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CANDU SAFETY MANAGEMENT

IN PAKISTAN

A Status Report by

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ABSTRACT

The nuclear power program in Pakistan consists of the 137 MWe Karachi Nuclear Power Plant (KANUPP), the only non-AECL-design offshore CANDU, operating for the last 25 years, and CHASNUPP, a 300 MWe PWR under construction, both owned by the Pakistan Atomic Energy Commission (PAEC). In the context of CANDU safety management, this paper is limited to KANUPP. The regulatory and licensing functions are implemented by the Pakistan Nuclear Regulatory Board (PNRB), independent of PAEC, whereas the prime responsibility for safety lies with the plant manager.

The basic objective of nuclear regulation is to limit public and personnel exposure. It is translated into specific conditions of the plant license, i.e. equipment and systems reliability targets derived from safety analysis of the plant design, and explicit operating policies & principles including presence and licensing of operating personnel, and qualification / monitoring of radiation workers. On-going compliance to these requirements is monitored by the regulatory body through routine quarterly inspections and review of annual reports including significant events. Plant modifications affecting safety are approved by the regulatory body.

The overall safety performance of KANUPP against these requirements has been quite good over the past 25 years. But the phenomena of equipment aging, equipment obsolescence and evolution of nuclear safety standards, faced by all older NPPs, were aggravated for KANUPP by complete technological isolation from the vendor country for more than 14 years. When it became possible following international attention in 1990, an IAEA sponsored project titled 'Safe Operation of KANUPP (SOK)' was started to assess and ensure compliance to the contemporary internationally acceptable level of safety, leading to a prioritized and Integrated Safety Review Master Plan (ISARMAP) implemented under the supervision of an international Steering Committee. This is our equivalent of the long-term safety review regime adopted in other countries, preparing the ground for later plant life extension.

Fortunately, the work done so far has indicated good overall equipment condition, effective obsolescence measures, adequate operational safety practices, and adequate design safety using uptodate analytical methods. Further detailed analyses and improvements are continuing, to avoid the future potential for an unacceptable level of safety. Difficulties in applying modern safety design standards to backfits are common to older NPPs.

Support of the IAEA has sustained KANUPP and brought it out of isolation. Strong international operating experience feedback through the IRS, ASSET and OSART programs of the IAEA, information exchange program of COG, and the information exchange and Peer Review programs of WANO are helping further to strengthen the safety culture and integrate KANUPP deeper into the international nuclear community.

CANDU SAFETY MANAGEMENT IN PAKISTAN

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1. INTRODUCTION

The Pakistan Atomic Energy Commission (PAEC) owns two nuclear power plants. The Karachi Nuclear Power Plant (KANUPP), a 137 MWe CANDU-PHWR has been in operation since 1972. The Chashma Nuclear Power Project (CHASNUPP), a 300 MWe PWR is under construction, due to be commissioned in 1999. In the context of the topic of this workshop, this report is limited to KANUPP.

KANUPP was designed and built on turn-key basis by the Canadian General Electric Company. The design, safety philosophy and operational practices are basically derived from the contemporary Canadian norms at that time. There are some basic differences from the AECL design in the fuel channel materials and design. The single containment building is designed for 27 psig. A unique aspect of the operating experience is total technical isolation from the vendor country for political reasons for about 14 years, disrupting the normal process of gradual technological upgradation.

The nuclear regulatory function is carried out by the Pakistan Nuclear Regulatory Board (PNRB) which is independent of PAEC. The PAEC does however have an internal Directorate of Nuclear Safety and Radiation Protection (DNSRP) which acts as the secretariat of the PNRB, issues licenses and in general implements the decisions and regulations made by the PNRB.

2. OBJECTIVES OF SAFETY MANAGEMENT

Like the rest of the world, the basic objective of regulation of nuclear activities and licensing of nuclear facilities in Pakistan is to ensure that the risk of undue exposure of human beings to ionizing radiation remains within acceptable limits. The limits are different for the general public and for personnel trained to work within the nuclear facilities (occupational dose), based on the recommendations of the International Commission on Radiological Protection (ICRP).

