Enhancing Safety Performance of Research Reactors at Trombay

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Outline

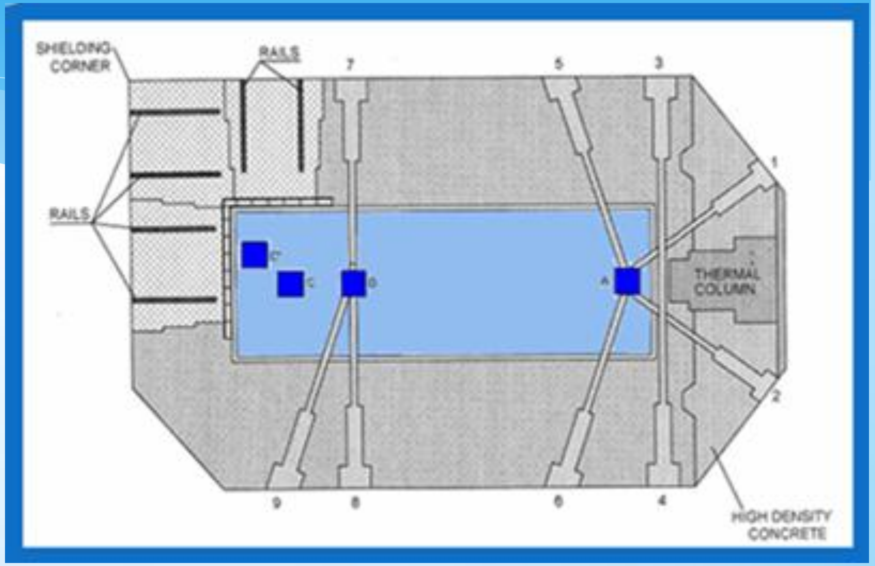
* Research Reactors and their role Indian Nuclear Program.
* Safety Management in Research Reactors.
* Enhancing the safety Performance by Engineering Change Management.
* Managing the Engineering Change
* Conclusion

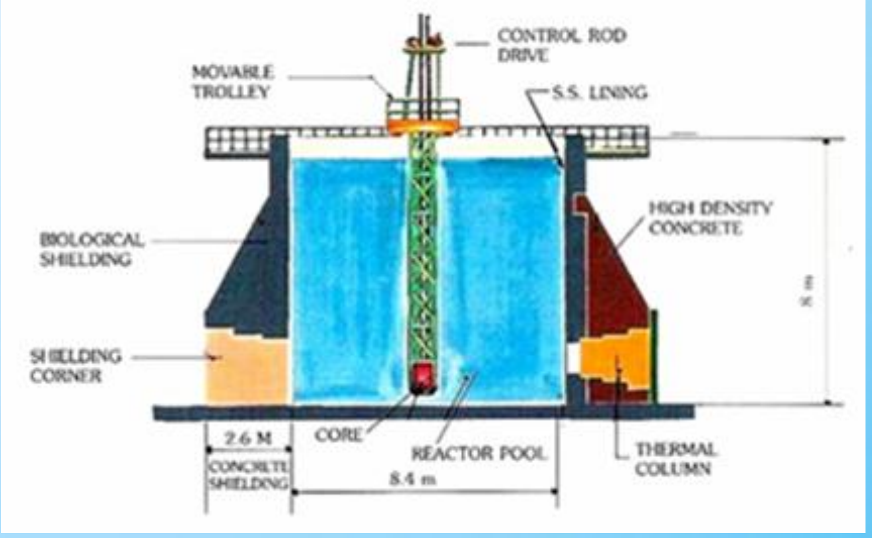
Indian Nuclear Power Program & Role of Research Reactors

- Three stage nuclear power program.
- Targeted at Thorium utilization energy generation.
- Research reactors have provided invaluable support
  - Testing of structural materials, fuel, equipment, reactor systems.
  - Shielding experiments, validation of codes etc.
  - During the construction of these reactors new technologies were developed, which became fore runners, for use in power reactors.
- Societal benefits by way of radioisotope production.
- They have opened new vistas
  - Medicine
  - Industry
  - Agriculture

