Università di Pisa

Dipartimento di Ingegneria Meccanica, Nucleare e della Produzione

11% UPPER PLENUM BREAK: APPLICATION OF RELAP5-3D© AND COMPARISON WITH OTHER CODES

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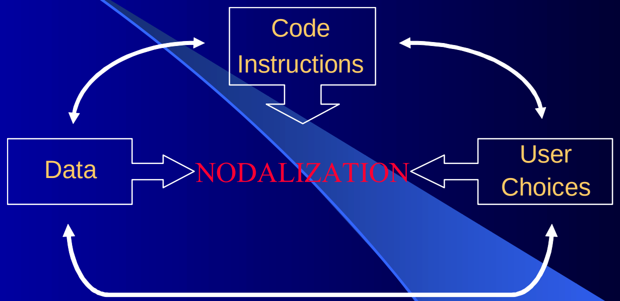
CONTENTS

INTRODUCTION

The nodalizations have been carried out using a standard methodology and all the steps foreseen have been fulfilled

- The nodalizations have been carried out using the experience acquired in the DIMNP



"Criteria for nodalization qualification at the steady-state level"

	QUANTITY	ACCEPTABLE ERROR (°)
1	Primary circuit volume	1 %
2	Secondary circuit volume	2 %
3	Non-active structures heat transfer area (overall)	10 %
4	Active structures heat transfer area (overall)	0.1 %
5	Non-active structures heat transfer volume (overall)	14 %
6	Active structures heat transfer volume (overall)	0.2 %
7	Volume vs. height curve (i.e. "local" primary and secondary circuit volume)	10 %
8	Component relative elevation	0.01 m
9	Axial and radial power distribution (°°)	1 %
10	Flow area of components like valves, pumps orifices	1 %
11	Generic flow area	10 %
(*)		
12	Primary circuit power balance	2 %
13	Secondary circuit power balance	2 %
14	Absolute pressure (PRZ, SG, ACC)	0.1 %
15	Fluid temperature	0.5 % (**)
16	Rod surface temperature	10 K
17	Pump velocity	1 %
18	Heat losses	10 %
19	Local pressure drops	10 % (^)
20	Mass inventory in primary circuit	2 % (^^)
21	Mass inventory in secondary circuit	5 % (^^)
22	Flow rates (primary and secondary circuit)	2 %
23	Bypass mass flow rates	10 %
24	Pressurizer level (collapsed)	0.05 m
25	Secondary side or downcomer level	0.1 m (^^)

(°) The % error is defined as the ratio

$$\frac{|\text{reference or measured value} - \text{calculated value}|}{|\text{reference or measured value}|}$$

The "dimensional error" is the numerator of the above expression

(°°) Additional consideration needed

(*) With reference to each of the quantities below, following a one hundred s "transient-steady-state" calculation, the solution must be stable with an inherent drift < 1% / 100 s.

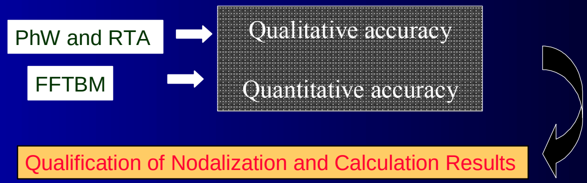
(**) And consistent with power error

(^) Of the difference between maximum and minimum pressure in the loop.

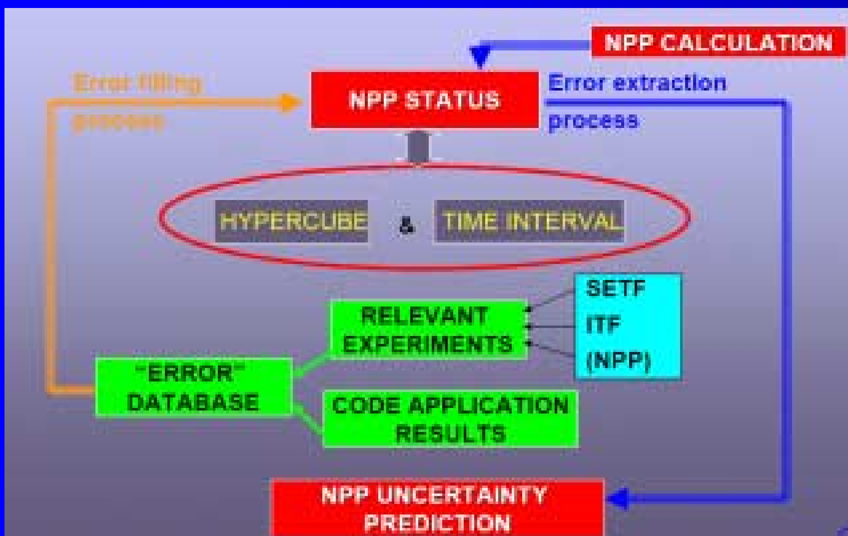
(^^) And consistent with other errors.

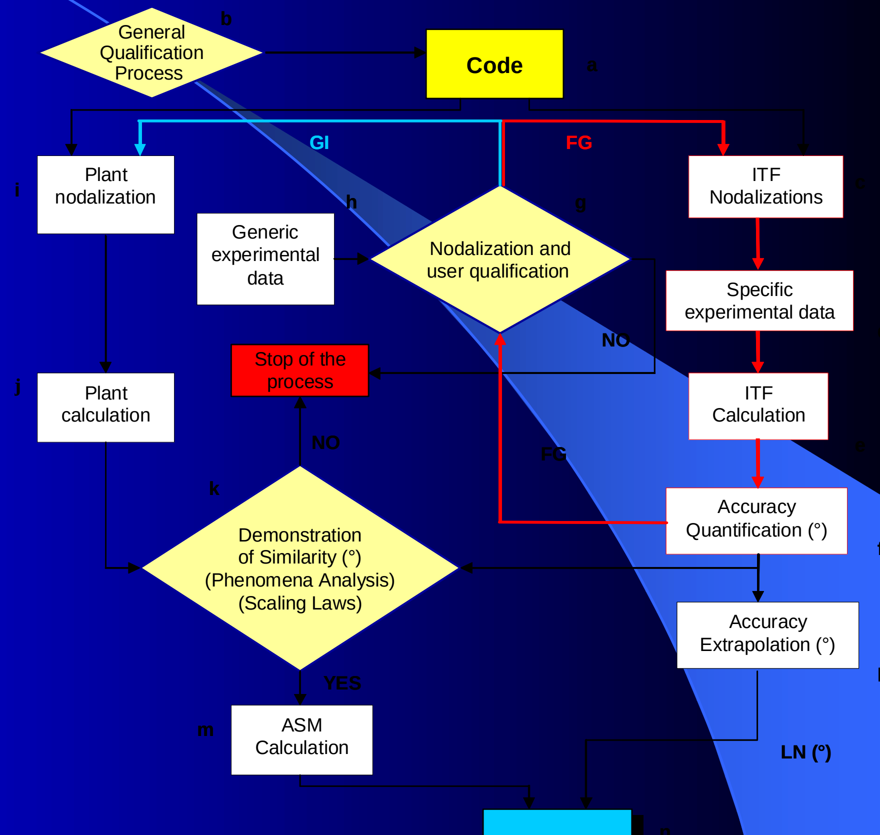
The qualification of the nodalizations have been fulfilled at steady state level, using our criteria as reference

- The on transient level qualification foressen in our procedure has been fulfilled



