EUR 4514 e

European Atomic Energy Community - EURATOM
FIAT S.p.A., Sezione Energia Nucleare - Torino
Società ANSALDO S.p.A. - Genova

FORCED CONVECTION BURNOUT AND HYDRODYNAMIC INSTABILITY EXPERIMENTS FOR WATER AT HIGH PRESSURE

Part VII : Burnout heat flux measurements on 3x3 rod bundles with non-uniform heat generation

by

A. CAMPANILE, G. GALIMI, M. GOFFI and G. PASSAVANTI
(SORIN, Centro Ricerche Nucleari, Saluggia, Italy)

1970

Contract No. 008-61-12 PNII

LEGAL NOTICE

This report is on sale at the addresses listed on cover page 4

at the price of Lit. 750.—	FB 60	DM 4.40	NF 6.65	Fl. 4.30

When ordering, please quote the EUR number and the title, which are indicated on the cover of each report.

Printed by Vanmelle, Ghent
Luxembourg, September 1970

EUR 4514 e

FORCED CONVECTION BURNOUT AND HYDRODYNAMIC INSTABILITY EXPERIMENTS FOR WATER AT HIGH PRESSURE
Part VII: Burnout heat flux measurements on 3 × 3 rod bundles with non-uniform heat generation

by A. CAMPANILE, G. GALIMI, M. GOFFI and G. PASSAVANTI
(SORIN, Centro Ricerche Nucleari, Saluggia - Italy)

European Atomic Energy Community - EURATOM
FIAT S.p.A., Sezione Energia Nucleare - Torino
Società ANSALDO S.p.A. - Genova
Contract No. 008-61-12 PNII
Luxembourg, September 1970 — 42 Pages — 19 Figures — FB 60,—

The present paper reports burnout experiments conducted with high pressure water in 3 × 3 rod bundles characterized by singularities either in the geometry or in the heat generation.

EUR 4514 e

FORCED CONVECTION BURNOUT AND HYDRODYNAMIC INSTABILITY EXPERIMENTS FOR WATER AT HIGH PRESSURE
Part VII: Burnout heat flux measurements on 3 × 3 rod bundles with non-uniform heat generation
by A. CAMPANILE, G. GALIMI, M. GOFFI and G. PASSAVANTI
(SORIN, Centro Ricerche Nucleari, Saluggia - Italy)

European Atomic Energy Community - EURATOM
FIAT S.p.A., Sezione Energia Nucleare - Torino
Società ANSALDO S.p.A. - Genova
Contract No. 008-61-12 PNII
Luxembourg, September 1970 — 42 Pages — 19 Figures — FB 60,—

The present paper reports burnout experiments conducted with high pressure water in 3 × 3 rod bundles characterized by singularities either in the geometry or in the heat generation.

264 data are presented which concern the following experimental conditions : obstruction in the flow area, some non-uniform transversal heat flux distributions and a non-uniform heat generation in both transverse and axial directions.

Whenever possible, the water temperature at several positions of the exit flow area of the channel was taken.

Further, for each experiment the location of the burnout in the rod bundle was recorded.

264 data are presented which concern the following experimental conditions : obstruction in the flow area, some non-uniform transversal heat flux distributions and a non-uniform heat generation in both transverse and axial directions.

Whenever possible, the water temperature at several positions of the exit flow area of the channel was taken.

Further, for each experiment the location of the burnout in the rod bundle was recorded.

EUR 4514 e

European Atomic Energy Community - EURATOM
FIAT S.p.A., Sezione Energia Nucleare - Torino
Società ANSALDO S.p.A. - Genova

FORCED CONVECTION BURNOUT AND HYDRODYNAMIC INSTABILITY EXPERIMENTS FOR WATER AT HIGH PRESSURE

Part VII : Burnout heat flux measurements on 3x3 rod bundles with non-uniform heat generation

by

A. CAMPANILE, G. GALIMI, M. GOFFI and G. PASSAVANTI
(SORIN, Centro Ricerche Nucleari, Saluggia, Italy)

1970

Contract No. 008-61-12 PNII

ABSTRACT

The present paper reports burnout experiments conducted with high pressure water in 3 × 3 rod bundles characterized by singularities either in the geometry or in the heat generation.

264 data are presented which concern the following experimental conditions : obstruction in the flow area, some non-uniform transversal heat flux distributions and a non-uniform heat generation in both transverse and axial directions.

Whenever possible, the water temperature at several positions of the exit flow area of the channel was taken.

Further, for each experiment the location of the burnout in the rod bundle was recorded.

KEYWORDS

BURNOUT
CONVECTION
HYDRODYNAMICS
WATER
PRESSURE
HEAT TRANSFER
RODS
TEMPERATURE

Index *)

*) Manuscript received on 19 June 1970

Reports on FORCED CONVECTION BURNOUT AND HYDRODYNAMIC INSTABILITY EXPERIMENTS FOR WATER AT HIGH PRESSURE already published:

EUR 2490e - Part I: (Full-size)	Presentation of Data for Round Tubes with Uniform and Non-uniform Power Distribution (1965).
EUR 2963e- Part II: (Full-size)	Presentation of Data for Water Flowing Upward Along a Uniformly Heated Rod in a Square Unheated Duct (1966).
EUR 3113e - Part III: (Full-size)	Comparison Between Experimental Burnout Data and Theoretical Prediction for Uniform and Non-uniform Heat Flux Distribution (1966).
EUR 3881e - Part IV: (Full-size)	Burnout Experiments in a Double Channel Test Section with Transversely Varying Heat Generation (1968).
EUR 4070e - Part V: (Full-size)	Analysis of Heating and Burnout Experiments in a Double Channel Test Section with Transversely Varying Heat Generation (1968).
EUR 4468e - Part VI: (Full-size)	Burnout Heat Flux Measurements on 9 Rod Bundles with Longitudinally and Transversally Uniform Heat Generation (1970).

1. Introduction

The experimental investigation of burnout conducted in the past eight years in the SORIN Heat Transfer Laboratory has been carried out in the framework of a Research and Development Program, with the basic objective of providing design basis for the thermal aspects of the design of a pressurized water reactor for ship propulsion being studied under an EURATOM - FIAT - ANSALDO - CNEN Contract.

It started in 1962 anticipating the accomplishment of a rather comprehensive research program on burnout according to the following testing schedule [1]*:

a) Experiments in round vertical tubes with both uniform and non-uniform axial heat flux distribution.
b) Experiments on a uniformly heated rod in a square unheated duct.
c) Experiments on two rods uniformly and indipendently heated centered within two adjacent and communicating channels having the walls partially heated.
d) Experiments in a 9 rod bundle on a 3x3 square pitch pattern with either uniform or non-uniform heat generation.

Each phase of the above program has been accomplished and the respective results have been published in previous reports [1][2][3].

As concerns the last phase, the experimental work on burn out with uniform heat generation has been completed and the data will be found in a Report in the press by EURATOM [4].

(*) Numbers in parenthesis refer to the Bibligraphy reported at the end of the Paper.

The present report only refers to all the unpublished results obtained more recently on the 9 rod bundle test section which concern experimental conditions characterized by singularities either in flow area or in the heat generation.

The large variety of tests conducted was requested to make an appraisal of how do the calculation codes, used to predict the burnout limits, account for the various causes of departure from the condition of full uniformity which are likely to be encountered in the core configurations of the pressurized water reactor being designed under the aforementioned Contract.

Comparatively few burnout data have been thus far published on this subject. This report aims simply at presenting the collected data with no attempt to either compare or analyze them, as this aspect will be covered in a next paper.

2. Experimental facilities

2.1. Test loops

The tests here referred to were carried out on the 650 kw water loop in the Heat Transfer Laboratory at the SORIN Nuclear Research Center (Saluggia), as well as on the 2400 kw water loop in the S.T.T. at the EURATOM CCR (Ispra).

These high pressure loops and the respective operating procedures were essentially the same as those described in details in the Ref. [1] and [5].

2.2. Test section

The test section used throughout the experiments,except for rods and grids of the bundle, which required to be changed for each set of tests every time, as will be shown later, was the same as the one described in details in Ref. [4].

Measurements and controls too were performed according to the procedures outlined in the above Reference. The specific modifications of the burnout detection device, made in conjunction with the tests performed on the bundle having non uniform longitudinal heat generation, will be described in the respective paragraph.

3. Experimental program

All the burnout experiments here reported were conducted on the larger of the two square channels housing the bundle which were described in Ref./4/, namely the one identified by capital letter B. A cross section of this channel is shown in Fig. 1.

The main dimensions of the tested 9 rod bundle test section are listed below:

Heated Rods O.D.	10.2 mm
Lattice Pitch	13.4 mm (square)
Heated Length	1183 mm
Channel Side	42,32 mm.

The whole of the experiments have been subdivided in a number of sets, each relating to a bundle characterized by specific singularities either in the geometrical configuration or in the heat generation.

Thus, the text will henceforth conform to the following subdivision, which, for a clearer understanding, is graphically explained in Fig. 2:

Set I. Experiments in a 9 rod bundle uniformly heated in both longitudinal and transversal directions, characterized by obstructions in the flow area.

Set II. Experiments in a 9 rod bundle characterized by singularities in the transversal heat generation across the bundle, the longitudinal heating being uniform:

- Set II.1 Experiments in a 9 rod bundle with the central rod unheated and of larger diameter as to simulate the guide tube of a "Cluster Control" element.

Set.II.2 Experiments in a 9 rod bundle with 3 side rods unheated and of the same O.D. as the heated ones.

Set II.3 Experiments in a 9 rod bundle with the 4 corner rods unheated and of the same O.D. as the 5 heated ones (Three of these 23% overloaded).

Set II.4 Experiments in a 9 rod bundle with the 4 corner rods unheated, one simulating the "Cluster Control" Guide Tube and the remaining of the same O.D. as the 5 heated ones (Three of these 23% overloaded).

Set II.5 Experiments in a 9 rod bundle in which the three rows of rods were heated at different power levels.

Set III. Experiments in a 9 rod bundle having the 4 corner rods unheated, one simulating the "Cluster Control" Guide Tube, and the remaining rods heated with a non-uniform longitudinal power distribution.

4. Peculiar features of the tested bundles

Here are described the main features of the bundles on which the experimental investigation was carried out:

Set I. Bundle uniformly heated in both longitudinal and transversal directions characterized by obstructions in the flow area.

This bundle was the same as the one employed in the experiments with all the 9 rods uniformly heated except for the ferrules. In fact, one of the central ferrules, at the position indicated in Fig. 3, was substituted by a solid stainless steel cylinder thus forming sequential obstructions in the flow area laying on the same vertical and spaced as the grids.

Set II. Bundles characterized by singularities in the transversal heat generation, the longitudinal heating being uniform.

The heater tubes of the bundles covered by this heading were generally the same as those reported in Ref./4/ except for the bundles used in the experiments of points II.3, II.4 and II.5 in which Inconel tubes of different thicknesses had to be used in order to obtain the desired differential heating in the rods, these being all connected in parallel.

The unheated rods, having the same O.D. as the heated tubes were, made of solid high grade aluminum oxide rods.

The unheated rods of larger diameter were obtained by assembling a required number of short aluminum oxide tubes 12 O.D. connected each other by means of stainless steel connectors having clamping end. Special ferrules had to be brazed on these connectors as shown in Fig. 4.

Set III. Bundles characterized by longitudinally non-uniform power distribution.

In these bundles the non-uniform longitudinal distribution of the heat flux, was accomplished by fabricating the heaters according to a special technique. Stainless steel tubes of constant bore were turned on the external surface so as to produce tubes of progressively increasing wall thickness towards each end. These tubes were then cold swaged with several die steps to obtain an external cylindrical surface down to the desired final size (10.2 mm O.D.) and a thickness profile such to give an approximately symmetrical chapped cosine flux distribution with a form factor nominally equal to 1,7.

Fig. 5 shows the flux profile of the heater located in the center of the bundle which was invariably and exclusively involved with the onset of burnout throughout this investigation.

Some modifications were requested for the burnout detection device to make it suitable for tests with non-uniform longitudinal flux distribution.

In fact, in this case, even assuming to carry out experiments in which it could be anticipated the occurrence of the burnout on a well defined rod in the cluster, it would still remain undetermined the axial position at which burnout would have incept.

To allow identification of the axial location of the burnout along the heated length of the rod undergoing the thermal crisis, the respective detector was provided with 11 thermocouples spaced 55 mm apart along the upper half of the active length.

The arrangement of the termocouples in the burnout detection device was according to the description made in Ref. [4].

The signals of the thermocouples were individually recorded on as many potentiometers, each provided with a microswitch for power tripping at burnout.

For practical limitations, the burnout detectors of all the rods but the one on which burnout was much likely expected, could not be of the type previously described. Nevertheless, to prevent failure of the heaters, they were required to perform a detection of the burnout occurrence, even though irrespective of its axial location. This was obtained by internally providing each heater with a set of an even number of Cromel-Alumel junctions in opposition (26 spaced cm apart along the upper half of the heater) whose signals were or could normally be balanced in operation. The device was suitably insulated in the interior of the heater by means of pyrex and ceramic tubes. The unbalance signal at burnout was recorded on a potentiometer suitable to trigger the power supply circuit breaker.

5. Experimental results

5.1. Test parameter ranges

The physical conditions of the coolant were generally varied within the following ranges:

Pressure:	43 ÷ 158 ata
Mass flow rate:	47 ÷ 308 gr/cm^2 sec.
Inlet temperature	174 ÷ 328 °C

5.2. Tabulation and graphical representation

The results of the burnout experiments are tabulated in Table I through XIV and plotted in Figg. 6 through 19.

The sequence of the various sets of experiments conforms to the subdivision already reported in paragraph 3.

For each set a separate Table is used for each pressure. Data are listed in the Tables in order of increasing mass flow rate and decreasing inlet temperature.

Tabulated values of the burnout power represent the heat generated in the active length of the heated rods of the entire bundle. The values reported for the heat flux represent average values referring to the burnout rod.

For each run the rod (or rods) on which burnout was detected has been also indicated by means of an identification number. Its location in the lattice may be easly identified with the help of Figg. 1, 2 and 3.

Fig. 1 allows also identification of the positions in the channel exit cross section of the six thermocouple junctions provided for measuring exit water temperature, whose values are listed in the Tables.

Concerning the tests with non-uniform longitudinal heat generation, the Tables indicate also the vertical coordinates, referred to the entire heated length, of the thermocouple junctions which detected the occurrence of burnout on the central rod.

The plots of the experimental data are graphical representations of the values of the burnout rod power versus inlet temperature.

Acknowledgement

The Authors are indebted to EURATOM for giving them the opportunity of carrying out part of the reported experiments in the Heat Transfer Laboratory of the ISPRA C.C.R. whose personnel deserve a special thank for the assistance rendered to them in making use of the EURATOM experimental apparatus.

