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Follow-up of IRIS design in support to the development of the SPES-3 facility

R. Ferri, F. Bianchi

Report RdS/2010/64

FOLLOW-UP OF IRIS DESIGN IN SUPPORT TO THE DEVELOPMENT OF THE SPES-3 FACILITY

R. Ferri, F. Bianchi

Settembre 2010

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Titolo

Follow-up of IRIS design in support to the development of the SPES-3 facility

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Descrittori

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Sommario

That report has been issued in the frame of the second research programme of ENEA-MSE agreement and it is one of the deliverables of the task B "IRIS Integral testing": Design review of SPES-3 facility and follow-up of IRIS design" of the work-programme 2 "Evolutionary INTD reactors" of the research theme on "Nuovo Nucleare da Fissione".
The document summarizes the activities performed by ENEA and SIET for updating the SPES3 final design owing to the decisions, taken during technical discussions and meetings in order to better reproduce the IRIS plant behaviour during a postulated SBLOCA transients.

Note

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REV.	DESCRIZIONE	DATA		REDAZIONE	CONVALIDA	APPROVAZIONE

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NOMENCLATURE

ADS	Automatic Depressurization System
ADS-DT	ADS-Double Train
ADS-ST	ADS-Single Train
APE	After Pressure Equalization
BAF	Bottom of Active Fuel
Bot	Bottom
BC	Base Case
BPE	Before Pressure Equalization
CAV	Cavity
CIRTEN	Consorzio Interuniversitario Nazionale per la Ricerca Tecnologica Nucleare
CV	Containment Volume
DC	Downcomer
DEG	Double Ended Guillotine
DP	Differential pressure
DT	Difference of temperature
DVI	Direct Vessel Injection
DW	Dry Well
EBS	Emergency Boration System
EBSIN	Emergency Boration Tank regarding INtact loop
EBSBR	Emergency Boration TanK regarding BRoken lInoop
EBT	Emergency Boration Tank
EHRS	Emergency Heat Removal System
FER	University of Zagreb
FL	Feed Line
FRC_{br}	Fractional rate of Change at the break
FRC_{1phV}	Fractional rate of Change single phase Vapour
FRC_{1phL}	Fractional rate of Change single phase Liquid
FRC_{2ph}	Fractional rate of Change two-phase
FW	Feed Water
GOTHIC	Generation Of Thermal-Hydraulic Information for Containments
HX	Heat Exchanger
IRIS	International Reactor Innovative and Secure
ITF	Integral Test Facility
LGMS	Long Term Gravity Make-up System

LM	LOCA Mitigation signal
LOCA	Loss of Coolant Accident
MFIV	Main Feed Isolation Valve
MSIV	Main Steam Isolation Valve
n.a.	Not available
NPP	Nuclear Power Plant
NRC	Nuclear Regulatory Commission
P	Pressure
PCC	Passive Containment Cooling
POLIMI	Politechnic of Milan
POLITO	Politechnic of Tourin
PRZ	Pressurizer
PSS	Pressure Suppression System
PWR	Pressurized Water Reactor
QT	Quench Tank
RC	Reactor Cavity
RCP	Reactor Coolant Pump
RELAP	REactor Loss of coolant Analysis Program
RIS	Riser
RV	Reactor Vessel
RWST	Refuelling Water Storage Tank
SG	Steam Generator
SIET	Società Informazioni Esperienze Termoidrauliche
SL	Steam Line
SPES	Simulatore Per Esperienze di Sicurezza
T	Temperature
TAF	Top of Active Fuel
UNIPA	University of Palermo
UNIPI	University of Pisa
WEC	Westinghouse Electric Company

1. INTRODUCTION AND PURPOSE

The SPES3 facility (1:100 volume scale and 1:1 height scale) is being designed at SIET laboratories to simulate the IRIS, an integral, modular, small-medium size PWR, belonging to the Innovative Nuclear Power Plants, under development by an international consortium led by Westinghouse, [1] [2].

The design of the facility has been carried-out following a series of steps:

- the Conceptual design [2];
- the development of a nodalization for the RELAP5 thermal-hydraulic code [3];
- the simulation of five Design Basis Events specified in the test matrix [4] [1];
- the issue of the final design [5] [6] [7] [8] [9];
- the design of a load bearing structure [10];
- the execution of sensitivity calculation on the SPES3 nodalization aimed at the facility design review to better match the IRIS behaviour by RELAP5 and GOTHIC code simulations [11] [12] [13] [14].

Based on the SPES3 conceptual design [2], the final design of the SPES3 RV has been carried-out with specific manufacturing solutions developed by Mangiarotti Nuclear [15] [16] [17] [18].

Moreover, a test loop for heater rod prototype testing has been designed at SIET to test different manufacturer products and select which one better responds to SPES3 specification [19].

In parallel to the above-mentioned activities and based on the results of the design basis events, the use of special instrumentation for two-phase flow measurement on the break lines and ADS lines has been investigated, [4] [20] [21] [22].

All the above design steps have been carried-out through a continuous interaction among the members of the IRIS consortium, each providing its contribution to the quality and reliability of the design.

During the reference period of the research programme funded by MSE (April 2009 and September 2010), conference-calls and meetings have provided important feedback on the SPES3 design, which main outcomes are summarized in this document. In particular it contains a synthesis of the decisions, taken during technical discussions and meetings, which led to update the SPES3 final design to better reproduce the IRIS plant behaviour during a postulated SBLOCA transient.

2. SPES3 PROJECT EVOLUTION BETWEEN APRIL 2009 AND SEPTEMBER 2010

This section summarizes the activity carried out by ENEA and SIET on the SPES3 design during the reference period. The activities performed by CIRTEN are described in the document [24].

2.1 SPES3 design status at April 2009

The geometrical details of the SPES3 facility design status at April 2009 are reported in the documents [3] [4] [5] [6] [7] [8] [9].

2.2 Interaction among IRIS consortium members and main outcomes

The SPES3 facility design review has been carried out on the basis of a continuous interaction among the members of IRIS consortium, during meetings and weekly conference-calls. The decisions and outcomes of discussions are detailed in the meeting and conference-call minutes, reported in Chapter 4 of this document.

The main investigated items are summarized in Tab. 2. 1, together with reasons for investigation, decisions, achievements and references.

Tab. 2. 1 – SPES3 primary, secondary loop B, and containment system layout

Item	Reasons for investigation	Decisions	Achievements	Reference
SPES3 DW inner surface insulation	Containment pressure discrepancy between SPES3 and IRIS	SIET: simulation of DW with different insulation materials and thickness. WEC and UNIPI provide possible insulating material characteristics. WEC and UNIPI develop a program for DW thermal insulation effect studies.	No inner surface insulation to be used in SPES3 DW	96th to 100th Conf-calls 21st IRIS Team meeting 101st and 102nd Conf-calls 106th and 107th Conf-calls 109th Conf-call
SPES3 DW heat structures	Containment pressure discrepancy between SPES3 and IRIS	SIET: simulation of SPES3 DW with IRIS equivalent heat structures. Heat structure preheating simulation. WEC-UniPi DW insulation performance investigation	SPES2 DW and other containment tank thickness reduction by design pressure reduction from 2 MPa to 1.5 MPa. DW heat structure preheating at 84°C to compensate for larger mass in SPES3 than IRIS	97th Conf-call 100th to 103rd Conf-calls 105th Conf-call
SPES3 DW volume	Containment pressure discrepancy between SPES3 and IRIS	SIET: simulation of SPES3 DW with reduced volume	DW volume exactly scaled 1:100 on IRIS	98th and 100th Conf-calls
Special instrumentation	Two-phase mass flow measurement in break and ADS lines	SIET and POLITO meet with Dr. Prasser at ETH (Zurich) for Wire Mesh Sensors (WMS) If no WMS or capacitive sensor can be used, SIET will use gamma-densitometers	Special instrumentation limited to lines: DVI split, EBT split, ADS split, ADS-Stag I ST and DT. WMS not suitable downstream of the break for high void fraction; critical upstream position for high pressure. Alternative solution: capacitive sensors.	SIET meeting April 17, 2009 105th to 106th Conf-calls 114th and 122nd Conf-calls
TRACE code modelling of SPES3	Facility modelling with a US-NRC reference code	UNIPA, in the frame of CIRTEN, to model the SPES3 facility with TRACE code		SIET meeting April 17, 2009
Condensation correlations in RELAP5	Incorrectness of RELAP5 vertical tube condensation correlations.		FER and Polimi produced a RELAP5 (L4 and L5) modified version to be tested on experimental data	97th to 98th Conf-call
DBE simulation in SPES3	Presentation of results			21st IRIS Team meeting
PSS vent lines and PSS sparger	Discrepancy between SPES3 and IRIS simulation of PSS vent outlet elevation and equivalent volume	SIET calibrates SPES3 PSS vent line pressure drops on IRIS DP by proper pipe size and calibrated orifice.	Set the PSS vents and PSS sparger at the same elevation in SPES3 and IRIS.	102nd Conf-call 108th to 114th Conf-calls
ADS Stage-I mass flow	Discrepancy between SPES3 and IRIS simulation	SIET resizes ADS Stage-I orifices to match IRIS mass flow	ADS ST Stage-I orifice 5.637 mm; ADS DT Stage-I orifice 7.973 mm	103rd and 106th Conf-calls
LGMS injection mass flow	Discrepancy between SPES3 and IRIS simulation			103rd and 106th Conf-calls
PSS to DW injection mass flow and differential pressure	Discrepancy between SPES3 and IRIS simulation			106th and 111th Conf-calls
PSS heat structures	Discrepancy in PSS pressure between SPES3 and IRIS simulation			103rd to 104th Conf-calls
Air volume in containment tanks	Containment pressure discrepancy between SPES3 and IRIS	Reduce air space in SPES3 containment tanks to scale correctly IRIS volume	Containment tank volumes to scale IRIS 1:100: PSS 4.59 m^3 LGMS 1.5 m^3 DW 32.27 m^3 RC 4.5 m^3	104th Conf-call

Item	Reasons for investigation	Decisions	Achievements	Reference
SPES3 Containment tank metal wall temperature control	Containment pressure discrepancy between SPES3 and IRIS	No need of temperature control on containment tank walls during the transient	All SPES3 containment tank walls preheated at 84°C (only in air zones). Water zones 48.9 °C	105th , 107th , 112th Conf-calls
SPES3 design documentation	Status of documentation check	SPES3 design is not based on the final approved IRIS design. SPES3 experimental data to be utilized for IRIS licensing	SPES3 documentation to follow QA plans that meet 10CFR50 App. B and ASME NQA1-1994.	109th Conf-call
IRIS containment heat structures	Containment pressure discrepancy between SPES3 and IRIS	Added metal and concrete structures to the IRIS containment compartments model for GOTHIC		109th Conf-call
SG tubes	Discrepancy between SPES3 and IRIS long term containment pressure	Check SG tube size and material in IRIS and SPES3 SG tube number scaling check: IRIS SG has 656 tubes, so 13 tubes/SG pairs would be a closer match than 14 tubes (SPES3 design). SIET performs transient runs with 13 and 14 SG tubes for comparison SIET resize SG tube inlet orifice for parallel tube row oscillation reduction	SPES3 SG tubes: OD 17.46 mm, 1.688 mm thickness, 32 m length, AISI 316 IRIS SG tubes: OD 17.46 mm, 2.11 mm thickness, 32 m length, Inconel 690	110th and 124th Conf-calls 126th to 128th Conf-calls
Quench Tank initial conditions	Containment pressure discrepancy between SPES3 and IRIS	Transient simulation with initially empty QT		110th Conf-call
FSA application to SPES3 and IRIS results	Quantification of main distortions between IRIS and SPES3	WEC-UNIPI apply FSA to SPES3-120 and IRIS-HT5d updated DVI SBLOCA transient results SIET transmit WEC-UNIPI SPES3-127 case for FSA UniPI applies FSA to SPES3-124 and IRIS HT5g		111th Conf-call 113th to 114th Conf-calls 117th and 123rd Conf-calls 119th to 120th Conf-calls
Feed lines, Steam lines, EHRS Hot and Cold leg layout	RV final design by Mangiarotti Nuclear: modified FL and SL connection points	SIET redesign the FL and SL layout according to MN final design of RV and consequently the EHRS HL and CL		113th Conf-call
Primary pump piping layout	RV final design by Mangiarotti Nuclear: modified pump piping connections	MN redesign the pump piping layout		114th Conf-call
TRACE modelling of IRIS	Code comparison	WEC performs a TRACE model of IRIS		114th , 116th and 120th Conf-calls
Heater rod simulators	SPES3 heat rod prototypes	SIET responsible for rod prototypes purchasing and testing. Possible manufacturers: Thermocoax, Rotfil.	SIET completed the Heater rod prototype test loop design. Prototype order to both Thermocoax and Rotfil	115th and 120th Conf-calls 128th to 133th Conf-calls
SPES3 primary to secondary to RWST heat transfer	Containment pressure opposite trend between SPES3 and IRIS, after 50 ks of transient			116th and 117th Conf-calls 133th Conf-call
RWST modelling	Energy conservation at RWST	FER and SIET compare the RWST models	FER simulates IRIS RWST according to SPES3 RWST modelling	116th and 117th Conf-calls 131st Conf-call
Droplets effect on condensation in DW	Containment pressure discrepancy between SPES3 and IRIS	FER investigates the droplet size effect on condensation in GOTHIC		116th Conf-call

Item	Reasons for investigation	Decisions	Achievements	Reference
EHRS-RWST stand alone model for SPES3 and IRIS	Containment pressure opposite trend between SPES3 and IRIS, after 50 ks of transient Influence of EHRS tube material	FER and SIET run EHRS-RWST stand alone model for IRIS and SPES3 with controlled boundary conditions to analyze the performance. SIET studies EHRS tube partial insulation with Teflon to reduce heat transfer FER and SIET study influence of SG-EHRS loop filling ratio SIET compares the SPES3 and IRIS EHRS-RWST stand alone models SIET redesign EHRS loop lines to fit IRIS DP. SIET compare three cases: SPES3-adjusted to PERSEO; IRIS adjusted to PERSEO; IRIS original in the pressure range 0.2 to 9 MPa.	SPES3 EHRS tubes partial thermal insulation with Teflon to compensate for extra-surface and material SPES3 and IRIS RWST “tube to slice area ratio” set as in PERSEO testing campaign SPES3 EHRS loop HL and CL layout and size redesigned Use IRIS EHRS-RWST model adjusted to PERSEO testing campaign	117th to 126th Conf-calls l
SPES3 SG-EHRS loop filling ratio	Containment pressure opposite trend between SPES3 and IRIS, after 50 ks of transient	SIET provides SPES3 EHRS loop mass distribution		120th Conf-call
ADS Stage-II actuation	Discrepancy between SPES3 and IRIS	FER modify the model to actuate LGMS on low LGMS mass as in SPES3		120th Conf-call
RWST water temperature	Discrepancy between SPES3 and IRIS	FER checks reasons for differences in RWST temperature between cases HT5g and HT5h FER adjust RWST model to correct the interaction between the water and NSSS building atmosphere		121st , 127th and 129th Conf-calls 131st to 133th Conf-calls
SPES3 piping		Piping layout and stress analysis review consequent to RV final design		132nd Conf-call
IRIS final results for DVI DEG break transient	Results for comparison with SPES3 and FSA application		SIET will use the data to conclude the analysis report for SPES3 design review	134th to 135th Conf-calls

3. CONFERENCE CALL AND MEETING MINUTES

This section reports the minutes of conference-calls and meetings between April 2009 and April 2010.

3.1 Conference call minutes

3.1.1 96th Conference Call on IRIS Integral Testing

2009 April 3rd

Participants:

F. Bianchi (ENEA)
D. Grgic (FER)
J. Carbajo, G. Yoder (ORNL)
C. Congiu, R. Ferri (SIET)
M. Dzodzo, G. Storrick (WEC)

1. We approved the minutes of the March 27th conference call.
2. Facility design
   - SIET finished the design documents and issued them to ENEA.
   - SIET finished the analysis documentation for the five base events and issued them to ENEA.
   - Roberta is working on the analysis documentation for the two sensitivity cases.
   - ENEA and SIET signed a contract for the final mechanical design of the reactor vessel and internals.
3. IRIS transient analyses
   - No progress due to an outage at Krsko that required Davor's support.
4. Scaling Analysis
   - Alessandro Carnevali will arrive at Westinghouse to assist Milorad, starting in mid-April.
   - Milorad still needs the drywell temperature vs. time data (spreadsheet form) from Davor's DVI break run.
   - Milorad is looking for a suitable insulating material for the inner surface of the drywell.
5. The next conference call will be on Friday, April 17th, 2009 at 9:00 a.m. US time, 3:00 p.m. EU time. **We will not have a conference call on Good Friday, April 10th.**

3.1.2 97th Conference Call on IRIS Integral Testing

2009 April 17th

Participants:

F. Bianchi (ENEA)
D. Grgic (FER)
J. Carbajo, G. Yoder (ORNL)
D. Papini (POLIMI)
C. Congiu (SIET)
M. Dzodzo, G. Storrick (WEC)
A. Carnevali (UNIPI/WEC)

1. We approved the minutes of the April 3rd conference call.
2. Facility design
   - SIET is finishing the documentation conclusions for the two sensitivity analyses completed earlier.
   - Cinzia is running two additional sensitivity analyses. The first reduces the drywell volume, and the second also adds internal insulation (3mm of the 902 material Milorad identified). These will finish running next week.
   - Davor recalls running similar sensitivity cases for IRIS while we were considering going to a 22.5 m. containment. He will research what he found at that time for comparison.
   - Cinzia intends to start another run including heat structures similar to what Davor has in the latest IRIS runs. Davor will supply the necessary information.
   - SIET reiterated their concerns about manufacturing difficulties associated with insulating the inside of the drywell tank.
   - Gary emphasized that we will never have a perfect model of the condensation in the drywell. Computer modeling alone will not solve the problem or provide confidence in the test results, so it is essential that we have a way to perform sensitivity studies in the containment as part of the test program. Milorad's idea of insulating the inner surface drywell tank and then adding various metal masses inside the tank is one way to accomplish this.
3. IRIS transient analyses
   - Davor is running a case with the new RWST/EHRS model and the latest containment model. He will document it over the weekend and send the results early next week.
   - Davide intends to use the new RELAP5 EHRS condensation heat transfer model for SPES-3 runs, and asked if Davor could do the validation. Davor believes that it should work (he is already using it for IRIS analyses). Davor will provide documentation
   - Davide had doubts about the containment condensation correlation; specifically, why Uchida? Davor replied that the Uchida correlation is licensed and recommended by the USNRC.
   - Davide will provide a preliminary report on his analyses tomorrow. Gary asked that it be placed in the eRoom (marked "Preliminary").
4. Scaling Analysis
   - Alessandro Carnevali started working at Westinghouse this week. He is researching insulation options (see attachment in file "IRIS_SPES3_Conf Call Minutes #97 Att 1 INSULATION.xls").
5. The next conference call will be on Friday, April 24th, 2009 at 9:00 a.m. US time, 3:00 p.m. EU time.

3.1.3 98th Conference Call on IRIS Integral Testing

2009 April 24th

Participants:

F. Bianchi (ENEA)
D. Grgic (FER)
J. Carbajo, G. Yoder (ORNL)
C. Congiu, R. Ferri (SIET)
M. Dzodzo, G. Storrick (WEC)
A. Carnevali (UNIPI/WEC)

1. We approved the minutes of the April 17th conference call.
2. Facility design
   - SIET completed the documentation for the two sensitivity analyses and has to send it to ENEA.
   - SIET restarted the two additional sensitivity analyses mentioned in last week's call.. The first reduces the drywell volume, and the second also adds internal insulation (3mm of the 902 material Milorad identified). These will finish running in about 10 days.
   - Davide gave SIET a modified version of RELAP5 (L4) containing revised condensation correlations. Earlier this week, Fosco authorized running a case to compare this with the PERSEO data. Davor thought that the L5 version may be more appropriate; he will confirm and then provide a copy to SIET, if necessary.
   - Roberta recommended that Milorad and Alessandro use the latest cases (currently running) for future Fractional Scaling Analyses. SIET will transfer the results to Westinghouse when they are available.
   - Gary emphasized that we will never have a perfect model of the condensation in the drywell. Computer modeling alone will not solve the problem or provide confidence in the test results, so it is essential that we have a way to perform sensitivity studies in the containment as part of the test program. Milorad's idea of insulating the inner surface drywell tank and then adding various metal masses inside the tank is one way to accomplish this.
3. IRIS transient analyses
   - No major changes. Davor is post-processing earlier results and reviewing Davide's results.
   - Davide intends to use the new RELAP5 EHRS condensation heat transfer model for SPES-3 runs, and asked if Davor could do the validation. Davor believes that it should work (he is already using it for IRIS analyses). Davor will provide documentation
   - Davide had doubts about the containment condensation correlation; specifically, why Uchida? Davor replied that the Uchida correlation is one that the USNRC approved and recommends.
   - Davide will provide a preliminary report on his analyses tomorrow. Gary asked Davide to place it in the eRoom (marked "Preliminary").
4. Scaling Analysis
   - Westinghouse is archiving the files left by Donato, Gaetano and Simone.
   - Alessandro continued researching drywell insulation options.
5. Schedules
   - Gary will update the schedule after he call to incorporate information just received from Fosco.
6. The next conference call will be on Thursday, April 30th, 2009 at 9:00 a.m. US time, 3:00 p.m. EU time. **NOTE THE CHANGE IN DAY (due to the European Holiday on Friday).**

3.1.4 99th Conference Call on IRIS Integral Testing

2009 April 30th

Participants:

F. Bianchi (ENEA)
D. Grgic (FER)
J. Carbajo, (ORNL)
D. Papini, M. Ricotti (POLIMI)
C. Congiu, R. Ferri (SIET)
M. Dzodzo, G. Storrick (WEC)
A. Carnevali (UNIPI/WEC)

1. We discussed changes to the minutes of the April 24th conference call.
2. Facility design
   - SIET is running a case with Davor's heat structures, scaled (area and mass) down to SPES-3.
   - SIET met with Mangiarotti to discuss the manufacturability of the reactor vessel.
     - It appears that the vessel thickness either has to increase or the material has to change from 304 to 304N. Mangiarotti needs to determine what the availability of 304N is.
     - They confirmed that the nozzle thicknesses need to increase, and that there is room for the increase.
     - Mangiarotti and SIET will look at the internal after completing the review of the vessel.
   - Roberta started a run to compare with the PERSEO data. Davide will need to extract the results. Davor confirmed that either version L4 or L5 are adequate (the coding differs but the underlying algorithms do not).
3. IRIS transient analyses
   - No major changes. Davor is relatively unavailable at present, but should start to have time free the week after next.
4. Scaling Analysis
   - Alessandro continued researching drywell insulation options.
     - SIET is still concerned about insulating the drywell interior and is looking at options. One suggestion is to adjust the drywell volume. A second is to reduce the design pressure which will reduce the required wall thickness. Milorad believes this will help, but not enough to eliminate the problem.
5. The next conference call will be on Thursday, May 7th, 2009 at 9:00 a.m. US time, 3:00 p.m. EU time. **NOTE THE CHANGE IN DAY (due to Gary being unavailable on Friday May 8th).**

3.1.5 100th Conference Call on IRIS Integral Testing

2009 May 7th

Participants:

J. Carbajo, (ORNL)
D. Papini, G. Tortora (POLIMI)
C. Congiu, R. Ferri (SIET)
M. Dzodzo, G. Storrick (WEC)
A. Carnevali (UNIPI/WEC)

1. We approved the minutes of the April 24th and April 30th conference calls.
2. Facility design
   - SIET was running three sensitivity cases, as follows:
     - The first case lowers the drywell volume to 1/100th the IRIS value. [Note: For historical reasons, the SPES-3 drywell volume in the equipment specification was ~9.6% larger - GDS]. This run is complete. The drywell pressure transient is essentially the same as the in the previous run with the larger volume. SIET observed that with a larger drywell, there is less air and more steam in the gas flow to the PSS, so the PSS condenses more steam. The PSS temperature increases more with a smaller drywell, but the drywell pressure does not change much.
     - The second run uses the same drywell volume as the first, but adds 3 mm of Contronics #902 alumina silicate insulation on the inner surface of the drywell. This run is still executing.
     - The second run uses the same drywell volume as the first, does not include insulation, but changes the heat structures to scale IRIS 1:100 in both area and volume. This run is still executing. The expectation is that this run will nearly reproduce the IRIS results.
   - RV: Mangiarotti found that 304N is not readily available, so they recommend using 304 as originally planned. This will require increasing the vessel thickness by ~5-7mm.
3. IRIS transient analyses
   - No report: Davor was not able to attend this week's call.
4. Scaling Analysis
   - Alessandro placed a table [IRIS_SPES3_Conf Call Minutes #100 Att 1 Insulation Table 2.doc] of insulating material properties in the eRoom. He continues researching drywell insulation options and is now contacting producers and reviewing their replies.
   - Milorad reported that the backup of Donato, Gaetano, and Simone's work is complete.
   - Milorad reported that Gaetano modified his results to account for steam partial pressures. The results did not change significantly. Donato also modified his model, but has not completed the revised analysis.
5. The next conference call will tentatively be on Friday, May 29th, 2009 at 9:00 a.m. US time, 3:00 p.m. EU time. **Because of the team meeting in Tallinn, we do not plan to have calls on May 15th or 22nd.**

3.1.6 101st Conference Call on IRIS Integral Testing

2009 May 29th

Participants:

F. Bianchi (ENEA)
D. Grgic (FER)
J. Carbajo, G. Yoder (ORNL)
C. Congiu, R. Ferri (SIET)
G. Storrick (WEC)
A. Carnevali (UNIPI/WEC)

1. We approved the minutes of the May 7th conference call.
2. Facility design
   - Roberta placed two documents (Attachments 1 & 2) in the eRoom describing recent sensitivity runs. In addition, refer to SIET's presentation at the Tallinn team meeting.
     - As stated in Tallinn, insulating the inner surface of the drywell does not appear to be useful.
       - Alessandro noted that the insulation thicknesses used (1 mm. Teflon, 1.5 mm. & 3 mm. of #902) are not enough to obtain the desired results.
       - Davor observed that, at present, insulating the inner surface of the drywell appears to be expensive, difficult, and questionable.
     - A sensitivity run reducing the size of the drywell (1:150 scale) did not produce the desired effects and has other disadvantages. Roberta will discuss these with Milorad next week.
     - Reducing the drywell wall thickness from 25 mm. to 15 mm. increases the peak pressure in the SPES3 drywell by ~100 kPa. This is promising.
       - Reducing the thickness requires decreasing the drywell design pressure to 1.5 MPa.
       - Davor has never observed an IRIS drywell pressure near 1.5 MPa; virtually all runs peak at less than 1.2 MPa. Roberta's SPES-3 runs peak lower.
     - Gary noted that we based the original SPES-3 drywell design on the achievable practical design pressure for the IRIS containment. Based on the runs made to date, reducing the SPES-3 drywell design pressure to 1.5 MPa looks desirable. In addition to the effect of making the pressure response for SPES-3 more like IRIS, reducing the design pressure might result in a cost savings. This applies to all containment-side vessels and piping in SPES-3.

   Action Item (Roberta): Roberta will submit a formal change request to modify the SPES-3 specification accordingly.

   Update: Roberta submitted change request 003 on May 29th.

     - Roberta needs to have Davor extract containment pressure, etc. responses from the GOTHIC side of the IRIS model so that she can plot them along with the SPES-5 esponses..

   Action Item (Davor): Provide the containment pressure & other responses that Roberta needs.
3. IRIS transient analyses
   - Because of University commitments, Davor will not be available for significant work until late June.
4. Scaling Analysis
   - Milorad was not able to attend the call.
   - Alessandro placed additional insulation material information (attachment 3) into the eRoom.
   - Westinghouse has received one insulation sample for test, and two more are coming.
5. The next conference call will be on Thursday, June 4th, 2009 at 9:00 a.m. US time, 3:00 p.m. EU time. **Note the change to Thursday for this week.**

3.1.7 102nd Conference Call on IRIS Integral Testing

2009 June 4th

Participants:

F. Bianchi (ENEA)
D. Grgic (FER)
D. Papini (POLIMI)
C. Congiu, R. Ferri (SIET)
M. Dzodzo, G. Storrick (WEC)
A. Carnevali (UNIPI/WEC)

1. We approved the minutes of the May 29th conference call.
2. Facility design
   - Because of holidays in Italy, there were no major changes since the last conference call.
   - Roberta raised an issue during the week about the PSS vent line arrangements in Davor's model. We agreed that this was only a modeling choice that does not reflect a change to the IRIS configuration. There is no change to the SPES-3 facility.
   - We discussed reducing the containment-side design pressures from 2.0 MPa to 1.5 MPa. The design temperatures will change to the corresponding saturation temperatures (where appropriate). This appears desirable and there were no objections; however, Roberta asked that we hold off on approving this until she checks some other analyses.
   - We discussed Roberta's sensitivity runs that investigated insulating the inner surface of the drywell.
     - As stated in Tallinn, SIET believes that insulating the inner surface of the drywell does not appear to be useful. Milorad has not had time to review the results.
     - Alessandro is developing a program to test insulation effects quickly. This should help chose the best thickness.
   - Roberta emphasized that insulating the inner surface of the drywell is a high-risk proposition.
     - SIET has no experience in this area.
     - Preheating the drywell wall appears to be an easy way to change the condensation rate. Davor noted that his IRIS runs show that containment pressure is sensitive to initial containment wall temperature.
     - Milorad is concerned that not insulating the drywell risks distorting the test results for the NRC.
     - Davor believes that the time of the flow reversal is more important than the peak containment pressure.
     - Milorad described another idea for insulating the drywell (using pipes). Gary asked Milorad to quantify the idea to see if it is feasible.
3. Scaling Analysis
   - Milorad and Alessandro continue to collect insulation data. They now have three samples for autoclave testing.
   - To support the schedule for completing the scaling analysis by September, Milorad needs the final SPES-3 and Analysis runs by the end of June.
4. IRIS transient analyses
   - Because of University commitments, Davor will not be available for significant work until late June.
5. The next conference call will be on Friday, June 12th, 2009 at 9:00 a.m. US time, 3:00 p.m. EU time.

3.1.8 103rd Conference Call on IRIS Integral Testing

2009 June 12th

Participants:

F. Bianchi (ENEA)
D. Grgic (FER)
J. Carbajo (ORNL)
C. Congiu, R. Ferri (SIET)
M. Dzodzo, G. Storrick (WEC)
A. Carnevali (UNIPI/WEC)

1. We approved the minutes of the June 4th conference call.
2. Facility design
   - SIET has been comparing the IRIS and SPES3 analysis results and noticed the following:
     - The SPES-3 ADS mass flow is about 1.5 times the scaled IRIS flow, and follows the same trend; indicating a need to check the valve areas.
     - The SPES-3 LGMS injection mass flow is about twice the scaled IRIS flow, indicating a need to check the orifice area.
     - The SPES-3 EBT injection mass flow is correctly scaling the IRIS flow, indicating that the orifice area is correct.
     - The SPES-3 break flows are scaled well to the IRIS flows.
   - Roberta placed several graphs (Attachment 1) into the eRoom prior to the call:
     - Curve 1 shows that the SPES-3 containment peak pressure is less than the IRIS analysis pressure, even with scaled heat structures. The response is similar for 400 seconds, and then the SPES-3 pressure rises more slowly than the IRIS pressure. This is about the time that the air from the drywell finishes moving to the PSS, and the PSS starts condensing steam.
     - Curves 2 and 3 show that the power transfer to the drywell heat structures is less in IRIS than in SPES-3. This appears to be because SPES3 does not have concrete. The SPES-3 run replaced the concrete with an equivalent metal mass, and concrete has a lower thermal conductivity than steel.
     - Milorad suggested looking at the PSS condensation efficiency. Davor's PSS model has no metal heat structures, but Roberta's SPES-3 model does.
     - After 3000 seconds, the pressure decrease in SPES-3 is greater than that in the IRIS runs. This is probably due to the excessive LGMS flow mentioned earlier.
   - Roberta asked Davor if the multi-node drywell model influenced the PSS function. Davor replied that it did, to some degree. Roberta's SPES-3 model has two volumes connected by transverse junctions, and it gives a symmetric response. Davor's model is connected top & bottom, and gives an asymmetric response.
   - SIET believes that heating the drywell wall before starting a test is feasible. Roberta has started another run with 15 mm. insulation and an initial wall temperature of 84 Celsius. (Earlier runs with 10 mm. insulation reached equilibrium at this temperature at about 2000 seconds).
   - SIET completed another run that showed that changing the PSS vent diameter had no significant effect.
3. IRIS transient analyses
   - Nothing to report.
4. Scaling Analysis
   - Nothing to report.
5. The next conference call will be on Friday, June 19th, 2009 at 9:00 a.m. US time, 3:00 p.m. EU time.

3.1.9 104th Conference Call on IRIS Integral Testing

2009 June 19th

Participants:

F. Bianchi (ENEA)
D. Grgic (FER)
D. Papini (POLIMI)
J. Carbajo, G. Yoder (ORNL)
C. Congiu, R. Ferri, M. Greco (SIET)
M. Dzodzo, G. Storrick (WEC)
A. Carnevali (UNIPI/WEC)

1. We corrected and approved the minutes of the June 12th conference call.
2. Facility design
   - SIET continued comparing the SPES-3 and IRIS analysis parameters:
     - The free volume at the top of the PSS and LGMS in SPES-3 is about 15% larger than the scaled IRIS volume. SIET would like to re-run their analysis with better-scaled volumes, and possibly adjust the size of some tanks.
     - SPES-3 shows a larger drywell to PSS injection than IRIS does. SIET ran a case with a reduced pipe diameter and obtained good agreement.
     - SIET rescaled the LGMS injection orifice and the ADS line orifice to get better agreement with the IRIS flows.
     - SIET started an analysis without PSS heat structures. The run terminated early, but the partial results show that these heat structures affect the response. The LGMS heat structures may also be important. Davor's IRIS model does not have these heat structures; he plans to add them.
3. IRIS transient analyses
   - Davor will have free time soon, and should have new analysis results in about 2 weeks.
4. Scaling Analysis
   - Alessandro is testing his program for analyzing drywell insulation performance
   - Milorad and Alessandro will need final SPES-3 and IRIS analysis runs to begin the final scaling analysis by mid-July. Davor and Roberta can support this schedule.
5. Schedule
   - Fosco emphasized that the contracts with the Italian Government require starting procurement in September. The analysis must be completed by then. Roberta and Davor can support this schedule. Roberta feels that any remaining changes to the facility design will be minor.
6. Facility specification change requests
   - Change request #001 (change to NQA-1 1994 revision). Roberta reminded Gary that this was OK if SIET's work only involved Part 1.

   Update: After the call, Gary confirmed this was OK. Gary will approve the Change Request.

   - Change requests #003, #004, and #005 involve SPES-3 and IRIS analysis dimensions. Roberta and Gary agreed to that it was best to hold these until we've identified all necessary changes (2-3 weeks).
7. The next conference call will be on **Monday, June 29th, 2009** at 9:00 a.m. US time, 3:00 p.m. EU time. **Note the change of day!**

   There will not be a call on July 3rd (USA holiday).

3.1.10 105th Conference Call on IRIS Integral Testing

2009 June 29th

Participants:

F. Bianchi (ENEA)
D. Grgic (FER)
J. Carbajo, G. Yoder (ORNL)
C. Congiu, R. Ferri, M. Greco (SIET)
M. Dzodzo, G. Storrick (WEC)
A. Carnevali (UNIPI/WEC)

1. We approved the minutes of the June 19th conference call.
2. Facility design
   - SIET is revising the model to resize the containment-size tanks and lines for 1.5MPa design pressure. The revised model will be ready by tomorrow.
   - We discussed the sensitivity runs for case SPES3-111 and some previous results.
     - Case 111 assumed 1.5 MPa design pressure (15 mm. wall) with the drywell wall initially at 84°C.
     - This temperature was obtained by an energy balance that compensates for the excess metal mass associated with the 15 mm. wall vs. a 10 mm. wall (obtained by IRIS mass-equivalent scaling).
     - The results are almost identical to case SPES3-105, which assumed a 10 mm. wall.
     - Both runs assumed 10 mm. rock wool insulation and 1 mm. aluminum on the outside of the drywell.
     - There is no need to provide wall temperature control during a test. SIET believes that they can easily preheat the wall with steam and then purge the steam before a test run. Electrical heating would be more difficult and expensive.
     - Davor noted that the IRIS curve in the attachment shows cavity pressure. Free drywell pressure will be lower after ~5 ks as the cavity begins to fill. The difference will be about 60 kPa at the end of the run.
     - The majority of the difference between the IRIS and SPES-3 runs from 2 ks-5 ks is related to greater drywell to PSS mass transfer.
     - The pressure rise at 4.5 ks in the SPES3 runs is due to flow from the RV to the drywell. Davor sees this in the IRIS runs a about 15 ks.
   - Matteo has been studying Annamaria's results on the transient evolution and fluid conditions downstream of the break orifices and ADS orifices. SIET decided to limit the lines with special instrumentation to the following:
     - DVI split
     - EBT split
     - ADS split
     - ADS Stage-I ST and DT

     These and all others will be equipped with a venture meter upstream of the orifices, except that the ADS Stage-II line will be equipped with a turbine.
3. IRIS transient analyses
   - Davor will have free time in July.
4. Scaling Analysis
   - Alessandro is running his program for analyzing drywell insulation performance using Davor's and Roberta's data. He can also use this program to look at the effects of preheating the vessels
   - Milorad will start the final scaling report soon.
5. The next conference call will be on Friday, July 10th at 9:00 a.m. US time, 3:00 p.m. EU time.

3.1.11 106th Conference Call on IRIS Integral Testing

2009 July 10

Participants:

F. Bianchi (ENEA)
D. Grgic (FER)
J. Carbajo (ORNL)
D. Papini (POLIMI)
C. Congiu, R. Ferri, M. Greco (SIET)
M. Dzodzo, G. Storrick (WEC)
A. Carnevali (UNIPI/WEC)

1. We approved the minutes of the June 29th conference call.
2. Facility design
   - SIET has been comparing the IRIS and SPES-3 analysis results in detail, and found some differences in the LGMS to RV cavity flows, PSS-drywell flows. Adjusting some orifice sizes has improved the agreement.
     - Roberta noted differences in the LGMS to DVI flows as noted in her email earlier today (Attachment 4). Injection flow is slowing suddenly when the cavity level reaches the break level. Davor confirms that the RC and DVI lines open together, but there is a check valve in the line. Davor will investigate, but it is clear that the elevation of the LGMS is high enough that flow should not stop.
     - SIET reduced the ADS orifices so that the SPES-3 flows matched the IRIS flows. In doing this, the ADS flow peaks due to water entrainment, evidenced in IRIS and originally in SPES-3, disappears in SPES3 as the reduced speed allows water separation in the PRZ dome and limits water entrainmet. After the SPES3 orifice reduction, the mass flows are similar. Davor and Roberta feel that this is OK for now.
   - Matteo summarized the ongoing work on special instrumentation that he and Annamaria are doing.
     - We need at least two instruments for each of the 2-phase lines - a drag plate and a turbine meter. These are adequate for mass flow measurement, but will not tell us void fraction; that will require a wire mesh sensor/densimeter.
     - Matteo and Annamaria have not ruled out using wire mesh sensors, but recognize that we need to balance cost vs. benefit.
     - Milorad agrees that the ADS Stage-II, EBT and LGMS lines probably do not need void fraction measurements (wire mesh sensors), but the break lines will because void fraction changes throughout the transients.
     - It may be difficult to find a good turbine meter for each application, and SIET still needs to investigate wire mesh sensor availability.
3. IRIS transient analyses
   - Davor will work on Roberta's flow problem over the weekend and have an answer on Monday, July 13th.
   - Davor will have new containment runs available by Friday, July 17th.
   - Davor will have final IRIS results for Milorad by July 31st (this is the highest priority).
4. Scaling Analysis
   - Alessandro provided three attachments (#1-3) summarizing his thermal analyses.
     - The first shows that the SPES-3 heat transfer to the containment wall is higher in SPES3 than in IRIS.
     - The second shows that we can get a better match using "frozen smoke" insulation. Since this insulation cannot survive exposure to steam, it will require a liner. The attachment shows one possible design idea.
     - The third file shows the effects of several different insulation materials. Some work well; some do not.

- The conclusion is that to fix the problem, we need to break the thermal communication between the drywell walls and the drywell atmosphere.
- Roberta believes that we need to fix some other distortions before deciding to insulate the drywell. Fosco agrees, he wants to see a completed analysis before making a decision to insulate the drywell. Milorad believes that the problem will remain (the fractional scaling analysis showed that the main distortion was the heat transfer to the drywell walls).

5. Heater rod testing
   - Cinzia and Andrea A. are designing a circuit to test prototype heater rods. It will be a natural circulation loop that can test 4 rods under SPES-3 conditions (thermal cycling, etc.)
6. Schedules
   - Gary will be on Vacation July 15-28. Most of the Italians will be on vacation in August.
7. The next conference call will be on Friday, July 17th at 9:00 a.m. US time, 3:00 p.m. EU time. Milorad will lead the call.

3.1.12 107th Conference Call on IRIS Integral Testing

2009 July 17th

Participants:

F. Bianchi (ENEA)
D. Grgic (FER)
D. Papini (POLIMI)
C. Congiu, R. Ferri, M. Greco (SIET)
M. Dzodzo (WEC)
A. Carnevali (UNIPI/WEC)

1. We approved the minutes of the July 10th conference call.
2. Facility design
   - SIET has been comparing the IRIS and SPES-3 analysis results in detail, and found some differences in the LGMS to DVI flows, PSS-drywell flows. Adjusting some orifice sizes has improved the agreement. Roberta informed that after the adjustment the SPES-3 and IRIS flow rates are closer.
   - Roberta is running three SPES-3 cases at this moment:
     - Initial temperature of drywell walls 48.9°C – as in IRIS
     - Initial temperature of drywell walls 84°C
     - Initial temperature of drywell walls 48.9°C – as in IRIS, IRIS drywell structure scaled, and PSS, LGMS and CAVITY mass removed (thickness reduced to 1 mm)

     Results are expected for the next week call.
   - It was suggested (Roberta and Davor) to check first the trends of some other important parameters before the scaling analysis. The best approach and timing were discussed. It was concluded that
     - One document representing "Basis for Scaling Analysis" should be prepared in the first half of September (Roberta and Davor).
     - Produce results of RELAP and RELAP&GOTHIC until the end of July
     - Use these preliminary results to start the scaling analysis in August.
     - Check of the availability of Donato, Gaetano, and Simone to help Alessadro in August and September
     - In the first half of September produce the document explaining the differences between RELAP SPES-3 and RELAP & GOTHIC IRIS models and results
     - Re-run the scaling analysis after that
     - Produce Scaling Document in October

3. IRIS transient analyses

   Davor will have final IRIS results for Milorad by July 31st (this is the highest priority).

4. Scaling Analysis
   - Alessandro provided corrected results of his thermal analyses for various metal and insulation thicknesses. The SPES-3 drywell temperature was corrected. The discrepancy between IRIS and SPES-3 accumulated heat is smaller.
   - Alessandro will submit several runs (for several material and thicknesses configurations) to run for 100,000 seconds to get data for the long term cooling evaluation
   - It was concluded that Alessandro will continue to search and analyze if some other combination of insulation and other material thicknesses might be able to produce better response, although at this point we are not considering/recommending to introduce an insulation layer at the inner side of the SPES-3 drywell.
   - Milorad proposed to evaluate decreasing the thickness of the outer (100 mm Rockwool) SPES-3 drywell insulation to allow and adjust the dissipation of the excessive accumulated heat. Alessandro will run models with several thicknesses and compare with IRIS data. This approach needs to be adjusted with the eventual pre-heating of the structure (at 84°C) at the beginning of the transient.
   - Effects of the RELAP modeling (not taking into account axial conduction in PSS walls) on PSS air

temperatures were discussed. 40°C higher air (than water) temperatures are observed in IRIS PSS top part, while gas and water temperatures are very similar in the bottom part. The difference is likely due to the inability to conduct the heat axially between walls surrounded by water and air and very different convective heat transfer coefficients for water and air.

5. Availability in August, 2009

   Davor will be available in August. We need to check if Andrea Maioli and/or Gary will be available – if some design and geometry data for IRIS Containment are needed. Also, we need to check status of the IRIS documents needed as a basis for Transient Analysis and Scaling Analysis.

6. Schedules

   - Gary will be on vacation July 15-28. Most of the Italians will be on vacation in August.

7. The next conference call will be on Friday, July 24th at 9:00 a.m. US time, 3:00 p.m. EU time. Milorad will lead the call.

3.1.13 108th Conference Call on IRIS Integral Testing

2009 July 24th

Participants:

F. Bianchi (ENEA)
D. Grgic (FER)
D. Papini (POLIMI)
C. Congiu, R. Ferri, M. Greco (SIET)
M. Dzodzo (WEC)

1. We approved the minutes of the July 17th conference call.
2. Facility design
   - Roberta presented results of three SPES3 runs (1. Initial temperature of drywell walls 48.9°C – as in IRIS, 2. Initial temperature of drywell walls 84°C, 3. Initial temperature of drywell walls 48.9°C – as in IRIS, IRIS drywell structure scaled, but PSS, LGMS and CAVITY mass removed). Comparison with Davor's IRIS run indicated that there are some discrepancies between SPES3 and IRIS PSS vent line outlet elevations, causing different containment pressure responses and LGMS flow rates.
     - SPES3 configuration is based on Luca's e-mail correspondence dated – February 16, 2007.
   - It was recommended to check with Luca and Andrea if there is any additional document related to PSS vent opening elevations (by e-mail, and/or small conference call if necessary).

Later news: e-mail Adrea Maioli July 29 2009

I don't think there is any "right configuration"

The conceptual design of the PSS in the plant description suggests that the main vent is somewhere above the main deck, with the auxiliary vent being as much high as possible in the containment. Given the current uncertainties in the design of the containment, identifying any additional source for the elevation looks futile to me at this point in time. The documentation that Roberta is using (mainly the sketch provided by Luca) is the only documentation that I am aware of that has any number associated with the PSS vent elevation (disregarding Davor's deck, which does not have any specific reference). I suspect that even Luca's document was an initial sizing of the system, and that the original idea was probably to use Davor's deck to optimize the elevation of the vents; to my knowledge, this was never done.

On this basis, and provided that the higher elevation still provide an acceptable pressure behavior, I would stick with Roberta's numbers and eliminate this additional difference between the two models.

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3. IRIS transient analyses
   - Davor will wait for the resolution of the PSS vent opening elevations. Than, if necessary make IRIS model changes and produce final IRIS results as soon as possible for Milorad (this is the highest priority) Scaling Analysis.
4. Scaling Analysis
   - No updates about Scaling Analysis. Alessandro was not in STD. He submitted long runs (100,000 s) to evaluate several wall and insulation thicknesses combinations. He will prepare data for the next call.
5. Other issues – Documentation
   - Fosco asked what is the status of IRIS documentation – design, control and other aspects, so that an input for SPES3, Analysis, Scaling is documented. This is necessary to avoid situation as we have now with PSS vent opening elevations. Milorad responded that he will ask Gary and Andrea, and that we need to systematize data as well as we can for Analysis and Scaling Reports. This will part of the activities in August and September.
6. Schedules
   - Davor will be available/reachable in August. We need to check with Donato, Simone and Gaetano if they can help Alessandro.

7. The next conference call will be on Friday, July 31th at 9:00 a.m. US time, 3:00 p.m. EU time.

3.1.14 109th Conference Call on IRIS Integral Testing

2009 July 31st

Participants:

D. Grgic (FER)
C. Congiu, R. Ferri, M. Greco (SIET)
M. Dzodzo, G. Storrick (WEC)
A. Carnevali (UNIPI/WEC)

1. We approved the minutes of the July 24th conference call.
2. Documentation Status

   Gary noted that there were several questions that arose while he was on vacation related to the status of the IRIS design documentation (e.g., item 5 from the July 24th conference call minutes). Gary summarized the status as follows:

   - Gary presented the high-level program at the Tirrenia team meeting nearly two years ago. In a simplified form, that program had the following program phases:

     Conceptual design (this is where we are)

     Requirements Development *(formal, not started yet)*

     Preliminary Design *(Strict design QA begins here)*

     Detailed Design

     Factory implementation

     Factor Test

     Installation

     - Field Test

     Individual projects will follow similar phases, which may occur out of synch with the main program phases. The SPES-3 test program is one such program: right now, SPES-3 is nearing the end of the Detailed Design Phase. Obviously, SPES-3 is not based on the final approved IRIS design (and ultimately, the SPES-3 test results will affect the IRIS design). Although the SPES-3 program is technically separate from IRIS in US DOE eyes, we want to be able to use the SPES-3 results for licensing IRIS, and that means that the SPES-3 program has to follow QA plans that meet 10CFR50 Appendix B and ASME NQA1-1994. Among other things, that means that we have to be able to trace the SPES-3 design to source documents

     Here is the document structure for the SPES3 scaling effort:

     1. Tier 1: IRIS Integral System Test Specification (STD-AR-08-01)

        This is the highest-level document for the SPES-3 test program. For SPES-3 design purposes, <u>this document defines IRIS</u> and gives the requirements for the test facility. Appendix 1 gives dimensions for both the facility and for the IRIS analyses that the facility is scaled to. *If there is a critical dimension that we need to add to this appendix, then submit a change request through the approved procedure.*

     2. Tier 2

        If there is a discrepancy between values in a Tier-2 document and the Tier-1 IRIS Integral System Test Specification (STD-AR-08-01), then for purposes of SPES-3 design and scaling, the Tier-1 IRIS Integral System Test Specification number has priority. *If we need to correct the test specification to agree with a Tier-2 document, then we will process a change request through the approved procedure.*

        A. IRIS

           We do not have a completed IRIS plant that we can measure or test results from an operating IRIS; therefore, we must use FER's RELAP/GOTHIC model as a surrogate. For purposes of SPES-3 design and scaling, FER's lower break reference run inputs will serve as the primary source document of record for dimensions, initial conditions, and other numerical data that is not included in the IRIS Integral System Test Specification.

The IRIS Plant Description Document (WCAP-16062) will serve as the primary source document of record for layout descriptions and illustrations needed for the scaling report. Gary and Andrea are working to revise this document, and plan to have a new issue at about the same time as Milorad completes his scaling report. Milorad has access to the working copy draft revision in a restricted area of the eRoom.

B. SPES-3

SIET's SPES-3 design documents are the primary source documents for the SPES-3 end of the scaling analysis. SIET created these under a QA plan that satisfies 10CFR50 Appendix B and ASME NQA-1-1994, Part 1. The SIET RELAP model is based on those designs.

Note: The SPES-3 Facility description in WCAP-16842-P was issued in 2007 and is now out of date. FPN-P9LU-009_rev 0 (September 2008) is the latest version, but SIET has made changes since issuing this document. At present, there is no schedule for revising FPN-P9LU-009_rev 0.

3. Tier 3: Anything else.

3. Facility design

- There were no changes this week. The latest runs show an improvement in the containment pressure response agreement between the IRIS and SPES-3 runs. The LGMS flows are different, and the reason is related to higher PSS and LGMS pressure in IRIS due to the PSS vent pipes that remain full of water after the PSS injection is over. In SPES3 they empty.

4. IRIS transient analyses

- (Attachment 5) Davor added metal and concrete structures to the containment model. Runs HT1 and HT4 had incorrect initial RWST liquid volume (~1/3 of correct value); run HT5 corrected this error. [Run HT5 crashed last night at ~15ks. The cause appears to be a random convergence issue and not a physical problem).
- Davide sent Davor his final documentation on the containment model. Davor is reviewing it.
- (Attachment 6)
  - o See the note on the Run HT5 crash above
  - o Run HT5 shows improved containment pressure agreement. From 2 to 5 ks, water expelled from the PSS goes to the drywell and then the cavity. After 5 ks, liquid in the vents returns to the PSS and no water flows to the drywell.
  - o Davor is using a close NSSS building model. He can change to a constant pressure boundary condition on the RWST later.
  - o Roberta asked if Davor had a check valve on the EBT lines as HT1 case shows both EBT partial refill after emptying. Davor replied that he does, but Luca may have disabled the check valve on EBT-1 for analysis - Davor will check
  - o Roberta asked if Davor's runs showed PSS sparger uncovery. Davor replied that they did not. Davor's spargers are 250 mm. above the base of the PSS; SIET's are ~1 m above.
  - o Roberta noted that the total mass injected from the PSS to the drywell are similar for IRIS an SPES-3.
  - o Davor notes that the PSS vent height has some influence on the transients. He thinks that Luca's sketch places it higher than necessary.
  - o Davor believes that he may have three times the PSS vent volume as SIET. Davor's model has three 20" sch. 40 vent pipes for each PSS. SPES-3 has only one pipe. We agreed that one pipe in SPES-3 is enough, provided it is scaled to simulate the three IRIS pipes.

Action Item: Gary to confirm the number of PSS vent pipes.

Update: Gary confirmed that the present IRIS description has three 20" sch. 40 went pipes.

- Davor's plans for August:

  Finish the reference run.

  Analyze the run to understand everything that is happening

  Work with Milorad to support the scaling analysis

  - o Reconcile any discrepancies with SIET in September.

5. Scaling Analysis

- Milorad's plans for Alessandro in early August:

  Alessandro will review Amy's spreadsheet and check pipe volumes, elevations, etc.

  Confirm that all initial conditions are correct.

  - o Review and revise time sequences as needed.

- Alessandro prepared 100ks drywell insulation runs and reran everything (Att. 1, 2, 3, & 4)
  - Attachment 3 shows the ideal agreement between SPES-3 and IRIS, but is not a practical solution.
  - Attachment 4 shows that eliminating the external insulation on the SPES-3 drywell does not produce any significant gain.
  - The only good option found is 1 liner with 10 mm. foam glass insulation, but this has other problems (e.g., moisture)
  - Milorad noted that we need to resolve the other known issues in August and September to isolate the drywell effect.

6. The next conference call will be on Thursday, September 3rd at 9:00 a.m. US time, 3:00 p.m. EU time.

3.1.15 110th Conference Call on IRIS Integral Testing

2009 September 4th

Participants:

F. Bianchi (ENEA)
D. Grgic (FER)
J. Carbajo, G. Yoder (ORNL)
C. Congiu, R. Ferri, M. Greco (SIET)
D. Papini (POLIMI)
M. Dzodzo (WEC)
A. Carnevali (UNIPI/WEC)

1. We approved the minutes of the July 31st conference call.

2. Facility Design and
3. IRIS transient analyses

- Roberta is redesigning vent pipes to PSS adjusting extension connection to DW elevation to match IRIS and adjusting orifice to maintain delta P as in IRIS (not flow rate). Davor needs to provide an input (DP during injection). Behavior of the vent pipes might explain the IRIS/SPES3 pressure response shift.
- Other differences (causing discrepancies) between SPES3 and IRIS models were discussed after the comparison between cases SPES3-120 and IRIS HT5d.
  - SPES3 has smaller thickness of Steam Generator tubes.
  - Amount of water in Quench ADS tank at the beginning.
  - Level of the water in PSS vents (same as PSS level).
  - Position of PSS sparger (higher in SPES3).
  - Need to recheck Emergency Heat Removal System conditions.

It was concluded:

- Davor will recheck Emergency Heat Removal System conditions.
- Remove water from Quench ADS Tank at the beginning of simulation
- Decrease thickness of Steam Generator tubes
- Provide delta P needed to expel water from the vents (delta P ~ 140 KPa)
- Use the same cross section for one pipe representing three PSS vent pipes
- Include all metal mass in pipe lines
- Provide info for all components to Roberta
- Roberta will provide dimensions of the SG tubes to Davor (OD=17.46 mm, 1.688 mm thickness, 32 m length)

4. Scaling Status

Alessandro is collecting all input, program and result files for Scaling Analysis from Geatano, Donato and Simone. Transfer of Gaetano's files is completed and some re-runs performed. Since this is Alesandro's last month in WEC and Roberta's SPES3 simulation takes one week to 10 days it was concluded to use the last results (reference case SPES3-120) for SPES3 Scaling Analysis. Also, Davor's IRIS results obtained during the next week will be used.

5. Other items

Davor and Davide need an approval for IRIS related conference paper. They are advised to send an e-mail to Mario Carelli, Gary Storrick and Mike Anness.

6. The next conference call will be on Friday, September 11th at 9:00 a.m. US time, 3:00 p.m. EU time.

3.1.16 111th Conference Call on IRIS Integral Testing

2009 September 11th

Participants:

F. Bianchi (ENEA)
D. Grgic (FER)
C. Congiu, R. Ferri, M. Greco (SIET)
M. Dzodzo, G. Storrick (WEC)
A. Carnevali (UNIPI/WEC)

1. We approved the minutes of the September 4th conference call.

2. Facility Design

- No changes to the facility design this week.

3. IRIS transient analyses

- SIET is comparing their SPES-3 results with FER's IRIS results. We understand most of the differences seen in the past. The remaining issue is a difference in the PSS vent behavior. The SPES-3 analyses give a higher PSS-Drywell ΔP than the IRIS analyses do. This is probably due to increased condensation in the SPES-3 drywell. The SPES-3 PSS empty to below the sparger level; SIET does not know the cause. There are also some aspects of the long-term response (>50ks) that SIET and FER are trying to understand better.
  - Davor believes that the real issue is why the energy balances differ; the pressure response is just a consequence.
  - Davor asked how SIET adjusted their model's initial steady state to account for the reduced SG tube thickness. Roberta replied that the thickness reduction came before the SPES-3 RELAP model, so SIET always had the reduced tube wall thickness in their model.
- Davor believes that the SPES-3 design is acceptable and that they should be able to proceed with procurement. He suggests that Roberta and he document their respective runs and submit them to Milorad.
  - Roberta agrees, although she wants to make one more run with a proper PSS vent orifice.
  - Gary agrees that the current SPES-3 design is acceptable and that SIET should be able to proceed with procurement. No one on the call disagreed. Gary reminded the team that there are some minor differences between the current design and the test facility specification, and that we need to process the necessary change requests to bring the specification up to date. We should do this in the next few weeks.
  - Davor suggested developing a companion document to the scaling manual that would explain some of the differences between the IRIS and SPES-3 analysis results. Roberta has written some of this for ENEA, and will share that draft with the team.

4. Scaling Status

- Milorad needs Roberta's and Davor's latest runs to begin the final scaling analysis.
  - Alessandro and he will start with Roberta's case 120 and evaluate what to do when the next case (see above) becomes available.
  - Alessandro and Milorad will also need Davor's latest run. This run is still running and will finish tomorrow (it has completed about 88 ks). They will need the same data from this run that Donato/Gaetano/Simone needed earlier this year.
- Milorad is now able to get all of Gaetano's and Donato's files. Simone is still finishing his thesis, but Milorad has some of his files as well.
- Alessandro will start with the containment pressure analyses and do the vessel level analyses afterward.

5. Other items

- Roberta and Fosco discussed submitting some papers on SPES-3, and asked for guidance on what information could be released. Gary said that they would have to clear everything through Mario and Mike Anness.

6. The next conference call will be on Friday, September 18th at 9:00 a.m. US time, 3:00 p.m. EU time.

3.1.17 112th Conference Call on IRIS Integral Testing

2009 September 18th

Participants:

F. Bianchi (ENEA)
D. Grgic (FER)
J. Carbajo, G. Yoder (ORNL)
C. Congiu, R. Ferri, M. Greco (SIET)
D. Papini (POLIMI)
M. Dzodzo (WEC)
A. Carnevali (UNIPI/WEC)

1. We approved the minutes of the September 11th conference call.

2. Facility Design and SPES3 transient analyses

- Roberta started the new run with several modifications:
    - After re-checking PSS vent pipes elevation is adjusted as in IRIS
    - Moved sparger from the PSS bottom as in IRIS
    - Orifices changed to produce pressure difference as in IRIS ht5g case
    - Diameter of the vent pipes extensions increased from ¾" to 1"
    - PSS model modified (bottom part is only one volume, sliced part is above)
    - Initial condition for containment, cavity and upper parts of PSS and LGMS (in air zone) is preheated to 84 °C as in 120 case, but water is at 49 °C.

  The run will take approximately 10 days.

- SIET had meeting in MANGIAROTTI to discuss SPES3 Reactor Vessel final design. The design is planned to be completed at the end of October, 2009.
- Cinzia and Matteo are working on preparing test facility to test prototype of the heated rod.

3. IRIS transient analyses

- Davor completed calculation and provided data to Alessandro.
- Davor will document changes in containment, volumes, flow paths, conditions in EHRS, heated structures ...
- Davor will document the case to describe time sequences of events
- Davor will help Alessandro to extract some other properties (flow rates, temperatures)
- 5 to 6 additional runs performed this summer will be separately documented

4. Scaling Status

Alessandro will transfer data from Davor and Roberta last runs. He will start preparing input data for the pressure response scaling analysis.

5. Other items

Roberta is planning to submit two abstracts to conferences in Barcelona (European Nuclear Conference 2010) and China (ICONE). She is advised to send an e-mail to Mario Carelli, Gary Storrick and Mike Anness.

6. The next conference call will be on Friday, September 25th at 9:00 a.m. US time, 3:00 p.m. EU time.

3.1.18 113th Conference Call on IRIS Integral Testing

2009 September 25th

Participants:

F. Bianchi (ENEA)
D. Grgic (FER)
J. Carbajo (ORNL)
C. Congiu, R. Ferri, M. Greco (SIET)
M. Dzodzo, G. Storrick (WEC)
A. Carnevali (UNIPI/WEC)

1. We approved the minutes of the September 18th conference call.
2. Facility Design
   - Mangiarotti reviewed the SG tube design for manufacture. They needed to make some changes to make room for the downcomer check valves. These changes require relocating the steam and feedwater line nozzles horizontally. SIET will need to revise the steam, feedwater, and associated break lines to match. They may also need to modify the EHRS hot and cold legs. The changes are straight-forward and should not invalidate any of the analyses done to date. SIET expects to deliver the RV final design to ENEA by the end of October. The containment piping review will follow.
3. IRIS transient analyses
   - SIET is running the case discussed last week (conference call #112). It has reached 60 ks and should finish at 100 ks by Wednesday or Thursday.
     - Roberta will send partial results no later than Tuesday so that Alessandro can start working before he returns to Pisa at the end of next week.
     - Milorad asks that Roberta wait until October 7th before transferring results for the completed case.
   - SIET still doesn't understand why their model shows PSS level dropping below the sparger inlet. They have two more cases running to investigate this, but these cases do not show any significant changes in the response. (These cases split the bottom of the PSS into two volumes).
   - Davor was not able to transfer the data promised last week. Milorad will work to restore Davor's access to the file transfer system.

4. Scaling Status

   - Alessandro is collecting input data.
     - Alessandro will use the current SIET run as the SPES-3 basis for his analyses.
     - He will concentrate on the containment pressure response first, building on Gaetano's and Donato's earlier works. Simone has not yet finished his thesis, but Alessandro will be able to work with Simone in Pisa.
     - Alessandro last day at Westinghouse before returning to Pisa will be October 1. For a variety of reasons, we will not be able to hold the standard exit presentation before he leaves, so he will prepare typical presentation material after his return to Pisa.

5. The next conference call will be on Friday, October 9th at 9:00 a.m. US time, 3:00 p.m. EU time. We will not have a conference call the week of October 2nd.

3.1.19 114th Conference Call on IRIS Integral Testing

2009 October 9th

Participants:

F. Bianchi (ENEA)
D. Grgic (FER)
G. Yoder (ORNL)
D. Papini (POLIMI)
C. Congiu, R. Ferri, M. Greco (SIET)
M. Dzodzo, G. Storrick (WEC)

1. We approved the minutes of the September 25th conference call.
2. Facility Design
   - Mangiarotti continued reviewing the RV design for manufacture. They recommended revisions to the RCP piping layout. The changes move pipe connections horizontally, so they will not affect any of the earlier transient results.
   - SIET met with POLITO (Panella/Mosetto) yesterday to discuss special instrumentation. They have selected five lines for 2-phase flow measurement and documented the required instrument ranges. They discussed plans for instrument testing at the University, using air/water mixtures.
     - Milorad talked to Prof. Prasser last week. Prof. Prasser feels that using the wire mesh sensors at the pressures and temperatures we require is feasible. He is willing to join a conference call with the appropriate parties.
     - Roberta states that Prof. Panella is already in contact with Prof. Prasser. They may visit his lab directly.
     - Milorad and Roberta will arrange a conference call in late October or early November.
3. IRIS transient analyses
   - SIET completed the cases run to investigate why PSS level was dropping below the sparger. One of these cases corrected a modelling error and produced the expected response. None of the other key process variables showed significant response changes from the previous base case.
   - Davor transferred his analysis to Westinghouse. He is now working on the description document.
   - Davor is working to transfer his model to the TRACE code for comparison. Gary notes that the NRC casually expressed a interest in a TRACE model during a visit earlier this year.

4. Scaling Status

   - No changes. Milorad has been out of town.

5. The next conference call will be on Friday, October 23rd at 9:00 a.m. US time, 3:00 p.m. EU time. We will not have a conference call the week of October 12th.

3.1.20 115th Conference Call on IRIS Integral Testing

2009 October 23rd

Participants:

F. Bianchi (ENEA)
D. Grgic (FER)
C. Congiu, R. Ferri (SIET)
M. Dzodzo, G. Storrick (WEC)

1. We approved the minutes of the October 9th conference call.
2. Facility Design
    - SIET continues to compare the latest SPES-3 and IRIS runs. The agreement is better than in the past, and SIET can explain the reason for the remaining differences except for the IRIS pressure recovery after 50 ks of the transient.
    - SIET gave Alessandro a copy of the latest SPES-3 run (#127) via the large file transfer system.
    - Cinzia is reviewing the drawings and 3D models of the tanks (with respect to the volume and thickness reductions).
    - Matteo is writing a document on instrument correlations.
    - ENEA entrusted SIET with the order four heater rods for testing in Cinzia's test loop (item included in the next ENEA-SIET contract). SIET requested a quote from Thermocoax this morning.
    - Milorad recommended confirming that break line connections to the drywell tank have rounded edges to avoid cavitation. Since the final tank design will be done by the manufacturer, SIET will note this in the specification.
3. IRIS transient analyses
    - Davor has not had time to do much during the past two weeks. He is documenting the latest containment model. Davor needs to upload the full 100 ks of his latest run to the large file transfer system (he previously uploaded 88 ks)

4. Scaling Status

    - Milorad has been out of town most of the past 2.5 weeks, and Alessandro has returned to Pisa.
    - Milorad wants to contact Prof. Prasser in the nest two weeks.

5. The next conference call will be on Friday, November 6th at 9:00 a.m. US time, 3:00 p.m. EU time. Both Europe and the US will be on normal time by then. We will not have a conference call the week of October 26-30th.

3.1.21 116th Conference Call on IRIS Integral Testing

2009 November 6th

Participants:

D. Grgic (FER)
J. Carbajo, G. Yoder (ORNL)
C. Congiu, R. Ferri, M. Greco (SIET)
D. Papini (POLIMI)
M. Dzodzo, G. Storrick (WEC)
A. Carnevali (UNIPI)

1. We approved the minutes of the October 23rd conference call.
2. Facility Design
   - Roberta provided a file (Att. 1) that explains, or tries to explain, the reasons for the drywell pressure difference between the SPES3 and IRIS simulations after 50 ks of transient.
     - After 50 ks, the IRIS simulation shows an increasing drywell pressure but the SPES-3 simulation shows a decreasing pressure. Milorad agrees that the opposing trends are not desirable from a scaling analysis perspective.
     - The heat transfer coefficients for the two runs differ in detail, but the global heat transfer coefficients are similar.
     - The SPES-3 run predicts a lower RWST temperature than the IRIS run. The SPES-3 run transfers significant mass and energy to the atmosphere, even thought the RWST temperature only reaches 94 °C.
     - Roberta verified that the SPES-3 results conserve energy.
     - Roberta and Davor have similar models for the RWST: IRIS has parallel channels at the bottom, a long top node with water, then one with air, and then a time-dependent volume of air (see Att. 2). SPES3 has, for each RWST, two parallel channels at the bottom, a two element vertical pipe at the top with water in the lowest element and air in the uppermost, then a time-dependent volume of air. SPES3 has also transversal junctions between the parallel channels.
     - Roberta and Davor will exchange files and continue investigating.
   - Mangiarotti has nearly completed the final RV design.
   - SIET contacted Thermocoax for a quote to supply four heater rods for testing. Rotfil (Turin) is also interested in supplying the rods.
3. IRIS transient analyses
   - Davor sent Alessandro information on the updated containment nodalization and some results files.
   - Davor noted that droplets in the discharge flow model could affect the scaling analysis.

   Update: After the call, Davor sent a discussion of the droplet effects and how one might deal with them (Att. 2).
   - Davor is proceeding with visualizing the data and looking at the SG/EHRS loop. He is using TRACE to provide a 'sanity check" on the RELAP/GOTHIC results.
   - Davor is continuing preparation of his final report on the analyses.
4. Scaling Status
   - Alessandro was having problems with the conference call line today. Milorad, Alessandro (and others) will arrange a separate conference call next week.
5. The next conference call will be on Friday, November 13th at 9:00 a.m. US time, 3:00 p.m. EU time.

3.1.22 117th Conference Call on IRIS Integral Testing

2009 November 13th

Participants:

F. Bianchi (ENEA)
D. Grgic (FER)
C. Congiu, R. Ferri, M. Greco (SIET)
M. Dzodzo, G. Storrick (WEC)
A. Carnevali (UNIPI)

1. We approved the minutes of the November 6th conference call.
2. Facility Design
   - SIET made another run (#129) that addressed the differences between the SPES-3 and IRIS RWST models. The drywell pressure response did not change from run #127 to #129.
   - Roberta provided a file (Att. 1) that lists some differences between the SG and EHRS thermal parameters in the IRIS HT5g and SPES3 #129 runs.
     - The SG wall thicknesses do not match.
     - The two runs are using different heat transfer correlations (HTC) (101 vs. 110). ENEA and SIET calibrated their HTCs with the PERSEO data by making an EHRS+RWST model, using the CATHARE code, obtaining heat transfer coefficients and adjusting l the FF parameter in the RELAP mode to get the same heat transfer coefficients. They tuned the coefficients at different pressures in steady-state conditions. Davor notes that the EHRS does not operate in a steady state.
     - Roberta notes that the SG powers seem to match between HT5g and #129, but the EHRS/RWST power is larger in SPES3 She needs time to look at this in detail.
     - The main problem is that the two runs have different trends after 50 ks. It is not clear which one is correct.
     - Davor suggested that Roberta and he each run stand-alone EHRS runs with controlled inputs to eliminate thermal/hydraulic interaction with the rest of the model. This will help isolate whatever is causing the difference. Davor will prepare two or three points where Roberta and he will analyze the performance (same pressure and temperature; scaled flow).
   - SIET's priority at present is cross-checking the detailed reactor vessel design with Mangiarotti.
   - SIET has an offer from Thermocoax to supply four heater rods for testing. Rotfil (Turin) is evaluating the specification and may make their own offer.
3. IRIS transient analyses
   - No changes.
4. Scaling Status
   - The scaling team had a conference call last Tuesday (Nov. 10).
     - Simone has a short time this month (before starting work at Ansaldo) when he is available to rerun his analysis using more recent results (HTG5 & #124) than what was available last Spring. He should complete these runs next week.
     - Alessandro will complete his work in the next month.
     - Milorad will develop a plan to proceed from there.
   - After last week's call, Davor sent an evaluation of the effects of the entrained droplets (Att. 2). His suggestion for the scaling team is that the first and most simple approach would be to add together liquid and droplet volume fractions in each volume. Alessandro and his Professor agree; Milorad will check.

5. The next conference call will be on Friday, November 20th at 9:00 a.m. US time, 3:00 p.m. EU time.

3.1.23 118th Conference Call on IRIS Integral Testing

2009 November 20th

Participants:

D. Grgic (FER)
C. Congiu, R. Ferri, M. Greco (SIET)
M. Dzodzo, G. Storrick (WEC)
A. Carnevali (UNIPI)

1. We approved the minutes of the November 13th conference call.
2. Facility Design
   - Davor found that one of the differences between the SPES3-127 and IRIS HT5g runs was that Davor included design fouling on the inner diameter of the SG tubes. He performed a calculation and comparison for DW pressure without the fouling. The pressure increase remained, but was smaller than before.
   - Roberta provided a file (Att. 1) with some results of her stand-alone EHRS model.
     - TheSPES-3 runs had a larger EHRS->RWST power transfer than the IRIS runs. One reason is that the SPES-3 EHRS heat exchangers are larger than the ideal.
       - For the smaller heat exchangers, SPES-3 uses 3 tubes where the scaled number is 2.4. To compensate, the SPES-3 design insulates the headers and 0.6 tube with Teflon. A close investigation shows that this is not enough insulation to reduce the heat transfer to the scaled value.
       - Milorad asked about changing the SPES-3 EHRS design; however, any significant design changes at this time would be costly and jeopardize the schedule.
       - We discussed plugging one tube, but this would result in an undersize EHRS heat exchanger.
       - Davor noted that having three tubes results in a smaller pressure drop than in IRIS; however, Roberta designed an orifice in the cold leg to compensate.
     - Roberta ran two cases to compare with similar IRIS cases. Davor will run the IRIS cases tomorrow.
     - Once Davor makes his results available, SIET will increase the Teflon thermal insulation on the SPES3-EHRS tubes to reduce the exchanged power to the IRIS scaled value.
   - SIET's continues cross-checking the detailed reactor vessel design with Mangiarotti.
     - Mangiarotti had to make some changes for manufacturing reasons. These included increasing some diameters and eliminating some of the dummy tubes in the steam generators. This increased some of the reactor vessel volumes. SIET and Mangiarotti are looking at ways to reduce and/or fill these volumes.
   - SIET has not yet received a reply from Rotfil about supplying heater rods for testing.
3. IRIS transient analyses
   - No changes.
4. Scaling Status
   - Simone was at UNIPI last week and started looking at the new data, but was not in this week.
   - Alessandro has both Word and .pdf versions of Simone's thesis, and will put them in the eRoom.
   - Alessandro has finished with Donato's and Gaetano's programs.
     - Milorad suggested that Alessandro look at their exit presentations. There are two ways to look at the data (instantaneous and averaged values), and we need both.
     - Some of the omegas will be irrelevant, but Alessandro still should calculate all of them. Afterward, focus on the important ones.
     - Milorad expects that Alessandro will find similar distortions as the others did, but the new ones should be smaller and may be shifted in time.
5. We will try to hold the next conference call early in the week of November 30th. Please send an email to Gary to tell him your availability, and then he will schedule the call.

3.1.24 119th Conference Call on IRIS Integral Testing

2009 December 1st

Participants:

F. Bianchi (ENEA)
D. Grgic (FER)
J. Carbajo (ORNL)
C. Congiu, R. Ferri, M. Greco (SIET)
M. Dzodzo, G. Storrick (WEC)

1. We approved the minutes of the November 20th conference call.
2. Facility Design
   - On November 30th, Davor sent some results (Att. 1) from his stand-alone model and a case for drywell pressure. Roberta initially compared (Att. 2) these to her results; however SIET had only run with one EHRS HX in the RWST pool while Davor used 2. Cinzia reran the SIET cases with 2 heat exchangers and got similar results (see Att. 3, 4).
     - There are still some differences that SIET and FER need to investigate
       - Need to check the masses in the EHRS loops
       - SG levels are different (see Att. 2, p. 8). The computed IRIS levels remain essentially constant while the SPES-3 levels show a drop at 3-4 ks, and then a return. Davor suggests looking not only at SG levels, but also at the mass distributions at all major parts of the EHRS loop (SL, FL, HX, SG, …)
       - EHRS Flows are different (see Att. 2, p. 6). The IRIS simulation has a higher peak and greater decrease. Davor notes that the response is sensitive to the initial water mass. Milorad recalls a Thesis on the subject done a few years ago. Davor replied that Davide had done more recent work, and provided Att. 5 right after the call.
       - The time delay between SL isolation and EHRS actuation are different in the two simulations, but this is probably not important.
       - The main issue is the difference in energy balance after 40 ks.
   - SIET and Mangiarotti have nearly finished the detailed RV design.
       - Some of the volumes required fillers to reduce the volume. The new volumes are within 5% of the scaled IRIS values and comparable to the volumes used in the SPES3 RELAP analyses.
3. Scaling Status
   - Alessandro was not on today's call, but he sent three documents out on November 30th that show considerable progress.. The first (Att. 6) summarized the scaling work that Donato and Gaetano did earlier this year. The second (Att. 7) looked at the changes in the time sequences. Milorad thinks that Alessandro has some questions in that area. The third (Att. 8) starts calculating the distortions. The initial outlook is that the scaling for the latest SPES-3 runs looks better than before.

5. The next conference call will be on Friday, December 11th at 9:30 a.m. US time, 3:30 p.m. EU time.

3.1.25 120th Conference Call on IRIS Integral Testing

2009 December 11th

Participants:

F. Bianchi (ENEA)
D. Grgic (FER)
D. Papini (Polimi)
J. Carbajo (ORNL)
C. Congiu, R. Ferri, M. Greco (SIET)
A. Carnevali (UNIPI)
M. Dzodzo, G. Storrick (WEC)

1. We approved the minutes of the December 1st conference call.
2. Facility Design
   - Roberta received the data that Davor sent yesterday, but SIET has not had time to analyze it. Davor will provide comparable information so that they can compare the two models. There was some discussion about the EHRS filling ratios. Roberta feels that the SPES-3 EHRS works well with 40%. Davide recalls tests and analyses at POLIMI that showed best results at 30 to 35%; however, those used horizontal tube EHRS heat exchangers rather than vertical-tube exchangers. Davor thinks that there may be some influence caused by the horizontal return piping as well.
   - SIET continues checking for differences between the SPES-3 and IRIS simulations. Roberta noted that the total core power at the end of the run is 3 to 4 kW lower in the SPES-3 case than in the IRIS case. Coupled with the higher EHRS power, this might explain the differences in the long-term containment pressure trends. Late in the transient, decay heat is the only significant power source in the IRIS model. Roberta uses the same power curve as Davor, but scaled. Roberta thinks that the difference might be due to the heat structure contributions.
   - SIET and Mangiarotti have nearly finished the detailed RV design. Mangiarotti has delivered most of the detailed drawings, but there are a small number outstanding.
   - SIET met with Rotfil this morning. Rotfil has a strong interest in supplying the SPES-3 fuel rod simulators. SIET believes that Rotfil has the necessary technology and that they may be able to deliver faster than the competition. SIET will ask for offers for 4 test rods and for the full set for the SPES-3 core.
3. IRIS Transient Analysis
   - Davor started a new run with changes to address the differences in ADS-II initiation that Roberta recently noticed. Due to the way FER coupled GOTHIC and RELAP, the initiation was not occurring on the RELAP side of the model until the LGMS emptied. The agreed operating point is to actuate ADS stage II when the LGMS tanks reach 20% level (In the IRIS model the LGMS is cylindrical and 20% level corresponds to 20% mass. In the SPES3 model, the LGMS shape simulates the IRIS torus volume versus height, and the signal for ADS-II actuation is 20% mass).
   - Davor is preparing a TRACE model to compare with the other model. This is for checking purposes only; FER does not intend to use TRACE for production analyses.
4. Scaling Status
   - Alessandro looked at different time averaging and will send results to Milorad after the call. He also evaluated the distortions, and showed that these have improved somewhat.
   - Alessandro asked whether he could neglect the first 15 time steps after the ADS-II initiation, where calculated negative flows lead to extreme distortions. Davor replied that he could, since these negative flows are not realistic and should disappear in the current run (which corrects the ADS-II actuation).
   - Alessandro has essentially finished the pressure response analyses. After finishing his Thesis next week, Alessandro will look at Simone's work and try to repeat it using the latest analyses.
5. The next conference call will be on Friday, December 18th at 9:00 a.m. US time, 3:00 p.m. EU time.

3.1.26 121st Conference Call on IRIS Integral Testing

2009 December 18th

Participants:

D. Grgic (FER)
D. Papini (Polimi)
C. Congiu, R. Ferri, M. Greco (SIET)
M. Dzodzo, G. Storrick (WEC)

1. We approved the minutes of the December 11th conference call.
2. Facility Design
    - SIET is comparing the IRIS and SPES-3 EHRS responses in the stand-alone sensitivity cases. The SPES-3 runs show about 15% larger heat transfer at low power. Part of this (~2%) is due to using 304SS tubes instead of inconel. SIET can compensate for this with insulation.
    - SIET found that the RWST temperature is lower in the new IRIS run HT5h than in the SPES-3 runs and old HT5g. There is no explanation for this at the moment. Davor recalls that the IRIS RWST used to heat to saturation. He will check the global heat transfer coefficient. It appears that there is an energy balance problem somewhere. Differences between HT5g and HT5h concern the removal of SG FF and modification of heat transfer parameters in at the EHRS tubes to set them similar to those used in SPES3.
    - Because of the need to move forward, SIET cannot continue with the analyses. Roberta will run a final case over the holidays and then will close the analyses.
    - Mangiarotti is still behind schedule with one document and one drawing. Cinzia has reviewed the rest of the design package and has identified some modifications.
3. IRIS Transient Analysis
    - Davor found an error in the run started last week. He corrected the error and then restarted the run.
4. Scaling Status
    - Alessandro should have defended his thesis this week.
5. The next conference call will be on Friday, January 15th at 9:00 a.m. US time, 3:00 p.m. EU time.

3.1.27 122nd Conference Call on IRIS Integral Testing

2010 January 15th

Participants:

F. Bianchi (ENEA)
D. Grgic (FER)
J. Carbajo (ORNL)
D. Papini (Polimi)
C. Congiu, R. Ferri, M. Greco (SIET)
M. Dzodzo, M. Memmott, H. Ormus, G. Storrick (WEC)

1. We approved the minutes of the December 18th conference call.
2. Facility Design
   - Roberta ran another case over the holidays. She increased the EHRS tube area insulated by Teflon by 2% to account for the difference in thermal conductivity of Inconel vs. stainless steel. The surprising result was that the long-term power transfer decreased by ~20%, bringing the results close to the HT5g IRIS case. Pressure is still decreasing at the end of the run (100 ks); Roberta suggests extending the run another 50 ks to try to reach equilibrium.
   - SIET continued comparing the stand-alone sensitivity runs. ENEA provided a document that SIET used to calibrate the PERSEO runs. This document indicated that the ratio between the ascending and descending pool areas was important. In SPES-3, we should match the area ratios to get the same power.
     - After discussions with Paride Meloni, Roberta has performed sensitivity runs to investigate the influence of the model area on the exchanged power to match the PERSEO ratio.
     - One conclusion is that it is not correct to use the PERSEO-calibrated parameters for IRIS/SPES3 without modifying the cross section area of the vertical slice containing the heat exchanger.
     - Davor asked what actions he should take in the IRIS model. At present, the IRIS model is based on physical dimensions (there is not appropriate experimental data to compare to).
     - Roberta replied that we could either stay with the first IRIS model which agrees reasonably well with the SPES-3 results, or Davor could model the IRIS pool with the same criteria used in the SPES-3 design based on PERSEO.

   Action Item (Roberta): Give Davor the information he needs to model the IRIS pool as it is in SPES-3.
     - A second modeling difference is that the SPES-3 model uses lateral junctions in the RWST (as in the PERSEO model) while the IRIS HT5 model does not. Roberta suggests modeling the IRIS stand-alone RWST as in the PERSEO model. Davor agreed, and also suggested that they look at low-pressure cases as well.
     - Davor cautioned against trying to over-solve the models. He recommends that the team establish the key parameters and model them, and then wait for test results before trying to improve the models.
   - ENEA's contract with SIET was signed by ENEA on December 23 and it will be soon under signature by SIET. The contract will end in September 2010. In this year, the only procurement activities will concern the load-bearing structure of SPES-3, the heater rod test loop, and the set up of some auxiliary, such as the power group of SPES-2 to be used also for SPES-3 , system control PLC in control room, etc. The contract also covers some engineering work; however, ENEA does not foresee any SPES-3 component procurement until the next (fiscal) year.
   - SIET met with Thermocoax to discuss acquiring heater rods for the fuel simulators. SIET expects to hear from Rotfil by January 20th.
   - Andrea Achilli, Matteo Greco, Stafno Gandolfi and some people from POLITO (Panella, Bertani, De Salve, Mosetto) visited Dr. Prasser in Zurich. Dr. Prasser did not think that wire mesh sensors would work downstream of the break orifices because of the high void fraction, while using them upstream was "dangerous" because of the high pressures. He suggested some alternate solutions (e.g., capacitive sensors). SIET is investigating. In the worst case, SIET will fall back to using gamma densitometers upstream of the break orifices.

3. IRIS Transient Analysis
   - Davor is missing the final run. He will start it tomorrow. It will include additional containment visualization capabilities, additional EHRS instrumentation modeling, and a corrected ADS-II actuation.
   - Milorad asked if this run was going to incorporate the RWST model changes that Roberta mentioned. Davor replied that he was not going to wait for them; instead, he will incorporate them later.
   - Roberta stated that once we have a solution on EHRS/RWST, she will need two more weeks to obtain new results that she can compare to Davor's results.
4. Scaling Status
   - Milorad has not seen Alessandro's thesis yet. Hopefully, Alessandro has started recreating Simone's analysis using the latest information. Milorad will push UNIPI to get the latest information.
   - Milorad needs the analysis inputs for both the IRIS and SPES-3 models for the scaling analysis report.
5. The next conference call will be on Friday, January 22nd at 9:00 a.m. US time, 3:00 p.m. EU time.

3.1.28 123rd Conference Call on IRIS Integral Testing

2010 January 22nd

Participants:

D. Grgic (FER)
D. Papini (Polimi)
C. Congiu, R. Ferri (SIET)
M. Dzodzo, H. Ormus, G. Storrick (WEC)
A. Carnevali (UNIPI)

1. We approved the minutes of the January 15th conference call.
2. Facility Design
   - Roberta received Davor’s stand-alone model and made some comparisons with the SPES-3 stand-alone model.
     - The area of the hot column in the EHRS/RWST model affects the results more than the side junctions. After setting the same area ratios, fouling, boundary conditions, etc. she ran a 700 kPa case and found that the power transfers were different because of differences in the pressure drops in the hot and cold lines lead to different levels in the EHRS heat exchangers. She is going to adjust the pipe pressure drops and then run again to see how that affects the power transfer.
     - Changing the heat transfer correlation from bundle to standard has little effect on the results.
     - Davor asked if the elevation matched. They are similar, with about an 0.5 meter difference.
     - Davor got his area ration from the volume/height of the RWST and the area of the heat exchanger. Roberta tried changing the up/down area ratio to match the PERSEO test; this did not change the results much.
     - Roberta suggested resizing SPES-3 piping to match IRIS before trying to solve the RWST/HX model issues. She is also looking at the relative EHRS loop volumes. In particular, she wants to match the steam and feedwater lines. She will also look at the SG tubes, but expects that they are already similar.
     - Davide mentioned Lorenzo’s work on EHRS filling rations. Roberta had checked that work, but since Lorenzo looked at horizontal tube heat exchangers, the results do not apply to IRIS. The optimum filling ration for SPES-3 is about 0.4; Lorenzo’s filling ration will flood the SPES-3 heat exchangers.
3. IRIS Transient Analysis
   - Davor restarted the final run after some hardware problems. The run includes additional containment visualization capabilities, additional EHRS instrumentation modeling, and a corrected ADS-II actuation logic. The run is now at about 15 ks and looking good.
   - Davor provided a word file (Attachment 1) showing the new containment visualization capability.
   - There is no change in the documentation status
   - Roberta asked whether she should be using the latest RELAP version. SIET is still using the L2 version because the later version gives an error. Davor is staying with the older version as well.
   - Gary asked Davor and Roberta to give priority to supporting Matt and Henri’s need for models, inputs and documentation.
     - Davor notes that much of the documentation is a combination of Luca’s old report and the latest version of Amy’s spreadsheet.
4. Scaling Status
   - Alessandro sent some results immediately before the call. Milorad needs time to review these results before commenting.
     - Alessandro pointed out that there is less “red” than before. He stated that the first two columns are the most important for most of the time sequences.
     - Milorad needs to get the omegas for each of the time sequences in order to interpret the table in detail.
   - Alessandro will upload his thesis and Simone’s thesis to the Westinghouse large file transfer ftp site.
   - Milorad asked if UNIPI has another graduate student who would be interested in an internship to help complete the scaling analyses.

5. The next conference call will be on Friday, January 29th at 9:00 a.m. US time, 3:00 p.m. EU time.

3.1.29 124th Conference Call on IRIS Integral Testing

2010 January 29th

Participants:

F. Bianchi (ENEA)
D. Grgic (FER)
J. Carbajo (ORNL)
D. Papini, M. Ricotti (Polimi)
C. Congiu, R. Ferri, M. Greco (SIET)
M. Dzodzo, H. Ormus, G. Storrick (WEC)

1. We approved the minutes of the January 22nd conference call.
2. Facility Design
   - Roberta continues making comparisons between the IRIS and SPES-3 stand-alone EHRS loop models.
     - Systematic comparisons part-by-part revealed different pressure drops. SIET revised the SPES-3 design to match the IRIS pressure drops. This required reducing the pipe diameter and adding a hot leg orifice. It also required increasing the size of the existing cold leg orifice.
     - Once Roberta completes the changes, she will compare the heat exchanger power. The hope is that the changes will result in similar operating tube levels in IRIS and SPES-3. After making the stand-alone comparisons, Roberta will start the final case with the full model. She expects to be able to start this next week.
     - Roberta noticed a discrepancy between the IRIS and SPES-3 SG tube areas. The area that Davor used corresponds to 656 tubes. SPES-3 uses 14 tubes to simulate 2 steam generators, corresponding to 700 tubes per SG. The actual IRIS SG has 656 tubes, so 13 tubes/SG pair would be a closer match than 14.
     - Davor asked if there were any modeling changes that he needed to make. Roberta wants to complete the stand-alone comparisons first
   - Rotfil provided data on the heat losses in the non-active zone of the fuel simulator. SIET is evaluating the effect on the closure flange region. Theremocoax has yet not provided similar information for comparison.
     - Roberta believes that Rotfil's technology is simpler than Thermocoax' technology.
     - Rotfil has not yet provided a formal offer. They should provide this within two weeks.
3. IRIS Transient Analysis
   - Davor sent some preliminary results from his latest run (Attachment 1). Westinghouse did not receive the results in time for the call. Davor will provide complete results this weekend.
     - Davor is now actuating the ADS-II when LGMS level reaches 0.5 meter. This is close to the old "20% mass" criteria.
     - The LGMS line now remains open after actuation (there is a check valve in the line to prevent reverse flow)
   - Gary again asked Davor and Roberta to give priority to supporting Matt and Henri's need for models, inputs and documentation.
4. Scaling Status
   - Milorad is reviewing Alessandro's repeat of Simone's runs using the latest data. There are differences between SPES-3 and IRIS, but it is too early to draw conclusions.
5. Miscellanea
   - Gaetano Tortora will start working at SIET on February 1.
6. The next conference call will be on Friday, February 5th at 9:00 a.m. US time, 3:00 p.m. EU time.

3.1.30 125th Conference Call on IRIS Integral Testing

2010 February 5th

Participants:

D. Grgic (FER)
D. Papini (Polimi)
C. Congiu, R. Ferri, M. Greco, G. Tortora (SIET)
M. Dzodzo, H. Ormus, M. Memmott, G. Storrick (WEC)

1. We approved the minutes of the January 2th conference call.
2. Facility Design
    - Roberta continues making comparisons between the IRIS and SPES-3 stand-alone EHRS loop models.
        - Roberta is looking at these three cases:
            - SPES-3: Adjusted to PERSEO area ratio and heat transfer coefficients. Changed the SPES-3 lines to match the IRIS pressure drops.
            - IRIS: Adjusted to PERSEO area ratio and heat transfer coefficients.
            - IRIS: Original
        - The two adjusted models give similar responses, with the SPES-3 model giving a 6% higher exchanged power at 7 MPa and 3% higher at 1 MPa. The original IRIS model has a larger heat transfer coefficient inside and outside the tubes, which gives more condensation, greater tube flooding, and a reduction in total heat transferred.
        - The heat exchanged is very sensitive to the line pressure drops. The pressure drop in the discharge line is particularly critical. Davor notes that the elevations are also critical. Gary has concerns that these sensitivities may indicate that the design is not robust. Davor agrees and suggests that we use the test data to improve our models first and then work on robustness.
        - Roberta wants to check the range from 0.3 to 8 MPa. Higher pressures lead to higher condensation and more flooding. Lower pressures leave the tubes and lower header empty.
        - Roberta expects to finish the comparisons early next week. She would then like Davor to modify his model to match the PERSEO area ratio and heat transfer coefficients. Davor wants to run a full case as soon as practicable because the interactions between the systems are important.
3. IRIS Transient Analysis
    - Davor sent some results that show that the corrected ADS-II actuation does not solve our problems.
    - Davor uploaded a RELAP executable to the eRoom. Matt and Henri now need the following:
        - The new coupled RELAP/GOTHIC executable.
        - Description of changes
        - Input decks
4. Scaling Status
    - Alessandro uploaded Simone and his thesis shortly before the call. Milrorad will need to review these in detail. Alessandro will soon be unavailable. Milorad believes that he is repeating Simone’s runs, but needs to confirm this.

5. The next conference call will be on Friday, February 12th at 9:00 a.m. US time, 3:00 p.m. EU time.

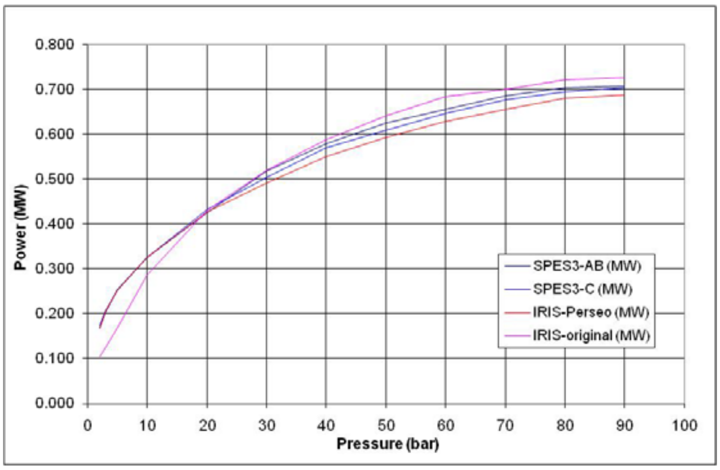
3.1.31 126th Conference Call on IRIS Integral Testing

2010 February 12th

Participants:

D. Grgic (FER)
D. Papini (Polimi)
C. Congiu, R. Ferri, M. Greco, G. Tortora (SIET)
M. Dzodzo, H. Ormus, M. Memmott, G. Storrick (WEC)

1. We approved the minutes of the February 5th conference call.
2. Facility Design
   - Roberta concluded her parametric comparisons between the IRIS and SPES-3 stand-alone EHRS loop models (see attachments 1 & 2).
     - Roberta is looking at these three cases:
       - SPES-3: Adjusted to PERSEO area ratio and heat transfer coefficients. Changed the SPES-3 lines to match the IRIS pressure drops.
       - IRIS: Adjusted to PERSEO area ratio and heat transfer coefficients.
       - IRIS: Original
     - Roberta looked at pressures ranging from 0.2 to 9.0 MPa. All cases held the same EHRS heat exchanger outlet conditions, and let the exchanger draw whatever steam it needed to offset condensation. Here are the main results:



     - The two SPES-3 SG types and the adjusted IRIS model give similar power transfers. The original IRIS model gave a significantly lower heat transfer at low pressure.
     - Davor changed his model to match the PERSEO area ratio and Roberta's model side junctions. He also noted and corrected some small inconsistencies in the model.
     - Roberta will summarize all of her work in the document that she is preparing for ENEA. Davor will need a copy of part of this so that he can make additional changes to his model.
     - Roberta started another large run today, as well as a run with only 13 (vs. 14) tubes per SG pair. We can decide later which is best for running the facility.
     - The team has now implemented its ideas for improving the facility response. Unless the scaling effort identifies new issues, we are probably as close as we can practically get without having actual test data in hand.
   - Cinzia, Matteo, and Gaetano are working to place the orders needed for the heater rod test loop. Rotfil has not yet provided a quote for supplying the rods.
3. IRIS Transient Analysis
   - Davor sent the initial (first 650 s) results from a run that he started yesterday. Although it is barely started, the initial results seem to be consistent with Roberta's results.

4. Scaling Status
   - Nothing to report
5. Other
   - Gary will be out next week, and may not have this conference call's minutes available before the next call.
6. The next conference call will be on Friday, February 19th at 9:00 a.m. US time, 3:00 p.m. EU time.

3.1.32 127th Conference Call on IRIS Integral Testing

2010 February 19th

Participants:

F. Bianchi (ENEA)
D. Grgic (FER)
C. Congiu, R. Ferri (SIET)
H. Ormus, G. Storrick (WEC)

1. Gary was out of the office this week and could not issue the minutes for last week's call until this morning. We will wait until next week to approve them.
2. Facility Design
   - Roberta completed a full facility run using the latest changes. The results are similar to expectations. Roberta noted that the change in pressure drops in the EHRS loops caused some oscillation in steam generator loop C. She will resize the tube inlet orifice to stabilize this loop.
   - Roberta is also running a case with 13 (vs. 14) tubes per IRIS SG pair.
   - Fosco is at SIET to discuss procurement activities.
3. IRIS Transient Analysis
   - Davor completed his latest run. Containment pressure is still increasing at the end of the run, despite the increase in EHRS heat transfer. Davor needs to adjust the RWST model (at the top) to correct the interaction between the water and NSSS building atmosphere. He will also incorporate Roberta's changes into his model.
   - Davor is documenting his model for Matt and Henri.
   - Due to similarities between results of Relap5 L2 and L3 versions, the larger stability of L3 and its faster running, we agreed to use L3 for next runs for IRIS and SPES3.
4. Scaling Status
   - Milorad was not available for the call. AP1000 issues require his attention; Gary will find out how this will affect the SPES-3 scaling schedule.
5. The next conference call will be on Friday, February 26th at 9:00 a.m. US time, 3:00 p.m. EU time.

3.1.33 128th Conference Call on IRIS Integral Testing

2010 February 26th

Participants:

F. Bianchi (ENEA)
D. Grgic (FER)
J. Carbajo (ORNL)
C. Congiu, R. Ferri, M. Greco, G. Tortora (SIET)
H. Ormus, G. Storrick (WEC)

1. We approved the minutes of the February 12th and 19th conference calls.
2. Facility Design
   - Roberta started two new runs, one with 13 SG tubes and one with 14. These runs feature reduced SG tube inlet orifices to help avoid the tube-to-tube instabilities noted recently in SG-C. The orifice diameter reduction from 12.5 mm to 11.7 mm should increase the nominal pressure drop at rated conditions from 150 to 200 kPa. The runs are currently at 20 ks and should finish next week.
   - SIET is organizing the SPES-3 reactor vessel final design documents.
   - SIET has issued the final heater rod test loop design documentation to ENEA.
   - SIET received a heater rod offer from Rotfil, and has an earlier offer from ThermoCoax. SIET will probably test rods from both firms.
3. IRIS Transient Analysis
   - Davor started another run. It has reached 15 ks out of a planned 150 ks. This run has changes in the upper RWST model designed to reduce the contact with the atmosphere. Davor expects this run to look more like case HT5g did. This run will probably have the same long-term behavior (increasing drywell pressure) as before.
   - Davor will try to work this weekend on documenting his model for Matt and Henri.
4. Scaling Status
   - Milorad was not available for this week's call.
5. The next conference call will be on Friday, March 5th at 9:00 a.m. US time, 3:00 p.m. EU time.

3.1.34 129th Conference Call on IRIS Integral Testing

2010 March 5th

Participants:

F. Bianchi (ENEA)
D. Grgic (FER)
J. Carbajo, G. Yoder (ORNL)
R. Ferri, M. Greco, G. Tortora (SIET)
H. Ormus, G. Storrick (WEC)

1. We approved the minutes of the February 26th conference calls.
2. Facility Design
    - Roberta started two new runs last week, one with 13 SG tubes and one with 14. These runs finished with very little difference between the two. The reason is that only part of the SG tube participates effectively during natural circulation.
        - SIET found and corrected some small errors in the inputs to these runs.
            - Some areas in the A and B SG hot and cold legs were incorrect.
            - The area of the sparger holes was ¼ of what it should have been.
            - SIET corrected the errors and is rerunning the cases. They are presently at about 25 ks.
    - **Roberta asked Davor to send his final case to her.**
    - SIET is placing orders for the heater rod test loop. They plan to have the test loop ready by the end of June. SIET plans to test two heater rods from Rotfil and two from ThermoCoax. The lead times for rod procurement are 3 and 6 months, respectively, so SIET will have to wait before starting tests.
3. IRIS Transient Analysis
    - Davor had run crashes at 30 and 45 ks. The available results show a similar RWST heatup as before, then saturation and an early slowdown; otherwise, the run results looked like earlier ones.
        - The Ht5g runs looked reasonable. Case Ht5h switched the heat transfer model and got slower results. The latest run comes to an end at a temperature lower than the SIET model. The current run is crashing on EHRS primary conditions. Something related to the RWST water is affecting the EHRS heat exchanger primary.
        - Roberta notes that Davor had a large area between the pool and atmosphere. Roberta's model had a pipe at the top (3. horizontal, 3 m vertical) connected to a time-dependent volume representing air.
            - Davor wants to keep a physical area.
            - Roberta and Davor discussed several details; however, Davor needs to investigate the problem over the weekend before drawing any conclusions.
            - Roberta suggestion is to maintain the same contact surface between water and air, but to reduce the volume of vol. 585. In order to maintain the total volume of air initially present in vol. 585, another air volume could be located over it and connected to it by a reduced section pipe (for example 100 time the area of SPES3 pipe). Such new volume could be connected to the atmosphere control volume (tmdpvol 587).
    - Gary asked Davor to send Matt the files that he requested. Davor will send the input deck and binary files over the weekend.
4. Scaling Status
    - Milorad was not available for this week's call.

5. The next conference call will be on Friday, ~~March 12th~~ **(later changed to March 19th)** at 9:00 a.m. US time, 3:00 p.m. EU time.

3.1.35 130th Conference Call on IRIS Integral Testing

2010 March 19th

Participants:

F. Bianchi (ENEA)
D. Grgic (FER)
J. Carbajo, G. Yoder (ORNL)
C. Congiu, R. Ferri, M. Greco, G. Tortora (SIET)
M. Dzodzo, H. Ormus, G. Storrick (WEC)

1. We approved the minutes of the March 5th conference calls.
2. Facility Design
    - Roberta is waiting for Davor's results to compare with her two recent runs (one with 13 SG tubes and one with 14). The results were similar to earlier runs.
        - **Roberta asked Davor to send his final case to her.**
    - Roberta reported having problems connecting to the Westinghouse large file transfer system (no access). Milorad will investigate.
    - SIET is placing orders for the heater rod test loop. SIET now plans to test four heater rods from Rotfil and four from ThermoCoax. The revised lead times for rod procurement are 3 and 3-1/2 months, respectively.
3. IRIS Transient Analysis
    - Davor solved the RWST problems and started a 150 ks run yesterday. It should finish on Wednesday.
    - Davor has not had time to send Matt the files that he requested. Davor understands the need but has to do this on his own time. He will try to send the files over the weekend.
4. Scaling Status
    - Milorad has been working on AP1000 issues and so the scaling effort is on hold.
    - Professor Oriolo has a student available to help Milorad. Milorad will meet with Mike Anness to determine how Mike wants to proceed.
5. Miscellaneous
    - Davor asked what the latest schedule is for IRIS deployment. Croatia is planning its energy future and the French Ambassador is inquiring about nuclear options. Davor needs information to protect the IRIS interest. Gary suggested that Davor ask Mike Anness with carbon copies to Mario and to Gary.
6. The next conference call will be on Friday, March 26th at **10:00 a.m**. US time, 3:00 p.m. EU time. **Note the time change in the USA. The USA is on daylight saving time and Europe is not.**

3.1.36 131st Conference Call on IRIS Integral Testing

2010 March 26th

Participants:

F. Bianchi (ENEA)
D. Grgic (FER)
J. Carbajo, G. Yoder (ORNL)
C. Congiu, R. Ferri, M. Greco, (SIET)
M. Dzodzo, G. Storrick (WEC)

1. We approved the minutes of the March 19th conference calls.

2. Facility Design
   - Roberta is resolving comments on her ENC2010 paper on SPES3 and IRIS simulation
   - Roberta is waiting for Davor's results of DVI break transient to complete her analysis report on SPES3 design review (see item 3).
   - Roberta continues having problems connecting to the Westinghouse large file transfer system (no access). Milorad asked Roberta to continue pursuing the issue with Mick Ritchie (Richie@westinghouse.com) directly.
   - SIET should be signing the orders for the test loop prototype heater rods today, for 4 rods from Thermocoax and 4 rods from Rotfil.

3. IRIS Transient Analysis
   - Davor is still not getting satisfactory results from the IRIS RELAP/GOTHIC runs. One run crashed this week, and others give nonphysical results. The RWST response is OK until it reaches saturation, and then either the steam flow is too high or the flow is reasonable but the steam is superheated. Davor is still trying to find a correlation between the changes he made and the new behavior that he sees.
   - Roberta suggested that Davor look at her recommendation in the minutes to conference call #129. This was as follows:
     - "Roberta suggestion is to maintain the same contact surface between water and air, but to reduce the volume of vol. 585. In order to maintain the total volume of air initially present in vol. 585, another air volume could be located over it and connected to it by a reduced section pipe (for example 100 time the area of SPES3 pipe). Such new volume could be connected to the atmosphere control volume (tmdpvol 587).
   - Davor will attempt to solve the problem and start another run today. If successful, he will have results to Roberta by Wednesday. He will also provide Westinghouse with the material Matt requested at the same time.

4. Scaling Status
   - Milorad has been working on AP1000 issues and so the scaling effort is on hold.

5. The next conference call will be on Friday, April 9th at 9:00 a.m.US time, 3:00 p.m. EU time. **There will not be a conference call on April 2nd (Good Friday).**

3.1.37 132nd Conference Call on IRIS Integral Testing

2010 April 9th

Participants:

F. Bianchi (ENEA)
D. Grgic (FER)
C. Congiu, R. Ferri, G. Tortora (SIET)
M. Dzodzo, H. Ormus, G. Storrick (WEC)

1. We approved the minutes of the March 26th conference calls.
2. Facility Design
   - Roberta finished the ENC2010 paper.
     - The paper is OK using the existing data. Davor has a run in progress (see item #3), and will advise Roberta on Monday if he feels it is worth substituting four figures using data from that run.
   - Roberta resolved the problems connecting to the Westinghouse large file transfer system (LFTS). She uploaded the latest 13- and 14-tube SG cases named SPES3-147 and SPES3-146, respectively.

Action Item [ASAP]: Henri to copy these from the LFTS server before they disappear.

   - SIET and Thermocoax are holding a kickoff meeting next week. Thermocoax has the order for the prototype heater rods and is starting their design.
   - Cinzia, Gaetano, and Matteo are verifying the SPES-3 piping mechanical design. They have reviewed the layout consequently to the RV final design and SPES3 design and are developing models for the verification.
3. IRIS Transient Analysis
   - Davor modified his model in a manner similar to Roberta's recommendation from conference calls #129 and #131. Although the transient behavior seems to be correct, he doesn't like the approach on physical grounds. The run is in progress and should finish on Monday or Tuesday. Davor will send his results to everyone when finished.
   - Davor continued working on his visualizations to try to understand the recent problems. These show some void distributions in the reactor vessel that are not always obvious.
4. Scaling Status
   - Milorad has been working on AP1000 issues and so the scaling effort is on hold.
5. The next conference call will be on Friday, April 16th at 9:00 a.m.US time, 3:00 p.m. EU time.

3.1.38 133rd Conference Call on IRIS Integral Testing

2010 April 16

Participants:

F. Biianchi (ENEA)
D. Grgic (FER)
D. Papini (POLIMI)
C. Congiu, R. Ferri, M. Greco, G. Tortora (SIET)
M. Dzodzo, H. Ormus, G. Storrick (WEC)

1. We approved the minutes of the April 9th conference calls.
2. Facility Design
   - Roberta saw the data that Davor posted this week. She placed a file (Attachment 1) comparing the SPES-3 and IRIS RWST temperatures in the eRoom just before the call.
     - The IRIS temperatures exceed 100 C. Davor attributes this to the higher pressure caused by the additional pipe in Roberta's RWST model. Davor limited the pipe area to $1m^2$ (a guess) to avoid sudden evaporation. This is much less than 100x the SPES-3 area. Davor will try the run with a larger area.
     - Roberta asked if Davor could restart the run at 150ks. Davor replied that he cannot start at that point because that restart file was damaged (electrical problems). Davor will restart the run at an earlier point (~72ks) and provide results on Monday or Tuesday.
   - SIET and Thermocoax met on April 15th. Thermocoax had the drawings and specifications before the meeting and is proceeding with the design. One key issue is the electrical connections at the bottom, where there is little room. Thermocoax is trying to reduce the diameter of the connectors.
3. IRIS Transient Analysis
   - Davor ran the previously-mentioned run using GOTHIC 7.2b and is currently running a 7.2a case.
     - All cases show a minimum drywell pressure at 50-60ks and then a pressure increase.
     - Davor expects stabilization at about 120ks. The interesting question is, "will the pressure will decrease or oscillate afterward?"
   - Davor placed a .zip file in the eRoom (now at My eRooms > IRIS > SPES-3 Test Facility > IRIS_SPES_R5G> distr 20100416.zip) that contains all the information from his latest cases. This includes GOTHIC7.2b input files.
     - Roberta could proceed with her report using this information, but she waits for the whole set of data (150 ks) to compare data only once.
     - Davor will start producing plots and descriptions of this run today.
     - Davor will give Westinghouse a 7.2b executable once the current test run is complete.
4. Scaling Status
   - Milorad has been working on AP1000 issues and so the scaling effort is on hold.

5. The next conference call will be on Friday, April 23rd at 9:00 a.m.US time, 3:00 p.m. EU time.

3.1.39 134th Conference Call on IRIS Integral Testing

2010 April 23

Participants:

D. Grgic (FER)
J. Carbajo (ORNL)
C. Congiu, R. Ferri, M. Greco, G. Tortora (SIET)
M. Dzodzo, H. Ormus, G. Storrick (WEC)

1. We approved the minutes of the April 16th conference call.
2. Facility Design
   - Roberta is finishing the analysis and IRIS design follow-up documents required by the ENEA/SIET contract. She needs Davor's final results so that she can finish the documents.
3. IRIS Transient Analysis
   - The last IRIS run restart (at 72 ks) had a discontinuity on the restart. Davor corrected the problem and then restarted the run at both the beginning and at 72 ks. The former should finish on Monday or Tuesday, the latter a day or two later.
     - Davor found and corrected a minor ADS line routing error. This should not affect the results of the run.
     - Davor's IRIS runs still show pressure increasing in the long-term, while Roberta's SPES-3 show decreasing pressure
   - Davor is having a student repeat earlier PANDA runs to check recent programming changes.
4. Scaling Status
   - Milorad has been working on AP1000 issues and so the scaling effort is on hold.
5. The next conference call will be on Friday, April 30th at 9:00 a.m.US time, 3:00 p.m. EU time.

3.1.40 135th Conference Call on IRIS Integral Testing

2010 April 30

Participants:

F. Bianchi (ENEA)
D. Grgic (FER)
J. Carbajo (ORNL)
C. Congiu, R. Ferri, M. Greco, G. Tortora (SIET)
M. Dzodzo, H. Ormus, G. Storrick (WEC)

1. We approved the minutes of the April 16th conference call.
2. Facility Design
   - Roberta is finishing the analysis and IRIS design follow-up documents required by the ENEA/SIET contract. She needs Davor's final results so that she can finish the documents.
3. IRIS Transient Analysis
   - Davor provided new results shortly before the call (see Attachment 1).
     - The new runs (c1 and d1) use a new coupling between the RELAP and GOTHIC parts of the model. Run c1 uses GOTHIC model 7.2a; d1 uses 7.2b.
     - The new results look more like the SPES3 results. The new coupling leads to more break and return line oscillations after 20 ks. This leads to more water going into the reactor vessel on average.
     - Roberta asked whether she should use run d1 or c1. Davor plans on using GOTHIC 7.2b from now on; however, he recommended that Roberta use whichever version matched the SPES3 run best for peak containment pressure. Davor will send the full run details to SIET and Westinghouse after the call. Roberta will study the results and choose which one to use.
4. Scaling Status
   - Milorad has been working on AP1000 issues and so the scaling effort is on hold.
5. Test Facility Specification
   - Roberta created several change requests for the test facility. Gary will try to process these quickly so that Roberta can refer to an updated (Rev. 2) specification in her document.

6. The next conference call will be on Friday, May 7th at 9:00 a.m.US time, 3:00 p.m. EU time.

3.2 Meeting minutes

3.2.1 SIET-ENEA-CIRTEN meeting April 17, 2009

Verbale di riunione 17-4-2009 SIET

Presenti: B. Panella, M.E. Ricotti, G. Vella, A. Mosetto, D. Papini (CIRTEN)

P. Meloni (ENEA)

G. Cattadori, R. Ferri, A. Achilli (part time) (SIET)

Oggetto della riunione: possibili applicazioni di codici T/H NRC al programma sperimentale SPES3 e attività su strumentazione speciale nell'ambito dell'A.d.P.

Inizialmente viene descritto lo stato del progetto dell'impianto sperimentale SPES3: progetto esecutivo dei circuiti secondari e del contenimento completato; progetto preliminare del canale centrale (RV) disponibile; SIET responsabile del progetto esecutivo del RV e Mangiarotti Nuclear incaricata per le verifiche strutturali e di costruibilità di RV e componenti interni (tempo disponibile 4 mesi).

Si discute in generale delle problematiche costruttive dell'impianto e di certe scelte progettuali:

in SPES3 una sola pompa esterna (bassa prevalenza e alta portata) che alimenta 4 bocchelli. Ad ogni ramo che dalla pompa va al RV è associato un by-pass per la circolazione naturale del fluido quando la pompa è ferma;

fascio di barrette scaldanti: individuato il costruttore in Thermocoax. Specifica barrette scritta da SIET, ma ENEA incaricata di procedere nella trattativa ed emissione degli ordini. Stato della situazione: fermo da settembre 2008;

possibile realizzazione in SIET di un circuito per prove su barrette campione (prima parte di un eventuale ordine verso Thermocoax);

griglie distanziatici delle barrette. Vengono prese a riferimento le griglie di SPES2. Mangiarotti ne verificherà la fattibilità. Una volta definite le griglie, verranno inviate a Thermocoax per il montaggio del fascio di barre.

Presenza di valvole di non ritorno nel RV, tra Riser e downcomer, a circa 1/3 dell'altezza dei generatori di vapore. Durante il funzionamento nominale, tali valvole sono mantenute chiuse dalla differenza di pressione tra zona GV (a pressione più alta) e zona Riser (a pressione più bassa). In caso di perdita della prevalenza pompa, le valvole si aprono e permettono la circolazione naturale a livello più basso nel RV.

Possibilità/necessità di verificare il funzionamento delle valvole di non ritorno (soluzione con sfere flottanti) su un circuito sperimentale.

Successivamente viene presentata la nodalizzazione di SPES3 per il codice RELAP5 Mod3.3 ed i calcoli di transitori effettuati per la verifica del progetto preliminare.

Sulla base di confronti preliminari con il transitorio IRIS di rottura del DVI, le differenze sostanziali tra SPES3 e IRIS sono legate all'evoluzione di pressione nel contenimento. Ciò è dovuto alle diverse capacità termiche delle pareti del Dry-Well, molto alte in SPES3 rispetto ad IRIS (~10 volte più grande la superficie di scambio e spessore delle pareti tale da sostenere la pressione di progetto, 2 MPa). Un effetto inferiore sembra legato alle perdite di calore verso l'esterno.

L'Università di Palermo, nell'ambito del CIRTEN, ha un particolare interesse nelle analisi di SPES3 con TRACE.

Ricotti cita l'AdP (LP5) come possibile fonte di finanziamento di questa attività.

Meloni ricorda che il CIRTEN ha firmato un non-disclosure agreement con Westinghouse nell'ambito del quale l'Università di Palermo può svolgere attività inerenti a SPES3-IRIS.

Ferri metterà in contatto Vella con Storrick (WEC) per avere le autorizzazioni necessarie all'ingresso nell'e-room ecc.

Meloni cita l'interesse di ENEA per il modello TRACE di SPES3 e raccomanda di lavorare in concerto.

Per iniziare il lavoro di "traduzione" del modello RELAP di SPES3 al modello TRACE, dietro autorizzazione di ENEA (rappresentata da Meloni), SIET fornisce a Vella un CD con i file dei tre documenti SIET: Progetto concettuale, Nodalizzazione e Analisi transitori (casi base).

Viene menzionato ISPRA, in quanto distributore dei codici Relap e Trace, e si sottolinea che i risultati delle attività di assesment dei codici su dati SPES3 non gli possono essere fornite in quanto vincolati all'accordo con WEC.

Ricotti propone che l'Italia, una volta acquisite competenze sui codici, si candidi nei confronti di WEC per le analisi di sicurezza di IRIS.

Ricotti cita inoltre alcune industri e italiane che possono avere interesse in IRIS (Saipem, Maire Tecnimont, ecc.).

