AN OVERVIEW OF THERMAL HYDRAULIC DESIGN VALIDATION STUDIES FOR AHWR

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Abstract

Core heat removal by natural circulation under the operating as well as accidental conditions is one of the several passive safety features of the Advanced Heavy Water Reactor (AHWR) being developed in India. Integral Test Loop (ITL) is an experimental test facility which simulates the Main Heat Transport System and safety systems of AHWR. Several experiments have been carried out to validate the thermal-hydraulic design features of AHWR such as flow stability during start-up, LOCA and performance of Isolation Condensers to remove decay heat using natural circulation. This paper presents an overview of these experimental studies.

1. Introduction

The Advanced Heavy Water Reactor (AHWR) being developed in India aims to meet the objectives of utilization of thorium based fuel cycle for power generation, sustenance of technologies and expertise developed for PHWRs and incorporation of advanced safety features [1]. AHWR is a vertical pressure tube type, boiling light water cooled and heavy water moderated reactor. It adopts several passive concepts with a view to simplify the design and to enhance safety and public acceptability. One of the attractive features of this reactor is that the heat removal from the core takes place by natural circulation during normal operation and accidental conditions. This enhances passive safety by eliminating the recirculation pumps, which are normally present in conventional forced circulation boiling water reactors (BWRs).

Natural circulation is susceptible to flow instabilities during certain operating conditions which are not desirable. Therefore, the operating procedures such as start-up of reactor are required to be designed to avoid the occurrence of flow instabilities. Start-up procedure proposed for AHWR adopts a stepwise pressurization using an external boiler to avoid low pressure instabilities. To mitigate LOCA, a provision for injecting emergency core coolant (ECC) directly in to the bundle has been provided in AHWR. The ECCS consists of high pressure injection from accumulator, low pressure injection from Gravity Driven Water Pool (GDWP) and long term core cooling by recirculation & cooling of reactor cavity water. Besides the main heat transport system, many other passive systems are incorporated in AHWR. Examples are the isolation condenser system (ICS), passive containment cooling system (PCCS) and passive containment isolation system (PCIS).

To facilitate thermal hydraulic design validation for AHWR, a scaled down test facility named Integral Test Loop (ITL) has been designed and constructed at Reactor Engineering Division, BARC. ITL simulates the MHTS, ECCS, ICS, Feed Water System (FWS) and associated control systems. Power to volume scaling philosophy has been adopted for the design of the ITL systems [2]. Experiments have been conducted in ITL to validate the proposed start up procedure and performance validation of ICS. Besides, LOCA experiments were carried out in ITL for Inlet Header (IH) break sizes varying from 5% to 200%. The test results have been simulated using the thermal hydraulic code RELAP5/MOD3.2. This paper describes the integral test loop, the thermal hydraulic experiments conducted, simulation of the tests with RELAP5/MOD3.2 code and the results obtained in detail.

2. Brief Description of AHWR

In the Main Heat Transport System (MHTS) of AHWR (Figure 1), the subcooled water flows from Reactor Inlet Header (RIH) to core through 452 feeder pipes. The subcooled water gets heated up as it rises through 452 fuel assemblies. Boiling takes place in the fuel assemblies and steam-water two-phase mixture comes out of the fuel channels. Low quality steam-water mixture flows from the core outlet to 4 horizontal Steam Drums (SDs) through 452 tail pipes. In the steam drum, steam gets separated from water by the action of gravity. Under normal operating conditions, steam flows to the turbine, which is returned to the steam drum as subcooled feed water at 130^{o} C. The feed water, after mixing with the separated saturated water in SD flows through 16 down comers to the inlet header and thus circulates around MHTS.

During normal shut down, the decay heat is rejected in the main condenser but during station blackout when the main condenser is not available the steam is diverted to Isolation Condenser (IC) for removing the decay heat passively. The ICs are heat exchangers immersed in a large pool of water called as Gravity Driven Water Pool (GDWP) having a volume of 6000 m^3. Each IC consists of two horizontal steam inlet headers and two horizontal outlet condensate headers of same size. Each inlet header is connected to corresponding outlet header through 90 vertical pipes, which serve as heat exchanger tubes. The condensate return line is connected to SD by two valves (one active and one passive).

During the postulated Loss of Coolant Accident (LOCA), Emergency Core Cooling System (ECCS) is provided to compensate the inventory loss and provide means to limit the fuel temperature rise. Figure 2 shows the schematic of ECCS circuit of AHWR. The ECCS accumulators and GDWP are connected to the MHT system by rupture discs, check valves and isolation valves kept in series. Following a postulated LOCA, when the MHT system pressure falls below 5 MPa, the rupture disc breaks allowing cold water from accumulators to flow into the core. Low pressure injection starts from GDWP having inventory of 6000 m^3 as the ECC Header pressure reaches below the GDWP head. The GDWP ensures low pressure injection, by passive means, for 3 days without any operator action. As GDWP is exhausted, water from the reactor cavity is pumped back into the core through heat exchangers for long term recirculation.

3. Integral Test Loop

Integral Test Loop is a 1:452 scaled down model of MHTS of AHWR [2]. It simulates a single channel of MHTS of AHWR along with various safety systems like ECCS injection system, Isolation Condensers for passive cooling during station back-out conditions and Gravity Driven Water Pool for long term cooling of reactor core in accidental conditions. MHT system consists of a down comer, an inlet header, a feeder, a 54-rod Fuel Channel Simulator (FCS), a tail pipe and a steam drum. The 4 operating ICs in AHWR have been simulated by a single IC in ITL, having 9 vertical heat exchanger tubes connected in parallel to IC inlet and outlet header. LOCA is simulated using a break simulation system which consists of a Quick Opening Valve (QOV), break simulating orifice (BSO) and a large tank to collect break flow (known as Break Flow Storage Tank (BFST)). The aim of the facility is to generate a database for validation of start-up procedure, performance validation of ECC and IC systems for postulated accidental scenarios. Figure 3 shows an isometric view of ITL.

3.1 Scaling Philosophy of ITL

Scaling philosophy of ITL is based on a 3-level approach [3]. The scaling philosophy gives due importance to Global or integral, local phenomena and boundary flow scaling. Global scaling is based on the power-to-volume scaling philosophy [3-7]. However, there are some important local phenomena that can affect the integral system performance, which needs to be scaled appropriately. Local phenomena considered in scaling are critical heat flux, parameters affecting the two-phase natural circulation instabilities like flashing, geysering, flow pattern transition, flow stratification and steam-water separation in steam drum. Boundary flow scaling simulates the appropriate boundary flow of mass and energy. It includes scaling of feed water flow, steam flow, accumulator injection, GDCS injection and critical flow during LOCA.

