ENERGY AND ENVIRONMENT DEPT. «DIPARTIMENTO DESTEC» – GRNSPG (San Piero a Grado)

UNIVERSITA' DI PISA
56100 PISA - ITALY

[116] THERMAL-HYDRAULIC PHENOMENA

N.Aksan, F. D'Auria, H. Glaeser

FONESYS
[FORUM & NETWORK OF SYS-TH CODES IN NUCLEAR REACTOR THERMAL-HYDRAULICS]

12th MEETING – Busan National University – Busan (Kr) Oct-11-12, 2018

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  - J NED 2018
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FOREWORD – triggering the need

The importance of phenomena is well established in nuclear thermal-hydraulics (… ***already in the year 1983, Wolfert and Frisch, 1983, proposed to establish a [phenomena based] validation matrix to be used for performing code validations*****) and in nuclear technology.**

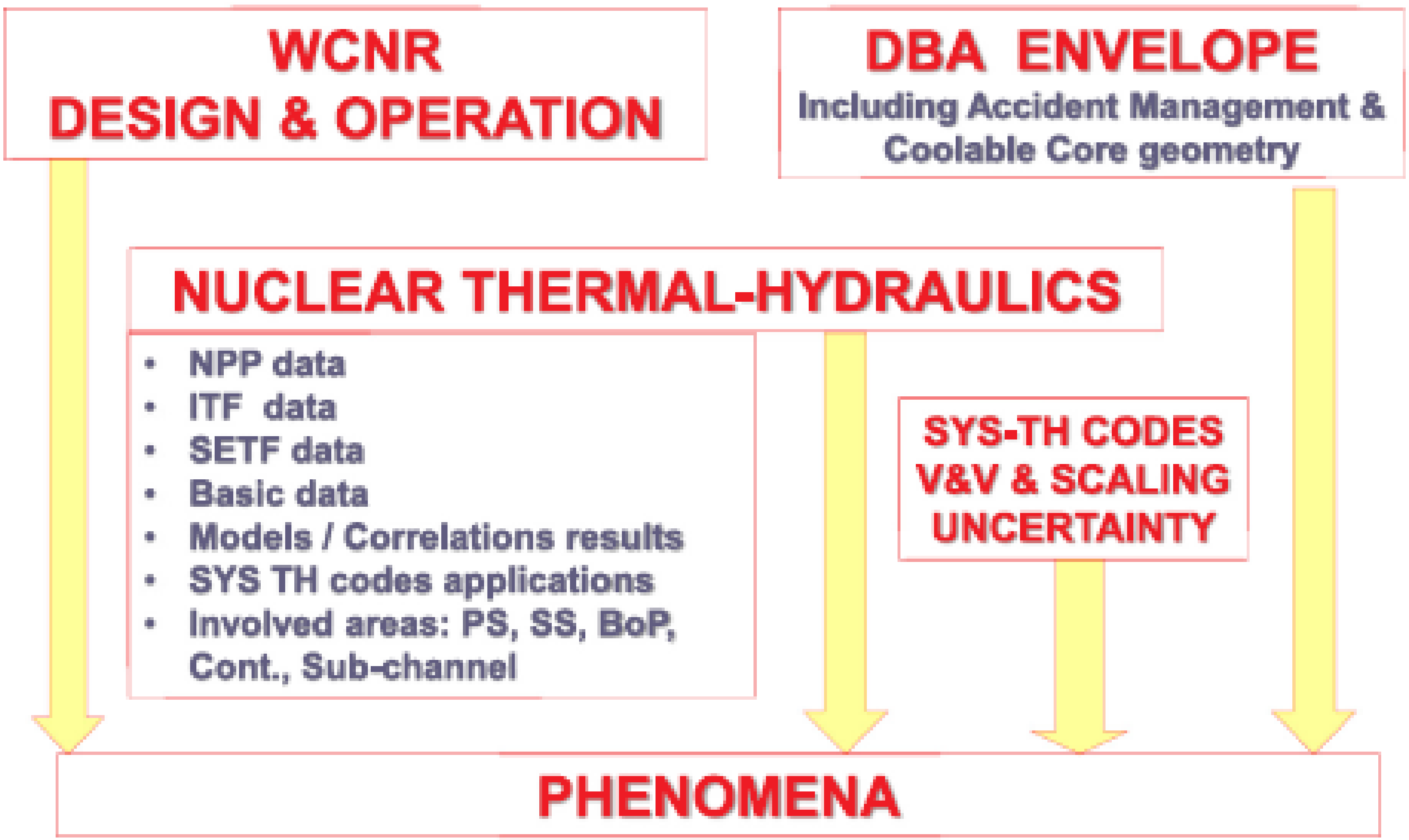
In the year 1987, the OECD/NEA/CSNI published a document that identified systematically a set of T-HP and tests detected from IET, "CSNI Code Validation Matrix of Thermo-Hydraulic Codes for LWR LOCA and Transients", followed by another report (1989) setting the connection between T-HP and ECCS ("CSNI SOAR ON TECC").

