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PAPER 6

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KANUPP

PAKISTAN

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INTRODUCTION

Nuclear power program of Pakistan

137 MWe KANUPP (1972)
300 MWe CHASNUPP (1999)

This report is limited to KANUPP (CANDU)

turnkey, CGE (non-AECL)
fuel channel material and design
technological isolation from vendors for 14 years

Regulatory Structure

PNRB
DNSRP

OBJECTIVE OF SAFETY MANAGEMENT

Maximum Probability of credible accident

10 e -5

Accumulated indirect dose to individual member of public from the environment

100 mRem per year

Maximum dose to radiation worker

2 Rem per year over 5 years (down from 5)

Organization

Pakistan Nuclear Regulatory Board (PNRB)

Owner - Pakistan Atomic Energy Commission (PAEC)

Directorate of Nuclear Safety & Radiation Protection (DNSRP)

Operator - Karachi Nuclear Power Plant (KANUPP)

General Manager

Site Safety Committee

Supervisory & Advisory Groups for Emergencies

Shift Operations Engineer (SOE)

Informal Groups

Local Emergency Organizations

DIFFICULTIES IN SAFETY MANAGEMENT

Small nuclear power program poses difficulties in

- **gaining experience in ISI data analysis**
- **developing our own system of validated safety analysis codes**
- **affording major safety improvements**

Applying modern safety criteria to backfitting in old plant

- **space constraints**
- **qualified equipment in non-qualified systems**

Safety Reviews

Routine Regulatory Inspections and Surveillance

- **Quarterly Inspections**
- **Annual Reviews - Annual Safety Report**

Event-based Reviews - Unusual Occurrence Reports

Plant Modifications

- **Site Safety Committee**
- **Affecting Safety - DNSRP**
- **Root Cause Analysis (RCA)**
  - **Internal**
  - **IAEA ASSET**

International Reviews

- **IAEA OSART - 1985, 1989**
- **WANO Peer Review - 1994, 1996**

Long Term Safety Review (LTSR)

Life Extension

Long Term Safety Review (LTSR)

Plant may approach unacceptable level of safety due to

- **Aging degradation- direct, indirect**
- **Obsolescence**
- **Evolution of Operational Safety Practices**
- **Evolution of Safety Standards**

Re-examine and upgrade safety case at regular interval (3 to 10 years worldwide)

Plant safety level acceptable upto next LTSR

Allow time to implement recommended improvements

Prioritization Factors

- **Safety Significance**
  - **Safety > Availability**
  - **Prevention > Mitigation**
  - **Maintain > Improve**
- **Priority - Immediate > Necessary > Recommended**
- **Phase - Assess > Implement**
- **Cost - Insignificant > Significant > Major**

Integrated Safety Review Master Plan (ISARMAP)

Documents for Safety Management

Preliminary / Final Safety Analysis Report (P/FSAR)

- **Site Selection**
- **Radio-active Release**
- **Radio-active Waste Handling and Disposal**
- **Barriers to release of radio-activity**
- **Classification of Systems**
- **Analysis of safety systems against postulated initiating events in operational systems**
- **Reliability of Safety Systems**

Operating Policies & Principles (OP&P)

- **Personnel Radiation Protection**
- **Licensing of Operating Personnel**
- **Testing of Safety Systems**
- **Jumpers and Setpoints**
- **Modification Control**
- **Operating Limits etc.**

Other Station Documents

SAFETY PERFORMANCE OF KANUPP

No evidence of excessive radiation exposure to public

Discharge through gaseous and liquid effluent < 3 % of limit

Solid Waste under control - no transportation

Personnel Radiation Dose
- **never beyond annual limit**
- **average life-time per worker = 400 mRem**

Reliability of Safety Systems
- **generally meeting targets**
- **Diesel Generators - adding a third one**
- **Neutron Power High Trip - replacing**

Good performance & condition of Operational Systems
- **fuel channels**
- **critical heat exchangers**
- **critical piping**
- **Steam Generators**