Overall scaling parameters are as below

- Pressure and Temperature Scaling: 1:1 (7 MPa and 285 ^{0}C)
- Power and Volume Scaling: 1:452
- Elevation Scaling: 1: 1 (only for MHT Loop)
- Maximum power to the test section: 3 MW

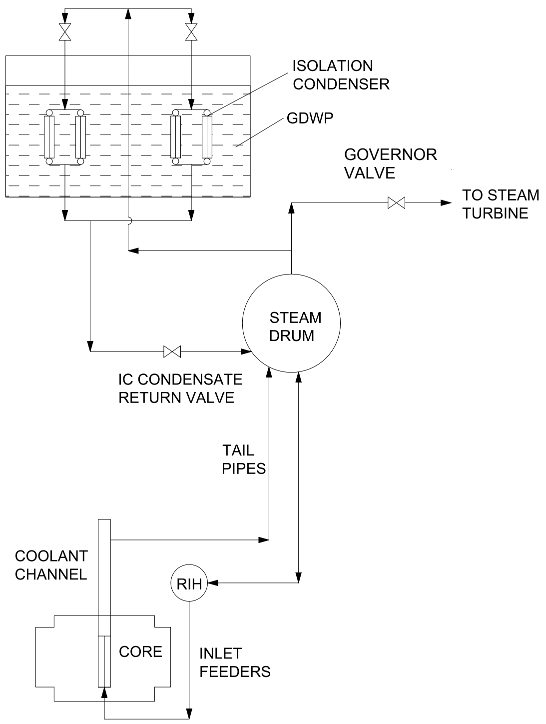

Figure 1 Schematic of AHWR

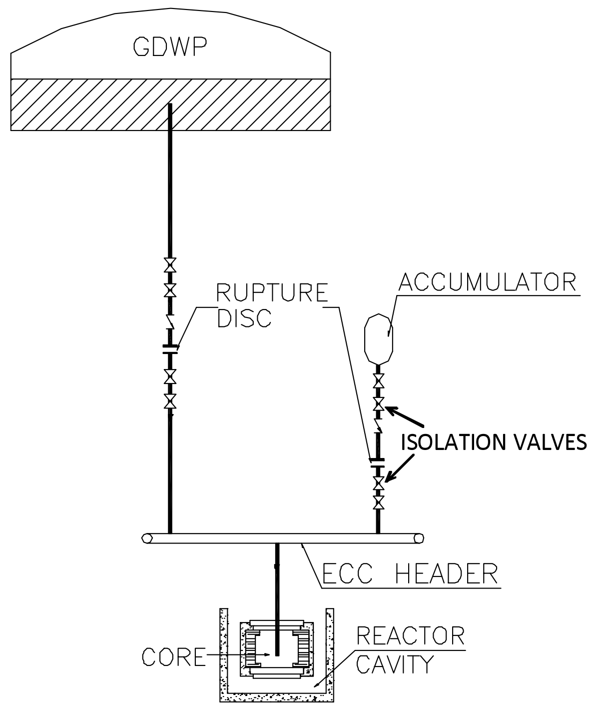

Figure 2 Schematic of ECCS circuit of AHWR

4. Experiments Conducted in ITL

Experiments have been conducted in ITL to validate the proposed start up procedure and performance validation of ICS. Besides, LOCA experiments were carried out in ITL for Inlet Header (IH) break sizes varying from 5% to 200%.

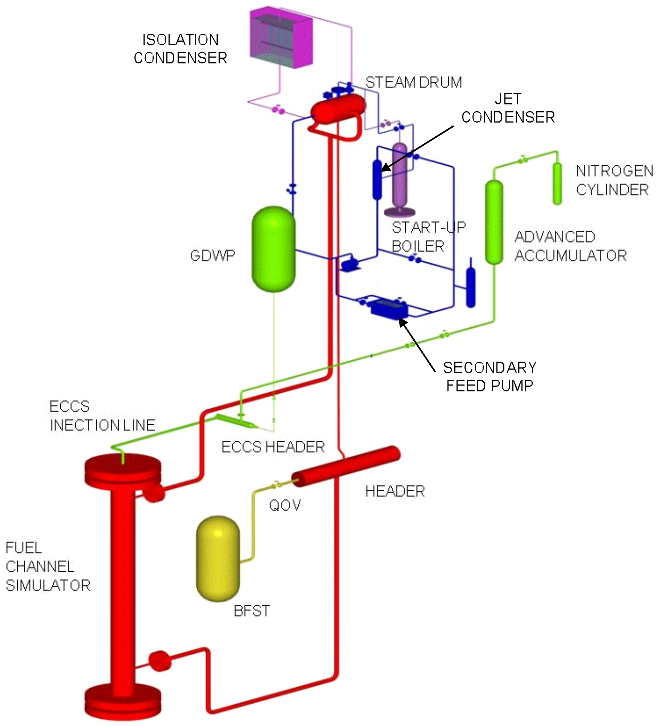

Figure 3 Integral Test Loop Simulating AHWR

4.1 Start-up procedure

The reactor has to be started up from low pressure (atmospheric) and ambient temperatures to its normal operating conditions (7 MPa and 285.9 ^{o}C). Experimental studies have revealed that two-phase natural circulation is more unstable at low pressures due to presence of flow instabilities like Geysering and Flashing that occur only at low pressures [8-12]. These instabilities are suppressed at higher pressures. Therefore low pressure instabilities, have to be considered while arriving at a rational start up procedure. Reactor start-up for AHWR consists of two stages as follows

I. System heat-up and pressurization up to 7 MPa and 285 ^{o}C, at reactor power < 4% of full power (FP).

II. Power rising further up to 100% FP at 7 MPa and 285 ^{o}C.

In the first stage, MHTS with atmospheric pressure and temperature is brought to working conditions of pressure and temperature by heating up and pressurizing. Power is kept at 2% FP to maintain the specified slow heating rate to avoid the thermal shock in structural components. At low powers the single phase natural circulation transports the heated fluid through all the MHTS components. Pressurization is carried out by admitting steam from start-up boiler. The pressurization is carried out in steps and in a fashion so that it does not violate the cold pressurization limits for the zircaloy based structural components in the MHTS. The pressurization steps also avoid boiling in system and single-phase natural circulation is maintained. Boiling is only allowed at 7 MPa pressure. External boiler is disconnected as soon as the boiling is initiated in MHTS. Once the MHT system is hot and pressurized (7 MPa, 285 ^{o}C) with two-phase natural circulation established, the reactor power is further raised up to 100 % FP in the second stage. The system pressure is maintained by removing steam separated in steam drum and feeding the same quantity of feed water into it. Two-phase natural circulation is maintained in MHTS by controlling the pressure and feed water temperature.

The start-up procedure described above requires an external boiler with pressure rating of 7 MPa. To reduce the capacity of boiler, boiling can be allowed at lower pressures without affecting the flow stability. Pressurization then can be carried out up to 7 MPa by boxing up the system (no removal of steam and no feed water injection). Reduction in boiler capacity is desirable considering the economics of the plant; therefore analytical as well as experimental investigations are necessary to establish a minimum pressure rating of external boiler without compromising on flow stability.

Start-up experiments were performed in ITL with self pressurization and with external pressurization. The pressure rating for available start-up boiler is 5 MPa, therefore start-up experiments with external pressurization up to 4.5 MPa were carried out. To determine the minimum pressure required to avoid the flow instability, external pressurization in steps with various pressure levels were carried out.

To study the low-pressure instabilities and effect of power on the start-up transient, experiments with self pressurization were carried out at power levels ranging from 52 kW to 175 kW.

