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FEBA — Flooding Experiments with Blocked Arrays Data Report 1, Test Series I through IV

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Abstract

This report presents typical data and a limited heat transfer analysis of test series I through IV from an experimental thermal-hydraulic program of Flooding Experiments with Blocked Arrays (FEBA). The experiments consisted of separate effect tests on a full-length 5x5 rod bundle of PWR fuel rod dimensions utilizing electrically heated rods with a cosine power profile approximated by 7 steps of different specific power. Eight test series were performed under idealized reflood conditions using forced feed and system pressure as parameters without the inclusion of the effects of a reactor cooling system. The individual test series were conducted to study the effect of grid spacers and of coplanar blockages of different blockage ratios with and without bypass on the reflood heat transfer. The purpose of the investigations was to obtain an insight into the most important heat transfer mechanisms and to broaden the data base for the development and assessment of improved thermal-hydraulic models.

FEBA - Flutexperimente mit blockierten Anordnungen
Datenbericht 1, Testserien I bis IV

Kurzfassung

In diesem Bericht werden typische Meßergebnisse und eine begrenzte Wärmeübergangsanalyse der Testserien I bis IV vorgestellt, die im Rahmen des FEBA-Programmes gewonnen wurden. Die Experimente zur Untersuchung thermohydraulischer Einzeleffekte in einem 5x5-Stabbündel mit DWR Brennstababmessungen voller Länge wurden mit elektrisch beheizten Stäben durchgeführt, deren axiale Leistung durch sieben Stufen einer Cosinusverteilung angenähert war. Das Programm bestand aus acht Testserien mit Zwangsfluten und Systemdruck als Parameter zur Idealisierung der Flutbedingungen. Effekte des Reaktorkühlsystems waren nicht eingeschlossen. Die einzelnen Testserien dienten der Untersuchung der Einflüsse von Abstandshaltern und koplanaren Blockaden mit und ohne zusätzlicher Umströmung auf den Wärmeübergang während des Flutens. Die Absicht war, ein verbessertes Verständnis der wichtigsten Wärmeübergangsmechanismen zu gewinnen und die Basis experimenteller Daten zu erweitern für Entwicklung und Überprüfung verbesserter thermohydraulicher Rechenmodelle.

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1. Introduction

During a loss-of-coolant accident (LOCA) of a pressurized water reactor (PWR) the emergency core cooling systems (ECCS) are usually assumed to provide sufficient capacity to avoid significant fuel damage for current design basis accident cases. However, during such an event situations may arise leading to the heatup of the core by nuclear decay heat for an extended time span. Under design basis accident conditions this may be the case, e.g. during the refill phase after blowdown. The reflood water injection has to terminate this "Second Heatup Phase" before fuel rod damage exceeds specified limits.

In a LOCA of a PWR the fuel in portions of the core may become overheated, whilst at the same time the reactor system pressure may decrease below the internal rod pressure. Under these circumstances the Zircaloy claddings could balloon and reduce considerably the cooling channel cross sections.

To obtain a better understanding of the flow conditions and to provide an expanded data base for an adequate analytical description of the complex heat transfer processes taking place in a bundle of ballooned rods during the reflood phase, separate effect tests under forced reflood conditions were performed. The Flooding Experiments with Blocked Arrays (FEBA) were carried out in eight consecutive test series using a 5x5 rod array as the main arrangement for all of the tests.

Details of the FEBA reflood program as well as a comparison of typical transients measured and evaluated from the different test series are presented in Ref. /1/.

This report is a broader sampling of data selected from tests of the first four 5x5 rod bundle test configurations. A second data report /2/ contains data selected from test series V through VIII.

From the tests presented all data measured as well as selected data evaluated are available on tapes from KfK. The data also are available from the Reactor Safety Research Data Bank of the USNRC at EG&G Idaho, Idaho Falls, ID, U.S.A.

2. FEBA Reflood Program

The specific objectives of the separate effect tests under forced reflood conditions were:

- To measure and to evaluate thermal-hydraulic data for unblocked bundle geometries,
- To measure and to evaluate the effect of grid spacers upon the thermal-hydraulic behavior,
- To measure and to evaluate thermal-hydraulic data for blocked bundle geometries with and without flow bypass.

The FEBA 5x5 rod bundle program consisted of eight test series with different grid spacer and sleeve blockage arrays within the bundle. The bundle geometries and the axial arrangement of grid spacers and flow blockages are shown in Fig. 1. The main purposes of the individual test series are:

Series I: Base line tests with undisturbed bundle geometry containing all (seven) grid spacers for comparison with the subsequent series,

Series II: Investigation of the grid spacer effect on the axial temperature profile at the bundle midplane, without grid spacer at the bundle midplane,

Series III: Investigation of the effects of a 90 % flow blockage with bypass, blockage at the bundle midplane of 3x3 rods placed in the corner of the 5x5 rod bundle, without grid spacer at the bundle midplane,

Series IV: Investigation of the effect of a 62 % flow blockage with bypass, blockage at the bundle midplane of 3x3 rods placed in the corner of the 5x5 rod bundle, without grid spacer at the bundle midplane,

Series V: Investigation of the effects of a 90 % flow blockage with bypass, blockage at axial level 2125 mm (100 mm upstream of the bundle midplane) of 3x3 rods placed in the corner of the 5x5 rod bundle, grid spacer at the bundle midplane,

Series VI: Investigation of the effects of a 90 % and 62 % flow blockage with bypass, 90 % blockage at axial level 2125 mm (100 mm upstream of the bundle midplane) and 62 % blockage at axial level 1925 mm (100 mm downstream of the bundle midplane) of 3x3 rods placed in the corner of the 5x5 rod bundle, grid spacer at the bundle midplane,

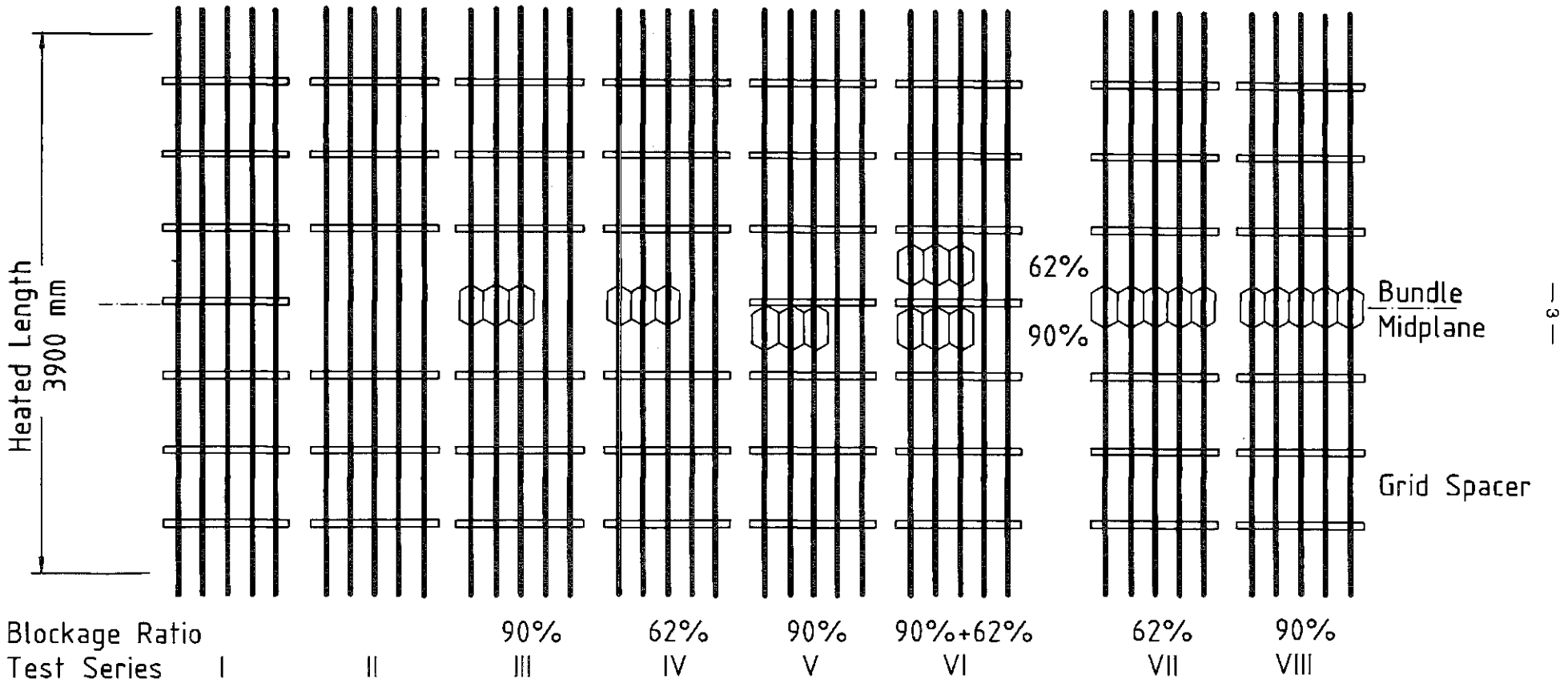
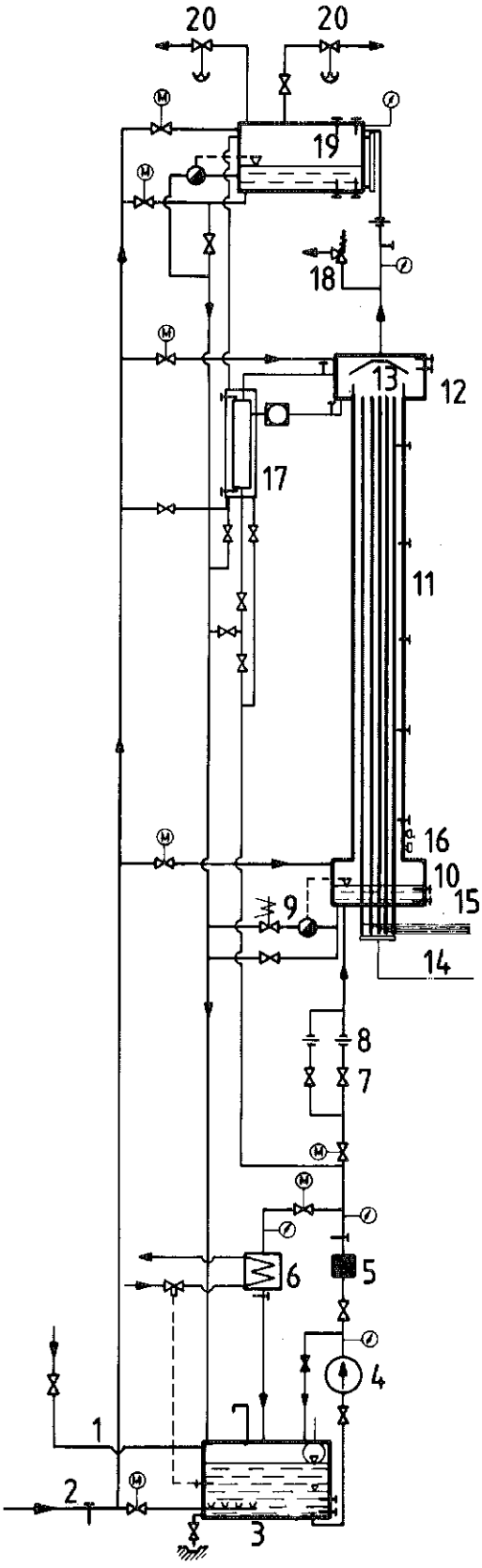


Fig. 1 5x5 rod bundle: Bundle geometries of test series I through VIII axial arrangement of grid spacers and sleeve blockages



LEGEND

1 Water Supply
2 Steam Supply
3 Storage Tank
4 Water Pump
5 Filter
6 Heat Exchanger
7 Throttle Valve
8 Turbine Meter
9 Water Level Regulation Valve

10 Lower Plenum
11 Test Section
12 Upper Plenum
13 Water Separator

14 Power Supply
15 Rod Instrumentation Exits
16 Water Level Detector
17 Water Collecting Tank
18 Outlet Valve
19 Buffer
20 Pressure Regulator

Fig. 2 FEBA test loop

Series VII: Investigation of the effects of a 62 % blockage without bypass, blockage at the bundle midplane of the 5x5 rod bundle,

Series VIII: Investigation of the effects of a 90 % blockage without bypass, blockage at the bundle midplane of the 5x5 rod bundle.

3. Test Loop

Figure 2 shows schematically the test loop. It is a forced-flow reflood facility with a back pressure control system. Coolant water is stored in a tank (3). During operation, coolant is pumped (4) through a throttle valve (7) and a turbine meter (8) into the lower plenum region (10) of the test section (11). The coolant flow may be directed either upwards through the test assembly, or through the lower plenum (10) and water level regulation valve (9) back into the water supply. When reflood is initiated, coolant water rises in the test assembly and two-phase flow results when water reaches the hot zone of the heater rods. Entrained water droplets are transported upwards by the rising steam and may impinge on the steam water separator (13) placed above the test assembly. The liquid then drains into a collecting tank (17), where the water content is continuously measured. Steam passes around the droplet deflector and is then flowing through a buffer tank (19) to the atmosphere. This tank has an automatic pressure regulator (20) for control of a constant back pressure for the test assembly. A large external steam supply is connected to the buffer to heat up the total system and the buffer contents and to maintain the system pressure. The heater rod instrumentations (15) exit from the lower end of the rod assembly as do the electric power connections (14) for the heater rods. However, the instrumentation of the sleeve blockages is led to the top end of the housing such that it does not influence the two-phase mixture rising from the bottom. The housing is insulated to reduce the heat loss to the outside air environment.

4. Test Section Design

Electrically heated rods of PWR dimensions are used to simulate the nuclear fuel rods. Figure 3, a working drawing of an instrumented heater rod, shows the axial dimensions. Figure 4 shows the cross section of the heater rod which has an outer diameter of 10.75 mm. A spiral wound heating element of NiCr 80 20 (ASTM B 344-60) is embedded in the electrical insulator

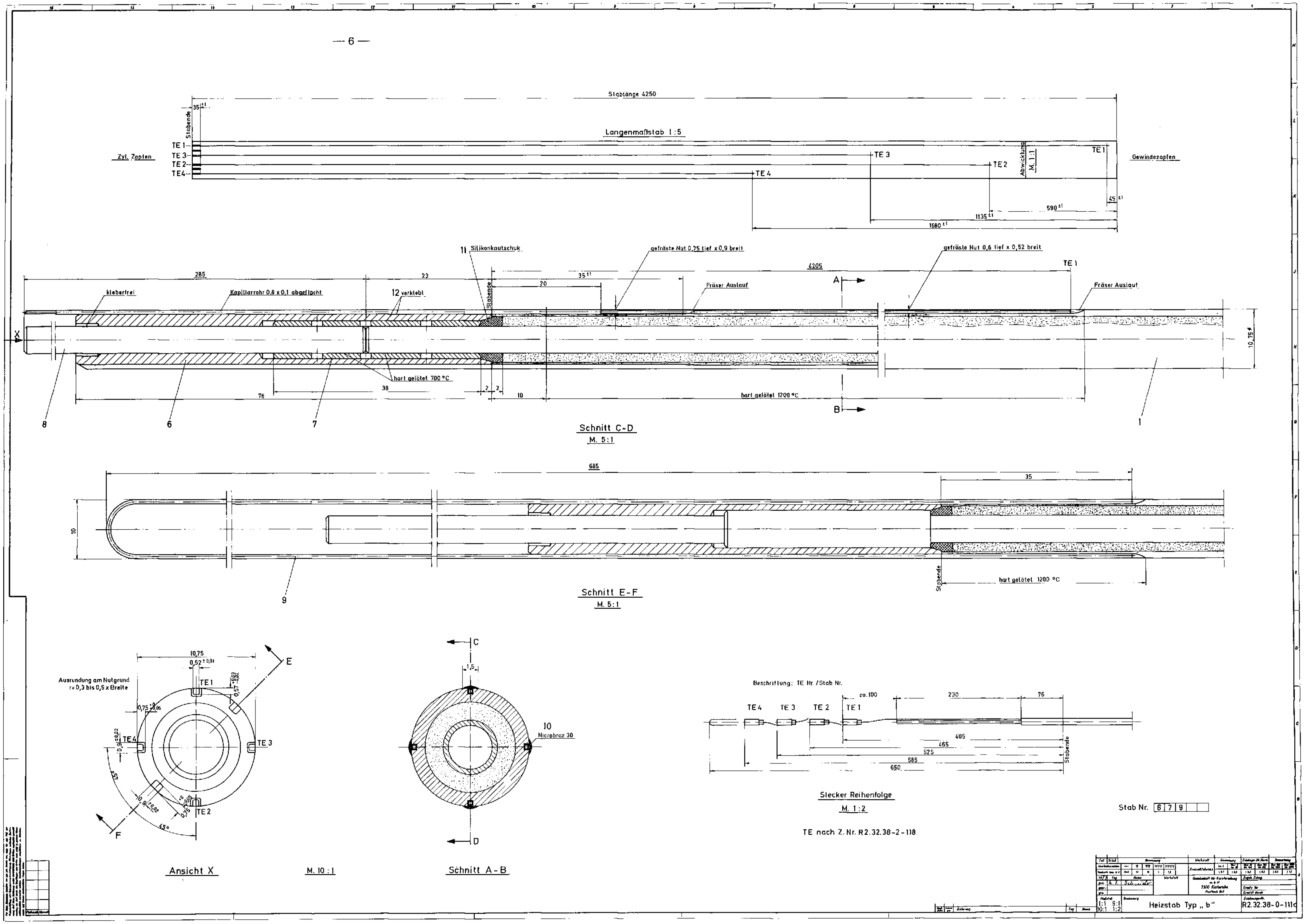


Fig. 3 Working drawing of an instrumented FEBA heater rod
(type b of the cladding instrumentation)

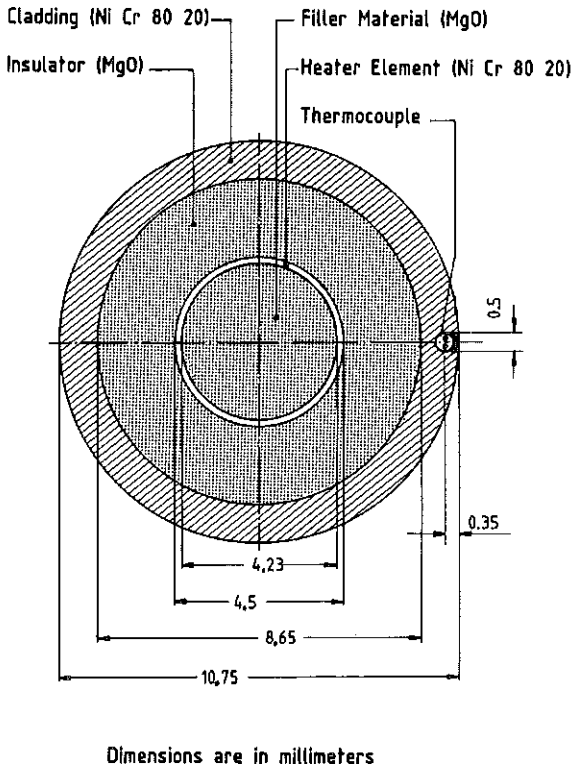


Fig. 4 Cross section of heater rod

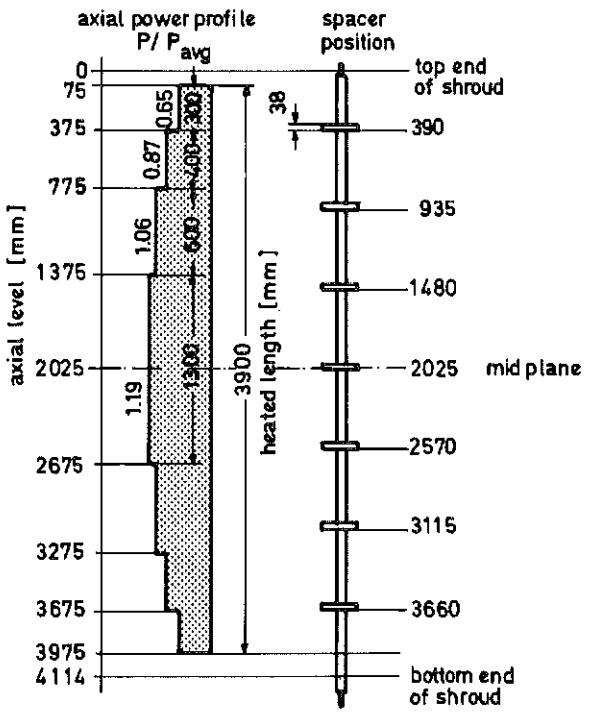


Fig. 5 Axial heater rod layout

(MgO), and then encapsulated in the clad of NiCr 80 20 which has a wall thickness of one millimeter. In contrast to a nuclear fuel rod with a Zircaloy cladding and a gas filled gap, this heater rod is a "solid type" usually used for thermal-hydraulic tests. A gas filled gap between cladding and the electrical insulation is not provided. The cosine power profile of the fuel rods is approximated by seven steps of different specific power. The left-hand side sketch of Fig. 5 shows the axial power distribution of the heater rod with a length of 3900 mm. The average power step level is shown together with the length of each power step. The axial power profile is flat. The peak to average ratio amounts to 1.19. The 5x5 rod bundle is placed in a square section housing with an inside width of 78.5 mm. The housing of stainless steel (AISI 316 Ti) has a wall thickness of 6.5 mm. The heater rod pitch is 14.3 mm. The right-hand side of Fig. 5 shows the axial position of seven original KWU-PWR grid spacers which are located at the bundle midplane (axial level 2025 mm) and every 545 mm above and below that level. The grid spacers are attached to the rods by friction. They are

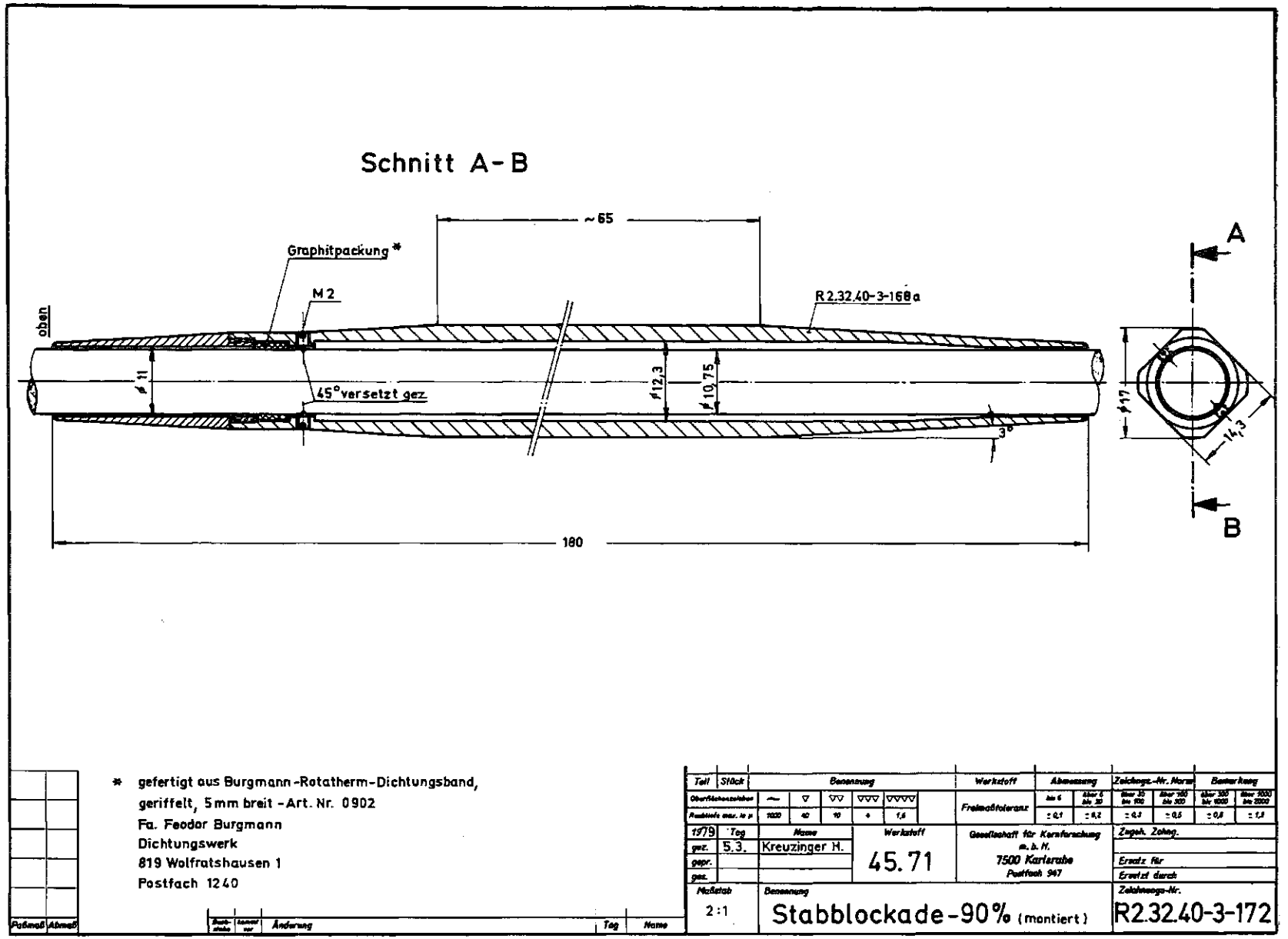


Fig. 6 5x5 rod bundle: Working drawing of the 90% blockage device

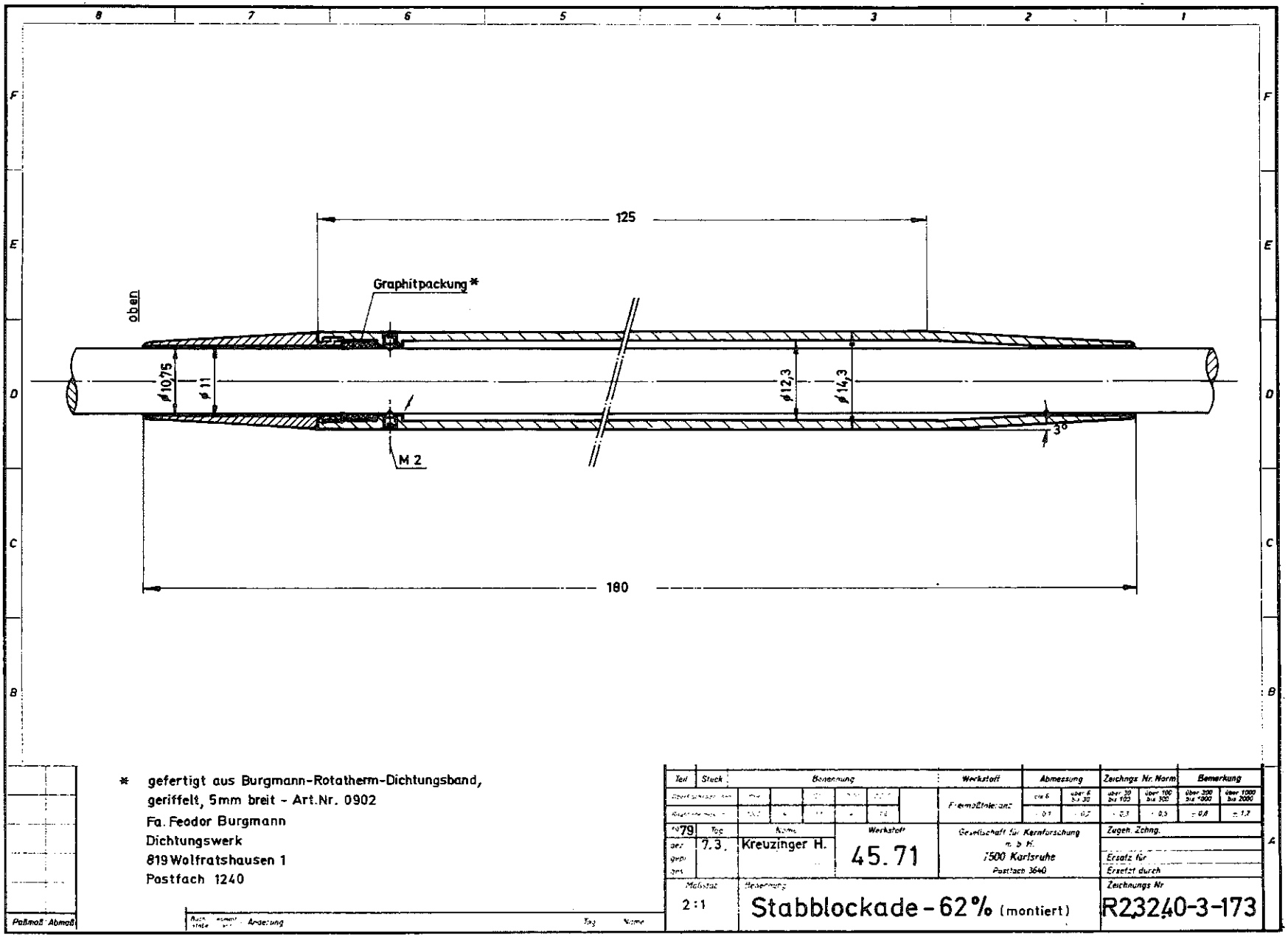


Fig. 7 5x5 rod bundle: Working drawing of the 62% blockage device

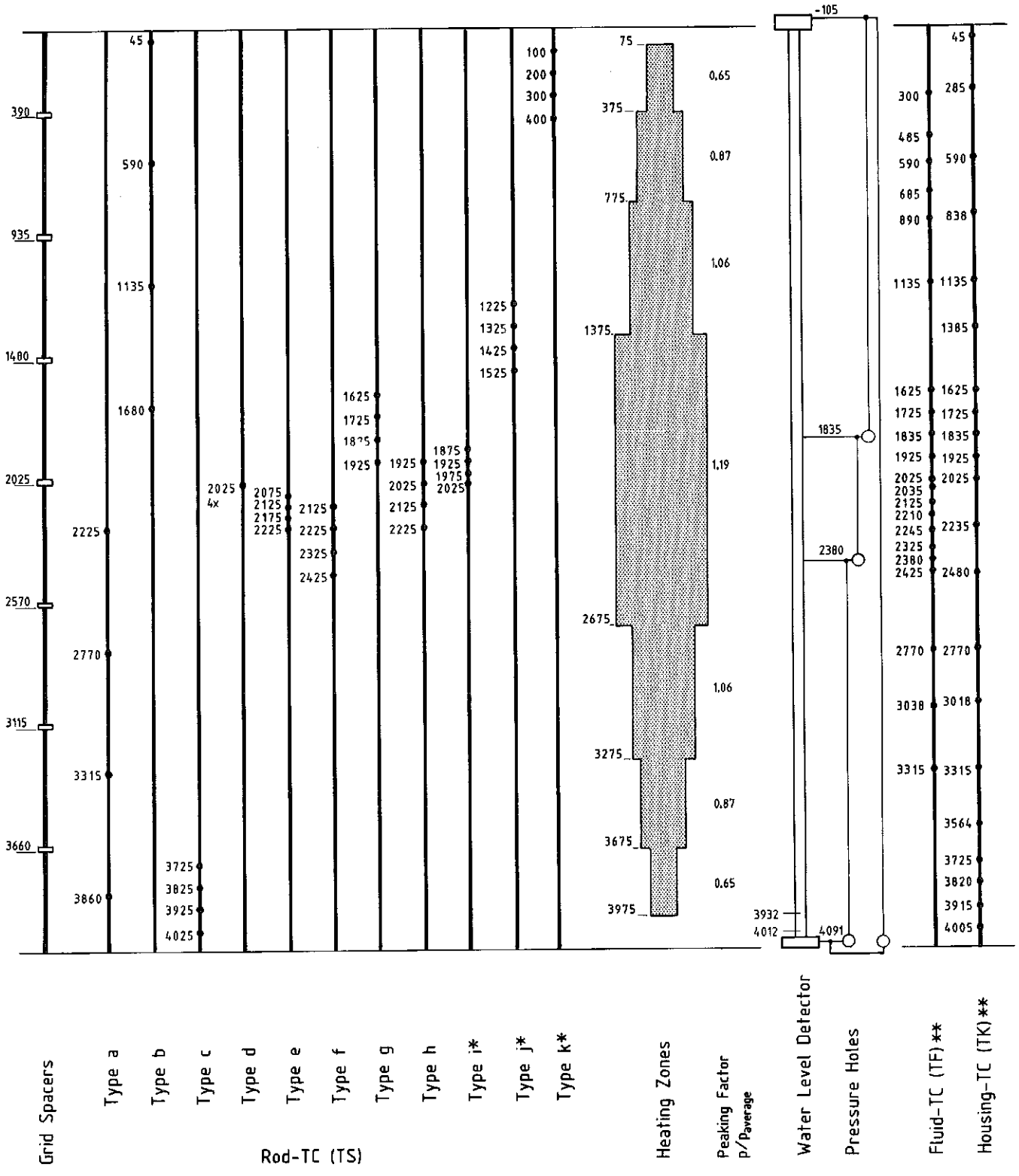
sliding in the housing in the case of different axial elongation of housing and rod bundle.

The heater rods are bolted to the top flange of the test section (zero level and therefore reference level for all axial bundle positions), and the lower ends of the rods penetrate through the test assembly pressure barrier. The penetration is accomplished using O-ring sealings and allows axial movement of the heater rods relative to the housing. Weights are hung from the bottom end of the rods to prevent them from bowing due to friction in the sealing during temperature changes.

To investigate effects of ballooned fuel rod claddings on the reflood thermohydraulics, sleeves of 180 mm length are used. Figures 6 and 7 show the shape of sleeves selected to simulate the smooth geometry expected from ballooned rod claddings with blockage of 90 % and 62 %, respectively, of the subchannel flow areas. In addition side plate devices are placed between the sleeves and the housing. They are attached to the sleeves. They are sliding in the housing in the case of different axial elongation of the housing and the rod bundle. The actual length of the remaining subchannels in the 90 % blocked zone is 65 mm. In the 62 % blocked zone, it is 125 mm. The sleeves touch the rod surfaces at the ends of the sleeves only. To simulate the gap resistance between a ballooned cladding and the fuel as well as to reduce the heat capacity of the artificial blockage, the remainder of the sleeve is separated from the rod by a gap of 0.8 mm filled with stagnant steam. The influences of the heat capacity of the sleeves and the heat resistance of the gap on the transient sleeve temperatures were compared by calculation with the behavior of a ballooned fuel rod.

5. Instrumentation

Most part of the test instrumentation consisted of thermocouples (Chromel-Alumel), since cladding (TS), sleeve (TH), fluid (TF), housing (TK) and grid spacer (TA, test series IV and VIII) temperatures were to be measured at various positions. Figure 8 shows a schematic diagram of the axial levels of the TC measuring positions. This diagram enables to relate the measuring positions to the grid spacer positions as well as to the specific power zones. However, not all TC measuring positions were instrumented for the individual test series. More details can be taken from the computer channel



* in Test Series V through VIII only

** not all positions set for the individual tests

Fig. 8 5x5 rod bundle: Axial levels of the measuring positions

listings included in this report for test series I through IV (cf. appendices at the end of the plotted data of each test series).

Cladding and sleeve temperatures were measured with 0.5 mm sheath diameter thermocouples having insulated junctions. These thermocouples were embedded in grooves which were milled into the outer surface of the rod claddings and the sleeves. The grooves were closed by brazing over the total length to avoid any disturbance of the coolant flow.

Generally, the fluid temperature was measured with unshielded thermocouples of 0.25 mm outer sheath diameter. The junctions protruded into the flow channels. Only for test series I through III some few shielded fluid thermocouples were installed. The effect of the shieldings is described in Ref. /1/. Pressures and pressure differences were measured with pressure transducers. In addition to the inlet and outlet pressure, the pressure differences were measured along the entire bundle length, along both the lower and upper portions of the bundle as well as along the bundle midplane. The flooding rate was measured with a turbo flowmeter. The amount of the water carried over was measured continuously by a pressure transducer at the water collecting tank.

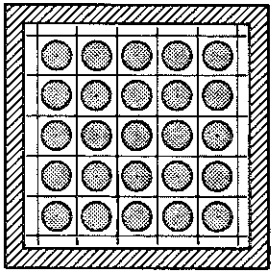
All data were digitally recorded with a scan frequency of 10 cycles per second.

The data acquisition system is described in Ref. /1/.

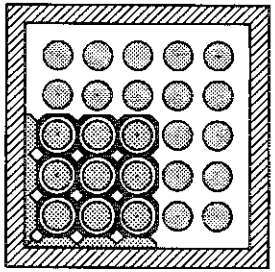
6. Test Parameters

The main test parameters varied are shown in Fig. 9:
- Bundle geometry,
- Flooding rate given as flooding velocity, i.e. the velocity of the rising water level in the cold bundle,
- System pressure.

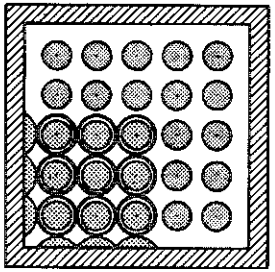
Flooding rate, system pressure, and feedwater temperature were kept constant during each test run. However, at the beginning of reflood, the feedwater was heated up by the hot environment of the lower plenum. Nevertheless, some few seconds later the feedwater temperature decreased and reached the de-



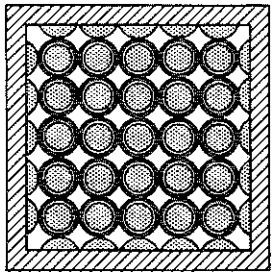
Test Series I
Test Series II



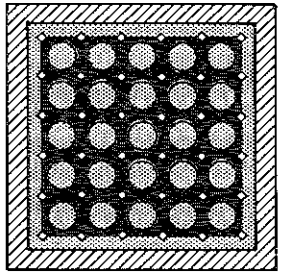
Test Series III
Test Series V
Test Series VI
90% Blockage



Test Series IV
Test Series VI
62% Blockage



Test Series VII
62% Blockage



Test Series VIII
90% Blockage

FLOODING PARAMETERS

Test Series		I	II	III	IV	V	VI	VII	VIII
Flooding Velocity (cold bundle) Constant During Each Test	cm/s	3.8, 5.8	3.8, 5.8	3.8, 5.8	3.8, 5.8 (2.2, 10.)	2.2, 3.8 5.8	2.2, 3.8 5.8	3.8, 5.8 (2.2)	3.8, 5.8 (2.2)
System Pressure Constant During Each Test	bar	2, 4, 6	2, 4, 6	2, 4, 6	2, 4, 6 (4)	4	4	2, 4, 6 (4)	2, 4, 6 (2, 4)
Feedwater Temperature Constant During Each Test	°C	40 °C, some few tests with 80 °C							
Max. Cladding Temperature (at start of reflooding)	°C	between 700 and 800 °C, some few tests between 600 and 700°C							
Max. Housing Temperature (at start of reflooding)	°C	between 600 and 700 °C, some few tests between 500 and 600°C							
Bundle Power	kW	at start of reflooding 200 kW, 120% ANS decay heat transient 40 s after shutdown, some few tests with constant bundle power							

Steam Cooling Tests

Test series VII and VIII include steady state and transient tests for which low bundle power and system pressures of 2, 4 and 6 bar were selected.

Fig. 9 5x5 rod bundle: Test matrix of test series I through VIII

sired value. The initial bundle power of about 200 kW was followed by a decay heat transient corresponding to 120 % ANS standard 40 s after shutdown of a reactor.

The tests performed are listed in Tables 1 through 4 by which the plotted data of each test series are introduced.

7. Data Informations

For the data transfer, data management, heat transfer analysis, and data representation a detailed computer code was written /3/ using the physical properties of the specific materials programmed in the PEW code /4/.

For each test series the following tables, figures, plots, and listings are included:

a) Summary and comment table.
   This table gives an overlook over the individual test runs, i.e. flooding velocity, system pressure, feedwater temperature, bundle power transient.

b) Information figure for identification of rod bundle measuring positions.
   The upper part of the figure shows the cross sectional geometry at the bundle midplane, the rod numbers, the type of rod instrumentation, the thermocouple numbers, the sleeve instrumentation (TH, in case of investigation of blockage effects), the fluid thermocouples (TF), the housing thermocouples (TK), the grid spacer thermocouples (TA, in case of its instrumentation).
   In the lower part of the figure the axial positions of the cladding instrumentation are listed.

c) Layout of the bundle geometry.
   The main purpose of this layout is to identify the main measuring positions upstream and downstream of the bundle midplane. Again, it is to point out that all axial levels are referenced to the top flange of the rod bundle (zero level).

d) Data plots of test series I.
   It should be noted that for each set of data of the individual test

series transients versus reflood time were plotted which were measured at identical rods and elevations, respectively. The same is valid for the transient fluid and housing temperatures which were taken from identical measuring devices to make easier a comparison from test run to test run and from test series to test series, respectively.

The plots show in detail:

- Initial axial temperature profile of the cladding,
- Test parameters: Flooding velocity /cm/s/, system pressure /bar/ measured in the buffer, feedwater temperature /°C/, bundle power /kW/,
- Cladding temperatures /°C/ measured at fixed levels of 345 mm downstream of the leading edge of each grid spacer,
  Heat transfer coefficients /W/(cm^2K)/ corresponding to the afore mentioned cladding temperatures,
  The heat transfer coefficients are related to the saturation temperature corresponding to the system pressure. In contrast to all other data plotted in this report, a smoothing subroutine of the computer code was applied to substitute each data point of the cladding temperature transient by the arithmetic mean value of the previous and following 25 points for heat transfer analysis only. In this context it should be reminded that the data were recorded with a scan frequency of 10 cycles per second.
- Cladding temperatures measured upstream of the bundle midplane,
  Corresponding heat transfer coefficients,
- Cladding temperatures at the bundle midplane,
  Corresponding heat transfer coefficients,
- Cladding temperatures measured downstream of the bundle midplane,
  Corresponding heat transfer coefficients,
- Cladding-, fluid-, housing temperatures measured at the same axial position,
- Pressure drop /bar/ along the entire bundle length, the lower portion of the bundle, the bundle midplane, the upper portion of the bundle,
- Coolant outlet: water carried over /kg/ measured in the water collecting tank, steam temperature /°C/ and pressure /bar/ both measured in the upper plenum,
- Axial positions of the quenchfront /mm/ as function of reflood time.

e) Listing of the computer channel numbers and of data identification for the data available on tapes or in the USNRC/RSR Data Bank.

f) Data plots of test series II.
Corresponding to the positions a) through e), the informations for test series II are included.

g) Data plots of test series III.
Corresponding to the positions a) through e), the informations for test series III are included.
However, the cladding temperatures and the corresponding heat transfer coefficients are plotted for both the bypass region and the blocked region.

h) Data plots for test series IV.
Corresponding to the positions a) through e), the informations for test series IV are included.
However, the cladding temperatures and the corresponding heat transfer coefficients are plotted for both the bypass region and the blocked region. In addition two diagrams show the grid spacer temperatures measured at two different axial positions.

i) Additional remarks concerning data informations.
The data acquisition system to recording the data of test series I through VI was limited to a maximum input voltage of 40 mV. This limitation has led to shut down of the thermocouple signals above about 1020 ^{o}C when the input was overloaded. In this case "room temperature" was indicated for the time span of the overflow. An example is plotted in Fig. 332 showing data of test run No. 267 of test series IV. This overflow occurred for few measuring positions in this test run only performed with the lowest flooding velocity selected. Such signals are valid for the whole range except the overflow, since it is not caused by thermocouple failures. Thermocouple failures are characterized by meaningless transients and they are easily detectable. However, in the most cases they are mentioned in the data channel listings for each individual test. Since the data are presented as measured please keep in mind these remarks using data from computer storage or tapes.

8. References

[1] Ihle, P.; Rust, K.:
"FEBA - Flooding Experiments with Blocked Arrays,
Evaluation Report"
KfK 3657, March 1984

[2] Ihle, P.; Rust, K.:
"FEBA - Flooding Experiments with Blocked Arrays,
Data Report 2, Test Series V Through VIII"
KfK 3659, March 1984

[3] Rust, K.; et al.:
"DAS - Ein Daten-Auswerte-System"
(to be published as KfK-Report)

[4] Rust, K.; Malang, S.; Götzmann, W.:
"PEW - Ein FORTRAN IV-Rechenprogramm zur Bereitstellung physikalischer Eigenschaften von Werkstoffen für LWR-Brennstäbe und deren Simulatoren"
KfK-Ext. 7/76-1, Dez. 1976

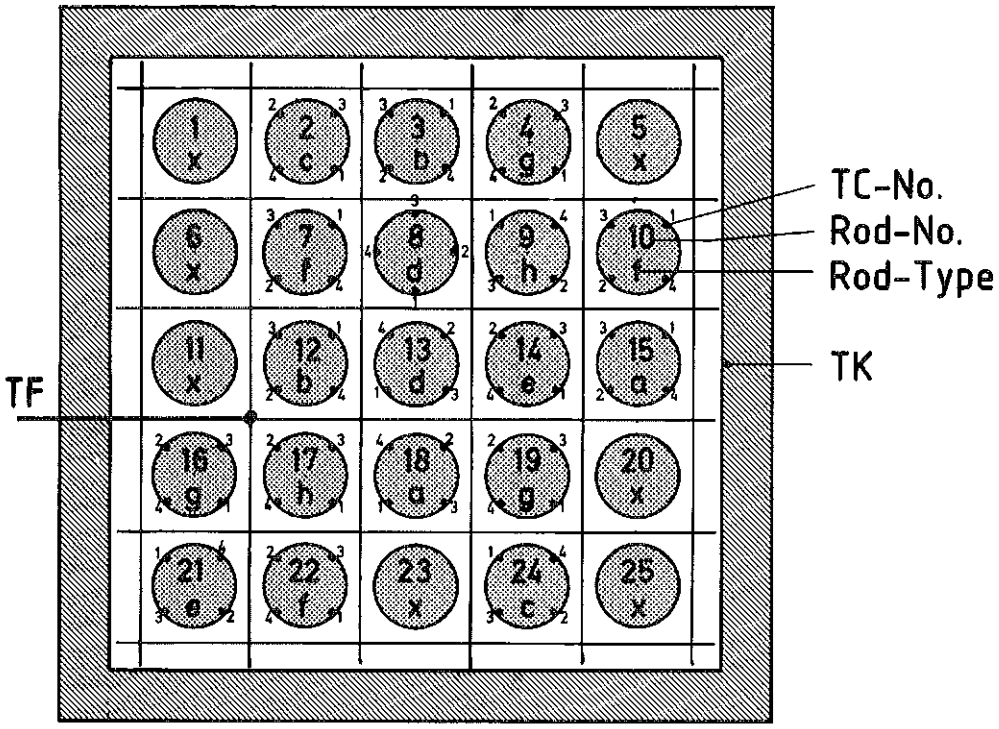
TEST SERIES I

Base Line Tests With Undisturbed Bundle Geometry,
7 Grid Spacers

Test No.	Flooding Velocity (cold) cm/s	System Pressure bar	Feedwater Temp.[1] °C 0-30 s	Feedwater Temp.[1] °C End	Bundle Power[2] kW 0 s	Bundle Power[2] kW Transient	Remarks
223	3.8	2.2	44	36	200	120% ANS	Figs. 12 Through 26
216	3.8	4.1	48	37	200	120% ANS	Figs. 27 Through 41
220	3.8	6.2	49	37	200	120% ANS	Figs. 42 Through 58
218	5.8	2.1	42	37	200	120% ANS	Figs. 57 Through 71
214	5.8	4.1	45	37	200	120% ANS	Figs. 72 Through 88
222	5.8	6.2	43	36	200	120% ANS	Figs. 87 Through 101
210	2.8	4.2	48	39	200	120% ANS	Data Not Plotted
221	2.8	6.1	51	37	200	120% ANS	Data Not Plotted
227	3.8	6.1	53	38	200	120% ANS	Data Not Plotted
219	5.8	6.1	50	37	200	120% ANS	Data Not Plotted

1) Measured in the lower plenum
2) Decay heat transient corresponding 120% ANS Standard 40 s after shutdown of the reactor

Table 1 FEBA 5x5 rod bundle: Main test parameters of test series I



Rod Type	TC No.	Axial Level mm
a	1	2225
	2	2770
	3	3315
	4	3860
b	1	45
	2	590
	3	1135
	4	1680
c	1	3725
	2	3825
	3	3925
	4	4025
d	1	2025
	2	2025
	3	2025
	4	2025

Rod Type	TC No.	Axial Level mm
e	1	2075
	2	2125
	3	2175
	4	2225
f	1	2125
	2	2225
	3	2325
	4	2425
g	1	1625
	2	1725
	3	1825
	4	1925
h	1	1925
	2	2025
	3	2125
	4	2225

Rod Type	TC No.	Axial Level mm
x	without TC's	

Fig. 10 5x5 rod bundle: Radial and axial location of cladding, fluid and housing TC's for test series I

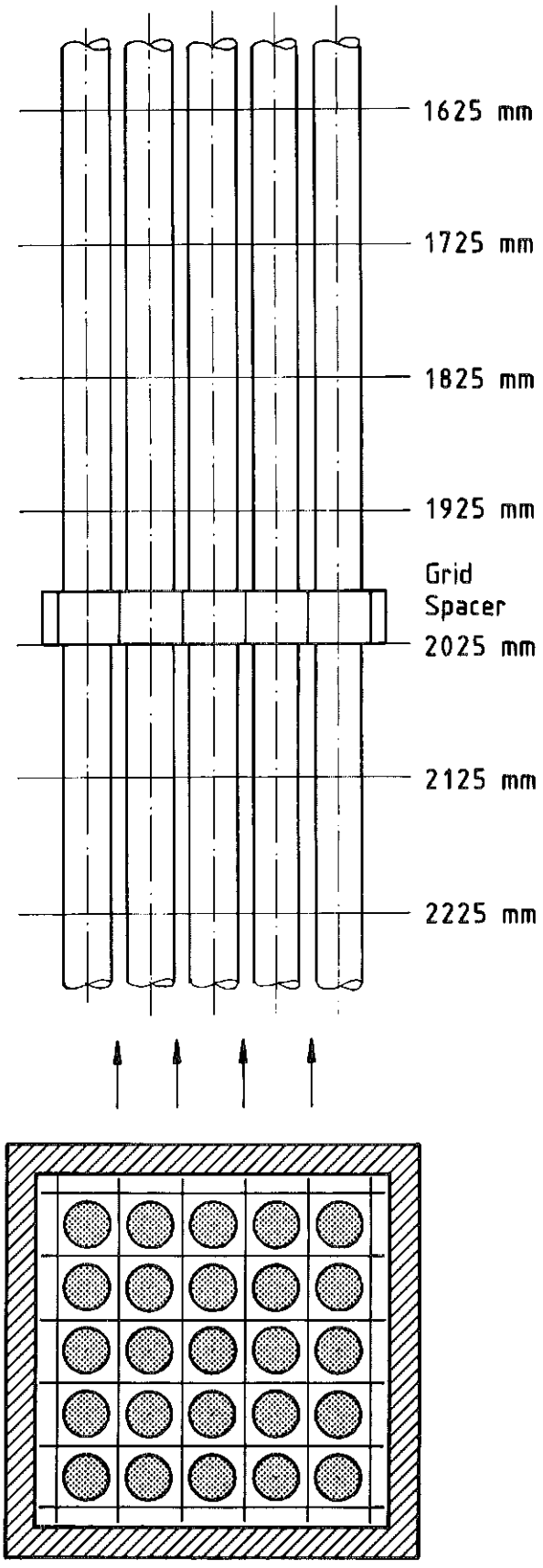
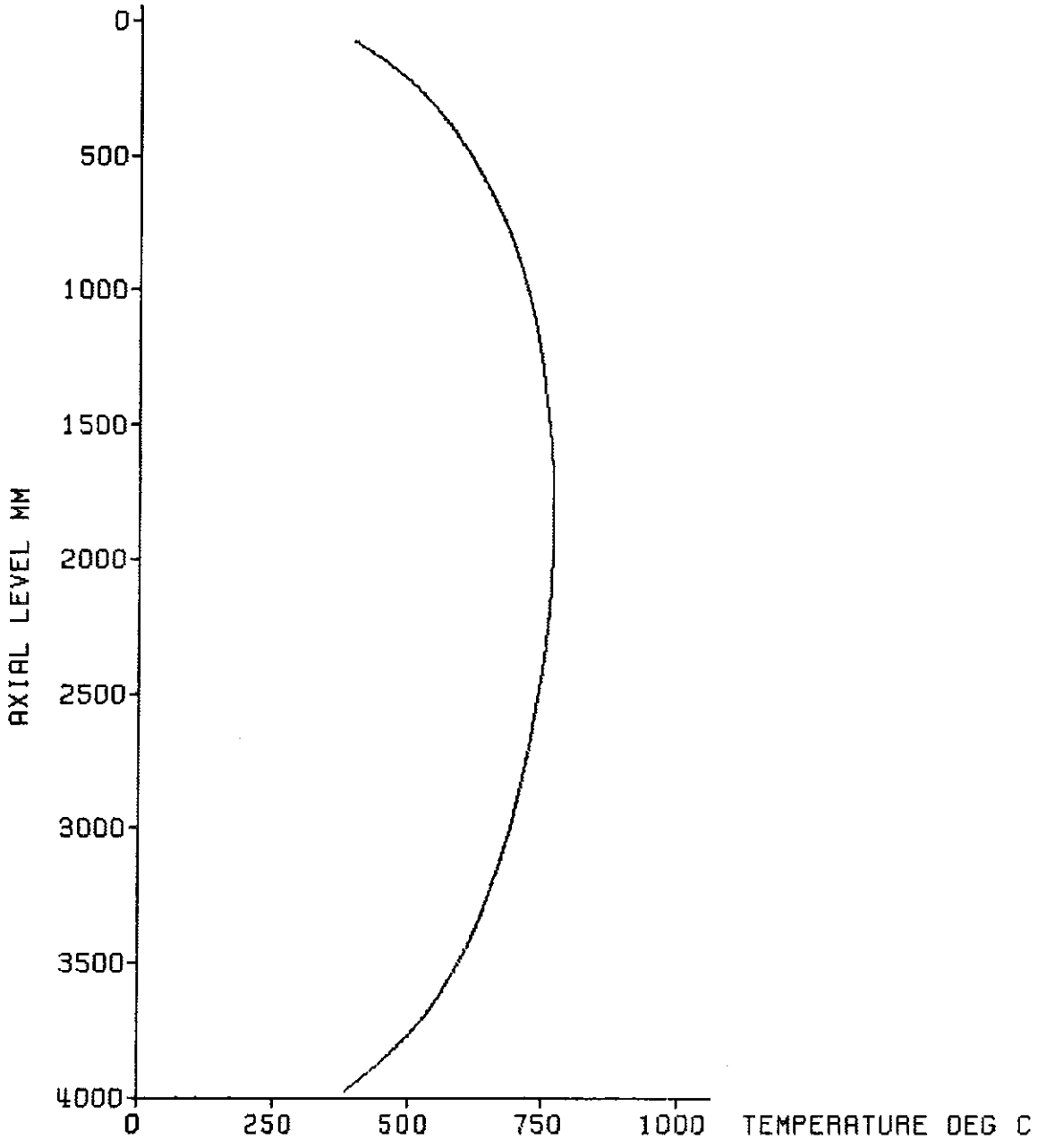


Fig. 11 5x5 rod bundle: Layout of the bundle geometry of test series I

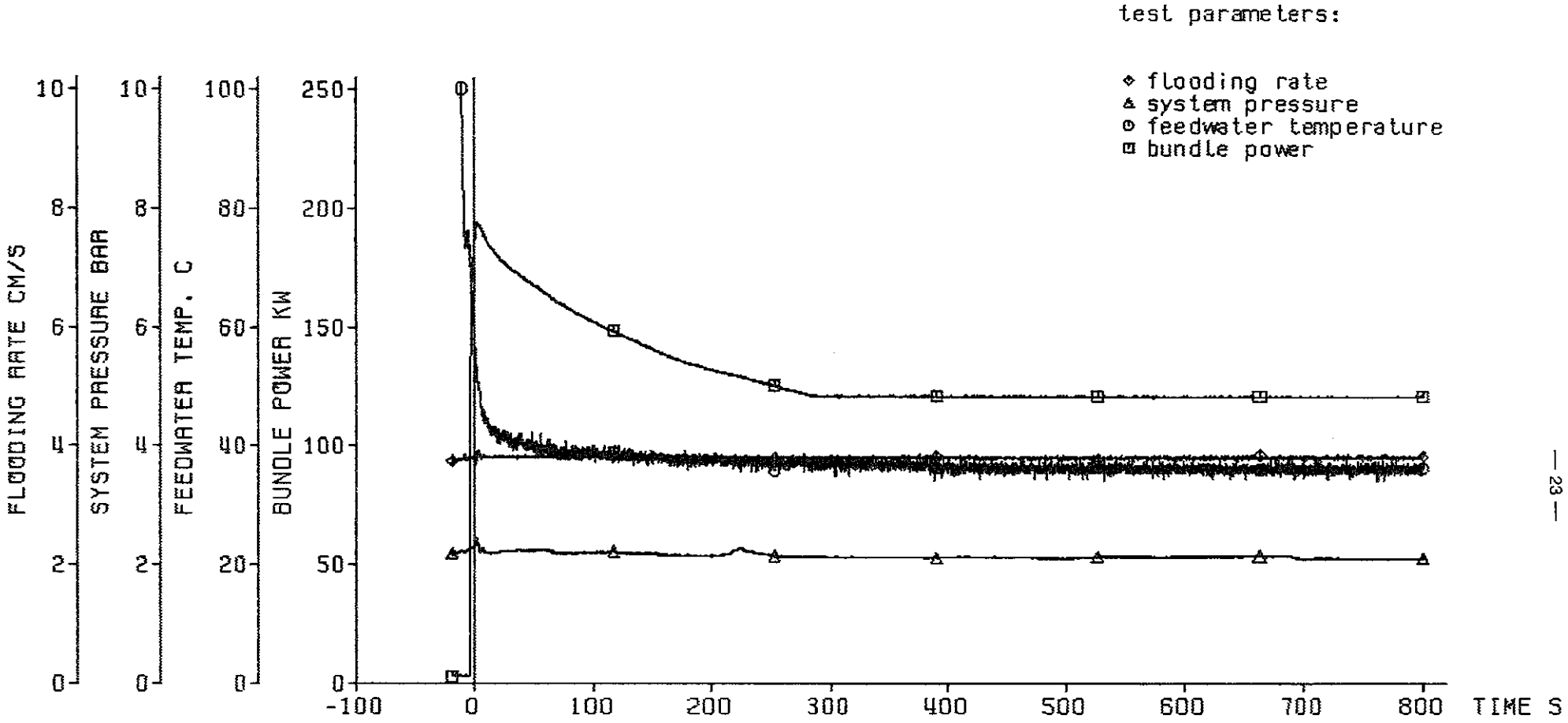
Initial axial temperature profile of the cladding



decay heat	120% ANS standard
flooding rate (cold)	3.82 cm/s
system pressure	2.21 bar
feedwater temperature	40 deg C

KfK IRB

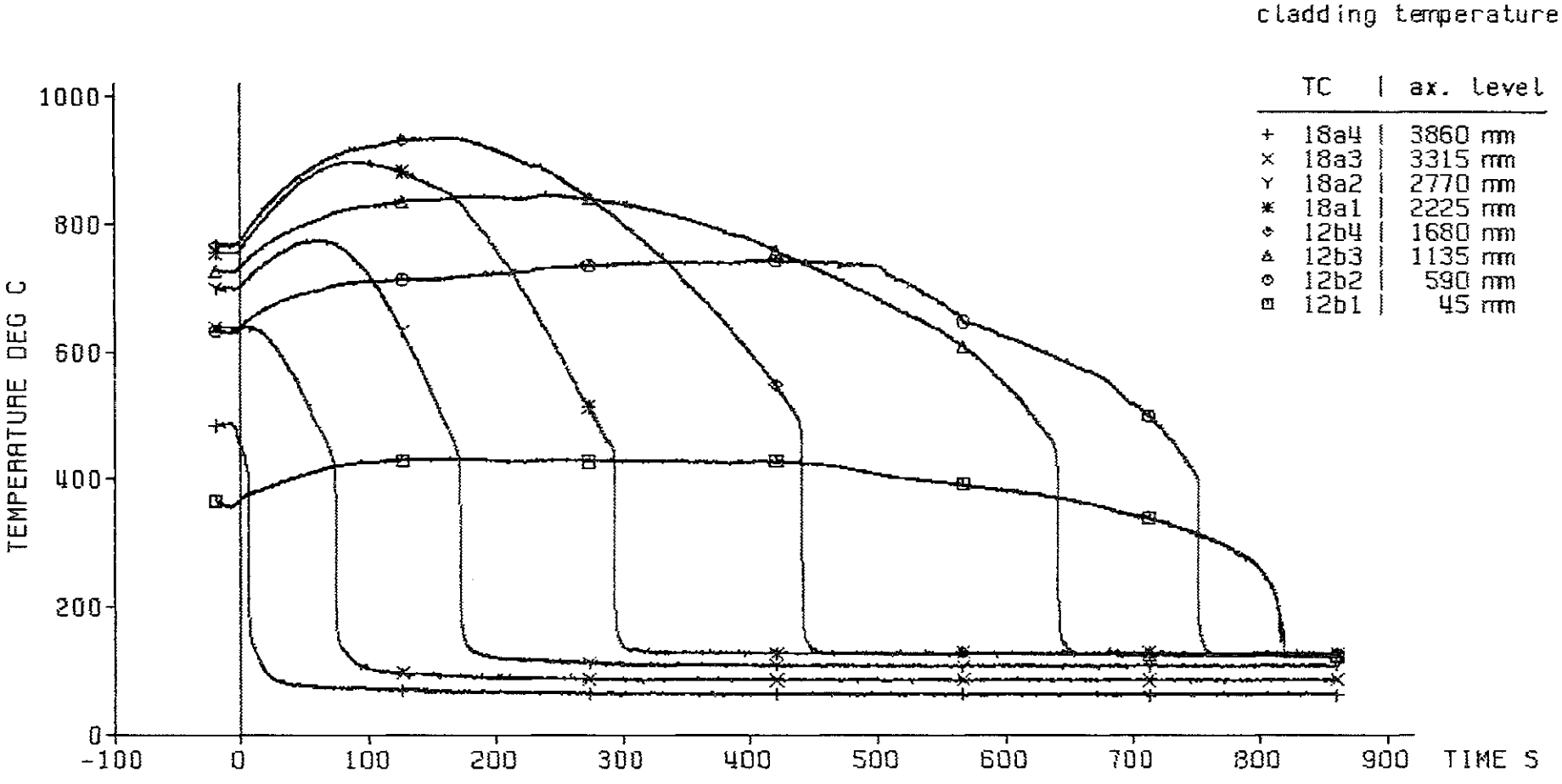
Fig. 12 FEBA: 5x5 ROD BUNDLE TEST SERIES 1, TEST-No. 223



decay heat	120% ANS standard
flooding rate (cold)	3.82 cm/s
system pressure	2.21 bar
feedwater temperature	40 deg C

KfK KIRB

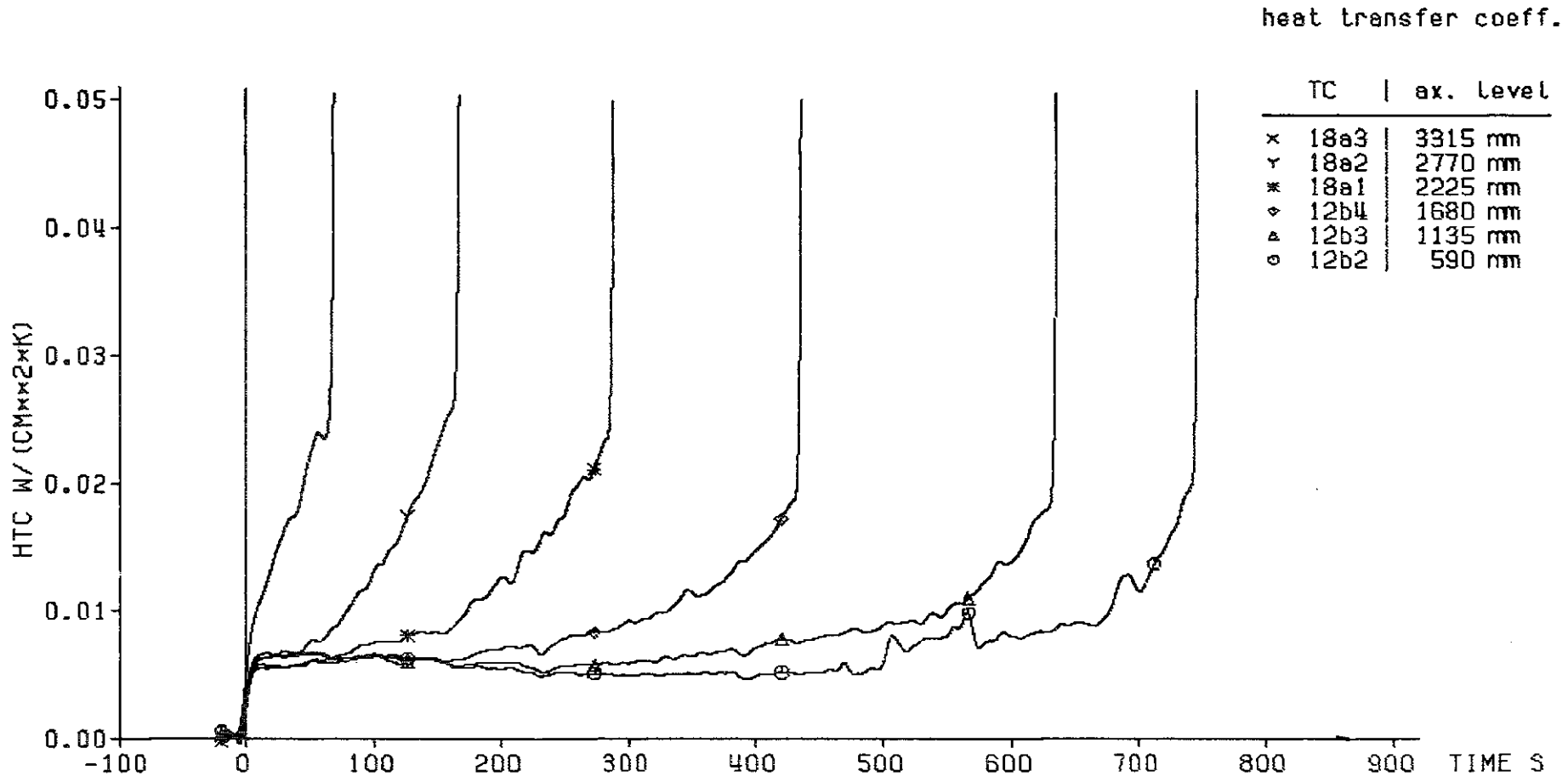
Fig. 13 FEBA: 5x5 ROD BUNDLE, TEST SERIES 1, TEST-No. 223



decay heat	120% ANS standard
flooding rate (cold)	3.82 cm/s
system pressure	2.21 bar
feedwater temperature	40 deg C

KfK IRB

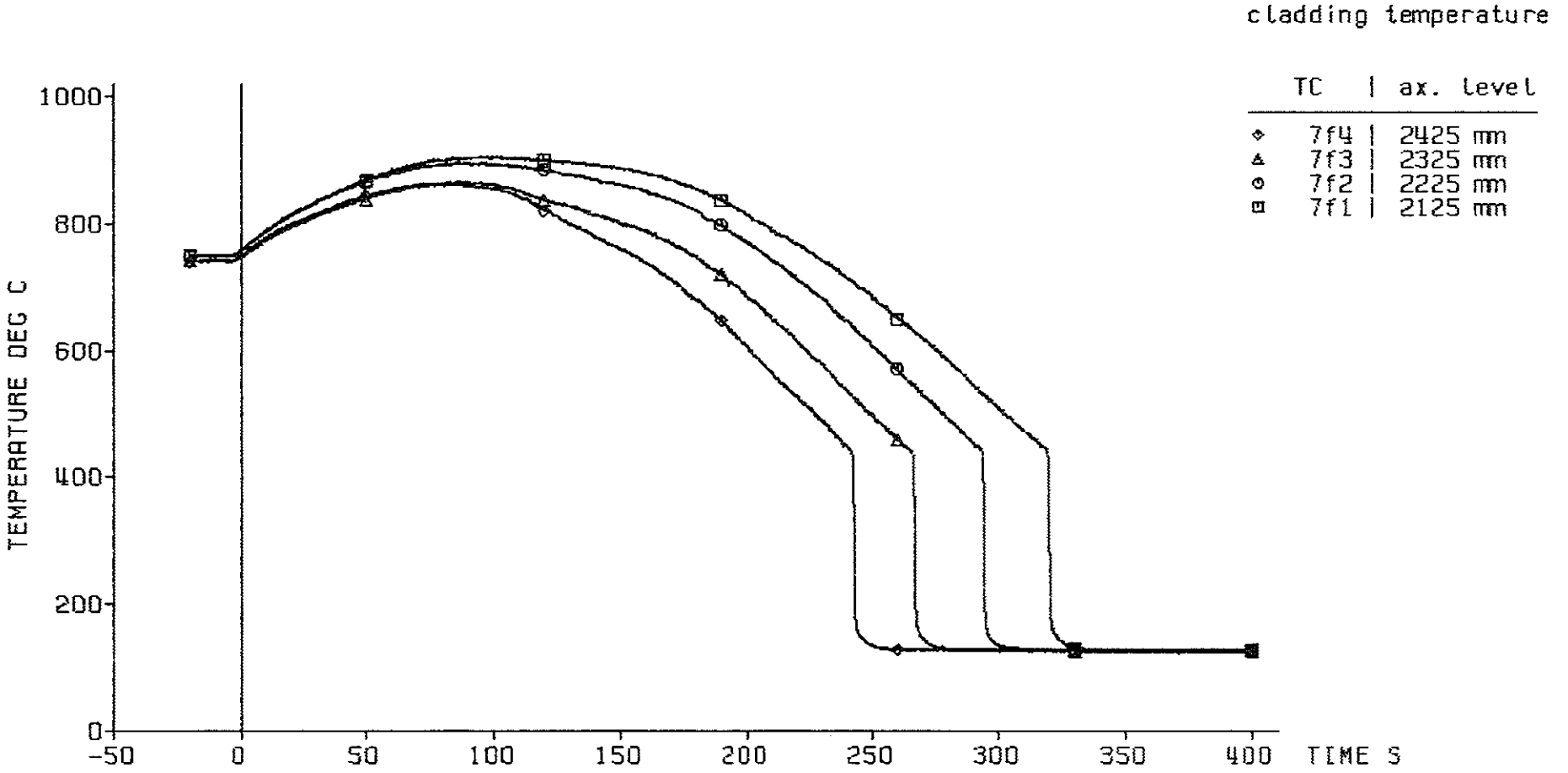
Fig. 14 FEBA: 5x5 ROD BUNDLE, TEST SERIES 1, TEST-No. 223



decay heat	120% ANS standard
flooding rate (cold)	3.82 cm/s
system pressure	2.21 bar
feedwater temperature	40 deg C

KfK IRB

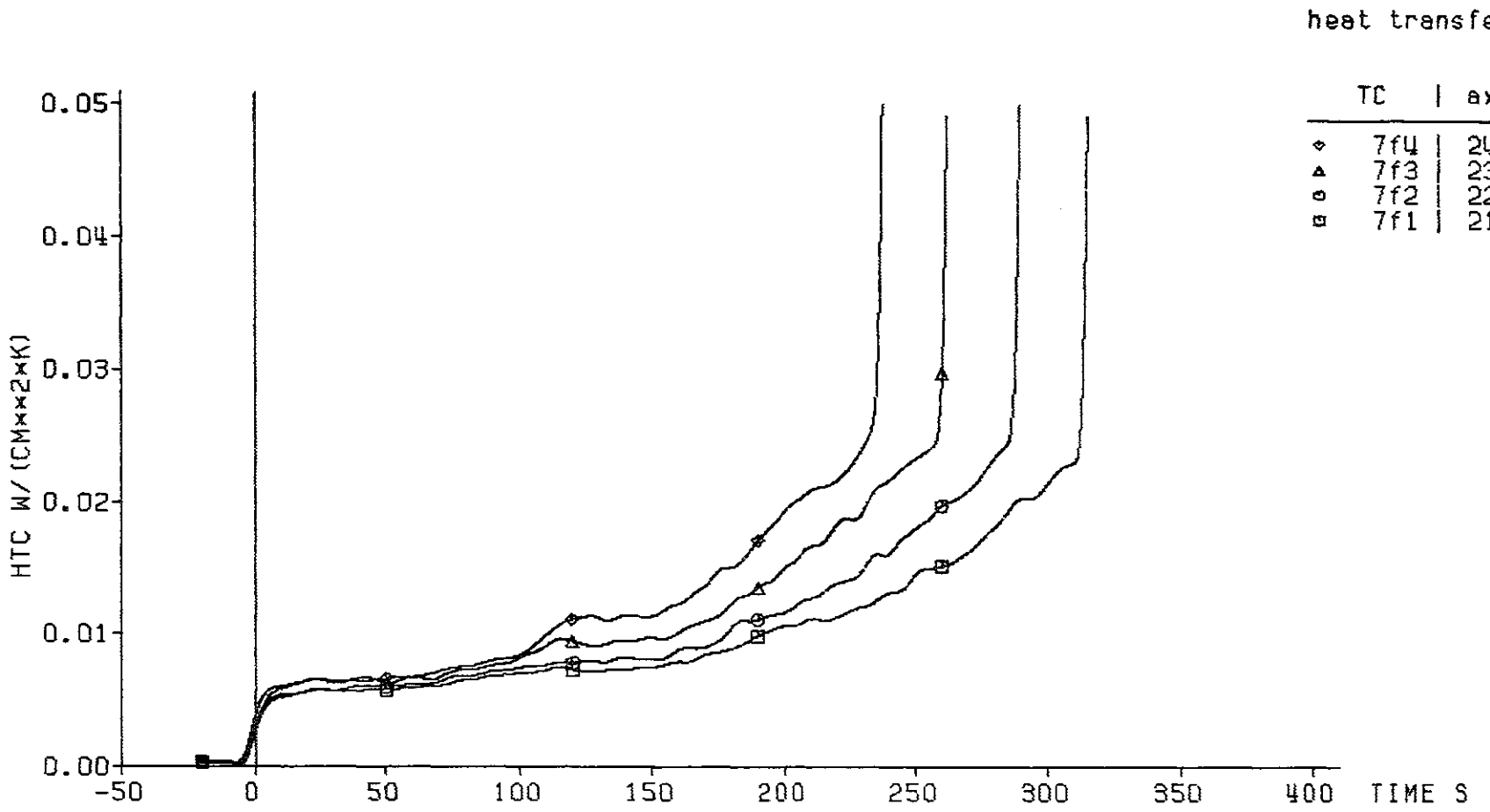
Fig. 15 FEBA: 5x5 ROD BUNDLE, TEST SERIES 1, TEST-No. 223



decay heat	120% ANS standard
flooding rate (cold)	3.82 cm/s
system pressure	2.21 bar
feedwater temperature	40 deg C

KfK KIRB

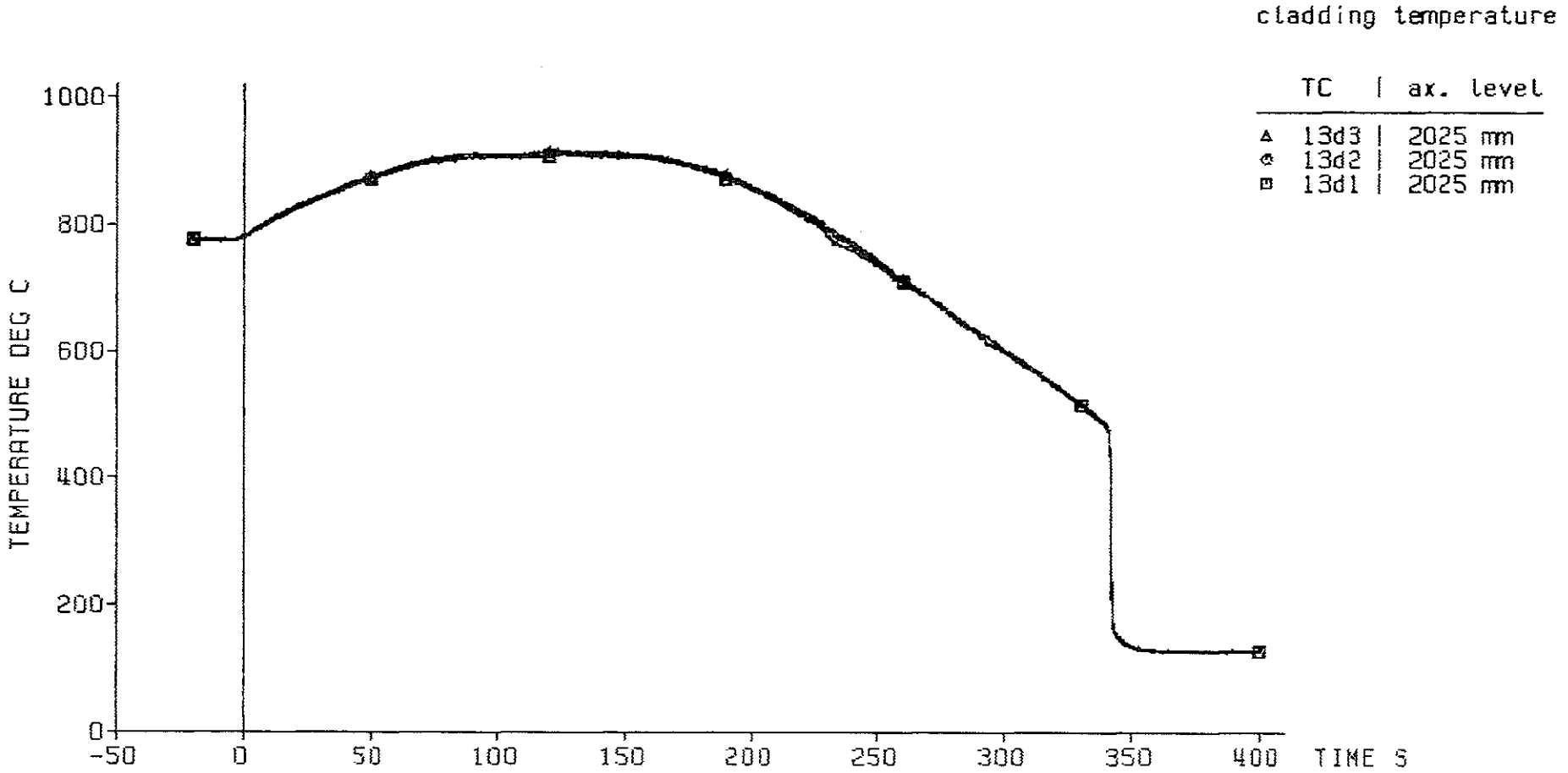
Fig. 16 FEBA: 5x5 ROD BUNDLE, TEST SERIES 1, TEST-No. 223



decay heat	120% ANS standard
flooding rate (cold)	3.82 cm/s
system pressure	2.21 bar
feedwater temperature	40 deg C

KfK IRB

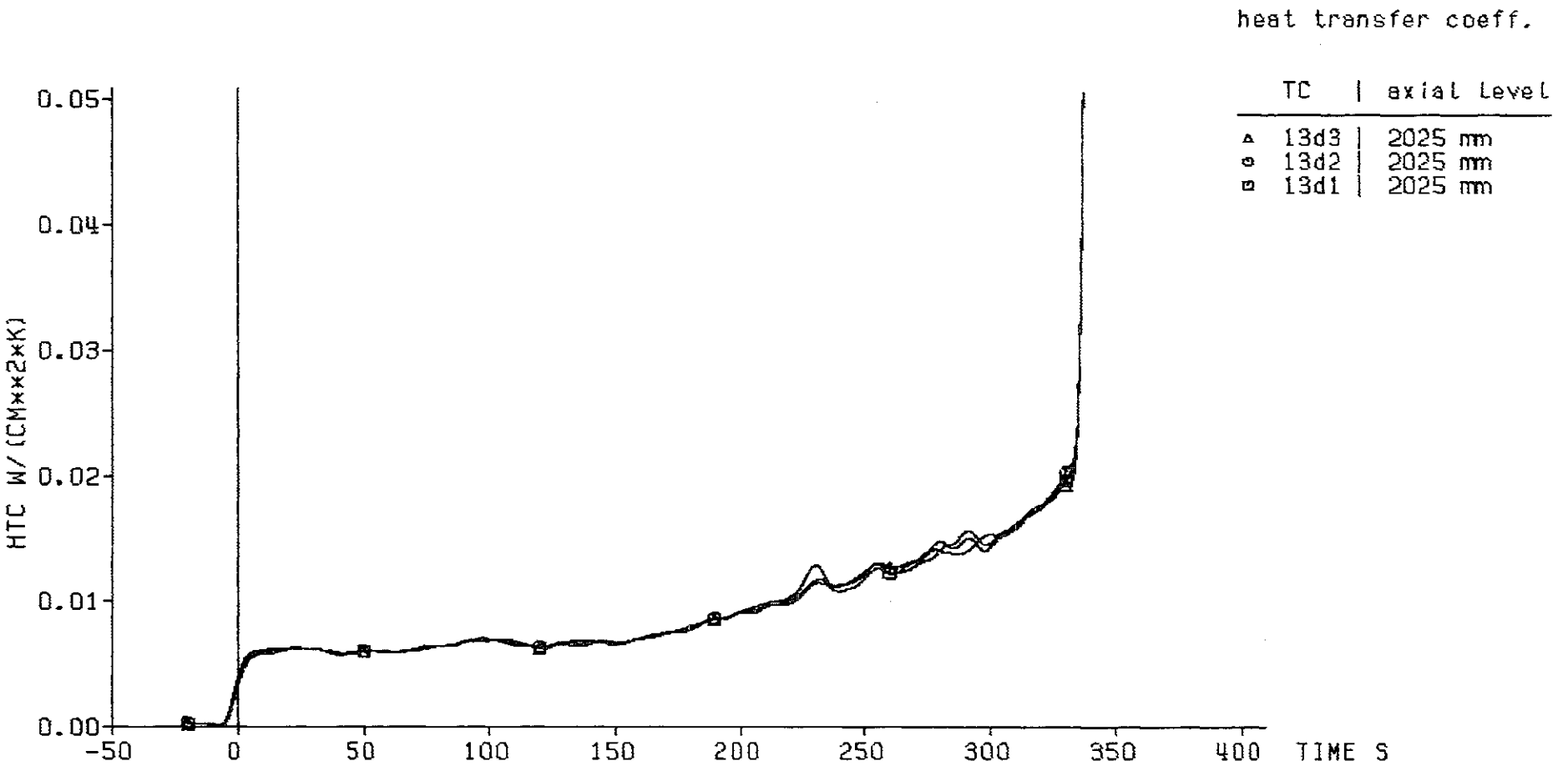
Fig. 17 FEBA: 5x5 ROD BUNDLE, TEST SERIES 1, TEST-No. 223



decay heat	120% ANS standard
flooding rate (cold)	3.82 cm/s
system pressure	2.21 bar
feedwater temperature	40 deg C

KfK IRB

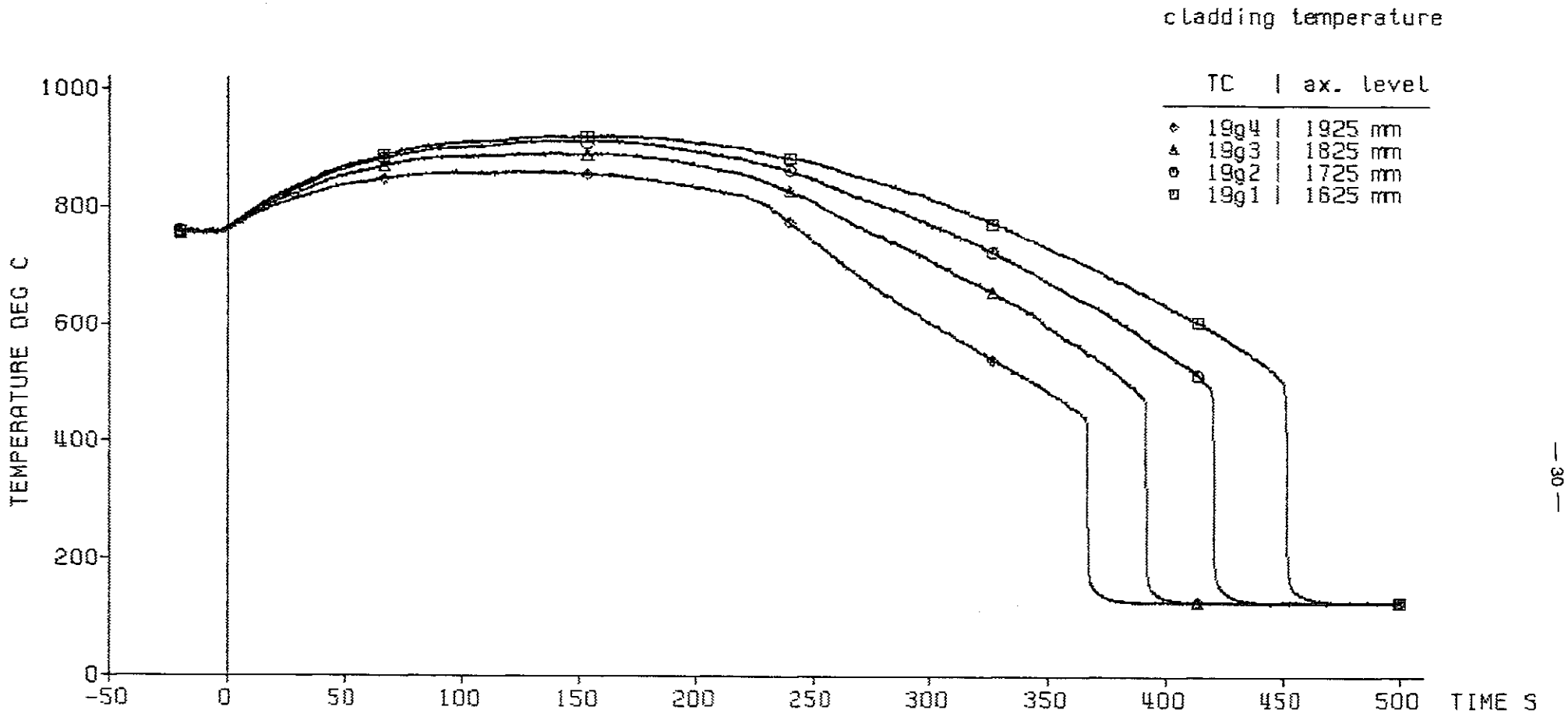
Fig. 18 FEBA: 5x5 ROD BUNDLE, TEST SERIES 1, TEST-No. 223



decay heat	120% ANS standard
flooding rate (cold)	3.82 cm/s
system pressure	2.21 bar
feedwater temperature	40 deg C

KfK IRB

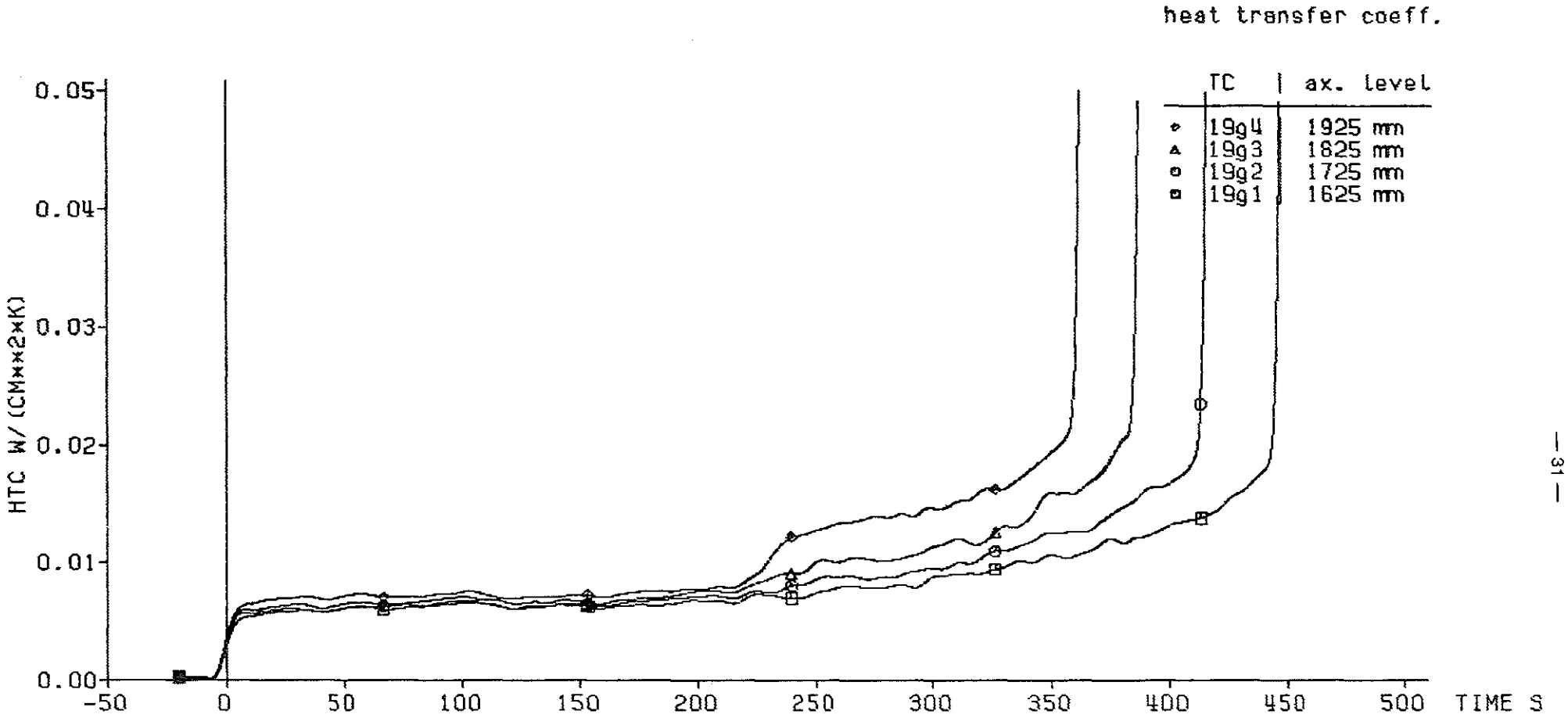
Fig. 19 FEBA: 5x5 ROD BUNDLE, TEST SERIES 1, TEST-No. 223



decay heat	120% ANS standard
flooding rate (cold)	3.82 cm/s
system pressure	2.21 bar
feedwater temperature	40 deg C

KfK IRB

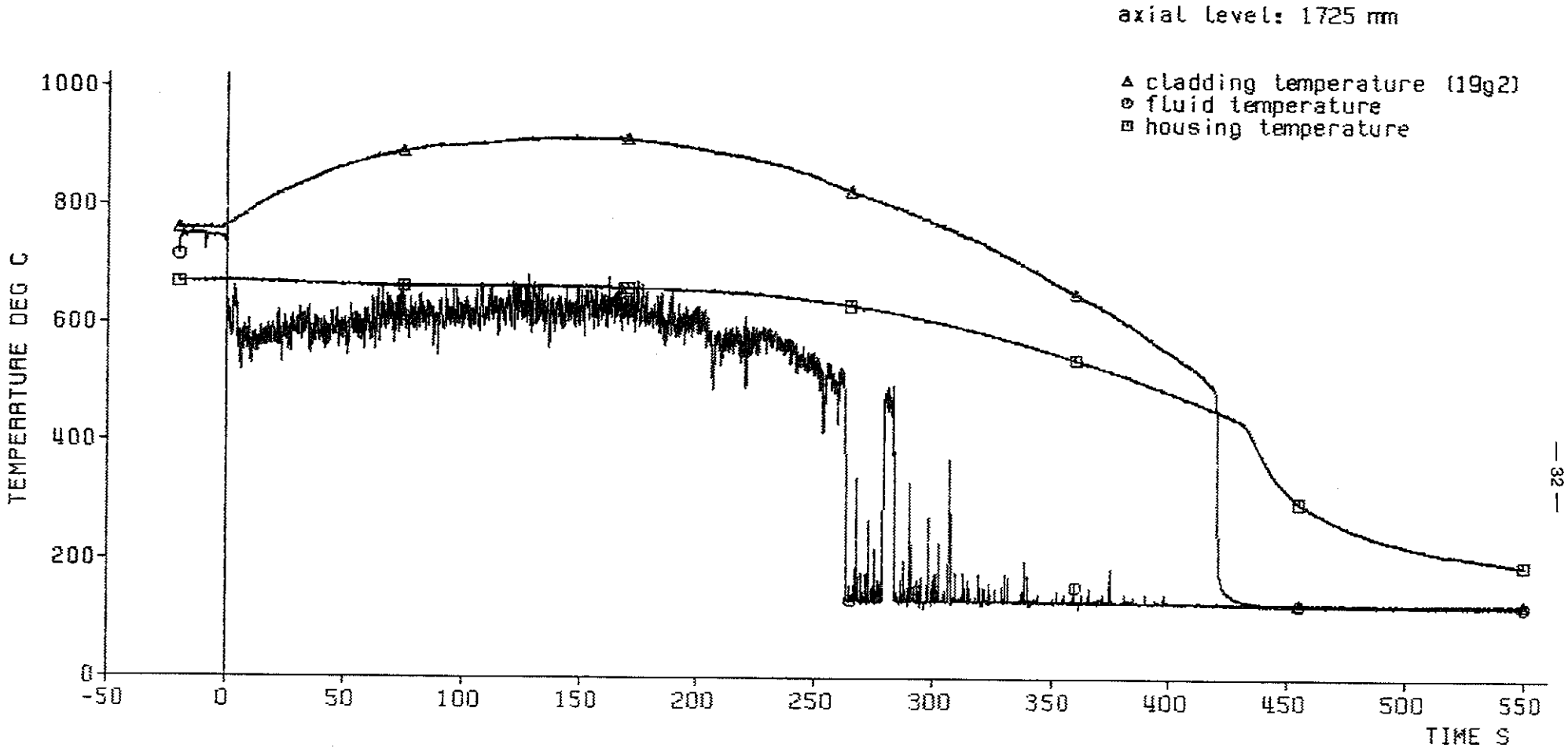
Fig. 20 FEBA: 5x5 ROD BUNDLE, TEST SERIES 1, TEST-No. 223



decay heat	120% ANS standard
flooding rate (cold)	3.82 cm/s
system pressure	2.21 bar
feedwater temperature	40 deg C

KfK ITRB

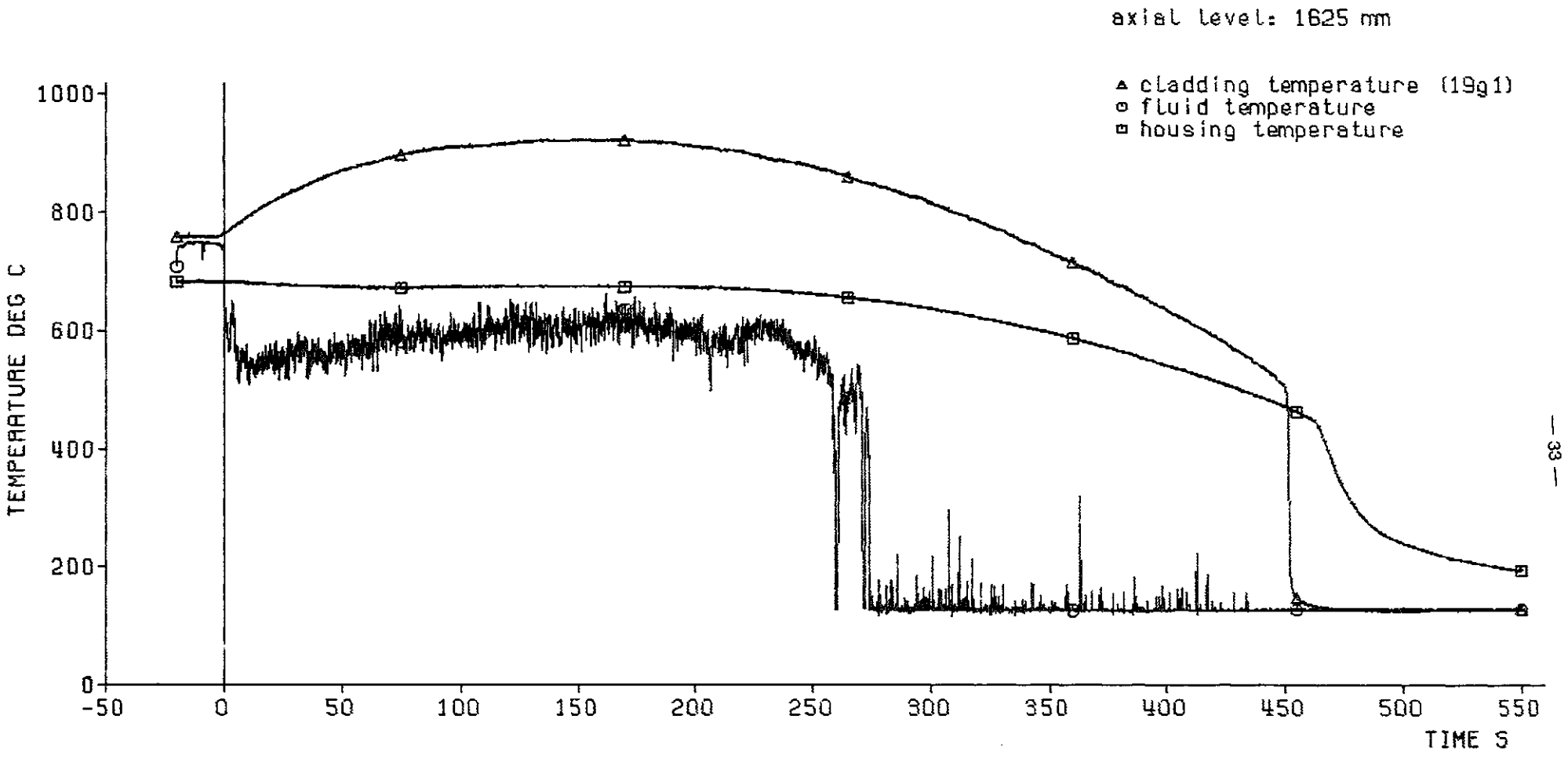
Fig. 21 FEBA: 5x5 ROD BUNDLE, TEST SERIES 1, TEST-No. 223



decay heat	120% ANS standard
flooding rate (cold)	3.82 cm/s
system pressure	2.21 bar
feedwater temperature	40 deg C

KfK KIRB

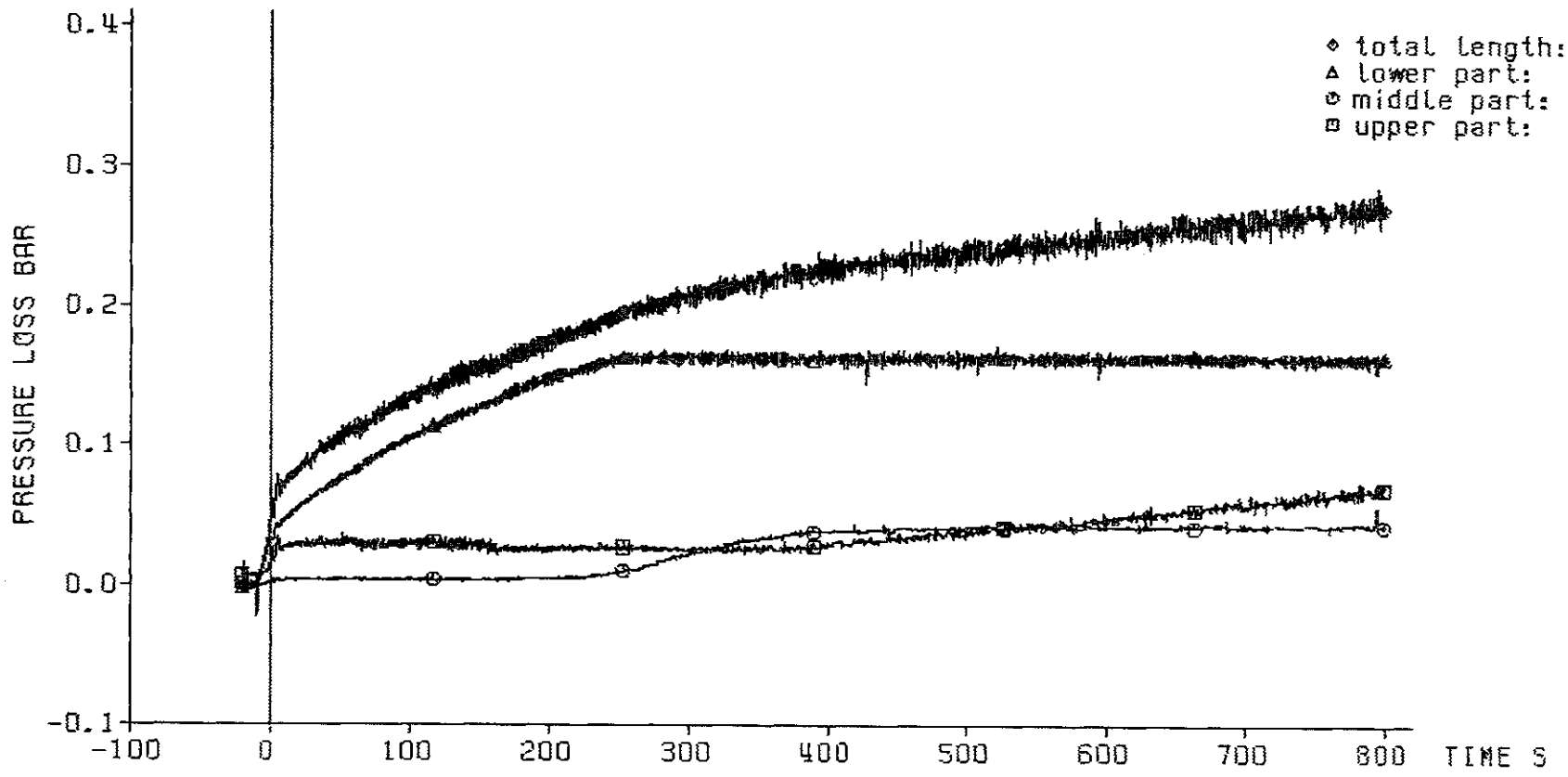
Fig. 22 FEBA: 5x5 ROD BUNDLE, TEST SERIES 1, TEST-No. 223



decay heat	120% ANS standard
flooding rate (cold)	3.82 cm/s
system pressure	2.21 bar
feedwater temperature	40 deg C

KfK IRB

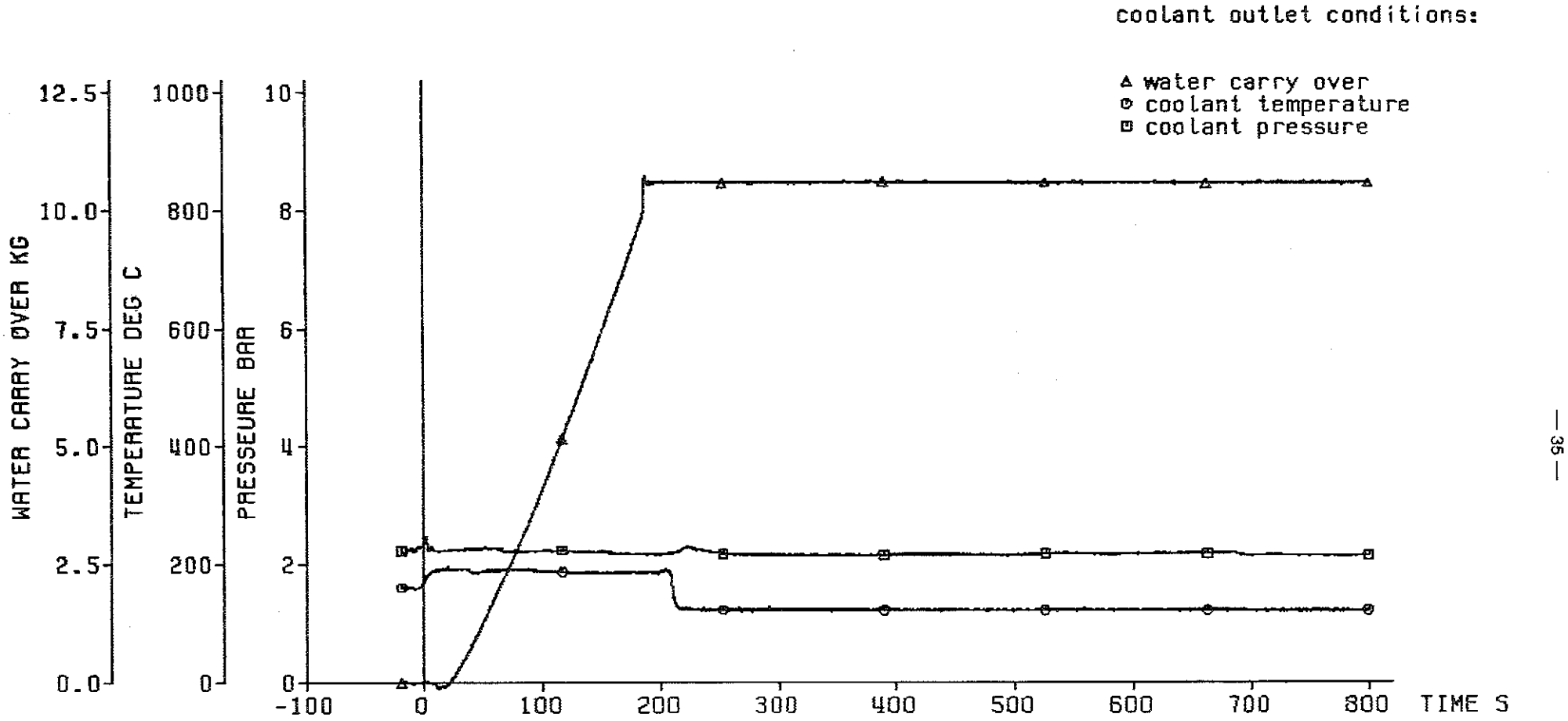
Fig. 23 FEBA: 5x5 ROD BUNDLE, TEST SERIES 1, TEST-No. 223



decay heat	120% ANS standard
flooding rate (cold)	3.62 cm/s
system pressure	2.21 bar
feedwater temperature	40 deg C

KfK IRB

Fig. 24 FEBA: 5x5 ROD BUNDLE, TEST SERIES 1, TEST-No. 223

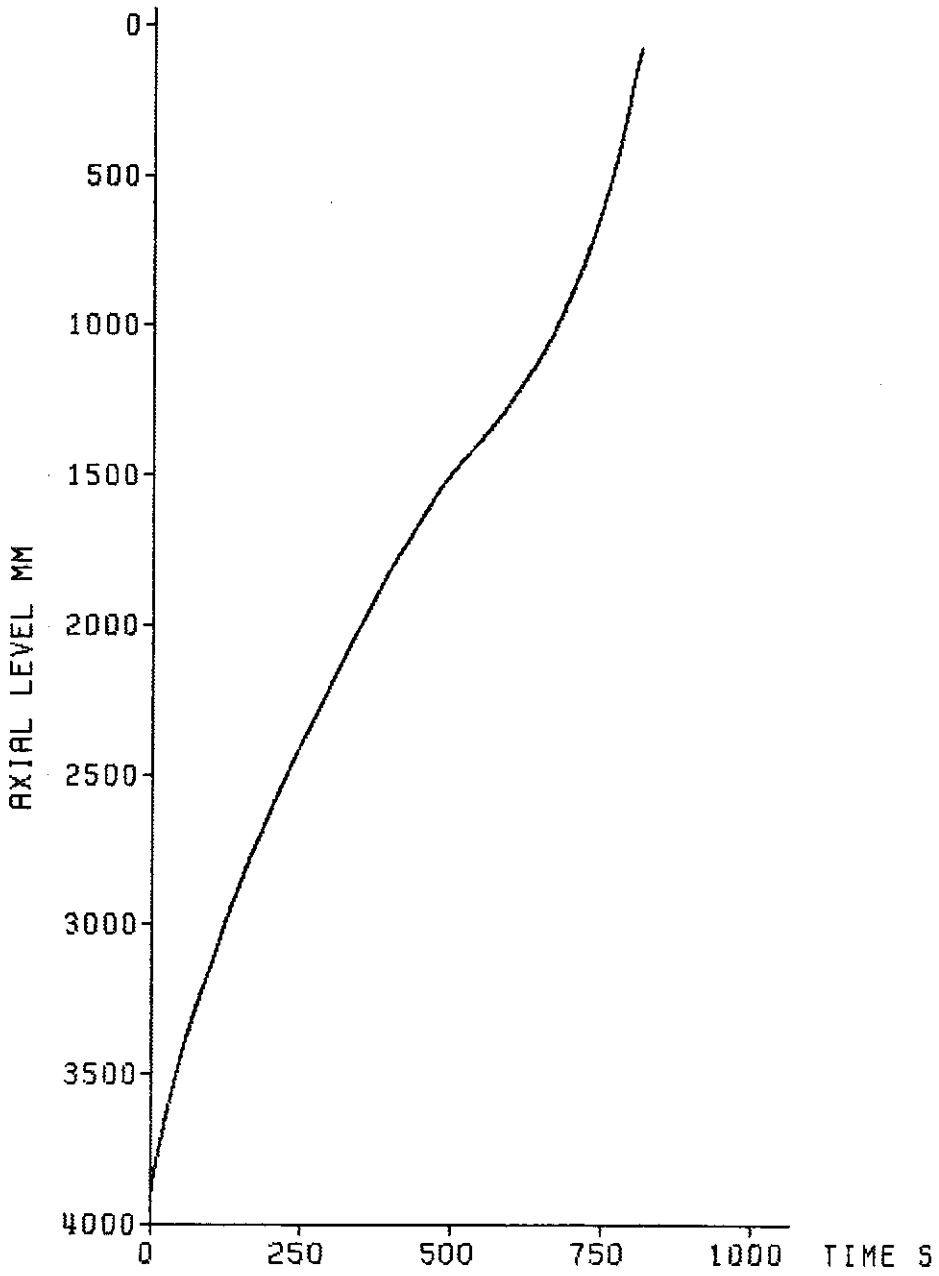


decay heat	120% ANS standard
flooding rate (cold)	3.82 cm/s
system pressure	2.21 bar
feedwater temperature	40 deg C

KfK KIRB

Fig. 25 FEBA: 5x5 ROD BUNDLE, TEST SERIES 1, TEST-No. 223

axial position of the quench front

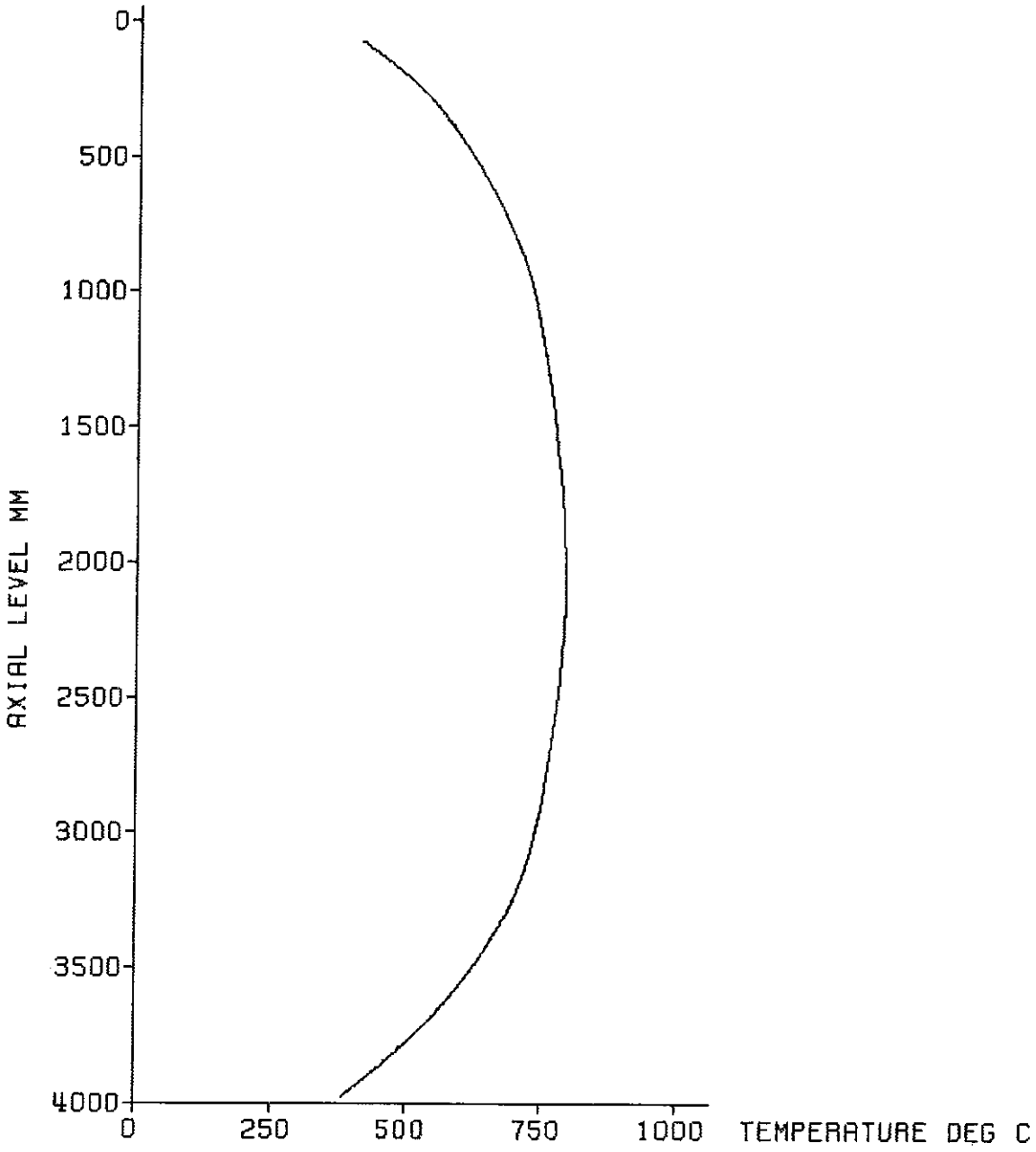


decay heat	120% ANS standard
flooding rate (cold)	3.82 cm/s
system pressure	2.21 bar
feedwater temperature	40 deg C

KfK IRB

Fig. 26 FEBA: 5x5 ROD BUNDLE TEST SERIES 1, TEST-No. 223

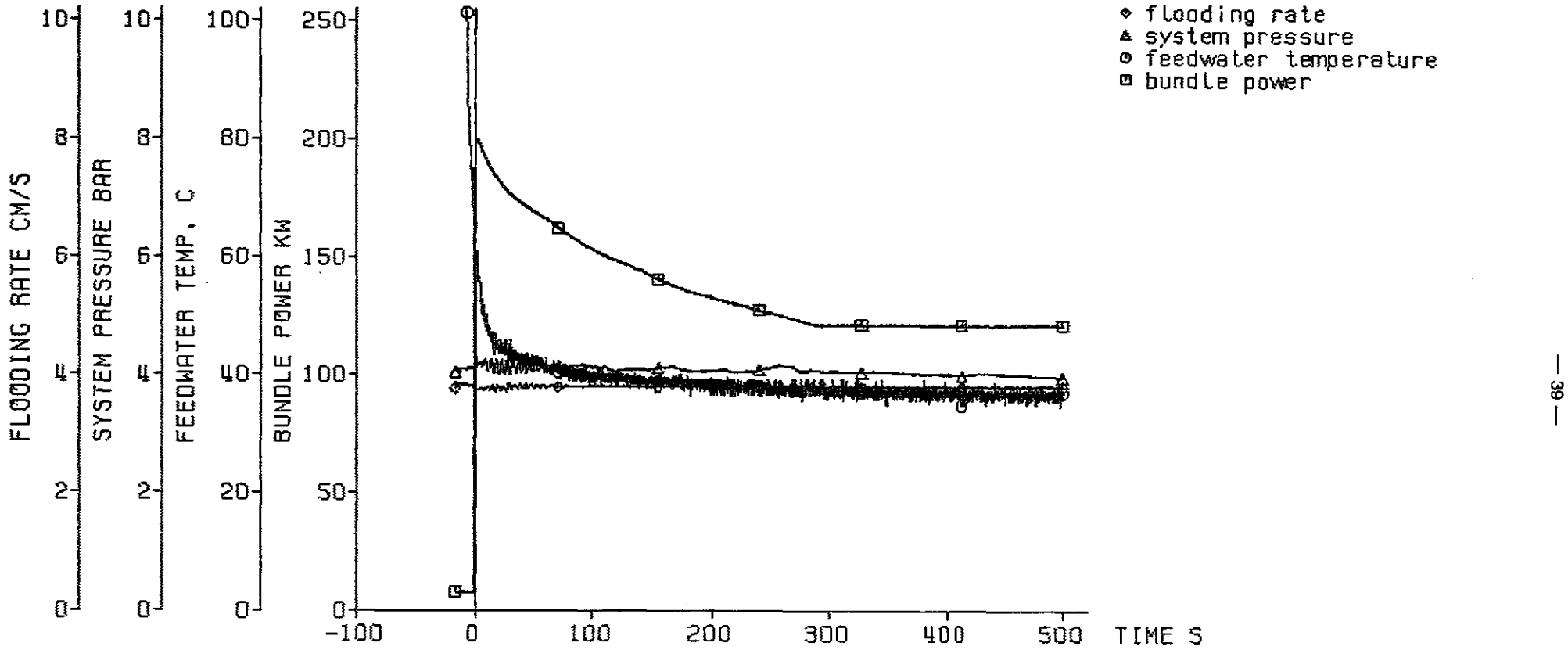
Initial axial temperature profile of the cladding



decay heat	120% ANS standard
flooding rate (cold)	3.81 cm/s
system pressure	4.12 bar
feedwater temperature	40 deg C

KfK IRB

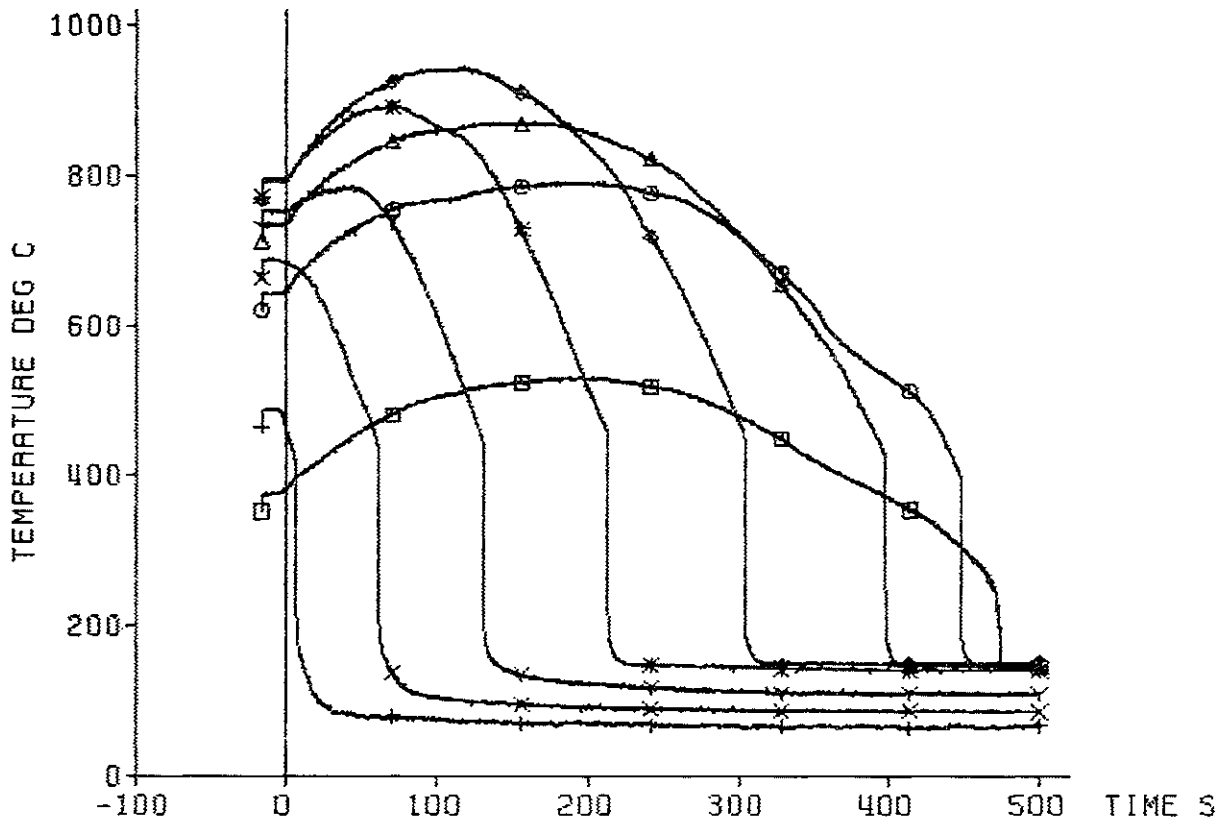
Fig. 27 FEBA: 5x5 ROD BUNDLE TEST SERIES 1, TEST-No. 216



decay heat	120% ANS standard
flooding rate (cold)	3.81 cm/s
system pressure	4.12 bar
feedwater temperature	40 deg C

KfK IRB

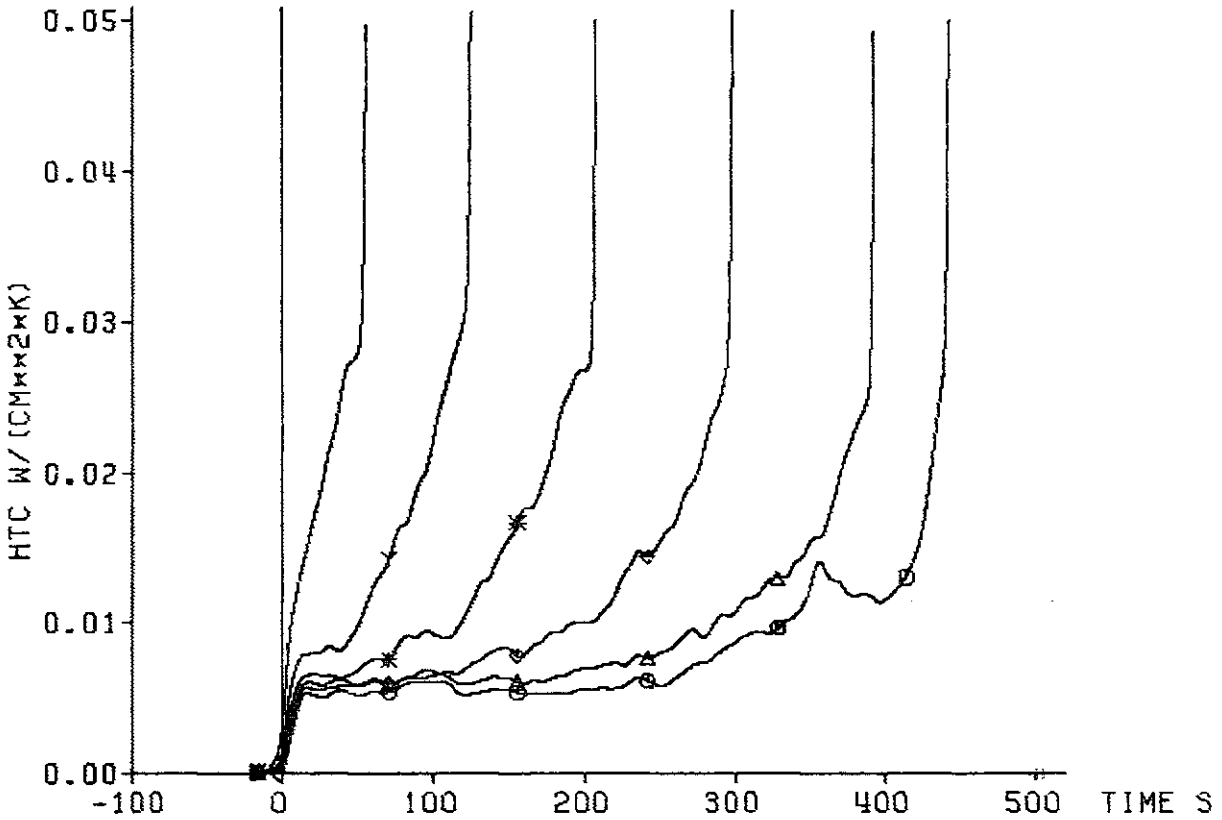
Fig. 28 FEBA: 5x5 ROD BUNDLE, TEST SERIES 1, TEST-No. 216



decay heat	120% ANS standard
flooding rate (cold)	3.81 cm/s
system pressure	4.12 bar
feedwater temperature	40 deg C

KfK KIRB

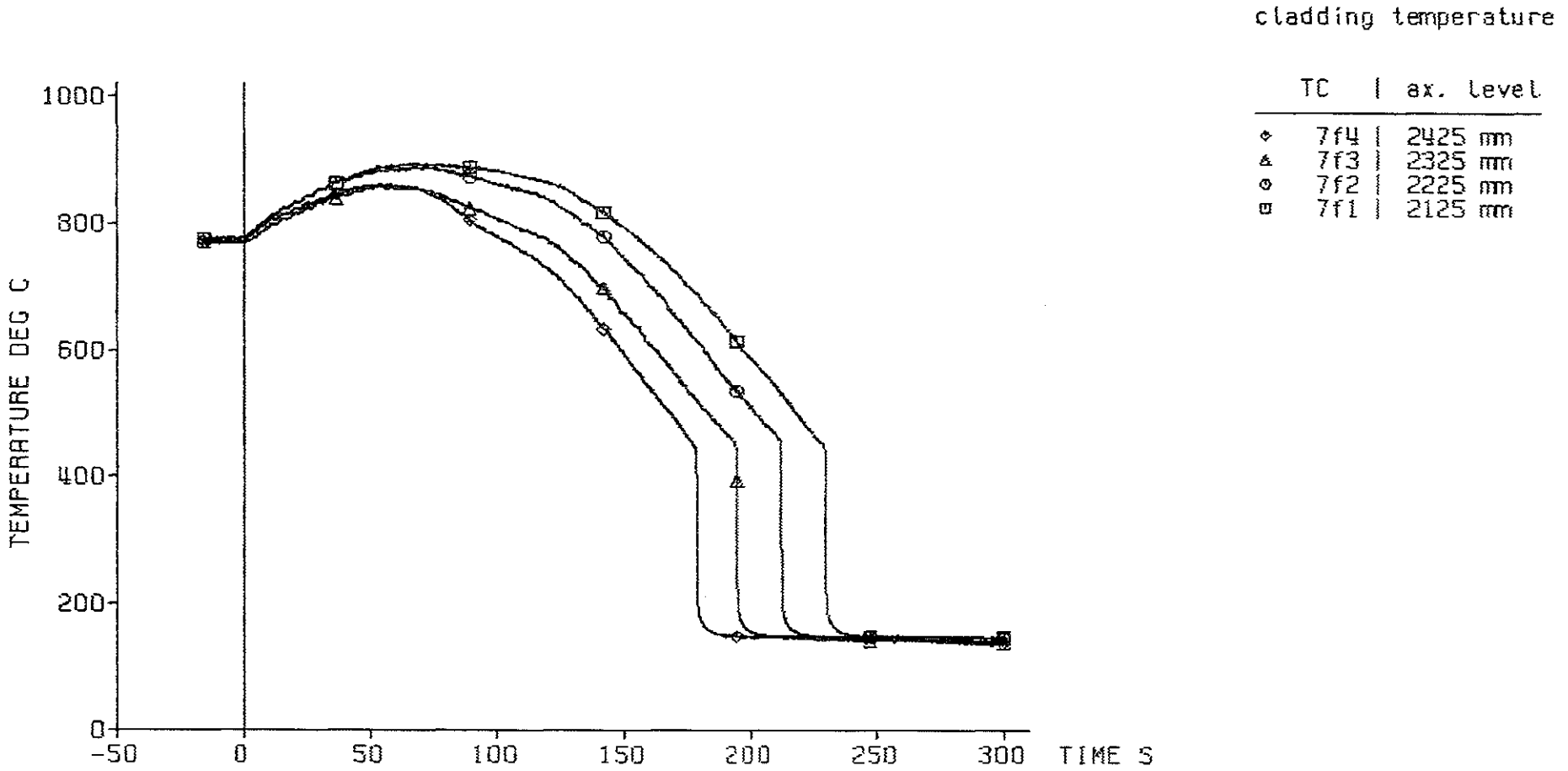
Fig. 29 FEBA: 5x5 ROD BUNDLE, TEST SERIES 1, TEST-No. 216



decay heat	120% ANS standard
flooding rate (cold)	3.81 cm/s
system pressure	4.12 bar
feedwater temperature	40 deg C

KfK IRB

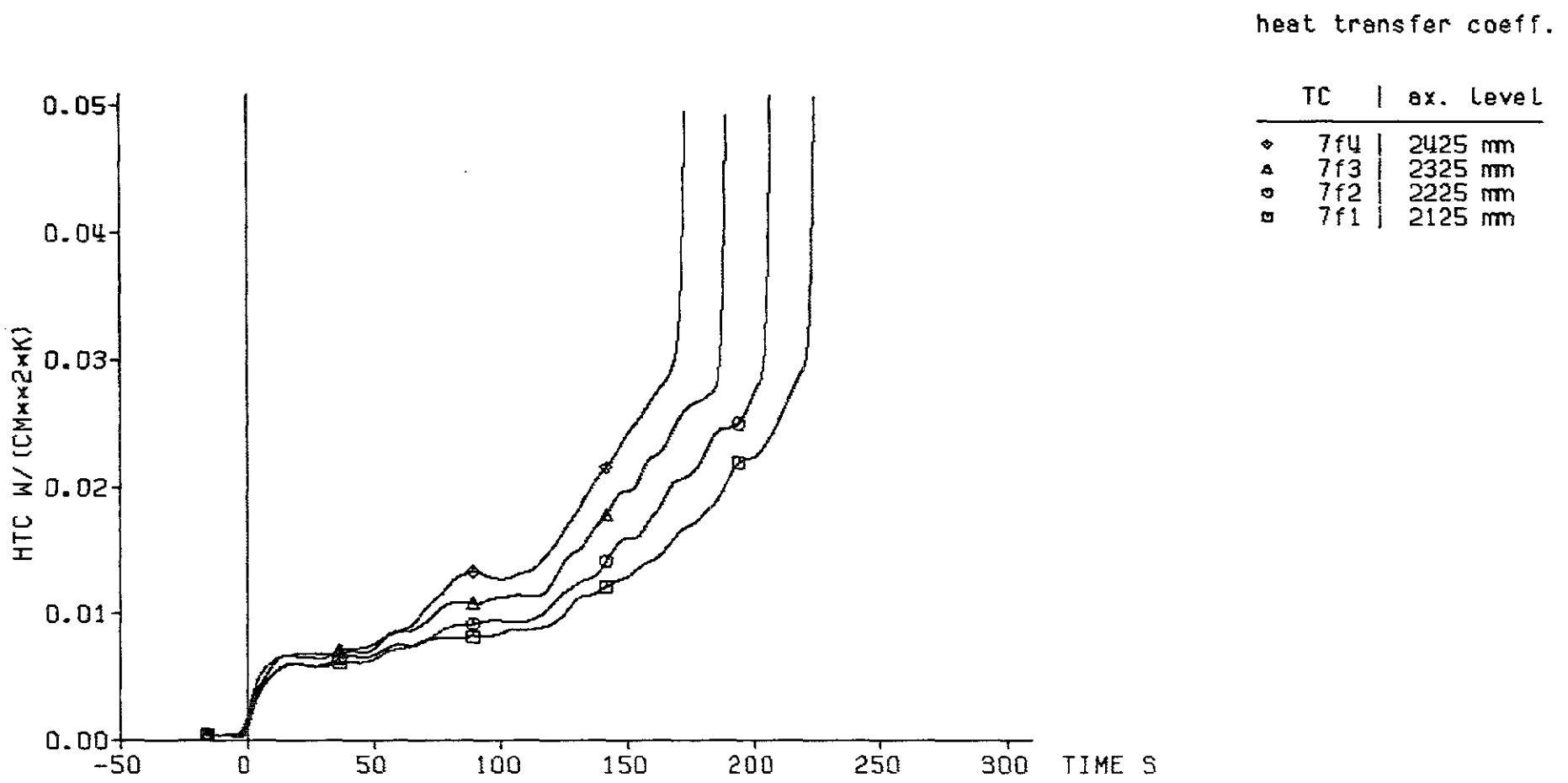
Fig. 30 FEBA: 5x5 ROD BUNDLE, TEST SERIES 1, TEST-No. 216



decay heat	120% ANS standard
flooding rate (cold)	3.81 cm/s
system pressure	4.12 bar
feedwater temperature	40 deg C

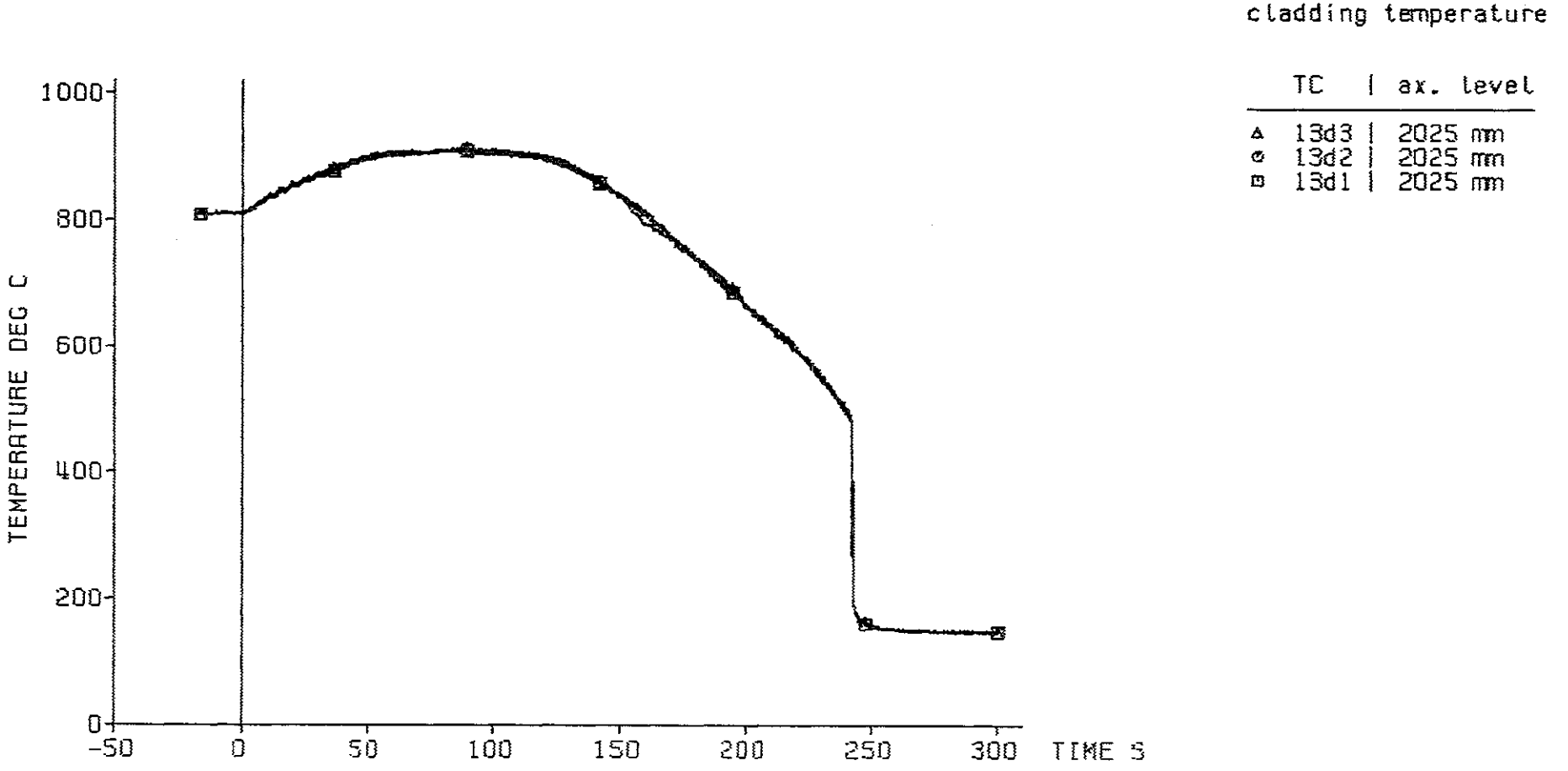
KfK IRB

Fig. 31 FEBA: 5x5 ROD BUNDLE, TEST SERIES 1, TEST-No. 216



decay heat	120% ANS standard
flooding rate (cold)	3.81 cm/s
system pressure	4.12 bar
feedwater temperature	40 deg C

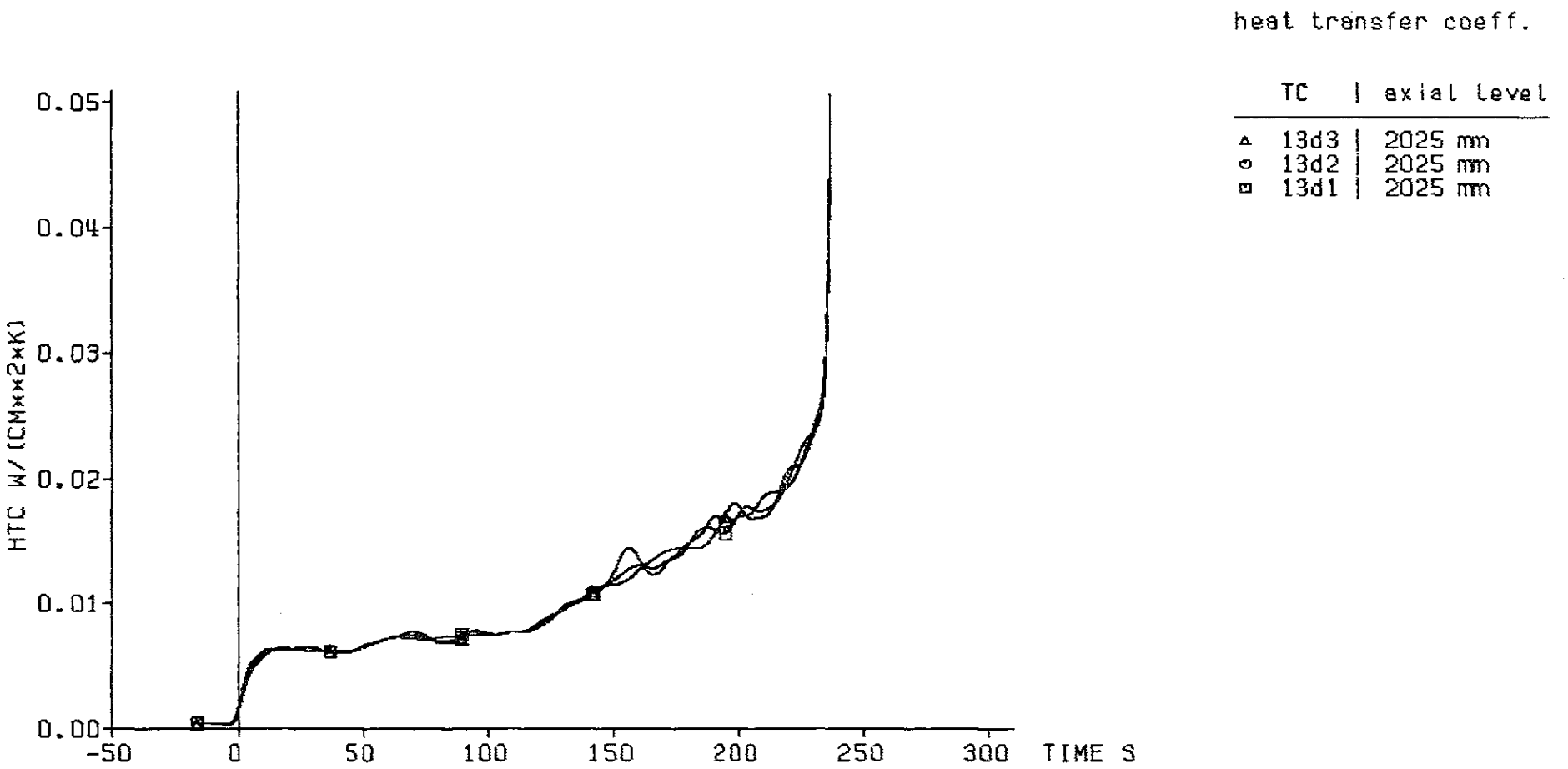
Fig. 32 FEBA: 5x5 ROD BUNDLE, TEST SERIES 1, TEST-No. 216



decay heat	120% ANS standard
flooding rate (cold)	3.81 cm/s
system pressure	4.12 bar
feedwater temperature	40 deg C

KfK KTRB

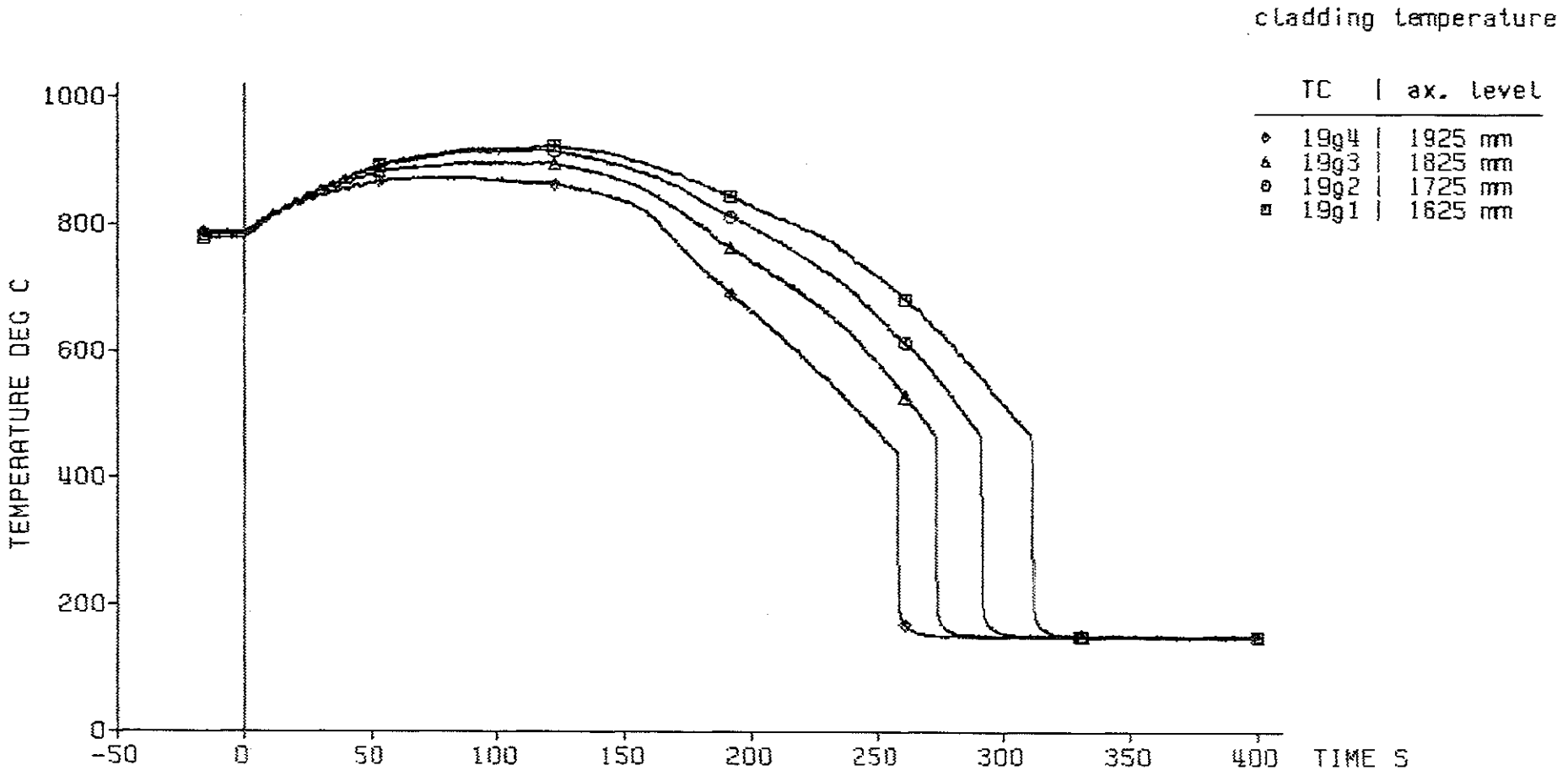
Fig. 33 FEBA: 5x5 ROD BUNDLE, TEST SERIES 1, TEST-No. 216



decay heat	120% ANS standard
flooding rate (cold)	3.81 cm/s
system pressure	4.12 bar
feedwater temperature	40 deg C

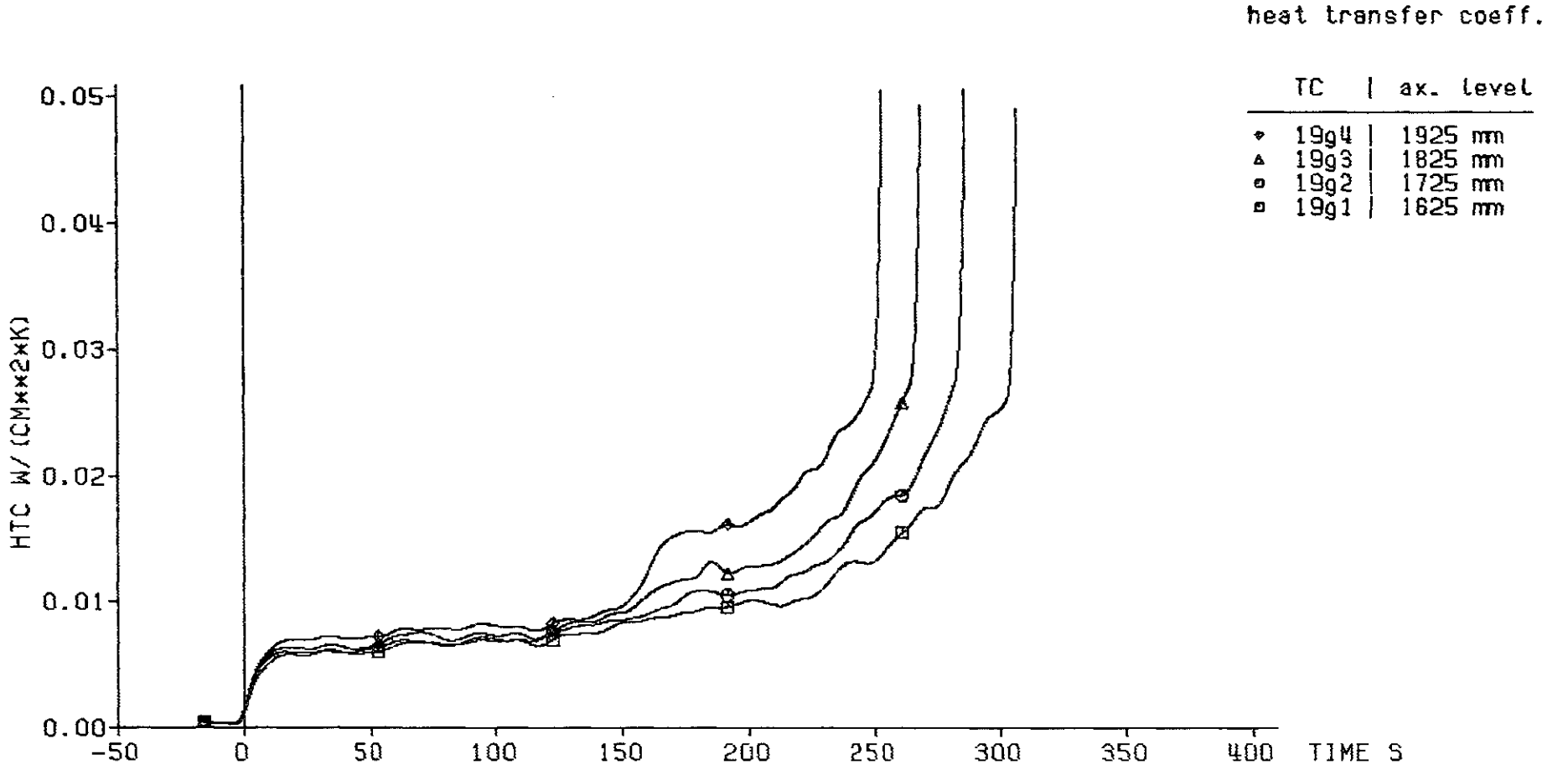
KfK IRB

Fig. 34 FEBA: 5x5 ROD BUNDLE, TEST SERIES 1, TEST-No. 216



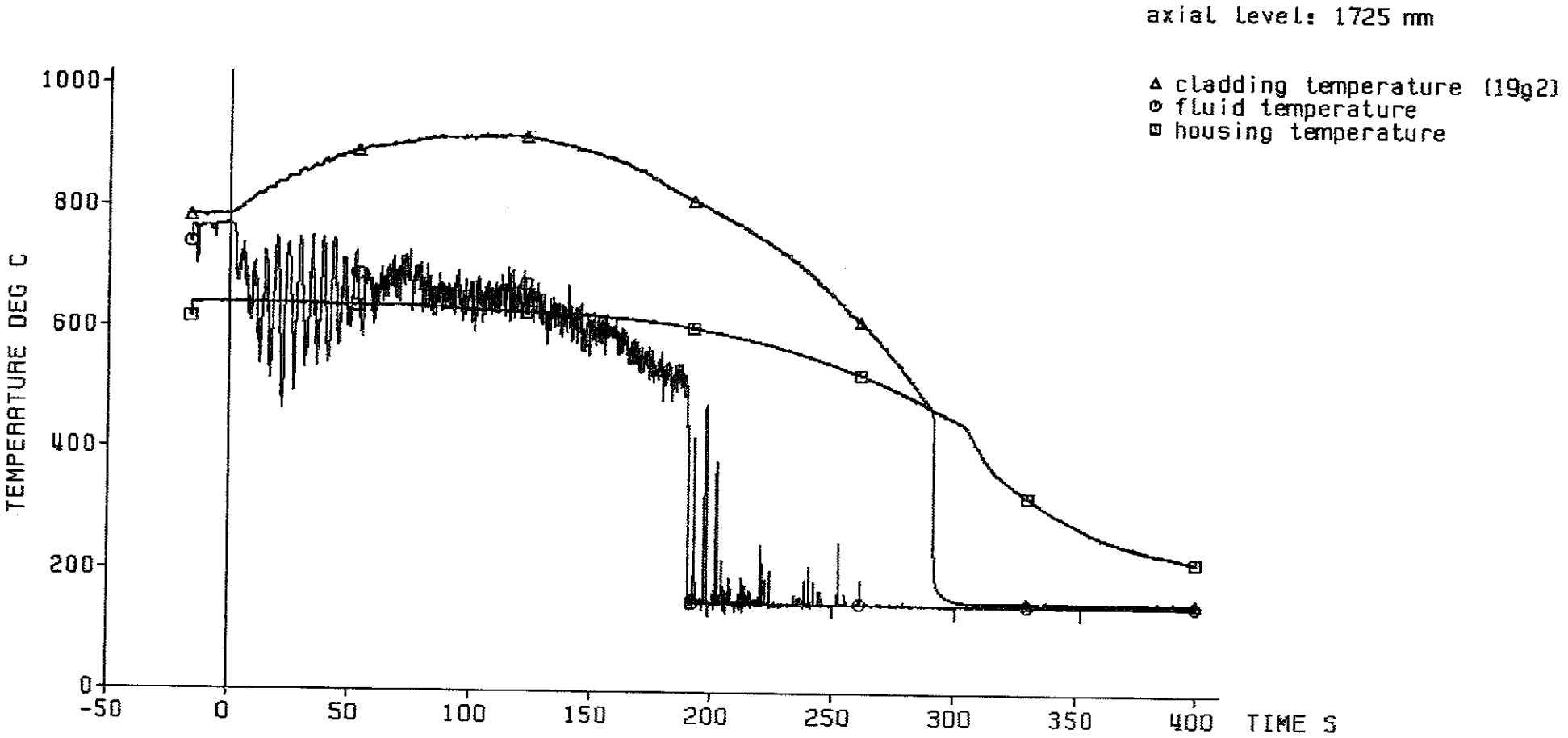
decay heat	120% ANS standard
flooding rate (cold)	3.81 cm/s
system pressure	4.12 bar
feedwater temperature	40 deg C

