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SAFETY EVALUATION OF

INDIAN NUCLEAR POWER PLANTS

BWRs AT

TARAPUR ATOMIC POWER STATION (TAPS-1&2)

SAFETY EVALUATION OF INDIAN NUCLEAR POWER PLANTS BWRs AT TARAPUR ATOMIC POWER STATION (TAPS-1&2)

1.0 INTRODUCTION

The Tarapur Atomic Power Station (TAPS-1&2) is located on the West Coast of India on the Arabian Sea in the Thane District of Maharashtra State, about 2-1/2 miles from Tarapur and 60 miles north of Mumbai, 72°-39'-30" East Long., 19°-50'-0 N. Latitude. The reactor is a dual-cycle, forced circulation Boiling Water Reactor (BWR) General Electric, USA design producing steam for direct use in the steam turbine. The fuel consists of enriched uranium dioxide pellets contained in sealed Zircaloy-2 tubes. Construction of both reactors started in 1964 and completed in the year 1969.Till now TAPS had generated 81 billion units of electrical energy.

Safety review of the design features to handle postulated Beyond Design Basis Event (BDBE) is presented for TAPS-1&2 in view of the recent occurrence of Tsunami incident at the Fukushima Nuclear Power Plant in Japan. Recent upgradation of TAPS-1&2 carried out to enhance safety levels complying with current standards and safety practices ensures management of design basis accidents including Station Blackout (SBO) event. To mitigate unavailability of Off-site Power, Emergency Diesel Generators (EDGs) have been provided and additionally, dedicated Station Black Out Diesel Generator (SBO DG) would supply a reliable and redundant electric power to cater to safety loads. Station is designed to handle and mitigate any Design Basis Accidents (DBA) with the Engineered Safeguard Systems. For mitigation of BDBA involving Loss of Coolant Accident (LOCA) with loss of Emergency Core Cooling System (ECCS), a backup cooling system namely Alternating Cooling Water System (ACWS) has been proposed, which is under AERB review prior to its implementation. Provision of proposed ACWS has preventive and mitigating characteristics of hydrogen management, which otherwise would have generated due to excessive metal water reaction imposing potential threat to containment integrity. The current provisions at TAPS-1&2 have the capability to handle external hazards involving design basis earthquake, tsunami (equivalent to design basis flood level), design basis flood and fire.

In light of the accident at Fukushima, Japan, initiated by natural calamity, the Task Force recommends short term as well as long term measures for mitigating conditions that result from severe natural events, which has rare/remote probability of occurrence. The conditions include the loss of significant operational and safety systems due to natural events such as earthquake, tsunami, consequential fires and explosion. Additional back fit provisions covering enhanced core cooling, fuel pool cooling and hydrogen management capabilities by containment inerting are proposed as corrective measures for assuaging impact of radiological consequences on the environment, thus ensuring plant and public safety.

2.0 OBJECTIVE

The objective of this Task Force is to review the consequences of occurrence of a similar situation like Fukushima Daiichi NPPs postulated at TAPS-1&2 assuming the unavailability of motive power and the designed water supply route and to recommend augmentation measures to mitigate the situation. This includes the review of Emergency Operating Procedures (EOPs) to evaluate the capabilities and to identify, finalize the required augmentation measures and infrastructure facilities, hook-up points to mitigate this beyond design basis situation.

3.0 PLANT UPGRADATION FOR ENHANCING SAFETY LEVEL

A comprehensive safety review was conducted for TAPS-1&2 in 2005, which included Station operating performance, Safety analysis, Ageing assessment & management, Structural integrity and Plant seismic studies to meet current safety principles and practices.

For enhancing plant safety levels corrective/compensating measures were implemented for electrical systems, mechanical system, control and instrumentation and fire protection system.

The salient modifications of systems are:

i) Upgradation of existing 3x50% capacity Emergency Diesel Generators by 3x100% Emergency Diesel Generators

ii) Segregation of electrical distribution system for Class-III, II & I supplies into two zones with physical barrier

iii) Redistribution of supplies to redundant loads from separate buses

iv) Cable re-routing through diverse routes for redundant loads

v) Augmentation and unit wise segregation of Emergency Feed to reactor by addition of one pair of Control Rod Drive pumps

vi) Unit wise segregation of reactor Shutdown Cooling System and delinking from fuel pool cooling system

vii) Upgradation of Compressed Air System by providing additional dryer and powering of compressor by Class-III power supply

viii) Installation of strong motion seismic instruments

ix) Major Recommendations on Fire Protection

- Electric power supply system modification

- Segregation of power supply sources into independent trains
- Diverse routes for cables to redundant equipment

- Augmentation of fire detection system : addressable type smoke detection system with optical, flame and heat detection covering all vital areas
  - Fire barriers (3 hr. rating) for cable penetration between control room and cable spreading room
  - Fire resistant false ceiling in Control Room
  - Fire doors, fire dampers
- Fire retardant coating on cables
- EOP for cold shutdown in event of fire in control room

The core damage frequency after plant upgradation has become $2.157x10^{-6}$ per reactor per year as compared to the original core damage frequency 3.2×10^{-5} per reactor per year without upgradations.