The maximum dose received by any member of the general public in case of the worst credible accident in a nuclear facility.

The maximum probability of such a credible accident in a particular nuclear facility..

The accumulated indirect dose received by any member of the general public through the environment.

The maximum dose allowed to a radiation worker.

3. MECHANISMS FOR SAFETY MANAGEMENT

There is no transportation of radioactive waste from the KANUPP site, and its de-commissioning is in a preliminary planning stage, so the safety management of these aspects of the CANDU plant life cycle is not covered in this report.

The following specific mechanisms have been established to ensure that the design, construction and operation of a particular nuclear facility complies to the above basic objectives.

3.1. Documents

Before a particular NPP is allowed to be constructed, a Preliminary Safety Analysis Report (PSAR) describes the specific design and safety measures and demonstrates analytically that it can meet the above fundamental safety criteria and objectives. Some of the important aspects addressed are as follows.

Site selection (similar to worldwide practice)

Systems and arrangements for handling of radio-active waste. Derived limits on release of radioactivity.

Multiple barriers to prevent release of radioactive material into the environment (defense-in-depth). The outer-most barrier is a concrete positive pressure containment building. The plant areas are classified into four zones with different levels of risk of radiation exposure, access to higher risk areas is controlled, escape of radioactivity from them monitored.

Plant equipment is classified into systems meant to operate the plant process whose failures can potentially lead to radiation release (Operational Systems, including their process control), and systems meant to mitigate the consequences of such failures (Safety Systems).

The design of the Safety Systems is analyzed to demonstrate their capability to mitigate all credible failures in the Operational Systems (postulated initiating events) so that the fundamental limits on public exposure are not exceeded.

Reliability targets are established for various parts of the Safety Systems so that the postulated failures of the Operational Systems will not result in an unacceptable risk to the general public. It is demonstrated that the safety systems are designed to meet the targets.

The assumptions and approximations in the PSAR are then validated during plant commissioning,, and a Final Safety Analysis Report (FSAR) is then issued accordingly.

The critical Operating Policies and Principles (OP&P) are established in a separate document to ensure that the plant will never be operated in a condition where the assumed integrity of the Operational Systems and reliability of the Safety Systems is jeopardized. This includes

- personnel classification and qualification for radiation protection measures,
- licensing / qualification / numbers of operating personnel,
- testing of passive safety systens to demonstrate their reliability,
- authority to approve jumpers, setpoints and modifications,
- plant operating limits,
- emergency control measures etc.

The KANUPP OP&P has been revised recently to provide more explicit guidance on some issues, to bring it in line with modern practice.

The FSAR and the OP&P are the basic and formal documents defining the license to operate the plant. A large number of other station documents are needed to ensure and assist compliance e.g.

Operating Manuals
Normal and Abnormal Operating Procedures
Emergency Operating Procedures
Radiation Protection Manual
Design Descriptions and Specifications
Equipment Vendor Manuals
Detailed Station Instructions (technical administrative procedures) e.g. equipment isolation for maintenance, plant and procedure modifications etc.

An Emergency Relief Plan is issued and practiced with the local civil administration to deal with Emergencies involving release of radiation.

3.2. Organization

The Directorate of Nuclear Safety and Radiation Protection (DNSRP) is the internal safety authority within PAEC.

The most basic principle governing safety management is that the primary responsibility of operating a nuclear facility safely lies with the operator. In this sense, the General Manager of KANUPP carries the prime responsibility. The regulatory body only recommends policy and advises on its specific interpretations.

Relevant responsible personnel are pre-designated as members of Supervisory and Advisory Groups for dealing with Radiological Emergencies.

