The LOBI Test Matrix

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Premise

The LOBI Project has been carried-out at the Joint Research Centre (JRC) in the framework of the European Commission (EC) Reactor Safety Research Programme under contractual agreement with the former Bundesminister für Forschung und Technologie (BMFT) of the Federal Republic of Germany and in close collaboration with institutional and/or industrial organizations of EC member countries. The primary objective of the research programme was the generation of an experimental data base for the assessment of the predictive capabilities of thermal-hydraulic system codes used in reactor safety analysis. Within this context, experiments have been conducted in the LOBI integral system test facility designed, constructed and operated at the Ispra Site of the Joint Research Centre. In its final configuration, the overall LOBI Test Matrix includes 70 experiments covering large and small break LOCA, Special Transients, emergency operating procedures and accident management strategies as well as test facility characterization tests.

1. Background

A general international consensus of opinions emerged in the early 70s on the need to provide reliable methodologies for a realistic estimate of emergency-core-cooling system (ECCS) performance which was being questioned as large power reactors were being introduced. Due to the limited sophistication of safety codes and to the lack of relevant experimental data for assessing their predictive capabilities, sufficient conservatism was prescribed in the safety evaluations of design basis accidents, such as loss-of-coolant accidents (LOCAs), to account for worst-case uncertainties. This entailed stringent licensing requirements and undesirable operational constraints on nuclear power plants.

Within this context, reactor safety research and development programmes were formulated at the international level to improve the current understanding and modeling capabilities of thermal-hydraulic phenomenologies governing the course of a LOCA or of any other anticipated abnormal occurrences in water cooled reactors. Emphasis was placed mainly on deterministic methodologies supported, as appropriate, by probabilistic risk assessment studies with the aim to better understand accident progression and to substantiate the request for the eventual relaxation of over-conservatism in some safety acceptance criteria.

The LOBI Project originated from a reactor safety research and development contract between the European Commission and the former Bundesminister für Forschung und Technologie of the Federal Republic of Germany. On the basis of contingent and perceived safety requirements, BMFT decided in 1972 on the need of an experimental programme to be conducted in a integral system test facility to investigate thermal-hydraulic phenomenologies relevant to accident conditions in pressurized water reactors (PWRs) of German design. As result of a tender, the execution of this study was awarded to the Joint Research Centre of the European Commission.

2. Research Objectives

The LOBI research programme, as initially conceived, has been mainly oriented towards the generation of an experimental data base relevant to risk dominant accidents and transients in PWRs. Specific research objectives included:

- identification and/or verification of basic phenomenologies governing the thermal-hydraulic response of an integral system test facility for a range of conditions relevant to LOCAs and Special Transients in current PWRs,

- generation of an experimental data base for model development and the independent assessment of the predictive capabilities of large thermal- hydraulic system codes used in water reactor safety analysis.

The experimental programme has been supported by comprehensive code application and assessment activities. State-of-art versions of major safety codes such as ATHLET (DRUFAN), CATHARE, RELAP4, RELAP5 and TRAC have been largely used either within JRC or by outside organizations for test design and test prediction calculations. Development and application of advanced two-phase flow measurement techniques have constituted an integral part of the overall research strategy. A considerable effort has also been devoted to the development of an IBM version of the RELAP5 code which, together with various model improvements introduced at the JRC, has been instrumental in enabling the calculation capabilities of may organisations within and outside the EC.

3. The LOBI Test Facility

The LOBI test facility is a full-power high-pressure integral system test facility representing an approximately 1 : 700 scale model of a 4-loop, 1300 MWe PWR. It incorporates the essential features of a typical PWR primary and secondary cooling system. The test facility was commissioned in December 1979 and was operated until June 1982 in the MOD1 configuration for the investigation of large break LOCAs; it was then extensively modified into the MOD2 configuration which was operated from April 1984 to June 1991 for the characterization of phenomenologies relevant to small break LOCAs and Special Transients in PWRs.

The measurement system comprised a total of about 470 measurement channels which allowed the measurement of all relevant thermal-hydraulic quantities at the boundaries (inlet and outlet) of each major primary and secondary system loop component and within the reactor pressure vessel model and steam generators. A process control system allowed the simulation of time or pressure dependent parameters such as core decay heat release, main coolant pump hydraulic behavior and safety injection flow rates. A fast running data acquisition system complemented the experimental installation.

The LOBI-MOD1 test facility reference plant is the Siemens-KWU 1300 MWe BIBLIS B nuclear power station. Major design and operation parameters of the experimental installation are reported in the following Table I.

Table I. LOBI-MOD2 Design and Operation Parameters

Reference Plant	Siemens-KWU	Biblis B
	Loops	4
	Power	1300 MWe
Primary System	Loops	2 (1:3)
	Total Volume	0.6 m³
	Scaling Factor	1:700
Core	Power	5.28 MWe
	Length	3.9 m
	Number of Rods	64
	Matrix	8x8 square
	Heater Rod OD	10.75 mm
	Pitch	14.3 mm
	Electrical Heating	Direct
Vessel Downcomer	Configuration	Annular
	Gap Width	MOD1: 50 and 12 mm
		MOD2: 12 mm
Steam Generators	Type	U-Tubes
	Number of Tubes	1-loop SG: 8
		3-loop SG: 24
	Downcomer	Annular
Main Coolant Pumps	Type	Centrifugal
	Specific Speed (DIN)	29.2
Nominal Operation	Primary System	
	- Pressure	15.8 MPa
	- Temperature	294/326 °C cold-leg/hot-leg
	Secondary system	
	- Pressure	6.4 MPa
	- Temperature	210/280 °C inlet/outlet
Operating Organisation	EC Joint Research Centre	Ispra, Italy

3.1 Mechanical Components

The test facility comprises two primary loops, the intact and the broken loop which represent respectively three loops and one loop of the reference PWR. Each primary loop contains a main coolant circulation pump and a steam generator. The simulated core consists of an electrically heated rod bundle arranged in a square matrix inside the pressure vessel model. The primary cooling system which is shown schematically in Figure 1 and 2, operates at normal PWR conditions; approximately 158 bar and 294 - 326° C pressure and temperature, respectively.

Heat is removed from the primary loops by the secondary cooling system which contains a condenser and a cooler, the main feedwater pump, and the auxiliary feedwater system, Figure 2. Normal operating conditions of the secondary cooling system are 210° C feedwater temperature and 64.5 bar pressure.