FOREWORD – scope (1 OF 2)

The original scope for TH-P related activities and related reports was the Design Basis Accident (DBA) in selected PWR (e.g. excluding VVER) and BWR (e.g. excluding NC BWR).

The scope for the present list (116 TH-P) includes all Water Cooled Nuclear Reactors (WCNR) – and AM measures with coolable core geometry, noticeably NOT INCLUDING current Design Extension Conditions (e.g. ballooning process, H2 generation, clad ruptures, etc.).

FOREWORD – scope (2 OF 2)



ISSUED PAPER

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Thermal-hydraulic phenomena for water cooled nuclear reactors

N. Aksan[a], F. D'Auria[b,*], H. Glaeser[c]

[a] *Scientific Consultant, Haldenstrasse 35, CH-5415 Nussbaumen, Switzerland*
[b] *DESTEC/GRNSPG, University of Pisa, Via Livornese 1291, San Piero a Grado, 56100 Pisa, Italy*
[c] *Consultant, Herbstrasse 9, 85386 Eching, Germany*

A R T I C L E I N F O

Keywords:
Validation
Scaling
Uncertainty analysis
Accident Analysis
Core design
System design
Computational tools

A B S T R A C T

Nuclear Reactor Safety (NRS), Deterministic Safety Assessment (DSA) and Accident Analysis (AA) constitute the general framework for the topic of the present paper. The class of Water-Cooled Nuclear Reactors (WCNRs) is concerned. This includes most of the nuclear reactors in operation, under construction or in advanced design stage. The required licensing process for those reactors, are further necessary elements to establish the context of the performed activity.

Best Estimate (BE) system thermal-hydraulic codes are adopted to demonstrate the safety of WCNR based on AA, namely focusing on the class of Design Basis Accidents (DBAs). On the one hand, the validation of BE codes is a necessary step to prove their applicability to calculate accident scenarios. On the other hand the knowledge of accident scenarios is a requirement for the design and the operation of WCNR. The validation of BE codes and the knowledge of accident scenarios needs the identification and the characterization of Thermal-hydraulic Phenomena (T-HP).

A list of 116 T-HP is derived in the present paper, based on the documents issued in the last three decades by the Committee on the Safety of Nuclear Installations of Nuclear Energy Agency of The Organization for Economic Cooperation and Development (OECD/NEA/CSNI) and by the International Atomic Energy Agency (IAEA). The T-HP list includes the consideration of Separate Effect Tests (SET) and Integral Effect Tests (IET) relevant in Reactor Coolant System (RCS) and Containment of WCNRs. A dozen WCNR types are considered and include Pressurized Water Reactors (PWRs), Boiling Water Reactors (BWRs), Russian design reactor types (e.g. VVER-440, VVER-1000 and RBMK), pressure tube heavy water reactor designs in Canada (CANDU) and in India (PHWR) and so-called 'advanced' reactors (in the text of this paper, they are sometimes assigned as "New Reactors"), which are also equipped with passive systems (for instance, AP-1000 and APR-1400 designed in US and Korea, respectively).

Each T-HP can be characterized by one or more parameters or variables which are part of numerical models and constitute calculational results from system codes. A cross link process can be established between T-HP, parameters and DBA scenarios. The basis for the process and selected cross-link examples are provided and discussed.

A variety of applications for the T-HP list is envisaged in nuclear thermal-hydraulics. Insights are given in the paper in relation to the use of phenomena: a) to address the scaling issue; b) to distinguish between constitutive equations part of the balance equations and 'special models' in BE system codes; c) to prioritize research in nuclear reactor thermal-hydraulics.

ORIGINATING DOCUMENTS*

mance of thermal hydraulic codes, "CSNI Code Validation Matrix of Thermo-Hydraulic Codes for LWR LOCA and Transients", OECD/NEA/CSNI, 1987. The report included all phenomena expected to occur in plant transients and LOCA analyses. This was followed by another report where the connections between T-HP and the design of ECCS were established, OECD/NEA/CSNI, 1989.

validation matrix, OECD/NEA/CSNI, 1994. Then, an updated integral test validation matrix report, OECD/NEA/CSNI, 1996, the VVER validation matrix, OECD/NEA/CSNI, 2001, and the containment phenomena validation report, OECD/NEA/CSNI, 2014, were issued. The

and at the International Atomic Energy Agency (IAEA): those efforts resulted in references D'Auria et al. (1992), Aksan and D'Auria (1996), and IAEA (2009).

