Operational Safety Issues

Operational Safety Review in Indian NPPs

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ATOMIC ENERGY REGULATORY BOARD

INDIA

Regulatory Basis

- AERB was constituted in 1983 regulatory and safety functions under the the Atomic Energy Act, 1962.
- AERB also has the mandate to administer industrial safety under Factories Act 1948.
- The regulatory authority of AERB is also derived from the rules
  - Radiation Protection Rules, 1971, Under revision.
  - Atomic Energy (Safe Disposal of Radioactive Wastes) Rules, 1987.
  - Atomic Energy (Factories) Rules, 1996.
  - Atomic Energy (Working of the Mines, Minerals and Handling of Prescribed Substances) Rules, 1984.

Regulatory Documents for Safety in NPPs

	Codes	Guides
Siting	1	13
Design	1	26
Operation	1	17
Quality Assurance	1	5
Emergency Preparedness	-	2

Plant Specific Regulating and Guidance Documents

- Approved by AERB
  - Final Safety Analysis Report
  - Technical Specifications for Operation
  - Station Policy for Operation
  - In-service Inspection Manual
  - Emergency Preparedness Manual

- Approved within the Utility
  - Normal Operating Procedure
  - Surveillance Procedures
  - Inspection Procedures
  - Maintenance Procedures
  - Emergency Operating Procedures

Operational Safety Review Process

- Authorisation for Operating NPPs
  - Initial stepwise Operating Authorization for NPPs
  - Application for Renewal of Authorisation (ARA), once in 3 years
  - Detailed Periodic Safety Review (PSR), once in 9 years
  - Safety upgradation and Life extension

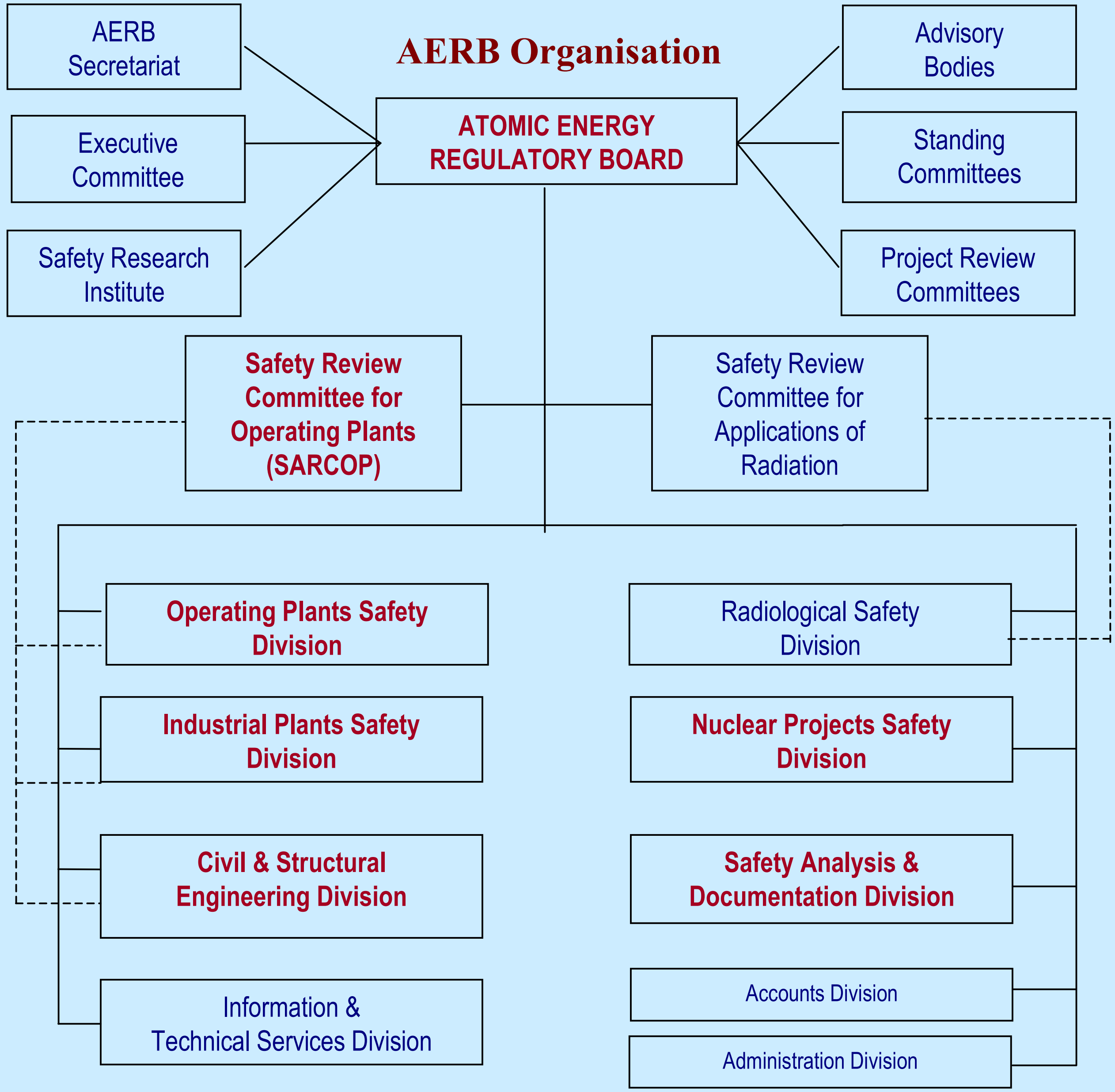
- Licensing of plant personnel
  - Management
  - Operating Staff

