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Improvement in Post Test Accident Analysis Results Prediction for the Test no. 2. in PSB Test Facility by Applying UMAE Methodology

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ABSTRACT

This paper mainly deals with the improvement in the post test accident analysis results prediction for the test no. 2, "Total loss of feed water with failure of HPIS pumps and operator actions on primary and secondary circuit depressurization", carried-out on PSB integral test facility in May 2005. This is one the most complicated test conducted in PSB test facility. The prime objective of this test is to provide support for the verification of the accident management strategies for NPPs and also to verify the correctness of some safety systems operating only during accident. The objective of this analysis is to assess the capability to reproduce the phenomena occurring during the selected tests and to quantify the accuracy of the code calculation qualitatively and quantitatively for the best estimate code Relap5/mod3.3 by systematically applying all the procedures lead by Uncertainty Methodology based on Accuracy Extrapolation (UMAE), developed at University of Pisa. In order to achieve these objectives test facility nodalisation qualification for both 'steady state level' and 'on transient level' are demonstrated. For the 'steady state level' qualification compliance to acceptance criteria established in UMAE has been checked for geometrical details and thermal hydraulic parameters. The following steps have been performed for evaluation of qualitative qualification of 'on transient level': visual comparisons between experimental and calculated relevant parameters time trends; list of comparison between experimental and code calculation resulting time sequence of significant events; identification/verification of CSNI phenomena validation matrix; use of the Phenomenological Windows (PhW), identification of Key Phenomena and Relevant Thermal-hydraulic Aspects (RTA). A successful application of the qualitative process constitutes a prerequisite to the application of the quantitative analysis. For quantitative accuracy of code prediction Fast Fourier Transform Based Method (FFTBM) has been used. It is concluded that most of the phenomena occurred in experiment are reproduced by code calculation and overall qualitative and quantitative accuracy of code prediction are acceptable as per UMAE.

Keywords: Accident Management, CIAU, FFTBM, PSB, Relap5, RTA, UMAE

1 Introduction

This paper mainly deals with the improvement in the post test accident analysis results prediction for the test no. 2, "Total loss of feed water with failure of HPIS pumps and operator actions on primary and secondary circuit depressurization", carried-out on PSB integral test facility in May 2005. The objective of this analysis is to assess the capability to reproduce the phenomena occurring during the selected tests and to quantify the accuracy of the code calculation qualitatively and quantitatively for the best estimate code RELAP5/mod 3.3 by systematically applying all the procedures lead by Uncertainty Methodology based on

Accuracy Extrapolation (UMAE), developed at University of Pisa. [1]. This is one the most complicated test conducted in PSB test facility. The prime objective of this test is to

- Provide support for the verification of the accident management strategies for NPPs and to verify the correctness of some safety systems operating only during accident
- Obtaining experimental data for validation of thermal-hydraulic system codes which are used for VVER NPP safety analyses
- Identification and/or verification of CSNI phenomena validation matrix applicable to this test [2]

The PSB-VVER is a full height integral test facility; power and volume are scaled 1:300. The primary and the secondary circuits of the ITF are designed in order to operate at nominal pressure of the VVER-1000 reactor. The facility has four loops (each one is constituted by a hot leg, a steam generator, a loop seal a main circulation pump and a cold leg), a Pressurizer (PRZ), connected via the surge line to the hot leg of loop 4 or 2, the ECCS includes active high and low pressure injection systems, four SIT, that are provided by four hydro-accumulators. The internals of the VVER vessel are represented in the facility by separate pipes: one for the downcomer, one for the core model and upper plenum, and one for the core bypass. The core model contains 168 fuel rods simulators with a uniform power profile and a central unheated rod. Up to now the experiments have been performed with the assembly power set to 1.5 MW (15 % of VVER 1000 nominal scaled power). The primary side of the steam generator consists of a hot and a cold collector and of 34 tubes coiled in 10 complete turns with 51 mm difference from inlet and outlet height. The length of one tube is the same like the one of the reference plant. Separators are completely absent. All the four SG are connected to a common steam header via a "small power" steam line. Finally the steam from the SG is discharged into a condenser. A atmospheric discharge valve BRU-A is connected to all the four steam line for secondary side cooling. Details about test facility description can be found in [3]. Test specifications and resulting time sequence of significant events for both code prediction and during the test are presented in table 1.3. The test 2 specifications and scenario can be found in detail in [4]