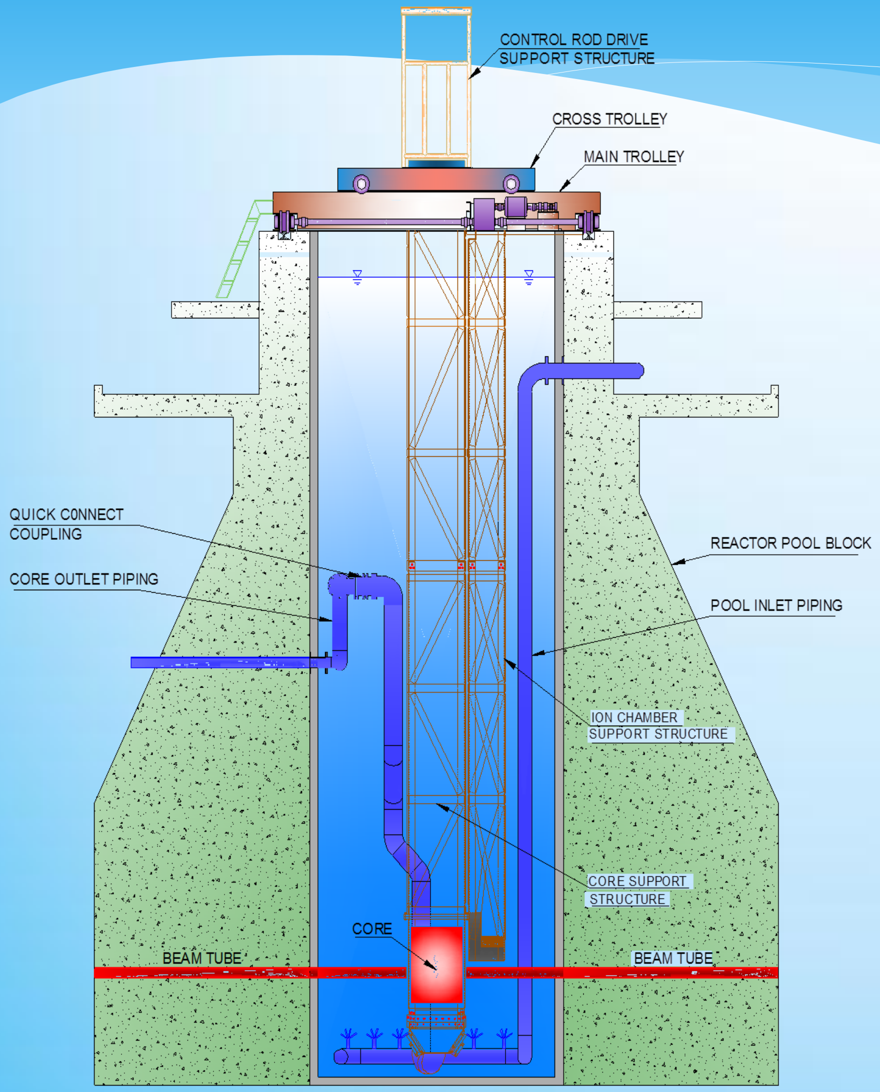
Apsara

* Pool type 1MW reactor.
* Fuel: Enriched Uranium–Aluminium alloy.
* Clad: Aluminium.
* Core suspended from movable trolley.
* SS lined pool 8.4 m x2.9 m x 8.0 m deep with DM light water.
* Average flux of 10^{12} n/cm^2/sec.
* It became operational on August 4, 1956.





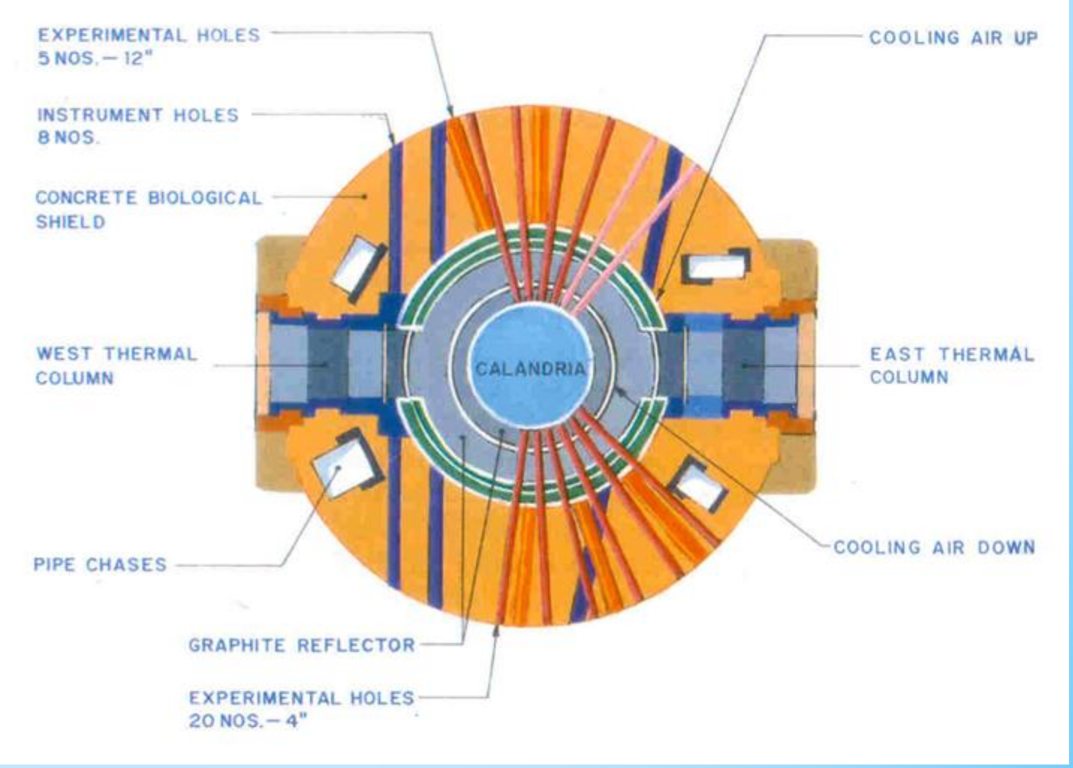
Apsara Future Plans



* Extensive refurbishment planned to extend life.
* Recently shut down, being upgraded to a 2 MW reactor
* Peak thermal flux of 6.2 x 10^{13} n/cm^2/se. Fast flux of 1.3 x 10^{13} n/cm^2/sec.
* Likely to commence operation by the end of 2013.

Cirus

* A vertical tank type 40 MW_{th} reactor.
* Fuel: natural uranium in metallic form.
* Heavy water moderated, graphite reflected and light water cooled.
* It produces a flux of 6.5 x 10^{13} n/cm^2/sec.
* It became operational in July 1960.



