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T16 - The CSNI Separate Effects Test and Integral Test Facility Matrices for Validation of Best-Estimate Thermal Hydraulic Computer Codes

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THE CSNI SEPARATE EFFECTS TEST (SET) AND INTEGRAL TEST FACILITY (ITF) MATRICES FOR VALIDATION OF BEST-ESTIMATE THERMAL-HYDRAULIC COMPUTER CODES

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COURSE ROADMAP

Opening Session

- INTRODUCTIONS
- ADMINISTRATION
- COURSE ROADMAP

Introduction

- GLOBAL NUCLEAR POWER
- ROLE OF N/C IN ADVANCED DESIGNS
- ADVANTAGES AND CHALLENGES

Local Transport Phenomena & Models

- LOCAL MASS, MOMENTUM AND ENERGY TRANSPORT PHENOMENA
- PREDICTIVE MODELS & CORRELATIONS

Integral System Phenomena & Models

- SYSTEMS MASS, MOMENTUM AND ENERGY TRANSPORT PHENOMENA
- N/C STABILITY AND NUMERICAL TECHNIQUES
- STABILITY ANALYSIS TOOLS
- PASSIVE SAFETY SYSTEM DESIGN

Natural Circulation Experiments

- INTEGRAL SYSTEMS TESTS
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- TEST FACILITY SCALING METHODS

Reliability &Advanced Computational Methods

- PASSIVE SYSTEM RELIABILITY
- CFD FOR NATURAL CIRCULATION FLOWS

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OVERVIEW

- Introduction
- Background and Objectives
- Definitions
- Separate effects Tests (SET) Validation Matrix
  - Methodology Developed
  - Forming a SET Cross-Reference Matrix
  - Establishing the SET Matrix
- Integral Test Facility (ITF) Validation Matrix
  - Integral Test Cross-Reference Matrices
  - Selection of Individual Tests
- Cross-Reference Matrices for WWER
- Use of the SET and ITF Validation Matrices in BE Thermal- Hydraulic Codes
- Conclusions and recommendations
- Experience and lessons learned
- Some of the references

INTRODUCTION

- Thirty years of computer code development
  - Homogeneous equilibrium model
  - Simulation of phase separation by gravity
  - Thermal and mechanical non-equilibrium, effects of non-condensables
- Thirty years of experiments
  - Separate effects tests for individual phenomena
  - Integral tests for large break LOCA, small break LOCA, transients, beyond design basis accidents and accident management
  - PWRs, BWRs, WWERs
- Enormous wealth of experimental data base is available for code assessment

BACKGROUND (I)

- **Last 25-30 years wealth of experimental data to support analytical work for simulating the behaviour of LWRs during thermal hydraulic transients and loss-of-coolant accidents**
- **In March 1987, OECD/NEA published "CSNI Code Validation Matrix of Thermohydraulic Codes for LWR LOCA and Transients" prepared by PWG2- Task Group on Thermal-hydraulic System Behaviour (TGTHSB)**
- **Decision was taken to bias the Validation Matrix towards integral tests. This was based on the assumption that sufficient comparison with SET data would be performed by code development that only very limited further assessment against SET data would be necessary**
- **This last expectation proved unrealistic. Continued comparison of calculations with separate effects test data is necessary to underwrite particular applications of codes, especially where a quantitative assessment of prediction accuracy is required, as well as for code model improvement**
- **Decision to develop a distinct SET Matrix rather than extend the original CSNI-Code Validation Matrix (CCVM)**
- **Consequently, establish a separate ITF Matrix from the CCVM and update the contents**
- **TGTHSB formed „Writing Groups" to carry out the work for the SET Matrix in 1988 and for ITF Matrix in 1994**

BACKGROUND (II)

- Decision to develop a distinct SET Matrix rather than extend the original CSNI-Code Validation Matrix (CCVM)
- The CSNI-SET Matrix would complement the CCVM
- TGTHSB formed a „Writing Group“ to carry out the work of producing the SET Matrix in 1988
- Present two volume report is the outcome of the work during the period 1988-1993
- The development of SET Matrix was found to require an extension of the methodology employed for the CCVM both in the scope and in the categorization and description of facilities
- Development of the methodology used for the SET Matrix were carried out during the period 1991 to mid-1993

DEFINITIONS

- Verification of a code or a model
  - To show that the code behaves as intended, i.e. it is a proper mathematical representation of the conceptual model, and the equations are correctly encoded and solved
- Validation
  - A process carried out by comparison of model prediction with experimental measurements that are independent of those used to develop the model
  - A model can not be considered validated until sufficient testing has been performed to ensure an acceptable level of predictive accuracy over the range of conditions for which the model may be applied
  - The acceptable level of accuracy is based on judgement and will vary depending on the specific problem or question to be addressed by the model

SEPARATE EFFECTS TEST VALIDATION (SET) MATRIX

OBJECTIVES (I)

- Development of individual code models often requires some iteration and a model, however well conceived, may need refinement as the range of applications widened.

- A key issue concerning the application of BE codes to LOCA and thermal-hydraulic transient calculations is quantitative code assessment. Quantitative code assessment is intended to allow predictions of nuclear power plant behaviour to be made with a well-defined uncertainty. Most schemes for achieving this quantification of uncertainty rely on assigning uncertainties to the modelling by the code of individual phenomena. This interest has placed a new emphasis on separate effects tests over and above that originally envisaged for model development. The more highly controlled environment of the SET is likely to lead to a more systematic evaluation of the accuracy of a model across wide range of conditions.

OBJECTIVES (II)

- A further incentive to conduct separate effects tests in addition to those carried out integral test facilities is the difficulty encountered in scaling predictions of phenomena from integral test facilities to plant applications. In general, it is desirable to have a considerable overlap of data from different facilities; successfully predicting data from different facilities provides some confirmation that a phenomenon is well understood

THE METHODOLOGY DEVELOPED

1. Characterisation of phenomena

2. Identification of phenomena relevant to two-phase flow

- Short description of each phenomenon
- Relevance to nuclear reactor safety
- Measurement ability, instrumentation and data base
- Present state of knowledge-predictive capability

3. Catalogue of information on facilities and tests

4. Forming a SET cross-reference matrix

5. Identification of the relevant parameter ranges and selection of relevant facilities related to each phenomenon

6. Establishing the Separate Effects Tests (SET) matrix

ADVANTAGES OF THE METHODOLOGY DEVELOPED

- Helps to collect and present the data and information collected in a comprehensive and systematic manner
- It is general and, in principal, applicable to the other type of validation matrices (e.g., on severe accidents, containment, etc.)

IDENTIFICATION OF PHENOMENA

- A total of 67 phenomena are identified and resulting phenomena list is given in a table
- Earlier works, e.g. CSNI Code Validation Matrix (CCVM), CSNI-State-of-the art report (SOAR) on thermal-hydraulics of emergency core cooling in light water reactors have been used as basis of the list of phenomena
- A new group named „basic phenomena“ has been added
- Several different types of phenomena, such as interphase friction which is very basic attribute of a two-phase flow, to those such as loop seal clearing which is essentially a system phenomena,
- A short description of each phenomena is provided, as included in the next item

Table 1. List of Phenomena

0	BASIC PHENOMENA	1	Evaporation due to Depressurisation
		2	Evaporation due to Heat Input
		3	Condensation due to Pressurisation
		4	Condensation due to Heat Removal
		5	Interfacial Friction in Vertical Flow
		6	Interfacial Friction in Horizontal Flow
		7	Wall to Fluid Friction
		8	Pressure Drops at Geometric Discontinuities
		9	Pressure Wave Propagation
1	CRITICAL FLOW	1	Breaks
		2	Valves
		3	Pipes
2	PHASE SEPARATION/VERTICAL FLOW WITH AND WITHOUT MIXTURE LEVEL	1	Pipes/Plena
		2	Core
		3	Downcomer
3	STRATIFICATION IN HORIZONTAL FLOW	1	Pipes
4	PHASE SEPARATION AT BRANCHES	1	Branches
5	ENTRAINMENT/DEENTRAINMENT	1	Core
		2	Upper Plenum
		3	Downcomer
		4	Steam Generator Tube
		5	Steam Generator Mixing Chamber (PWR)
		6	Hot Leg with ECCI (PWR)
6	LIQUID-VAPOUR MIXING WITH CONDENSATION	1	Core
		2	Downcomer
		3	Upper Plenum
		4	Lower Plenum
		5	Steam Generator Mixing Chamber (PWR)
		6	ECCI in Hot and Cold Leg (PWR)
7	CONDENSATION IN STRATIFIED CONDITIONS	1	Pressuriser (PWR)
		2	Steam Generator Primary Side (PWR)
		3	Steam Generator Secondary Side (PWR)
		4	Horizontal Pipes
8	SPRAY EFFECTS	1	Core (BWR)
		2	Pressuriser (PWR)
		3	Once-Through Steam Generator Secondary Side (PWR)
9	COUNTERCURRENT FLOW / COUNTERCURRENT FLOW LIMITATION	1	Upper Tie Plate
		2	Channel Inlet Orifices (BWR)
		3	Hot and Cold Leg
		4	Steam Generator Tube (PWR)
		5	Downcomer
		6	Surgeline (PWR)
10	GLOBAL MULTIDIMENSIONAL FLUID TEMPERATURE, VOID AND FLOW DISTRIBUTION	1	Upper Plenum
		2	Core
		3	Downcomer
		4	Steam Generator Secondary Side
11	HEAT TRANSFER: NATURAL OR FORCED CONVECTION	1	Core, Steam Generator, Structures
	SUBCOOLED/NUCLEATE BOILING	2	Core, Steam Generator, Structures
	DNB/DRYOUT	3	Core, Steam Generator, Strucutres
	POST CRITICAL HEAT FLUX	4	Core, Steam Generator, Strucutres
	RADIATION	5	Core
	CONDENSATION	6	Steam Generator, Structures
12	QUENCH FRONT PROPAGATION/REWET	1	Fuel Rods
		2	Channel Walls and Water Rods (BWR)
13	LOWER PLENUM FLASHING		
14	GUIDE TUBE FLASHING (BWR)		
15	ONE AND TWO PHASE IMPELLER-PUMP BEHAVIOUR		
16	ONE AND TWO PHASE JET-PUMP BEHAVIOUR (BWR)		
17	SEPARATOR BEHAVIOUR		
18	STEAM DRYER BEHAVIOUR		
19	ACCUMULATOR BEHAVIOUR		
20	LOOP SEAL FILLING AND CLEARANCE (PWR)		
21	ECC BYPASS/DOWNCOMER PENETRATION		
22	PARALLEL CHANNEL INSTABILITIES (BWR)		
23	BORON MIXING AND TRANSPORT		
24	NONCONDENSABLE GAS EFFECT (PWR)		
25	LOWER PLENUM ENTRAINMENT		

