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NUCLEAR ENERGY AGENCY
COMMITTEE ON THE SAFETY OF NUCLEAR INSTALLATIONS

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ANSWERS TO REMAINING QUESTIONS ON BUBBLER CONDENSER

Activity Report of the OECD NEA Bubbler-Condenser Steering Group

January 2003

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ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

Pursuant to Article 1 of the Convention signed in Paris on 14th December 1960, and which came into force on 30th September 1961, the Organisation for Economic Co-operation and Development (OECD) shall promote policies designed:

- to achieve the highest sustainable economic growth and employment and a rising standard of living in Member countries, while maintaining financial stability, and thus to contribute to the development of the world economy;
- to contribute to sound economic expansion in Member as well as non-member countries in the process of economic development; and
- to contribute to the expansion of world trade on a multilateral, non-discriminatory basis in accordance with international obligations.

The original Member countries of the OECD are Austria, Belgium, Canada, Denmark, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, the United Kingdom and the United States. The following countries became Members subsequently through accession at the dates indicated hereafter: Japan (28th April 1964), Finland (28th January 1969), Australia (7th June 1971), New Zealand (29th May 1973), Mexico (18th May 1994), the Czech Republic (21st December 1995), Hungary (7th May 1996), Poland (22nd November 1996), Korea (12th December 1996) and the Slovak Republic (14th December 2000). The Commission of the European Communities takes part in the work of the OECD (Article 13 of the OECD Convention).

NUCLEAR ENERGY AGENCY

The OECD Nuclear Energy Agency (NEA) was established on 1st February 1958 under the name of the OEEC European Nuclear Energy Agency. It received its present designation on 20th April 1972, when Japan became its first non-European full Member. NEA membership today consists of 27 OECD Member countries: Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Luxembourg, Mexico, the Netherlands, Norway, Portugal, Republic of Korea, Spain, Sweden, Switzerland, Turkey, the United Kingdom and the United States. The Commission of the European Communities also takes part in the work of the Agency.

The mission of the NEA is:

- to assist its Member countries in maintaining and further developing, through international co-operation, the scientific, technological and legal bases required for a safe, environmentally friendly and economical use of nuclear energy for peaceful purposes, as well as
- to provide authoritative assessments and to forge common understandings on key issues, as input to government decisions on nuclear energy policy and to broader OECD policy analyses in areas such as energy and sustainable development.

Specific areas of competence of the NEA include safety and regulation of nuclear activities, radioactive waste management, radiological protection, nuclear science, economic and technical analyses of the nuclear fuel cycle, nuclear law and liability, and public information. The NEA Data Bank provides nuclear data and computer program services for participating countries.

In these and related tasks, the NEA works in close collaboration with the International Atomic Energy Agency in Vienna, with which it has a Co-operation Agreement, as well as with other international organisations in the nuclear field.

COMMITTEE ON THE SAFETY OF NUCLEAR INSTALLATIONS

The NEA Committee on the Safety of Nuclear Installations (CSNI) is an international committee made up of scientists and engineers. It was set up in 1973 to develop and co-ordinate the activities of the Nuclear Energy Agency concerning the technical aspects of the design, construction and operation of nuclear installations insofar as they affect the safety of such installations. The Committee's purpose is to foster international co-operation in nuclear safety amongst the OECD Member countries.

CSNI constitutes a forum for the exchange of technical information and for collaboration between organisations which can contribute, from their respective backgrounds in research, development, engineering or regulation, to these activities and to the definition of its programme of work. It also reviews the state of knowledge on selected topics of nuclear safety technology and safety assessment, including operating experience. It initiates and conducts programmes identified by these reviews and assessments in order to overcome discrepancies, develop improvements and reach international consensus in different projects and International Standard Problems, and assists in the feedback of the results to participating organisations. Full use is also made of traditional methods of co-operation, such as information exchanges, establishment of working groups and organisation of conferences and specialist meeting.

The greater part of CSNI's current programme of work is concerned with safety technology of water reactors. The principal areas covered are operating experience and the human factor, reactor coolant system behaviour, various aspects of reactor component integrity, the phenomenology of radioactive releases in reactor accidents and their confinement, 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.

In implementing its programme, CSNI establishes co-operative mechanisms with NEA's Committee on Nuclear Regulatory Activities (CNRA), responsible for the activities of the Agency concerning the regulation, licensing and inspection of nuclear installations with regard to safety. It also co-operates with NEA's Committee on Radiation Protection and Public Health and NEA's Radioactive Waste Management Committee on matters of common interest.

Answers to Remaining Questions on Bubbler-Condenser

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Table of Contents

Executive Summary

The Russian design VVER-440 (type 213) pressurised water reactors are fitted with a pressure-suppression containment structure, called bubbler-condenser, having the function to reduce the pressure of the entire containment in case of a design basis accident (DBA), such as a loss of coolant accident (LOCA). This device consists of a tower of typically 12 floors communicating with the reactor containment building. Each floor is flooded with a pool of cold water (at room temperature) and includes gap-cap inlet openings. In the unlikely case of a LOCA, the steam from the primary circuit of the reactor and air enter the bubbler-condenser tower and are forced by the gap-cap system to bubble into the cold water present at each floor of the bubbler-condenser. This causes the steam to condense, thus maintaining both temperature and pressure within containment below given limits during the entire course of a postulated design basis accident

The bubbler-condenser was designed to withstand design basis accident conditions and to maintain its integrity in order to fulfil its safety function. Nevertheless, particularly for design basis accidents, detailed analyses identified the need to improve the modelling of accidents and to extend the knowledge of integral and separated effects. There was also a need to produce qualified experimental data in order to strengthen the basis for computer codes validation.

During the 1990ies, a number of investigations, including analyses and experiments by the utilities, as well as EU PHARE projects and related OECD NEA Expert Group activities, have been performed in order to fully ascertain the capabilities of the VVER-440/213 bubbler-condenser. These investigations consisted among others of experiments intended to simulate large break LOCA conditions (i.e. the most challenging ones for the bubbler-condenser structure) and provided adequate answers to the most important issues related to the bubbler-condenser function. However, certain questions still remained open and needed further assessment.

In response to a request of their safety authorities to answer the remaining questions and complete the bubbler-condenser assessment, the Hungarian, Czech and Slovak utilities took the initiative in 2001 to perform a joint experimental programme. This was to be realised at a specialised facility in the Russian Federation, i.e. the EREC facility located at Electrogorsk near Moscow, which had also been used for earlier bubbler-condenser experimental work. The utilities involved were the Hungarian Paks NPP, the Slovak Bohunice NPP and Mochovce NPP and the Czech Dukovany NPP.

Parallel to the initiative for establishing this consortium, the Hungarian Safety Authority (HAEA) requested the assistance of the OECD NEA Committee on the Safety of Nuclear Installations (CSNI) for the preparatory phase of the experimental work as well as for the analyses of code calculations and experimental results. The CSNI supported the HAEA request of assistance and approved the establishment of a Bubbler-Condenser Steering Group (BC SG) to carry out given tasks according to an agreed mandate. The Steering Group consisted of a representative of each of the Czech, Hungarian and Slovak regulatory bodies and of each of the utilities involved, as well experts from the German GRS, the French IRSN, the US DOE and the EU. These organisations had all been involved with previous bubbler-condenser work.
The objectives of the Steering Group were:

- to produce convincing evidence that the VVER-440/V213 type bubbler-condenser works during DBAs as designed
- To help in the planning of the new EREC experiments and in the interpretation of the results
- to provide well qualified experimental results serving as basis for the validation of best estimate calculation tools.

In particular, it was considered important that, through the planned EREC experiments and through adequate code calculations, the SG provided answers to the questions that remained open from the previous experimental work, and were as follows:

Q1. The scaling of energy discharge rate is important for determining the thermal-hydraulic load on containment structure. Can estimates be made on whether the conclusions drawn are conservative or not, and if they are, on the degree of conservatism?

Q2. Are the conservatism and adequacy of the [EREC] facility properly addressed?

Q3. Unexpected non-uniformity of flow rates and of water temperatures has been observed in earlier tests. Are these observations relevant and why? Can specific code calculations help in this assessment?

Another issue to be addressed was the oscillatory loading of the water pool trays by condensation phenomena. It was hypothesised that these phenomena might be more likely to occur under longer duration small break LOCA conditions, such as in case of steam line break or small/medium size primary breaks.

The BC SG activities, as well as the experimental work at EREC, were carried out in 2002. The BC SG held four meetings, one at the end of 2001 and three in 2002, and had extensive inter-meeting consultations. The major items covered in these meetings are outlined below.

Meeting 1, Paris, December 7, 2001

- Overview of the bubbler condenser issue including former projects
- Formation of the SG, approval of the mandate and of the work-scope
- Overview of the new tests

Meeting 2, Budapest, February 25-26, 2002

- Post-test calculations of the previous experiments and remaining uncertainties
- Status of the related EU projects
- Status of definition of the new experiments

Meeting 3, Bratislava, 29-30 April, 2002

- Status of the preparations to the experiments and status of the facility
- Discussion on the relevance of certain phenomena previously not investigated experimentally
- Proposed content of the BCSG Activity Report

Meeting 4, Prague, 25-26 November 2002

- Review of experimental results and code calculations
- Discussion of the Final Report prepared by the utilities
- Review of the BCSG Activity Report
- Main conclusions and answers to the questions remaining from previous work

The EREC experiments and the related pre- and post-test calculations addressed the following postulated events:

- Main steam-line break (MSLB) of the Paks NPP, modelled by a d=55 mm break at the EREC facility. Pre- and post-test calculations were co-ordinated by the Paks NPP (calculated by VEIKI, Budapest). The experimental work was done in June 17-21, 2002.

- Medium break loss-of-coolant accident (MBLOCA) of the Dukovany NPP Unit 1, loop 1. cold leg (200 mm, modelled by a d=19 mm break at the EREC facility). Pre- and post-test calculations were co-ordinated by the Dukovany NPP (calculated by NRI, Rez). The experimental work was done in July 01-05, 2002.

- Small/medium break loss-of-coolant accident at the Mochovce NPP, in loop 1 with the pressurizer (90 mm, modelled by a d=8,5 mm break at the EREC facility). Pre- and post-test calculations were co-ordinated by the Mochovce and Bochunice NPPs (calculated by VUJE, Trnava). The experimental work was done in July 15-19.

The conclusions from the three experiments were that:

- The test parameters measured by different transducers provide values that are generally consistent with each other
- The discrepancies between the measured and calculated values are not significant and the calculations are conservative.
- The observed differences between the measured and calculated values can be adequately explained
- The maximum pressure experienced in the tests is far from the 0.25 MPa design pressure of the containment system.
- The maximum pressure load on the tray walls measured during the tests, is far less than the 30 kPa limit value
- Water level fluctuations were experienced but were found to be minor and disappeared when the steam started to flow into the bubbler condenser pool
- Within the range of conditions explored in the EREC tests, condensation-oscillation phenomena were not observed
- The sequences investigated in the tests do not cause any significant challenge for the VVER-440/213 type BC and localization system

Based on the experimental and analytical evidences of the newly performed investigations and in-depth discussions, the OECD Bubbler-condenser Steering Group has concluded with the following answers to the three open questions mentioned above:

A1. The verification of the blow-down mass and energy rates (MER) producing loads to the BC was performed in the frame of the present project for both the previous LBLOCA tests and for the recent tests. Results confirmed conservative mass and energy estimations. It was shown that the injected MER were higher in the tests than the scaled MER (NPP/100) values. These findings confirmed the conservative nature of the approach. Conclusions were that the related loads do not represent a challenge to containment integrity. A parallel assessment of this issue with respect to LBLOCA tests is going on in the PHARE project PR/TS/17.

A2. The first part of the question concerning conservatism (initial conditions, scenarios, test conditions, different break locations, etc.) can be answered positively. The adequacy was addressed by the scaling of the facility and possible distortions were compensated by different measures (e.g. installation of additional insulation).

A3. Non-uniformities of flow rates and water temperatures have been observed in the experiments. An appropriate understanding of the non-uniformities was obtained by detailed (3D) code calculations. The reasons and the nature of the distributions have been satisfactorily explained by code calculations.

The activity and conclusions of the Steering Group have been summarised in a BC-SG Activity Report, which is primarily meant for the Nuclear Regulatory Bodies of the Czech Republic, Hungary and Slovak Republic. However, it can be of interest also for regulatory bodies in other CSNI member countries. The draft report was submitted for CSNI approval in December 2002 and is to be published as a CSNI report.

List of abbreviations

AQG - Atomic Question Group

BC - Bubbler Condenser

BCC - Bubbler Condenser Containment

DBA - Design Basis Accident

ECCS - Emergency Core Cooling Pump

EREC - Electrogorsk Research end Engineering Centre on Nuclear Plant Safety

FWLB - Feed Water Line Break

LB - Large Break

LOCA - Loss of Coolant Accident

MB - Medium Size Break

MCP - Main Circulation Pump

MSLB - Main Steam Line Break

SB - Small Break

TAC - Technical Advisory Committee

1. Introduction

A number of investigations, including analyses and experiments by the utilities, as well as previous EU PHARE projects and related OECD NEA Expert Group activities have been performed in order to clarify the role and capabilities of the VVER-440/V213 type bubbler-condenser (BC) in design basis accidents. Most of the related important issues have been treated satisfactorily, certain questions, however, have remained open or needed further assessment.

In order to complete the investigations related to the proper functioning of the bubbler-condenser during design basis accidents, the Atomic Question Group on Nuclear Safety in the context of enlargement recommended to the candidate countries operating VVER-440/213 nuclear power plants to “report on progress [….] concerning measures to complete the regulatory review regarding full verification of the performance of the containment bubbler condenser system for all design basis accidents”.

As a reaction to that the Hungarian Atomic Energy Authority (HAEA – the nuclear regulatory body in Hungary) had requested the Hungarian Paks Nuclear Power Plant to have additional experiments performed. The Czech and Slovak nuclear regulatory bodies have raised similar requests to the utilities under their authority. As a follow-up on this, the Hungarian, Czech and Slovak utilities formed a consortium aimed to perform on a joint basis a series of relevant experiments in the Russian EREC facility. The participants of the consortium financing and evaluating the new experiments were: Paks NPP (Hungary), Jaslovske Bohunice NPP and Mochovce NPP (Slovakia) and Dukovany NPP (Czech Republic). Parallel to the initiative for establishing this consortium, HAEA requested OECD NEA CSNI for assistance in advising during the preparatory phase of the experimental work as well as during the analysis of the experimental and numerical results.

In specific the following three questions were considered important to be answered:

Q1. The scaling of energy discharge rate is important for determining the thermal-hydraulic load on containment structure. Can estimates be made on whether the conclusions drawn are or are not conservative, and if they are, on the degree of conservatism?
Q2. Are the conservatism and adequacy of the BC facility properly addressed?
Q3. Unexpected non-uniformity of flow rates and of water temperatures has been observed in earlier tests. Are these observations relevant and why? Can specific code calculations help in this assessment?

The CSNI supported the HAEA request of assistance for answering these questions and approved the establishment of a Steering Group (SG) to carry out such task according to the mandate presented in the following.

The objectives of the Steering Group activities have been defined as follows:

- to produce convincing evidence that the V-213 type containment works during DBAs as designed
- to help in the planning of new tests and in the interpretation of the test results
- to ensure well qualified experimental results serving as basis for the validation of best estimate calculation tools.

During later discussions of the Steering Group it was made clear that producing convincing evidence does not presume that all aspects will be responded to by the intended tests. The national safety authorities will in any case determine the extent to which the experimental evidence is sufficient for their assessments and conclusions on BC safety.

The mandate is attached in Appendix 1.

The Steering Group included as members one representative from each of the Czech, Hungarian and Slovak regulatory bodies and from the utilities involved, representatives of GRS, IRSN, DOE and the EC.

The role of the Steering Group was intended as follows:

- The SG shall review the scope of new tests and make recommendations as to the test set-up and conduct, including, e.g., instrumentation and pre- and post test calculations.
- The agreed experiments and analyses shall be carried out and reported upon in the SG by the Project Operating Agent.
- The SG shall be entitled to receive relevant experimental results and will aim to reach consensus on their interpretation. The technical conclusions will be intended for the use of national regulators.

The first meeting of the SG was held on December 7, 2001 in Paris and had as items on the Agenda the following activities:

- overview of the bubbler-condenser issue including former projects
- formation of the SG, acceptance of the mandate and of the work-scope
- overview of the new tests.

During the second meeting, held in Budapest on February 25-26, 2002 the items below were discussed:

- post-test calculations of the previous experiments and remained uncertainties
- status of the related EC projects
- status of the new experiments.

The third meeting was held in Bratislava on 29-30 April, 2002 and included the topics as below:

- status of the preparations to the experiments and status of the facility
- importance and relevance of certain phenomena previously not investigated experimentally
- proposed contents of the SG Activity Report.

The fourth meeting was held in Prague on 25-26 November 2002 and addressed the status of the Final Report prepared by the utilities on the experimental and analysis results, and discussed certain parts of the SG Activity Report.

The minutes of the meetings and the SG members are attached in Appendix 2 and 3

Between two consecutive SG meetings in-depth discussions were held via e-mail on the pre-test calculations and related issues.

The experiments performed by the consortium included:

- Main steam-line break (MSLB) of the Pask NPP, modelled by a d=55 mm break at the EREC facility. Pre- and post-test calculations, performed by VEIKI, Budapest are provided by the Paks NPP. The measurements were held on June 17-21, 2002.
- Medium break loss of coolant accident (MBLOCA) of the Dukovany NPP Unit 1, loop 1, cold leg (200 mm, modelled by a d=19 mm break at the EREC facility). Pre- and post-test calculations carried out by NRI, Rez are provided by the Dukovany NPP. The measurements were held on July 01-05, 2002.

- Small/medium break loss of coolant accident at the Mochovce NPP, in loop 1 with the pressurizer (90 mm, modelled by a d=8,5 mm break at the EREC facility). Pre- and post-test calculations by VUJE Trnava are provided by the Mochovce and Bochunice NPPs. The measurements were held on July 15-19, 2002.

The present Project Activity Report summarises the activity and conclusions of the Steering Group, and is primarily meant for the Nuclear Regulatory Bodies of the Czech Republic, Hungary and Slovak Republic. However, it can be of interest also for the regulatory bodies in other CSNI member countries. Further, the Bubbler-condenser issue and the way in which the open questions have been handled here can be of interest for various institutions in the EU member states.

2. Background

2.1 BC description and function

In NPPs with VVER-440/213, the containment system (also called Bubbler Condenser Containment – BCC) consists of the following main parts:

- the hermetic compartment system (2 and 3 in Fig. 2.1) with the primary system coolant loop components. The system consists of more than 40 compartments and is connected with the bubbler condenser building (tower) via corridors (7 in Fig. 2.1);
- the bubbler condenser (BC, 8 in Fig. 2.1), which provides the passive pressure suppression;
- the air traps (9 in Fig. 2.1), which in case of accidents holds non-condensable gases transferred from the hermetic compartment system through the bubbler condenser, and
- active and passive spray systems providing long-term pressure reduction.

The interaction of hermetic compartment system, bubbler condenser and air traps determines the design pressure of the containment system, 245 kPa absolute pressure.

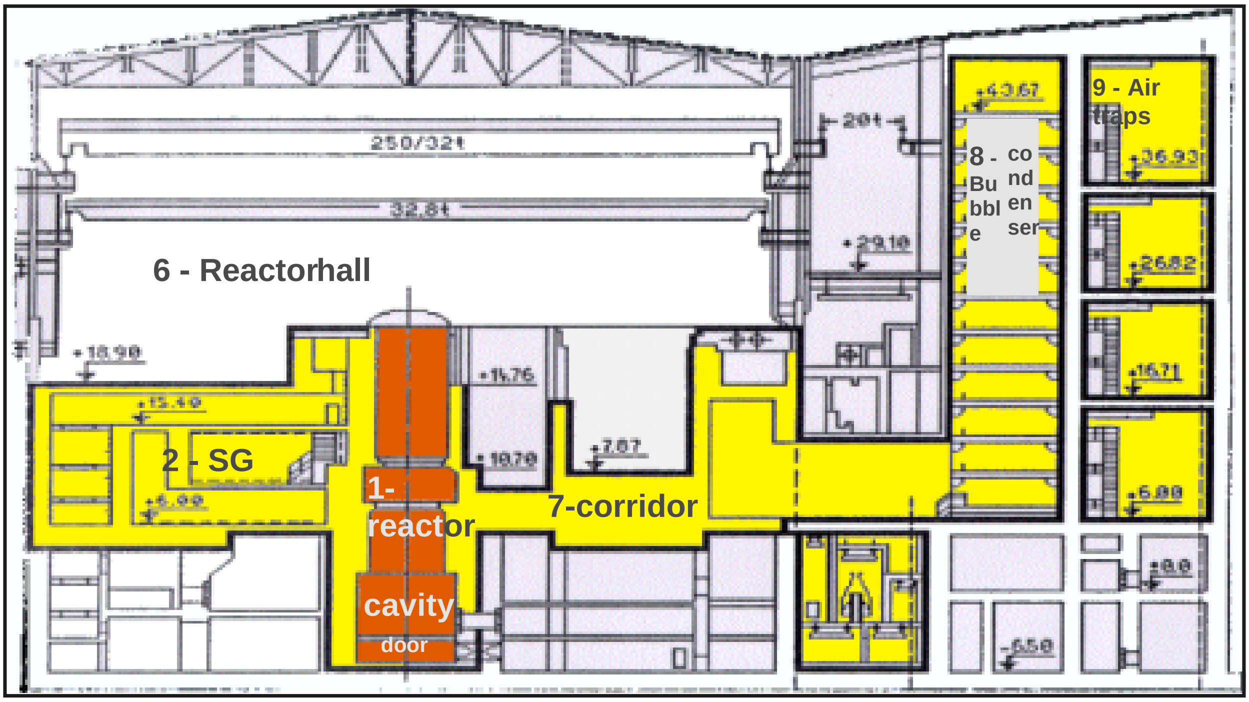
The bubbler condenser is the specific feature of the BCC. It provides reduction of the accident containment pressure by the expansion of the released steam to a large volume and condensation in water pools. The BC consists of 12 staggered water trays (pools). Each tray is made of 17 sections, whereas each section comprise 9 so-called gap-cap systems (see Fig. 2.2). Every three trays are connected to one air trap (see Fig. 2.1). The gap-cap system provides intensive contact between the air-steam mixture and the cold water in the water pools and thus a highly-effective condensation.

In case of an accident (LOCA, MSLB, FWLB) the air-steam mixture generated inside the hermetic compartment system will be transferred through the corridors into the BC shaft (1 in Fig. 2.2) and further on to individual trays. Through the volumes between ceilings and bottoms of the floors the mixture enters about 1800 gap-cap systems (2 in Fig. 2.2). After the expulsion of water column (vent clearing) in the gap-cap systems the mixture bubbles through the water layer where steam condenses, what finally causes a corresponding reduction of the mixture volume.

Air and other non-condensable gases will be accumulated above water level and due to arising overpressure be transferred through the check valve DN 500 into the air traps (4 in Fig. 2.2).

The time history of the presented process is governed by the pressure difference arising between BC shaft (1 in Fig. 2.2) and air traps (5 in Fig. 2.2). In case of a LB LOCA the accident is characterised by significant dynamic impacts of jet flows on all technological devices, as well as on the structures of bubbler-condenser and compartment system. Dynamic effects of the steam-air mixture flow at the bubbler condenser inlet are captured by a special reflexive wall anchored to the bearing structure of BC trays and in this way to the reinforced concrete building.

Fig. 2.1 Containment system of VVER-440/213



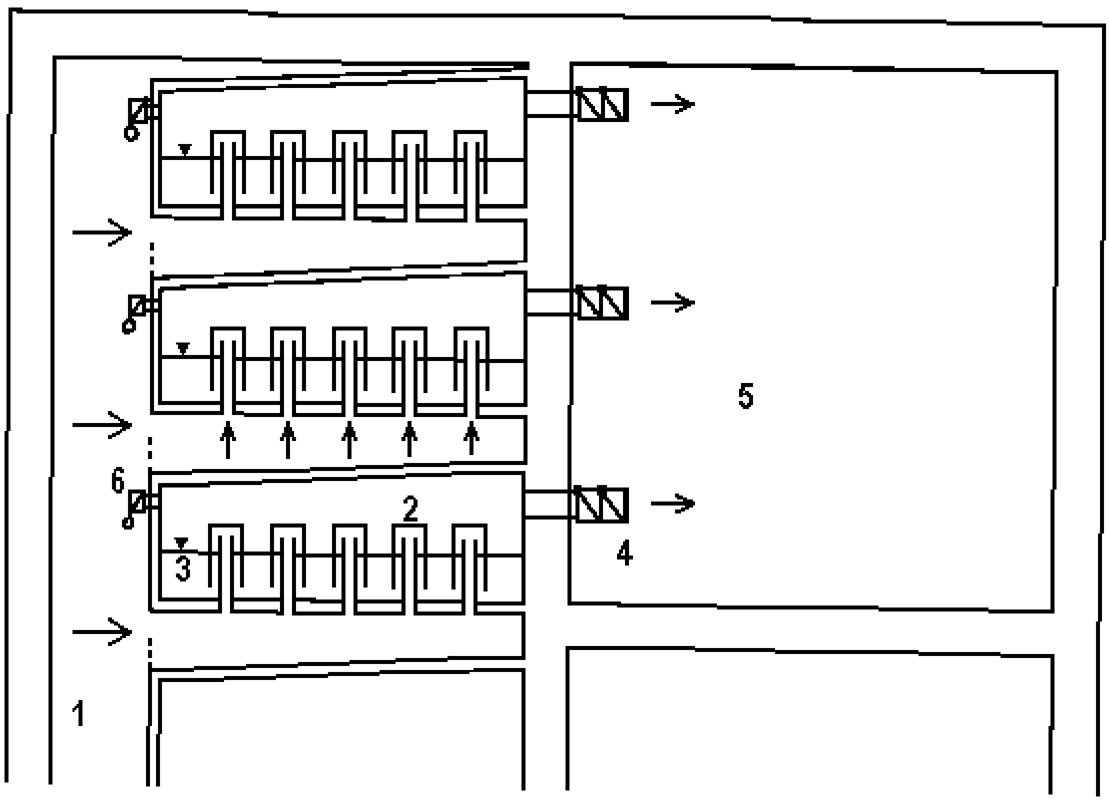
1	*Reactor Pressure Vessel*	*7*	*Corridor*
2	*Steam Generator Box*	*8*	*BC unit*
6	*Reactor hall*	*9*	*Air trap*

In the further course of the accident the pressures in gasrooms, i.e. above the water level, and in air traps equalise while DN500 check valves (4 in Fig. 2.2) automatically close retaining compressed air and other non-condensable gases in the traps. The flow of hot water and steam from the break continuously decreases and pressure in the BCC begins to fall due to steam condensation and heat transfer to the walls as well as due to operation of an active spray system.