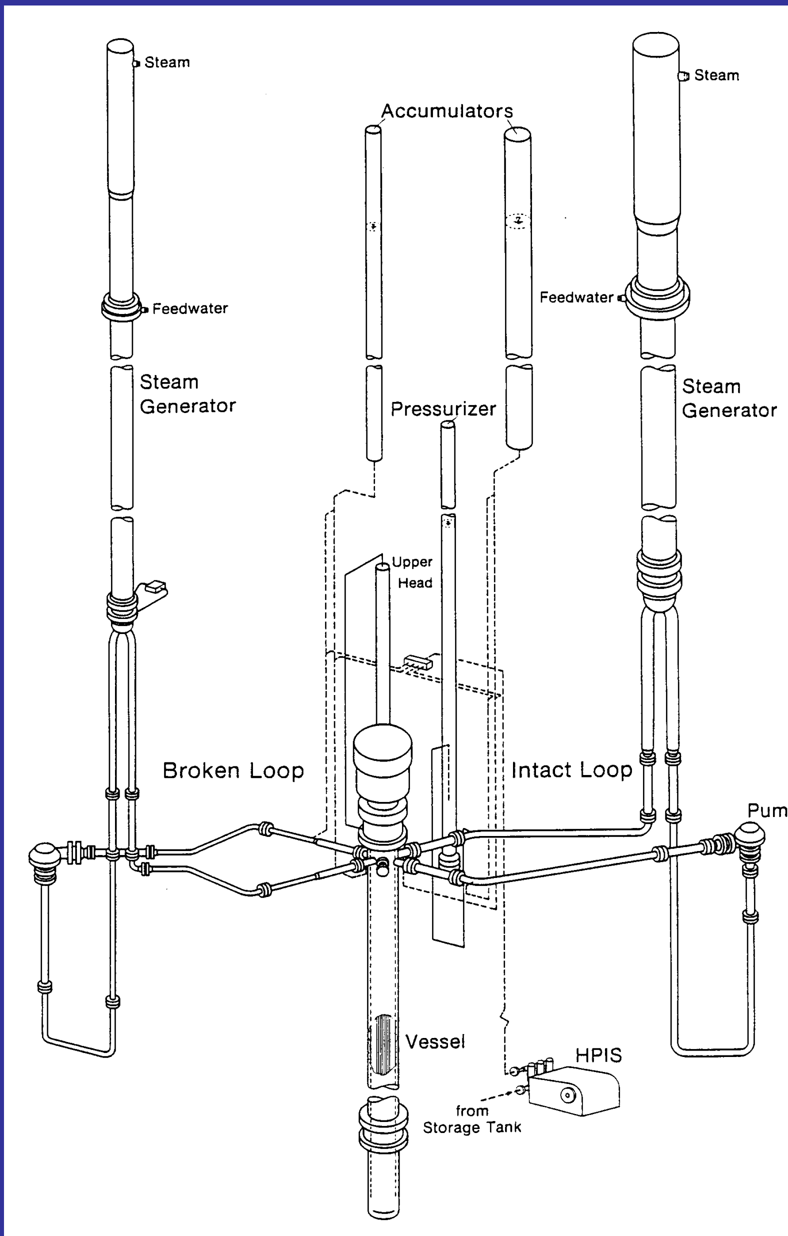

Fig. 1: The LOBI-MOD2 Test Facility

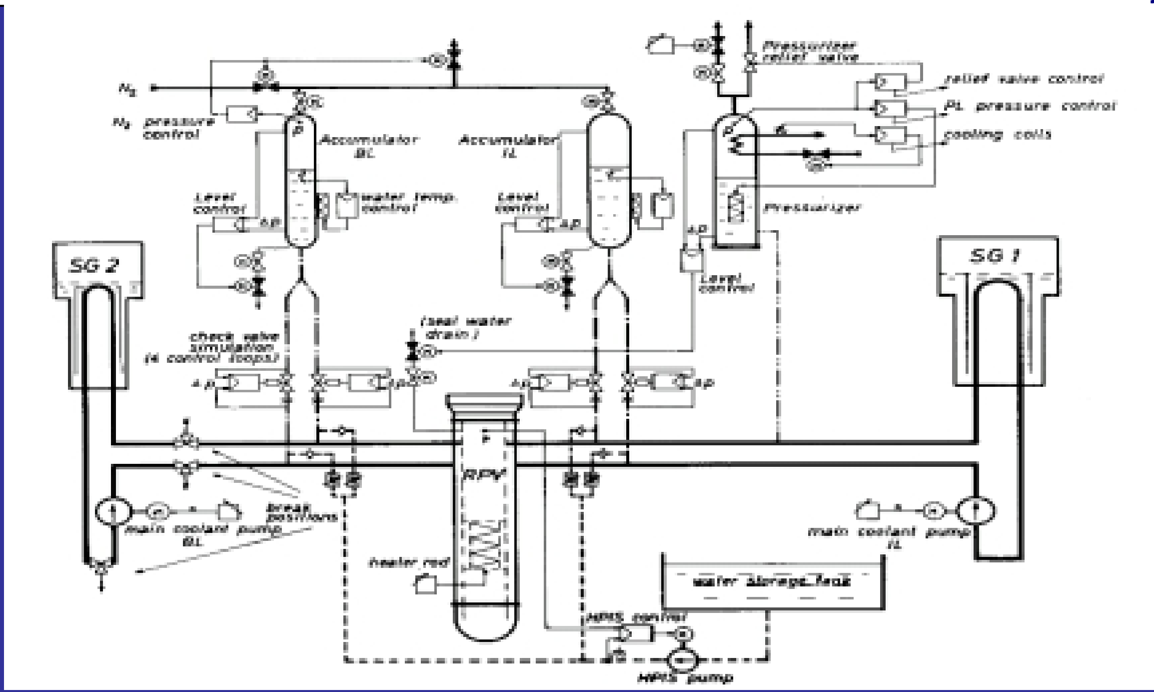

Fig. 2: LOBI-MOD2 Primary System Schematic Flow Chart

3.1.1 Reactor Pressure Vessel Model

The reactor pressure vessel model comprises the pressure vessel, the core barrel tube and the core simulator. Lower plenum, upper plenum, an annular downcomer and an externally mounted upper head simulator are additional major components of the overall pressure vessel assembly.

The reactor core is simulated by an electrically heated rod bundle consisting of 64 rods arranged in an 8x8 square matrix inside the flow shroud; heater rod bundle dimensions are reactor typical. The heater rods are directly heated hollow tubes (material 1.4948 DIN 17007) and the rod wall thickness within the heated length is varied in 5 steps to achieve a chopped cosine shaped axial power distribution.

The upper part of the rod bundle which extends entirely into the upper plenum is formed by hollow nickel tubes connected to the upper power plate. The lower part is formed by nickel rods and flexible nickel braids which extend partially into the lower plenum where they connect to the lower power connecting ring. The heat dissipated within these ‘unheated’ regions amounts to about 14%. Nine grid spacers of original design are placed along the heated length; five additional spacers are mounted in the upper unheated part of the rod bundle. Ceramic segments are arranged inside the core barrel tube forming a square flow shroud which extends over the heated length region of the rod bundle.

The upper head is simulated by an external vessel connected to the upper plenum and to the upper downcomer. Volume as well as height and relative elevations of the reference plant upper head are preserved. In the initial MOD1 version of the test facility, the annular downcomer formed by the pressure vessel and the core barrel tube had a gap width of 50 mm which was later decreased to 12 mm to better represent fluid volume distribution.

3.1.2 Steam Generators

The LOBI test facility contains two shell and inverted U-tube type steam generators having a geometrical configuration similar to that of the reference plant In the MOD1 configuration, the steam generators were designed to preserve heat transfer capabilities without proper simulation of secondary side fluid distribution. In the MOD2 configuration, the steam generators were designed with the aim to better represent thermal-hydraulic phenomenologies of interest in intact circuit faults.

The overall scaling ratio which required a capacity ratio of 3:1 between the intact and the broken loop steam generator led to a heat transfer exchange power of 3.96 MW (24 U-tubes + 1 installed spare) and 1.32 MW (8 U-tubes + 1 installed spare) for the intact and broken loop SG, respectively. Each steam generator consists of a single cylindrical pressure vessel with an annular downcomer separated from the riser region by a skirt tube which is supports at the top end the coarse separator; a fine separator is arranged in the uppermost part of the steam dome. The U-tubes are arranged in a circle within the riser region around an axially mounted filler tube, with the U-bends crossing over one another above it. This design permits cross flow between co-current and counter-current legs of the U-tubes over their entire length and heat and mass transfer between riser and downcomer to account for the recirculation characteristics of the prototypical system. An adjustable throttle device is installed at the lower end of the downcomer to properly set the recirculation ratios.