Fig. 35 FEBA: 5x5 ROD BUNDLE, TEST SERIES 1, TEST-No. 216



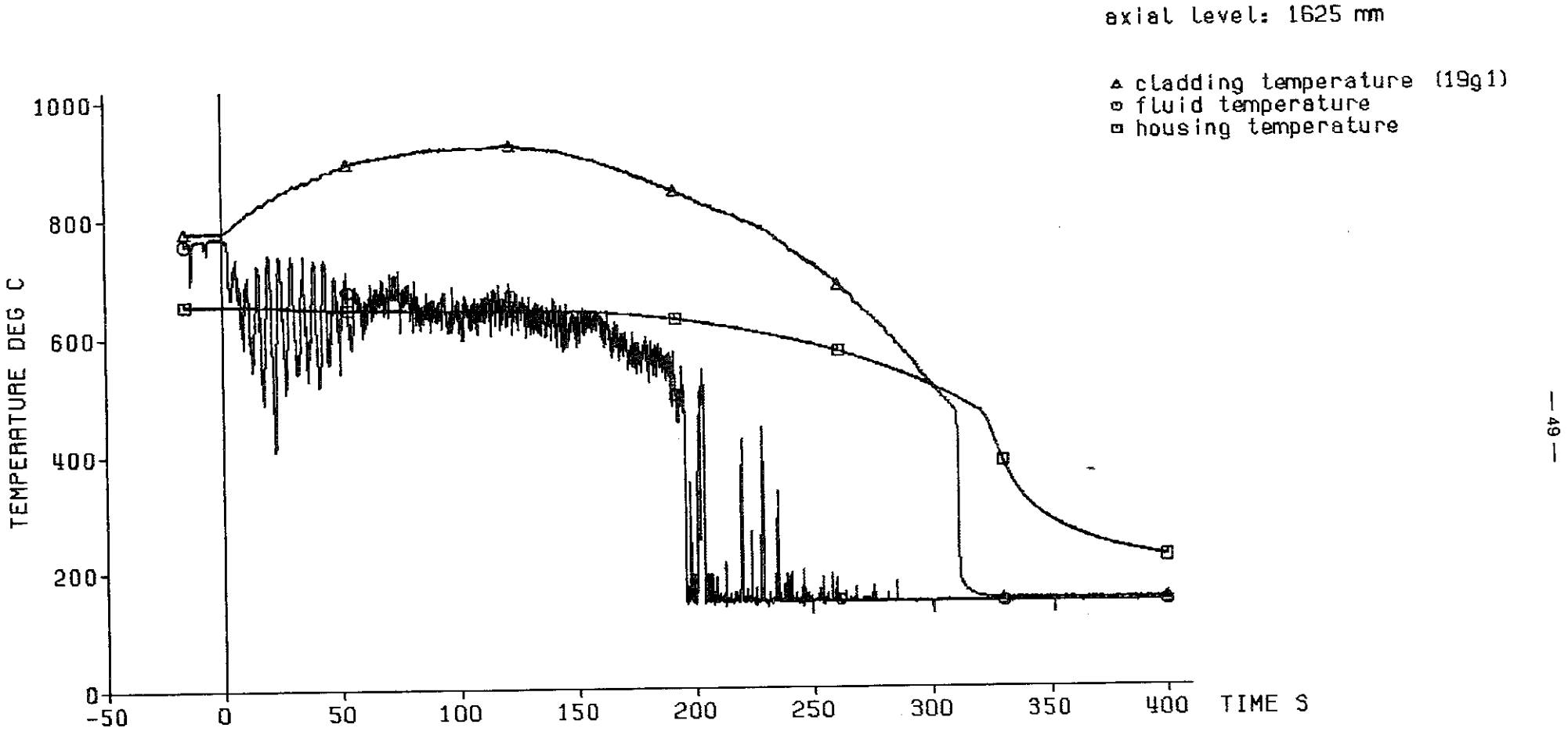
decay heat	120% ANS standard
flooding rate (cold)	3.81 cm/s
system pressure	4.12 bar
feedwater temperature	40 deg C

Fig. 36 FEBA: 5x5 ROD BUNDLE, TEST SERIES 1, TEST-No. 216



decay heat	120% ANS standard
flooding rate (cold)	3.81 cm/s
system pressure	4.12 bar
feedwater temperature	40 deg C

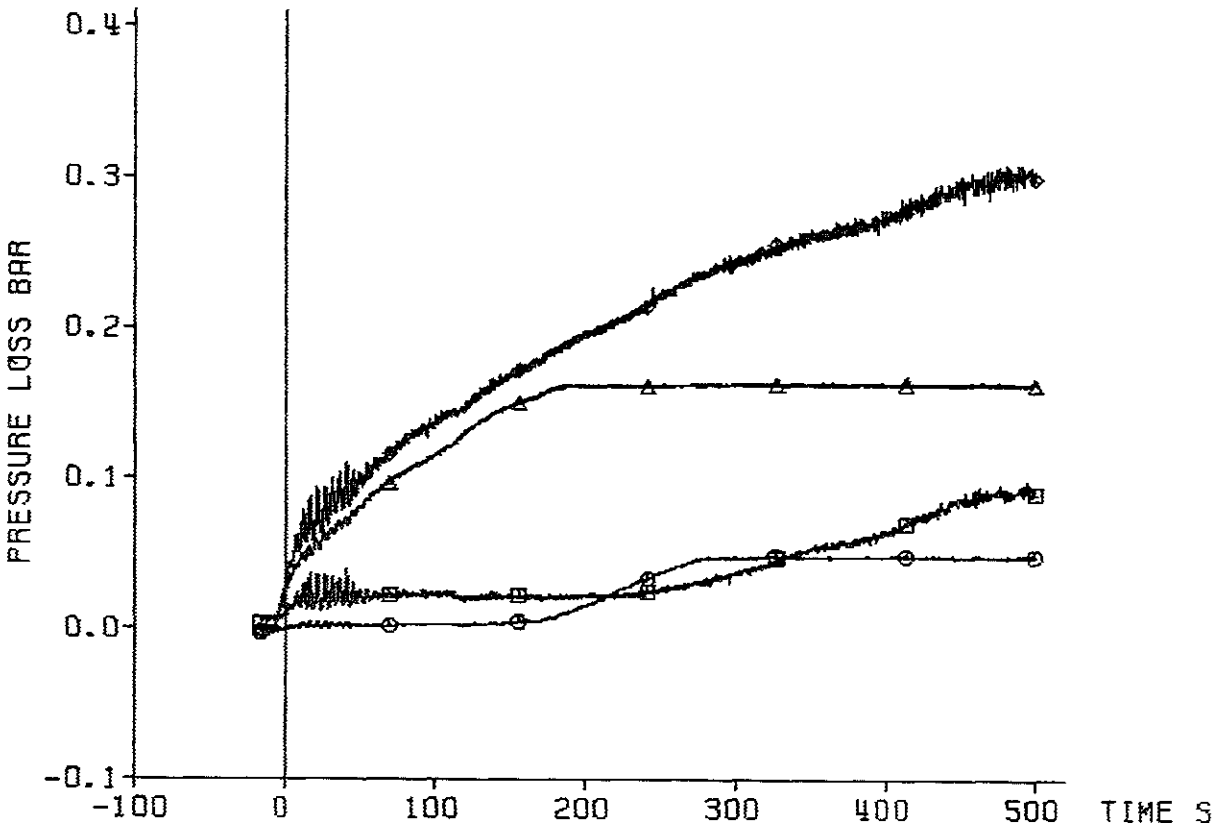
Fig. 37 FEBA: 5x5 ROD BUNDLE, TEST SERIES 1, TEST-No. 216



decay heat	120% ANS standard
flooding rate (cold)	3.81 cm/s
system pressure	4.12 bar
feedwater temperature	40 deg C

KfK IRB

Fig. 38 FEBA: 5x5 ROD BUNDLE, TEST SERIES 1, TEST-No. 216



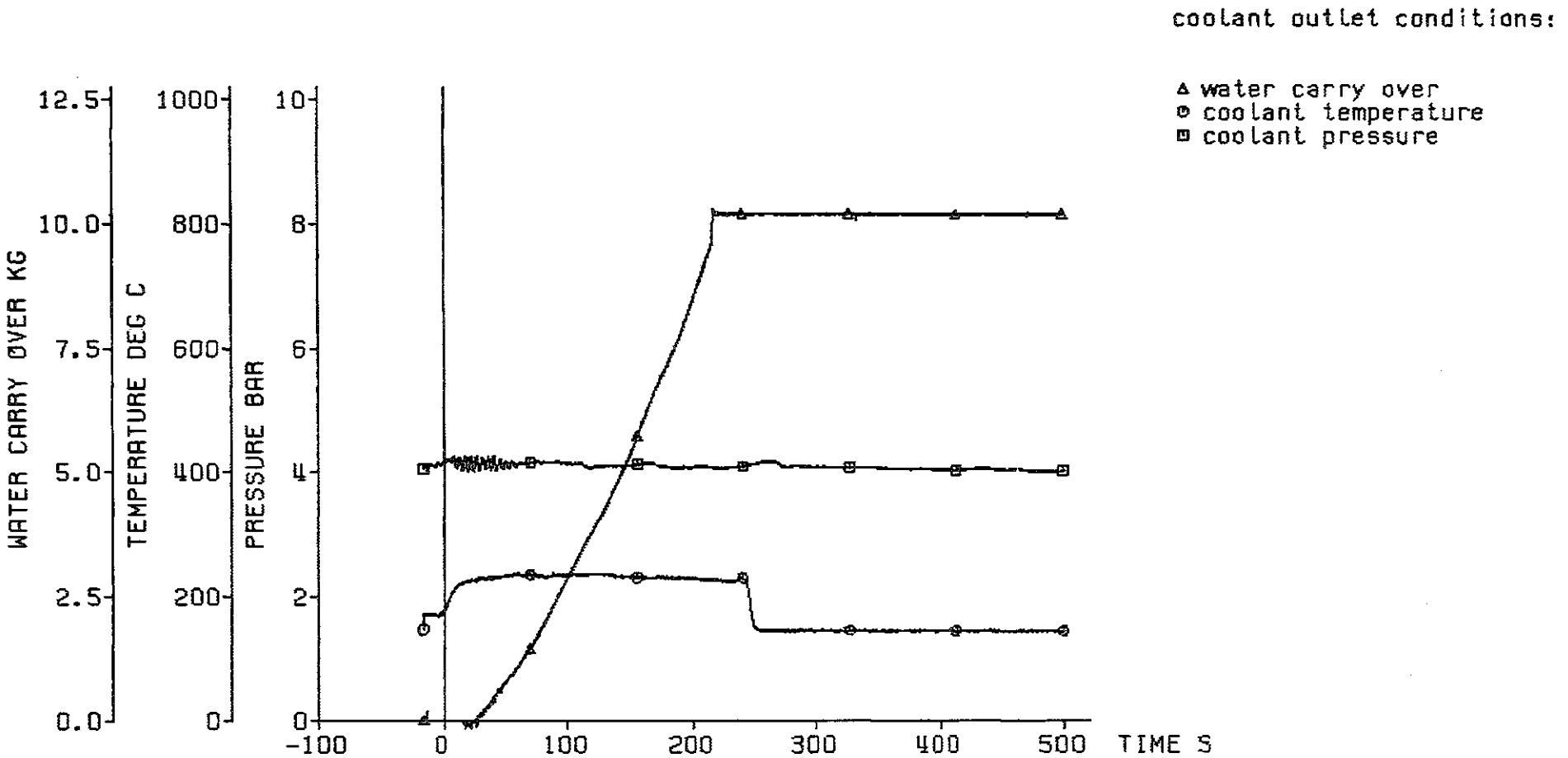
pressure loss
along the test section:

◇ total length: 4196 mm
△ lower part: 1711 mm
○ middle part: 545 mm
□ upper part: 1940 mm

decay heat	120% ANS standard
flooding rate (cold)	3.81 cm/s
system pressure	4.12 bar
feedwater temperature	40 deg C

KfK IRB

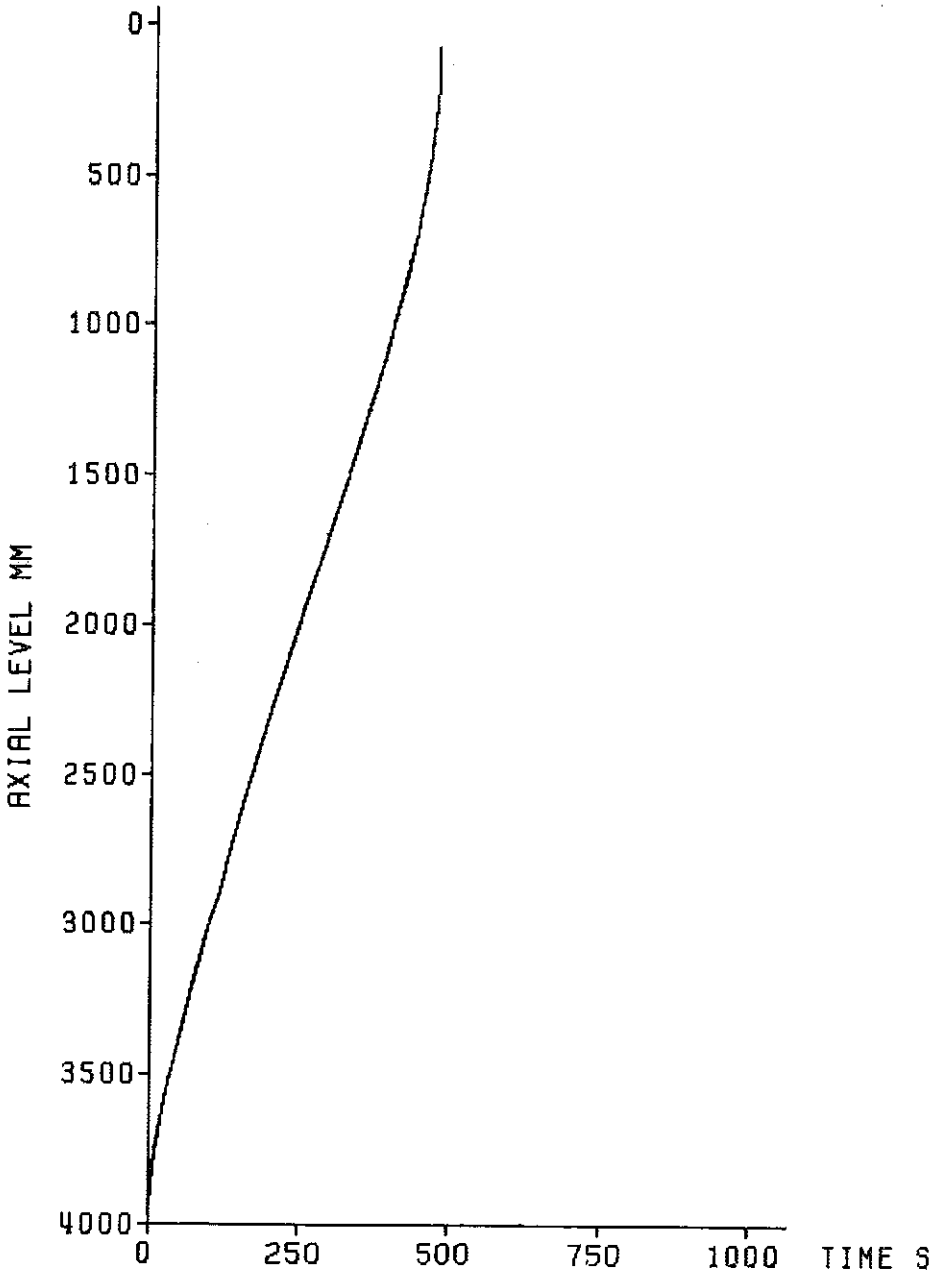
Fig. 39 FEBA: 5x5 RØD BUNDLE, TEST SERIES 1, TEST-No. 216



decay heat	120% ANS standard
flooding rate (cold)	3.81 cm/s
system pressure	4.12 bar
feedwater temperature	40 deg C

Fig. 40 FEBA: 5x5 ROD BUNDLE, TEST SERIES 1, TEST-No. 216

axial position of the quench front

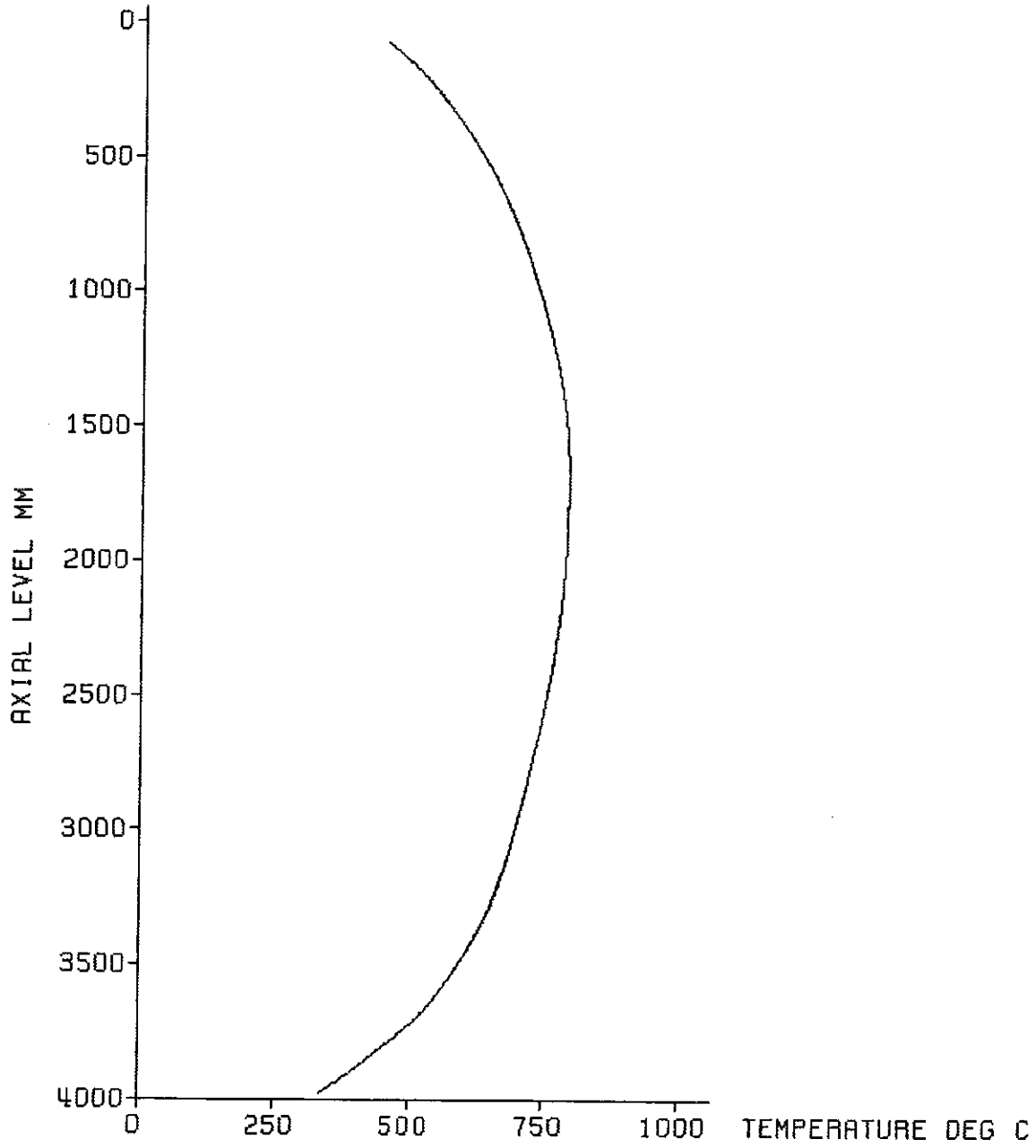


decay heat	120% ANS standard
flooding rate (cold)	3.81 cm/s
system pressure	4.12 bar
feedwater temperature	40 deg C

KfK IRB

Fig. 41 FEBA: 5x5 ROD BUNDLE
TEST SERIES 1, TEST-No. 216

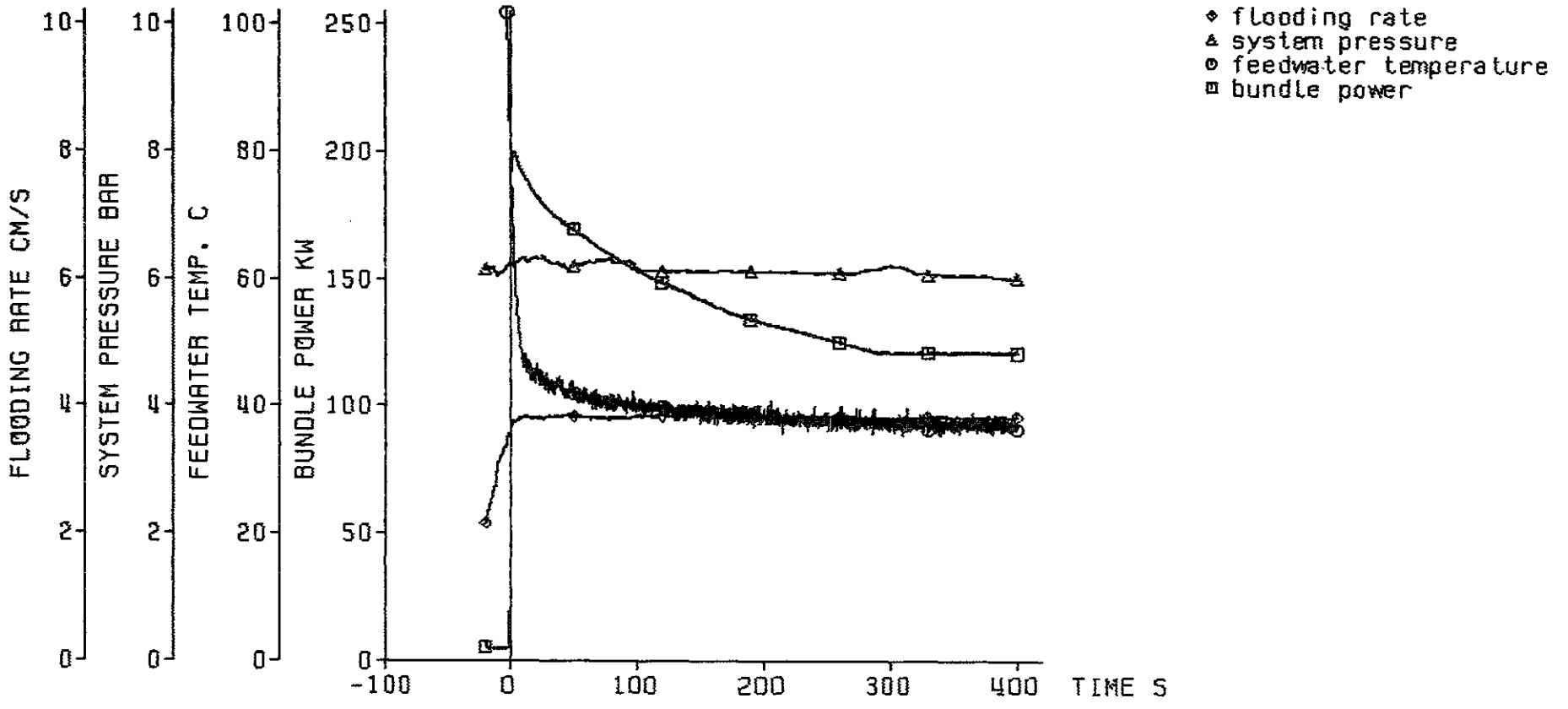
Initial axial temperature profile of the cladding



decay heat	120% ANS standard
flooding rate (cold)	3.85 cm/s
system pressure	6.18 bar
feedwater temperature	40 deg C

KfK IRB

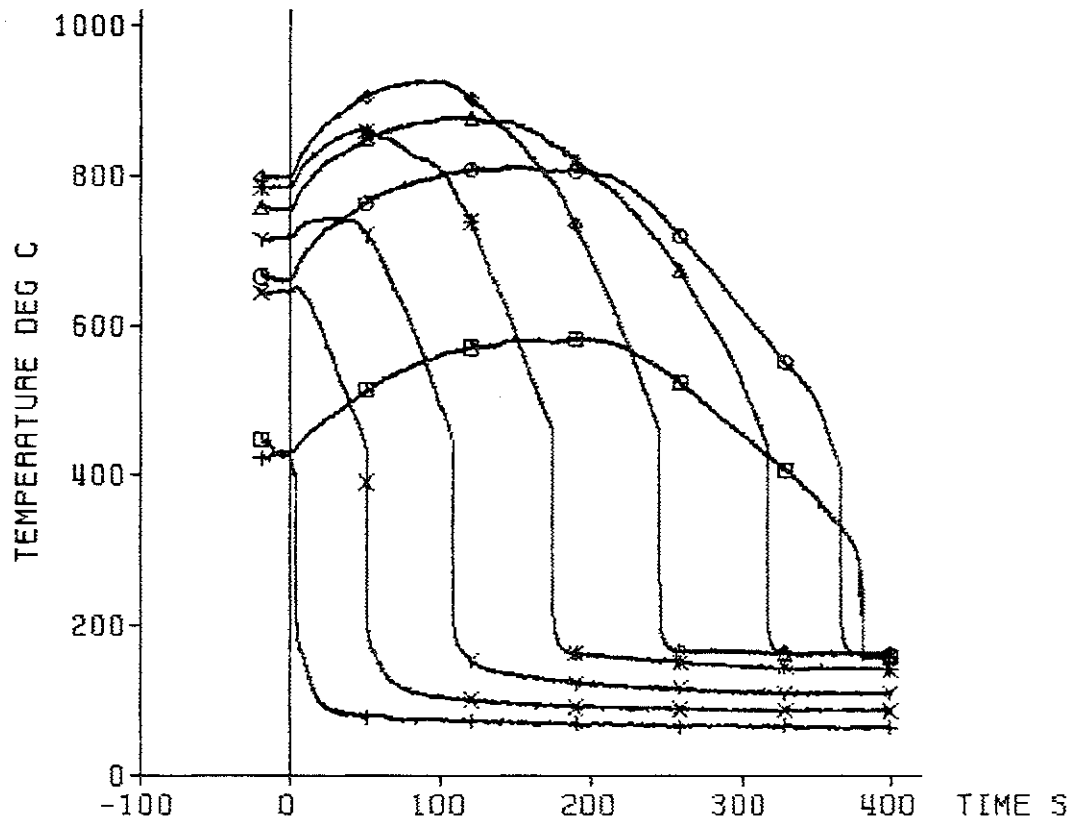
Fig. 42 FEBA: 5x5 ROD BUNDLE TEST SERIES 1, TEST-No. 220



decay heat	120% ANS standard
flooding rate (cold)	3.85 cm/s
system pressure	6.18 bar
feedwater temperature	40 deg C

KfK IRB

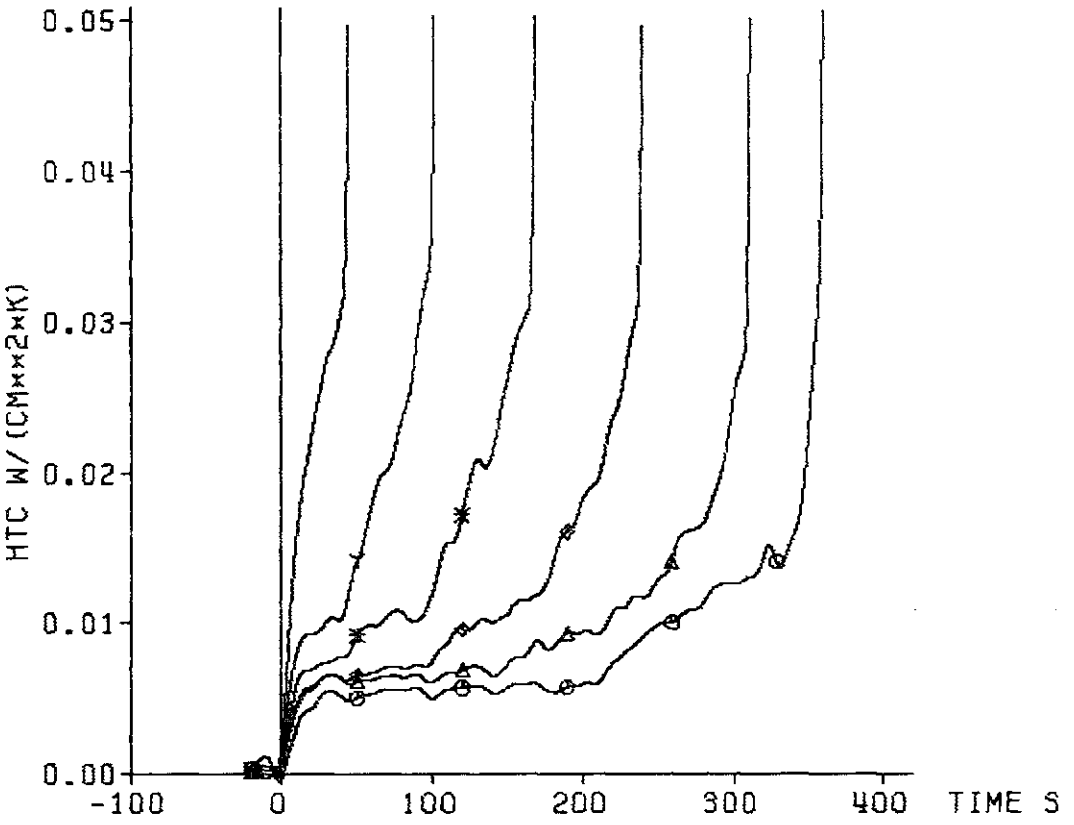
Fig. 43 FEBA: 5x5 ROD BUNDLE, TEST SERIES 1, TEST-No. 220



decay heat	120% ANS standard
flooding rate (cold)	3.65 cm/s
system pressure	6.18 bar
feedwater temperature	40 deg C

KfK IRB

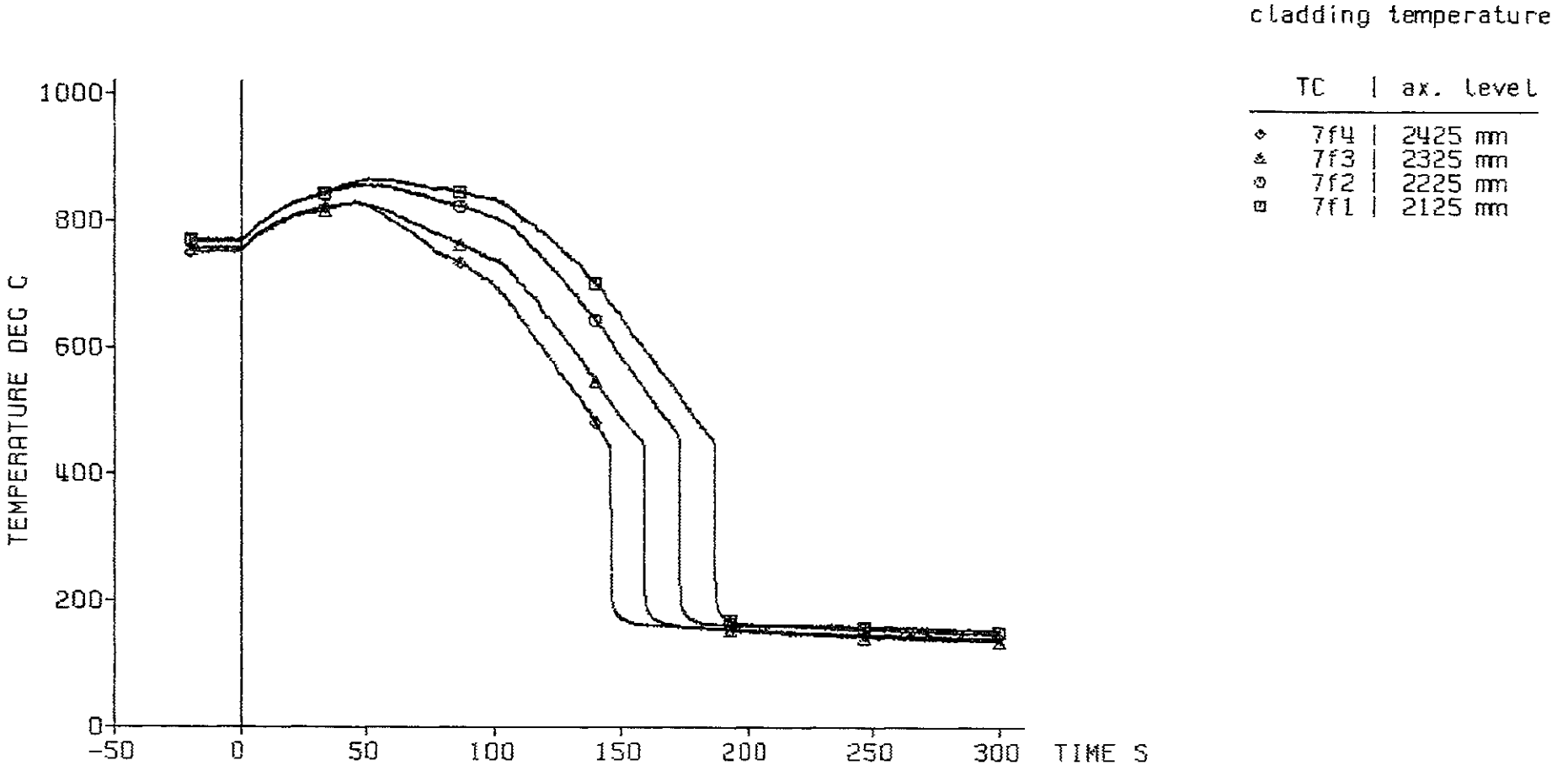
Fig. 44 FEBA: 5x5 ROD BUNDLE, TEST SERIES 1, TEST-No. 220



decay heat	120% ANS standard
flooding rate (cold)	3.85 cm/s
system pressure	6.18 bar
feedwater temperature	40 deg C

KfK IRB

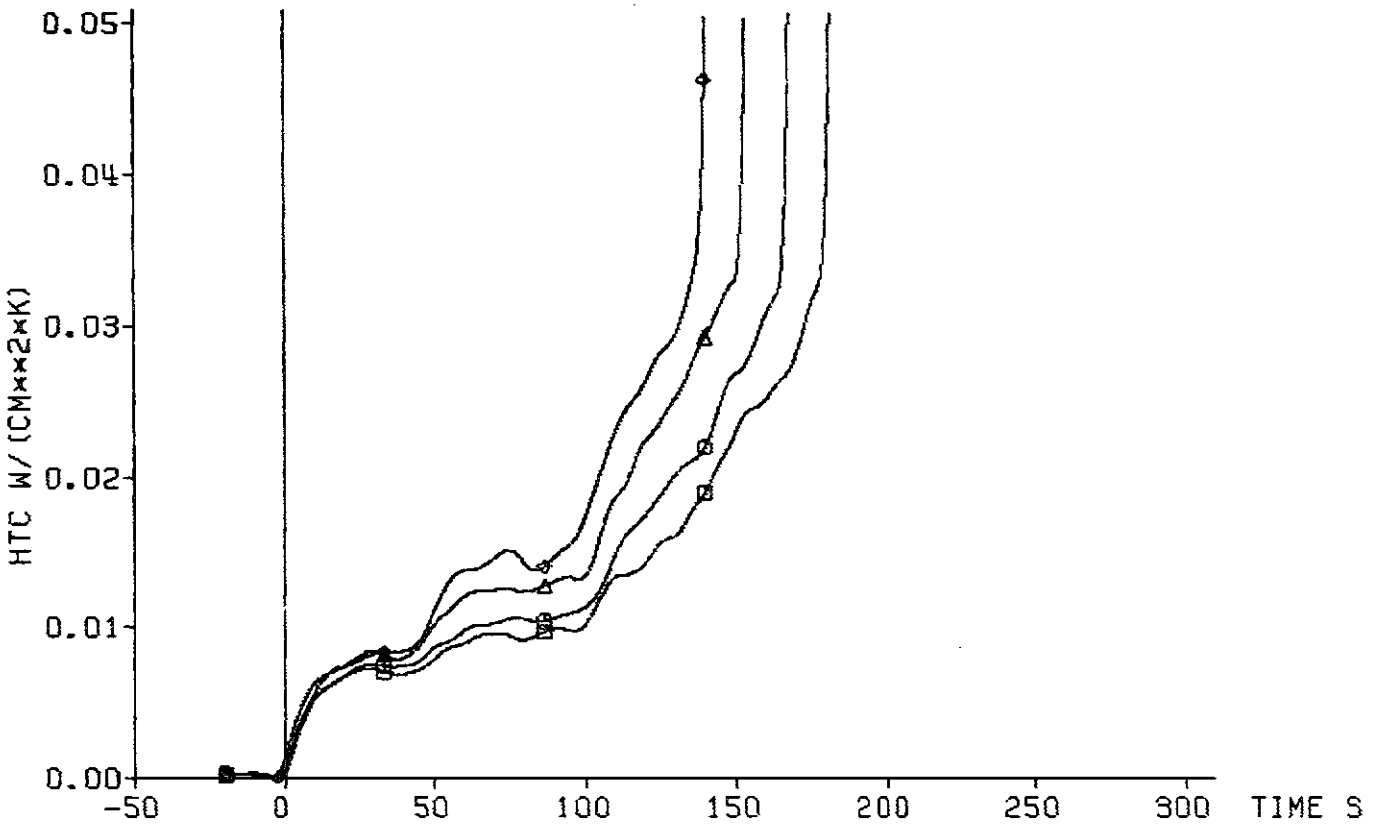
Fig. 45 FEBA: 5x5 ROD BUNDLE, TEST SERIES 1, TEST-No. 220



decay heat	120% ANS standard
flooding rate (cold)	3.65 cm/s
system pressure	6.18 bar
feedwater temperature	40 deg C

KfK KIRB

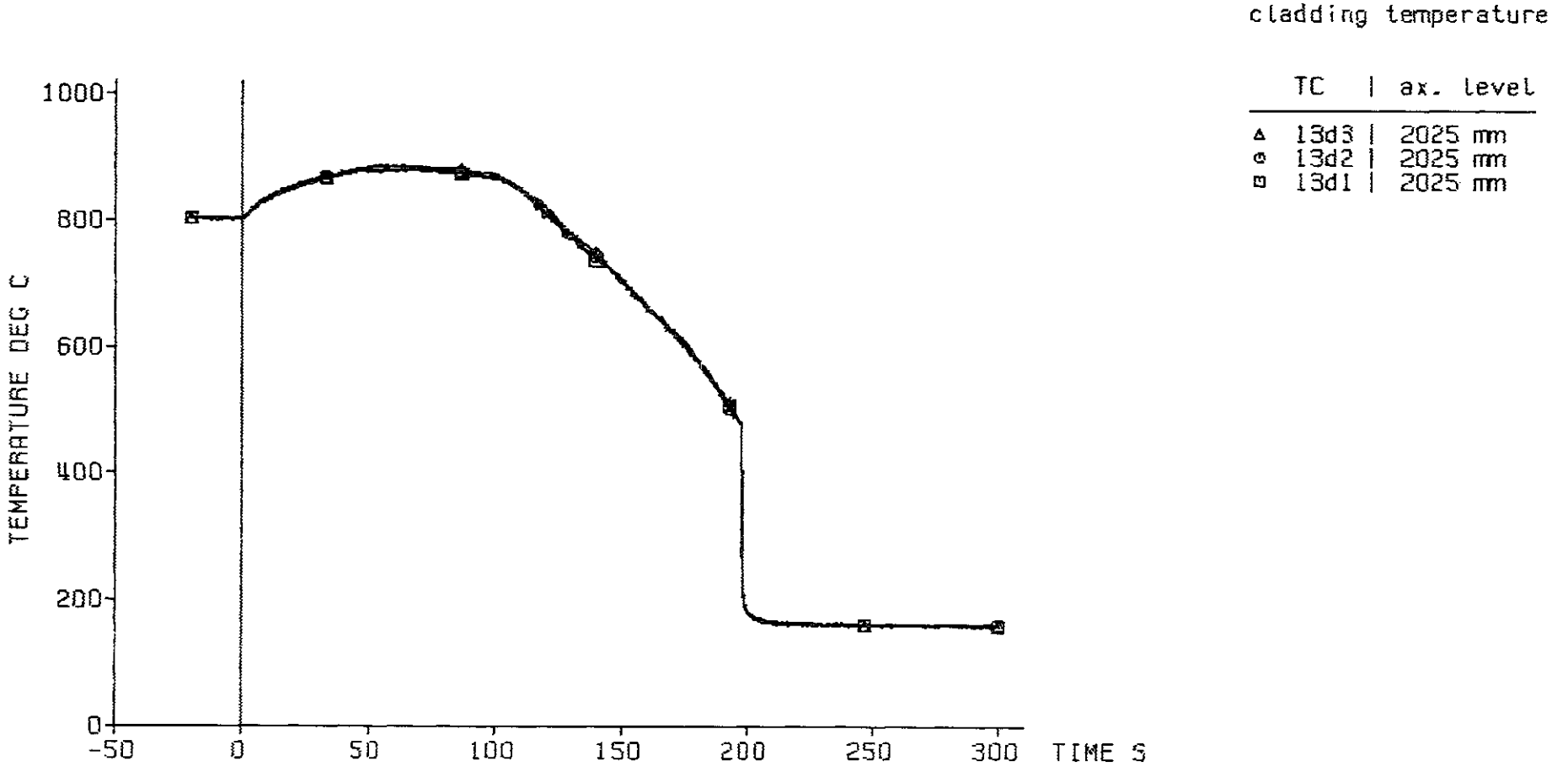
Fig. 46 FEBA: 5x5 ROD BUNDLE, TEST SERIES 1, TEST-No. 220



decay heat	120% ANS standard
flooding rate (cold)	3.85 cm/s
system pressure	6.18 bar
feedwater temperature	40 deg C

KfK IRB

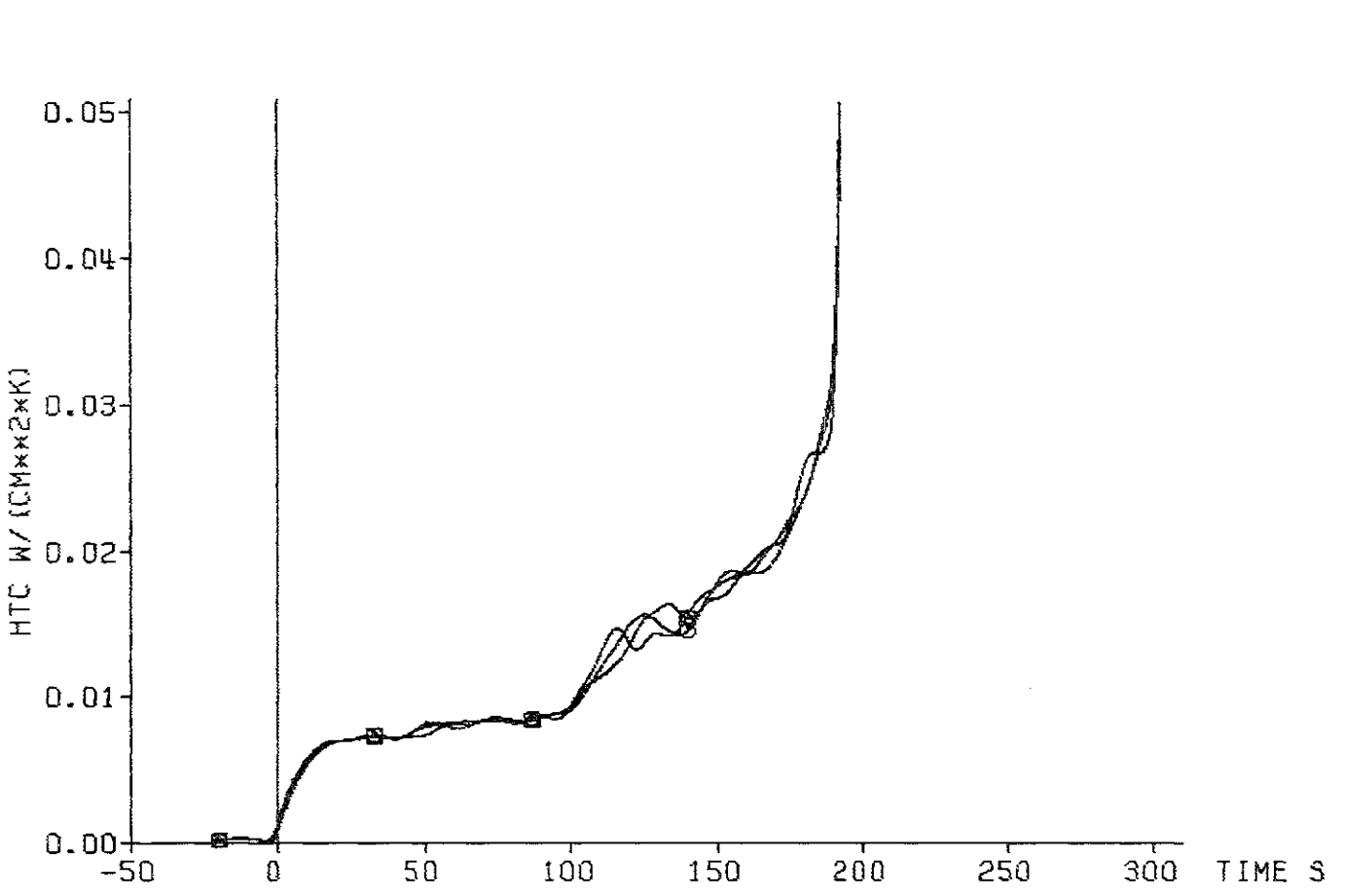
Fig. 47 FEBA: 5x5 ROD BUNDLE, TEST SERIES 1, TEST-No. 220



decay heat	120% ANS standard
flooding rate (cold)	3.85 cm/s
system pressure	6.18 bar
feedwater temperature	40 deg C

KfK IRB

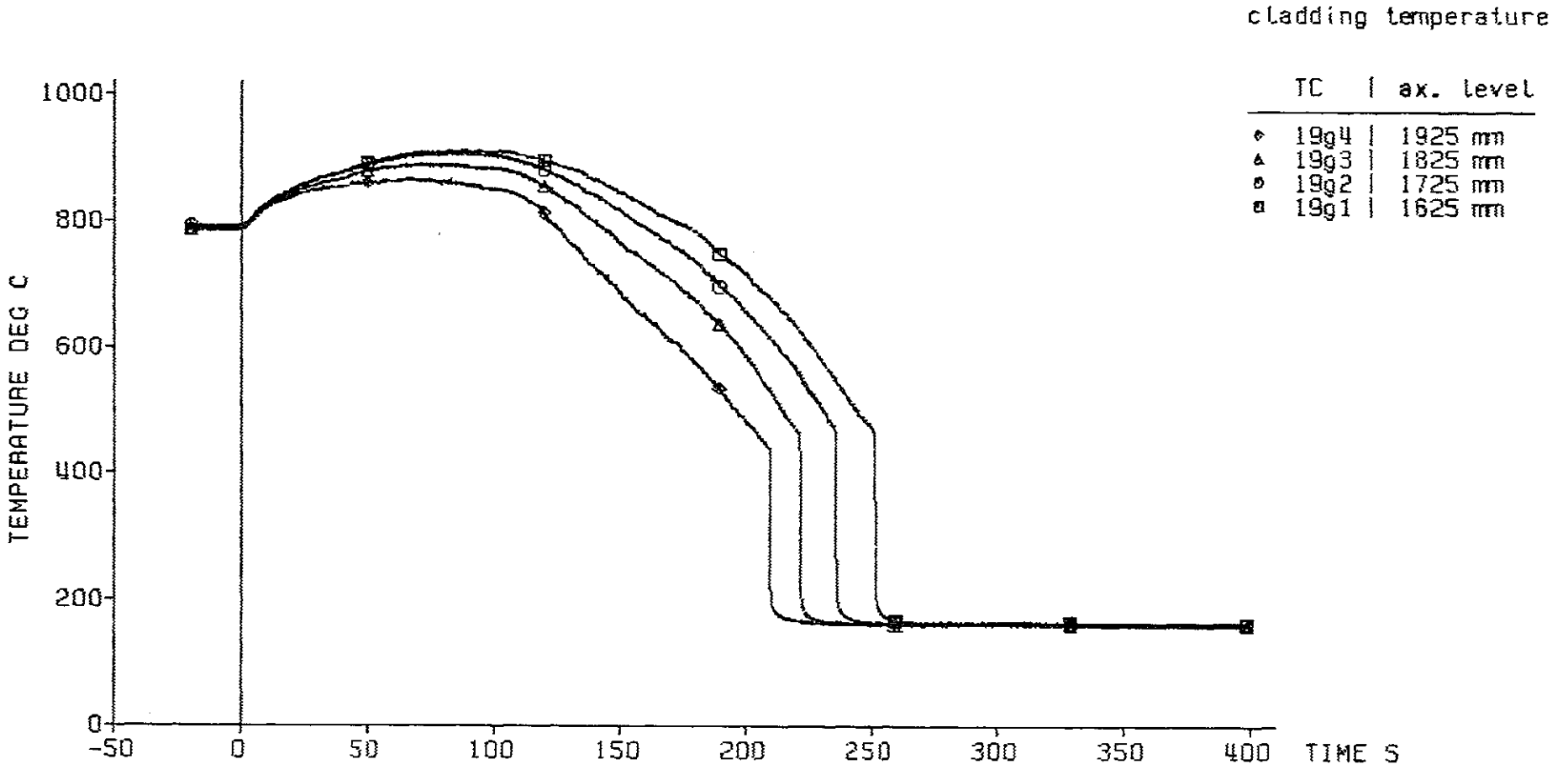
Fig. 48 FEBA: 5x5 ROD BUNDLE, TEST SERIES 1, TEST-No. 220



decay heat	120% ANS standard
flooding rate (cold)	3.85 cm/s
system pressure	6.18 bar
feedwater temperature	40 deg C

KfK IRB

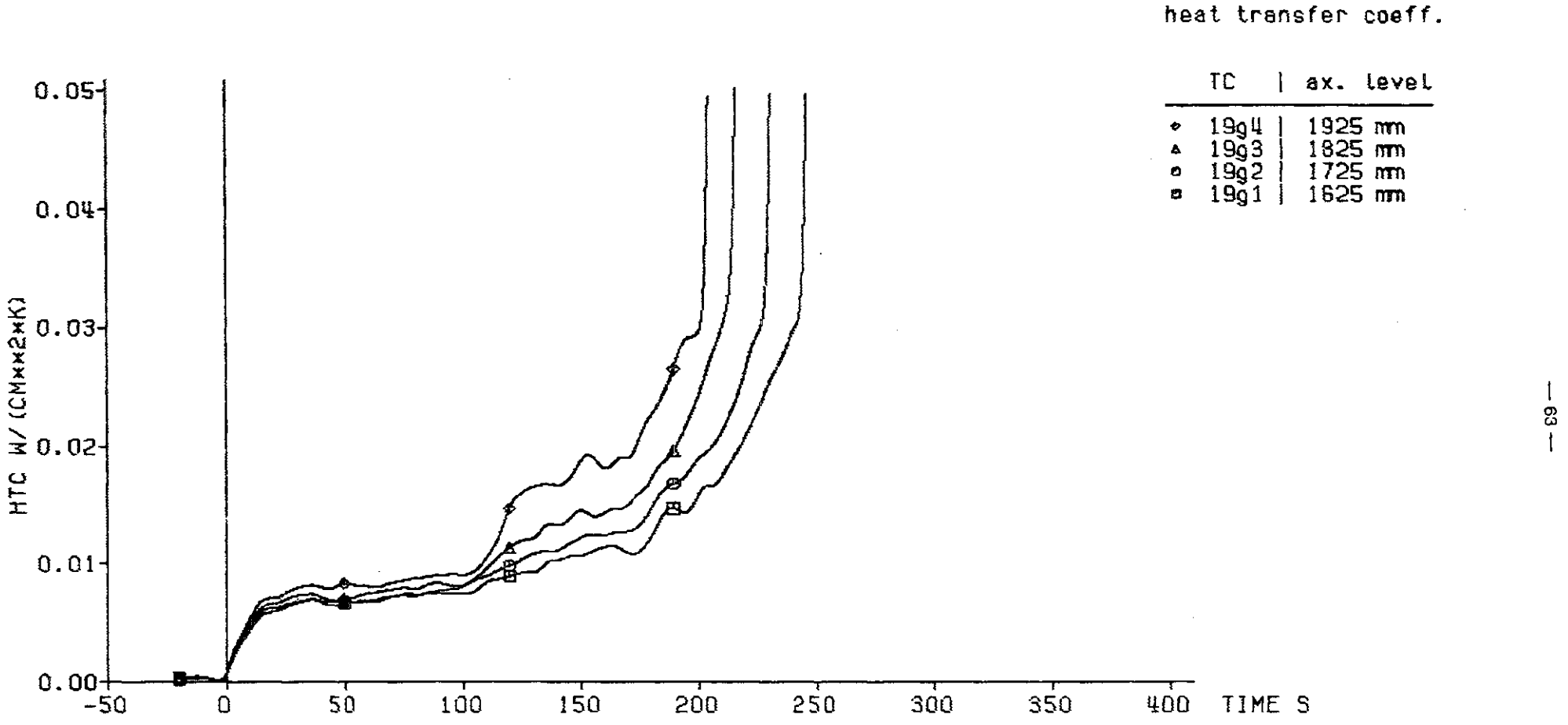
Fig. 49 FEBA: 5x5 ROD BUNDLE, TEST SERIES 1, TEST-No. 220



decay heat	120% ANS standard
flooding rate (cold)	3.85 cm/s
system pressure	6.18 bar
feedwater temperature	40 deg C

KfK IRB

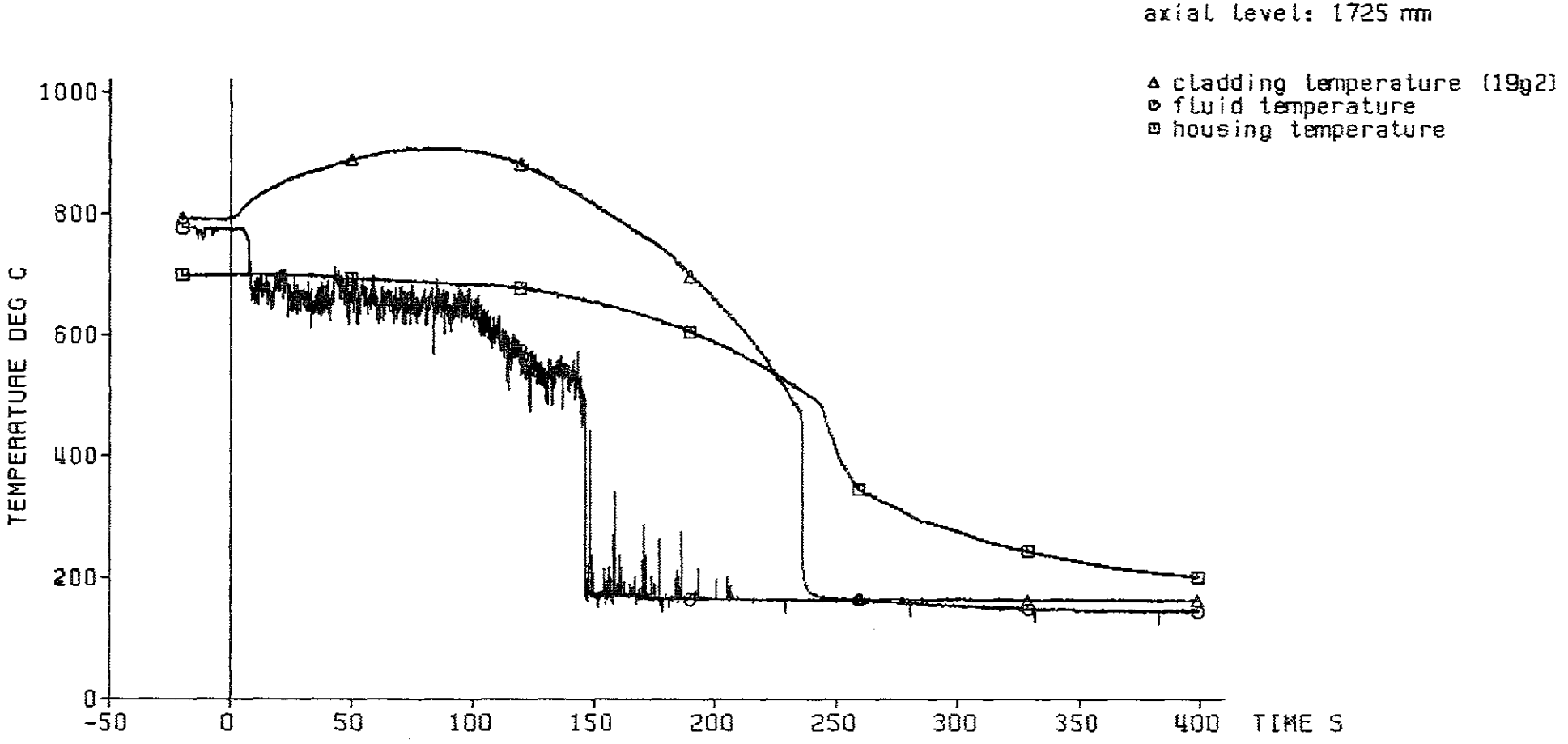
Fig. 50 FEBA: 5x5 ROD BUNDLE, TEST SERIES 1, TEST-No. 220



decay heat	120% ANS standard
flooding rate (cold)	3.85 cm/s
system pressure	6.18 bar
feedwater temperature	40 deg C

KfK IRB

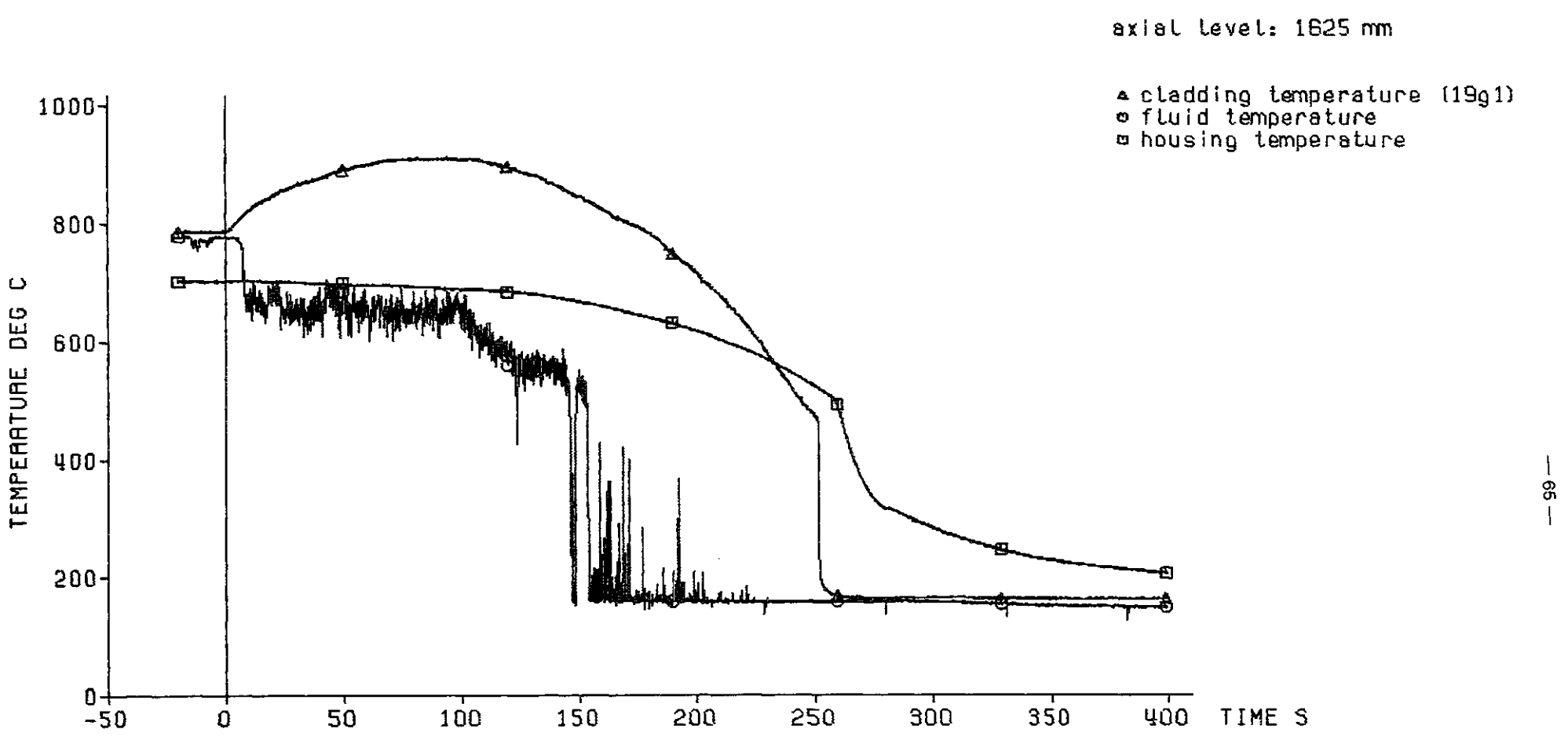
Fig. 51 FEBA: 5x5 ROD BUNDLE, TEST SERIES 1, TEST-No. 220



decay heat	120% ANS standard
flooding rate (cold)	3.65 cm/s
system pressure	6.18 bar
feedwater temperature	40 deg C

KfK KIRB

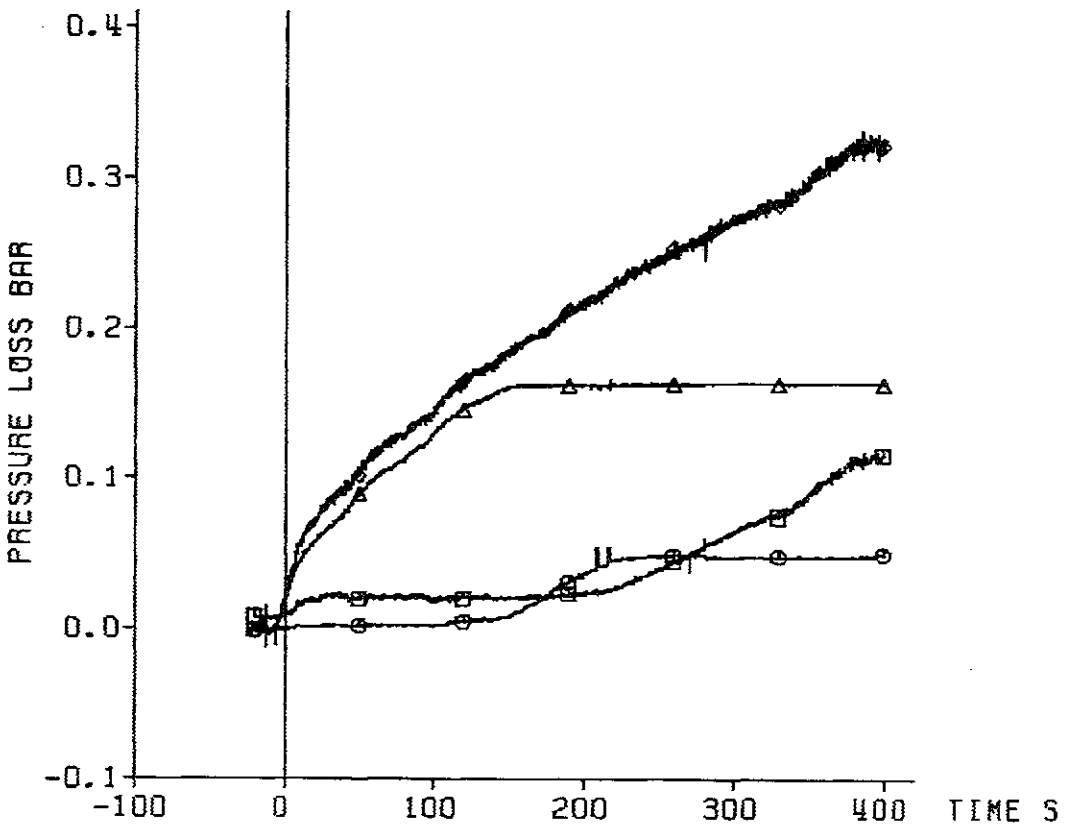
Fig. 52 FEBA: 5x5 ROD BUNDLE, TEST SERIES 1, TEST-No. 220



decay heat	120% ANS standard
flooding rate (cold)	3.85 cm/s
system pressure	6.16 bar
feedwater temperature	40 deg C

KfK IRB

Fig. 53 FEBA: 5x5 ROD BUNDLE, TEST SERIES 1, TEST-No. 220



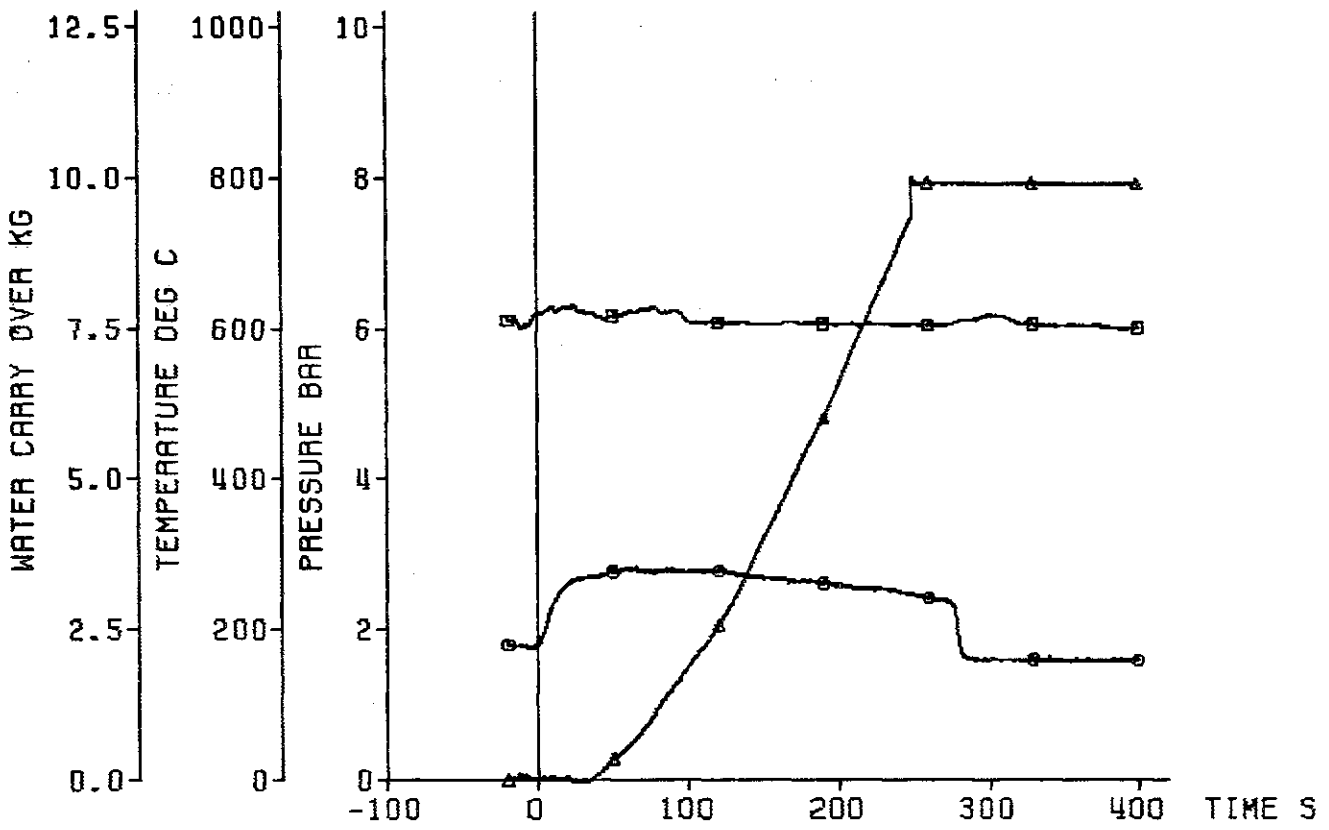
pressure loss
along the test section:

◆ total length: 4196 mm
△ lower part: 1711 mm
○ middle part: 545 mm
□ upper part: 1940 mm

decay heat	120% ANS standard
flooding rate (cold)	3.85 cm/s
system pressure	6.18 bar
feedwater temperature	40 deg C

KfK IRB

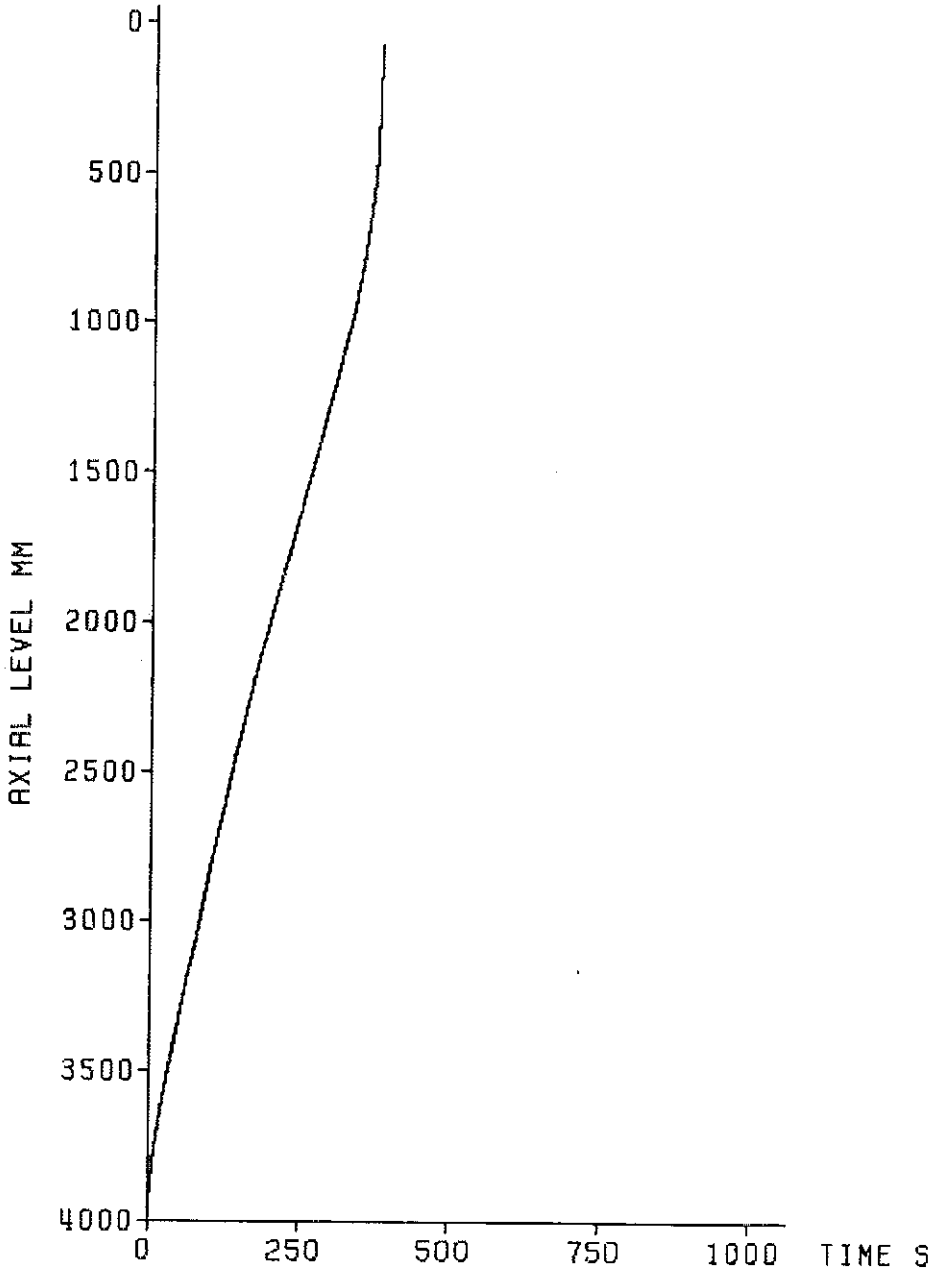
Fig. 54 FEBA: 5x5 ROD BUNDLE, TEST SERIES 1, TEST-No. 220



decay heat	120% ANS standard
flooding rate (cold)	3.65 cm/s
system pressure	6.18 bar
feedwater temperature	40 deg C

Fig. 55 FEBA: 5x5 ROD BUNDLE, TEST SERIES 1, TEST-No. 220

axial position of the quench front

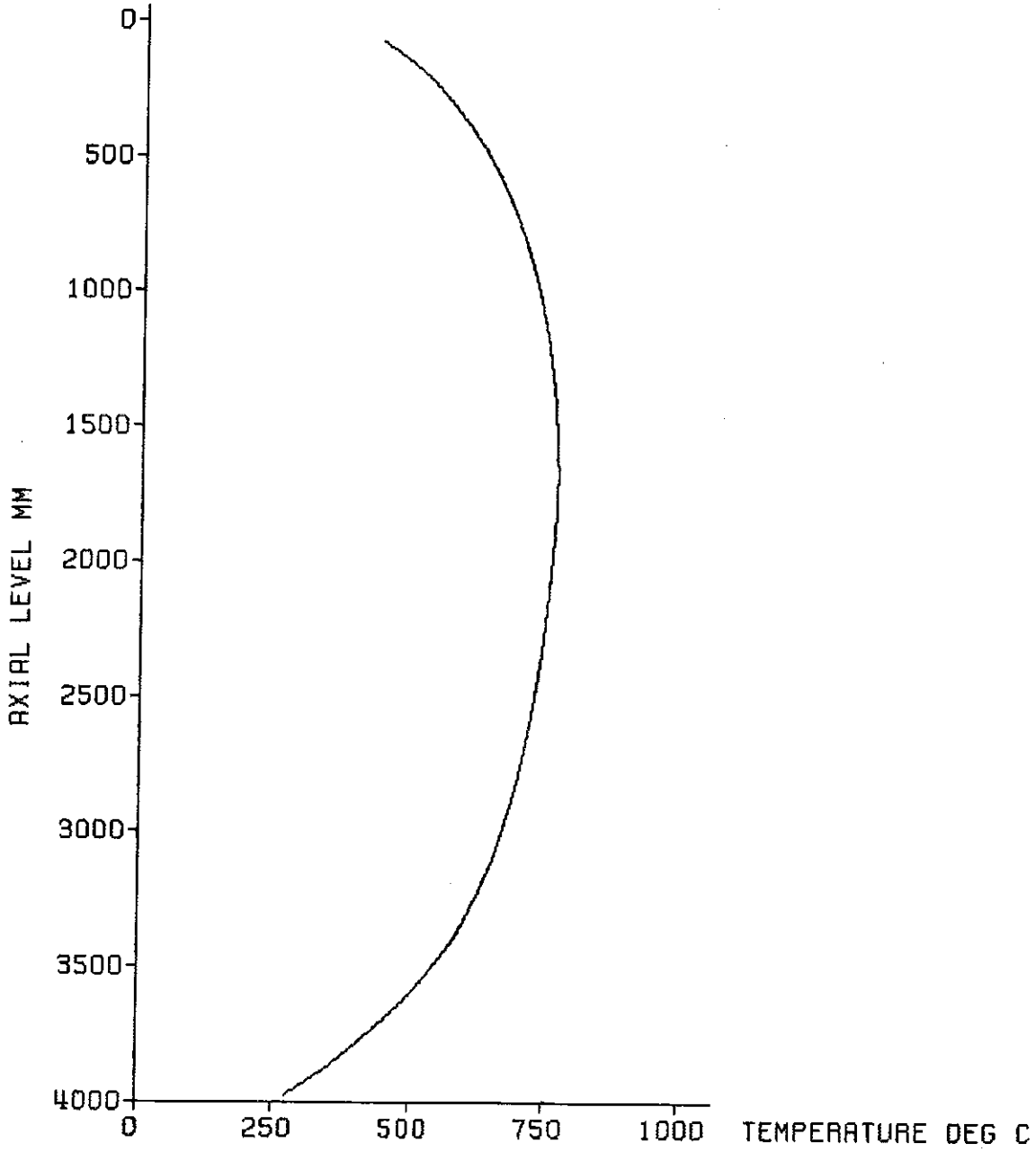


decay heat	120% ANS standard
flooding rate (cold)	3.85 cm/s
system pressure	6.18 bar
feedwater temperature	40 deg C

KfK IRB

Fig. 56 FEBA: 5x5 ROD BUNDLE TEST SERIES 1, TEST-No. 220

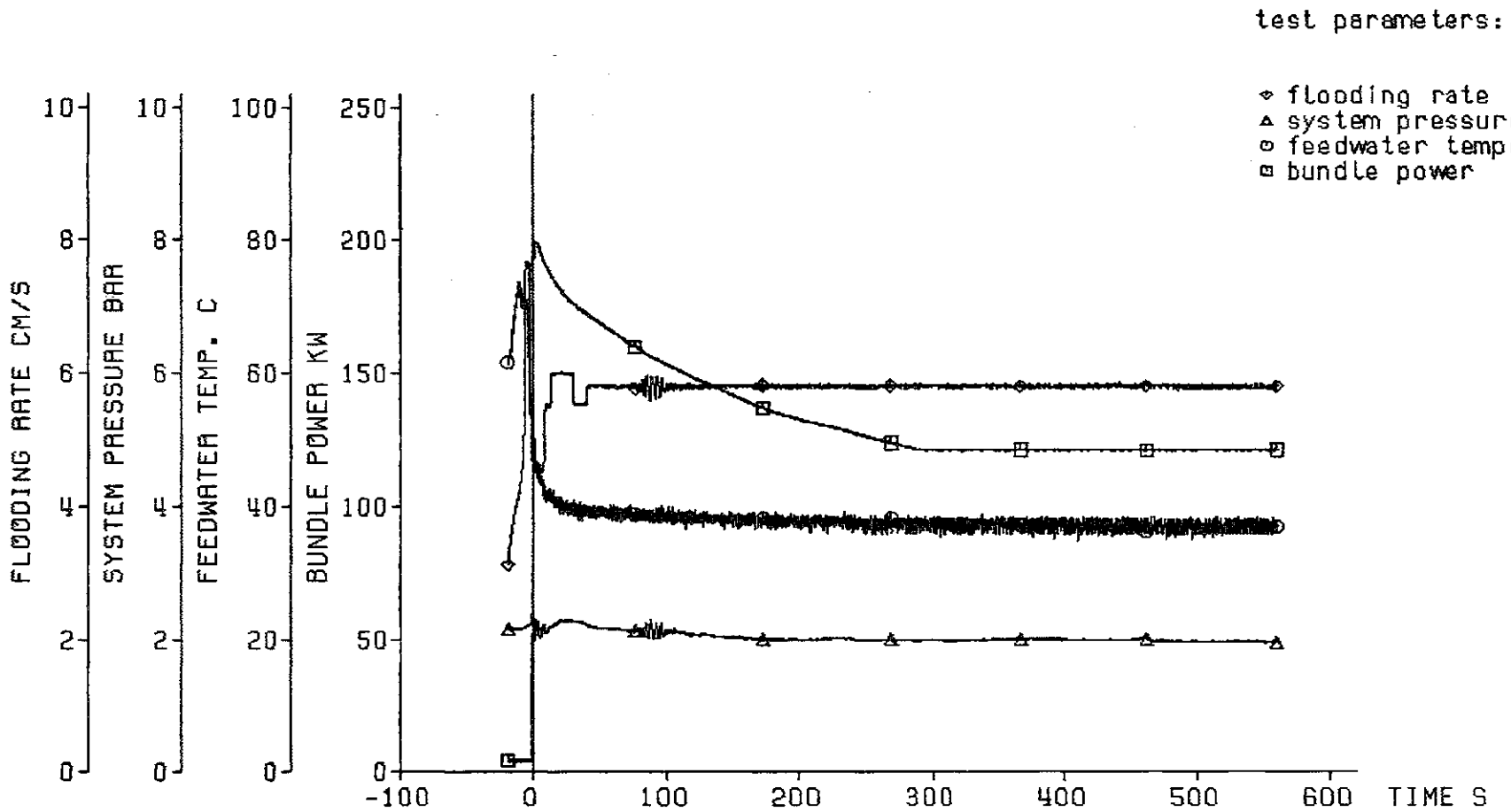
Initial axial temperature profile of the cladding



decay heat	120% ANS standard
flooding rate (cold)	5.81 cm/s
system pressure	2.08 bar
feedwater temperature	40 deg C

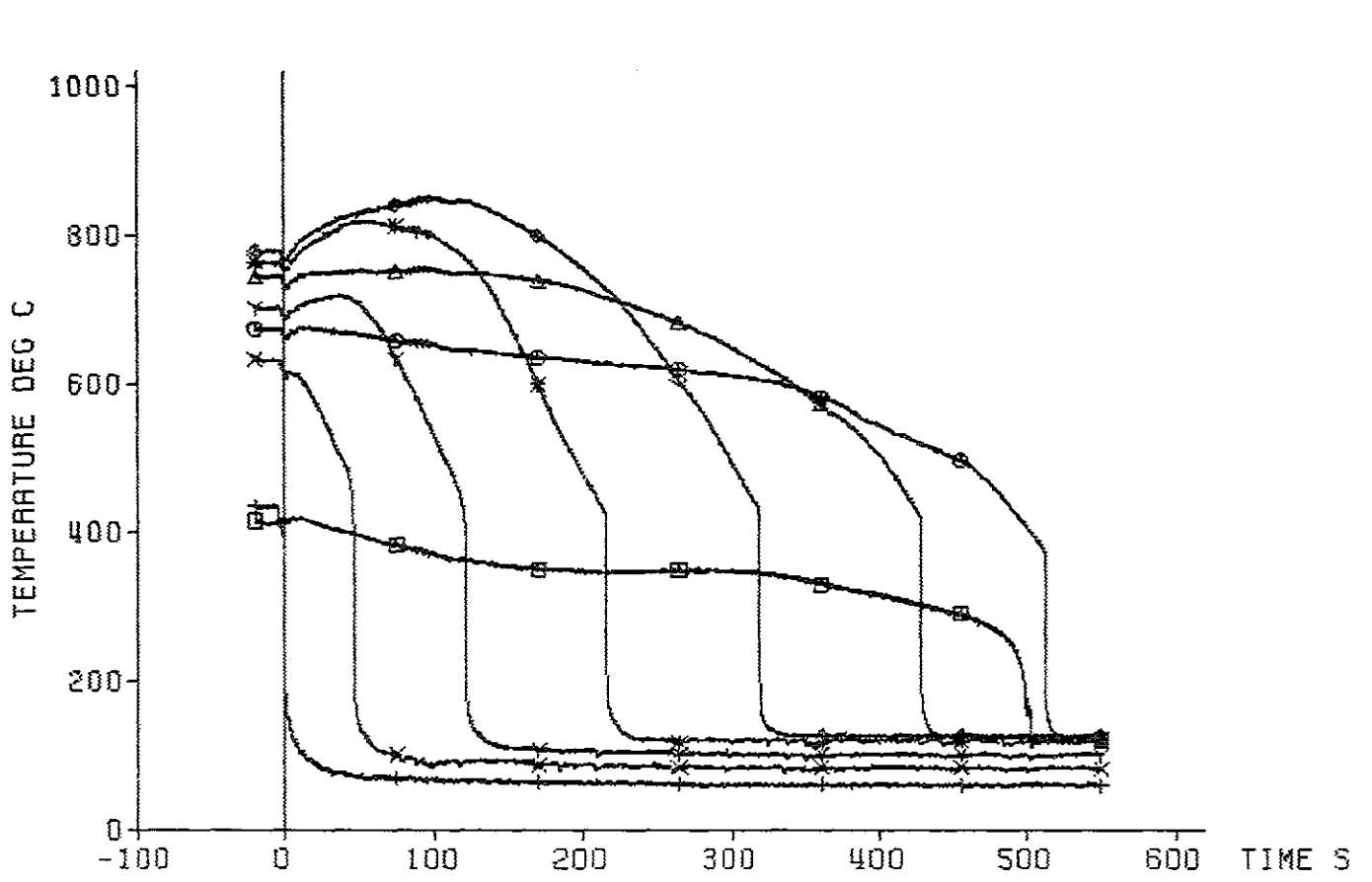
KfK IRB

Fig. 57 FEBA: 5x5 ROD BUNDLE TEST SERIES 1, TEST-No. 218



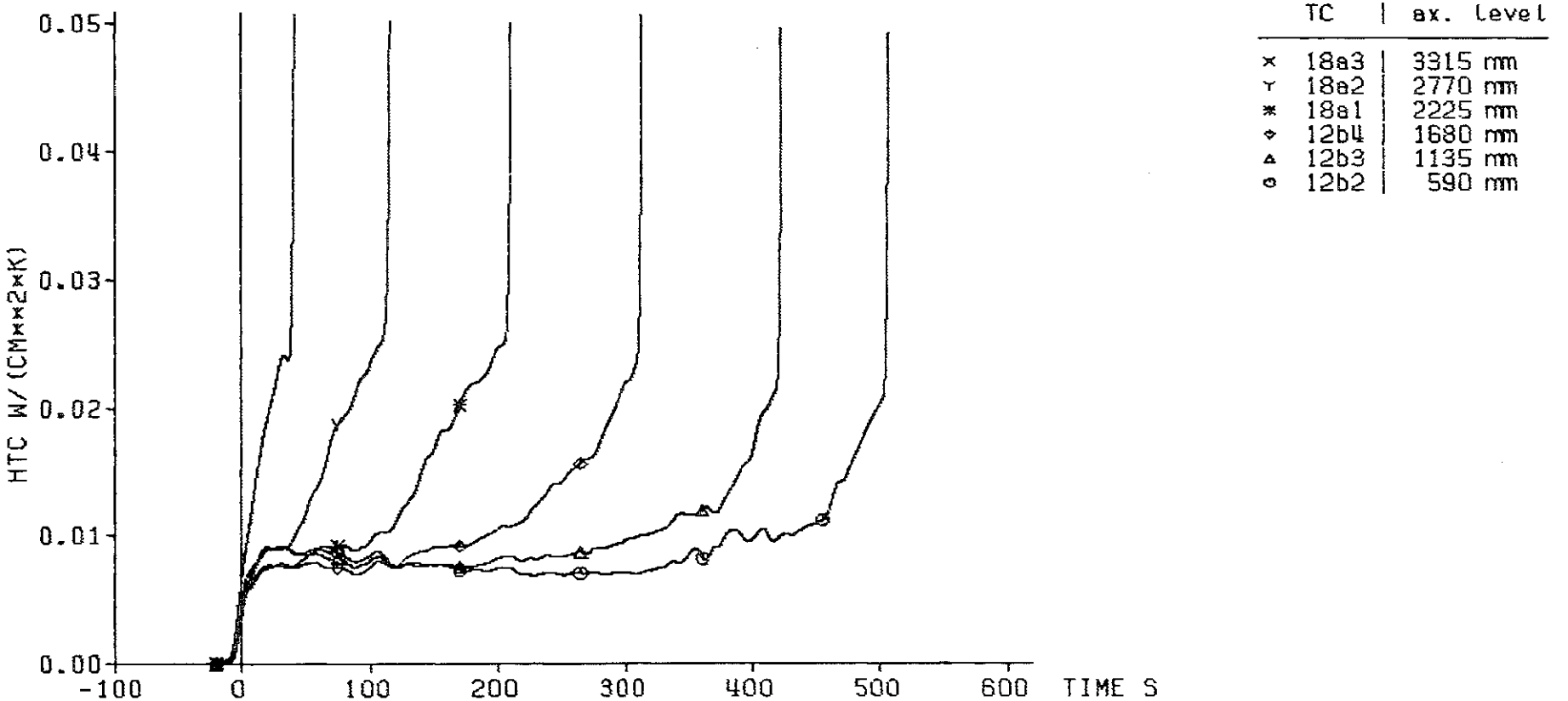
decay heat	120% ANS standard
flooding rate (cold)	5.81 cm/s
system pressure	2.08 bar
feedwater temperature	40 deg C

Fig. 58 FEBA: 5x5 ROD BUNDLE, TEST SERIES 1, TEST-No. 218



decay heat	120% ANS standard
flooding rate (cold)	5.81 cm/s
system pressure	2.08 bar
feedwater temperature	40 deg C

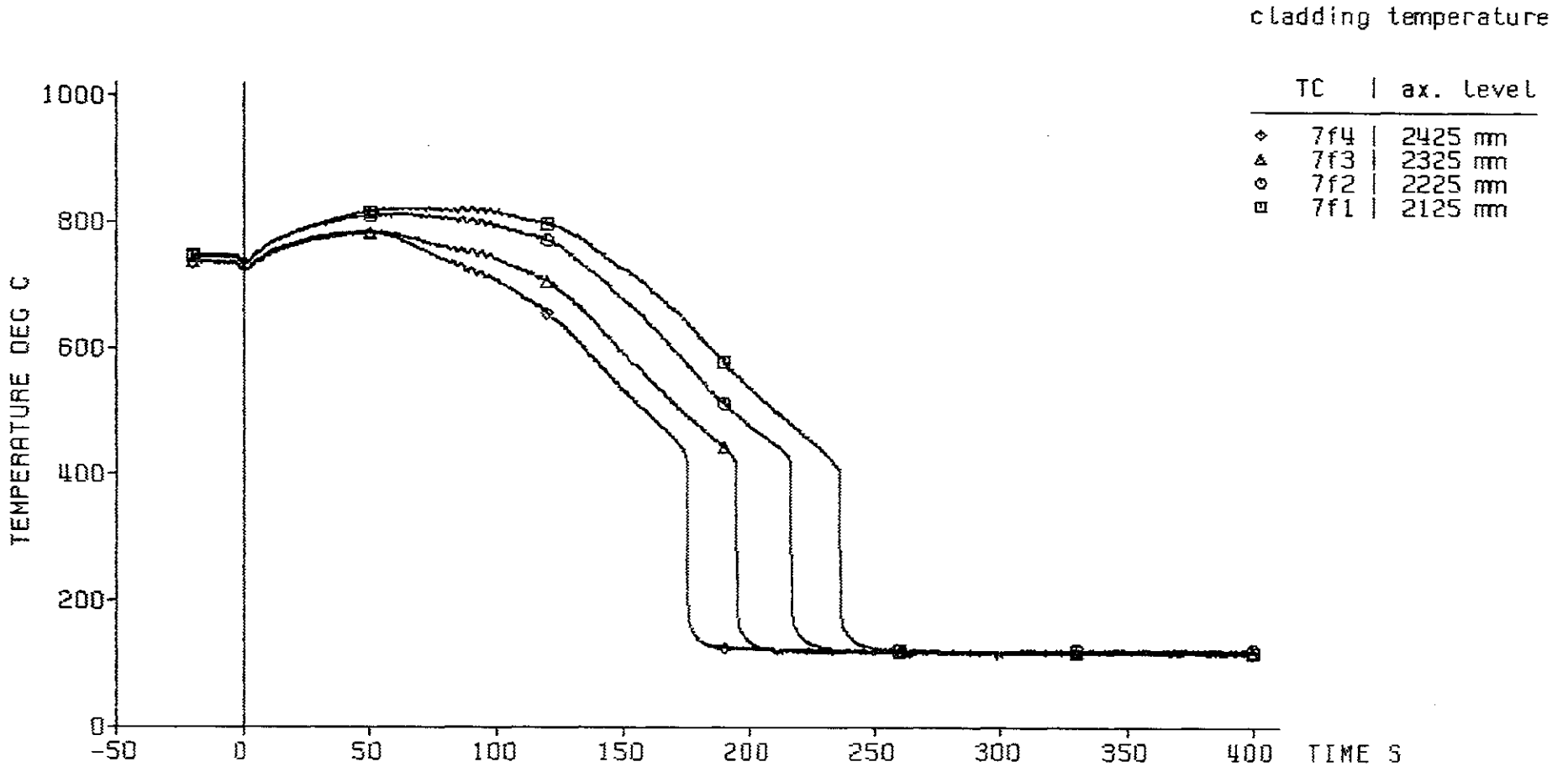
Fig. 59 FEBA: 5x5 ROD BUNDLE, TEST SERIES 1, TEST-No. 218



decay heat	120% ANS standard
flooding rate (cold)	5.81 cm/s
system pressure	2.08 bar
feedwater temperature	40 deg C

KfK IRB

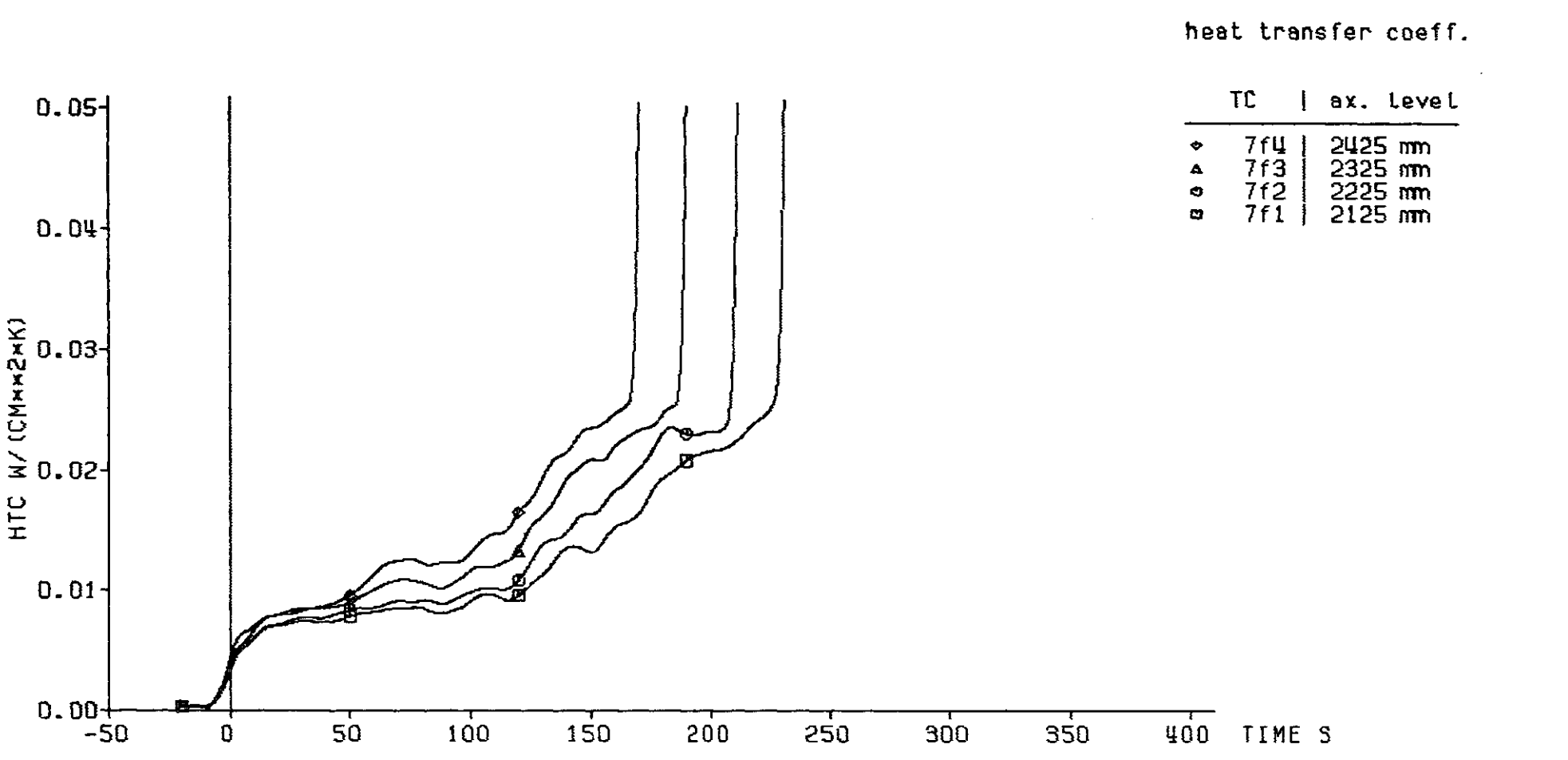
Fig. 60 FEBA: 5x5 ROD BUNDLE, TEST SERIES 1, TEST-No. 218



decay heat	120% ANS standard
flooding rate (cold)	5.81 cm/s
system pressure	2.08 bar
feedwater temperature	40 deg C

KfK IRB

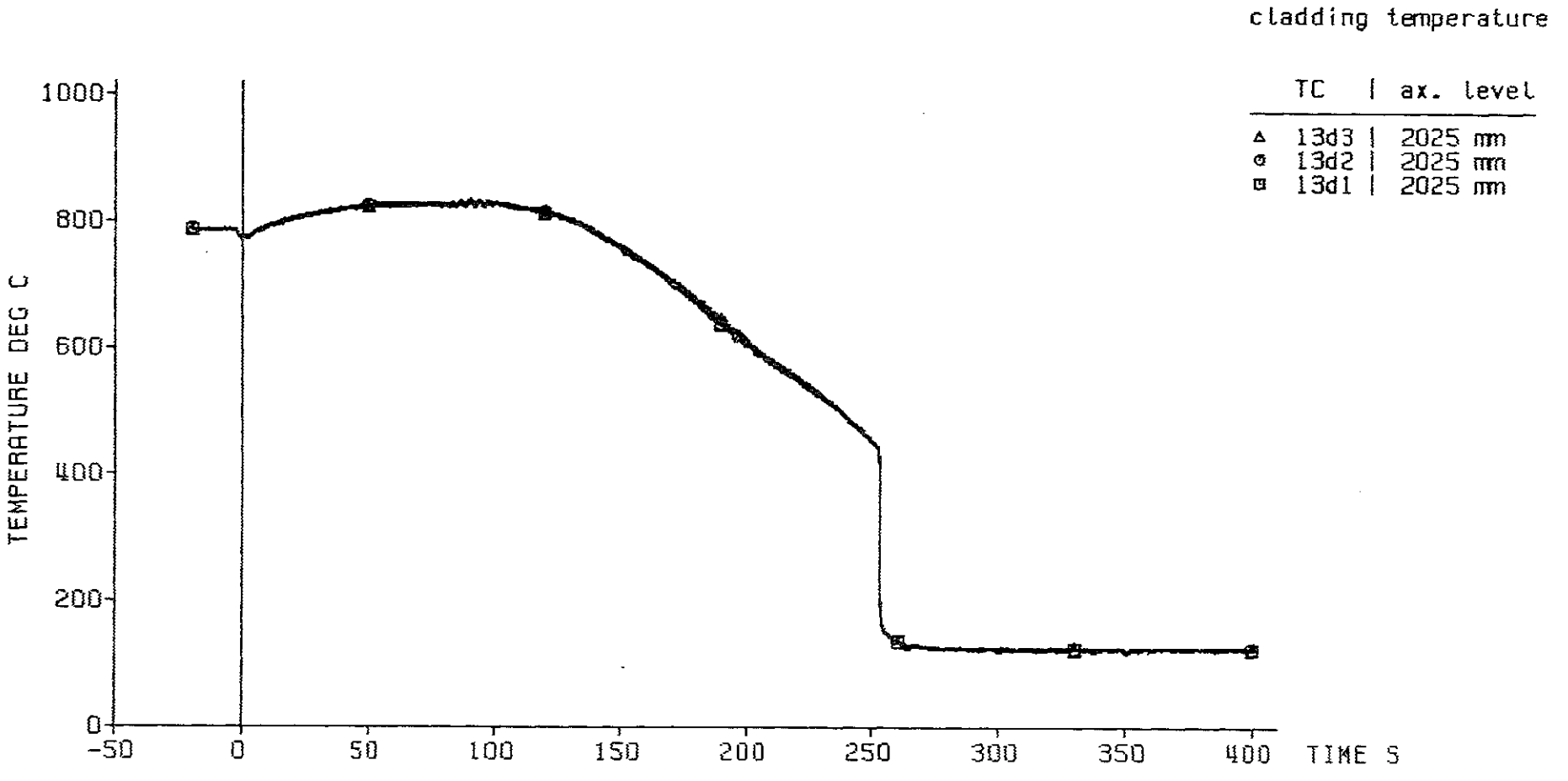
Fig. 61 FEBA: 5x5 ROD BUNDLE, TEST SERIES 1, TEST-No. 218



decay heat	120% ANS standard
flooding rate (cold)	5.81 cm/s
system pressure	2.08 bar
feedwater temperature	40 deg C

KfK IRB

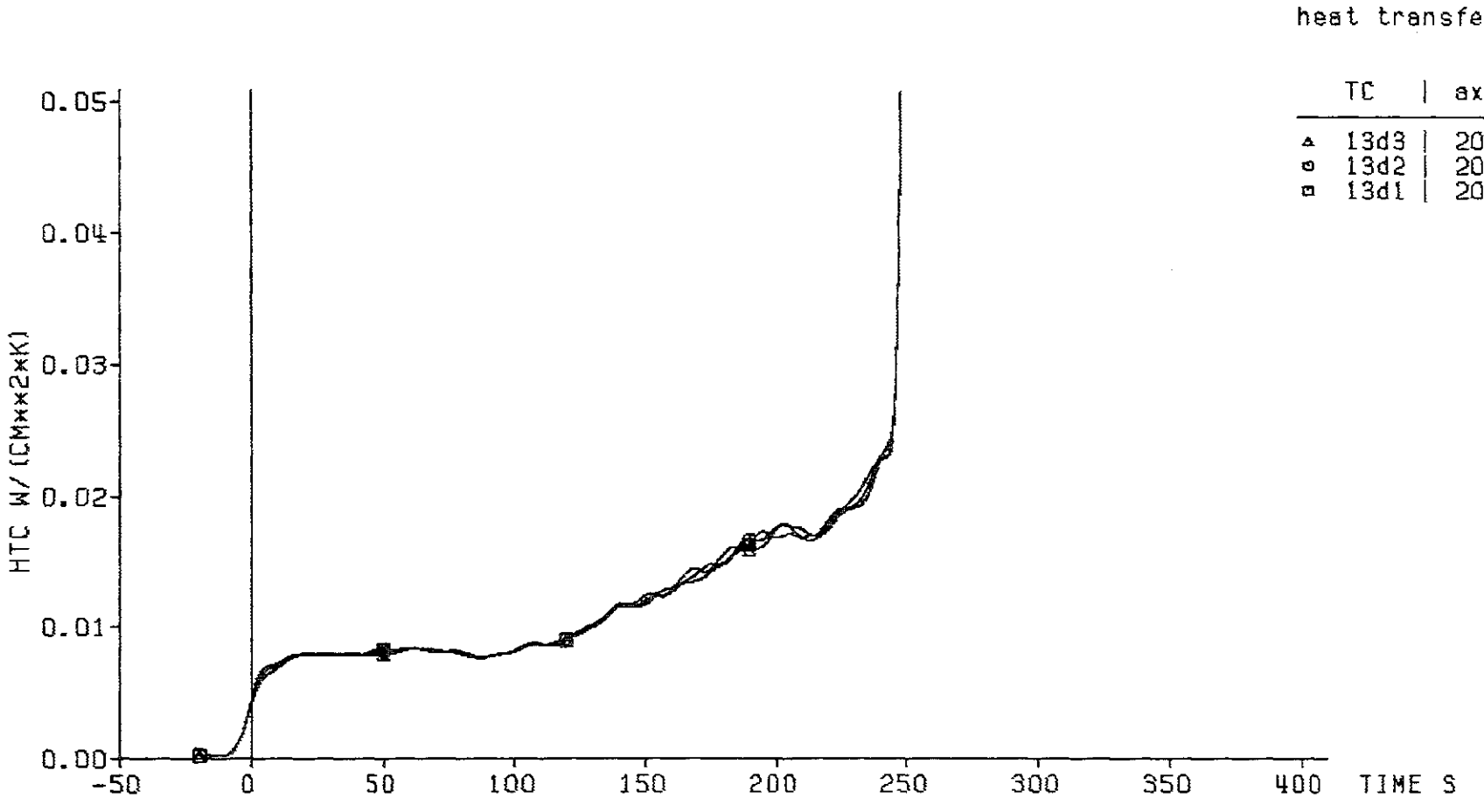
Fig. 62 FEBA: 5x5 ROD BUNDLE, TEST SERIES 1, TEST-No. 218



decay heat	120% ANS standard
flooding rate (cold)	5.81 cm/s
system pressure	2.08 bar
feedwater temperature	40 deg C

KfK IRB

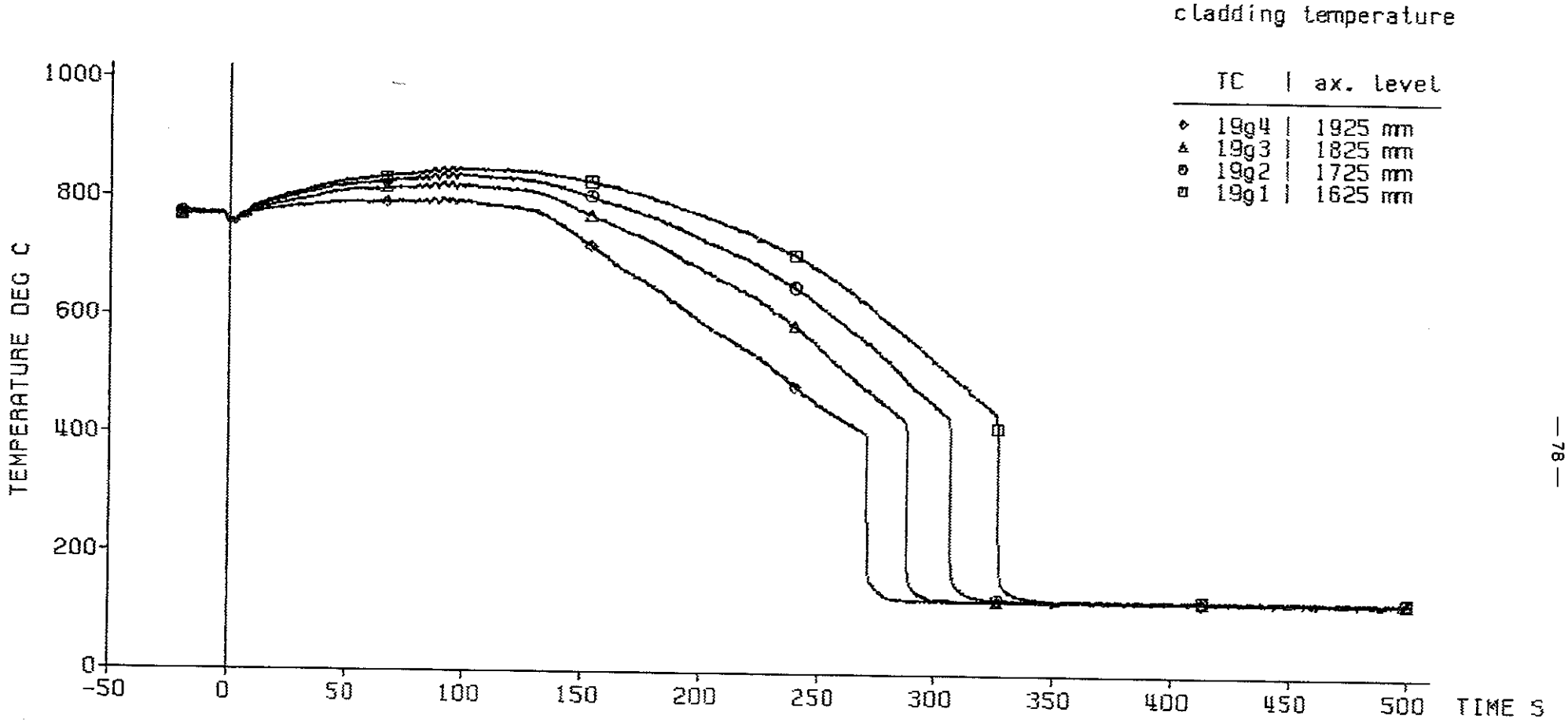
Fig. 63 FEBA: 5x5 ROD BUNDLE, TEST SERIES 1, TEST-No. 218



decay heat	120% ANS standard
flooding rate (cold)	5.81 cm/s
system pressure	2.08 bar
feedwater temperature	40 deg C

KfK IRB

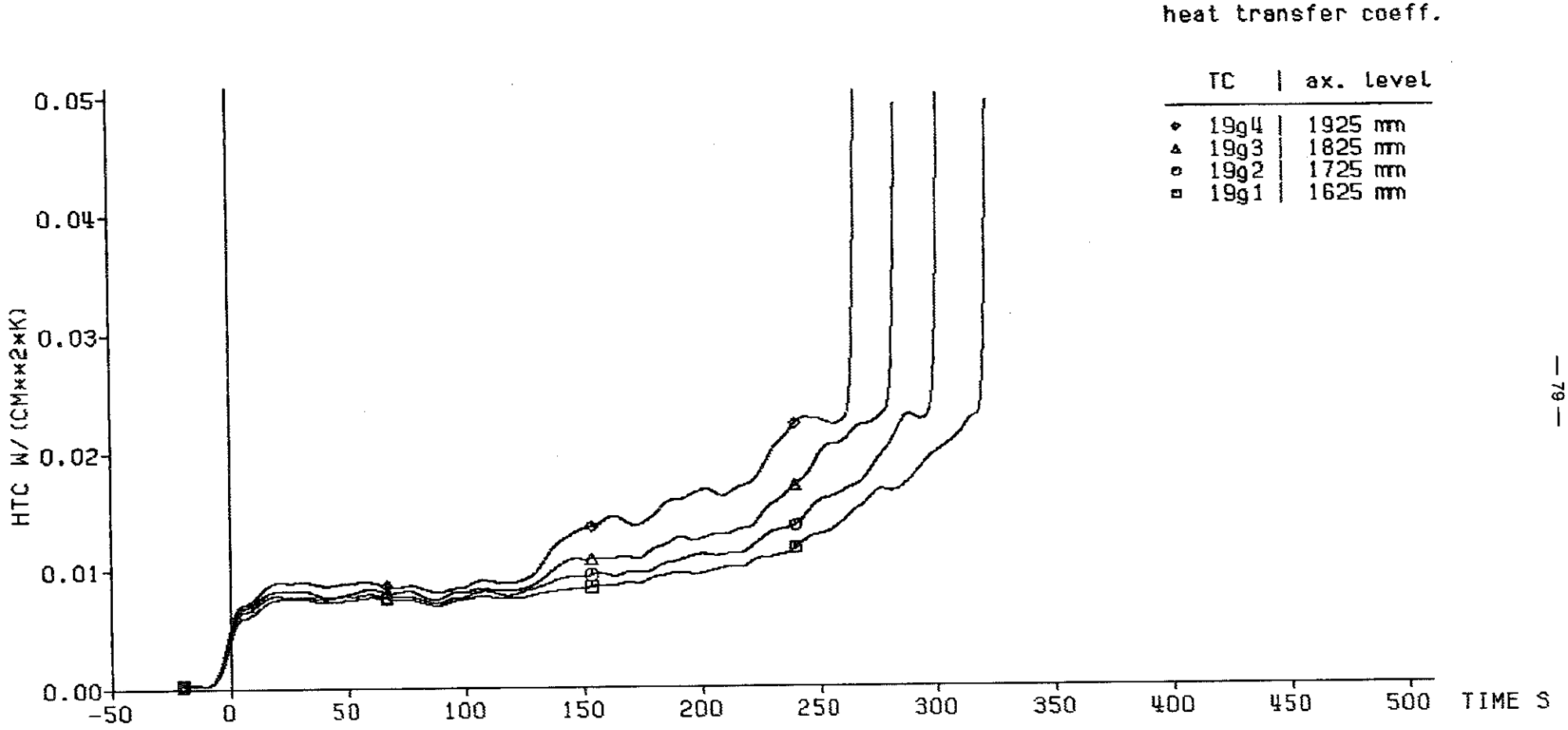
Fig. 64 FEBA: 5x5 ROD BUNDLE, TEST SERIES 1, TEST-No. 218



decay heat	120% ANS standard
flooding rate (cold)	5.81 cm/s
system pressure	2.08 bar
feedwater temperature	40 deg C

KfK KTRB

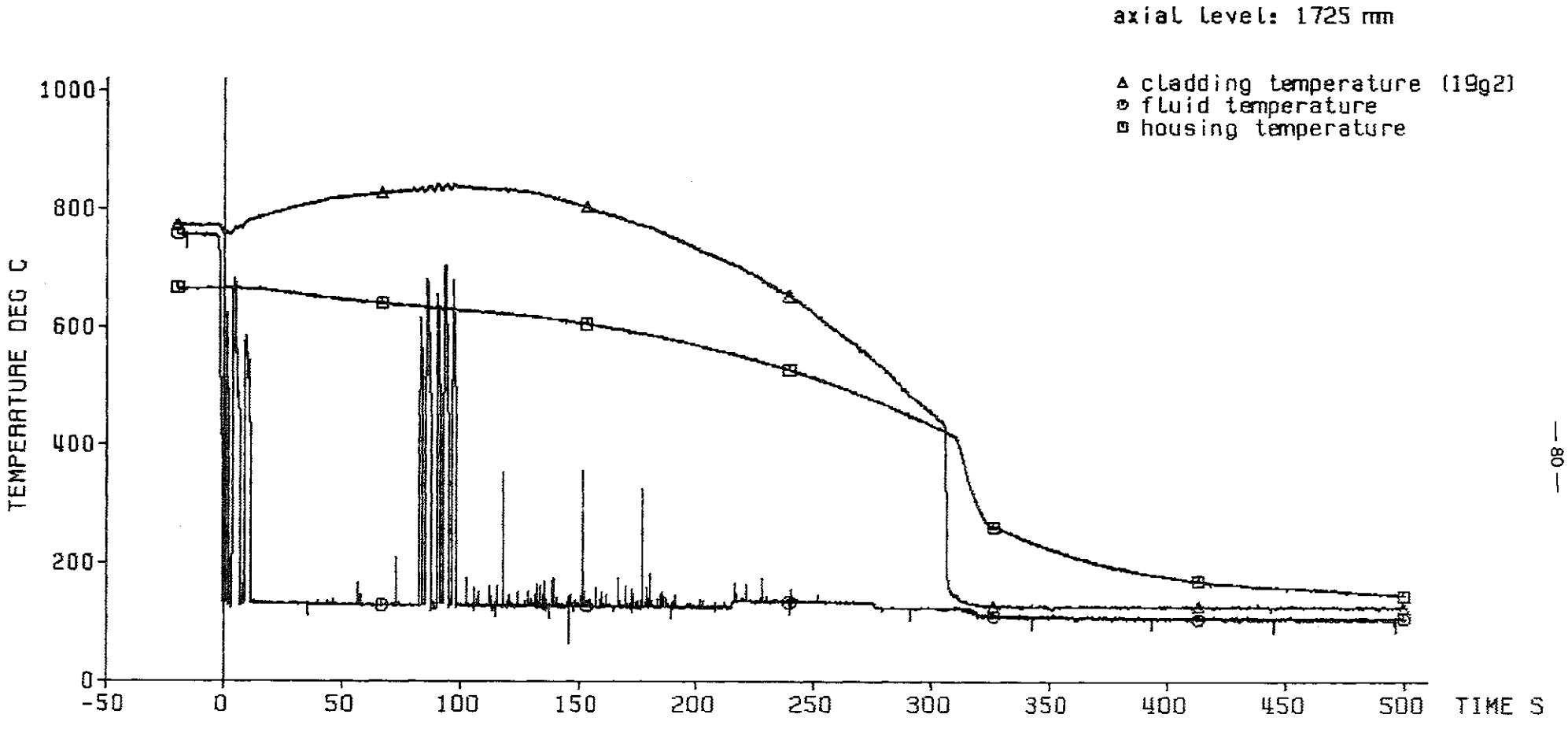
Fig. 65 FEBA: 5x5 ROD BUNDLE, TEST SERIES 1, TEST-No. 218



decay heat	120% ANS standard
flooding rate (cold)	5.81 cm/s
system pressure	2.08 bar
feedwater temperature	40 deg C

KfK IRB

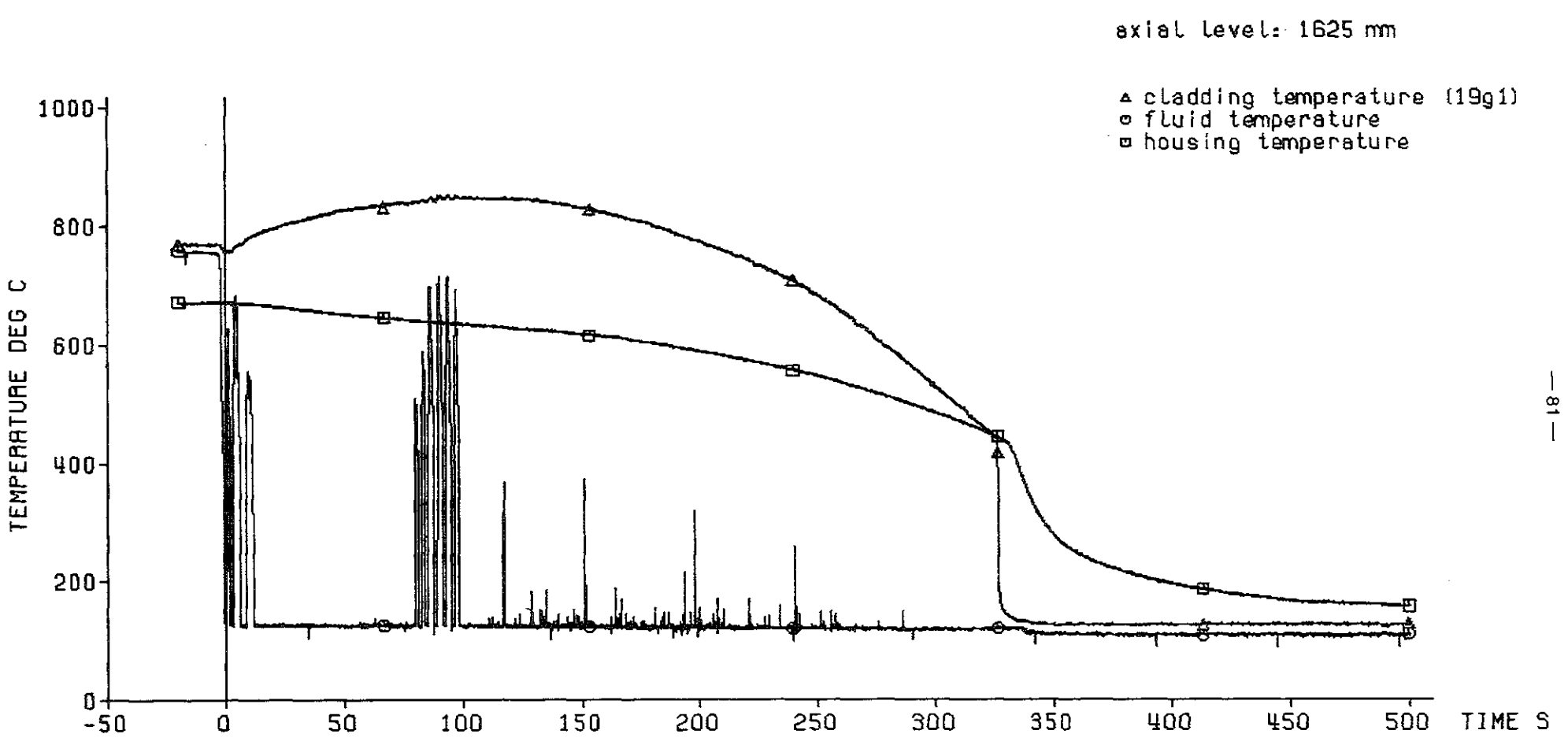
Fig. 66 FEBA: 5x5 ROD BUNDLE, TEST SERIES 1, TEST-No. 218



decay heat	120% ANS standard
flooding rate (cold)	5.81 cm/s
system pressure	2.08 bar
feedwater temperature	40 deg C

KfK IRB

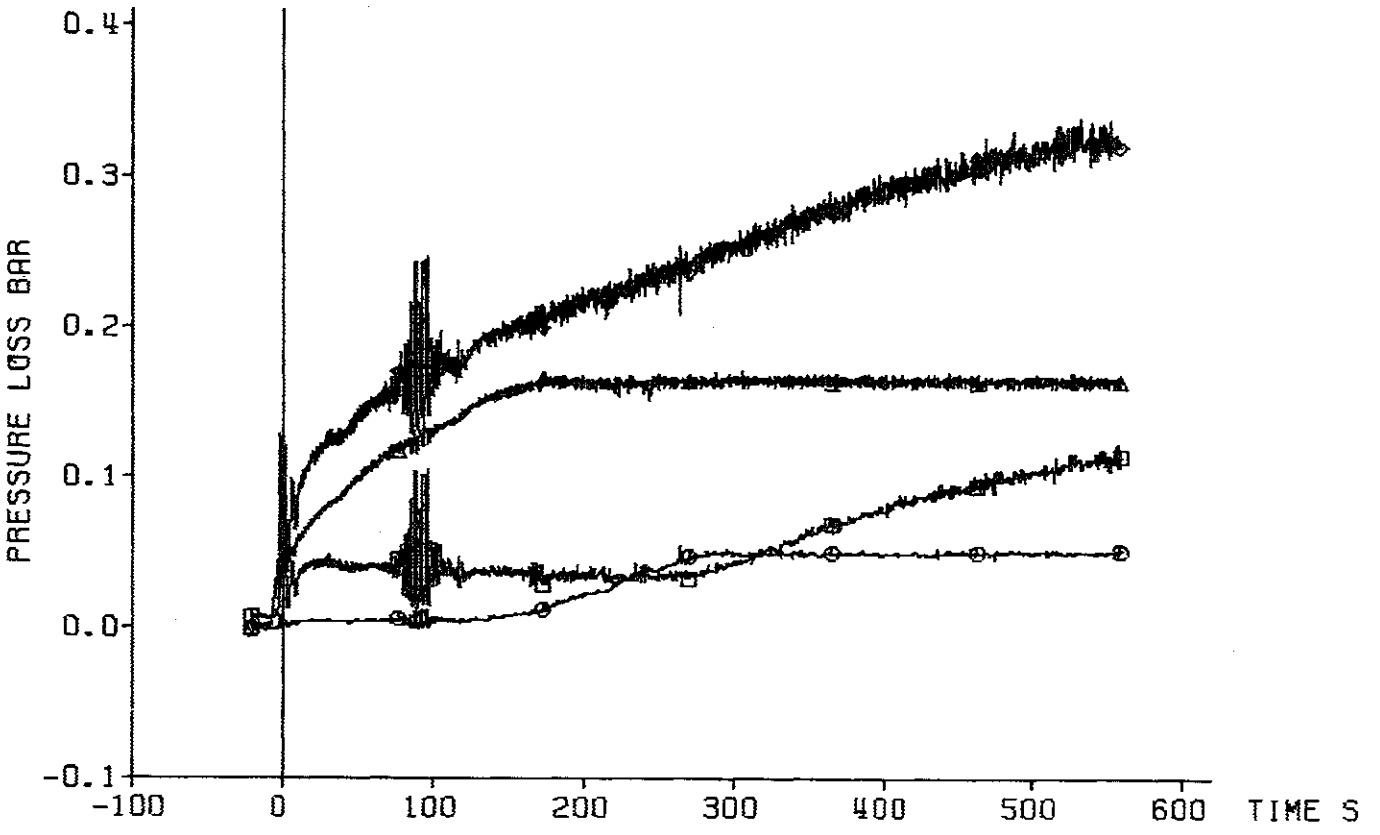
Fig. 67 FEBA: 5x5 ROD BUNDLE, TEST SERIES 1, TEST-No. 218



decay heat	120% ANS standard
flooding rate (cold)	5.81 cm/s
system pressure	2.08 bar
feedwater temperature	40 deg C

KfK IRB

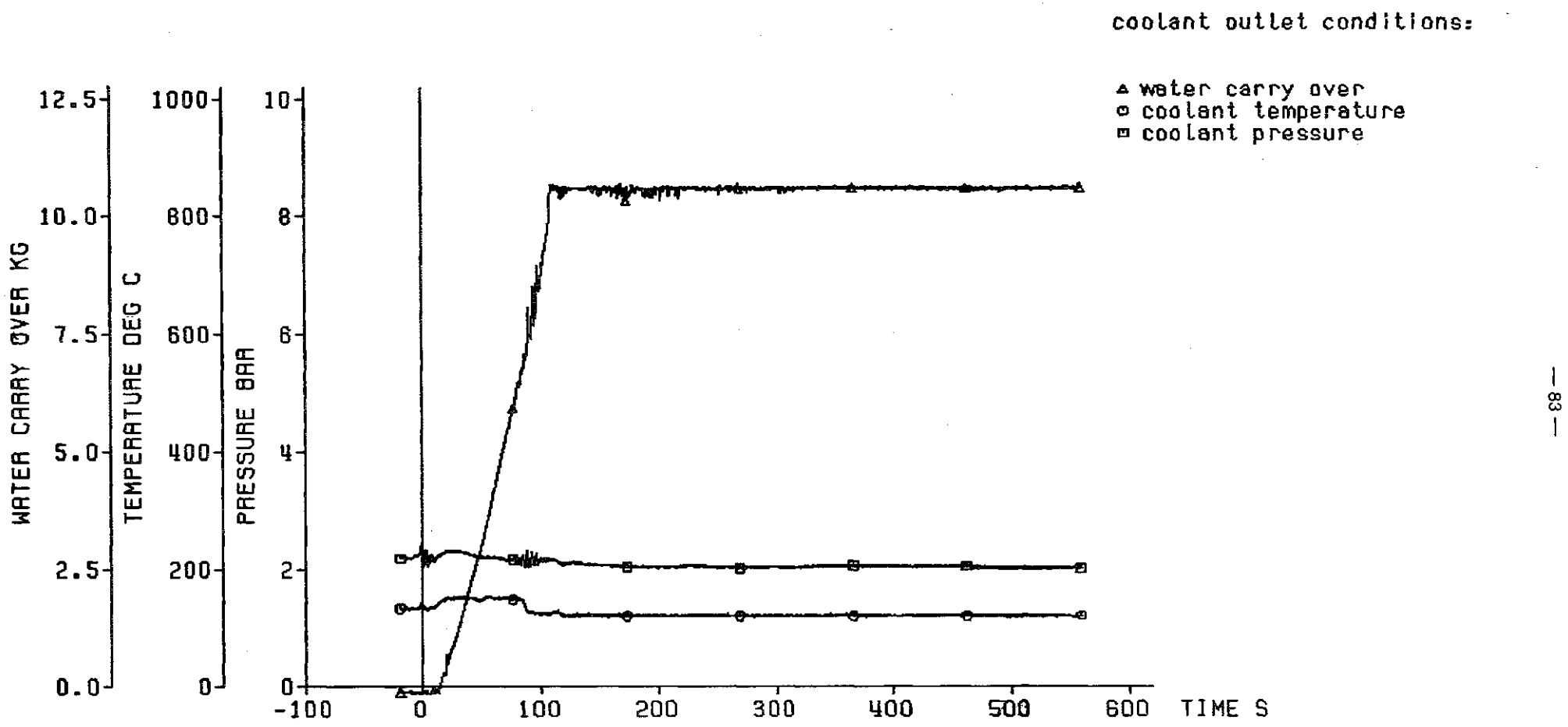
Fig. 68 FEBA: 5x5 ROD BUNDLE, TEST SERIES 1, TEST-No. 218



decay heat	120% ANS standard
flooding rate (cold)	5.81 cm/s
system pressure	2.08 bar
feedwater temperature	40 deg C

KfK IRB

Fig. 69 FEBA: 5x5 ROD BUNDLE, TEST SERIES 1, TEST-No. 218

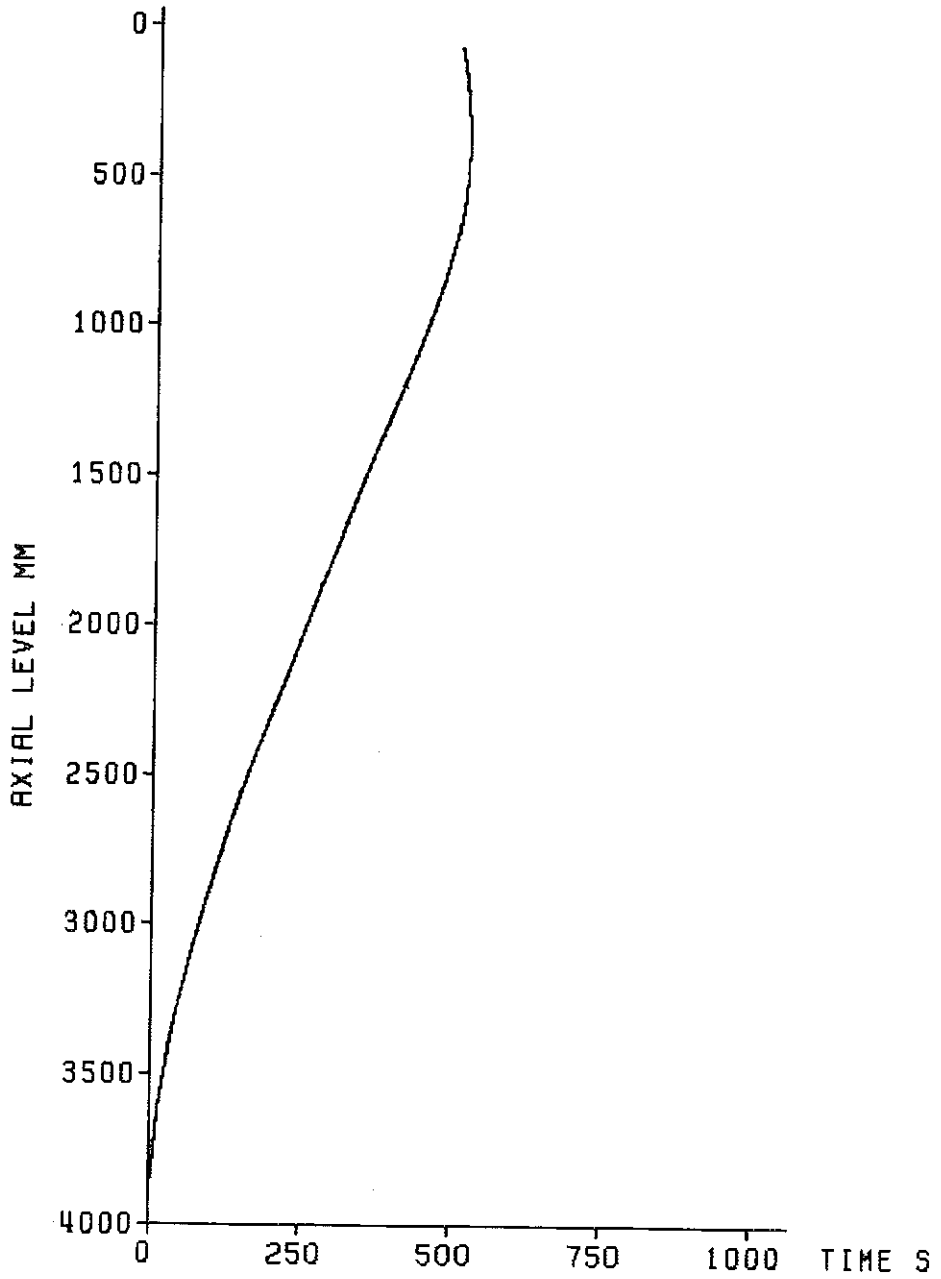


decay heat	120% ANS standard
flooding rate (cold)	5.81 cm/s
system pressure	2.08 bar
feedwater temperature	40 deg C

KfK IRB

Fig. 70 FEBA: 5x5 ROD BUNDLE, TEST SERIES 1, TEST-No. 218

axial position of the quench front

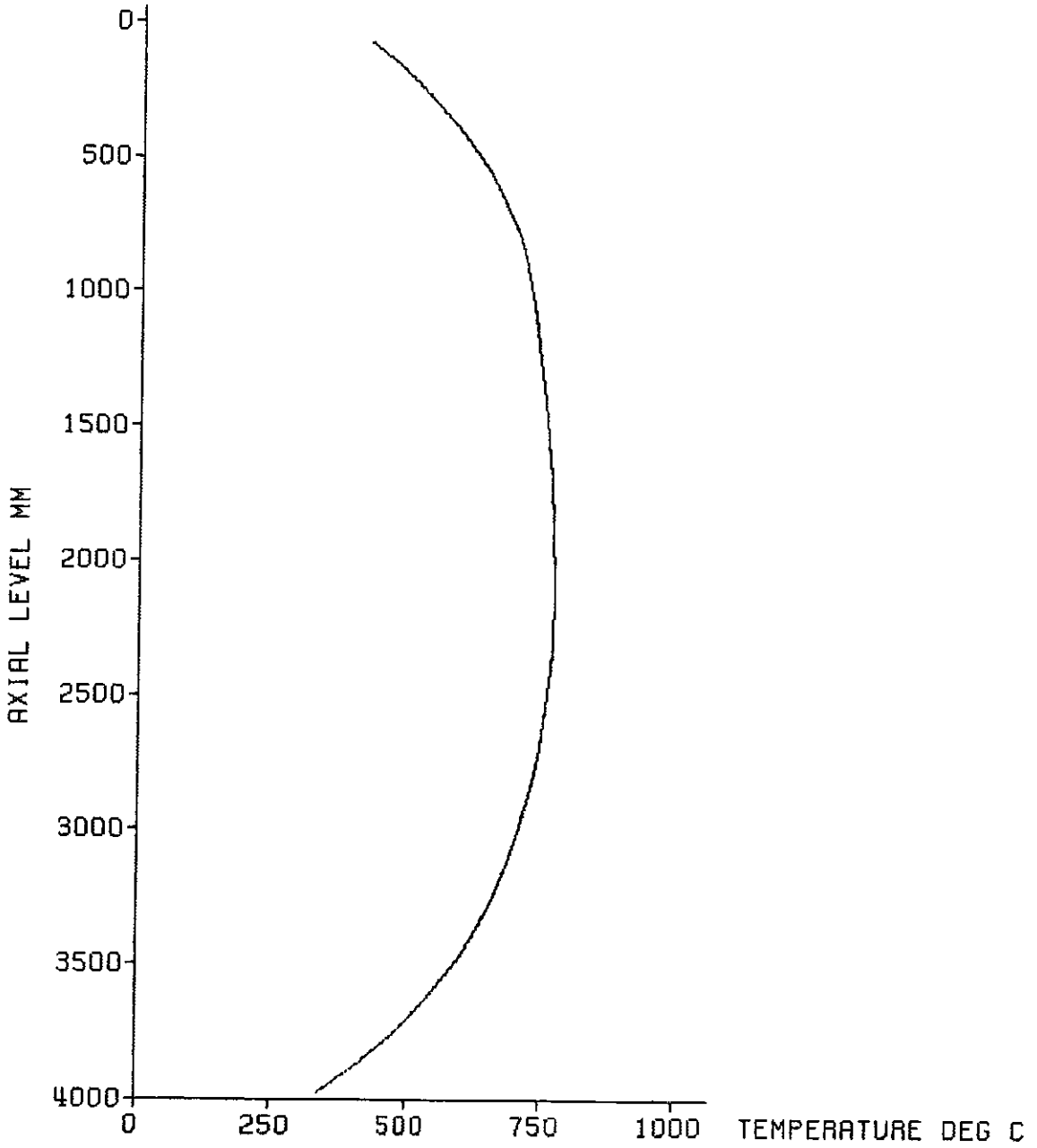


decay heat	120% ANS standard
flooding rate (cold)	5.81 cm/s
system pressure	2.08 bar
feedwater temperature	40 deg C

KfK IRB

Fig. 71 FEBA: 5x5 ROD BUNDLE TEST SERIES 1, TEST-No. 218

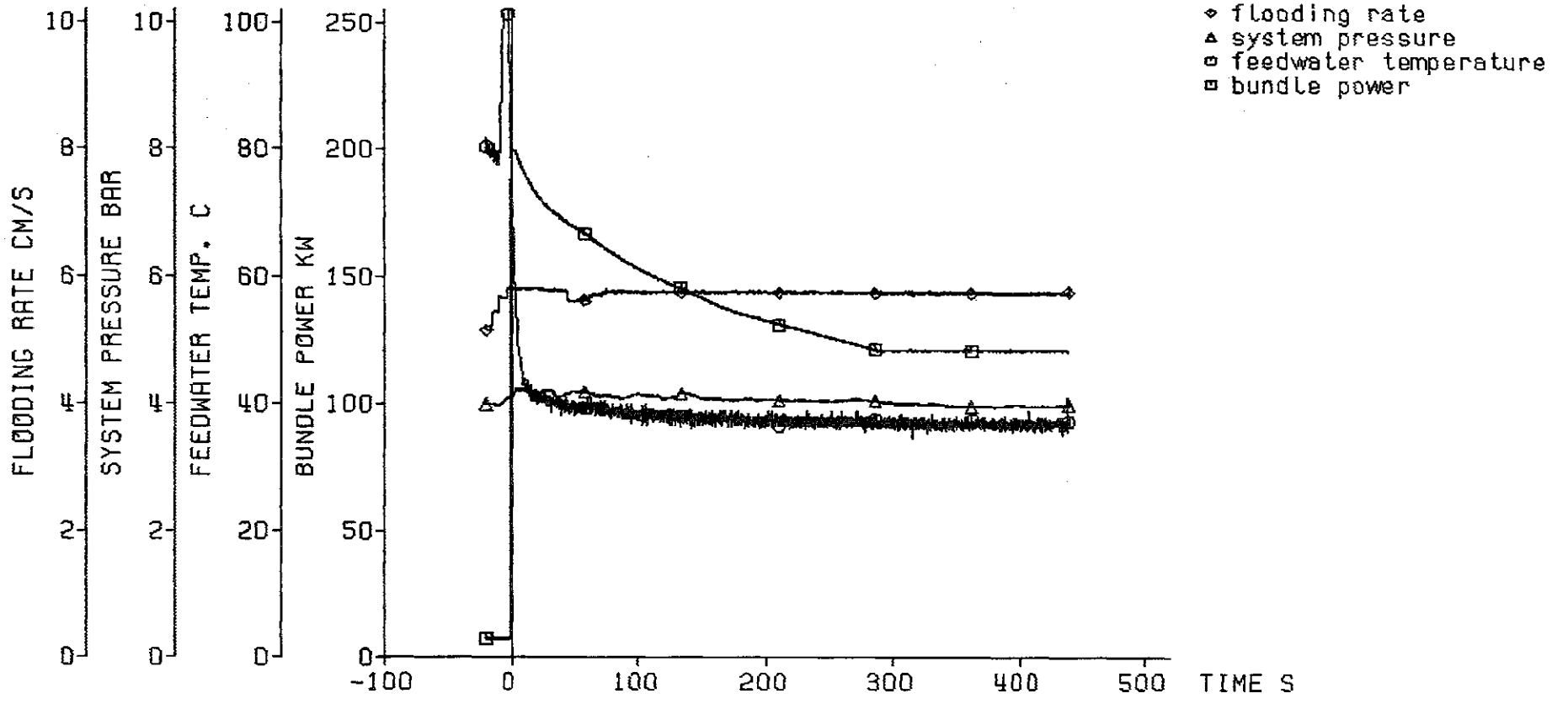
initial axial temperature profile of the cladding



decay heat	120% ANS standard
flooding rate (cold)	5.77 cm/s
system pressure	4.11 bar
feedwater temperature	40 deg C

KfK IRB

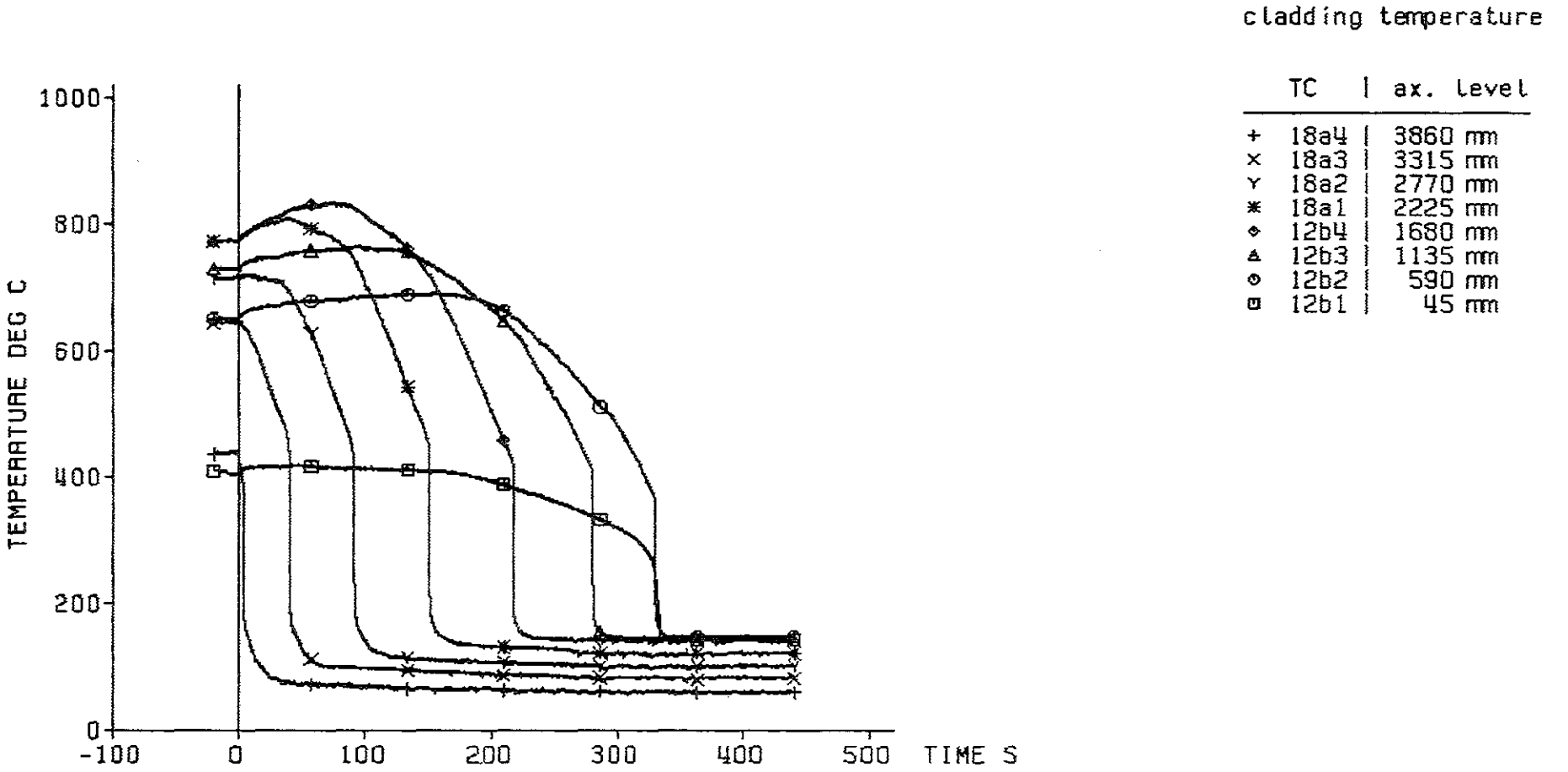
Fig. 72 FEBA: 5x5 ROD BUNDLE TEST SERIES 1, TEST-No. 214



decay heat	120% ANS standard
flooding rate (cold)	5.77 cm/s
system pressure	4.11 bar
feedwater temperature	40 deg C

KfK IRB

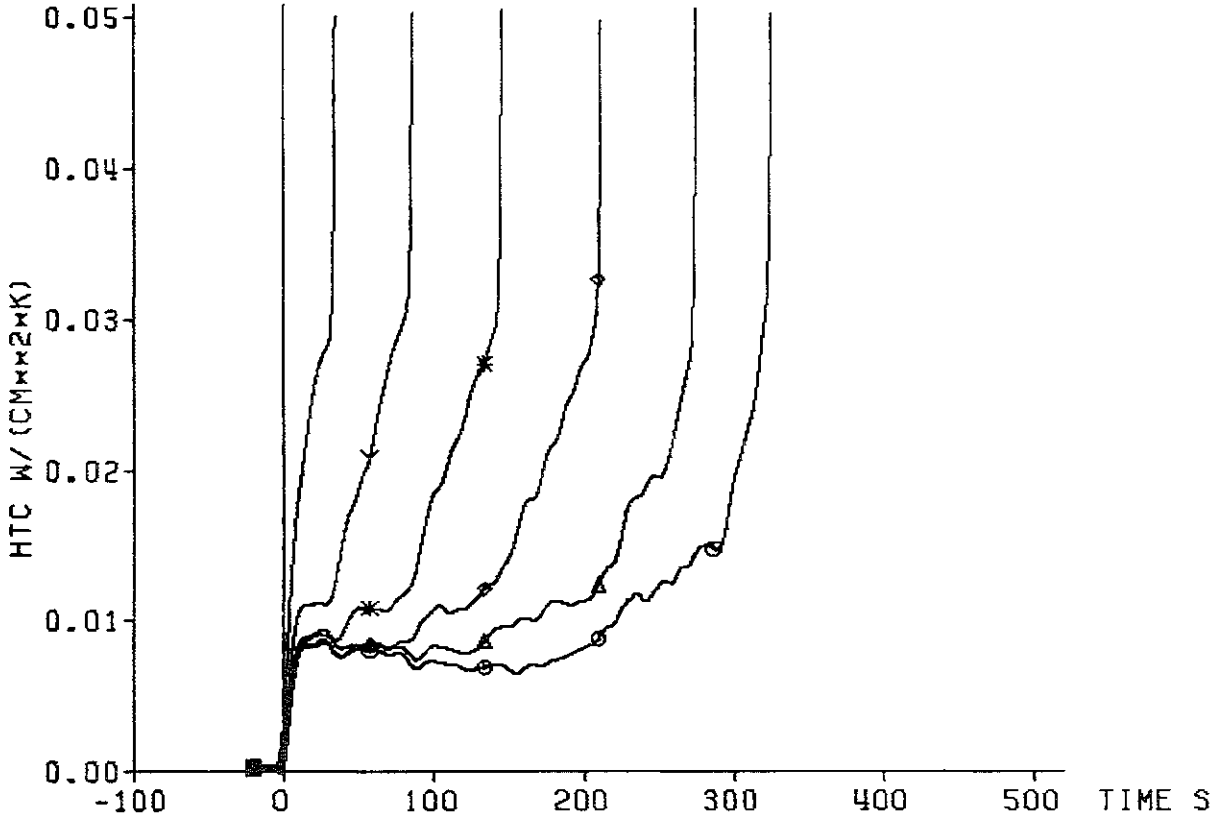
Fig. 73 FEBA: 5x5 ROD BUNDLE, TEST SERIES 1, TEST-No. 214



decay heat	120% ANS standard
flooding rate (cold)	5.77 cm/s
system pressure	4.11 bar
feedwater temperature	40 deg C

KfK KIRB

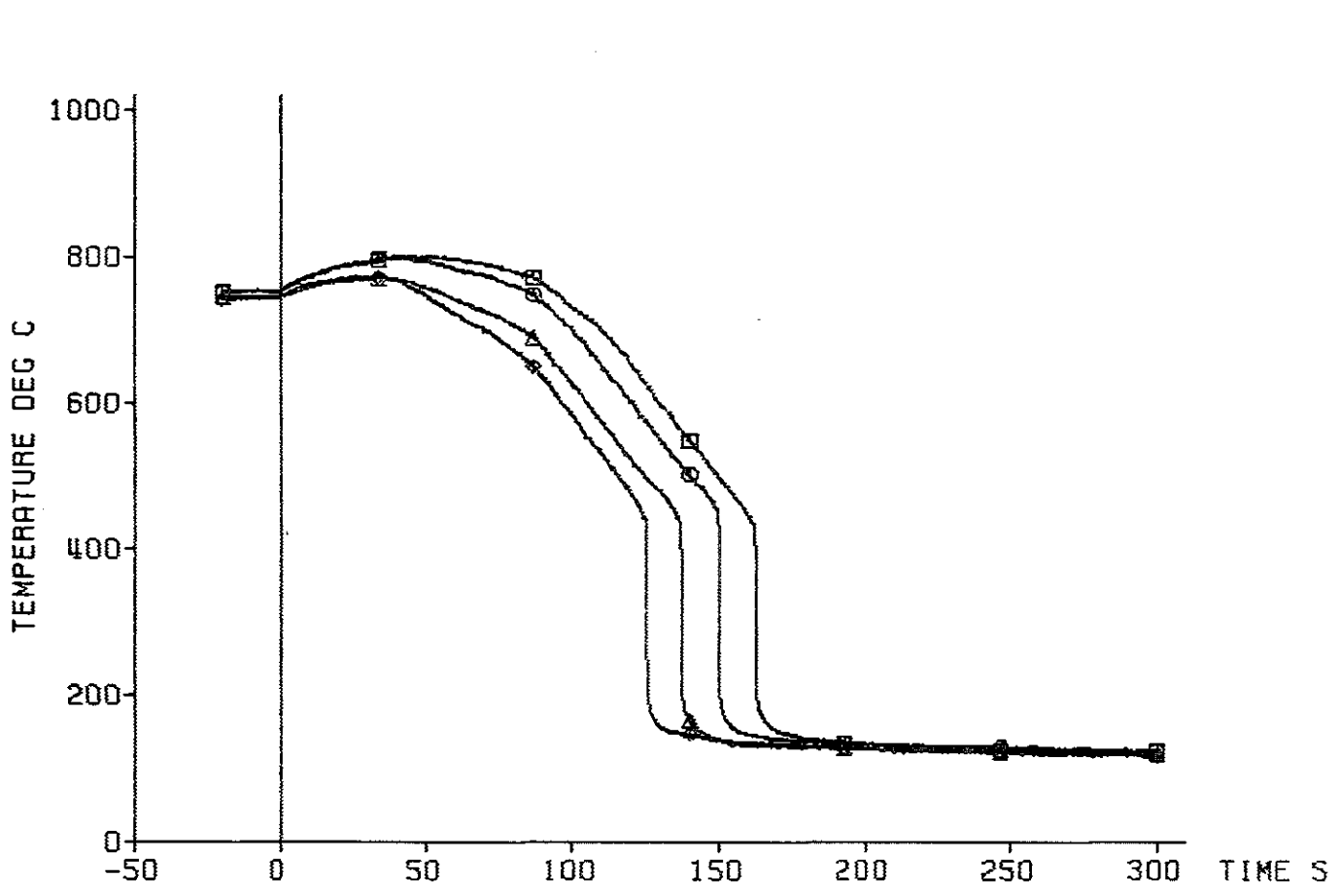
Fig. 74 FEBA: 5x5 ROD BUNDLE, TEST SERIES 1, TEST-No. 214



decay heat	120% ANS standard
flooding rate (cold)	5.77 cm/s
system pressure	4.11 bar
feedwater temperature	40 deg C

KfK IRB

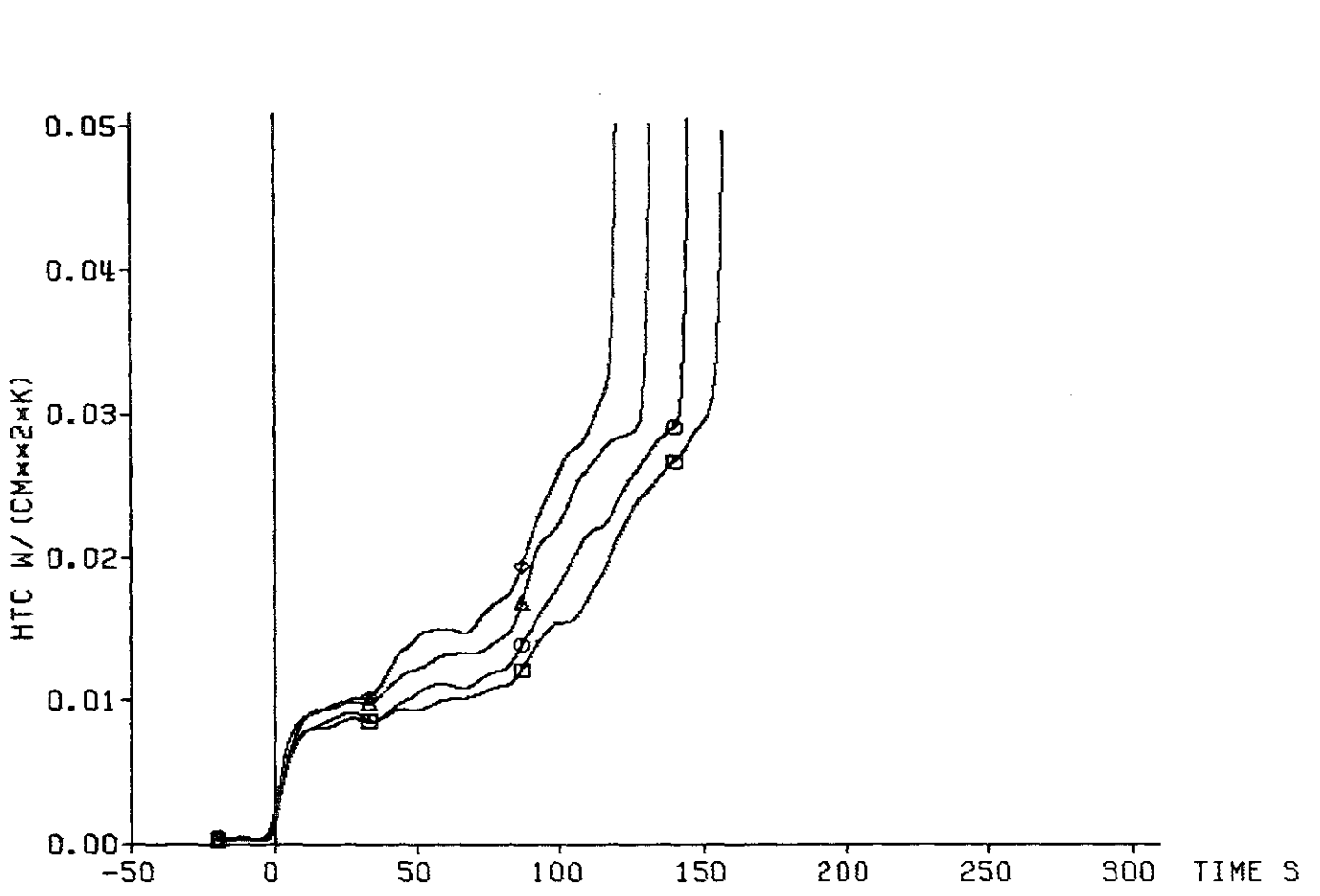
Fig. 75 FEBA: 5x5 ROD BUNDLE, TEST SERIES 1, TEST-No. 214



decay heat	120% ANS standard
flooding rate (cold)	5.77 cm/s
system pressure	4.11 bar
feedwater temperature	40 deg C