Once post test analysis was previously performed for this test (notation- old) [5]. But in old analysis UMAE were not followed systematically. Old analysis results showed that still some improvement is required. Therefore, improvement is done in this analysis (notation-new) by systematically applying all the procedures lead by UMAE after incorporating some changes in input deck for some of the boundary conditions based on observations made in old analysis, listed table 1.2 and as per test specification. Both the results are provided in this paper. A brief description for the code used and modeling aspects of nodalization are reported in sec.2.0. 'Steady sate level' and 'on transient level' qualifications are demonstrated in sec 3.0. Discussions on the results prediction are presented in sec. 4.0 followed by conclusions summarized in sec.5.0.

2 Modeling of Experiments Using RELAP5/mod3.3

The light water reactor transient analysis code, Relap5/mod 3.3 has been used for this analysis. This code has been developed for the best estimate simulation of light water reactor coolant system transients during postulated accidents. Relap5/Mod 3.3 version is highly generic and suitable for the analysis of all transient and postulated accidents in LWR system, including small and large break Loss of Coolant Accidents (LOCA). This code is based on one-dimensional, transient, non-homogeneous and non-equilibrium hydrodynamic model for the steam and liquid phases, code uses a set of six partial derivative balance equations and can treat a non-condensable component in the steam phase and a non-volatile component (boron) in the liquid phase. A partially implicit numeric scheme is used to solve the equations inside control volumes connected by junctions.

The Relap5 input deck adopted for simulating the PSB-VVER facility behavior is a detailed nodalization carried out with a “sliced” approach. This nodalization scheme is suitable for a better code response, especially in natural circulation and/or during low flow rate regimes. All the components of the test facility have been modeled in the nodalization. It is not possible to describe all the details [6] of modeling aspects of nodalsation in this paper. This analysis has been carried out after putting appropriate initial and boundary conditions as per test specification in the reference input deck developed at University of Pisa

3 ‘Steady State Level’ and ‘On Transient Level’ Qualification of Nodalisation

The UMAE (Uncertainty Methodology based on Accuracy Extrapolation) is developed at University of Pisa to derive the uncertainty related to the code application. As per UMAE a nodalization representing an actual system (Integral Test Facility or NPP) can be considered qualified when it is qualified for both ‘Steady State Level’ and ‘On Transient Level’ Qualifications.

‘Steady State Level’ Qualification: The nodalization is qualified against data available from nominal stationary conditions measured in the simulated system. To this aim: (a) Relevant geometrical parameters of the facility (e.g. volume, heat transfer area, elevations, etc.) are compared (table 1.1) with the input deck data and the differences among them must be acceptably small, of course the uncertainties related to each parameter must be taken into account. Two curves: the volume versus height for the primary and the secondary side must

Table 1.1 Acceptance criteria for nodalization qualification at steady state level