Feedwater is directed into the downcomer by a ‘J-nozzle’ feed ring sparger and flows downward mixed with the recirculation water returned by the coarse and fine separators. The steam water mixture leaving the bundle region flows upward upward into the coarse separator where the moisture is partially removed by centrifugal separation and returned to the downcomer. Additional separation is attained in the fine, box-grid type separator from where saturated, practically dry steam flows into the outlet nozzle. On the primary side, fluid enters the U-tubes through an inlet chamber and flows first upward and then downward exchanging heat with the secondary fluid.

3.1.3 Main Coolant Pumps

The LOBI main coolant pumps are of the centrifugal type with a specific speed of 29.2 (DIN). The two pumps are equal in size and are therefore operated at two different speeds such as to yield the two different steady-state mass flows of 21 Kg/s and 7 Kg/s for the intact and broken loop at the same pressure head. A special control and drive system allows variation of the pump speed in the forward and backward directions over a range of $\pm$ 8500 rpm. Since the locked rotor resistance of the MCPs is less than the equivalent reactor pump, there are provisions for the insertion of an additional flow resistance at the outlet of each pump.

To account for the injection of the main coolant pump seal water, a closed loop seal water compensation system is installed. This system works on a mass balance principle regulated in an externally mounted seal water supply tank. Drainage of the injected mass is made from the upper plenum in steady-state for practical reasons which aim at increasing circulation and cooling of the upper rod bundle and is diverted to the lower plenum during the transient to ensure drainage.

3.1.4 Pressurizer

The pressurizer design is geometrically similar to that of the reference plant; however, it is scaled in volume but not in height. The surgeline rises within the pressurizer and leaves it radially. The pressurizer is provided with normal and additional heaters; the spray system is simulated with cooling coils placed in the steam region. There are provisions for connecting the surgeline to either the intact or broken loop hot legs. Simulation of power operated relief valves (PORV) as well as safety relief valves (SRV) is provided in the pressurizer relief line.

3.1.5 Primary Loop Pipework

The main coolant pipes connecting the major primary loop components have inner diameters of 73.7 mm and 46.1 mm for the intact and broken loop, respectively. Measurement insert are installed at the inlet and outlet of each major component forming integral part of the main pipe-work. Since the main coolant pumps are equal in size with an inlet-outlet diameter of 65 mm, special cross-sections adapters are installed at the inlet-outlet of each pump to fit the main loop pipes.

The break assembly consists of a T-shaped insert with the break orifice housed in a recess machined in the insert. The break assembly can be connected to the main coolant pipe at the selected break location; e.g., cold leg, hot leg or pump seal. Pressurizer breaks or inadvertent opening of the valves are simulated by an orifice inserted in the relief line. A proper connection can be established between primary and secondary systems at the tube plate elevation to simulate steam generator tube rupture (SGTR) sequences.

3.1.6 Safety Injection Systems

The LOBI-MOD2 emergency-core-cooling system (ECCS) comprises the high pressure injection system (HPIS) and the accumulator injection system (AIS). As required, the low pressure injection system (LPIS) could also be simulated. Provisions are made for cold leg, hot leg or combined cold and hot leg ECC injection in both primary loops. In the MOD1 version of the test facility only the accumulator system was simulated.

The HPIS water is supplied by a positive displacement pump driven by a variable speed motor. The pump is rated for a maximum flow of 0.39 Kg/s at a total head of 200 bars. A special speed control system provides appropriate flow regulation to match the reactor HPIS expected performance. Properly designed and calibrated throttling devices are installed in the main injection line to provide the required partitioning (depending on particular simulation needs) of the injection rate between the broken and the intact loop.

The AIS is composed of two accumulators, one in each loop. The accumulator of the intact loop has three times the volume and water capacity of that of the broken loop. The total volume of each accumulator is scaled to that of the reference plant having one accumulator for each loop; gas space, water volume as well as height and elevations are preserved. Both accumulators are rated for a maximum pressure of 60 bar and a temperature of 50 C.

Additional safety injection systems consist of the Volume Control System (VCS) and of the Auxiliary Feedwater System (AFWS). The VCS consists of a feed pump and a water pre-heating system which allows the control of the injected water at the prevailing cold leg fluid temperature. Similarly, the AFWS consists of a feed pump an a water pre-heating system as the injected water is preheated to generally about 130 C to prevent thermal shocks in the SG feed line and J-nozzle feed ring.

3.2 LOBI Measurement System

The LOBI test facility in both the MOD1 and MOD2 configurations has been fitted with a comprehensive measurement system. Relevant thermal-hydraulic quantities were measured at the boundaries of each major component and within the reactor pressure vessel model and the steam generators.

Measurement in the primary loop pipework are performed within the measurement inserts at the inlet and outlet of each major component; i.e., the reactor pressure vessel model, the steam generators and the main coolant pumps. The inserts in the horizontal pipework are properly instrumented in the lower and upper part of the flow cross-section to characterize eventual flow and thermal stratification phenomena. Fluid and wall temperatures, absolute and differential pressures,

fluid velocities and density as well as flow direction indicators are generally provided at each measurement insert.

Measurement of temperatures, pressures and differential pressures are extensively made along the downcomer, lower plenum, rode bundle section and upper plenum flow paths. Fluid velocity and fluid density are measured at the rod bundle inlet box.

Each rod bundle is supplied with three thermocouples brazed into grooves of 0.8 mm depth and 10 mm length machined into the outer surface of the heater rod tubes and then led through the wall to the inside of the tubes; they leave the rods through the open upper end.

The LOBI-MOD2 steam generators are instrumented to provide a maximum of information on both the magnitude and location of the heat transfer process taking place between the primary and the secondary systems. In particular, the instrumentation is concentrated in the region of the lowest U-bend and immediately above the tube plate in order to detect changes in heat transfer regime.

Steam generators measurements include fluid temperatures, U-tube wall temperatures and differential pressures on both the primary and secondary side. Primary side instrumentation is applied to two representative U-tubes in each steam generator; the highest U-tube is fitted with temperature sensors whereas differential pressures are measured in the shortest U-tube. Special Pitot tubes are installed in the downcomer of the steam generator secondary side to measure fluid velocities at three peripheral positions.

Measurements in the secondary system is concentrated in the feed-water and in the steam lins at the inlet and outlet of each steam generator. Feed-water line measurement include fluid temperature and velocity whereas in the steam line fluid temperature and volumetric flow is measured. A special spool piece with low density measurement capability may be mounted at the outlet of the broken loop steam generator for detecting eventual carry-over in those tests involving blowdown of the secondary side.

The pressurizer and the surgeline are provided with fluid temperature and differential pressure measurements; also, a full flow turbine is installed within the pressurizer surgeline. All ECC injection lines are provided with full flow turbines and fluid temperature measurements. Mass flow measurement is also provided in the main coolant pump seal water injection lines.

The break flow measurement system consists of a condenser-catch tank system. Initially, the high energy flow is condensed in the cold liquid pool contained in the catch tank; thereafter, long-term low flow energy removal is ensured by a small 250 KW condenser. The break flow in its integral form is obtained by the incremental mass of the catch tank.

3.3 LOBI Data Acquisition System

A special tailored data acquisition system is used to record all measurement signals. The sampling rate can be varied up to 20000 samples/s as appropriate for the representation of the experimental information. Selected data are then read back from the analog tape, converted into engineering units and stored on 300 Mbyte disk modules ready for normalization and correction.