KfK IRB

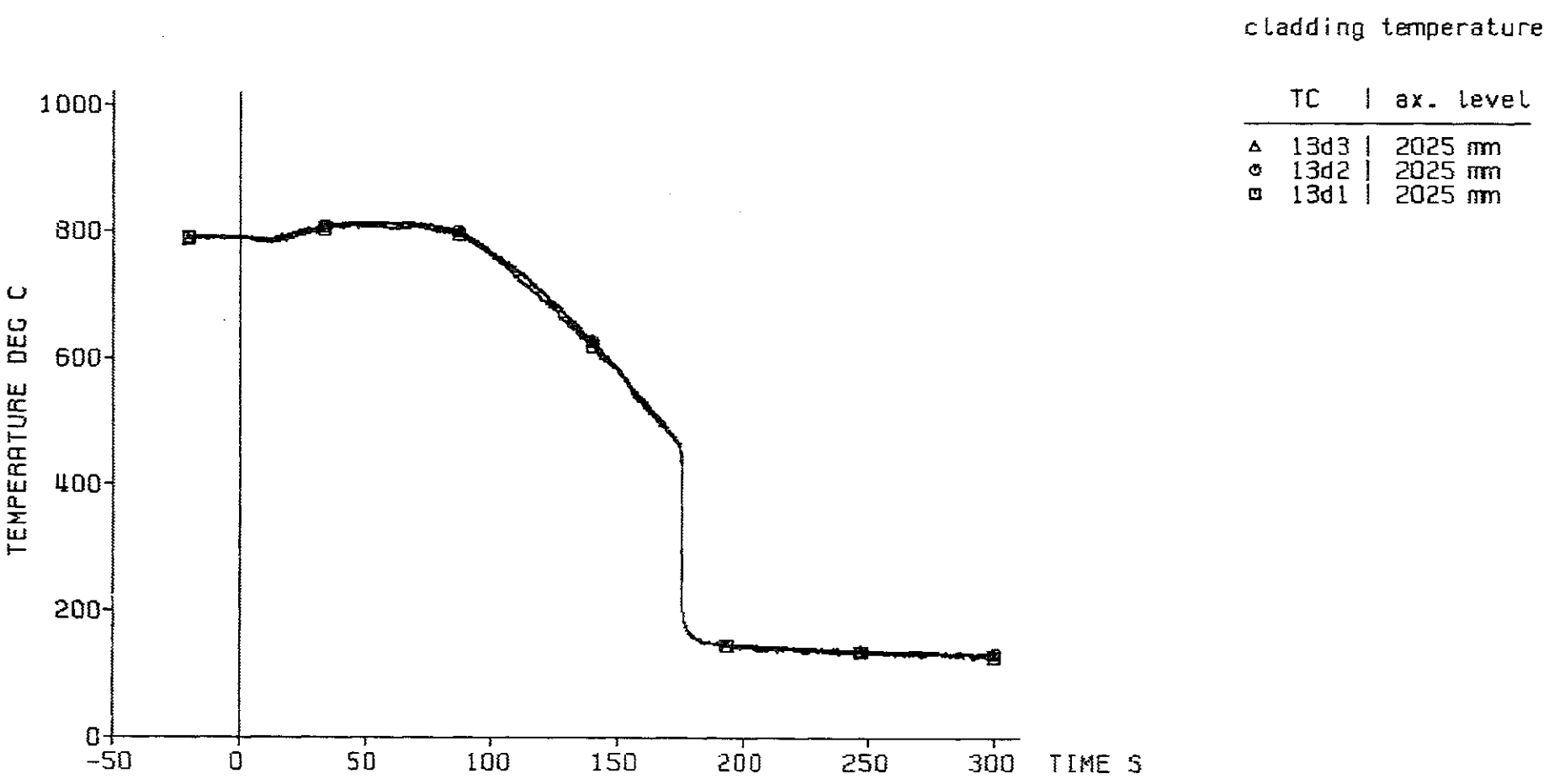
Fig. 76 FEBA: 5x5 ROD BUNDLE, TEST SERIES 1, TEST-No. 214



decay heat 120% ANS standard
flooding rate (cold) 5.77 cm/s
system pressure 4.11 bar
feedwater temperature 40 deg C

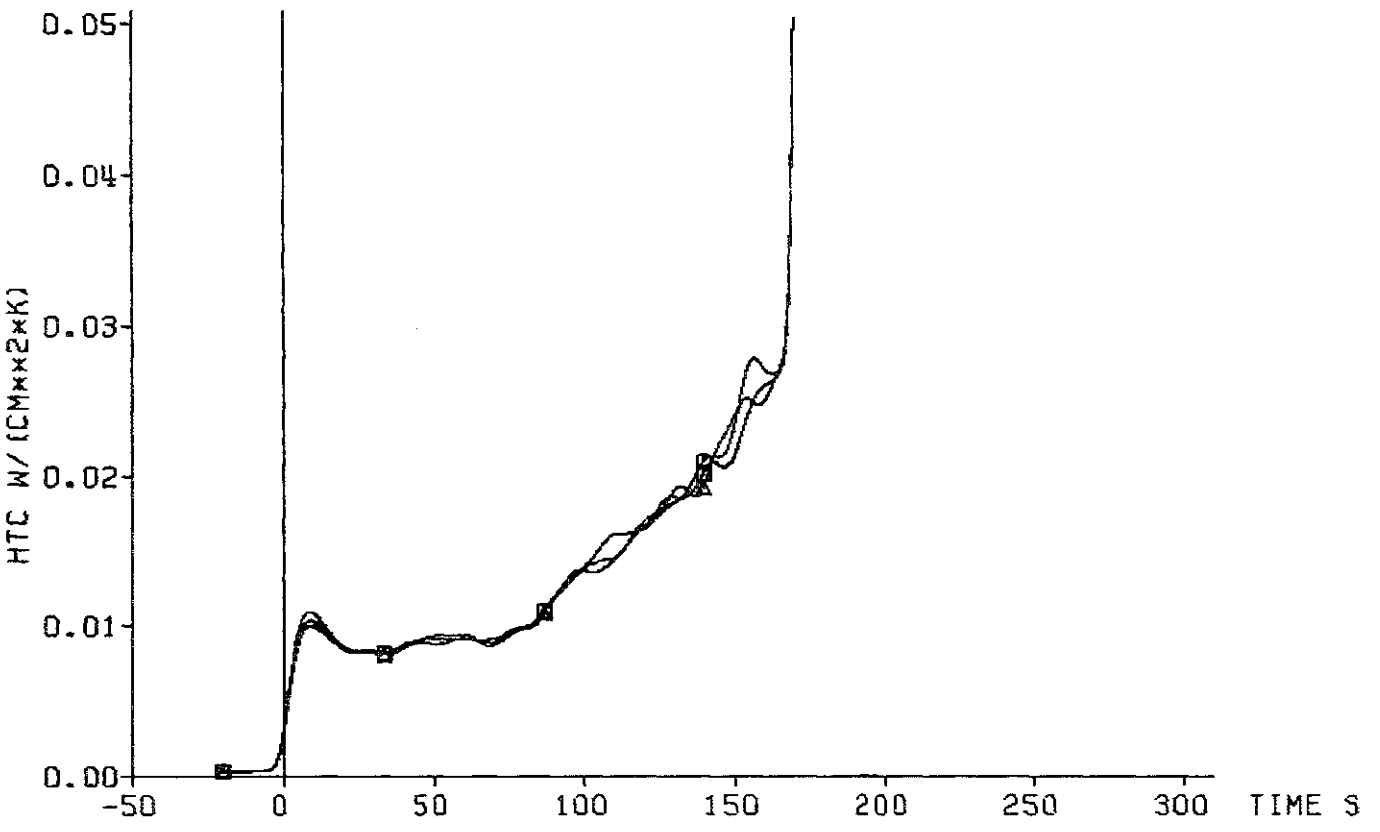
KfK IRB

Fig. 77 FEBA: 5x5 ROD BUNDLE, TEST SERIES 1, TEST-No. 214



decay heat	120% ANS standard
flooding rate (cold)	5.77 cm/s
system pressure	4.11 bar
feedwater temperature	40 deg C

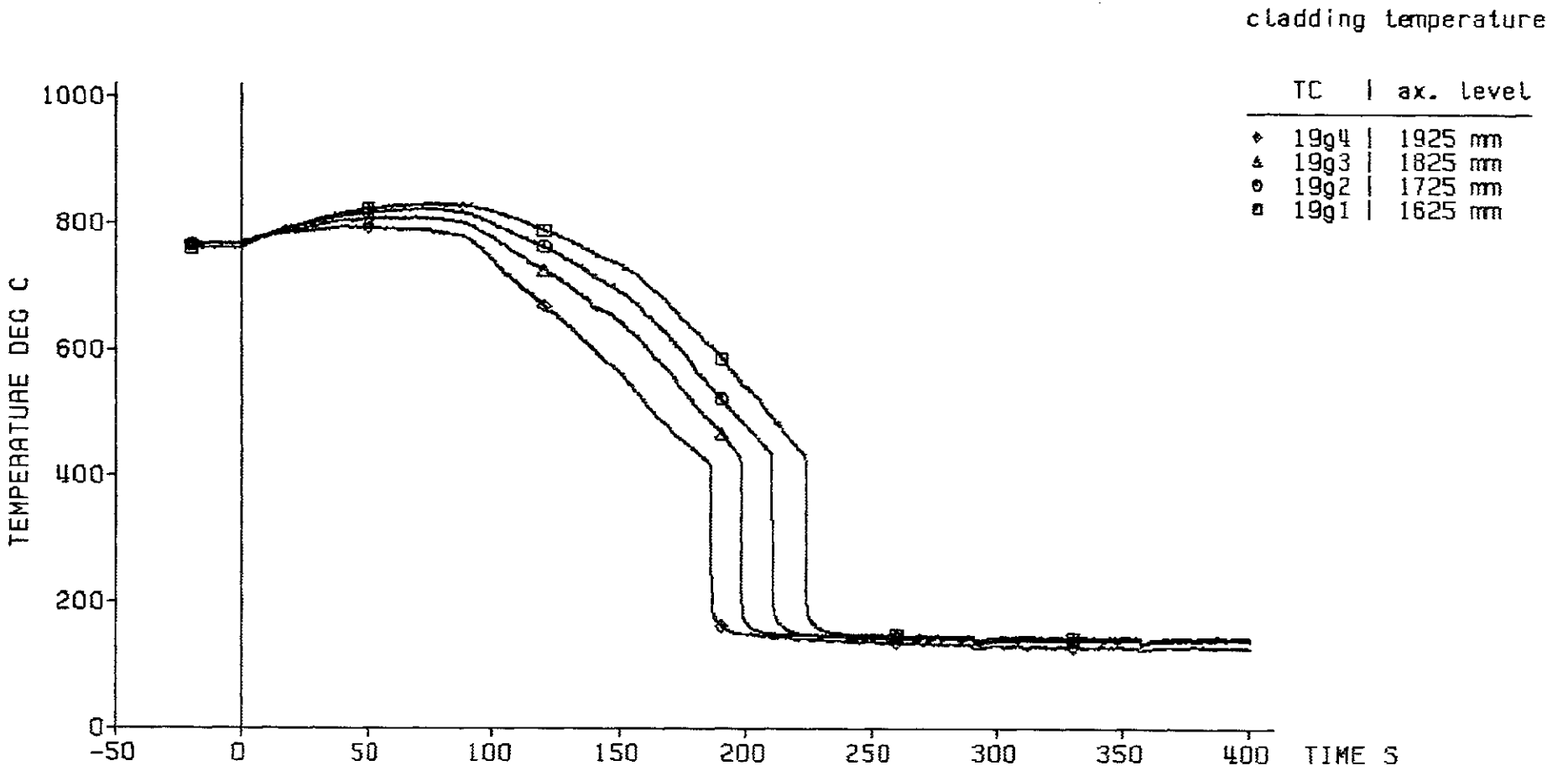
Fig. 78 FEBA: 5x5 ROD BUNDLE, TEST SERIES 1, TEST-No. 214



decay heat	120% ANS standard
flooding rate (cold)	5.77 cm/s
system pressure	4.11 bar
feedwater temperature	40 deg C

KfK IRB

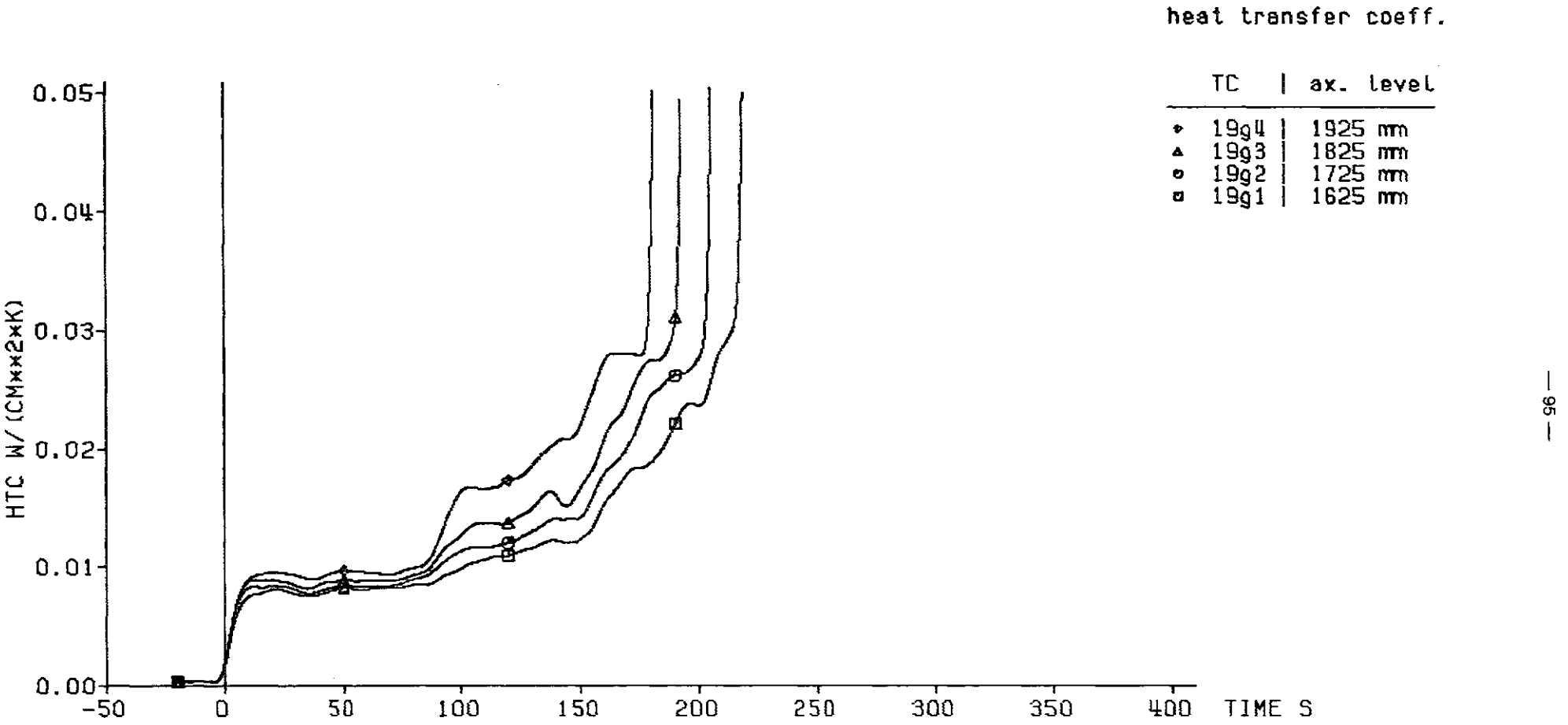
Fig. 79 FEBA: 5x5 ROD BUNDLE, TEST SERIES 1, TEST-No. 214



decay heat	120% ANS standard
flooding rate (cold)	5.77 cm/s
system pressure	4.11 bar
feedwater temperature	40 deg C

KfK KIRB

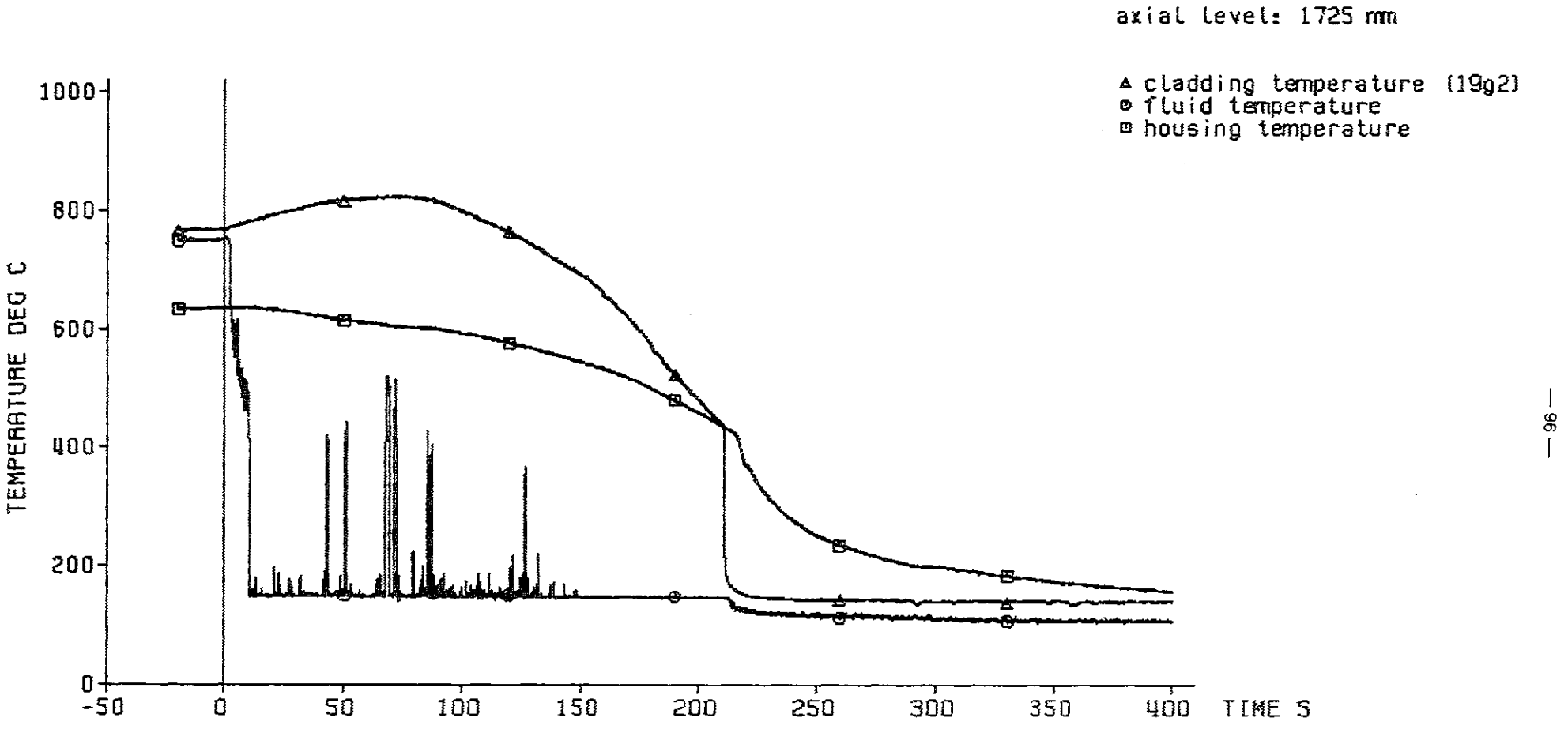
Fig. 80 FEBA: 5x5 ROD BUNDLE, TEST SERIES 1, TEST-No. 214



decay heat	120% ANS standard
flooding rate (cold)	5.77 cm/s
system pressure	4.11 bar
feedwater temperature	40 deg C

KfK IRB

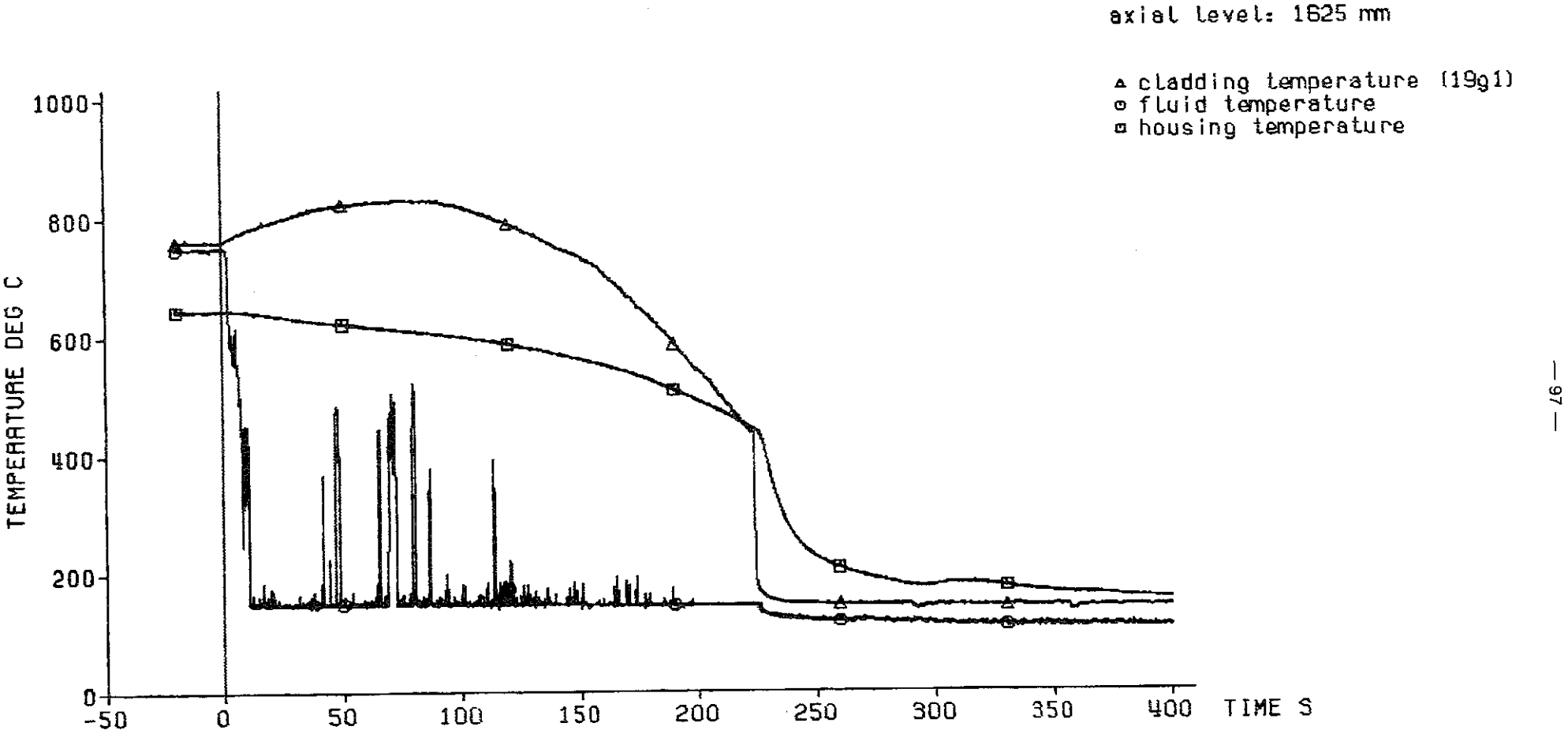
Fig. 81 FEBA: 5x5 ROD BUNDLE, TEST SERIES 1, TEST-No. 214



decay heat	120% ANS standard
flooding rate (cold)	5.77 cm/s
system pressure	4.11 bar
feedwater temperature	40 deg C

KfK IRB

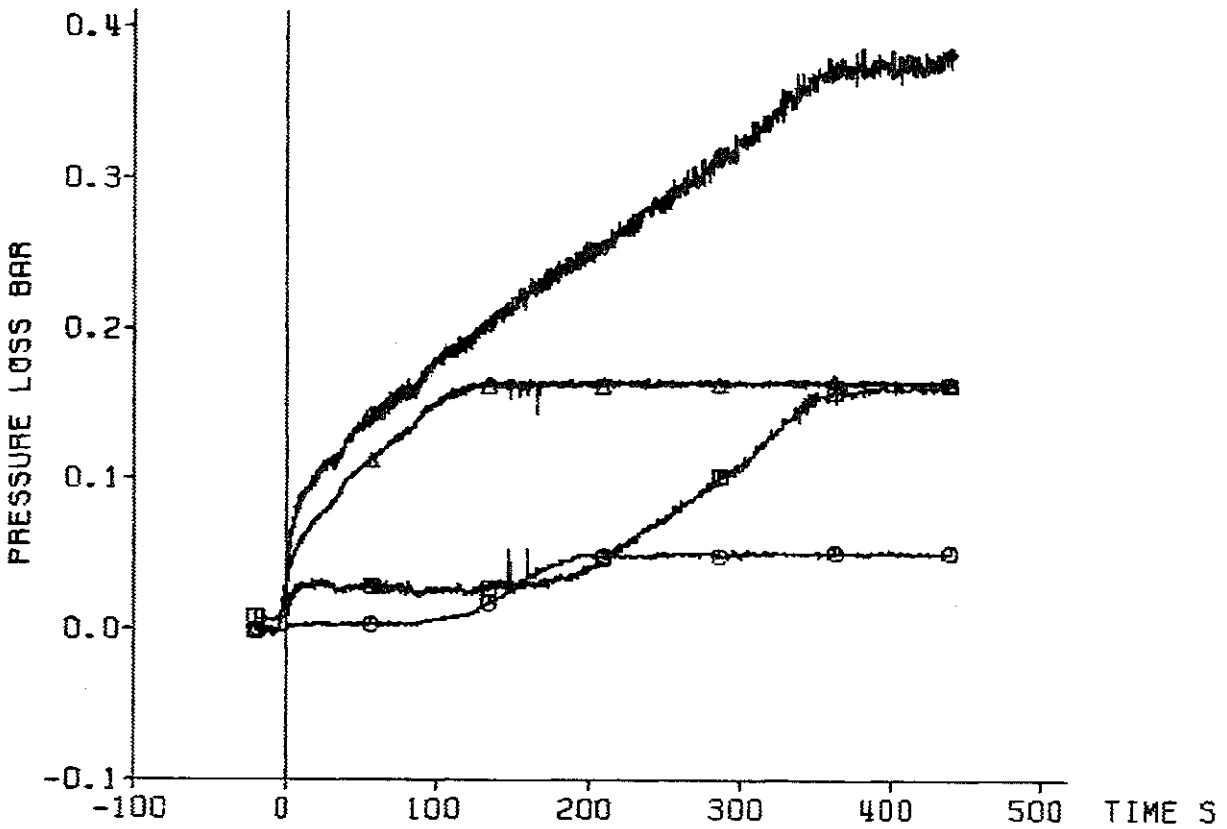
Fig. 82 FEBA: 5x5 ROD BUNDLE, TEST SERIES 1, TEST-No. 214



decay heat	120% ANS standard
flooding rate (cold)	5.77 cm/s
system pressure	4.11 bar
feedwater temperature	40 deg C

KfK IRB

Fig. 83 FEBA: 5x5 ROD BUNDLE, TEST SERIES 1, TEST-No. 214



pressure loss
along the test section:

◆ total length: 4196 mm
△ lower part: 1711 mm
○ middle part: 545 mm
□ upper part: 1940 mm

decay heat	120% ANS standard
flooding rate (cold)	5.77 cm/s
system pressure	4.11 bar
feedwater temperature	40 deg C

KfK IRB

Fig. 84 FEBA: 5x5 ROD BUNDLE, TEST SERIES 1, TEST-No. 214

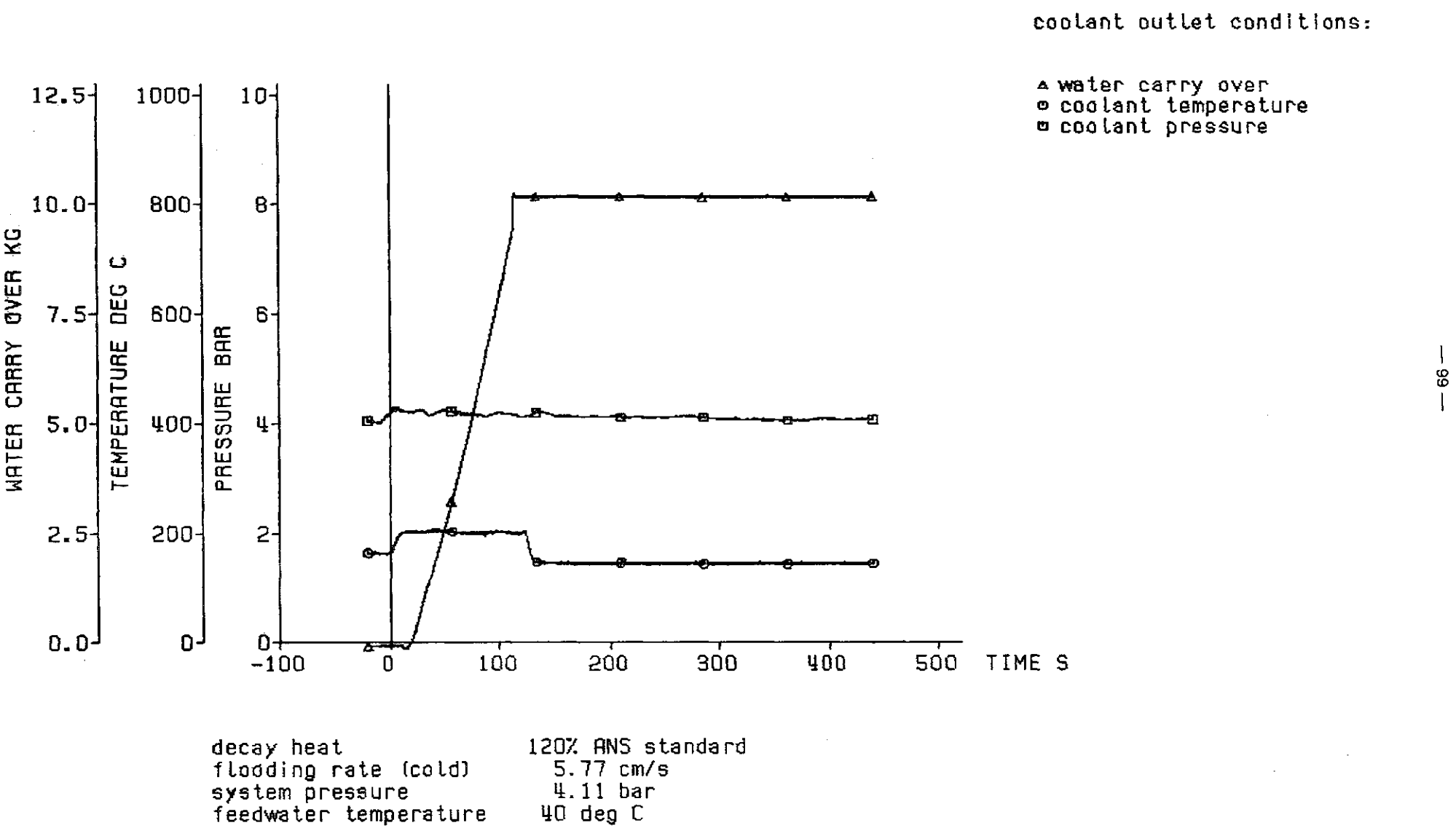
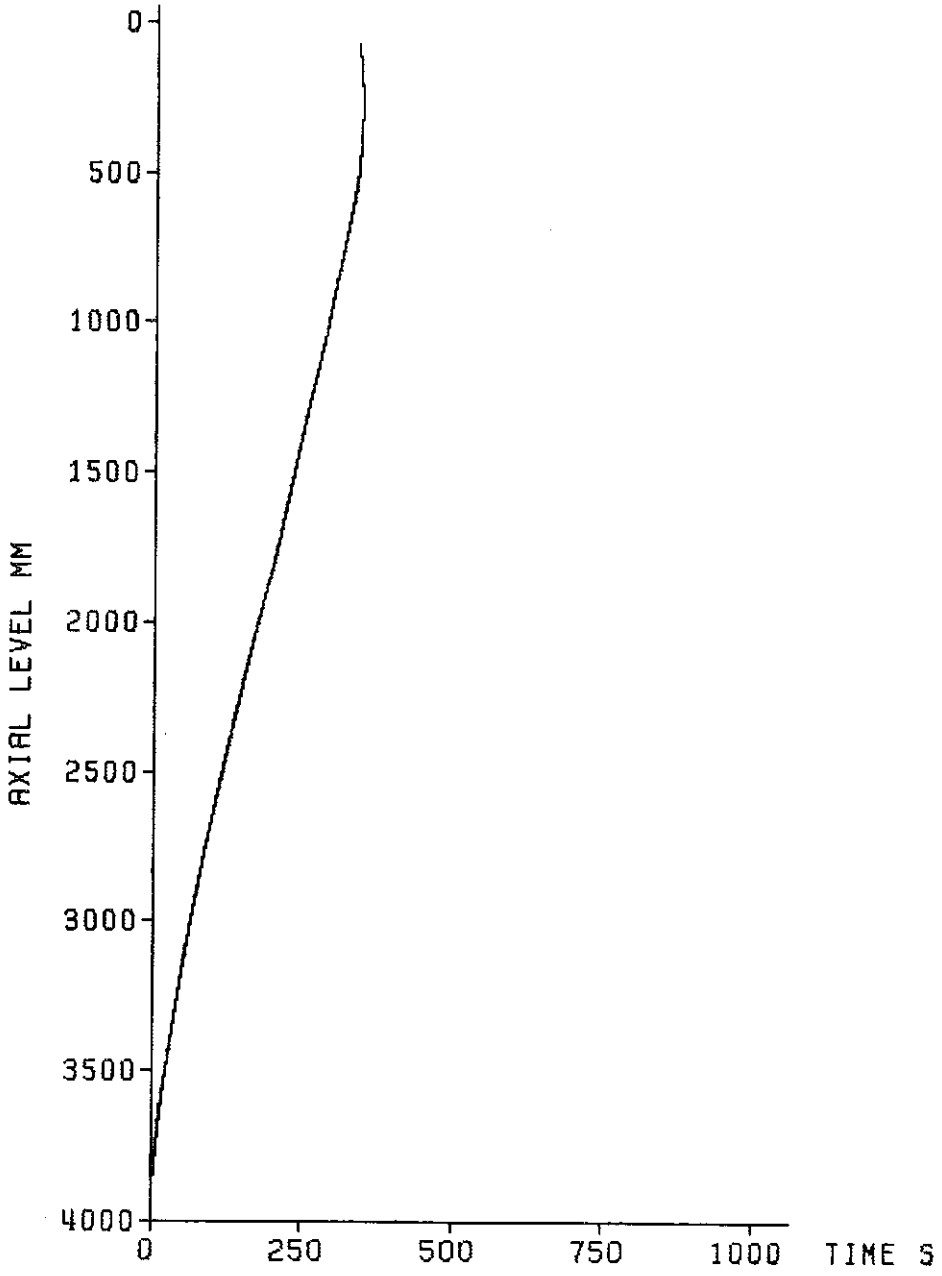


Fig. 85 FEBA: 5x5 ROD BUNDLE, TEST SERIES 1, TEST-No. 214

axial position of the quench front

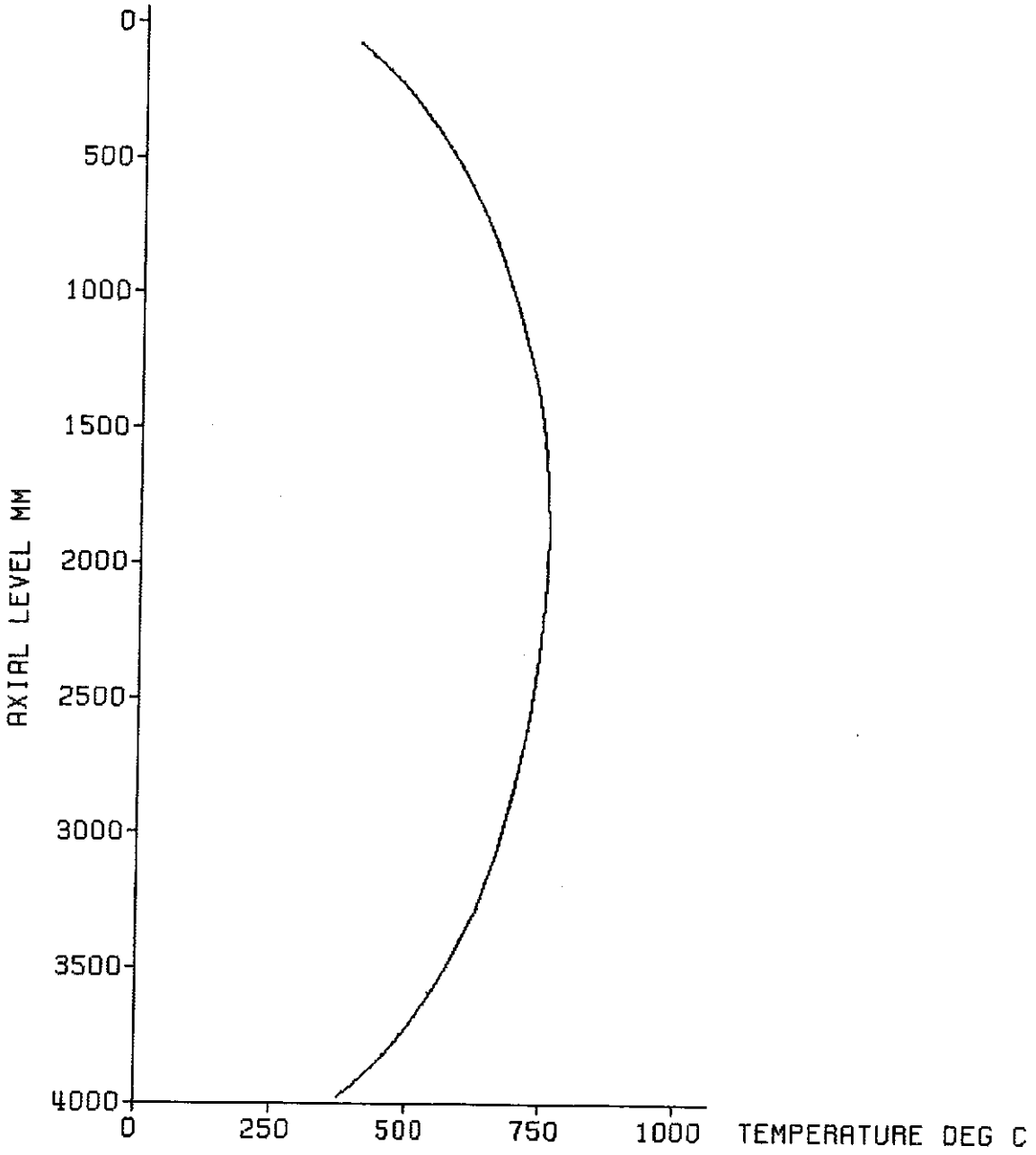


decay heat	120% ANS standard
flooding rate (cold)	5.77 cm/s
system pressure	4.11 bar
feedwater temperature	40 deg C

KfK IRB

Fig. 86 FEBA: 5x5 ROD BUNDLE TEST SERIES 1, TEST-No. 214

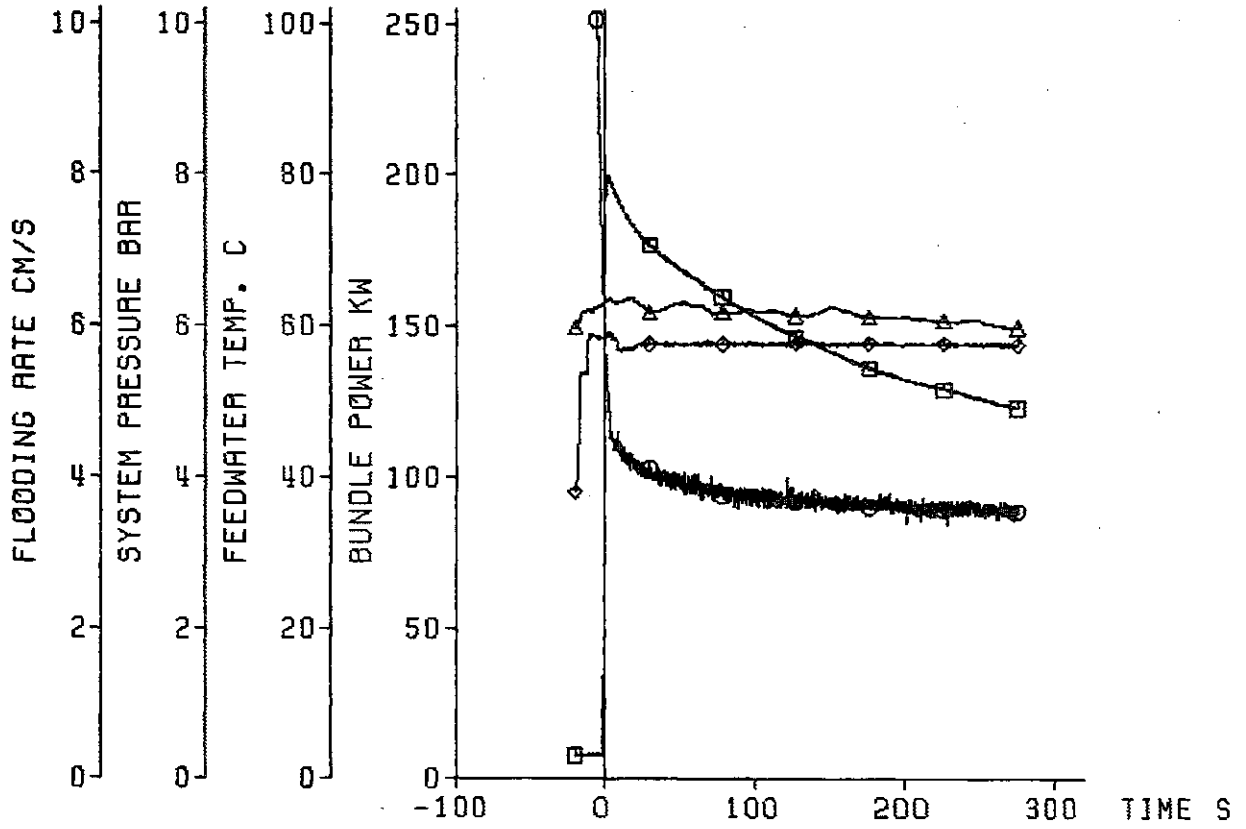
initial axial temperature profile of the cladding



decay heat	120% ANS standard
flooding rate (cold)	5.78 cm/s
system pressure	6.18 bar
feedwater temperature	40 deg C

KfK IRB

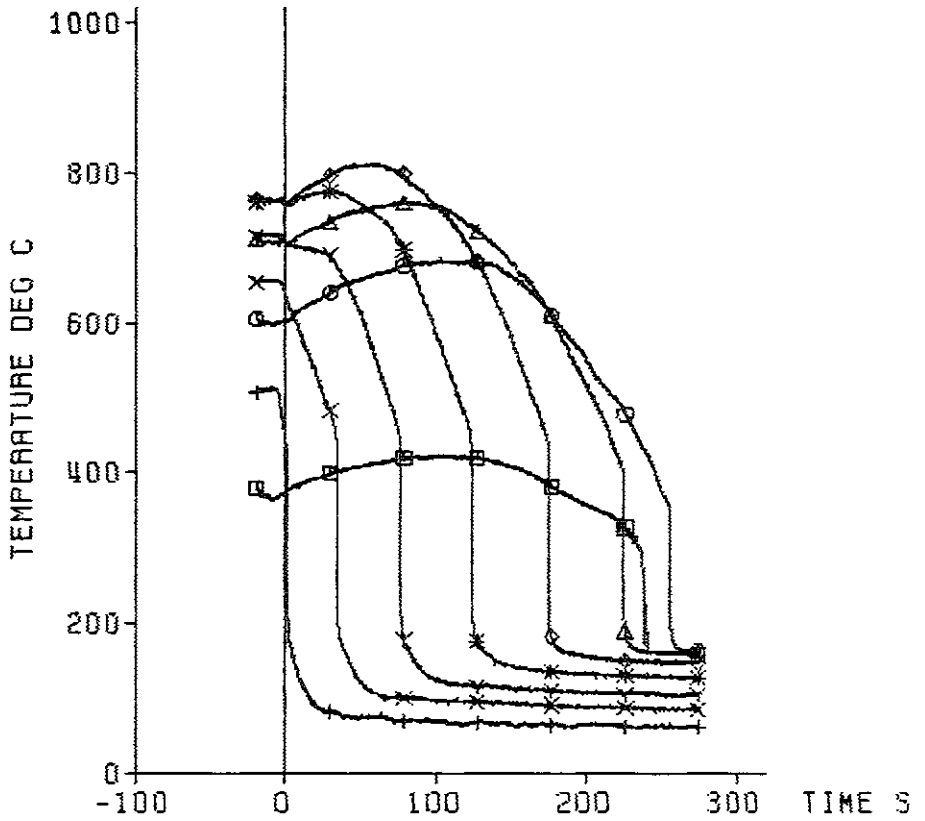
Fig. 87 FEBA: 5x5 ROD BUNDLE TEST SERIES 1, TEST-No. 222



decay heat	120% ANS standard
flooding rate (cold)	5.78 cm/s
system pressure	6.18 bar
feedwater temperature	40 deg C

KfK IRB

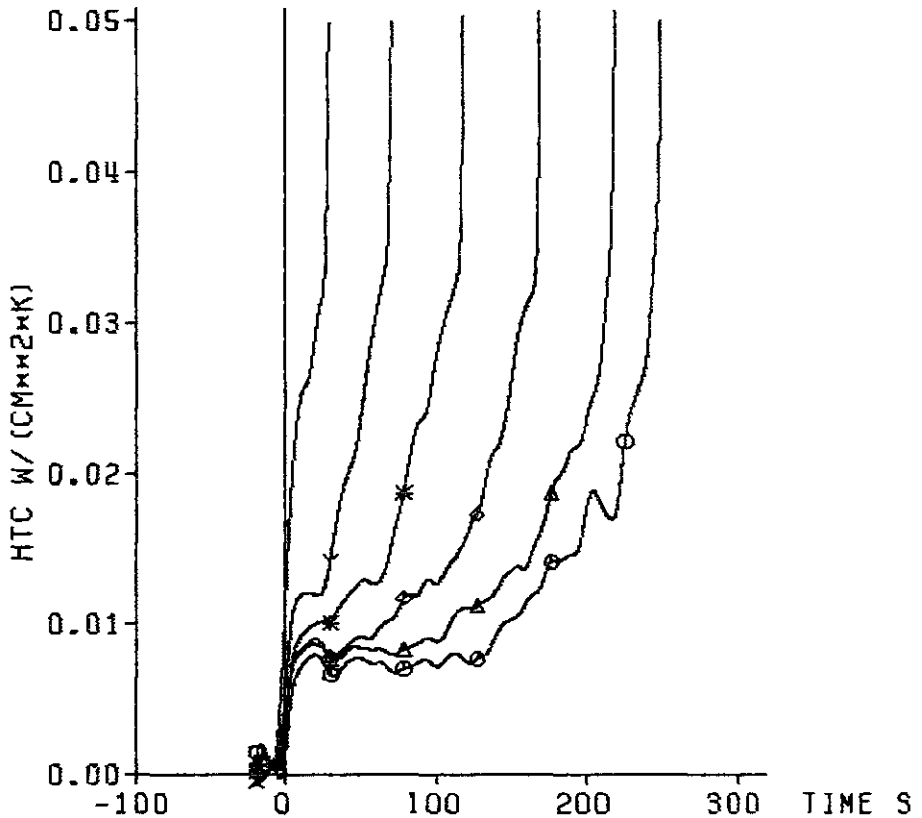
Fig. 88 FEBA: 5x5 ROD BUNDLE, TEST SERIES 1, TEST-No. 222



decay heat	120% ANS standard
flooding rate (cold)	5.78 cm/s
system pressure	6.18 bar
feedwater temperature	40 deg C

KfK KIRB

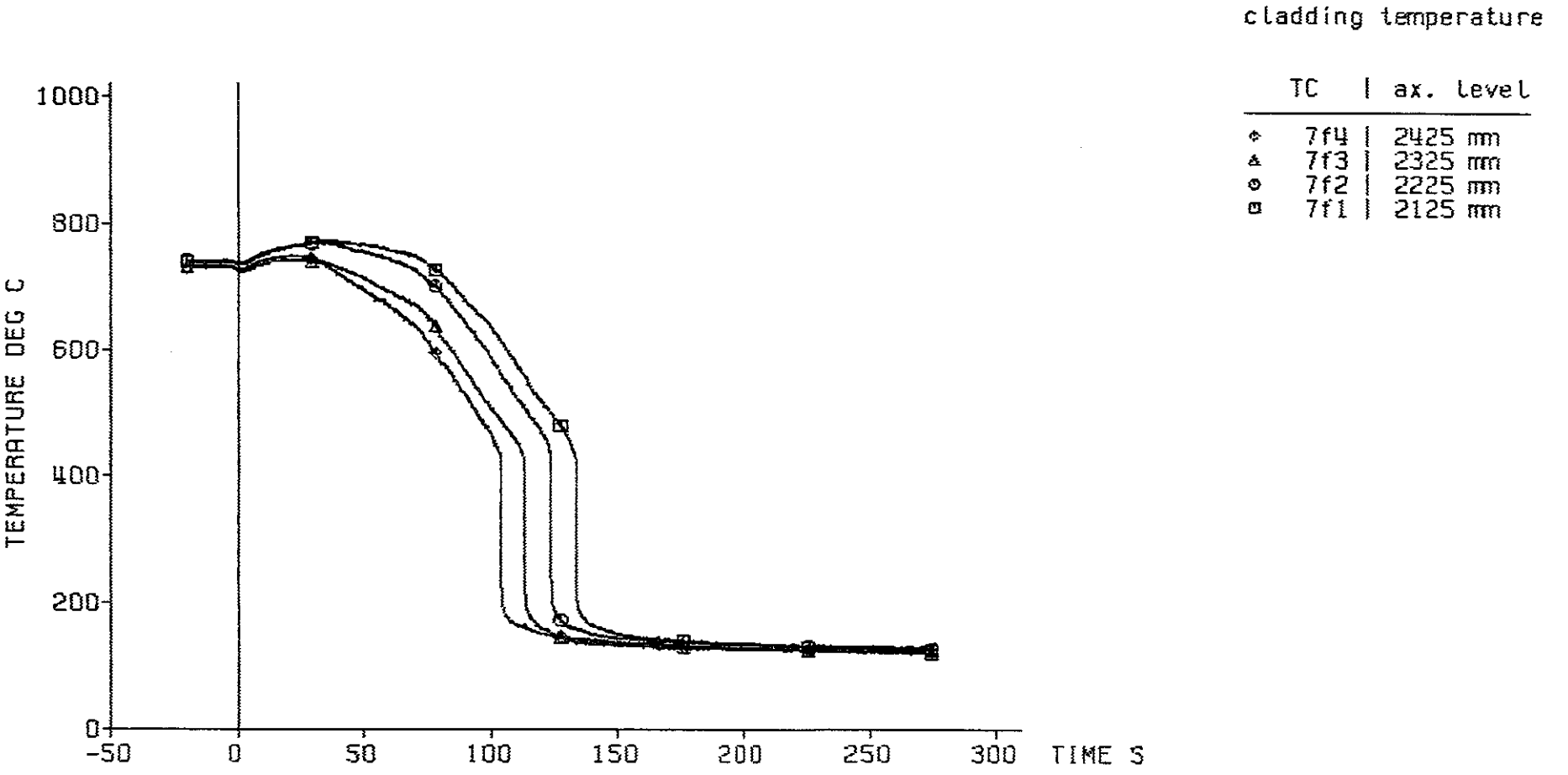
Fig. 89 FEBA: 5x5 ROD BUNDLE, TEST SERIES 1, TEST-No. 222



decay heat	120% ANS standard
flooding rate (cold)	5.78 cm/s
system pressure	6.18 bar
feedwater temperature	40 deg C

KfK IRB

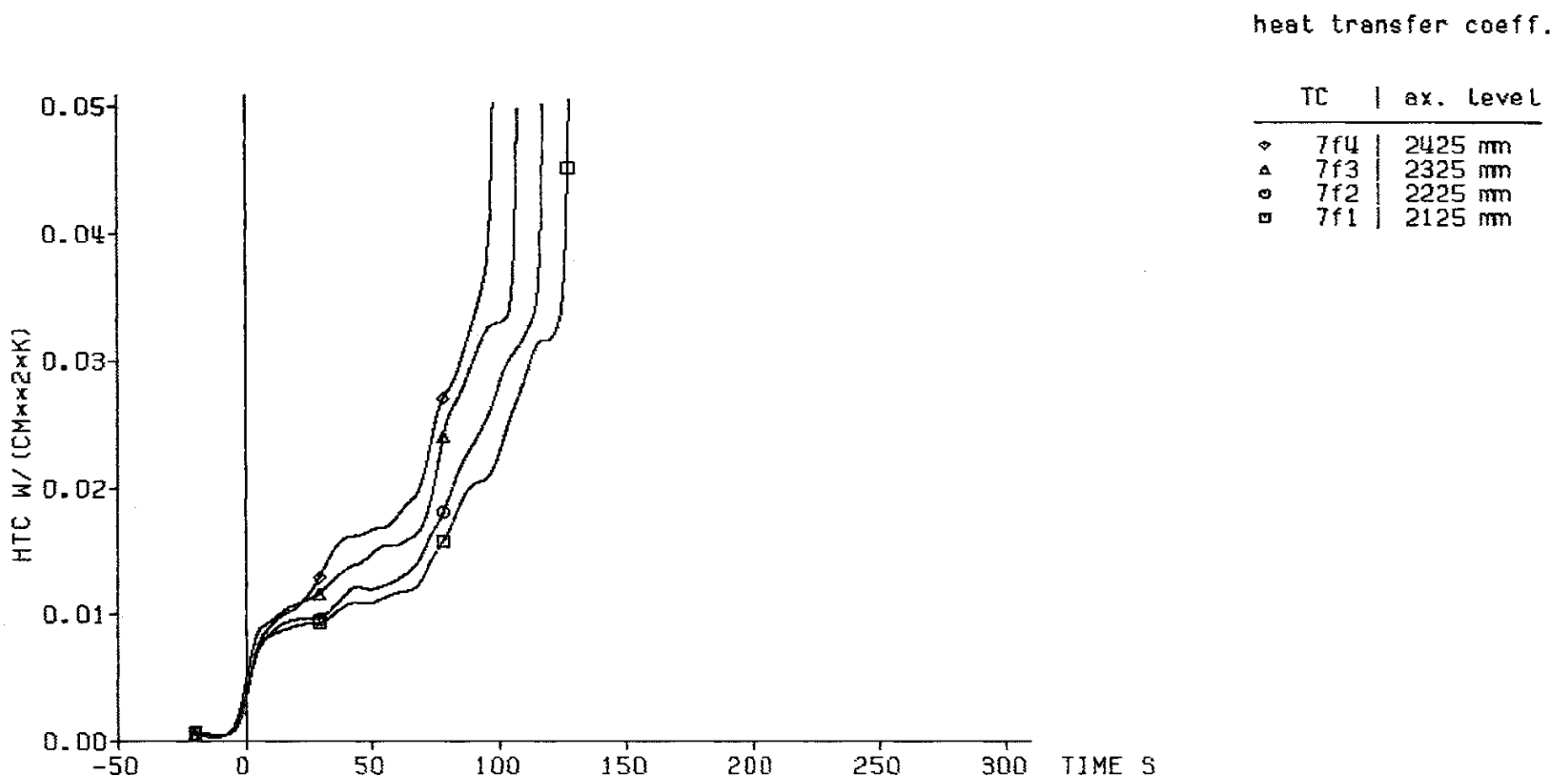
Fig. 90 FEBA: 5x5 ROD BUNDLE, TEST SERIES 1, TEST-No. 222



decay heat	120% ANS standard
flooding rate (cold)	5.78 cm/s
system pressure	6.18 bar
feedwater temperature	40 deg C

KfK IRB

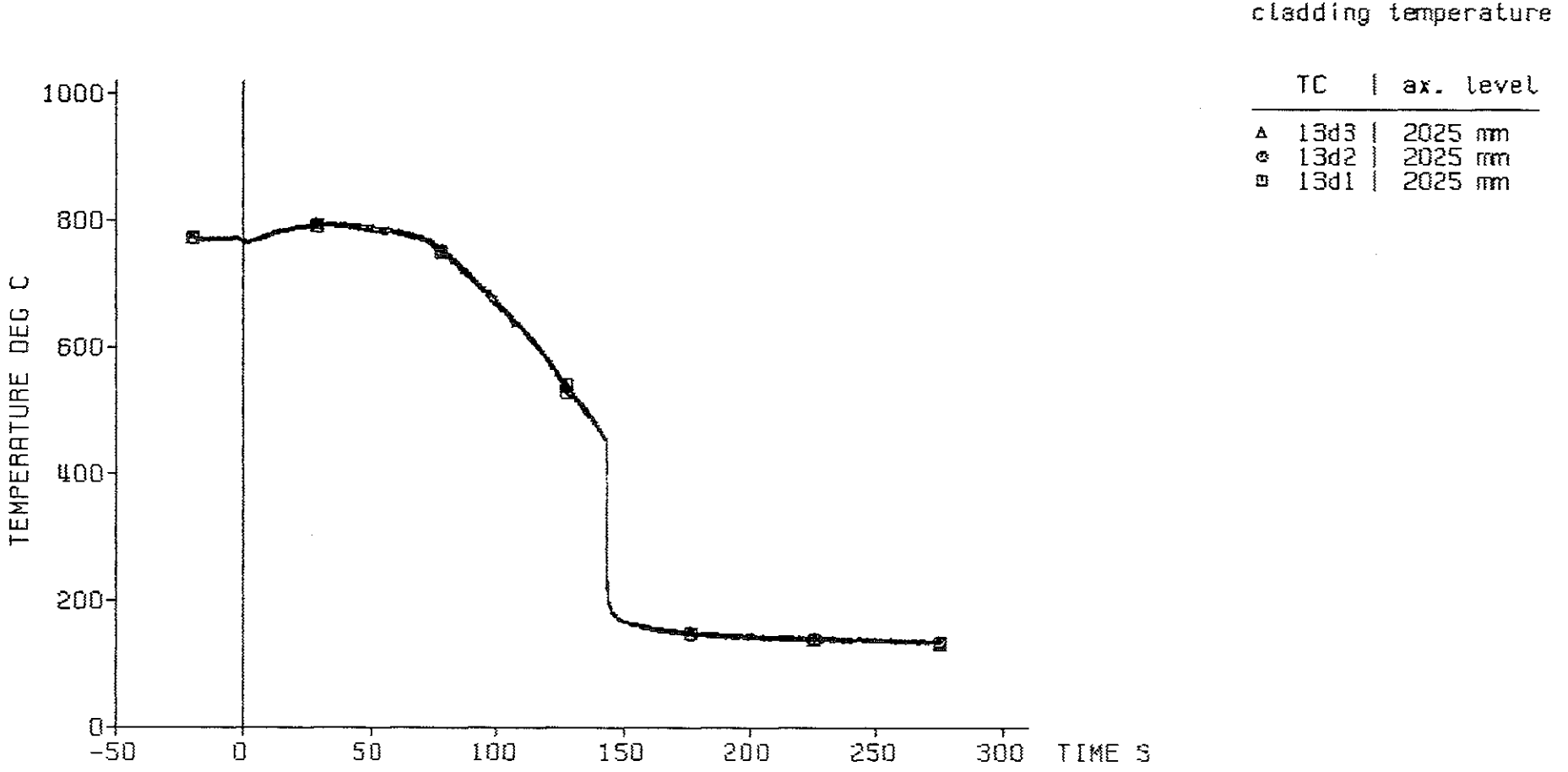
Fig. 91 FEBA: 5x5 ROD BUNDLE, TEST SERIES 1, TEST-No. 222



decay heat	120% ANS standard
flooding rate (cold)	5.78 cm/s
system pressure	6.18 bar
feedwater temperature	40 deg C

KfK IRB

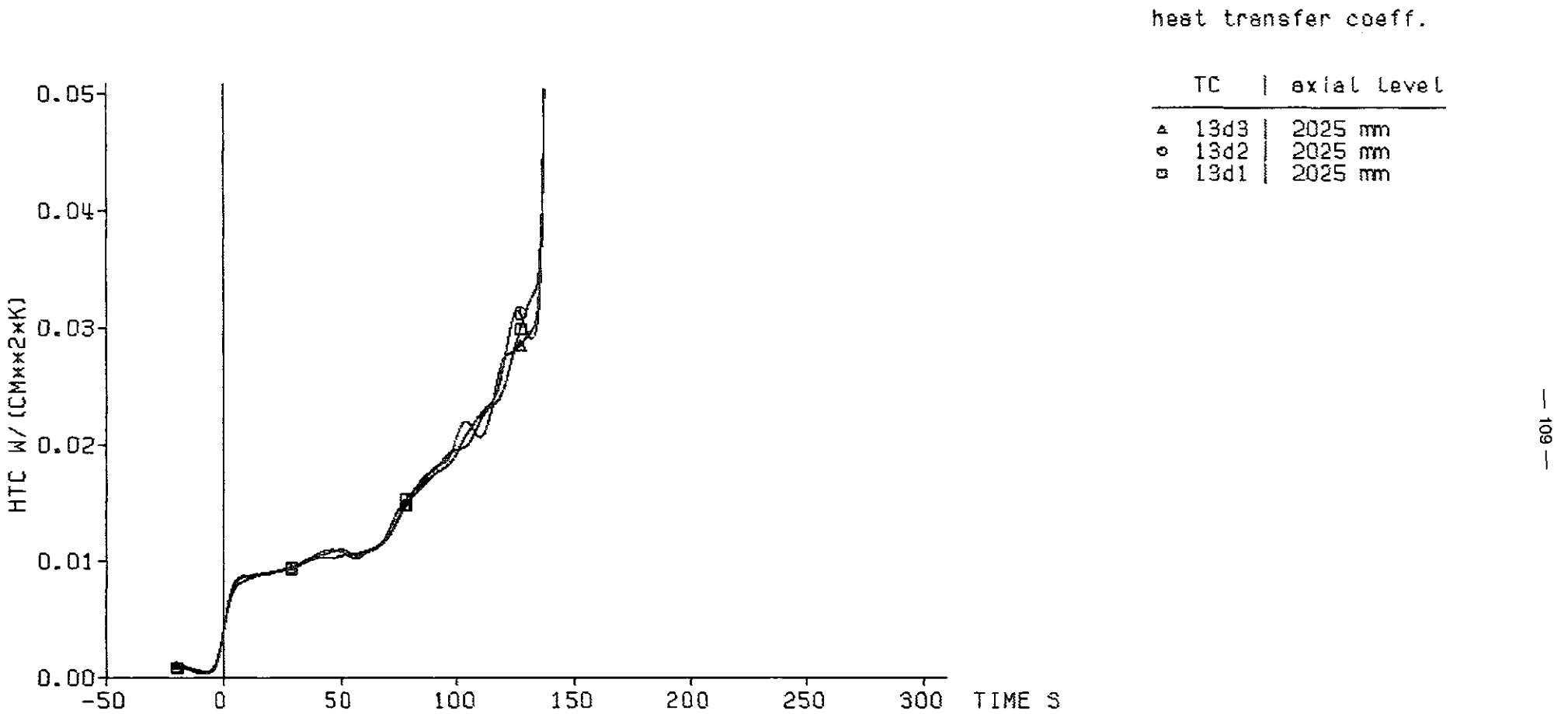
Fig. 92 FEBA: 5x5 ROD BUNDLE, TEST SERIES 1, TEST-No. 222



decay heat	120% ANS standard
flooding rate (cold)	5.78 cm/s
system pressure	6.18 bar
feedwater temperature	40 deg C

KfK KIRB

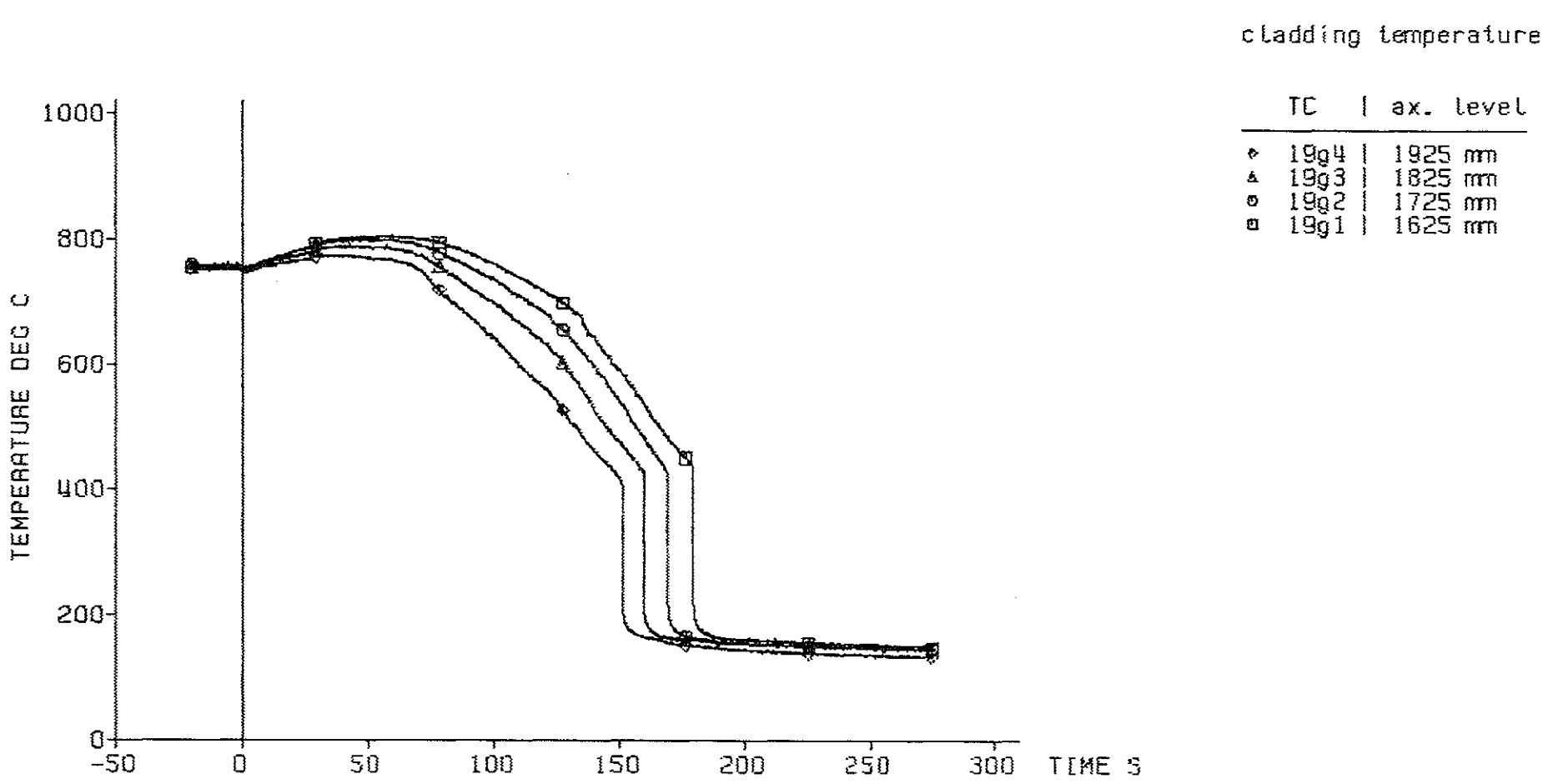
Fig. 93 FEBA: 5x5 ROD BUNDLE, TEST SERIES 1, TEST-No. 222



decay heat	120% ANS standard
flooding rate (cold)	5.78 cm/s
system pressure	6.18 bar
feedwater temperature	40 deg C

KfK IRB

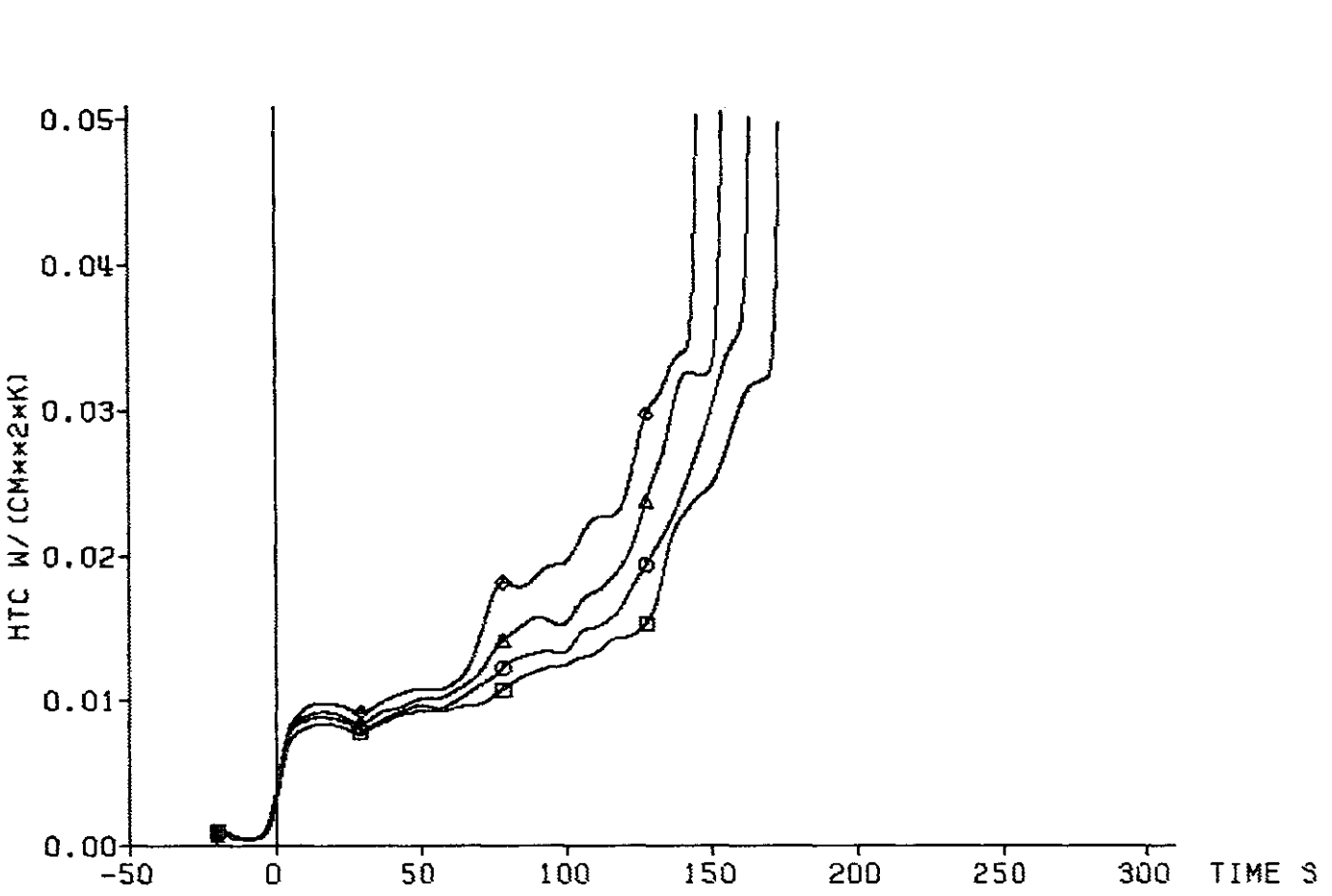
Fig. 94 FEBA: 5x5 ROD BUNDLE, TEST SERIES 1, TEST-No. 222



decay heat	120% ANS standard
flooding rate (cold)	5.78 cm/s
system pressure	6.18 bar
feedwater temperature	40 deg C

KfK KTRB

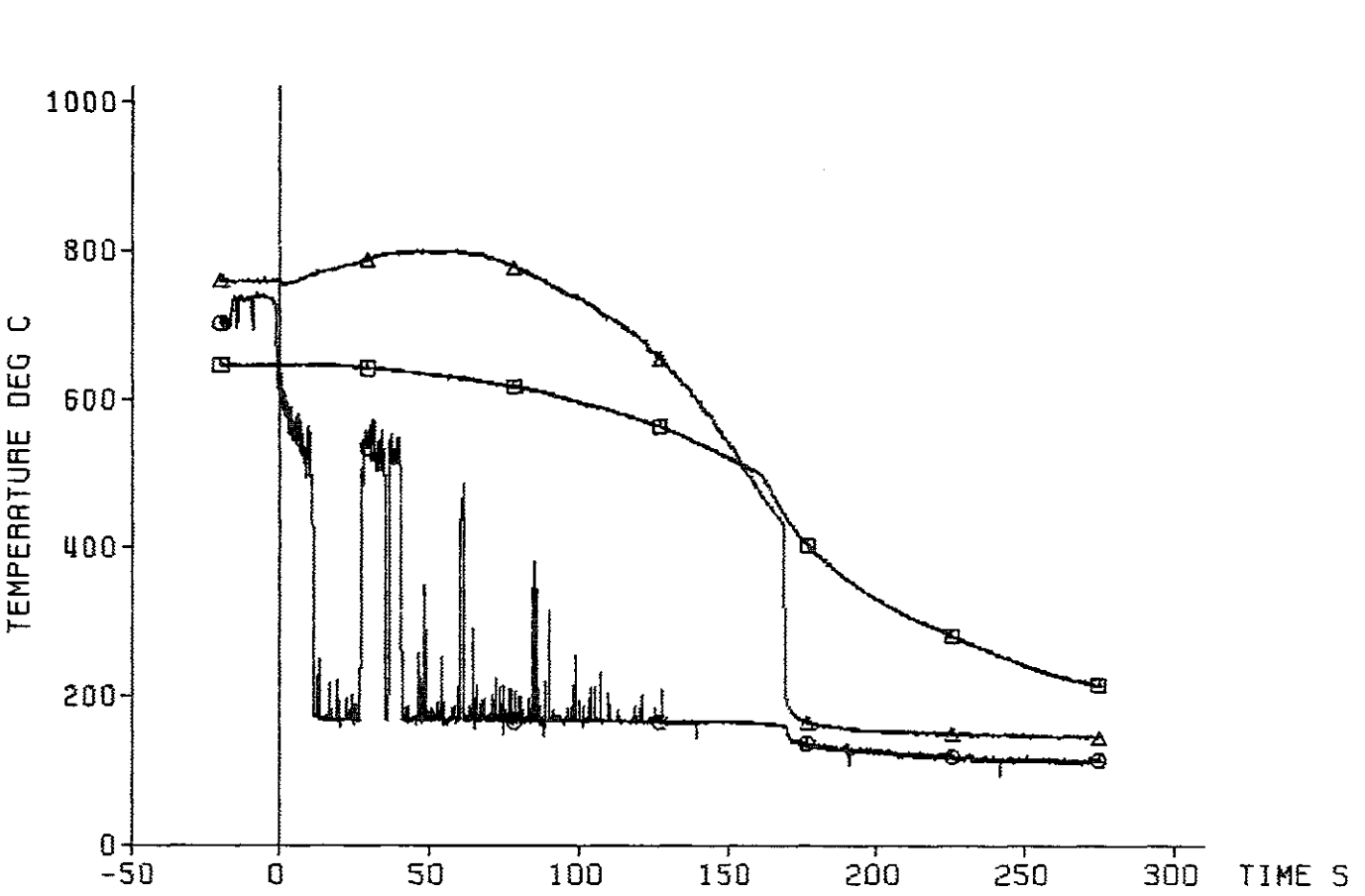
Fig. 95 FEBA: 5x5 ROD BUNDLE, TEST SERIES 1, TEST-No. 222



decay heat	120% ANS standard
flooding rate (cold)	5.78 cm/s
system pressure	6.18 bar
feedwater temperature	40 deg C

KfK IRB

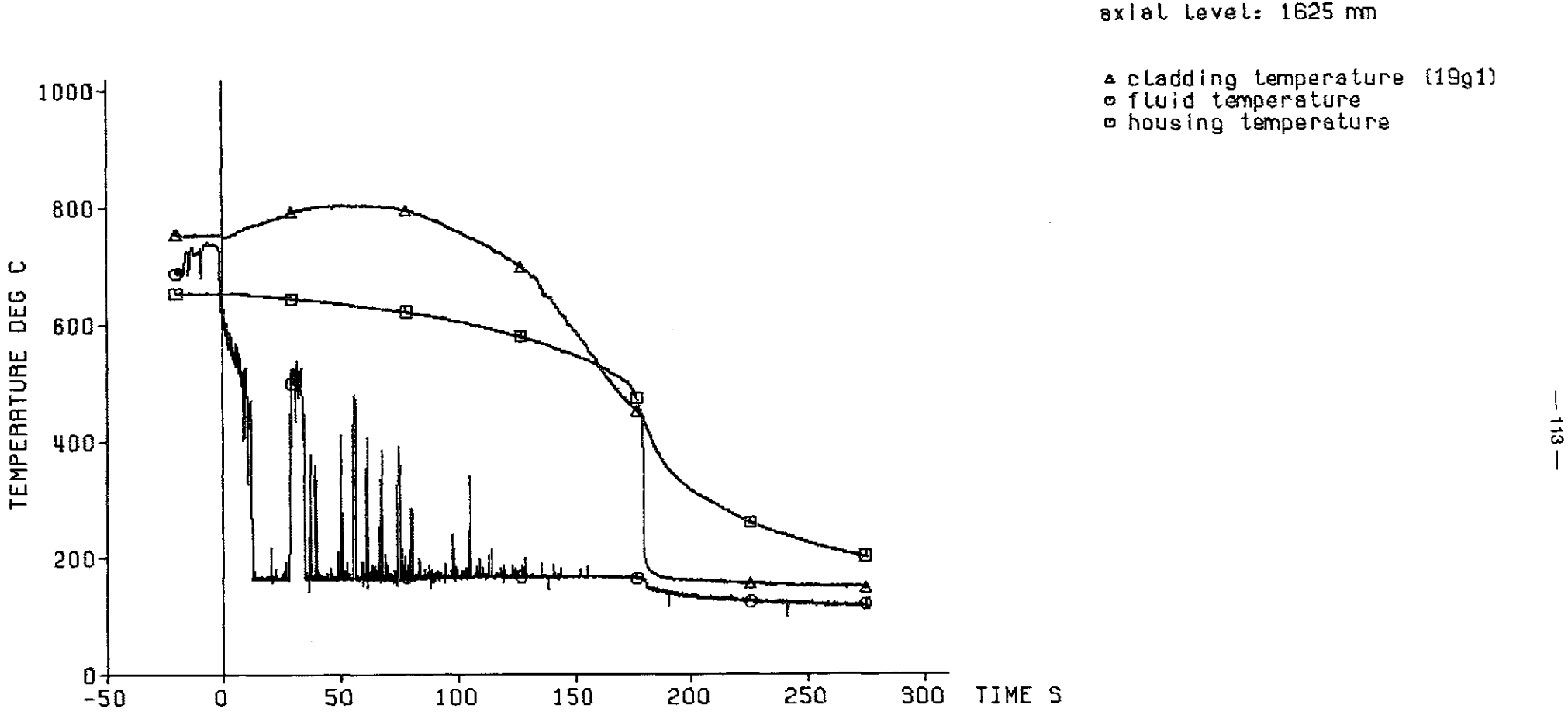
Fig. 96 FEBA: 5x5 ROD BUNDLE, TEST SERIES 1, TEST-No. 222



decay heat	120% ANS standard
flooding rate (cold)	5.78 cm/s
system pressure	6.18 bar
feedwater temperature	40 deg C

KfK KIRB

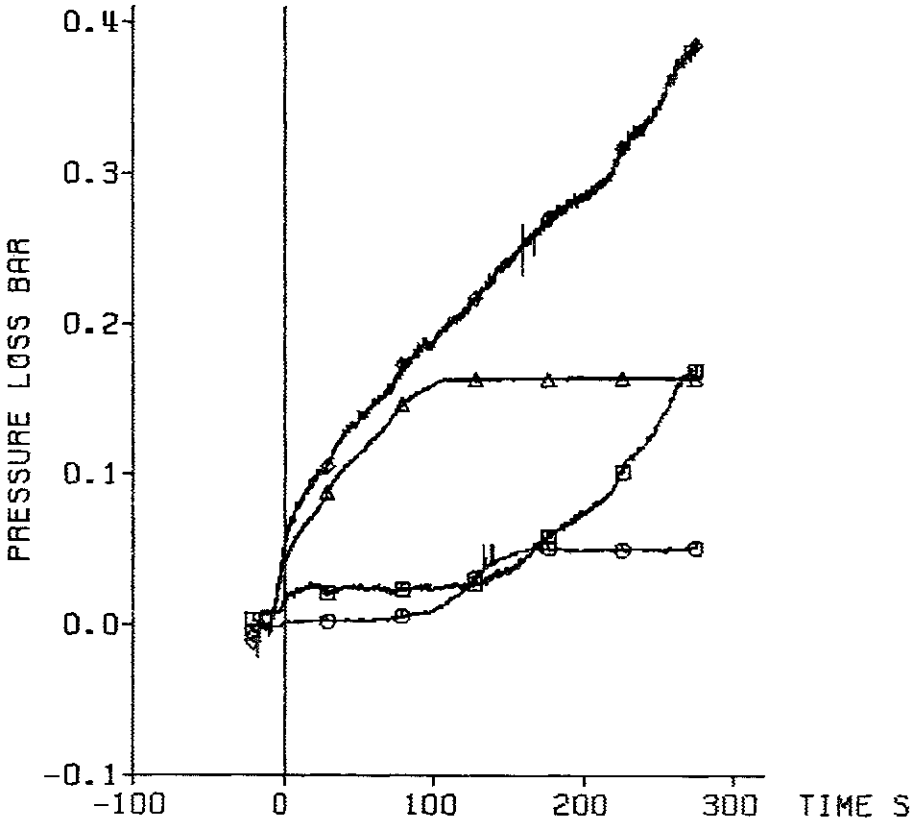
Fig. 97 FEBA: 5x5 ROD BUNDLE, TEST SERIES 1, TEST-No. 222



decay heat	120% ANS standard
flooding rate (cold)	5.78 cm/s
system pressure	6.18 bar
feedwater temperature	40 deg C

KfK IRB

Fig. 98 FEBA: 5x5 ROD BUNDLE, TEST SERIES 1, TEST-No. 222



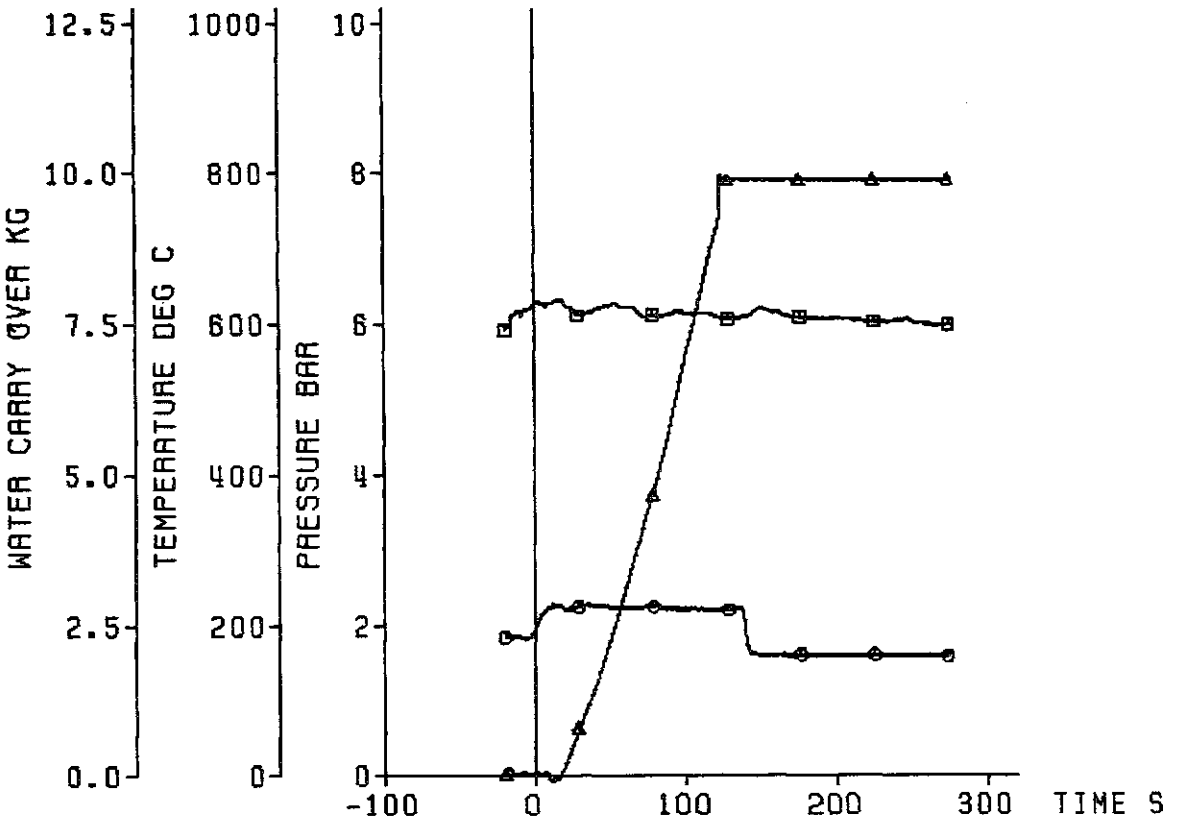
pressure loss
along the test section:

◇ total length: 4196 mm
△ lower part: 1711 mm
○ middle part: 545 mm
□ upper part: 1940 mm

decay heat	120% ANS standard
flooding rate (cold)	5.78 cm/s
system pressure	6.18 bar
feedwater temperature	40 deg C

KfK IRB

Fig. 99 FEBA: 5x5 RØD BUNDLE, TEST SERIES 1, TEST-No. 222

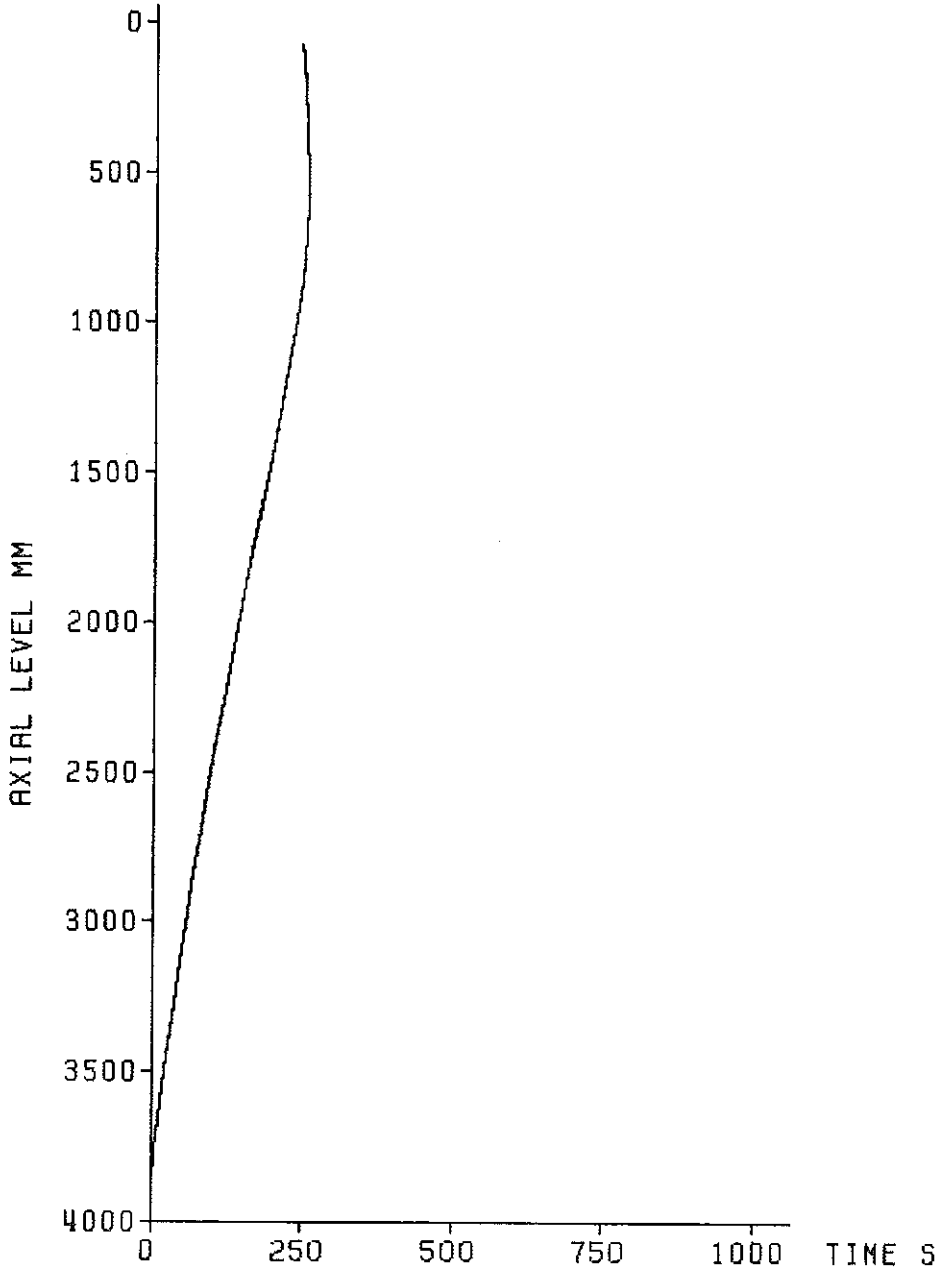


decay heat	120% ANS standard
flooding rate (cold)	5.78 cm/s
system pressure	6.18 bar
feedwater temperature	40 deg C

KfK IRB

Fig.100 FEBA: 5x5 ROD BUNDLE, TEST SERIES 1, TEST-No. 222

axial position of the quench front



decay heat	120% ANS standard
flooding rate (cold)	5.78 cm/s
system pressure	6.18 bar
feedwater temperature	40 deg C

KfK IRB

Fig. 101 FEBA: 5x5 ROD BUNDLE TEST SERIES 1, TEST-No. 222

TEST SERIES I

Base Line Tests With Undisturbed Bundle Geometry,
7 Grid Spacers

Channel Listing and Data Identification for Test No. 210 Through 227

Channel No.	Data Identification Type	Location	Unit	Remarks
1	Cladding Temperature	18a4.3860[1]	°C	
2	Cladding Temperature	18a3.3315	°C	
3	Cladding Temperature	18a2.2770	°C	
4	Cladding Temperature	18a1.2225	°C	
5	Cladding Temperature	12b4.1680	°C	
6	Cladding Temperature	12b3.1135	°C	
7	Cladding Temperature	12b2. 590	°C	
8	Cladding Temperature	12b1. 45	°C	
9	Cladding Temperature	17h4.2225	°C	
10	Cladding Temperature	17h3.2125	°C	
11	Cladding Temperature	17h2.2025	°C	
12	Cladding Temperature	17h1.1925	°C	
13	Fluid Temperature	TF[2] 3315	°C	
14	Fluid Temperature	TFS[3] 2380	°C	
15	Fluid Temperature	TF 1725	°C	
16	Fluid Temperature	TFS 485	°C	TC of 0.5 mm Diameter
17	Housing Temperature	TK[4] 3315	°C	
18	Housing Temperature	TK 2235	°C	
19	Housing Temperature	TK 1725	°C	
20	Housing Temperature	TK 590	°C	

TEST SERIES I

Channel No.	Data Identification Type	Location	Unit	Remarks
21	Fluid Temperature	Lower Plenum	°C	
22	Water Level Detector	4012	°C	Heated + Unheated TC's
23	Feedwater Temperature		°C	
24	Fluid Temperature	Upper Plenum	°C	
25	Room Temperature		°C	
26	Cladding Temperature	22f4.2425[1]	°C	
27	Cladding Temperature	22f3.2325	°C	
28	Cladding Temperature	22f2.2225	°C	
29	Cladding Temperature	22f1.2125	°C	
30	Cladding Temperature	21e4.2225	°C	
31	Cladding Temperature	21e3.2175	°C	
32	Cladding Temperature	21e2.2125	°C	
33	Cladding Temperature	21e1.2075	°C	
34	Cladding Temperature	19g4.1925	°C	
35	Cladding Temperature	19g3.1825	°C	
36	Cladding Temperature	19g2.1725	°C	
37	Cladding Temperature	19g1.1625	°C	
38	Cladding Temperature	16g4.1925	°C	
39	Cladding Temperature	16g3.1825	°C	TC Failed
40	Cladding Temperature	16g2.1725	°C	
41	Cladding Temperature	16g1.1625	°C	
42	Cladding Temperature	15a4.3860	°C	
43	Cladding Temperature	15a3.3315	°C	
44	Cladding Temperature	15a2.2770	°C	
45	Cladding Temperature	15a1.2225	°C	
46	Cladding Temperature	14e4.2225	°C	
47	Cladding Temperature	14e3.2175	°C	
48	Cladding Temperature	14e2.2125	°C	
49	Cladding Temperature	14e1.2075	°C	

TEST SERIES I

Channel No.	Data Identification Type	Location	Unit	Remarks
50	Cladding Temperature	13d3.2025[1]	°C	
51	Cladding Temperature	13d2.2025	°C	
52	Cladding Temperature	13d1.2025	°C	
53	Cladding Temperature	10f4.2425	°C	
54	Cladding Temperature	10f3.2325	°C	
55	Cladding Temperature	10f2.2225	°C	
56	Cladding Temperature	10f1.2125	°C	
57	Cladding Temperature	9h4.2225	°C	
58	Cladding Temperature	9h3.2125	°C	
59	Cladding Temperature	9h2.2025	°C	
60	Cladding Temperature	9h1.1925	°C	
61	Cladding Temperature	8d4.2025	°C	
62	Cladding Temperature	8d3.2025	°C	
63	Cladding Temperature	8d2.2025	°C	
64	Cladding Temperature	8d1.2025	°C	
65	Cladding Temperature	7f4.2425	°C	
66	Cladding Temperature	7f3.2325	°C	
67	Cladding Temperature	7f2.2225	°C	
68	Cladding Temperature	7f1.2125	°C	
69	Cladding Temperature	4g4.1925	°C	
70	Cladding Temperature	4g3.1825	°C	
71	Cladding Temperature	4g2.1725	°C	
72	Cladding Temperature	4g1.1625	°C	
73	Cladding Temperature	3b4.1680	°C	
74	Cladding Temperature	3b3.1135	°C	
75	Cladding Temperature	3b2. 590	°C	
76	Cladding Temperature	3b1. 45	°C	TC Failed

TEST SERIES I

Channel No.	Data Identification Type	Location	Unit	Remarks
77	Cladding Temperature	2c4.4025[1]	°C	
78	Cladding Temperature	2c3.3925	°C	
79	Cladding Temperature	2c2.3825	°C	
80	Cladding Temperature	2c1.3725	°C	
81	Electrical Power Input	8 Rods	kW	Rods No. 1 Through 8
82	Electrical Power Input	8 Rods	kW	Rods No. 9 Through 16
83	Electrical Power Input	9 Rods	kW	Rods No. 17 Through 25
84	Housing Temperature TK[4]	4005	°C	
85	Housing Temperature TK	3915	°C	
86	Housing Temperature TK	3820	°C	
87	Housing Temperature TK	3725	°C	
88	Housing Temperature TK	3018	°C	
89	Housing Temperature TK	2770	°C	
90	Housing Temperature TK	2025	°C	
91	Housing Temperature TK	1925	°C	
92	Housing Temperature TK	1825	°C	
93	Housing Temperature TK	1625	°C	
94	Housing Temperature TK	1135	°C	
95	Housing Temperature TK	835	°C	
96	Housing Temperature TK	45	°C	
97	Fluid Temperature TF[2]	3038	°C	TC Failed
98	Fluid Temperature TFS[3]	2425	°C	
99	Fluid Temperature TF	2770	°C	
100	Fluid Temperature TFS	2325	°C	
101	Fluid Temperature TFS	2125	°C	
102	Fluid Temperature TF	2025	°C	TC Failed
103	Fluid Temperature TFS	1925	°C	
104	Fluid Temperature TF	1135	°C	
105	Fluid Temperature TF	1625	°C	
106	----------		-	Open

TEST SERIES I

Channel No.	Data Identification Type	Location	Unit	Remarks
107	Cladding Temperature	24c4.4025[1]	°C	
108	Cladding Temperature	24c2.3925	°C	
109	Cladding Temperature	24c1.3825	°C	
110	Time (10 Scans/s)		s	t = 0: Start of Reflooding
111	Pressure in Lower Plenum	4091	bar	
112	Pressure in Upper Plenum	-105	bar	
113	Pressure in Buffer		bar	
114	Bundle Power		kW	Channels: 81 + 82 + 83
115	Flooding Velocity (cold)		cm/s	
116	Water Carry Over Collected		kg	Downstream of Bundle Exit
117	Pressure Diff.	1835 and -105 mm	bar	
118	Measured	2380 and 1835 mm	bar	
119	Between	4091 and 2380 mm	bar	
120	Axial Level	4091 and -105 mm	bar	Values Measured Separately

1) TC's of 0.5 mm diameter embedded in rod cladding. Measuring position: Example: rod No. = 18, type of rod instrumention = a, TC No. = 4, axial level = 3860 mm, referenced to the top flange of the bundle.

2) TF = TC's of 0.25 mm diameter (bare).
TC's placed in subchannel surrounded by rods No. 12, 17, 16 and 11.

3) TFS = TC's of 0.25 mm diameter protected by a radiation shielding.
TC's placed in subchannel surrounded by rods No. 12, 17, 16 and 11.

4) TK = TC's of 0.5 mm diameter placed in the wall of the bundle housing of of 6.5 mm thickness.

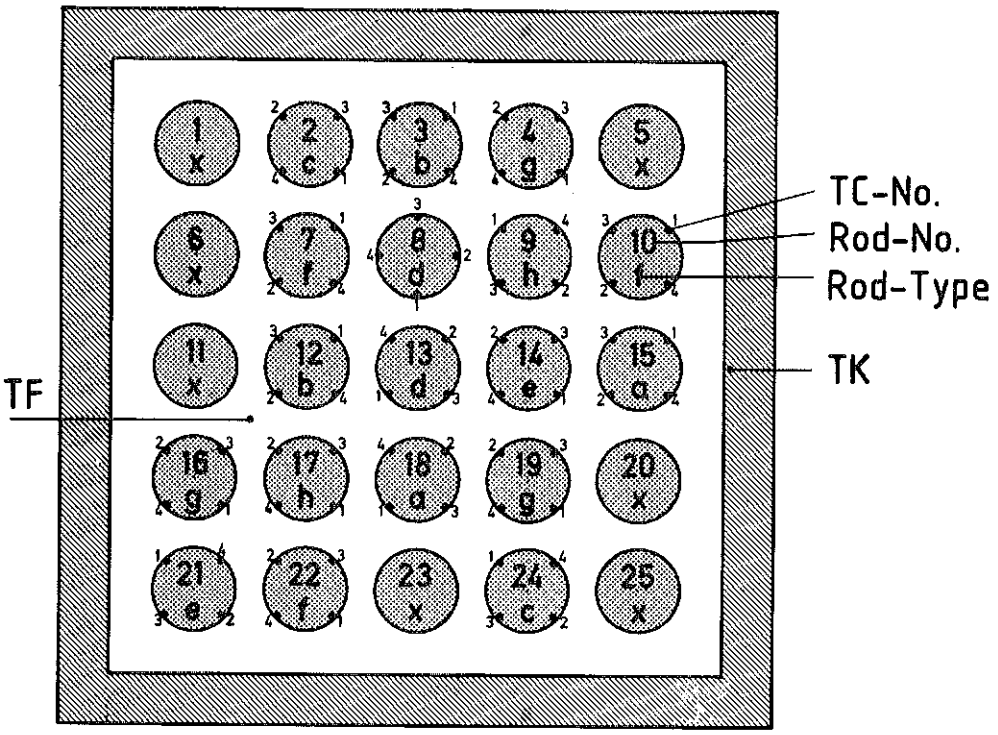
TEST SERIES II

Investigation of the Effects of a Grid Spacer,
Without Grid Spacer at the Bundle Midplane

Test No.	Flooding Velocity (cold) cm/s	System Pressure bar	Feedwater Temp.[1] °C 0-30 s	Feedwater Temp.[1] °C End	Bundle Power[2] kW 0 s	Bundle Power[2] kW Transient	Remarks
234	3.8	2.0	46	37	200	120% ANS	Figs. 104 Through 118
229	3.8	4.1	53	38	200	120% ANS	Figs. 119 Through 133
231	3.8	6.2	54	40	200	120% ANS	Figs. 134 Through 148
233	5.8	2.0	47	37	200	120% ANS	Figs. 149 Through 163
228	5.7	4.1	50	37	200	120% ANS	Figs. 164 Through 178
230	5.8	6.2	48	37	200	120% ANS	Figs. 179 Through 193

1) Measured in the lower plenum
2) Decay heat transient corresponding 120% ANS Standard 40 s after shutdown of the reactor

Table 2 FEBA 5x5 rod bundle: Main test parameters of test series II



Rod Type	TC No.	Axial Level mm
a	1	2225
	2	2770
	3	3315
	4	3860
b	1	45
	2	590
	3	1135
	4	1680
c	1	3725
	2	3825
	3	3925
	4	4025
d	1	2025
	2	2025
	3	2025
	4	2025

Rod Type	TC No.	Axial Level mm
e	1	2075
	2	2125
	3	2175
	4	2225
f	1	2125
	2	2225
	3	2325
	4	2425
g	1	1625
	2	1725
	3	1825
	4	1925
h	1	1925
	2	2025
	3	2125
	4	2225

Rod Type	TC No.	Axial Level mm
x	without TC's	

Fig. 102 5x5 rod bundle: Radial and axial location of cladding, fluid and housing TC's for test series II

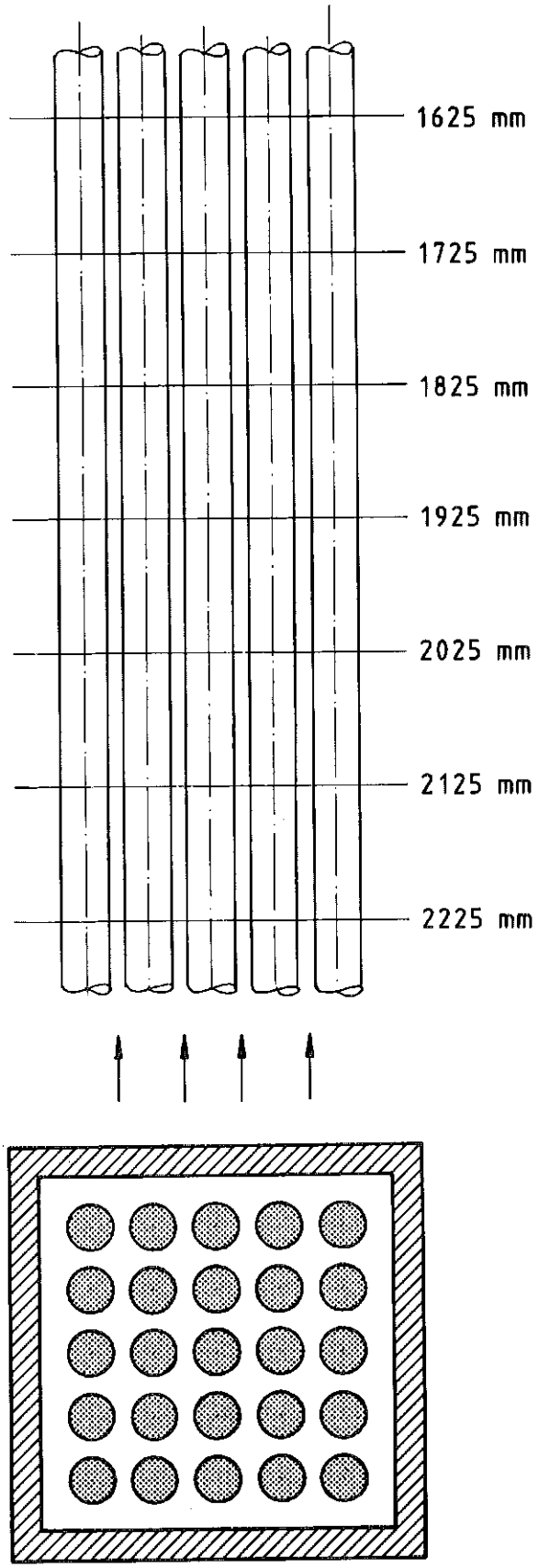
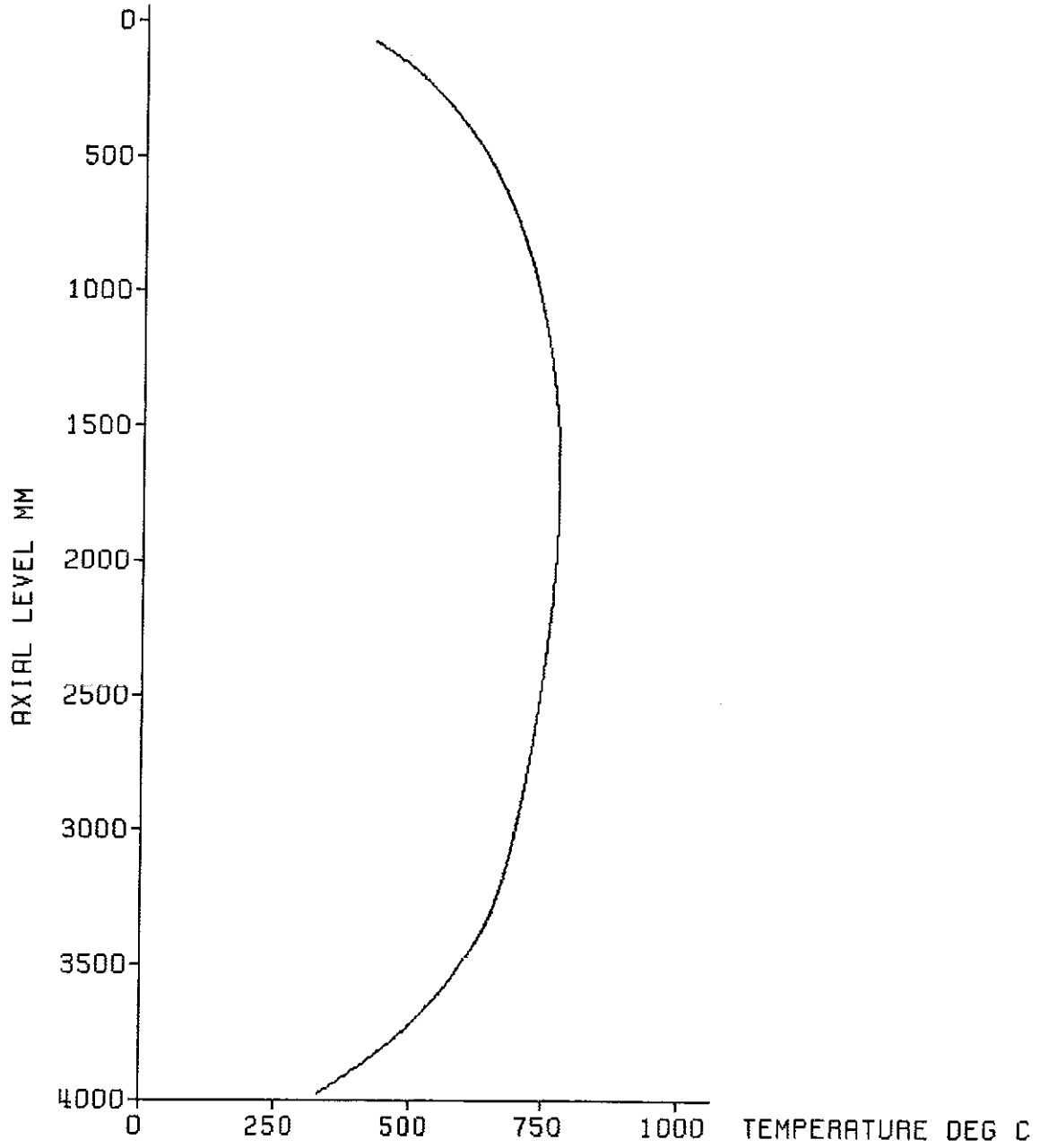


Fig. 103 5x5 rod bundle: Layout of the bundle geometry of test series II

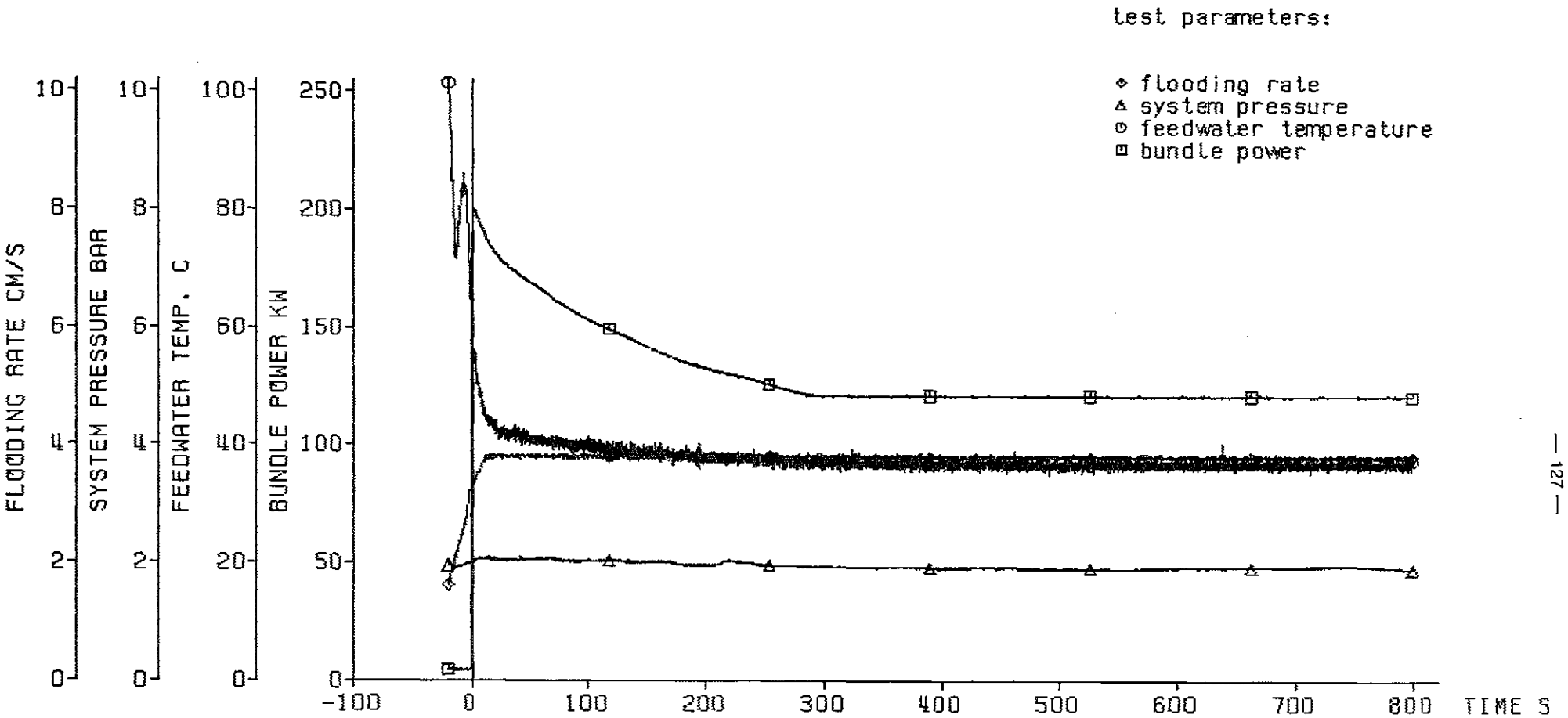
initial axial temperature profile of the cladding



decay heat	120% ANS standard
flooding rate (cold)	3.80 cm/s
system pressure	2.02 bar
feedwater temperature	40 deg C

KfK IRB

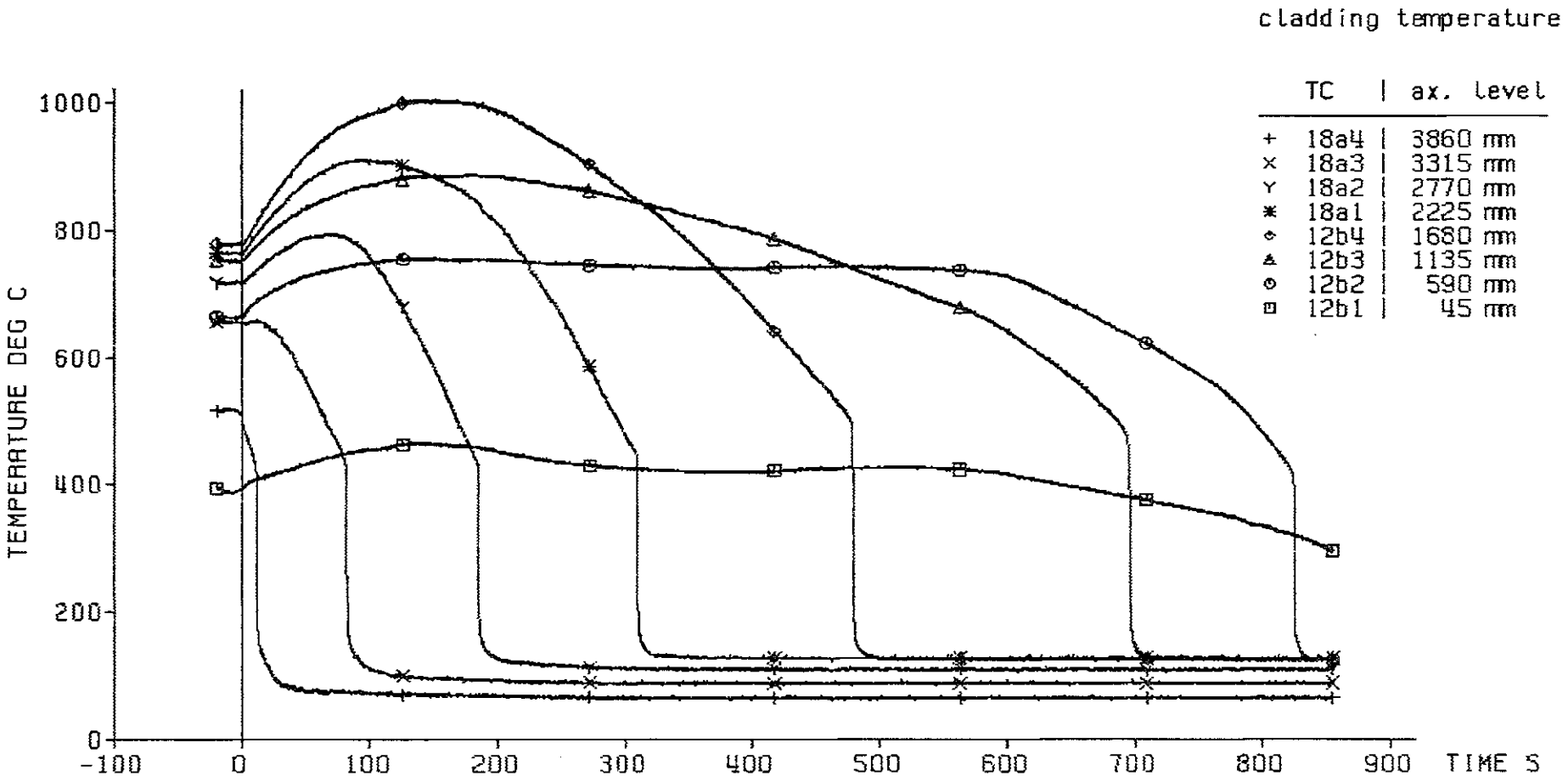
Fig. 104 FEBA: 5x5 ROD BUNDLE TEST SERIES 2, TEST-No. 234



decay heat	120% ANS standard
flooding rate (cold)	3.80 cm/s
system pressure	2.02 bar
feedwater temperature	40 deg C

KfK KIRB

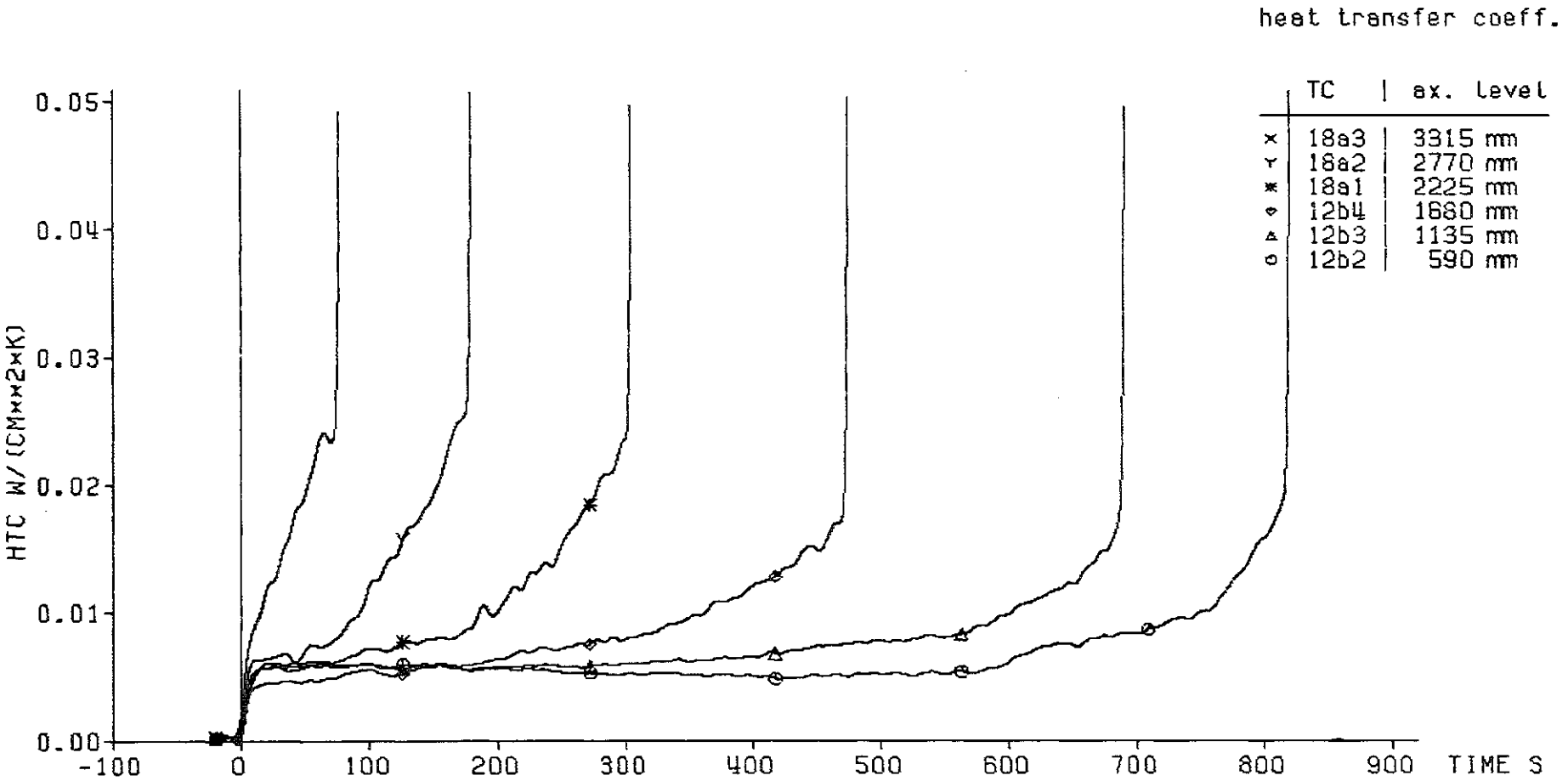
Fig. 105 FEBA: 5x5 ROD BUNDLE, TEST SERIES 2, TEST-No. 234



decay heat	120% ANS standard
flooding rate (cold)	3.80 cm/s
system pressure	2.02 bar
feedwater temperature	40 deg C

KfK IRB

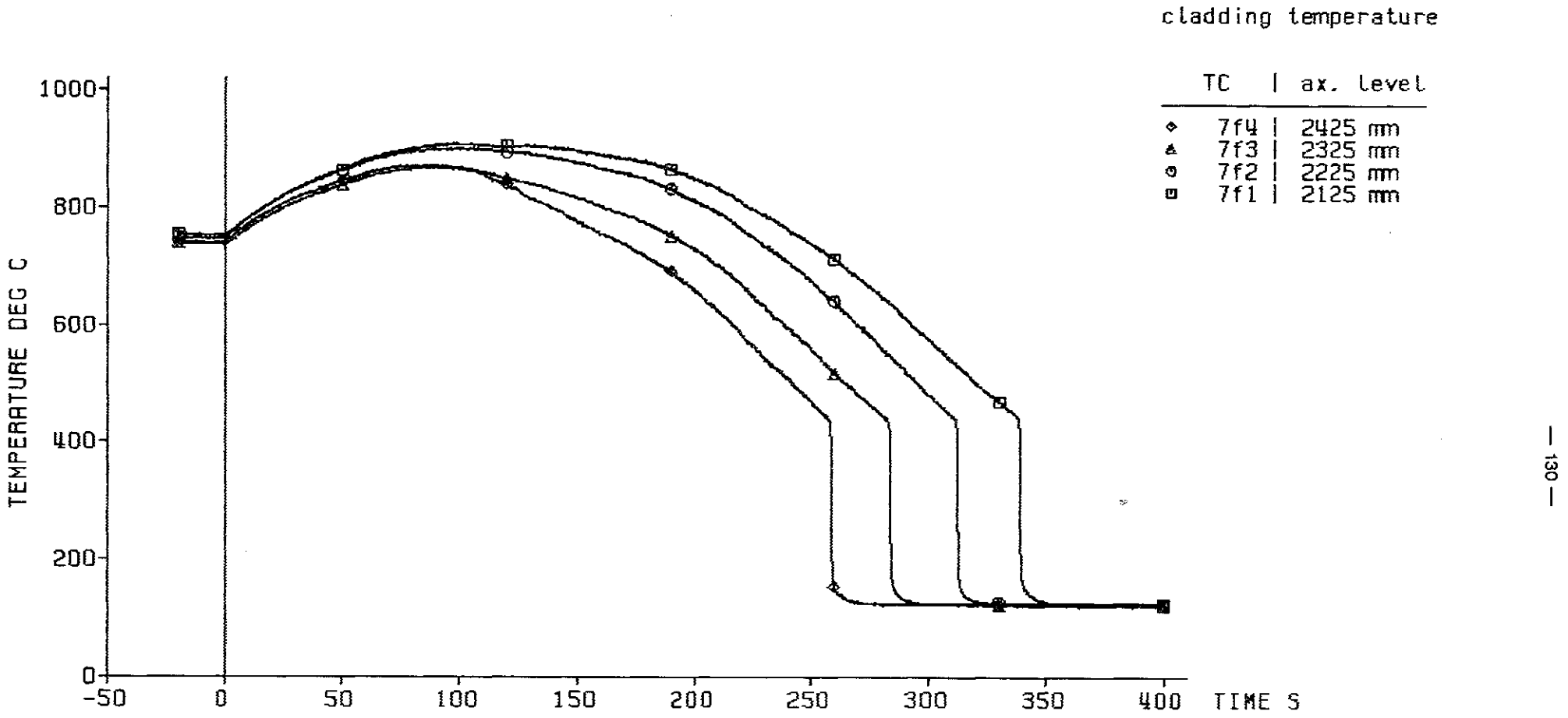
Fig. 106 FEBA: 5x5 ROD BUNDLE, TEST SERIES 2, TEST-No. 234



decay heat	120% ANS standard
flooding rate (cold)	3.80 cm/s
system pressure	2.02 bar
feedwater temperature	40 deg C

KfK IRB

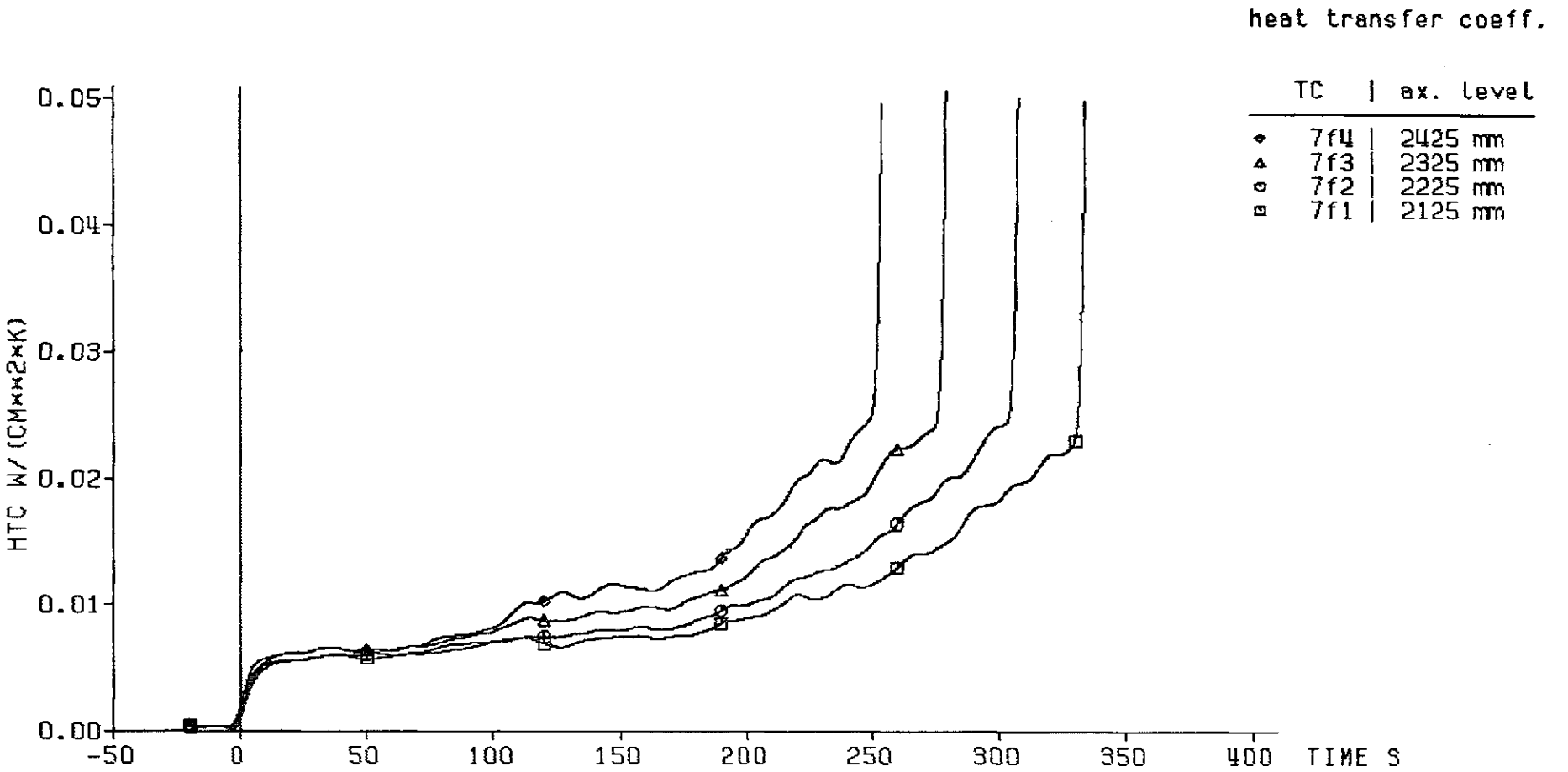
Fig.107 FEBA: 5x5 ROD BUNDLE, TEST SERIES 2, TEST-No. 234



decay heat	120% ANS standard
flooding rate (cold)	3.80 cm/s
system pressure	2.02 bar
feedwater temperature	40 deg C

KfK IRB

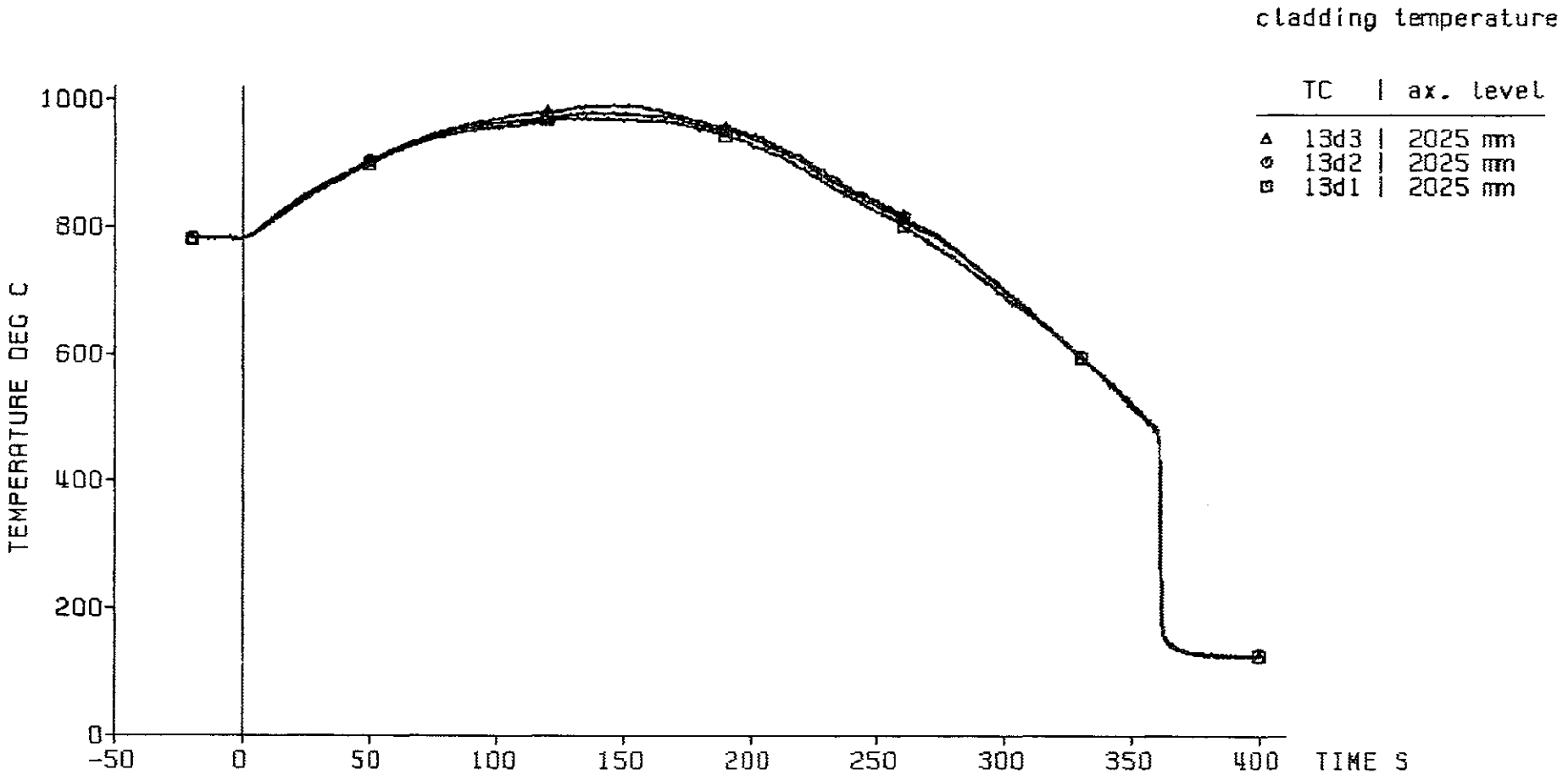
Fig. 108 FEBA: 5x5 ROD BUNDLE, TEST SERIES 2, TEST-No. 234



decay heat	120% ANS standard
flooding rate (cold)	3.80 cm/s
system pressure	2.02 bar
feedwater temperature	40 deg C

KfK IRB

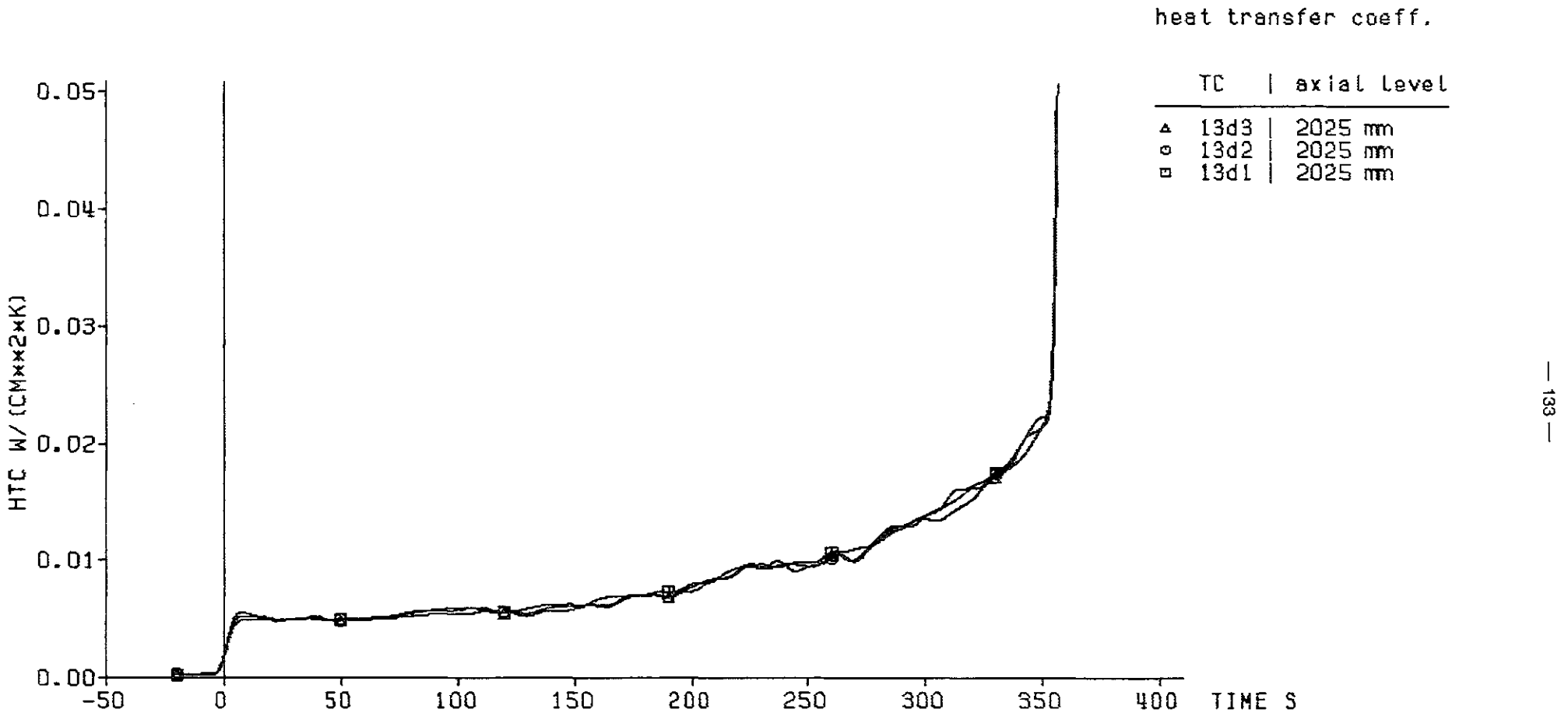
Fig. 109 FEBA: 5x5 ROD BUNDLE, TEST SERIES 2, TEST-No. 234



decay heat	120% ANS standard
flooding rate (cold)	3.80 cm/s
system pressure	2.02 bar
feedwater temperature	40 deg C

KfK IRB

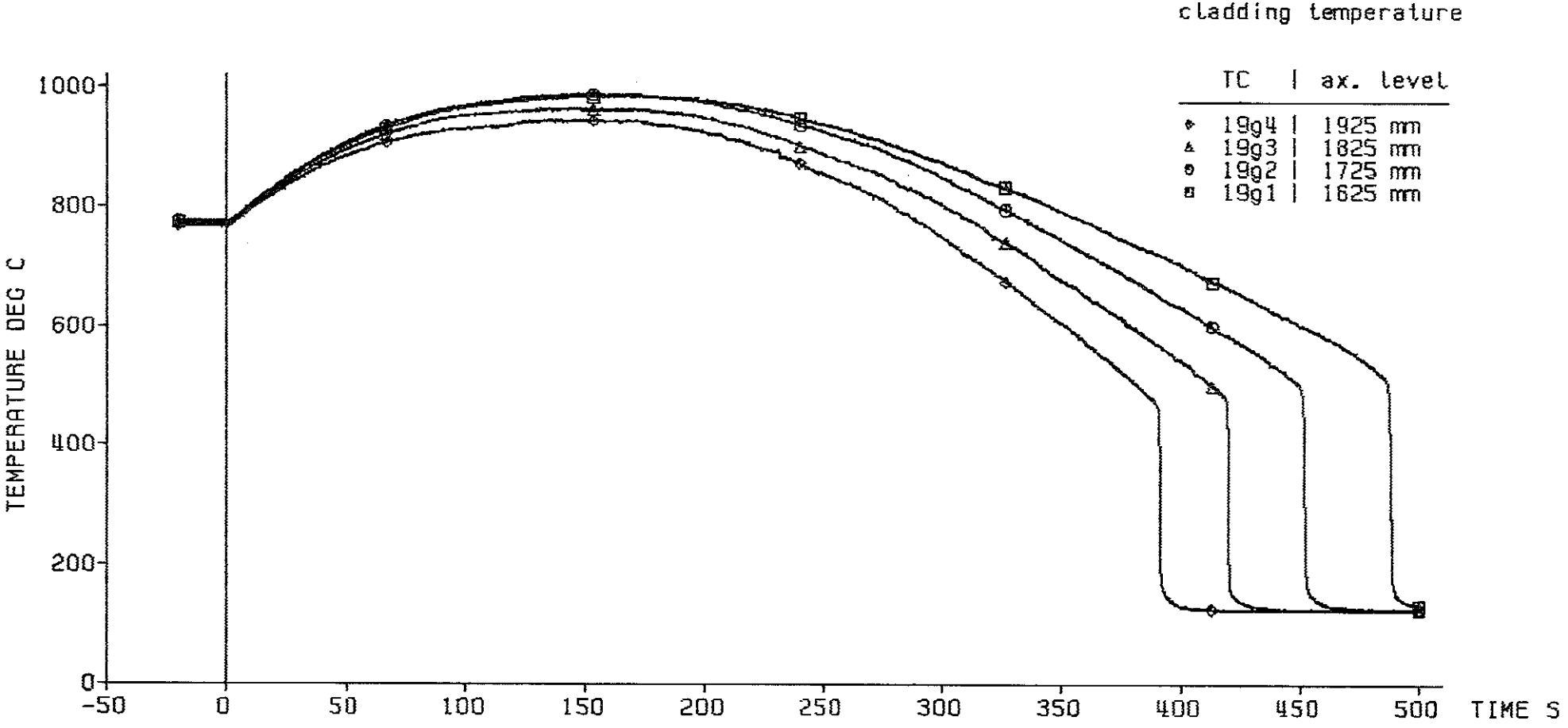
Fig. 110 FEBA: 5x5 ROD BUNDLE, TEST SERIES 2, TEST-No. 234



decay heat	120% ANS standard
flooding rate (cold)	3.80 cm/s
system pressure	2.02 bar
feedwater temperature	40 deg C

KfK IRB

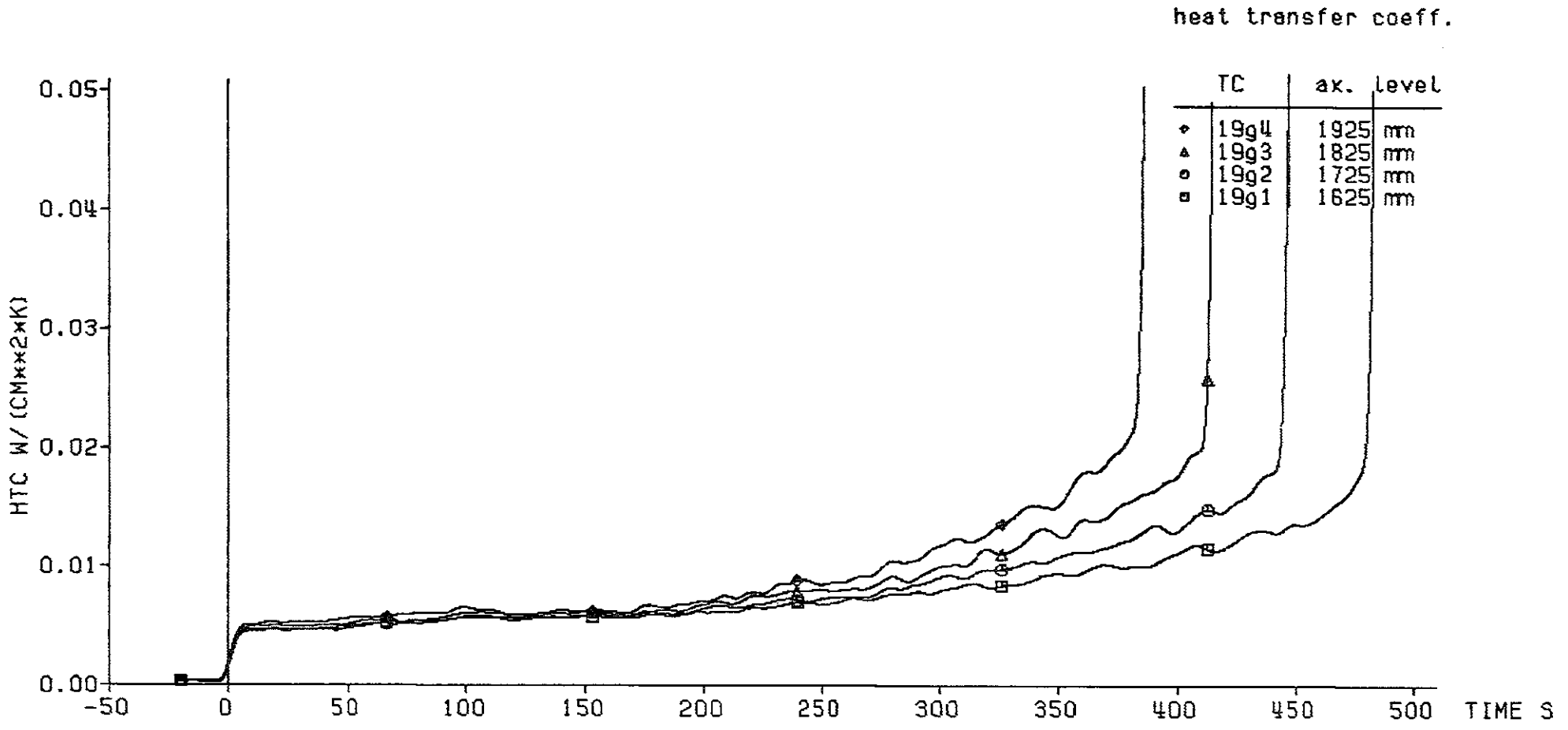
Fig. 111 FEBA: 5x5 ROD BUNDLE, TEST SERIES 2, TEST-No. 234



decay heat	120% ANS standard
flooding rate (cold)	3.80 cm/s
system pressure	2.02 bar
feedwater temperature	40 deg C

KfK IRB

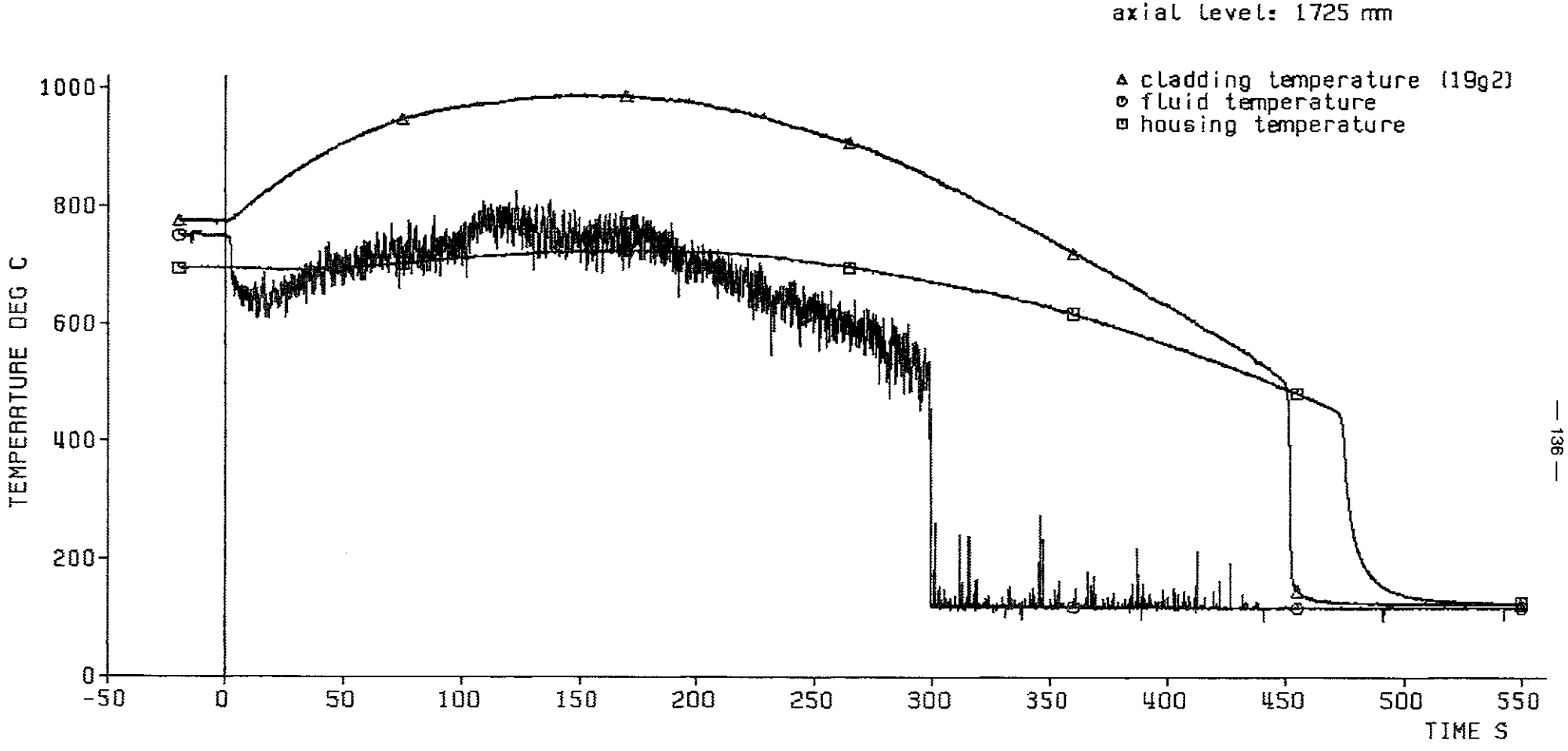
Fig. 112 FEBA: 5x5 ROD BUNDLE, TEST SERIES 2, TEST-No. 234



decay heat	120% ANS standard
flooding rate (cold)	3.80 cm/s
system pressure	2.02 bar
feedwater temperature	40 deg C

KfK IRB

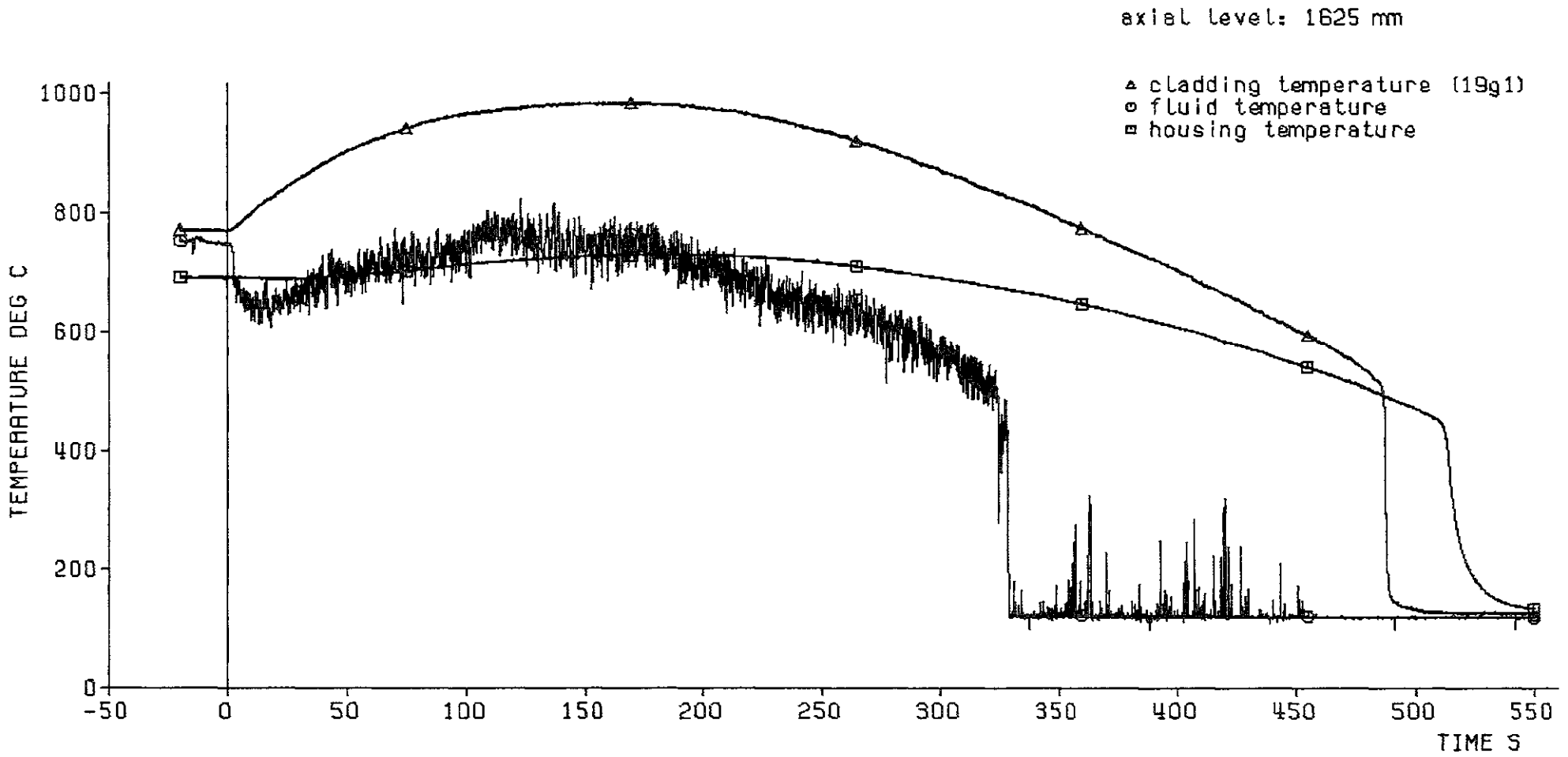
Fig. 113 FEBA: 5x5 ROD BUNDLE, TEST SERIES 2, TEST-No. 234



decay heat	120% ANS standard
flooding rate (cold)	3.80 cm/s
system pressure	2.02 bar
feedwater temperature	40 deg C

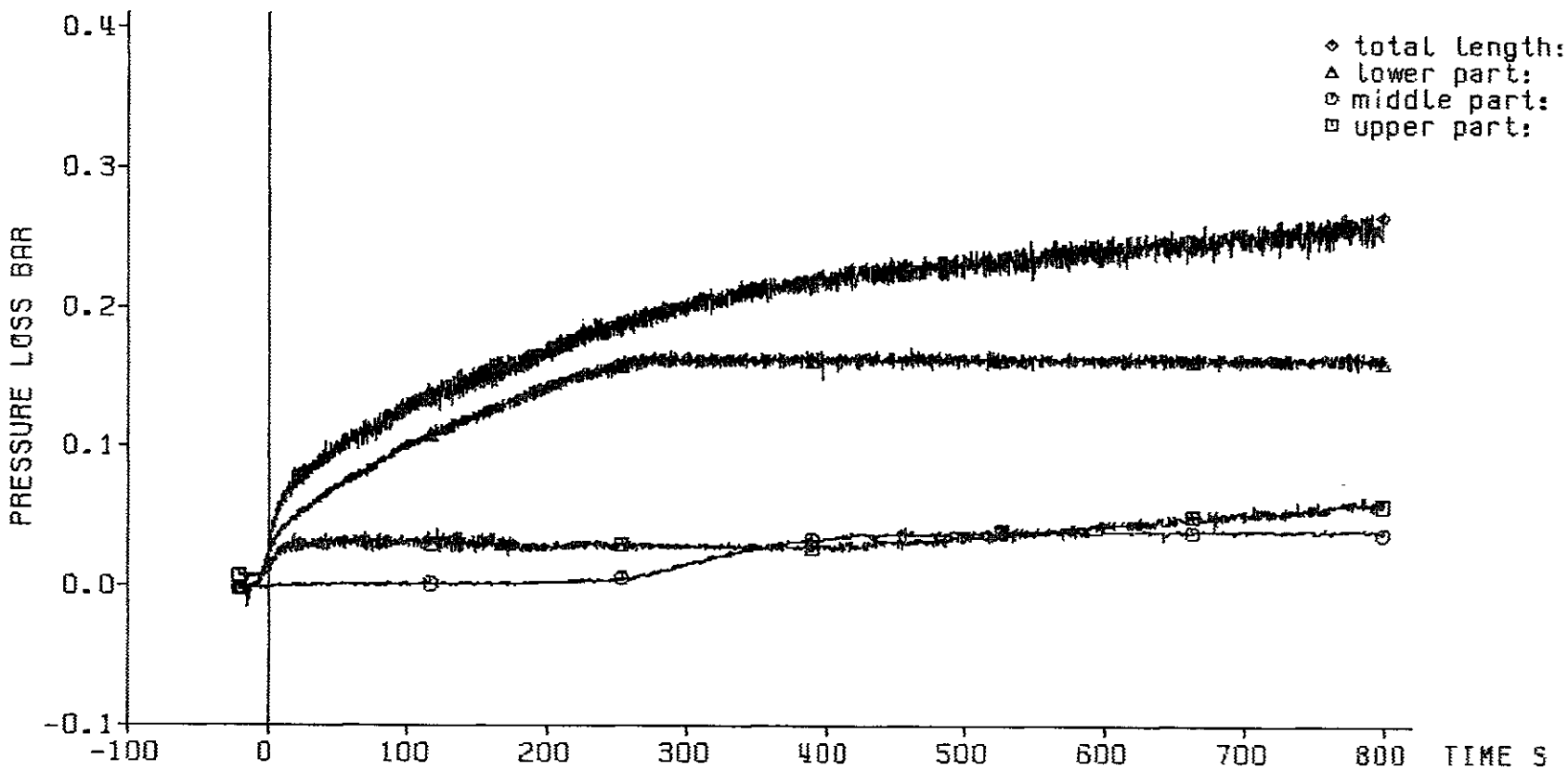
KfK IRB

Fig. 114 FEBA: 5x5 ROD BUNDLE, TEST SERIES 2, TEST-No. 234



decay heat	120% ANS standard
flooding rate (cold)	3.80 cm/s
system pressure	2.02 bar
feedwater temperature	40 deg C

