COMPARISON REPORT OF
THE OECD/CSNI INTERNATIONAL STANDARD PROBLEM 21
(PIPER-ONE EXPERIMENT PO-SB-7)

Volume 1

COMPARISON REPORT

November 1989

COMMITTEE ON THE SAFETY OF NUCLEAR INSTALLATIONS
OECDOECD NUCLEAR ENERGY AGENCY
38, boulevard Suchet, 75016 Paris, France
COMPARISON REPORT OF THE OECD/CSNI INTERNATIONAL

STANDARD PROBLEM 21 (PIPER-ONE EXPERIMENT PO-SB-7)

F. D'Auria
M. Mazzini
F. Oriolo
S. Paci

Work performed in the frame of ENEA LWRs Safety Research Programme OECD/CSNI

ISF 21 Final Workshop (Contract AC-6) - Pisa (I), April 13-14 1989

Pisa, Aug. 1989

NT 140(89)
The OECD Nuclear Energy Agency (NEA) was established on 20th April 1972, replacing OECD's European Nuclear Energy Agency (ENE, established on 20th December 1957) on the adhesion of Japan as a full member.

NEA now groups all European Member countries of OECD and Australia, Canada, Japan and the United States. The Commission of the European Communities takes part in the work of the Agency.

The primary objectives of NEA are to promote co-operation between its Member governments on the safety and regulatory aspects of nuclear development, and on assessing the future role of nuclear energy as a contributor to economic progress.

This is achieved by:

- encouraging harmonization of governments' regulatory policies and practices in the nuclear field, with particular reference to the safety of nuclear installations, protection of man against ionizing radiation and preservation of the environment, radioactive waste management, and nuclear third party liability and insurance;

- keeping under review the technical and economic characteristics of nuclear power growth and of the nuclear fuel cycle, and assessing demand and supply for the different phases of the nuclear fuel cycle and the potential future contribution of nuclear power to overall energy demand;

- developing exchanges of scientific and technical information on nuclear energy, particularly through participation in common services;

- setting up international research and development programmes and undertakings jointly organised and operated by OECD countries.

In these and related tasks, NEA works in close collaboration with the International Atomic Energy Agency in Vienna, with which it has concluded a Co-operative Agreement, as well as with other international organisations in the nuclear field.
The NEA Committee on the Safety of Nuclear Installations (CSNI) is an international committee made up of scientists and engineers who have responsibilities for nuclear safety research and nuclear licensing. The Committee was set up in 1973 to develop and co-ordinate the Nuclear Energy Agency's work in nuclear safety matters, replacing the former Committee on Reactor Safety Technology (CREST) with its more limited scope.

The Committee's purpose is to foster international co-operation in nuclear safety amongst the OECD Member countries. This is done in a number of ways. Full use is made of the traditional methods of co-operation, such as information exchanges, establishment of working groups, and organisation of conferences. Some of these arrangements are of immediate benefit to Member Countries, for example by improving the data base available to national regulatory authorities and to the scientific community at large. Other questions may be taken up by the Committee itself with the aim of achieving an international consensus wherever possible. The traditional approach to co-operation is reinforced by the creating of co-operative (international) research projects, such as PISC and LOFT, and by a novel form of collaboration known as the international standard problem exercise, for testing the performance of computer codes, test methods, etc. used in safety assessments. These exercises are now being conducted in most sectors of the nuclear safety programme.

The greater part of the CSNI co-operative programme is concerned with safety technology for water reactors. The principal areas covered are operating experience and the human factor, reactor system response during abnormal transients, various aspects of primary circuit integrity, the phenomenology of radioactive releases in reactor accidents, containment performance, risk assessment, and severe accidents. The Committee also studies the safety of the fuel cycle, conducts periodic surveys of reactor safety research programmes and operates an international mechanism for exchanging reports on nuclear power plant incidents.

The Sub-Committee on Licensing, consisting of the CSNI Delegates who have responsibilities for the licensing of nuclear installations, examines a variety of nuclear regulatory problems and provides a forum for the review of regulatory questions, the aim being to develop consensus positions in specific areas.
# INDEX

<table>
<thead>
<tr>
<th>ACKNOWLEDGEMENTS</th>
<th>Pag.</th>
<th>V</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>ABSTRACT</th>
<th>&quot;</th>
<th>VII</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>LIST OF TABLES</th>
<th>&quot;</th>
<th>IX</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>LIST OF FIGURES IN THE TEXT</th>
<th>&quot;</th>
<th>XI</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>ABBREVIATIONS AND SYMBOLS</th>
<th>&quot;</th>
<th>XV</th>
</tr>
</thead>
</table>

## 1. INTRODUCTION

" 1

## 2. PIPER-ONE EXPERIMENT PO-SB-7

2.1 Outline of the Facility  " 5
2.2 Initial and boundary conditions  " 6
2.3 Main phenomena observed  " 7

## 3. OVERVIEW OF PARTICIPANTS MODELS

3.1 ABB (Sweden)  " 23
3.2 ANSALDO (Italy)  " 25
3.3 ENEL-CRTN (Italy)  " 25
3.4 JAERI (Japan)  " 26
3.5 VTT (Finland)  " 28

## 4. EVALUATION OF PARTICIPANTS PREDICTIONS

4.1 ABB (Sweden)  " 39
4.2 ANSALDO (Italy)  " 40
4.3 ENEL-CRTN (Italy)  " 41
4.4 JAERI (Japan)  " 41
4.5 VTT1 (Finland)  " 42
4.6 VTT2 (Finland)  " 42

## 5. OVERALL COMPARISON BETWEEN BLIND PREDICTIONS AND EXPERIMENTAL DATA

5.1 Sequence of events  " 43
5.2 Pressure  " 44
5.3 Fluid temperatures  " 45
5.4 Liquid levels  " 46
5.5 Fluid densities and qualities  " 48
5.6 Mass flowrates and pressure drops  " 48
5.7 Rod surface temperatures  " 49
5.8 Structures temperatures  " 51
5.9 Other quantities  " 51
5.10 Qualitative judgement concerning blind predictions  " 52
5.11 Information sent by participants after the final workshop

6. CONCLUSIONS

7. REFERENCES

APPENDIX A: FIGURES COMPARING THE ABB BLIND PREDICTION WITH SELECTED EXPERIMENTAL DATA

APPENDIX B: FIGURES COMPARING THE ANSALDO BLIND PREDICTION WITH SELECTED EXPERIMENTAL DATA

APPENDIX C: FIGURES COMPARING THE ENEL-CRTN BLIND PREDICTION WITH SELECTED EXPERIMENTAL DATA

APPENDIX D: FIGURES COMPARING THE JAERI BLIND PREDICTION WITH SELECTED EXPERIMENTAL DATA

APPENDIX E: FIGURES COMPARING THE VTT1 BLIND PREDICTION WITH SELECTED EXPERIMENTAL DATA

APPENDIX F: FIGURES COMPARING THE VTT2 BLIND PREDICTION WITH SELECTED EXPERIMENTAL DATA

APPENDIX G: COMPARISON PLOTTERS OF QUANTITIES CHARACTERIZED BY LARGE CALCULATED SPIKES

APPENDIX H: DETAILS ABOUT INFORMATION SENT BY PARTICIPANTS AFTER THE FINAL WORKSHOP

H.1 ABB
H.2 ANSALDO
H.3 ENEL
H.4 VTT
ACKNOWLEDGEMENTS

The following people are gratefully acknowledged for the collaboration given at different levels in the activity done at DCMN:

- Prof P. Vigni, Dr. G.M. Galassi for participating to activities that constituted the basis of the present work;
- Drs. P. Breghi, P. Di Marco, G. Frutuoso, L. Giannini, V. Lorefice and S. Pintore for performing code calculations, solving different computer related problems and evaluating experimental data;
- the technicians engaged in the experimental activities and in the editing and typing of the various documents.
ABSTRACT

The present report deals with the comparison of 6 blind predictions, submitted by 5 participants, and the experimental results measured during the test PO-SB-7 performed in PIPER-ONE facility. The PIPER-ONE apparatus is an experimental simulator of a General Electric BWR. The test PO-SB-7 simulates a SBLOCA originated by a break in one recirculation line of the reference BWR-6 plant, without intervention of high pressure ECCS. The overall activity constitutes the CSNI ISP-21.

The main parts of the report are:

a) outline of the test facility and of the PO-SB-7 experiment;
b) overview of input models used by participants;
c) evaluation of participant predictions on the basis of one-by-one comparison with selected experimental trends;
d) evaluation of present code capabilities and accuracy, on the basis of the overall comparison between measured data and participants double blind predictions.

Finally, a judgement is given in relation to the overall value of the activity.
LIST OF TABLES

Tab. 2.1 - Hardware configuration of the PIPER-ONE facility
Tab. 2.2 - Thermofluiddynamic initial conditions
Tab. 2.3 - Specified event time sequence
Tab. 2.4 - Significant events and phenomena measured during the test
Tab. 3.1 - Summary of ISP 21 participants
Tab. 3.2 - Summary of utilized code resources
Tab. 3.3 - Relevant information about the calculations
Tab. 5.1 - Measured and calculated sequence of events
Tab. 5.2 - Main phenomena occurring (or presumed to occur) during the experiment
Tab. 5.3 - Limitations and advantages of the experimental data base
Tab. 5.4 - Qualitative evaluation of blind calculations (period I)
Tab. 5.5 - Qualitative evaluation of blind calculations (period II)
Tab. 5.6 - Qualitative evaluation of blind calculations (period III)
Tab. 5.7 - Qualitative evaluation of code capabilities
LIST OF FIGURES IN THE TEXT

Fig. 2.1 - Sketch of the PIPER-ONE facility
Fig. 2.2 - Core and bypass power
Fig. 2.3 - LPCI and LPCS flowrates as a function of system pressure
Fig. 2.4 - Heat losses from the fuel box
Fig. 2.5 - Lower plenum pressure
Fig. 2.6 - Core mixture and collapsed level
Fig. 2.7 - Downcomer collapsed level
Fig. 2.8 - Rod surface temperature - level A
Fig. 2.9 - Rod surface temperature - level D
Fig. 2.10 - Rod surface temperature - level G
Fig. 2.11 - Break flowrate
Fig. 2.12 - Residual mass in the loop

Fig. 3.1 - PIPER-ONE nodalization set up at ABB for GOBLIN code
Fig. 3.2 - PIPER-ONE nodalization set up at ANSALDO for RELAP5/MOD2 code
Fig. 3.3 - PIPER-ONE nodalization set up at ENEL-CRTH for RELAP4/MOD6 code
Fig. 3.4 - PIPER-ONE nodalization set up at JAERI for THYDE code
Fig. 3.5 - PIPER-ONE nodalization set up at VTT for SMABRE code

Fig. 5.1 - ISP-21 comparison: pressure in lower plenum
Fig. 5.2 - ISP-21 comparison: pressure in steam dome
Fig. 5.3 - ISP-21 comparison: fluid temperature in lower plenum
Fig. 5.4 - ISP-21 comparison: fluid temperature at core inlet
Fig. 5.5 - ISP-21 comparison: fluid temperature in core region-level A
Fig. 5.6 - ISP-21 comparison: fluid temperature in core region-level C
Fig. 5.7 - ISP-21 comparison: fluid temperature in core region-level E
Fig. 5.8 - ISP-21 comparison: fluid temperature in core region level G
Fig. 5.9 - ISP-21 comparison: fluid temperature in guide tubes
Fig. 5.10 - ISP-21 comparison: fluid temperature in core bypass-center
Fig. 5.11 - ISP-21 comparison: fluid temperature in core bypass-bottom
Fig. 5.12 - ISP-21 comparison: fluid temperature in upper plenum
Fig. 5.13 - ISP-21 comparison: fluid temperature in steam separator
Fig. 5.14 - ISP-21 comparison: fluid temperature in steam separator annulus - bottom
Fig. 5.15 - ISP-21 comparison: fluid temperature in steam separator annulus - center
Fig. 5.16 - ISP-21 comparison: fluid temperature in steam dome-upper junction
Fig. 5.17 - ISP-21 comparison: fluid temperature in steam dome-middle junction
Fig. 5.18 - ISP-21 comparison: fluid temperature in downcomer
Fig. 5.19 - ISP-21 comparison: fluid temperature in lower downcomer - top
Fig. 5.20 - ISP-21 comparison: fluid temperature in jet pump
Fig. 5.21 - ISP-21 comparison: fluid temperature at jet pump bottom
Fig. 5.22 - ISP-21 comparison: fluid temperature in lower downcomer-bottom
Fig. 5.23 - ISP-21 comparison: collapsed level in downcomer
Fig. 5.24 - ISP-21 comparison: collapsed level in core
Fig. 5.25 - ISP-21 comparison: collapsed level in core bypass
Fig. 5.26 - ISP-21 comparison: collapsed level in steam dome-annular part
Fig. 5.27 - ISP-21 comparison: collapsed level in steam dome-middle junction
Fig. 5.28 - ISP-21 comparison: density in lower plenum
Fig. 5.29 - ISP-21 comparison: density in steam dome middle junction
Fig. 5.30 - ISP-21 comparison: mean quality at core inlet
Fig. 5.31 - ISP-21 comparison: mean quality at core outlet
Fig. 5.32 - ISP-21 comparison: mean quality at core bypass
Fig. 5.33 - ISP-21 comparison: mean quality at steam dome top
Fig. 5.34 - ISP-21 comparison: mean quality at break
Fig. 5.35 - ISP-21 comparison: differential pressure at core inlet
Fig. 5.36 - ISP-21 comparison: differential pressure at core outlet
Fig. 5.37 - ISP-21 comparison: differential pressure at bypass venturi nozzle
Fig. 5.38 - ISP-21 comparison: differential pressure in lower junction
Fig. 5.39 - ISP-21 comparison: mass flowrate at core inlet
Fig. 5.40 - ISP-21 comparison: mass flowrate at core outlet
Fig. 5.41 - ISP-21 comparison: mass flowrate in core bypass
Fig. 5.42 - ISP-21 comparison: mass flowrate at jet pump exit
Fig. 5.43 - ISP-21 comparison: mass flowrate at break
Fig. 5.44 - ISP-21 comparison: mass flowrate through ADS
Fig. 5.45 - ISP-21 comparison: mass flowrate through SRV
Fig. 5.46 - ISP-21 comparison: mass flowrate through MSIV
Fig. 5.47 - ISP-21 comparison: mass flowrate of LPCI system
Fig. 5.48 - ISP-21 comparison: mass flowrate of LPGS system
Fig. 5.49 - ISP-21 comparison: rod surface temperature - level A
Fig. 5.50 - ISP-21 comparison: rod surface temperature - level B
Fig. 5.51 - ISP-21 comparison: inner rod surface temperature level-C
Fig. 5.52 - ISP-21 comparison: inner rod surface temperature level-D
Fig. 5.53 - ISP-21 comparison: inner rod surface temperature level-E
Fig. 5.54 - ISP-21 comparison: inner rod surface temperature level-F
Fig. 5.55 - ISP-21 comparison: inner rod surface temperature level-G
Fig. 5.56 - ISP-21 comparison: outer rod surface temperature level-A
Fig. 5.57 - ISP-21 comparison: outer rod surface temperature level-D
Fig. 5.58 - ISP-21 comparison: outer rod surface temperature level-G
Fig. 5.59 - ISP-21 comparison: structure temperature in lower plenum
Fig. 5.60 - ISP-21 comparison: structure temperature in steam dome
Fig. 5.61 - ISP-21 comparison: structure temperature in bypass
Fig. 5.62 - ISP-21 comparison: structure temperature in fuel box level A
Fig. 5.63 - ISP-21 comparison: structure temperature in fuel box level C
Fig. 5.64 - ISP-21 comparison: structure temperature of UTP
Fig. 5.65 - ISP-21 comparison: fluid mass in the loop
Fig. 5.66 - ISP-21 comparison: fluid energy in the loop
Fig. 5.67 - ISP-21 comparison: overall heat exchange between fluid and structures
Fig. 5.68 - ISP-21 comparison: thermal power from the break
Fig. 5.69 - ISP-21 comparison: mixture level in the core.