Cirus

* Four decades of operation.
* Ageing studies to identify SSCs requiring Refurbishment.
* Refurbishment taken up

  from 1997 to 2002.
* Along with major safety upgrades meeting present safety standards.
* Cirus permanently shut down in December 2010

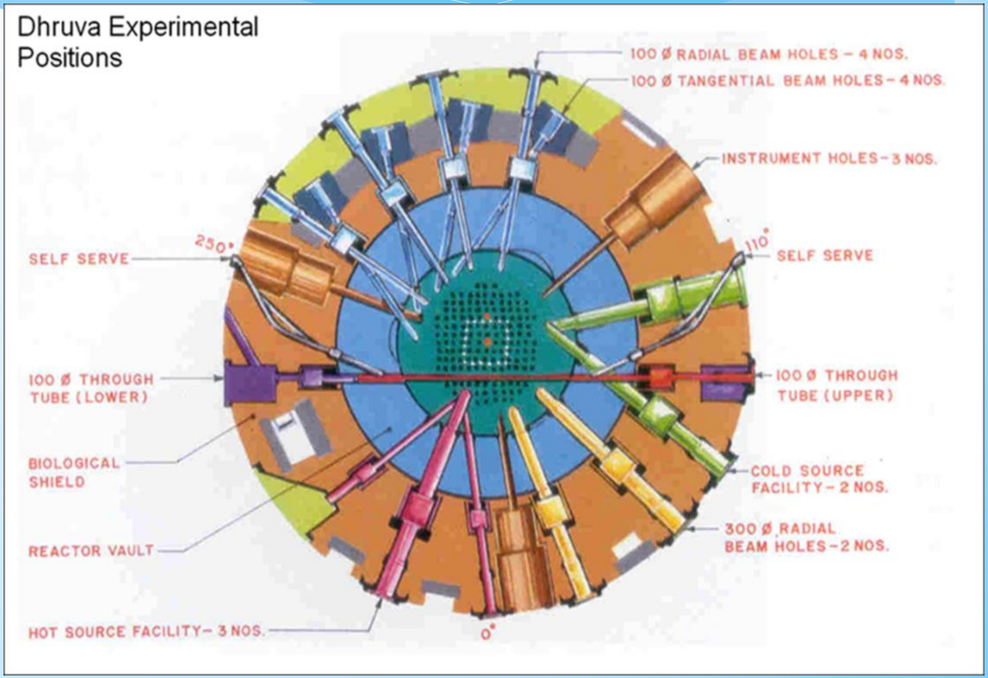
Dhruva

- 100 MW_{th} tank type reactor
- Fuel: metallic natural uranium.
- Clad: Aluminium
- Heavy water as moderator, coolant and reflector,
- Maximum thermal neutron flux 1.8×10^{14} n/cm^2/ sec.
- Became operational on 8th August 1985.

Dhruva

- Dhruva has completed two and half decades of operation.

* Based on
  * Systematic ISI program
  * Structured system and plant performance monitoring & review
  * Periodic Safety Review (PSR)



Certain mid-term safety upgrades in various systems of Dhruva Reactor were carried out.

AHWR CF

- Advanced Heavy Water Reactor (AHWR) 300 MWe power reactor.
- Aimed at early utilization of thorium.
- For conducting lattice physics experiments for validating (AHWR) core design.
- A 400 W reactor called Advanced Heavy Water Reactor Critical Facility (AHWR CF) was commissioned in 2008

Safety Requirements of Research Reactors

- Research Reactors have multiple objectives, hence complex safety requirements.
  - Basic research, materials testing, fuel testing, equipment testing, irradiation experiments, isotope production, criticality experiments and research related to future power reactor programme etc.
- To meet these requirements a strong safety management system has been evolved along with these reactors.

Safety Management Principles

* i. Well Structured Operating Organization with clearly defined roles and responsibilities.
* ii. Detailed documentation.
  * DBR, SAR, Technical Specification, QA manual, ISI Programme, EOP, Radiation Emergency Procedures, Operations & Maintenance procedures, P & I Diagram etc. form part of regular operating documents.

Safety Management Principles

* iii. Adopting good practices & procedures for carrying out any activity.
  * SWPs, Valve Slips, Checklists, Window form, Transfer slips for fuel movement, PIR for irradiation of samples, approved Refuelling agenda, Attention to chemistry of fluid are practiced.
* iv. QA, Technical Audit and internal and external Regulatory Inspection.
* v. Authorizations for waste disposals with detailed reporting to the regulatory bodies.

Safety Management Principles

* vi. Periodic authorization to operate based on safety performance of the facility and safety systems.
* vii Radiation safety with prompt investigations of exposures beyond investigation limits as per radiation protection rules.
* viii. Engineering change Management.

Safety Management Principles

- ix. Safety review of reactor utilization experiment, in line with norms for new reactors & approval commensurate with safety significance of experiment.
- x. Event reporting, prompt reporting of violation of "Technical Specifications" (within 24 hours) to the regulatory body.
- xi. Emergency preparedness and regular "Mock Emergency Exercises".
- xii. A multitier regulatory review.

Enhancing the safety Performance by Engineering Change Management

- There can be several weaknesses in the operating plant
  - Weakness in the system configuration
  - Material degradation
  - Cultural degradation.
- An effective change management system is necessary to identify weaknesses and to take corrective actions in time.

Tools for Change Management

* Systematically gained experience, with the reactor systems.
  * System and plant performance review by low level event reporting (Anomaly Reports) and analysis.
  * In Service Inspection (ISI):
  * Probabilistic Safety Assessments. (PSA)
  * Dose Budgets
* Experiences of other reactors and improvement in the safety norms.
  * Periodic Safety Review (PSR)

Anomaly Reports

* Anomaly reports highlight deviation of system or components from its design function with in limits.
* These are not ERs or SERs.
* They expose incipient system deficiencies in time, to avert significant events.
* This involves processing large volume of data,
* It has to be dealt with in an efficient manner, with graded approach.