Reverse pressure difference, when the pressure above water seal becomes higher than the pressure in the BC shaft, causes the reverse water flow from trays into the BC shaft. Water flows along the inclined ceiling of the lower floor to the perforated collectors on the front wall of the lower tray and is sprayed into the shaft volume. This passive spraying leads to further depressurisation inside the BCC. Spilled water from trays is collected on the BC shaft bottom and due to the inclination of the bottom flows through the corridor to the SG boxes. There it is accumulated together with water from the break and from the active spray system in the containment sump. Finally, it is transferred to the suction side of ECCS and spray pumps (recirculation mode).

Accidents with significant smaller coolant release have a similar but longer lasting course on lower pressure level. In order to prevent an undesirable reverse flow of the tray water, there are two DN250 relief valves installed in parallel on each tray (6 in Fig. 2.2).

Fig. 2.2 Details of the bubbler-condenser system



1	*BC shaft*	*4*	*Check valve DN500 (2 in series)*
2	*gap-cap systems*	*5*	*Air trap*
3	*Level of water solution (H_3BO_3)*	*6*	*Lockable relief valve DN250*

The valves are fitted with a special blocking system which, depending on BC shaft pressure, automatically locks or unlocks the valve. The blocking system is set to the value of 165 ± 5 kPa (absolute pressure). Above this value the valves are locked. Consequently, if during an accident (MB and SB LOCAs) pressure in the shaft does not exceed 165 ± 5 kPa, the valves remain unlocked and, in case of pressure drop in the shaft, allow equalisation of pressures before and behind the water seal - thus water remains in the trays.

The localisation of the accident is accomplished by active spraying into SG boxes which gradually reduces pressure in containment up to the minimum allowed value of 80 kPa (absolute) when the spray system is automatically switched off. A moderate vacuum in sealed area will prevent the release of radioactive substances. The vacuum is maintained by controlled actuation of active spray systems. A pressure decrease under the minimum value with possible consequent violation of system tightness is prevented by the deactivation of active spray systems.

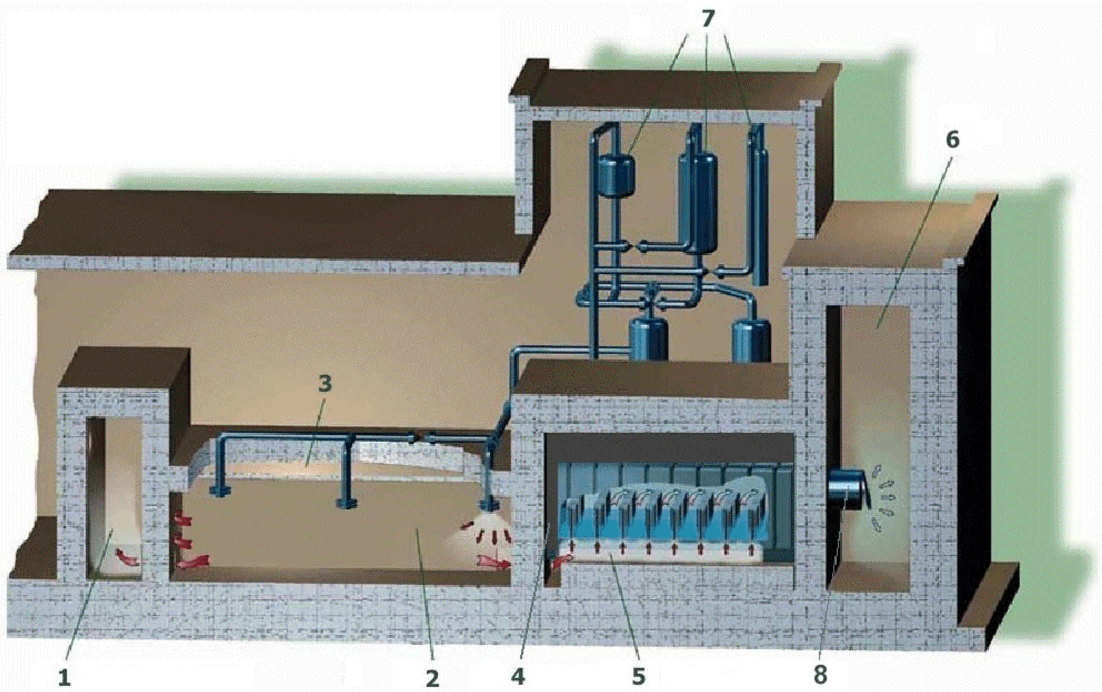
2.2 Short description of the EREC experimental facility BC V-213

The test facility BC V-213 (Fig. 2.3) has been designed and built-up especially for investigating thermal-hydraulic and fluid-structure interactions of the BC system under conditions typically expected during DBAs[1]. It is located in a separate building and consists of the following main systems and components:

- a simplified room system simulating the hermetic compartment system of the Paks NPP containment upstream of the BC tower;
- a bubbler condenser model consisting of 2x9 original sized gap-cap systems, corresponding side walls, bottom and ceiling parts with mechanical properties identical to the Paks Nuclear Power Plant and a corresponding air space above the bubbler condenser water volume of the trays;
- an air trap connected to the aforementioned air volume by a check valve;
- a relief valve to the BC shaft and a spray system providing the simplified room system with spray water;
- a blowdown system consisting of 5 interconnected pressure vessels, pipe systems and blowdown nozzles to provide the necessary mass- and energy reservoir to simulate the anticipated DBA blowdown rates at three different locations inside the compartments;
- the necessary auxiliary equipment including instrumentation and the data acquisition system.

[1] The facility was built under the funding of a PHARE project

Fig. 2.3   General view of the EREC test facility BC V-213



1	*Dead-end volume (V_0)*	*5*	*BC module (V_4)*
2	*SG box (break node, V_1)*	*6*	*Air trap (V_5)*
3	*SG box (V_2)*	*7*	*High pressure vessel system*
4	*BC shaft (V_3)*	*8*	*DN500 check valve*

Other items characterising the test facility are:

- dimensioning of the blowdown nozzle derived on the basis of the scale results of ATHLET calculations for the anticipated failure conditions of the reference NPP;
- preservation of the mechanical properties of the tray and the gap-cap systems, closely linked to the existing configuration of the Paks Nuclear Power Plant;
- preservation of scale characteristic main volumes and/or flow cross section areas of the prototype plant with limited modelling of the corridors between the steam generator boxes and the BC shaft;

scaling factor 1/100 for the design of the test rig volumes and the necessary mass- and energy reservoirs to simulate the variety of DBA conditions.

Geometrical data of the test facility BC V-213 are provided in Table 2.1.

Table 2.1. The Dimensions of Test Facility and Paks NPP Compartments

Designation unit symbol	Paks NPP	Test facility	Dimensions of Test Facility Compartments [m]
V0, m3	4670	46.53	1.42x6.5x5.04
V1, m3	7450	74.36	10.0x2.86x2.60
V2, m3	7400	73.84	10.0x2.84x2.60
V3, m3	6500	65	
V4, m3	6252	61.29	6.75x4.0x2.27
V5, m3	17800	178.20	3.24x5.50x10.0
Vw, m3	1354	12.70	(6.75x4.0x0.50)-0.5 F34
F01 = F10, m2	5.5	0.055	0.1x0.55
F02 = F20, m2	5.5	0.055	0.1x0.55
F12 = F21, m2	38.4	0.39	0.148x2.6
F13 = F23, m2	34.0	0.34	0.485x0.7
F34, m2	167	1.67	(1.855x0.05)x18
F45, m2	2.35	0.0235	diameter - 0.173

V 0 — deadline compartment volume;
V 1 and V 2 — volumes of the right-hand and left-hand side SG boxes respectively;

V 3 — volume of the accident localization shaft space upstream of the water seal:
V 4 — volume above water level in the BC;
V 5 — air traps volume;
V w — water volume in the BC trays;

F 01 , F 02 — cross sections of openings between the deadline compartment and the SG boxes;
F 12 = F 21 — cross section of opening interconnecting the SG boxes;

F 13 = F 23 — cross section of each half of the steam discharge corridor between SG boxes and shaft of BC;
F 34 — total cross-section area of the cap sections;
F 45 — cross-section area of the check valve.

Specific features of BC V-213

For the correct understanding of the tests results and for the transfer of these results to the real units specific features of the test facility should be taken into account. These features are: distortion of the volume-to-surface ratio; modelling of the break location; modelling of two BC sections.

Distortion of the volume-to-surface ratio

The scaling factor during the test facility design and construction was 1:100 concerning the volume, the relevant flow cross section areas and the energy input. Due to this the scaling of the linear and surface dimensions could not meet this factor. As a consequence of the scaling the test facility has approximately two times larger structure surfaces than the real containment, whereas the metallic structures of the BC module are about 35% larger. To make the ratio more similar to that of Paks NPP, most of the concrete walls of the test facility are insulated with wood. This feature should be taken into account regarding the assessment of heat losses and leads, finally, to a substantial complication in experimental results interpretation. The wooden insulation and the areas of the insulated surfaces are substantiated with corresponding calculations for the LB LOCA case (limited to 30 s, [2.10]).

Modelling of the break location

In the real unit the break will appear in the primary circuit (or main steam lines). At the test facility the break - rupture disk - is located at the end of the relatively long pipe-line. This causes flashing effects during the blow-down, which became significant specially in tests with relatively low energy input or steam flow.

Number of sections in the test facility

The 1:100 scaling factor in terms of BC sections was met installing two sections of original sizes instead of 1:100 scaled down 200 elements. It was chosen as appropriate solution under consideration that the main concern was the strength behaviour of the thin walled gap-cap systems. As a consequence the two sections in the test facility worked in conditions different from the real unit. There, the majority of single sections is located in the surroundings of other sections (from the point of view of heat losses for example). These circumstances should be taken into account during the transfer of the tests results to the plant.

A detailed description of the test facility BC V-213 is given in [2.9].

2.3 Previous BC research

A short summary of the BC research history

The early works related to the BC and performed in the former USSR have been summarised in a status report by OECD NEA CSNI (c.f. [2.0]) and in a number of publications therein. Accordingly the first experimental facilities involved a single gap-cap system and a multi gap-cap system, respectively, which were meant to confirm the design decisions.

A so called “Reduced BC Model”, including two halves of one gap-cap system of reduced length served to study condesation efficiency. This was followed by an “Enlarged Experimental Model” to investigate a system with several gap-cap systems connected to an air-trap simulator.

The OECD Support Group on "VVER-440 Bubbler Condenser Containment Research Work" (1991-1994) stated that supplementary research work is needed in various areas such as: dynamic loading of the cap-gap systems by mass flow induced differential pressure upon occurrence of a LOCA, oscillatory loading of the flat water pool trays by condensation phenomena, water carry-over into the air traps during the impulsive air transfer period.

Since that the BC research history can be briefly summarised as follows:

1994 EC launched the PHARE project NUC 93428 Bubbler-condenser Qualification Feasibility Study. It was completed in early 1996 and had the following conclusions:

- The structural behaviour of the pressure retaining boundary of the bubbler-condenser needs to be studied in depth experimentally.
- The thermal-hydraulic behaviour of the bubbler-condenser system needs to be tested on a test section which could replicate in full size the original configuration of a portion of the BC floor and which models the relevant adjacent systems. These tests shall generate the maximum loads to which the pressure retaining boundary can be subjected in case of DBAs.

1996 PHARE project PH2.13/95 “Bubbler-condenser Experimental Qualification” (BSEQ) was launched. The main objectives of the project were to investigate experimentally and analytically the behaviour of the BC during phenomena induced by postulated DBA.

1997 Licensing procedure of the Mochovce NPP, (c.f. [2.1] through [2.8])

1997 September: PH2.13/95 contract was awarded to Siemens-EdF-EA consortium.
December: PH2.13/95 project Kick-off meeting

Main tasks of the PH2.13/95 project:

- to design and to erect a test facility, which replicates a portion of a prototypical BC configuration of the Paks NPP; to perform thermal-hydraulic and fluid-structure interaction tests on a test prototype configuration which replicates the BC of Paks NPP; to perform pre-test and post-test analyses with appropriate computer codes.
- to design and to erect a test facility which replicates a portion of a prototypical BC configuration of the Dukovany and Bohunice NPPs; to perform structural verification tests on the weaker pressure-retaining steel structure of Dukovany and Bohunice NPPs under differential pressure which occurs during the first moments of a LOCA; to perform pre-test and post-test analyses with appropriate computer codes.
- both the above tasks were accompanied by analytical support with established computer codes, in order to make sure that the test configurations reproduce the NPPs and that the test results are relevant for the NPPs. In addition, some small-scale separate effect tests were carried out to support the large-scale test facilities.

1998 Start of the construction of the EREC facility

February: Kick-off meeting of the TSO project SK/HU/CZ/TS/08 "EU TSO Support to CEEC and CIS Nuclear Regulatory Authorities and their TSOs in the Safety Related Evaluation of the VVER-440/213 Bubbler-condenser Experimental Qualification Project";

December: Completion of the TSO project SK/HU/CZ/TS/08; issue of the project final report [2.11].

1999 June: EREC test facility is completed with 7 months delay. September - October: Three tests performed; Users team and TAC meetings

December: Issue of the final project report [2.12]; in general conclusions of the BCEQ project stressed that the tests demonstrated the BC functionality and the physical parameters are far below the values which could create any risk to the BC.

2000 April: 11th OECD Support Group Meeting in Berlin; discussions had evidenced several contradictory points of view amongst the experts addressing interpretation and extrapolation of the obtained results. The OECD Support Group recommended [2.13]:

- to perform further post-test analyses of the results obtained so far (incl. investigations of non-uniformities in temperature and flow velocity distributions observed in the EREC tests);
- to use post-test calculation results for the bubbler condenser design qualification, code validation and modelling improvements;
- to perform tests for completion of the EREC test matrix i.e. simulating MSLB, the medium and small break LOCA accidents ;
- to perform further bubbler condenser investigations for the Kola nuclear power plant.

October: VEIKI performed detailed post test calculations answering questions raised by the OECD group with regard to the three EREC experiments.

2001 Atomic Question Group (AQG) report on Nuclear Safety in the context of EU enlargement: “Measures to complete the regulatory review regarding full verification of the performance of the containment bubbler condenser system for all design basis accident.”

2002 June: Kick-off meeting of the TSO project PR/TS/17 "EU TSO Support to CEEC Nuclear Regulatory Authorities and their TSOs in the safety related evaluation of the VVER 440/213 Bubbler-condenser Experimental Qualification Project".

Main tasks of the project:

- Evaluation of EREC Test Facility related investigations performed in the PH 2.13/95 Project;
- Evaluation of VUEZ Test Facilities related activities performed in the PH 2.13/95 Project;
- Performance of independent post-test calculations; incl. post-test calculations of experiments in the EREC and VUEZ test facilities, investigation of the possible behaviour of BC during SBLOCA and MSLB, evaluation of experimental results with respect to the measured space effects;
- Review of the PH 2.13/95 Project final report.

Open questions prior to the BC Trilateral project

The OECD group recommended to perform post-test calculations and to carry out further tests. The following critical remarks have been raised [2.13]:

- Post-test analyses were not completed
- Non-uniformities in temperature and flow velocity distributions

- Differences in values of pressure (dp) between test and calculation
- Assessment of conservatism (test facility ↔ real BC)
- Further tests are needed to study the oscillation phenomena.

Methodological and technical preconditions set up for the additional tests

Clarification of the blow-down rate problem:

After the 11th Meeting of the OECD Support Group the EREC verified the blow-down rate by means of additional ATHLET calculations using measured vessel parameters (P, L). The blow-down rate used in the PH2.13/95 project was confirmed. It became clear that the VTI tube measurement did not give correct results on the first tenths second due to their inertia [2.14].

A question after the post-test calculation remained pending:

The calculation predicted 50% higher heat-up of water in the BC comparing the test results. To use the calorimetric method for determination the heat balances transient scenarios "with no water spill back" was selected.

Some minor changes in the instrumentation (relocation of and adding a few new sensors) were made which improved the outcome of the test significantly.

2.5 References

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[2.6] Evaluation of containment compartment members for load capability and final assessment, CONT04, NDA2/97/0336, Mochovce NPP, Slovakia, 1997 (restricted)

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[2.12] Kühlwein, K.; Hoffmann, D.; Orden, A.; Peturaud, P
Final Project Report, Rep.-Nr. BC-D-SI-EC-0535, Revision 0
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EREC, April 2002

3 Analyses

3.1 VEIKI post-test calculations of the BCEQ tests

The objective of the work was the resolution of open issues of the PHARE/TACIS Project PH 2.13/95 "Bubbler Condenser Experimental Qualification (BCEQ)" with more detailed post-test analysis. The calculations were performed with the CONTAIN code utilizing detailed nodalisation and with the GASFLOW 3D computational fluid dynamics (CFD) code. The most important conclusions of the work are summarized below.

Flow patterns and material distributions in the experimental facility

GASFLOW simulations provide flow velocity fields and material distributions in much greater detail compared to lumped parameter code modeling. 3D analysis was applied to thermal-hydraulic transient phenomena in the experimental facility.

Analyses predicted a rather complex flow pattern around the bubbler condenser. The fluid flow leaving the boxes and passing through the connecting channel goes around the BC facility at both sides. The stream then enters the volume below the BC trays in different paths: one part passes through the holes of the I-beams, another part turns around at the rear end of the facility. A relatively small part of the stream enters the facility from the front side. The reason is that the front flow is impacted and redirected by the BC pedestal and front gridplate.

According to the 3D calculations, early phase gas flows are directed in opposite directions at two sides of the connecting channel (Fig. 3.1, Fig. 3.2). This flow pattern was confirmed by measurements, too.

GASFLOW simulations facilitated the development of detailed nodalisation for the CONTAIN code (Figs 3.3 and 3.4). Detailed CONTAIN analyses concerning velocities and mass fluxes are basically in agreement with the 3D calculation. Mass flow, concentration and temperature distributions in the BC were obtained with detailed modeling of the volumes around and within the bubbler condenser.

Pressure load on the BC wall

Measurement and calculation results concerning the pressure difference load on the BC wall deviated to substantial extent: calculated values (26 kPa) exceeded the measured loads (19.8 kPa) more, than to 25 %. First calculations performed with detailed nodalisation within the present study reproduced basically the same results.

Elastic compression of the BC walls – and a corresponding internal pressure rise – was a suspected reason of this controversy. Therefore, a specific input was developed for the CONTAIN code to model the volume shrink due to the deformation of the BC membrane walls. Volume compression was determined from linear displacement measurements located at different walls (bottom, top, side) indicating displacements up to 15-22 mm.

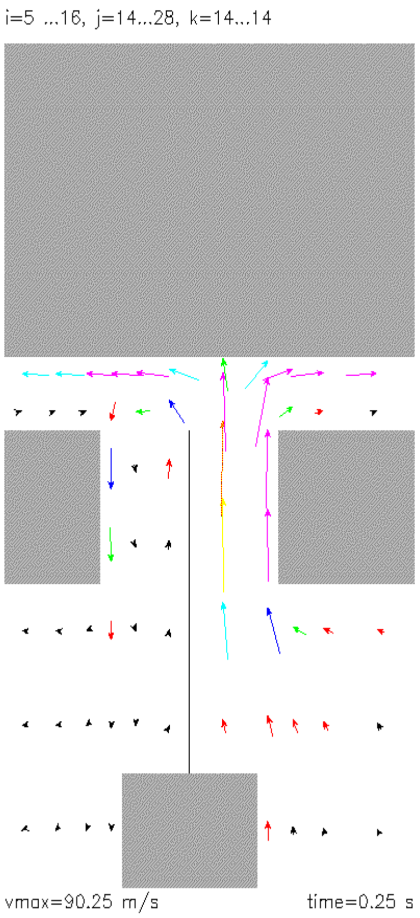

Fig. 3.1 - Flow through the connecting channel (top view fragment)

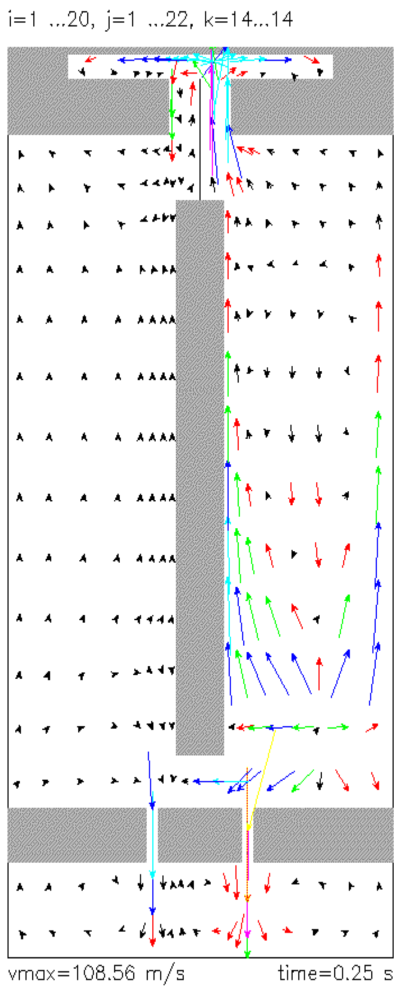

Fig. 3.2 - Flow between the boxes, the conn. channel and the dead volume (top view)

Sensitivity analyses indicated that pressure differences calculated with assumption of the BC volume compression were close to the test results within measurement error bounds (Fig. 3.5). The pressure load issue therefore can be resolved by the BC volume compression effect, and the discrepancy between measurement and calculation results can be explained.

Temperature distribution in the BC trays

Test results indicated the existence of a temperature distribution along the bubbler condenser (Fig. 3.7). Temperature values were higher at the front and the rear trays, while lower values were obtained for the middle tray rows. CONTAIN calculations with a subdivided bubbler condenser model predicted the same tendency of temperature distribution (Fig. 3.6). However, the calculated differences between maximum and minimum values were smaller than the measured temperature differences. The phenomenon is caused by non-homogeneous steam mass flows to individual tray rows as a result of flow distributions. Smaller water pool masses existing at the front and rear trays also contribute to this effect.

The energy balance issue remained unresolved. The calculations for all the three tests predicted much higher heating of the BC water, than the average heating derived from the temperature measurements.

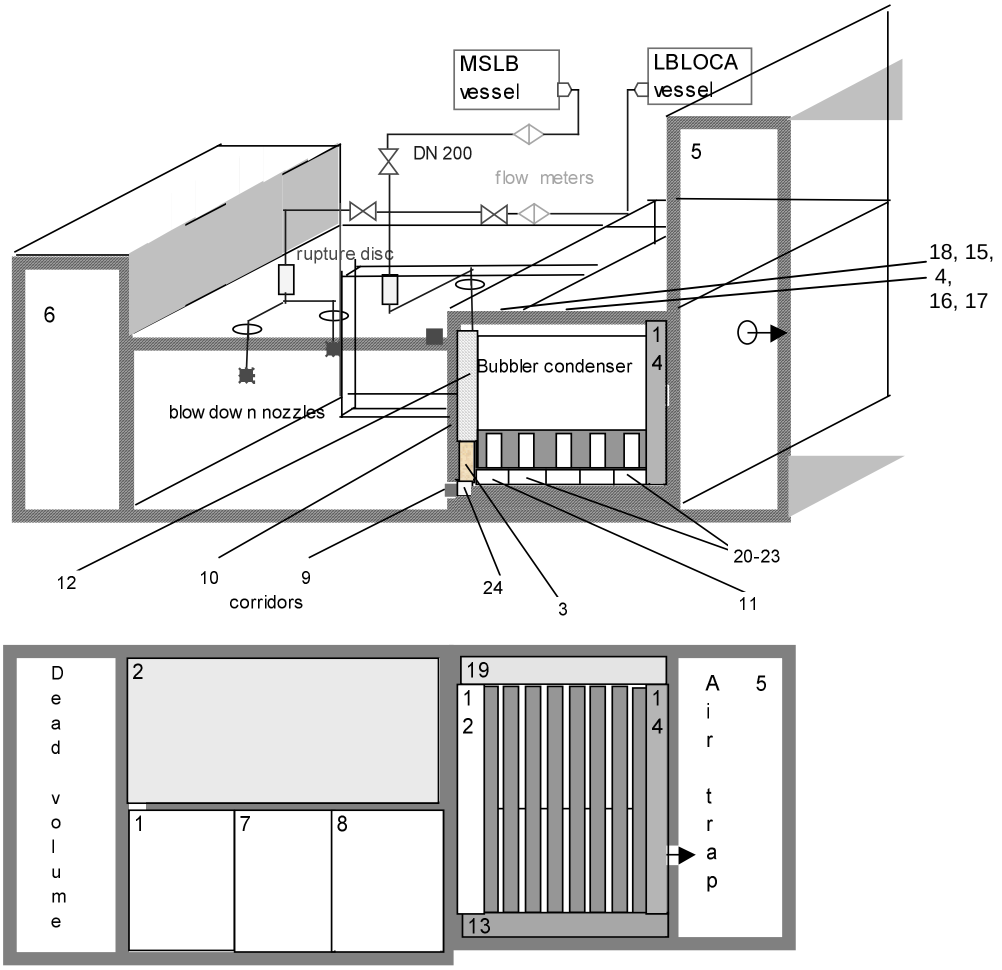

Fig. 3.3 - The EREC Test Facility and its nodalisation concept

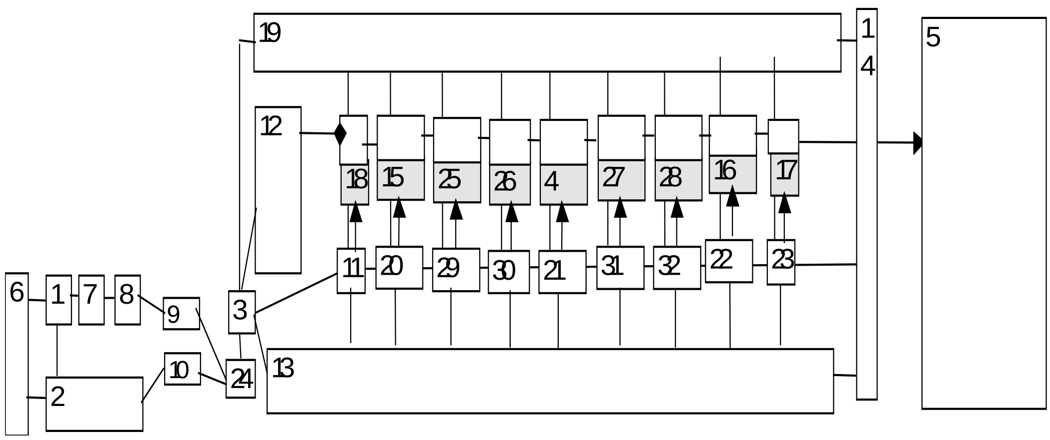

Fig. 3.4 - Detailed nodalisation of the EREC Test Facility for the CONTAIN code

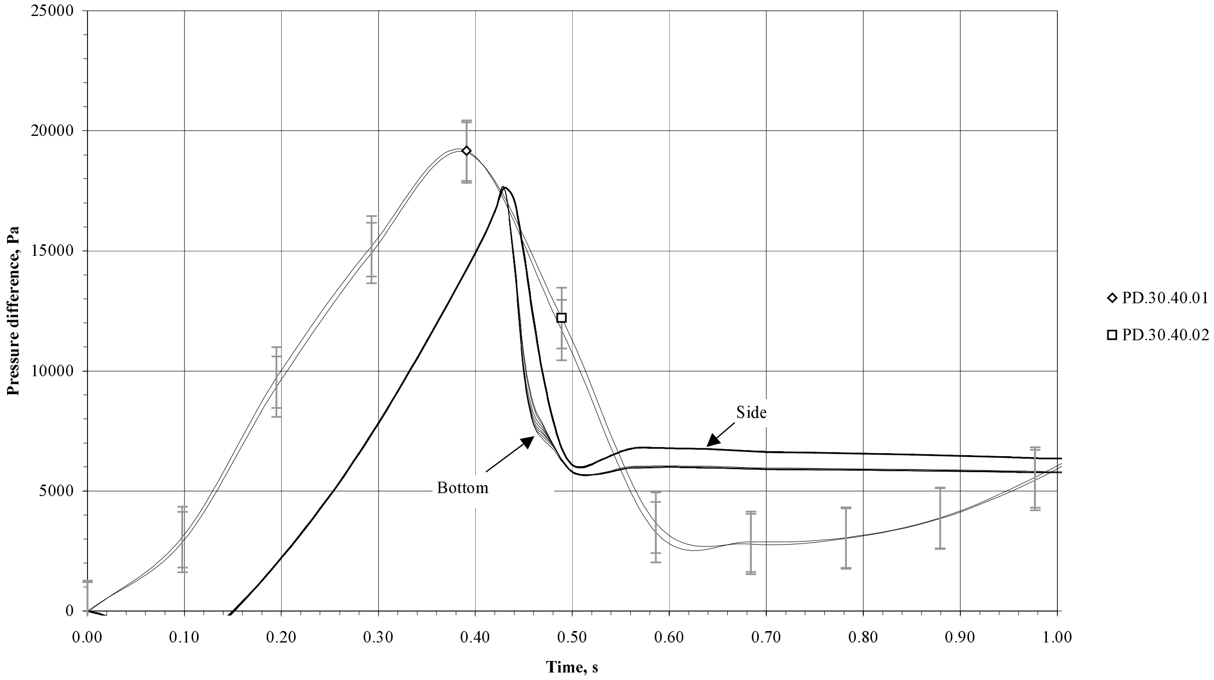

Fig. 3.5 - CONTAIN code calculation with assumption of the BC compression. (Test No. 5)

