भाभा परमाणु अनुसंधान केंद्र
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Ageing management, refurbishment and modernization of Research Reactor Dhruva

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Dhruva Reactor

India's research reactor DHRUVA which became critical in 1985

Its natural uranium fuelled, heavy water moderated and heavy water cooled research reactor

Its rated power level of 100 MWt and maximum thermal neutron flux of 1.8 x 10^{14} n/cm2/sec.

The reactor start-up and power regulation are by controlled adjustment of D_2O level in the calandria.

Nine cadmium shut-off rods are provided as primary shut-down devices.

Basic Purpose

Testing of prototype fuel elements for Indian power reactors at appropriate flux levels.

Research in the fields of physics, chemistry, activation analysis and biology.

Isotope production facilities and also to provide for the production of radio-isotopes of higher specific activity.

Neutron Beam Research. Neutron activation analysis.

Special experiments like validation of thermal hydraulic codes.

To develop a pool of trained man-power to be used in nuclear power plants.

Ageing Management Programme

Structures, Systems & Components (SSCs) of Dhruva are in service for last 36 years.

Ageing management programme is defined as engineering, operation, and maintenance strategy to control within acceptable limits the ageing degradation of SSCs. Research reactors experience two kinds of time dependent changes:

Degradation of SSCs (physical ageing), gradual deterioration in physical characteristics.

Obsolescence of SSCs (non-physical ageing), i.e. their becoming out of date in comparison with current knowledge, standards and technology.

Ageing Management Program (AMP)

AMP to ensure safe operation of the reactor during the period of designed life and to evaluate residual life of SSCs for long term operation.

Review the performance & assess the condition of SSCs.

Formulate action plan for qualitative assessment of residual life of SSCs which are non-replaceable & non- isolatable i.e. replacement warrants core unloading & requires long outage of reactor for repair/replacement.

To formulate an ageing management program in line with the guidelines as per relevant codes, standards & practices.

To formulate refurbishment requirements to enhance operating life of reactor by another 30 years.

Ageing Management Program (AMP)

AMP was developed, in line with AERB guides (AERB Safety Guide/O-14), IAEA guides(Safety Guide No. SSG-10,NS-G-2.12/Tech Docs(792 &1736) & reports of ageing studies carried out on NPPs. Classification of SSCs was carried out based on “The Guidelines and practices for heavy water reactors” as explained in IAEA document –TECDOC-1503 and AERB Safety Guide/O-14. The SSCs are categorized into four categories as follows:

Category 1 Major critical SSCs Limiting plant life

Category 2 Critical SSCs.

Category 3 Important SSCs

Category 4 Other SSCs.

Ageing Management Program (AMP)

Elements considered for preparation of health assessment of SSCs of Dhruva Reactor were identified.

1. Design & Environment Conditions
2. Deviation from design condition
3. Operation & Maintenance feedback
4. Neutron Fluence seen by SSCs
5. Corrosion / ageing study
6. Estimation of life
7. Design changes/upgrades required
8. Refurbishment need
9. Effect on reactor safety and availability

Ageing management of Concrete Structure

Need for Ageing Management of Concrete Structures

Containment structures are designed to withstand loadings that may result from postulated events and act as the final physical barrier against radioactive material release to environment.

Both external and internal events are considered in the design of containment structures. External events include earthquake and severe weather conditions (floods).

Critical internal events include loss of coolant accidents (LOCA).

The containment building and other concrete structures often have to perform for a time period significantly greater than their service life as delayed decommissioning strategies involve the use of containment as a ‘safe store’ beyond plant service life.

Modelling & Analysis for Ageing Management

Modelling & Analysis of structures for design re-qualifications and identification of required retrofitting/refurbishment works.

Finite element models of structures are used for predicting structure response to ageing mechanism.

Use of known structural material properties with finite element structural model indicates areas of high tensile stress.

It also indicates the areas where surveillance or NDT would be focused. NDT results are fed back into the model to further refine it.