4.1.1 Start-up with Self-Pressurization

To study the flow instabilities at low pressures during start up of ITL, experiments were carried out wherein MHTS was allowed to pressurize itself by boxing it up. The experiment starts with MHTS of ITL filled with demineralised water at ambient temperature and pressure with steam drum level as 400 mm which is above the height of baffle plates. This is necessary to ascertain that single phase natural circulation would prevail. Experiments were performed with power levels from 52 to 175 kW (~2-7% FP) to study the effect of power on flow oscillations during start-up. Figure 4 to Figure **7** show the experimental results.

The flow oscillations are observed at low pressures in two different patterns. The initial oscillations due to flashing are of large amplitude and have period of oscillation of 700 – 900 seconds. In the second pattern the oscillations are of constant amplitude and are relatively small in magnitude with oscillation period of the order of 120 – 130 seconds (see Figure 4). Interestingly, the measured void fraction at core outlet is practically zero till the end of flashing oscillations, indicating that the flashing is occurring in the unheated riser. This indicates that even with self pressurization power oscillations induced by void reactivity feedback can be avoided in AHWR.

It is seen that with higher FCS power the flow stability is achieved at low system pressures. With FCS power of 52 kW, flow is unstable up to 3.5 MPa while with FCS power of 150 kW flow is stable above 2.1 MPa. However, there is limit on power level during start-up as it is undesirable to heat the system components with rate more than 2 ^{o}C /minute from thermal stress point of view. It is seen that the limit on heat up rate is violated for short intervals with FCS power level 75 kW and above.

4.1.2 Start-up with external pressurization

During these experiments the system heat-up was carried out with constant power input (2% FP, i.e. 52 kW) and external pressurization using start-up boiler. The objective of the experiments was to establish the lowest pressure at which start-up specific instabilities disappear. The start-up tests were performed with external pressurization up to different test pressures (1, 1.5, 2, 3, 3.5, 4 and 4.5 MPa) and subsequent self-pressurization up to 7 MPa by boxing up the system. Figure 9 to 11 show the results of the tests.

During start-up experiments with external pressurization in ITL, the two-phase natural circulation was observed to be unstable up to 3.5 MPa system pressure. For external pressurization of 2 MPa and above the flashing induced oscillations are suppressed. All ITL Start-up transients with external pressurization of 3.5 MPa and above are observed to be stable in single-phase as well as two-phase natural circulation. Therefore, to arrive at a stable start-up (i.e. avoidance of Flashing and Type-I DWO) minimum 3.5 MPa external pressurization is required.

