989, which developed upto 4 Kg/hr over two weeks at the end of 1990. The plant had to be shutdown for more than a month and a special procedure was developed to isolate the leaky boilers and operate the plant with four instead of six steam generators in service.

After performing necessary modifications the plant was operated with four out of the normal six boilers. This was a unique operation as no such previous experience was available in any CANDU nuclear power plant. The regulatory body gave short-term permission to operate in this condition at 50% power. The leaky tube (only one) was later plugged after acquiring necessary training and confidence on locally assembled steam generator test mock-up.

9.2.1.5 **Dump Valves**

Six dump valves, connected in series parallel arrangement, are provided in the helium balance line to trip the reactor. The valves are 10 inch butterfly valves with diaphragms and elastomer seals connected to the upstream pressure to minimize leakage when the valves are closed.

The dump valves, provided by the vendor, were modified and special elastomer seals were installed by Canadian General Electric. No spare seals, their drawings and other parts are available. Only once a dump valve was opened for inspection. Due to daily trip tests and relatively frequent plant trips experienced, the dump valves have been subjected to rather severe duty. It is planned to replace the valves with new ones, and efforts are underway for their procurement.

9.2.1.6 Fuelling Machines/Fuel Handling.

Fuelling Machines and end fitting components are a critical part of the primary pressure boundary when in use. They are highly complex, custom built, and subject to very high radiation levels. We have experienced the following ageing-induced problems so far. Some have been solved for now, but the basic issue of fabricating replacements for custom-built parts remains and becomes more serious with time.

- A D_2O hose ruptured leading to a major heavy water spill.
- D_2O head circulating pump canned motor developed micro-crack due to excessive rubbing. D_2O seeped into stator winding deforming the stator can.
- Snout jaws developed cracks over a period of time within & along the groove, being the maximum stressed areas. The snout jaws cracks propagated in 1988 as revealed by ISI. Plant operation was not allowed by the regulatory body till replacement with locally manufactured and extensively tested snout jaws.
- *Failure of mechanical seal 'o' ring installed in charge tube axial drive due to ageing.*
- Closure plug locking problem. The shield plug was found damaged and the charge tube latch finger had broken inside the end fitting.
- Shield plugs sticking on rotation. Investigation revealed that tail end was causing restriction both in axial and rotary motion due to bulging/deformation. Machined to original size before replacement.
- Two fuel bundles entangled due to damaged end plate of one, entered Fuelling machine magazine together and prevented rotation. Dislodged by special procedures. The incident is attributed to hammering received by the bundle against the channel sealing surface.

9.2.1.7 Reactor Fuel Channels

In 1989, fuelling problems led to detection of two sagged reactor fuel channels in cold shutdown condition. Subsequent inspection revealed reactor fuel channel G-12 to be sagged by 49 mm and F-15 by 12 mm. The problem is not unique to KANUPP as similar problems had been discovered in other Canadian plants and rectified successfully. In 1993, the Canadians under the IAEA assistance carried out an assessment of the fuel channel integrity and removed G-12 to identify the root cause of its retraction. The problem was found to be specific with only G-12, whereas all other reactor channels inspected were found to be in perfectly good condition. The reactor resumed operation with one channel removed.

9.2.2 Plant Computers

9.2.2.1 Control Computer

Plant Control computers consist of a dual redundant digital computers, GE-PAC-4020, for reactor power regulation. These computers were designed in mid sixties and were installed as part of reactor control system by the original vendor.

The computers were maintained through indigenous modifications until 1989. The modification include recoding of the real time computer control software, a 15 man year effort which considerably improved the performance of main plant control system. Performance of these computers have now deteriorated to the extent that their replacement is essential for reliability and continued safe operation of the plant. The replacement of regulating computers is being undertaken as part of Technical Upgradation Project (TUP).

9.2.2.2 Fuel Handling Computers

The existing PDP-8 computer system for Fuel Handling Control has been replaced by an Industrial IBM PC-AT Computer system, utilizing the expertise available in PAEC. A new software package written in Microsoft-86 assembly language has been provided to execute the same functions as the PDP-8 fuel handling control computer.