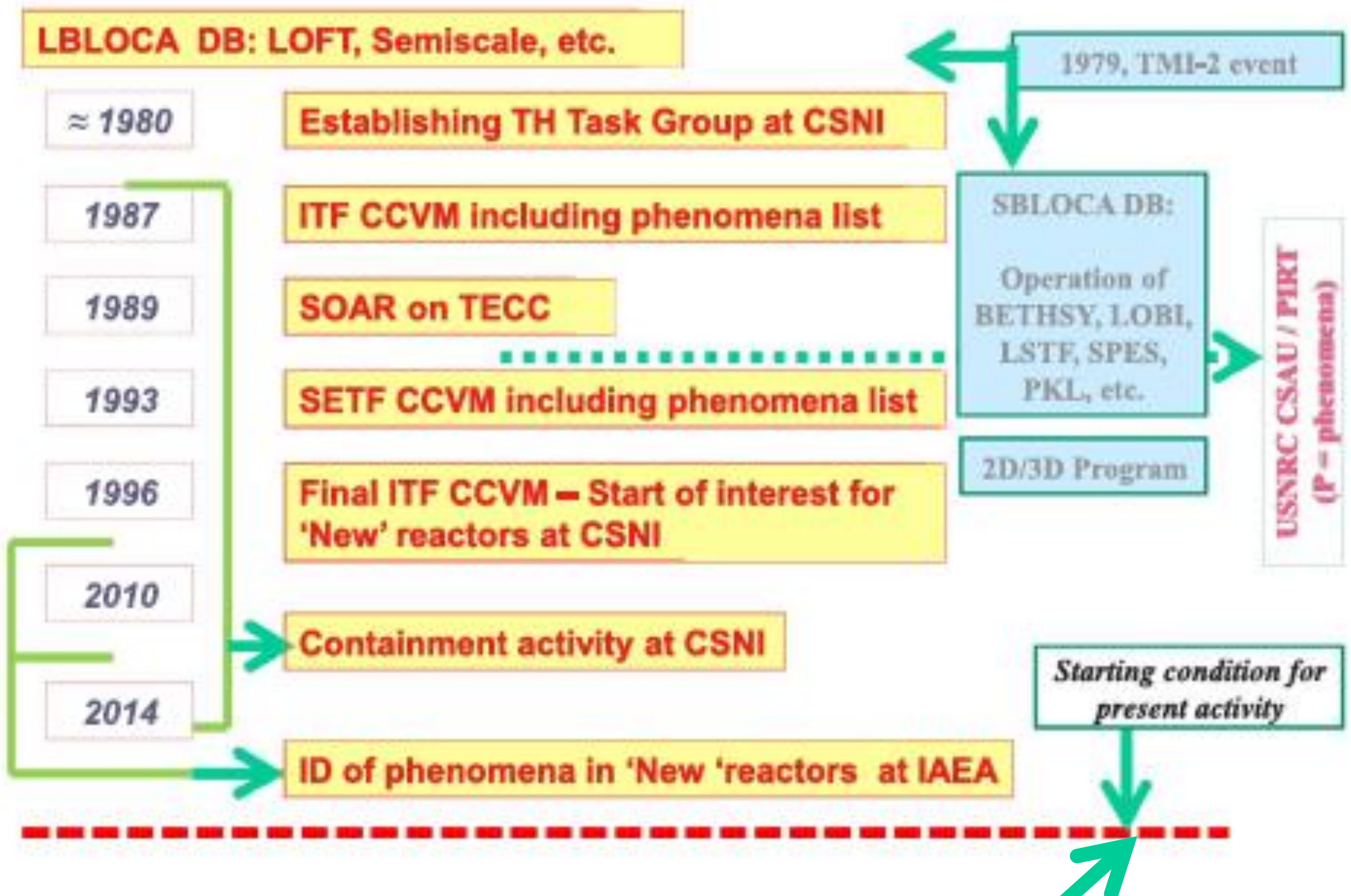
Within the framework of a recent activity for issuing a book on Thermal-Hydraulics in Nuclear Reactors, D'Auria [Ed.], 2017, an in-

- The documents mentioned in the previous two paragraphs, plus related follow-up investigations, e.g. Pochard et al., 1994, D'Auria et al., 1995, D'Auria et al., 1995a, OECD/NEA/CSNI, 1997, and Aksan et al., 1997.
- Natural Circulation and other T-HP expected in the operation of passive systems following accident scenarios noticeably in advanced reactors as given by references IAEA, 2001, IAEA, 2002, IAEA, 2005, and IAEA, 2012.
- T-HP expected in heavy water moderated, channel type Canadian Deuterium-Uranium (CANDU) reactors, e.g. IAEA, 2003, and Prosek et al., 2004.
- T-HP expected in heavy water moderated and cooled, vessel type Pressurized Heavy Water Reactors (PHWR), e.g. D'Auria et al., 2008, UNIPI-GRNSPG, 2008, and D'Auria et al., 2012.
- T-HP expected in graphite moderated, boiling water reactors, Russian type RBMK, e.g. D'Auria et al., 2005, and D'Auria et al., 2008a.
- Transient scenarios in containment, in addition to the already mentioned document (OECD/NEA/CSNI, 2014), e.g. OECD/NEA/CSNI 1986, OECD/NEA/CSNI, 1989a, and OECD/NEA/CSNI, 1999.