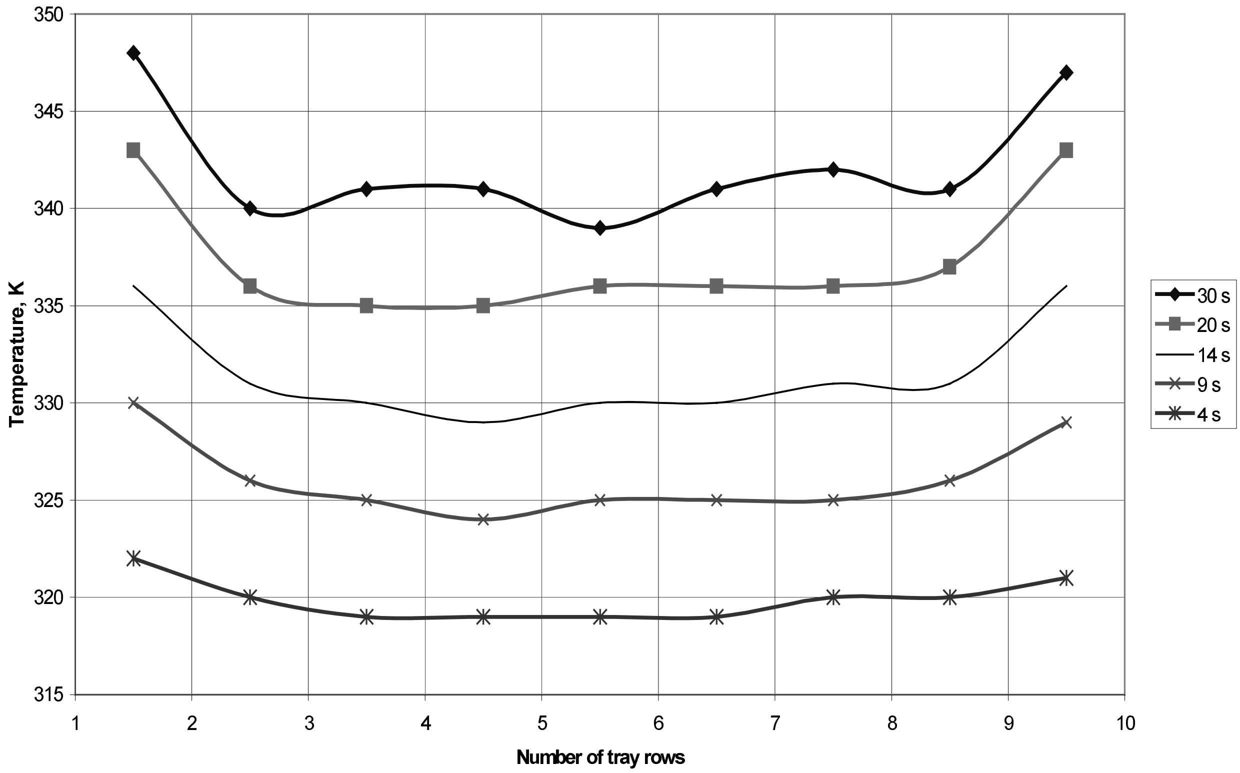

Fig. 3.6 - Calculated water temperature distribution along the BC at different times. CONTAIN code calculation.

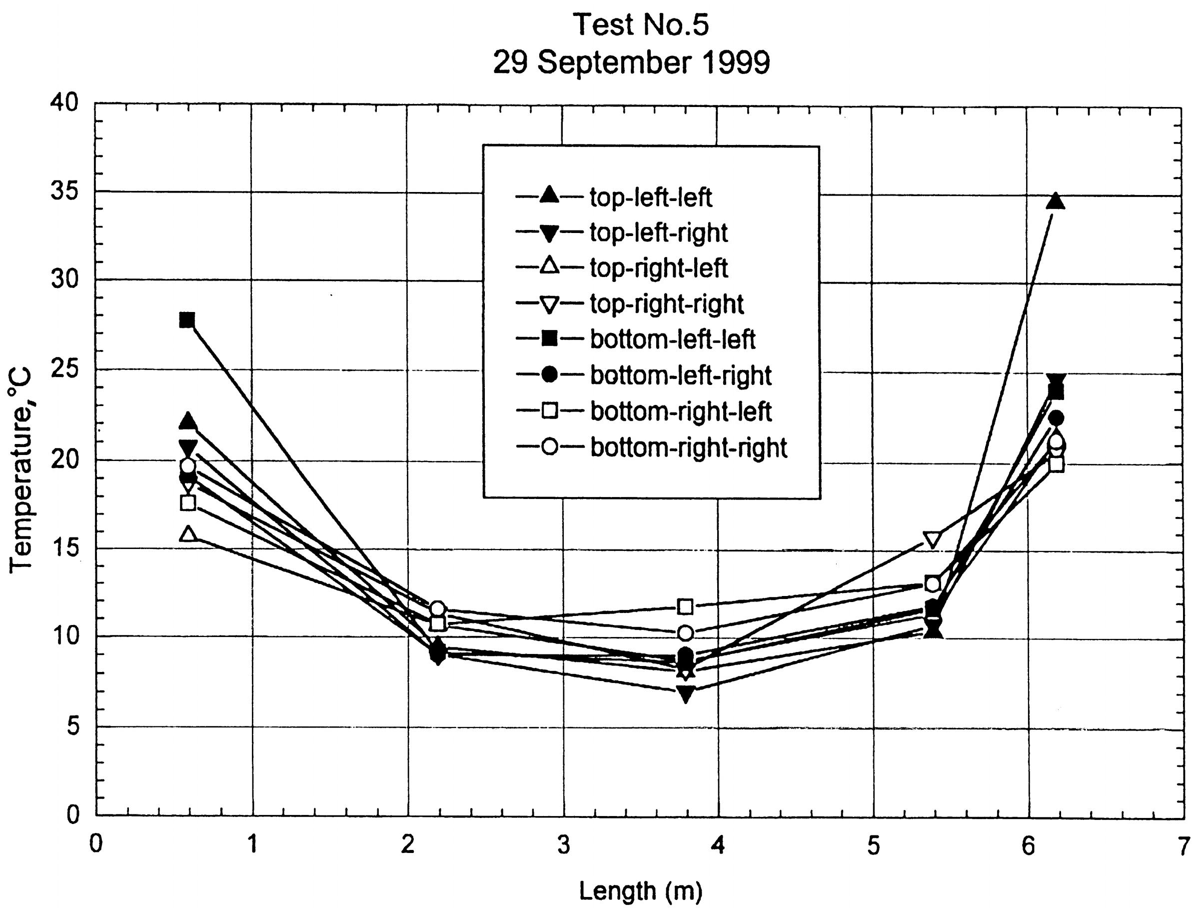

Fig. 3.7 - Measured water temperature heat-up distribution along the BC length at 40 s.

BC air volume temperature and air trap temperature

Earlier BCEQ post-test analyses indicated much higher values than test measurements for BC air volume and air trap temperatures. The CONTAIN code originally did not model any water entrainment from the pool to the atmosphere region. At the same time, video records of the tests confirmed the existence of very intense two-phase flows in the BC. Therefore, a simplified entrainment model was added to the CONTAIN code to take into account the effect.

Sensitivity calculations confirmed that discrepancies between calculated and measured temperature values can be attributed to water entrainment phenomena (Fig. 3.6). Temperatures calculated with this model were close to the test values, and inexplicable temperature peaks in the previous BCEQ calculations did not appear any more.

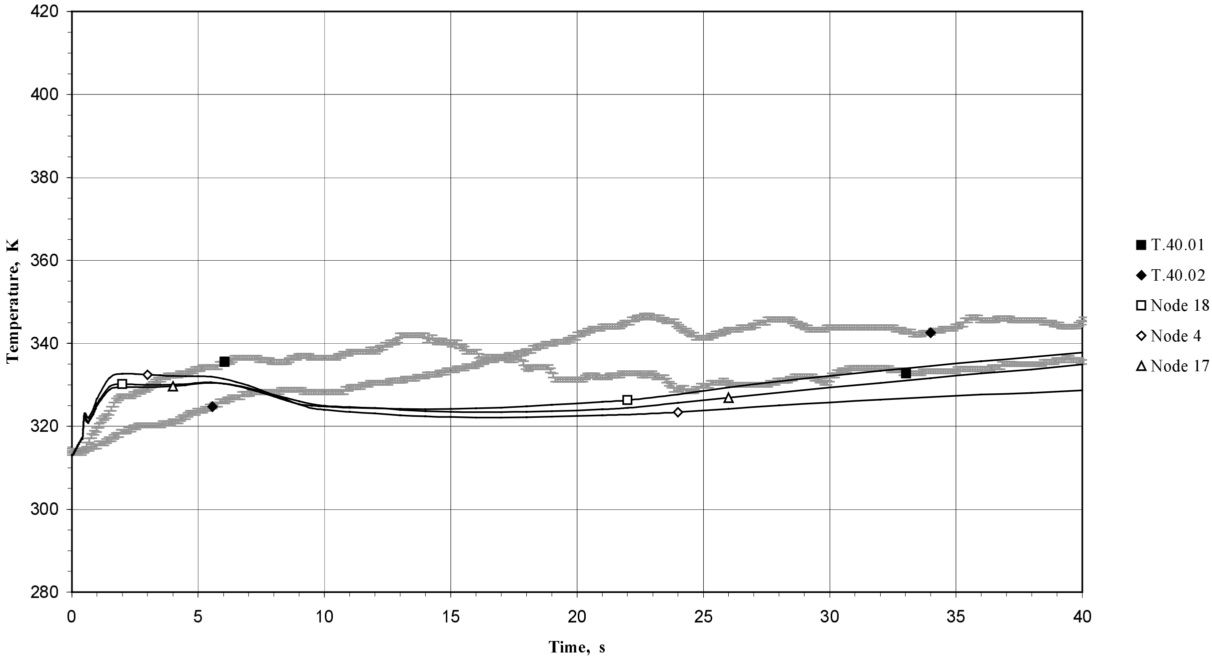

Fig. 3.8 - CONTAIN code calculation vs. BCEQ Test No. 5 results. Temperature of the BC air volume

3.2 Calculations of MB and SBLOCA

In the frame of the OECD Support Group on Bubbler-condenser Containment Research Work and of the OECD Bubbler-condenser Steering Group the issue of possible consequences of MB and SBLOCA on processes ongoing in the BC system of NPP with VVER-440/213 was discussed thoroughly. From former BWR related experiments it is known that in case of LOCA with low mass flows with a high steam content injected into a cold water pool the BWR suppression system is likely to run into condensation oscillations, which may endanger the construction. As the working principle of VVER Bubbler-condensers is the same as in BWR pressure suppression systems the issue has also to be assessed.

In order to get a better insight into the processes during MB and SBLOCA at VVER a set of calculations was performed by VEIKI and GRS. CONTAIN calculations were performed by VEIKI for the Paks NPP containment in the Phare/Tacis Project PH 2.13/95 “Bubbler Condenser Experimental Qualification” for LOCAs DN73 and DN46 [3.1]. The RALOC code has been applied by GRS for the investigation of the response of a typical VVER-440/213 containment in the frame of a project sponsored by the German BMU (Federal Ministry of the Environment, Nature Conservation and Nuclear Safety) for anticipated LOCA DN40 and DN10 [3.2].

3.4 References

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RALOC4 analysis of postulated LOCAs DN10 and DN40 in NPP with
WWER-440/W-213
Technical Note, TN-WFF-1/02, GRS Berlin, October 2002

4. Experimental approach

4.1 Motivation and objectives for the tests

The concerned nuclear plants decided in 2001 to perform additional to Phare project tests at the EREC facility to close the open issues and answer remaininig questions (eg oscillation phenomena). Although part of the open questions were answered by that time by VEIKI post test calculations, it was decided to go ahead with the test to dispel any doubt concerning the safety function of the BC in case of DBAs. Additional goal was to get extra experimental data for the code verification and validation.

Knowing the results from the tests performed in 1999 it deemed unnecessary to go on with the previous test matrix. That matrix was set up during the design and construction of the test facility and covered large variety of the possible transients and loads to the BC. After several rounds of discussions it was decided to perform a main steam line break test and two medium break LOCA transients. Definition of the size of LOCA was influenced by the existing transient calculations and by the judgement of the test facility limitation concerning modeling very small breaks. Finally the 200 and 90 mm break sizes were selected.

During the consideration of break sizes as an important aspect was taken into count to avoid the water spill back from the bubble trays providing better conditions for the calorimetric assessment of heat losses.

4.2 Analytical and experimental approach

Characteristics of the planned tests:

MSLB (Main Steam Line Break simulation) under conditions proposed originally in the PHARE Project (BC water level 500 mm, duration 1800 sec, simulated break location - as close as possible to Bubbler Condenser).

MBLOCA (Medium Break **LOCA 200 mm** simulation) the size of the simulated break was proposed to be 200 mm, in order to prevent total water discharge from tray (BC water level 500 mm, duration 1800 sec, simulated location of break - as close as possible to BC).

SBLOCA (Small Break LOCA - according to EREC equipment possibility scenario was changed via Medium Break **LOCA 90 mm** simulation). The necessary time for accident simulation was determined based on the pre-test calculations (BC water level 500 mm, duration 3600 sec, simulated break location - medium distance from the Bubbler Condenser), due to smaller flow rates condensation effects in BC are of interest.

The detailed specific test conditions were based on consultations with the national research institutes and on discussions within the SG.

Scope of the analytical works performed

<u>Pre-test calculations</u>

A. Plant blow-down and containment calculations for the representative scenario

These calculations were performed to have a basis for preparation of test scenario and for comparison with the EREC pre test blow-down proposal.

B. EREC TF blow-down

For the EREC facility the blow down calculations of each specific case were performed with ATHLET code to define the blow down rates and enthalpy in order to define and agree initial and boundary conditions of each test to be convenient as possible to NPP scenario. When it was necessary, several iteration steps were made to achieve the best results.

C. Plant containment calculations

These calculations prior to the tests (also with proposed EREC data) were done to have a basis for comparison and possible requirements to EREC to modify test conditions in order to keep representativeness and/or conservatism of the tests being prepared. Wide discussion was concentrated especially to MSLB test preparation, where several proposals have been treated to reach a technical consensus.

D. EREC TF containment calculations

It was appropriate to perform these calculations prior to the tests, in order to be ready for the discrepancies caused by the modeling.

Responsible organizations and codes used in pre-test phase

	A	B	C	D
Transient	Blow-down, plant	Blow-down, EREC TF	Containment plant	Containment EREC TF
MSLB	VEIKI/ APROS	EREC/ ATHLET VEIKI	VEIKI/ CONTAIN NRI/ COCOSYS VUJE/ TRACO	VEIKI/ CONTAIN NRI/ COCOSYS VUJE/ TRACO
SBLOCA	VUJE/ RELAP	EREC/ ATHLET VUJE	VEIKI/ CONTAIN NRI/ COCOSYS VUJE/ TRACO	VEIKI/ CONTAIN NRI/ COCOSYS VUJE/ TRACO
MBLOCA	NRI/ RELAP	EREC/ ATHLET NRI	VEIKI/ CONTAIN NRI/ COCOSYS VUJE/ TRACO	VEIKI/ CONTAIN NRI/ COCOSYS VUJE/ TRACO

<u>Post-test calculations</u>

The goal was to perform additional validation of containment codes and provide both industry and regulators with well-validated codes serving as best estimate calculation tools for any type of DBAs involving BC functioning. Results of post test calculations were summarized in 3x3 reports on transients which give a unique possibility to assess the capability of applied codes. This work – consequence of which goes well beyond the present trilateral project – can be valued as a benchmarking practice.

Responsible organizations and codes used in post-test calculations

	A	B	C	D
Transient	Blow-down corrected – based on measured data	EREC TF Containment	EREC TF Containment	EREC TF Containment
MSLB	EREC/ATHLET + VEIKI + NRI + VUJE	VEIKI/CONTAIN	NRI/ COCOSYS	VUJE/TRACO
SBLOCA		VEIKI/CONTAIN	NRI/ COCOSYS	VUJE/TRACO
MBLOCA		VEIKI/CONTAIN	NRI/ COCOSYS	VUJE/TRACO

The diagram of the methodology is in the figure below.

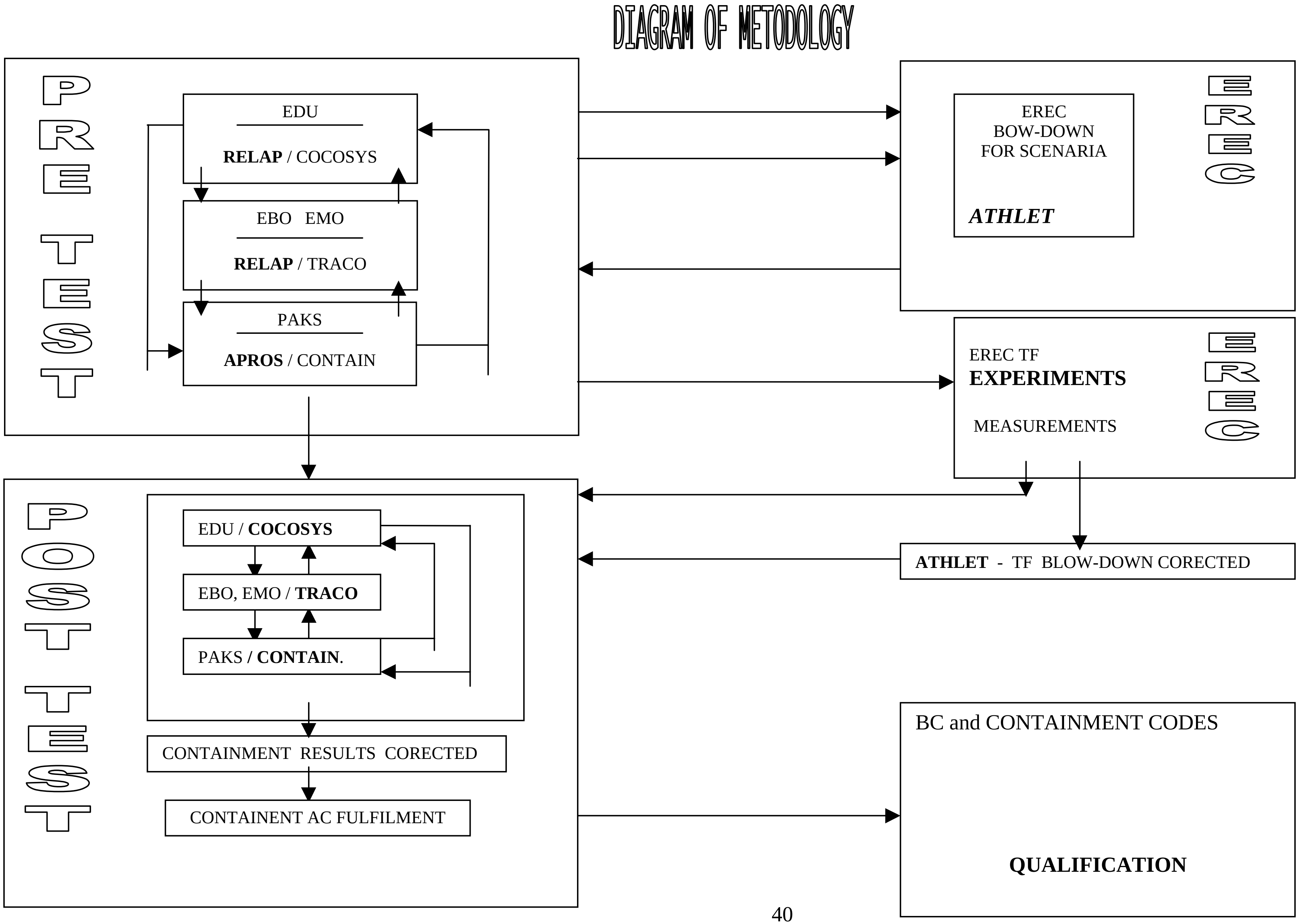


DIAGRAM OF METODOLOGY
PRE TEST
EDU
RELAP / COCOSYS
EBO EMO
RELAP / TRACO
PAKS
APROS / CONTAIN
EREC
EREC
BOW-DOWN
FOR SCENARIA
ATHLET
EREC
EREC TF
EXPERIMENTS
MEASUREMENTS
POST TEST
EDU / COCOSYS
EBO, EMO / TRACO
PAKS / CONTAIN.
CONTAINMENT RESULTS CORECTED
CONTAINENT AC FULFILMENT
ATHLET - TF BLOW-DOWN CORECTED
BC and CONTAINMENT CODES
QUALIFICATION

4.3 Justification for the choice of scenario

During the discussion of tests scenarios two main questions were considered: Should a small break LOCA test be performed and what sizes of the small break would have. The utilities and their support organizations expressed concerns regarding the added value of the small break test at the test facility. Due to the specificity of the test facility mentioned in Chapter 2 there were doubts that SBLOCAs will produce any effects to the bubbler-condenser.

The results of the performed tests justified the expert's concern: In the case of the 90 mm LOCA the maximum of dp on the trays was 5 kPa, which demonstrated that the inflow of the air-steam mixture was ongoing without dynamic effects. In case of smaller breaks this value of dp would not have been reached or just for a short interval of time.

4.4 Test description and conduct

Tests were performed in June and July of 2002. The EREC staff prepared the test facility (TF) according to the agreement reached during the iteration process of pre-test analyses. The type and number of necessary measurement devices were agreed during the preparation.

Operation manual for the test preparation and the execution was compiled and handed over to the utility representatives. Representatives from the involved plants and their support organizations participated at the final checks of TF prior the test and during the test performance.

Prior each test a zero-stage printout was made about the measured values to document the initial conditions and the possible deterioration in the measuring channels. Test data were recorded on the TF computer with 10 Hz sampling speed. Tests were recorded on video as in the case of previous Phare project tests.

4.5 Results

The most important data from the tests – including tests from 1999 – are shown in Table 4.1. Columns contain the measured and the calculated values as well. The CONTAIN calculation results have been selected here because these data are available from the previous post test calculation.
The new tests have not revealed any problems concerning the BC function.
During tests no oscillation effects were observed.

Table 4.1. Values of the main parameters (measured/calculated by CONTAIN)

Test	Break location	P_1max [kPa]	T_1max [^{0}C]	P_5 max [kPa]	dPmax [kPa]	dTwa [^{0}C]
LBLOCA N5	F	276/286	130/132	208/216	19.17/17.62	15/29
LBLOCA N4	C	251/248	127/127	202/202	15.84/18.25	15/28
LBLOCA N1	M	209/225	121/124	19/196	11.16/11.09	13/19
MSLB	C	152/160	112/172	150/152	7.1/8.8	5/12
200 mm LOCA	C	145/156	104/112	145/149	5.7/6.9	5/10
90 mm LOCA	M	136/142	102/108	137/137	4.8/5.2	5/17

Legend: P1,T1 – pressure and temperature in the break compartment P5 – pressure in the airtrap
dP – pressure load on the tray dTwa – average value of the heat-up of the tray water
F,C,M – location of the break: far, close and middle

The discrepancy between the measured and calculated maximum atmosphere temperatures in the MSLB test is discussed in detail in Chapter 5.

Systematic discrepancies remained between measured and calculated values of the BC water heat-up caused most likely by the differences between the actual and the modeled heat losses from the trays.

4.6 References

[4.1] Post test calculations of tests on EREC TF, VEIKI, 2002 November

[4.2] Post test calculations of tests on EREC TF, VUJE, 2002 November

[4.3] Post test calculations of tests on EREC TF, UJV REZ, 2002 November

5. INTERPRETATION OF THE RESULTS

The following discussion is based on the comparison of the test results with the post-test calculation results. Three codes have been used in the analyses: CONTAIN (VEIKI) [5.1], COCOSYS (NRI) [5.2] and TRACO (VUJE) [5.3]. The codes provided generally similar, but obviously not identical results for most parameters. The aim of this chapter is the interpretation of the results, not code comparison, therefore the discussion will be based on CONTAIN data, unless specifically indicated. However, the diagrams of parameter histories include plots of COCOSYS and TRACO results as well.

Measurement error bands are shown in the plots of test measurements. For the sake of clarity, the error bands are listed here as follows:

- Error of pressure measurements: +/- 6 kPa
- Error of pressure difference measurements: +/- 1 kPa
- Error of temperature measurements: +/- 0.5 ^{o}C

5.1 Main Steam Line Break - MSLB

Blow-down history

The difference between the mass flow rate of pre- and post-test ATHLET calculations is quite large in the first few seconds. After 8 seconds both curves are very similar. The discrepancy between the injected mass curves is about 10% at 1800 s.

The pre-test and post-test enthalpy versus time curves calculated by EREC using ATHLET code are very similar from 5 seconds. The calculated enthalpy curve from the measured values shows a very good agreement with the ATHLET calculation until 50 s. Then the difference becomes about 100-200 kJ/kg.

Pressure history

<u>Pressure in the break compartment (Fig. 5.2).</u>

The shape of the calculated pressure curve by CONTAIN code is similar to the measured one. The discrepancy between the measured and calculated overpressure values in the highest degree is about 20% all the while.