N.B.: Further figures are reported in Appendixes A to F, comparing the results of each participant with selected experimental data and in Appendix G reporting some Figures with large spikes that are part of the group of Figures from 5.1 to 5.69. Finally, Figures are reported in Appendix H dealing with corrections of previously submitted data as suggested by participants (cases of ABB and ANSALDO) or with results of calculations performed following the release of experimental data.
<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABB</td>
<td>Asea Brown Boveri</td>
</tr>
<tr>
<td>ADS</td>
<td>Automatic Depressurization System</td>
</tr>
<tr>
<td>BAF</td>
<td>Bottom of Active Fuel</td>
</tr>
<tr>
<td>BD</td>
<td>Blow Down</td>
</tr>
<tr>
<td>BY</td>
<td>Core Bypass</td>
</tr>
<tr>
<td>BWR</td>
<td>Boiling Water Reactor</td>
</tr>
<tr>
<td>CCFL</td>
<td>Counter Current Flow Limiting</td>
</tr>
<tr>
<td>CPU</td>
<td>Central Process Unit</td>
</tr>
<tr>
<td>CRTN</td>
<td>Centro Ricerche Tecniche e Nucleari</td>
</tr>
<tr>
<td>CSNI</td>
<td>Committee on the Safety of Nuclear Installations</td>
</tr>
<tr>
<td>DC</td>
<td>Down Comer</td>
</tr>
<tr>
<td>DCMN</td>
<td>Dipartimento di Costruzioni Meccaniche e Nucleari</td>
</tr>
<tr>
<td>DNB</td>
<td>Departure from Nucleate Boiling</td>
</tr>
<tr>
<td>ECC</td>
<td>Emergency Core Cooling</td>
</tr>
<tr>
<td>ECCS</td>
<td>Emergency Core Cooling Systems</td>
</tr>
<tr>
<td>EDR</td>
<td>Experimental Data Report</td>
</tr>
<tr>
<td>ENEA</td>
<td>Comitato Nazionale per lo Sviluppo dell'Energia Nucleare e delle Energie Alternative</td>
</tr>
<tr>
<td>ENEL</td>
<td>Ente Nazionale Energia Elettrica</td>
</tr>
<tr>
<td>FW</td>
<td>Feed Water</td>
</tr>
<tr>
<td>GE</td>
<td>General Electric Co.</td>
</tr>
<tr>
<td>GT</td>
<td>Guide Tubes (Control Rod Drive Mechanisms zone)</td>
</tr>
<tr>
<td>HP</td>
<td>High Pressure</td>
</tr>
<tr>
<td>HPCI</td>
<td>High Pressure Coolant Injection</td>
</tr>
</tbody>
</table>
HPCS = High Pressure Core Spray
ISP = International Standard Problem
JAERI = Japan Atomic Energy Research Institute
JP = Jet Pump
LJ = Lower Junction
LOCA = Loss Of Coolant Accident
LP = Lower Plenum or Low Pressure
LPCI = Low Pressure Coolant Injection
LPCS = Low Pressure Core Spray
LPCSB = Low Pressure Core Spray in the Bypass region
LWR = Light Water Reactor
MSIV = Main Steam Isolation Valve
NC = Not Calculated
NO = Not Occurred
OECD = Organization for Economic Cooperation and Development
PC = Personal Computer
PCT = Peak Cladding Temperature
PO = PIPER-ONE
PWR = Pressurized Water Reactor
RCIC = Reactor Core Isolation Cooling
RPV = Reactor Pressure Vessel
SB = Small Break
SBLOCA = Small Break LOCA
SD = Steam Dome
SDIS = Steam Dome Injection System
SRV = Steam Relief Valve
SS = Steam Separator
TAF = Top of Active Fuel
UP = Upper Plenum
UPIS = Upper Plenum Injection System
UTP = Upper Tie Plate
VTT = Valtion Teknillinee Tutkimuskeskus (Technical Research Centre of Finland)

SYMBOLS

$A_{\text{max}} = \text{Maximum pipe area connected with RPV}$
1. INTRODUCTION

In the frame of the development and assessment of large system codes, the International Standard Problem series of CSNI constitutes a recognized, fundamental issue for the evaluation of actual code capabilities. The methodology pursued to achieve the above goal consists of analyzing the comparison between the experimental results related to reactor safety aspects with the results of code simulations.

Essentially, three classes of ISP are distinguished:

- open: the experimental data are available at the moment of setting up the nodalization;
- blind: the experimental data are available only after the submission of results by the participants, but some features of the involved facility can be known by the participants, owing to the availability of data from other tests already performed;
- double blind: no information is available to participants before the submission of results, in relation to the experiments performed on the involved facility.

The first class of ISP allows the execution of sensitivity analyses, which in principle could lead to a clear identification of code limits; unfortunately strong nodalization effects and uncertainties in measured conditions generally do not permit a direct achievement of this goal.

On the other hand, the third class of ISPs could lead to the actual evaluation of user-and-code capability in predicting a transient scenario. The limits of this kind of exercise can be identified in the incomplete knowledge of important facility features and in the larger possibility of
errors, both in submitting initial and boundary conditions by experimentalists and in setting up the code models by users.

In December 1985, the Italian "Comitato Nazionale per lo Sviluppo dell'Energia Nucleare e delle Energie Alternative" (ENEA) and the "Dipartimento di Costruzioni Meccaniche e Nucleari" (DCMN) of Pisa University offered the PIPER-ONE test PO-SB-7 as the basis for the double blind OECD-CSNI ISP-21/1. Specific objectives of the test were to ascertain the capabilities of the codes in describing a test performed in a geometrically simple apparatus:

- absence of complex by-pass flow paths;
- 1-D zones;
- absence, as far as possible, of items which are sources of uncertainties for codes analyses.

The PIPER-ONE facility simulates a GE/BWR-6 plant/2/; it is characterized by volume and height scaling ratios of 1/2200 and 1/1, respectively.

The available core rod electrical power (20% of the nominal value) is sufficient to simulate the nuclear heat decay. No recirculation loops are included in the facility, considering their low importance in a small break LOCA and the willingness to achieve the maximum simplicity of the loop operation.

The test simulates a SB-LOCA in a BWR-6 plant/3/, with the break located in the downcomer; ECCS interventions are provided during the test. The experiment is the counterpart of tests already carried out in ROSA-III and FIST, at JAERI/4/ and GE/5/ respectively.
During the first workshop, held in "Marina di Grosseto" (Italy) on September 22-23, 1986 /6/ the participants agreed on a list of 69 variables, to be compared with the experimental data.

As a basis for setting up the nodalization of the experimental apparatus, three reports were distributed to the participants; they include the PIPER-ONE facility description, the test specifications and the instrumentation related to ISP-21/7/,/8/,/9/.

The ISP-21 experiment was executed on March 25, 1988. After the necessary data qualification and consistency checks, experimental initial and boundary conditions were sent to the participants on July 1988/10/. The participant had about 4 months for performing the prediction calculation and the last date for sending of the calculated data tape to Pisa University was October 31, 1988.

During this time period no experimental data were released for the test PO-SB-7 and for any other experiment carried-out on the PIPER-ONE facility.

The results of 6 prediction calculations were submitted at the DCMN of Pisa University by 5 different organizations.

This report documents the comparisons between the participants computer code calculations and the experimental results of PIPER-ONE test PO-SB-7. The principal goal is to evaluate the code performance and to point out the discrepancies between experimental and calculated data, but it is beyond the scope to assess and to analyze the reasons for these disagreements.
2. **PIPER-ONE EXPERIMENT PO-SB-7**

Experiment PO-SB-7 was the first test carried out in the PIPER-ONE facility, located at the "Scalbretaio Laboratory" of Pisa University.

The facility was built in the frame of a cooperation agreement between ENEA and DCMN of Pisa University. In this section an outline is given of the PIPER-ONE facility and of the test measured initial and boundary conditions; more details can be found in refs. /9/, /10/, /11/.

2.1 **Outline of the facility**

The simplified sketch of the apparatus is shown in Fig. 2.1. PIPER-ONE consists essentially of a primary loop and of a series of circuits with different interfaces with the main one. The one-dimensionality, as well as the overall simplicity of the system, are evident and, as already stated, are the direct outcome of the basic purpose of the research /12/.

The major components of the system are: the lower plenum, the core, the core bypass, the upper plenum, the region of separators and dryers, the steam dome, the upper downcomer, the lower downcomer and the jet pump region; these reproduce the vessel of the real plant.

The volume scaling factor is about 1/2000, while the core cell geometry and the piezometric heads acting on the lower core support plate are the same in the model and in the prototype. The heights of the steam dome and of the lower plenum have not been fully preserved, because they do not affect the most important phenomena assumed to occur during SB-LOCAs and that constitute the object of the research (natural circulation).

Some features of the apparatus have to be emphasized:
- the external core bypass, to make easier the measurement of the mass
flowrate;
- the valve in the lower plenum, necessary to achieve the initial test conditions.

The hardware configuration for the test PO-SB-7 is given in Tab. 2.1.

2.2 Initial and boundary conditions

Before starting the transient, the loop system was brought to steady state conditions, sufficiently similar to the specified ones/13/. The most significant thermalhydraulic conditions, measured immediately before the test, are given in Table 2.2; in this table the values given to participants and the estimated error for each quantity are reported too.

The following quantities, assumed as boundary conditions, were supplied to ISP-21 participants:
- core and bypass power (Fig. 2.2);
- LPCI and LPCS flowrate as a function of pressure (Fig. 2.3);
- heat losses from the fuel box (Fig. 2.4);
- trip values for actuation of various systems (Tab. 2.3).

It should be noted that heat losses from structures were assumed to be compensated by proper actuation of the structure heating systems/13/; so, they were considered negligible.

The core power curve (Fig. 2.2), after the initial step increase, remained constant up to 50 s; then it was set to decrease continuously, achieving the nuclear power decay value at 142 s.

The steam line valve started to open at 10 s, closing at 55 s after the transient start. A leak was detected in the MSIV after closure; the
equivalent area was estimated to be $1.5 \times 10^{-6}$ m$^2$.

The relief valve (SRV) was set to limit the primary pressure to 7.5 MPa, closing when pressure decreased below 7.3 MPa; the delay in opening and closing the relief valve makes these set-points equivalent to 7.65 and 7.25 MPa, with instantaneous actuations of the valve.

The ADS valve was opened by the specified low downcomer level trip (with 120 s of delay); this caused a rapid depressurization of the primary circuit, with injection of low pressure ECCS at the specified pressure set-points.

2.3 Main phenomena observed

Significant variable trends measured during the test are given in Figs. 2.5 to 2.12; the sequence of main events, is reported in Tab. 2.4.

The test scenario is characterized by three phases (Fig. 2.5).

During the first phase, the system pressure remains nearly constant. When the downcomer water level reaches roughly Level 1 (Tab. 2.3), the MSIV closure causes the pressure to rise. The pressure increase is controlled by the opening of the SRV (at 80. s), which closes at 148. s; then the pressure drops slowly, due to the relatively low power input to the fluid and to the continuous leakage of steam.

The low fluid mass inventory in the PIPER-ONE core (Fig. 2.6) causes a dry-out occurring in the highest part of the core simulator (Figs. 2.8, 2.9 and 2.10).

After the specified 120. s time delay with respect to the achievement of the Li level set-point in the DC, the activation of the ADS initiates the second phase of the tests, with rapid system depressurization and
increased rate of coolant loss (Fig. 2.5).

Phase three begins with ECCS injections which refill the core. In this period, two facts have to be noted:

- the heat release from the structures brings to a small increase in the system pressure at around 400. s, which also affects the ECCS flowrates;
- the subcooled liquid coming into the core causes the surface rod temperatures to decrease below the fluid saturation temperature; the subsequent stagnant situation, allows a recovery of the rod temperature.

The total mass inventory, shortly after ECCS injection beginning, starts to recover.

In the first period, subcooled liquid outflows from the break (Fig. 2.11); after break uncovering, the break flow becomes a two-phase mixture of steam and liquid; at the end of the test subcooled liquid outcomes again from the break.

The DC level trend shows a relatively fast initial decrease; in particular, Level 1 is reached at 62. s; so, ADS starts at 182. s (Fig. 2.7). The system depressurization rate after ADS actuation is rather high; in this connection, it can be recalled that the ADS flowrate limiting orifice is larger than the properly scaled value, in order to compensate the heat release from the structures.

The ADS depressurization leads to flashing in the downcomer, lower plenum, core and bypass, and level swelling in the downcomer and in the core regions.

Actually, two subsequent level swell phenomena must be considered.

The former swell occurs soon after the ADS actuation and concerns the
nearly saturated liquid present in the core region. In this case the level rise causes the quench in all rod thermocouple positions with the exception of the highest ones. A new dryout situation occurs, following this first level swell, presumably as a consequence of flow stagnation in the core.

The latter swell occurs when the system pressure reaches the saturation value corresponding to the bulk temperature of the LP fluid. In this case the level rise is able to quench the core rods at all the locations.