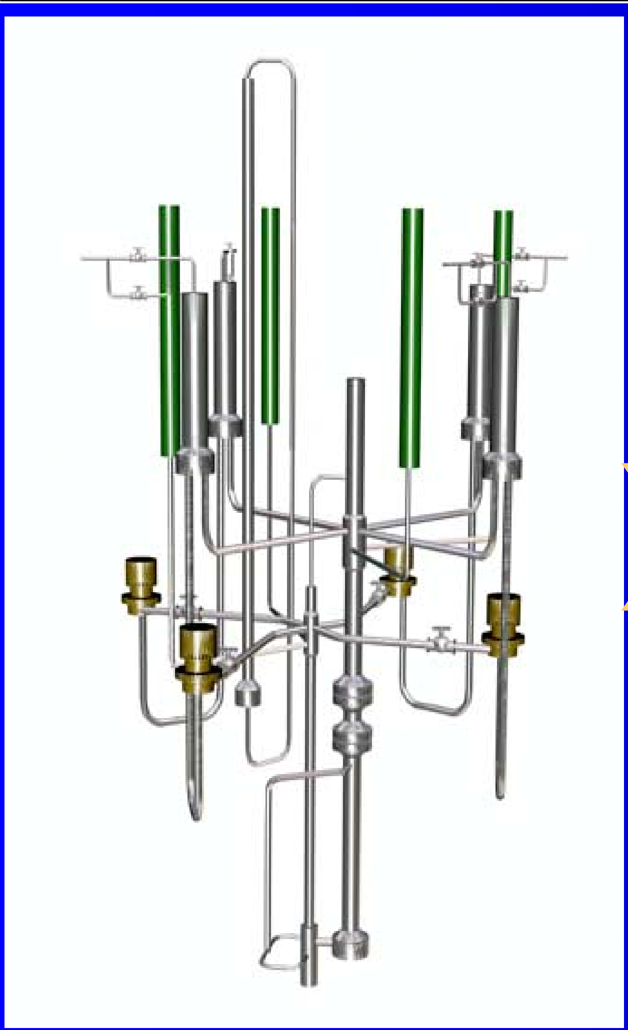
CIAU & UMAE FLOW DIAGRAM



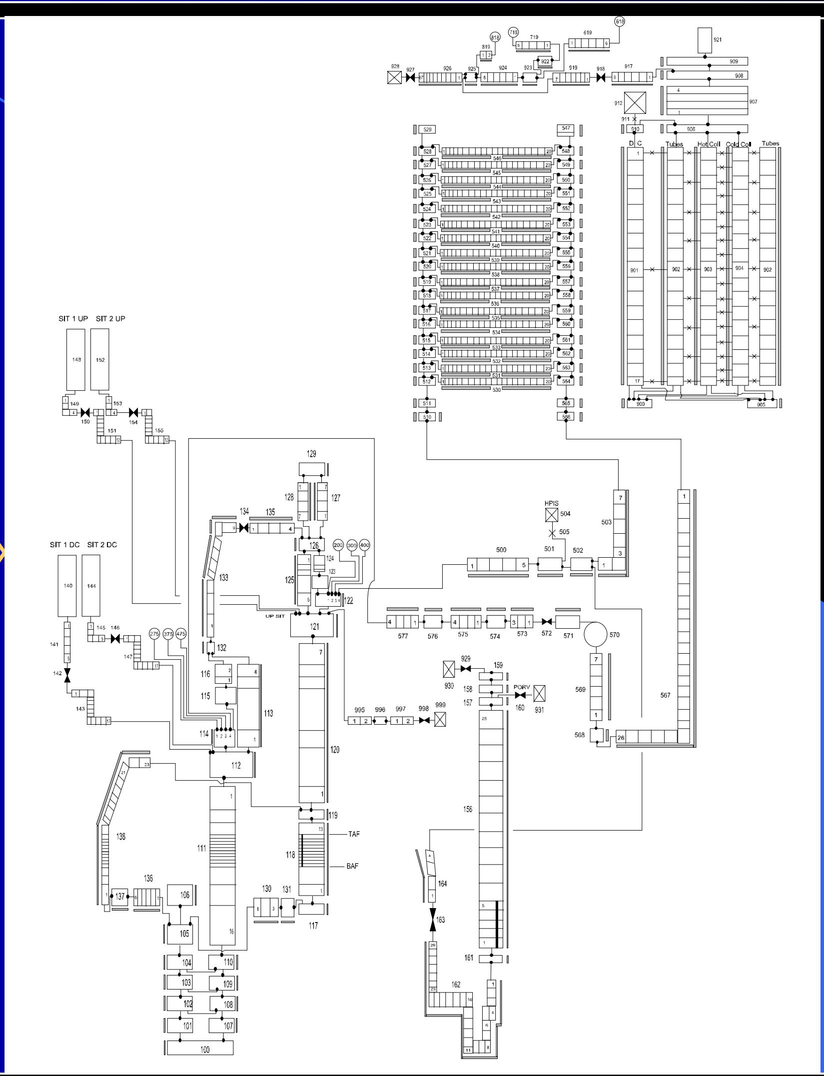


(°) Special methodology developed

PSB LAYOUT AND CODES INPUT DECK

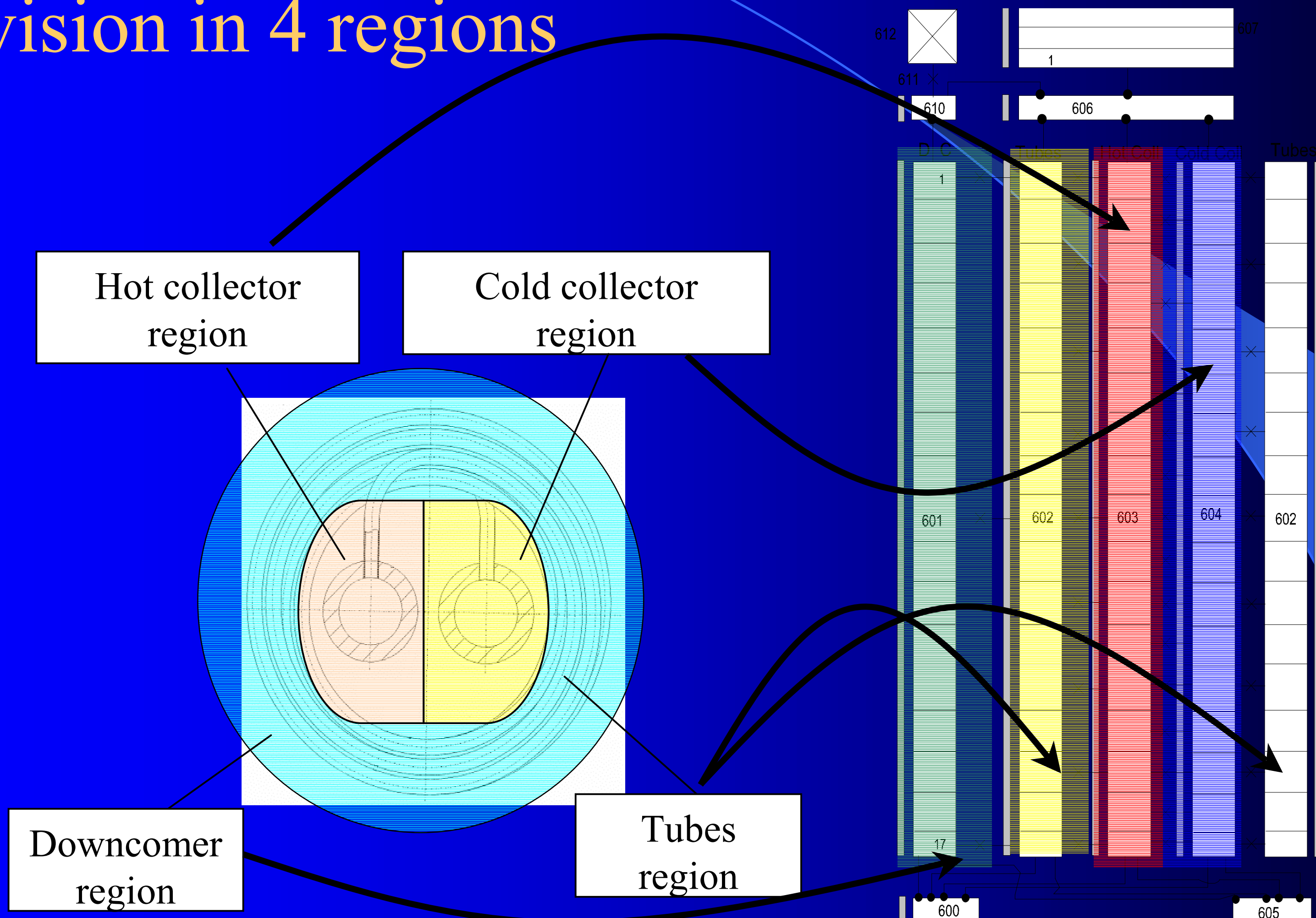


Relap5
nodalization



RELAP5 NODALIZATION

Division in 4 regions

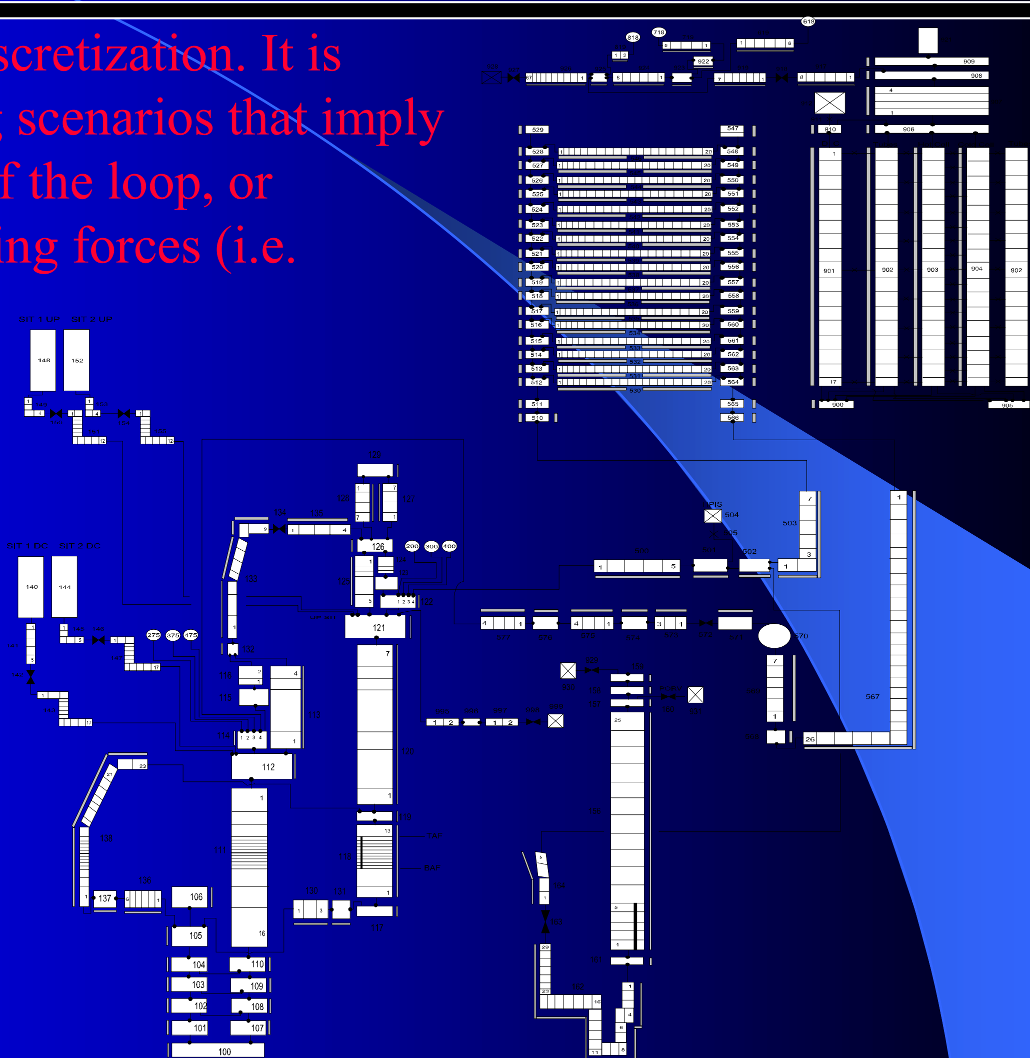


RELAP5 NODALIZATION

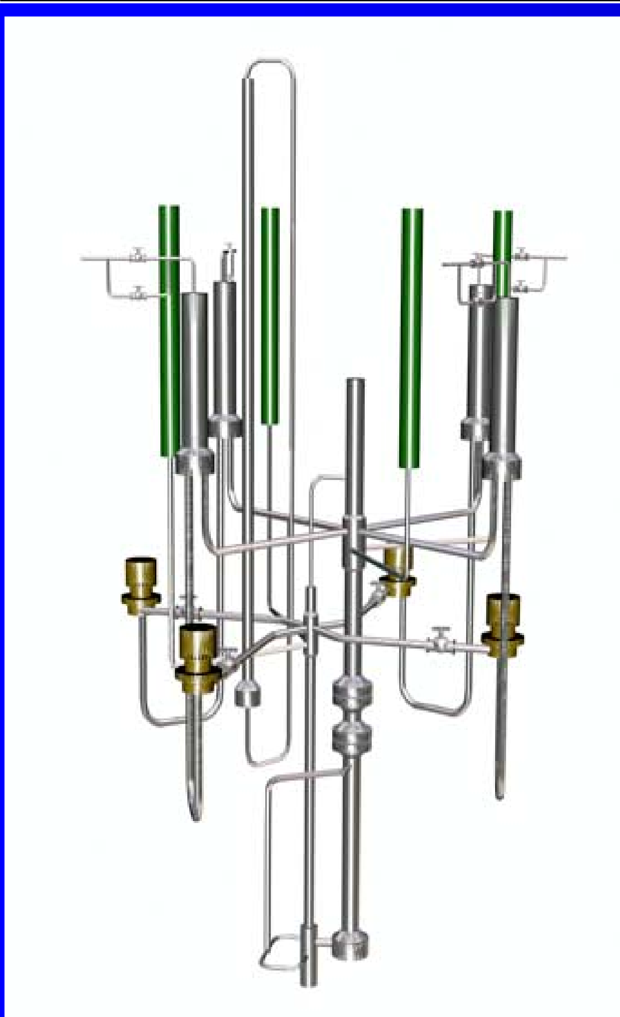
A sliced approach is used in the discretization. It is specifically suitable for calculating scenarios that imply fluid stagnation in different parts of the loop, or scenario characterized by low driving forces (i.e. natural circulation).