Papini spiega il lavoro che ha svolta a Zagabria con Grgic sul confronto tra i risultati dei codici Gothic e Relap nella simulazione del contenimento. Parla inoltre dell'implementazione nel codice Relap di modelli di condensazione migliori di quelli presenti. Emerge la necessità di validare i nuovi modelli su dati sperimentali, possibilmente quelli del PERSO, in cui uno scambiatore di calore a tubi verticali, immerso in piscina, era stato provato alla SIET, in un'attività finanziata da ENEA.

Per la strumentazione speciale, sono interessati sia il Politecnico di Torino che quello di Milano.

Mosetto, dottoranda del POLITO, ha già seguito in passato le prime fasi dell'attività con una ricerca bibliografica per identificare la strumentazione più idonea per le misure di flussi bifase in SPES3.

Individuata una catena di misura costituita da Wire Mesh Sensors + Turbina + Drag disk, la fase successiva dell'attività riguarderà l'elaborazione dei segnali strumentali per ottenere le portate di massa alle rotture e alle linee degli ADS.

Dai risultati delle analisi Relap dei cinque transitori (casi base), Mosetto sta definendo i range di misura per la strumentazione speciale per ciascuna linea interessata. Sulla base della sua sintesi, si potrà contattare il costruttore/inventore (Prasser, EHT) e verificare l'effettiva applicabilità.

In SPES2, la massa scaricata dalle rotture veniva condensata, raccolta e pesata, ma in SPES3 ciò non è possibile perché l'evoluzione del transitorio verrebbe compromessa (in SPES2 il contenimento non era simulato).

Visto che l'attività sulla strumentazione speciale richiede tempo e risorse, l'idea iniziale che Mosetto potesse svolgere analisi con codici CFD sul DW è superata. Potranno invece essere usati i risultati delle simulazioni TRACE in programma all'Università di Palermo.

Oltre alla strumentazione speciale, sulle linee interessate da flussi bifase, verrà impiegata anche strumentazione convenzionale che fornirà le misure di portata, almeno nella prima fase dell'efflusso (monofase).

Dovranno comunque essere fatte prove sperimentali sulla catena di misura (WMS+Turbina+drag disk), prima di procede all'utilizzo su SPES3.

Cattadori evidenzia l'importanza di utilizzo dei segnali della strumentazione convenzionale, opportunamente elaborati, per risalire a grandezze tipiche del transitorio come, ad esempio, la massa scaricata dalla rottura (misura di livello nei serbatoi del contenimento con stima del film di condensato alla parete…).

Ricotti propone di sviluppare, nell'ambito dell'AdP, una facility a piccola scala, in SIET, per analisi di diverse problematiche. Potrebbe essere lo stesso circuito di prova per i prototipi delle barre scaldanti o anche il circuito di prova su tubi elicoidali a riscaldamento indiretto.

Papini riprenderà l'attività sulla facility a tubi elicoidali, in SIET, per studiare il problema dell'instabilità sui tubi in parallelo. I risultati saranno molto importanti anche ai fini dell'orifiziatura dei tubi dei GV di SPES3.

Panella propone prove in aria/acqua al Politecnico di Torino, sempre ai fini della strumentazione speciale.

Il Politecnico di Milano potrà contribuire alle ricerche sulla strumentazione speciale, anche sulla base di una tesi svolta con Lombardi, negli anni '80, da Guido Franzoni.

3.2.2 21st IRIS Team meeting May 19-21, 2009 Tallin, Estonia

Relazione relativa al
21esimo IRIS TEAM MEETING
Tallinn, Estonia, 19-21 maggio 2009

A cura di F. Bianchi e S. Monti

Il meeting si è tenuto a Tallinn (Estonia) dal 19 al 21 Maggio. L'agenda dei lavori e la lista dei partecipanti sono riportate rispettivamente negli allegati 1 e 2. Merita sottolineare che il 50% dei partecipanti era italiano e che erano presenti come osservatori italiani anche le società SAPIEM (gruppo ENI) e ATB Riva Calzoni che sembrano essere molto interessate a diventare membri dell'IRIS Team, aggiungendosi dunque a ENEA, CIRTEN, Ansaldo Nucleare, Mangiarotti Nuclear, e Maire Tecnimont (ultima entrata a far parte dell'IRIS Team).
La mattinata del primo giorno è stata dedicata a presentare il reattore IRIS alle organizzazioni estoni (università e industria) e ad individuare possibili collaborazioni, mentre il pomeriggio e gli altri giorni sono stati dedicati alla presentazione delle attività svolte dall'ultimo IRIS meeting (20esimo) e alla definizione delle attività future. Per l'ENEA hanno partecipato gli ingg. Bianchi F., Forni M., Monti S. e il dott. Burn KW.
Una copia delle presentazioni è disponibile presso i redattori della relazione.
Di seguito si riporta una breve sintesi dei principali argomenti tecnici trattati e delle questioni discusse:

S. Liive (Presidente di Eesti Energia - esercente elettrico estone) ha dichiarato che l'energia elettrica è prodotta principalmente con olio combustibile "oil shale", ma c'è necessità di diversificare le fonti e di aumentare l'indipendenza energetica. Si pensa alle fonti rinnovabili e all'energia nucleare, non essendo la popolazione contraria agli impianti nucleari. Naturalmente l'opzione nucleare è perseguibile in Estonia solo se i costi di produzione sono più bassi rispetto alle altre opzioni e se il costo di investimento si mantiene entro valori ragionevoli. Per questi motivi sono interessati alla costruzione di un reattore di piccola-media taglia. Sono stati già individuati sei possibili siti.

A. Tropp (Responsabile del dipartimento Nucleare di Eesti Energia) ha affermato che il costo dell'energia elettrica prodotta in Estonia è il più basso dei paesi dell'EU e che il piano energetico per il medio e lungo termine è stato approvato dal Governo in Febbraio. Per rispettare i vincoli europei sulle emissioni, tale piano prevede una riduzione significativa della quota di olio combustibile, lo sviluppo delle fonti rinnovabili (impianti eolici, ecc,) e lo sviluppo di nuovi impianti, ma non parla esplicitamente della costruzione di impianti nucleari; però entro il 2012 è previsto che in Estonia vengano create le condizioni legislative per rendere il nucleare fattibile e, inoltre, è prevista la creazione di una Autorità di Sicurezza e lo sviluppo di competenze nel settore nucleare. Manca, infatti, in Estonia un adeguato background tecnico sul nucleare e la conoscenza del nucleare nella popolazione è molto scarsa. Educare la popolazione è ritenuto importante per lo sviluppo del nucleare. Attualmente il piano è in discussione nel Palamento estone; gli argomenti già discussi hanno riguardato la sicurezza degli approvvigionamenti, la creazione di nuove interconnessioni elettriche con i paesi limitrofi (Finlandia, Lituania, ecc.), la creazione di un mercato energetico unico per i paesi del Baltico. In estate cominceranno gli studi geologici per un possibile sito nucleare a 50 km a ovst di Tallinn. Riguardo al nucleare, cinque partiti su sei hanno espresso pubblicamente parere favorevole al suo sviluppo, mentre la popolazione è favorevole sia alle fonti rinnovabili che all'energia nucleare, ma non vuole gli impianti vicino alla propria casa (sindrome NIMBY). A livello internazionale l'Estonia è membro di GNEP dall'Agosto 2008; in questo ambito seguono con interesse le attività relative agli SMR, alla gestione dei rifiuti radioattivi e alle forniture internazionali di combustibile nucleare. In sintesi, il processo di avvicinamento al nucleare da parte dell'Estonia appare piuttosto lungo ma c'è un chiaro impegno nazionale.

M. Kirst (Vice Presidente di WEC per l'Europa Centrale ed Orientale) ha illustrato la società, il "core business" (fornitura di combustibile per PWR, BWR, VVER, AGR e MAGNOX; progettazione impianti nucleari refrigerati ad acqua, gas, sodio e forse a piombo; fornitura di servizi: riparazione e sostituzione di componenti, ecc.) e la politica Westinghouse in campo nucleare. Ha dichiarato che il rilancio del nucleare nel mondo (renaissance) sarà possibile solo se gli attuali impianti saranno eserciti in condizioni di sicurezza (senza incidenti). Ha fatto presente che il 50% degli impianti nucleari costruiti nel mondo ed il 60% dei reattori americani sono basati sulla tecnologia WEC. Ha evidenziato i principali requisiti dei nuovi impianti: standardizzazione, semplificazione dell'esercizio e della manutenzione, incremento della sicurezza (ricorso a sistemi passivi), riduzione dei costi di costruzione ed esercizio. In particolare per l'AP1000 WEC ha cercato di ridurre il rischio di investimento con il ricorso a sistemi passivi (minor numero di componenti), pre-licensing e certificazione del progetto da parte di NRC, disponibilità del progetto esecutivo prima di iniziare la costruzione, costruzione modulare, ecc.. Nel 2007 l'AP1000 ha ottenuto anche la certificazione EUR. Ad oggi nel mondo sono stati ordinati 10 impianti AP1000: 4 in Cina e 6 in USA. E' previsto lo sviluppo di un AP1700 in base alle richieste del mercato. Per quanto riguarda IRIS, WEC crede nel nuovo mercato degli SMR ma ovviamente è necessario valutare bene il possibile mercato per giustificare gli investimenti necessari a certificare IRIS.

M. Carelli (Project leader di IRIS in WEC) ha presentato il reattore IRIS, che si basa su una tecnologia provata, le possibili applicazioni, le principali caratteristiche e gli "atouts" rispetto agli altri impianti: safety-by-design, eliminazione di molti incidenti, che sono molto improbabili, e i relativi sistemi di sicurezza, nessun programma di sorveglianza per il vessel, possibile utilizzo del vessel come sarcofago per il deposito definitivo, assenza di sistemi attivi, limitata pianta degli edifici, eliminazione/riduzione del rischio sismico, ecc.. Circa il 90% dei componenti è di derivazione AP1000, per cui solo il 10% richiede una certificazione sperimentale. Ha parlato delle fasi future, che si possono così sintetizzare: fine delle campagne sperimentali entro il 2012, presentazione a NRC della richiesta di certificazione del progetto nel 2013 ed interazione con NRC per ottenere l'approvazione finale del progetto entro il 2015-2017. I programmi sperimentali riguarderanno i generatori di vapore, le pompe, il pressurizzatore, le barre di controllo e le prove integrali. Il costo unitario di un impianto IRIS è stato valutato in circa 1500 $/KWe, ma può scendere a 1300-1400 $/KWe in caso di impianti multipli. Il tempo di costruzione è stato stimato pari a tre anni dalla società Betchel.

M. Ricotti (POLIMI), **G. Forasassi** (UNIPI), H. **Ninokata** (Tokyo Inst. of Technology), **N. Cavlina** (Università di Zagabria), **M. Carelli** (in sostituzione del prof. F. Rahnema dell'università americana di Atlanta) e **M. Kirm** (università estone di Tartu) hanno presentato l'organizzazione dei dipartimenti/Istituti, i corsi e le attività di R&D delle rispettive università. In particolare il prof. Ricotti ha illustrato il ruolo delle università in IRIS e il prof. Forasassi il nuovo piano di studi in Italia (laurea breve, laurea specialistica, Master e PHD), il prof. Cavlina ha affermato che il suo istituto è autorizzato ad eseguire "safety review" per la Croazia e la Slovenia (TSO) e l'ing. Carelli, ha presentato il programma americano SUNRISE, a cui partecipano diverse università, laboratori nazionali ed industrie con lo scopo di creare un centro di eccellenza per l'insegnamento, la ricerca e l'addestramento del personale sulla tecnologia dei reattori avanzati.

G. O'Brien (WEC), responsabile delle attività commerciali di WEC (d'ora in avanti rimpiazzerà la Layla Sander, ndr), ha dichiarato che WEC non costruisce, ma si appoggia su altre società, che devono essere capaci di garantire la qualità, la standardizzazione, un costo competitivo ed il planning di realizzazione dei componenti. Ha affermato che le possibilità di intervento di altre società per l'isola nucleare e per i sistemi di sicurezza sono molto limitate, mentre sono molto estese per le opere civili e la parte convenzionale (BOP). Ciò è particolarmente vero per IRIS, considerato che la maggior parte dei sistemi e componenti non è classificata nelle classi di sicurezza. Inoltre IRIS si adatta meglio all'esperienza industriale dei paesi in via di sviluppo. Per diventare fornitori di WEC è necessario che: 1) il paese interessato esegua una valutazione delle potenzialità della propria industria nazionale (IAEA fase 1); 2) l'industria sia capace di assicurare la qualità, la standardizzazione, un costo competitivo e la pianificazione temporale; 3) far iniziare il più presto possibile il processo di valutazione dei fornitori da parte WEC al fine di essere inseriti nel "Approved Supplier List". Infine ha ricordato che la filosofia WEC è " We buy where we build™ ".

A. A. Pajula (membro del Consiglio direttivo dell'Associazione degli Industriali dell'Estonia) ha presentato le attività dell'industria estone, che dà lavoro a circa 32000 persone (5% della forza lavoro). I principali settori di intervento riguardano: il settore della meccanica, elettronica ed elettrostrumentale, che ha contribuito al fatturato del 2007 per il 36,5%, l'alimentare per il 19,2%, il tessile e l'abbigliamento per il 7,6%, la chimica, plastica e gomma per il 4,6%, e il settore cartario e della lavorazione del legno per il 19,9

%. Hanno diverse collaborazioni con università (Tallinn, ecc.) ed Associazioni degli industriali di altri paesi (Lituania e Lettonia).

La prima parte del meeting è terminata con una discussione tra i vari partecipanti. Merita segnalare che il rappresentante lettone ha posto una domanda sulla convenienza di costruire un reattore della taglia di IRIS in un paese piccolo come l'Estonia, considerato che la rete europea è molto interconnessa e, quindi, è possibile partecipare alla costruzione di un impianto nucleare di grossa taglia e ricevere in cambio una quota di energia elettrica corrispondente alla propria partecipazione economica (la Lituania ha proposto all'Estonia di partecipare alla realizzazione in un impianto nucleare sul proprio territorio). Inoltre i tempi per la realizzazione di una rete di distribuzione di potenza sono lunghi (circa 10 anni). WEC ha risposto diplomaticamente affermando che dipende dalla strategia che l'Estonia vuole perseguire.

M. Carelli (Project leader di IRIS in WEC) ha presentato i principali risultati conseguiti dall'ultimo meeting. In particolare si è soffermato sui risultati eccellenti ottenuti dal gruppo ENEA riguardo alle problematiche di schermaggio e radioprotezione (dimostrazione della non necessità di un programma di sorveglianza per il vessel e di ulteriori schermaggi per ridurre le dosi agli operatori, ecc.) e con la proposta di un sistema di isolamento sismico (riduzione del rischio sismico rispetto all'impianto non isolato simicamente). Ha dichiarato che: 1) possono essere considerate terminate da parte WEC le attività relative alla verifica dello "scaling" dell'impianto SPES-3 con il metodo NRC della FSA (Fractional Scaling Analysis) e al progetto concettuale dell'IRIS-50; 2) c'è un forte interesse da parte di alcuni paesi piccoli dell'Europa; 3) il Messico è interessato a impianti destinati alla desalinizzazione dell'acqua; 4) sta nascendo anche negli USA un mercato per i reattori di piccola e media taglia.

V. Kuznetsov (IAEA) ha parlato sulle attività dell'IAEA sui reattori di piccola e media taglia nell'ambito di CRP (Co-ordinated Research Programme). Un reattore è considerato di piccola taglia se la potenza è <300 MWe e di media taglia se la potenza è <700 MWe. Circa un terzo dei reattori eserciti nel mondo rientra in tale tipologia e ad oggi sono stati sviluppati o analizzati quaranta soluzioni differenti (Argentina, Cina, India, Giappone, ecc.). Lo sviluppo di questi reattori è condizionato dal grado di soddisfacimento delle esigenze dei paesi in via di sviluppo. Sono disponibili per la commercializzazione solo poche soluzioni: CANDU-6/EC-6 (Canada), PHWR-220 e PHWR (India) e NC200 (Cina).

S. Monti (ENEA) ha illustrato la nuova strategia del governo per la rinascita del nucleare in Italia e le principali attività di R&S sul nucleare da fissione in Italia e in particolare all'ENEA. Le attività in supporto a IRIS sono quelle a cui viene riservata la percentuale maggior del budget disponibile. La presentazione è riportata nell'allegato 3.

G. Storrick (WEC) ha esposto il programma di Garanzia della Qualità (GQ) di WEC, cercando di sensibilizzare i vari partner, in particolare le università, sull'importanza di lavorare in garanzia della qualità: se un lavoro non è fatto seguendo le procedure di GQ, WEC sarà costretta a farlo nuovamente e di conseguenza l'attività fatta dal partner sarà considerata inesistente. Per evitare ciò, ciascun partner dovrà, quindi, elaborare il proprio programma di GQ, che dovrà essere conforme, oltre alla propria normativa nazionale, anche a quella americana (10 CFR50, Appendix B e ASME NQA-1-1994). Ha illustrato, inoltre, il modo con cui WEC identifica e processa un documento emesso da un partner. Lavorare in GQ comporta un grosso impegno per ciascun partner. Ad esempio il lavoro fatto sulla nodalizzazione da SIET, a rigore, non è stato eseguito in GQ, anche se il suo piano di qualità è stato approvato da WEC ed il documento è stato emesso ed archiviato correttamente, in quanto l'input del codice RELAP5 non è stato verificato in maniera indipendente da una altra persona. La stessa conclusione vale per il lavoro fatto da ENEA per i calcoli dello schermaggio e radioprotezione. E' stato deciso dal Project Leader (Carelli) di inviare il documento sulla verifica dello schermaggio e quello sulla descrizione dell'impianto SPES-3 a NRC per verificare le sue reazioni a questo modo ibrido di procedere e, quindi, decidere le contromisure da attuare. Con questa proposta WEC ha richiesto indirettamente ad ENEA (SIET) di revisionare il documento sull'impianto SPES-3, già inviato a NRC nel 2007, per prendere in conto le modifiche impiantistiche fatte.

R. Ferri (SIET) ha illustrato l'impianto SPES-3, le attività completate e in corso di completamento a partire dall'ultimo meeting. Ad oggi sono state completate tutte le attività di progettazione esecutiva della parte d'impianto SPES-3, che simula il contenimento ed il circuito secondario, della nuova struttura di supporto dell'impianto e del sistema di controllo, comando ed acquisizione dati. Resta da terminare la progettazione esecutiva del canale centrale, che dovrebbe terminare entro la fine di Settembre. Riguardo ai calcoli termoidraulici a supporto della progettazione, ha presentato i risultati di cinque transitori, ritenuti dal gruppo di lavoro sulle prove integrali significativi per verificare la capacità di simulazione dell'impianto dei fenomeni fisici che si verificano sull'impianto IRIS durante un incidente, e di alcuni calcoli di sensibilità, effettuati per cercare di comprendere le cause della differenza del picco e dell'andamento temporale della pressione nel Dry Well durante i transitori, rispetto ai valori di IRIS.

M. Forni (ENEA) ha presentato l'attività, svolta da ENEA in collaborazione con il CIRTEN, sull'isolamento sismico dell'Edificio degli Ausiliari. Tale soluzione impiantistica permette di ridurre drasticamente le accelerazioni e quindi le forze di inerzia e le tensioni sui componenti. L'unico svantaggio, derivante dall'uso di questa tecnologia, è rappresentato da un costo aggiuntivo, dovuto agli isolatori, ai giunti di espansione da applicare alle tubazioni in corrispondenza del passaggio dalla zona isolata simicamente da quella non isolata, e ad una ulteriore platea di fondazione. La valutazione dei costi, fatta da ENEA, dimostra che l'incremento (5-6 M-€) può essere compensato dalla riduzione dei costi di progettazione e realizzazione componenti. Inoltre Forni ha presentato la campagna di prove sperimentali che l'ENEA si accinge a fare per la valutazione del comportamento meccanico di alcuni isolatori, opportunamente scalati. Le prove previste sono conformi alla normativa europea prEN15129.

G. Forasassi (CIRTEN) ha presentato uno studio teorico basato sul teorema di Buckingham per giustificare la rappresentatività del comportamento di isolatori a piena scala con isolatori scalati.

K. W. Burn (ENEA) ha presentato l'attività sullo schermaggio svolta da ENEA con l'ausilio di WEC, Università di Atlanta (USA) e POLIMI. Grazie ai calcoli effettuati con metodi Montecarlo, ENEA ha dimostrato che: 1) il flusso neutronico sul vessel non costituisce un problema; 2) non c'è necessità di un programma di sorveglianza sul vessel; 3) lo schermo di protezione del fondo del vessel non è necessario; 4) le dosi nella sala controllo e nelle varie zone dell'Edificio Ausiliari sono inferiori a limiti imposti dalla normativa, assumendo uno spessore di 1,5 m per lo schermo biologico. Per considerare terminata la prima fase di calcolo dello schermaggio e di radioprotezione, resta da completare la valutazione delle dosi durante le operazioni di manutenzione. Attività future riguarderanno la valutazione delle dosi fuori del contenimento durante gli incidenti, delle sorgenti esterne al vessel e delle dosi integrate durante le fasi di manutenzione.

F. Inzoli (CIRTEN) ha presentato le attività già completate dal gruppo CFD, relativamente ai modelli di turbolenza e ai protocolli CFD, e quelle in corso a supporto del progetto IRIS, che riguardano lo studio dei fenomeni di miscelamento del Boro nel downcomer, del campo di moto del fluido nel fondo vessel e all'uscita dei generatori di vapore

Side meetings

Come di consueto, oltre alla sessione principale, si sono tenuti alcuni side meeting. Alcuni erano riservati alle industrie interessate alle sistemazioni impiantistiche e al BOP (Balance of Plant). In particolare Marie Tecnimont avrà il compito di definire e progettare il BOP di IRIS.

WEC ha organizzato un **side meeting di tipo "executive"** specifico per tutte le organizzazioni italiane.
Vi hanno preso parte:
WEC: Carelli, G. O'Brien, L. Sander
ENEA: Monti
CIRTEN: Forasassi, Ricotti
Ansaldo Nucleare: A. Alemberti
Mangiarotti Nuclear: F. Berra
Maire Tecnimont: P. Gauna, D. Signorile, F. Mariani

ATB Riva Calzoni: G. Ronchetto
SAIPEM: D. Brkic

La riunione era di fatto stata sollecitata dalle stesse organizzazioni italiane al fine di discutere con WEC alcune importanti questioni che possono sintetizzarsi nella maniera seguente:

- le organizzazioni italiane partecipanti al progetto IRIS intendono perseguire la medesima strategia e, nel rispetto delle proprie prerogative e finalità nel progetto, intendono interloquire con voce unica nei confronti di WEC. Tale coordinamento è anche inteso per aumentare il peso e l'impatto delle organizzazioni italiane, che stanno fornendo contributi molto importanti al progetto in molteplici aree (integral test, sviluppo componenti e sistemi, sismica, schermaggio, calcoli CFD, valutazioni economiche SMR e, nel prossimo futuro, BOP);
- E' assolutamente necessario conoscere quali siano le attività che mancano per ottenere il "Final Design Approval" (FDA) di IRIS ed i relativi costi. Ciò anche al fine di individuare possibili investitori disponibili a coprire tali costi (il concetto qui sotto è che le organizzazioni italiane vogliono conoscere anche il resto del progetto e quanto costa ottenere la FDA, per capire se è realistico arrivare fino in fondo, ndr);
- E' necessario sviluppare almeno una prima bozza del business plan di IRIS per la commercializzazione di tale reattore nel mondo (su questo Carelli ci ha fatto sapere in camera caritatis che esiste già un lavoro fatto sia da WEC sia, in maniera indipendente, da Rolls Royce ma che per il momento la parte commerciale di WEC non vuole rilasciare, ndr). Per quanto di loro competenza e capacità, le organizzazioni italiane sono disponibili ad aiutare WEC nel formulare tale business plan;
- Si intende valutare i possibili ritorni al sistema italiano che possono derivare dallo sviluppo e dalla futura commercializzazione di IRIS.

Questi punti costituiscono la parte principale di un Memorandum of Understanding (MoU) preparato in bozza dalle organizzazioni italiane e riportato in allegato 4. Esso è stato brevemente illustrato da Monti nel corso della riunione. Monti ha anche annunciato a WEC che l'MoU sarà formalizzato fra i firmatari nel mese di giugno [1] e verrà successivamente inviato formalmente a WEC con lettera di accompagnamento.

Ovviamente l'MoU fa anche riferimento alla precedente lettera di intenti firmata da un gruppo italiano più ristretto in ottobre 2005 (in un certo senso il MoU è un'estensione e un rafforzamento della posizione italiana rispetto a quella lettera di intenti). La lettera del 2005 è richiamata e allegata al MoU.

Nel discutere i contenuti del MoU con WEC, WEC stessa ha preso l'impegno di inviarci una lista di azioni su cui si responsabilizza, entro 15-20 giorni. Nel frattempo le organizzazioni italiane - ENEA, CIRTEN, Ansaldo Nucleare, Mangiarotti Nuclear e Maire Tecnimont - dovrebbero procedere alla firma di questo MoU ed al suo invio a WEC. Ovviamente l'MoU deve essere processato internamente da ogni organizzazione firmataria, in quanto la bozza qui allegata è solamente il risultato dei rappresentanti tecnici italiani nell'IRIS Team. Il MoU verrà firmato anche da SIET e, se nel frattempo entreranno formalmente a far parte dell'IRIS Team, anche da SAPIEM e ATB Riva Calzoni.

Nel corso della riunione WEC ha chiarito quali sono i passi successivi per arrivare alla commercializzazione di IRIS. Essi possono così riassumersi:

- Pre-application verso NRC: in corso
- Fine dei test: 2012
- Preparazione del DCD (Design Certification Dossier) e sua sottomissione a NRC: 2013
- NRC review e, in parallelo, sviluppo progetto fino ad ottenere il livello necessario per la call for tender: 2015

[1] Le parti italiane si sono date appuntamento per la settimana del 15 giugno per verificare lo stato di formalizzazione del MoU

- Final Design Approval (FDA) e Design Certification e, in parallelo, FOAKE (First of a Kind Engineering): 2017-2018
- A questo punto IRIS è pronto per la commercializzazione

Conclusioni e considerazioni finali

Carelli intende istituire un nuovo gruppo di lavoro per vedere qual è la massima potenza elettrica ottenibile da IRIS, mantenendo invariate le dimensioni del vessel e del contenitore di sicurezza. Tale WG comprende: WEC, Eesti Energia (Estonia), AN con il supporto di Mangiarotti Nuclear (soprattutto per GV), ENSA (Vessel), Maire Tecnimont (BOP), Japan Institute of Technology (Giappone).

Carelli ha anche riconosciuto che è stato svolto di recente un ottimo lavoro in molte parti chiave del progetto (schermaggio, sismica, integral test, ecc.) ma occorre cambiare passo per arrivare in tempi ragionevoli alla commercializzazione di IRIS. Per fare ciò è necessario un importante supporto finanziario per ottenere l'FDA e questo sarà il focus del progetto per i prossimi mesi.

Nei prossimi mesi nell'ambito della pre-application verranno sottoposti a NRC alcuni report che faranno parte del Rapporto di Sicurezza. Fra essi ci sarà il rapporto sullo schermaggio. Premesso che il rapporto formale con NRC verrà mantenuto da WEC, è richiesto il supporto tecnico da parte ENEA (Burn). Successivamente verranno sottoposti dossier sull'isolamento sismico e sull'integral testing.
Verrà anche chiarito con NRC la questione del codice di termoidraulica da utilizzare per l'analisi di sistema e di sicurezza in GQ.

Il prossimo meeting si terrà in Italia, probabilmente il prossimo ottobre. Possibili sedi sono: Venezia o Frascati.

Nota finale: fuori meeting, Carelli ha detto a Bianchi di non scrivere più IRIS per esteso, ma di utilizzare solo l'acronimo. La sua decisione è conseguenza dell'osservazione di un senatore americano che ritiene non accettabile la parola "International" sulla dizione estesa di IRIS, essendo il progetto finanziato con fondi americani.

Allegato 1. Agenda dei lavori

21st IRIS Team Meeting

Tallinn, Estonia

Tuesday, May 19, 2009

8:00	Greetings, etc	
8:30	Welcome	S. Liive, Eesti Energia
8:45	Estonia Nuclear Plans	TBD, Ministry
9:15	Introduction to Westinghouse	M. Kirst, WEC
9:45	IRIS Overview	M. D. Carelli
10:30	Break	
10:45	Opportunities for Collaboration between IRIS and Estonian universities	M. Ricotti, Polytechnic of Milano G. Forasassi, Univ. of Pisa H. Ninokata, Tokyo Inst of Technology N. Cavlina, Univ. of Zagreb M. Carelli for F. Rahnema, SUNRISE Universities E. Realo, Tartu University A. Paist, Tallinn University of Technology
12:00	Collaboration Opportunities for Estonian Industry	G. O'Brien, WEC A. Pajula, Federation of Estonia Engineering Industry
12:30	Press Questions & Answers	
13:00	Lunch	
14:30	Project Progress since Last Meeting (Oct 08)	M. D. Carelli, WEC
14:50	Update on IAEA Activation for SMRs	V. Kuznetsov, IAEA
15:20	Advanced Reactors Nuclear Research in Italy	S. Monti, ENEA
15:45	Quality Assurance Activities	G. Storrick, WEC
16:00	Break	
16:15	Integral Test Facility at SIET	R. Ferri, SIET
16:45	IRIS Seismic Isolation System	M. Forni, ENEA
17:10	Upgraded Shielding Design	K. Burn, ENEA
17:35	Adjourn	

Wednesday, May 20, 2009

8:30	Working Groups Report Accomplishments since October 2008:
	Shielding, K. Burns
	Seismic, M. Forni
	CFD, F. Inzoli
	Integral Testing, R. Ferri
10:00 – 13:00	Containment System side meeting
10:00 – 18:30	Working Groups (Seismic, CFD, Integral Testing meetings)
10:30 – 18:30	Ad hoc side meetings
13:00	Lunch
14:00 – 17:00	Architect Engineers Side meeting
19:30	Team Dinner

Thursday, May 21, 2009

Morning	Side meetings, Working Groups
12:00	Lunch
13:00	WG Reports, this meeting and future
14:30	Next steps
15:00	Next team meeting
15:15	Adjourn

Allegato 2 Lista dei Partecipanti

Westinghouse, USA
Mario Carelli
Gary Storrick
Layla Sandell
Michael Anness
Mike Kirst
Gregg O'Brien

Eesti Energia, Estonia
S. Liive
A. Tropp
A. A. Pajula

POLIMI, Italy
Marco Ricotti
Fabio Inzoli
Marco Pellegrini
Federico Perotti
Carlo Lombardi

ENEA/SIET, Italy
Stefano Monti

ENEA, Italy
Fosco Bianchi
Massimo Forni
Kenneth Burn

SIET, Italy
Gustavo Cattadori
Roberta Ferri

Ansaldo Nucleare, Italy
Alessandro Alemberti

Mangiarotti Nuclear, Italy
Fabio Berra

Rolls Royce, UK
Tony Donaldson

NUCLEP, Brazil
Carlos Frederico

Tokyo Institute of Technology, Japan
Hisashi Ninokata

ENSA, Spain
Jesus Collado
Ian Fraser

LEI, Lithuania
Jurgis Vilemas

University of Pisa, Italy
Rosa LoFrano
Giuseppe Forasassi
Francesco Oriolo

University of Zagreb, Croatia
Nikola Cavlina

Maire Tecnimont, Italy
Pierino Gauna
Daniele Signorile
Ferdinando Mariani

Empresarios Agrupados, Spain
Jesus Soriano

Guests

IAEA
Vladimir Kuznetsov

VAE, Lithuania
Marius Grinevičius
Valdas Ledzinskas
Gintautas Klevinskas
Linas Koraliovas
Sergej Abdulajev
Dmitrij Pokidyšev

ATB Riva Calzoni, Italy

Giovanni Ronchetto

Saipem, Italy
Daslav Brkic

Allegato 3: Presentazione di S. Monti

21st IRIS Team Meeting
Tallinn Estonia
19-21 May 2009

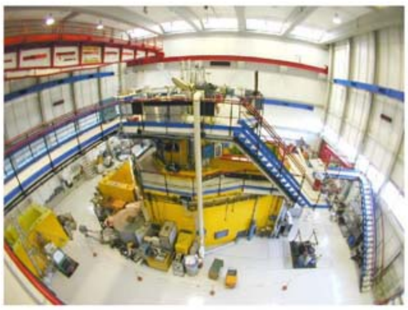
Advanced Reactors
Nuclear Research in Italy

Stefano Monti

ENEA - Fusion, Fission & Related Technologies Department

Background of the new nuclear policy in Italy

- **Italy was amongst the earliest countries to adopt nuclear and in the 1970s was the world's third largest producer of nuclear energy**
- **A 1987 referendum after the Chernobyl accident resulted in a shut down of all of its nuclear facilities (4 NPPS and several ENEA fuel cycle facilities). Only three research reactors (out of which two at ENEA: TRIGA and TAPIRO) are still in operation. All of the other nuclear facilities are under decommissioning/dismantling (by SOGIN)**

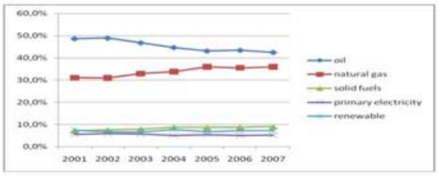


TRIGA RC-1 – 1 MW

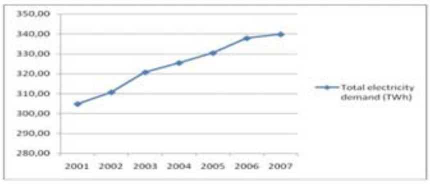
RSV TAPIRO – 5 kW

Background of the new nuclear policy in Italy

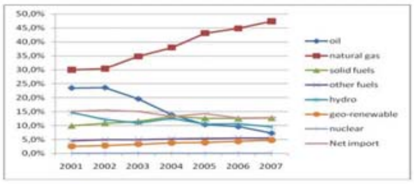
- In the intervening years, the country has developed a strong dependence on energy imports, and now suffers from electricity prices much higher than the EU average (one third higher than in most of Europe)



Total primary energy consumption



Total electricity grid demand



Share of electricity generation

Background of the new nuclear policy in Italy

- The cost of closing down of all the nuclear power plants following the 1987 referendum totaled over €50 billion (approximately $68 billion), if you count direct and indirect costs
- The closing down of all the nuclear power plants following the 1987 referendum is considered by the present government "a terrible mistake"
- The Italian government has been strongly supportive of the resurrection of nuclear energy in Italy since the very beginning of its mandate in April 2008

New Nuclear Policy in Italy

- **The minister of economic development, Claudio Scajola, has repeatedly stated that Italy has no other option than to develop nuclear energy in order to fulfill its environmental duties while having access to cheaper energy**
- **Nuclear is now seen as a way to address cost, emissions and import dependence simultaneously → an important Minister's statement in favor of nuclear energy at the 50th anniversary of the OECD's Nuclear Energy Agency**
- **The long term aim is to rebalance the power generation in Italy. By 2030 the Italian government would like to see nuclear power taking a 25% share in generation, with renewables on the same level and fossil fuels making up the remaining 50%. → "*Italy will begin new nuclear power station construction by 2013*"**
- **Scajola has said that the population are supportive of the government's energy plans and has called for international cooperation and harmonization to facilitate the process.**

New Nuclear Legislation

- **Last week Italy's Senate has approved a modified version of a bill that will clear the way for a revival of nuclear energy in the country.**
- The Senate passed the bill, initially proposed by Silvio Berlusconi's government in August 2008, with 154 votes in favour, 98 against and 3 abstentions.
- The bill had already been revised and passed by the lower house, the *Camera dei Deputati*, in November 2008. However, as the version approved by the Senate contains several further modifications, it must go back before the lower house for re-approval before it can become law.
- Mid-June is seen as a realistic date for the bill to pass into law.
- The government will then have up to 6 months to define criteria for identification of building sites (production and waste disposal), reactor technology and so on
- **With this new bill the government is going to setting up a new Nuclear Regulatory Agency for nuclear safety, security and safeguard in charge to oversee reactor safety, reactor licensing, radioactive material safety and licensing, and waste management (storage and disposal)**

Reference Nuclear Technologies

- French nuclear giant Electricite de Francé (EDF) and ENEL, the biggest Italian supplier of energy, have already signed last February an agreement to build at least 4 EPR nuclear power plants in Italy, starting work by 2013.
- However, Italy's minister of economic development, Claudio Scajola, has underlined that the February 2009 agreement between EDF and ENEL is 'non-exclusive' of other technological opportunities, suggesting there is room for other potential suppliers (AP1000 ?)

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ENEA and the New Nuclear Policy in Italy

- **Also ENEA has been invited by the government to contribute to reopening the nuclear option in the country – due to its institutional function and acknowledged competences and capabilities in the field**
- **Minister Scajola has called ENEA to contribute to the fast development of competences and scientific/technical infrastructures through:**
  - **Participation to international and European R&D programs**
  - **Development of innovative fuel cycle technologies, including nuclear waste treatment**
  - **Comparison of present scientific/technical options for nuclear energy production from the sustainability and competitiveness viewpoint**
  - **Definition of basic site requirements for both NPPs and waste storage facilities**
- **In order to comply with this request, at the end of 2008 the ENEA Board has set up a Coordination Committee on Nuclear Fission Activities which must guarantee overall coordination among the different Departments (nuclear and non-nuclear) as for nuclear fission related matters**

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What about R&D on Nuclear Fission

- Deployment of EPRs and/or other commercialized reactors don't need R&D

BUT:

- R&D on advanced nuclear systems is very helpful in gathering young people in nuclear sector and may make nuclear more appealing than present technologies → availability of high skilled people is considered the real bottleneck for nuclear renaissance worldwide
- Participation to international R&D projects leaded by well renown and experienced scientists/engineers and including experimental activities is the most effective way to perform Education & Training "on the job"
- Some infrastructures and facilities may support both nuclear industry qualification as well as systems and components certification and R&D needs (SIET @ Piacenza is a good and actual example)
- R&D activities allow to maintain and strengthen fruitful relationships at international level (and in particular with Euratom, NEA, IAEA, etc.)
- Some open issues of the fuel cycle and of nuclear waste management still require R&D effort

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What about R&D on Nuclear Fission

R&D activities carried out in four main areas:

- Cross cutting topics (modeling and simulation, safety, innovative materials, etc.)
- GENIII+ evolutionary nuclear systems
- GENIV nuclear systems
- Advanced fuel cycles (P&T, innovative fuels and reprocessing, new waste matrix, etc.)

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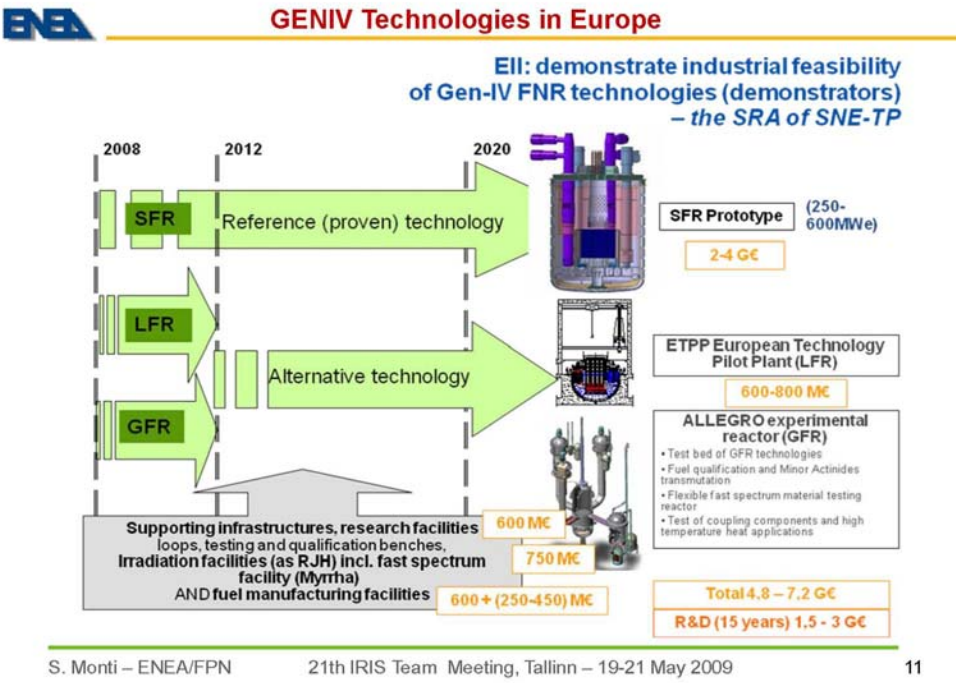
GENIV Technologies in Europe
EII: demonstrate industrial feasibility
of Gen-IV FNR technologies (demonstrators)
– the SRA of SNE-TP
2008
2012
2020
SFR
Reference (proven) technology
SFR Prototype
(250-600MWe)
2-4 G€
LFR
Alternative technology
ETPP European Technology Pilot Plant (LFR)
600-800 M€
GFR
ALLEGRO experimental reactor (GFR)
• Test bed of GFR technologies
• Fuel qualification and Minor Actinides transmutation
• Flexible fast spectrum material testing reactor
• Test of coupling components and high temperature heat applications
Supporting infrastructures, research facilities
loops, testing and qualification benches,
Irradiation facilities (as RJH) incl. fast spectrum facility (Myrrha)
AND fuel manufacturing facilities
600 M€
750 M€
600 + (250-450) M€
Total 4,8 – 7,2 G€
R&D (15 years) 1,5 - 3 G€
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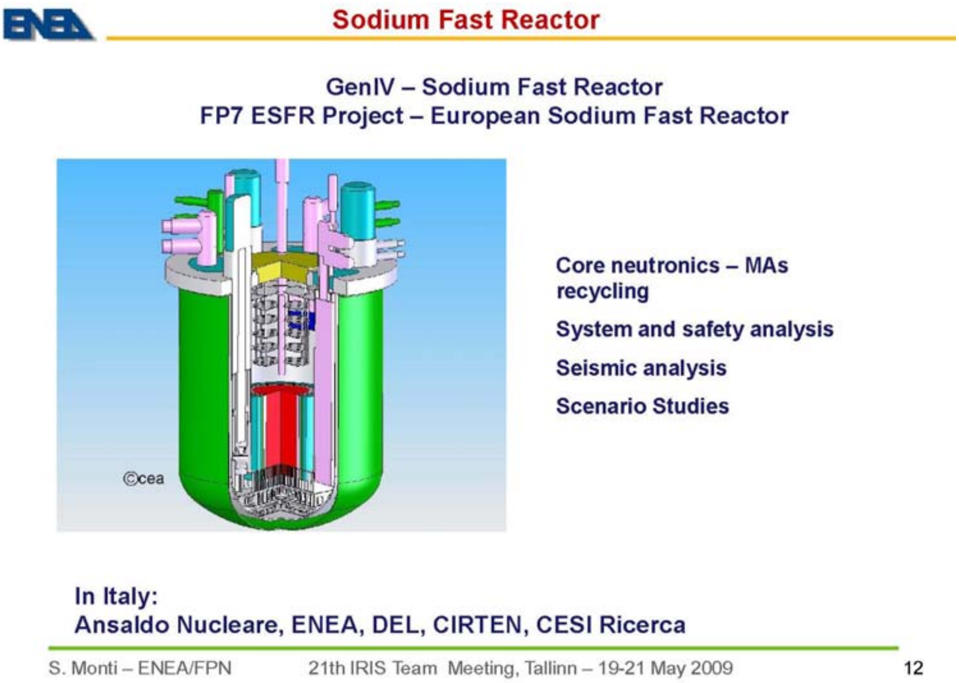
Sodium Fast Reactor
GenIV – Sodium Fast Reactor
FP7 ESFR Project – European Sodium Fast Reactor
©cea
Core neutronics – MAs recycling
System and safety analysis
Seismic analysis
Scenario Studies
In Italy:
Ansaldo Nucleare, ENEA, DEL, CIRTEN, CESI Ricerca
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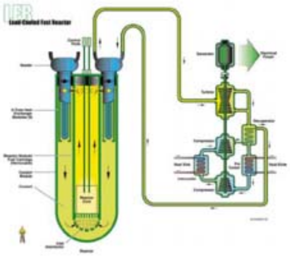
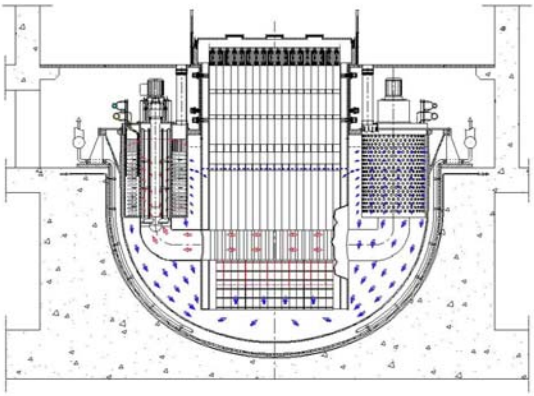
Lead-cooled Fast Reactor

ELSY in FP6: *European Lead-cooled System*
LEADER in FP7: DEMO LFR

In Italy:
AN, DEL, ENEA, CIRTEN, CESI Ricerca, SRS





CIRCE facility @ ENEA Brasimone

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European Lead-cooled SYstem (ELSY)

- ELSY is a 600 MWe (1500 MWt) Pb-cooled fast reactor for central station electricity generation
- ELSY concept is being developed by a consortium of 17 European Organizations (industries, research institutes, and universities) led by Ansaldo Nucleare. Key partners are ENEA and DEL
- ELSY is supported with funding (50 % of the overall budget) from the 6th Euratom Framework Program.
- Contract commenced on September 1, 2006
- 625 man-months of effort over three years

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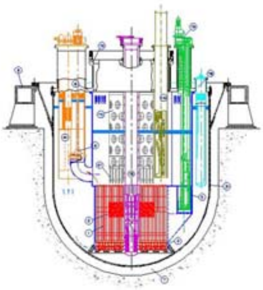
Lead-cooled European Advanced DEmonstration Reactor (LEADER)

- Proposal submitted to European Commission for evaluation
  - If funded, work would be carried out from 2010 through 2012
- Based upon achievements of ELSY program
- Development of a LFR industrial-sized plant and a scaled demonstrator (demo) of suitable size
- Updated ELSY configuration will be used to design a low-cost and fully representative scaled-down prototype
- Demo would be ready to construct within the next decade
- Involvement of end-users and safety authorities
- Involvement of universities in education and training

Accelerator Driven Systems for Waste Transmutation

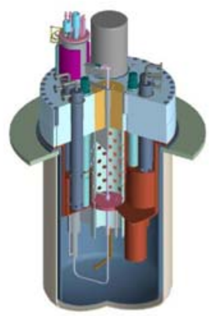


ADS – EFIT

European Facity for Industrial Transmutation

MYRRHA

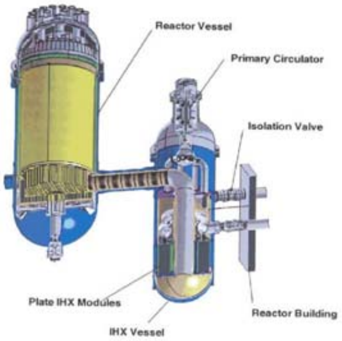
Fast Neutron Irradiation Facility
To be built at Mol (Belgium)



In Italy:
Ansaldo Nucleare, ENEA, INFN, CIRTEN, SRS, CRS4

Very High Temperature Reactors

GenIV - Very High Temperature Reactor
RAPHAEL - ReActor for Process heat, Hydrogen and Electricity generation



He-FUS3 Facility @ ENEA-Brasimone

TAPIRO Reactor @ ENEA-Casaccia

In Italy:
Ansaldo Nucleare, ENEA, CIRTEN

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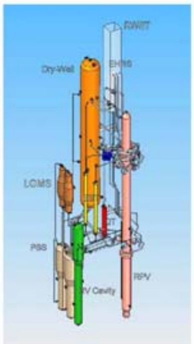
GENIII+ Evolutionary Nuclear Systems

IRIS → In Italy: ENEA, SIET, CIRTEN, Ansaldo Nucleare, Mangiarotti Nuclear, Maire Tecnimont

GEN-III+ System
IRIS - *International Reactor Innovative and Secure*



SPES-3 Facility @ SIET

SPES-2 Facility @ SIET

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IRIS Work Packages --> about 3 M€ per year

- *Integral Testing on SPES-3 facility at SIET* → ENEA – SIET – CIRTEN – Ansaldo Nucleare & Mangiarotti Nuclear
- *Systems and Components development* e.g. Downcomer, SGs, EHRS……….→ ENEA, SIET and CIRTEN
- *Seismic analyses* (new methods for probabilistic assessment, isolation & energy dissipation systems, etc.) ……… → ENEA & CIRTEN
- *Shielding activities* ……… → ENEA (starting from former work performed by POLIMI)
- *General-purpose studies* of IRIS interest (economy of scale and competitive technological options for SMR (see e.g. IAEA CRP), scenario studies) → CIRTEN & ENEA
- *CFD analyses* → CIRTEN

THANK YOU FOR YOUR ATTENTION

Allegato 4: Bozza MoU Italian Partners

Memorandum of Understanding

WHEREAS

1. the International Reactor Innovative and Secure (IRIS) project, leaded by Westinghouse and involving today 24 Organizations from 10 Countries, is an international R&D&D activity recognized worldwide as a promising "near term deployment" project, offering a key solution to the potential Small-to-Medium Reactor market due to its features of innovative design, modular approach, deployment strategy that reduces the financial exposure and risk and suitable size to fit electrical grid development and constraints;
2. the Italian Organizations have been active on the IRIS project since the beginning, through the participation of CIRTEN (POLIMI) in the early phases of concept and founding of the developing team (1999), with an increasing involvement through the participation of Ansaldo Nucleare, then Ansaldo Camozzi (now Mangiarotti Nuclear), ENEA and, in a recent phase, Maire Tecnimont;
3. a letter of interest, constituting the Italian Team Membership of the IRIS project, was signed by ENEA, Ansaldo Camozzi, Ansaldo Energia and CIRTEN in October 2005. In the letter the signatory parties declare their willingness to support the IRIS Project and to seek adequate funding to further develop their participation and contribution to the project (see Annex I);
4. the IRIS Italian Team has assured to the project a very valuable support (see Annex II) and our Country is considered by WEC a key actor for the success of the project and its potential development to market;
5. other Parties may join the IRIS Italian Team in the next future, subject to the agreement of the present MoU signatory Parties;
6. the Italian Team Members of the IRIS project cover different competencies and experiences and are geographically strongly linked, therefore with more potential close interaction opportunities.

NOW THEREFORE

due to above and in order i) to share common requirements and perspectives, ii) to aggregate and deliver fast feedback solutions to the IRIS International Team Members, iii) to meet the needs of the IRIS project, iv) to agree on mutual satisfactory strategy and v) to assure adequate returns to the Signatory Parties,

the present Memorandum of Understanding (MoU) has been agreed between the Parties:

- Ansaldo Nucleare
- CIRTEN
- ENEA
- Maire Tecnimont
- Mangiarotti Nuclear

- SIET

- This MoU records the common understanding between the parties to create the IRIS Italian Team Network in order to develop different capabilities and to increase the performance of the IRIS Team, in synergy and cooperation with the other Team Members. The Network will operate to yield benefits to the IRIS Team that streamline, accelerate and facilitate the process of designing, building, and managing the IRIS project and all the related activities, the closer and first aim being to obtain the "Final Design Approval" by US NRC within next five years and later on the "FOAK Engineering at tender-level".

- The above with the wish to significantly generate positive cost reduction considering the mid term programming period, characteristic of the IRIS project.

- The IRIS Italian Team Network considers the assessment of the remaining overall activities and costs for FDA and FPD, a key factor for a possible decision to invest in the fulfillment of the IRIS project, as well as for the research of possible capital ventures.

- The IRIS Italian Team Members deem necessary to develop a business plan outlining the prospects for world-wide sales of IRIS modules in the time period to 2030. This will include a Cash Flow analysis based on a best estimate of appropriate input parameters, taking into account country requirements of those companies participating in the development of IRIS and countries possibly interested in purchasing IRIS. It is intended that the business plan will be mainly worked out by Westinghouse; the IRIS Italian Team Network declare its availability in contributing to the task.

- The business plan should also assess the breakdown of type, amount of work, actions and related costs, needed to bring the IRIS project to a "ready to market" shape. That will consider specifically the work to obtain the "Final Design Approval" by the US NRC and the subsequent work to obtain the "FOAK Engineering at tender-level".

- In this context the IRIS Italian Team Network considers necessary to assess the range of benefits that may be achieved by each Italian partner participating in the development and future commercialization of IRIS.

- To duly pursue i) an effective partnership with Westinghouse and the IRIS Team Partners and ii) the objectives of the IRIS Project hence of the IRIS Italian Team Network, the Network will be managed by a Steering Committee, with one representative per signing organization.

ANNEX I

DICHIARAZIONE DI INTENTI

Premesso che:

L'International Reactor Innovative and Secure (IRIS) è un reattore di nuova generazione di tipo modulare, raffreddato ad acqua leggera in pressione, con circuito primario integrato. Il progetto è stato proposto da Westinghouse nel 1999 e attualmente vede la partecipazione di 21 organizzazioni di 10 paesi. Nell'ambito del programma internazionale Generation IV lo sviluppo dell'IRIS è inserito nel "near term deployment", ossia nell'orizzonte temporale da oggi al 2015.

L'IRIS viene progettato per soddisfare quattro requisiti chiave: aumentata sicurezza rispetto alla generazione attuale di reattori, riduzione dei costi di investimento e di esercizio, resistenza alla proliferazione e minimizzazione dei rifiuti radioattivi. Il progetto IRIS, grazie all'approccio modulare che ne riduce l'esposizione ed i rischi finanziari, risulta particolarmente promettente nell'attuale fase di riconsiderazione del nucleare in sede internazionale.

Le attività ad oggi (fase 1) hanno riguardato il progetto preliminare del reattore con identificazione delle soluzioni ingegneristiche dell'impianto, studi di fattibilità e valutazioni economiche dei costi di investimento ed esercizio e l'iter di pre-licensing presso l'Autorità di Sicurezza USA (NRC).

Le organizzazioni italiane ANSALDO-CAMOZZI Energy Special Components S.p.A , ANSALDO ENERGIA S.p.A. – Divisione Nucleare, CIRTEN – Consorzio Interuniversitario per la Ricerca Tecnologica Nucleare (rappresentato in IRIS da Politecnico di Milano, Politecnico di Torino, Università di Pisa, Università La Sapienza di Roma) hanno attivamente partecipato alla fase 1 con contributi specifici riguardanti in particolare lo sviluppo del generatore di vapore, calcoli termoidraulici, neutronici ed analisi di sicurezza inclusiva di studi sul contenimento, calcoli di schermaggio e dosi in esercizio.

L'attuale programma di attività della fase 2 previsto partire ad inizio 2006 ha come obiettivo il consolidamento del concetto, lo sviluppo del progetto di dettaglio, le prove a supporto dell'iter di licensing al fine di ottenere nel 2010 la certificazione da parte NRC ed implementare le prime realizzazioni nel prossimo decennio.

La partecipazione al progetto permette alle organizzazioni coinvolte di ottenere diritti derivanti dal futuro sfruttamento industriale con modalità e clausole in corso di definizione.

Si dichiara che:

Le organizzazioni italiane di cui sopra intendono mantenere il loro impegno nella più impegnativa fase 2, commisurando il proprio investimento alla disponibilità di contributi da parte delle sedi istituzionali preposte. L'obiettivo è quello di rendere l'industria italiana pre-assegnataria della progettazione e realizzazione di sistemi e componenti e l'Università e gli Enti di ricerca partecipi del know-how prodotto e di attività di ricerca e sviluppo, in particolare dei programmi di validazione sperimentale a supporto del licensing, nonche' di attivita' di analisi specialistica anche durante la fase di realizzazione.

ENEA, visto il ruolo di referente per la ricerca del nucleare in Italia, intende partecipare alla fase 2 apportando specifiche competenze progettuali, di ricerca e sviluppo e di prove e qualificazione di sistemi e componenti, partecipando in particolare alla fase di validazione sperimentale con i suoi laboratori e quelli di sue controllate (es. SIET), operando nel ruolo di membro coordinatore del gruppo di organizzazioni di cui sopra.

Al fine di valorizzare ed incrementare il ruolo dell'Italia nell'ambito del progetto e gli attesi ritorni, le organizzazioni firmatarie si impegnano ad agire in modo coordinato nei riguardi del gruppo di progetto IRIS costituendo un team organico italiano che complementi in modo efficiente le rispettive esperienze e competenze.

Le organizzazioni firmatarie si impegnano nel contempo a farsi parte attiva, in modo coordinato, al fine di reperire presso le sedi istituzionali preposte i contributi finanziari necessari a coprire parte dell'investimento previsto.

ANSALDO-CAMOZZI Energy Special Components S.p.A.
Ing. E. Lumini, Responsabile Sales

ANSALDO ENERGIA S.p.A. – Divisione Nucleare
Ing. Roberto Adinolfi, Direttore

CIRTEN – Consorzio Interuniversitario per la Ricerca Tecnologica Nucleare
Prof. Giuseppe Forasassi, Presidente

ENEA – Ente per le Nuove tecnologie, l'Energia e l'Ambiente
Ing. Giovanni Lelli, Direttore Generale

25 Ottobre 2005

ANNEX II

Date of involvement and contribution of the Participants into the IRIS Project:

Ansaldo Nucleare has been involved in the IRIS project since XXXX, specifically for the identification of the most suitable solution and design for the Steam Generator modules. During recent years, the contribution has been extended to the design of the condenser for the Emergency Heat Removal System (EHRS). Other areas of collaboration will be the safety analysis for the FDA and the study of the compliance of IRIS with the EUR (European Utilities Requirements).

CIRTEN has been involved since the beginning in the IRIS project, by means of Politecnico di Milano, one of the four originators of IRIS together with Westinghouse, MIT and UC Berkeley. Beyond 1999, other CIRTEN members were active in the project (University of Pisa XXXX, Politecnico di Torino YYYY). Main areas of contribution to the project were safety and containment analyses including severe accidents, neutronics and shielding, thermal hydraulics and thermal mechanics both at theoretical and experimental level, simulation and control, seismics, economics, bio-fuel co-generation. The contribution to the project will continue on the above mentioned areas, also in strict cooperation with ENEA and SIET as far as the actions related to the FDA process are concerned.

ENEA is being involved in the IRIS project since October 2005, when a letter of intent was signed among the Italian IRIS Team Members (Annex II). Main areas of investigation of ENEA are: computer simulations for the planning of experiments and interpretation of test data, system and safety analysis, seismic and shielding analyses and economic studies. All the IRIS-related activities are financially supported by the Minister of Economic Development (MED), through a specific three-year Program Agreement on "New Nuclear Fission" signed between MED and ENEA in 2007. The integral testing – which also foresees the design, erection and operation of a large experimental facility called SPES3 – is also the object of an Action Sheet signed in February 2006 between ENEA and the Oak Ridge National Laboratory.

Maire Tecnimont has been involved into the IRIS project starting January 2009 for the so called "balance of plant" (BOP); the areas of collaboration have been identified as per following: Steam/turbine auxiliary system; Secondary systems, Electrical Powers Generation systems, Auxiliary fluid systems, Buildings and related system except those related to the nuclear system.

Mangiarotti Nuclear has been active in the IRIS project since XXXX, formerly as Ansaldo-Camozzi, as a design and solutions developer for the manufacturing of the Steam Generator modules and EHRS. Mangiarotti Nuclear will be active also on the SPES3 facility design and erection, in strict cooperation with SIET and the other partners involved.

SIET has been active in the IRIS project since 2005 as a key laboratory for thermal-hydraulic testing on NPP components and systems, having a long term experience on the field. In the nineties SIET participated to the AP-600 US-NRC licensing process carrying out the experimental tests on the SPES-2 facility. ENEA contracted SIET to perform the integral testing of IRIS reactor. The Project concerns the design, construction and operation of a new integral test facility, SPES-3, to support IRIS licensing process. Since 2007 SIET is involved also in the development of the SPES-3 facility Relap-5 model to carry out pre- and post-test calculations for the facility and will co-operate to the comparison between facility and plant behavior.

4 CONCLUSIONS

This document summarizes the activities performed by ENEA and SIET for the SPES3 project during the reference period of the second research program of the ENEA – MSE agreement..

The design activities concerned both the facility area set-up and the facility design review, aimed at reproducing as better as possible the IRIS plant behaviour. Moreover, the design of a test loop for heater rod prototypes was developed in parallel.

The status of the SPES3 activities at September 2010 is the following:

SPES3 area and boundaries:

- the dismantling activities of SPES elevetor in the area is ended and the procurent of the load bearing structure of the SPES3 facility is in progress and its erection will be ended at the beginning of the new year (2011) [25] [29];

SPES3 loop design:

- the new piping layout design owing to some modifications to RPV nozzles is completed and the final mechanical verification is ended [28];;

SPES3 side activities

- the erection of the heater rod test loop is completed [26];;
- procurement of two types of the heater rod prototypes is in progress;
- special instrumentation have been investigated for two-phase flow measurement and the conceptual and detailed design of void fraction detector prototype has been completed [27];.

The present status of the SPES3 project is sufficiently advanced to proceed with the purchasing orders of the main components simulating the containment and the primary system of IRIS reactor.

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ATTACHMENTS

A.1 Attachment to conf-call #9

file "IRIS_SPES3_Conf Call Minutes #101 Att 1 scaling sensitivities.doc

N	PRODUCT	COMPANY	WEB PAGE	CONTACT
1	**902 MACHINABLE ALUMINA SILICATE**	COTRONICS CORPORATION *Shore Parkway, Brooklyn, N.Y. 11235 Duralco 4525 - 3*	http://www.cotronics.com	Voice (Mabel Denny) *(718) 788-5533* Fax *(718) 788-5538*
2	**914 MACHINABLE GLASS CERAMICS**	COTRONICS CORPORATION *Shore Parkway, Brooklyn, N.Y. 11235 Duralco 4525 - 3*	http://www.cotronics.com	Voice (Mabel Denny) *(718) 788-5533* Fax *(718) 788-5538*
3	**MACOR™ GLASS CERAMIC (Machinable) RESCOR 915**	COTRONICS CORPORATION *Shore Parkway, Brooklyn, N.Y. 11235 Duralco 4525 - 3*	http://www.cotronics.com	Voice (Mabel Denny) *(718) 788-5533* Fax *(718) 788-5538*
4	**MACOR® machinable GLASS-CERAMIC**	ACCURATUS CORPORATION *35 HOWARD STREET PHILLIPSBURG, NJ 08865*	http://www.accuratus.com	*VOICE: 908-213-7070* *FAX: 908-213-7069*
5	**MYKROY-MYCALEX CERAMICS (MM 1100) Glass-Mica Composites**	CRYSTEX Composites LLC *125 Clifton Blvd Clifton NJ 07011*	http://www.crystexcomposites.com	*Phone 973-779-8866* *Toll Free 800-638-8235* *Fax 973-779-2013* *info@crystexcomposites.com*
6	**CERAMIC SG70-130 Machinable (Silicato Aluminosilicate Alumina)**	***DISTRIBUTOR:*** *Red Seal Electronic Company, 3835 West 150th Street Cleveland, OH 44111-5891* ***FABRICATOR:*** *Smart Ceramics, Inc., P.O., .Box 3177, Woburn, MA 01888*	http://www.redseal.com/non-metallic-insulation-products	***DISTRIBUTOR:*** *Red Seal Phone (Glenn) : 216-941-3900* *Fax: 216-941-5305* *e-mail: contact@redseal.com* ***FABRICATOR:*** *Smart Ceramics Phone (John Han):* *781-935-2221* *781-856-0342* *Info sales@smart-ceramics.com*
7	**Micatemp Machinable Glass/Mica Ceramic Composite**	Foundry Service & Supplies, Inc. *11808 E. Burke Street Santa Fe Springs, CA 90670*	http://www.foundryservice.com	*Phone: 562-945-6511* *Fax: 562-696-1633*

	SI	1	2	3	4	5	6	7
Melting point	*ºC*	*1760*						
Max Service Temp.	*ºC*		*538*	*982*	*1000*		*1260*	*595*
Continuous UseT.	*ºC*	*1149*	*427*		*800*	*595*	*816*	
Density	*Kg/m3*	*1922*	*2600*	*2520*	*2520*	*2800*	*2000*	*2768*
Thermal Conductivity	*W/(m*K)*	*1.08*	*0.4*	*1.73*	*@ 25°C 1.46*	*1.32*	*@ 205 ºC 0.605*	*0.58*
							@ 425 ºC 0.63	
							@ 625 ºC 0.67	
							@ 1000 ºC 0.70	
Expansion Coefficient	*exp(-6) / K*	*3.24*	*9.36*	*10.44*	*(–200°C to 25°C) 7.4*	*(25°C) 10.48*		*9.4*
					(25°C to 300°C) 9.3	*350°C 9.74*		
					(25°C to 600°C) 11.4	*500°C 9.39*		
					(25°C to 800°C) 12.6			
Dielectric Strength	*exp(6) W/ m*	*4*	*19.2*	*250*		*16.8*	*6.64*	*15*
Dielectric Constant	*@1MHz*	*5.3*	*7.5*			*6.8*	*5.5*	*6.8*
Specific Heat (25°C)	*kJ/ (kg*K)*				*0.79*	*0.46*	*@ 538°C 1.17*	*0.46*
Porosity	*%*			*0*	*0*		*30*	
Volume Resistivity	*ohm-m*	*exp12*	*exp12*	*exp12*		*exp10*	*52 exp(8)*	*exp12*
Compression Strength	*Mpa*	*261.8*	*275.6*	*344.5*	*345*	*220*	*85*	*220*
Modules of Elasticity	*Gpa*			*64*	*(25°C) 66.9*	*73*		*73*
Flexural Strength	*MPa*	*96.5*	*179*	*103.3*	*94*	*75.8*	*58*	*75.8*
Poisson's Ratio					*0.29*			
Shear Modulus (25°C)	*GPa*				*25.5*			
Loss Factor	*@1MHz*	*0.04*	*0.01*			*0.012*		*0.012*
Fracture Toughness	*MPa/m2*				*1.53*			
Coefficient of Kinetic Friction (25°C)		`			*ag steel 0.12*			
					ag Al 0.15			
					ag Macor 0.15			
Hardness					*250 Kn*	*91 H*		*RockwH 90 H*
					48 Rockw A	*47 A*		*Brinell 56 H*
Moisture Absorption	*%*					*Nil*		*Nil*
Flammability						*NOT*		*NOT*
Arc Resistance	*Seconds*					*345*	*345*	*325*
Dissipation factor	*@1MHz*					*0.0017*		*0.0017*
Tensile Strength	*Mpa*					*34.5*		*34*
Surface Resistivity	*(25°C)*					*exp11 ohm/sq*		*exp(14) Dry ohm-m*
								exp(9) Wet ohm-m
Impact Strength— IZOD (notched)	*J/m*					*69.4*		*69.4*
Specific Gravity								*2.8*
Radiation resistance (Rads-Cobalt)	*3 x exp(10)*							*Excellent*
Permittivity	*@1MHz*							*6.8*

A.2 Attachments to conf-call #101

file "IRIS_SPES3_Conf Call Minutes #101 Att 1 scaling sensitivities.doc

Sensitivities on the SPES3 Dry-Well

R. Ferri, SIET May 28th 2009

The file #32 21st IRIS (SIET) SPES3 WG achievement.ppt,

available in e-room at: My eRooms > IRIS > IRIS Team Meetings > 21st Tallinn > May 21 (Thursday), summarizes the results of some sensitivity cases devoted to compare the influence on the DW pressure trend and peak of an eventual DW inner insulation and possible DW mass reduction.

Here, the results of two additional cases are reported together with further consideration and comparison among results.

Summary of performed cases:

- SPES3-94: sensitivity on the DW inner surface thermal insulation (1 mm Teflon layer). DW volume 35.36 m^3.

- SPES3-99: sensitivity on the DW volume (35.36 m^3 volume reduced to 32.27 m^3 to scale IRIS volume)

- SPES3-103 and SPES3-100: sensitivity on the DW volume with DW inner surface thermal insulation (3 mm and 1.5 mm Rescor 902 Aluminium Silicate layer). DW volume 32.27 m^3.

- SPES3-102: sensitivity on the DW volume and heat structures (IRIS DW heat structures surface and mass scaled 1:100 and imposed to SPES3 DW). DW volume 32.27 m^3.

- SPES3-104: sensitivity on the DW metal mass: Thickness 15 mm (possible reduction from 25 mm, in case of reducing the design pressure from 2 bar to 15 bar). DW volume 32.27 m^3.

- SPES3-105: sensitivity on the DW metal mass: Thickness 10 mm (theoretical case with IRIS DW metal and concrete mass, scaled 1:100, distributed on the SPES3 DW surface). Concrete mass converted in an equivalent AISI 304 mass (Mass concrete * cp concrete = Mass equiv. AISI * cp AISI). DW volume 32.27 m^3.

Fig.A3. 1 compares the DW pressure trends with different DW metal wall thickness and masses.

The thickness reduction has a positive effect on pressure trend and peak.

Case 104 could be realized after a verification of 15 mm thickness by a manufacturer, and this would reduce the IRIS to SPES3 DW pressure peak difference from ~3 to ~2 bar.

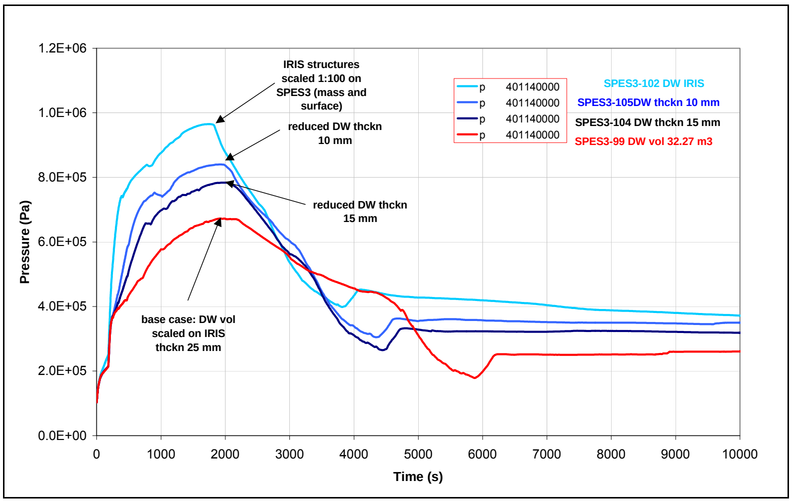


Fig.A3. 1 DW pressure

Fig.A3. 2 compares the power transferred to structures with different DW metal wall thickness and masses.

As expected, the thickness reduction reduces energy given to the structures, even if no sensible change in the power peak is observed.

Case 102, related to the IRIS DW mass and surface scaled 1:100 directly on SPES3, shows that energy released to structures is much lower.

The comparison between cases 102 (IRIS DW mass and surface scaled on SPES3) and 105 (IRIS DW equivalent mass distributed on SPES3 DW surface)

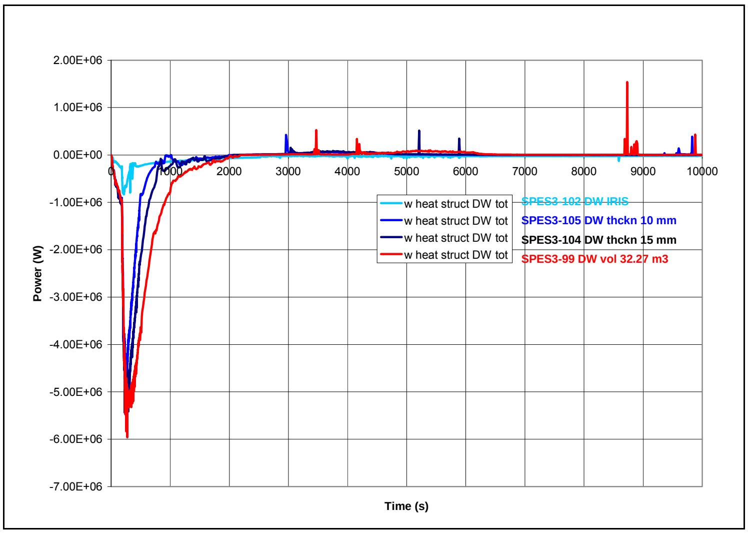


Fig.A3. 2 Power transferred to DW wall

Comments

The comparison between cases 102 (IRIS DW mass and surface scaled 1:100 on SPES3) and 105 (IRIS DW equivalent mass distributed on SPES3 DW surface) shows that both mass and surface affect the heat release to the DW structures and that surface has a large influence.

The cases with the insulating material in the DW showed that such solution is not effective in compensating the over-surfaced DW in SPES3, due to the limited effect in time of the insulating material (timing of phenomena leads insulation to reach a thermal equilibrium with metal so limiting the effect to the early phases of the transient).

Open items

Possibilities:

1) Accept the reachable 2 bar DW peak pressure difference between IRIS and SPES3 based on the fact that SPES3 is mainly devoted to code validation;

2) Try to reduce the surface and mass effect by a different scaling factor applied to the DW.

To investigate item 2), Case SPES3-106 is running at SIET (results available in a week).

It has the SPES3 DW scaled 1:150 on the IRIS DW. DW volume 21.51 m3, Inner diameter 1.32 m, Thickness 15 mm. Initial air pressure in the DW as in base case (this means less non-condensable gas in the containment)

A further case could be run to investigate the effect of quantity of air initially present in the containment. The original mole number of air could be reproduced in a case with 1:150 DW by increasing the initial pressure correspondingly to the volume reduction.

Need of discussion…

file "IRIS_SPES3_Conf Call Minutes #101 Att 2 scaling sensitivities2.doc

Sensitivities on the SPES3 Dry-Well

R. Ferri, SIET May 29th 2009

Reference files:

- #32 21st IRIS (SIET) SPES3 WG achievement.ppt,
- DW scaling sensitivities.doc

Performed additional case:

Case SPES3-106: sensitivity on the DW volume scaled 1:150 on IRIS DW (partial results).

DW volume 21.51 m3, Inner diameter 1.32 m, Thickness 15 mm. Initial air pressure in the DW as in base case (this means less non-condensable gas in the containment)

Fig.A3. 3 compares the DW pressure trends with different DW metal wall thickness and masses.
Green curve: DW pressure response with SPES-3 DW volume scaled 1:150 on IRIS.
The pressure peak is higher than in the base case (red), but worse than in case with correct scaling factor and 15 mm thickness (dark blue).

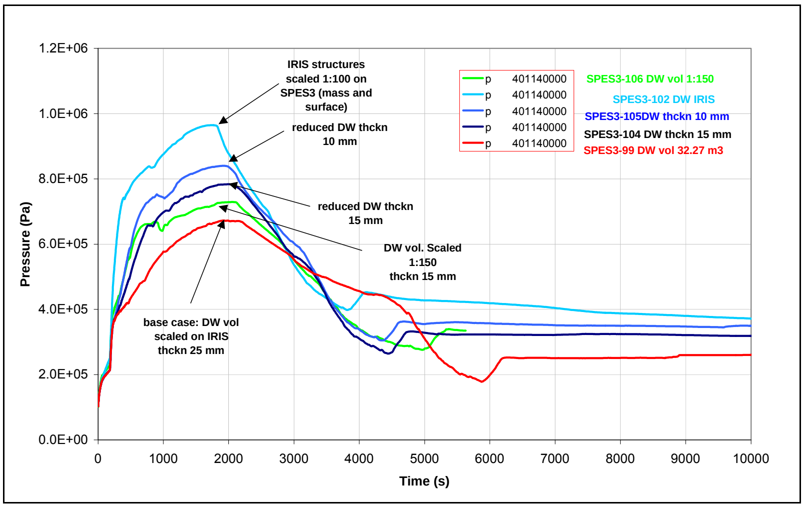


Fig.A3. 3 DW pressure

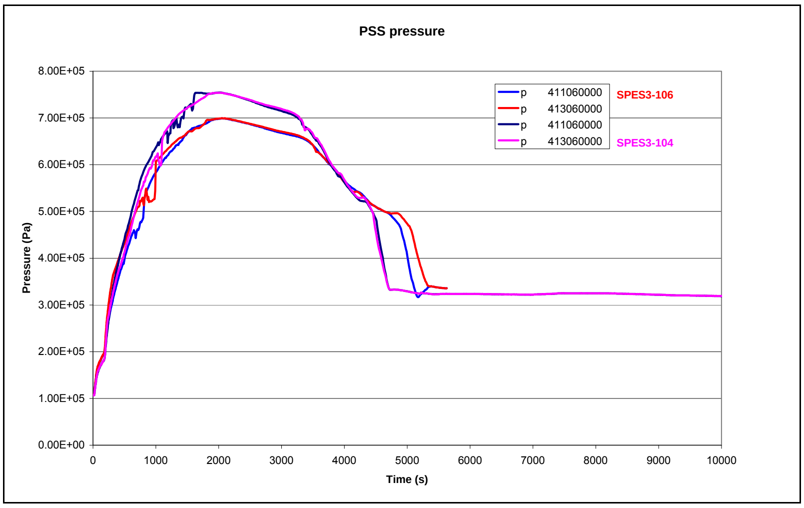


Fig.A3. 4 PSS pressure

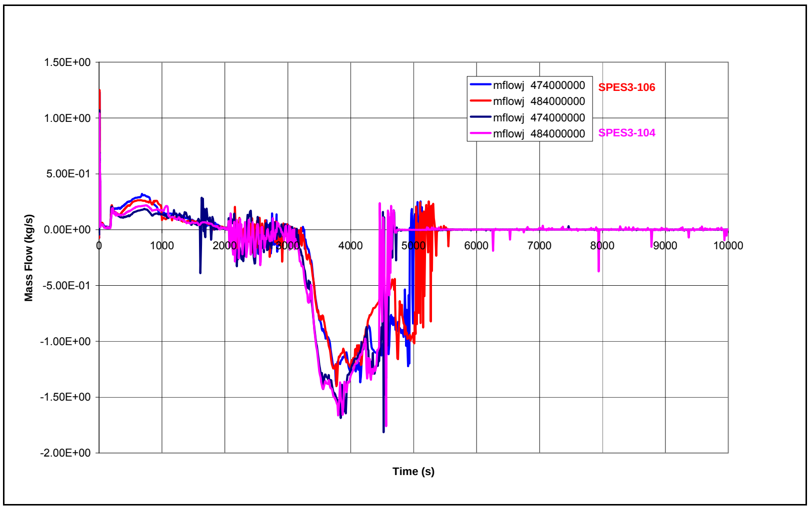


Fig.A3. 5 DW to PSS mass flow

Comments

The early results of the case with DW volume scaled 1:150 indicates that the gain on DW pressure, with respect to the base case, is not large enough to justify such a design choice. Similarity in PSS pressure and PSS injection into the DW.

Doubts on disadvantages or phenomena distortion that can be brought in the followings of the transient by a different scaling of DW.

file "IRIS_SPES3_Conf Call Minutes #101 Att 3 Insulation material_4.doc

	SI	Sproule WR-1200	Foamglas® ONE ™ insulation	Promat MONALITE® M1	Aspen Pyrogel XT
Melting point	*ºC*				
Max Service Temp.	*ºC*	*649*	*480*		*650*
Continuous UseT.	*ºC*				
Density	*Kg/m3*	*208.3*	*120*	*850*	*180*
Thermal Conductivity	*W/(m*K)*	*@ 38 ºC 0.068* *@ 93 ºC 0.074*	*@ 0 ºC 0.039*	*@ 750 ºC* *0.26*	*@ 0 ºC 0.02* *@ 100 ºC 0.023*
		@ 149 ºC 0.081 *@ 204 ºC 0.089*	*@ 10 ºC 0.04*		*@ 200 ºC 0.028* *@ 300 ºC 0.035*
		@ 260 ºC 0.098 *@ 316 ºC 0.107*			*@ 400 ºC 0.046* *@ 500 ºC 0.064*
		@ 371 ºC 0.114 *@ 427 ºC 0.123*			*@ 600 ºC 0.089*
Thermal Diffusivity	*m2/sec*		*4.2 exp(-7)*		
Expansion Coefficient	*exp(-6)/ K*		*9*	*(100 – 750) ºC* *6.1*	
Dielectric Strength	*exp(6) W/ m*				
Dielectric Constant	*@1MHz*				
Specific Heat (25°C)	*kJ/ (kg*K)*		*0.84*		
Porosity	*%*				
Volume Resistivity	*ohm-m*				
Compression Strength	*Mpa*	*0.552 to produce 5% compression*	*0.6*	*15*	*Stress at 10% strain 0.102* *Stress at 25% strain 0.183*
Modules of Elasticity	*Gpa*		*900*		
Flexural Strength	*MPa*	*0.345-0.414*	*0.48*	*8*	
Poisson's Ratio					
Shear Modulus (25°C)	*GPa*				
Loss Factor	*@1MHz*				
Fracture Toughness	*MPa/m2*				
Hardness				*60 Shore D*	
Moisture Absorption	*%*	*Water absorption 0.4 By volume Avg* *Water absorption 6.02 By weight Avg*	*Moisture absorption 0.2* *Water-Vapour Permeability 0.0* *Hygroscopicity No increase in weight at 90% relative humidity*		Hydrophobic Water Vapour Sorption 2.25 (by weight) Liquid Water Retention After Submersion 4 (by weight)
Capillarity			*none*		
Flammability		*not*	*NOT*		
Arc Resistance	*Seconds*				
Dissipation factor	*@1MHz*				
Tensile Strength	*Mpa*				
Surface Resistivity	*(25°C)*				
Impact Strength—IZOD (notched)	*J/m*				
Specific Gravity					
Radiation resistance (Rads-Cobalt)	*3 x exp(10)*				
Permittivity	*@1MHz*				
Heat and Vibration Aging	*%*				-0.19 mass change after 6 hr vibration

PRODUCT	COMPANY	WEB PAGE	CONTACT
Sproule WR-1200 (expanded perlite uniformly reinforced with a high strength fiber)	Industrial Insulation Group, LLC 2100 Line Street Brunswick, GA 31520	www.iig-llc.com	**For Customer Service and Order Placement** (800) 334-7997 Fax: (912) 267-6096 **For Sales Information** (800) 866-3234 (800) Fax: (912) 267-6096 **For Technical Information** (800) 872-0338 Fax: (970) 858-9641
Aspen Pyrogel XT (formed of silica aerogel and reinforced with a non-woven, glass-fiber batting)	Aspen Aerogels, Inc. 30 Forbes Road, Building B Northborough, MA 01532	www.aerogel.com	phone 508.691.1111 fax 508.691.1200 email info@aerogel.com Voice (John Williams) 508-691-1137
Foamglas® ONE ™ Insulation	*Pittsburgh Corning USA (Corporate Headquarters) 800 Presque Isle Drive Pittsburgh, PA 15239*	www.foamglas.com	Telephone: +1-724-327-6100 Fax: +1-724-387-3807
Promat MONALITE® M1 (technical ceramics" made from calcium silicate)	**Promat UK Limited** The Sterling Centre Eastern Road, Bracknell Berkshire RG12 2TD	www.promat.co.uk/	Telephone: 01344 381300 Fax: 01344 381301 **Customer Services Department** Telephone: 01344 381381 Fax: 01344 381380 **Technical Services Department** Telephone: 01344 381400 Fax: 01344 381401 **Marketing Services Department** Telephone: 01344 381350 Fax: 01344 381401

A.3 Attachments to conf-call #103

file "IRIS_SPES3_Conf Call Minutes #103 Att 1 DW sensitivity graphs.doc

R. Ferri, SIET June 12th 2009

Sensitivities on the SPES3 Dry-Well

Reference cases:

- SPES3-108: repeated case (corresponding case SPES2-102 had an error in DW structure thickness) with IRIS DW structures scaled 1:100 on SPES3 mass and surface.
- SPES3-105: IRIS DW structures scaled on SPES3 in terms of mass, but with SPES3 DW surface
- IRIS plant

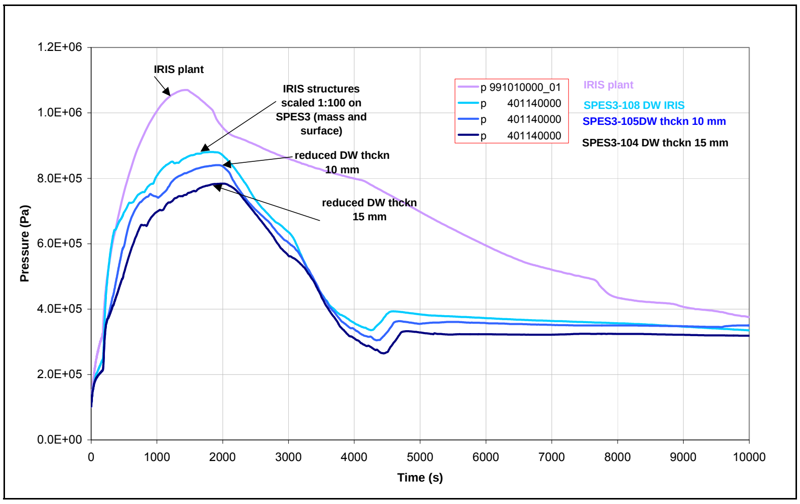


Fig.A4. 1 DW pressure

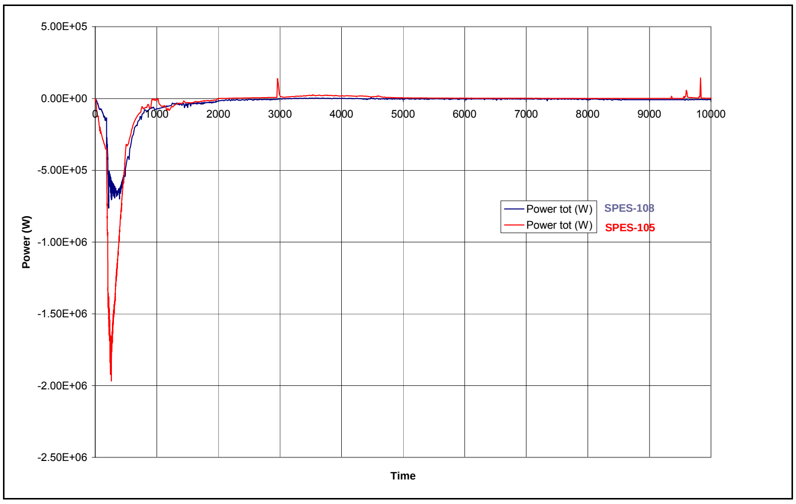


Fig.A4. 2 Power to DW heat structures

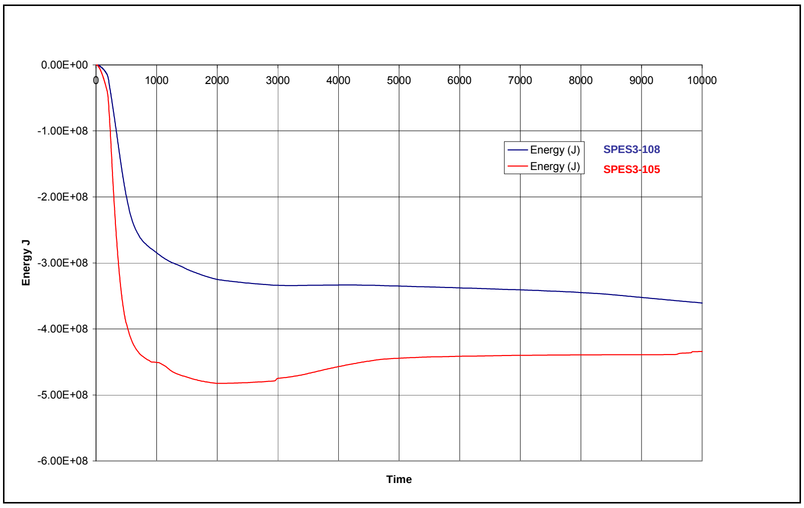


Fig.A4. 3 Energy to DW heat structures

A.4 Attachments to conf-call #104

file "IRIS_SPES3_Conf Call Minutes #104 Att 1 DW sensitivity graphs.pdf

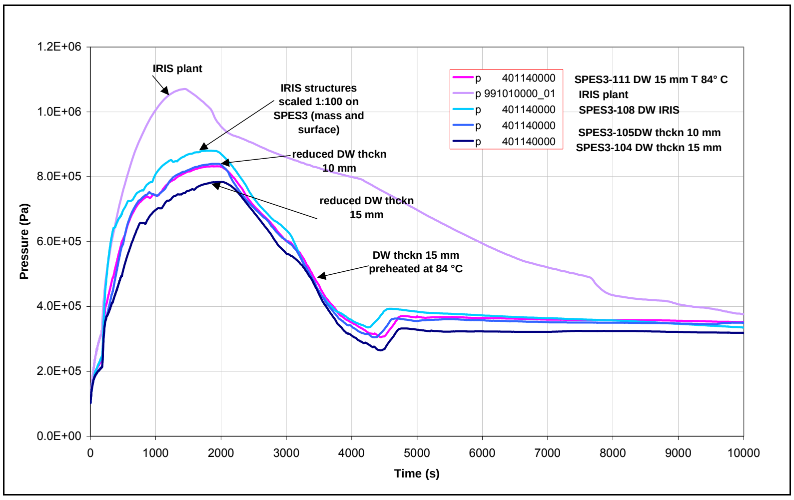


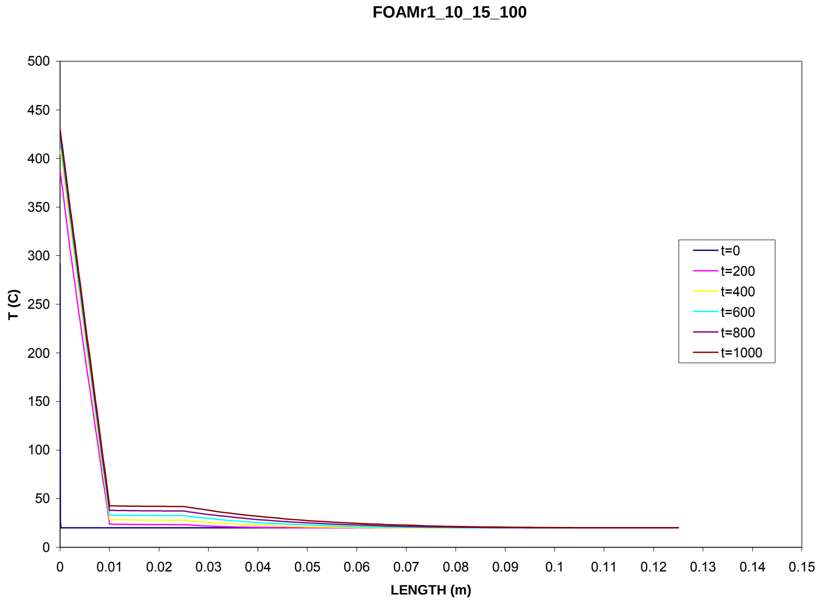
Fig.A5. 1 DW pressure

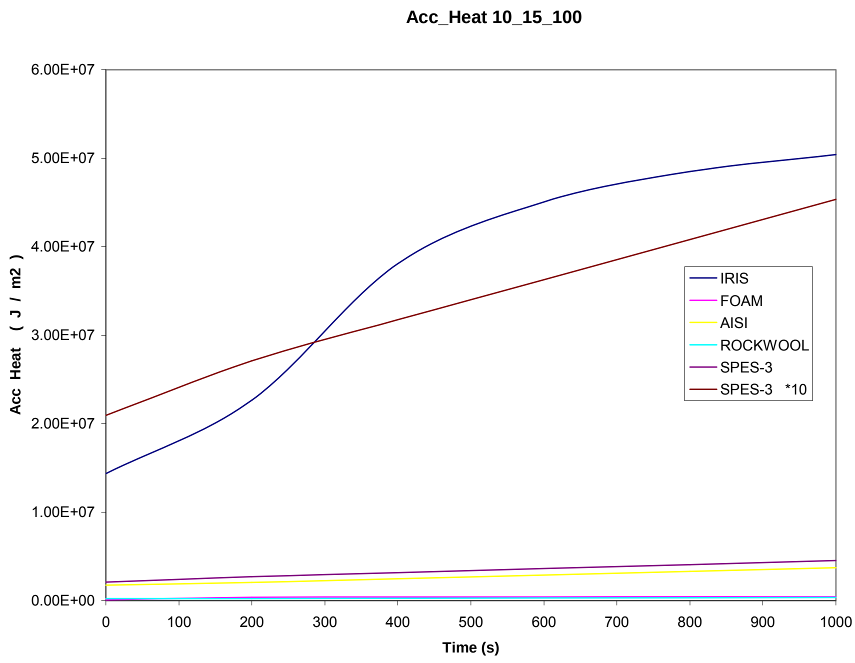
A.5 Attachments to conf-call #106

file "IRIS_SPES3_Conf Call Minutes #106 Att 1 different_insulations.doc

DIFFERENT_INSULATION
CASE1_FOAMGLASS

SPES-3 Dry-well		IRIS CONTAINMENT	
MATERIAL	***THICKNESS***	***MATERIAL***	***THICKNESS***
FOAMGLASS	10 mm	CARBON STEEL	44 mm
AISI 304	15 mm		
ROCKWOOL	100 mm		
INITIAL TEMPERATURE 20 C		***INITIAL TEMPERATURE 48.9 C***	

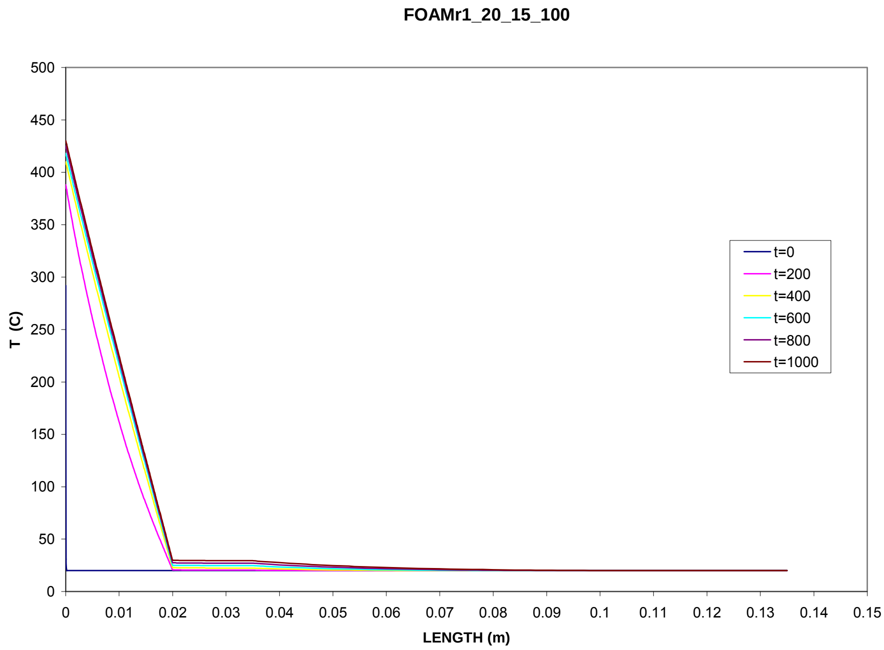


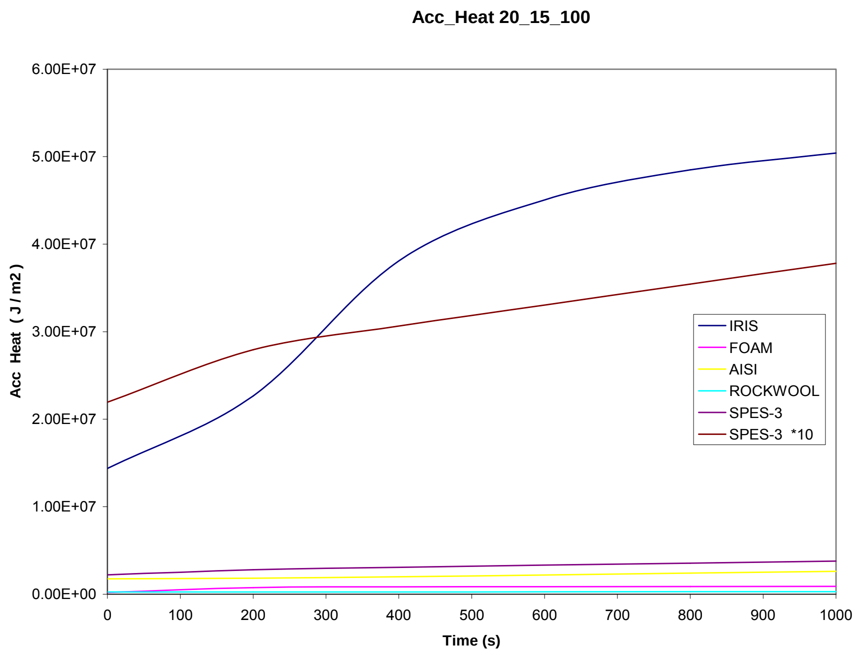


Different_insulation

CASE2_FOAMGLASS

SPES-3 Dry-well		IRIS CONTAINMENT	
MATERIAL	***THICKNESS***	***MATERIAL***	***THICKNESS***
FOAMGLASS	20 mm	CARBON STEEL	44 mm
AISI 304	15 mm		
ROCKWOOL	100 mm		
INITIAL TEMPERATURE 20 C		***INITIAL TEMPERATURE 48.9 C***	

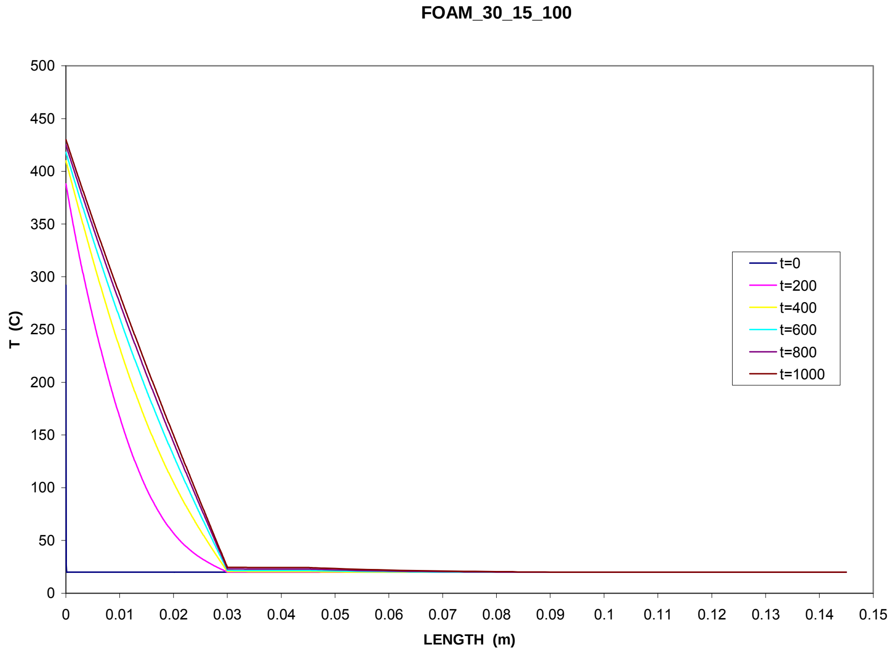


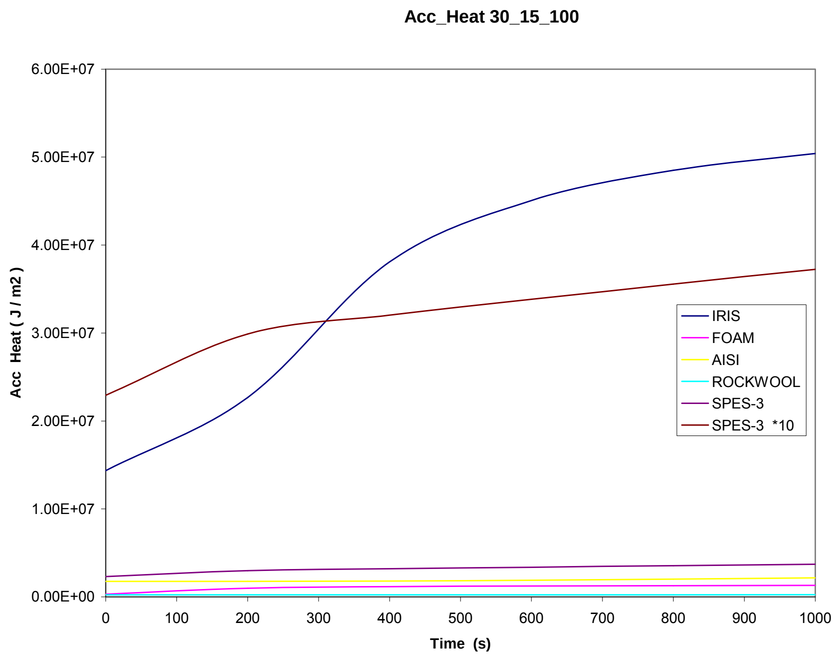


Different_insulation

CASE3_FOAMGLASS

SPES-3 Dry-well		IRIS CONTAINMENT	
MATERIAL	***THICKNESS***	***MATERIAL***	***THICKNESS***
FOAMGLASS	30 mm	CARBON STEEL	44 mm
AISI 304	15 mm		
ROCKWOOL	100 mm		
INITIAL TEMPERATURE 20 C		***INITIAL TEMPERATURE 48.9 C***	

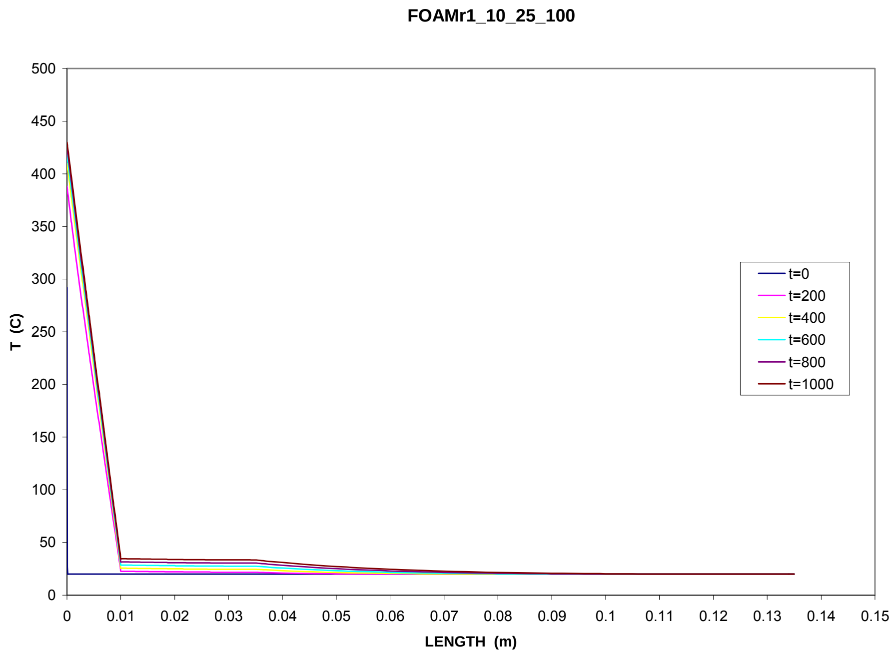


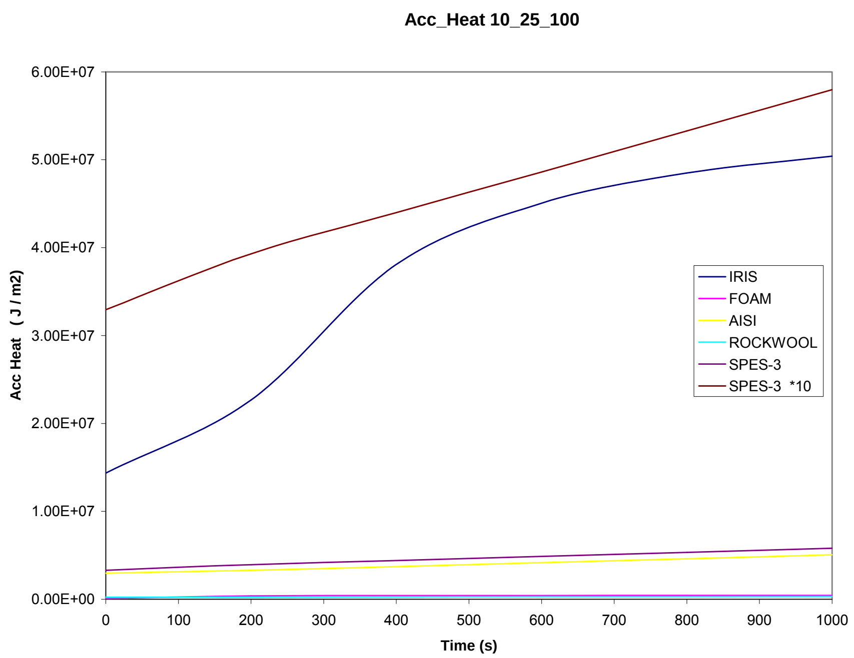


Different_insulation

CASE4_FOAMGLASS

SPES-3 Dry-well		IRIS CONTAINMENT	
MATERIAL	***THICKNESS***	***MATERIAL***	***THICKNESS***
FOAMGLASS	10 mm	CARBON STEEL	44 mm
AISI 304	25 mm		
ROCKWOOL	100 mm		
INITIAL TEMPERATURE 20 C		***INITIAL TEMPERATURE 48.9 C***	

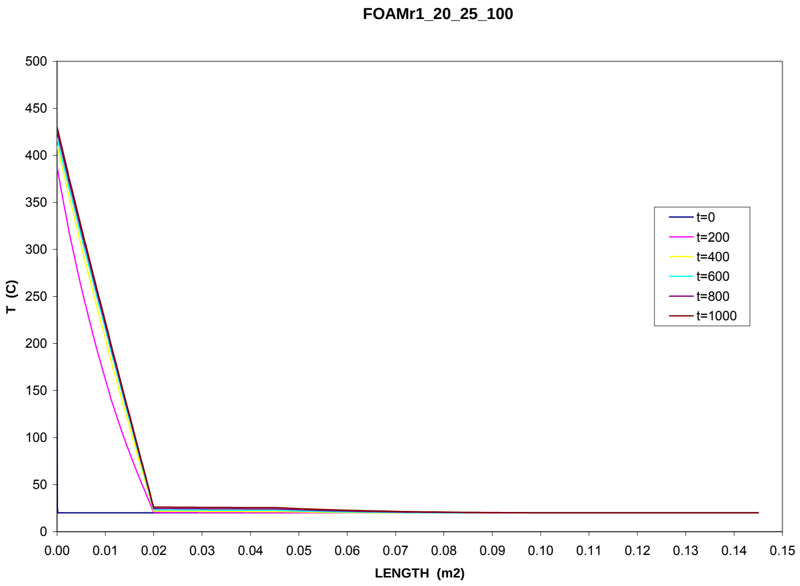


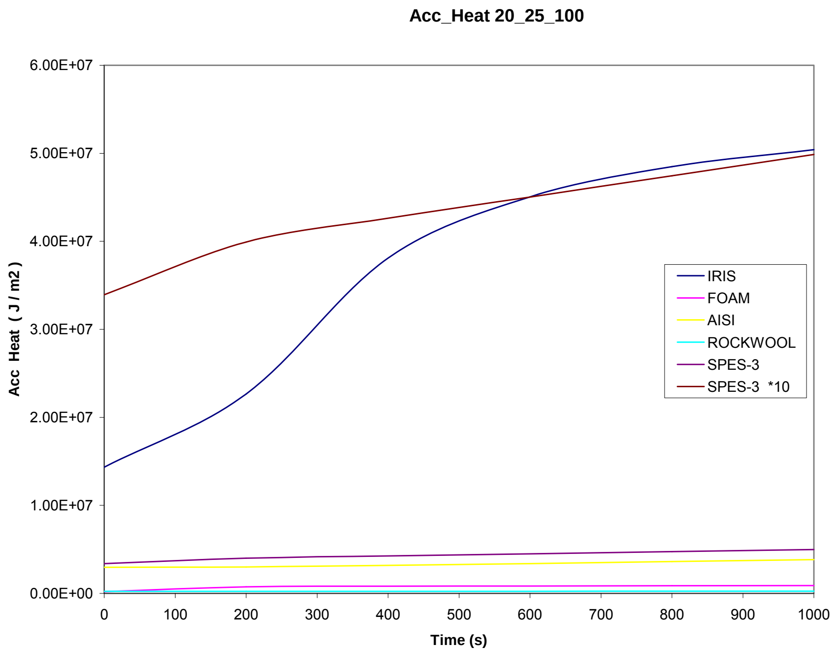


Different_insulation

CASE5_FOAMGLASS

SPES-3 Dry-well		IRIS CONTAINMENT	
MATERIAL	***THICKNESS***	***MATERIAL***	***THICKNESS***
FOAMGLASS	20 mm	CARBON STEEL	44 mm
AISI 304	25 mm		
ROCKWOOL	100 mm		
INITIAL TEMPERATURE 20 C		***INITIAL TEMPERATURE 48.9 C***	

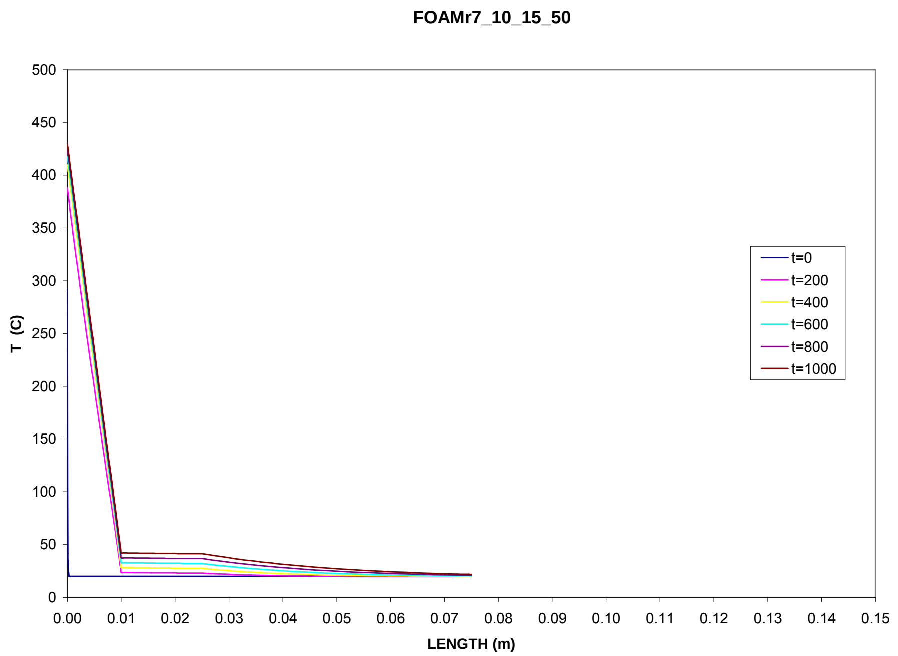


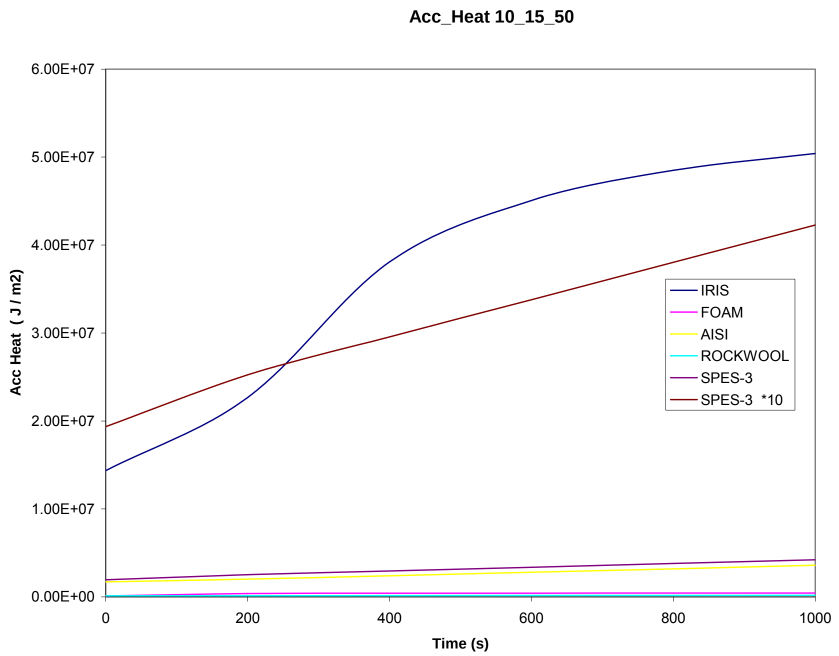


Different_insulation

CASE6_FOAMGLASS

SPES-3 Dry-well		IRIS CONTAINMENT	
MATERIAL	***THICKNESS***	***MATERIAL***	***THICKNESS***
FOAMGLASS	10 mm	CARBON STEEL	44 mm
AISI 304	15 mm		
ROCKWOOL	50 mm		
INITIAL TEMPERATURE 20 C		***INITIAL TEMPERATURE 48.9 C***	

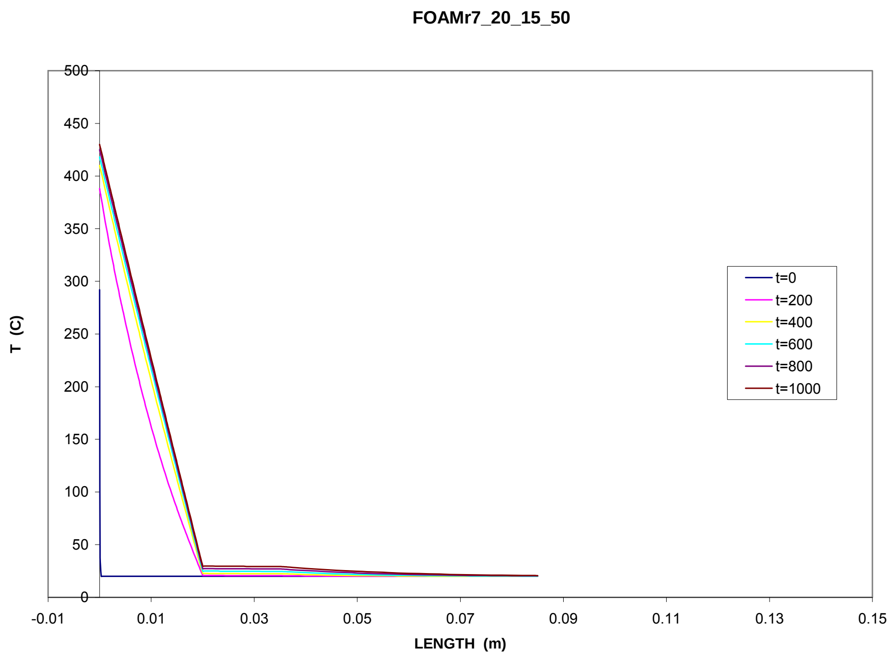


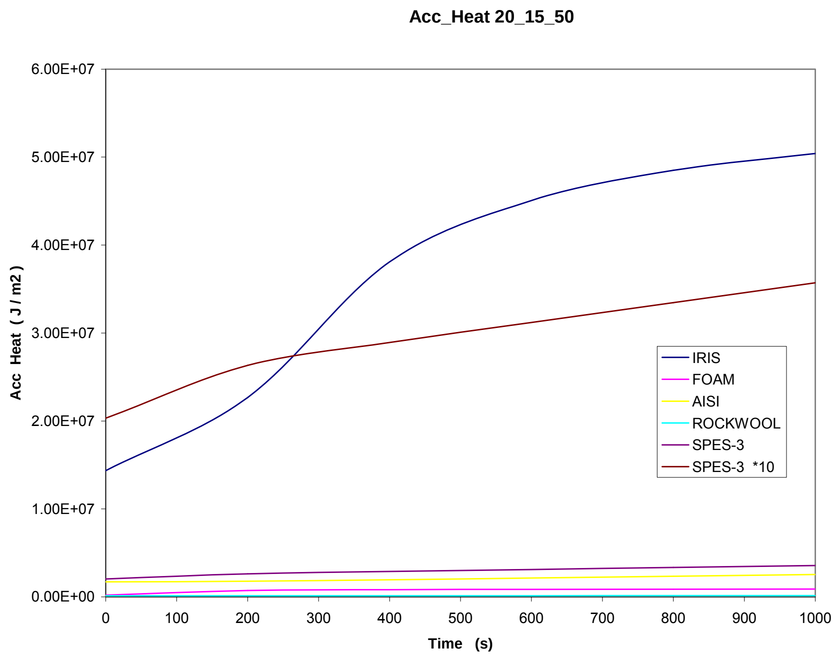


Different_insulation

CASE7_FOAMGLASS

SPES-3 Dry-well		IRIS CONTAINMENT	
MATERIAL	***THICKNESS***	***MATERIAL***	***THICKNESS***
FOAMGLASS	20 mm	CARBON STEEL	44 mm
AISI 304	15 mm		
ROCKWOOL	50 mm		
INITIAL TEMPERATURE 20 C		***INITIAL TEMPERATURE 48.9 C***	