The PCT is nearly equal to 660 K and occurs in the highest rod position.
- Break configuration:
  single ended, 2.6% Amax small break, located at the downcomer bottom
  active, starting 300 s before time 0. and up to ADS intervention time (to
  compensate heat losses)
- Structure heating system:
  not active
- Structure cooling system:
  operated
- Valves of the primary loop:
  not used
  operated
  active
- High pressure ECCS (HPCS):
  active (pressure set point: 2.0 MPa)
- ADS:
  active (pressure set point: 1.6 MPa)
- Low pressure ECCS-LPCS:
- Low pressure ECCS-LPCI:

Table 2.1 - Hardware Configuration of the PIPER-ONE facility.
<table>
<thead>
<tr>
<th>NUMBER</th>
<th>QUANTITY</th>
<th>UNIT</th>
<th>SPECIFIED VALUES</th>
<th>VALUES GIVEN TO ISP21 PARTICIPANTS</th>
<th>BEST ESTIMATE VALUES</th>
<th>ERROR BAND</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Steam Dome pressure</td>
<td>(MPa)</td>
<td>7.23</td>
<td>7.05</td>
<td>7.05</td>
<td>±0.05</td>
</tr>
<tr>
<td>2</td>
<td>Fluid temperature subcooling in Lower Plenum</td>
<td>(K)</td>
<td>10.0</td>
<td>60.0</td>
<td>60.0</td>
<td>±5.0</td>
</tr>
<tr>
<td>3</td>
<td>Fluid temperature subcooling in Core</td>
<td>(K)</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>±5.0</td>
</tr>
<tr>
<td>4</td>
<td>Fluid temperature subcooling in Core Bypass</td>
<td>(K)</td>
<td>0.0</td>
<td>25.0</td>
<td>25.0</td>
<td>±5.0</td>
</tr>
<tr>
<td>4a</td>
<td>Fluid temperature subcooling in Core Bypass horizontal part</td>
<td>(K)</td>
<td>-</td>
<td>-</td>
<td>75.0</td>
<td>±5.0</td>
</tr>
<tr>
<td>4b</td>
<td>Fluid temperature subcooling in Guide Tubes</td>
<td>(K)</td>
<td>10.0</td>
<td>100.0</td>
<td>75.0</td>
<td>±5.0</td>
</tr>
<tr>
<td>5</td>
<td>Fluid temperature superheating in Upper Plenum</td>
<td>(K)</td>
<td>0.0</td>
<td>0.0</td>
<td>5.0</td>
<td>±5.0</td>
</tr>
<tr>
<td>6</td>
<td>Fluid temperature subcooling in Steam Dome</td>
<td>(K)</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>±2.0</td>
</tr>
<tr>
<td>6a</td>
<td>Fluid temperature subcooling in SS Annulus</td>
<td>(K)</td>
<td>-</td>
<td>-</td>
<td>10.0</td>
<td>±2.0</td>
</tr>
<tr>
<td>7</td>
<td>Fluid temperature subcooling in Upper Downcomer</td>
<td>(K)</td>
<td>1.0</td>
<td>1.0</td>
<td>0.0</td>
<td>±2.0</td>
</tr>
<tr>
<td>8</td>
<td>Fluid temperature subcooling in Lower Downcomer</td>
<td>(K)</td>
<td>10.0</td>
<td>10.0</td>
<td>10.0</td>
<td>±5.0</td>
</tr>
<tr>
<td>9</td>
<td>Fluid temperature subcooling in Jet Pump</td>
<td>(K)</td>
<td>10.0</td>
<td>10.0</td>
<td>10.0</td>
<td>±5.0</td>
</tr>
<tr>
<td>9a</td>
<td>Fluid temperature subcooling in horizontal part of Lower Plenum</td>
<td>(K)</td>
<td>-</td>
<td>50.0</td>
<td>50.0</td>
<td>±5.0</td>
</tr>
<tr>
<td>10</td>
<td>Collapsed liquid level in Downcomer (+)</td>
<td>(m)</td>
<td>10.5</td>
<td>9.5</td>
<td>9.2</td>
<td>±0.1</td>
</tr>
<tr>
<td>11</td>
<td>Collapsed liquid level in Core region (*)</td>
<td>(m)</td>
<td>5.38</td>
<td>4.3</td>
<td>4.3</td>
<td>±0.3</td>
</tr>
<tr>
<td>12</td>
<td>Collapsed liquid level in BY region (**)</td>
<td>(m)</td>
<td>5.1</td>
<td>4.05</td>
<td>3.95</td>
<td>±0.1</td>
</tr>
<tr>
<td>13</td>
<td>Collapsed liquid level in SS annulus</td>
<td>(m)</td>
<td>0.0</td>
<td>0.6</td>
<td>1.0</td>
<td>±0.1</td>
</tr>
<tr>
<td>14</td>
<td>Steam quality above liquid levels</td>
<td>(-)</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Total fluid mass in the loop</td>
<td>(Kg)</td>
<td>78.0</td>
<td>78.0</td>
<td>80.0</td>
<td>±2.0</td>
</tr>
</tbody>
</table>

Table 2.2 - Thermo-fluidodynamic initial conditions.

(+): From the bottom of the Lower Downcomer (elevation = - 1.545 m from BAF).
(*) : From the bottom of the Lower Plenum (elevation = - 2.672 m from BAF).
(**): From the bottom of Guide Tubes (elevation =- 2.42 m from BAF).
(*) : Estimate taking into account fluid temperature distribution along the zone length.
(**): The fluid in the Core region is subcooled at the bottom (-5K) and superheated at the top (+5K).
(**): The fluid in the Upper Plenum is slightly superheated.
<table>
<thead>
<tr>
<th>Event/Quantity</th>
<th>Unit</th>
<th>Measured Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Break Occurrence</td>
<td>s</td>
<td>9.</td>
</tr>
<tr>
<td>Closure of MSIV</td>
<td>s</td>
<td>55.</td>
</tr>
<tr>
<td>Intervention of ADS</td>
<td>s</td>
<td>182.</td>
</tr>
<tr>
<td>Intervention of LPCS</td>
<td>s</td>
<td>263.</td>
</tr>
<tr>
<td>Intervention of LPCI</td>
<td>s</td>
<td>295.</td>
</tr>
<tr>
<td>Time interval between events 3 and 5</td>
<td>s</td>
<td>113.</td>
</tr>
<tr>
<td>Time of DNB occurrence at level G in the fuel rods</td>
<td>s</td>
<td>117.</td>
</tr>
<tr>
<td>Time of DNB occurrence at level D in the fuel rods</td>
<td>s</td>
<td>200.</td>
</tr>
<tr>
<td>Time of DNB occurrence at level A in the fuel rods</td>
<td>s</td>
<td>-</td>
</tr>
<tr>
<td>Residual mass in the loop at the time when event 8 occurs</td>
<td>Kg</td>
<td>43.9</td>
</tr>
<tr>
<td>Time of rewet at level D in the fuel rods (surface temperature roughly equals the fluid temperature)</td>
<td>s</td>
<td>215.</td>
</tr>
<tr>
<td>Time interval between events 8 and 11</td>
<td>s</td>
<td>15.</td>
</tr>
<tr>
<td>Residual mass in the loop at the time when event 5 occurs</td>
<td>Kg</td>
<td>36.</td>
</tr>
<tr>
<td>Average void fraction in the core region when event 8 occurs</td>
<td></td>
<td>0.85</td>
</tr>
<tr>
<td>Time of end of experiment</td>
<td>s</td>
<td>500.</td>
</tr>
<tr>
<td>Residual mass in the loop at the time when event 15 occurs</td>
<td>Kg</td>
<td>116.7</td>
</tr>
</tbody>
</table>

Table 2.3 - Specified event time sequence.
<table>
<thead>
<tr>
<th>NUMBER</th>
<th>EVENT</th>
<th>SPECIFIED VALUE</th>
<th>ACTUAL VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Transient beginning</td>
<td>0.</td>
<td>0.</td>
</tr>
<tr>
<td>1</td>
<td>Opening of the valve in LJ</td>
<td>(1) 0.</td>
<td>0.4</td>
</tr>
<tr>
<td>2</td>
<td>Power trip in core and core bypass regions</td>
<td>(2) 0.5</td>
<td>1.0</td>
</tr>
<tr>
<td>3</td>
<td>Break opening</td>
<td>(3) 5.</td>
<td>9.</td>
</tr>
<tr>
<td>4</td>
<td>Opening of MSIV</td>
<td>(4) 5.</td>
<td>10.</td>
</tr>
<tr>
<td>5</td>
<td>Power decay begins</td>
<td>(5) 50.</td>
<td>50.</td>
</tr>
<tr>
<td>6</td>
<td>Closure of MSIV</td>
<td>(6) 55.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(collapsed level in DC)</td>
<td>(6.82 m)</td>
<td>(6.15 m)</td>
</tr>
<tr>
<td>7</td>
<td>Opening of SRV</td>
<td>(6) 80.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(pressure in LP)</td>
<td>(7.5 MPa)</td>
<td>(7.65 MPa)</td>
</tr>
<tr>
<td>8</td>
<td>Closure of SRV</td>
<td>(6) 148.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(pressure in LP)</td>
<td>(7.3 MPa)</td>
<td>(7.25 MPa)</td>
</tr>
<tr>
<td>9</td>
<td>Bundle dry-out begins</td>
<td>(7) 117.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(L1 collapsed level in DC)</td>
<td>(6.82 m)</td>
<td>(5.6 m)</td>
</tr>
<tr>
<td>10</td>
<td>Intervention of ADS</td>
<td>(7) 182.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(L1 collapsed level in DC)</td>
<td>(8) 200.</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Lower plenum flashing</td>
<td>(8) 215.</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>PCT occurs (at level G)</td>
<td>(9) 230.</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Bundle rewet completed</td>
<td>(10) 263.</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Actuation of LPCSB</td>
<td>(8) 263.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(pressure in LP)</td>
<td>(1.6 MPa)</td>
<td>(2.1 MPa)</td>
</tr>
<tr>
<td>15</td>
<td>Actuation of LPCS</td>
<td>(8) 263.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(pressure in LP)</td>
<td>(1.97 MPa)</td>
<td>(2.1 MPa)</td>
</tr>
<tr>
<td>16</td>
<td>Actuation of LPCI</td>
<td>(9) 295.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(pressure in LP)</td>
<td>(1.6 MPa)</td>
<td>(1.6 MPa)</td>
</tr>
<tr>
<td>17</td>
<td>Bundle refill completed</td>
<td>(10) 335.</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>Test end</td>
<td>(10) 500.</td>
<td></td>
</tr>
</tbody>
</table>

Table 2.4 - Significant events and phenomena measured during the test.

1. 0.1 second after the valve opening, the flowrate is limited by the nozzle in the connection between Lower Plenum and Jet Pump.
2. The electrical powers supplied to the bundle and to core bypass heating system follow the trends given in Fig. 2.2.
3. 0.1 second after this signal the flowrate is limited by the orifice.
4. The flowrate reaches 0.11 Kg/s in 1. s.
5. Closure time is 1. s.
6. Consider 0.1 s as opening and closure time.
7. The ADS is actuated with 120. s of delay after achieving the specified L1 level.
8. The flowrate is given in Fig. 2.3 as function of LP pressure.
9. The flowrate is given in Fig. 2.3 as function of LP pressure.
10. The mixture level is above the top of active fuel and the steam dome pressure is less than 1. MPa.
Fig. 2.1 - Sketch of the PIPER-ONE facility.
Fig. 2.2 - Core and bypass power.
Fig. 2.3 a - LPCI flowrate as a function of system pressure.

Fig. 2.3 b - LPCS flowrate as a function of system pressure.
<table>
<thead>
<tr>
<th>TIME PERIOD</th>
<th>FB1(*) (KW)</th>
<th>FB2(*) (KW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BEFORE ADS ACTUATION</td>
<td>10.8</td>
<td>0.2</td>
</tr>
<tr>
<td>AFTER ADS ACTUATION</td>
<td>2.2</td>
<td>1.5</td>
</tr>
</tbody>
</table>

(*) With reference to the above sketch.

Fig. 2.4 - Heat losses from the fuel box.
Fig. 2.5 - Lower plenum pressure.

Fig. 2.6 - Core mixture and collapsed level.
Fig. 2.7 - Downcomer collapsed level.

Fig. 2.8 - Rod surface temperature - level A.
Fig. 2.9 - Rod surface temperature - level D.

Fig. 2.10 - Rod surface temperature - level G.
Fig. 2.11 - Break flowrate.

Fig. 2.12 - Residual mass in the loop.
3. OVERVIEW OF PARTICIPANTS MODELS

Input models (nodalizations) and computer resources utilized by the participants to the ISP-21 are outlined in this section.

A total of 6 submittals, qualified as blind calculations, using 5 different codes, were sent to the DCMN. The participating organizations and the codes used are presented in Table 3.1 (refs./14/ to /19/). Details of the used codes can be found in refs. /20/ to /24/. The Table 3.1 also contains the directory descriptor which is used in the plots to identify a particular participant or prediction.

In Tables 3.2 and 3.3 the summaries of utilized code and computer resources are reported.

It should be noted that the 5 participants used different codes, with a very different detail in the consideration of geometric features of the PIPER-ONE facility (e.g., the number of nodes ranges between 6 and 83). The different code capabilities in modelling the various phenomena (e.g. level tracking) should be considered in this connection.

Even the physical time calculated by the various participant is very different ranging between 370. and 1000. seconds (the length of the experiment is 500. s).

3.1 ABB (Sweden)

The nodalization used by the ABB is shown in Fig. 3.1. Essentially, 83 nodes were used to describe the facility and 1377 mesh points to simulate the conduction heat transfer phenomena /20/.

The GOBLIN code performs the detailed thermal-hydraulic calculation
for the entire reactor following a postulated loss-of-coolant accident.

The reactor or other system under study is divided into a number of principal volumes which are further divided into any number of subvolumes. The subvolumes are the computational cells of the hydraulic model. All types of BWRs can be analyzed with the code.

Four main sections of the code can be defined:

1 - The hydraulic model which performs the solution of the basic mass, energy and momentum balances together with the equation of state for each sub-volume. This model includes empirical correlations for the calculation of pressure drops, critical flow rate, steam-water separator efficiency and steam dryer efficiency. A drift flux correlation is used to calculate the flow rates of steam and water which can predict accurately counter-current flow limiting (CCFL) phenomena.

2 - The system models. This section of the code contains models of the various safety systems that are activated after a LOCA such as core spray and coolant injection systems and the automatic depressurization system (ADS). A model for the level measurement system is included. Main steam flow and feedwater flow are modelled as time-dependent sinks and sources.

3 - The fuel thermal model calculates the heat transferred from the fuel rods to the coolant. This model includes the solution of the heat conduction equation for the fuel rods, and calculation of the appropriate heat transfer coefficients at the fuel cladding outside surface.
4 - The pressure vessel and internals thermal model calculates the heat transferred from the pressure vessel and the internals to the coolant. The model includes the solution of the heat conduction equation for the components and calculation of the appropriate heat transfer coefficients.

3.2 ANSALDO (Italy)

A very detailed documentation was submitted by ANSALDO/15/ in relation to the pre-test prediction. RELAP5/MOD2 cycle 36.02/21/ code was used; the related nodalization is shown in Fig. 3.2. The numbers of nodes and of structures mesh points hold 62 and 405, respectively. Among the user choices, the simulation of the separator of the PIPER-ONE facility by a single volume and the multipliers selected for the junctions where critical flow is expected (Break, ADS, SRV), can be mentioned. In particular, the subcooled discharge coefficient was set equal to 0.91 in the cases of Break, ADS and SRV, while the two-phase coefficient was set equal to 0.83 in the case of the Break and equal to 0.85 in the cases of ADS and SRV.

Besides the Venturi nozzles installed in the facility were simulated by means of localized loss coefficients defined on the basis of the information given to the participants.

3.3 ENEL-CRTN (Italy)

The ENEL calculation was performed by the standard RELAP4/Mod6 code, running on IBM 3090 Computer/16/.

A relatively limited number of nodes (19) and structures mesh-points are used to simulate the PIPER-ONE facility (see nodalization in Fig. 3.3).

Among the significant user options necessary for setting up the
calculation by RELAP4/MOD6 code\cite{22}, the following can be mentioned:

- critical flow is evaluated by Moody and Henry-Fauske correlations respectively for saturated and subcooled conditions;

- the Wallis flooding correlation is used in the junctions near the LPCS injection point;

- the GE critical heat flux correlation was used to foresee dry-out situations of the rods.

3.4 JAERI (Japan)

Even in this case, a very comprehensive documentation of the calculation was submitted to DCMN/17/.

The THYDE-B1/MOD2 code\cite{23}, specifically developed for BWR SBLOCA analyses, was used for ISP-21.

The coolant behaviour in the code is simulated by a volume-and-junction method, based on the assumptions of thermal equilibrium and homogeneous conditions for two-phase flow. A characteristic feature of this code is a three-region representation of the state of the coolant in a control volume; the three regions consist of subcooled liquid, saturated mixture and saturated steam regions, starting from the volume bottom. The regions are separated by two horizontal moving boundaries, which are tracked by mass and energy balances for each region. With this three-region node model, the BWR pressure vessel can be represented by only two volumes: one for the volume inside the shroud and the other for outside, while other portions of the system are treated with the homogeneous node model. This method, although it seems to be very simple, has been verified to be
adequate for cases of BWR SBLOCAs, in which the thermal-hydraulic behaviour is relatively slow and gravity controlled.

The code has been improved and modified from the previous version (THYDE-Bi/MOD1), especially in the phase separation model, which is used in the mixture level calculation in the three-region mode model. Then, a good predictability of the code has been indicated through the comparison of calculated results with various SBLOCA test data, including ROSA-III of JAERI and FIST of the General Electric Co.