A Site Safety Committee is established to advise the General Manager on safety issues. It consists of all Managers, with Manager (Health Physics) as Secretary, providing liaison with DNSRP. The Site Safety Committee reviews all proposed plant modifications, and

event reports from a safety viewpoint, and monitors action on all regulatory recommendations.

The Shift Operations Engineer (SOE) on duty carries complete technical responsibility for safe operation of the plant according to the OP&P.

Some other informal groups are called upon by the KANUPP Site Safety Committee to focus on particular activities related to safety e.g. an Internal Safety Audit Group (INSAG), a Safety Analysis Group, a Root Cause Analysis Group etc.

3.3. Routine Regulatory Inspections and Surveillance

Compliance to the FSAR and OP&P is monitored continuously through the following mechanisms.

3.3.1. Quarterly Inspections

The DNSRP sends a team of inspectors for a thorough regulatory inspection of KANUPP every three months.

In general, conformance to the OP&P and Station Instructions is verified on sample basis. Particularly, the surveillance / preventive maintenance activities and their results, temporary Operating Memos, documentation control, record of jumper sheets, hazard permits, industrial safety practices, quality assurance audit reports, radiation protection measures and dose records etc. are checked according to established procedures.

Minor deficiencies identified are discussed with the responsible plant engineers and future course of actions determined to remove the shortcomings. Major or significant deficiencies are recorded on 'Inspection Reports' and then follow-up actions in the form of periodic meetings and reminders are initiated if necessary.

The deficiencies identified in the DNSRP 'Inspection Reports' are put on the agenda of Site Safety Committee meetings and resources are mobilized to remove the deficiencies. After satisfactory implementation of the corrective actions the regulatory Inspectors perform follow-up inspection & update the list of outstanding corrective actions.

3.3.2. Annual Safety Review

The DNSRP performs annual re-evaluation of KANUPP safety performance, based on a special technical report titled 'Safety Aspects of KANUPP Operation', issued annually by KANUPP in pursuance of regulatory requirement laid down in the OP&P. The main topics are:

- Plant Operation Statistics and Events - outages, unusual occurrences
- Performance of Safety Systems - routine tests done and results, reliability achieved, significant problems, radiological doses and releases, radioactive waste

- Performance of Operational Systems - Maintenance (breakdown, replacements, overhaul, preventive), Surveillance and In-Service Inspection results
- Operational Safety Practices - Jumper Control, Modifications, Procedures, Documentation, Routine Drills etc., Licensing Training & Qualification
- Projects

The DNSRP reviews this report in detail in a joint meeting to analyze the performance of all plant systems in general and the safety systems in particular. They also check both the numerical results (i.e. various reliability parameters monitored) and the supporting information from which the results are derived. The agenda of the annual review meeting also includes monitoring of progress on earlier recommendations.

Any areas where the performance or compliance is not satisfactory, or further improvements are desirable, are identified, and the continued operation of the plant is decided upon. If necessary, more thorough or external safety re-evaluation may be recommended in some areas.

3.4. Event-based Reviews

Besides the above routine safety reviews, it is also mandatory for the plant to report all outages and unusual events to DNSRP within 48 hours. This preliminary Unusual Occurrence Report (UOR) is followed up later by another detailed analysis report.

Recently, all un-planned outages have also been designated as unusual occurrences.

UORs are also reviewed independently by the Site Safety Committee to assess the safety concern and ensure appropriate corrective actions to prevent or minimize re-occurrence. Where necessary, the UOR is followed by a systematic Root Cause Analysis (RCA) by a diverse group established internally and trained for this purpose. Our methodology has evolved from the IAEA ASSET methodology with some adaptation based on the INPO methodology.

If the plant does not have the expertise to establish the Root Cause, PAEC / DNSRP draws on other consultants / experts, directly or through IAEA, *for example, the IAEA Assessment of Safety Significant Events Team (ASSET) Mission in 1989 to analyze the retraction of fuel channel G12 in KANUPP.*

The DNSRP assigns an INES level to the UOR and conveys the event to the IAEA, and also makes any additional recommendations back to the plant.