Parameter	Exp.	New	Old	EEB	Error Old %	Error New %	AE %
Primary circuit volume, m^3	2.1245	2.1772	2.1524	--	--	--	1
Secondary circuit volume, m^3	2.9582	2.0217	2.0217	--	--	--	2
Fuel rod heat transfer surface area	16.95	16.95	16.95	--	--	--	0.1
SG tube heat transfer surface area, m^2	18.22	18.22	18.22	--	--	--	2.1
Core power, kw	1511	1519	1519	± 15	0.0	0.0	2.0
Power on core bypass, kw	15.1	15.1	14.4	± .4	2.04	0.0	2.0
PRZ power , kW	10.2	10.2	11.0	± .5	2.8	0.0	2.0
Heat transferred PS to SS, kw	--	1435.9	1411.6	--	--	--	2
Heat transferred to turbine from SS, kw	--	1365.0	1337.4	--	--	--	2
Upper plenum pressure, MPa	15.76	15.764	15.577	± .1	0.52	0.0	0.1
SG 1 pressure, MPa	6.27	6.288	6.291	± .05	0.0	0.0	0.1
Core inlet temp., K	550.1	550.1	549.4	± 3	0.0	0.0	0.5
Core outlet temp. K	581.1	583.2	582.3	± 3	0.0	0.0	0.5
SG feed water temp. K	493.1	493.1	473.1	± 3	3.4	0.0	0.5
Clad temp. at 1906 mm from bottom of core	584.1	579.0	574.9	± 3	6.2	2.1	10 K
Loop 1 pump velocity, rpm	319	319	308.84	± 1	2.8	0.0	1
Total primary heat losses, kw	--	109	133	--	--	--	10
Total Secondary heat losses, kw	--	70.2	73.5	--	--	--	10
Local pressure drop	Fig 1.1	Fig 1.1	Fig 1.1	--	--	--	10
Mass inventory in primary circuit, kg Excluding HP Accumulator and LPIS and related piping	890	911	898	± 40	0.0	0.0	5
Loop 1 flow rate , kg/s	2.2	2.25	2.18	± .1	0.0	0.0	2
PRZ level, m	8.62	8.55	8.36	± .3	0.0	0.02	0.05 m
Secondary side or down comer level, m	2.3	2.17	2.26	± .05	.04	0..0	0.1m

Note: -- details are not available for exp. unless Exp Error Band (EEB) is not available Acceptable Error (AE) can not be can not be calculated. Some of the acceptable errors are judged in Kelvin or meter not by % error be generated for both exp. and input deck, this has been done in [6] for the PSB test facility. (b) All the significant thermal-hydraulic parameters necessary to identify the facility/plant status are being selected from exp. and steady state achieved by code and these should be compared. Some of the important relevant parameters are presented in table 1.1 to evaluate the 'steady state level' qualification; detailed report is available in [8]. Error should be calculated as per instruction stated in [7]. Normalized primary pressure distribution versus loop length curves are obtained for experimental and code calculations, and compared in fig 1.1.

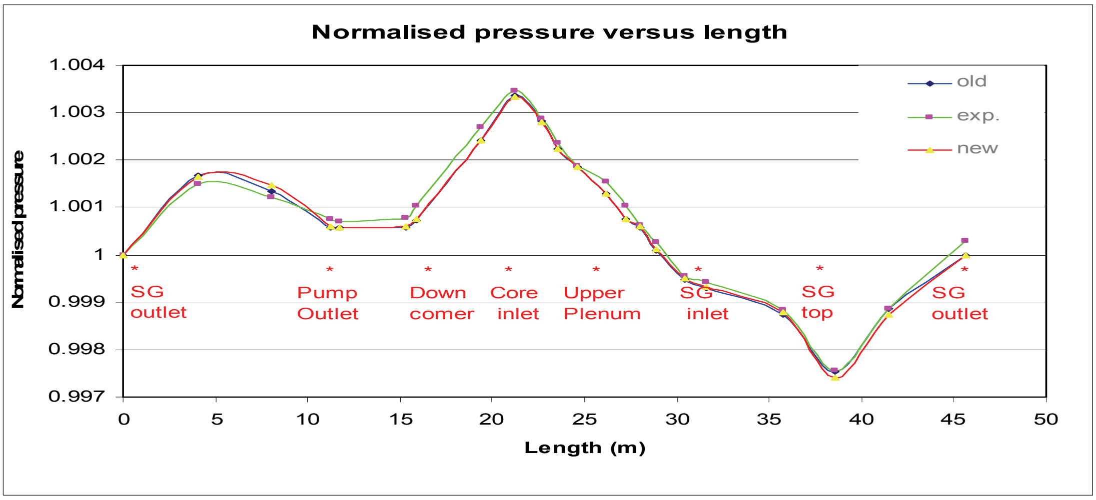

Fig. 1.1 Normalized primary pressure vs length for primary system including loop1