Operational Safety Review Process, Contd.

- Continuous Operational Safety Surveillance and Feedback
  - Routine reporting (Monthly performance and HP reports)
  - Reporting of significant events and their review
  - Regulatory Inspection
  - Manrem budget
  - Periodic emergency preparedness exercise
  - Authorisation for radioactive waste disposal

- New Initiatives introduced in Operational Safety
  - Reporting and analysis of low-level events.
  - Special Regulatory Inspection
  - Regulatory Approval for restart of NPPs after long outages

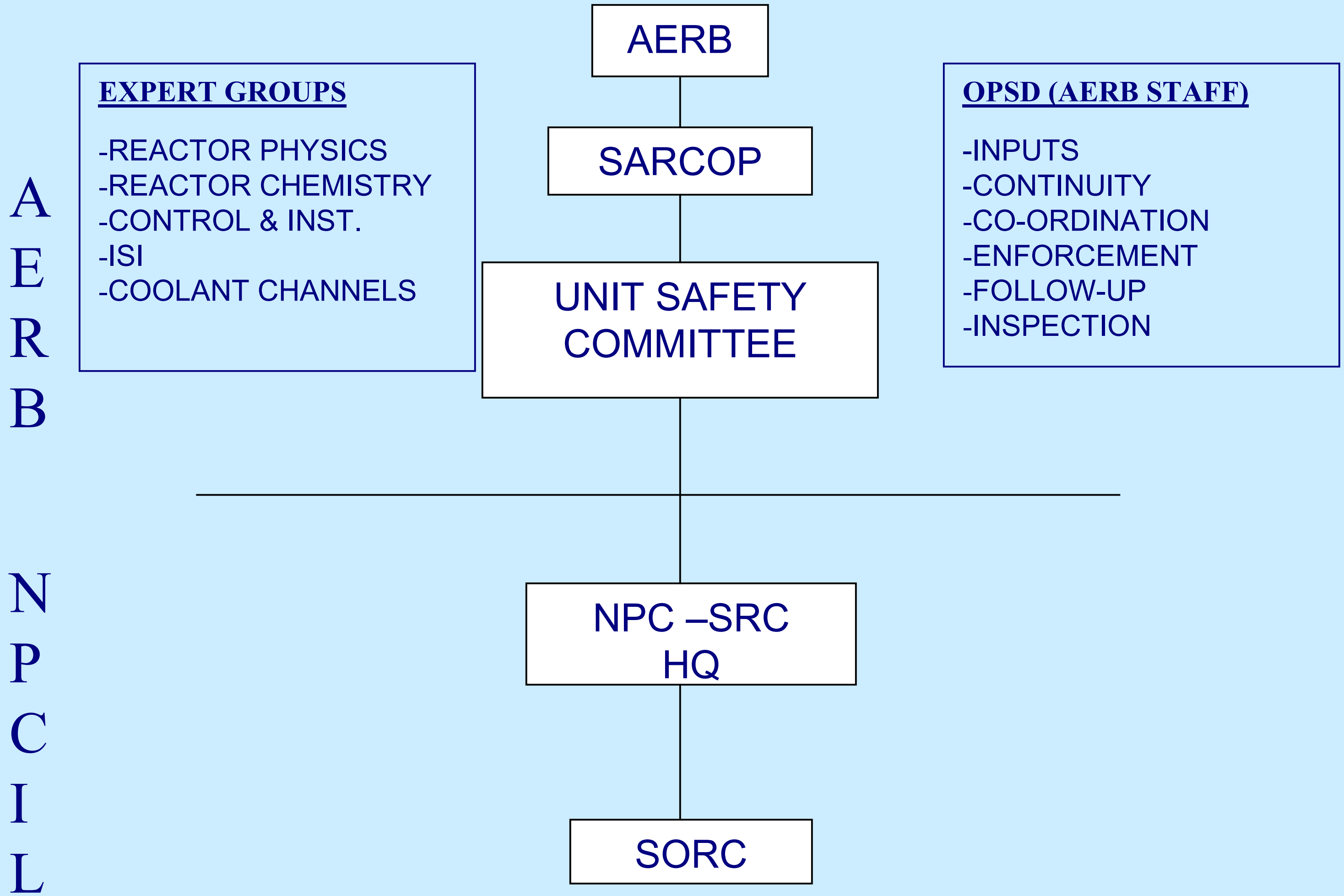
AERB Organisation



Regulatory Mechanism

- Multi-tier review by Safety Committees
  - In NPCIL (self assessment/review)
    - Station Operations Review Committee (SORC)
    - Safety Review Committee at the NPCIL's Headquarters (NPC-SRC) where design and quality assurance experts are also involved.
  - In AERB (the regulatory review)
    - Plant specific Unit Safety Committee (USC)
    - Apex Committee known as Safety Review Committee for Operating Plants (SARCOP).
    - Board of AERB
- Operating Plants Safety Division (OPSD) of AERB.
  - Provides inputs for review process
  - Continuity and co-ordination
  - Enforcement and follow-up regulatory decisions
  - Regulatory inspection and follow-up

Safety Review Mechanism for Operating NPPs



Initial Operating Authorization for NPPs

- The authorizations for NPPs are issued for,
  - Pre-commissioning tests & System Commissioning
  - Criticality and Low power tests
  - Medium and High power tests
  - Stage wise power operation (50%,90% FP)
  - Provisional authorisation for 90 days at FP
  - 3 Year authorisation

Initial Operating Authorization for NPPs

- Initial Authorization is issued after ensuring