3.1 Existing Design Safety Features to Handle Design Basis Accident (DBA)

Recent Plant upgradation as brought out above has improved the reliability of the power supply system and auto blow down system in order to enhance availability of low pressure core spray system and post incident containment spray system for mitigating postulated DBA as well as pipe ruptures of various sizes at various locations that includes recirculation line, steam line and feed water line resulting in loss of coolant accident to prevent fuel damages**.** Core spray system is capable of maintaining reactor core adequately cooled for long term by removing fuel decay heat. The containment spray system is capable of maintaining the pressure at normal operating level under these postulated events.

3.1.1 <u>Design Basis Accident (DBA) Related to Large Loss of Coolant Accident (LOCA)</u>

The postulated design basis accident involving double ended rupture of recirculation line may empty out reactor pressure vessel within 12 secs., during which initiation of automatic injection of core spray may disallow fuel core heat up, thus, prevents hydrogen generation. The reactor will automatically scram on sensing any of the parameters during the event.

Leak inside Dry Well will give following indications:

i) Decrease in the primary steam flow

ii) Decrease in the Reactor pressure

iii) Feed Water flow may remain same or may increase depending on size of leak

iv) Increase in drywell pressure followed by alarm

v) Dry Well (DW) Ultrasonic Leak Detection System (DW-USLD) annunciation

vi) DW sump cooling water outlet high temperature

vii) DW sump pumps high level & continuous running of pumps if size of leak is big

viii) Increase in DW areas temperatures and alarm

Reactor will scram on DW high pressure as well as on above parameters. PSIV's closure scram will take place on high flow if leak is after restricted orifice in steam lines. Loss of inventory now depends only on the size of the leak and Reactor pressure. It can be controlled only by bringing down reactor pressure (by cooling).

Core Spray (CS) and Post Incident (PI) system auto actuation would take place on concurrent signals of reactor low lever, feed water low flow and DW high pressure. PI system is to be kept in service to keep drywell pressure under control.

3.1.2 Handling Small Loss of Coolant Accident

3.1.2.1 Auto Blow Down System (ABDS)

In Boiling Water Reactors (BWR), Loss of Coolant Accident is one of the most severe accidents, which may lead to core uncovering resulting into core damage. LOCA could occur due to breakage of pipeline connected with primary system. The severity of LOCA would depend upon the size of break. In case of pipe break having break size greater than 0.1257 ft^2 (116.8 cm^2), reactor will depressurize (through break in pipe itself) fast enough to 200 psig and core spray system would be able to spray water into reactor in stipulated time and core damage will be avoided. But if break size is smaller than 0.1257 ft^2, reactor will not get depressurized by itself fast enough and core spray system will remain poised for longer time.

Under this situation, if feed water is also not available, depending upon the leak size core may get uncovered and may lead to core damage. The Auto Blow Down System (ABDS) is provided to take care of such eventuality. In this condition, auto blow down system will operate and depressurize the reactor below 200 psig enabling core spray system to spray water into reactor

The system consists of three air operated relief valves. All the discharges from these relief valves are directed to the suppression pool, outside the drywell. The operator can reset the circuit when the parameter values return to normal. The operator can manually operate these valves using the control switches provided on the control panel in control room.

The auto-blow down or auto-depressurization system is designed to make core spray system effective under small breaks in reactor coolant pressure boundary by depressurizing the reactor vessel rapidly so that the core spray system becomes effective.

Following are the salient design features of the system:

i) Three air operated relief valve in each reactor (instrumented relief valve)

ii) System actuates automatically on following concurrent signals

- Reactor vessel water low level and
- Dry Well high pressure and
- Primary feed water low flow

iii) De-pressurization of the reactor by releasing steam through relief valves into suppression pool

3.1.3 Handling Station Black Out (SBO)

3.1.3.1 Equipment/Systems Available for Ensuring Safe Shutdown of Reactor and Cooling Down during SBO

i) Reactors get shutdown by insertion of CRDs, as accumulators have sufficient stored energy, apart from self insertion aid available at Reactor pressure above 55 Kg/cm^2.

ii) Emergency condenser comes in service immediately for cooling the reactor. With normal shell side water volume, it is expected that decay heat removal is possible for eight hours.

iii) Station has two independent battery banks of 240V, 1200 AH capacity (each) and expected to power the essential equipments like inverters, emergency lights, emergency seal oil pump, emergency bearing oil pump etc. for at least 8 hrs.

iv) Two banks of 48V (80 AH capacity) batteries provide power to neutron monitoring instruments of each unit. These batteries are rated to provide power for 10 hrs.

v) Diesel fire pump will be available to provide necessary fire protection. It has two independent banks of batteries for starting and engine control. (12V, 250AH capacity for 8 Hrs. discharge rate). The Diesel Fire Pump has a diesel day tank of 24 hours capacity which can be filled from a diesel storage tank.