Ageing management of Concrete Structure

Understanding Ageing of concrete structures

Parts of concrete structures that are susceptible to degradation,

Key degradation mechanisms, their symptoms and potential rates of actions,

Impact of degradation, structure's ability to perform safety functions,

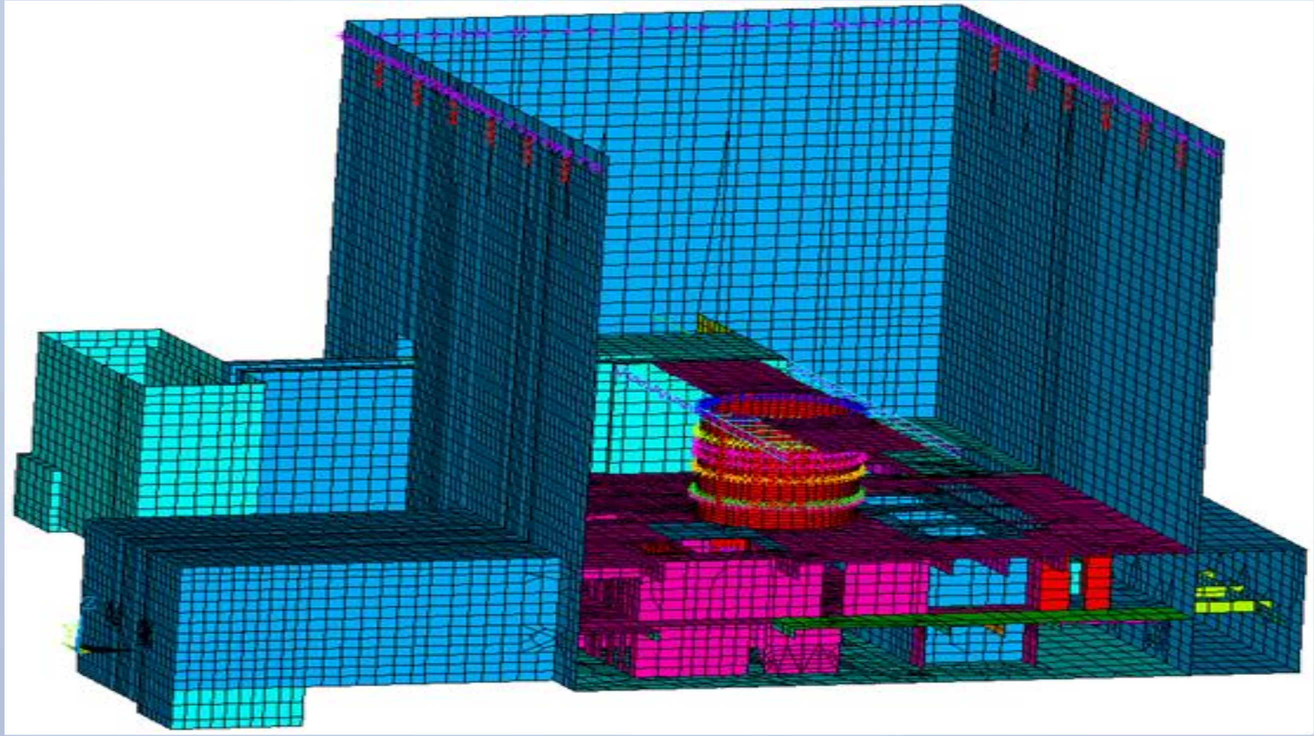
Appropriate remedial actions

Design considerations: original design error, primarily those related to inadequate structural design

Construction considerations: Construction defects

Stressors & Environment considerations: Percolation of fluids, flowing gases or liquid, Cyclic loads & vibrations Flood, cyclone, wind, seismic & impact loading

Ageing management of Concrete Structure



3 Dimensional Finite Element Model of Dhruva Reactor

Some portion of the walls is not meeting the present requirements.

Retrofitting to strengthen the wall being done

Ageing management of Concrete Structure

Assessment of degradations in concrete structures

Visual Inspection

Non-destructive testing (NDT)

Rebound Hammer Test

Ultra Sonic Pulse Velocity (USPV) Tests

Carbonation depth test

Half-cell Potentiometer test

Concrete core test

Chemical analysis of concrete dust samples in laboratory

In-situ permeability test

Ageing management of Concrete Structure

Design checks have indicated some portion of containment wall and SFSB brick wall not meeting the current standards for seismic loading, retrofitting/refurbishment suggested.

Health assessment of concrete structures indicated good condition of structures except stack and service building columns at basement. Localized distresses were observed here and there on structures. In general carbonation depths on structures are less than concrete cover above rebar which is good for rebar health.

Sea water spillage was found to be main reason for degradation in service building structures. Structures were repaired and water spillage was stopped.

Reactor Vessel , End Shield & Annular Shield

Potential ageing mechanisms considered for the reactor assembly components were Neutron irradiation embrittelment, Stress corrosion cracking (SCC), Corrosion, Erosion, Fatigue, Stress relaxation and wear.

These components are classified as category #1 components which limit the life of reactor.

Considering the service conditions, actual fluence seen by SSCs and operation feedback it is concluded that Reactor vessel, Annual Shield and end shield can be in service for another 30 years

Primary coolant & cover gas system

Various components of Heavy Water and Cover Gas systems are classified as per the guide. It was observed that values of operating parameters remained consistent through the service period.

As per ISI data of visual inspection and thickness measurement, pipe thinning of less than 0.01 mm (max at the HX bend location) / every 3-4 years was observed. SS 304 L pipe lines for HW and He system will perform for at least 50 years from now.