CHARACTERIZATION OF PHENOMENA

Short summaries relevant to each phenomenon have been provided under the headings:

- **Description of the phenomenon:**

A Brief description of each phenomenon used in the SET Matrix is given

- **Relevance to nuclear reactor safety:**

A brief discussion of the impact of the phenomenon on nuclear reactor safety is presented

- **Measurement ability, instrumentation and data base:**

A summary of the data requirements and the degree to which they are satisfied by the available data base are presented

- **Present state of knowledge-predictive capability:**

An assessment of the present state of knowledge and predictive capabilities are included

CATALOGUE OF INFORMATION SHEETS

- A catalogue of the SET facilities used within the OECD member Nations was compiled, as a preliminary to establishing a list of tests for code assessment and validation
- Various laboratories or organizations owing and/or operating test facilities or programs were invited to supply information. Additionally members of the Writing Group provided information on other facilities described in the open literature and known to them
- As a result, a list of 187 SET facilities has been compiled
- On 113 of those facilities, it was possible to produce information sheets
- The aim of the information sheets is to provide enough information to decide on the most appropriate test facility/programs to select for code validation/assessment with respect to particular phenomena
- This information collected primarily to enable the selection of appropriate sets of test data for inclusion in the SET Cross-Reference Matrix

INFORMATION SHEETS

For each facility, a standard brief information sheet has been prepared with following items:

- **Objectives of the facility**
- **Geometry**
- **Experimental conditions and parameter ranges**
- **Measurements**
- **Information concerning documentation**
- **Use of data**
- **Special features of experiments**
- **Phenomena investigated**

Contained with full documentation in Volume II of the SET Validation Matrix report

EXAMPLE FOR INFORMATION SHEETS

SET FACILITY	No. 9.1, 9.2
Subject	**Description**
• Test Facility	NEPTUN / PSI-Villigen-Switzerland
- Operating Period	1981 - 1992 (presently different configuration and test section)
- Availability	Available
• Objectives	• emergency core cooling heat transfer tests in PWR core geometry • boil-off and reflooding during LOCA
• Test Period	1981 - 1986
• Facility Geometry	• main test loop: - 33 rods + 4 guide tubes test bundle indirectly electrically heated - chopped cosine axial power distribution, 1.68 m heated length - octagonal inconel 600 bundle shroud, core bypass flow < 9 % - pressure vessel to house shroud with bundle, shroud-pressure vessel annulus filled with insulation material • steam-water separator, with windows for flow visualisation, and water carry-over tank • water supply loop, steam boiler and other ancillary systems to provide test facility initial conditions and normal operating control
• Experimental Conditions and Parameter Range	• reflood tests at constant test section pressure, controlled by back pressure regulator • initially test section under steam atmosphere with predfined maximum heater rod surface temperature achieved from power supply • boil-off experiments: NEPTUN I - pressure: 1,5 bar - subcooling: 0,12, 39 K - bundle power: 24.6, 42.1, 75.1 kW • reflooding experiments: NEPTUN I + II - pressure: 1.0, 4.1 bar - flooding water: - velocity: 1.5, 2.5, 4.5, 10, 15 cm/s; - subcooling: 11, 78° C - single rod power: 2.45, 4.19 kW - initial cladding temperature 757, 867 °C

EXAMPLE (Cont.)

SET FACILITY		No. 9.1, 9.2 /2
Subject	**Description**	
• Measurement Instrumentation	· temperature: - rod cladding: 18 rods = 8 levels; 15 rods = 4 levels guide tubes: 4 tubes = 8 levels steam, fluid: 8 levels within bundle · pressure, diff. pressure: 8 levels of bundle; carry-over tank · flow rate: · turbine flow meter · · rotameter for back-up measurements · measurement range: ? · measurement uncertainty: ?	Chromel/Alumel TCs, stainless steel or Inconel sheath, MgO insulator, some resistance thermometers (PE-100) Rosemount capacity type transducer, pressure sensing lines
• Data Acquisition	HP-2100 computer and associated equipment. 300 channels of analog input data.	
• Data Documentation	· system description, experimental procedure: EIR-Report Nr. 386, 1980 · experimental data, assessment results: EIR-Report Nr. 629 + 624, 1987 · data sets available on magnetic tape and as plots	
• Data Availability	?	
• Use of Data	· independent assessment: RELAP5/MOD2, TRAC-BD1/MOD1 within ICAP/NRC	
• Special Features	· boil-off experiments: phase separation, vertical flow with/without mixture level · entrainment / deentrainment in core bundle geometry · interfacial drag, CHF, post-CHF, quench front propagation, rewet	
• Correctness of Phenomena	· phenomena have been checked · test results suitable for code validation	
• Comments	· relevant and reliable boil-off and reflood data for PWR core geometry · information to be completed, see "?"	

SET FACILITY	No. 9.3/2
Subject	**Description**
• Data Documentation	· plant description and some results: PSI internal report under preparation (1989)
• Data Availability	?
• Use of Data	· data on quench front propagation, phase mixing, heat transfer in highly transient conditions;
• Special Features	see "Use of Data"
• Correctness of Phenomena	· phenomena have been checked · tests suitable for code validation (?) (tube geometry) ·
• Comments	· simple test section geometry, fundamental study · information to be completed, see "?"

LIST OF FACILITIES

Table 2. List of Facilities

No.	Facility	Info sheet	Selected in the CCVM
1	CANADA		
1.1	Elbow Flooding Rig	a	
1.2	CWIT (CANDU reactors)	a	
1.3	Pumps		
1.4	Header Test Facility (CANDU reactors)	a	
2	FINLAND		
2.1	REWET-I	a	
2.2	REWET-II	a	x
2.3			
2.4	VEERA	a	
2.5			
2.6	IVO-CCFL (air.water)	a	x
2.7	IVO-Thermal Mixing	a	x
2.8	IVO-Loop Seal Facility (Air/Water)	a	x
3	FRANCE		
3.1	MOBY-DICK	a	x
3.2	SUPER MOBY-DICK	a	x
3.3	CANON and SUPER CANON (Horiz)	a	x
3.4	VERTICAL CANON	a	
3.5			
3.6	TAPIOCA (Vertical)	a	x
3.7	Dadine (Vertical Tube, Inside)	a	x
3.8	PERICLES Rectangular	a	x
3.9	PERICLES Cylindrical	a	x
3.10	PATRICIA GV 1	a	X
3.11	PATRICIA gv 2	a	X
3.12	ERSEC Tube (Inside)	a	x
3.13	ERSEC Rod Bundle	a	x
3.14	OMEGA Tube (Inside)	a	x
3.15	OMEGA Rod Bundle	a	x
3.16	ECTHOR Loop Seal (Air/Water)	a	x
3.17	COSI	a	x
3.18	SUPER MOBY-DICK TEE	a	x
3.19	PIERO (Air/Water)	a	x
3.20	EPOPEE		
3.21	EVA	a	x
3.22	SEROPS		
3.23	BETHSY Pressuriser		
3.24	SUPER MOBY-DICK Horizontal	a	x
3.25	REBECA	a	x
3.26	ECOTRA		
4	GERMANY		
4.1	UPTF	a	x
4.2	HDR Vessel	a	x
4.3	BATTELLE PWR RS 16	a	x
4.4	BATTELLE BWR 150396	a	x
4.5	Blowdown Heat Transfer RS 37		
4.6	Het Transfer Refill/Reflod RS 36		
4.7	Steady state DNB Exp. RS 164		
4.8	Trans. Boil. Inst. Tube (Freon) RS 370	a	
4.9	Rewet RS 62/184	a	
4.10	Thermodyn. Nonequilibrium RS 77	a	x
4.11	LOCA Pump Behaviour RS 92	a	
4.12	Thermalhyd. UP-BBR 373		
4.13	Pressuriser-Valve RS 240, 347 636		
4.14	Steam/Water Disch. Flow RS 93, 397	a	
4.15			
4.16	T-Junction Test Facility (KfK)	a	x
5	ITALY		
5.1	Pressuriser (Vapore Plant) ENEA	a	x
5.2	Pressuriser Spray, TURIN	a	x
5.3	Pressuriser Flooding, CISE		
5.4	JETI-4 Fuel Channel SIET	a	x
5.5	Safety VALVE SIET	a	x
5.6	Gen 3x3 (Steam Generator), SIET	a	x
5.7	8x8 Bundle, CISE		
5.8	FREGENE (Steam Generator) ENEA		
5.9	ARAMIS (Separator) ENEA		
5.10	Jet Condensation, TURIN		
5.11	Jet Condensation, ENEA		
5.12	CHF, ENEA		
5.13	CCF, ENEA		
5.14	FOB Blowdown, ANSALDO		
5.15	GEST-SEP, SIET	a	x
5.16	GET-GEN (20 M W SG), SIET		
5.17	PIPER (Blowdown), PISA	a	x
5.18	JF Blowdown, ENEA		
6	JAPAN		
6.1	TPTF, JAERI	a	x
6.2	Air/Water Horiz. Flow Loop JAERI	a	
6.3	T-Break TF (Air/Water), JAERI	a	
6.4	Air/Water Rod Bundle TF, JAERI		
6.5	SG U-Tube TF, JAERI		
6.6	Single Pin Heat Transf. TF, Jaeri	a	
6.7	SRTF (Reflood), Toshiba	a	
6.8	ESTA (18 Degree Sector), Toshiba		
6.9	ESTA-KP (KWU-PWR), Toshiba		
6.10	RRTF (Refill/Reflood), Toshiba		
6.11	SHTF (Spray Heat Transf.) Toshiba		
6.12	Guide Tube CFL TF, Toshiba		
6.13	Swell Level Tests, Toshiba		
6.14	SCTF, JAERI	a	x
6.15	CCTF, JAERI	a	
6.16	HICOF (Hitachi Core and Fuel Tests		
6.17			
6.18	Hot Leg CCFL Rig, JAERI	a	
7	NETHERLANDS		
7.1	Bcn Boiloff/Reflood Tests (36 rods)	a	
7.2			
7.3	NEPTUNUS	a	x
8	SWEDEN		
8.1	GÖTA BWR ECC Tests	a	x
8.2	MARVIKEN	a	x
8.3	FRIGG/FRÖJA	a	x
8.4	120 bar Loop		
8.5	SIV		
8.6	SEPA		
9	SWITZERLAND		
9.1	NEPTUN-I (Boiloff)	a	x
9.2	NEPTUN-I and II (Reflood)	a	x
9.3	PEANUT (Reflood Inside Tube)	a	
10	UNITED KINGDOM		
10.1	ACHILLES Reflood Loop	a	x
10.2	THETIS Bundle	a	x
10.3	REFLEX Tube Reflood		
10.4	Post Dryout Ins. Tube (HP, Winfrith)	a	x
10.5	TITAN/9 MW Rigs	a	
10.6	High Pressure Rig	a	
10.7	Post Dryout Ins. Tube (LP, Harwell)	a	x
10.8	Air/Water Pipeline Fac. (Large Sc.)		
10.9	Hot Leg (Air/Water, Offt., Large Sc.)	a	
10.10			
10.11	Horiz. CCFL Rig (Air/Water, Small Sc.)	a	
10.12	Air/Water Rigs (Small Scale)		
10.13	LOTUS (Air/Water Ann. Flow in Tube)	a	x
10.14	Single Tube Level Swell (Harwell)	a	x
10.15	Single Tube Reflood (Harwell)	a	
10.16	Crossflow Two-Phase Wind Tunnel	a	
10.17	Loop Seal Air/Water Rig		
10.18	Hot Leg Co and CCF Rig		
10.19	Single tube Reflood (Leatherhead)	a	
10.20	Boiler Dynamics Rig	a	
10.21	Valve Blowdown Test Facility	a	x
10.22	Single Pin Reflood		
10.23	Multipin Cluster Rig		
10.24	Blowdown Rig		
10.25	ECCS Condensation Rig		
10.26	1/6th Sc. Broken Cold Leg Nozzle Rig	a	
10.27	1/10th Scale PWR Refill Strath Clyde		
10.28	R113 Vertical Forced Circul. Loop		
10.29	R113 Horiz. Forced Circul. Loop		
10.30	Vertical Flow Rigs		
10.31	High Press. Steam/Water Forced Circ.		
10.32	Low Pressure Boiling Fac. (Harwell)	a	