3.1.3.2 Instrumentation Availability to Monitor Reactor Status during SBO

Reactor safety system invertors provide power supply to following vital instruments along with 48V batteries:

i) Neutron monitoring instruments

ii) Control rod position indication

iii) Instrumentation for reactor level & pressure

iv) Yarway level instruments for monitoring reactor level upto 59" above core top

v) Annunciation system will be available

vi) Reactor rate of cooling monitoring

3.1.3.3 SBO Scenario

SBO involving simultaneous loss of offsite and on site power immediately scrams the reactor by inserting the control rod drive into the core sensing loss of power. The reactor core cooling is provided by automatic valving in of emergency condenser system which continues to remove core decay heat. The reactor has inherent design feature that water inventory is retained above core top upto 6 hrs in the event of Loss of Station Power without any feed to reactor vessel and Emergency Condenser system removing decay heat. Availability of Emergency condenser as a passive system heat sink for reactor core for 8 hrs without the need for any operator action and beyond 8 hrs with make up on shell side may be carried out with the operator action. Additionally, there is a provision of SBO DG which may provide dedicated power supply to the Station to meet Station load should emergency diesel generators be rendered unavailable. Thus, in the event of SBO reactor can be safely shutdown, maintained cool for long period keeping containment isolated ensuring plant and public safety against any radiological risk.

4.0 MEASURES TO HANDLE BEYOND DESIGN BASIS ACCIDENTS

4.1 Mitigating Strategy to Handle BDBA

4.1.1 Using Proposed Alternate Cooling Water System (ACWS)

Alternate Cooling Water System (ACWS) is designed to cool the reactor core and prevent the fuel-clad temperature from rising in the postulated event of “Beyond Design Basis Accident” (BDBA) scenario. For the purpose of this report the BDBA is defined as an event, wherein LOCA takes place with simultaneous unavailability of Emergency Core Cooling System (ECCS). The ACWS is a post severe accident management system. It is essentially designed to handle the post severe accident scenario as a preventive and mitigating measure.

In case of BDBA appreciable amount of hydrogen may be generated and may be of potential concern for containment integrity. Alternate Cooling Water system will limit the metal water reaction in such a case and limit the hydrogen generation in primary containment below the deflagration limit, thereby maintaining primary containment integrity.

In case of loss of coolant accident simultaneous with emergency core cooling system unavailability, ACWS can be utilized to cool the reactor core and reduce metal water reaction and thereby generation of hydrogen. The functional requirements of the ACWS system are:

i) To inject coolant into the reactor core at around 20 kg/s as a preventive and mitigating measure in the event of failure of existing ECCS.

ii) To cool and maintain the core cooling in the event of BDBA condition.

iii) To keep the hydrogen concentration in the drywell below detonation/ deflagration level.

The following combinations of the signals are used for ACWS automatic injection:

i) CS and PI initiation signal

ii) Failure of the core spray pumps sensed by the discharge header pressure switches and pumps failure relays

5.0 PROPOSED MEASURES FOR HANDLING SEVERE ADVERSE EVENTS

5.1 Postulated Initiators

Rare/remote events**,** if unmitigated can have far reaching radiological consequences. Some of these are:

i) Seismic Event exceeding SSE of Site

ii) Tsunami exceeding Design Basis Flood

iii) Fire

Postulated worst earthquake of 9.0 magnitude on Richter scale occurring at Makran fault in Pakistan would generate tsunami wave of height around 2.0 m at TAPS Site. The net effect is rendering all Classes of station AC power unavailable.

5.1.1 <u>Measures for Fire fighting at TAPS-1&2 during Tsunami Event</u>

In case of Fukushima type event at TAPS, liquid fire protection system will not be available as jockey fire pump, electric fire pump and diesel fire pump will not be available due to submergence by sea water. In such cases, services of fire brigade will be required to charge liquid fire protection system headers.