CONTAIN gives conservative evaluation, the maximum pressure is about 10 kPa higher, and a pressure decrease is minor between 150 and 300 s than the measured one. From 400 s CONTAIN predicts well the pressure decrease due to the steam condensation on spray droplets and on walls.

<u>Pressure in other compartments.</u>

Similar trends can be observed in these cells. CONTAIN slightly overestimates the maximum pressure.

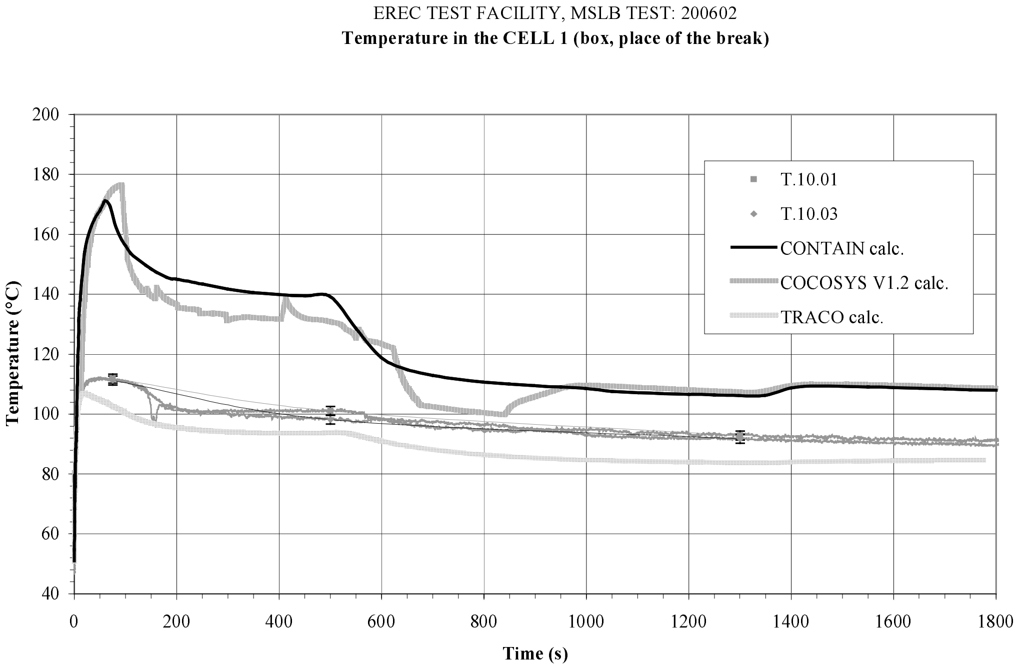

EREC TEST FACILITY, MSLB TEST: 200602
Temperature in the CELL 1 (box, place of the break)
T.10.01
T.10.03
CONTAIN calc.
COCOSYS V1.2 calc.
TRACO calc.
Temperature (°C)
Time (s)

Fig. 5.1

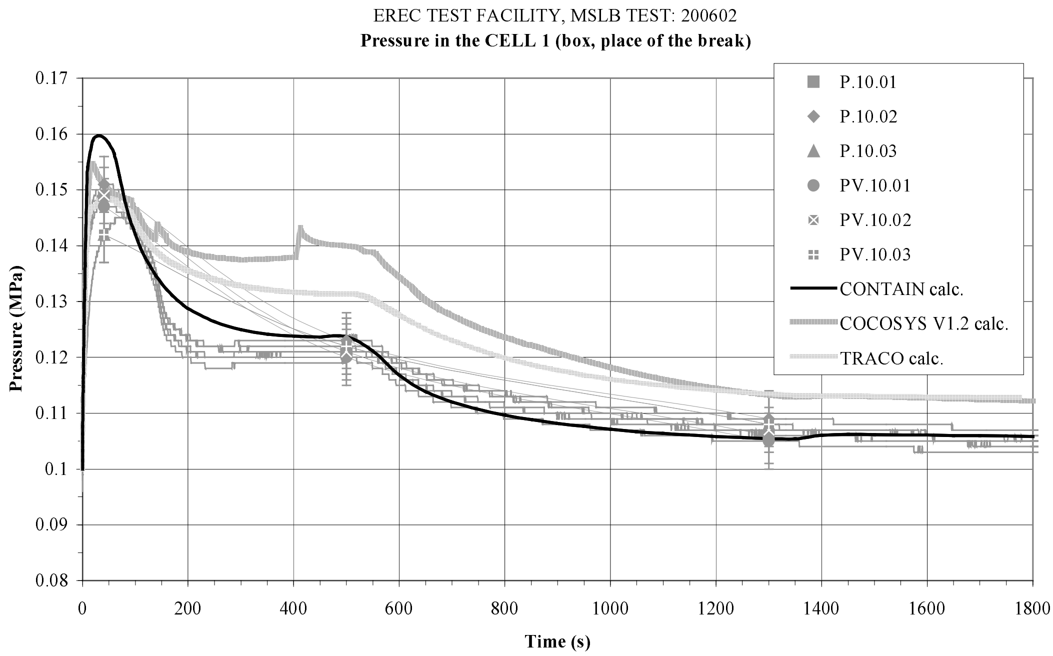

EREC TEST FACILITY, MSLB TEST: 200602
Pressure in the CELL 1 (box, place of the break)
P.10.01
P.10.02
P.10.03
PV.10.01
PV.10.02
PV.10.03
CONTAIN calc.
COCOSYS V1.2 calc.
TRACO calc.
Pressure (MPa)
Time (s)

Fig. 5.2

Temperature history

Temperature in the break compartment (Fig. 5.1).

Water droplets fall out from the gas volume or evaporate at the very start, therefore CONTAIN predicts that the maximum temperature of the gas volume is nearly the same as the temperature of inlet steam (around 200 ^{o}C). Due to the effect of heat loss and the injected water droplets (spray system) the temperature decreases and converges to the measured values. There is a discrepancy between the calculated and measured values, which amount in the maximum value to about 70 ^{o}C and to less than 20 ^{o}C after 10 minutes.

The reason of this deviation is that the non-equilibrium CONTAIN model predicts superheated state in the break compartment with water droplets depleted from the break compartment gas volume. Similar trend was obtained with COCOSYS, while the TRACO code reproduced the trend very well. In case of CONTAIN the sensitivity studies proved that artificial droplet retention in the break volume would eliminate the discrepancy between the code predictions and test results.

Temperature in other cells

The difference between the predicted and the measured temperatures is generally less than 10 - 15 ^{o}C. Mostly the calculated value is between the two measured temperatures.

Pressure difference on the tray structure

Figs 5.3, 5.4 and 5.5 show the measured and calculated pressure differences in different time frames.

CONTAIN calculates only the opening of the water seal, then the inertial effect of the water is not modelled. The calculated maximum pressure load is 8.8 kPa versus the measured 4.8 kPa, overestimated by CONTAIN, the conservatism of the code is about 4 kPa. The measured pressure load fluctuation, which is not calculated, has a maximal amplitude of 4 kPa. This oscillation lasts about 5 s.

The steam-air mixture flows through the water seal while the pressure load is higher than the hydrostatic pressure of the water on the tray. The duration of this period is about 54 s, CONTAIN predicts quite well this value (50 s).

Water conditions on the trays

Water level on the tray

CONTAIN calculates a nearly constant water level, about 0.49 m, because the condensed steam mass changes the water level negligibly and the code does not calculate the pool swelling. According to the measurement the water level behaves in a different manner. After the water lock opens, there is a strong fluctuation between 0.1 and 1 m, then the water level becomes 0.53-0.58 m. From about 60 s until 150 s the water level sinks under 0.45 m.

It was assumed that part of the water spills back from the trays because the check valve suspected to be closed or partly closed during that time.

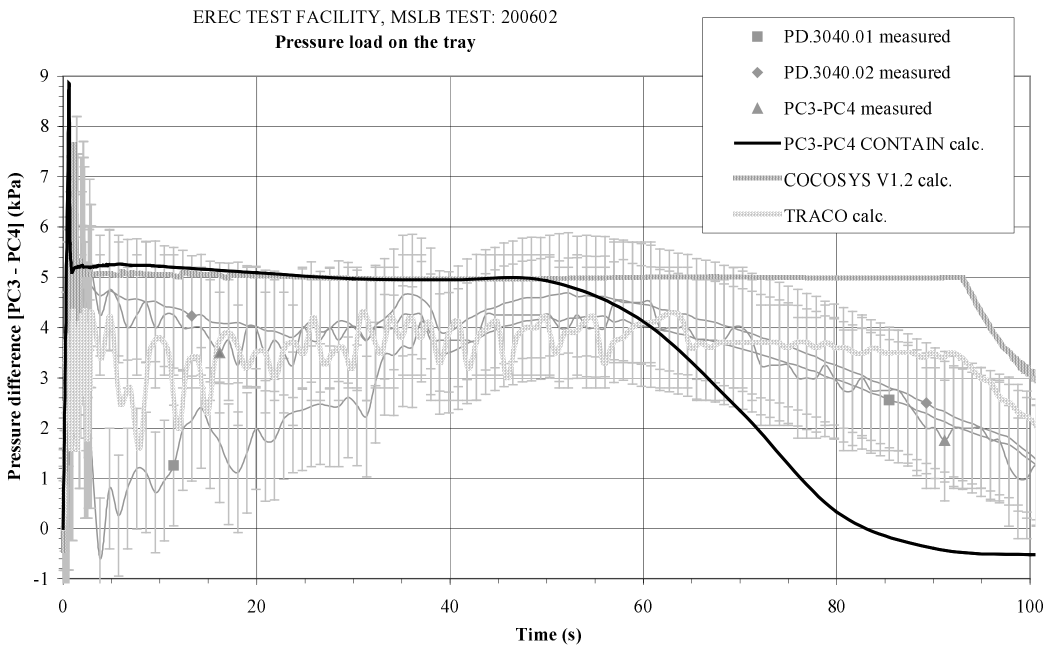

EREC TEST FACILITY, MSLB TEST: 200602
Pressure load on the tray
PD.3040.01 measured
PD.3040.02 measured
PC3-PC4 measured
PC3-PC4 CONTAIN calc.
COCOSYS V1.2 calc.
TRACO calc.
Pressure difference [PC3 - PC4] (kPa)
Time (s)

Fig. 5.3

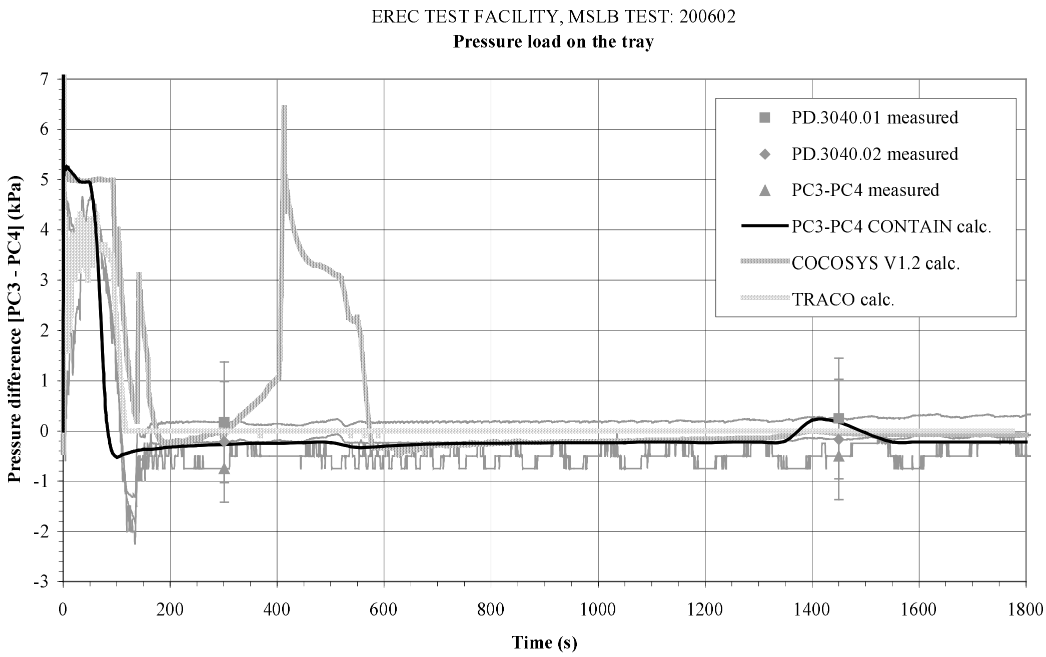

EREC TEST FACILITY, MSLB TEST: 200602
Pressure load on the tray
PD.3040.01 measured
PD.3040.02 measured
PC3-PC4 measured
PC3-PC4 CONTAIN calc.
COCOSYS V1.2 calc.
TRACO calc.
Pressure difference [PC3 - PC4] (kPa)
Time (s)

Fig. 5.4

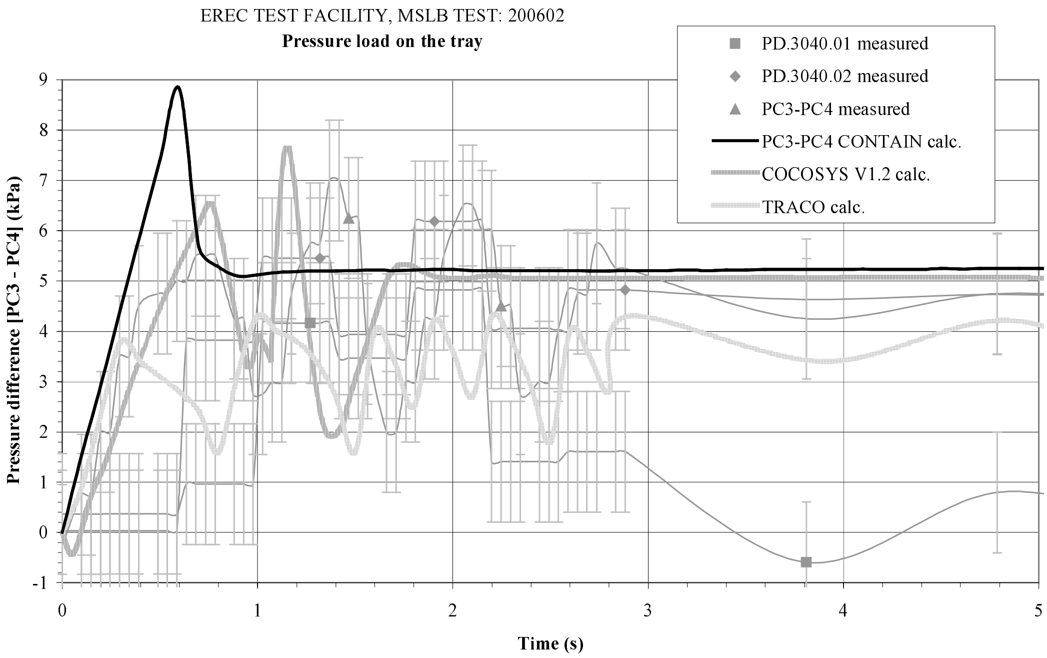

EREC TEST FACILITY, MSLB TEST: 200602
Pressure load on the tray
PD.3040.01 measured
PD.3040.02 measured
PC3-PC4 measured
PC3-PC4 CONTAIN calc.
COCOSYS V1.2 calc.
TRACO calc.
Pressure difference [PC3 - PC4] (kPa)
Time (s)
9
8
7
6
5
4
3
2
1
0
-1
0
1
2
3
4
5

Fig. 5.5

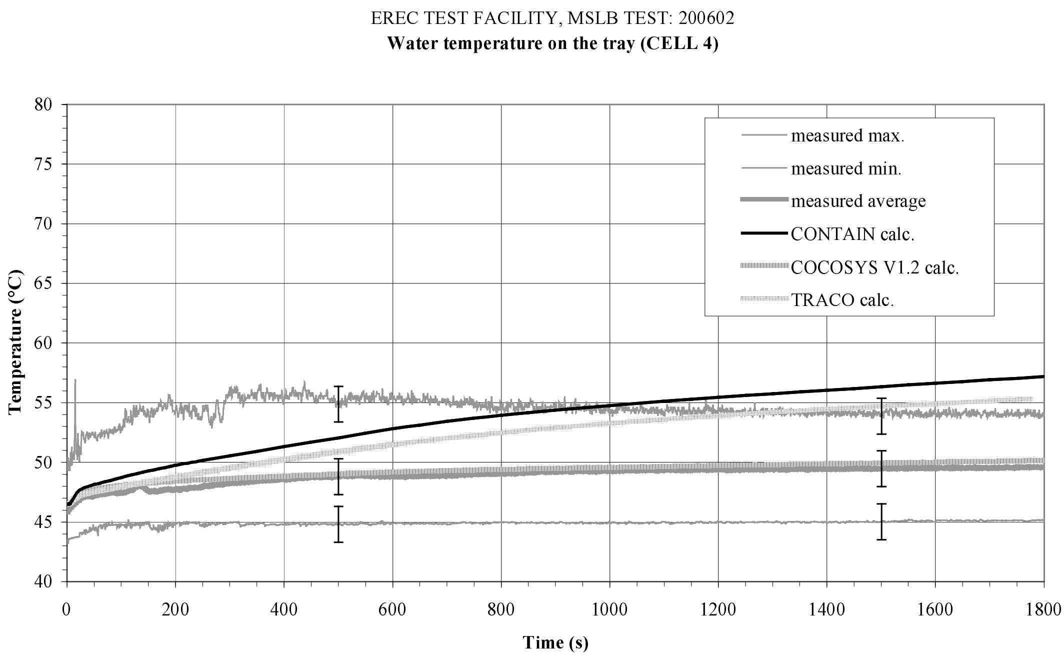

EREC TEST FACILITY, MSLB TEST: 200602
Water temperature on the tray (CELL 4)
measured max.
measured min.
measured average
CONTAIN calc.
COCOSYS V1.2 calc.
TRACO calc.
Temperature (°C)
Time (s)
80
75
70
65
60
55
50
45
40
0
200
400
600
800
1000
1200
1400
1600
1800

Fig. 5.6

In the CONTAIN calculation the suspected operation of the valve was not modelled, therefore the spill of the water could not be predicted.

Water temperature on the trays
The calculated water temperature (Fig. 5.6) is in the range of the average measured temperatures until 150 seconds. This time interval includes "the gas flow through the pool" period. From 150 s, when the heat transfer through the bubbler condenser walls, (temperature in shaft, cell 3) determines the water temperature, the code overestimates the water temperature. The calculated water temperature gradient deviates from the measured one from 150 seconds.

In the first 150 s CONTAIN predicts well the water heat up due to flow through the pool.

Flows between cells

Flow between box and shaft.

In the first 20s the velocity measurement and the calculated inter-cell flow pattern agree, and the values are similar. The maximum velocity (in the corridor between cell 1 and cell 3) is about 35 m/s for both measured and calculated cases. The timing of this maximum occurs at around 1 s. From 100 s till 1800 s, the CONTAIN predicting velocity is about 2-3 m/s in this corridor, but the flow meters for velocity in both corridors start and stop in this time span. It seems that this velocity is too small to measure it.

Flow through the check valves

Flow-meters were not installed to measure the velocity through the check valves. CONTAIN predicts flow between 4^{th} (bubbler condenser) cell and 5^{th} (air trap) from about 0.7 s until about 100 s. The maximum calculated velocity exceeds 100 ms. The relief valve between shaft and bubbler condenser (DN 250 valve) opens a few seconds after the other check valve locks. The predicted maximum mass flow through the DN 250 valve is 0.18 kg/s, it corresponds to about 5 m/s through the valve.

Conclusions

- Test parameters measured by different transducers provide values that are generally in agreement within the error bounds
- Most discrepancies between the measured and calculated values are not significant and the character of the predictions is conservative
- A few observed differences between the measured and calculated values can be explained

Challenge for the real nuclear power plant:

- Maximum pressure (0,151 MPa) is far from the design pressure (0.25 MPa)
- Maximum pressure load on the tray walls is 7 kPa, far less than the 30 kPa limit value
- The water level fluctuation disappears when steam starts to flow into the bubbler condenser pool
- Condensation-oscillations were not found. There was a water level fluctuation with a period of about 1 s at the very beginning, but it disappeared when steam started to flow into the bubbler pool. The reason of the fluctuation is the dynamic motion of the water seal. The amplitude of the fluctuation due to air flow is 3-5 kPa in the first 5 s.
- The main steam line break sequence investigated does not cause any significant challenge for the VVER-440/213 type BC and localization system

5.2 Medium Break LOCA (200 mm) - MBLOCA

Blowdown history

The difference between the mass flow rate of pre- and post-test ATHLET calculations is negligible in the first 100 seconds. Between 100 and 150 seconds the two curves are parallel but there is a difference of about 40% in the mass flowrate. After 300 seconds the pre- and post-test ATHLET mass flowrate calculations are identical.

The pre-test and post-test enthalpy versus time curves calculated by EREC using ATHLET code are fairly similar.

Pressure history

<u>Pressure in the break compartment (Fig. 5.8)</u>

The shape of the calculated pressure curve by CONTAIN code is similar to the measured one after 200 s. The gradients of the measured and calculated pressure curves are different in the first 10 seconds. Between 10 and 60 seconds the shape of the curves is similar. There is a discrepancy in the maximum pressure, it is about 20%. The calculated pressure is nearly constant between 60 and 150s while the measured value increases until 125s, then decreases. From 270 s the deviation between the measured and calculated values is less than 5 %.

CONTAIN gives conservative evaluation, the maximum pressure is about 0.1 bar higher, than the measured maximum. From 300 s CONTAIN predicts well the pressure decrease due to the steam condensation on spray droplets and on walls

<u>Pressure in other compartments</u>

Similar trends can be observed in the other cells, CONTAIN slightly overestimates the maximum pressures.

Temperature history

<u>Temperature in the break compartment (Fig. 5.7)</u>

In the first 600 seconds the T.10.01 thermometer indicates higher temperature (sometimes the difference is 10 ^{o}C) than the value of T.10.03. CONTAIN predicts higher temperatures, but the maximum difference between T.10.01 and the calculated values is about 10 ^{o}C. Between 300 and 400 seconds the CONTAIN results are equal to T.10.01 readings.

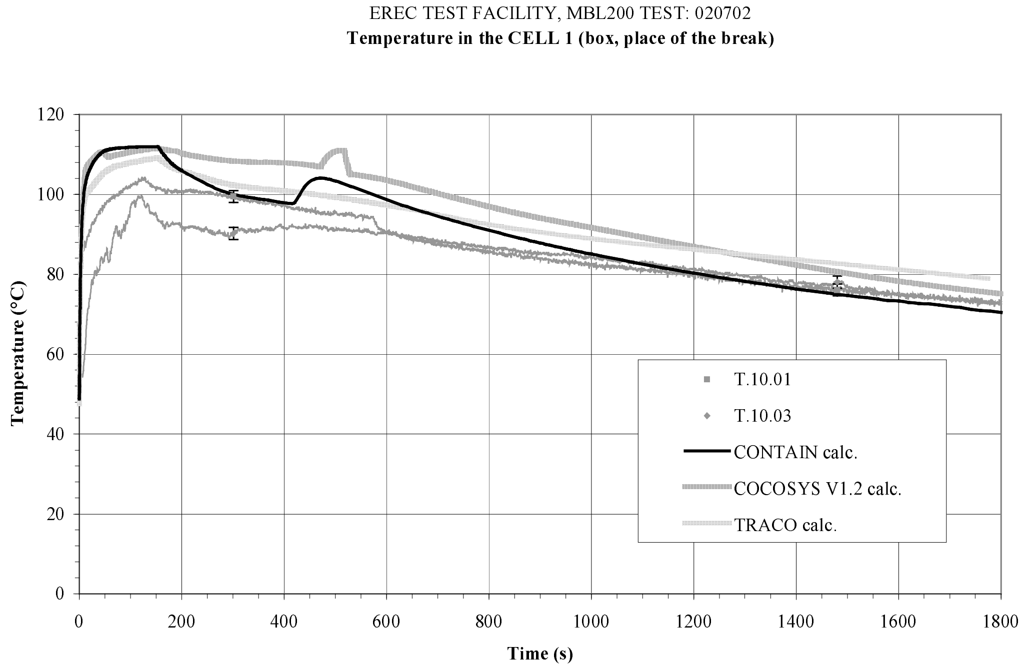

EREC TEST FACILITY, MBL200 TEST: 020702
Temperature in the CELL 1 (box, place of the break)
Temperature (°C)
Time (s)
T.10.01
T.10.03
CONTAIN calc.
COCOSYS V1.2 calc.
TRACO calc.

Fig. 5.7

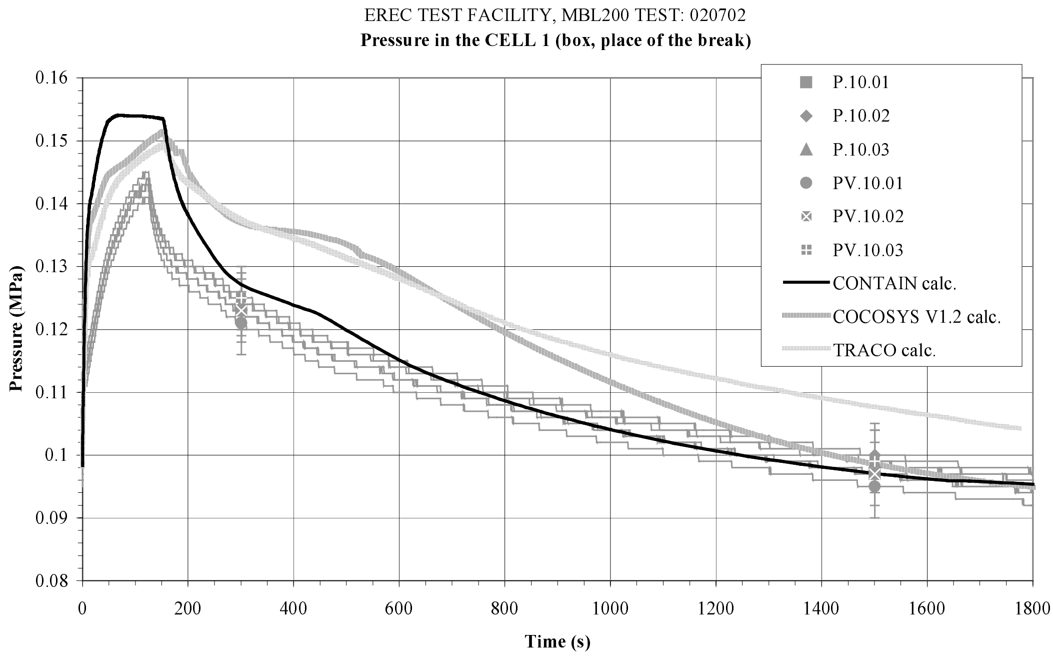

EREC TEST FACILITY, MBL200 TEST: 020702
Pressure in the CELL 1 (box, place of the break)
Pressure (MPa)
Time (s)
P.10.01
P.10.02
P.10.03
PV.10.01
PV.10.02
PV.10.03
CONTAIN calc.
COCOSYS V1.2 calc.
TRACO calc.

Fig. 5.8

Temperature in other cells

The difference between the measured values (T40.01, T40.02) and the measured and calculated values is generally less than 10 ^{o}C, with a maximum of 20 ^{o}C for some limited time periods.

