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CRITICAL HEAT FLUX DATABASE OF JAERI FOR HIGH HEAT FLUX COMPONENTS FOR FUSION APPLICATION

August 1997

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Critical Heat Flux Database of JAERI for High Heat Flux Components for Fusion Application

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This report presents the first compiling bringing together all the critical heat flux (CHF) experimental results of the test campaigns carried out by JAERI for the design of high heat flux components for tokamaks or for the International Thermonuclear Experimental Reactor, ITER. Experiments have been performed in the Particle Beam Engineering test Facility of JAERI in the specific thermal hydraulic conditions of plasma facing components: high heat flux and one-side heating. Test sections were cooled by subcooled pressurized water-flow. Tests are presented in a tabular form in order to provide an efficient tool to get the evolution of the CHF versus thermal hydraulic conditions for different geometries of cooling channel. Additional new calculations about the latest CHF experimental results of smooth and swirl tubes are also included.

Keywords: Fusion Engineering, Divertor Plate, Critical Heat Flux, Subcooled Boiling, One-side Heating, Swirl Tube, Screw Tube, Hypervapotron.

+ Department of ITER Project

* French fellow of the Science and Technology Agency

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原研における核融合実験炉用高熱負荷受熱機器の限界熱流束データベース

日本原子力研究所那珂研究所核融合工学部
ジャン・ボスカリ*・荒木　政則+・秋場　真人

(1997年7月2日受理)

本報告はこれまで原研においてＩＴＥＲ等の核融合実験装置用高熱負荷受熱機器開発の一環として実施された限界熱流速実験の結果をまとめたものである。実験は原研の粒子工学試験装置（ＰＢＥＦ）において、核融合実験装置用高熱負荷受熱機器のおかれる特殊な環境（高熱負荷・片面加熱場）を模擬して実施された。実験中の試験体テストセクションにおける冷却水はサブクール沸騰領域にある。得られた実験結果は、異なる形状を有する冷却管の限界熱流速と伝熱流動条件の関係を明らかにするために表形式にまとめられている。さらに、本報告には平滑管とスワール管の最新の限界熱流束実験結果に対する数値解析も含まれている。

那珂研究所：〒311-01　茨城県那珂郡那珂町向山801－1
+ ＩＴＥＲ開発室
* 科学技術庁リサーチフェロー

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1. Comments on the Database

This report presents the first compiling bringing together all the critical heat flux (CHF) experimental results of the test campaigns carried out by JAERI for the design of high heat flux components and points out the important invest of this institute in this research field. It is introduced a new international presentation in tabular format to describe CHF. Additional new calculations about the latest CHF experimental results (Ref. 3) are also presented. The purpose of this report is to provide an efficient tool for the design of plasma facing components, especially in the frame of the International Thermonuclear Experimental Reactor (ITER) design. It is proposed a simple way to know the evolution of CHF versus thermal hydraulic conditions for different tested geometries of cooling channel.

Experiments have been performed under typical thermal hydraulic conditions of fusion machines such as tokamaks or ITER: high heat fluxes of several tens of MW/m^2, one-side heating conditions. Experiments were carried out in the ion beam facility PBEF, or Particle Beam Engineering test Facility, of JAERI located at Naka. Test sections were cooled by subcooled and pressurized water-flow. Detailed descriptions of these tests can be found from Ref. 1 to Ref. 4.

So far, JAERI performed a total of 128 CHF tests. Test sections were made of two different materials: Cu (0.2%Ag) and OFHC-Cu. In order to develop a high performance cooling device, various concepts were proposed and tested: smooth tube, swirl tube, internally finned tube, externally finned smooth tube, externally finned swirl tube, screw tube and hypervapotron. A swirl tube is a tube equipped with a twisted tape made of Inconel 625 inserted in the circular cooling channel as a turbulence promoter. This tube is characterized by the twist ratio, which is the number of inner diameter in a 180° twist. A screw tube is a tube manufactured according to the ISO-261 standard (the ISO general-purpose screw thread-general plan) with a thread at the inner wall of the cooling channel. The distribution of the test number performed according to the different geometries is presented in Fig. 1 Example of mesh model for FE calculations: half part of a smooth tube

Fig. 2. Test conditions and the range of experimental parameters is listed in Table 1: laboratory facility, geometry and material of the test section, thermal hydraulic conditions.