The very low number of control nodes (6), utilized for the nodalization of the PIPER-ONE facility, results from the sketch in Fig. 3.4. This is possible considering the capabilities of the level tracking model in the code.

The PIPER-ONE facility was represented by 3 heterogeneous ("three-region-node") volumes and 3 homogeneous volumes, 16 junctions and 44 heat slabs, as shown in Fig. 3.4. As said above, for a standard THYDE-Bi calculation of a BWR LOCA, only two heterogeneous volumes are used to represent the in-shroud region and the downcomer. For the present calculation, however, a third heterogeneous volume (volume 4) was added to represent the mixture level behaviour in the core-bypass region.

The three homogeneous volumes were also used to model the lower piping which had different initial subcoolings from one volume to another.

The liquid which existed in the annular part of the steam separator at the test initiation cannot be modelled by this coarse nodalization. Therefore, the volume corresponding to the liquid was moved from the steam dome to the downcomer bottom below the break nozzle.
The valve connecting the jet pump (JP) to the lower plenum (LP) in the horizontal pipe was represented by the form loss at the corresponding junction.

The LPCI flowrate was injected into the guide tube (GT) to avoid the strong pressure oscillation originated by the steam condensation in this region when the ECC water came from the core-bypass after the initiation of flashing in the GT. Direct LPCI injection into the GT, coupled with the assumption of large inertia in the junction between the GT and the core-bypass bottom, caused no flashing in the GT.

The break flow was calculated by two models; Bernoulli model when the quality was less than 0.02 and Moody model when the quality was greater than 0.02 including the single phase steam. (In the THYDE-B1 code steam is assumed always saturated). These models were also used to calculate the steam flow rate of the steamline before MSIV closure and steam leakage through the MSIV and ADS.

3.5 VTT (Finland)

Two predictions were submitted at DCMN/18\(^{18}\),/19/ based on calculations performed by SMABRE code/24/, developed in the Technical Research Centre of Finland (VTT) for the analysis of small breaks in pressurized water reactors. Presently, the code is used for boiling water reactors, too, especially in simulator applications.

The code solves in the nodes the conservation equations for the vapour mass and liquid mass. In junctions, the momentum equation is solved for the mixture and the drift flux model is used for the phase separation.
The drift flux model is used for the phase separation in vertical junctions as well as in horizontal junctions.

The heat transfer package includes a description for convection, nucleate boiling, critical heat flux, transition boiling, film boiling and convection into steam. No radiation between structure walls is described and neither absorption into the mixture. The deficiencies may have effects on results at high temperatures.

The PIPER-ONE facility was described using 36 volumes, 37 junctions and 52 heat slabs (Fig. 3.5). Water levels were calculated in the upper part of the downcomer, in the core bypass and in upper part of the separator.

The leaks from the system, break and flows through valves, were calculated using the Moody model. The break contraction coefficient for the saturated flow was 0.45 and for the subcooled flow 0.9. For valves leaking pure steam, the contraction coefficient 0.9 was used.

In the calculation no separate subchannels were used for the core due to a poor understanding of interchannel mixing. The corner rods were described with different heat slabs, however. Heat losses from the core to the surroundings were described using the time dependent heat slabs and the negative power input.

The first calculation is labelled by VTT1 and the second one is labelled by VTT2.

The VTT2 calculation differs from the VTT1 one, due to the choice of a new film boiling correlation suitable for small diameter geometry.
<table>
<thead>
<tr>
<th>ORGANIZATION</th>
<th>PARTICIPANT</th>
<th>CODE</th>
<th>_DESCRIPTOR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asea Brown Boveri</td>
<td>H. Wijkstrom</td>
<td>GOBLIN</td>
<td>ABBS</td>
</tr>
<tr>
<td>(Sweden)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ANSALDO (Italy)</td>
<td>R. Dones</td>
<td>RELAP5/Mod.2</td>
<td>ANSA</td>
</tr>
<tr>
<td></td>
<td>D. Gallori</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>G. Proto</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ENEL-CRTN (Italy)</td>
<td>F. Donatini</td>
<td>RELAP4/Mod.6</td>
<td>ENEL</td>
</tr>
<tr>
<td></td>
<td>R. Lanza</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Japan Atomic Energy</td>
<td>H. Nakamura</td>
<td>THYDE-B1/Mod.2</td>
<td>JAER</td>
</tr>
<tr>
<td>Research Institute</td>
<td>Y. Kukita</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Japan)</td>
<td>K. Tasaka</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Technical Research</td>
<td>A. Hamalainen</td>
<td>SMABRE</td>
<td>VTT1, VTT2</td>
</tr>
<tr>
<td>Centre of Finland</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Finland)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 3.1 - Summary of ISP-21 participants.
<table>
<thead>
<tr>
<th>QUANTITY</th>
<th>ABBS</th>
<th>ANSA</th>
<th>ENEL</th>
<th>JAER</th>
<th>VTT1</th>
<th>VTT2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of control nodes (volumes)</td>
<td>83</td>
<td>62</td>
<td>19</td>
<td>6</td>
<td>36</td>
<td>36</td>
</tr>
<tr>
<td>Number of junctions</td>
<td>85</td>
<td>64</td>
<td>28</td>
<td>16</td>
<td>37</td>
<td>37</td>
</tr>
<tr>
<td>Number of thermal structures</td>
<td>83</td>
<td>65</td>
<td>30</td>
<td>44</td>
<td>52</td>
<td>52</td>
</tr>
<tr>
<td>Overall number of mesh points</td>
<td>903+474</td>
<td>405</td>
<td>21</td>
<td>66</td>
<td>125</td>
<td>125</td>
</tr>
<tr>
<td>Number of time dependent volumes</td>
<td>-</td>
<td>9</td>
<td>0</td>
<td>0</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Number of time dependent junctions (f1l1s)</td>
<td>2</td>
<td>4</td>
<td>3</td>
<td>0</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Number of valves</td>
<td>1</td>
<td>6</td>
<td>6</td>
<td>3</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Number of core slabs</td>
<td>-</td>
<td>7</td>
<td>7</td>
<td>7</td>
<td>21</td>
<td>21</td>
</tr>
<tr>
<td>Number of trips</td>
<td>1</td>
<td>19</td>
<td>9</td>
<td>14</td>
<td>29</td>
<td>29</td>
</tr>
</tbody>
</table>

Table 3.2 - Summary of utilized code resources.
<table>
<thead>
<tr>
<th>QUANTITY</th>
<th>ABBS</th>
<th>ORGANIZATION</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>GOBLIN-EM</td>
<td>RELAP5 Mod.2</td>
</tr>
<tr>
<td>Code utilized</td>
<td></td>
<td>CY 36/02</td>
</tr>
<tr>
<td>Computer utilized</td>
<td>NORD-570</td>
<td>CDC 180/8627 (°)</td>
</tr>
<tr>
<td>Memory requested (Mbyte)</td>
<td>2.7</td>
<td>3.7</td>
</tr>
<tr>
<td>Steady state &quot;physical&quot; time (s)</td>
<td></td>
<td>100</td>
</tr>
<tr>
<td>CPU time consumed during steady state (s)</td>
<td></td>
<td>918</td>
</tr>
<tr>
<td>CPU time consumed during steady state/ unit physical time/number of nodes</td>
<td></td>
<td>280</td>
</tr>
<tr>
<td>Transient &quot;physical&quot; time (s)</td>
<td>395.6</td>
<td>0.403</td>
</tr>
<tr>
<td>CPU time consumed during the transient (s)</td>
<td>15107</td>
<td>45834</td>
</tr>
<tr>
<td>CPU time consumed during transient time/unit physical time/number of nodes</td>
<td>0.46</td>
<td>4.020</td>
</tr>
</tbody>
</table>

(°) The computer has 9 MIPS; 1 s CPU is roughly equivalent to 7-11 s in a VAX 780.

Table 3.3 - Relevant informations about the calculations.
Fig. 3.1 - PIPER-ONE nodalization set up at ABB for GOBLIN code.
Fig. 3.2 - PIPER-ONE nodalization set up at ANSALDO for RELAP5/MOD2 code.
Fig. 3.3 - PIPER-ONE nodalization set up at ENEL-CRTN for RELAP5/MOD6 code.
Fig. 3.4 - PIPER-ONE nodalization set up at JAERI for THYDE code.
Fig. 3.5 - PIPER-ONE nodalization set up at VTT for SMABRE code.
4. **EVALUATION OF PARTICIPANTS PREDICTIONS**

In this section the results of each participant are compared with the available experimental variable trends, in the attempt to identify the capabilities and limitations of the submitted prediction. Twenty-six significant variables have been identified for this aim, considering the availability of both experimental data and participant predictions.

The Appendixes A to G contain all the comparison plots from ABB, ANSALDO, ENEL-CRTN, JAERI, VTT1 and VTT2, respectively.

It should be noted that two predictions are reported in Appendix C related to ENEL-CRTN contribution. The prediction labelled by ENEL1 was submitted before the ISP 21 dead line/16/; the prediction ENEL2/25/ differs from the ENEL1 one only for the values assumed by the LPCS and LPCI flowrates, having discovered a mistake in the ENEL input deck. The ENEL2 results are labeled ENEL in sect.5, where they are compared with the others.

4.1 **ABB (Sweden)**

A good understanding of the involved physical phenomena appears from the results prediction was submitted by ABB, as can be seen from Figs. A.1 to A.26 in App. A. Almost all important phenomena measured during the test have been simulated by this calculation.

The major discrepancy between calculation and experimental data regards the break flowrate trend (Fig. A.16): the predicted value is roughly 1/2 of the experimental one during the subcooled blowdown period. Nevertheless this appears not to affect substantially the overall transient
evolution.

Discrepancies also appear in the calculation of DC level (Fig. A.11) and in the pressure drop between lower plenum and jet pump; however these last ones seem to be due to differences in the definition of the variables with respect to the position of the experimental pressure taps.

Minor discrepancies can be found in the evaluation of DC level and of LPCI/CS flowrates.

This last ones are essentially due to an incorrect specification of these quantity by the experimentalists (see ref./3/).

On the other hand, the very close agreement between measured and calculated rod surface temperature trends should be noted, as well as the good qualitative prediction of the level rise in the annular part of the steam done.

4.2 ANSALDO (Italy)

Even in the case of Ansaldo the involved physical phenomena have been well predicted, as results from Figs. B.1 to B.26 in App. B.

The comparison between measured and calculated trends shows discrepancies on fluid temperatures. These are due to the fact that only liquid temperatures were submitted by this participant, while the measured superheated conditions can be observed only in the comparison with steam temperatures (see App. H2).

Minor discrepancies outcome also from the observation of surface rod temperatures (Figs. B.23 and B.24): in particular, predicted PCT is lower than the measured value.

Finally, the very close agreement between measured and calculated
pressure trends can be noted.

4.3 ENEL-CRTN (Italy)

Two ENEL calculations have been reported, as already mentioned.

The three periods of the experiment (that is high pressure before ADS actuation, ADS caused depressurization and refill/reflood) are predicted by ENEL, as seen in Figs. C.1 to C.26 in App. C. Not all the main phenomena occurred in the experiment are provided in the calculation; in particular, extended dryouts occur too early in the upper part of the core and are not quenched by the flashings consequent to the ADS actuation; this demonstrates the conservatism of the RELAP4/MOD6 heat transfer correlations. Still the break flowrate is strongly underpredicted (Fig. C.16).

The discrepancy in the ENEL case related to residual mass (Fig. C.25) derives from the wrong values assumed for LPCI/CS flowrates; as a consequence, in this calculation no core quench is predicted.

4.4 JAERI (Japan)

The same consideration done for the ABB and ANSALDO calculations hold in the case of JAERI: all the main phenomena are predicted reasonably well by THYDE code (App. D, Figs. D.1 to D.26). It has to be noted that only 35 variables were submitted for the comparison with the experimental data, due to the lumped parameter characteristic of the code.

Only liquid temperatures were supplied; so, also in this case, discrepancies occur in the comparison with the PIPER-ONE thermocouples that give indication of superheated steam.
The major discrepancy between the calculation result and the experimental data appears to be the too early core dryout, that however is quenched by the ADS caused flashing.

Finally a very good prediction of ADS actuation time and then of the DC level can be emphasized.

4.5 VTT1 (Finland)

In the VTT1 case (App. E, Figs. E.1 to E.26), the main phenomena are only qualitatively predicted; core dryout occurs too early in the calculation and it is not quenched neither by the ADS caused flashing, neither by the intervention of LPCI/CS (Figs. E.22 to E.24).

Still, the break flowrate is largely underpredicted, leading to a delayed actuation of ADS and of LPCI/CS.

A further remark concerns the fact that DC level does not recover after LPCI and LPCS injections.

The very high value of PCT should be observed in this calculation.

4.6 VTT2 (Finland)

The VTT2 calculation (App. F, Figs. F.1 to F.26) is similar to the VTT1 one. In particular the same value is provided for the rod surface PCT.

The effect of the new post-CHF heat transfer correlation appears to be negligible.
5. OVERALL COMPARISON BETWEEN BLIND PREDICTION AND EXPERIMENTAL DATA

In this section, the results submitted by the participants are compared among each other and with the experimental data. The sequence of the events is discussed firstly; then, the graphical results are presented for all the 69 variables requested to the participants\(^9\). Not all these variables were submitted by participants; in the same way six experimental quantities are not available. Nevertheless, 69 plotters (Figs. 5.1 to 5.69) are presented and discussed hereafter.

Considering that each participant calculation is discussed separately in the previous section, the aim of the present section is to evaluate, on an overall basis, the predictive capabilities of the utilized computer codes, considering the phenomenology of the transient and the double blind nature of the calculations.

Finally, it should be mentioned that:

- the quantitative accuracy of the various predictions is evaluated in a proper document\(^{26}\);
- more insights into the phenomena and in the comparison between code calculations and experimental data can be found in the EDR/\(^3\) and in the post test analysis carried out at DCMN/\(^27\).

5.1 Sequence of events

The measured and calculated sequences of events for test PO-SB-7 are summarized in Table 5.1. The data reported in this table were required by DCMN together with the tape containing the blind predictions.

The closure of MSIV is slightly delayed in the various calculations as
well as the time of actuation of ADS.

The depressurization time (period between ADS and LPCI actuation (item 6 in Tab. 5.1) is well predicted by the all participants with the exception of VTT.

The time of occurrence of dryout at the various levels is generally underestimated by the various participants, showing a degree of conservativism in the used models. The same limitation appears for the rewet phenomenon that is delayed in the various calculation with respect to the experimental evidence; in some case no rewet is predicted (e.g. VTT1).

The residual mass reported in the last row of Table 5.1 is really not comparable in the various cases, owing to the different timing when it is evaluated (row 15).

5.2 Pressure

In Figs. 5.1 and 5.2 the experimental pressure trends in the lower plenum and in the steam dome are compared with the blind predictions.

The qualitative accuracy of the various predictions is reasonably good, in the sense that the time of ADS opening and the subsequent depressurization rate are well calculated by the various participants.

Quantitative discrepancies are mainly due to erroneous evaluations of:

- the DC level behaviour that affects the time of ADS opening;
- the early dryout occurrence that reduces the thermal power exchanged between core rods and the fluid.

Minor discrepancies in the high pressure period depend upon erroneous
evaluation of the MSIV and SRV opening and closure times; the discrepancies in the evaluation of break flowrates also have a relatively small effect on the system pressure.

Finally two other aspects can be mentioned:

a) the two measured pressure trends in the lower plenum and in the steam dome are slightly different, mainly after 350 seconds, emphasizing the order of magnitude of the experimental uncertainty in this part of the transient;

b) the small repressurization occurring in the final part of the transient is due to the thermal exchange between hot structures and the ECC liquid: the phenomenon is not predicted by the calculations.