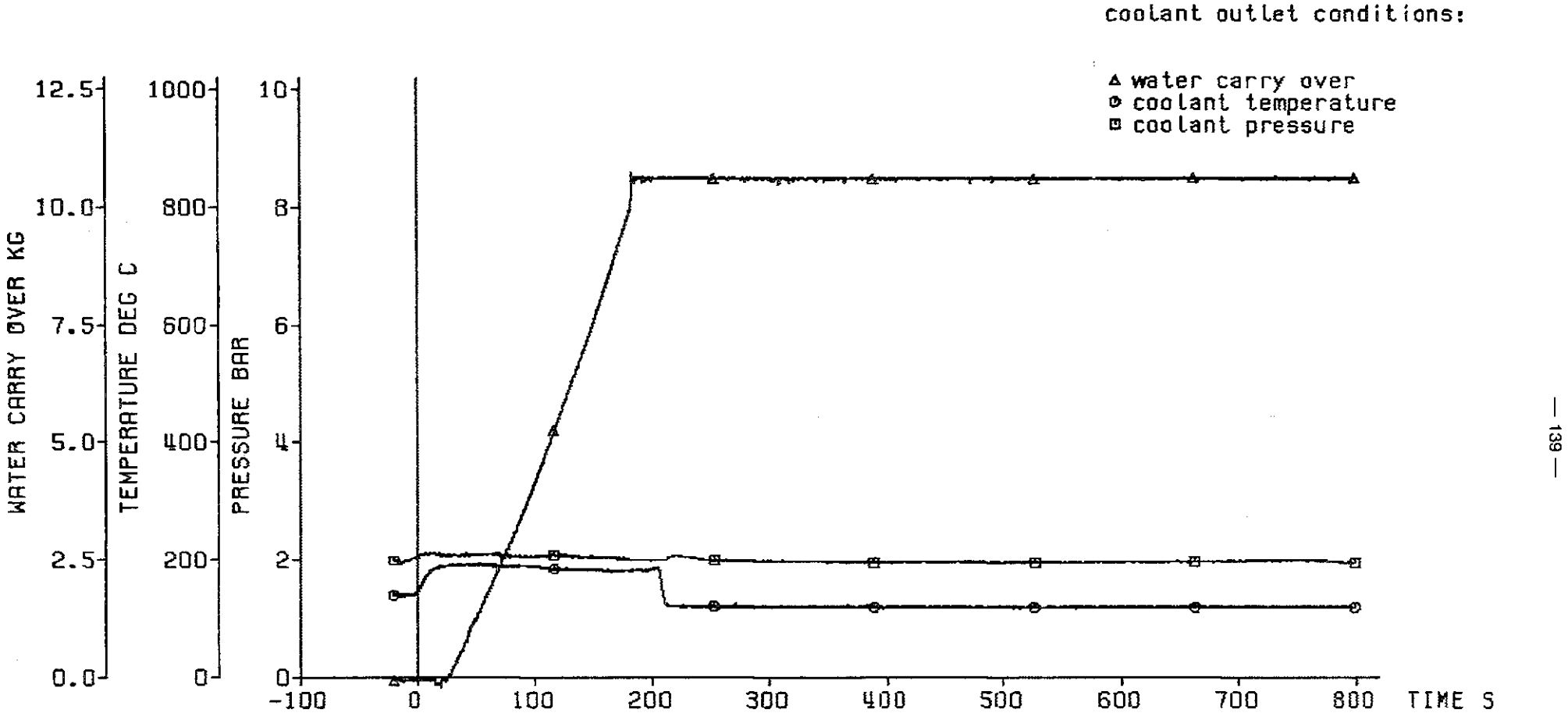
Fig.115 FEBA: 5x5 ROD BUNDLE, TEST SERIES 2, TEST-No. 234



decay heat	120% ANS standard
flooding rate (cold)	3.80 cm/s
system pressure	2.02 bar
feedwater temperature	40 deg C

KfK IRB

Fig. 116 FEBA: 5x5 ROD BUNDLE, TEST SERIES 2, TEST-No. 234

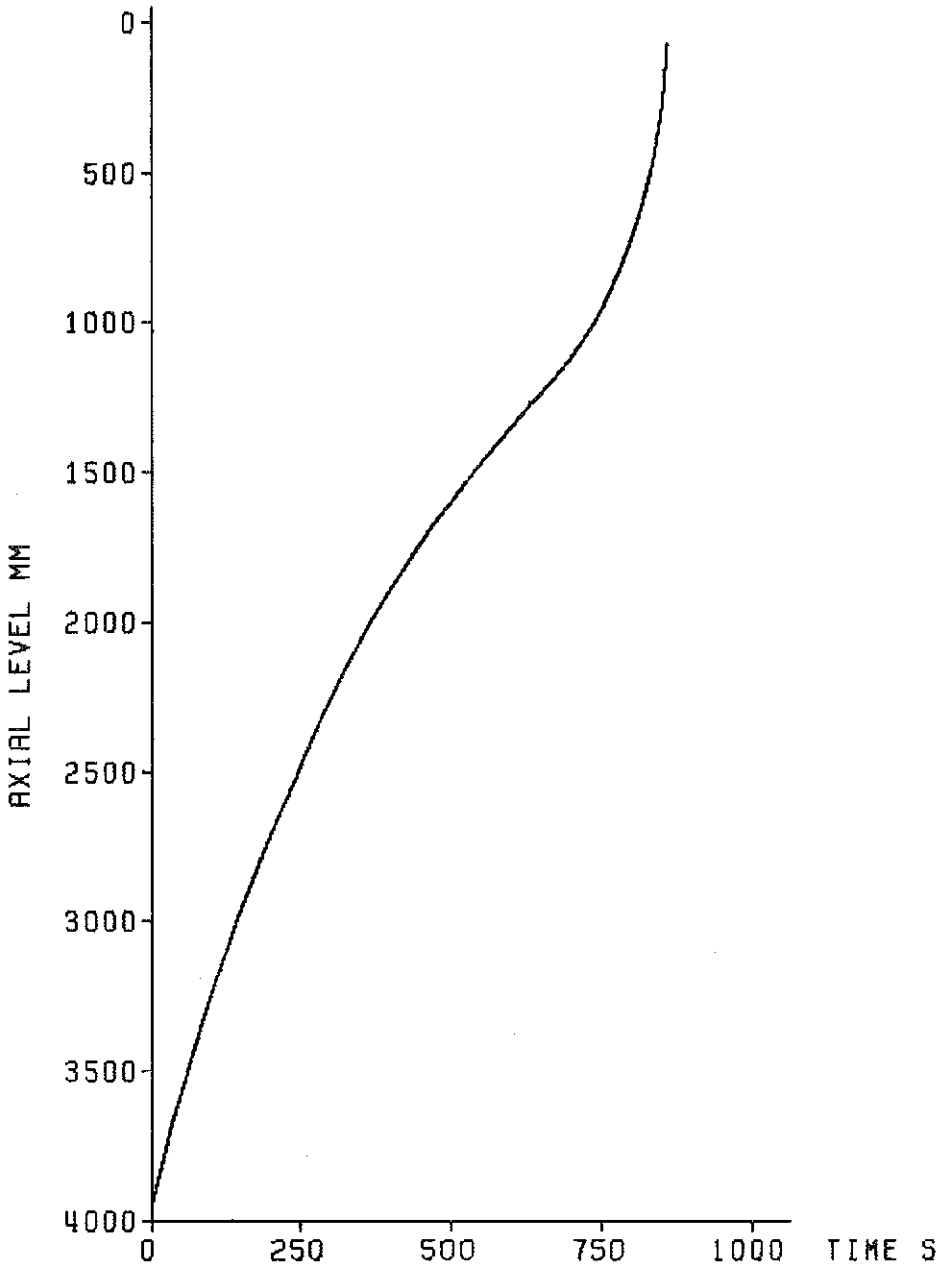


decay heat	120% ANS standard
flooding rate (cold)	3.80 cm/s
system pressure	2.02 bar
feedwater temperature	40 deg C

KfK IRB

Fig. 117 FEBA: 5x5 ROD BUNDLE, TEST SERIES 2, TEST-No. 234

axial position of the quench front

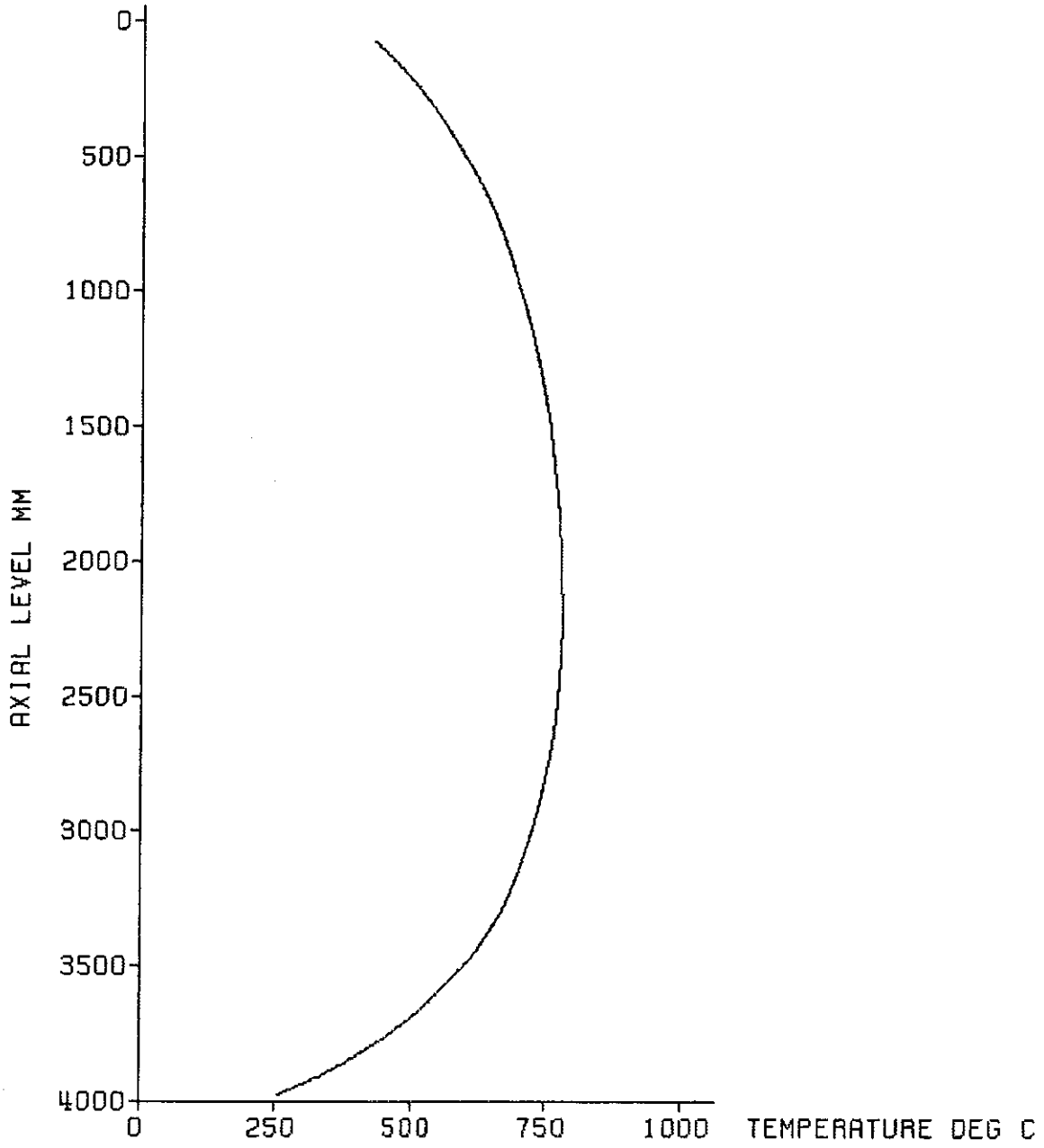


decay heat	120% ANS standard
flooding rate (cold)	3.80 cm/s
system pressure	2.02 bar
feedwater temperature	40 deg C

KfK IRB

Fig. 118 FEBA: 5x5 ROD BUNDLE TEST SERIES 2, TEST-No. 234

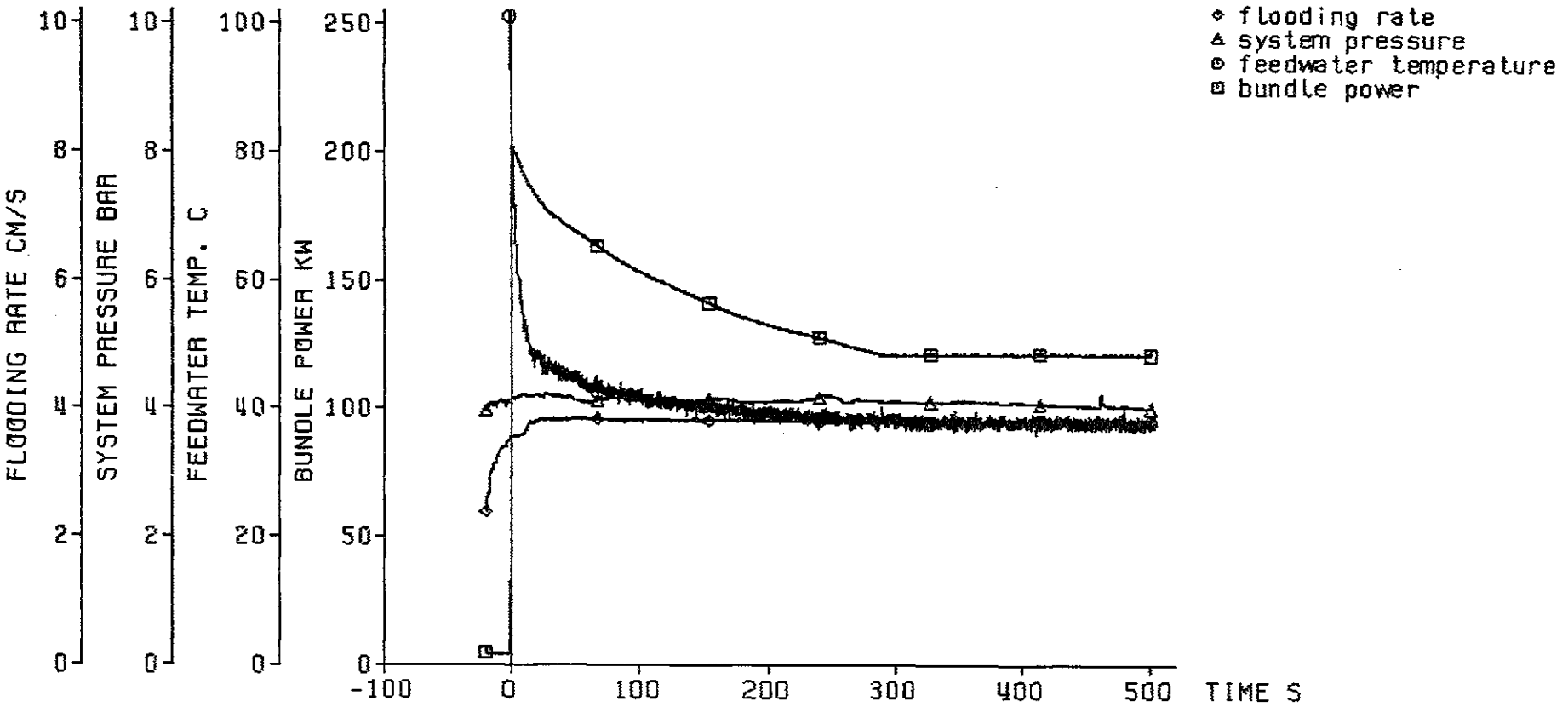
initial axial temperature profile of the cladding



decay heat	120% ANS standard
flooding rate (cold)	3.82 cm/s
system pressure	4.15 bar
feedwater temperature	40 deg C

KfK IRB

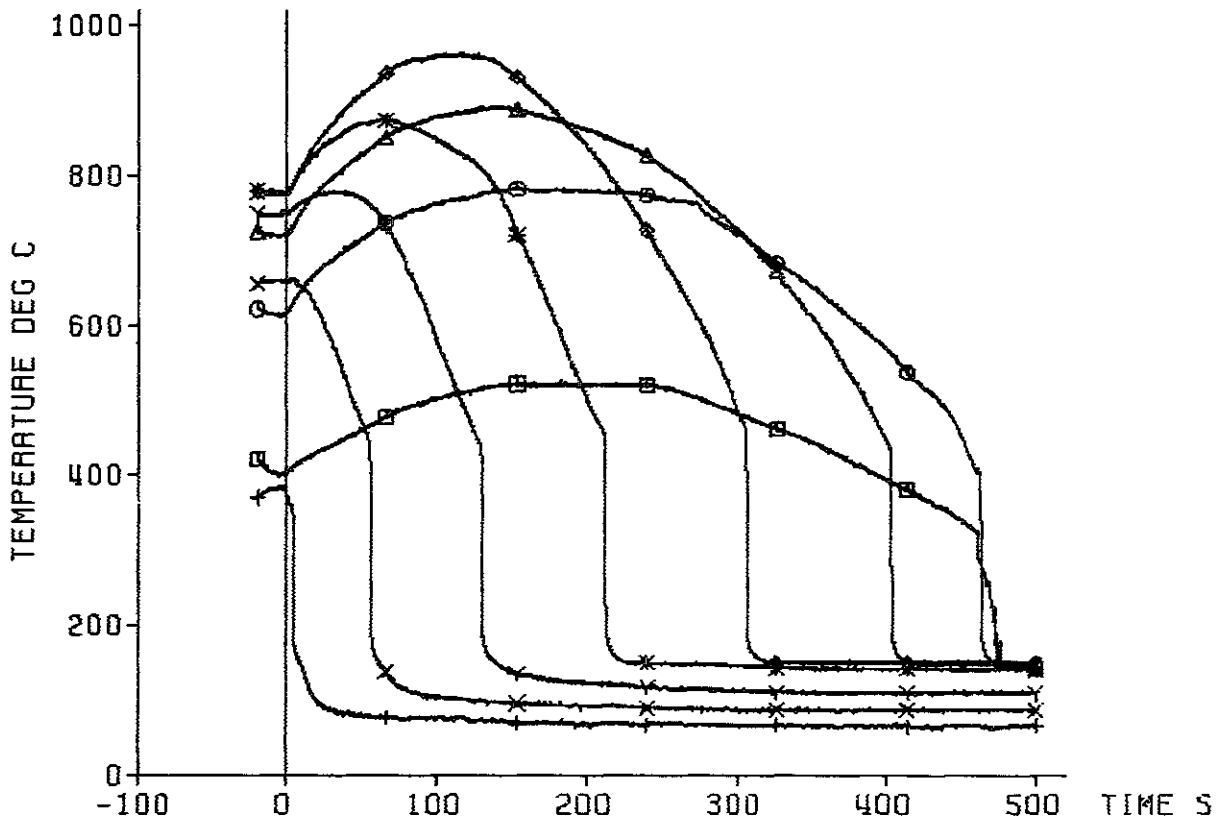
Fig. 119 FEBA: 5x5 ROD BUNDLE TEST SERIES 2, TEST-No. 229



decay heat	120% ANS standard
flooding rate (cold)	3.82 cm/s
system pressure	4.15 bar
feedwater temperature	40 deg C

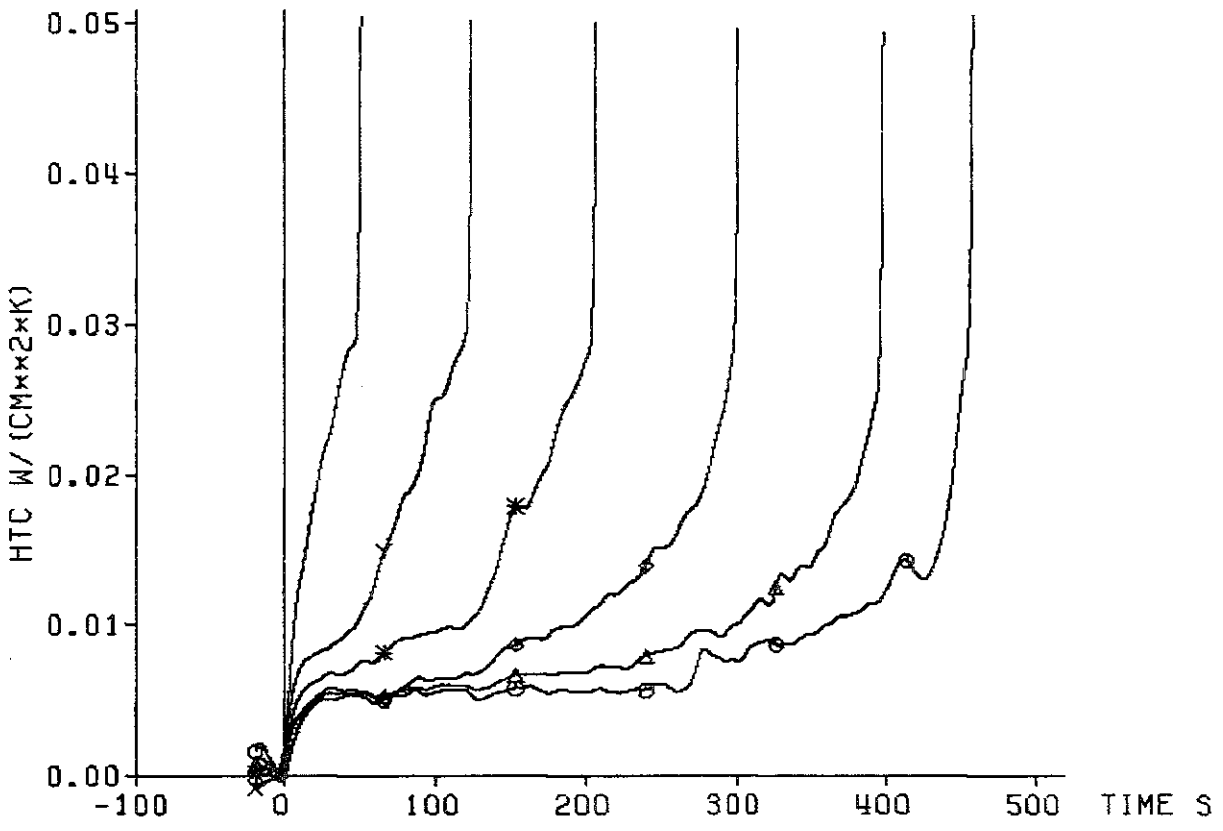
KfK IRB

Fig. 120 FEBA: 5x5 ROD BUNDLE, TEST SERIES 2, TEST-No. 229



decay heat	120% ANS standard
flooding rate (cold)	3.82 cm/s
system pressure	4.15 bar
feedwater temperature	40 deg C

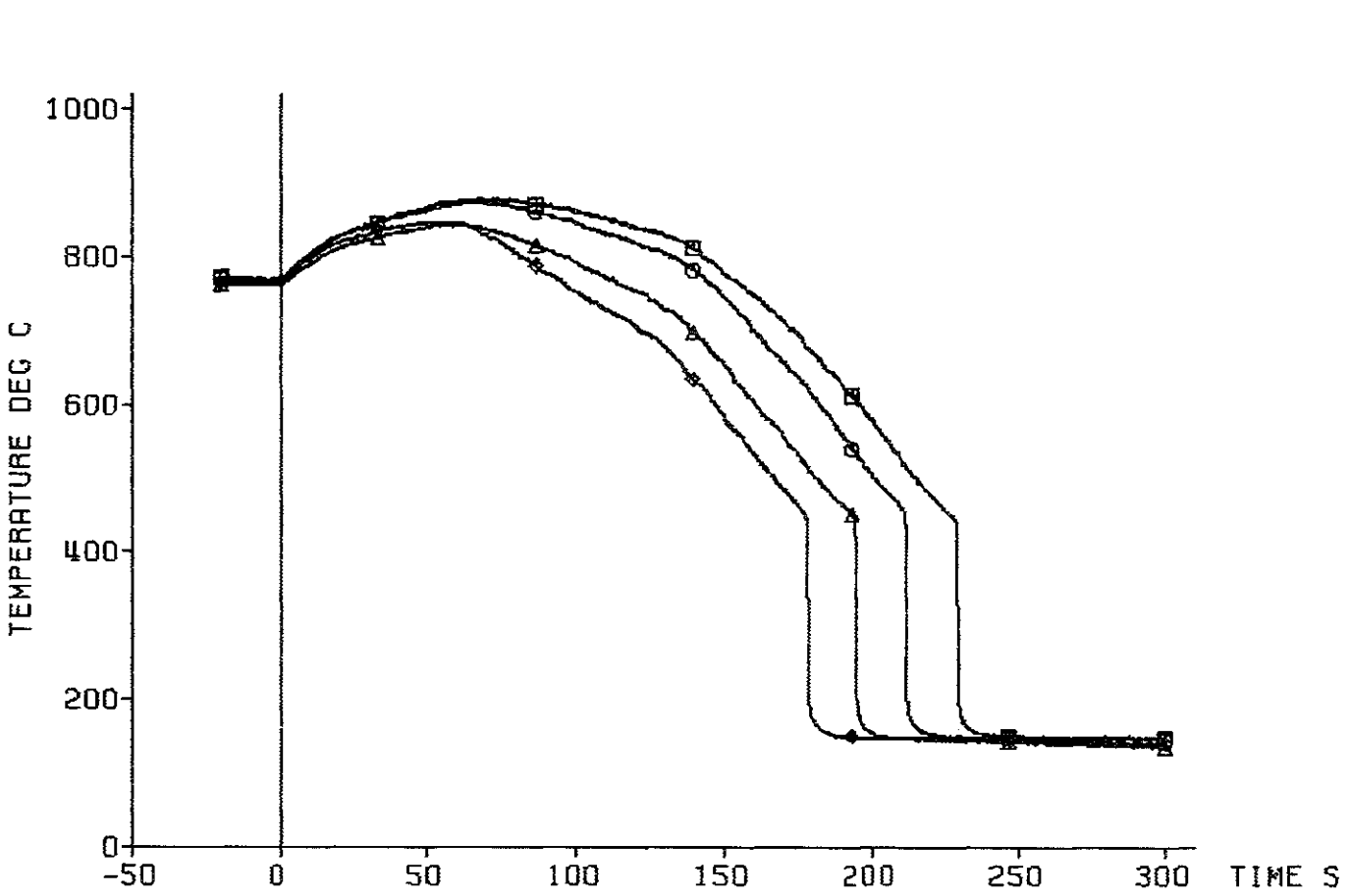
Fig. 121 FEBA: 5x5 ROD BUNDLE, TEST SERIES 2, TEST-No. 229



decay heat	120% ANS standard
flooding rate (cold)	3.82 cm/s
system pressure	4.15 bar
feedwater temperature	40 deg C

KfK IRB

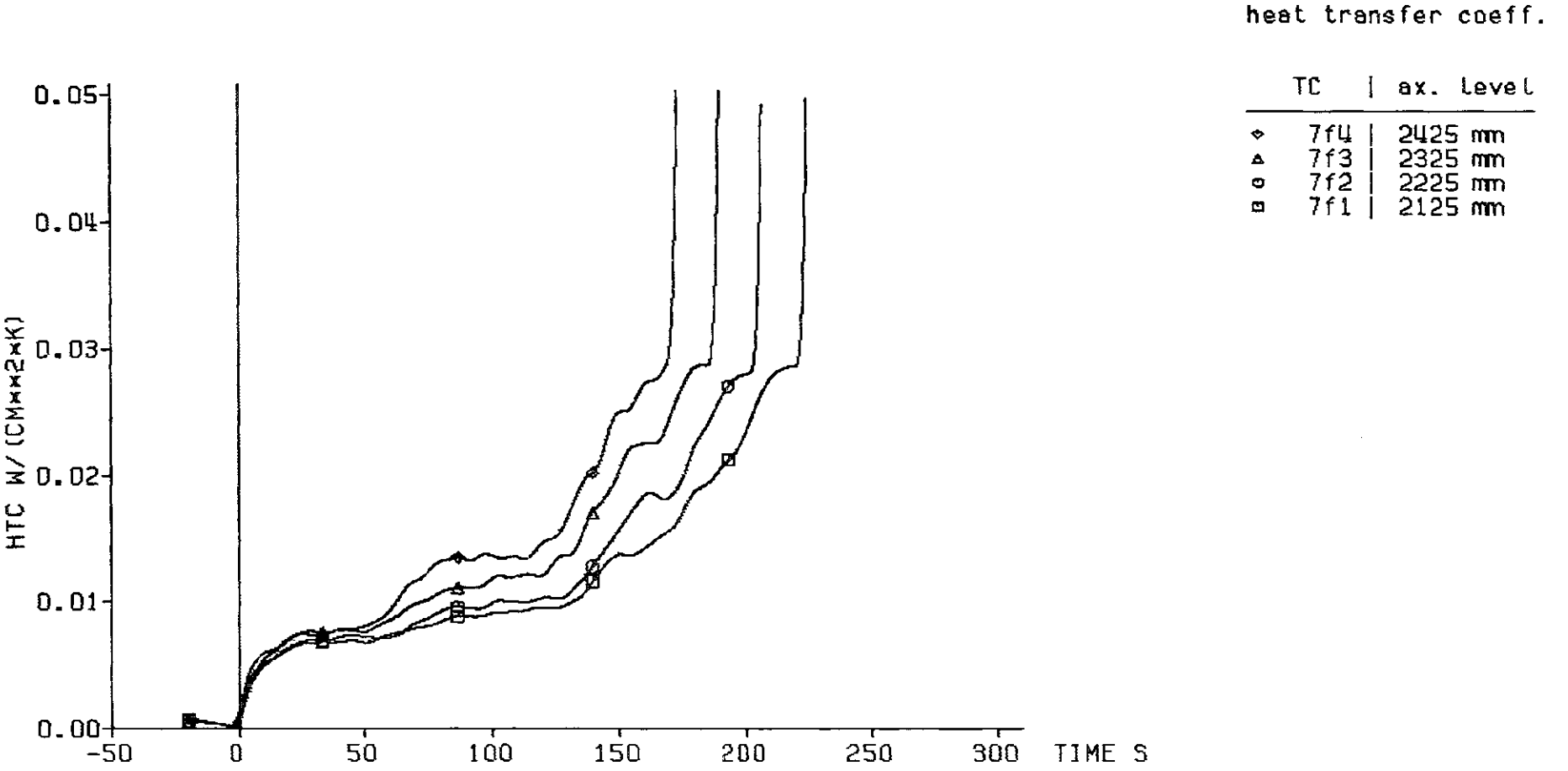
Fig. 122 FEBA: 5x5 ROD BUNDLE, TEST SERIES 2, TEST-No. 229



decay heat	120% ANS standard
flooding rate (cold)	3.82 cm/s
system pressure	4.15 bar
feedwater temperature	40 deg C

KfK KIRB

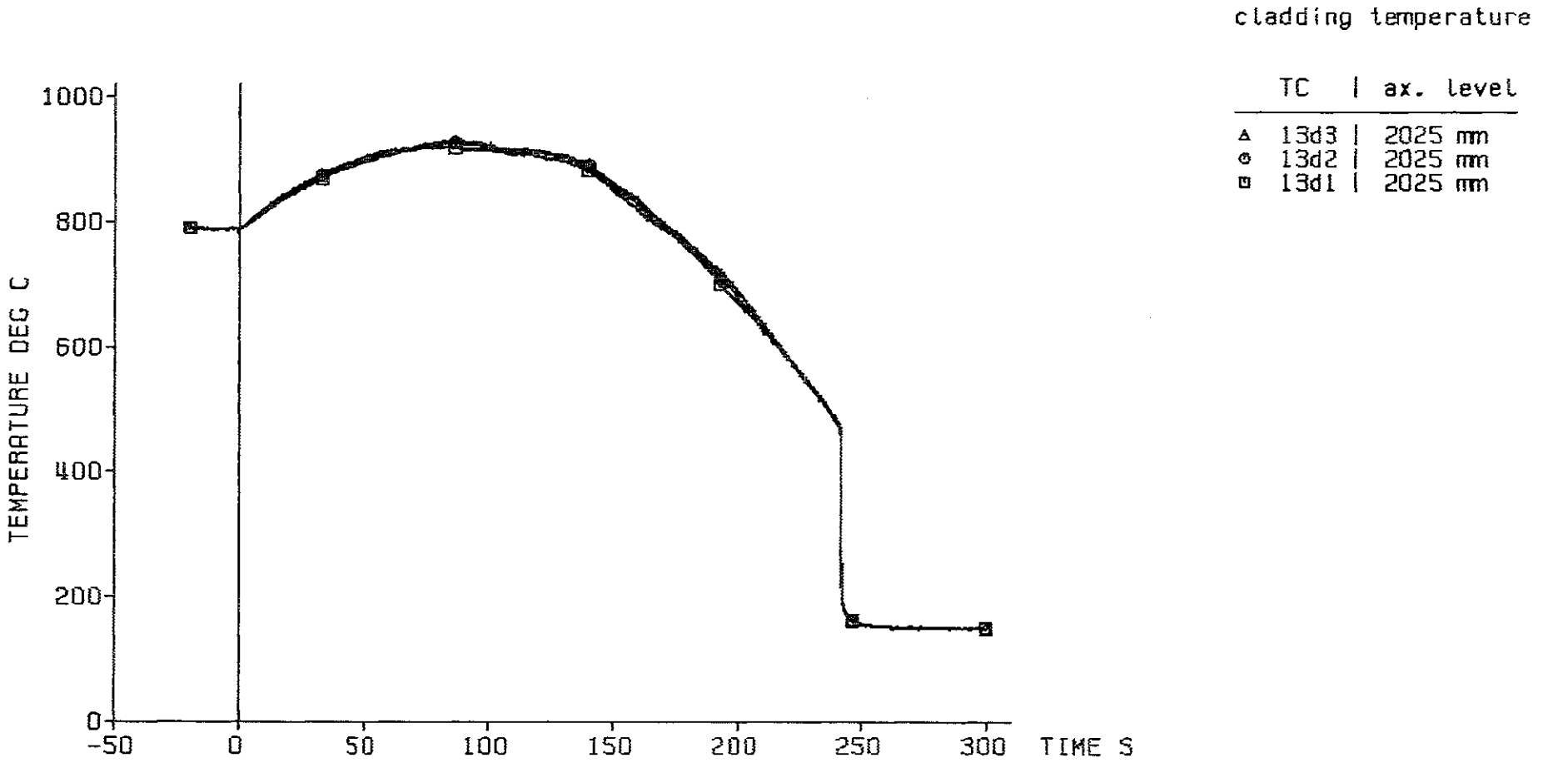
Fig. 123 FEBA: 5x5 ROD BUNDLE, TEST SERIES 2, TEST-No. 229



decay heat	120% ANS standard
flooding rate (cold)	3.82 cm/s
system pressure	4.15 bar
feedwater temperature	40 deg C

KfK IRB

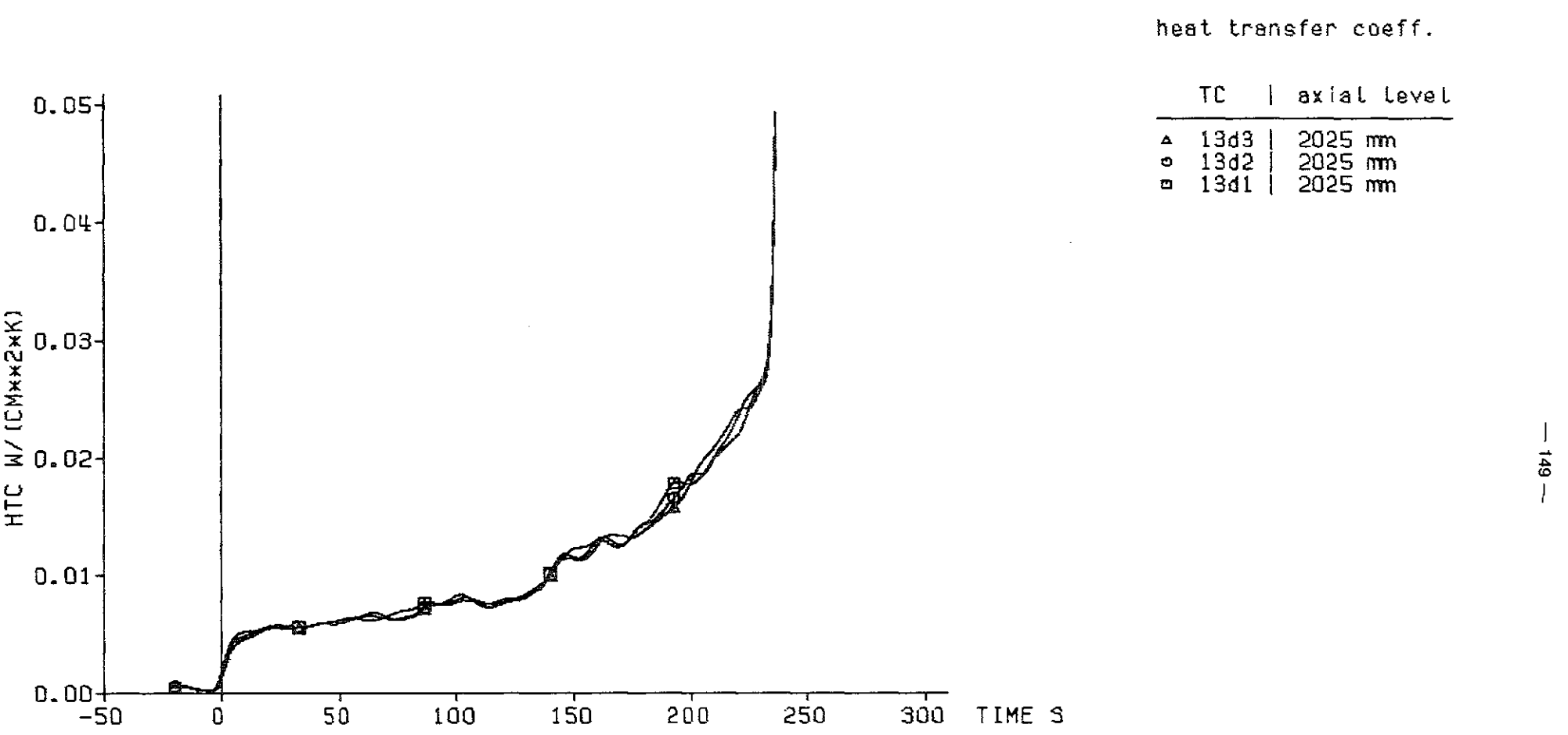
Fig. 124 FEBA: 5x5 ROD BUNDLE, TEST SERIES 2, TEST-No. 229



decay heat	120% ANS standard
flooding rate (cold)	3.82 cm/s
system pressure	4.15 bar
feedwater temperature	40 deg C

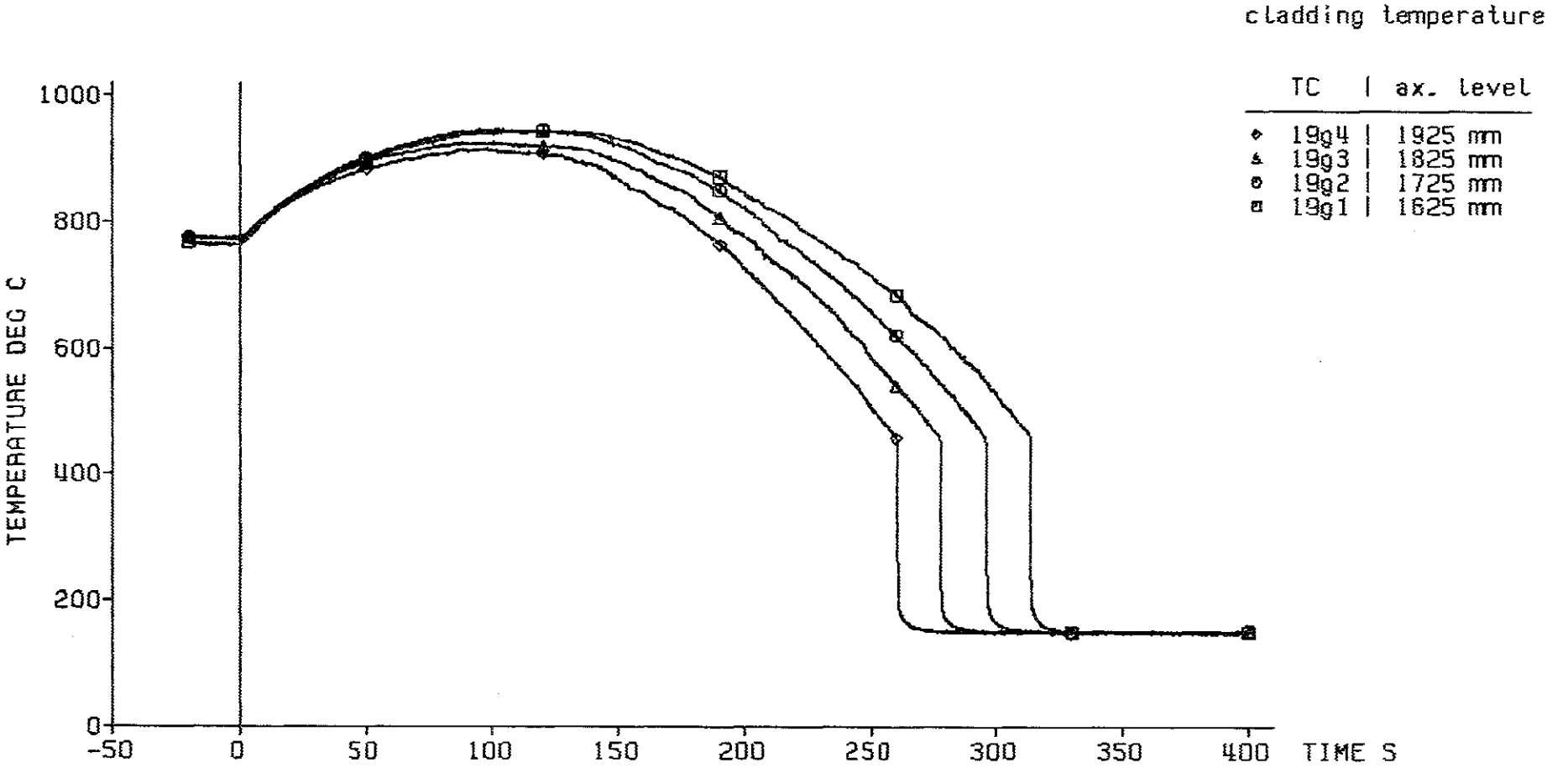
KfK IRB

Fig. 125 FEBA: 5x5 ROD BUNDLE, TEST SERIES 2, TEST-No. 229



decay heat	120% ANS standard
flooding rate (cold)	3.82 cm/s
system pressure	4.15 bar
feedwater temperature	40 deg C

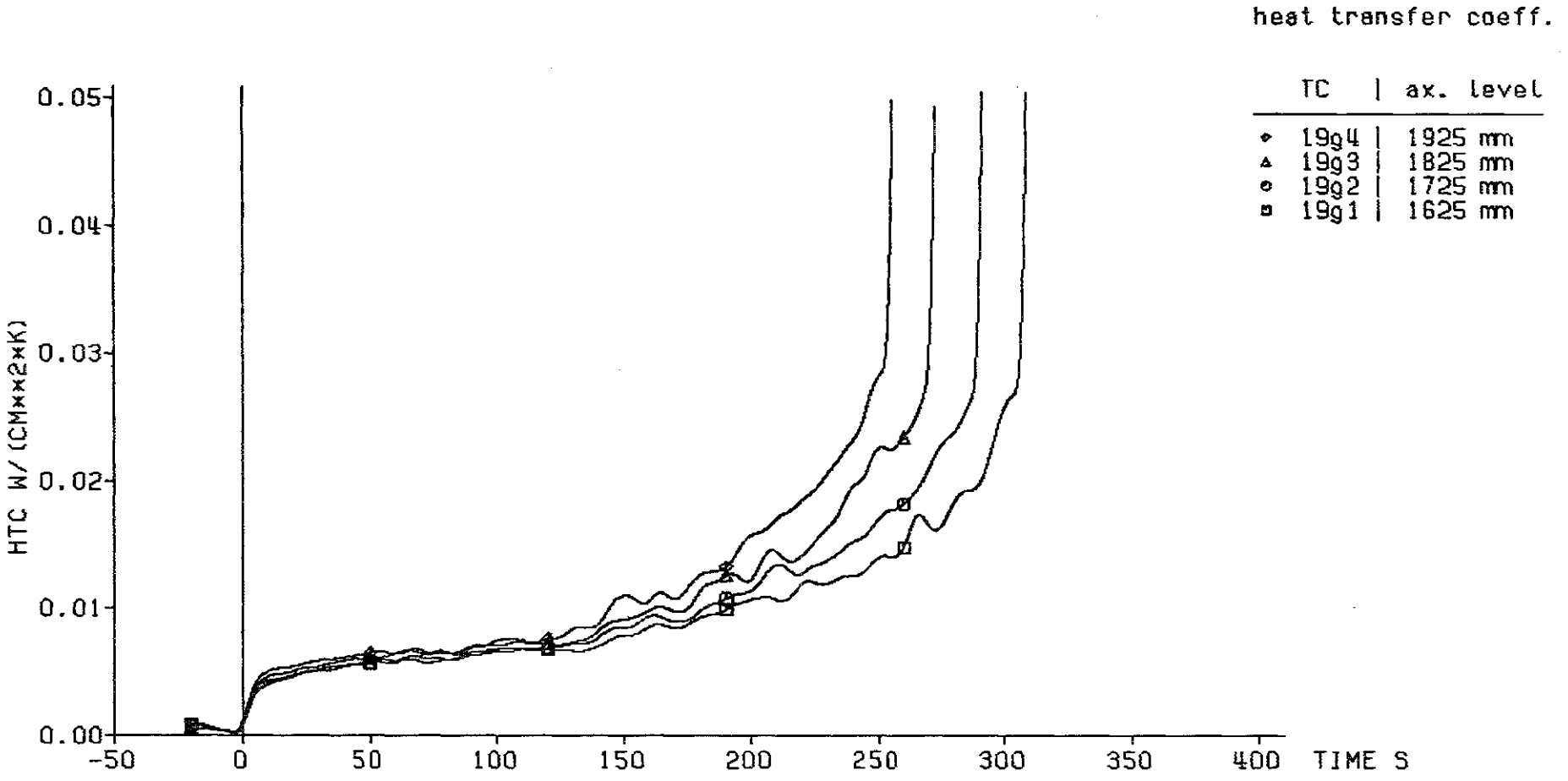
Fig. 126 FEBA: 5x5 ROD BUNDLE, TEST SERIES 2, TEST-No. 229



decay heat	120% ANS standard
flooding rate (cold)	3.82 cm/s
system pressure	4.15 bar
feedwater temperature	40 deg C

KfK IRB

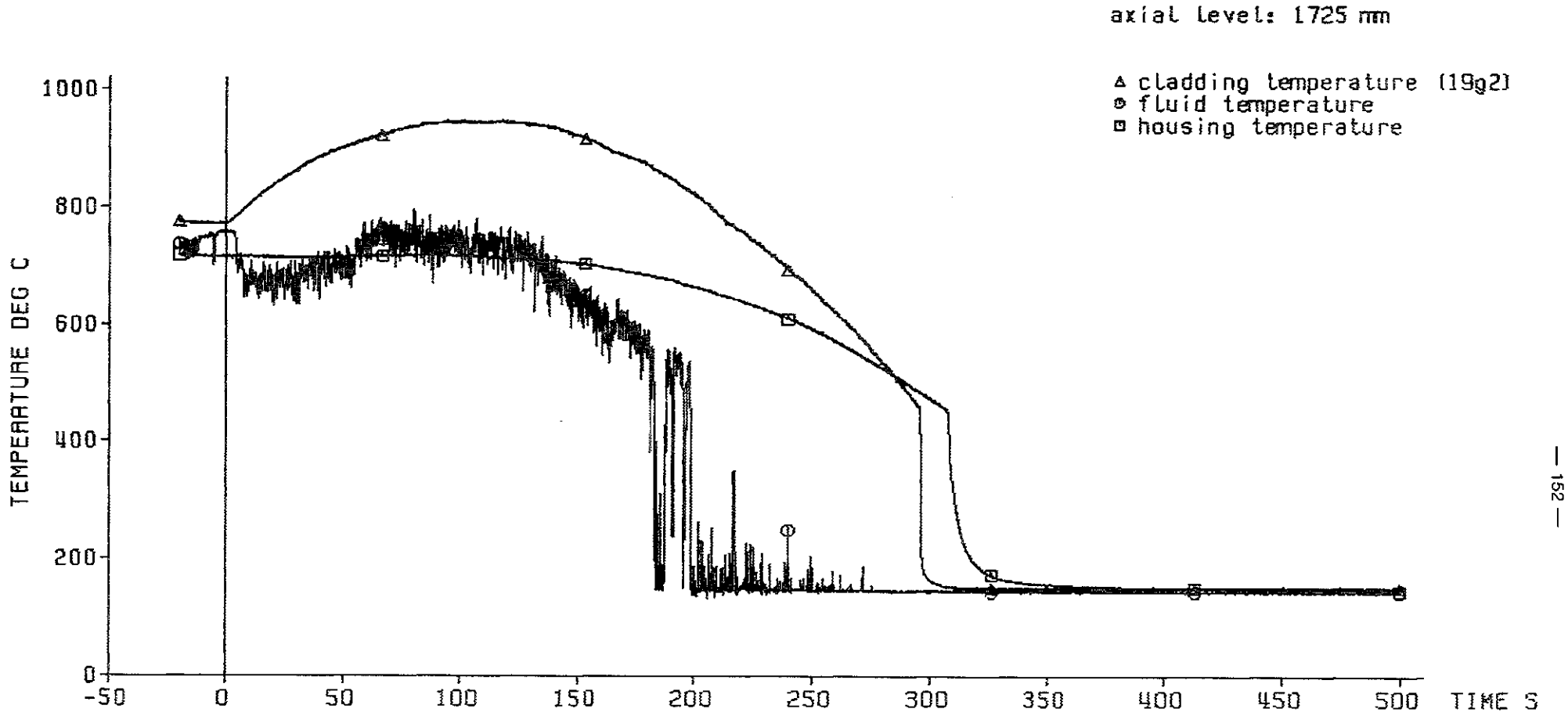
Fig. 127 FEBA: 5x5 ROD BUNDLE, TEST SERIES 2, TEST-No. 229



decay heat 120% ANS standard
flooding rate (cold) 3.62 cm/s
system pressure 4.15 bar
feedwater temperature 40 deg C

KfK IRB

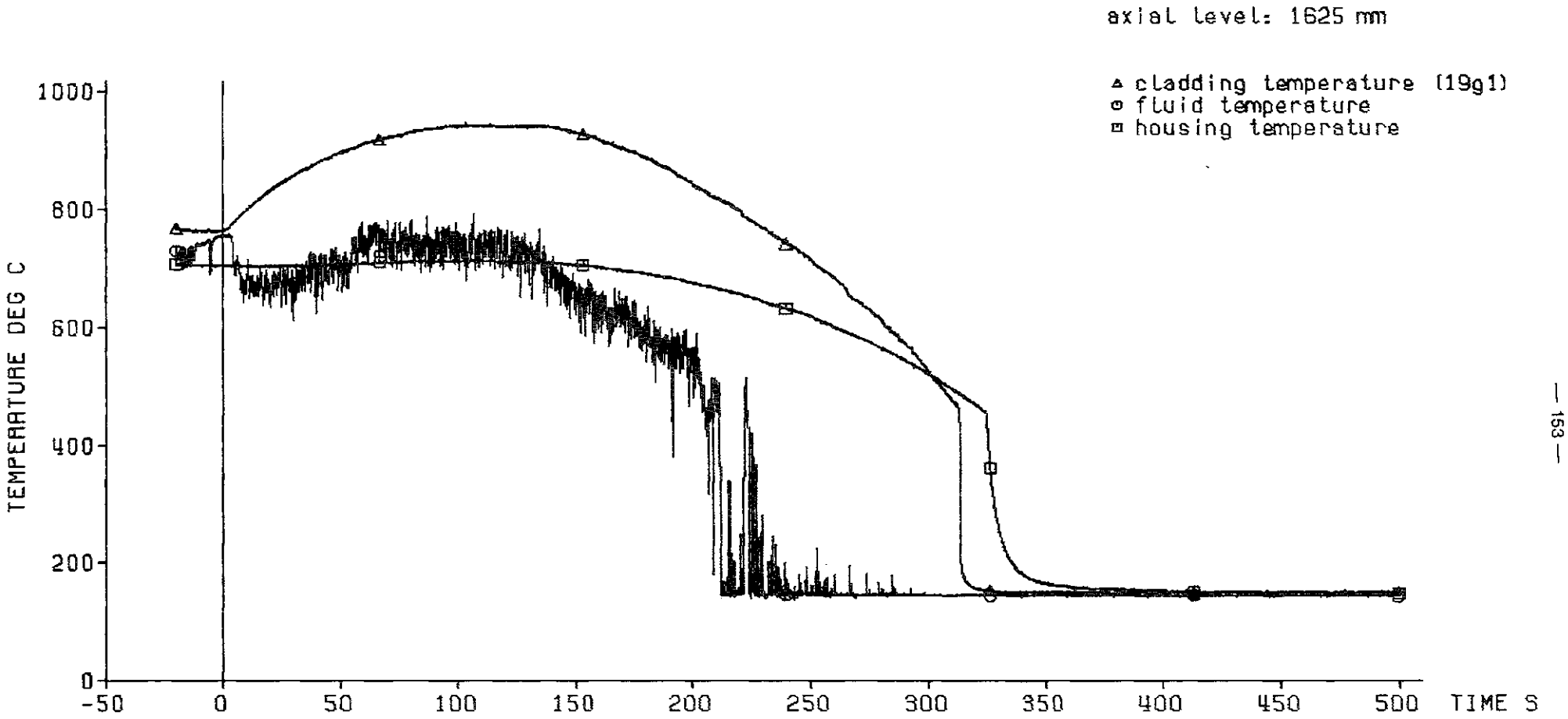
Fig. 128 FEBA: 5x5 ROD BUNDLE, TEST SERIES 2, TEST-No. 229



decay heat	120% ANS standard
flooding rate (cold)	3.82 cm/s
system pressure	4.15 bar
feedwater temperature	40 deg C

KfK IRB

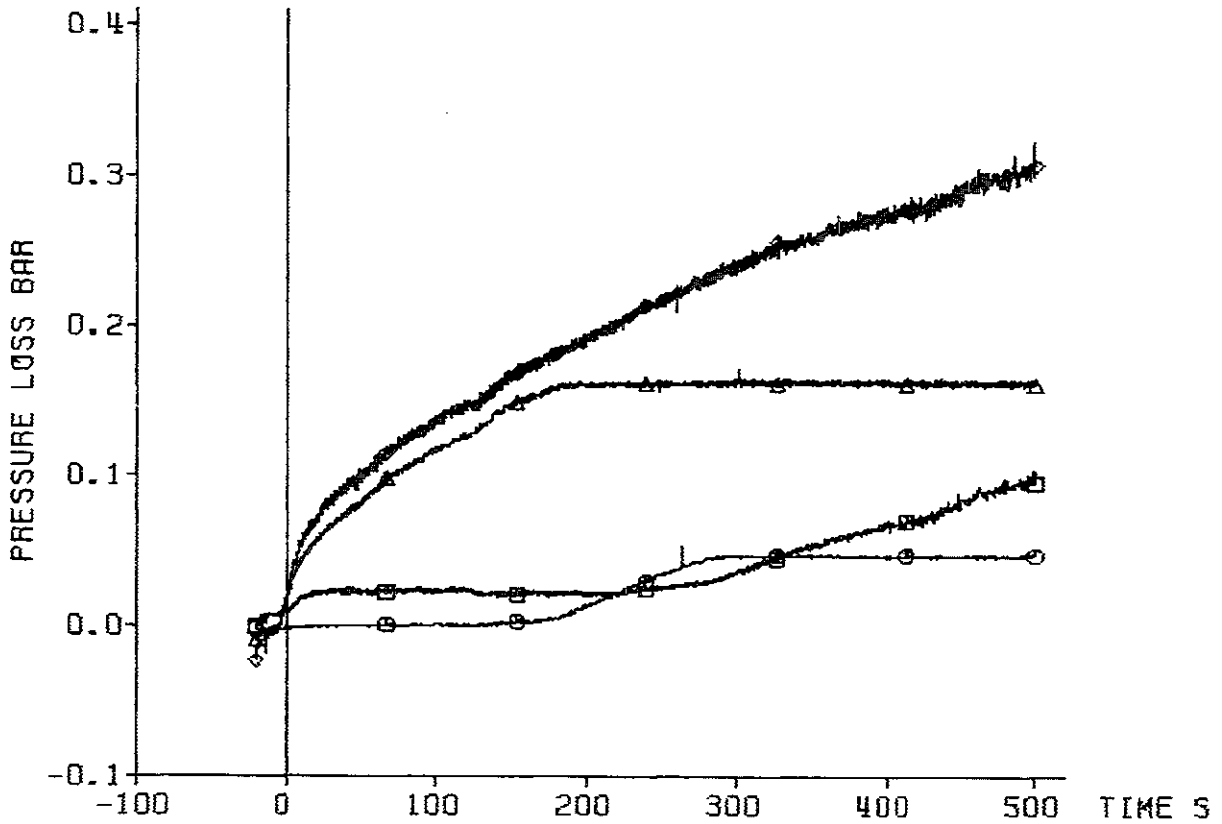
Fig. 129 FEBA: 5x5 ROD BUNDLE, TEST SERIES 2, TEST-No. 229



decay heat	120% ANS standard
flooding rate (cold)	3.82 cm/s
system pressure	4.15 bar
feedwater temperature	40 deg C

KfK IRB

Fig. 130 FEBA: 5x5 ROD BUNDLE, TEST SERIES 2, TEST-No. 229



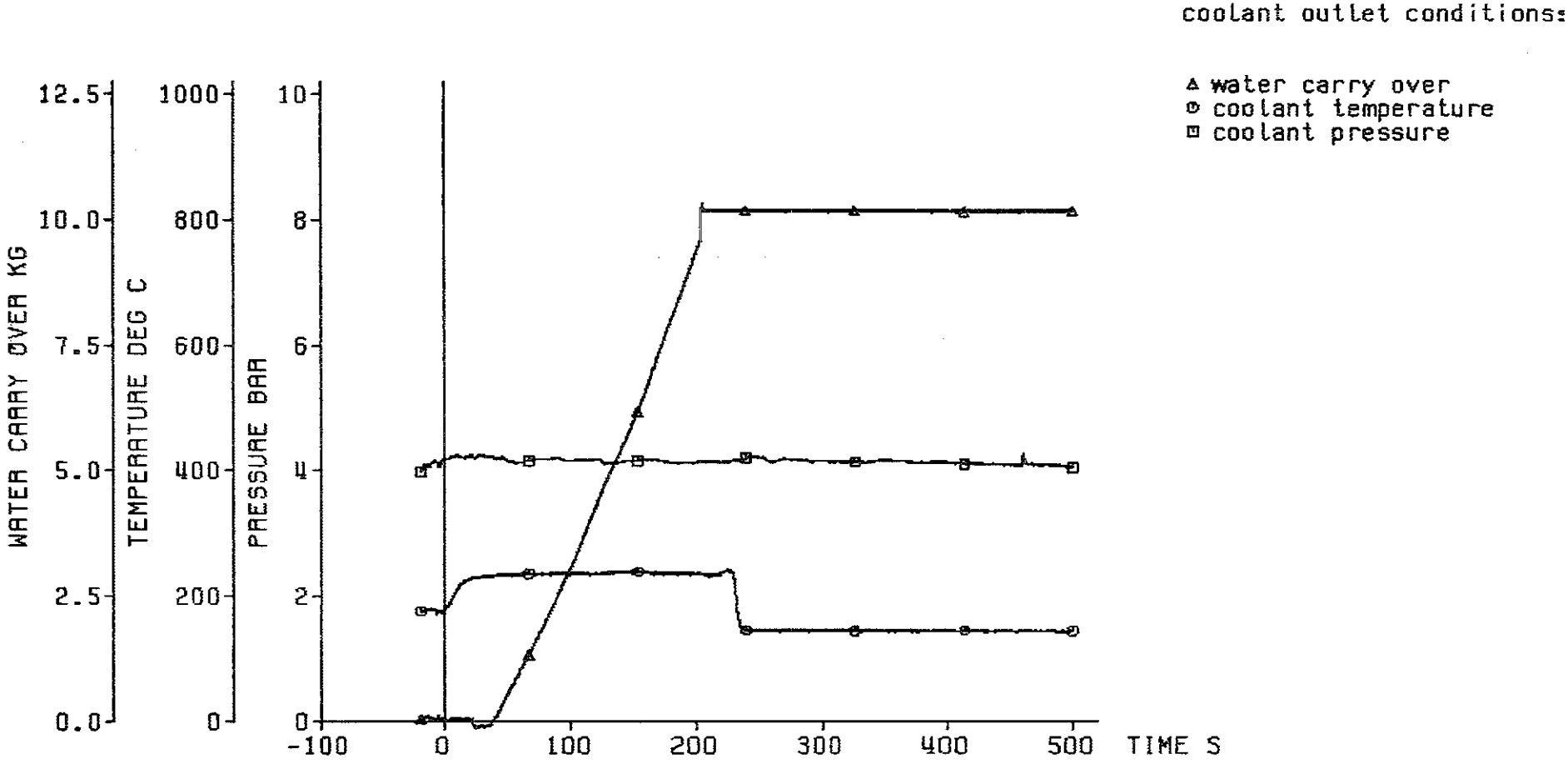
pressure loss
along the test section:

◆ total length: 4196 mm
△ lower part: 1711 mm
⊙ middle part: 545 mm
⊡ upper part: 1940 mm

decay heat	120% ANS standard
flooding rate (cold)	3.62 cm/s
system pressure	4.15 bar
feedwater temperature	40 deg C

KfK IRB

Fig. 131 FEBA: 5x5 ROD BUNDLE, TEST SERIES 2, TEST-No. 229

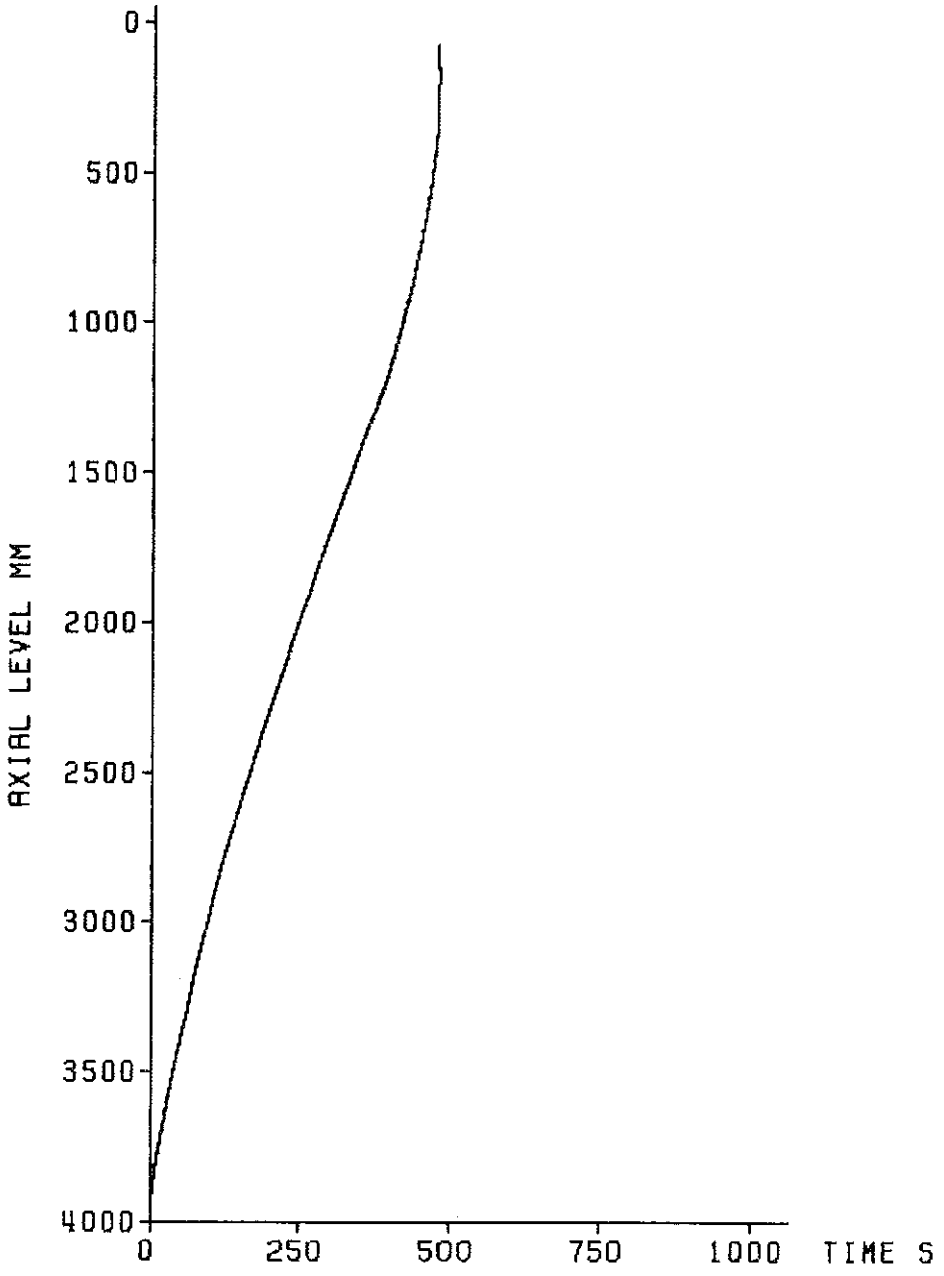


decay heat	120% ANS standard
flooding rate (cold)	3.82 cm/s
system pressure	4.15 bar
feedwater temperature	40 deg C

KfK IRB

Fig. 132 FEBA: 5x5 ROD BUNDLE, TEST SERIES 2, TEST-No. 229

axial position of the quench front

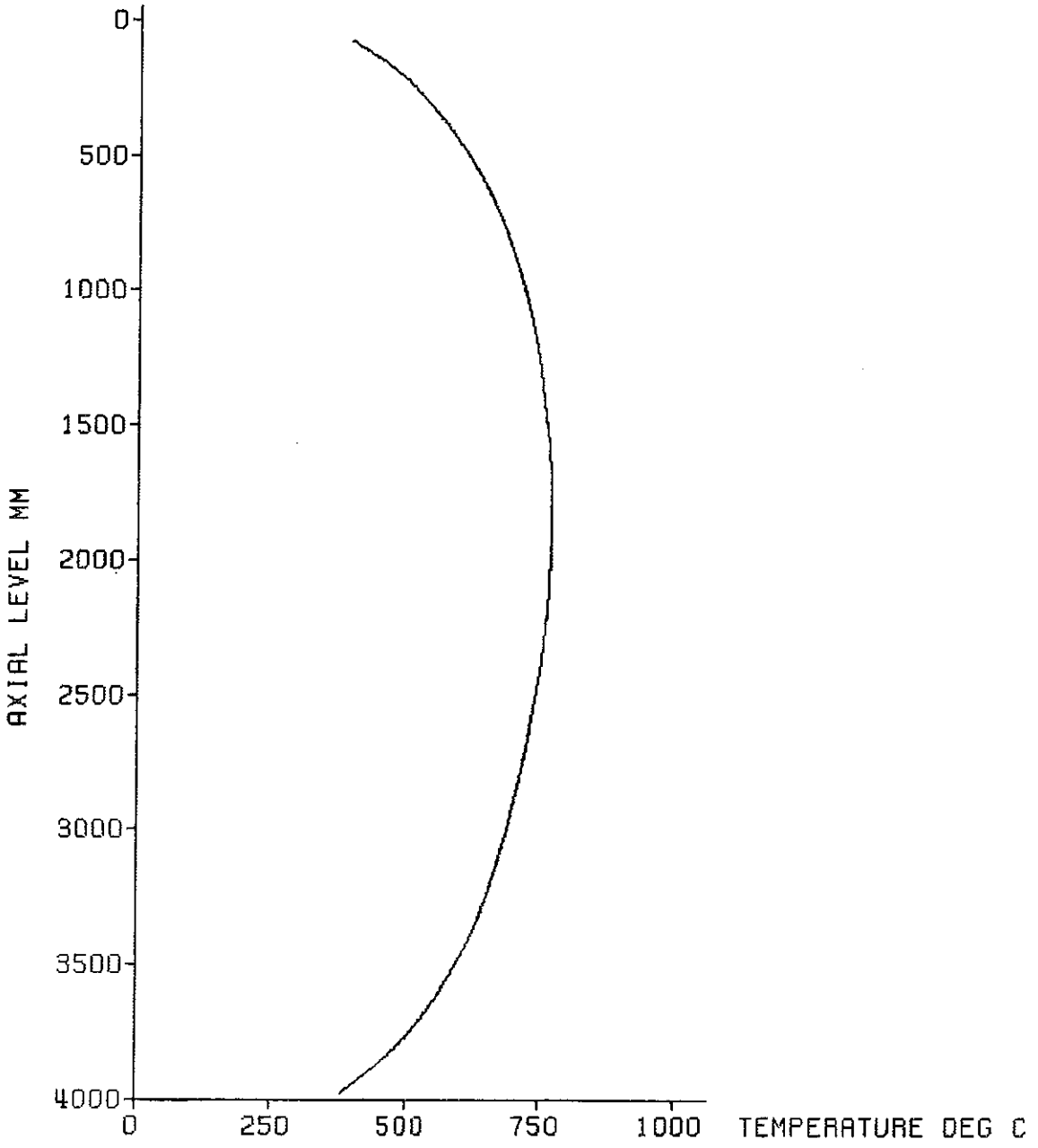


decay heat	120% ANS standard
flooding rate (cold)	3.82 cm/s
system pressure	4.15 bar
feedwater temperature	40 deg C

KfK IRB

Fig. 133 FEBA: 5x5 ROD BUNDLE TEST SERIES 2, TEST-No. 229

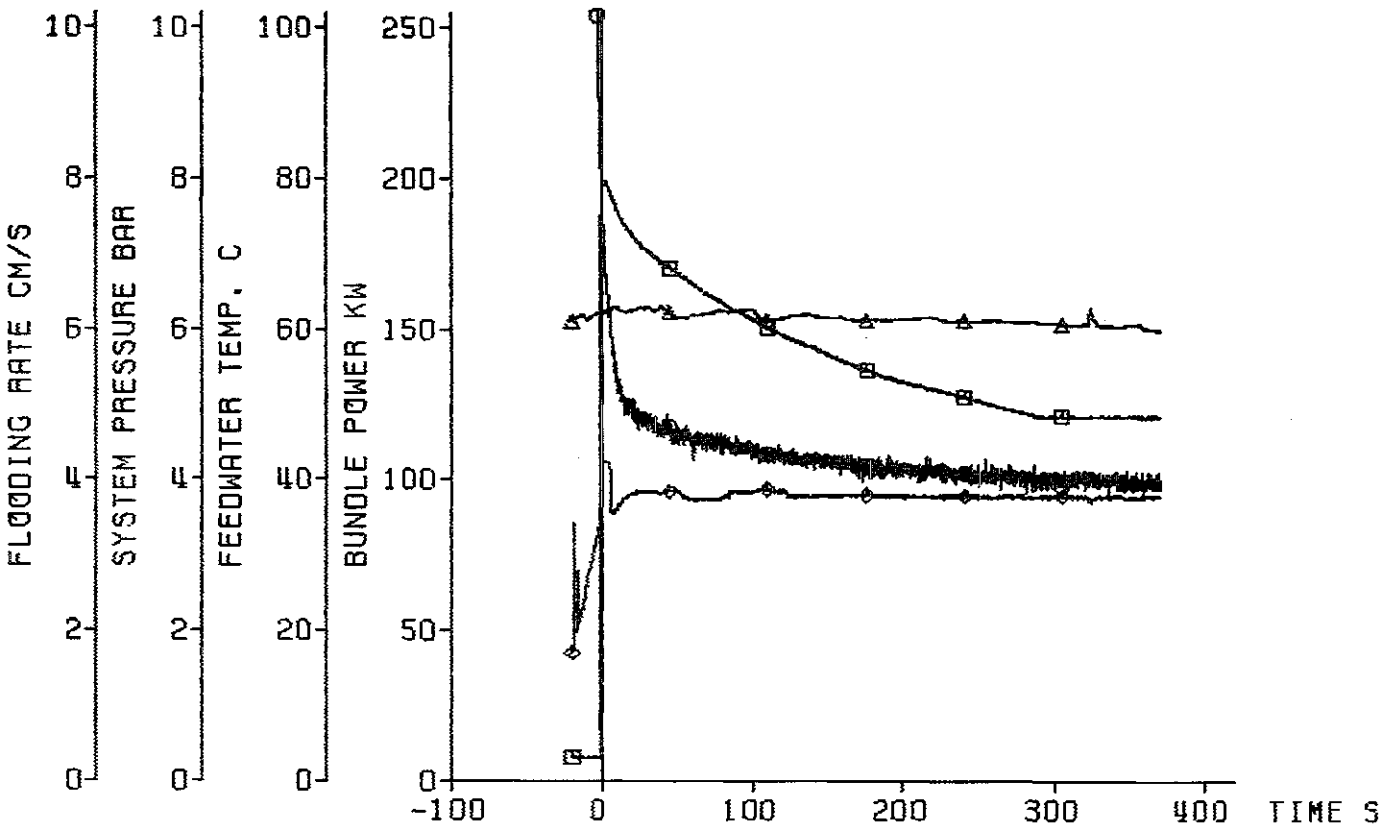
initial axial temperature profile of the cladding



decay heat	120% ANS standard
flooding rate (cold)	3.80 cm/s
system pressure	6.19 bar
feedwater temperature	40 deg C

KfK IRB

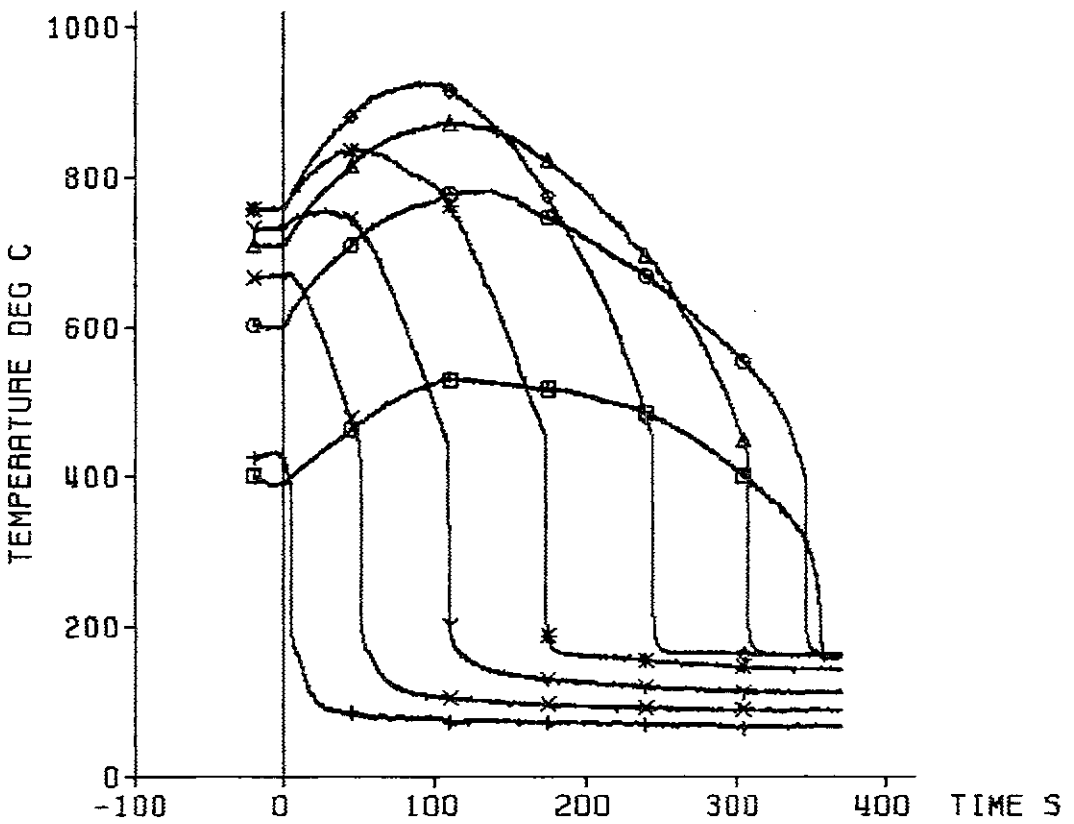
Fig. 134 FEBA: 5x5 ROD BUNDLE TEST SERIES 2, TEST-No. 231



decay heat	120% ANS standard
flooding rate (cold)	3.80 cm/s
system pressure	6.19 bar
feedwater temperature	40 deg C

KfK IRB

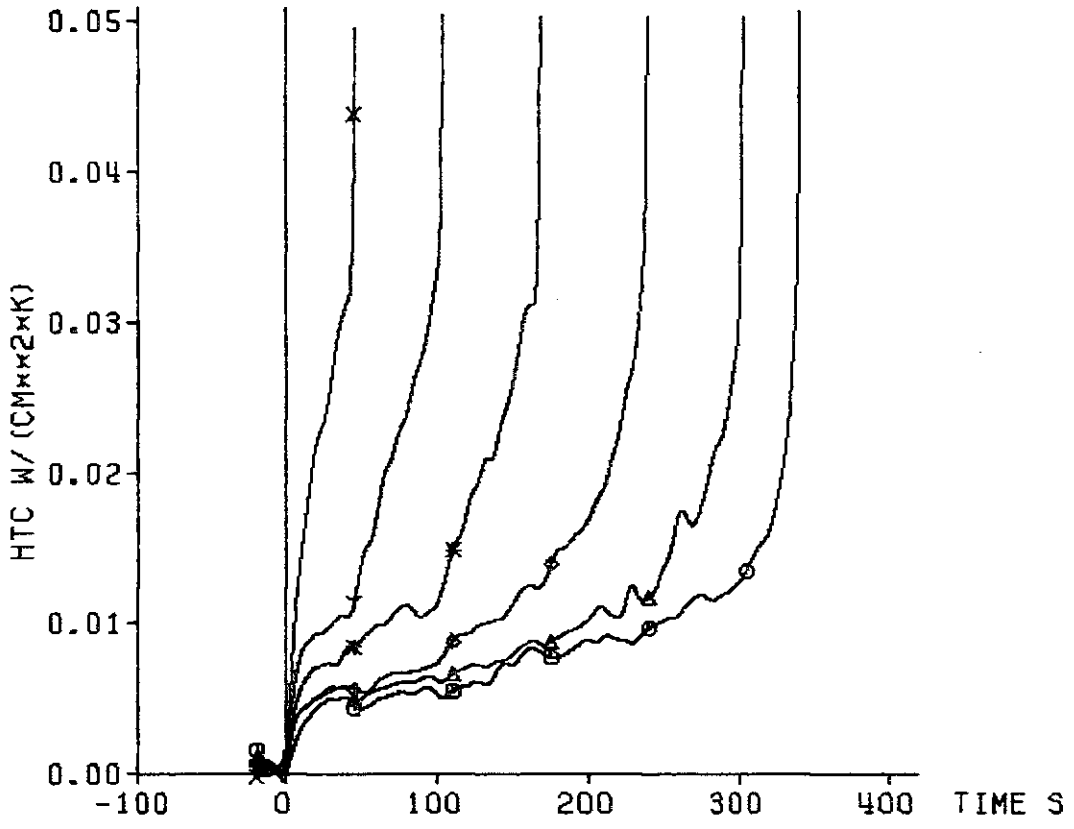
Fig. 135 FEBA: 5x5 ROD BUNDLE, TEST SERIES 2, TEST-No. 231



decay heat	120% ANS standard
flooding rate (cold)	3.60 cm/s
system pressure	6.19 bar
feedwater temperature	40 deg C

KfK IRB

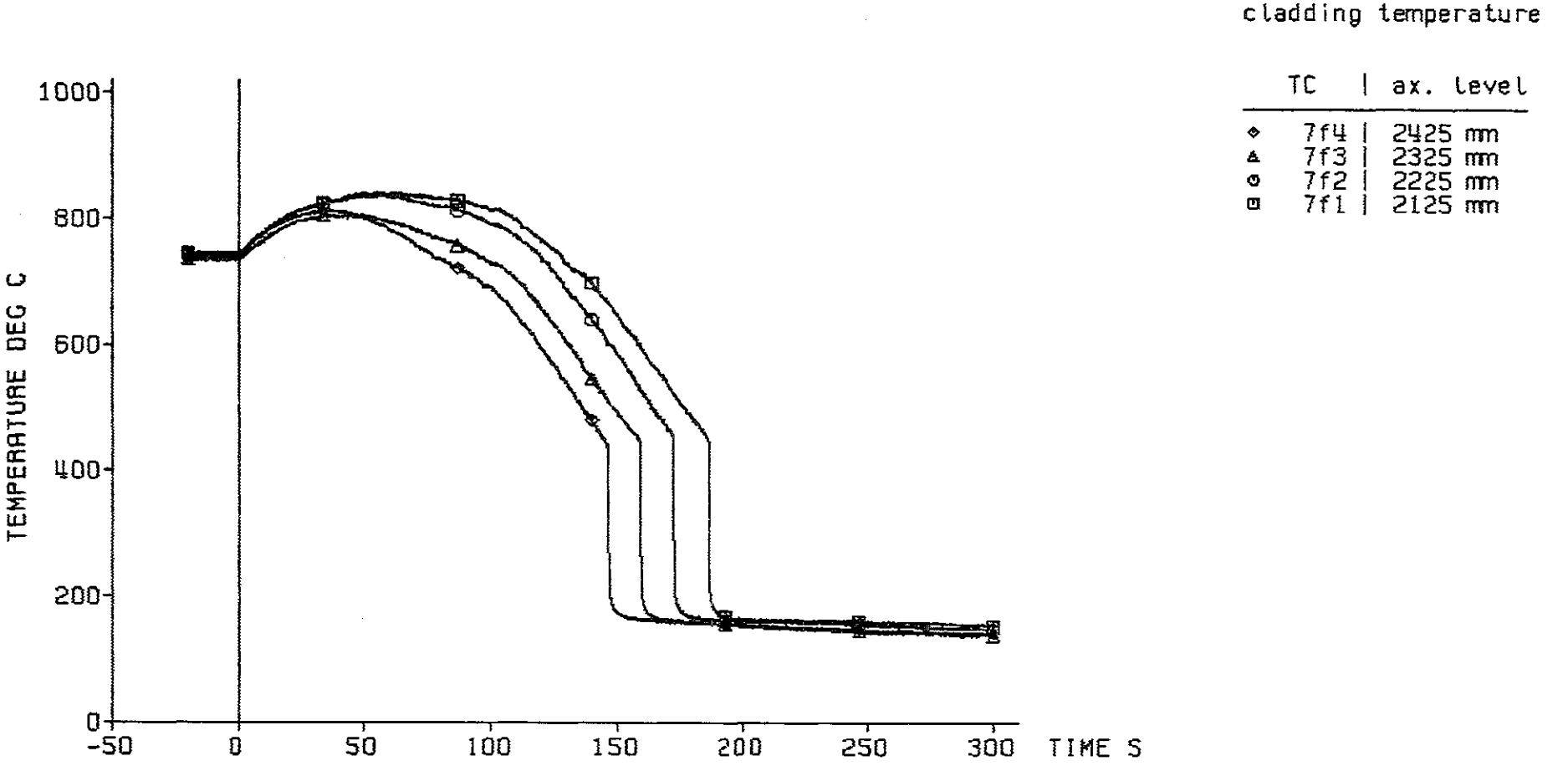
Fig. 136 FEBA: 5x5 ROD BUNDLE, TEST SERIES 2, TEST-No. 231



decay heat	120% ANS standard
flooding rate (cold)	3.80 cm/s
system pressure	6.19 bar
feedwater temperature	40 deg C

KfK IRB

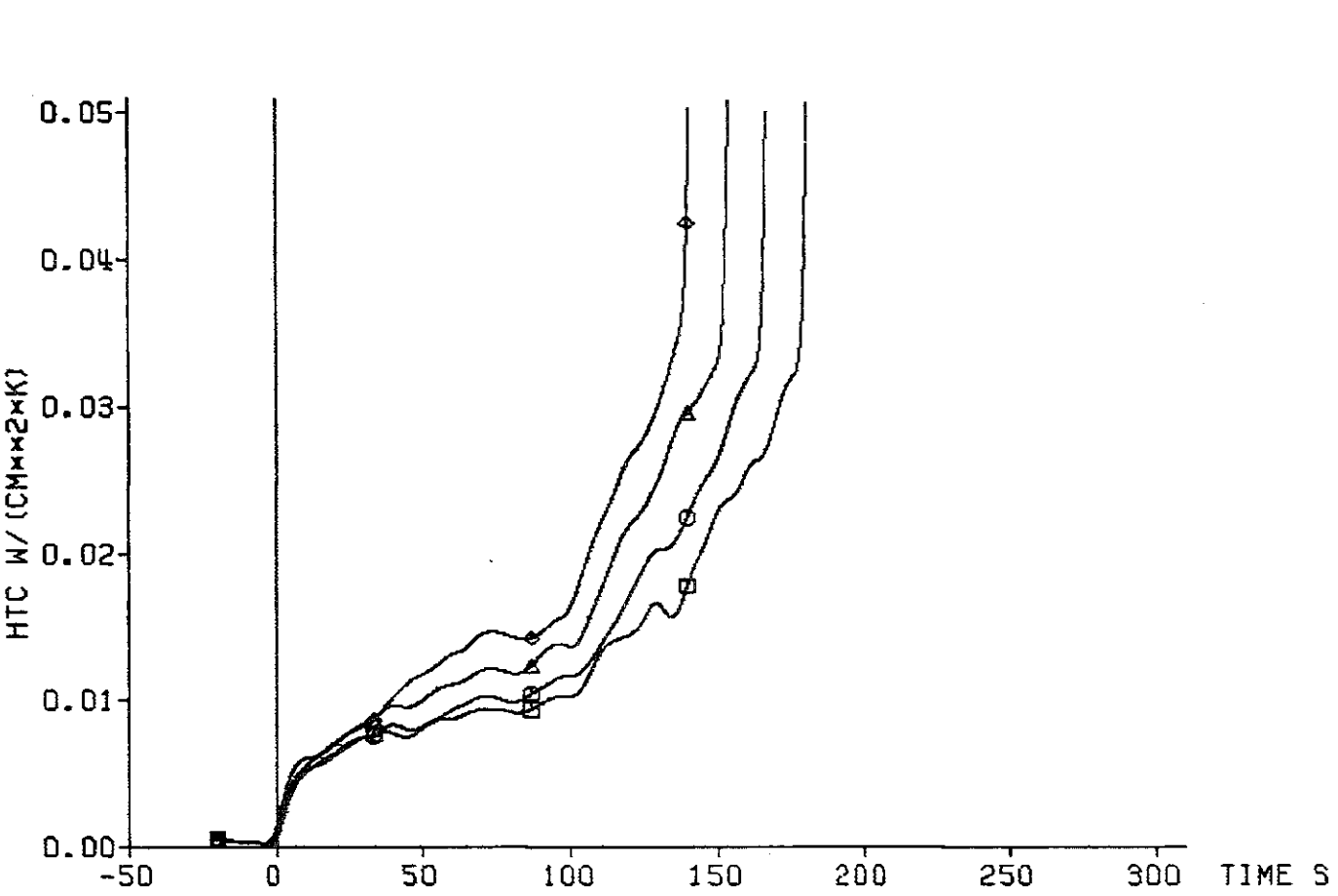
Fig. 137 FEBA: 5x5 ROD BUNDLE, TEST SERIES 2, TEST-No. 231



decay heat	120% ANS standard
flooding rate (cold)	3.80 cm/s
system pressure	6.19 bar
feedwater temperature	40 deg C

KfK KIRB

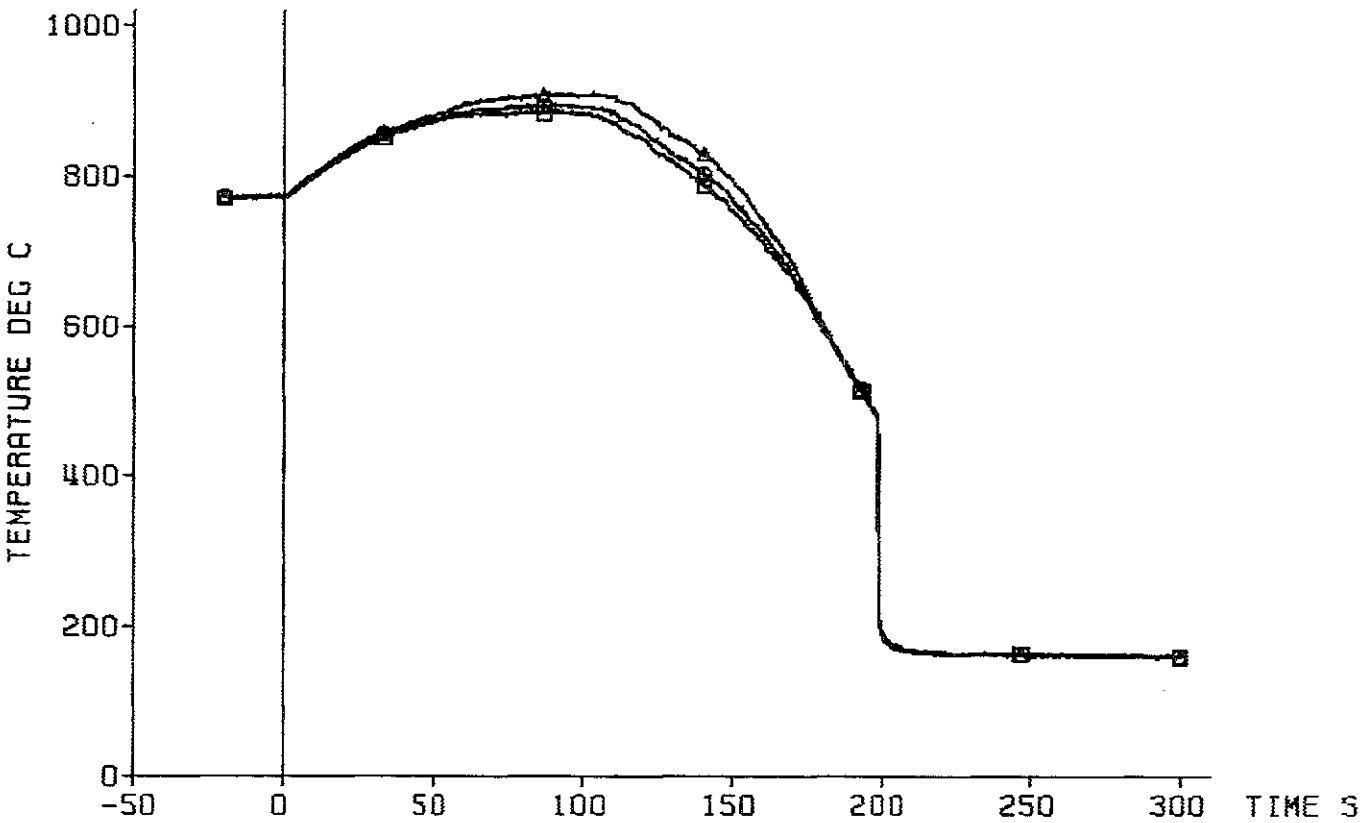
Fig. 138 FEBA: 5x5 ROD BUNDLE, TEST SERIES 2, TEST-No. 231



decay heat	120% ANS standard
flooding rate (cold)	3.80 cm/s
system pressure	6.19 bar
feedwater temperature	40 deg C

KfK IRB

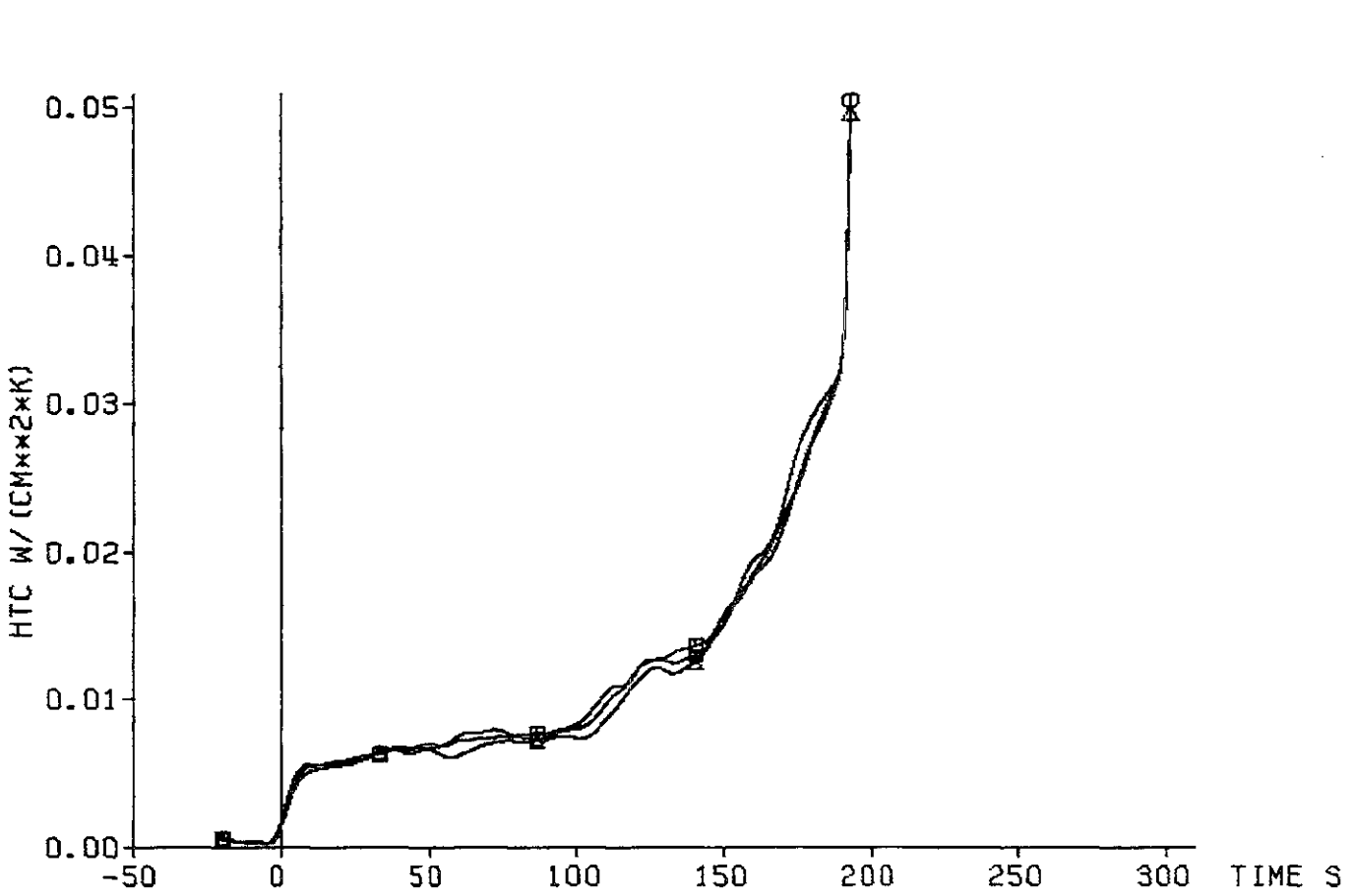
Fig. 139 FEBA: 5x5 ROD BUNDLE, TEST SERIES 2, TEST-No. 231



decay heat	120% ANS standard
flooding rate (cold)	3.80 cm/s
system pressure	6.19 bar
feedwater temperature	40 deg C

KfK IRB

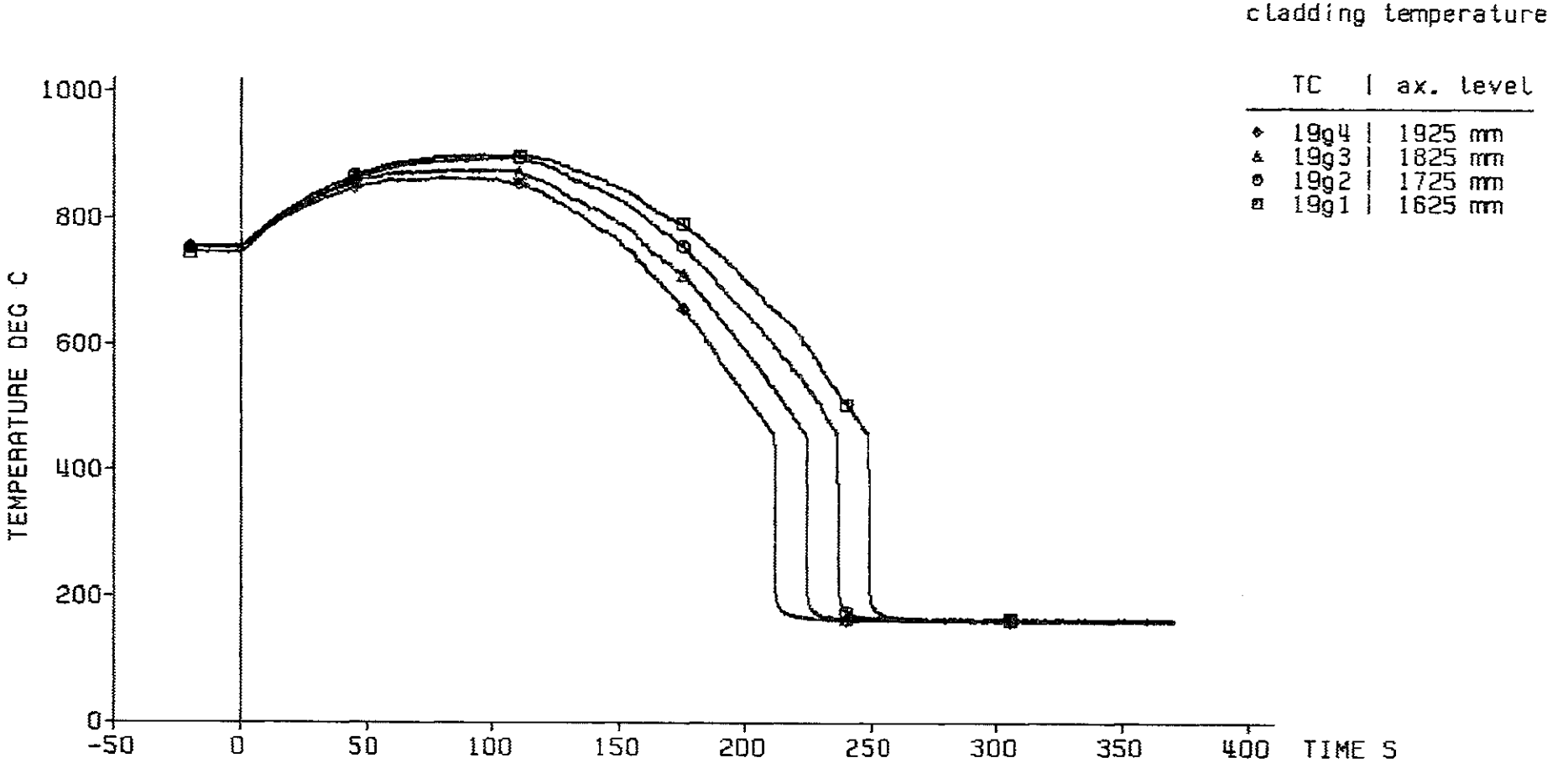
Fig. 140 FEBA: 5x5 ROD BUNDLE, TEST SERIES 2, TEST-No. 231



decay heat	120% ANS standard
flooding rate (cold)	3.80 cm/s
system pressure	6.19 bar
feedwater temperature	40 deg C

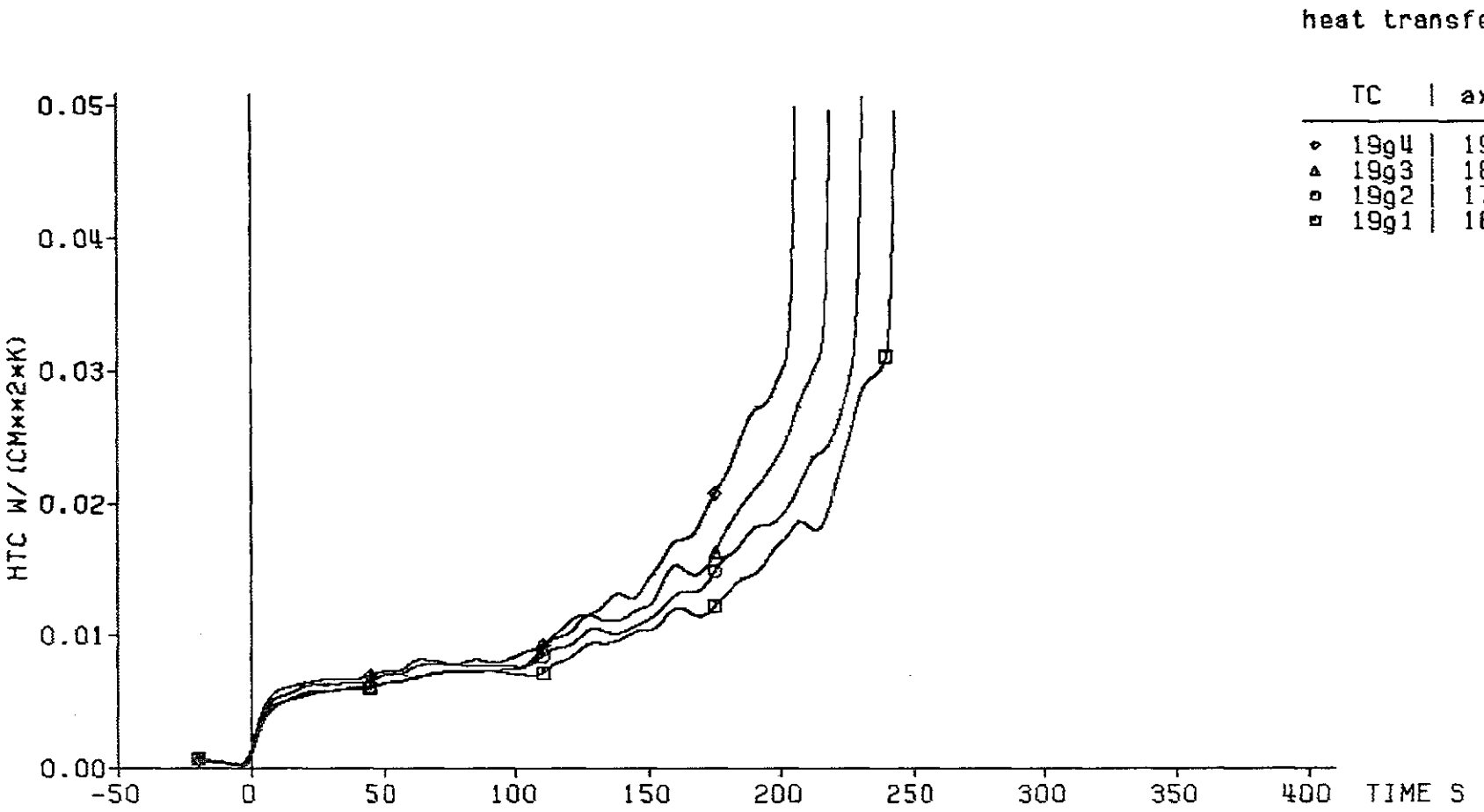
KfK IRB

Fig. 141 FEBA: 5x5 ROD BUNDLE, TEST SERIES 2, TEST-No. 231



decay heat	120% ANS standard
flooding rate (cold)	3.80 cm/s
system pressure	6.19 bar
feedwater temperature	40 deg C

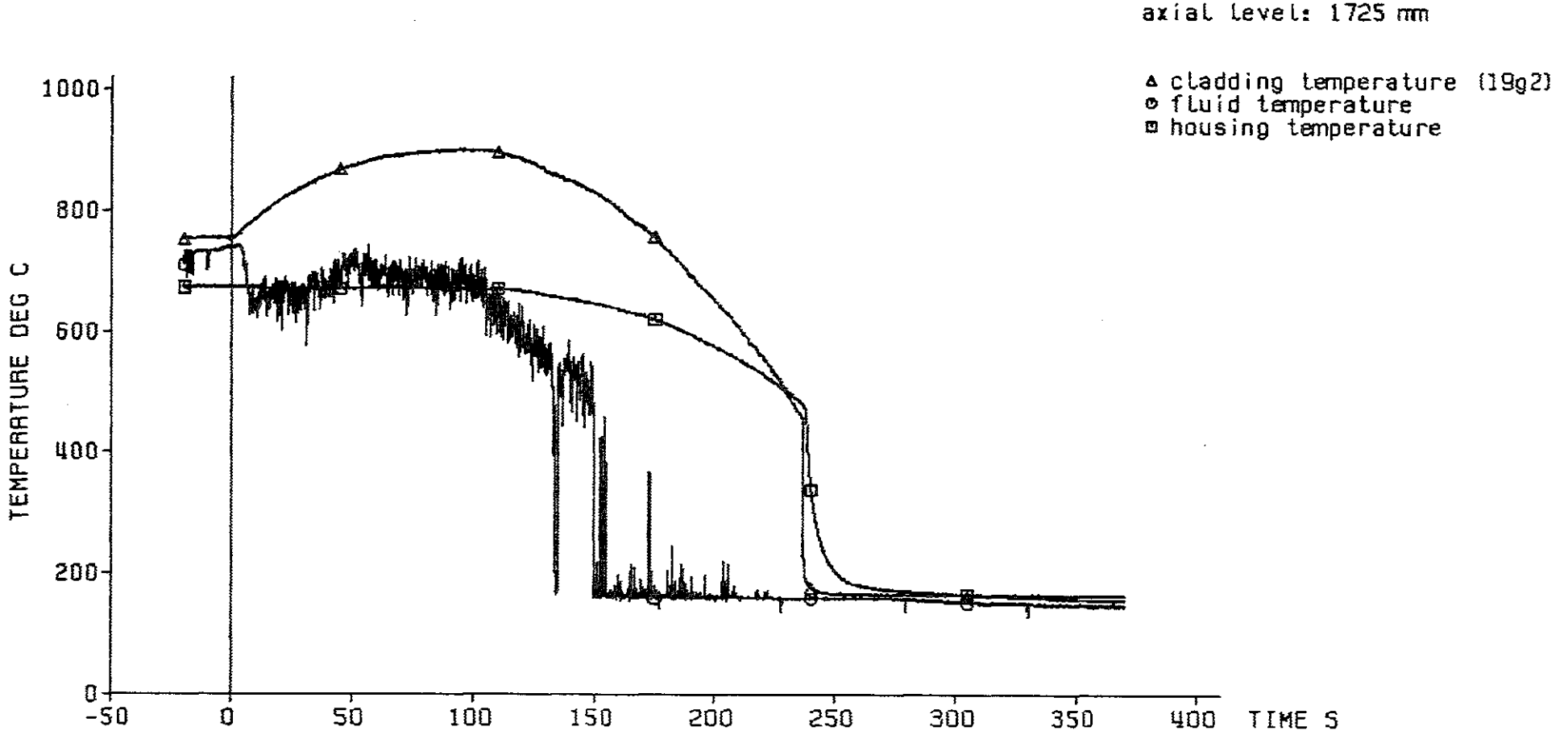
Fig. 142 FEBA: 5x5 ROD BUNDLE, TEST SERIES 2, TEST-No. 231



decay heat	120% ANS standard
flooding rate (cold)	3.80 cm/s
system pressure	6.19 bar
feedwater temperature	40 deg C

KfK IRB

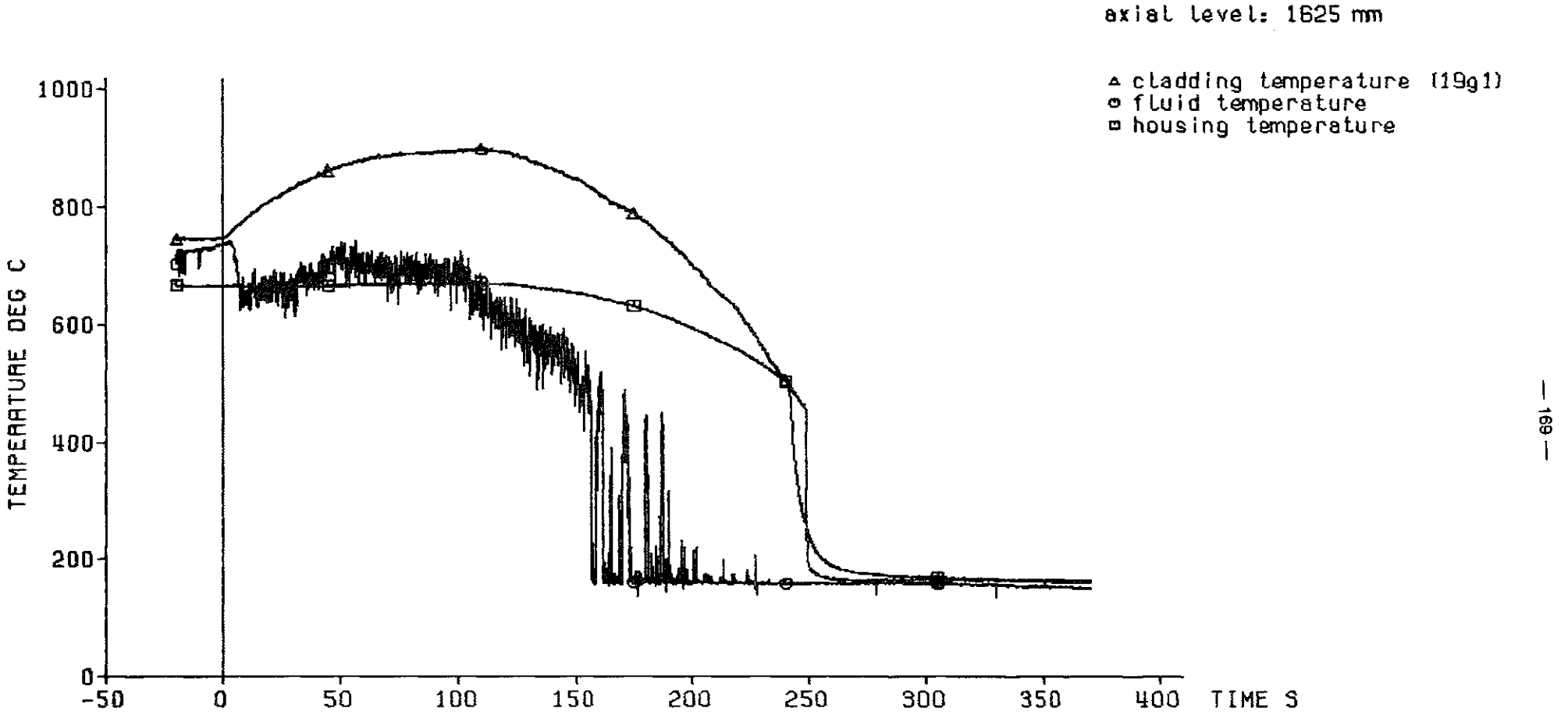
Fig. 143 FEBA: 5x5 ROD BUNDLE, TEST SERIES 2, TEST-No. 231



decay heat	120% ANS standard
flooding rate (cold)	3.80 cm/s
system pressure	6.19 bar
feedwater temperature	40 deg C

KfK IRB

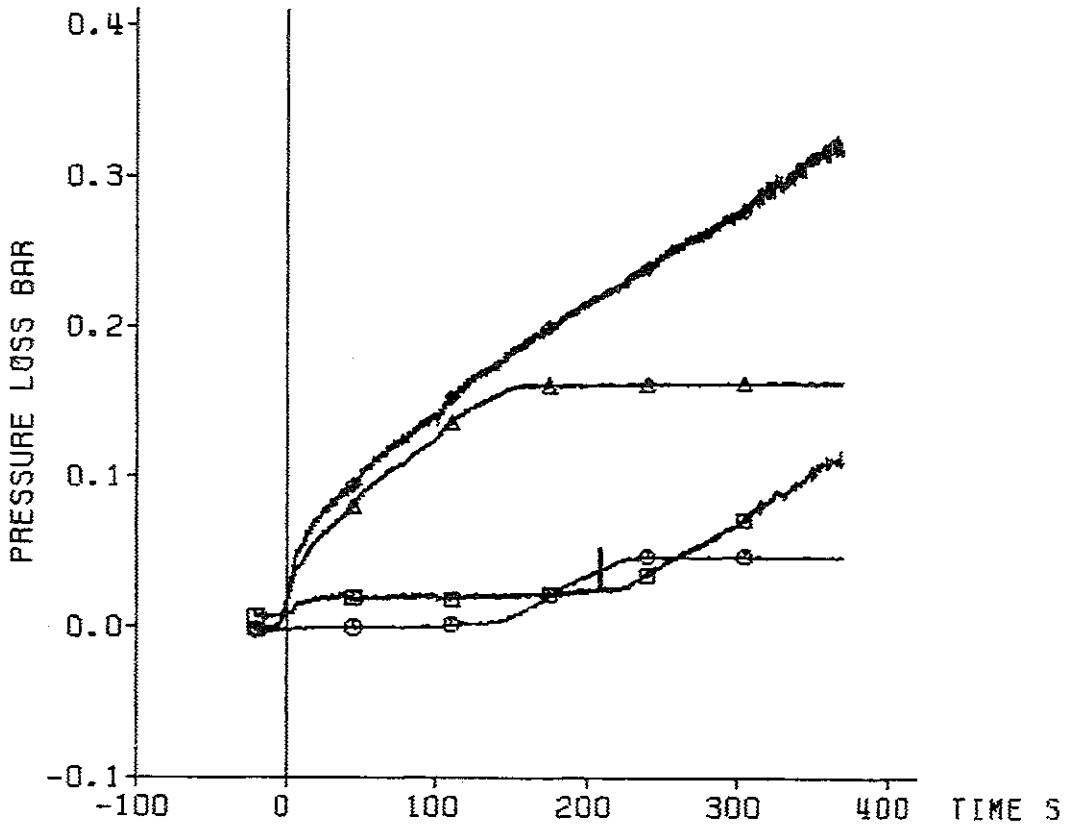
Fig. 144 FEBA: 5x5 ROD BUNDLE, TEST SERIES 2, TEST-No. 231



decay heat	120% ANS standard
flooding rate (cold)	3.80 cm/s
system pressure	6.19 bar
feedwater temperature	40 deg C

KfK IRB

Fig. 145 FEBA: 5x5 ROD BUNDLE, TEST SERIES 2, TEST-No. 231



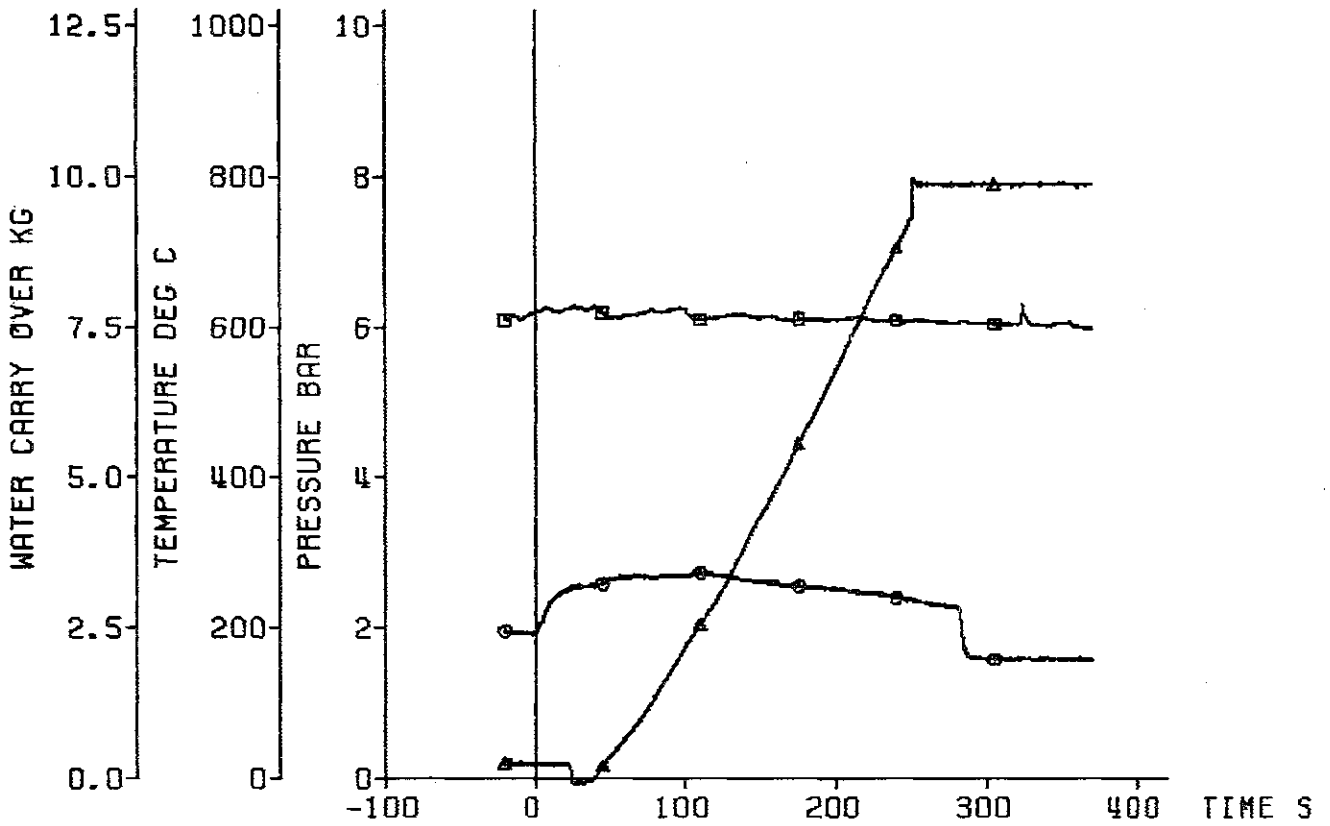
pressure loss
along the test section:

◆ total length: 4196 mm
△ lower part: 1711 mm
○ middle part: 545 mm
□ upper part: 1940 mm

decay heat	120% ANS standard
flooding rate (cold)	3.80 cm/s
system pressure	6.19 bar
feedwater temperature	40 deg C

KfK IRB

Fig. 146 FEBA: 5x5 ROD BUNDLE, TEST SERIES 2, TEST-No. 231

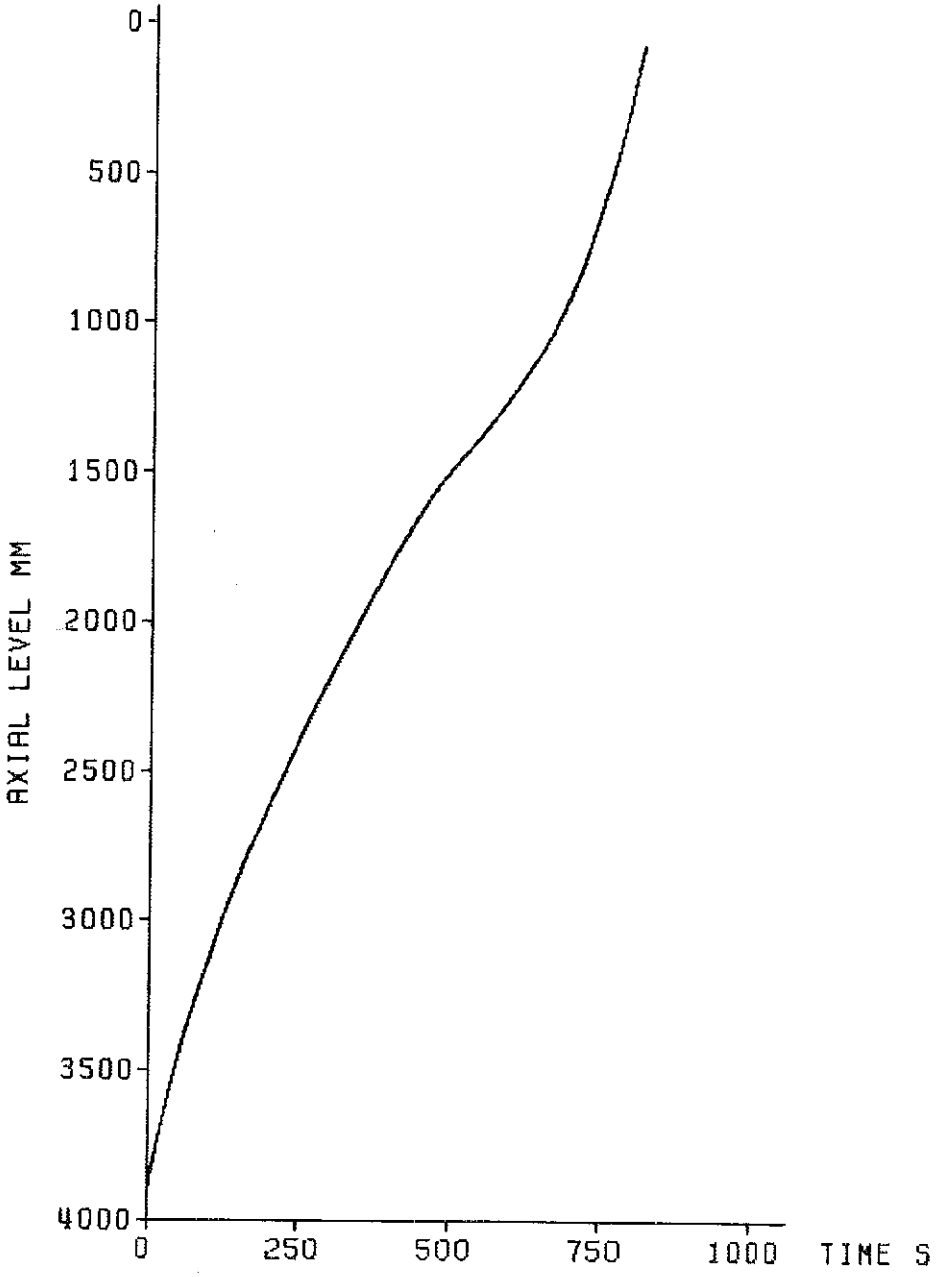


decay heat	120% ANS standard
flooding rate (cold)	3.80 cm/s
system pressure	6.19 bar
feedwater temperature	40 deg C

KfK IRB

Fig. 147 FEBA: 5x5 ROD BUNDLE, TEST SERIES 2, TEST-No. 231

axial position of the quench front

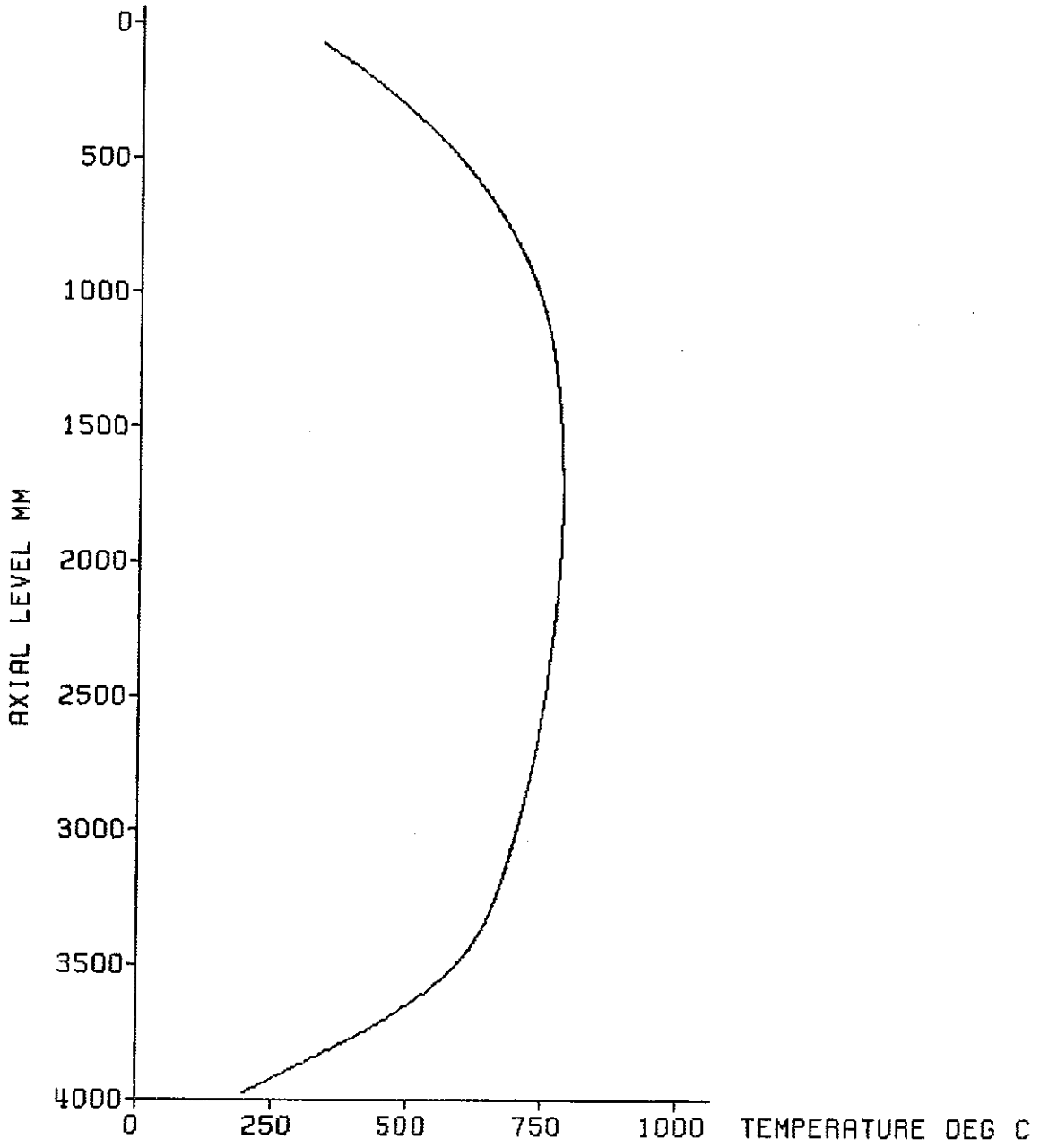


decay heat	120% ANS standard
flooding rate (cold)	3.80 cm/s
system pressure	6.19 bar
feedwater temperature	40 deg C

KfK IRB

Fig. 148 FEBA: 5x5 ROD BUNDLE TEST SERIES 2, TEST-No. 231

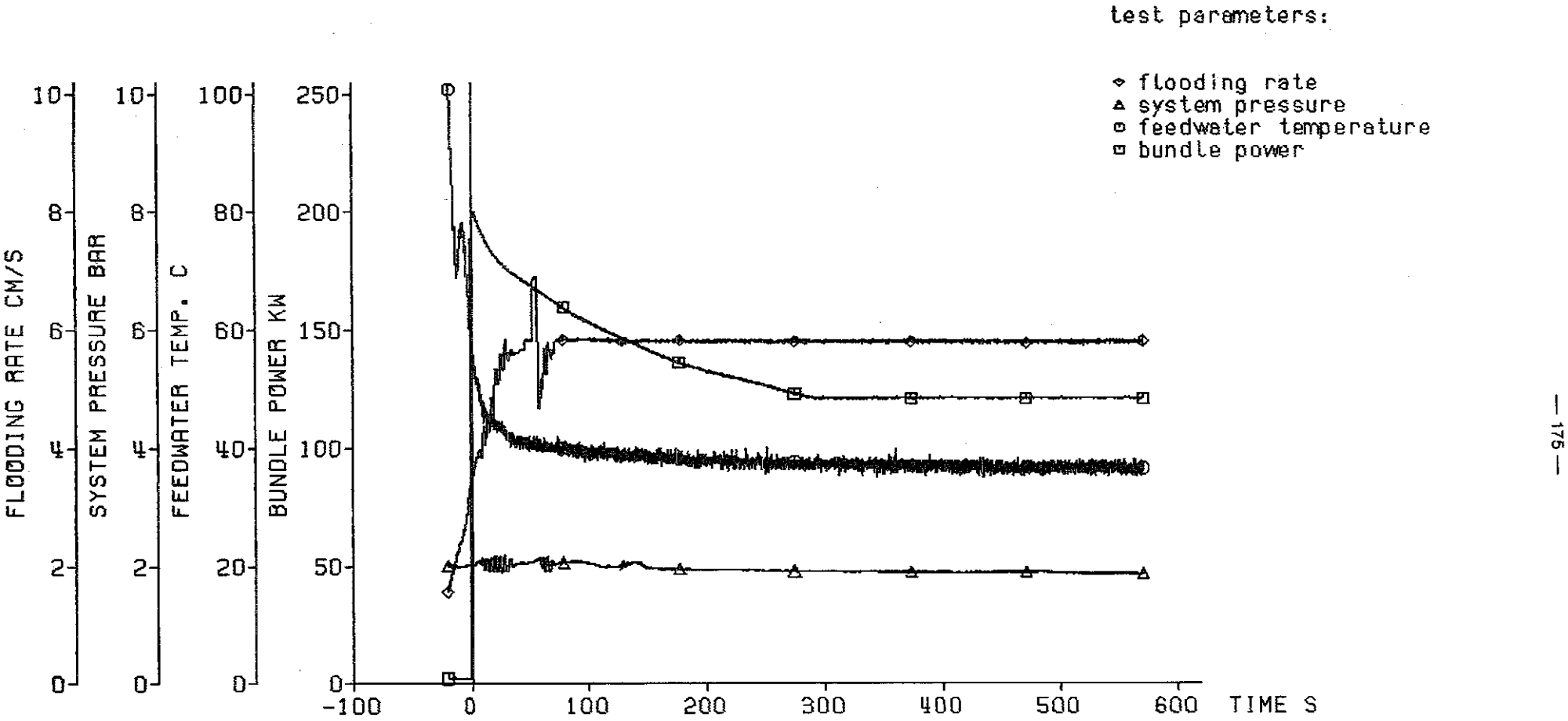
initial axial temperature profile of the cladding



decay heat	120% ANS standard
flooding rate (cold)	5.82 cm/s
system pressure	1.99 bar
feedwater temperature	40 deg C

KfK IRB

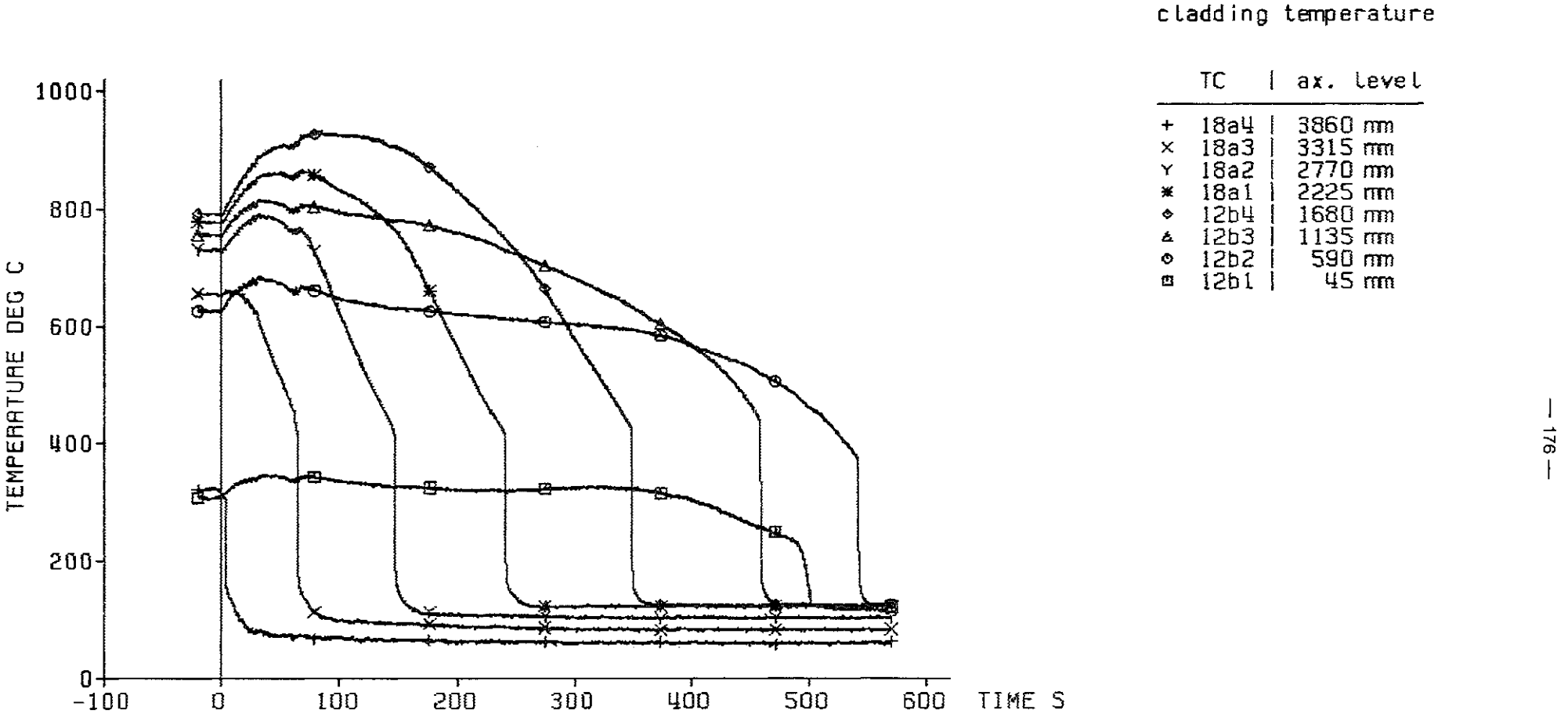
Fig. 149 FEBA: 5x5 ROD BUNDLE TEST SERIES 2, TEST-No. 233



decay heat	120% ANS standard
flooding rate (cold)	5.82 cm/s
system pressure	1.99 bar
feedwater temperature	40 deg C

KfK IRB

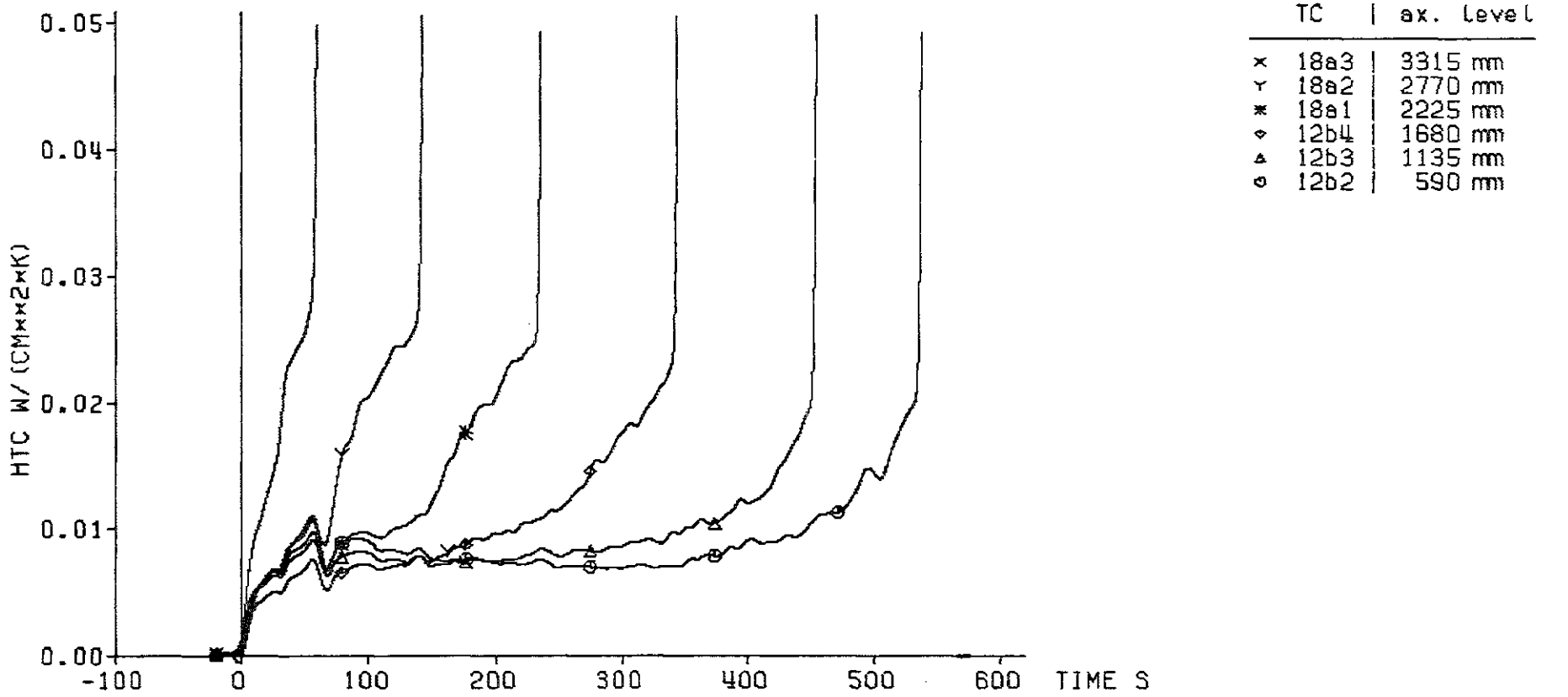
Fig. 150 FEBA: 5x5 ROD BUNDLE, TEST SERIES 2, TEST-No. 233



decay heat	120% ANS standard
flooding rate (cold)	5.82 cm/s
system pressure	1.99 bar
feedwater temperature	40 deg C

KfK IRB

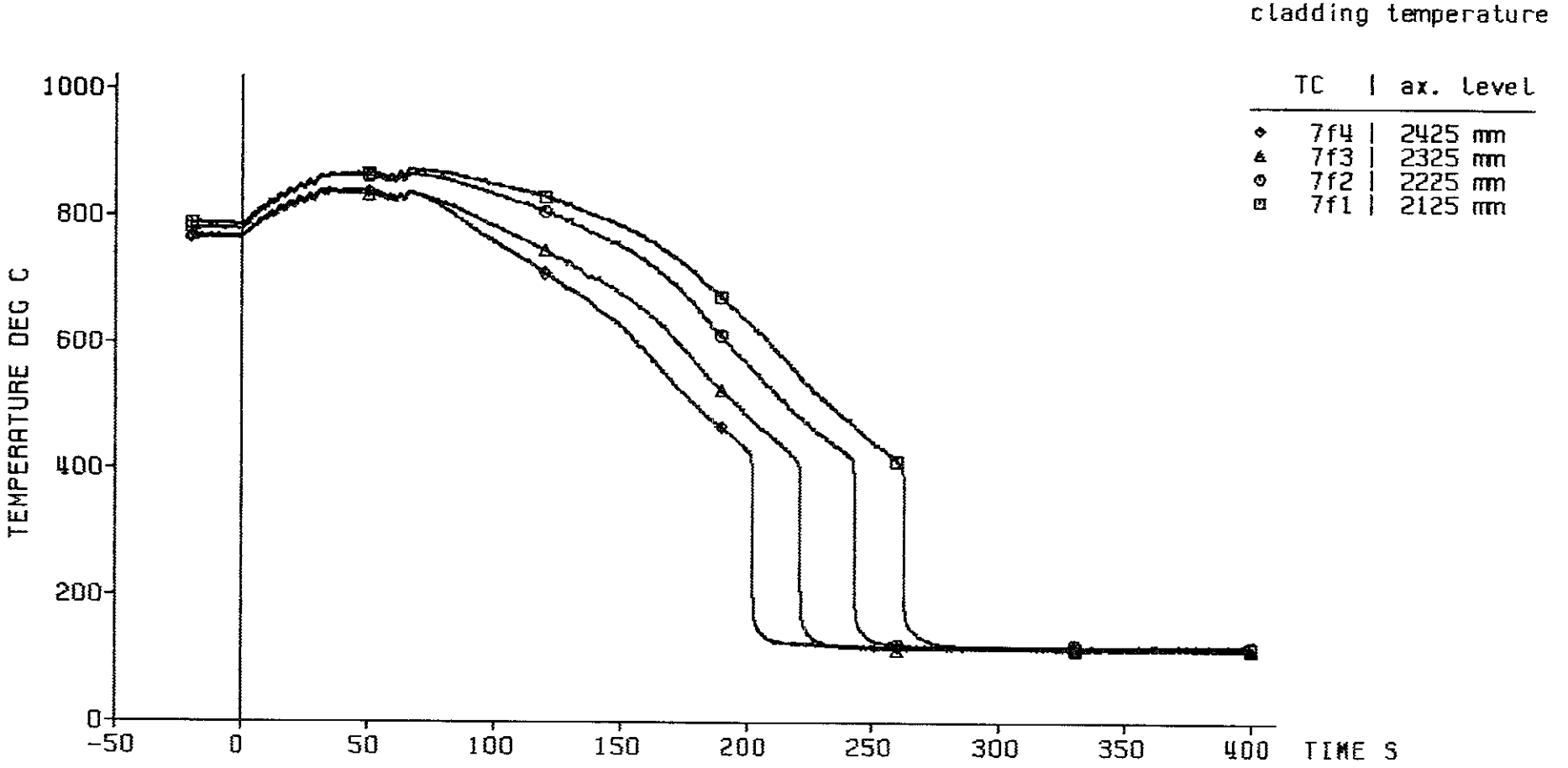
Fig. 151 FEBA: 5x5 ROD BUNDLE, TEST SERIES 2, TEST-No. 233



decay heat	120% ANS standard
flooding rate (cold)	5.82 cm/s
system pressure	1.99 bar
feedwater temperature	40 deg C

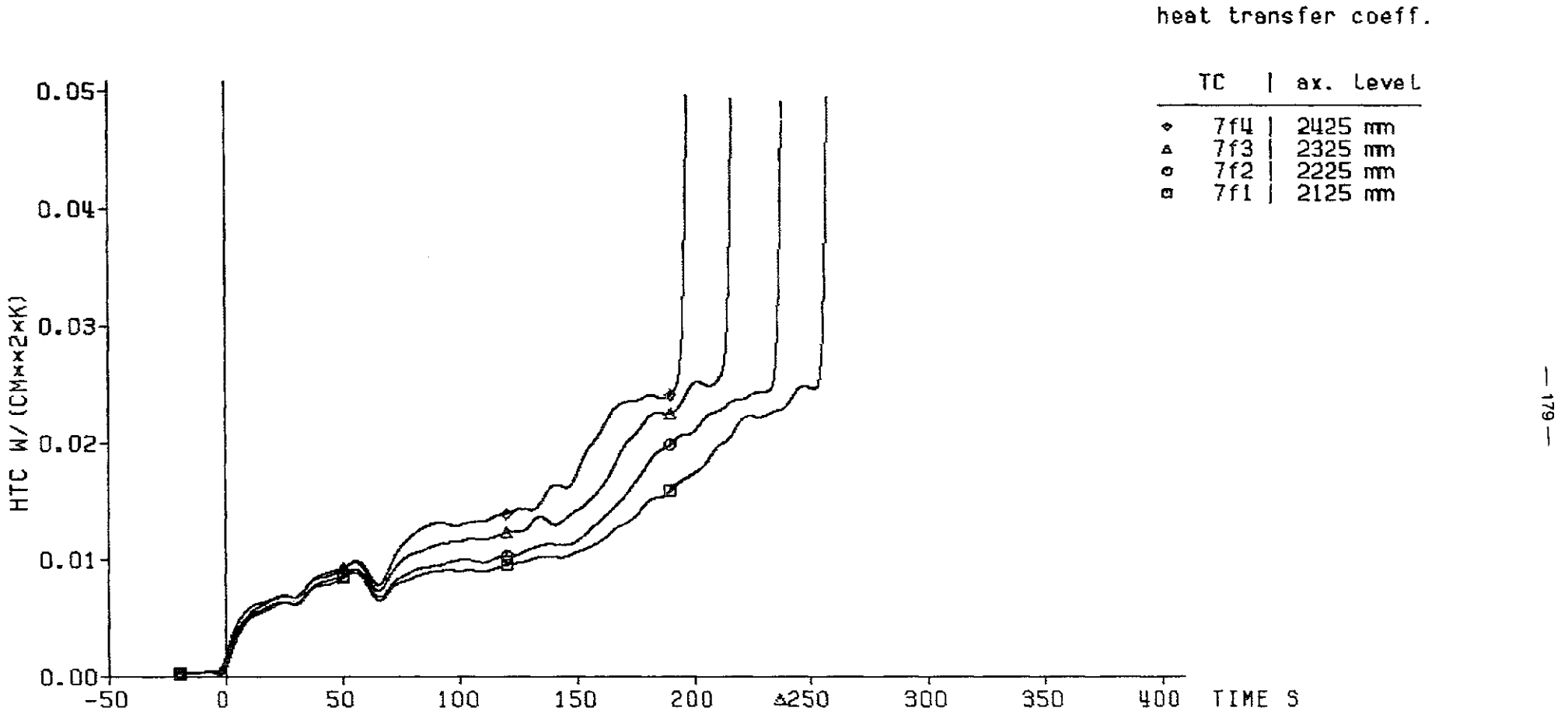
KfK IRB

Fig. 152 FEBA: 5x5 ROD BUNDLE, TEST SERIES 2, TEST-No. 233



decay heat	120% ANS standard
flooding rate (cold)	5.82 cm/s
system pressure	1.99 bar
feedwater temperature	40 deg C

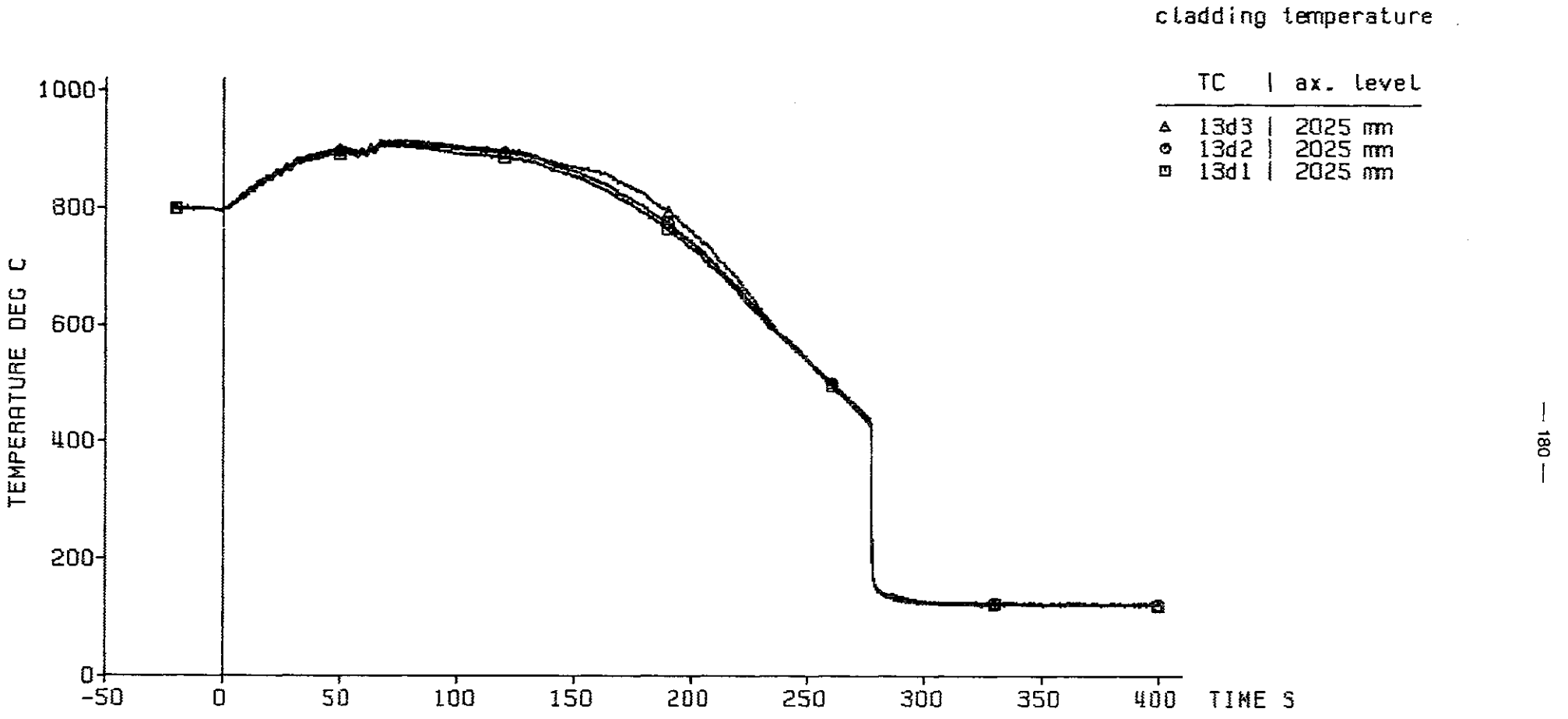
Fig. 153 FEBA: 5x5 ROD BUNDLE, TEST SERIES 2, TEST-No. 233



decay heat	120% ANS standard
flooding rate (cold)	5.82 cm/s
system pressure	1.99 bar
feedwater temperature	40 deg C

KfK IRB

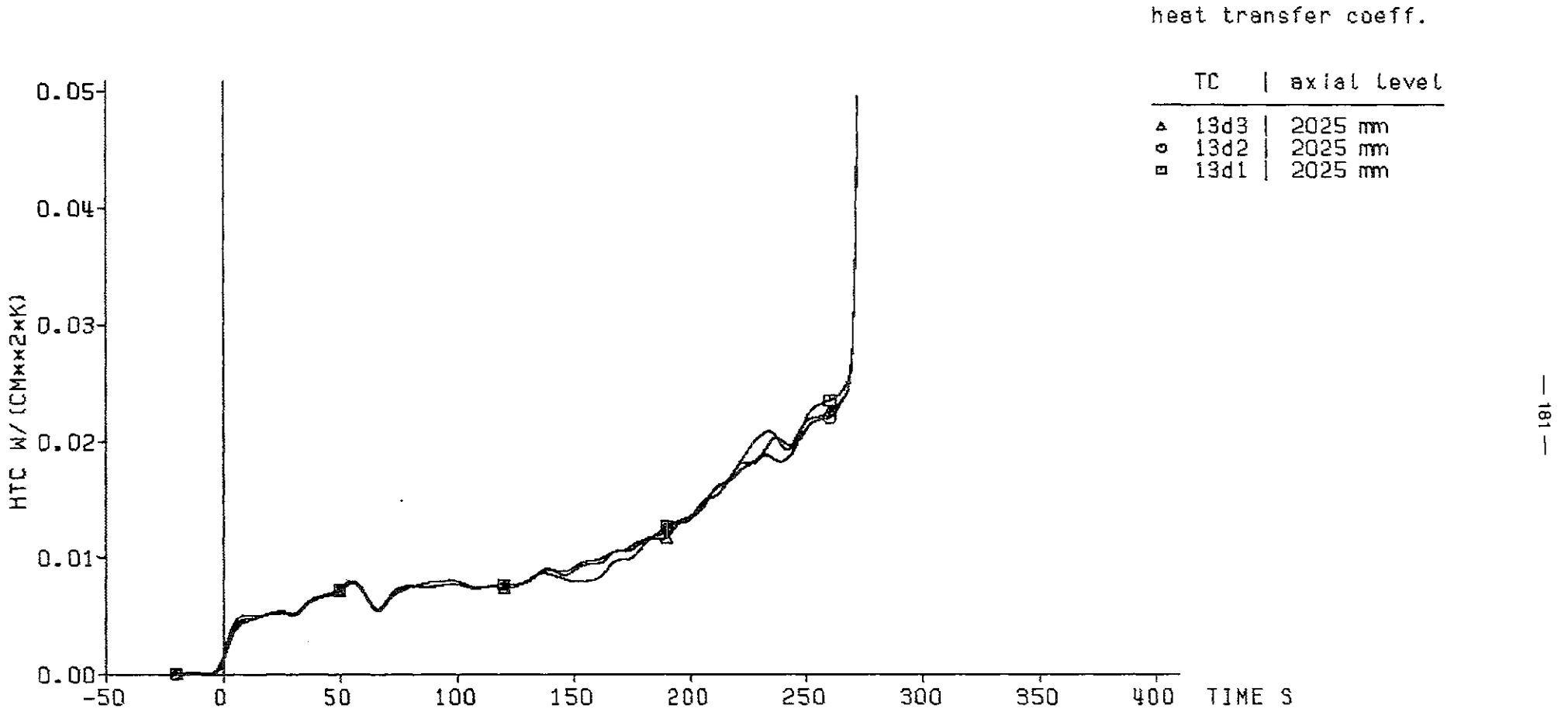
Fig. 154 FEBA: 5x5 ROD BUNDLE, TEST SERIES 2, TEST-No. 233



decay heat	120% ANS standard
flooding rate (cold)	5.82 cm/s
system pressure	1.99 bar
feedwater temperature	40 deg C