  - All the pending safety related recommendations are complied with
  - Plant fulfils all the consenting conditions specified in regulatory guides,
    - Consenting Process for NPPs & Research Reactors: Regulatory Review and Assessment, AERB SG G-1
    - Regulatory Consents for Nuclear and Radiation Facilities: Contents and Formats, AERB SG G-7
  - Final Safety Analysis Report and Technical Specifications for Operation are duly approved by the Regulatory Body
  - Approved Emergency Preparedness Plan is in place

Application for renewal of Authorisation (ARA)

- Utility submits an Application for Renewal of Authorisation every three years
- Major elements of ARA are:
  - Safety Performance
    - Operational Performances and Problems
    - Status of implementation of safety related recommendations
    - Compliance with the regulatory inspection findings
    - Radiological status and effluent management
  - Operational Experience Feedback
    - Significant events
    - Unusual Occurrences from other NPPs (India and abroad)
  - Physical Status of Plant
    - ISI programme and findings
    - Major jobs carried out in long outages
  - Public concern in operational safety

Periodic Safety Review (PSR)

- Comprehensive periodic safety reviews (PSR), carried out every 9 years. i.e., after ARA at 3 years and 6 years.
- Additional elements of PSR are as per AERB guide on 'Renewal of Authorization for Operation of Nuclear Power Plants' (AERB/SG/0-12).,
  - Review of Safety Analysis
  - Equipment Qualification
  - Life Cycle Management
  - Procedures
  - Organisational / Management changes
  - Human factor
  - Emergency Preparedness
  - Environmental Impact
- Integrated review of all safety factors to provide assurance that till the next PSR, the plant can continue to operate with adequate safety margins.