System and plant performance review by low level event reporting and analysis

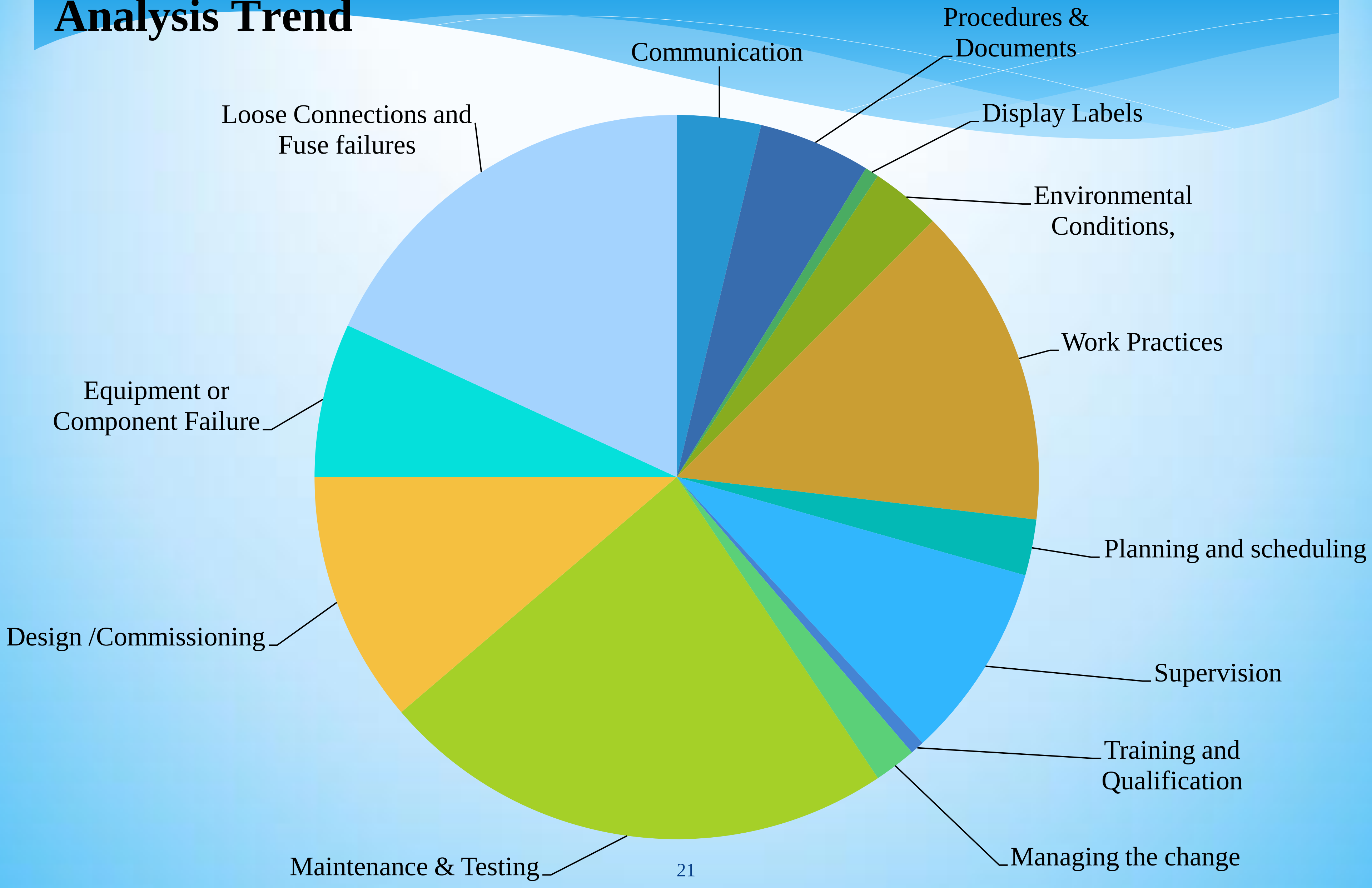
* Classification and trending of data generated is carried out based on the circumstances under which the fault occurred and the causes which are responsible for these faults.

* This forms the basis for the system performance review.

System and plant performance review by low level event reporting and analysis

- Other than the material or the process degradation, analyses of these anomaly reports also bring out cultural degradation in the plant.
- Based on these trend analysis, Reactor Building air treatment plant, Main air compressors, Machinery cooling water cooling towers, Class-II power supply motor alternator sets and various circuit breakers have been refurbished.

Typical Anomaly Report Analysis Trend



Up-gradation of Control & Instrumentation for reactor and fuelling machine

* The pneumatic instrumentation which was designed in mid-seventies was facing problem of obsolescence.
* Hence, all the control room and fuelling machine panels were replaced.
* Old pneumatic transmitters and indicators were replaced with electronics transmitters and chartless recorders.

In Service Inspection (ISI)

- In service inspection (ISI) of SSCs is carried out as per approved ISI program at specified intervals.
- This helps in ensuring the healthiness of SSCs for continued operation or indicating the need for timely corrective action.