ADOPTED CODE RESOURCES

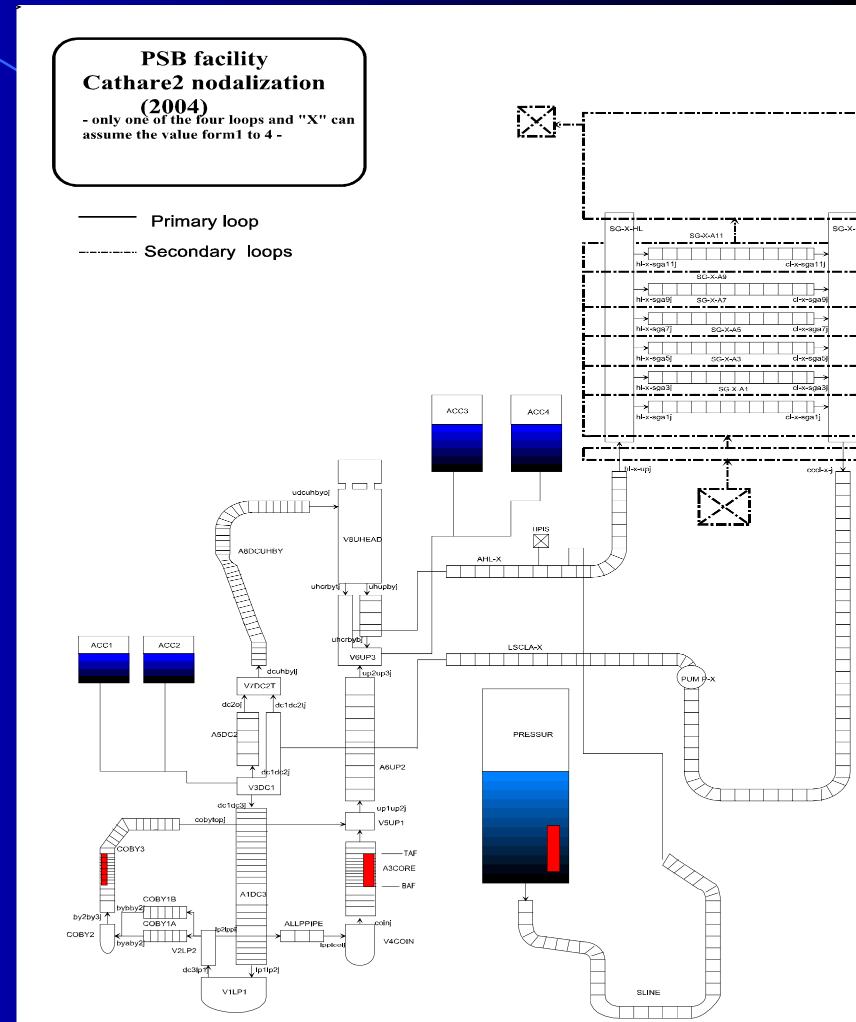
N. nodes	2492
N. junctions	2742
N. heat structures	2231
N. mesh points	11383
N. core heat structures	10



PSB LAYOUT AND CODES INPUT DECK



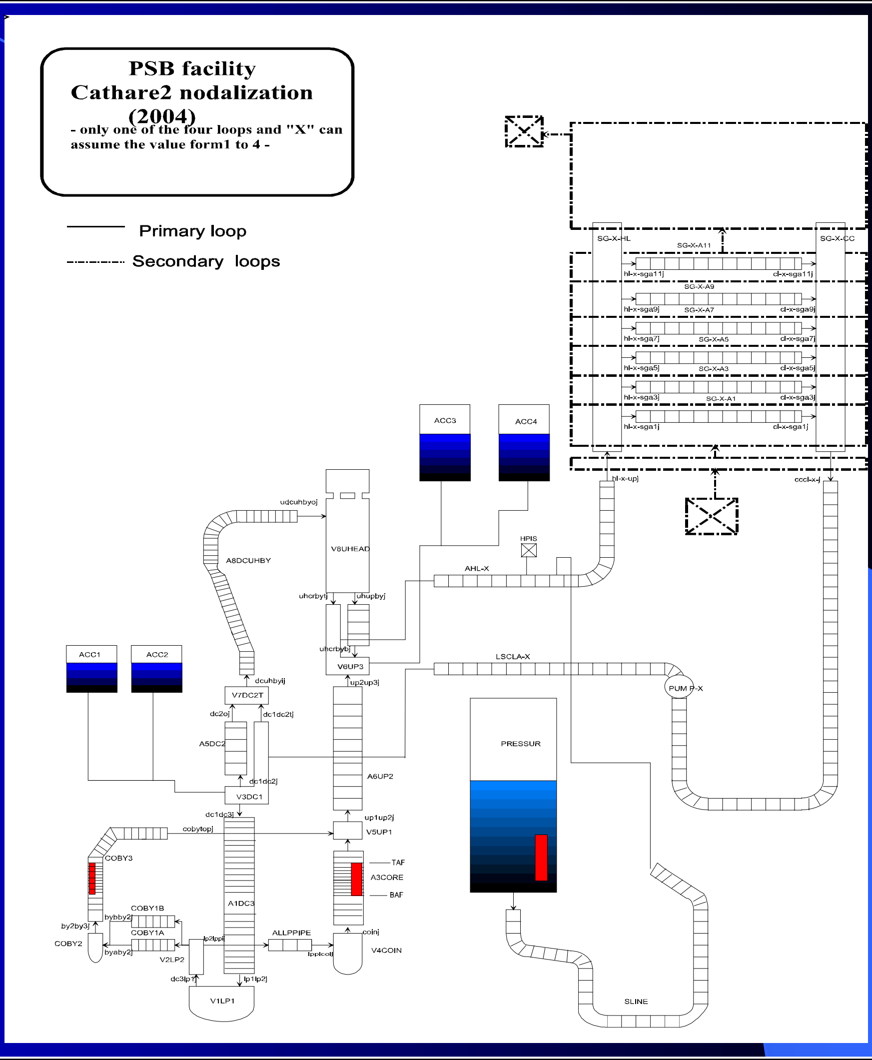
Cathare2V1.5 nodalization



CATHARE2V1.5B NODALIZATION

ADOPTED CODE RESOURCES

PARAMETER	VALUE
Code	**Cathare2**
1. Total N. of Hydraulic Modules	
–primary side	63 (1742)
–secondary side	20 (64)
–total	83 (1806)
•2. N. OF JUNCTIONS	
–primary side	92
–secondary side	16
–total	108
•3. N. OF THERMAL STRUCTURES	
–primary side	117
–secondary side	24
•total	141
•5. NUMBER OF CORE ACTIVE STRUCTURES	10
•7. N. OF MESH POINTS	
–core slabs	120
–steam generator slabs	392
9. OVERALL VOLUME (m³)	1.78927



11% UP BREAK POST TEST ANALYSES

The experimental data available for the selected post test analysis is a test called "UP 11% break". It simulates a rupture on one upper plenum accumulator line. It is a counterpart of a test performed in an other facility (ISB-VVER) and the initial and boundary conditions derive from that test. UP 11% break test is also used by EREC as shake-down test for the PSB facility namely to check all the instrumentation and all the system behaviour. The break is side oriented, it is installed 200 mm under the hot legs connection and discharges in a catch tank at atmospheric pressure where an appropriate system measured the ejected flow rate.