Safety Upgradation and Life Extension

- Safety Upgradation jobs were taken up at
  - RAPS-2 in 1996 - 98
  - MAPS-2 in 2002 - 03
  - MAPS-1 in August 2003 (In progress)
- Life Extension study was taken-up for
  - Tarapur Atomic Power Station (TAPS) after over 30 years of service in May 2000, Upgradation in 2005

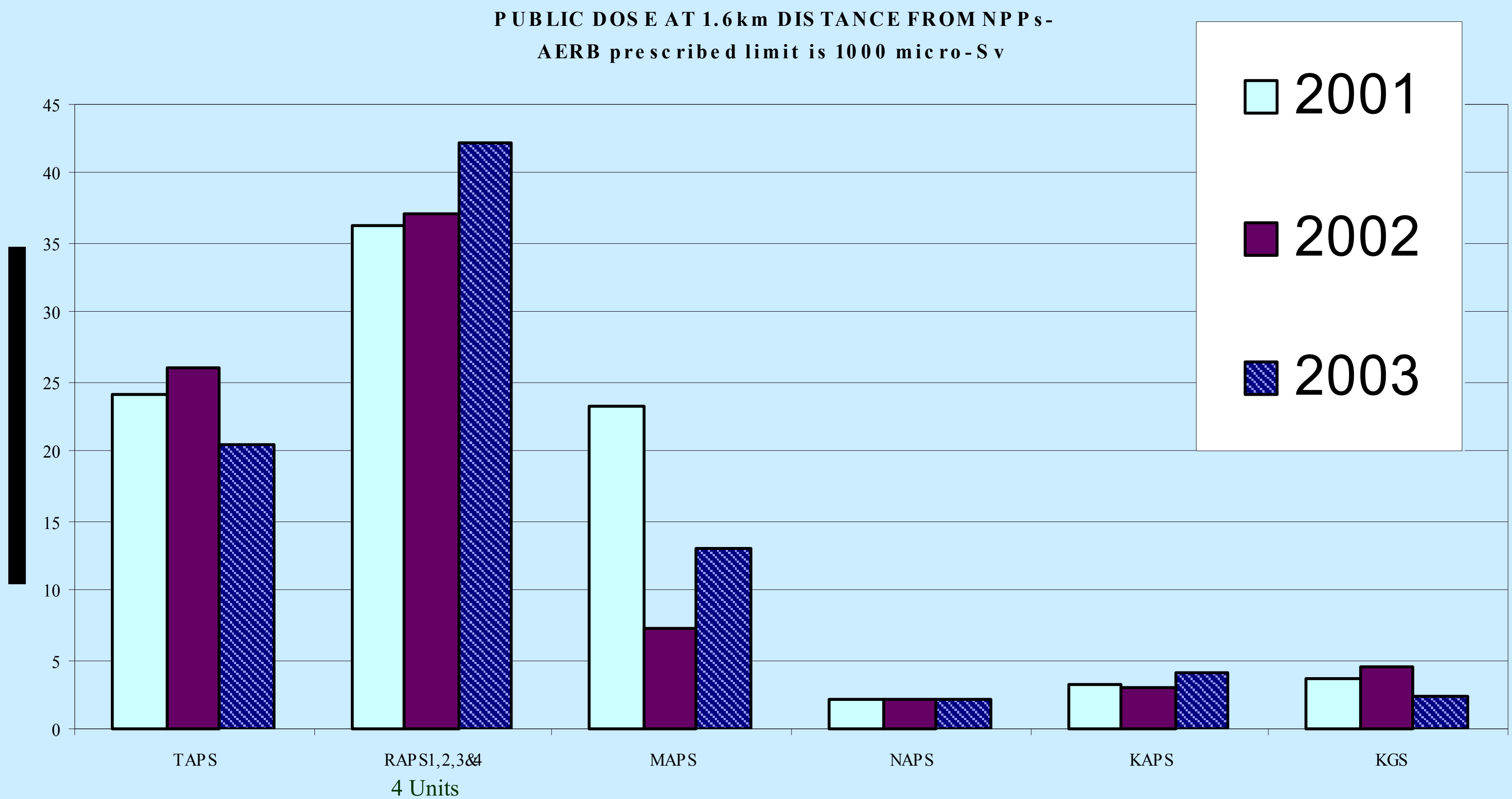
Doses to Individual Workers

- AERB has prescribed an annual dose limit of 30 mSv for individual radiation worker and a limit of 100 mSv over a period of five consecutive years.