Table 1.2 List of changes made in input for the new analysis

Sr. No.	**Changes made for new analysis with respect to old analysis as per test specifications**
1	SG feed water temp. is changed to 219 ^{o}C from 200 ^{o}C as per test specification.
2	SG external feed water temp. is changed to 30 ^{o}C from 20 ^{o}C as per test specification.
3	Heat loss coefficient for all primary piping have been changed to 4.15 from 5.15 W/m^2/K.
4	Pump heat loss 15 kw for (-500 to 250 s), 20.7 kw (250 to 4500 s), 25 kw for (4500 to 13500 s), 17 kw for (13500 to 23000 s). In the old analysis it was 15 kw for (-500 s to 0) and 18 kw for all the transients. It is tried that overall heat loss should be decreased in new analysis with respect to old analysis for the period (-500 s to 4500s) and increased from 4500 s to 13000 s then decrease from 13000 s to end of the transient by combining item 3 and 4 above. (discussed in item a, b, c, and d in sec 4.0)
5	PRZ heater power has been changed 10.2 kw for (-500 to 0 s), 12 kw for (0 to 8900 s), 16 kw for (8900 s to 11000 s). In the old analysis it was constant 12 kw for (-500 to 10000 s).
6	By pass heater power changed to 15.1 kw from 14.4 kw as per test specification.
7	External feed water injection rate changed to 55 g/s from 66 g/s to each SG 1 and 4, (item-d, sec. 4).
8	Area of 'ECCS piping and valve' changed to 6.15e-4 m^2, 4.19 e-4 m^2 as per geometrical details.
9	PRZ volume changed to 259.58e-3 m^3 from 236.98e-3 m^3 geometrical details.
10	LPIS modelling included in input deck as it was not modelled in old analysis.

'On Transient level' Qualification: This includes both qualitative and quantitative for 'on transient level' qualification. The following steps have been performed for qualitative evaluation:

(a) List of comparison between experimental and code calculation resulting time sequence of significant events are demonstrated in table 1.3.

(b) Identification/verification of CSNI phenomena validation matrix applicable to this test: In this experiment a number of thermal hydraulic phenomena are observed for code assessment.

These are also well predicted by results prediction of code (table 1.4.). PSB VVER test 2 capability to reproduce phenomena and code capability to predict phenomena are evaluated on basis of following grading, S-suitable for code assessment, R- restricted suitable for the code assessment, S-well predicted by code, R- partially predicted by code.

Table 1.3 List of comparison between experimental and code calculation resulting time sequence of significant events

Exp. (s)	**New (s)**	**Old (s)**	**Event**	**Remarks**
0.0	0.0	0.0	Signals to initiate the accident	To stop the steam dumping from SG and to stop the feed water supply
10.8	10.8	10.8	Feed water supply stop in all SG	Value given for SG 2 (for example)
16.1	16.0	16.0	Full Closing of Turbine Stop Valve (TSV)	As pre Initiating Event (IE)
71	54.9	54.0 s	BRU-A opening (first)	Reaching set point limit 7.16 MPa
71 237	109 209	-- --	The first operation of PRZ spray The second operation of PRZ spray	Opening pressure 16.08 MPa, closing pressure 15.98 MPa
255.7	217.1	273.2	Start of MCP coast-down	Level decrease in SG-2 by 0.5 m
261.7	217.3	273.3	SCRAM	More than two MCP trip
4645 8689	4724 8489	4149 7064	PRZ safety valve first opening Last closing	Opening set pressure 18.14 MPa Closing set pressure 16.67 MPa
8992	8479	7134.8	To start Accident Management (first)	Core outlet temp. reaches 350 ^{o}C
8969	8495	7150	Closure of MSIV in SG 2 and 3	As per AM, delay of 16 s
8977	8495	7150	Opening of BRU-A in SG 1 and 4	As per AM, delay of 16 s
9219	8574	7234	Water supply into SG 1and 4	When pressure reduces to 1 MPa
11054	10834	8964	Switching off PRZ heater	Minimum PRZ level 4.2 m
12007	12064	--	PRZ PORV opening	Second time operator action *
16535	15071	12842	HPA injection starts	Set point of HPA 5.9 MPa
20400	21328	--	The second time PRZ full of water	Due to PORV opening
21412	21519	--	Start of LPIS operation	Primary pressure less than 2.43 MPa
23240	22200	15919	Stop of experiment	