KfK IRB

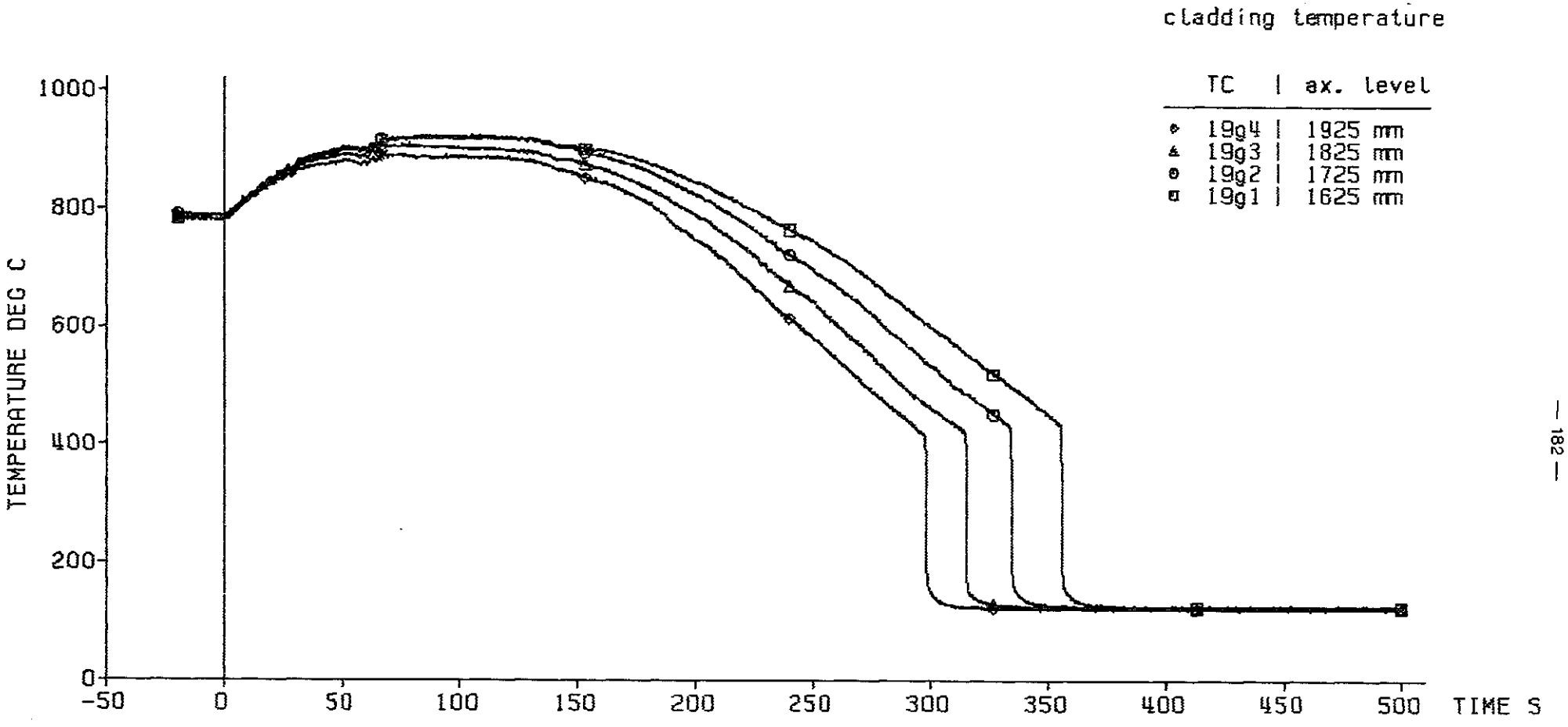
Fig. 155 FEBA: 5x5 ROD BUNDLE, TEST SERIES 2, TEST-No. 233



decay heat	120% ANS standard
flooding rate (cold)	5.82 cm/s
system pressure	1.99 bar
feedwater temperature	40 deg C

KfK IRB

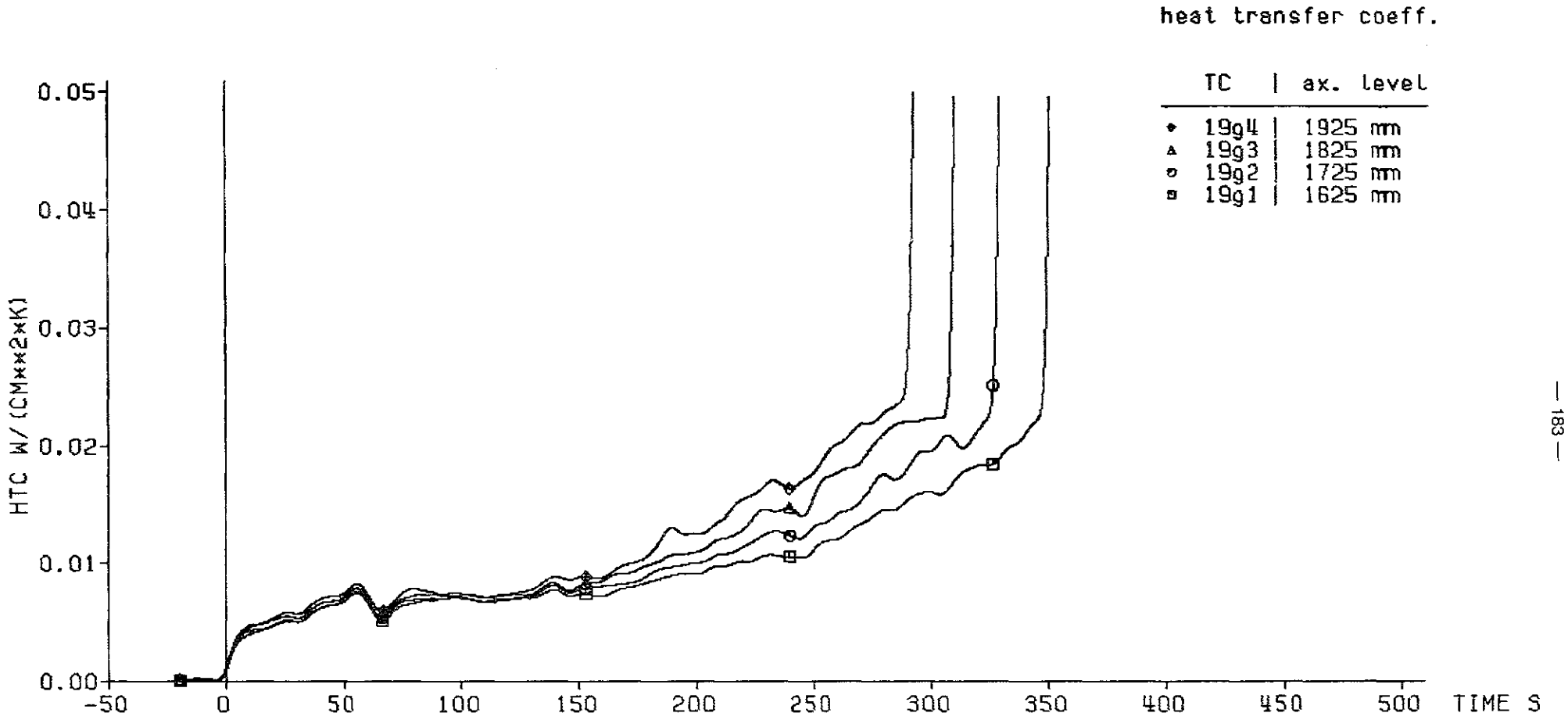
Fig. 156 FEBA: 5x5 ROD BUNDLE, TEST SERIES 2, TEST-No. 233



decay heat	120% ANS standard
flooding rate (cold)	5.82 cm/s
system pressure	1.99 bar
feedwater temperature	40 deg C

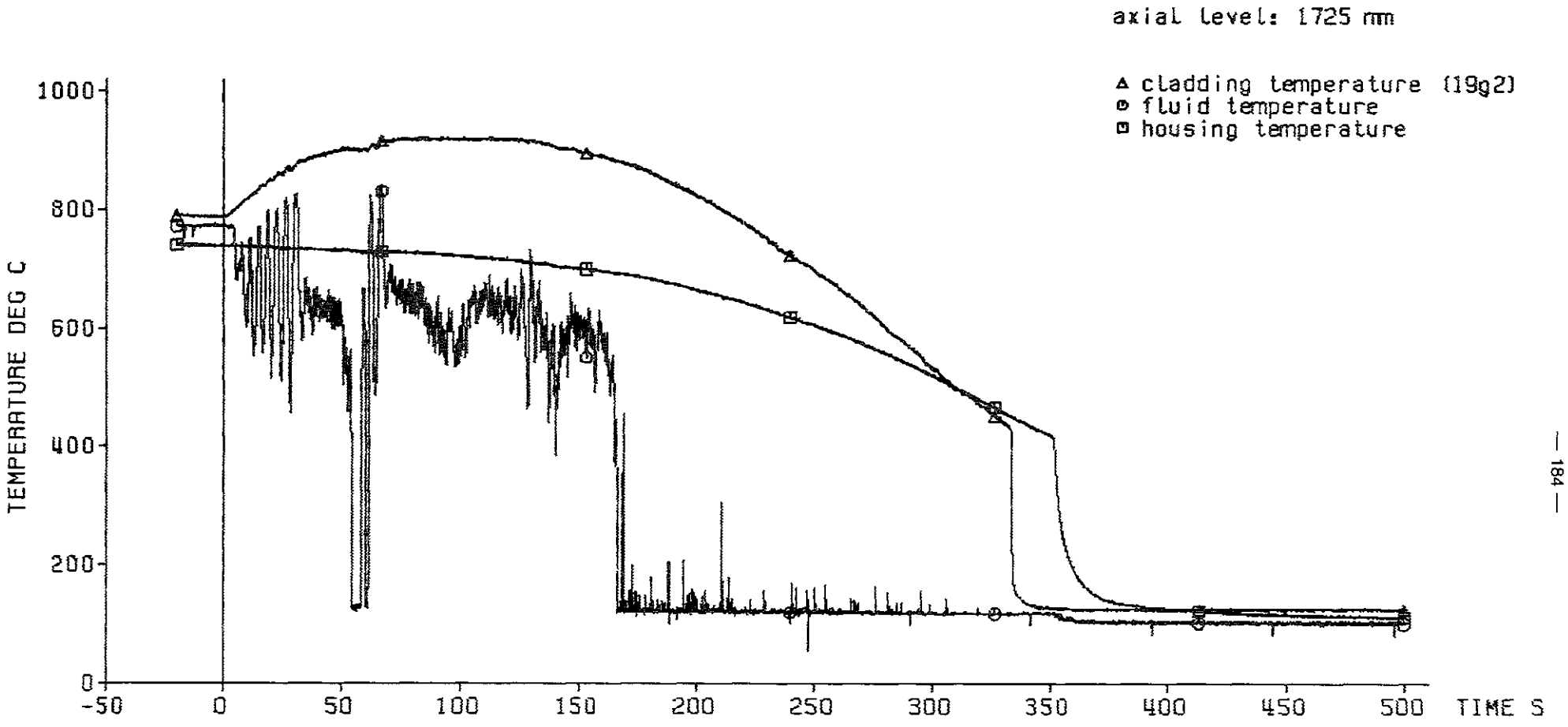
KfK IRB

Fig. 157 FEBA: 5x5 ROD BUNDLE, TEST SERIES 2, TEST-No. 233



decay heat	120% ANS standard
flooding rate (cold)	5.82 cm/s
system pressure	1.99 bar
feedwater temperature	40 deg C

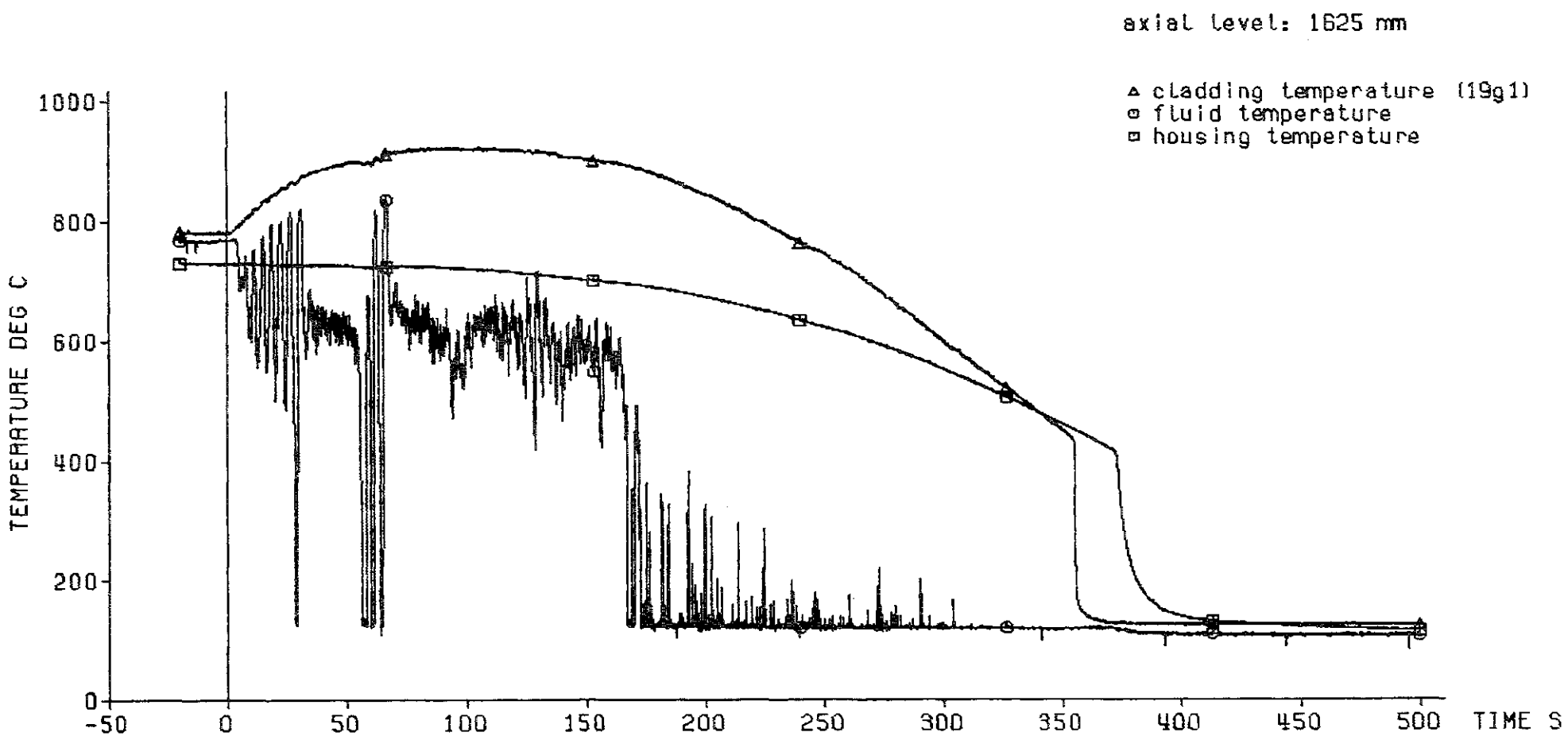
Fig. 158 FEBA: 5x5 ROD BUNDLE, TEST SERIES 2, TEST-No. 233



decay heat	120% ANS standard
flooding rate (cold)	5.82 cm/s
system pressure	1.99 bar
feedwater temperature	40 deg C

KfK IRB

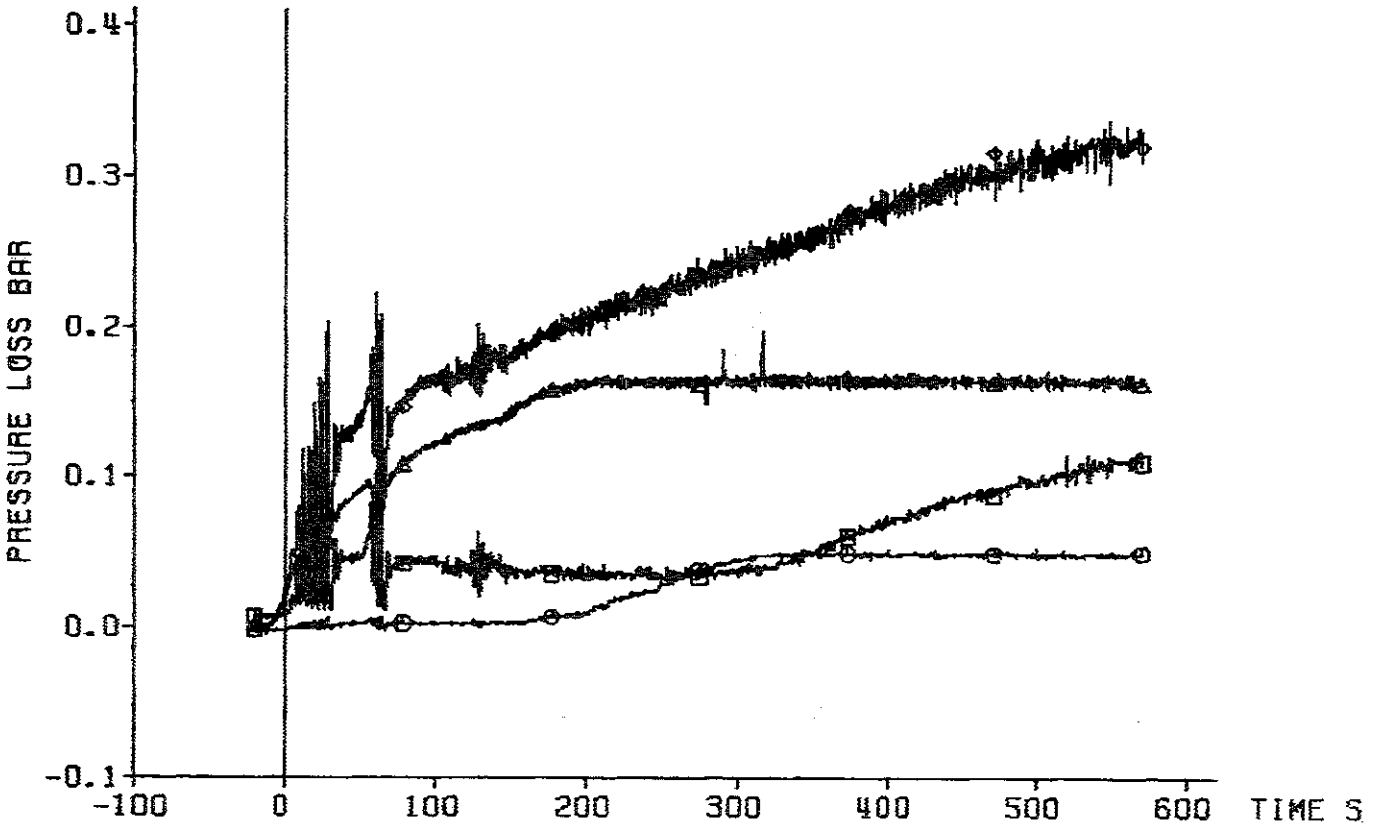
Fig. 159 FEBA: 5x5 ROD BUNDLE, TEST SERIES 2, TEST-No. 233



decay heat	120% ANS standard
flooding rate (cold)	5.82 cm/s
system pressure	1.99 bar
feedwater temperature	40 deg C

KfK IRB

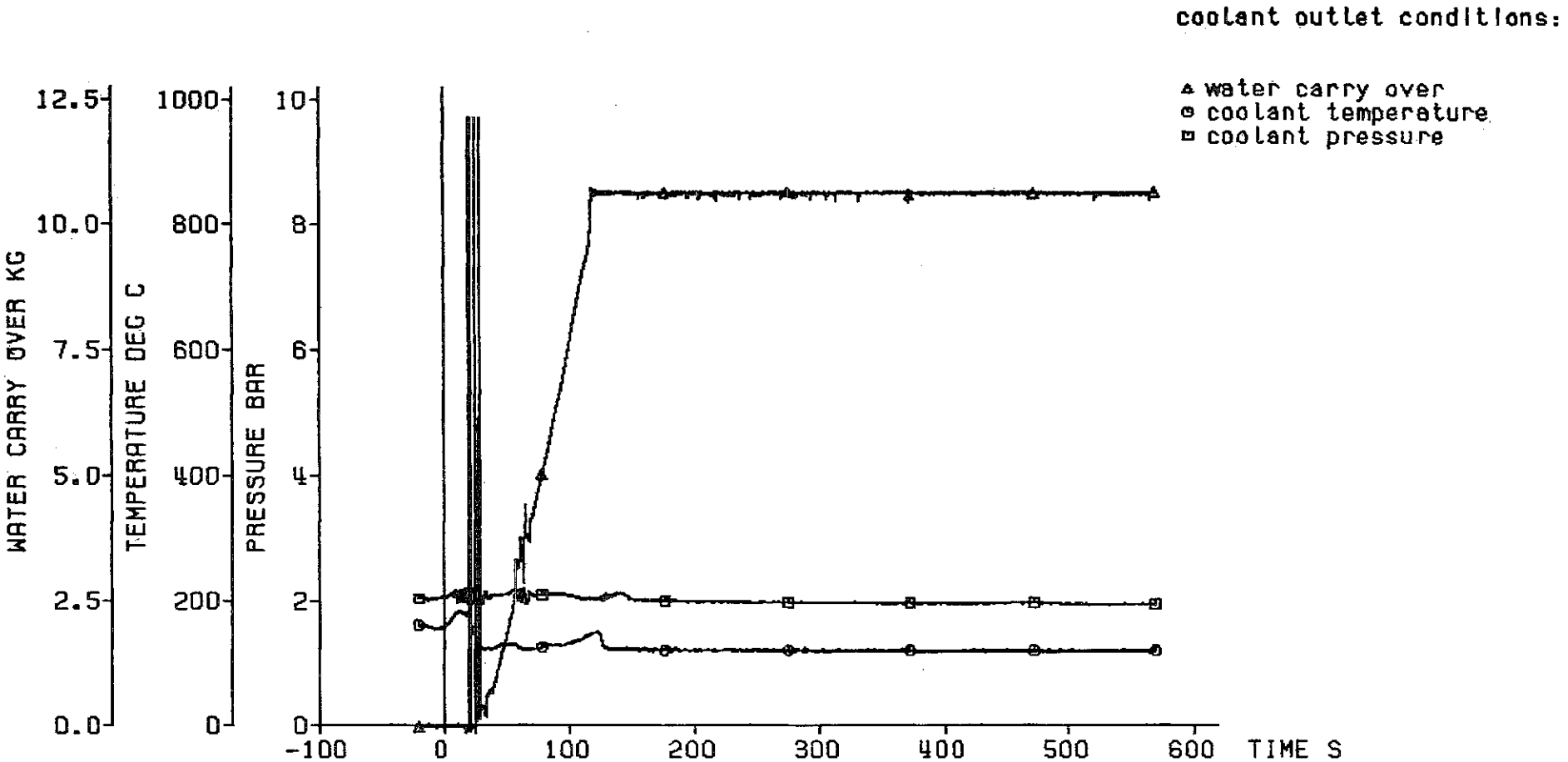
Fig. 160 FEBA: 5x5 ROD BUNDLE, TEST SERIES 2, TEST-No. 233



decay heat	120% ANS standard
flooding rate (cold)	5.82 cm/s
system pressure	1.99 bar
feedwater temperature	40 deg C

KfK IRB

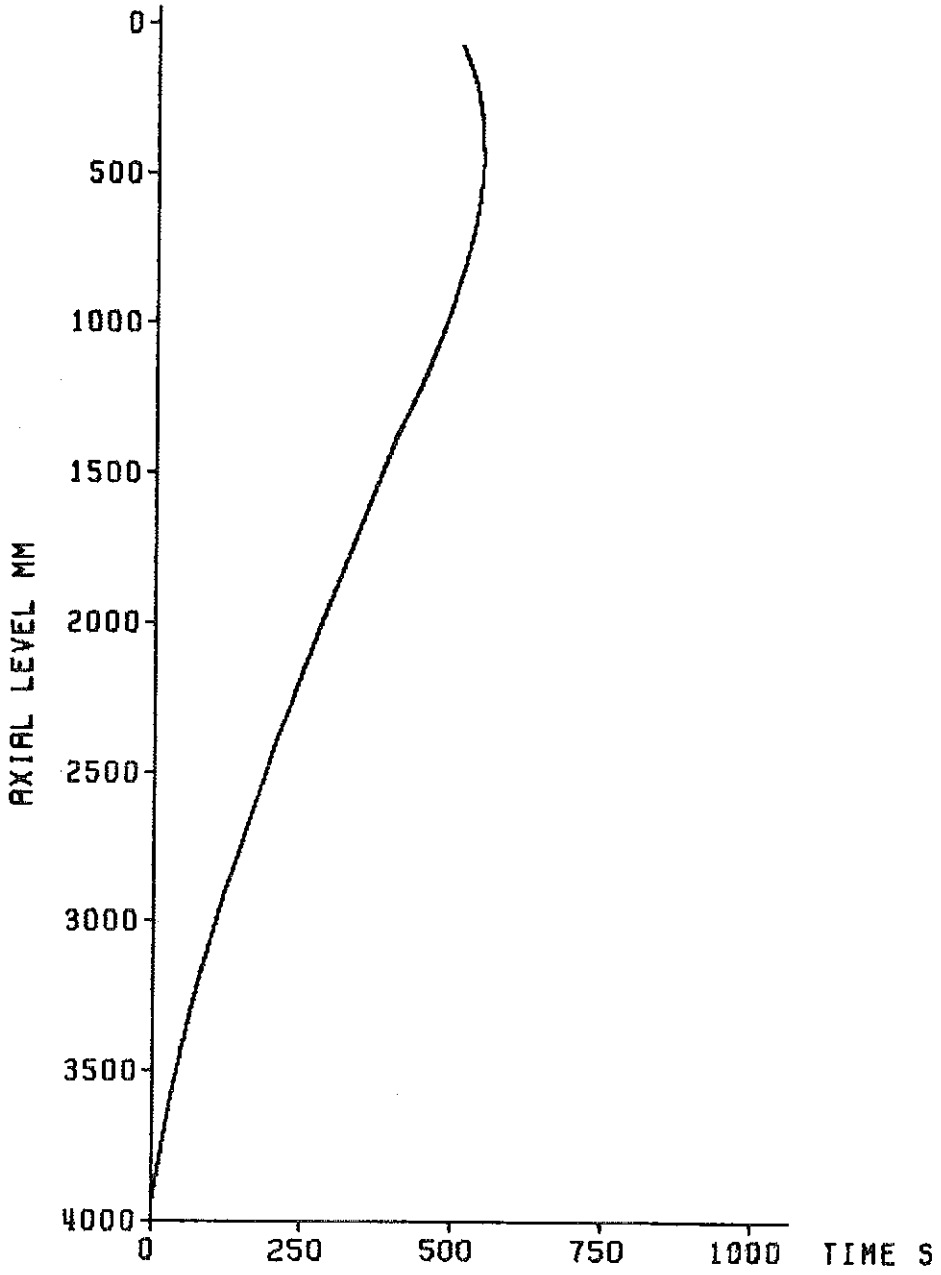
Fig. 161 FEBA: 5x5 ROD BUNDLE, TEST SERIES 2, TEST-No. 233



decay heat	120% ANS standard
flooding rate (cold)	5.82 cm/s
system pressure	1.99 bar
feedwater temperature	40 deg C

Fig. 162 FEBA: 5x5 ROD BUNDLE, TEST SERIES 2, TEST-No. 233

axial position of the quench front

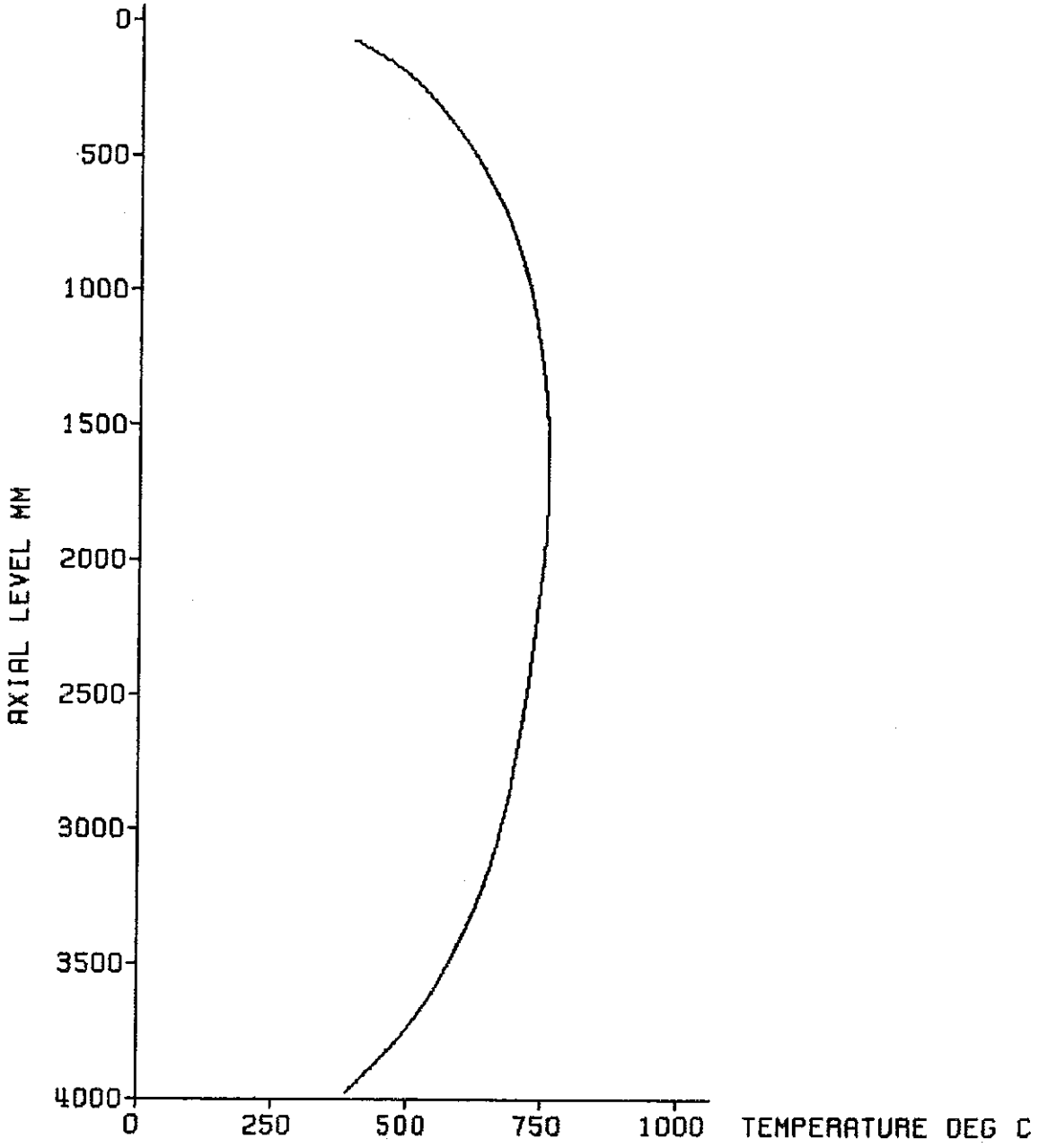


decay heat	120% ANS standard
flooding rate (cold)	5.82 cm/s
system pressure	1.99 bar
feedwater temperature	40 deg C

KfK IRB

Fig. 163 FEBA: 5x5 ROD BUNDLE TEST SERIES 2, TEST-No. 233

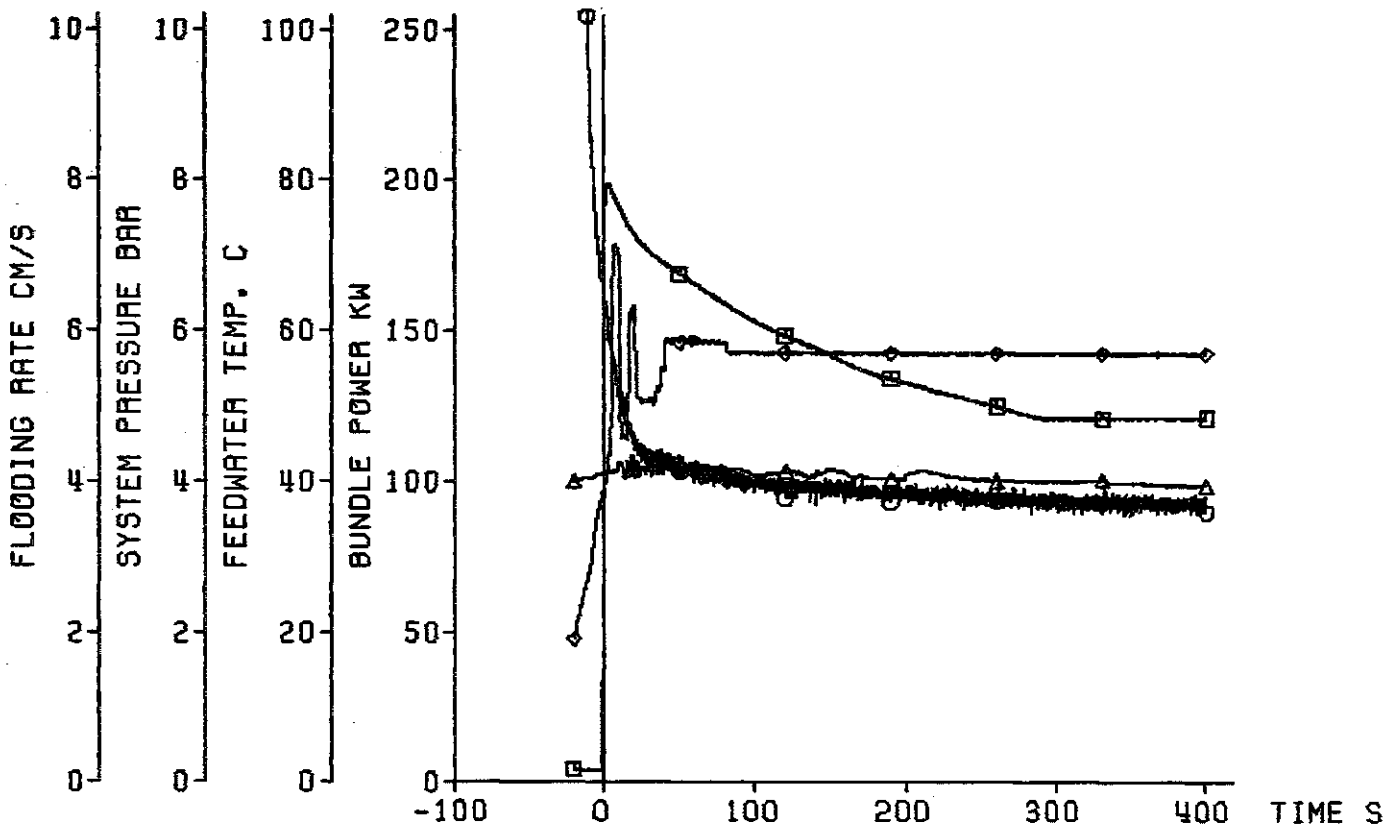
initial axial temperature profile of the cladding



decay heat	120% ANS standard
flooding rate (cold)	5.72 cm/s
system pressure	4.11 bar
feedwater temperature	40 deg C

KfK IRB

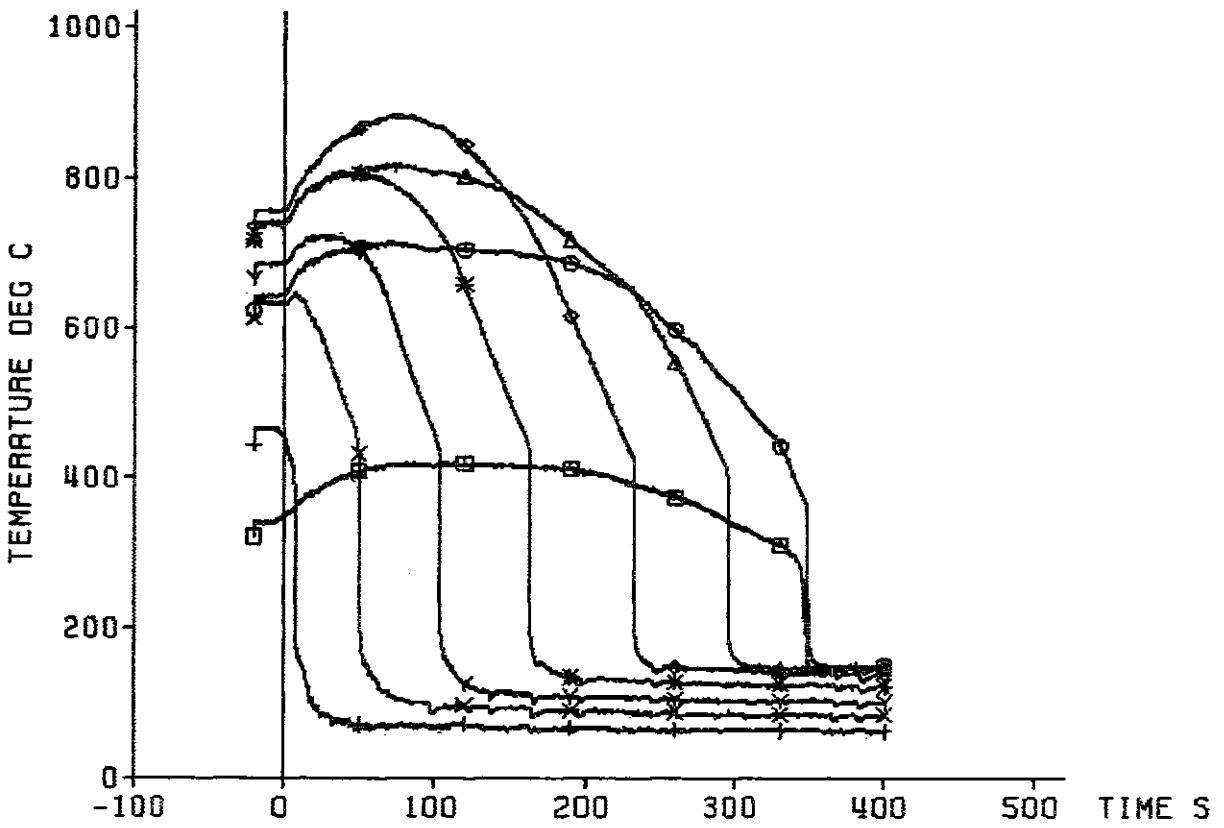
Fig. 164 FEBA: 5x5 ROD BUNDLE TEST SERIES 2, TEST-No. 228



decay heat	120% ANS standard
flooding rate (cold)	5.72 cm/s
system pressure	4.11 bar
feedwater temperature	40 deg C

KfK IRB

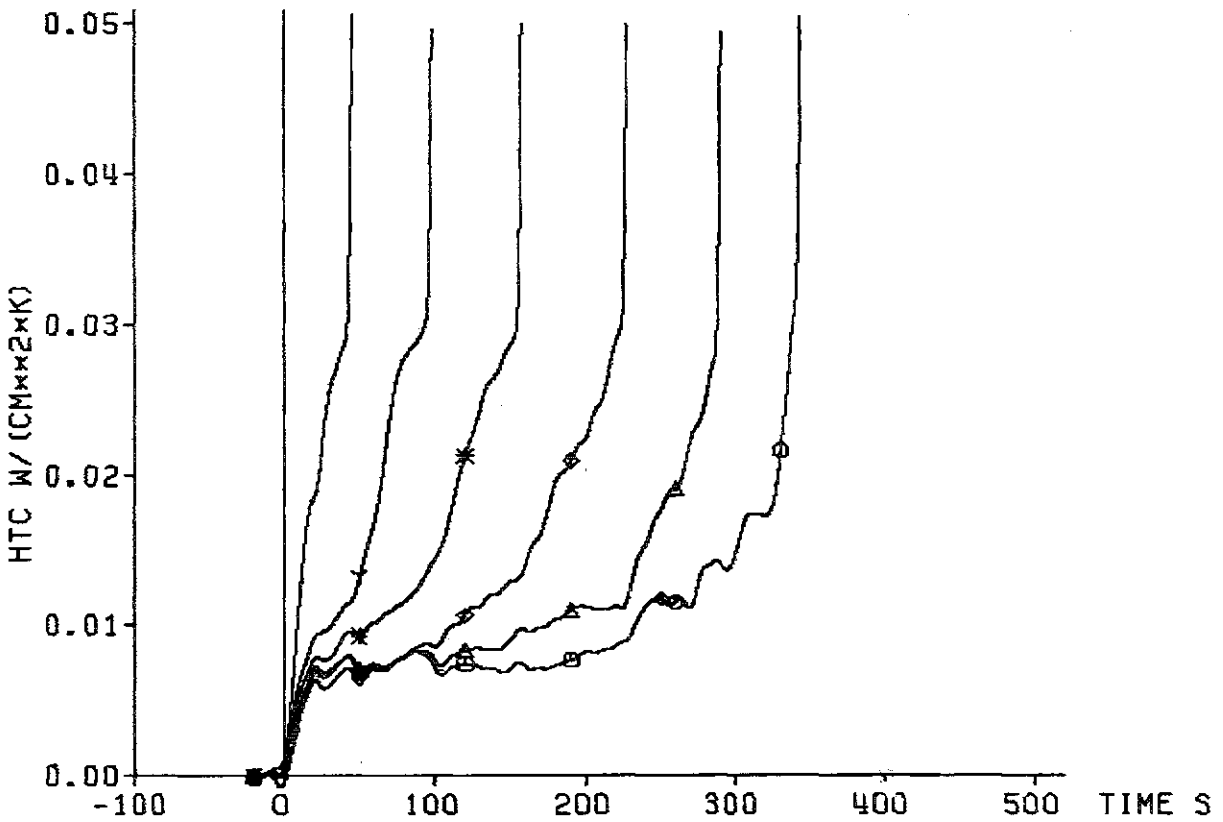
Fig. 165 FEBA: 5x5 ROD BUNDLE, TEST SERIES 2, TEST-No. 228



decay heat	120% ANS standard
flooding rate (cold)	5.72 cm/s
system pressure	4.11 bar
feedwater temperature	40 deg C

KfK IRB

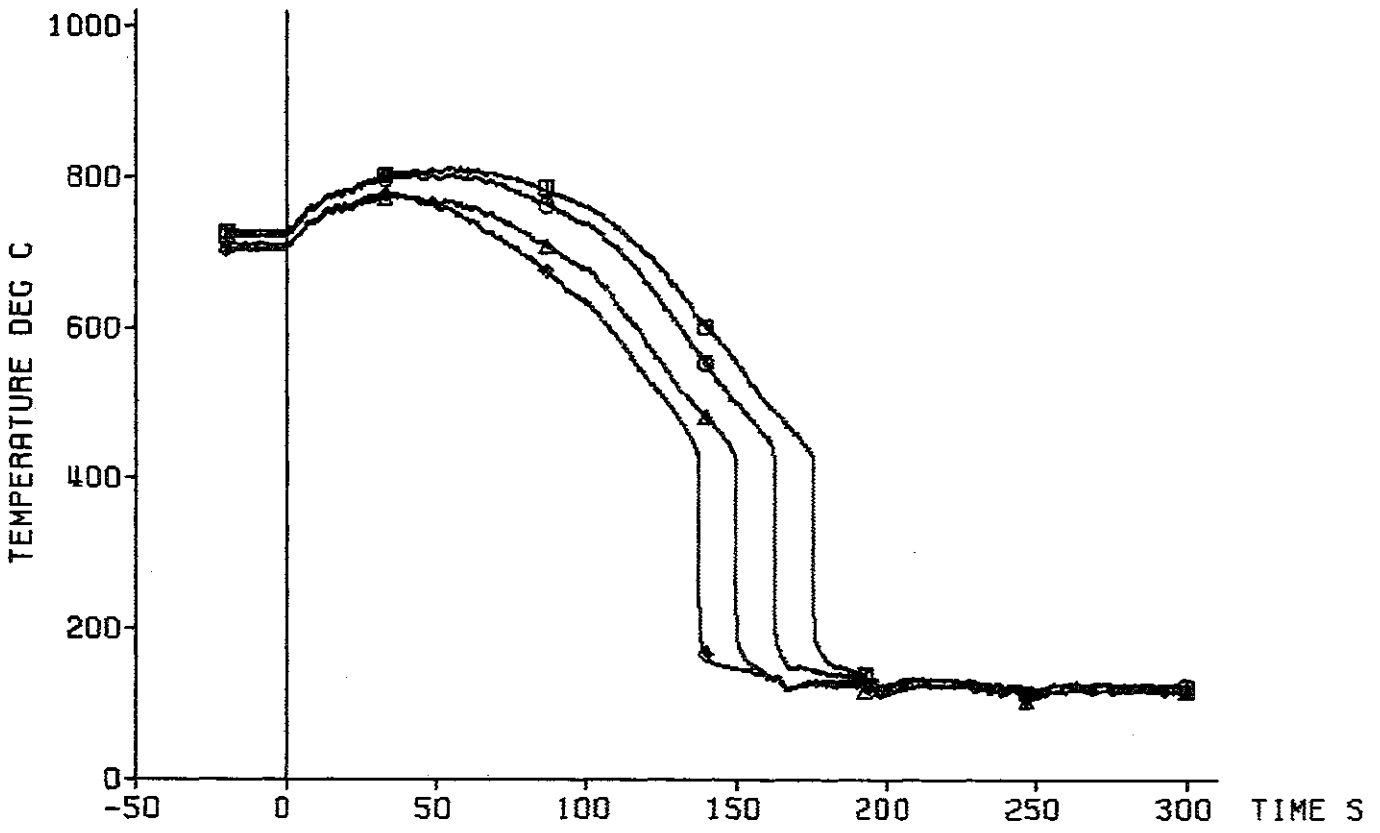
Fig. 166 FEBA: 5x5 ROD BUNDLE, TEST SERIES 2, TEST-No. 228



decay heat	120% ANS standard
flooding rate (cold)	5.72 cm/s
system pressure	4.11 bar
feedwater temperature	40 deg C

KfK IRB

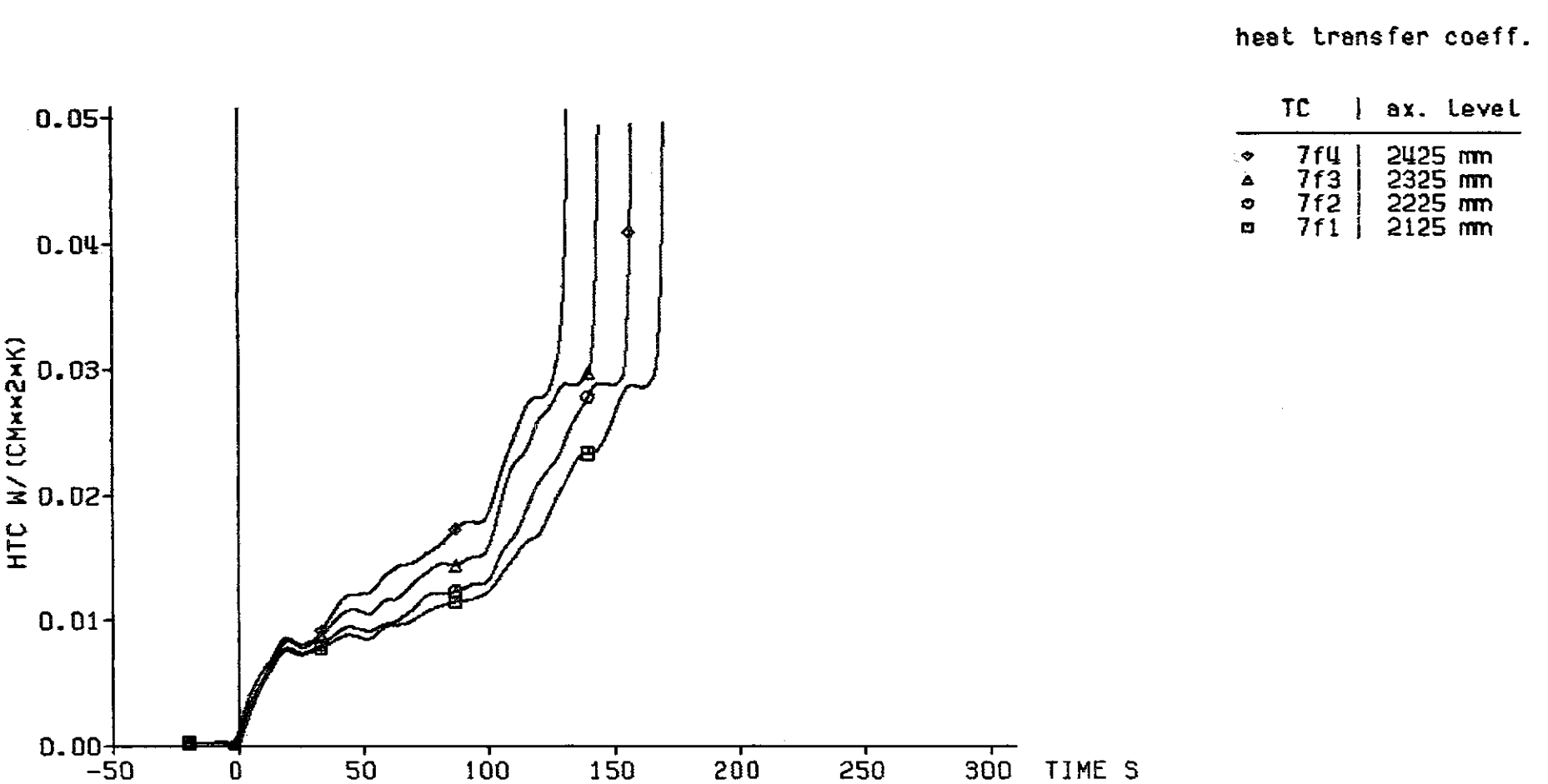
Fig. 167 FEBA: 5x5 ROD BUNDLE, TEST SERIES 2, TEST-No. 228



decay heat	120% ANS standard
flooding rate (cold)	5.72 cm/s
system pressure	4.11 bar
feedwater temperature	40 deg C

KfK IRB

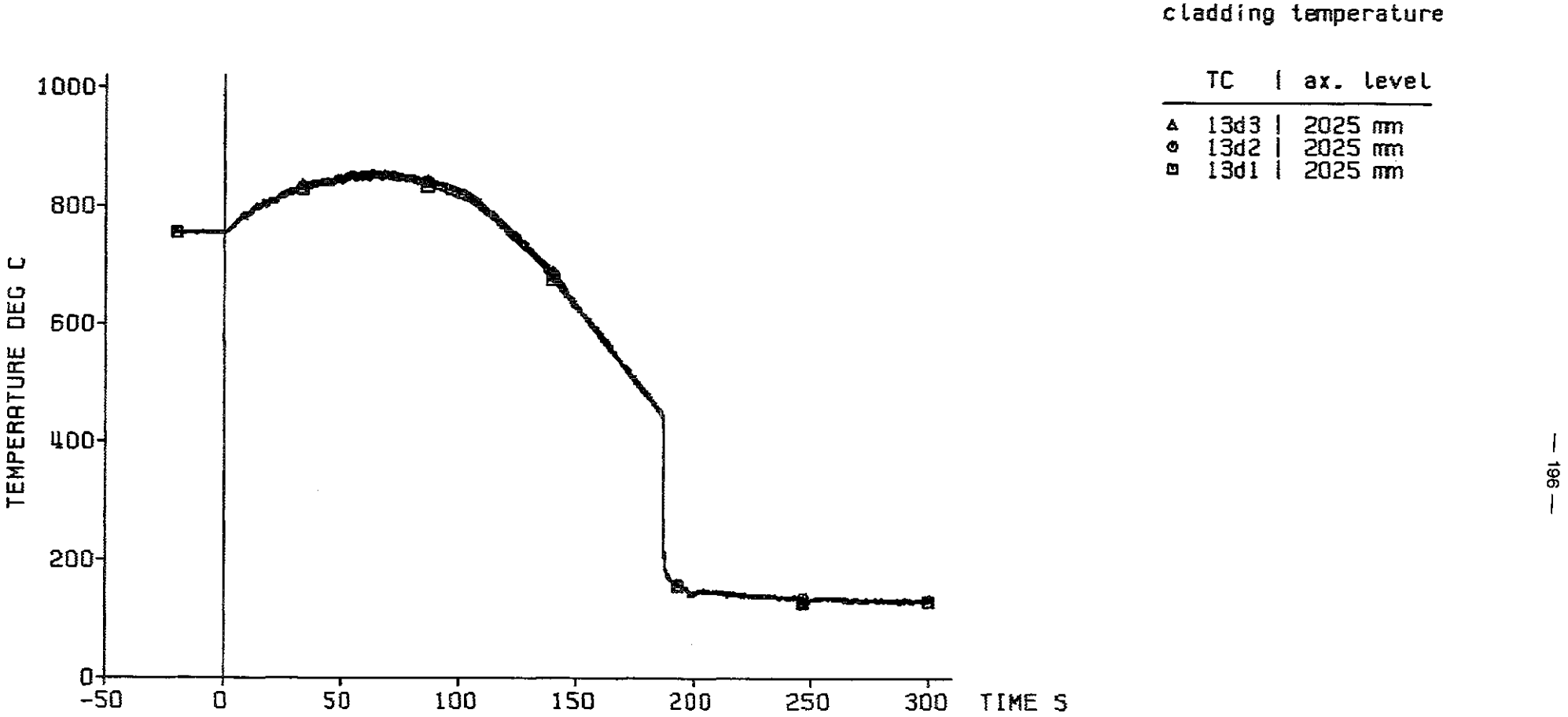
Fig. 168 FEBA: 5x5 ROD BUNDLE, TEST SERIES 2, TEST-No. 228



decay heat	120% ANS standard
flooding rate (cold)	5.72 cm/s
system pressure	4.11 bar
feedwater temperature	40 deg C

KfK IRB

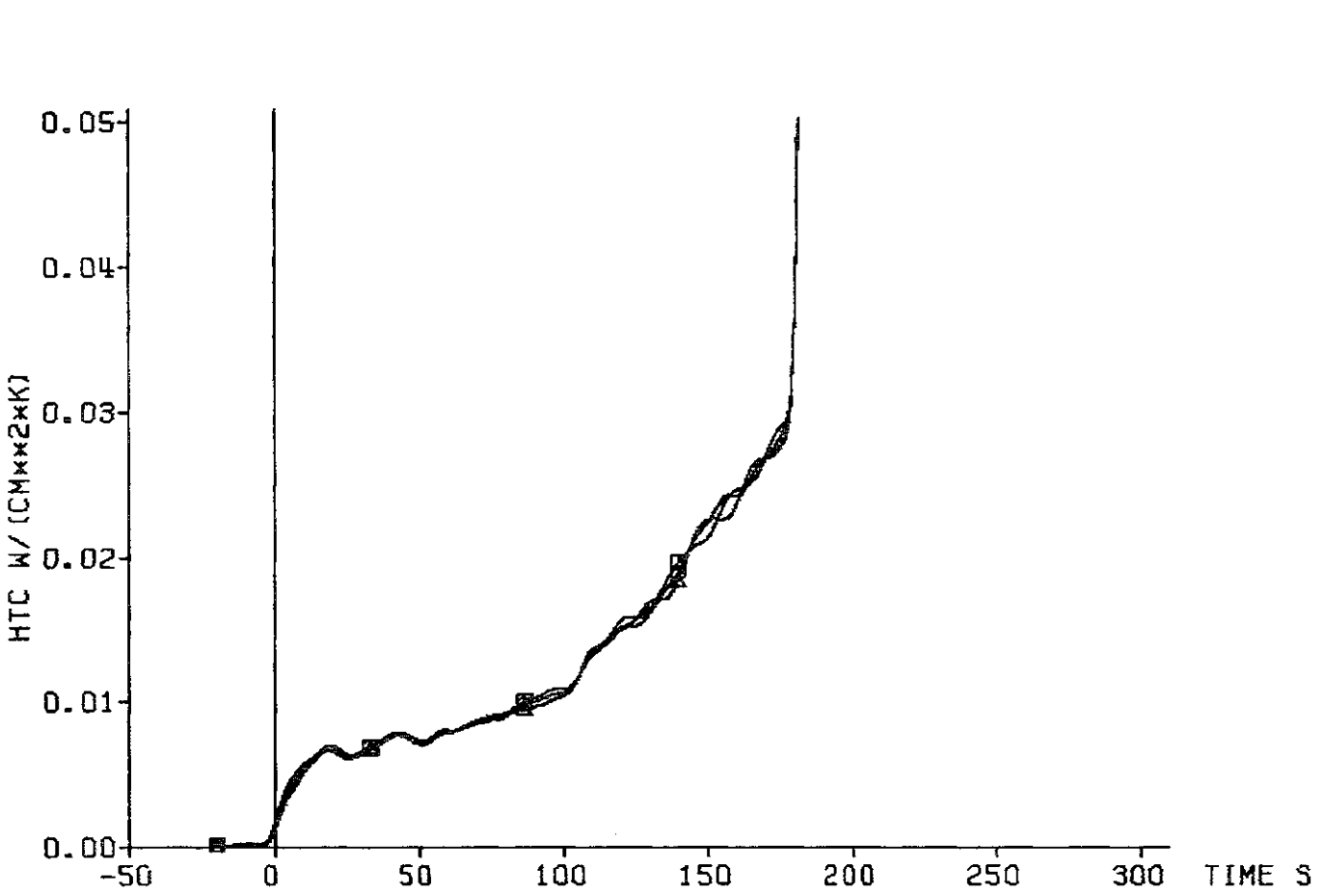
Fig. 169 FEBA: 5x5 ROD BUNDLE, TEST SERIES 2, TEST-No. 228



decay heat	120% ANS standard
flooding rate (cold)	5.72 cm/s
system pressure	4.11 bar
feedwater temperature	40 deg C

KfK ITRB

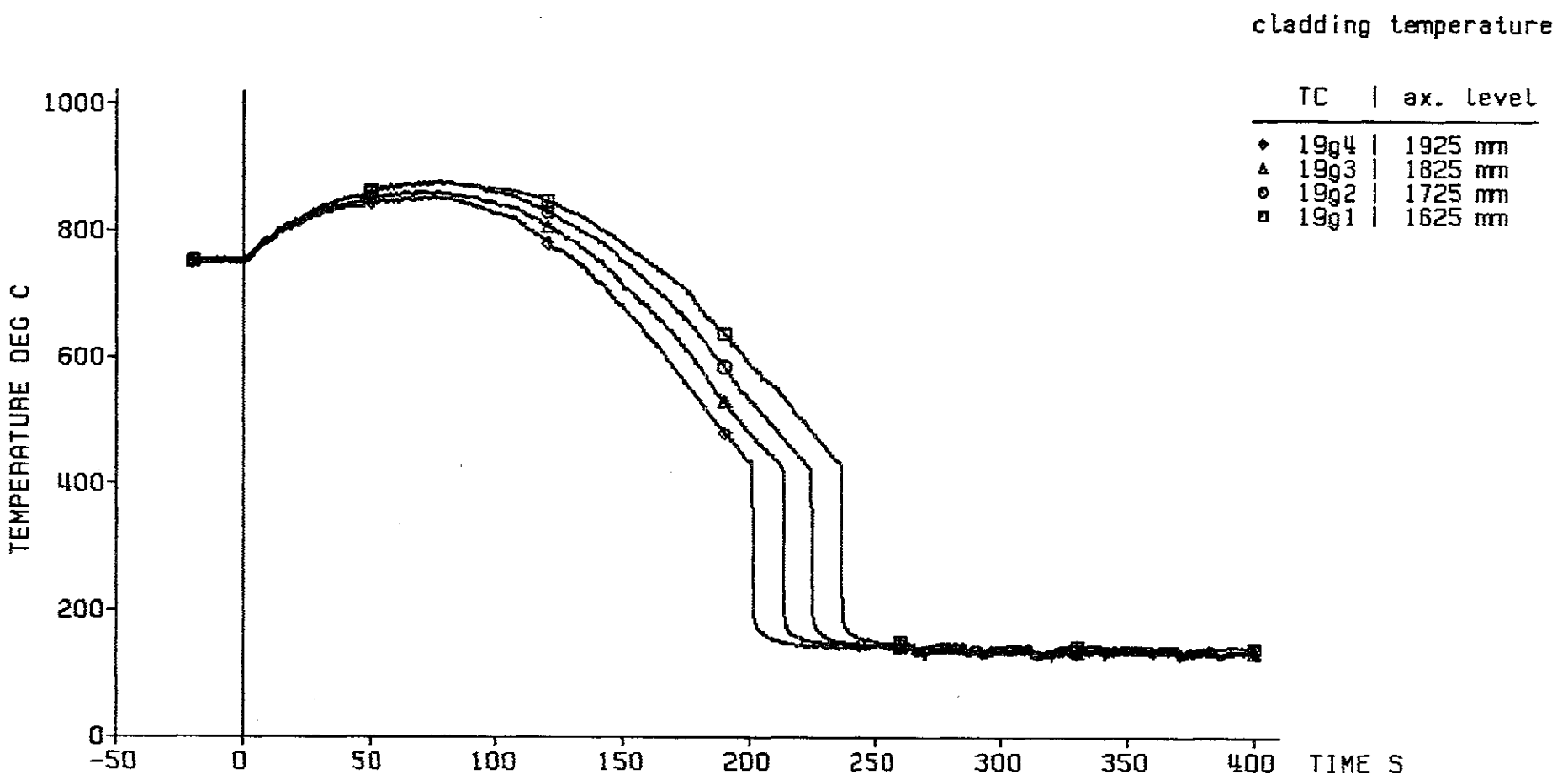
Fig. 170 FEBA: 5x5 ROD BUNDLE, TEST SERIES 2, TEST-No. 228



decay heat	120% ANS standard
flooding rate (cold)	5.72 cm/s
system pressure	4.11 bar
feedwater temperature	40 deg C

KfK IRB

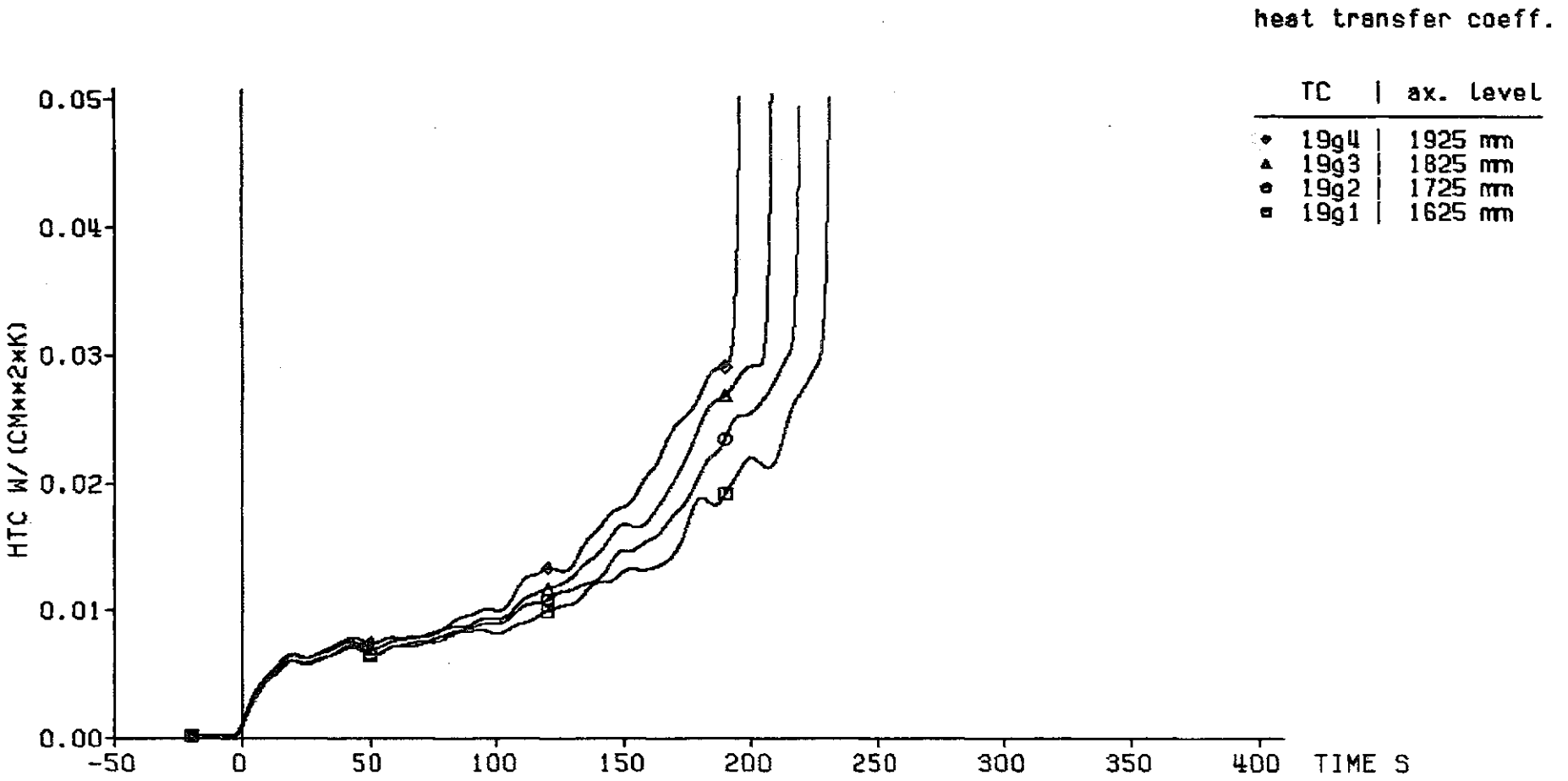
Fig. 171 FEBA: 5x5 ROD BUNDLE, TEST SERIES 2, TEST-No. 228



decay heat	120% ANS standard
flooding rate (cold)	5.72 cm/s
system pressure	4.11 bar
feedwater temperature	40 deg C

KfK IRB

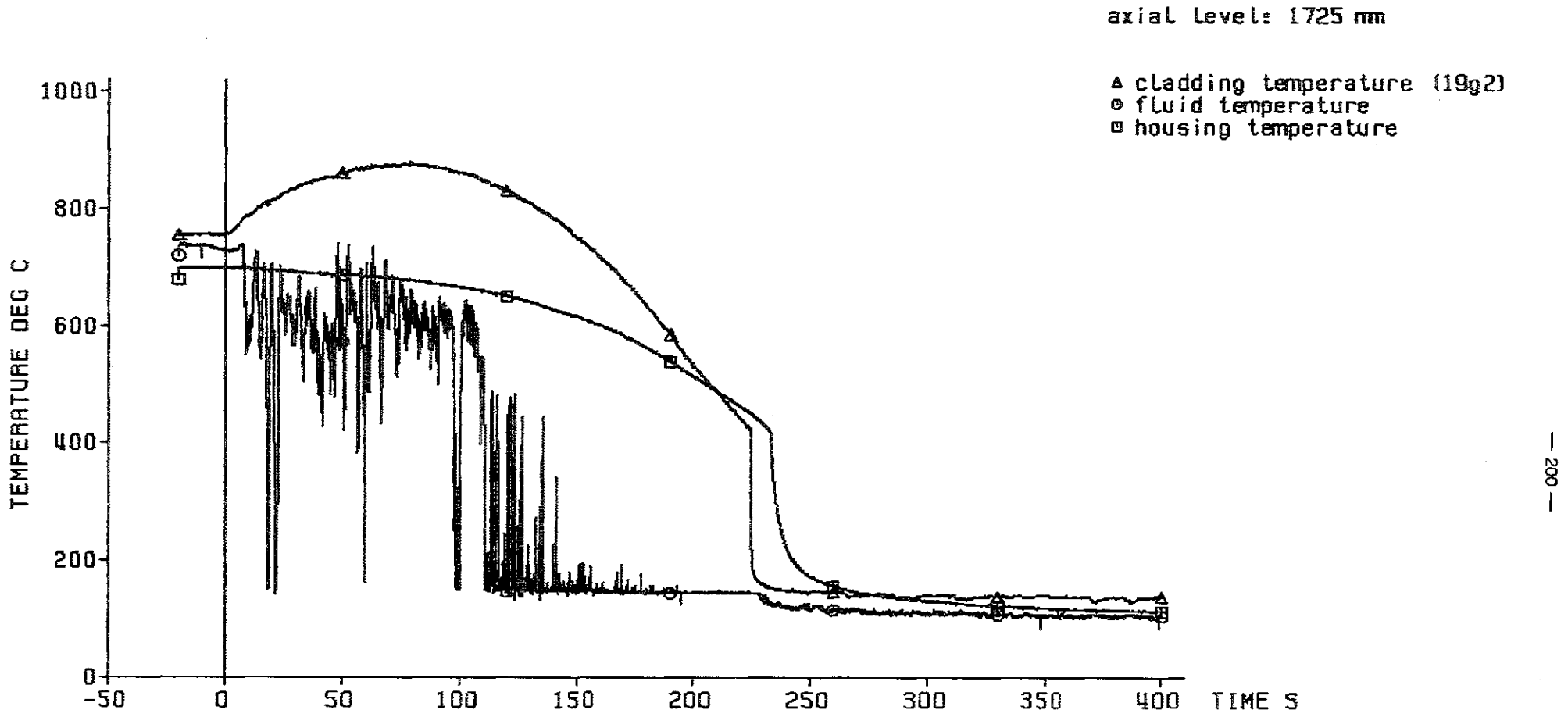
Fig. 172 FEBA: 5x5 ROD BUNDLE, TEST SERIES 2, TEST-No. 228



decay heat	120% ANS standard
flooding rate (cold)	5.72 cm/s
system pressure	4.11 bar
feedwater temperature	40 deg C

KfK IRB

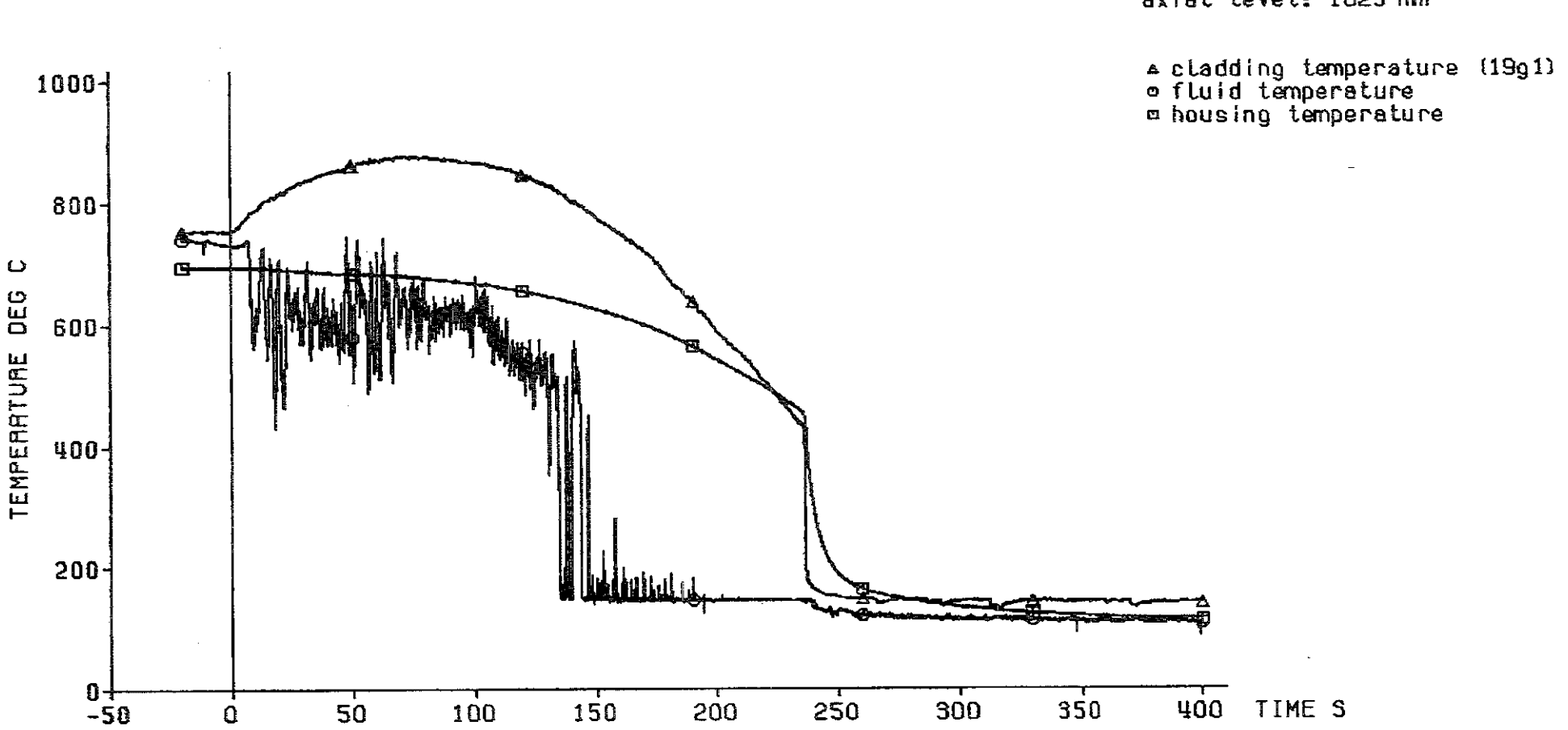
Fig. 173 FEBA: 5x5 ROD BUNDLE, TEST SERIES 2, TEST-No. 228



decay heat	120% ANS standard
flooding rate (cold)	5.72 cm/s
system pressure	4.11 bar
feedwater temperature	40 deg C

KfK IRB

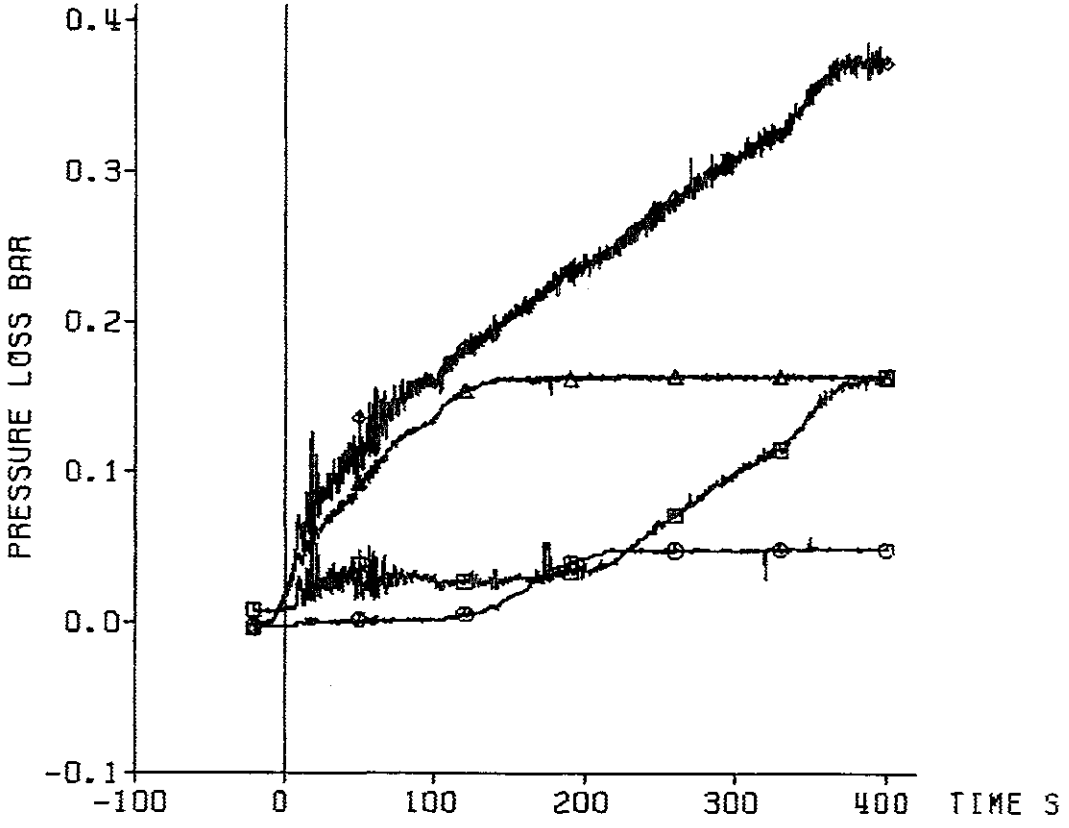
Fig. 174 FEBA: 5x5 ROD BUNDLE, TEST SERIES 2, TEST-No. 228



decay heat	120% ANS standard
flooding rate (cold)	5.72 cm/s
system pressure	4.11 bar
feedwater temperature	40 deg C

KfK IRB

Fig. 175 FEBA: 5x5 ROD BUNDLE, TEST SERIES 2, TEST-No. 228



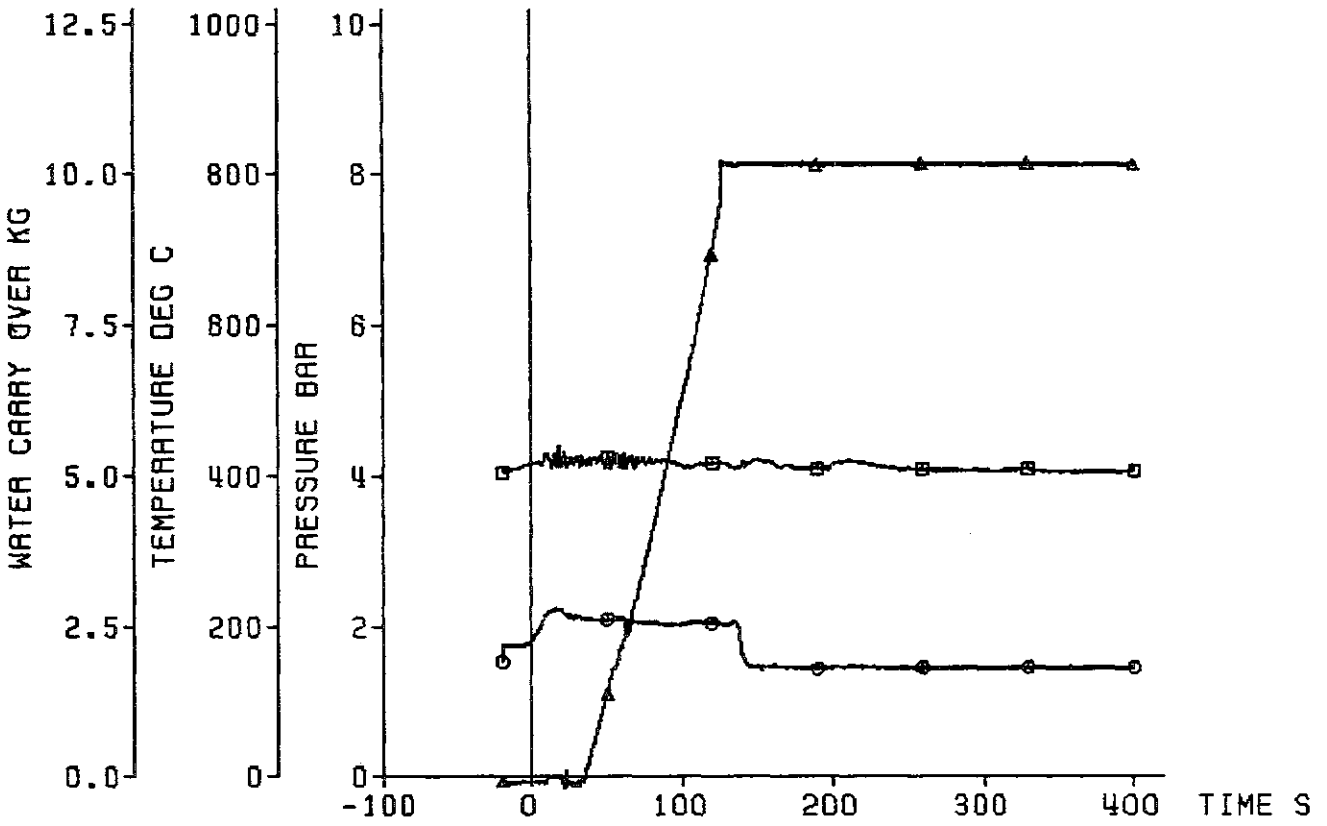
pressure loss
along the test section:

◆ total length: 4196 mm
△ lower part: 1711 mm
⊙ middle part: 545 mm
⊡ upper part: 1940 mm

decay heat	120% ANS standard
flooding rate (cold)	5.72 cm/s
system pressure	4.11 bar
feedwater temperature	40 deg C

KfK IRB

Fig. 176 FEBA: 5x5 ROD BUNDLE, TEST SERIES 2, TEST-No. 228

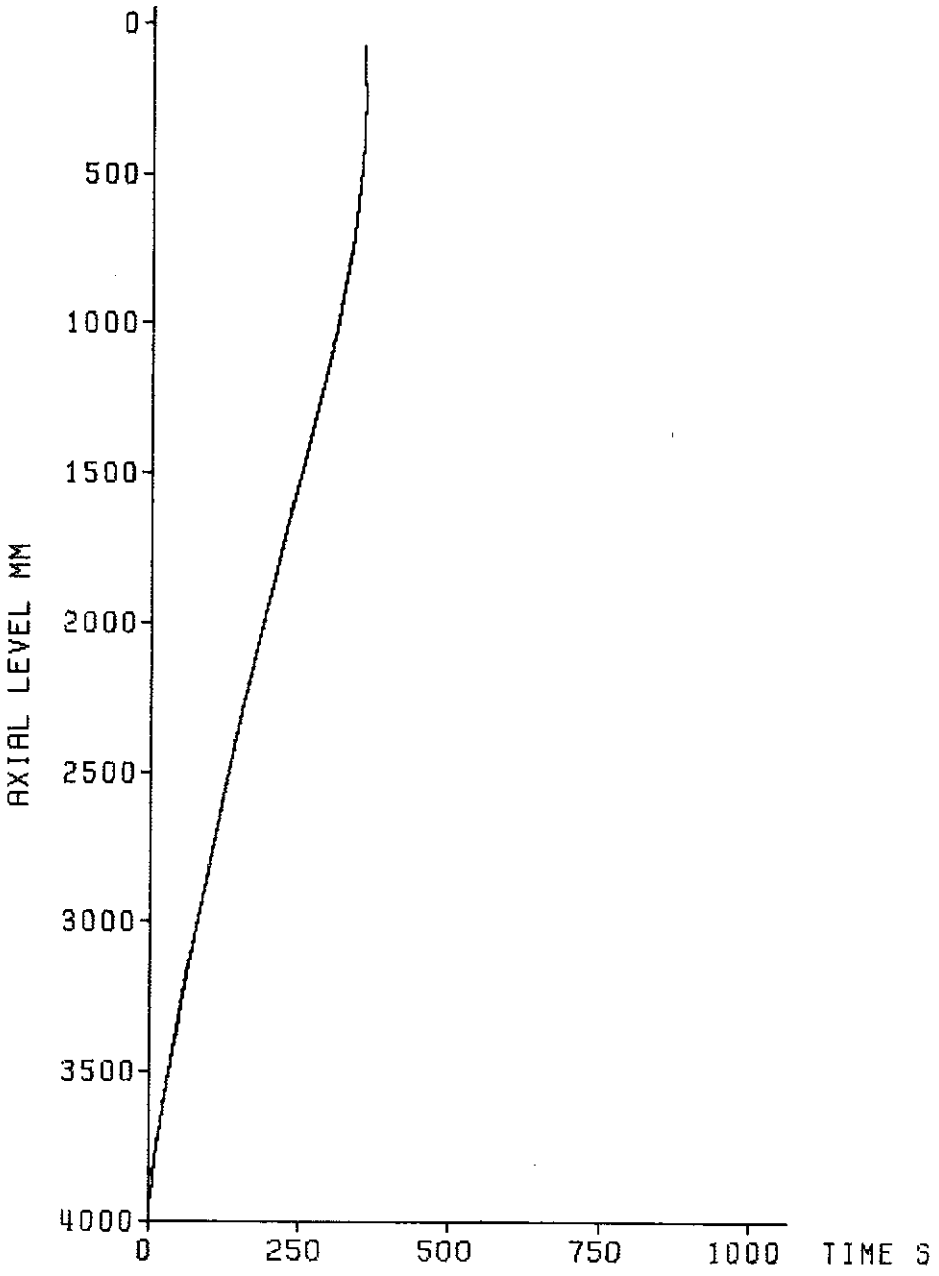


decay heat	120% ANS standard
flooding rate (cold)	5.72 cm/s
system pressure	4.11 bar
feedwater temperature	40 deg C

KfK IRB

Fig. 177 FEBA: 5x5 ROD BUNDLE, TEST SERIES 2, TEST-No. 228

axial position of the quench front

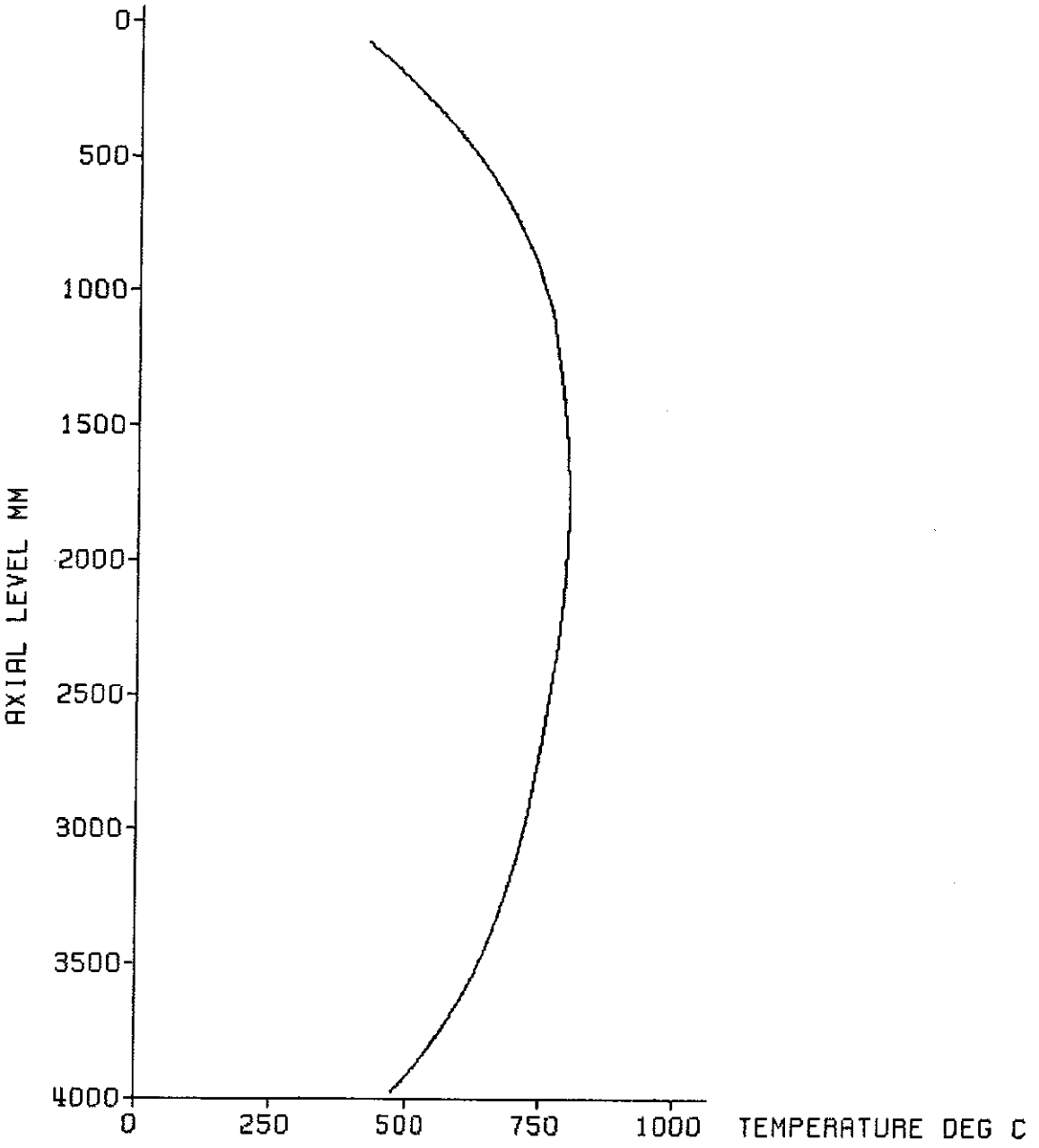


decay heat	120% ANS standard
flooding rate (cold)	5.72 cm/s
system pressure	4.11 bar
feedwater temperature	40 deg C

KfK IRB

Fig. 178 FEBA: 5x5 ROD BUNDLE
TEST SERIES 2, TEST-No. 228

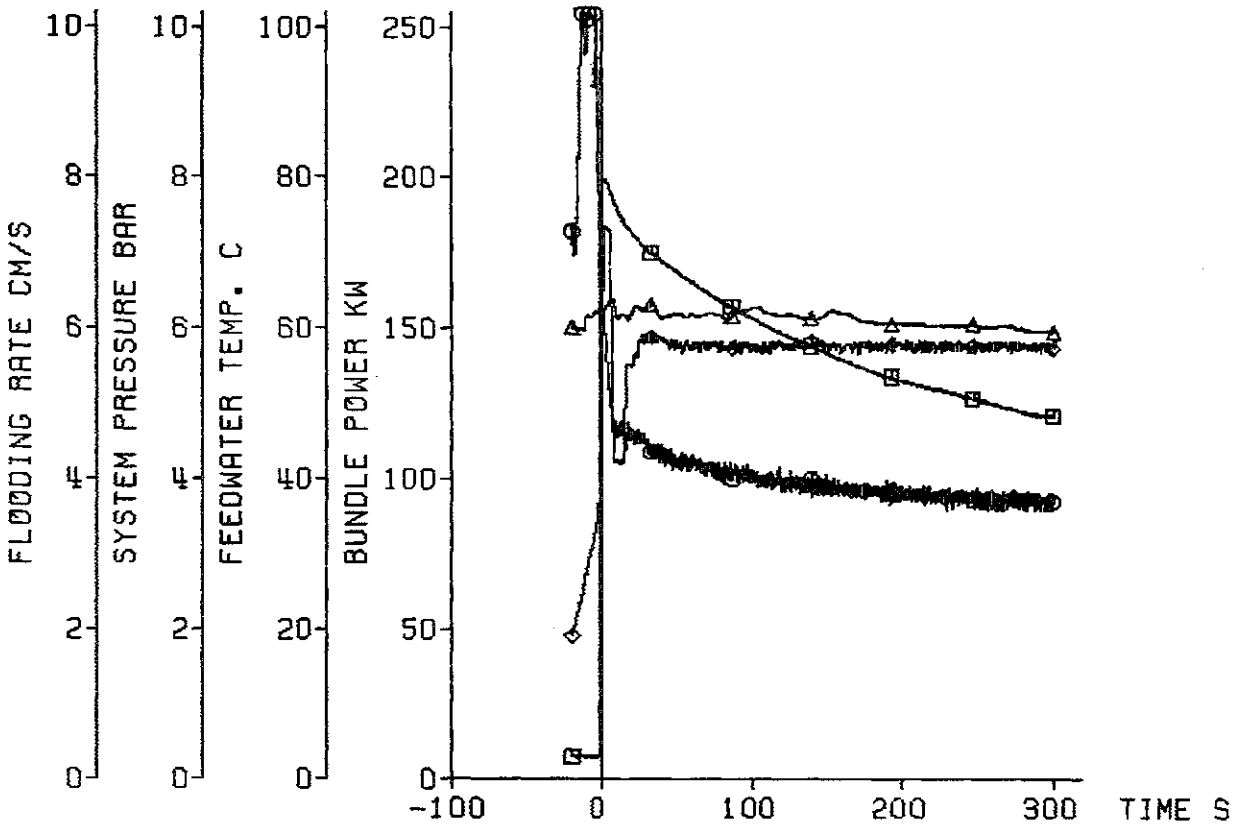
initial axial temperature profile of the cladding



decay heat	120% ANS standard
flooding rate (cold)	5.77 cm/s
system pressure	6.15 bar
feedwater temperature	40 deg C

KfK ITRB

Fig. 179 FEBA: 5x5 ROD BUNDLE TEST SERIES 2, TEST-No. 230



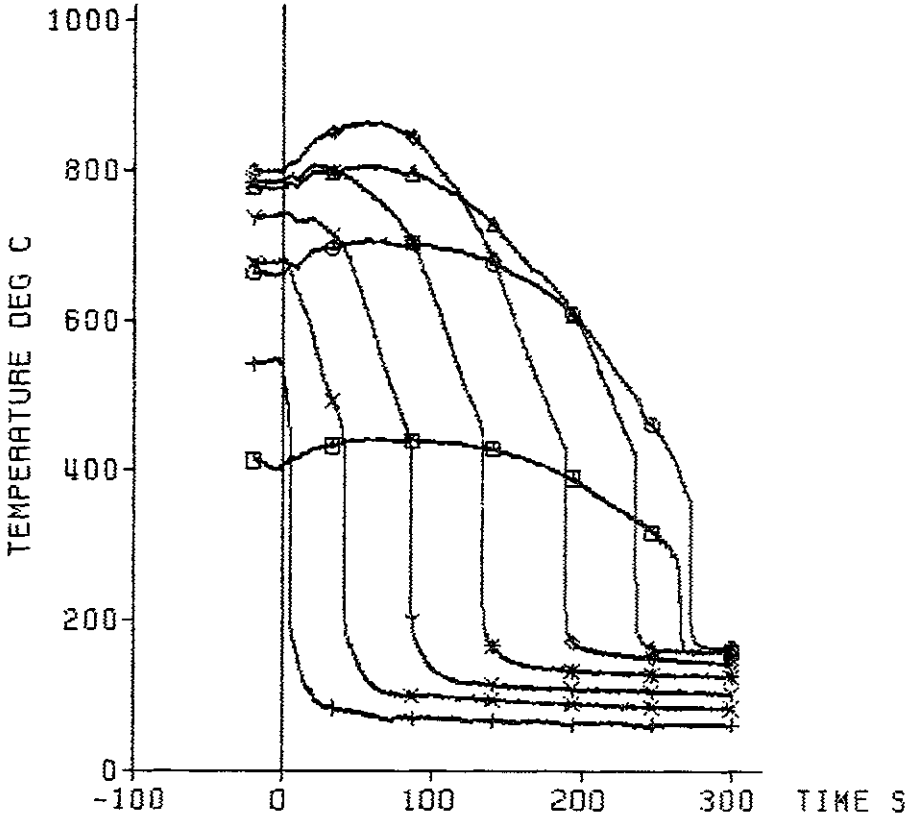
test parameters:

- flooding rate
- system pressure
- feedwater temperature
- bundle power

decay heat	120% ANS standard
flooding rate (cold)	5.77 cm/s
system pressure	6.15 bar
feedwater temperature	40 deg C

KfK IRB

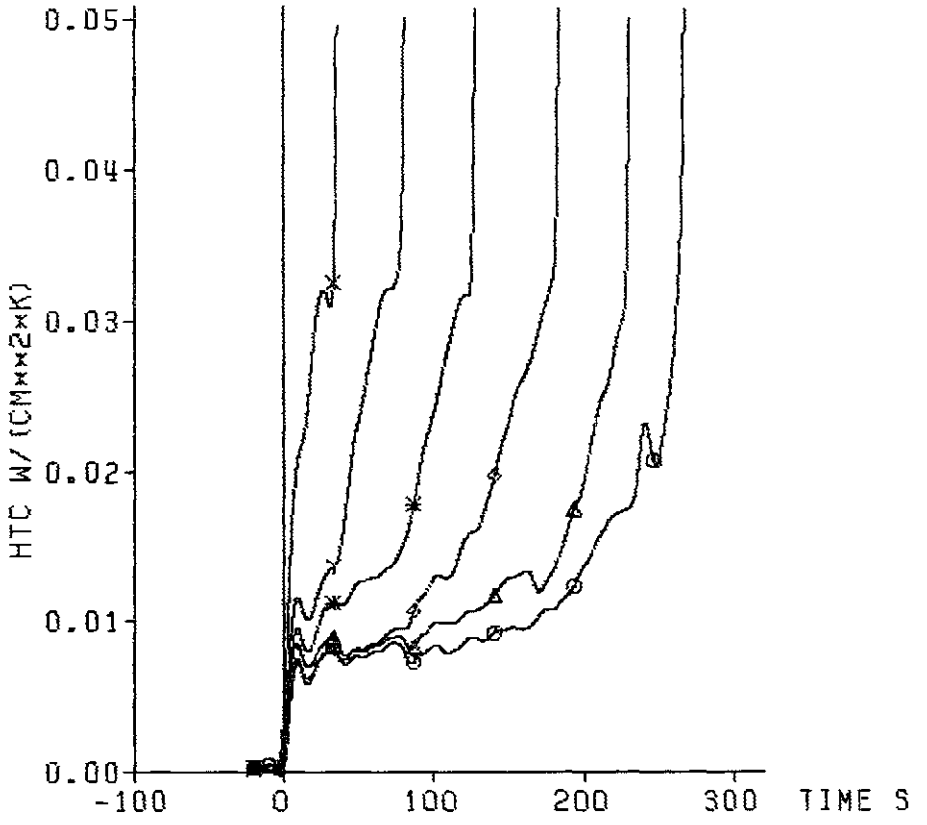
Fig. 180 FEBA: 5x5 ROD BUNDLE, TEST SERIES 2, TEST-No. 230



decay heat	120% ANS standard
flooding rate (cold)	5.77 cm/s
system pressure	6.15 bar
feedwater temperature	40 deg C

KfK KIRB

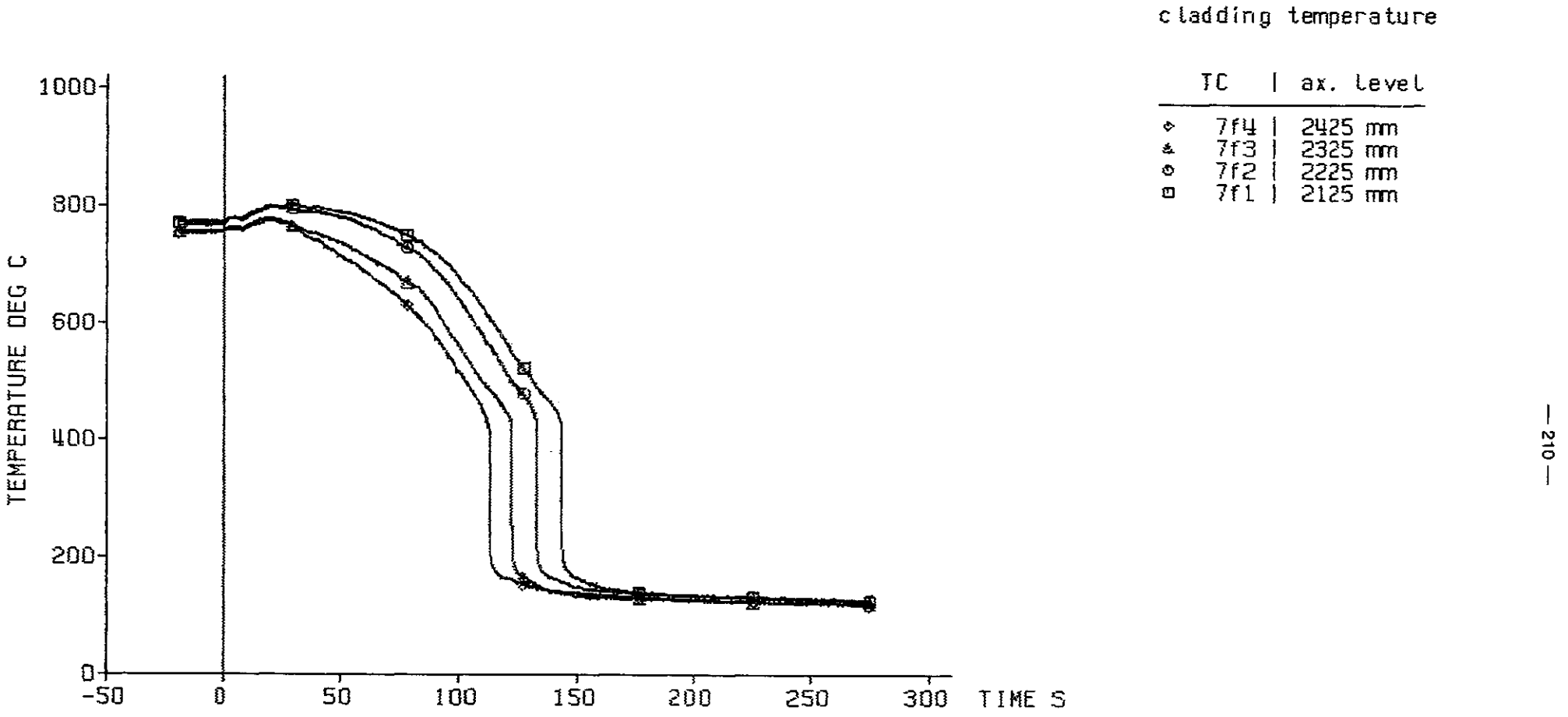
Fig. 181 FEBA: 5x5 ROD BUNDLE, TEST SERIES 2, TEST-No. 230



decay heat	120% ANS standard
flooding rate (cold)	5.77 cm/s
system pressure	6.15 bar
feedwater temperature	40 deg C

KfK IRB

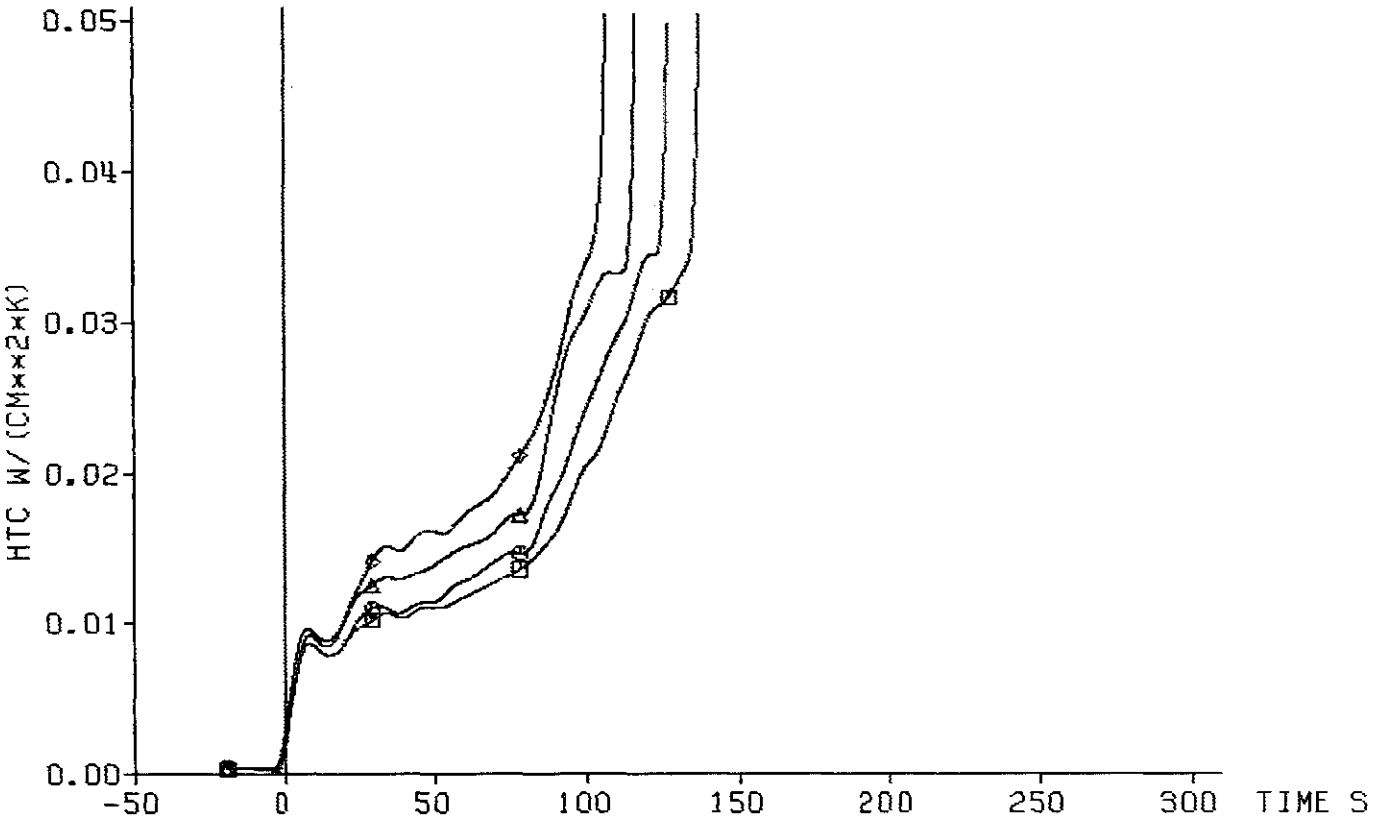
Fig. 182 FEBA: 5x5 ROD BUNDLE, TEST SERIES 2, TEST-No. 230



decay heat	120% ANS standard
flooding rate (cold)	5.77 cm/s
system pressure	6.15 bar
feedwater temperature	40 deg C

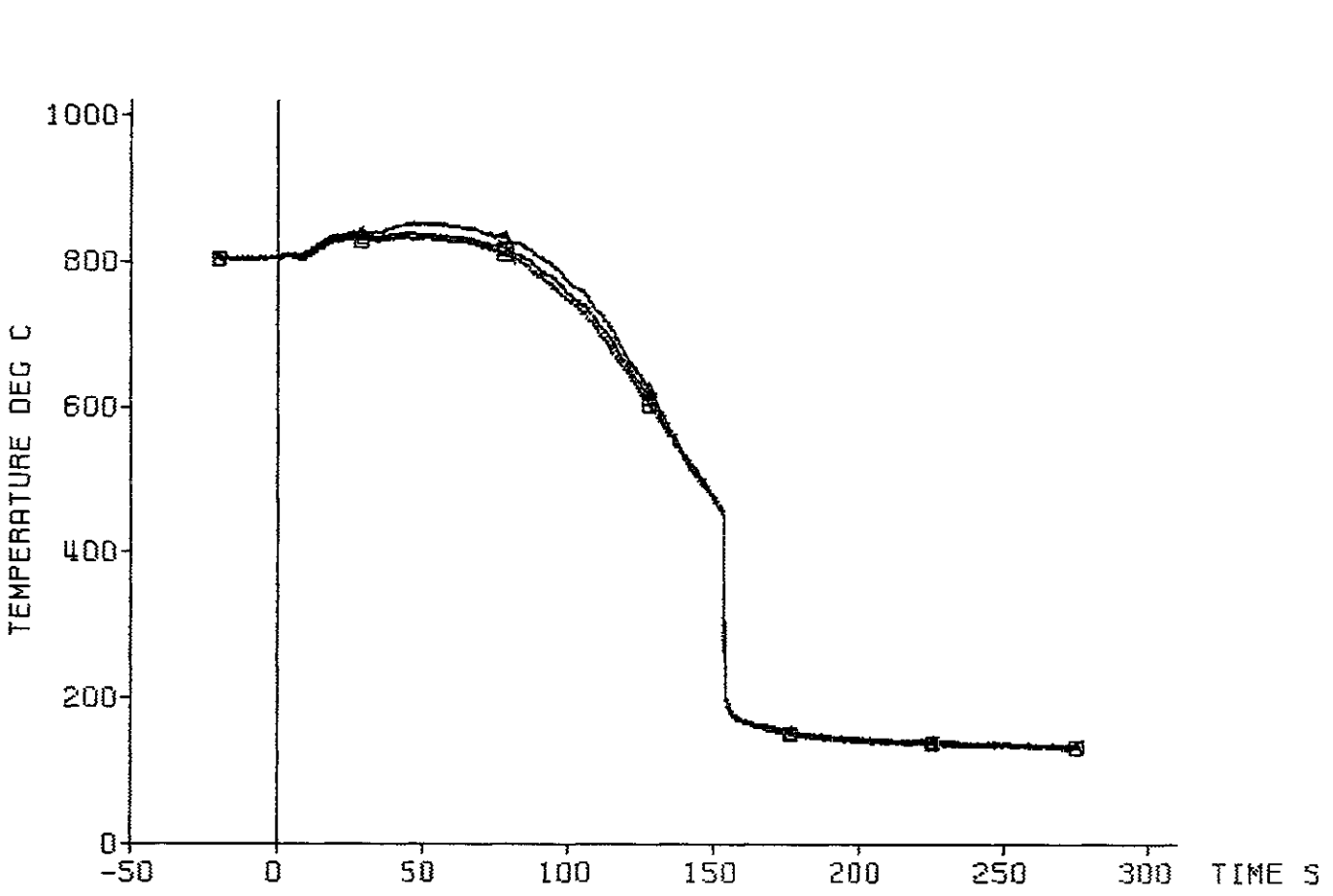
KfK KIRB

Fig. 183 FEBA: 5x5 ROD BUNDLE, TEST SERIES 2, TEST-No. 230



decay heat	120% ANS standard
flooding rate (cold)	5.77 cm/s
system pressure	6.15 bar
feedwater temperature	40 deg C

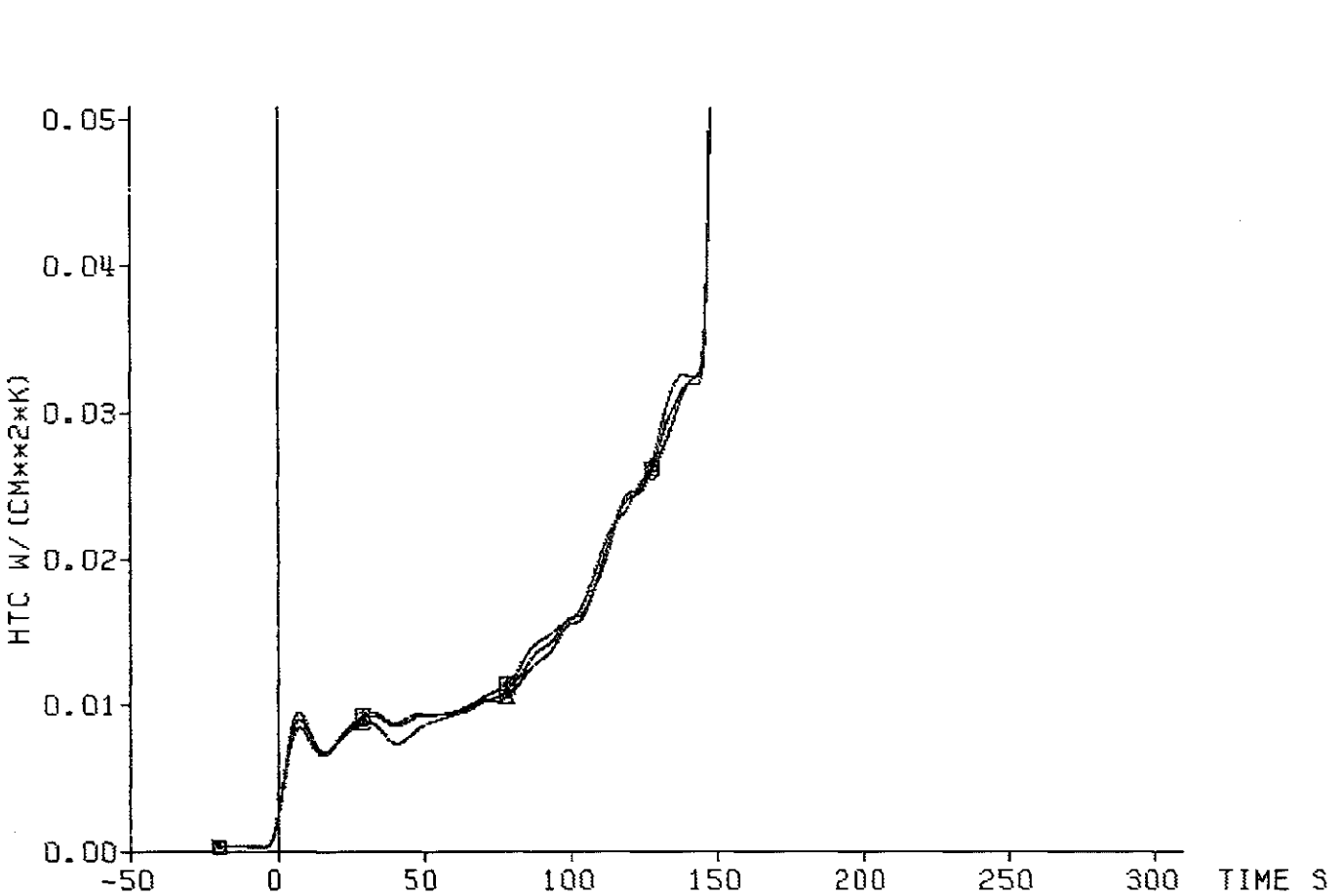
Fig. 184 FEBA: 5x5 ROD BUNDLE, TEST SERIES 2, TEST-No. 230



decay heat	120% ANS standard
flooding rate (cold)	5.77 cm/s
system pressure	6.15 bar
feedwater temperature	40 deg C

KfK IRB

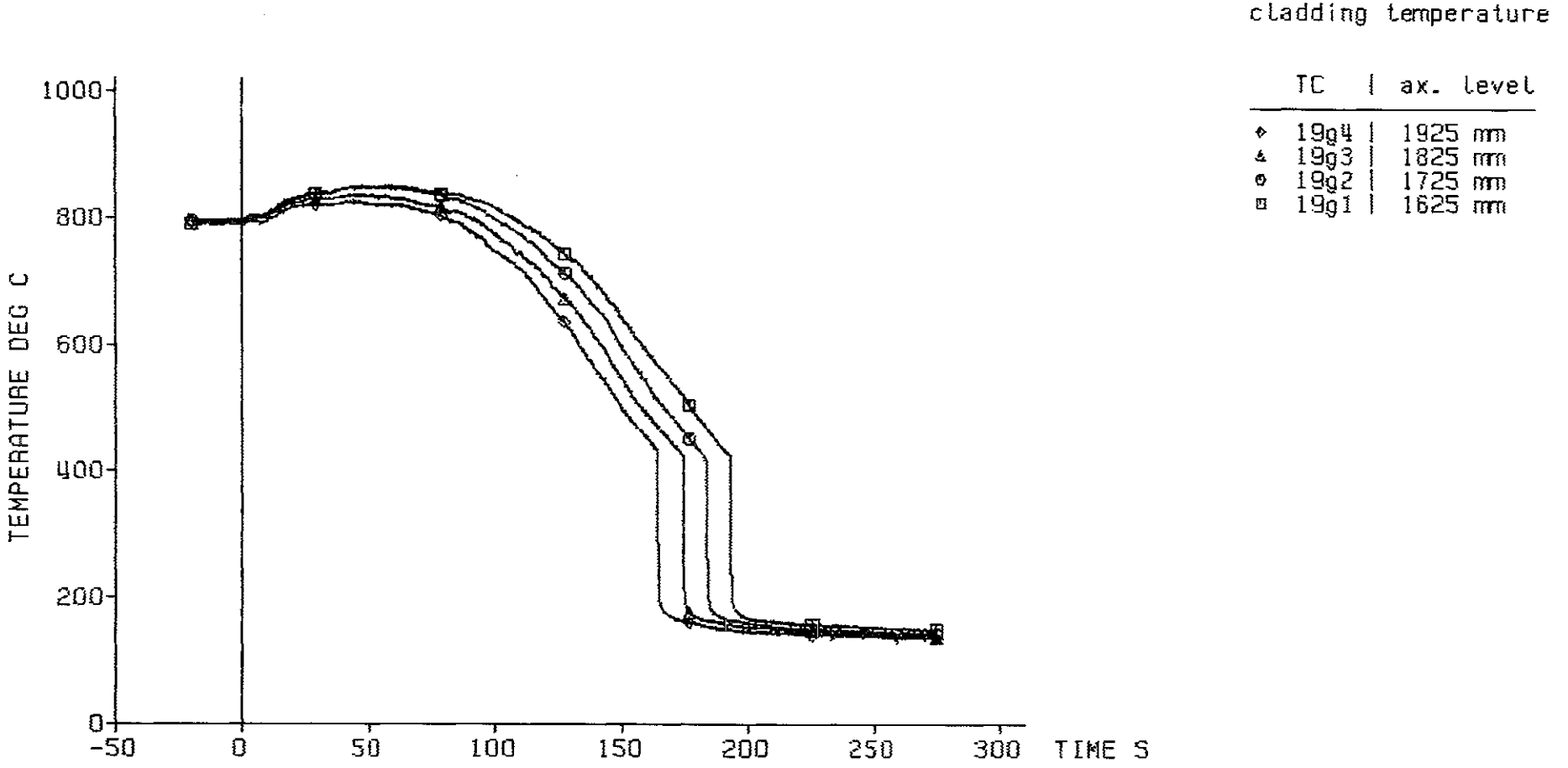
Fig.185 FEBA: 5x5 ROD BUNDLE, TEST SERIES 2, TEST-No. 230



decay heat	120% ANS standard
flooding rate (cold)	5.77 cm/s
system pressure	6.15 bar
feedwater temperature	40 deg C

KfK IRB

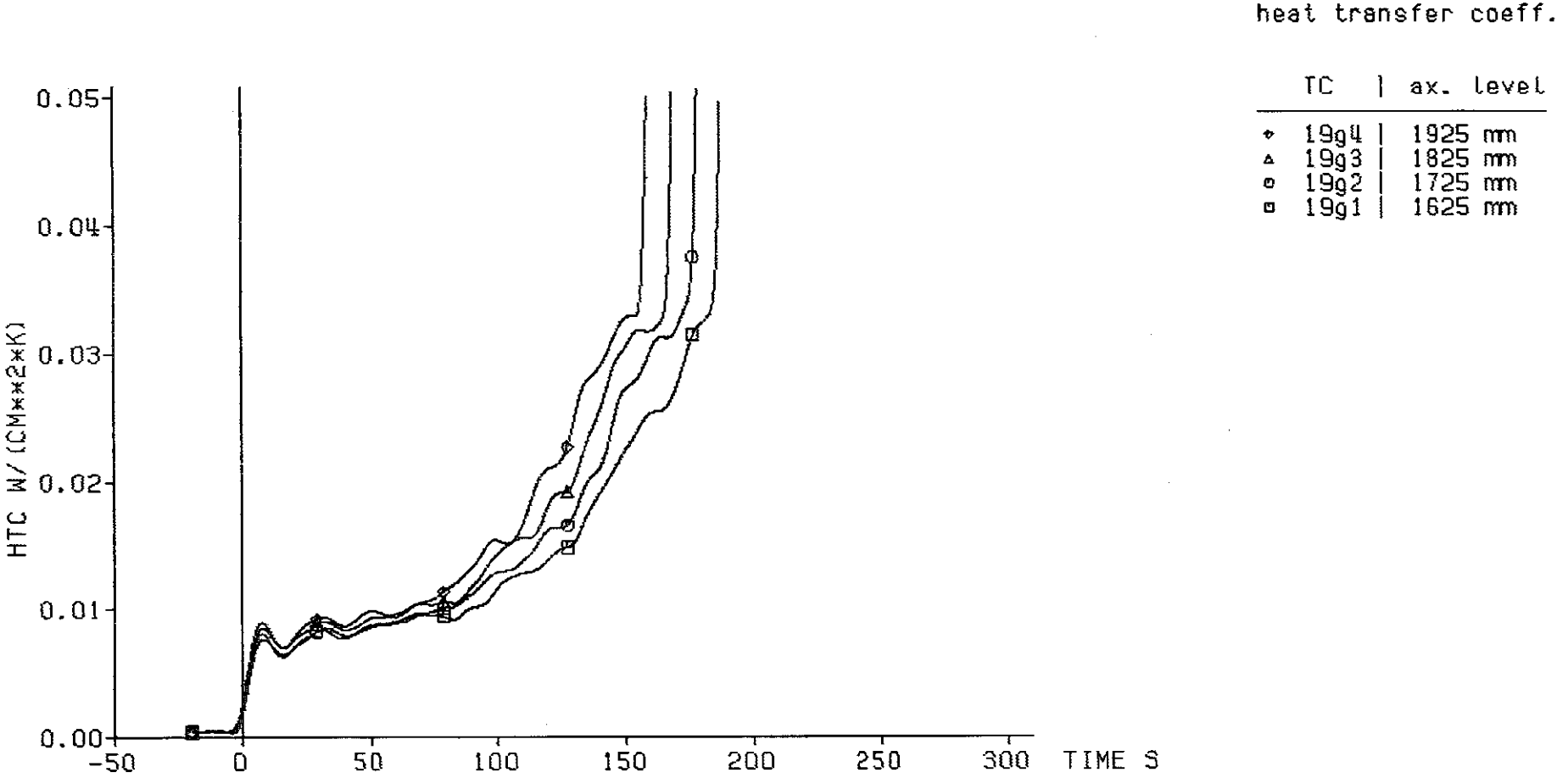
Fig. 186 FEBA: 5x5 ROD BUNDLE, TEST SERIES 2, TEST-No. 230



decay heat	120% ANS standard
flooding rate (cold)	5.77 cm/s
system pressure	6.15 bar
feedwater temperature	40 deg C

KfK IRB

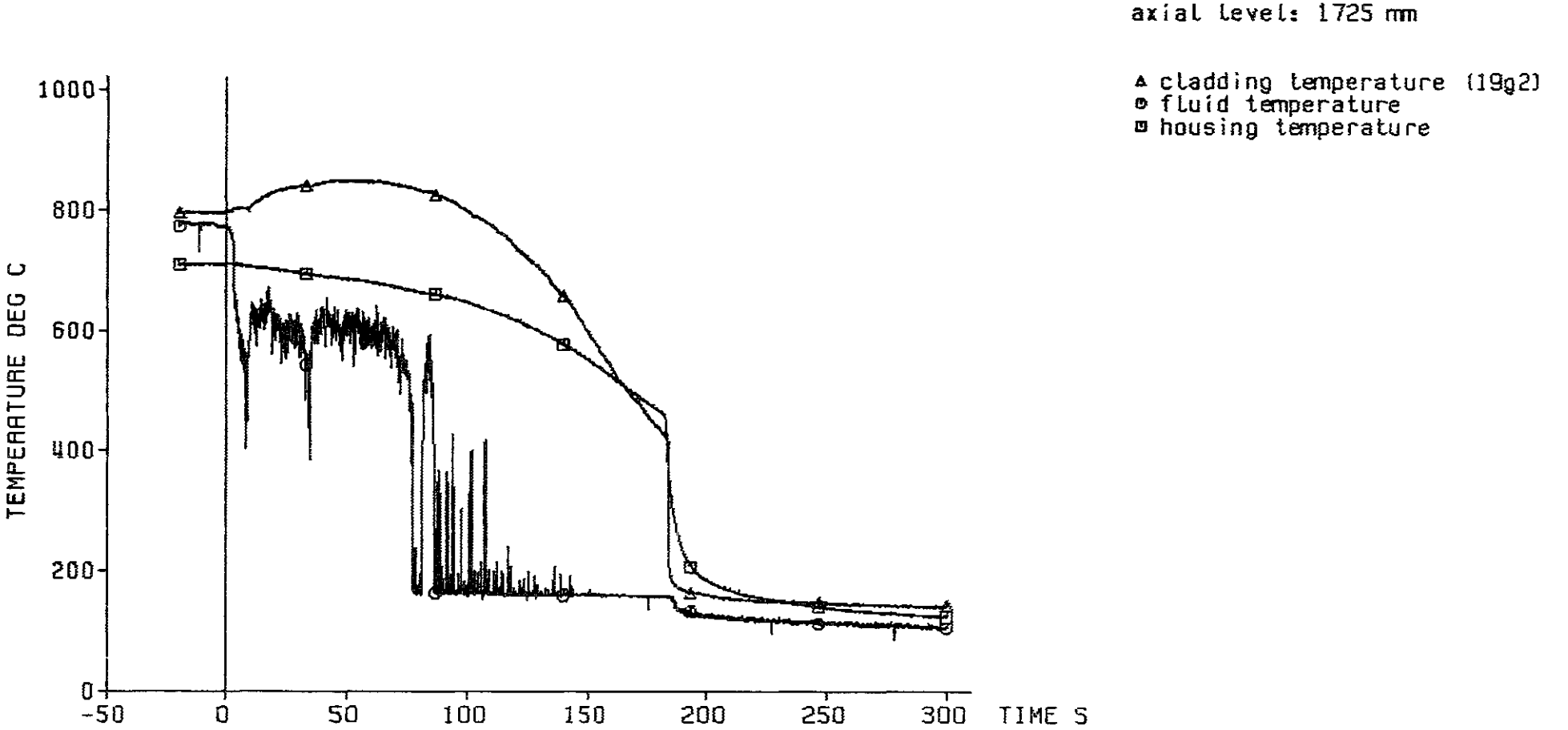
Fig. 187 FEBA: 5x5 ROD BUNDLE, TEST SERIES 2, TEST-No. 230



decay heat	120% ANS standard
flooding rate (cold)	5.77 cm/s
system pressure	6.15 bar
feedwater temperature	40 deg C

KfK IRB

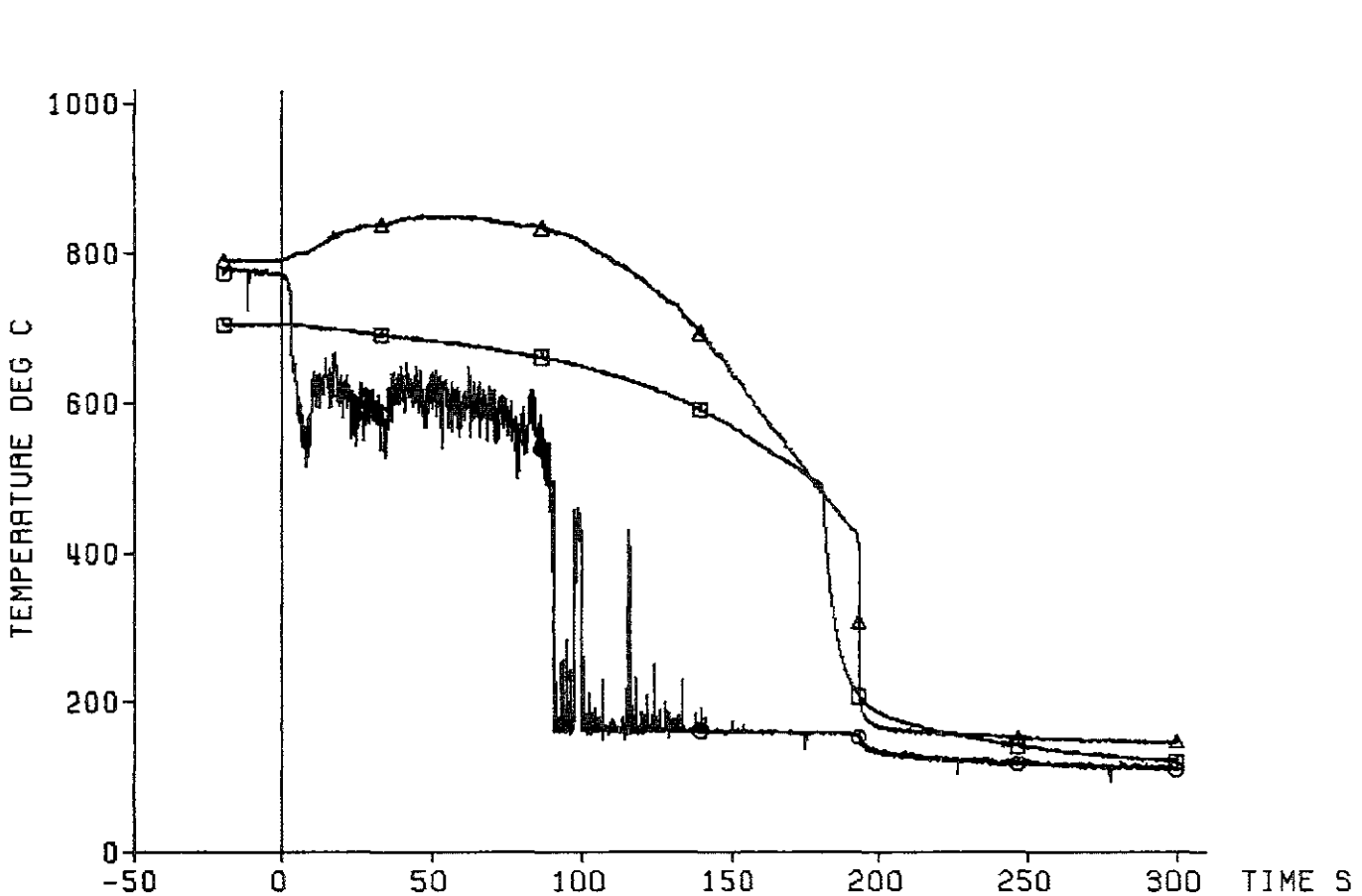
Fig. 188 FEBA: 5x5 ROD BUNDLE, TEST SERIES 2, TEST-No. 230



decay heat	120% ANS standard
flooding rate (cold)	5.77 cm/s
system pressure	6.15 bar
feedwater temperature	40 deg C

KfK KIRB

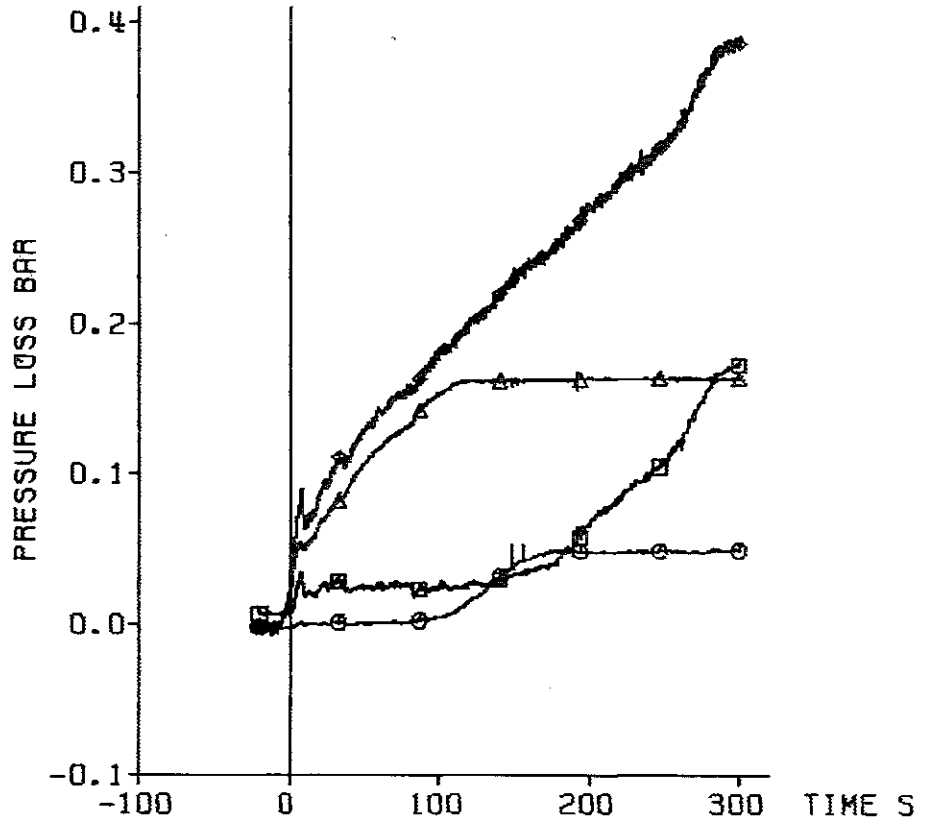
Fig. 189 FEBA: 5x5 ROD BUNDLE, TEST SERIES 2, TEST-No. 230



decay heat	120% ANS standard
flooding rate (cold)	5.77 cm/s
system pressure	6.15 bar
feedwater temperature	40 deg C

KfK IRB

Fig. 190 FEBA: 5x5 ROD BUNDLE, TEST SERIES 2, TEST-No. 230



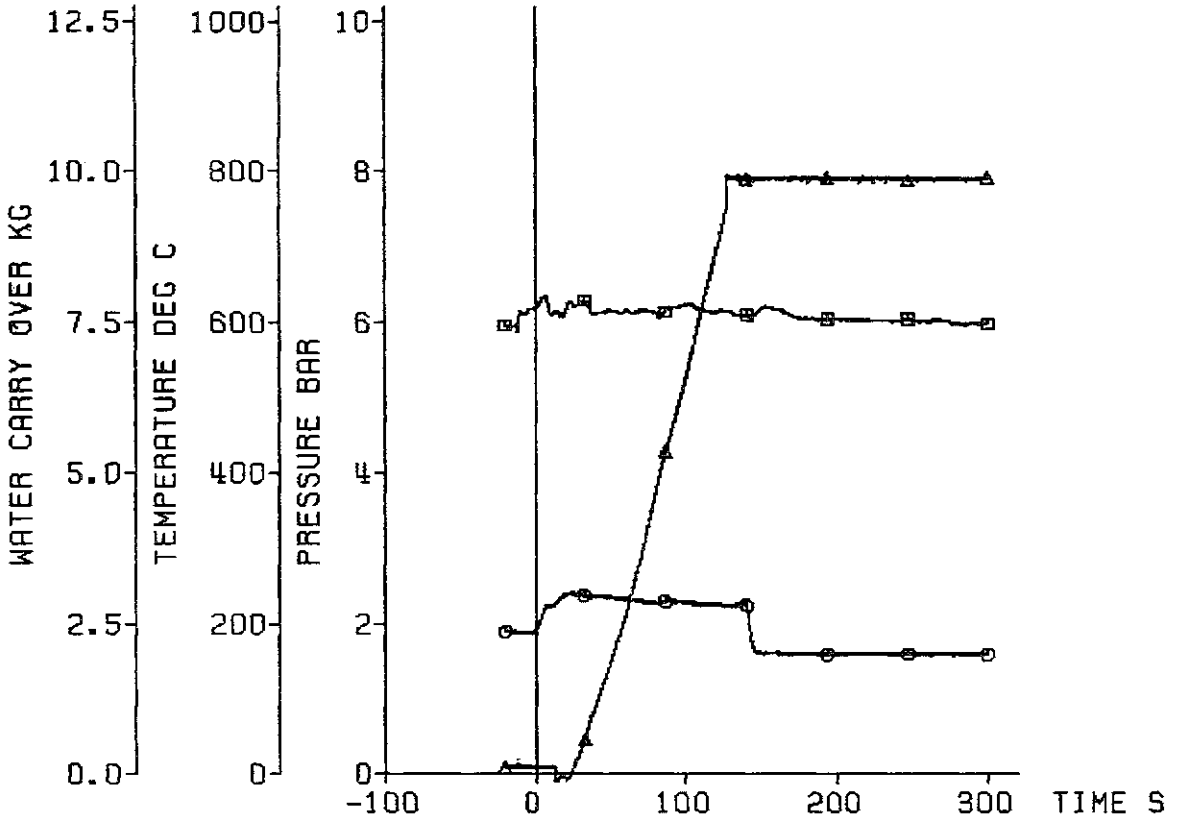
pressure loss
along the test section:

◇ total length: 4196 mm
△ lower part: 1711 mm
○ middle part: 545 mm
□ upper part: 1940 mm

decay heat	120% ANS standard
flooding rate (cold)	5.77 cm/s
system pressure	6.15 bar
feedwater temperature	40 deg C

KfK KIRB

Fig. 191 FEBA: 5x5 ROD BUNDLE, TEST SERIES 2, TEST-No. 230

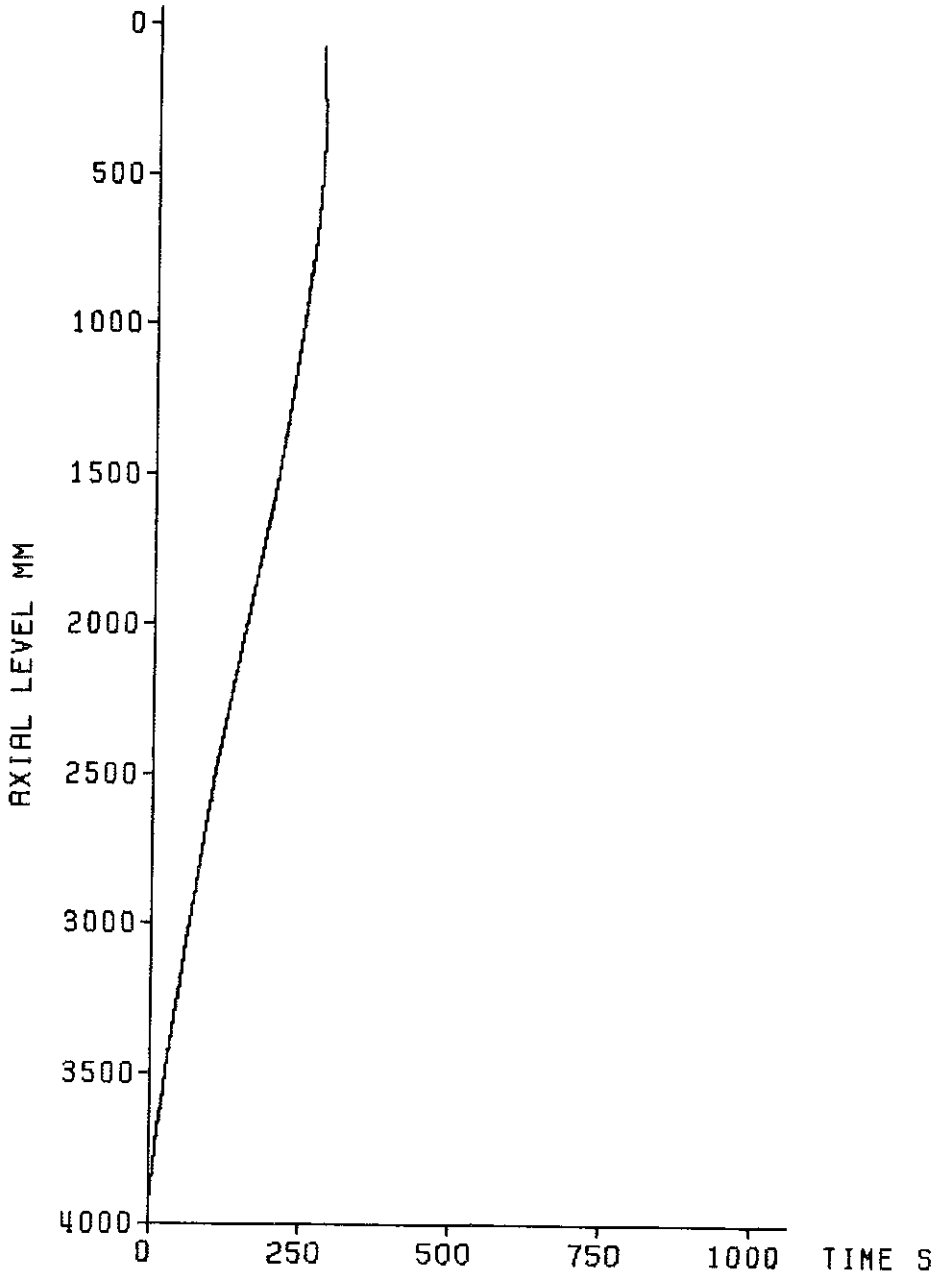


decay heat	120% ANS standard
flooding rate (cold)	5.77 cm/s
system pressure	6.15 bar
feedwater temperature	40 deg C

KfK IRB

Fig. 192 FEBA: 5x5 ROD BUNDLE, TEST SERIES 2, TEST-No. 230

axial position of the quench front



decay heat	120% ANS standard
flooding rate (cold)	5.77 cm/s
system pressure	6.15 bar
feedwater temperature	40 deg C

KfK IRB

Fig. 193 FEBA: 5x5 ROD BUNDLE TEST SERIES 2, TEST-No. 230

TEST SERIES II

Investigation of the Effects of a Grid Spacer,
Without Grid Spacer at the Bundle Midplane

Channel Listing and Data Identification for Test No. 228 Through 234

Channel No.	Data Identification Type	Location	Unit	Remarks
1	Cladding Temperature	18a4.3860[1]	°C	
2	Cladding Temperature	18a3.3315	°C	
3	Cladding Temperature	18a2.2770	°C	
4	Cladding Temperature	18a1.2225	°C	
5	Cladding Temperature	12b4.1680	°C	
6	Cladding Temperature	12b3.1135	°C	
7	Cladding Temperature	12b2. 590	°C	
8	Cladding Temperature	12b1. 45	°C	
9	Cladding Temperature	17h4.2225	°C	
10	Cladding Temperature	17h3.2125	°C	
11	Cladding Temperature	17h2.2025	°C	
12	Cladding Temperature	17h1.1925	°C	
13	Fluid Temperature	TFS[3] 3315	°C	TC of 0.5 mm Diameter
14	Fluid Temperature	TFS 2380	°C	TC of 0.5 mm Diameter
15	Fluid Temperature	TF[2] 1725	°C	
16	Fluid Temperature	TFS 485	°C	TC of 0.5 mm Diameter
17	Housing Temperature	TK[4] 3315	°C	
18	Housing Temperature	TK 2235	°C	
19	Housing Temperature	TK 1725	°C	
20	Housing Temperature	TK 590	°C	

TEST SERIES II

Channel No.	Data Identification Type	Location	Unit	Remarks
21	Fluid Temperature	Lower Plenum	°C	
22	Water Level Detector	4012	°C	Heated + Unheated TC's
23	Feedwater Temperature		°C	
24	Fluid Temperature	Upper Plenum	°C	
25	Room Temperature		°C	
26	Cladding Temperature	22f4.2425[1]	°C	
27	Cladding Temperature	22f3.2325	°C	
28	Cladding Temperature	22f2.2225	°C	
29	Cladding Temperature	22f1.2125	°C	
30	Cladding Temperature	21e4.2225	°C	
31	Cladding Temperature	21e3.2175	°C	
32	Cladding Temperature	21e2.2125	°C	
33	Cladding Temperature	21e1.2075	°C	
34	Cladding Temperature	19g4.1925	°C	
35	Cladding Temperature	19g3.1825	°C	
36	Cladding Temperature	19g2.1725	°C	
37	Cladding Temperature	19g1.1625	°C	
38	Cladding Temperature	16g4.1925	°C	
39	Cladding Temperature	16g3.1825	°C	
40	Cladding Temperature	16g2.1725	°C	
41	Cladding Temperature	16g1.1625	°C	
42	Cladding Temperature	15a4.3860	°C	
43	Cladding Temperature	15a3.3315	°C	
44	Cladding Temperature	15a2.2770	°C	
45	Cladding Temperature	15a1.2225	°C	
46	Cladding Temperature	14e4.2225	°C	
47	Cladding Temperature	14e3.2175	°C	
48	Cladding Temperature	14e2.2125	°C	
49	Cladding Temperature	14e1.2075	°C	

TEST SERIES II

Channel No.	Data Identification Type	Location	Unit	Remarks
50	Cladding Temperature	13d3.2025[1]	°C	
51	Cladding Temperature	13d2.2025	°C	
52	Cladding Temperature	13d1.2025	°C	
53	Cladding Temperature	10f4.2425	°C	
54	Cladding Temperature	10f3.2325	°C	
55	Cladding Temperature	10f2.2225	°C	
56	Cladding Temperature	10f1.2125	°C	
57	Cladding Temperature	9h4.2225	°C	
58	Cladding Temperature	9h3.2125	°C	
59	Cladding Temperature	9h2.2025	°C	
60	Cladding Temperature	9h1.1925	°C	
61	Cladding Temperature	8d4.2025	°C	
62	Cladding Temperature	8d3.2025	°C	
63	Cladding Temperature	8d2.2025	°C	
64	Cladding Temperature	8d1.2025	°C	
65	Cladding Temperature	7f4.2425	°C	
66	Cladding Temperature	7f3.2325	°C	
67	Cladding Temperature	7f2.2225	°C	
68	Cladding Temperature	7f1.2125	°C	
69	Cladding Temperature	4g4.1925	°C	
70	Cladding Temperature	4g3.1825	°C	
71	Cladding Temperature	4g2.1725	°C	
72	Cladding Temperature	4g1.1625	°C	
73	Cladding Temperature	3b4.1680	°C	
74	Cladding Temperature	3b3.1135	°C	
75	Cladding Temperature	3b2. 590	°C	
76	Cladding Temperature	3b1. 45	°C	TC Failed

TEST SERIES II

Channel No.	Data Identification Type	Location	Unit	Remarks
77	Cladding Temperature	2c4.4025[1]	°C	
78	Cladding Temperature	2c3.3925	°C	
79	Cladding Temperature	2c2.3825	°C	
80	Cladding Temperature	2c1.3725	°C	
81	Electrical Power Input	8 Rods	kW	Rods No. 1 Through 8
82	Electrical Power Input	8 Rods	kW	Rods No. 9 Through 16
83	Electrical Power Input	9 Rods	kW	Rods No. 17 Through 25
84	Housing Temperature TK[4]	4005	°C	
85	Housing Temperature TK	3915	°C	
86	Housing Temperature TK	3820	°C	
87	Housing Temperature TK	3725	°C	
88	Housing Temperature TK	3018	°C	
89	Housing Temperature TK	2770	°C	
90	Housing Temperature TK	2025	°C	
91	Housing Temperature TK	1925	°C	
92	Housing Temperature TK	1825	°C	
93	Housing Temperature TK	1625	°C	
94	Housing Temperature TK	1135	°C	
95	Housing Temperature TK	835	°C	
96	Housing Temperature TK	45	°C	
97	Fluid Temperature TF[2]	3038	°C	
98	Fluid Temperature TFS[3]	2425	°C	
99	Fluid Temperature TF	2770	°C	
100	Fluid Temperature TF	2325	°C	
101	Fluid Temperature TF	2125	°C	
102	Fluid Temperature TF	2025	°C	
103	Fluid Temperature TF	1925	°C	
104	Fluid Temperature TF	1135	°C	
105	Fluid Temperature TF	1625	°C	
106	----------		-	Open

TEST SERIES II

Channel No.	Data Identification Type	Location	Unit	Remarks
107	Cladding Temperature	24c4.4025[1]	°C	
108	Cladding Temperature	24c2.3925	°C	
109	Cladding Temperature	24c1.3825	°C	
110	Time (10 Scans/s)		s	t = 0: Start of Reflooding
111	Pressure in Lower Plenum	4091	bar	
112	Pressure in Upper Plenum	-105	bar	
113	Pressure in Buffer		bar	
114	Bundle Power		kW	Channels: 81 + 82 + 83
115	Flooding Velocity (cold)		cm/s	
116	Water Carry Over Collected		kg	Downstream of Bundle Exit
117	Pressure Diff.	1835 and -105 mm	bar	
118	Measured	2380 and 1835 mm	bar	
119	Between	4091 and 2380 mm	bar	
120	Axial Level	4091 and -105 mm	bar	Values Measured Separately

1) TC's of 0.5 mm diameter embedded in rod cladding. Measuring position: Example: rod No. = 18, type of rod instrumention = a, TC No. = 4, axial level = 3860 mm, referenced to the top flange of the bundle.

2) TF = TC's of 0.25 mm diameter (bare).
TC's placed in subchannel surrounded by rods No. 12, 17, 16 and 11.

3) TFS = TC's of 0.25 mm diameter protected by a radiation shielding.
TC's placed in subchannel surrounded by rods No. 12, 17, 16 and 11.

4) TK = TC's of 0.5 mm diameter placed in the wall of the bundle housing of of 6.5 mm thickness.