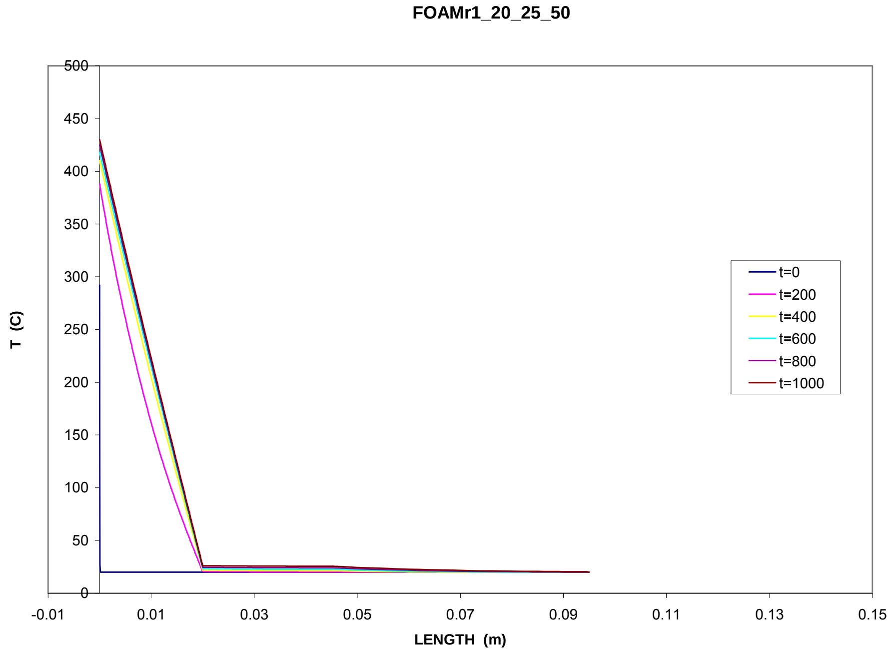


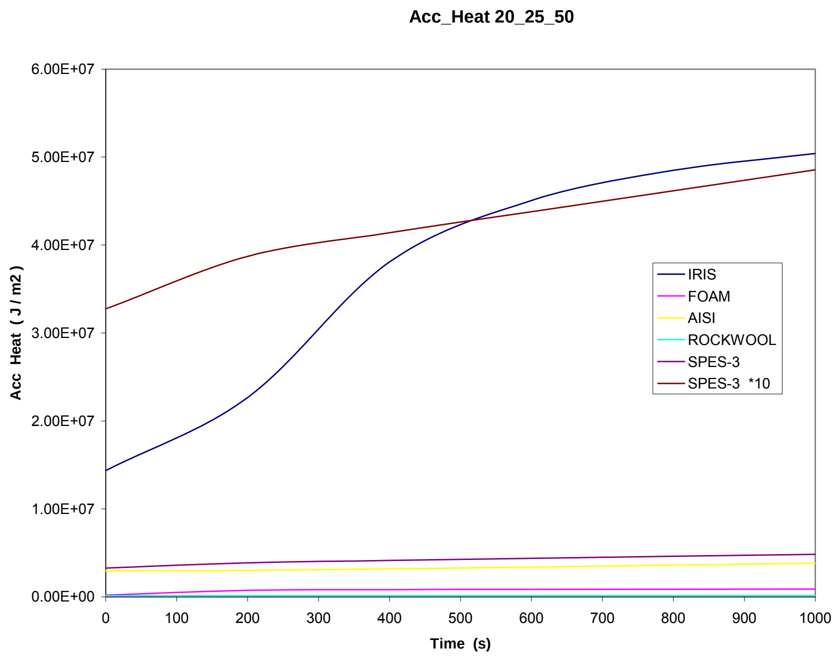


Different_insulation

CASE8_FOAMGLASS

SPES-3 Dry-well		IRIS CONTAINMENT	
MATERIAL	***THICKNESS***	***MATERIAL***	***THICKNESS***
FOAMGLASS	20 mm	CARBON STEEL	44 mm
AISI 304	25 mm		
ROCKWOOL	50 mm		
INITIAL TEMPERATURE 20 C		***INITIAL TEMPERATURE 48.9 C***	

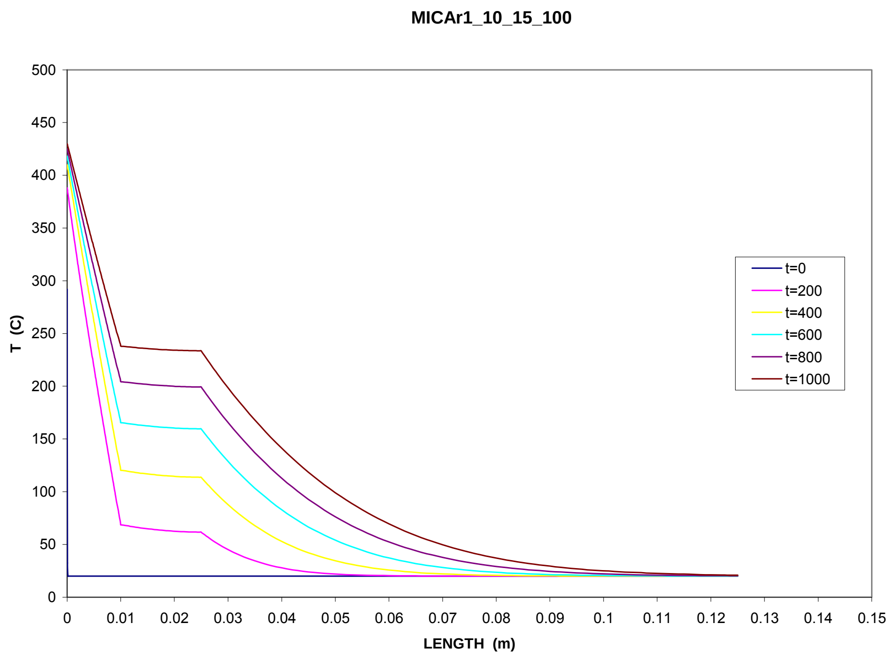


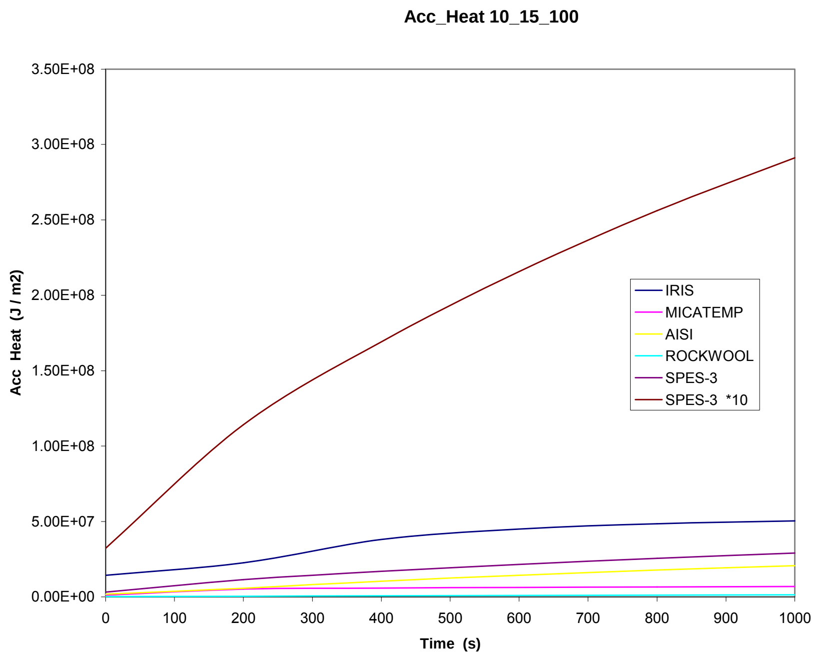


Different_insulation

CASE1_MICATEMP

SPES-3 Dry-well		IRIS CONTAINMENT	
MATERIAL	***THICKNESS***	***MATERIAL***	***THICKNESS***
MICATEMP	10 mm	CARBON STEEL	44 mm
AISI 304	15 mm		
ROCKWOOL	100 mm		
INITIAL TEMPERATURE 20 C		***INITIAL TEMPERATURE 48.9 C***	

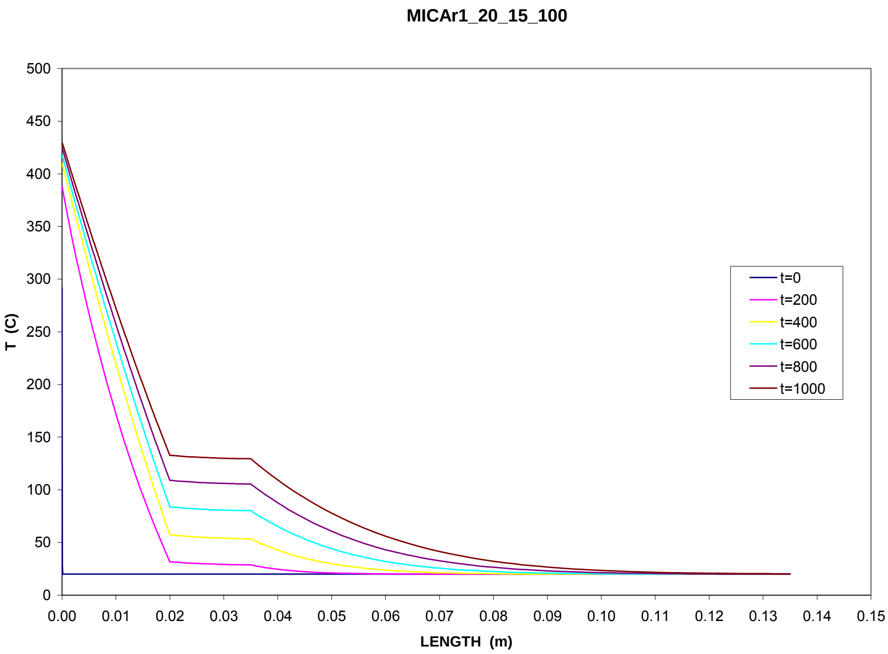


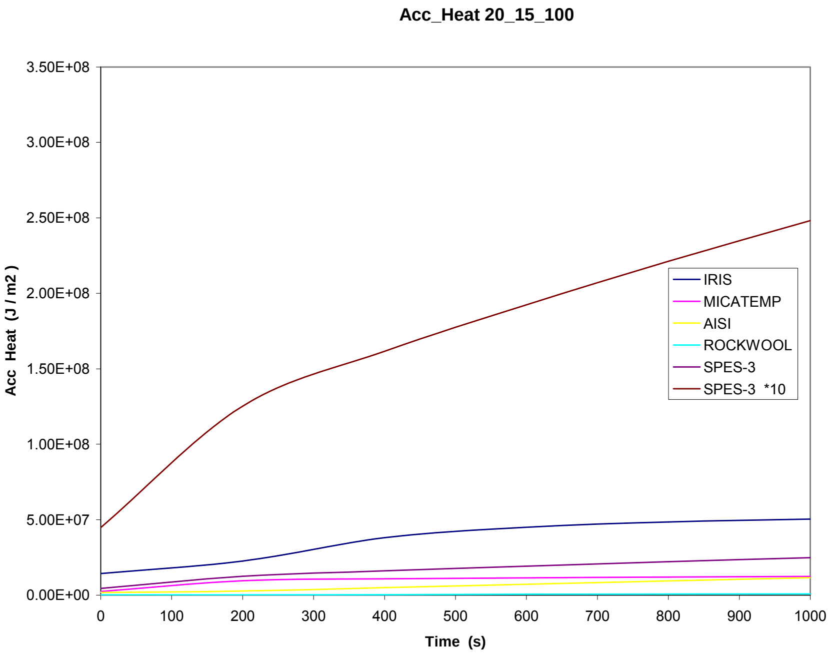


Different_insulation

CASE2_MICATEMP

SPES-3 Dry-well		IRIS CONTAINMENT	
MATERIAL	***THICKNESS***	***MATERIAL***	***THICKNESS***
MICATEMP	20 mm	CARBON STEEL	44 mm
AISI 304	15 mm		
ROCKWOOL	100 mm		
INITIAL TEMPERATURE 20 C		***INITIAL TEMPERATURE 48.9 C***	

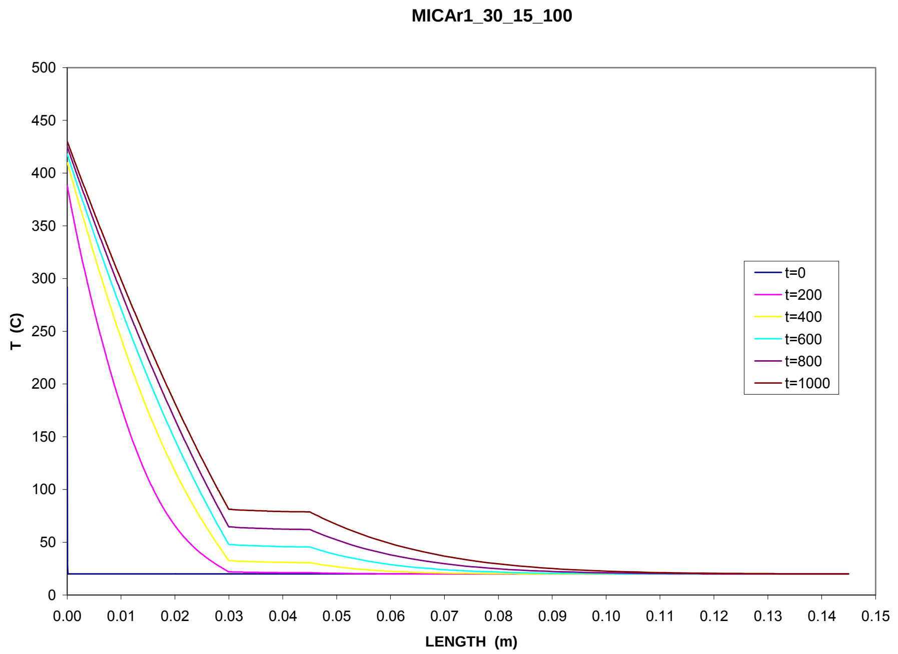


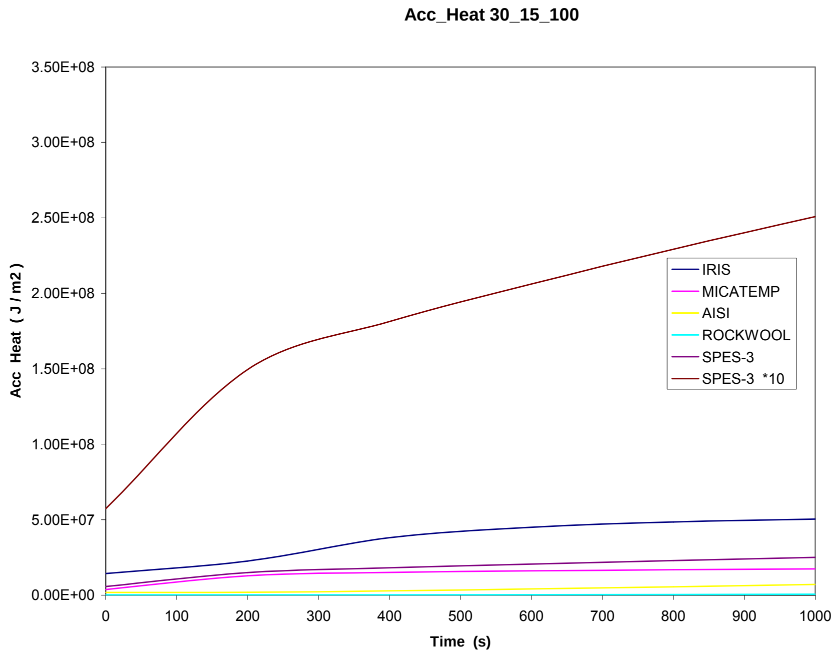


Different_insulation

CASE3_MICATEMP

SPES-3 Dry-well		IRIS CONTAINMENT	
MATERIAL	***THICKNESS***	***MATERIAL***	***THICKNESS***
MICATEMP	30 mm	CARBON STEEL	44 mm
AISI 304	15 mm		
ROCKWOOL	100 mm		
INITIAL TEMPERATURE 20 C		***INITIAL TEMPERATURE 48.9 C***	

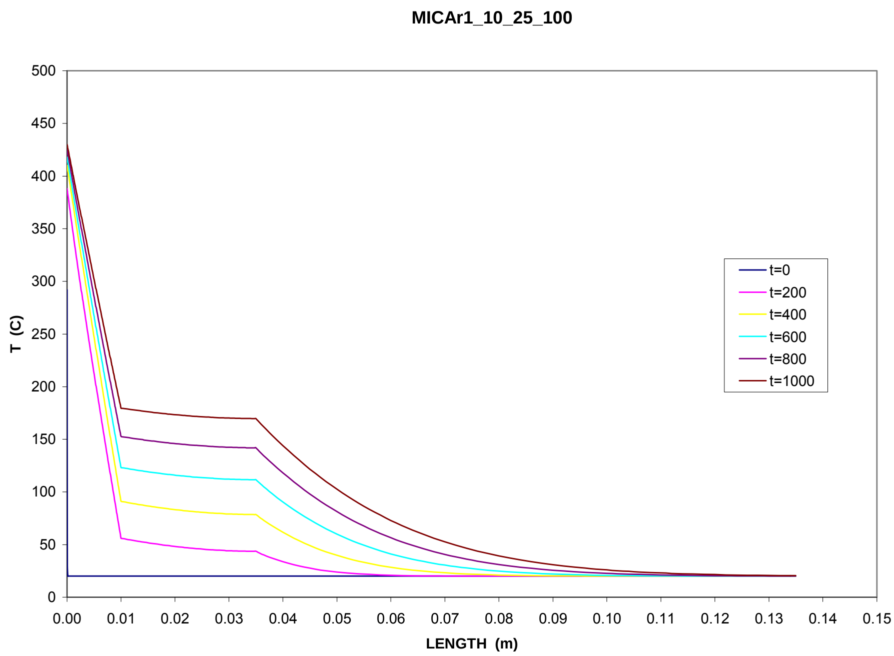


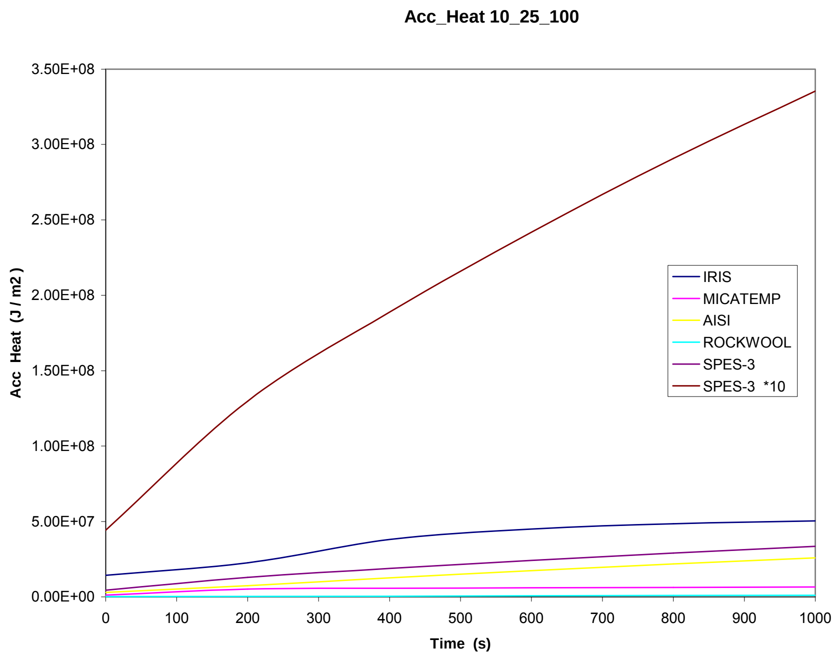


Different_insulation

CASE4_MICATEMP

SPES-3 Dry-well		IRIS CONTAINMENT	
MATERIAL	***THICKNESS***	***MATERIAL***	***THICKNESS***
MICATEMP	10 mm	CARBON STEEL	44 mm
AISI 304	25 mm		
ROCKWOOL	100 mm		
INITIAL TEMPERATURE 20 C		***INITIAL TEMPERATURE 48.9 C***	



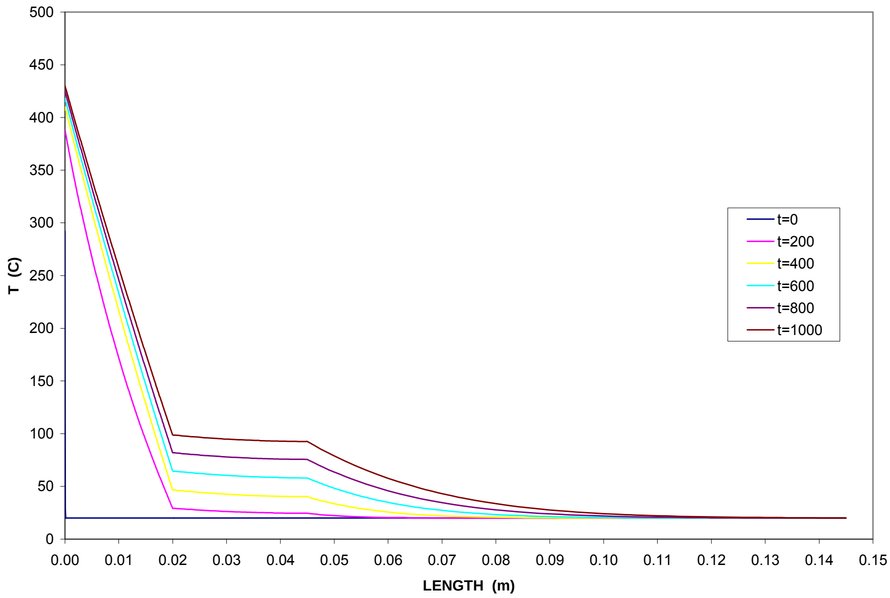


Different_insulation

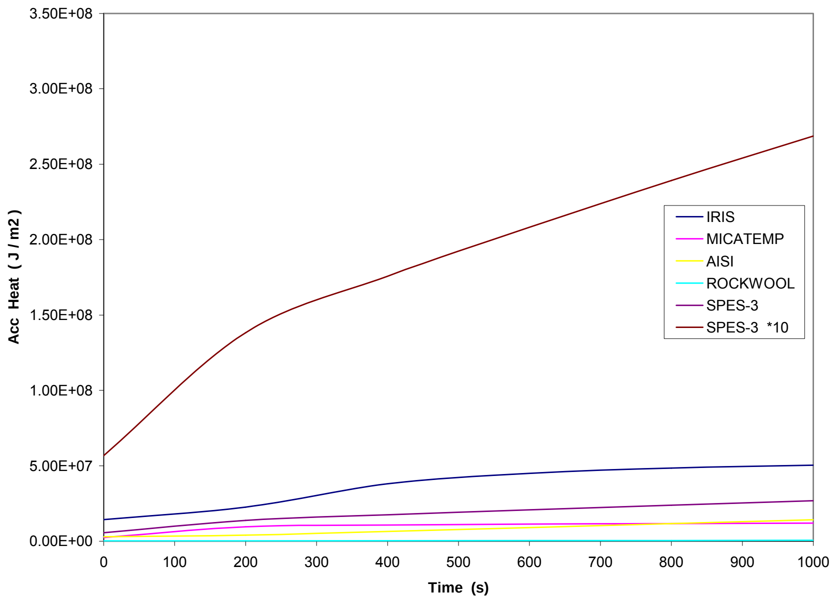
CASE5_MICATEMP

SPES-3 Dry-well		IRIS CONTAINMENT	
MATERIAL	***THICKNESS***	***MATERIAL***	***THICKNESS***
MICATEMP	20 mm	CARBON STEEL	44 mm
AISI 304	25 mm		
ROCKWOOL	100 mm		
INITIAL TEMPERATURE 20 C		***INITIAL TEMPERATURE 48.9 C***	

MICAr1_20_25_100



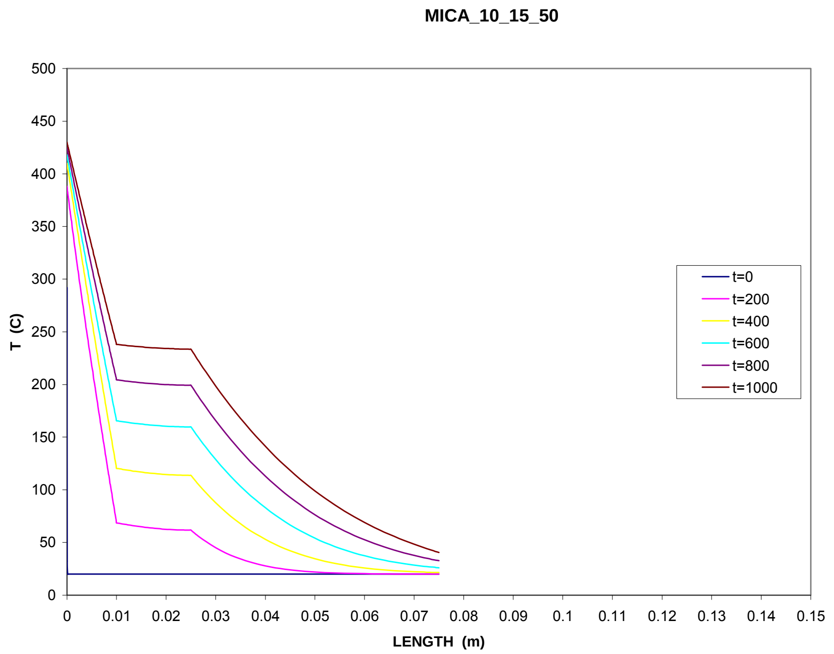
Acc_Heat 20_25_100

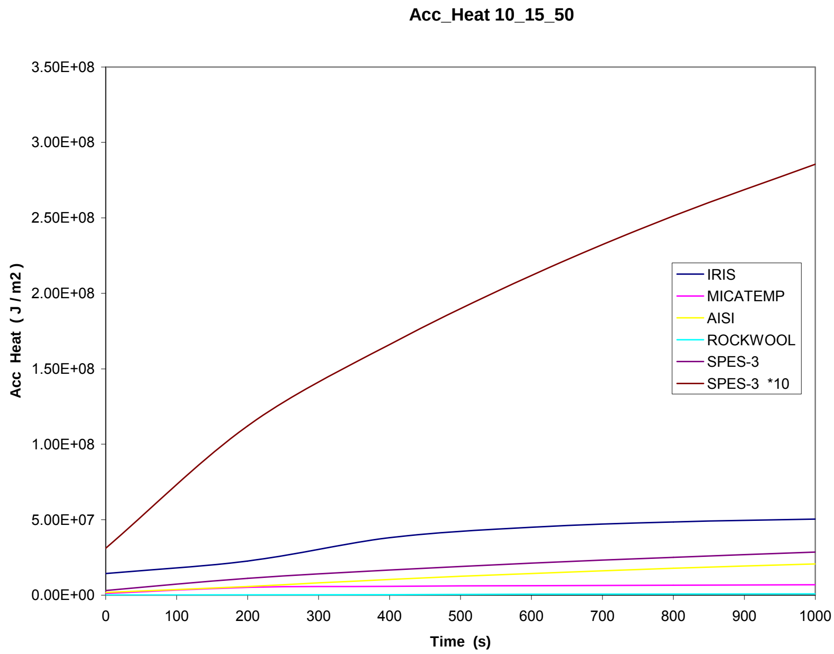


Different_insulation

CASE6_MICATEMP

SPES-3 Dry-well		IRIS CONTAINMENT	
MATERIAL	***THICKNESS***	***MATERIAL***	***THICKNESS***
MICATEMP	10 mm	CARBON STEEL	44 mm
AISI 304	15 mm		
ROCKWOOL	50 mm		
INITIAL TEMPERATURE 20 C		***INITIAL TEMPERATURE 48.9 C***	

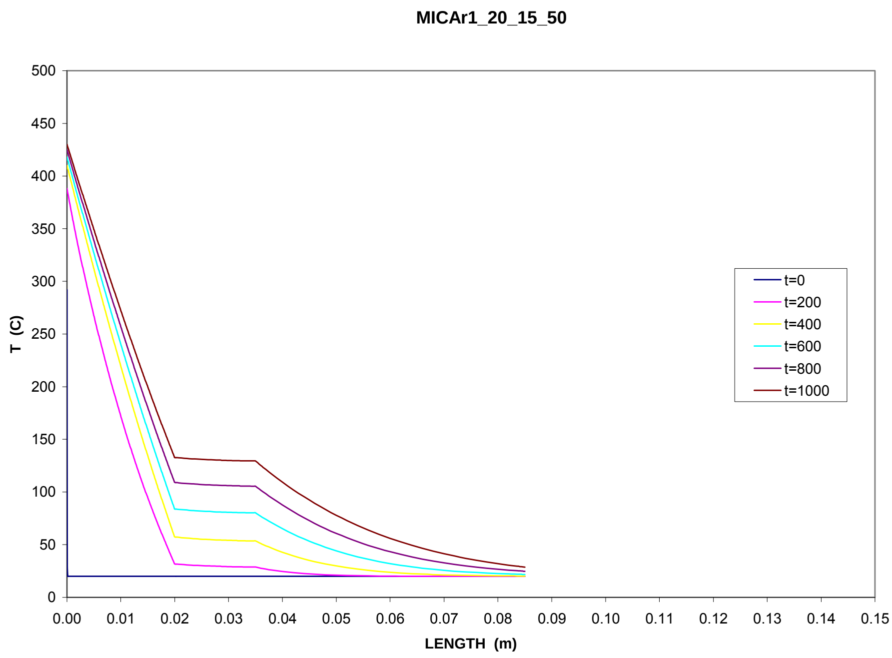


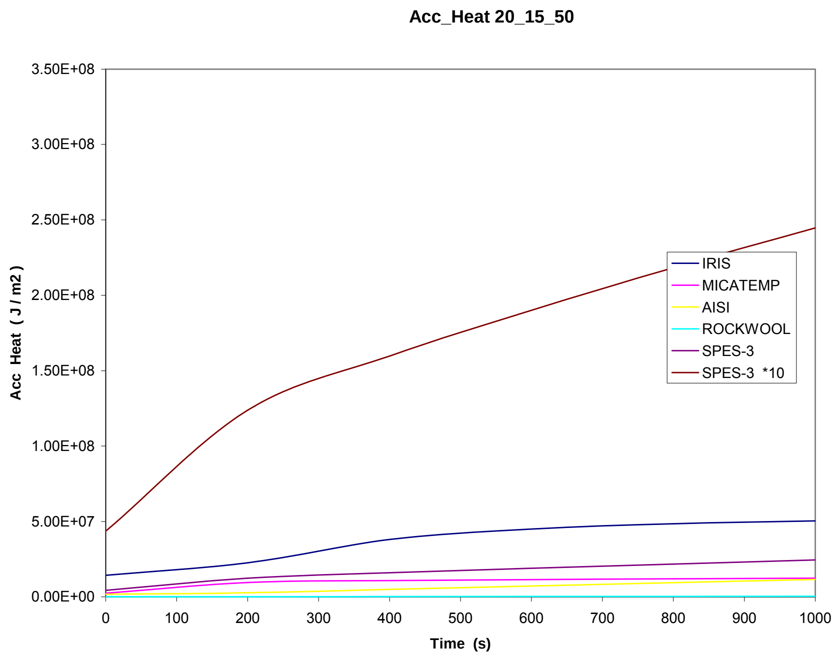


Different_insulation

CASE7_MICATEMP

SPES-3 Dry-well		IRIS CONTAINMENT	
MATERIAL	***THICKNESS***	***MATERIAL***	***THICKNESS***
MICATEMP	20 mm	CARBON STEEL	44 mm
AISI 304	15 mm		
ROCKWOOL	50 mm		
INITIAL TEMPERATURE 20 C		***INITIAL TEMPERATURE 48.9 C***	

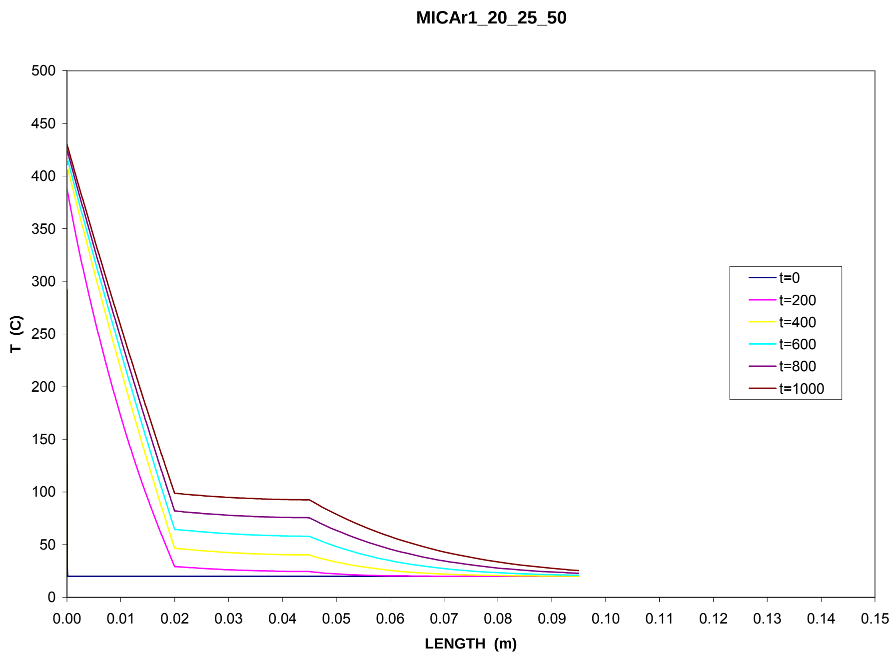


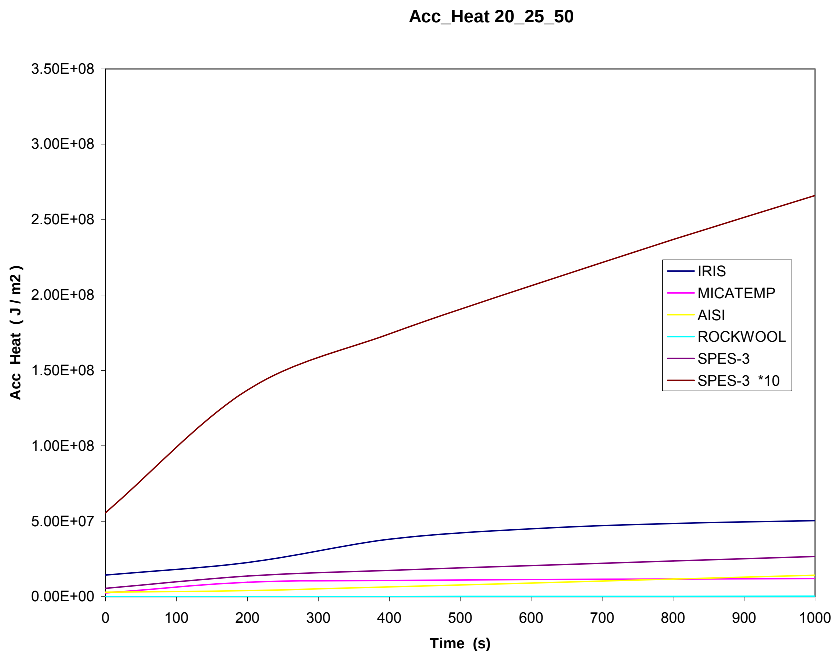


Different_insulation

CASE8_MICATEMP

SPES-3 Dry-well		IRIS CONTAINMENT	
MATERIAL	***THICKNESS***	***MATERIAL***	***THICKNESS***
MICATEMP	20 mm	CARBON STEEL	44 mm
AISI 304	25 mm		
ROCKWOOL	50 mm		
INITIAL TEMPERATURE 20 C		***INITIAL TEMPERATURE 48.9 C***	

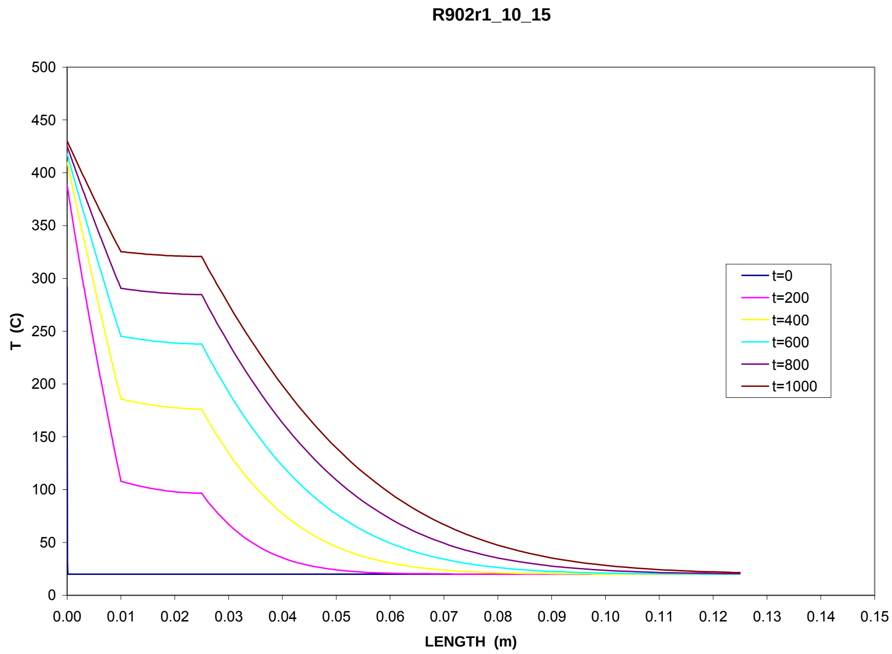


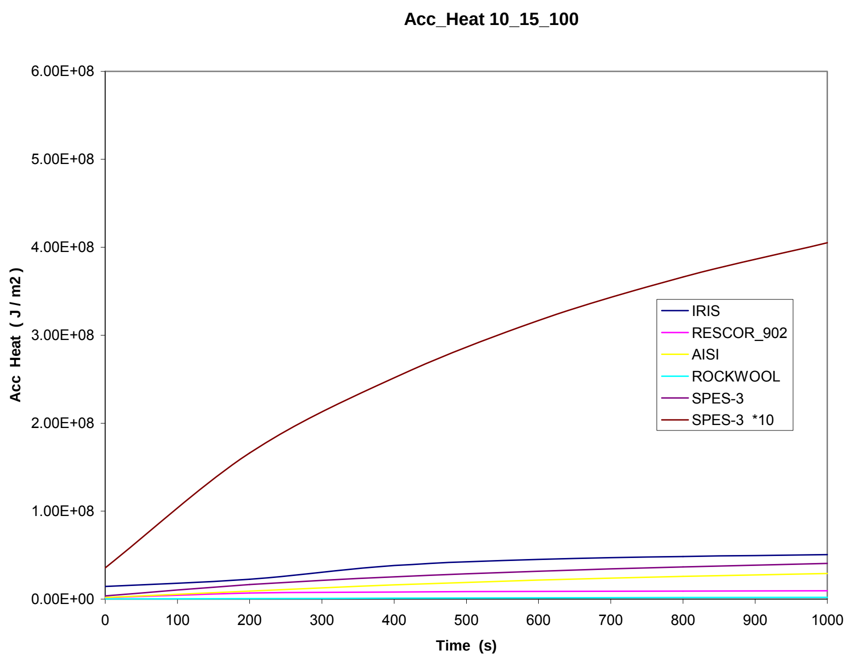


Different_insulation

CASE1_RESCOR902

SPES-3 Dry-well		IRIS CONTAINMENT	
MATERIAL	***THICKNESS***	***MATERIAL***	***THICKNESS***
RESCOR902	10 mm	CARBON STEEL	44 mm
AISI 304	15 mm		
ROCKWOOL	100 mm		
INITIAL TEMPERATURE 20 C		***INITIAL TEMPERATURE 48.9 C***	

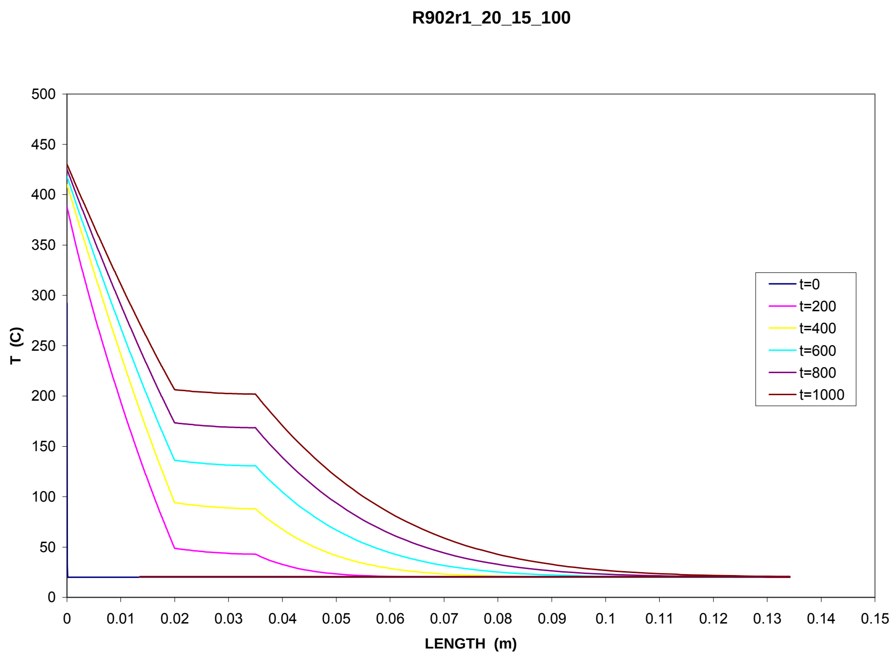


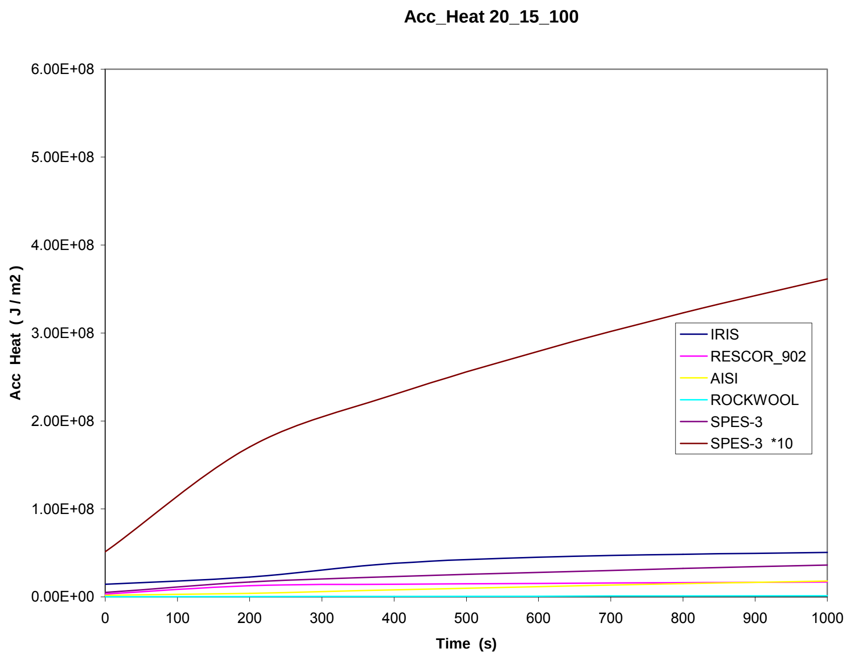


Different_insulation

CASE2_RESCOR902

SPES-3 Dry-well		IRIS CONTAINMENT	
MATERIAL	***THICKNESS***	***MATERIAL***	***THICKNESS***
RESCOR902	20 mm	CARBON STEEL	44 mm
AISI 304	15 mm		
ROCKWOOL	100 mm		
INITIAL TEMPERATURE 20 C		***INITIAL TEMPERATURE 48.9 C***	

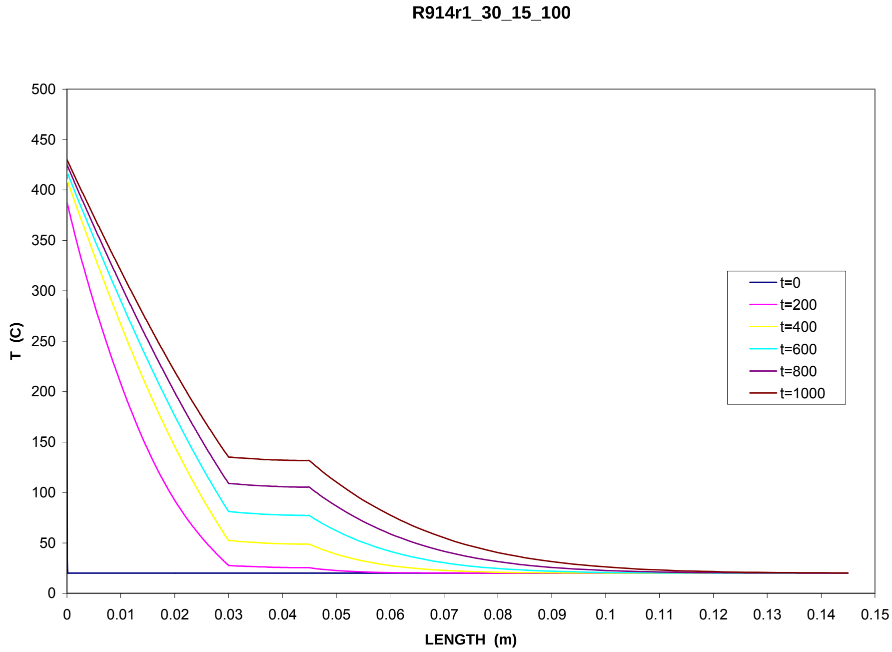


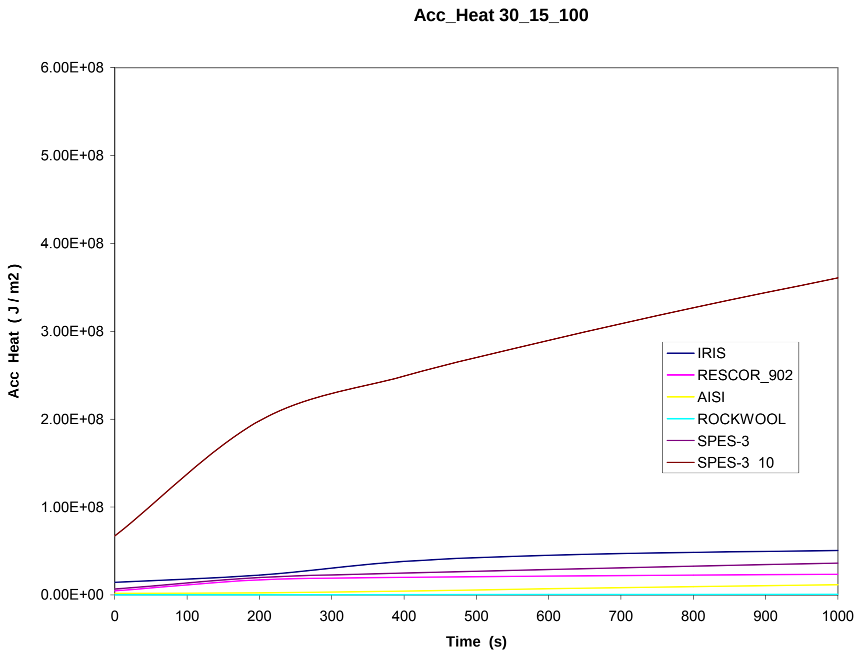


Different_insulation

CASE3_RESCOR902

SPES-3 Dry-well		IRIS CONTAINMENT	
MATERIAL	***THICKNESS***	***MATERIAL***	***THICKNESS***
RESCOR902	30 mm	CARBON STEEL	44 mm
AISI 304	15 mm		
ROCKWOOL	100 mm		
INITIAL TEMPERATURE 20 C		***INITIAL TEMPERATURE 48.9 C***	

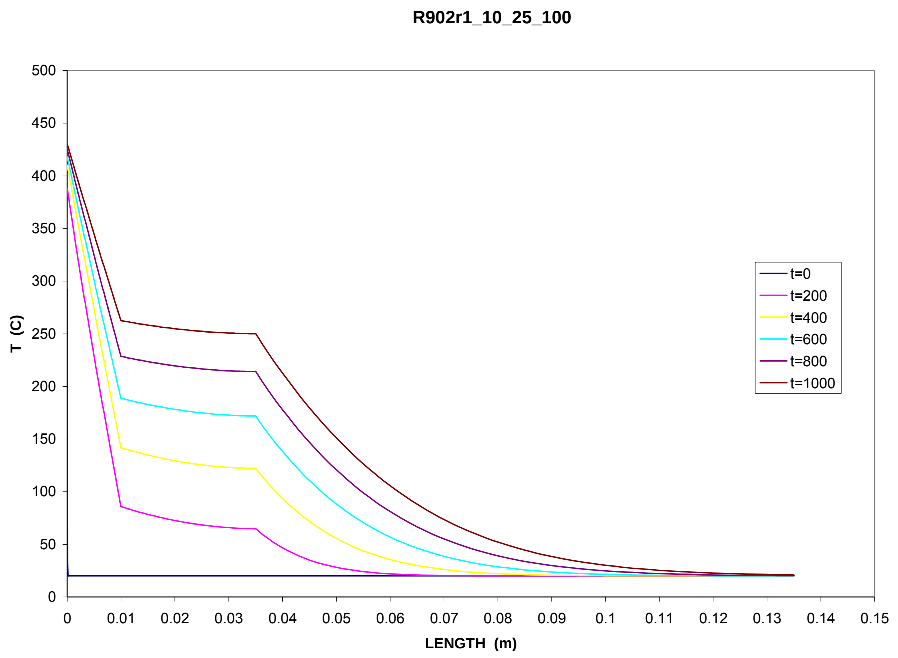


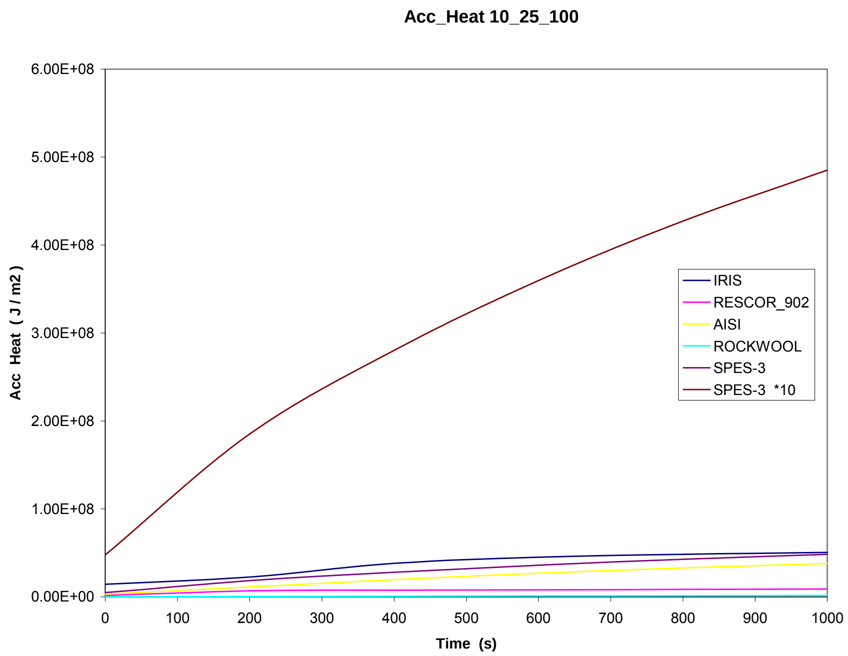


Different_insulation

CASE4_RESCOR902

SPES-3 Dry-well		IRIS CONTAINMENT	
MATERIAL	***THICKNESS***	***MATERIAL***	***THICKNESS***
RESCOR902	10 mm	CARBON STEEL	44 mm
AISI 304	25 mm		
ROCKWOOL	100 mm		
INITIAL TEMPERATURE 20 C		***INITIAL TEMPERATURE 48.9 C***	

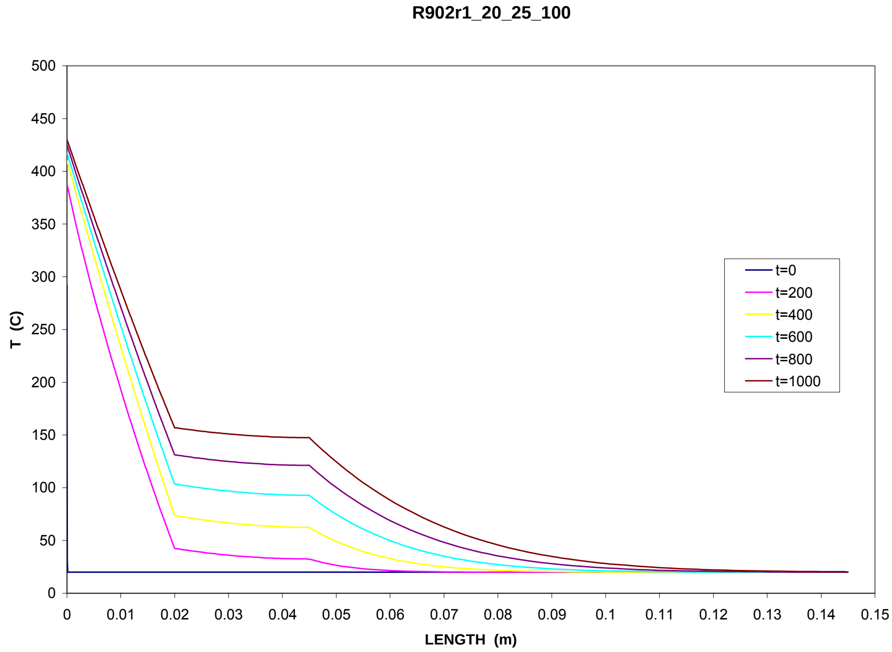


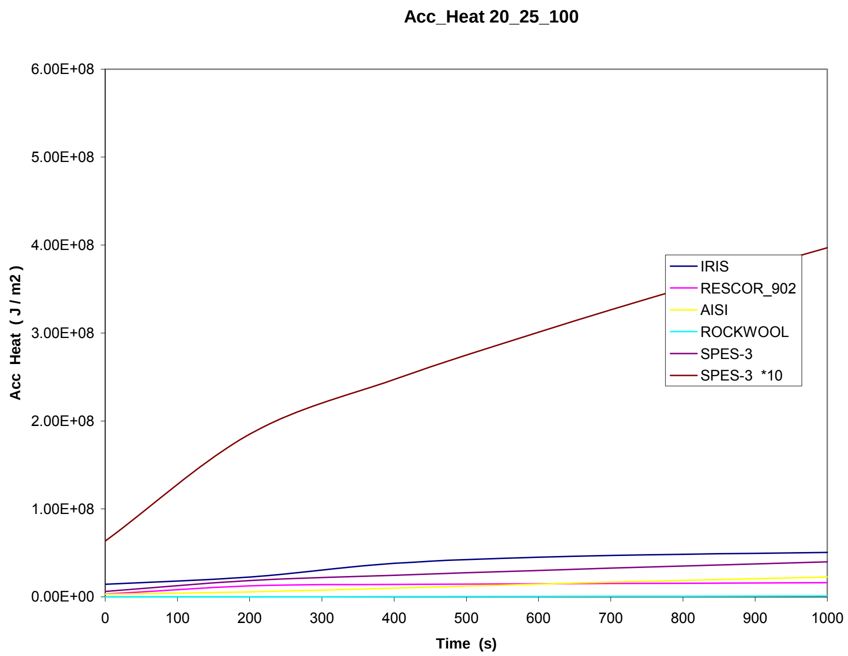


Different_insulation

CASE5_RESCOR902

SPES-3 Dry-well		IRIS CONTAINMENT	
MATERIAL	***THICKNESS***	***MATERIAL***	***THICKNESS***
RESCOR902	20 mm	CARBON STEEL	44 mm
AISI 304	25 mm		
ROCKWOOL	100 mm		
INITIAL TEMPERATURE 20 C		***INITIAL TEMPERATURE 48.9 C***	

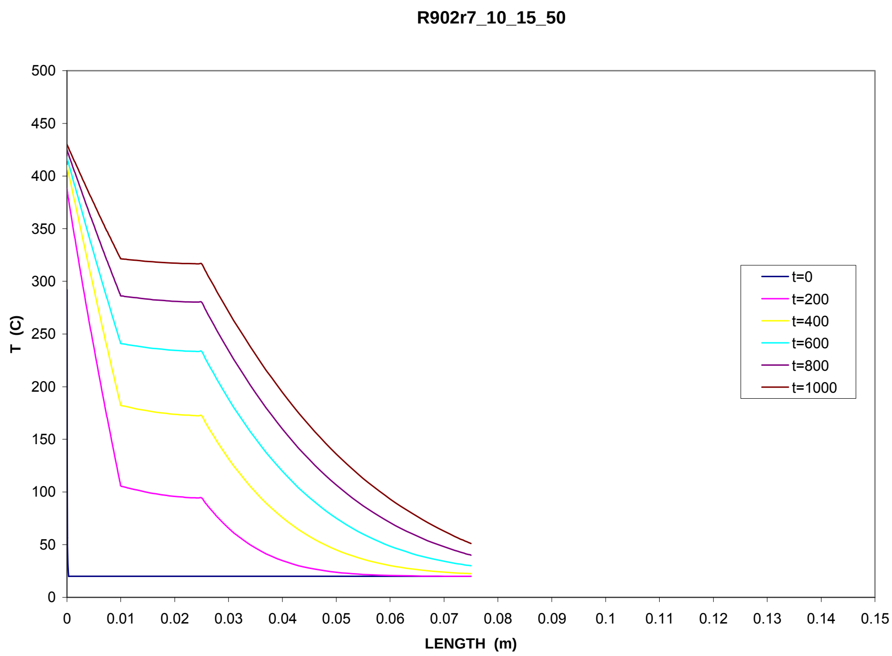


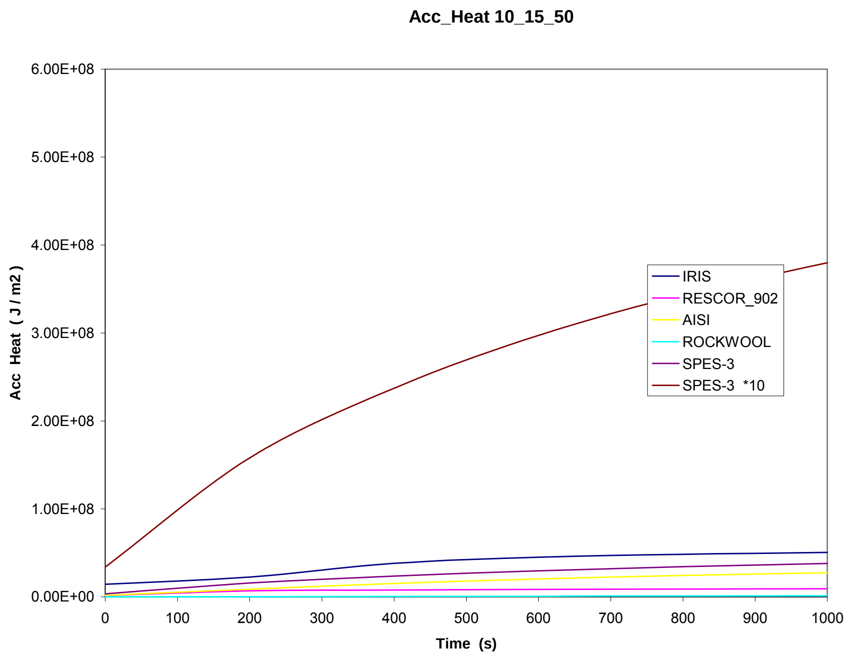


Different_insulation

CASE6_RESCOR902

SPES-3 Dry-well		IRIS CONTAINMENT	
MATERIAL	***THICKNESS***	***MATERIAL***	***THICKNESS***
RESCOR902	10 mm	CARBON STEEL	44 mm
AISI 304	15 mm		
ROCKWOOL	50 mm		
INITIAL TEMPERATURE 20 C		***INITIAL TEMPERATURE 48.9 C***	

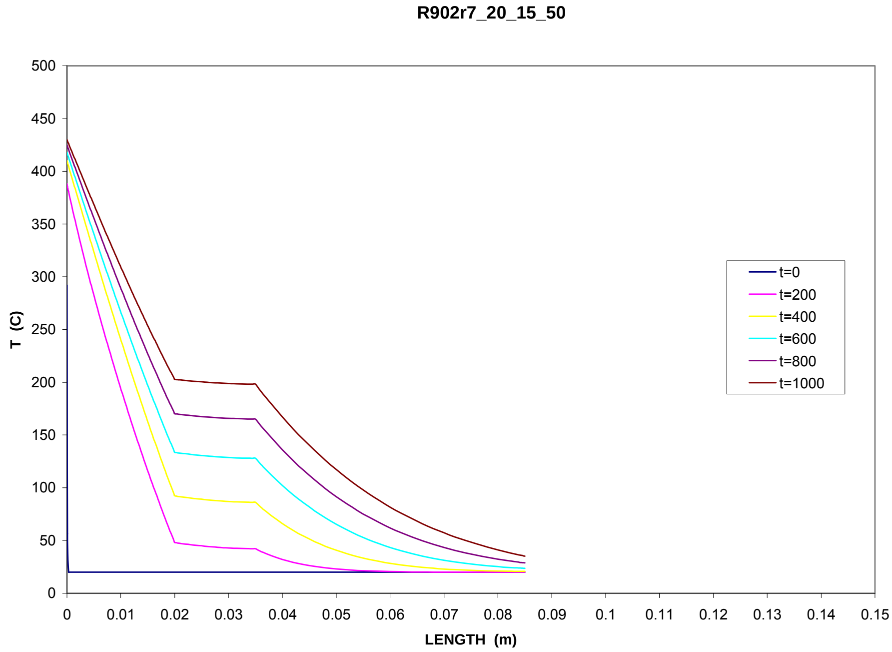


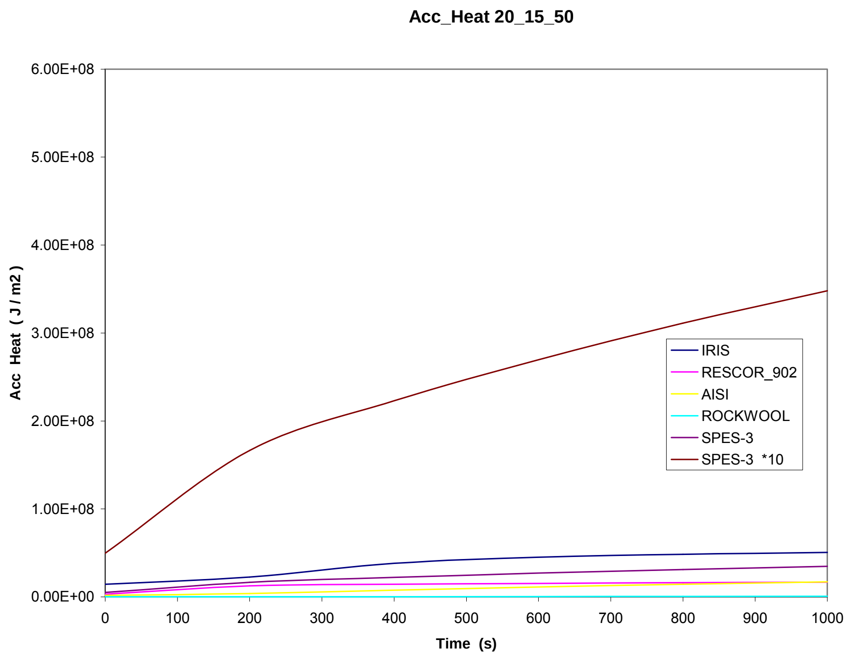


Different_insulation

CASE7_RESCOR902

SPES-3 Dry-well		IRIS CONTAINMENT	
MATERIAL	***THICKNESS***	***MATERIAL***	***THICKNESS***
RESCOR902	20 mm	CARBON STEEL	44 mm
AISI 304	15 mm		
ROCKWOOL	50 mm		
INITIAL TEMPERATURE 20 C		***INITIAL TEMPERATURE 48.9 C***	

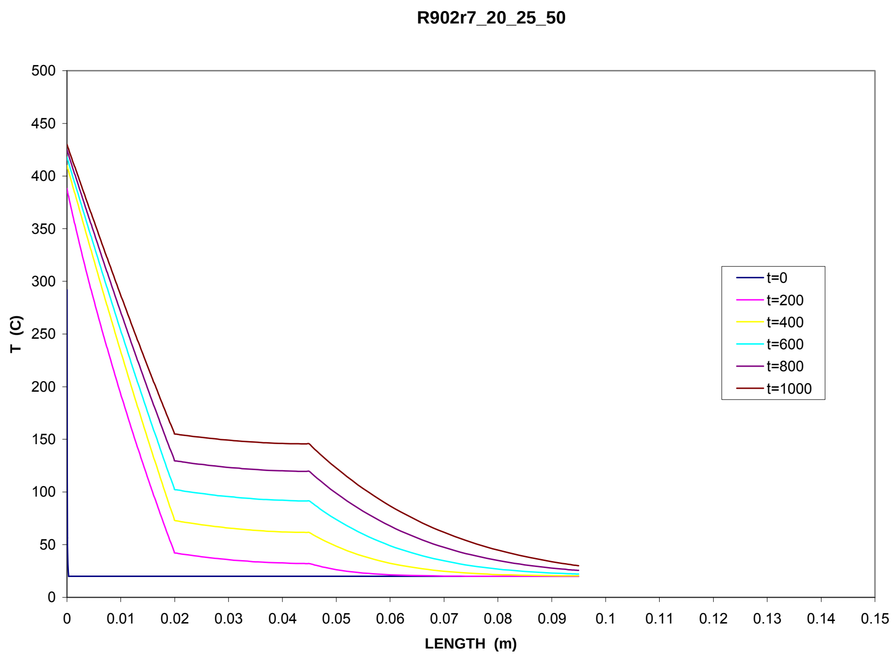


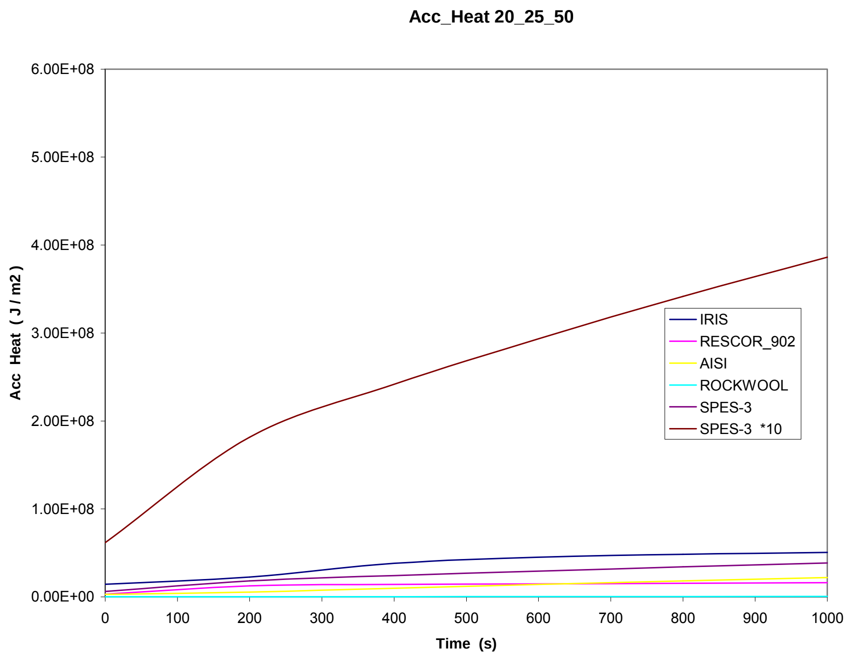


Different_insulation

CASE8_RESCOR902

SPES-3 Dry-well		IRIS CONTAINMENT	
MATERIAL	***THICKNESS***	***MATERIAL***	***THICKNESS***
RESCOR902	20 mm	CARBON STEEL	44 mm
AISI 304	25 mm		
ROCKWOOL	50 mm		
INITIAL TEMPERATURE 20 C		***INITIAL TEMPERATURE 48.9 C***	

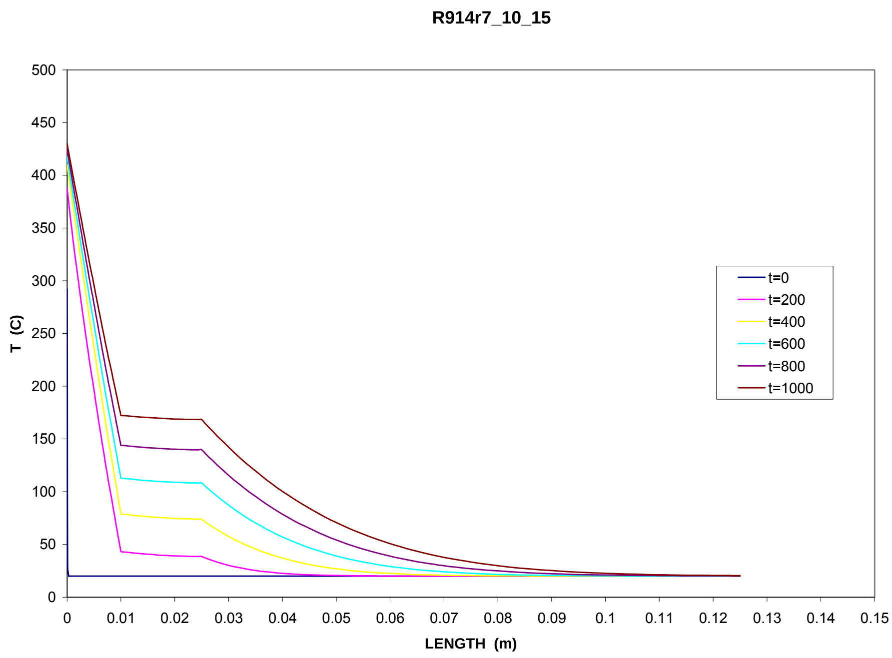


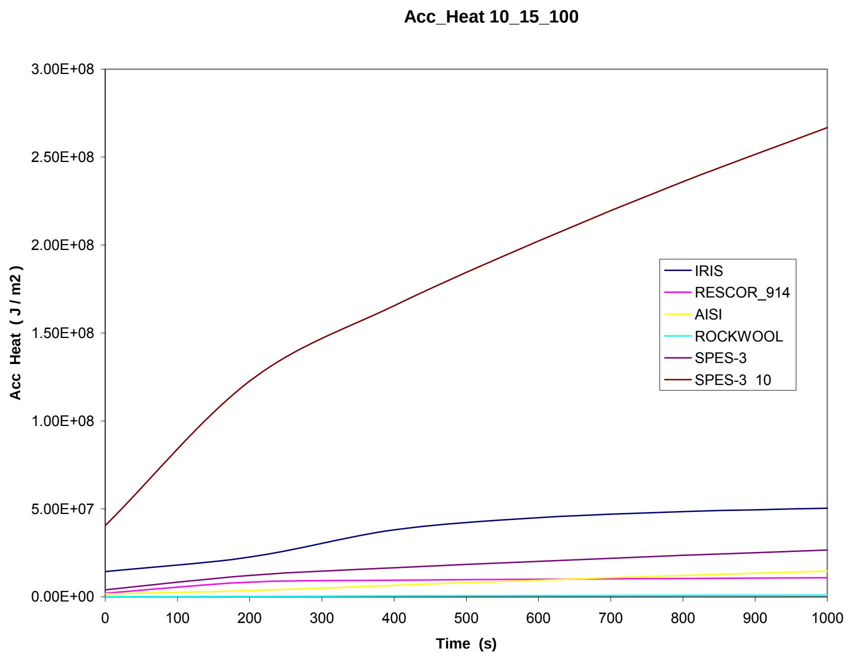


Different_insulation

CASE1_RESCOR914

SPES-3 Dry-well		IRIS CONTAINMENT	
MATERIAL	***THICKNESS***	***MATERIAL***	***THICKNESS***
RESCOR914	10 mm	CARBON STEEL	44 mm
AISI 304	15 mm		
ROCKWOOL	100 mm		
INITIAL TEMPERATURE 20 C		***INITIAL TEMPERATURE 48.9 C***	

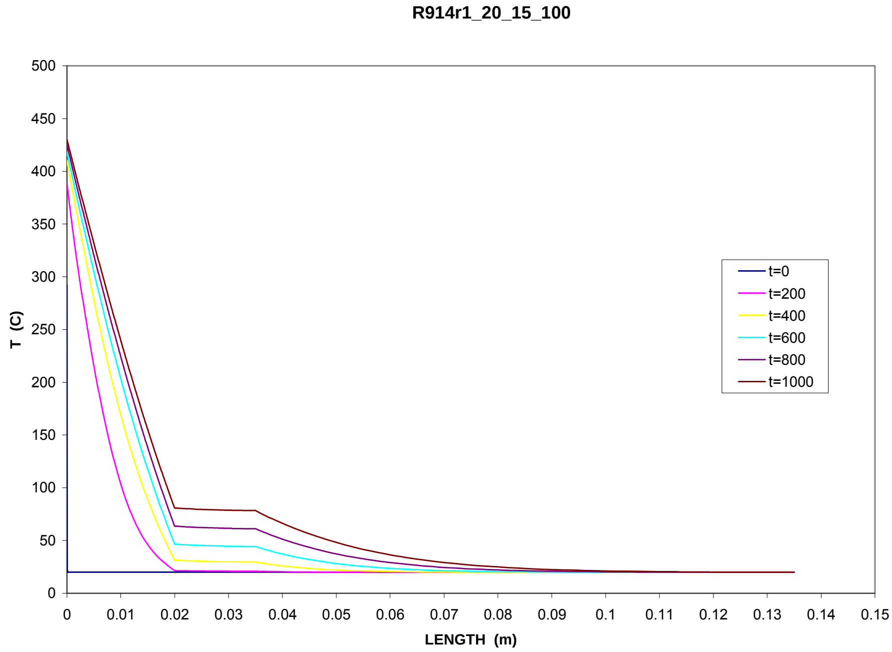


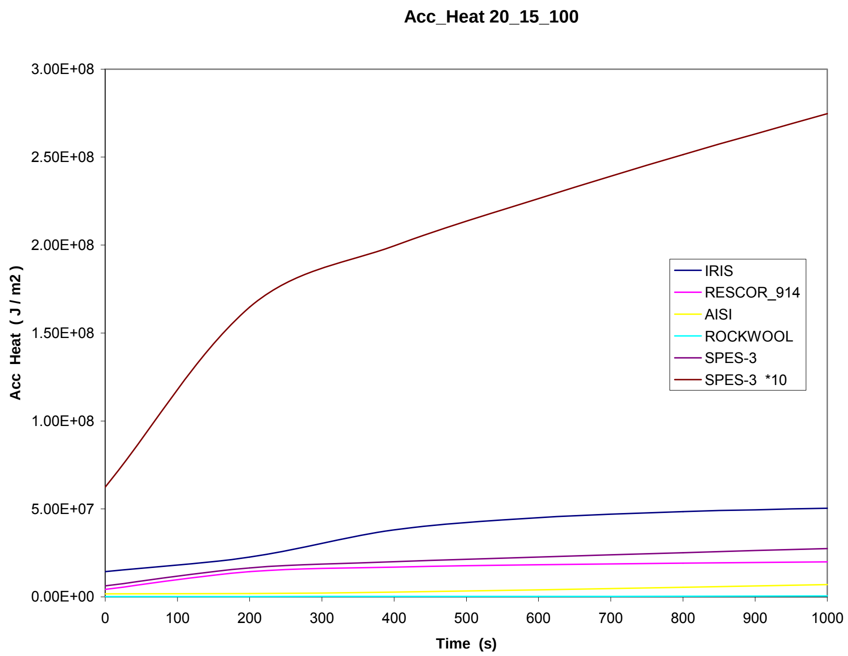


Different_insulation

CASE2_RESCOR914

SPES-3 Dry-well		IRIS CONTAINMENT	
MATERIAL	***THICKNESS***	***MATERIAL***	***THICKNESS***
RESCOR914	20 mm	CARBON STEEL	44 mm
AISI 304	15 mm		
ROCKWOOL	100 mm		
INITIAL TEMPERATURE 20 C		***INITIAL TEMPERATURE 48.9 C***	

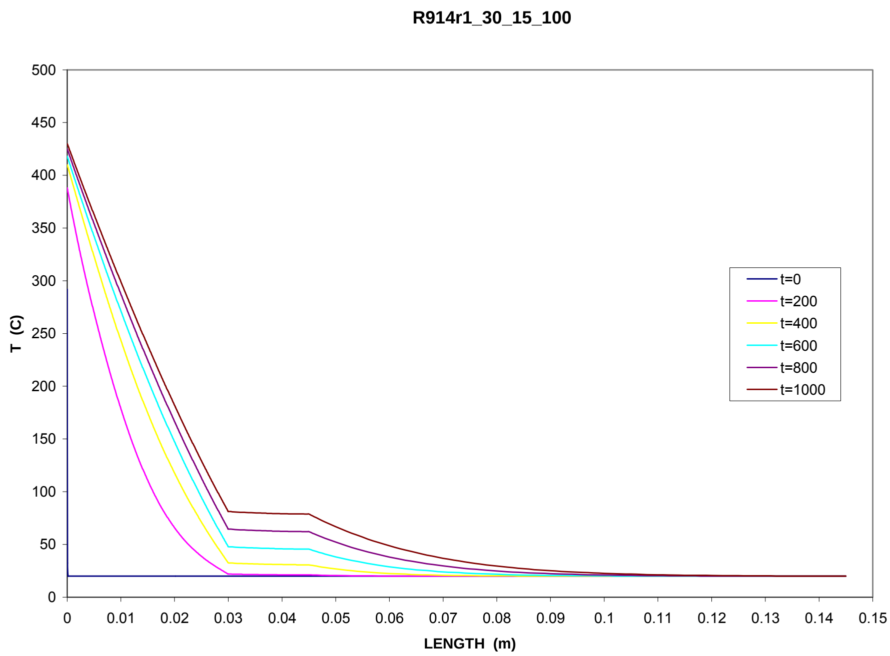


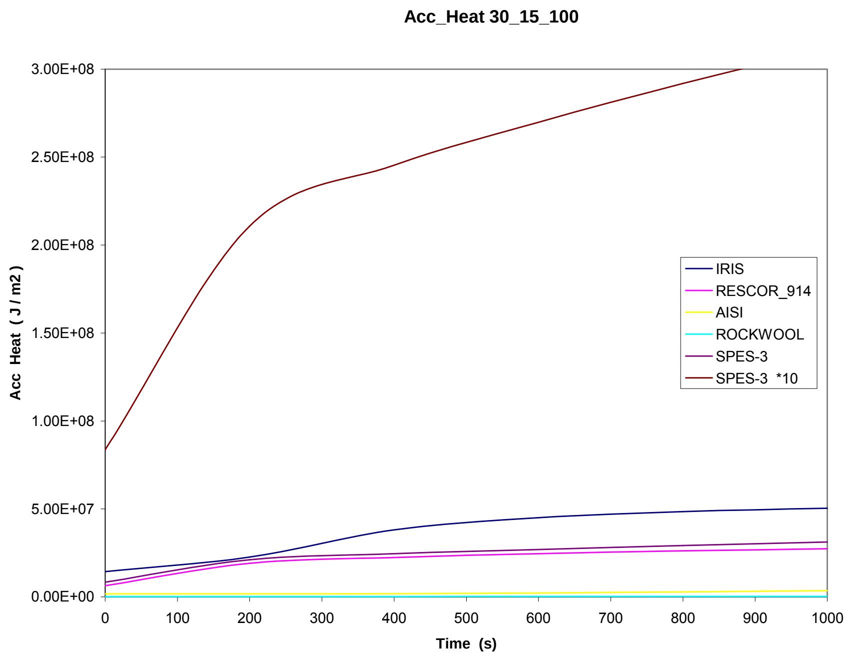


Different_insulation

CASE3_RESCOR914

SPES-3 Dry-well		IRIS CONTAINMENT	
MATERIAL	***THICKNESS***	***MATERIAL***	***THICKNESS***
RESCOR914	30 mm	CARBON STEEL	44 mm
AISI 304	15 mm		
ROCKWOOL	100 mm		
INITIAL TEMPERATURE 20 C		***INITIAL TEMPERATURE 48.9 C***	

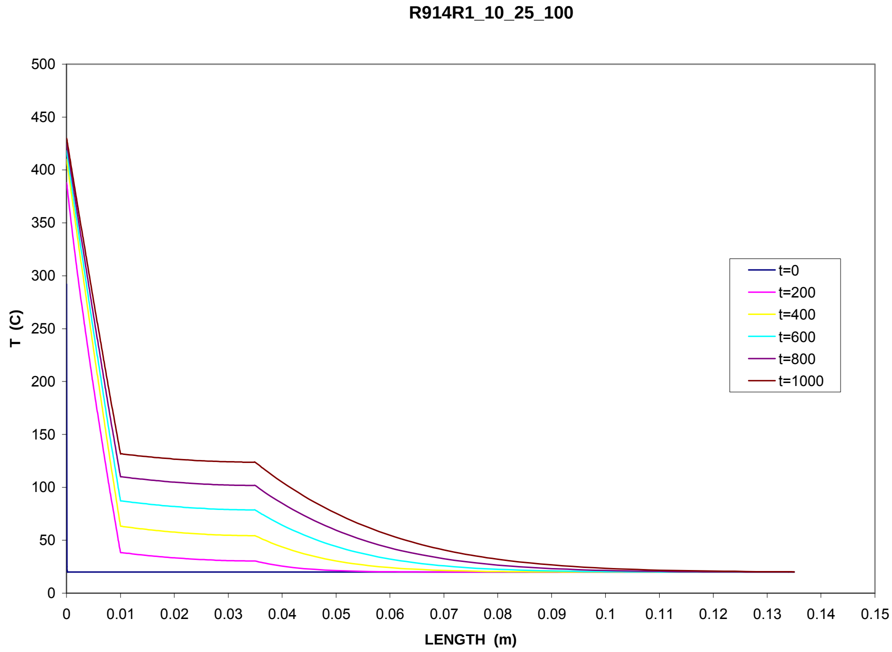


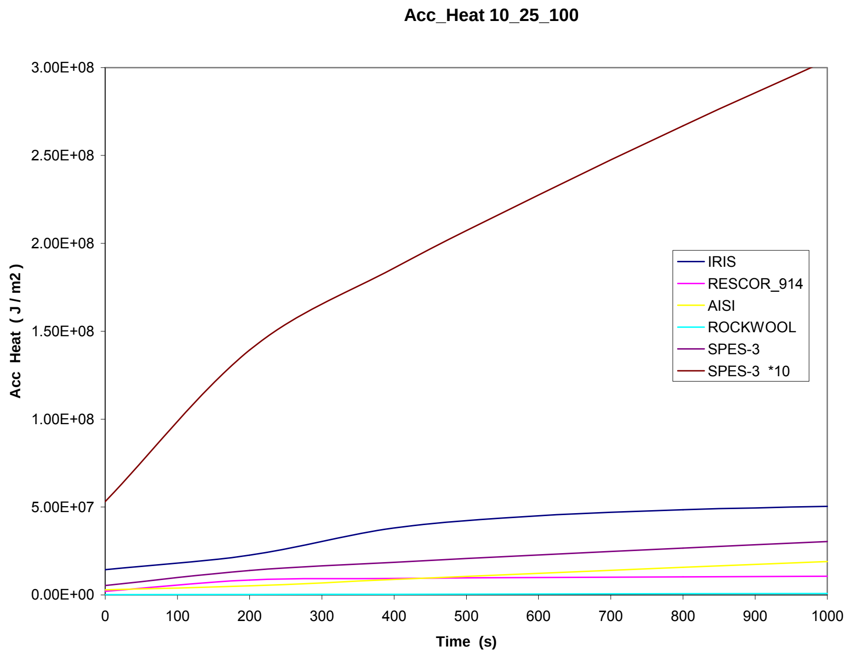


Different_insulation

CASE4_RESCOR914

SPES-3 Dry-well		IRIS CONTAINMENT	
MATERIAL	***THICKNESS***	***MATERIAL***	***THICKNESS***
RESCOR914	10 mm	CARBON STEEL	44 mm
AISI 304	25 mm		
ROCKWOOL	100 mm		
INITIAL TEMPERATURE 20 C		***INITIAL TEMPERATURE 48.9 C***	

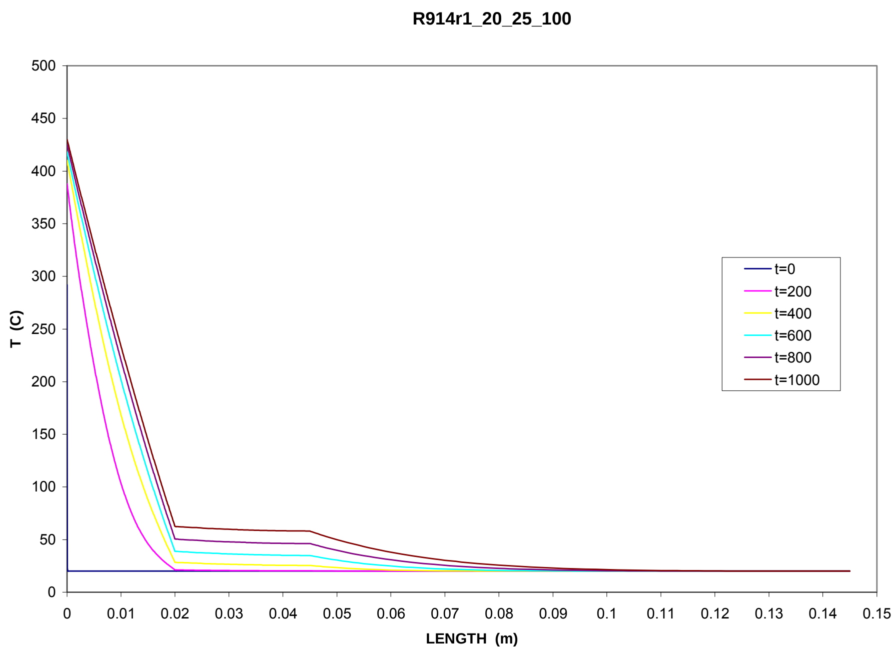


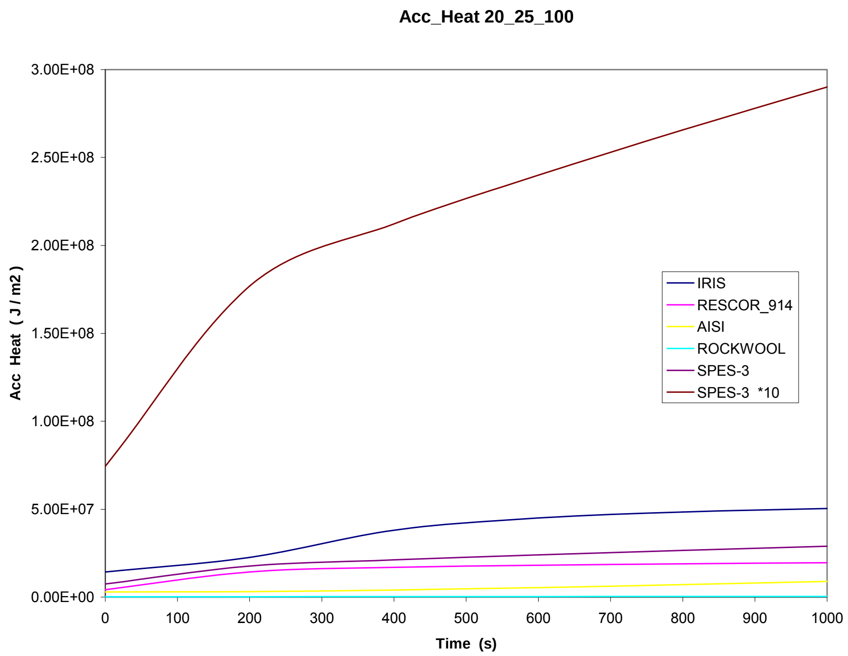


Different_insulation

CASE5_RESCOR914

SPES-3 Dry-well		IRIS CONTAINMENT	
MATERIAL	***THICKNESS***	***MATERIAL***	***THICKNESS***
RESCOR14	20 mm	CARBON STEEL	44 mm
AISI 304	25 mm		
ROCKWOOL	100 mm		
INITIAL TEMPERATURE 20 C		***INITIAL TEMPERATURE 48.9 C***	

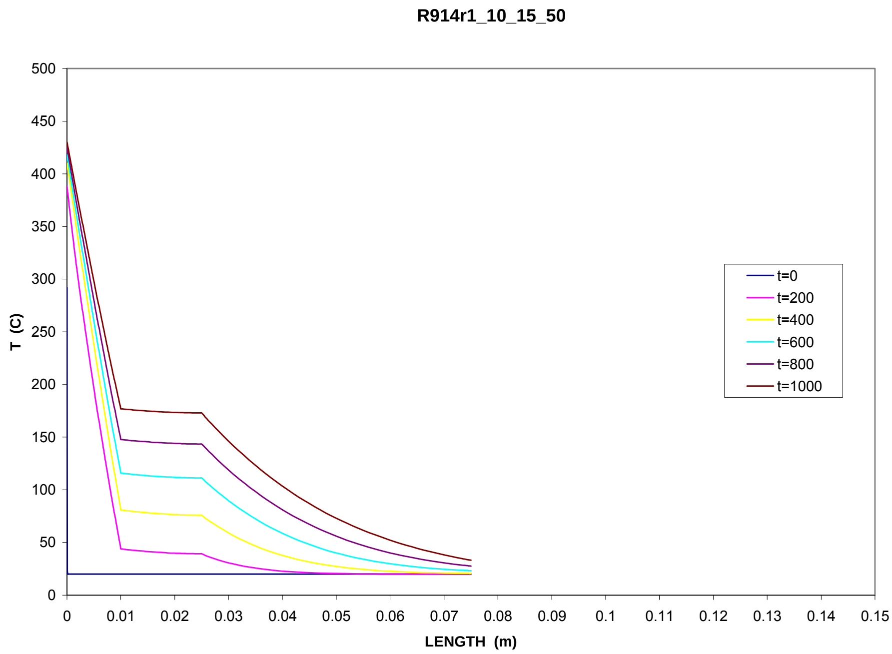


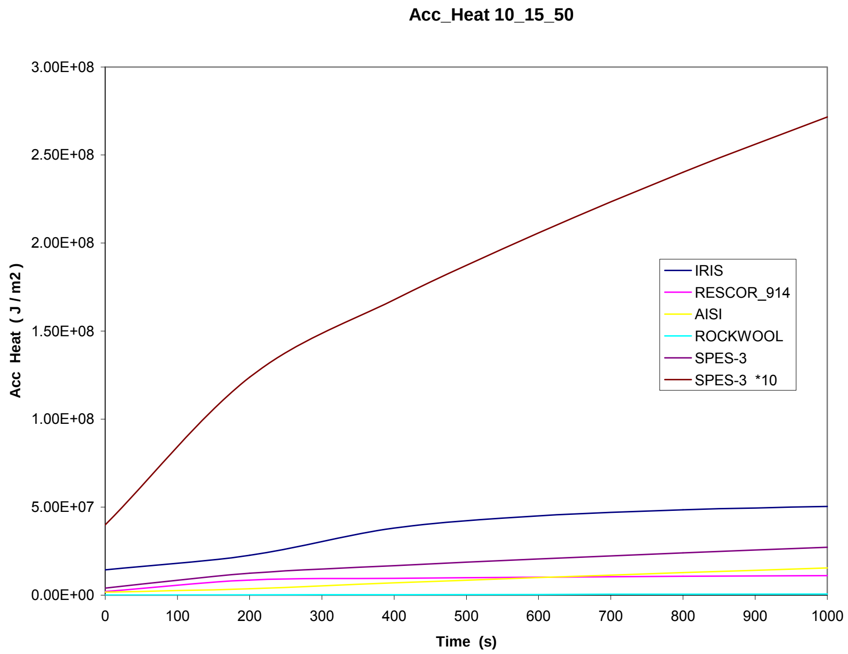


Different_insulation

CASE6_RESCOR914

SPES-3 Dry-well		IRIS CONTAINMENT	
MATERIAL	***THICKNESS***	***MATERIAL***	***THICKNESS***
RESCOR914	10 mm	CARBON STEEL	44 mm
AISI 304	15 mm		
ROCKWOOL	50 mm		
INITIAL TEMPERATURE 20 C		***INITIAL TEMPERATURE 48.9 C***	

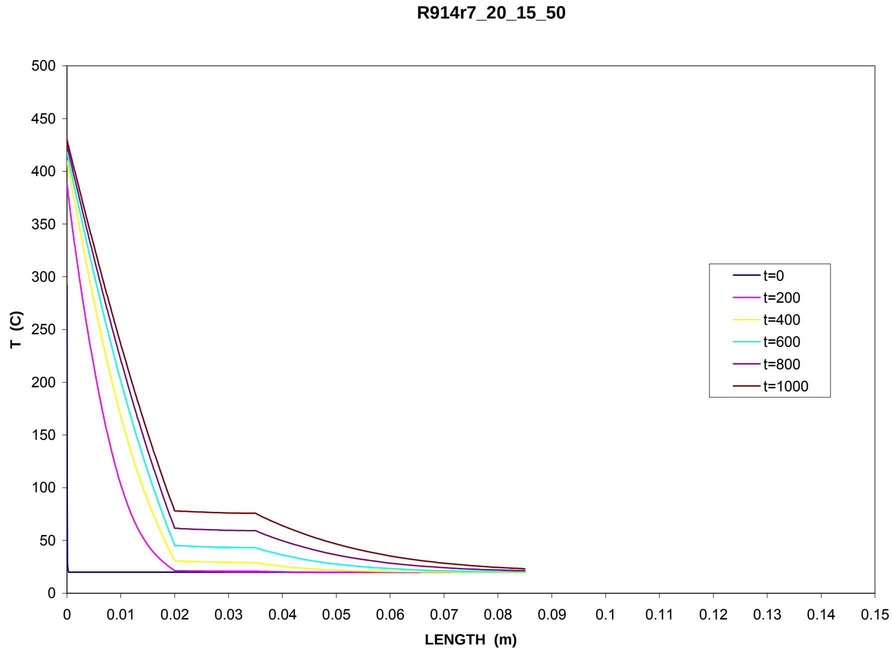


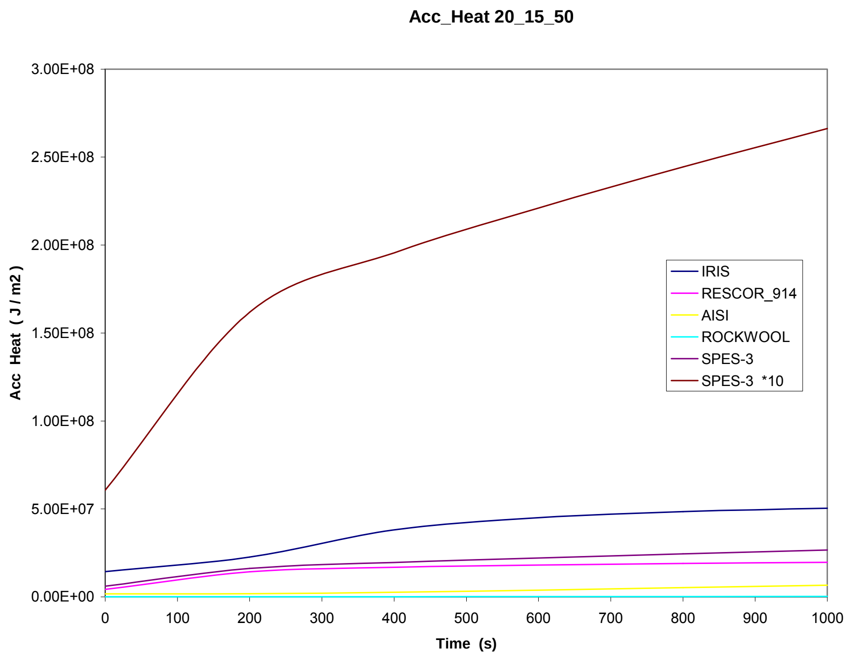


Different_insulation

CASE7_RESCOR914

SPES-3 Dry-well		IRIS CONTAINMENT	
MATERIAL	***THICKNESS***	***MATERIAL***	***THICKNESS***
RESCOR914	20 mm	CARBON STEEL	44 mm
AISI 304	15 mm		
ROCKWOOL	50 mm		
INITIAL TEMPERATURE 20 C		***INITIAL TEMPERATURE 48.9 C***	

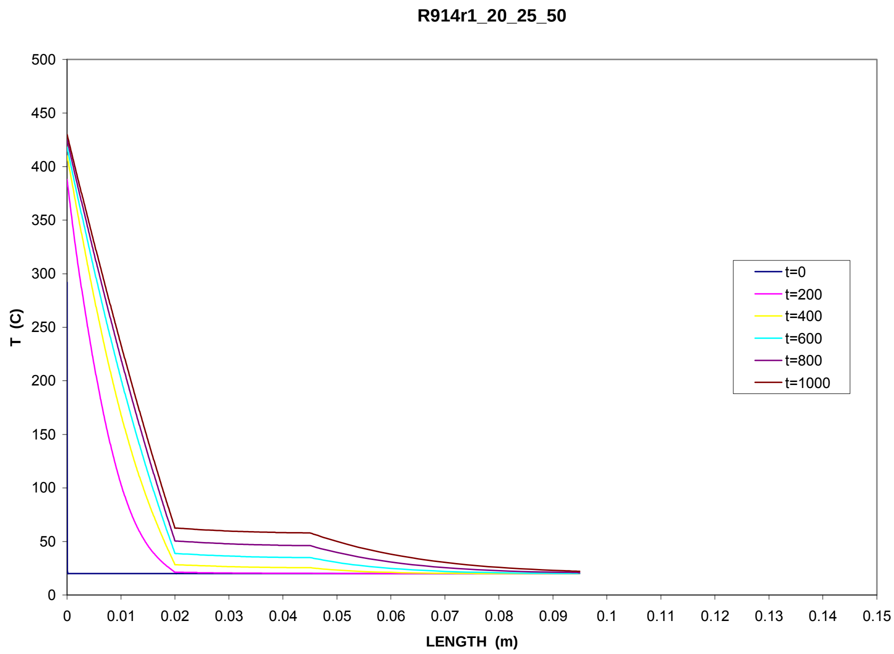


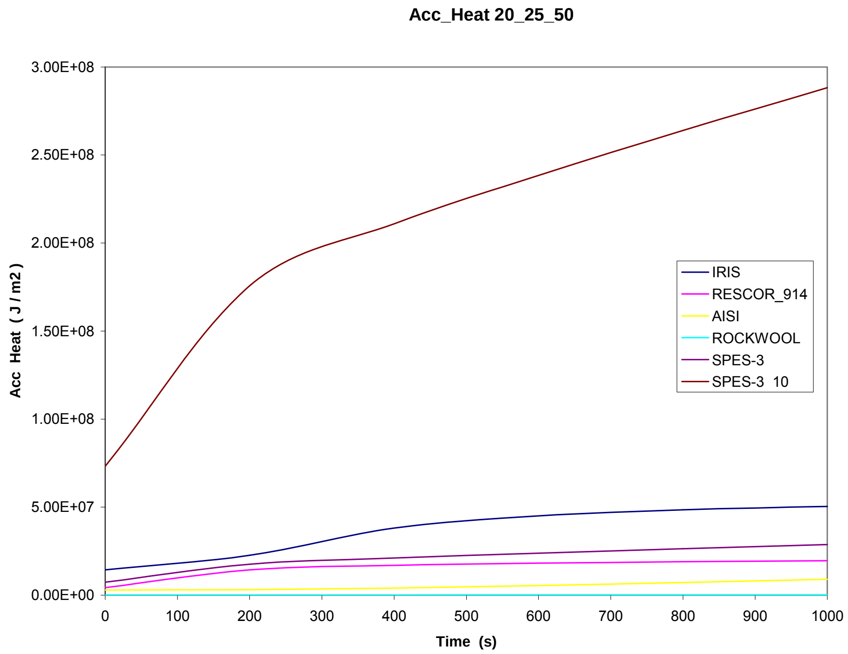


Different_insulation

CASE8_RESCOR914

SPES-3 Dry-well		IRIS CONTAINMENT	
MATERIAL	***THICKNESS***	***MATERIAL***	***THICKNESS***
RESCOR914	20 mm	CARBON STEEL	44 mm
AISI 304	25 mm		
ROCKWOOL	50 mm		
INITIAL TEMPERATURE 20 C		***INITIAL TEMPERATURE 48.9 C***	



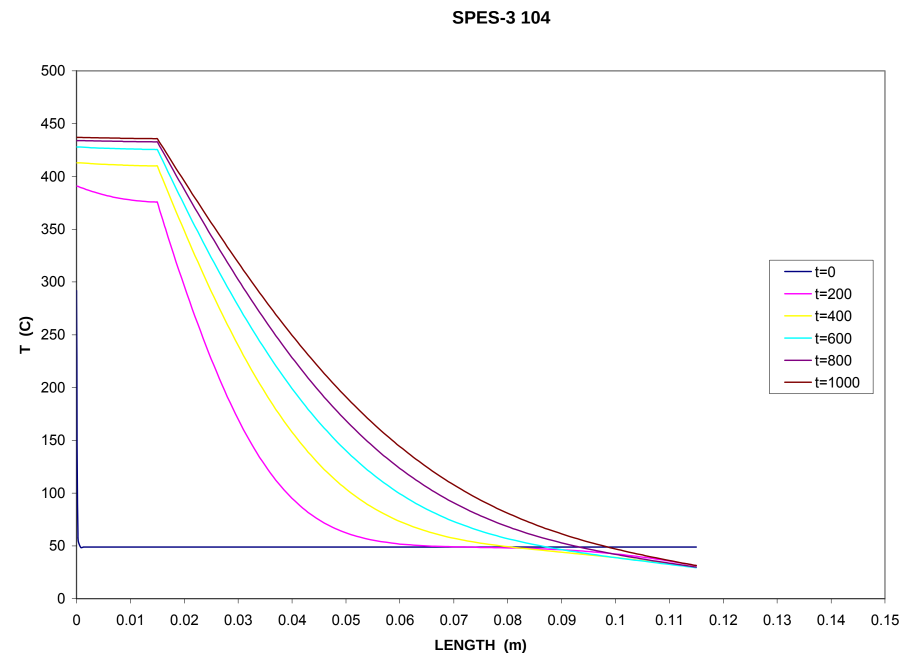


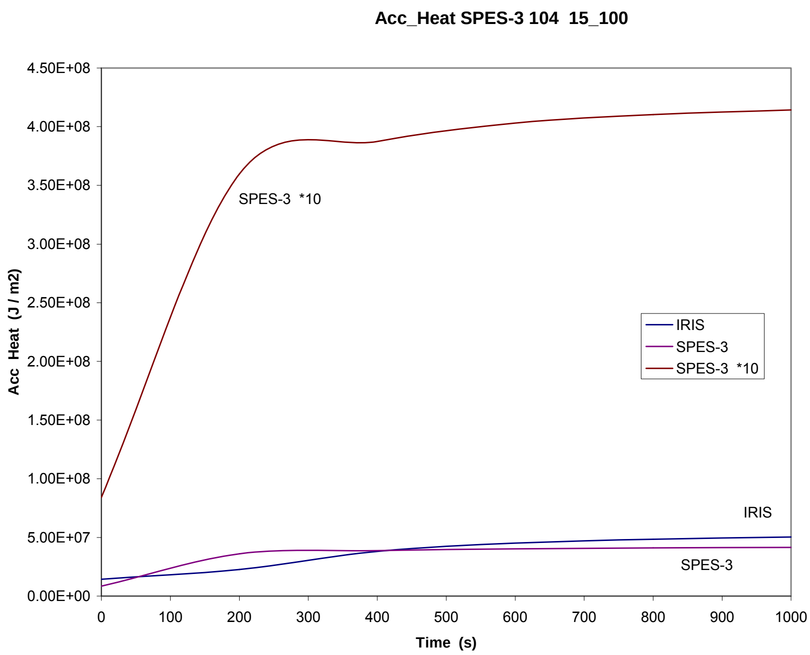
Different_insulation

file "IRIS_SPES3_Conf Call Minutes #106 Att 2 Spes3_Without_Insulation.*doc*

SPES-3_WITHOUT_INSULATION
CASE1_SPES-3 104

SPES-3 Dry-well		IRIS CONTAINMENT	
MATERIAL	***THICKNESS***	***MATERIAL***	***THICKNESS***
AISI 304	15 mm	CARBON STEEL	44 mm
ROCKWOOL	100 mm		
INITIAL TEMPERATURE 48.9 C		***INITIAL TEMPERATURE 48.9 C***	

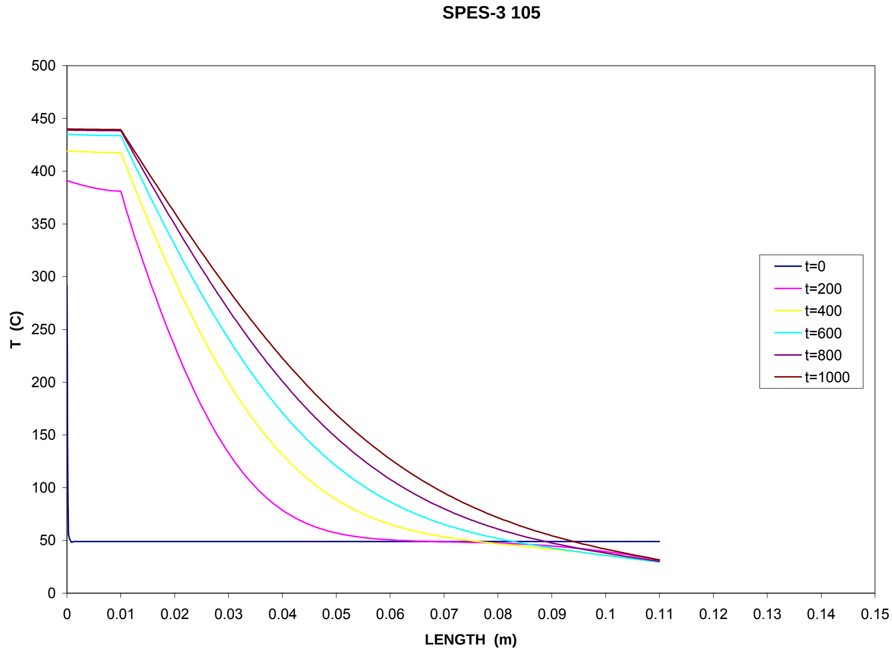


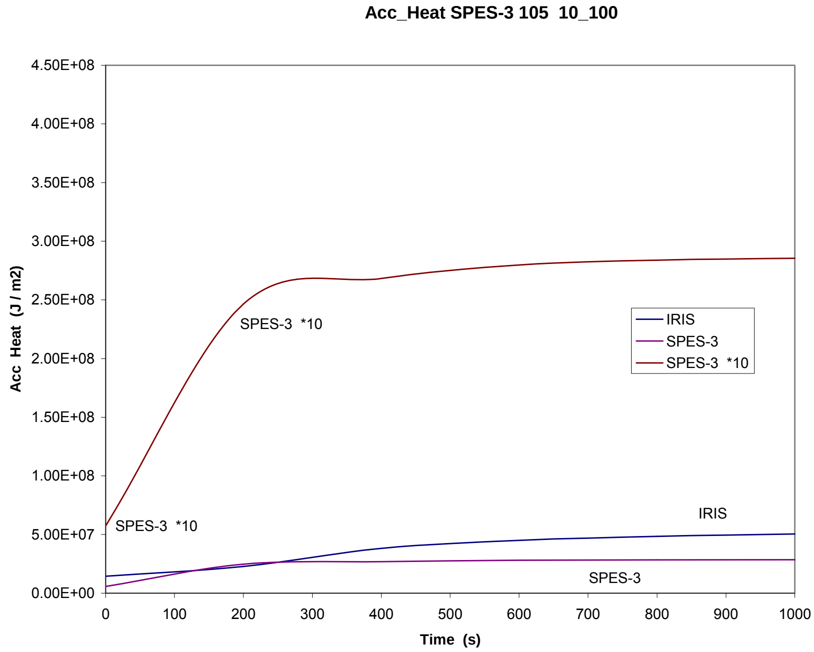


Spes3_without_insulation

CASE2_SPES-3 105

SPES-3 Dry-well		IRIS CONTAINMENT	
MATERIAL	***THICKNESS***	***MATERIAL***	***THICKNESS***
AISI 304	10 mm	CARBON STEEL	44 mm
ROCKWOOL	100 mm		
INITIAL TEMPERATURE 48.9 C		***INITIAL TEMPERATURE 48.9 C***	



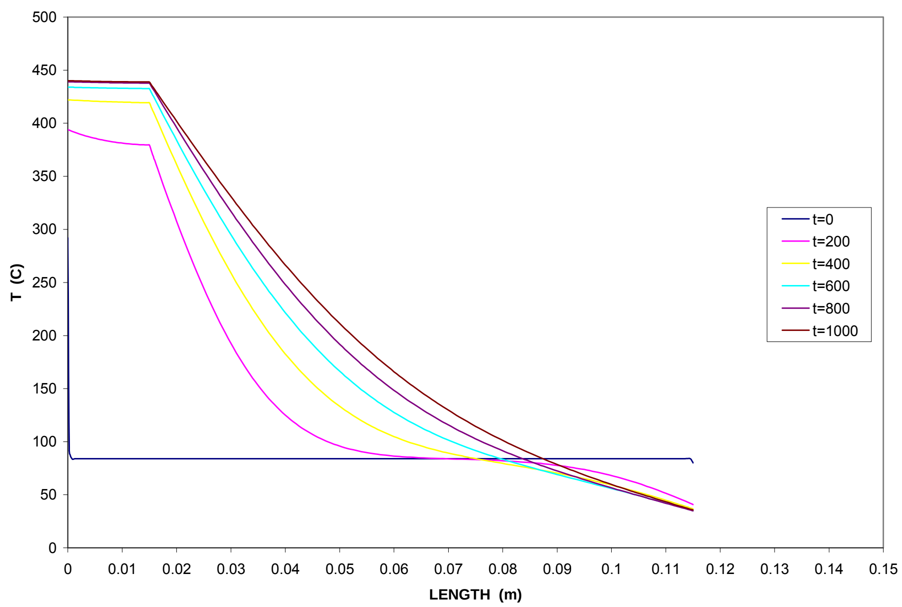


Spes3_without_insulation

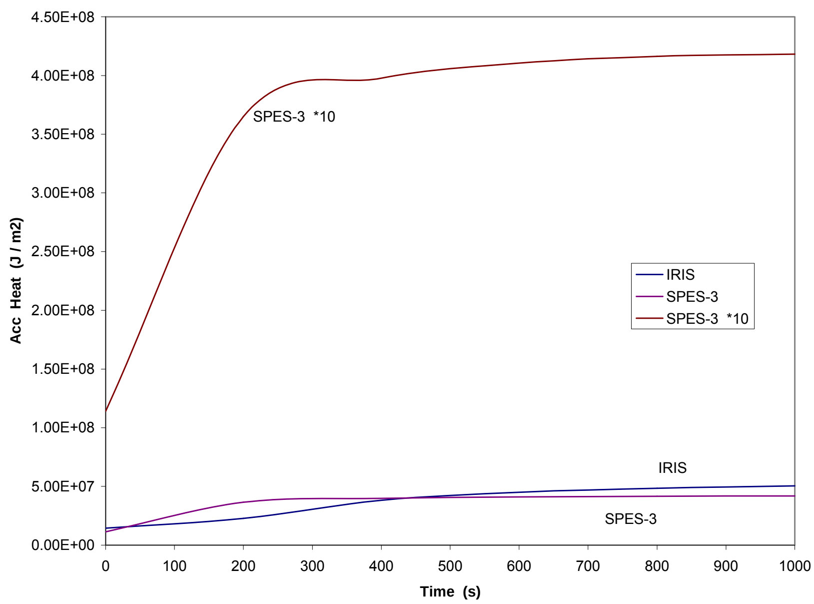
CASE3_SPES-3 111

SPES-3 Dry-well		IRIS CONTAINMENT	
MATERIAL	***THICKNESS***	***MATERIAL***	***THICKNESS***
AISI 304	15 mm	CARBON STEEL	44 mm
ROCKWOOL	100 mm		
INITIAL TEMPERATURE 84 C		***INITIAL TEMPERATURE 48.9 C***	

SPES-3 111



Acc_Heat SPES-3 111 15_100

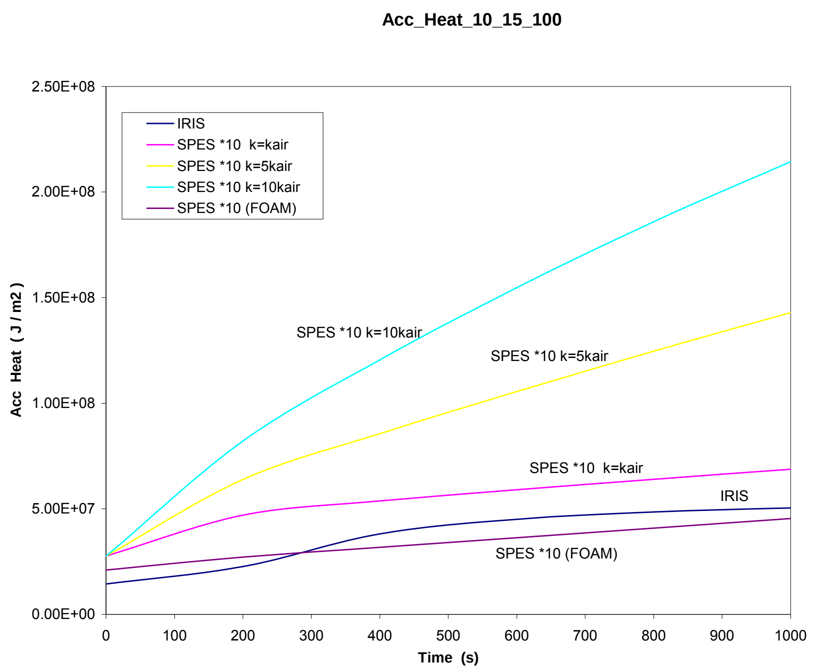


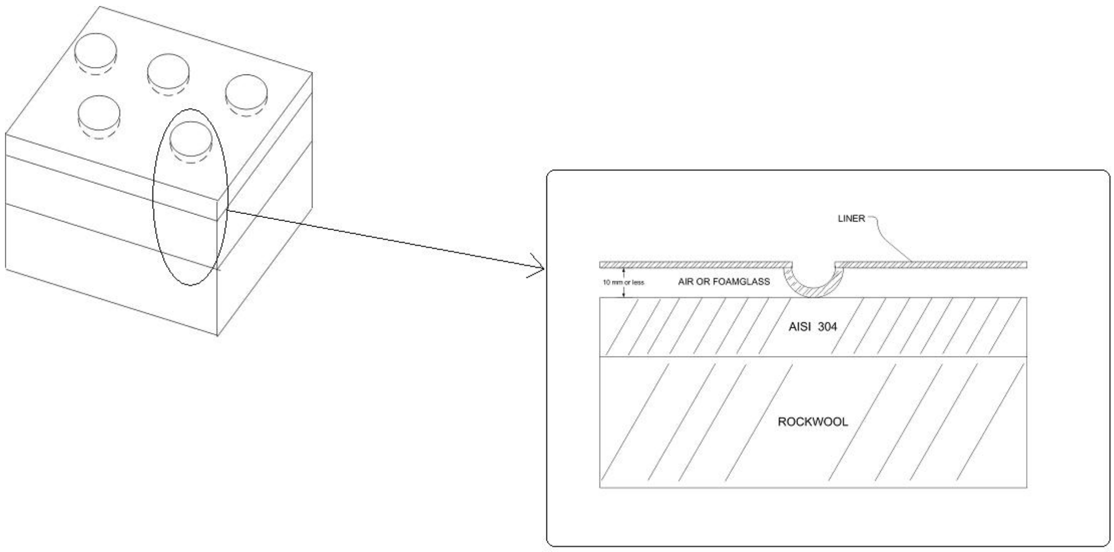
Spes3_without_insulation

file "IRIS_SPES3_Conf Call Minutes #106 Att 3 Air_Foamglass_Insulation_Spes-3.doc

Air_Foamglass_Insulation_Spes3

SPES-3 Dry-well		IRIS CONTAINMENT	
MATERIAL	***THICKNESS***	***MATERIAL***	***THICKNESS***
INSULATION	10 mm	CARBON STEEL	44 mm
AIR k=0.04 W/m K			
*AIR k=5*0.04 W/m K*			
*AIR k=10*0.04 W/m K*			
FOAMGLASS @ 10 C 0.04 W/m K			
AISI 304 k = 17.95 *W/m K*	15 mm		
ROCKWOOL k = 0.0705 *W/m K*	100 mm		
INITIAL TEMPERATURE = 20 C		***INITIAL TEMPERATURE = 48.9 C***	





Air_Foamglass_Insulation_Spes3

file "IRIS_SPES3_Conf Call Minutes #106 Att 4 LGMS DVI flow.pdf

Storrick, Gary D.

From: Roberta Ferri [ferri@siet.it]
Sent: Friday, July 10, 2009 6:28
To: Davor Grgic
Cc: Storrick, Gary D.; Cinzia Congiu; Andrea Achilli; Fosco Bianchi; greco@siet.it; Gustavo Cattadori; Dzodzo, Milorad B.
Subject: RC to DVI line question

Dear Davor,
going-on with the comparison between SPES3 and IRIS, I've found a different behaviour of the LGMS injection: in SPES3, injection is stronger than IRIS in the first phase (probably due to less pressure drops in the line to be solved by reducing the orifice hole), but later it suddenly decreases when the RC level reaches the DVI connection and a large amount of water enters the DVI so limiting the LGMS injection. In IRIS, the LGMS injection remains about constant until they are empty because such water transfer from RC to DVI does not occur when the RC level reaches the threshold and I don't undestand why. Moreover, in IRIS such transfer starts around 18000 s with very little values.
I open the RC to DVI valves together with the LGMS valves. Is it correct or such valves must be opened later?
Surely I need to insert an orifice also on the RC to DVI line to limit the mass flow. I've a 3/8" Sch. 40 pipe (12.5 mm Din), but maybe it's too large.