Experimental results are presented from Table 2 to Table 8 in tabular form. For each CHF test, following information and parameters are provided:

- date of the test and name of the laboratory, test section and facility
- cross section with geometrical characteristics and material of the test section
- transversal and longitudinal profiles of the incident heat flux
- heated length L_h
- <u>hydraulic characteristics</u>:
  CHF was detected by means of thermocouples inserted into the material close to the heated surface: the temperature suddenly quickly increased within 200 ms to reach the value of the trigger-setting used to avoid burn-out. According to the experimental test campaigns, CHF location is 10mm downstream the maximum

of the gaussian profile and does not correspond to the end of the heated length. Therefore, the subscripts 'local' is used for hydraulic parameters at CHF location.

pressure: local pressure P_{local}
temperature: inlet temperature T_{in}
local temperature T_{local}
local subcooling T_{sat} - T_{local}
T_{sat} is the saturation temperature related to the local pressure
mass flux G and axial velocity V_{axial}

lineic pressure drop ΔP_{lineic}. The pressure drop was not measured during experiments but on testing bench at room temperature.

- heat fluxes:
The incident CHF, ICHF, is an experimental value. One-side heating conditions induce the concentration of the heat flux at the inner wall. It may be reasonably expected that the dry-out responsible for CHF occurrence is partly related to the maximum flux at the inner wall, WCHF.
A first evaluation of this value is the geometrical WCHF:

$$\text{Geom. WCHF} = \text{ICHF} * \text{Geom. Peaking factor}$$

The geometrical peaking factor is indicated in the first column of the table. The geometrical peaking factor characterizes the difference between the section directly heated by the beam and the water-cooled section. For hypervapotron, it is the ratio between the width of the test section and the width of the channel. For smooth and swirl tubes, it is the ratio between the outer and inner diameter of the tube.
For example, let us consider the smooth tube presented in Table 5. The outer diameter is 10 mm and the inner diameter is 7 mm. The geometrical peaking factor of this tube is the ratio 10/7, that is to say, 1.43. For the shot number E54, the geometrical WCHF is obtained by multiplying the incident CHF, which is 30.7 MW/m^2, by 1.43.

The maximum heat flux at the inner wall can be directly obtained from the incident CHF, which is experimentally determined, by solving the heat conduction in the solid, provided that boundary conditions at the inner wall are known. The heat transfer correlations in the convective and in the subcooled boiling regimes have been determined for smooth and swirl tubes by JAERI (Ref. 4). For these geometries, it is possible to calculate the heat flux at the inner wall by a 2D finite element (FE) method. In this report, FE WCHF is newly calculated using ABAQUS code and PATRAN code for the mesh with QUAD4 elements. A typical mesh model used for present calculations is shown in Fig. 1. For other geometries as screw tubes and hypervapotron, this calculation is not possible because the heat transfer correlations are not yet available.

From the FE WCHF, the FE peaking factor is calculated:

$$\text{FE peaking factor} = \text{FE WCHF/ICHF}$$

For example, let us consider the externally finned swirl tube and the shot number B52, which is presented in Table 6. The incident CHF is determined from experiments, that is to say 39.6 MW/m^2. From thermal hydraulic conditions, the heat transfer coefficient in the forced convective and in the subcooled boiling regimes is calculated. FE calculation provides the maximum heat flux at the inner wall, FE WCHF, which is 52.3 MW/m^2. Thus, FE peaking factor is deduced by the ratio 52.3/39.6, that is to say 1.32.

Acknowledgments

Authors would like to thank Dr. Y. Okumura and other members of NBI Heating Laboratory for their valuable discussions and comments. They would acknowledge Dr. M. Ohta and Dr. H. Kishimoto for their support and encouragement.