a: info sheet available in [1, volume 2] - *x: selected in the SETs matrix [1, volume 1, chapter 6]*

LIST OF FACILITIES (Cont.)

Table 2 (Continued). List of Facilities

		Info sheet	Selected in the CCVM
11	USA		
11.1	LTSF 1/6 Scale Jet Pump	a	x
11.2	Univ. California SB. LP BWR	a	x
11.3	THEF Post CHF Ins.Tube	a	x
11.4	Battle Columbus Laboratory		
11.5	Wyle Lab. Marshall Steam Station TF		
11.6	Micellaneous Sources		
11.7	Univ. California SB. Vert. Tube		
11.8	Univ. California B. Tube Reflood	a	x
11.9	Univ. California Berkeley		
11.10	Columbia rod Bundle	a	x
11.11	State Univ. New York at Buffalo		
11.12	State Univ. New York at Buffalo		
11.13	1/30, 1/5 + 1/5 VESSEL CREARE	a	x
11.14	1/5 DC + CL CREARE	a	
11.15	CDN DART Bubbly Flow Nozzles	a	
11.16	VERT TUBE PL/DART Annular CCF	a	x
11.17	TUBE + CHANNEL DART Air/Water		
11.18	SNTF DART BWR Spray Nozzle		
11.19	CE + MIT		
11.20	J-Loop Test Fac. Westinghouse		
11.21	HCNTL Univ. of Cincinnati		
11.22	Heat Transf. Loop Baboock and Wilcox		
11.23	FLECHT SEASET Westinghouse	a	x
11.24	Univ. California Los Angeles		
11.25	SCTF Univ. California LA	a	x
11.26	Univ. California Santa Barbara		
11.27	Univ. California Berkeley		
11.28	HST, SSTF, VSF/GE Spray Tests	a	x
11.29	Four Loop Natural Circulation/SRI		
11.30	U-Tube SG Two-Loop Test Fac/SRI	a	
11.31	1/5 EPRI-CREARE Mixing Facility		
11.32	EPRI-SAI Thermal Mixing Test Fac.	a	
11.33	½ Scale Test Facility/CREARE	a	x
11.34	EPRI-Wyle Pipe Rupture Test Fac.		
11.35	TPFL/INEL Tee Critical Flow	a	x
11.36	EPRI-SAI Carryover Large Dim.		
11.37	PHSE/PURDUE ½ Scale Facility		
11.38	Thermal Hydr. Test Fac/ORNL		
11.39	INEL Pump Charcterisation	a	x
11.40	Semiscale/INEL		
11.41	BWR-FLECHT/GE	a	x
11.42	LEHIGH Post CHF Heat Tr. Bundle	a	x
11.43	MIT Pressuriser	a	x
11.44	LS/GE Level Swell in Blowdown	a	
11.45	HOUSTON		
11.46	Cocurrent Hor, Flow/Northwest	a	x
11.47	ANL Power-Void Transf. Funct. BWR	a	x
11.48	Natural Circulation Boiling/ANL	a	
11.49	G2 Loop/Westinghouse		
11.50	Air/Water TF/B. Willamette Pump		
11.51	Univ. California Berkley		
11.52	MB-2 SG Transient/Westinghouse	a	x
11.53	Strat. Condens. Flow/Northwest	a	
11.54	Critical Flow Rig/GE	a	x
11.55	Reflux Rig/Univ. Cal. St. Barbara	a	x
11.56	LTSF Blowdown Quench/INEL	a	x
11.57	LEHIGH Post CHF Vertical Tube	a	x
12	NORWAY		
12.1	Halden Reactor, Reflood Tests	a	x

a: info sheet available in [1, volume 2] - *x: selected in the SETs matirix [1, volume 1, chapter 6]*

FORMING A SET CROSS-REFERENCE MATRIX (CRM)

- The main objective in producing the SET facility Cross-Reference Matrix is to identify the best available sets of data for the assessment, validation, and finally, the improvement of code predictions of the individual physical phenomena
- List of 67 thermohydraulic phenomena forms one axis of the SET facility CRM; the second axis of the matrix consists of the 187 facilities identified as potential sources of separate effects data, yielding the SET CRM. The test facilities are compiled according to the country in which they operate
- The correlation between phenomena and SET facility is assigned to one of three levels:
  - Suitable for model validation (x)
  - Limited suitability for model validation (o)
  - Not suitable for model validation (-)
- CRM shows both the number of different phenomena covered by the experimental investigation with one test facility, and the number of different facilities in which an individual phenomenon has been investigated