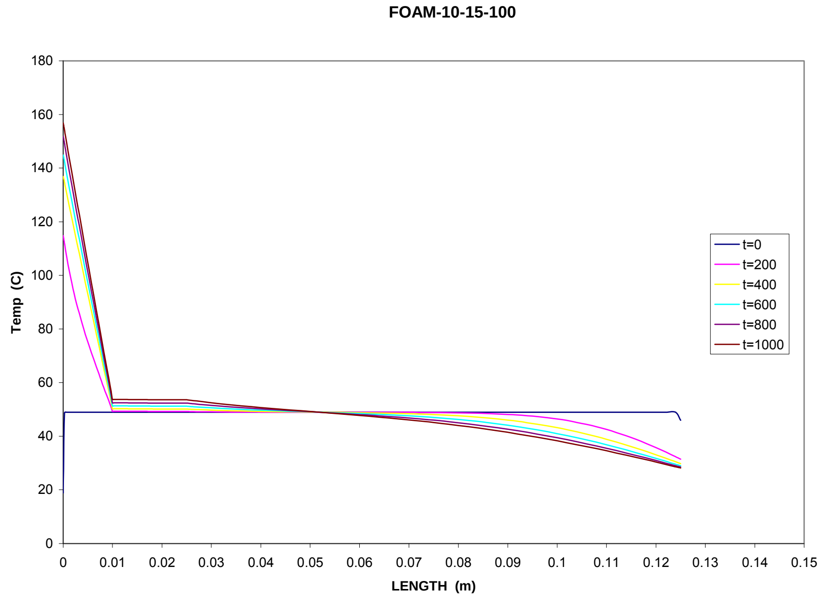
Thank you and best regards,
Roberta

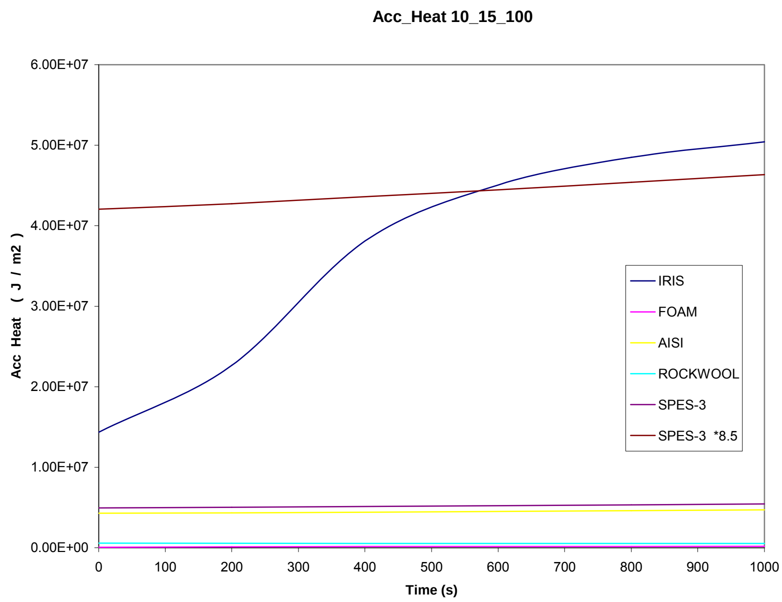
A.6 Attachments to conf-call #107

file "IRIS_SPES3_Conf Call Minutes #107 Att 1 Different_insulation_2.doc

DIFFERENT_INSULATION_2
CASE1_FOAMGLASS

SPES-3 Dry-well		IRIS CONTAINMENT	
MATERIAL	***THICKNESS***	***MATERIAL***	***THICKNESS***
FOAMGLASS	10 mm	CARBON STEEL	44 mm
AISI 304	15 mm		
ROCKWOOL	100 mm		
INITIAL TEMPERATURE 48.9 C		***INITIAL TEMPERATURE 48.9 C***	
BOUNDARY CONDITION ON RIGHT: Tair=25 h=10 W/m2K		***BOUNDARY CONDITION ON RIGHT: Tair=35 h=10 W/m2K***	

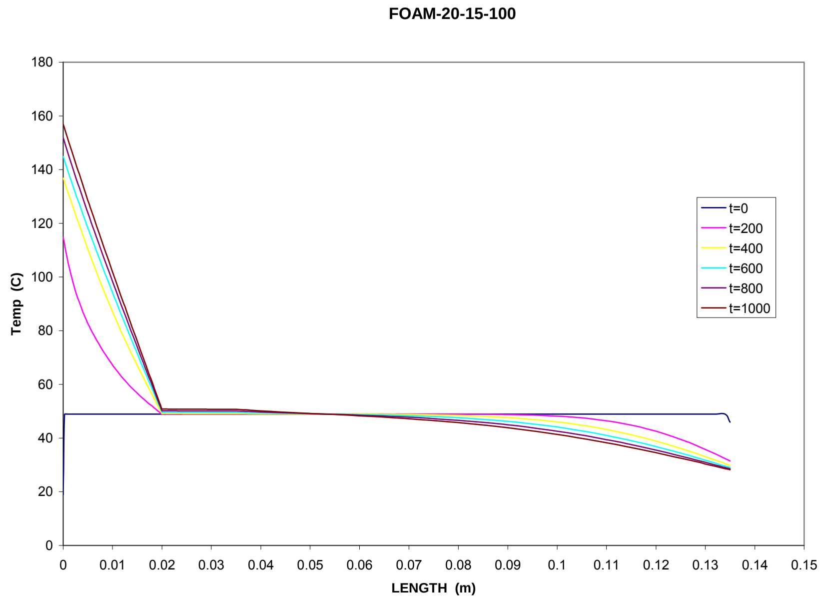


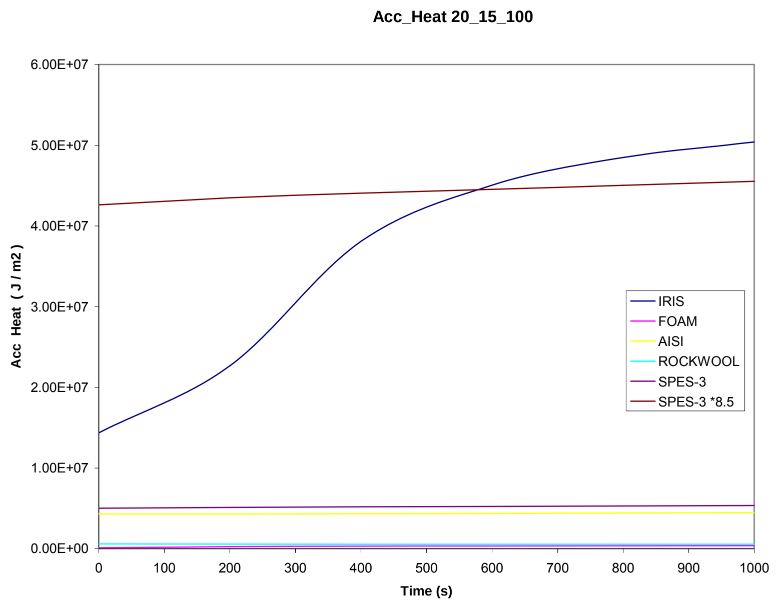


Different_insulation_2

CASE2_FOAMGLASS

SPES-3 Dry-well		IRIS CONTAINMENT	
MATERIAL	***THICKNESS***	***MATERIAL***	***THICKNESS***
FOAMGLASS	20 mm	CARBON STEEL	44 mm
AISI 304	15 mm		
ROCKWOOL	100 mm		
INITIAL TEMPERATURE 48.9 C		***INITIAL TEMPERATURE 48.9 C***	
BOUNDARY CONDITION ON RIGHT: Tair=25 h=10 W/m2K		***BOUNDARY CONDITION ON RIGHT: Tair=35 h=10 W/m2K***	

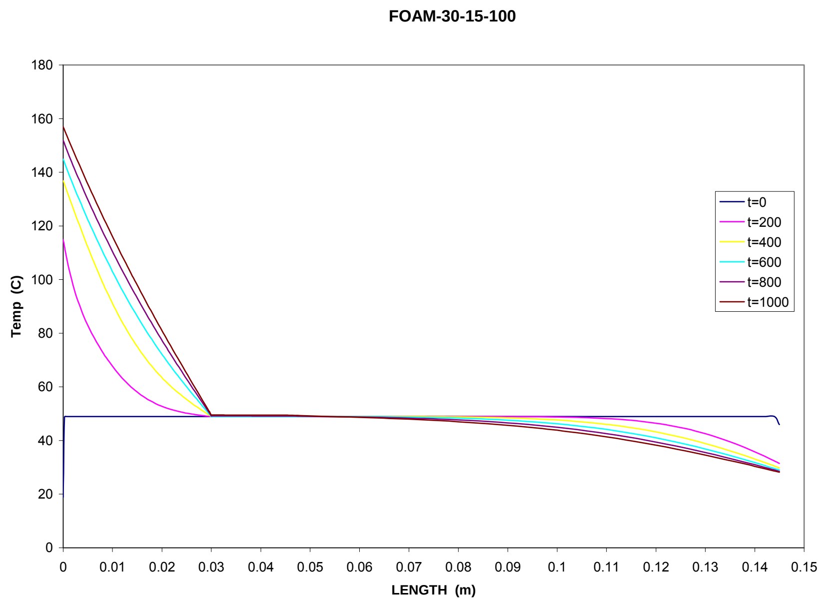


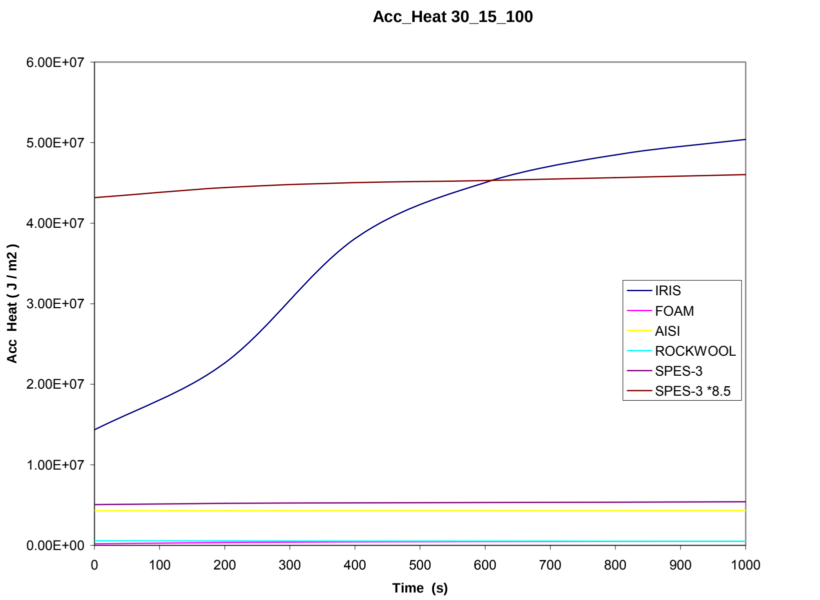


Different_insulation_2

CASE3_FOAMGLASS

SPES-3 Dry-well		IRIS CONTAINMENT	
MATERIAL	***THICKNESS***	***MATERIAL***	***THICKNESS***
FOAMGLASS	30 mm	CARBON STEEL	44 mm
AISI 304	15 mm		
ROCKWOOL	100 mm		
INITIAL TEMPERATURE 48.9 C		***INITIAL TEMPERATURE 48.9 C***	
BOUNDARY CONDITION ON RIGHT: Tair=25 h=10 W/m2K		***BOUNDARY CONDITION ON RIGHT: Tair=35 h=10 W/m2K***	

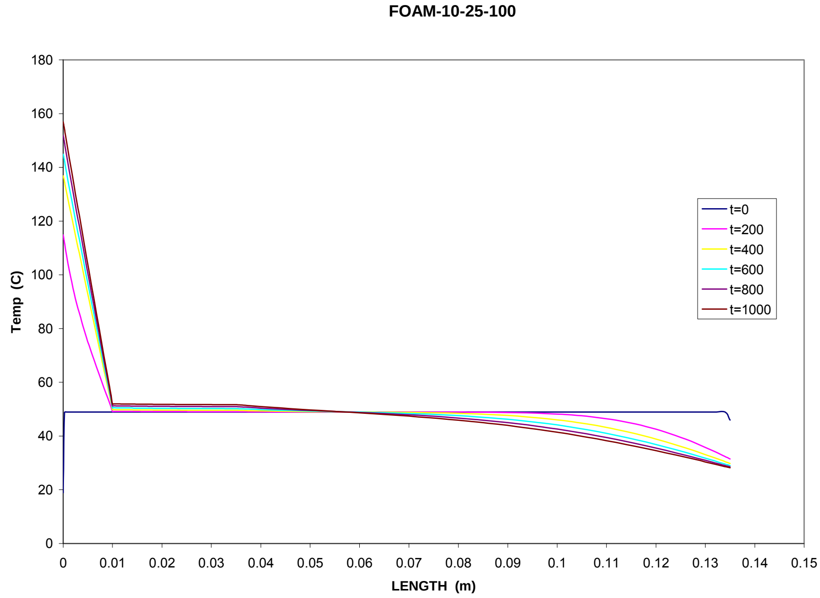


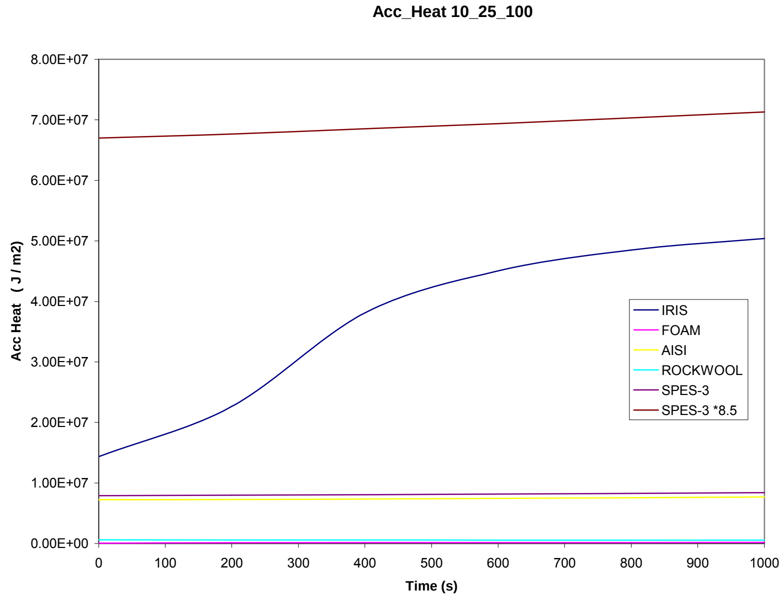


Different_insulation_2

CASE4_FOAMGLASS

SPES-3 Dry-well		IRIS CONTAINMENT	
MATERIAL	***THICKNESS***	***MATERIAL***	***THICKNESS***
FOAMGLASS	10 mm	CARBON STEEL	44 mm
AISI 304	25 mm		
ROCKWOOL	100 mm		
INITIAL TEMPERATURE 48.9 C		***INITIAL TEMPERATURE 48.9 C***	
BOUNDARY CONDITION ON RIGHT: Tair=25 h=10 W/m2K		***BOUNDARY CONDITION ON RIGHT: Tair=35 h=10 W/m2K***	

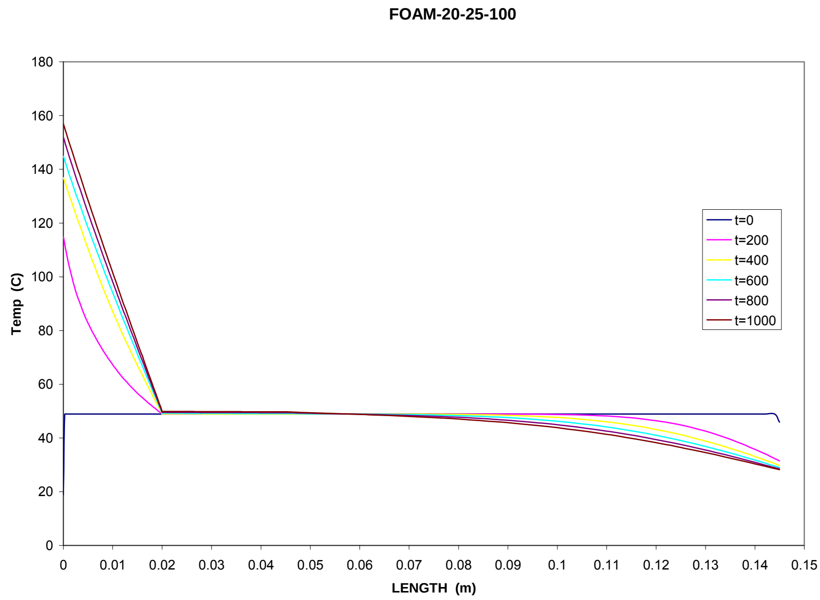


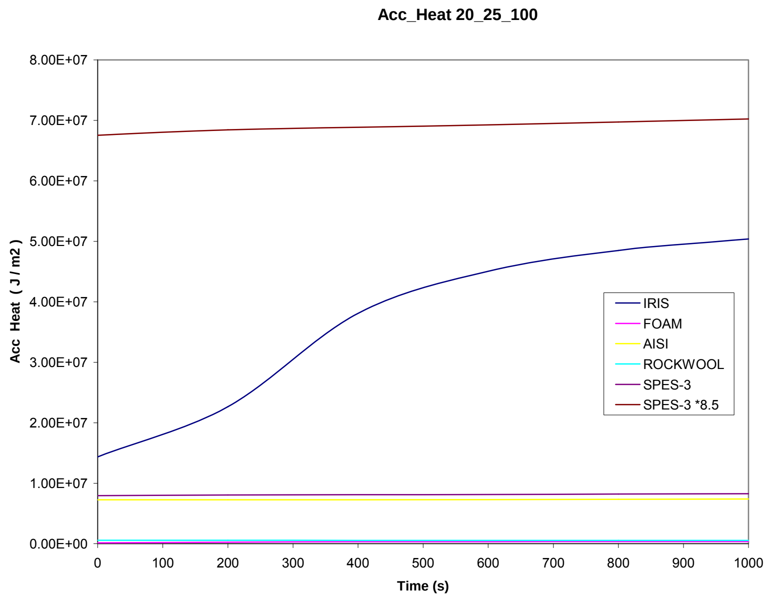


Different_insulation_2

CASE5_FOAMGLASS

SPES-3 Dry-well		IRIS CONTAINMENT	
MATERIAL	***THICKNESS***	***MATERIAL***	***THICKNESS***
FOAMGLASS	20 mm	CARBON STEEL	44 mm
AISI 304	25 mm		
ROCKWOOL	100 mm		
INITIAL TEMPERATURE 48.9 C		***INITIAL TEMPERATURE 48.9 C***	
BOUNDARY CONDITION ON RIGHT: Tair=25 h=10 W/m2K		***BOUNDARY CONDITION ON RIGHT: Tair=35 h=10 W/m2K***	

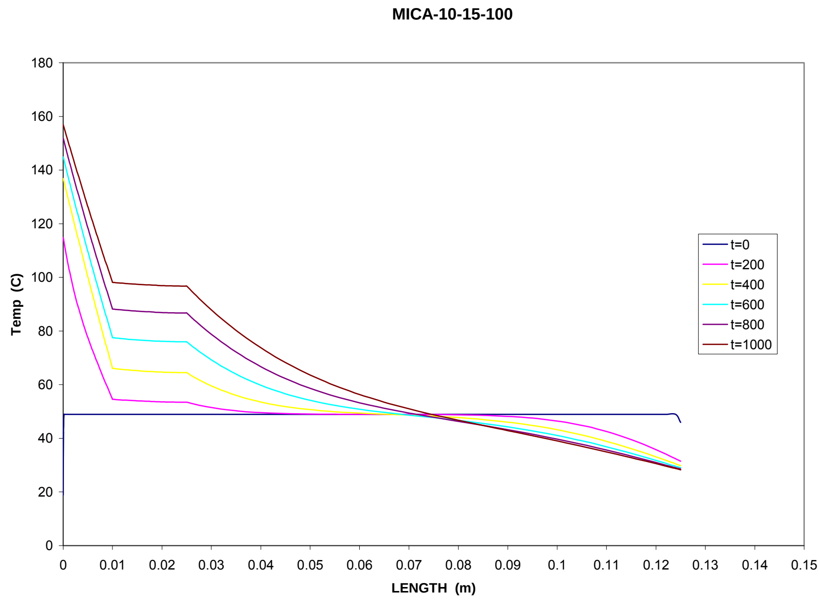


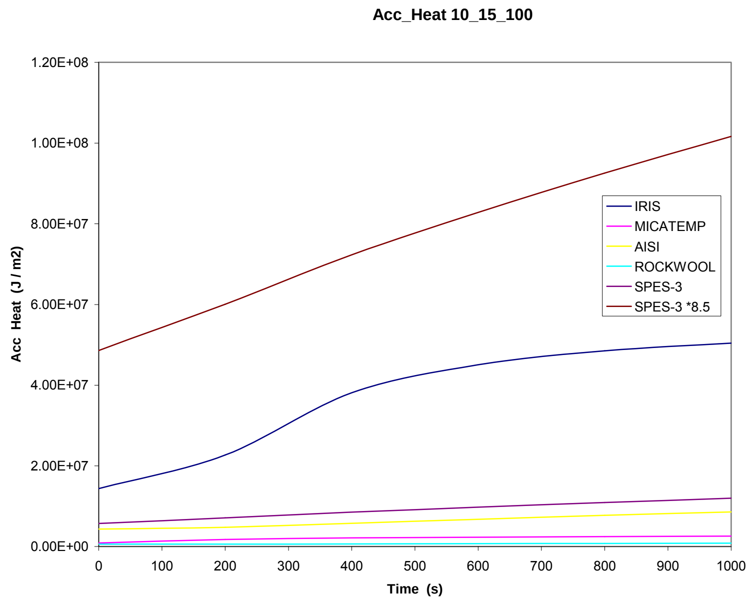


Different_insulation_2

CASE1_MICATEMP

SPES-3 Dry-well		IRIS CONTAINMENT	
MATERIAL	***THICKNESS***	***MATERIAL***	***THICKNESS***
MICATEMP	10 mm	CARBON STEEL	44 mm
AISI 304	15 mm		
ROCKWOOL	100 mm		
INITIAL TEMPERATURE 48.9 C		***INITIAL TEMPERATURE 48.9 C***	
BOUNDARY CONDITION ON RIGHT: Tair=25 h=10 W/m2K		***BOUNDARY CONDITION ON RIGHT: Tair=35 h=10 W/m2K***	

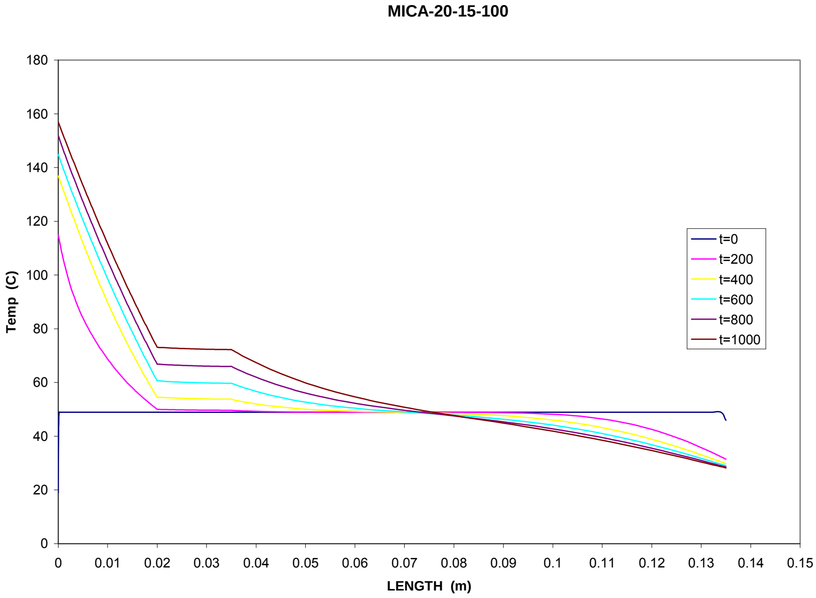


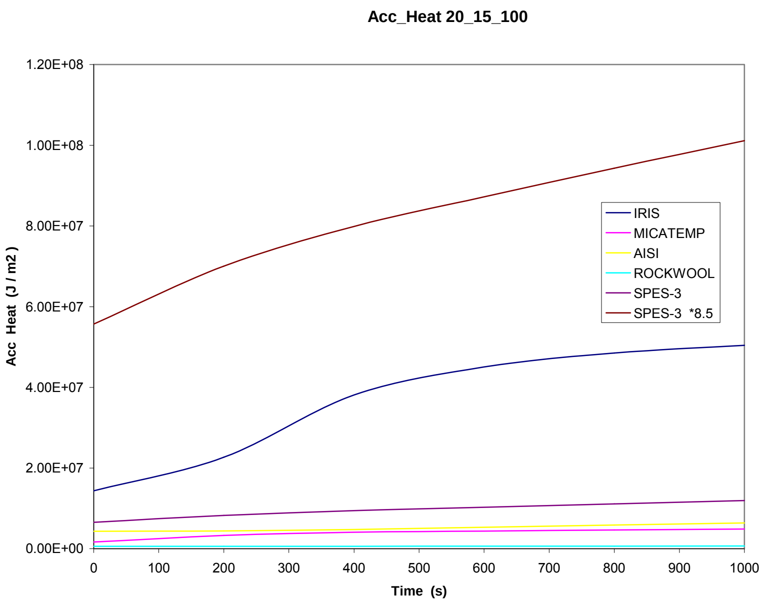


Different_insulation_2

CASE2_MICATEMP

SPES-3 Dry-well		IRIS CONTAINMENT	
MATERIAL	***THICKNESS***	***MATERIAL***	***THICKNESS***
MICATEMP	20 mm	CARBON STEEL	44 mm
AISI 304	15 mm		
ROCKWOOL	100 mm		
INITIAL TEMPERATURE 48.9 C		***INITIAL TEMPERATURE 48.9 C***	
BOUNDARY CONDITION ON RIGHT: Tair=25 h=10 W/m2K		***BOUNDARY CONDITION ON RIGHT: Tair=35 h=10 W/m2K***	

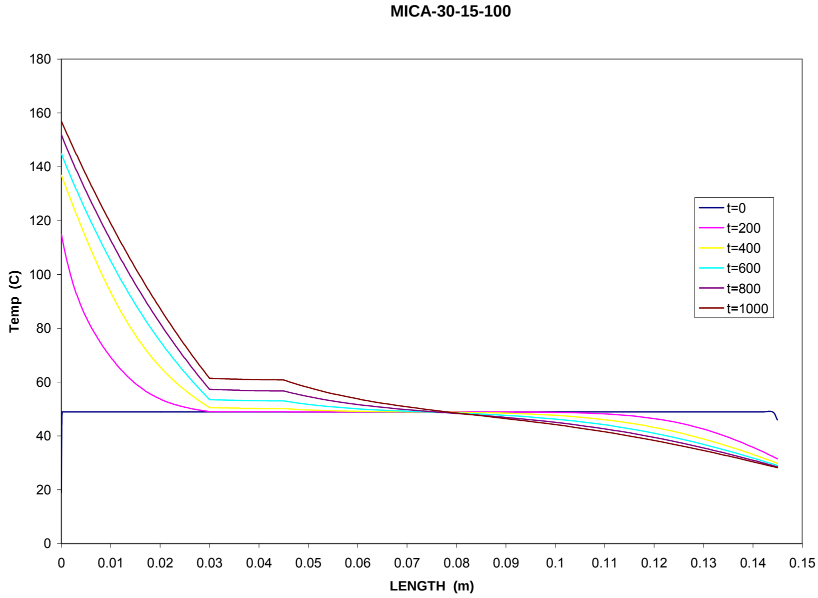


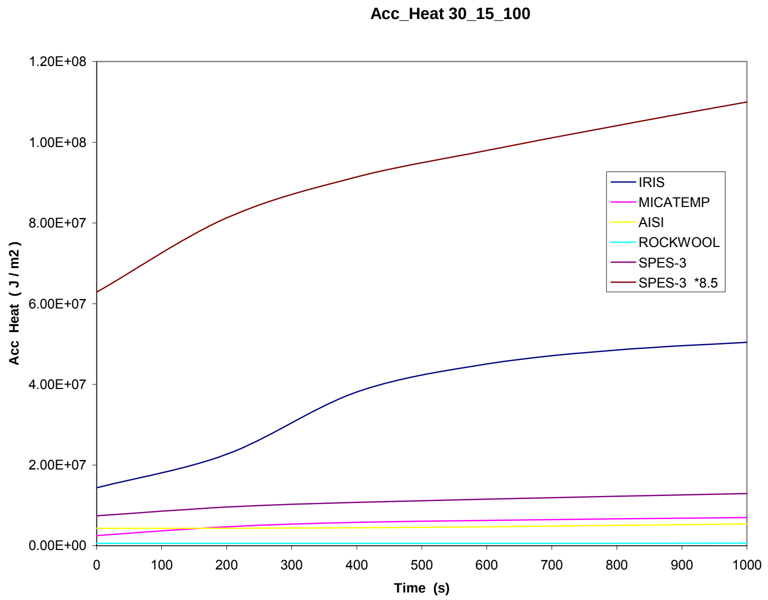


Different_insulation_2

CASE3_MICATEMP

SPES-3 Dry-well		IRIS CONTAINMENT	
MATERIAL	***THICKNESS***	***MATERIAL***	***THICKNESS***
MICATEMP	30 mm	CARBON STEEL	44 mm
AISI 304	15 mm		
ROCKWOOL	100 mm		
INITIAL TEMPERATURE 48.9 C		***INITIAL TEMPERATURE 48.9 C***	
BOUNDARY CONDITION ON RIGHT: Tair=25 h=10 W/m2K		***BOUNDARY CONDITION ON RIGHT: Tair=35 h=10 W/m2K***	

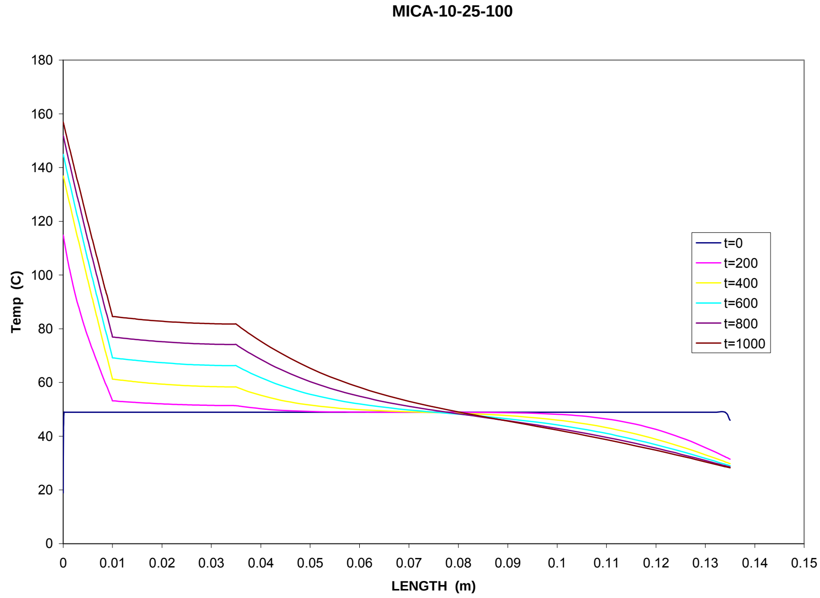


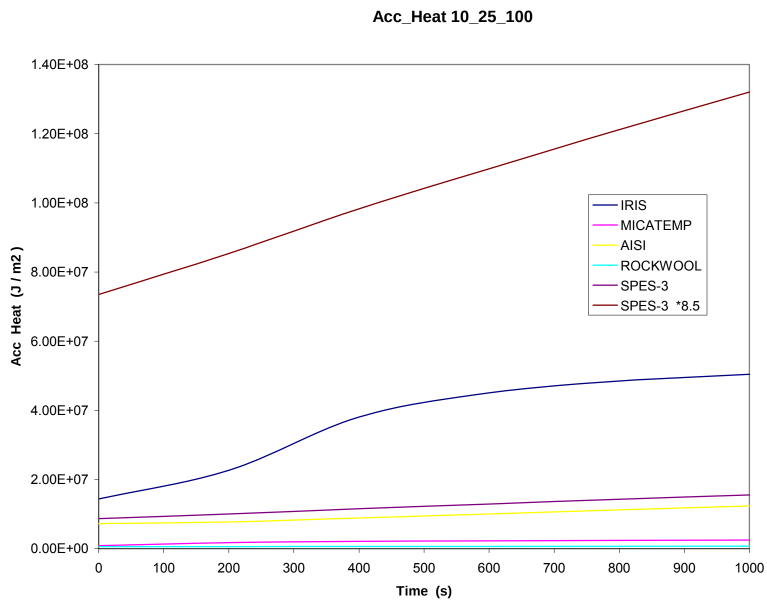


Different_insulation_2

CASE4_MICATEMP

SPES-3 Dry-well		IRIS CONTAINMENT	
MATERIAL	***THICKNESS***	***MATERIAL***	***THICKNESS***
MICATEMP	10 mm	CARBON STEEL	44 mm
AISI 304	25 mm		
ROCKWOOL	100 mm		
INITIAL TEMPERATURE 48.9 C		***INITIAL TEMPERATURE 48.9 C***	
BOUNDARY CONDITION ON RIGHT: Tair=25 h=10 W/m2K		***BOUNDARY CONDITION ON RIGHT: Tair=35 h=10 W/m2K***	



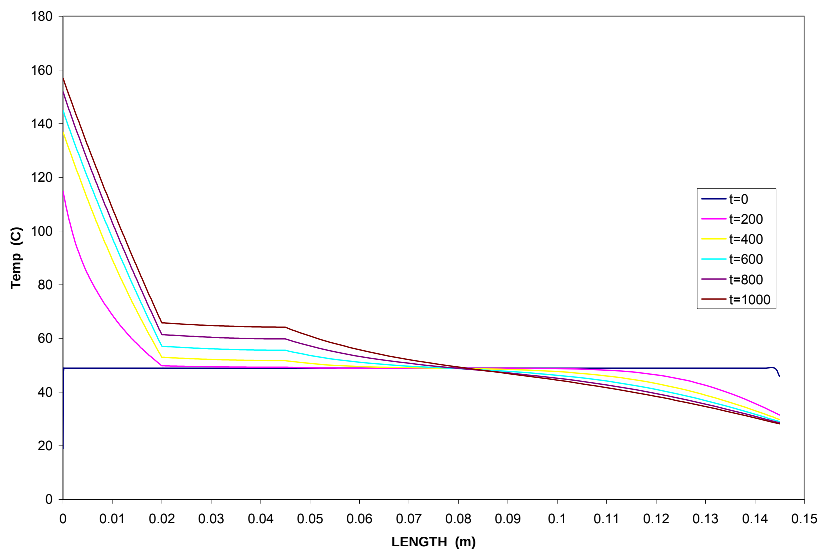


Different_insulation_2

CASE5_MICATEMP

SPES-3 Dry-well		IRIS CONTAINMENT	
MATERIAL	***THICKNESS***	***MATERIAL***	***THICKNESS***
MICATEMP	20 mm	CARBON STEEL	44 mm
AISI 304	25 mm		
ROCKWOOL	100 mm		
INITIAL TEMPERATURE 48.9 C		***INITIAL TEMPERATURE 48.9 C***	
BOUNDARY CONDITION ON RIGHT: Tair=25 h=10 W/m2K		***BOUNDARY CONDITION ON RIGHT: Tair=35 h=10 W/m2K***	

MICA-20-25-100



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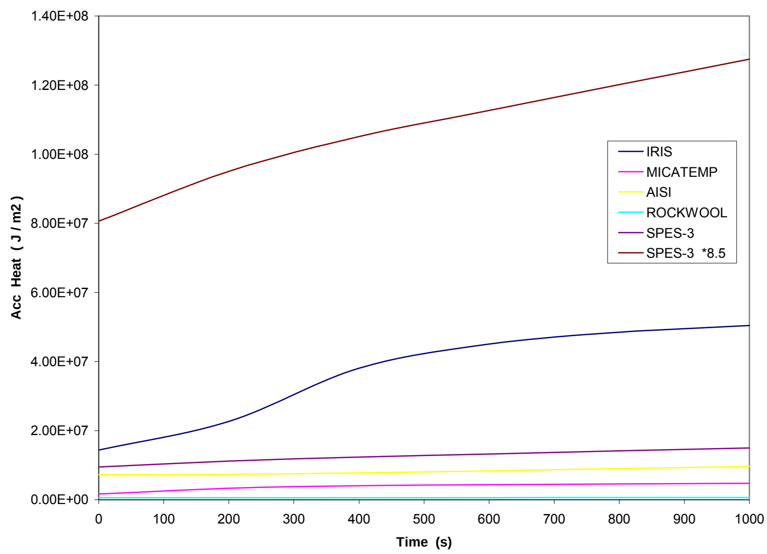
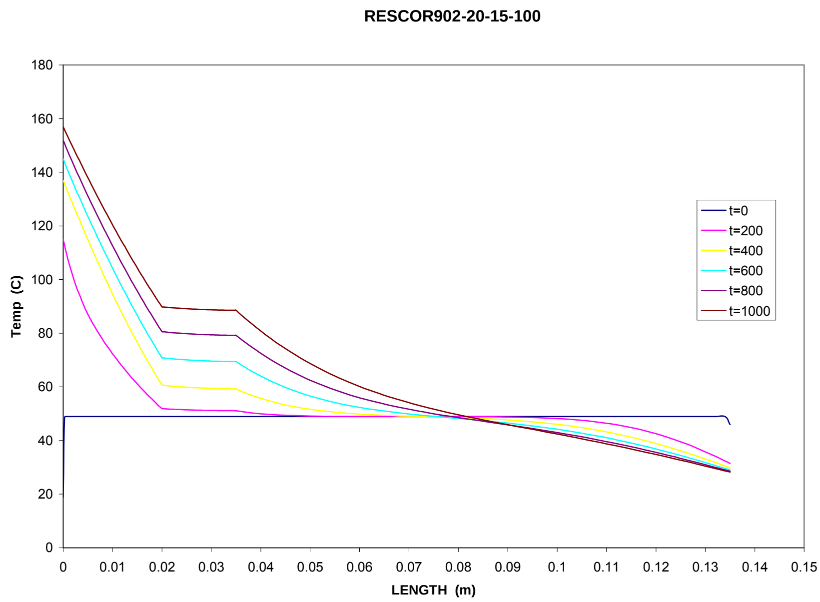
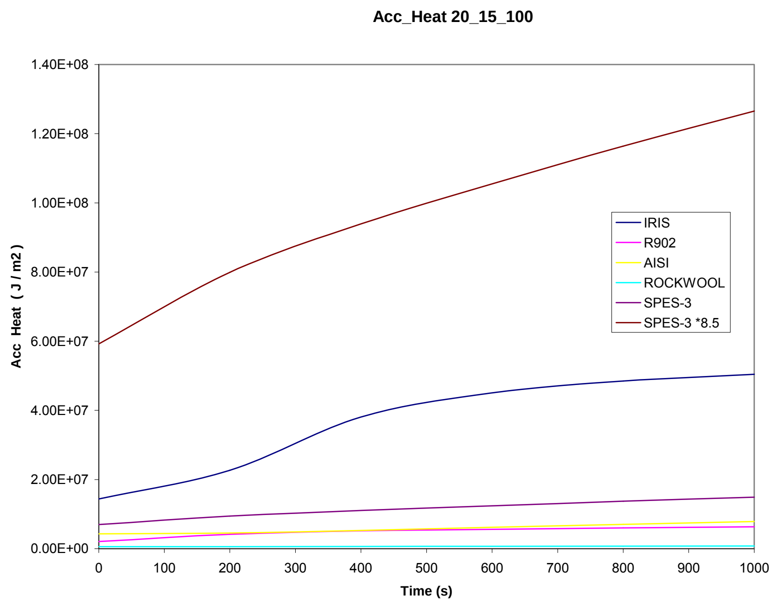


Different_insulation_2

CASE2_RESCOR902

SPES-3 Dry-well		IRIS CONTAINMENT	
MATERIAL	***THICKNESS***	***MATERIAL***	***THICKNESS***
RESCOR902	20 mm	CARBON STEEL	44 mm
AISI 304	15 mm		
ROCKWOOL	100 mm		
INITIAL TEMPERATURE 48.9 C		***INITIAL TEMPERATURE 48.9 C***	
BOUNDARY CONDITION ON RIGHT: Tair=25 h=10 W/m2K		***BOUNDARY CONDITION ON RIGHT: Tair=35 h=10 W/m2K***	

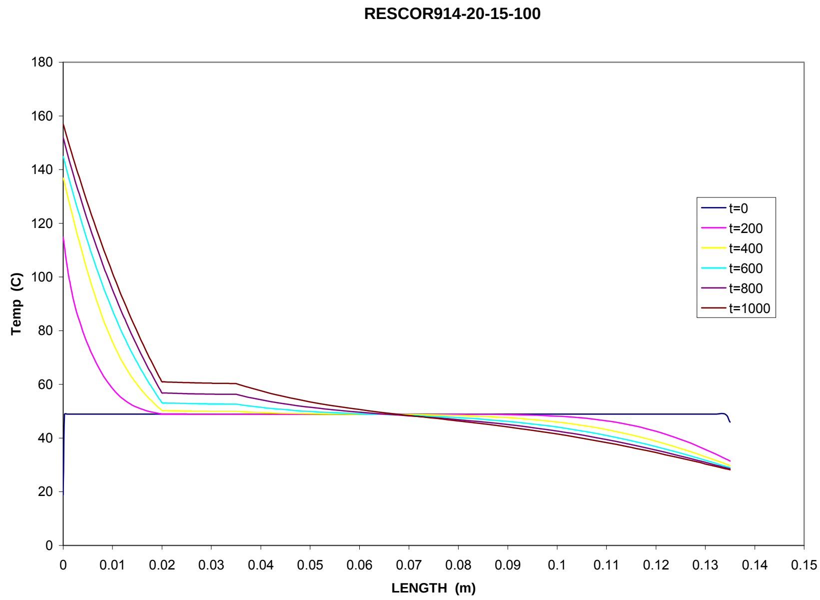


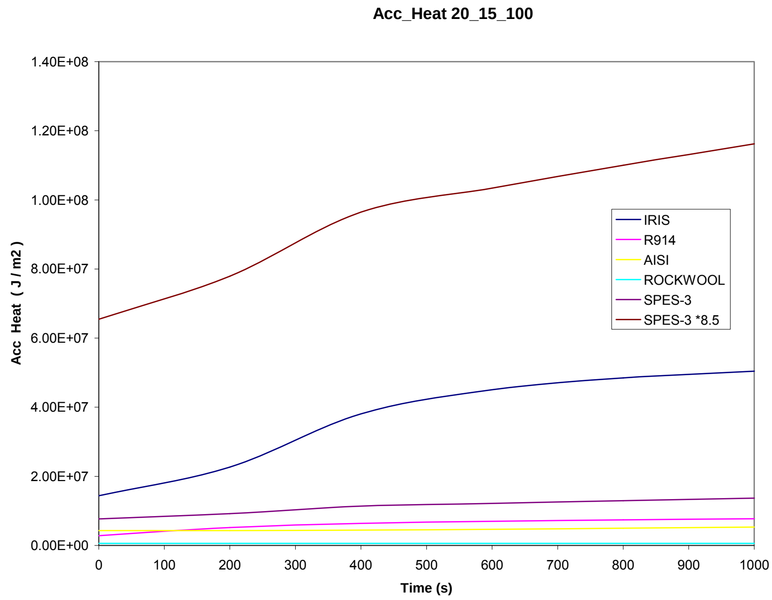


Different_insulation_2

CASE2_RESCOR914

SPES-3 Dry-well		IRIS CONTAINMENT	
MATERIAL	***THICKNESS***	***MATERIAL***	***THICKNESS***
RESCOR914	20 mm	CARBON STEEL	44 mm
AISI 304	15 mm		
ROCKWOOL	100 mm		
INITIAL TEMPERATURE 48.9 C		***INITIAL TEMPERATURE 48.9 C***	
BOUNDARY CONDITION ON RIGHT: Tair=25 h=10 W/m2K		***BOUNDARY CONDITION ON RIGHT: Tair=35 h=10 W/m2K***	



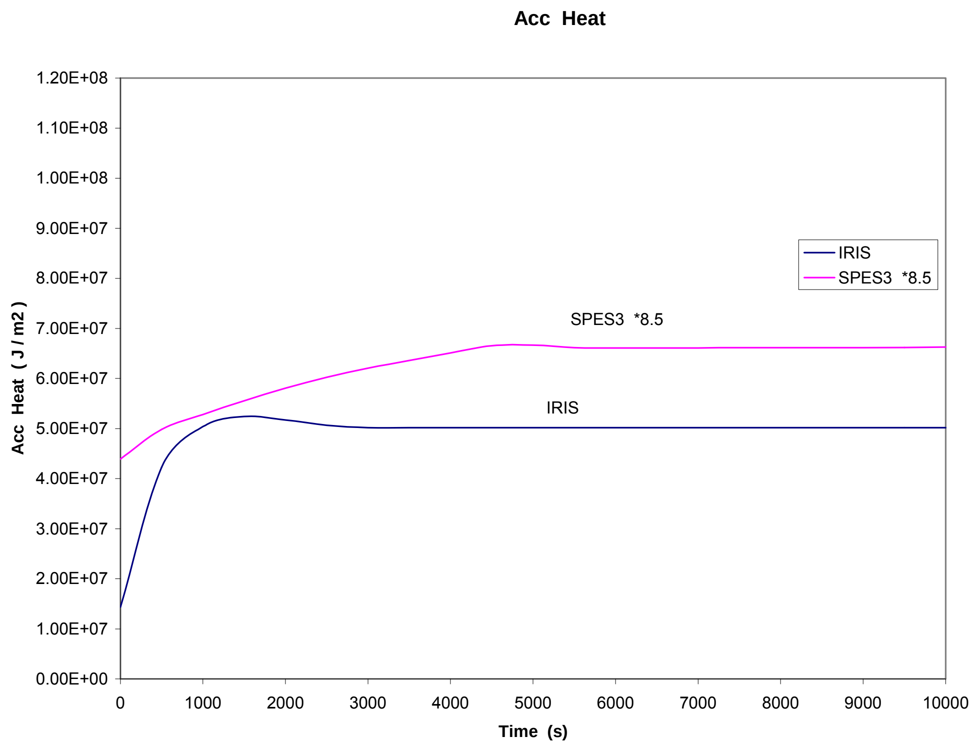


Different_insulation_2

file "IRIS_SPES3_Conf Call Minutes #107 Att 2 LINER_Foamglass_Insulation.doc

LINER_Foamglass_Insulation
CASE1_1mm

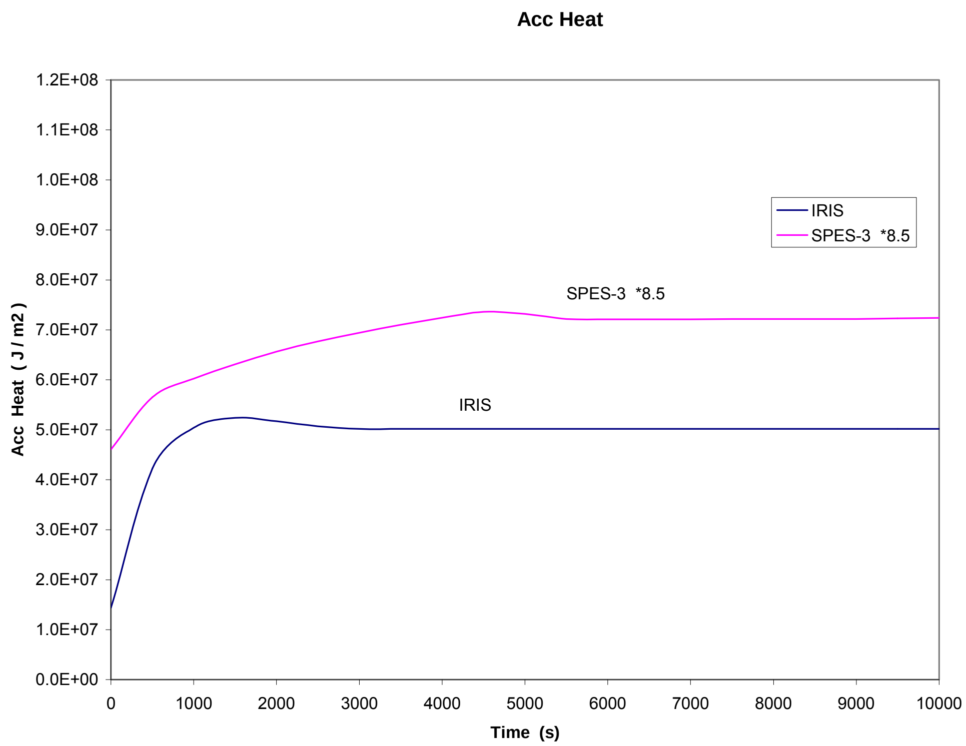
SPES-3 Dry-well		IRIS CONTAINMENT	
MATERIAL	***THICKNESS***	***MATERIAL***	***THICKNESS***
AISI 304 k = 17.95 *W/m K*	1mm	CARBON STEEL	44 mm
FOAMGLASS @ 10 C *0.04 W/m K*	10 mm		
AISI 304 k = 17.95 *W/m K*	15 mm		
ROCKWOOL k = 0.0705 *W/m K*	100 mm		
INITIAL TEMPERATURE = 48.9		***INITIAL TEMPERATURE = 48.9 C***	
BOUNDARY CONDITION RIGHT ***Tair= 25 C h =10W/ m2K***		***BOUNDARY CONDITION RIGHT*** ***Tair= 35 C h =10W/ m2K***	



LINER_Foamglass_Insulation

CASE2_2mm

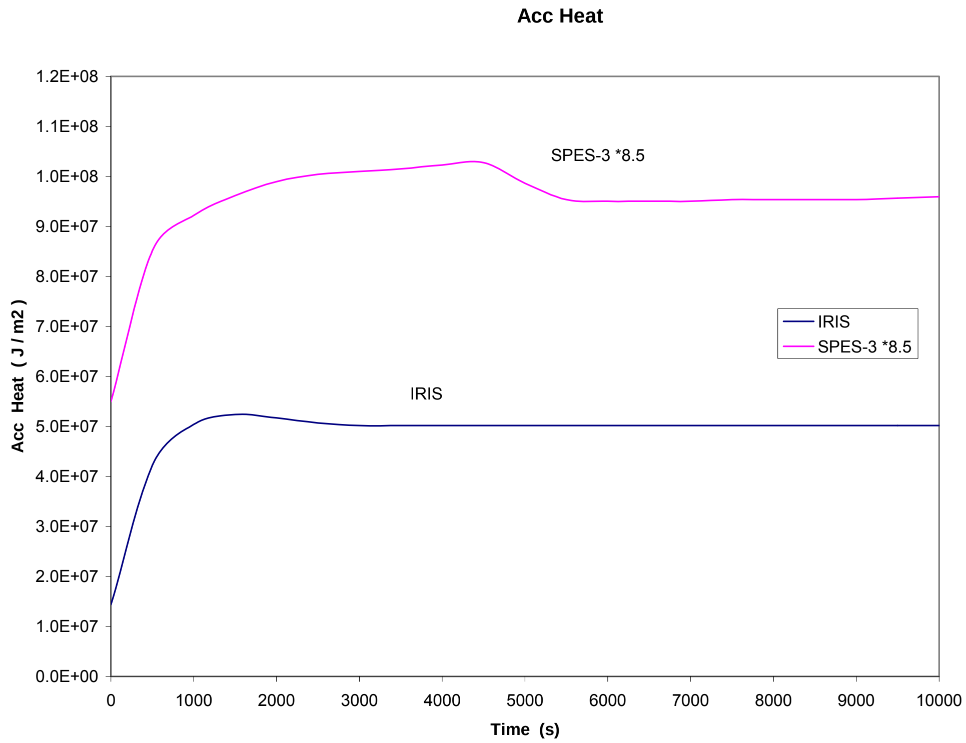
SPES-3 Dry-well		IRIS CONTAINMENT	
MATERIAL	***THICKNESS***	***MATERIAL***	***THICKNESS***
AISI 304 k = 17.95 *W/m K*	2mm	CARBON STEEL	44 mm
FOAMGLASS @ 10 C 0.04 W/m K	10 mm		
AISI 304 k = 17.95 *W/m K*	15 mm		
ROCKWOOL k = 0.0705 *W/m K*	100 mm		
INITIAL TEMPERATURE = 48.9		***INITIAL TEMPERATURE = 48.9 C***	
BOUNDARY CONDITION RIGHT Tair= 25 C h =10W/ m2K		***BOUNDARY CONDITION RIGHT Tair= 35 C h =10W/ m2K***	



LINER_Foamglass_Insulation

CASE3_6mm

SPES-3 Dry-well		IRIS CONTAINMENT	
MATERIAL	***THICKNESS***	***MATERIAL***	***THICKNESS***
AISI 304 k = 17.95 *W/m K*	6mm	CARBON STEEL	44 mm
FOAMGLASS @ 10 C *0.04 W/m K*	10 mm		
AISI 304 k = 17.95 *W/m K*	15 mm		
ROCKWOOL k = 0.0705 *W/m K*	100 mm		
INITIAL TEMPERATURE = 48.9		***INITIAL TEMPERATURE = 48.9 C***	
BOUNDARY CONDITION RIGHT ***Tair= 25 C h =10W/ m2K***		***BOUNDARY CONDITION RIGHT*** ***Tair= 35 C h =10W/ m2K***	



LINER_Foamglass_Insulation

A.7 Attachments to conf-call #108

file "IRIS_SPES3_Conf Call Minutes #108 Att 1 DWair SPES3-108.pdf

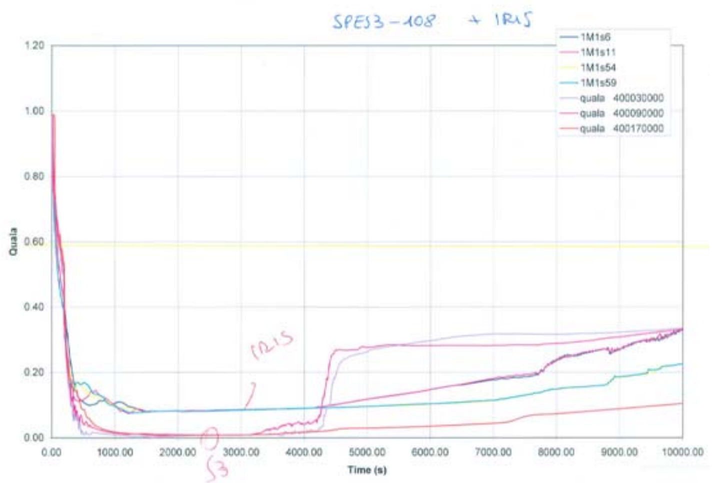


Fig.A8. 1 SPES3-108 and IRIS DW non-condensable quality

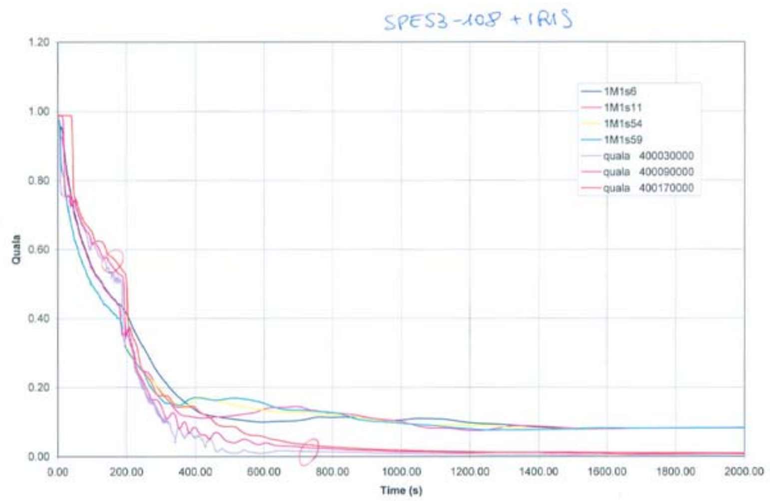


Fig.A8. 2 SPES3-108 and IRIS DW non-condensable quality (short term)

file "IRIS_SPES3_Conf Call Minutes #108 Att 2 SPES3-119-120-122-IRIS DW P.pdf

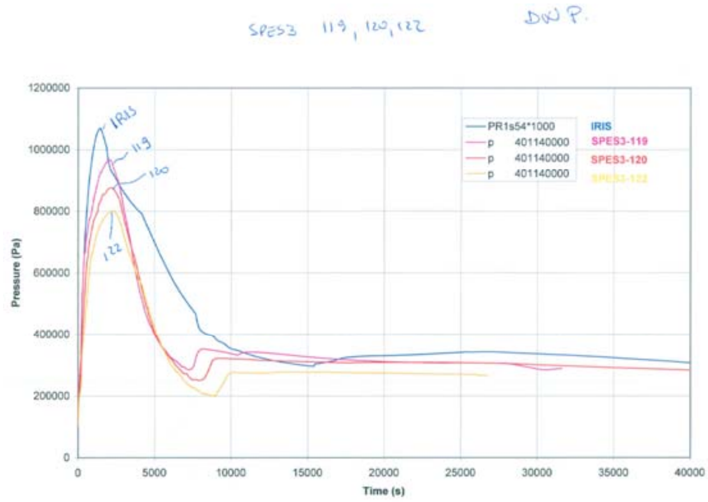


Fig.A8. 3 SPES3-119, 120, 122 and IRIS DW pressure

file "IRIS_SPES3_Conf Call Minutes #108 Att 3 SPES3-120 graphs.pdf

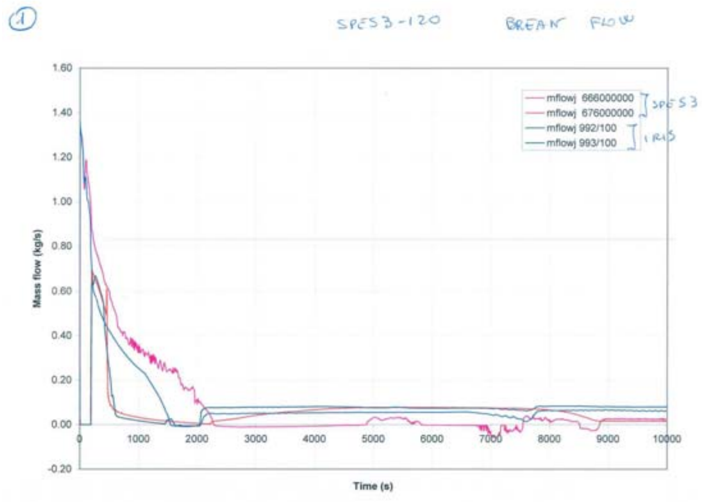


Fig.A8. 4 SPES3-120 break flow

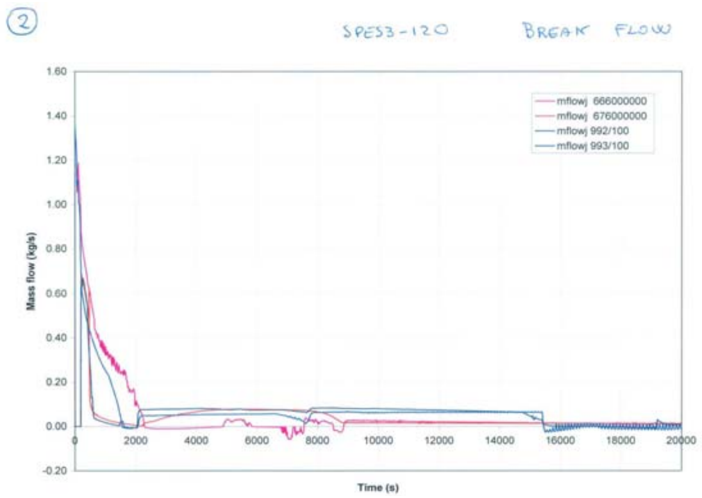


Fig.A8. 5 SPES3-120 break flow

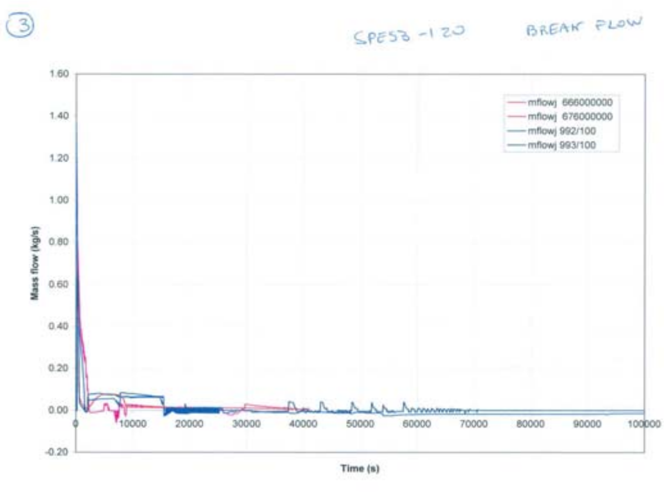


Fig.A8. 6 SPES3-120 break flow

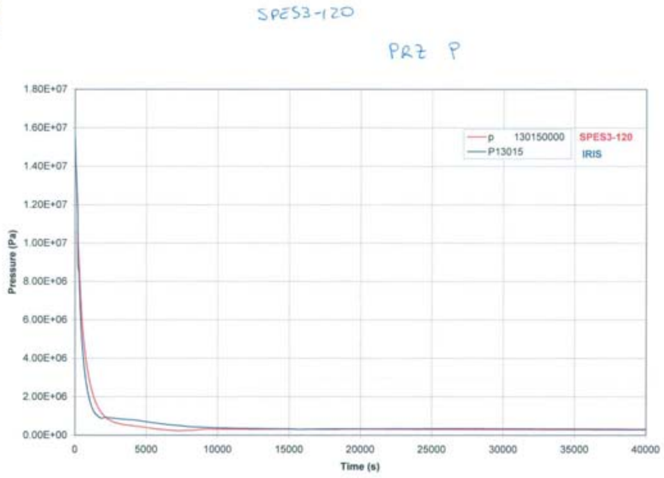


Fig.A8. 7 SPES3-120 PRZ pressure

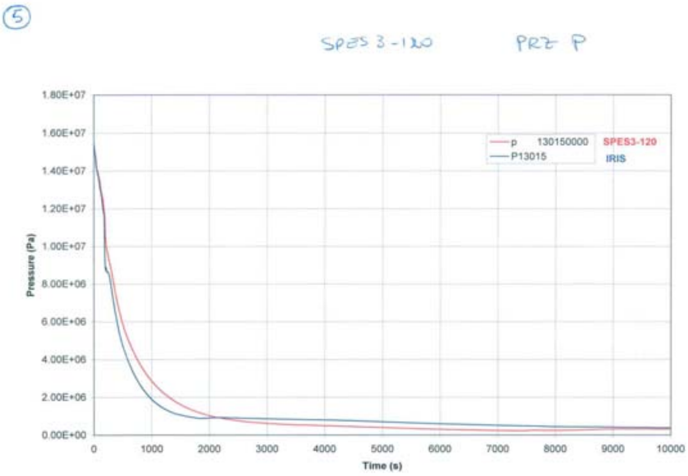


Fig.A8. 8 SPES3-120 PRZ pressure

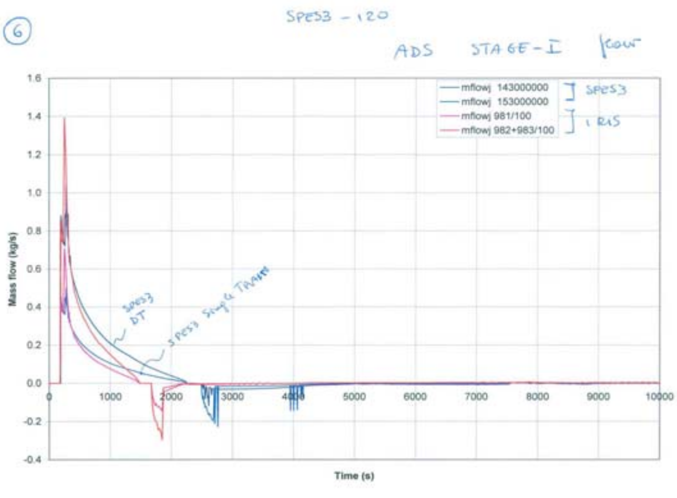


Fig.A8. 9 SPES3-120 ADS Stage-I mass flow

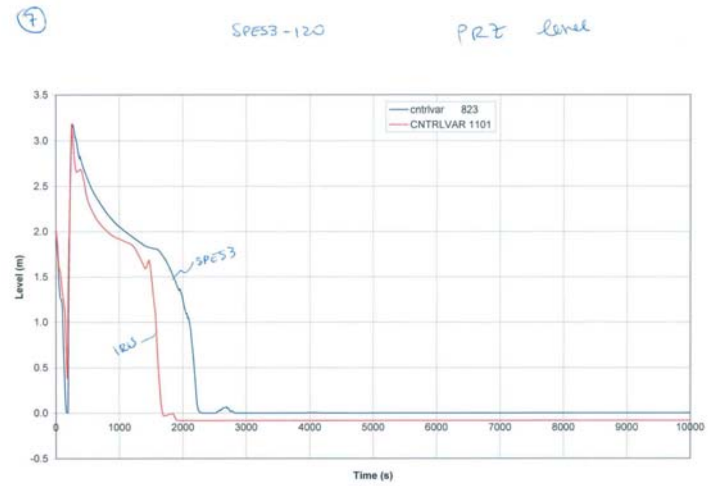


Fig.A8. 10 SPES3-120 PRZ level

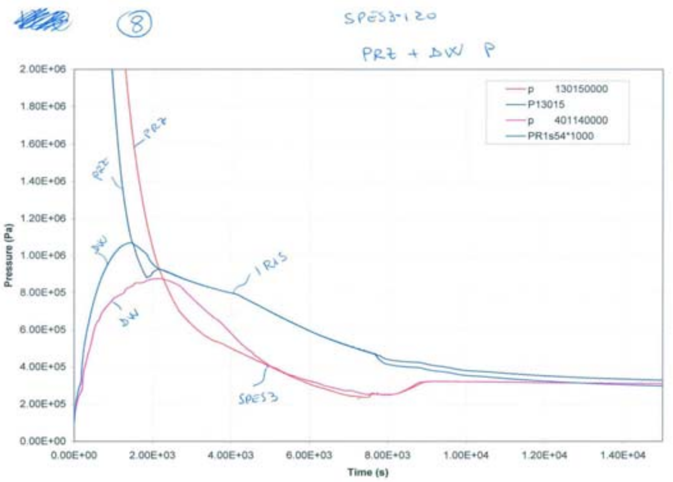


Fig.A8. 11 SPES3-120 PRZ and DW pressure

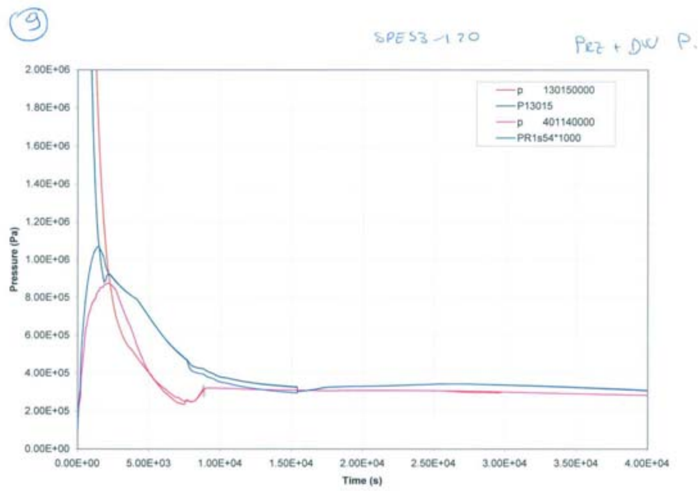


Fig.A8. 12 SPES3-120 PRZ and DW pressure

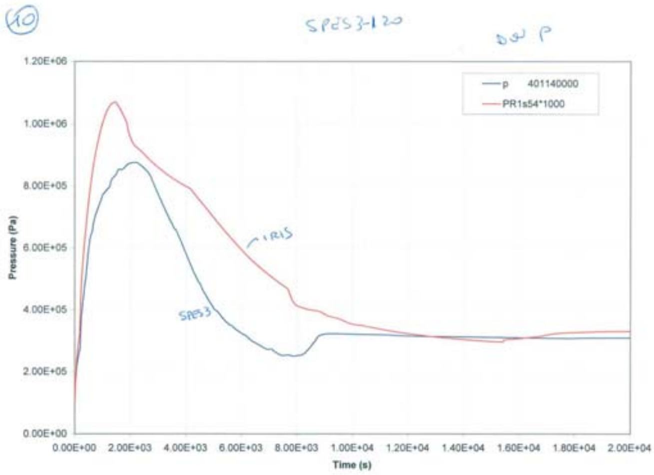


Fig.A8. 13 SPES3-120 and IRIS DW pressure

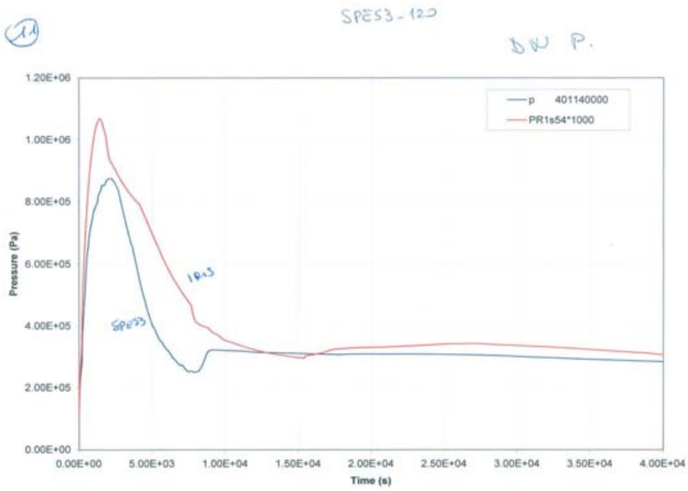


Fig.A8. 14 SPES3-120 and IRIS DW pressure

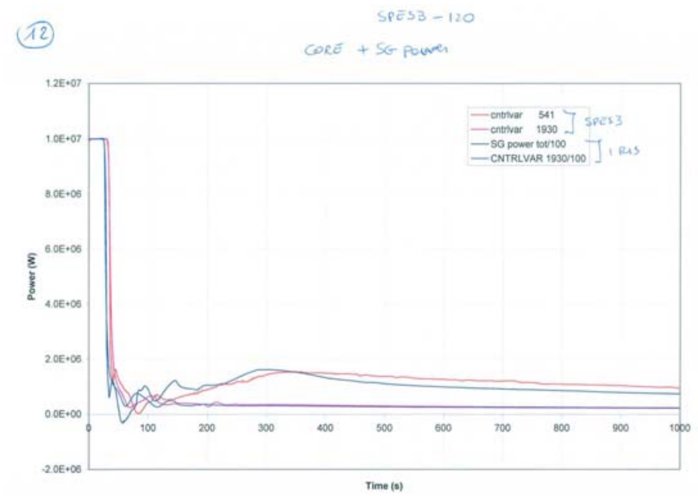


Fig.A8. 15 SPES3-120 core and SG power

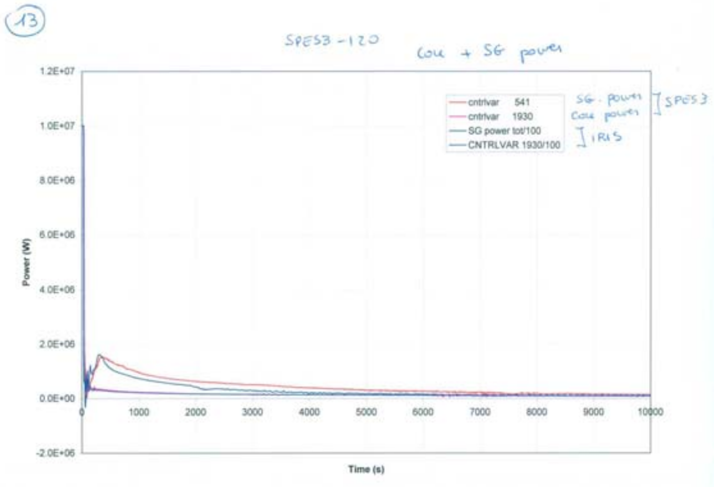


Fig.A8. 16 SPES3-120 core and SG power

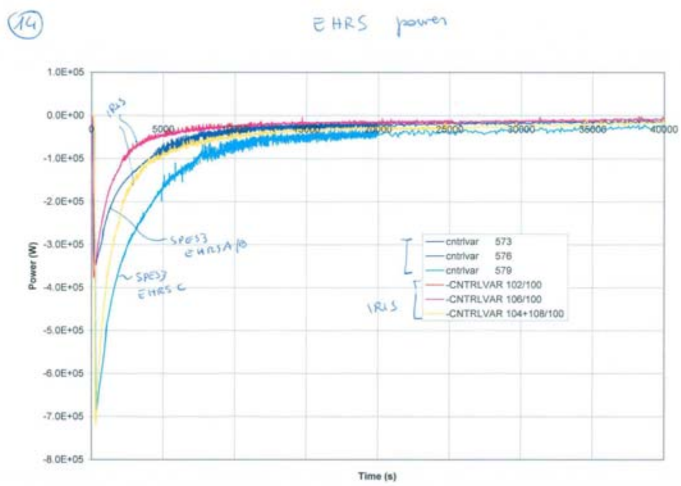


Fig.A8. 17 SPES3-120 EHRS power

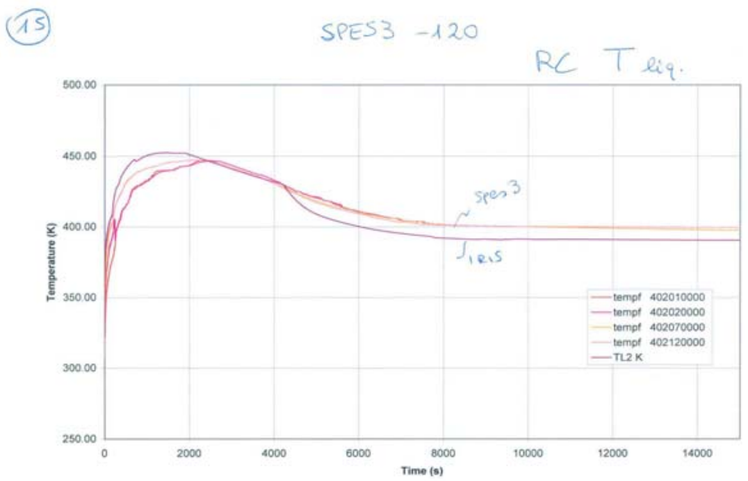


Fig.A8. 18 SPES3-120 RC liquid temperature

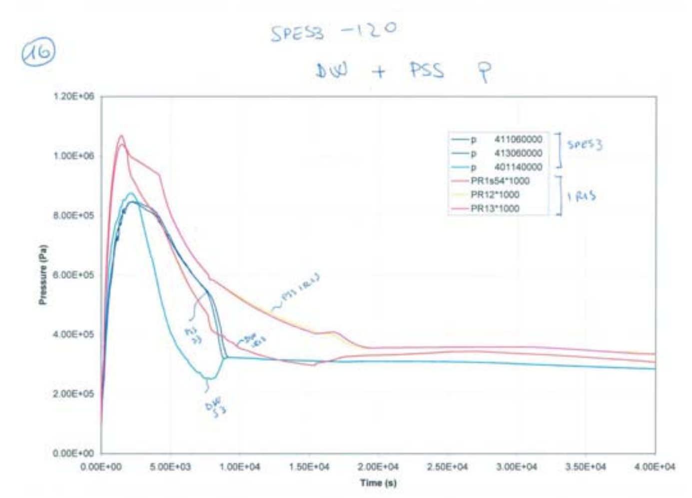


Fig.A8. 19 SPES3-120 DW and PSS pressure

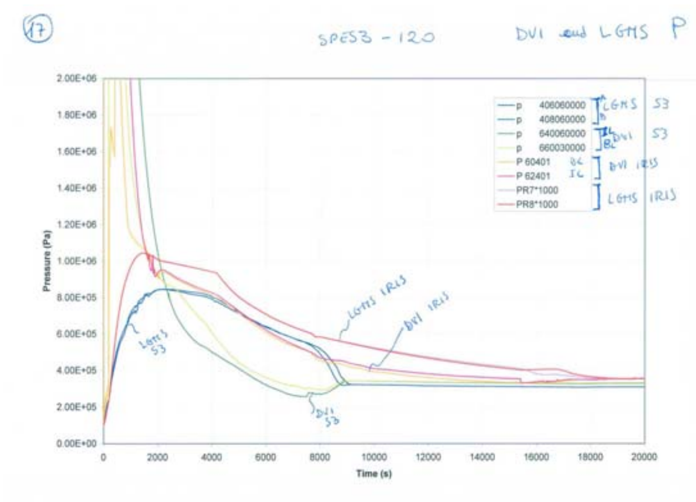


Fig.A8. 20 SPES3-120 DVI and LGMS pressure

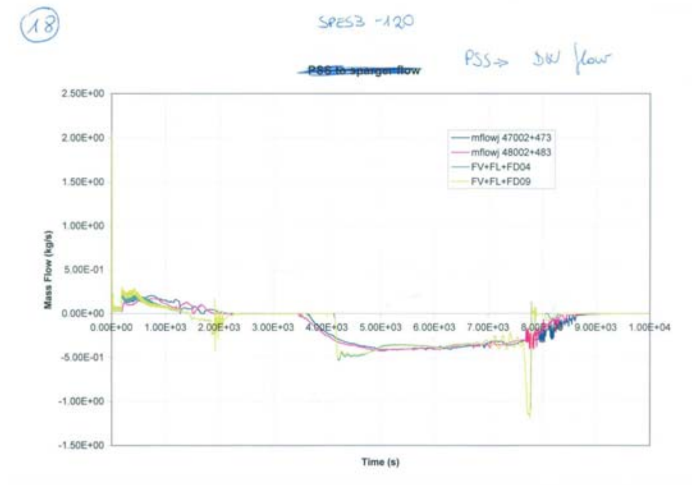


Fig.A8. 21 SPES3-120 PSS to DW flow

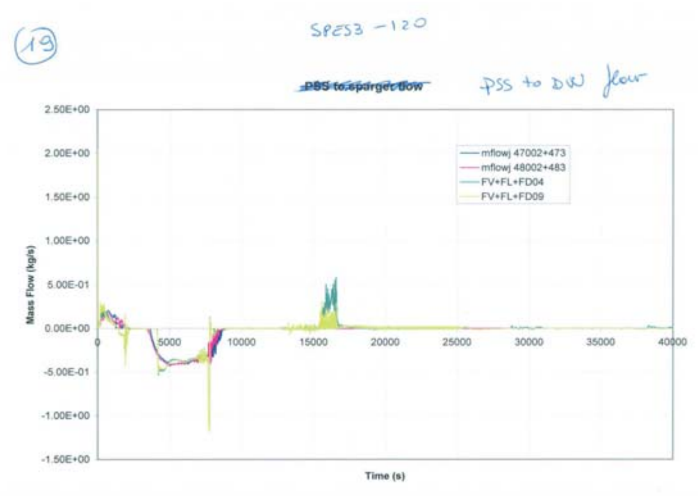


Fig.A8. 22 SPES3-120 PSS to DW flow

Fig.A8. 23 SPES3-120 PSS mass

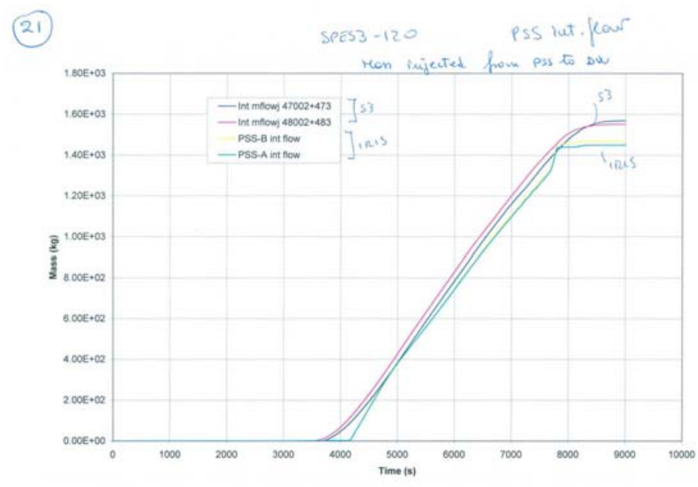


Fig.A8. 24 SPES3-120 PSS integral flow

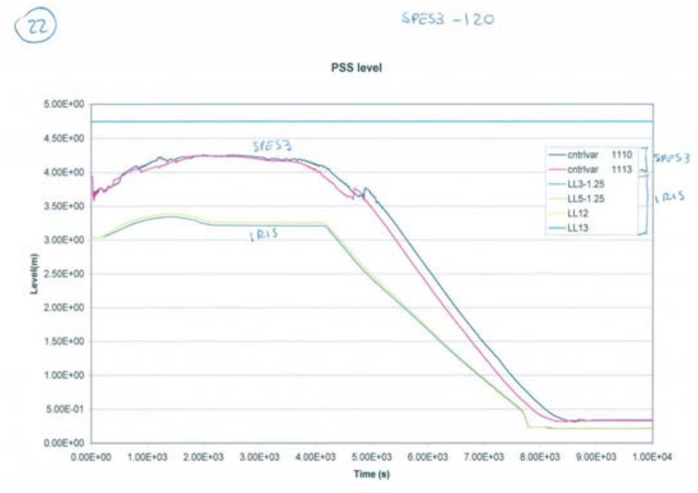


Fig.A8. 25 SPES3-120 PSS level

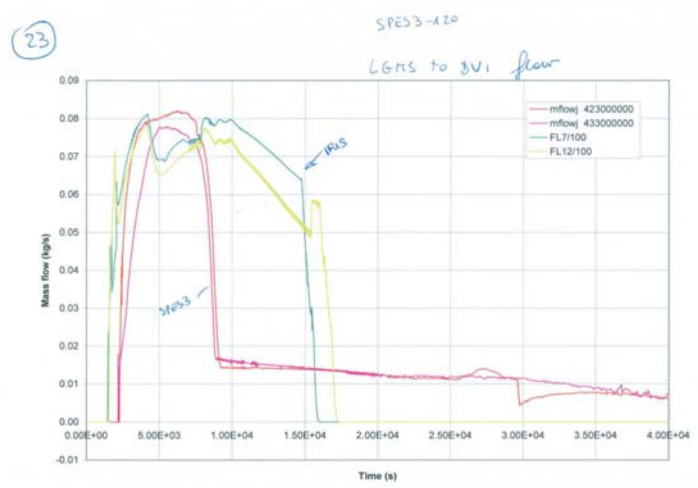


Fig.A8. 26 SPES3-120 LGMS to DVI flow

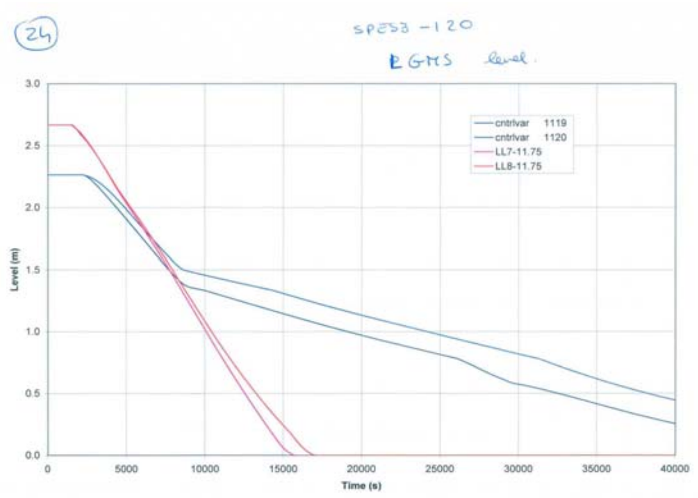


Fig.A8. 27 SPES3-120 LGMS level

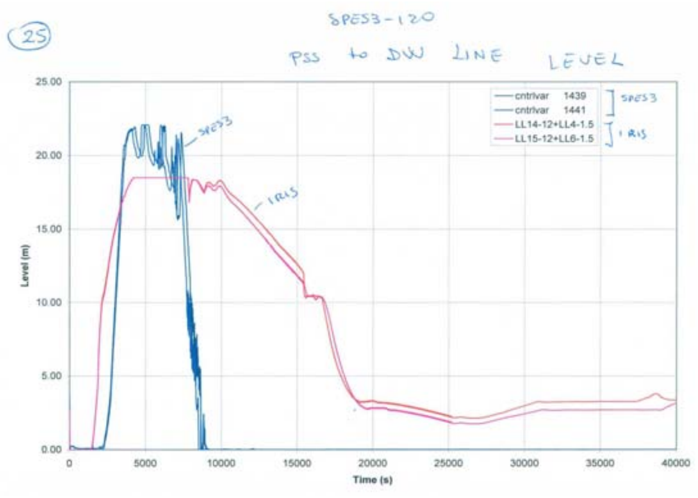


Fig.A8. 28 SPES3-120 PSS to DW vent line level

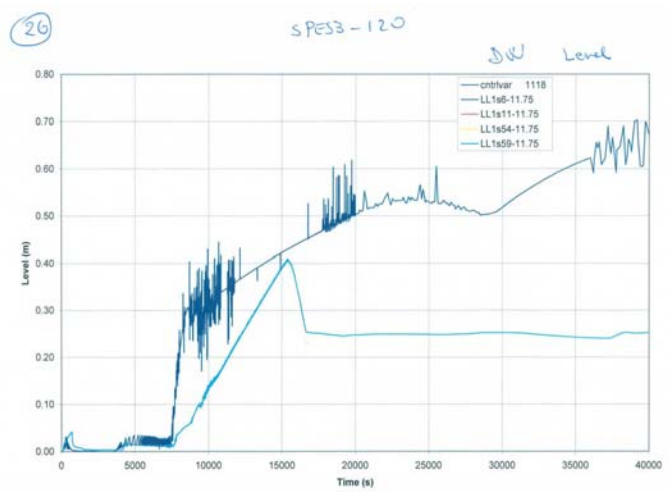


Fig.A8. 29 SPES3-120 PSS to DW level

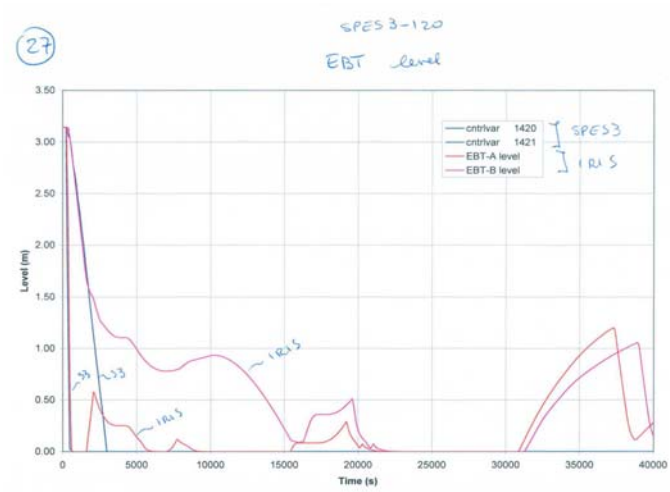


Fig.A8. 30 SPES3-120 EBT level

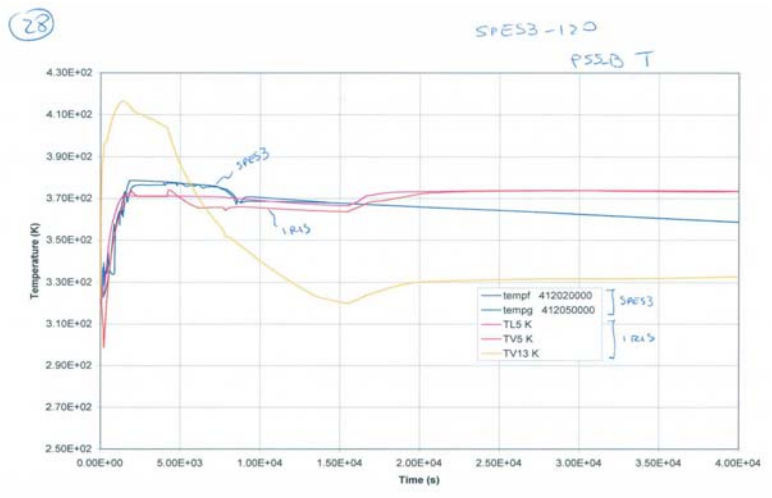


Fig.A8. 31 SPES3-120 PSS-B temperature

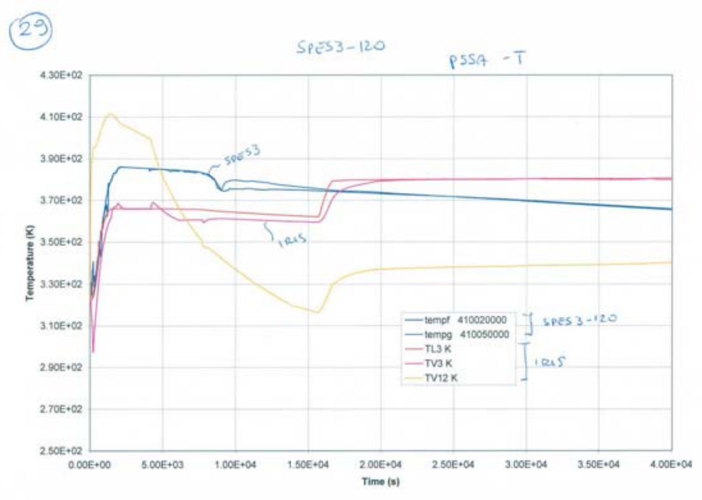


Fig.A8. 32 SPES3-120 PSS-A temperature

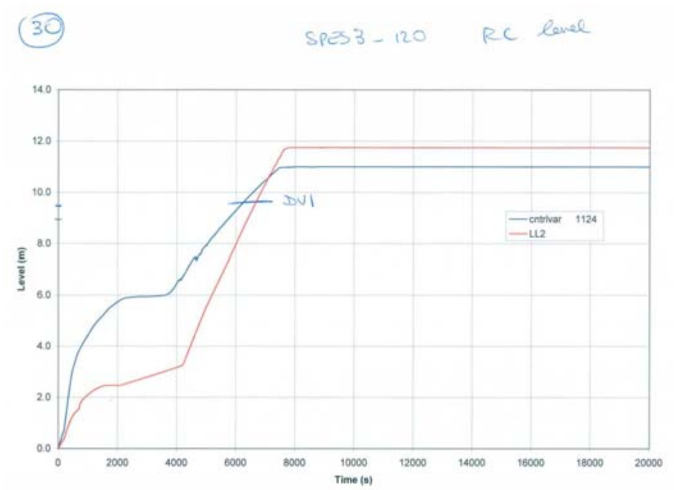


Fig.A8. 33 SPES3-120 RC level

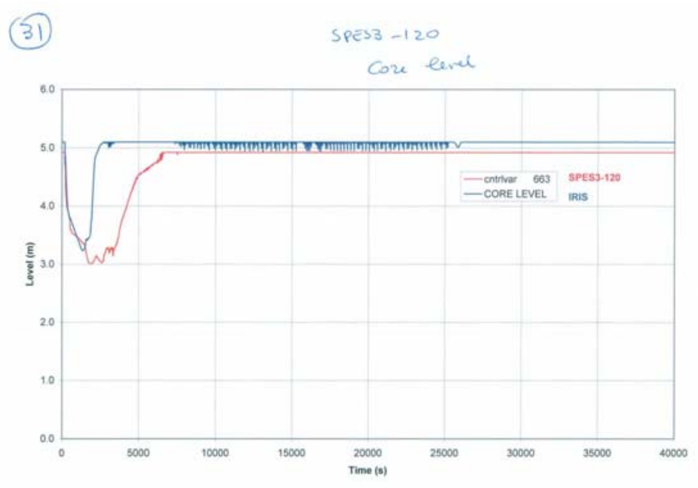


Fig.A8. 34 SPES3-120 core level

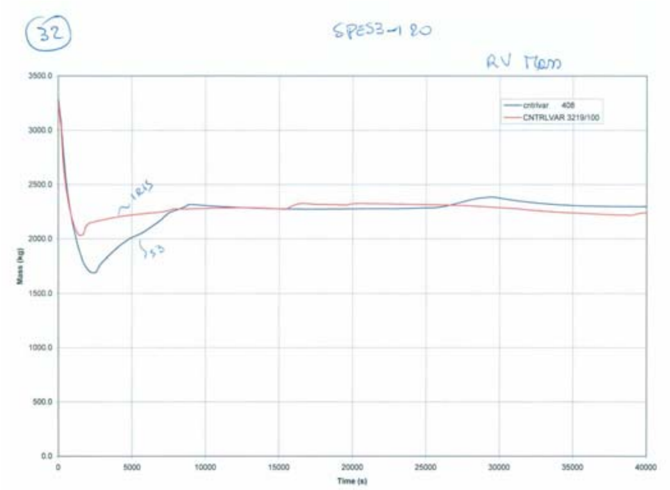


Fig.A8. 35 SPES3-120 RV mass

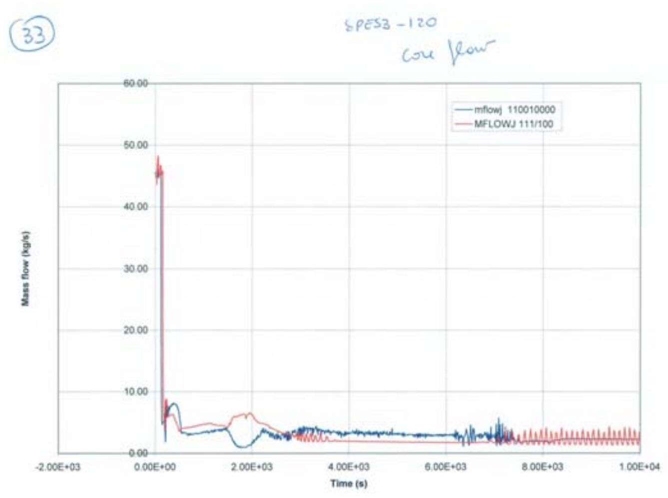


Fig.A8. 36 SPES3-120 core flow

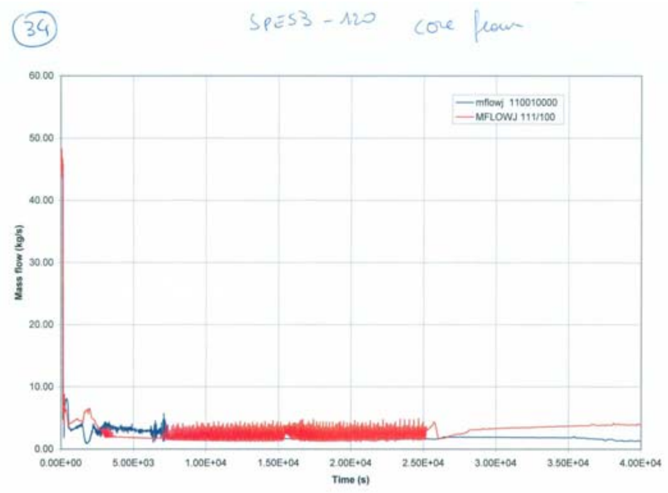


Fig.A8. 37 SPES3-120 core flow

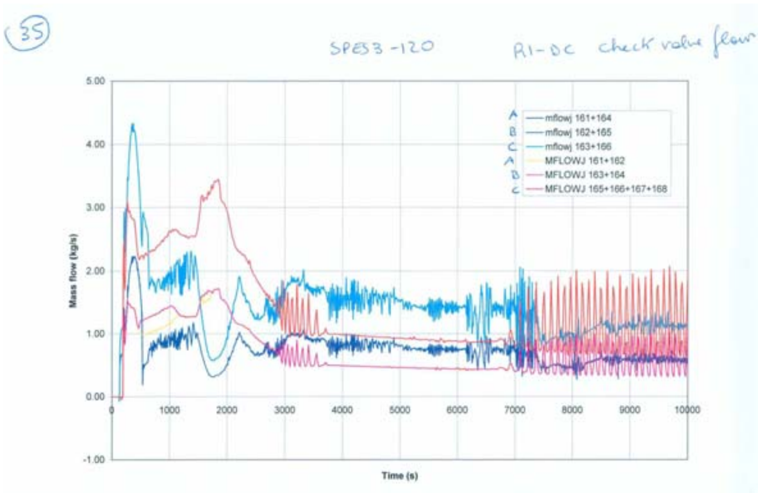


Fig.A8. 38 SPES3-120 Riser to DC check valve flow

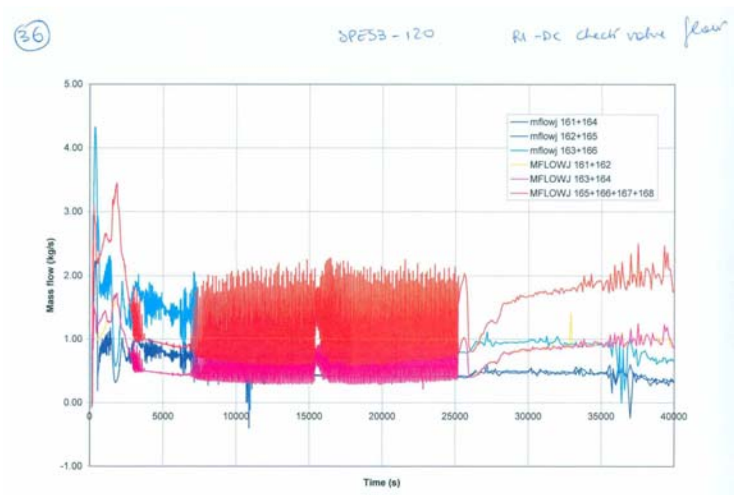


Fig.A8. 39 SPES3-120 Riser to DC check valve flow

Fig.A8. 40 SPES3-120 RC to DVI flow

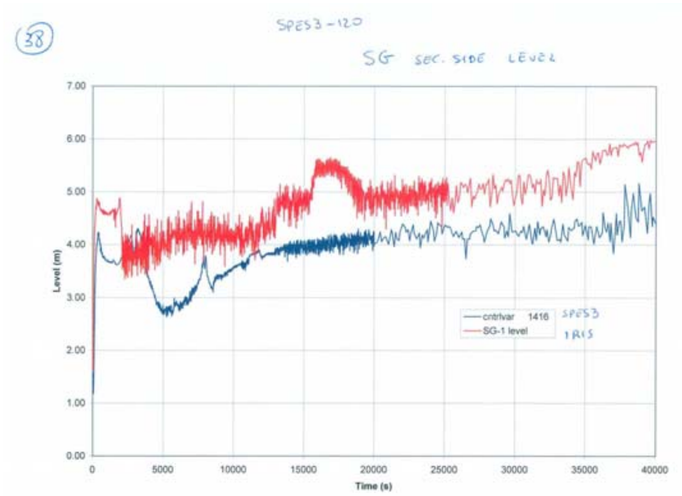


Fig.A8. 41 SPES3-120 SG secondary side level

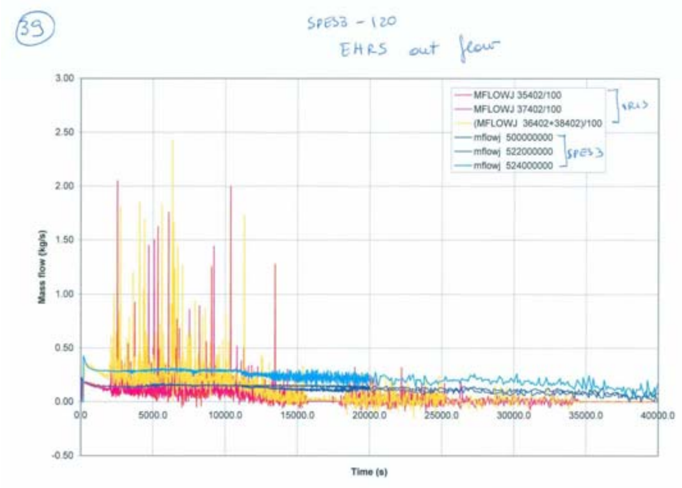


Fig.A8. 42 SPES3-120 EHRS outlet flow

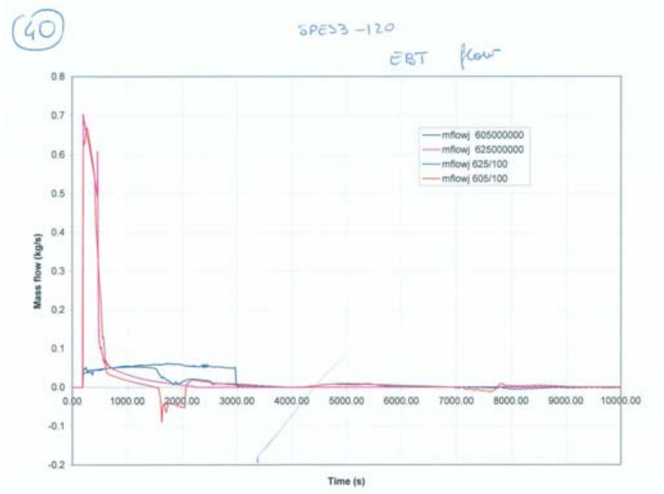


Fig.A8. 43 SPES3-120 EBT to DVI flow

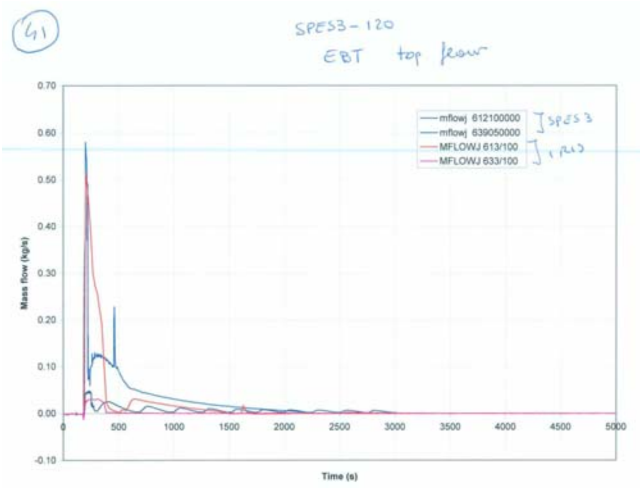


Fig.A8. 44 SPES3-120 EBT to RV balance line flow

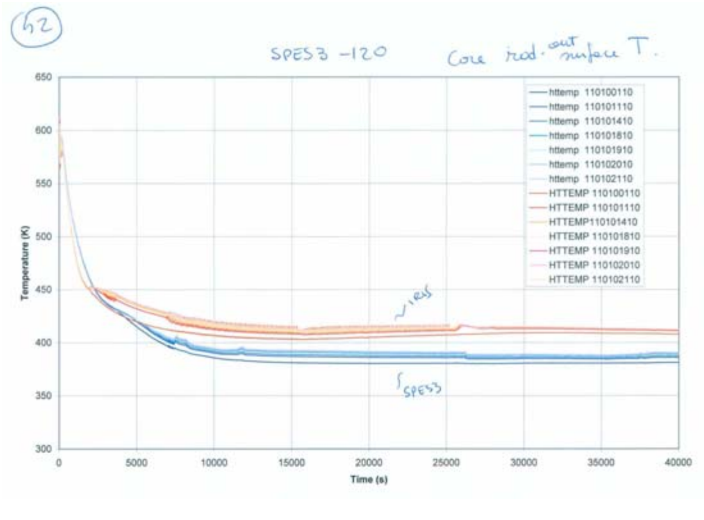


Fig.A8. 45 SPES3-120 core heting rod outer surface temperature

file "IRIS_SPES3_Conf Call Minutes #108 Att 4 SPES3-120 comments.doc

SIET, R. Ferri, July 22nd 2009

DVI DEG break

SPES3-120 compared to **iris30h_lb_ht1**

The overlapped graphs of the main quantities are reported in file "SPES3-120 graphs.pdf" that compare the SPES3 and IRIS results.

The SPES3-120 case has the containment thickness for 1.5 MPa design pressure and initially pre-heated heat structures to compensate for the excess of mass in SPE3 with respect to IRIS.

The break mass flow is very similar until the critical flow is present, then in SPES3 the outgoing mass is larger than IRIS due to the lower containment pressure, Fig.A8. 4, Fig.A8. 5, Fig.A8. 6, Fig.A8. 11.

The DW pressure in SPES3 increases more slowly than IRIS and reaches a lower peak due to the larger heat structures mass and surface in SPES3 than IRIS, Fig.A8. 11, Fig.A8. 12, Fig.A8. 13, Fig.A8. 14.

After the peak, the pressure decrease in the DW is mostly due to condensation for the PSS to DW injection, Fig.A8. 21, Fig.A8. 22.

Similar injected mass flow, cause different pressure reduction in DW probably due to different condensation models in RELAP and GOTHIC. It seems in Gothic less steam is condensed and this is confirmed by the lower temperature of water collected at the RC bottom after ~4000 s, graph 15.

A large difference between SPES3 and IRIS is related to the LGMS injection into the DVI, Fig.A8. 26. In IRIS it always driven by the LGMS (and PSS) pressure that is always higher than the DVI pressure, while in SPES3, it is driven by such overpressure only in the first phase of injection, later, when LGMS and DVI pressure equalize, it is driven by gravity and the mass flow is largely reduced, Fig.A8. 20, Fig.A8. 26.

In SPES3, after the PSS injection to the DW is over, the PSS, LGMS and DW volumes are directly connected through pipes PSS-LGMS and PSS-DW and pressures equalize with the DVI one (LGMS gravity head a part), Fig.A8. 19, Fig.A8. 20.

In IRIS, the PSS and LGMS remain pressurized with respect to DW as the PSS-DW pipe remains full of water preventing the free circulation of air between PSS and DW and the pressure equalization, Fig.A8. 19, Fig.A8. 28.

The above different behaviour is probably related to the difference in the PSS to DW connection pipe that in SPES3 is connected at the DW top, while in IRIS it is connected at the DW bottom, where a water level forms, Fig.A8. 29, and can form a siphon with a back flow from DW to PSS (Fig.A8. 22 and Fig.A8. 29 at ~15000 s).

Which is the behaviour expected for IRIS for the PSS to DW line level? Are they expected to empty after the PSS injection to DW or not?

Another difference evidenced between SPES3 and IRIS is the EBT behaviour. The injection phase is very similar until the RV and containment pressure equalization (~2000 s). After that, a back flow is present in IRIS that relents the level decrease and later causes also level increase, Fig.A8. 30.It seems there is no check valve on the EBT discharge lines in IRIS, while it is present in SPES3.

The larger mass lost from the break and from the ADS in SPES3, causes a larger and more lasting core level decrease than in IRIS, Fig.A8. 34, anyway core is covered again by the LGMS injection. The RV masses are shown in Fig.A8. 36 and they are very similar after ~8000 s.

Due to the lower RV level (corresponding to the lower core level) in SPES3, the core natural circulation flow is lower than in IRIS around 2000 s, when also the circulation through the RI-DC check valves is reduced, Fig.A8. 36, Fig.A8. 37, Fig.A8. 38, Fig.A8. 39.

The RC level shows different trends due to the tank shape, but level reaches the DVI connection at a similar time after ~6000 s, Fig.A8. 33.

The RC to DVI mass flow, Fig.A8. 40, is limited in SPES3 by an orifice.

The EHRS out flow and power are very similar in the first phase of the transient (until ~500s), then the SPES3 flow and power are higher than in IRIS, as well as SG power, Fig.A8. 42, Fig.A8. 17, Fig.A8. 15, Fig.A8. 16. This is probably due to the SPES3 larger SG tube inside diameter, decided after the tube thickness reduction (Dout 17.46 mm, thickness IRIS 2.11, thickness SPES3 1.688).

SPES3-119-120-122 compared to **iris30h_lb_ht1**

Cases SPES3-119, 120, 122 have the same geometry of containment tank.

Case SPES3-119 has the IRIS DW heat structures scaled on SPES2 in mass and surface and heat structures of PSS, LGMS and RC reduced to 1 mm thickness.

Case SPES3-120 has the containment thickness for 1.5 MPa design pressure and initially pre-heated heat structures (84 °C) to compensate for the excess of mass in SPE3 with respect to IRIS.

Case SPES3-122 has the containment thickness for 1.5 MPa design pressure without any preheating (T containment structures 48.9 °C as in IRIS).

The overlapped graphs of the DW pressures are reported in file "SPES3-119-120-122-IRIS DW P.pdf".

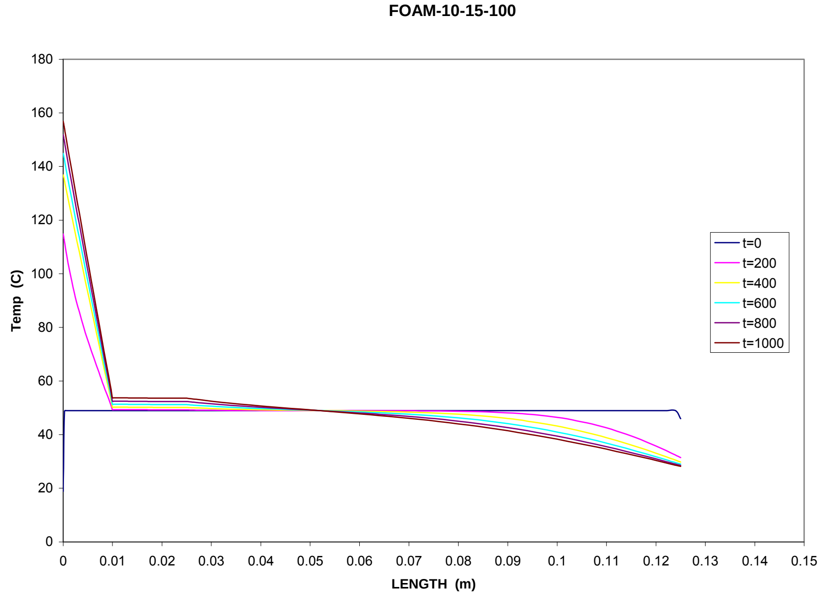
The SPES3 DW pressure get closer to the IRIS one, in the rising phase, by preheating the heat structures (case 120) and by reducing them (case 119). Instead, the heat structures seem not to have large importance in the decreasing phase, when the condensation effect by the PSS injection dumps pressure more in SPES3 than IRIS. IRIS and case 119 should have very similar trends if heat structures drove the phenomenon, but they haven't due to condensation.