9.2.3 Control and Instrumentation (C&I)

During the last decade extensive advancement and innovation has taken place in computers and high technology electronics and informatics. This has completely changed the design and operational philosophy of modern nuclear plants. Nowadays, the modern plants are being controlled by a very sophisticated software based technology. The Control & Instrumentations systems of KANUPP were designed in mid sixties and have now become totally outdated and obsolete. Due to their obsolescence and ageing extreme difficulty is being encountered in their maintenance and upkeep. In fact, at a certain stage, it was felt that due to ageing and obsolescence their maintainability may aggravate to a level where it will become very difficult to ensure reliability and safety of plant operation. Therefore, a systematic and comprehensive programme has been prepared for functional replacement of obsolete C&I equipment. A Technological Upgradation Project (TUP) has been initiated and a contract has been signed with a foreign firm for the supply of CC&I equipment the design of which has been completed by KANUPP engineers. New CC&I equipment is expected to be installed and made operational by end of 1996. In addition, the following C&I jobs have already been completed either indigenously or in association with some other foreign vendors.

- Replacement of T/G Instrumentation.
- Upgradation of Plant Communication System.
- Installation of a close circuit TV system for monitoring various areas of Reactor Building.
- Radiation monitoring system.
- Plant Switch Yard Extension etc.

9.2.4 **Conventional Systems**

Following steps have been taken to resolve problems due to proximity to sea (corrosion due to airborne sea-salts) and use of sea water for condensing steam and for Cooling Process Water, causing corrosion, erosion, carry-over of silt, sea weeds, in-rush of sardines and barnacles growth on pump house equipment and associated systems.

- Traveling intake salt water screens replaced with corrosion resistant material such as stainless steel.
- Condenser tubes kept clean by reversing flow, and ferrous sulfate addition at frequent intervals to create protective layer on tubes.
- Process cooling water pump casing and main headers piping replaced.
- Radiator air cooling installed for diesel generators, replacing the sea water cooling.
- Other equipment i.e. meteorological tower, station transformer radiators and high voltage transmission towers, which were badly affected by corrosion, were replaced.
- Frequency of painting of all the plant equipment which is exposed to corrosive atmosphere/environment increased.
- Complete retubing of Process salt water Heat exchangers with titanium tubes.
- Replacement of chlorinating plant.
- Salt Water pumps and casings.
- Boiler Blowdown line replacement.
- TLO separater replacement.
- Complete replacement of Fire Water Ring, etc.

10.0 International Co-Operation and Safety Updgradation

10.1 Role of IAEA

The Three Mile Island and Chernobyl accidents have greatly increased the role of IAEA in ensuring safe plant operation all over the world. KANUPP has been inspected by 'IAEA Operation Safety & Review Team (OSART)' in 1985 and in 1989 and on both occasions the plant was found to conform to IAEA operational standards. An IAEA 'Assessment of Safety Significant Evaluation Team (ASSET)' mission also visited KANUPP in 1989 and performed in-depth analysis of plant operational safety practices. The ASSET mission made several recommendations for improving the safety of the plant. An overall plan identifying, prioritizing and scheduling the activities important to plant safety was developed based on the experience of KANUPP and the recommendations of ASSET missions. An 'Integrated Safety Review Master Plan (ISARMAP)' was established in 1991. Based on ISARMAP, the IAEA approved initially a four year (now revised till 1997) technical assistance project namely 'Safe Operation of KANUPP (SOK)' and approached the Canadian Government which agreed to provide initial consultancy for expert assessment and planning for the required safety improvement through CANDU Owner's Group (COG) of which KANUPP was a member. The objective of this IAEA project (PAK/9/010 'Safe Operation of KANUPP) was to arrange the necessary international technical support for the tasks listed in ISARMAP. The support under PAK/9/010 was envisaged in following three ways.