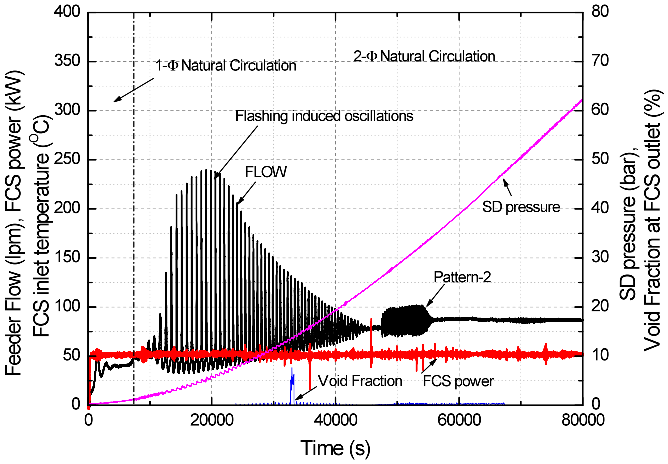

Figure 4 Self-pressurized Start-up at 52 KW

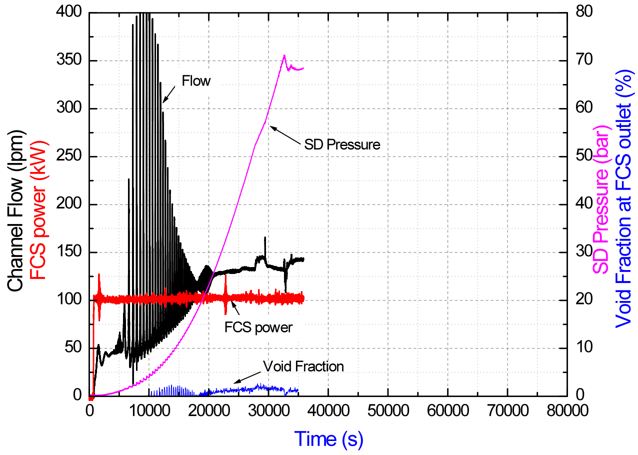

Figure 5 Self-pressurized Start-up at 100 kW

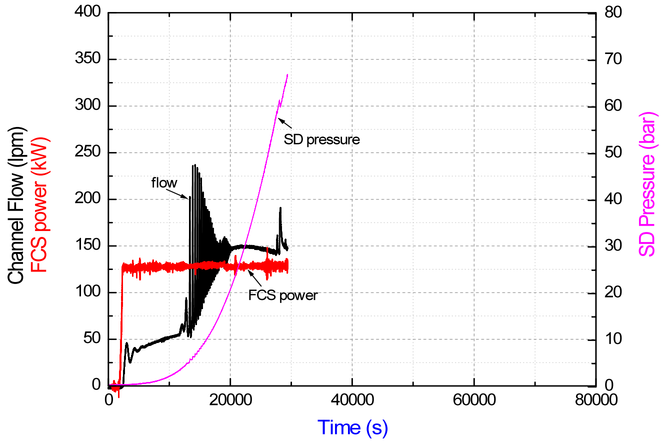

Figure 6 Self-pressurized Start-up at 125 kW

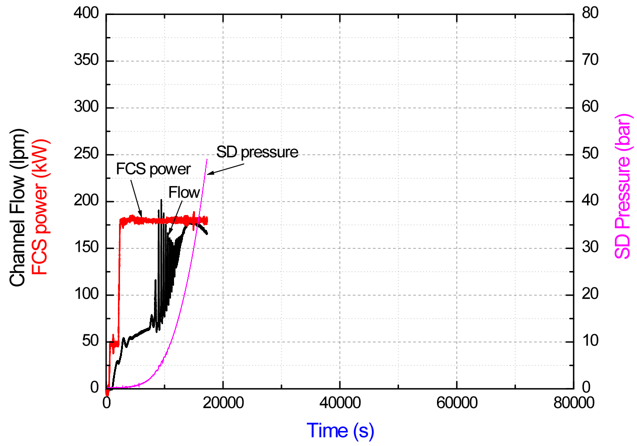

Figure 7 Self-pressurized Start-up at 175 kW

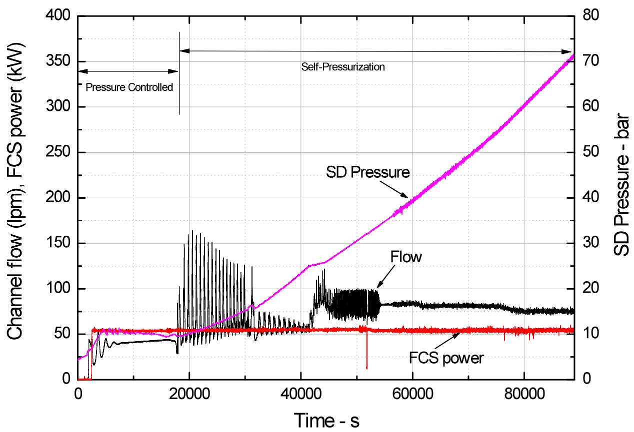

Figure 9 ITL start-up with external pressurization of 1 MPa and 52 kW

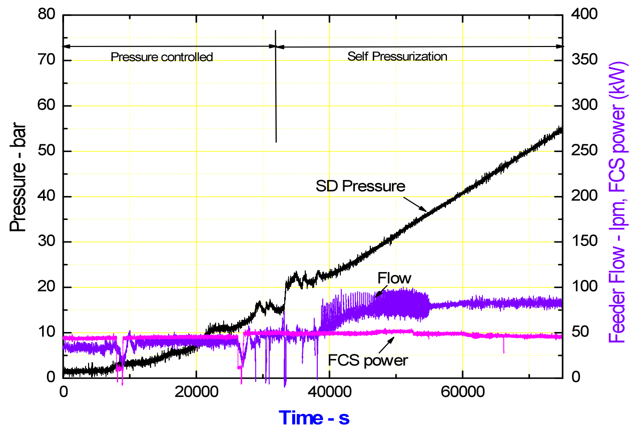

Figure 9 ITL start-up with external pressurization of 2 MPa and 52 kW

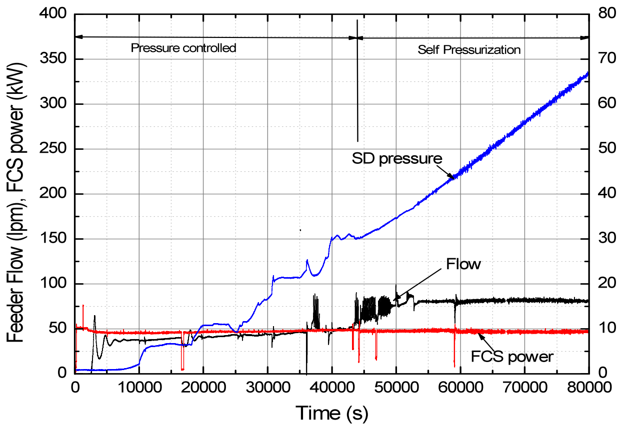

Figure 10 ITL start-up with external pressurization of 3 MPa and 52 kW

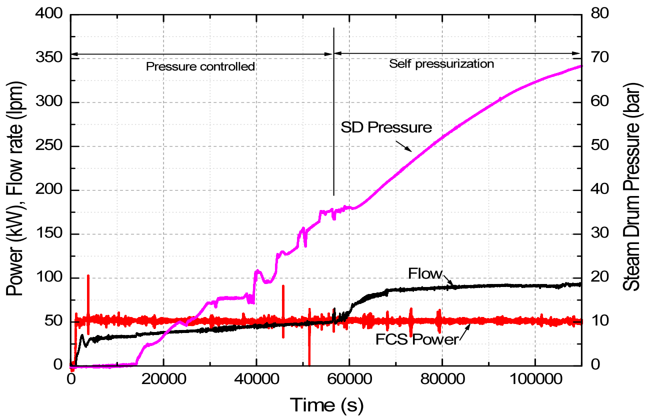

Figure 11 ITL start-up with external pressurization of 3.5 MPa and 52 kW

4.2 Performance Validation of ICS

In AHWR, the isolation condenser system is used to remove decay heat during station blackout. The ICs are designed to remove a maximum power of 6% FP. Station blackout scenario has been simulated in ITL. The experiments were conducted with FCS power of 156 kW which is equivalent to 6% of the maximum channel power of AHWR. This is sufficient for simulating the decay heat as the reactor power reaches 6% of its initial value within 25 s of reactor trip.

Due to local boiling on the pool side of IC, the IC-pool level decreases resulting in the exposure of IC tubes and the performance of IC degrades. The degradation in IC performance results in the increase in MHT/ SD pressure. The experiments were conducted at different FCS powers (e.g 3%., 4%, 5% and 6%) to obtain degradation as a function of MHT pressure and IC-pool level. The tests were conducted at two different initial levels of IC-pool e.g 1.75m and 0.83 m.

The scenario considered for experimentation is as follows

I. The ITL is operating at steady state at a given constant power (e.g 3%., 4%, 5% and 6%).
II. The steam outlet valve and feed water inlet valve are closed.
III. The bottled up system pressure starts increasing and as the SD pressure reaches 8 MPa the IC active valve opens fully.
IV. After IC active valve opens fully, the power is kept constant as in step (i).

Figure 12 and Figure 13 show the variation of Steam drum pressure and IC-pool temperatures at 75 kW (3% power) when IC starts operating at 8 MPa by opening of active valve. The initial IC-pool level is 1.75m. The MHT keeps depressurizing till pressure reaches 0.69 MPa and corresponding IC-pool level is 0.95 m and then pressure rises very slightly till the total duration of experimentation.

Height of IC pool is 1.9 m and level of IC top and bottom header is 1.01 m and 0.3 m respectively from the bottom of the IC-pool. Figure 13 indicates that though the thermocouples at top of the pool show a simultaneous increase in temperature but thermocouple towards the bottom of the pool shows a delayed increase in temperature indicating thermal stratification, but after some time (>10000 s) temperatures become almost same at all elevations. The temperature of the top thermocouples (1.6 m & 1.2 m) reduce suddenly after some time due to exposure of these thermocouples to air because of reduction of pool level.

At 128 kW (5% power), degradation in IC performance is observed at 2.15 MPa at 0.8 m IC-pool level for 1.75m initial pool level as shown in Figure 14. Similar degradation in IC performance is observed at 3.42 MPa at 0.87 m level for 154 kW (6% power, Figure 15). Tests were repeated with an initial IC pool level of 0.83m to obtain IC performance degradation curve as function of MHTS pressure and the corresponding IC pool level are shown in Figure 16 and Figure **17**. Degradation pressure is the minimum pressure observed during a particular experiment and degradation level is the IC pool level corresponding to the minimum pressure observed during the same experiment.

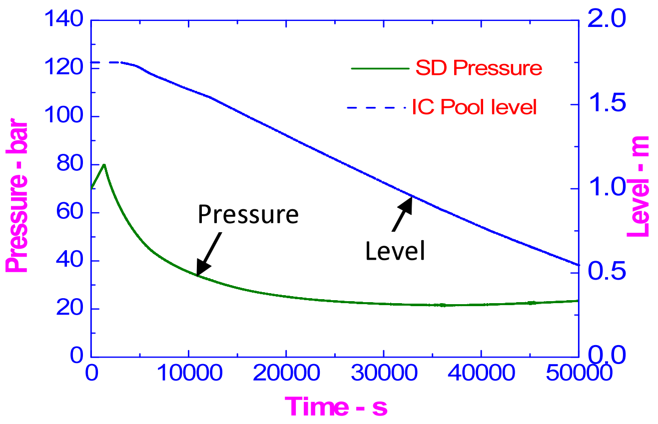

Figure 14 Variation of SD pressure and IC-pool level at 128 kW and 1.75 m initial pool level