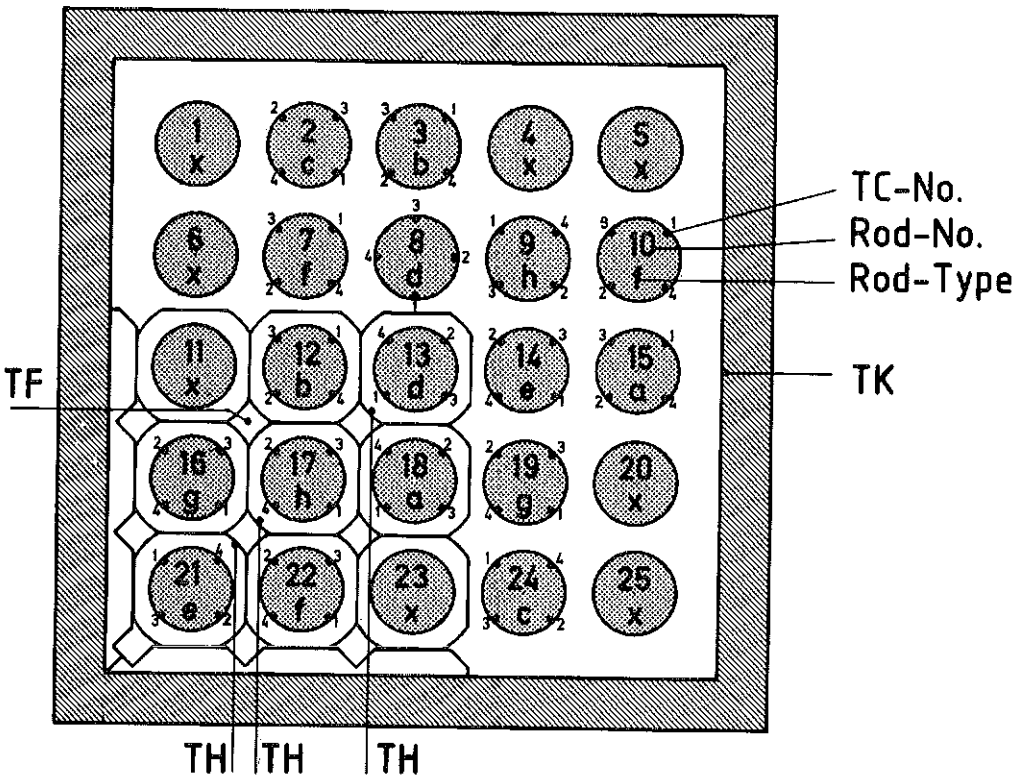
TEST SERIES III

Investigation of the Effects of a 90% Flow Blockage With Bypass,
Blockage at the Bundle Midplane of 3x3 Rods Placed in the Corner
of the 5x5 Rod Bundle,
Without Grid Spacer at the Bundle Midplane

Test No.	Flooding Velocity (cold) cm/s	System Pressure bar	Feedwater Temp.[1] °C 0-30 s	Feedwater Temp.[1] °C End	Bundle Power[2] kW 0 s	Bundle Power[2] kW Transient	Remarks
241	3.8	2.0	42	37	200	120% ANS	Figs. 196 Through 217
239	3.8	4.1	49	37	200	120% ANS	Figs. 218 Through 239
236	3.8	6.2	48	37	200	120% ANS	Figs. 240 Through 261
240	5.8	2.0	46	40	200	120% ANS	Figs. 262 Through 283
238	5.7	4.1	49	37	200	120% ANS	Figs. 284 Through 305
235	5.8	6.2	46	37	200	120% ANS	Figs. 306 Through 327
242	3.9	2.0	40	36	200	120% ANS	Data Not Plotted
243	3.9	2.0	76	74	200	120% ANS	Data Not Plotted
237	5.6	4.2	45	37	200	120% ANS	Data Not Plotted

1) Measured in the lower plenum
2) Decay heat transient corresponding 120% ANS Standard 40 s after shutdown of the reactor

Table 3 FEBA 5x5 rod bundle: Main test parameters of test series III



Rod Type	TC No.	Axial Level mm
a	1	2225
	2	2770
	3	3315
	4	3860
b	1	45
	2	590
	3	1135
	4	1680
c	1	3725
	2	3825
	3	3925
	4	4025
d	1	2025
	2	2025
	3	2025
	4	2025

Rod Type	TC No.	Axial Level mm
e	1	2075
	2	2125
	3	2175
	4	2225
f	1	2125
	2	2225
	3	2325
	4	2425
g	1	1625
	2	1725
	3	1825
	4	1925
h	1	1925
	2	2025
	3	2125
	4	2225

Rod Type	TC No.	Axial Level mm
x	without TC's	

Fig. 194 5x5 rod bundle: Radial and axial location of cladding, sleeve, fluid and housing TC's for test series III

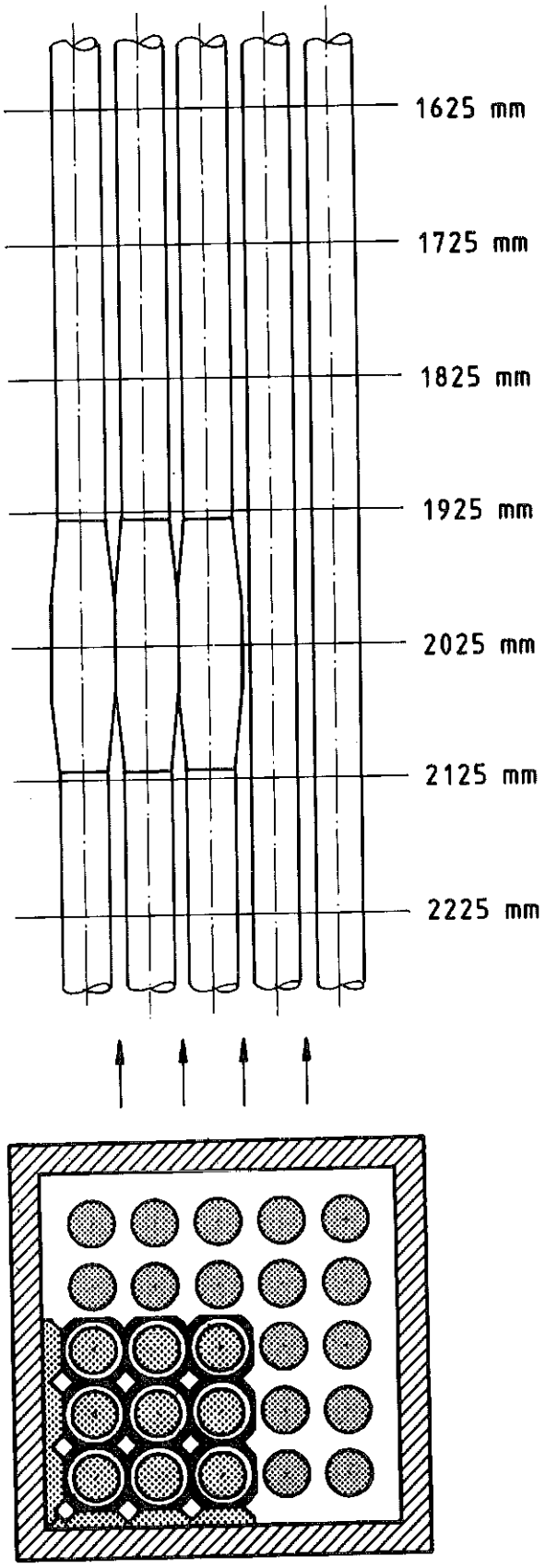
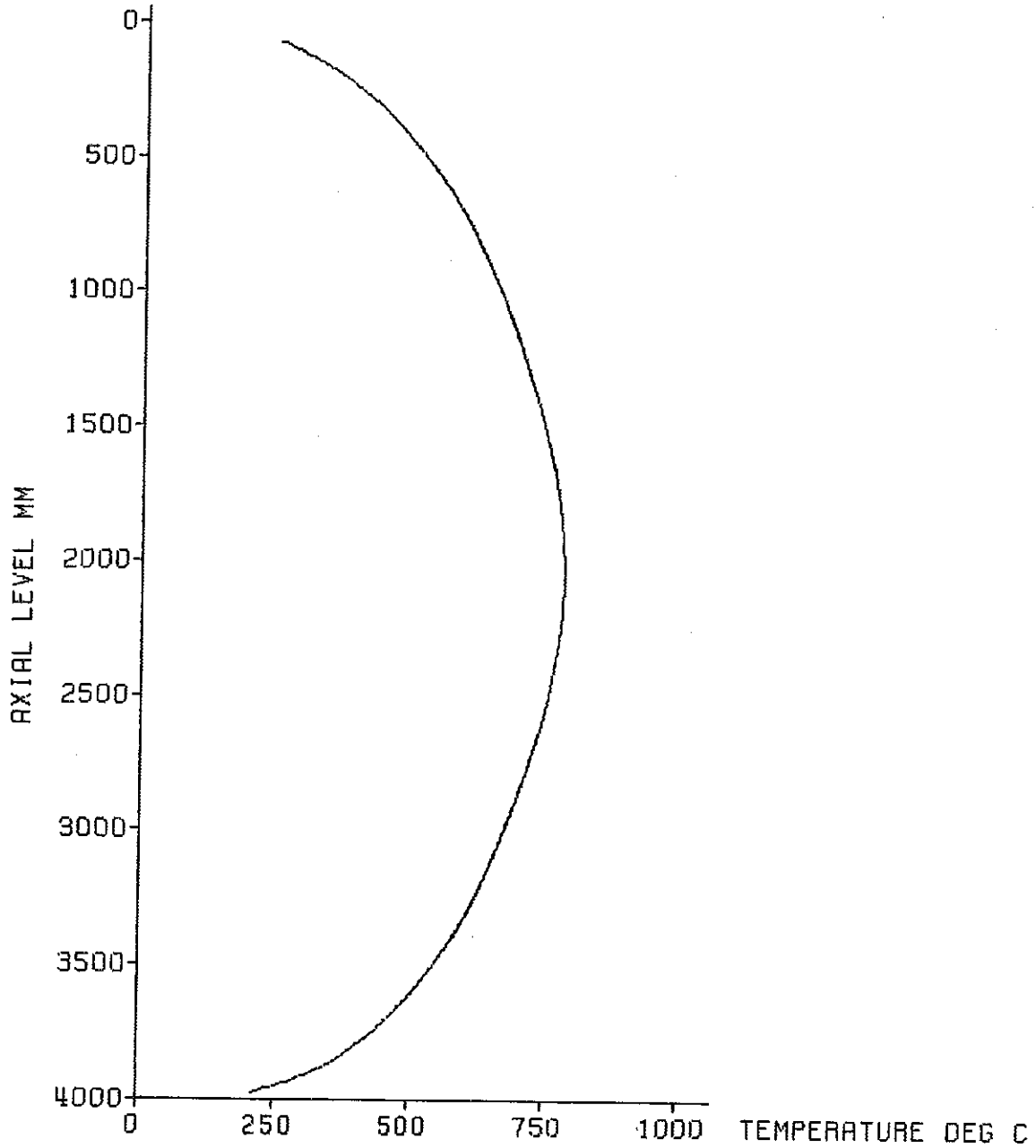


Fig. 195 5x5 rod bundle: Layout of the bundle geometry of test series III

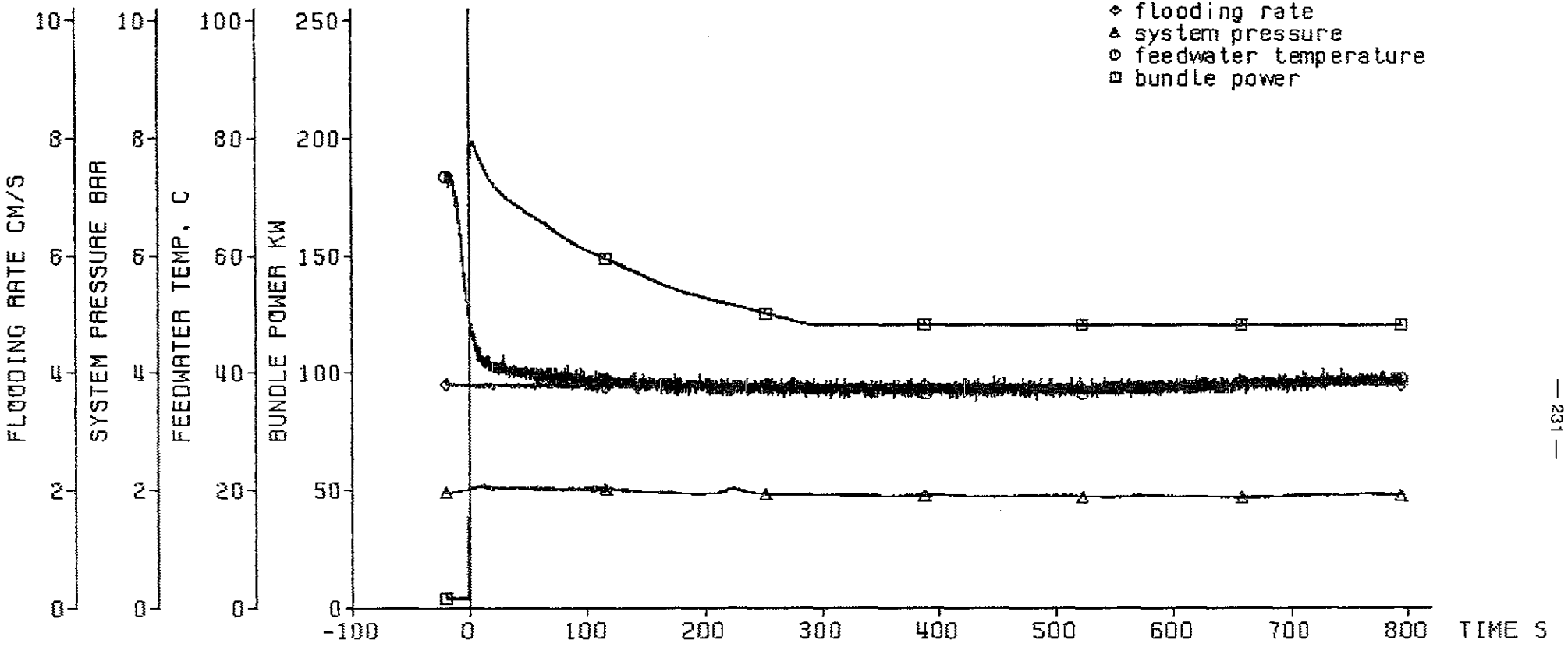
initial axial temperature profile of the cladding



decay heat	120% ANS standard
flooding rate (cold)	3.60 cm/s
system pressure	2.00 bar
feedwater temperature	40 deg C

KfK IRB

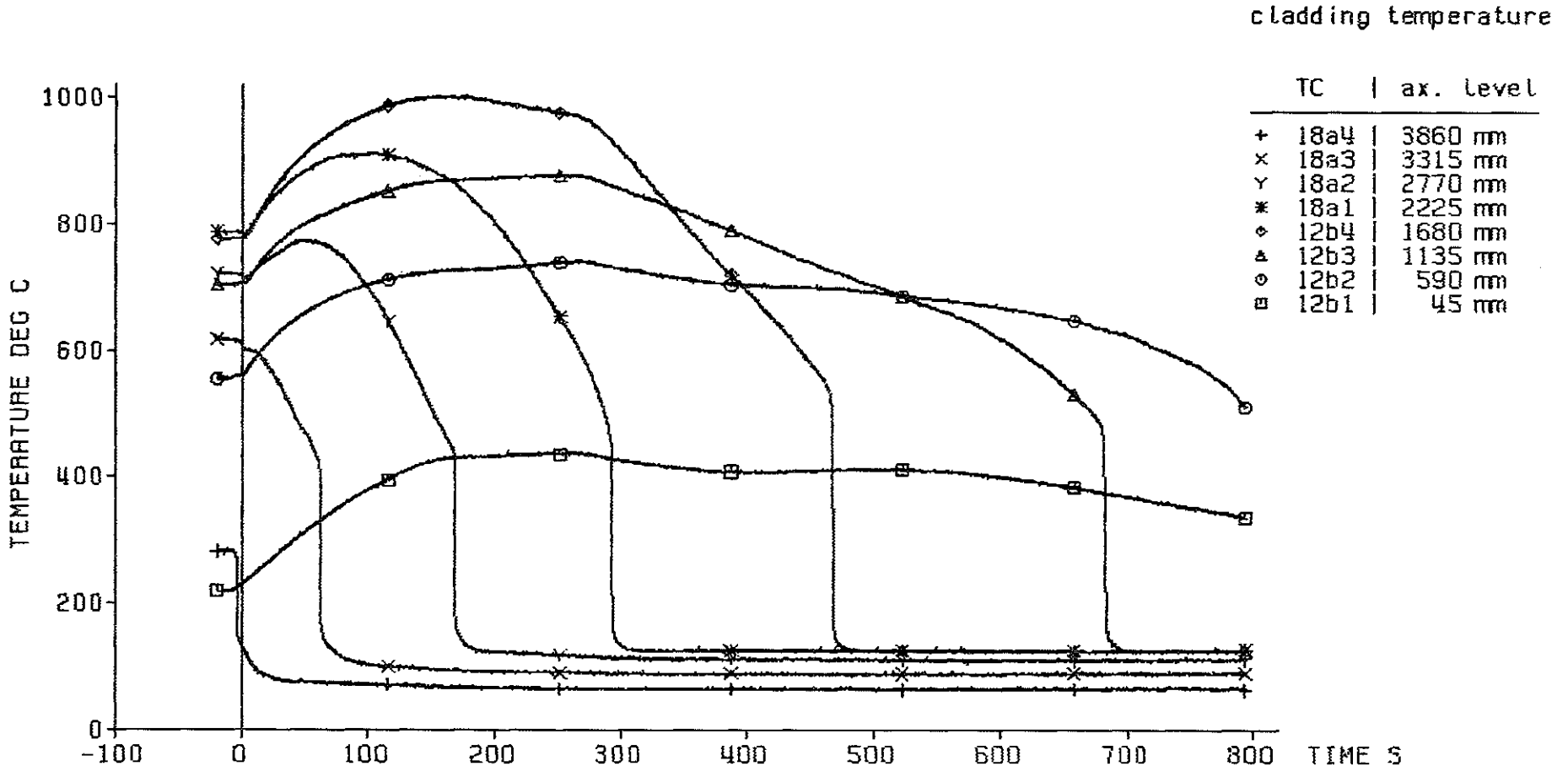
Fig. 196 FEBA: 5x5 ROD BUNDLE TEST SERIES 3, TEST-No. 241



decay heat	120% ANS standard
flooding rate (cold)	3.80 cm/s
system pressure	2.00 bar
feedwater temperature	40 deg C

KfK KIRB

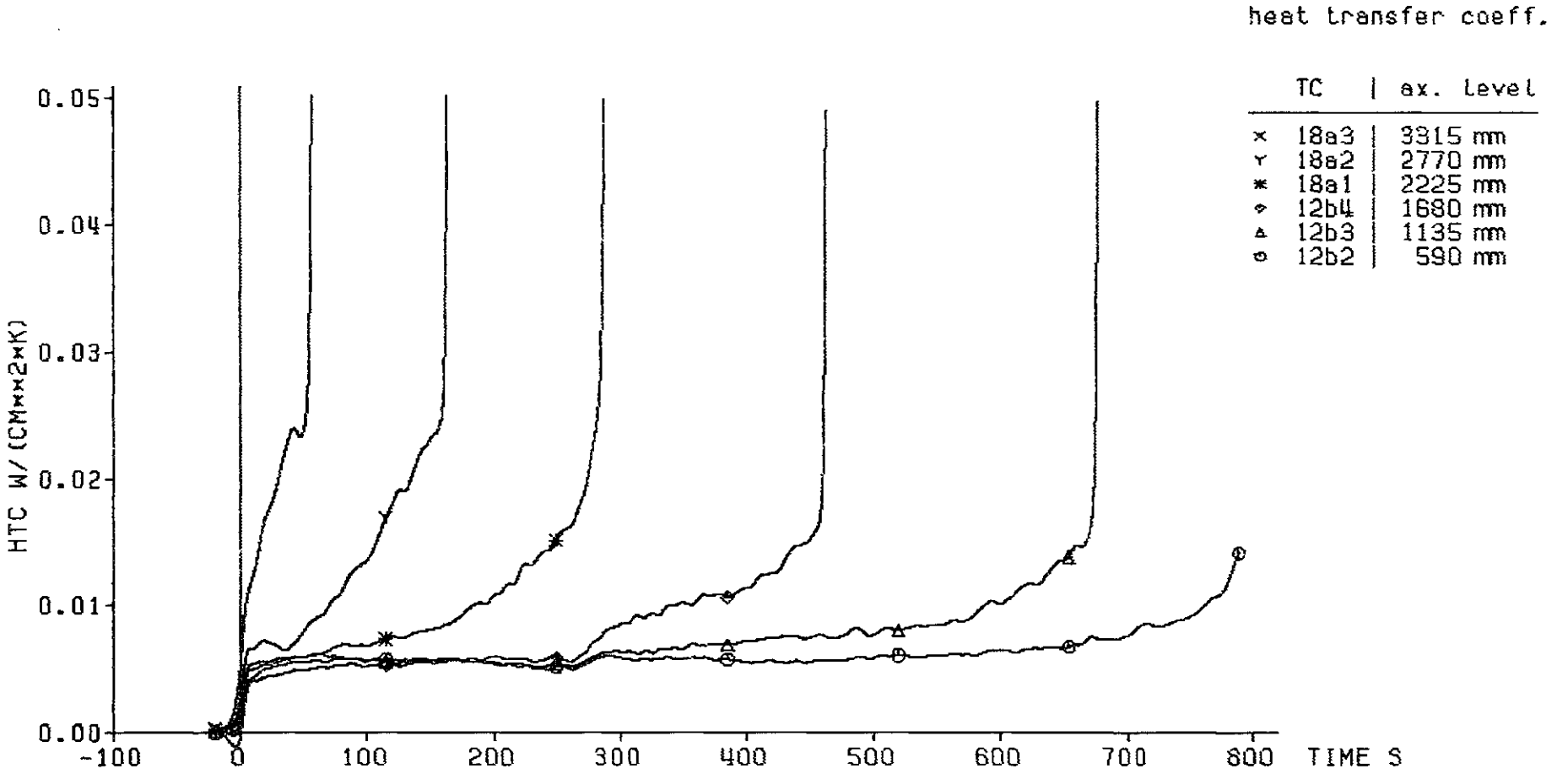
Fig. 197 FEBA: 5x5 ROD BUNDLE, TEST SERIES 3, TEST-No. 241



decay heat	120% ANS standard
flooding rate (cold)	3.80 cm/s
system pressure	2.00 bar
feedwater temperature	40 deg C

KfK IRB

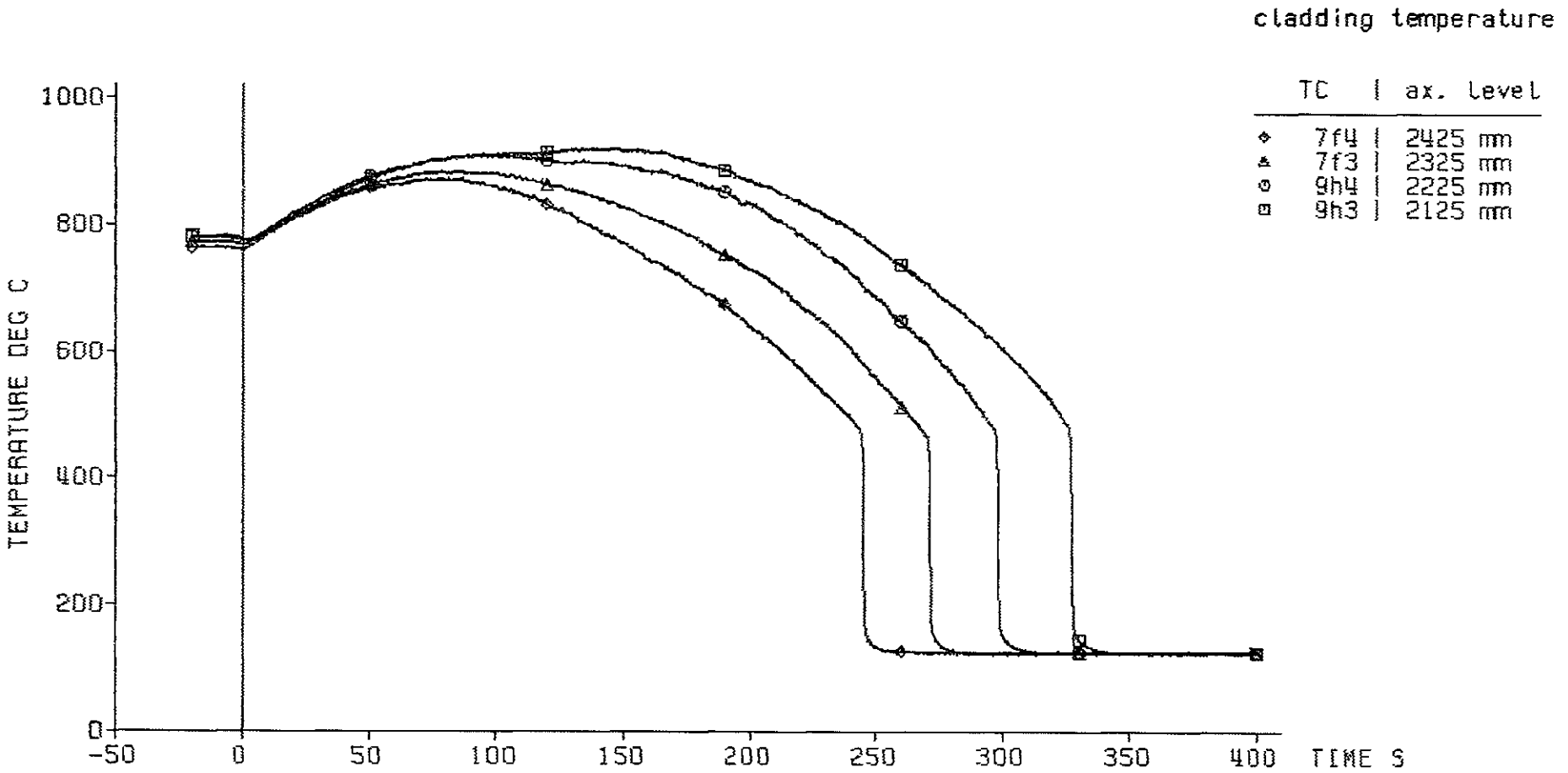
Fig. 198 FEBA: 5x5 ROD BUNDLE, TEST SERIES 3, TEST-No. 241



decay heat	120% ANS standard
flooding rate (cold)	3.80 cm/s
system pressure	2.00 bar
feedwater temperature	40 deg C

KfK IRB

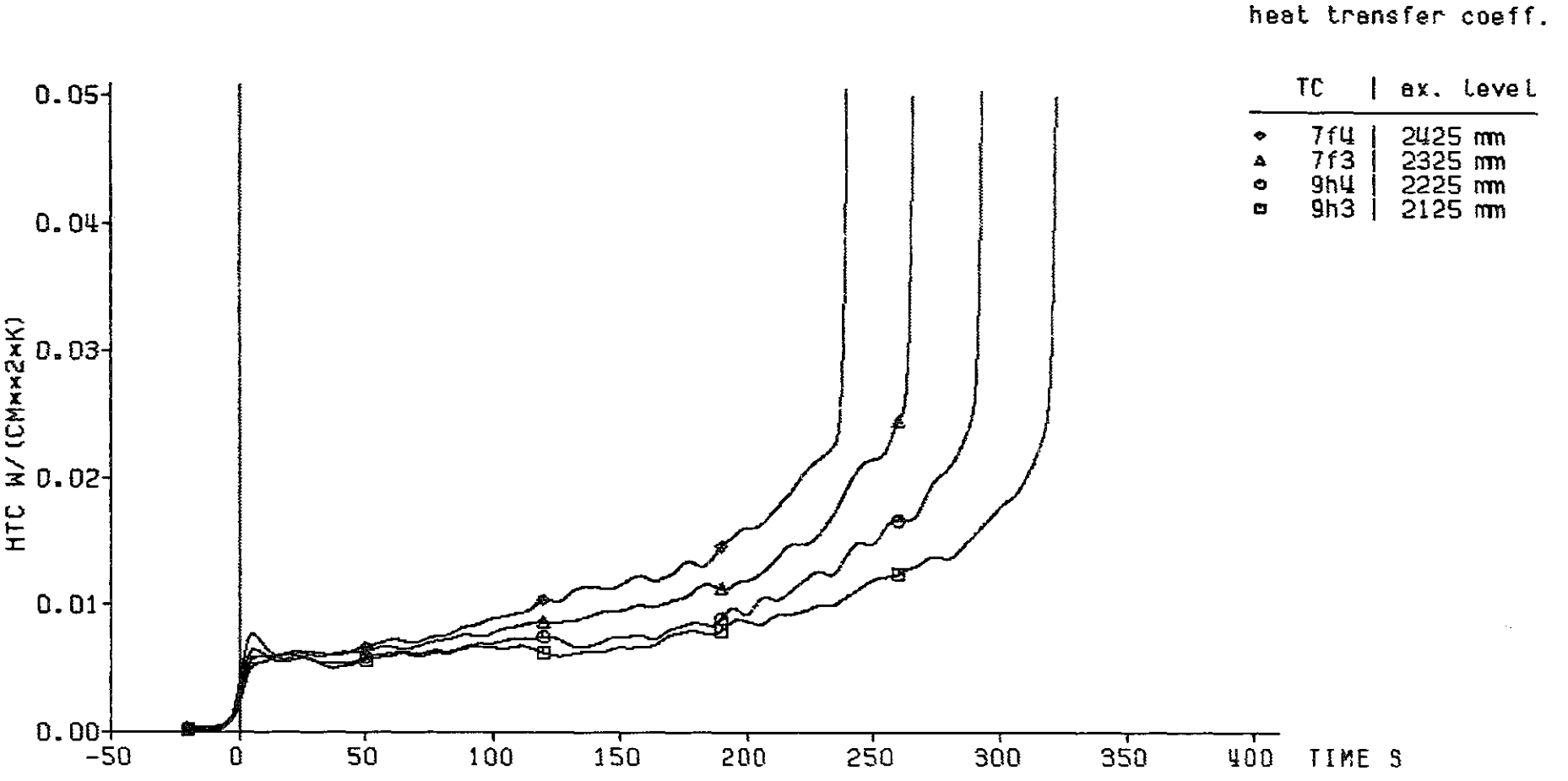
Fig. 199 FEBA: 5x5 ROD BUNDLE, TEST SERIES 3, TEST-No. 241



decay heat	120% ANS standard	bypass
flooding rate (cold)	3.80 cm/s	======
system pressure	2.00 bar	
feedwater temperature	40 deg C	

KfK KIRB

Fig. 200 FEBA: 5x5 ROD BUNDLE, TEST SERIES 3, TEST-No. 241

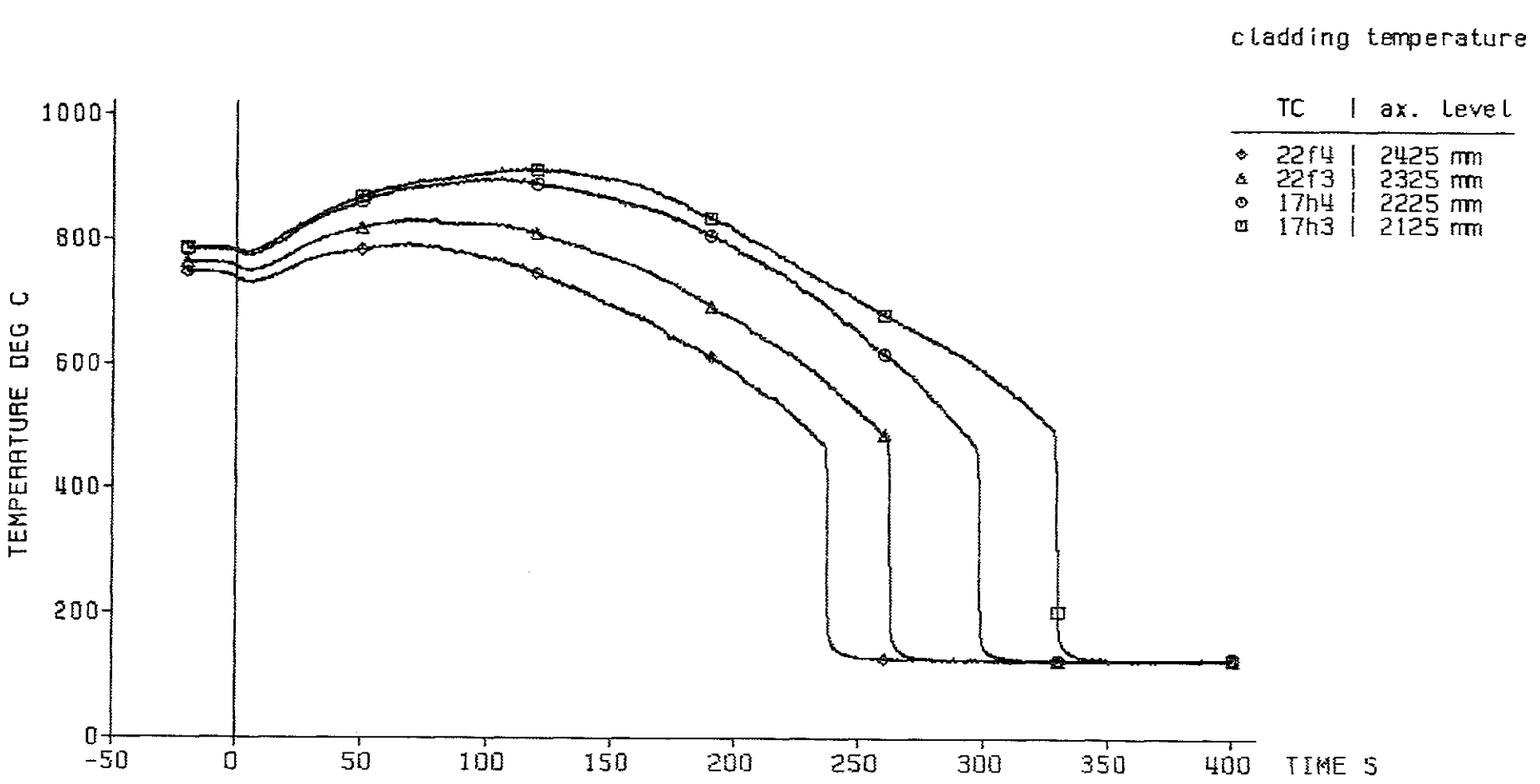


decay heat 120% ANS standard
flooding rate (cold) 3.80 cm/s
system pressure 2.00 bar
feedwater temperature 40 deg C

bypass
======

KfK IRB

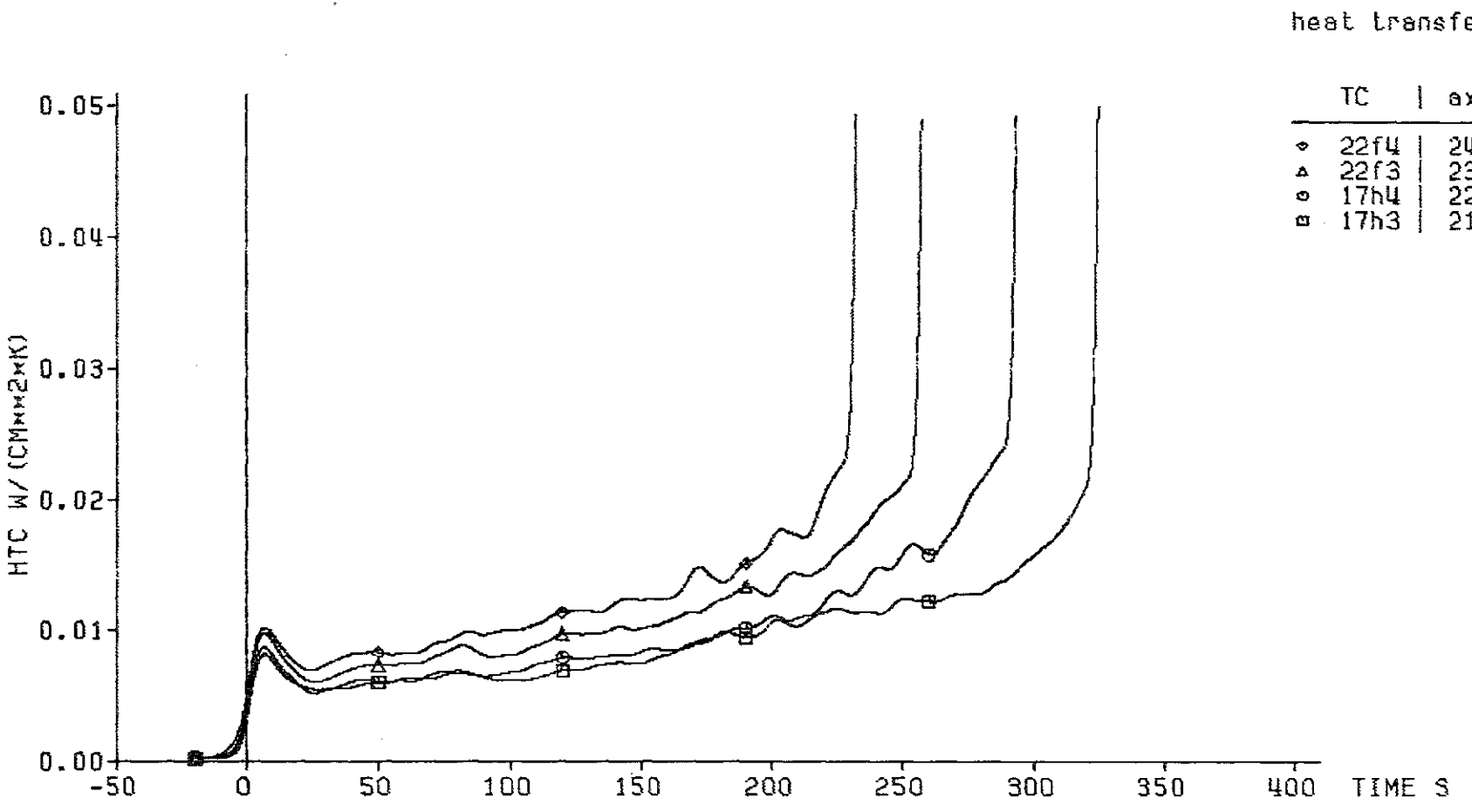
Fig. 201 FEBA: 5x5 ROD BUNDLE, TEST SERIES 3, TEST-No. 241



decay heat	120% ANS standard	blockage
flooding rate (cold)	3.80 cm/s	========
system pressure	2.00 bar	
feedwater temperature	40 deg C	

KfK IRB

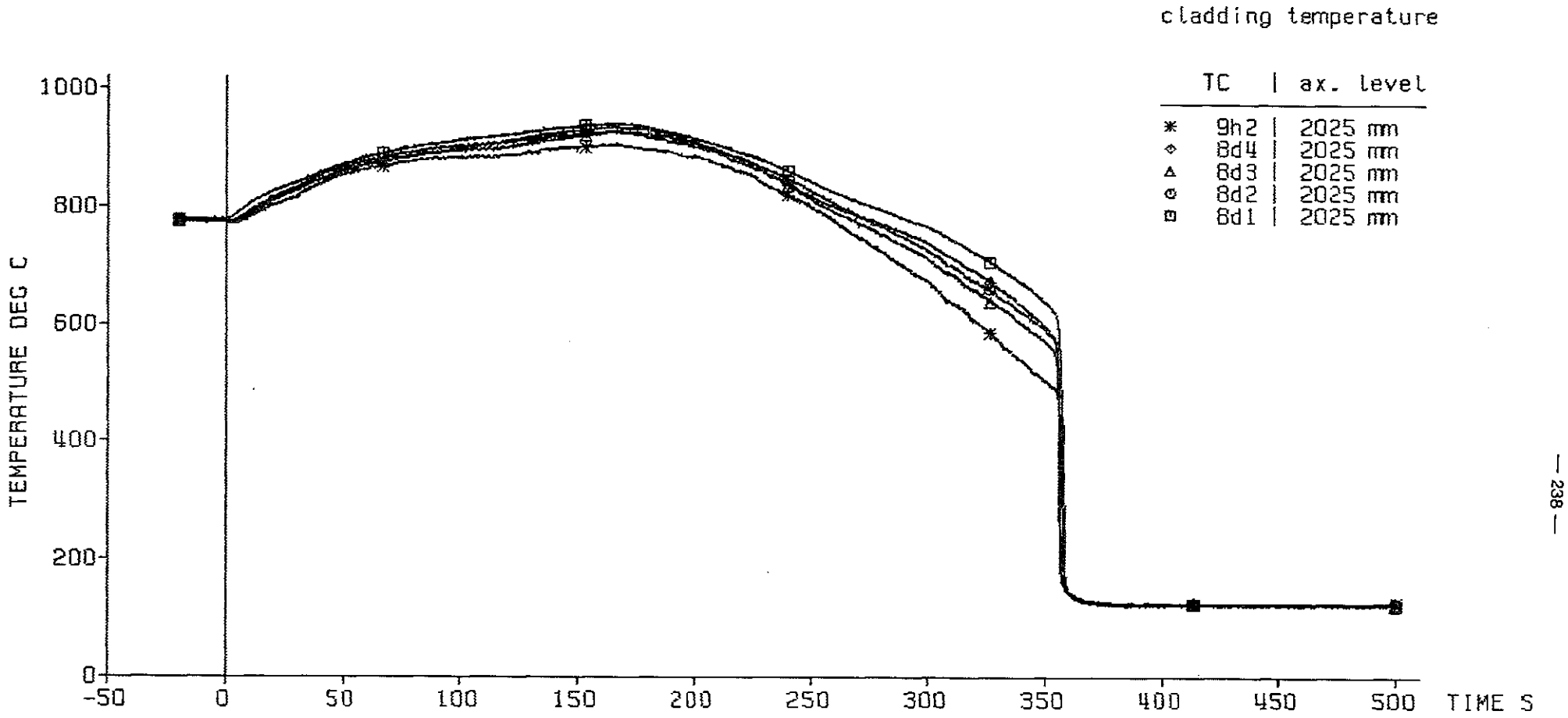
Fig. 202 FEBA: 5x5 ROD BUNDLE, TEST SERIES 3, TEST-No. 241



decay heat	120% ANS standard	blockage
flooding rate (cold)	3.80 cm/s	========
system pressure	2.00 bar	
feedwater temperature	40 deg C	

KfK IRB

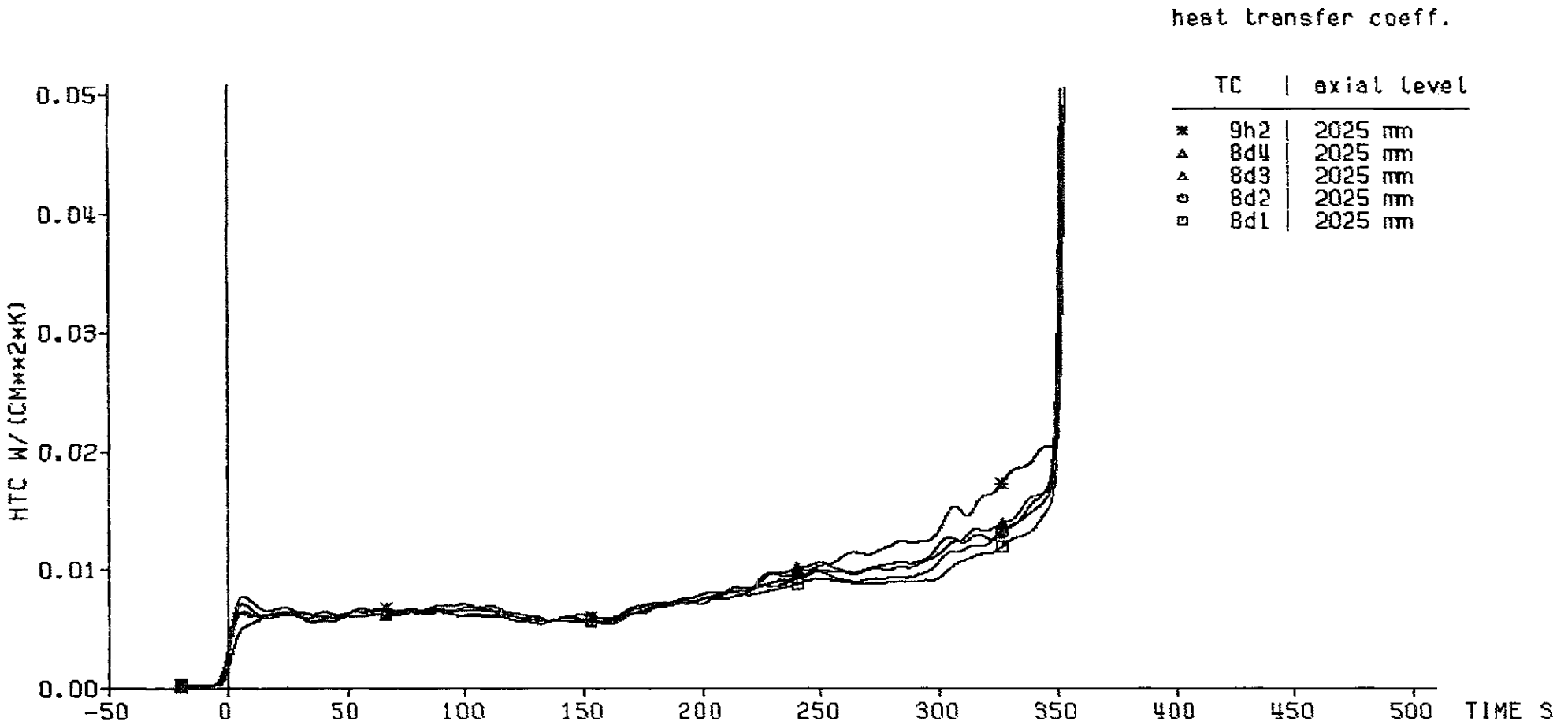
Fig. 203 FEBA: 5x5 ROD BUNDLE, TEST SERIES 3, TEST-No. 241



decay heat	120% ANS standard	bypass
flooding rate (cold)	3.80 cm/s	======
system pressure	2.00 bar	
feedwater temperature	40 deg C	

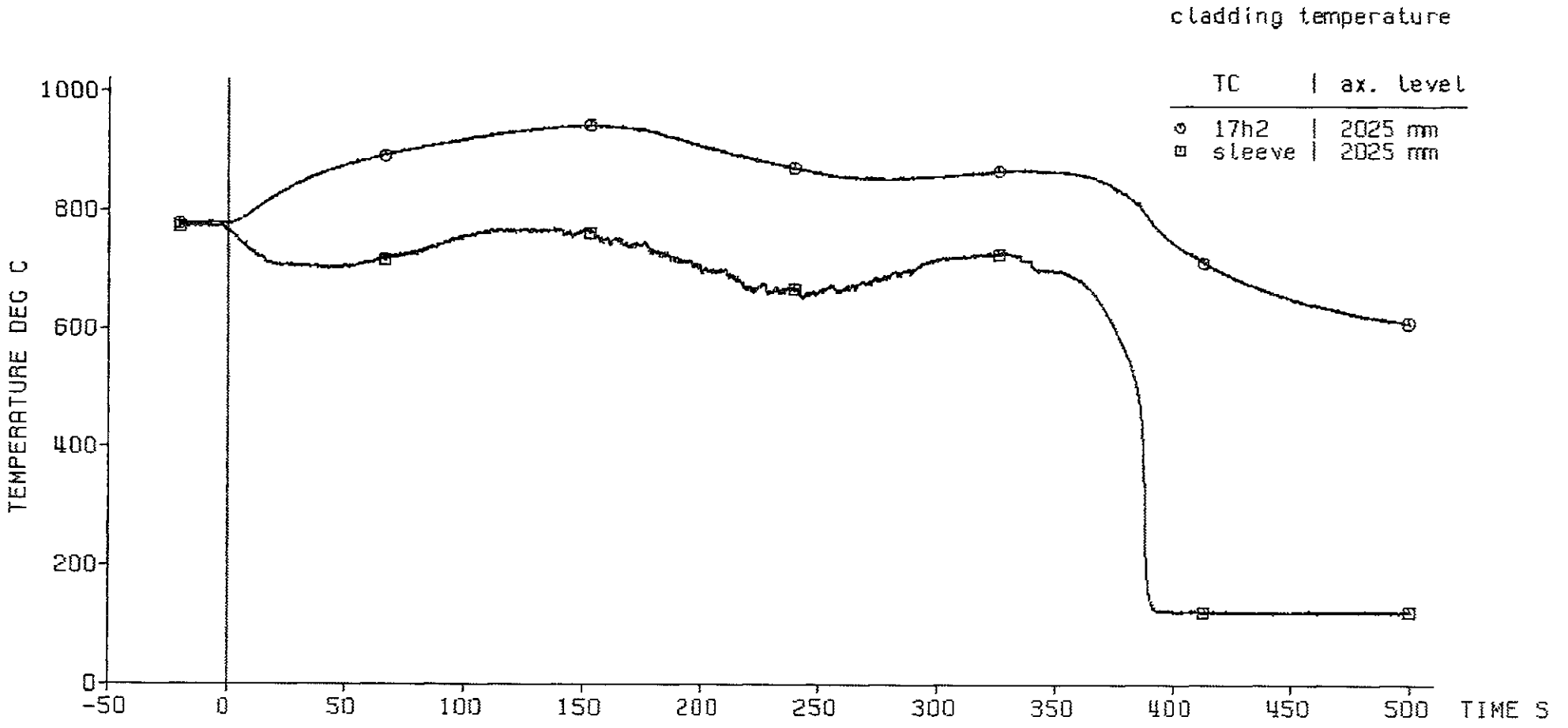
KfK IRB

Fig. 204 FEBA: 5x5 ROD BUNDLE, TEST SERIES 3, TEST-No. 241



decay heat	120% ANS standard	bypass
flooding rate (cold)	3.80 cm/s	======
system pressure	2.00 bar	
feedwater temperature	40 deg C	

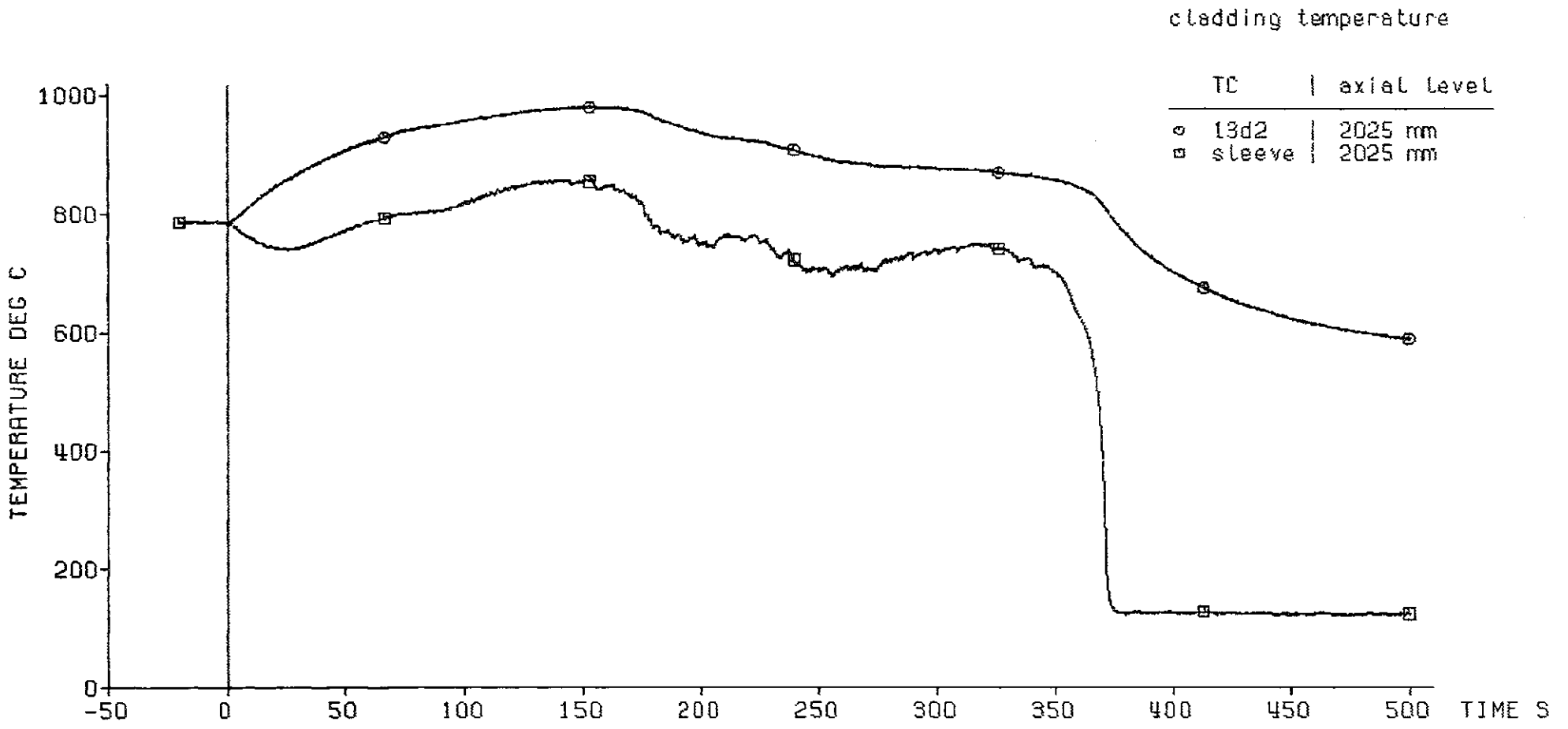
Fig. 205 FEBA: 5x5 ROD BUNDLE, TEST SERIES 3, TEST-No. 241



decay heat	120% ANS standard	blockage
flooding rate (cold)	3.80 cm/s	========
system pressure	2.00 bar	
feedwater temperature	40 deg C	

KfK IRB

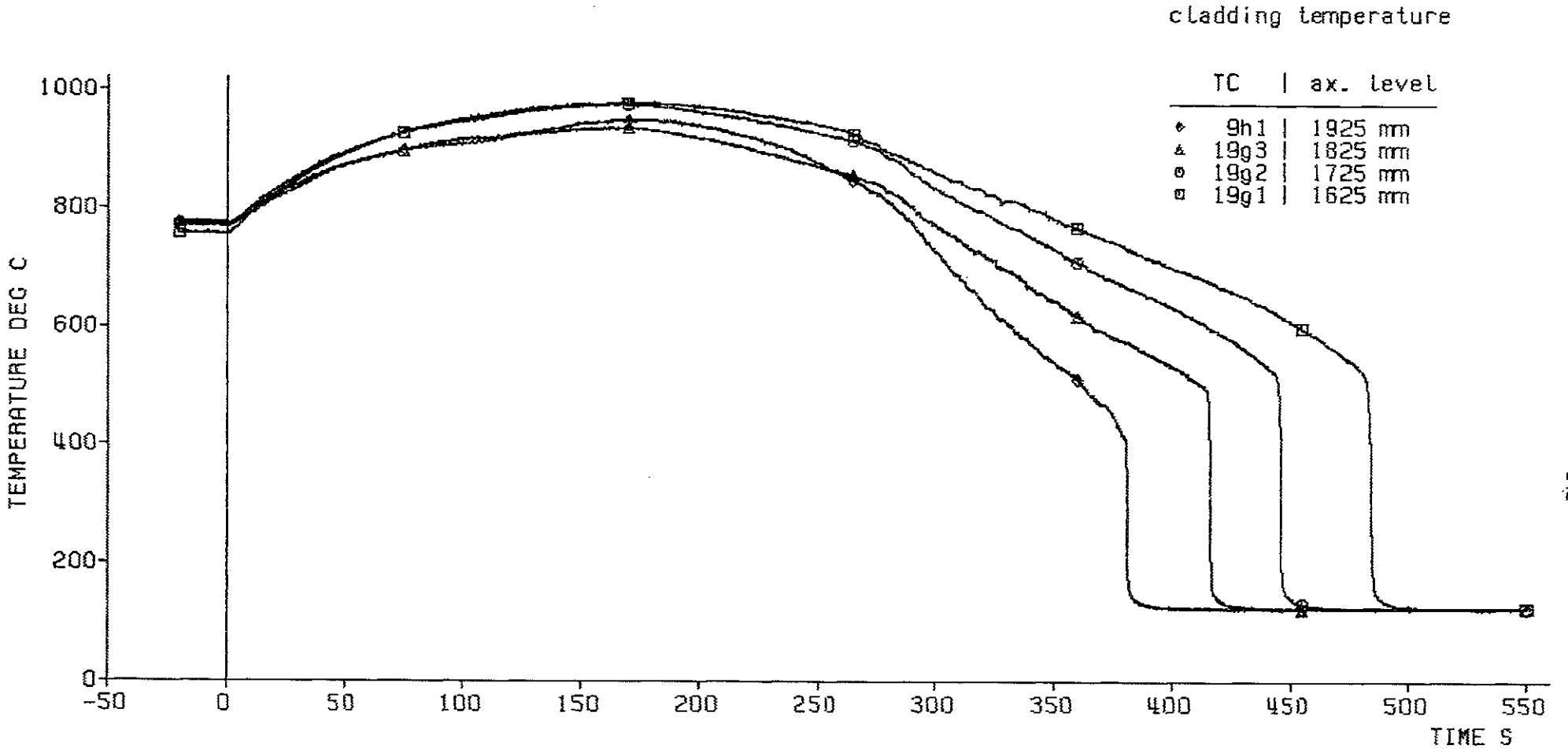
Fig. 206 FEBA: 5x5 ROD BUNDLE, TEST SERIES 3, TEST-No. 241



decay heat	120% ANS standard	blockage
flooding rate (cold)	3.80 cm/s	========
system pressure	2.00 bar	
feedwater temperature	40 deg C	

KfK KIRB

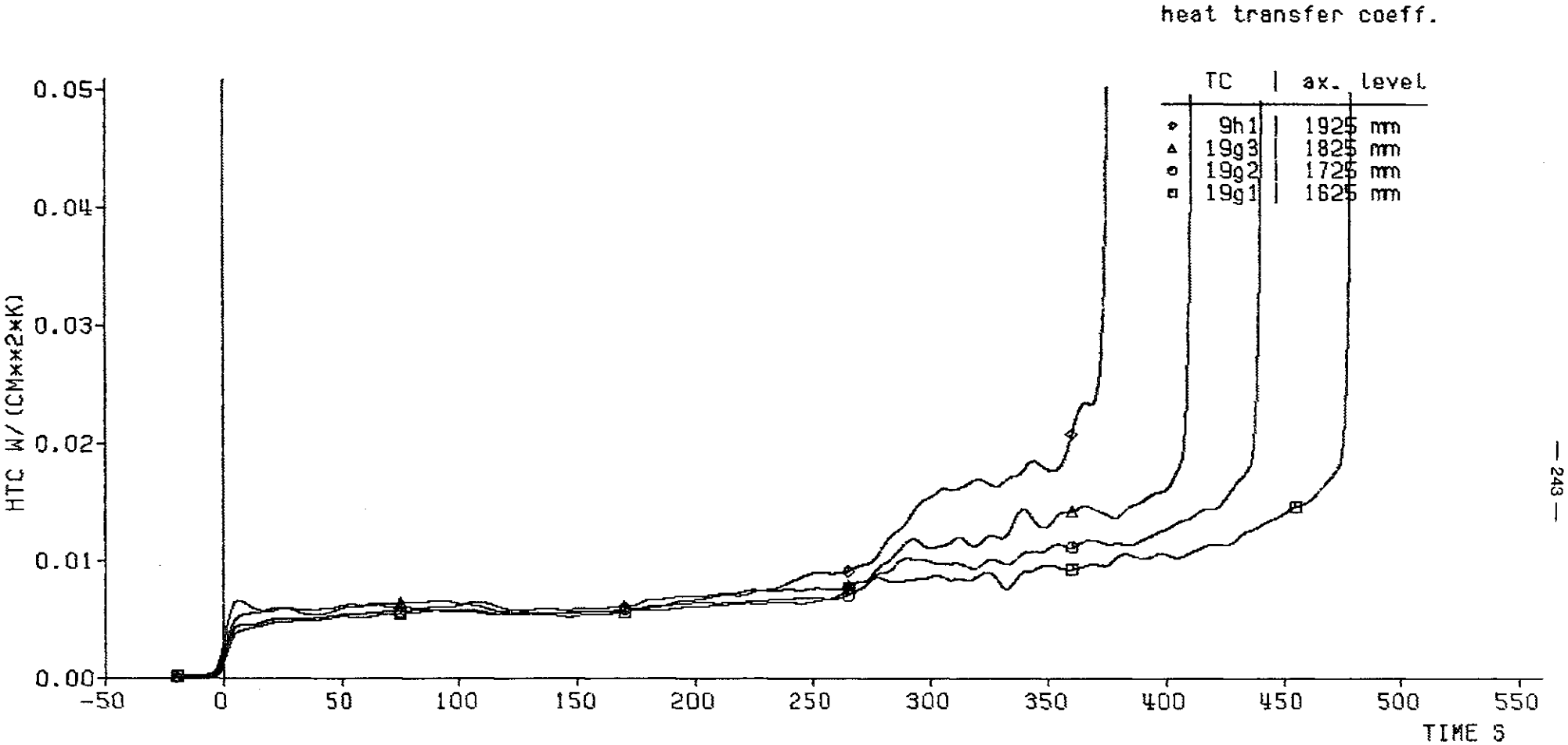
Fig. 207 FEBA: 5x5 ROD BUNDLE, TEST SERIES 3, TEST-No. 241



decay heat	120% ANS standard	bypass
flooding rate (cold)	3.80 cm/s	======
system pressure	2.00 bar	
feedwater temperature	40 deg C	

KfK IRB

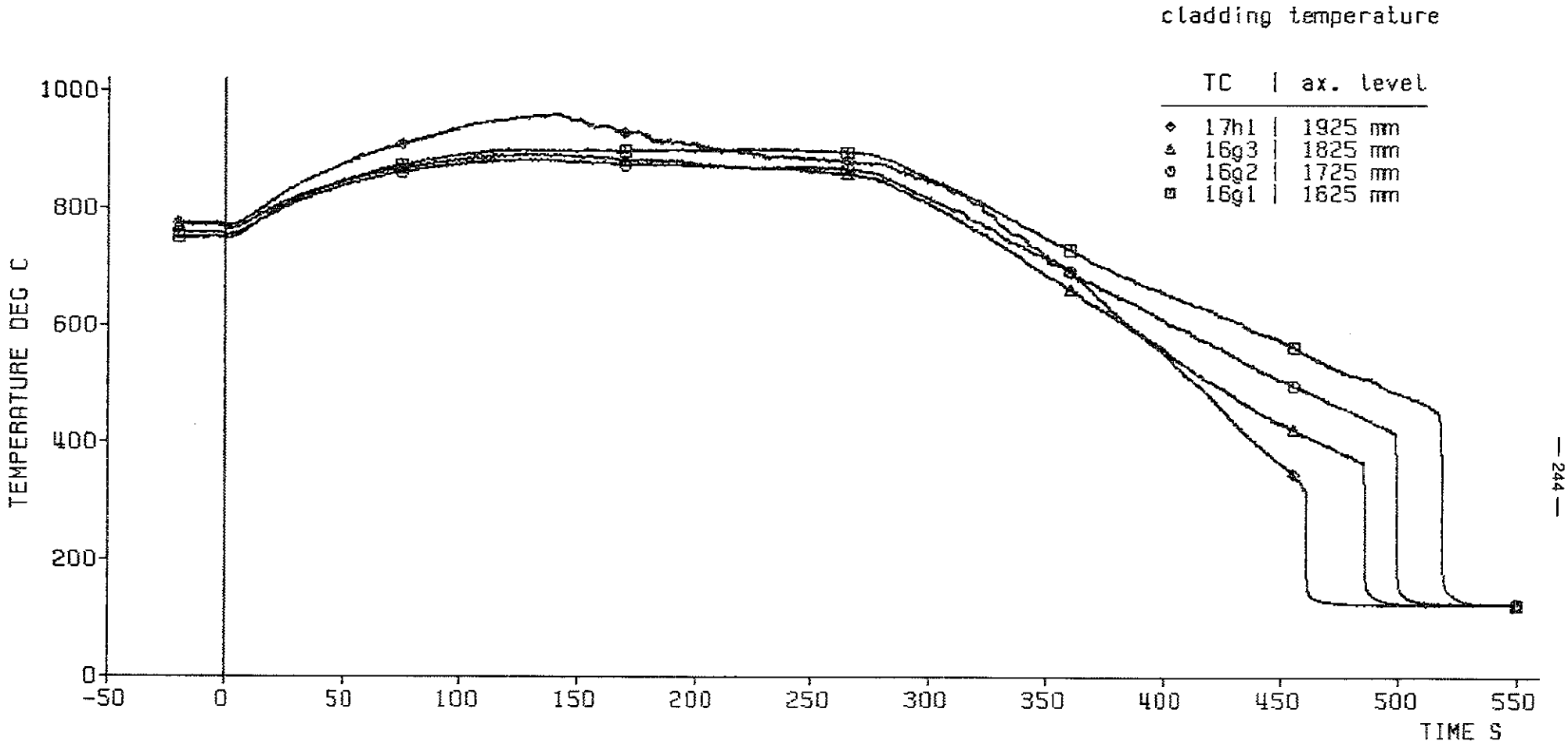
Fig. 208 FEBA: 5x5 ROD BUNDLE, TEST SERIES 3, TEST-No. 241



decay heat	120% ANS standard	bypass
flooding rate (cold)	3.80 cm/s	======
system pressure	2.00 bar	
feedwater temperature	40 deg C	

KfK IRB

Fig. 209 FEBA: 5x5 ROD BUNDLE, TEST SERIES 3, TEST-No. 241

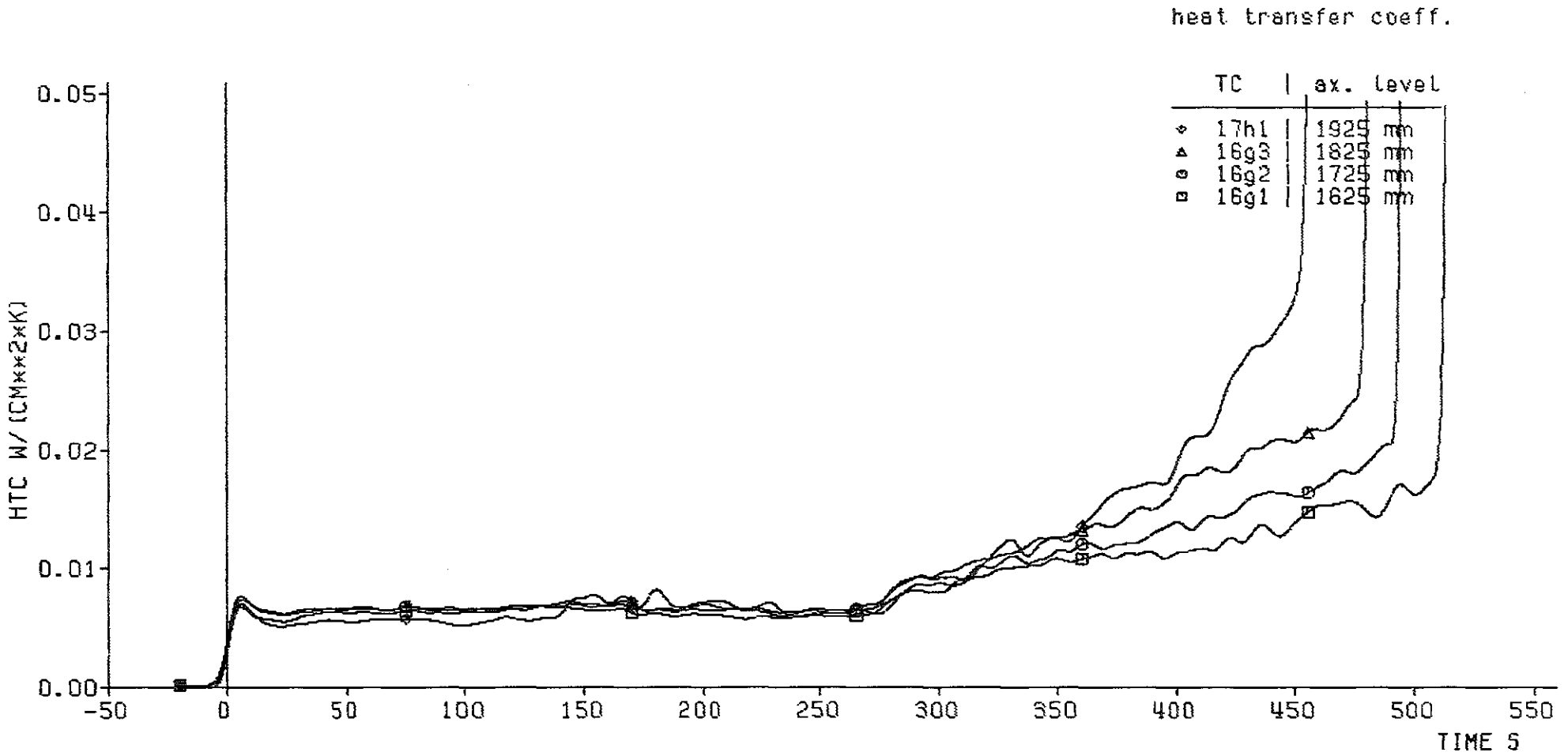


decay heat	120% ANS standard
flooding rate (cold)	3.80 cm/s
system pressure	2.00 bar
feedwater temperature	40 deg C

blockage
========

KfK IRB

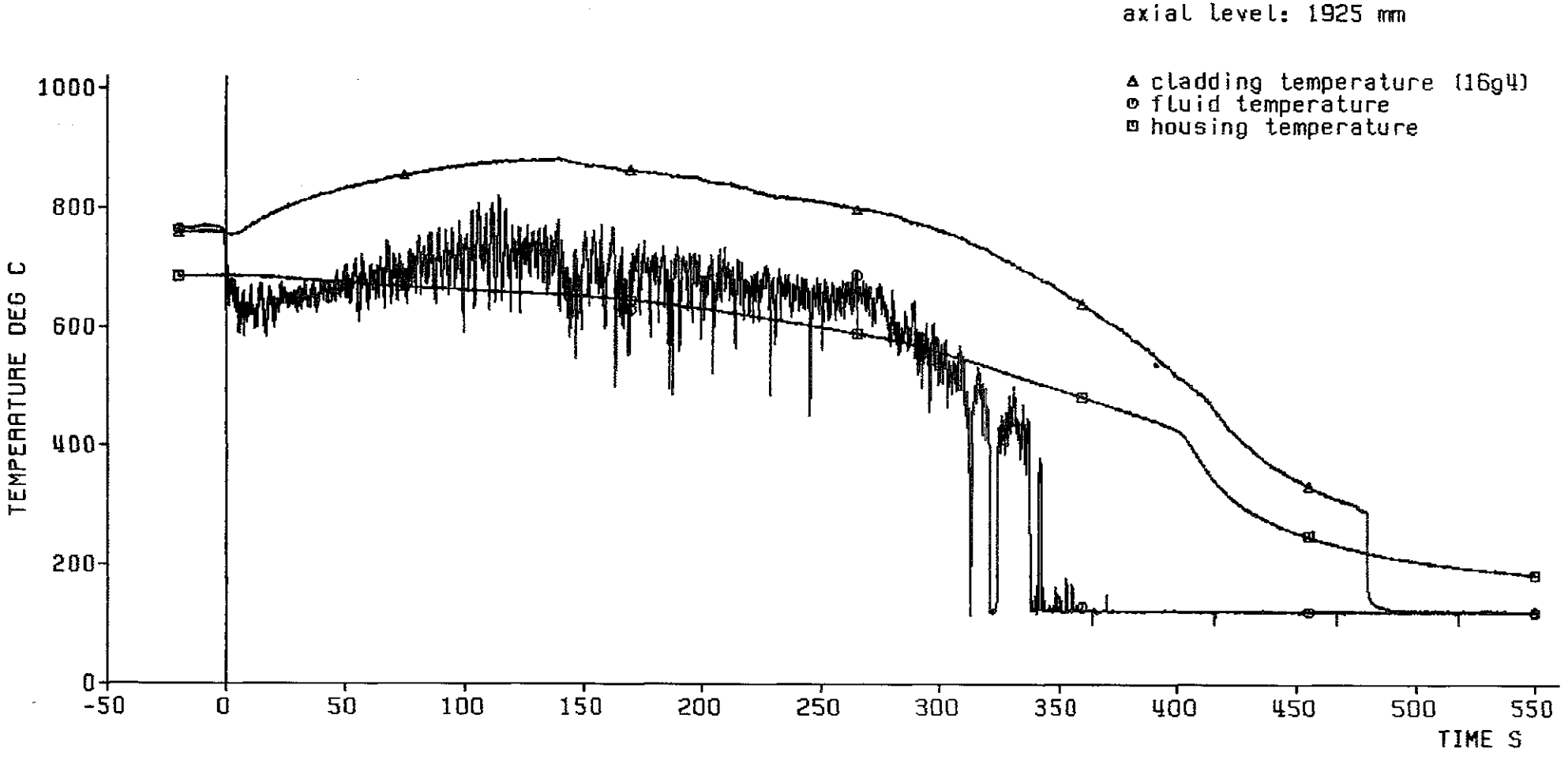
Fig. 210 FEBA: 5x5 ROD BUNDLE, TEST SERIES 3, TEST-No. 241



decay heat	120% ANS standard	blockage
flooding rate (cold)	3.80 cm/s	========
system pressure	2.00 bar	
feedwater temperature	40 deg C	

KfK IRB

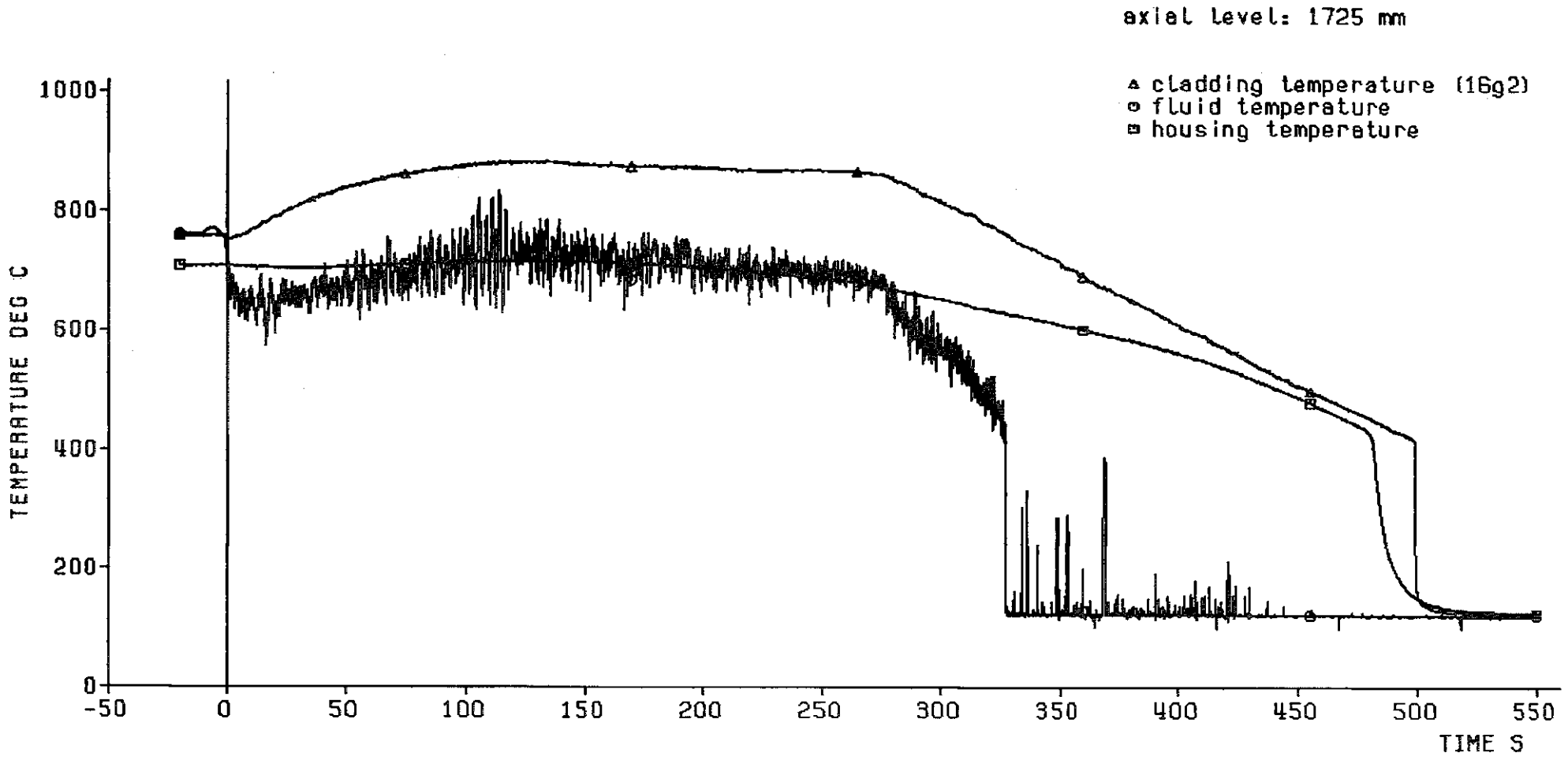
Fig. 211 FEBA: 5x5 ROD BUNDLE, TEST SERIES 3, TEST-No. 241



decay heat	120% ANS standard	blockage
flooding rate (cold)	3.80 cm/s	========
system pressure	2.00 bar	
feedwater temperature	40 deg C	

KfK IRB

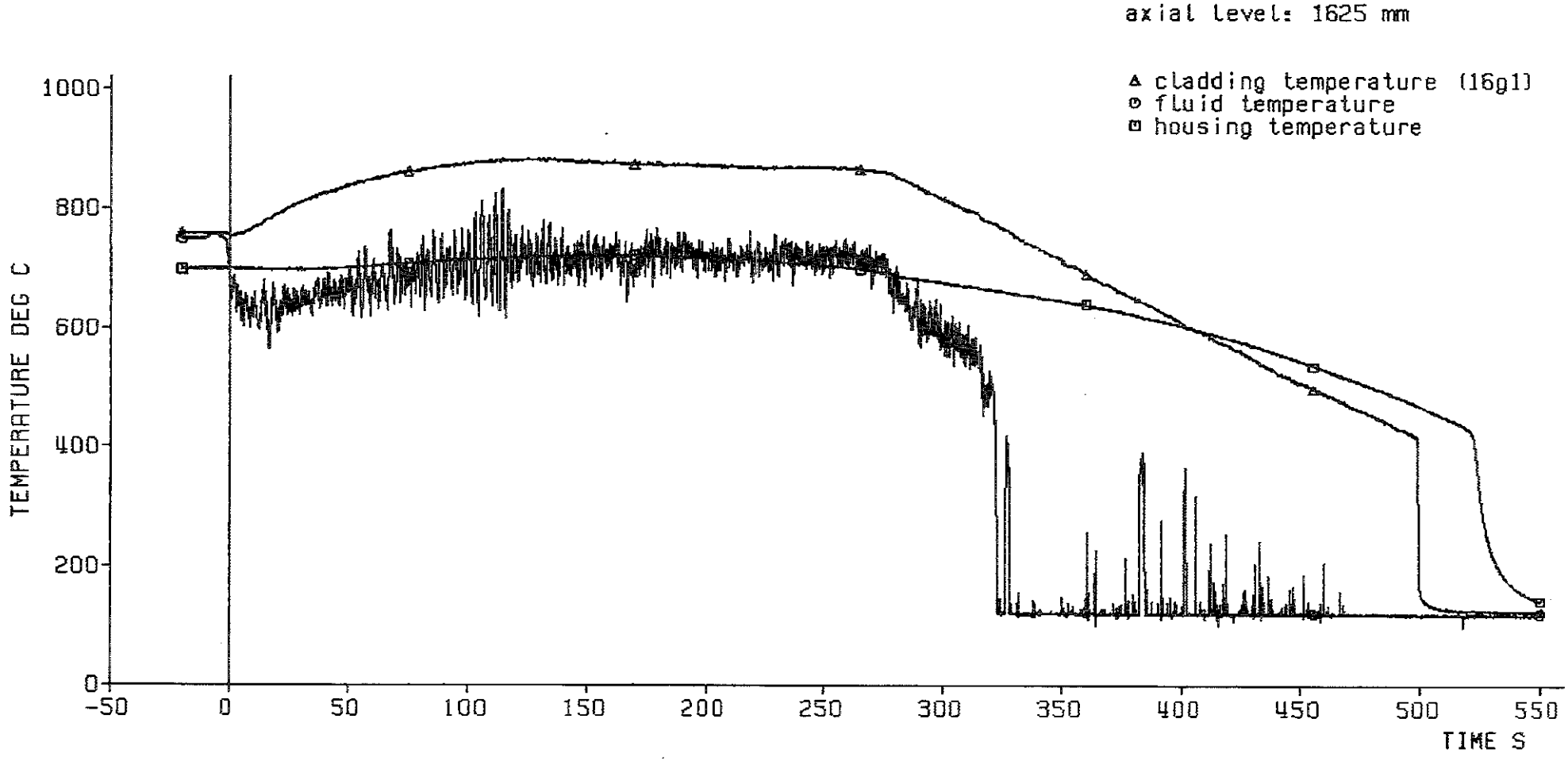
Fig. 212 FEBA: 5x5 ROD BUNDLE, TEST SERIES 3, TEST-No. 241



decay heat	120% ANS standard	blockage
flooding rate (cold)	3.80 cm/s	========
system pressure	2.00 bar	
feedwater temperature	40 deg C	

KfK IRB

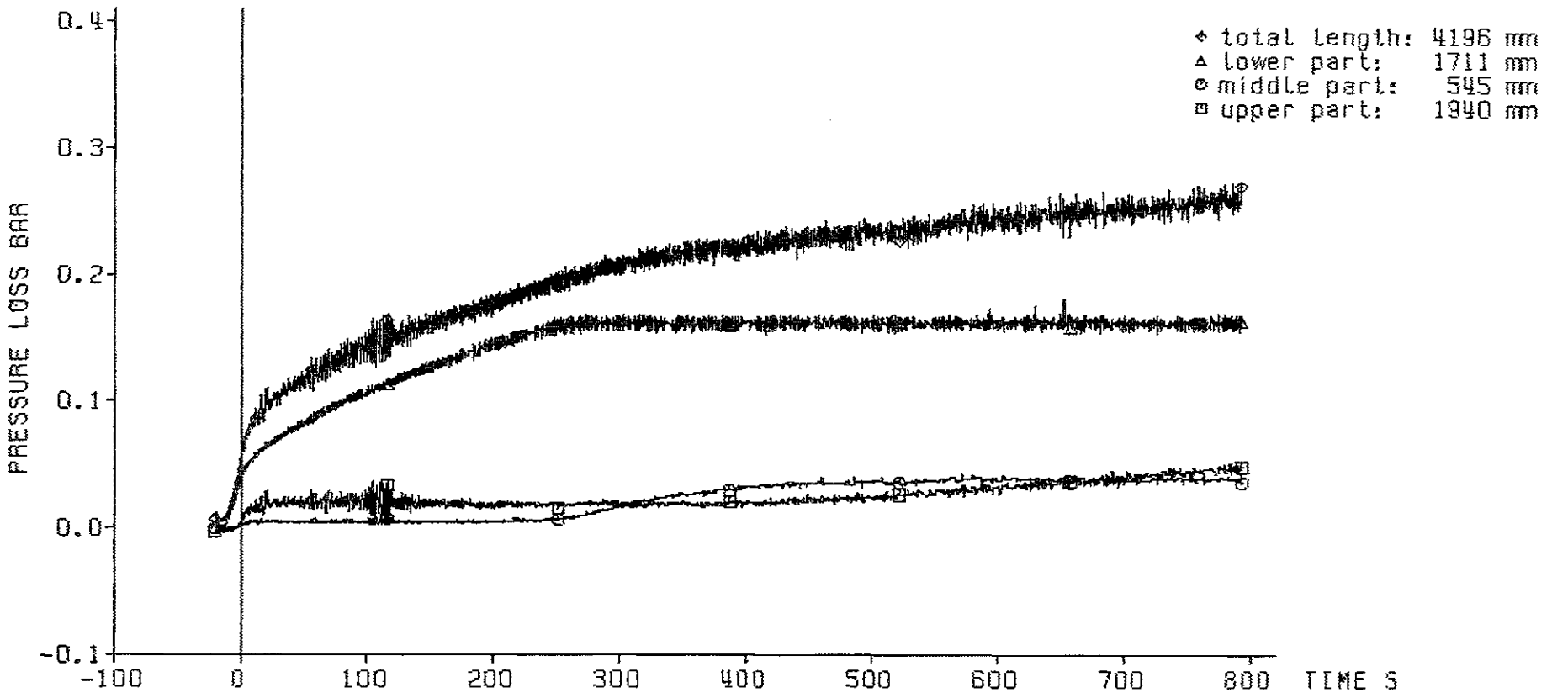
Fig. 213 FEBA: 5x5 ROD BUNDLE, TEST SERIES 3, TEST-No. 241



decay heat	120% ANS standard	blockage
flooding rate (cold)	3.80 cm/s	========
system pressure	2.00 bar	
feedwater temperature	40 deg C	

KfK IRB

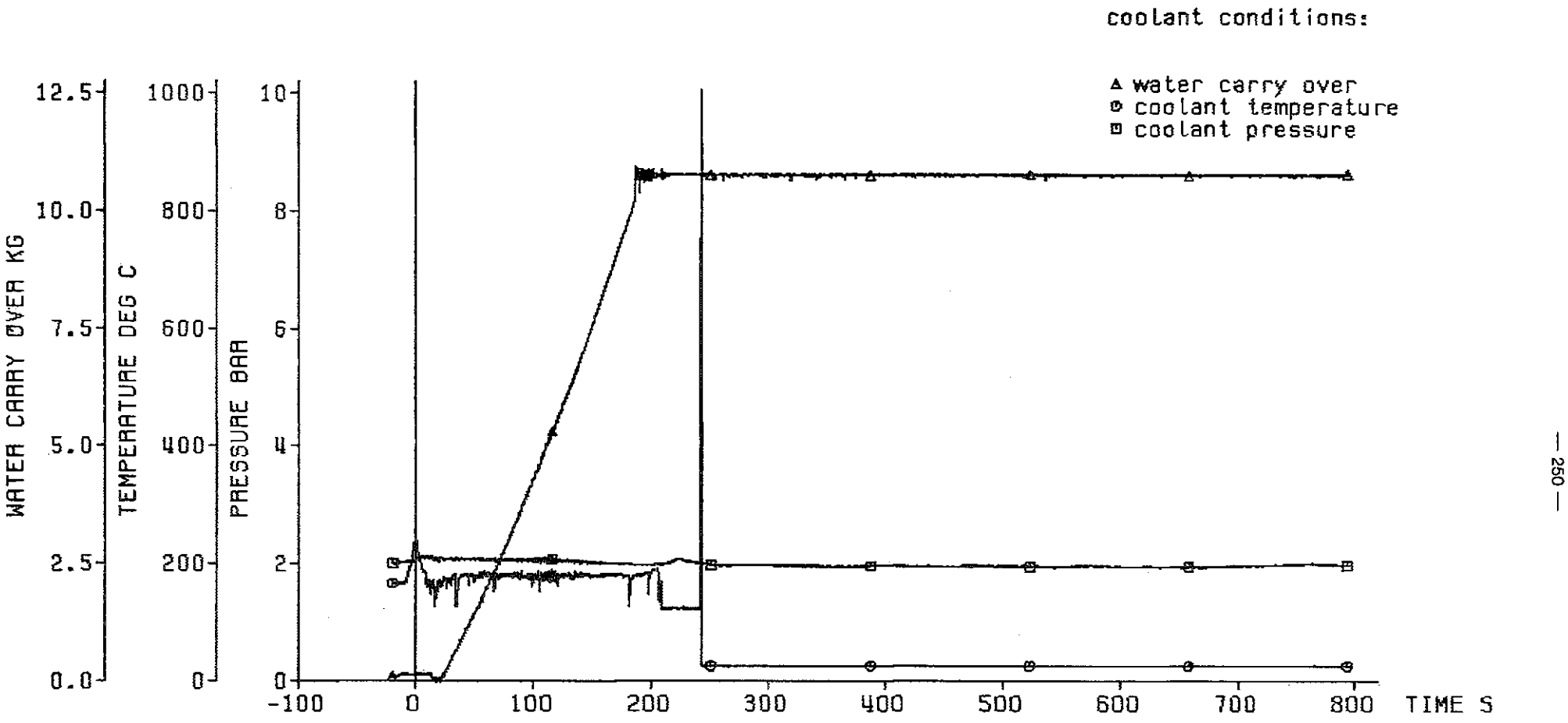
Fig. 214 FEBA: 5x5 ROD BUNDLE, TEST SERIES 3, TEST-No. 241



decay heat	120% ANS standard
flooding rate (cold)	3.80 cm/s
system pressure	2.00 bar
feedwater temperature	40 deg C

KfK KIRB

Fig. 215 FEBA: 5x5 ROD BUNDLE, TEST SERIES 3, TEST-No. 241



decay heat	120% ANS standard
flooding rate (cold)	3.80 cm/s
system pressure	2.00 bar
feedwater temperature	40 deg C

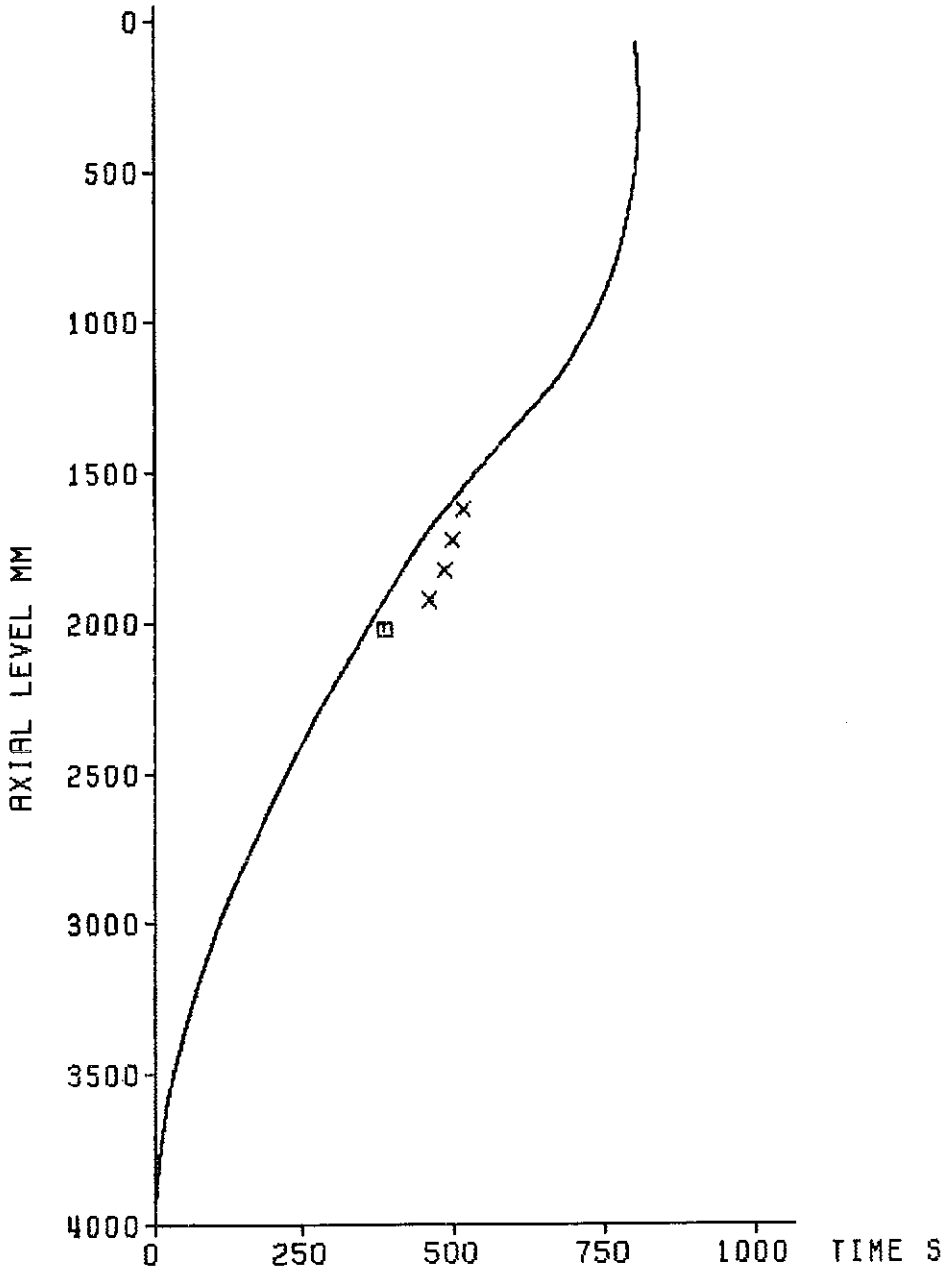
KfK KIRB

Fig. 216 FEBA: 5x5 ROD BUNDLE, TEST SERIES 3, TEST-No. 241

axial position of the quench front

▫ rewetting of the sleeve at the bundle midplane

× rewetting of the rod downstream of the blockage

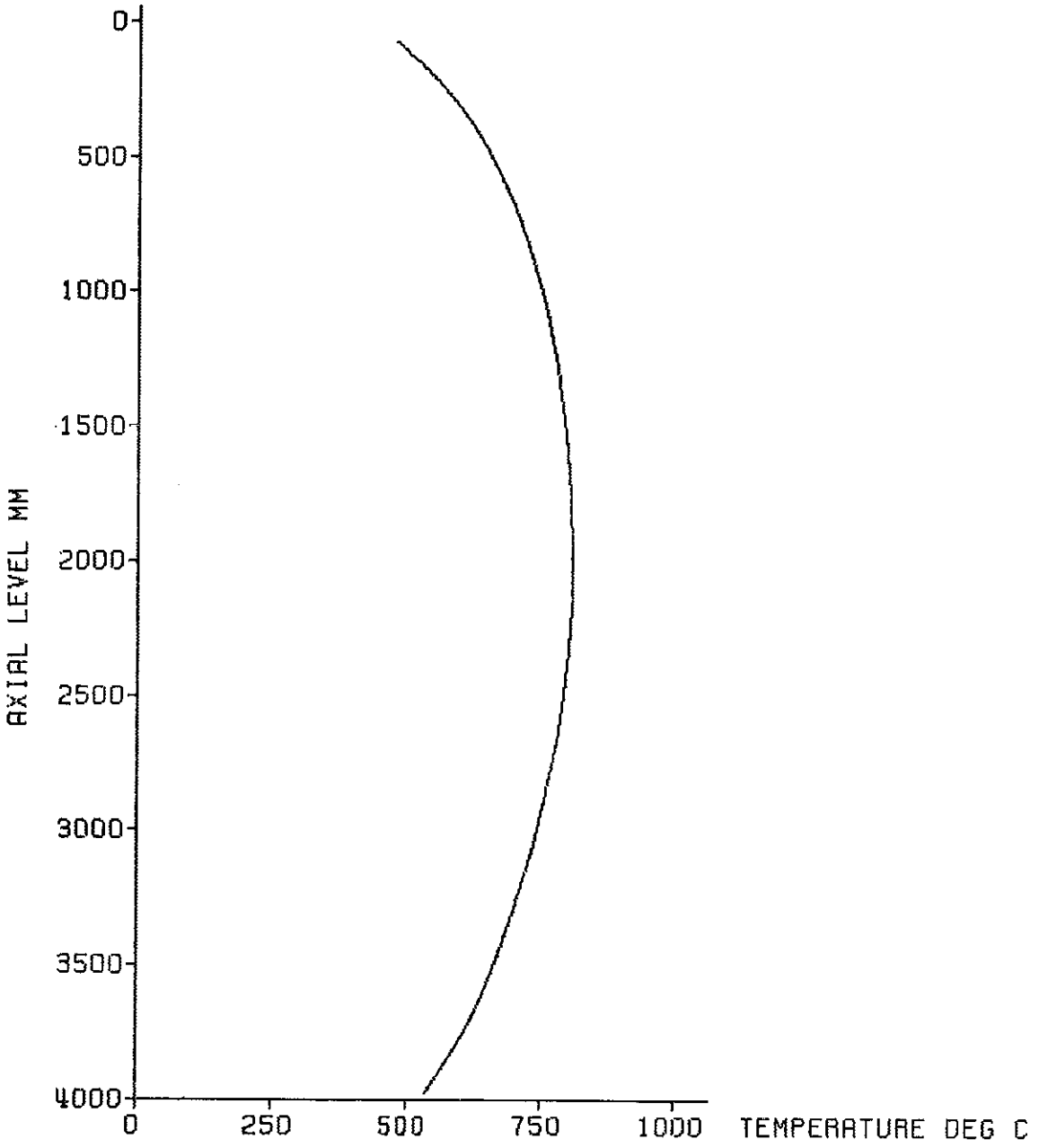


decay heat	120% ANS standard
flooding rate (cold)	3.80 cm/s
system pressure	2.00 bar
feedwater temperature	40 deg C

KfK IRB

Fig. 217 FEBA: 5x5 ROD BUNDLE TEST SERIES 3, TEST-No. 241

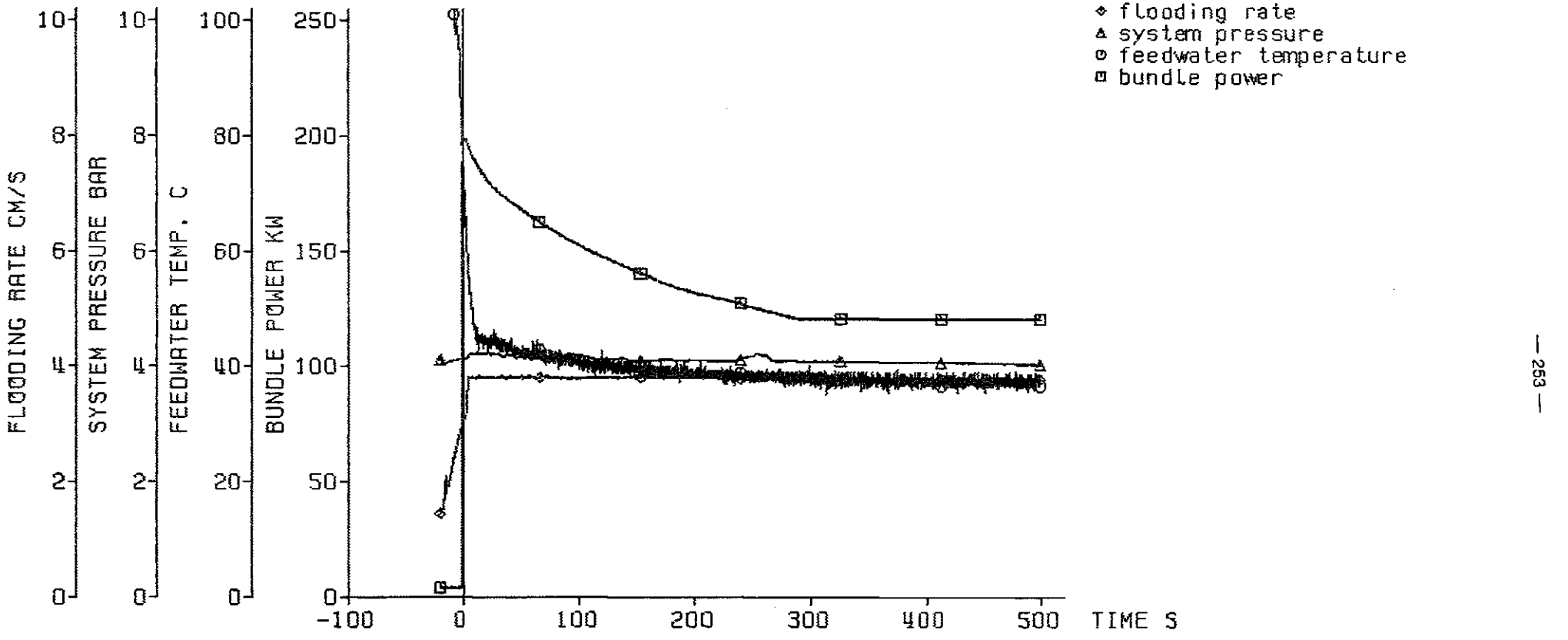
Initial axial temperature profile of the cladding



decay heat	120% ANS standard
flooding rate (cold)	3.81 cm/s
system pressure	4.15 bar
feedwater temperature	40 deg C

KfK IRB

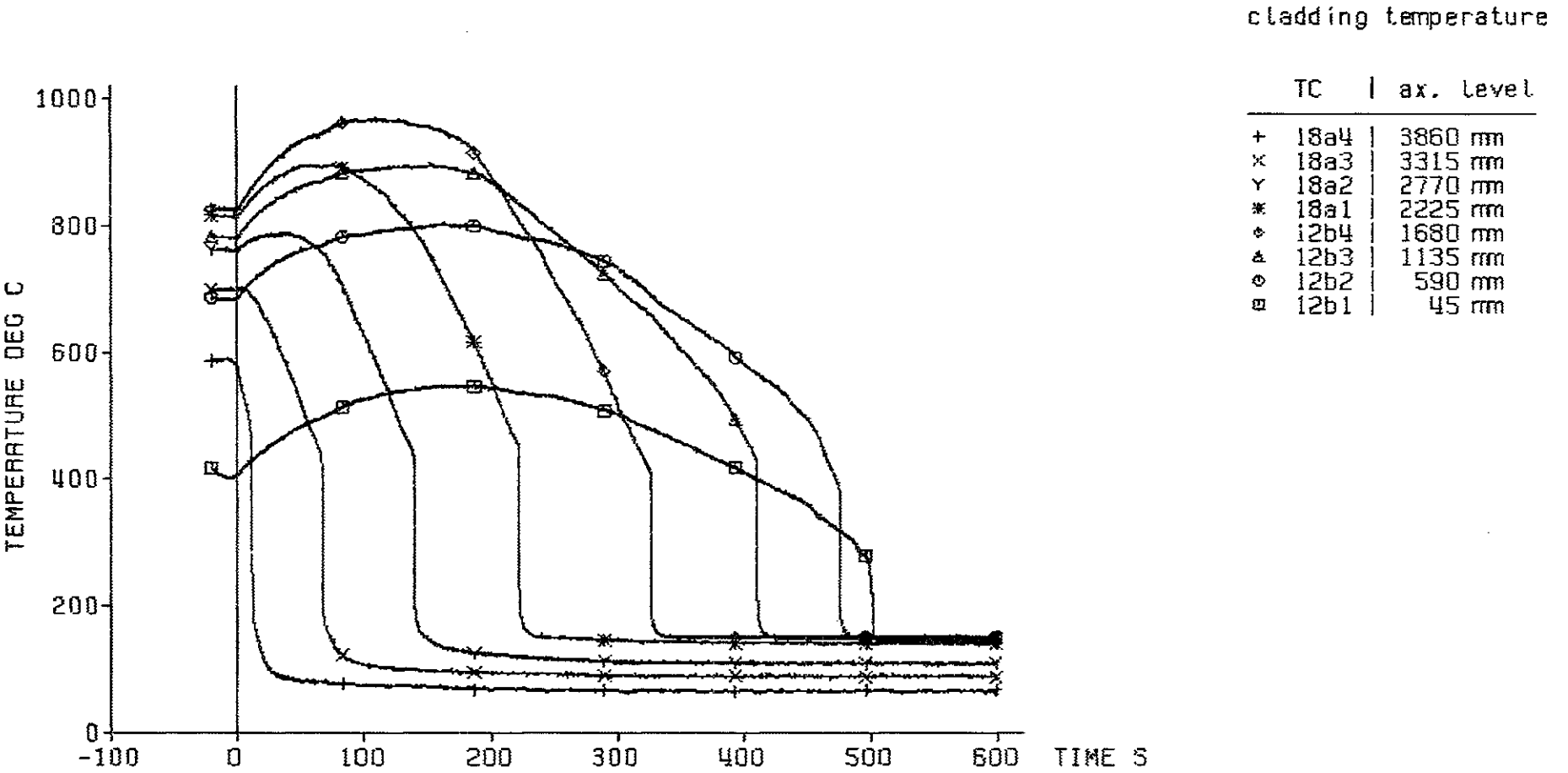
Fig. 218 FEBA: 5x5 ROD BUNDLE TEST SERIES 3, TEST-No. 239



decay heat	120% ANS standard
flooding rate (cold)	3.81 cm/s
system pressure	4.15 bar
feedwater temperature	40 deg C

KfK IRB

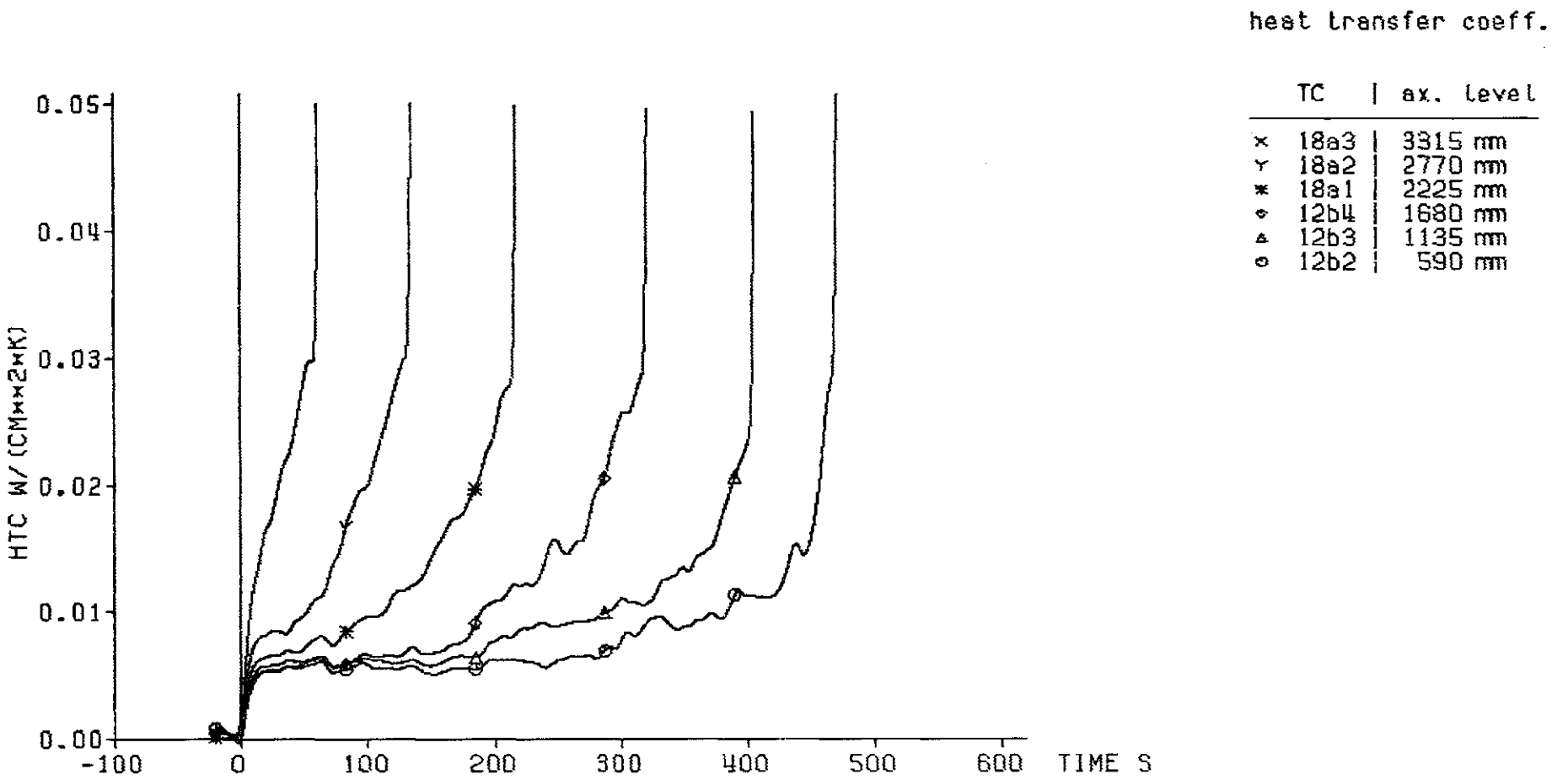
Fig. 219 FEBA: 5x5 ROD BUNDLE, TEST SERIES 3, TEST-No. 239



decay heat	120% ANS standard
flooding rate (cold)	3.81 cm/s
system pressure	4.15 bar
feedwater temperature	40 deg C

KfK IRB

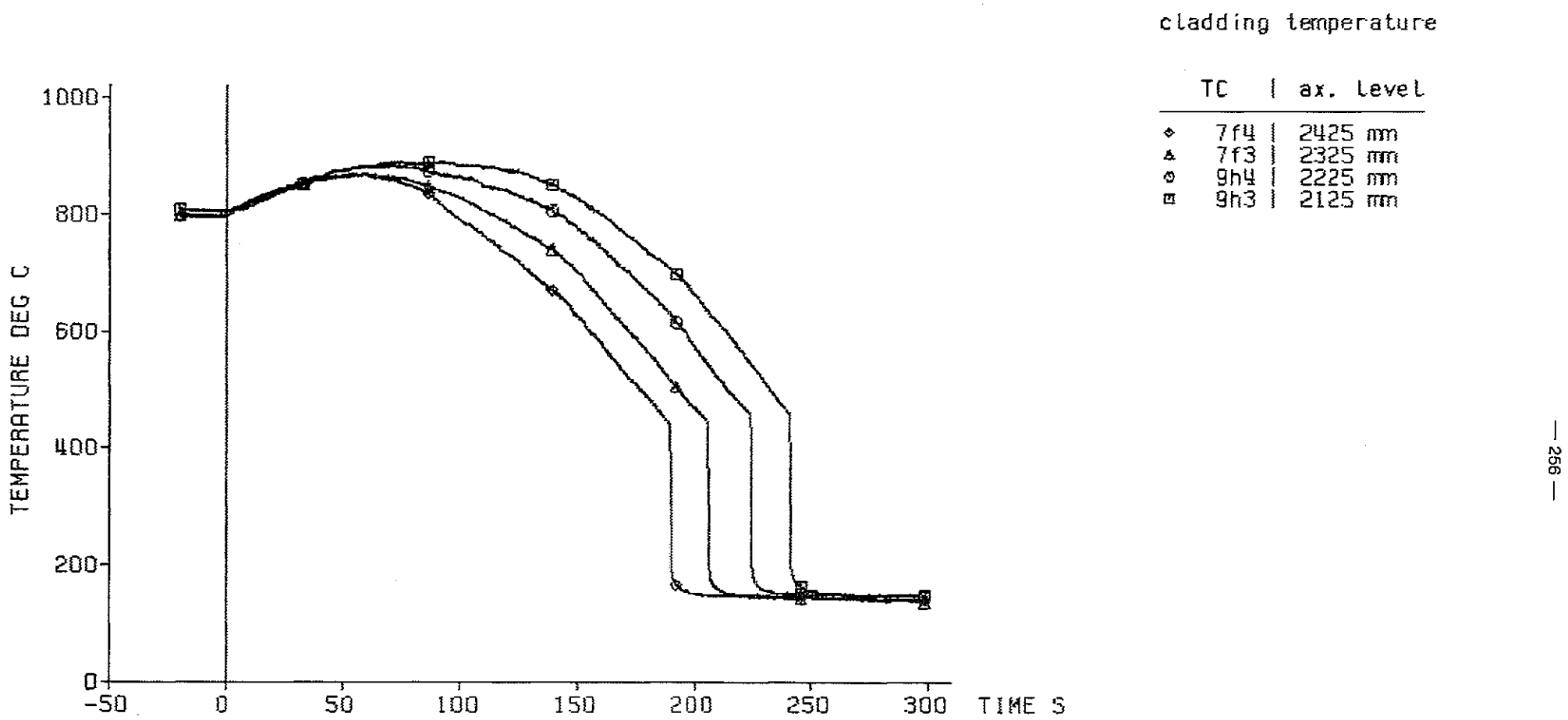
Fig. 220 FEBA: 5x5 ROD BUNDLE, TEST SERIES 3, TEST-No. 239



decay heat	120% ANS standard
flooding rate (cold)	3.81 cm/s
system pressure	4.15 bar
feedwater temperature	40 deg C

KfK IRB

Fig. 221 FEBA: 5x5 ROD BUNDLE, TEST SERIES 3, TEST-No. 239

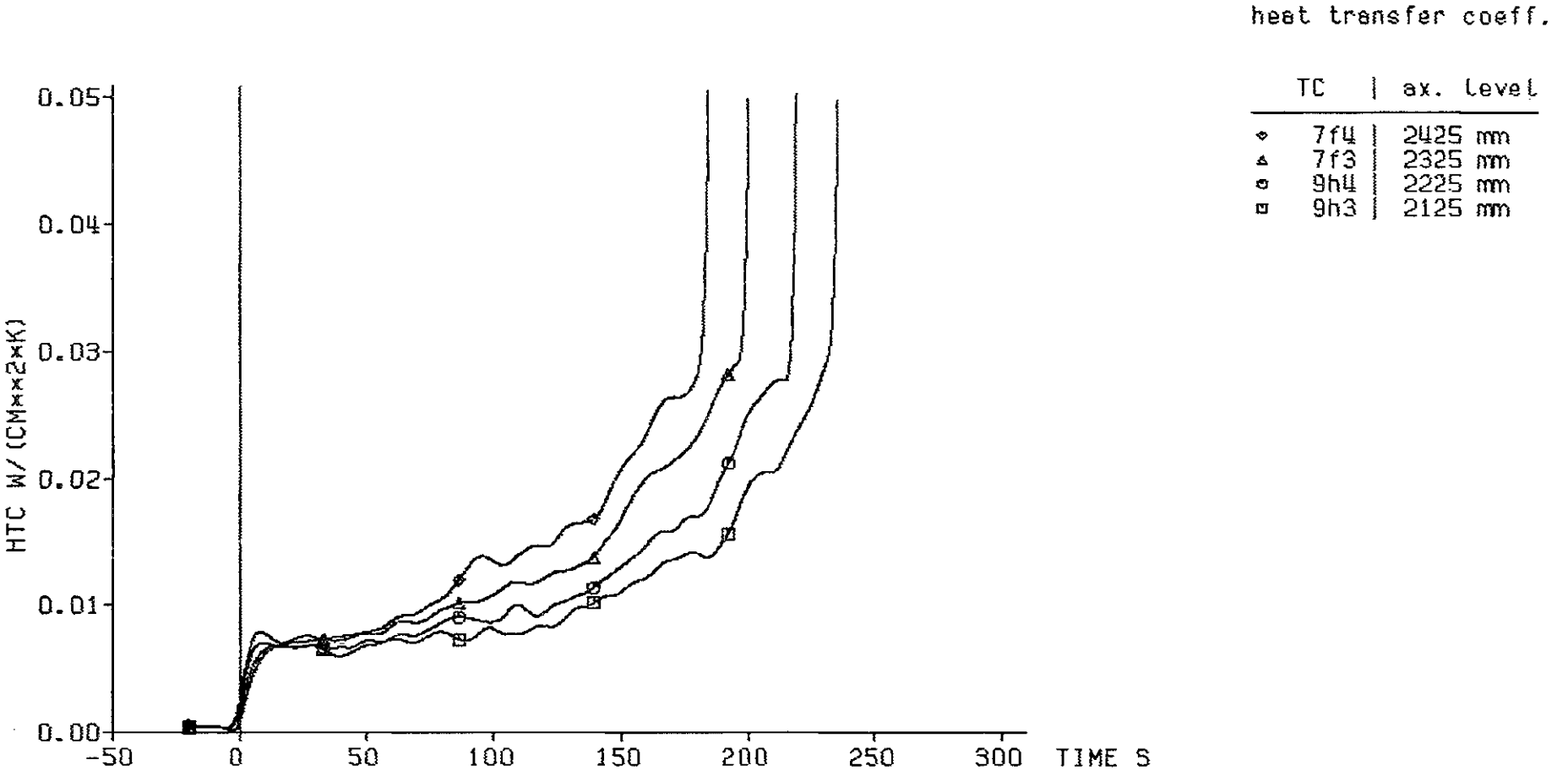


decay heat	120% ANS standard	
flooding rate (cold)	3.81 cm/s	
system pressure	4.15 bar	
feedwater temperature	40 deg C	

bypass
======

KfK IRB

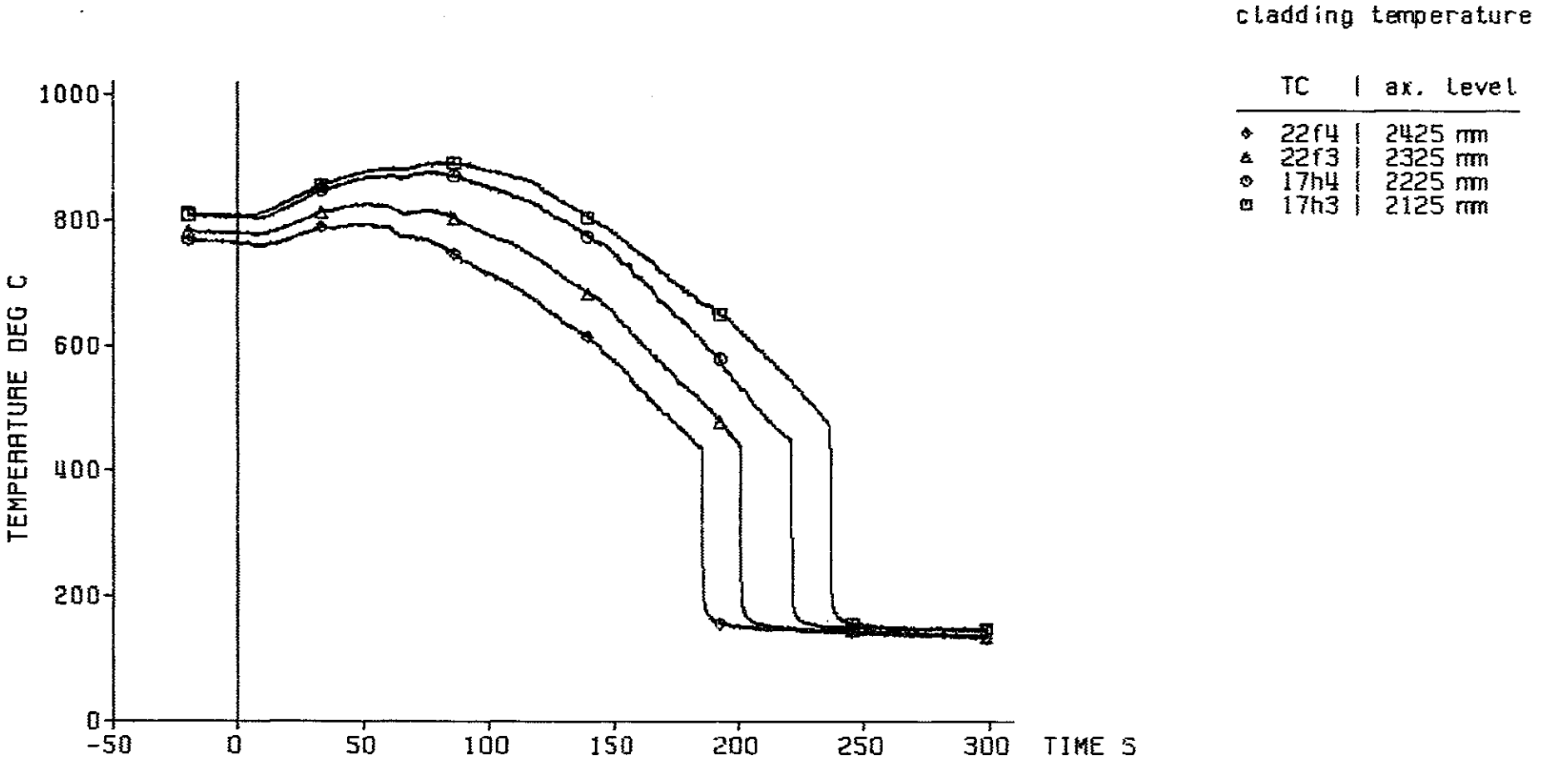
Fig. 222 FEBA: 5x5 ROD BUNDLE, TEST SERIES 3, TEST-No. 239



decay heat	120% ANS standard	bypass
flooding rate (cold)	3.81 cm/s	======
system pressure	4.15 bar	
feedwater temperature	40 deg C	

KfK IRB

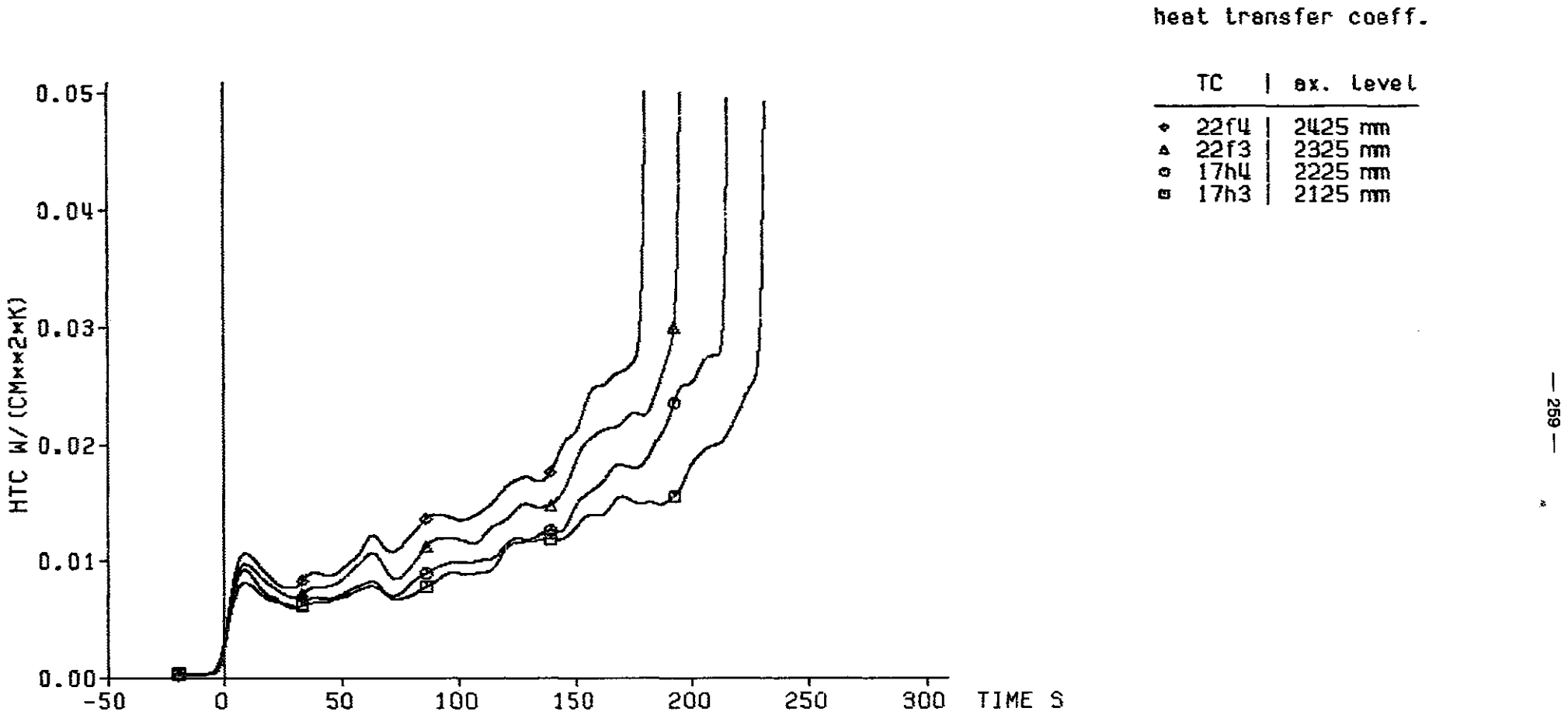
Fig. 223 FEBA: 5x5 ROD BUNDLE, TEST SERIES 3, TEST-No. 239



decay heat	120% ANS standard	blockage
flooding rate (cold)	3.81 cm/s	========
system pressure	4.15 bar	
feedwater temperature	40 deg C	

KfK IRB

Fig. 224 FEBA: 5x5 ROD BUNDLE, TEST SERIES 3, TEST-No. 239

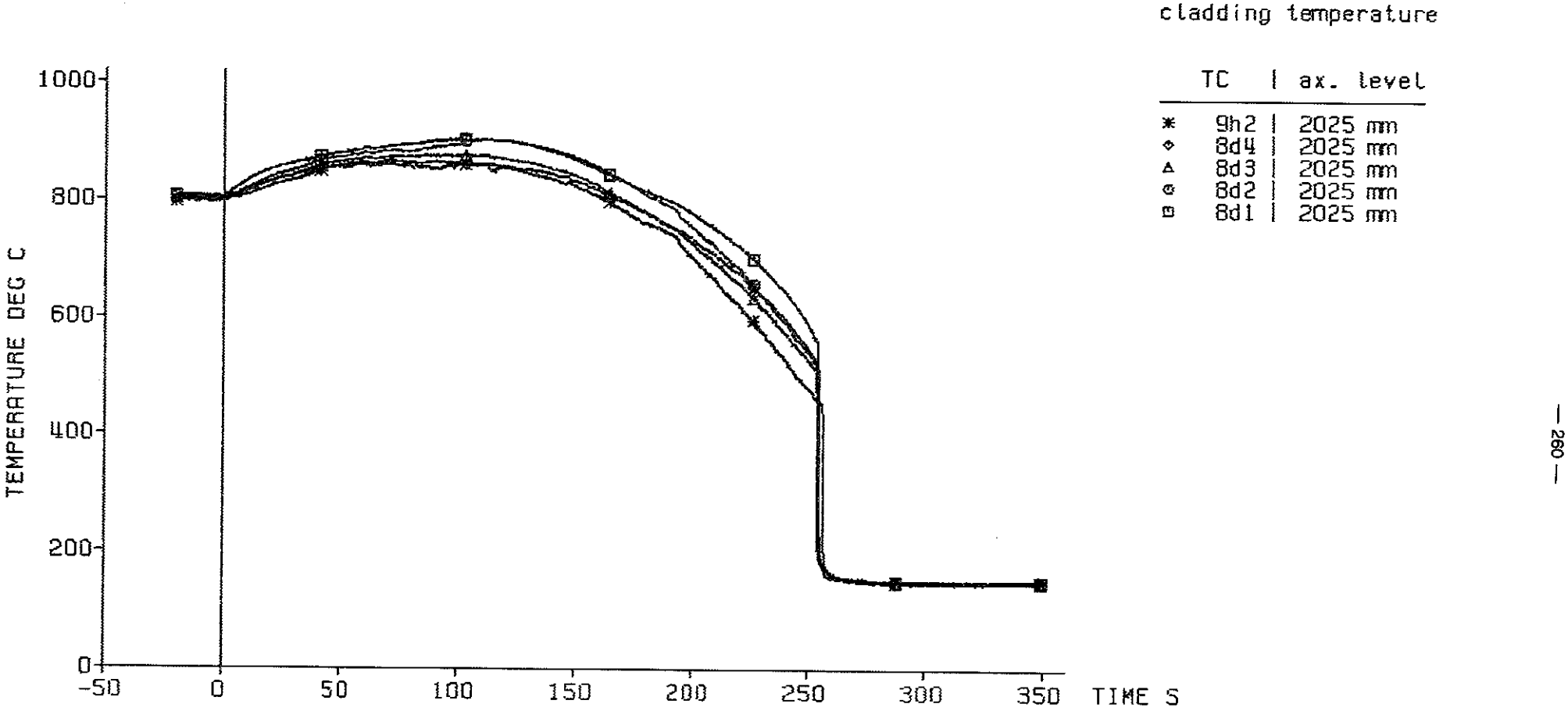


decay heat	120% ANS standard
flooding rate (cold)	3.81 cm/s
system pressure	4.15 bar
feedwater temperature	40 deg C

blockage
========

KfK IRB

Fig. 225 FEBA: 5x5 ROD BUNDLE, TEST SERIES 3, TEST-No. 239

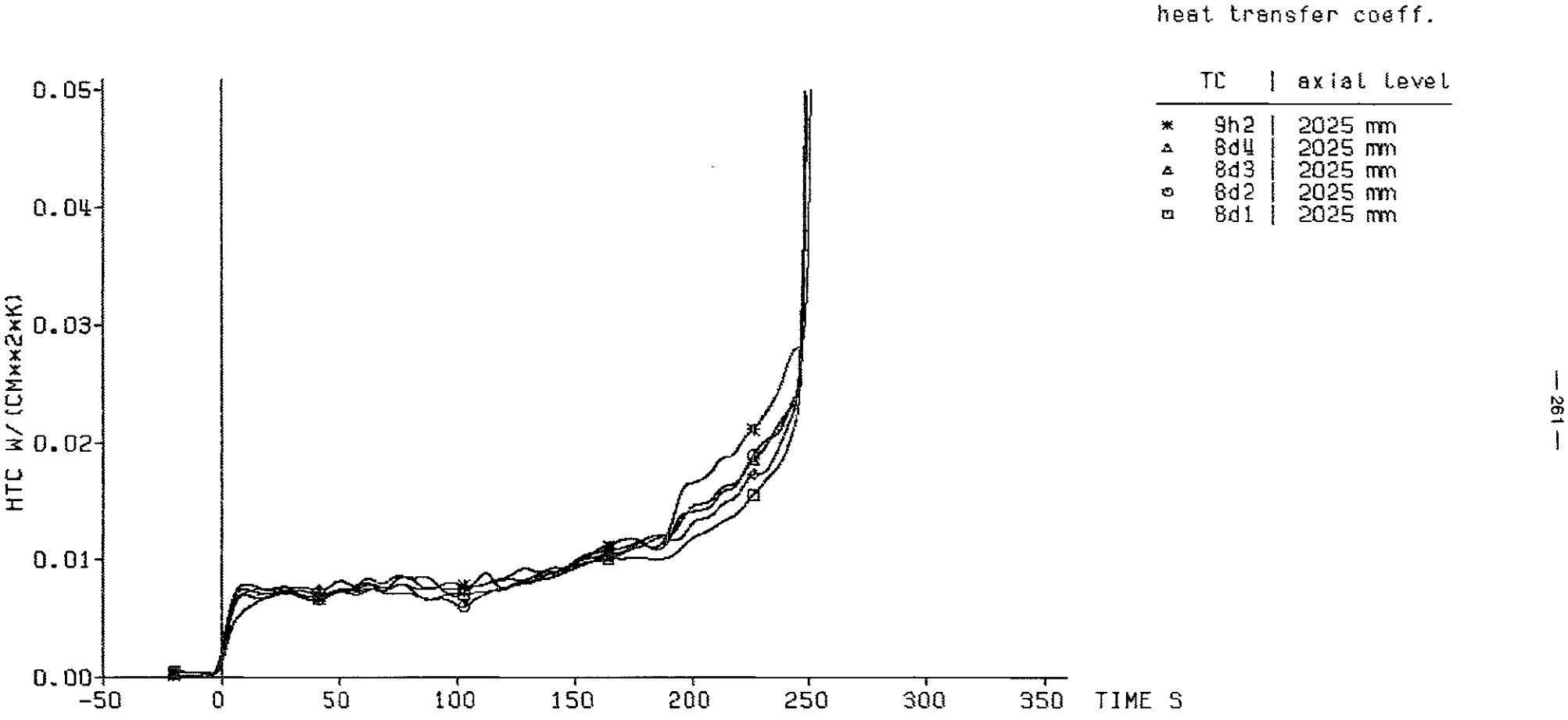


decay heat 120% ANS standard
flooding rate (cold) 3.81 cm/s
system pressure 4.15 bar
feedwater temperature 40 deg C

bypass
======

KfK IRB

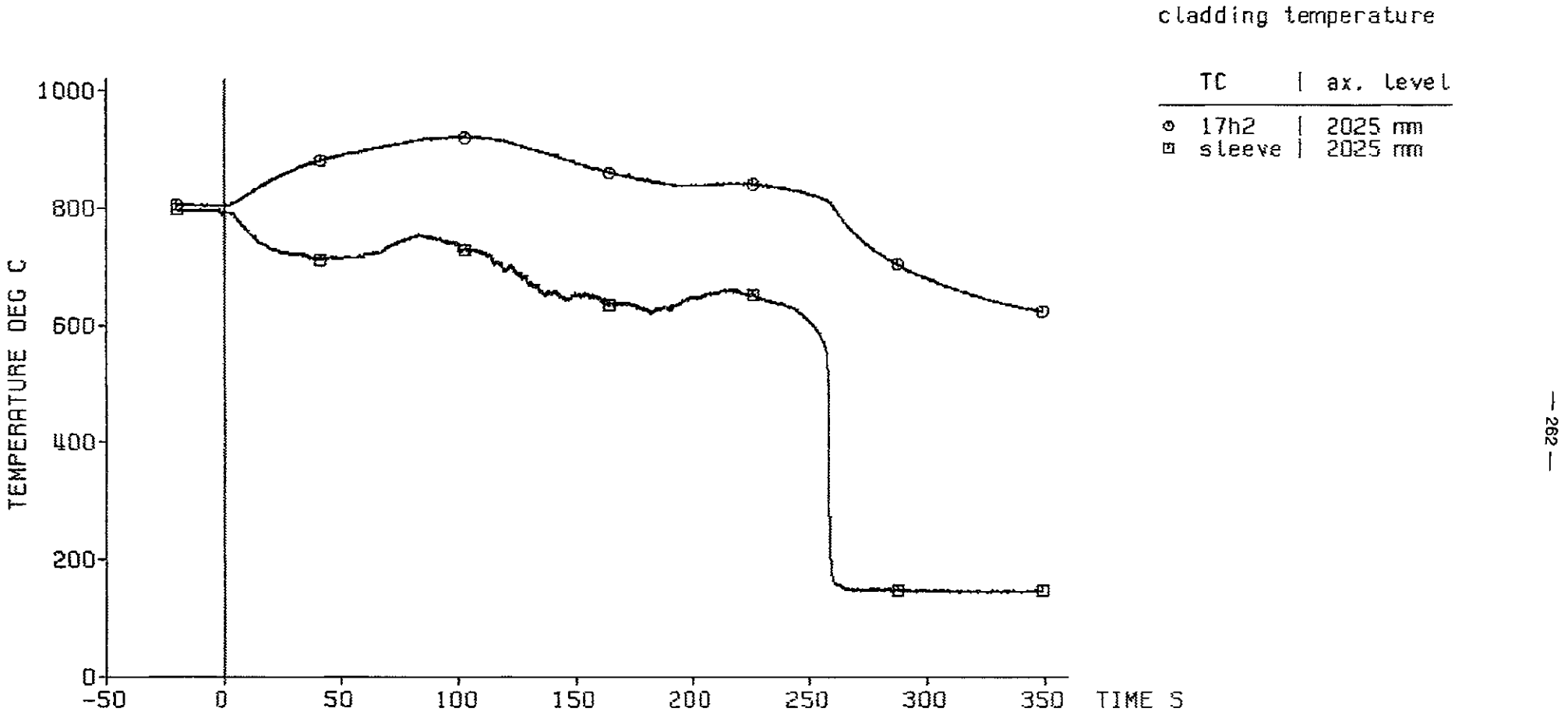
Fig. 226 FEBA: 5x5 ROD BUNDLE, TEST SERIES 3, TEST-No. 239



decay heat	120% ANS standard	bypass
flooding rate (cold)	3.81 cm/s	======
system pressure	4.15 bar	
feedwater temperature	40 deg C	

KfK IRB

Fig. 227 FEBA: 5x5 ROD BUNDLE, TEST SERIES 3, TEST-No. 239

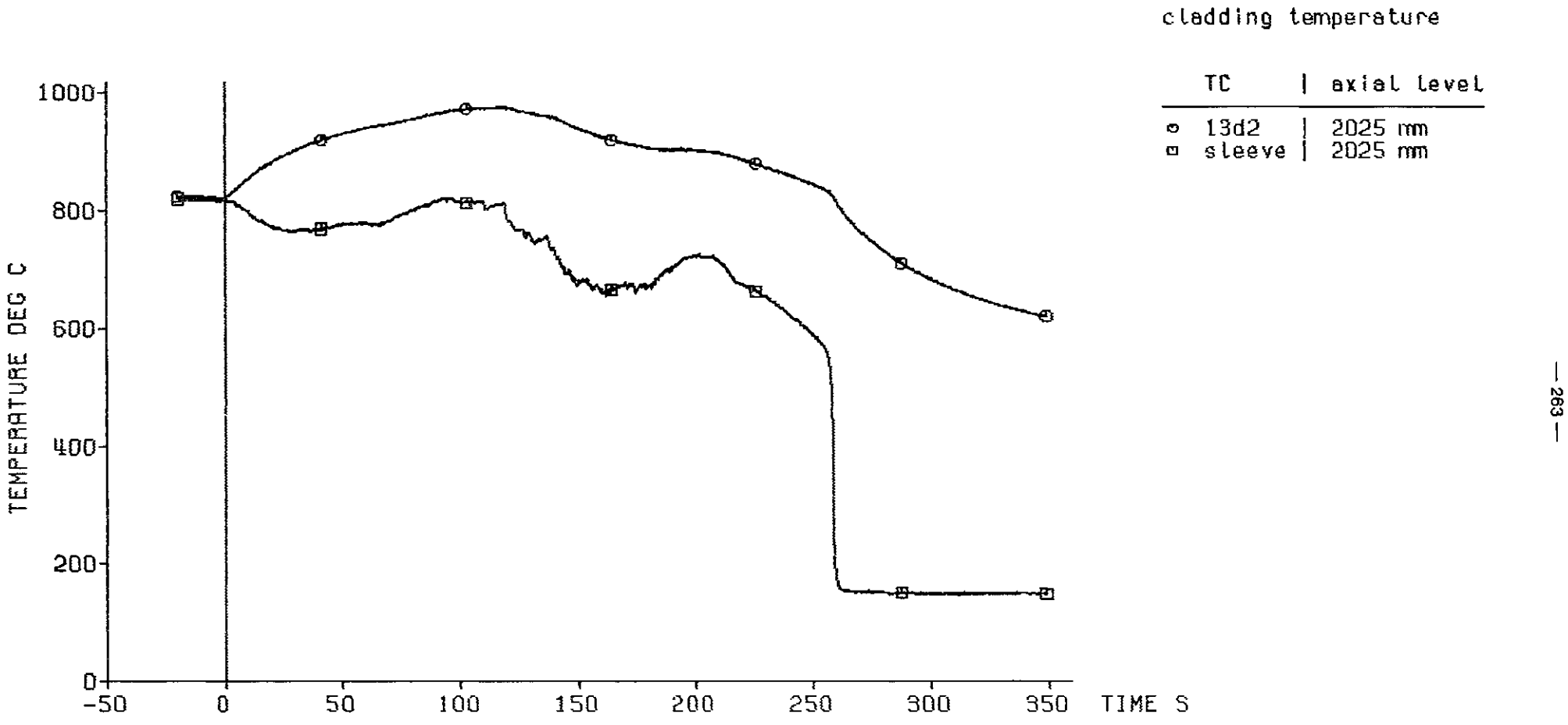


decay heat 120% ANS standard
flooding rate (cold) 3.81 cm/s
system pressure 4.15 bar
feedwater temperature 40 deg C

blockage
========

KfK IRB

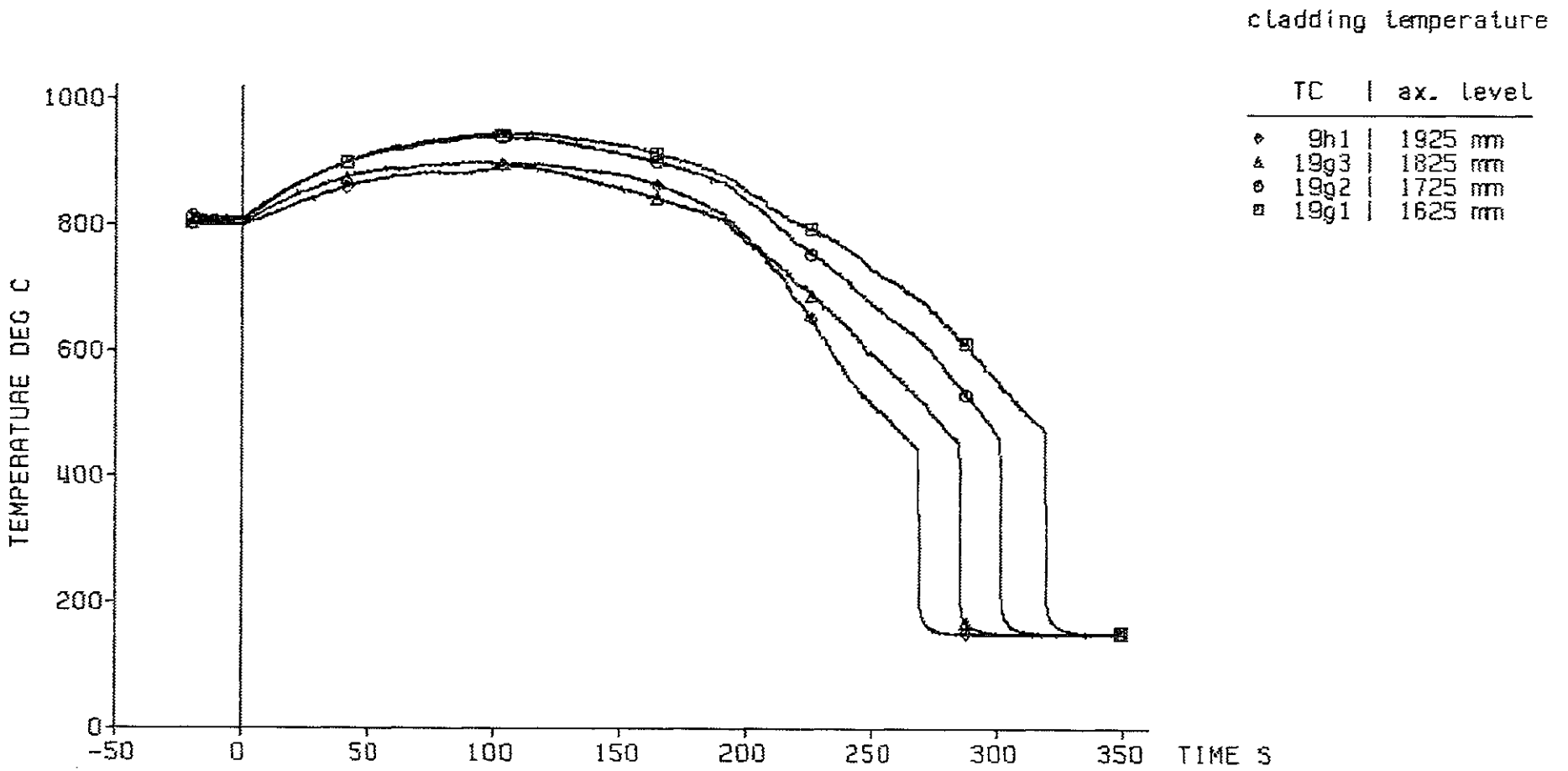
Fig. 228 FEBA: 5x5 ROD BUNDLE, TEST SERIES 3, TEST-No. 239



		blockage
decay heat	120% ANS standard	========
flooding rate (cold)	3.81 cm/s	
system pressure	4.15 bar	
feedwater temperature	40 deg C	

KfK IRB

Fig. 229 FEBA: 5x5 ROD BUNDLE, TEST SERIES 3, TEST-No. 239

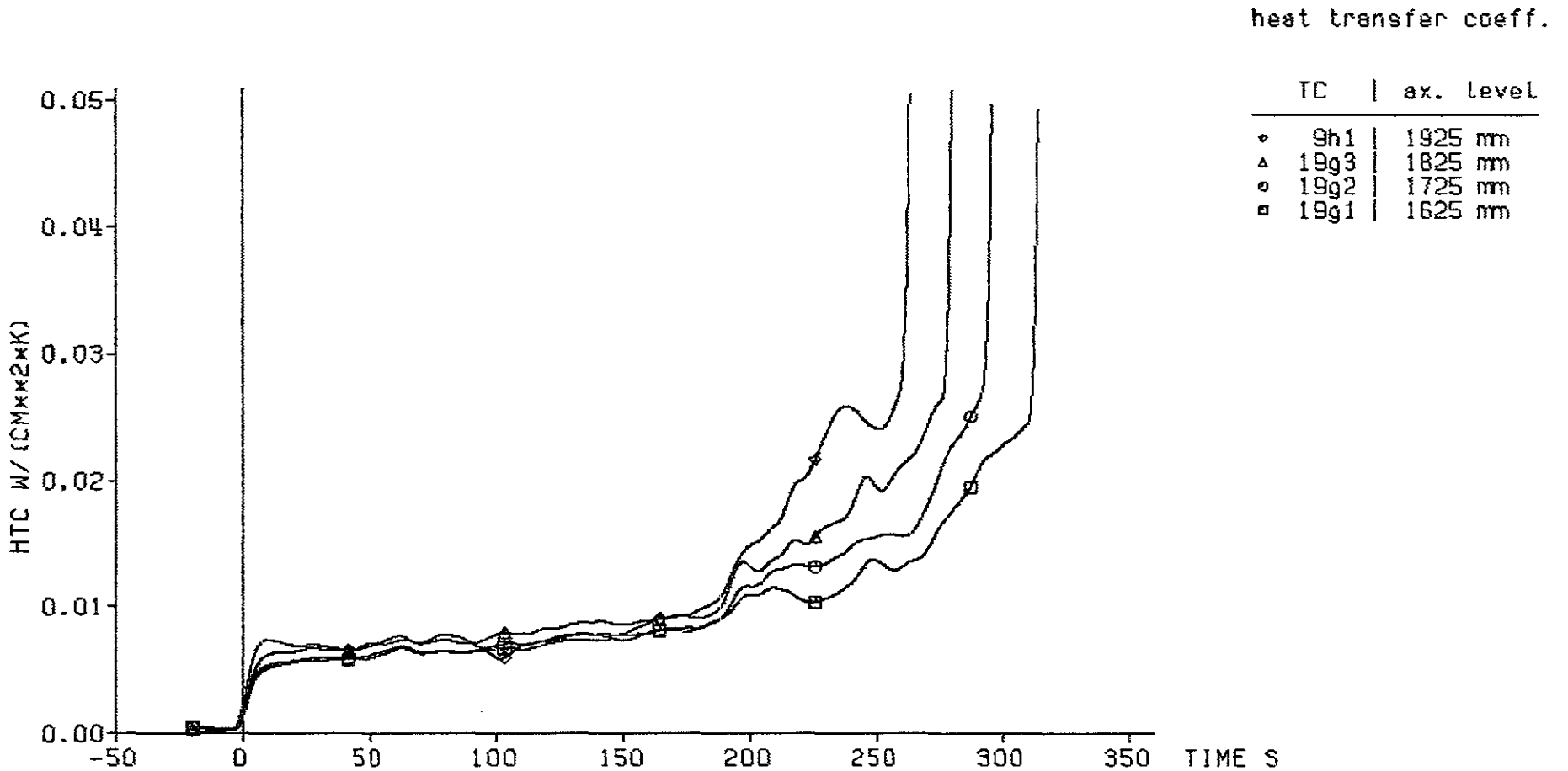


decay heat	120% ANS standard
flooding rate (cold)	3.81 cm/s
system pressure	4.15 bar
feedwater temperature	40 deg C

bypass
======

KfK KTRB

Fig. 230 FEBA: 5x5 ROD BUNDLE, TEST SERIES 3, TEST-No. 239

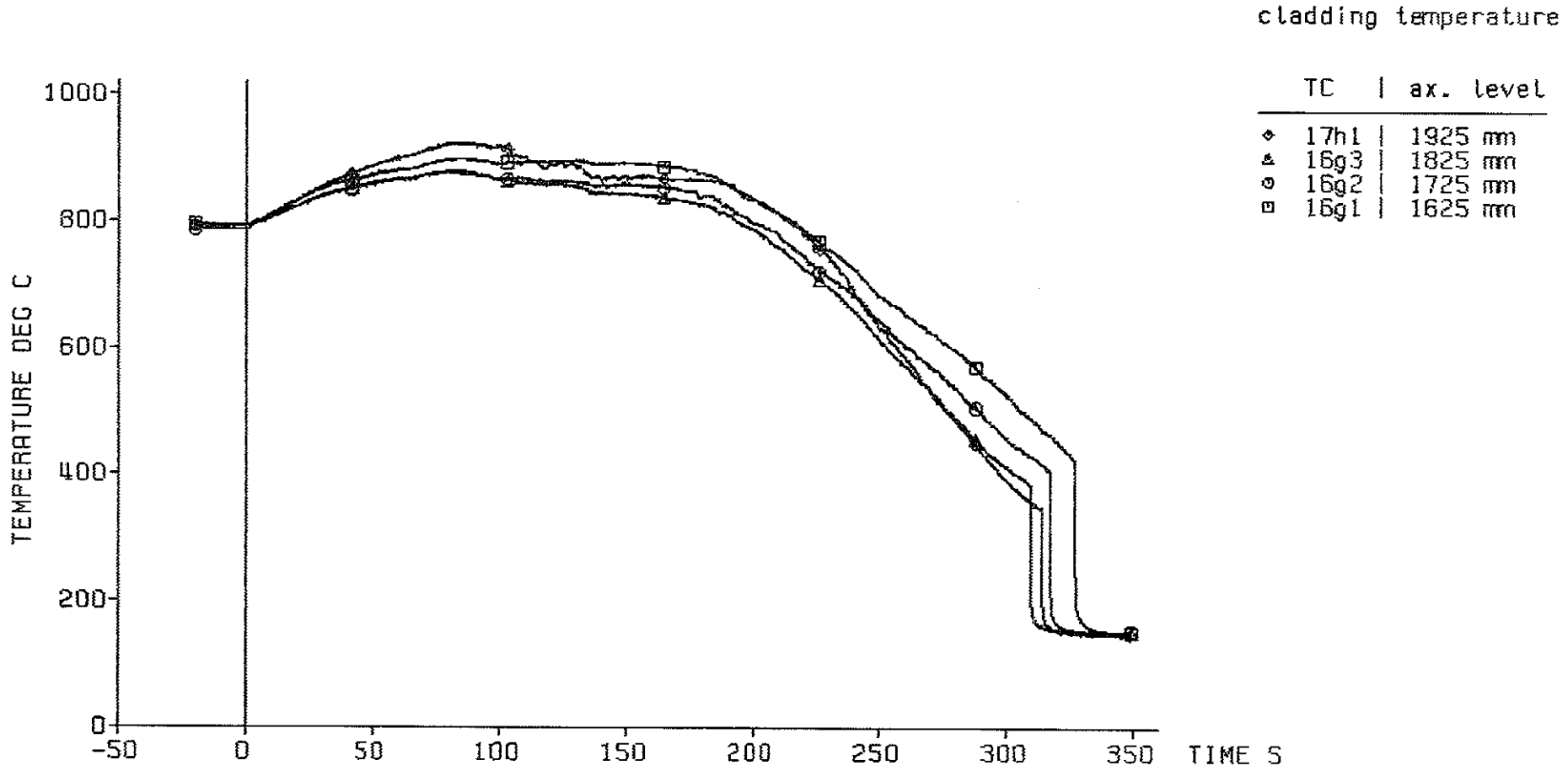


decay heat 120% ANS standard
flooding rate (cold) 3.81 cm/s
system pressure 4.15 bar
feedwater temperature 40 deg C

bypass
======

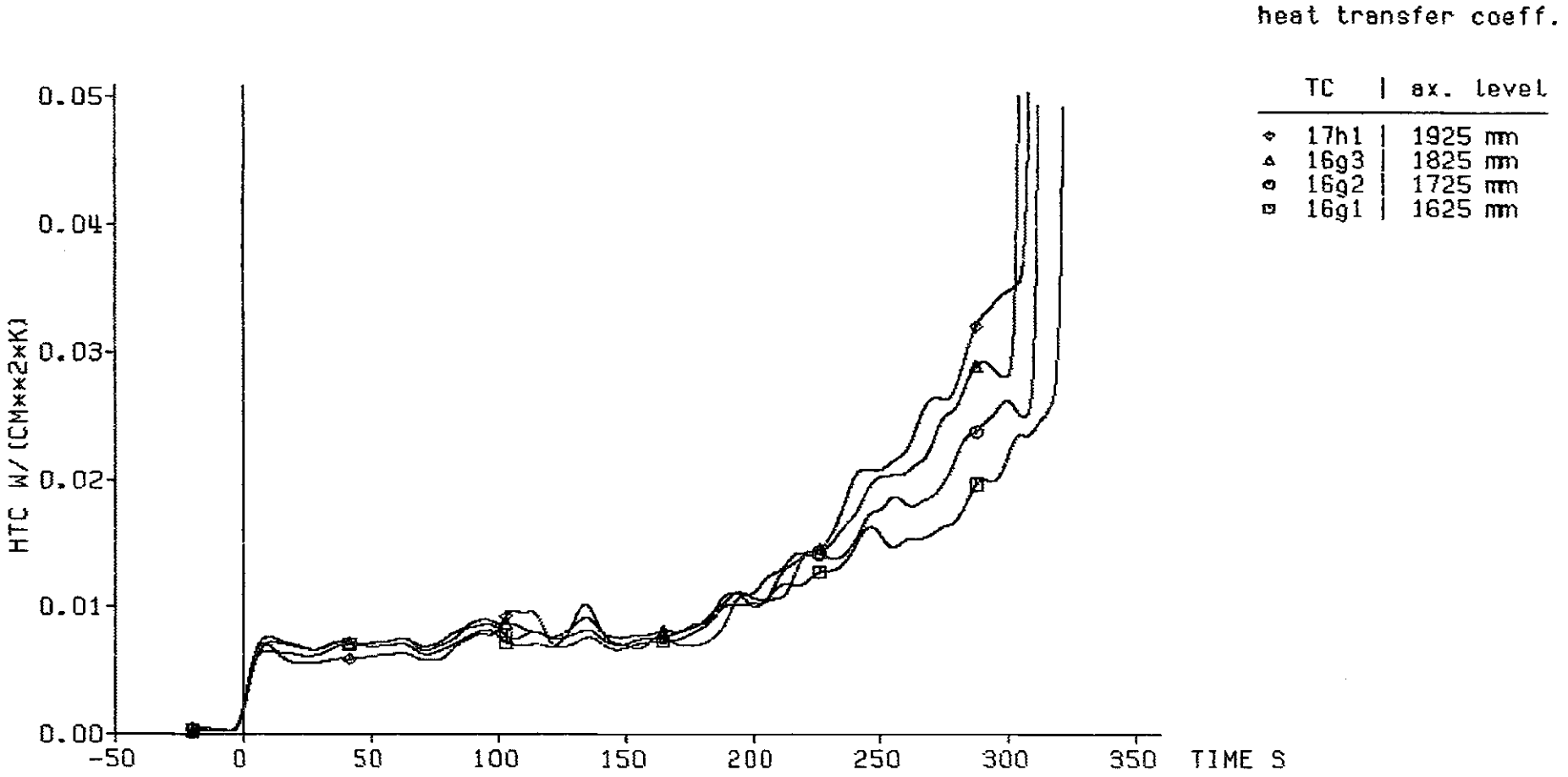
KfK IRB

Fig. 231 FEBA: 5x5 ROD BUNDLE, TEST SERIES 3, TEST-No. 239



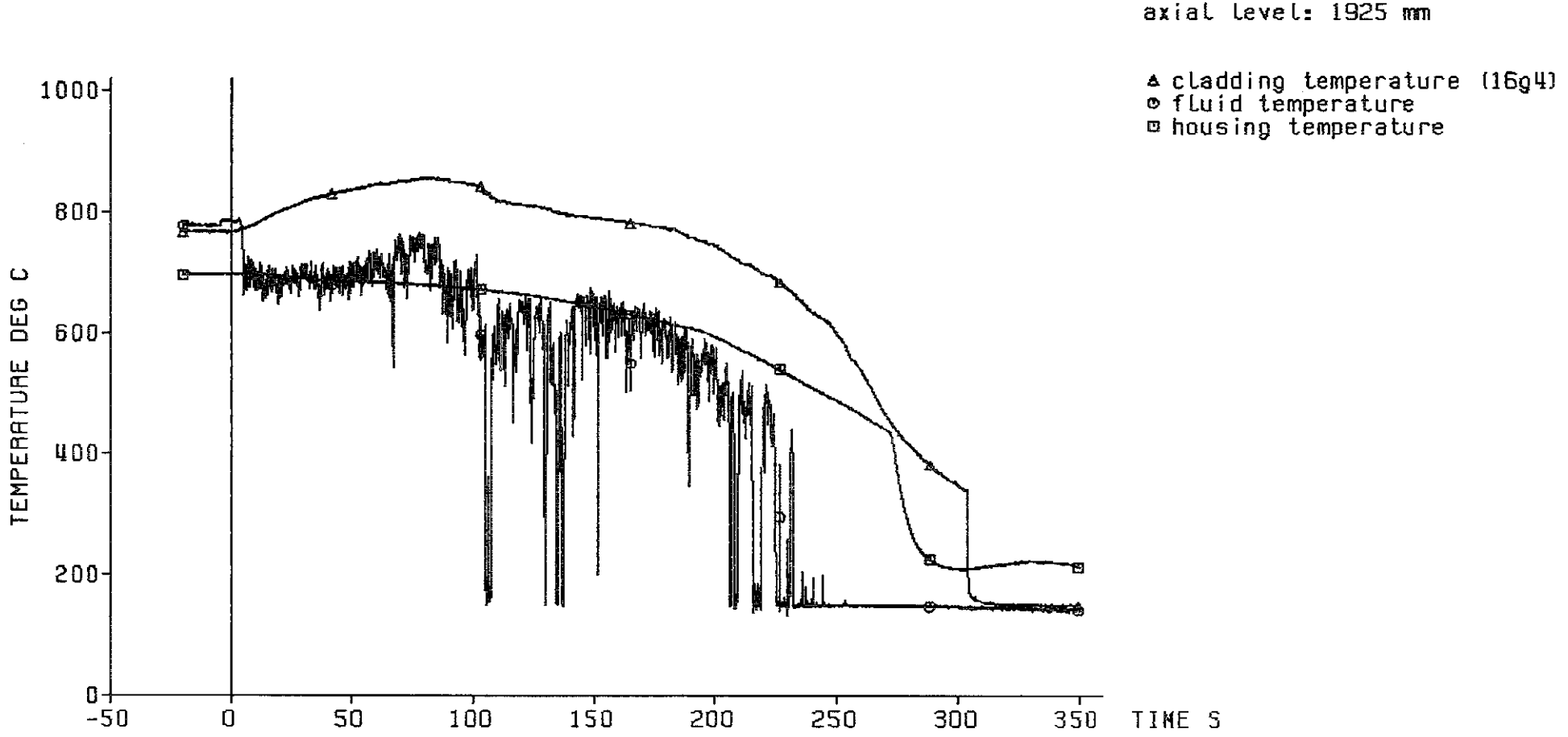
decay heat	120% ANS standard	blockage
flooding rate (cold)	3.81 cm/s	========
system pressure	4.15 bar	
feedwater temperature	40 deg C	

Fig. 232 FEBA: 5x5 ROD BUNDLE, TEST SERIES 3, TEST-No. 239



decay heat	120% ANS standard	blockage
flooding rate (cold)	3.81 cm/s	========
system pressure	4.15 bar	
feedwater temperature	40 deg C	