Table 3. Separate Effects Test Facility Cross Reference Matrix

LEGEND

x suitable for model validation

o limited suitability for model validation

- not suitable for model validation

Separate Effects Test Facilities — 3. France

Phenomena		1 MOBY-DICK	2 SUPER MOBY-DICK	3 CANON and SUPER CANON (Horiz)	4 VERTICAL CANON	5	6 TAPIOCA (Vertical)	7 DADINE (Vertical Tube, Inside)	8 PERICLES Rectangular	9 PERICLES Cylindrical	10 PATRICIA GV 1	11 PATRICIA GV 2	12 ERSEC Tube (Inside)	13 ERSEC Rod Bundle	14 OMEGA Tube (Inside)	15 OMEGA Rod Bundle	16 ECTHOR Loop Seal (Air/Water)	17 COSI	18 SUPER MOBY-DICK TEE	19 PIERO (Air/Water)	20 EPOPEE	21 EVA
	Facility No. Info Sheet available	a	a	a	a		a	a	a	a	a	a	a	a	a	a	a	a	a	a		a
0 BASIC PHENOMENA	1 Evaporation due to Depressurization	x	x	x	x		x	-	-	-	-	-	-	-	o	o	-	-	-	-	-	-
	2 Evaporation due to Heat Input	-	-	-	-		-	o	-	-	-	-	o	o	o	o	-	-	-	-	-	-
	3 Condensation due to Pressurisation	-	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	4 Condensation due to Heat Removal	-	-	-	-		-	-	-	-	o	-	-	-	-	-	-	o	-	-	-	-
	5 Interfac. Frict. Vertic. Flow	-	-	-	o		o	x	-	-	-	o	-	-	o	o	o	-	-	-	-	-
	6 Interfac. Frict. Horiz. Flow	-	-	o	-		-	-	-	-	-	-	-	-	-	-	o	o	-	-	-	-
	7 Wall to Fluid Friction	x	x	x	-		-	-	-	-	-	-	-	-	-	-	-	-	x	-	-	-
	8 Press. Drops at Geometr. Discontinuities	-	x	-	o		o	-	-	-	-	-	-	-	-	-	-	-	x	-	-	-
	9 Pressure Wave Propagation																					
1 CRITICAL FLOW	1 Breaks	-	x	x	x		x	-	-	-	-	-	-	-	x	x	-	-	x	-	-	-
	2 Valves	-	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	3 Pipes	x	x	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2 PHASE SEPARATION/VERTICAL FLOW WITH AND WITHOUT MIXTURE LEVEL	1 Pipes/Plena	-	-	-	x		x	o	-	-	o	x	-	-	-	-	-	-	-	o	-	-
	2 Core	-	-	-	-		-	-	x	x	-	-	-	-	-	-	-	-	-	-	-	-
	3 Downcomer	-	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3 STRATIFICATION IN HORIZ. FLOW	1 Pipes	-	-	-	-		-	-	-	-	-	-	-	-	-	-	o	o	x	-	-	-
4 PHASE SEPARATION AT BRANCHES	1 Branches	-	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-	x	-	-	-
5 ENTRAINMENT/DEENTRAINMENT	1 Core	-	-	-	-		-	o	x	x	-	-	-	x	-	x	-	-	-	-	-	-
	2 Upper Plenum	-	-	-	-		-	-	o	x	-	-	-	-	-	-	-	-	-	-	-	-
	3 Downcomer	-	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	4 SG-Tube	-	-	-	-		-	-	-	-	x	-	-	-	-	-	-	-	-	-	-	-
	5 SG-Mix. Chamber (PWR)	-	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	6 Hot Leg with ECCI (PWR)	-	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
6 LIQUID-VAPOUR MIXING WITH CONDENSATION	1 Core	-	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	2 Downcomer	-	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	3 Upper Plenum	-	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	4 Lower Plenum	-	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	5 SG-Mix. Chamb. (PWR)	-	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	6 ECCI in Hot and Cold Leg (PWR)	-	-	-	-		-	-	-	-	-	-	-	-	-	-	-	x	-	-	-	-
7 CONDENSATION IN STRATIFIED CONDITIONS	1 Pressuriser (PWR)	-	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	2 SG-Primary Side (PWR)	-	-	-	-		-	-	-	-	x	-	-	-	-	-	-	-	-	-	-	-
	3 SG-Secondary Side (PWR)	-	-	-	-		-	-	-	-	-	x	-	-	-	-	-	-	-	-	-	-
	4 Horizontal Pipes	-	-	-	-		-	-	-	-	-	-	-	-	-	-	-	x	-	-	-	-
8 SPRAY EFFECTS	1 Core (BWR)	-	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	2 Pressuriser (PWR)	-	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	3 OTSG Second. Side (PWR)	-	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
9 CCF/CCFL	1 Upper Tie Plate	-	-	-	-		-	-	o	o	-	-	-	-	-	-	-	-	-	-	-	-
	2 Channel Inlet Orifices (BWR)	-	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	3 Hot and Cold Leg	-	-	-	-		-	-	-	-	-	-	-	-	-	-	o	-	-	-	-	-
	4 SG-Tube (PWR)	-	-	-	-		-	-	-	-	x	-	-	-	-	-	-	-	-	-	-	-
	5 Downcomer	-	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	6 Surgeline (PWR)	-	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10 GLOBAL MULTIDIMENSIONAL FLUID TEMPERATURE, VOID AND FLOW DISTRIBUTION	1 Upper Plenum	-	-	-	-		-	-	o	-	-	-	-	-	-	-	-	-	-	-	-	-
	2 Core	-	-	-	-		-	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-
	3 Downcomer	-	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	4 SG-Secondary Side	-	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
11 HEAT TRANSF.: NAT. FORC. CONV.	1 Core, SG, Structures	-	-	-	-		-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SUBC./NUCL. BOIL.	2 Core, SG, Structures	-	-	-	-		-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DNB/DRYOUT	3 Core, SG, Structures	-	-	-	-		-	x	-	-	-	x	x	-	x	x	-	-	-	-	-	-
POST CHF	4 Core, SG, Structures	-	-	-	-		-	x	-	-	-	-	x	-	x	x	-	-	-	-	-	-
RADIATION	5 Core	-	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CONDENSATION	6 SG, Structures	-	-	-	-		-	-	-	-	x	-	-	-	-	-	-	-	-	-	-	-
12 QUENCH FRONT PROPAG./REWET	1 Fuel Rods	-	-	-	-		-	-	x	x	-	-	o	x	-	-	-	-	-	-	-	-
	2 Channel Walls and Water Rods (BWR)	-	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
13 LOWER PLENUM FLASHING		-	-	-	-		o	-	-	-	-	-	-	-	x	x	-	-	-	-	-	-
14 GUIDE TUBE FLASHING (BWR)		-	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15 ONE AND TWO PHASE IMPELLER-PUMP BEHAVIOUR		-	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	x	x
16 ONE AND TWO PHASE JET-PUMP BEHAVIOUR (BWR)		-	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
17 SEPARATOR BEHAVIOUR		-	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
18 STEAM DRYER BEHAVIOUR		-	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
19 ACCUMULATOR BEHAVIOUR		-	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
20 LOOP SEAL FILLING AND CLEARANCE (PWR)		-	-	-	-		-	-	-	-	-	-	-	-	-	-	x	-	-	-	-	-
21 ECC BYPASS/DC PENETRATION		-	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
22 PARALLEL CHANNEL INSTABILITIES (BWR)		-	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
23 BORON MIXING AND TRANSPORT		-	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
24 NONCONDENSABLE GAS EFFECT (PWR)		-	-	-	-		-	-	-	-	x	-	-	-	-	-	-	x	-	-	-	-
25 LOWER PLENUM ENTRAINMENT		-	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	x	-	-

SELECTION OF FACILITIES AND PARAMETER RANGES

- The identification of parameters relevant to each specific facility that characterize the phenomena
- 67 tables, that give an idea of the quantity and the scope of experimental research carried out to investigate the phenomena with the aim of qualifying thermal-Hydraulic system computer codes, have been produced with reference to each phenomenon
- The tables should be seen primarily as aiming at the selection of the facilities where the considered phenomenon has been investigated, the resulting information is utilized for the selection of individual experiments

DATA BASE FOR SELECTED FACILITIES

- 67 tables corresponding to the 67 phenomena and including 137 identified facilities:
  - Phenomenon
  - Facility identification: No.; Status in the Matrix; Name
  - Keywords
  - Relevant parameter ranges
  - Reasons for selection or specific notes:
    1. Well known to the Writing Group;
    2. Well defined and clear boundary conditions;
    3. Good measurement and instrumentation (quality of data)
    4. Quality of documentation;
    5. Already used for code development;
    6. Suitable for independent assessment;
    7. To cover an important parameter range;
    8. To cover the effect of a specific parameter.

Table 4. Phenomenon No. 11.4 – Heat Transfer Post-CHF in the Core, in the Steam-Generator and at Structures (Part A)

FACILITY IDENTIFICATION			KEYWORDS	RELEVANT PARAMETERS RANGES			REASONS FOR SELECTION OR NOTES
No.	Status in the matrix	Name		Pressure (MPa)	Inlet mass flow ($kg/m^2/s$)	Heat flux (W/cm^2)	
3.7	a x	DADINE (VERTICAL TUBE INSIDE)	Vertical tube, Steady-state, Boil-off	0.1-0.6	20-150	1-3	
3.12	a x	ERSEC TUBE (INSIDE)	Tube, reflooding	0.1-0.6	10-120	1-7	1 5 6
3.14	a x	OMEGA TUBE (INSIDE)	Blowdown	16	–	60-125	5 6 7
3.15	a x	OMEGA ROD BUNDLE	Blowdown	13-15	–	44-60	5 6 7
4.5	a x	BLOWDOWN HEAT TRANSFER RS 37	Blowdown Rod bundle	15-1.3	3828-3300	163-74	5 6 7
4.9	a x	REWET (RS 62/184)	Reflooding, tube, single rod	0.1-0.45	2-10 cm/s	2-6	5 6
5.6	a x	GEN 3x3 (STEAM GENERATOR) ENEA	SG Secondary, Steady-state, transient	3.5-8	200-600	–	
5.7	a x	8x8 BUNDLE CISE	BWR-6 Bundle, Steady state	7.1	125-1600	–	6 7
5.12	x	CHF ENEA					
6.1	a x	TPTF JAERI	Core heat transfer, Boil-off, Reflooding, BWR and PWR bundle	0.5-12	20-410	3-25	2 3 5 6
6.16	x	HICOF (HITACHI CORE AND FUEL TESTS)					
8.4	x	120 BAR LOOP					
9.1	a x	NEPTUN-I (BOIL-OFF)	Bundle	0.15	–	25-75 kW	2 3 5 6
10.3	x	REFLEX TUBE REFLOOD					
10.4	a x	POST DRYOUT INST. TUBE (HP, WINFRITH)	Hot patch	0.2-7	50-2000	1-30	2 3 5 6
10.7	a x	POST DRYOUT INST. TUBE (LP, HARWELL)		0.2-0.4	25-200		2 3 5 6
10.20	a x	BOILER DYNAMICS RIG	SG, transient boundary conditions	28	12 kg/s	12 MW	6 7
10.23	x	MULTIPIN CLUSTER RIG					
11.3	a x	THEF POST CHF INS. TUBE	Steady state, quasi-steady state	0.2-7	12-70	0.8-22.5	2 3 4 5 6
11.7	x	UNIV. CALIFORNIA B. TUBE REFLOOD					
11.8	a x	UNIV. CALIFORNIA B. TUBE REFLOOD	Reflooding	0.1-0.3	2.5-18 cm/s		1 5 6

Table 4 (Continued) Phenomenon No. 11.4 – Heat Transfer Post-CHF in the Core, in the Steam Generator and at Structures (Part B)