Plant Modifications - many safety improvements

Regulatory Reviews - regular and satisfactory

International Reviews - satisfactory, improvements done

Long Term Safety Review
- **ISARMAP - very successful so far**

Life Extension - hopefully by 10 years

MECHANISMS FOR SAFETY MANAGEMENT

Documents

Organization

Reviews

- **Routine Regulatory Inspections**
- **Event-based Reviews**
- **Modifications**
- **International Reviews**
- **Long-term Safety Reviews (LTSR)**
- **Life Extension**

IMPROVEMENTS IN THE SAFETY REGIME

Independent Pakistan Nuclear Regulatory Board (PNRB)

International Reviews (OSART, Peer Review)

Long Term Safety Review (LTSR) every 10 years

SLIDE 2 - 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.

SLIDE 3 - OBJECTIVE

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 maximum dose received by any member of the general public in case of the worst credible accident in a nuclear facility shall not exceed 10 Rem (based on PAEC Intervention Level).

The maximum probability of such a credible accident in a particular nuclear facility shall not exceed 1 in 100,000.

The accumulated indirect dose received by any member of the general public through the environment shall not exceed 100 mRem per year.

The maximum dose allowed to a radiation worker shall not exceed 2 Rem per year averaged over 5 years. This was reduced from 5 to 2 Rems in 1996 to implement the latest ICRP recommendations.

SLIDE 4 - MECHANISMS

There has been no transportation of radioactive waste from the KANUPP site so far, and its de-commissioning is in a preliminary planning stage, so I will not describe the safety management of these aspects of the CANDU plant life cycle.

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

- the documents describing the license to operate

- the organizational arrangements, and

- the various types of reviews to verify compliance

I will now take these up in a bit more detail, at the risk of boring you to death.

SLIDE 5 - Documents

The documents describing the license essentially consist of a Safety Analysis Report and the Operating Policies & Principles.

The Preliminary Safety Analysis Report required to obtain a license to construct, is then revised after commissioning to become the Final Safety Analysis Report, mainly covering

- Site Selection
- Radioactive waste handling and derived limits on the discharge of radio-activity
- The barriers to the release of radio-activity to the environment, including the Containment Building.
- The classification of plant equipment into process systems and safety systems
- The description and analysis to prove that the safety systems are adequate to protect against the postulated failures of the process systems.
- The reliability targets required from the safety systems.

The OP&P is the fundamental guideline for the operating personnel, to ensure that the plant is never operated in a condition where the assumed integrity of the process systems or reliability of the safety systems is jeopardized.

A large number of other Station documents based on these fundamental conditions of the license are prepared and used.

One of the most interesting and critical is the Emergency Relief Plan, prepared and exercised in conjunction with the local civil administration.

SLIDE 6 - Organization

The Pakistan Nuclear Regulatory Board is the independent body which makes the regulations to govern nuclear power.

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

The primary responsibility for safe operation lies with the operator. In this sense, the General Manager of KANUPP carries the prime responsibility.

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.

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

SLIDE 7 - Safety Reviews

The third essential mechanism are reviews to verify that the organization is working according to the documents.

There are two routine reviews by DNRSP
- a quarterly inspection for physical verification of compliance to instructions ona sample basis. The deficiencies in the DNSRP Inspection Reports become the agenda of the Site Safety Committee to follow up.
- annual review against a report prepared by KANUPP, where the annual performance and reliability statistics are discussed in detail. The progress on earlier recommendations is also monitored.

All safety significant events are reported formally to DNSRP in the form of Un-usual Occurrence Reports (UORs) within 48 hours, followed by later analysis reports. The DNSRP assigns INES level and reports to the IAEA IRS. The Site Safety Committee analyzes the UOR in detail and expedites followup of the recommendations. Root Cause Analysis is done if necessary by an external body like the IAEA ASSET service.

Recently Internal Event Reports have also been started to cover near-miss events.

All recommendations for improvement ultimately result in requests for plant modifications which are reviewed by the Site Safety Committee, and if concerning safety, by the DNSRP.