Year	Total No. of Radiation Workers	No. of workers exposed to >30mSv
1998	10145	3
1999	10233	5
2000	10276	1
2001	13059	2
2002	14019	2
2003	13568	0

Environmental releases and radiation dose to public

- Environmental surveillance at all NPPs is carried out by an Environmental Survey Laboratory at each site.



Safety Significant Events and Their INES Ratings

- AERB uses the International Nuclear Event Scale (INES) of IAEA to categorise the events in accordance with their safety significance.

INES Levels	1999-2000	2000-2001	2001-2002	2002-2003	April-Dec 2003
Out of Scale	3	2	0	0	0
0	16	42	43	26	21
1	2	10	2	5	10
2	0	0	0	*1	0
3	0	0	0	0	0
>3	0	0	0	0	0
Total	21	54	45	31	31

* This level 2 event, which occurred in MAPS, involved overexposure (31.5 mSv) of a radiographer while engaged in industrial radiography and was not connected with NPP operation

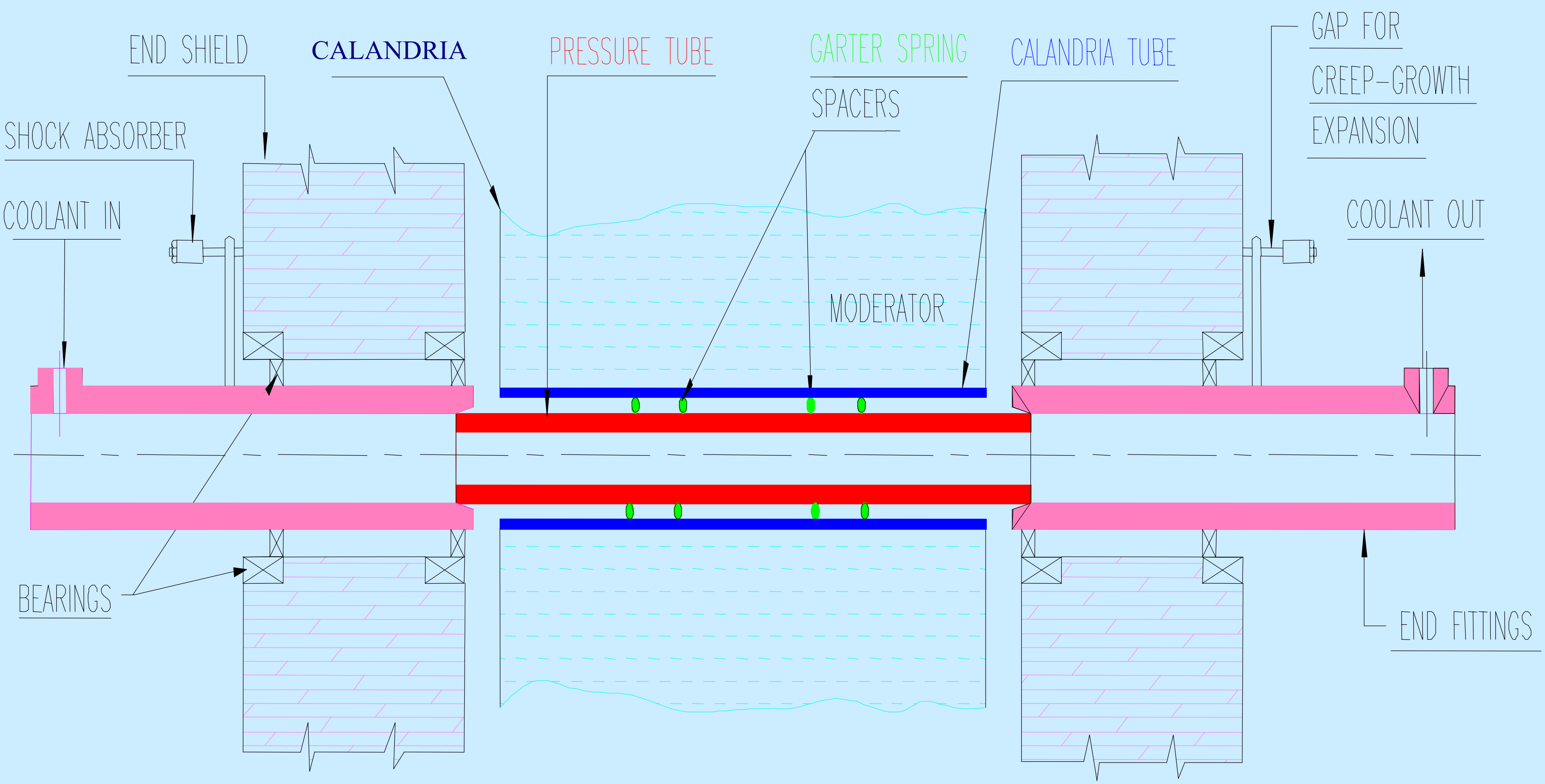
IRS reports sent to IAEA-IRS

No	Title	Plant Name	Date of Incident
1.	Unintended reactor power rise due to total incapacitation of reactor regulating system	KAPS-1	10/3/2004
2.	Loading of fuel bundles with slightly deformed end plates in Reactor core	KGS-1	25/1/2003
3.	Holdup during reactor start up with insufficient subcriticality margin	RAPS-3	28/5/2002
4.	Flash over in Process water pump breaker cubicle leading to Class III,415 V failure	KAPS-1	27/9/2001
5.	Reactor trip on PHT pressure high due to malfunction of PHT pressure control	KAPS-2	3/1/2001
6.	Light water leakage from Endshield cooling system	KAPS-2	12/4/2001
7.	Failure of dry quartined channel O-14	MAPS-1	5/9/2000
8.	Ingress of PHT heavy water to ECCS heavy water accumulator during ECCS monthly test	KAPS-2	17/7/2000
9.	Moderator water leak from suction flange of Moderator Pump	NAPS-2	15/4/2000
10.	Heavy water leak from PHT system due to failure of Inspection plug	MAPS-2	26/3/1999
11.	Overexposure of two maintenance workers	NAPS-2	11/9/1998
12.	Heavy water leak from flow transmitters in PHT system	KAPS-2	1998
13.	Entry of foreign material in PHT system in PHWRs in India	Genric	

Some Significant Safety Issues

- Coolant channels life management
  - Degradation and health assessment
  - Life management
  - Hot pressurisation
  - LBB
  - Creep adjustment
  - EMCCR
- Feeder Thinning
- Tritium in PHT
- Online surveillance tests
- Safety culture