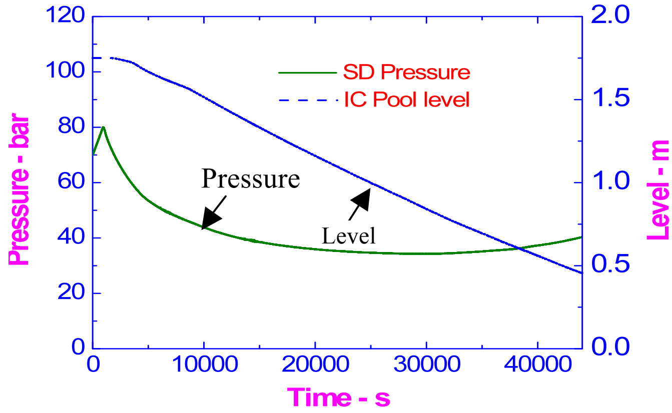

Figure 15 Variation of SD pressure and IC-pool level at 154 kW and 1.75 m initial pool level

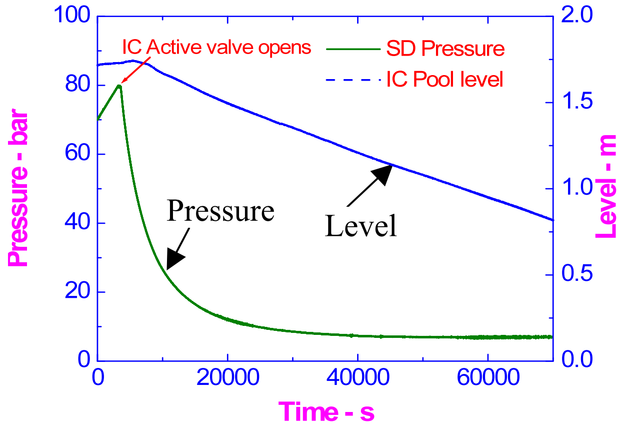

Figure 12 Variation of SD pressure and IC-pool level at 75 kW and 1.75 m initial pool level

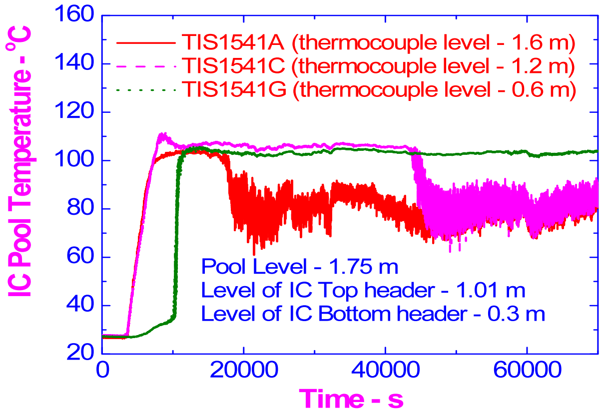

Figure 13 Variation of IC-pool temperatures at 75 kW and 1.75 m initial pool level

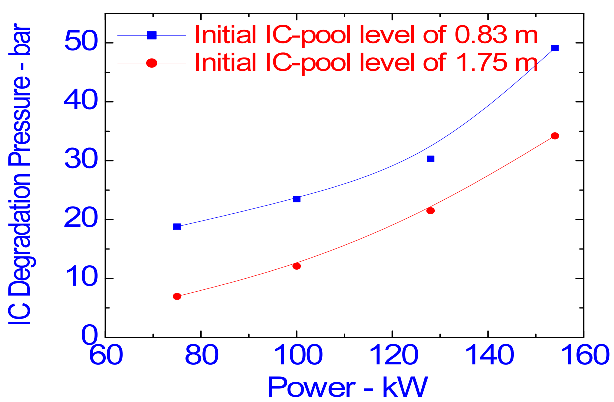

Figure 16 IC performance degradation as function of MHT pressure.

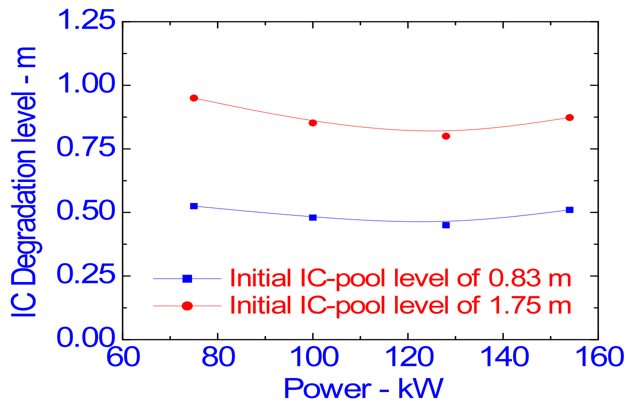

Figure 17 IC performance degradation as function of IC-pool level.

4.3 LOCA

LOCA tests for different inlet header break sizes (i.e. 5% - 200%) were carried out by changing the sizes of break simulating orifice before the QOV. The scenario considered for experimentation is as follows:

I. Achievement of steady state at 2 % FP (i.e. 52 kW of power in the FCS)
II. LOCA initiation by opening QOV by operator action.
III. Power trip at Steam Drum low pressure (i.e. 6 MPa) and feed & bleed valves are closed. As the decay power simulation was not carried out, the FCS power continues to remain at 2% of FP.
IV. When MHTS pressure reaches 5 MPa, the advanced accumulator is brought in to action by opening motorized isolation valve after the accumulator by operator action.
V. When MHTS pressure reaches 0.3 MPa, the GDWP tank is brought in to action by opening motorized isolation valve after the tank on operator action.

Experimental data for 100% inlet header (IH) break is shown in Figure 19 and Figure **20**. The LOCA initiation is reflected by reduction in MHT pressure and when the MHT pressure reaches 5 MPa accumulator (kept at initial N_2 pressure of 5.5 MPa & 2.9 m) starts injecting in to the FRCS. The blow down time is 460 s for MHTS pressure to reach 0.15 MPa. As soon as the Accumulator level becomes low and the accumulator is isolated by isolation valve, GDWP starts injecting in to the MHTS.

Small IH break LOCA (i.e. 5%) is shown in Figure 22 and 21. For 9.6% break accumulator exhausts in 1650 s and corresponding MHT pressure is 0.6 MPa. The MHT pressure reduces to 0.4 MPa at 2950s, but again starts increasing reaches 0.45 MPa at 3100s. Hence Low pressure injection never comes in to operation. The FRCS power was switched off when the FRCS outlet fluid temperature increases beyond 100°C (FRCS outlet fluid temperature reached 60°C at the end of accumulator injection).