* opening- When difference between saturation temperature in hot leg and (Ts) and the maximal temperature in hot pipelines (T_{HL}) more than 30 ^{o}C and coolant temp is less than 300 ^{o}C and closing- when margin less than 15 ^{o}C (For new analysis set point is fixed to 27 ^{o}C to see the effect considering measurement error), -- not detected

(c) Each test scenario (measured and calculated) is divided in 9 Phenomenological Windows (i.e., time spans in which a unique relevant physical process mainly occurs and a limited set of parameters control the scenario. These PhWs can also be seen in line with fig. 1.2 to 1.5

(d) Key Phenomena and Relevant Thermal-hydraulic Aspects (RTA). In each PhW, key phenomena and RTA must be identified. RTAs are defined for a single transient and characterized by numerical values of significant parameters: Single value parameters (SVP), Non-dimensional parameters (NDP), Time sequence of events (TSE), Integral parameters (IPA) etc. The qualitative analysis is based on five subjective judgment marks (E, R, M, U, -) the list of RTAs. E means excellent and a good agreement exists between code and experimental results; R is for reasonable and means that the phenomenon is reproduced by the code, but some minor discrepancies exist; M is for minimal and means that a relevant discrepancy is present between the code results and the experiment, but reason for the difference is identified and it is not caused by a nodalization deficiency; U is for unqualified and means that a relevant discrepancy exists but reasons for the difference are intrinsic to the code and nodalization capability are not known. – means not applicable to selected test. Even if one U result is present during the qualitative evaluation process then nodalization is not said to be qualified and sensitivity analysis is recommended by suitably modifying the nodalization till route cause is not get detected and rectified. It is not possible to provide all the details of RTA which about 40 parameters [8] in this paper. Some important parameters are given for example in the table 1.6.

Table 1.4 CSNI phenomena validation matrix for code assessment

Sr. No.	Name of phenomena	Exp.	Code	Identification based on
1	Natural circulation in 1-phase flow, primary side	S	S	Loop flow rate, fluid temperature, pressure gauges as well as power supplied to core and by-pass
2	Natural circulation in 2-phase flow, primary side	R	R	Differential pressure pickups, temperature and pressure gauges as well as power supplied to core and by-pass
3	Asymmetrical loop behaviour	S	S	Loop flow rate, coolant velocities and temperature gauges.
4	Mixture level and entrainment in to SG	R	R	Differential pressure pickup
5	Core thermal hydraulic	S	S	Clad temperature, coolant temperature, core power supply, core level,
6	PRZ thermal hydraulics	S	S	PRZ level, differential pressure pick up, temperature and pressure gauge
7	Surge line hydraulics	S	S	Differential pressure pickup and temperature gauges
8	Structure heat and heat loses	S	R	By heat flux gauges, primary piping outer surface temperature, coolant temperature
9	Effect of integral system	S	S	By overall measurement and code prediction

Table 1.5 List of Phenomenological Windows (PhW)

Sr. No.	Exp. (s)	Cal. (s) (new)	Cal. (s) (old)	Governing important phenomena
1	0-100	0-120	0-100	SG pressure increase, first spray injection in PRZ, First BRU-A opening
2	100-260	120-230	100-280	SG level decreases due to BRU-A cycling and coast down of pumps and scram occurs, PS temperature increase PRZ level increase
3	250-3700	230-3635	280-3500	BRU-A valve cycling and slight increase in PS pressure and then constant. PS temperature continued to rise, PRZ level rises and at the end full of water
4	3700-8975	3635-8489	3500-6800	PS pressure starts rising and PRZ safety valve cycling, PS rises, small variation in SG pressure inside the range of BRU-A but no further opening
5	8975-9200	8489-8990	6800-7200	Core outlet temperatures reached to 350 ^{o}C, AM starts, fast depressurisation in SG 1and by opening SG 1 and 4 BRU-A, SG 2 and 3 pressure constant,
6	9200-11054	8990-10834	7200-12842	PS system pressure decreases, SG pressure decreases to 1 MPa and external water injection to SG 1 and 4 starts, PRZ level decreases.
7	11054-16500	10834-15071	--	PRZ level decreases and PRZ heater off, PS pressures decreases fast and PRZ PORV opening based on saturation margin operator action
8	16500-21412	15071-21519	--	HPA accumulator injection starts and PRZ level starts to increase, PS pressure and temperature continued to decrease
9	21412-23240	21519-22200	--	LPIS actuate, PRZ is full of water, PS temperature is about 180 ^{o}C, PS pressure is about 2.43 MPa and constant. AM procedure is successful.