The helpful cooperation of Mr. Mörk-Mörkenstein is particularly acknowledged. Thanks are due to FIAT - Sen for the manufacturing of all the grids employed as well as the special heaters requested in the texts with non uniform axial heating.

Acknowledgement of the assistance of Mr. O.Morocutti of the EURATOM is here expressed.

The contribution of the SORIN Heat Transfer Laboratory Staff is worth of mention.

References

[1] F. Biancone, A. Campanile, G. Galimi, M. Goffi: Forced Convection Burnout and Hydrodynamic Instability Experiments for Water at High Pressure; Part I: Presentation of Data for Round Tubes with Uniform and Non-uniform Power Distribution. EUR 2490.e-1965.

[2] A. Campanile, G. Galimi, M. Goffi: Forced Convection Burnout and Hydrodynamic Instability Experiments for Water at High Pressure; Part II: Presentation of Data for Water Flowing Upward along a Uniformly Heated Rod in a Square Unheated Duct. EUR 2963.e - 1966.

[3] A. Campanile, G. Galimi, M. Goffi: Forced Convection Burnout and Hydrodynamic Instability Experiments for Water at High Pressure, Part IV: Burnout Experiments in a Double Channel Test Section with Transversely Varying Heat Generation. EUR 3881.e - 1968.

[4] A. Campanile, G. Galimi, M. Goffi, G. Passavanti: Forced Convection Burnout and Hydrodynamic Instability Experiments for Water at High Pressure; Part VI: Burnout Heat Flux Measurements on 9 Rod Bundles with Longitudinally and Transversally Uniform Heat Generation. EURATOM REPORT (In the Press).

[5] H. Herkenrath, P. Mörk-Mörkenstein: 2,4 MW Druck-und Siedewasserkeislauf zur Untersuchung des Wärmeübergangs. EUR 3605.d - 1967.

Burnout Experiments: SET I

TABLE I

Nominal pressure: 132 ata

Run	Pressure ata	Flow l/h	Mass flow rate gr/cm²sec.	Inlet °C subcooling	Inlet °C temperature	Exit temperature a	a'	b	b'	c	c'	Power kw.	Heat flux watt / cm²	Exit quality %	Burnout rods position in the lattice: central	side	corner
85 (21-8-68)	138	2780	50,3	17,5	316,5	328,7	329,1	330,2	331,5	331,0	331,5	303,9	89,1	41,2		2-4-8	1
35 (9-8-68)	139	2600	50,1	37,8	296,7	328,7	330,2	333,2	333,2	331,2	333,2	337,9	99,0	36,9		8	
14 (19-8-68)	135	2410	50,9	76,2	256,0	325,0	327,7	328,9	330,0	329,1	330,0	440,5	129,1	35,3	9	2-4-6-8	1
12 (21-8-68)	133	2380	50,3	75,6	255,5	326,2	328,9	328,9	329,8	329,1	329,1	437,1	128,1	35,7	9	2-8	
16 (21-8-68)	136	2310	51,1	105,1	227,7	328,7	329,1	331,0	331,0	330,5	331,0	481,3	141,1	29,6		2	
19 (21-8-68)	135	2250	50,6	115,7	216,5	327,5	329,1	331,0	331,2	330,5	331,5	505,5	148,1	30,1		2	
23 (21-8-68)	136	2080	47,9	133,1	199,7	328,9	330,0	332,5	332,5	332,7	331,0	522,6	153,2	31,1	9	2	
33 (21-8-68)	134	2170	51,5	157,4	174,2	323,8	328,2	329,5	330,0	329,1	329,8	575,2	168,6	23,7	9	2	
53 (21-8-68)	140	5200	94,5	20,0	315,1	328,9	329,5	333,0	333,2	332,0	333,7	382,2	112,0	22,7			7
79 (9-8-68)	135	5150	100,9	40,9	290,5	326,5	331,0	331,5	331,5	330,2	330,2	460,7	135,0	16,0		4-6-8	
40 (19-8-68)	140,5	4720	95,8	59,9	275,5	326,2	331,5	333,0	333,5	333,0	333,7	514,7	150,8	14,5	9	2	
30 (19-8-68)	134,5	4610	94,6	61,4	270,5	322,7	328,7	329,1	330,0	329,4	330,0	528,5	154,9	15,7		2-4	
44 (21-8-68)	132	4490	96,4	84,0	246,5	326,2	328,9	329,5	329,5	329,5	329,8	586,0	171,7	10,2		2	
60 (21-8-68)	134	8500	157,1	21,1	310,5	325,0	328,7	329,1	330,2	328,9	329,8	476,5	139,6	13,0	9		
90 (9-8-68)	135	8220	161,3	42,2	290,0	323,8	329,3	329,8	331,5	330,2	331,5	554,7	162,6	6,2		2	
55 (19-8-68)	132	7820	158,7	55,0	275,5	319,0	326,2	328,5	329,3	328,5	329,3	620,1	181,7	4,5		2	
67 (21-8-68)	137	12200	224,1	21,1	312,2	328,7	329,8	331,0	331,2	331,2	331,2	549,2	161,0	8,1	9		
73 (19-8-68)	137	11890	223,9	28,9	304,5	327,0	329,8	331,0	331,5	331,2	331,7	630,5	184,8	7,25	9		

Burnout Experiments: SET II.1

TABLE II

Nominal pressure: 84 ata

Run	Pressure ata	Flow 1/h	Mass flow rate gr/cm² sec.	Inlet °C subcooling	Inlet °C temperature	Exit temperature			Power kw.	Heat flux watt / cm²	Exit quality %	Burnout rods position in the lattice		
						a	b	c				central	side	corner
98 (20-9-68)	84,5	2550	52,2	12,2	285,2	292,7	295,0	294,4	354,4	116,9	41,6			3-5-7
62 (20-9-68)	87	2500	52,1	22,5	277,0	293,6	295,7	295,7	382,2	126,1	42,0		6	1-3-5-7
106 (20-9-68)	84,5	2460	51,9	25,7	271,7	293,0	295,2	294,5	396,5	130,8	42,6			3
77 (20-9-68)	84,5	2450	52,1	29,9	267,5	294,0	295,4	295,0	410,0	135,2	42,7			3
24 (20-9-68)	83	2340	50,9	39,9	256,2	291,7	293,6	293,6	424,9	140,2	42,4			3-7
17 (20-9-68)	80	2325	51,7	49,9	243,7	289,4	291,0	291,0	456,3	150,5	41,9			3-5
118 (20-9-68)	84,5	2250	51,1	67,2	230,2	293,9	295,5	293,9	471,2	155,4	39,5			3
8 (19-9-68)	84	2240	52,3	85,5	211,5	293,4	295,2	295,2	496,0	163,6	35,5			1-3-7
16 (19-9-68)	84	2130	50,4	95,8	201,2	293,7	295,2	295,2	538,7	177,7	40,5		4-8	1-3-5
9 (20-9-68)	82	2130	51,5	111,1	184,2	292,2	294,7	294,7	556,3	183,5	36,4		4	1-3
85 (20-9-68)	87	4850	98,4	10,8	288,7	294,7	297,2	296,7	474,7	156,6	28,9			3
111 (20-9-68)	89	4730	96,6	15,4	285,7	295,4	298,7	298,2	486,8	160,6	28,9			3
55 (20-9-68)	84,5	4680	97,4	19,4	278,0	293,7	295,0	294,6	514,7	169,8	28,7			1-3
70 (20-9-68)	83	4600	97,2	25,2	271,0	291,5	294,4	294,4	543,3	179,2	28,6			3
49 (20-9-68)	84	4470	95,4	31,3	265,7	292,2	295,0	294,1	555,3	183,2	28,1			1-3-5
32 (20-9-68)	84	4440	96,6	41,3	255,7	291,9	293,4	293,2	583,7	192,5	26,2			1-3

Burnout Experiments: SET II.1

TABLE III

Nominal pressure: 132 ata

Run	Pressure ata	Flow l/h	Mass flow rate gr/cm^2 sec.	Inlet °C subcooling	Inlet °C temperature	Exit temperature a	b	c	Power kw.	Heat flux watt / cm^2	Exit quality %	Burnout rods position in the lattice: central	side	corner
83 (23-9-68)	134,5	2790	52,9	20,2	311,7	325,2	328,8	328,7	292,1	96,4	36,0			3-5
46 (23-9-68)	133,0	2600	51,2	36,2	294,9	327,0	329,5	329,2	344,2	113,5	37,7			3-5
40 (11-9-68)	131,5	2460	51,2	56,2	278,0	324,7	326,6	326,6	367,3	121,2	34,8		4	3
74 (12-9-68)	135,0	2350	50,9	73,7	258,5	325,5	329,0	329,0	414,3	136,7	34,1			3
39 (12-9-68)	134,0	2250	50,5	94,1	237,5	325,4	328,7	328,3	446,6	147,3	31,4		4	
14 (12-9-68)	135,5	2240	51,3	107,8	224,7	327,6	329,6	329,4	467,9	154,4	28,3			5-3-7
22 (12-9-68)	134,5	2140	50,0	120,4	211,5	326,6	328,8	328,7	491,6	162,2	29,5		4	1-3-7
30 (12-9-68)	134,0	2150	51,9	145,0	186,0	324,8	328,8	328,3	531,4	175,3	23,1		6	7
80 (23-9-68)	133,0	5180	97,3	16,8	314,2	326,0	328,8	328,5	350,4	115,6	20,9			3
35 (23-9-68)	134,5	4860	96,4	34,7	297,2	326,2	329,0	328,8	392,5	129,5	16,2			3
25 (11-9-68)	134,0	4650	96,3	51,6	280,0	325,4	329,2	329,0	433,5	143,0	12,0			5
82 (12-9-68)	133,5	4430	94,6	65,6	265,7	322,5	328,5	328,3	497,1	164,0	12,4			3-5
53 (12-9-68)	134,5	4260	95,0	89,9	242,0	325,4	328,7	328,3	558,3	184,2	7,4			5-7-3
61 (12-9-68)	136,0	4080	92,2	98,8	234,0	326,6	329,3	329,1	581,8	191,9	7,4			1-3-5-7
70 (23-9-68)	133,0	8850	166,0	16,4	314,7	326,1	328,8	328,4	416,3	137,3	11,7		8	7-3
9 (23-9-68)	135,0	8170	159,2	28,9	303,3	327,4	330,2	329,4	464,3	153,2	8,9			3-5
42 (13-9-68)	134,5	8260	161,7	30,2	301,7	325,1	329,0	328,8	475,6	156,9	8,4			3-5
22 (23-9-68)	137,0	8200	162,4	35,9	297,5	327,6	330,9	330,5	489,2	161,4	6,2			3-5-7
52 (11-9-68)	133,0	7860	163,1	52,0	279,1	320,4	328,4	327,9	536,0	176,8	1,4			5-7
88 (12-9-68)	139,0	7530	161,4	70,8	263,7	312,4	329,2	328,6	587,7	193,9	-4,5			7
21 (13-9-68)	132,0	7510	161,4	68,0	262,5	312,5	328,1	327,1	615,7	203,1	-0,9			7
9 (13-9-68)	135,0	7350	162,5	85,2	247,0	300,1	326,2	323,5	647,0	213,4	-7,2			7
63 (23-9-68)	133,5	12680	240,2	19,4	312,0	326,9	329,4	329,1	500,6	165,1	6,5			3-5
54 (23-9-68)	137,0	11740	230,9	33,1	300,2	327,6	331,2	330,9	572,4	188,8	2,8			5-3-7
31 (13-9-68)	132,0	11190	230,0	47,2	283,2	318,3	328,8	328,7	636,1	209,8	-0,8			7-5

Burnout Experiments: SET 11.2

TABLE IV

Nominal pressure: 132 ata

Run	Pressure ata	Flow l/h	Mass flow rate gr/cm²sec.	Inlet °C subcooling	Inlet °C temperature	Exit temperature a	a'	b	b'	c	c'	Power kw.	Heat flux watt/cm²	Exit quality %	Burnout rods position in the lattice: central	side	corner
33 (24-10-68)	135	2580	48,3	28,9	303,3	325,0	328,4	328,9	329,8	328,7	329,8	233,6	102,7	24,0		8	
103(24-10-68)	134	2600	49,6	34,9	296,7	326,7	329,1	330,0	330,2	330,7	330,7	262,8	115,5	24,9		8	
48 (24-10-68)	137	2540	50,0	48,9	284,5	327,5	329,8	329,1	330,5	329,3	330,7	283,1	124,5	21,6		8	
59 (24-10-68)	128	2460	51,3	70,8	257,2	319,7	324,7	325,6	326,2	325,3	326,2	323,1	142,0	17,0		8	
31 (24-10-68)	135	5250	96,0	22,7	309,5	323,3	328,7	329,3	330,2	329,3	330,5	281,6	133,8	11,0			7-1
93 (24-10-68)	138,5	5080	97,2	38,2	296,0	322,7	331,2	328,7	332,5	330,5	333,0	315,6	138,7	6,1			7
84 (24-10-68)	136	4820	95,8	52,1	280,7	317,7	330,0	317,7	331,5	327,7	331,5	355,3	156,2	3,0			7
75 (24-10-68)	132	4630	95,0	64,2	266,2	314,2	328,0	310,5	328,9	322,2	329,3	391,2	172,0	1,9		8	
16 (24-10-68)	138	9100	164,7	20,2	313,7	326,2	331,2	331,5	333,5	331,5	333,5	339,0	149,0	5,0		8	7
22 (24-10-68)	137	8920	163,4	22,9	310,5	324,0	331,2	328,7	332,2	330,2	332,7	335,3	147,4	3,6			7
112(24-10-68)	138	8950	164,4	24,2	309,8	324,0	330,2	328,7	331,5	330,2	331,7	337,4	148,3	2,9			7
110(23-10-68)	136	8560	157,7	24,1	308,7	323,8	328,9	328,7	329,5	329,0	329,8	333,4	146,5	3,5			7
100(23-10-68)	135	8240	155,1	30,5	301,7	323,8	328,7	323,8	330,0	328,7	330,2	373,2	164,1	2,8			7
92 (23-10-68)	133,5	8120	160,0	46,9	284,5	319,2	328,7	314,0	329,3	321,5	329,8	419,8	184,5	-2,9			7
64 (23-10-68)	134	12750	233,0	20,4	311,2	323,8	327,7	327,5	329,5	328,7	329,8	401,5	176,5	2,2			7
21 (23-10-68)	135	12370	232,8	30,5	301,7	324,2	328,9	322,7	330,2	328,7	330,2	424,5	186,6	-2,1		8	
76 (23-10-68)	136	12030	233,9	42,8	290,0	321,5	328,9	314,2	329,8	322,4	331,0	489,6	215,2	-5,8		8	1
39 (23-10-68)	134,5	11710	230,3	46,7	285,2	316,5	329,5	310,7	329,5	316,5	329,0	494,6	217,4	-7			1