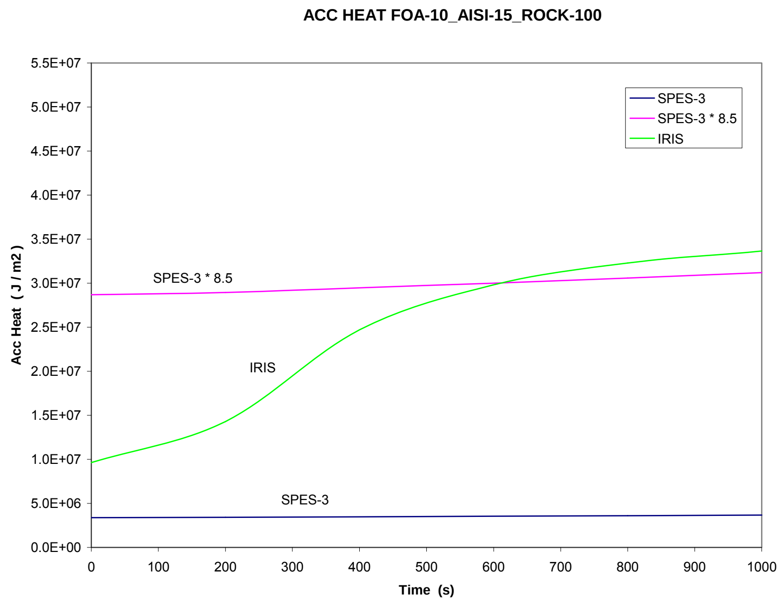
A.8 Attachments to conf-call #109

file "IRIS_SPES3_Conf Call Minutes #109 Att 1 Different_insulation_3.doc

DIFFERENT_INSULATION_3
CASE1_FOAMGLASS

SPES-3 Dry-well		IRIS CONTAINMENT	
MATERIAL	***THICKNESS***	***MATERIAL***	***THICKNESS***
FOAMGLASS	10 mm	CARBON STEEL	44 mm
AISI 304	15 mm		
ROCKWOOL	100 mm		
INITIAL TEMPERATURE 48.9 C		***INITIAL TEMPERATURE 48.9 C***	
BOUNDARY CONDITION RIGHT SIDE: Tair=25 h=10 W/m2K		***BOUNDARY CONDITION RIGHT SIDE: Tair=35 h=10 W/m2K***	

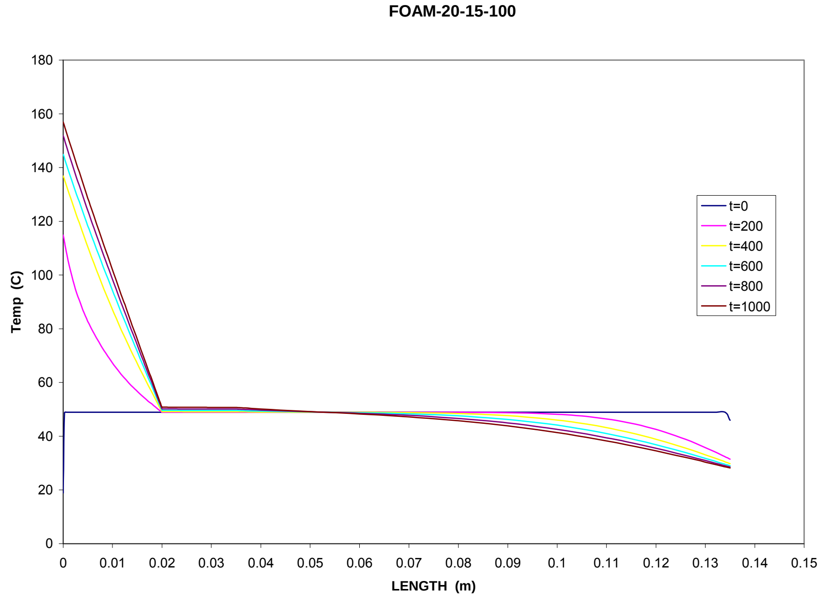


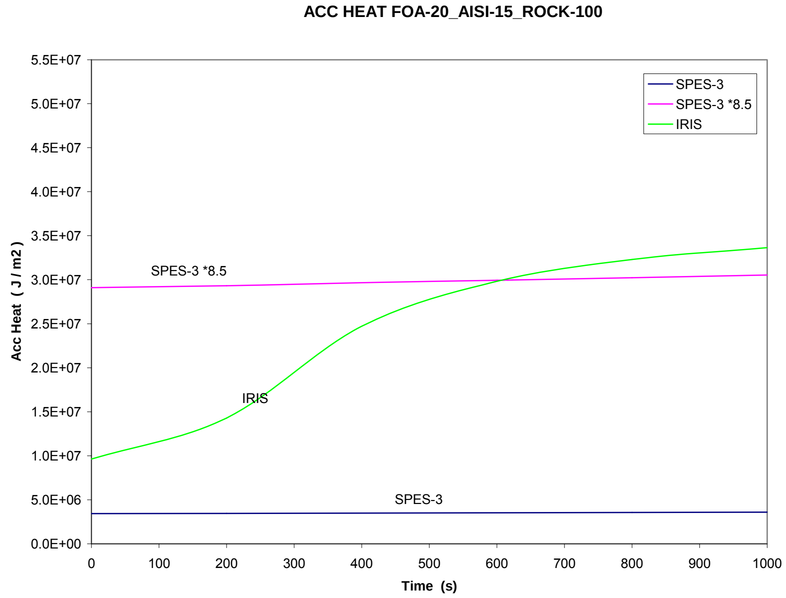


Different_insulation_3

CASE2_FOAMGLASS

SPES-3 Dry-well		IRIS CONTAINMENT	
MATERIAL	***THICKNESS***	***MATERIAL***	***THICKNESS***
FOAMGLASS	20 mm	CARBON STEEL	44 mm
AISI 304	15 mm		
ROCKWOOL	100 mm		
INITIAL TEMPERATURE 48.9 C		***INITIAL TEMPERATURE 48.9 C***	
BOUNDARY CONDITION ON RIGHT: Tair=25 h=10 W/m2K		***BOUNDARY CONDITION ON RIGHT: Tair=35 h=10 W/m2K***	



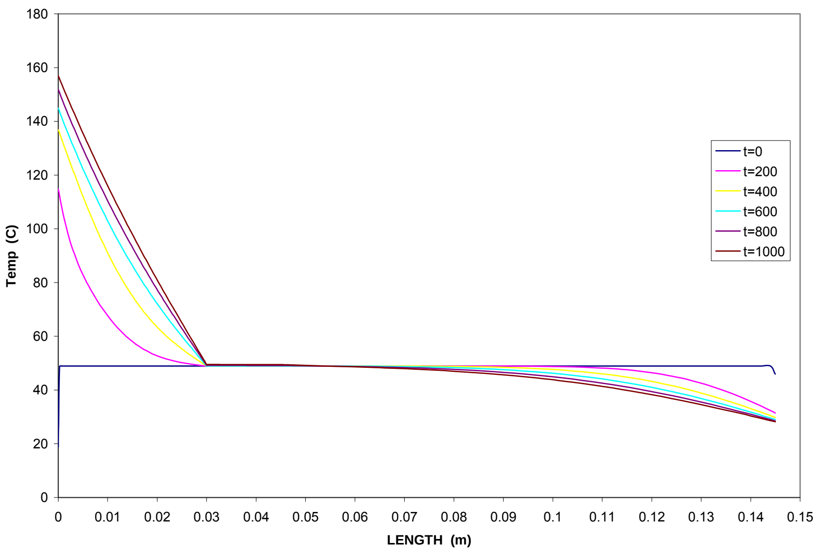


Different_insulation_3

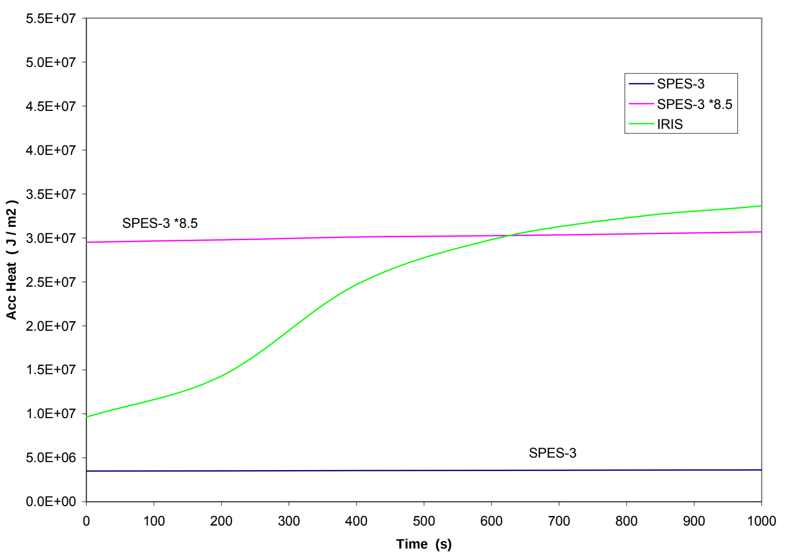
CASE3_FOAMGLASS

SPES-3 Dry-well		IRIS CONTAINMENT	
MATERIAL	***THICKNESS***	***MATERIAL***	***THICKNESS***
FOAMGLASS	30 mm	CARBON STEEL	44 mm
AISI 304	15 mm		
ROCKWOOL	100 mm		
INITIAL TEMPERATURE 48.9 C		***INITIAL TEMPERATURE 48.9 C***	
BOUNDARY CONDITION ON RIGHT: Tair=25 h=10 W/m2K		***BOUNDARY CONDITION ON RIGHT: Tair=35 h=10 W/m2K***	

FOAM-30-15-100



ACC HEAT FOA-30_AISI-15_ROCK-100

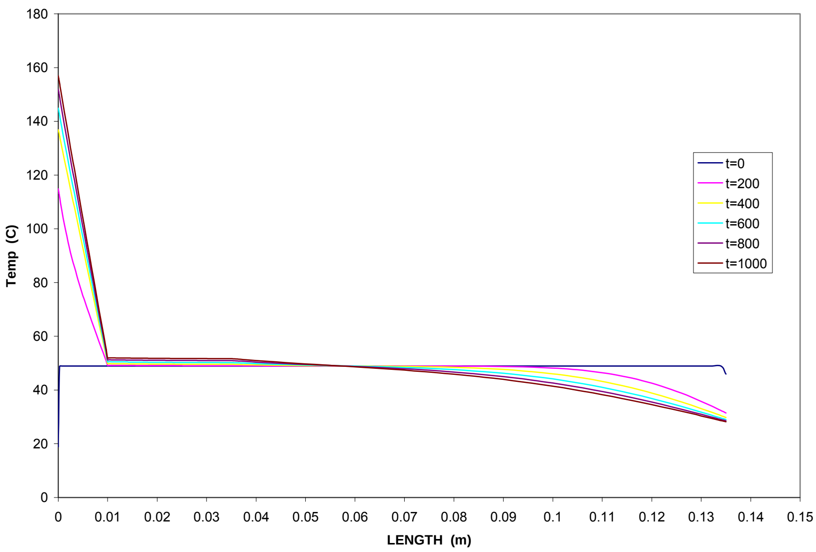


Different_insulation_3

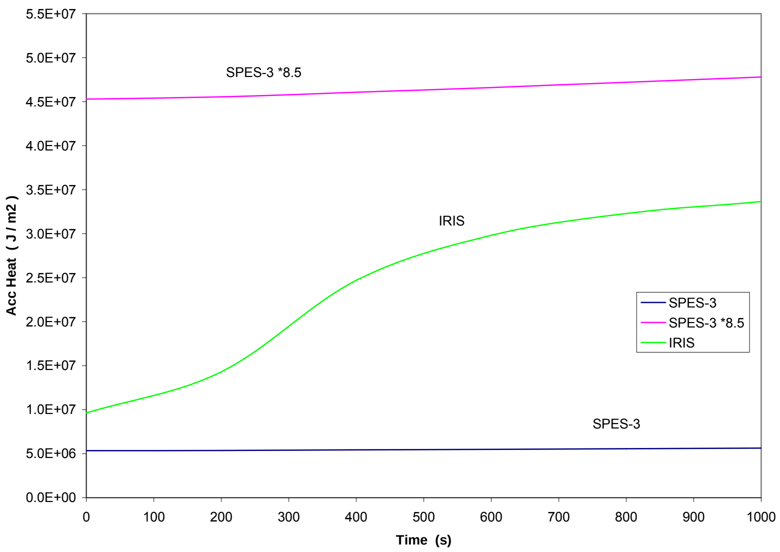
CASE4_FOAMGLASS

SPES-3 Dry-well		IRIS CONTAINMENT	
MATERIAL	***THICKNESS***	***MATERIAL***	***THICKNESS***
FOAMGLASS	10 mm	CARBON STEEL	44 mm
AISI 304	25 mm		
ROCKWOOL	100 mm		
INITIAL TEMPERATURE 48.9 C		***INITIAL TEMPERATURE 48.9 C***	
BOUNDARY CONDITION ON RIGHT: Tair=25 h=10 W/m2K		***BOUNDARY CONDITION ON RIGHT: Tair=35 h=10 W/m2K***	

FOAM-10-25-100



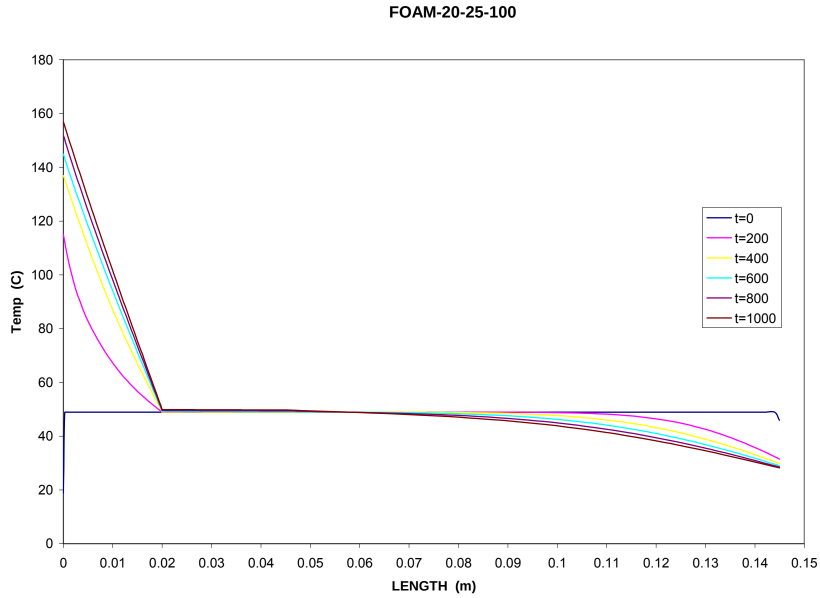
ACC HEAT FOA-10-AISI-25-ROCK-100

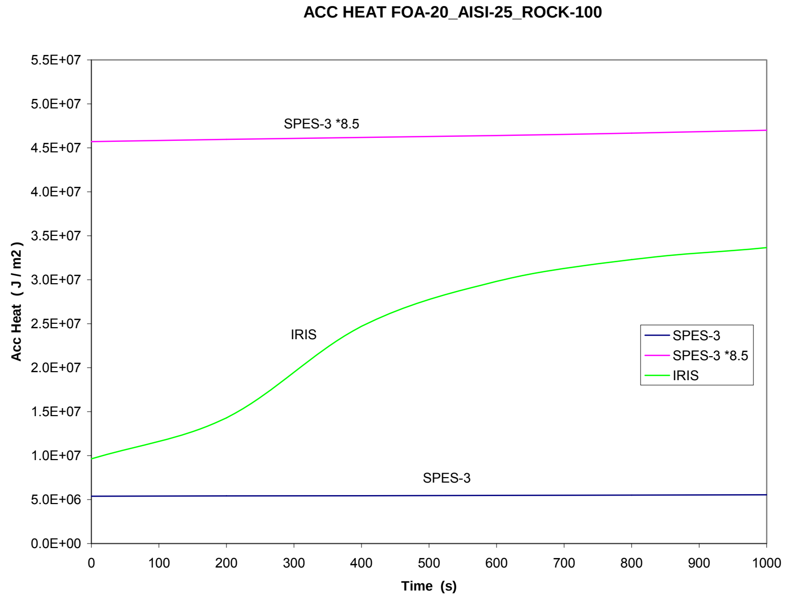


Different_insulation_3

CASE5_FOAMGLASS

SPES-3 Dry-well		IRIS CONTAINMENT	
MATERIAL	***THICKNESS***	***MATERIAL***	***THICKNESS***
FOAMGLASS	20 mm	CARBON STEEL	44 mm
AISI 304	25 mm		
ROCKWOOL	100 mm		
INITIAL TEMPERATURE 48.9 C		***INITIAL TEMPERATURE 48.9 C***	
BOUNDARY CONDITION ON RIGHT: Tair=25 h=10 W/m2K		***BOUNDARY CONDITION ON RIGHT: Tair=35 h=10 W/m2K***	

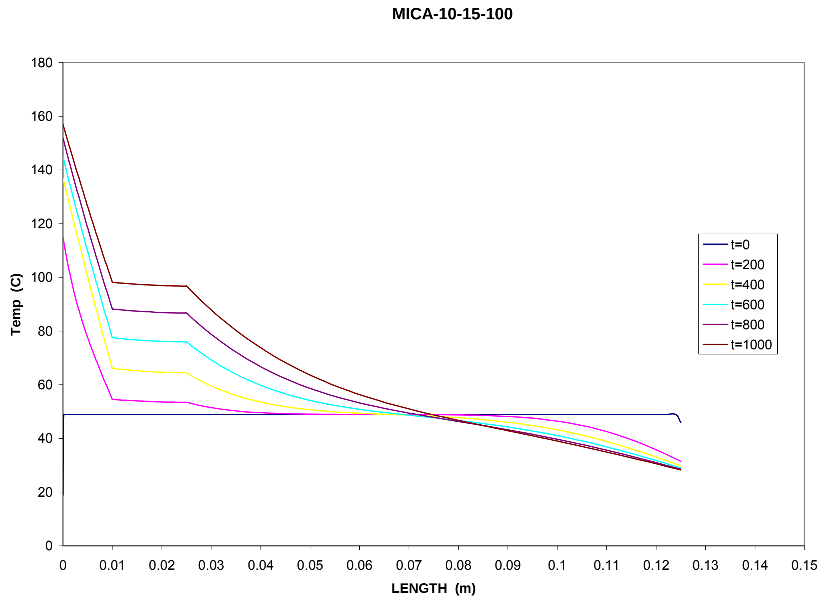


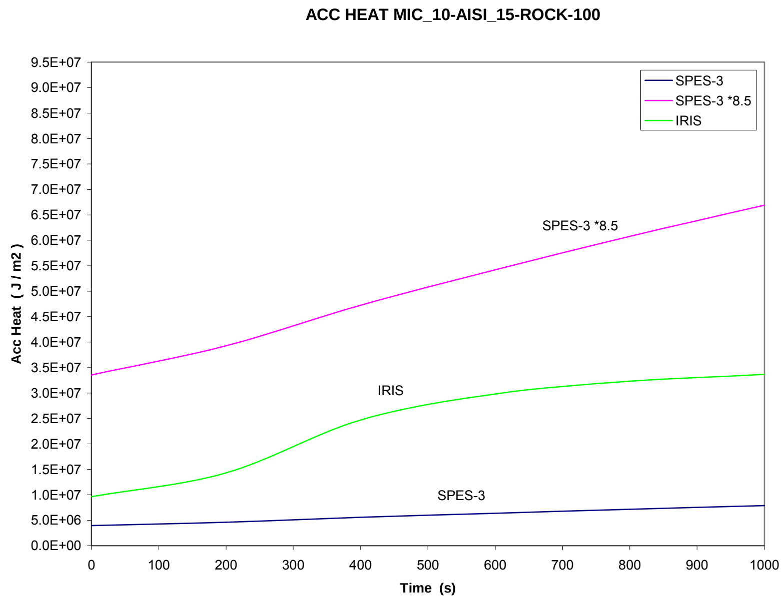


Different_insulation_3

CASE1_MICATEMP

SPES-3 Dry-well		IRIS CONTAINMENT	
MATERIAL	***THICKNESS***	***MATERIAL***	***THICKNESS***
MICATEMP	10 mm	CARBON STEEL	44 mm
AISI 304	15 mm		
ROCKWOOL	100 mm		
INITIAL TEMPERATURE 48.9 C		***INITIAL TEMPERATURE 48.9 C***	
BOUNDARY CONDITION ON RIGHT: Tair=25 h=10 W/m2K		***BOUNDARY CONDITION ON RIGHT: Tair=35 h=10 W/m2K***	

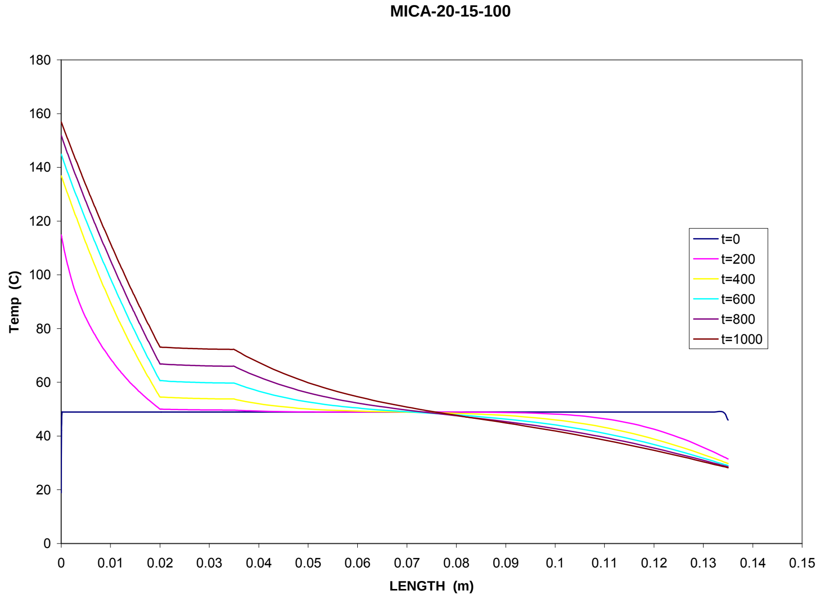


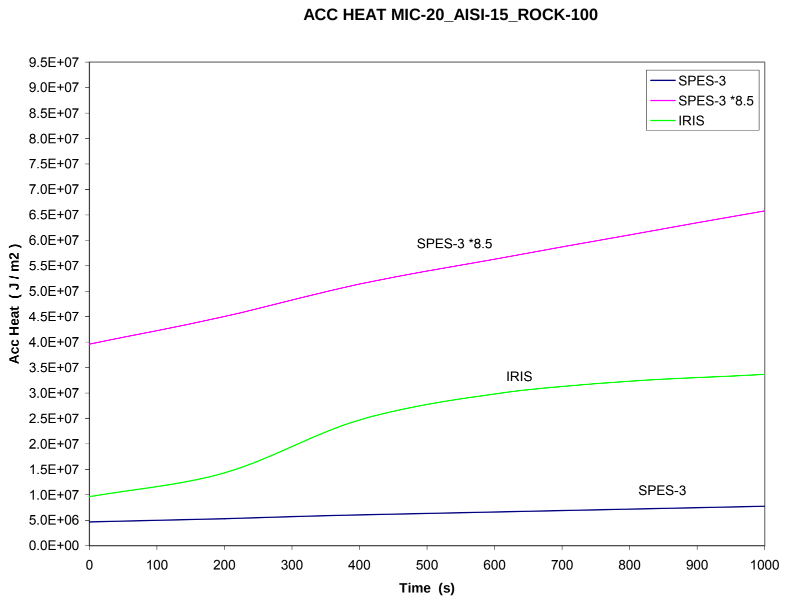


Different_insulation_3

CASE2_MICATEMP

SPES-3 Dry-well		IRIS CONTAINMENT	
MATERIAL	***THICKNESS***	***MATERIAL***	***THICKNESS***
MICATEMP	20 mm	CARBON STEEL	44 mm
AISI 304	15 mm		
ROCKWOOL	100 mm		
INITIAL TEMPERATURE 48.9 C		***INITIAL TEMPERATURE 48.9 C***	
BOUNDARY CONDITION ON RIGHT: Tair=25 h=10 W/m2K		***BOUNDARY CONDITION ON RIGHT: Tair=35 h=10 W/m2K***	

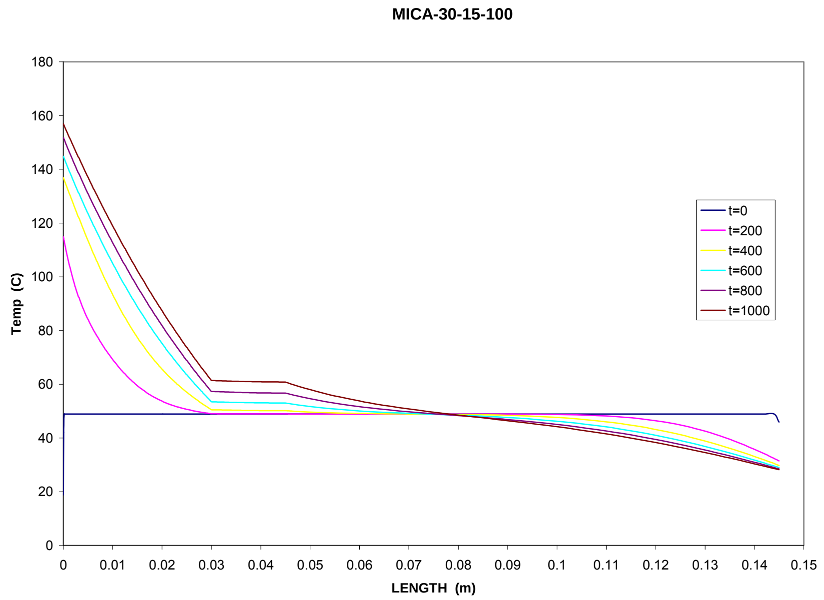


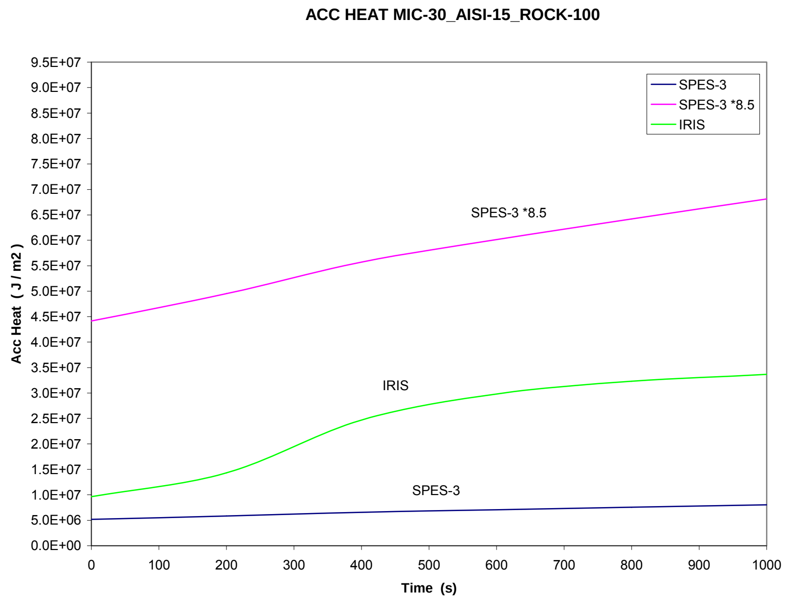


Different_insulation_3

CASE3_MICATEMP

SPES-3 Dry-well		IRIS CONTAINMENT	
MATERIAL	***THICKNESS***	***MATERIAL***	***THICKNESS***
MICATEMP	30 mm	CARBON STEEL	44 mm
AISI 304	15 mm		
ROCKWOOL	100 mm		
INITIAL TEMPERATURE 48.9 C		***INITIAL TEMPERATURE 48.9 C***	
BOUNDARY CONDITION ON RIGHT: Tair=25 h=10 W/m2K		***BOUNDARY CONDITION ON RIGHT: Tair=35 h=10 W/m2K***	

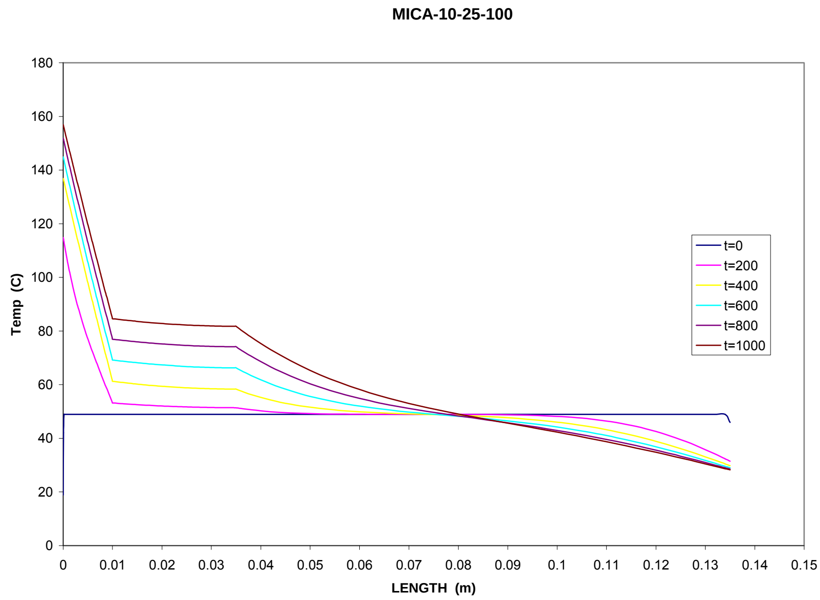


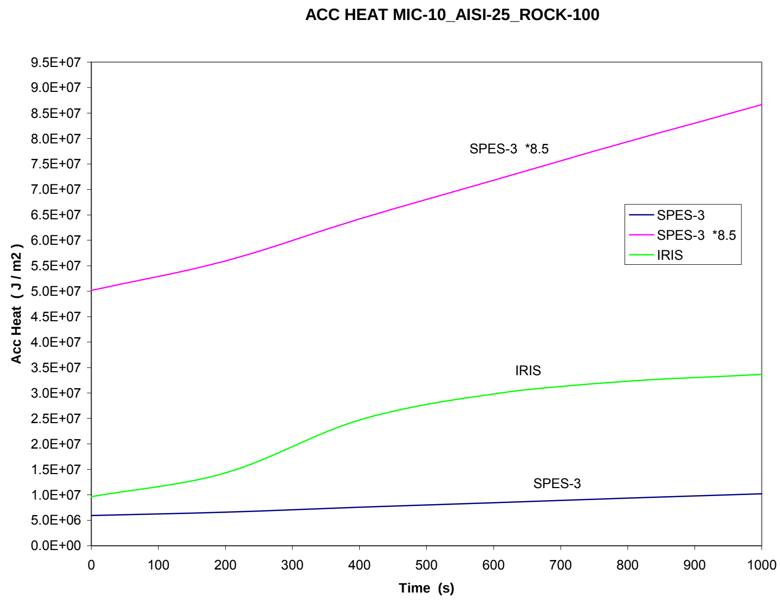


Different_insulation_3

CASE4_MICATEMP

SPES-3 Dry-well		IRIS CONTAINMENT	
MATERIAL	***THICKNESS***	***MATERIAL***	***THICKNESS***
MICATEMP	10 mm	CARBON STEEL	44 mm
AISI 304	25 mm		
ROCKWOOL	100 mm		
INITIAL TEMPERATURE 48.9 C		***INITIAL TEMPERATURE 48.9 C***	
BOUNDARY CONDITION ON RIGHT: Tair=25 h=10 W/m2K		***BOUNDARY CONDITION ON RIGHT: Tair=35 h=10 W/m2K***	

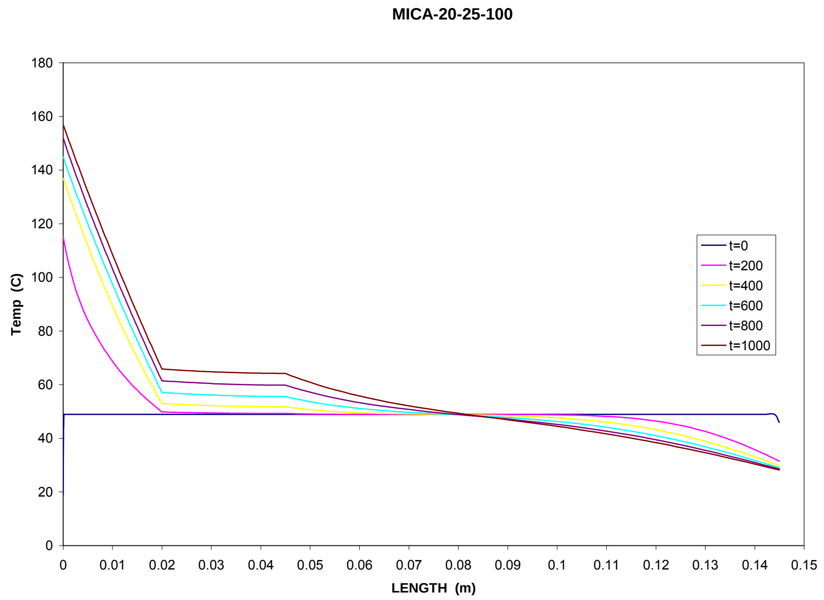


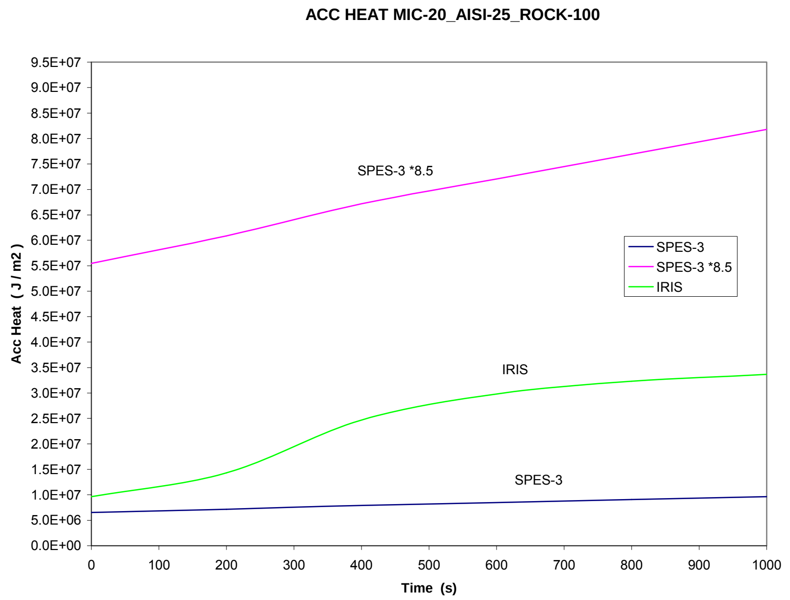


Different_insulation_3

CASE5_MICATEMP

SPES-3 Dry-well		IRIS CONTAINMENT	
MATERIAL	***THICKNESS***	***MATERIAL***	***THICKNESS***
MICATEMP	20 mm	CARBON STEEL	44 mm
AISI 304	25 mm		
ROCKWOOL	100 mm		
INITIAL TEMPERATURE 48.9 C		***INITIAL TEMPERATURE 48.9 C***	
BOUNDARY CONDITION ON RIGHT: Tair=25 h=10 W/m2K		***BOUNDARY CONDITION ON RIGHT: Tair=35 h=10 W/m2K***	

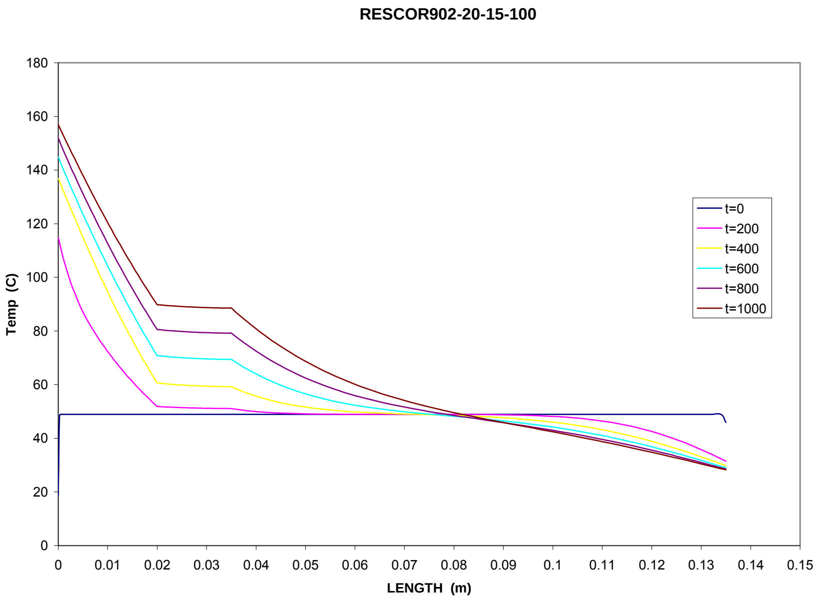


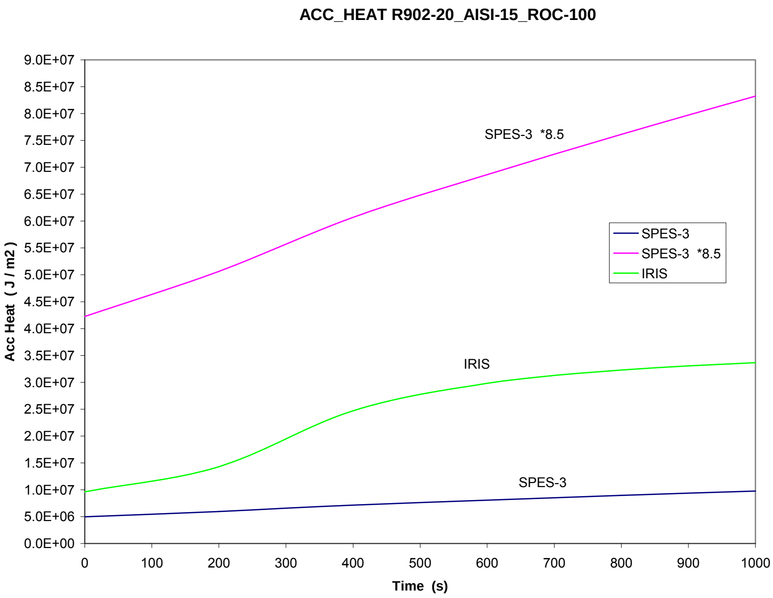


Different_insulation_3

CASE2_RESCOR902

SPES-3 Dry-well		IRIS CONTAINMENT	
MATERIAL	***THICKNESS***	***MATERIAL***	***THICKNESS***
RESCOR902	20 mm	CARBON STEEL	44 mm
AISI 304	15 mm		
ROCKWOOL	100 mm		
INITIAL TEMPERATURE 48.9 C		***INITIAL TEMPERATURE 48.9 C***	
BOUNDARY CONDITION ON RIGHT: Tair=25 h=10 W/m2K		***BOUNDARY CONDITION ON RIGHT: Tair=35 h=10 W/m2K***	

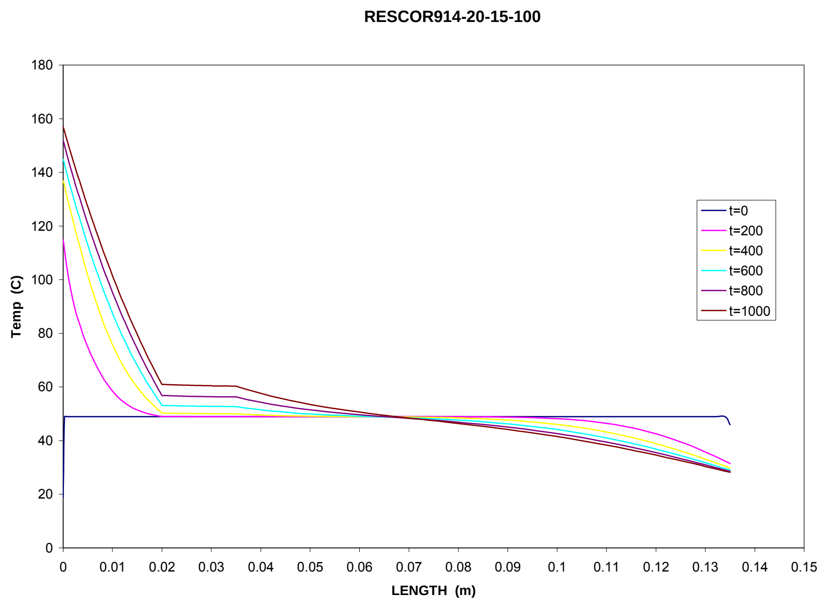


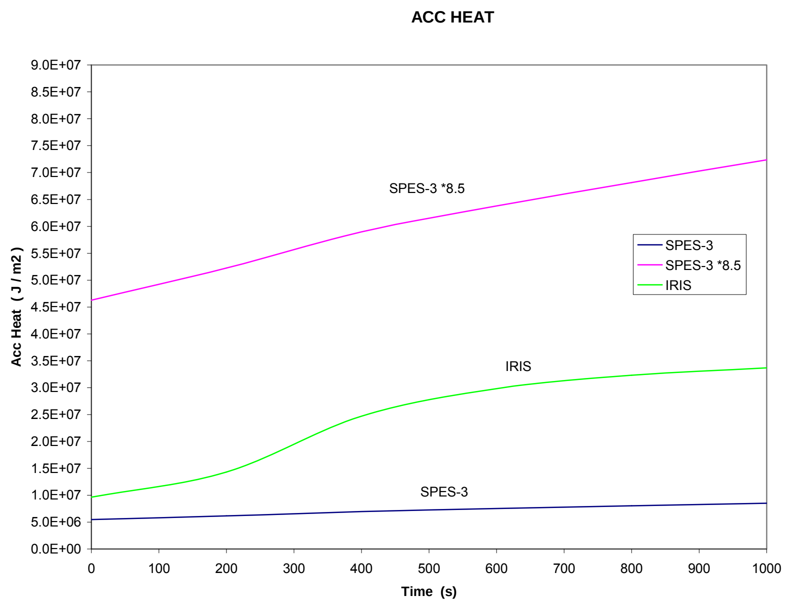


Different_insulation_3

CASE2_RESCOR914

SPES-3 Dry-well		IRIS CONTAINMENT	
MATERIAL	***THICKNESS***	***MATERIAL***	***THICKNESS***
RESCOR914	20 mm	CARBON STEEL	44 mm
AISI 304	15 mm		
ROCKWOOL	100 mm		
INITIAL TEMPERATURE 48.9 C		***INITIAL TEMPERATURE 48.9 C***	
BOUNDARY CONDITION ON RIGHT: Tair=25 h=10 W/m2K		***BOUNDARY CONDITION ON RIGHT: Tair=35 h=10 W/m2K***	





Different_insulation_3

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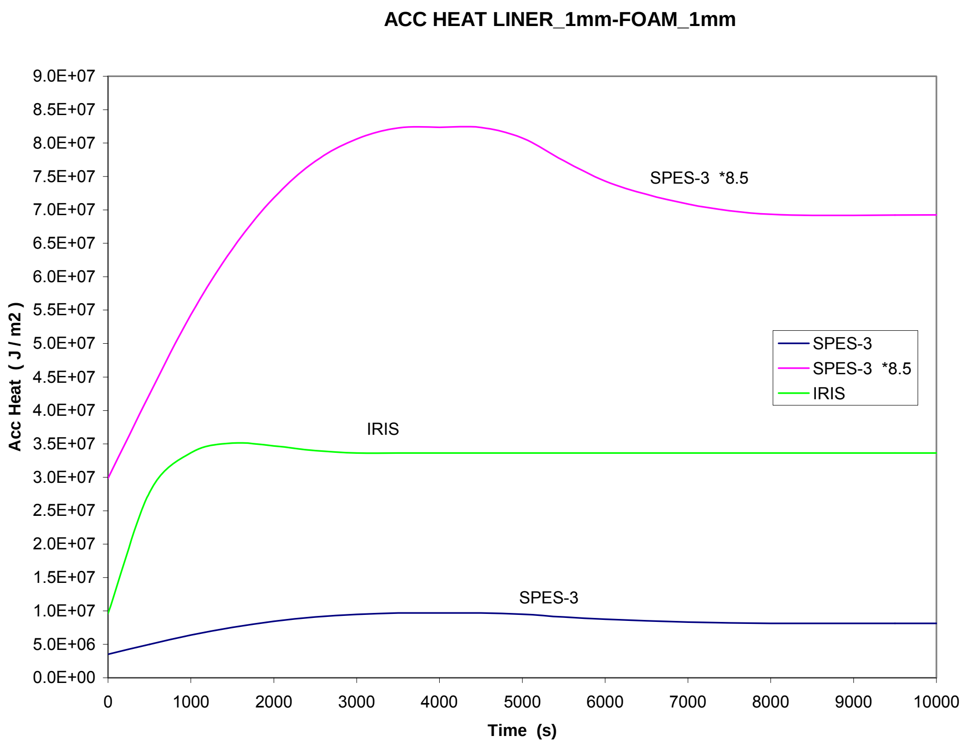
LINER_Foamglass_Insulation_2
CASE1_1mm Liner

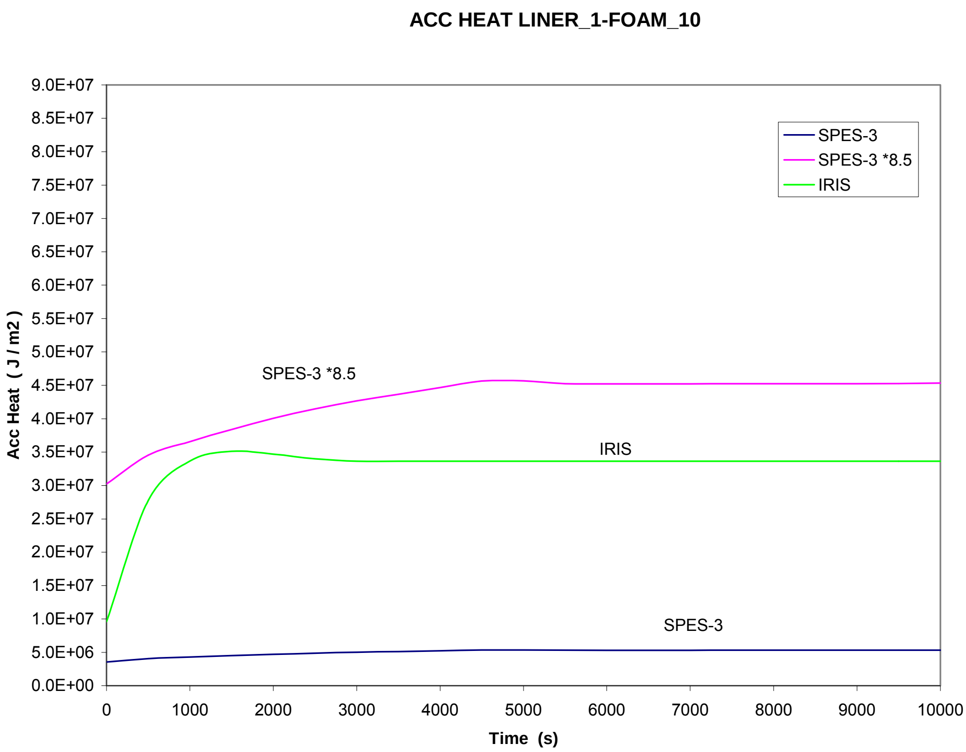
SPES-3 Dry-well		IRIS CONTAINMENT	
MATERIAL	***THICKNESS***	***MATERIAL***	***THICKNESS***
AISI 304 k = 17.95 *W/m K*	1mm	CARBON STEEL	44 mm
FOAMGLASS @ 10 C *0.04 W/m K*	1 mm		
AISI 304 k = 17.95 *W/m K*	15 mm		
ROCKWOOL k = 0.0705 *W/m K*	100 mm		
INITIAL TEMPERATURE = 48.9		***INITIAL TEMPERATURE = 48.9 C***	
BOUNDARY CONDITION RIGHT ***Tair= 25 C h =10W/ m2K***		***BOUNDARY CONDITION RIGHT*** ***Tair= 35 C h =10W/ m2K***	



LINER_Foamglass_Insulation_2

CASE2_1mm Liner

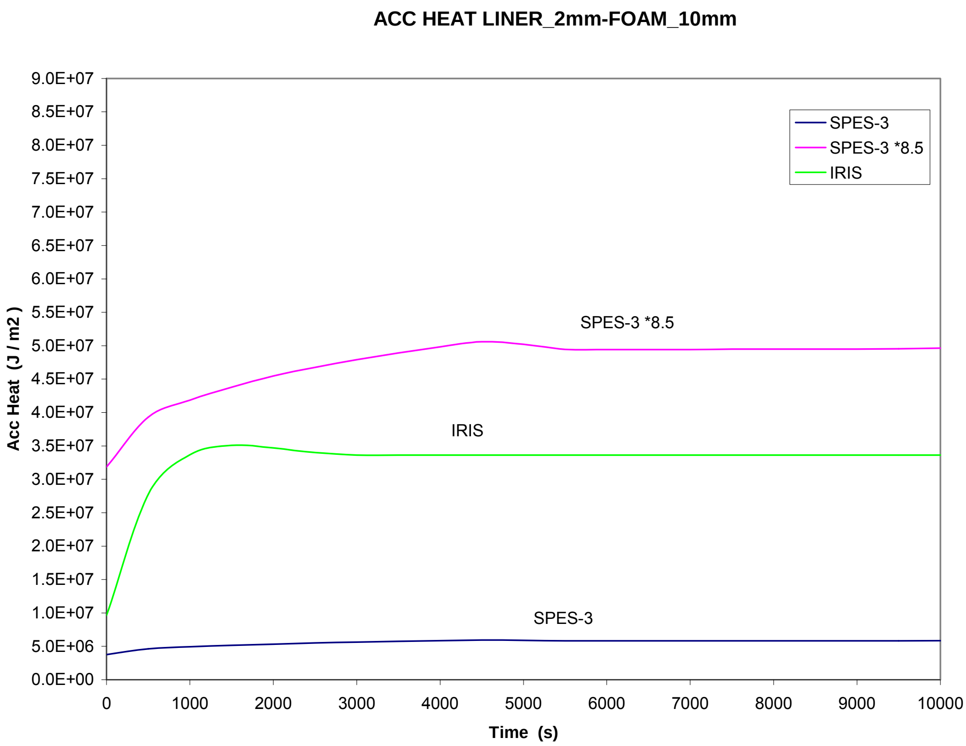
SPES-3 Dry-well		IRIS CONTAINMENT	
MATERIAL	***THICKNESS***	***MATERIAL***	***THICKNESS***
AISI 304 k = 17.95 *W/m K*	1mm	CARBON STEEL	44 mm
FOAMGLASS @ 10 C *0.04 W/m K*	10 mm		
AISI 304 k = 17.95 *W/m K*	15 mm		
ROCKWOOL k = 0.0705 *W/m K*	100 mm		
INITIAL TEMPERATURE = 48.9		***INITIAL TEMPERATURE = 48.9 C***	
BOUNDARY CONDITION RIGHT ***Tair= 25 C h =10W/ m2K***		***BOUNDARY CONDITION RIGHT*** ***Tair= 35 C h =10W/ m2K***	



LINER_Foamglass_Insulation_2

CASE3_2mm Liner

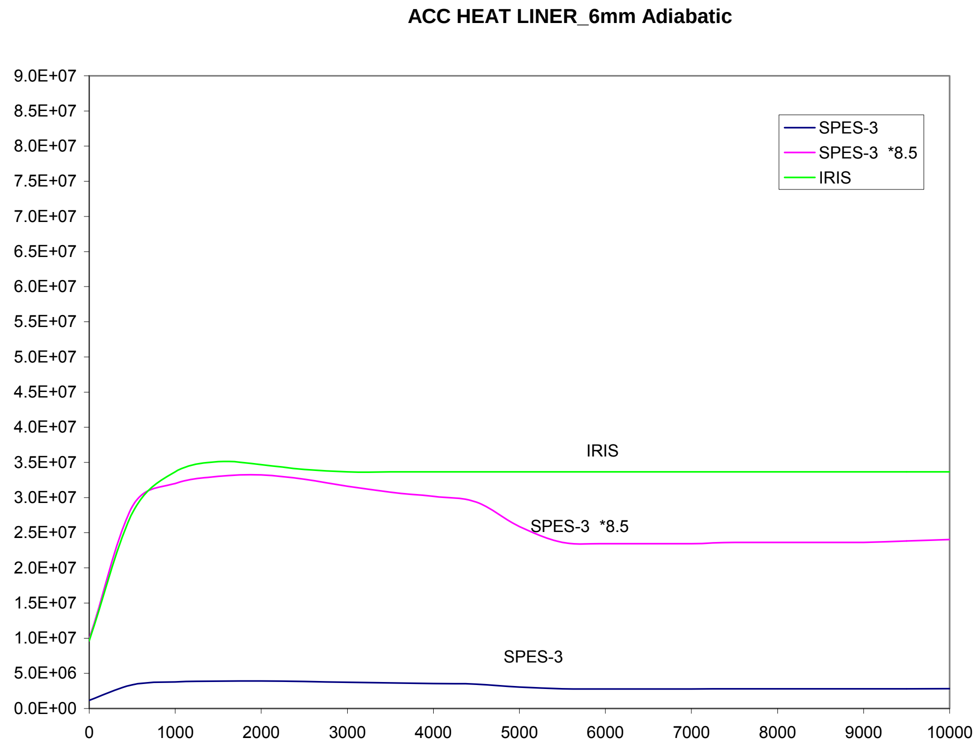
SPES-3 Dry-well		IRIS CONTAINMENT	
MATERIAL	***THICKNESS***	***MATERIAL***	***THICKNESS***
AISI 304 k = 17.95 *W/m K*	2mm	CARBON STEEL	44 mm
FOAMGLASS @ 10 C *0.04 W/m K*	10 mm		
AISI 304 k = 17.95 *W/m K*	15 mm		
ROCKWOOL k = 0.0705 *W/m K*	100 mm		
INITIAL TEMPERATURE = 48.9		***INITIAL TEMPERATURE = 48.9 C***	
BOUNDARY CONDITION RIGHT ***Tair= 25 C h =10W/ m2K***		***BOUNDARY CONDITION RIGHT*** ***Tair= 35 C h =10W/ m2K***	



LINER_Foamglass_Insulation_2

CASE4_6mm Adiabatic
(Heat Capacity Iris Wall Scaled)

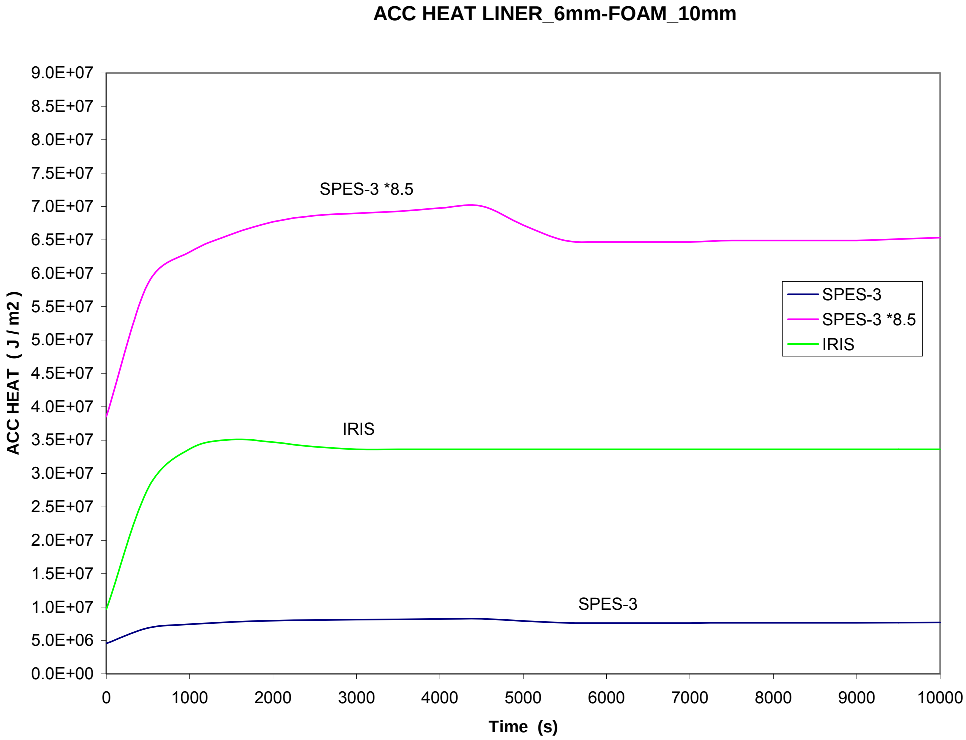
SPES-3 Dry-well		IRIS CONTAINMENT	
MATERIAL	***THICKNESS***	***MATERIAL***	***THICKNESS***
AISI 304 k = 17.95 *W/m K*	6mm	CARBON STEEL	44 mm
INITIAL TEMPERATURE = 48.9		***INITIAL TEMPERATURE = 48.9 C***	
BOUNDARY CONDITION RIGHT ***Tair= 25 C h =10W/ m2K***		***BOUNDARY CONDITION RIGHT*** ***Tair= 35 C h =10W/ m2K***	



LINER_Foamglass_Insulation_2

CASE5_6mm
(Heat Capacity Iris Wall Scaled)

SPES-3 Dry-well		IRIS CONTAINMENT	
MATERIAL	***THICKNESS***	***MATERIAL***	***THICKNESS***
AISI 304 k = 17.95 *W/m K*	6mm	CARBON STEEL	44 mm
FOAMGLASS @ 10 C *0.04 W/m K*	10 mm		
AISI 304 k = 17.95 *W/m K*	15 mm		
ROCKWOOL k = 0.0705 *W/m K*	100 mm		
INITIAL TEMPERATURE = 48.9		***INITIAL TEMPERATURE = 48.9 C***	
BOUNDARY CONDITION RIGHT ***Tair= 25 C h =10W/ m2K***		***BOUNDARY CONDITION RIGHT*** ***Tair= 35 C h =10W/ m2K***	

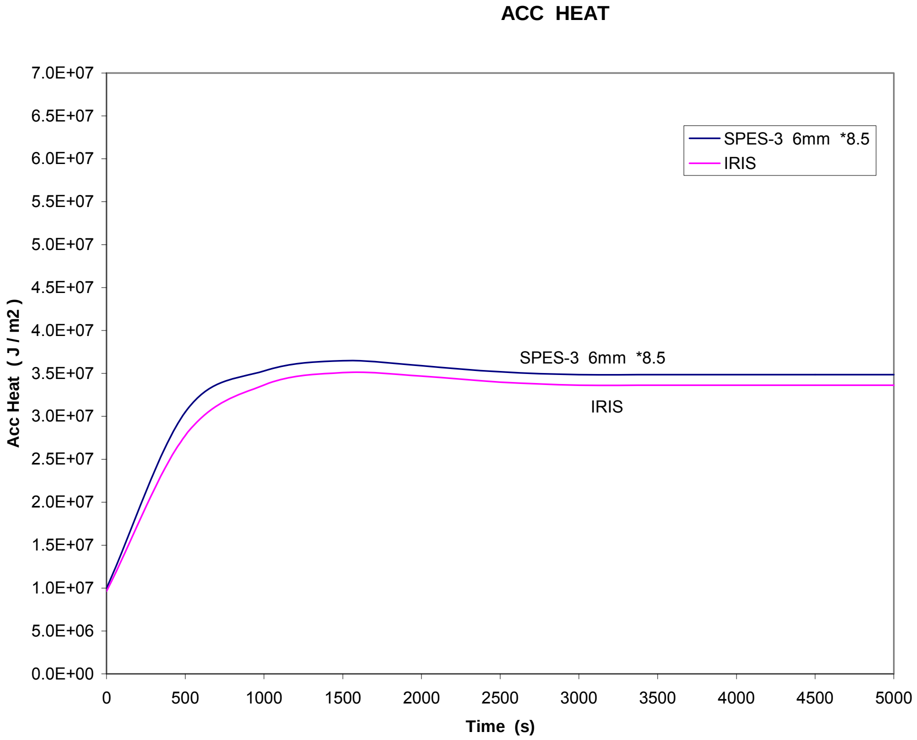


LINER_Foamglass_Insulation_2

file "IRIS_SPES3_Conf Call Minutes #109 Att 3 MATCH IRIS_SPES-3.doc

MATCH IRIS_SPES-3
(Heat Capacity scaled 1:100)

SPES-3 Dry-well		IRIS CONTAINMENT	
MATERIAL	***THICKNESS***	***MATERIAL***	***THICKNESS***
AISI 304	6 mm	CARBON STEEL	44 mm
INITIAL TEMPERATURE 48.9 C		***INITIAL TEMPERATURE 48.9 C***	
BOUNDARY CONDITION RIGHT SIDE (IRIS INTERNAL TEMPERATURE)		***BOUNDARY CONDITION RIGHT SIDE (IRIS INTERNAL TEMPERATURE)***	
BOUNDARY CONDITION LEFT SIDE Tair =35 Hconv=10 W/m2-K		***BOUNDARY CONDITION LEFT SIDE Tair =35 Hconv=10 W/m2-K***	



MATCH IRIS_SPES-3

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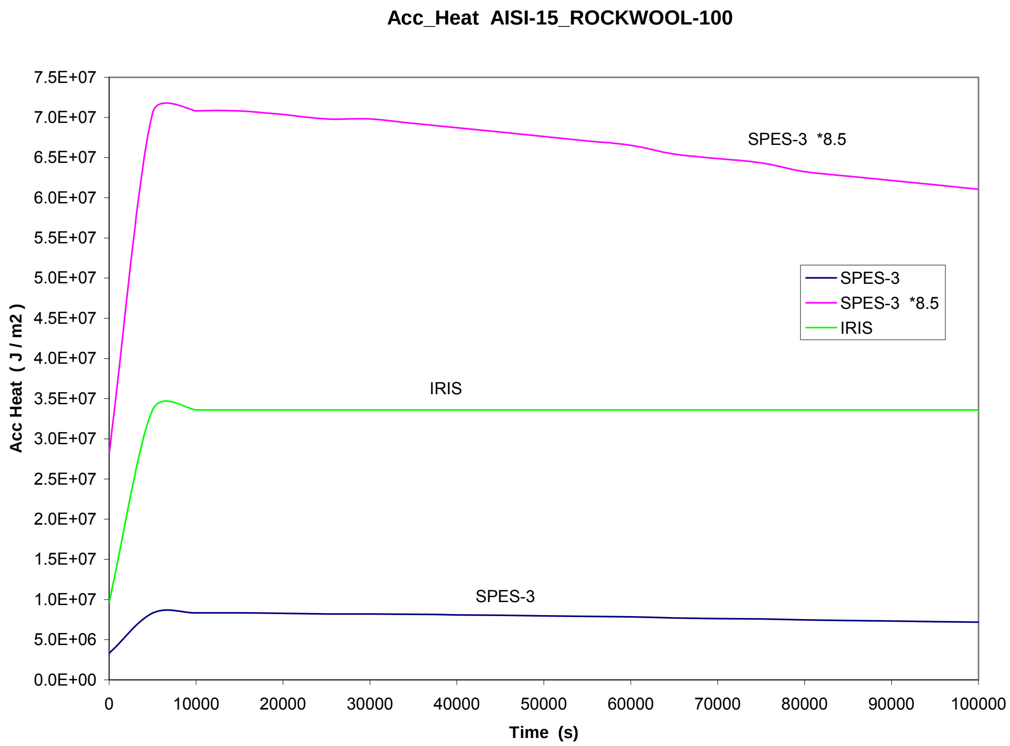
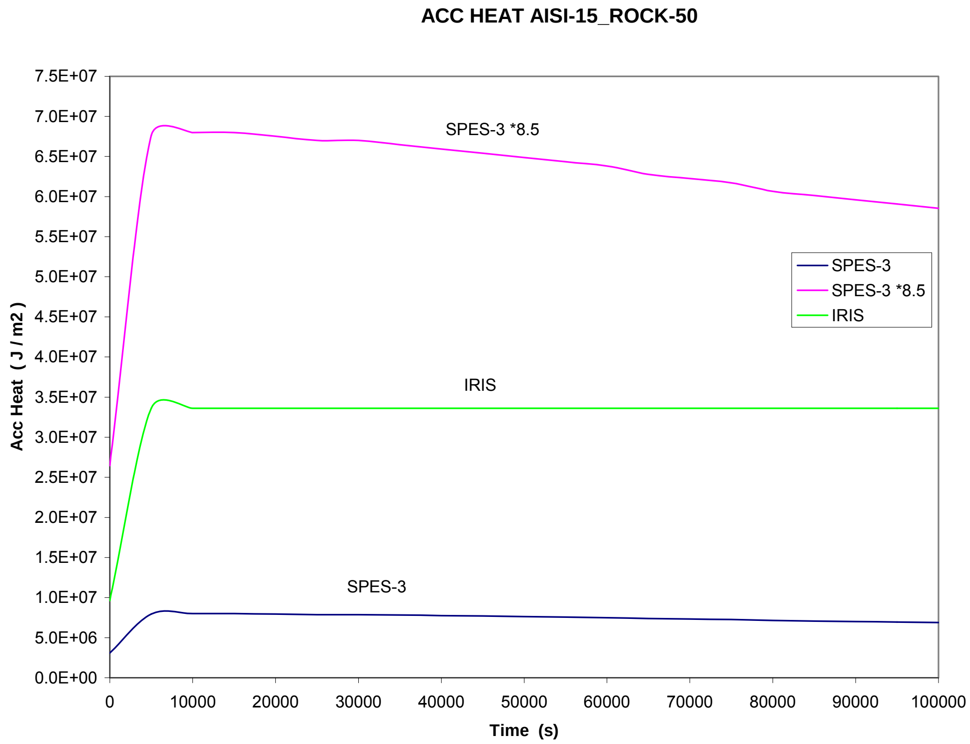
NO_INSULATION
CASE1_100mm ROCKWOOL

SPES-3 Dry-well		IRIS CONTAINMENT	
MATERIAL	***THICKNESS***	***MATERIAL***	***THICKNESS***
AISI 304	15 mm	CARBON STEEL	44 mm
ROCKWOOL	100 mm		
INITIAL TEMPERATURE 20 C		***INITIAL TEMPERATURE 48.9 C***	



CASE2_50mm ROCKWOOL

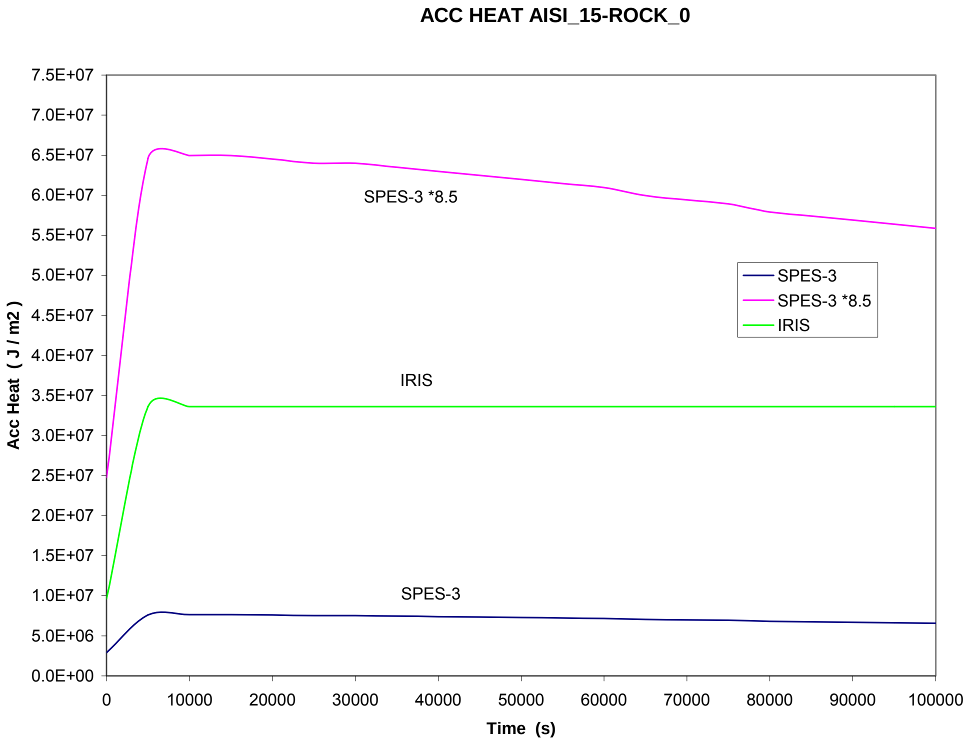
SPES-3 Dry-well		IRIS CONTAINMENT	
MATERIAL	***THICKNESS***	***MATERIAL***	***THICKNESS***
AISI 304	15 mm	CARBON STEEL	44 mm
ROCKWOOL	50 mm		
INITIAL TEMPERATURE 20 C		***INITIAL TEMPERATURE 48.9 C***	



NO_INSULATION

CASE3_0mm ROCKWOOL

SPES-3 Dry-well		IRIS CONTAINMENT	
MATERIAL	***THICKNESS***	***MATERIAL***	***THICKNESS***
AISI 304	15 mm	CARBON STEEL	44 mm
ROCKWOOL	0 mm		
INITIAL TEMPERATURE 20 C		***INITIAL TEMPERATURE 48.9 C***	



NO_INSULATION

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Ht1 is model used for comparison till now
Ht4 is like Ht1 except discharge to containment in form of droplets (not continous liquid as in Ht1) and recirculation RWST pool model (with roughly the same reduced water amount like Ht1)
Ht5 is like Ht4 except new main PSS vents, correct amount of water in RWST pools and added heat structures in containment model (Ht5 is upt 15070 s)

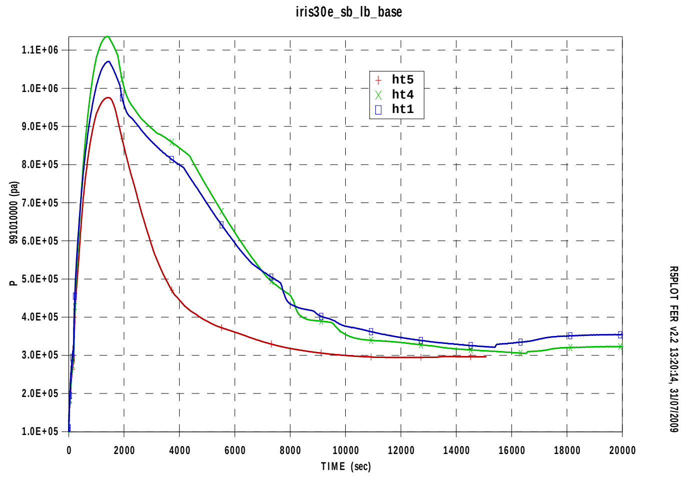

Fig.A9. 1 IRIS DW pressure

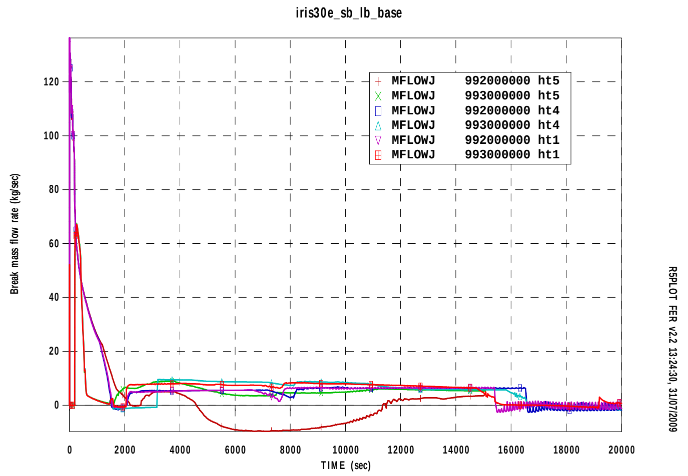

Fig.A9. 2 IRIS break mass flow

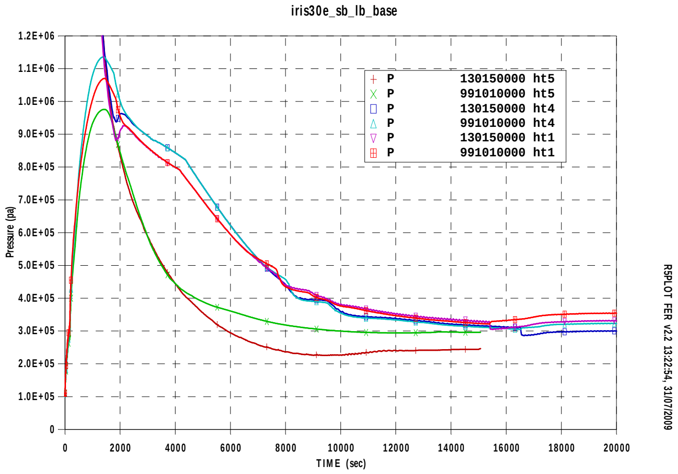

Fig.A9. 3 IRIS PRZ and DW pressure

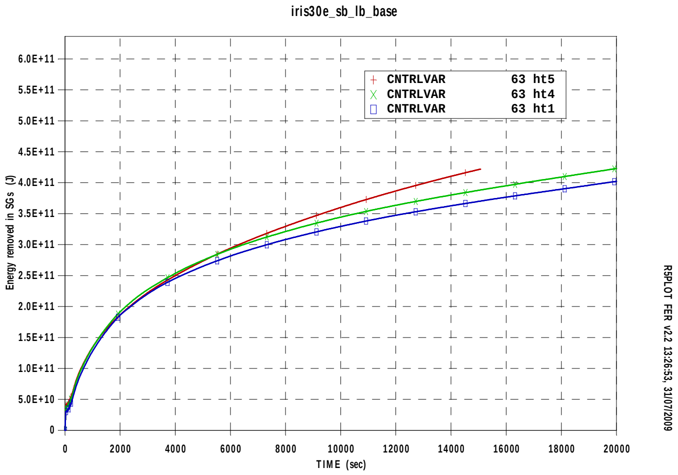

Fig.A9. 4 IRIS SG removed energy

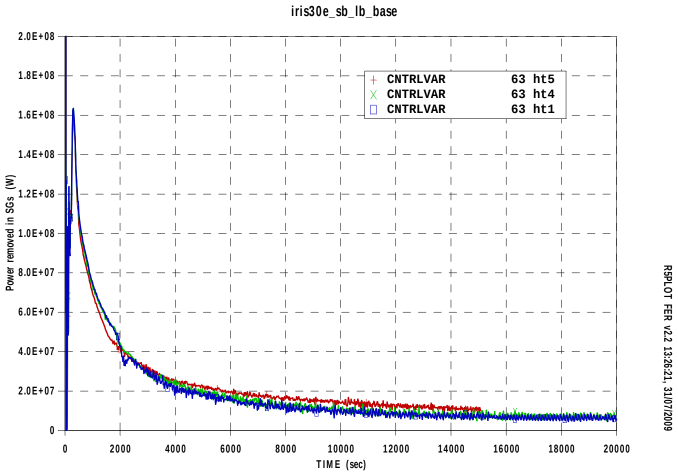

Fig.A9. 5 IRIS SG removed power

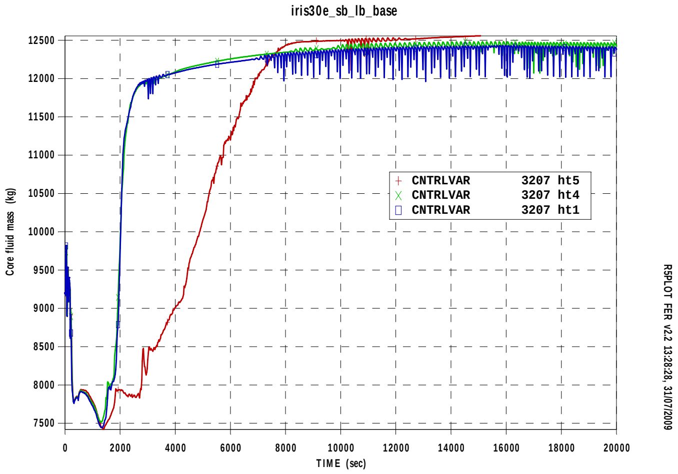

Fig.A9. 6 IRIS core fluid mass

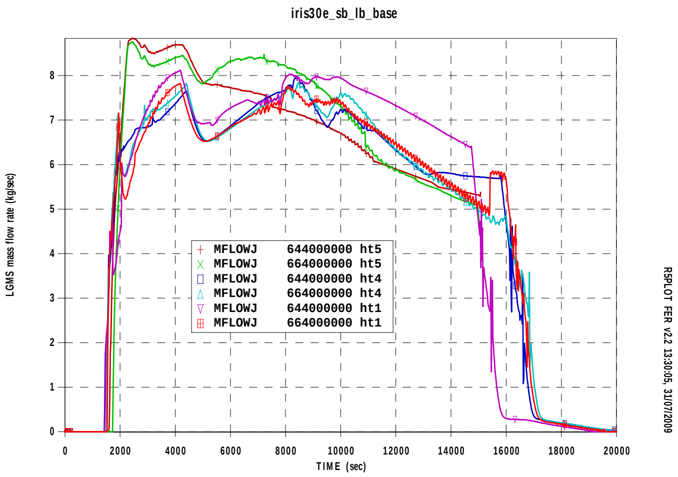

Fig.A9. 7 IRIS LGMS to DVI mass flow

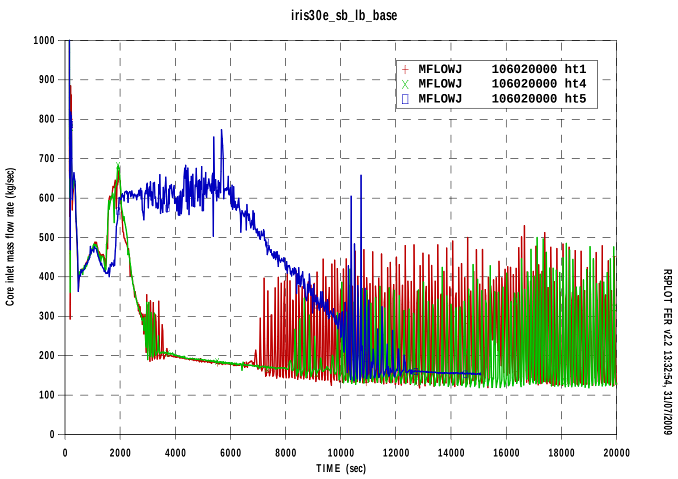

Fig.A9. 8 IRIS core inlet mass flow

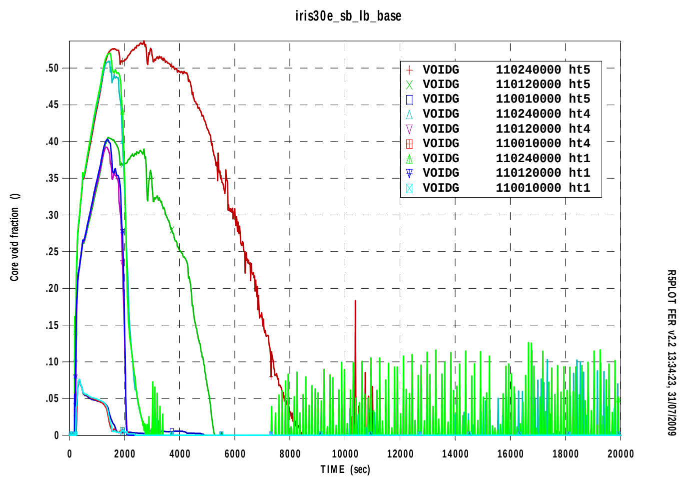

Fig.A9. 9 IRIS core void fraction

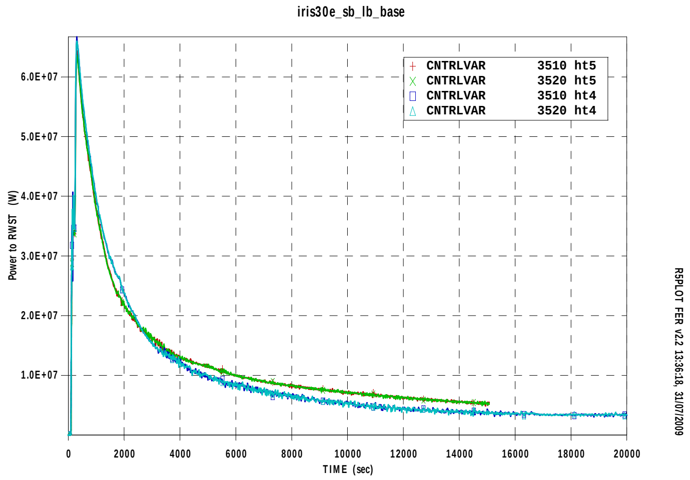

Fig.A9. 10 IRIS RWST removed power

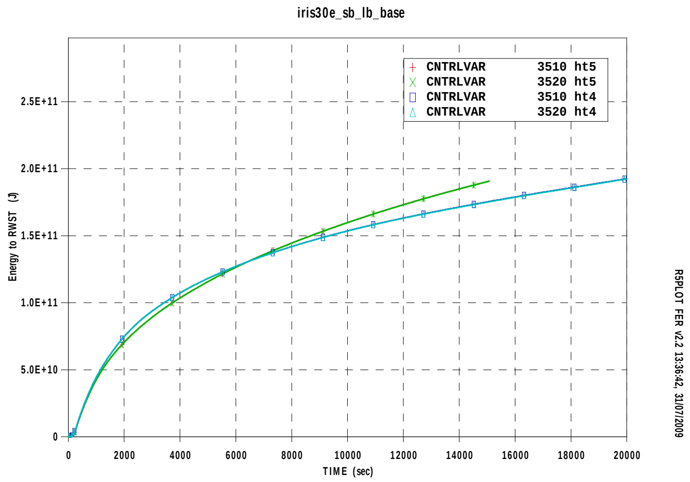

Fig.A9. 11 IRIS RWST removed energy

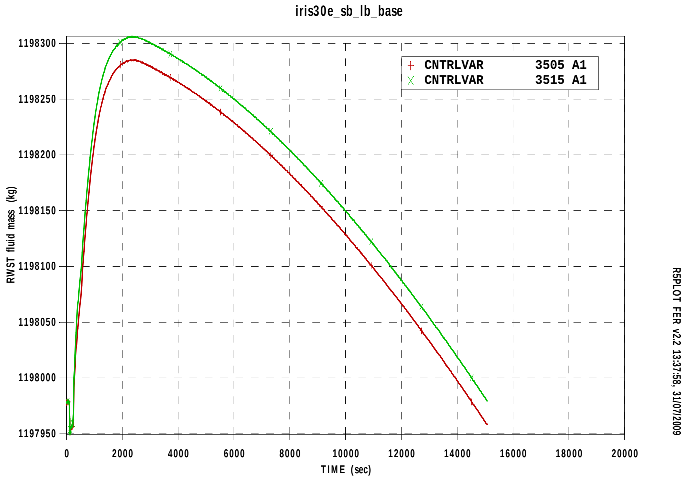

Fig.A9. 12 IRIS RWST fluid mass

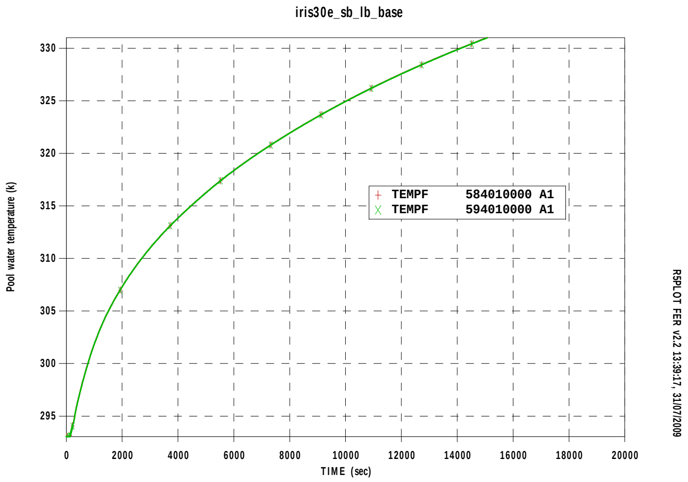

Fig.A9. 13 IRIS RWST water temperature

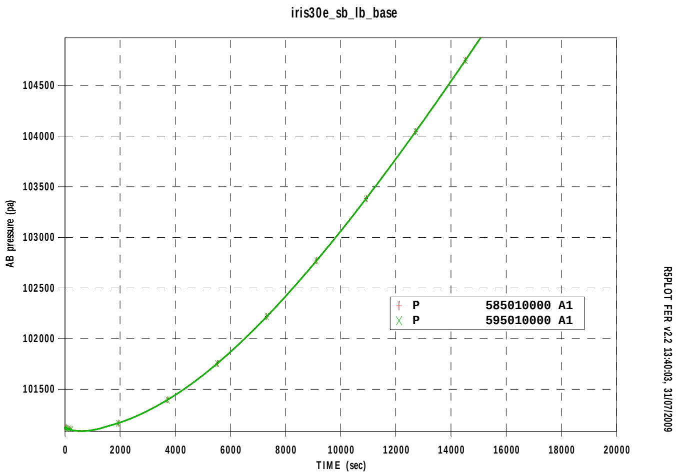

Fig.A9. 14 IRIS RWST pressure

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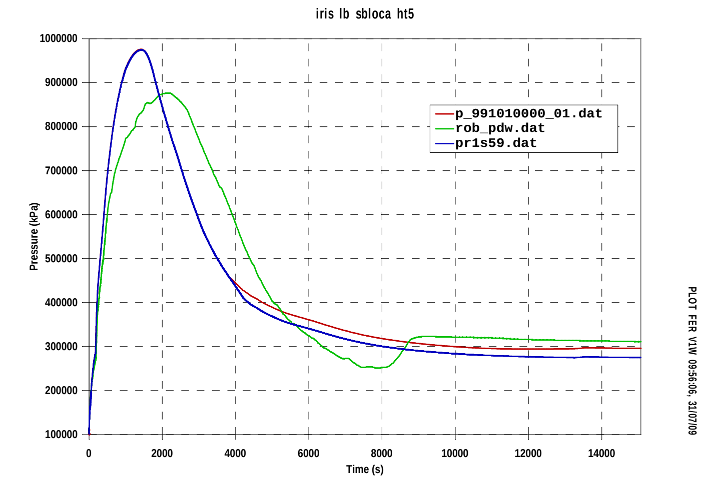


Fig.A9. 15 IRIS DW pressure

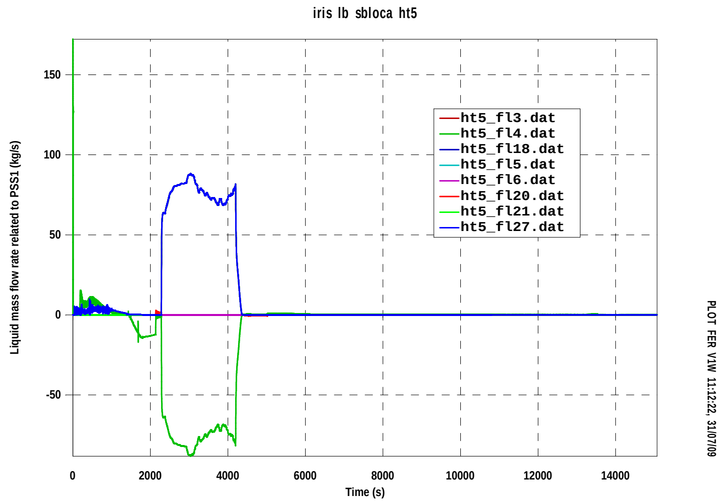


Fig.A9. 16 IRIS mass flow to PSS1

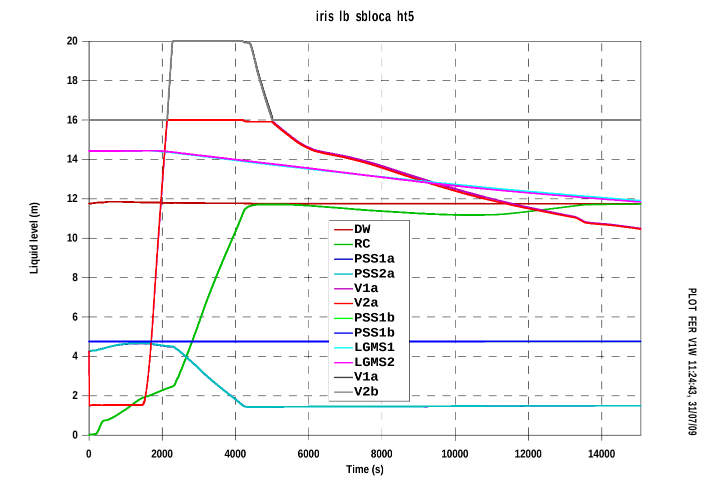


Fig.A9. 17 IRIS containment tank liquid level

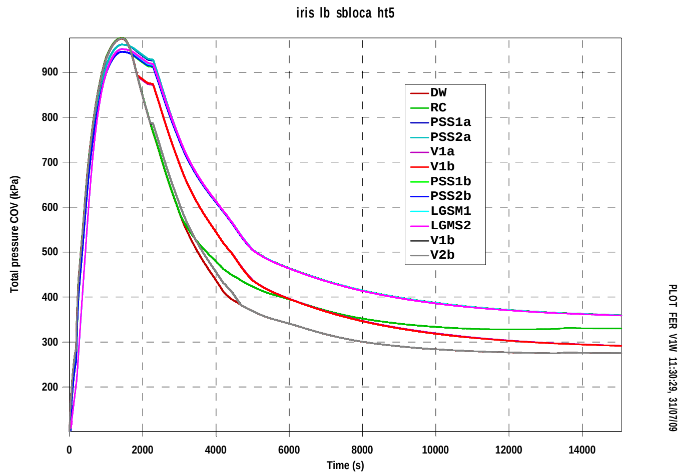


Fig.A9. 18 IRIS containment volume pressure

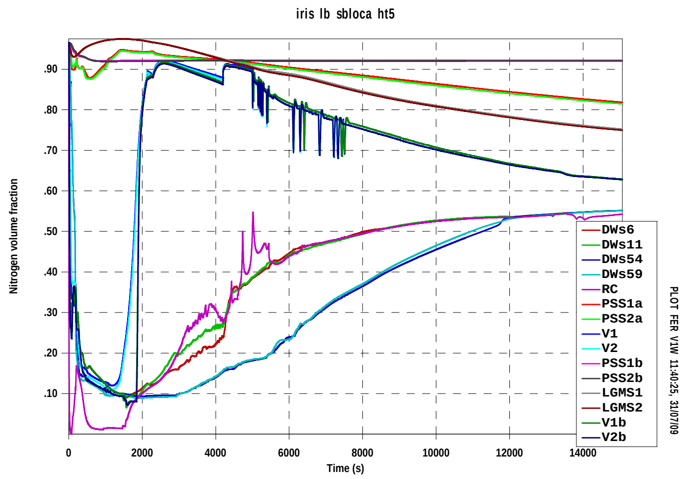


Fig.A9. 19 IRIS containment volume nitrogen fraction

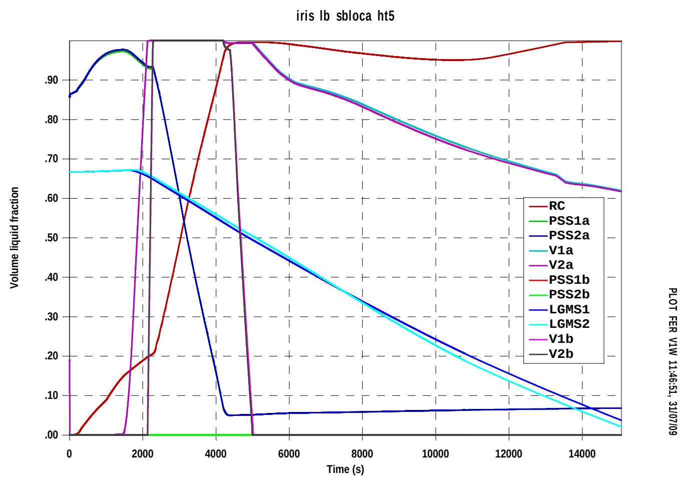


Fig.A9. 20 IRIS containment volume liquid fraction

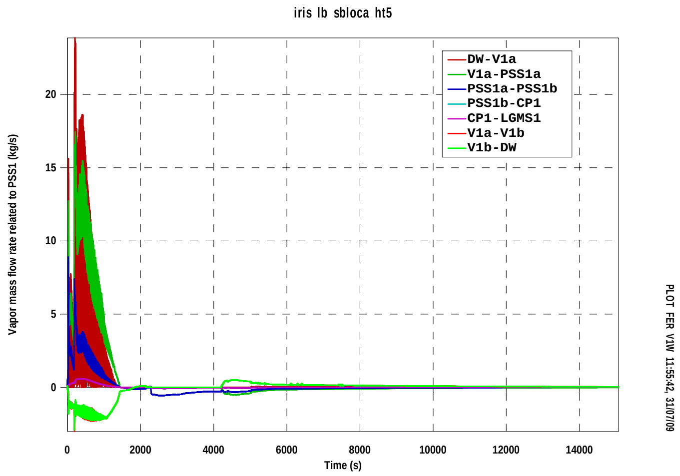


Fig.A9. 21 IRIS PSS1 vapor mass flowrate

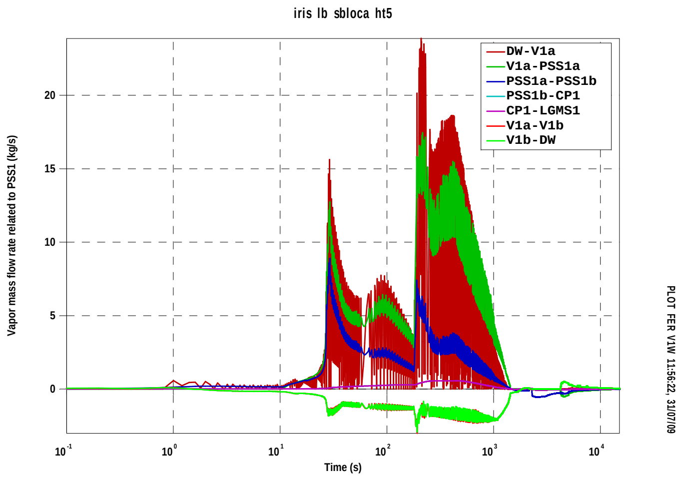


Fig.A9. 22 IRIS PSS1 vapor mass flowrate

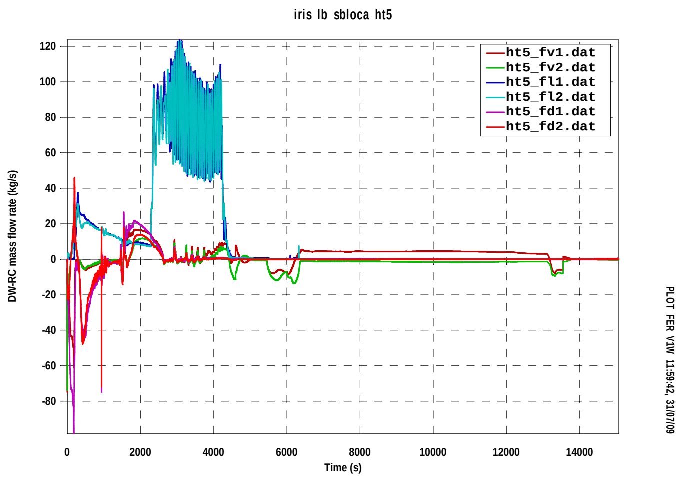


Fig.A9. 23 IRIS DW-RC mass flowrate

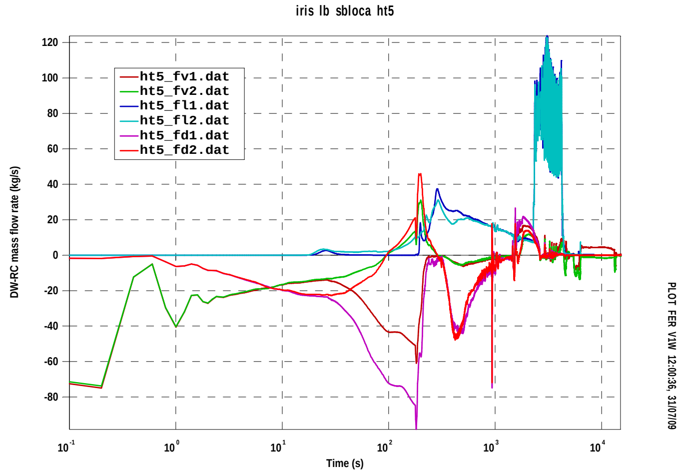


Fig.A9. 24 IRIS DW-RC mass flowrate

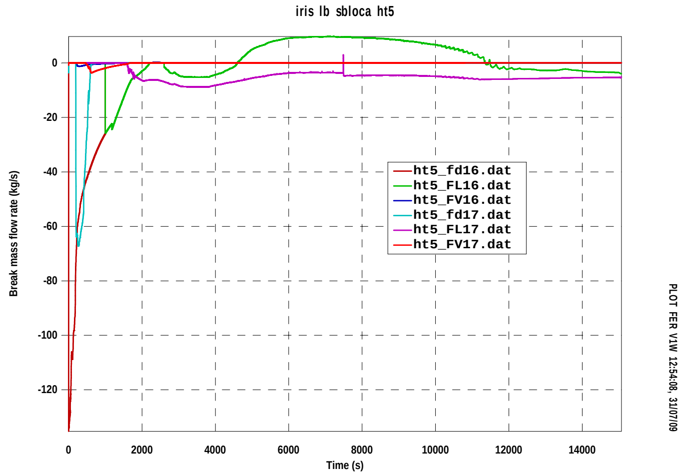


Fig.A9. 25 IRIS break mass flowrate

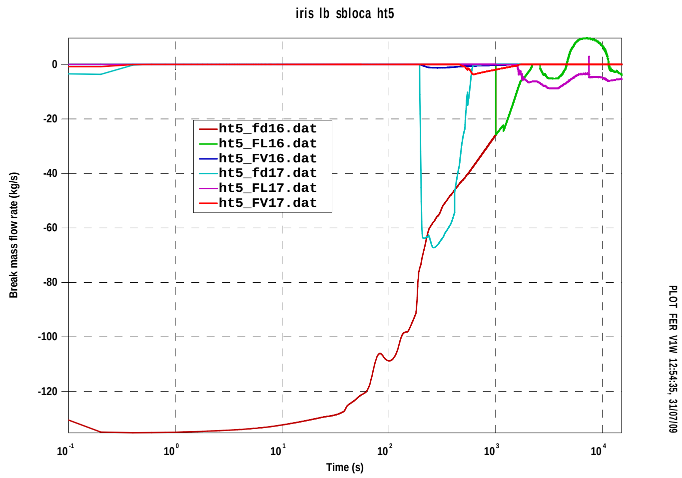


Fig.A9. 26 IRIS break mass flowrate

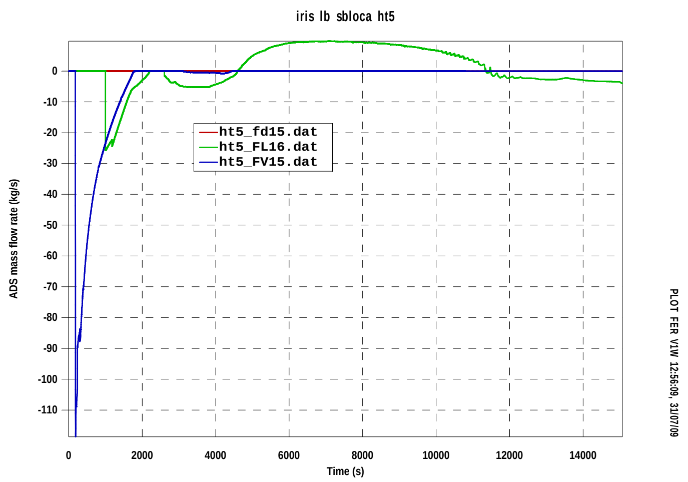


Fig.A9. 27 IRIS ADS mass flowrate

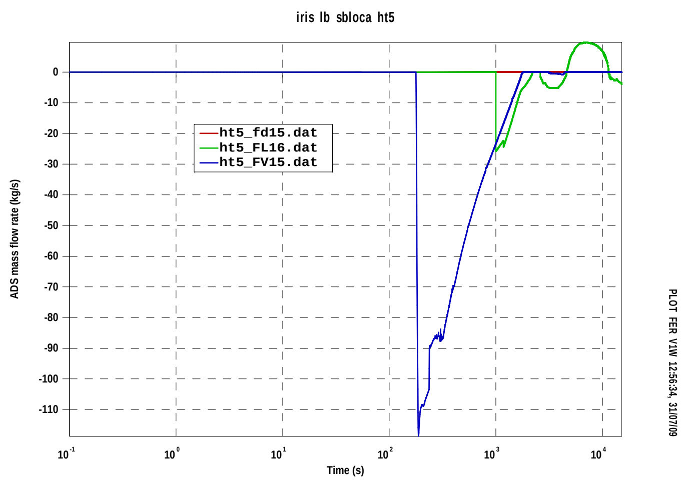


Fig.A9. 28 IRIS ADS mass flowrate

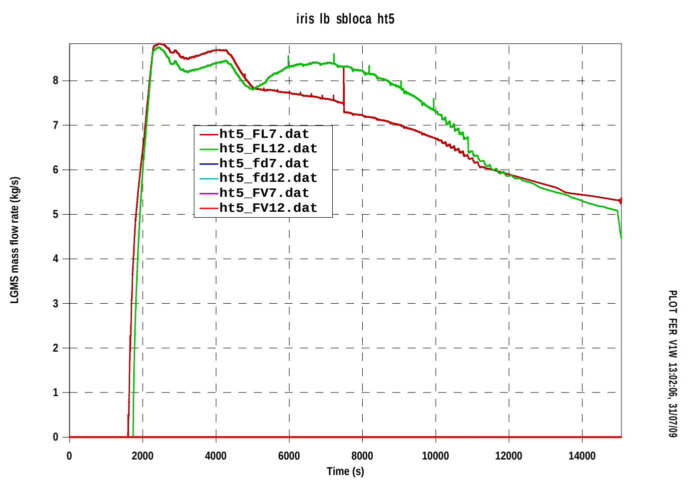


Fig.A9. 29 IRIS LGMS mass flowrate

A.9 Attachments to conf-call #116

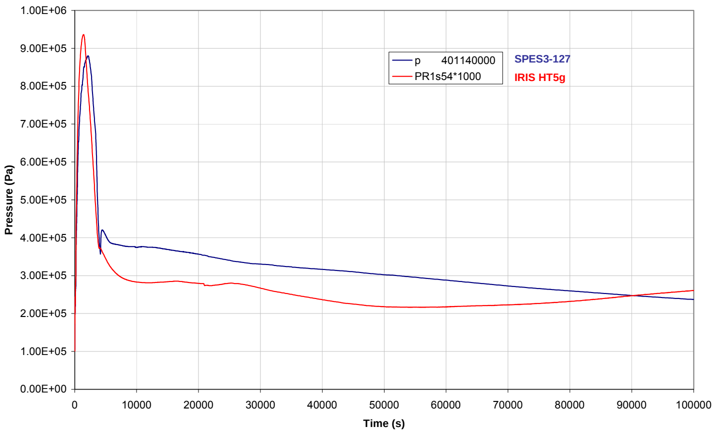
file "IRIS_SPES3_Conf Call Minutes #116 Att 1 Energy balance-127-HT5g.doc"

R. Ferri, A. Achilli SIET, Nov. 6th, 2009

SPES3-127 and IRIS HT5g DVI DEG break
HEAT TRANSFER

Starting point: investigation of differences between SPES3 and IRIS DW pressures in the long term, Fig.A10. 1

Fig.A10. 1 DW pressure



Investigated the Heat transfer between Primary circuit and SG and between EHRS and RWST.

(check after time 40000 s)

PRIMARY CIRCUIT - SG

P (PRZ) => Tsat (P_{PRZ})
P (SG) => Tsat (P_{SG})
DT_1 = T (PRZ-SG)
SG tot power / DT_1 = h * S (SG) heat transfer coefficient * Surface

EHRS - RWST

P (EHRS) => Tsat (P_{EHRS})
T_{RWST} (P_{SG})
DT_2 = T (EHRS-RWST)
EHRS tot power / DT_2 = h * S (EHRS) heat transfer coefficient * Surface

Globally: **Primary circuit- RWST**

DT_3 = T (PRZ-RWST)
EHRS tot power / DT_3 = h * S (Global) heat transfer coefficient * Surface

Comparing SPES3 and IRIS we observe an opposite operation:

at SG, in SPES3 there is higher DT and lower h*S than in IRIS, Fig.A10. 2 and Fig.A10. 3;
at EHRS, in SPES3 there is lower DT and higher h*S than in IRIS, Fig.A10. 4 and Fig.A10. 5.
Globally in SPES3 there is a higher DT and the same h * S as in IRIS, Fig.A10. 6 and Fig.A10. 7.
This means a higher removed power in SPES3 than IRIS.

The reason for the higher DT in SPES3 than IRIS is that SPES3 RWST is at a lower temperature.

SPES3 RWST model has an upper tmdpvol full of dry air at 20 °C and atmospheric pressure.

Temperature in SPES3 RWST does not reach saturation, even if energy transferred from the primary would say that it boils (9.73E9 J in 100000 s to 23800 kg water with initial temperature 20 °C). RWST max. temperature 94 °C. Local boiling occurs evidenced by voidf oscillations. Void oscillations cause level oscillations of about 1 mm that cause a mass transfer through the upper junction of about 0.01 kg/s.

When cold dry air enters the RWST top volume, it heats up and it is a solvent for water that gets in solution in it.
This is the main reason for RWST loss of mass and low temperature in SPES3.

In IRIS, the total transferred energy is 8.23E9 J in 100000 s to 24000 kg water at initial temperature 20 °C). RWST reached temperature 102 °C.

The energy balance with the evaporated mass at the reached temperature is satisfied.

CONCLUSIONS

1) Observed an inverted heat transfer mode at SG and EHRS between SPES3 and IRIS.

2) RWST model in SPES3 affect the final pool temperature and the decay heat removal that results larger than in IRIS.
Possibility to initialise the control volume with saturated steam instead of cold dry air.

Fig.A10. 2 T (PRZ) – T (SG)

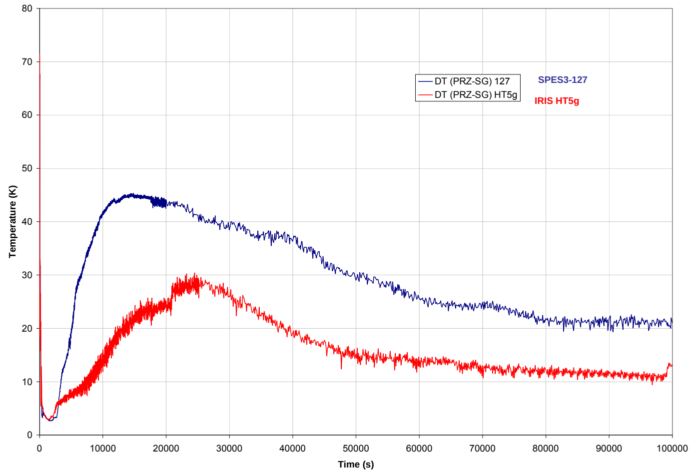


Fig.A10. 3 SG heat transfer coefficient * Surface

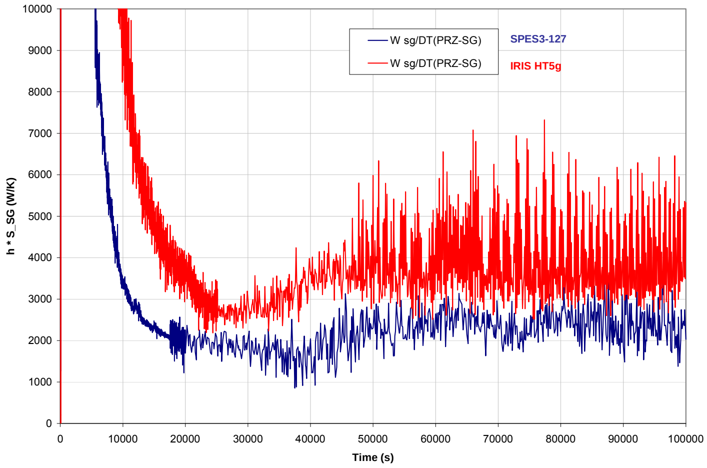


Fig.A10. 4 T (EHRS) – T (RWST)

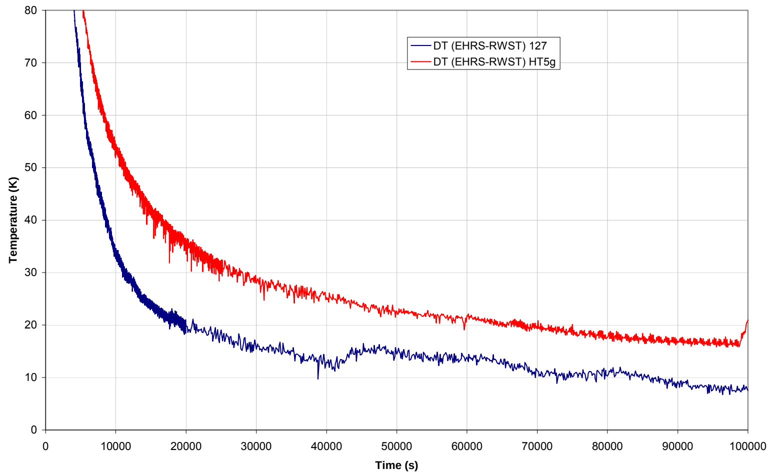


Fig.A10. 5 EHRS heat transfer coefficient * Surface

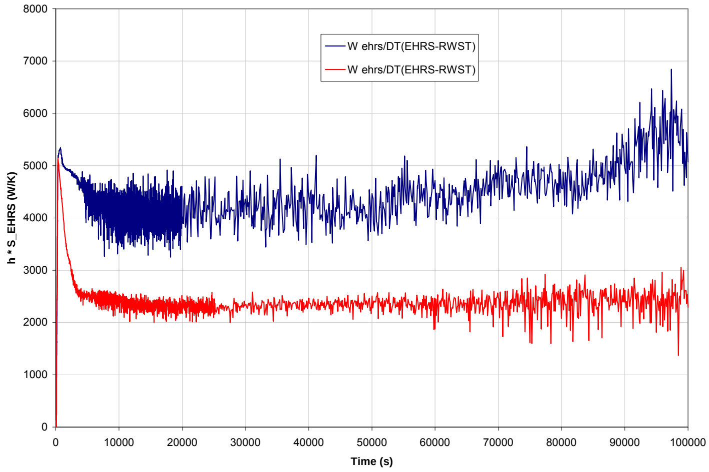


Fig.A10. 6 T (PRZ) – T (RWST)

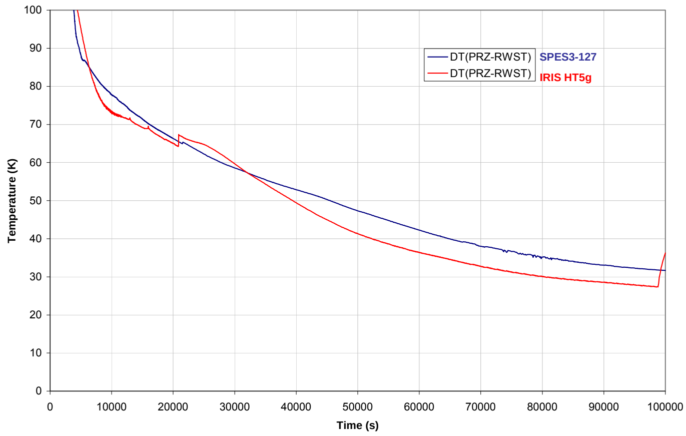


Fig.A10. 7 Global (PRZ-RWST) heat transfer coefficient * Surface

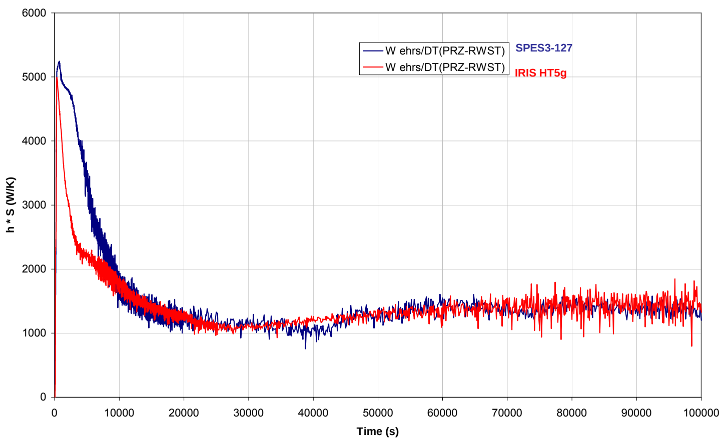


Fig.A10. 8 RWST temperatures

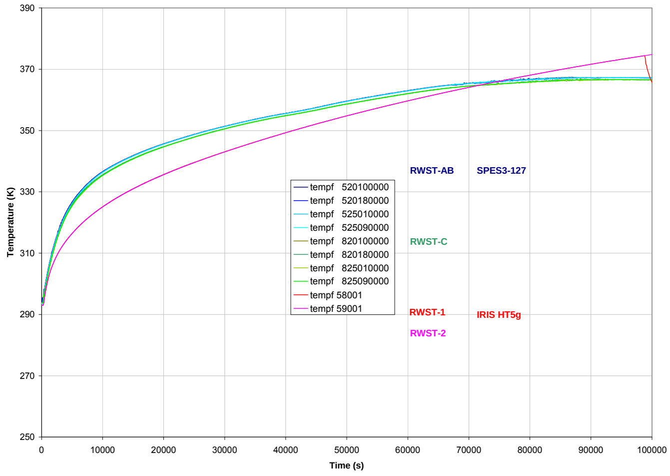
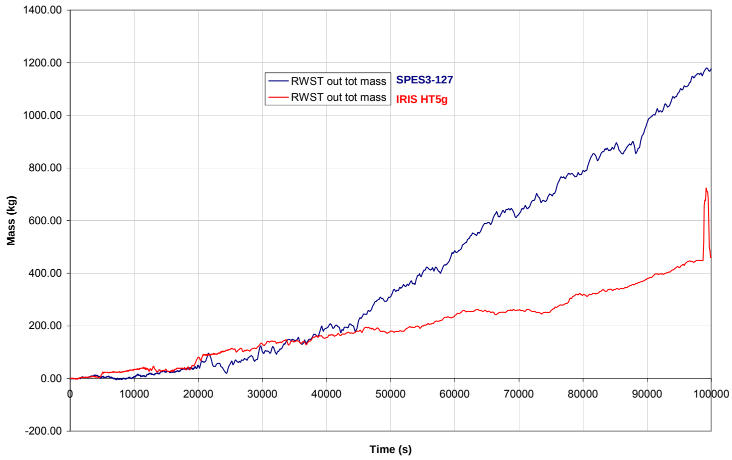
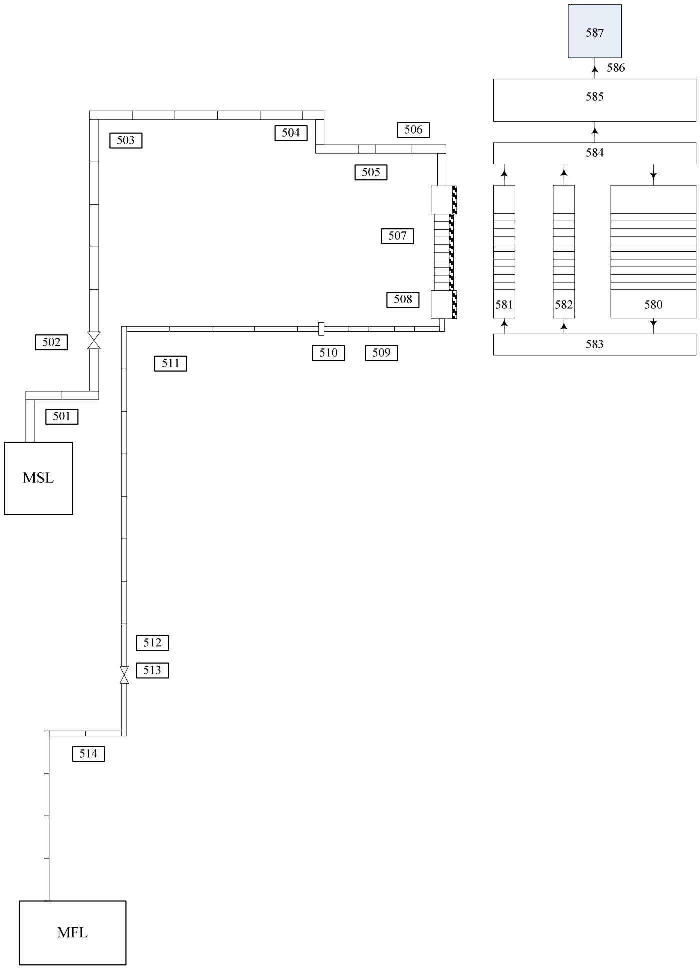


Fig.A10. 9 RWST outgoing mass (mass flow integration in time)



file "IRIS_SPES3_Conf Call Minutes #116 Att 2 Nodalization and droplets.doc"

First part is to explain difference in r5 nodalization
That is basically the only difference in nodalization structure since ht1
Other changes (e.g. change of sg tubes dia) doesn't affect nodalizaiton numbers



You can find dimensions in sent input file starting at line 9994.

580 is pipe representing main water body of rwst1,
581 and 582 are upward oriented pipes representing parts of the pool interacting with ehrs1 and ehrs2 (12 subdivisions, the same slices in all three pipes)
583 and 584 are lower and upper branch where mixing is taking place
585 is single volume connected using single junction 586 to time dependent volume 587
This part is related to droplets
Situation is little bit more complicated than I expected. Droplets are introduced only at break position as you can see in Fig.A10. 11. There are no more droplets in flow paths 16/17 after exactly 1000 s, but introduced droplets are persistent for some time (as you can see for sure not after 10000 s) in affected volumes (settlement and evaporation), Fig.A10. 10. Most affected is reactor cavity and after that drywell volume, vents and vent extensions, ads QT etc. In order to arrive there the droplets are present in flow paths connecting cavity to DW and DW to other volumes. In Fig.A10. 12 and Fig.A10. 13 you can see droplet mass flows in flow paths connecting cavity to DW and DW to main vents (can't be neglected). These are bad news. Good news are in Fig.A10. 14 and Fig.A10. 15, droplet (ED, DD) and liquid enthalpies and densities (EL, DL) are close enough. I am not sure how your programs work, but first and most simple approach would be to add together

liquid and droplet volume fractions in each volume AL=AL+AD and to use only liquid enthalpy and density for resulting liquid. If you are using mass flow rates for something than you have to add together liquid and droplet mass flow rates FL=FL+FD.
I am sending you 3 additional zip files, rwstg_ad with droplet volume fractions (the same as before liquid volume fractions), rwstg_dd with droplet densities (kg/m^3) and rwstg_ed with droplet enthaplies (kJ/kg). Mass flow rates for all 3 components you received earlier.

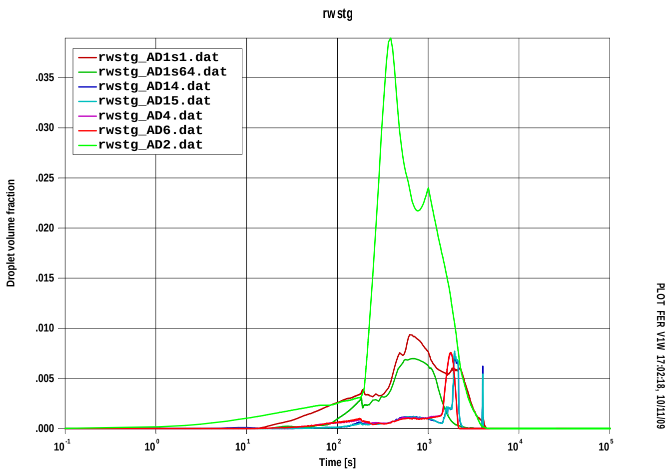


Fig.A10. 10 Droplet volume fraction

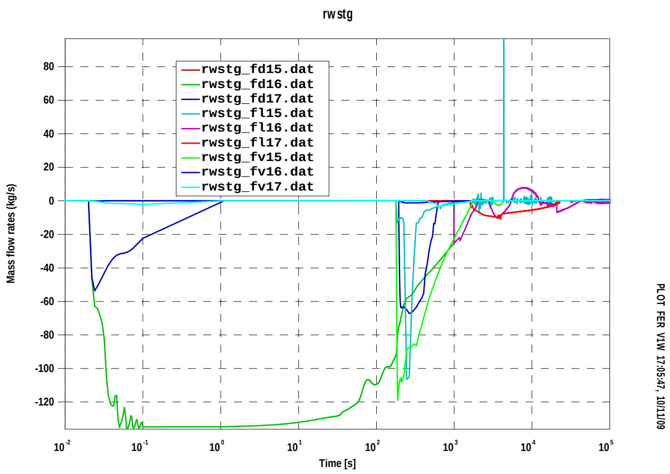


Fig.A10. 11 Containment connection mass flowrates

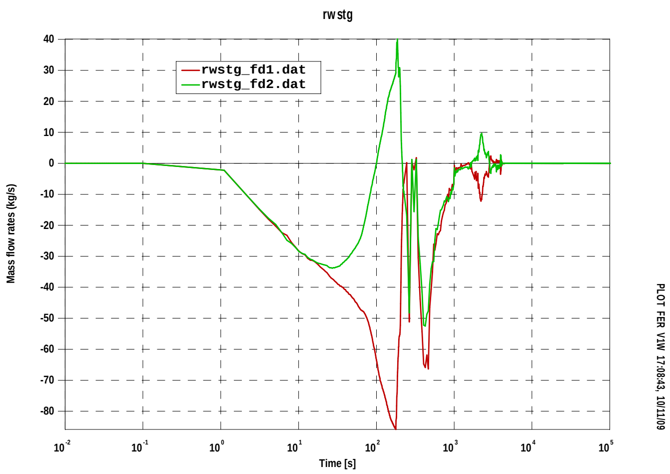


Fig.A10. 12 RC to DW junction droplet mass flow

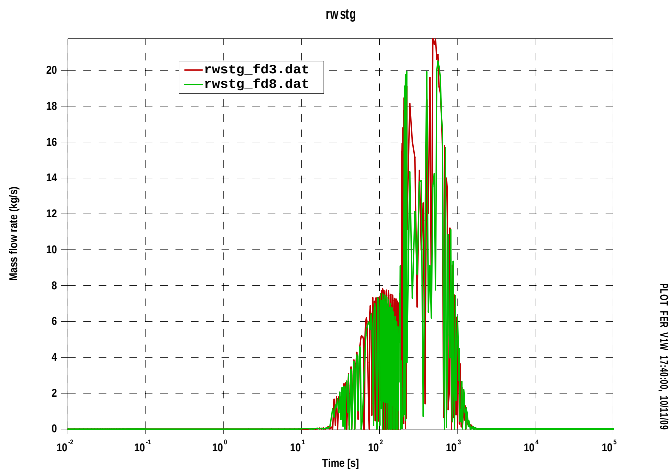


Fig.A10. 13 DW to PSS main vent droplet mass flow

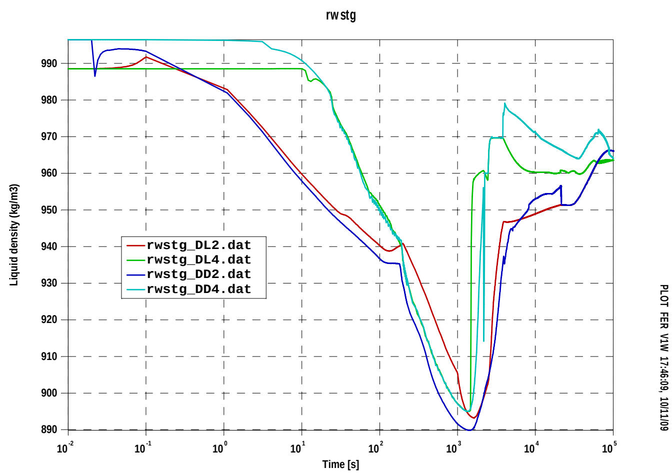


Fig.A10. 14 Liquid and droplet density1

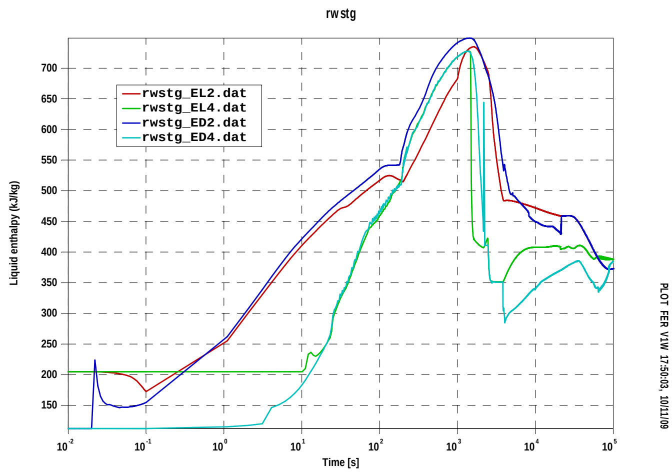


Fig.A10. 15 Liquid and droplet enthalpy

A.10 Attachments to conf-call #117

file "IRIS_SPES3_Conf Call Minutes #117 Att 1 HT5g-129SG and EHRS thermal parameter comparison at SG and EHRS.doc""

SPES3-127 and IRIS HT5g

The comparison between the input parameter reported below shows that:

1) at the SG
In SPES3 there is no correction on the DTh nor on the FF
In IRIS corrections are present on both of them
It seems the left coordinate is different.