No deviation in chemistry parameters was observed.

System activity was brought down by increasing the no of mixed beds in D_2Opurification system. Failed Fuelled Detection (FFD) system was up graded to detect fuel failure at the earliest.

Process and ECW water system

The following modifications in ECW system has been carried out to improve availability and to provide redundancy in the system.

Additional pumps were provided for makeup of over head storage tank (OHST).

Dedicated diesel generator sets were provided for makeup pump motors.

Engine driven pumps were installed to take care of external events like flooding.

Additional pipe lines were laid for makeup to OHST and down comers from OHST to ECW pumps.

Spent Fuel Storage Bay purification system was upgraded to reduce its activity and man-rem consumption.

Emergency Core Cooling System

Modification in ECCS system was carried to increase the redundancy in pumps, valves and provision was made for long term cooling. The following changes were made in the system.

Three additional pumps were in the two injection lines. Pump motors were provided with Class II power supply.

Motorized valve was provided in the interconnecting line.

Additional valves were provided in the light water injection system.

Heat exchangers were provided in each injection line for long term cooling.

Pneumatic instrumentation was replaced with electronic instrumentation.

Embedded pipe lines were provided with polymer coating.

Power supply system

Electrical system of Dhruva is classified into four classes based on reliability (Class I, II, III and IV).

Class IV supply consists of two no of 22 KV incomers, transformers, 3.3 KV Buses and 415 V Buses.

Class III supply consists of three no of 750 KVA DG sets, 415 V Buses.

Class II is uninterrupted AC supply fed from two no of 250 KVA MA sets and four no of 20 KVA inverters.

Class I is fed from two no of 1200 AHr battery banks and ACVRs.

Life Estimation

The residual life of a transformer can be accessed by monitoring its oil condition and condition of paper insulation. The transformer oil is analyzed on annual basis and Furan analyses of the oil were carried out.

Residual life of power cables can be assessed by carrying out accelerated ageing test on piece of power cable.

Residual life of battery banks can be monitored by testing its electrolyte and carrying out the battery bank capacity test.

Residual life of motors is assessed by condition monitoring methods like current signature analysis and polarisation index.

Power Supply System Up gradation

Based on the condition monitoring mitigating actions were taken against aging degradation of various electrical systems

Refurbishment of 22 KV, 3.3 KV and 415 V Panels

Replacement of MA sets

Replacement of Inverters and ACVRs

Replacement of Battery Banks

Replacement of Motors

Replacement of Motor protection relays with new generation protection system. Replacement of power cables

Overhauling of transformer

Replacement of DG sets

Instrumentation and control system up grades

The design of the instrumentation of Dhruva was incorporated, based on the technology available during early eighties.

Up gradation requirement of the instrumentation was felt in the data acquisition and processing systems, due to either obsolescence or for augmenting the facilities provided by the existing systems.

Upgrade of Fuel Channel Flow Monitoring Differential Pressure Gauges with Electronic Differential Pressure Switches (EDPIS)

Up gradation of I&C System Using PLC Based System

Reactor Trip Logic System (RTLS)

Up gradation of DHRUVA Alarm Annunciation System

Upgrade of Start up Logic System

Reactor Regulating System - Data Acquisition System

Supplementary Control Panel (SCP):

Supplementary Control Panel was developed a back up to Main Control Room (MCR). In the event of un inhabitality of Main Control Room, it is necessary to have supplementary control room with sufficient instrumentation to ensure basic safety functions such as, to trip or shutdown the reactor, monitor reactor shut down status, maintains long term cooling and maintains radiological containment. Monitoring important parameters such as shut-down devices status, neutron power, moderator level, containment pressure, containment radiation level, containment damper positions.

Dedicated sensors and power supplies should be provided for monitoring the parameters.

Future Modifications planned

A few jobs are planned which requires core unloading.

1. Fuelling Machine Magazine replacement.
2. Replacement of ‘O’ rings of the Guide tubes.
3. Replacement of PW/HW heat exchangers.
4. Inspection of rolled joints of coolant channel and poison tube.
5. Replacement of rubber diaphragms valves in HW system.
6. Replacement of existing elastomeric joints with flexitallic joints
7. Exposing the embedded portions of ECW pipelines.

Conclusion

Significant up gradations have been implemented in various Systems in Dhruva reactors, by either modifying the old systems or incorporating new systems. Availability of the reactor has increased considerably and the associated maintenance has been reduced to a large extent. Dose consumption to workers and activity release to public has came down significantly. Up gradation done in Dhruva shall be useful in future research reactor designs. With the modifications and up gradation carried out and proposed, Dhruva should be able to provide services for next thirty years.

Thank You