Burnout Experiments: SET II.2

TABLE V

Nominal pressure: 140 ata

Run	Pressure ata	Flow l/h	Mass flow rate gr/cm^2 sec.	Inlet °C subcooling	Inlet °C temperature	Exit temperature						Power kw.	Heat flux watt / cm^2	Exit quality %	Burnout rods position in the lattice		
						a	a'	b	b'	c	c'				central	side	corner
49 (23-10-68)	140	13200	238,1	20,4	314,7	328,5	330,5	331,0	333,0	331,7	333,0	368,5	162,0	0,5		8	
10 (25-10-68)	145	11280	225,3	59,2	278,7	310,5	331,0	309,3	328,7	314,2	336,2	532,6	234,2	-12,5			1
16 (25-10-68)	141	11320	233,6	72,4	263,2	300,2	324,7	301,0	317,7	304,5	333,5	571,8	251,4	-17,1			1
29 (25-10-68)	139	11000	230,0	78,3	256,2	296,2	321,5	295,0	314,2	301,0	331,5	607,2	266,9	-17,7			7

Burnout Experiments: SET II.3

TABLE VI

Nominal pressure: 132 ata

Run	Pressure ata	Flow l/h	Mass flow rate $gr/cm^2 sec.$	Inlet °C subcooling	Inlet °C temperature	Exit temperature a	a'	b	b'	c	c'	Power kw.	Heat flux watt / cm^2	Exit quality %	Burnout rods position in the lattice: central	side	corner
33 (16-4-69)	133,5	5120	93,5	21,0	310,5	310,5	-	330,7	329,0	-	330,5	223,5	127,1	7,4	9		
25 (16-4-69)	134,5	5103	93,8	22,6	308,5	308,9	-	330,2	328,2	-	330,2	224,0	127,4	6,6	9		
23 (16-4-69)	134,0	4950	93,2	30,6	300,5	304,5	-	329,5	326,5	-	330,2	245,0	139,3	4,7	9		
16 (16-4-69)	132,2	4693	93,4	51,5	279,1	290,2	-	327,5	312,0	-	330,0	291,5	166,0	-0,8	9		
10 (16-4-69)	131,2	4510	92,9	67,5	262,5	278,4	-	321,0	302,9	-	328,7	333,3	189,7	-3,9	9		
46 (16-4-69)	132,3	4340	93,0	90,1	240,5	264,2	-	305,5	293,7	-	328,0	361,3	205,5	-11,1	9		
56 (16-4-69)	132,7	4215	93,0	108,9	222,0	246,0	-	292,2	271,0	-	322,7	387,0	220,3	-16,5	9		
65 (16-4-69)	132,4	4100	93,0	129,2	204,0	233,0	-	288,2	261,0	-	308,0	418,5	237,9	-21,7	9		
64 (26-3-69)	136,2	8620	157,1	21,0	311,0	310,0	-	331,2	324,7	331,0	331,0	253,9	144,3	0,9	9		
10 (2-4-69)	137,1	8580	157,0	24,1	308,5	306,2	-	331,5	326,0	331,5	331,5	261,0	148,5	-0,1	9		
57 (26-3-69)	132,7	8330	157,4	31,3	299,5	300,5	-	327,5	317,0	329,5	329,5	276,0	156,9	-2,9	9		
45 (26-3-69)	133,2	8100	156,8	40,7	290,5	294,7	-	327,0	307,2	330,0	329,8	300,8	170,9	-6,0	9		
21 (24-3-69)	131,7	7871	153,4	41,9	287,8	291,0	-	322,2	305,2	329,3	329,1	297,8	169,3	-6,4	9		
32 (26-3-69)	132,6	7870	157,7	55,0	275,8	277,2	-	320,3	296,2	329,8	329,0	337,1	191,8	-10,6	9		
34 (24-3-69)	132,5	7610	156,1	66,0	264,7	270,5	-	308,0	288,0	329,2	327,2	355,0	202,1	-14,2	9		
21 (26-3-69)	132,0	7565	158,0	75,2	255,3	262,2	-	304,7	277,0	325,7	320,5	378,5	215,2	-17,1	9		
49 (24-3-69)	132,5	7358	155,2	80,8	250,0	257,2	-	302,0	275,0	328,5	323,3	389,5	221,6	-18,6	9		
25 (27-3-69)	132,4	7400	156,5	81,5	249,2	258,2	-	300,0	277,5	327,0	316,2	380,0	216,0	-19,5	9		
9 (26-3-69)	132,6	7280	156,0	90,3	240,5	251,2	-	295,0	264,0	320,0	314,0	393,0	223,7	-22,5	9		
88 (1-4-69)	132,5	7220	154,9	90,8	240,0	247,2	-	293,0	270,2	316,2	319,2	390,0	221,8	-22,7	9		
71 (26-3-69)	132,4	7262	156,8	94,7	236,0	249,8	-	288,2	268,7	318,2	308,0	378,5	215,5	-25,1	9		
7 (27-3-69)	132,7	7246	156,8	95,8	235,5	245,7	-	292,2	272,0	318,5	301,2	389,5	221,5	-25,1	9		
7 (25-3-69)	132,4	7150	156,3	102,7	228,0	236,0	-	289,7	256,2	315,0	306,7	405,6	230,8	-26,9	9		
18 (25-3-69)	132,7	7120	156,9	108,4	222,5	236,5	-	287,0	250,7	314,0	300,0	418,4	237,9	-28,7	9		
18 (27-3-69)	132,3	7030	156,0	113,1	217,5	231,0	-	281,0	259,0	313,2	290,7	421,0	239,5	-30,2	9		
40 (25-3-69)	132,0	6960	156,7	123,4	207,1	222,2	-	277,0	242,2	308,0	294,7	454,3	258,8	-32,5	9		
30 (25-3-69)	132,2	6914	156,6	128,1	202,5	217,5	-	275,5	236,0	310,2	292,2	464,0	222,7	-33,9	9		

Follows TABLE VI - Burnout Experiments SET II.3 - Nominal pressure: 132 ata

Run	Pressure ata	Flow l/h	Mass flow rate gr/cm^{2}sec.	Inlet °C subcooling	Inlet °C temperature	Exit temperature						Power kw.	Heat flux watt / cm^2	Exit quality %	Burnout rods position in the lattice		
						a	a'	b	b'	c	c'				central	side	corner
58 (31-3-69)	134,1	12380	225,3	19,6	311,5	306,7	-	329,1	321,7	329,6	329,8	307,0	174,6	-0,3	9		
65 (31-3-69)	132,5	12210	225,6	24,0	306,8	303,1	-	327,7	316,2	329,1	329,1	317,4	180,7	-2,2	9		
48 (27-3-69)	132,0	12020	227,4	31,5	299,0	297,0	-	324,2	313,0	329,0	328,7	348,0	198,1	-4,8	9		
46 (28-3-69)	132,4	11995	227,8	33,1	297,6	295,8	-	325,5	315,5	329,2	329,0	348,0	198,1	-5,6	9		
51 (31-3-69)	133,1	11770	225,1	36,2	294,9	293,7	-	322,5	309,3	329,3	327,5	353,1	201,0	-6,8	9		
40 (28-3-69)	132,4	11630	226,7	43,0	287,7	286,2	-	318,0	307,5	328,5	324,5	377,0	214,5	-9,1	9		
37 (27-3-69)	132,2	11380	224,9	48,6	282,0	285,0	-	312,5	298,2	327,2	323,3	394,2	224,2	-10,8	9		
43 (31-3-69)	132,7	11240	225,4	55,4	275,5	274,7	-	311,2	293,0	324,5	318,5	402,2	229,0	-13,7	9		
36 (31-3-69)	132,5	11170	226,7	60,8	270,0	273,7	-	310,5	289,5	322,0	315,8	430,0	244,5	-15,1	9		
31 (28-3-69)	132,8	11120	226,3	62,2	268,7	269,8	-	306,5	288,7	322,7	316,0	423,0	240,6	-16,0	9		
59 (27-3-69)	132,3	10900	224,8	68,6	262,0	266,7	-	303,8	281,7	323,0	314,2	435,6	248,0	-18,1	9		
13 (28-3-69)	131,7	10850	226,9	74,6	254,5	256,0	-	300,5	279,8	318,5	308,2	458,0	260,6	-20,4	9		
24 (31-3-69)	132,7	10698	225,1	79,6	251,3	254,5	-	298,0	278,7	313,0	304,7	472,5	268,8	-21,5	9		
63 (1-4-69)	132,4	10630	224,9	82,5	248,2	252,2	-	293,0	273,5	313,2	304,0	489,5	278,5	-22,0	9		
47 (1-4-69)	133,2	10625	224,8	83,2	248,0	250,0	-	293,0	269,3	313,5	302,0	488,0	277,8	-22,6	9		
37 (1-4-69)	132,2	10615	225,1	83,8	246,7	250,0	-	293,0	269,8	313,5	301,7	486,0	276,4	-22,7	9		
14 (31-3-69)	132,4	10500	223,9	87,2	243,5	249,3	-	293,0	275,0	311,2	302,2	499,0	283,8	-23,6	9		
14 (1 - 4-69)	132,0	10515	224,8	88,6	241,9	246,0	-	294,0	264,2	311,7	303,6	502,0	285,7	-24	9		

Burnout Experiments: SET II.3

TABLE VII

Nominal pressure: 157 ata

Run	Pressure ata	Flow l / h	Mass flow rate gr/cm²sec.	Inlet °C subcooling	Inlet °C temperature	Exit temperature						Power Kw.	Heat flux Watt/cm².	Exit quality %	Burnout rods position in the lattice		
						a	a'	b	b'	c	c'				Central	Side	Corner
14 (10-4-69)	157,7	8805	155,8	24,3	320,2	319,5	-	340,5	334,7	343,5	343,7	243,0	138,2	-3,2	9		
9 (10-4-69)	157,2	8800	156,0	24,6	319,7	317,3	-	339,8	334,2	343,0	344,0	246,5	140,3	- 3,1	9		
6 (10-4-69)	158,0	8380	158,0	43,7	301,0	300,7	-	329,3	320,7	342,7	338,6	290,3	165,1	-12,0	9		
10 (11-4-69)	157,0	7830	155,7	64,0	280,2	281,7	-	322,5	310,5	336,5	327,7	341,4	194,1	-19,2	9		
52 (11-4-69)	156,5	7690	156,3	73,7	270,2	275,0	-	314,7	302,4	-	321,2	342,8	194,9	-24,1	9		
75 (11-4-69)	157,2	7630	156,2	77,8	266,5	281,0	-	310,2	293,7	-	321,7	364,5	207,3	-25,0	9		
18 (11-4-69)	156,5	7530	156,4	84,7	259,2	263,0	-	303,0	296,2	329,8	315,3	378,2	215,2	-27,4	9		
31 (11-4-69)	156,9	7415	155,6	90,9	253,3	259,3	-	303,3	291,7	324,7	308,2	380,2	216,3	-30,3	9		
26 (11-4-69)	157,0	7290	155,6	100,5	243,7	250,2	-	297,0	284,2	322,4	302,7	398,7	226,8	-33,9	9		
37 (11-4-69)	157,8	7060	155,8	122,4	222,2	235,0	-	282,5	268,1	311,5	285,5	444,2	252,7	-41,8	9		
41 (11-4-69)	155,4	6880	155,9	140,1	203,2	223,2	-	266,0	257,5	307,0	273,2	469,4	267,0	-47,3	9		
84 (11-4-69)	157,0	6880	156,1	142,2	202,0	232,7	-	268,0	252,2	-	279,2	478,0	272,0	-48,5	9		
21 (2-4-69)	157,7	16870	297,8	23,8	320,8	316,0	-	336,0	330,7	342,2	242,5	371,5	211,3	-5,8	9		
52 (10-4-69)	157,0	16940	300,6	24,7	319,5	314,9	-	336,7	332,2	340,7	338,4	396,0	225,3	-5,7	9		
49 (2-4-69)	156,5	16660	300,0	28,6	315,3	309,0	-	335,8	327,5	341,0	342,0	444,0	235,6	-6,4	9		
26 (2-4-69)	156,0	16355	300,9	34,6	309,1	304,2	-	331,5	323,6	337,5	339,3	435,2	247,4	-10,3	9		
39 (2-4-69)	157,2	15800	298,1	43,5	300,8	296,7	-	327,0	318,2	335,0	337,0	473,2	269,3	-14,2	9		
54 (2-4-69)	157,4	15580	298,7	49,5	294,9	290,5	-	324,5	310,0	331,0	336,7	518,0	294,7	-16	9		
63 (1-4-69)	157,0	15330	297,0	53,2	291,0	287,5	-	318,5	312,2	-	324,2	535,5	304,7	-17,3	9		

Burnout Experiments: SET II.4

TABLE VIII

Nominal pressures: 45 and 84 ata

Run	Pressure ata	Flow l/h	Mass flow rate gr/cm^2 sec.	Inlet °C subcooling	Inlet °C temperature	Exit temperature a	a'	b	b'	c	c'	Power kw.	Heat flux watt / cm^2	Exit quality %	Burnout rods position in the lattice: central	side	corner
100 (26-11-68)	43	2320	50,9	13,2	240,2	-	251,0	251,2	251,0	251,0	251,5	272,3	154,8	20,5	9		
97 (26-11-68)	47	2280	50,8	27,4	231,5	-	256,0	257,2	257,0	257,2	257,7	311,5	177,3	22,7	9		
76 (26-11-68)	90	2590	51,5	8,9	293,0	-	296,7	299,0	298,7	298,7	299,7	229,6	130,6	27,0	9		
69 (26-11-68)	87	2520	52,0	22,0	277,5	-	294,4	296,2	296,0	296,0	298,0	266,9	151,9	26,6	9		
34 (26-11-68)	86	2410	50,8	31,4	267,2	-	291,5	295,8	295,6	296,0	296,0	283,5	161,1	26,2	9		
10 (26-11-68)	83	2320	51,5	56,7	239,5	-	290,5	294,2	294,2	293,7	294,9	323,4	183,8	22,3	9		
40 (26-11-68)	86	2255	51,3	75,9	222,7	-	295,0	296,2	296,5	296,0	297,7	348,5	198,4	24,5	9		
84 (26-11-68)	89	4790	96,8	14,6	286,5	-	296,0	298,7	298,7	298,5	299,7	289,3	164,6	14,6	9		
60 (26-11-68)	87	4600	95,3	23,8	275,7	-	292,5	296,2	296,0	295,8	296,7	310,6	176,7	13,1	9		
16 (26-11-68)	84	4490	96,5	39,5	257,5	-	290,0	295,3	295,3	295,1	295,6	341,5	194,4	9,5	9		
23 (26-11-68)	82	4280	93,6	47,1	248,2	-	-	294,2	293,2	294,4	294,4	359,0	204,2	9,0	9		
52 (26-11-68)	82	4130	93,3	67,6	227,7	-	-	291,2	287,6	293,7	294,4	399,5	227,4	5,3	9		