Schematic of coolant channel assembly



Coolant Channel Degradation

- Coolant channels are part of the Primary Heat Transport System boundary
- Made from Zircaloy material which is vulnerable to fast fracture due to hydrogen embrittlement
- Older reactors were fitted with Zircaloy-2 tubes and two loose fit spacers in each channel
- Channels in these reactors were contacting cold calandria tubes due to displacement of spacers
- Accelerated H pick up and possibility blister formation puts fitness for service of these channels in question

Coolant Channel Health Assessment

- Considerable work has been done for determining actual hydrogen content in irradiated pressure tubes, including
  - Post Irradiation Examination (PIE) of tubes from MAPS, RAPS and NAPS, which have seen 3.6 to 10 EFPY,
  - H/D estimation of sliver samples taken from large number of channels.
- Based on this data, the Computer Codes developed over the years are now able to predict the hydrogen pick-up and blister size much more accurately
- The Regulatory Criteria on fitness for service is developed

Coolant Channel Fitness for Service

- Channels are short listed for inspection based on conservative assessment of hydrogen pickup and blister growth using developed and validated codes
- Inspection indicates contact locations and slivering indicates hydrogen pickup
- Actual assessment based on above is used to determine fitness for service as per regulatory criteria

Coolant Channel Life Management

- Repositioning of Spacers
- Wet Quarantine
- Replacement or Removal of few channels
- En-Masse Coolant Channel Removal
- Hot Pressurisation

Coolant Channel Hot Pressurisation

- Facture toughness of Coolant tubes reduces with service life
- NDTT increases due to Irradiation
- Cold pressurisation increases potential for unstable failure of tubes
- Hot pressurisation needs to be gradual and limited by
  - Sub cooling margin of primary fluid
  - Heat up capability
  - Operating temperature margin for brittle failure
- In Old Reactors following provisions were made
  - Modification was required in Shutdown cooling system
  - Criticality and 1% FP operation without PCP operation
  - Necessary modifications in logics and Technical Specifications
- Technical Specification calls for Hot pressurisation after 1.2 FPY of service