Pressure difference on the tray structure

Figs 5.10, 5.11 and 5.12 show the measured and calculated pressure differences in different time frames.

The maximum pressure load is 6.5 kPa, overestimated by CONTAIN, the conservatism of the code is about 1.5 kPa. The pressure load fluctuation, which is not calculated, has a maximal amplitude of 1 kPa. The oscillation lasts about 3 s.

The steam-air mixture flows through the water on the trays while the pressure load is higher than the hydrostatic pressure of the water on the tray. The measured duration of this period is about 124 s, while CONTAIN predicts this interval for 153 s.

Water conditions on the trays

Water level on the tray

CONTAIN calculates a nearly constant water level, about 0.49 m, because the condensed steam mass adds to the water level negligibly and the code does not calculate the pool swelling. CONTAIN predicts the average water level on the trays. According to the measurement the water level behaves in different manner. After the water lock opens, there is a fluctuation between 0.4 and 0.7 m, then the water level becomes 0.53-0.56 m (because the water from the gap is added to the water on the trays). From about 124 s until 160 s the water level sinks to 0.5 m (the initial level).

Water temperature on the trays (Fig. 5.9)

The calculated water temperature ranges with the average measured temperatures until 260 seconds. This time interval includes "the gas flow through the pool" period. In the first 260 s CONTAIN predicts well the water heat up due to flow through the pool. The discrepancy between the measured and calculated average value is 3 ^{o}C. The code overestimates the water temperature from 260 seconds.

Flows between cells

Flow between box and shaft

In the first second the flow from break compartment to the shaft is predicted very well. The calculated velocity is between the two measured ones in the first 20s. The maximum velocity is about 25-35 m/s at around 1 s.

The flow from the other box half to the shaft is underestimated until 10 s. From 10 s the velocity measurement and CONTAIN calculated inter-cell flow pattern agrees and the values are roughly similar.

From 150 seconds the predicted velocity and measured velocity are in the same range, they are between 0-3 m/s.

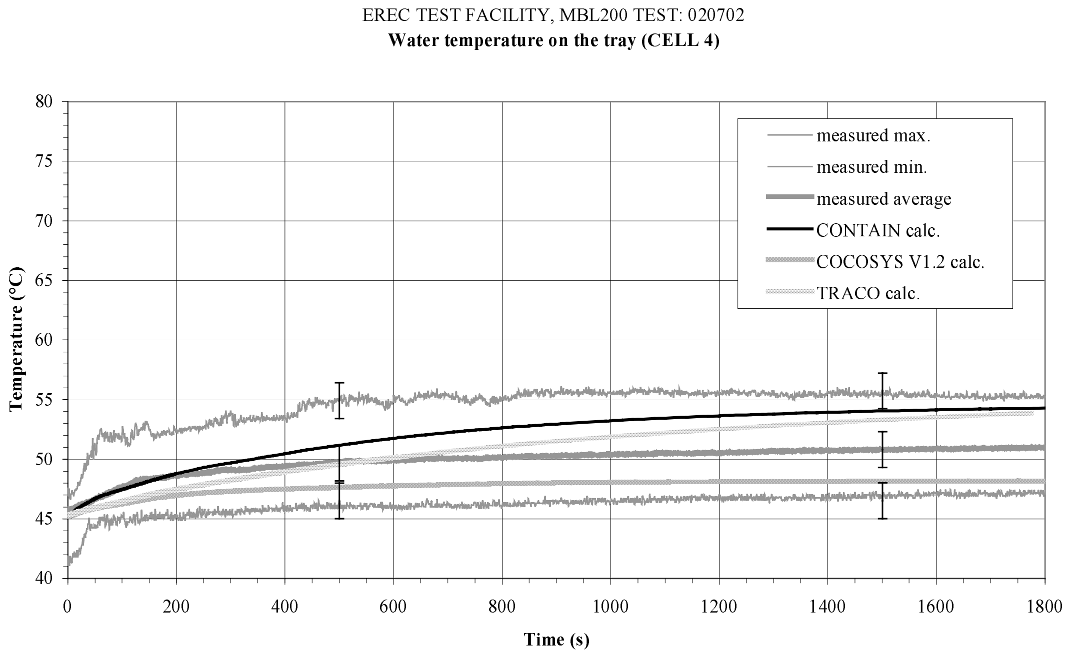


Fig. 5.9

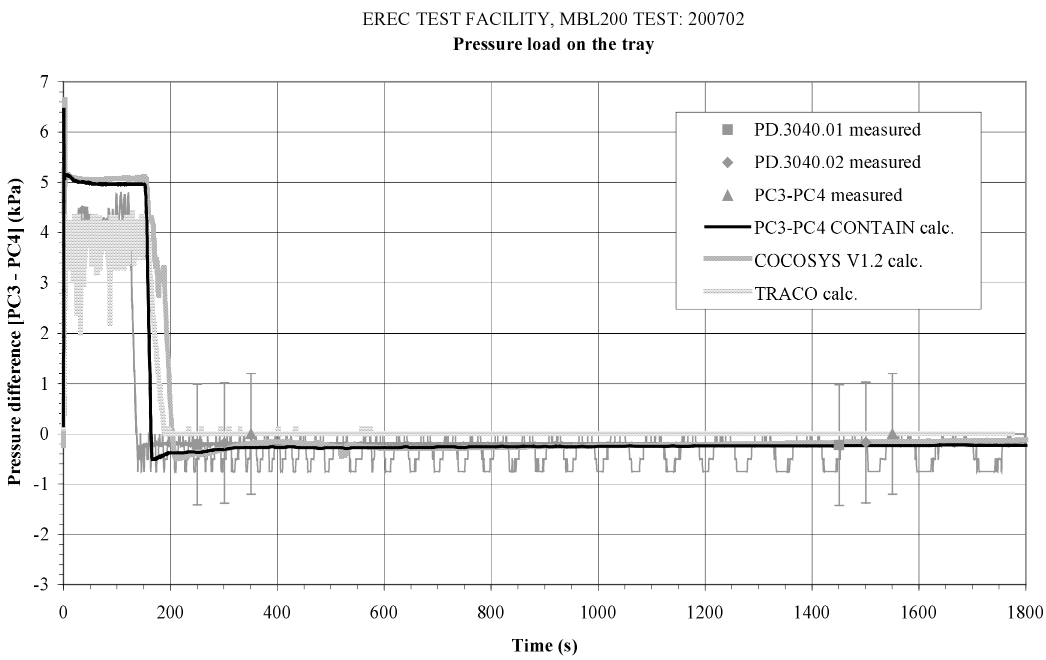


Fig. 5.10

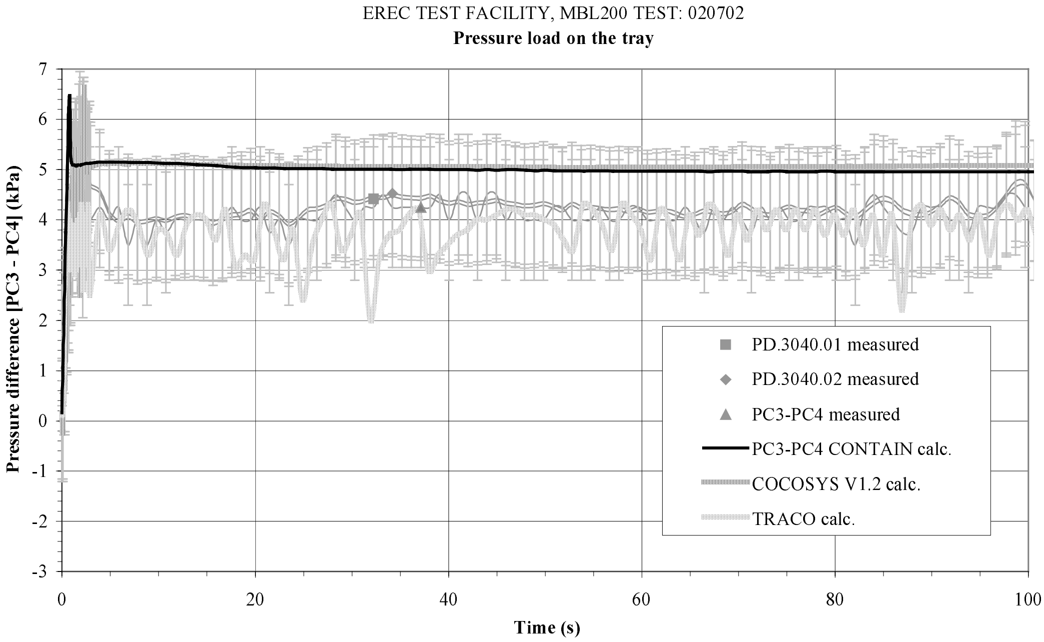


Fig. 5.11

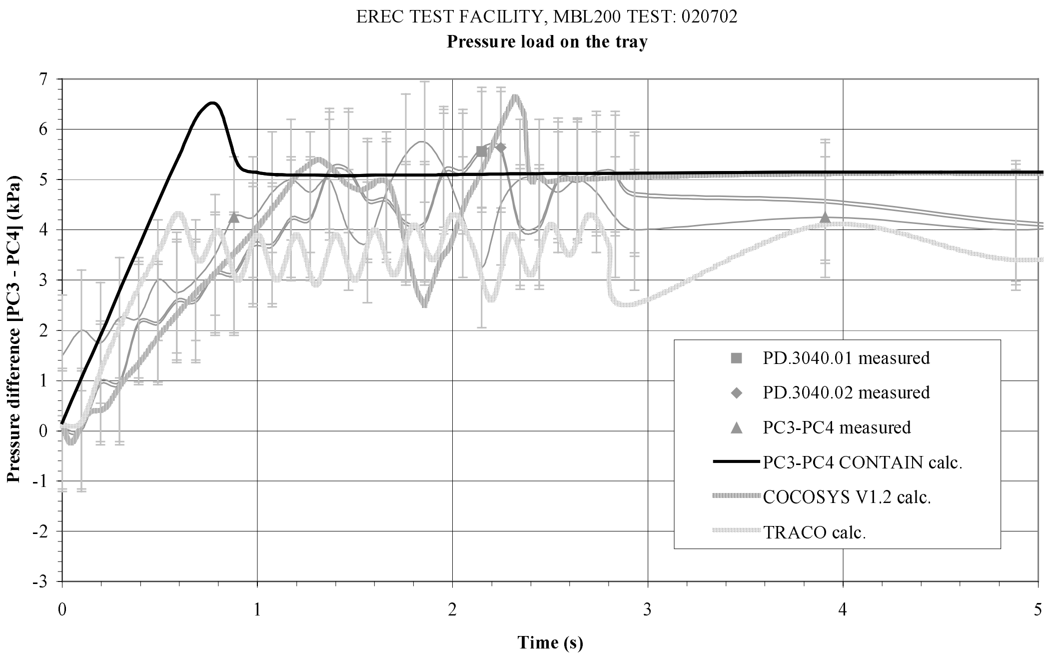


Fig. 5.12

The mass flow rates measured by different flow meters differ from each other, and from the calculated mass flow rate.

Flow through the check valves

Flow-meters were not installed to measure the velocity through the check valves. CONTAIN predicts flow between 4th (bubbler condenser) cell and 5th (air trap) from about 1.2 s until about 165 s. The maximum calculated velocity is about 85 m/s (2.5kg/s). The check valve between shaft and bubbler condenser (ND 250 valve) opens when the other check valve locks. The predicted maximum mass flow through the ND 250 valve is 0.18 kg/s, it corresponds to about 5 m/s through the valve.

Conclusions

- Test parameters measured by different transducers provide values that are generally in agreement within the error bounds.
- There were some minor problems as a few wrong thermocouples.
- The discrepancies between the measured and calculated values are not significant and the character of these predictions is conservative.
- The differences between the measured and calculated values can be explained.

Challenge for the real nuclear power plant:

- Maximum pressure (0.145 MPa) is far from the design pressure (0.25 MPa).
- Maximum pressure load on the tray walls (5.75 kPa) is far less than the 30 kPa limit value.
- The water level fluctuation is minor (a few milimeters) the pressure difference oscillation is smaller than 1 kPa.
- Condensation-oscillation did not appear during the test. The main reason of the pressure fluctuation is the dynamic motion of the water seal in the first 3 seconds.
- The medium break loss of coolant accident does not cause any significant challenge for the VVER-440/213 type containment and localisation system.

5.3 Small Break LOCA (90 mm) - SBLOCA

Blowdown history

The difference between the mass flow rate of pre- and post-test ATHLET calculations is minor. The largest discrepancy between the injected mass curves can be found at 600 s, it is about 2 kg/s. At 1300 seconds the total injected mass is 2000 kg in both cases. From this time the pre and post test mass flow calculations are identical.

The pre-test and post-test enthalpy versus time curves calculated by EREC using ATHLET code are very similar. The integrated energy difference becomes about 50 MJ (1.5%) at the end of the calculation.

Pressure history

Pressure in the break compartment (Fig. 5.14)

The calculated pressure gradient is increasing faster than the measured one in the first 100 s, then the calculated curve is enveloping the measured pressures from above.

The shape of the calculated pressure curve by CONTAIN code is similar to the measured one. The slope of the calculated pressure curve after the maximum value is similar to the measured one. Between 600 and 1500 s the shape of the calculated and measured curves is similar.

CONTAIN gives conservative evaluation, the maximum pressure is about 6 kPa higher than measured, and a pressure decrease is minor. It seems that the calculated heat loss is less than in reality.

Pressure in other compartments

Similar trends can be observed in other cells. CONTAIN slightly overestimates the maximum pressures and the calculated values are above the measured ones. The maximums of the discrepancies are about 0.1 bar, but the most part of the calculation time span the calculated values are inside of the given error limit of the measurements.

Temperature history

Temperature in the break compartment (Fig. 5.13)

During the whole test CONTAIN overestimates the temperature. The discrepancy is in the range of 1 to 7 ^{o}C. Calculated temperature shows the same trend as the predicted pressure. This overestimation may be caused by the heat transfer calculation between the atmosphere and walls. The accuracy of the CONTAIN calculation is 10%, assuming that the measurement is exact.

Temperature in other cells

The difference between the predicted temperature and the measured one is generally less than 10 ^{o}C with a maximum of 20 ^{o}C.

Pressure difference on the tray structure

Figs 5.15, 5.16 and 5.17 show the measured and calculated pressure differences in different time frames.
In this sequence the maximum pressure load equals to nearly the height of the water column on the tray. The inertial effect of the water is not too important in the SBLOCA case. The measured maximum pressure load is less than 5 kPa, but CONTAIN overestimates this value by 10%. During the time period when the flow through the water seal occurs (from 2.5 s till 490 s), a certain pressure difference oscillation could be observed. The maximum amplitude of this measured oscillation is about 1 kPa and the period of it is between 10 - 30 s. This oscillation is very slow, therefore it cannot be caused by condensation. The most probable reason for this oscillation is the opening and closing of the water seal.

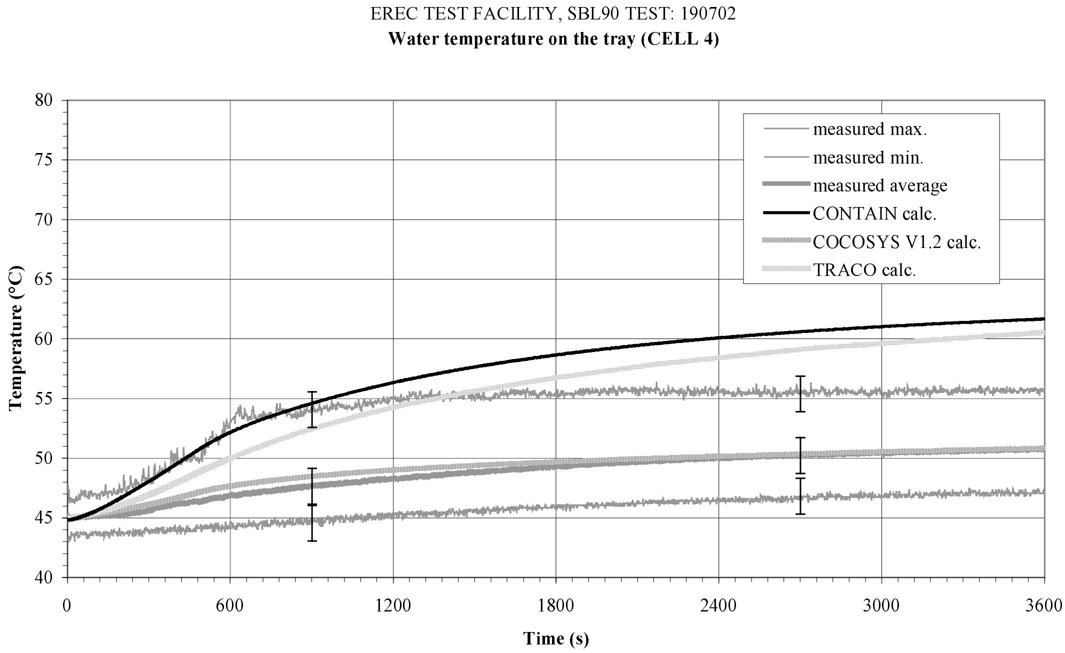


Fig. 5.13

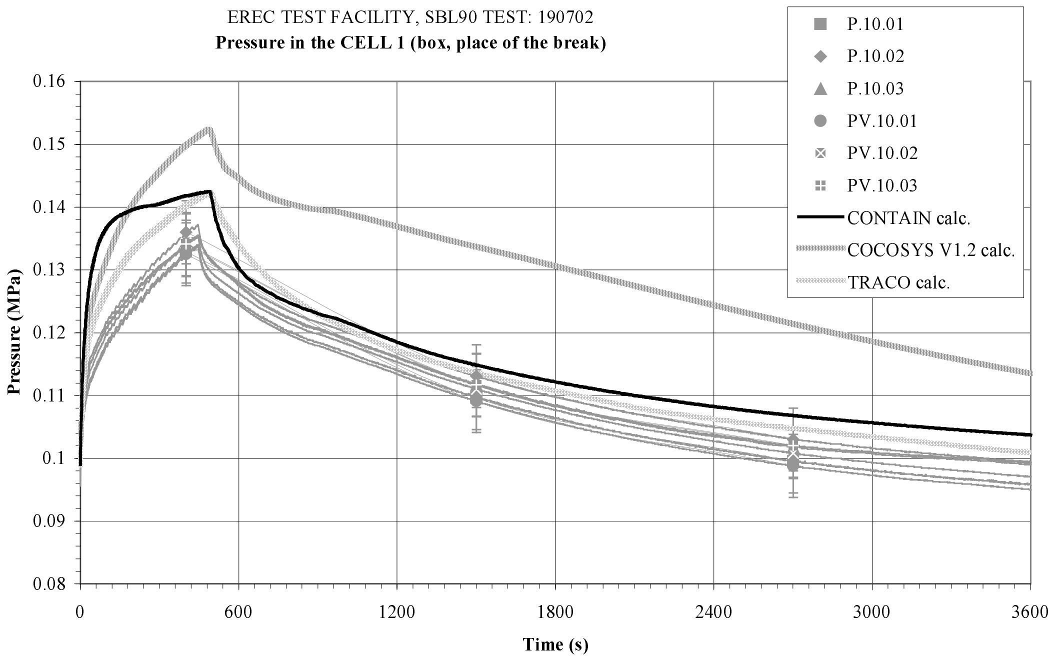


Fig. 5.14

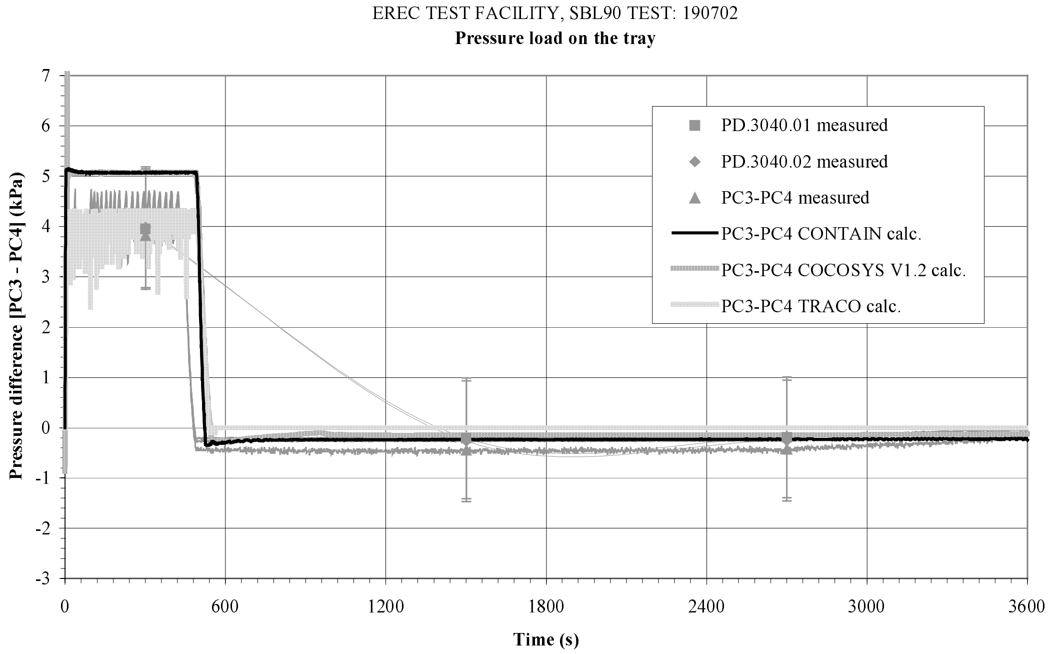


Fig. 5.15

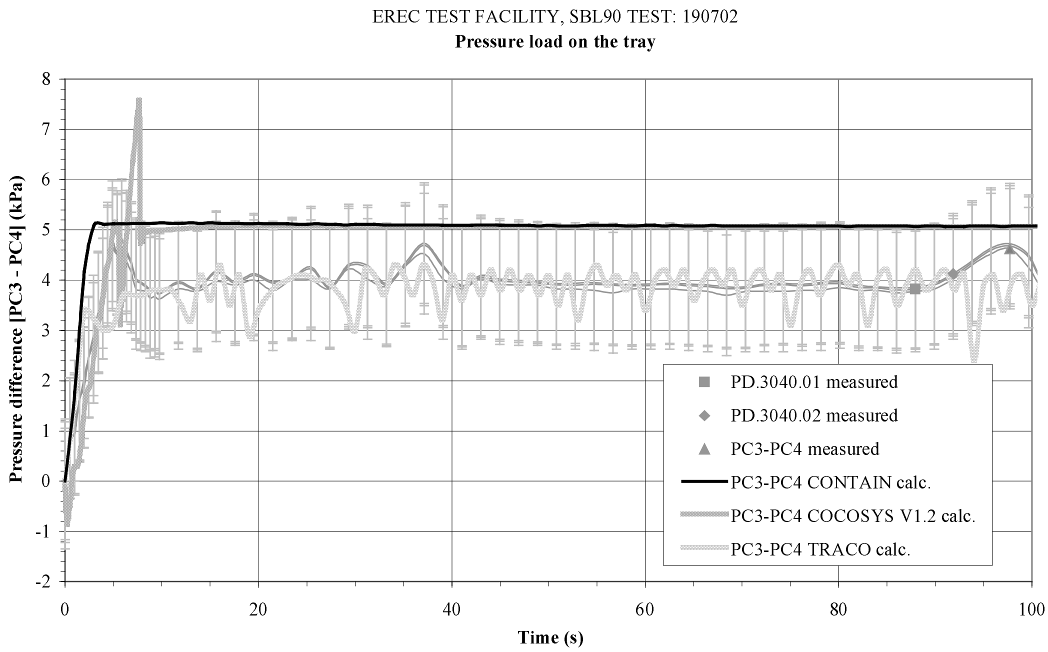


Fig. 5.16

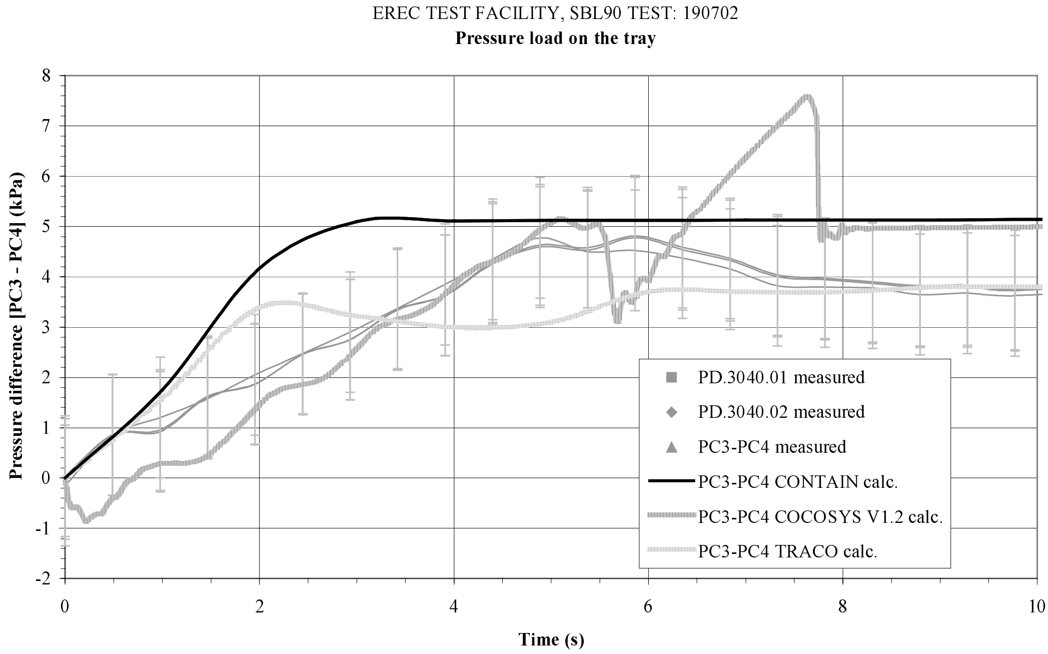


Fig. 5.17

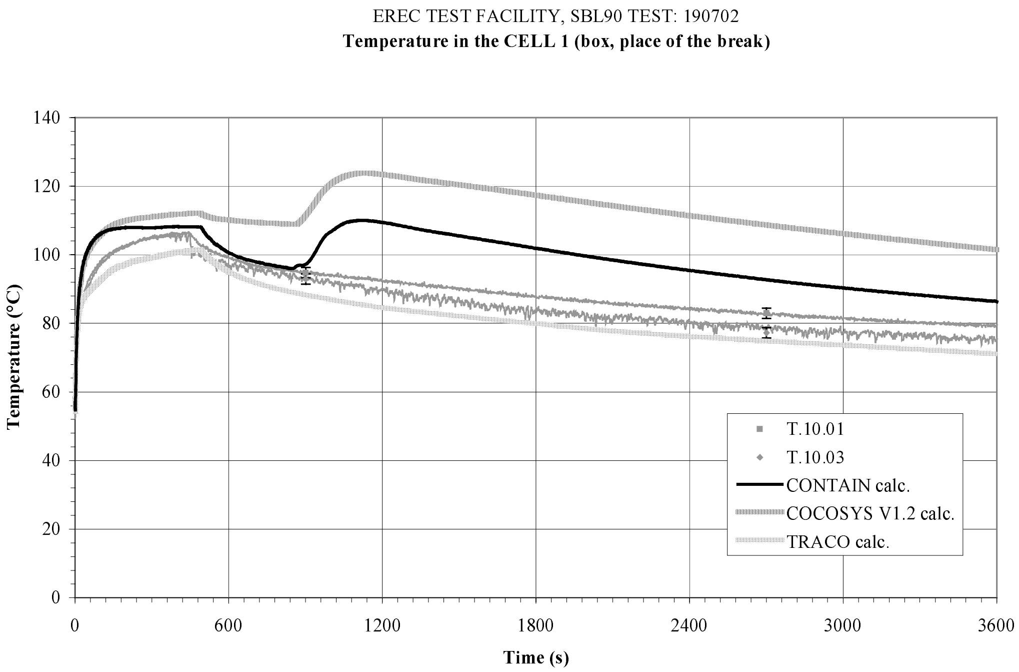


Fig. 5.18

Water conditions on the trays

Water level on the tray

CONTAIN calculates a nearly constant water level, about 0.49 m, because the condensed steam mass changes the water level negligibly and the code does not calculate the pool swelling. According to the measurement the water level behaves in different manner. After the water lock opens, there is a fluctuation between 0.46 and 0.58 m, then the water level becomes 0.52-0.56 m. From about 440 s until 490 s the water level sinks to the initial level. CONTAIN predicts the water level behaviour with its modelling limitation.