FACILITY IDENTIFICATION			KEYWORDS	RELEVANT PARAMETERS RANGES			REASONS FOR SELECTION OR NOTES
No.	Status in the matrix	Name		Pressure (MPa)	Inlet mass flow ($kg/m^2/s$)	Heat flux (W/cm^2)	
11.9	x	UNIV. CALIFORNIA BERKELEY					
11.10	a x	COLUMBIA ROD BUNDLE BLOWDOWN HT	Post-CHF	13.8	3500	1.8	Similar to OMEGA (rod bundle) 3.15
11.11	x	STATE UNIV. NEW YORK AT BUFFALO					
11.21	x	HCNTL UNIV. OF CINCINNATI					
11.23	a x	FLECHT SEASET WESTINGHOUSE	Reflooding, Unblocked and blocked bundle	0.14-0.4	1.5-15 cm/s	0.9-3.3 kw/s	1 2 3 5 6
11.25	x	SCTF UNIV. CALIFORNIA LA					
11.38	x	THERMAL HYDR. TEST FAC./ORNL					
11.40	x	SEMISCALE/INEL					
11.42	a x	LEHIGH POST CHF HEAT TR: BUNDLE	Bundle, hot patch, reflooding	0.1-1.	Up to 300	Up to 10	2 3 5 6
11.49	x	G2 LOOP / WESTINGHOUSE					
11.52	a x	MB-2 SG TRANSIENT/ WESTINGHOUSE	SG, transient conditions	7		6.7 MWt	6 7
11.56	a x	LSTF BLOWDOWN QUENCH/INEL	Single rod, bundle	0.1-7	0.4-6 m/s		2 5 6 7
11.57	a x	LEHIGH POST CHF VERTICAL TUBE	Hot patch	0.2-0.6	13-85	1.8-5.8	2 3 5 6
12.1	a x	HALDEN REACTOR; REFLOOD TESTS	Reflooding, Fuel and heater rods	0.2-0.4	4-60 g/s	1.8-5.8	2 3 5 6

ESTABLISHING THE SET MATRIX

- For each of the 67 phenomena, a table presents the tests which have been identified as suitable for code validation with respect to that phenomenon, from the test facilities selected
- Tests have been chosen on the basis of available information, applying the established criteria for selection
- It is not always possible to determine how satisfactory data is for code validation until the specific data is actually used
- The tests have been selected in order to cover the experimental data range as defined, knowing that the plant range is not always covered
- Particular attention has been given to the geometric scaling problem
- The main references are provided in the tables, for the chosen tests
- This matrix has been published as a first attempt. It may be updated by new and additional input from the owners and remarks from the users
- SET Matrix covers a large number of phenomena within a large range of selected parameters
- If a thermal-hydraulic code is to be used to cover certain number phenomena, then calculation of the relevant identified tests in the matrix is considered to be a basic step toward the achievement of code qualification

Table 5: Evaporation due to Depressurization (Phenomenon No. 6.0.1)

FACILITIES IDENTIFIER		3.2	3.6	4.4	4.10	8.2
Main parameters						
P (MPa)	D 10^{-3} m					
0.75					228	
2.59					239	
3		31B234C 33B234C 30B 9X				
5		48B234C			256	
	509 160					509 mm
6.37					88	
8.8				BWR steam line break		
	76			76 mm		
9.17					208	
11.58					168	
12		12R305 12R318 12R324 12ORSA 12OEB324				
	10		break 10 mm			
15			top lateral			
	20		break 20 mm lateral			
		SELECTED TESTS				

<u>References:</u>

3.2- B. Spinler: Reconstitution d'essais SUPER MOBY DICK avec le code TRAC PF1/MOD1, version 14.3, N. Technique CEA/DTE/SETh/LEML n° 88-134

3.6 FRAMATOME report TP/CT/DC 494 June 1980

4.4 System description, experimental procedures: BF-R64. 167-01, 1982=(1) data reports: BF-R64. 167-30-1 to 11 and (3.1)-(3.9) in (1)
B. Hoizer, et.al.: Specification of OECD Standard Problem No. 6, GRS/Battelle Frankfurt, February, 1977

4.10 System description, experimental procedure: results (plots): RS 77 Final Report, C.E.C. ISPRA 1976 to BMFT-Bonn

8.2- The Marviken Full Scale Critical Flow Tests. Conclusions. Joint Reactor Safety Experiments in the Marviken Power Station, Sweden. MXC-402. December 1979

<u>Additional information</u>

3.2- Convergent inlet diameter 87.5 mm, outlet diameter 20 mm

4.10- Liquid expansion experiment.

Table 6: Critical Flow in Breaks (Phenomenon No. 6.1.1)

FACILITIES IDENTIFIER		3.2	3.25	8.2	11.54	
Main parameters						
P (MPa)	Temp (K)					
0.3			3 B X 06 3 B X 20 3 B X 100			
0.5			5 B X 29 5 B X 100			
0.8			8 B X 40			
2.0	465	20 B 192				
2.0	477	20 B 204				
2.0	484	20 B 211				
4.0	501	40 B 227				
4.0	514	40 B 240				
4.00	522	40 B 249				
P, T_{sub}=5.0,30	D, L/D=0.2,3.0			13		
P, T_{sub}=5.0,30	D, L/D=0.2,3.0			6		
P, T_{sub}=5.0,30	D, L/D=0.2,3.0			12		
P, T_{sub}=5.0,30	D, L/D=0.2,3.0			18		
P, T_{sub}=5.0,30	D, L/D=0.2,3.0			24		
P, T_{sub}=5.0,30	D, L/D=0.2,3.0			21		
P, T_{sub}=5.0,30	D, L/D=0.2,3.0			22		
6.89	x_0= 0.003				Nozzle 3	
6.62	x_0= -0.002				Nozzle 3	
8.0	567	80 B 293				
		SELECTED TESTS				

References:

3.2 Report CEA/DRE/STT No. TT-163, July 1981
Note CEA/CDR/STT No. TT/SETRE/82-32, January 1983.
Note CEA/CDR/STT No. TT/SETRE/71, September 1983.

3.25- Note CEA/DRE/SETRE/LTA 784/612, July 1984.

8.2- The Marviken Full Scale Critical Flow Test. MXC-301. Summary Report, December 1979

11.54 Sozzi G. L., Sutherland W. A.. : Critical Flow of Saturated and Subcooled Water at High Pressure. General Electric Report NEDO-13418, May 1975

Table 7: Global Multidimensional Fluid Temperature, Void and Flow Distribution in the Core (Phenomenon No. 6.10.2)

FACILITIES IDENTIFIER	3.8	6.14	6.15	10.1	10.2	11.23
Main parameters						
P (MPa)						
< 1.0 MPa	31B	S2-16/621 Cold leg ECC inj.	C2-12/71 Cold leg ECC inj.	Level swell, 0.2 Mpa: A1L069 A1L070 A1L071		Boil off: 35.557 35.658 35.759
	32A 35	S3-11/715 combined ECC inj.	C2-20/80 combined ECC inj.	Voidage Distribution: A3L040 A3L046 A3L049 BE reflood: A1B091 A1B099 A1B101 A1B112		steam cooling: 32.753 36.160 36.261 36.262 36.463 36.564 36.766 36.867
0.5-4.0 MPa					7 tests, selected in Ref.3.8/10.2	
		SELECTED TESTS				

References:

3.8 a R. Deruaz, P. Clement, J. M. Veteau: "Final Report – Study of Two Dimensional Effects in the Core of Light Water Reactor During the Reflooding Phase of a LOCA" contract N. 002 SRF

3.8/10.2- A. Forge, et.al.: "Comparative Calculations on Selected Two-Phase Flow Phenomena Using Major PWR System Codes" CEC, EUR 12901 EN, 1990.

6.14- Data Reports on Large Scale Reflood Tests for each SCTF-Test.

6.15- Data Reports on Large Scale Reflood Tests for each CCTF-Test.

10.1- Technical Reports to ACHILLES Steering Group: UK Nucl. Industry and CEGB Chairman for Experimental Program.

10.2- C. A. Cooper, K. G. Pearson, D. Jowitt: Contract SR-030-UK

G. L. Shires, et. al.: "The Thermal Performance of a Partially Water Filled Fuel Cluster,Part1: An Exploratory Experimental Study of Level Swell at Pressures from 2 to 40 bars" AEEW-R-1369, June 1980.

11.23 S. Wong, L. E. Hochreiter: Analysis of the FLECHT-SEASET Unblocked Bundle Steam Cooling and Boil-off Tests; NUREG/CR-1533, May 1981.

Table 8: Heat Transfer: Post-CHF in the Core, in the Steam Generator and at Structures (Phenomenon No. 6.11.4) (5/7)

FACILITIES IDENTIFIER		11.8	11.23			
Main parameters						
P (MPa)	Inlet velocity (cm/s)					
0.1	7.5	3076				
0.3	7.5	3070				
0.3	12.5	3060				
0.2	2.5	3051				
0.3	7.5	3059				
	Mass Flux kg/m^2s					
0.1	74					
0.1	74					
0.1	74					
0.1	74					
0.4	74					
0.4	74					
0.4	26					
	Road peak power (KW/m)					
0.28	1.6		33056			
	0.16		36160	steam cooling		
	0.79		36262			
	0.039		36564			
	0.02		36867			
		SELECTED TESTS				

References:

11.8 R. Seban: "Reflooding of a Vertical Tube at 1.2 and 3 Atmospheres" EPRI-NP-3191, July 1981

R. Seban: "Heat Transfer During Quench and Dryout in a Vertical Tube" EPRI-NP-4157, July 1985

11.23 S. Wong, L. E. Hochreiter: "Ànalysis of the FLECHT SEASET Unblocked Bundle Steam Cooling and Boil-off Tests" NUREG/CR1533, May 1981

N. Lee, et. al.: "PWR FLECHT SEASET Unblocked Bundle, Forced and Gravity Reflood Task: Data Evaluation and Analysis Report" NUREG/CR-2256, February 1982.

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Table 8 (Cont.): Heat Transfer: Post-CHF in the Core, in the Steam Generator and at Structures (Phenomenon No. 6.11.4) (6/7)

FACILITIES IDENTIFIER		11.23 (cont.)	11.42	11.49		
Main parameters						
P (MPa)	Road peak power					
0.28	2.4	31504				
0.28	2.5	32114				
0.41	2.64	32013				
0.14	2.7	31922				
0.28	7.6	31302				
0.28	2.1	31805				
0.28	3.8	31203				
0.27	1.5	31701				
0.28	15	34006				
	Mass Flux (kg/m^2s)					
0.1	13.46		3			
	7.23		9			
	18.48		12			
	18.69		14			
	25.13		20			
	25.58		22			
0.56				716		
0.56				718		
0.1				736		
		SELECTED TESTS				

References:

11.55 K. Tuzla, et. al.: "Thermodynamic Non-Equilibrium in Post-Critical Heat-Flux Boiling in a Rod Bundle" NUREG/CR-5095, June 1988, Vols. 1-3.
M. Sencar and N. Aksan: "Independent Assessment of RELAP5/Mod3 with Lehigh University and PSI- NEPTUN Reflooding Tests" Code Assessment and Maintenance Program Meeting, PSI, Switzerland June 1992.