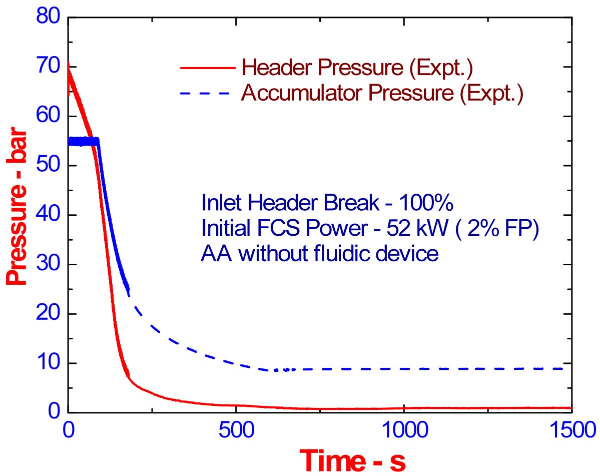

Figure 19 Variation of Header and Accumulator pressure following 100% Inlet Header break

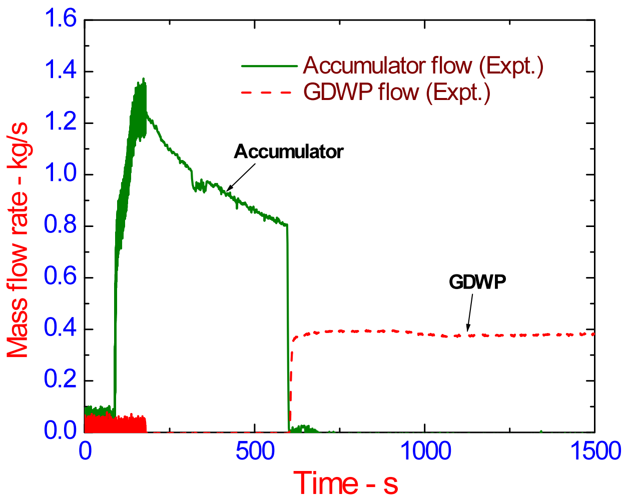

Figure 20 Variation of Accumulator & GDWP flow rate following 100% Inlet Header break

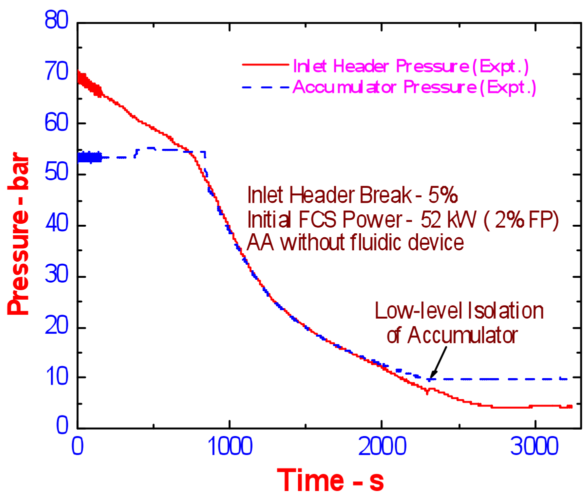

Figure 22 Variation of Header and Accumulator pressure following 5% Inlet Header break in ITL

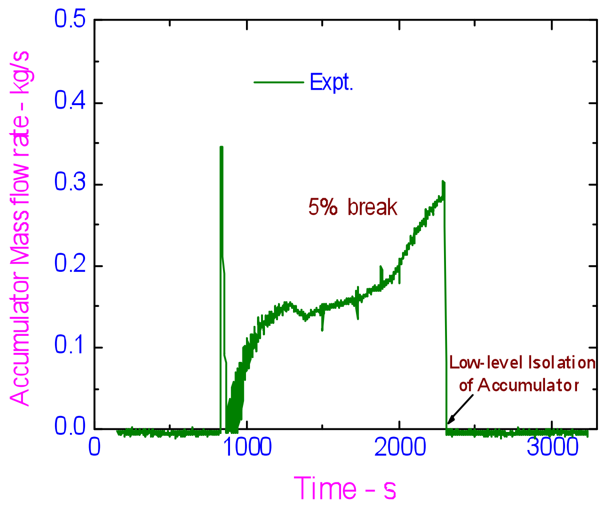

Figure 23 Variation of Accumulator & GDWP flow rate following 5% Inlet Header break in ITL

5. Simulation with RELAP5/M3.2

RELAP5/M3.2 is one of the best estimate codes to simulate the thermal-hydraulics of nuclear reactors. The computer code adopts finite volume fluid cells to describe the hydrodynamics of the system. Two-fluid model is utilized to describe the transfer phenomenon of mass, momentum and energy. Six differential equations pertaining to mass, momentum and energy conservation for the two phases, i.e. water and vapor are solved for each fluid cell. The governing equations are solved in time domain utilizing partial implicit scheme. Constitutive models are used to model phenomena like inter-phase mass, momentum and energy transfer, momentum and energy transfer with walls, counter-current flow, choked flow, etc. [13].

RELAP5/M3.2 has been utilized to simulate the experimental transients in ITL. The various components of ITL are descritized in finite volume fluid cells and are connected to each other via junctions. Figure 24 shows the RELAP5/M3.2 nodalisation of the ITL. Boundary conditions of pressure, temperature and heat exchange is simulated using time dependent volume (infinite source and sink with pre-defined state of fluid that can be varied with time), time-dependent junctions (junctions with pre-defined flow conditions) and heat structures (simulates the heater, insulation etc. and appropriate heat exchange between fluid walls to fluid or to sink). The steam and feed water system is simulated using time-dependent volumes with pre-defined conditions. The removal of steam is simulated with valve acting on defined trip signals. The feed water injection is controlled using a time-dependent junction that injects an equal amount of water to the amount of steam withdrawn. The steam pipe to IC, IC inlet headers, IC heat exchanger tubes, IC outlet headers and condensate pipe from IC to steam drum have been simulated as multi volume pipes. IC-pool is simulated by a multi volume pipe filled with water. It is connected at top to a large volume filled with saturated air which takes care of expansion of water. The ECCS system is modeled using accumulator component available in RELAP5/M3.2. The GDWP is simulated using ECCS-S tank component. The heat addition at FCS is simulated with a heat structure describing the geometry of flow through the heated rod bundle and appropriate bundle heat transfer area. Heat loss from the piping is also considered by modeling heat structures at tail pipe, downcomer, feeder and FCS with geometry and thermal properties of insulation provided. The loss coefficients are modeled at the bends in loop and at the spacers in FCS. The loss coefficients at locations of flow area change are calculated by the code.