2) at the EHRS
In SPES3 there is a correction only on the FF (calibrated on the PERSEO exp-data by means of the Cathare code)
In IRIS there is a correction only on the DTh.

SG

Left geometry
```
*      crdno       Naxial   Nradialmeshp  Geomtype  StState  Leftcoord
SPES3 12711000    48      6             2        1        0.007042
IRIS  12711000    50      6             2        1        0.006542
```

Right geometry
```
*      crdno      Nointervals    Rightcoord
SPES3 12711101   5             0.00873
IRIS  12711101   1             0.007042
IRIS  12711102   4             0.00873
```

```
* left boundary conditions
*      crdno     Boundvol   Incr   BCtype  SAcode  SAfactor[m] Heatstr
SPES3  12711501  271010000  10000  1       1
IRIS   12711501  271010000  10000  1       1
```

```
* right boundary conditions
*      crdno     Boundvol   Incr   BCtype  SAcode  SAfactor[m]  Heatstr
SPES3  12711601  211010000  0      134     1
IRIS   12711601  211010000  0      134     1
```

```
* additional left boundary conditions
*      crdno     Dth       Hlf Hlr gslf gslr gKF gKR boilf natcl   PvsD  FF  Hstr
SPES3  12711801  0.        10. 10. 0.   0.   0.  0.  1.    8.2     1.1   1.  48
IRIS   12711801  0.014084  10. 10. 0.   0.   0.  0.  1.    0.01323 1.1   1.1 50
```

```
* additional right boundary conditions
*      crdno     Dth      Hlf Hlr gslf gslr gKF gKR boilf natcl   PvsD  FF Hstr
SPES3  12711901  0.0      10. 10. 0.   0.   0.  0.  1.    8.2     1.317 1. 48
IRIS   12711901  0.0310   10. 10. 0.   0.   0.  0.  1.    7.9     1.317 1. 50
```

EHRS

```
Left geometry
*      crdno     Naxial  Nradialmeshp  Geomtype  StState  Leftboundary
SPES3  15581000  18      6             2         1        0.022352
IRIS   15071000  10      5             2         1        0.022352

Right geometry
*     crdno          Nointervals     Rightcoord
SPES3 15581101       5               0.025400
IRIS  15071101       4               0.02540


* left boundary conditions
*     crdno     Boundvol   Incr    BCtype  SAcode  SAfactor[m] Heatstr
SPES3 15581501  558010000  10000   101     1
IRIS  15071501  507010000  10000   1       0

* right boundary conditions
*     crdno     Boundvol   Incr    BCtype  SAcode  SAfactor[m]  Heatstr
SPES3 15581601  520180000  -10000  101     1
IRIS  15071601  581110000  -10000  110     0

* additional left boundary conditions
*      crdno     Dth      Hlf  Hlr gslf gslr gKF gKR boilf natcl PvsD FF     Hstr
SPES3  15581801  0.0      10.  10. 0.   0.   0.  0.  1.    1.8   1.1  2.725  18
IRIS   15071801  0.00028  0.9  0.9 0.   0.   0.  0.  1.    0.1   1.0  1.0    10

* additional right boundary conditions
*      crdno     Dth      Hlf Hlr gslf gslr gKF gKR boilf natcl PvsD FF      Hstr
SPES3  15581901  0.0      10. 10. 0.   0.   0.  0.  1.    1.8   1.1  3.54284 18
IRIS   15071901  0.19300  0.9 0.9 0.   0.   0.  0.  1.    1.75  2.1  1.0     10
```

SPES3-129

Modifications with respect to SPES3-127: added a 5 inch pipe on RWST top, 4 m long (2 m horizontal and 2 m vertical), to discharge steam to atmosphere.
Such pipe dumps mass oscillations observed in SPES3-127 and solves the RWST behavior problem: water saturation is reached.

Anyway it does not solve the DW pressure differences.

Fig.A11. 1 DW Pressure

red = IRIS

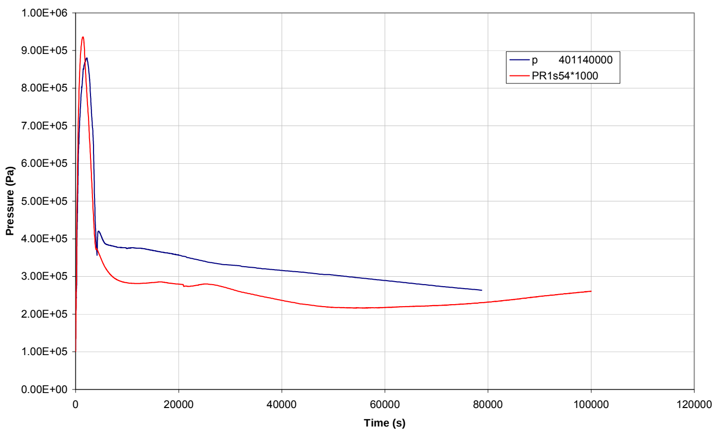


Fig.A11. **2** RWST temperature

pink = IRIS

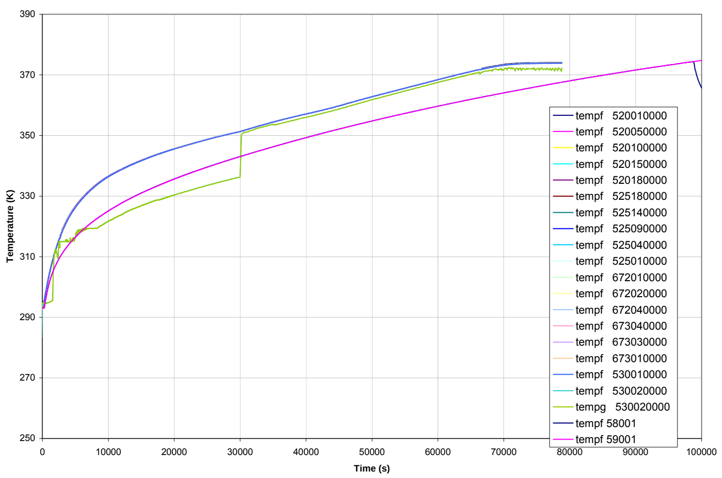


Fig.A11. 3 RWST outgoing mass

red = IRIS

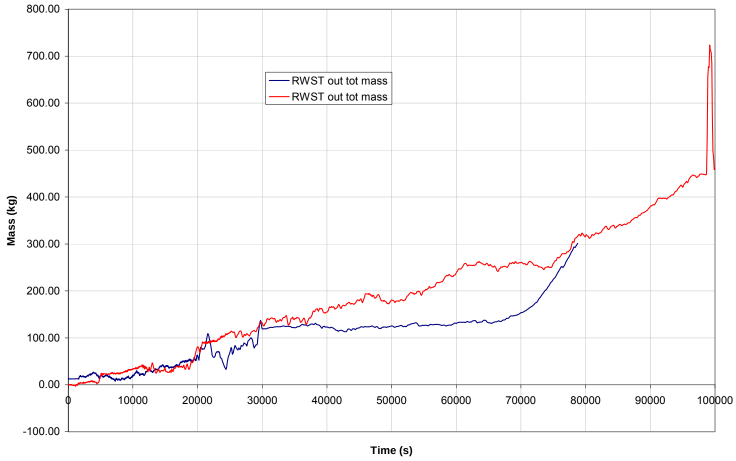


Fig.A11. 4 RWST power

red = IRIS

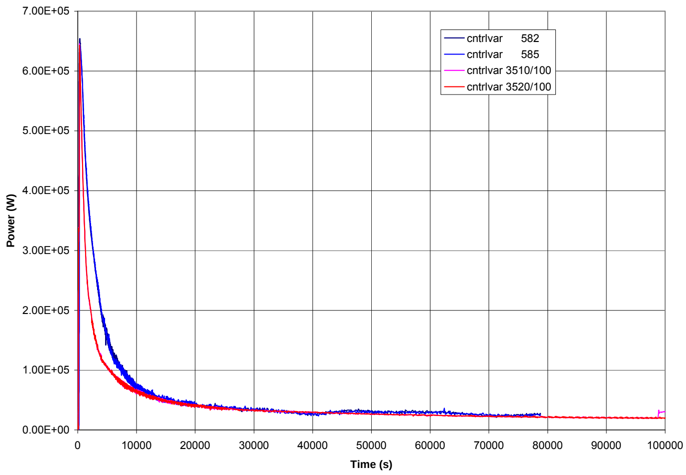
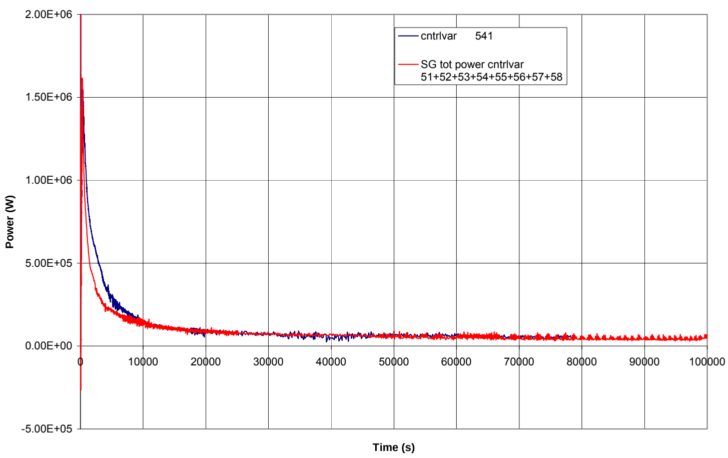


Fig.A11. 5 SG power

red = IRIS



A.11 Attachments to conf-call #118

file "IRIS_SPES3_Conf Call Minutes #118 Att 1 RWST-EHRSA stand alone.doc"

C. Congiu, R. Ferri, Nov 20 2009

Stand alone model EHRS-RWST

CASE 1

1 EHRS module in RWST (EHRS-A).

Inlet pressure 80 bar, inlet mass flow 0.17 kg/s, saturated steam
Outlet pressure 80 bar, saturated water.
RWST initial temperature 20 °C, atmospheric pressure.

Quasi-steady conditions reached around 600 s.
EHRS power 331 kW (average between 1000s and 2000 s)

CASE 2

1 EHRS module in RWST

Inlet pressure 1.5 bar, inlet mass flow 0.012 kg/s, saturated steam
Outlet pressure 1.5 bar, saturated water.
RWST initial temperature 20 °C, atmospheric pressure.
EHRS power 26.9 kW (average between 4000s and 5000 s)

Considerations:

Both cases begins with RWST cold water and the low pressure heat transfer conditions are surely different from reality when water is boiling.

EHRS-A in SPES3 has three tubes. IRIS has 240 tube.
In order to simulate 2.4 tubes, 0.6 tube is thermally insulated with a layer of teflon as well as the top and bottom header.
This insulation reduces the heat transfer coefficient, but it is not completely led to zero.
So, this can be a possible explenation for the larger heat transfer in SPES3 EHRS observed in SPES3-127 case compared to IRIS HT5g.

EHRS-B in SPES3 has 3 tubes as well (0.6 insulated) and EHRS-C has 5 tubes (with no insulation).
EHRS-B and C are not simulated in this stand-alone model.

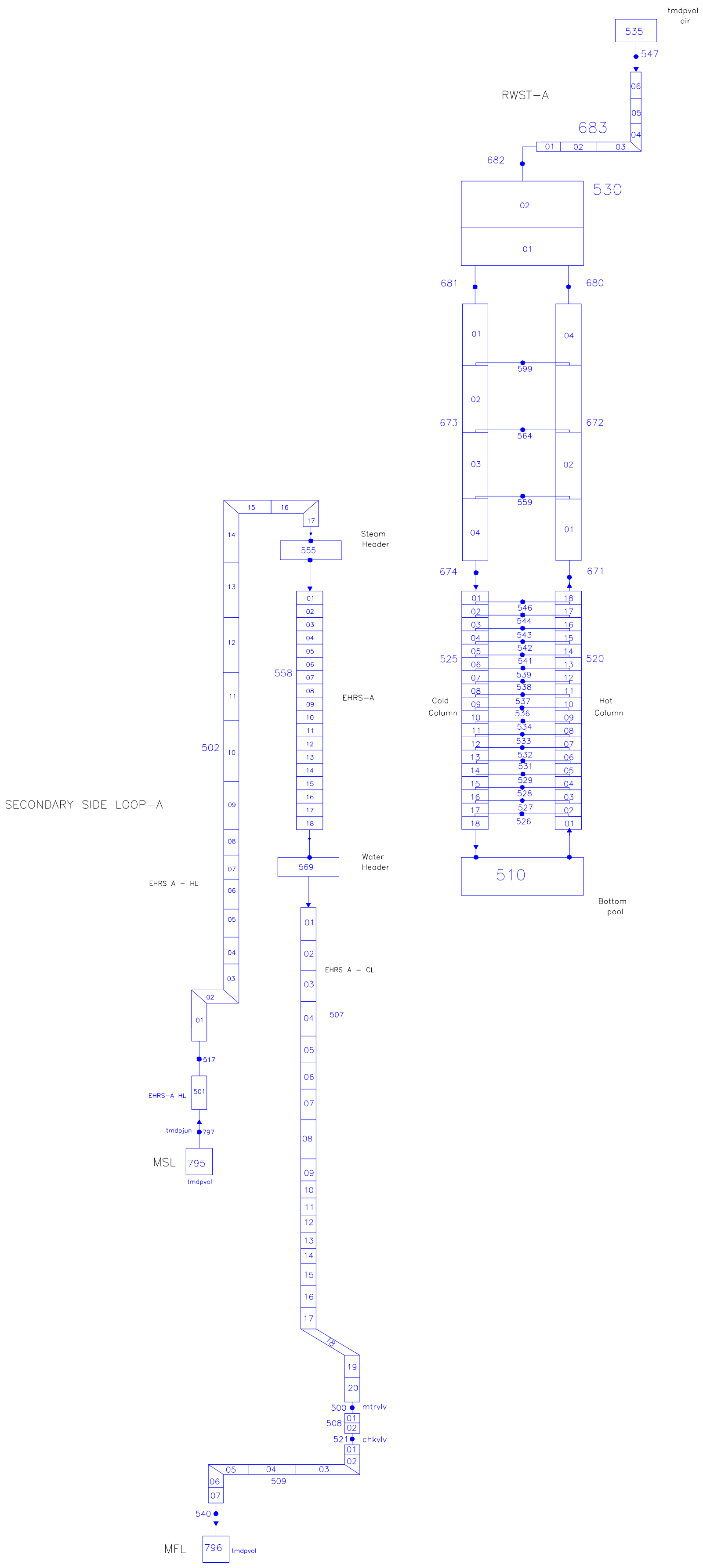


Fig.A12. 1 SPES3 EHRS-RWST stand alone RELAP model

CASE 1

Tab.A12. 1 EHRS-RWST stand alone model CASE1

Time (s)	RWST Power (kW) Aver 1000-2000s	EHRSA Power (kW) Aver 1000-2000s	Inlet flow (kg/s)	Pressure (MPa)
1000 - 2000	339	331	0.17	8

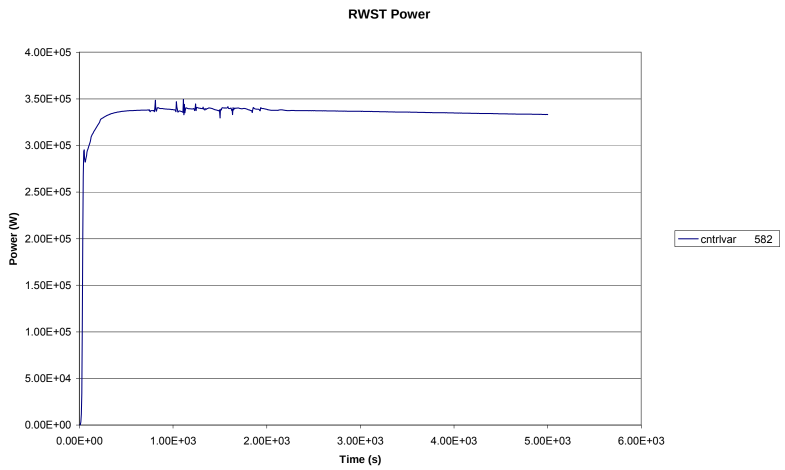


Fig.A12. 2 EHRS-RWST stand alone model CASE1 RWST power

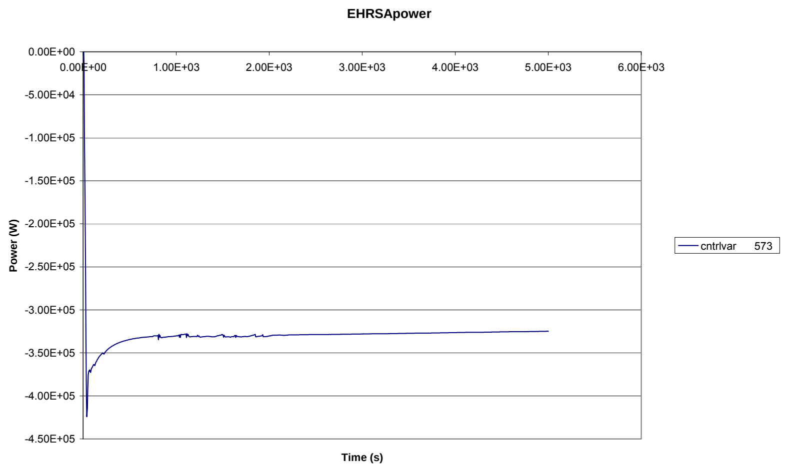


Fig.A12. 3 EHRS-RWST stand alone model CASE1 EHRSA power

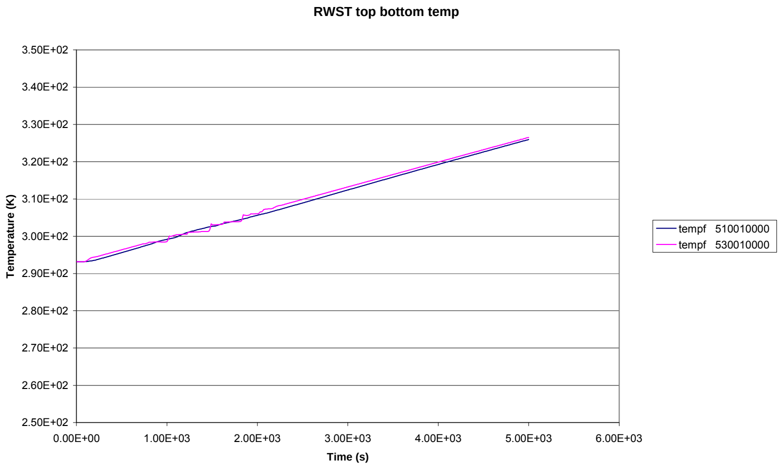


Fig.A12. 4 EHRS-RWST stand alone model CASE1 pool temperature

EHRS heat transfer cefficient at EHRS

```
0 HEAT STRUCTURE OUTPUT +++time=     1800.04     sec
  str.no. side   bdry.vol.  surface  heat-trf.    heat-flux    critical    CHF   ht   heat-trf.   int.-heat    conv+rad     vol.ave.
                number    temp.    convection   convection   heat-flux    mul  mode  coef.conv    source      -source       temp.
                           (K)      (Watt)       (Watt/m2)    (Watt/m2)            (Watt/m2-K)  (Watt)       (Watt)       (K)

 5551-001  left  555-010000  567.738  -1149.1      -3540.1       0.0000      0.00  10     27600.       0.0000      -38.059     483.67
           right 672-010000  308.201   1111.0       2004.8       0.0000      0.00  20     1159.4
 5581-001  left  558-010000  520.227  -25948.    -7.40957E+05   0.0000      0.00  10     27430.       0.0000      -86.264     459.05
           right 520-180000  401.340   25861.     6.49874E+05  1.44897E+07 0.85  23     17955.
 5581-002  left  558-020000  509.436  -23598.    -6.73868E+05   0.0000      0.00  10     19626.       0.0000      -29.719     453.48
           right 520-170000  400.785   23568.     5.92257E+05  1.47008E+07 0.85  23     15487.
 5581-003  left  558-030000  503.700  -22421.    -6.40261E+05   0.0000      0.00  10     16580.       0.0000      -24.223     450.38
           right 520-160000  400.228   22397.     5.62821E+05  1.48604E+07 0.85  23     14445.
 5581-004  left  558-040000  499.708  -21609.    -6.17078E+05   0.0000      0.00  10     14769.       0.0000      -20.239     448.21
           right 520-150000  399.820   21589.     5.42520E+05  1.49745E+07 0.85  23     13729.
 5581-005  left  558-050000  496.611  -20990.    -5.99402E+05   0.0000      0.00  10     13508.       0.0000      -16.888     446.51
           right 520-140000  399.458   20974.     5.27049E+05  1.50413E+07 0.85  23     13219.
 5581-006  left  558-060000  494.043  -20497.    -5.85306E+05   0.0000      0.00  10     12556.       0.0000      -12.750     445.06
           right 520-130000  399.067   20484.     5.14749E+05  1.50367E+07 0.85  23     12903.
 5581-007  left  558-070000  491.811  -20092.    -5.73756E+05   0.0000      0.00  10     11794.       0.0000      -10.730     443.73
           right 520-120000  398.616   20082.     5.04636E+05  1.49536E+07 0.85  23     12768.
 5581-008  left  558-080000  489.845  -19750.    -5.63966E+05   0.0000      0.00  10     11176.       0.0000      -9.4940     442.54
           right 520-110000  398.159   19740.     4.96051E+05  1.48322E+07 0.85  23     12735.
 5581-009  left  558-090000  488.058  -19448.    -5.55367E+05   0.0000      0.00  10     10629.       0.0000      -8.6039     441.43
           right 520-100000  397.696   19440.     4.88507E+05  1.46850E+07 0.85  23     12782.
 5581-010  left  558-100000  486.474  -19191.    -5.48027E+05   0.0000      0.00  10     10214.       0.0000      -7.9243     440.42
           right 520-090000  397.240   19183.     4.82065E+05  1.45214E+07 0.85  23     12912.
 5581-011  left  558-110000  484.885  -18939.    -5.40826E+05   0.0000      0.00  10     9706.7       0.0000      -7.3858     439.40
           right 520-080000  396.759   18932.     4.75741E+05  1.41718E+07 0.85  23     13097.
 5581-012  left  558-120000  483.650  -18783.    -5.36374E+05   0.0000      0.00  10     9595.6       0.0000      -9.3513     438.51
           right 520-070000  396.198   18774.     4.71774E+05  1.37418E+07 0.85  23     13615.
 5581-013  left  558-130000  479.388  -18129.    -5.17692E+05   0.0000      0.00  10     6176.2       0.0000      -12.638     435.72
           right 520-060000  394.821   18116.     4.55252E+05  1.33107E+07 0.85  23     14206.
 5581-014  left  558-140000  455.591  -13970.    -3.98917E+05   0.0000      0.00  10     6205.8       0.0000      -14.295     421.54
           right 520-050000  389.775   13955.     3.50688E+05  1.28941E+07 0.85  23     8598.8
 5581-015  left  558-150000  447.153  -12699.    -3.62634E+05   0.0000      0.00  2      6450.2       0.0000      -11.949     416.05
           right 520-040000  387.084   12687.     3.18818E+05  1.27496E+07 0.85  23     5665.5
 5581-016  left  558-160000  435.599  -11415.    -3.25953E+05   0.0000      0.00  2      6148.4       0.0000      -11.759     407.46
           right 520-030000  381.271   11403.     2.86543E+05  0.0000      0.00  20     3783.0
 5581-017  left  558-170000  424.976  -10307.    -2.94338E+05   0.0000      0.00  2      5880.3       0.0000      -10.659     399.40
```

	right	520-020000	375.629	10297.	2.58749E+05	0.0000	0.00	20	3678.8			
5581-018	left	558-180000	415.261	-9318.8	-2.66108E+05	0.0000	0.00	2	5624.8	0.0000	-9.3783	392.00
	right	520-010000	370.404	9309.4	2.33939E+05	0.0000	0.00	2	3573.0			
5582-001	left	558-010000	558.073	-84.203	-9618.0	0.0000	0.00	10	20922.	0.0000	-5.7916	446.75
	right	520-180000	310.644	78.411	5655.2	0.0000	0.00	22	1458.4			
5582-002	left	558-020000	554.320	-78.229	-8935.6	0.0000	0.00	10	16897.	0.0000	-0.71543	444.60
	right	520-170000	310.384	77.513	5590.5	0.0000	0.00	20	1495.7			
5582-003	left	558-030000	552.516	-77.985	-8907.8	0.0000	0.00	10	15300.	0.0000	-0.90436	443.51
	right	520-160000	310.096	77.081	5559.3	0.0000	0.00	20	1566.4			
5582-004	left	558-040000	551.400	-77.328	-8832.8	0.0000	0.00	10	14333.	0.0000	-0.55094	442.81
	right	520-150000	309.889	76.777	5537.4	0.0000	0.00	20	1614.2			
5582-005	left	558-050000	550.656	-77.015	-8797.0	0.0000	0.00	10	13649.	0.0000	-0.46227	442.33
	right	520-140000	309.746	76.553	5521.2	0.0000	0.00	20	1638.3			
5582-006	left	558-060000	550.133	-76.733	-8764.8	0.0000	0.00	10	13127.	0.0000	-0.38425	442.01
	right	520-130000	309.685	76.349	5506.5	0.0000	0.00	20	1625.9			
5582-007	left	558-070000	549.772	-76.514	-8739.7	0.0000	0.00	10	12704.	0.0000	-0.33386	441.81
	right	520-120000	309.721	76.180	5494.3	0.0000	0.00	20	1572.8			
5582-008	left	558-080000	549.481	-76.315	-8717.0	0.0000	0.00	10	12354.	0.0000	-0.28523	441.70
	right	520-110000	309.832	76.030	5483.5	0.0000	0.00	20	1499.2			
5582-009	left	558-090000	549.363	-76.217	-8705.8	0.0000	0.00	10	12047.	0.0000	-0.36979	441.65
	right	520-100000	309.936	75.847	5470.3	0.0000	0.00	20	1436.2			
5582-010	left	558-100000	549.060	-76.102	-8692.7	0.0000	0.00	10	11799.	0.0000	-0.34230	441.46
	right	520-090000	309.886	75.760	5464.0	0.0000	0.00	20	1435.0			
5582-011	left	558-110000	549.470	-76.180	-8701.6	0.0000	0.00	10	11524.	0.0000	-0.28328	441.66
	right	520-080000	309.841	75.897	5473.9	0.0000	0.00	20	1434.8			
5582-012	left	558-120000	548.252	-75.891	-8668.6	0.0000	0.00	10	11412.	0.0000	-0.36803	440.96
	right	520-070000	309.767	75.523	5446.9	0.0000	0.00	22	1432.0			
5582-013	left	558-130000	562.553	-81.510	-9310.4	0.0000	0.00	10	5979.5	0.0000	-1.5250	448.85
	right	520-060000	309.861	79.985	5768.7	0.0000	0.00	22	1451.0			
5582-014	left	558-140000	516.736	-77.738	-8879.6	0.0000	0.00	10	2220.6	0.0000	-12.370	423.13
	right	520-050000	309.203	65.369	4714.5	0.0000	0.00	22	1379.3			
5582-015	left	558-150000	500.331	-65.862	-7523.0	0.0000	0.00	2	2471.5	0.0000	-5.4442	414.08
	right	520-040000	308.902	60.418	4357.5	0.0000	0.00	22	1351.2			
5582-016	left	558-160000	485.690	-60.681	-6931.3	0.0000	0.00	2	2371.1	0.0000	-4.7929	405.88
	right	520-030000	308.571	55.888	4030.8	0.0000	0.00	20	1323.3			
5582-017	left	558-170000	472.229	-55.924	-6387.8	0.0000	0.00	2	2279.8	0.0000	-4.1611	398.31
	right	520-020000	308.177	51.762	3733.2	0.0000	0.00	20	1295.2			
5582-018	left	558-180000	459.883	-51.588	-5892.6	0.0000	0.00	2	2192.2	0.0000	-3.5435	391.31
	right	520-010000	307.666	48.045	3465.1	0.0000	0.00	2	1266.4			
5691-001	left	569-010000	460.023	-680.44	-2096.3	0.0000	0.00	2	1731.5	0.0000	-14.206	410.02
	right	510-010000	305.573	666.24	1202.2	0.0000	0.00	2	1000.7			

CASE 2

Tab.A12. 2 EHRS-RWST stand alone model CASE2

Time (s)	RWST Power (W) Aver 4000 – 5000	EHRSA Power (kW) Aver 4000 – 5000	Inlet flow (kg/s)	Pressure (MPa)
4000 - 5000	28.4	26.9	0.012	0.15

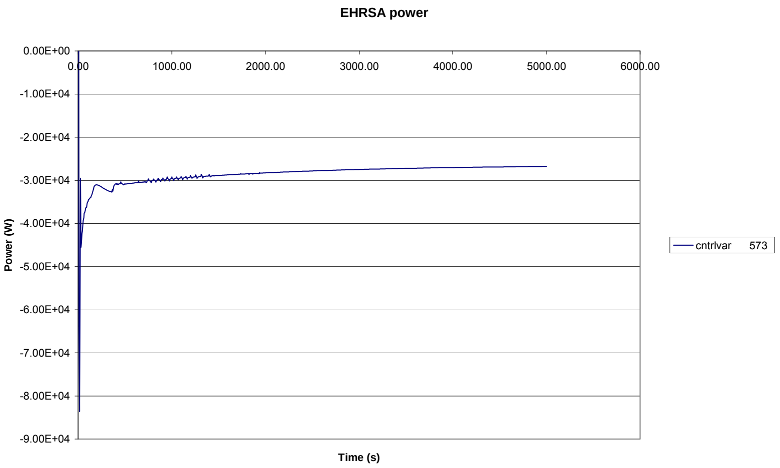


Fig.A12. 5 EHRS-RWST stand alone model CASE2 EHRSA power

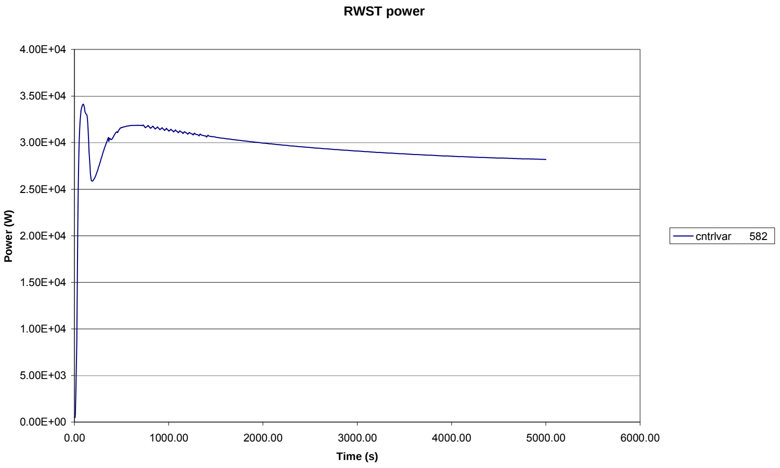


Fig.A12. 6 EHRS-RWST stand alone model CASE2 RWST power

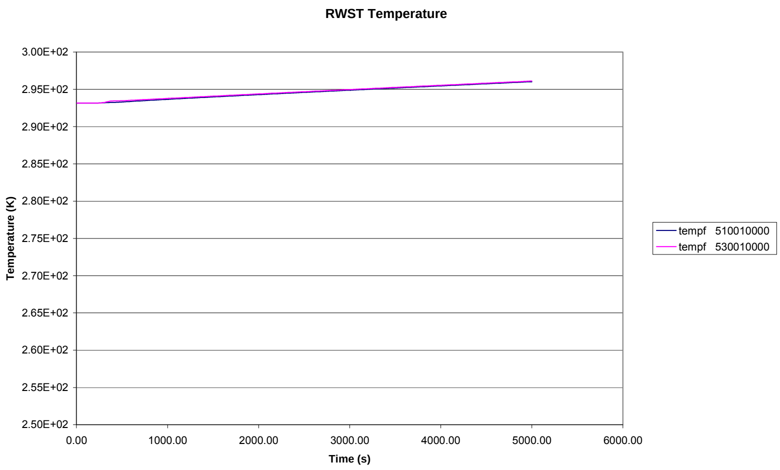


Fig.A12. 7 EHRS-RWST stand alone model CASE2 pool temperature

EHRS heat transfer cefficient at EHRS

```
0 HEAT STRUCTURE OUTPUT +++time=     1800.04     sec
  str.no. side   bdry.vol.  surface  heat-trf.   heat-flux   critical    CHF   ht   heat-trf.   int.-heat    conv+rad     vol.ave.
                  number     temp.   convection  convection  heat-flux    mul  mode  coef.conv    source      -source       temp.
                              (K)      (Watt)      (Watt/m2)   (Watt/m2)           (Watt/m2-K)  (Watt)      (Watt)       (K)
 5551-001  left  555-010000  326.418  -2.0637     -6.3579      0.0000     0.00   9    11.870      0.0000       130.49     316.92
          right 672-010000  296.458   132.55      239.19      0.0000     0.00   2    770.91
 5581-001  left  558-010000  323.644  -1571.9     -44887.      0.0000     0.00  10    56439.      0.0000     -9.02554E-02 319.40
          right 520-180000  315.492   1571.8      39498.      0.0000     0.00   2    2043.0
 5581-002  left  558-020000  323.213  -1542.3     -44040.      0.0000     0.00  10    43019.      0.0000     -0.10155     319.05
          right 520-170000  315.212   1542.2      38753.      0.0000     0.00   2    2033.2
 5581-003  left  558-030000  322.934  -1523.1     -43494.      0.0000     0.00  10    37050.      0.0000     -0.10633     318.82
          right 520-160000  315.030   1523.0      38272.      0.0000     0.00   2    2026.8
 5581-004  left  558-040000  322.722  -1508.6     -43080.      0.0000     0.00  10    33410.      0.0000     -0.10873     318.65
          right 520-150000  314.891   1508.5      37908.      0.0000     0.00   2    2021.9
 5581-005  left  558-050000  322.547  -1496.8     -42742.      0.0000     0.00  10    30858.      0.0000     -0.11017     318.50
          right 520-140000  314.776   1496.7      37610.      0.0000     0.00   2    2017.8
 5581-006  left  558-060000  322.397  -1486.7     -42454.      0.0000     0.00  10    28922.      0.0000     -0.11170     318.38
          right 520-130000  314.678   1486.6      37356.      0.0000     0.00   2    2014.3
 5581-007  left  558-070000  322.266  -1477.9     -42202.      0.0000     0.00  10    27388.      0.0000     -0.11296     318.27
          right 520-120000  314.591   1477.8      37135.      0.0000     0.00   2    2011.2
 5581-008  left  558-080000  322.148  -1470.0     -41978.      0.0000     0.00  10    26129.      0.0000     -0.11400     318.18
          right 520-110000  314.513   1469.9      36938.      0.0000     0.00   2    2008.4
 5581-009  left  558-090000  322.042  -1463.0     -41777.      0.0000     0.00  10    25069.      0.0000     -0.11489     318.09
          right 520-100000  314.443   1462.9      36761.      0.0000     0.00   2    2005.8
 5581-010  left  558-100000  321.944  -1456.6     -41594.      0.0000     0.00  10    24159.      0.0000     -0.11566     318.01
          right 520-090000  314.378   1456.5      36600.      0.0000     0.00   2    2003.5
 5581-011  left  558-110000  321.854  -1450.7     -41426.      0.0000     0.00  10    23343.      0.0000     -0.11634     317.93
          right 520-080000  314.317   1450.6      36452.      0.0000     0.00   2    2001.2
 5581-012  left  558-120000  321.770  -1445.3     -41271.      0.0000     0.00  10    22608.      0.0000     -0.11695     317.86
          right 520-070000  314.261   1445.2      36316.      0.0000     0.00   2    1999.2
 5581-013  left  558-130000  321.692  -1440.2     -41128.      0.0000     0.00  10    21949.      0.0000     -0.11749     317.80
          right 520-060000  314.208   1440.1      36189.      0.0000     0.00   2    1997.2
 5581-014  left  558-140000  321.617  -1435.5     -40993.      0.0000     0.00  10    21357.      0.0000     -0.11799     317.74
          right 520-050000  314.158   1435.4      36071.      0.0000     0.00   2    1995.4
 5581-015  left  558-150000  321.547  -1431.2     -40868.      0.0000     0.00  10    20815.      0.0000     -0.11845     317.68
          right 520-040000  314.110   1431.0      35961.      0.0000     0.00   2    1993.6
 5581-016  left  558-160000  321.480  -1427.0     -40750.      0.0000     0.00  10    20326.      0.0000     -0.11887     317.62
          right 520-030000  314.064   1426.9      35857.      0.0000     0.00   2    1991.8
 5581-017  left  558-170000  321.416  -1423.1     -40639.      0.0000     0.00  10    19862.      0.0000     -0.11927     317.57
          right 520-020000  314.019   1423.0      35760.      0.0000     0.00   2    1990.2
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5581-018  left  558-180000  321.355  -1419.5    -40534.    0.0000    0.00  10    19464.    0.0000    -0.11964    317.52
         right 520-010000  313.977   1419.3     35667.    0.0000    0.00   2    1988.6
5582-001  left  558-010000  325.113  -9.0275    -1031.2    0.0000    0.00  10    29909.    0.0000    -3.32159E-02 312.31
         right 520-180000  296.684   8.9943     648.69    0.0000    0.00   2    1234.1
5582-002  left  558-020000  325.068  -9.0122    -1029.4    0.0000    0.00  10    23259.    0.0000    -3.34707E-02 312.29
         right 520-170000  296.688   8.9788     647.57    0.0000    0.00   2    1206.5
5582-003  left  558-030000  325.034  -8.9993    -1027.9    0.0000    0.00  10    20306.    0.0000    -3.36130E-02 312.27
         right 520-160000  296.696   8.9657     646.63    0.0000    0.00   2    1178.4
5582-004  left  558-040000  325.006  -8.9878    -1026.6    0.0000    0.00  10    18506.    0.0000    -3.36931E-02 312.26
         right 520-150000  296.704   8.9541     645.79    0.0000    0.00   2    1149.7
5582-005  left  558-050000  324.981  -8.9771    -1025.4    0.0000    0.00  10    17246.    0.0000    -3.37227E-02 312.25
         right 520-140000  296.713   8.9433     645.02    0.0000    0.00   2    1120.4
5582-006  left  558-060000  324.958  -8.9668    -1024.2    0.0000    0.00  10    16290.    0.0000    -3.37806E-02 312.24
         right 520-130000  296.723   8.9330     644.27    0.0000    0.00   2    1090.6
5582-007  left  558-070000  324.938  -8.9569    -1023.1    0.0000    0.00  10    15532.    0.0000    -3.38331E-02 312.24
         right 520-120000  296.734   8.9231     643.55    0.0000    0.00   2    1060.2
5582-008  left  558-080000  324.919  -8.9472    -1022.0    0.0000    0.00  10    14910.    0.0000    -3.38780E-02 312.23
         right 520-110000  296.746   8.9133     642.85    0.0000    0.00   2    1029.4
5582-009  left  558-090000  324.901  -8.9376    -1020.9    0.0000    0.00  10    14387.    0.0000    -3.39167E-02 312.23
         right 520-100000  296.759   8.9036     642.15    0.0000    0.00   2    998.30
5582-010  left  558-100000  324.885  -8.9279    -1019.8    0.0000    0.00  10    13938.    0.0000    -3.39502E-02 312.22
         right 520-090000  296.773   8.8940     641.46    0.0000    0.00   2    966.98
5582-011  left  558-110000  324.870  -8.9186    -1018.7    0.0000    0.00  10    13546.    0.0000    -3.39853E-02 312.22
         right 520-080000  296.788   8.8846     640.78    0.0000    0.00   2    935.64
5582-012  left  558-120000  324.856  -8.9093    -1017.7    0.0000    0.00  10    13200.    0.0000    -3.40088E-02 312.22
         right 520-070000  296.803   8.8753     640.11    0.0000    0.00   2    904.54
5582-013  left  558-130000  324.843  -8.9001    -1016.6    0.0000    0.00  10    12890.    0.0000    -3.40291E-02 312.22
         right 520-060000  296.820   8.8661     639.44    0.0000    0.00   2    874.02
5582-014  left  558-140000  324.831  -8.8910    -1015.6    0.0000    0.00  10    12612.    0.0000    -3.40462E-02 312.22
         right 520-050000  296.836   8.8569     638.78    0.0000    0.00   2    844.54
5582-015  left  558-150000  324.820  -8.8822    -1014.6    0.0000    0.00  10    12359.    0.0000    -3.40630E-02 312.22
         right 520-040000  296.853   8.8481     638.15    0.0000    0.00   2    816.68
5582-016  left  558-160000  324.808  -8.8739    -1013.6    0.0000    0.00  10    12128.    0.0000    -3.40753E-02 312.22
         right 520-030000  296.867   8.8398     637.55    0.0000    0.00   2    791.30
5582-017  left  558-170000  324.798  -8.8668    -1012.8    0.0000    0.00  10    11915.    0.0000    -3.40952E-02 312.22
         right 520-020000  296.879   8.8327     637.04    0.0000    0.00   2    769.58
5582-018  left  558-180000  324.786  -8.8611    -1012.2    0.0000    0.00  10    11719.    0.0000    -3.41004E-02 312.22
         right 520-010000  296.886   8.8270     636.63    0.0000    0.00   2    753.46
5691-001  left  569-010000  325.178  -133.88    -412.47    0.0000    0.00  10    21542.    0.0000     -9.8150    315.82
         right 510-010000  296.404   124.07     223.88    0.0000    0.00   2    597.69
```

A.12 Attachments to conf-call #119

file "IRIS_SPES3_Conf Call Minutes #119 Att 1 Stand alone IRIS cases + DW pressure.doc"

Fig.A13. 1 EHRS-RWST IRIS stand alone model EHRS and RWST power

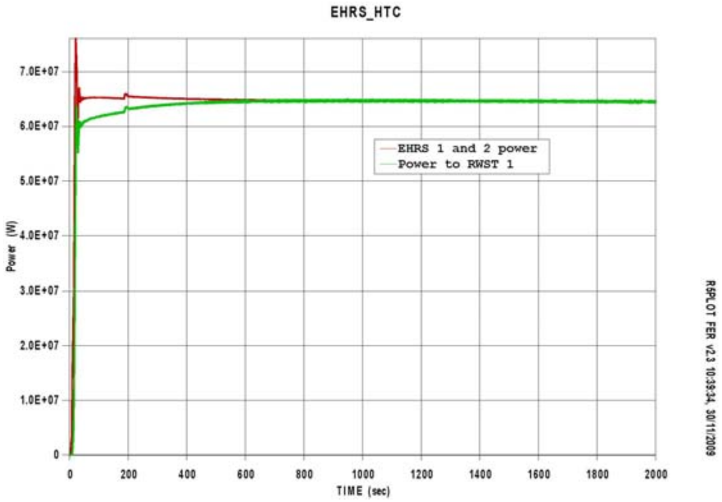


Fig.A13. 2 EHRS-RWST IRIS stand alone model RWST temperature

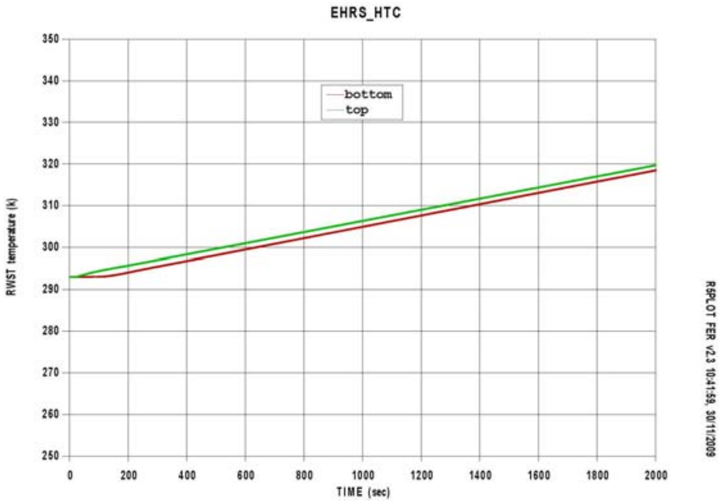


Fig.A13. 3 EHRS-RWST IRIS stand alone model EHRS and RWST power

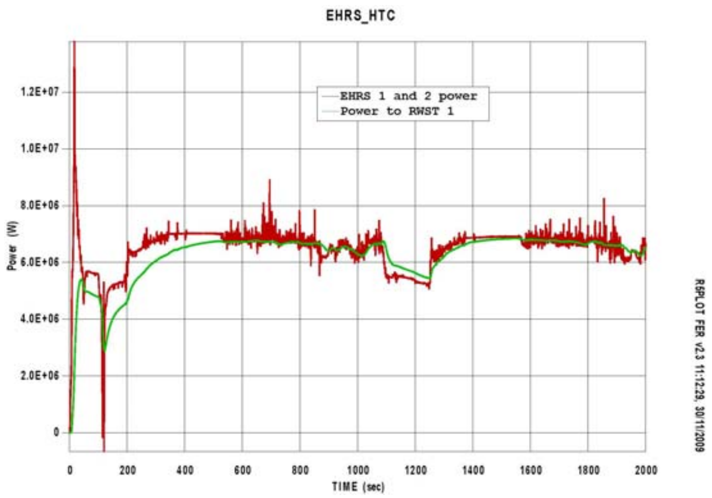


Fig.A13. 4 EHRS-RWST IRIS stand alone model RWST temperature

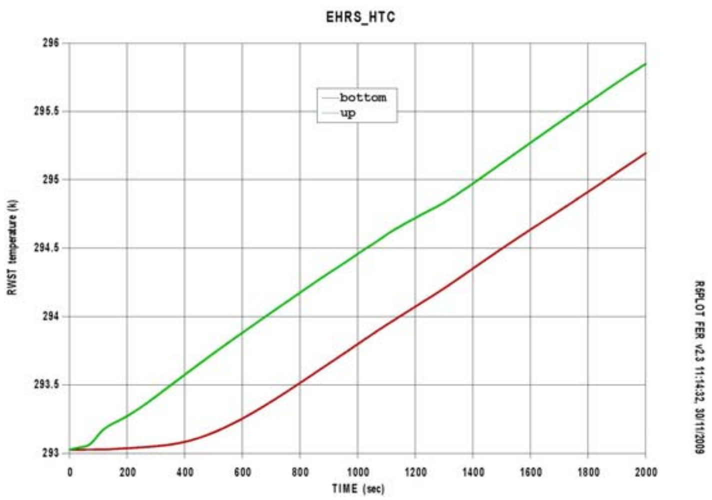
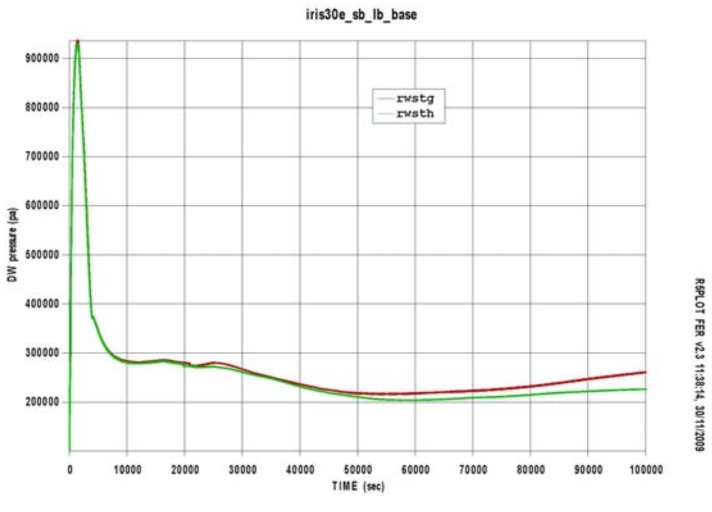


Fig.A13. 5 IRIS model DW pressure



file "IRIS_SPES3_Conf Call Minutes #119 Att 2 RWST-EHRS stand alone model and EHRS mass.doc"

R. Ferri, Nov 30 2009

Stand alone model EHRS-RWST

CASE 1 (high pressure)

SPES3: 1 EHRS module in RWST (EHRS-A).
IRIS: 2 EHRS modules in RWST

Inlet pressure 80 bar, inlet mass flow 0.17 kg/s, saturated steam
Outlet pressure 80 bar, saturated water.
RWST initial temperature 20 °C, atmospheric pressure.

Comparison between IRIS and SPES3 just doubling the SPES3 EHRS power

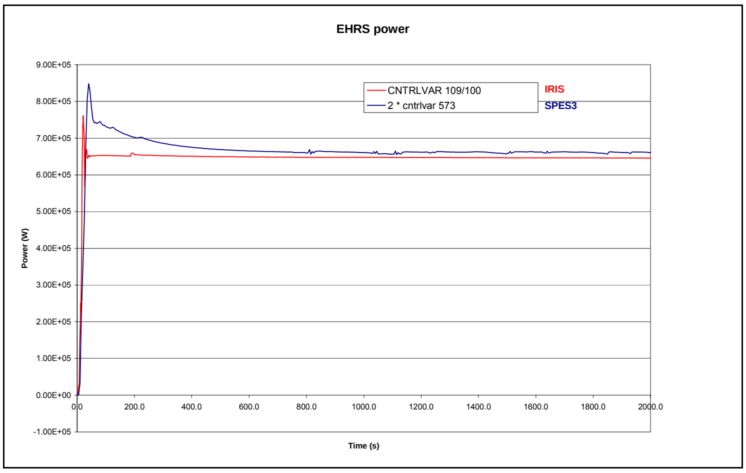


Fig.A13. 6 SPES3 EHRS-RWST stand alone model CASE1: EHRS power

At 2000 s:
SPES3 EHRS power 662 kW
IRIS EHRS power 645 kW.
Difference 17 kW

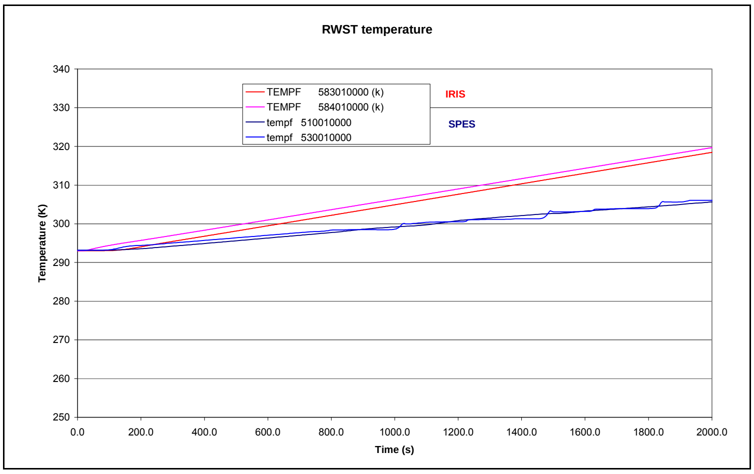


Fig.A13. 7 EHRS-RWST stand alone model CASE1 pool temperature

CASE 2 (low pressure)

SPES3: 1 EHRS module in RWST (EHRS-A).
IRIS: 2 EHRS modules in RWST

Inlet pressure 1.5 bar, inlet mass flow 0.012 kg/s, saturated steam
Outlet pressure 1.5 bar, saturated water.
RWST initial temperature 20 °C, atmospheric pressure.

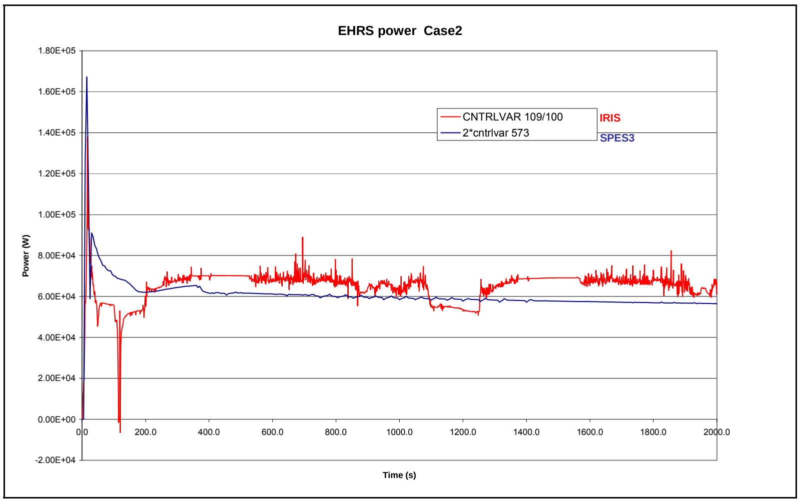


Fig.A13. 8 EHRS-RWST stand alone model CASE2 EHRS power

EHRS power 26.9 kW (average between 4000s and 5000 s)

At 1500 s (steady power in IRIS):
SPES3 EHRS power 57 kW
IRIS EHRS power 69 kW.
Difference -12 kW

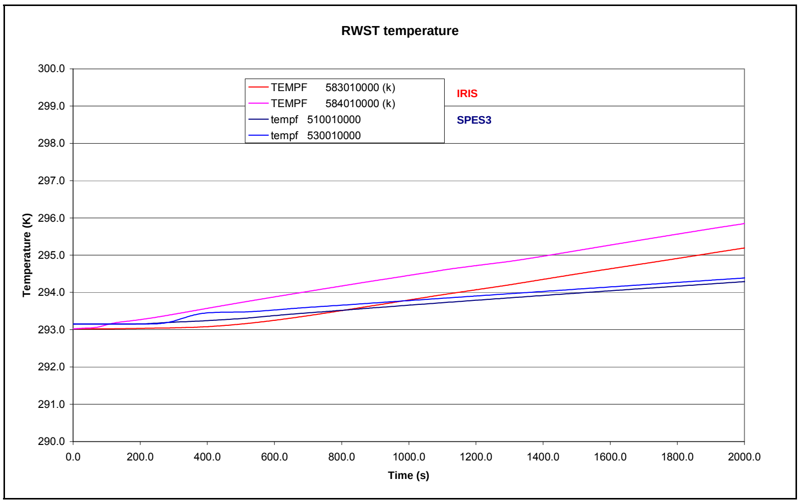


Fig.A13. 9 EHRS-RWST stand alone model CASE2 RWST temperature

Cases SPES3-127 and IRIS HT5g

Fig.A13. 10 SPES3-127 and IRIS HT5g SG ss mass flow (window)

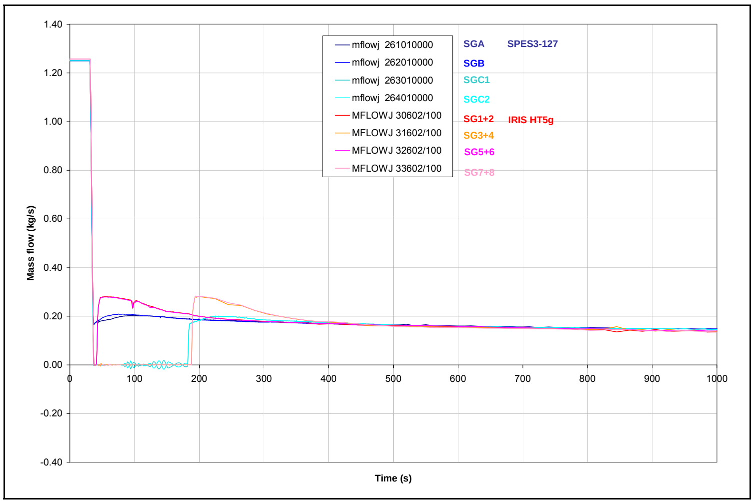


Fig.A13. 11 SPES3-127 and IRIS HT5g SG ss mass flow (window)

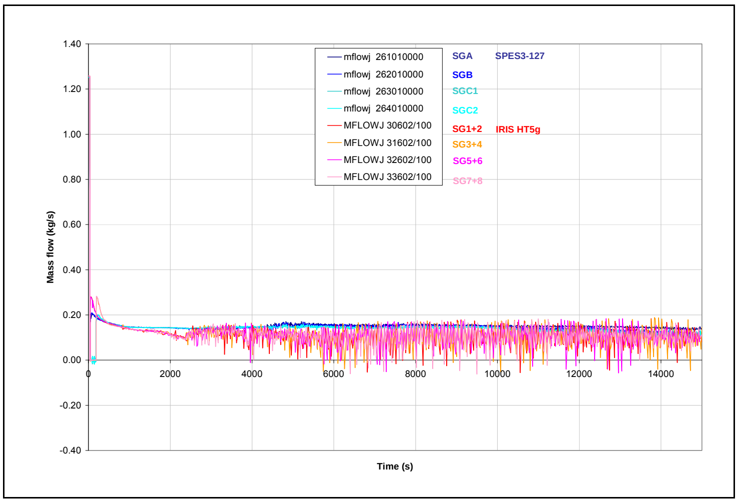


Fig.A13. 12 SPES3-127 and IRIS HT5g EHRS cold leg mass flow (window)

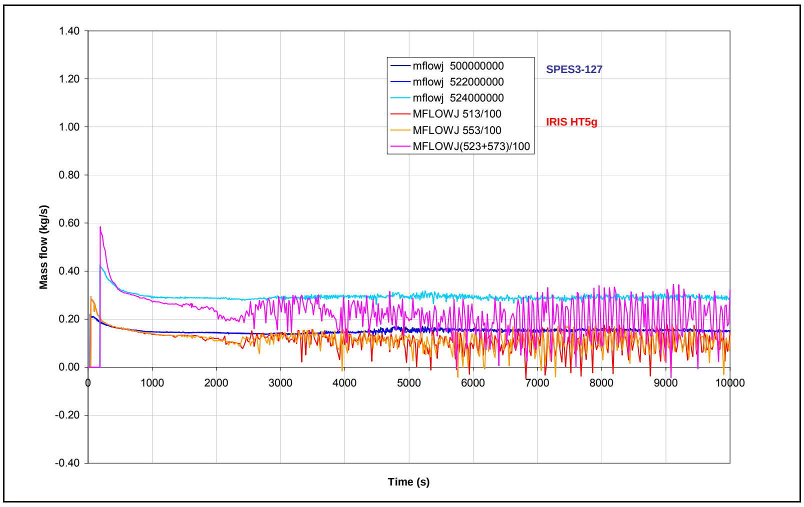


Fig.A13. 13 SPES3-127 and IRIS HT5g SG power flow (window)

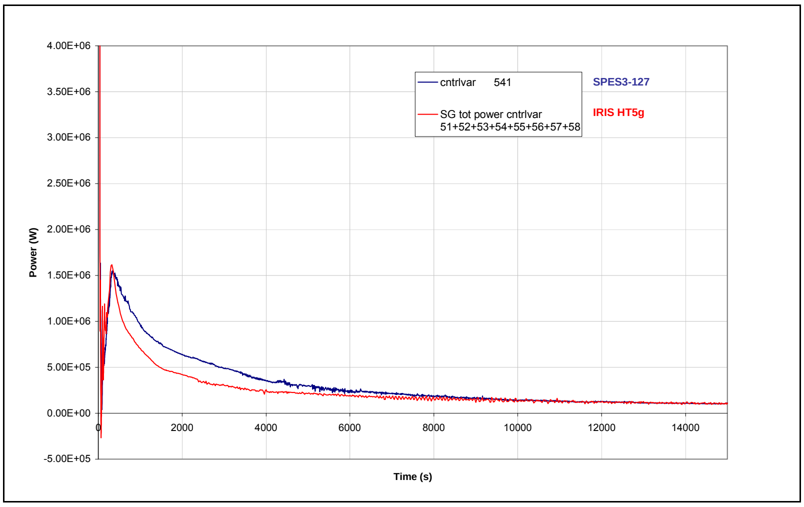


Fig.A13. 14 SPES3-127 and IRIS HT5g EHRS power (window)

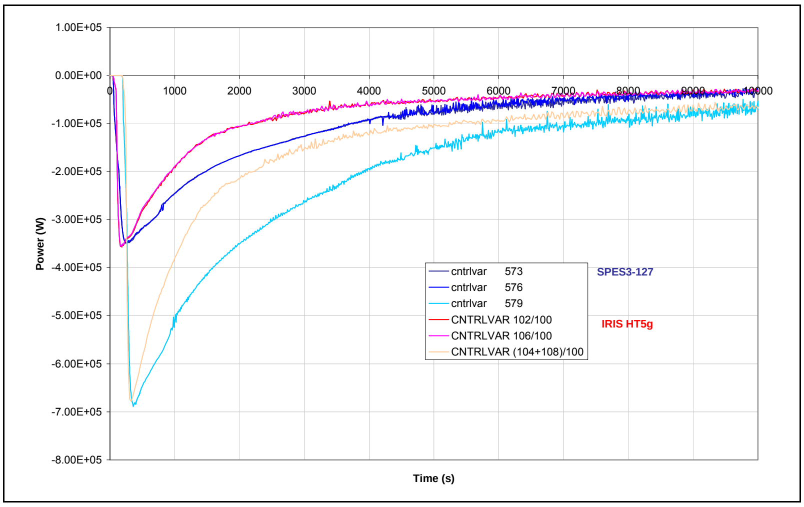


Fig.A13. 15 SPES3-127 and IRIS HT5g EHRS power

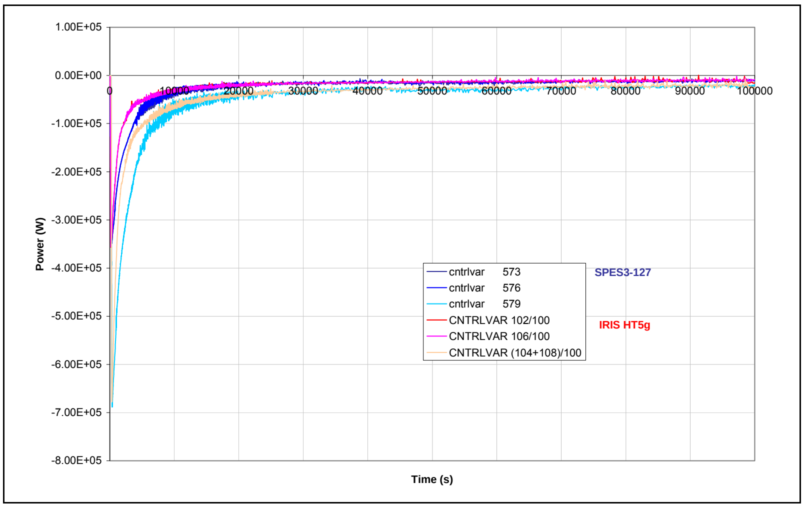


Fig.A13. 16 SPES3-127 and IRIS HT5g SG-1ss collapsed level (window)

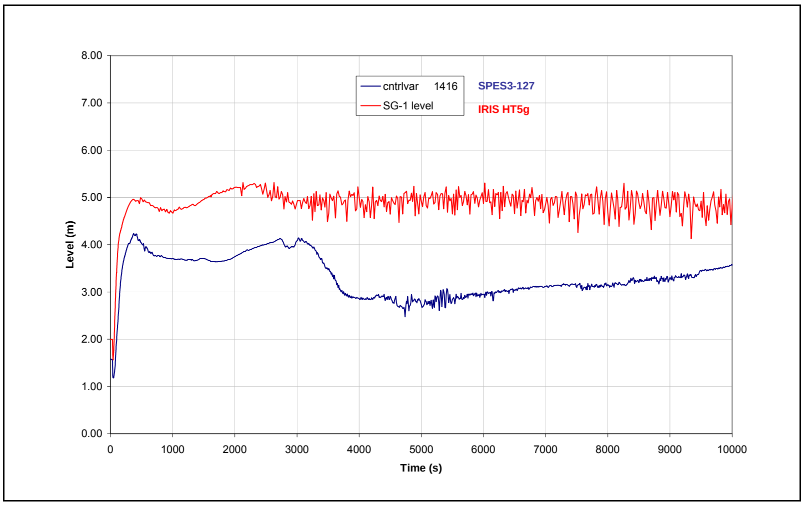


Fig.A13. 17 SPES3-127 and IRIS HT5g SG-1ss collapsed level

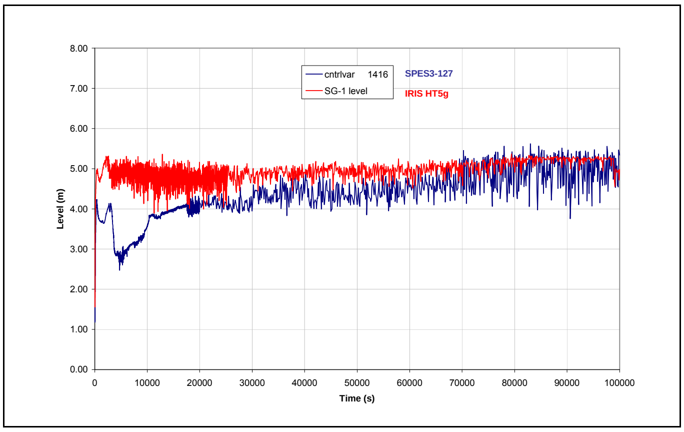
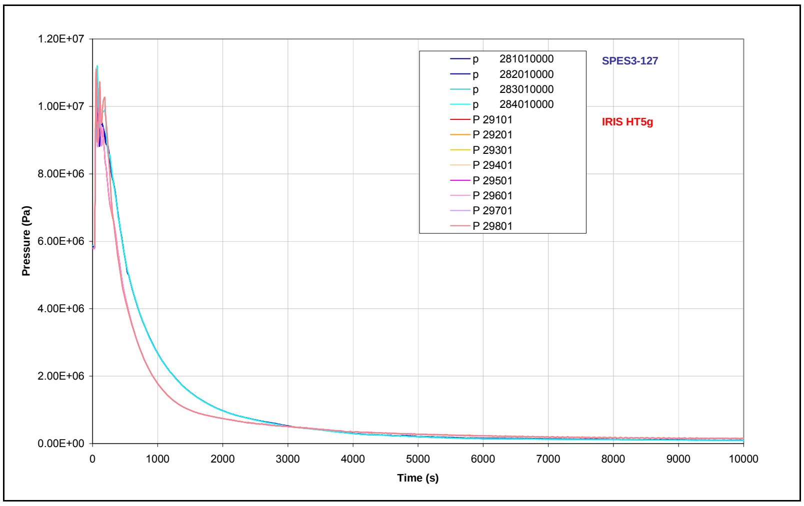


Fig.A13. 18 SPES3-127 and IRIS HT5g SG-ss pressure



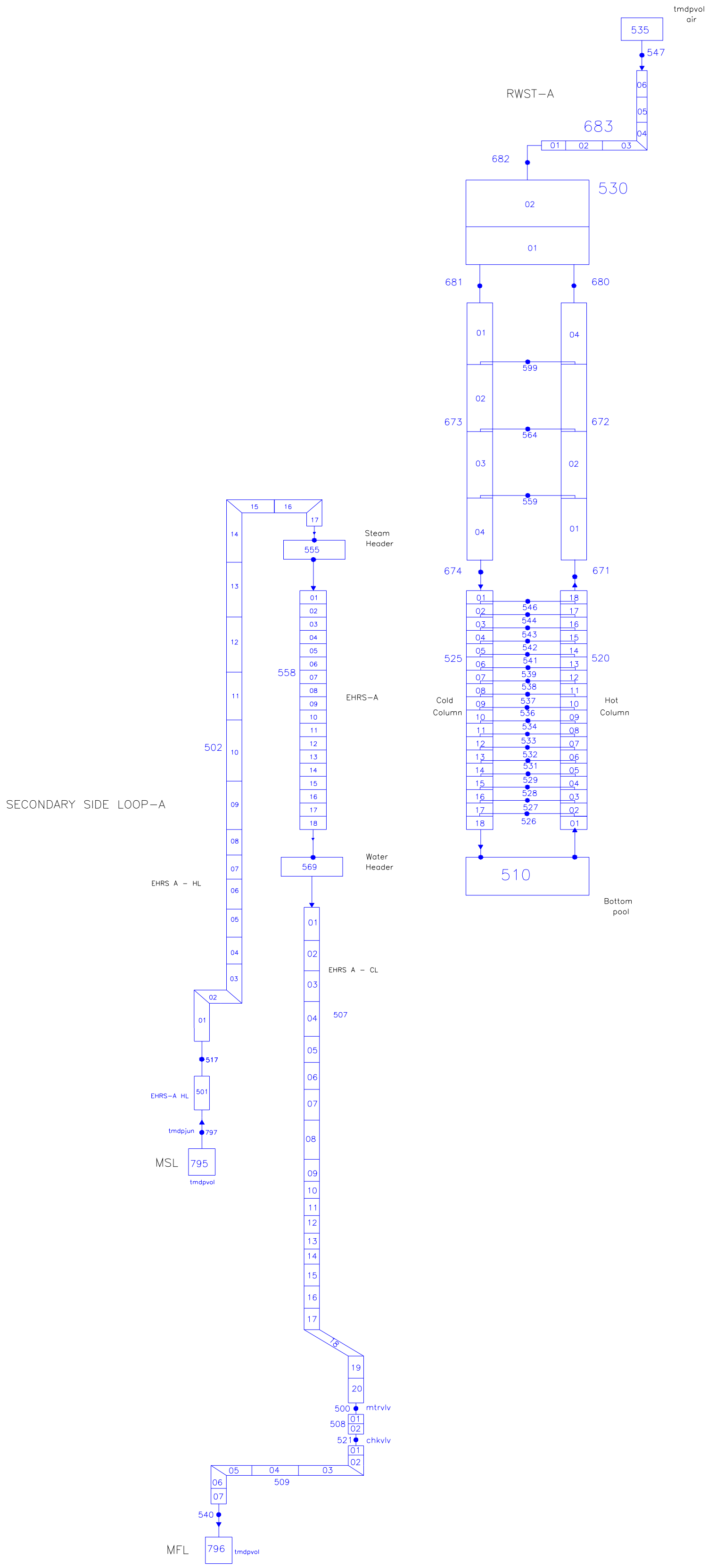


Fig.A13. 19 SPES3 EHRS-RWST stand alone model

file "IRIS_SPES3_Conf Call Minutes #119 Att 3 SPES-3 RWST + 2EHRS.xls"

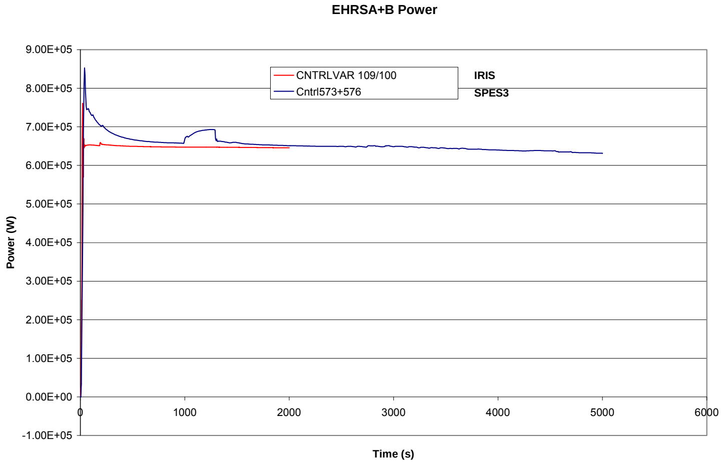


Fig.A13. 20 IRIS and SPES3 EHRS power

file "IRIS_SPES3_Conf Call Minutes #119 Att 4 SPES-3 RWST + 2EHRS low Pres.xls"

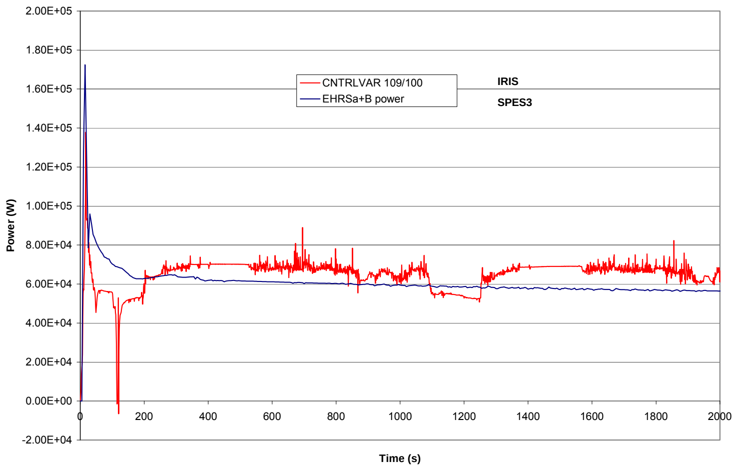


Fig.A13. 21 IRIS and SPES3 EHRS power (low pressure case)

file "IRIS_SPES3_Conf Call Minutes #119 Att 5 EHRS study (864709.v1).pdf"

EHRS studies reported in the draft version of Paper: L. Santini, D. Papini, M. E. Ricotti: Experimental Characterization of a Passive Emergency Heat Removal System for a GenIII+ Reactor. Science and Technology of Nuclear Installations Volume 2010 (2010), Article ID 864709, 12 pages. [23].

file "IRIS_SPES3_Conf Call Minutes #119 Att 6 Scaling – Old Results"

OLD RESULTS

Based on Tortora and Lioce works, a quick description of old results has been reported to point out original discrepancies in SPES3 and IRIS behaviors, in order to justify modifications made on IRIS and SPES3 models by Davor Grgc (FER) and Roberta Ferri (SIET)
All the old results has been gotten by using input data files for IRIS and SPES3 named 'ht1_case' and 'spes3_89' respectively. Here are listed all time events for IRIS and SPES3 related to old case and times in which they occur:

Event #	Event description	Time (s)
1	Break initiation	0
2	SCRAM begins	25.1
3	MFIV 1-4 closing	25.1
4	MSIV 1-4 closing	25.1
5	EHRS-AOV 1,3 opening	36.1
6	RCP costdown starts	146
7	ADS Stage I start opening (3 trains)	174
8	EHRS-AOV 2,4 opening	186
9	Natural circulation begins through shroud valves	184
10	Flashing begins at core outlet	184
11	EBS valves opening	189
12	Natural circulation interrupted at SGs top	265
13	EBT-RV connections uncovered	385
14	EBT broken loop empty	605
15	LGMS tank of broken loop start injecting into Cavity	1543.82
16	Containment and RV pressure equalization	1530
17	LGMS-intact loop starts to inject into RV through DVI intact loop	1643.33
18	Steam and gas mixture flows again from RV to QT	3900
19	ADS stage II start opening	15400
20	LGMS-broken loop empty	16095.4
21	LGMS-intact loop empty	16400.5
22	Flow from Cavity starts	≈18000

Tab.A13. 1 : Time decomposition for the DVI SBLOCA in IRIS.

Event #	Event description	Time (s)
1	Break initiation	0
2	SCRAM begins	48.77
3	MFIV-A,B,C closure start	48.77
4	MSIV-A-B-C closure start	48.77
5a	EHRS-A,B opening start (EHRS 1 and 3 in IRIS)	48.77
6	RCP costdown starts	90.26
5b	EHRS-C opening start (EHRS 2 and 4 in IRIS)	180.83
7	ADS Stage I start opening (3 trains)	180.83
8	Natural circulation begins through shroud valves	108-110
9	Flashing begins at core outlet	113
10	EBT A/B valve opening start	180.83
11	Natural circulation interrupted at SGs top	212
12	EBT-RV connections uncovered	204
13	EBT-B empty	510
14	LGMSA/B valve opening start	2090.35
16	LGMS-A starts to inject into RV through DVI intact loop	2170
15	Containment and RV pressure equalization	2250
17	Steam and gas mixture flows again from RV to QT	5530
18	ADS stage II start opening	11860
19	LGMS-A empty	26190
20	LGMS-B empty	26190
21	Flow from RC to RV (loop-A) start	26890

Tab.A13. 2: Time decomposition for the DVI SBLOCA in SPES3

BEFORE PRESSURE EQUALIZATION

Before showing old results, it has to be pointed out that for studying situation before pressure equalization, Control Volume that must be taken into account is just CV. In OMEGA program concerning Tortora work, only LGMS (2), PSS (4), DW, CAVITY and ADS-QT have been considered.
In Fig.A13. 22 dimensionless pressure gradients of IRIS and SPES3 are matched. As it can be noted, general shape of IRIS curve was similar to SPES3, even if there was a quantitatively difference; IRIS gradient in fact is higher than SPES3, in particular at the beginning of the transient.

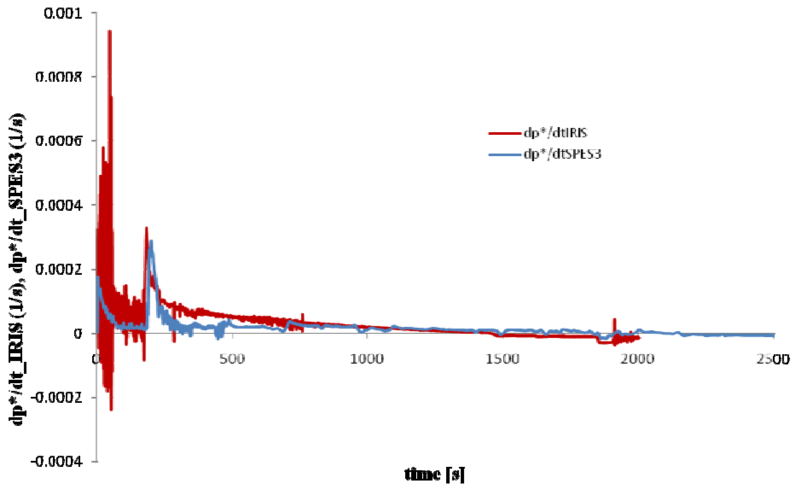


Fig.A13. 22 IRIS/SPES3 dimensionless pressure gradients during

DVI-SBLOCA transient BPE

Fig.A13. 23 lists all evaluated FRCs for IRIS and, as it can be seen, it shows that only three driving phenomena are relevant, which are FRC_br, FRC_1phV and FRC_2ph. In particular, FRC_1phV is the only important one, since FRC_br and FRC_2ph effects are deleting each other, and it will be up to pressure equalization.

In Fig.A13. 24 the same case has been analyzed referred to SPES3 case. In this case the same FRCs are relevant as in IRIS, but FRC_1phV is a driving phenomenon up to 60 s. After 60s in fact, it assumes values closed to 0 while FRC_br and FRC_2ph continue to be the most important.

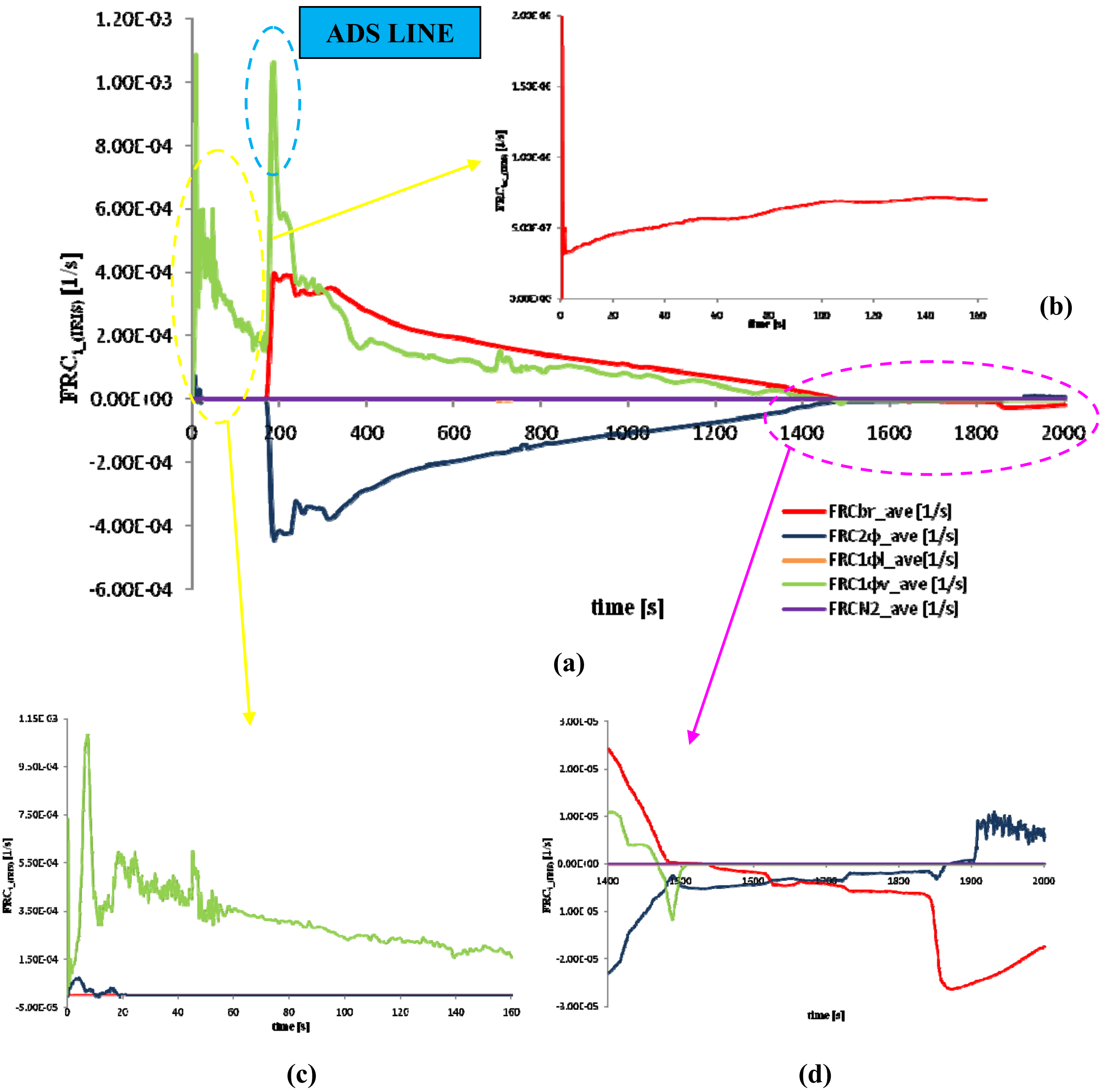


Fig.A13. 23 : (a) FRCs' trend in IRIS BPE (b) zoom on the FRC_{br} and (c) on $FRC_{1\varphi v}$ and $FRC_{2\varphi}$ for the first 160 s of IRIS DVI-SBLOCA transient, (d) zoom from 1400 s to 2000s

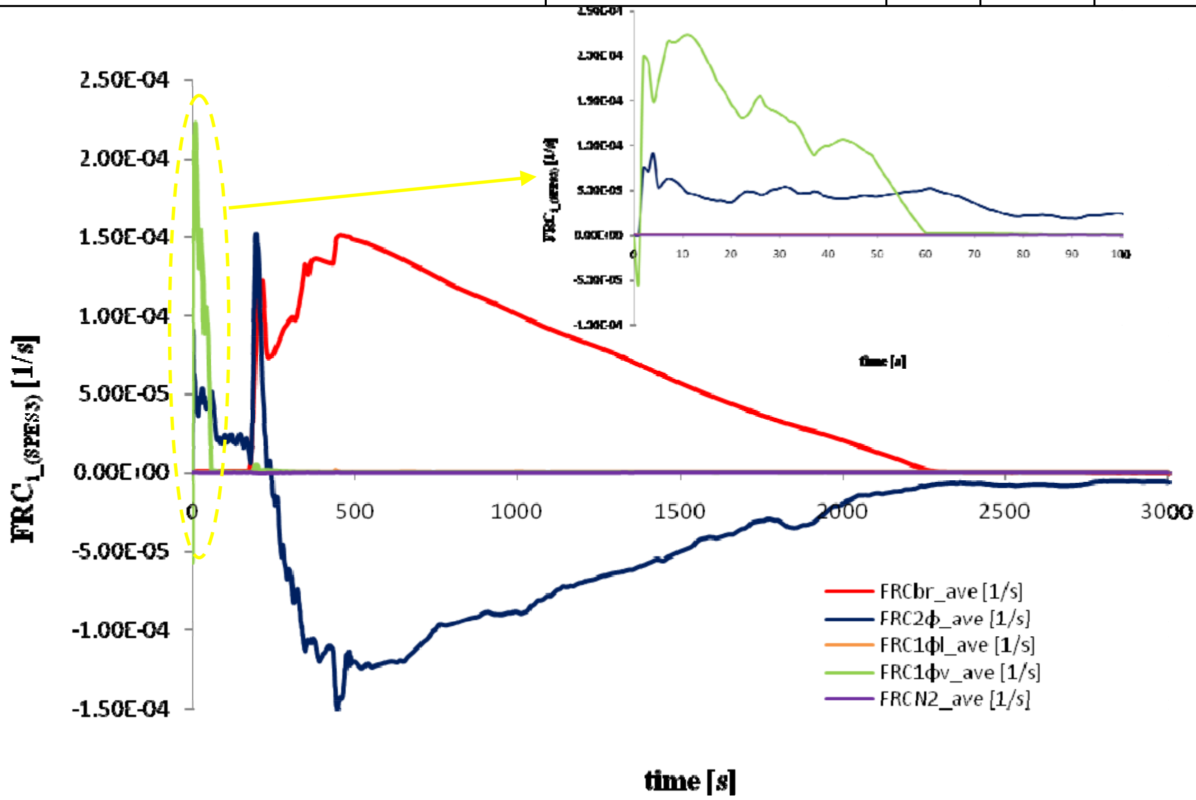


Fig.A13. 24 Dimensionless pressure gradient versus each FRCs summation in SPES3 BPE with zoom on the first 100 s of the transient

Here, from Fig.A13. 25 through Fig.A13. 27 the 3 more relevant omegas concerning with break flow, 2 phases and vapour single phase are showed and matched for IRIS and SPES3. As it can be easily seen in these comparisons, a delay effect is present in all SPES3 cases compare to IRIS ones. Basically, different phases are present in IRIS and SPES3 at the same considered time. In particular, the super-heated steam phase that is more persistent in IRIS can be explained by examining the elements wall structures considered during simulation. In fact, while in IRIS only DW structure was taken into account, in SPES3 all heat structures were considered. It proved, obviously, that at the beginning of IRIS transient, containment temperature was higher than in SPES3 because no structure was absorbing produced heat, since no structures were considered (except for DW), and it caused more super heated steam presence than in SIET Facility.

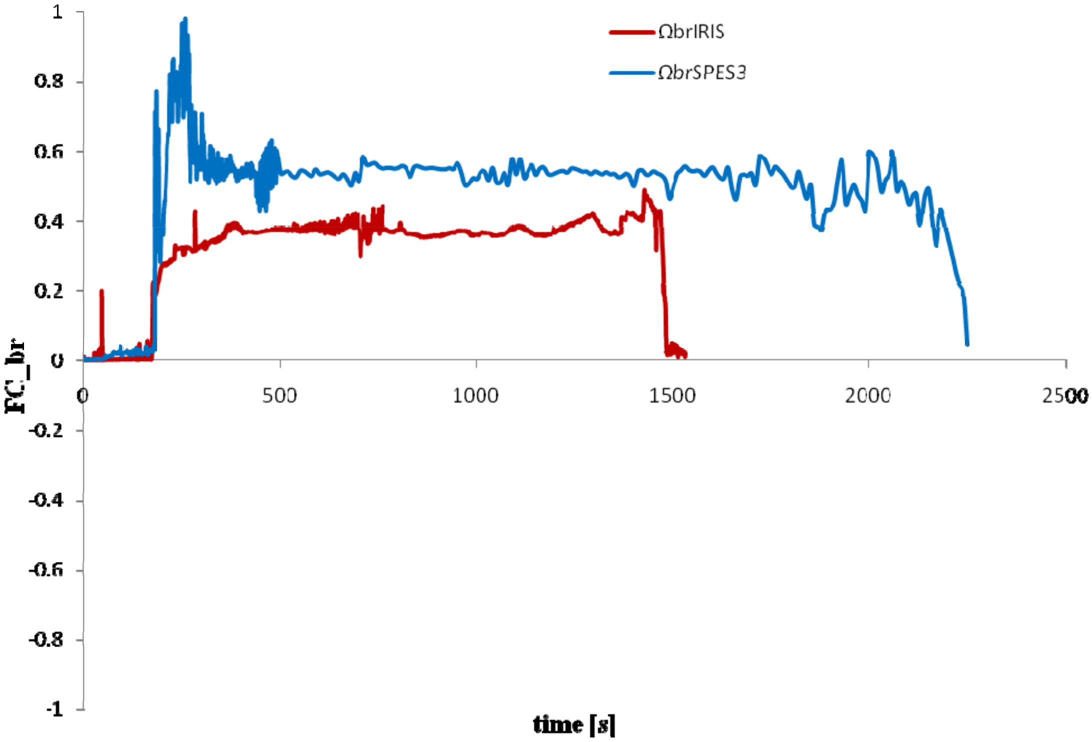


Fig.A13. 25 IRIS & SPES3 OMEGA_br vs time

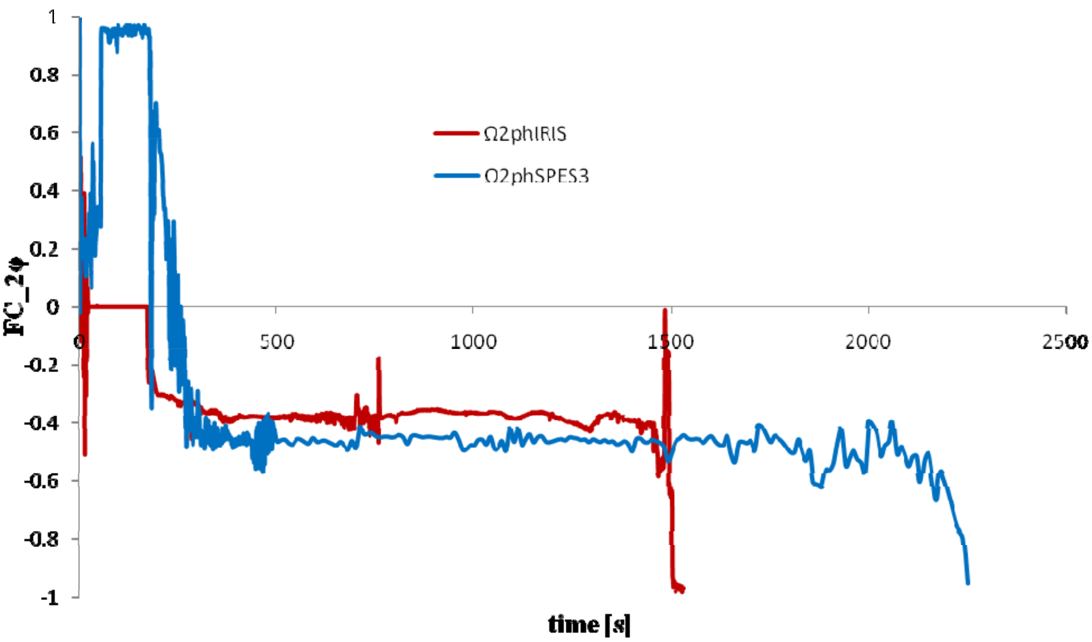


Fig.A13. 26 IRIS & SPES3 OMEGA_2ph vs time

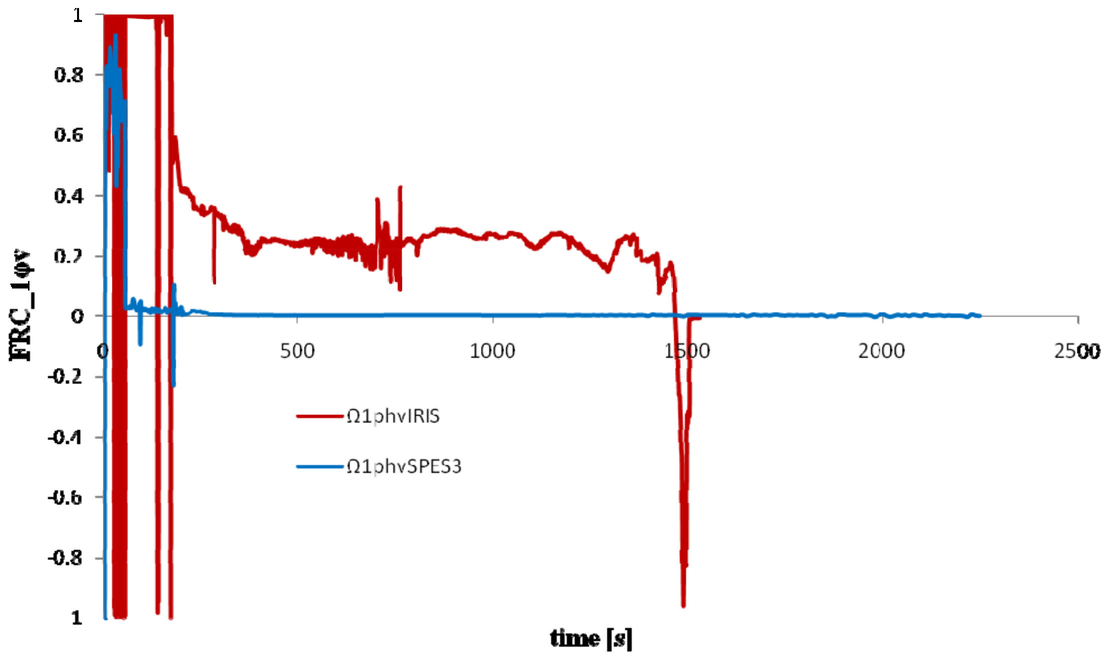


Fig.A13. 27 IRIS & SPES3 OMEGA_1phV vs time

Finally, Distorsion parameters are listed for the main time events (listed in Tab.A13. 1 and Tab.A13. 2) As it can be seen:

- Break distortions, D_{br}, are in good agreement with Wulff's distortions scaling criteria at the very beginning of the transient (first time sequence) and close to the pressure equalization (from 12th to 14th time sequence);
- Two phase mixture distortions, $D_{2\varphi}$, are in good agreement with Wulff's distortions scaling criteria around the pressure equalizion (from 14th to 16th time sequence);
- Single-phase vapour, $D_{1\varphi v}$, are in good agreement with Wulff's distortions scaling criteria at the very beginning of the transient (from 2nd to 5th time sequence), after about 50 s this term cannot be properly scaled as there is no longer super-heated steam in SPES3;
- No time sequence is scaled well according to Wulff's criteria .

Tab.A13. 3 Distorsion parameters

Time sequence	Time	D_{br}	$D_{2\varphi}$	$D_{1\varphi v}$
1	0	0.641	NaN	NaN
2	25.1	4.702	NaN	1.470
3	25.1	4.702	NaN	1.421
4	25.1	4.702	NaN	1.469
5	36.1	3.766	NaN	1.469
6	146	9.027	NaN	36.925
7	174	6.369	-1.93	22.627
8	186	3.356	-1.00	12.403
9	184	0.155	-4.22	24.210
10	184	0.137	-4.27	27.377
11	189	3.076	-3.67	23.964
12	265	1.939	-1.10	52.984
13	385	1.169	-1.34	55.339
14	605	1.432	1.21	307.331
15	1526	17.678	0.52	-7.336
16	1530	5.225	0.97	4.769

AFTER PRESSURE EQUALIZATION

In this case Control Volume to be considered are CV+RV (containment volume + reactor vessel). In fact in OMEGA program all elements have been considered. During this analysis, due to the studied Control Volume, break terms are cancelling each other and therefore they has been not considered.
In Fig.A13. 28, Fig.A13. 29, Fig.A13. 30 average dimensionless pressure gradients of IRIS and SPES3 are matched. All results after pressure equalization are considered as averaged on 11 time steps, in order to give a better comparison between IRIS and SPES3. In fact, after pressure equalization, a lot of values changes very slowly around small values and using singular point as reference should furnish not realistic results. As it can be noted, IRIS and SPES3 dimensionless pressure gradients are qualitatively similar since trend is smooth, while as one of these curves starts rising or decreasing rapidly, differences in values (and sign) begin to be consistent.

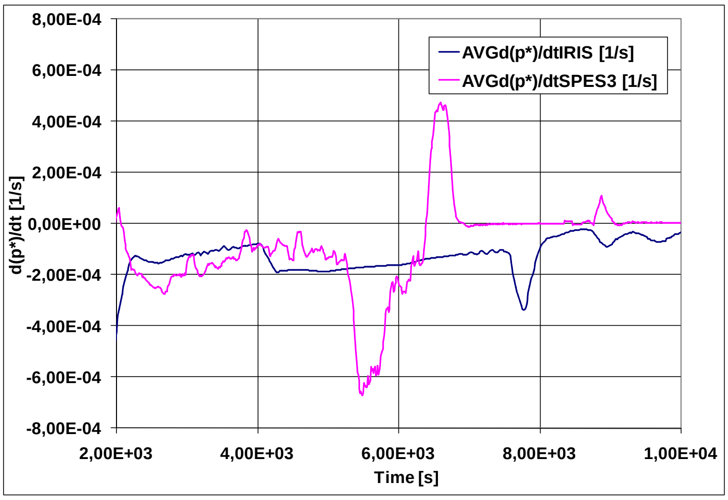


Fig.A13. 28 Average dimensionless pressure gradient in IRIS and SPES3 vs time

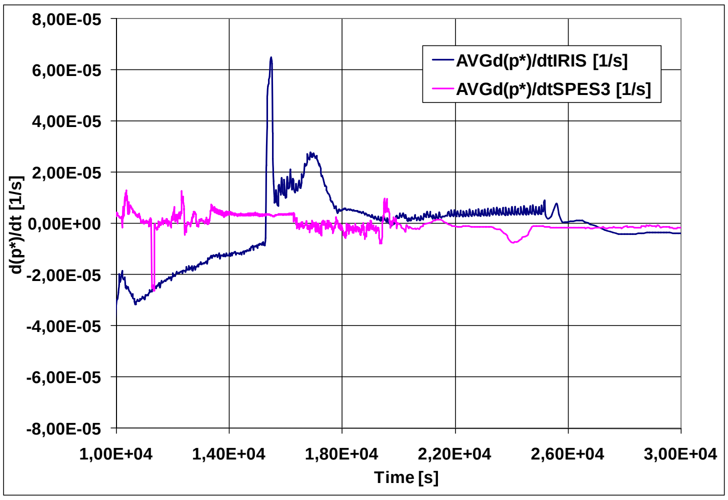


Fig.A13. 29 Average dimensionless pressure gradient in IRIS and SPES3 vs time

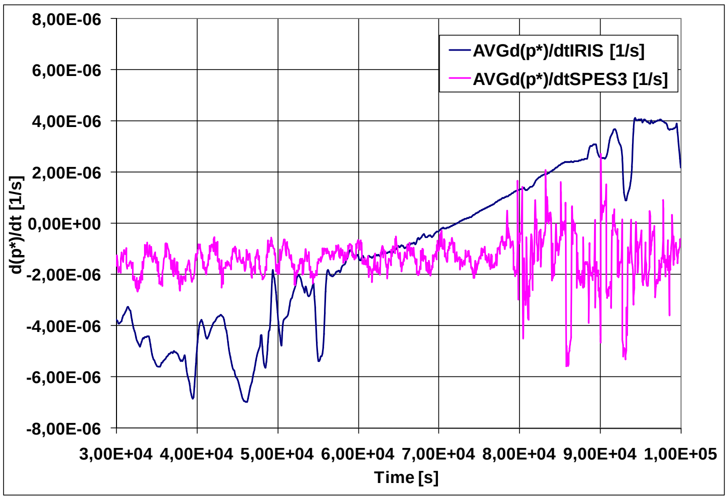


Fig.A13. 30 Average dimensionless pressure gradient in IRIS and SPES3 vs time

In all the figures below AVG FRCs of each phase are represented for IRIS and SPES3 divided in 3 time windows. It is worth underlining that:

- Big differences are present between IRIS and SPES3. As mentioned before, in IRIS only DW has heat structures simulated, while in all SPES3 elements heat structures have been taken into account. It causes almost only bulk steam (super-heated steam) up to 1900 s, because the only DW heat structures in IRIS do not provide enough cooling to make saturated the super-heated steam entering the DW from the vessel. Until 1900 s, in fact, the steam temperature in IRIS DW is larger than the saturation temperature. This explains the dominance of FRC_{1phs} up to 1900 s. Then the action of heat structures and the mass flux from containment to reactor vessel causing an expansion of the steam present in the IRIS DW, make some amount of steam to reach saturation and to condense, explaining why the FRC_{2ph} becomes the most relevant one up to 6500 s. After that, heat structures are able to cool down the super-heated steam which is again coming from the vessel after 3500 s , but only a part of this steam is cooled to saturation and condenses; this explains the dominance of FRC_{1phs} after 6500 s up to 10000s.
- In SPES3, before pressure equalization the modeled heat structures cool down the steam to saturation and condense practically all the superheated steam coming from the vessel; this results in a two-phase volume in SPES3 DW. After pressure equalization the heat released by the structures is enough to keep super-heated the steam. The main difference between the two cases is therefore that the heat released from structures keeps the steam super-heated immediately after pressure equalization in SPES3, while this occurs only after 6500 s in IRIS.
- FRCs for IRIS and SPES3 between 10000 and 30000 are shown in Fig.A13. 33 and Fig.A13. 34. It can be noted that in this period the dominant FRC is FRC_{1phs} for both IRIS and SPES3 because heat structures can keep super-heated the steam
- In the last part of the transient (from 30000 to 100000 s), it can be noted that in IRIS FRC_{2ph} is the most important one while in SPES3 FRC_{1phs} is the most important one. This is due to the fact that IRIS heat structures cannot keep super-heated the steam present that becomes almost all saturated (for example, in IRIS DW no super-heated steam is present anymore after 30,000) while SPES3

structures keep the steam super-heated. Besides, because of thick SPES3 structure, there is a big amount of heat released and absorbed frequently.

Summing up, FRC_{1phs} and FRC_{2ph} are the most important terms for IRIS and SPES3 and the pressure response mainly depends on these terms: in particular, pressure response is driven for a long time by FRC_{2ph} in IRIS, whereas in SPES3 the trend is mainly determined by FRC_{1phs}.

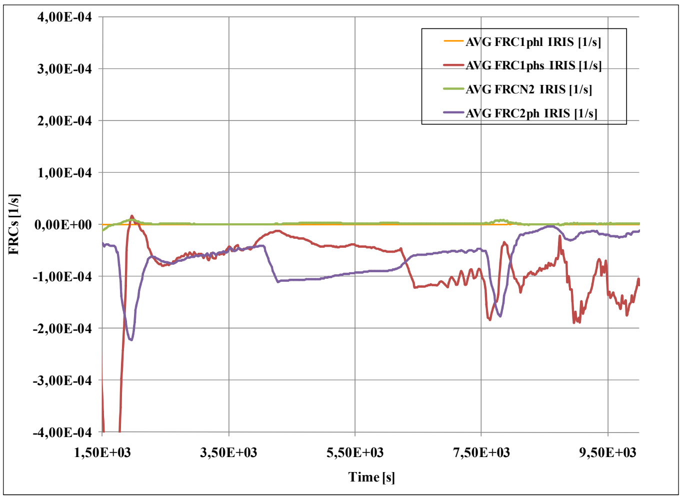


Fig.A13. 31 AVG FRCs for IRIS vs time

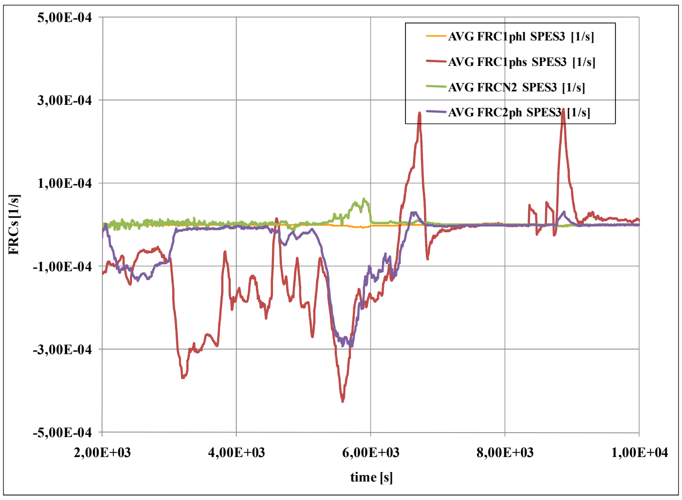


Fig.A13. 32 AVG FRCs for SPES3 vs time

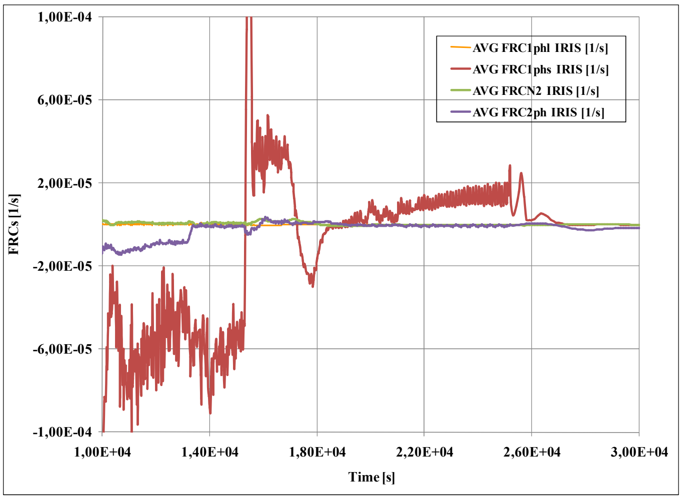


Fig.A13. 33 AVG FRCs for IRIS vs tim

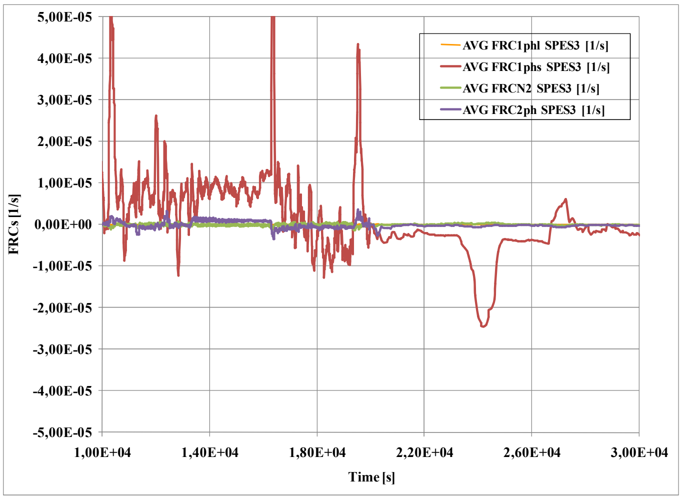


Fig.A13. 34 AVG FRCs for IRIS vs time

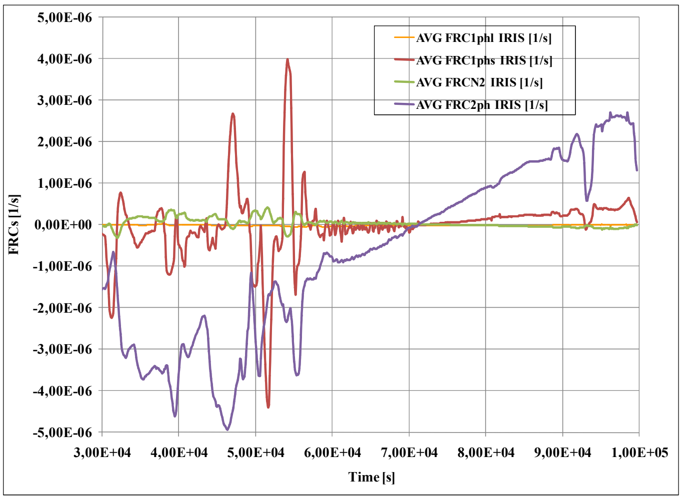


Fig.A13. 35 AVG FRCs for IRIS vs time

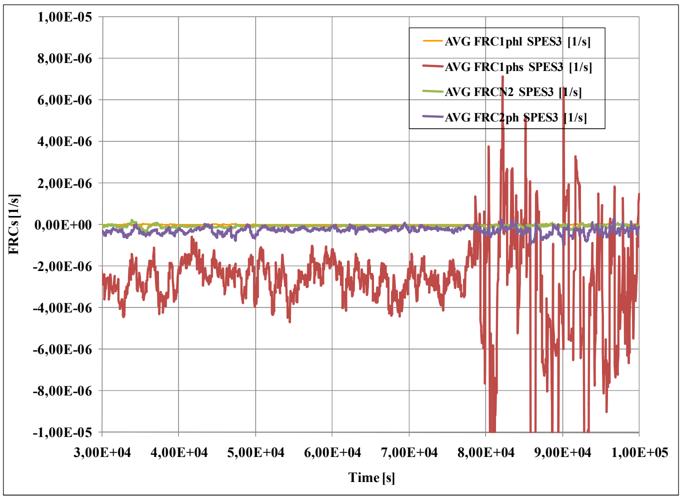


Fig.A13. 36 AVG FRCs for IRIS vs time

Main averaged distorsion parameters has been evaluated and listed in Tab.A13. 4. As it was expected, different accumulated/released heat influence gives good results just for time event 18 and 19, while some 1st and 2nd distorsion are present in previous time event. By the way, the worst result is for last 3 time events, during what opposite behavior in IRIS and SPES3 has been found.

Tab.A13. 4 : Distortions of two-phase and one-phase steam effect metrics in the selected time sequences

Sequence	AVGD1phs	AVGD2ph
15	8.42E-01	3.03E+00
16	4.55E-01	6.17E+00
17	5.78E-01	6.74E+00
18	1.17E+00	7.96E-01
19	9.67E-01	1.48E+00
20	-1.12E+00	-4.69E-01
21	-1.04E+00	-1.05E+00
22	-8.93E-01	-2.05E+00

DIFFERENCES ENCOUNTRED IN OLD SCALING ANALYSIS

As showed above concerning with old resuts, the main responsible which caused different pressure response in IRIS and SPES3 models can be summarized as follows:

1) In IRIS model only Dry Well structure had been considered, while in SPES3 simulation a heat structure had been taken into account for each elements. It caused in IRIS higher presence of super heated steam than what is there really.
2) The thickness of the SPES3 element structures (based on Pressure Design of 20 bar) was too high compare to IRIS ones, it means that condensation phenomena evolved for different times and, obviously, it affected pressure trend.
3) SPES3 elements volumes were bigger than scaled IRIS ones and it also affected Pressure response. In fact, when DVI break occurred in SPES3 simulation, the flux was injected into a bigger volume and, obviously, the pressure was lower than in IRIS

In order to explain IRIS and SPES3 heat structure differences, see Fig.A13. 37, Fig.A13. 38, Fig.A13. 39, Fig.A13. 40, where saturation temperatures (Gothic variable Tsat for IRIS DW and RELAP variable sattemp for SPES3 DW) and vapour temperatures (Gothic variable TV for IRIS DW and RELAP variable tempg for SPES3 DW) are reported (2 time windows for IRIS and 2 for SPES3). As it can be easily seen, vapour temperature in IRIS is higher than saturation temperature during the first 1800s, while in SPES3 the same curves are overlapped till 3000s. It means that in IRIS simulation heat is not absorbed by structure (because of adiabatic conditions imposed as boundary in elements except for DW) and it is taken by internal environment that, obviously, is hotter improving superheated steam, while in SPES3, the increasing heat is first absorbed by structure (which are considered for each component), keeping environment temperature lower and, consequentially, a large amount of 2-phase fluid is present.
Starting from this time up to the end of transient, IRIS vapour temperature is lower than saturation temperature (due to non released heat rate from structures) and, as consequence, super heated steam is gradually reduced and only 2-phase fluid is present. Indeed, in SPES3 starting from 3000s up to 5200s, vapour temperature is higher than saturation temperature and produces super heated steam. From 5200s up to 6800 the two curves again match while, from 6800s up to end, saturation temperature is always lower, improving a wider amount of super heated steam. It happens because of releasing heat from wall structure, which gives back what has been collected during the previous considered time.
These differences explained why IRIS reactor and SPES3 facility scaling analysis results were different, and it furnished help in order to change their models.

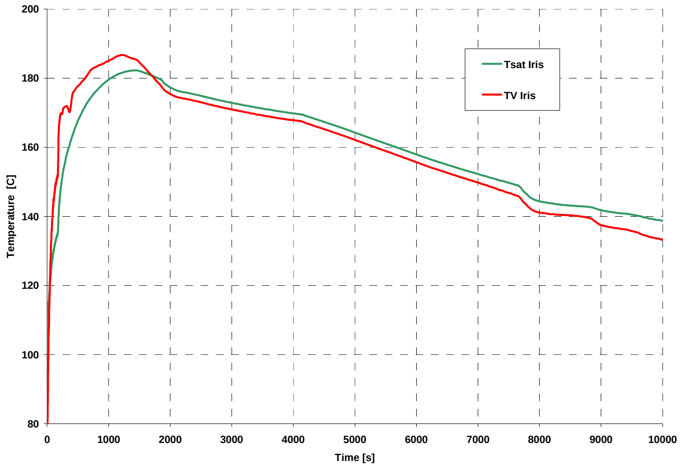


Fig.A13. 37 Saturation and vapour temperatures vs time IRIS

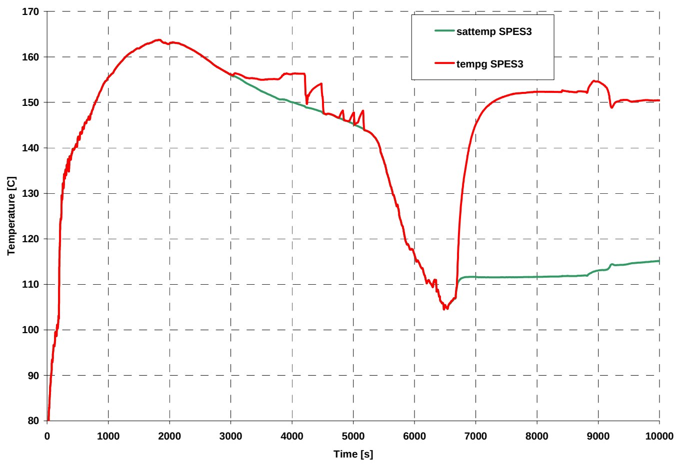


Fig.A13. 38 Saturation and vapour temperatures vs time SPES3

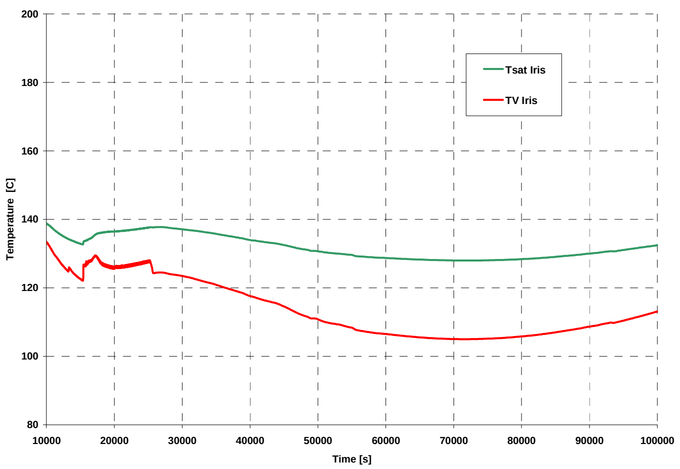


Fig.A13. 39 Saturation and vapour temperatures vs time IRIS

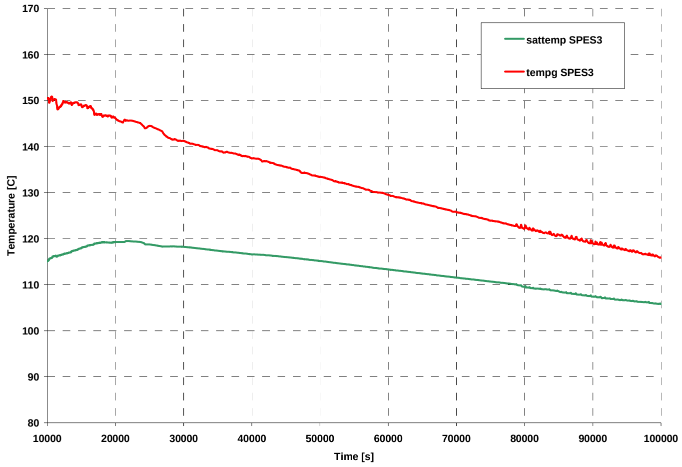


Fig.A13. 40 Saturation and vapour temperatures vs time SPES3

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IRIS AND SPES3 CHANGES AND NEW TIME DECOMPOSITION

Starting from previous Scaling Analysis performed by Lioce & Tortora and based on ht1_case (for IRIS) and spes3_89 case (for SPES3), some changes have been done on IRIS reactor and SPES3 facility models developed by Davor Grgic (FER) and Roberta Ferri (SIET) respectively, in order to reduce different behaviors observed during transient.
The following changes has been made.