Probabilistic Safety Assessments (PSA)

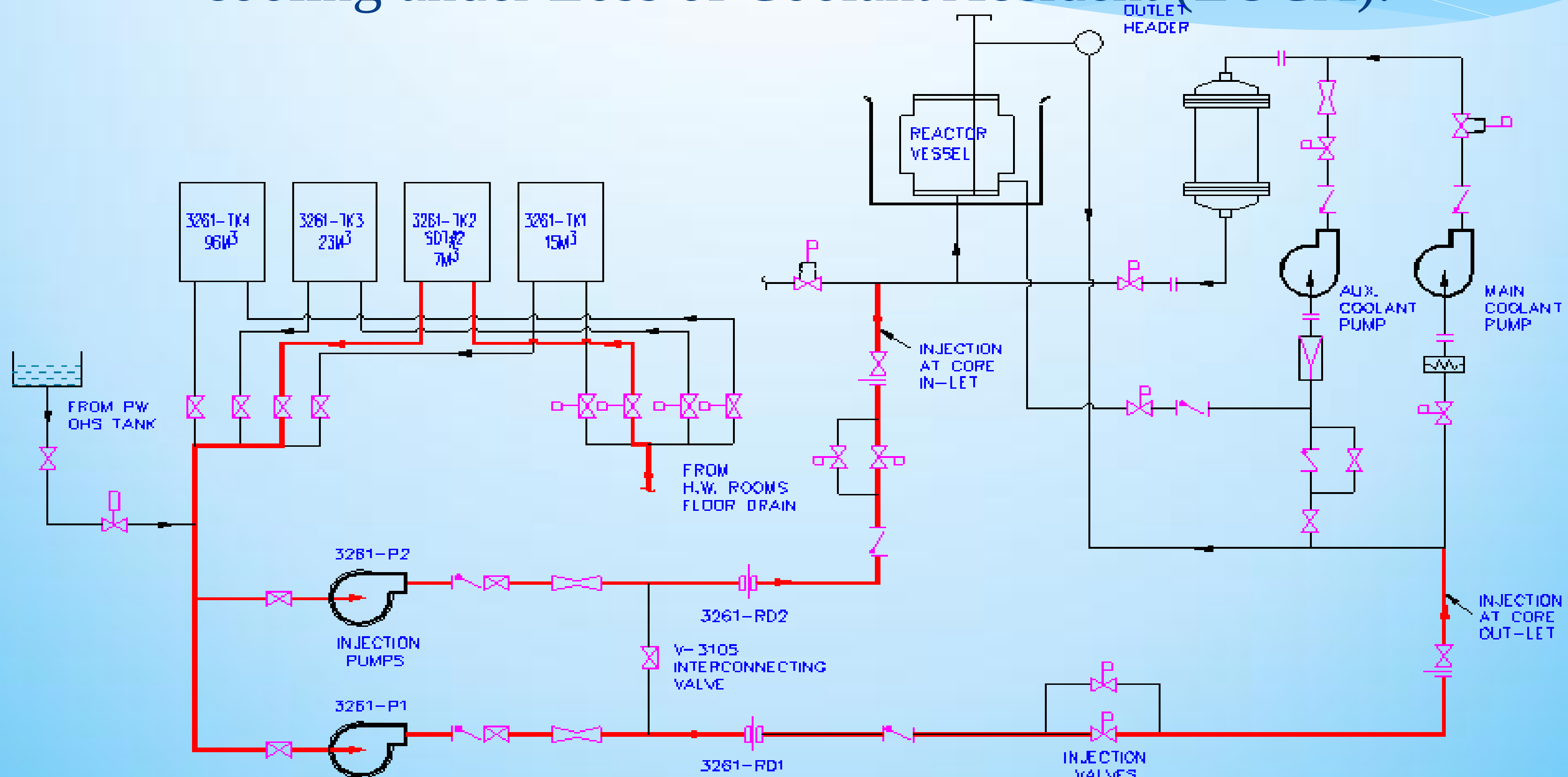
* Level#1 Probabilistic Safety Assessment (PSA) of Dhruva has been carried out to assess
  * Reliability of safety systems,
  * Estimation of failure frequency of the initiating events
  * Modelling of accident sequences towards giving the statement of core damage frequency.
  * One of the areas where PSA has also helped in freezing the final scheme is up-gradation of the "Emergency Core Cooling System" (ECCS).

Up-gradation of Emergency Core Cooling System (ECCS)

* Operation of ECCS had been very satisfactory
* No failures observed during the routine quarterly surveillance.
* It was upgraded to enhance its reliability by improving redundancy and diversity of
  * SDT pumps
  * Light water injection valve.
  * Provision was made for passive light water injection from OHST directly into the core, remotely from control room.

Up-gradation of Emergency Core Cooling System (ECCS)

* Emergency Core Cooling System (ECCS) ensures core cooling under Loss of Coolant Accident (LOCA).



EMERGENCY CORE COOLING SYSTEM FLOW SHEET (EXISTING)

Dose Budgets

- Dose Budgets help in identification of areas prone to high dose consumption.
- These areas are reviewed and measures are taken to cut down dose consumption.

SFSB purification system upgraded to achieve reduction in plant dose consumption

* One of the areas identified was SFSB purification system resin handling facility.
* It was designed as a regenerative facility.
* Due to change in the policy, to avoid generation of high level activity liquid waste regeneration was stopped.
* Fluidization and ejection of the exhausted resin was remotely done it was causing increased background field.

SFSB purification system upgraded to achieve reduction in plant dose consumption

* Exposing the operating staff in case of a problem.
* Standalone stainless steel hopper enclosed in a shielded cask designed, handled as a single unit.
* It is coupled to system with quick disconnect couplings.