Burnout Experiments: SET II.4

TABLE IX

Nominal pressure: 132 ata

Run	Pressure ata	Flow l/h	Mass flow rate gr/cm^2 sec.	Inlet °C subcooling	Inlet °C temperature	Exit temperature						Power kw.	Heat flux watt / cm^2	Exit quality %	Burnout rods position in the lattice		
						a	a'	b	b'	c	c'				central	side	corner
122 (25-11-68)	132	2740	51,9	21,4	309,1	-	323,9	327,7	327,5	327,5	328,7	187,2	106,7	18,2	9		
73 (25-11-68)	137	2640	52,2	38,5	294,9	-	326,2	331,0	330,2	330,2	331,5	211,7	120,5	13,9	9		
63 (25-11-68)	138,5	2500	51,0	52,2	282,0	-	324,0	330,2	330,2	331,7	332,2	228,7	130,0	11,1	9		
29 (22-11-68)	137	2390	51,0	71,6	261,7	-	314,0	330,2	329,8	330,2	331,7	248,1	141,1	5,8	9		
38 (25-11-68)	135	2300	51,2	94,7	237,5	-	314,6	328,7	325,2	330,0	331,0	298,5	169,9	4,5	9		
30 (25-11-68)	135	2250	51,2	109,2	223,0	-	299,7	327,5	319,0	329,3	329,8	315,8	179,6	1,4	9		
113 (25-11-68)	135	5180	97,7	21,5	310,7	-	317,0	329,8	328,7	329,3	330,5	207,4	117,9	5,5	9		
79 (25-11-68)	134	4910	96,1	33,1	298,5	-	305,7	328,4	324,2	329,3	330,7	235,0	133,7	2,5	9		
12 (22-11-68)	136	4640	95,1	52,1	280,7	-	287,6	323,8	320,2	330,2	331,5	250,7	142,7	-4,8	9		
19 (22-11-68)	133	4420	92,7	60,8	270,2	-	275,2	321,5	311,0	329,8	329,8	272,1	154,8	-5,8	9		
20 (25-11-68)	134	4280	94,7	90,4	241,2	-	249,9	299,8	286,5	328,9	329,8	323,9	184,4	-14,4	9		
10 (25-11-68)	134	4450	101,2	108,4	223,2	-	232,0	284,0	269,2	326,2	329,8	341,7	194,4	-22,2	9		
103 (25-11-68)	134	8600	161,1	19,1	312,5	-	319,0	329,8	329,6	329,8	330,2	238,2	135,6	1,2	9		
87 (25-11-68)	136	8100	157,2	31,3	301,5	-	307,5	326,2	323,8	330,5	331,0	276,2	157,2	-2,7	9		
50 (22-11-68)	129	7700	157,3	46,7	282,0	-	288,7	315,3	304,2	328,7	328,7	295,2	168,0	-8,1	9		
128 (25-11-68)	130	7500	155,6	54,3	275,0	-	280,2	307,5	307,0	326,2	328,2	331,7	188,6	-9,4	9		
48 (22-11-68)	130	7350	157,5	70,2	259,1	-	267,0	301,0	297,7	326,7	328,7	372,5	211,8	-14,2	9		
42 (25-11-68)	134	7130	157,1	87,9	243,7	-	251,0	285,2	280,2	322,9	326,2	394,6	224,5	-21,2	9		
97 (25-11-68)	134	12500	234,9	19,9	311,7	-	317,7	328,9	328,4	328,9	330,0	276,2	157,2	-1,8	9		
93 (25-11-68)	134,5	11600	226,4	32,2	299,7	-	305,7	320,5	319,7	329,3	330,0	316,4	179,9	-6,1	9		
61 (22-11-68)	131,5	10860	223,2	50,8	279,4	-	284,7	307,0	300,0	326,2	326,0	364,5	207,1	-12,3	9		
52 (25-11-68)	134,5	8650	183,0	66,2	265,7	-	272,7	296,0	290,0	322,7	326,2	417,1	237,4	-14,0	9		

Burnout Experiments: SET 11.5

TABLE X

Nominal pressure: 84 ata

Run	Pressure ata	Flow l/h	Mass flow rate $gr/cm^2 sec.$	Inlet °C subcooling	Inlet °C temperature	Exit temperature						Power kw.	Heat flux $watt/cm^2$	Exit quality %	Burnout rods position in the lattice		
						a	a'	b	b'	c	c'				central	side	corner
130 (16-12-68)	88	2615	51,2	9,8	290,5	292,7	295,1	297,7	299,2	298,0	299,5	336,9	129,3	40,2		4-8	
120 (16-12-68)	87	2460	51,1	35,5	264,0	293,2	296,7	296,7	299,0	296,7	299,7	383,3	146,9	37,0		4-8	
94 (16-12-68)	85	2430	52,5	55,6	242,2	290,2	292,5	295,3	295,3	295,5	295,3	417,9	160,3	33,0		4	
106 (16-12-68)	88	2320	51,2	70,6	229,7	294,9	296,0	299,2	297,2	299,5	297,2	428,7	164,5	31,2		4	
111 (16-12-68)	90	2300	51,5	81,7	220,2	295,5	297,5	299,7	299,7	300,0	300,0	460,0	176,6	31,6	9	4	
135 (16-12-68)	87	4940	98,0	14,3	285,2	293,0	294,9	296,5	296,7	296,7	297,5	445,3	170,8	24,7		8	
142 (16-12-68)	89	4820	97,5	23,9	277,2	294,9	296,7	299,7	299,7	300,0	300,2	468,1	179,5	23,1		8-4	

Burnout Experiments: SET II.5

TABLE XI

Nominal pressure: 132 ata

Run	Pressure ata	Flow l/h	Mass flow rate gr/cm^{2}sec.	Inlet °C subcooling	Inlet °C temperature	Exit temperature a	a'	b	b'	c	c'	Power kw.	Heat flux watt/cm^2	Exit quality %	Burnout rods position in the lattice: central	side	corner
22 (16-12-68)	139,5	2695	51,3	34,1	300,7	326,5	328,7	331,7	333,5	332,0	333,7	285,8	109,6	28,5	9	4	
53 (13-12-68)	134,5	2560	51,4	51,7	280,2	324,7	328,7	331,2	331,2	331,5	331,7	323,5	124,0	26,0	9	4	
21 (13-12-68)	135	2440	51,1	71,7	260,5	323,8	327,5	329,3	331,0	329,8	331,2	351,0	134,5	22,1	9	4-8	
29 (13-12-68)	132	2390	52,1	92,7	237,7	321,5	323,5	328,7	330,0	328,7	328,7	382,5	146,6	17,2	9	4-8	
41 (13-12-68)	136	2330	52,2	113,8	219,0	322,7	327,5	329,8	330,7	330,2	331,0	422,5	162,1	14,7	9	4	
33 (16-12-68)	137	5400	97,1	15,4	318	323,8	327,2	329,1	332,2	330,2	332,2	306,3	117,4	17,3	9	4	
93 (13-12-68)	136	4960	94,5	32,1	300,7	323,8	325,7	329,3	329,8	329,3	331,0	334,1	128,2	11,8	9	4	
62 (13-12-68)	134,5	4775	95,9	51,7	280,2	319,2	321,7	329,6	328,9	329,5	329,8	399,6	153,2	8,0	9		
10 (16-12-68)	134,5	4665	95,9	62,4	269,6	311,7	315,8	326,2	328,7	329,1	330,0	419,0	160,8	5,0	9		
7 (13-12-68)	129	4560	95,7	69,6	259,1	304,7	313,0	324,2	320,2	326,5	328,7	455,3	174,7	5,4	9		
39 (16-12-68)	138	8990	161,1	15,0	319,0	324,2	327,5	331,0	332,5	330,5	332,7	336,5	129,0	8,4	9		
59 (16-12-68)	134	8650	161,4	24,1	307,5	321,0	324,5	328,7	328,7	328,9	329,1	371,3	142,4	5,3	9		
77 (13-12-68)	134	8370	161,5	35,4	296,2	319,0	322,2	328,7	328,7	328,9	330,0	402,5	154,2	1,4	9		
69 (13-12-68)	136	7915	157,1	47,6	285,2	314,7	319,0	328,7	326,2	329,8	332,2	462,4	177,3	-0,6	9		
69 (16-12-68)	137	12940	235,0	18,0	315,3	324,2	326,7	329,8	330,0	330,0	330,2	406,2	155,8	3,6	9		
81 (16-12-68)	140	12525	229,4	22,1	313,0	324,7	328,7	332,7	332,7	333,0	333,5	436,6	167,4	2,8	9		
86 (13-12-68)	140	12080	227,1	30,1	305,0	321,0	325,5	331,5	330,2	331,7	331,5	456,5	175,0	-0,5	9		

Burnout Experiments: SET III

TABLE XII

Nominal Pressure: 84 ata

Run	Pressure ata	Flow l/h	Mass flow rate gr/cm^{2}sec.	Inlet °C subcooling	Inlet °C temperature	Exit temperature a	a'	b	b'	c	c'	Power Kw.	Average heat flux Watt / cm^2	Exit quality %	B.O. Axial Position on the Central Rod Z/L
7 (3-10-69)	85,5	2410	48,5	8,4	288,5	-	297,7	299,5	297,7	297,7	296,2	226,0	119,2	27,7	0,7 - 0,94 - 0,98
43 (2-10-69)	85,5	2370	48,7	16,6	280,2	-	298,2	299,7	298,0	298,5	296,5	237,3	125,3	26,2	0,94 - 0,98
38 (2-10-69)	87,4	2300	48,2	26,7	271,2	-	300,0	301,2	299,7	299,7	297,7	242,1	127,7	23,6	0,66 - 0,94 - 0,98
32 (2-10-69)	85,0	2310	49,5	37,7	259,6	-	299,0	300,5	298,7	299,2	297,0	256,4	135,3	21,1	0,66
25 (2-10-69)	85,0	2200	48,8	55,7	240,0	-	297,0	299,2	290,7	297,7	296,0	274,0	144,5	17,5	0,66
21 (2-10-69)	86,2	2170	49,6	77,3	220,0	-	298,0	299,7	298,0	298,7	296,7	288,5	152,2	12,1	0,66 - 0,84
51 (2-10-69)	87,4	2160	50,8	97,9	200,2	-	297,7	300,0	299,5	299,7	298,7	311,0	164,1	7,8	0,66
14 (2-10-69)	92,5	2100	49,4	101,1	200,0	-	298,7	302,4	302,2	303,6	302,2	294,8	155,6	5,2	0,52
56 (2-10-69)	85,9	2080	49,5	107,3	189,7	-	296,5	298,5	298,0	298,2	296,5	322,1	169,9	7,3	0,56 - 0,66

Burnout Experiments: SET III

TABLE XIII

Nominal pressure: 132 ata

Run	Pressure ata	Flow l/h	Mass flow rate gr/cm²sec.	Inlet °C subcooling	Inlet °C temperature	Exit temperature a	a'	b	b'	c	c'	Power Kw.	Average heat flux watt/ cm²	Exit quality %	B.O. Axial Position on the Central Rod Z/L
10 (22- 9-69)	135,0	2585	47,2	10,3	320,7	-	330,0	334,2	332,0	332,5	330,2	135,6	71,5	17,2	0,86
5 (22- 9-69)	135,0	2515	47,5	19,8	311,2	-	330,5	333,7	332,0	332,5	330,5	140,4	74,1	12,8	0,86
17 (3-10-69)	135,0	2410	47,4	33,3	297,7	-	332,0	334,0	331,7	332,2	330,2	171,0	90,2	11,8	0,66 - 0,84 - 0,94 - 0,98
32 (19 -9-69)	135,5	2410	48,5	42,9	288,5	-	324,2	330,5	331,2	332,5	330,5	173,7	91,7	7,3	0,69 - 0,86
26 (19- 9-69)	136,8	2200	46,2	61,4	270,5	-	324,5	331,0	330,5	333,5	330,0	192,0	101,3	3,5	0,86 - 0,94
18 (19- 9-69)	134,0	2180	47,6	81,5	249,0	-	309,6	325,2	323,0	330,0	327,2	209,0	110,3	-2,8	0,6 - 0,69 - 0,81
11 (19- 9-69)	130,0	2180	48,2	86,3	241,7	-	307,0	323,2	320,2	328,6	322,8	222,2	117,2	-2,5	0,69 - 0,81 - 0,9
24 (3-10-69)	133,0	2220	49,9	98,3	231,7	-	319,5	327,7	325,2	331,0	328,4	257,5	135,8	-3,0	0,52 - 0,56 - 0,66
16 (22-9- 69)	132,1	2140	49,0	109,7	219,7	-	303,0	322,2	320,0	322,2	321,5	258,7	136,5	-6,4	0,5
29 (3-10-69)	133,2	2140	50,3	130,5	199,5	-	293,7	314,9	302,2	301,5	321,5	275,0	145,1	-13,1	0,52
13 (9-10-69)	133,7	4950	94,4	22,6	308,0	-	325,2	329,1	330,0	332,2	329,8	173,0	91,3	1,8	0,94 - 0,98
18 (9-10-69)	134,1	4790	93,6	30,6	300,0	-	317,5	326,2	326,0	332,5	330,0	184,8	97,5	-0,9	0,94 - 0,98
6 (9-10-69)	134,6	4670	91,3	30,9	300,0	-	316,7	324,0	327,5	332,7	330,2	182,0	96,0	-1,0	0,94 - 0,98
28 (8-10-69)	133,4	4615	94,4	47,9	282,2	-	304,7	315,0	320,5	332,0	329,5	220,3	116,3	-5,6	0,94
33 (9-10-69)	134,0	4355	93,0	68,7	261,7	-	290,5	299,5	310,7	332,0	330,0	234,8	124,0	-13,5	0,8 - 0,89
21 (8-10-69)	134,0	4420	95,2	73,0	257,2	-	281,0	302,0	307,5	332,2	329,2	253,6	133,7	-14,2	0,89
14 (21-10-69)	133,2	4275	93,6	81,8	248,2	256,7	259,8	277,0	288,2	309,6	321,2	254,9	134,5	-17,0	0,7 - 0,75
7 (8-10-69)	133,3	4200	93,9	94,8	235,2	-	260,7	283,5	288,0	331,7	328,6	278,5	146,9	-20,3	0,52
14 (8-10-69)	133,3	4075	93,1	109,3	220,7	-	251,2	279,0	291,2	330,7	325,0	303,7	160,1	-23,7	0,52 - 0,66 - 0,8 - 0,89
4 (10-10-69)	133,1	4015	92,9	117,7	212,2	-	248,0	264,0	282,2	317,2	324,5	284,9	150,4	-28,7	0,61 - 0,66 - 0,7 - 0,75
3 (21-10-69)	134,0	3970	92,0	120,0	210,5	233,0	220,5	272,5	256,7	316,5	285,5	290,7	153,3	-29,1	0,61 - 0,66 - 0,7
29 (9-10-69)	133,1	3960	92,7	127,0	203,0	-	248,7	250,5	277,7	313,2	323,6	292,9	154,6	-31,5	0,8
24 (9-10-69)	133,1	3960	93,0	129,0	201,0	-	228,0	258,4	264,0	320,0	316,7	307,5	162,2	-31,0	0,52 - 0,56 - 0,8 - 0,89
7 (21-10-69)	133,3	3810	89,6	130,1	200,0	218,7	216,0	246,0	248,0	312,5	287,0	304,4	160,6	-30,7	0,61 - 0,66 - 0,7
6 (11-11-69)	134,6	8080	152,4	19,4	311,5	-	324,2	327,7	-	330,0	-	225,0	118,7	0,17	0,66
11 (11-11-69)	133,3	8055	156,9	28,8	301,2	-	-	323,2	-	328,8	-	250,0	131,9	-2,3	0,66 - 0,75 - 0,8