The water level oscillation is small, its amplitude is not more than 2-3 cm and the period of it changes quite irregularly from 10 s till 30 s. Any kind of condensation oscillation was not found.

Water temperature on the trays (Fig. 5.18)

The calculated water temperature is in the range of the average measured temperatures until 200 seconds. This time interval includes "the gas flow through the pool" period. From 200 s the heat transfer through the bubbler condenser walls, (temperature in shaft – cell 3) determines the water temperature. The code overestimates the water temperature, the calculated water temperature gradient diverge from the measured one from 200 seconds. At the end of the test (3600 s) the difference between the average water temperature and calculated one is 10 ^{o}C. The heat transfer between the shaft gas volume and the water pool through a steel structure is overestimated by CONTAIN.

Flows between cells

Flow between box and shaft

During the test CONTAIN predicts quite well the flow direction and gas velocity between the break compartment and the shaft. In the first 3s and after 480 s the calculated and measured flow direction in the vent between the other box-half and shaft is opposite. From 10 s till 480 s, the code predicts suitably the velocity between volume 2 and 3. After 800 seconds the calculated velocity is about 1 m/s, while the measured value is 0 m/s.

Flow through the check valves

Flow-meters were not installed to measure the velocity through the check valves. CONTAIN predicts flow between 4th (bubbler condenser) cell and 5th (air trap) from 3 s until 527 s. The maximum calculated mass flow rate is 1 kg/s (mass velocity: 42.6 kg/m^2-s). The check valve between shaft and bubbler condenser (ND 250 valve) opens a few seconds after the other check valve locks. The predicted maximum mass flow through the ND 250 valve is 0.06 kg/s (which corresponds to about 1.2 kg/m^2.s mass velocity).

Conclusions

- Test parameters measured by different transducers provide values that are generally in agreement within the error bounds
- The discrepancies between the calculated and measured values are not significant and the character of these predictions is conservative

Challenge for the real nuclear power plant:

- Maximum pressure (0.137 MPa) is far from the design pressure (0.25 MPa)
- Pressure load on the trays is negligible, less than 5 kPa
- Condensation-oscillation was not found. At the beginning there was a water level fluctuation, but it disappeared when steam started to flow into the bubbler pool. At a later stage the reason of this fluctuation is the opening and closing of the water seal. The amplitude of the fluctuation is about 1 kPa and the period is between 10 and 30 s.
- The small break LOCA accident does not cause any challenge for the VVER-440/213 type containment and localisation system

5.4 References

[

5.1] K.K. Murata et. al.: “User’s Manual for CONTAIN 1.1, A Computer Code for Severe Nuclear Reactor Accident Containment Analysis”, Revised for Revision 1.11 NUREG/CR-5026, SAND87-3209, Revised July 1990.

[5.2] W. Klein-Hessling, S. Arndt, M. Heitsch: COCOSYS V1.2 User Manual, GRS, July 2000.

[5.3] User’s Manual of the TRACO5/MOD1 Code, VUJE Nr. 151/89, December 1989.

6. Conclusions

Conclusions of the experimental work are twofold. On one hand certain general conclusions of technical merit follow from the experimental results that pertain to the safety and functionality of the VVER-440/213 Bubbler-condenser. On the other hand the Steering Group has drawn conclusions that answer the questions that remained open in the previous projects and were meant to be answered on the basis of the trilateral experiments.

6.1 General conclusions drawn from the experiments

The three experiments described in the previous parts allow to conclude in general in certain points. As a summary of the conclusions given in Chapter 5, the following statements hold:

- The test parameters measured by different transducers provide values that are generally in agreement within the error bounds.
- The discrepancies between the measured and calculated values are not significant and the character of the predictions is conservative.
- The observed differences between the measured and calculated values can be explained.
- The maximum pressure experienced in the tests is far from the design pressure of the containment system (0.25 MPa).
- The maximum pressure load on the tray walls measured during the tests, is far less than the 30 kPa limit value.
- Water level fluctuations were experienced but were found to be minor and disappeared when the steam started to flow into the bubbler condenser pool.
- Condensation-oscillations were not found within the investigated experimental conditions.
- The sequences investigated in the tests do not cause any significant challenge for the VVER-440/213 type BC and localization system

6.2 Answers to the open questions

As described in Chapter 1 three questions were considered important to be answered following the newly performed tests. Based on the experimental and analytical evidences of the newly performed investigations the OECD Bubbler-condenser Steering Group has concluded in the following answers to the open questions:

A1. The verification of the blow-down mass and energy rates (MER) producing loads to the BC was performed in the frame of the present project for both the previous LBLOCA tests and for the recent tests. Results confirmed conservative mass and energy estimations. It was shown that the injected MER were higher in the tests than the scaled MER (NPP/100) values.

These findings confirmed the conservative nature of the approach. Conclusions were that the related loads do not represent a challenge to containment integrity.

A parallel assessment of this issue with respect to LBLOCA tests is going on in the PHARE project PR/TS/17.

A2. The first part of the question concerning conservatism (initial conditions, scenarios, test conditions, different break locations, etc.) can be answered positively. The adequacy was addressed by the scaling of the facility and possible distortions were compensated by different measures (e.g. installation of additional insulation).

A3. Non-uniformities of flow rates and water temperatures have been observed in the experiments. An appropriate understanding of the non-uniformities was obtained by detailed (3D) code calculations. The reasons and the nature of the distributions have been satisfactorily explained by code calculations.

APPENDIX 1

BUBBLER CONDENSER STEERING GROUP (SG)
Outline of mandate and programme

1. Overall objectives

The activities will be organised as a Project having the following main objectives:

- Produce convincing evidence that the V-213 type containment works during DBAs as designed
- Help in the planning of new tests and in the interpretation of the test results
- To provide well qualified experimental results serving as basis for the validation of best estimate calculation tools.

2. Pending questions

Q1. The scaling of energy discharge rate is important for determining the thermal-hydraulic load on containment structure. Can estimates be made on whether the conclusions drawn are or not conservative, and if they are, on the degree of conservatism?

Q2. Are the conservatism and adequacy of the BC facility properly addressed?

Q3. Unexpected non-uniformity of flow rates and of water temperatures has been observed in earlier tests. Are these observations relevant and why? Can specific code calculations help in this assessment?

3. Organisation

- The Project's Steering Group (SG).
- The Operating Agent.
- The OCED-Nuclear Energy Agency.

There will be no financial compensations associated with the activity of the Steering Group.

4. Role the Project's Steering Group

- The SG shall review the scope of new tests and make recommendations as to the test set-up and conduct, including, e.g., instrumentation and pre- and post test calculations.

- The SG shall be entitled to receive relevant experimental results and will aim to reach consensus on their interpretation. The technical conclusions will be intended for the use of national regulators.
- The SG shall define content and provide approval of the Project Final Report.
- The agreed experiments and analyses shall be carried out and reported upon in the SG by the Project Operating Agent.
- The SG will elect its chairperson who will be responsible for the correct SG operation.
- There will be no voting in the SG.

5. SG members

- It is intended that the following organisations be represented in the Group:
  - Hungarian, Czech and Slovak utilities
  - Hungarian, Czech and Slovak regulatory bodies
  - GRS, Germany
  - IPSN, France
  - DOE, USA
  - EU
- With the approval of the chairperson, SG members may be accompanied by supporting personnel.

6. Role of the Operating Agent

- The Operating Agent will be the consortium of three utilities, which will be funding the experiments and will be represented in the SG by three or more members.
- The Operating Agent will be entitled to establish work relations and contracts with third parties and in particular with relevant experimental facilities for executing the experimental work scope.
- The Operating Agent shall be responsible for carrying out the experiments and the analyses according to agreed specifications.
- The Operating Agent will in general support the SG work, preparing in particular the Project overall workscope and reporting on results to the SG.
- The Operating Agent will nominate a Project Manager who will be responsible of the co-ordination with, and of the reporting to and from the SG.

7. Role of the OCDE-NEA

- The OECD-NEA will cover secretariat functions and will support SG establishment and operation, seeking for the achievement of the Project’s objective within the agreed time frame.

8. Time table

• Meeting 1 December 01	Discussion of the SG mandate and work scope. Preliminary discussion on test needs, requirements and objectives.
• Meeting 2 Jan/Febr 02	In-depth discussion of the test objectives, test set-up and experimental procedures, boundary conditions and instrumentation
• Meeting 3 April 02	Final specification of the tests and outline of the SG activity report.
• Experimental May - October 02	Test execution and initial write up of final report. Discussion of the test results and on the answers to the three pending questions via e-mail.
• Meeting 4 November 02	Test results, interpretation and conclusion, including answers to the three pending questions. Review of the report.
• Reporting December 02	Activity report.

APPENDIX 2

ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

PROJECT USE ONLY

NUCLEAR ENERGY AGENCY

ENGLISH TEXT ONLY

STEERING COMMITTEE FOR NUCLEAR ENERGY

Bubbler-Condenser Project

Minutes of the Meetings of the BUBBLER CONDENSER STEERING GROUP (SG)

Minutes of the
First Meeting of the
BUBBLER CONDENSER STEERING GROUP (SG)

Paris, 7 December 2001

Summary of actions

A1. This Group endorsed the proposed tests in that they address the B-C remaining issues.

A2. The Group recommends that the planned experimental work be co-ordinated to the feasible extent with the German - Russian bilateral activities.

A3. Co-ordination with the EU -TSO project is to be ensured by members of the OECD SG.

A4. The Czech, Hungarian and Slovak utilities shall address their authority and receive formal endorsement and/or recommendations on the proposed tests.

A5. Mr. Bajsz is to co-ordinate further definition of test details with Mr. Wolff and keep IPSN informed

A6. The Operating Agent will nominate a Project Manager by end of January and communicate the nomination to the SG chairman and to Mr. Vitanza.

A7. The next meeting date is February 25 and 26. The meeting will be held at the HAEA premises in Budapest. The topics on the agenda include in-depth discussions on

- Status on actions from the first SG meeting (Operating Agent, NEA)
- Status of contract with EREC.
- Test objectives and boundary conditions (Operating Agent).
- Test set-up, experimental procedures, schedule (Operating Agent)
- Test instrumentation (Operating Agent)
- Interaction with other B-C activities (EU and D-RU bilateral work)
- VEIKI presentation of calculations of flow and temperature non-uniformities.
- VEIKI presentation of calculations of expected pressure differential for various type of test initial and boundary conditions.

1. Opening

Mr. Frescura, director of Nuclear Safety at the NEA, welcomed the participants, expressing his satisfaction that in spite of the difficulties with transportation, so many participants were able to attend. He said that the Bubbler-Condenser (B-C) issue had been on the agenda for a long time. He reminded of what has been done in approximately the last decade, and added that additional experimental work is expected to occur during next year. At the last CSNI meeting (summer 2001), the NEA had been asked to support this experimental work, which is to be financed by Czech, Hungarian and Slovak utilities. The aim is to define the experiments in such a manner that they respond to remaining B-C issues in a practical and convincing manner. He concluded that the NEA was looking forward to fruitful discussions in this Steering Group and that these would help to arrive to make significant progress on the matter.

Mr. Vitanza said that apologies for absence had been received from Mr. Sabata, Krajmer and Macek. He added that the US Department of Energy had expressed its desire to join the project and that the DOE designated representative would be Mr. Jim Sienicki of Argonne National Laboratory.

2. Election of the SG chairman

Mr. Vitanza proposed Mr. Ivan Lux, of the Hungarian Atomic Energy Authority, as chairman of the Steering Group. Mr. Lux, who is very familiar with the B-C issue, raised the matter of an OECD project on bubbler condenser experiments at the June CSNI meeting. The Group approved the nomination.

Mr. Lux thanked for the confidence of the Group, adding that he would do his utmost to make the SG work as effective as possible.

3. Adoption of the Agenda

The chairman proposed to discuss agenda point 4 after the technical discussions on the new intended tests, such that the mandate is seen in the context of the work scope of the SG (Agenda point 8). The Group agreed.

With this modification, the Agenda was approved.

4. Overview and status of the Bubbler-Condenser issue

The chairman invited Mr. Wolff of GRS, Germany, to address this point. Mr. Wolff said that the B-C as a safety issue was addressed by the OECD NEA since 1992. An OECD meeting was held on the subject in April 2000. The IAEA and WENRA have also addressed this matter.

On the OECD work, Mr. Wolff recalled that there were a number of phenomena that were suggested for consideration, as well as for separate effects experiments and integral experiments. Experimental work was carried out under a PHARE project (PH 2.13/95), which lasted 27 months. Tests were to be performed at

EREC on thermal-hydraulics and structural tests, at VUEZ on static structural tests and at SVUSS on small scale tests and thermal-hydraulic analyses. The general project conclusions were that

- The analytical results indicate that the loads on the B-C structure due to LB LOCA envelopes the loads by MB LOCA, SB LOCA and MSLB with respect to confinement pressure and differential pressure on the BC structure.
- Tests and analyses showed that for Paks, Dukovany, Bohunice (and Rovno) NPP's, the B-C structure is capable to withstand the imposed loads and maintain their functionality. For Kola NPP further investigations were recommended.

However, Mr. Wolff noticed that only 3 out of 16 (+ 3 contingency) EREC tests were carried out in the Project, and that the initial and boundary conditions have been matter of discussion.

In the PHARE TSO project (SK/HU/CZ/TS/08), recommendations were expressed as to the experimental work at EREC and at the VUEZ static structural test facility. Further, the OECD support group at its meeting of April 2000, recommended amongst others, that

- Further test analyses on existing results be carried out
- Existing results be used for design qualification, code validation and modelling improvements
- MSLB and medium/small break LOCA tests be performed in order to better understand non-uniformities.

In the frame of a German-Russian bilateral contract one test on Steam Line Break (SLB) at the EREC facility together with a repeat test will be investigated. This bilateral contract is due for completion in 2003. During Mr. Wolff's presentation, there were a number of questions, mainly related to remaining issues and to how relevant some considerations are for the actual B-C function. One of these issues is on the extent to which LB LOCA is bounding other transients. Mr. Wolff expressed consideration that SB-LOCA might induce pressure oscillations, which under some conditions might endanger the structure. To that, Mr. Bajsz observed that there is no other basis than speculation that such phenomenon can occur or that it has safety implications. However, as noticed by Mr Wolff, the OECD support group "…agreed that additional work is necessary to reach comprehensive understanding of "….oscillatory problems and associated sensitivities under medium-break and small-break loss-of-coolant accident" [Report NEA/SEN/SIN(2000)6]".

Mr. Deksnis said that the view of the regulatory authority in the Czech Republic, Hungary and Slovak Republic are essential in the definition of what phenomena or aspects represent a safety concern. Mr. Frescura added that in general it should indeed be up to the regulators to decide the depth required for given safety assessments.

Mr. Bajsz (Hungarian utility) started his presentation on the history of the BC experimental projects, basically from the same basis as Mr. Wolff. Chronologically, things went as described below.

- 1991-94: OECD Support Group on VVER-440 Bubbler Condenser Containment Research Work → supplementary research work needed.
- 1994: EC launched the PHARE project (NUC 93428) Bubbler Condenser (BC) Qualification Feasibility Study. It was completed in early 1996 → need for additional research.
- 1996: PHARE project PH2.13/955 was launched.
- 1997: BCEQ was awarded to a Consortium consisting of Siemens/KWU, EdF and Empresarios Agrupados. The following subcontractors were selected:

- EREC (Electrogorsk, Moscow, Russia), for TH tests and structural tests
- VUEZ (Levice, Slovak Republic), for static structural tests
- SVUSS (Bechovice, Czech Republic), for small scale tests and TH analyses

- 1998: Start of the construction of the EREC facility.
- 1998 (December): TSO project is terminated.
- 1999: EREC test facility is ready in June, with 7 months delay.
- 1999: 3 tests were performed in September-October, Users team and TAC meeting → Final report in December.
- 2000: Berlin meeting of the OECD group and TAC → Significant differences in opinions.
- 2000: In October VEIKI performed the detailed post test calculations, most of the questions of OECD group is answered.
- 2001: AQG report on Nuclear Safety in the context of enlargement: "Measures to complete the regulatory review regarding full verification of the performance of the containment bubbler condenser system for all design basis accident".
- 2001 (August) Start of the trilateral cooperation (CZ-SL-HU) to perform additional tests and analyses.
- 2001: A new TSO project is under preparation.

Mr. Bajsz said that the recommendations made by the OECD support group were or are being followed up. In particular

- Further post-test analyses to understand non-uniformities in temperature and flow distribution have been performed.
- Further testing under MSLB and MB LOCA are in preparation.
- The analytical support for pre- and post-test calculation is being set up.

On the questions that are remaining, Mr. Bajsz commented that

- The question as to whether further tests are needed or not, the tests that are being planned provide a practical answer.
- The question on the scaling of the energy discharge rate and its effects has been definitely addressed. From blow-down calculations based on pressure and level parameters, it has been derived that the flow measurements had an inertia in the first 4-5 tenths of a second.
- The issue of non-uniformities has been analysed with CFD calculations. The outcome is that this phenomenon can be explained by the calculated flow pattern and by the changing steam content in the gas-steam mixture.
- The item of conservatism of the EREC facility is being addressed in preparation of the next tests.

5. Ongoing assessments at the EU

Mr. Deksnis provided an overview of the status of the B-C issue as seen from the EU perspective. He stated that there is a marked difference now between the PHARE and the TACIS perspective, mainly in that the PHARE activities are being incorporated into the EU Directorate General for Enlargement.

For what concerns TACIS, the Kola-relevant experimental programme is being launched, how soon is to be seen. From what Mr. Deksnis had seen on time-scale, there should be no interference time-wise between the TACIS-Kola work and the "trilateral" tests, i.e. those planned by Cz, Hu and Sk utilities.

For what concerns PHARE, Mr. Deksnis pointed out that the original programme could not be extended beyond reasonable time limits, that is why it had to be limited to three tests. The PHARE programme is now devised to help the EU to enlarge. On the B-C issue, there is a request (by the EU) to the Cz, Hu and Sk regulatory authorities to come with a report stating the degree to which the resolution of B-C issues is satisfactorily accomplished. Mr. Deksnis said that, while realising that only few tests have been done, there is a hope that the community of experts will come to a consensus, possibly with the support of the tests being planned now. He reiterated that one simply not in the position to postpone the resolution of this subject beyond the time period given, which is mid 2003. These are the boundary conditions given to the TSO. The TSO activities will be based on existing tests, the kick-off meeting is expected in January at the earliest. The TSO project is a form of collaboration of EU and candidate countries on an analytical effort. Through this, one hopes to get good support to document that the B-C works under DB scenarios. Mr. Deksnis concluded that the TSO is to be intended as a support to the regulatory authority of the candidate countries and as such, the three beneficiaries have to agree on it. The EU-TSO contract is not yet signed.

The chairman noticed that this is an appreciable shift in EU policy and asked if the TSO participants are aware of it. Mr. Deksnis replied that the shift is a fact and was decided under the French presidency of the EU.

6. The new intended tests

Mr. Bajsz provided information about the tests that the Czech, Hungarian and Slovak utilities intend to carry out at the EREC facility in Electrogorsk. The experimental proposal consists of three tests and is to address the following points:

- Main steam line break (MSLB). This transient is a long time process with high temperature conditions. The break flow rate is 1000 kg/s at beginning of transient. Mr. Bajsz said that the envisaged time duration is up to 1200 s. To a question on feasibility, Mr. Bajsz said that this had been checked with EREC experts and that this long time duration can be achieved by using the steam produced by a power plant, which is at the EREC site. Mr. Wolff said that in his view it might be not necessary to have such long time duration. It was agreed that the item of duration be clarified in further discussions between Mr. Bajsz and Mr. Wolff.

- Medium Break LOCA (MB LOCA). The proposal contemplates that a 250 mm break, when the reverse flow of tray water is not yet occurring. Mr. Wolff said that the actual size should be assessed by calculations. Also in this case, it was recommended that the test parameters be optimised through consultations between Mr. Bajsz and Mr. Wolff.

- Small Break LOCA (SB LOCA). Mr. Bajsz said that, although this item had been recommended for consideration by the OECD support group [Report NEA/CSNI/R(2001] the utilities doubts that a test on SB LOCA would provide valuable data. Mr. Bajsz expectation is that in a SB LOCA one would hardly measure any significant differential pressure on the structure. The three utilities feel that one would perhaps make a better use of the third test by addressing the BC function with decreased water level.

Mr. Amri raised the issue of oscillatory condensation and chugging, which are more likely to occur and are of longer duration in a SB LOCA. Mr. Wolff referred to the above-mentioned report of the OECD Support Group, where this specific item was mentioned as one of the point of diverging opinion within that group (Page 31, point 3 of the quoted NEA report). Mr. Lipar and Mr. Bajsz said that arguments on possible oscillations and/or chugging are of speculative nature. There is no calculation showing that such phenomena are likely to occur to an extent that it can really endanger the BC structure. Mr. Deksnis stressed the point that the key requirement is that the B-C structure is kept during its function, i.e. once. It does not need to be in full shape for a second time. Mr. Amri said, that we need to understand if oscillations and chugging can have a real impact on the integrity under which conditions it can occur. Mr. Bajsz said that chugging may occur and be relevant for other configurations, but he just sees no realistic basis for this to be relevant in the B-C case. The option of studying SB LOCA however, remains open; he does not exclude it at all. However, he feels it will be a waste to make a test at conditions in which nothing significant is expected to occur. Also on this point it was agreed that Mr. Bajsz and Mr. Wolff would consult on the merit to address SB LOCA or, alternatively, lower B-C water level in the third test.

In conclusion, the tests proposed by the utilities are as follows

Test No.	*Leak type*	*Pressure (MPa)*	*Break position*	*Water level (mm)*
1	1.5 MSLB	4.7	Near	500
2	LOCA (250 mm)	12.5	Middle	500
3, option 1	LOCA (250 mm)	12.5	Middle	100
3, option 2	SB LOCA	12.5	Middle	500

As to the time schedule, Mr. Bajsz said that the contract with EREC is in preparation, and that an agreement on the overall test scope is to be reached by end of 2001. The subsequent steps will be:

- Pre-test analyses until April 2002
- Test performance May - June 2002
- Post-test evaluations and reporting October 2002

At this point, the chairman asked the participants to express their opinion about the proposed tests.

Mr. Svab from the Czech regulatory body, said that the regulator will have the responsibility for the overall B-C safety assessment and to define the conditions under which the B-C functionality is to be confirmed. The Czech regulator has defined the scenarios to be addressed, which are reflected in the proposal. He acknowledges that there can be a number of interesting aspects that can be studied, but one must focus on conditions that are relevant to safety assessments.

Mr. Lipar said that the three regulators must agree on scenarios. The Slovak utilities, however, have not yet approached their authority on this matter.

Mr. Amri stated that the proposed tests do address the recommendations of the OECD Support Group in terms of initiating event, but we must ensure that we are speaking about the right scenario. On SB LOCA the aim is to close the subject. For this purpose, either one performs a test or one should have a demonstration that the SB LOCA is not important.

Mr. Deksnis was interested in the schedule and how this relates to the EU TSO schedule and to the Russian-German contract schedule. The chairman replied that the interaction between this SG and the TSO will be discussed in the next agenda point. For what concerns the time schedule, the scheme shown below (see next page) gives a representation of the B-C activities for the next two years.

Mr. Wolff said the tests were addressing the right issues, but that details are to be better defined. He added that he would like to explain the methodology he uses (which is given below) and that he was willing to continue the dialogue with the utilities in order to optimise the outcome of the tests.

Project	*2002*	*2003*
OECD B-C SG 3-utility tests __	___________________________ _ _ _	_ _
German - Russian bilateral tests	_ _ _ _ _ _	_ ______________________________
EU - TSO activities _	_ ______________________________	_______________

The chairman, Mr. Lux summarised this discussion with the following conclusions:

A1. This Group endorsed the proposed tests in that they address the B-C remaining issues.

A2. The Group recommends that the planned experimental work be co-ordinated to the feasible extent with the German - Russian bilateral activities.

A3. Co-ordination with the EU -TSO project is to be ensured by members of the OECD SG (see next agenda point).

A4. The Czech, Hungarian and Slovak utilities shall address their authority and receive formal endorsement and/or recommendations on the proposed tests.

A5. Mr. Bajsz is to coordinate further definition of test details with Mr. Wolff and keep IPSN informed.

The Group agreed on these chairman conclusions.

Mr. Wolff gave a concise explanation on what he suggests as a methodology that can be followed for checking the adequacy of the TH loads on the B-C model. This consists basically of defining the scenario to be investigated, to calculate the corresponding mass and energy release rate from a NPP and to verify that the B-C test facility provides adequate conditions based on few criteria, which Mr. Wolff explained in details. He gave also examples of how this methodology, which is based on calculation sequences, works in practice.

7. Mandate, role and work scope of the SG

The chairman went through the points of the draft mandate that had been communicated to the SG members at an earlier stage. The mandate, revised according to the suggestions made by the SG, is given in Appendix 1 (most of the items addressed in this agenda point are contained in Appendix 1).

Overall objectives

The objectives as stated in the draft mandate were endorsed by the participants.

Pending questions

The second question in the draft mandate was modified by the SG to read.

Q2. Are the conservatism and adequacy of the B-C facility properly addressed?

With this modification, the pending questions were approved.

Role of the Project's Steering Group (SG)

The chairman explained the details of this point, which are

- The SG shall review the scope of new tests and make recommendations as to the test set up and conduct including, e.g. instrumentation and pre- and post-test calculations.
- The SG shall be entitled to receive experimental results and will aim to reach consensus on their interpretation. The technical conclusions will be intended for the use of national regulators.
- The SG shall define content and provide approval of the Project Final Report.
- The agreed experiments and analyses shall be carried out and reported upon in the SG by the Project Operating Agent.
- The SG will elect its chairperson who will be responsible for the correct SG operation.
- There will be no voting in the SG.