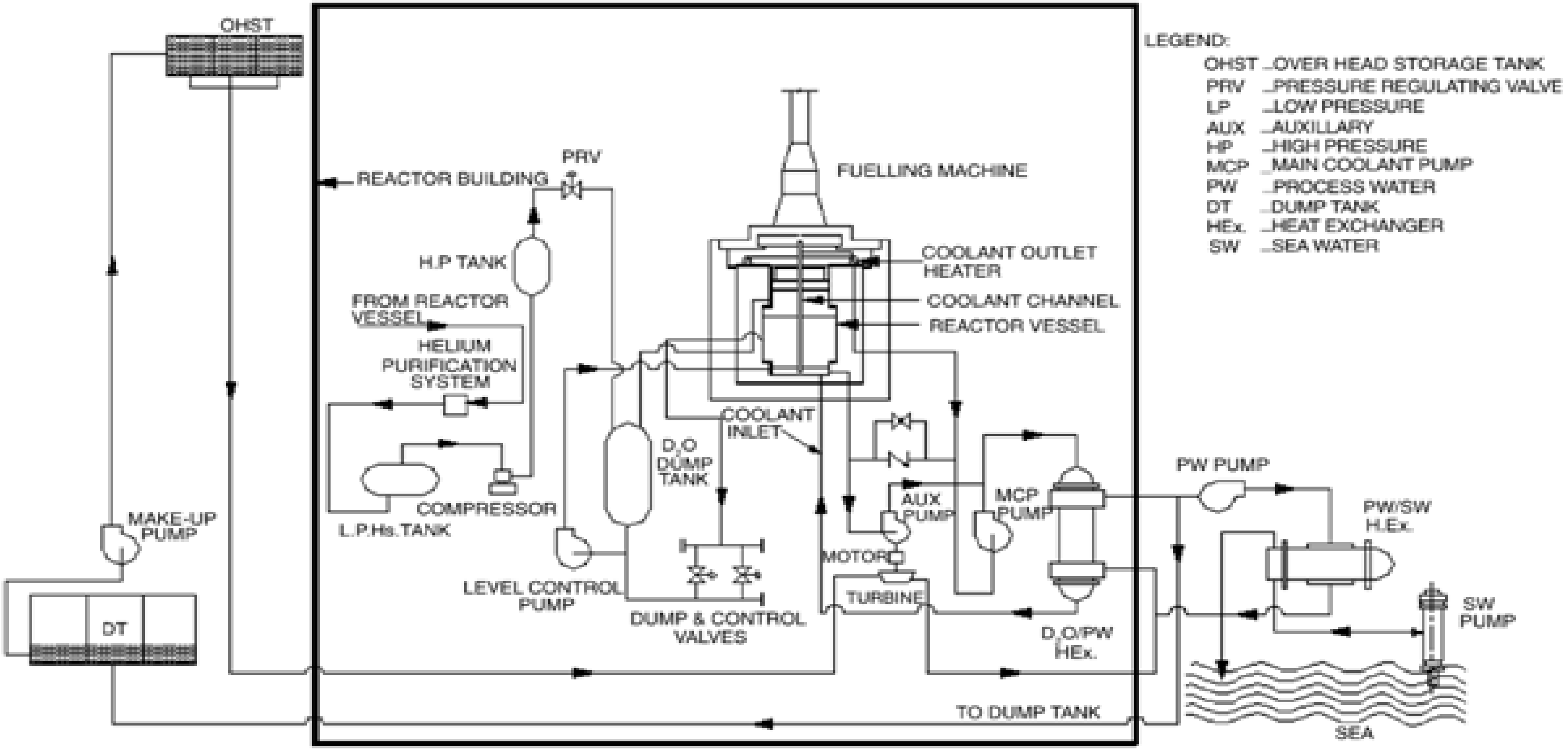
SFSB purification system upgraded to achieve reduction in plant dose consumption

* Resin hopper and the shielded cask are transferred to the waste management facility.
* Resin is ejected to another hopper in a hot cell and polymer fixed and disposed.
* Resin hopper & shielded cask returned back to the plant for further use.