Follows TABLE XIII - Burnout Experiments: SET III - Nominal pressure: 132 ata

Run	Pressure ata	Flow l/h	Mass flow rate gr/cm^{2}sec.	Inlet °C subcooling	Inlet °C temperature	Exit temperature						Power Kw.	Average heat flux watt / cm^2	Exit quality %	B.O. Axial Position on the Central Rod Z/L
						a	a'	b	b'	c	c'				
31 (21-10-69)	133,5	8240	163,1	34,9	295,2	-	301,5	-	315,2	-	329,2	257,7	135,8	-6,1	0,75 - 0,8 - 0,84 - 0,89
12 (22-10-69)	135,0	7950	160,6	43,7	287,4	-	291,7	-	310,2	333,0	330,0	270,9	143,0	-9,6	0,7 - 0,75 - 0,8 - 0,84
25 (21-10-69)	133,5	7950	163,1	49,2	281,0	-	286,2	-	306,2	-	328,6	295,5	155,9	-10,6	0,52 - 0,75 - 0,8
15 (11-11-69)	129,5	7830	161,0	47,8	280,0	-	299,0	310,2	-	326,7	-	287,1	151,5	-10,2	0,66 - 0,75
5 (22-10-69)	134,0	7455	157,8	64,5	266,0	268,2	270,0	-	291,5	332,2	324,2	307,6	162,2	-16,5	0,7 - 0,75
22 (21-10-69)	133,0	7520	161,6	71,7	258,5	-	281,5	-	288,2	315,0	325,2	322,5	170,1	-18,9	0,52
21 (11-11-69)	133,2	7025	153,6	81,3	248,7	253,7	262,0	292,7	-	323,5	-	346,3	182,8	-20,8	0,61 - 0,66
27 (26-11-69)	135,0	11560	216,1	17,2	314,0	-	-	319,7	-	331,5	330,5	247,2	130,3	- 1,4	0,66
23 (26-11-69)	134,2	11390	217,8	23,3	307,2	-	-	315,6	-	330,0	329,0	266,0	140,3	-3,9	0,66
14 (26-11-69)	133,5	11100	216,9	29,9	300,2	-	-	309,8	-	329,5	327,7	277,0	146,1	-6,4	0,66
9 (26-11-69)	134,5	10800	216,5	40,3	290,5	-	-	302,2	-	329,0	325,2	302,3	159,6	-10,3	0,66
36 (26-11-69)	134,2	10940	225,0	50,8	279,8	-	-	293,0	-	325,2	318,5	336,3	177,5	-14,3	0,66
6 (26-11-69)	133,4	10960	225,8	51,1	279,0	-	-	292,5	-	323,0	318,0	344,3	181,7	-14,0	0,66
10 (28-11-69)	133,6	10550	220,9	58,7	271,5	-	-	288,5	-	325,0	312,5	367,5	193,9	-16,6	0,66
17 (28-11-69)	134,5	10550	225,3	69,0	261,7	-	-	278,7	-	319,0	307,2	387,7	204,4	-20,4	0,66

Burnout Experiments: SET III

TABLE XIV

Nominal Pressure: 157 ata

Run	Pressure ata	Flow l/h	Mass flow rate gr/cm²sec.	Inlet °C subcooling	Inlet °C temperature	Exit temperature						Power Kw.	Average heat flux Watt / cm²	Exit quality %	B.O. Axial Position on the Central Rod Z/L
						a	a'	b	b'	c	c'				
17 (20-11-69)	157,8	8550	157,6	26,6	318,0	-	-	332,7	320,5	343,7	340,7	223,2	117,8	-5,5	0,66
12 (20-11-69)	156,5	8220	155,9	34,0	310,0	-	-	327,7	316,2	342,7	338,2	239,0	126,1	-8,7	0,66
3 (20-11-69)	153,5	7850	152,7	40,9	301,5	-	-	321,7	312,0	340,7	333,0	252,4	133,2	-10,9	0,66
3 (21-11-69)	153,2	7890	155,4	45,0	297,2	-	-	314,0	294,8	339,8	332,0	263,5	139,0	-12,6	0,66
22 (20-11-69)	151,0	7890	158,0	50,1	291,0	-	-	312,0	291,0	338,7	328,6	280,9	148,2	-14,0	0,66
13 (27-11-69)	150,0	7790	156,4	50,6	290,0	-	-	306,5	290,0	339,0	330,7	270,3	142,7	-14,5	0,66
9 (27-11-69)	152,3	7620	157,2	63,3	278,5	-	-	297,5	278,7	334,6	321,7	290,5	153,3	-20,3	0,66
4 (28-11-69)	157,0	17140	302,8	16,0	328,2	-	-	332,2	325,2	343,0	341,2	263,0	138,7	-4,0	0,66
7 (27-11-69)	157,2	16400	299,3	23,6	320,7	-	-	327,5	317,7	342,2	338,0	300,8	158,8	-7,7	0,66
3 (27-11-69)	156,0	15680	297,4	33,7	310,0	-	-	317,5	308,2	338,0	332,2	325,1	171,5	-12,8	0,66
8 (27-11-69)	147,5	15350	298,5	37,5	301,7	-	-	311,5	299,7	333,5	325,5	350,0	184,6	-12,6	0,66

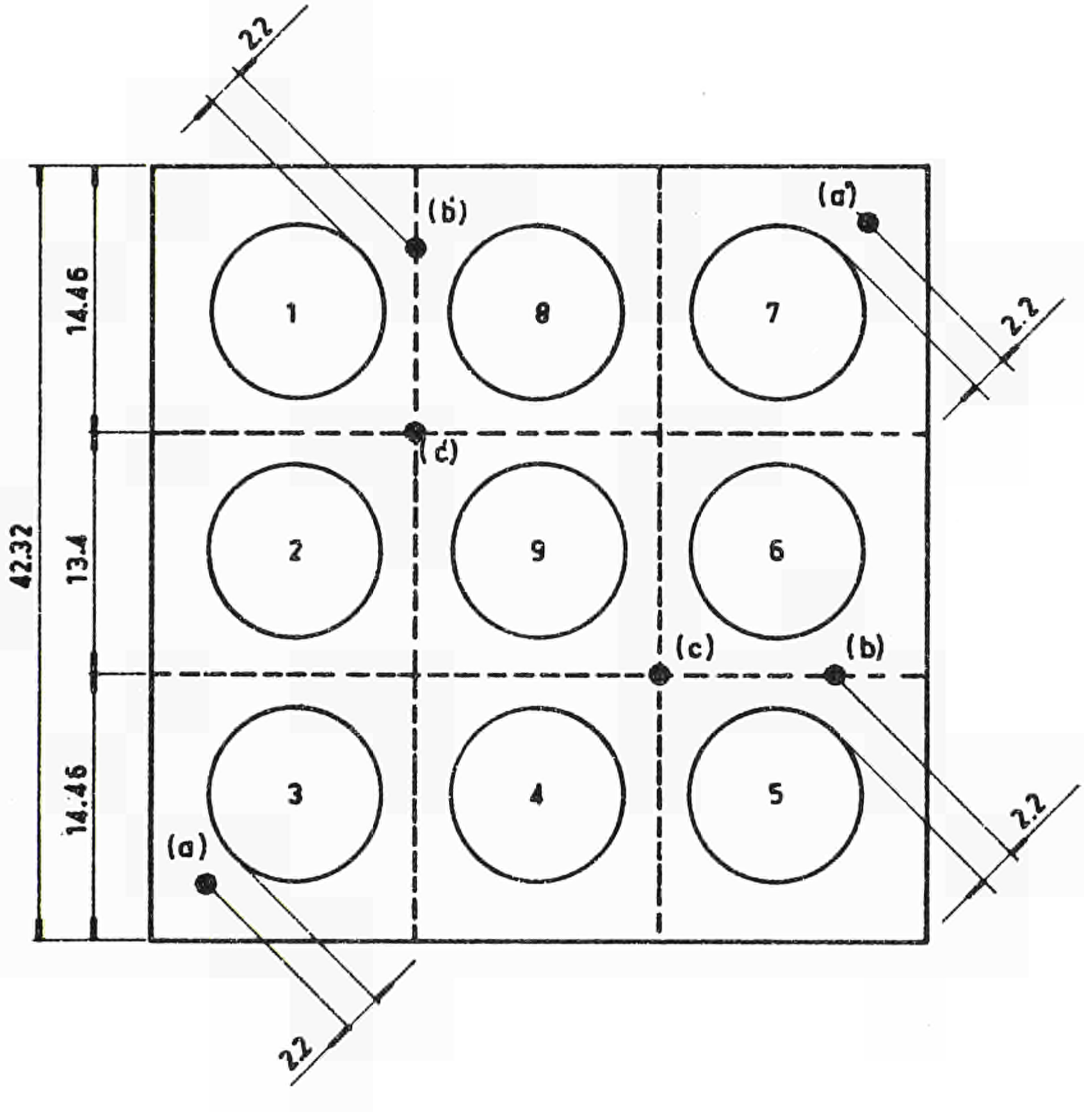
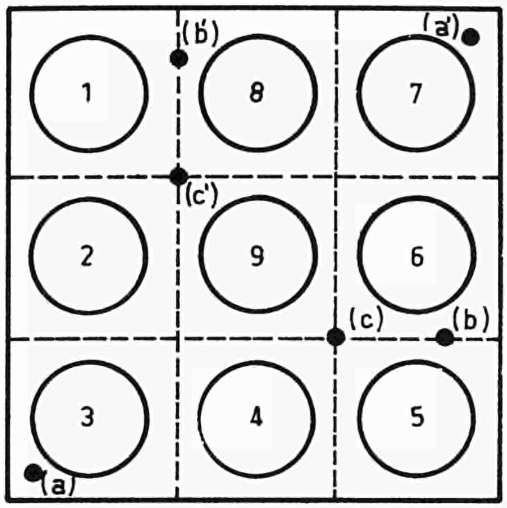


Fig. 1 - Schematic cross section of the square channel showing location of the water exit temperature probes and rod identification numbers.



ROD SPECIFICATION		SYMBOLS
Base Load	Axially Uniform	○
Base Load	Axially Non Unif.	⊗
23% Overload	Axially Uniform	23
70% Overload	Axially Uniform	70
Unheated		●
Unheated	Cluster Control	◉

SET nº	ROD POSITION IN THE LATTICE								
	1	2	3	4	5	6	7	8	9
I (*)	○	○	○	○	○	○	○	○	○
II.1	○	○	○	○	○	○	○	○	◉
II.2	○	●	○	●	○	●	○	○	○
II.3	●	○	●	23	●	23	●	○	23
II.4	●	○	●	23	◉	23	●	○	23
II.5	○	○	○	70	23	23	23	70	70
III	●	⊗	●	⊗	◉	⊗	●	⊗	⊗

(*) Channel with obstruction in the flow area as indicated in Fig. 3.

Fig. 2 - Identification scheme of the singularities in the bundles for each Set of experiments.

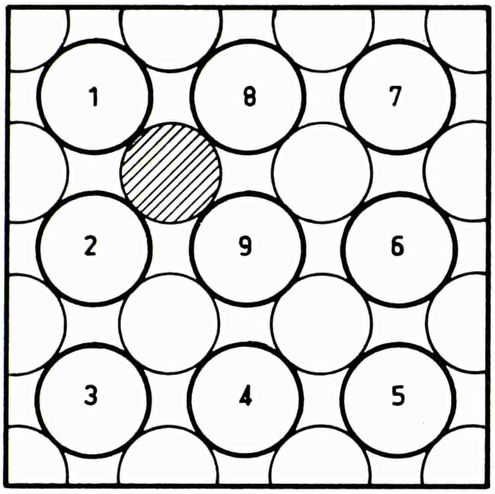


Fig. 3 - Bundle cross section at grids elevation
showing the obstructed ferrule.