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Nomenclature

Dh [mm] Hydraulic diameter
G [$Mg.m^{-2}.s^{-1}$] Mass flux
ICHF [MW/m^2] Incident CHF
ID [mm] Inner diameter
L_h [mm] Heated length
OD [mm] Outer diameter
P [MPa] Pressure
ΔP_{lineic} [MPa/m] Lineic pressure drop
T [°C] Temperature
V [m/s] Velocity
WCHF [MW/m^2] Wall CHF

Subscripts
in inlet
sat saturation
out outlet

References

Ref. 1 M. Araki, M Dairaku, T. Inoue, M. Komata, M. Kuriyama, S. Matsuda, M. Ogawa, Y. Ohara, M. Seki, K. Yokoyama 1989
Burnout experiments on the externally finned swirl tube for steady-state and high heat flux beam stops, Fusion Eng. Des. 9, 231-236

Ref. 2 M. Araki, T.D. Watson, T.D. Marshall, P.D. Rockett, M. Akiba 1994
Effect of subcooling on the critical heat flux under one-side heating conditions, 18th SOFT, Karlsruhe, 1, 251-254

Ref. 3 M. Araki, K. Sato, S. Suzuki, M. Akiba 1996
Critical heat flux experiment on the screw tube under one-side heating conditions, Fusion Technology 29, 519-528.

Ref. 4 M. Araki, M. Ogawa, T. Kunugi, K. Satoh, S. Suzuki 1996
Experiments on heat transfer of smooth and swirl tubes under one-side heating conditions, Int. J. Heat Mass Transfer 39(14) 3045-3055.

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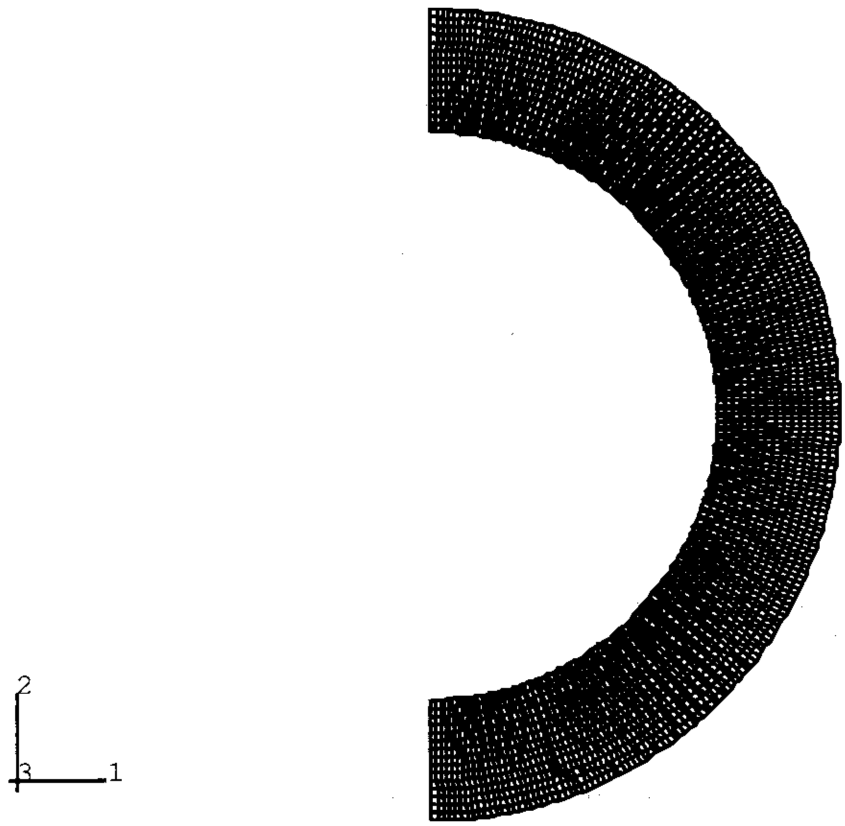