Following fire fighting equipments are available at Centralized Fire Station, TMS-

i) Two fire tenders
   a) 4500 L tank (water capacity) and pump with 2250 lpm flow @ 7 Kg/cm^2 pressure and portable petrol generator
   b) 4000 L tank (water capacity) and pump with 2250 lpm flow @ 7 Kg/cm^2 pressure

ii) Two trailer fire pumps of 1800 lpm flow @ 7 Kg/cm^2 pressure each

iii) Two diesel driven portable fire pumps of 1600 lpm flow @ 7 Kg/cm^2 pressure each

iv) One Portable diesel pump of 280 lpm flow @ 7 Kg/cm^2 pressure

v) One Portable diesel generator

When the Tsunami alert is declared, the above fire fighting equipment should be safely moved to higher elevations. After the Tsunami attack is over and water recedes to normal level, ground elevation of TAPS-1&2 is expected to be accessible. At that time, fire fighting equipments can be deployed at different locations in the plant and fire system can be charged. For this purpose, blind flanges connected to fire system ring headers are available in Reactor Building, Service Building and Turbine Building.

5.2 Systems Rendered Unavailable

In this scenario, the postulated initiator disables the electrical power of Class-IV and Class-III rendering ECCS Pumps, Emergency Feed Pumps, Salt Service Water Pumps, Electrical Fire Pumps, Diesel Fire Pump and Emergency Ventilation System unavailable due to flooding. As a result, the normal reactor core cooling design functions are lost. Communication system inside the plant will be partly available. PA system and emergency siren will be available.

5.2.1 <u>Instrumentation and Monitoring Devices Unavailable</u>

Postulated event assumes that the essential instrumentation to monitor safety parameters/status of reactor is lost. Sensing signals of Instrumentation for monitoring following parameters is rendered unavailable in the Control Room:

i) Reactor Water Level

ii) Containment Pressure

iii) Area Radiation Monitoring*

iv) Process Radiation Monitoring*

v) Stack Discharge Monitoring

* Partially available

5.2.2 <u>Instrumentation And Monitoring Devices Available</u>

i) Reactor Pressure (from Emergency Condenser Steam Line)

ii) Reactor Pressure Vessel Metal Temperature

iii) Neutron Monitoring

iv) Control Rods position indication

5.3 Systems Available

Following systems will be available to perform their intended design safety functions along with their status by indication and monitoring:

i) Reactor SCRAM

ii) Primary Pressure Boundary Isolation

iii) Primary Containment Isolation

iv) Emergency Condenser – Core Cooling

v) Station Batteries

   a) Battery power supply will be available (250 VDC) as it is located at 133 feet elevation (30 feet above ground level). The cables from the batteries to the different loads assumed to be available during the scenario are routed at around 133 feet elevation. The different loads powered by the batteries are located in the accessible areas of the reactor building. Batteries are sized to supply DC power to all emergency loads for a period of 8 hours.

vi) Water sources

   a) EC shell side (22,000 gallons)

   b) Suppression pool (4,00,000 gallons)

   c) Underground raw water (6,00,000 gallons)

Control Room will be habitable and emergency lighting will be available.

5.4 Essential Safety Functions

For ensuring Plant and public safety the reactor is required to perform following three essential safety functions involving:-

i) Reactor shutdown to maintain core in sub-critical state
ii) Reactor core cooling for maintaining core in sub-cooled state
iii) Isolation of reactor containment to prevent release of radio activity to the environment ensuring public safety against radiological consequences.

5.5 Essential Requirements

To ensure the core and containment integrity, following functions are essentially to be fulfilled:

i) Reactor Cooling
ii) Reactor Depressurization
iii) Feed to Reactor
iv) Make Up Water for EC
v) Containment Cooling
vi) Containment Depressurization

vii) Fuel Pool Cooling
viii) Hydrogen Management
ix) Reliable Monitoring of Reactor Parameters (Pressure, Level, Temperature)
x) Reliable Monitoring of Containment Parameters (Pressure, Temperature, Hydrogen Concentration, Radiation, Water Level)
xi) Venting of Containment (Dry Well, Wet Well, Common Chamber)
xii) Venting of RPV
xiii) Spent Resin Tank (SPERT)/Radwaste Tanks /Spent Fuel Dry Storage Cask Integrity

5.6 Safety Assessment

5.6.1 <u>Ensuring Reactor Shutdown</u>

Following loss of electric power as a consequence of the above mentioned postulated initiators (5.1), the control rods relays will be de-energized thereby pushing control rods into the core making reactor sub-critical in the shutdown state ensuring necessary and sufficient conditions of first safety function of stopping neutron chain reaction within 5.0 seconds.