IRIS changes

As discussed above, IRIS behavior showed the need of adding heat structures in the model not only for DW, but for all elements considered. New heat structure has been considered in the following elements:

1)LGMS content to DW: a 2.54 cm thickness wall of stainless steel (SS) has been considered as structure. Total metal is divided in 3 slabs representing bottom, top and side heat transfer (side A is LGMS, side B is first and second layer within drywell). Top and bottom areas are 42.04 m^2 and side slab has area 84.06 m^2. That is for one LGMS.

2)EBT content to DW**:** a 11.5 cm thickness wall of stainless steel (SS) has been considered as structure Total metal was divided in 3 slabs representing bottom, top and side heat transfer (side A is drywell, side B is insulated in this setup). Top and bottom areas are 8.94 m^2 and side slab has area 32.476 m^2. That is for one EBT.

3)PSS related heat structures are assumed to be concrete. All PSS structures are subdivided between a and b part of PSS tank by using height as weighting criteria. First set of structures are related to the wall between PSS and cavity. The thickness of concrete wall is 1m. Heat structures 34-39 takes into account communication between : CAV-PSS1a, CAV-PSS1b, CAV-PSS2a, CAV-PSS2b, PSS1b top, PSS2b top. For first 4 heat transfer areas are 43.98 m^2 and 34.56 m^2 (lower and upper PSS part). A side is cavity. For last two area is 140.357 m^2. Concrete slab is 1 m thick and B side is insulated (A is within PSS upper part). Each PSS has internal concrete wall (HS 40-43, PSS1a int, PSS1b int, PSS2a int, PSS2b int). The thickness of the wall is 1 m, but thickness of the slab is 0.5 m with two-times original area and one side exposed to PSS and other insulated. First two areas are 27.75 m^2 and 19.45 m^2 (lower and upper part of PSS). There are two concrete walls between PSS 1 and 2 (splitted in lower and upper part, HS 44-45, PSS1a-2a, PSS1b-2b). The areas are again 24.75 m^2 and 19.45 m^2 (lower and upper PSS part). The thickness is again 1 m. Side A is exposed to PSS (lower and upper part HS 46-49,PSS1a-env, PSS1b-env, PSS2a-env, PSS2b-env) and side B is insulated. The areas for lower and upper side of each PSS are 125.9 m^2 and 98.9 m^2.

4)Reactor Cavity heat structures. Concerning the heat structures connecting RC and PSS, one has been added at the bottom (HS51) and one takes into account part of concrete above PSS top elevation (HS52). One meter thick slab with the area of 50.265 m^2 was used for bottom of the cavity. Side A is exposed to RC and side B is insulated. HS52 is concrete cylinder with inner radius of 4 m and thickness of 1 m. Again side A is exposed to RC and side B is insulated. There is no SS liner on RC inner surface. Area of the structure is 106.8 m^2 (based on height above top of PSS of 4.25 m).

5) Main PSS vent wall has a 1.508 cm thickness of SS (based on 20” sch 40 pipe). There are 3 structures per lumped vent. Height is based on height of vent within PSSa, PSSb and drywell (3.25 m, 2.75 m, 4.25 m). Inner diameter is 0.4778 m. Calculated areas are 15.56 m^2, 13.14 m^2, and 20.35 m^2. Side A is always vent inside, side B is PSSa, PSSb or drywell. Part of the pipe wall within concrete (above PSS and below operating deck) is not modeled). HS 52-54 (Vent1-PSS1a, Vent1-PSS1b, Vent1-DW) are used for vents attached to PSS 1 and HS 55-57 (Vent2-PSS2a, Vent2-PSS2b, Vent2-DW) are used for vents attached to PSS 2.

IRIS Containment Vessel nodalization has been slightly changed in order to get better results, and the new configuration is showed in Fig.A13. 41.

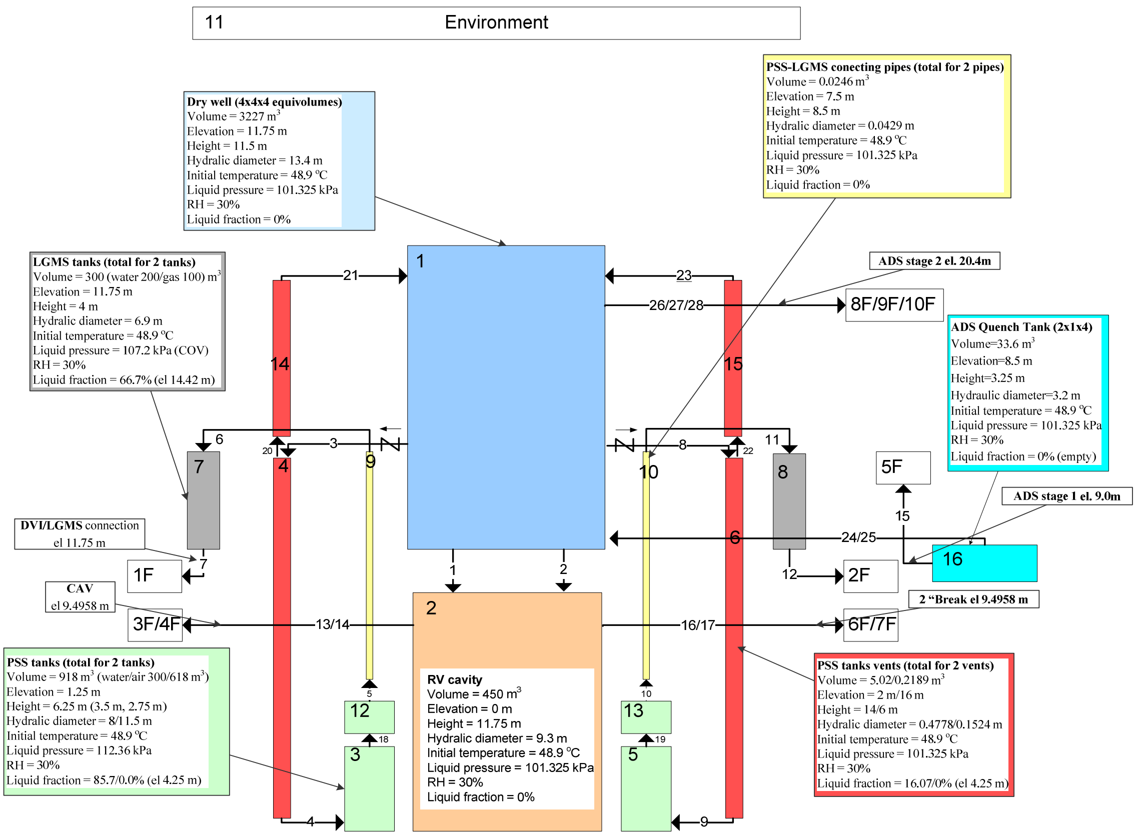

Fig.A13. 41 new IRIS Containment Vessel nodalization (Gothic)

Compared to ht1_case, two extension pipes have been deleted as well as one volume related to ADS QT. Three flow boundary conditions, representing ADS stage 2, are directly connected to DW trough junctions and one volume used to model atmosphere in AB.

Another change has been applied to RWST pool model, because in ht1_case model a wrong amount of water in pools (around 400 m^3 instead of 1200 m^3) has been found. The ht1_case model is based on single volume representing RWST pool and a part of new adopted model is showed below(only EHRS 1 HX). Basically, two pools with 1200 m^3 of water in each have been considered. There are two HXs in each pool. Pipes 581 and 582 are used to model pool water around EHRS 1 and 2 HX and pipes 591 and 592 are doing the same in pool 2 for EHRS HX 3 and 4. Main of water body is represented by pipes 580 for pool 1 and 590 for pool 2. Axial subdivision follows the one used for EHRS HX (0.665 m for top and bottom header and then 10 subdivisions for HX tubing 10*0.18=1.8 m). Braches 583/593 and 584/594 models water below and above HX at full pool cross section. Height of lower branch is 0.6 m and the one of upper branch is 6.02 m. Total height up to the AB elevation 17.25 m is 9.75 m. Cross section area of the pool is 131.5 m^2 and total amount of water per pool is 1200 m^3. Volume 585/595 is AB atmosphere and the volume is estimated to 34980 m^3 each.to DW.

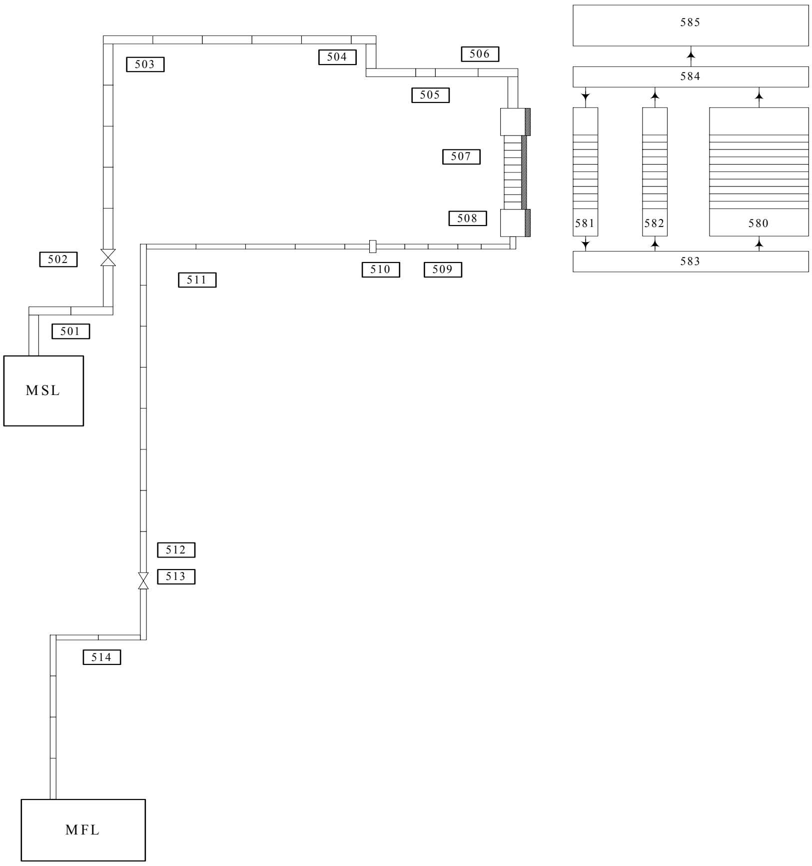

Fig.A13. 42 RWST pool model

Finally, all elements are considered at 48.9 C.

SPES3 changes

In order to reduce Accumulated Heat and to get pressure behavior closer to IRIS, the thickness of the wall of some elements in SPES3 have been reduced by changing design pressure from 20 bar to 15 bar, in particular:

1. Dry Well's structure thickness is reduced from 25mm to 15 mm
2. Cavity wall is changed (from 10 mm on the top and 14mm in the middle to 10mm on the top and 8 mm in the bottom)
3. Two Pressure Suppression System (PSSA,PSSB) thickness of the wall is reduced from 18mm on the top and 12mm in the bottom to 12mm on the top and 8mm in the bottom
4. Long Term gravity Makeup System tank 1 and 2 thickness of the wall is reduced from top & bottom 10mm and middle 14mm to top & bottom 8mm and middle 10mm

To achieve a higher value of the pressure during the transient (closer to IRIS simulation), total volume of the tanks has been reduced, in particular:

a. Dry Well volume is reduced from 35.36 m3 to 32.22m3
b. Cavity volume is reduced from 5m3 to 4.5m3
c. Two Pressure Suppression System (PSSA,PSSB) volume is reduced from 5.01m3 to 4.59m3
d. Emergency Boration tank regarding Intact and Broken Loop (EBSIN,EBSBR) is reduced from 0.18m3 to 0.13m3
e. Long Term gravity Makeup System tank 1 and 2 volume is reduced from 0.16m3 to 1.5m3

In the table below, SPES3 and IRIS RV volumes are listed and compared to highlight that SPES3 volumes are well scaled on IRIS ones.

Tab.A13. 5 SPES3 and IRIS RV volumes

IRIS volumes	IRIS/100	SPES-3 volumes	Zones	weight on IRIS vol %	%
17.018	0.170	0.192	LP	0.427	12.695
13.338	0.133	0.103	Core	-0.593	-22.483
0.977	0.010	0.015	Core by-pass	0.108	56.035
66.800	0.668	0.695	Lower riser	0.535	4.055
75.281	0.753	0.761	Upper riser	0.164	1.104
14.898	0.149	0.161	pump suction plenum	0.239	8.110
76.672	0.767	0.768	PRZ	0.019	0.125
28.236	0.282	0.417	pump	2.652	47.531
74.757	0.748	0.865	SGs	2.329	15.761
138.005	1.380	1.319	lower DC	-1.208	-4.429
505.981	**5.060**	**5.296**	TOTAL	4.673	4.673

Finally, orifices in SPES3 pipes have been recalibrated in order to get the same pressure drop of the IRIS pipes (in particular, in PSS vent pipe). The purpose is, once the same different of pressure is reached in IRIS and SPES3, the same mass flow rate is achieved.
As in IRIS, also SPES3 nodalization is changed and it is shown in Fig.A13. 43 and Fig.A13. 44
Finally, initial temperature in DW, RC and QT has been assumed equal to 84 C as PSS and LGMS heat structures, while water space is at 48.9 C.

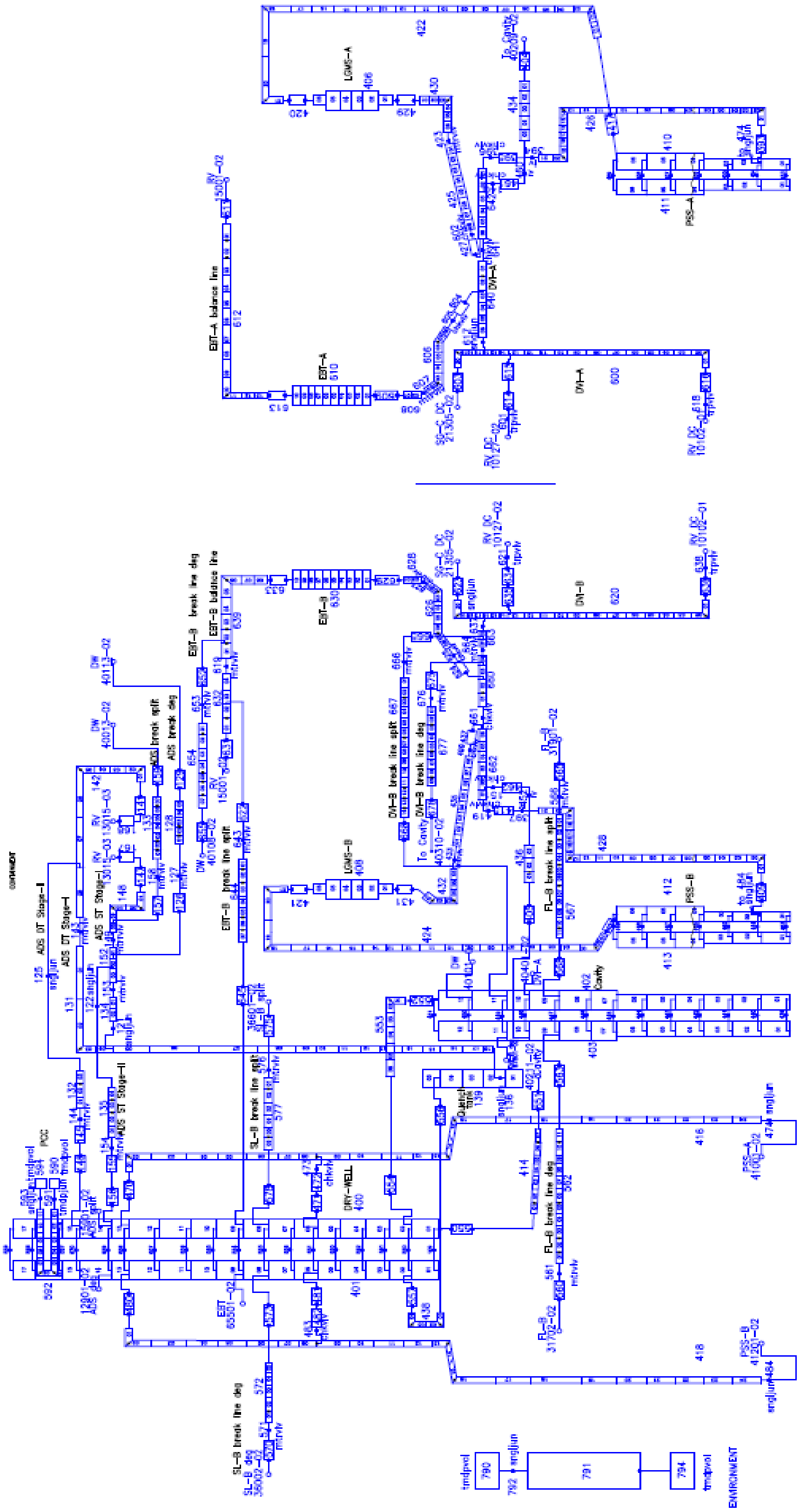

Fig.A13. 43 SPES3 Containment (Relap)

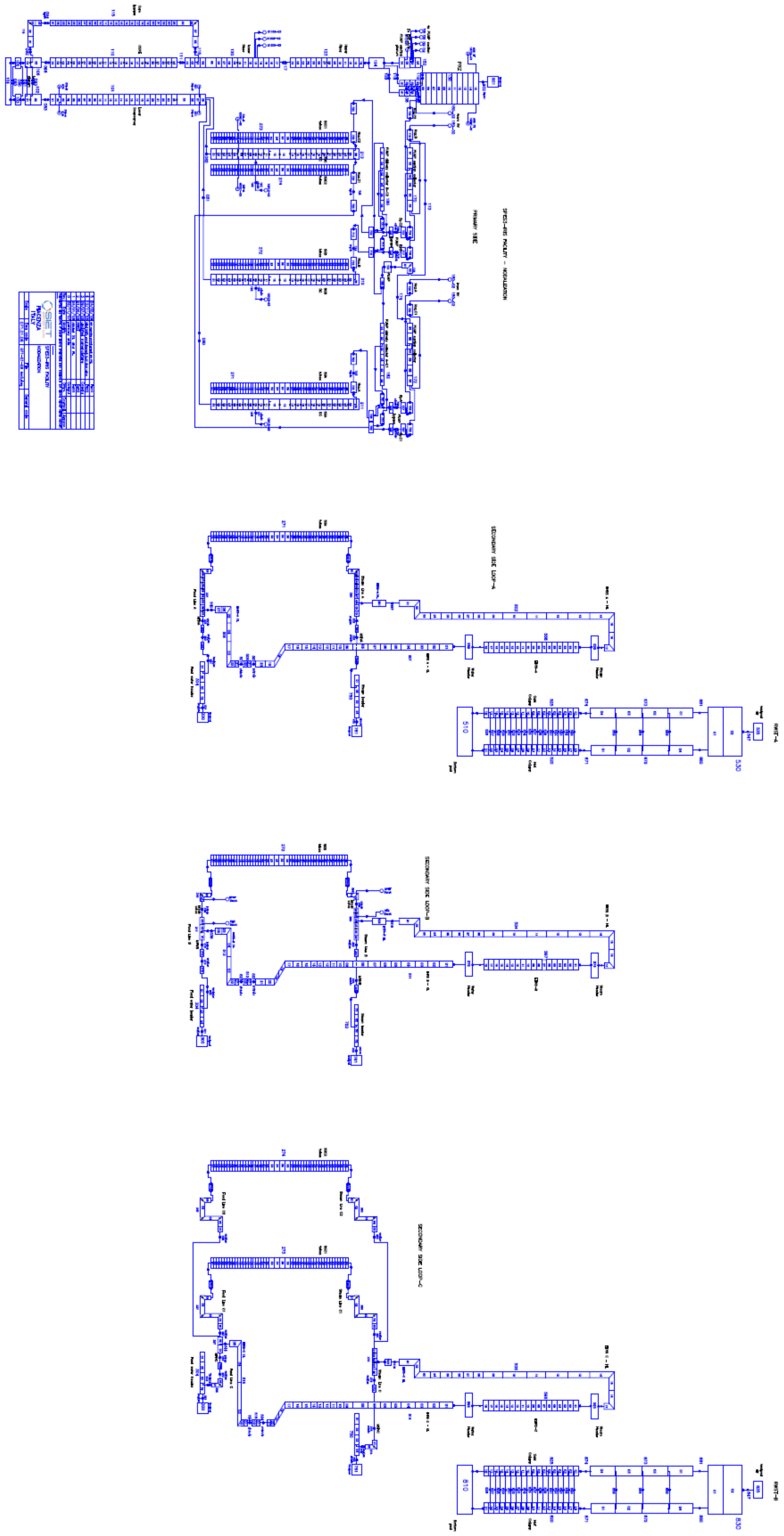

Fig.A13. 44 SPES3 primary and secondary

IRIS and SPES3 time decomposition

Space decomposition has to be developed in order to perform Scaling analysis. In

Tab.A13. 6 and

Tab.A13. 7 the new time decompositions applicable to the DVI SBLOCA sequences in IRIS and SPES3 are reported as simulated by the above-mentioned code models. Indeed, old time decomposition has been listed too in order to show the effects of the changes performed on IRIS and SPES3 models. The times at which each time event occurs have been evaluated based on Grgic (2009) and Ferri (2009) input data.

Tab.A13. 6 Time decomposition for the DVI SBLOCA in IRIS (new results)

Event #	Event description	Time old (s)	Time new (s)
1	Break initiation	0	0
2	SCRAM begins	25.1	31
3	MFIV 1-4 closing	25.1	31
4	MSIV 1-4 closing	25.1	31
5	EHRS-AOV 1,3 opening	36.1	42
6	RCP costdown starts	146	147
7	ADS Stage I start opening (3 trains)	174	176
8	EHRS-AOV 2,4 opening	186	178
9	Natural circulation begins through shroud valves	184	188
10	Flashing begins at core outlet	184	189
11	EBS valves opening	189	195
12	Natural circulation interrupted at SGs top	265	285
13	EBT-RV connections uncovered	385	395
14	EBT broken loop empty	605	620
15	LGMS tank of broken loop start injecting into Cavity	1543.82	1612
16	Containment and RV pressure equalization	1530	1830
17	LGMS-intact loop starts to inject into RV through DVI intact loop	1643.33	1730
18	Steam and gas mixture flows again from RV to QT	3900	3190
19	ADS stage II start opening	15400	20860
20	LGMS-broken loop empty	16095.4	20873
21	LGMS-intact loop empty	16400.5	22300
22	Flow from Cavity starts	≈18000	49116

Tab.A13. 7 Time decomposition for the DVI SBLOCA in SPES3 (new results)

Event #	Event description	Time old (s)	Time new (s)
1	Break initiation	0	0
2	SCRAM begins	48.77	31
3	MFIV-A,B,C closure start	48.77	31
4	MSIV-A-B-C closure start	48.77	31
5a	EHRS-A,B opening start (EHRS 1 and 3 in IRIS)	48.77	32
6	RCP costdown starts	90.26	113
5b	EHRS-C opening start (EHRS 2 and 4 in IRIS)	180.83	182
7	ADS Stage I start opening (3 trains)	180.83	184
8	Natural circulation begins through shroud valves	108-110	133
9	Flashing begins at core outlet	113	202
10	EBT A/B valve opening start	180.83	183
11	Natural circulation interrupted at SGs top	212	249
12	EBT-RV connections uncovered	204	221
13	EBT-B empty	510	481
14	LGMSA/B valve opening start	2090.35	2150
16	LGMS-A starts to inject into RV through DVI intact loop	2170	2260
15	Containment and RV pressure equalization	2250	2230
17	Steam and gas mixture flows again from RV to QT	5530	2270
18	ADS stage II start opening	11860	31569
19	LGMS-A empty	26190	40000
20	LGMS-B empty	26190	30790
21	Flow from RC to RV (loop-A) start	26890	28815

It is worth underlining that the time events are obviously the same for both IRIS and SPES3, but the actual time at which each event occurs is slightly different. Compared with the old time decomposition, it has to be pointed out that IRIS and SPES3 pressure response during transient is closer, even if some different behaviors are still present. By the way, a more detailed description of the time decomposition is reported below only for IRIS, because of the equality between IRIS and SPES3 time sequences.

Time event 1 Break Initiation

At time $t=0^+$ the transient starts with the break in one of the DVI lines, as represented in Fig.A13. 45 .

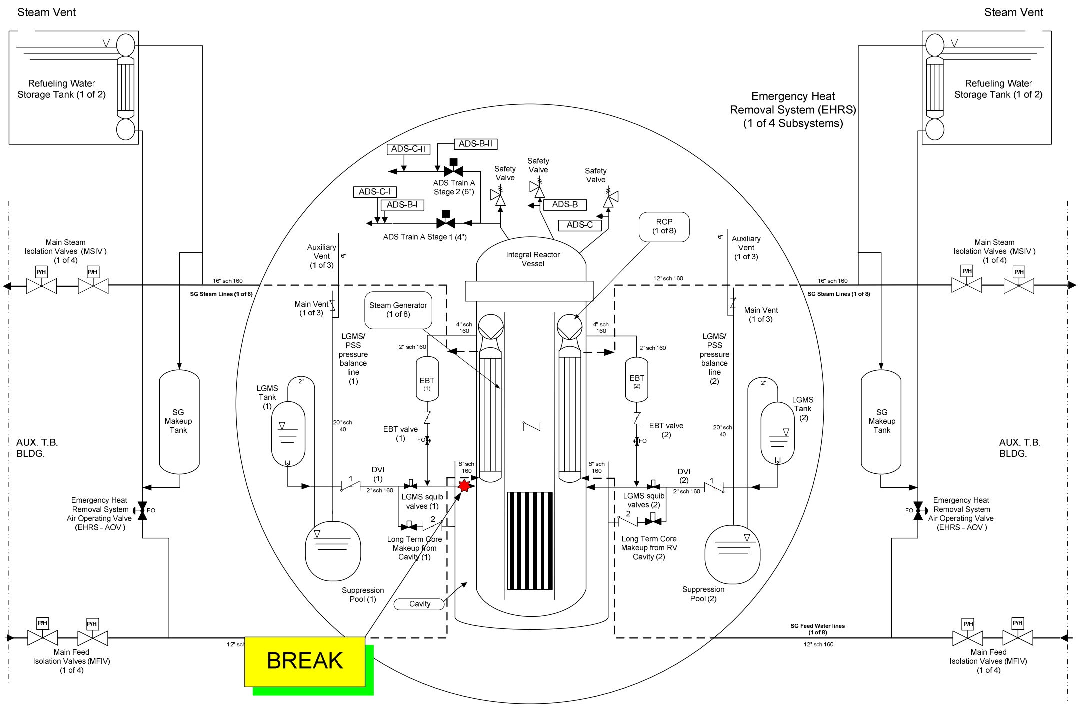

Fig.A13. 45 Break initiation

Time event 2. Scram begins

Rods begin to fall into the core at t = 31 s, and the scram is initiated by the Containment High Pressure signal (RPS High). Accordingly the core power decreases as represented in Fig.A13. 46.

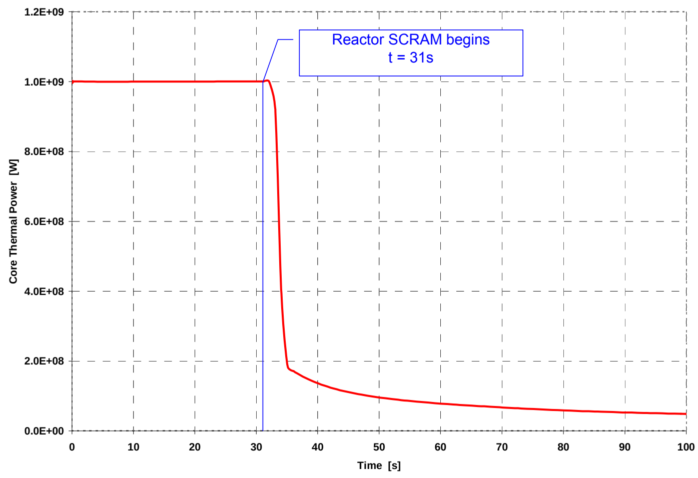

Fig.A13. 46 Reactor Power vs Time

Time event 3-4. MFIVs and MSIVs 1-4 starts closing

After the reactor trip, ensuing from the signal of High Containment Pressure (t =31 s), the isolation sequence of the secondary loops starts with the removal of decay heat by EHRS. Main Feed line Isolation Valves (MFIVs) start to close at the same time in which rods begin to fall into Core (see Fig.A13. 47 and Fig.A13. 48). MFIVs full closure corresponds to the time at which the Main Steam Isolation Valves (MSIVs) starts to close (see Fig.A13. 49 and Fig.A13. 50).
In RELAP run, performed by Davor Grgic (FER), DVI-SBLOCA MSIVs and MFIVs close together starting at time t = 31. s while in IRIS actuation strategy MSIVs should begin to close only when MFIVs are fully closed.

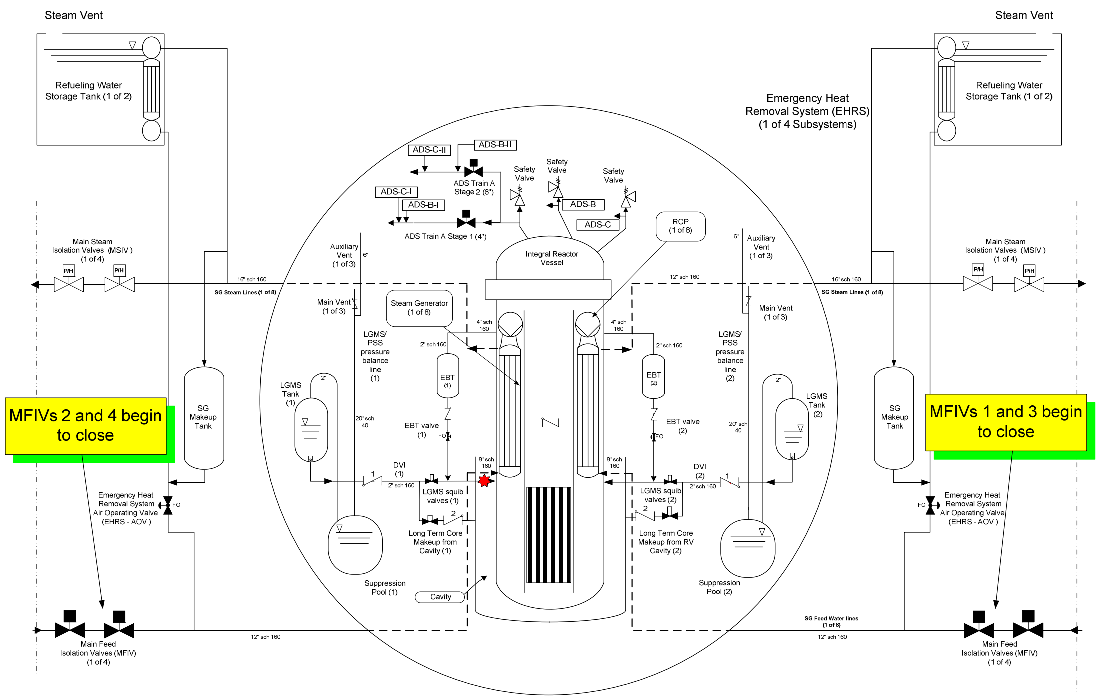

Fig.A13. 47 MFIVs 2 and 4 start closing

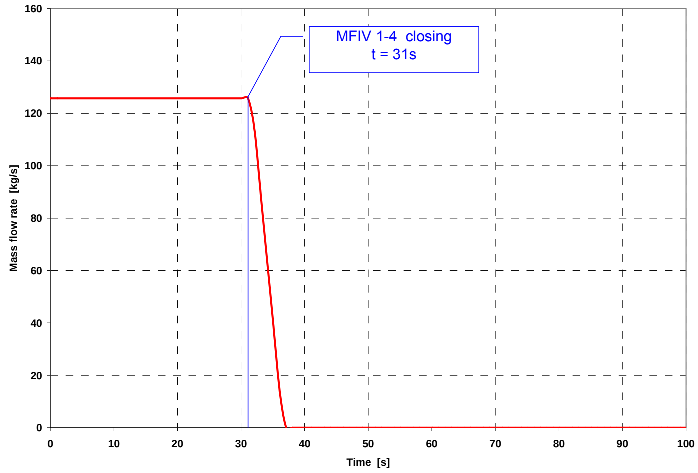

Fig.A13. 48 MFIVs mass flow rate

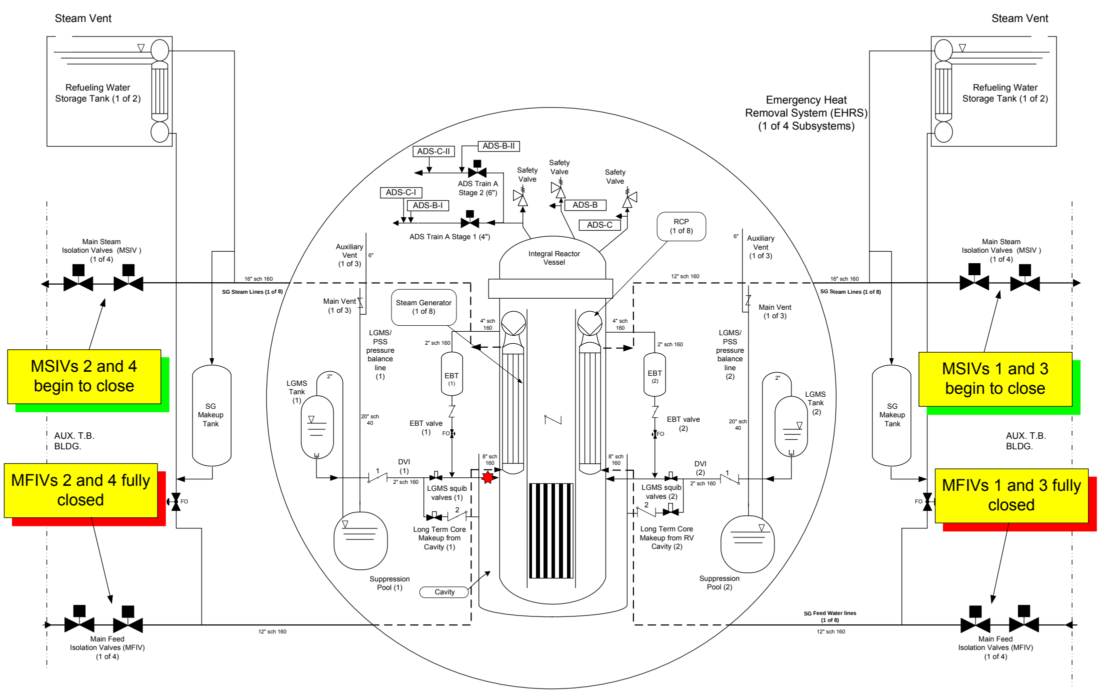

Fig.A13. 49 MFIVs fully closed and MSIVs begin to close

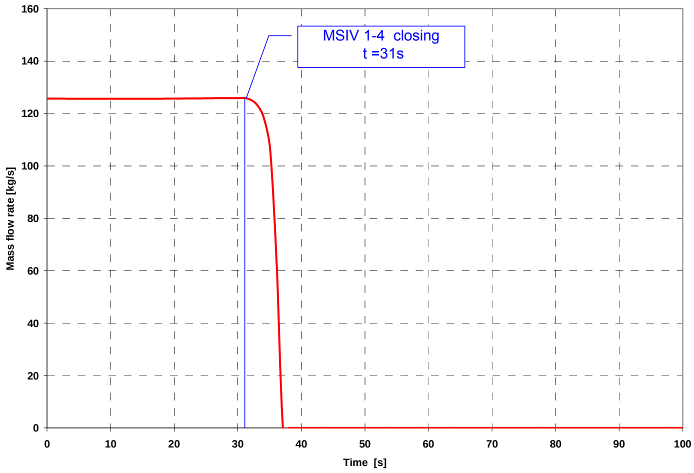

Fig.A13. 50 MSIVs mass flow rates

Time event 5: EHRS-AOVs 1-3 opening

As soon as the isolation of the primary loop is completed (MFIVs and MSIVs completely closed), the emergency cooling of the CORE by EHRS (Emergency Heat Removal System) is initiated by the opening of AOVs (Air Operated Valves) 1 and 3 (Fig.A13. 51 and Fig.A13. 52). That happens at t=42 s, which means that the complete isolation of the primary loop is achieved in 11 s after the High Containment Pressure signal.

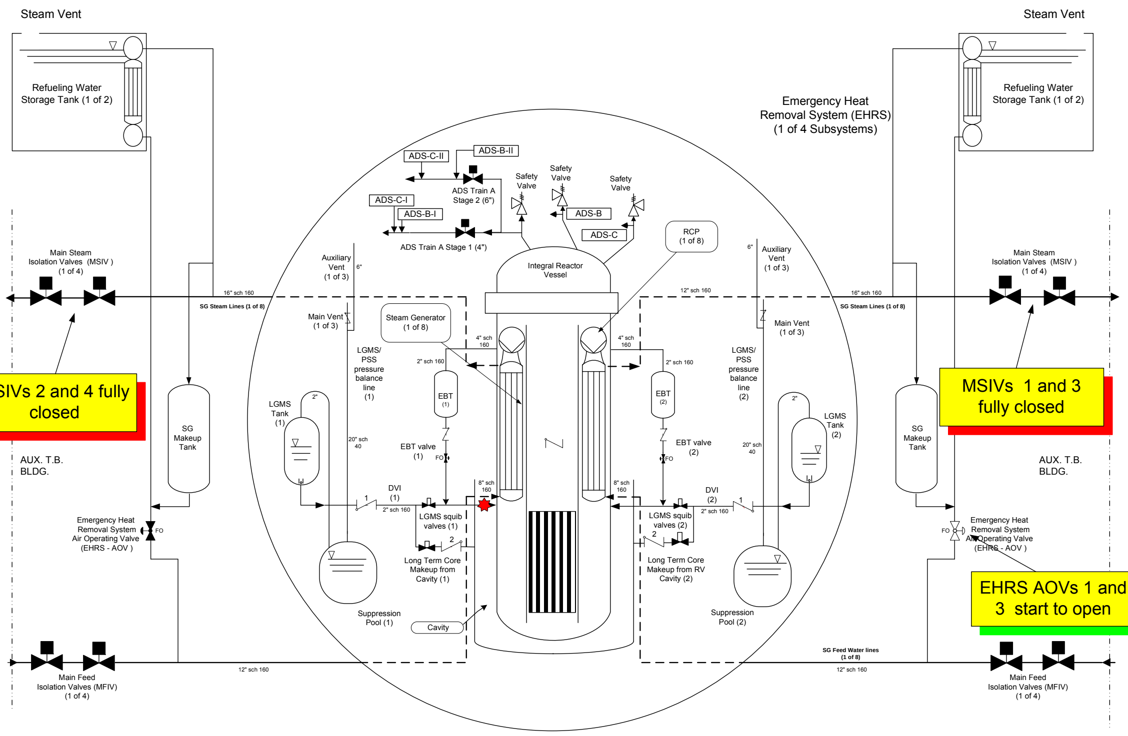

Fig.A13. 51 EHRS-AOV 1-3 starts opening

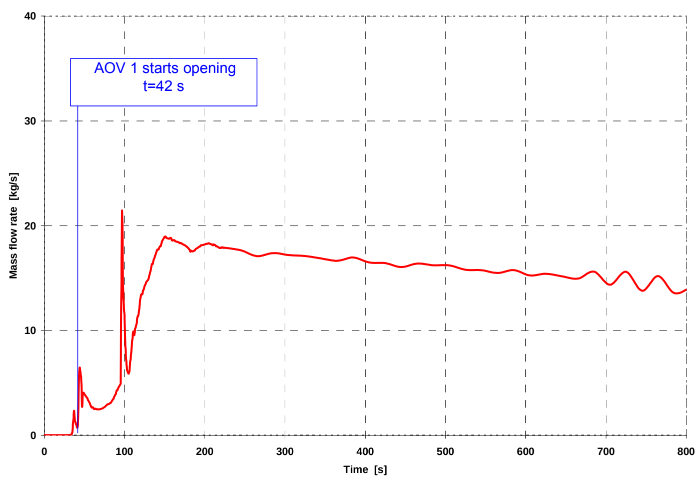

Fig.A13. 52 mass flow rate vs time

Time event 6: RCPs coastdown starts

The Low Pressurizer Water Level signal triggers the Reactor Coolant Pumps trip with some delay in order to allow reactor trip to occur first in the case that reactor trip were produced by Low Pressurizer Water Level signal as well. Fig.A13. 53 shows the pump head trend during the first 1000 s of IRIS DVI-SBLOCA transient.

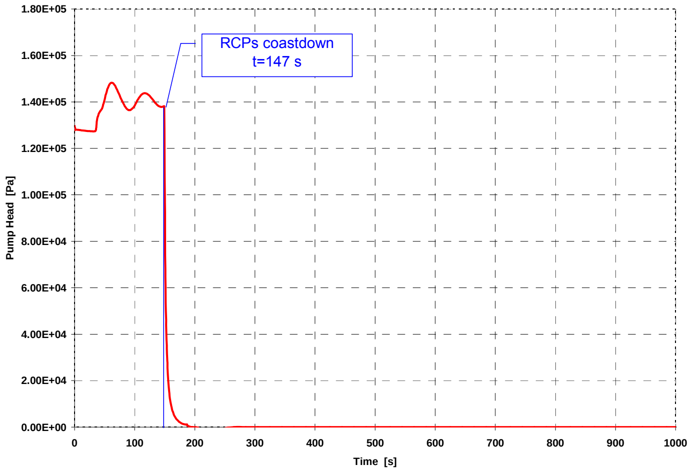

Fig.A13. 53 Pump Head vs Time

Time event 7: ADS Stage I starts opening

At t=176 s in the pressurizer (PZR) the pressure reaches the value of 11.72 MPa that corresponds to the set point of Low-2 PZR pressure signal.
ADS Stage I starts to open and discharges steam into the quench tank, Fig.A13. 54. In Fig.A13. 55 the linear trend of the ADS Stage I mass flow rate due to the linear opening curve

of the ADS valves is shown. After the ADS Stage I is completely open, the mass flow rate is driven by the pressure difference between RPV and CV.

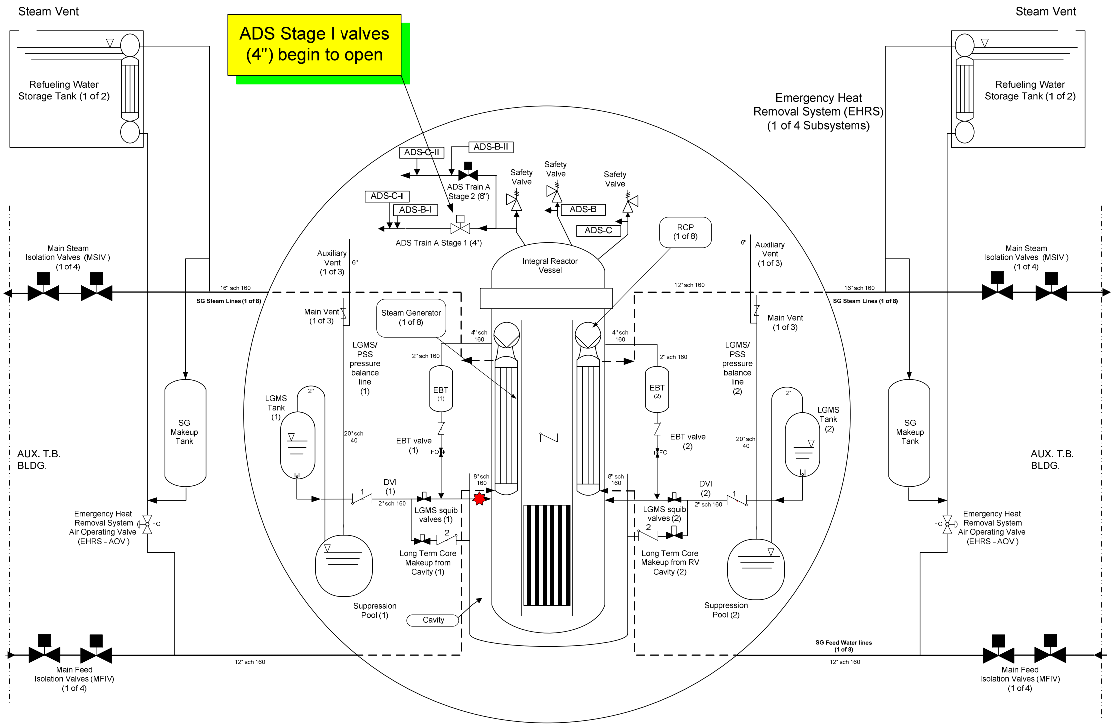

Fig.A13. 54 Time event 7

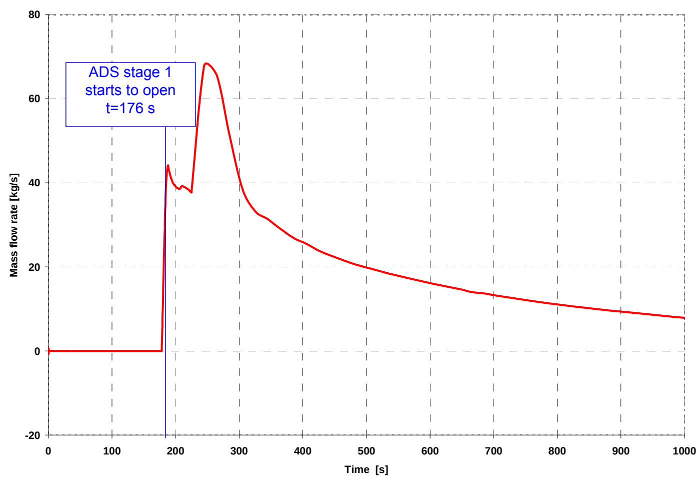

Fig.A13. 55 ADS mass flow rate stage I vs time

Time event 8: EHRS-AOVs 2-4 start opening

At t=178 s, AOVs 2-4 start to open and the mass flow rates through these valves become positive (see Fig.A13. 56 and Fig.A13. 57)

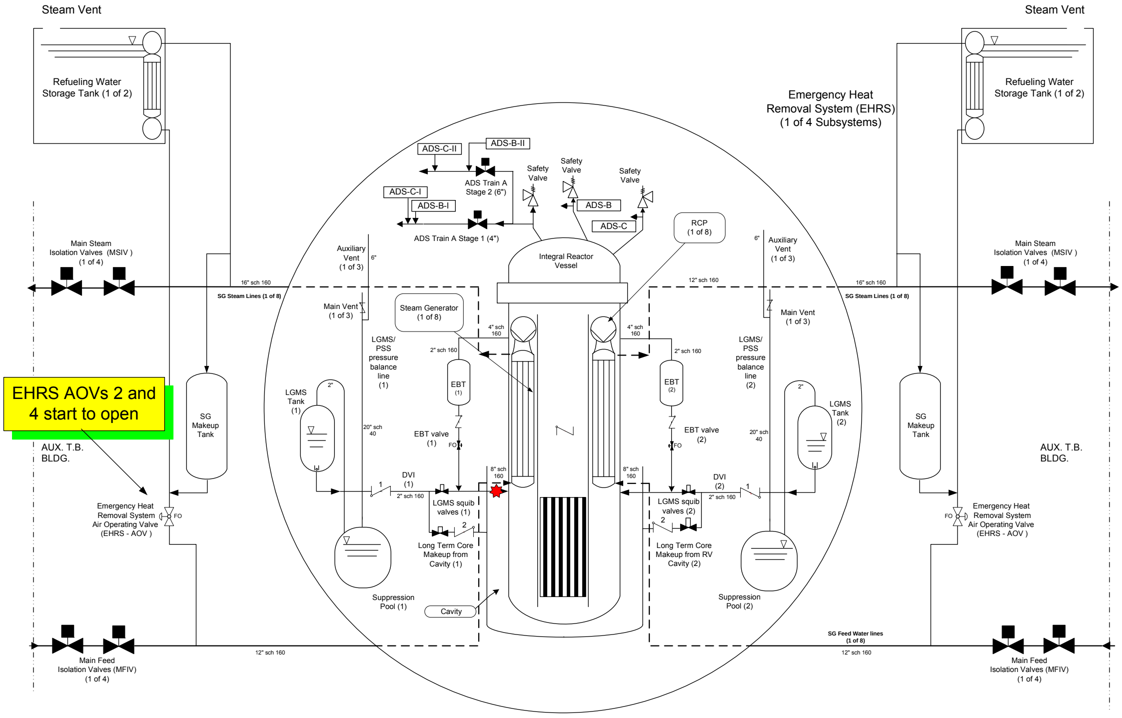

Fig.A13. 56 Time event 8

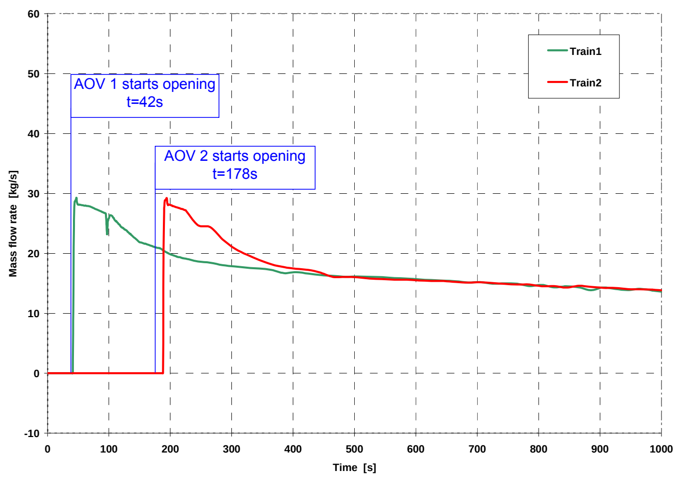

Fig.A13. 57 EHRS Train 1 and 2 Mass flow rate vs time

Time event 9: Natural circulation begins through shroud valves

Shroud valves (Fig.A13. 58) remain closed until their pressure difference set-point is reached by the ΔP between Riser (RIS) volume and Steam Generators (SGs) volumes. When that occurs, the shroud valves start to open and the mass flow rates become positive (see Fig.A13.

59). Since the pressure difference between the RIS and SGs volumes is mostly due to the pumps head, the flow paths through opened shroud valves start after RCP coast down termination.

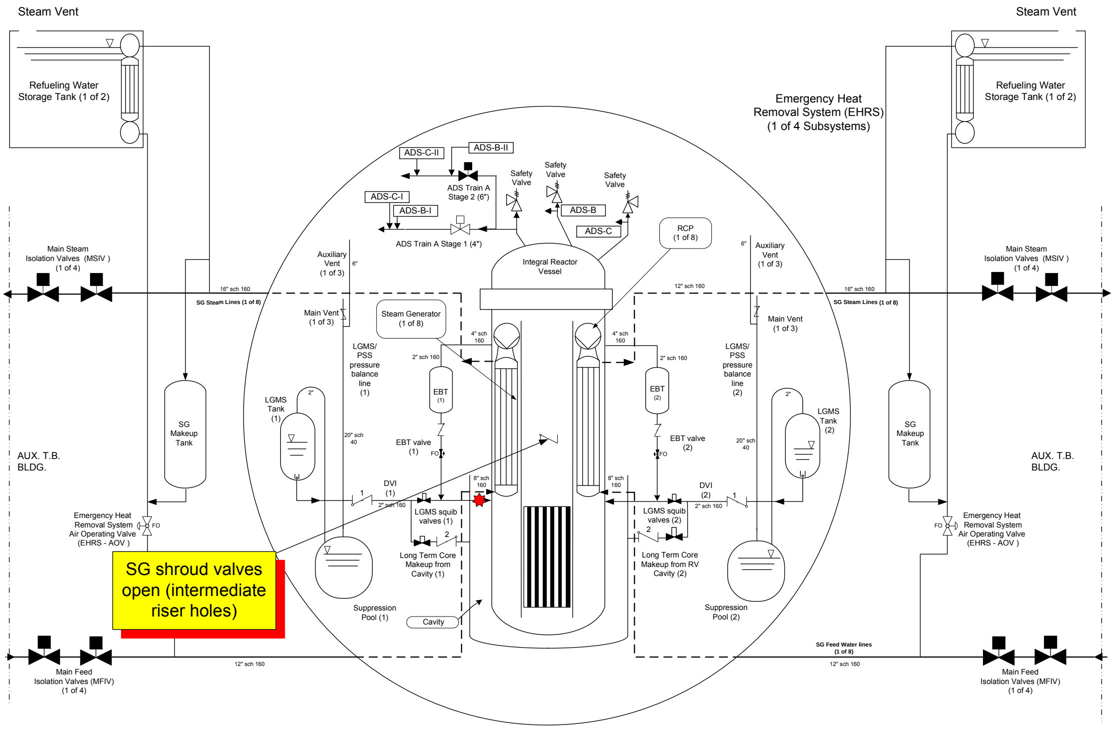

Fig.A13. 58 Time event 9

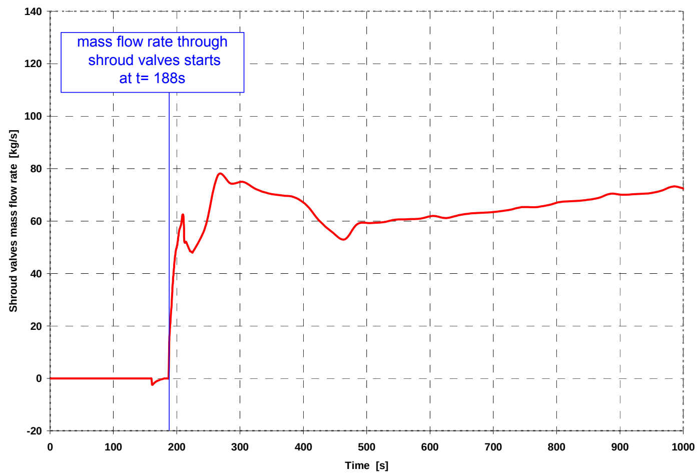

Fig.A13. 59 Mass flow rate through shroud valves vs time

Time event 10: Flashing begins at core outlet

When the liquid temperature reaches the saturation temperature, flashing begins (see Fig.A13. 60). This occurs first at CORE outlet, where the difference between saturation temperature and liquid temperature is minimum.

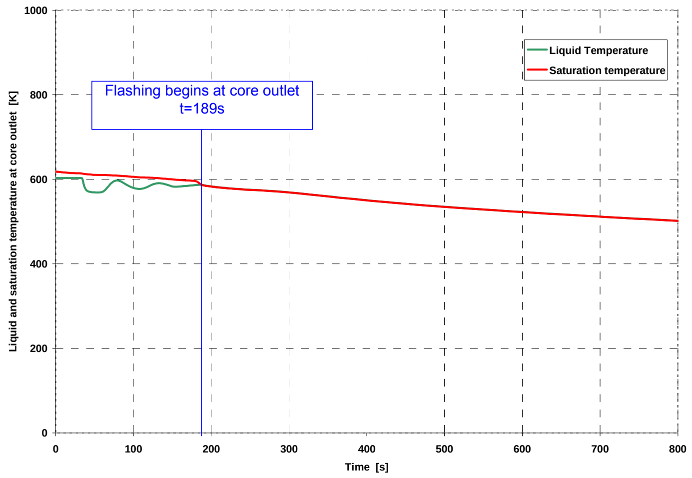

Fig.A13. 60 Liquid and saturation temperature vs time

Time event 11: EBS valves opening

As represented in Fig.A13. 61 and Fig.A13. 62 at t=195 s EBS valves open and flow rate through these valves starts. EBT of broken loop discharges in the reactor cavity while EBT of intact loop discharges in the reactor vessel.

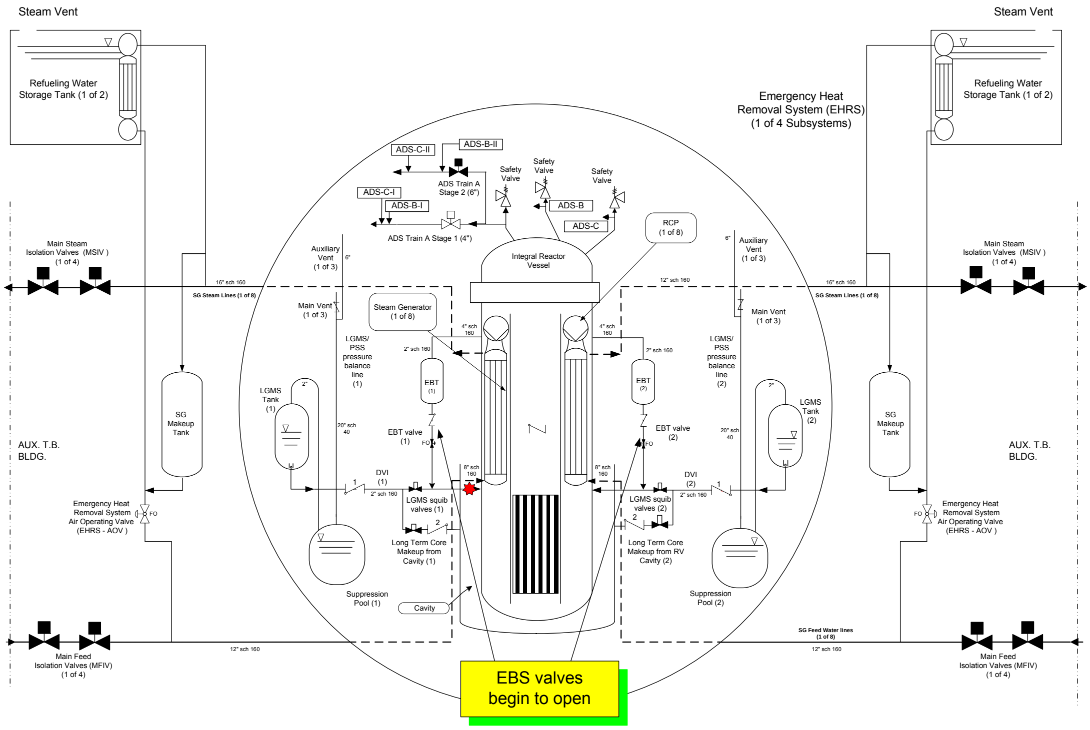

Fig.A13. 61 EBS valves begin to open

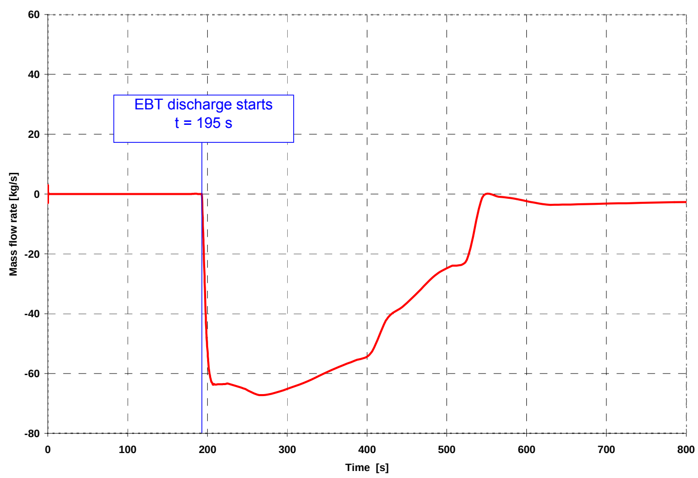

Fig.A13. 62 EBT mass flow rate vs time

Time event 12: Natural circulation interrupted at SGs upper portion

When liquid level drops below the pump suction plenum, natural circulation in the upper portion of SGs is interrupted. From Fig.A13. 63, in which mass flow rate and void fraction for steam generators upper sub-volume are shown, it can be seen that at t=285 s the mass flow rate becomes zero and that at the same time the void fraction reaches 1. That means that no liquid is flowing anymore through SGs upper sub-volumes.

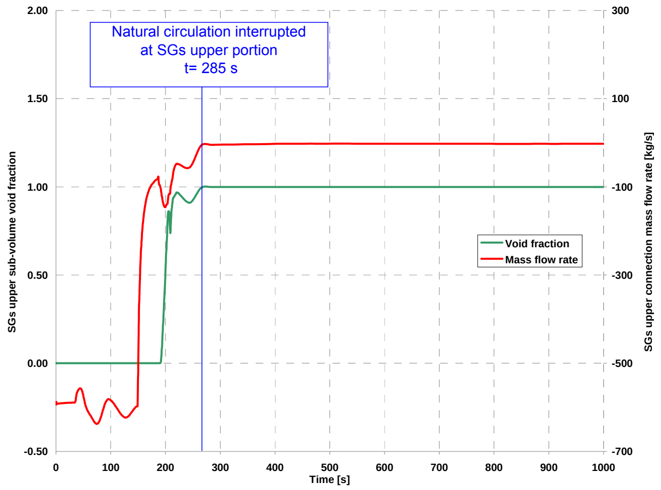

Fig.A13. 63 SGs upper portion mass flow rate and void fraction vs. time

Time event 13: EBT-RV upper connections uncovered

Water liquid level in Reactor Vessel is assumed to drop below the upper connection between EBT and RV when steam fraction in this region becomes 1. As represented in Fig.A13. 64 this phenomenon takes place at t = 395 s.

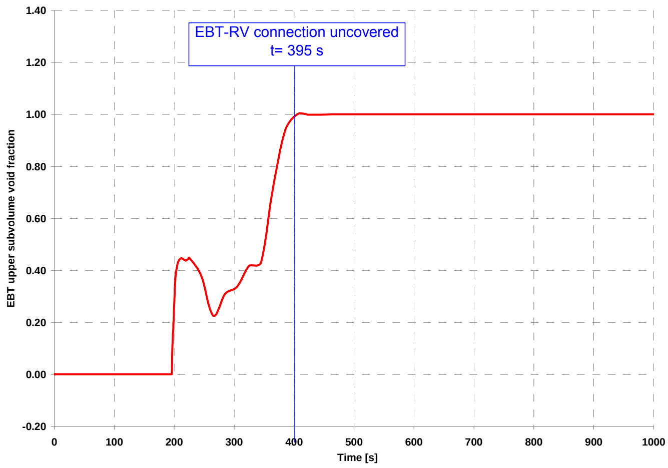

Fig.A13. 64 void fraction in EBT upper connection vs time

Time event 14: EBT of broken loop is empty

The EBT of broken loop injects water in reactor cavity since t=195s (time event 11) and it is empty at t=620 s, as showed in Fig.A13. 65, in which the EBT of broken loop void fraction vs. time is reported. The EBT of broken loop is empty, when the void fraction becomes 1.

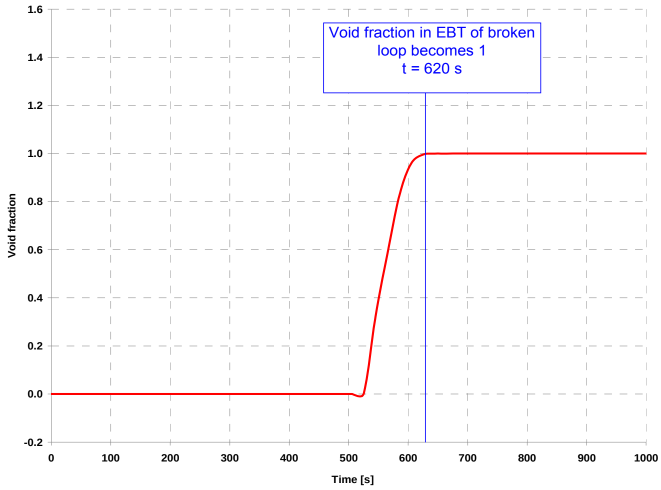

Fig.A13. 65 void fraction vs time

Time event 15: LGMS tank of broken loop starts injecting into Reactor Cavity

Since the beginning of the transient, pressure in Reactor Vessel decreases while pressure in Containment Vessel rises. When the pressure difference between RV and CV reaches the minimum set-point value, the Long-term Gravity Makeup System (LGMS) squib valves start to open in both broken and intact loops (Fig.A13. 66). At this point, starting of the flow from LGMS tanks of broken and intact loops into reactor cavity and reactor vessel respectively is possible only when LGMS check valves 1 in broken and intact loops open. This occurs first for broken loop at t=1612 s. Fig.A13. 67shows that the mass flow rate through LGMS check valve 1 in broken loop becomes positive at t=1612 s.

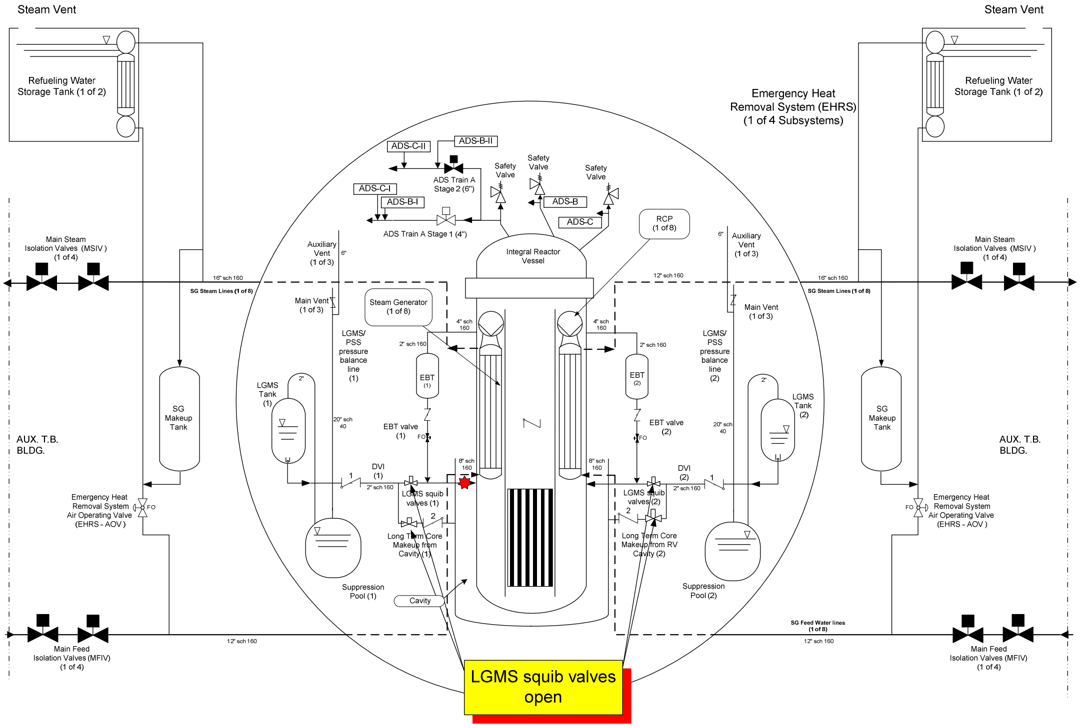

Fig.A13. 66 time event 15

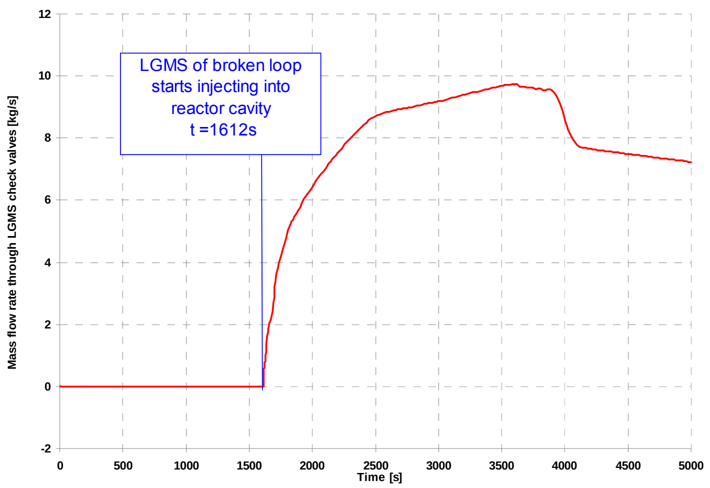

Fig.A13. 67 Mass flow rate through LGMS check valve (Broken loop) vs time

Time event 16: Containment and Reactor Vessel pressure equalization

Since the beginning of the transient, there is a discharge from DVI line break and then from ADS stage I into containment vessel. It means that pressure in the reactor pressure vessel is decreasing while pressure in the containment is rising. At t=1830 s there is a pressure equalization between containment and reactor vessel (see Fig.A13. 68).
After that containment pressure remains higher then vessel pressure and ADS stage I line starts to supply a mixture of nitrogen and steam into reactor vessel till 3190 s.

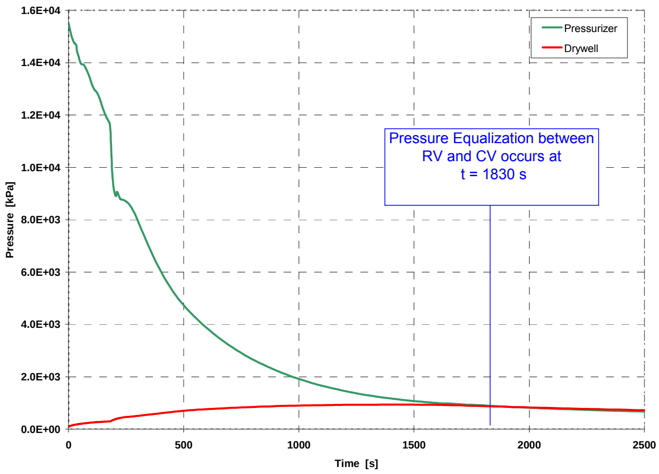

Fig.A13. 68 Reactor vessel and Containment vessel vs time

Time event 17: LGMS tank of intact loop starts injecting into reactor vessel

When the LGMS check valve I of the intact loop (see Fig.A13. 69) opens, LGMS tank starts injecting into the reactor vessel (see Fig.A13. 70). That occurs at t=1730 s.

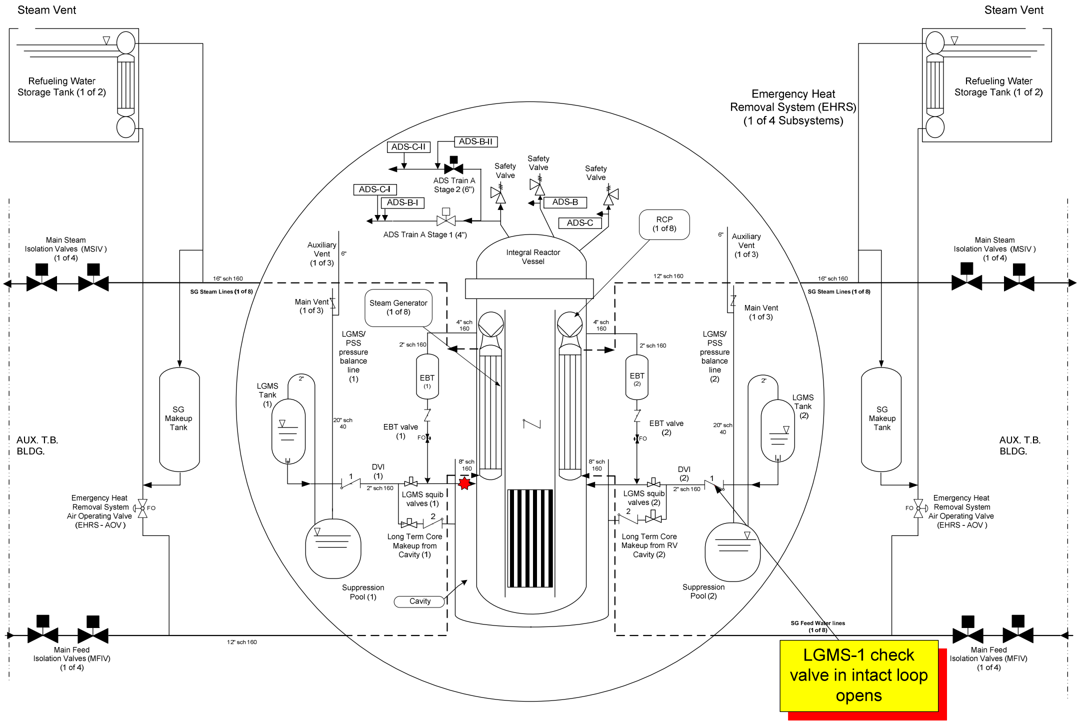

Fig.A13. 69 Time event 17

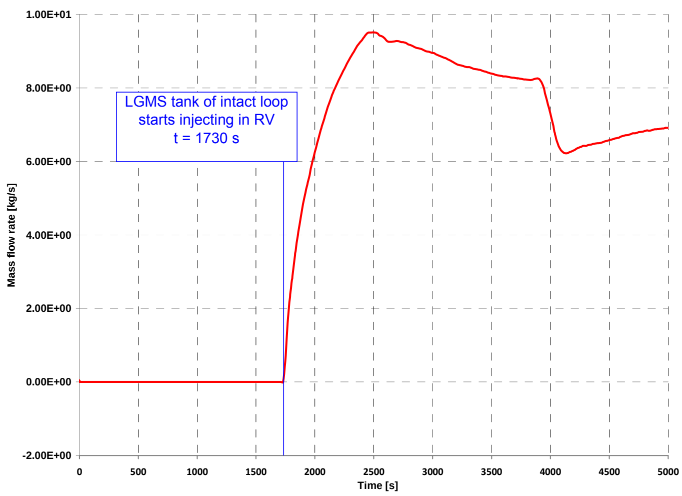

Fig.A13. 70 Mass flow rate through LGMS check valve (Intact loop) vs time

Time event 18: Steam and gas mixture flows again from RV to QT

Since the pressure equalization (t=1830 s), ADS stage I is supplying a mixture of steam and nitrogen to Reactor Pressure Vessel. That is due to the condensation which takes place mainly in the steam generators region.
As well known, in this case there is a bulk motion of the mixture of nitrogen (non condensable gas) and steam towards the heat sink (steam generators), but while steam is condensed, nitrogen fraction rises in the steam generator regions, causing a degradation in condensation heat transfer.
The degradation of condensation heat transfer, in addition to the core residual decay heat power, is responsible of a new pressure equalization at t=3190 s after which pressure in reactor pressure vessel remains larger than in the containment and nitrogen mass fraction in steam generators region starts to decrease. Nitrogen and steam mass flow rate is then observed from vessel to containment (see Fig.A13. 71) through ADS stage I.

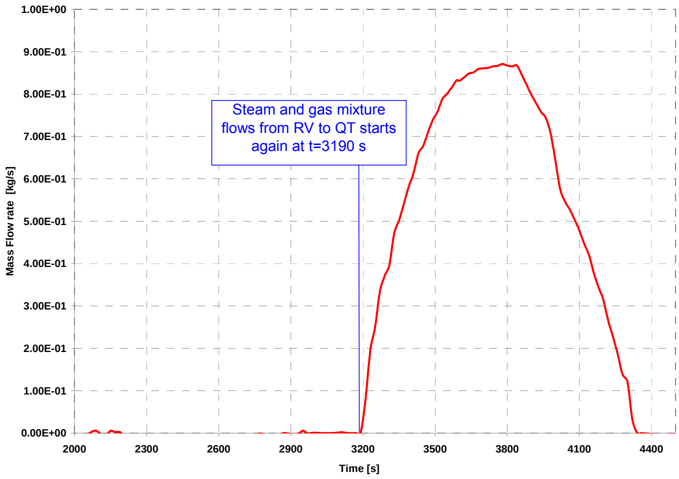

Fig.A13. 71 Steam and gas mixture mass flow rate vs time

Time event 19: ADS stage II starts opening

Opening of ADS stage II depends on the level in the LGMS tank of broken loop. When this level reaches the minimum level set-point, ADS stage II starts to open (t=20860 s, Fig.A13. 72).

Fig.A13. 73shows that ADS Stage II mass flow rate becomes positive after 20860 s from the beginning of the transient.

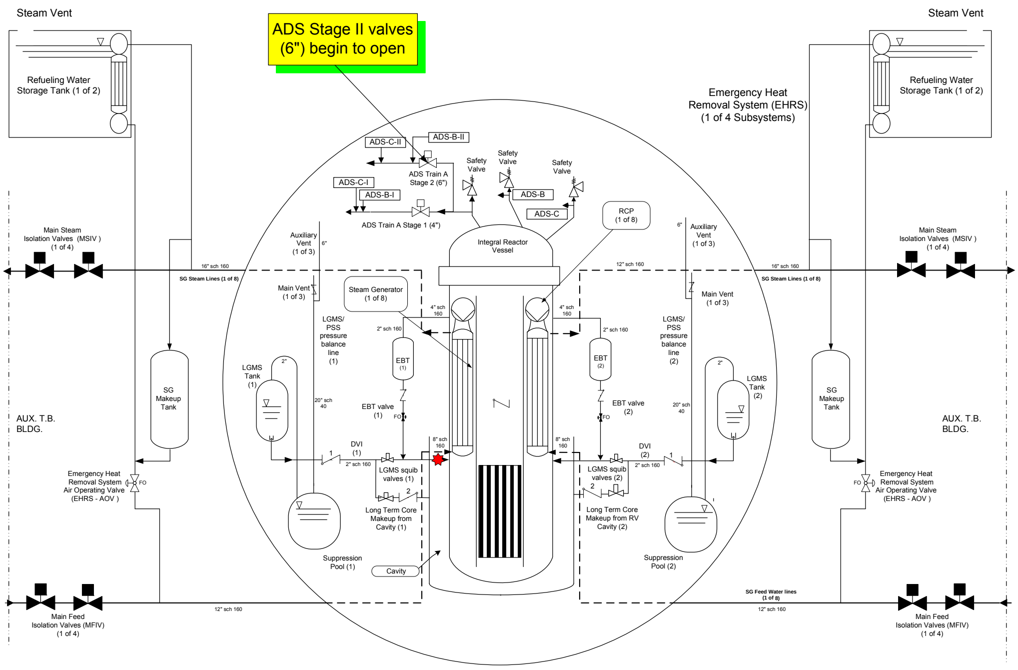

Fig.A13. 72 time event 19

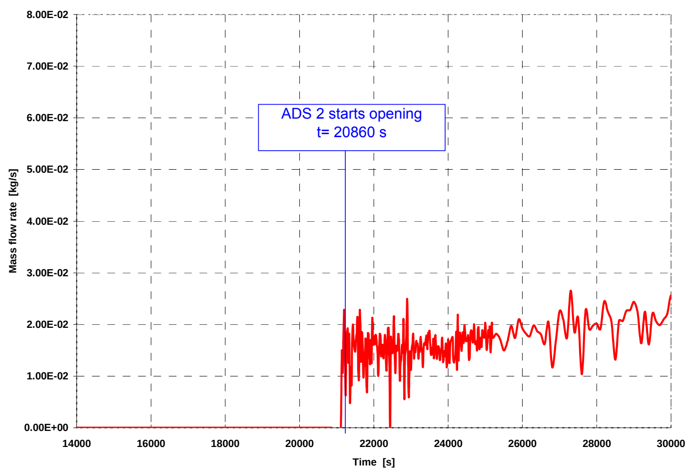

Fig.A13. 73 Mass flow rate through ADS 2 vs time

Time event 20: LGMS tank of broken loop is empty

LGMS tank of the broken loop is almost empty at t=20873 s, when the water level, which had started to decrease since the opening of LGMS check valve I, reaches the bottom of LGMS tank. It is completely empty only after 37300 s (Fig.A13. 74)

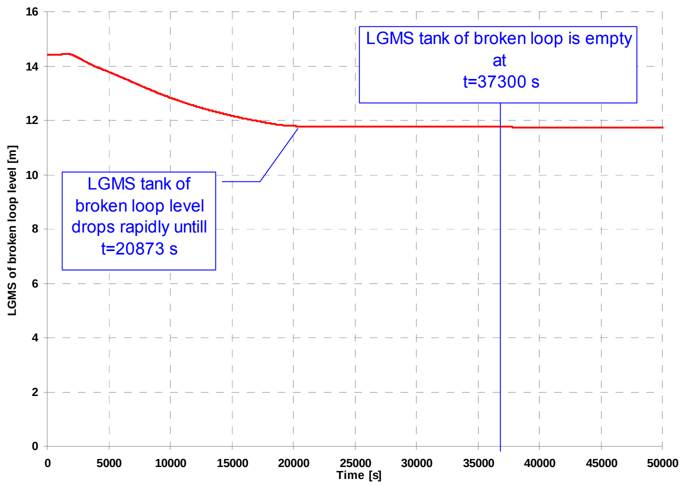

Fig.A13. 74 LGMS (broken loop) level vs time

Time event 21: LGMS tank of intact loop is empty

LGMS tank of the intact loop is empty at t=22300 s, when the water level, which had started to decrease since the opening of LGMS check valve I, reaches the bottom of LGMS tank (Fig.A13. 75).

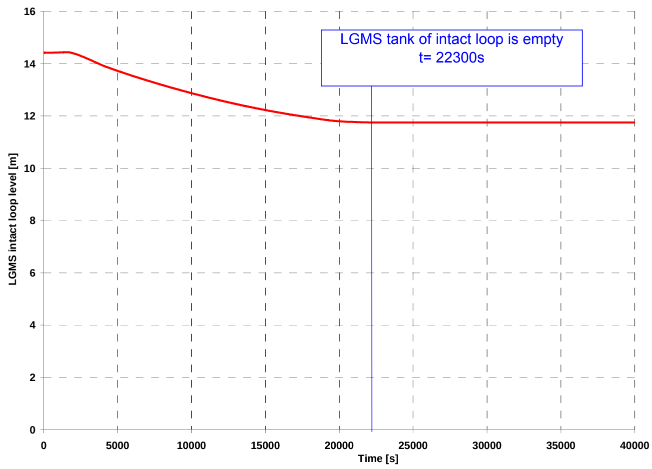

Fig.A13. 75 LGMS (intact loop) level vs time

Time event 22: Flow from Reactor Cavity

Water level in the cavity increases since the beginning of the transient, due to the water discharge from the break. When the hydrostatic head due to the level in cavity becomes greater than the set-point of LGMS check valve II in intact loop increased by the flow resistance of the associated piping, water enters the vessel by DVI line. This occurs at around t=49000 s (Fig.A13. 76 and Fig.A13. 77). The same occurs also in broken loop but, obviously, water cannot enter the reactor vessel because of the break in DVI line.
Starting of flow from reactor cavity into reactor vessel is the last time event and now the reactor is safely cooled by all the emergency safety features, which are all passive systems.

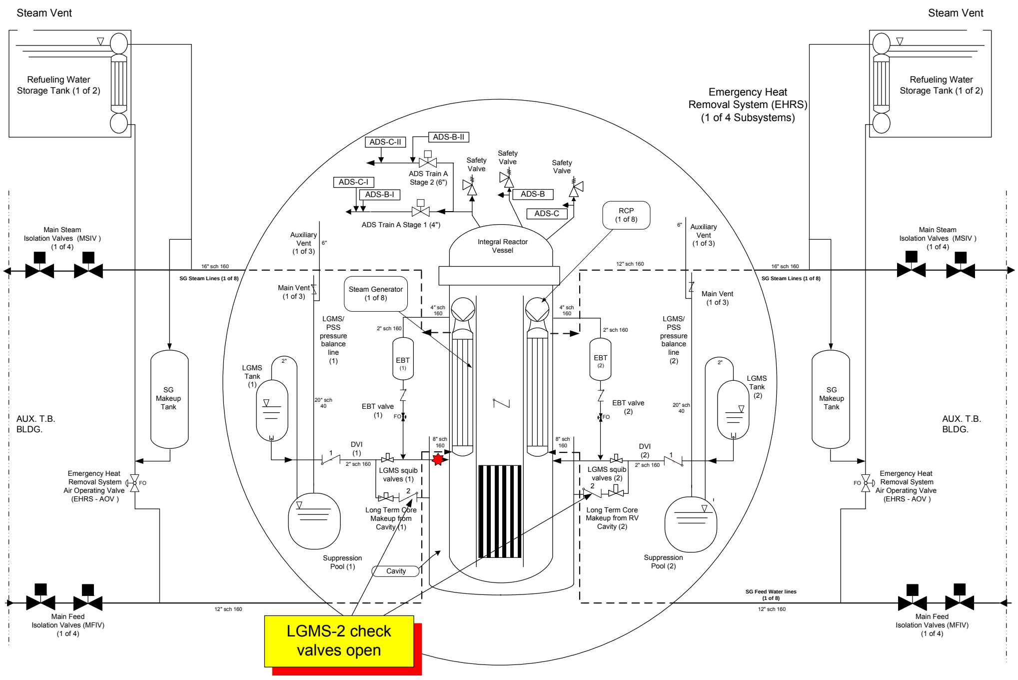

Fig.A13. 76 time event 22

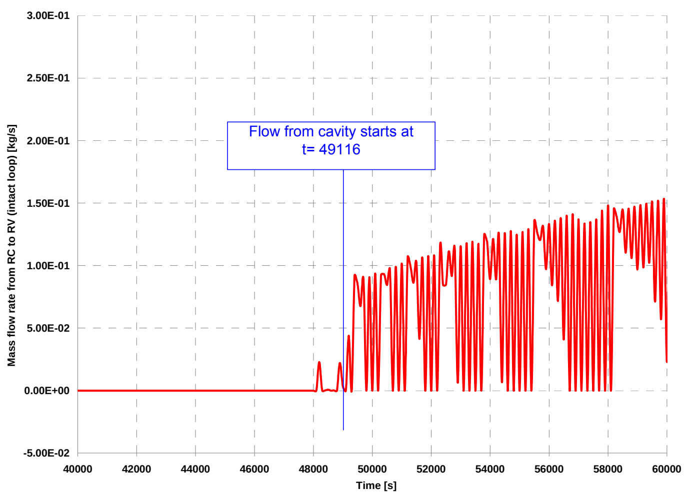

Fig.A13. 77 mass flow rate vs tim

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NEW RESULTS OF SCALING ANALYSIS APPLIED FOR IRIS AND SPES3 PRESSURE RESPONSE

This section deals with the outputs of program OMEGA, i.e. the Fractional Rates of Change and scale distortions between IRIS and SPES3 before and after Pressure Equalization (BPE and APE).
However, before starting with the presentation of the obtained results, it is worth pointing out that the use of different codes for simulating IRIS and SPES3 DVI-SBLOCA transients has important effects on the scale distortions between the plant and the Integral Test Facility (ITF), firstly for the different nature of the codes (GOTHIC is suitable for IRIS Containment Analysis while RELAP for plant transient analysis and it has been used for IRIS Reactor Vessel and the SPES3 facility) and secondly for the modeling choices (e.g. heat structure modeling and heat transfer models implemented into the codes).
Accordingly the large scale distortions between IRIS and SPES3 cannot be attributed only to an imperfect application of the scaling criteria (not all tanks in SPES3 are exactly scaled with a volume ratio 1/100) or to the scaling criteria adopted (the heat transfer area in SPES3 is 10 times higher than in IRIS).
Based on previous works developed by Donato Lioce and Gaetano Tortora about Pressure response after DVI-SBLOCA, new results have been evaluated considering separately the following time cases:

- Before Pressure Equalization between RV and CV (BPE)
- After Pressure Equalization between RV and CV (APE)

In Fig.A13. 78 and Fig.A13. 79 IRIS and SPES3 pressures vs. time from RELAP and GOTHIC calculations are shown. It can be noted that:

- peak pressures are different, approximately 0.94 MPa for IRIS and 0.88 MPa for SPES3
- the time at which pressure equalization occurs is different: 1830s for IRIS and 2260s for SPES3;

It has to be pointed out that, compared to previous work performed by Lioce and Tortora using for IRIS and SPES3 respectively ht1_case and spe3_89 case, even if the peak of pressure in IRIS is still greater than in SPES3, this difference has been greatly reduced. Furthermore, while SPES3 pressure peak has been achieved basically at the same time, IRIS pressure peak occurs about 300s later than previous results. It depends on the new heat structure adopted for IRIS elements and on reduced thickness considered for SPES3. In fact, even if condensation phenomena development is still different in IRIS and SPES3 simulation, it becomes closer than before, and the heat subtracted by the structure of tanks is not so different as before.

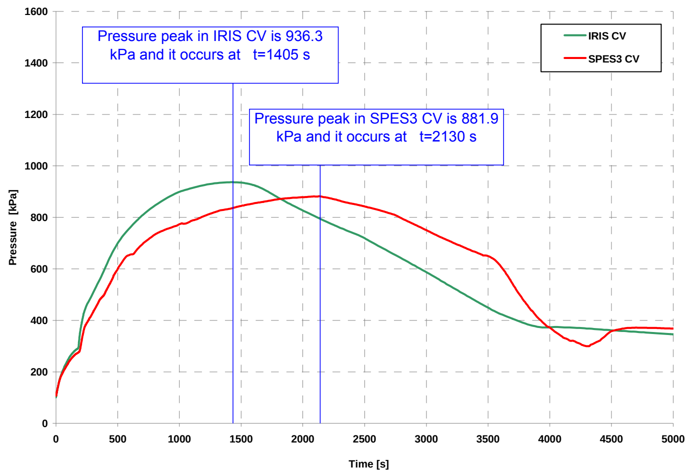


Fig.A13. 78 IRIS & SPES3 CV Pressure vs time (first 5000s)

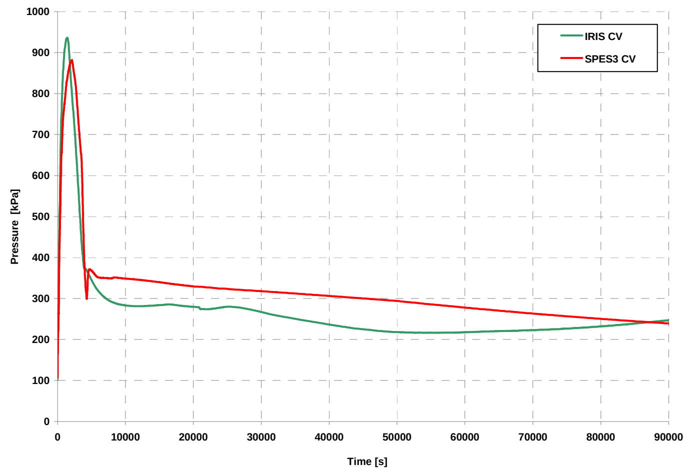


Fig.A13. 79 IRIS & SPES3 CV Pressure vs time

It has to be pointed out that in this section, some results have been showed as averaged on 11 time steps (all variables and parameters with 'AVG'). That has been performed in order to reduce wide oscillations in variables values that vary very slowly (in particular after pressure equalization). Beside, it is necessary to stress that the comparison of the non dimensional pressure time derivative with the sum of FRCs is not directly part of scaling analysis and, hence,it is not required in a scaling analysis. Anyway, this comparison has been performed for both of cases (BPE and APE) as a check to assure that the evaluated FRCs are correctly calculated by the developed program basing on the adopted physical and mathematical models. This supports the subsequent conclusions of scaling analysis, which are based on the performed FRCs evaluation.

New Results Before Pressure equalization between RV and CV

Before showing results achieved by running Fortran programs developed by Tortora concerning with pressure response, it is necessary to define the dimensionless pressure gradient as follows:

$$p^* = \frac{p - p_{CV}}{\Delta p_0}$$

where the reference pressure difference Δp_0 is equal to the initial pressure difference between the pressurizer and the drywell, i.e. the higher pressure difference between RV and CV before the break occurrence.

$$\Delta p_0 = p_{RV_0} - p_{CV_0} = 15.52 - 0.11 = 15.41\, MPa$$

In Fig.A13. 80 a comparison between IRIS and SPES3 response based on dimensionless pressure gradient is performed. It can be noted that behavior in Reactor and Facility is closer than before.

Fig.A13. 80 IRIS d(p*)/dt and SPES3 d(p*)/dt vs time

IRIS Fractional Rates of Change

Fig.A13. 81 and Fig.A13. 82 report the trends of Fractional Rates of Change sum and dimensionless pressure gradient for IRIS DVI-SBLOCA. It is worth underlining that:

- there is qualitative and almost quantitative agreement (i.e. the trends are really closed but they don't match perfectly each other until t=1400s);
- there is quantitative agreement in the time period between 1400 s and 2000 s, as showed in the zoomed part.

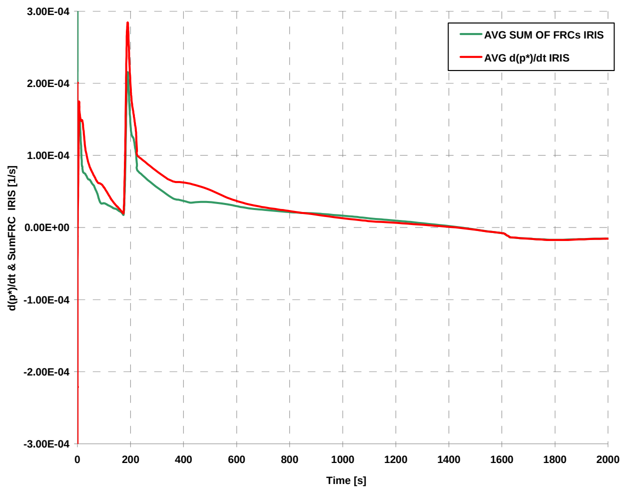


Fig.A13. 81 Avg Sum of FRCs & d(p*)/dt vs time

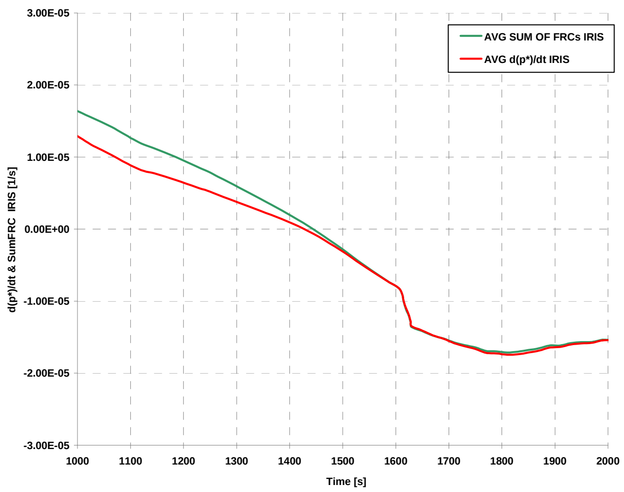


Fig.A13. 82 Avg Sum of FRCs & d(p*)/dt vs time (zoomed)

AVG FRCs results concerning IRIS has been reported in Fig.A13. 83 and Fig.A13. 84.
IRIS behavior during DVI-SBLOCA transient can be interpreted as follows:

1. At the beginning of the transient liquid water flashes immediately after the DVI break because of the lower pressure in the Containment Vessel and the steam already present in the CV, is heated up by the incoming jet. Accordingly, see Figure 6.6, two-phase and single-phase vapour terms are affected from the break; in fact, even if the FRC_{br} is small (its effect starts to be consistent at t=176s), as showed in Figure 6.7, the liquid mass flow rate is high and the amount of energy released by it is considerable.
2. After ADS line starts, FRC_{2ph} and FRC_{br} are the driving phenomena, even if FRC_{br} seems to be more relevant. It shows the effect of heat structure now considered for elements in IRIS simulation. In order to figure out the different behavior compared to the old results in which driving phenomena has been FRC_{1phV}, in Figure 6.8 and Figure 6.9 vapour temperature and Saturation temperature are shown for old and new

case respectively. While old case shows a higer value of vapour temperature compared to Saturation Temperature (it dues to the absence of the wall structure for all elements and therefore to consider all thermal boundary condition, except for DW, as adiabatic), in new comparison the new trends of temperatures cannot be distinguished each others. That means only 2 phase flux is present, because the temperature of the whole flux is not higher than Saturation temperature during the considered transient, and super heated steam is not so important as before. Only during the first 20 s FRC_{1phV} seems to be relevant.

3. After the pressure equalization, which occurs at t = 1830s, the break mass flow rate from RV to CV is extincted. In fact, as already discussed during IRIS Time Decomposition Analysis (see chapter 5), the pressure difference between CV and RV becomes negative after pressure equalization, and the flux of steam and gas (driven by Pressure gradient)l changes direction.

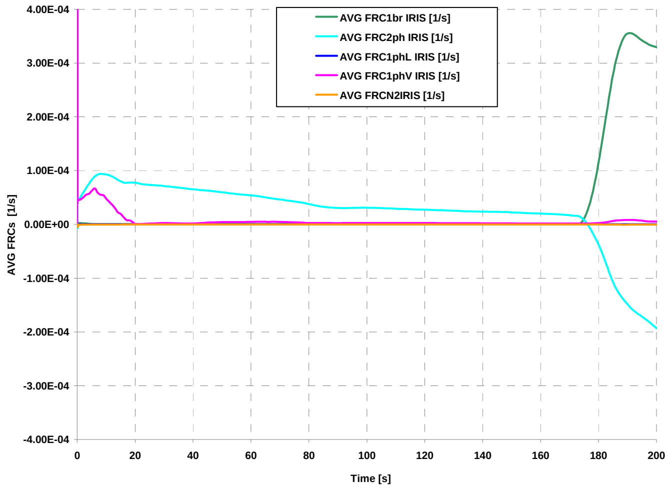


Fig.A13. 83 AVG FRCs IRIS vs Time (s) zoomed

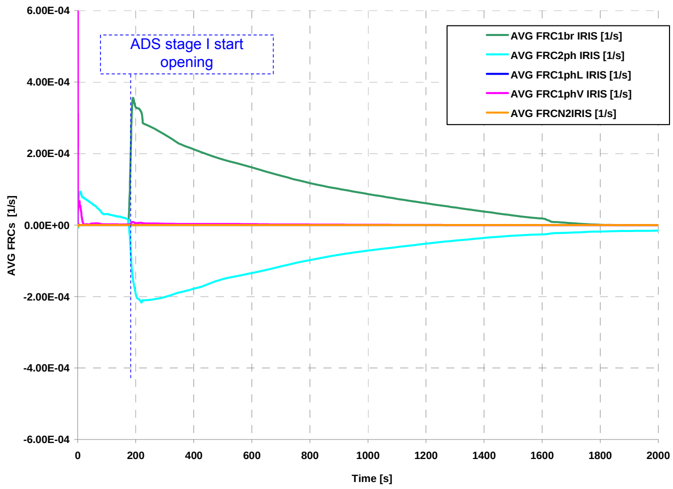


Fig.A13. 84 AVG FRCs IRIS vs Time (s)

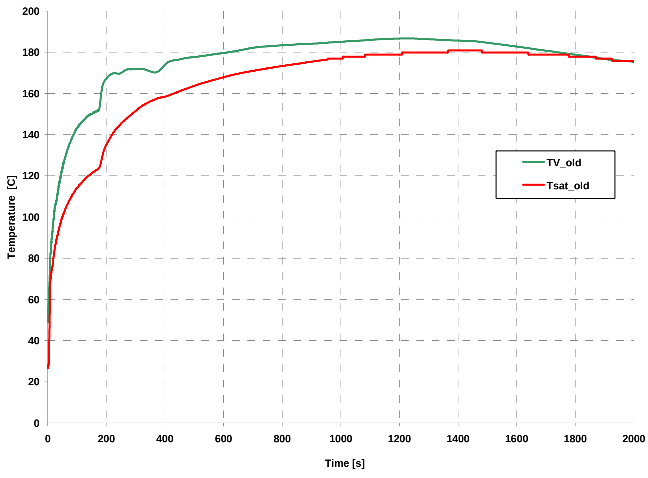


Fig.A13. 85 Vapour and Saturation temperature in IRIS Dry Well (old results)

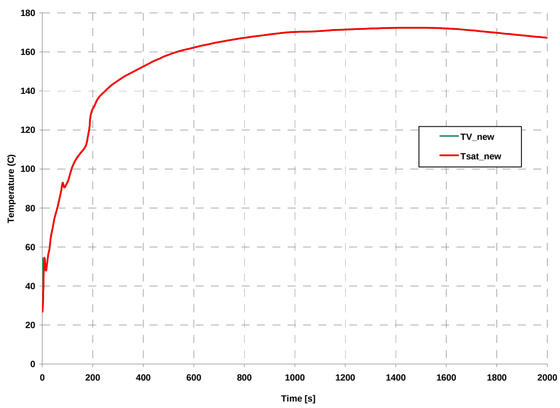


Fig.A13. 86 Vapour and Saturation temperature in IRIS Dry Well (new results)

Finally, it has to be pointed out the non influence of liquid and N2 phase, as their AVG FRCs trends are close to 0 for all the considered transient time, see Fig.A13. 83 and Fig.A13. 84.

SPES3 Fractional Rates of Change

In SPES3, as represented in Fig.A13. 87, there is qualitative and almost quantitative agreement between the dimensionless pressure gradient and the FRCs sum from the beginning of the transient up to the pressure equalization. In particular, as it can be seen, a large difference (about 10^{-4}) can be noted at the beginning of the transient Fig.A13. 88, but it is considerable just for first 60s.

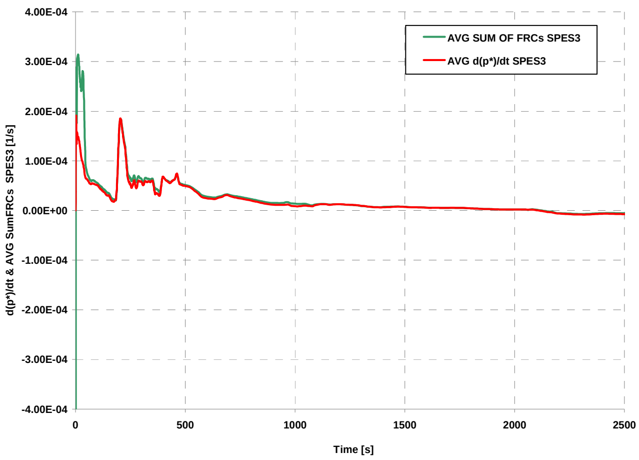


Fig.A13. 87 AVG FRCs & d(p*)/dt vs time in SPES3

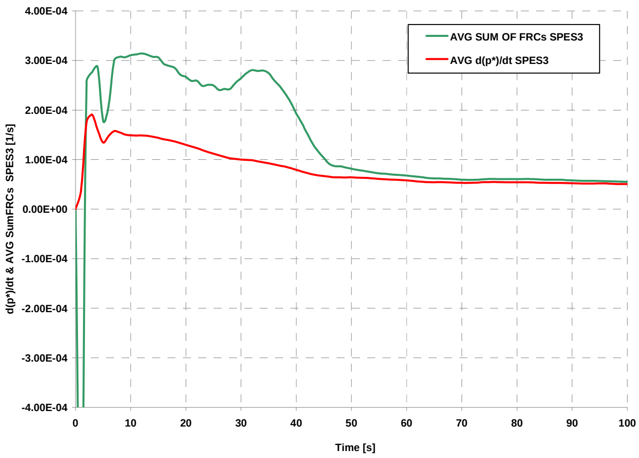


Fig.A13. 88 AVG FRCs & d(p*)/dt vs time in SPES3 (zoomed)

From Fig.A13. 89 and Fig.A13. 90 it must be pointed out that:

1. single-phase vapour FRC is present only at the very beginning of the transient, for the first 47 s and it results closer to IRIS than in old cases. FRC_{br} starts to be consistent from time t=184s, when ADS stage I starts opening.
2. break and two-phase mixture FRCs balance each other during the entire piece of transient analyzed, accordingly they are the driving phenomena.

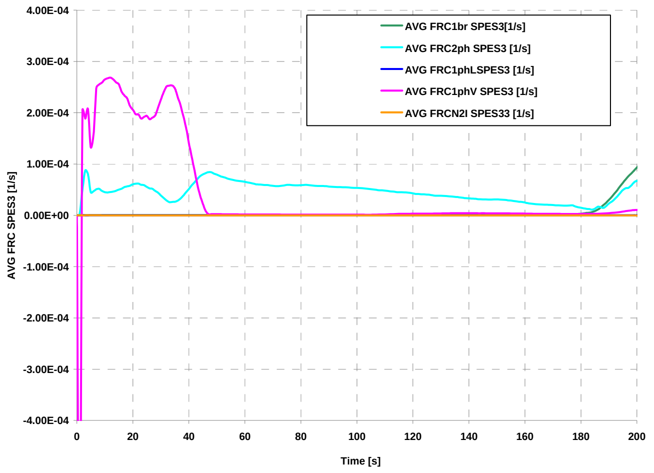


Fig.A13. 89 AVG FRCs Spes3 vs time (zoomed)

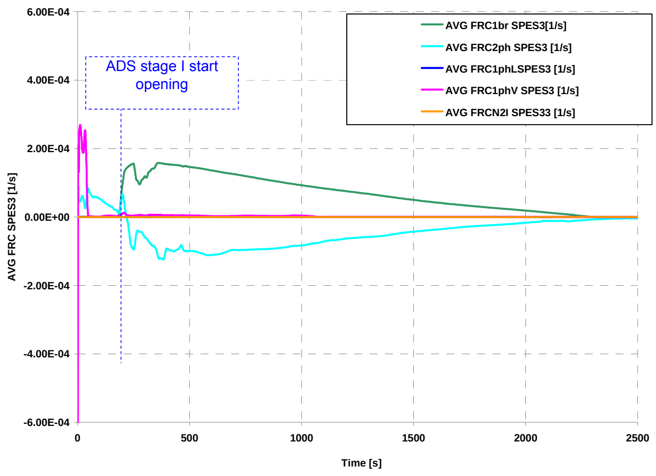


Fig.A13. 90 AVG FRCs Spes3 vs time

Scale distortions between IRIS & SPES3 during DVI-SBLOCA transient

From Fig.A13. 91 though Fig.A13. 95, respectively representing the Fractional Changes for break, two-phase mixture, sub-cooled liquid, single-phase vapour and nitrogen terms, it can be inferred that:

- all the terms are affected by a *delay effect*, since the different time of IRIS and SPES3 pressure equalization, 1830 s for IRIS whereas in SPES3 is 2260 s;
- the single-phase vapour Fractional Change is different to zero in SPES3 for the first 47 s of DVI-SBLOCA transient, while in IRIS just for the first 20 s. Once again, IRIS heat structure let FRC_{1phs} behavior in IRIS and SPES3 to be closer, even if SPES3 is not yet perfectly scaled (there is more steam than in IRIS) and it will cause some distorsions. Sub-cooled liquid and nitrogen phase Fractional Changes are negligible;
- during the middle part of the analyzed transient, from the beginning up to 1500 s the trend in IRIS & SPES3 for break and two-phase mixture terms are very similar.

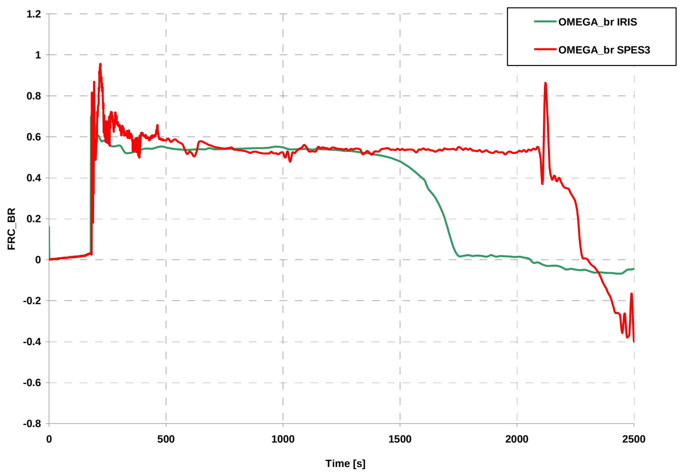


Fig.A13. 91 Omega br IRIS vs SPES3

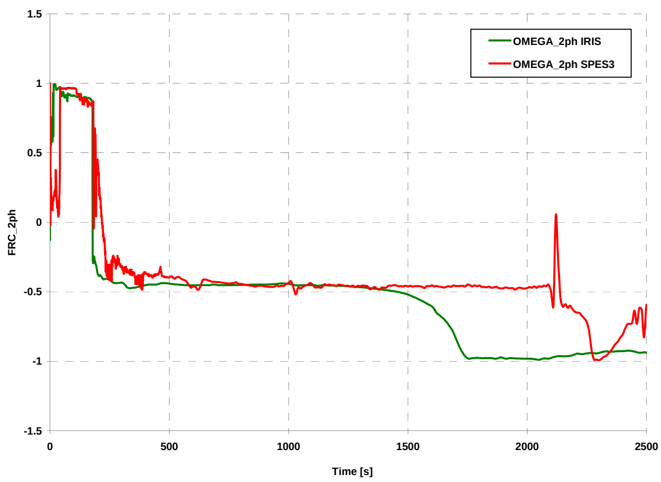


Fig.A13. 92 Omega 2ph IRIS vs SPES3

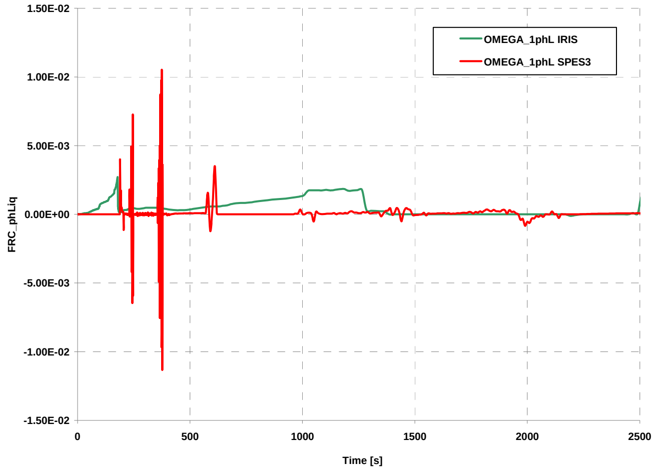


Fig.A13. 93 Omega 1phL IRIS vs SPES3

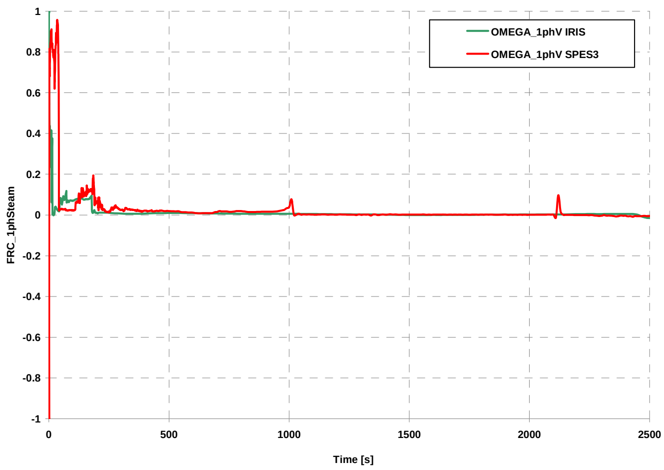


Fig.A13. 94 Omega 1phV IRIS vs SPES3

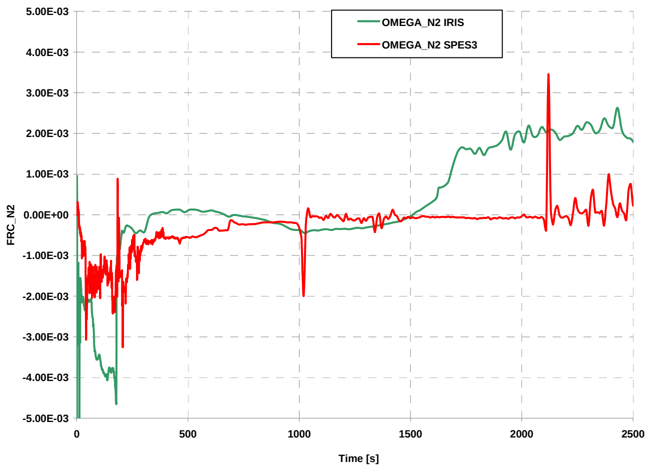


Fig.A13. 95 Omega N2 IRIS vs SPES3

Scale distortions between IRIS and SPES3 has been calculated. In Fig.A13. 96 and Fig.A13. 97, omegas for each phase for each time event are listed for IRIS and SPES3 respectively. Fig.A13. 98 reports all distorsion D parameters, while Fig.A13. 99 shows only two phases, steam phase and break distorsions are evaluated (N2 and liquid phase are negligible)

Time sequence	ΩbrSPES3	Ω2phSPES3	Ω1phlSPES3	Ω1phvSPES3	ΩN2SPES3
1) t=0 s	0	1	0	0	0
2) t=31 s	0.002573	0.13628833	2.4064E-08	0.860132566	-0.001006
3) t=31 s	0.002573	0.13628833	2.4064E-08	0.860132566	-0.001006
4) t=31 s	0.002573	0.13628833	2.4064E-08	0.860132566	-0.001006
5) t=32 s	0.0020254	0.14996231	6.2187E-08	0.847196068	-0.000816
6) t= 113 s	0.0132709	0.92449725	1.0593E-07	0.060872253	-0.001359
7) t=182 s	0.0249646	0.86749231	0	0.105555672	-0.001987
8) t=184 s	0.58055	0.23728838	2.6132E-07	0.181305691	0.0008557
9) t=133 s	0.0154011	0.88531333	7.466E-08	0.098022545	-0.001263
10) t= 202 s	0.5482085	0.3817176	0.00014369	0.068508247	-0.001422
11) t= 183 s	0.7965441	-0.0239603	0	0.17870729	-0.000788
12) t= 249 s	0.572267	-0.4152311	-5.985E-06	0.011876515	-0.000619
13) t= 221 s	0.9248112	-0.0231875	7.4624E-06	0.050197618	-0.001796
14) t= 481 s	0.5843917	-0.3961381	6.9264E-05	0.018838971	-0.000562
15) t= 2150 s	0.3909356	-0.6082245	-1.634E-07	0.000744423	9.537E-05
16) t= 2260 s	0.2137823	-0.7853323	1.8322E-05	-0.000814972	5.207E-05

Fig.A13. 96 omega SPES3

Time sequence	ΩbrIRIS	Ω2phIRIS	Ω1phlIRIS	Ω1phvRIS	ΩN2IRIS
1) t=0 s	0.0019541	0.55903345	0	0.437131911	-0.001881
2) t=31 s	0.0133525	0.91664012	0.00036524	0.066172396	-0.00347
3) t=31 s	0.0059535	0.95903525	8.7002E-05	0.032794573	-0.00213
4) t=31 s	0.0059535	0.95903525	8.7002E-05	0.032794573	-0.00213
5) t=42 s	0.0145436	0.91105088	0.00057221	0.070296128	-0.003537
6) t= 147 s	0.6131426	-0.3752683	0.00027524	0.010812985	-0.000501
7) t=176 s	0.5229591	-0.4710125	0.00047607	0.005503296	-4.91E-05
8) t=178 s	0.52653	-0.4670761	0.00047215	0.005873594	4.817E-05
9) t=188 s	0.5374098	-0.4526806	0.00051467	0.009320055	7.483E-05
10) t= 189 s	0.5361946	-0.4542289	0.00055832	0.008932102	8.605E-05
11) t= 195 s	0.5397568	-0.4521921	0.00080354	0.007243755	-3.81E-06
12) t= 285s	0.5186556	-0.4788188	0.00020924	0.002063529	-0.000253
13) t= 395 s	0.4952324	-0.5040337	0	0.000604841	-0.000129
14) t= 620 s	0.3483946	-0.6504175	0	0.000727564	0.0004604
15) t= 1612 s	-0.038884	-0.9422062	0.00020863	-0.016977285	0.0017235
16) t= 1830 s	0.0147546	-0.9491464	0.01251799	-0.021389957	0.0021911

Fig.A13. 97 omega IRIS

Time event	Dbr	D2ph	D1phl	D1phv	DN2
1	#DIV/0!	#DIV/0!	#DIV/0!	0	0
2	0.4321868	0.14210982	0.00027659	26.2278931	0.4723992
3	0.4321868	0.14210982	0.00027659	26.2278931	0.4723992
4	0.4321868	0.14210982	0.00027659	26.2278931	0.4723992
5	0.2943656	0.15416107	0.00064253	46.89486571	0.3721671
6	0.6747851	1.02617125	8.2609E-05	0.818468318	0.361715
7	0.7696769	0.99896127	0	1.146232171	0.4362433
8	16.748651	0.27503691	9.6702E-05	1.90365428	-0.184281
9	0.0221026	-3.153442	0.00046049	4.599664826	1.2852783
10	0.7941006	-1.3384167	0.84261148	2.935736316	1.5107281
11	1.2037697	0.07341959	0	16.34499334	0.9780291
12	1.0330584	0.94933555	-0.0142921	1.512734007	1.6100112
13	1.7355898	0.05038029	0.01822227	7.81591711	-26.46214
14	1.0855089	0.87449213	0.1223489	2.353123836	-7.167788
15	1.0625307	0.96312459	#DIV/0!	4.122644064	0.2516589
16	10.583045	0.80401454	#DIV/0!	-0.519368744	0.0355033

Fig.A13. 98 DIstorsion SPES3 IRIS

Time event	Dbr	D2ph	D1phv
2	0.432187	0.14211	26.2279
3	0.432187	0.14211	26.2279
4	0.432187	0.14211	26.2279
5	0.294366	0.154161	46.8949
6	0.674785	1.026171	0.81847
7	0.769677	0.998961	1.14623
8	16.74865	0.275037	1.90365
9	0.022103	-3.15344	4.59966
10	0.794101	-1.33842	2.93574
11	1.20377	0.07342	16.345
12	1.033058	0.949336	1.51273
13	1.73559	0.05038	7.81592
14	1.085509	0.874492	2.35312
15	1.062531	0.963125	4.12264
16	10.58305	0.804015	-0.51937

well scaled	green
Distorsion 1st class	pink
Distorsion 2nd class	magenta
Opposite behavior	red

Fig.A13. 99 relevant Distorsion SPES3 IRIS

It can be seen:

- Break distortions, D_{br}, are in good agreement with Wulff's distortions scaling criteria at the end of the transient (staring from time event 10) excepted during pressure equalization, where a 2^{nd} disistorsion grade is present. Beside, at the beginning of transient, a 1^{st} distorsion grade is present, but D value is almost close to the good one.