All selected data records per measurement channel are reduced to about 1000 data points over the experiment time range; each value is simply an average over the time interval between data points. The corrected data in its final form are stored on the corresponding experimental data tape. As appropriate, special selects again of 1000 data points each are made for time intervals characterized by fast transients and stored on a related data tape.

A real time loop control and monitoring system provides defined set of time ordered operations to represent components response during the simulated transient. Control of main coolant pump speed, core heating power, high pressure injection system flow rate and steam generator level is performed on a real-time basis in response to pre-defined trip signals.

Operator control or intervention is via a special push-button panel and a control keyboard input-status information is displayed on colour monitors which can show the evolution of any selected analog or digital signal. In addition, a log of all status changes and trip signals is kept on disk and displayed both on the colour monitor and on a line-printer.

3.4 Scaling Criteria

The LOBI test facility was scaled to preserve, insofar as possible or practical, similarity of thermal-hydraulic behaviour with respect to the reference plant. As general scaling principle, a power-to-volume scaling criterion was adopted in the design of the facility to ensure the preservation of the specific power input into the primary fluid.

3.4.1 Rationales

To meet general scaling requirements, the test facility was designed to preserve, taking into account the selected 1:700 power to volume scaling ratio, the following parameters:

- core power to system volume ratio
- volumes and relative volumes of individual components
- rupture size to primary system volume ratio
- pressure drop and temperature distribution along main flow paths
- height and elevation of major components
- core and steam generators heat transfer surfaces.

The elevation of the major components were maintained at full height with exception of the pressurizer which, while preserving the total volume and the steam to liquid volume ratios, was somehow shortened to allow increased radial dimensions to accommodate the internal heaters. The core and steam generators heat transfer and flow areas were matched to the scale factor. Strict adherence to the power-to-volume scale factor would have resulted in unacceptably high wall frictional pressure losses in the primary loop pipework which was appropriately shortened to increase the pipe diameter in order to match the expected pressure drop in the reference plant.

In the MOD2 configuration of the test facility special emphasis was given to the scaling of the steam generator primary and secondary sides due to their importance on the thermal-hydraulic evolution of small break LOCAs and special transients. In particular, volume ratio, heat transfer surface to volume ratio, hydraulic resistances and elevations, especially with respect to the lowest U-tube bend elevation, were preserved.

A major exception to the general scaling concept is the design of the reactor pressure vessel model annular downcomer. The test facility has been configured with a downcomer of two different gap widths. Initially, a downcomer gap of 50 mm was installed in the MOD1 configuration to prevent ECC bypass which is largely influenced by hot wall delay and counter-current flow limitation phenomena; this, however, resulted in a 6.3 times too large a downcomer volume and as a consequence, in an atypical thermal-hydraulic system response during large break LOCAs. The downcomer gap width was later changed to 12 mm which again, was a technical compromise between a 7 mm volume scaled and a 25 mm pressure drop scaled downcomer.

3.4.2 Simulation Constraints

The LOBI test facility, as any other scaled test facility, has inherent distortions with respect to the reference plant which may impair the typicality of some results. The power-to-volume scaling concept results in a design which exhibits a basically one-dimensional thermal-hydraulic response, components high surface area to fluid volume ratio and large metal mass to fluid volume ratio. The structural stored energy and system heat losses are important contributors to distortions in those components, such as the reactor pressure vessel and steam generator downcomers, where the coupling between wall heat transfer and fluid flow is at time dominant.

System heat losses may significantly influence primary as well as secondary side energy removal especially during the long-term phase of a small break LOCA or intact circuit fault simulations. The

LOBI test facility exhibits larger heat losses, c. 1.5% of nominal power, relative to the reference plant due to design (surface area to volume ratio of fluid retaining components) and operation constraints (main coolant pump seal and instrument cooling); typically, heat losses in a full size plant account for about 0.05% of the nominal thermal power.

All in all, the experimental results acquired in the LOBI test facility cannot be directly extrapolated to full-size plants; they provide, however, a reference data base for the understanding of governing thermal-hydraulic phenomenologies and for the development of analytical models and the assessment of system codes used in water reactor safety analysis.

4. Evolution of the LOBI Project

The LOBI experimental programme includes two parts; the MOD1 programme and the MOD2 programme. Within each experimental programme, some tests were defined by experts assembled by the BMFT contractual partner (A tests) in the LOBI A Working Group (A Test Matrix) and/or by experts from EC member countries research organisations (B Test Matrix) assembled in the LOBI Working Group B (B Test Matrix). In its final configuration the overall LOBI Test Matrix includes 70 experiments covering a wide spectrum of accident scenarios.

Generally, the methodology used in the definition of each test case and in the establishment of the corresponding test profile, was to reproduce governing physical phenomena rather than reference plant specific behaviour. While the test cases of the A matrix were specified to reproduce phenomenologies of specific interest to PWRs of Siemens-KWU design, the test cases of the B matrix were instead specified to represent conditions of general interest in reactor safety analysis. Also, a partner country was allocated to each test of the B matrix; that is, an EC member country organization having the task to collaborate, on behalf of all participating countries, with the LOBI staff in 1) the detailed test specification as well as in 2) the pre- and post-test analysis of the results with large system codes.

4.1 Execution of the MOD1 Programme

The LOBI test facility became fully operational in December 1979 with the execution of the first 200 % cold leg break LOCA experiment which was used for an international pre-test prediction exercise (PREX). Early in the programme and in response to the TMI-2 accident which occurred in March 1979, new research priorities were formulated to emphasize small break LOCA and Special Transients tests envisaged in the already follow-up programme.

After the execution of an initial test series and due to experimental evidences on the atypical influence of the large downcomer on the system thermal-hydraulic response, the original 50 mm downcomer was replaced with a downcomer having a smaller 12 mm gap width. In the meantime, while the small downcomer was being procured, an interim test programme was carried out to assess test reproducibility, break geometry and size effects on the course of a large break LOCA.

The experimental programme with the small 12 mm downcomer was initiated in March 1981 with test A1-66, a 200 % cold leg break LOCA with cold leg ECC injection. The LOBI-MOD1 experimental programme was then concluded in June 1982. From December 1979 to June 1982, 28 experiments were carried out including 25 large break LOCA and 3 small break LOCA tests.

4.2 Execution of the MOD2 Programme

After extensive modifications to the test facility, the experimental programme was resumed in April 1984 with the facility in the MOD2 configuration. The first small break LOCA test, a 1 % cold leg break LOCA which was used for the OECD-CSNI International Standard Problem 18, was performed in September 1984 and the first Special Transient test case (A2-90) simulating a 'Station Blackout' transient was performed in March 1985. The first MOD2 test of the Community programme, a 0.4 % cold leg break LOCA specified by the French representatives in the LOCA Programme Task Force was executed in July 1985.

As the LOBI-MOD2 experimental programme was evolving, the catastrophic Chernobyl accident took place in April, 1985, which, however, due to the peculiarities of the accident hat no significant impact on the LOBI established research priorities.

The last experiment of the BMFT contractual programme was executed in November 1989 with the termination of the CEC-BMFT contract in December 1989. Thereafter, the experimental programme was exclusively dedicated to the execution of tests from the Community matrix. With the execution

in June 1991 of test BL-06, a 1 % cold leg break LOCA designed to address the pump on-off issue, the execution of the envisaged LOBI experimental programme was successfully concluded.