PAEC sets great store by the International Reviews e.g. IAEA OSART and WANO Peer Reviews. We participate strongly in the information exchange programs of IAEA, COG and WANO, and the performance indicator program of WANO. The IAEA has been our mainstay during the period of our isolation from the vendor country, but since 1989 COG has also been of great help. WANO Peer Reviews have caused great improvement in KANUPP.

A system of long-term safety reviews every 10 years against current safety standards and criteria is now accepted by PAEC. An LTSR at the end of the design life can be the basis for license renewal for life extension.

So I will describe the long term safety review in more detail.

SLIDE 8 - Long Term Safety Review

In the long term, the overall safety of a nuclear power plant can be affected by
- Aging degradation of the equipment, causing direct and indirect changes,
- Obsolescence causing lack of maintainabililty and thus safety degradation, replacement of equipment involves new technology which then has to be proven
- Evolution of better operational safety practices
- Evolution of design safety standards and practices

Older nuclear power plants have to be evaluated against current safety standards and practices, deficiencies identified, and then justified if possible, or removed. This can best be done in a periodic fashion. A re-evaluation of the safety case against current criteria should result in acceptance till the next such review, with some recommendations for improvement by that time.

PAEC entered this situation for KANUPP by chance, when an IAEA ASSET Mission in 1989 realized that KANUPP was not abreast of evolving CANDU safety standards, and recommended a complete review of all safety features. This review identified some improvements, and recommended an integrated and prioritized program for that.

An Integrated Safety Review Master Plan (ISARMAP) was prepared by KANUPP, and a 'Safe Operation of KANUPP (SOK)' Project started, with technical support from IAEA and Canadian technical support from COG.

But identification of safety improvements does not mean that the plant is not safe to operate now; they only avert the future potential for an unacceptable safety level.

The Prioritization scheme is based on four factors as you can see.
- Safety significance: Safety takes priority over other improvements, Prevention of accidents takes priority over mitigation, and maintenance of the existing safety level takes priority over improvement.
- Priority is obvious - immediate, then necessary and then mere recommendations.
- Assessment of the safety level takes priority over actual implementation phase.
- Cost is considered in the reverse order, i.e. expensive items are lower priority.

PAEC has accepted a 10 year interval for future LTSRs.

An LTSR in 1990 led to the ISARMAP, which is very successful so far in restoring international confidence in the safe operation of KANUPP, and in possible life extension after another LTSR in 2002 AD. Details are given in Annexure B.

SLIDE 9 - SAFETY PERFORMANCE OF KANUPP

Now I will summarize the performance of KANUPP against the fundamental safety criteria and objectives to demonstrate the success of the safety management.

There has never been any 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 is still very sparsely populated.

The radio-active discharge through the liquid and gaseous effluent has remained within 3% of the derived annual limit for KANUPP.

Solid waste is buried in a disposal area at site. The filled-up original spent resin tanks 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 individual average annual radiation dose so far is 400 mRem (20% of permissible).

The performance of the safety systems remains generally satisfactory. The un-availability of the Neutron Power High trip has been rather high, and it is being replaced. A third Diesel Generator is being installed to reduce unavailability.

The performance of the operational systems is also satisfactory. The condition of the fuel channels, critical heat exchangers and piping is generally quite good. The Steam Generators are also okay at present but some sludge accumulation and constricted tubes indicate the need for cleaning, planned later this year. Obsolete I&C is expected to be replaced early next year.

A large number of plant modifications have been implemented, about a dozen needing DNSRP approval. Annexure A lists those which have improved safety.

The quarterly and annual Regulatory Reviews have been regular and successful.

Two IAEA OSART Missions, and two WANO Peer Reviews have found KANUPP operating safely, and progress on recommendations satisfactory.

SLIDE 10 - IMPROVEMENTS IN THE SAFETY REGIME

Besides the plant modifications which have improved safety which I mentiioned before, 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 achievements under the ISARMAP (due to the LTSR in 1990) are listed in Annexure B. The most important ones are

- 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.

SLIDE 11 - 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.

SLIDE 12 - 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.