- Two phase mixture distortions, $D_{2\varphi}$, are in good agreement with Wulff's distortions scaling criteria around the pressure equalizion (from 14th to 16th time sequence) but 2 opposite trend are present at time event 9 and 10;
- Single-phase vapour, $D_{1\varphi v}$, are in good agreement with Wulff's distortions scaling criteria in the middle of the transient, while 2nd distorsion grade is present basically through all transient.

New Results after Pressure equalization between RV and CV

As did before, first of all it has to be evaluated the dimensionless pressure gradient defined as

$$p^* = \frac{p - p_{CV}}{\Delta p_0}$$

where the reference pressure difference Δp_0 is equal to the pressure difference evaluated when pressure equalization between CV and RV is got and the end of considered time i.e. the higher pressure difference.

$$\Delta p_0 = p_{RV_{begin}} - p_{RV_{end}} = 0.93 - 0.3 \approx 0.63\,MPa$$

Fig.A13. 100, Fig.A13. 101 and Fig.A13. 102deal with the non dimensional pressure time derivatives from Relap and Gothic calculations for IRIS and SPES3 at different time intervals during the transient after pressure equalization. It can be noted that these variables are quite different in IRIS and SPES3, since the non-dimensional pressure time derivative is equal to the sum of the FRCs, this represents an indication that some distortions are present as it will be shown in the following. In particular, a worst behavior is achieved for the first 5000s compared to old results, while better results are obtained for longer time.

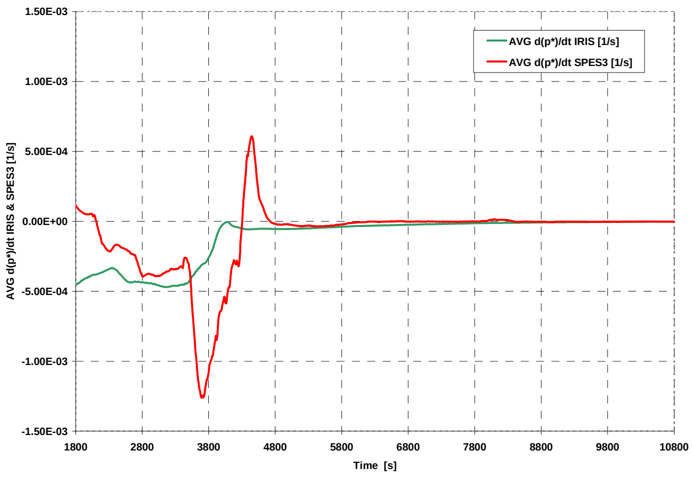


Fig.A13. 100 AVG d(p*)/dt IRIS and SPES3 vs time

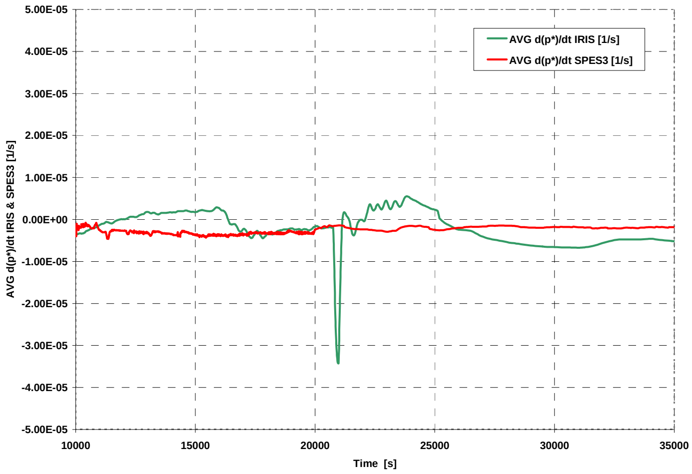


Fig.A13. 101 AVG d(p*)/dt IRIS and SPES3 vs time

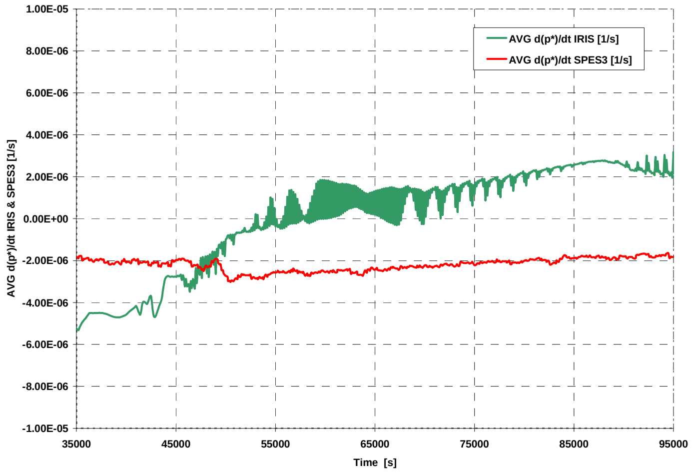


Fig.A13. 102 AVG d(p*)/dt IRIS and SPES3 vs time

IRIS Fractional Rates of Change

A comparison between the non dimensional pressure time derivative calculated for IRIS by RELAP and GOTHIC and the corresponding sum of fractional rates of change (FRCs) evaluated with the aid of the developed program, is shown in Fig.A13. 103, Fig.A13. 104 and Fig.A13. 105 with reference to different time windows after pressure equalization,. These quantities should be equal by definition. It can be easily seen that:

- during the fist 10000 s there is a qualitative agreement between the curves, even if AVG sum of FRCs evaluated by program seems to be lower until the end of time step considered;

- the second time window shows a greatly agreement between two trends;
- in the last part of the transient, the curves are closer and closer except for the last 5000 s where AVG sum of FRCs is higher.

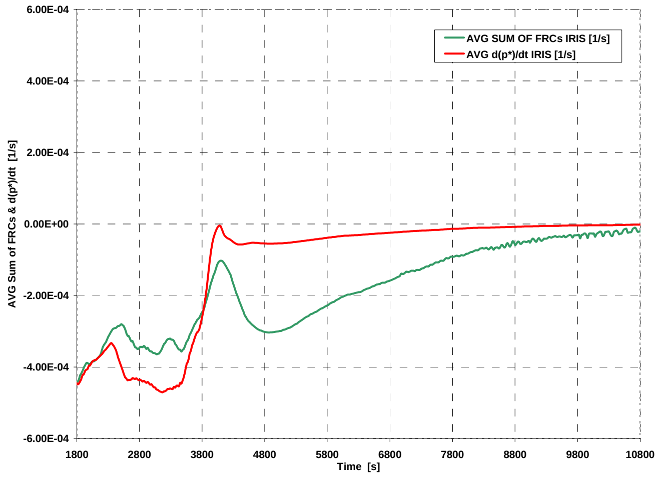


Fig.A13. 103 AVG sum of FRCs 1 AVG d(p*)/dt IRIS vs time

Fig.A13. 104 AVG sum of FRCs 1 AVG d(p*)/dt IRIS vs time

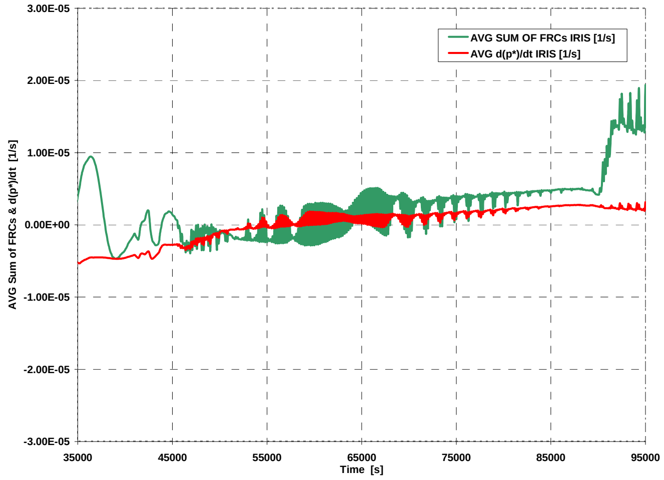


Fig.A13. 105 AVG sum of FRCs 1 AVG d(p*)/dt IRIS vs time

In Fig.A13. 106, Fig.A13. 107 and Fig.A13. 108 AVG FRCs for IRIS are shown, starting from pressure equalization up to the end of transient,.It can be seen that:

- Soon after pressure equalization FRC_{1phV} and FRC_{2ph} are the dominant rate of change up to 2300 s; on the other hand, from 2300 s to 4200 s the most important parameter is FRC_{2ph}. Later on, FRC_{1phs} becomes again the most important one. This means that for IRIS, in the time window between pressure equalization and 10000 s, 2phase fluid is condensed while super-heated steam is cooled down and partly condensed.
- Between 10000 and 25000 s the steam phase is greatly the more consistent phase present. In fact, FRC_{1phs} assumes values different to 0, while FRC_{2ph} is little lower than 0 during all the considered time. As already seen in Fig.A13. 103, the big oscillation at time t=21000s should be addressed to a not perfect representation of dimensionless pressure gradient rather than to an effective strange FRC_{1phV} droplet. Starting from 25000 s up to the end of the transient, 1phase super heated steam is not longer present in a big amount. It basically depends of cooling down due to the heat absorbtion performed by IRIS structure.
- Starting from 35000 up to the end of the transient, FRC_{1phV} and FRC_{2ph} are again the only ones different to 0, even if the first one is the driving phenomenon until the end.

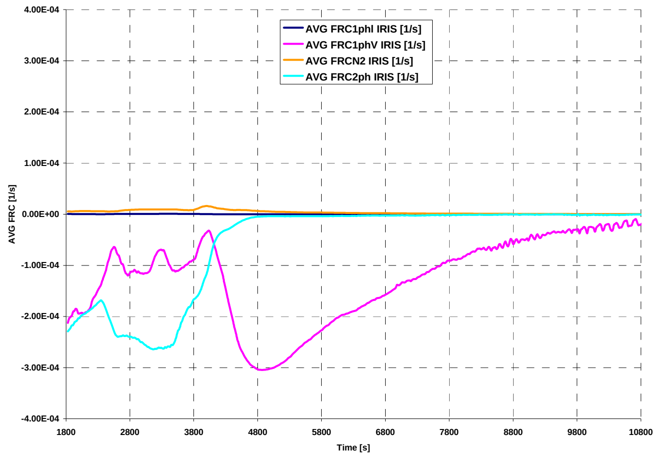


Fig.A13. 106 AVG FRCs IRIS vs time

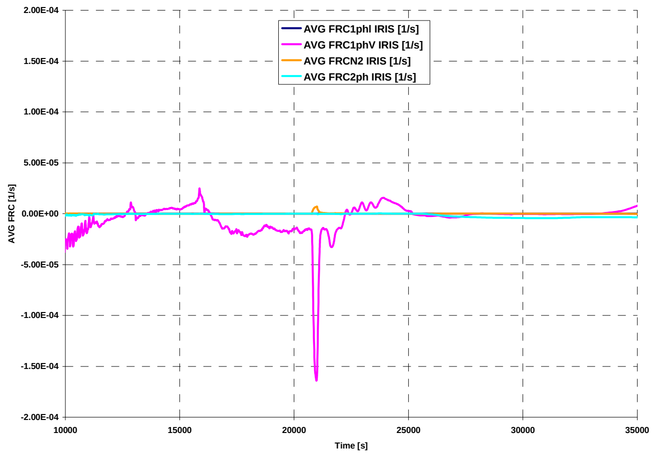


Fig.A13. 107 AVG FRCs IRIS vs time

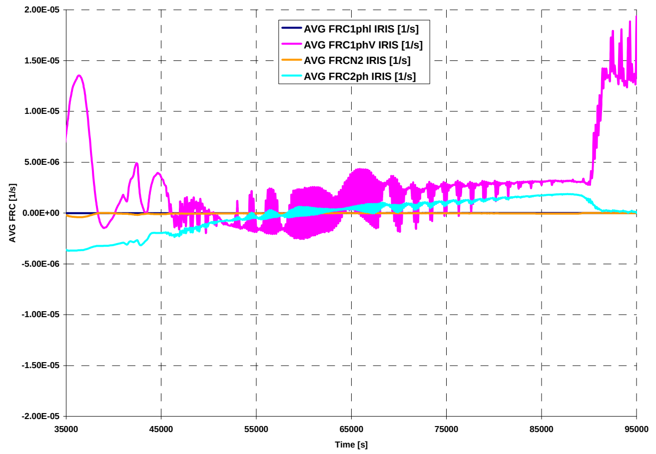


Fig.A13. 108 Figure 6.31 AVG FRCs IRIS vs time

SPES3 Fractional Rates of Change

In Fig.A13. 109, Fig.A13. 110 and Fig.A13. 111 a comparison between dimensionless pressure gradient and the sum of FRCs for SPES3 is performed again considering averaged values on 11 time steps. As usual, the match between the curves has been performed in 3 different time windows. It can be noted that:

- During the first 4000 seconds after pressure equalization that occurs at t=2260 s, there is a qualitative agreement, and even if d(p*)/dt trend is not perfectly reproduced, there is a better agreement than in IRIS.
- In the second time windows, it can be seen that AVG sum of FRCs amplifies dimensionless pressure gradient oscillations up to 26000 s. By the way, calculated sum of FRCs keeps the same trends.
- For the rest of the transient, the curves match each others and their shapes can be considered very similar

.

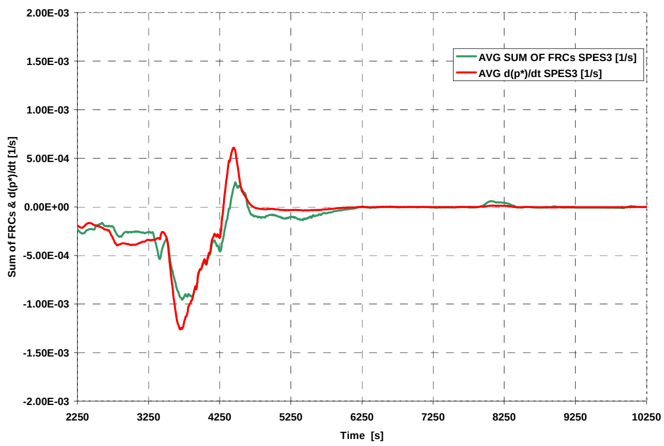


Fig.A13. 109 AVG sum of FRCs & AVG d(p*)/dt SPES3

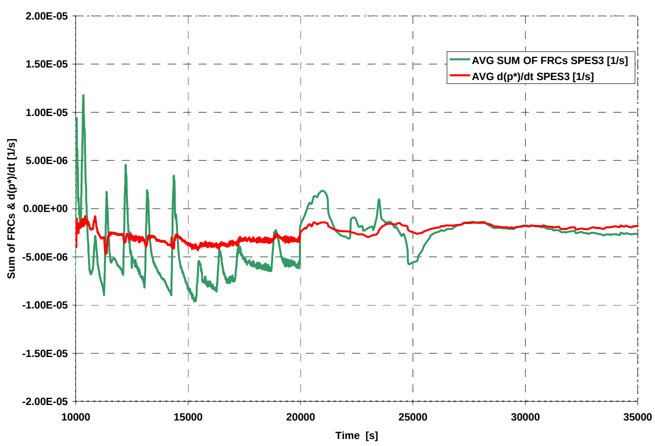


Fig.A13. 110 AVG sum of FRCs & AVG d(p*)/dt SPES3

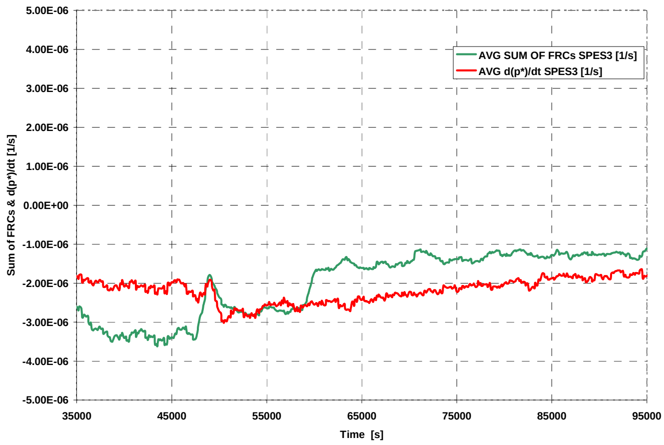


Fig.A13. 111 AVG sum of FRCs & AVG d(p*)/dt SPES3

Finally, in Fig.A13. 114, Fig.A13. 115, Fig.A13. 116 AVG FRCs are showed for SPES3 in order to find driving phenomena during the transient. The following consideration can be done:

- After Pressure equalization up to 4300 s FRC_{1phV} and FRC_{2ph} are driving phenomena. In fact, during this period a lot of steam is present in environment and it had not enough time for condensing. At t = 4300 2phase effect is reduced and FRC_{2ph} curve is closed to 0 while FRC_{1phV} is still present even if it starts to reduce greatly. All these behaviors can be adducted to SPES 3 structure presence that subtracts heat from the environment causing condensation phenomena
- Once FRC_{2ph} starts to be almost constant (just below 0 line as in IRIS), FRC_{1phV} continues to be driving phenomenon. As in IRIS, the wide amplitude oscillation present up to 20000s, can be adducted more to not perfect reproduction of dimensionless pressure gradient by AVG sum of FRCs rather then to the real behavior of 1 phase steam exchanged heat.
- Starting from 57000 s up to the end, FRC_{1phV} is basically extinguished, while FRC_{2ph} become driven phenomenon up to the end. Other FRCs are negligible.

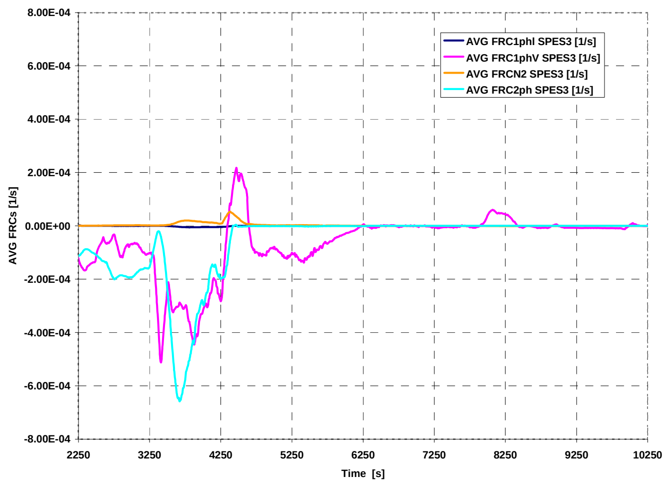


Fig.A13. 112 AVG FRCs SPES3 vs time

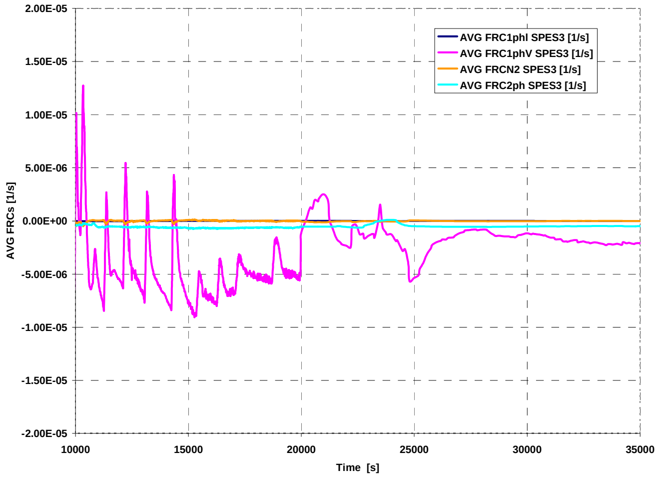


Fig.A13. 113 AVG FRCs SPES3 vs time

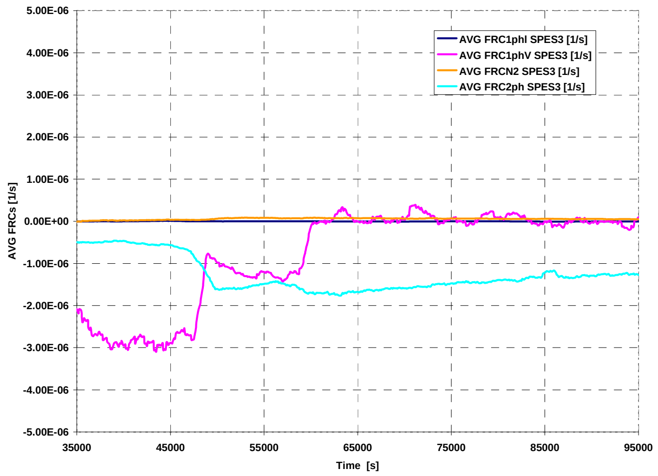


Fig.A13. 114 AVG FRCs SPES3 vs time

Scale distortions between IRIS & SPES3 during DVI-SBLOCA transient

In Fig.A13. 115 through Fig.A13. 126, averaged Omega for each phase has been reported for IRIS and SPES3 to show the different influence of the phases in different time period. As done for the BPE work, three time windows for each case have been considered. By matching IRIS and SPES3 omegas curves it can be noted that:

- AVG OMEGA 2ph curve in SPES3 up to 25000 s has a shape characterized by many oscillations. It basically means that the exchanged heat from a phase to the other switches direction rapidly and frequently, more than what happens in IRIS, where the trend of the curve is slower and sweeter. SPES3 oscillations aside, both IRIS and SPES3 average omega 2ph are used to have almost the same sign (negative or positive) and a closed direction. Starting from 25000s up to 47000s, SPES3 2phase omega curve is lower (absolute value is higher) than IRIS, even if they kept the same sign. Last 40000s of the transient show the worst behavior. In fact, IRIS 2ph omega seems to have opposite trends compare to SPES3, namely while one is cooling down, the other is heating up.

- Liquid phase, as discussed above, is not a driving phenomenon and it will not affect general Scaling Analysis results. In any case, as it can be seen from Figure 6.41, Figure 6.42 and Figure 6.43, some differences are encountered at t= 6500 s, when SPES3 omega's curve has wide oscillations while IRIS has a sweeter trend. The same event takes place at t=57000 s, but now IRIS omega is characterized by big oscillations. By the way, the curves rarely assume values very different to 0.
- Omega 1phV is an important factors to take into account in order to get Scaling analysis results. In fact, as already shown, it is a driving phenomena during long time phase. Up to 4200s SPES3 and IRIS behavior is closer, from 4200 to 4800s SPES3 1phV omega starts growing up till when it gets a positive sign that is opposite to IRIS. Then, up to 6200s the two curves are almost matched while, whereas after SPES3 has big amplitude oscillation trend with opposite sign compare to IRIS. It means that a lot of heat is absorbed and released frequently for short periods. At t=13000, also IRIS starts showing a similar behavior and up to 33000 s (even if with a lower frequency) and then, while SPES3 1phV curve trend become slower and sweeter, IRIS omega 1phV assumes values which change so faster that single curve representing this trend is not longer visible (see Figure 6.46)
- Omega N2 finally, is not important for scaling analysis. In fact the curves for IRIS and SPES3 are almost constant and close to 0.

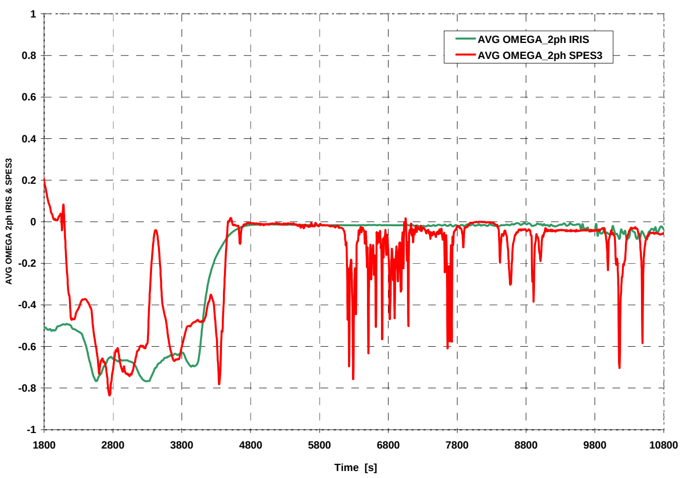


Fig.A13. 115 AVG OMEGA 2ph IRIS & SPES3 vs time

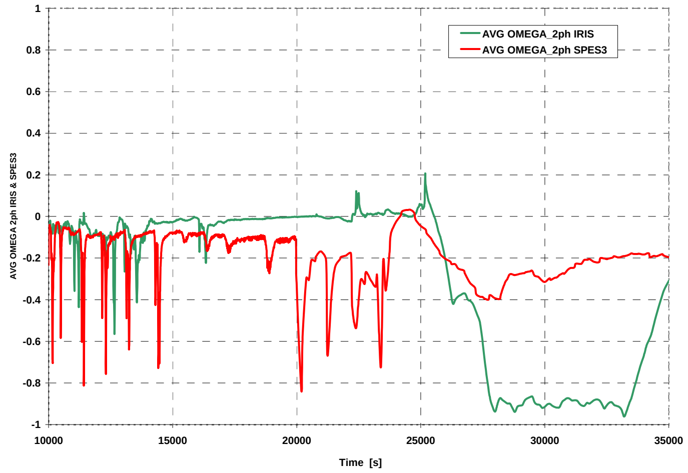


Fig.A13. 116 AVG OMEGA 2ph IRIS & SPES3 vs time

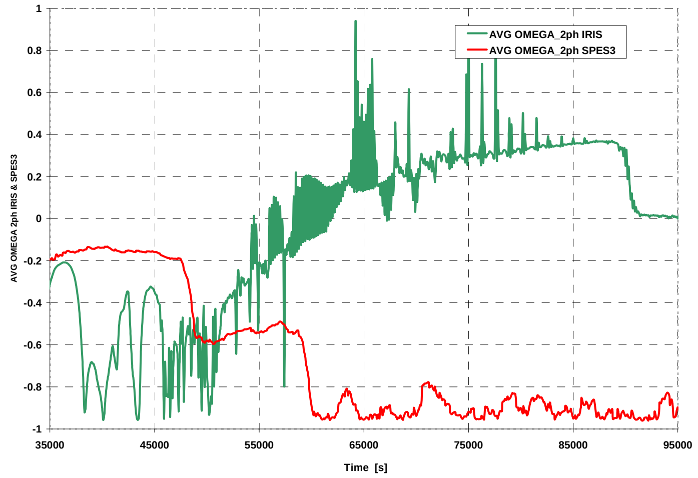


Fig.A13. 117 AVG OMEGA 2ph IRIS & SPES3 vs time

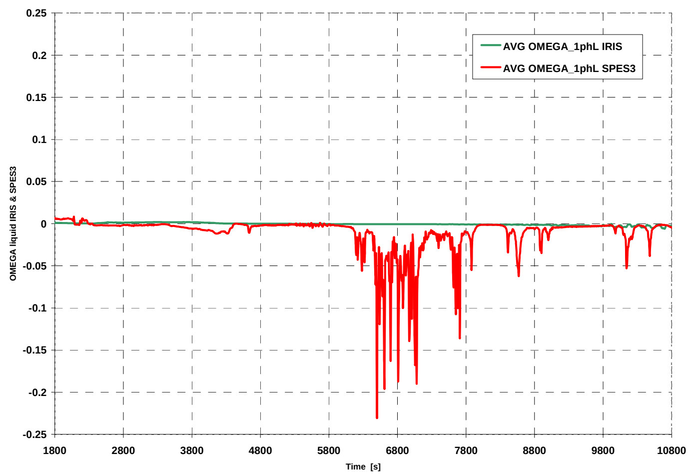


Fig.A13. 118 AVG OMEGA liquid phase IRIS & SPES3 vs time

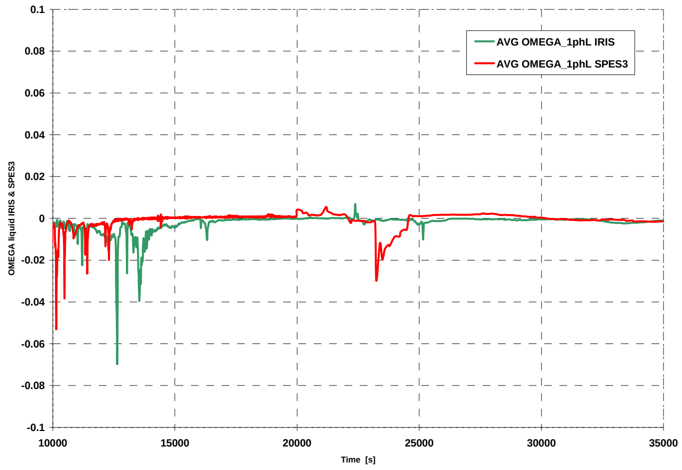


Fig.A13. 119 AVG OMEGA liquid phase IRIS & SPES3 vs time

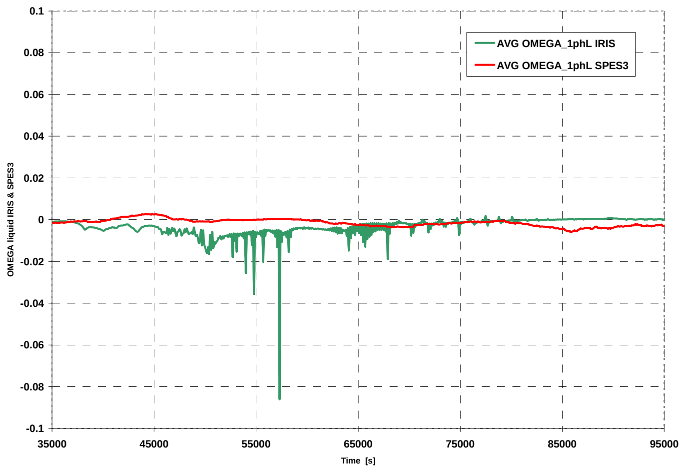


Fig.A13. 120 AVG OMEGA liquid phase IRIS & SPES3 vs time

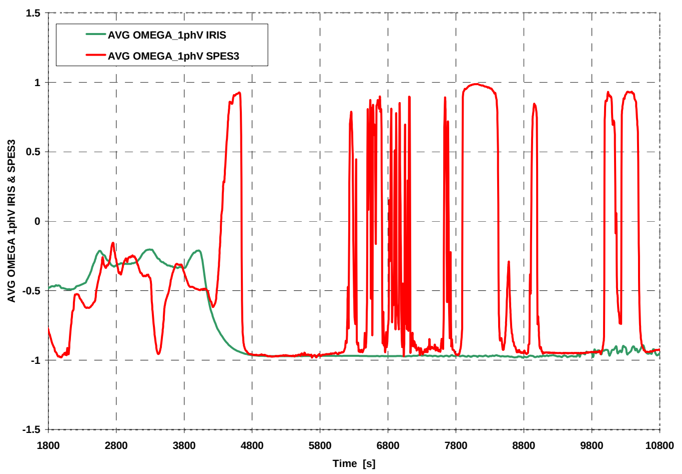


Fig.A13. 121 AVG OMEGA vapor phase IRIS & SPES3 vs time

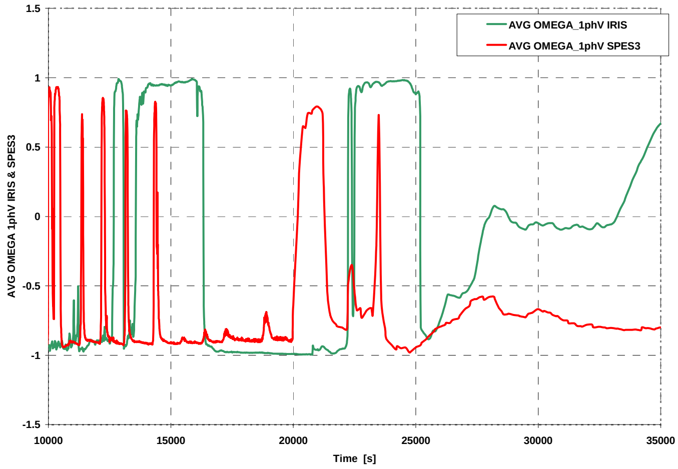


Fig.A13. 122 AVG OMEGA vapor phase IRIS & SPES3 vs time

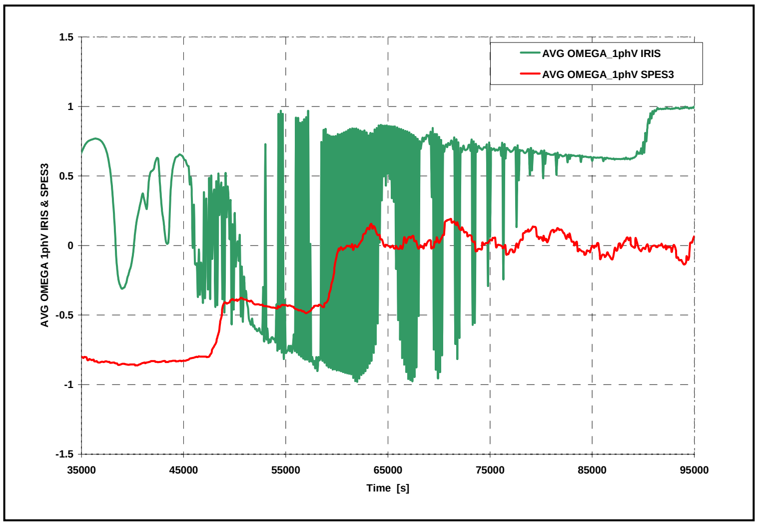


Fig.A13. 123 AVG OMEGA vapor phase IRIS & SPES3 vs time

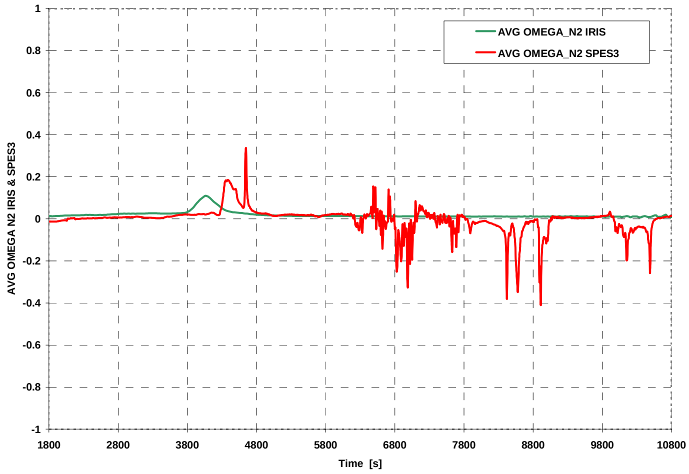


Fig.A13. 124 AVG OMEGA N2 phase IRIS & SPES3 vs time

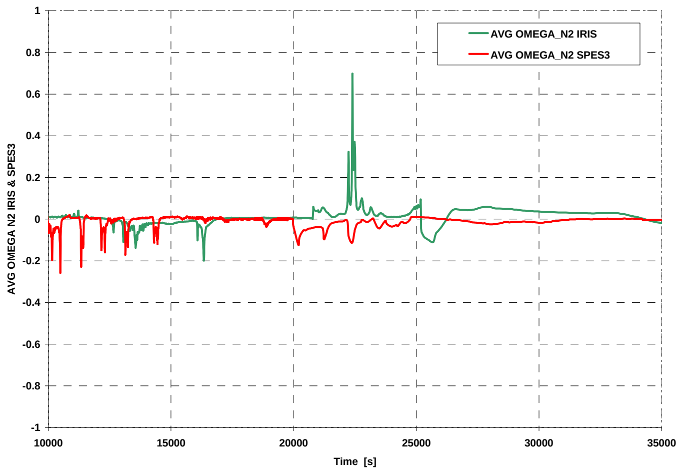


Fig.A13. 125 AVG OMEGA N2 phase IRIS & SPES3 vs time

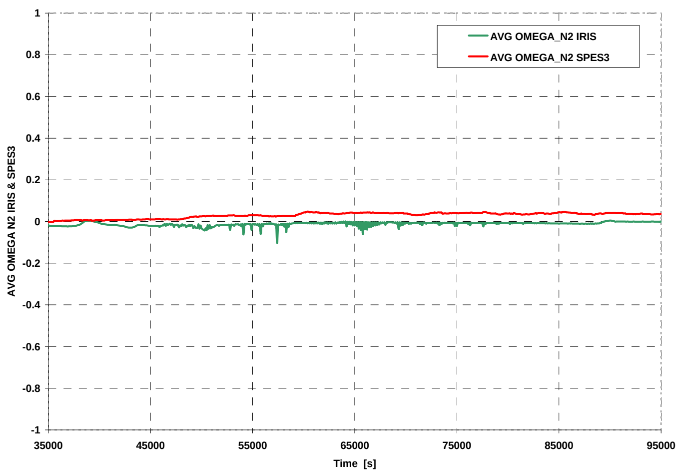


Fig.A13. 126 AVG OMEGA N2 phase IRIS & SPES3 vs time

Scale distortions between IRIS and SPES3 have been calculated. In Tab.A13. 8, omegas for each phase for each time event are listed for IRIS and SPES3 respectively. In Tab.A13. 9 all distorsion D parameters are evaluated while in Tab.A13. 10 only two phases and steam phase are evaluated (N2 and liquid phase are negligible)

IRIS					SPES3				
Sequence	AVGΩ 1phl	AVGΩ 1phV	AVGΩ N2	AVGΩ 2ph	Sequence	AVGΩ 1phl	AVGΩ 1phV	AVGΩ N2	AVGΩ 2ph
15) t=1612 s	5.61E-04	-6.57E-01	8.14E-03	-3.34E-01	15) t=2150 s	-1.16E-03	-6.69E-01	2.73E-03	-3.27E-01
16) t=1830 s	9.76E-04	-4.75E-01	1.24E-02	-5.12E-01	16) t=2260 s	4.35E-03	-5.52E-01	6.66E-04	-4.43E-01
17) t=1730 s	1.33E-03	-5.12E-01	1.28E-02	-4.74E-01	17) t=2230 s	4.45E-03	-5.26E-01	-4.04E-04	-4.69E-01
18) t=3190 s	1.66E-03	-2.33E-01	2.56E-02	-7.39E-01	18) t=2270 s	4.09E-03	-5.59E-01	1.54E-03	-4.36E-01
19) t=20860 s	6.13E-05	-9.57E-01	4.17E-02	1.50E-03	19) t=31569 s	-8.93E-04	-7.89E-01	9.76E-04	-2.09E-01
20) t=20873 s	5.44E-05	-9.59E-01	4.04E-02	9.75E-04	20) t=40000 s	-6.39E-04	-8.55E-01	6.18E-03	-1.38E-01
21) t=22300 s	-3.98E-04	9.17E-01	7.10E-02	1.20E-02	21) t=30790 s	-5.21E-04	-7.18E-01	-7.24E-03	-2.75E-01
22) t=49116 s	-6.12E-03	5.00E-01	-1.97E-02	-4.74E-01	22) t=28815 s	1.55E-03	-7.01E-01	-1.57E-02	-2.82E-01

Tab.A13. 8 IRIS and SPES 3 AVG OMEGA for each phase

DISTORTIONS

Sequence	AVGD1phl	AVGD1phV	AVGDN2	AVGD2ph
15) t=2150 s	-2.07E+00	1.02E+00	3.35E-01	9.78E-01
16) t=2260 s	4.46E+00	1.16E+00	5.37E-02	8.66E-01
17) t=2230 s	3.34E+00	1.03E+00	-3.15E-02	9.90E-01
18) t=2270 s	2.46E+00	2.39E+00	6.02E-02	5.89E-01
19) t=31569 s	-1.46E+01	8.25E-01	2.34E-02	-1.39E+02
20) t=40000 s	-1.17E+01	8.92E-01	1.53E-01	-1.42E+02
21) t=30790 s	1.31E+00	-7.83E-01	-1.02E-01	-2.29E+01
22) t=28815 s	-2.53E-01	-1.40E+00	7.96E-01	5.95E-01

Tab.A13. 9 IRIS and SPES3 AVG Distorsion for each phase

Sequence	AVGD1phV	AVGD2ph
15	1.02E+00	9.78E-01
16	1.16E+00	8.66E-01
17	1.03E+00	9.90E-01
18	2.39E+00	5.89E-01
19	8.25E-01	-1.39E+02
20	8.92E-01	-1.42E+02
21	-7.83E-01	-2.29E+01
22	-1.40E+00	5.95E-01

well scaled	(green)
Distorsion 1st class	(pink)
Opposite behavior	(red)

Tab.A13. 10 Distorsion of relevant OMEGA phase

Finally, it has to be noted that:

- During the first period of time, starting from pressure equalization up to 18th time event, Distorsion parameters keep a great value, which means SPES3 is well scaled (in time event 18 a 1st class distorsion is present)
- From time event 19 up to the end there is always at least one Distorsion parameter with a minus sign. It means that IRIS and SPES3, when the same event happens, develop different behavior, while IRIS is heating up SPES is cooling down and vice versa. It means, obviously, that SPES3 is not well scaled.

A.13 Attachments to conf-call #120

file "IRIS_SPES3_Conf Call Minutes #120 Att 1 SPES3-130i EHRS mass dist.xls"

Filling ratio = ratio between total mass in the closed loop and total mass of cold water that could be stored in the loop

EHRS-SG A loop	Volume (m3), mass (kg)	Notes
SG-A tubes volume	0.069796	
FL-A from MFIV to SG inlet volume	0.016801	
SL-A from SG outlet to MSIV volume	0.035637	
HL-A volume	0.021797	
EHRS-A HX volume	0.034296	
CL-A volume	0.014955	
Total loop A volume	0.193282	
Total loop A cold mass	193.2825	
Initial mass (spes3-130)	79.8	
Initial mass SG isolated (spes3-130)	76.2	mass after Secondary loop isolation
Filling ratio	0.394242	
EHRS-SG B loop	Volume m3	
SG-B tubes volume	0.069796	
FL-B from MFIV to SG inlet volume	0.012108	
SL-B from SG outlet to MSIV volume	0.02949	
HL-B volume	0.021541	
EHRS-B HX volume	0.034296	
CL-B volume	0.01438	
Total loop B volume	0.18161	
Total loop B cold mass	181.61	
Initial mass (spes3-130)	76.1	
Initial mass SG isolated (spes3-130)	72.49	mass after Secondary loop isolation
Filling ratio	0.399152	
EHRS-SG C loop	Volume m3	
SG-C1+C2 tubes volume	0.139592	
FL-C from MFIV to SG inlet volume	0.02894	
SL-C from SG outlet to MSIV volume	0.066118	
HL-C volume	0.029235	
EHRS-C HX volume	0.058828	
CL-C volume	0.019189	
Total loop C volume	0.341902	

Total loop C cold mass	341.9019	
Initial mass (spes3-130)	135.7	
Initial mass SG isolated (spes3-130)	131.68	mass after Secondary loop isolation
Filling ratio	0.38514	

Tab.A14. 1 EHRS-SG loop volume and mass

Fig.A14. 1 EHRS-SG loop mass

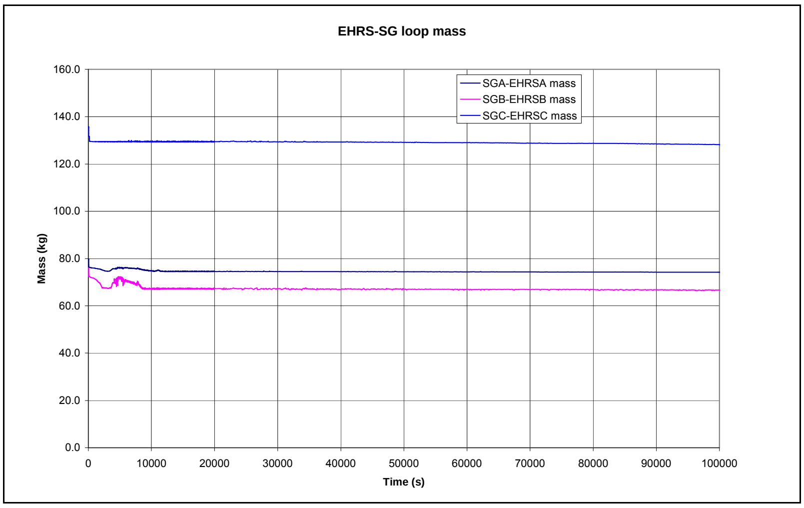


Fig.A14. 2 Loop A partial mass

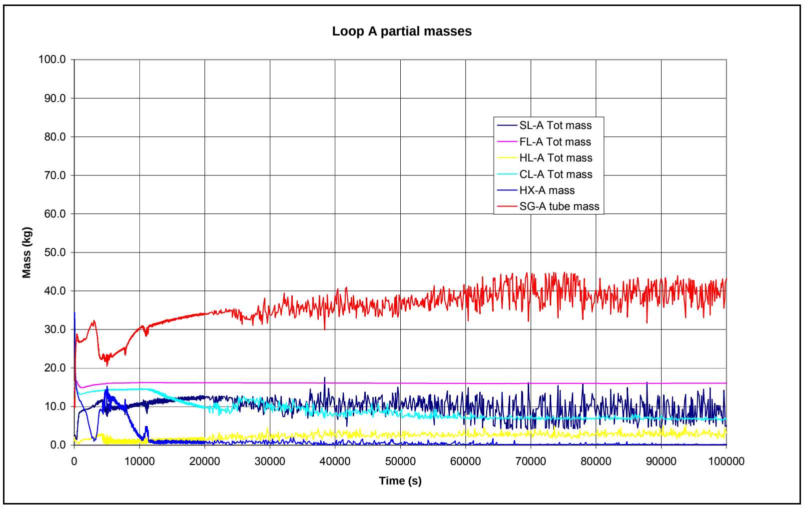


Fig.A14. 3 Loop B partial mass

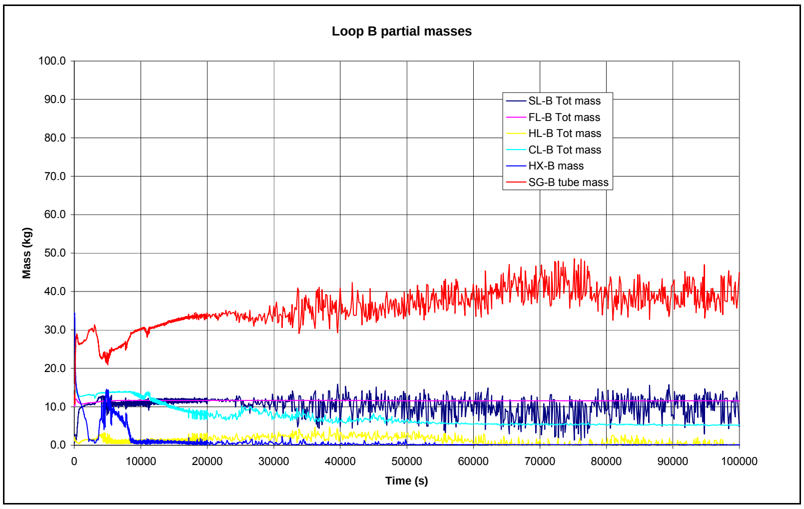


Fig.A14. 4 Loop C partial mass

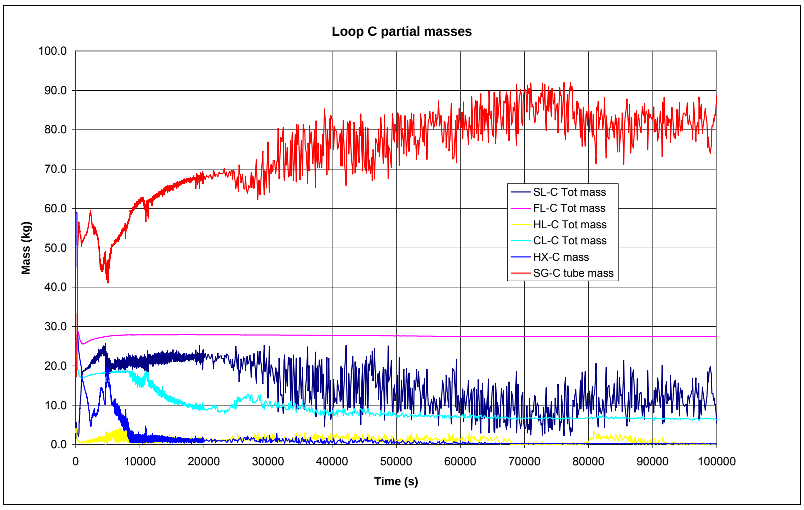
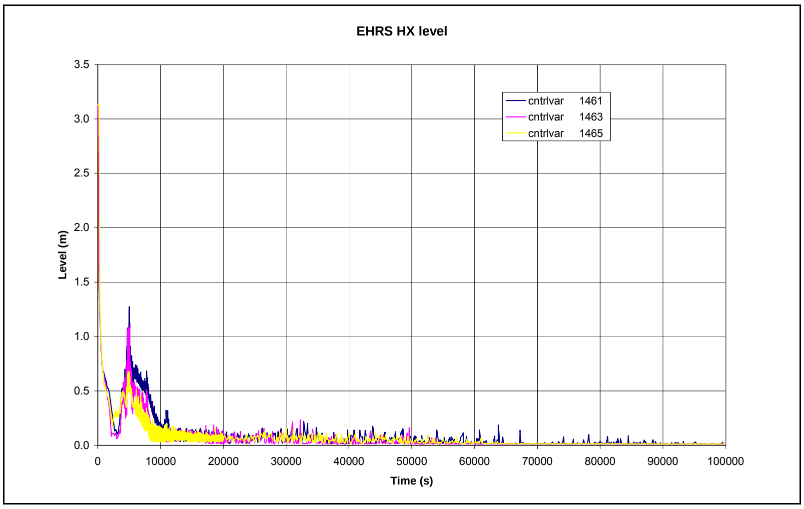


Fig.A14. 5 EHRS HX level



A.15 Attachments to conf-call #123

file "IRIS_SPES3_Conf Call Minutes #123 Attachment 1- liquid distribution.doc"

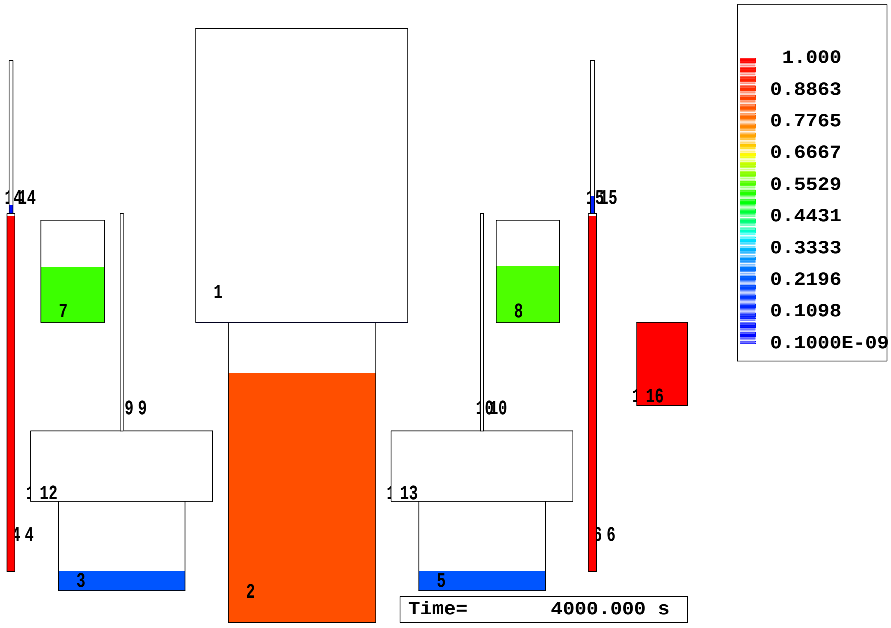


Fig.A15. 1 Liquid distribution

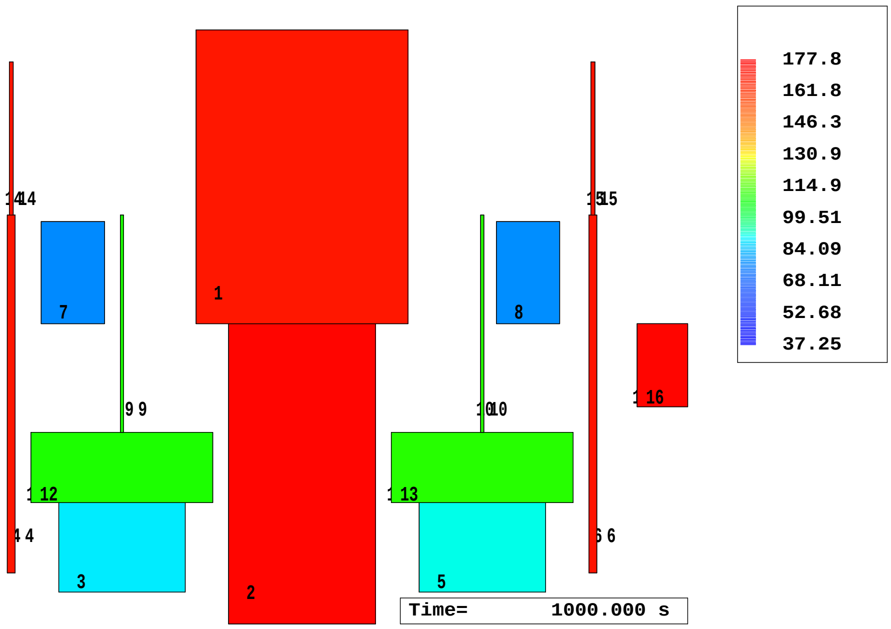


Fig.A15. 2 Temperature of the gas mixture

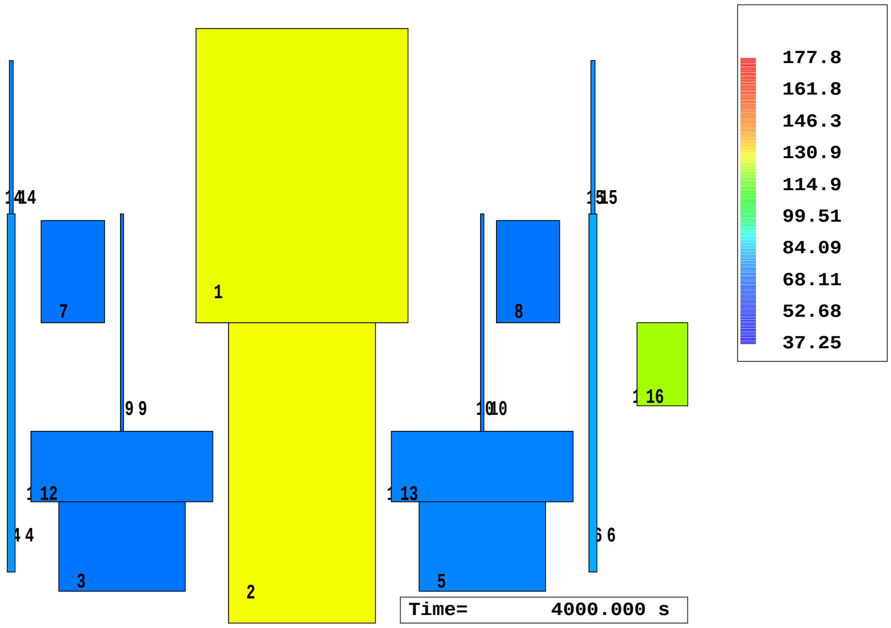


Fig.A15. 3 Temperature of the gas mixture

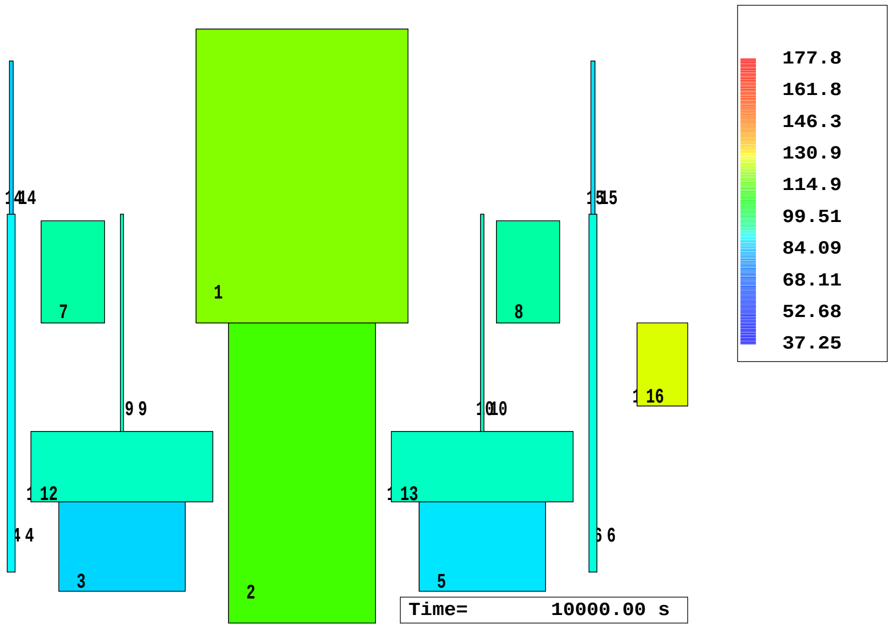


Fig.A15. 4 Temperature of the gas mixture

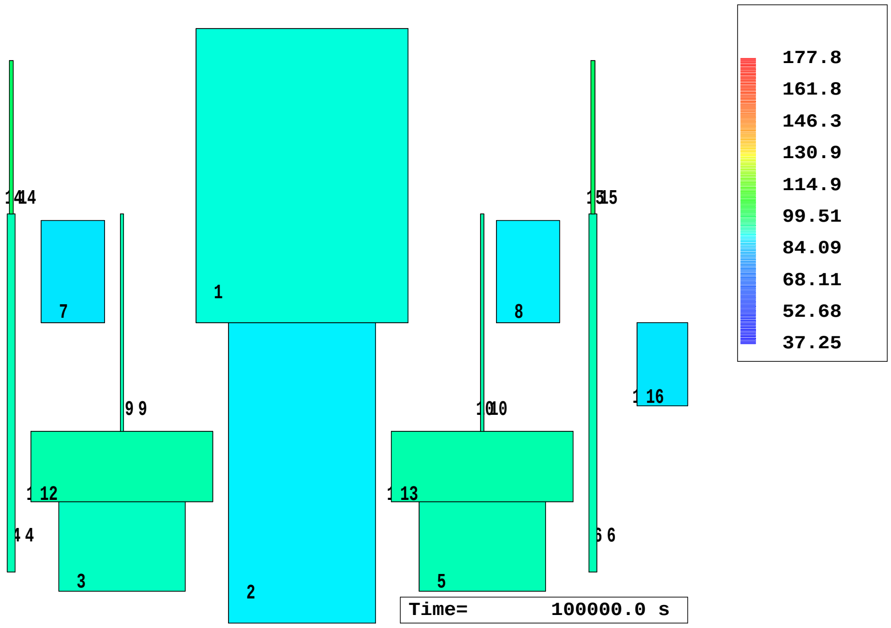


Fig.A15. 5 Temperature of the gas mixture

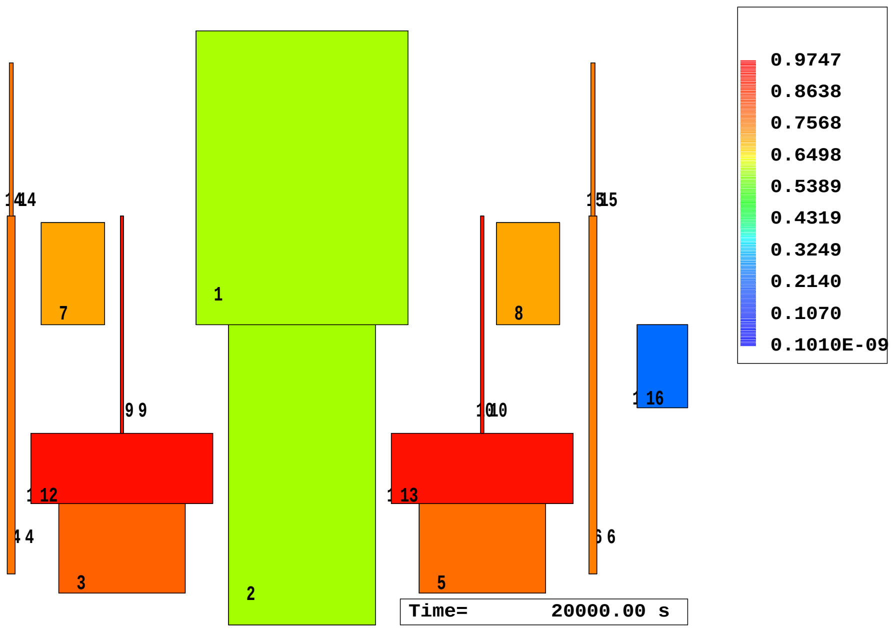


Fig.A15. 6 N2 volume fraction

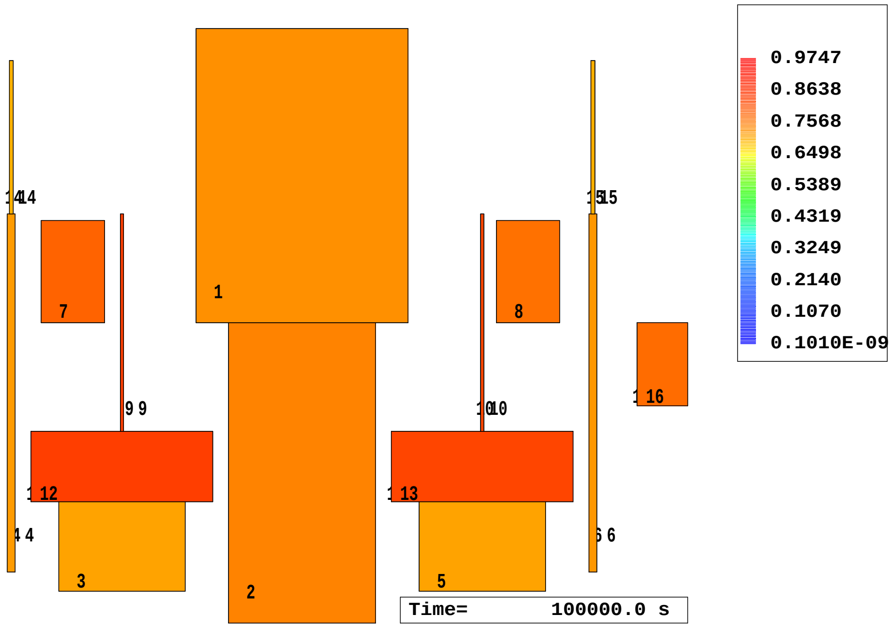


Fig.A15. 7 N2 volume fraction

file "IRIS_SPES3_Conf Call Minutes #123 Attachment 2- liquid level response.doc"

RV LIQUID LEVEL RESPONSE

In this section Fractional Rate of Changes Analysis has been performed considering Liquid level Response in IRIS and SPES3 RV for all the transient that follows a DVI LINE Break (SBLOCA).
All calculations have been performed based on RELAP output files based on HT5 (IRIS) and SPES3_124 (SPES3).
First, all EFFECTIVE METRICS evaluated by running omega program developed by Martiello and Bergamo have been reported for IRIS and SPES3 cases. In both of cases (as for all the following graphs), averaged values have been considered. In particular, 11 averaged time steps have been considered starting from considered time events. When many time events occur close each other, the average has been performed on few time events, in order not to consider different time events in evaluations.

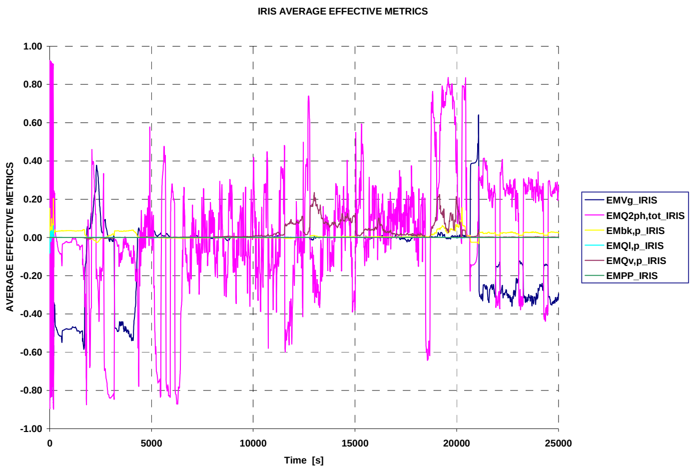


Fig.A15. 8 IRIS averaged effective metrics from 0s up to 25000s

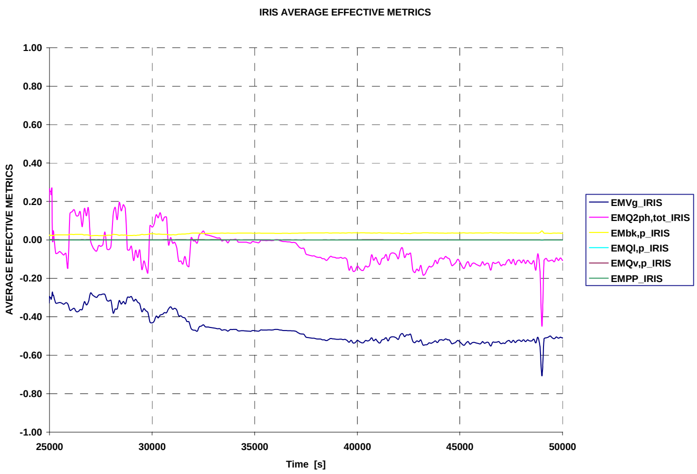


Fig.A15. 9 IRIS averaged effective metrics from 25000s up to 50000s

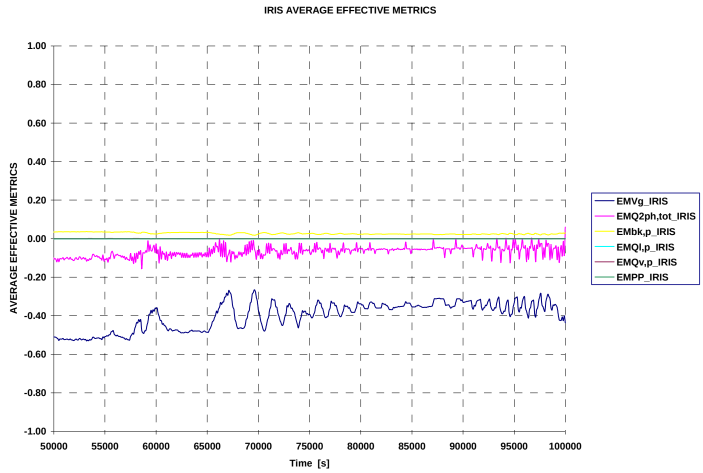


Fig.A15. 10 IRIS averaged effective metrics from 50000s up to the end

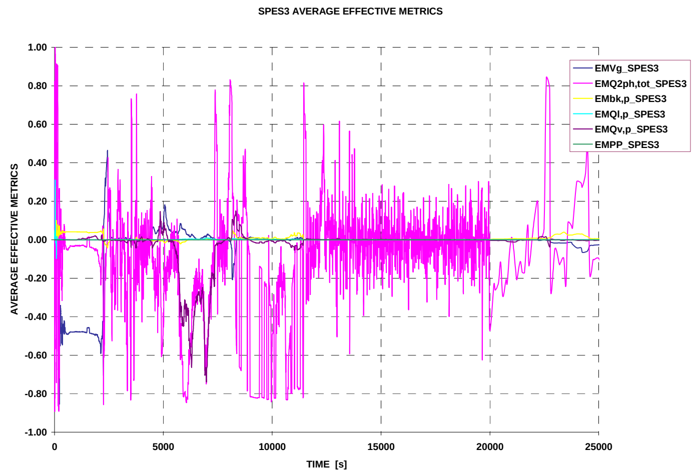


Fig.A15. 11 SPES3 averaged effective metrics from 0s up to 25000s

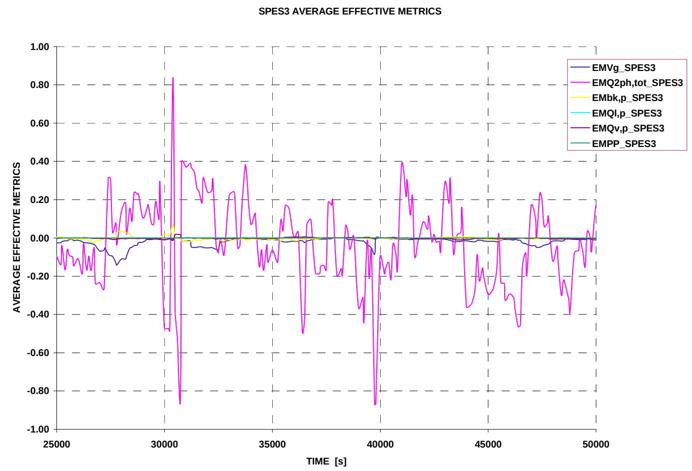


Fig.A15. 12 SPES3 averaged effective metrics from 25000s up to 50000s

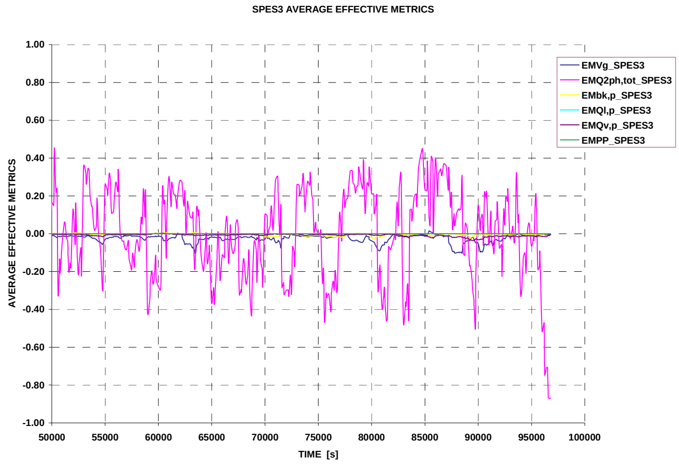


Fig.A15. 13 SPES3 averaged effective metrics from 50000s up to the end

In the following, all IRIS and SPES3 EFFECTIVE METRICS are matched in order to point out differences between Plant and Facility.

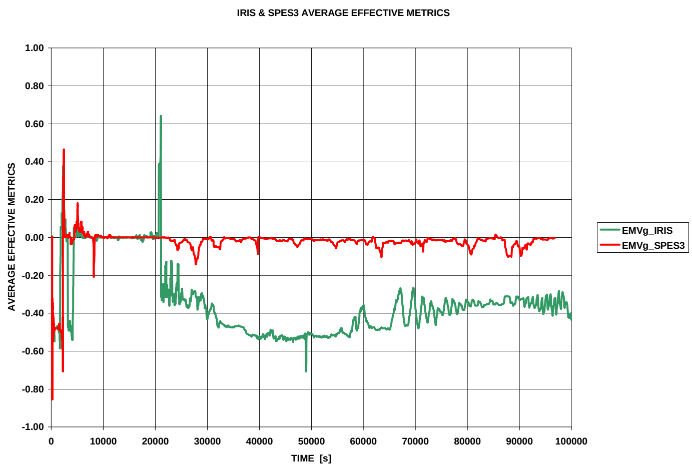


Fig.A15. 14 IRIS & SPES3 Effect Metrics for Break Vapour Volumetric Flow Rate

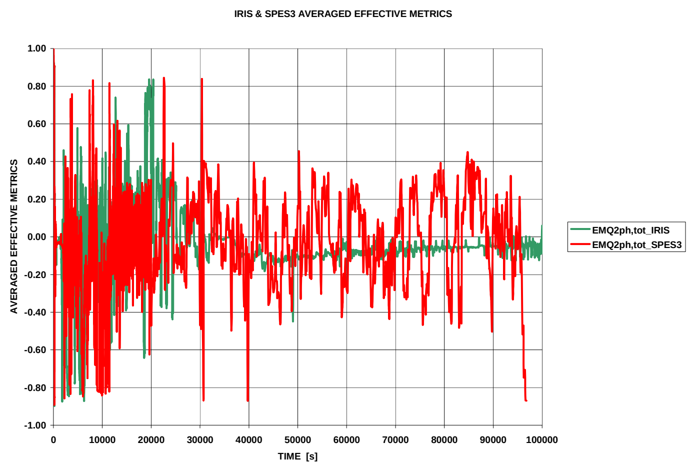


Fig.A15. 15 IRIS & SPES3 Effect Metrics for Phase change Heating/Cooling

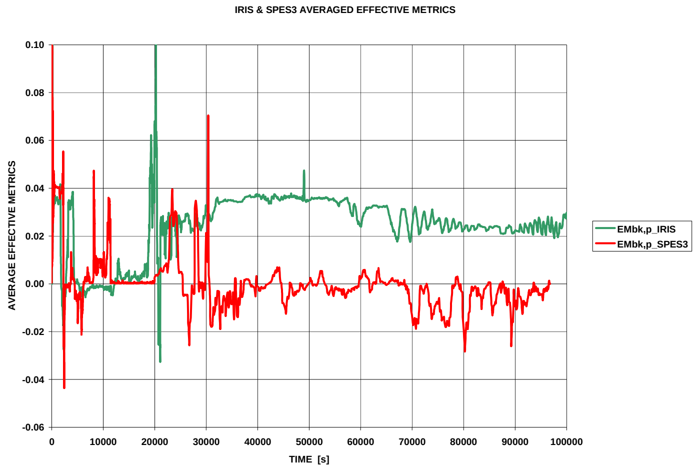


Fig.A15. 16 IRIS & SPES3 Effect Metrics related to break effect

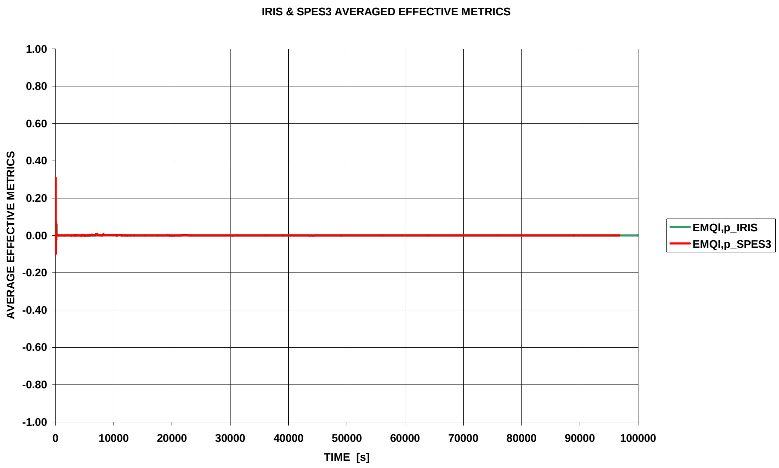


Fig.A15. 17 IRIS & SPES3 Effect Metrics related to liquid

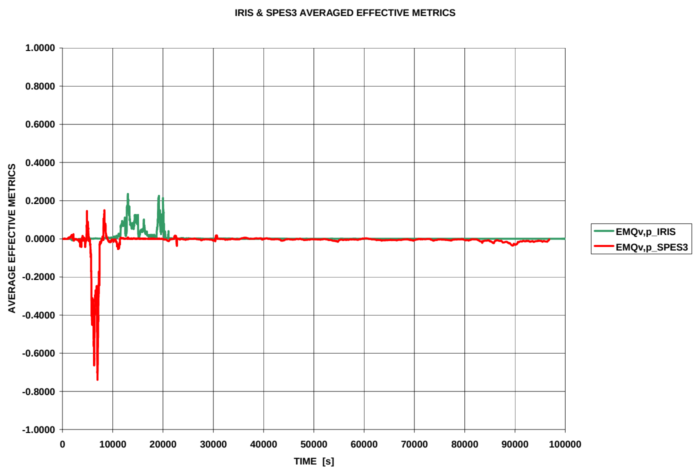


Fig.A15. 18 IRIS & SPES3 Effect Metrics related to single vapour phase

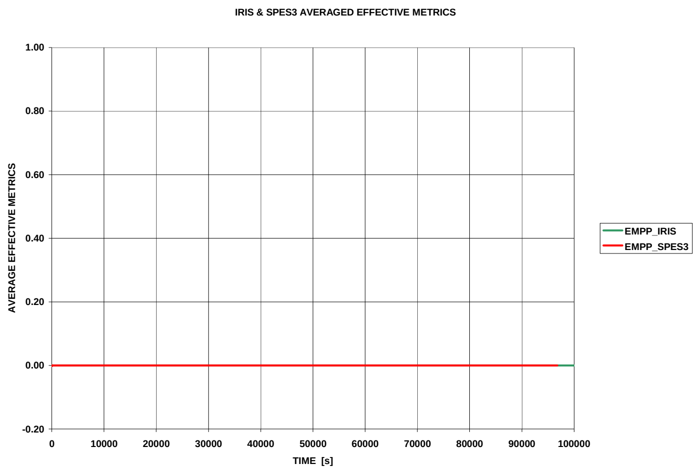


Fig.A15. 19 IRIS & SPES3 Effect Metrics related to the pump

Distorsion parameters evaluated for each time events are here listed. In particular, it is worth noting that: 1) Many Distorsion parameters related to vapour phase DQv,p are '#DIV/0!' because the value of EFFECTIVE METRICS for IRIS and SPES3 are 0; 2) Distorsion parameters related to Pump are often '#DIV/0!'because IRIS and SPES3 effective metrics are 0.

ACTUAL VALUES

IRIS Time event	DVg	DQ2ph,tot	Dbk,p	DQl,p	DQv,p	DPP
1	#DIV/0!	1.09	#DIV/0!	-0.35	#DIV/0!	0.06
2	0.31	1.01	0.75	-4.06	#DIV/0!	0.63
3	0.31	1.01	0.75	-4.06	#DIV/0!	0.63
4	0.31	1.01	0.75	-4.06	#DIV/0!	0.63
5	0.27	1.01	0.71	-3.72	#DIV/0!	0.60
6	0.04	-1.50	0.20	0.21	#DIV/0!	0.14
7	-114.88	-0.91	0.43	0.02	#DIV/0!	0.00
8	0.11	-0.95	0.34	0.06	#DIV/0!	0.00
9	0.00	-1.02	0.20	0.90	#DIV/0!	5.45
10	0.68	0.21	0.72	0.26	#DIV/0!	0.00
11	0.02	1.98	1.17	1.14	#DIV/0!	#DIV/0!
12	1.01	0.83	1.01	0.62	#DIV/0!	#DIV/0!
13	0.79	-47.06	1.02	1.14	#DIV/0!	#DIV/0!
14	0.80	-2.47	1.01	#DIV/0!	#DIV/0!	#DIV/0!
15	1.17	-1.87	1.30	#DIV/0!	4.48	#DIV/0!
16	26.28	-0.58	7.74	0.00	2.02	#DIV/0!
17	0.52	0.02	0.54	#DIV/0!	0.71	#DIV/0!
18	0.04	1.61	0.01	0.07	0.42	#DIV/0!
19	-0.01	32.25	-0.12	-0.04	#DIV/0!	#DIV/0!
20	0.00	-15.71	0.05	1.19	100.03	#DIV/0!
21	-0.01	3.61	0.07	1.60	#DIV/0!	#DIV/0!
22	-0.01	-10.60	0.86	24.33	2.70	#DIV/0!

well scaled
Distorsion 1st class
Distorsion 2nd class
Opposite behavior

Tab.A15. 1 Distorsion parameters for each time event

AVERAGED VALUES

IRIS Time event	DVg	DQ2ph,tot	Dbk,p	DQl,p	DQv,p	DPP
1	3.40	0.97	35.02	-12.40	#DIV/0!	2.26
2	0.31	1.01	0.75	-4.06	#DIV/0!	0.63
3	0.31	1.01	0.75	-4.06	#DIV/0!	0.63
4	0.31	1.01	0.75	-4.06	#DIV/0!	0.63
5	0.21	1.19	0.81	1.58	#DIV/0!	0.66
6	0.37	1.03	1.59	1.93	#DIV/0!	2.71
7	-93.22	-2.17	0.18	0.00	#DIV/0!	0.00
8	0.00	1.19	0.46	0.94	#DIV/0!	0.03
9	0.00	-1.02	0.27	0.76	#DIV/0!	3.22
10	0.77	0.13	0.88	0.18	#DIV/0!	0.00
11	0.02	26.69	1.61	1.55	#DIV/0!	#DIV/0!
12	0.95	3.10	1.07	1.25	#DIV/0!	#DIV/0!
13	0.67	-5.92	0.84	2.45	#DIV/0!	#DIV/0!
14	0.93	-0.37	1.14	#DIV/0!	8.02	#DIV/0!
15	0.99	0.99	1.10	#DIV/0!	-35.63	#DIV/0!
16	1.14	4.15	6.07	0.00	0.99	#DIV/0!
17	2.25	0.52	2.20	0.00	1.69	#DIV/0!
18	0.01	-6.82	0.05	-14.46	66.33	#DIV/0!
19	0.05	-0.82	0.45	-0.27	0.59	#DIV/0!
20	0.03	-5.51	-0.46	-0.11	3.33	#DIV/0!
21	0.00	-0.40	-0.04	0.26	0.39	#DIV/0!
22	0.00	3.43	0.12	-8.79	80.59	#DIV/0!

well scaled
Distorsion 1st class
Distorsion 2nd class
Opposite behavior

Tab.A15. 2 Distorsion parameters for each time event

A.14 Attachments to conf-call #124

Comparison of old IRIS case (Capital letter in the legend) and new IRIS case with corrected ADS-II actuation logic.
file "IRIS_SPES3_Conf Call Minutes #124 Attachment 1- partial IRIS results.doc"

Fig.A16. 1 Containment pressure

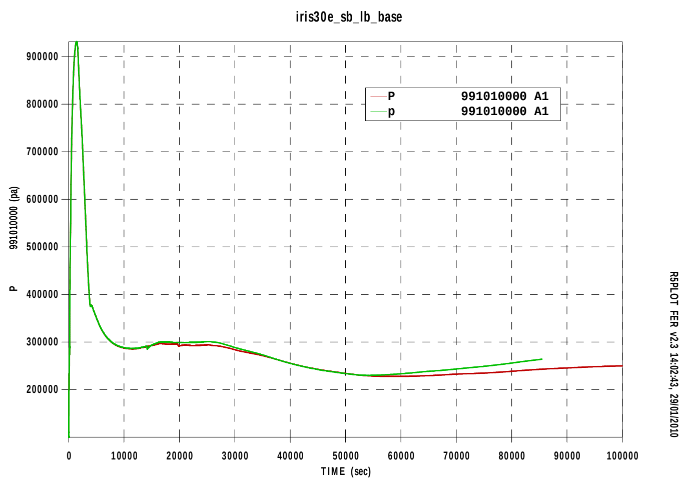


Fig.A16. 2 Core inlet flow

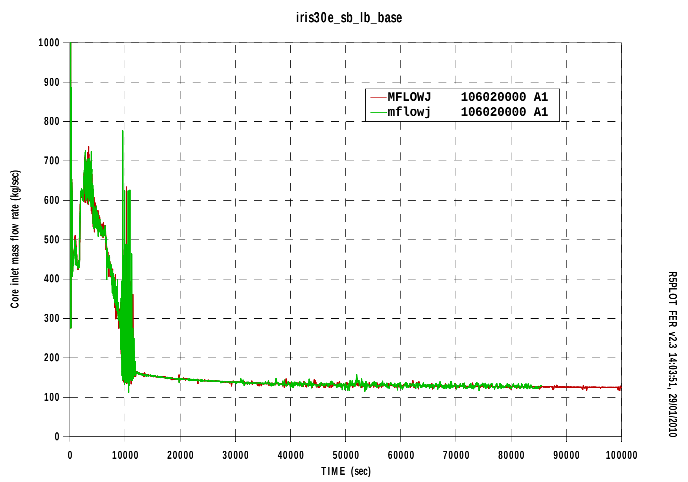


Fig.A16. 3 Break mass flow

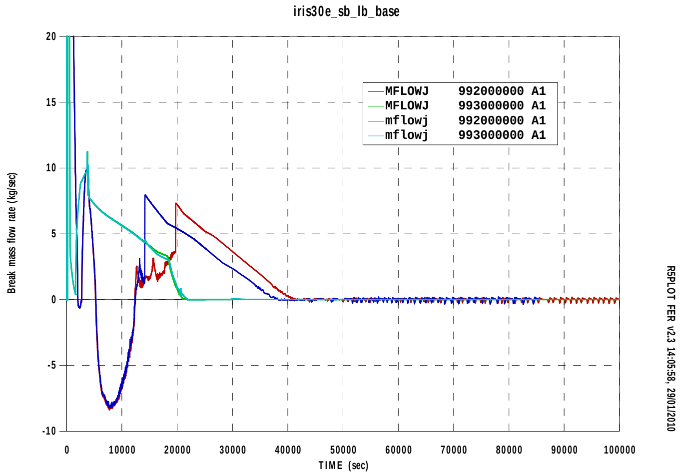


Fig.A16. 4 LGMS mass flow

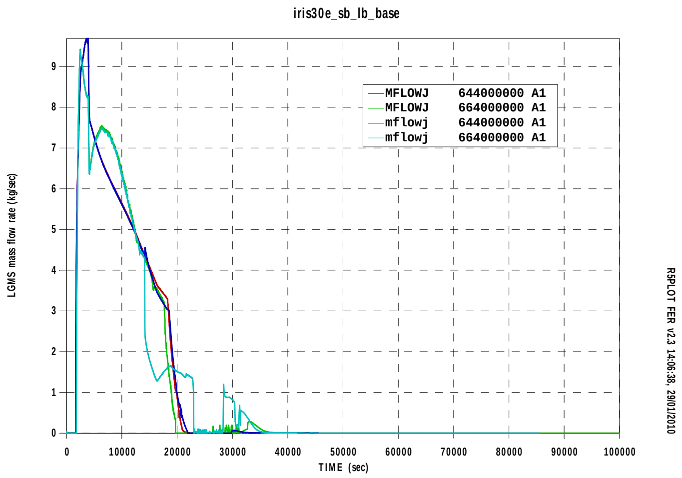


Fig.A16. 5 LGMS delivered mass

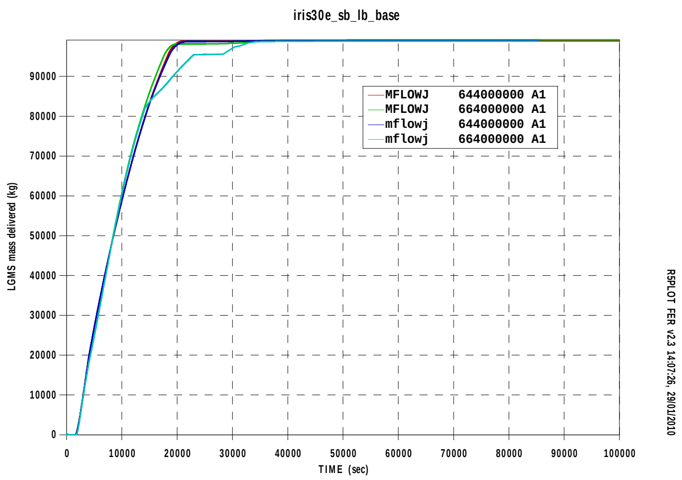
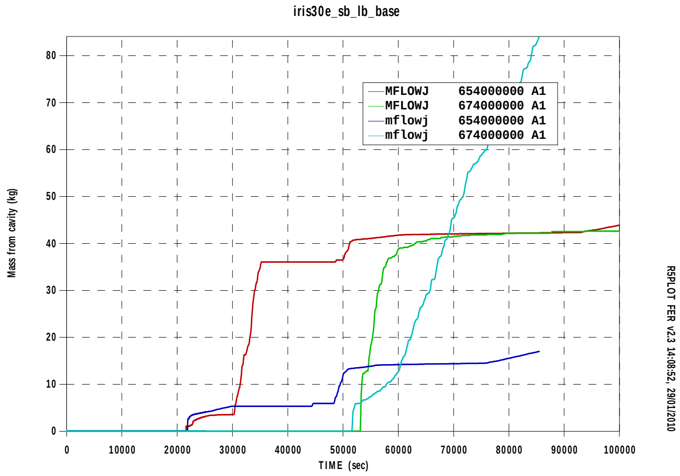


Fig.A16. 6 Mass from cavity


iris30e_sb_lb_base
Mass from cavity (kg)
TIME (sec)
MFLOWJ 654000000 A1
MFLOWJ 674000000 A1
mflowj 654000000 A1
mflowj 674000000 A1
RSPLOT FER v2.3 14:08:52, 29/01/2010

A.15 Attachments to conf-call #126

file "IRIS_SPES3_Conf Call Minutes #126 Attachment 1- EHRS-RWST new model for IRIS.msg"

Dear Davor,

you find here attached the final model of IRIS EHRS/RWST we tested and we think it should be used for IRIS simulation to compare with SPES3.

The model is based on the same PERSEO RWST area/tube ratio, applied to SPES3 with the heat transfer coefficients (through fouling factor) as calibrated by ENEA.

The results of parametric studies for 1) SPES3 based on PERSEO, 2) IRIS based on PERSEO and 3) IRIS original model are summarized in the excel file. A graph reports power versus pressure. The SPES3 and IRIS cases based on PERSEO are similar in all the range of pressure, while IRIS original is largely different at lower pressures.

The IRIS PERSEO input file contains the geometry for IRIS (only RWST1 and EHRS 1 and 2). The second pool and other HX should be modified accordingly.

If you want to discuss something, feel free to call me anytime.

I'll proceed to modify our SPES3 global model to run the "final"case. In parallel, I'll run also a case with 13 tubes per SG, instead of 14 to see how transferred power is affected.

Best regards,
Roberta

file "IRIS_SPES3_Conf Call Minutes #126 Attachment 2- EHRS-IRIS calculations.xls"

P (bar)	SPES3-AB (MW)	SPES3-C (MW)	IRIS-Perseo (MW)	IRIS-original (MW)	IRISorig/IRISpers %	IRISpers/SPES3ab %	IRISpers/SPES3c %
90	0.707	0.704	0.688	0.726	5.234	-2.762	-2.326
80	0.704	0.694	0.68	0.722	5.817	-3.529	-2.059
70	0.686	0.677	0.656	0.699	6.152	-4.573	-3.201
60	0.655	0.646	0.629	0.684	8.041	-4.134	-2.703
50	0.624	0.608	0.592	0.641	7.644	-5.405	-2.703
40	0.578	0.569	0.55	0.588	6.463	-5.091	-3.455
30	0.518	0.504	0.492	0.52	5.385	-5.285	-2.439
20	0.425	0.432	0.427	0.43	0.698	0.468	-1.171
10	0.325	0.325	0.325	0.286	-13.636	0.000	0.000
5	0.254	0.253	0.253	0.168	-50.595	-0.395	0.000
3	0.203	0.206	0.205	0.124	-65.323	0.976	-0.488
2	0.169	0.173	0.167	0.105	-59.048	-1.198	-3.593

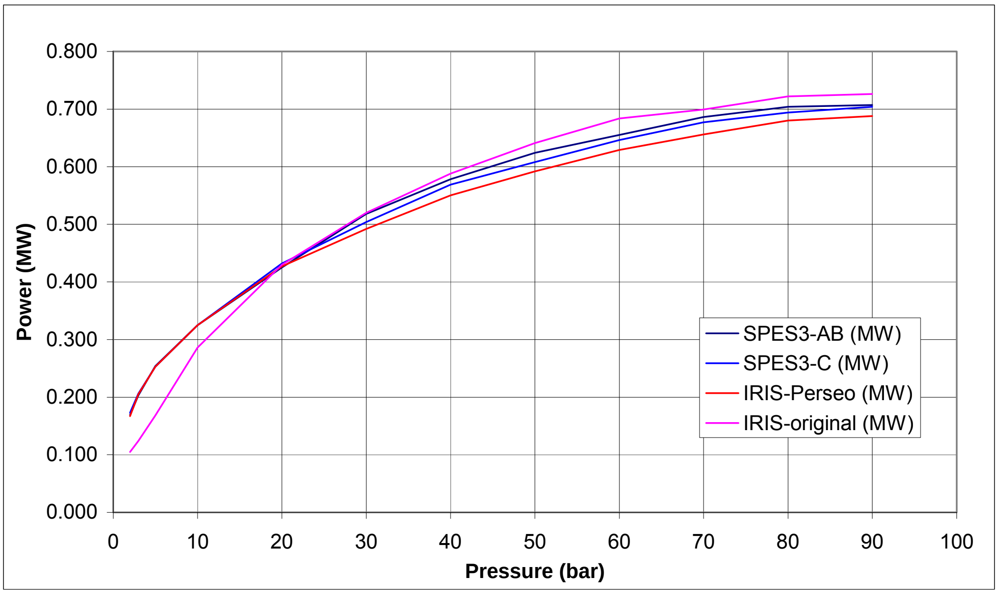


Fig.A17. 1 EHRS-RWST stand alone models SPES3 and IRIS exchanged power parametric comparison

file "IRIS_SPES3_Conf Call Minutes #126 Attachment 4 – new_EHRS results.doc"

Early IRIS results with new EHRS model based on SPES3 PERSEO one

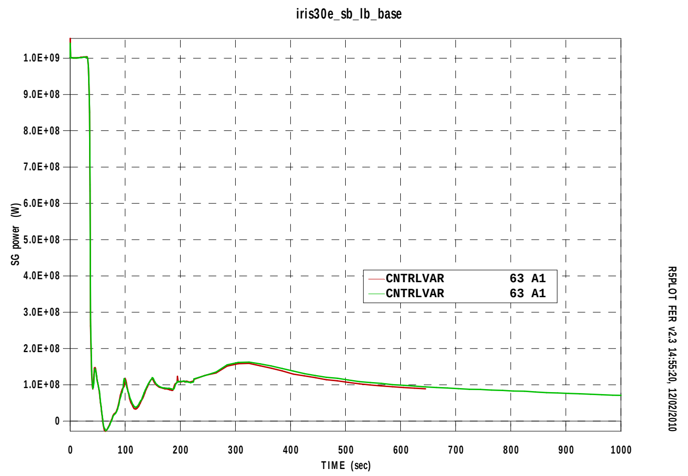


Fig.A17. 2 SG power

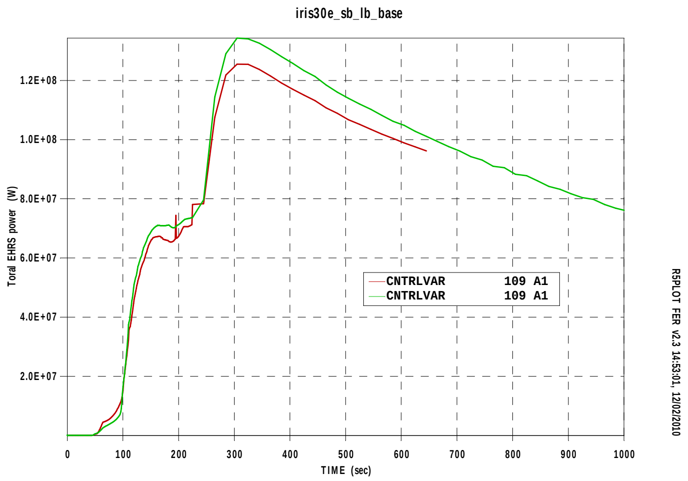


Fig.A17. 3 Total EHRS power

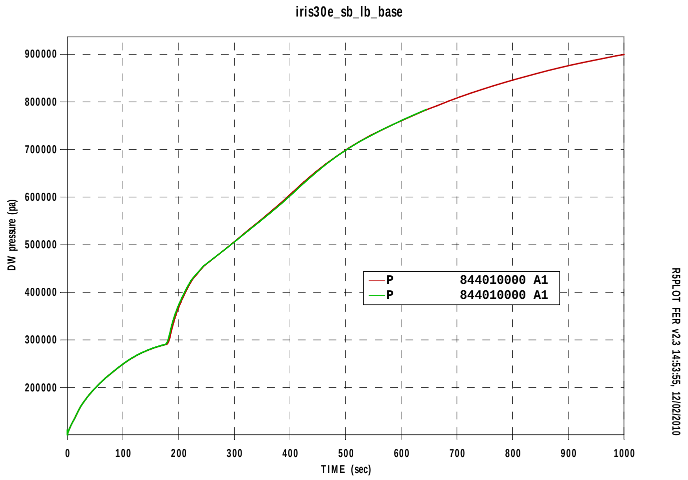


Fig.A17. 4 DW pressure

A.16 Attachments to conf-call #127

IRIS Complete run results with new EHRS model based on SPES3 PERSEO one

file "IRIS_SPES3_Conf Call Minutes #127 Attachment 1- new_EHRS.doc"

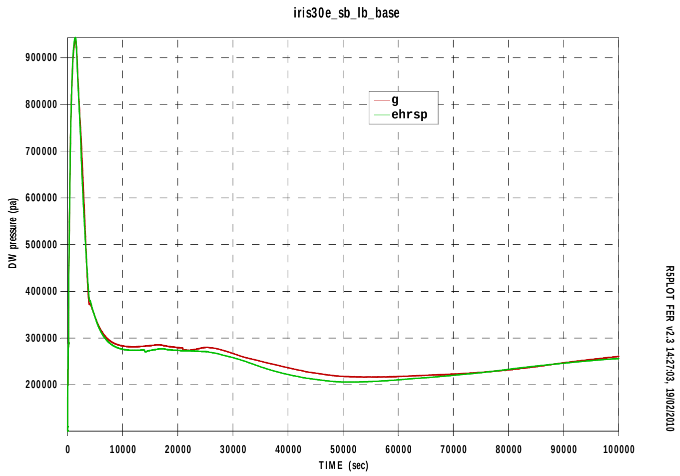


Fig.A18. 1 DW pressure

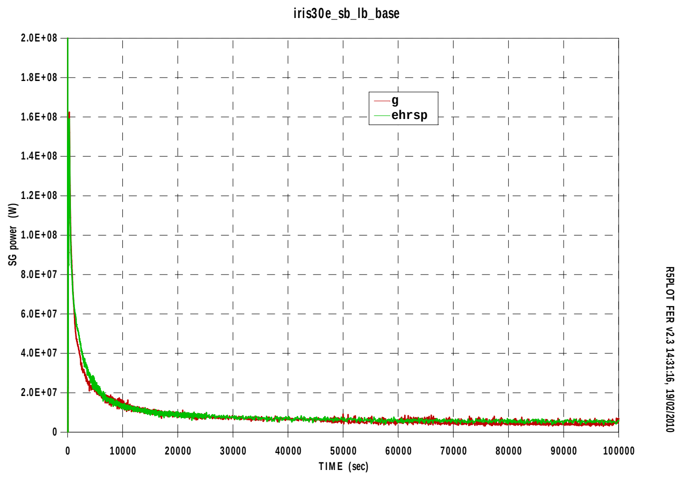


Fig.A18. 2 SG power

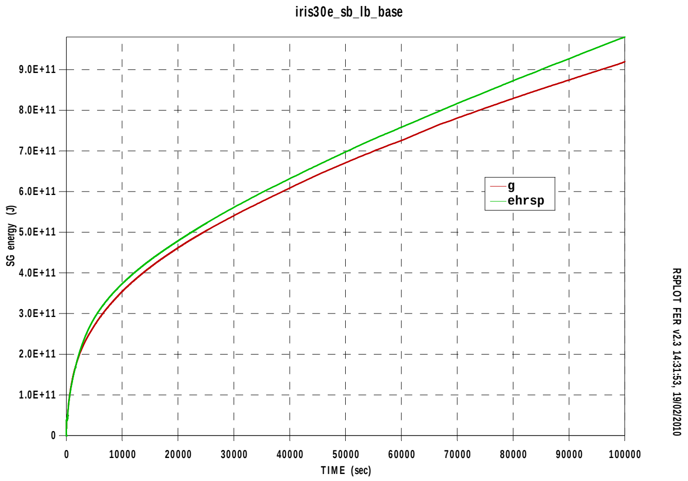


Fig.A18. 3 SG energy

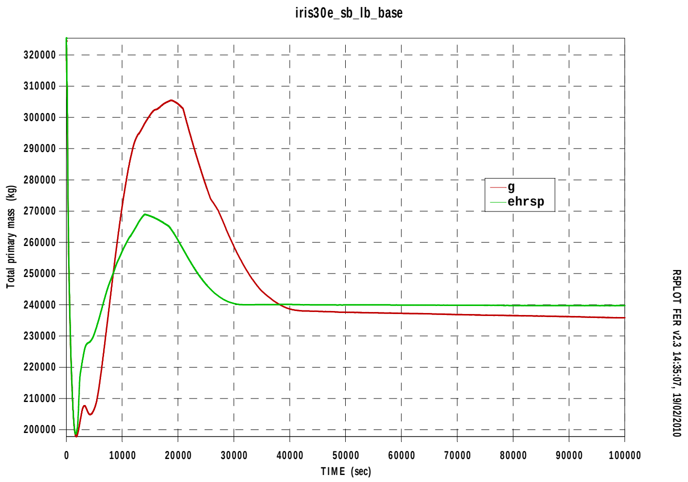


Fig.A18. 4 Total primary mass

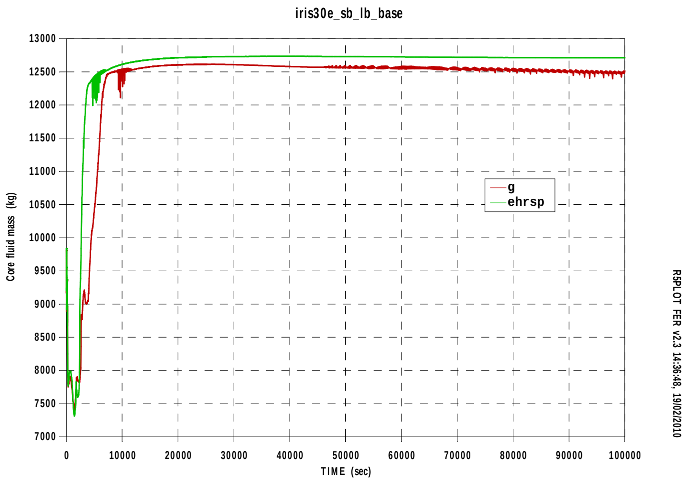


Fig.A18. 5 Core fluid mass

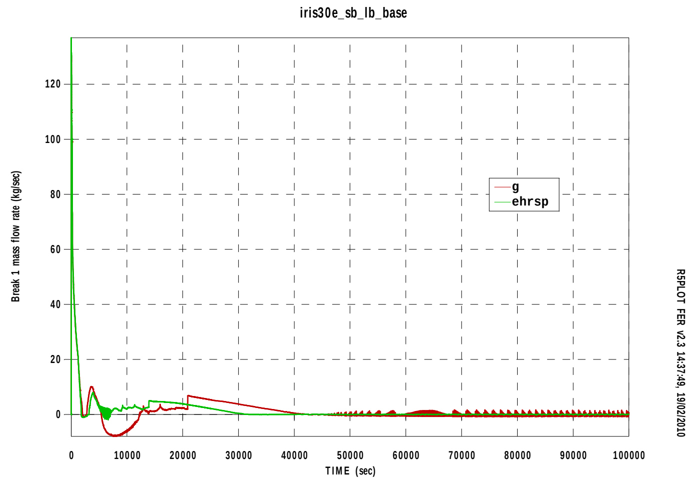


Fig.A18. 6 Core fluid mass

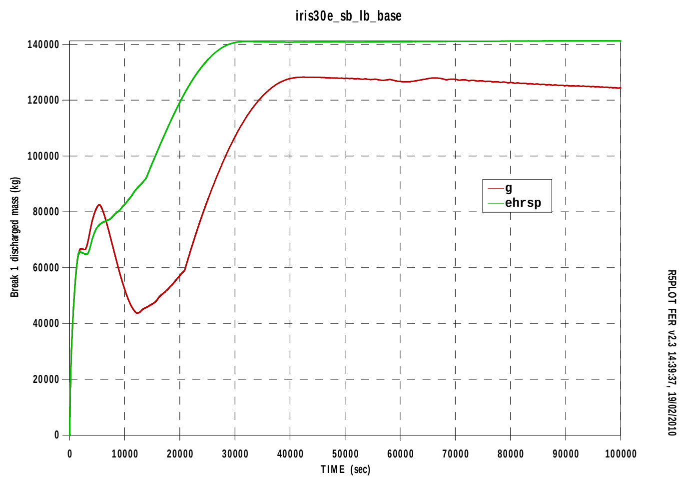


Fig.A18. 7 Break discharged mass

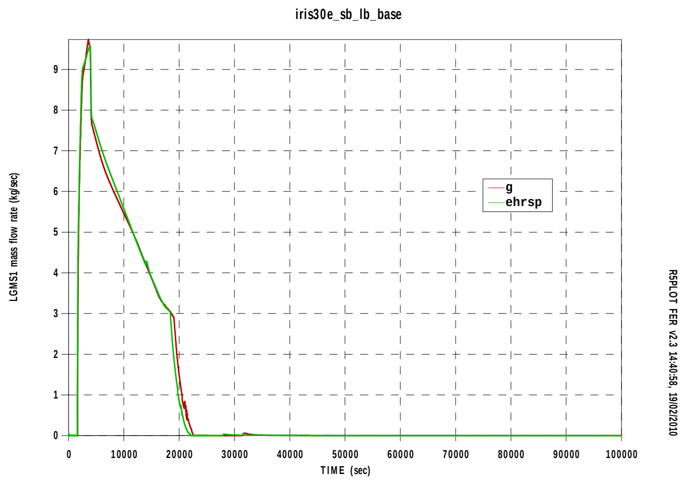


Fig.A18. 8 LGMS mass flowrate

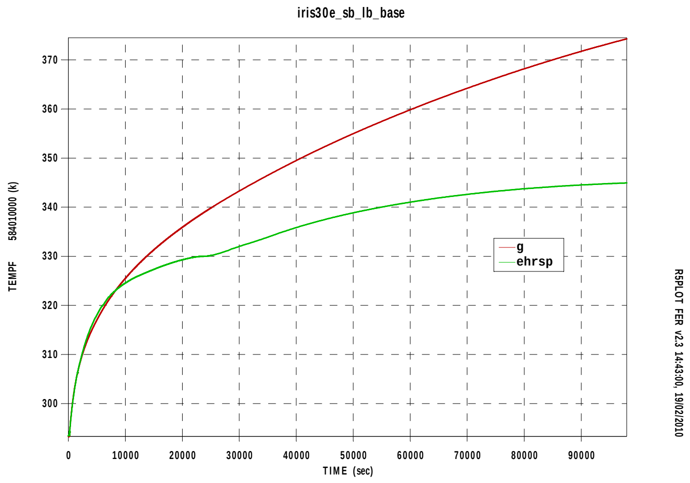


Fig.A18. 9 RWST liquid temperature

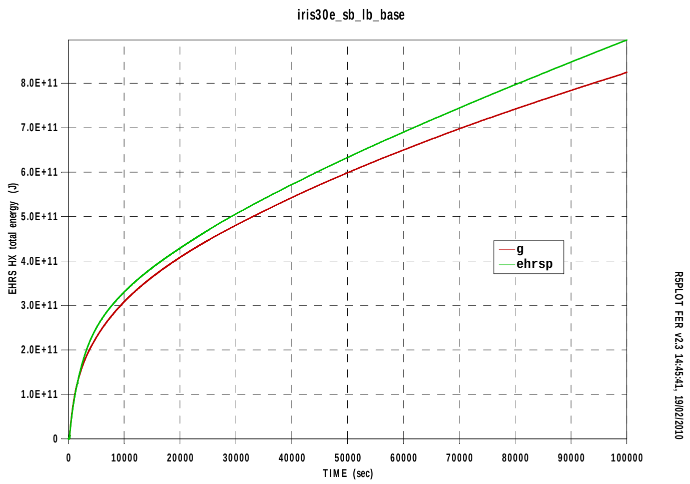


Fig.A18. 10 EHRS HX total enery

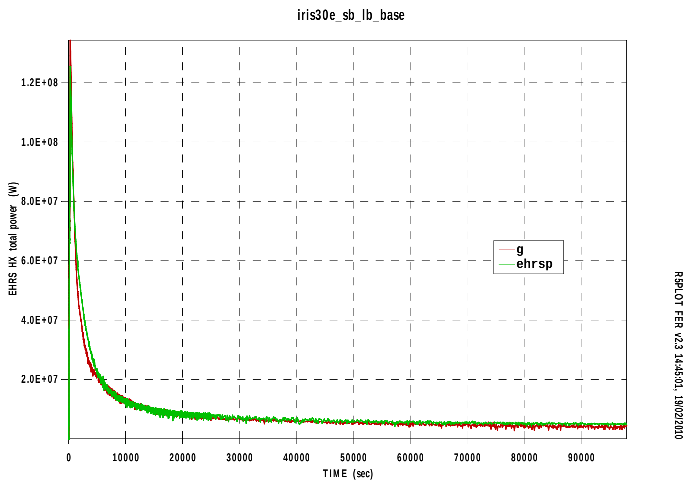


Fig.A18. 11 EHRS HX total power

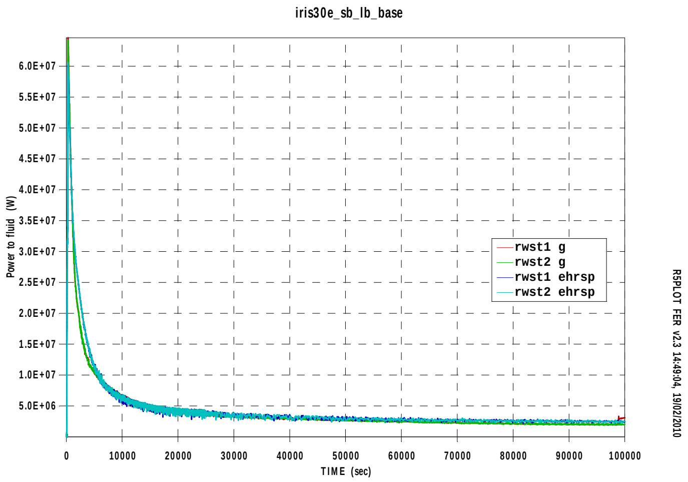


Fig.A18. 12 Power to fluid

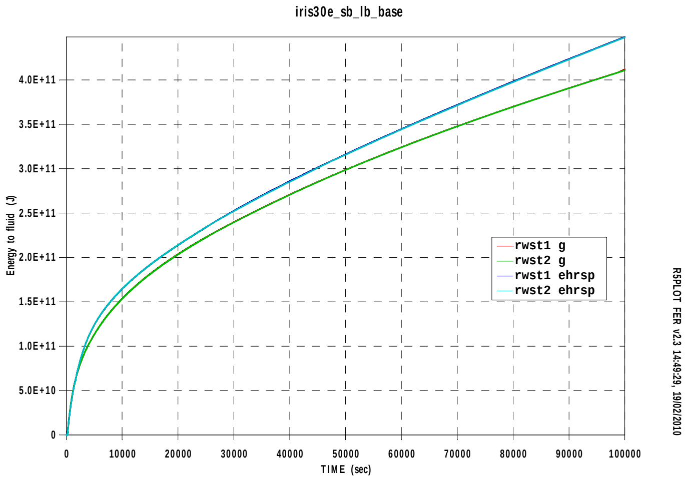


Fig.A18. 13 Energy to fluid

A.17 Attachments to conf-call #133

SPES3 and IRIS RWST water temperature comparison

file "IRIS_SPES3_Conf Call Minutes #133 Attachment 1- RWST Tempf SPES3-146 IRIS HT6_rwst1.pdf"

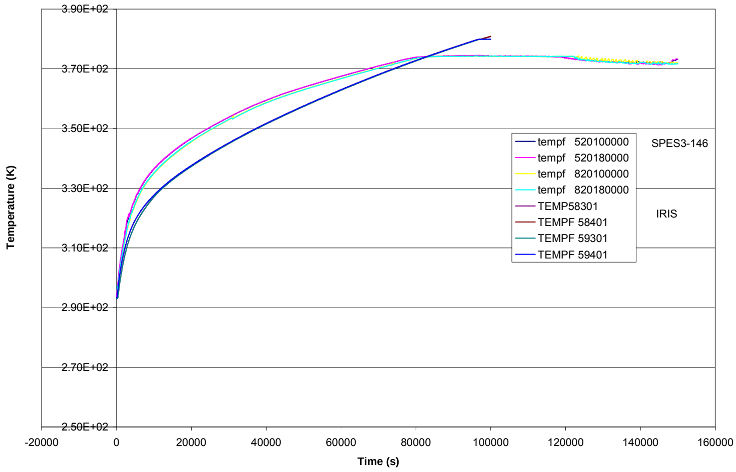


Fig.A19. 1 RWST liquid temperature

A.18 Attachments to conf-call #135

IRIS results with a new coupling between RELAP5 and GOTHIC codes

file "IRIS_SPES3_Conf Call Minutes #135 Attachment 1- IRIS results.doc"

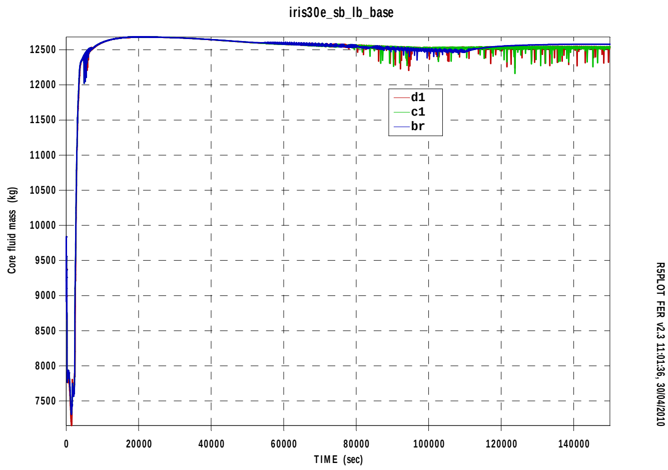


Fig.A20. 1 Core fluid mass

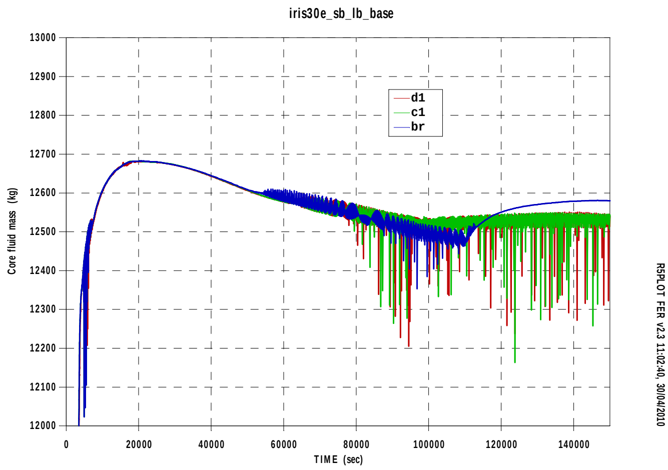


Fig.A20. 2 Core fluid mass

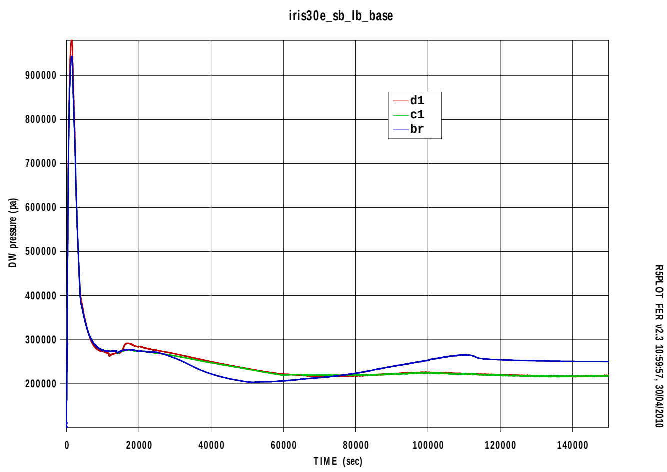


Fig.A20. 3 DW pressure

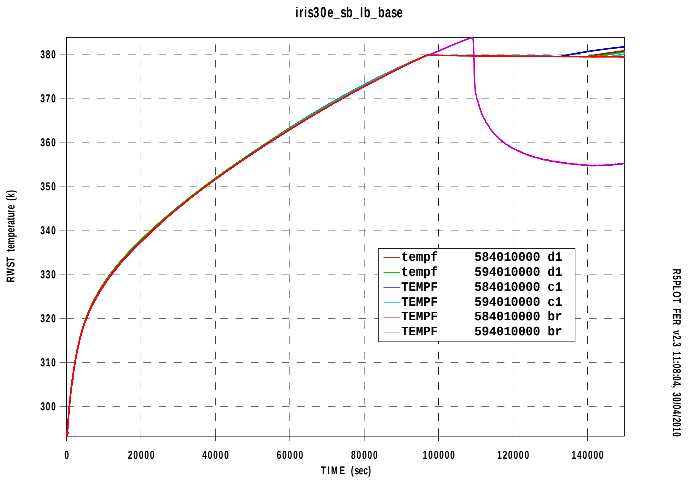


Fig.A20. 4 RWST temperature