5. The LOBI-MOD1 and LOBI-MOD2 Test Matrices

According to the special contractual agreements which originated the research programme, the **MOD1** phase of the LOBI experimental programme was mainly devoted to the investigation of large break LOCA phenomenologies. During the MOD1 testing phase, 25 LOCA tests covering the large to intermediate break size range and 3 small break LOCA scoping tests were successfully performed. Most of the tests were specified by the German contract partner with exception of 4 tests which were executed in the framework of the Community B programme.

A summary review of the LOBI-MOD1 experimental programme is given in Table II. With the exception of the initial 14 tests of the MOD1 programme which were performed with a large downcomer having a gap width of 50 mm, all the other tests were performed with the small downcomer having a gap width of 12 mm. Major parametric variations included:

- Break size: 0.25 % to 200 %
- Break location: cold leg, hot leg, pump suction
- Downcomer width: 50 mm and 12 mm
- MCP operation mode: fast and delayed coast-down
- ECCS injection mode: no injection, cold leg injection, combined injection.

The large break LOCA A tests with the large downcomer were essentially aimed at establishing the nominal heating power which would allow a proper simulation of reactor decay and stored heat release as well as at a preliminary investigation of different ECC injection modes on the course of the blowdown transient. Cold leg and combined cold and hot leg ECC injection which is typical for reactors of Siemens-KWU design were simulated.

The objectives of the small break LOCA scoping tests were to establish test facility response in the 0.4 % to 10 % break size range and to confirm as well as to identify modification and simulation requirements for the already planned MOD2 configuration. The interim tests were aimed at investigating the effect of break size and break geometry on the course of blowdown and at assessing the reliability of the test facility in reproducing experimental data.

The large break LOCA A test with the small downcomer covered a wide range of parametric variations, such as break size and location, ECC injection mode, main coolant pumps operation mode as well as downcomer gap width through a comparison with previous tests.

The **MOD2** phase of the LOBI experimental programme reflected the change in emphasis in water reactor safety early in 1980. as previously mentioned, it was started in April 1984 with the test facility in the MOD2 configuration. A summary review of the MOD2 programme is given in Table 5. The overall test matrix includes 42 tests of which 16 BMFT contractual or A tests and 26 Community or B tests. The range of postulated accidents and operational procedures included:

- Small Break LOCA
- Special Transients
- Emergency operating procedures
- Accident management strategies
- Characterization Tests

The MOD2 test matrix contains 26 small break LOCA tests covering a variety of initial and transient assumptions. Major characterizing features included:

- Break locations: cold leg, hot leg, pressurizer, SG U-Tube
- Break size: 0.4 % to 10 %
- ECC injection mode: cold leg, hot leg, cold and hot leg
- MCP operation: off, delayed off
- Accident management: intentional depressurization.

The Special Transient test matrix includes 12 test cases featuring primary system intact circuit faults and, as appropriate, plant recovery procedures and accident management strategies. Emphasis has been placed on:

- Loss of main feedwater
- Loss of main and auxiliary feedwater
- Station blackout
- Steam line break
- Feed line break
- Primary and secondary system Feed and Bleed.

Test facility and component characterization tests have been an integral part of the research programme; these tests include:

- System heat losses measurements
- Secondary system inventories measurements
- Core bypass tests
- Steam generator performance tests
- Natural circulation tests.

The general objective of these tests was to characterize basic heat transport phenomenologies and to provide data to reduce uncertainties which could impair code modeling accuracy.

The international context in which the LOBI research Programme has been carried-out has offered an opportunity for a close collaboration among delegates of national research laboratories. It has also provided an independent forum for the exchange of concerns and expertise among the participants contributing thus to the harmonization of national views on reactor safety related matters.

As previously mentioned, while the tests of the A matrix were exclusively defined by the German contractual partner, the tests of the B matrix were allocated to EC member countries through representing research organizations. Generally the test cases were agreed upon within the LOBI Task Forces and Working Group on the B Programme. Based upon specific interests, a national organization took charge of the responsibility to collaborate with the LOBI staff in the detailed specification of the test profile providing also in-house resources and computational tools for the pre-test prediction. Within this context a close collaboration was established with:

- Belgium: TRACTEBEL
- France: CEA, FRAMATOME, EdF
- Germany: BMFT, GRS, Siemens-KWU
- Italy: ENEA, U of Pisa
- Spain: CIEMAT, UNION FENOSA
- UK: NE (CEGB), AEA, NII.

Large system codes used in reactor safety analysis are generally benchmarked against experimental data from scaled integral system or separate effect test facilities; comparison of the predicted transient response with test data from the full-size plant would be desirable but this is, clearly, prohibitive for obvious economic and practical considerations; controversy, thus, arises when the predictive capability of a system code is scaled-up.

It is, therefore, desirable although not strictly required to asses the code against a set of data obtained from different scale test facilities under similar initial and boundary conditions. This, to a certain extent, would de-couple the assessment process from physical assumptions emphasizing, instead, the relevance of the geometrical scaling parameters especially on the qualitative rather than quantitative evolution of the predicted test case.

Within this context, a number of tests of the MOD1 and MOD2 test matrices were defined and executed as counter part to similar tests performed in other test facilities such as Semiscale (Test B-R1M) and PKL (Test A1-92 and A1-87) and BETHSY, LSTF and SPES (Test BL-34).

6. Documentation of the LOBI Test Results

The LOBI test results have been properly documented in the following standard reports and the data archived in electronic format which has been progressively updated to comply with advancement in computer hardware and software technologies.

- Experimental Data Report EDR
- Quick Look Report QLR
- Experimental Data File EDF

Originally, these documents were stored on magnetic or paper support. Currently, they are available in electronic format on the JRC STRESA web-based informatic platform.

6.1 Experimental Data Report - EDR

The EDR contains plots or overlays of fully and corrected and checked data channels, including measured initial and boundary conditions, uncertainty bands and all additional information required for a detailed interpretation of the data. There is a brief description of test specification, test objectives, test facility configuration and mechanical drawings of components, and a rather detailed description of the instrumentation system and data processing procedures.

6.2 Experimental Data File – EDF

This file contains a complete set of all measured data which are then included in the EDR in their final and corrected form. In this file are also included the necessary constants and references for the calculation of uncertainty bands relevant to each individual channel. The EDF contains the definitive version of the test data in engineering units. Originally, the test data were stored on magnetic support (tapes, CD-ROM, ..). Currently, all the LOBI Data are available and downloadable on the Internet provide that access is authorized.

6.3 Quick Look Report – QLR

The QLR contains a first evaluation of the test results supported by a series of plots of fully corrected key parameters characterizing the evolution of the test. This evaluation is primarily based on checks of the physical consistency of initial and boundary conditions and on the interpretation of major thermal-hydraulic phenomenologies governing test evolution. As appropriate, calculated parameters (e.g., water levels, mass flows, fluid inventory, ..) are derived from measured data. The QLR contains all the information concerning initial and boundary conditions needed for code prediction calculation, a description of test specification and test objectives as well as information on test facility configuration and relevant instrumentation.