… SUMMING UP TO SEVERAL «1000» PAGES

*** clear-blue reports listed in the ISSUED PAPER.**

BRIEF HISTORY



i.e. activity leading to the ISSUED PAPER

LIST OF 116 TH-P (alphabetic order) – 1 of 6

<table>
<tr><th>ID</th><th>PHENOMENA ID</th><th>TYPE</th><th>REACTOR</th><th>DETAILS & NOTES</th></tr>
<tr><td>S-1-ACC</td><td>Accumulator behaviour</td><td>SETF</td><td rowspan="3">PWR</td><td></td></tr>
<tr><td>I-1-ASY-L</td><td>Asymmetric loop behaviour</td><td>ITF</td><td></td></tr>
<tr><td>I-2-ASY-D</td><td>Asymmetry due to the presence of a dam</td><td>ITF</td><td>Shutdown conditions</td></tr>
<tr><td>A-1-CHV-c</td><td>Behavior of check valves</td><td colspan="2" rowspan="6">New Reactors</td><td>Including BWR-PSP valves</td></tr>
<tr><td></td><td>Behavior of containment emergency systems (e.g. PCCS)</td><td>See A-2-CE-c</td></tr>
<tr><td>A-3-CMT-c</td><td>Behavior of core make-up tanks</td><td></td></tr>
<tr><td>A-4-DL-c</td><td>Behavior of density locks</td><td></td></tr>
<tr><td>A-5-PC-c</td><td>Behavior of emergency heat exchangers including PRHR and IC</td><td></td></tr>
<tr><td>A-6-POO-c</td><td>Behavior of large pools of liquid</td><td></td></tr>
<tr><td>I-3-BD</td><td>Blowdown</td><td colspan="2">ITF/SETF/Basic</td><td>PHW rather than PH</td></tr>
<tr><td>I-4-NCBC</td><td>Boiler condenser mode (of NC)</td><td>ITF</td><td>PWR-O</td><td></td></tr>
<tr><td></td><td>Boil-off</td><td colspan="2">ITF/SETF/Basic</td><td>See B-4-EV2</td></tr>
<tr><td>S-2-BO</td><td>Boron mixing and transport (also A-12-BO)</td><td>SETF</td><td>PWR</td><td>Also ITF</td></tr>
<tr><td>S-3-CCF1</td><td>CCF/CCFL-Channel inlet orifice</td><td rowspan="6">.SETF</td><td>BWR</td><td></td></tr>
<tr><td>S-4-CCF2</td><td>CCF/CCFL-Downcomer</td><td rowspan="4">PWR</td><td></td></tr>
<tr><td>S-5-CCF3</td><td>CCF/CCFL-HL & CL</td><td></td></tr>
<tr><td>S-6-CCF4</td><td>CCF/CCFL-SG tubes</td><td></td></tr>
<tr><td>S-7-CCF5</td><td>CCF/CCFL-Surgeline</td><td></td></tr>
<tr><td>S-8-CCF6</td><td>CCF/CCFL-UTP</td><td>N/A</td><td></td></tr>
<tr><td></td><td>Centrifugal pump</td><td></td><td></td><td>See Impeller pump</td></tr>
</table>

EACH PHENOMENON IS DESCRIBED IN:

D'Auria, F. (Ed.), 2017. Thermal-Hydraulics of Water Cooled Nuclear Reactors. Elsevier Woodhead Publishing.

LIST OF 116 TH-P (alphabetic order) – 2 of 6

I-5-BC	Channel and bypass axial flow and void distribution	ITF	BWR	
I-6-CLDO	Collapsed level behavior in downcomer	ITF	BWR	See also phase separation
B-1-COH	Condensation due to heat removal	Basic	N/A	
B-2-COP	Condensation due to pressurization	Basic		
S-9-CO1	Condensation in stratified conditions-Horizontal Pipes	SETF	PWR/BWR	
S-10-CO2	Condensation in stratified conditions-PRZ		PWR	
S-11-CO3	Condensation in stratified conditions-SG-PS			
S-12-CO4-c	Condensation in stratified conditions-SG-SS & BWR-PSP		BWR	Also BWR wet-well
A-2-CE-c	Containment emergency systems including passive cooling	Also New Reactors		Including passive condenser
	Containment pressure and temperature	ITF		See I-18-PRB & S-42-NCOC
S-62-CPC-c	Containment pump performance including sump clogging (added T-HP)	SETF	All	
I-7-COTH	Core thermal-hydraulics	ITF	BWR	See Global multi-D
	Core wide void and flow distribution	ITF		See Global multi-D
S-13-CRGT	CRGT flashing	SETF	BWR	
A-7-CSC	Critical and supercritical flow in discharge pipes	New Reactors		Also CANDU and RBMK
	Critical flow			See TPCF
	Critical Power Ratio	ITF	BWR	See HT CHF
	De-entrainment			See Entrainment
	Depressurization			See Blowdown
S-14-ECCB	ECC bypass/Downcomer penetration	SETF	PWR	
	ECC mixing and condensation	ITF		See Liquid vapor mixing
S-15-ED1	Entrainment/De-entrainment-Core	SETF	All	
S-16-ED2	Entrainment/De-entrainment-Downcomer		PWR	
S-17-ED3	Entrainment/De-entrainment-Hot leg with ECCI			
S-18-ED4	Entrainment/De-entrainment-SG mixing chamber			
S-19-ED5	Entrainment/De-entrainment-SG tubes			
S-20-ED6	Entrainment/De-entrainment-UP			