Such operating experience feedback decreases the potential for un-usual occurrences. Further improvement is possible only by learning lessons from near-miss events as well. Recently, an Internal Event Report (IER) has also been started at KANUPP, to highlight such events and disseminate operating experience about equipment and system peculiarities or reduce them.

3.5. Plant Modifications

Problems and potential improvements identified through the Operating Experience Feedback mechanisms, internal or external, and recommendations from the regulatory inspections, all eventually lead to proposals for modifications in plant equipment and systems or in the organization, procedures and practices.

A systematic procedure for Change Approval (CA) Requests is followed. If a conceptual study of alternatives and estimation of the resources required reveals that the change is feasible, a CA request is initiated and the detailed engineering completed. The CA request is then reviewed and approved by the Site Safety Committee. If the proposed modification affects safety in any way, the CA request is then sent to DNSRP as well for further review and approval before it can be implemented. After implementation and commissioning, the station documentation is updated as-built. Some modifications are done on a trial basis as Temporary CA, regularized later if found successful.

In other words, modifications affecting plant safety cannot be implemented without regulatory review and approval.

Purely temporary changes in the equipment to allow plant operation or testing of redundant equipment with a particular malfunction (Jumpers) are recorded on Jumper Sheets, reviewed by relevant personnel and authorized by the Station Manager for a limited duration. A Safety Equipment Degradation is also recorded if necessary.

Temporary changes in the important alarm or trip Setpoints (to counter equipment inaccuracies etc.) are recorded with reason and approved by the Operations Manager in a register maintained for that purpose. Permanent changes in Trip Setpoints if any have to be authorized by DNSRP.

3.6. International Reviews

The Three Mile Island and Chernobyl events raised public awareness about the global importance of nuclear power plant safety, and that operating experience feedback offers the only means to improve it continuously during the operational phase of the plant life cycle. The Incident Reporting System (IRS), International Nuclear Information System (INIS) and the International Nuclear Event Scale (INES) were all established by the IAEA. The Institute of Nuclear Power Operations (INPO) in the US and the World Association of Nuclear Operators (WANO) on a wider scale, and more specific Owners Groups for particular NPP vendors like Westinghouse, B&W, Framatome and CANDU, were all established with somewhat similar broad motives.

PAEC participates in the information exchange, operating experience feedback and exchange visit programs by the IAEA, WANO and COG. The CANNET established by COG is of particular importance and relevance to KANUPP.

Besides these general programs, considerable efforts have been made to develop and standardize methodologies for assessing the overall safety of particular NPP organizations e.g. the IAEA the Operational Safety Assessment Review Team (OSART) and the Peer Review methodology developed by INPO and adopted by WANO. Although the review can be quite broad, there is an overall emphasis and great impact on safety culture.

PAEC has realized this from the outset and has been very active in participating and benefiting from these programs. KANUPP has welcomed two OSART Missions, in 1985 and 1989, a WANO Peer Reviews in 1994 and 1996. The safety-relevant recommendations of these reviews become action items followed up by DNSRP.

PAEC participates in the Performance Indicators (PI) program of WANO, and it appears to be very useful, but it is not a part of the formal safety management regime.

Being a non-vendor country with little relevant infra-structure, nuclear power in Pakistan relies heavily on international inter-action. We gratefully acknowledge the technical support provided by the IAEA in the form of large number of guideline documents, some equipment, training of our personnel in many specialized areas, and expert assistance. The IAEA has been our mainstay particularly during the period of our complete isolation from the vendor country from 1976 to 1990. Since 1989, the COG has also contributed strongly to bring KANUPP back into the world nuclear community. The WANO Peer Reviews have had great impact on KANUPP.

3.7. Long Term Safety Review (LTSR)

In the long term, the overall safety of a nuclear power plant can be affected by the following phenomena.