Fig. 1 Example of mesh model for FE calculations: half part of a smooth tube

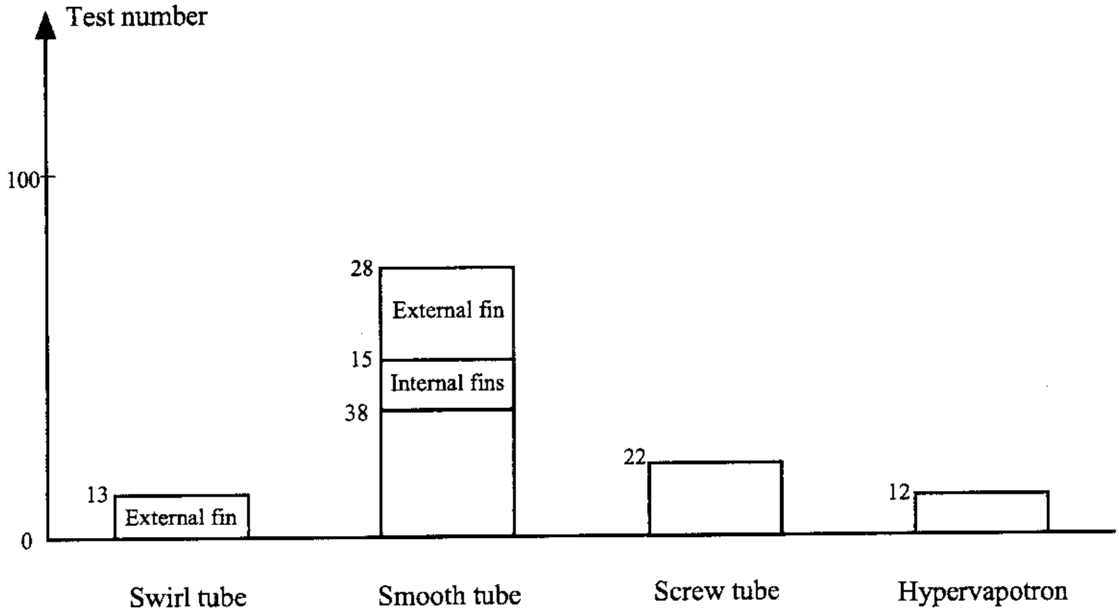


Fig. 2 Distribution of test number according to the geometry

Table 1 Range of thermal hydraulic experimental parameters

Laboratory Facility	Geometry Material	Dh (mm)	G ($Mg.m^{-2}.s^{-1}$)	P_{local} (MPa)	T_{in} (°C)	T_{local} (°C)	T_{sat}-T_{local} (°C)	ICHF (MW/m^2)	FE WCHF (MW/m^2)
JAERI SNL-EBTS	Smooth OFHC-Cu	7	6-13	1	50-145	60-160	20-120	15-65	19-90
JAERI PBEF	Smooth Cu (0.2%Ag)	7	4-14	0.5-0.9	20			14-21	
	Internal fins Cu (0.2%Ag)		4-15	0.5-0.9	20			10-30	
	External fin smooth Cu (0.2%Ag)	7	4-13	0.5-0.9	20			23-31	
	External fin swirl Cu (0.2%Ag)	4	4-13	0.5-0.9	20			25-42	
JAERI PBEF	Smooth OFHC-Cu	7	6-25	1	28-30	35-40	140-145	15-33	19-41
	External fin swirl OFHC-Cu	4	4-20	1-1.5	21-26	35-60	120-155	20-46	28-59
	Hypervapotron OFHC-Cu	8	2-10	0.7-1	26-31	30-50	115-145	7-24	8-32
	Screw OFHC-Cu	6-15	4-20	1-1.5	25-31	30-65	110-150	17-42	22-60