Imposed sequence of main events

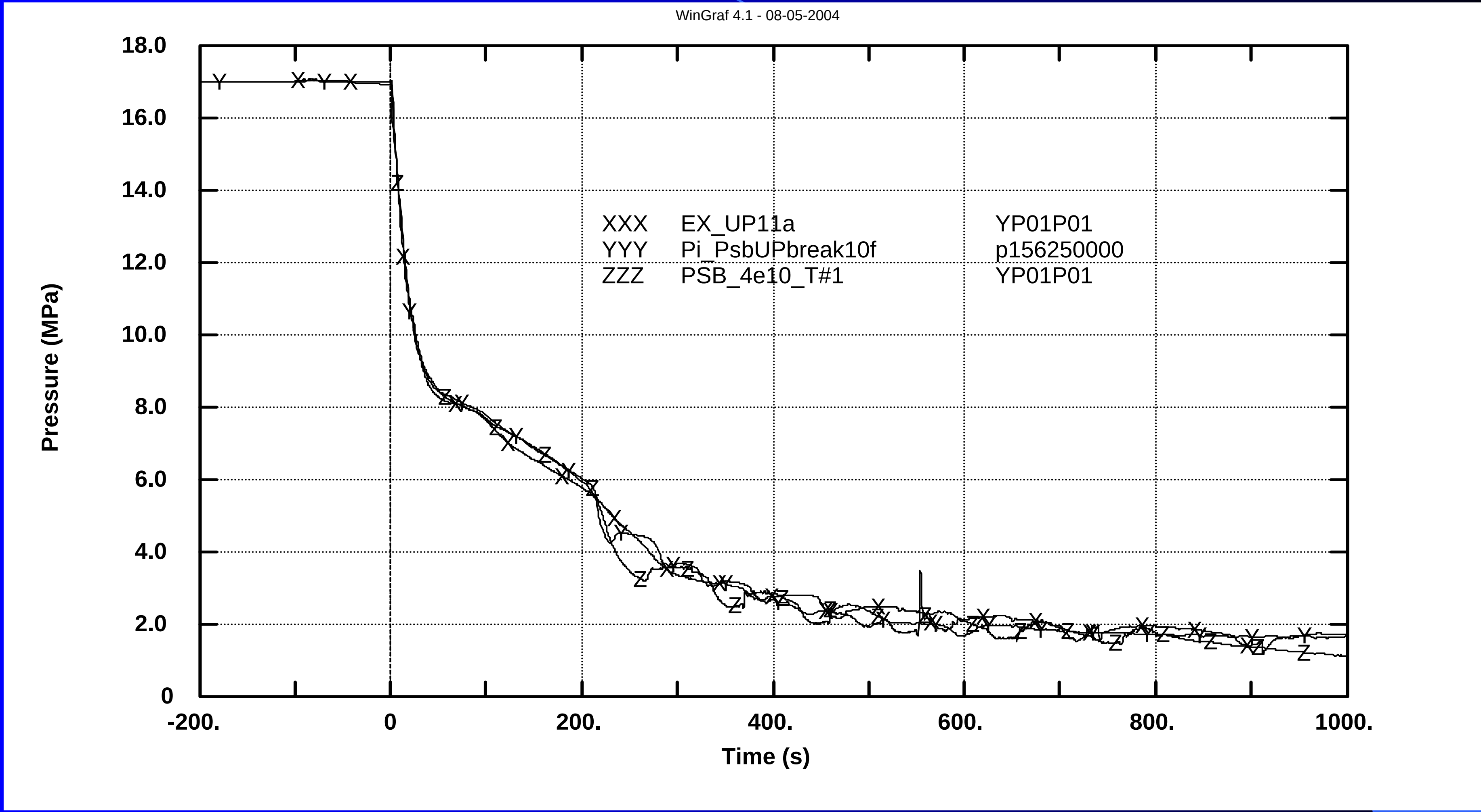
EVENT	TIME AND/OR SET POINT VALUES
Break opening	0 s
SCRAM signal	5 s
Pumps coastdown initiation	10 s, full stop at 14 s
SG SS isolated	5 s
Normal SG SS FW supply stopped	15 s
Pressurizer internal heaters stop	Prz pressure = 13.73 Mpa
SG SS safety valves opening	Not operative
Safety injection signal (HPIS active)	Primary pressure = 10.5 Mpa
Accumulators injection start	Primary pressure = 5.89 MPa
Accumulators injection stop	About 900 s
End of transient	1037 s

STEADY STATE CONDITIONS

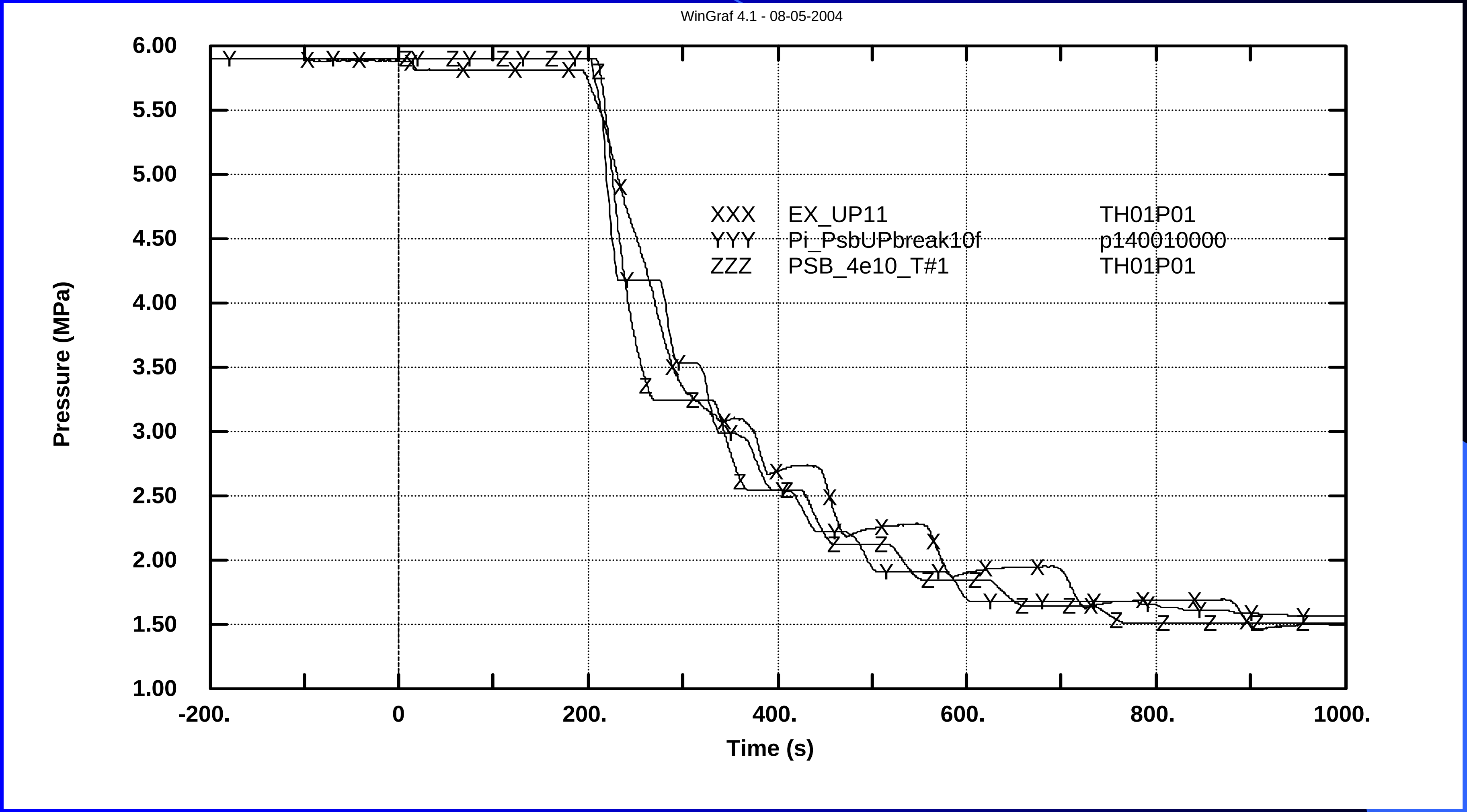
The main parameters assumed for the steady state conditions has been respected

Parameter	Code Measure	Actual value	Set value		
			Cathare2V1.5	R5Mod3.3	R5-3D
PRIMARY SIDE					
Pressure in Upper Plenum (MPa)	YC01P17	16.9±0.06	16.9	16.94	16.94
Coolant temperature (K) -at DC inlet -at UP outlet	YA01-04T02 YA01-04T03	559.7±3 589.7±3	560.6 589.8	563 592	563 592
Flow rate in circulation loops (kg/s) -loop 1 -loop 2 -loop 3 -loop 4	YA01F01 YA02F01 YA03F01 YA04F01	2.3±0.05 2.3±0.05 2.3±0.05 2.4±0.05	2.29 2.29 2.29 2.27	2.32 2.32 2.32 2.32	2.32 2.32 2.32 2.33
Power of FRS bundle (kW)	YC01N01	1520±15	1521	1520	1521
By-pass power (kW)	YC01N02	17.4±0.7	17.4	17.4	17.4
Coolant level in PRZ (m)	YP01L02	6.99±0.3	6.94 (8.83)	7.05 (8.949)	7.06 (8.950)
SECONDARY SIDE					
Pressure (MPa) -SG1 -SG2 -SG3 -SG4	YB01P01 YB02P01 YB03P01 YB04P01	7.43±0.05 7.47±0.05 7.33±0.05 7.43±0.05	7.42 7.40 7.40 7.40	7.47 7.47 7.45 7.47	7.43 7.43 7.42 7.43
Level (m) -SG1 -SG2 -SG3 -SG4	YB01L01 YB02L01 YB03L01 YB04L01	1.71±0.07 1.71±0.07 1.84±0.07 1.74±0.07	1.71 1.71 1.80 1.72	1.71 1.71 1.89 1.73	1.71 1.71 1.88 1.73
ACC-S					
Pressure (MPa) -ACCU 1 -ACCU 2 -ACCU 3 -ACCU 4	TH01P01 TH02P01 TH03P01 TH04P01	5.8±0.03 5.9±0.03 5.9±0.03 5.9±0.03	5.9 5.9 5.9 5.9	5.9 5.9 5.9 5.9	5.9 5.9 5.9 5.9
Level (m) -ACCU 1 -ACCU 2 -ACCU 3 -ACCU 4	TH01L01 TH02L01 TH03L01 TH04L01	4.84±0.07 4.84±0.07 4.86±0.07 4.85±0.07	4.84 4.84 4.84 4.84	4.84 4.84 4.86 4.85	4.84 4.84 4.86 4.85