11.49 Heat Transfer Above the Two-Phase Mixture Level Under Core Uncovery Conditions In a 336-Rod Bundle: Vol. 1- Westinghouse Electric Corp.
Vol. 2- T. S. Andreychek, Westinghouse Electric corp., Pittsburgh
EPRI-NP-1692, Vols. 1 and 2
H. C. Yeh et. al., Westinghouse Electric Corp, USA
Heat Transfer Above the Two-Phase Mixture Level Under Core Uncovery Conditions in a 336-Rod Bundle

Table 8 (Cont.): Heat Transfer: Post-CHF in the Core, in the Steam Generator and at Structures (Phenomenon No. 6.11.4) (7/7)

FACILITIES IDENTIFIER		11.56	11.57	12.1		
Main parameters						
P (MPa)	Inlet fluid velocity (m/s)					
6.86	3.7	12				
6.92	0.4	7				
	Mass Flux (kg/m^2s)					
0.378	14.8		100			
0.255	14.9		105			
0.409	20.7		112			
0.396	42.7		124			
0.39	29.5		130			
0.272	42.9		158			
0.302	60		174			
0.395	29.9		191			
	Reflood rate (cm/s)					
				IFA-511-2		
0.2-0.4	9.6			5236		
	5.6			5239		
	7.4			5247		
				IFA-511-3		
	9.6			5258		
	5.6			5261		
	7.4			5265		
	2.1			5266		
		SELECTED TESTS				

References:

11.56 N. Aksan: "Evaluation of Analytical Capability to predict cladding Quench" EGG-LOFT 5555, August 1982.

11.57 D.G. Evans, et al. "Measurement of Axially Varying Nonequilibrium in Post-Critical Heat-Flux Boiling in a Vertical Tube" NUREG/CR-3363, Vols. 1 and 2, June 1983.

12.1 C. Vitanza et al.:"Blowdown/reflood tests with Nuclear Heated Rods (IFA-511.2)" OECD Halden Reactor Project, HPR-248, May 1980.

T. Johnsen, C. Vitanza: "Blowdown/Reflood Tests with Semiscale Heaters (IFA-511.3)" OECD Halden Reactor Project HWR-17, May 1981.

INTEGRAL FACILITY TEST VALIDATION (ITF) MATRIX

TEST TYPES FOR PWRs

- Large break
- Small and intermediate breaks
- Transients
- Transients at shutdown conditions
- Accident management for non-degraded core

TEST TYPES FOR BWRs

- Loss-of coolant accidents
- Transients

BASIS FOR SELECTION OF EXPERIMENTS AND INDIVIDUAL TESTS

- Typicality of facility and experiment to expected reactor conditions,
- Quality and completeness of experimental data (measurement and documentation),
- Relevance to safety issues,
- Test selected must clearly exhibit phenomena,
- Each phenomenon should be addressed by tests of different scaling (at least one test if possible)
- High priority to International Standard Problems (ISP), counterpart and similar tests
- Challenge to system codes.

Matrix I
CROSS REFERENCE MATRIX FOR LARGE BREAKS IN PWRs

Phenomena versus test type
+ occurring
o partially occurring
- not occurring

- test facility versus phenomenon
+ suitable for code assessment
o limited suitability
- not suitable

- test type versus test facility
+ performed
o performed but of limited use
- not performed or planned

		Test Type			Test Facility and Volumetric						
		Blowdown	Refill	Reflood	CCTF 1:25	LOFT 1 : 50	BETHSY 1 : 100	PKL 1 : 145	LOBI 1 : 712	SEMISCALE 1 : 1600	UPTF 1 : 1 (a)
Phenomena	Break flow	+	+	+	o	o	o	o	o	o	o
	Phase separation (condition or transition)	o	+	+	+	+	+	+	+	+	+
	Mixing and condensation during injection	o	+	+	o	o	o	o	o	o	+
	Core wide void + flow distribution	o	+	+	o	o	o	o	o	-	o
	ECC bypass and penetration	o	+	o	+	+	-	o	o	-	+
	CCFL (UCSP)	o	+	+	o	o	o	o	o	-	+
	Steam binding (liquid carry over, ect.)	-	o	+	o	o	-	o	o	o	o
	Pool formation in UP	-	+	+	o	o	o	o	o	o	+
	Core heat transfer incl. DNB, dryout, RNB	+	+	+	o	+	+	+	o	o	-
	Quench front propagation	o	o	+	+	+	+	+	-	+	-
	Entrainment (Core, UP)	o	o	+	o	o	+	o	o	o	+
	Deentrainment (Core, UP)	o	o	+	o	o	o	o	o	o	+
	1 - and 2-phase pump behaviour	+	o	o	-	o	-	o	+	+	-
	Noncondensable gas effects	-	o	o	-	-	o	-	-	-	o
Test Facility	CCTF	-	o	+							
	LOFT	+	+	+							
	BETHSY	-	-	+							
	PKL	o	+	+							
	LOBI	+	+	-							
	SEMISCALE	+	+	+							
	UPTF	o	+	+							

important test parameter
- break location/break size
- pumps off/pumps on
- cold leg injection/combined injection

(a) UPTF integral tests

Matrix II
CROSS REFERENCE MATRIX FOR SMALL AND INTERMEDIATE BREAKS

Phenomenon versus test type
+ occurring
o partially occurring
- not occurring

- Test facility versus phenomenon
+ suitable for code assessment
o limited suitability
- not suitable

- Test type versus test facility
+ performed
o performed but of limited use
- not performed or planned

		Test Type							Test Facility and Volumetric Scaling								
		Stationary test addressing energy	Stationary test addressing energy transport on secondary side	Small leak overfed by HPIS, secondary side necessary	Small leak without HPIS	Intermediate leak, secondary side not necessary	Pressurizer leak	U-tube rupture	PWR 1 : 1	LOFT 1 : 50	LSTF 1 : 50	BETHSY 1 : 100	PKL-III 1 : 145	SPES 1 : 430	LOBI-II 1 : 712	SEMISCALE 1 : 1600	UPTF, TRAM 1 : 1 (2)
Phenomena (3)	Natural circulation in 1-phase flow, primary side	+	+	+	o	-	+	+	+	+	+	+	+	+	+	+	-
	Natural circulation in 2-phase flow, primary side	+	-	o	+	+	o	-	-	+	+	+	+	+	+	+	o
	Reflux condenser mode and CCFL	+	-	-	+	+	-	-	-	o	+	+	o	o	o	o	+
	Asymmetric loop behaviour	-	-	+	+	-	o	+	-	-	o	+	+	+	o	o	+
	Break flow	-	-	+	+	+	+	+	-	+	+	+	+	+	+	+	o
	Phase separation without mixture level formation	+	-	o	+	+	+	o	-	o	+	+	+	+	+	o	+
	Mixture level and entrainment in SG second side	-	+	+	+	+	+	+	-	-	+	+	+	o	o	-	-
	Mixture level and entrainment in the core	+	-	-	+	+	+	-	-	o	+	+	+	o	o	o	o
	Stratification in horizontal pipes	+	-	-	+	+	-	-	-	+	+	o	o	+	o	o	+
	Phase separation in T-junct. and effect on breakflow	-	-	-	+	+	-	-	-	o	o	o	o	o	o	-	+
	ECC-mixing and condensation	-	-	o	+	+	+	+	-	o	o	o	o	o	o	o	+
	Loop seal clearing	-	-	-	+	+	o	-	-	+	+	+	+	+	+	+	+
	Pool formation in UP/CCFL (UCSP)	+	-	-	o	+	+	-	-	o	o	o	o	o	-	o	+
	Core wide void and flow distribution	+	-	-	o	+	+	-	-	o	o	o	o	-	-	-	o
	Heat transfer in covered core	+	+	+	+	+	+	+	o	+	+	+	+	+	+	+	-
	Heat transfer in partly uncovered core	+	-	-	o	+	-	-	-	+	+	+	+	o	o	o	-
	Heat transfer in SG primary side	+	o	o	+	+	o	o	-	o	+	+	+	+	+	o	-
	Heat transfer in SG secondary side	o	+	+	+	+	+	+	-	o	+	+	+	o	+	o	-
	Pressurizer thermohydraulics	o	-	o	o	+	+	+	o	o	o	o	o	o	o	-	+
	Surgeline hydraulics	o	-	-	o	+	+	o	-	o	o	o	o	o	o	o	+
	1- and 2-phase pump behaviour	-	-	-	o	+	-	-	o	o	o	o	o	o	+	+	-
	Structural heat and heat losses (1)	+	-	o	+	+	o	o	-	o	o	o	o	o	o	o	o
	Noncondensable gas effects	+	-	-	-	-	-	-	-	-	o	o	o	-	-	o	+
	Boron mixing and transport	+	-	+	+	+	+	+	-	-	-	-	-	-	-	-	o
Test Facility	PWR	-	-	o	-	-	+	+									
	LOFT	-	-	+	+	+	+	-									
	LSTF	+	+	+	+	+	+	+									
	BETHSY	+	+	+	+	+	+	+									
	PKL-III	+	+	+	+	+	+	+									
	SPES	+	+	+	+	-	-	-									
	LOBI-II	+	+	+	+	+	+	+									
	SEMISCALE	o	o	+	+	+	+	+									

(1) problem for scaled test facilities
(2) UPTF integral tests
(3) for intermediate breaks phenomena included in large break reference matrix may be also important

Matrix IV
CROSS REFERENCE MATRIX FOR TRANSIENTS IN PWRs

Phenomenon versus test type
- \+ occurring
- o partially occurring

- test facility versus Phenomenon
- \+ suitable for code assessment
- o limited suitability
- \- not suitable