Table 2 JAERI tests for smooth and internally finned tubes in PBEF facility

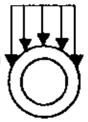
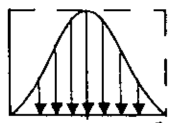
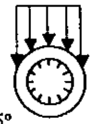
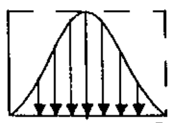
Name, geometry and transversal incident flux profile	Longitudinal incident flux profile	L_h (mm)	P_{local} (MPa)	T_{in} (°C)	T_{local} (°C)	T_{sat}-T_{local} (°C)	G ($Mg.m^{-2}.s^{-1}$)	V_{axial} (m/s)	ΔP_{lineic} (MPa/m)	Power (kw)	ICHF (MW/m^2)	Geom.WCHF (MW/m^2)	FE WCHF (MW/m^2)	FE peaking factor	Shot number
1988 **JAERI** Cu (0.2%Ag) OD = 10 mm ID = 7 mm PBEF Ion Beam Geom. Peaking factor: 1.19 	 Gaussian profile		0.9	20			14.0	14			21.2	30.4			
			0.9	20			11.0	11			20.9	29.9			
			0.9	20			4.0	4			19.4	27.7			
			0.9	20			11.0	11			13.8	25.4			
			0.9	20			9.0	9			17.8	19.6			
			0.9	20			7.0	7			15.3	21.9			
			0.7	20			13.0	13			20.9	29.9			
			0.7	20			11.0	11			19.7	28.1			
			0.7	20			9.0	9			17.8	25.4			
			0.5	20			13.0	13			20.6	29.4			
			0.5	20			11.0	11			19.4	27.7			
			0.5	20			6.0	6			15.6	22.3			
			0.5	20			4.0	4			13.7	19.6			
1988 **JAERI** Cu (0.2%Ag) OD = 10 mm ID = 7 mm Helix angle: 5° Fin number: 16 Inner fin length: 1.2 mm PBEF Ion Beam Geom. Peaking factor: 1.19 	 Gaussian profile		0.9	20			15.0	15			28.7	41.1			
			0.9	20			13.0	13			25.0	35.7			
			0.9	20			11.0	11			21.2	30.4			
			0.9	20			9.0	9			18.1	25.9			
			0.9	20			6.0	6			14.1	20.1			
			0.9	20			4.0	4			10.0	14.3			
			0.7	20			13.0	13			24.4	34.8			
			0.7	20			11.0	11			20.3	29.0			
			0.7	20			9.0	9			17.8	25.4			
			0.7	20			6.0	6			14.4	20.5			
			0.7	20			4.0	4			9.7	13.8			
			0.5	20			13.0	13			24.1	34.4			
			0.5	20			9.0	9			17.5	25.0			
			0.5	20			6.0	6			12.5	17.9			
			0.5	20			4.0	4			9.7	13.8			

Table 3 JAERI tests for externally finned smooth and swirl tubes in PBEF facility

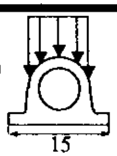
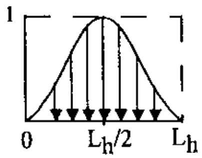
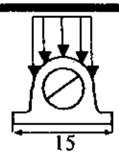
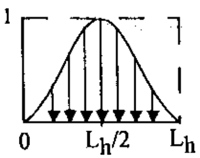
Name, geometry and transversal incident flux profile	Longitudinal incident flux profile	L_h (mm)	P_{local} (MPa)	T_{in} (°C)	T_{local} (°C)	T_{sat}-T_{local} (°C)	G ($Mg.m^{-2}.s^{-1}$)	V_{axial} (m/s)	ΔP_{lineic} (MPa/m)	Power (kw)	ICHF (MW/m^2)	Geom.WCHF (MW/m^2)	FE WCHF (MW/m^2)	FE peaking factor	Shot number
1988 JAERI Cu (0.2%Ag) OD = 10 mm ID = 7 mm  PBEF Ion Beam Geom. Peaking factor: 1.43	 Gaussian profile		0.9	20			13.0	13			31.2	44.6			
			0.9	20			11.0	11			29.7	42.4			
			0.9	20			9.0	9			27.5	39.3			
			0.9	20			6.0	6			24.7	35.3			
			0.9	20			4.0	4			23.4	33.5			
			0.7	20			11.0	11			30.6	43.8			
			0.7	20			9.0	9			26.6	37.9			
			0.7	20			6.0	6			24.7	35.3			
			0.7	20			4.0	4			23.4	33.5			
			0.5	20			11.0	11			30.3	43.3			
			0.5	20			9.0	9			26.6	37.9			
			0.5	20			6.0	6			24.7	35.3			
			0.5	20			4.0	4			23.4	33.5			
1988 JAERI Cu (0.2%Ag) OD = 10 mm ID = 7 mm Twist ratio:2.5  Tape thickness:0.35 mm Tape material: Inconel 625 PBEF Ion Beam Geom. Peaking factor: 1.43	 Gaussian profile		0.9	20			13.0	13			41.9	59.8			
			0.9	20			11.0	11			38.1	54.5			
			0.9	20			9.0	9			33.8	48.2			
			0.9	20			6.0	6			30.6	43.8			
			0.9	20			4.0	4			25.0	35.7			
			0.7	20			11.0	11			39.1	55.8			
			0.7	20			9.0	9			35.3	50.4			
			0.7	20			6.0	6			31.9	45.5			
			0.7	20			4.0	4			25.9	37.1			
			0.5	20			11.0	11			37.5	53.6			
			0.5	20			9.0	9			34.4	49.1			
			0.5	20			6.0	6			31.6	45.1			
			0.5	20			4.0	4			26.9	38.4			