Aging degrades the efficiency and margins to failure of plant equipment directly. Some aging phenomena can also indirectly create new safety issues e.g. creep elongation of fuel channels increases the gap available for fuel movement causing reactivity insertion during LOCA.

Replacement of equipment to combat Obsolescence and lack of maintainability involves change in technology, which may in turn imply changes in human-machine interface, failure modes and effects, repair times, maintenance skills required etc. This phenomenon was specially acute in the area of informatics over the 70's and 80's.

Better operational safety practices may evolve in some areas e.g. systematic operating experience feedback, computerization in planning and control of maintenance work, in-service inspection techniques, performance indicators, in the recent past.

Better safety criteria, design practices and safety analysis methodologies evolve, making the design safety inadequate by current standards. This has been specially acute over the past three decades when nuclear power plant technology has grown from infancy to relative maturity. Nuclear power plants built to older standards have to be evaluated against current safety criteria, inadequacies identified, and then justified if possible.

Although continuous updating is desirable, and also possible in many cases, it is not easy to plan on that basis. The broad practice which seems to have evolved to defer the gradual but inexorable approach towards unacceptable safety levels, is an exhaustive re-examination and update of the plant safety case at regular long intervals varying from 3 to 10 years in different countries, to accept it upto the next LTSR, identifying and allowing time for the improvements which have to be implemented meanwhile.

Technological isolation masked the need for such long-term safety reviews until the IAEA ASSET Mission to KANUPP in 1989. Besides analyzing and recommending corrective measures about the retraction of fuel channel G12, the ASSET Mission identified an overall deficiency in keeping abreast of evolving safety standards, and recommended an expert review of the safety features of KANUPP against modern CANDU safety criteria and practices. Further technical cooperation in implementing these recommendations was arranged through an IAEA Project 'Safe Operation of KANUPP (SOK)', and under that project, from the Canadian vendors.

An expert review against modern CANDU safety features in 1990 led to further recommendations broadly including

Modernization of operational safety practices,

Updating of the FSAR using modern tools and methodology followed by implementation of any modifications found necessary, and

Design safety improvements obvious even without the FSAR update, if feasible.

Integrated planning and prioritization of all safety improvement activities,

An Integrated Safety Review Master Plan (ISARMAP) was accordingly prepared by KANUPP in 1992, whose implementation is monitored by an international Steering Committee established by the IAEA, and technically supported through the IAEA Technical Cooperation Project PAK-9/010 'Safe Operation of KANUPP (SOK)', with Canadian technical support arranged through COG.

Besides project management, the ISARMAP is divided into activities addressing Aging, Obsolescence, Operational Safety practices, and Design Safety. A detailed list and progress can be seen in Annexure B.

The safety improvement activities in the ISARMAP are prioritized on the basis of

Safety Significance	(Prevent > Mitigate, Maintain > Improve) (safety improvement activities take priority over other improvements anyway)
Priority	(Immediate > Necessary > Recommended)
Phase	(Assessment > Implementation)
Cost	(Insignificant > Significant > Major)

Identification of many potential safety improvements tends to create the impression of unacceptable safety. But the various reviews leading to, and the assessments completed under the ISARMAP, have found KANUPP acceptably safe by its existing criteria. The improvements are recommended to avoid future potential for an unacceptable level of safety. Higher design safety standards or criteria maybe adopted under the FSAR update task.

The policy now adopted to manage the safety of KANUPP (and other future plants) in the long term is thus broadly similar to the systematic approach emerging worldwide towards the safety of aging nuclear power plants i.e.

Operate the plant as well as possible with the existing design, and

Review plant safety against current safety standards at regular pre-scheduled intervals, to establish the feasible safety improvements to be implemented upto the next review, to keep the plant acceptably safe all the time.

An LTSR interval of 10 years has been adopted.