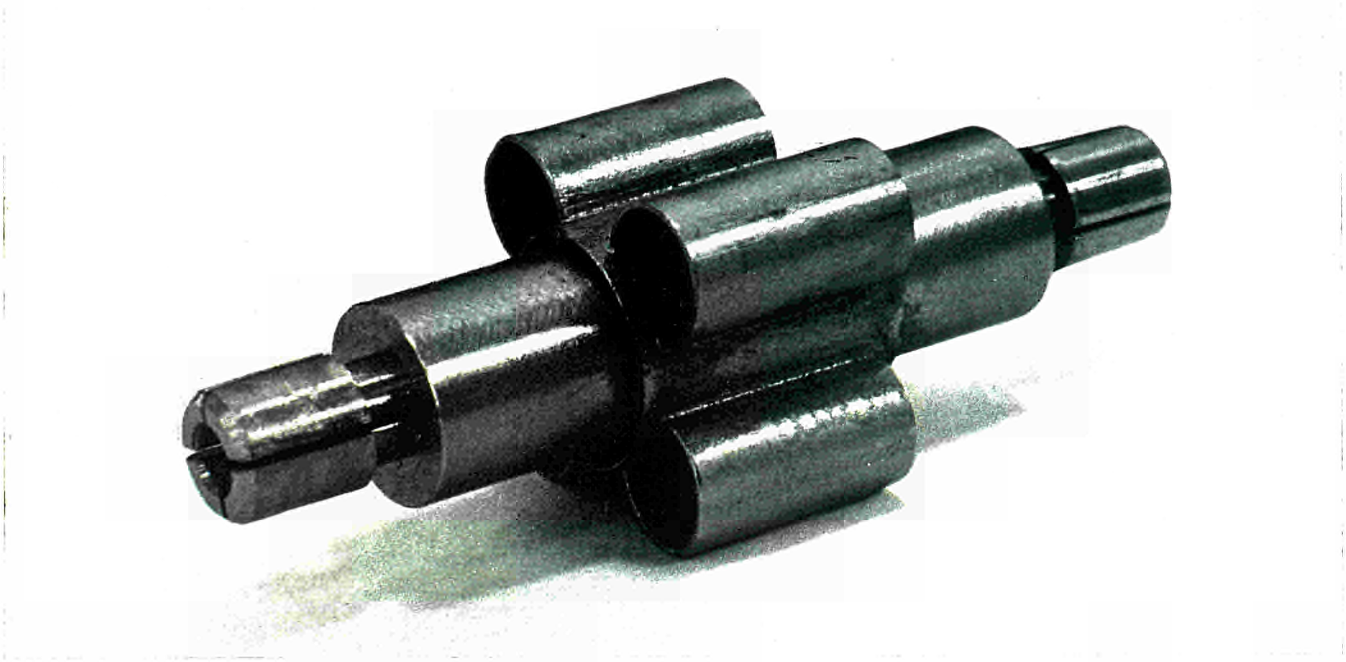


Fig. 4 - Close-up view of the special ferrules used in the
rod bundle with "Cluster Control" unheated rod.

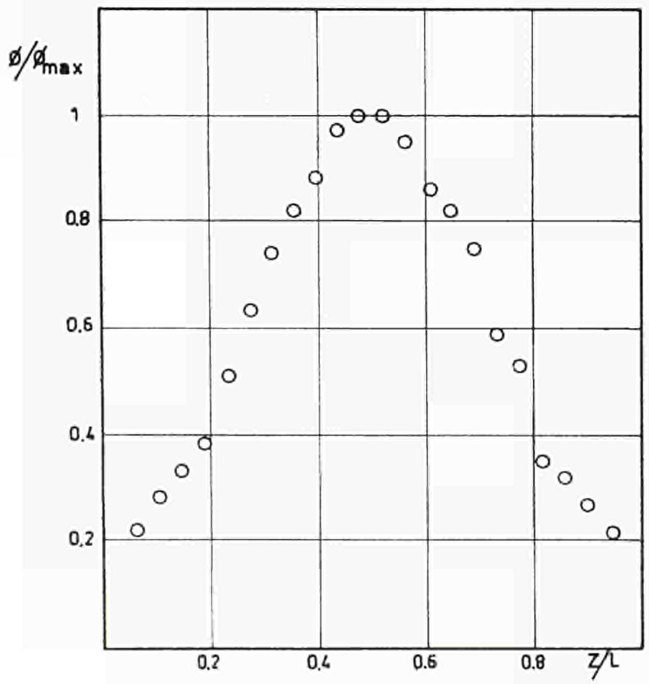


Fig. 5 - Longitudinal heat flux distribution of the central rod of the bundle employed in Set. III experiments.