Table 4 JAERI/SNL tests for smooth tube in EBTS facility

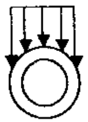
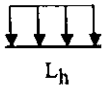
Name, geometry and transversal incident flux profile	Longitudinal incident flux profile	L_h (mm)	P_{local} (MPa)	T_{in} (°C)	T_{local} (°C)	T_{sat}-T_{local} (°C)	G ($Mg.m^{-2}.s^{-1}$)	V_{axial} (m/s)	ΔP_{lineic} (MPa/m)	Power (kw)	ICHF (MW/m^2)	Geom.WCHF (MW/m^2)	FE WCHF (MW/m^2)	FE peaking factor	Shot number
1994 **JAERI / SNL** 		20	1.0	50	58	122	12.8	13			65.5	93.6	90.1	1.38	124965
OFHC-Cu		20	1.0	50	58	122	10.9	11			61.6	88.0	84.9	1.38	124911
OD = 10 mm		20	1.0	50	58	122	8.9	9			57.8	82.6	79.2	1.37	124923
ID = 7 mm		20	1.0	50	59	121	6.9	7			53.9	77.0	74.2	1.38	124933
Twist ratio: 2.5		20	1.0	99	104	76	12.5	13			50.1	71.6	68.2	1.36	125161
Thick.: 0.5 mm		20	1.0	99	104	76	10.6	11			45.7	65.3	62.1	1.36	125197
Tape material: Inconel 625		20	1.0	99	104	76	10.6	11			41.8	59.7	56.8	1.36	125190
EBTS Electron Beam		20	1.0	99	105	75	10.6	11			40.7	58.1	55.2	1.36	125122
Geom. Peaking factor: 1.43		20	1.0	99	105	75	8.6	9			38.0	54.3	51.5	1.36	125137
		20	1.0	99	104	76	7.7	8			32.5	46.4	43.7	1.34	125143
		20	1.0	145	158	22	12.0	13			21.0	30.0	27.5	1.31	125078
		20	1.0	145	158	22	10.1	11			23.7	33.9	31.4	1.32	124990
		20	1.0	145	159	21	10.1	11			18.7	26.7	24.5	1.31	125006
		20	1.0	145	158	22	10.1	11			18.2	26.0	23.8	1.31	125004
		20	1.0	145	159	21	8.3	9			16.0	22.9	20.7	1.29	125025
		20	1.0	145	158	22	6.4	7			14.9	21.3	19.2	1.29	125042

Table 5 JAERI tests for smooth tube in PBEF facility

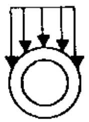
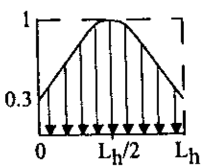
Name, geometry and transversal incident flux profile	Longitudinal incident flux profile	L_h (mm)	P_{local} (MPa)	T_{in} (°C)	T_{local} (°C)	$T_{sat}-T_{local}$ (°C)	G ($Mg.m^{-2}.s^{-1}$)	V_{axial} (m/s)	ΔP_{lineic} (MPa/m)	ICHF (MW/m^2)	Geom.WCHF (MW/m^2)	FE WCHF (MW/m^2)	FE peaking factor	Shot number
1996 JAERI OFHC-Cu OD = 10 mm ID = 7 mm PBEF Ion Beam Geom. peaking factor: 1.43 		160	1.0	30	36	143	25.1	25	1.01	32.7	46.7	41.5	1.27	E59
		160	1.0	30	37	142	20.0	20	0.71	30.7	43.9	39.1	1.27	E54
		160	1.0	28	35	144	18.1	18	0.56	30.7	43.9	39.1	1.27	E47
		160	1.0	28	37	142	16.1	16	0.46	30.7	43.9	39.1	1.27	E38
		160	1.0	28	37	142	14.1	14	0.37	27.0	38.6	34.5	1.28	E44
		160	1.0	29	38	141	12.0	12	0.29	25.3	36.1	32.2	1.27	E41
		160	1.0	28	38	141	10.0	10	0.18	21.8	31.1	27.5	1.26	E23
		160	1.0	28	40	139	8.1	8	0.13	21.8	31.1	27.6	1.27	E29
		160	1.0	28	39	140	6.0	6	0.07	15.3	21.9	19.1	1.25	E30