(e) Visual comparisons between experimental and code calculated relevant parameters time trends are presented for some of the important thermal hydraulic parameters like primary pressure (upper plenum), secondary side pressure (SG 1), core outlet fluid temperature primary mass inventory in fig.1.2 to 1.5 respectively. Plot for about 40 parameters is given in [8].

Table 1.6 Example of key phenomena and relevant thermal-hydraulic aspects (RTA)

(RTA)	Type	Exp.	New	Old	C J New	C J Old
Opening of spray valve (s)	TSE	71.1, 237	109, 209	--	R	U
Duration of the PRZ relief valve cycling (s)	TSE	4645-8689	4724-8489	4149-7064	E	R
Duration of BRU-A cycling (s)	TSE	75-5534	54.9-5634	54-5635	E	E
Percentage of primary mass inventory at 8500 s	NDP	0.92	0.90	0.88	E	R
Percentage mass inventory at 15000 s	NDP	0.875	0.89	0.95	R	R
Percentage mass inventory in PS at 21300 s	NDP	1.05	1.003	--	E	U
Integral PRZ heater power (MW)	IPA	141.904	134.37	107.5	E	M
Total no of PRZ safety valve cycling	IPA	12	11	12	E	R
Maximum clad temperature (^{o}C)	SVP	356.18 (9230 s)	354.15 (8475 s)	356.5 (7414 s)	R	M
SG 1 level at the end of BRU-A cycling (m)	SVP	0.66	0.527	508	R	R
PRZ level at the at 8900 s (m)	SVP	11.29	11.38	4.57	E	M

CJ- Calculation Judgment, -- not detected

A successful application of the qualitative process constitutes a prerequisite to the application of the quantitative analysis. The accuracy of code calculations has been quantified using Fast Fourier Transform Based Method (FFTBM) developed at University of Pisa [9], [10]. This method mainly works on transformation from time to the frequency domain to avoid the dependence of the error from the transient duration. The accuracy quantification of a code calculation is based on the amplitude of the FFT of the experimental signal and the difference between experimental and calculated trend. This tool produces a couple of values in the frequency domain from each comparison between calculated and measured time trends: 1) the so-called “average accuracy” AA and 2) the “weighted frequency” WF. The most significant value is given by AA which represents the relative magnitude of the discrepancy deriving from the comparison between the addressed calculation and the corresponding experimental trend (AA=0.5 means a calculation affected by a 50 % error). Overall accuracy of an obtained code results prediction is calculated by AA_{tot} and WF_{tot}. Better accuracy is generally represented by low AA values at high WF values. AA_{tot} and WF_{tot} are calculated by averaging AA and WF for all the parameters with the help of weighting factors which varies with type of parameters.

Each weighting factors takes into account of experimental accuracy, safety relevance and importance of selected parameters and physical correlations governing most of the thermal hydraulic quantities. AA, WF for primary pressure (UP) and AA_{tot} and WF_{tot} for both new and old analysis are presented in table 1.7, detailed list are available in [8].

4 Discussion on the Results

It was observed that most of the discrepancies for old analysis in table 1.1 was related to boundary conditions therefore by putting appropriate boundary conditions as per table 1.2 steady state level qualification is achieved. For the ‘on transient level’ qualification it can be seen form the table 1.3, 1.5 and 1.6 and fig 1.2 to 1.5 that code prediction for the transient part in the old analysis was not qualified. The following observations are made based on old analysis and corrective actions are proposed in table1.2 and implemented for achieving on transient level qualification.