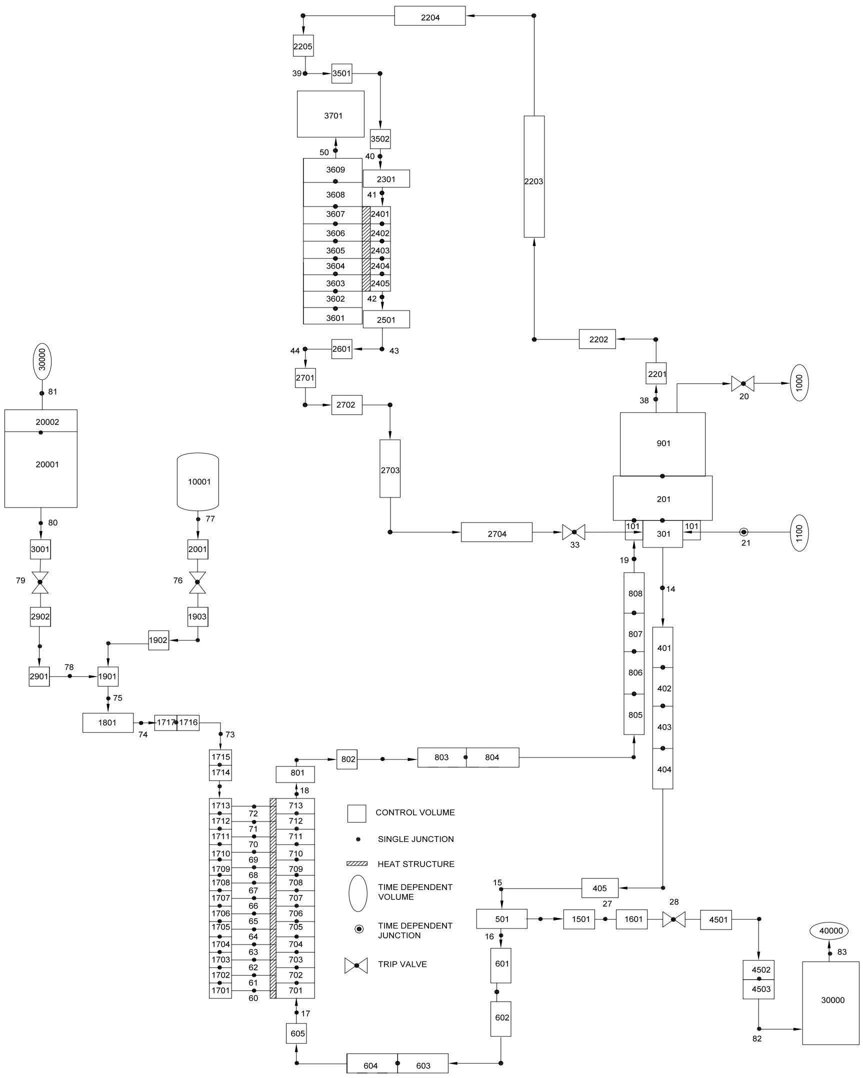

Figure 24 RELAP5/M3.2 Nodalisation for ITL

5.1 Simulation of Start-up experiments

RELAP5/M3.2 simulations of experimental transients predicted the different stages of start-up and flow stability well in agreement with the experimental observations in qualitative manner (Figure 25 to Figure 28). The RELAP5/M3.2 code prediction shows the absence of Type-I DWO at pressures of 3 MPa and above while in the experiments it was seen that Type-I DWO is absent above 3.5 MPa pressure.

5.2 Simulation of IC performance tests

RELAP5/MOD3.2 computer code has been found to adequately simulate the performance of isolation condenser in ITL. Typical results for 75 kW (3% of maximum rated channel of AHWR) are shown in Figure 29 and Figure **30** for 1.75 m initial IC-pool level. Figure 28 shows that thermal stratification indicated by delay in temperature rise at lower elevation of pool during experimentation could not be adequately simulated by RELAP5/MOD3.2 due to the one dimensional nature of the code whereas natural convection in a stagnant pool is a three dimensional phenomenon.

5.3 Simulation of LOCA experiments

RELAP5/MOD3.2 computer code has been found to adequately simulate the LOCA experiments in ITL. Typical simulation results for large break LOCA (100%) are shown in Figure 32 and Figure **33**. There is no increase in clad temperature during the simulated transient for 100% break as shown in Figure 35. Hence large break LOCA can be easily mitigated by ECC system.

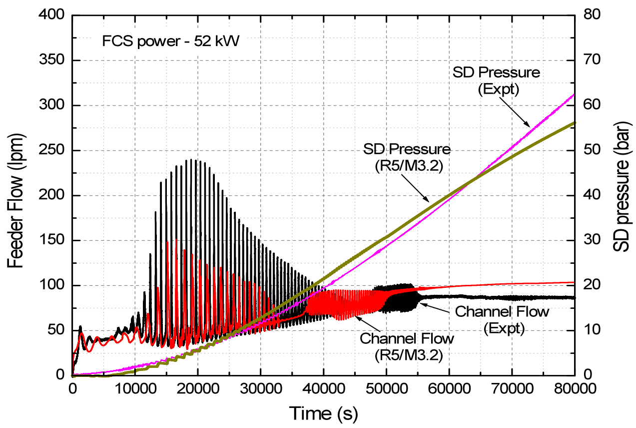

Figure 25 RELAP5/M3.2 prediction of start-up with self-pressurization at 150 kW.

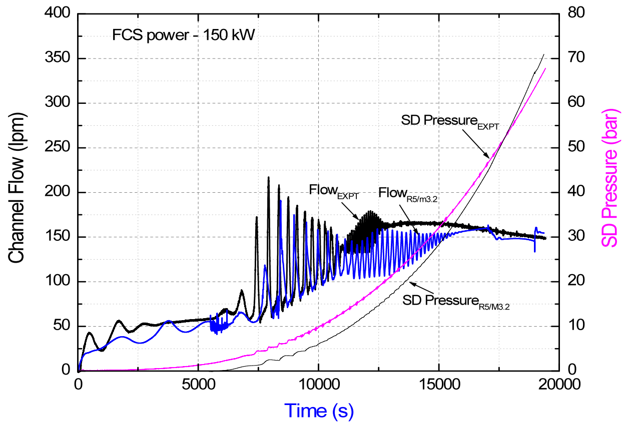

Figure 24 RELAP5/M3.2 prediction of start-up with self-pressurization at 150 kW.

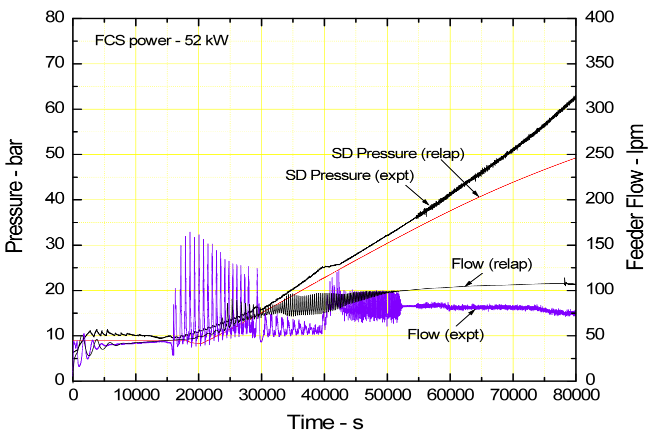

Figure 25 RELAP5/M3.2 prediction of start-up with external pressurization of 1 MPa at 52 kW.

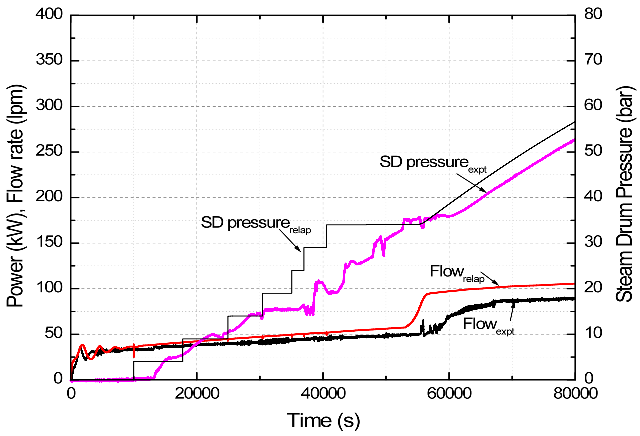

Figure 28 RELAP5/M3.2 prediction of start-up with external pressurization of 1 MPa at 52 kW.