Table 6 JAERI tests for externally finned swirl tube in PBEF facility

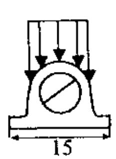
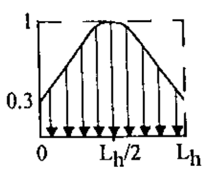
Name, geometry and transversal incident flux profile	Longitudinal incident flux profile	L_h (mm)	P_{local} (MPa)	T_{in} (°C)	T_{local} (°C)	$T_{sat}-T_{local}$ (°C)	G ($Mg.m^{-2}.s^{-1}$)	V_{axial} (m/s)	ΔP_{lineic} (MPa/m)	ICHF (MW/m^2)	Geom.WCHF (MW/m^2)	FE WCHF (MW/m^2)	FE peaking factor	Shot number
1996 JAERI OFHC-Cu OD = 10 mm ID = 7 mm Twist ratio:3 Thick.: 0.35 mm Tape material: Inconel 625 PBEF Ion Beam Geom. peaking factor: 1.43 		160	1.5	24	43	155	14.0	14	0.90	39.6	56.6	52.3	1.32	B52
		160	1.5	25	45	153	12.0	12	0.68	36.8	52.6	49.1	1.33	B47
		160	1.5	25	48	150	10.0	10	0.47	34.7	49.6	46.9	1.35	B30
		160	1.5	25	50	148	8.0	8	0.30	30.7	43.9	42.0	1.37	B36
		160	1.5	25	54	144	6.0	6	0.17	27.0	38.6	37.7	1.40	B39
		160	1.5	24	56	142	4.1	4	0.09	19.8	28.3	27.8	1.40	B42
		160	1.0	22	37	142	20.0	20	1.82	45.8	65.4	59.1	1.29	C35
		160	1.0	21	37	142	18.0	18	1.49	43.5	62.1	58.4	1.34	C30
		160	1.0	21	38	141	16.0	16	1.19	41.6	59.4	54.0	1.30	C25
		160	1.0	21	40	139	14.1	14	0.93	39.6	56.6	52.6	1.33	C20
		160	1.0	22	41	138	12.1	12	0.71	36.8	52.6	48.5	1.32	C15
		160	1.0	23	45	135	10.0	10	0.48	34.7	49.6	46.6	1.34	B57
		160	1.0	24	47	132	8.0	8	0.32	28.9	41.3	39.1	1.35	B60
		160	1.0	23	50	129	6.0	6	0.17	25.4	36.3	34.8	1.37	C05
		160	1.0	23	58	121	4.0	4	0.11	21.8	31.1	31.1	1.43	C10