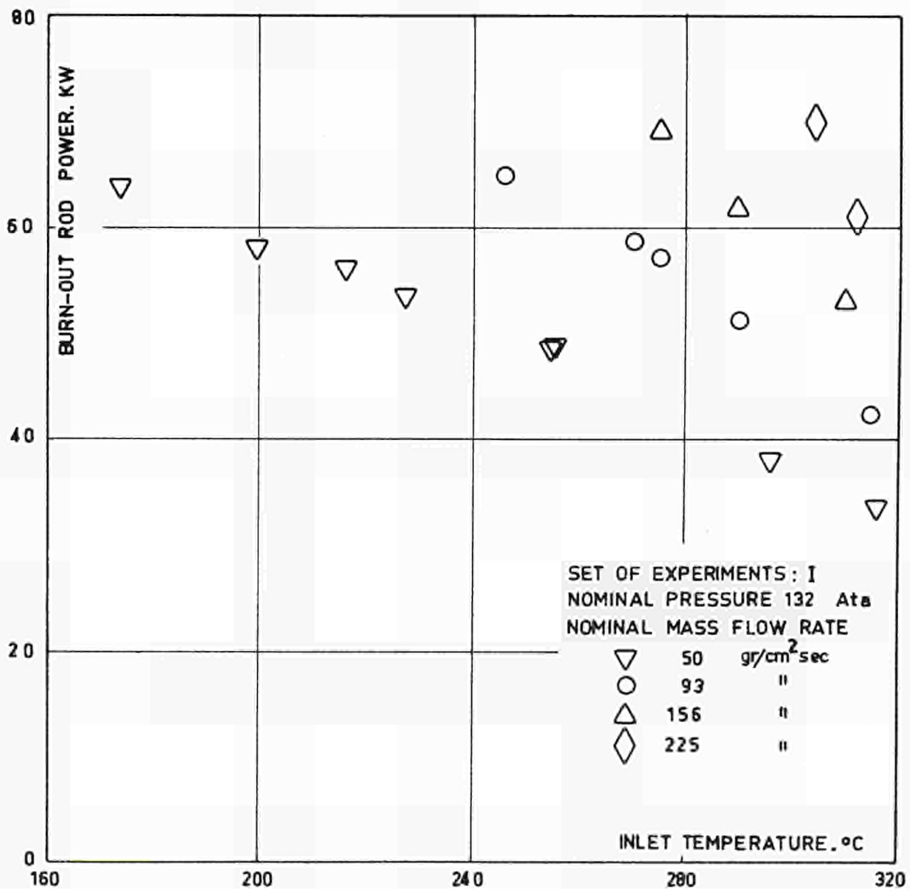


Fig. 6 - Burn-out experiments at 132 ata: Set I

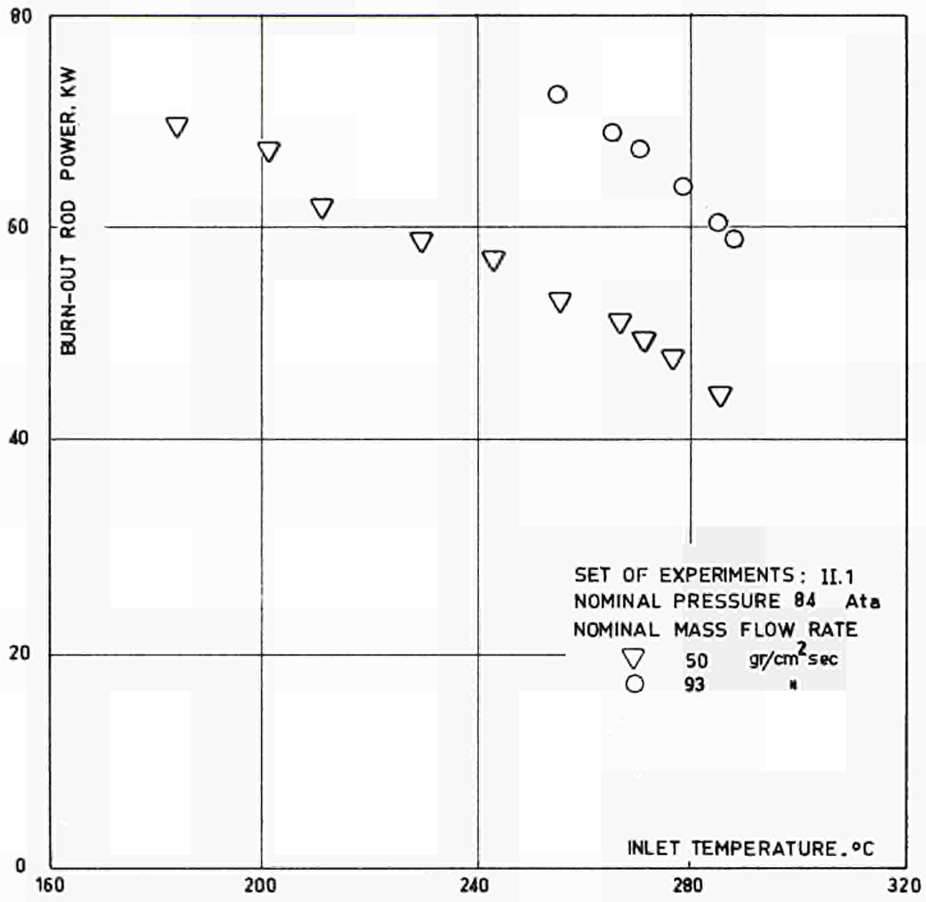


Fig. 7 - Burn-out experiments at 84 ata: Set II.1

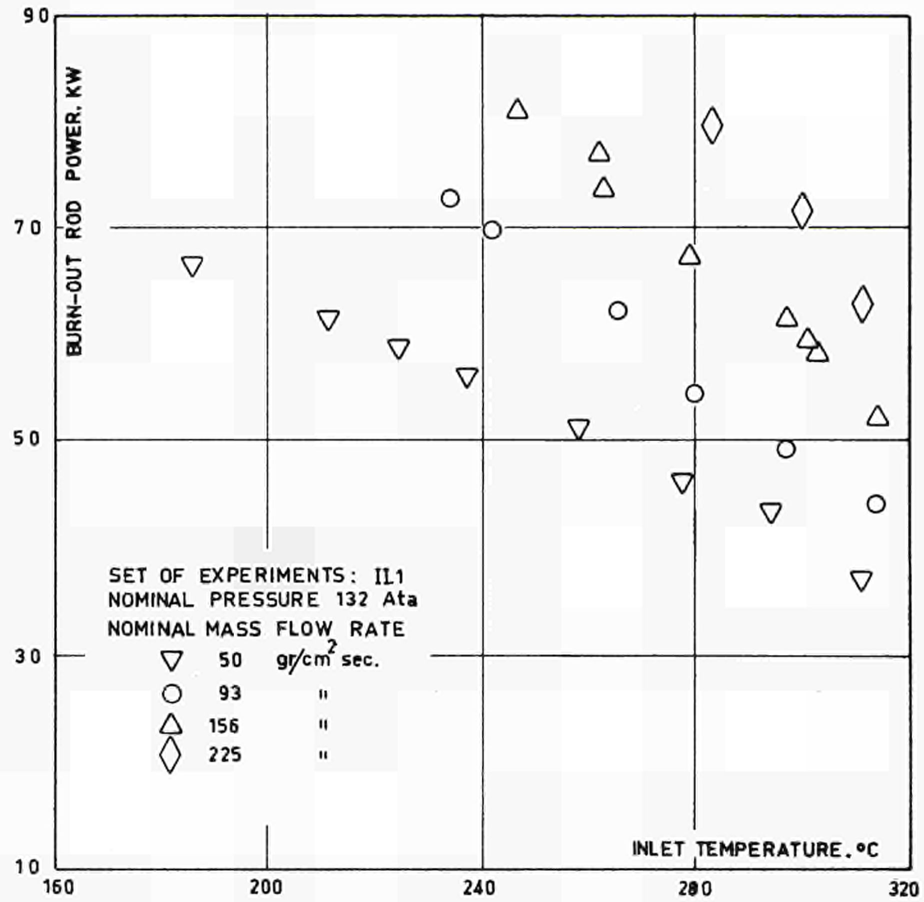


Fig. 8 - Burn-out experiments at 132 ata: Set II.1

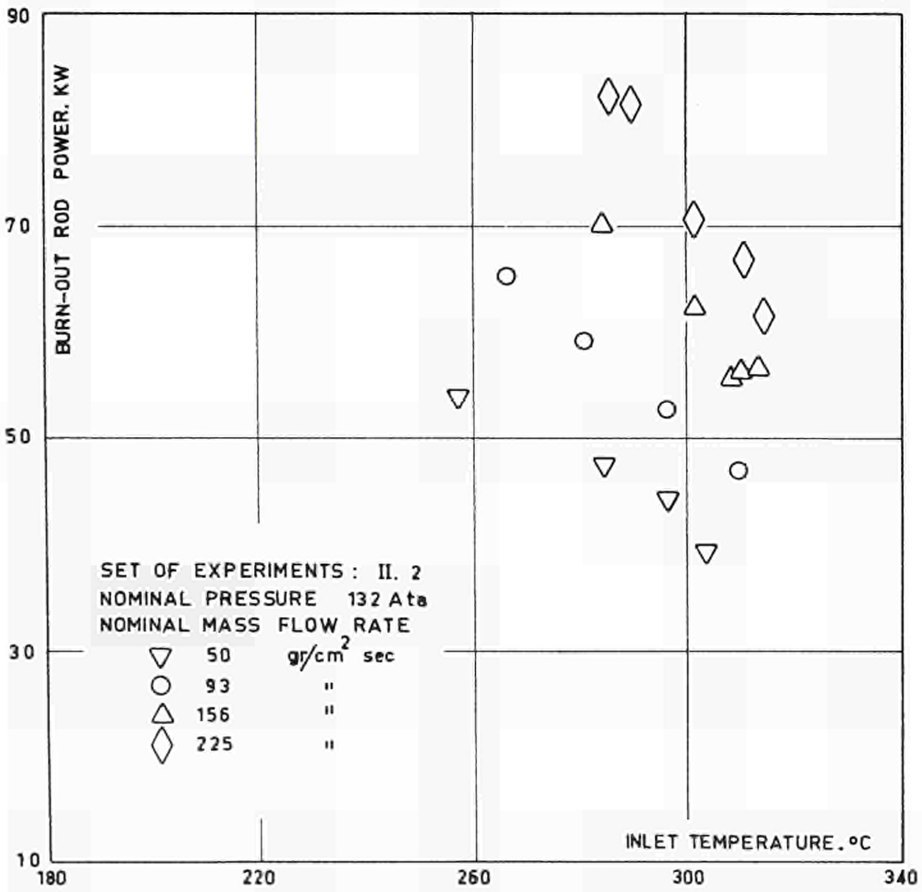


Fig. 9 - Burn-out experiments at 132 ata: Set II.2

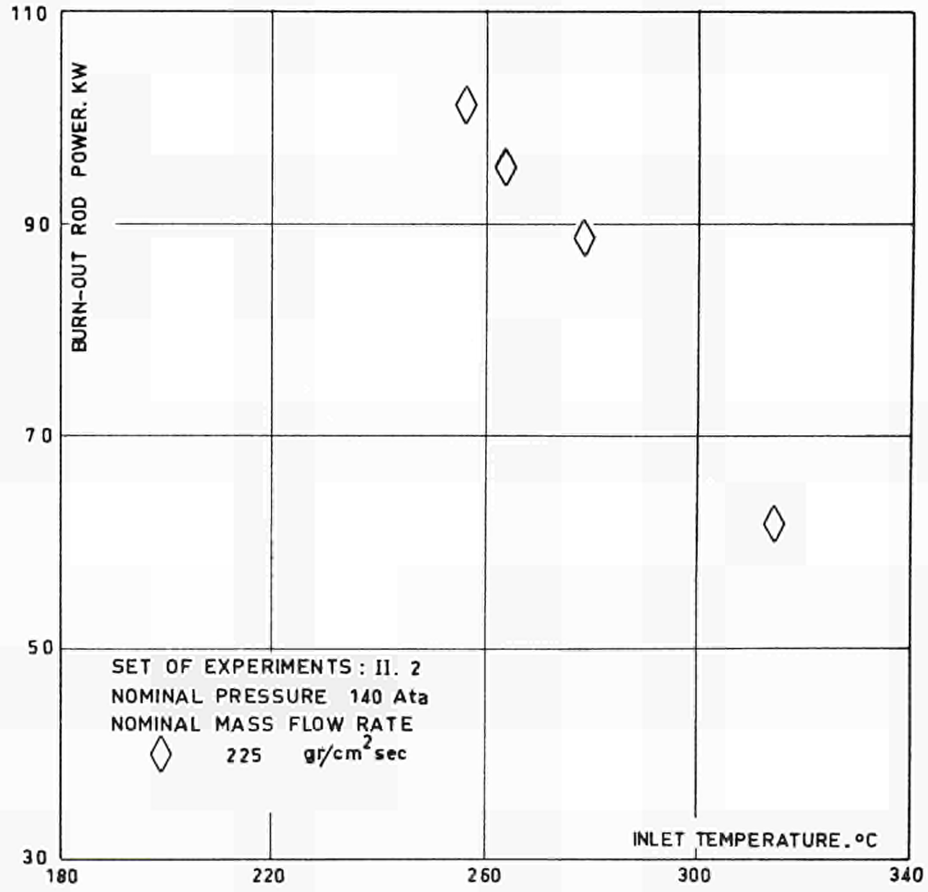


Fig. 10 - Burn-out experiments at 140 ata: Set II.2

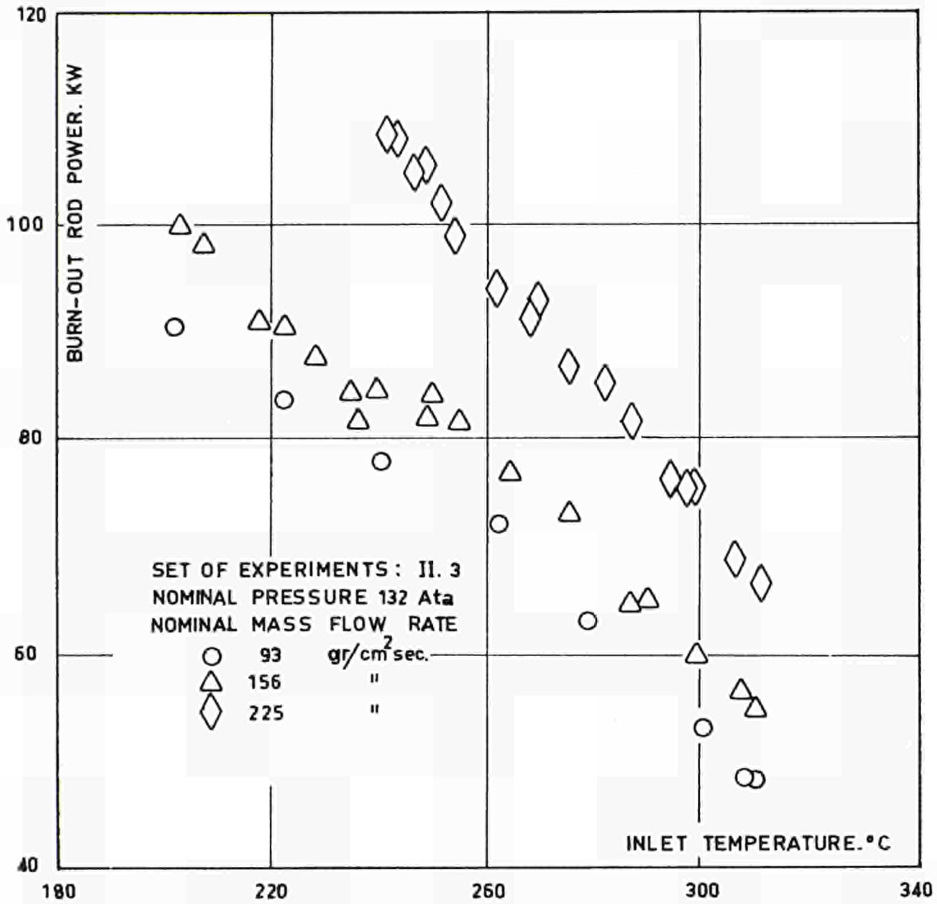


Fig. 11 - Burn-out experiments at 132 ata: Set II.3

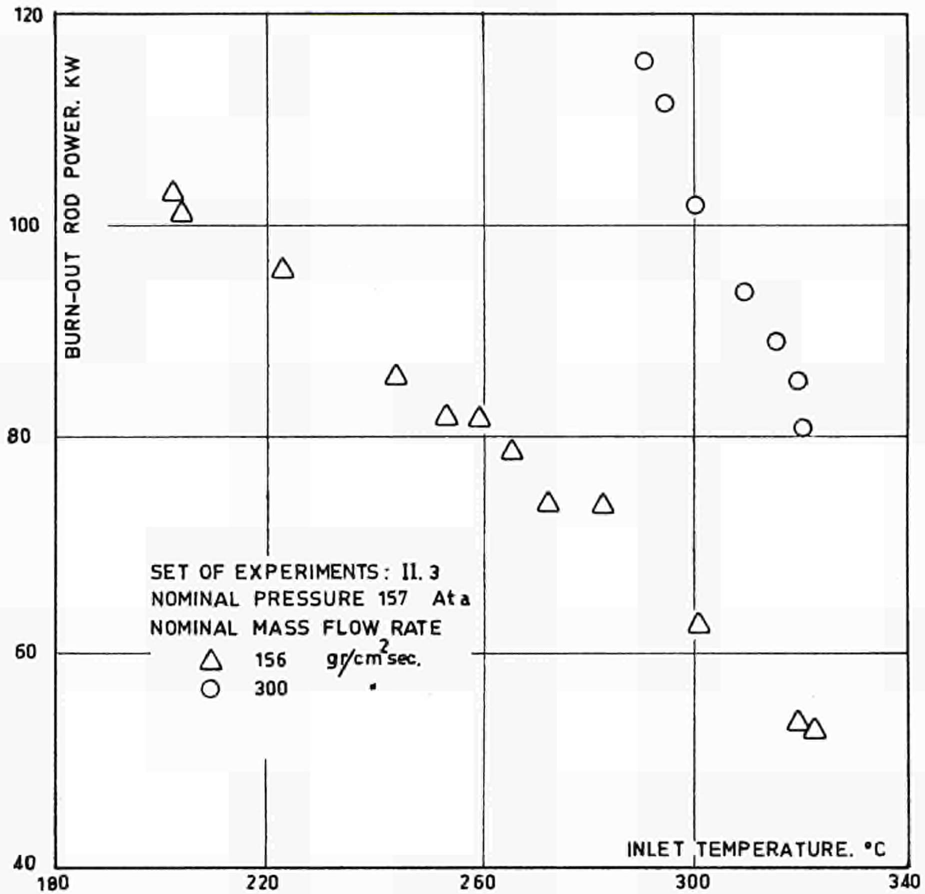


Fig. 12 - Burn-out experiments at 157 ata: Set II.3

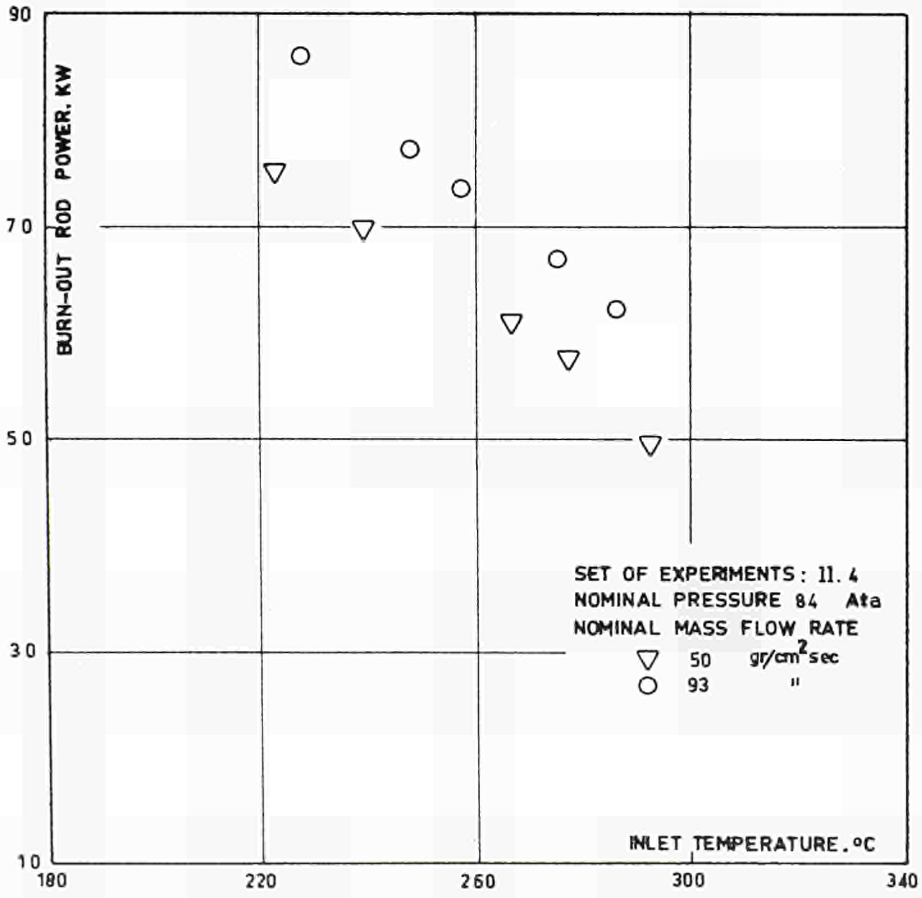


Fig. 13 - Burn-out experiments at 84 ata: Set II.4

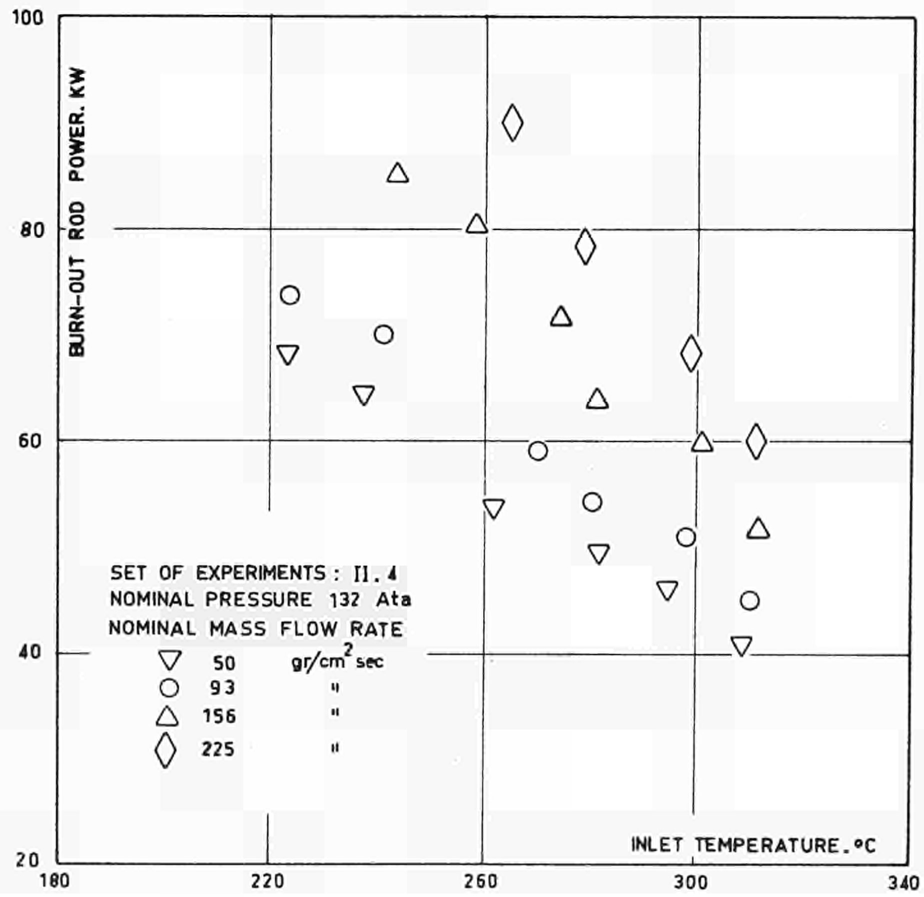


Fig. 14 - Burn-out experiments at 132 ata: Set II.4

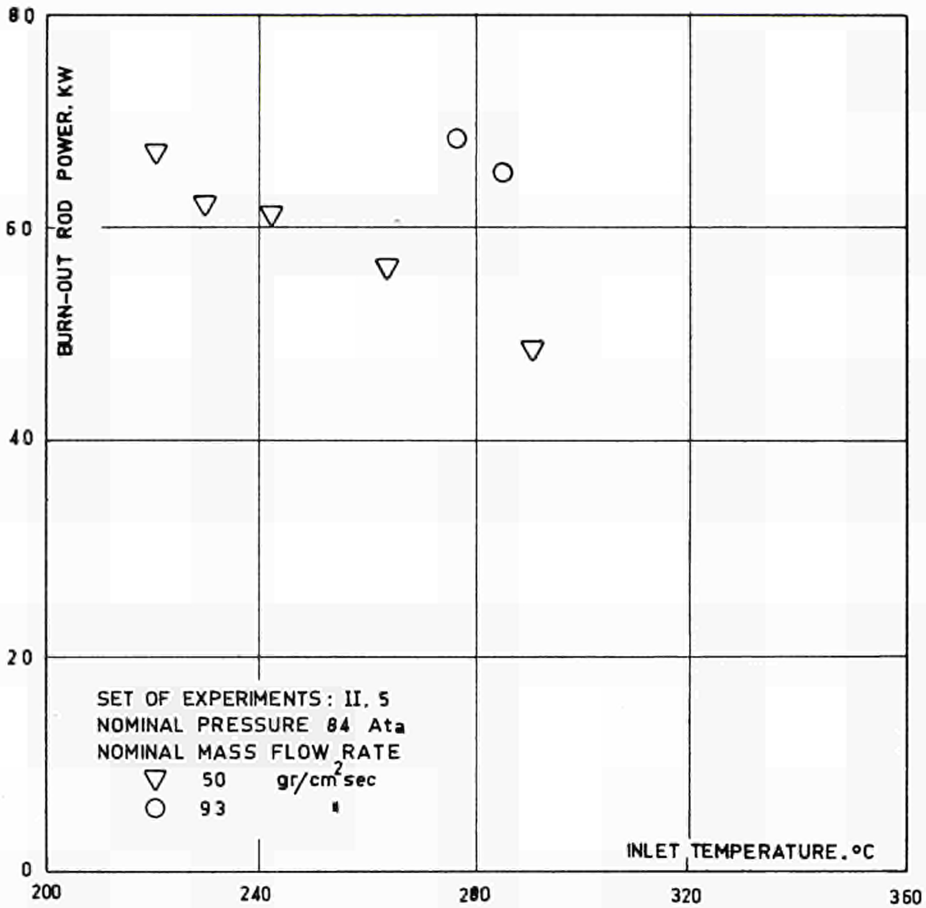


Fig. 15 – Burn-out experiments at 84 ata: Set II.5

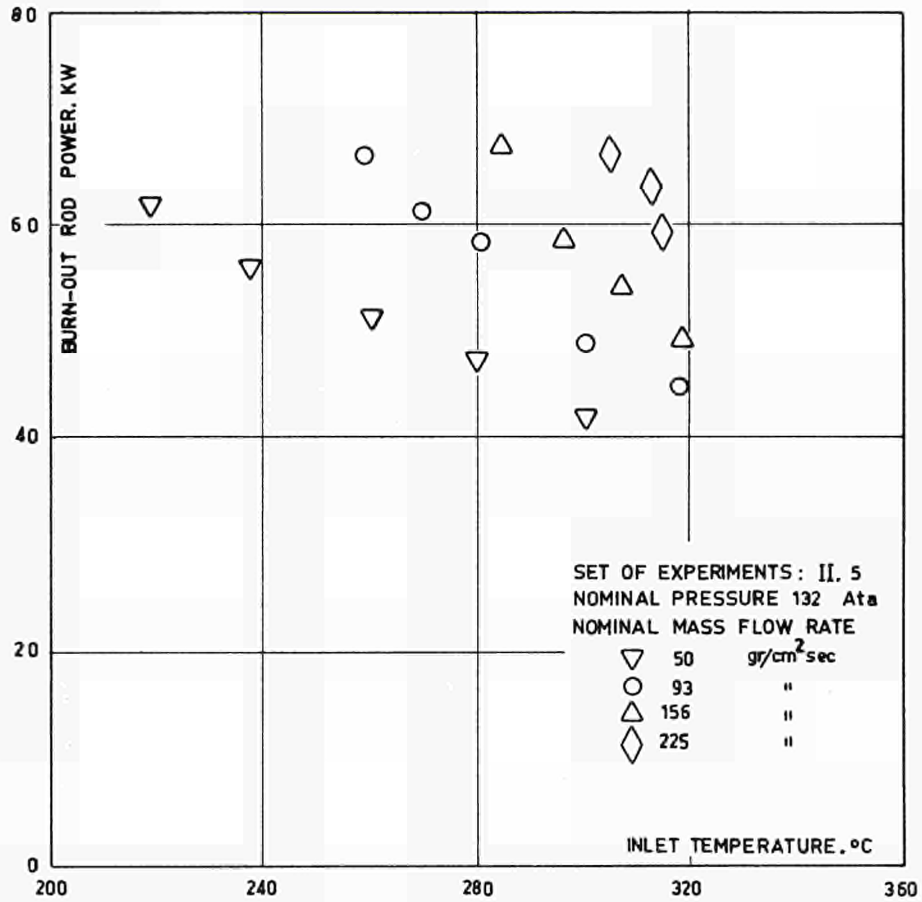


Fig. 16 – Burn-out experiments at 132 ata: Set II.5

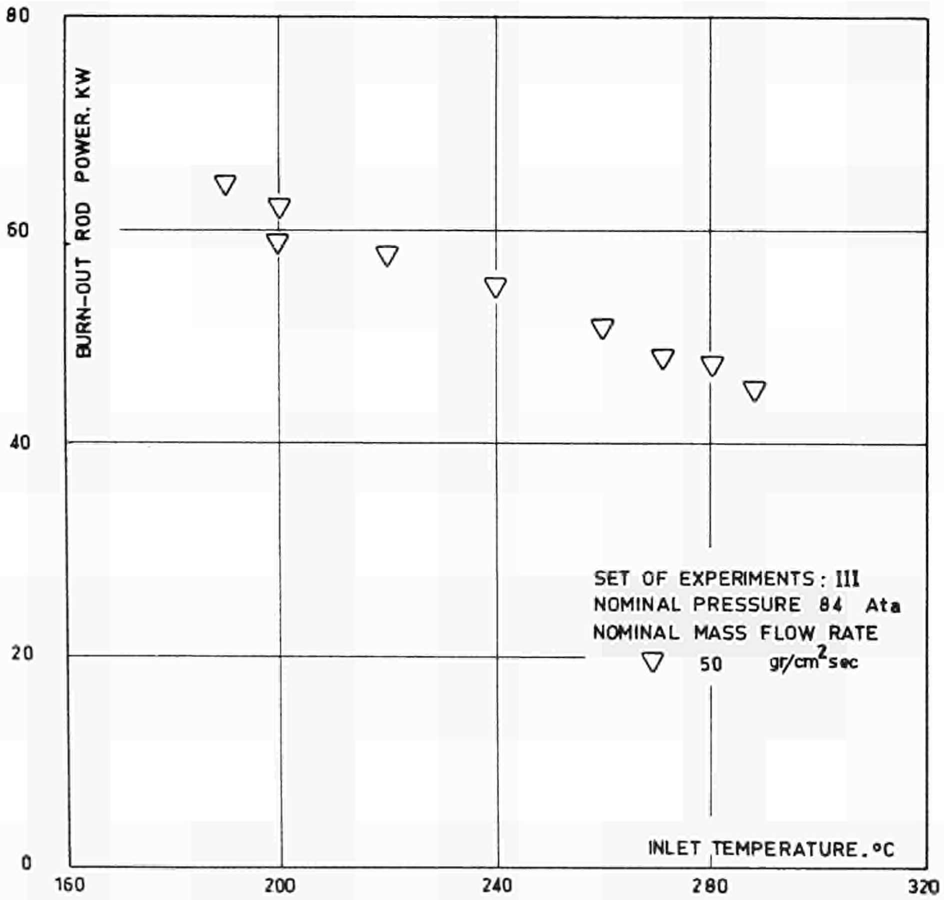


Fig. 17 - Burn-out experiments at 84 ata: Set III

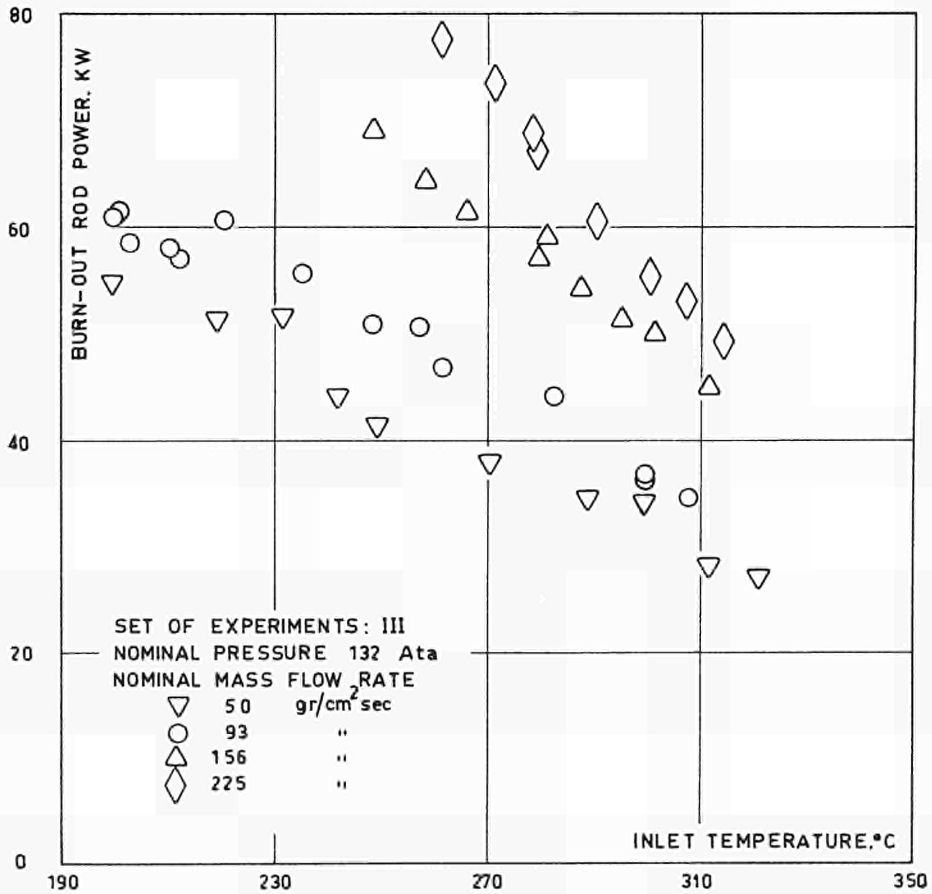


Fig. 18 - Burn-out experiments at 132 ata: Set III

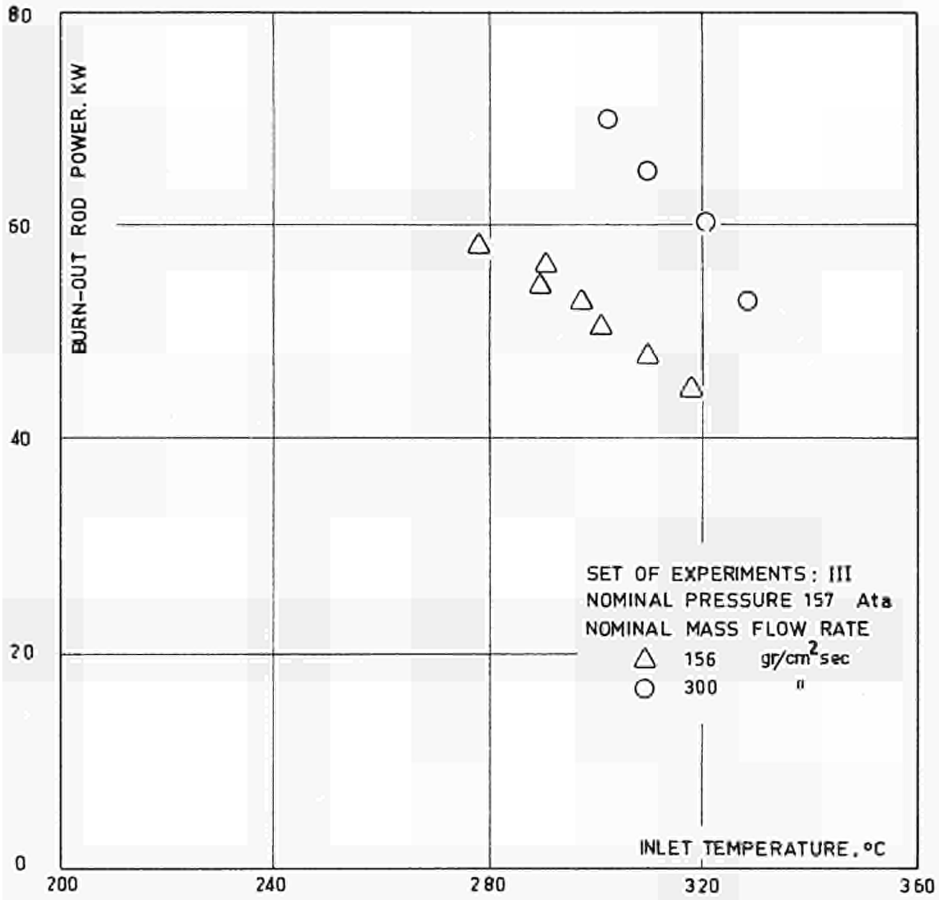


Fig. 19 – Burn-out experiments at 157 ata: Set III

NOTICE TO THE READER

All scientific and technical reports are announced, as and when they are issued, in the monthly periodical **"euro abstracts"**, edited by the Centre for Information and Documentation (CID). For subscription (1 year : US$ 16.40, £ 6.17, BF 820) or free specimen copies please write to :