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2. C. Addabbo, B. Worth: LOBI-MOD2 Experimental Programme on Small Break Loss-of-Coolant Accidents and Special Transients – BMFT Final Report
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Table II: LOBI Test Matrix - Summary Description

Test	Date	Country	Definition and Objectives	Phenomenologies
A1-04	12.12.79	Germany BMFT-GRS	200% CL break LOCA , AIS in CL, DC 50 mm first test in power ascension series, 1.8 FPS, PREX test	DNB, early rewet, dryout, final rewet, system performance at low power, 18
A1-01	29.01.80	Germany BMFT-GRS	200% CL break LOCA, AIS in CL+HL, DC 50 mm second test in power ascension series, 3.0 FPS	DNB, early rewer, dryout, final rewet, oscillatory refill behaviour, DEGB partially communicative
A1-02	14.02.80	Germany BMFT-GRS	200 % CL break LOCA, AIS in CL+HL, DC 50 mm third test in power ascension test series, 8.2 FPS	DNB, early rewet, dryout, final rewet, oscillatory refill behaviour
A1-03	19.03.80	Germany BMFT-GRS	200% CL break LOCA, AIS in CL+HL, DC 50 mm fourth test in power ascension series 8.8 FPS, power off from 3.2s to 5s	DNB, early rewet, dryout, final rewet, oscillatory refill behaviour
A1-04R	17.04.80	Germany BMFT-GRS	200% CL break LOCA, AIS in CL, DC 50 mm counterpart to A1-04 at nominal power 10.2 FPS, baseline CL LOCA	DNB, early rewet, dryout no final rewet before power shutoff, no sustained oscillation during refill
A1-05	06.05.80	Germany BMFT-GRS	200% CL break LOCA, AIS in CL+HL, DC 50 mm counterpart to A1-04R with respect to AIS mode, enhanced AIS injection, 10.2 FPS	DNB, early rewet, dryout no effective improvement of AIS performance, oscillatory refill behaviour
SD-SL-01	04.06.80	Germany BMFT-GRS	10% CL break LOCA, ECCS in CL first small break LOCA scoping test instrumentation response to slow transients link between small and large break LOCAs	No degradation of core heat transfer
SD-SL-02	04.06.80	Germany BMFT-GRS	1% CL break LOCA, ECCS in CL, DC 50 mm second small break LOCA scoping test secondary 100 K/h cooldown	Flow to the break mainly from vessel side, flow from pump side impeded due to closure of break valve, no degradation of core heat transfer
SD-SL-03	24.09.80	Germany BMFT-GRS	0.4% CL break LOCA, ECCS in CL, DC 50 mm third test of the small break LOCA scoping series secondary 100 K/h cooldown, HPIS represented by MCP seal water injection	No degradation of core heat transfer, natural circulation and reflux condenser heat transport detected

A2-59	27.10.80	Germany BMFT-GRS	100% CL break LOCA, AIS in CL, DC 50 mm first test of interim matrix, system response to communicative break	DNB, early rewet, dryout, final rewet, clear bottom-up rewet trend, response similar to DEGB
B-101	26.11.80	France CEA-FAR	2x50% CL break LOCA, AIS in CL, DC 50 mm second test of the interim matrix, Influence of non-communicative break configuration	DNB, early rewet comparison of B-101 with A2-59 precluded by difference in power load
A2-55	19.01.81	Germany BMFT-GRS	50% CL break LOCA, AIS in CL, DC 50 mm third test of the interim matrix, system response to intermediate large break sizes	DNB and early rewet only at core upper levels, thereafter effective core cooling prevailed
A2-59R	11.02.81	Germany BMFT-GRS	100% CL break LOCA, AIS in CL, DC 50 mm fourth test of interim matrix, Counterpart to A2-59 with respect to reproducibility	A2-59R and A2-59 system thermal-hydraulic response similar, MOD1reproducibility confirmed
B-R1M	17.03.81	Germany BMFT-GRS	25% CL break LOCA, AIS in CL, DC 50 mm fifth test of the interim matrix system response to small large break sizes	core thermal response followed prevailing system saturation temperature, no core thermal excursions tendency to loop seal formation
A1-66	03.07.81	Germany BMFT-GRS	200% CL break LOCA, AIS in CL baseline test, DC 12 mm counterpart to A1-04R with respect to DC size	DNB, early rewet at core bottom and top ends, dryout, no conclusive rewet observed, CCFL and hot wall delay effects in downcomer
A1-07	09.07.81	Germany BMFT-GRS	200% CL break LOCA, AIS disabled, DC 12 mm system response with no ECCS baseline test for ECCS injection mode	DNB, early rewet at core bottom and top ends dryout, rod temperatures high after power shutoff
A1-06	21.07.81	Germany BMFT-GRS	200% CL break LOCA, AIS in CL+HL, DC 12 mm system response with combined ECCS injection baseline test with respect to ECC injection mode	DNB, early rewet at core bottom and top ends, dryout, heater rod temperature turnaround after ECC injection starts, no clear rewet with power on
A1-67	30.09.81	Germany BMFT-GRS	25% CL break LOCA, AIS in CL+HL, DC 12 mm system response to a small large break LOCA break size test series	delayed dryout at core mid and upper elevations rewet, tendency towards small break LOCA features, loop seal formation and clearout
A1-68	28.10.81	Germany BMFT-GRS	50% CL break LOCA, AIS in CL+HL, DC 12 mm system response to intermediate break sizes break size test series	dryout, rewet, clear top-down rewet behaviour
A1-10A	25.11.81	Germany BMFT-GRS	200% HL break LOCA, AIS in HL+CL, DC 12 mm system response to hot leg break break location test series, core power low	dryout, rewet only at core mid and upper elevations, hot leg ECC core penetration hindered by sustained positive core flow, CCFL at core exit

A1-10B	10.12.81	Germany BMFT-GRS	200% HL break LOCA, AIS in HL+CL, DC 12 mm system response to hot leg break, similar to A1-10A break location test series, nominal core power	dryout, rewet limited at core upper elevations, higher peak cladding temperatures with respect to A1-10A, CCFL at core exit
A1-70	13.01.82	Germany BMFT-GRS	200% PS break LOCA, AIS in CL+HL, DC 12 mm system response to pump suction break break location test series	DNB, rewet, less severe overal core heat transfer degradation with respect to similar cold and hot leg break DEGB-LOCA
A1-73	04.02.82	Germany BMFT-GRS	25% HL break LOCA, AIS in CL+HL, DC 12 mm system response to hot leg small large break LOCA break size and break location test series	no core heat transfer degradation, heater rod temperatures at the prevailing system saturation temperature
A1-72	24.03.82	Germany BMFT-GRS	200% CL break LOCA, AIS in CL+HL, DC 12 mm influence of pump operation mode, pump coastdownd delayed off, pump head simulation	DNB, early rewet, dryout, enhancement of initial recovery of positive core flow, lower peak cladding temperatures with respect to A1-06
A1-69	06.04.82	Germany BMFT-GRS	100% CL break LOCA, AIS in CL+HL, DC 12 mm, system response to intermediate large break LOCA, break size effect test series	DNB, early rewet, dryout, final rewet, typical DEGB LOCA blowdown features, preferentially top-down rewet observed
A1-74	21.04.82	Germany BMFT-GRS	200% CL break LOCA, AIS in CL+HL, DC 12 mm, system response to ECCS injection in both intact and broken loop, counterpart to A1-72	DNB, early rewet, dryout, no discernible impact on overall system response from addition of ECC injection into broken loop
B-222	05.05.82	France CEA-FAR	100% CL break LOCA, AIS in CL, DC 12 mm non-communicative (2x50%) CL break configuration, counterpart to B-101 with respect to downcomer size	DNB, early rewet, dryout, limited effectiveness of cold leg ECCS injection
B-302	16.0.82	Italy ENEA	100% HL break LOCA, AIS in CL, DC 12 mm non-communicative (2x50%) HL break configuration	dryout at core mid and upper elevations, rewet, positive core flow throughout the whole transient, enhanced refill and effective core cooling
A1-76	12.04.84	Germany BMFT-GRS	SG Performance under primary forced circulation, variation of secondary inventory and core power: - flooding of SG coarse separator at nominal core power - flooding of SG coarse separator at 50% core power and reduced secondary water level - boiloff of SG secondary side at 10% core power	data on coarse and fine separator efficiency, variation of recirculation ratios, void distribution in the SG riser region, degradation of SG heat transfer
A2-81	27.09.84	Germany BMFT-GRS	1% CL break LOCA, HPIS in CL, AIS off secondary cooldown at 100 K/h, DC 12 mm first test of the small break LOCA test series, OECD International Standard Problem 18 (ISP 18)	I coupling of primary and secondary systems, 2 phase NC and reflux condenser heat transport, flow separation and stratification in horizontal pipes liquid hold-up in hot legs and SG U-tubes

Table II: Summary of LOBI-MOD1 and MOD2 Test Conditions and Results (cont.)