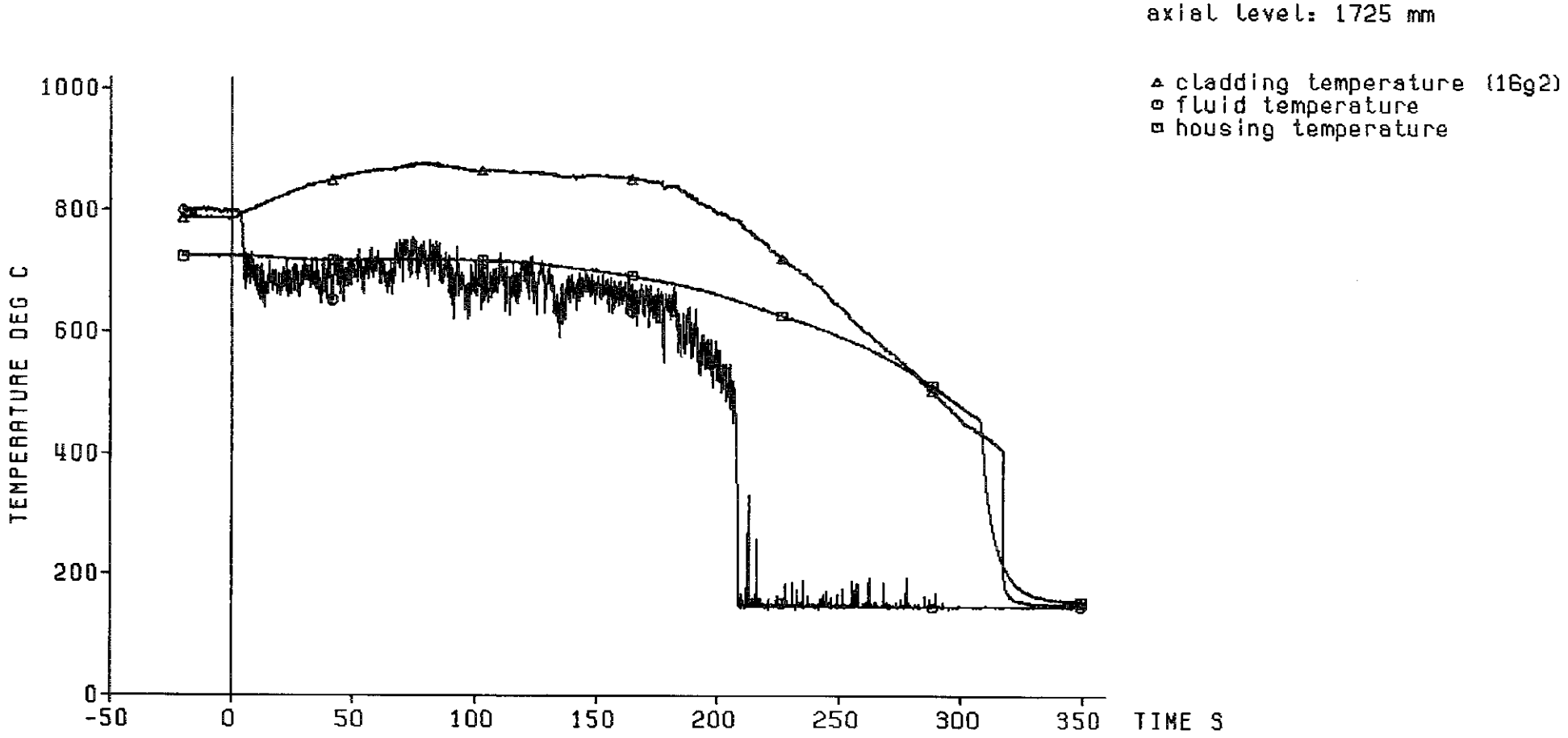
Fig. 233 FEBA: 5x5 ROD BUNDLE, TEST SERIES 3, TEST-No. 239



decay heat	120% ANS standard	blockage
flooding rate (cold)	3.81 cm/s	========
system pressure	4.15 bar	
feedwater temperature	40 deg C	

KfK IRB

Fig. 234 FEBA: 5x5 ROD BUNDLE, TEST SERIES 3, TEST-No. 239

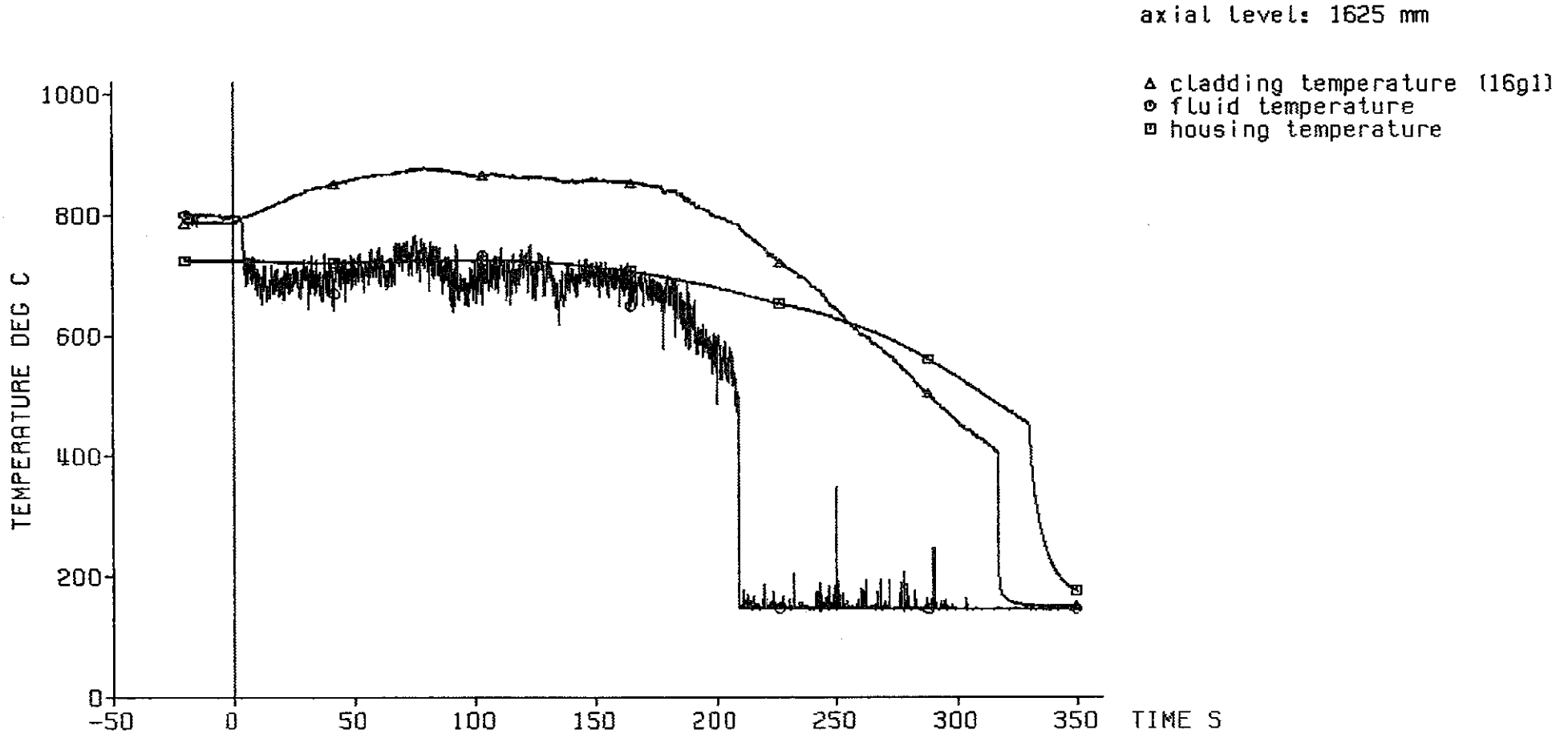


decay heat	120% ANS standard
flooding rate (cold)	3.81 cm/s
system pressure	4.15 bar
feedwater temperature	40 deg C

blockage
========

KfK IRB

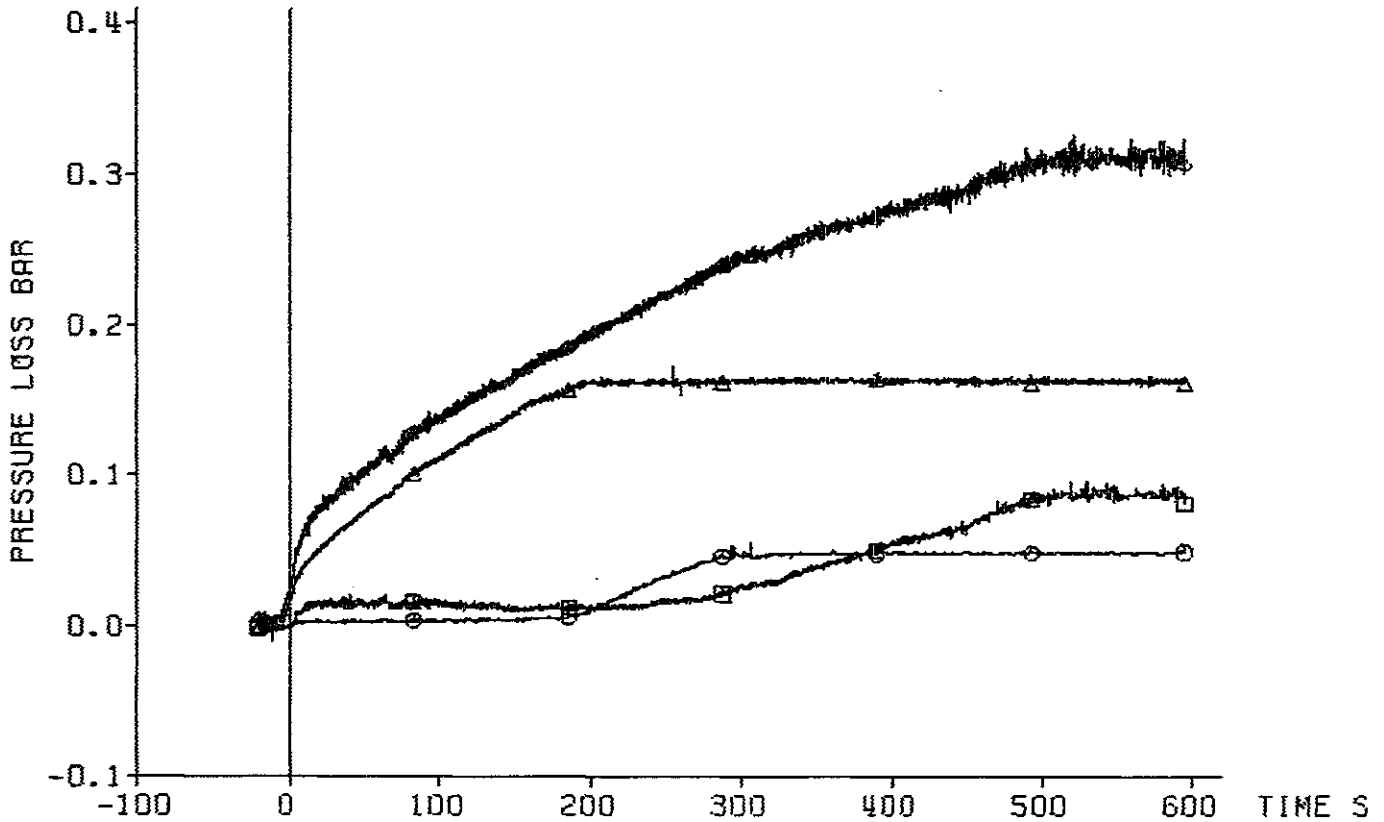
Fig. 235 FEBA: 5x5 ROD BUNDLE, TEST SERIES 3, TEST-No. 239



decay heat	120% ANS standard
flooding rate (cold)	3.81 cm/s
system pressure	4.15 bar
feedwater temperature	40 deg C

blockage
========

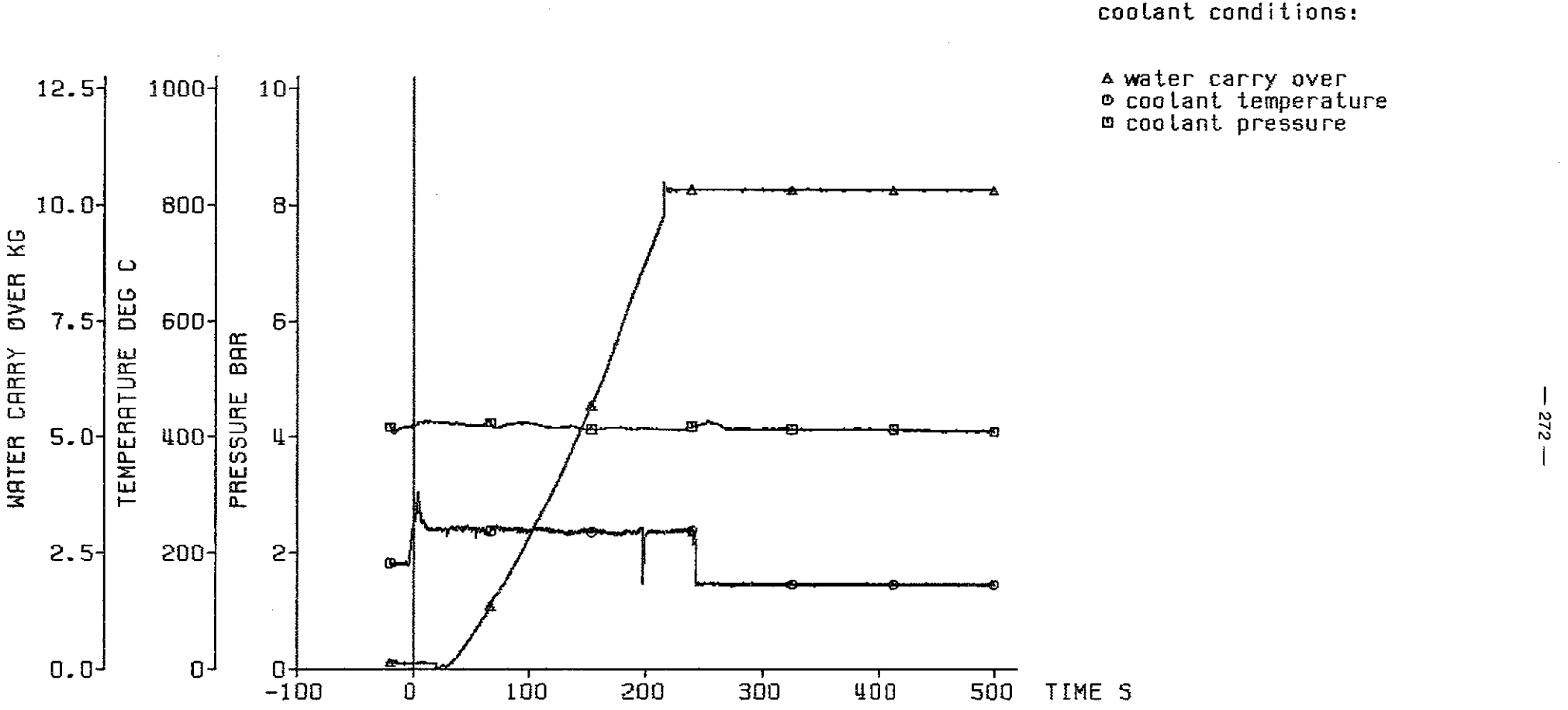
Fig. 236 FEBA: 5x5 ROD BUNDLE, TEST SERIES 3, TEST-No. 239



decay heat	120% ANS standard
flooding rate (cold)	3.61 cm/s
system pressure	4.15 bar
feedwater temperature	40 deg C

KfK IRB

Fig. 237 FEBA: 5x5 ROD BUNDLE, TEST SERIES 3, TEST-No. 239



decay heat	120% ANS standard
flooding rate (cold)	3.81 cm/s
system pressure	4.15 bar
feedwater temperature	40 deg C

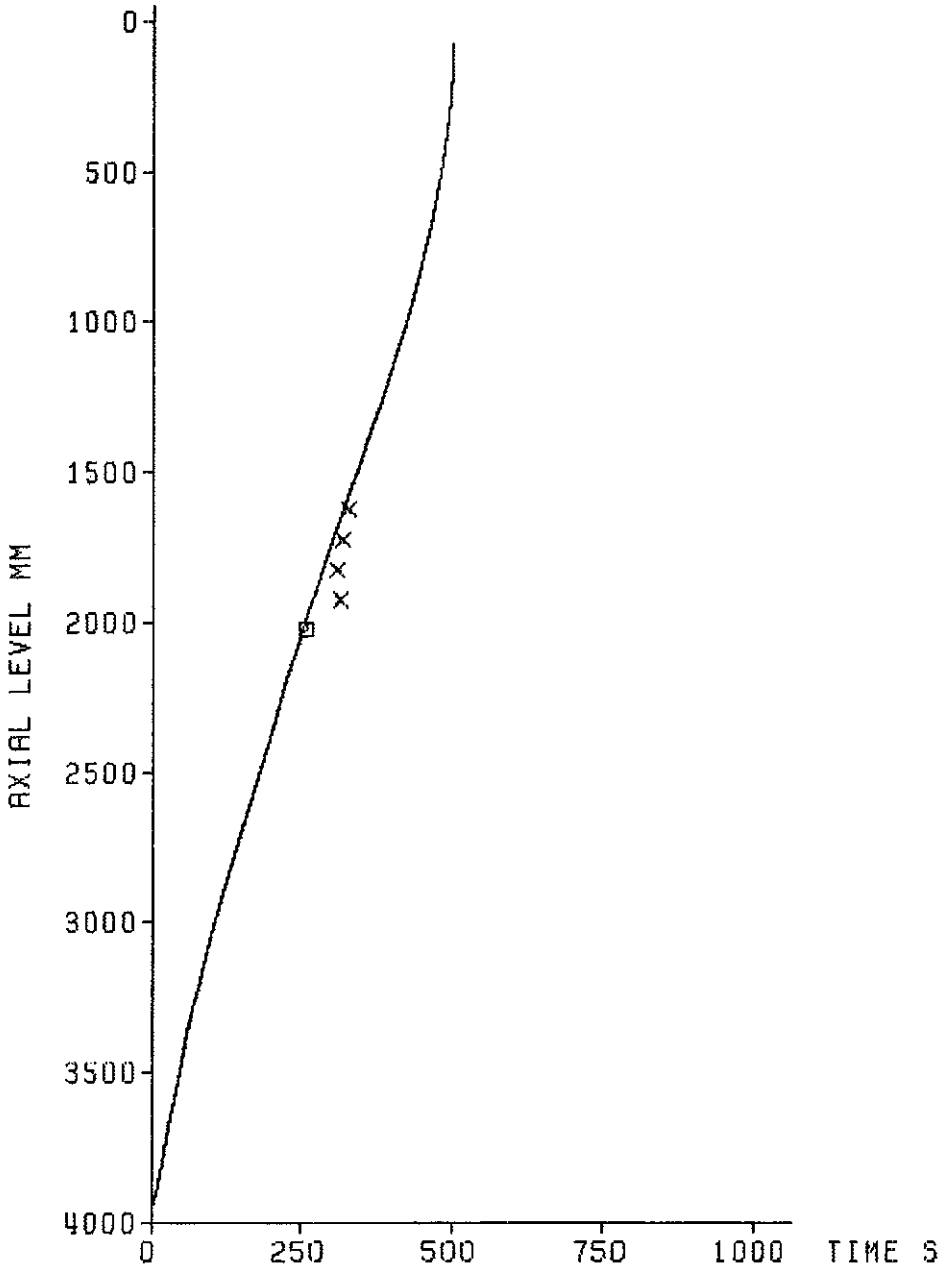
KfK IRB

Fig. 238 FEBA: 5x5 ROD BUNDLE, TEST SERIES 3, TEST-No. 239

axial position of the quench front

⊡ rewetting of the sleeve at the bundle midplane

× rewetting of the rod downstream of the blockage

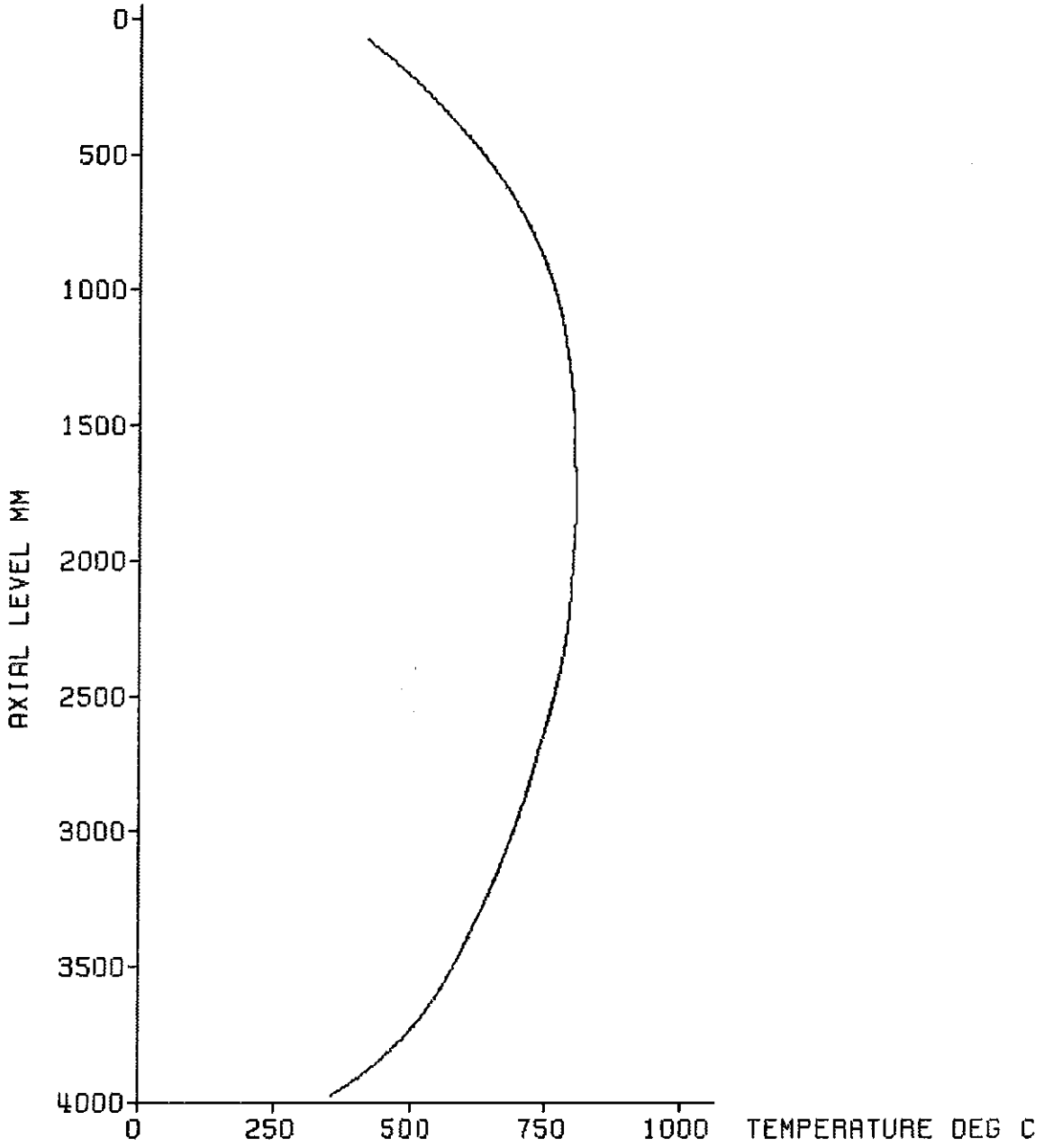


decay heat	120% ANS standard
flooding rate (cold)	3.81 cm/s
system pressure	4.15 bar
feedwater temperature	40 deg C

KfK IRB

Fig. 239 FEBA: 5x5 ROD BUNDLE TEST SERIES 3, TEST-No. 239

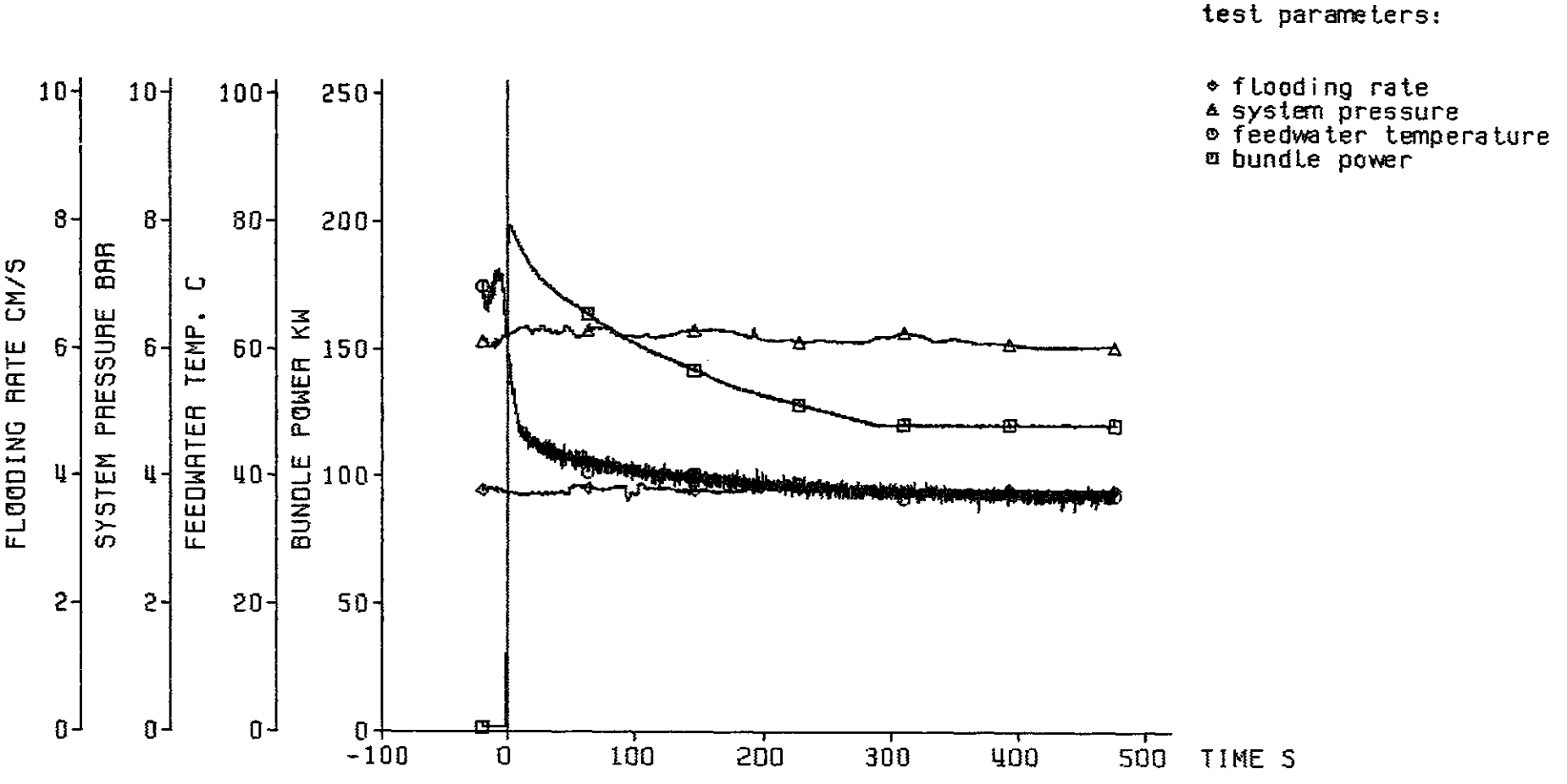
Initial axial temperature profile of the cladding



decay heat	120% ANS standard
flooding rate (cold)	3.80 cm/s
system pressure	6.24 bar
feedwater temperature	40 deg C

KfK IRB

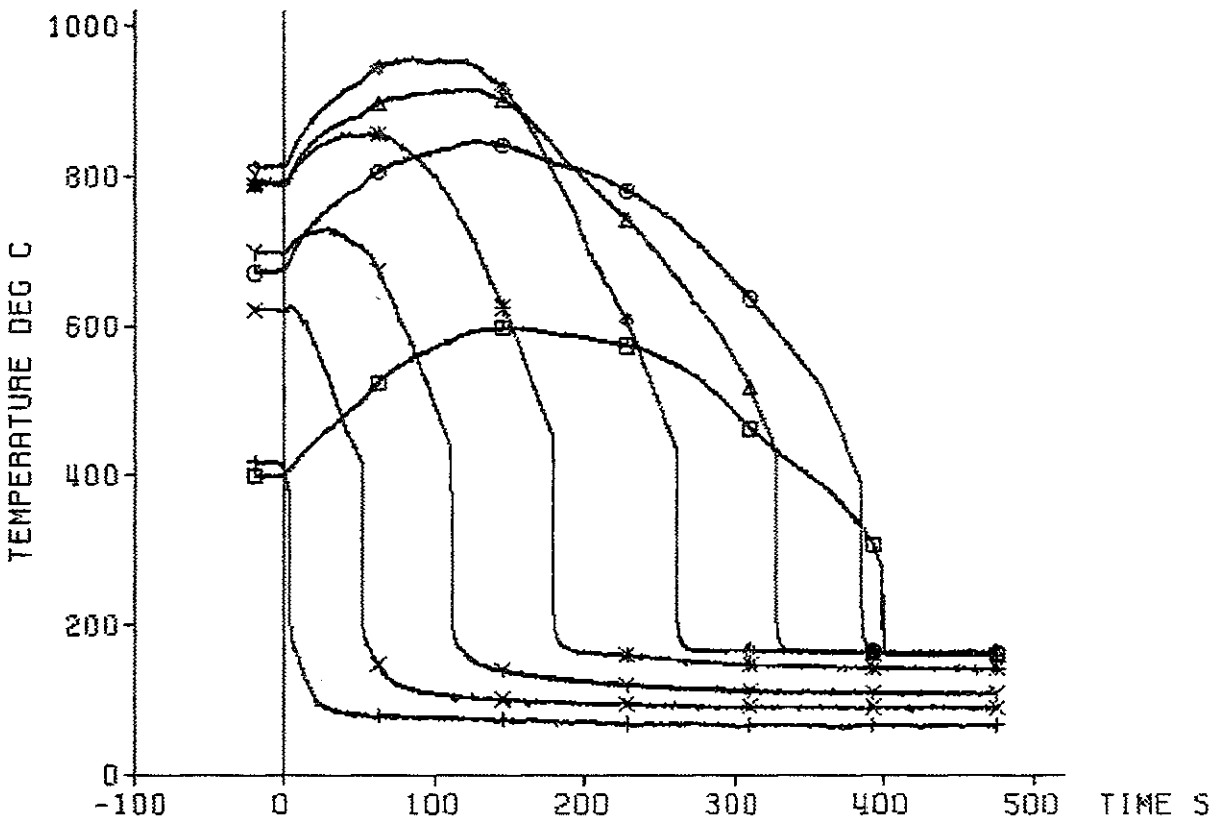
Fig. 240 FEBA: 5x5 ROD BUNDLE TEST SERIES 3, TEST-No. 236



decay heat	120% ANS standard
flooding rate (cold)	3.80 cm/s
system pressure	6.24 bar
feedwater temperature	40 deg C

KfK IRB

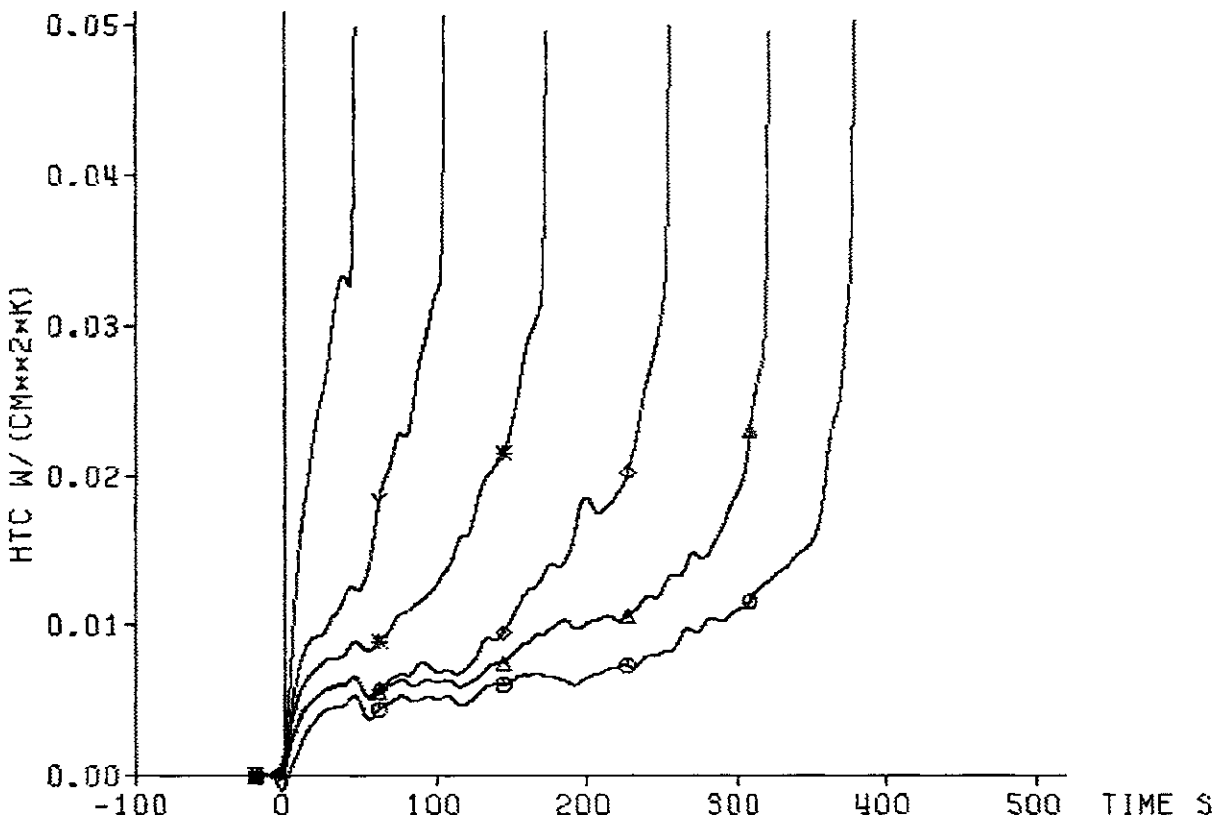
Fig. 241 FEBA: 5x5 ROD BUNDLE, TEST SERIES 3, TEST-No. 236



decay heat	120% ANS standard
flooding rate (cold)	3.80 cm/s
system pressure	6.24 bar
feedwater temperature	40 deg C

KfK KIRB

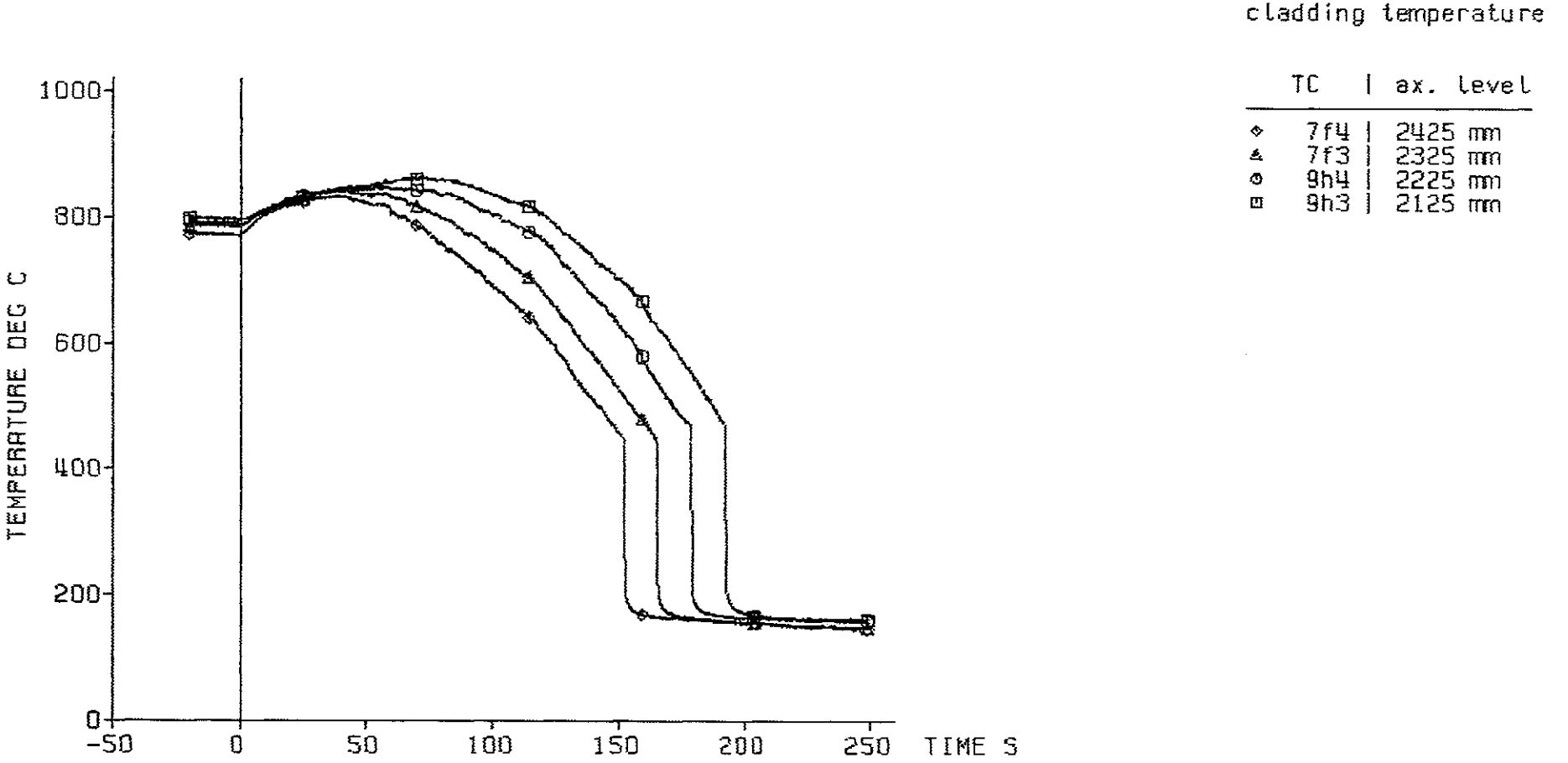
Fig. 242 FEBA: 5x5 ROD BUNDLE, TEST SERIES 3, TEST-No. 236



decay heat	120% ANS standard
flooding rate (cold)	3.80 cm/s
system pressure	6.24 bar
feedwater temperature	40 deg C

KfK IRB

Fig. 243 FEBA: 5x5 ROD BUNDLE, TEST SERIES 3, TEST-No. 236

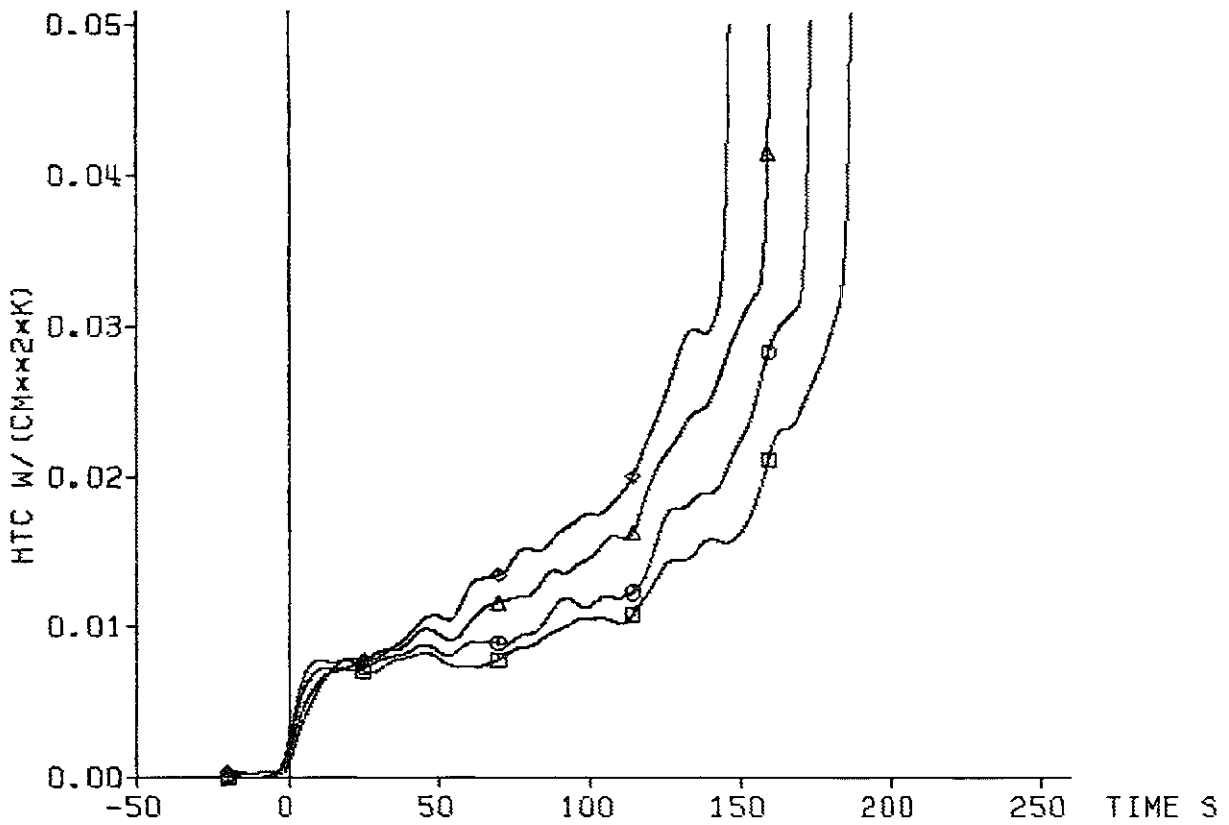


decay heat	120% ANS standard
flooding rate (cold)	3.80 cm/s
system pressure	6.24 bar
feedwater temperature	40 deg C

bypass
======

KfK IRB

Fig. 244 FEBA: 5x5 ROD BUNDLE, TEST SERIES 3, TEST-No. 236

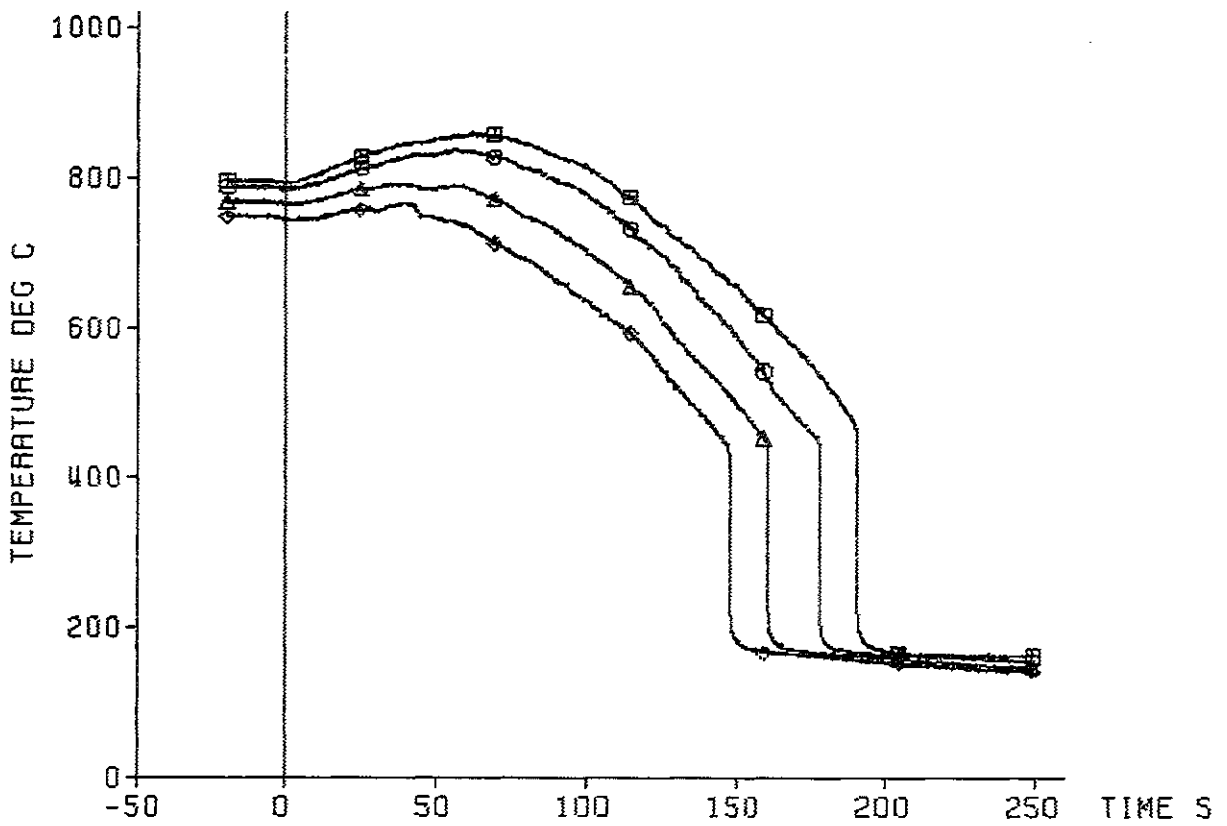


decay heat	120% ANS standard
flooding rate (cold)	3.80 cm/s
system pressure	6.24 bar
feedwater temperature	40 deg C

bypass
======

KfK IRB

Fig. 245 FEBA: 5x5 ROD BUNDLE, TEST SERIES 3, TEST-No. 236

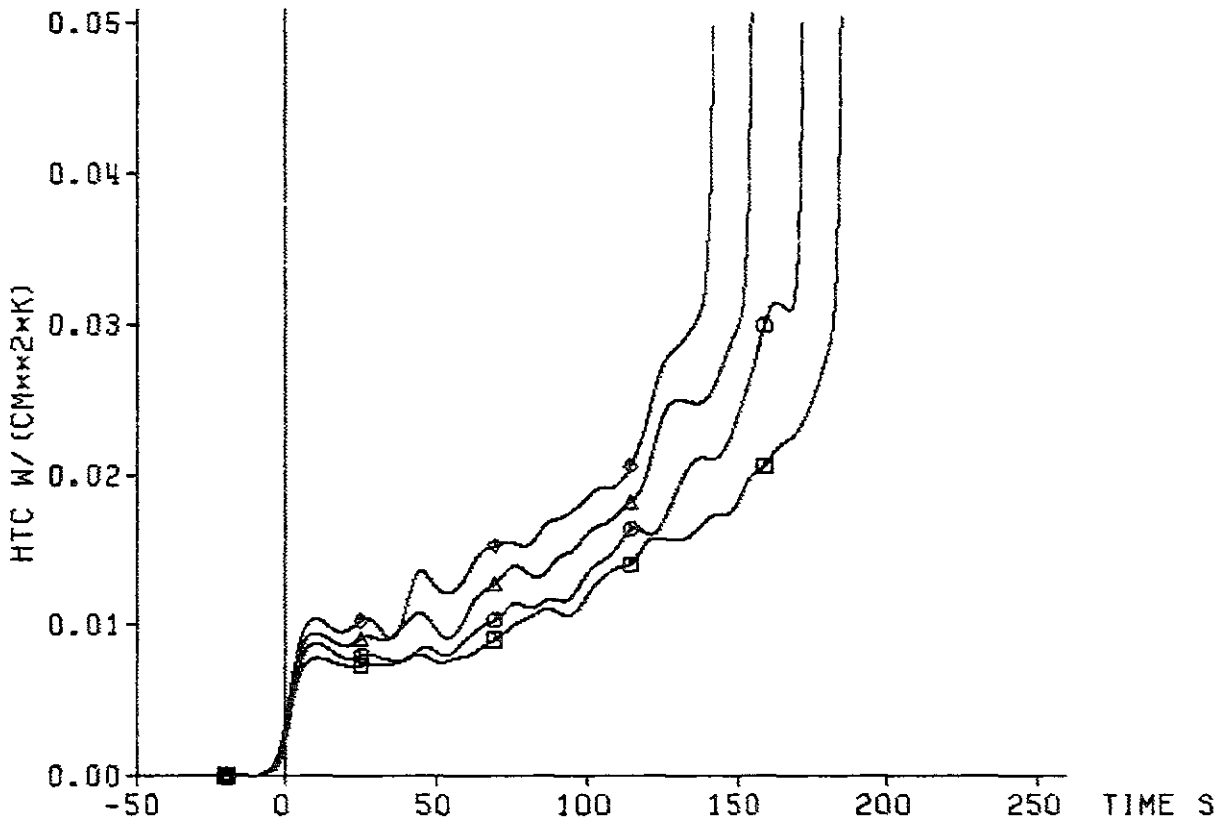


decay heat	120% ANS standard
flooding rate (cold)	3.80 cm/s
system pressure	6.24 bar
feedwater temperature	40 deg C

blockage
========

KfK IRB

Fig. 246 FEBA: 5x5 ROD BUNDLE, TEST SERIES 3, TEST-No. 236

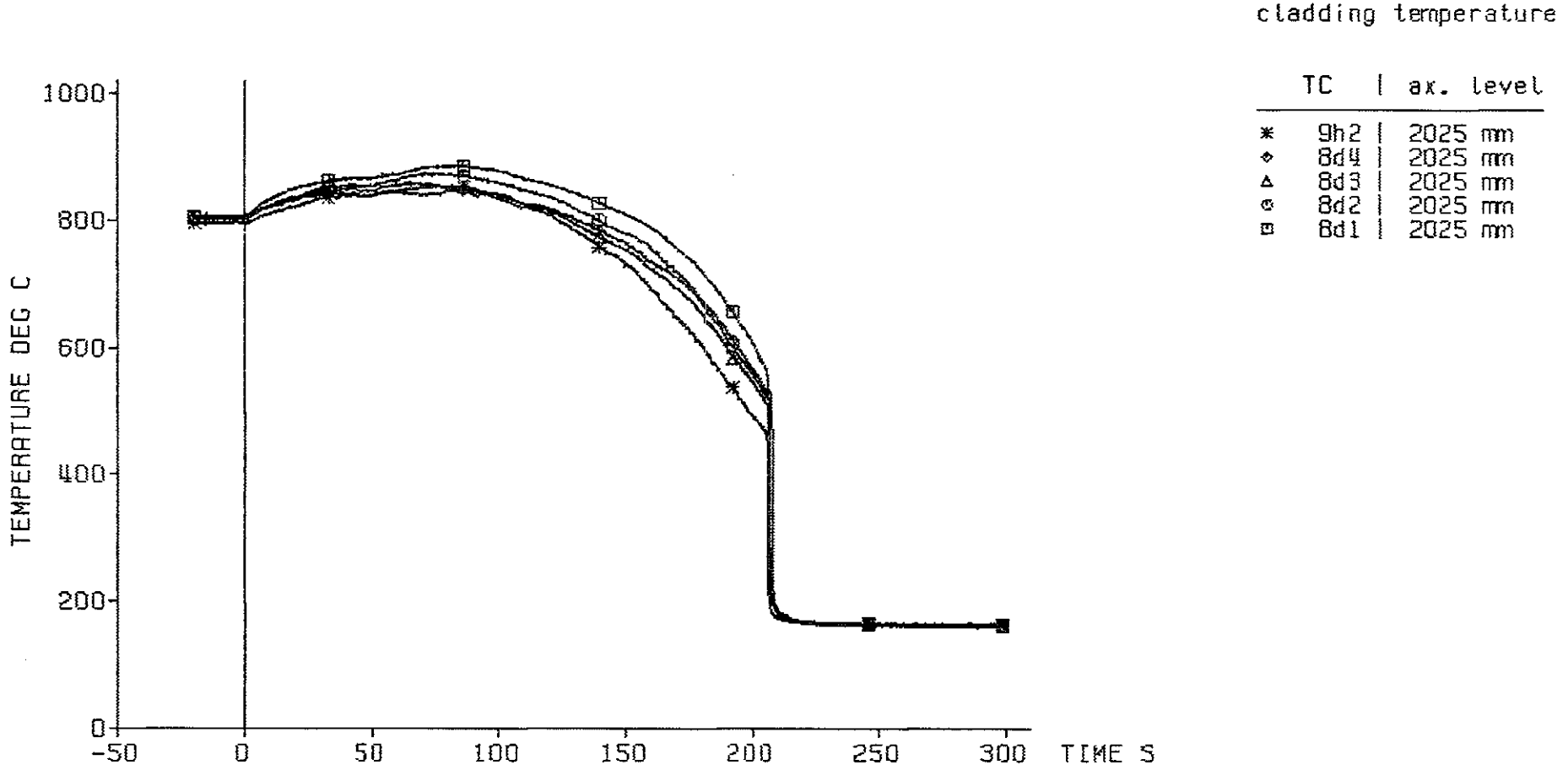


decay heat	120% ANS standard
flooding rate (cold)	3.80 cm/s
system pressure	6.24 bar
feedwater temperature	40 deg C

blockage
========

KfK IRB

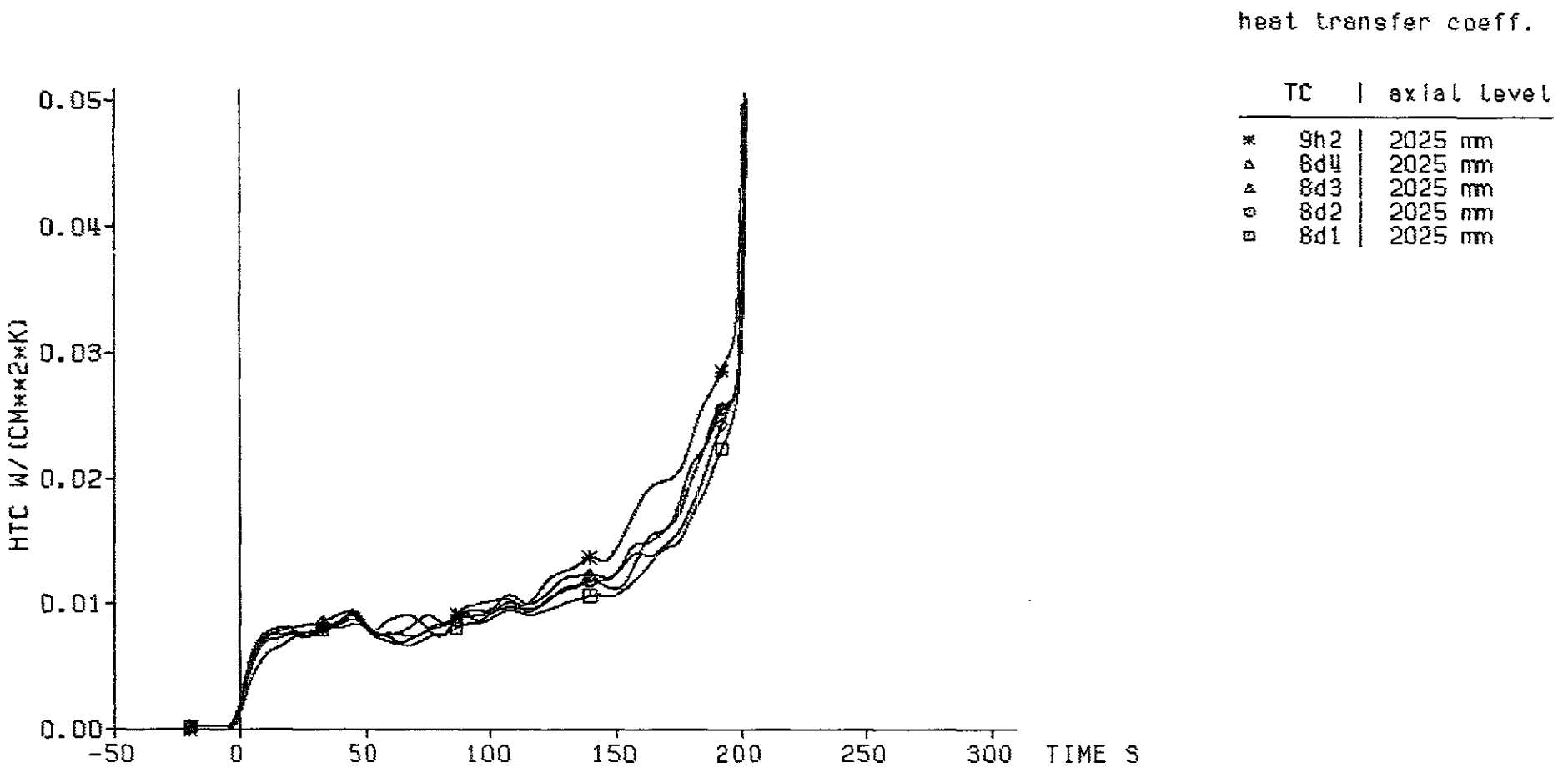
Fig. 247 FEBA: 5x5 ROD BUNDLE, TEST SERIES 3, TEST-No. 236



decay heat	120% ANS standard	bypass
flooding rate (cold)	3.80 cm/s	======
system pressure	6.24 bar	
feedwater temperature	40 deg C	

KfK IRB

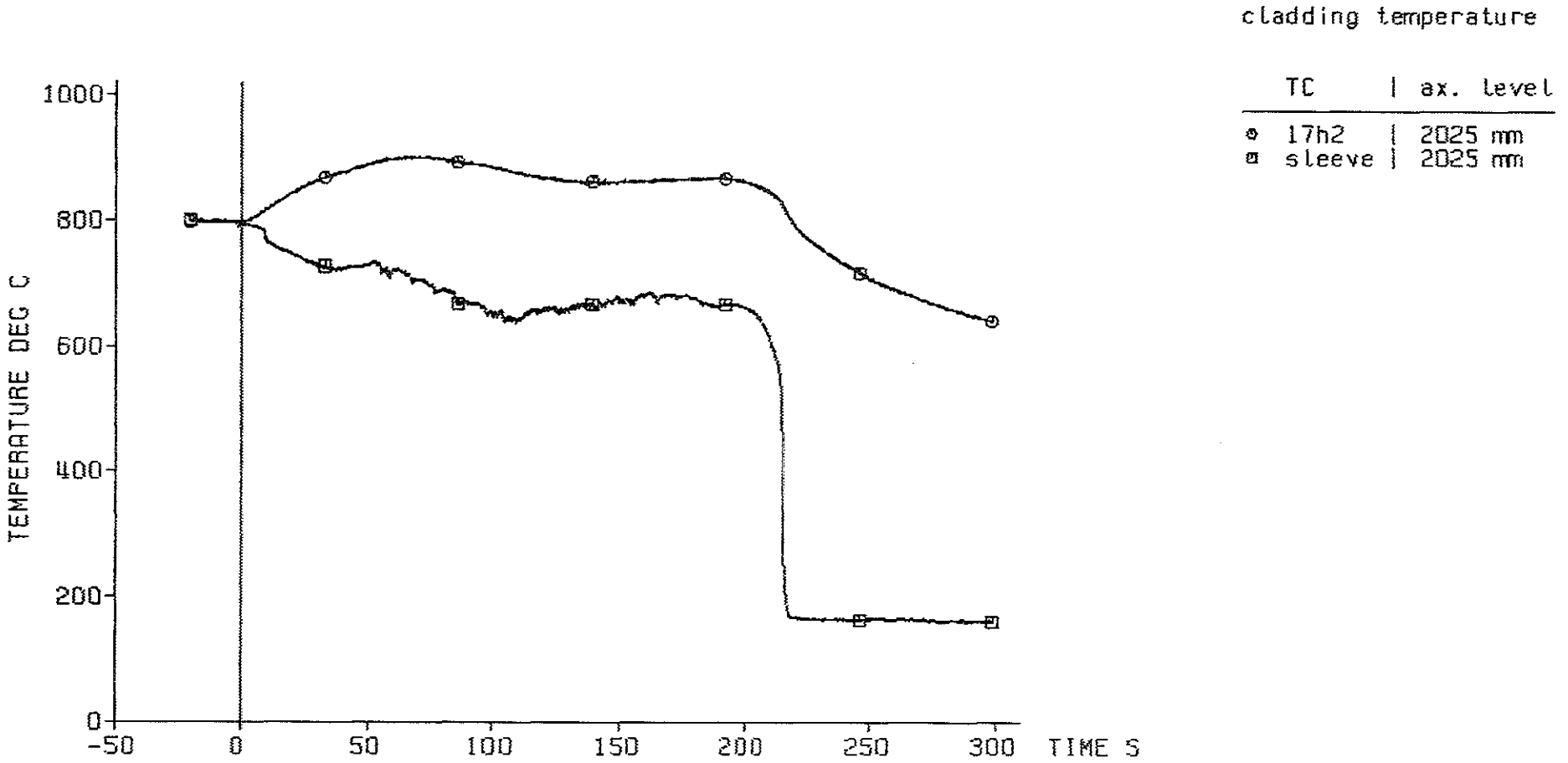
Fig. 248 FEBA: 5x5 ROD BUNDLE, TEST SERIES 3, TEST-No. 236



decay heat 120% ANS standard
flooding rate (cold) 3.80 cm/s
system pressure 6.24 bar
feedwater temperature 40 deg C

bypass
======

Fig. 249 FEBA: 5x5 ROD BUNDLE, TEST SERIES 3, TEST-No. 236

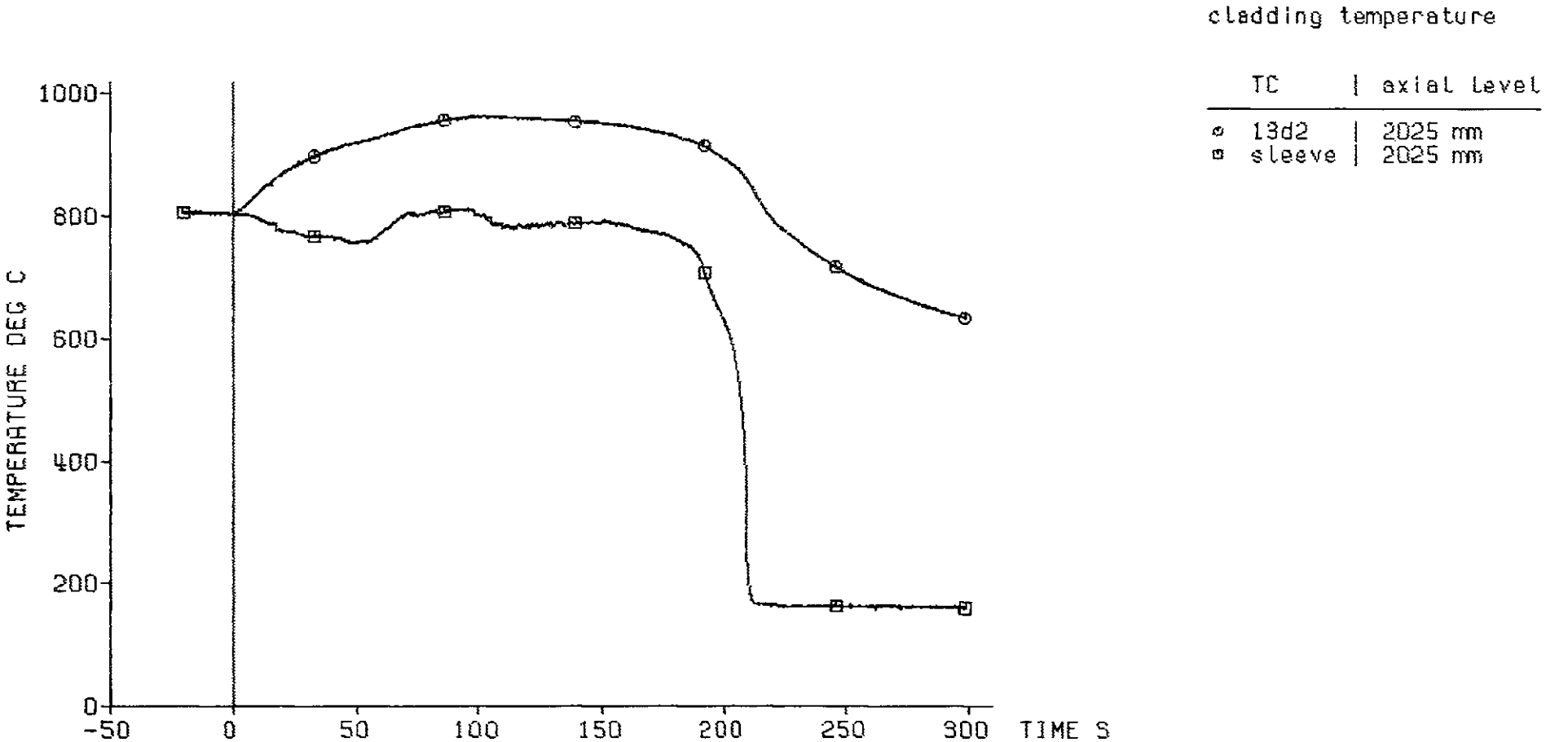


decay heat 120% ANS standard
flooding rate (cold) 3.80 cm/s
system pressure 6.24 bar
feedwater temperature 40 deg C

blockage
========

KfK IRB

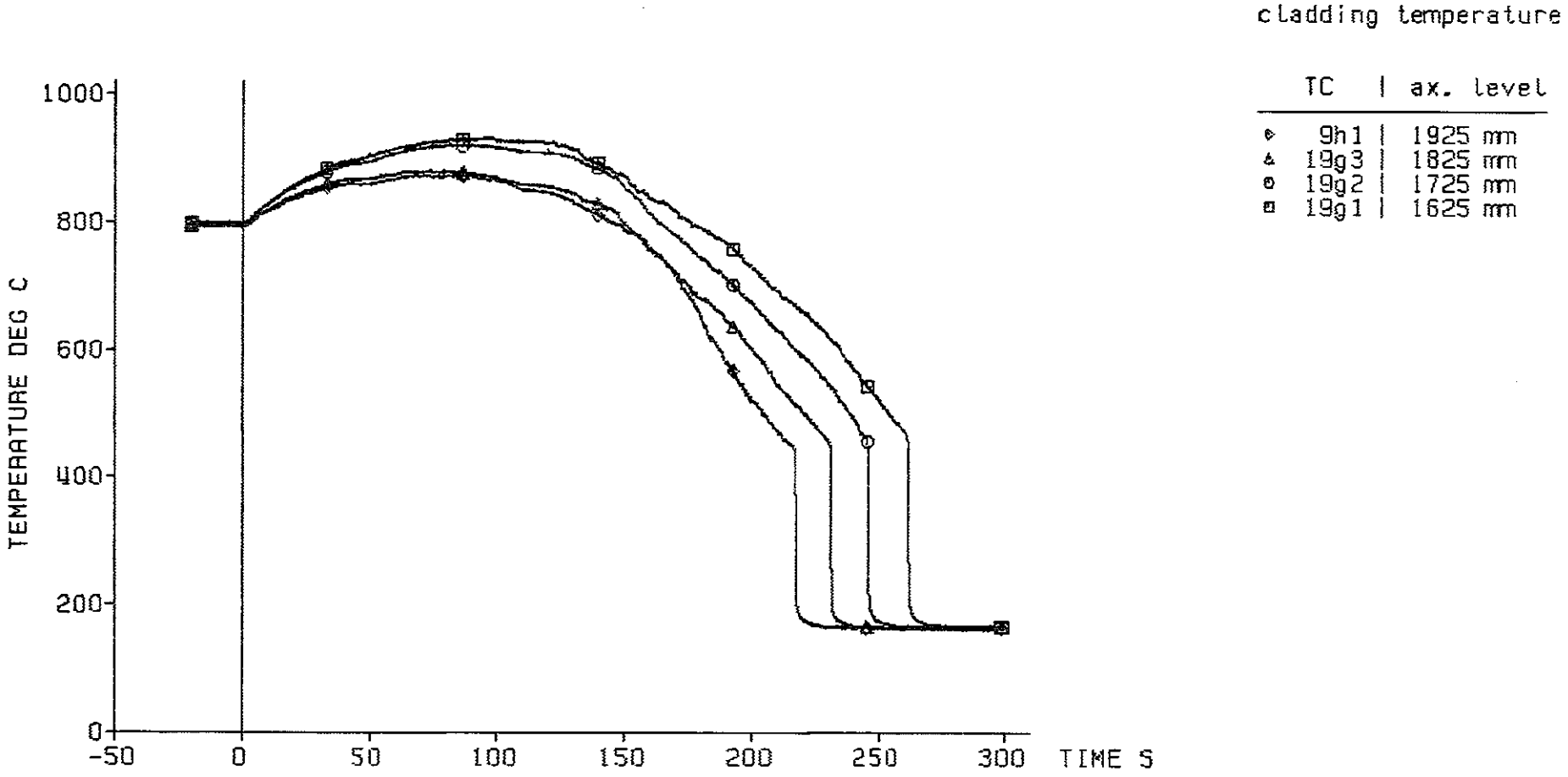
Fig. 250 FEBA: 5x5 ROD BUNDLE, TEST SERIES 3, TEST-No. 236



decay heat	120% ANS standard	blockage
flooding rate (cold)	3.80 cm/s	========
system pressure	6.24 bar	
feedwater temperature	40 deg C	

KfK IRB

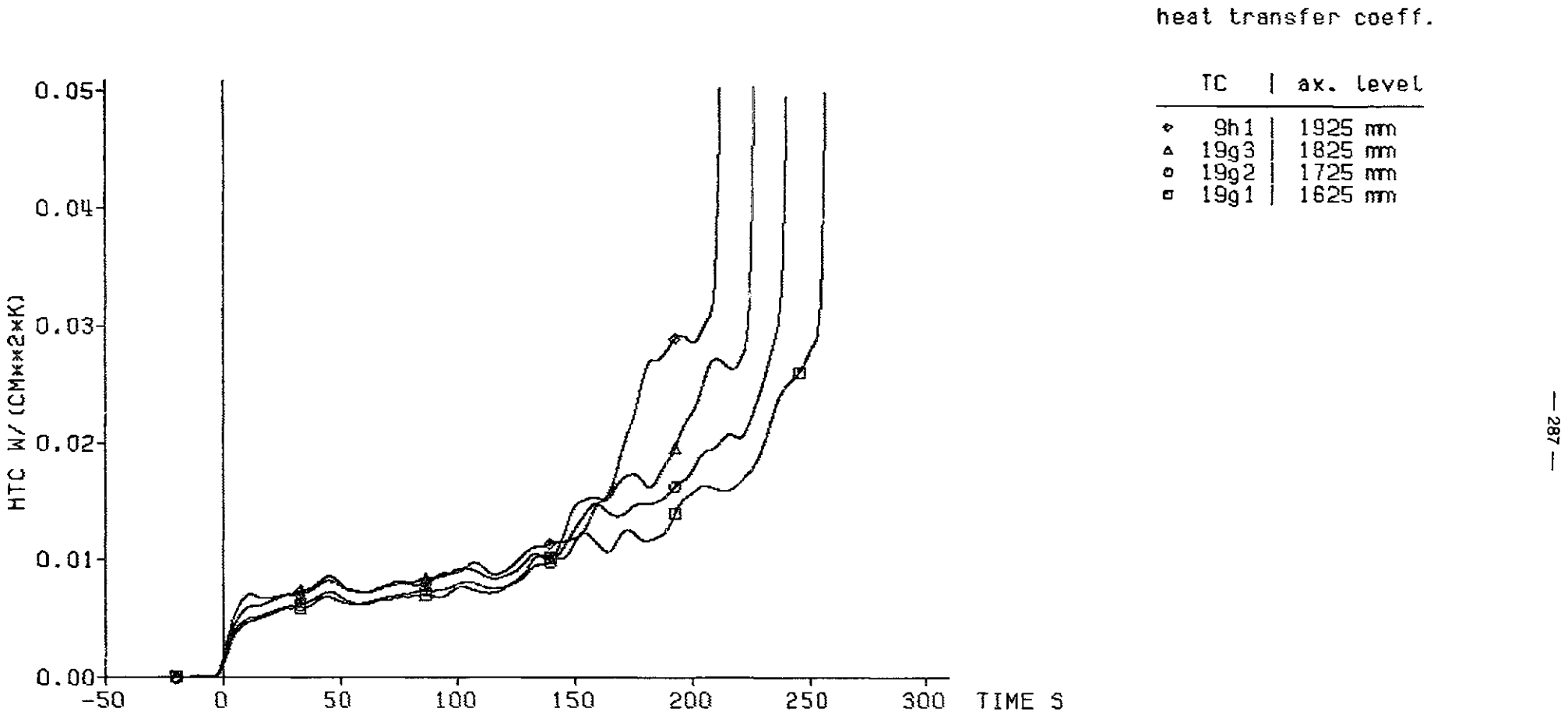
Fig. 251 FEBA: 5x5 ROD BUNDLE, TEST SERIES 3, TEST-No. 236



decay heat	120% ANS standard	bypass
flooding rate (cold)	3.80 cm/s	======
system pressure	6.24 bar	
feedwater temperature	40 deg C	

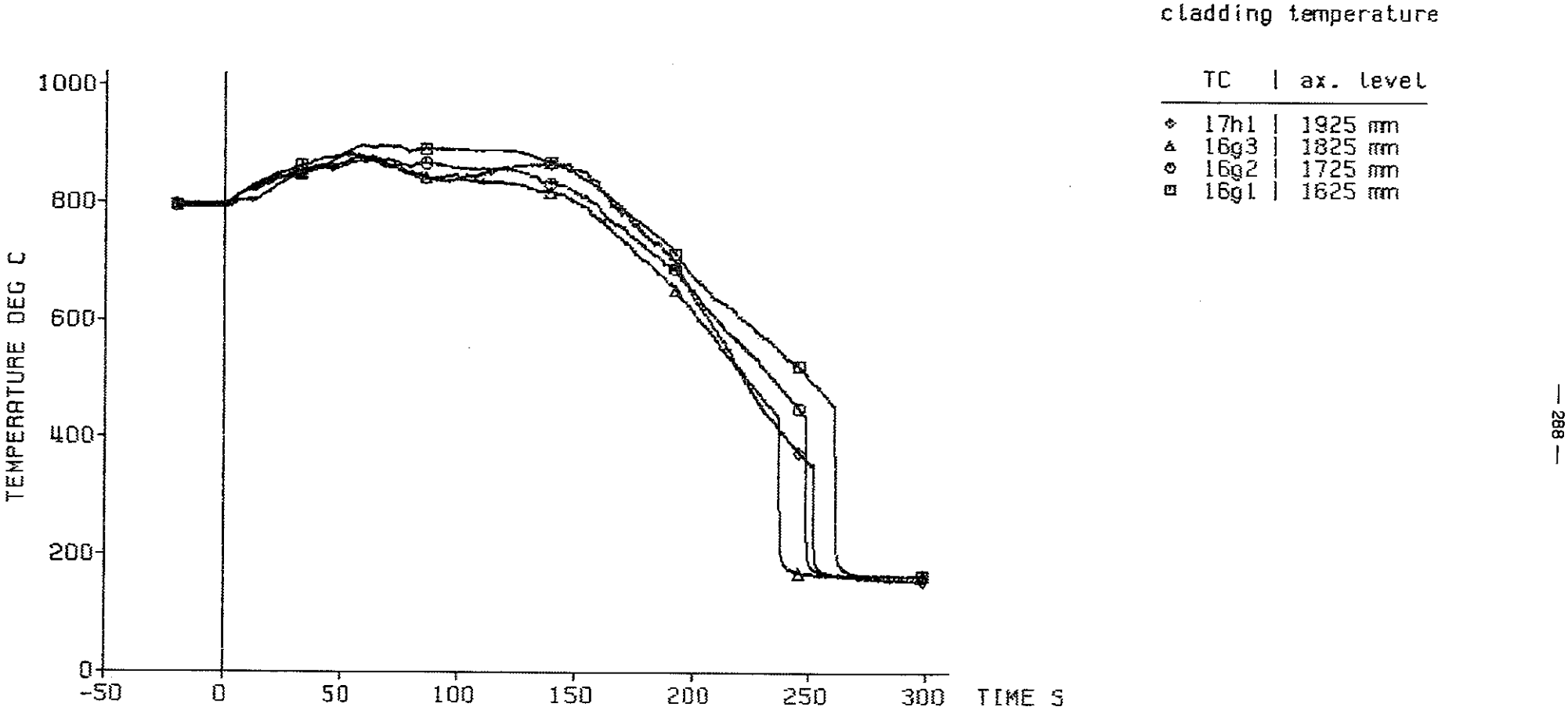
KfK IRB

Fig. 252 FEBA: 5x5 ROD BUNDLE, TEST SERIES 3, TEST-No. 236



decay heat	120% ANS standard	bypass
flooding rate (cold)	3.80 cm/s	======
system pressure	6.24 bar	
feedwater temperature	40 deg C	

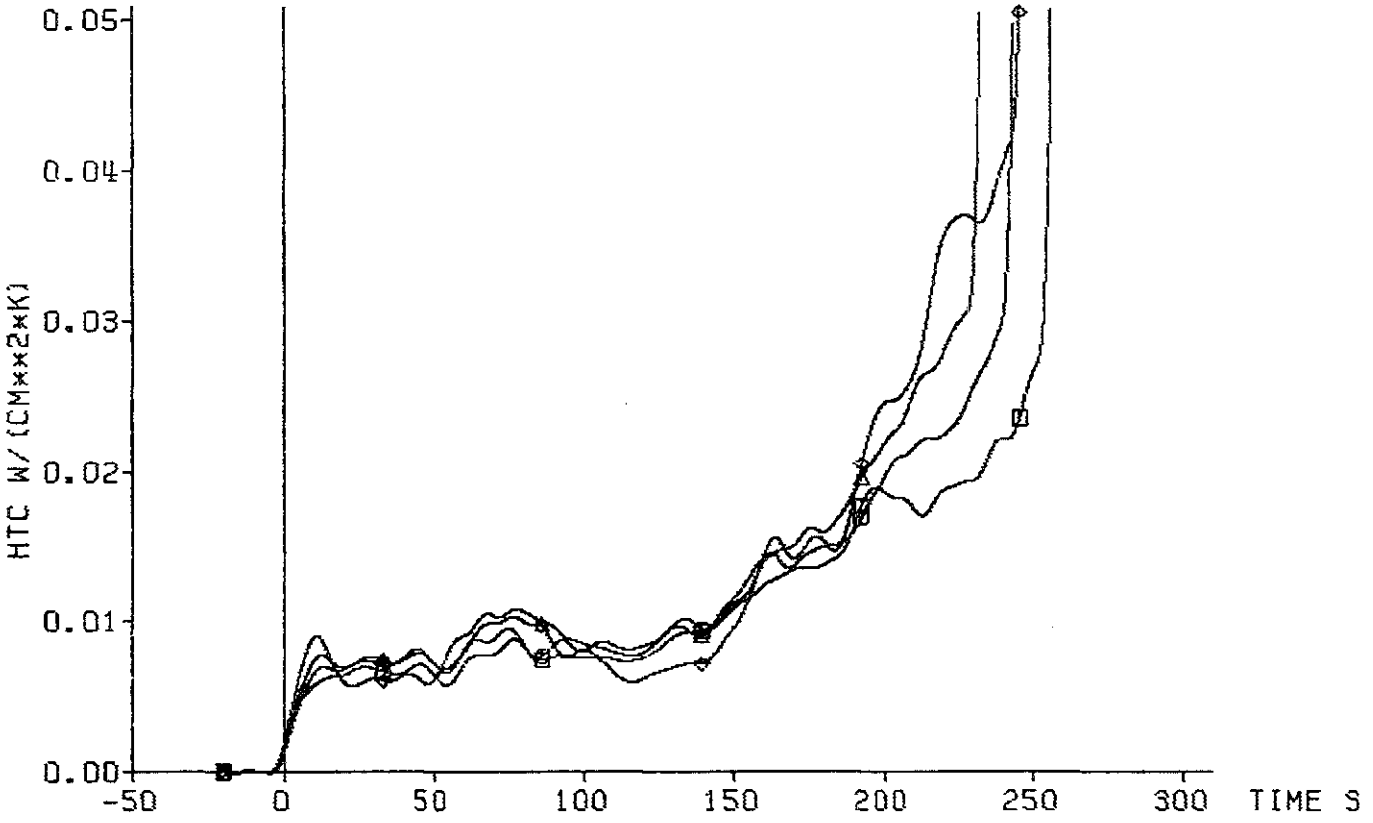
Fig. 253 FEBA: 5x5 ROD BUNDLE, TEST SERIES 3, TEST-No. 236



decay heat	120% ANS standard	blockage
flooding rate (cold)	3.80 cm/s	========
system pressure	6.24 bar	
feedwater temperature	40 deg C	

KfK IRB

Fig. 254 FEBA: 5x5 ROD BUNDLE, TEST SERIES 3, TEST-No. 236

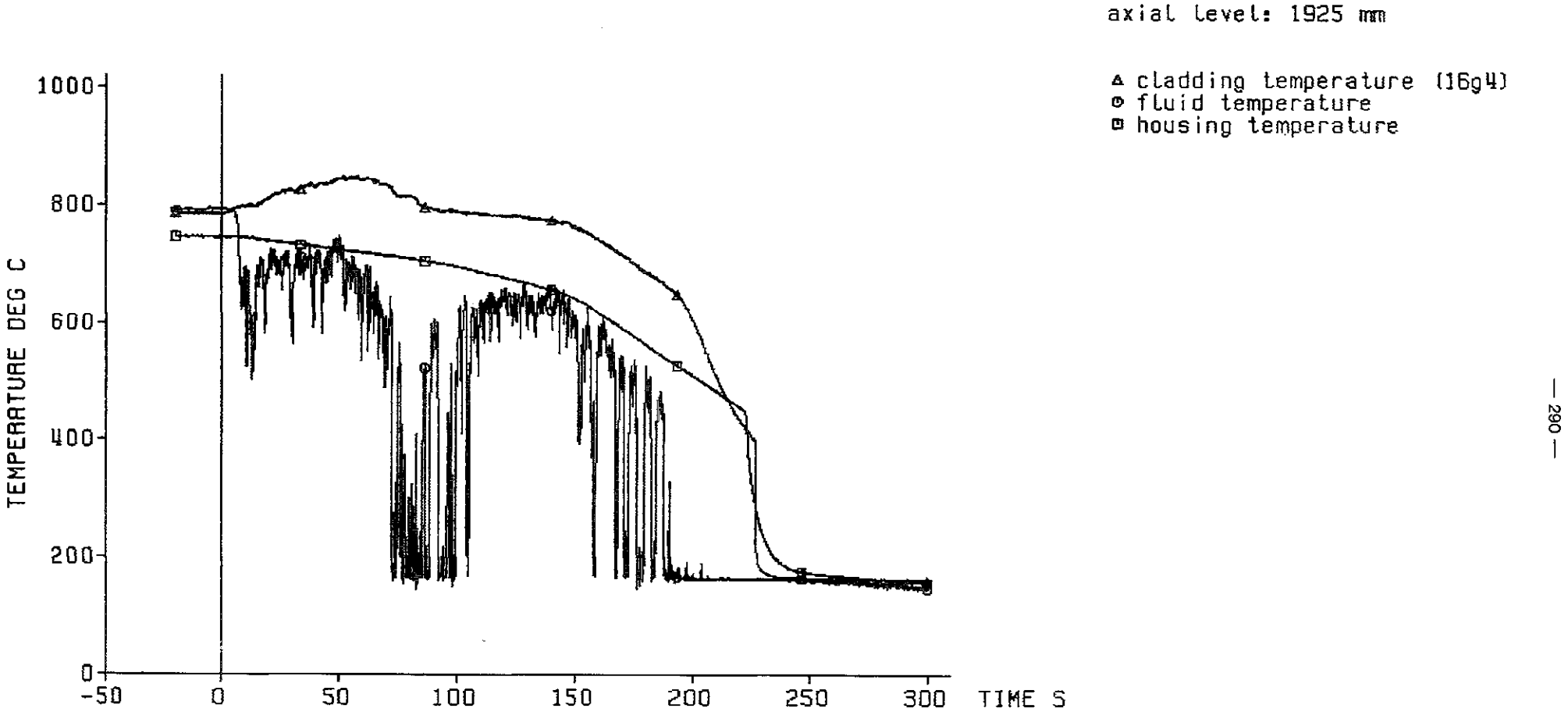


decay heat	120% ANS standard
flooding rate (cold)	3.80 cm/s
system pressure	6.24 bar
feedwater temperature	40 deg C

blockage
========

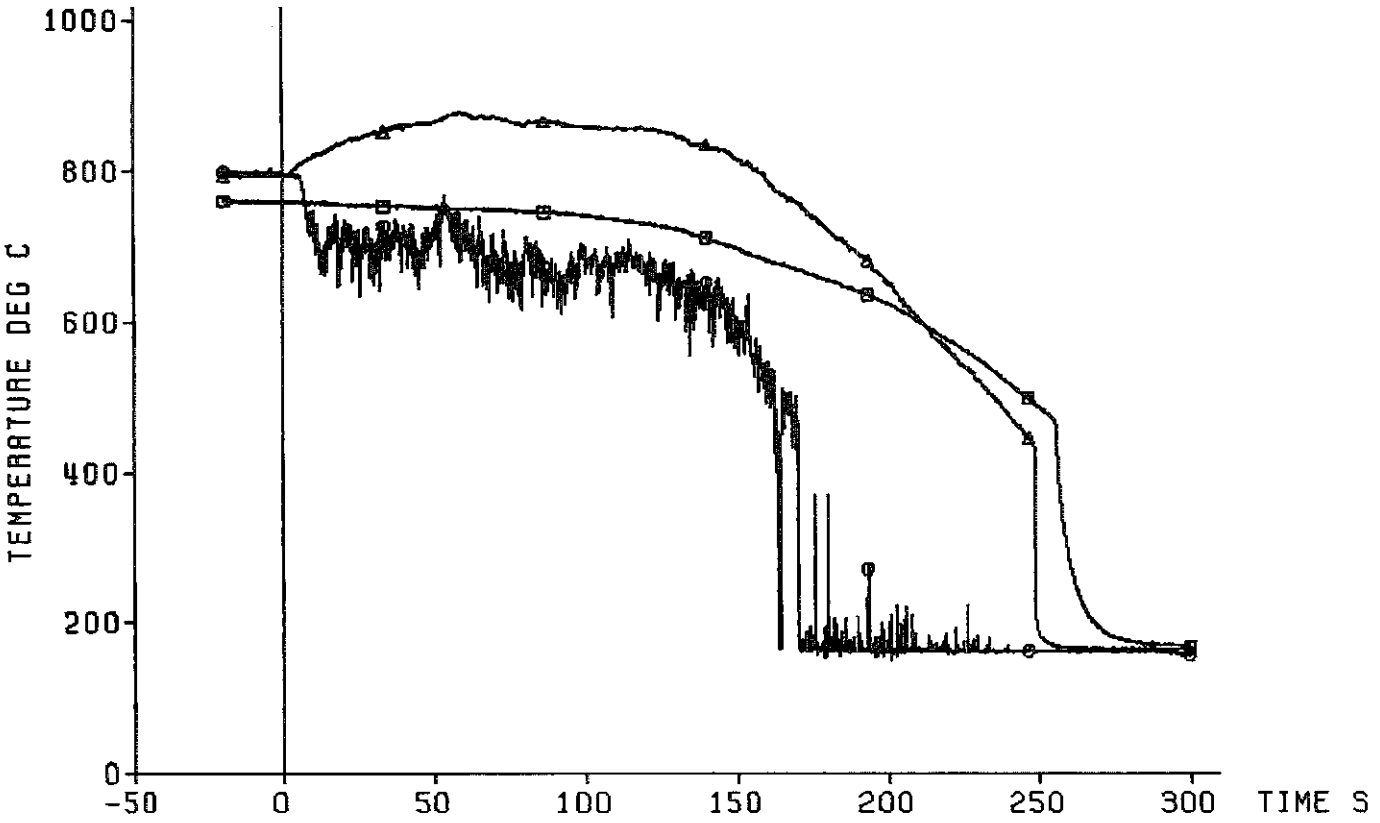
KfK IRB

Fig. 255 FEBA: 5x5 ROD BUNDLE, TEST SERIES 3, TEST-No. 236



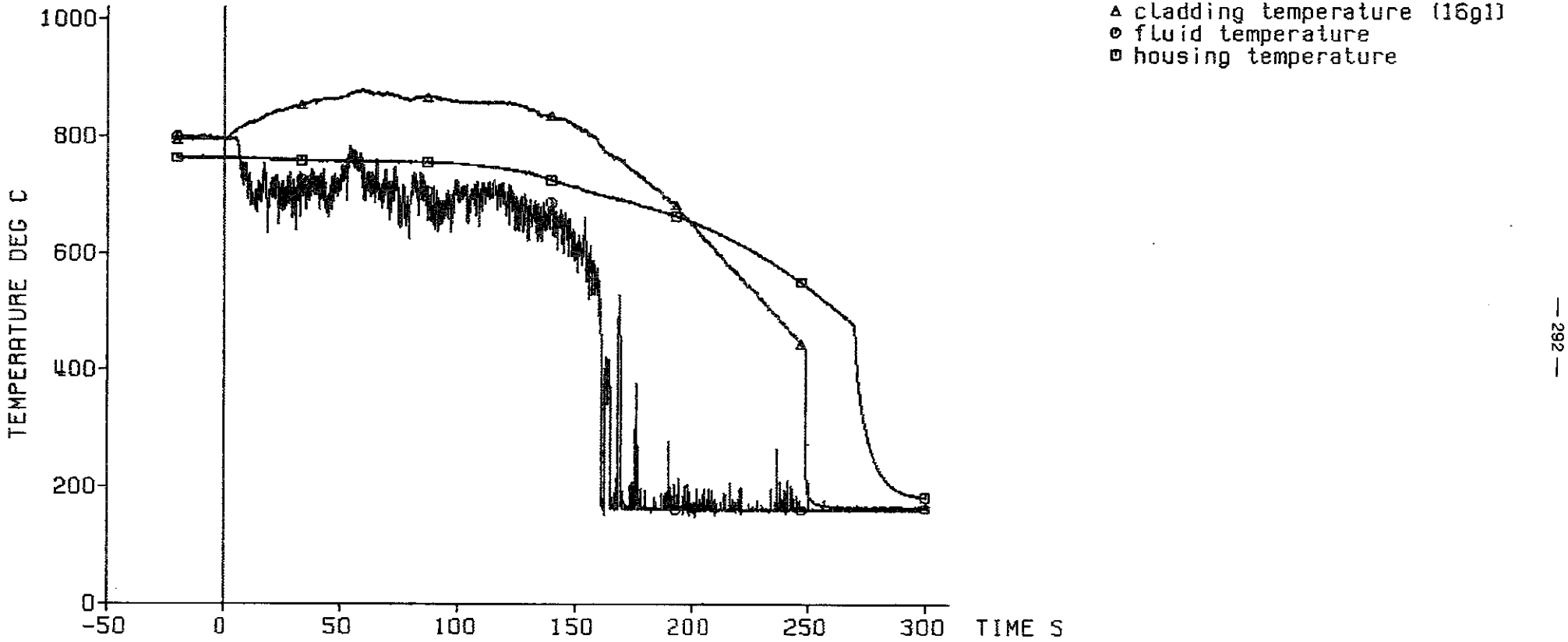
KfK IRB

Fig. 256 FEBA: 5x5 ROD BUNDLE, TEST SERIES 3, TEST-No. 236



decay heat	120% ANS standard	blockage
flooding rate (cold)	3.80 cm/s	========
system pressure	6.24 bar	
feedwater temperature	40 deg C	

Fig. 257 FEBA: 5x5 ROD BUNDLE, TEST SERIES 3, TEST-No. 236

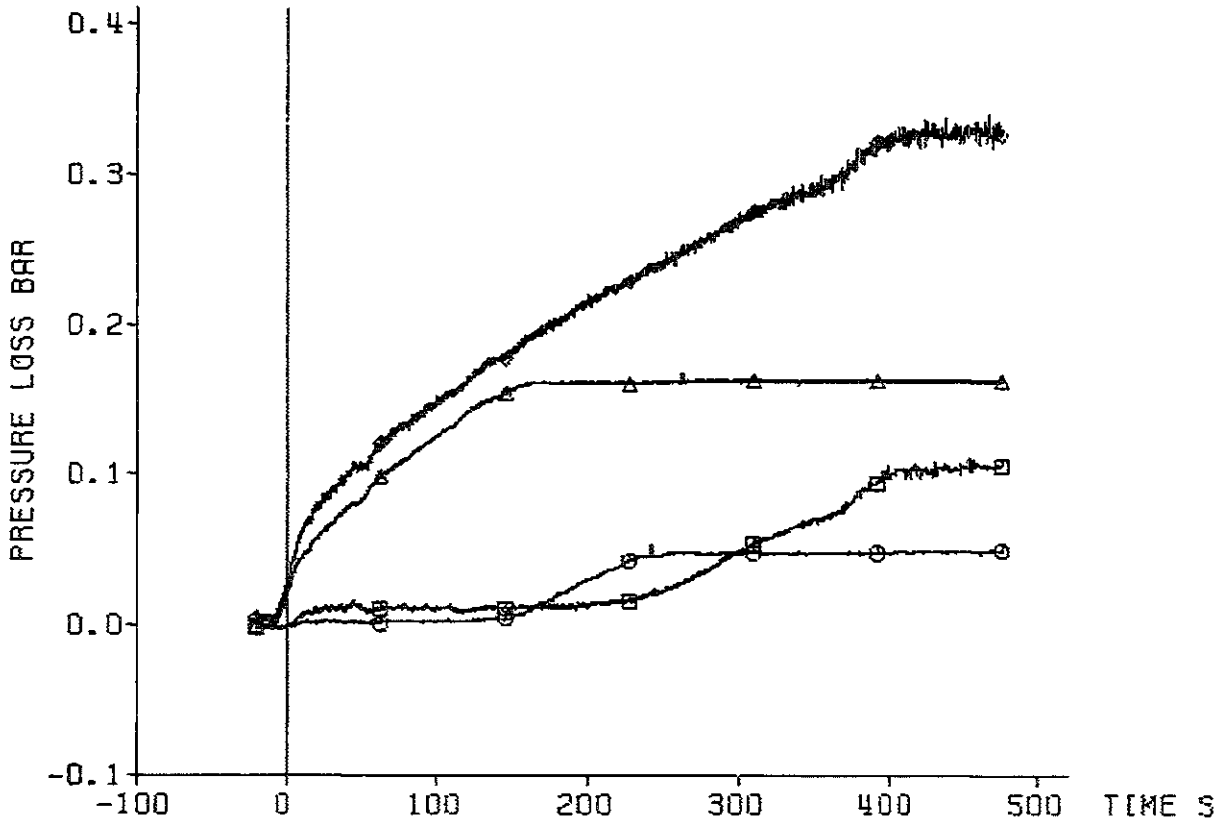


decay heat	120% ANS standard
flooding rate (cold)	3.60 cm/s
system pressure	6.24 bar
feedwater temperature	40 deg C

blockage
========

KfK IRB

Fig. 258 FEBA: 5x5 ROD BUNDLE, TEST SERIES 3, TEST-No. 236



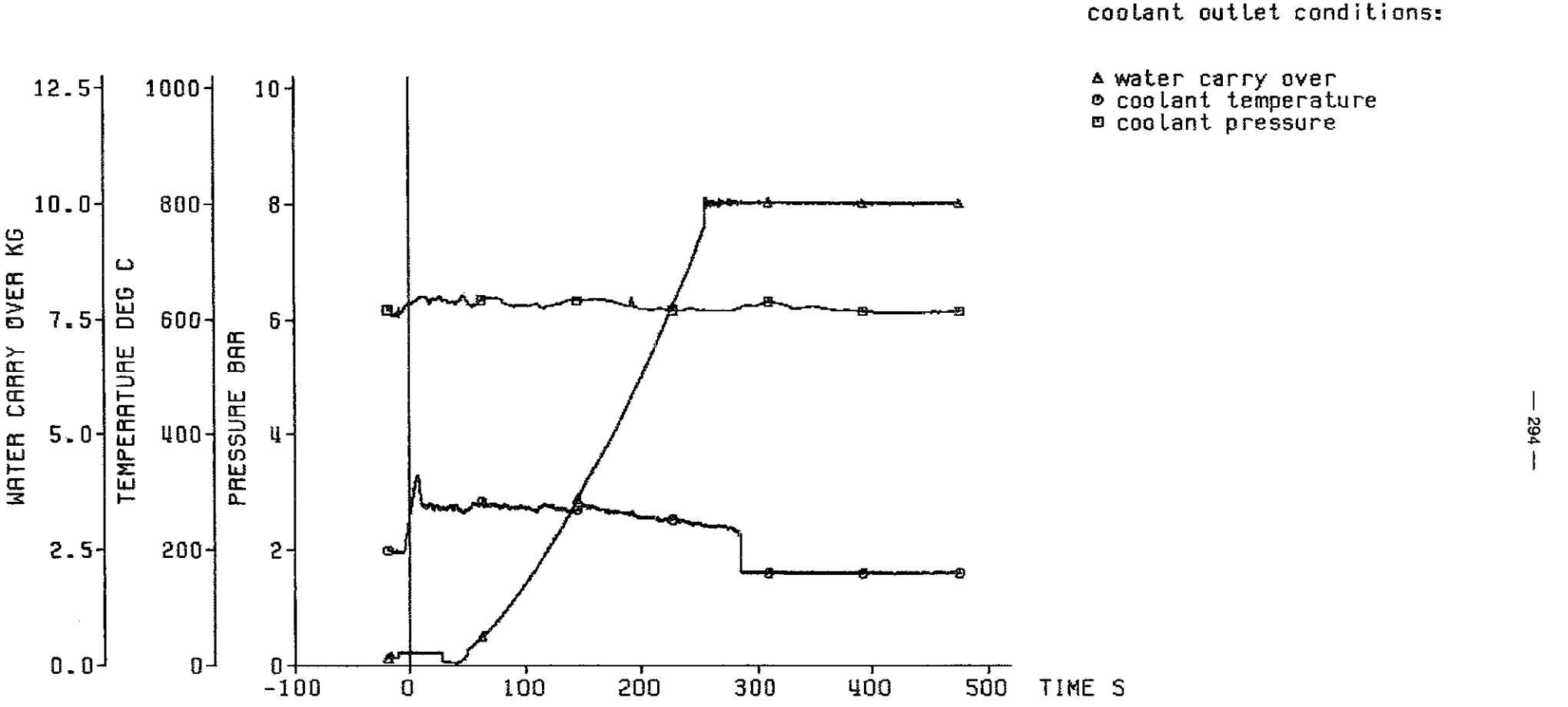
pressure loss
along the test section:

◇ total length: 4196 mm
△ lower part: 1711 mm
○ middle part: 545 mm
□ upper part: 1940 mm

decay heat	120% ANS standard
flooding rate (cold)	3.80 cm/s
system pressure	6.24 bar
feedwater temperature	40 deg C

KfK IRB

Fig. 259 FEBA: 5x5 ROD BUNDLE, TEST SERIES 3, TEST-No. 236



decay heat	120% ANS standard
flooding rate (cold)	3.80 cm/s
system pressure	6.24 bar
feedwater temperature	40 deg C

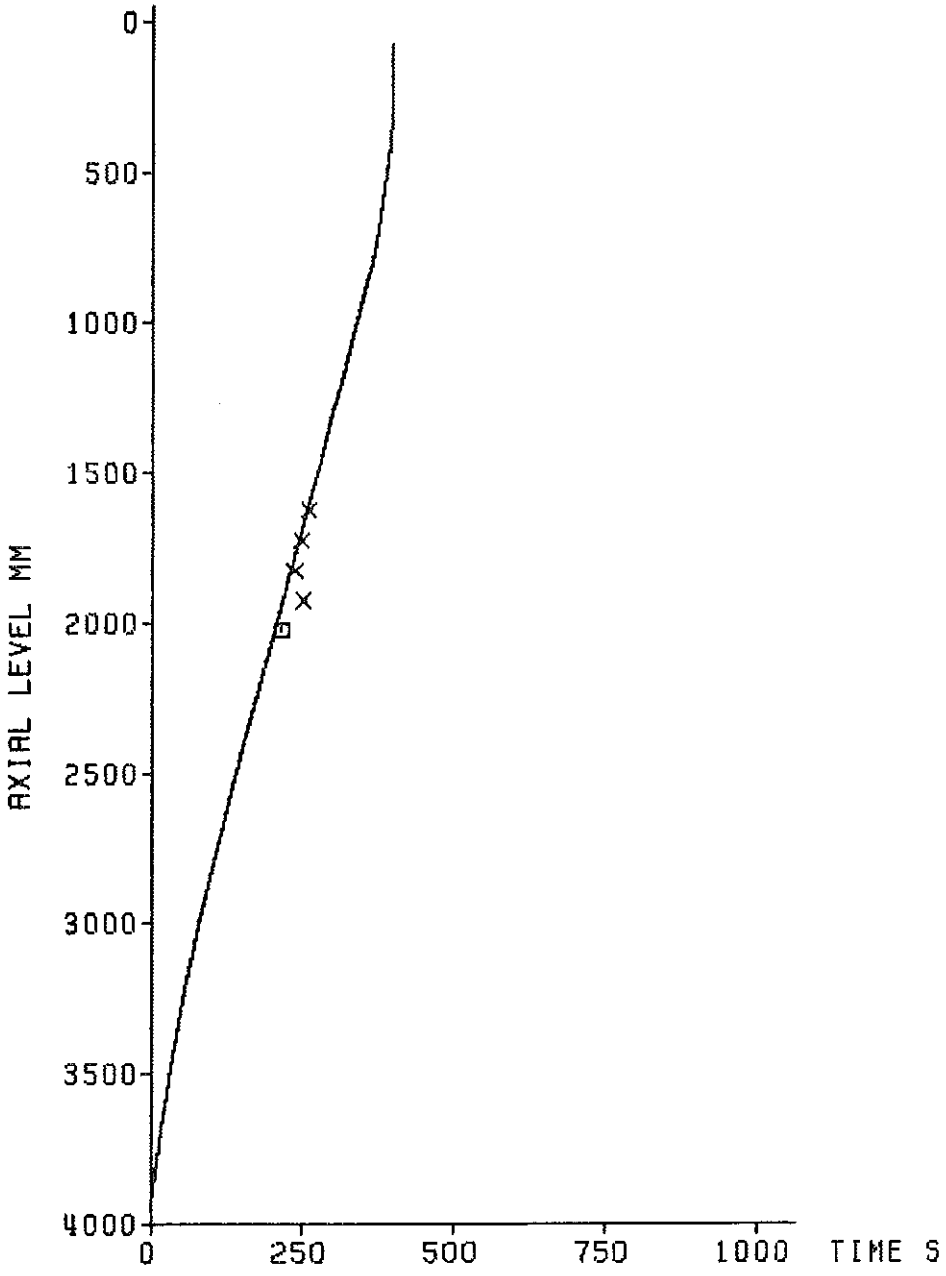
KfK KIRB

Fig. 260 FEBA: 5x5 ROD BUNDLE, TEST SERIES 3, TEST-No. 236

axial position of the quench front

□ rewetting of the sleeve at the bundle midplane

× rewetting of the rod downstream of the blockage

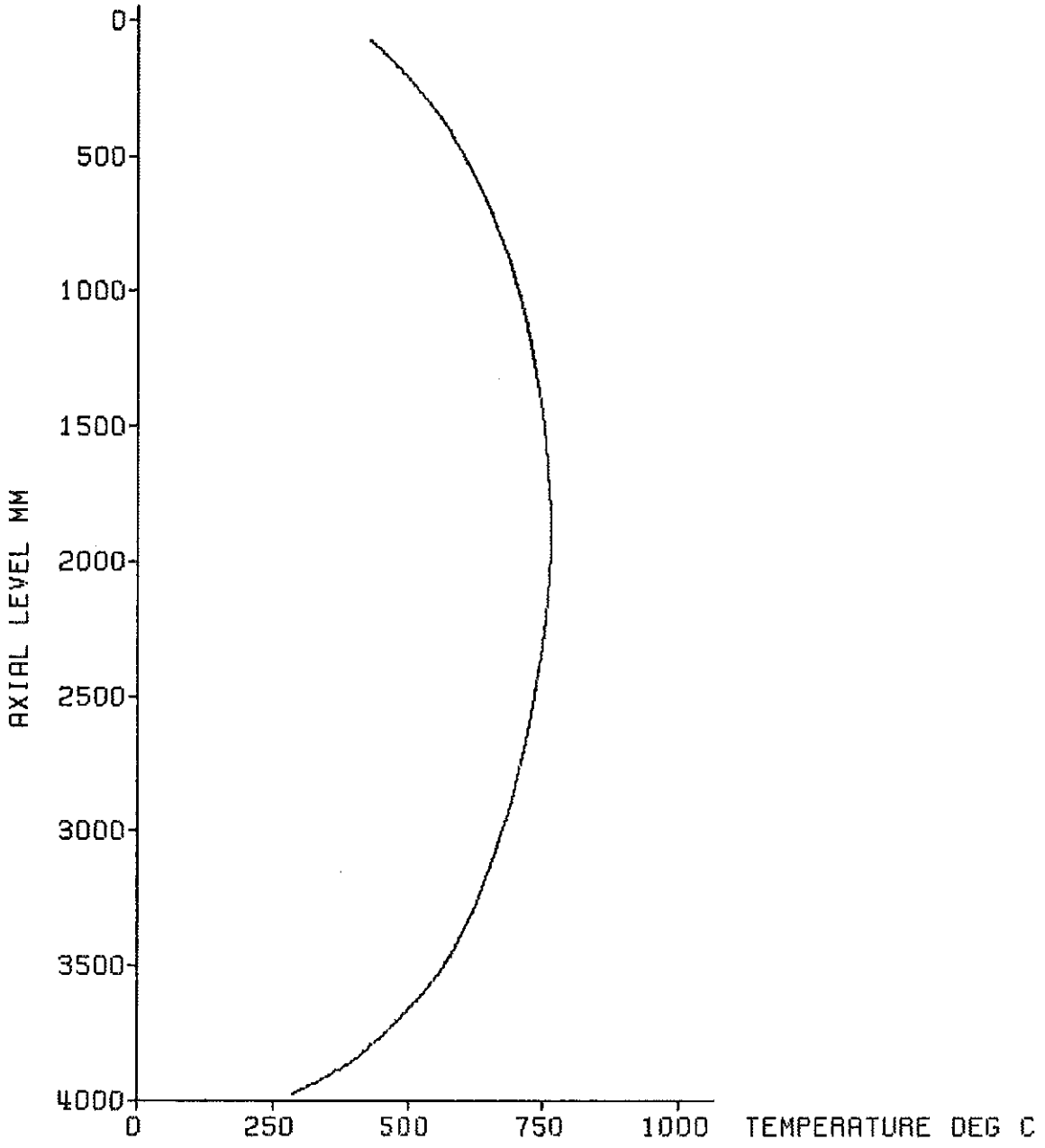


decay heat	120% ANS standard
flooding rate (cold)	3.80 cm/s
system pressure	6.24 bar
feedwater temperature	40 deg C

KfK IRB

Fig. 261 FEBA: 5x5 ROD BUNDLE
TEST SERIES 3, TEST-No. 236

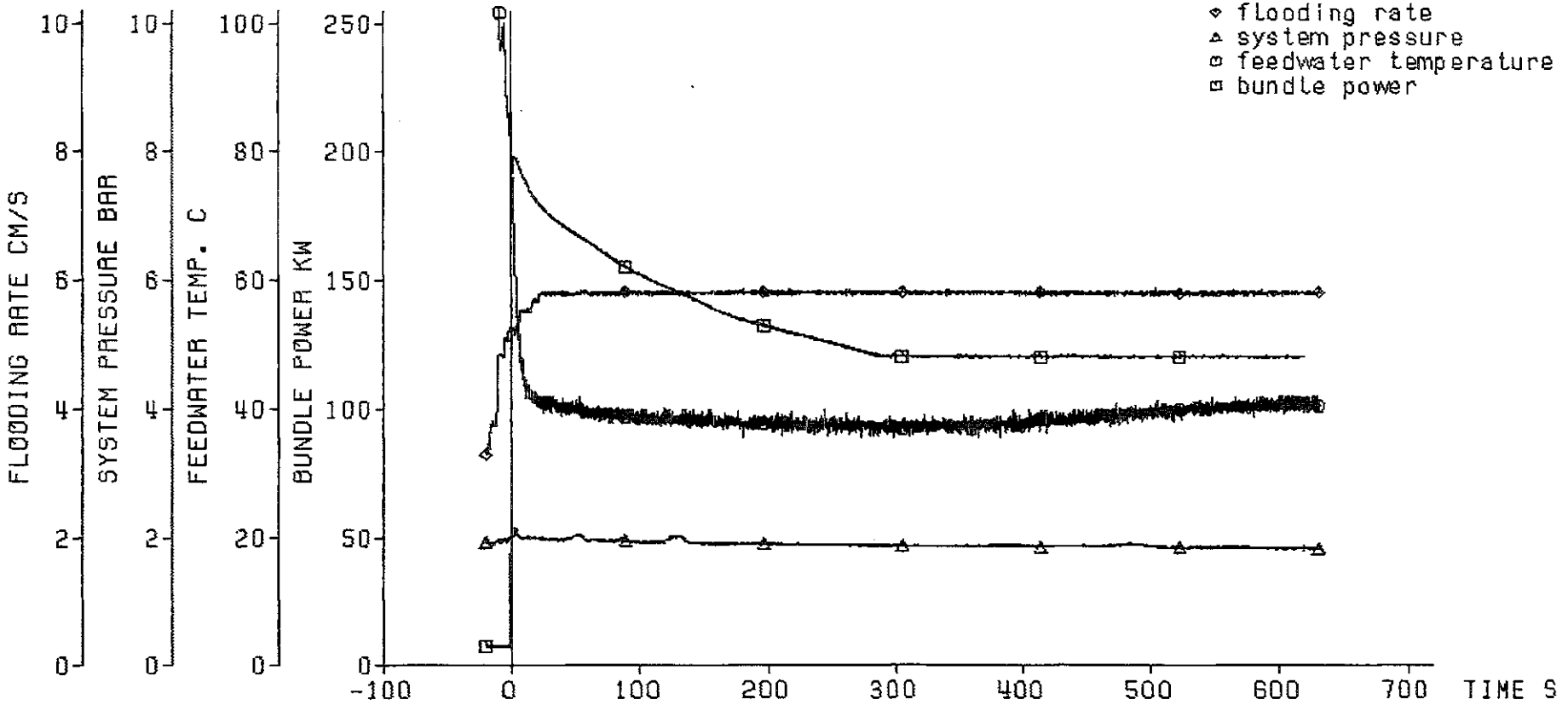
initial axial temperature profile of the cladding



decay heat	120% ANS standard
flooding rate (cold)	5.80 cm/s
system pressure	1.93 bar
feedwater temperature	40 deg C

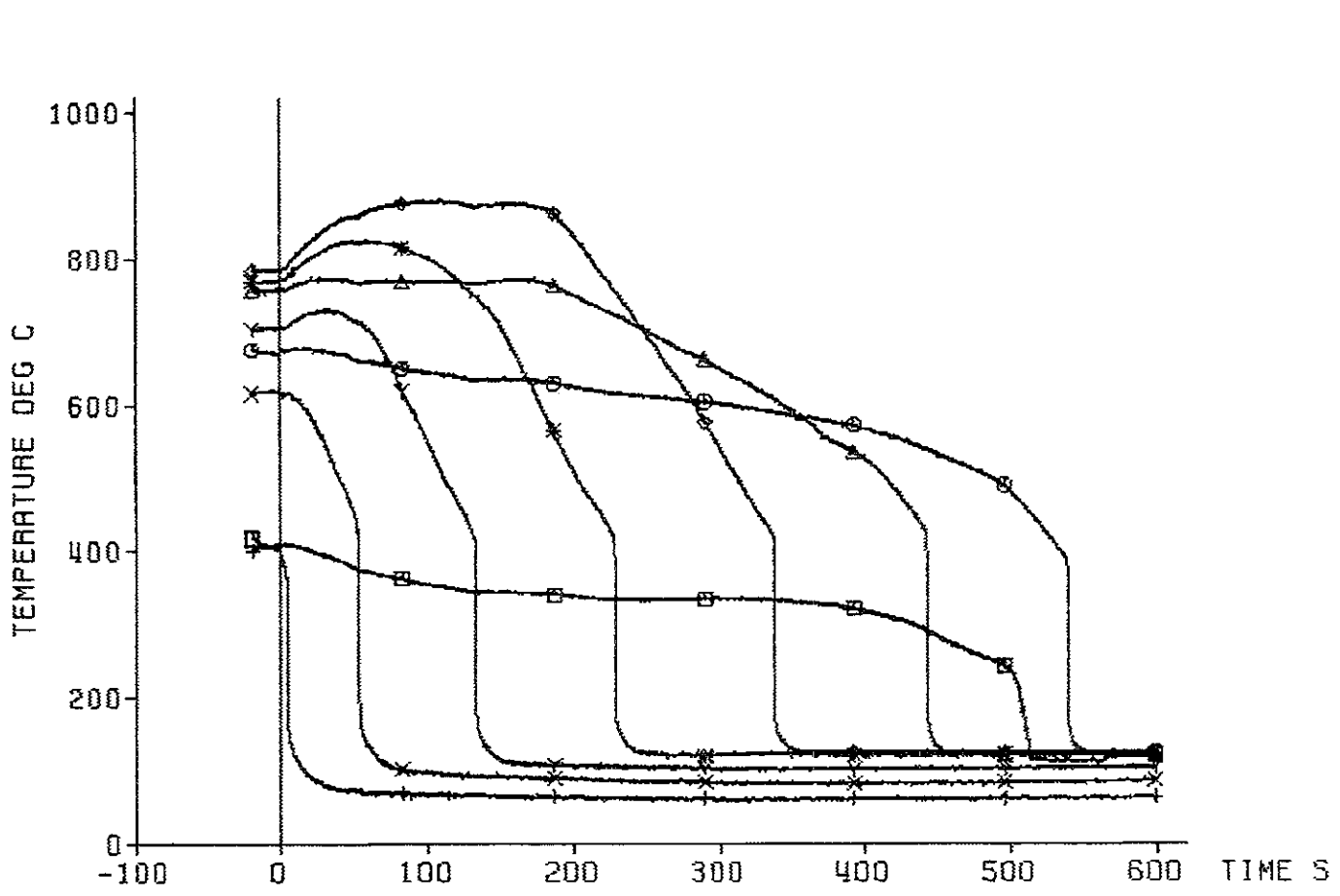
KfK IRB

Fig. 262 FEBA: 5x5 ROD BUNDLE TEST SERIES 3, TEST-No. 240



decay heat	120% ANS standard
flooding rate (cold)	5.80 cm/s
system pressure	1.93 bar
feedwater temperature	40 deg C

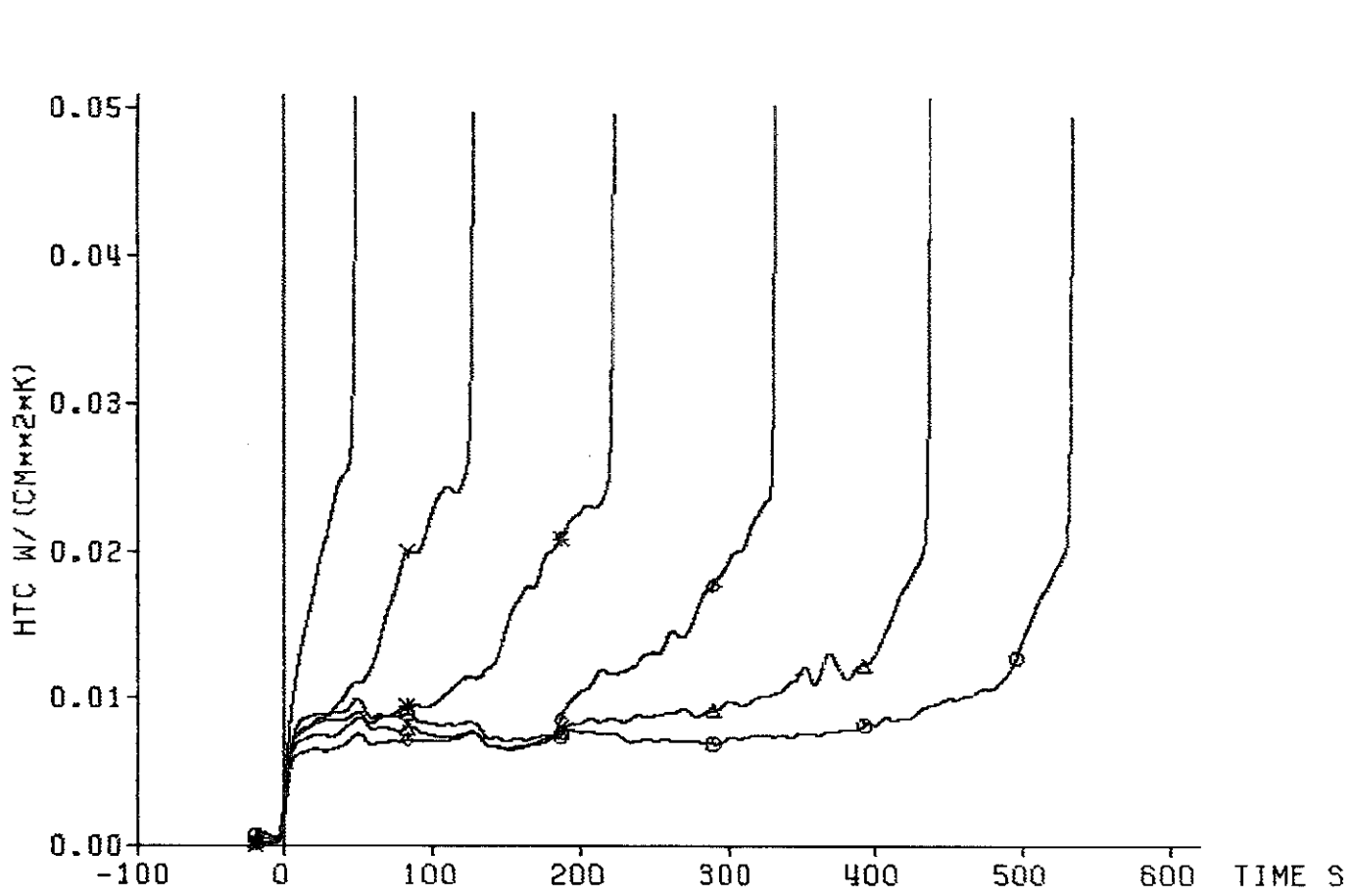
Fig. 263 FEBA: 5x5 ROD BUNDLE, TEST SERIES 3, TEST-No. 240



decay heat	120% ANS standard
flooding rate (cold)	5.80 cm/s
system pressure	1.93 bar
feedwater temperature	40 deg C

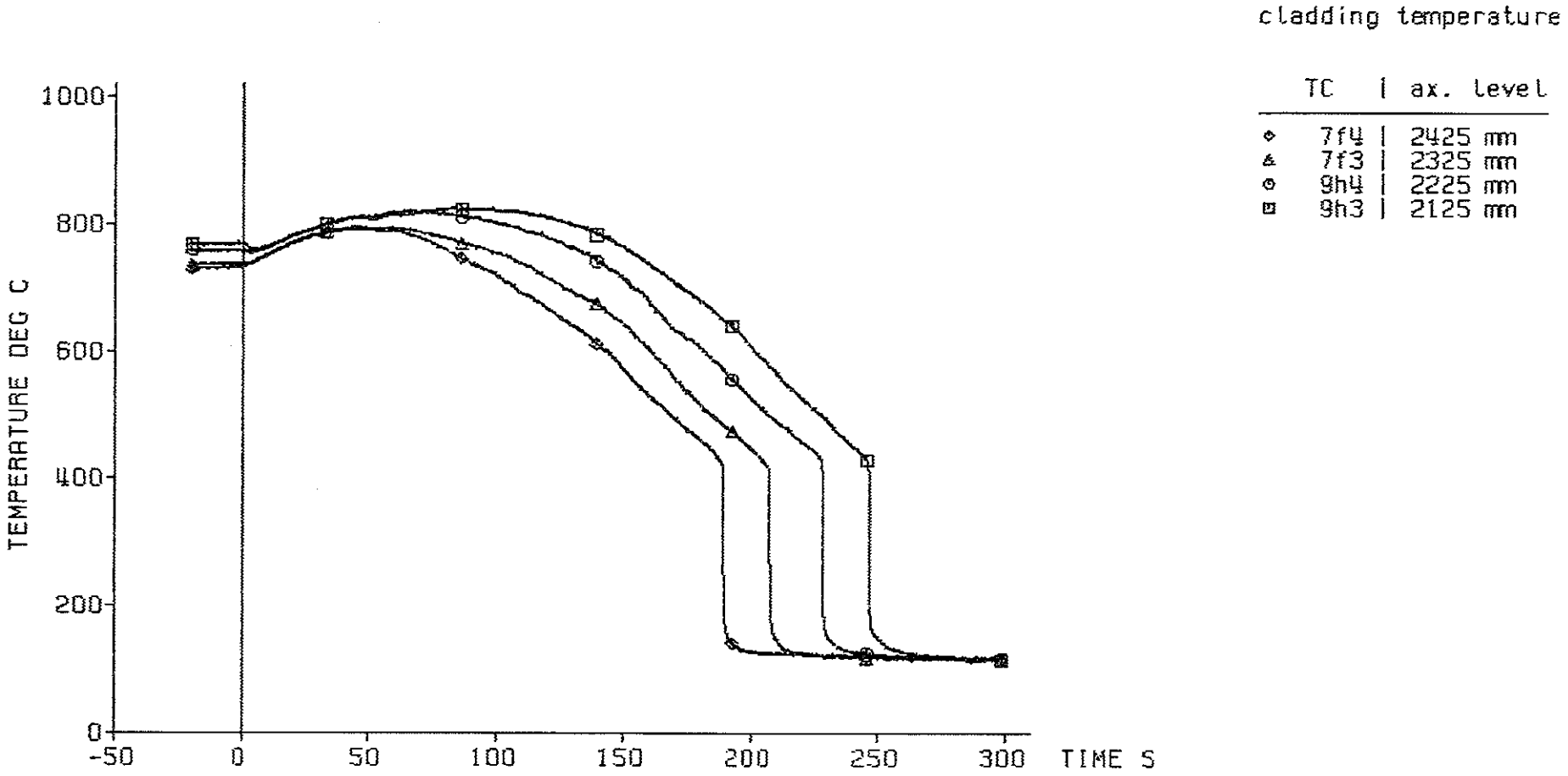
KfK IRB

Fig. 264 FEBA: 5x5 ROD BUNDLE, TEST SERIES 3, TEST-No. 240



decay heat	120% ANS standard
flooding rate (cold)	5.80 cm/s
system pressure	1.93 bar
feedwater temperature	40 deg C

Fig. 265 FEBA: 5x5 ROD BUNDLE, TEST SERIES 3, TEST-No. 240

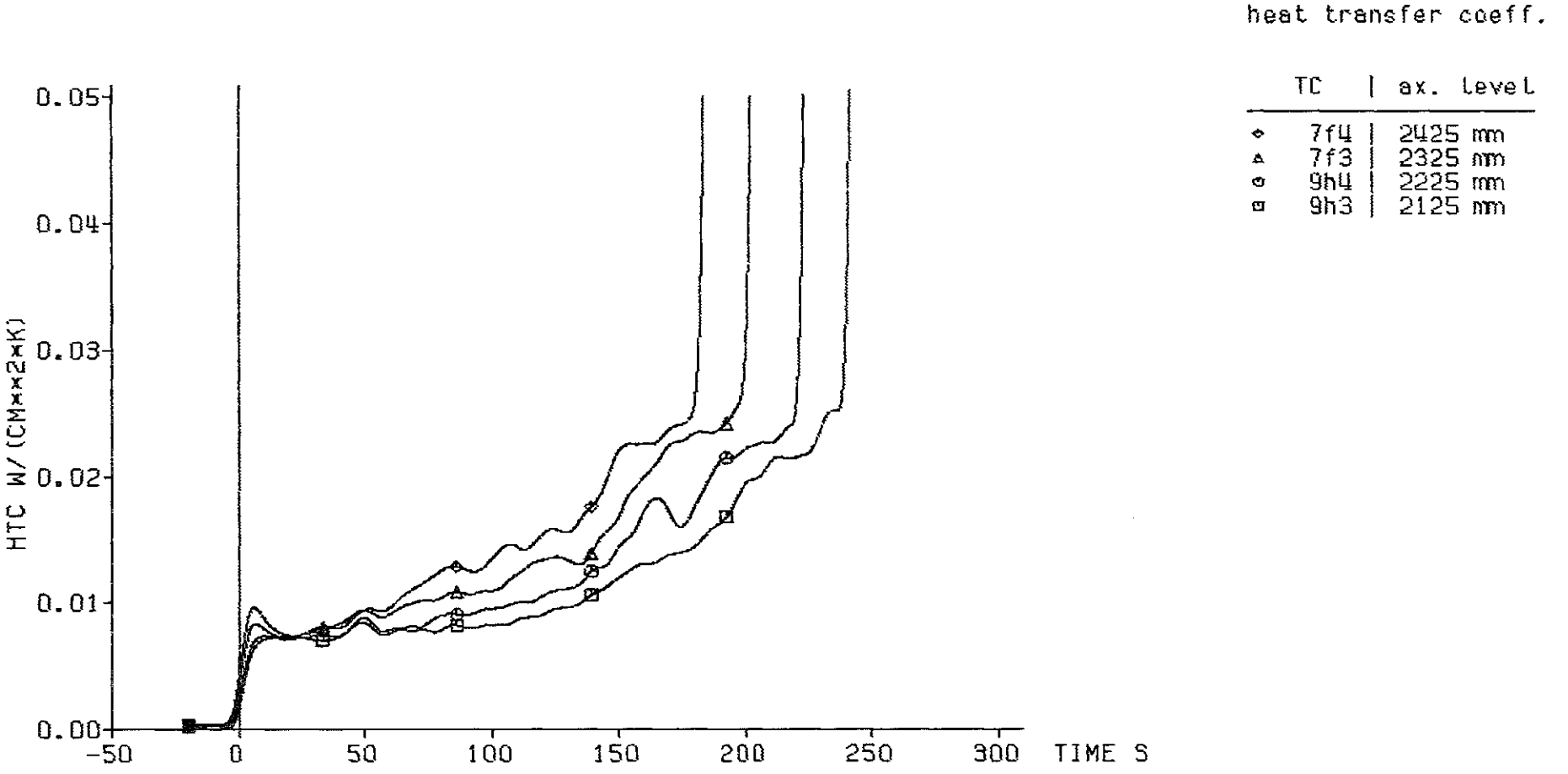


decay heat	120% ANS standard
flooding rate (cold)	5.80 cm/s
system pressure	1.93 bar
feedwater temperature	40 deg C

bypass
======

KfK KIRB

Fig. 266 FEBA: 5x5 ROD BUNDLE, TEST SERIES 3, TEST-No. 240

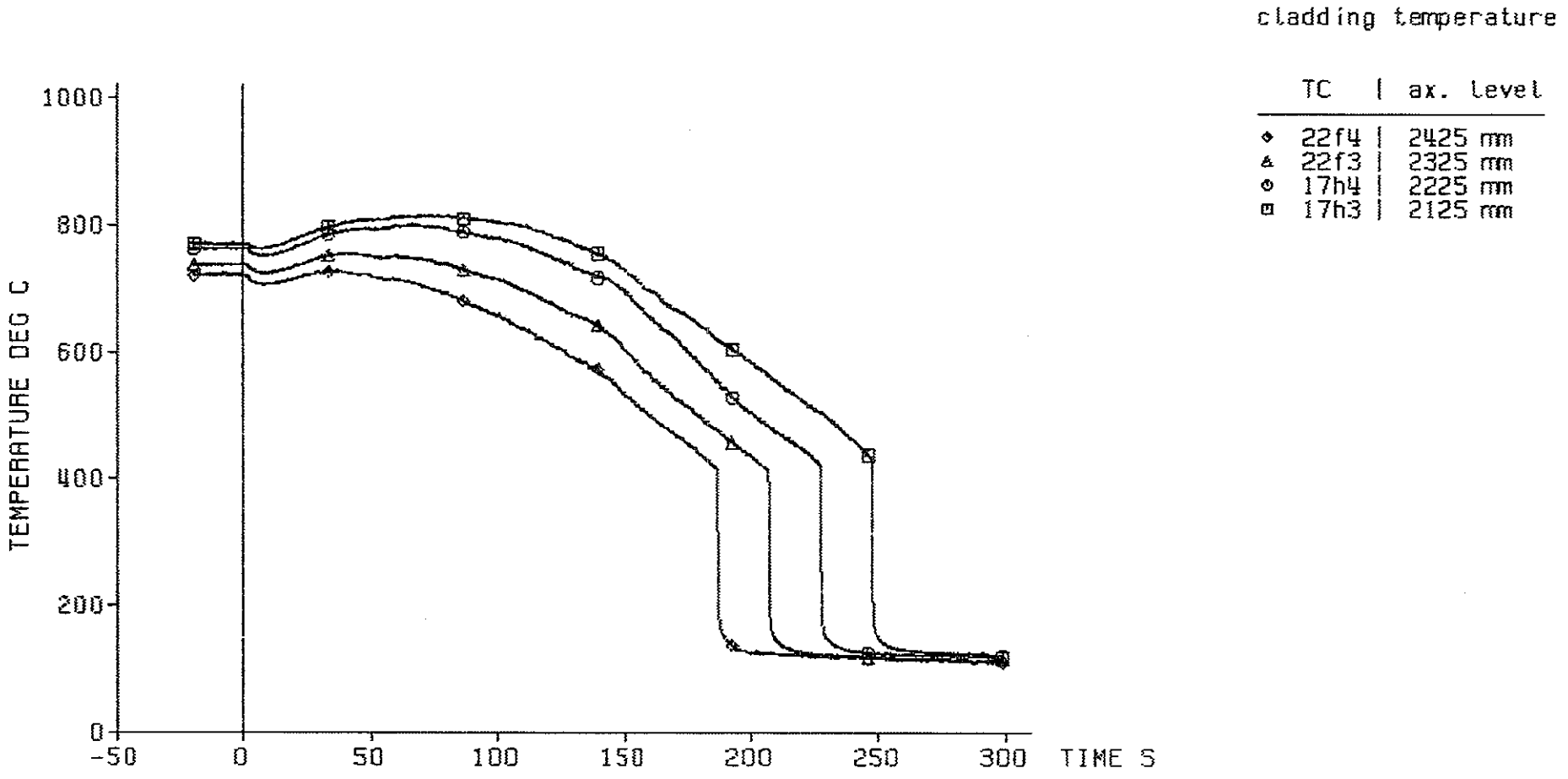


decay heat	120% ANS standard
flooding rate (cold)	5.80 cm/s
system pressure	1.93 bar
feedwater temperature	40 deg C

bypass
======

KfK IRB

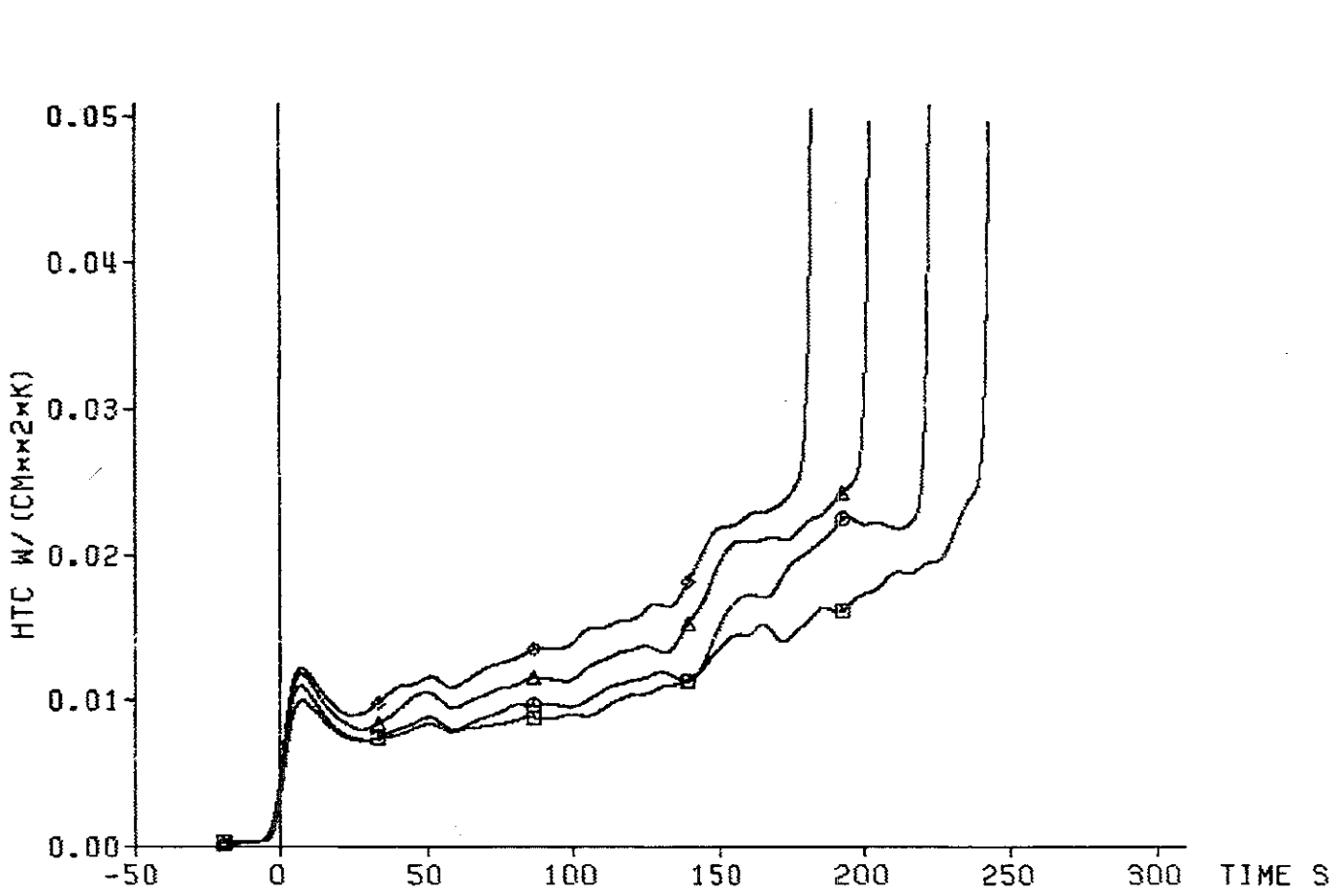
Fig. 267 FEBA: 5x5 ROD BUNDLE, TEST SERIES 3, TEST-No. 240



decay heat	120% ANS standard	blockage
flooding rate (cold)	5.80 cm/s	========
system pressure	1.93 bar	
feedwater temperature	40 deg C	

KfK IRB

Fig. 268 FEBA: 5x5 ROD BUNDLE, TEST SERIES 3, TEST-No. 240

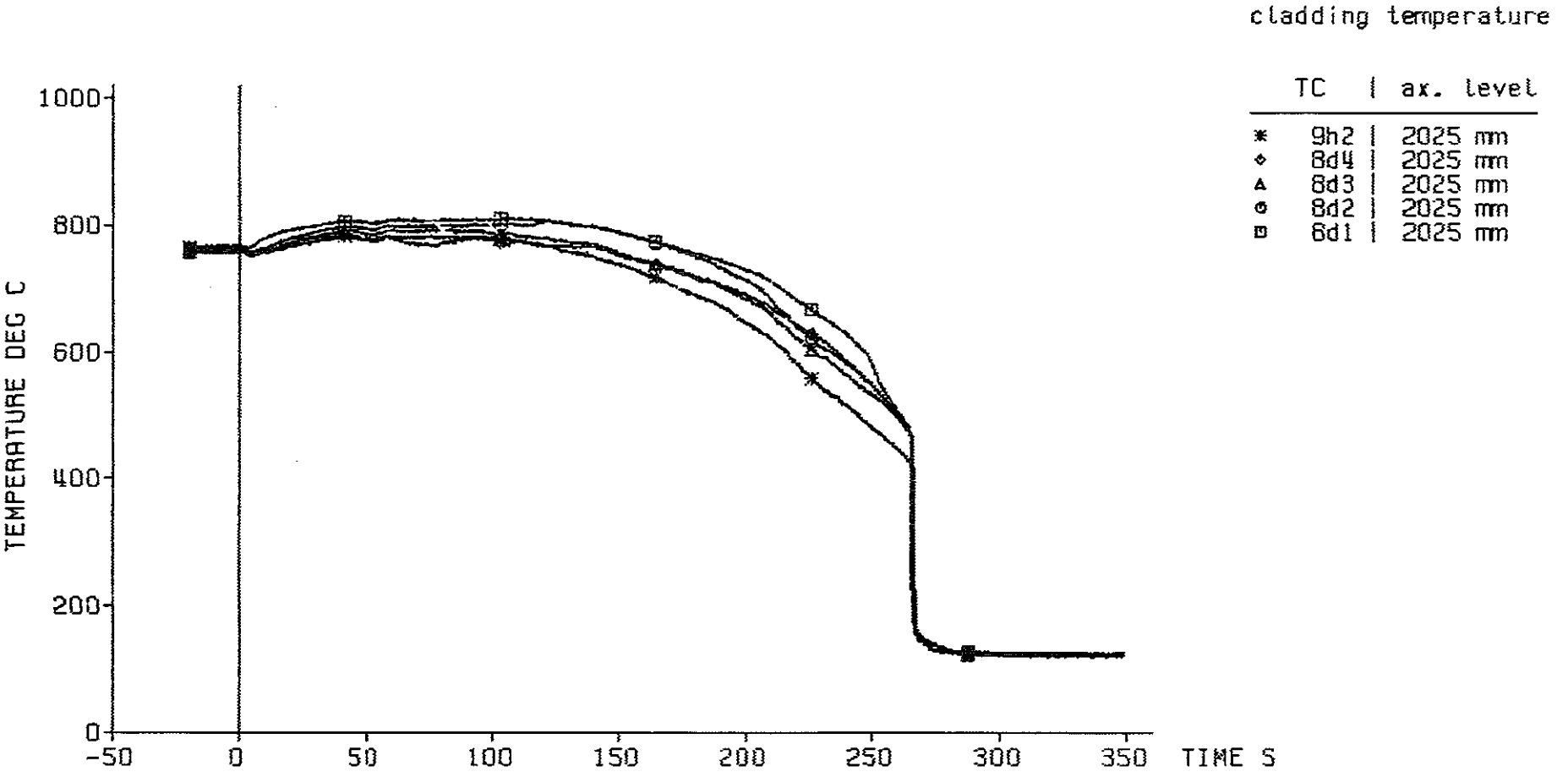


decay heat	120% ANS standard
flooding rate (cold)	5.80 cm/s
system pressure	1.93 bar
feedwater temperature	40 deg C

blockage
========

KfK IRB

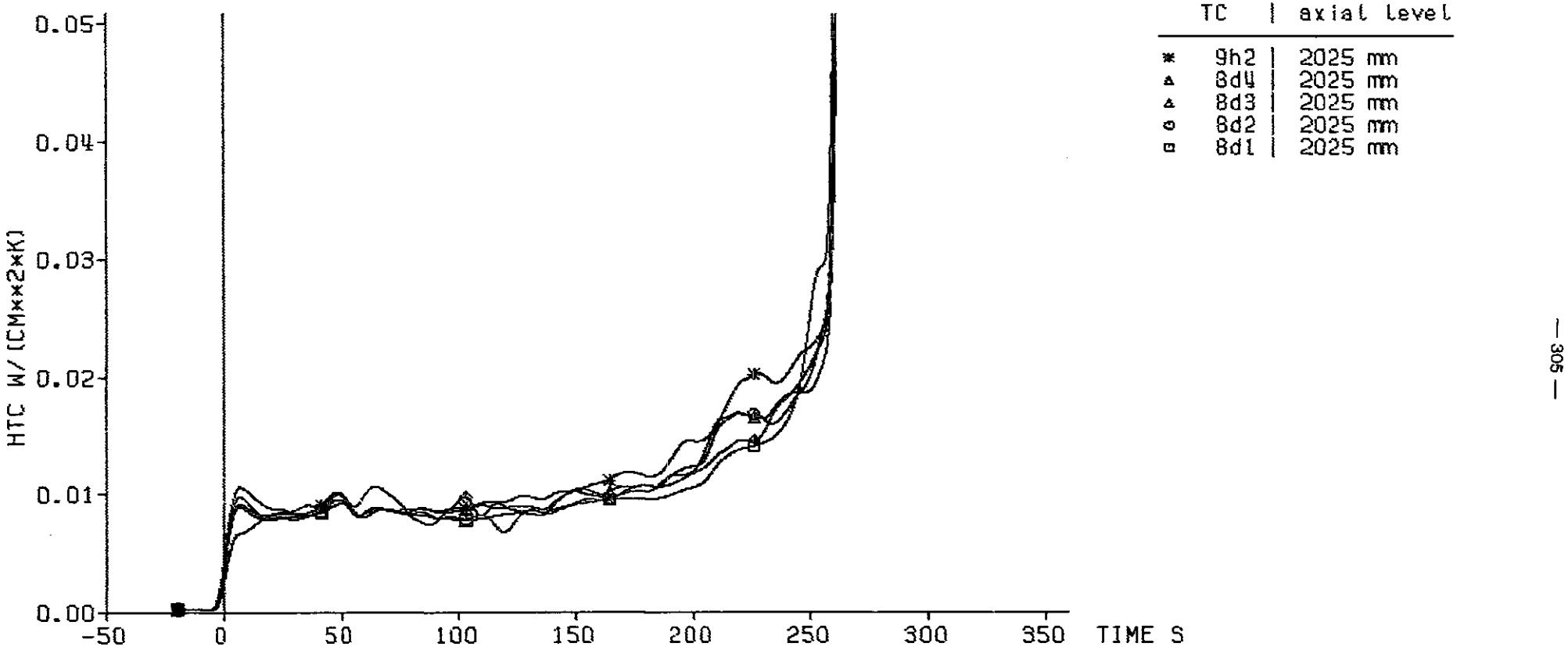
Fig. 269 FEBA: 5x5 ROD BUNDLE, TEST SERIES 3, TEST-No. 240



decay heat	120% ANS standard	bypass
flooding rate (cold)	5.80 cm/s	======
system pressure	1.93 bar	
feedwater temperature	40 deg C	

KfK IRB

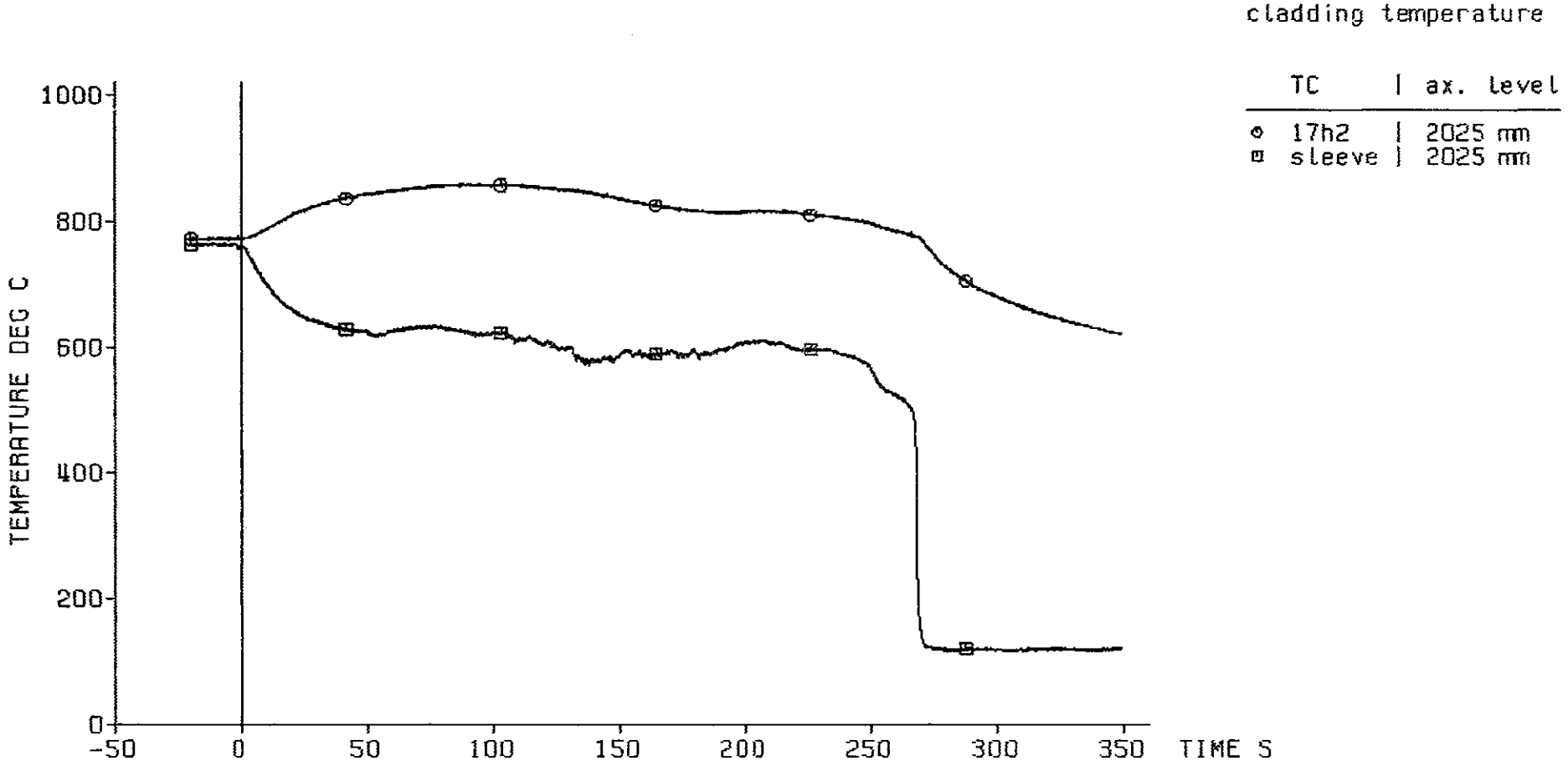
Fig. 270 FEBA: 5x5 ROD BUNDLE, TEST SERIES 3, TEST-No. 240



decay heat	120% ANS standard	bypass
flooding rate (cold)	5.80 cm/s	======
system pressure	1.93 bar	
feedwater temperature	40 deg C	

KfK IRB

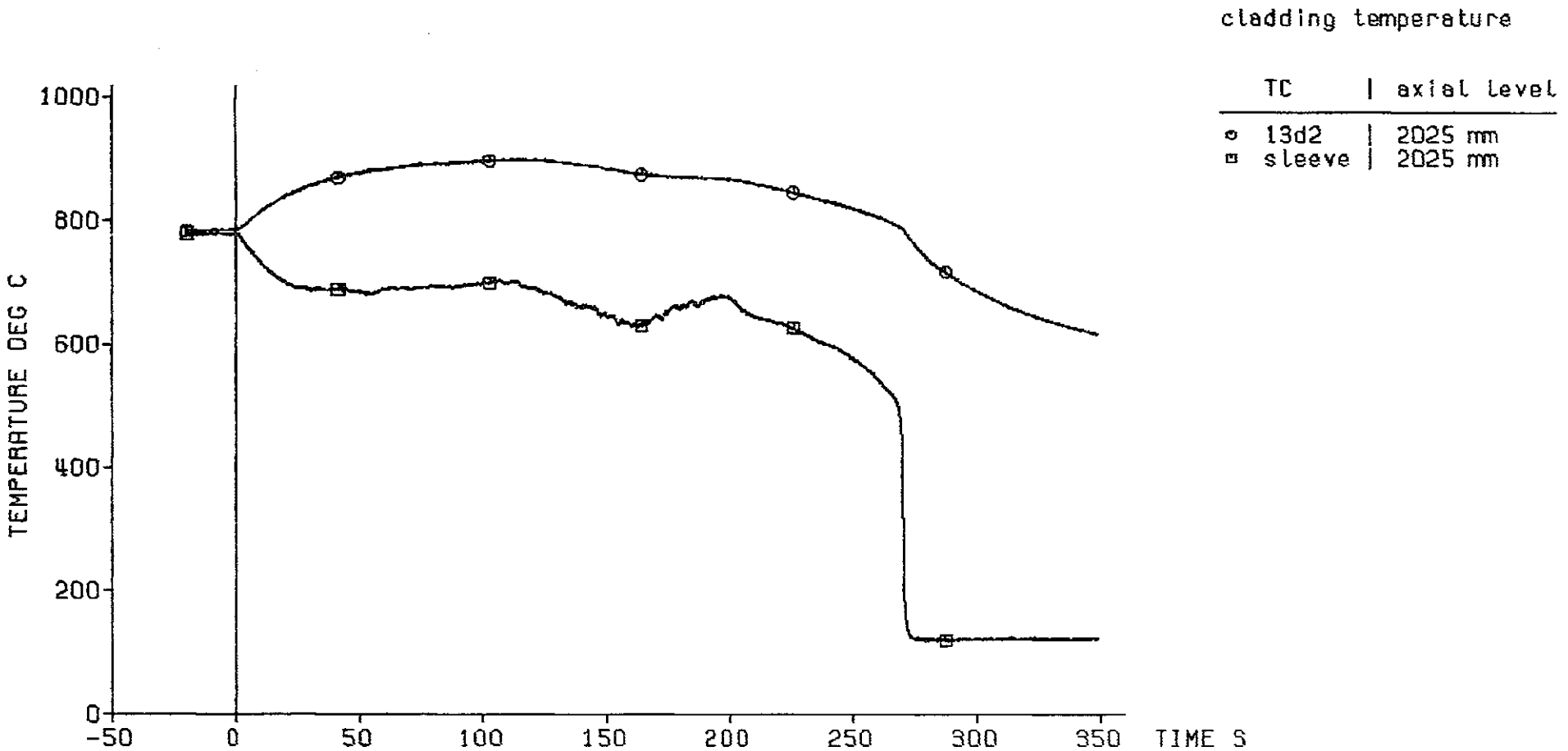
Fig. 271 FEBA: 5x5 ROD BUNDLE, TEST SERIES 3, TEST-No. 240



decay heat	120% ANS standard	blockage
flooding rate (cold)	5.60 cm/s	========
system pressure	1.93 bar	
feedwater temperature	40 deg C	

KfK IRB

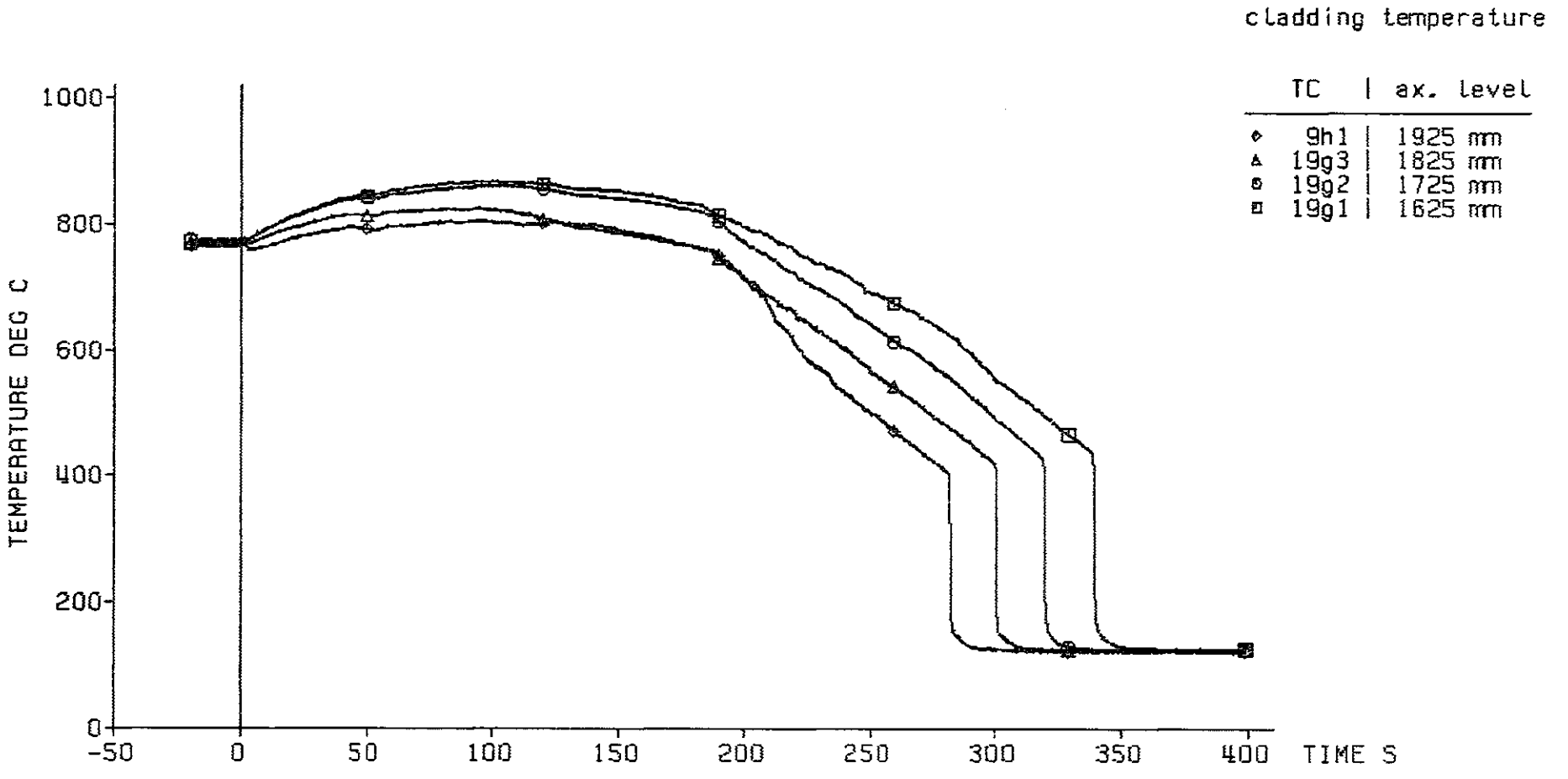
Fig. 272 FEBA: 5x5 ROD BUNDLE, TEST SERIES 3, TEST-No. 240



decay heat	120% ANS standard	blockage
flooding rate (cold)	5.80 cm/s	========
system pressure	1.93 bar	
feedwater temperature	40 deg C	