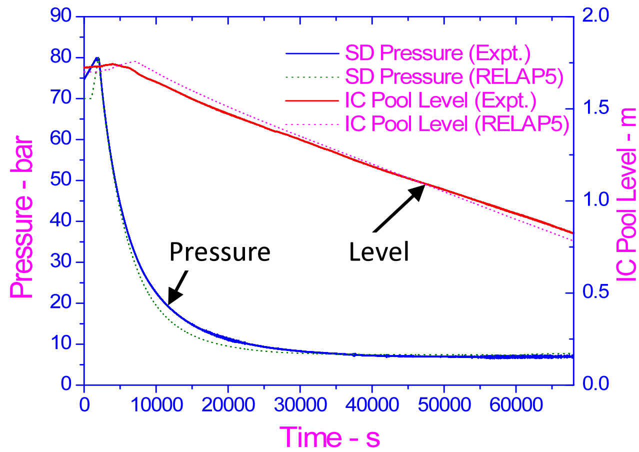

Figure 29 Simulation of IC performance at 75 kW and 1.75 m initial pool level

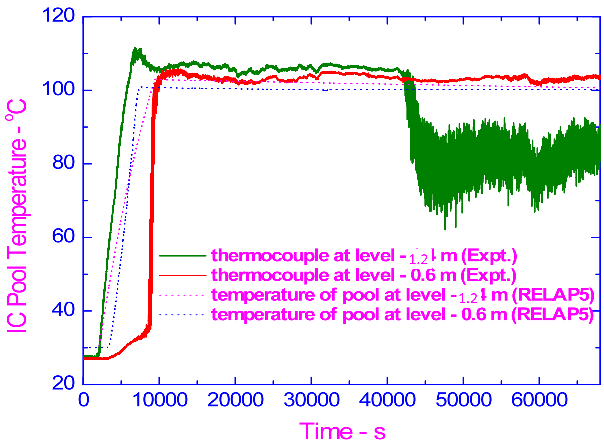

Figure 30 Simulation of IC pool temperatures at 75 kW and 1.75 m initial pool level

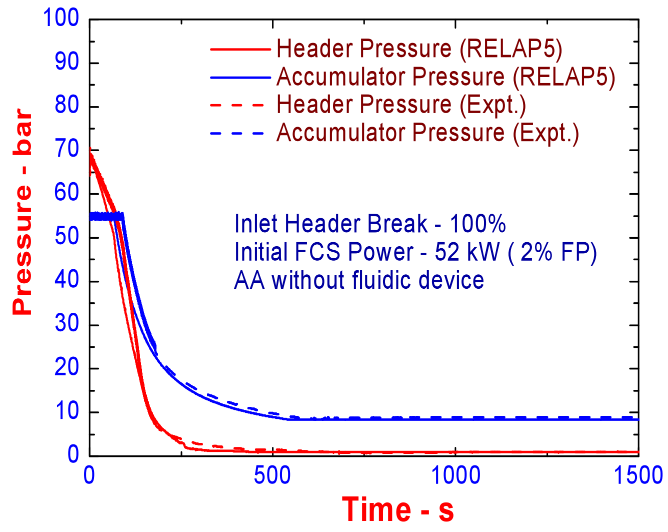

Figure 32 Variation of Header and Accumulator pressure following 100% Inlet Header break in ITL

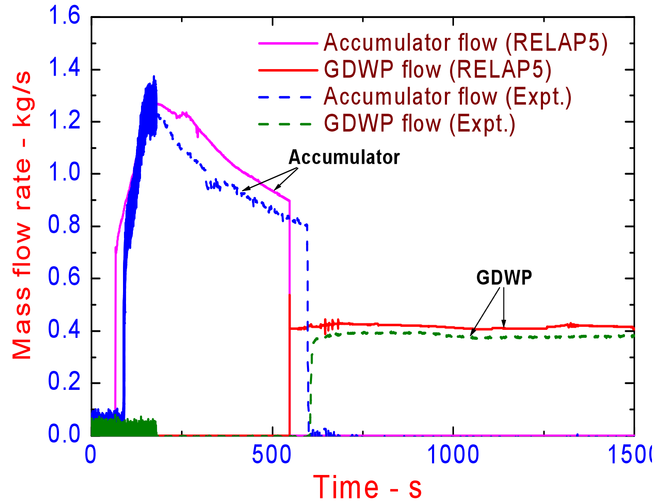

Figure 33 Variation of Accumulator & GDWP flow rate following 100% Inlet Header break in ITL

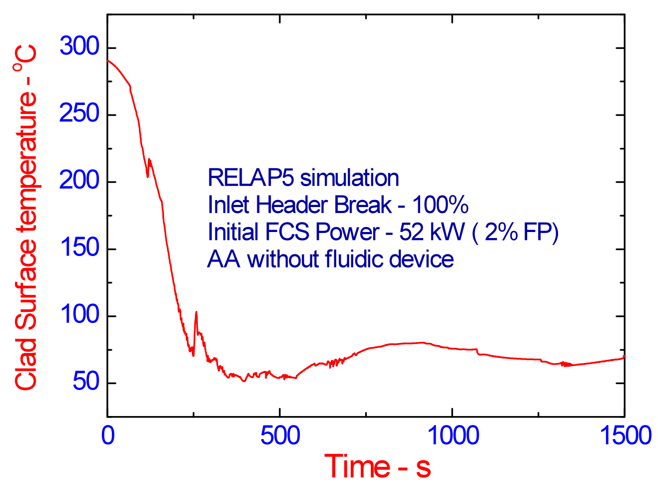

Figure 35 Variation of Clad temperature following 100% Inlet Header break in ITL

6. Conclusion

Start-up experiments were carried out in ITL to demonstrate the pressurized start-up concept as proposed for AHWR.

Experiments with self pressurization revealed the presence of Type-I DWO including flashing instability at low pressures. The flashing is dominant at pressures below 2 MPa which is followed by Type-I DWO up to 3.5 MPa pressure. The boiling inception occurs inside the FCS in the later stage of flashing.

With increasing FCS power the threshold of instability is decreased in terms of system pressure. The oscillation amplitude and duration also decreases with power. However, at powers higher than 75 kW the limit on heat up rate is violated.

The experiments with external pressurization revealed that minimum 3.5 MPa external pressurization is required to suppress the Type-I instability. The system can be further pressurized by self pressurization which is observed to be stable in all these experiments. The proposed AHWR start-up procedure envisages boiling only at 7 MPa. The present work demonstrated that the proposed AHWR start-up procedure is highly stable.

RELAP5/M3.2 simulations of experimental transients predicted the different stages of start-up well in agreement with the experimental observations.

Isolation Condenser design is found to be adequate to remove the designed heat rate of 6% FP. Although thermal stratification is observed, it does not significantly degrade the heat transfer to pool if IC tubes are submerged. Experimental results show that thermal stratification in IC-pool is present only during initial period of the transient and will not significantly affect the overall performance of IC.

RELAP5/MOD3.2 adequately simulates the performance of Isolation condenser and its effect on MHTS behavior, but due to one dimensional nature of the code the thermal stratification in the pool could not be adequately simulated.

LOCA experiments were carried out in ITL at Inlet Header break sizes varying from 5% to 200%. For large IH breaks (e.g. 21% - 200%), the ECCS injection by Advanced Accumulator (AA) followed by GDWP has been found to be adequate. For small IH breaks (e.g. 9.6% & 5%), after the AA had exhausted there was a large time lag for GDWP to come as MHT was not depressurizing to 0.3MPa. RELAP5/M3.2 was found to be adequately simulating the experimental transient.

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