Coolant Channel Design Improvements

- Number of spacers in each channel has been increased to 4 from 2
- Spacers are now tight fitted to reduce the chance of moving apart
- Tube material is changed to Zr-2.5% Nb with low initial hydrogen content and stricter control on trace elements (impurities)
- Improved Leak detection capability through Annulus Gas Monitoring system to meet LBB
- Standardizing the In-service Inspection Requirements for Coolant Channels

Coolant Channel and LBB

- Service life of Coolant tube is determined by allowable creep and capability to satisfy LBB criteria
- The response time for leak detection and corrective action is determined by
  - The characteristic of crack (Shape, Length and Depth)
  - Crack growth rate by Delayed Hydride cracking
  - Expected leak rate at various crack size
  - Sensitivity of leak detection system
- Annulus Gas Monitoring System (AGMS) provides a sensitive leak detection system
- Use of Zr-2.5% Nb in lieu of Zircaloy-2 calls for more sensitive leak detection methods
- In old reactors in absence of AGMS, calandria vault leakage collection and due point measurement is used
- In new reactors AGMS has been modified to increase the sensitivity of leak detection

Coolant Channels Creep Adjustment

- End fittings in old PHWRs are fitted with shock absorber assembly to restrict outward missile during postulated guillotine rupture of coolant tube
- Allowance for axial creep needs to be adjusted frequently (minimum once in two year) in shock absorber assembly
- Frequent creep adjustment causes higher man-rem as well as schedule outages
- Design change proposed,
  - Fixing the channel at one side and free expansion at other end
  - No adjustment till creep exceeds full bearing length
- Regulatory concerns,
  - Acceptance of guillotine rupture as very low probability event
  - Higher sensitivity and reliability of annulus gas monitoring system
  - Assurance of LBB in coolant tubes

Enmasse Coolant Channel Replacement

- Major steps are as follows,
  - Removal of insulation panels, anti-torque hardware, feeder connections
  - Cutting of pressure tube at both ends
  - Removal and disposal of end fittings, tubes and spacers
  - Cleaning and Inspection of retained core components
  - Installation of tubes with north end-fitting prerolled
  - Shrink fitting of south side end-fitting and rolling
  - Boroscopic examination and Helium leak test.
  - ECT probing for GS location

Enmasse Coolant Channel Replacement, Contd.

Main regulatory concerns were the following,

- Minimize radiation exposure and control spread of contamination
- Avoid any damage to core components that will remain in service
- Safe disposal of all radioactive waste generated from this activity
- Generate data for validation of Computer Codes used for health assessment
- Generate adequate records for Quality Assurance and future reference

Feeder Thinning

- Long feeder pipes connecting headers to coolant tubes form part of primary pressure boundary
- Thickness measurements in the Canadian NPPs e.g., Point Lepreau and Gentilly-2 in 1995 and 1996 indicated wall thinning of feeder pipes relatively faster than expected
- Erosion-corrosion is the main reason for wall thinning of outlet feeder pipe made of carbon steel
- Likely to reduce the design life of some feeders
- Periodic monitoring of the wall thickness to estimate remaining life
- Measurements in Indian reactors indicate existence of this phenomenon
- Currently the issue is under discussion

Tritium in PHT System

- Tritium (H^3) formation in primary coolant due to neutron capture by Deuterium
- Hard Beta radiation from H^3 increases
  - Manrem expenditure during maintenance
  - Activity release through stack
- To reduce tritium level in PHT system
  - Coolant from old reactors is used as moderator in new reactors after improving isotopic purity
  - Fresh D_2O is added in Primary system
  - Development of detritiation facility
- To reduce collective dose
  - Use of ventilated plastic suit
  - Entry for maintenance allowed only after reduction of DAC

Online Surveillance Tests

- Testing requirements for all Safety Systems and ESFs are specified in Technical Specifications
- Some surveillance tests require shut down of the reactor
- With improved performance unscheduled outages have reduced
- Long maintenance outages are taken once in two years and not annually
- Steps to overcome this problem
  - On power test provisions
  - Review of surveillance frequency based on experience and PSA

Safety Culture

- **Degraded safety culture was observed in recent incidents in Indian NPPs**
- **Unintended reactor power rise due to total incapacitation of reactor regulating system**
  - Inappropriate reactor trip setting
  - Improper and inadequate operator actions
  - Inadequate appreciation of low power but peak flux operation
- **Holdup during reactor start up with insufficient subcriticality margin**
  - Suspended criticality with low shut down margin
  - Possibility for unintended criticality
  - Unsafe operating practice