3.8. Life Extension

Each LTSR is a demonstration that the NPP is safe to operate till the next scheduled LTSR, if the recommended improvements are implemented meanwhile. So the LTSR at the end of the design life provides the logical basis for life extension.

The next LTSR of KANUPP, in 2002 AD, will be at the end of the originally intended design life, and will be the basis of an extension of its operating license for 10 years.

4. SAFETY PERFORMANCE OF KANUPP

The performance of KANUPP against the fundamental safety criteria and objectives is summarized here to demonstrate the success of the mechanisms described above.

There has never been any evidence of notice-able radiation exposure to the general public, abnormal radiation levels in the air or biological samples taken

at several points in the city of Karachi. The exclusion zone around KANUPP is still very sparsely populated.

The radio-active discharge through the liquid and gaseous effluent has never exceeded the limit, and in fact the annual average release has never exceeded 3 % of the derived limits for KANUPP.

Solid waste (including ashes from and incinerator for combustible low-level waste) is buried in a disposal area at site. The original spent resin tanks which have filled up due to a rather high frequency of outages have also been buried, and replaced by new ones. Spent fuel is stored under light water at site. Dry storage is being studied.

Personnel radiation dose has never exceeded the maximum annual limits. The average annual radiation dose to individual workers over the plant life so far is 400 mRem (20% of permissible).

The performance of the safety systems remains generally satisfactory. Recently the un-availability of the Neutron Power High trip has been rather high due to poor maintainability of the N16 measurement which is being replaced. A third Diesel Generator is being installed to improve the unavailability of emergency standby power.

The performance of the operational systems is also satisfactory. Among the life-limiting components important to safety, the condition of the fuel channels, critical heat exchangers and piping is generally quite good. The Steam Generators are also in good condition at present but some sludge accumulation and constricted tubes indicate the need for cleaning to stem further deterioration, planned this year. An upgrade of the obsolete I&C expected to be installed early next year.

A total of 851 plant modifications have been requested, 602 of them approved, 530 implemented so far, less than a dozen involving DNSRP approval because they affected safety. Some significant modifications which have directly improved plant safety are listed in Annexure A.

The routine Regulatory Reviews (quarterly and annual) have been regular and successful.

Two IAEA OSART Missions, one IAEA ASSET Mission have found KANUPP operating safely. The improvements recommended by them are being implemented. A follow-up WANO Peer Review in 1996 reported that most of the improvements identified in the earlier WANO Peer Review in 1994 have been completed, and the progress on the others is satisfactory.

A long-term review of the safety features of KANUPP against modern CANDU safety criteria and practices was done in 1990. An integrated safety

review master plan (ISARMAP) was established accordingly to implement the recommendations. The work done so far under this plan has restored confidence in the ability of KANUPP to operate safely. The availability of KANUPP also appears to have improved somewhat.

Life extension by 10 years (upto 2012 AD) is expected to be possible based on another long-term safety review in 2002 AD.

5. IMPROVEMENTS IN THE SAFETY REGIME

Some modifications in the equipment and procedures which have improved the safety of KANUPP have been mentioned above and listed in Annexure A, because they are plant-specific and the mechanism for such on-going improvements already existed.

But there have been three major fundamental improvements over the years in the safety management regime for the nuclear power program of Pakistan.

- Pakistan Nuclear Regulatory Board established independent of PAEC

- International Reviews of Operational Safety - OSART and Peer Reviews

- Long Term Safety Reviews

The Integrated Safety Review Master Plan (ISARMAP) established after the review of the safety features of KANUPP against modern CANDU safety standards and practices in 1990, is being implemented under the Project 'Safe Operation of KANUPP (SOK)' with IAEA Technical Cooperation and Canadian technical support arranged by COG. It has been very instrumental in improving the safety of KANUPP. The following are the major achievements so far.