5.3 Fluid temperatures

Fluid temperatures in the loop are compared in Figs. 5.3 to 5.22.

Thermal stratification occurred during the steady state part of the PO-SB-7 test in different zones of the facility. This explains the reason for large temperature variations soon after the test beginning. Besides, superheated steam conditions are measured in the uppermost zones of the facility during the ADS depressurization period; in some cases the thermocouple responses are affected by the conduction and radiation heat transfer from the walls (see also ref./26/). In connection with this item, it should be precised that all the participants submitted only one fluid temperature (the liquid one); so, the superheated steam does not appear in the calculations, even in the case of codes based on non equilibrium models.
Experimental data are lacking in Figures 5.4, 5.9 and 5.13, related to core inlet, guide tube and steam separator zones, respectively.

The following main observations outcome from the analysis of the figures 5.3 to 5.22:
- the ENEL calculation foresees early saturation conditions in the lower plenum (Fig. 5.3) and in guide tubes (Fig. 5.9): this appears to be due to the basically homogeneous model adopted in RELAP4/MOD6 code;
- strong superheating is calculated in various parts of the loop by VTT (calculations VTT1 and VTT2); it is worthwhile noting that the superheating is in very good agreement with experimental data in the upper part of the facility (Figs. 5.16 and 5.17);
- apart from the above two exceptions, the spread in the calculations of fluid temperatures in the loop is closely linked to the spread of pressure trends.

5.4 Liquid levels

Liquid levels are reported in Figs. 5.23 to 5.27.

Two experimental curves are reported for the DC collapsed levels (Fig. 5.23); the first one (CL23) is related to the liquid level measured through the JP; the second one (CL70) is related to the annular part of the DC and constitutes the actual variable requested to the participants.

The level decrease in the initial part of the test is the result of the flowrates through the break, toward LP and coming from SD. The level increase after 350 seconds is due to ECC water, that refill DC through the JP.
Almost all the participants predict well the trend of CL70 experimental quantity. The initial overestimate of the assigned steady state data resulting from the ABB calculation is due to the particular way of handling steady state by the code/20/ and has been corrected in App. H1. The discrepancy calculated by ENEL appears to depend upon the fact that the level calculated by RELAP4/MOD6 code, is the mixture level and not the required collapsed one.

The core collapsed level (Fig. 5.24), after the initial increase due to water coming from the DC, continuously decreases up to the intervention of ECC. Only ANSALDO and JAERI predict reasonably well this quantity.

The same scenario occurs for the bypass level (Fig. 5.25); in this case ENEL and VTT are far from the experimental data.

The SD annular part level is shown in Fig. 5.26. The experimental trend presents two fast increases just at the test beginning and after 60 seconds, in correspondence with the system pressure increase. These increases appear to be due to liquid deentrainment in SD and steam condensation on the SD walls. These phenomena appear qualitatively well predicted by ABB, ANSALDO and VTT.

Finally, the level in the horizontal pipe of SD is shown in Fig. 5.27. The experimental trend exhibits a strong increase due to liquid formation in this pipe in the period between 70 and 150 seconds, following the pressurization of the loop.

No code was able to predict this phenomenon, presumably due to the liquid deentrainment and condensation in the upper part of the facility.
5.5 Fluid densities and qualities

Densities and mixture qualities are reported in Figs. 5.28 to 5.34. Only one experimental signal is available, that is the density in the lower horizontal pipe (Fig. 5.28).

Voiding of this zone occurs in the experiment, roughly at 200. seconds into the transient.

The trend is qualitatively well predicted by all participants; discrepancies occur in the prediction of absolute density value in the period comprised between the (partial) voiding and the refill.

The comparisons among code calculations for the other variables show that:

- almost all calculations foresee the bypass filling with liquid soon after ECCS intervention, apart from VTT1 and VTT2 (Fig. 5.32);

- there is the experimental evidence that the quality at the break becomes near equal to 1. at around 150. s; almost all calculations predict a delayed occurrence of this event (Fig. 5.34).

5.6 Mass flowrates and pressure drops

Mass flowrates and pressure drops are compared in Figures 5.35 through 5.48. In a limited number of cases, the experimental signals are not available (Figs. 5.36, 5.37, 5.39 and 5.40). In order to make more meaningful the figures, the ordinate scales were reduced in some cases; in this way, some predicted peaks have been cut. In these cases the complete Figures are reported in App. G.

The experimental signals demonstrate that there is a relatively large
natural circulation between the DC and the core (Fig. 5.42) while the flowrate between core and bypass (Fig. 5.41) is lower, at least up to the intervention of ECCS: almost all codes predict reasonably well the above phenomenology.

With reference to the remaining variables, the following remarks can be done:

- almost all codes strongly underpredicted the break flowrates in the subcooled or nearly saturated period (Fig. 5.43) (factor ranging between 2., for ABB, and 1.3 for ANSALDO);

- the ADS flowrate is well predicted by the participants, with the exceptions of ENEL and VTT, that noticeably overestimate the experimental values; still ABB initial flowrate is not equal to zero;

- the flowrates across SRV (apart from ABB, Fig. 5.45), MSIV (Fig. 5.46) and LPCI/CS (Fig. 5.47 and 5.48) are reasonably well predicted by all codes, even considering that the best estimate values of the last two variables are slightly different from the values communicated to the participants (see the EDR/3/).

5.7 Rod surface temperatures

Rod surface temperatures are reported in Figs. 5.49 to 5.58. In particular, the Figs. 5.49 to 5.55 are related to the seven axial levels of the rods placed inside the bundle, while Figs. 5.56 to 5.58 are related to three axial levels of a peripheral rod.

The description of the dryout occurrences has already been given in sect. 2.3.

The following considerations can be added hereafter in relation to the
experimental scenario:

- the dryout before the time of actuation of ADS did not occur in the experiments performed in FIST and ROSA-III (counterpart of test PO-SB-7)/28/: this is due to the higher power supplied to PIPER-ONE rods (in order to compensate the heat losses through the fuel box) and to the amount of coolant stored into the annular part of the SD, that is not available for cooling the core;

- differences between internal rods and peripheral rods can be clearly seen looking at Figs. 5.55 and 5.58, related to the upper-most level; the dryout occurring in the inner rod is more pronounced than that occurring in the peripheral rod;

- at the end of the transient, after 350. seconds, the rod temperatures at the various levels reach a value very similar to the saturation temperature (comparison of experimental trends in Figs. 5.5. to 5.8 with the corresponding ones in Figs. 5.49 to 5.58), notwithstanding the very subcooled liquid (ambient temperature) injected by LPCI/CS; this is a consequence of stratification phenomenon occurring in the vessel with very cold liquid at the bottom of LP (Fig. 5.3) and nearly saturated liquid at core inlet.

Finally, it should be recalled that thermocouples are embedded between two sheaths/7/ and so they do not measure exactly the surface temperature. During the high power period the difference between surface temperature and thermocouple response has been estimated in the range of 10. K/27/. After about 100. seconds and during dryout, this difference reduces to less than 5. K
The comparison between experimental and calculated trends shows that all participants predict the occurrence of dryout before the ADS actuation, at least in the uppermost elevation of the rods. Still in all cases, the rods are quenched at the end of the transient, after the ECCS injection. ABB, ANSALDO and JAERI predict the quench occurrence due to flashing of core and LP liquid, following the ADS actuation.

No participant calculates the different behaviour of central and peripheral rods (Figs. 5.55 and 5.58).

5.8 Structure temperatures

Structure temperatures are represented in Figs. 5.59 to 5.64.

The measured transient scenario is consistent with fluid temperature trends.

Almost all codes predict reasonably well this transient. An exception is represented by JAERI calculation, where the fuel box temperature remains constant (Figs. 5.62 and 5.63).

5.9 Other quantities

The variables reported in Figs. 5.65 to 5.69 are included in this group. The experimental trend is not available in the case of the overall heat exchange between fluid and structures (Fig. 5.67); moreover, it should be mentioned that relatively large uncertainties are associated with the experimental evaluations of fluid energy in the loop (Fig. 5.66) owing to the assumptions needed in the algorithm developed to obtain this quantity/3/.

The overall heat exchange between fluid and structures (Fig. 5.67)
calculated by 4 participants, with the exception of ABB, also includes the heat transfer in the core region and so the related values are always greater than zero.

5.10 Qualitative judgement concerning blind prediction

In order to achieve an objective (as far as possible) qualitative judgement of the various code predictions, the ISP-21 transient has been subdivided into four periods (phenomenological windows) including the steady state one. The three remaining phenomenological windows are the high pressure period, the depressurization and the refill-reflood phases.

The main physical phenomena occurring in each period are outlined in Tab. 5.2; in particular, 2 significant phenomena have been identified for the steady state period, while 7 phenomena have been identified in periods I and III and 8 phenomena in period II.

The main limitations and advantages of the available data base are summarized in Tab. 5.3. This allows a better understanding of the meaning of the discrepancies between measured and calculated trends.

The capability to predict each phenomenon by the blind participants is evaluated in Tabs. 5.4 to 5.6, distinguishing the three aforementioned periods into the experiment. Four levels of judgement are considered:

- occurring/predicted;
- partially occurring/predicted;
- there is some evidence;
- not occurring or not clear.

Finally, Tab. 5.7 contains the main positive and negative aspects of
the various calculations.

5.11 Information sent by participants after the final workshop

Various participants sent additional data concerning their calculation, as a consequence of the discussion had during the final workshop.

These data are reported in App. H. In particular:

- App. H1 contains corrected trends of the blind ABB prediction related to collapsed levels in the downcomer, core and bypass and to LPCS flow rate. These are simply corrections of Figs. 5.23, 5.24, 5.25 and 5.48 of the main test;

- App. H2 contains additional data from the ANSALDO blind calculation related to some steam temperatures that better compare (with respect to liquid) with the measured trends;

- App. H3 contains the comparison between measured trends and results of the post-test analysis carried out at ENEL by RELAP4/MOD6 code utilizing the MOD5 heat transfer package (the pre-test calculation was carried out by MOD6 heat transfer package). The post-test compares much better with experimental data;

- App. H4 contains the comparison between measured and calculated trends of rod surface temperature (level P) and lower plenum pressure obtained in a post test calculations performed at VTT by SMABRE code. An error was discovered in the pre-test calculation concerning the thermal conductivity of the fuel rod simulators. The correction of this error strongly improves the predictions as can be seen in Figs. H4.1 and H4.2.
<table>
<thead>
<tr>
<th>N. EVENT OR QUANTITY</th>
<th>MEASURED VALUE</th>
<th>ABBS</th>
<th>ANSA</th>
<th>CALCULATED VALUE</th>
<th>VTT1</th>
<th>VTT2</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Break Occurrence</td>
<td>(s) 9.</td>
<td>9.</td>
<td>9.</td>
<td>9.</td>
<td>9.</td>
<td>9.</td>
</tr>
<tr>
<td>2 Closure of MSIV</td>
<td>(s) 55.</td>
<td>61.5</td>
<td>64.</td>
<td>74.8</td>
<td>70.</td>
<td>79.</td>
</tr>
<tr>
<td>3 Intervention of ADS</td>
<td>(s) 182.</td>
<td>186.</td>
<td>186.</td>
<td>198.5</td>
<td>192.</td>
<td>208.</td>
</tr>
<tr>
<td>4 Intervention of LPCS</td>
<td>(s) 263.</td>
<td>272.5</td>
<td>258.</td>
<td>273.88</td>
<td>300.</td>
<td>345.</td>
</tr>
<tr>
<td>5 Intervention of LPC</td>
<td>(s) 295.</td>
<td>295.</td>
<td>278.</td>
<td>291.9</td>
<td>325.</td>
<td>370.</td>
</tr>
<tr>
<td>6 Time interval between events 3 and 5</td>
<td>(s) 113.</td>
<td>109.</td>
<td>92.</td>
<td>93.4</td>
<td>132.</td>
<td>162.</td>
</tr>
<tr>
<td>7 Time of DNB occurrence at level G in the fuel rods</td>
<td>(s) 117.</td>
<td>130.</td>
<td>158-209</td>
<td>29.7</td>
<td>76,207,295</td>
<td>60.</td>
</tr>
<tr>
<td>8 Time of DNB occurrence at level D in the fuel rods</td>
<td>(s) 200.</td>
<td>-</td>
<td>N.O.</td>
<td>221.9</td>
<td>211.</td>
<td>85.</td>
</tr>
<tr>
<td>9 Time of DNB occurrence at level A in the fuel rods</td>
<td>(s) -</td>
<td>-</td>
<td>N.O.</td>
<td>239.3</td>
<td>N.O.</td>
<td>-</td>
</tr>
<tr>
<td>10 Residual mass in the loop at the time when event 8 occurs</td>
<td>(Kg) 43.9</td>
<td>-</td>
<td>N.C.</td>
<td>45.9</td>
<td>43.7</td>
<td>64.43</td>
</tr>
<tr>
<td>11 Time of rewet at level D in the fuel rods (surface temperature roughly equals the fluid temperature)</td>
<td>(s) 215.</td>
<td>-</td>
<td>N.O.</td>
<td>590.1</td>
<td>226.</td>
<td>-</td>
</tr>
<tr>
<td>12 Time interval between events 8 and 11</td>
<td>(s) 15.</td>
<td>-</td>
<td>N.C.</td>
<td>377.2</td>
<td>24.</td>
<td>-</td>
</tr>
<tr>
<td>13 Residual mass in the loop at the time when event 5 occurs</td>
<td>(Kg) 36.</td>
<td>34.5</td>
<td>31.5</td>
<td>26.13</td>
<td>31.6</td>
<td>17.25</td>
</tr>
<tr>
<td>14 Average void fraction in the core region when event 8 occurs</td>
<td>0.85</td>
<td>-</td>
<td>N.C.</td>
<td>0.137224</td>
<td>0.75</td>
<td>0.74</td>
</tr>
<tr>
<td>15 Time of end of calculation</td>
<td>(s) 500.</td>
<td>395.6</td>
<td>417.</td>
<td>609.</td>
<td>369.</td>
<td>1000.</td>
</tr>
<tr>
<td>16 Residual mass in the loop at the time when event 15 occurs</td>
<td>(Kg) 116.7</td>
<td>82.5</td>
<td>100.9</td>
<td>10.47</td>
<td>47.6</td>
<td>117.6</td>
</tr>
</tbody>
</table>

Table 5.1 - Measured and calculated sequence of events.
O STEADY STATE

- LIQUID STRATIFICATION
- PRESENCE OF SUPERHEATED STEAM
  (ESTIMATED ENERGY CONTRIBUTION = 0.5 - 0.8 MJ;
  INITIAL FLUID ENERGY ~ 90. MJ)

O PERIOD I (HIGH PRESSURE)

- CORE AND CORE BYPASS LEVEL RISE / DC EMPTYING
- NATURAL CIRCULATION BETWEEN CORE AND BYPASS
- PRESSURIZATION FOLLOWING MSIV CLOSURE
- CONDENSATION (AND DEENTRAINMENT) IN SD; FILLING
  OF SD HORIZONTAL PIPE
- BREAK UNCOVERY
- DRYOUT OCCURRENCE
- NET LIQUID FLOW FROM CORE TO DC

O PERIOD II (ADS DEPRESSURIZATION)

- DEPRESSURIZATION RATE
- FLASHING OF CORE LIQUID
- EARLY REWET
- NEW CHF CONDITION
- FLASHING OF LP LIQUID
- DEFINITIVE REWET
- NATURAL CIRCULATION BETWEEN CORE AND BYPASS
- VOIDING OF LP HORIZONTAL PIPE