The chairman notices in particular the second bullet point related to the sharing of information. Mr. Vitanza added that if requirements on confidentiality (i.e. on restrictions beyond SG use) are needed, they should be set forth by the Operating Agent.

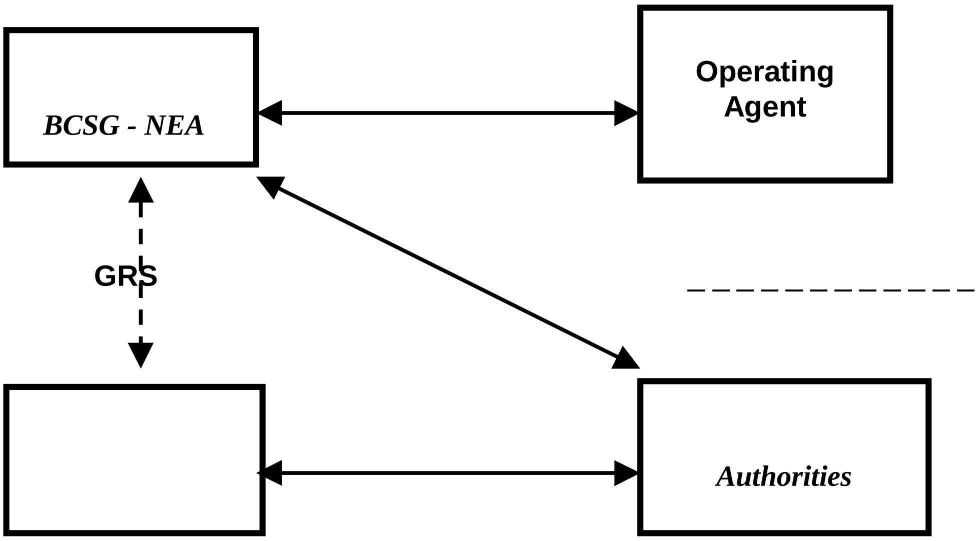
The interaction of the SG with the various parties involved in the B-C issue is schematised in the figure given on the next page.

SG members

The chairman recalled that the SG members, besides the Czech, Hungarian and Slovak regulators and utilities, include a representation from the EU, from the French IPSN, from the German GRS and from the US Department of Energy. As to the latter, a communication had been received that Mr. Jim Sienicki of Argonne National Laboratory would represent DOE in the SG.

The chairman noticed that the SG mandate recognises the possibility that SG members be accompanied by support personnel - for instance EREC experts, subject to chairman approval.

ROLES AND RELATIONSHIPS IN THE B-C PROJECT



Role of the Operating Agent

The provisions of the mandate related to the role of the Operating Agent, i.e. by the consortium of the three utilities sponsoring the test, were reviewed by the chairman.

It was agreed that

A6. The Operating Agent will nominate a Project Manager by end of January and communicate the nomination to the SG chairman and to Mr. Vitanza.

Role of the OECD-NEA

The OECD-NEA is to support the SG establishment and operation, seeking for the Project's objectives within the agreed time frame.

Time table

Meeting 1	December 01	Discussion of the SG mandate and work scope. First discussion on test needs, requirements and objectives.
Meeting 2	Febr 02	In-depth discussion of the test objectives, test set-up and experimental procedures, boundary conditions, instrumentation.
Meeting 3	April 02	Final specification of the tests, outline of the SG activity report
Meeting 4	November 02	Test results, interpretation, conclusions, answers to the pending questions. Review of the report.
Reporting	December 02	Activity report.

The chairman observed that this timetable is consistent with the one presented by Mr. Bajsz for the tests and for the related analyses. He asked if, with the modification of the second pending question (Q2. in paragraph 2), the Steering Group would approve the mandate. The Steering Group approved.

8. Next meeting

Upon proposal from the chairman, the following was agreed

A7. The next meeting date is February 25 and 26. The meeting will be held at the HAEA premises in Budapest. The topics on the agenda include in-depth discussions on

- Status on actions from the first SG meeting (Operating Agent, NEA)
- Status of contract with EREC.
- Test objectives and boundary conditions (Operating Agent).
- Test set-up, experimental procedures, schedule (Operating Agent)
- Test instrumentation (Operating Agent)
- Interaction with other B-C activities (EU and D-RU bilateral work)
- VEIKI presentation of calculations of flow and temperature non-uniformities.
- VEIKI presentation of calculations of expected pressure differential for various type of test initial and boundary conditions.

Minutes of the Second Meeting of the BUBBLER CONDENSER STEERING GROUP (SG)

Budapest, 25th-26th February, 2002

Actions and deliberations

A 8 The SG agreed that VEIKI calculations using the 3D code GASFLOW provide a satisfactory answer to the issue of non-uniformities of temperature and flow distributions observed in the experiments (Deliberation)

A.9 A scenario description of test 2 and 3, similarly to what presented for test 1, shall be made available by the OA (PM)

A.10 Efforts will be made to enable to perform calorimetric energy balance, which was an uncertainty in previous tests (OA/PM)

A 11 The SB size for test 3 needs to be finalised (OA/PM)

A 12 The SG agreed that the three proposed tests were relevant ones and addressed the recommendations expressed in earlier assessments (Deliberation)

A 13 There was agreement on the suggested instrumentation improvements. Details to be provided at the next meeting (OA/PM)

A 14 An understanding emerged that the issues of possible reduction of oscillations and resonance for smaller breaks shall in one way or another be addressed. Many in the group believe that this is an issue of a theoretical and speculative nature and that, if it exists, this phenomenon does not pose a challenge to the confinement structure of the BC. The Operating Agents should provide a way to resolve this issue, which appears to be the only one that is left without response

A 15 It was agreed that the next meeting will take place in Bratislava on 29th and 30th April. It will address:
- EREC contract
- Finalisation of the experimental programme
- Scenarios to be addressed (for MB and SBLOCA)
- Position with regard to the investigation of the oscillation issue
- SG activity report

A 16 On the SG activity report, consultations between the SG Chairman, the Project Manager and the NEA Secretariat are to take place to set forth a tentative structure of the SG report, ahead of the next meeting

1. Opening

The Chairman, Mr. Lux, welcomed the participants and expressed satisfaction that so many were present. He asked that one person per each organisation speak on behalf of that organisation, such that the discussion could be conducted efficiently. After a tour de table, where the participants introduced themselves, the Chairman summarised the goals of the meeting, which were basically to:

- Explain the flow and temperature distributions that were observed in the previous EREC tests.

- Define to the maximum extent possible the new tests that are to be carried out in the Slovak, Hungarian, Czech trilateral cooperation.

2. Adoption of the Agenda

In relation to point 10 of the Agenda (in-depth discussions), Mr. Amri requested that any relevant material to be presented at an SG meeting, should be circulated beforehand. The chair took note of this discussion.

The Agenda was adopted.

3. Approval of the Minutes of the Previous Meeting

Two small corrections were made on page 2 and page 6 of the Minutes. With these corrections the Minutes of the previous meeting were approved.

4. Status of Actions

With reference to the list of actions given on page 2 of the SG1 Minutes, the status of actions was as follows:

A1 The SG endorsement of test goals had been obtained.

A2 Co-ordination with Germany - Russia at the last meeting. Bilateral activities.
Mr. Wolff explained that there had been a meeting addressing the scenario that GRS intends to investigate. The meeting took place on 16th January. Exchange of information took place also after this meeting. Mr. Wolff pointed out that there will be no duplication between the GRS Russian co-operative programme and the programme addressed by the OECD SG.

A3 Coordination with the EU-TSO project. This is ensured by the participation of EU representatives in the SG. There will be a presentation on the status of the EU project under agenda item 8.

A4 Endorsement of Czech, Hungarian, and Slovak safety authorities. Mr.Bajsz explained that the Operating Agents, i.e., the utilities of the three countries, have addressed their respective authorities and received formal endorsement on the intended programme of work.

A5 Communication between Mr. Bajsz, Mr. Wolff and Mr. Amri on further definition of tests. As confirmed by Mr. Amri and Mr. Wolff, such communication has taken place, but limited extend.

A6 Nomination of the Project Manager. Mr. Lux noted that the Operating Agent nominated Mr. Bajsz as Project Manager and asked for the SG approval. The SG approved.

A7 Points to be addressed in the second SG meeting. These are reflected in the Agenda.

With this, the review of actions from the previous meeting was completed.

5. Post-test calculations of previous experiments

Mr. Techy, from the Hungarian VEIKI, presented the post -test calculations of previous experiments. The content of his presentation was as follows:

- Main Findings of the PH2.13/95 (BCEQ) Project
- Objectives of the Post-Test Calculations
- 3D Calculations with the GASFLOW Code
- Detailed Nodalisation Scheme for the CONTAIN Code
- Pressure Difference on the Bubbler Condenser
- Temperature Distribution in the Bubbler Condenser Pool
- Temperature in the Bubbler Condenser Air Volume and in the Air Trap
- Conclusions

The Main Findings of the PH2.13/95 (BCEQ) Project were:

- Pressure loads in case of LBLOCA have been found up to 210 kPa for containment pressure maximum and 20 kPa for maximum pressure difference on the BC walls
- The tests indicated the existence of
  - Temperature gradients in the BC water pool in vertical direction, also significant differences between individual tray rows in horizontal direction. However, temperature values are far from saturation, no challenge for BC operation.
  - Complex flow patterns exist in the corridors between the steam generator boxes and the BC shaft.
- Code predictions (both CONTAIN and DRASYS) overestimated the actual measured pressure differences on the bubbler condenser.

Further analyses were recommended to understand the involved phenomena.
The Objectives of the Complementary BCEQ Post-Test Calculations included:
Detailed study of phenomena not fully understood in the PH2.13/95 BCEQ Project. This consisted of:

- Flow patterns in the corridors and the bubbler condenser
- Pressure loads on the bubbler condenser membrane walls
- Temperature distribution in the bubbler condenser pools
- Temperatures above the condenser pools and in the air traps

The codes used for analysis were:

- GASFLOW code for 3D modelling of flow fields
- CONTAIN code with detailed noding for thermal-hydraulic analyses

GASFLOW 2.1 is a 3D computational fluid dynamics (CFD) code developed at Los Alamos National Laboratory (LANL) and Forschungszentrum Karlsruhe (FZK) for velocity and material concentration field analysis of nuclear reactor containments.

VEIKI obtained the GASFLOW Code from the USNRC under the Cooperative Severe Accident Research Program (CSARP) agreement

The computational domain or 3D block is discretized using a rectangular finite difference mesh. Several 3D blocks can be defined, which are connected via one-dimensional ducts.

Mr. Techy explained how the bubbler condenser of the EREC facility geometry were treated in GASFLOW. The outcome of the calculations were that:

- The Pressures trend is satisfactory, but the calculated pressure maxima are less than the measured values.

- The temperatures were predicted with relatively good agreement for the break room and before the BC. Discrepancies between calculated and measured values above the suppression pool were observed.

With regard to flow directions and patterns, Mr. Techy reported that:

- First phase - until water seal clearing
  Flow proceeding from the break room impacted at the pedestal of the BC, passing at both sides forward and returning at the rear of the structure. Opposite flow directions exist at the sides of the connecting channel.

- Second phase - after seal clearing
  Forward direction flow at both sides in the upper part of the BC returning at the rear and passing backward near the bottom. The flow enters the space below the pool from behind and from both sides through the holes of I-beams.

With regard to the heat-up of the BC water pool, the calculations gave the following outcome:

- GASFLOW predicts a higher heat-up at both ends of the BC in agreement with the experimental results

- Non-uniform steam distribution of steam fluxes entering the pool and different water masses available at both ends of the BC contribute to the effect

The summary of GASFLOW calculation results was that:

- GASFLOW provided detailed results for spatial distribution of thermal-hydraulic parameters, velocity fields and gas concentrations.

- Complex flow patterns obtained in the tests were explained by the code predictions.

- BC pool temperature distributions could be explained by the calculated flow and steam concentration fields.

- GASFLOW simulations supported the development of detailed nodalisation for the CONTAIN code, used in other tasks of the study.

On the Pressure load on the BC wall earlier tests and calculations were that:

- Measurement and calculation results concerning the pressure difference load on the BC wall deviated: calculations predicted 26 kPa versus measured loads of 20 kPa (deviation up to 25 %). Plant (Paks NPP) calculations indicated a pressure difference of 24 kPa.

- Linear displacement measurements performed during the tests indicated the displacement of the BC membrane walls. This could lead to elastic compression of the BC structure with a corresponding internal pressure rise and modification of the pressure difference load.

The CONTAIN code was used in VEIKI subsequent assessments. A specific input was developed for the CONTAIN code to model the volume shrink due to the deformation of the BC membrane walls. Volume compression was determined from linear displacement measurements.

The conclusion of the VEIKI work on the pressure load on the BC wall were that:

- CONTAIN analyses indicated that pressure differences calculated with assumption of the BC volume compression were close to the test results within measurement error bounds.

- The discrepancy between measurement and calculation results can be explained, therefore the pressure load issue can be resolved by the BC volume compression effect.

On temperature in the BC pools, the results from earlier tests indicated a temperature distribution along the bubbler condenser. Temperature values were higher at the front and the rear trays, while lower values were obtained for the middle tray rows.

CONTAIN calculations with a detailed bubbler condenser model predicted the same tendency of temperature distribution. The phenomenon is caused by non-homogeneous steam mass flow to individual pools as a result of flow distribution. Smaller water pool masses existing at the front and rear trays also contribute to this effect.

The calculations for all the three tests predict much higher heat-up of the BC water, than the average heat-up derived from the temperature measurements.

With relation to the BC air volume and air trap temperatures, earlier BCEQ post-test analyses indicated much higher values for BC air volume and air trap temperatures than actually measured values.

At the same time, video records of the tests confirmed the existence of very intense droplet entrainment into the BC air volume. The CONTAIN code does not model any water entrainment from the pool to the atmosphere region. Water entrainment was artificially added to the BC atmosphere.

Temperatures calculated with this model are close to the test values. Unphysical temperature peaks in the previous BCEQ calculations were removed this way.

The overall conclusions of VEIKI post-test evaluations were that:

- Flow patterns in the corridors between the steam generator boxes and the BC shaft.
  GASFLOW analyses provided explanation for the complex flow distribution patterns.

- Pressure difference load on the bubbler condenser
  Discrepancy between the measured and calculated values explained by the compression of the bubbler condenser structure

- Temperature distribution in the bubbler condenser pool
  Temperature distribution explained by non-uniform steam flow distribution to the BC pools. However, average heat-up of the water pool derived from the measurements still deviates from the calculated average heat-up.

- Temperatures of the BC air volume and the air trap.
  Temperatures calculated with assumption of water entrainment are very close to the measured values

6. Discussion of the post-test results

The discussion of the post-test results basically confirmed the validity of VEIKI approach and conclusions.

As summarised by the Chairman, the work presented by Mr. Techy was intended to respond to the need to understand the reasons for the observed non-uniformities in the previous test and to the recommendation that further post-test analyses of the results obtained so far should b e performed in order to explain such non-uniformities.

Upon questions from the Chairmen, the SG agreed that VEIKI calculations provide a satisfactory answer to the issue of non-uniformities of temperature and flow distributions observed in the experiments.

7. Other issues on previous tests

There were no other issues.

8. Status of the EU Projects on BC

Mr. Deksnis presented the status of EU activities related to the bubbler condenser. He reviewed the Bubbler Condenser Qualification project, which had as major aims to create a unique large-scale engineering test facility and to provide experimental verification of BC functions. Not all foreseen experiments were done, however. There was a general conclusion that the function of the bubbler condenser was assured for LBLOCA. Of the intended matrix, three tests were carried out, i.e.:

Test 1: Integral LBLOCA
Test 4: Initial LBLOCA with higher steam content
Test 5: Initial LBLOCA with higher air content.

Post-test calculations led to the following conclusions:

- Tests adequately represented a LOCA with a large pipe line beak in the primary circuit, as applied to Paks NPP.
- DRASYS code predictions seem "conservative" as to maximum pressure and pressure difference over the BC

- Pressure increases in the boxes in tests are not higher than postulated values. For a LBLOCA the maximum pressure in Paks NPP compartments < 0.21 MPa. (acceptable)
- Measured •p over the BC is lower than predicted; maximum •p will not be higher than 22 kPa for a LBLOCA for Paks NPP (acceptable for Paks,? For Dukovany and Bohunice NPP)

With regard to the EU policy, Mr. Deksnis mentioned that the Council Report addresses nuclear safety in the context of Enlargement (June 2001). The issues of relevance in the BC context are:

- The legislation in the nuclear sector, organisation and management of regulatory authorities and the level of safety of installations in each of the Candidate States

- Regarding bubbler condenser systems:

Measures to complete a regulatory review - full verification of the performance of the containment bubbler condenser system for all design basis accidents.

The New TSO Project must be seen in the dynamics of H, CZ, SK accession in the EU and it involves the following principal activities:

After an initial phase of six months duration, there follows an extended phase of additional numerical analysis: The final task is to

- Evaluate bubble condenser function from a nuclear safety standpoint in compliance with western standards applied within the licensing process in EU countries for similar facilities:
- Review of BCEQ results & others that become available, including a critical review of available experimental data.

The implementation is to take place in the time period first quarter 2002 - third quarter 2003.

Mr. Deksnis also mentioned the TACIS R2.01/99. The objectives are:

- to evaluate bubble-condenser experimental qualification test results.
- to perform specific tests and relevant post-test analysis for the Bubbler Condenser at Kola NPP Units 3 and 4

The tentative time period is 15 months duration from the third quarter 2002 (earliest).

9. Status of the preparation of the new experiments

Mr. Bajsz presented the developments since the last meeting in Paris

9.1. *EREC contract*

There is an agreement on scope, i.e., on three tests including pre-test calculations. There is a preliminary agreement on test schedule and price. EREC had expressed a positive attitude for possible instrumentation additions or modifications. A draft contract is under preparation.

9.2. *Preparations and the work scope*

On the tests contemplated in the trilateral co-operation, there had been a meeting in Slovakia, where an agreement on test scope was reached. This consists of:

- One MSLB test
- One MBLOCA, with 200 mm break size
- One SBLOCA orientatively with 90 mm break size (size to be confirmed)

There was also an agreement on the analytical work to be carried out by the three parties. The Hungarian parties will focus on the analyses of the MSLB test, Czech parties on the MBLOCA and Slovak parties on the SBLOCA.

Mr. Bajsz observed that additional temperature sensors on the BC walls will be needed. Further, there is a request to measure the water temperature of three different levels at some locations. Other sensors, such as ultrasonic level monitors, strain gauges, composition or velocity measurements, were not considered necessary and could in some cases be misleading due to lack of qualification or to interference with the environment to be monitored. The overall work scope and responsibility are shown in the following table.

Tests and analysis will be shared by the NPPs as follows:

Pre-test analysis		**PLANT**		**EREC Test Facility**	
Transient	Responsiblity	Blow down	Containment	Blow down	Containment
MSLB	PAKS	PAKS	ALL	EREC	ALL
MB LOCA	EDU	EDU	ALL	EREC	ALL
SB LOCA	EBO, EMO	EBO, EMO	ALL	EREC	ALL

Post-test analysis		**EREC Test Facility**	
Transient	Responsibility	Blow-down corrected with the measured data	Containment
MSLB	PAKS	EREC	ALL
MB LOCA	EDU	EREC	ALL
SB LOCA	EBO, EMO	EREC	ALL

The related administrative work has been started, aiming to perform the first test in June 2002.

Following the presentation of Mr. Bajsz, three presentations were given on the description of the three tests and related boundary conditions. These were given by Ms. Toth, of Paks NPP, by Mr. Macek of the Czech NRI and by Mr. Tka• of the Slovak VUJE…[however, handouts were provided only for the first presentation] As to the selected MSLB scenario, the case of MSLB on SG1 (steam line closed, feedwater line opened, 2 valves, which were stuck, opened after dp> 5 bar) was selected in consideration of its severity and negative frequency rate. A similar description is expected for the second and third test (ACTION)

10. Discussion

The discussion clarified, among others, the following aspects:

- There will not be repeated tests, but there will be enough time for feedback from one test to the following one.

- The main consideration is to collect data useful for code validation (more than to try to reproduce all sorts of scenarios). The test parameter range on e.g. break size was chosen accordingly.

- Efforts will be made to enable to perform calorimetric energy balance, which was an uncertainty in previous tests (ACTION)

- The MSLB contains in reality a cluster of possible events. In recovering the test, consideration was given to relevant possible events, as well as to difference among plants.

- The MB and SBLOCA extend considerably the range of break size (500 mm in the previous LB test, 200 mm in the planned MB and 90 mm in the SB). The SB size needs to be finalised (ACTION)

- Altogether, the group agreed that the three proposed tests were relevant ones and addressed the recommendations expressed in earlier assessments (Deliberation)

- There was agreement on the suggested instrumentation improvements. Details to be provided at the next meeting (ACTION).

- An understanding emerged that the issues of possible reduction of oscillations and resonance for smaller breaks shall in one way or another be addressed. Many in the group believe that this is an issue of a theoretical and speculative nature and that, if it exists, this phenomenon does not pose a challenge to the confinement structure of the BC. The Operating Agents should provide a way to resolve this issue, which appears to be the only one which is left without response (ACTION)

11. Next meeting

It was agreed that the next meeting will take place in Bratislava on 29th and 30th April. It will address:

- EREC contract
- Finalisation of the experimental programme
- Scenarios to be addressed (for MB and SBLOCA)
- Position with regard to the investigation of oscillation issue
- SG report

[On the latter point, consultations between the SG Chairman, the Project Manager and the NEA Secretariat are to take place to set forth a tentative structure of the SG report, ahead of the next meeting - ACTION].

Minutes of the
Third Meeting of the
BUBBLER CONDENSER STEERING GROUP (SG)

(Bratislava, 29-30 April, 2002)

1. Welcome and Opening Remarks

The Chairman, Mr. Ivan Lux, welcomed the participants and thank the host, the Slovakian Safety authority UJD and Mr. Husarcek for the preparation of the meeting. He then introduced Mr. Sienicki, from ANL, USA, who attended the meeting for the first time. Mr. Sienicki said that for practical reasons he could not attend the previous meetings, but he received information through the OECD on what was going on. He said that he has been working for about 25 years at ANL, mostly in the field of water reactor safety, and that for the last several years he has addressed VVER safety including Bubbler-Condenser issues.

Mr. Frescura also welcomed the participants. He briefly recalled the motivations for this project and the CSNI support to this Steering Group and mandate. He was looking forward to fruitful discussions and progress during this meeting.

The meeting agenda is given in Appendix 1, the list of participants is given in Appendix 2.

2. Adoption of the agenda

It was agreed that a brief presentation of the status of the B-C PHARE project will be given on point 10 of the Agenda (other issues). Mr. Vitanza said that a suggestion to re-discuss and possibly modify the B-C SG mandate had been received by the OECD. It was agreed that also this item be addressed on point 10 of the Agenda. With this, the proposed Agenda was approved. The Chairman recalled that each participating organisation speaks with one voice only, so as to make the discussion more efficient.

3. Approval of the minutes of the previous meeting

The minutes contained some errors on page 2 (Second Meeting in title and "reduction of" to be eliminated in A 14) and page 3 ("at the last meeting" to be eliminated in A2 and "to a limited extent" to be corrected at end of A5). With these corrections the minutes of the previous meeting were approved.

4. Status of Action Items

The Chairman reviewed the status of the actions from the previous meeting, which were listed on the first page of the Minutes.

- A8. This was a deliberation.

- A9 The scenario description was distributed to SG members ahead of the meeting.

- A10 Mr. Bajsz said that the key point for calorimetric energy balance is to avoid the water spill-back. This will be addressed during the meeting.

- A 11 The size of break for the test no. 3 is 90 mm

-A 12 This was a deliberation

- A 13 Details of the instrumentation of the tests will be presented during the meeting

- A14 The issue of oscillations is on the meeting agenda (point 7)

- A15 The present meeting has been planned according to what was recommended in this action item.

- A 16 There have been consultations between the SG Chairman, the Project Manager and the NEA Secretariat on the structure of the SG report. This would be presented on point 9 of the Agenda.

With this, the action items from the previous meeting were completed.

5. Status of the preparation of the experiments

Mr. Bajsz presented this item recalling the following points:

- Blowdown calculations for the plant were performed for the three tests. In particular, the MSLB calculations were performed by the Hungarian NPP, the MB 200 mm break calculations were made by the Czech NRI, and the 90 mm break was calculated by the Slovak VUJE.

- The above plant blowdown calculations were carried out for conditions and settings as specified in the reports that were circulated to participants ahead of the meeting.

- The corresponding test facility calculations are to be made by EREC personnel. The choice of the break location at EREC has also been made: MSLB middle, 200 mm closest, 90 mm LOCA middle position.

- EREC has completed the MSLB calculations for the facility itself.

- For the 90 mm break, the corresponding EREC orifice diameter is 8.5 mm.

- The blowdown calculations (for NPP) made by the three OA parties provide the energy release vs. time for the three types of tests. The outcome is (Energy in M Joule)

Break	MSLB	200 mm	90 mm
At 400 s	$1.2.10^{5}$	$2.2.10^{5}$	$1.4.10^{5}$
At 1000 s	$1.5.10^{5}$	$3.0.10^{5}$	$1.8.10^{5}$
At 2000 s	$2.2.10^{5}$	$4.0.10^{5}$	$2.6.10^{5}$

6. Discussion

The observation was made that the 90 mm break and the MSLB exhibit similar energy release (Wolff), implying that the statement made earlier that performing tests at lower beak size (i.e. < 90 mm) would have been difficult, was perhaps an exaggeration (Amri).

Mr. Wolff addressed a point, which he raised in earlier meetings on methodology pointing out that the 1:100 energy scale is not necessarily the optimal way to run the tests. In fact, the GRS intends to use a different methodology (for the German-Russian bilateral test).

Mr. Téchy agreed with the above and noticed that the calculations for the EREC test facility are still pending. The blowdown rate for EREC will be used to re-calculate CONTAIN loads for both NPP and EREC. In practice, there will be an iterative procedure to define the EREC test parameters.

Mr. Bajsz recalled the table presented on page 10 of the second meeting minutes, which shows that all three parties will make pre-test calculations on containment (pressure) for both plant and facility, for each of the three tests.

Mr. Wolff was satisfied that such an iterative procedure would be put to work, noticing that this will take some time.

The Chairman proposed to use the time ahead of the tests for more in-depth discussions and communications, both by e-mail or when needed by small group meetings. It was (later in the meeting) agreed that the NEA would set up an electronic discussion group constituted of the following persons: Ivan Lux, J. Bajsz, M. Sabata, J. Macek, J. Sipek, J. Sienicki, A. Amri. H. Wolff, J. Husarcek, Z. Téchy, A. Tkac.

During this discussion, Mr. Lux will be the group moderator. Mr. Bajsz presented the intended content of the test report that would be prepared by the OA. It was (later in the meeting) clarified that there would be two reports. One is a technical report that in the parts relevant to the new tests will be made available to the SG. This contains the items as outlined in Appendix 3. This is a detailed experimental and analytical report. The second report will be a SG report to the CSNI, containing the main outcome of the project, the progress made for the B-C assessment and key conclusions. This will not be a detailed technical report, and the intention is to issue it as an OECD/CSNI report. The context is discussed in Agenda point 9.
The following comments were made on the proposed OA report layout.