- Fuel Channel Integrity Assessment. Life expectation well beyond 5 years.
- Safety Significance of CO2 AGS in LBB detection realized. Monitoring improved.
- Some critical heat exchangers re-tubed.
- Turbine Overhaul which was long overdue - completed.
- ISI Program established for fuel channels, steam generators, critical heat exchangers and piping etc.
- Operating Experience Feedback computerized
- FSAR Update Phase I completed with modern Canadian safety analysis codes. Shutdown and Emergency Injection System found adequate against large break LOCA. Phase II started. Many new PIEs considered.
- PSA Level I nearing completion.
- Use of Boosters abandoned to settle cooling concern.
- 3rd Standby Diesel Generator being installed.
- Independent seismically qualified Emergency Feedwater System being installed.

- A seismic expert Walk-through found KANUPP building and structures safe for twice the design basis. Maximum ground acceleration re-evaluated using modern methodology and revised from 0.1 to 0.2 g. Minor improvements in equipment anchoring are being installed.

A complete list of activities and their status is given in Annexure B.

6. DIFFICULTIES

The small size of our nuclear power progam poses limitations in three areas.

- our in-service inspection and surveillance personnel do not have access to enough data / experience to develop sufficient expert 'judgment' / skill in analyzing the data acquired from our process equipment.

- even if we develop our own system of safety analysis codes, we cannot afford the R&D resources needed to validate them.

- it is difficult to afford major safety backfits.

There are considerable practical difficulties in applying modern safety design criteria to backfits in old plants. Besides space constraints, sometimes it appears ludicrous to go to great length to achieve safety qualification in equipment which is becoming part of a system which is not qualified.

7. CONCLUSION

The present regime for CANDU safety management in Pakistan has evolved in line with contemporary international practice, and is essentially adequate to ensure the continued safety of KANUPP and other future CANDU reactors, as confirmed by international reviews as well.

But the small size of our nuclear power progam poses limitations in developing
- expert judgment in analysis of in-service inspection data, and
- our own methodology for CANDU safety analysis.

Open interaction among all NPP vendors, owners and operators is the only way to achieve continuous improvement for all. We gain a lot in exchange for an open attitude about our experiences. But the vendors also learn from our experiences for improving their future products, in exchange for an open attitude in providing technical support about earlier products.

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ANNEXURE A

SIGNIFICANT PLANT MODIFICATIONS WHICH HAVE IMPROVED SAFETY

Mechanical

Replacement of some heavy water heat exchangers

Extension of Heavy Water Upgrading Plant

Complete replacement of Fire Water Ring with fiber-glass

Electrical & Control

Regulating System Memory Expansion & Software Improvements

Regulating System - Valve Control Standby

Replacement of obsolete Fuel Handling Control Computers

Replacement of obsolete Turbine Instrumentation

Replacement of obsolete Radiation Monitoring Instrumentation

Installation of CCTV for remote monitoring in Reactor Building

Organization & Practices

Formal Maintenance Procedures

Quality Assurance Division reporting to GM

Computerization of

- **Preventive Maintenance / Surveillance program**
- **Maintenance History**
- **Chemistry Data and History**
- **Control Room Reading Sheets / Trending / Anomaly Checks**
- **General Log Summary**

Industrial Safety Group

In-Service Inspection Laboratory

Training Institute at KANUPP for incoming technicians and engineers

In-Plant Training Unit

Licensing of Operations Engineers

Independent Health Physics Division

Karachi Emergency Relief Plan (KERP)

Emergency Operating Procedures (ATOG)

Dedicated Groups to operate / maintain special equipment

- **Diesel Generators**
- **Fuel Handling System**

ANNEXURE B

SAFETY IMPROVEMENTS ACHIEVED UNDER THE

INTEGRATED SAFETY REVIEW MASTER PLAN (ISARMAP)

AGING AFFECTING SAFETY

Fuel Channel Integrity Assessment
completed with very good results, ISI program established.

Improve CO_2 Annulus Gas System
Safety significance of this system for LBB detection realized. Monitoring improved. Long term improvements being designed.