O PERIOD III (LPCI / CS ACTUATION - REFILL / REFLOOD)

- OVERFILLING OF BYPASS
- LEVEL FORMATION ABOVE UTP
- LEVEL RISE IN THE CORE
- LEVEL RISE IN DC
- SUBCOOLED LIQUID FROM THE BREAK
- THERMAL STRATIFICATION IN LP AND BYPASS
- SLIGHT REPRESSURIZATION (DUE TO HEAT
  TRANSFER FROM STRUCTURES)

Table 5.2 - Main phenomena occurring (or presumed to occur)
            during the experiment
MAIN LIMITATION OF THE EXPERIMENTAL DATA BASE

1. INSTRUMENTATION NOT SUITABLE (OR NOT EFFECTIVE) TO MEASURE DIRECTLY
   - BYPASS FLOWRATE
   - LEVEL FORMATION ON UTP
   - FLOWRATE FROM CORE REGION TO DC REGION
   - LIQUID DEENTRAINMENT (AND CARRYOVER)

MAIN ADVANTAGE OF THE EXP. DATA BASE

1. SMALL VALUE OF UNCERTAINTY IN HEAT LOSSES (LESS THAN 5. KW)
2. EVALUATION OF ALL FLOWRATES INTEGRALS FROM AND TOWARD THE LOOP
3. ABSENCE OF 3D EFFECTS

Table 5.3 - Limitations and advantages of the experimental data base
<table>
<thead>
<tr>
<th>CORE AND BYPASS LEVEL RISE / DC EMPTYING</th>
<th>ABBS</th>
<th>ANSA</th>
<th>ENEL</th>
<th>JAERI</th>
<th>VTT1</th>
<th>VTT2</th>
<th>EXP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>NATURAL CIRCULATION BETWEEN CORE AND BYPASS</th>
<th>ABBS</th>
<th>ANSA</th>
<th>ENEL</th>
<th>JAERI</th>
<th>VTT1</th>
<th>VTT2</th>
<th>EXP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material</td>
<td>X</td>
<td>O</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>PRESSURIZATION FOLLOWING MSIV CLOSURE</th>
<th>ABBS</th>
<th>ANSA</th>
<th>ENEL</th>
<th>JAERI</th>
<th>VTT1</th>
<th>VTT2</th>
<th>EXP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material</td>
<td>X</td>
<td>X</td>
<td>*</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CONDENSATION (AND DEENTRAINMENT) IN SD</th>
<th>ABBS</th>
<th>ANSA</th>
<th>ENEL</th>
<th>JAERI</th>
<th>VTT1</th>
<th>VTT2</th>
<th>EXP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material</td>
<td>X</td>
<td>O</td>
<td>-</td>
<td>-</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>BREAK UNCOVERY</th>
<th>ABBS</th>
<th>ANSA</th>
<th>ENEL</th>
<th>JAERI</th>
<th>VTT1</th>
<th>VTT2</th>
<th>EXP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material</td>
<td>-</td>
<td>X</td>
<td>-</td>
<td>-</td>
<td>*</td>
<td>*</td>
<td>X</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>DRYOUT OCCURRENCE</th>
<th>ABBS</th>
<th>ANSA</th>
<th>ENEL</th>
<th>JAERI</th>
<th>VTT1</th>
<th>VTT2</th>
<th>EXP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material</td>
<td>X</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>X</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>NET LIQUID FLOW FROM CORE TO DC</th>
<th>ABBS</th>
<th>ANSA</th>
<th>ENEL</th>
<th>JAERI</th>
<th>VTT1</th>
<th>VTT2</th>
<th>EXP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material</td>
<td>-</td>
<td>O</td>
<td>*</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0</td>
</tr>
</tbody>
</table>

X = OCCURRING / PREDICTED

* = OCCURRING / PARTIALLY PREDICTED

O = THERE IS SOME EVIDENCE

- = NOT OCCURRING OR NOT CLEAR

Table 5.4 - Qualitative evaluation of blind calculations (period I)
<table>
<thead>
<tr>
<th></th>
<th>ABBS</th>
<th>ANSA</th>
<th>ENEL</th>
<th>JAERI</th>
<th>VTT1</th>
<th>VTT2</th>
<th>EXP</th>
</tr>
</thead>
<tbody>
<tr>
<td>DEPRESSURIZATION RATE</td>
<td>X</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>X</td>
</tr>
<tr>
<td>FLASHING OF CORE LIQUID</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>X</td>
</tr>
<tr>
<td>EARLY REWET</td>
<td>X</td>
<td>*</td>
<td>-</td>
<td>*</td>
<td>-</td>
<td>-</td>
<td>X</td>
</tr>
<tr>
<td>NEW CHF CONDITION</td>
<td>X</td>
<td>X</td>
<td>-</td>
<td>*</td>
<td>-</td>
<td>-</td>
<td>X</td>
</tr>
<tr>
<td>FLASHING OF LP LIQUID</td>
<td>O</td>
<td>O</td>
<td>-</td>
<td>O</td>
<td>-</td>
<td>-</td>
<td>X</td>
</tr>
<tr>
<td>DEFINITIVE REWET</td>
<td>X</td>
<td>X</td>
<td>-</td>
<td>X</td>
<td>-</td>
<td>-</td>
<td>X</td>
</tr>
<tr>
<td>NATURAL CIRCULATION</td>
<td>O</td>
<td>*</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>BETWEEN CORE AND</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BYPASS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VOIDING OF LP HORIZONTAL PIPE</td>
<td>X</td>
<td>X</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>X</td>
</tr>
</tbody>
</table>

X = OCCURRING / PREDICTED  
* = OCCURRING / PARTIALLY PREDICTED  
O = THERE IS SOME EVIDENCE  
- = NOT OCCURRING OR NOT CLEAR

Table 5.5 - Qualitative evaluation of blind calculations (period II)
<table>
<thead>
<tr>
<th></th>
<th>ABB</th>
<th>ANSA</th>
<th>ENEL</th>
<th>JAERI</th>
<th>VTT1</th>
<th>VTT2</th>
<th>EXP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overfilling of bypass</td>
<td>*</td>
<td>X</td>
<td>*</td>
<td>X</td>
<td>-</td>
<td>-</td>
<td>X</td>
</tr>
<tr>
<td>Level formation above UTP</td>
<td>X</td>
<td>X</td>
<td>*</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>O</td>
</tr>
<tr>
<td>Level rise in the core</td>
<td>-</td>
<td>X</td>
<td>-</td>
<td>O</td>
<td>-</td>
<td>-</td>
<td>X</td>
</tr>
<tr>
<td>Level rise in DC</td>
<td>X</td>
<td>*</td>
<td>O</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>X</td>
</tr>
<tr>
<td>Subcooled liquid from the break</td>
<td>-</td>
<td>-</td>
<td>*</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>X</td>
</tr>
<tr>
<td>Thermal stratification in LP and bypass</td>
<td>-</td>
<td>*</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>X</td>
</tr>
<tr>
<td>Slight repressurization</td>
<td>-</td>
<td>-</td>
<td>*</td>
<td>-</td>
<td>0</td>
<td>0</td>
<td>X</td>
</tr>
</tbody>
</table>

X = occurring / predicted

* = partially predicted

O = there is some evidence

- = not occurring or not clear

Table 5.6 - Qualitative evaluation of blind calculations (period III)
<table>
<thead>
<tr>
<th>PARTICIPANT</th>
<th>MAJOR DISCREPANCIES</th>
<th>MINOR DISCREPANCIES</th>
<th>NOTICEABLE RESULT</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABB</td>
<td>-CORE LEVEL;</td>
<td>-DC LEVEL;</td>
<td>-CONDENSATION IN SD</td>
</tr>
<tr>
<td></td>
<td>-DP ACROSS JP AND LP;</td>
<td>-LPCI / CS FLOWRATES</td>
<td>-DRYOUT ANNUlus;</td>
</tr>
<tr>
<td></td>
<td>-BREAK FLOW-RATE</td>
<td></td>
<td>-PREDICTION AND REWET;</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>-DEPRESSURIZATION RATE</td>
</tr>
<tr>
<td>ANSALDO</td>
<td>-DELAYED DNB OCCURRENCE</td>
<td>-BREAK FLOWRATE, MAINLY FOLLOWING DC REFILL</td>
<td>-GOOD OVERALL COMPARISON</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>-THERMAL STRATIFICATION</td>
</tr>
<tr>
<td>ENEL</td>
<td>-PRESSURE INCREASE AT TEST BEGINNING; -BREAK FLOWRATE; -ROD TEMPERATURE TRENDS; -RESIDUAL MASS IN THE LOOP</td>
<td>-LEVELS IN VARIOUS ZONES</td>
<td>-LIQUID OCCURRENCE IN THE SD TOP</td>
</tr>
<tr>
<td>JAERI</td>
<td>-REDUCED TIME LENGTH OF THE CALCULATION</td>
<td></td>
<td>-REWET TIME AND PHENOMENOLOGY</td>
</tr>
<tr>
<td></td>
<td>-DELAYED BREAK UNCOVERY</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>-PCT AT UPPERMOST LEVELS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>VTT1 &amp; VTT2</td>
<td>-EARLY DNB; -NO REWET DURING DEPRESSURIZATION</td>
<td>-COLLAPSED LEVEL FOLLOWING REFILL</td>
<td>-FLUID TEMP. DISTRIBUTION</td>
</tr>
<tr>
<td></td>
<td>-BREAK FLOWRATE</td>
<td></td>
<td>-CONDENSATION IN SD</td>
</tr>
</tbody>
</table>

Table 5.7 - Qualitative evaluation of code capabilities
FIG. 5.1 ISP-21 COMPARISON: PRESSURE IN LOWER PLENUM

FIG. 5.2 ISP-21 COMPARISON: PRESSURE IN STEAM DOME
FIG. 5.3 ISP-21 COMPARISON: FLUID TEMPERATURE IN LOWER PLENUM

FIG. 5.4 ISP-21 COMPARISON: FLUID TEMPERATURE AT CORE INLET
**FIG. 5.5** ISP-21 COMPARISON: FLUID TEMPERATURE IN CORE REGION LEVEL A

**FIG. 5.6** ISP-21 COMPARISON: FLUID TEMPERATURE IN CORE REGION LEVEL C
**Fig. 5.7 ISP-21 Comparison: Fluid Temperature in Core Region Level E**

**Fig. 5.8 ISP-21 Comparison: Fluid Temperature in Core Region Level G**
FIG. 5.9 ISP-21 COMPARISON: FLUID TEMPERATURE IN GUIDE TUBES

FIG. 5.10 ISP-21 COMPARISON: FLUID TEMPERATURE IN CORE BYPASS CENTER
FIG. 5.11 ISP-21 COMPARISON: FLUID TEMPERATURE IN CORE BYPASS, BOTTOM

FIG. 5.12 ISP-21 COMPARISON: FLUID TEMPERATURE IN UPPER PLENUM
FIG. 5.13 ISP-21 COMPARISON: FLUID TEMPERATURE IN STEAM SEPARATOR

FIG. 5.14 ISP-21 COMPARISON: FLUID TEMPERATURE IN STEAM SEPARATOR ANNULUS - BOTTOM
FIG. 5.15 ISP-21 COMPARISON: FLUID TEMPERATURE IN STEAM SEPARATOR ANNUlus - CENTER

FIG. 5.16 ISP-21 COMPARISON: FLUID TEMPERATURE IN STEAM DOME UPPER JUNCTION
FIG. 5.17 ISP-21 COMPARISON: FLUID TEMPERATURE IN STEAM DOME MIDDLE JUNCTION

FIG. 5.18 ISP-21 COMPARISON: FLUID TEMPERATURE IN UPPER DOWNCOMER
Fig. 5.19 ISP-21 Comparison: Fluid Temperature in Lower Downcomer Top

Fig. 5.20 ISP-21 Comparison: Fluid Temperature in Jet Pump
Fig. 5.21 ISP-21 Comparison: Fluid Temperature at Jet Pump Bottom

Fig. 5.22 ISP-21 Comparison: Fluid Temperature in Lower Downcomer Bottom
FIG. 5.23 ISP-21 COMPARISON: COLLAPSED LEVEL IN DOWNCOMER

FIG. 5.24 ISP-21 COMPARISON: COLLAPSED LEVEL IN CORE
FIG. 5.25 ISP-21 COMPARISON: COLLAPSED LEVEL IN CORE BYPASS

FIG. 5.26 ISP-21 COMPARISON: COLLAPSED LEVEL IN STEAM DOME ANNULAR PART
Fig. 5.27 ISP-21 Comparison: Collapsed Level in Steam Dome Middle Junction

Fig. 5.28 ISP-21 Comparison: Density in Lower Junction
\textbf{FIG. 5.29 ISP-21 COMPARISON: DENSITY IN STEAM DOME MIDDLE JUNCTION}

\textbf{FIG. 5.30 ISP-21 COMPARISON: MEAN QUALITY AT CORE INLET}
FIG. 5.31 ISP-21 COMPARISON: MEAN QUALITY AT CORE OUTLET

FIG. 5.32 ISP-21 COMPARISON: MEAN QUALITY AT CORE BYPASS TOP
FIG. 5.33 ISP-21 COMPARISON: MEAN QUALITY AT STEAM DOME TOP

FIG. 5.34 ISP-21 COMPARISON: MEAN QUALITY AT BREAK
FIG. 5.37 ISP-21 COMPARISON: DIFFERENTIAL PRESSURE AT BYPASS VENTURI NOZZLE

FIG. 5.38 ISP-21 COMPARISON: DIFFERENTIAL PRESSURE IN LOWER JUNCTION
FIG. 5.39 ISP-21 COMPARISON: MASS FLOWRATE AT CORE INLET

FIG. 5.40 ISP-21 COMPARISON: MASS FLOWRATE AT CORE OUTLET
FIG. 5.41 ISP-21 COMPARISON: MASS FLOWRATE AT CORE BYPASS BOTTOM

FIG. 5.42 ISP-21 COMPARISON: MASS FLOWRATE AT JET PUMP EXIT
FIG. 5.43 ISP-21 COMPARISON: MASS FLOWRATE AT BREAK

FIG. 5.44 ISP-21 COMPARISON: MASS FLOWRATE THROUGH ADS
Fig. 5.45 ISP-21 Comparison: Mass Flowrate Through SRV

Fig. 5.46 ISP-21 Comparison: Mass Flowrate Through MSIV
FIG. 5.47 ISP-21 COMPARISON: MASS FLOWRATE OF LPC1 SYSTEM

FIG. 5.48 ISP-21 COMPARISON: MASS FLOWRATE OF LPCS SYSTEM
FIG. 5.49 ISP-21 COMPARISON: ROD SURFACE TEMPERATURE - LEVEL A

FIG. 5.50 ISP-21 COMPARISON: ROD SURFACE TEMPERATURE - LEVEL B
FIG. 5.51 ISP-21 COMPARISON: INNER ROD SURFACE TEMPERATURE LEVEL C

FIG. 5.52 ISP-21 COMPARISON: INNER ROD SURFACE TEMPERATURE LEVEL D
FIG. 5.53 ISP-21 COMPARISON: INNER ROD SURFACE TEMPERATURE LEVEL E

FIG. 5.54 ISP-21 COMPARISON: INNER ROD SURFACE TEMPERATURE LEVEL F
FIG. 5.55 ISP-21 COMPARISON: INNER ROD SURFACE TEMPERATURE LEVEL C

FIG. 5.56 ISP-21 COMPARISON: OUTER ROD SURFACE TEMPERATURE LEVEL A
**FIG. 5.57 ISP-21 COMPARISON: OUTER ROD SURFACE TEMPERATURE LEVEL D**

**FIG. 5.58 ISP-21 COMPARISON: OUTER ROD SURFACE TEMPERATURE LEVEL G**
FIG. 5.59 ISP-21 COMPARISON: STRUCTURE TEMPERATURE IN LOWER PLENUM

FIG. 5.60 ISP-21 COMPARISON: STRUCTURE TEMPERATURE IN STEAM DOME
FIG. 5.61 ISP-21 COMPARISON: STRUCTURE TEMPERATURE IN BYPASS

FIG. 5.62 ISP-21 COMPARISON: STRUCTURE TEMPERATURE OF FUEL BOX LEVEL A
FIG. 5.63 ISP-21 COMPARISON: STRUCTURE TEMPERATURE OF FUEL BOX LEVEL C

FIG. 5.64 ISP-21 COMPARISON: STRUCTURE TEMPERATURE OF UTP
FIG. 5.65 ISP-21 COMPARISON: FLUID MASS IN THE LOOP

FIG. 5.66 ISP-21 COMPARISON: FLUID ENERGY IN THE LOOP
Fig. 5.67 ISP-21 Comparison: Overall Heat Exchange Between Fluid and Structures

Fig. 5.68 ISP-21 Comparison: Thermal Power from the Break
FIG. 5.69 ISP-21 COMPARISON: MIXTURE LEVEL IN THE CORE
6. CONCLUSIONS

The experimental trends, measured during the test PO-SB-7, performed in the PIPER-ONE facility, have been compared with six blind predictions performed by 5 different organizations using five different codes; the overall activity constitutes the OECD/CSNI ISP-21.