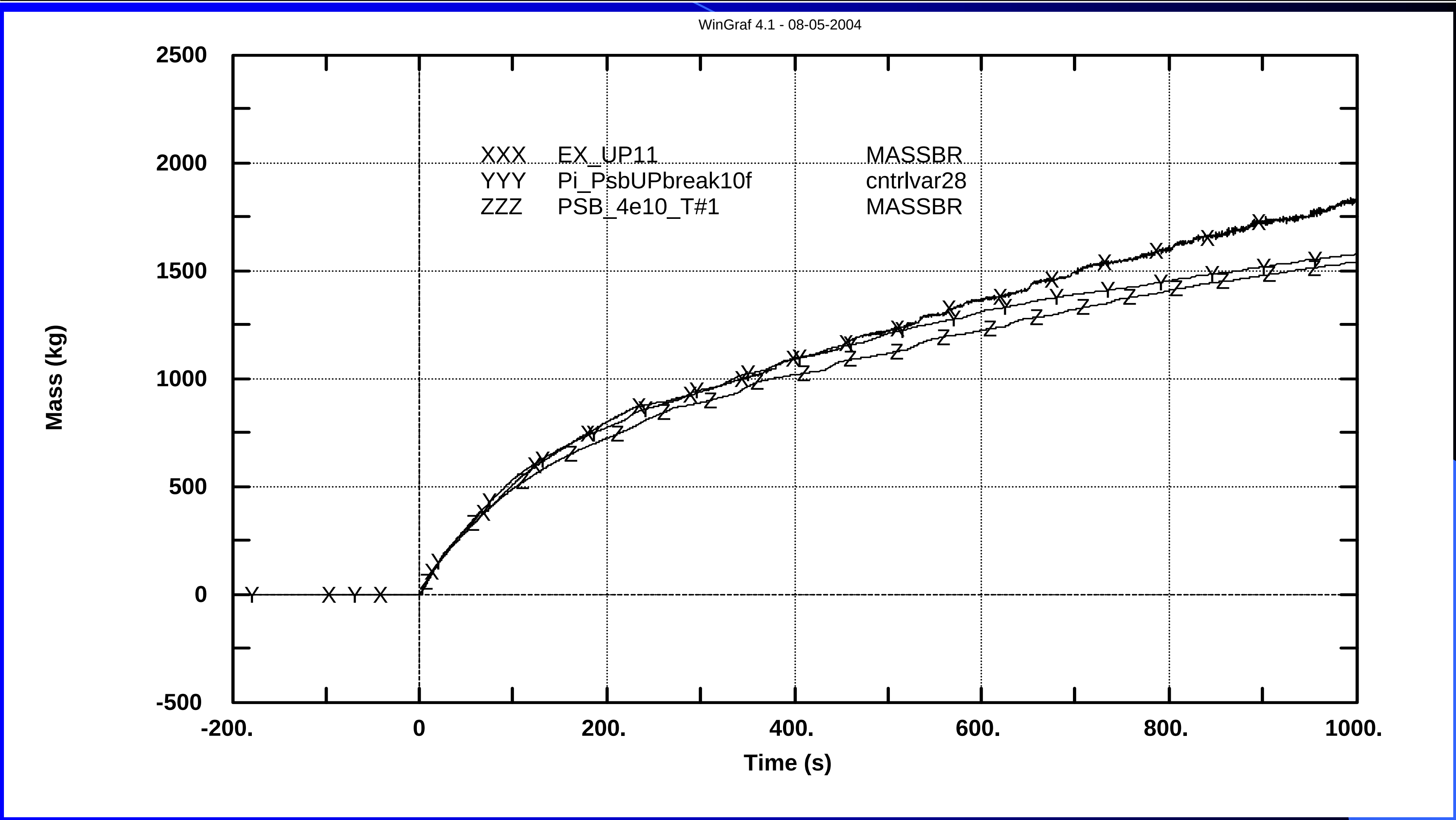
PRZ PRESSURE – EXP, R5M3.3, C2



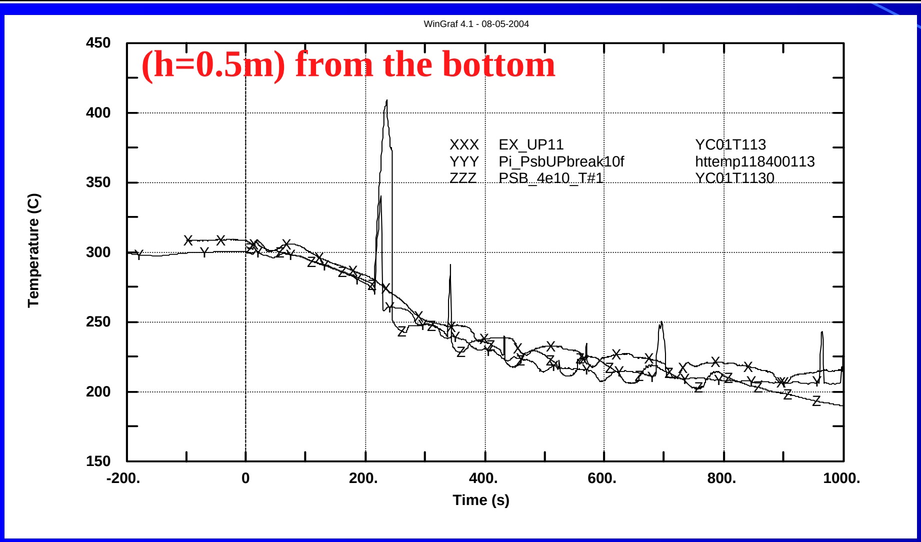
ACCU 1 PRESSURE – EXP, R5M3.3, C2

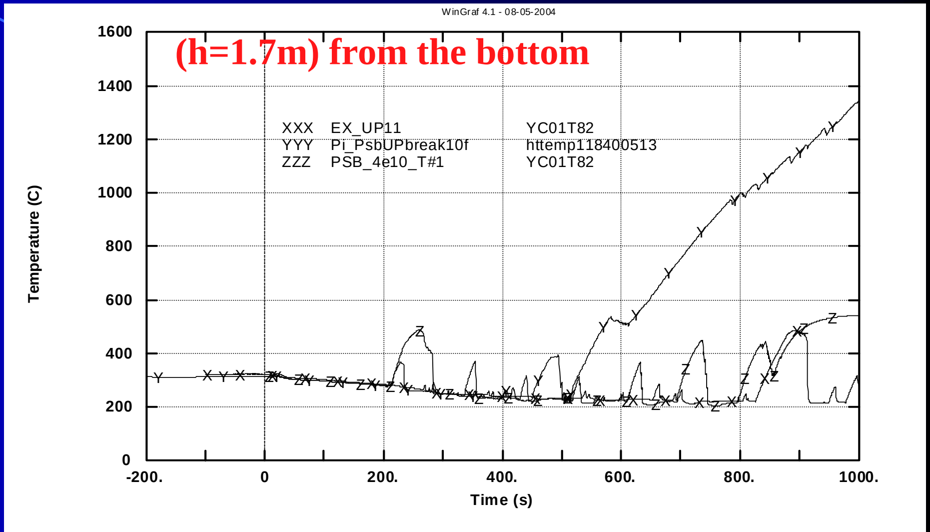


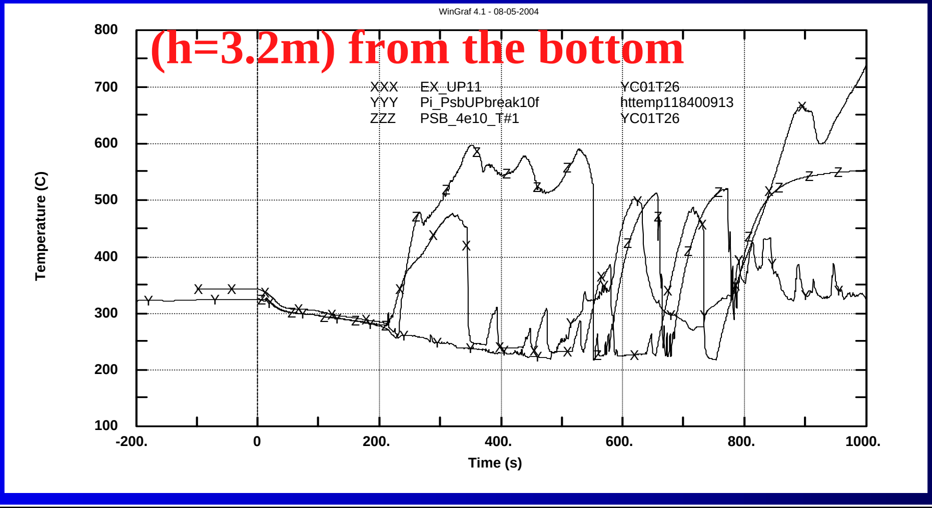
INTEGRAL BREAK FLOW – EXP, R5M3.3, C2



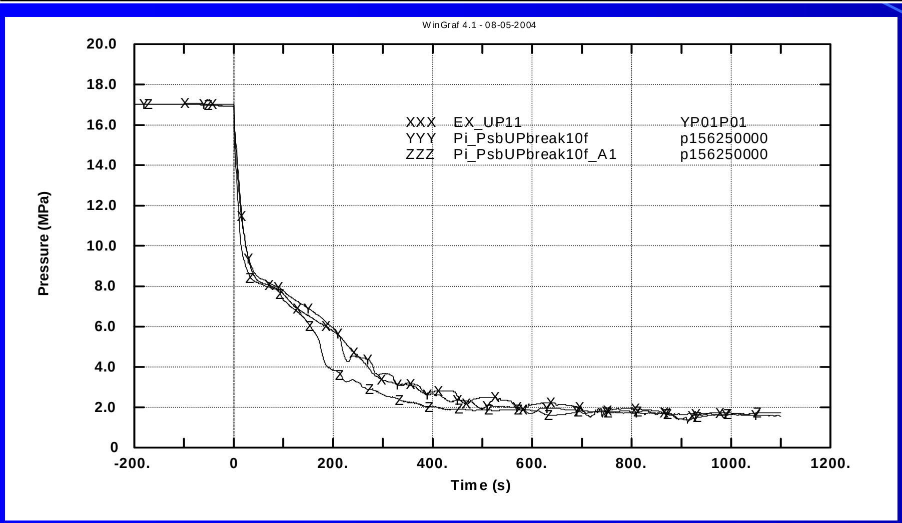
ROD CL TEMP– EXP, R5M3.3, C2

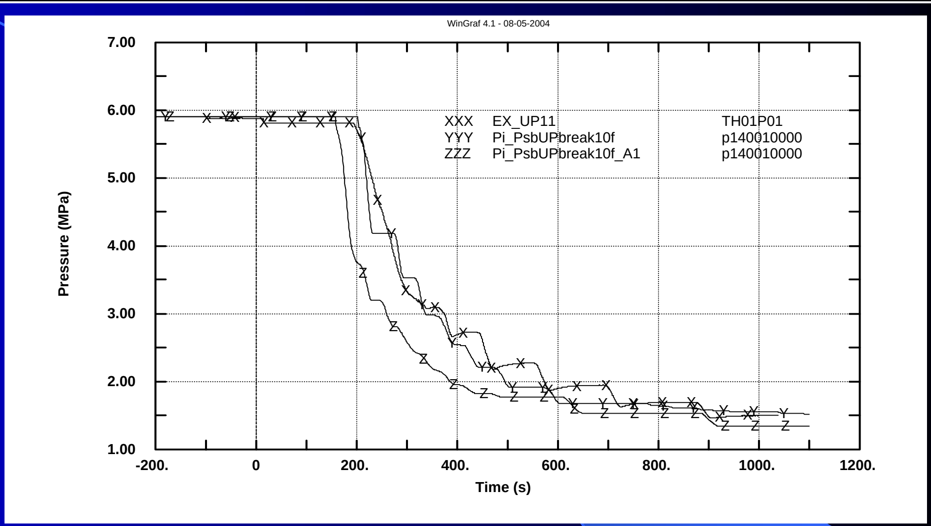


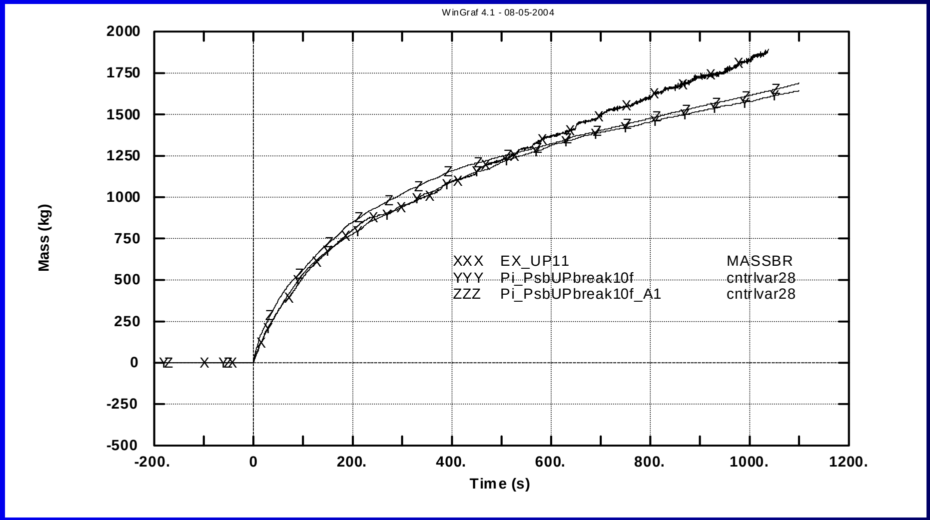




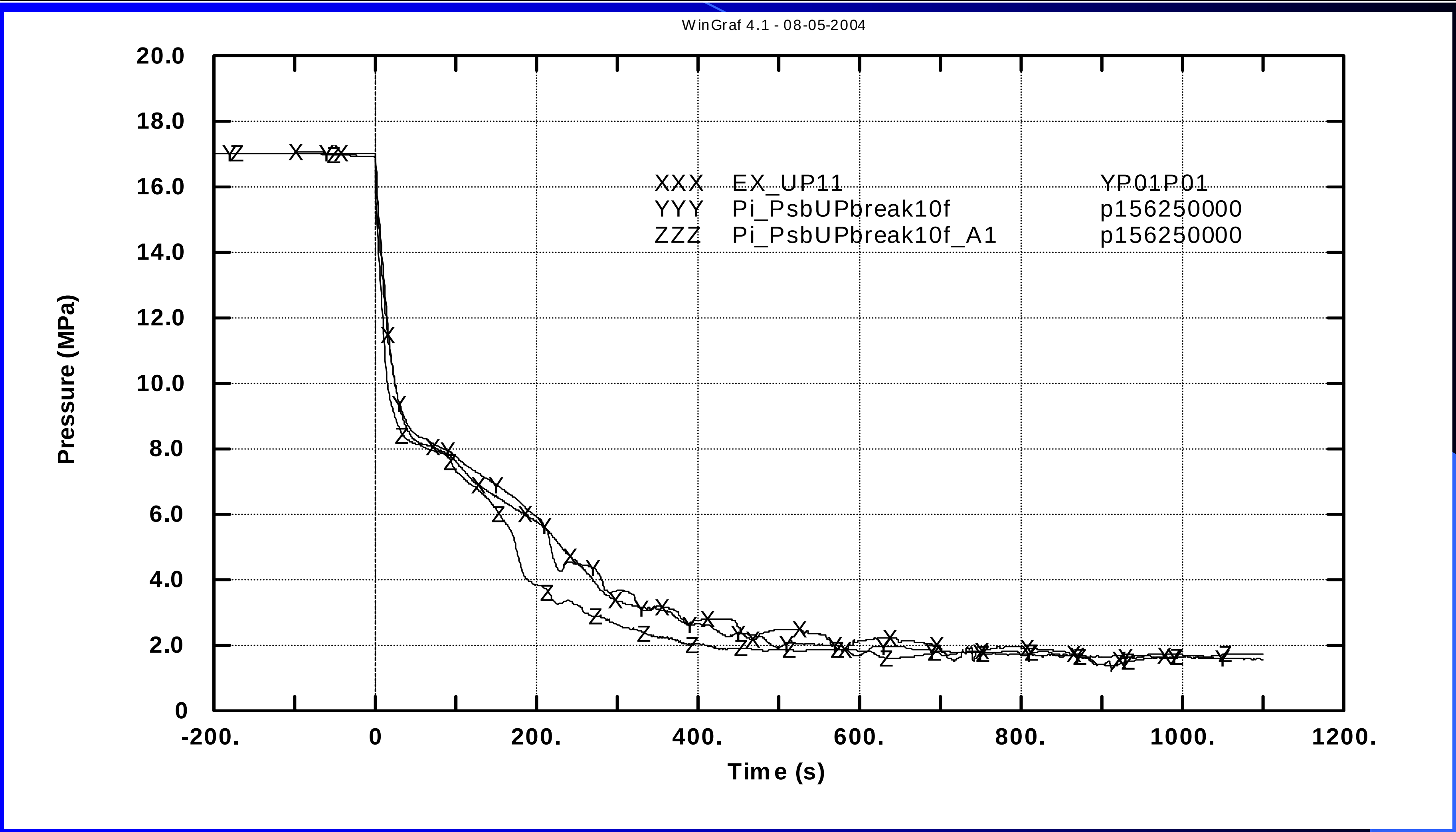
RESULTS - EXP, R5M3.3, R5-3D



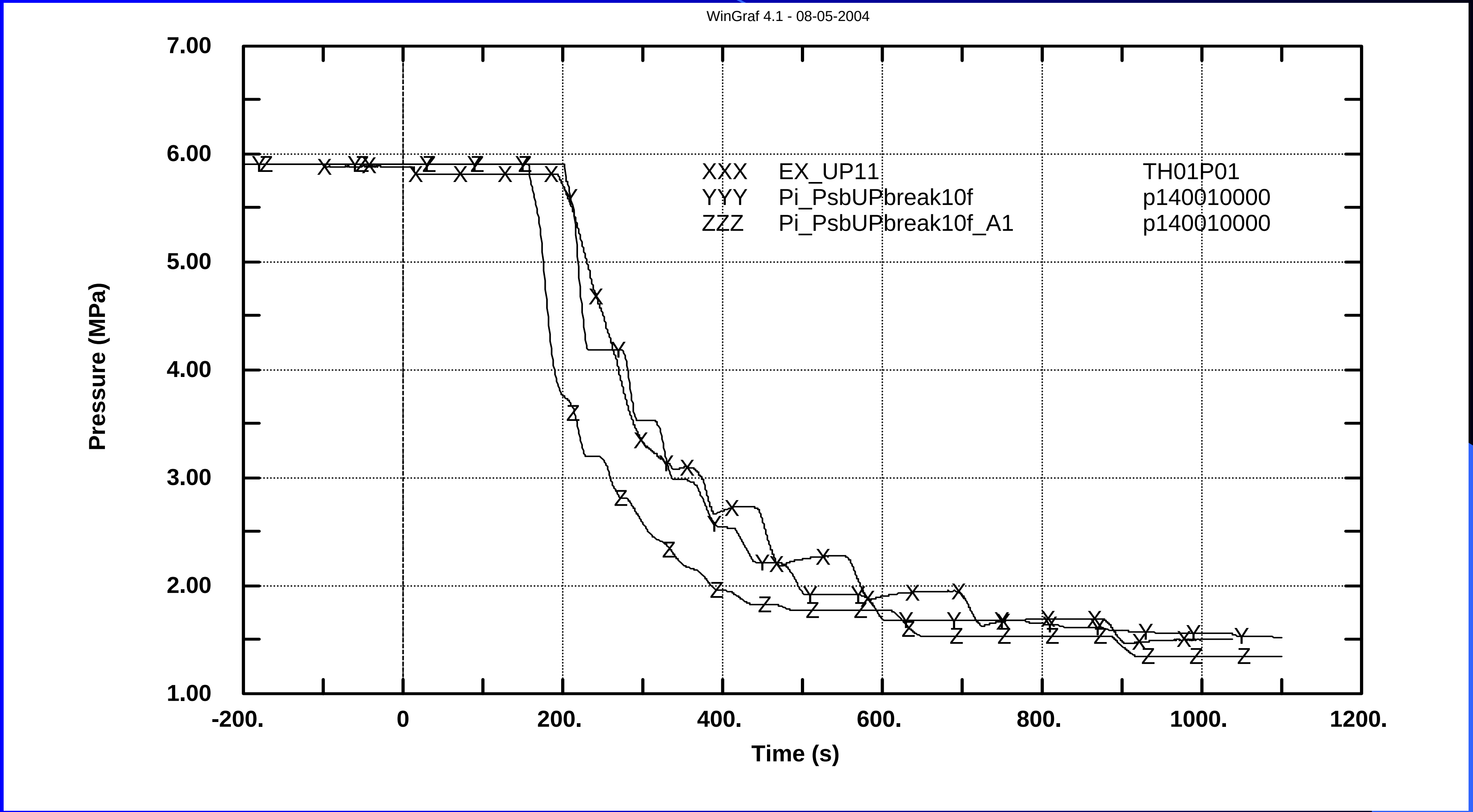




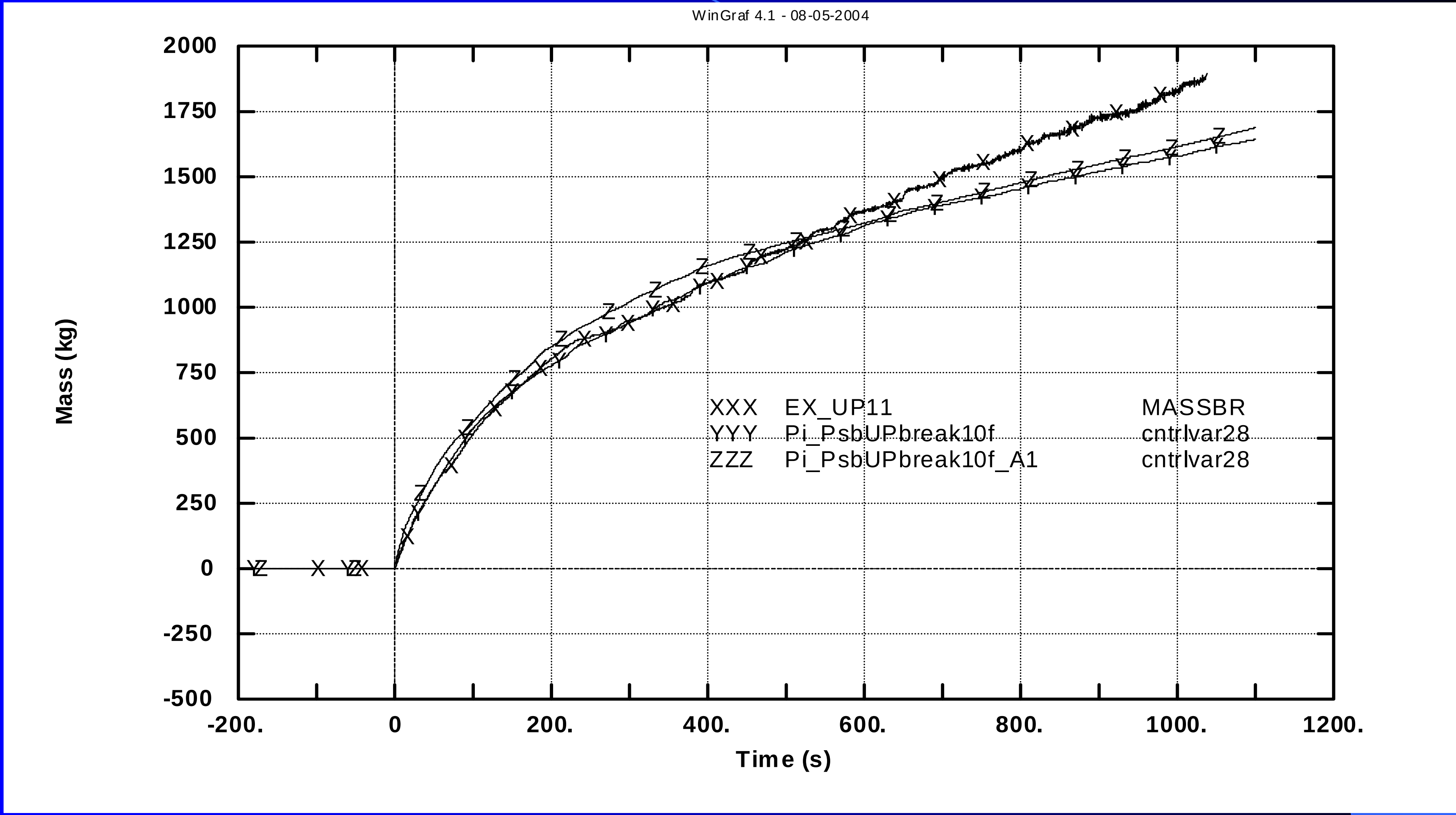
PRZ PRESSURE – EXP, R5M3.3, R5-3D



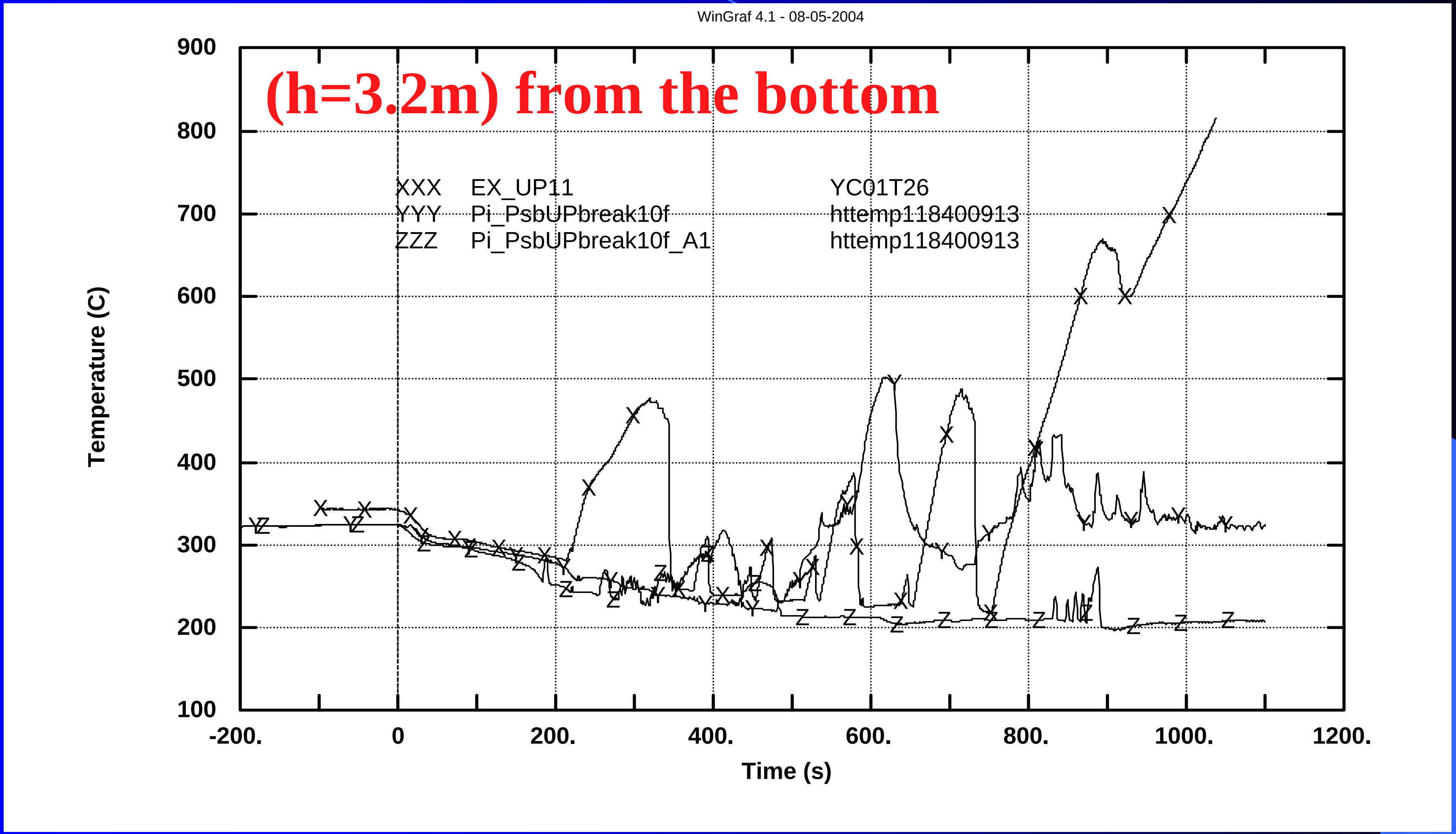
ACCU 1 PRESSURE – EXP, R5M3.3, R5-3D



INTEGRAL BREAK FLOW – EXP, R5M3.3, R5-3D



ROD CL TEMP– EXP, R5M3.3, R5-3D

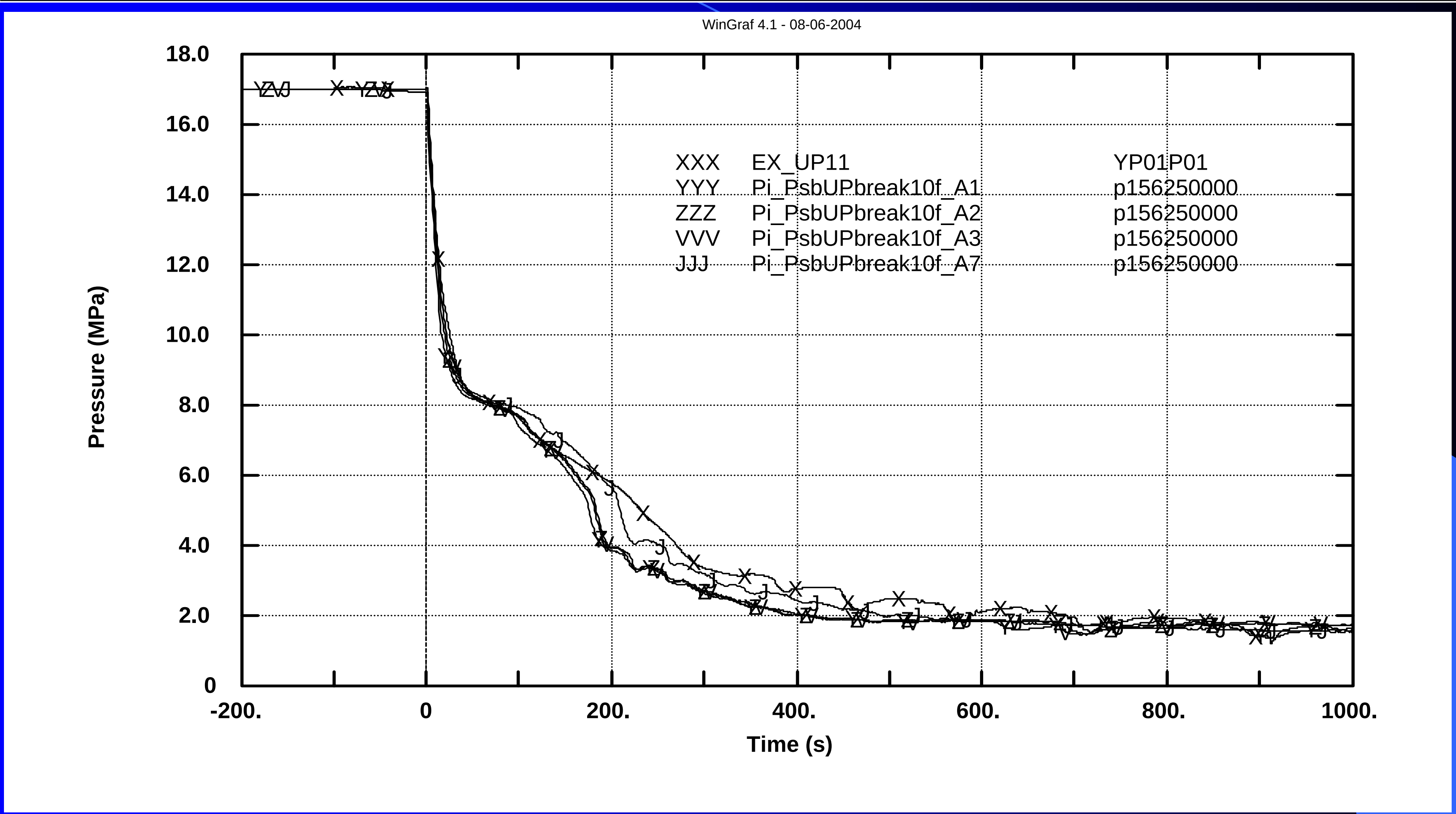


SENSITIVITY STUDY

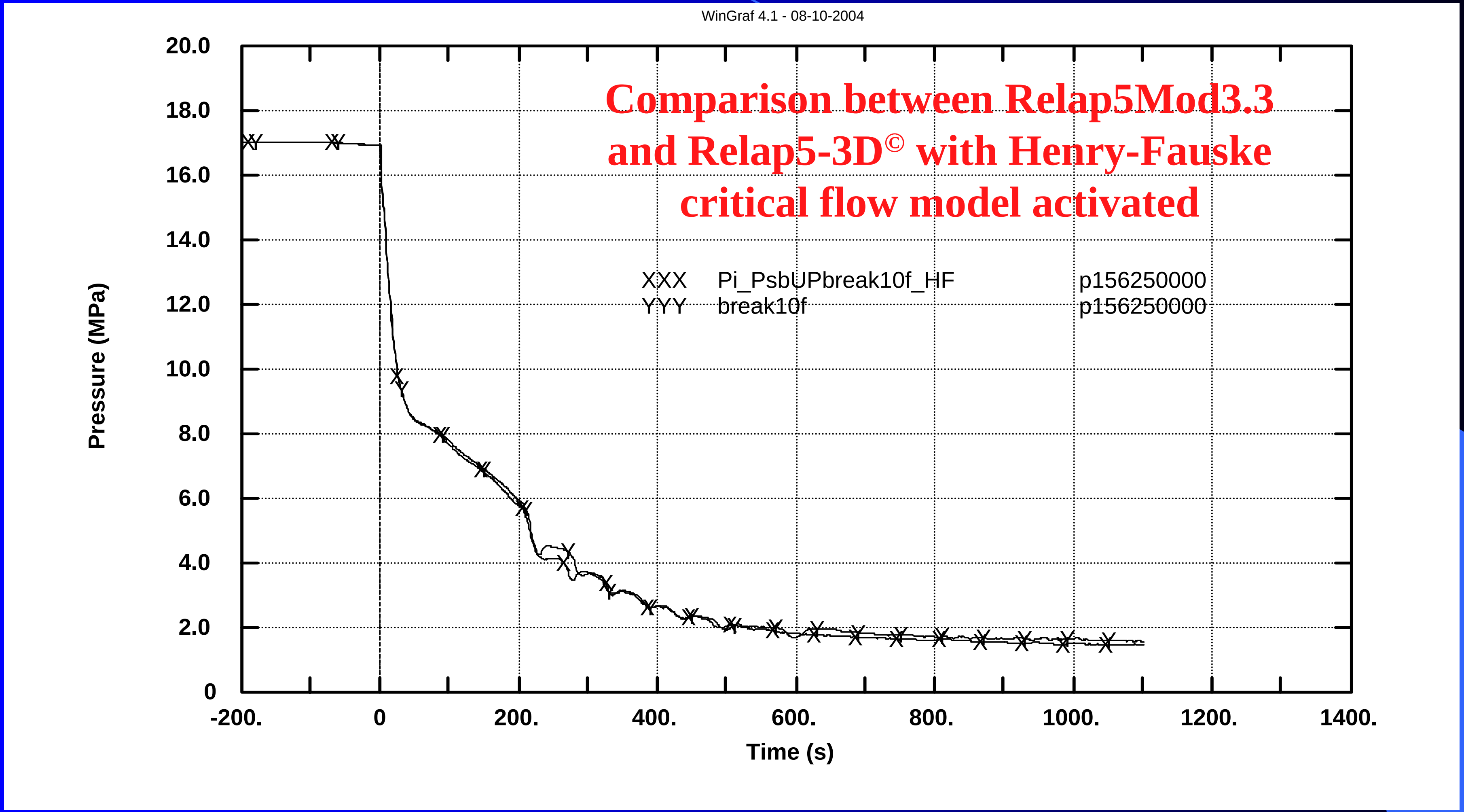
Different calculation has been performed in order to evaluate the infuence of the dicharge coefficients variation to the final results

Name input	Subcooled discharge coefficient	Two-phase discharge coefficient	Superheated discharge coefficient	Average accuracy: Prim. press. / Total	Note
Pi_PsbUPbreak10f_A1	-	-	-	0.126 / **0.351**	NQ
Pi_PsbUPbreak10f_A2	0.75	1	1	0.114 / **0.360**	NQ
Pi_PsbUPbreak10f_A3	0.65	1	1	0.116 / **0.354**	NQ
Pi_PsbUPbreak10f_A7	0.65	0.9	0.8	0.089 / **0.337**	Q
Pi_PsbUPbreak10f_HF	-	-	-	0.0773 / **0.347**	Q
	Henry Fauske option active				