- On point 2 one should explain that there are differences among plants and how these are relevant or accounted for in the experiments.
- On point 3 one should recall key phenomena relevant for B-C and for different scenarios.
- The iterative methodology for the pre-test calculation should be included in point 4

The Chairman summarised the discussion as follows: The test description has been provided with a sufficient degree of detail in terms of scenario, event sequence and released energy.

- The pre-test calculations are pending and efficient discussions are needed such that input and comments from participants can be provided to the OA. The time set for discussions for the three tests will be:

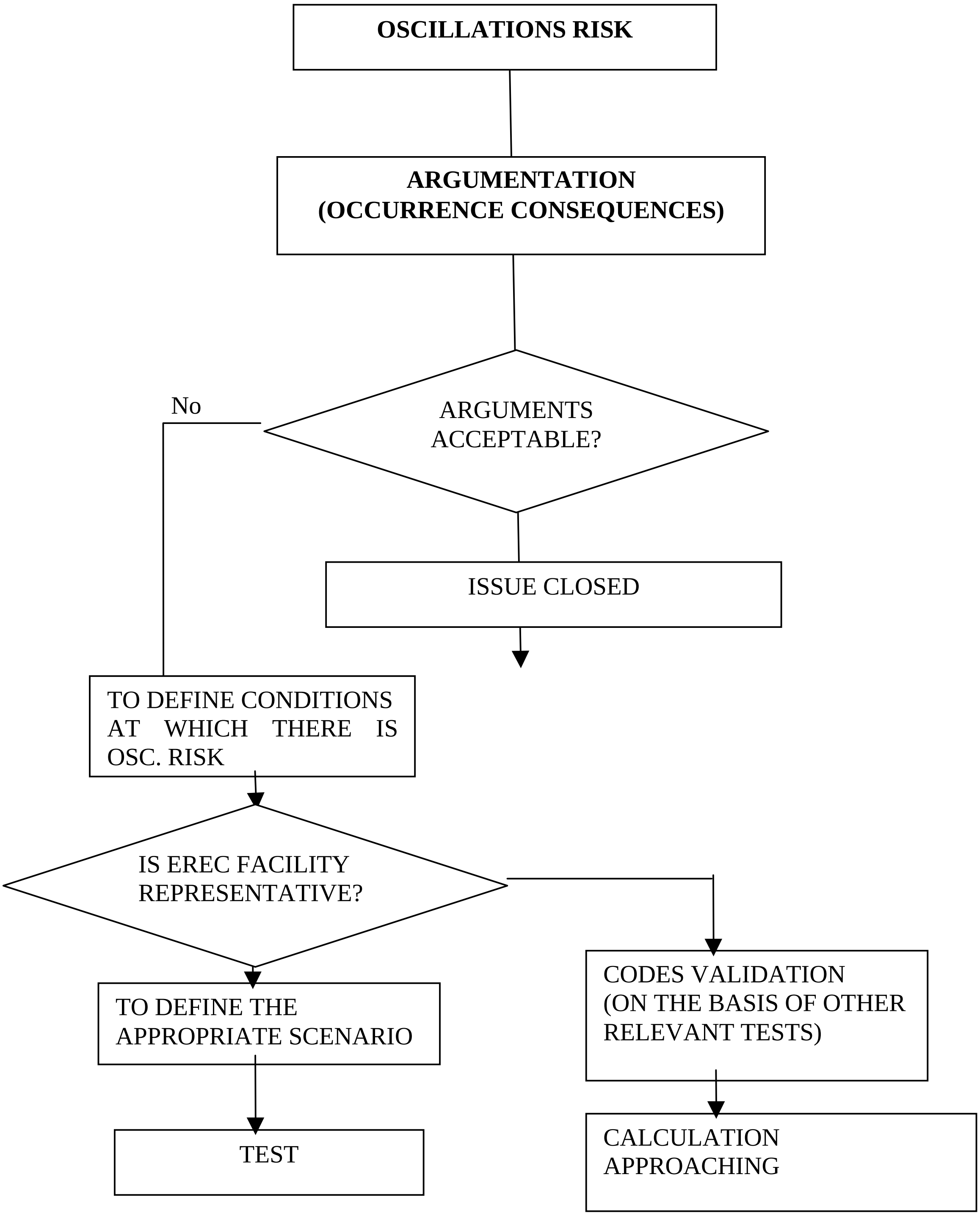
  May 13-17 for MSLB LOCA
  May 20-24 for 200 mm break
  May 27-31 for 90 mm break

  Each of these three steps will be preceded by communication of EREC calculation results.
- The proposed OA final report structure, with the suggestion made above, was approved.

Finally, the Chairman asked Mr. Bajsz to return to the point of calorimetric determinations and instrumentation. Mr. Bajsz reiterated that the best way to provide calorimetric assessments is to avoid water spill-back. Upon a question from Mr. Téchy, he pointed out that the water spray system does not interfere with such measurement and that in any case the spray will not be activated for the 90 mm break. With concern to instrumentation, there will be more temperature measurements, including in-water measurements.

7. Discussion on relevance of possible oscillations.

Mr. Amri proposed a structure for the process to decide how to deal with this issue. This is shown in the following figure


OSCILLATIONS RISK
ARGUMENTATION (OCCURRENCE CONSEQUENCES)
No
ARGUMENTS ACCEPTABLE?
ISSUE CLOSED
TO DEFINE CONDITIONS AT WHICH THERE IS OSC. RISK
IS EREC FACILITY REPRESENTATIVE?
TO DEFINE THE APPROPRIATE SCENARIO
CODES VALIDATION (ON THE BASIS OF OTHER RELEVANT TESTS)
TEST
CALCULATION APPROACHING

Mr. Téchy suggested a pragmatic approach, i.e., wait and see if oscillation arises in the three tests contemplated in the project or not.

Mr. Amri noted that we do not know when the oscillations may arise. Mr. Téchy agreed, adding, however, that one cannot for ever chose a phenomena that is thought it might occur but never observed (at relevant conditions). If the tests show something, we will take it from there.

Mr. Bajsz presented a diagram of test 1 of the previous industrial project, which shows that some oscillations took place in that test. However, they were of small amplitude (~4 kPa) and decreasing. Mr. Bajsz also showed calculations indicating that for breaks of 200 mm or lower, the pressure load is below 2 bar regardless if the B-C is in function or not. For SBLOCA, the B-C function is not even needed, only for LBLOCA (for which the anticipated pressure is 3 bar in absence of B-C, vs. a 2.5 bar confinement pressure limitation) the B-C function is essential.

The Chairman asked at this point that the licensing authority state their position on the issue in question. Mr. Husarcek said that in the Slovak Republic the issued license implies that the B-C function is considered satisfactory. There is no formal request to review this position. The tests done so far confirm this position. We will see if the planned tests provide further confirmation or if some aspects such as oscillations need to be reviewed.

Mr. Sipek from the Czech authority said that one in-depth review had been made based on earlier results. In all experiments there was no trace that relevant oscillations might occur. Based on 25 years of experience, he can mention no technical conditions (relevant for B-C) for which oscillations can occur.

Mr. Téchy reiterated his viewpoint: wait and see the outcome of the tests.

Mr. Sienicki said that based on old experience, a correlation exists for the insurgence of oscillations. He considered to come back after the meeting with remarks on this point.

Mr. Amri added that concerning the consequences, one might refer to radiological consequences, i.e., conditions for which fuel failure occurs. In principle, if there is no fuel failure, there should be no problem with B-C liner failure. (At this point, an observation was made that there is no failure anticipated in a SBLOCA).

Mr. Téchy returned to the point that for SB LOCA the spray system will take care of suppressing pressure rise.

Mr. Wolff said that the presentation from Mr. Bajsz was interesting. He agreed that we wait for the outcome of the tests and monitor if any oscillation occurs. He said, however, that some consideration on oscillations was made in designing the B-C, since plastic burst foils were originally present in order to separate the compartment system from the B-C. These were lately removed. He conceded that the issue of oscillations was raised in relation to BWRs, in which however the conditions are quite different from a B-C situation, including flow of nearly air-free mixture through the B-C. Concerning the absence of oscillations in B-C experiments performed so far Mr. Wolff mentioned, that they have all been related to LB LOCA conditions and, thus, to a short process duration due to the reverse flow (spill-back) of water.

Mr. Bajsz added that in the BWR the pipe configuration is quite different from the one in B-C. One should be very cautious about drawing comparisons.

Mr. Macek stated that we do not know if and when oscillations occur. But, if they occur, we should remember that there are 12 floors with trays, each responding differently. It is difficult to imagine that the whole construction would vibrate with one frequency only.

Mr. Tkac said that if oscillations occur, there will be siphon effects that will end oscillations. This point will be included in the OA report.

Mr. Wolff said that it would be useful to have a lower "cut" in terms of break size, below which no concern exists for the B-C function. This "cut" can simply be an indicative value and will be addressed in the OA report.

Mr. Téchy stated that if relevant oscillations occur in the EREC facility, this would perhaps be conservative with respect to the actual NPP situation (due to the 12 floors). He also stated that oscillations are not related to a specific break size, so we should look for such evidence in the upcoming tests. They will be long duration tests, which should favor spotting the size of such phenomena, if it does arise.

Mr. Wolff said that the MSLB scenarios in the bilateral test and in this tri-lateral project are quite different, so we will cover a wide range for exploring insurgence of oscillations. Code calculations would be very useful to link such test cases. As one SG member added, one thing is if oscillation may or may not occur, another is if it has safety related consequences on the B-C function.

The Chairman summarised the discussion as follows:

- The methodology proposed by Mr. Amri for addressing oscillations is a good one.

- Relevant oscillation phenomena have not been observed experimentally. However, the experimental basis is limited at present.

- For authorities, oscillations are not a concern currently. They would reconsider this position if applicable experiments show that relevant oscillations occur.

- The group takes the position to wait for the outcome of the tests. If the tests show no relevant oscillations, then the matter is settled for the sake of this group. This would however not prevent others from pursuing this issue further. If so, it is deemed useful.

8. Status of the preparations at EREC

The current plans call for the following schedule

- June 17-21: Performance of the MSLB test
- July 01-05 Performance of the 200 mm test
- July 15-19 Performance of the 90 mm test

The status of EREC preparation was circulated prior to the meeting and is as follows:

1. The electrical equipment of the test facility has been revised. Status of the equipment appropriates to requirements of exploitation. Control scheme of electrical heaters of vessels Vv1, Vv2, Vv5 will be tested up to 30th April, 2002.

2. The main standard measurements (pressure, flow rate, temperature, pressure difference, level) have been revised and re-activated. These measurements are operational according to the nominal status.

3. The electrical valves (53 units) of all test facility systems have been revised. Substitution of grease has been realized. The function of valves has been verified. Defects of electrical drivers of valves has been eliminated.

4. The system of air supply to hermetic boxes has been verified. The system is operational according to the nominal status.

5. The sprinkler system has been verified. The system functions are under nominal status. The system of water supply to the test facility and the system of drainage of the test facility have been verified. The systems function under nominal status.

9. Steering Group Activity Report

It was agreed that the structure of the activity report would be as follows:

Executive Summary (C. Vitanza, A. Amri)

1. **Introduction** (I. Lux) by end of September
- Motivation for setting up the OECD SG
- Abstract of mandate
- Intended audience
- Way of working
- Layout of report

2. **Background** (J. Bajsz. H. Wolff) by the end of September
- BC description and function
- Experimental facility
- Previous BC research
- Open questions prior to BC Trilateral project
- Analytical and experimental approach to respond to the open questions

3. **Analyses** (Zs. Techy, H. Wolff) by the end of September
- VEIKI calculations of flow/temperature
- Calculations of SBLOCA cases
- Other

4. **Experimental Approach** (J. Bajsz)
- Pre-test calculational results
- Motivation and objectives for the tests
- Justification for choice of scenario
- What do the tests cover, what do they not cover, why is SBLOCA not considered?
- Test description and conduct
- Results

5. **Results interpretation** (Zs. Techy)
- Post test calculations
- Answers to the open questions from the experiments

6. **Conclusions** (I. Lux, A. Amri)

Appendix 1: Mandate

Appendix 2: Minutes…..

The OA report will be ready by the end of October, thus the draft Activity Report should be prepared by mid-November. Parts of it, as indicated above, should be made ready by September.

A key recommendation is the consistency of the Activity Report and the OA report.

10. Other items

10.1 Information on PHARE programme

Mr. Husarcek informed the participants that this programme has now been agreed upon and will involve the three safety authorities on Hungary, Czech and Slovak republic. GRS will have the technical project leadership. There will be an UK (SERCO), an Italian (ANPA) and a Russian party involved.

The kick-off meeting is foreseen to be held place in Prague in June.

The programme will concentrate on the review of the results of the past industrial experimental project (PH 2.13/95), i.e., no experiments are envisaged. Details were provided in the previous meetings (see minutes of the SG meeting).

10.2 Mandate

It was agreed not to change the mandate. It was agreed that the mandate does state that the intention of the project is to produce "convincing evidence" to resolve remaining questions on B-C function. However, it does not presume that all aspects will be responded to by the intended tests. The national safety authorities will in any case determine the extent to which the experimental evidence is sufficient for their assessments and conclusions on B-C safety.

This concept should be adequately expressed in the introduction of the Activity report.

Further, it was agreed that the 4th SG meeting will be dedicated to the review of the SG Activity Report

11. Next meeting

The next meeting will be held on 25th and 26th November, tentatively in Prague (Bratislava second option).

Operating Agent Final Report, Structure and Content

(Attachment to the Trilateral Agreement)

1. Report purpose and objective

Content: *Annotation and brief description of history of Final Report origin on the basis of EU and IAEA activities; to what the report should be used; what is the objective of the report. It will also contain a very brief description with an overview of missions held in individual NPPs as well as opinion of appropriate state regulatory body with references to developed documents. This part has to be prepared by each participant among all three parties.*

2. Description of the bubbler condenser system and comparison of individual NPPs

Content: *description in the sense of already developed description of structure and design functions (performed jointly by Mochovce NPP, Bohunice NPP and Dukovany NPP). This description is completed by tables providing comparison of volume differences, main DBA parameters etc.*

3. Requirements for bubbler condenser qualification

Content: *Fulfillment of bubbler condenser design function as response to change of parameters inside a hermetically sealed area (pressure reduction); specification of reasons for changes and course of parameters inside hermetically sealed area (three types of LOCA, MSLB); boundary conditions for bubbler condenser qualification –summary of established parameters for environment and their courses as response to DBA; requirements for bubbler condenser design functions.*

4. Qualification requirements fulfillment safety case

Content: *This section will contain subsections with summary of conclusions to safety cases for initial events (Max. LB LOCA, MSLB, ML LOCA and SB LOCA) inclusive their analytical parts. Each responsible party shall create an appropriate subsection for the newly prepared tests. Such subsection will contain in particular:*

- *Specification for complementary experiment*
- *Established representative discharge characteristics*
- *Defined process for assessment and approval of results from analyses and experiments.*
- *Summary developed by each respective responsible party containing description and conclusions of final report with regard to experiment performance.*
- *Summary of BC Steering Group standpoints.*

A separate part for each individual experiment shall be an assessment of impact of previously identified inhomogenity in distributions as well as assessment of phenomena attendant bubbler condenser behavior during fulfillment of its design functions. It must be proved that these phenomena do not affect function and integrity of system. The following belongs to the observed phenomena:

- *Temperature distribution inhomogenity*
- *Flow distribution inhomogenity*
- *Chugging*
- *Water escape from trays to chambers*
- *Pressure waves occurrence*
- *Water expulsion/ retaining from/out trays – passive sprinkling (feedback to check valve from pressure in containment)*

The subsection „max. LB LOCA„ shall be prepared jointly by all participants based on conclusions from the PH2.12/95.

5. Summary of performed and remaining remedy measures for qualification completion.

Content: *In relation to conclusions of subsections the participants shall jointly prepare an overview of remaining remedy measures for completion of qualification (if any). Each party will complete this part by an overview of its own already performed actions on bubbler condenser tower.*

6. Overall conclusions

Content: *Brief summary of analyzed DBAs with an approved scope of conclusions for presentation of overall opinion on bubbler condenser tower qualification before the Bubbler Condenser Steering Group.*

7. References (Literature)

Content: *Numbered list of relevant documents to which references are made in text of individual sections.*

8. Appendices

Content: *Final reports to individual experiments could be appended as well as other documents approved by participants of this trilateral agreement.*

Minutes of the
Fourth Meeting of the
BUBBLER CONDENSER STEERING GROUP (SG)

Prague, 25th and 26th November, 2002

1. Opening of the Meeting

The Chairman welcomed the participants and thanked the State Office for Nuclear Safety (SUJB) for organising the meeting. Mr. Svab gave his welcome and said that all necessary arrangements were made in order to have a successful meeting

2. Adoption of the agenda

The meeting Agenda was approved

3. Approval of the Minutes from the Previous Meeting

With a minor correction on page 7 (chase instead of chose), the minutes were approved.

4. Status of Actions

- The Chairman recalled that for the first test, pre-test calculations were distributed and thoroughly commented on. The comments were fewer for the other two tests.

- With concern to the oscillations, the scheme of Mr. Amri on method was followed.

- The tests were carried out as scheduled.

- The first step of the activity report is done and the draft version of all chapters is available, except for the conclusions (and Executive Summary), which will be discussed during the meeting. With this, all the actions from the previous meeting were completed.

5. Review of Test Results

Mr. Bajsz gave an overview of the test results. The tests were carried out as agreed in the SG. Their execution was successful. The OA experts were present during the test execution. As agreed, additional temperature measurements were arranged. The tests showed similarities with previous tests in the sense that no new physical phenomena were observed. Some uneven temperature distribution was registered as in previous experiences. The measured pressure and •P was much lower than the safety limit. A summary of the main measured and calculated results is provided in the table below, which is also shown at the end of Section 4 of the SG activity report.

Test	Break Location from BC	P_1 max (bar)	T_1 max (bar)	P_s max (bar)	dPmax (Kpa)	dTwa (^oC)
LBLOCA N4	near	2.76/2.86	130/132	2.08/2.16	19.2/17.6	15/29
LBLOCA N5	far	2.51/2.48	127/127	2.02/2.02	15.8/18.2	15/28
LBLOCA N1	middle	2.09/2.25	121/124	1.90/1.96	11.2/11.1	13/10
MSLB	near	1.52/1.60	112/172	1.50/1.52	7.1/8.8	5/12
200mmLOCA	near	1.45/1.56	104/112	1.45/1.49	5.7/6.9	5/10
90mmLOCA	middle	1.36/1.42	102/108	1.37/1.37	4.8/5.2	5/17

The first value is the experimental result, whereas the second one represents the calculated value by the CONTAIN code. As seen, the comparison is, with the exception of the temperature difference dTwa and the temperature T_1max in the MSLB case, rather satisfactory. Some minor oscillations with 2 Hz frequency were observed in the early phase of the tests.

On the MSLB test, Mr. Bajsz also explained how the results of the tests were fed into the post-test code calculations in order to verify critical test measurements or results.

Mr. Macek and Mr. Denk provided a review of the NRI (Czech Republic) pre- and post-calculations on the 200 mm LOCA test. The pre-test conclusions were that the EREC tests would provide a good applicability to NPP. The post-test calculations gave a good comparison with temperature data, whereas pressures were somewhat overestimated.

Mr. Tkac presented the post-test analyses which were carried out at VUJE (Slovakia) and an overview of how calculations compare with experiments. Such a comparison was in general rather satisfactory.

Mr. Amri asked if the nodalisation in COCOSYS was fine enough for the purpose of the comparison made by NRI. Mr. Macek replied that a standard nodalisation was used (the same 6 node model as in the previous industrial project).

Mr. Wolff expressed his appreciation for the analyses carried out by the Hungarian, Czech and Slovak colleagues. He added that there are differences between the EREC set-up and the NPP, which need to be modeled. He suggested the following scheme:

NPP calculations • BC pre-test • TEST • BC post-test • NPP calculations
Calculations calculations

Since EREC is a satisfactory model of the reference plant bubble condenser containment. However, there is a number of differences between the EREC model and the BCC, which restrict the trivial implementation of results to the plant. Therefore codes are needed to link the test results to NPP situations. Mr. Bajsz said that this is exactly the purpose of the analytical effort made by the OAs. Mr. Wolff was satisfied that the blowdown rate was correctly quantified and verified, as this was an important issue, which had raised questions in the past. With regard to the calculated temperature in the MSLB case he mentioned the importance of the thermocouple orientation on the measured value. In order to avoid a possible collection of water at downward oriented thermocouples, the orientation was changed to upwards shortly before the steam line break accidents test (in the frame of the German-Russian bilateral project).

Mr. Techy went through the interpretation of the results, which basically consisted of a review of Chapter 5 of the Activity Report. Mr. Amri observed that in one of the tests the peak pressure was predicted by one code (CONTAIN, MBLOCA 200 mm) much earlier than in the other two codes (COCOSYS and TRACO). Mr. Techy said that in fact there was a pressure plateau, which lasted for quite some time.

6. Status of the Final Report on the Experiments

Mr. Bajsz had already explained the outcome of the tests and related analyses, which will be compiled into the Final Report made by the utilities and addressed to the safety organistions in Hungary, the Czech Republic and the Slovak Republic.

During the discussion, it became clear that a clarification is needed as to which reports will be produced by whom and their denomination. Mr. Vitanza observed that there is in fact an ambiguity in the SG Mandate, where reference is made to an "activity report" and to a "final report". At the time when the SG Mandate was written, it was not known that the OAs would prepare their own "final report", thus, the two terms were used to refer to one report only.

In conclusion:

- For the purpose of the BC-SG work, there will be one report only and it will be called "SG Activity report". This report is the one being produced by SG as agreed at the last SG meeting, and which will be discussed under Agenda item 7. The draft report will be made available before the end of January and will be subject to CSNI approval for publication as a CSNI report.

- For the purpose of the Hungarian, Czech and Slovak utilities reporting to their safety authorities, there will be another report called "Final Report". This will be ready by the end of January. The utilities plan to have the SG Activity Report included as an appendix in their "Final Report. The content of this Final Report was presented at the last SG meeting, and is outlined in Appendix 3 of the minutes from the last meeting.

7. Discussion on Answers to Pending Questions

The SG agreed on the following answer to the pending questions:

Q1. The scaling of energy discharge rate is important for determining the thermal-hydraulic load on containment structure. Can estimates be made on whether the conclusions drawn are or not conservative, and if they are, on the degree of conservatism?

A1. The verification of the blow-down mass and energy rates (MER) producing loads to the BC was performed in the frame of the present project for both the previous LBLOCA tests and for the recent tests. Results confirmed conservative mass and energy estimations. It was shown that the injected MER were higher in the tests than the scaled MER (NPP/100) values.

These findings confirmed the conservative nature of the approach. Conclusions were that the related loads do not represent a challenge to containment integrity.

A parallel assessment of this issue with respect to LBLOCA tests is going on in the PHARE project PR/TS/17.

Q2. Are the conservatism and adequacy of the BC facility properly addressed?

A2. The first part of the question concerning conservatism (initial conditions, scenarios, test conditions, different break locations, etc.) can be answered positively. The adequacy was addressed by the scaling of the facility and possible distortions were compensated by different measures (e.g. installation of additional insulation).

Q3. Unexpected non-uniformity of flow rates and of water temperatures has been observed in earlier tests. Are these observations relevant and why? Can specific code calculations help in this assessment?

A3. Non-uniformities of flow rates and water temperatures have been observed in the experiments. An appropriate understanding of the non-uniformities was obtained by detailed (3D) code calculations. The reasons and the nature of the distributions have been satisfactorily explained by code calculations.

The above questions are the ones contained in the SG Mandate to be answered. The answers represent the SG consensus and will be included in the conclusions of the Activity Report.

8. Status of the SG Activity Report

The Chairman went through a detailed review of the various chapters of the draft Activity report. A number of changes were proposed to contributors of the various chapters. It was agreed that the answers on pending questions will be included in the conclusions and executive summary. Mr. Sienicki will help with a clarification of the concept of conservatism.

The following steps were agreed upon:

1. The corrections to the various chapters will be made by mid-December

2. The conclusions will be prepared by the end of December.

3. The executive summary and the entire Draft Activity Report will be prepared before the end of January

Mr. Wolff requested that in Chapter 5 the COCOSYS calculations made by NRI be skipped, since no explanation is given for the differences with respect to measured pressure values in steam generator boxes during SBLOCA. Mr. Techy did not agree. Mr. Macek said the COCOSYS predictions were not bad (the trend of calculated and experiment values are the same) and heat losses can explain differences in most cases (definition of boundary conditions). For an exact evaluation of results of computer code against experimental data all main parameters must be take in to account (pressure, temperature in all main volumes of hermetic boxes and BC).

It was also agreed that the minutes of the SG meetings be included as Appendices to the Activity Report. The Chairman said that he would report on the BC SG outcome at the next CSNI meeting.

9. Other information from SC members

Mr. Wolff reported on the progress of the PHARE Project. There will be a meeting in mid-December with the Hungarian, Czech and Slovak regulatory bodies for finalising the experiment propagation and reviewing the analytical support. He added that the SG activity might be referred to in the reporting made within the PHARE Project. However, they will b e referred to as neutral statements, i.e., it is not intended to "evaluate" such activities yet.

10. Closure

The Chairman thanked all the participants and in particular the project manager, Mr. Bajsz for their constructive contribution to the project.

Appendix 3

SG Members
(and participants of last meeting)

Mr. Ivan LUX, *Chairman*	Hungarian Atomic Energy Authority
Mr. Pavel KRESAN	EDU, Czech Republic
Mr. Miroslav SABATA	EDU, Czech Republic
Mr. Miroslav SVAB	SUJB, Czech Republic
Mr. Jiri MACEK,	NRI, Rez, Czech Republic
Mr. Jaromir SIPEK	State Office for Nuclear Safety, Czech Republic
Mr. Lubomir DENK	NRI, Rez, Czech Republic
Mr. Abdallah AMRI	IRSN, France
Mr. Holger WOLFF	GRS, Germany
Mr. Zsolt TECHY	Institute for Electric Power Research Co., Hungary
Mr. Jozsef BAJSZ	Paks NPP, Hungary
Mr. Jan HUSARCEK	Nuclear Regulatory Authority of the Slovak Rep.
Mr. Pavol BAUMEISTER	NPP Mochovce, Slovak Republic
Mr. Jaroslav HOLUBEC	NPP Mochovce, Slovak Republic
Mr Jozef HUTTA	Jaslovske Bohunice NPP, Slovak Republic
Mr. Imrich KRAJMER	Jaslovske Bohunice NPP, Slovak Republic
Mr. Jan BORAK	Jaslovske Bohunice NPP, Slovak Republic
Mr. Andrej TKAC	VUJE, Slovak Republic
Mr. James SIENICKI	Argonne National Laboratory, USA
Mr. Eduard DEKSNIS	EC
Mr. Carlo VITANZA	OECD Nuclear Energy Agency