- test type versus test facility
- \+ performed
- o performed but of limited use
- \- not performed or planned

		Test Type								Test Facility and Volumetric Scaling							
		ATWS	Loss of feedwater, non ATWS	Loss of heat sink, non ATWS (c)	Station blackout	Steam line break	Feed line break	Reactivity disturbance	Overcooling	PWR 1 : 1	LOFT 1 : 50	LSTF 1 : 50	BETHSY 1 : 100	PKL-III 1 : 134	SPES 1 : 430	LOBI-II 1 : 712	SEMISCALE 1 : 1000
Phenomena	Natural circulation in 1-phase flow	+	+	+	+	+	+	o	o	+	o	+	+	+	+	+	+
	Natural circulation in 2-phase flow	+	+	+	+	-	-	o	-	-	o	+	+	+	+	+	+
	Core thermohydraulics	+	+	+	+	o	o	+	o	o	+	+	+	+	+	+	+
	Thermohydraulics on primary side of SG	+	o	o	+	o	o	o	+	o	o	+	+	+	+	+	o
	Thermohydraulics on secondary side of SG	+	+	+	+	+	+	o	+	o	o	+	+	+	o	+	o
	Pressurizer thermohydraulics	+	+	+	+	o	o	o	+	o	o	o	o	o	o	o	o
	Surgeline hydraulics (CCFL, choking)	+	+	+	+	o	o	o	o	o	o	o	o	o	o	o	o
	Valve leak flow (a)	+	+	+	+	+	+	+	+	-	o	o	o	o	o	o	o
	1- and 2-phase pump behaviour	+	+	+	+	o	o	o	+	o	o	+	o	o	o	+	+
	Thermohydraulic-nuclear feedback	+	-	-	-	-	-	+	-	+	+	-	-	-	-	-	-
	Structural heat and heat losses (b)	o	o	o	o	o	o	o	o	-	o	o	o	o	o	o	o
	Boron mixing and transport	-	-	-	-	o	-	-	o	-	-	-	-	-	-	-	-
	Separator behaviour	o	-	-	-	+	-	-	-	-	-	-	-	-	o	o	-
Test Facility	PWR	-	-	-	-	-	-	-	o								
	LOFT	+	+	+	o	-	-	+	+								
	LSTF	-	+	-	+	+	+	-	+								
	BETHSY	-	+	+	-	+	+	-	-								
	PKL-III	-	+	+	+	+	+	-	+								
	SPES	-	+	-	+	-	-	-	-								
	LOBI-II	+	+	+	+	+	+	-	-								
	SEMISCALE	-	+	+	+	+	+	-	+								

(a) valve flow behaviour will be strongly design-dependent, specific experimental data should be used if possible
(b) problem for scaled test facilities
(b) problem for scaled test facilities

	Matrix V CROSS REFERENCE MATRIX FOR TRANSIENTS AT SHUT-DOWN CONDITIONS IN PWRS	Test Type				Test Facility and Volumetric Scaling		
	Phenomenon versus test type + occurring o partially occurring - not occurring - Test facility versus phenomenon + suitable for code assessment o limited suitability - not suitable - Test type versus test facility + performed o performed but of limited use - not performed or planned	Loss of RHR with no opening	Loss of RHR with openings	Loss of RHR with dam in HL	Boron dilution at shut-down	LSTF	BETHSY	PKL III
Phenomena	Pressurization due to boiling	+	+	+	-	+	+	+
	Reflux condenser mode and CCFL	+	+	o	-	+	+	o
	Asymmetric loop behaviour	-	o	+	-	+	+	+
	Flow through openings (manways, vents)	-	+	+	-	+	+	-
	Mixture level formation in upper plenum and hot legs	+	+	+	-	+	+	+
	Mixture level and entrainment in the core	+	+	+	-	+	+	+
	SG syphon draining	-	-	+	-	+	-	-
	Asymmetry due to the presence of a dam	-	-	+	-	+	-	-
	Stratification in horizontal pipes	+	+	+	-	+	o	+
	Phase separation in T-junctions and effect on flow	-	+	+	-	o	o	o
	ECC mixing and condensation	+	+	+	-	o	o	o
	Loop seal clearing and filling	+	+	+	-	+	+	-
	Pool formation in UP/CCFL (UCSP)	-	-	-	-	-	-	-
	Core 3D thermalhydraulics	+	+	+	+	o	o	o
	Heat transfer in covered core	+	+	+	-	+	+	+
	Heat transfer in partially uncovered core	+	+	+	-	o	o	-
	Heat transfer in SG primary side	+	+	+	-	+	+	+
	Heat transfer in SG secondary side	+	+	+	-	+	+	+
	Pressurizer thermalhydraulics a)	-	x	x	-	o	o	o
	Surge line thermalhydraulics a)	-	x	x	-	o	o	o
	Structural heat and heat losses	-	-	-	-	-	-	o
	Non-condensible gas effects	+	+	+	-	+	+	+
	Boron mixing and transport	-	-	-	+	-	-	-
	Thermalhydraulics-nuclear feedback	-	-	-	+	-	-	-
Test Facility	LSTF	+	+	+	-			
	BETHSY	-	+	-	-			
	PKL III	+	-	-	-			

a) x is dependent on opening location
+ pressuriser manway open
- pressuriser manway shut

Matrix VI
CROSS REFERENCE MATRIX FOR ACCIDENT MANAGEMENT FOR A NON DEGRADED CORE IN PWRs

- Phenomenon versus test type
  - + occurring
  - o partially occurring
  - - not occurring
- Test facility versus phenomenon
  - + suitable for code assessment
  - o limited suitability
  - - not suitable
- Test type versus test facility
  - + performed
  - o perfomed but of limited use
  - - not performed or planned

		Test Type: High pressure primary side feed and bleed	Test Type: Low pressure, primary side feed and bleed	Test Type: Secondary side, feed and bleed	Test Type: RCP-Restart in a highly, voided PCS	Test Type: Primary to secondary break with multiple failures	Test Facility and Volumetric Scaling: LOFT 1 : 50	LSTF 1 : 50	BETHSY 1 : 100	PKL-III 1 : 1 : 145	SPES 1 : 430	LOBI-II 1 : 712	UPTF, TRAM 1 : 1 (2)
Phenomena	Natural circulation in 1-phase flow, primary side	+	-	+	-	+	+	+	+	+	+	+	-
Phenomena	Natural circulation in 2-phase flow, primary side	+	+	+	-	+	+	+	+	+	+	+	o
Phenomena	Reflux condenser mode and CCFL	-	-	+	-	+	o	+	o	o	o	o	+
Phenomena	Asymmetric loop behaviour	+	+	+	+	+	-	o	+	+	+	o	+
Phenomena	Break flow	+	+	o	+	+	+	+	+	+	o	+	o
Phenomena	Phase separation without mixture level formation	+	+	+	+	+	o	+	+	+	+	+	+
Phenomena	Mixture level and entraiment in SG secondary side	-	-	+	-	+	-	+	+	+	o	o	-
Phenomena	Mixture level and entraiment in the core	+	+	+	o	+	o	+	+	+	o	o	o
Phenomena	Stratification in horizontal pipes	+	+	+	o	+	+	+	o	o	o	o	+
Phenomena	Phase separation in T-junct. and effect on breakflow	+	+	o	-	+	o	o	o	o	o	o	+
Phenomena	ECC-mixing and condensation	+	+	+	-	+	o	o	o	o	o	o	+
Phenomena	Loop seal clearing (3)	o	o	+	o	+	+	+	o	o	+	+	+
Phenomena	Pool formation in UP/CCFL (UCSP)	+	+	+	-	+	o	o	o	o	o	-	+
Phenomena	Core wide void and flow distribution	+	+	+	+	+	o	o	o	o	-	-	o
Phenomena	Heat transfer in covered core	o	o	+	-	+	+	+	+	+	+	+	-
Phenomena	Heat transfer in partly uncovered core	+	+	+	+	+	+	+	+	+	o	o	-
Phenomena	Heat transfer in SG primary side	-	-	+	o	+	o	+	+	+	+	+	-
Phenomena	Heat transfer in SG secondary side	-	-	+	o	+	o	+	+	+	o	+	-
Phenomena	Pressurizer thermohydraulics	+	+	o	o	+	o	o	o	o	o	o	+
Phenomena	Surgeline hydraulics	+	+	o	o	+	o	o	o	o	o	o	+
Phenomena	1- and 2-phase pump behaviour	o	o	+	+	+	o	o	o	o	o	+	-
Phenomena	Structural heat and heat losses (1)	+	+	+	+	+	o	o	o	o	o	o	o
Phenomena	Noncondensable gas effects	o	+	+	+	+	-	o	o	+	-	-	+
Phenomena	Accumulator behaviour	-	+	+	-	o	o	+	+	+	+	+	+
Phenomena	Boron mixing and transport	+	+	+	+	+	-	-	-	-	-	-	o
Phenomena	Thermohydraulic-nuclear feed back	-	-	-	+	-	-	-	-	-	-	-	-
Phenomena	Separator behaviour	-	-	-	-	-	-	-	-	-	-	-	-
Test Facility	LOFT	-	-	+	-	-							
Test Facility	LSTF	+	+	+	-	o							
Test Facility	BETHSY	+	+	+	-	+							
Test Facility	PKL-III	o	+	+	+	-							
Test Facility	SPES	+	+	+	-	+							
Test Facility	LOBI-II	+	+	+	-	+							
Test Facility	UPTF, TRAM	o	+	-	-	-							

(1) problem for scaled test facilities
(2) UPTF integral tests
(3) long term cooling not included

Matrix VII
CROSS REFERENCE MATRIX FOR LOCA IN BWRs

- Phenomena versus test type
  - \+ occurring
  - o partially occurring
  - \- not occurring
- Test facility versus phenomenon
  - \+ suitable for code assessment
  - o limited suitability
  - \- not suitable
- Test type versus test facility
  - \+ performed
  - o perfomed but of limited use
  - \- not perfomed or planned