Repair Steam Generator # 3 - completed

Fueling Machine Aging
Expert ageing assessment being arranged. Some parts already replaced.

Refurbish Protective System Dump Valves - in progress

Assess / Refurbish Heat Exchangers Critical To Safety - Two replaced.

Refurbish Valves In The Emergency Injection System
Some valves procured. SH valves replaced.

Overhaul Turbine-Generator (overdue) - completed

OBSOLESCENCE AFFECTING SAFETY

Replace Radiation Monitoring Instrumentation - completed

Replace Neutron Power Instrumentation - in progress

Upgrade Computers, Control & Instrumentation - in progress

Replace Fuel Handling Control Computers - completed

Replace Fire Alarm System - in progress

On-Line Chemical Instrumentation - in progress, some equipment received.

OPERATIONAL SAFETY PRACTICES

Review Modern CANDU Maintenance Techniques - reviewed, some being adopted.

Routine ISI Of Reactor Fuel Channels - established, condition very good.

ISI Of Steam Generators - established.
Some sludge pile-up and tube constriction observed. Cleaning planned this year.

ISI Of Critical PHT And Bop Piping - established. Condition satisfactory.

Overall ISI And PIP Programs - established.

Improve Safety Culture
Course in Basic Safety Principles added in training curriculum.
Root Cause Analysis Group established.

Modernize Operating Policies And Principles (OP&P) Document - done.

Modernize Emergency Operating Procedures - in progress.

Review Modern Emergency Preparedness - done, minor improvements adopted.

Establish Comprehensive Surveillance Program - reviewed by expert - okay

Establish Operation Quality Assurance Program - established, reviewed by expert.

Improve Manpower Development Program
Okay for Operations,
Interactive Graphic Simulator being developed,
Program for Maintenance being developed

Computerize Operating Experience Feedback - done

Reduce Unplanned Outages - program established

DESIGN SAFETY

Update The Final Safety Analysis Report (FSAR)
FSAR Update Phase I completed with Canadian Safety Analysis codes. Shutdown and Emergency Injection System found adequate against large break LOCA. The following new factors considered.

- re-calculated Fuel Properties and Void Fraction
- Boron Poison, actual lower Moderator and PHT isotopic
- Moderator Dump Rate re-established practically
- Fuel String relocation due to creep elongation of channels

FSAR Update Phase II with Canadian safety analysis codes started. The following new PIEs will be considered

- Coolant flow blockage in a channel
- Bounded Loss of Regulation
- Loss of Boiler Feedwater Control
- Loss of Boiler Pressure Control
- Partial Loss of Class IV Power
- LOCA with Vault Cooling Failure

Probabilistic Safety Analysis (PSA) Level 1 - nearing completion.
Will be used for prioritization of subsequent safety improvements.
PSA is not included in the formal safety management regulatory regime so far.

Improve Handling Of LOCA Consequences
Some components in the Emergency Injection System will be duplicated.
Environmental Qualification of LOCA credited equipment being implemented.

Improve Booster Cooling Reliability
Use of boosters abandoned to settle the safety concern.

Improve Secondary Heat Sink Reliability
Independent seismically qualified Emergency Feedwater System being installed. Equipment received. Civil work almost complete. Tapping to Feedwater lines already done.

Improve Reliability Of Emergency Power
3rd Standby Diesel Generator being installed. DG received. Civil work in progress.

Improve Containment Test Pressure
5 psig test done with good results. Test at 10 psig planned in 1998.

Review Redundancy And Separation - not yet.

Review Seismic And Other Hazards
Seismic Expert Walk-through done. Existing structures and equipment found adequate for more than twice the design basis. Maximum ground acceleration re-calculated with latest satellite information, revised from 0.1 to 0.2 g. Some minor improvements in equipment anchoring being implemented.

Improve Control Room Habitability - in progress.