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LIST OF 116 TH-P (alphabetic order) – 3 of 6

B-3-EV1	Evaporation due to depressurization (including at geometric discontinuities*)	Basic	N/A	* reversible part
B-4-EV2	Evaporation due to heat input	Basic		
I-8-FO-c	Flow through openings	ITF	PWR/BWR	Shutdown conditions
S-21-GM1	Global multi-D fluid temperature, void and flow distribution-Core	SETF		
S-22-GM2	Global multi-D fluid temperature, void and flow distribution-Downcomer			
S-23-GM3	Global multi-D fluid temperature, void and flow distribution-SG SS		PWR	
S-24-GM4	Global multi-D fluid temperature, void and flow distribution-UP			
A-8-GDR	Gravity driven reflood	New Reactors		
S-25-HOHT	Horizontal heated channel HT [added T-HP]	SETF	CANDU	Including HT below
S-26-HT1	HT [NCO, FCO, SNB, SANB, CHF/DNB, post-CHF]-Core, SG, structures	SETF	All	Including VVER conditions
S-27-HT2	HT [radiation]-core			
S-28-HT3	HT [condensation]-SG structures			
A-9-HTCO-c	HT condensation in containment structures, with or w/o non-condensable	New Reactors		Also containment
S-29-IMPU	Impeller pump behavior	SETF	All	External pumps
	Instability (in boiling channels)	SETF/ITF		See S-44-PCEI
B-5-IF1	Interfacial friction in horizontal flow	Basic	N/A	
B-6-IF2	Interfacial friction in vertical flow	Basic		
I-9-INC	Intermittent 2-phase NC	ITF	PWR-O	
S-30-IPU	Internal pump behavior (specific geometry) [added T-HP]	SETF	ABWR	Also AP-1000
S-31-JPU	Jet pump behavior	SETF	BWR	
S-32-LA	Liquid accumulation in horizontal SG tubes	ITF	PWR-V	
	Liquid carry-over			See Entrainment & I-24-SBI
A-10-LTS-c	Liquid temperature stratification	New Reactors		
S-33-LVM1	Liquid-Vapor mixing with condensation-Core	SETF	All	

EACH PHENOMENON IS DESCRIBED IN:

D'Auria, F. (Ed.), 2017. Thermal-Hydraulics of Water Cooled Nuclear Reactors. Elsevier Woodhead Publishing.

LIST OF 116 TH-P (alphabetic order) – 4 of 6

ID	PHENOMENA ID	TYPE	REACTOR	DETAILS & NOTES
S-34-LVM2	Liquid-Vapor mixing with condensation-Downcomer*	SETF	PWR	Also ITF. * Including cold-hot liquid mixing (3D effect)
S-35-LVM3	Liquid-Vapor mixing with condensation-ECCI in HL and CL*			
S-36-LVM4	Liquid-Vapor mixing with condensation-Lower plenum*			
S-37-LVM5	Liquid-Vapor mixing with condensation-SG mixing chamber		PWR	
S-38-LVM6	Liquid-Vapor mixing with condensation-UP			
S-39-LSC	Loop seal filling and clearance (or clearing)	SETF	PWR	Also ITF
S-40-LPE	LP entrainment	SETF	PWR	
S-41-LPF	LP flashing	SETF	PWR/BWR	See also Blowdown
	Mixture level & entrainment-Core, downcomer and SG SS	ITF		See Phase separation
I-10-NC1	NC, 1-phase & 2-phase-PS & SS	ITF	PWR/BWR	SS only for PWR
I-11-NC2	NC core and downcomer		BWR	
I-12-NC3	NC core bypass, hot and cold bundles		BWR, CANDU*	*also RBMK
I-13-NC4	NC core, gap, downcomer, dummy elements		PWR-V	
I-14-NC5	NC core, vent valves, downcomer		PWR-O	
I-15-NC6	NC with horizontal SG		PWR-V	
A-11-NC	NC RPV and containment & various system configurations	New Reactors		Also containment
S-42-NC0-c	Natural convection and H2 distribution	SETF		Inside containment
S-43-NCG	Non condensable gas effect including condensation HT in RCS	SETF	PWR	Also ITF
	Nuclear fuel behavior	SETF/ITF		See I-29-NTF2
I-16-NTF1	Nuclear thermal-hydraulics feedback and spatial effect (see also I-29-NTF2)	ITF	BWR	Also RBMK, ABWR, etc.
	Nuclear thermal-hydraulics instabilities	ITF	BWR	See I-16 and S-44

EACH PHENOMENON IS DESCRIBED IN:

D'Auria, F. (Ed.), 2017. Thermal-Hydraulics of Water Cooled Nuclear Reactors. Elsevier Woodhead Publishing.