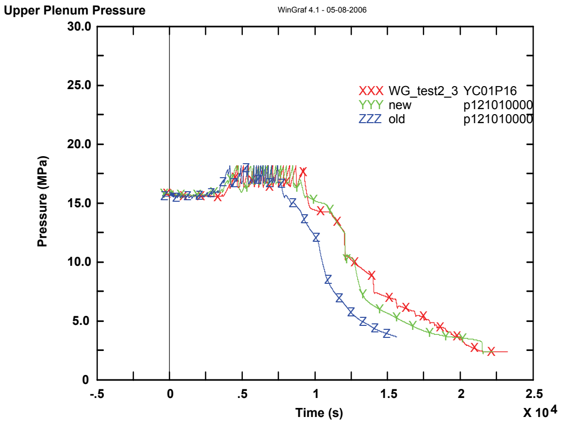

Fig. 1.2 Comparison of Upper Plenum Pressure

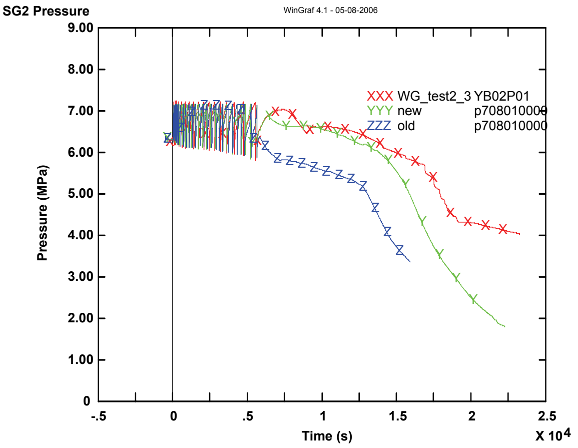

Fig. 1.3 Comparison of SG 1 Pressure

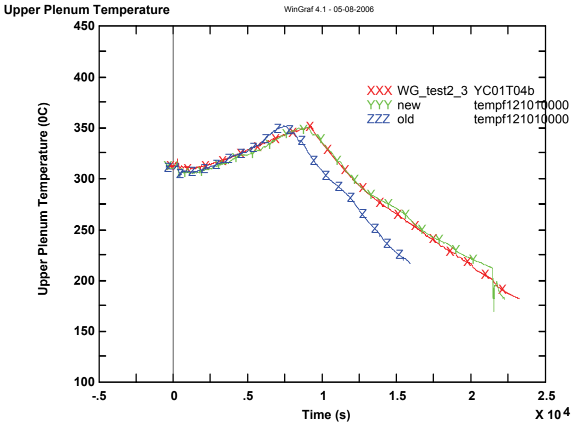

Fig.1.4 Core Outlet Temperature

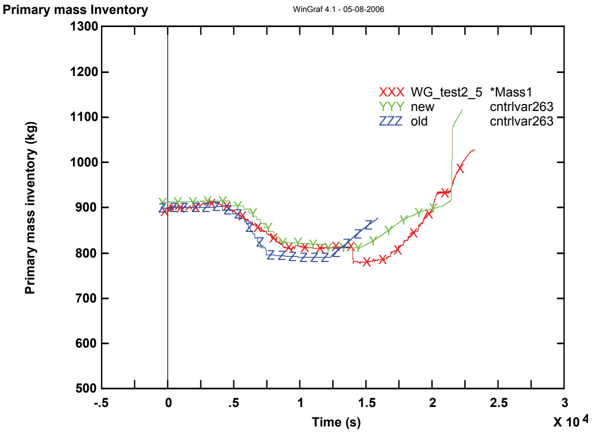

Fig. 1.5 Comparison of Primary Mass Inventory

Table 1.7 Average accuracy and weighted frequency for quantitative accuracy of results prediction

New (Improved analysis) (time start from 0 s to value given in columns e.g. 0-500 s, 0-10000 s)												
Parameter	500 AA	500 WF	1000 AA	1000 WF	2500 AA	2500 WF	5000 AA	5000 WF	10000 AA	10000 WF	22250 AA	22250 WF
Primary pressure	.048	.030	.063	.058	.074	.030	.281	.046	.419	.016	.260	.010
AA total	.102	.048	.115	.057	.125	.044	.153	.029	.247	.022	.289	.012
Old (Previous Analysis) (time start from 0 s to value given in columns e.g. 0-500 s, 0-10000 s)												
Parameter	500 AA	500 WF	1000 AA	1000 WF	2500 AA	2500 WF	5000 AA	5000 WF	10000 AA	10000 AA	15900 AA	15900 WF
Primary Pressure	.053	.069	.066	.050	.091	.081	.269	.025	.490	.017	.399	.010
AA total	.081	.057	.096	.054	.115	.049	.147	.033	.330	.022	.390	.015

(a) PRZ spray valve opening are observed two times in new analysis by achieving steady state pressure in PRZ close to experiment and modified heat loss form primary circuit including pump heat loss.