The PIPER-ONE facility simulates a GE BWR-6; the experiment simulates a SBLOCA, with break located in one recirculation line and unavailability of high pressure ECCS.

The experimental transients is described with detail in references /3/ and /28/; it seems worthwhile recalling few significant considerations from the above documents:
- the experimental scenario is similar to those measured in the counterpart tests performed in ROSA-III and FIST, notwithstanding the large difference in absolute dimensions of the facilities, in operating conditions and in several specific features; this demonstrates the good degree of knowledge in defining the scaling factors of PIPER-ONE and in specifying the boundary and initial conditions (counterpart test factors);
- the relative simplicity of the facility hardware led to a clear understanding of phenomena occurred during the test, without uncertainties linked to complex flow paths, thus allowing a more direct comparison with code results; few uncertainties in the experimental data depend upon the fact that this is the first test executed in the PIPER-
ONE facility;

- the occurrence of core dryout before the ADS actuation is not typical of BWR; it was due to the liquid condensed, even during the steady state period, in the annular part of the steam dome, that was not available for cooling the core; also the slightly higher value of core power (with respect to ideal scaling) necessary to compensate the heat losses through the fuel box, contributed to this event.

The double blind nature of the ISP, should be considered in judging the comparison between measured and calculated trends and the performance of the involved codes.

Almost all participants calculated qualitatively the main features of the experiment, with the exception of rod quenching that was not predicted by VTT (at least up to the time of calculation end).

The quantitative agreement was quite different among the various participants/25/; in this connection, two groups of codes can be distinguished. The former comprises advanced codes (RELAP5/MOD2) and codes specifically developed to handle BWR related transient (THYDE and GOBLIN); the latter includes a first generation code (RELAP4/MOD6) and a code developed and qualified for PWR typical conditions (SMABRE).

The results obtained by the first group can be retained substantially in good quantitative agreement with the measured scenario. The predictions of dryout timing, PCT, quench time and of phenomena causing the quench (i.e. level swell), testify the capabilities of these codes in calculating the main phenomena, when the hydraulic situation is clearly specified and predicted; the lack of 3-D phenomena and of complex paths inside the
facility should be recalled: this constituted one of the main purposes of the PIPER-ONE research/3/.

The poor quantitative agreement obtained by the remaining two codes, demonstrates the difficulties of the user in defining adequate input choices when a double blind prediction has to be computed (mainly in the case of RELAP4) and the importance of user experience (mainly in the case of SMABRE applied for the first time to a BWR scenario).
7. REFERENCES


/ 8/ L. Cioni, F. D'Auria, P. Di Marco, G.M. Galassi, M. Mazzini: "PIPER-


PO-SB-7 test Analysis by THYDE-B1/Mod 2 Computer Code". JAERI, Tokai,


/20/ W. Baltyn: "ISP21: Comments to the ABB Atom calculation". ASEA report
021/107322, April 1989.

/21/ V.H. Ransom et alii: "RELAP5/Mod2 Code manual Volume 1: code
structure, system models and solution methods". NUREG/CR-4312, Aug.
1985.

/22/ S.R. Fisher et alii: "RELAP4/Mod6 A Computer Program for Transient
Thermal-Hydraulic Analysis of Nuclear Reactor and Related System"

/23/ H. Nakamura, K. Maramatsu, Y. Kukita, K. Tasaka: "THYDE-BI/Mod2: A
Computer Code for Analysis of SB-LOCA of Boiling Water Reactor".

/24/ J. Miettinen: "Development and Assessment of the SB-LOCA Code SMABRE".
Spec. Meet. on Small Break LOCA Analyses in LWRs. Pisa(I), June 23-27,
1985.


/26/ W. Ambrosini, R. Bovalini, F. D'Auria: "Evaluation of codes accuracy
in the prediction of OECD/CSNI ISP-21 performed in PIPER-ONE
apparatus". OECD-CSNI Final Workshop on ISP-21. Pisa(I), April 13-14,
1989.

/27/ F. D'Auria, G. Frutuoso: "OECD/CSNI ISP21 PIPER-ONE test PO-SB-7:
R. Bovalini, F. D'Auria, A. De Varti, P. Maugeri, M. Mazzini:
"Analysis of Counterpart Test performed in BWR experimental simulators". OECD-CSNI Final Workshop on ISP-21. Pisa (I), April 13-14, 1989
APPENDIX A: FIGURES COMPARING THE ABB BLIND PREDICTION WITH SELECTED EXPERIMENTAL DATA
Fig. A.1 ISP-21 ABBs Comparison: Pressure in Lower Plenum

Fig. A.2 ISP-21 ABBs Comparison: Fluid Temperature in Lower Plenum
FIG. A.3  ISP-21 ABBS COMPARISON: FLUID TEMPERATURE IN CORE REGION LEVEL C

FIG. A.4  ISP-21 ABBS COMPARISON: FLUID TEMPERATURE IN CORE REGION LEVEL G
FIG. A.5 ISP-21 ABBS COMPARISON: FLUID TEMPERATURE IN CORE BYPASS CENTER

FIG. A.6 ISP-21 ABBS COMPARISON: FLUID TEMPERATURE IN STEAM DOME UPPER JUNCTION
FIG. A.7 ISP-21 ABBS COMPARISON: FLUID TEMPERATURE IN STEAM DOME MIDDLE JUNCTION

FIG. A.8 ISP-21 ABBS COMPARISON: FLUID TEMPERATURE IN UPPER DOWNCOMER
FIG. 4.9 ISP-21 ABBS COMPARISON: FLUID TEMPERATURE IN JET PUMP

FIG. 4.10 ISP-21 ABBS COMPARISON: FLUID TEMPERATURE IN LOWER DOWNCOMER BOTTOM
FIG. A.11 ISP-21 ABBS COMPARISON: COLLAPSED LEVEL IN DOWNCOMER

FIG. A.12 ISP-21 ABBS COMPARISON: COLLAPSED LEVEL IN CORE
Fig. A.13 ISP-21 ABBS Comparison: Collapsed Level in Core Bypass

Fig. A.14 ISP-21 ABBS Comparison: Collapsed Level in Steam Dome Annular Part
FIG. A.15 ISP-21 ABBS COMPARISON: DENSITY IN LOWER JUNCTION

FIG. A.16 ISP-21 ABBS COMPARISON: MASS FLOWRATE AT BREAK
FIG. A.17 ISP-21 ABBS COMPARISON: MASS FLOWRATE THROUGH ADS

FIG. A.18 ISP-21 ABBS COMPARISON: MASS FLOWRATE THROUGH SRV
FIG. A.19 ISP-21 ABBS COMPARISON: MASS FLOW RATE THROUGH MSIV

FIG. A.20 ISP-21 ABBS COMPARISON: MASS FLOW RATE OF LPCS SYSTEM
FIG. 4.21 ISP-21 ABB8 COMPARISON: ROD SURFACE TEMPERATURE - LEVEL A

FIG. A.22 ISP-21 ABB8 COMPARISON: INNER ROD SURFACE TEMPERATURE - LEVEL D
FIG. A.23 ISP-21 ABBS COMPARISON: INNER ROD SURFACE TEMPERATURE LEVEL E

FIG. A.24 ISP-21 ABBS COMPARISON: INNER ROD SURFACE TEMPERATURE LEVEL F
FIG. A.25 ISP-21 ABBS COMPARISON: FLUID MASS IN THE LOOP

FIG. A.26 ISP-21 ABBS COMPARISON: FLUID ENERGY IN THE LOOP
APPENDIX B: FIGURES COMPARING THE ANSALDO BLIND PREDICTION WITH SELECTED EXPERIMENTAL DATA
FIG. B.1 ISP-21 ANSALDO COMPARISON: PRESSURE IN LOWER PLENUM

FIG. B.2 ISP-21 ANSALDO COMPARISON: FLUID TEMPERATURE IN LOWER PLENUM
FIG. B.3 ISP-21 ANSALDO COMPARISON: FLUID TEMPERATURE IN CORE REGION LEVEL C

FIG. B.4 ISP-21 ANSALDO COMPARISON: FLUID TEMPERATURE IN CORE REGION LEVEL G
FIG. 9.7 ISP-21 ANSALDO COMPARISON: FLUID TEMPERATURE IN STEAM DOME MIDDLE JUNCTION

FIG. 9.8 ISP-21 ANSALDO COMPARISON: FLUID TEMPERATURE IN UPPER DOWNCOMER
FIG. B.9  ISP-21 ANSALDO COMPARISON: FLUID TEMPERATURE IN JET PUMP

FIG. B.10  ISP-21 ANSALDO COMPARISON: FLUID TEMPERATURE IN LOWER DOWNCOMER BOTTOM
FIG. B.11 1SP-21 ANSAADO COMPARISON: COLLAPSED LEVEL IN DOWNCOMER

FIG. B.12 1SP-21 ANSAADO COMPARISON: COLLAPSED LEVEL IN CORE
FIG. 9.13 ISP-21 ANSALDO COMPARISON: COLLAPSED LEVEL IN CORE BYPASS

FIG. 9.14 ISP-21 ANSALDO COMPARISON: COLLAPSED LEVEL IN STEAM DOME ANNULAR PART
FIG. B.15 ISP-21 ANSALDO COMPARISON: DENSITY IN LOWER JUNCTION

FIG. B.16 ISP-21 ANSALDO COMPARISON: MASS FLOWRATE AT BREAK
FIG. B.17 ISP-21 ANSALDO COMPARISON: MASS FLOWRATE THROUGH ADS

FIG. B.18 ISP-21 ANSALDO COMPARISON: MASS FLOWRATE THROUGH SRV
FIG. 9.19 ISP-21 ANSALDO COMPARISON: MASS FLOW RATE THROUGH MSIV

FIG. B.20 ISP-21 ANSALDO COMPARISON: MASS FLOW RATE OF LPCS SYSTEM
FIG. B.21 ISP-21 ANSALDO COMPARISON: ROD SURFACE TEMPERATURE - LEVEL A

FIG. B.22 ISP-21 ANSALDO COMPARISON: INNER ROD SURFACE TEMPERATURE
LEVEL D
FIG. B.23 ISP-21 ANSALDO COMPARISON: INNER ROD SURFACE TEMPERATURE LEVEL E

FIG. B.24 ISP-21 ANSALDO COMPARISON: INNER ROD SURFACE TEMPERATURE LEVEL F
FIG. B.25 ISP-21 ANSALDO COMPARISON: FLUID MASS IN THE LOOP

FIG. B.26 ISP-21 ANSALDO COMPARISON: FLUID ENERGY IN THE LOOP
APPENDIX C: FIGURES COMPARING THE ENEL-CRTN BLIND PREDICTION WITH SELECTED EXPERIMENTAL DATA
FIG. C.1 ISP-21 ENEL COMPARISON: PRESSURE IN LOWER PLENUM

FIG. C.2 ISP-21 ENEL COMPARISON: FLUID TEMPERATURE IN LOWER PLENUM
FIG. C.3 ISP-21 ENEL COMPARISON: FLUID TEMPERATURE IN CORE REGION LEVEL C

FIG. C.4 ISP-21 ENEL COMPARISON: FLUID TEMPERATURE IN CORE REGION LEVEL G
**Fig. C.5 ISP-21 ENEL Comparison: Fluid Temperature in Core Bypass Center**

**Fig. C.6 ISP-21 ENEL Comparison: Fluid Temperature in Steam Dome Upper Junction**
FIG. C.7 ISP-21 ENEL COMPARISON: FLUID TEMPERATURE IN STEAM DOME MIDDLE JUNCTION

FIG. C.8 ISP-21 ENEL COMPARISON: FLUID TEMPERATURE IN UPPER DOWNGOER
FIG. C.9 ISP-21 ENEL COMPARISON: FLUID TEMPERATURE IN JET PUMP

FIG. C.10 ISP-21 ENEL COMPARISON: FLUID TEMPERATURE IN LOWER DOWNCOMER BOTTOM
FIG. C.11 ISP-21 ENEL COMPARISON: COLLAPSED LEVEL IN DOWNCOMER

FIG. C.12 ISP-21 ENEL COMPARISON: COLLAPSED LEVEL IN CORE
FIG. C.13 ISP-21 ENEL COMPARISON: COLLapsed LEVEL IN CORE BYPASS

FIG. C.14 ISP-21 ENEL COMPARISON: COLLapsed LEVEL IN STEAM DOME ANNULAR PART

- 145 -
FIG. C.15 ISP-21 ENEL COMPARISON: DENSITY IN LOWER JUNCTION

FIG. C.16 ISP-21 ENEL COMPARISON: MASS FLOWRATE AT BREAK
FIG. C.17 ISP-21 ENEL COMPARISON: MASS FLOWRATE THROUGH ADS

FIG. C.18 ISP-21 ENEL COMPARISON: MASS FLOWRATE THROUGH SRY
FIG. C.19 ISP-21 ENEL COMPARISON: MASS FLOW RATE THROUGH MSIV

FIG. C.20 ISP-21 ENEL COMPARISON: MASS FLOW RATE OF LPCS SYSTEM
**Fig. C.21 ISP-21 ENEL Comparison: Rod Surface Temperature - Level A**

**Fig. C.22 ISP-21 ENEL Comparison: Inner Rod Surface Temperature - Level D**
FIG. C.23 ISP-21 ENEL COMPARISON: INNER ROD SURFACE TEMPERATURE
LEVEL E

FIG. C.24 ISP-21 ENEL COMPARISON: INNER ROD SURFACE TEMPERATURE
LEVEL F
FIG. C.25 ISP-21 ENEL COMPARISON: FLUID MASS IN THE LOOP

FIG. C.26 ISP-21 ENEL COMPARISON: FLUID ENERGY IN THE LOOP
APPENDIX D: FIGURES COMPARING THE JAERI BLIND PREDICTION
WITH SELECTED EXPERIMENTAL DATA
FIG. D.1 ISP-21 JAERI COMPARISON: PRESSURE IN LOWER PLENUM