5.6.2 <u>Reactor Cooldown</u>

Following reactor shutdown, the reactor power decreases to decay heat level which will be removed through Emergency Condenser System (ECS) for initial 8 hours on valving in ECS till the secondary side coolant inventory is exhausted. The ECS removes heat at a rate of 55^{O}C/hr bringing the reactor core temperature to 150^{O}C and depressurized to 5 kg/cm^2. On replenishing the secondary side coolant inventory of emergency condenser the decay heat can be continuously removed. In the process, there is a possibility of lowering of coolant level above the core in reactor pressure vessel due to system leakages and shrinkage. This reduction of coolant level is required to be made up for maintaining the reactor at low pressure (<5 kg/cm^2) and low temperature (<150^{O}C), if not the reactor pressure will continue to rise and stay maintained at pressure of around 70 kg/cm^2 by intermittent operation of relief valves discharging inventory into suppression pool raising the pressure of primary containment (dry well, suppression pool and common chamber). Consequently, the reactor pressure vessel may continue to lose the coolant inventory with a potential of exposing the fuel rods, raising clad temperature promoting metal water reaction associated with release of exothermic heat in the clad and generation of hydrogen in cascading uncontrolled manner in the long run, the scenario that is undesirable. This calls for provision of adequate cooling inventory.

5.6.2.1 <u>Depressurization of reactor pressure vessel through high point vent</u>

Should RPV pressure remain high around the set point of relief valves, the high point vent is to be used to depressurize RPV in order to maintain it at low pressure. Suitable provision in the high point vent is to be carried out, if necessary.

5.6.3 Containment Isolation

On sensing loss of power, reactor containment system would be isolated preventing external leakages from the containment to the environment. However, unwarranted core heat-up would consequently pressurize the containment having potential of exceeding design pressure, which is required to be vented out into the environment for maintaining containment integrity.

5.6.4 Proposed Mitigating Options

In view of the scenario discussed in Section 5.6.2 above, the coolant inventory is required to be replenished in the reactor pressure vessel, secondary side of emergency condenser system and heat exchangers of shutdown cooling system for ensuring long term core cooling measures. For meeting the requirements, the provision of motive power as well as source of coolant is necessary.

5.6.4.1 Provision of Reliable Electric Power

For providing the motive power to operate the pumps, following multiple options are suggested, which may be used to ensure availability of reliable power as measure of defense-in-depth approach.

i) Locating mobile DG inside the plant (not vulnerable under tsunami).
ii) Locating CNG/Gas operated generator at adequate elevation outside the plant and supplying electric power through over head cables passing through available EP in the containment.
iii) Relocating the existing SBO DG at higher elevation beyond reach of Tsunami wave height say 5m elevation ensuring availability of electric power and transmitting to reactor building through newly laid overhead cables.
iv) Raising Tsunami resistant thick wall castling around the EDGs and Diesel Storage tanks ensuring availability of emergency power.

5.6.4.2 Ensuring Core Cooling Measures

5.6.4.2.1 Provision of Water Sources

The first and foremost requirement of core cooling measures is provision of source of water as coolant which are:

- Suppression pool
- Suction from pit of intake canal
- Underground raw water tank
- Availability of fire tenders in tandem
- Constructing an over head water tank away from site

5.6.4.2.2 Provision of Injecting Coolant into RPV, Containment, ECS and Post Incident Heat Exchangers

i) Injection of coolant into feed water line for filling up RPV through any of the water sources as suggested in 5.6.4.2.1. The choking of water line is not envisaged as the feed water sparger has bigger elliptical holes.
ii) Injection of coolant into RPV through low pressure core spray line using ACWS. The ACWS pumps will be powered by motive power as suggested in 5.6.4.1 and will draw water from suppression pool and dry well and additionally will have flanges available outside the containment as hookup arrangement for providing the clean water from fire tenders to prevent choking of sparger nozzles with adequate flow rate to keep fuel core submerged and cooled.
iii) Injection of coolant into drywell as well as through post incident containment sprays system for cooling the containment and reactor pressure vessel.
iv) Hook up arrangement for replenishing shell side inventory of heat exchangers of Emergency Condenser by availing of the water sources as brought out in 5.6.4.2.1 above.

5.6.4.3 Maintaining Containment Pressure below Design Pressure

For maintaining containment integrity under the postulated worst scenario, the containment pressure is required to be kept below containment design pressure.

5.6.4.3.1 Provision of Containment Venting

Venting of containment at suitable locations would facilitate in maintaining containment pressure well below design pressure. Provision of venting from dry well, wet well, common chamber and secondary containment is required either directly into the environment or through stack to which can be appropriately invoked through back fitting and EOPs depending upon the severity of the scenario.

5.6.4.4 Hydrogen Management

Under hypothetical severe adverse event, an unmitigated scenario related to core cooling, fuel may excessively over heat promoting metal water reaction and generation of hydrogen within the reactor pressure vessel. Hydrogen so generated may either remain within RPV or may escape through relief valves into suppression pool, dry well and common chamber of primary containment and into secondary containment. There is a potential of deflagration or detonation depending upon the ratios of hydrogen, oxygen/air and steam. For keeping containment integrity intact the hydrogen management strategy needs to be devised.