PRZ PRESSURE – RELAP5-3D©



PRZ PRESSURE – EXP, R5M3.3, R5-3D



FFT-BM APPLICATION

Parameters		Relap5/Mod3.3 Pi_PsbUPbreak10f		Relap5-3D© v2.2.4 Pi_PsbUPbreak10f_A1		Cathare2v1.5b PSB_04e10_test#1	
#	Measured parameter	AA	WF	AA	WF	AA	WF
1	PRZ pressure	0.08	0.06	0.12	0.03	0.10	0.062
2	SG2 pressure - secondary side	0.1	0.05	0.13	0.04	0.09	0.042
3	SG3 pressure - secondary side	0.07	0.05	0.30	0.05	0.24	0.058
4	ACC1 pressure	0.1	0.02	0.23	0.01	0.08	0.019
5	ACC2 pressure	0.1	0.03	0.21	0.01	0.08	0.025
6	Core inlet fluid temperature	0.07	0.03	0.12	0.02	0.32	0.052
7	Core outlet fluid temperature	0.07	0.03	0.11	0.02	0.10	0.034
8	Upper head fluid temperature	0.79	0.04	0.75	0.05	0.82	0.057
9	Heater rod temp. (bottom level)	0.12	0.06	0.14	0.04	0.24	0.069
10	Heater rod temp. (middle level)	0.78	0.14	0.57	0.08	0.99	0.068
11	Heater rod temp. (high level)	0.04	0.13	0.87	0.05	1.00	0.043
12	Integral break flow rate	0.26	0.06	0.09	0.06	0.06	0.055
13	Break flow rate	1.98	0.05	0.67	0.14	0.98	0.162
14	Primary side total mass	0.97	0.05	0.14	0.08	0.18	0.065
15	Core power	0.16	0.07	0.97	0.12	0.13	0.068
16	DP inlet-outlet SG 2	1.10	0.13	0.99	0.13	0.98	0.134
17	DP SG 2 inlet hot header top	0.06	0.13	0.45	0.08	0.34	0.090
18	ECCS flow rate	0.48	0.10	0.04	0.12	0.06	0.136
TOTAL		**0.4**	0.05	**0.35**	0.04	**0.36**	0.221

FFT-BM APPLICATION – SENSTIVITY STUDIES

Parameters		Relap5-3D© v2.2.4 Pi_PsbUPbreak10f_A2		Relap5-3D© v2.2.4 Pi_PsbUPbreak10f_A3		Relap5-3D© v2.2.4 Pi_PsbUPbreak10f_A7	