(b) From the table 1.3 it is clear that PRZ safety valve cycling duration is achieved in new analysis very close to experimental value. This has been achieved by modified heat loss from primary circuit including pump heat loss and by slightly increasing PRZ safety valve area as per table 1.2.

(c) Starting time of first accident management (table. 1.3) for opening BRU-A in SG 1 and SG 4, closing of MSIV of SG 2 and SG 3 and injecting external feed water in SG in new analysis, is achieved close to experiment value with compared to old analysis by changes made in item (b) above.

(d) It is observed from the old analysis that rate of cooling of primary system is more with respect to experiment from the time of external water injection to SG 1 and 4 to the end of transient. This is one of the reasons for old analysis failure at 15900 s. It is noted from the analysis of experimental data that injections of external water to SGs are not exactly as per test specification value (66 g/s). The average value for these injection rate in exp. for initial 1000 s, 4000 s 9000s are 52g/s, 56g/s and 62 g/s respectively. It is also observed that errors in measuring the injection flow are of the order of 50 g/s. In view of the above a sensitivity analysis have been carried out and concluded that that 55 g/s injection gives better results for cooling of primary circuit.

(e) for the start of second accident management (opening of PRZ PORV table 1.3), this phenomenon was not observed at all in the old analysis while in experiments it is first observed at 12007 s and operated 19 times during transients. Considering the error in measurement (3 ^{o}C) this set point is reduced to 27 ^{o}C to see the effect in new analysis and two times valve opening is observed. This is the main reason for significant difference in primary mass inventory is observed between experimental value and new analysis from 12000 s to about 21300 s (LPIS starts) fig. 1.5.

(f) From table 1.3 it can be seen that high pressure accumulator injection timing is improved and LPIS actuation is also observed in new analysis.

Improvements for qualitative point of view in the results prediction for the new analysis are observed from the above discussion and also can be seen from table 1.1, 1.3, 1.5 1.6 and 1.7 and from fig 1.2 to 1.5. However, opening of PRZ PORV on operator action is also not fully predicted in new analysis as per test specifications. For quantitative evaluation it is noted from table 1.7 that AA_{tot} for the new analysis is well below the acceptable limit (0.38) for all the time. However AA for the primary pressure is more than acceptable limit (0.1) for some of the time interval. The reason for this may be due to difference in PRZ safety valve opening and this cycling duration. The effect of these two on primary pressure is prompt and significant. Considering the selected transient is complicated and of very long duration, it is difficult to achieve this acceptable limit. Therefore AA value obtained for primary pressure in new analysis is satisfactory and appreciated.

5 Conclusions

Improvement in post test analysis of results prediction for the test no. 2, carried-out on PSB integral test facility in May 2005, has been achieved by systematically applying all the procedure lead by Uncertainty Methodology based on Accuracy Extrapolation**.**

‘Steady state level’ and ‘on transient level’ qualification for nodalization of PSB test facility has been demonstrated for test no. 2. The capability to induce the phenomena by test facility for the code assessment and capability to reproduce the same phenomena by Relap5/mod 3.3 code prediction as per CSNI phenomena validation matrix has been identified and verified. Overall quantitative code accuracy for the analysis is quantified using Fast Fourier Transform Based Method. The results of the new analysis carried out are acceptable as per UMAE acceptance criteria.

Results of test carried out in the test facility and analysis results prediction are very useful for the point of view of verification of the accident management strategies for NPPs and to verify the correctness of some safety systems operating only during accident. Results of this analysis may be utilized for expanding the data base for Code with the capability of Internal Assessment of Uncertainty (CIAU) [11], [12].

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