A1-82	28.09.84	Germany BMFT-GRS	1% CL break LOCA, HPS in HL, AIS in HL+CL secondary cooldown at 100K/h, DC 12 mm, counterpart to A2-81 relatively to HPIS location	coupling of primary and secondary systems, 2 phase NC and reflux condenser heat transport, low subcooling in pressure vessel downcomer, reduced ECC bypass to the break
A1-78	24.10.84	Germany BMFT-GRS	2% CL break LOCA, HPIS in HL, AIS in HL+CL secondary cooldown at 100 K/h, DC 12 mm, test of the break size effect test series	decoupling of primary and secondary systems, reverse SG heat transfer, voiding in SG U-tubes and liquid hold-up in hot legs, loop seal formation and core liquid level depression
A2-77A	28.11.84	Germany BMFT-GRS	characterization of NC and reflux condenser heat transport mechanisms at a primary system pressure of 90 bar and 70 bar, DC 12 mm, - 90 bar: 1 and 2 phase NC and reflux condenser - 70 bar 2 phase NC and reflux condenser	NC heat transport mechanisms characterized as function of primary system mass inventory, minimum mass inventory of c. 45% at c. 3% of core power to sustain effective reflux heat transport and prevent core heat transfer degradation, oscillatory transition from 2 phase NC to reflux
A1-83	19.12.84	Germany BMFT-GRS	10% CL break LOCA, HPIS in HL, AIS in HL+CL secondary cooldown at 100 K/h, DC 12 mm larger of the break size effect test series	decoupling of primary and secondary systems, early voiding of SG U-tubes and hot legs, initial core dryout and rewet coupled to loop seal formation and clear-out, second core dryout and rewet coupled to mass inventory boiloff and AIS injection
A2-90	27.03.85	Germany BMFT-GRS	LONOP-ATWS otherwise referred to as 'SBO', anticipated transient caused by loss of offsite and normal on-site electrical power with failure to SCRAM - boiloff of SG secondary system down to a level of c 1m above tube plate, - SG refill and cooldown at 100 K/h	pressure increase in primary and secondary systems, fluid discharge from pressurizer PORV and SG SRV pressurizer insurge/outsurge, SG heat transfer degradation, re-establishment of primary to secondary heat transfer, 1 and 2 phase NC
A1-85	07.05.85	Germany BMFT-GRS	0.4% PZR break LOCA, HPIS in HL, AIS in HL+CL secondary cooldown at 100 K/h, DC 12 mm test of the break location effect test series	coupling of primary and secondary systems, pressurizer insurge, primary system overfeeding
BL-00	03.07.85	France CEA	0.4% CL break LOCA, HPIS in CL secondary cooldown at 57 K/h, DC 12 mm, first test of the EC B test matrix	primary and secondary systems thermally coupled, liquid hold-up in SG U-tubes, stratification in horizontal pipework, thermal non-equilibrium downstream ECC injection points, 2 phase and reflux condenser heat transport, primary overfeeding and refill, no core dryout
A1-84	14.10.85	Germany BMFT-GRS	10% HL break LOCA, HPIS in HL, AIS in CL+HL secondary cooldown at 100 K/h, DC 12 mm test of the break location effect test series, counterpart to A!-83	decoupling of primary and secondary systems, early voiding of SG U-tubes and hot legs, hold-up and CCFL at core exit, ECC penetration and flow channeling

BT-00	30.11.85	U.K. CEGB	LOFW with primary Feed and Bleed . loss of main feedwater and SG boildown to c. 1m . loss of auxiliary fedwater and SG dryout . long term cooldown via primary Feed and Bleed	SG boil-off and heat transfer degradation, PORV and SRV fluid discharge, Pressurizer insurge/outsurge, PORV flow compensation via HPIS flow, Primary system refill, Verification of Feed and Bleed as an Accident Management procedure
BT-01	24.01.86	Belgium Tractebel	10% SLB with PTS and plant recovery procedure . small steam line break transient . establishment of PTS conditions . accident mitigation and recovery procedures	SG secondary blowdown and heat transfer, primary system cooldown rate, pressurizer insurge/outsurge, downcomer temperature stratification, primary depressurization via PRZ cooling system and mass inventory control via HPIS injection
BL-02	22.03.86	U.K. CEGB	3% CL break LOCA, HPIS in CL, AIS in CL SCS cooldown at 56 K/h, DC 12 mm test of the break size effect test series	primary and secondary systems decoupled, SG heat transfer reversed, formation and clear-out of loop seal, no core dryout
A1-79	15.05.86	Germany BMFT-GRS	1% CL break LOCA, HPIS in HL, AIS off secondary cooldown at 100 K/h, DC 12 mm effect of high (4/4) HPIS injection rate	coupling of primary and secondary systems primary system overfeeding, NC heat transport hindered by condensation in hot legs and upper plenum induced by high HPIS rate
A1-88	11.06.86	Germany BMFT-GRS	0.4% CL break LOCA, HPIS in HL, AIS off SCS cooldown at 100 K/h in IL-SG, DC 12 mm asymmetric cooldown of secondary system	primary system pressure coupled to isolated SG, pressurizing effect of isolated SG, primary system repressurization, break flow compensated by HPIS flow
BL-01	20.09.86	Germany BMFT-GRS	5% CL break LOCA, HPIS in HL, AIS on secondary cooldown at 100 K/h, DC 12 mm test of the break size effect test series	decoupling of primary and secondary systems, SG reverse heat transfer, clear-out of intact loop seal, liquid hold up in HL
BC-01	18.10.86	JRC	SG secondary mass inventory determination LOBI-MOD2 characterization test	SG mass inventory determined at various power levels, relationship of SG mass vs. downcomer water level determined
BC-02	26.11.86	JRC	SG heat losses determination LOBI-MOD2 characterization test	SG heat losses determined via: . steady-state method balancing core power . cooldown method SG heat losses unacceptably high: ILSG: 24 kW, BLSG: 18 kW, request for improvement of thermal insulation
BL-21	24.01.87	Italy ENEA	SGTR: Steam Generator Tube Rupture (0.4%) Intentional PCS depressurization through PORV and AIS actuation as recovery procedure	Break and PCS depressurization, Natural circulation and reflux condenser heat transport, Core uncovery and dryout, PORV discharge, AIS actuation and core rewet

Table II: Summary of LOBI-MOD1 and MOD2 Test Conditions and Results (cont.)