#	Measured parameter	AA	WF	AA	WF	AA	WF
1	PRZ pressure	0.114	0.05	0.116	0.03	0.089	0.04
2	SG2 pressure - secondary side	0.12	0.04	0.13	0.04	0.04	0.05
3	SG3 pressure - secondary side	0.30	0.05	0.30	0.05	0.09	0.06
4	ACC1 pressure	0.22	0.01	0.22	0.02	0.22	0.02
5	ACC2 pressure	0.19	0.01	0.19	0.01	0.19	0.01
6	Core inlet fluid temperature	0.12	0.02	0.12	0.02	0.12	0.02
7	Core outlet fluid temperature	0.10	0.02	0.10	0.02	0.10	0.02
8	Upper head fluid temperature	0.75	0.05	0.75	0.05	0.75	0.05
9	Heater rod temp. (bottom level)	0.19	0.05	0.14	0.04	0.14	0.04
10	Heater rod temp. (middle level)	0.89	0.06	0.57	0.08	0.60	0.08
11	Heater rod temp. (high level)	0.97	0.05	0.91	0.05	0.89	0.06
12	Integral break flow rate	0.08	0.05	0.08	0.06	0.09	0.06
13	Break flow rate	0.70	0.13	0.70	0.14	0.69	0.13
14	Primary side total mass	0.14	0.08	0.14	0.08	0.14	0.08
15	Core power	0.16	0.07	0.06	0.12	1.04	0.11
16	DP inlet-outlet SG 2	0.96	0.13	0.96	0.13	0.96	0.13
17	DP SG 2 inlet hot header top	0.43	0.08	0.40	0.08	0.43	0.08
18	ECCS flow rate	0.04	0.12	0.04	0.12	0.05	0.12
TOTAL		0.360	0.04	0.354	0.04	0.337	0.048

CONCLUSIONS (1 of 2)

The test 11% UP break has been analyzed with ***Relap5/Mod3.3beta, Relap5-3D©v2.2.4, and Cathare2v1.5b*** codes

In particular:

- The analyses performed, during the set up of the nodalizations, have showed that particularly critical are the break schematization, the hydroaccumulator modeling and the loss coefficient in the break.
- The difficulties to reproduce the dry-out in the core have been highlighted.
- For each code has been investigated the quantitative accuracy evaluation of the results by the application of the FFT-BM and the obtained results have been compared.
- Sensitivity studies have been performed in order to evaluate the discharge coefficient, used in the critical flow model, suitable to get results similar to the experimental trends with Relap5-3D code.
- The activation of the Henry Fauske option in Relap5-3D code has shown results very similar to the Relap5Mod3.3 code and in good agreement with the experimental results.

CONCLUSIONS (2 of 2)

- These nodalizations (Relap5 and Cathare2) will be applied to other experiments performed in the PSB facility in the framework of the Tacis and the OECD projects (at present the preliminary pre-tests have been almost finished for 12 experiments in the framework of the Tacis project with both codes).
- The results from the analyses will be expected to enlarge the error database of the CIAU method for Relap5 code and to realize the first database for Cathare2 code. At present this methodology has been already applied several times (e.g. including Angra-2, Kozloduy-3 and Mochovce analyses). It must been stressed that the error database enlargement or realization must be achieved without changes in the nodalisation structure and in user options.