LIST OF 116 TH-P (alphabetic order) – 5 of 6

S-44-PCEI	Parallel channel effects and instabilities PCEI	SETF	BWR	
S-45-PSB	Phase separation at branches (including effect on TPCF)	SETF	All	Also ITF (T-branches)
S-46-PS1	Phase separation/vertical flow with and w/o mixture level-Core	SETF		Also ITF
S-47-PS2	Phase separation/vertical flow with and w/o mixture level-Downcomer			
S-48-PS3	Phase separation/vertical flow with and w/o mixture level-Pipes & Plena			
I-17-PFU	Pool formation in UP	ITF	PWR	See also S-8-CCF6
B-7-PD-c	Pressure drops at geometric discontinuities, including containment	Basic	N/A	Also New Reactors
B-8-PW	Pressure wave propagation including CIWH	Basic		
I-18-PRB	Pressure-temperature increase & boiling due to energy and mass input	ITF	PW/BWR	Containment & Shutdown
I-19-PRZ	PRZ thermal-hydraulics	ITF	PWR	
S-49-QF1	QF propagation/rewet-Fuel rods	SETF	PWR/BWR	
S-50-QF2	QF propagation/rewet-Channel walls, Water rods		BWR	
I-20-RF	Refill including loop refill in PWR-O	ITF	PWR/BWR	PHW rather than PH
I-21-RE	Reflood			
I-22-RCM	Reflux condenser mode and CCFL	ITF	PWR	
	Return to Nucleate Boiling (RNB)			See Reflood & QF
S-51-SEP	Separator behavior (&* flooding, steam penetration, liquid carry-over)	SETF	PWR/BWR	*Mainly for BWR
I-23-SIP	SG siphon draining (SG interaction with ESF, including gravity driven)	ITF	PWR	Shutdown conditions
S-63-SPR-c	Spray effects-Containment (added T-HP)	SETF	All	
S-52-SPR1	Spray effects-Core (including cooling and distribution)	SETF	BWR	
S-53-SPR2	Spray effects-OTSG SS		PWR-O	
S-54-SPR3	Spray effects-PRZ		PWR	

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LIST OF 116 TH-P (alphabetic order) – 6 of 6

I-24-SBI	Steam binding (liquid carry-over, etc.)	ITF	PWR	
S-55-SDR	Steam dryer behavior	SETF	PWR/BWR	Mainly BWR
I-25-SLD	Steam line dynamics	ITF	BWR	
S-56-STR	Stratification in horizontal flow-Pipes (in 1-phase & 2-phase conditions)	SETF	PWR	Also ITF
A-12-BO	Stratification of boron	New Reactors		See S-2-BO
I-26-SHH	Structural heat and heat losses	ITF	All	Scaling issue
I-27-SULI	Surgeline hydraulics	ITF	PWR	
I-28-SH	Superheating in OTSG SS	ITF	PWR-O	
I-29-NTF2	Thermal-hydraulics – Nuclear fuel feedback (see also I-16-NTF1)	ITF	All	H2 production & ballooning
S-57-HOSG	Thermal-hydraulics of horizontal SG, PS and SS	SETF	PWR-V	
S-58-OTSG	Thermal-hydraulics of OTSG, PS and SS	SETF	PWR-O	See spray effect OTSG
S-59-CF1	TPCF-Breaks	SETF	All	Jet impingement, jet thrust and pipe whip to be considered here
S-60-CF2	TPCF-Pipes			
S-61-CF3	TPCF-Valves			
A-13-NCG	Tracking of non-condensable gases	New Reactors		See S-43 NCG & containment
	Valve leak flow (connected with construction, operation, maintenance)	ITF		See also TPCF Valves
	Vapor (or steam) carry-under	ITF		See S-51-SEP & I-10-NC1
	Vapor pull through	SETF		See S-45-PSB
S-64-VEB-c	Ventilation blower characteristics (added T-HP)	SETF	All	
I-30-VCP	Void collapse and temperature distribution during pressurization	ITF	BWR	Also Basic condensation
B-9-FR	Wall to fluid friction	Basic	N/A	
	Water accumulation in horizontal SG tubes	ITF	PWR-V	See Liquid accumulation

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LIST OF WCNR AND ACCIDENT SCENARIOS (AS)

WCNR

No	WCNR ID	Key Design Feature	Notes
1	PWR	U-tubes Steam Generators (SG), 2-3-4 loops, ECCS in CL and/or HL	Reference WCNR, OECD/NEA/
2	BWR	Jet Pump or Internal pumps, or with external recirculation loop	NEA/CSNI, 1996
3	PWR-OTSG	Once Through SG, 2 loops, four cold legs, two hot legs, vent valves inside RPV	
4	VVER-440	Horizontal Tube Steam Generators (HOSG), 6 loops, loop seal in hot leg, hexagonal Fuel Assembly (FA) with triangular pitch	OECD/NEA/CSNI, 2001
5	VVER-1000	HOSG, 4 loops hexagonal FA with triangular pitch	
6	CANDU	Channel type, horizontal/cylindrical FA, channel inlet and outlet feeders, headers, heavy water, atmospheric pressure moderator tank	
7	PHWR	Vessel type with channels, vertical/cylindrical FA, moderator cooling loops, heavy water	
8	RBMK	Boiling channel type, vertical/cylindrical FA, channel inlet and outlet feeders, graphite moderated	
9	AP1000	No loop seal, passive ECCS	IAEA, 2005, 2009, 2012
10	APR1400	Passive ECCS in SG	
11	EPR	Evolution of PWR	Same as WCNR No 1
12	SMR	PWR-Loop type equipped with HOSG, immersed into the sea	Different designs available
13	ABWR	Internal pumps	Same as WCNR No 2