BL-12	19.02.87	France CEA	1% CL Break LOCA, HPIS off, AIS in CL SCS cooldown off, DC 12 mm System response with degraded safety systems	Core uncovery and dryout at high PCS pressure, Phase separation and stratification, thermal non-equilibrium downstream AIS location, loop seal formation and clearout, Core rewet
BT-02	09.05.87	France CEA	LOFW+LOAF: Loss of Main and Auxiliary Feedwater PCS Bleed and Feed as recovery procedure	SG boiloff and heat transfer degradation, PCS heatup and pressurization, pressurizer insurge/outsurge, PORV discharge and HPIS compensation, recovery of PCS inventory
BT-12	17.06.87	UK CEGB-AEA	SLB: Steam Line Break (100% orifice limited) SCS break size effect and location test series	Faulted SG depressurization, break flow and steam line carryover, faulted SG heat extraction, reverse heat transfer in unaffected SG, pressurizer behaviour, PCS overcooling and thermal stratification
A1-91	26.09.87	Germany BMFT-GRS	1% CL break LOCA, HPIS in HL, AIS off secondary cooldown at 100 K/h, DC 12 mm effect of low (1/4) HPIS injection rate	PCS and SCS thermal coupling, core thermal response with reduced HPIS capacity, core liquid level depression, loop seal formation, no core dryout at reduced HPIS capacity
BT-03	24.10.87	Italy ENEA	LOFW-ATWS: Loss of Feed Water - Anticipated Transient Without SCRAM PCS Passive Recovery Procedure	PCS heat-up and pressurization PORV and SRV discharge, voiding and refill of SG, pressurizer insurge/outsurge, intentional PCS depressurization and AIS actuation, core dryout
A1-92	30.11.87	Germany BMFT-GRS	Characterization of NC and reflux condenser heat transport at a primary pressure of 40 bar, 1 and 2 phase NC and reflux condenser, counterpart to PKL test AC.1	NC and reflux condenser heat transport mechanisms as function of primary mass inventory, minimum mass inventory to sustain reflux condenser and prevent core heat transfer degradation c. 45%, rather stable transition from 2 phase NC to reflux condenser
BL-16	19.03.88	Germany BMFT-GRS	0.4% Small Break LOCA, HPIS in HL, AIS off SCS cooldonwn in BLSG at 100 K/h, DC 12 mm MCPs off and restart	Asymmetric SCS cooldown, pressurizing effect of isolated SG, thermal homogenization and fluid redistribution following MCPs restart
BC-03	15.04.88	JRC	SG Heat Losses determination LOBI-MOD2 characterization test	Measurement of SG heat losses after improvement of thermal insulation (ref.: BC-02) ILSG: 6.8 kW, BLSG: 5.0 kW
A1-93	30.04.88	Germany BMFT-GRA	2% CL break LOCA, HPIS off, AIS on secondary system cooldown at 100 K/h, DC 12 mm accident management procedure, pressurizer PORV on on high core heater rod temperature	Decoupling of primary and secondary systems, loop seal formation and core level depression, core dryout and AIS injection, enhancement of primary depressurization and AIS actuation through intentional opening of pressurizer PORVs

A1-94	27.05.88	Germany BMFT-GRS	4% CL break LOCA at 40 bar, HPIS off, AIS on LOBI counterpart to PKL test, secondary system cooldown, DC 12 mm AIS on at high core heater rod temperature	Core uncovery and dryout, AIS injection and core rewetting, verification of PKL-III pressure scaling concept,
BC-04	07.02.89	JRC	Core bypass flow measurement LOBI-MOD2 characterization test	Determination of upper plenum to upper downcomer flow bypass: c. 3% of core flow
BL-30	15.04.89	JRC	5% CL Break LOCA, HPIS in CL, AIS in CL SCS cooldown at 100 K/h, DC 12 mm Test of the break size effect test series	Primary depressurization at a moderate rate, primary and secondary systems thermally decoupled, loop seal formation and clearout
BL-22	17.06.89	Belgium Tractebel	SGTR: Steam Generator Tube Rupture (0.4%) Accident initiation and mitigation phases	Break flow, overfilling of affected SG and SRV discharge, auto-stabilizing mechanism for break flow when affected SG level reaches U bend elevation, verification of emergency operating procedures
A1-87	11.11.89	Germany BMFT-GRS	Cooldown transient, LOBI counterpart to PKL-III test	1 phase NC under saturated conditions, upper head steam bubble formation and propagation, SG heat transfer
BT-04	10.02.90	France CEA	Cooldown Transient under asymmetric conditions BLSG isolated, ILSG cooldown at 56 K/h	Reverse heat transfer in isolated SG, pressurizing effect of isolated SG, flow reversal in secondary of isolated SG
BL-34	22.03.90	JRC	6% CL Break LOCA, HPIS off, AIS on at 40 bar initial conditions scaled to low power (10%) SCS cooldown disabled, DC 12 mm Counter Part Test to BETHSY, LSTF and SPES	Sequence of 3 core thermal excursions 1) dryout and rewet due to loop seal formation and clearout, 2) dryout due to boiloff and rewet due to AIS, 3) dryout due to depletion of AIS injection and rewet due to LPIS injection.
BL-44	26.04.90	JRC	6% CL Break LOCA, HPIS off, AIS on at 40 bar initial conditions scaled to full power (100%) SCS cooldown disabled, DC 12 mm Counter Part Test to BL-34 (full power - low power)	Phenomenologies similar to BL-34, sequence of 3 core dryout/rewet phases, first dryout less extensive due to less pronounced core liquid level depression
BT-56	03.07.90	UK AEA	Multiple Failure Transient evolving from an original LOFW: isolation of ILSG, MCP power off, SCRAM failure, PCS blowdown through upper plenum due to rupture os the safety disk.	PCS heatup and pressurization, pressurizer insurge/outsurge, primary and secondary systems decoupled, dryout at high pressure, blowdown of the PCS through a relatively large break in upper plenum represented by the rupture disk opening
BT-15/16	22.11.90	UK AEA	LOFW: Loss of Feed Water with MCP on (BT-15) SG boiloff and refill with MCPs off (BT-16)	BT-15: SG boiloff and heat transfer degradation with MCPs on, primary system heatup, reestablishment of SG heat transfer following AFW actuation, BT-16: SG boiloff and heat transfer degradation with MCPs off, natural circulation in PCS, SG refill

Table II: Summary of LOBI-MOD1 and MOD2 Test Conditions and Results (cont.)

BT-17	07.02.91	Germany BMFT-GRS Siemens	LOFW; Loss of Feed Water and Secondary Feed and Bleed recovery procedure Intentional PCS depressurization from Upper plenum	SG boiloff, PCS heatup and pressurization, presurizaer insurge and PORV discharge, SCS blowdown and PCS depressurization due to condensation in SG U-tubes, PCS depressurization from upper plenum, pressurizer outsurge, core dryout and partial rewet.
BT-06	21.03.91	France CEA	FLB: Feed Line Break (10%) MCPs on, AFW on in ILSG MCPs off and asymmetric natural circulation in PCS with a voided SG	Blowdown and heat transfer from faulted SG, break flow feed from different flow paths, residual heat removal by unaffected SG, pressurizer insurge/outsurge
BL-40	16.05.91	Spain Union FENOSA	SGTR: Steam Generator Tube rupture in 1-loop PWR (Jose' Cabrera NPP), E-3 emergency recovery procedures	Break flow, PCS natural circulation, PCS depressurization and control of subcooling margin and pressurizer level cycling PORV and HPIS flow.
BL-06	21.06.91	UK-France AEA-CEA	1% CL Break LOCA, HPIS off, AIS on at 40 bar SCS cooldown as in BL-12, MCPs on Effect of MCP on/off issue	PCS depressurization with MCPs on, core dryout and rewet, PCS pressure stagnation, termination of AIS injection, depressurization from PORV and actuation of LPIS.