10.3 **Integrated Safety Review Master Plan (ISARMAP) Task and Status**

SR. NO.	ISARMAP TASK	CURRENT STATUS
01.	**Project Management**	
	a) Establish an Integrated Master Plan for SOK.	Established in 1991. Reviewed by Steering Committee five times.
	b) Umbrella agreement with COG for Canadian Technical Assistance.	Only safety investigations, assessment diagnostics tasks and expert and services have been allowed.
02.	**Equipment Ageing Affecting Safety**	
	a) Fuel Channel Integrity Assessment (FCIA).	Sagged pressure tube G-12 was removed and ISI of this and other 7 selective reactor channels, done with Canadian technical support. A local, non-generic problem with only G-12 due to a leaky rolled joint was identified.
	b) Improve CO_2 Annuals Gas System	The CO_2 system at KANUPP is once through and needs review for its adequacy to provide leak-before-break detection. This is important as a creak in pressure tube could be detected well before it reaches the critical crack length (~15hrs.).
	c) Repair of Steam Generator	One leaky tube was detected and plugged by KANUPP. Canadian Technical support was proposed but ultimately not required.
	d) Fuelling Machine Ageing	The fuelling machine forms a part of the coolant pressure boundary during on-power fuelling. Replacement of its aged parts is essential, however, Canadian government has so far not considered it as a safety issue.
03.	**Equipment Obsolescence Affecting Safety**	
	a) Replacement of Radiation Instrumentation	Obsolete radiation monitoring instrument has been replaced.
	b) Replacement of obsolete Computers Control & Instrumentation.	- Fuelling Machine PDP-8 computers have been replaced with Industrial Grade PC's. - Replacement of plant regulating computers GEPAC-4020 and instrumentation is planned in 1996.
04.	**Improve Operational Safety Practices**	
	a) ISI of Steam Generator and BOP Piping.	Primary system pressure boundary and critical BOP pipings were inspected in 1992 by Canadian specialists. The Systems were found in excellent condition. Eddy current testing of two steam generators was done in May 1993 by B&W Canada and tube conditions were found to be very good. Only one tube in steam generator # 3 with 26% 'Through Wall Thickness (TWT)' detected & plugged.

SR. NO.	ISARMAP TASK	CURRENT STATUS
	b) Review of modern Maintenance Technique.	Techniques followed in modern CANDU plants such as infra-red thermography & laser shaft alignment are being implemented.
	c) Improvement of Safety Culture.	Courses to improve safety culture at KANUPP were arranged in 1991 by IAEA. Two IAEA experts delivered lecture in 'Basic Safety Principles for Nuclear Power Plants' and 'Analysis and Prevention of Safety Significant Events. Root cause analysis of safety significant events have been established after these course.
	d) Review of Modern Emergency Preparedness	Emergency preparedness arrangements in modern Candu were reviewed by a KANUPP specialist in 1992. Required improvements and practices are being adopted in KANUPP.
	e) QA Programme.	Operations Quality Assurance programme was reviewed by a Canadian specialist in July 1994 and found in line with Canadian practices.
	f) Operating Experience Feedback.	International Operating experience feedback has been computerized on an internal LAN, connected to CANDU OWNERS GROUP (COG) and WANO, INPO Networks.
05.	<u>Improve Design Safety</u>	
	a) Update of Final Safety Analysis Report (KFSAR)	Work on Phase-I (Analysis of special safety systems against limiting large break LOCA) has been completed. Work on Phase-2, i.e. complete updating of final safety report is planned to be undertaken in 1996.
	b) Probabilistic Safety Analysis Level-1.	The work on KANUPP PSA Level-1 is in progress and expected to be completed by end of 1996. Reviews are done by IAEA experts at required intervals.
	c) Equipment Qualifications (EQ) Review Against LOCA.	Expert review was done in 1993 by two Canadians. No major problem identified, however, they recommended establishment of a systematic EQ programme. Few modifications were implemented as part of EQ programme.
	d) Booster Cooling.	The use of booster has been discontinued because of the safety concerns with respect to its cooling. Canadian plants do not use boosters any more.
	e) Emergency Boiler Feed Water Supply.	In order to provide an un-interrupted heat sink to reactor, an independent supply of emergency feed water to steam generator is being planned. Independent review by a Canadian expert of the design has been done. New system is expected to be installed by early next year.