Table 7 JAERI tests for screw tubes in PBEF facility

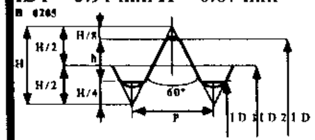
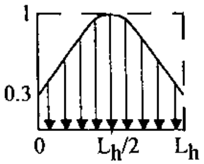
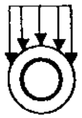
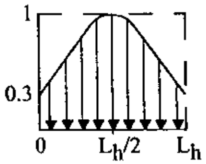
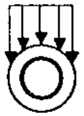
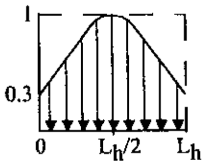
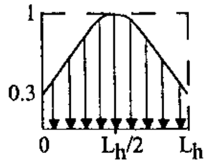
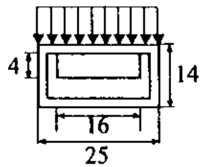
Name, geometry and transversal incident flux profile	Longitudinal incident flux profile	L_h (mm)	P_{local} (MPa)	T_{in} (°C)	T_{local} (°C)	$T_{sat}-T_{local}$ (°C)	G ($Mg.m^{-2}.s^{-1}$)	V_{axial} (m/s)	ΔP_{lineic} (MPa/m)	ICHF (MW/m^2)	Geom.WCHF (MW/m^2)	FE WCHF (MW/m^2)	FE peaking factor	Shot number
1996 **JAERI** OFHC-Cu ISO 261 : B 0205 M7 OD = 10 mm ID = 7 mm ID2 = 6.35 mm P = 1 mm ID1 = 5.91 mm H = 0.87 mm   PBEF Ion Beam Geom. peaking factor:1.43		160	1.5	28	48	150	10.0	10	0.46	32.7	46.7			E12
		160	1.5	28	51	147	8.0	8	0.31	30.7	43.9			E18
		160	1.0	30	43	136	19.9	20	2.00	41.6	59.4			E07
		160	1.0	31	44	135	17.9	18	1.60	41.6	59.4			E04
		160	1.0	29	44	135	15.9	16	1.26	39.6	56.6			D35
		160	1.0	30	46	133	13.9	14	0.96	36.8	52.6			D32
		160	1.0	31	47	132	11.9	12	0.70	32.7	46.7			D19
		160	1.0	31	49	130	10.0	10	0.46	30.7	43.9			D09
		160	1.0	31	51	128	8.0	8	0.32	27.0	38.6			D14
		160	1.0	31	54	125	6.0	6	0.15	23.7	33.9			D22
		160	1.0	30	65	114	4.0	4	0.06	23.7	31.1			D28
1996 **JAERI** OFHC-Cu ISO 261 : B 0205 M12 OD = 15 mm ID = 12 mm ID2 = 10.86 mm P = 1.75 mm ID1 = 10.11 mm H = 1.51 mm PBEF Ion Beam Geom. peaking factor: 1.25 		160	1.0	25	32	147	15.0	15	0.81	32.7	40.9			B06
		160	1.0	26	33	146	14.0	14	0.68	32.7	40.9			B03
		160	1.0	26	42	137	12.0	12	0.52	30.7	38.4			A55
		160	1.0	26	35	144	10.0	10	0.36	28.9	36.1			A41
		160	1.0	25	35	144	8.0	8	0.24	27.0	33.8			A45
		160	1.0	25	37	142	6.0	6	0.16	23.7	29.7			A48
		160	1.0	25	42	141	4.0	4	0.09	16.8	21.0			A51
1996 **JAERI** OFHC-Cu ISO 261 : B 0205 M16 OD = 19 mm ID = 16 mm ID2 = 14.70 mm P = 2 mm ID1 = 13.84 mm H = 1.73 mm PBEF Ion Beam Geom. peaking factor: 1.19 		160	1.0	25	32	147	8.0	8	0.23	27.0	32.1			B20
		160	1.0	30	38	141	6.0	6	0.13	23.7	28.1			B15
		160	1.0	30	40	139	4.0	4	0.04	18.3	21.7			B10
		160	1.0	25	32	147	2.0	2	0.001	6.8	8.0			B22

Table 8 JAERI tests for hypervapotron in PBEF facility





Name, geometry and transversal incident flux profile	Longitudinal incident flux profile	L_h (mm)	P_{local} (MPa)	T_{in} (°C)	T_{local} (°C)	T_{sat}-T_{local} (°C)	G ($Mg.m^{-2}.s^{-1}$)	V_{axial} (m/s)	ΔP_{lineic} (MPa/m)	ICHF (MW/m^2)	Geom.WCHF (MW/m^2)	FE WCHF (MW/m^2)	FE peaking factor	Shot number
1996		160	1.0	26	30	149	10.0	10	0.80	25.3	31.6			Aa26
JAERI		160	1.0	31	41	138	8.0	8	0.48	23.7	29.6			A08
OFHC-Cu		160	1.0	28	35	144	8.0	8	0.49	23.7	29.6			Aa16
Wall thickness: 2.5 mm		160	1.0	31	44	135	5.9	6	0.33	22.0	27.5			A05
Fin thickness: 3 mm		160	1.0	28	38	141	6.0	6	0.29	22.0	27.5			Aa08
Gap between fins: 3 mm		160	1.0	31	48	131	4.0	4	0.18	19.8	24.8			A11
		160	1.0	27	42	137	4.0	4	0.11	19.8	24.8			Aa11
		160	1.0	30	42	137	2.0	2	0.07	6.8	8.5			A16
		160	1.0	27	36	143	2.0	2	0.004	6.8	8.5			Aa13
		160	0.7	26	36	129	8.5	9	0.53	23.7	29.6			A22
		160	0.7	26	38	127	6.0	6	0.32	23.7	29.6			A23
		160	0.7	26	44	121	4.0	4	0.18	19.8	24.8			A29
PBEF Ion Beam														
Geom. Peaking factor: 1.25														