Periodic Safety Review

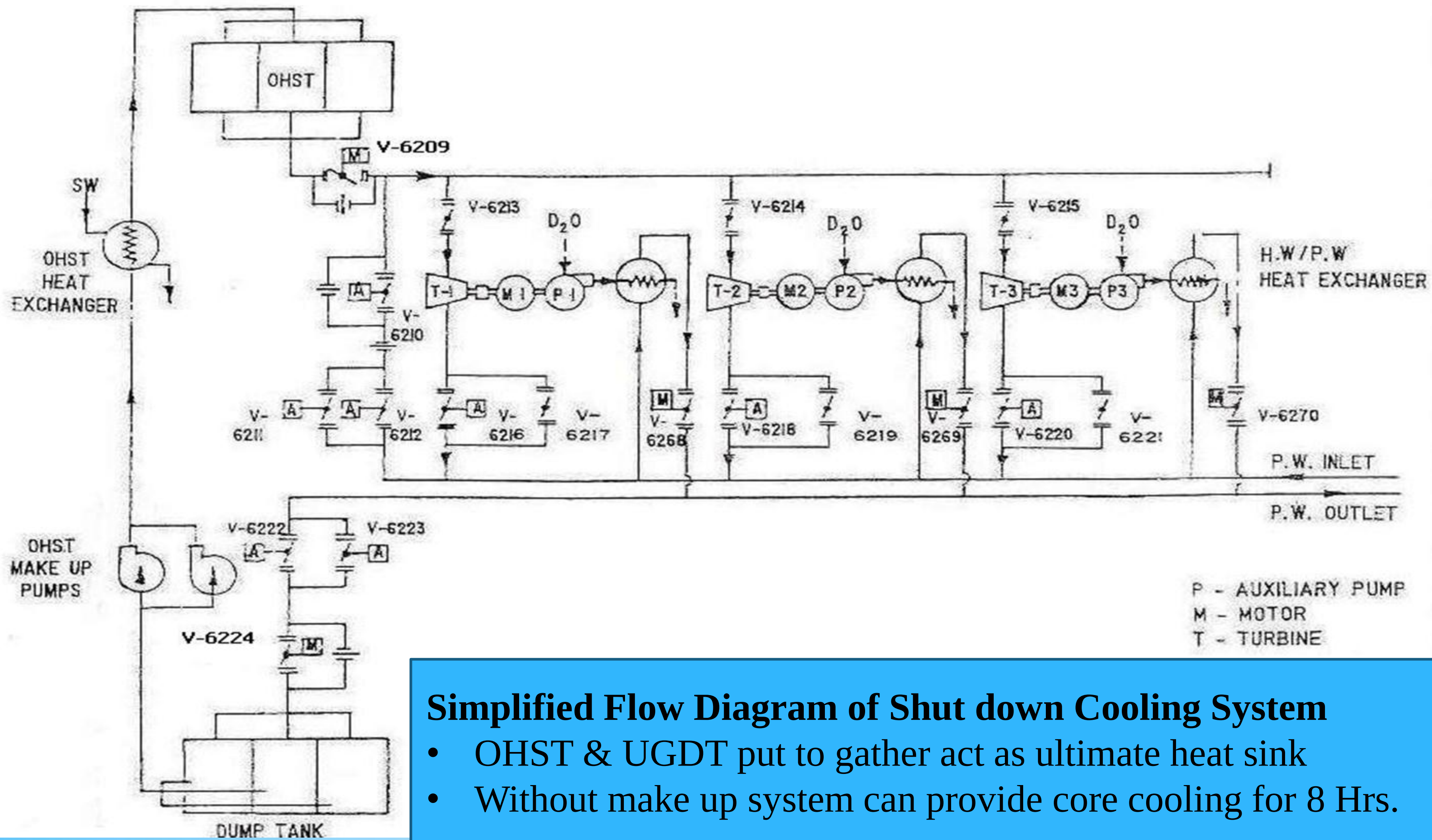
- PSR is an important tool, for identifying weakness in the system configuration with respect to the latest safety norms in the nuclear industry.
- Based on these reviews, certain mid-term safety up grades in various systems of Dhruva Reactor were carried out, one of the major change was additional **provision to take care of prolonged station blackout condition.**

Simplified Process Flow Diagram



Simplified process flow diagram of Dhruva

Shut Down cooling System



Simplified Flow Diagram of Shut down Cooling System

- OHST & UGDT put to gather act as ultimate heat sink
- Without make up system can provide core cooling for 8 Hrs.

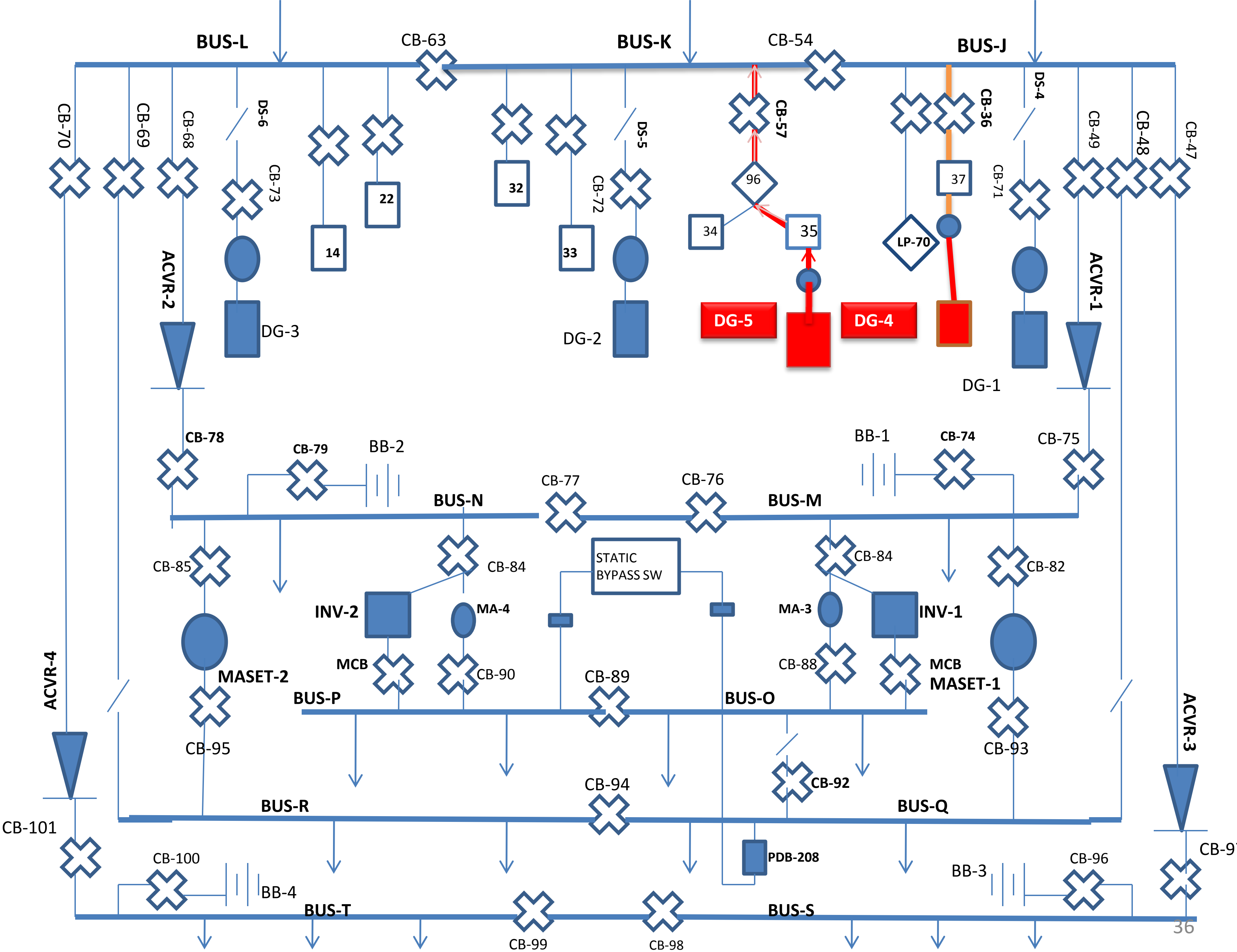
Additional provision to take care of prolonged station blackout condition