SR. NO.	ISARMAP TASK	CURRENT STATUS
	f) Adequacy of Emergency Power.	KANUPP has two standby Diesel Generators. A third Diesel generator is being added to improve the emergency power supply needs and decrease the allowed outage times.
	g) Containment Testing at Higher Pressure.	The containment Pressure test was done at full pressure (27 psig) during commissioning and afterwards it is being done at 2 psig. In order to assess the leak rate at higher boiler room pressure it is now planned to perform the test at elevated pressure. Test at 5 psig has already been done successfully. KANUPP is now approaching COG to provide expert services from Point Lepreau NGS for developing necessary procedures, to test containment at a reasonably high pressure.
	h) Seismic Walkthrough of the Plant.	KANUPP is designed for 0.1 g earthquake. A walkthrough by IAEA experts in 1993 concluded that KANUPP can withstand twice the design basis earthquake with minor modifications. Necessary steps being taken to implement the recommendations.

- Foreign Experts visit to KANUPP
- Some Assistance in purchase of equipment
- Some fellowship assistance for KANUPP personnel.

A steering committee was also constituted by IAEA to review the ISARMAP tasks, their scope and priorities, the results of the activities for the enhancement of KANUPP safety system and recommendations for further actions.

The ISARMAP could be broadly classified into the following five areas with a number of tasks in each area.

- Project Management
- Ageing
- Obsolescence
- Operational Safety
- Design Safety Improvements.

A detailed description of the tasks alongwith their current status is given in section 10.3

10.2 Role of Other International Organizations

The complete isolation of KANUPP from international channels of communication partially ended in 1989 following the Three Mile Island and Chernobyl incidents which aroused an instant realization among the nuclear community to promote global safety in nuclear power plant operation. The CANDU Owners Group (COG) and, later, the World Association of Nuclear Operators (WANO) were formed to provide a forum for promoting closer co-operation among nuclear utilities in matters relating to operational experience feedback, human performance and plant safety. KANUPP joined COG and WANO in 1989 and has now access to public domain informations from nuclear utilities around the world.

COG is playing the leading role in accomplishment of jobs under the 'Safe Operation of KANUPP (SOK)' Project. An agreement to this context exists between KANUPP and COG.

WANO has done a two week 'Peer Review' of KANUPP in November 1994 and 20 experts from all over the world conducted in-depth safety review of the plant. The identified weak areas are being strengthened. Under the aegis of WANO-TC, a number of technical exchange visits to other nuclear power plants has also been arranged, providing opportunity for operational experience exchange.

11.0 Conclusion

It is an accepted fact that nuclear power plant must operate with the technical support of the vendor country and other international help, since the quantum of R&D, design and operational & safety experience of the vendor country can not be matched by NPP operating country alone. This aspect of nuclear power plant operation has been recognized well by the international community and as a consequence institutions such as INPO, WANO & COG have been created. These institutions alongwith IAEA are playing vital role in providing necessary technical services and support to the operating power plants in assessing the extent to which they are complying with their original safety standards and also suggesting the improvements and modifications required to achieve an acceptable level of current international safety standards.

KANUPP has amply demonstrated that nuclear power is feasible in a developing country. The plant can operate despite heavy odds and numerous challenges. It has also established that nuclear power is environmentally clean and safety remains paramount in the operation of a nuclear power station.

In more than 20 years of operation, not a single KANUPP employee has lost a day's work due to radiation exposure - a testimony to the good design and safe operation of the plant.

Radioactive emission to the environment throughout the operational history of KANUPP has remained below 3% of the Derived Release Limits.

Various safety reviews and investigations done in the past by IAEA and other international organizations confirmed that KANUPP has maintained an excellent safety record and that its critical components such as Reactor, Boilers and Turbine Generator are in perfect condition.

KANUPP is striving hard to resolve its current ageing-induced equipment problems to satisfy the original safety requirements and public risk targets which are still internationally acceptable. However, as a policy the management is committed to upgrade the safety as far as possible , towards current standards and criteria.

It is envisaged that the economical life of the plant would be extended 10 years beyond its design life of 30 years after providing all the required replacements of its obsolete informatics and refurbishing of nuclear island as well as conventional equipments.

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