LIST OF WCNR AND ACCIDENT SCENARIOS (AS)

AS - 'ALL' DBA

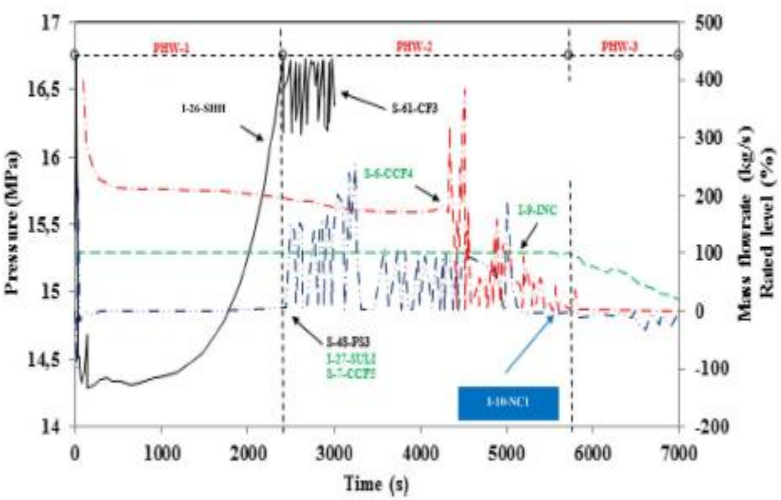
No	Accident Scenario (AS)	WCNR
1	ATWS (Anticipated Transient Without Scram)	ABWR, BWR, PWR
2	Boron dilution*	PWR
3	Critical Heat Flux (CHF)	–
4	Containment performance*	ABWR, AP1000
5	CRE (Control Rod Ejection)	PWR
6	FCB (Fuel Channel Blockage)	RBMK
7	FWLB (Feedwater Line break)	APR1400
8	HEBR (Header Break)	CANDU, RBMK
9	LBLOCA (Large Break Loss of Coolant Accident)	AP1000, BWR, EPR, PHWR, PWR
10	LCC/SW (Loss of Component Cooling Service Water)	PWR
11	LOFA (Loss of Flow Accident)	EPR
12	LOFW (Loss of Feed Water)	PWR
13	LOOSP (Loss of On- and Off-Site Power)	VVER-1000, BWR, CANDU
14	MBLOCA (Medium Break Loss of Coolant Accident)	PWR
15	MCP-trip (Main Coolant Pump trip)	VVER-1000
16	MPTR (Multiple Pressure Tube Rupture)	RBMK
17	MSLB (Main Steam Line Break)	PWR, PWR-OTSG
18	NC (Natural Circulation)*	PWR, PWR-OTSG, VVER-440, VVER-1000, CANDU
19	PRISE (Primary to Secondary [leakage])	VVER-440
20	PTS (Pressurized Thermal Shock)*	–
21	RIA (Reactivity Insertion Accident)	–
22	SBLOCA (Small Break Loss of Coolant Accident)	AP1000, APR1400, BWR, EPR, PWR*, PWR-OTSG, VVER-1000**
23	SBO (Station Blackout)	APR1400, PWR, VVER-1000
24	SGTR (Steam Generator Tube Rupture)	PWR
25	SH-D (Shutdown [transient])	PWR
26	TT (Turbine Trip)	BWR, SMR

CROSS-LINKING

THE FOLLOWING CROSS-LINK IS CREATED AND DESCRIBED:

(GP = Generalized Parameter characterizing TH-P and AS – *[TP used instead of TH-P in table below]*)