		Test Type						Test Facility and Volumetric Scaling						
		Large Steam Line Break with Fast Depressurization	Large Break Below Water Level with Fast Depress.	Small Break without Depress. before ADS Activation	Intermediate Break with Slow Depress.	Spray Line Break	Refill - Reflood	BWR 1 : 1 (a)	TBL, 1 : 382, 2 Chan., Full Pow., Full Height	ROSA III, 1 : 424, 4 Channels	TLTA, 1 : 624, 1 Chan., Full Power	FIST, 1: 624, 1 Chan., Full Pow., Full Height	FIX 2, 1 : 777, 1 Chan., Full Pow., Full Height	PIPER 1, 1 : 2200, 1 Chan., Full Height
Phenomena	Break flow	+	+	+	+	+	o	-	o	o	o	o	o	+
	Channel and Bypass Axial Flow and Void Distribution	+	+	+	+	+	+	o	+	o	+	+	+	+
	Corewide Radial Void Distribution	o	o	+	+	+	+	o	o	+	o	o	o	-
	Parallel Channel Effects-Instabilities	-	-	+	+	+	+	-	o	+	-	-	-	o
	ECC Bypass	-	-	o	o	o	+	-	o	o	o	o	-	+
	CCFL at UCSP and Channel Inlet Orifice	o	+	-	+	+	+	-	o	o	-	o	o	o
	Core Heat Transf. incl. DNB, Dryout, RNB. Surf. to Surf Radiation	+	+	o	+	o	+	-	+	+	+	+	+	+
	Quench Front Propagation for both Fuel Rods and Channel Walls	-	-	-	-	-	+	-	+	+	+	+	-	+
	Entrainment and Deentrainment in Core and Upper Plenum	+	+	o	o	o	+	-	-	o	o	o	-	o
	Separator Behavior incl. Flooding, Steam Penetration and Carryover	+	+	o	o	o	-	o	+	o	o	+	o	o
	Spray Cooling	-	-	o	o	o	+	-	o	o	o	o	-	+
	Spray Distribution	-	-	o	o	o	+	-	-	o	-	-	-	-
	Steam Dryer - Hydraulic Behavior	+	-	o	o	-	-	o	o	o	o	o	-	o
	One and Two Phase Pump Recirc. Behavior incl. Jet Pumps	o	o	+	+	+	o	o	o	o	o	o	o	-
	Phase Separation and Mixture Level Behavior	+	+	+	+	+	+	-	o	+	o	+	+	o
	Guide Tube and Lower Plenum Flashing	+	+	-	o	o	-	-	+	+	+	+	+	+
	Natural Circulation- Core and Downcomer	-	-	+	o	o	+	+	+	o	o	+	+	+
	Natural Circulation Core Bypass, Hot and Cold Bundles	-	-	+	o	o	+	-	o	o	o	o	o	o
	Mixture Level in Core	-	-	+	o	o	+	-	+	+	+	+	+	o
	Mixture Level in Downcomer	+	+	+	+	+	+	-	+	o	o	+	+	o
	ECC Mixing and Condensation	-	-	+	o	+	+	-	o	o	o	o	-	o
	Pool Formation in Upper Plenum	o	o	-	o	o	+	-	o	o	o	o	o	o
	Structural Heat and Heat Losses	o	o	o	+	+	+	-	+	o	o	o	o	o
	Phase Separ. in T - Junction and Effect on Break Flow	-	-	+	o	+	-	-	-	-	-	-	-	+
Test Facility	BWR	-	-	-	-	-	-	(a) These are non-LOCA data but may be used for assessment						
	TBL	+	+	+	+	-	+							
	ROSA III	+	+	+	+	-	+							
	TLTA	+	+	-	+	-	+							
	FIST	+	+	+	+	-	+							
	FIX 2	-	+	-	+	-	-							
	PIPER 1	-	+	+	+	-	+							

Matrix VIII
CROSS REFERENCE MATRIX FOR TRANSIENTS IN BWRs

Phenomenon versus test type
- \+ occurring
- o partially occurring
- \- not occurring

Test facility versus phenomenon
- \+ suitable for code assessment
- o limited suitability
- \- not suitable

Test type versus test facility
- \+ performed
- o performed but of limited use
- \- not performed or planned

		Test Type									Test Facility and Volumetric Scaling			
		Stationary Test Measuring Power Flow Map	Recirculation Pump Trip	Core Stability	Loss of Main Heat Sink	[illegible] LOFW	[illegible] Pressure	Inadvertent Increase in Steam Flow	ATWS	Station Blackout (Loss-of-Offsite Power)	BWR 1 : 1	ROSA III, 1 : 424, 4 Channels	FIST, 1 : 642, 1 Channel, Full Power, Full Height	FIX 2, 1 : 777, 1 Channel, Full Power, Full Height
Phenomena	Natural Circulation in One- and Two-Phase Flow	+	+	+	+	-	-	-	+	+	+	o	+	o
	Collapsed Level Behaviour in Downcomer	-	+	o	+	+	+	+	+	+	+	o	+	+
	Core Thermal Hydraulics	o	+	+	+	o	o	o	+	+	o	+	+	+
	Valve Leak Flow	-	-	-	+	-	-	-	+	+	o	o	o	-
	Single Phase Pump Behaviour (a)	o	+	o	+	o	o	+	+	+	o	o	o	o
	Parallel Channel Effects and Instabilities	-	+	+	o	-	-	-	+	+	o	+	-	-
	Nuclear Thermalhydraulic Feedback Including Spatial Effects	o	o	+	-	o	o	o	+	-	+	-	-	-
	Nuclear Thermalhydraulic Instabilities	-	o	+	-	-	-	o	+	-	+	-	-	-
	Downcomer Mixing	-	-	-	-	+	+	-	+	+	o	o	-	-
	Boron Mixing and Distribution	-	-	-	-	-	-	-	+	-	-	-	-	-
	Steam Line Dynamics	-	-	-	+	-	-	+	+	+	o	-	o	-
	Void Collapse and Temp. Distribution During Pressurization	-	-	-	+	-	-	-	+	+	o	+	+	+
	Critical Power Ratio	-	+	+	+	+	+	+	+	+	o	+	+	+
	Rewet after DNB at High Press. and High Power Incl. High Core Flow	-	+	-	+	-	-	o	+	o	-	o	+	+
	Structural Heat and Heat Losses	-	o	-	o	-	o	o	o	o	-	o	o	o
Test Facility	BWR	+	+	+	+	+	+	+	-	o				
	ROSA III	-	+	+	+	-	+	-	-	+				
	FIST	-	o	-	+	-	+	+	o	+				
	FIX 2	-	+	-	+	-	-	-	-	-				

(a) Two-phase pump behaviour is of interest for certain special ATWS and inadvertent increase of steam flow transients

CROSS REFERENCE MATRICES FOR WWER ANALYSIS (INTEGRAL AND SEPARATE EFFECTS TESTS)

- OECD Support Group on WWER Validation Matrix 1995-2000
- Develop a supplement to the existing OECD SET and ITF Validation Matrices
- Consideration of specific features of WWER-440 and WWER-1000 systems and their behavior in normal and abnormal situations
- WWER Validation Matrix contains
  - Large break LOCAs
  - Small and intermediate brak LOCAs
  - Transients
- Phenomena identified relevant for WWERs
- Phenomena od WWER compared to Western PWR and similarities clarified
- Facilities and experiments (both ITFs and SETs) identified that supplement the CSNI Validation Matrices and are suitable for WWER specific code assessment

USE OF THE VALIDATION MATRICES IN BEST-ESTIMATE THERMAL-HYDRAULIC CODES

- OECD/NEA-CSNI SET and ITF validation matrices have been used heavily in establishing the validation matrices for the major BE thermal-hydraulic system codes, e.g. RELAP5, CATHARE, TRAC, TRACE and ATHLET
- Depending on the application needs of the specific computer code, additional separate effects tests are included into the code's validation matrix, e.g. ATHLET considers specific aspects of the German combined ECC injection system, RELAP5 and TRACE consider specific aspects of AP1000 and ESBWR advanced reactor designs by including additional separate effects tests (SET) and ITF tests into the specific validation matrix

CONCLUSIONS AND RECOMMENDATIONS (I)

- Information collected, recorded and classified in three main areas:
  - On test facilities and test parameters,
  - State of the art knowledge with regard to a full range of thermal-hydraulic phenomena
  - Source of data for validation of codes with respect to individual phenomenon
- SETs and ITF validation matrices are established for PWRs and BWRs. WWER validation matrix has been also completed
- The SETs validation matrix, two-volumes report, contains the most comprehensive compendium of tests and facilities brought together in one document, nevertheless, it is recognized that the work did not succeed in reaching all world data
- A methodology has been developed for establishing SET Validation Matrix. This methodology can be used for establishing other validation matrices, e.g. on severe accidents, containment thermohydraulics, 3D thermal-hydraulic code assessment, etc.
- Sufficiently complete list of relevant phenomena for thermal-hydraulic transient applications of PWRs and BWRs have been identified. The majority of these phenomena are also relevant to advanced water-cooled reactors

CONCLUSIONS AND RECOMMENDATIONS (II)

- About 2094 tests are included in the SET Matrix. This SET Matrix has to be considered as a living, evolving document
- The SET Matrix also provides a basis for evaluating the existing data base and defining the main axes for further research in LWR safety thermal-hydraulics in relation to separate effects testing
- Based on the SET validation matrix evaluation, need of additional experimental data are identified (CSNI report, OECD/GD (97) 9, Nov. 1996), such as:
  - Basic phenomena: pressure drops at geometric discontinuities
  - Critical flow in valves
  - Phase separation at branches
  - Quench front propagation/rewet, fuel rods
  - Parallel channel instabilities (BWR)
  - Boron mixing and transport
  - Non-condensable gas effect (PWR)
- Systematic approach is very beneficial- provides basis for assessment and quantification of code uncertainties for plant calculations, which is the major task for the future
- Work to ensure all data sets qualified an excellent way to protect investment in R&D data

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