5.6.4.4.1 Provision of Passive Recombiners

For managing hydrogen within acceptable steam, air and hydrogen, mixture ratio, the passive recombiners are required to be installed at appropriate locations for mitigating potential threat emanated from generation of hydrogen.

5.6.4.4.2 Provision of Containment Venting

Provision of containment venting as discussed in Section 5.6.4.3.1 would facilitate in depressurizing the containment as well as reducing the concentration of hydrogen within the containment bringing out the concentration levels below deflagration limit. The vacuum breakers between drywell and suppression pool will equalize pressure in the containment by replenishing air inventory from ventilation system for maintaining the design intent of structure.

5.6.4.4.3 Requirement of Containment Inerting

With provision of engineered multiple redundant and diverse power sources and measures of core cooling systems, fuel core cooling would be maintained under all eventualities, thus, core heat-up and subsequent hydrogen generation is not envisaged, which may obviate the containment inerting requirements. However, as a measure of defense-in-depth, containment pre-inerting alongwith requisite numbers of hydrogen recombiners are proposed to be put in appropriate locations within containment for maintaining containment integrity. The provision of hydrogen recombiner would facilitate continuous removal of hydrogen, should it generate, which would offer advantage in quick removal, disallowing build up of hydrogen locally. Further, containment venting would facilitate in preventing formation of local hydrogen pocket and rendering hydrogen concentration below deflagration/detonation limits.

5.6.4.5 Maintaining Spent Fuel Pool Cooling including Away From Reactor (AFR) Spent Fuel Bay

The AFR Spent Fuel Storage pool contains fuel bundles of TAPS-1&2 BWR and PHWR fuels which have been cooled for 10-40 years. The heat load due to the fuel bundles is less than 200 KW. The pool can withstand 7 days loss of cooling before the pool water temperature reaches 60 Deg.C. The building and the equipment are designed for 0.3 g SSE.

Provision needs to be made for fuel pool filling to compensate for evaporation through external source.

5.6.4.6 Handling Major Fire

Major fire in Reactor Building or Turbine Building can be handled by external fire tender sources connected to hookup provision already provided in reactor building north and south entrances.

5.6.4.7 AFR/SPERT/Radwaste Tanks/Spent Fuel Dry Storage Cask Integrity

i) The AFR spent fuel storage pool can withstand 7 days loss of cooling before the pool water temperature reaches 60°C. The building and the equipments are designed SSE.

ii) The top of SPERT tank is at 116’ el. (5 m above ground level) Tsunami water may wash over the tank and some sea water may enter the tank but over all integrity of the tank and the stored resins will be maintained.

iii) Low level liquid is stored in the tanks located outside Radwaste building and also inside the basement floor in the radwaste building. The total radioactivity in the outside tanks is limited as per Technical Specifications. The limit ensures that unacceptably high concentrations do not exist in the effluents reaching the sea in the unlikely event of rupture of the tanks.

iv) There are four spent fuel dry storage cask stored within the plant premises. Each cask contains 37 fuel assemblies which have seen more than 30 years cooling and is anchored to seismically qualified foundations.

There will be negligible impact of the above on the plant premises or other nearby DAE facilities.

6.0 RECOMMENDATIONS

To mitigate the consequences of postulated initiating events related to rare Tsunami, following recommendations for strengthening multiple redundancy and diversity in motive force and core cooling features are proposed. Short term recommendations are provided for assurance that the plant is in a state of readiness to respond to severe adverse events. Long term recommendations include infrastructural facilities and hook up points to mitigate the situation. It is expected that a time line for the long term recommendations will be generated within a month.

6.1 Short Term Recommendations

- Preparation of Guidelines for severe natural events and review of existing EOPs
- Regular training for EOPs
- Mockup drills of Plant personnel for simulated events
- Disaster Management training for personnel at multiple plants Site
- Provisions for self sufficiency in handling emergencies for 7 days without external help
- Comply with the recommendations of WANO SOER 2011-2 (Fukushima Daiichi Nuclear Station Fuel Damage caused by Earthquake and Tsunami.

These short term recommendations may be completed within two months’ period.

6.2 Long Term Recommendations

- **Handling Seismicity**
  - Initiation of automatic SCRAM sensing earthquake

- **Provision of Reliable Electric Power**
  - Raising Tsunami resistant thick wall around the EDGs and diesel tank ensuring availability of emergency power.
  - Locating mobile DG inside the plant.
  - Locating CNG/Gas operated generator at adequate elevation outside the plant and supplying electric power through over head cables passing through available EP in the containment.
  - Relocating the existing SBO DG at higher elevation beyond reach of Tsunami wave height say 5m elevation ensuring availability of electric power and transmitting to reactor building through newly laid overhead cables.