WCNR ⟷ AS ⟷ TH-P ⟷ GP



CROSS LINK MATRIX

TP vs GP & AS

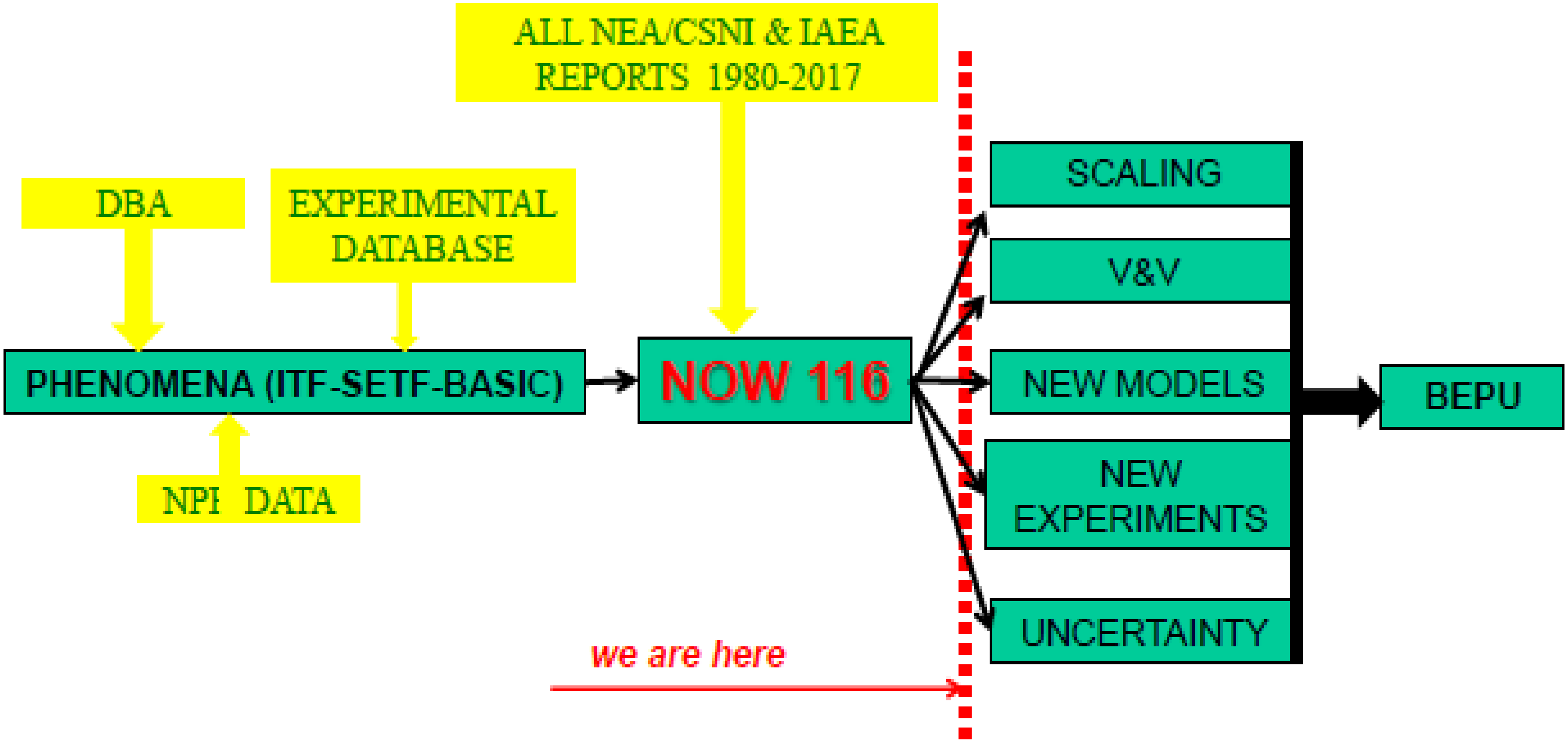
No	PHENOMENON	ACCIDENT SCENARIO VS PHENOMENON	RPV / PRZ pressure	Reactivity & boron concentration	SG pressure	Core / RPV level	PRZ level	SG level (PS and SS)	Flowrate (core inlet, break, etc.)	Core Thermal Power / Heat flux / DNBR	Coolant temp (core, HL, LP, etc.)	RST & Nuclear Fuel parameter	Coolant mass in RCS	Local fluid velocity, flow, void, load & DP	Containment pressure & temperature	ESF performance (excluded passive systems)	Passive system performance
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
			PARAMETERS VS - ACCIDENT SCENARIO (A) - PHENOMINA (P)														
1	S-1-ACC	LBLOCA-5 LBLOCA-1	A									A					AP
2	I-1-ASY-L	MSLB-1	A						AP	A				A			
3	I-2-ASY-D	SH-D	P								P	P					
4	A-1-CHV	SBLOCA-1*							P					P			
5	A-2-CC	CONT-1	AP						A						A		
6	A-3-CMT	LBLOCA-1	A			A			A			A				A	AP
7	A-4-DL	LOFW-PIUS*									P			P			
8	A-5-PC	SBLOCA-1	A							A							AP
9	A-6-POO	ATWS-1													P		
10	I-3-BD	LBLOCA-1	P						P								

DETAILED PROCEDURE & APPLICATION ARE DESCRIBED IN:

D'Auria, F. (Ed.), 2017. Thermal-Hydraulics of Water Cooled Nuclear Reactors. Elsevier Woodhead Publishing.

INNOVATION & PERSPECTIVES

ALL AS PART OF BEPU



CONCLUSIONS AND WHAT IS NEEDED

116 THERMAL-HYDRAULIC PHENOMENA IDENTIFIED BASED ON A COUPLE DOZEN DOCUMENTS ISSUED BY OECD/NEA AND IAEA.

FURTHERMORE

47 AS, calculated in relation to 13 WCNR, discussed in 68 reference documents (RD), utilizing 15 GP have been cross-linked with 116 TH-P in order to prove the origin of phenomena

WHAT REMAINS TO BE DONE (AT LEAST:

A) Endorsing/expanding (as needed) the list of phenomena

B) Connecting the phenomena with 5 'BEPU ISSUES':
Scaling, V&V(&C), New Models, New Experiments, Uncertainty

C) Preparing Knowledge Management database (e.g. for future training)

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