Handelsblatt GmbH
"euro abstracts"
Postfach 1102
D 4 Düsseldorf 1 (Deutschland)

or

Office de vente des publications officielles
des Communautés européennes
37, rue Glesener
Luxembourg

To disseminate knowledge is to disseminate prosperity — I mean general prosperity and not individual riches — and with prosperity disappears the greater part of the evil which is our heritage from darker times.

Alfred Nobel

SALES OFFICES

All reports published by the Commission of the European Communities are on sale at the offices listed below, at the prices given on the back of the front cover. When ordering, specify clearly the EUR number and the title of the report which are shown on the front cover.

SALES OFFICE FOR OFFICIAL PUBLICATIONS OF THE EUROPEAN COMMUNITIES

37, rue Glesener, Luxembourg (Compte chèque postal N° 191-90)

BELGIQUE — BELGIË
MONITEUR BELGE
rue de Louvain 40-42 - 1000 Bruxelles
BELGISCH STAATSBLAD
Leuvenseweg 40-42 - 1000 Brussel

DEUTSCHLAND
BUNDESANZEIGER
Postfach - 5000 Köln 1

FRANCE
SERVICE DE VENTE EN FRANCE
DES PUBLICATIONS DES
COMMUNAUTES EUROPEENNES
26, rue Desaix - 75 Paris 15e

ITALIA
LIBRERIA DELLO STATO
Piazza G. Verdi, 10 - 00198 Roma

LUXEMBOURG
OFFICE DE VENTE
DES PUBLICATIONS OFFICIELLES
DES COMMUNAUTES EUROPEENNES
37, rue Glesener - Luxembourg

NEDERLAND
STAATSDRUKKERIJ
Christoffel Plantijnstraat - Den Haag

UNITED KINGDOM
H. M. STATIONERY OFFICE
P.O. Box 569 - London S.E.1

**Commission of the
European Communities
D.G. XIII - C.I.D.**
29, rue Aldringer
Luxembourg