- **Ensuring Core Cooling Measures**

  Provision of Water Sources
  - Suppression pool
  - Suction from pit of intake canal
  - Underground raw water tank
  - Availability of fire tenders in tandem
  - Constructing an over head water tank away from site

- **Provision of Injecting Coolant into RPV, ECS and Post Incident Heat Exchangers**
  - Injection into feed water line for filling up RPV through any of the water sources as suggested in 5.6.4.2.1. The choking of water line is not envisaged as the feed water sparger has bigger elliptical holes.
  - Injection into RPV through low pressure core spray line using ACWS. The ACWS pumps will be powered by motive power as suggested in 5.6.4.1 and will draw water from suppression pool and drywell. It will additionally have flanges available outside the containment as hookup arrangement for providing the clean water from fire tenders.
  - Injection of fresh water into dry well and suppression pool.
  - Hook up arrangement for replenishing secondary side inventory of heat exchangers of ECS and Post Incident Heat Exchangers by availing of the water sources as brought out in 5.6.4.2.1 above.

- **Maintaining Containment Pressure below Design Pressure**
  - Provision of Containment Venting

- **Maintaining Reactor Pressure Vessel below Design Pressure**
  - Depressurization of reactor pressure vessel through high point vent.

- **Hydrogen Management**
  - Provision of Containment Pre-inerting
  - Provision of Containment Venting

- Provision of Passive Recombiners

- **Maintaining Spent Fuel Pool Cooling by replenishing pool water**
  - Provision has to be made for fuel pool filling to compensate for evaporation through external source.

- **Alternate public address/communication system**

- **Redundant path ways for hookup arrangements**

- **Availability of fire tenders at Site**

7.0 CONCLUSION

With the recent upgradation carried out at TAPS-1&2 enhancing safety levels, the existing design provisions are adequate to mitigate all DBAs, SBO and external events like earthquake upto SSE, Tsunami wave height upto design basis flood and fire. In view of the recent series of events unfolded during Fukushima Daiichi Nuclear Power Plant in Japan, a comprehensive study of TAPS-1&2 BWRs on those aspects was carried out. Some of the back fit provisions related to electric power system, cooling water sources, decay heat removal, containment and RPV depressurization through venting and hydrogen management strategies have been recommended to augment the capabilities to handle the highly unlikely severe natural events. Further, revisions of EOPs, regular training and Mockup drills of Plant personnel for simulated events are recommended for emergency preparedness.

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B1

SCENARIO PROGRESSION

AT TAPS- 1&2

UNDER SEVERE NATURAL EVENT

SCENARIO PROGRESSION AT TAPS- 1&2 UNDER SEVERE NATURAL EVENT

1.0 INTRODUCTION

Design Basis Flood Level (DBFL) for TAPS-1&2 is calculated, on the basis of postulation of highest tide level, wave run up and storm surge for the sites. Structures, Systems and Components (SSCs) are located above this level and up to this level of flood, all design provisions related to fulfillment of fundamental safety functions are available.

Seismic instrumentation is available for detecting seismic activity and annunciating the same in control room. Shutdown of the reactors and maintaining long term sub-criticality is automatically achieved by fail safe system of Control Rods System.

Practically there would be a certain time gap (of the order of around one hour) between seismic activity and the effects of tsunami to be experienced in the plant. This time can be gainfully utilized for bringing the operating units to cold shutdown state and mobilizing other resources. Information on Tsunami will be transmitted to site from the India Tsunami warning System co-ordinated by Indian National Centre for Ocean Information Services (INCOIS), Hyderabad.

2.0 CLASS-IV POWER SUPPLY FAILURE

Class-IV power supply will be lost a result of earthquake, but the reactors can be brought to cold shot down utilizing Class-III power supply from emergency diesel generators which are seismically qualified and would be available.

3.0 CLASS-III POWER SUPPLY FAILURE – CORE COOLING AVAILABLE THROUGH EMERGENCY CONDENSER

At a later stage, when the Tsunami hits the site if water level at site exceeds the design basis flood level then emergency diesel generators could become unavailable. This situation would essentially lead to a Station Black Out (SBO) situation and depending upon severity of the incident and effects on plant systems and facilities, SBO may be extended for a longer duration.

The core cooling is not affected as the Emergency Condenser (EC) can passively remove the decay heat generated in the reactor for a period of 8 hours. Beyond this period, EC shell side water inventory has to be replenished. The Task Force recommendation brings out how this can be done by hooking up the firewater system and utilizing alternate redundant sources of water.