* For extended class IV and class III failure (**Station Black out**) due to any common cause, two independently located 125 kW DG sets were commissioned in 2000.
* They provide **dedicated supply** to OHST make up pump.

Additional provision to take care of prolonged station blackout condition

* SBO DG sets are kept isolated from the regular class III system.

* In 2009, **two more emergency portable diesel pumps of 60 kW capacity** have also been procured and commissioned.
* To augment the diversity and redundancy of OHST make up capability, **through an independent line**.


BUS-L
CB-63
BUS-K
CB-54
BUS-J
CB-70
CB-69
CB-68
DS-6
CB-73
14
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32
33
CB-72
DS-5
CB-57
96
34
35
CB-36
37
LP-70
DS-4
CB-71
CB-49
CB-48
CB-47
ACVR-2
DG-3
DG-2
DG-5
DG-4
DG-1
ACVR-1
CB-78
CB-79
BB-2
BB-1
CB-74
CB-75
BUS-N
CB-77
CB-76
BUS-M
CB-85
CB-84
STATIC
BYPASS SW
CB-84
CB-82
INV-2
MA-4
MA-3
INV-1
MCB
CB-90
CB-89
CB-88
MCB
MASET-2
MASET-1
BUS-P
BUS-O
ACVR-4
CB-95
CB-93
ACVR-3
CB-94
CB-92
BUS-R
BUS-Q
CB-101
CB-100
BB-4
PDB-208
BB-3
CB-96
CB-97
BUS-T
BUS-S
CB-99
CB-98

Managing the Engineering Change

* Though Changes are carried out during shut down state, However, core un-loading is usually not considered.
* Managing the engineering change is an important multidimensional problem. With issues ranging from
  * Familiarity of the operator to the change,
  * Safety issues involved in the execution of the change
  * Testing.

Managing the Engineering Change

- Though the initial and the final system configuration are well analysed and established, during the transition phase adequate care has to be exercised to ensure that the system configuration does not lead to an unsafe state.
- Taking into account various possible failures of the system under commissioning.

The important issues addressed, while managing these changes

* Involvement of operators / users from the conceptual stage.
* Adequate interactive sessions were held to emphasize the benefits likely to accrue.
* A detailed document highlighting the changes were made available well in advance.
* In certain cases, a mock facility was provided, which becomes more helpful instead of discussion and documents.

The important issues addressed, while managing the changes

- Draft modified documents such as EOPs, SARs, drawings and operating policies, technical specification & manuals were made available before the implementation.
- Final documents made available on completion, before reactor startup.
- Formal authorization sessions were held to check the proficiency of the operators before reactor start up.

The important issues addressed, while managing the changes

- Obtaining safety approval for the design from:
  - Plant management
  - Regulatory authorities based on the safety significance of the system being modified.
- Change implementation schemes can be approved by the plant management or by regulatory bodies.

The important issues addressed, while managing the changes

* Preparation of a detailed procedure, giving sequential steps for the execution of the change, including
  * Perquisites for initiating the job
  * Verification by a third party
  * Test plan.

Issues addressed while preparing sequential steps for execution of change

* Identification of SSCs likely to get affected during execution of these changes,
  * Their safety significance, based on role of these SSCs in SAR
  * Emergency Operating Procedures EOPs
  * Minimum monitoring requirement of the technical specifications.
  * Time duration for the unavailability of these SSCs, alternative arrangements and the class of these arrangements, vis-à-vis the class of the original SSC.
* Commissioning of the alternate arrangements, confirming that the alternate arrangement is performing satisfactorily.

Issues addressed while preparing sequential steps for execution of change

* Action plan to deal with Anticipated Operational (AOOs), while these changes are being incorporated, considering failure of the systems to perform under commissioning.
* Advance checking of the SSCs required for mitigating these situations.
* Detailed qualification tests to be carried out and acceptance criterion.
* Adequacy of the simulation tests and their differences with respect to the actual testing.

Conclusion

* Experience has shown that the precursors of a significant event are present long before the significant event occurs.
* Many of the precursors present, as degrading safety culture and degrading plant material condition.
* Effective trending and analysis provides early identification of the accumulating less significant, low impact events and provide opportunity to take effective corrective actions prior to the occurrence of more significant events, this is an important contributor in improving safety performance.

Conclusion

- Periodic Safety Review helps in identification of weaknesses in the plant configuration.
- Though on many occasions, complete adaptation of new system designs is not possible in an existing reactor, however, if the concepts are understood and the system configuration are suitably modified to adopt the spirit of these changes substantial improvement in the safety performance of the plant can be brought about.

Conclusion

* Regular ISI, PSR and analysis and trending of the low level events are very effective tools for improvements in the safety performance of the plant.

Thank You