FIG. D.2 ISP-21 JAERI COMPARISON: FLUID TEMPERATURE IN LOWER PLENUM
FIG. D.3 ISP-21 JAERI COMPARISON: FLUID TEMPERATURE IN CORE REGION LEVEL C

FIG. D.4 ISP-21 JAERI COMPARISON: FLUID TEMPERATURE IN CORE REGION LEVEL G
**Fig. D.5 ISP-21 JAERI Comparison: Fluid Temperature in Core Bypass Center**

**Fig. D.6 ISP-21 JAERI Comparison: Fluid Temperature in Steam Dome Upper Junction**
FIG. D.7  ISP-21 JAERI COMPARISON: FLUID TEMPERATURE IN STEAM DOME MIDDLE JUNCTION

FIG. D.8  ISP-21 JAERI COMPARISON: FLUID TEMPERATURE IN UPPER DOWNCOMER
FIG. D.9 ISP-21 JAERI COMPARISON: FLUID TEMPERATURE IN JET PUMP

FIG. D.10 ISP-21 JAERI COMPARISON: FLUID TEMPERATURE IN LOWER DOWNCOMER BOTTOM
FIG. D.11 ISP-21 JAERI COMPARISON: COLLAPSED LEVEL IN DOWNCOMER

FIG. D.12 ISP-21 JAERI COMPARISON: COLLAPSED LEVEL IN CORE
FIG. D.13 ISP-21 JAERI COMPARISON: COLLAPSED LEVEL IN CORE BYPASS

FIG. D.14 ISP-21 JAERI COMPARISON: COLLAPSED LEVEL IN STEAM DOME ANNULAR PART
FIG. D.15 ISP-21 JAERI COMPARISON: DENSITY IN LOWER JUNCTION

FIG. D.16 ISP-21 JAERI COMPARISON: MASS FLOWRATE AT BREAK
FIG. 9.17 ISP-21 JAERI COMPARISON: MASS FLOWRATE THROUGH ADS

FIG. 9.18 ISP-21 JAERI COMPARISON: MASS FLOWRATE THROUGH SRV
FIG. D.19 15P-21 JAERI COMPARISON: MASS FLOWRATE THROUGH MSIV

FIG. D.20 15P-21 JAERI COMPARISON: MASS FLOWRATE OF LPCS SYSTEM
FIG. D.21 ISP-21 JAERI COMPARISON: ROD SURFACE TEMPERATURE - LEVEL A

FIG. D.22 ISP-21 JAERI COMPARISON: INNER ROD SURFACE TEMPERATURE - LEVEL D
FIG. 9.25 ISP-21 JAERI COMPARISON: FLUID MASS IN THE LOOP

FIG. 9.26 ISP-21 JAERI COMPARISON: FLUID ENERGY IN THE LOOP
APPENDIX E: FIGURES COMPARING THE VTT1 BLIND PREDICTION WITH SELECTED EXPERIMENTAL DATA
FIG. E.1 ISP-21 VITI COMPARISON: PRESSURE IN LOWER PLENUM

FIG. E.2 ISP-21 VITI COMPARISON: FLUID TEMPERATURE IN LOWER PLENUM
FIG. E.3 ISP-2I VTTI COMPARISON: FLUID TEMPERATURE IN CORE REGION LEVEL C

FIG. E.4 ISP-2I VTTI COMPARISON: FLUID TEMPERATURE IN CORE REGION LEVEL G
FIG. E.5  ISP-21 VTTI COMPARISON: FLUID TEMPERATURE IN CORE BYPASS CENTER

FIG. E.6  ISP-21 VTTI COMPARISON: FLUID TEMPERATURE IN STEAM DOME UPPER JUNCTION
FIG. F.7  ISP-21 VTT1 COMPARISON: FLUID TEMPERATURE IN STEAM DOME
MIDDLE JUNCTION

FIG. F.8  ISP-21 VTT1 COMPARISON: FLUID TEMPERATURE IN UPPER DOWNCOMER
FIG. E.9 ISP-21 VFI1 COMPARISON: FLUID TEMPERATURE IN JET PUMP

FIG. E.10 ISP-21 VFI1 COMPARISON: FLUID TEMPERATURE IN LOWER DOWNCOMER BOTTOM
FIG. E.11 ISP-21 VTTI COMPARISON: COLLAPSED LEVEL IN DOWNCOMER

FIG. E.12 ISP-21 VTTI COMPARISON: COLLAPSED LEVEL IN CORE
FIG. F.13 ISP-21 VTTI COMPARISON: COLLAPSED LEVEL IN CORE BYPASS

FIG. F.14 ISP-21 VTTI COMPARISON: COLLAPSED LEVEL IN STEAM DOME ANNULAR PART
FIG. E.15 ISP-21 VITI COMPARISON: DENSITY IN LOWER JUNCTION

FIG. E.16 ISP-21 VITI COMPARISON: MASS FLOWRATE AT BREAK
Fig. F.17 ISP-21 VITI Comparison: Mass Flowrate Through ADS

Fig. F.18 ISP-21 VITI Comparison: Mass Flowrate Through SRV
FIG. E.19 ISP-21 VT11 COMPARISON: MASS FLOW RATE THROUGH MS IV

FIG. E.20 ISP-21 VT11 COMPARISON: MASS FLOW RATE OF LPCS SYSTEM
FIG. E.21 ISP-21 VTT1 COMPARISON: ROD SURFACE TEMPERATURE - LEVEL A

FIG. E.22 ISP-21 VTT1 COMPARISON: INNER ROD SURFACE TEMPERATURE - LEVEL D
FIG. E.23 ISP-21 VTI COMPARISON: INNER ROD SURFACE TEMPERATURE LEVEL E

FIG. E.24 ISP-21 VTI COMPARISON: INNER ROD SURFACE TEMPERATURE LEVEL F
**FIG. E.25 ISP-21 VTTI COMPARISON: FLUID MASS IN THE LOOP**

**FIG. E.26 ISP-21 VTTI COMPARISON: FLUID ENERGY IN THE LOOP**
APPENDIX F: FIGURES COMPARING THE VTT2 BLIND PREDICTION WITH SELECTED EXPERIMENTAL DATA
FIG. F.1  ISP-21 VTT2 COMPARISON: PRESSURE IN LOWER PLENUM

FIG. F.2  ISP-21 VTT2 COMPARISON: FLUID TEMPERATURE IN LOWER PLENUM
FIG. F.3 ISP-21 VIT2 COMPARISON: FLUID TEMPERATURE IN CORE REGION LEVEL C

FIG. F.4 ISP-21 VIT2 COMPARISON: FLUID TEMPERATURE IN CORE REGION LEVEL G
FIG. F.5 ISP-21 VIT2 COMPARISON: FLUID TEMPERATURE IN CORE BYPASS CENTER

FIG. F.6 ISP-21 VIT2 COMPARISON: FLUID TEMPERATURE IN STEAM DOME UPPER JUNCTION
FIG. F.7  ISP-21 VTT2 COMPARISON: FLUID TEMPERATURE IN STEAM DOME MIDDLE JUNCTION

FIG. F.8  ISP-21 VTT2 COMPARISON: FLUID TEMPERATURE IN UPPER DOWNCOMER
FIG. F.9 ISP-21 VTT2 COMPARISON: FLUID TEMPERATURE IN JET PUMP

FIG. F.10 ISP-21 VTT2 COMPARISON: FLUID TEMPERATURE IN LOWER DOWCOMER BOTTOM
FIG. F.11 ISP-21 VIT2 COMPARISON: COLLAPSED LEVEL IN DOWNCOMER

FIG. F.12 ISP-21 VIT2 COMPARISON: COLLAPSED LEVEL IN CORE
FIG. F.13 ISP-21 VTT2 COMPARISON: COLLAPSED LEVEL IN CORE BYPASS

FIG. F.14 ISP-21 VTT2 COMPARISON: COLLAPSED LEVEL IN STEAM DOME ANNULAR PART
FIG. F.15 ISP-21 VIT2 COMPARISON: DENSITY IN LOWER JUNCTION

FIG. F.16 ISP-21 VIT2 COMPARISON: MASS FLOWRATE AT BREAK
Fig. F.17 ISP-21 VIT2 Comparison: Mass Flowrate Through ADS

Fig. F.18 ISP-21 VIT2 Comparison: Mass Flowrate Through SRV
FIG. F.19 ISP-21 VTT2 COMPARISON: MASS FLOWRATE THROUGH MSIV

FIG. F.20 ISP-21 VTT2 COMPARISON: MASS FLOWRATE OF LPCS SYSTEM
FIG. F.21 ISP-21 VTT2 COMPARISON: ROD SURFACE TEMPERATURE - LEVEL A

FIG. F.22 ISP-21 VTT2 COMPARISON: INNER ROD SURFACE TEMPERATURE - LEVEL D
FIG. F.23 ISP-21 VTT2 COMPARISON: INNER ROD SURFACE TEMPERATURE LEVEL E

FIG. F.24 ISP-21 VTT2 COMPARISON: INNER ROD SURFACE TEMPERATURE LEVEL F
FIG. F.25 ISP-21 VTT2 COMPARISON: FLUID MASS IN THE LOOP

FIG. F.26 ISP-21 VTT2 COMPARISON: FLUID ENERGY IN THE LOOP
APPENDIX G: COMPARISON PLOTTERS OF QUANTITIES CHARACTERIZED BY LARGE CALCULATED SPIKES
FIG. 5.33 ISP-21 COMPARISON: MEAN QUALITY AT STEAM DOME TOP

FIG. 5.34 ISP-21 COMPARISON: MEAN QUALITY AT BREAK
Fig. 5.35 ISP-21 Comparison: Differential Pressure at Core Inlet

Fig. 5.36 ISP-21 Comparison: Differential Pressure at Core Outlet
FIG. 5.37 ISP-21 COMPARISON: DIFFERENTIAL PRESSURE AT BYPASS VENTURI NOZZLE

FIG. 5.38 ISP-21 COMPARISON: DIFFERENTIAL PRESSURE IN LOWER JUNCTION
FIG. 5.39 ISP-21 COMPARISON: MASS FLOWRATE AT CORE INLET

FIG. 5.40 ISP-21 COMPARISON: MASS FLOWRATE AT CORE OUTLET
FIG. 5.41 ISP-21 COMPARISON: MASS FLOWRATE AT CORE BYPASS BOTTOM

FIG. 5.42 ISP-21 COMPARISON: MASS FLOWRATE AT JET PUMP EXIT
APPENDIX H: DETAILS ABOUT INFORMATION SENT BY PARTICIPANTS

AFTER THE FINAL WORKSHOP
FIG. H1.1 ISP-21 CORRECTED COMPARISON PLOTTER: COLLAPSED LEVEL IN DOWNCOMER

FIG. H1.2 ISP-21 CORRECTED COMPARISON PLOTTER: COLLAPSED LEVEL IN CORE
FIG. H1.3 ISP-21 CORRECTED COMPARISON PLOTTER: COLLAPSED LEVEL IN CORE BYPASS

FIG. H1.4 ISP-21 CORRECTED COMPARISON PLOTTER: MASS FLOWRATE OF LPCS SYSTEM
FIG. H2.1 ISP-21 CORRECTED COMPARISON PLOTTER: FLUID TEMPERATURE IN UPPER PLENUM

FIG. H2.2 ISP-21 CORRECTED COMPARISON PLOTTER: FLUID TEMPERATURE IN STEAM SEPARATOR ANNULUS - CENTER
FIG. H2.3 ISP-21 CORRECTED COMPARISON PLOTTER:
FLUID TEMPERATURE IN STEAM DOME UPPER JUNCTION

FIG. H2.4 ISP-21 CORRECTED COMPARISON PLOTTER:
FLUID TEMPERATURE IN STEAM DOME MIDDLE JUNCTION
Fig. H2.5 ISP-21 Corrected Comparison Plotter: Fluid Temperature in Upper Downcomer

Fig. H2.6 ISP-21 Corrected Comparison Plotter: Fluid Temperature in Lower Downcomer Top
FIG. H3.1  ISP-21 ENEL POST TEST COMPARISON:
PRESSURE IN LOWER PLENUM

FIG. H3.2  ISP-21 ENEL POST TEST COMPARISON:
FLUID TEMPERATURE IN LOWER PLENUM
FIG. H3.3 ISP-21 ENEL POST TEST COMPARISON:
FLUID TEMPERATURE IN CORE REGION LEVEL C

FIG. H3.4 ISP-21 ENEL POST TEST COMPARISON:
FLUID TEMPERATURE IN CORE REGION LEVEL C
Fig. H3.5 ISP-21 ENEL POST TEST COMPARISON:
FLUID TEMPERATURE IN CORE BYPASS CENTER

Fig. H3.6 ISP-21 ENEL POST TEST COMPARISON:
FLUID TEMPERATURE IN STEAM DOME UPPER JUNCTION
FIG. H3-7 ISP-21 ENEL POST TEST COMPARISON:
FLUID TEMPERATURE IN STEAM DOME MIDDLE JUNCTION

FIG. H3-8 ISP-21 ENEL POST TEST COMPARISON:
FLUID TEMPERATURE IN UPPER DOWCOMER
**FIG. H3.9** ISP-21 ENEL POST TEST COMPARISON:
FLUID TEMPERATURE IN JET PUMP

**FIG. H3.10** ISP-21 ENEL POST TEST COMPARISON:
FLUID TEMPERATURE IN LOWER DOWNCOMER BOTTOM
FIG. H3.11 ISP-21 ENEL POST TEST COMPARISON:
COLLAPSED LEVEL IN DOWNCOMER

FIG. H3.12 ISP-21 ENEL POST TEST COMPARISON:
COLLAPSED LEVEL IN CORE
FIG. H3.13 ISP-21 ENEL POST TEST COMPARISON: COLLAPSED LEVEL IN CORE BYPASS

FIG. H3.14 ISP-21 ENEL POST TEST COMPARISON: COLLAPSED LEVEL IN STEAM DOME ANNULAR PART
FIG. H3.15 ISP-21 ENEL POST TEST COMPARISON:
DENSITY IN LOWER JUNCTION

FIG. H3.16 ISP-21 ENEL POST TEST COMPARISON:
MASS FLOWRATE AT BREAK
FIG. H3.17 ISP-21 ENEL POST TEST COMPARISON:
MASS FLOWRATE THROUGH ADS

FIG. H3.18 ISP-21 ENEL POST TEST COMPARISON:
MASS FLOWRATE THROUGH SRV
Fig. H3.19 ISP-21 ENEL POST TEST COMPARISON:
MASS FLOW RATE THROUGH HSIV

Fig. H3.20 ISP-21 ENEL POST TEST COMPARISON:
MASS FLOW RATE OF LPCS SYSTEM
FIG. H3.21 ISP-21 ENEL POST TEST COMPARISON:
ROD SURFACE TEMPERATURE - LEVEL A

FIG. H3.22 ISP-21 ENEL POST TEST COMPARISON:
INNER ROD SURFACE TEMPERATURE LEVEL D
FIG. H3.23 ISP-21 ENEL POST TEST COMPARISON:
INNER ROD SURFACE TEMPERATURE LEVEL E

FIG. H3.24 ISP-21 ENEL POST TEST COMPARISON:
INNER ROD SURFACE TEMPERATURE LEVEL F
Fig. H3.25 ISP-21 ENEL POST TEST COMPARISON:
FLUID MASS IN THE LOOP

Fig. H3.26 ISP-21 ENEL POST TEST COMPARISON:
FLUID ENERGY IN THE LOOP
FIG. H4.1 ISP-21 VTT Post-Test Comparison: Pressure in lower plenum

FIG. H4.2 ISP-21 VTT Post-Test Comparison: Inner rod surface temperature, level E