4.0 LOSS OF WATER INVENTORY IN REACTOR PRESSURE VESSEL (RPV)

Due to the effect of shrinkage and maximum design leaks, the core may start uncovering and fuel rods may expose after 6 hrs. into accident. To prevent the core uncoverage injection of water to the RPV is necessary with in 6hrs. The Task Force recommendation brings out how this can be done by different methods like through the Alternate Cooling Water System and /or hooking up the firewater system to the emergency feedwater inlet line from outside the Reactor Building. With heat sink ensured, core cooling can be continued for extended duration and there is no concern for radioactivity release as the fuel temperature is kept under control.

5.0 DC POWER SUPPLY

The availability of DC power supply to the various monitoring systems and emergency lighting will be limited to 8 hrs. Hence recommendation is made on how to ensure their availability through portable GENSETS located at high elevation inside the Plant. Recommendation for alternate sources of power supply is also made.

6.0 SPENT FUEL STORAGE POOL

The spent fuel is stored in a large pool of water and water cover over spent fuel which can sustain loss of cooling for at least 7 days. With recommendation of augmenting spent fuel pool water inventory, the spent fuel safety is ensured for extended duration and there would be no release of radioactivity from these stored spent fuels.

7.0 CONCLUSION

The recommendation of supplying water to reactor and Emergency Condenser through appropriate hook up arrangements will prevent any possibility of core damage and the resultant threat to the containment due to hydrogen generation would also be taken care of. Alternate provisions for high point venting of the RPV and Containment will ensure that they do not get pressurized beyond their design. The recommendation to provide pre-inerting of containment and passive hydrogen recombiners will address the hydrogen generation. With containment integrity maintained there is no concern of radioactivity release.

Therefore a situation caused by severe natural event resulting in beyond design basis situation can be handled with recommended hook ups and unacceptable radioactivity release to the environment can be avoided.

Further scenario covering sequence of event is tabulated below:

Time	**Event**	**Intervention required**
T = 0	Earthquake initiated.	
T = 0 + 5 sec	Earthquake beyond SSE will lead to loss of Class-IV power supply. This will de-energize SCRAM Solenoid Valves and reactor will SCRAM. Systems designed for SSE will be available i.e. i) Class-I, II and III power supply ii) ECCS iii) EF iv) EC v) Instrument Air supply	
T = 5 sec	Reactor Trips on loss of power. All control rods inserted automatically	None
T = 10 sec	Reactor Pressure around 70 kg / cm^2 and temperature around 280°C. Emergency condenser comes online. Reactor cooling starts.	None (EC comes on line automatically by opening of a DC operated Valve. In case it does not open, it can be opened manually.)
T = 30 min	Tsunami hits TAPS	None
T = 30 min + 2 sec	Loss of Class IV and Class III Power supply (SBO)	None
31 min < T < 6 hrs	i) Provision to feed water into the RPV within 6 hours will ensure that the fuel will not get uncovered. ii) Provision to feed water into EC shell side will ensure indefinite cooling for the RPV. iii) Both above will ensure RPV cooling and does not get pressurized and coolant inventory is maintained.	
T = 6 hrs	Reactor pressure around 5 kg/cm^2 and temperature around 150^0C. Water Inventory	Feed to RPV to be established before this.

Time	Event	Intervention required
	reduction has taken place due to shrinkage and maximum design leaks. Fuel bundles on verge of getting uncovered.	
6 hrs < T < 8 hrs	Provision to vent RPV and containment within 8 hours that will ensure integrity of both, should reactor pressure remain around relief valve set point. The batteries will last for 8 hours. Class-III power has to be restored within 8 hours or provision to recharge the batteries has to be made for: i) Lighting ii) Control & Indication	
6 hrs < T ≤ 8 hrs	Emergency condenser shell side inventory depleted.	Makeup water to emergency Condenser to be established before this.
T > 8 hrs	DC batteries depleted causing i) Loss of all indications ii) Loss of lighting iii) Loss of power supply to available emergency equipment.	Emergency Power supply to be restored before this.
8 hrs < T < 7 days	Provision to make up water in fuel pools needs to be made within 7 days.	
T ≥ 7 days	Water in Spent fuel Storage pool boils off above the fuel bundles (assuming full fresh core is stored along with full capacity load of discharge bundles). There is 26 feet of water above the top of the fuel bundles stored in the pool. Assuming some amount of water inventory loss due to sloshing during the seismic event and heatup and evaporation of the remaining water above the fuel due to decay heat of the fuel, the fuel will get uncovered in 7 days time. Radioactivity and hydrogen release due to clad failure and metal water reaction.	Water addition to spent fuel pool to be done before this.

Provisions as recommended in Sections 6.1 and 6.2 of this report will ensure that integrity of the core, containment and spent fuel stored ion spent fuel pool will be maintained indefinitely thereby assuring no radiological consequence to the public domain.