KfK IRB

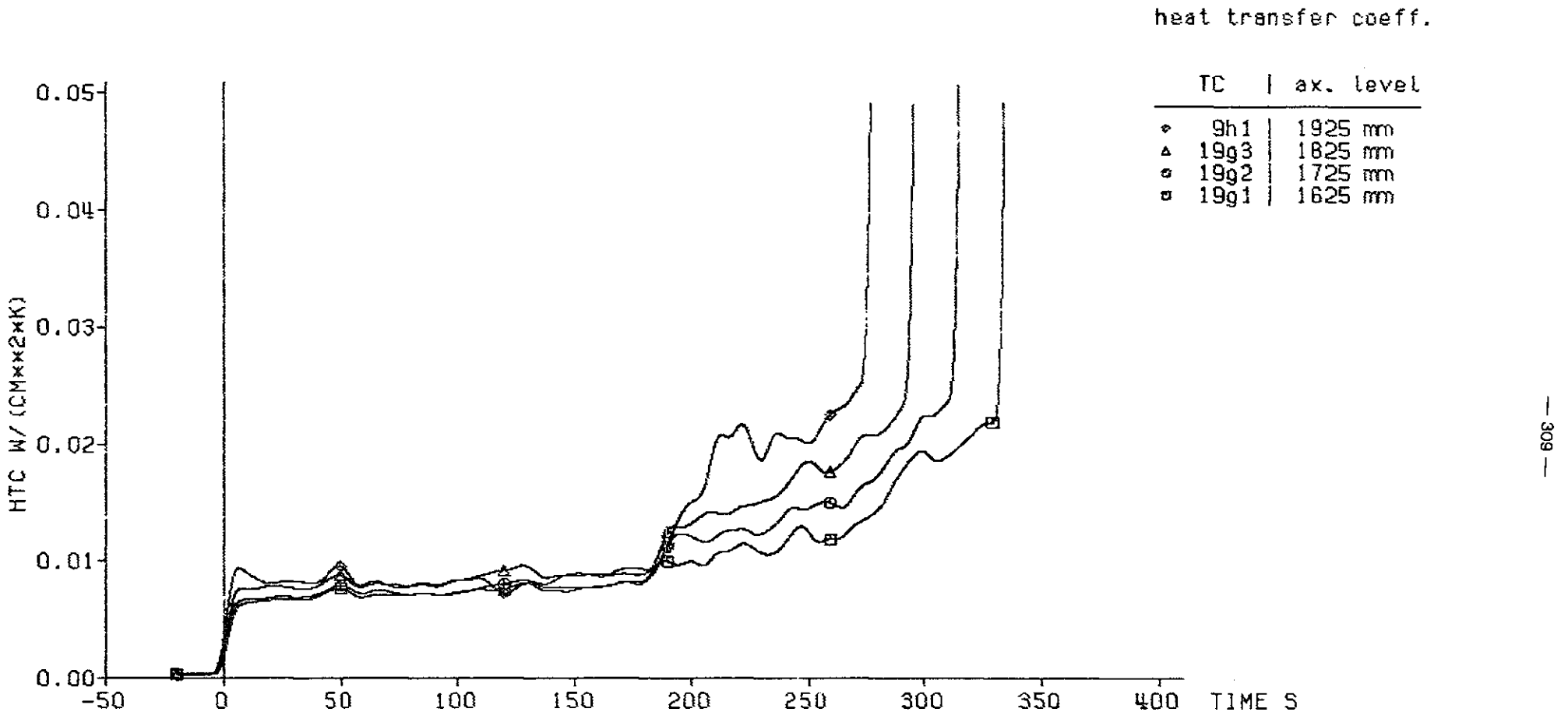
Fig. 273 FEBA: 5x5 ROD BUNDLE, TEST SERIES 3, TEST-No. 240



decay heat	120% ANS standard	bypass
flooding rate (cold)	5.80 cm/s	======
system pressure	1.93 bar	
feedwater temperature	40 deg C	

KfK IRB

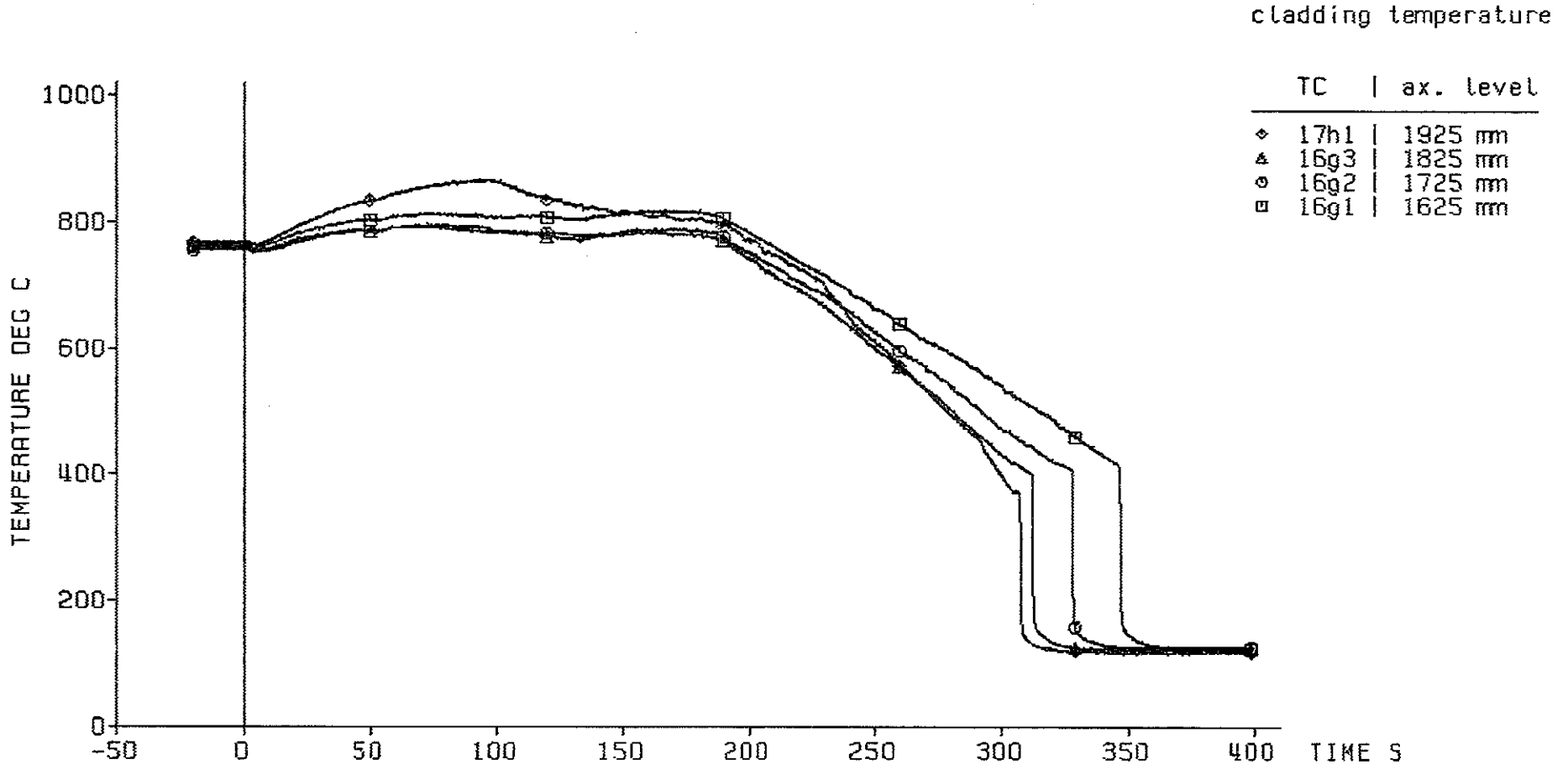
Fig. 274 FEBA: 5x5 ROD BUNDLE, TEST SERIES 3, TEST-No. 240



decay heat	120% ANS standard	bypass
flooding rate (cold)	5.80 cm/s	======
system pressure	1.93 bar	
feedwater temperature	40 deg C	

KfK IRB

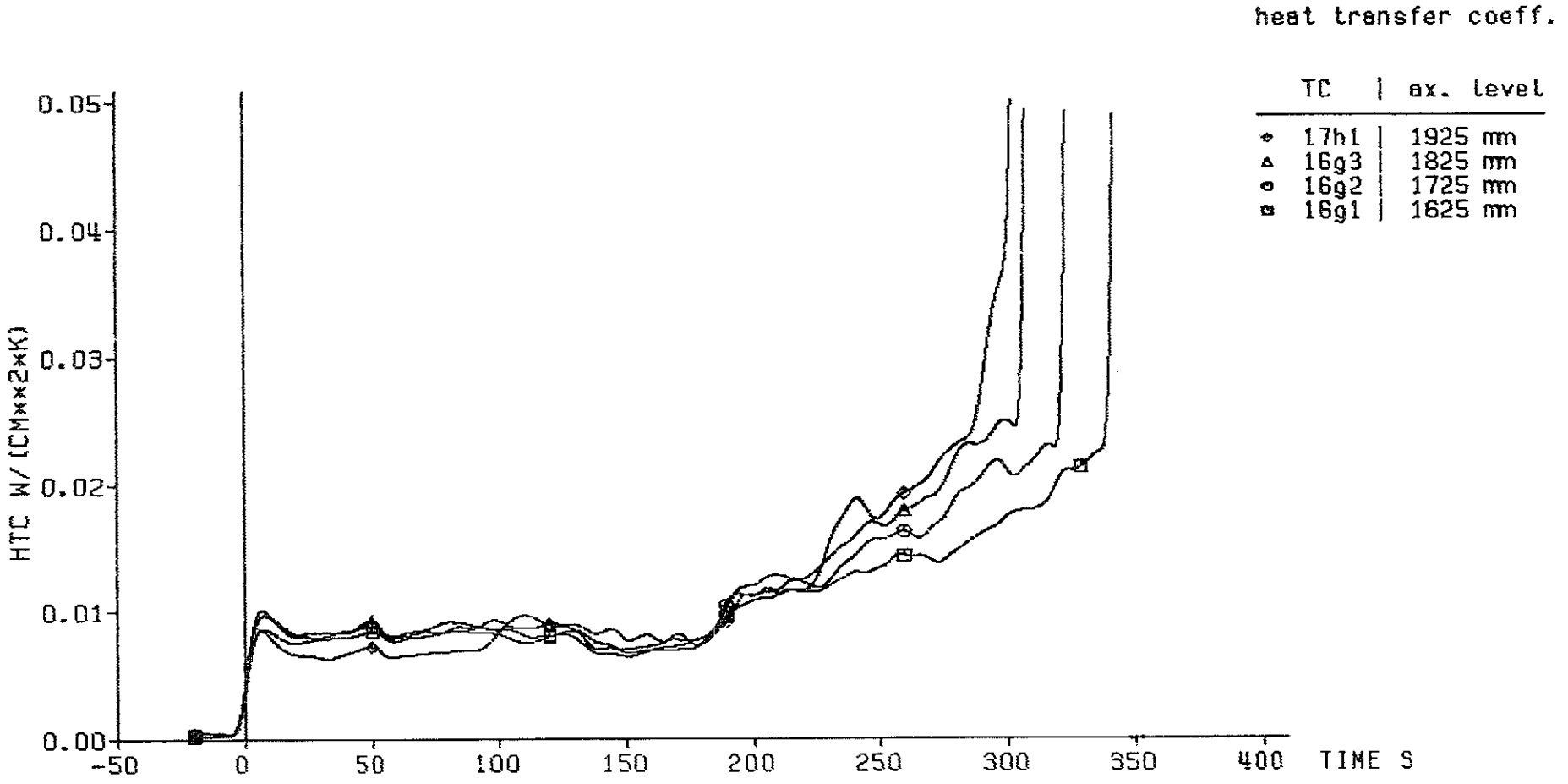
Fig. 275 FEBA: 5x5 ROD BUNDLE, TEST SERIES 3, TEST-No. 240



decay heat	120% ANS standard	blockage
flooding rate (cold)	5.80 cm/s	========
system pressure	1.93 bar	
feedwater temperature	40 deg C	

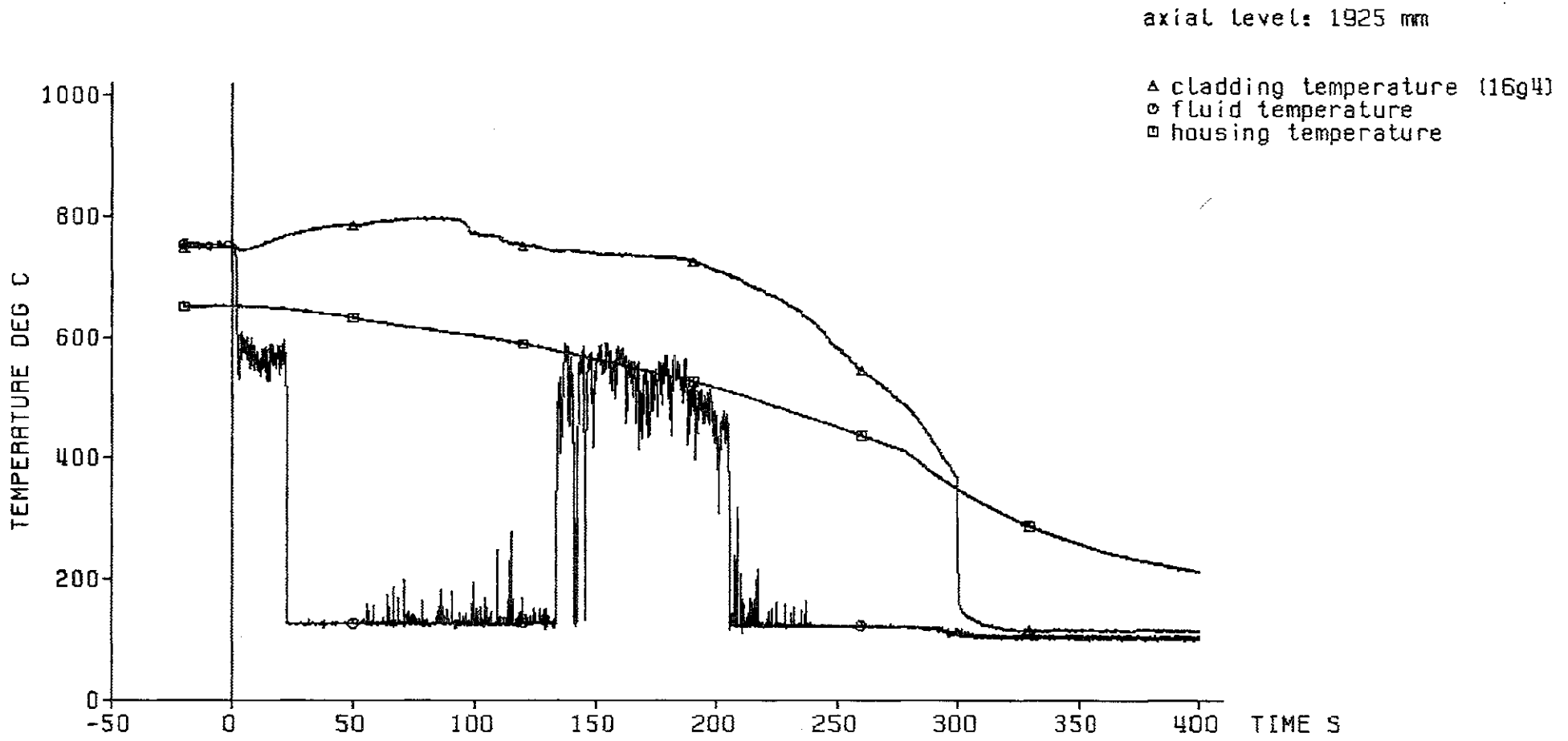
KfK IRB

Fig. 276 FEBA: 5x5 ROD BUNDLE, TEST SERIES 3, TEST-No. 240



decay heat	120% ANS standard	blockage
flooding rate (cold)	5.80 cm/s	========
system pressure	1.93 bar	
feedwater temperature	40 deg C	

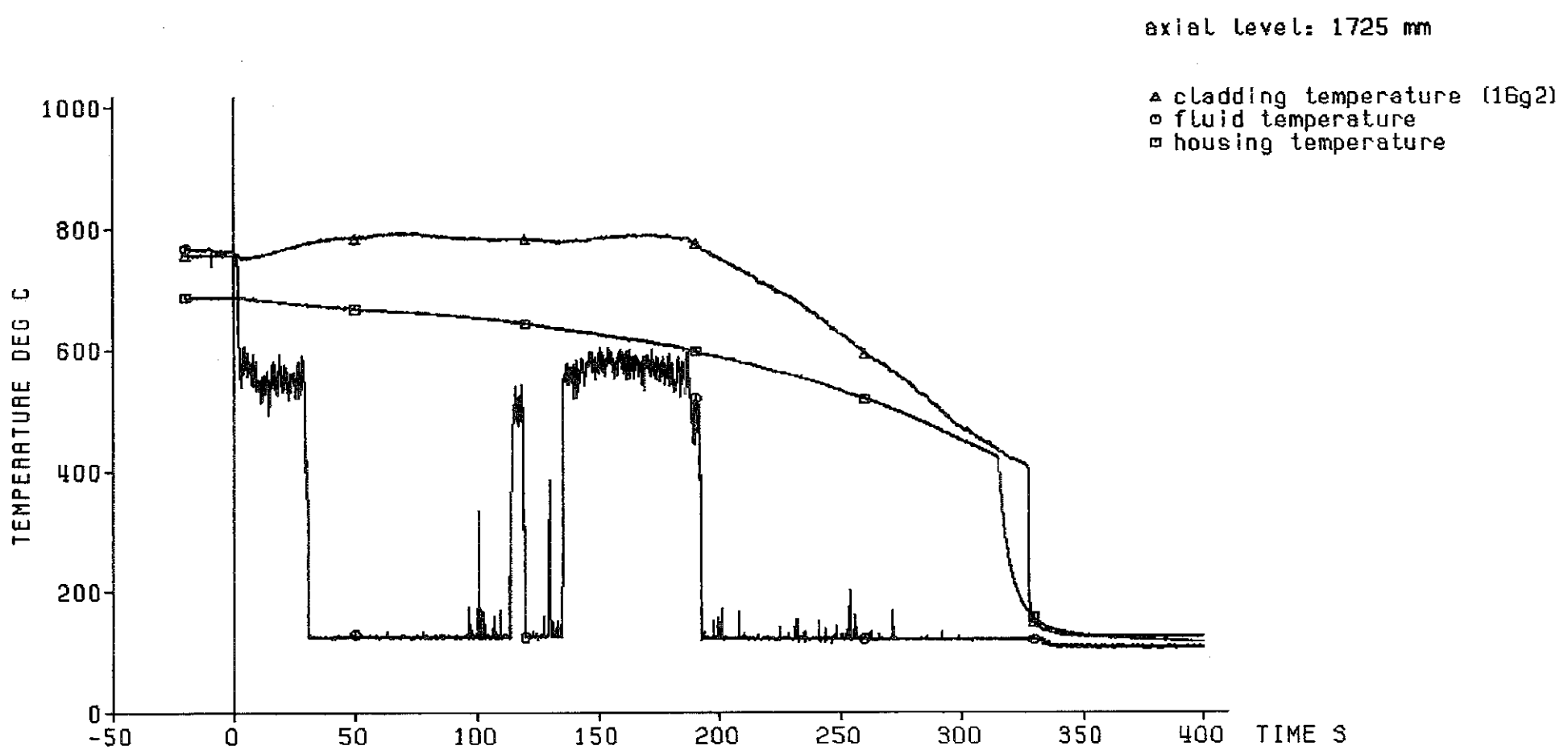
Fig. 277 FEBA: 5x5 ROD BUNDLE, TEST SERIES 3, TEST-No. 240



decay heat	120% ANS standard	blockage
flooding rate (cold)	5.80 cm/s	========
system pressure	1.93 bar	
feedwater temperature	40 deg C	

KfK IRB

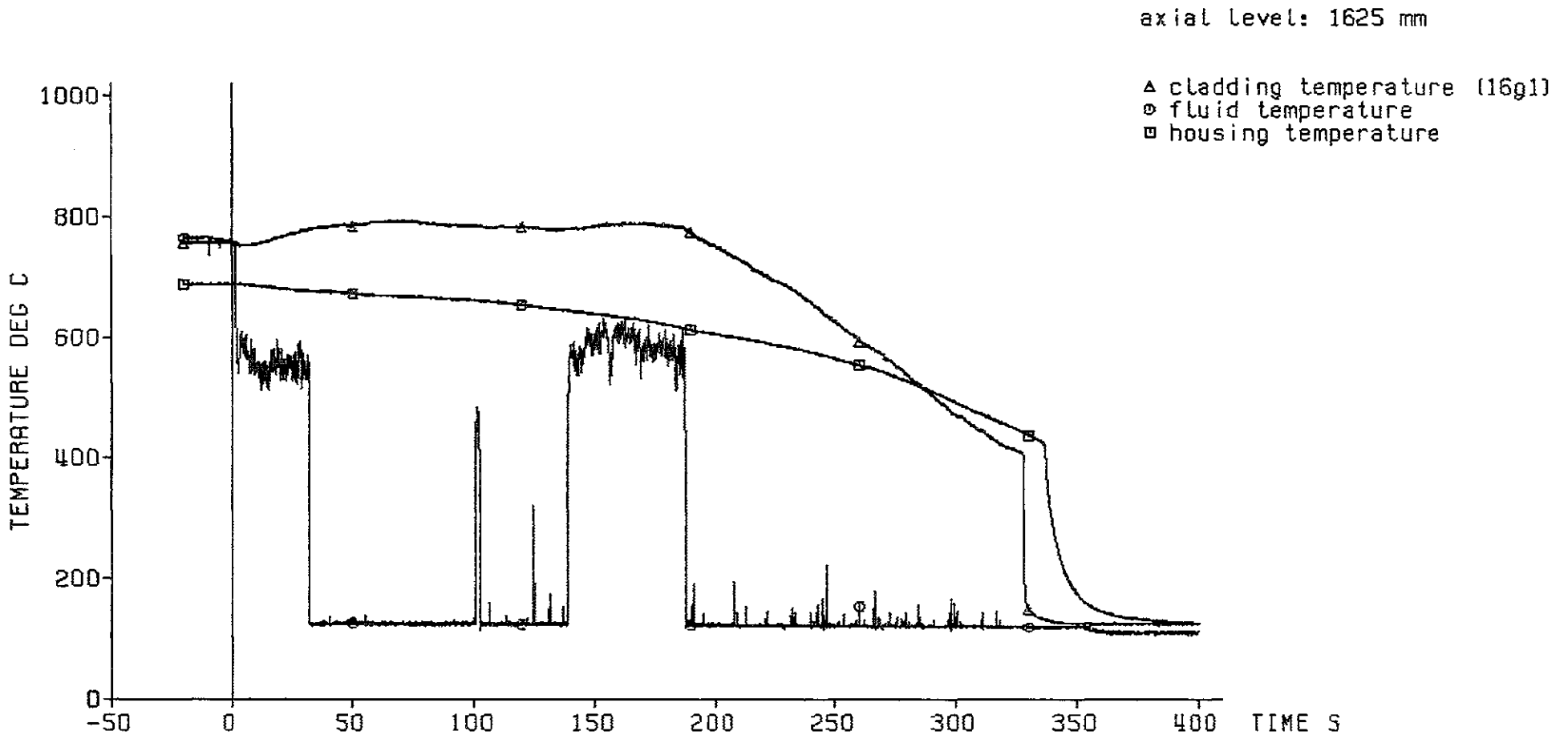
Fig. 278 FEBA: 5x5 ROD BUNDLE, TEST SERIES 3, TEST-No. 240



decay heat	120% ANS standard	blockage
flooding rate (cold)	5.80 cm/s	========
system pressure	1.93 bar	
feedwater temperature	40 deg C	

KfK IRB

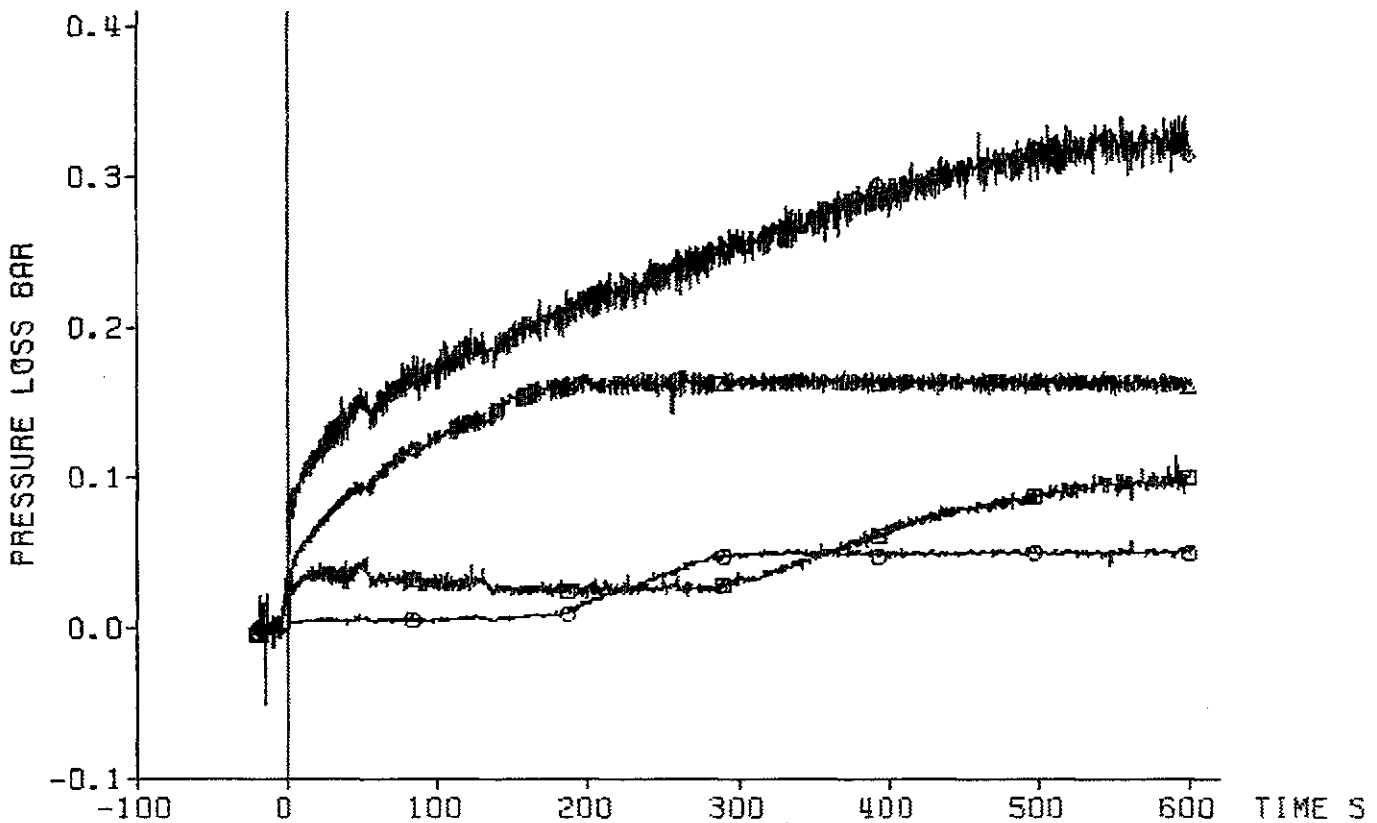
Fig. 279 FEBA: 5x5 ROD BUNDLE, TEST SERIES 3, TEST-No. 240



decay heat	120% ANS standard	blockage
flooding rate (cold)	5.80 cm/s	========
system pressure	1.93 bar	
feedwater temperature	40 deg C	

KfK IRB

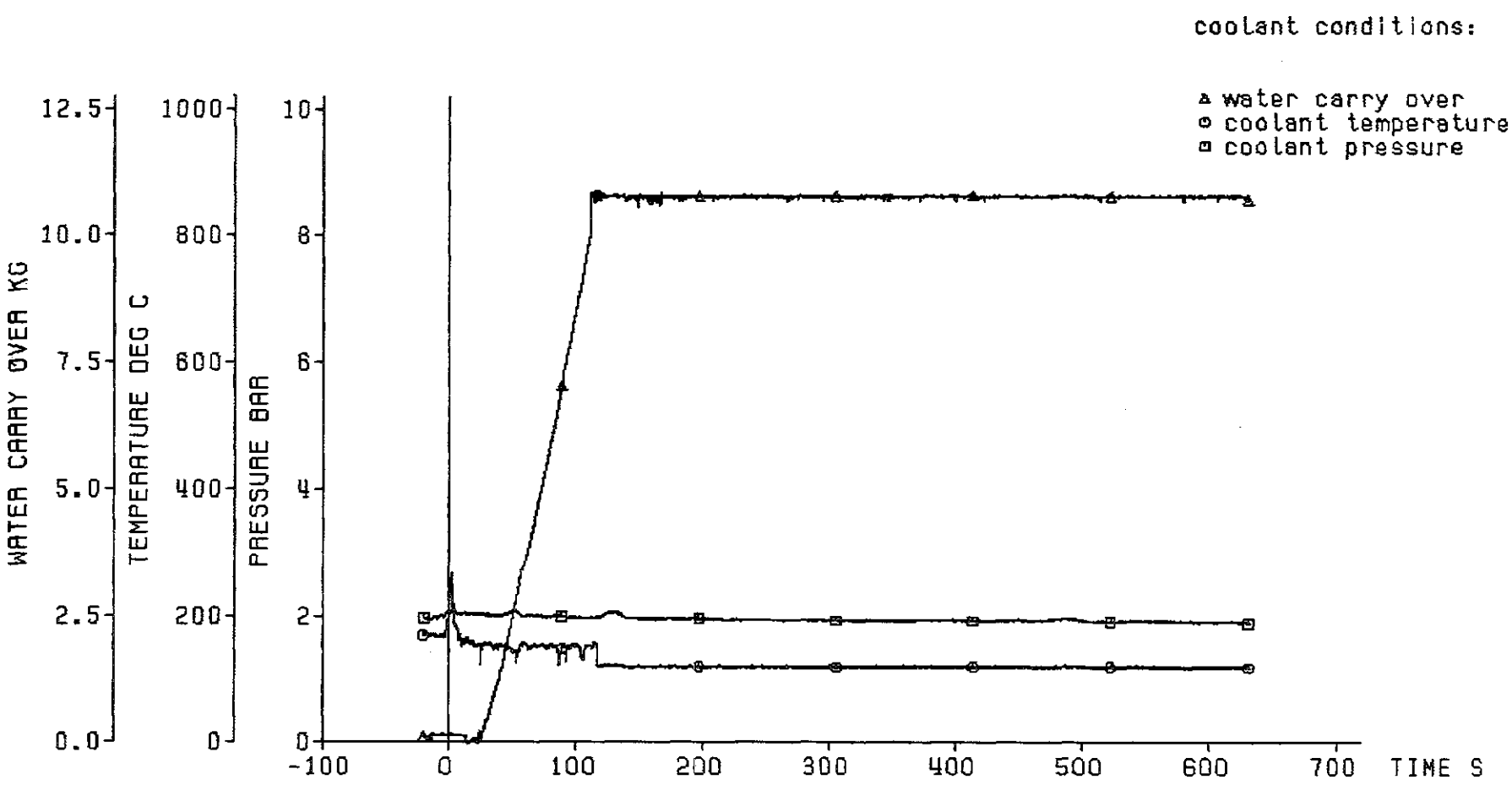
Fig. 280 FEBA: 5x5 ROD BUNDLE, TEST SERIES 3, TEST-No. 240



decay heat	120% ANS standard
flooding rate (cold)	5.80 cm/s
system pressure	1.93 bar
feedwater temperature	40 deg C

KfK IRB

Fig. 281 FEBA: 5x5 ROD BUNDLE, TEST SERIES 3, TEST-No. 240



decay heat	120% ANS standard
flooding rate (cold)	5.80 cm/s
system pressure	1.93 bar
feedwater temperature	40 deg C

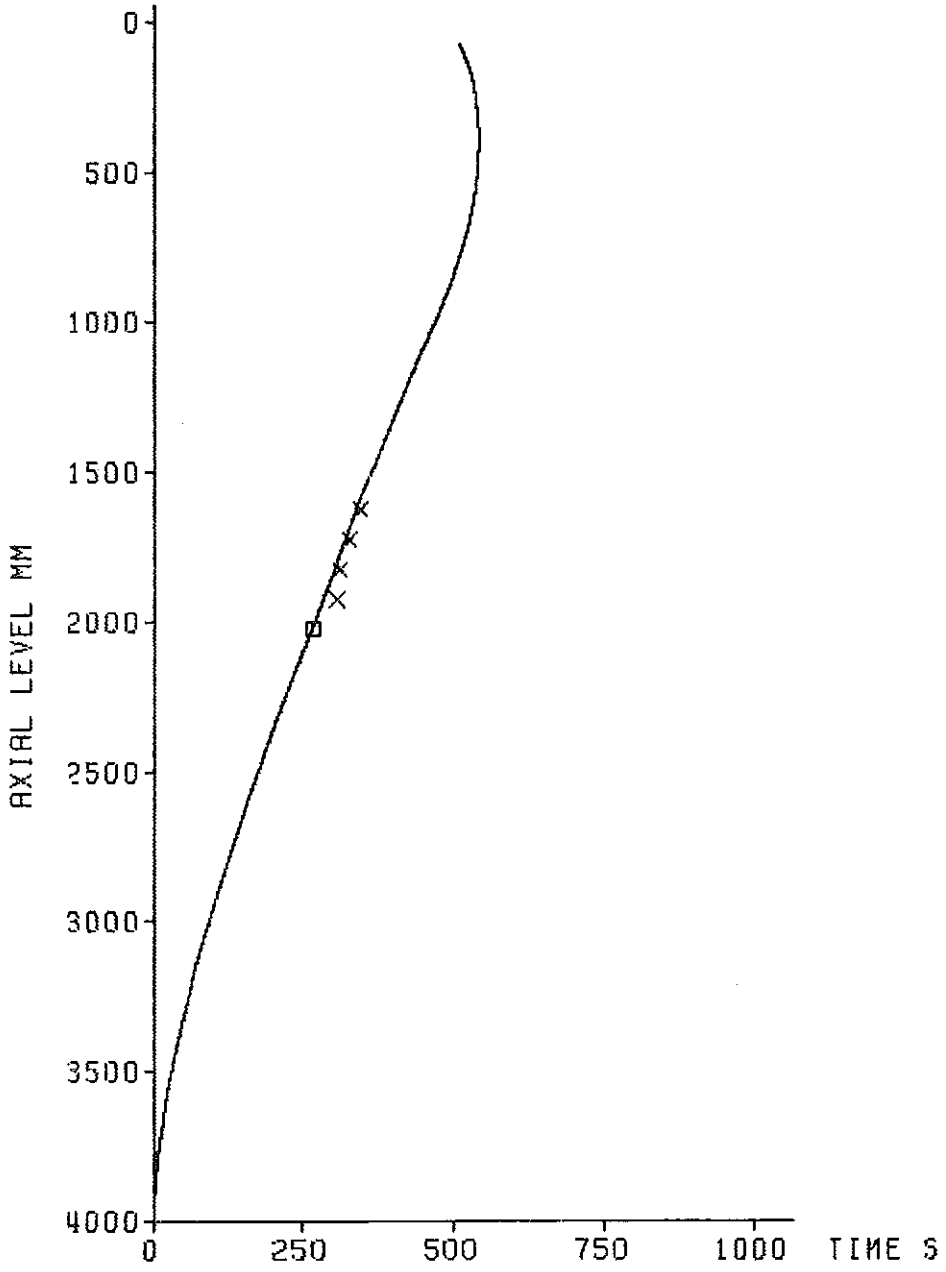
KfK IRB

Fig. 282 FEBA: 5x5 ROD BUNDLE, TEST SERIES 3, TEST-No. 240

axial position of the quench front

□ rewetting of the sleeve at the bundle midplane

× rewetting of the rod downstream of the blockage

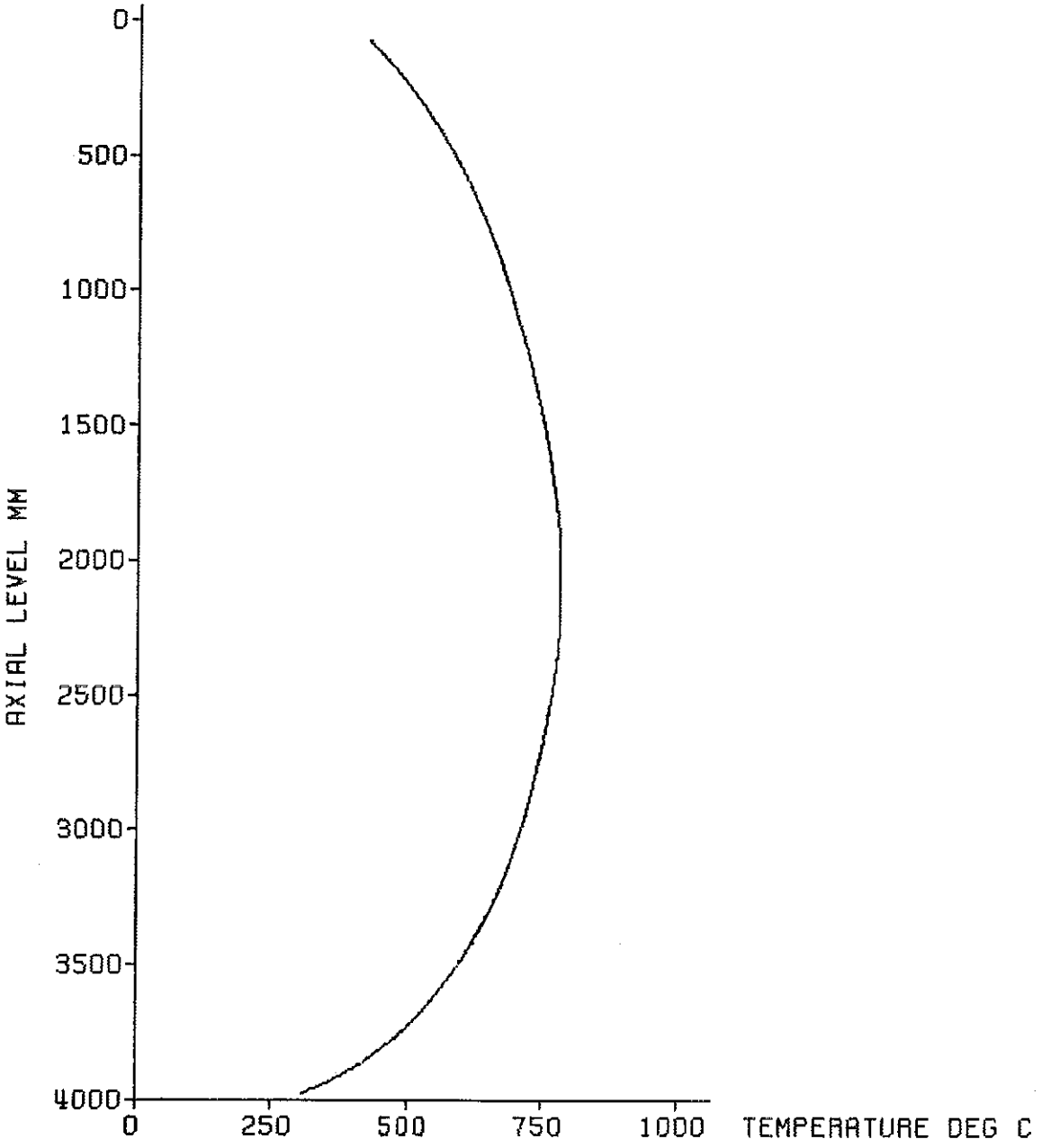


decay heat	120% ANS standard
flooding rate (cold)	5.80 cm/s
system pressure	1.93 bar
feedwater temperature	40 deg C

KfK IRB

Fig. 283 FEBA: 5x5 ROD BUNDLE TEST SERIES 3, TEST-No. 240

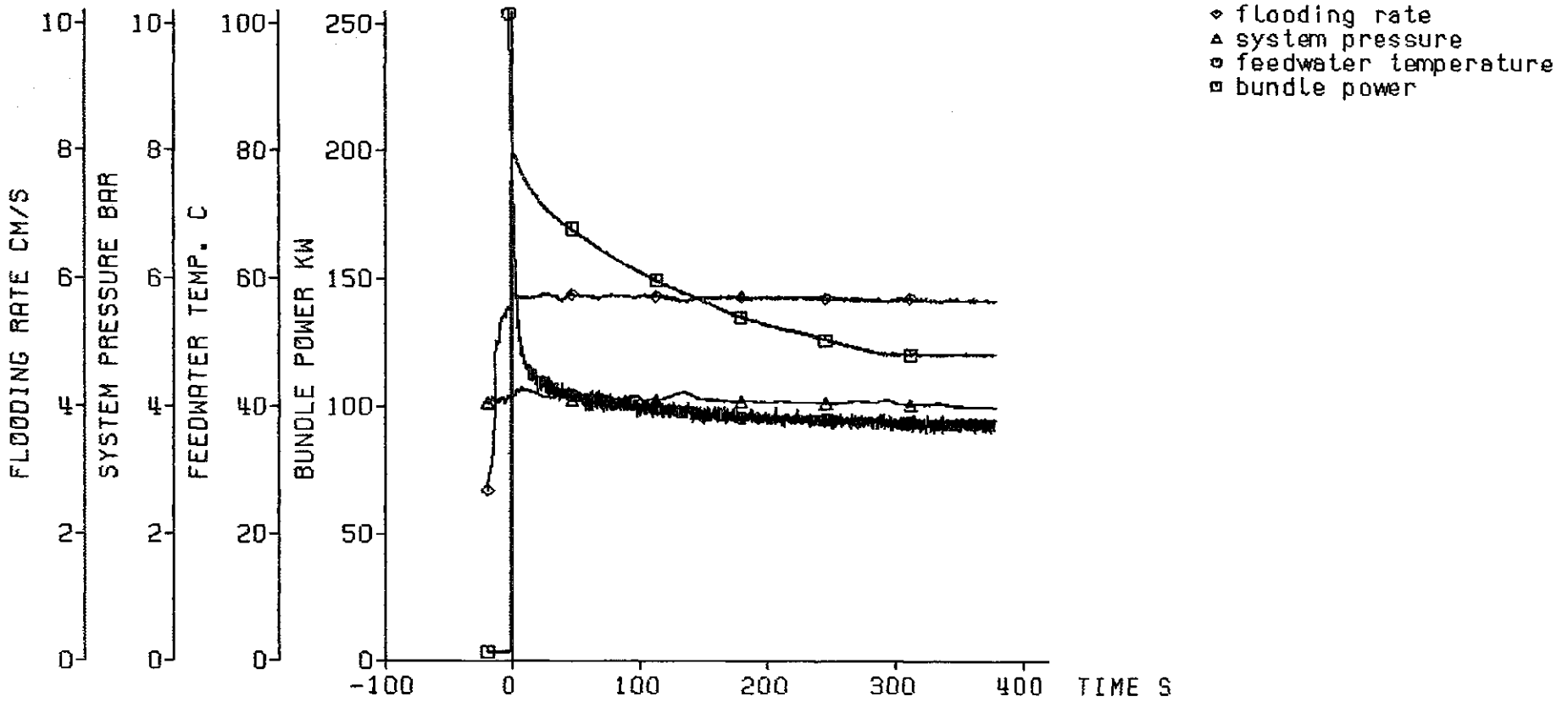
initial axial temperature profile of the cladding



decay heat	120% ANS standard
flooding rate (cold)	5.72 cm/s
system pressure	4.13 bar
feedwater temperature	40 deg C

KfK IRB

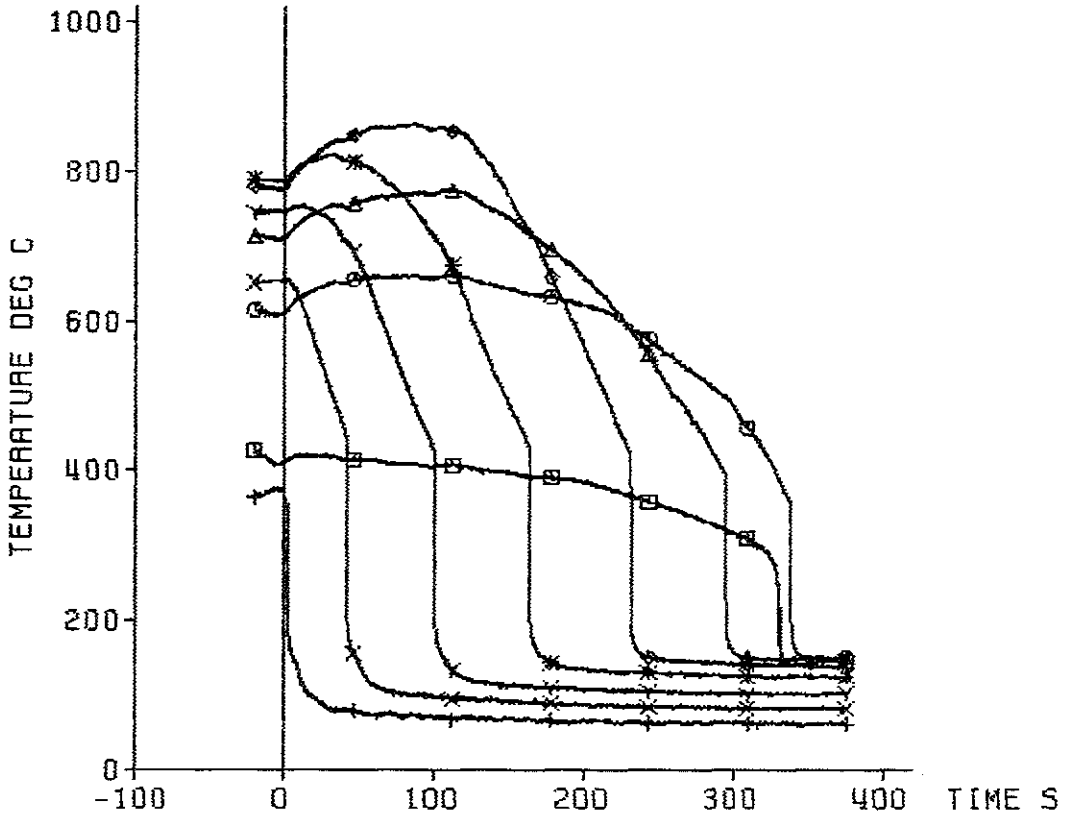
Fig. 284 FEBA: 5x5 ROD BUNDLE TEST SERIES 3, TEST-No. 238



decay heat	120% ANS standard
flooding rate (cold)	5.72 cm/s
system pressure	4.13 bar
feedwater temperature	40 deg C

KfK IRB

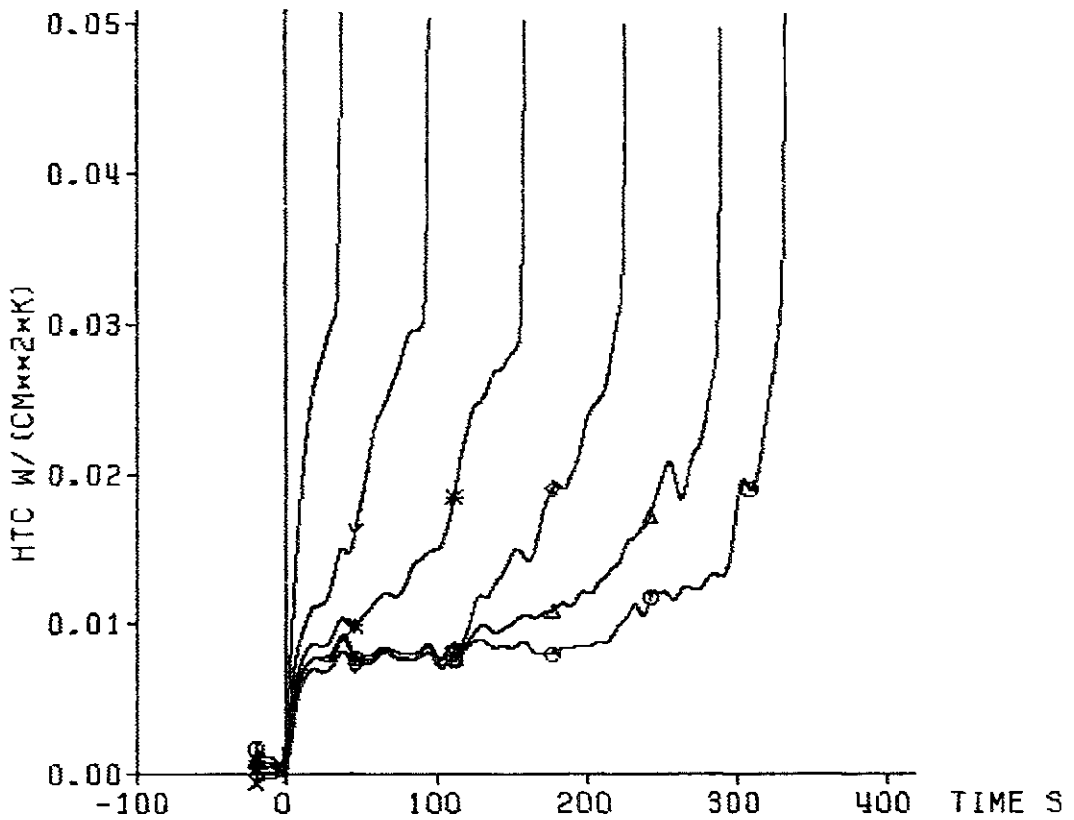
Fig. 285 FEBA: 5x5 ROD BUNDLE, TEST SERIES 3, TEST-No. 238



decay heat	120% ANS standard
flooding rate (cold)	5.72 cm/s
system pressure	4.13 bar
feedwater temperature	40 deg C

KfK IRB

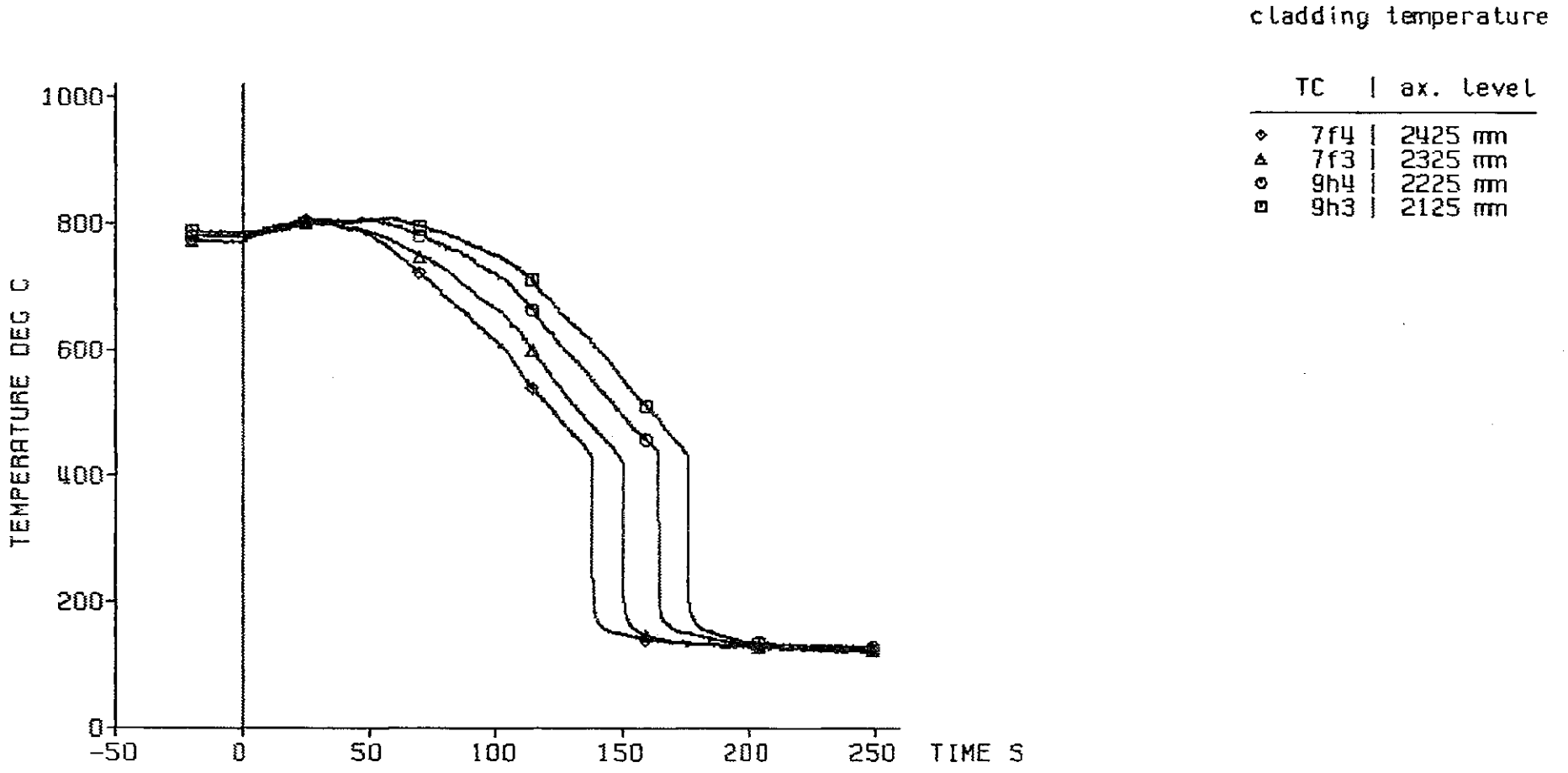
Fig. 286 FEBA: 5x5 ROD BUNDLE, TEST SERIES 3, TEST-No. 238



decay heat	120% ANS standard
flooding rate (cold)	5.72 cm/s
system pressure	4.13 bar
feedwater temperature	40 deg C

KfK IRB

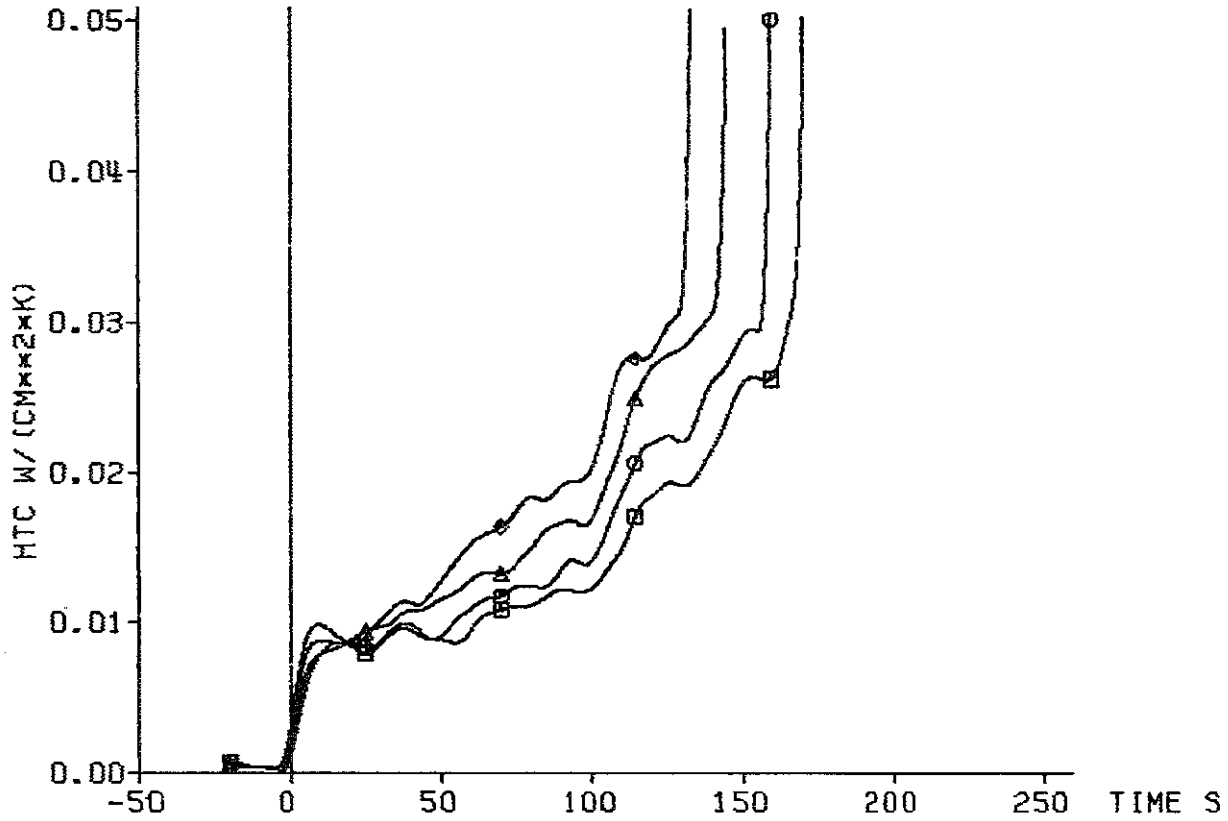
Fig. 287 FEBA: 5x5 ROD BUNDLE, TEST SERIES 3, TEST-No. 238



decay heat	120% ANS standard	bypass
flooding rate (cold)	5.72 cm/s	======
system pressure	4.13 bar	
feedwater temperature	40 deg C	

KfK IRB

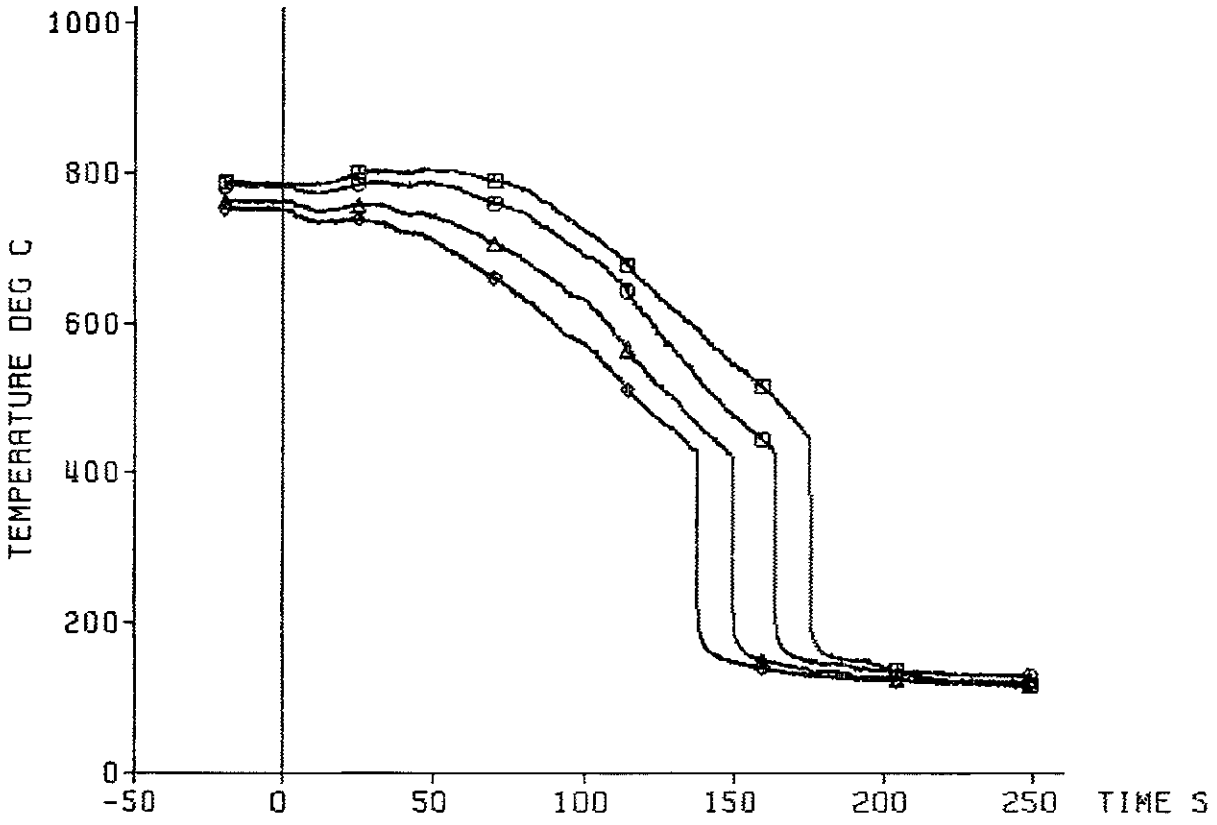
Fig. 288 FEBA: 5x5 ROD BUNDLE, TEST SERIES 3, TEST-No. 238



decay heat	120% ANS standard	bypass
flooding rate (cold)	5.72 cm/s	======
system pressure	4.13 bar	
feedwater temperature	40 deg C	

KfK IRB

Fig. 289 FEBA: 5x5 ROD BUNDLE, TEST SERIES 3, TEST-No. 238

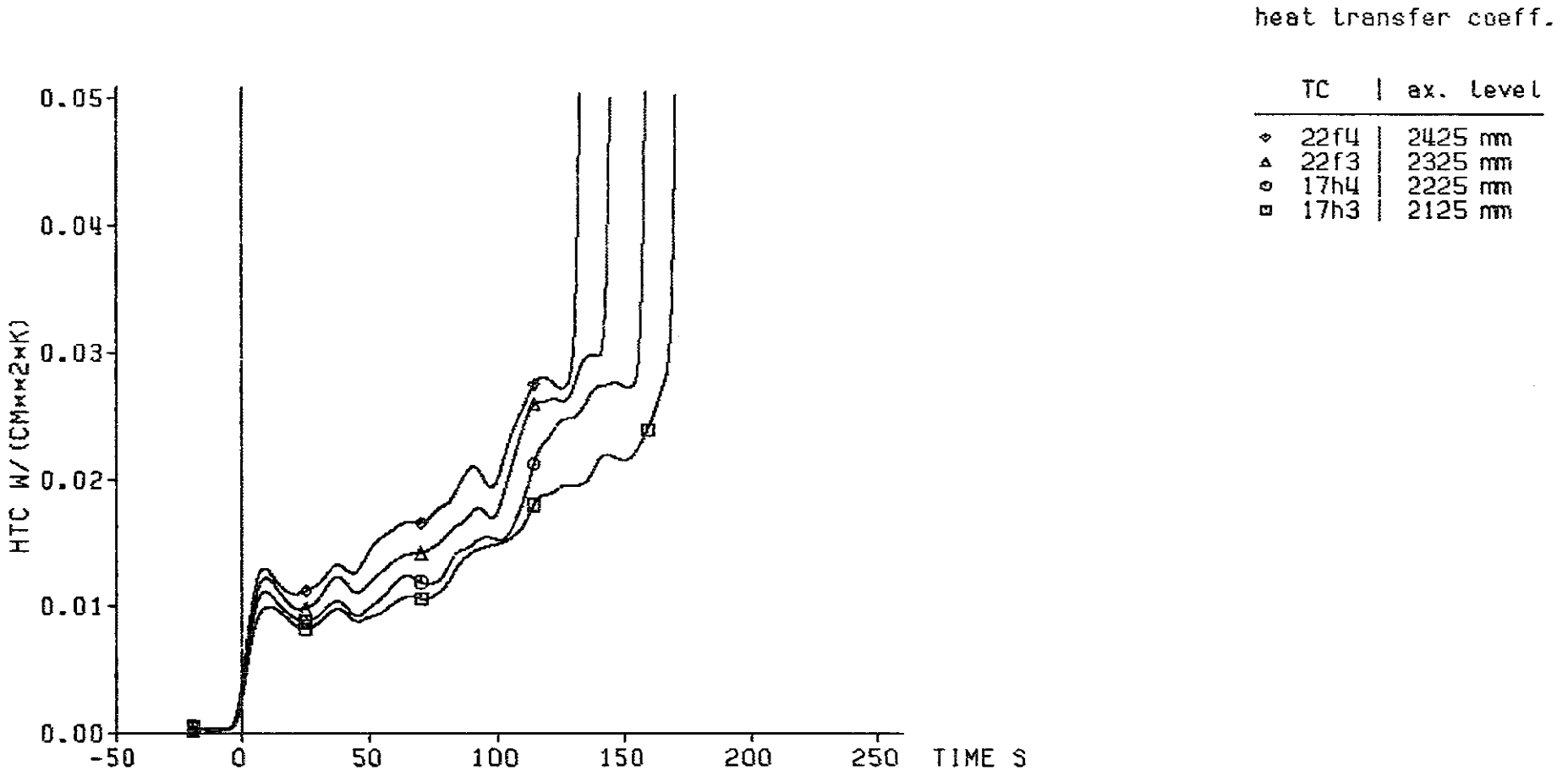


decay heat	120% ANS standard
flooding rate (cold)	5.72 cm/s
system pressure	4.13 bar
feedwater temperature	40 deg C

blockage
========

KfK KIRB

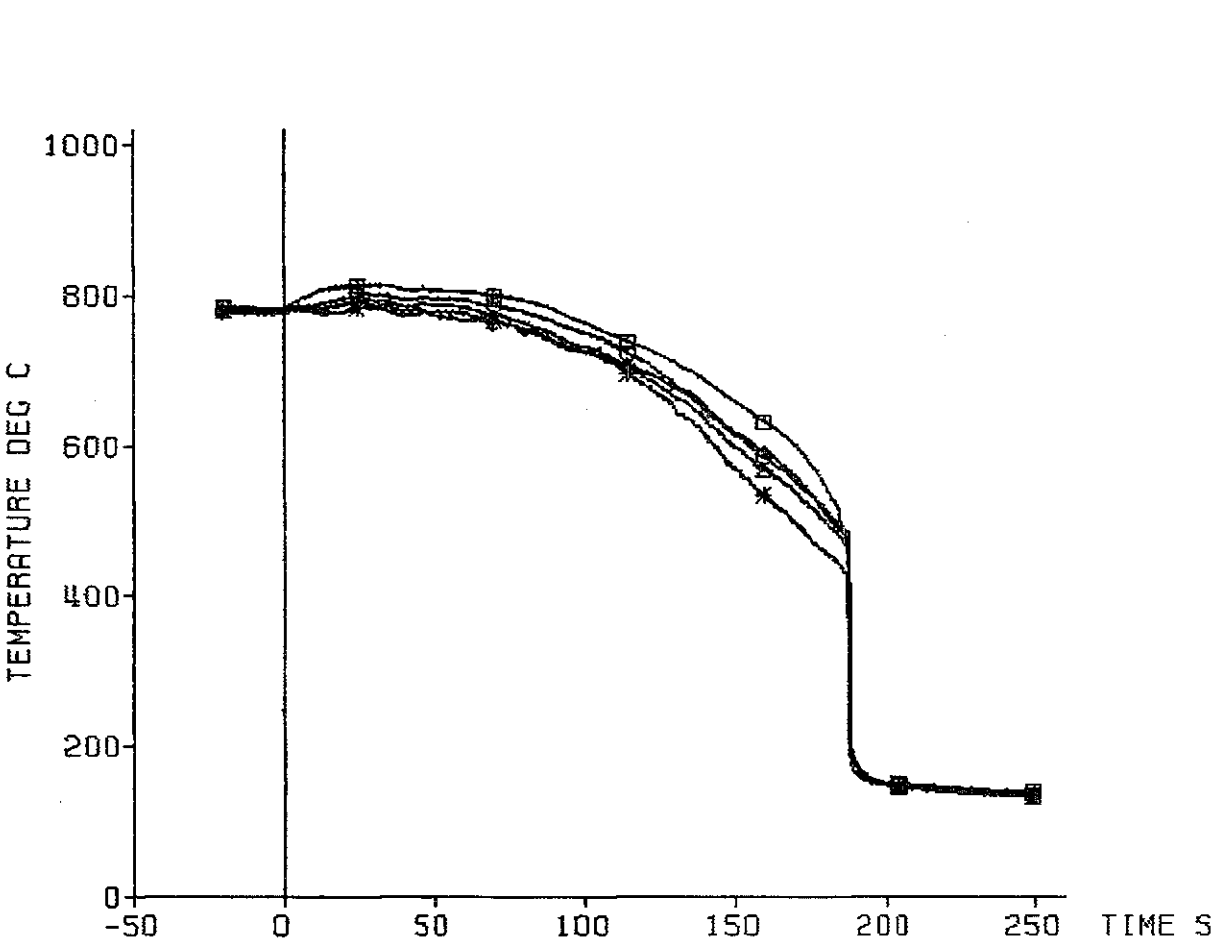
Fig. 290 FEBA: 5x5 ROD BUNDLE, TEST SERIES 3, TEST-No. 238



decay heat	120% ANS standard	blockage
flooding rate (cold)	5.72 cm/s	========
system pressure	4.13 bar	
feedwater temperature	40 deg C	

KfK IRB

Fig. 291 FEBA: 5x5 ROD BUNDLE, TEST SERIES 3, TEST-No. 238

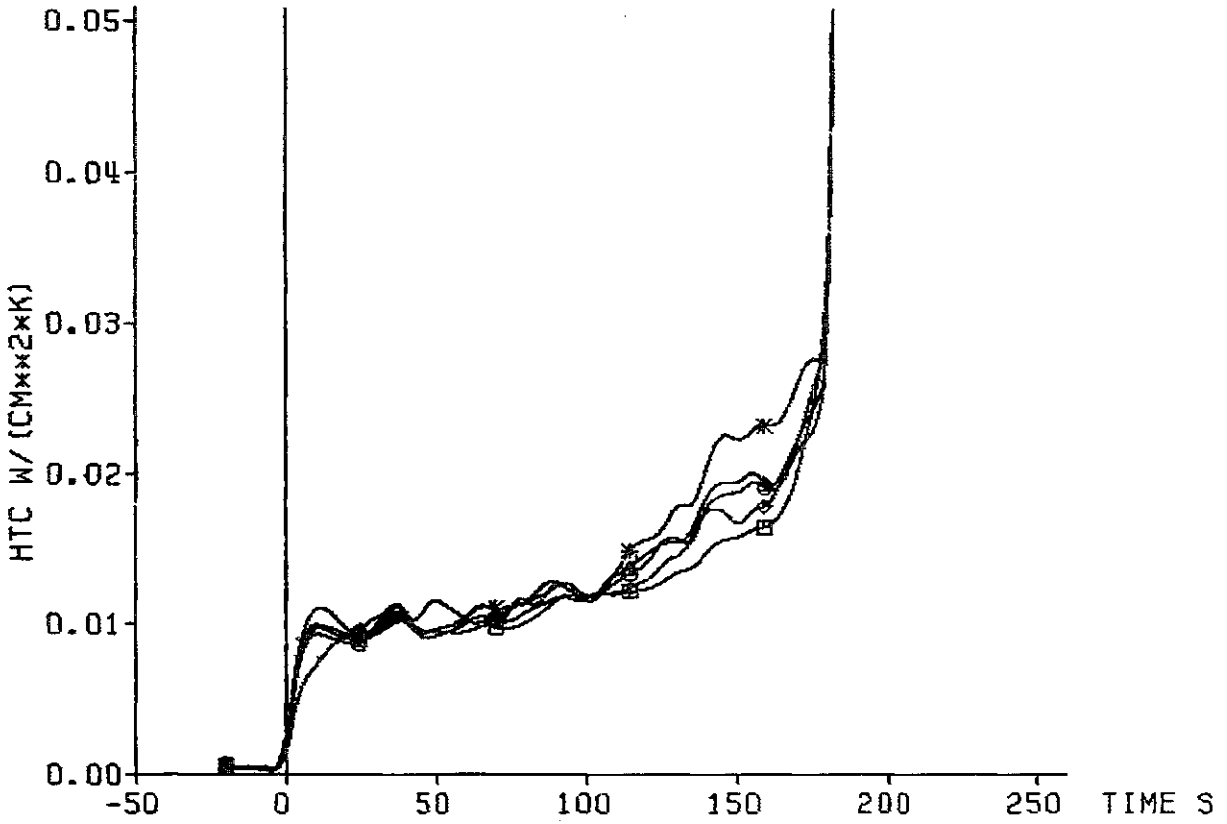


decay heat	120% ANS standard
flooding rate (cold)	5.72 cm/s
system pressure	4.13 bar
feedwater temperature	40 deg C

bypass
======

KfK IRB

Fig. 292 FEBA: 5x5 ROD BUNDLE, TEST SERIES 3, TEST-No. 238

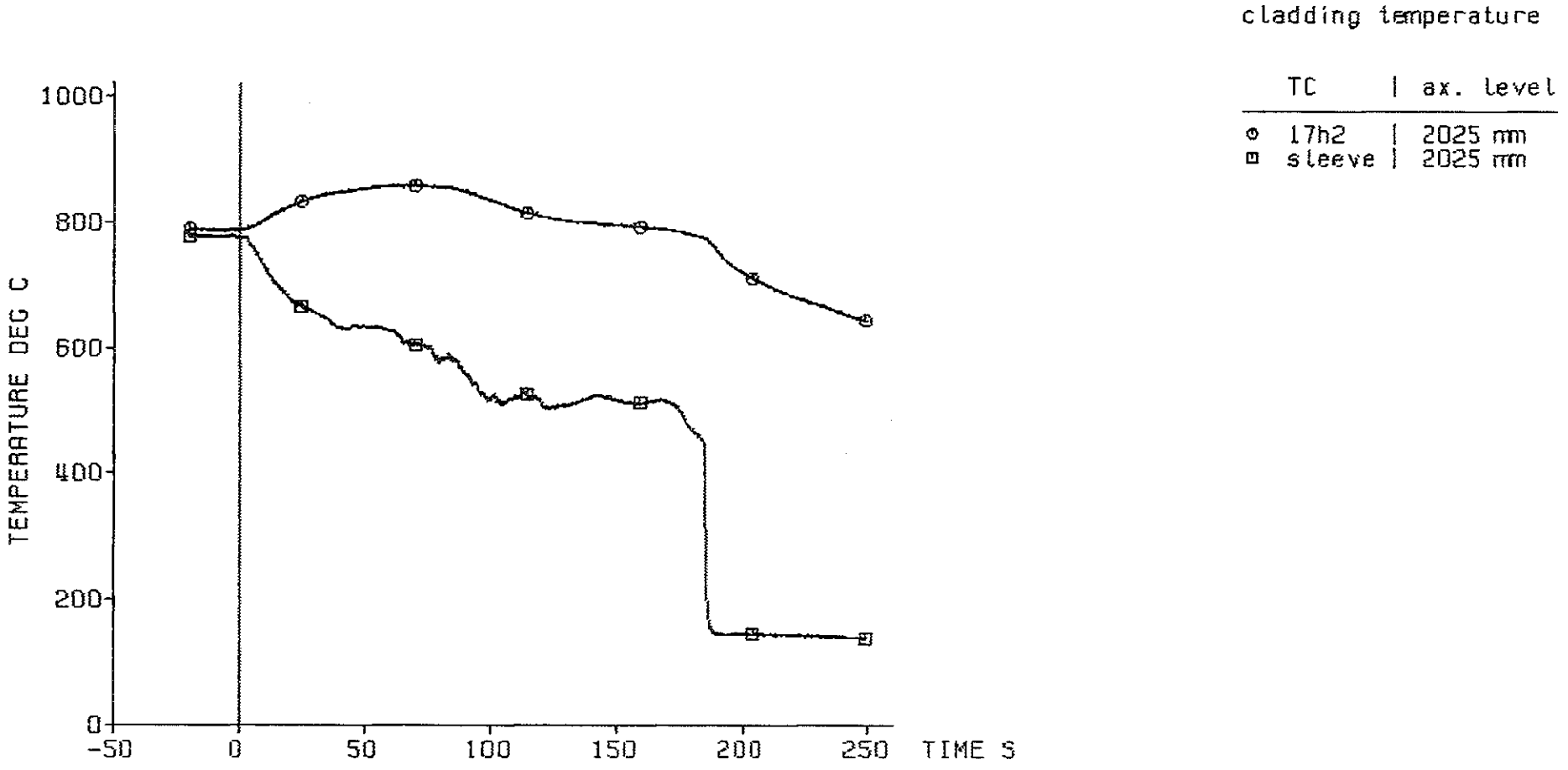


decay heat	120% ANS standard
flooding rate (cold)	5.72 cm/s
system pressure	4.13 bar
feedwater temperature	40 deg C

bypass
======

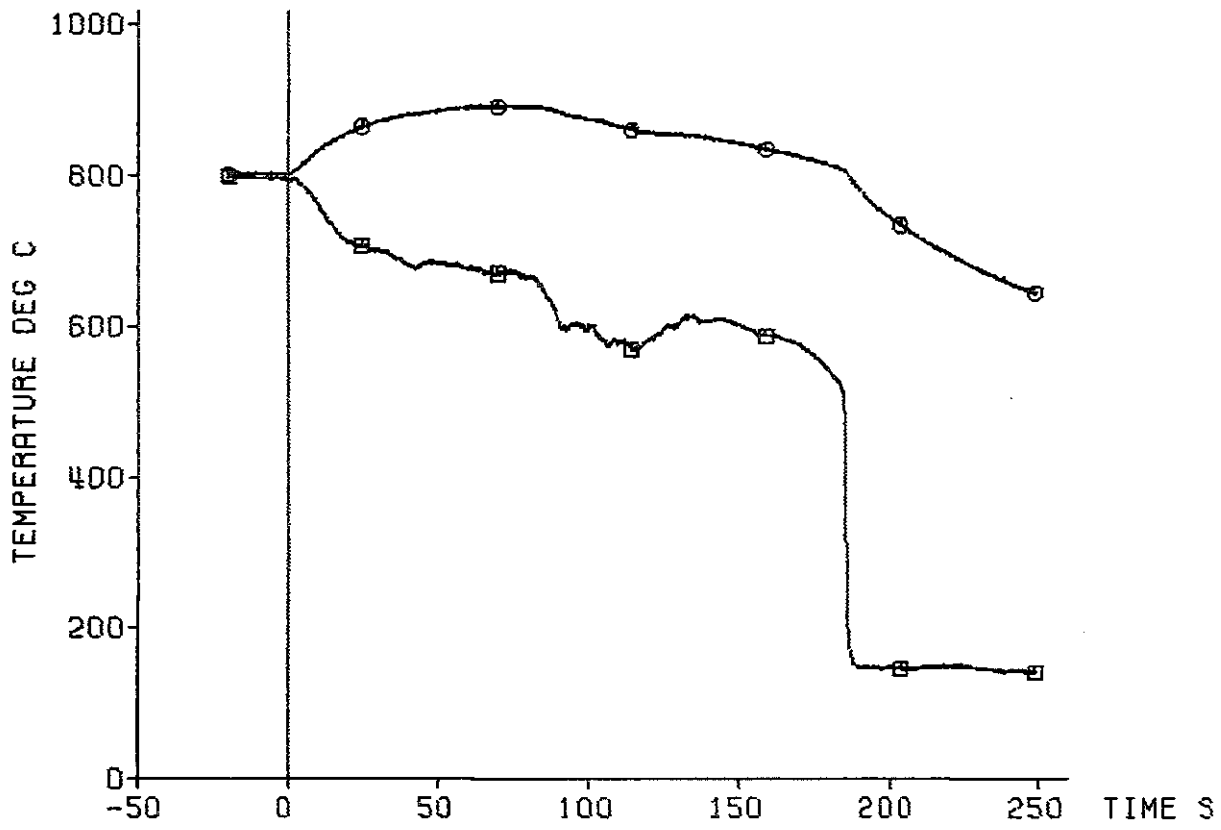
KfK IRB

Fig. 293 FEBA: 5x5 ROD BUNDLE, TEST SERIES 3, TEST-No. 238



KfK KIRB

Fig. 294 FEBA: 5x5 ROD BUNDLE, TEST SERIES 3, TEST-No. 238

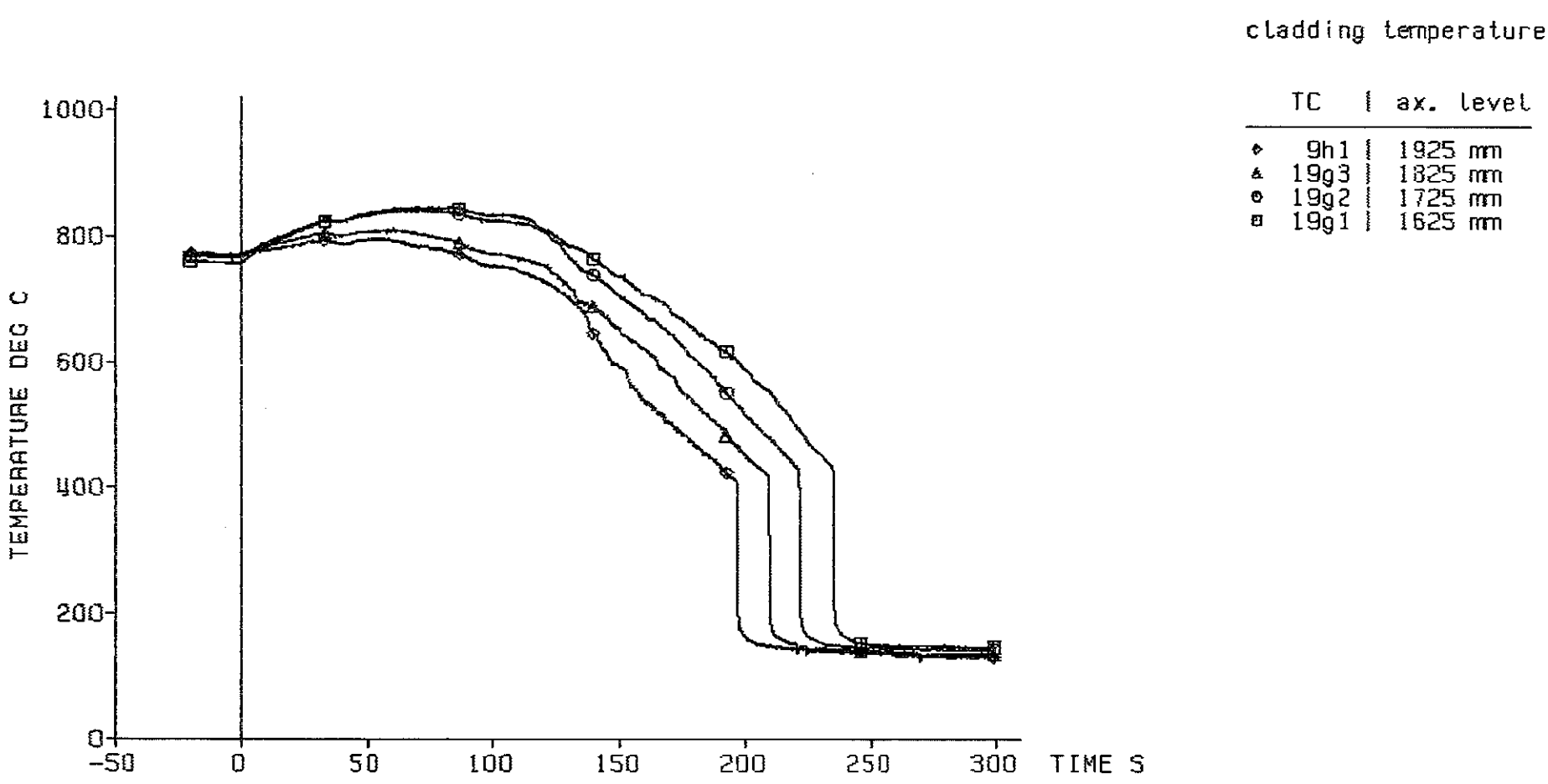


decay heat	120% ANS standard
flooding rate (cold)	5.72 cm/s
system pressure	4.13 bar
feedwater temperature	40 deg C

blockage
========

KfK IRB

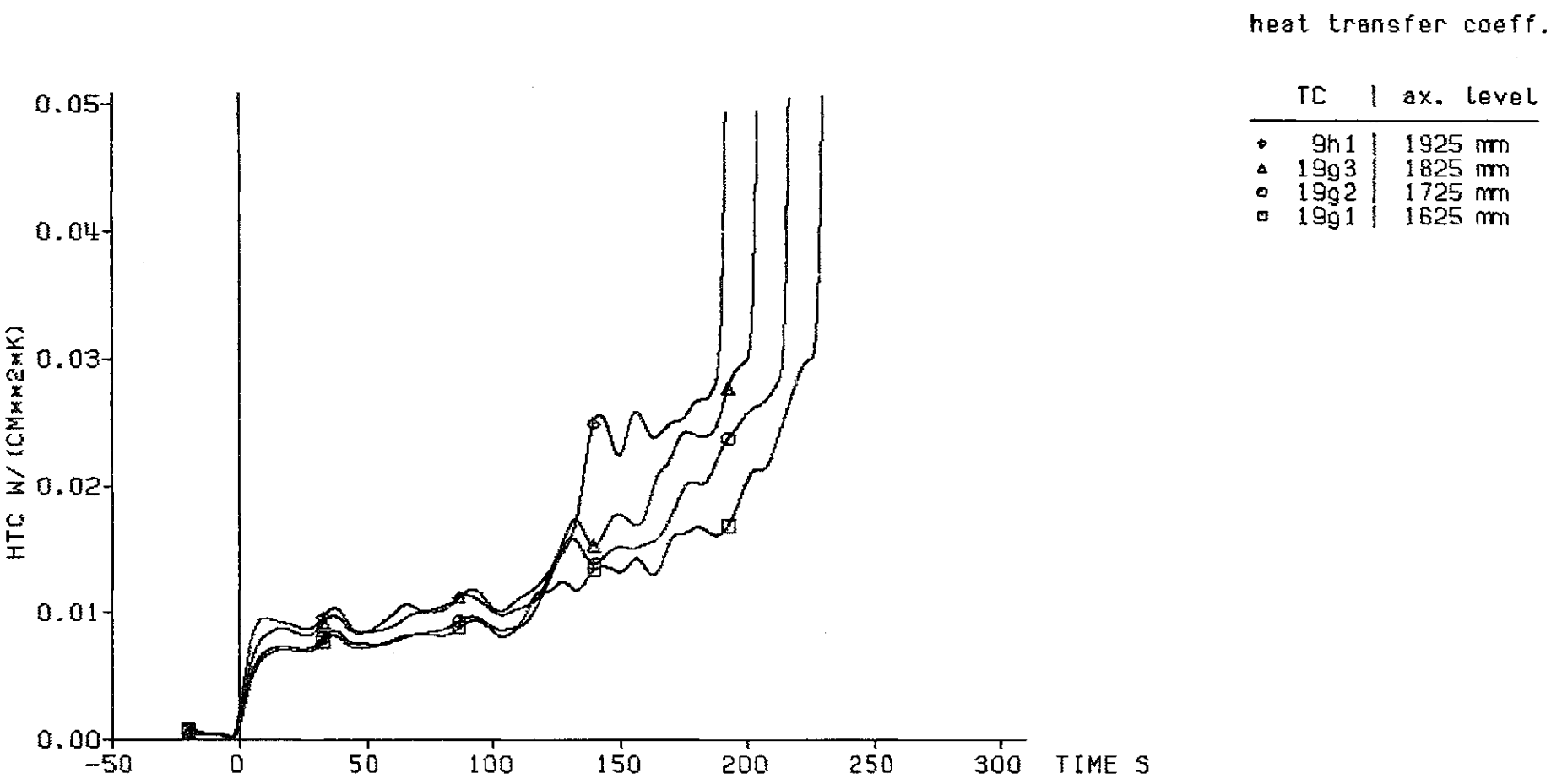
Fig. 295 FEBA: 5x5 ROD BUNDLE, TEST SERIES 3, TEST-No. 238



decay heat	120% ANS standard	bypass
flooding rate (cold)	5.72 cm/s	======
system pressure	4.13 bar	
feedwater temperature	40 deg C	

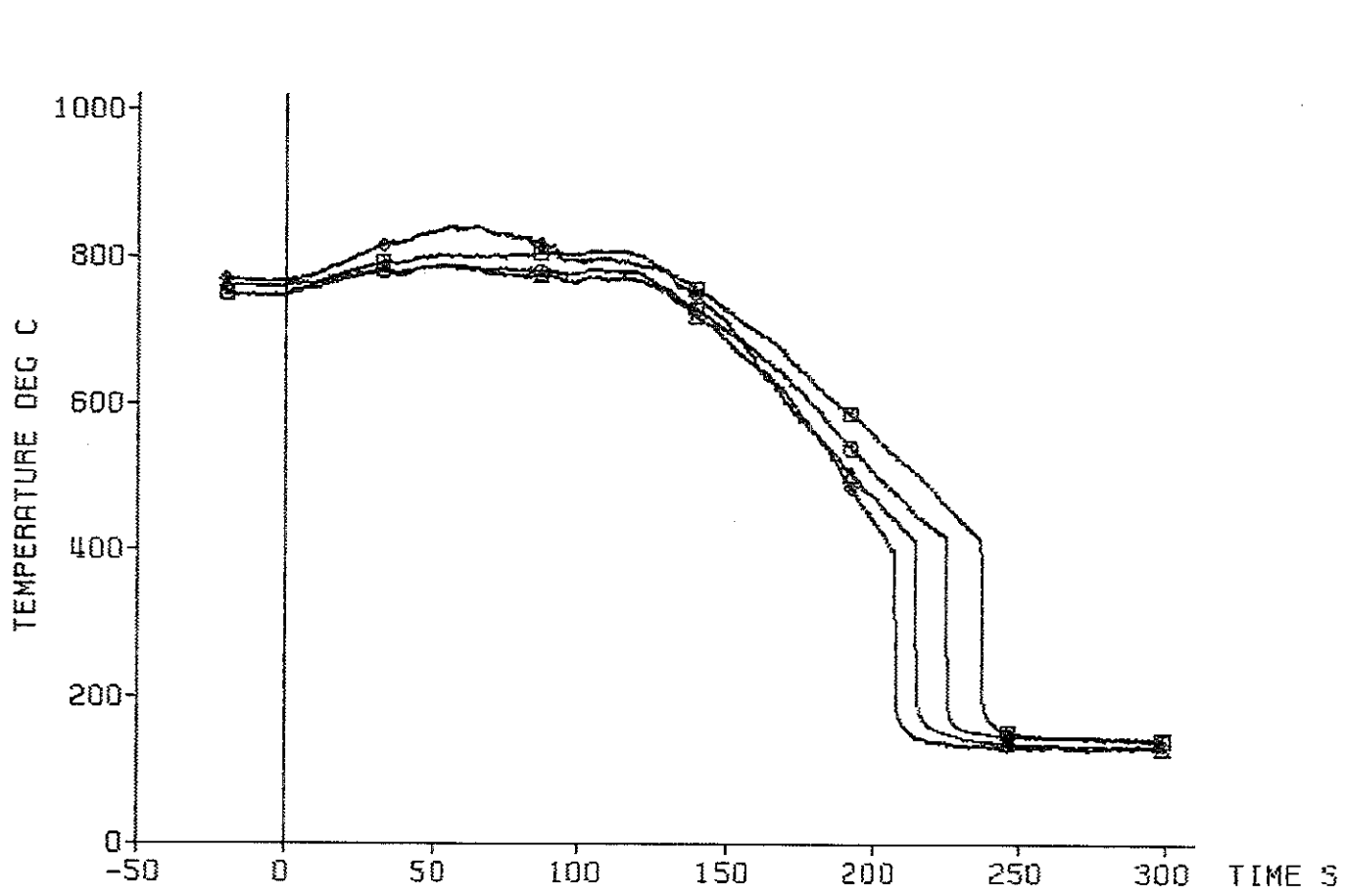
KfK IRB

Fig. 296 FEBA: 5x5 ROD BUNDLE, TEST SERIES 3, TEST-No. 238



decay heat	120% ANS standard	bypass
flooding rate (cold)	5.72 cm/s	======
system pressure	4.13 bar	
feedwater temperature	40 deg C	

Fig. 297 FEBA: 5x5 ROD BUNDLE, TEST SERIES 3, TEST-No. 238

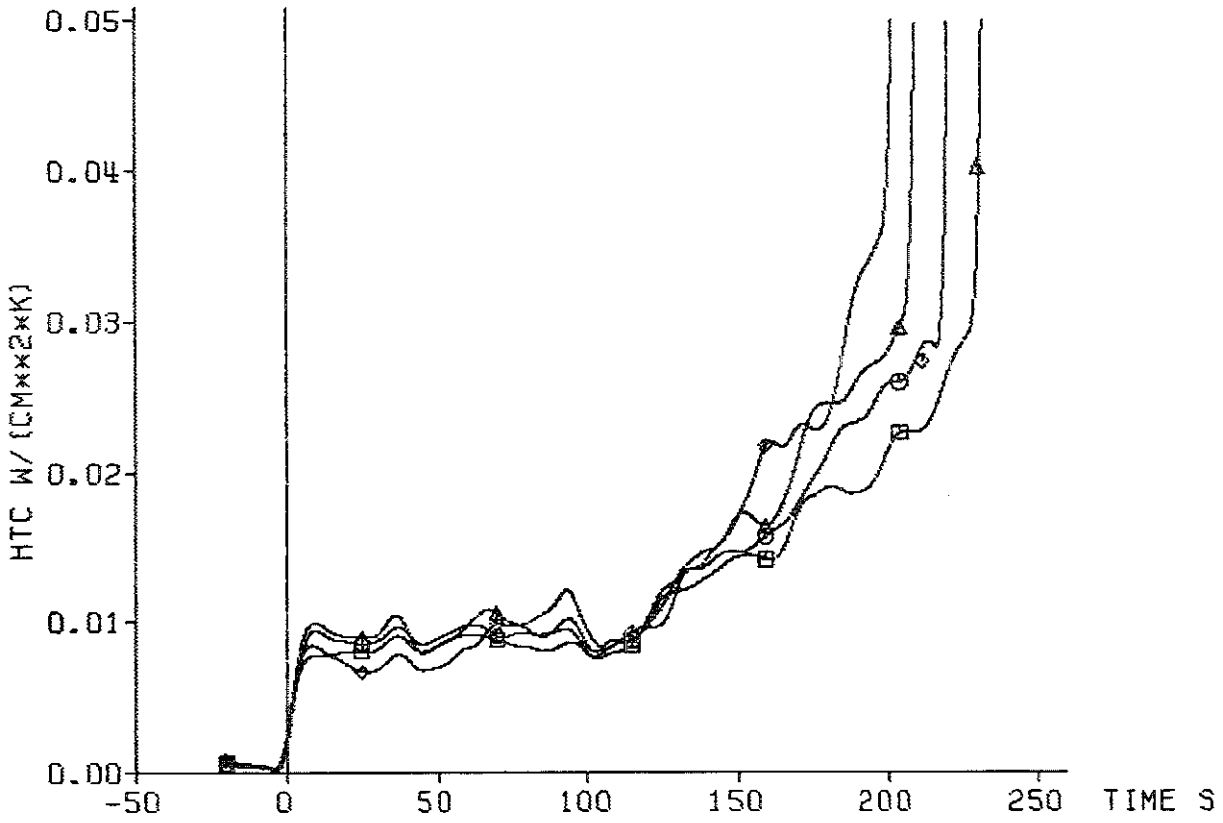


decay heat 120% ANS standard
flooding rate (cold) 5.72 cm/s
system pressure 4.13 bar
feedwater temperature 40 deg C

blockage
========

KfK IRB

Fig. 298 FEBA: 5x5 ROD BUNDLE, TEST SERIES 3, TEST-No. 238

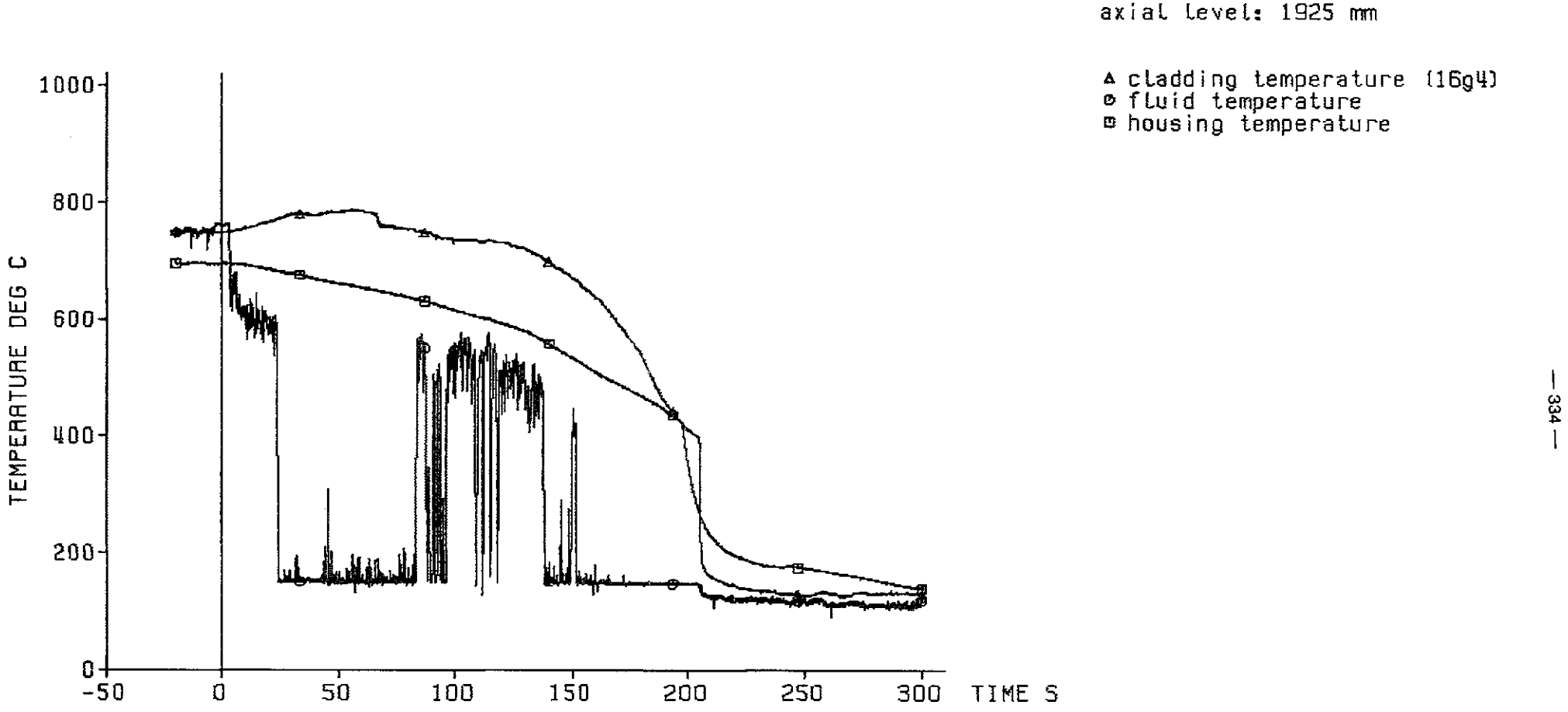


decay heat	120% ANS standard
flooding rate (cold)	5.72 cm/s
system pressure	4.13 bar
feedwater temperature	40 deg C

blockage
========

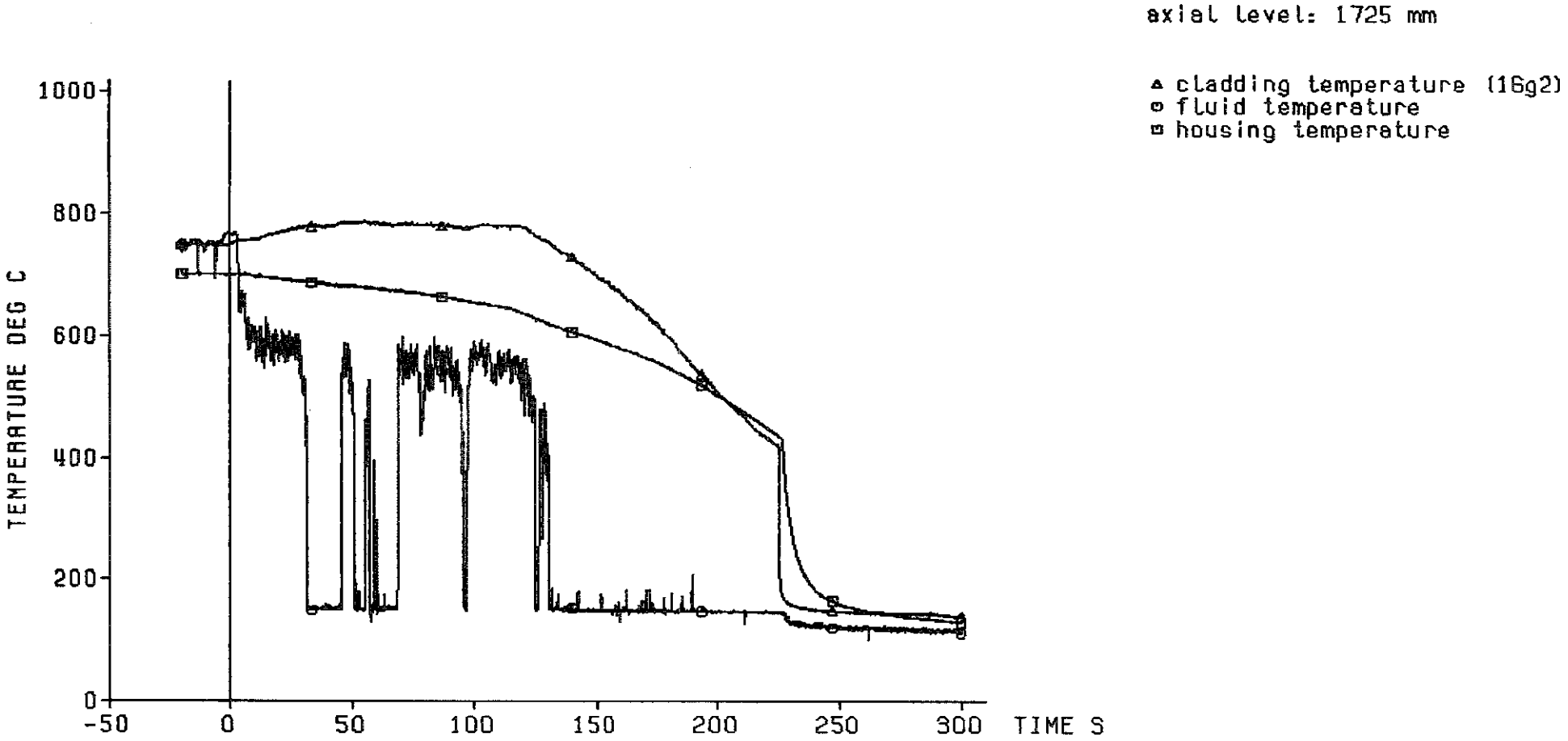
KfK IRB

Fig. 299 FEBA: 5x5 ROD BUNDLE, TEST SERIES 3, TEST-No. 238



KfK IRB

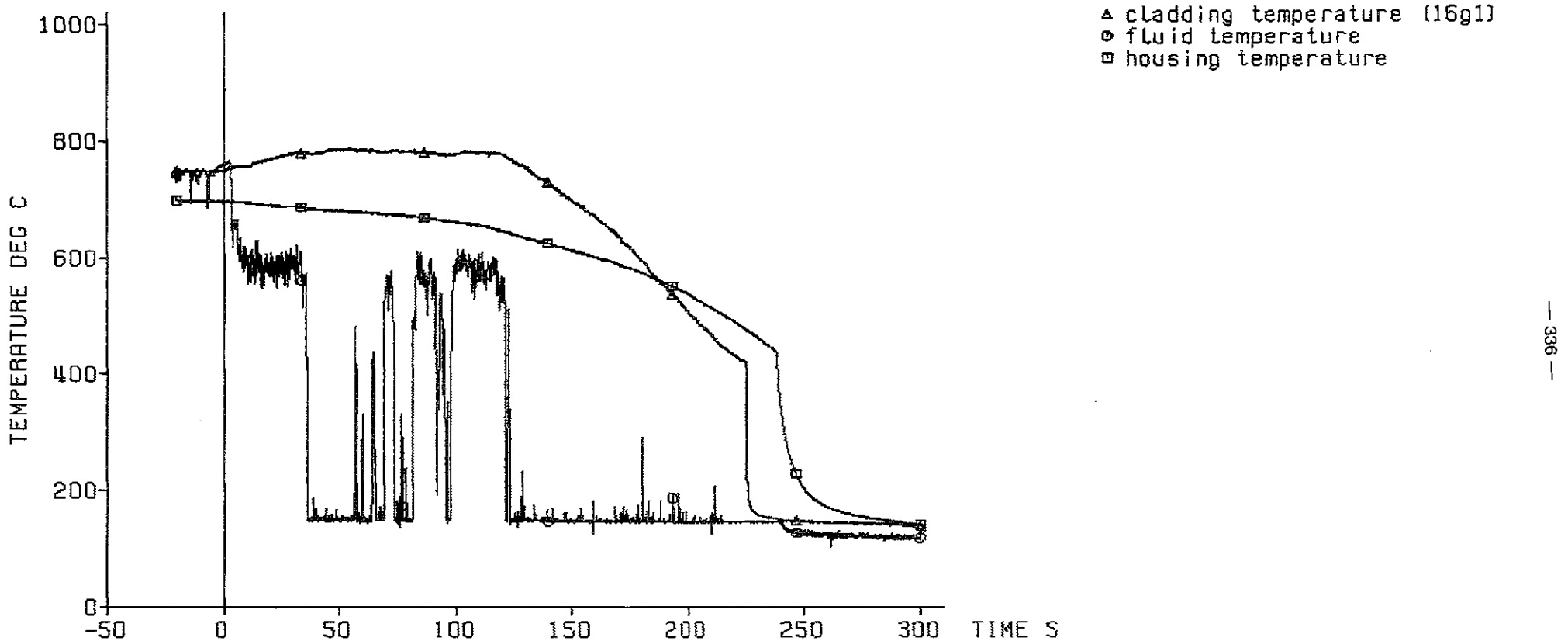
Fig. 300 FEBA: 5x5 ROD BUNDLE, TEST SERIES 3, TEST-No. 238



decay heat	120% ANS standard	blockage
flooding rate (cold)	5.72 cm/s	========
system pressure	4.13 bar	
feedwater temperature	40 deg C	

KfK IRB

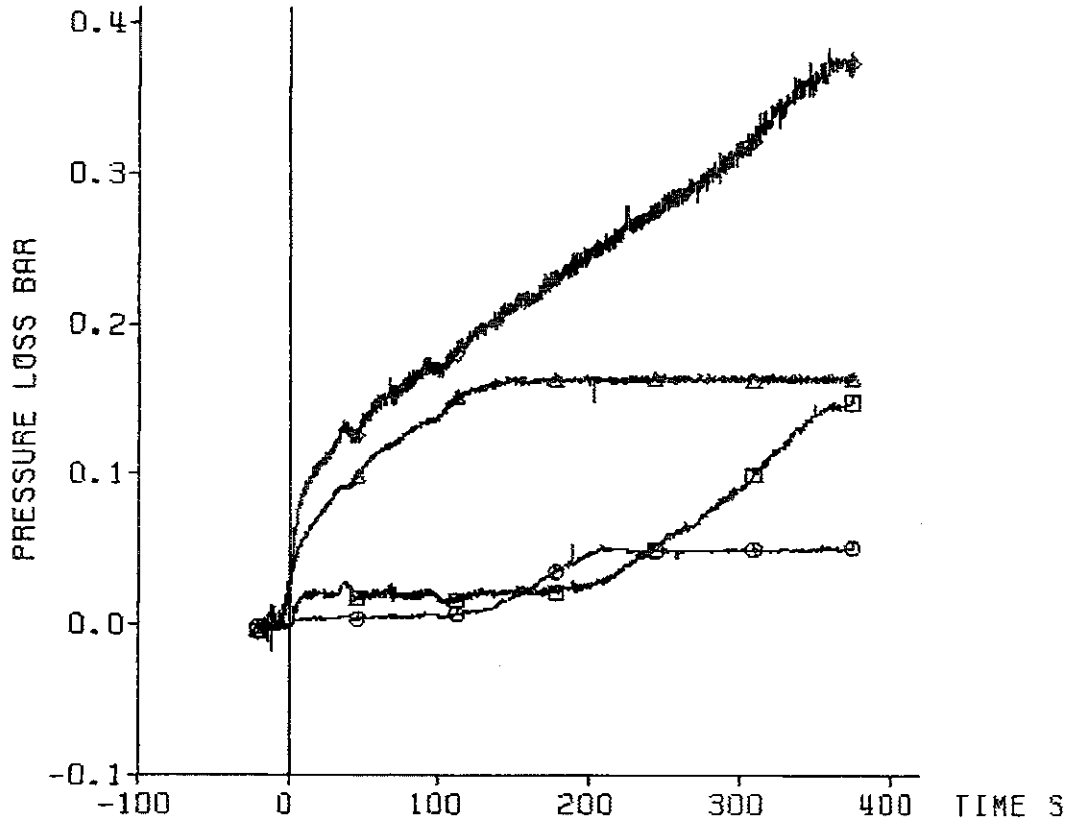
Fig. 301 FEBA: 5x5 ROD BUNDLE, TEST SERIES 3, TEST-No. 238



decay heat	120% ANS standard	blockage
flooding rate (cold)	5.72 cm/s	========
system pressure	4.13 bar	
feedwater temperature	40 deg C	

KfK IRB

Fig. 302 FEBA: 5x5 ROD BUNDLE, TEST SERIES 3, TEST-No. 238



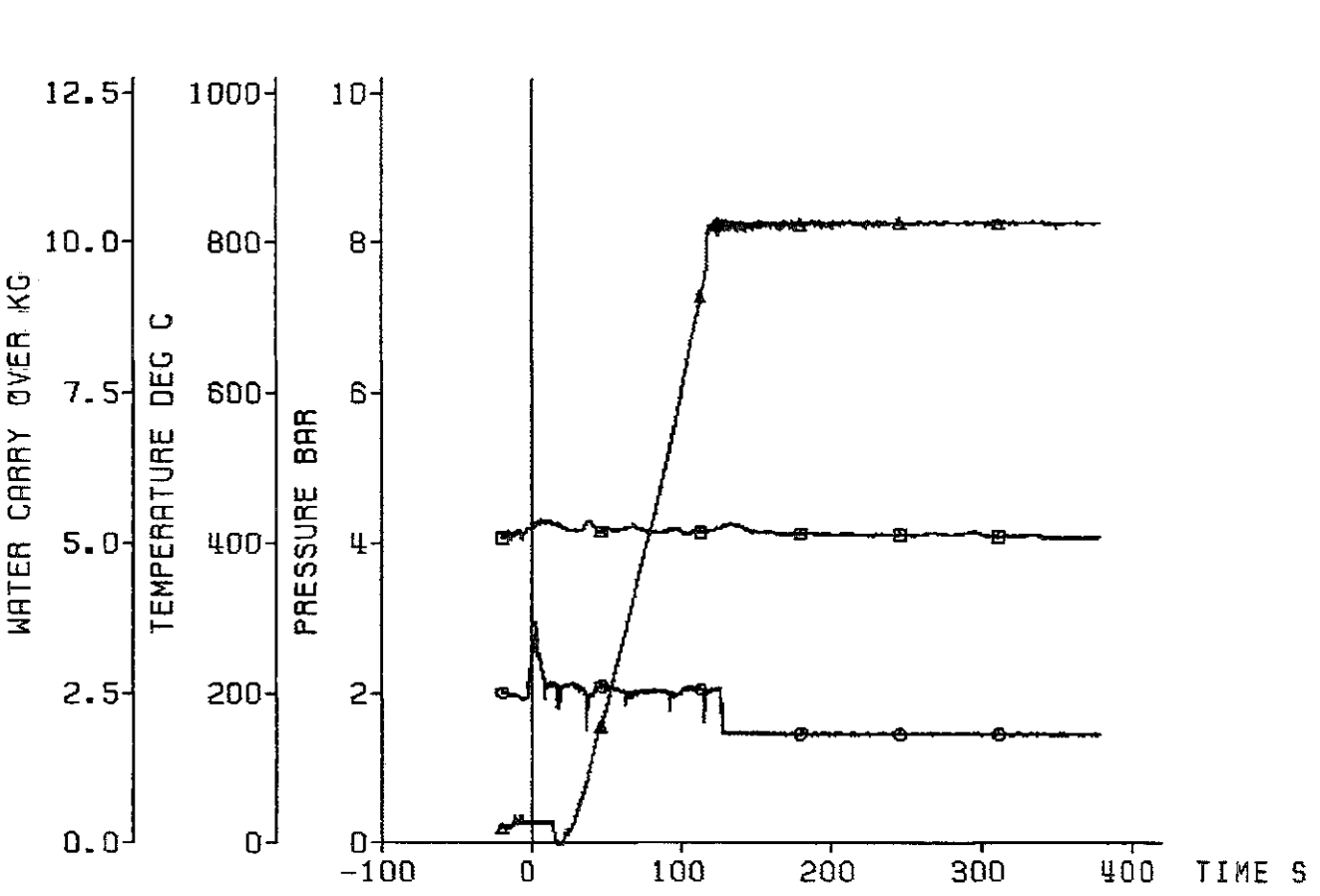
pressure loss
along the test section:

◇ total length: 4196 mm
△ lower part: 1711 mm
○ middle part: 545 mm
□ upper part: 1940 mm

decay heat	120% ANS standard
flooding rate (cold)	5.72 cm/s
system pressure	4.13 bar
feedwater temperature	40 deg C

KfK KIRB

Fig. 303 FEBA: 5x5 ROD BUNDLE, TEST SERIES 3, TEST-No. 238



decay heat	120% ANS standard
flooding rate (cold)	5.72 cm/s
system pressure	4.13 bar
feedwater temperature	40 deg C

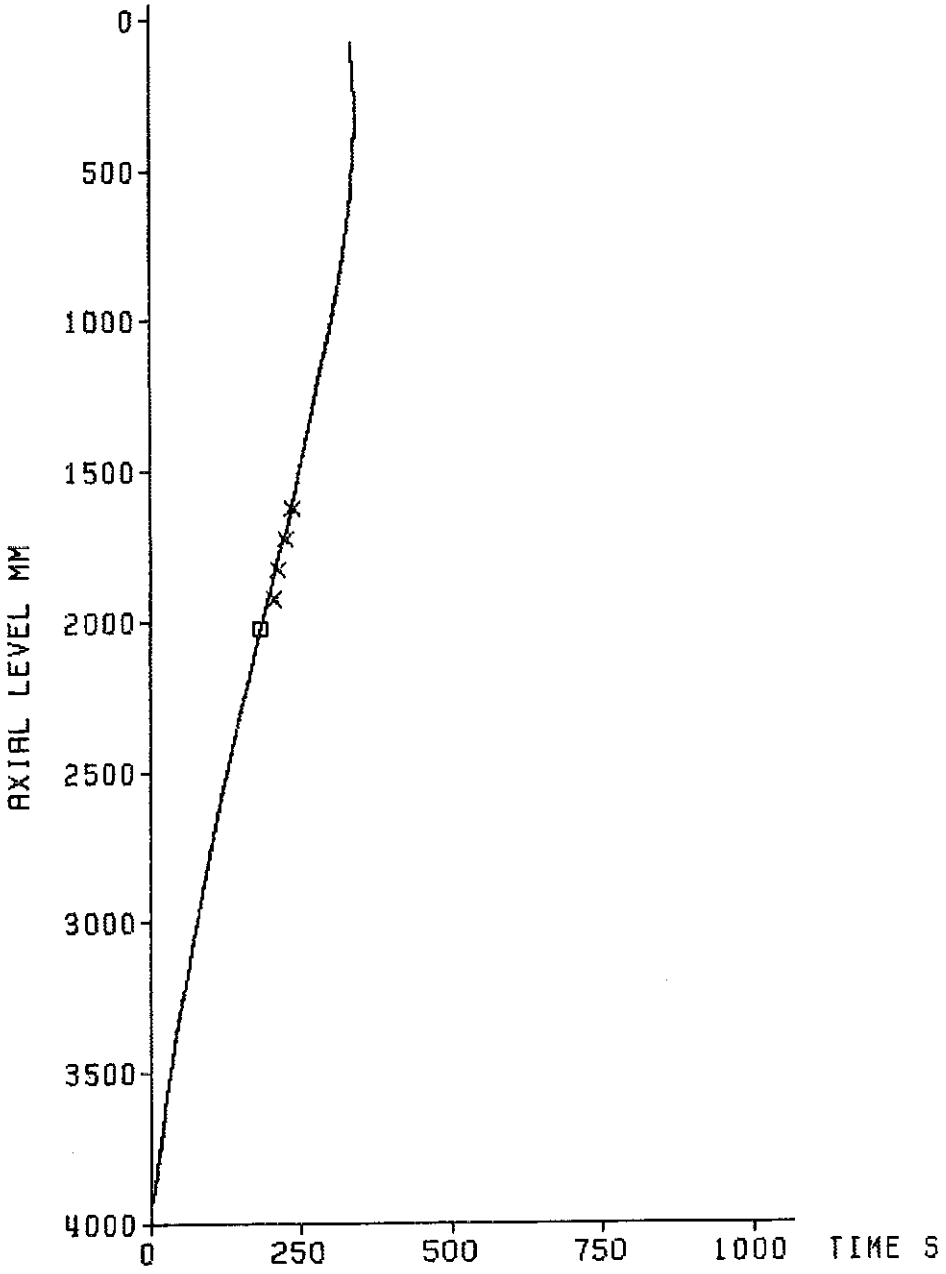
KfK IRB

Fig. 304 FEBA: 5x5 ROD BUNDLE, TEST SERIES 3, TEST-No. 238

axial position of the quench front

▫ rewetting of the sleeve at the bundle midplane

× rewetting of the rod downstream of the blockage

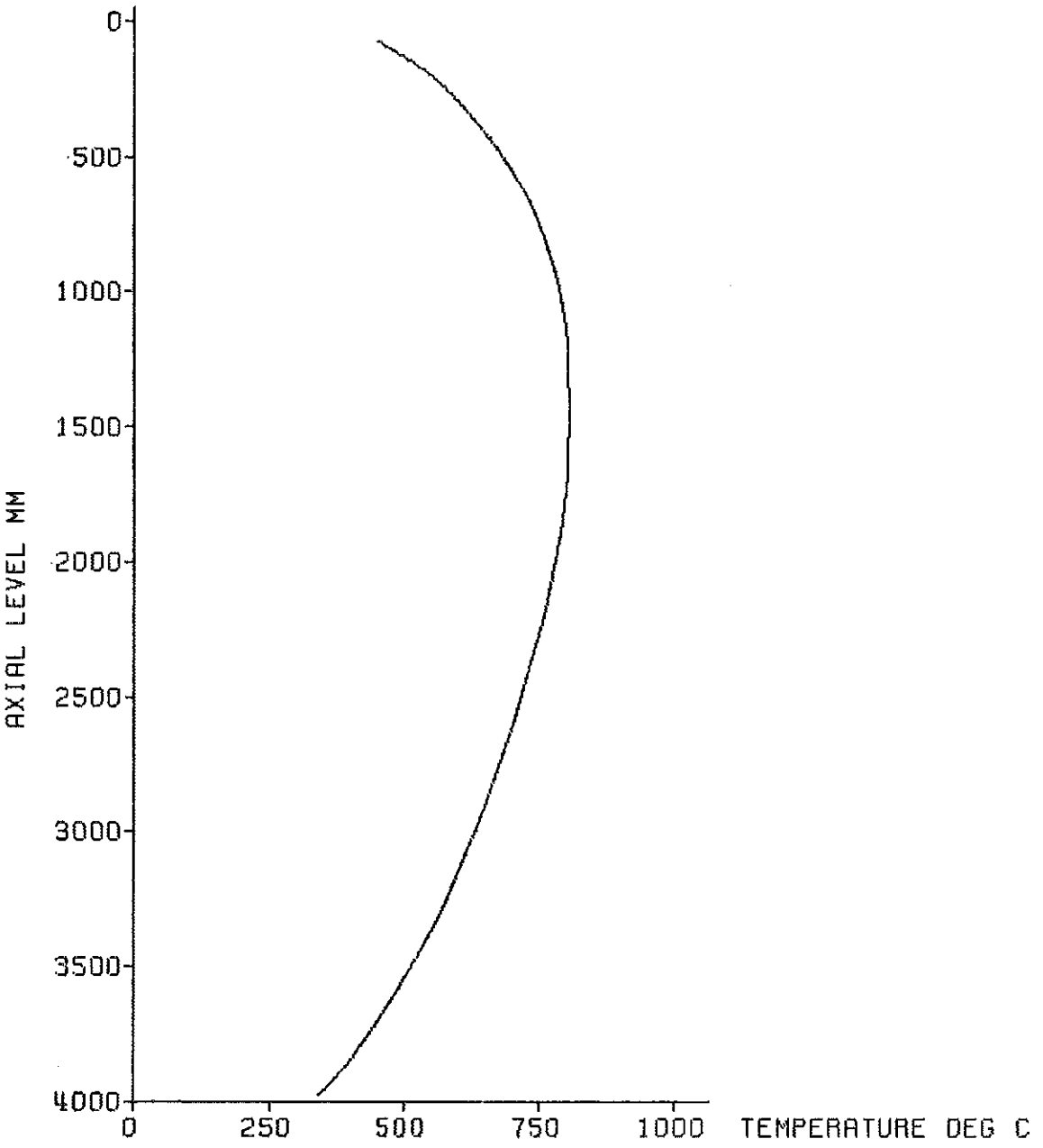


decay heat	120% ANS standard
flooding rate (cold)	5.72 cm/s
system pressure	4.13 bar
feedwater temperature	40 deg C

KfK IRB

Fig. 305 FEBA: 5x5 ROD BUNDLE
TEST SERIES 3, TEST-No. 238

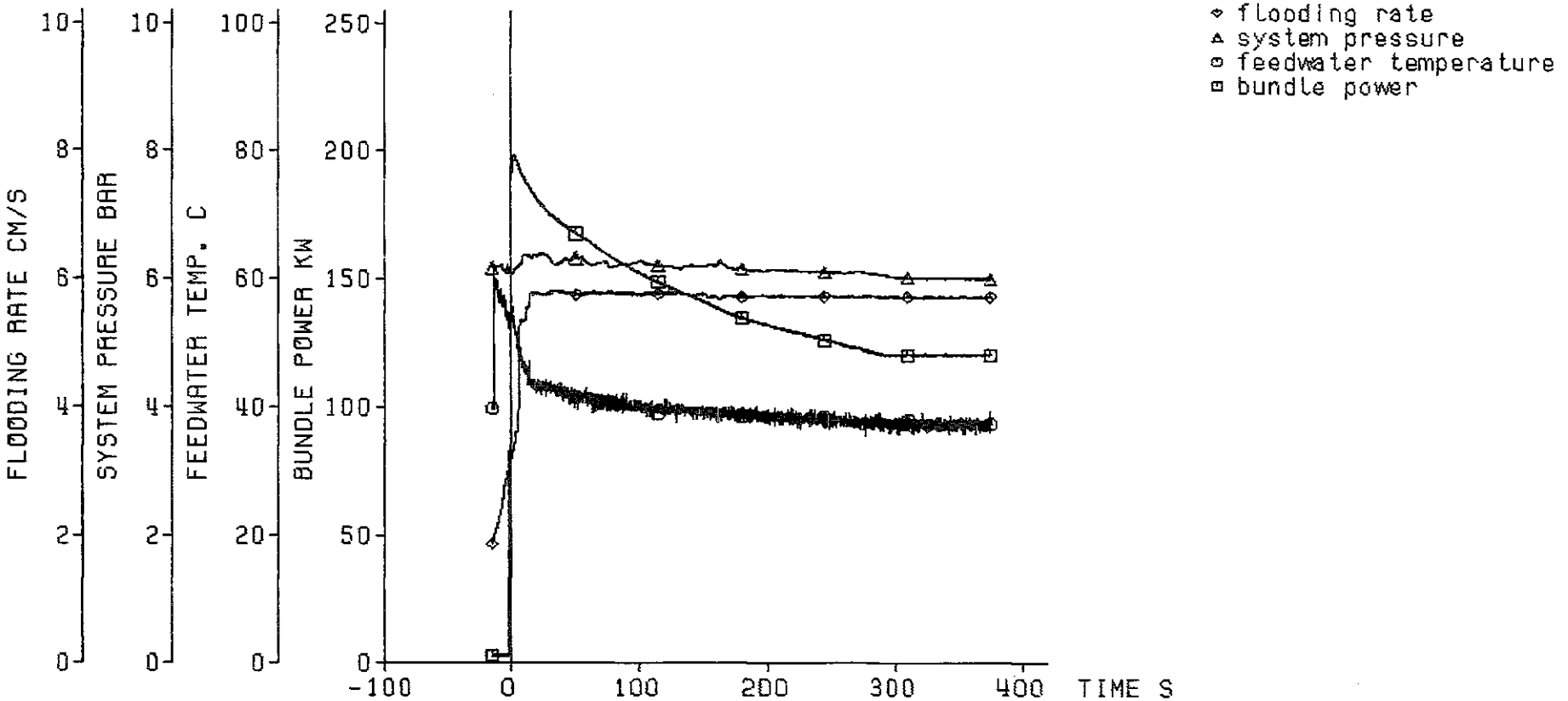
initial axial temperature profile of the cladding



decay heat	120% ANS standard
flooding rate (cold)	5.71 cm/s
system pressure	6.21 bar
feedwater temperature	40 deg C

KfK IRB

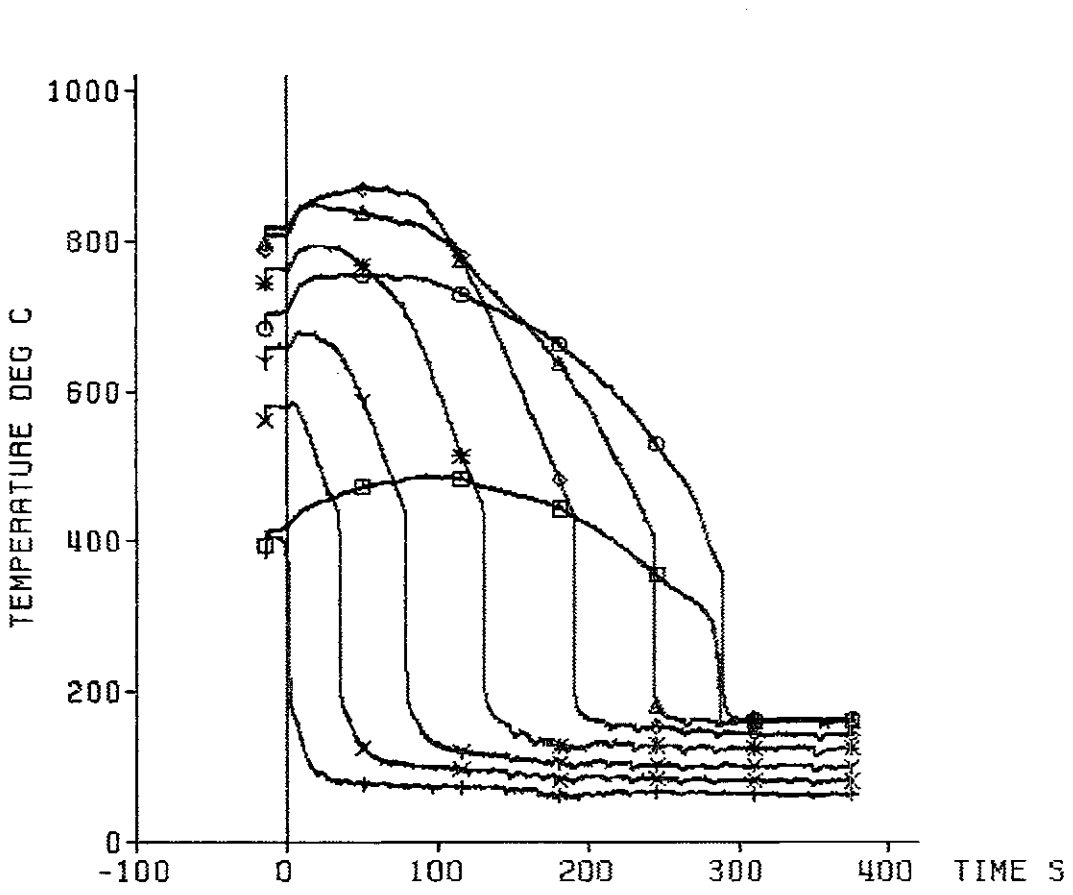
Fig. 306 FEBA: 5x5 ROD BUNDLE
TEST SERIES 3, TEST-No. 235



decay heat	120% ANS standard
flooding rate (cold)	5.71 cm/s
system pressure	6.21 bar
feedwater temperature	40 deg C

KfK IRB

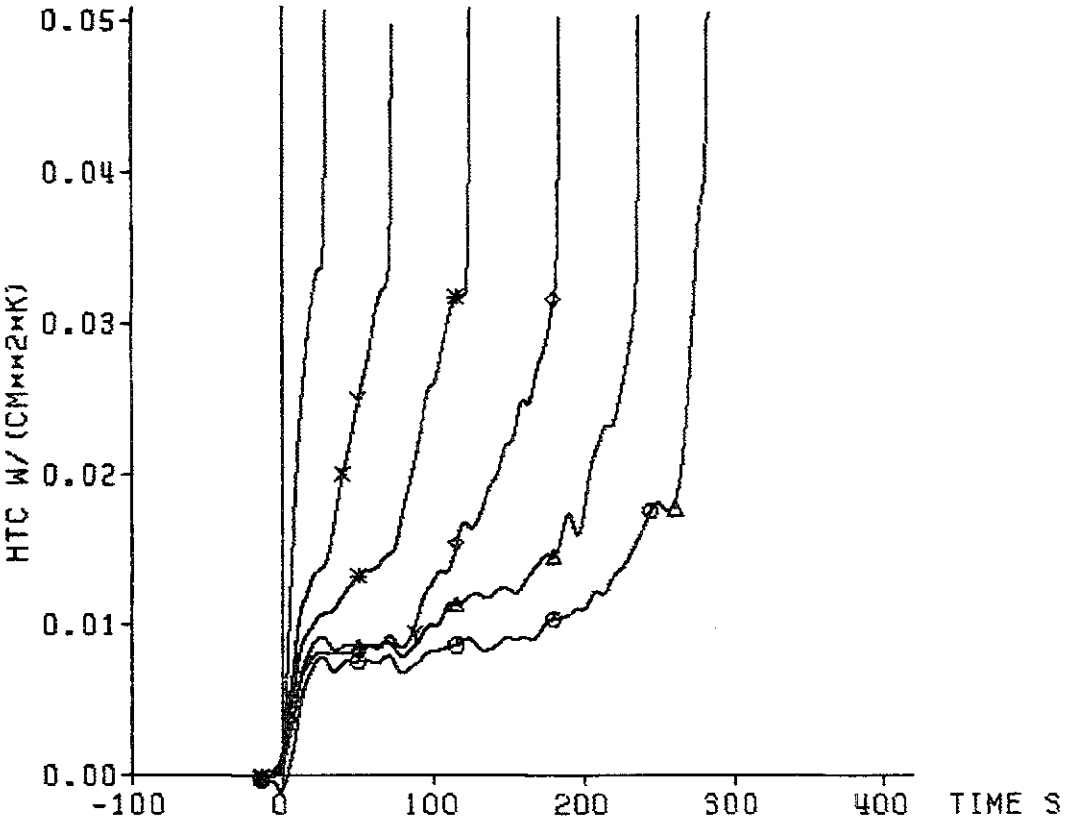
Fig. 307 FEBA: 5x5 ROD BUNDLE, TEST SERIES 3, TEST-No. 235



decay heat	120% ANS standard
flooding rate (cold)	5.71 cm/s
system pressure	6.21 bar
feedwater temperature	40 deg C

KfK IRB

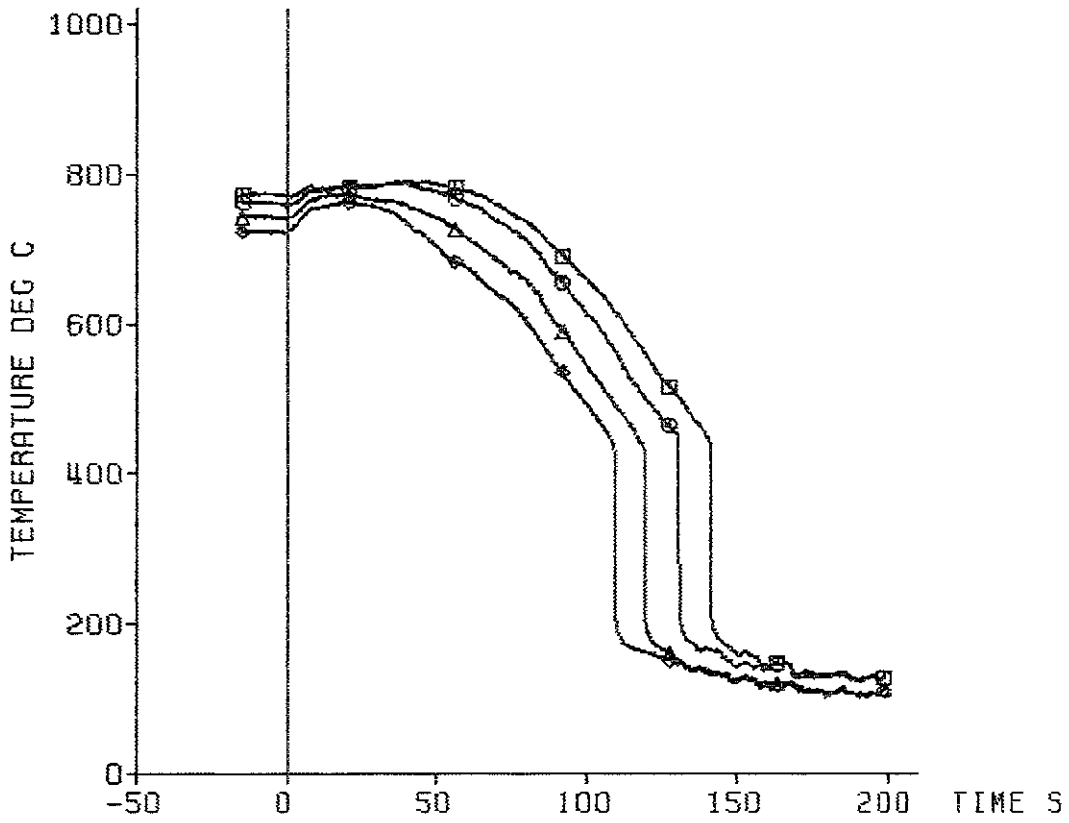
Fig. 308 FEBA: 5x5 ROD BUNDLE, TEST SERIES 3, TEST-No. 235



decay heat	120% ANS standard
flooding rate (cold)	5.71 cm/s
system pressure	6.21 bar
feedwater temperature	40 deg C

KfK IRB

Fig. 309 FEBA: 5x5 ROD BUNDLE, TEST SERIES 3, TEST-No. 235

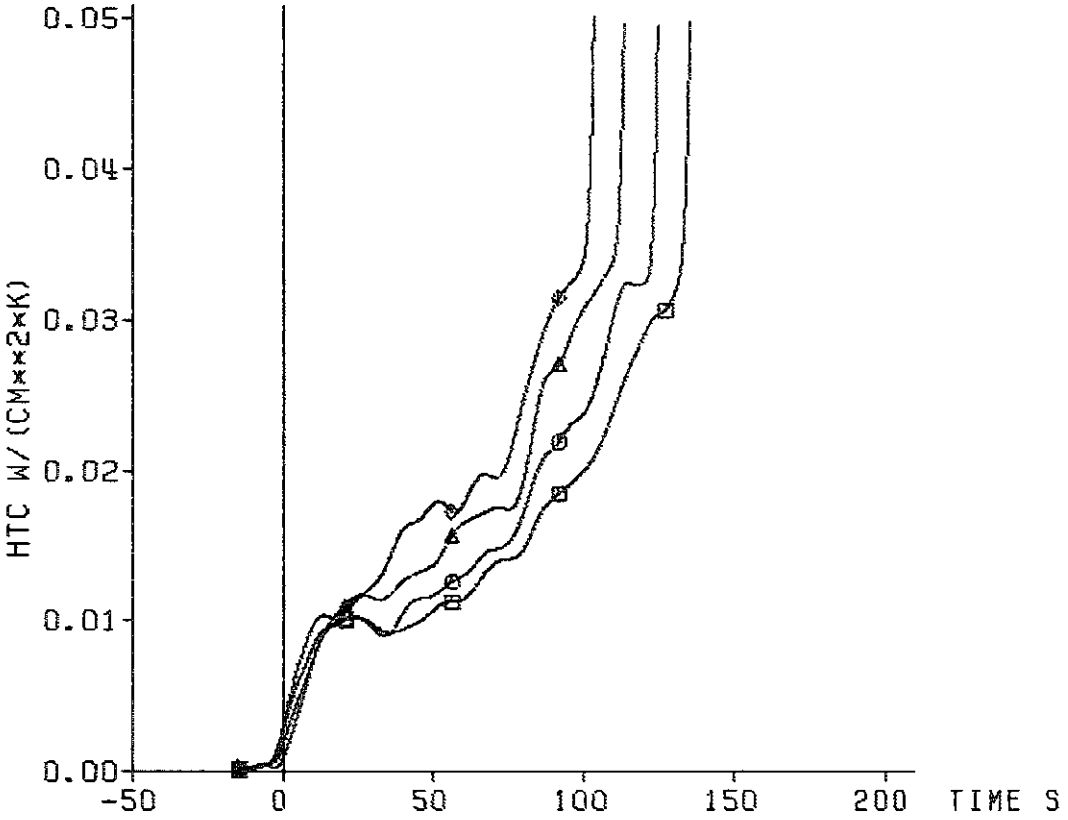


decay heat	120% ANS standard	bypass
flooding rate (cold)	5.71 cm/s	======
system pressure	6.21 bar	
feedwater temperature	40 deg C	

KfK KIRB

Fig. 310 FEBA: 5x5 ROD BUNDLE, TEST SERIES 3, TEST-No. 235

heat transfer coeff.



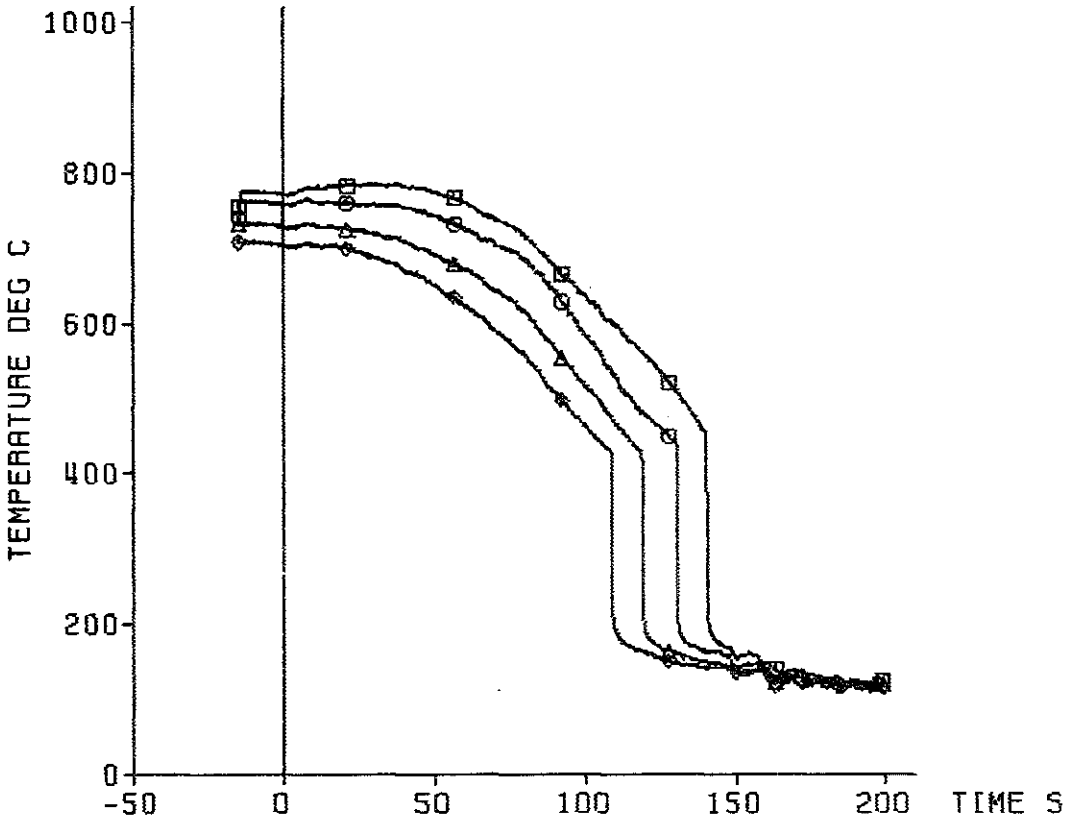
TC	ax. Level
7f4	2425 mm
7f3	2325 mm
9h4	2225 mm
9h3	2125 mm

decay heat	120% ANS standard
flooding rate (cold)	5.71 cm/s
system pressure	6.21 bar
feedwater temperature	40 deg C

bypass
======

KfK IRB

Fig. 311 FEBA: 5x5 ROD BUNDLE, TEST SERIES 3, TEST-No. 235

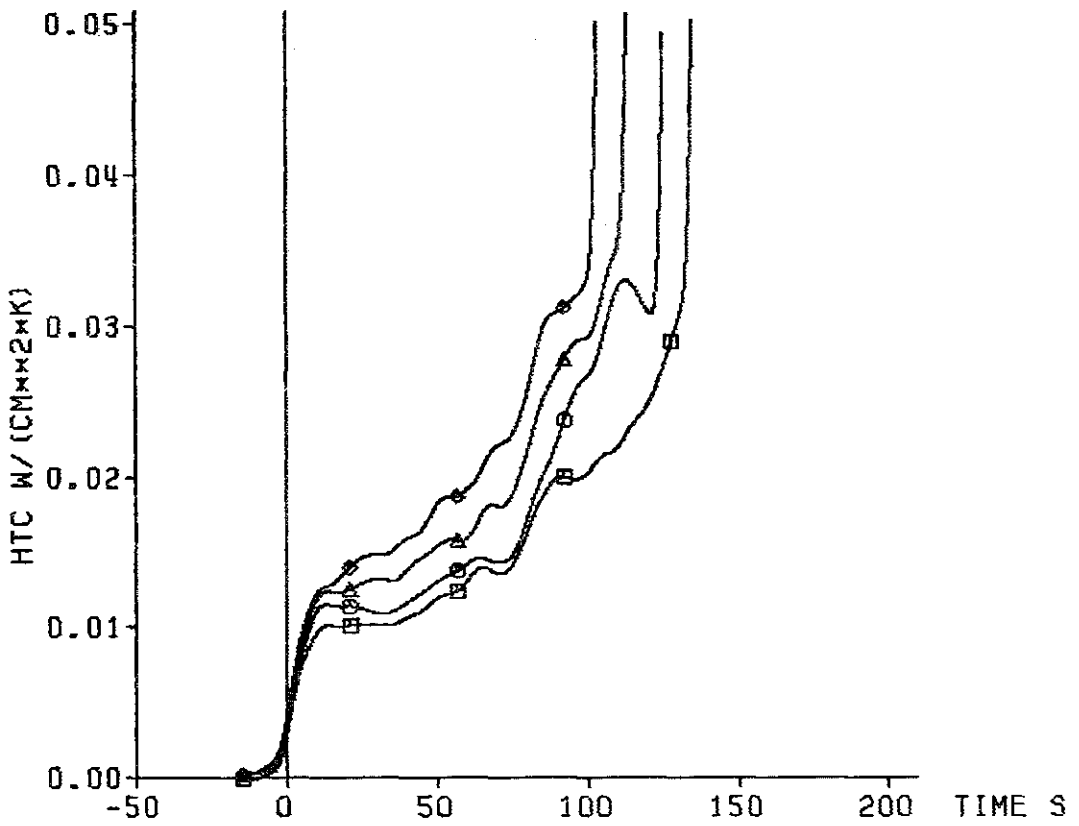


decay heat	120% ANS standard
flooding rate (cold)	5.71 cm/s
system pressure	6.21 bar
feedwater temperature	40 deg C

blockage
========

KfK IRB

Fig. 312 FEBA: 5x5 ROD BUNDLE, TEST SERIES 3, TEST-No. 235

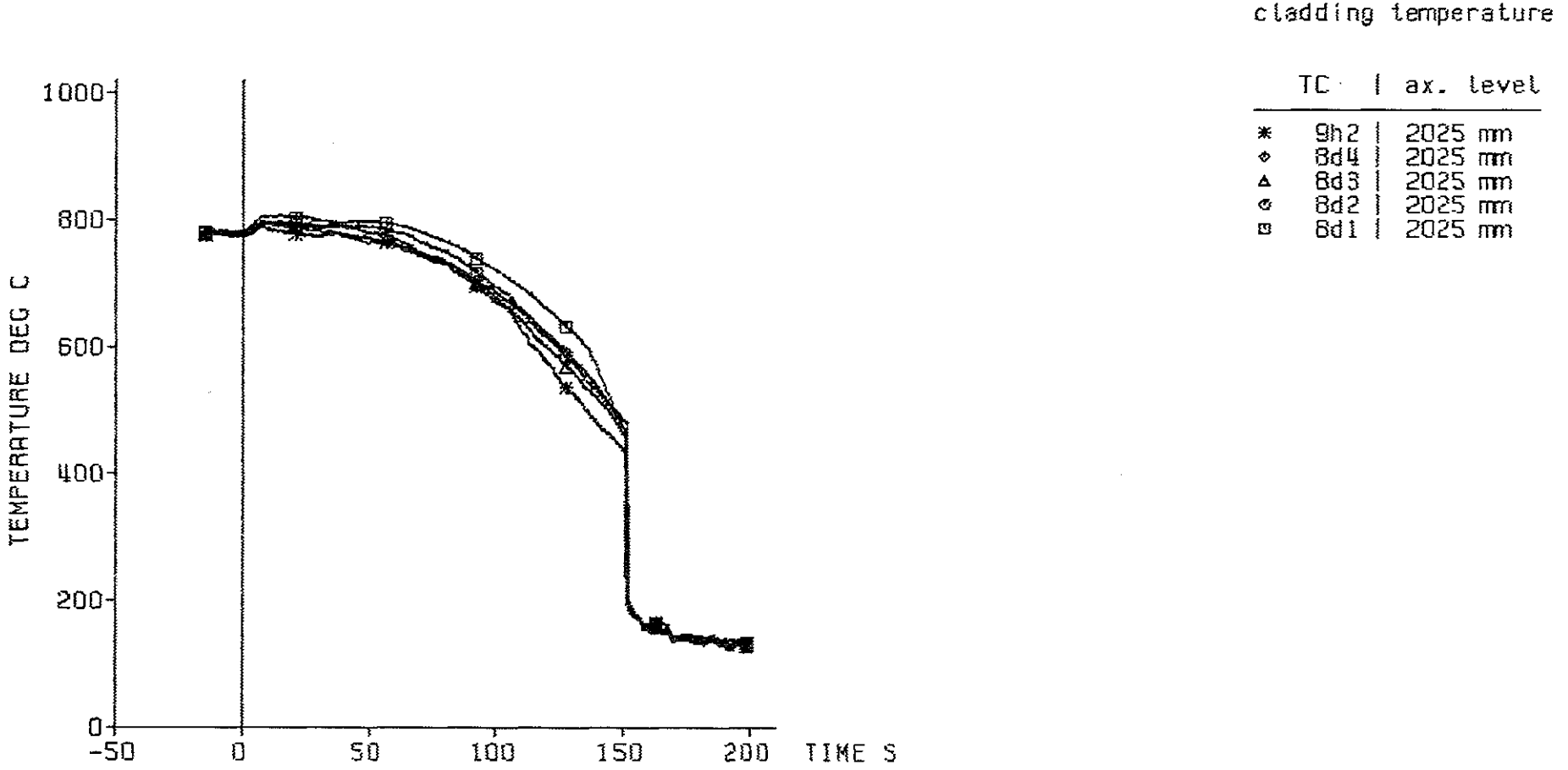


decay heat	120% ANS standard
flooding rate (cold)	5.71 cm/s
system pressure	6.21 bar
feedwater temperature	40 deg C

blockage
========

KfK IRB

Fig. 313 FEBA: 5x5 ROD BUNDLE, TEST SERIES 3, TEST-No. 235

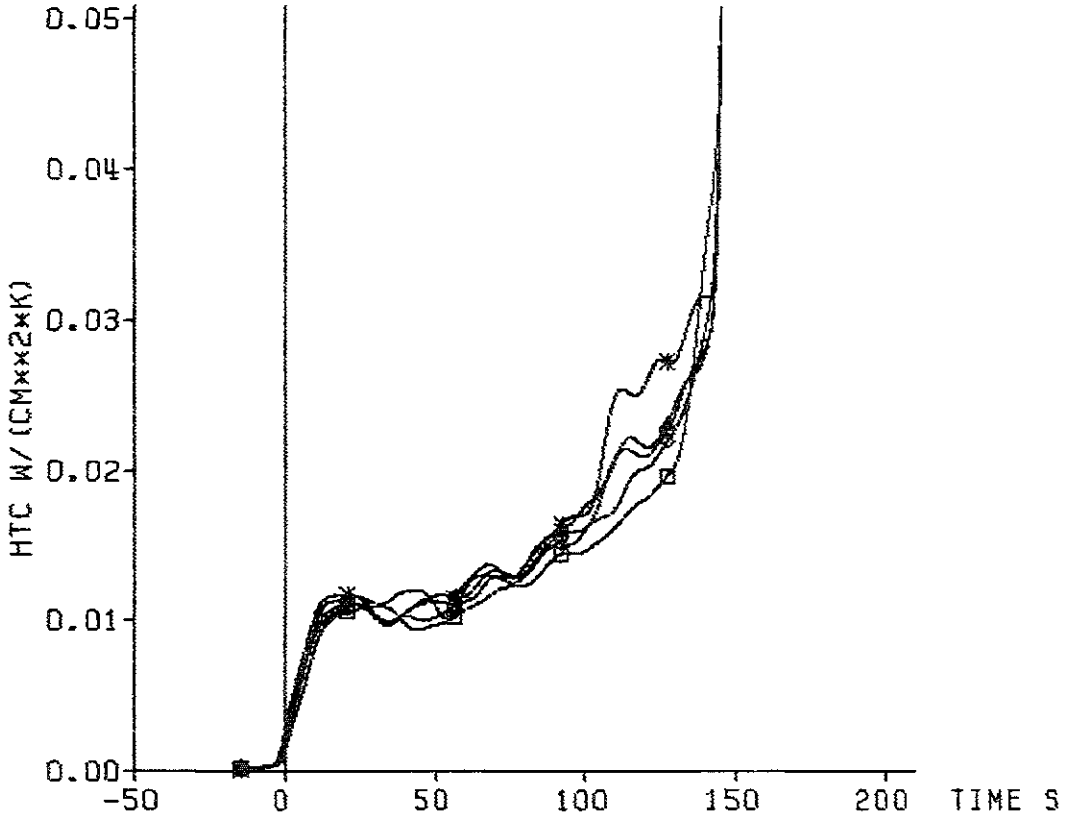


decay heat	120% ANS standard
flooding rate (cold)	5.71 cm/s
system pressure	6.21 bar
feedwater temperature	40 deg C

bypass
======

KfK IRB

Fig. 314 FEBA: 5x5 ROD BUNDLE, TEST SERIES 3, TEST-No. 235

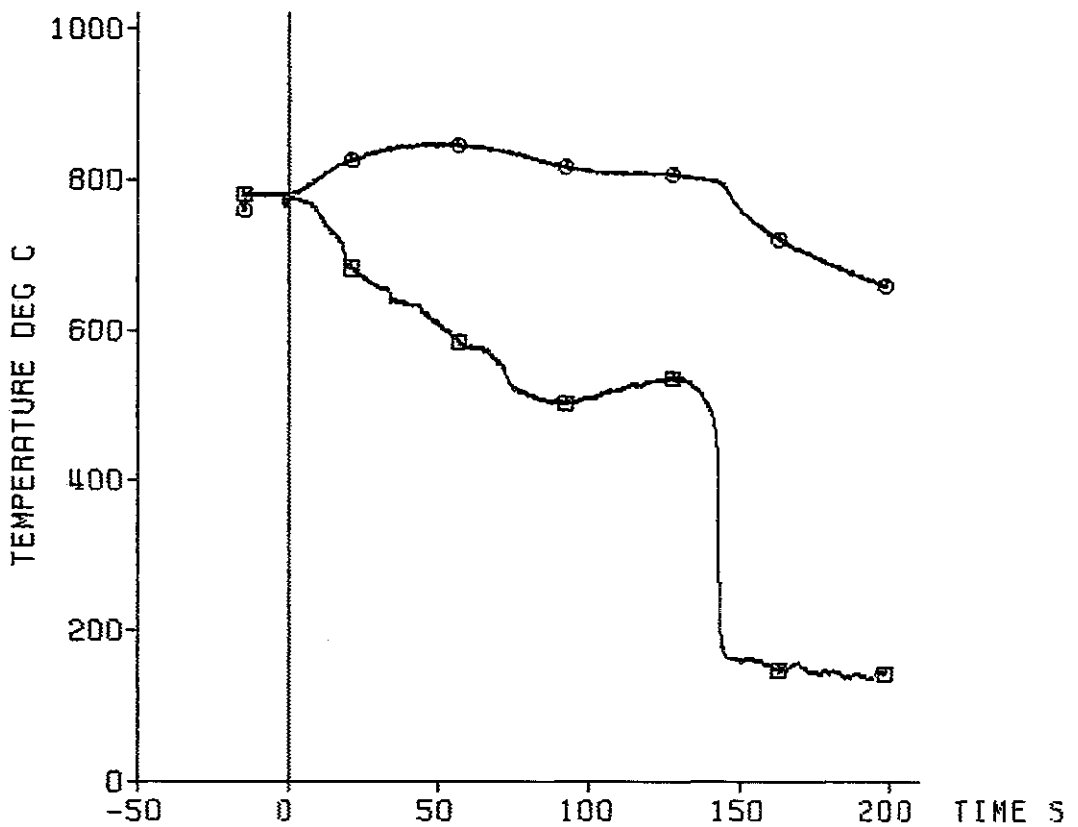


decay heat	120% ANS standard
flooding rate (cold)	5.71 cm/s
system pressure	6.21 bar
feedwater temperature	40 deg C

bypass
======

KfK IRB

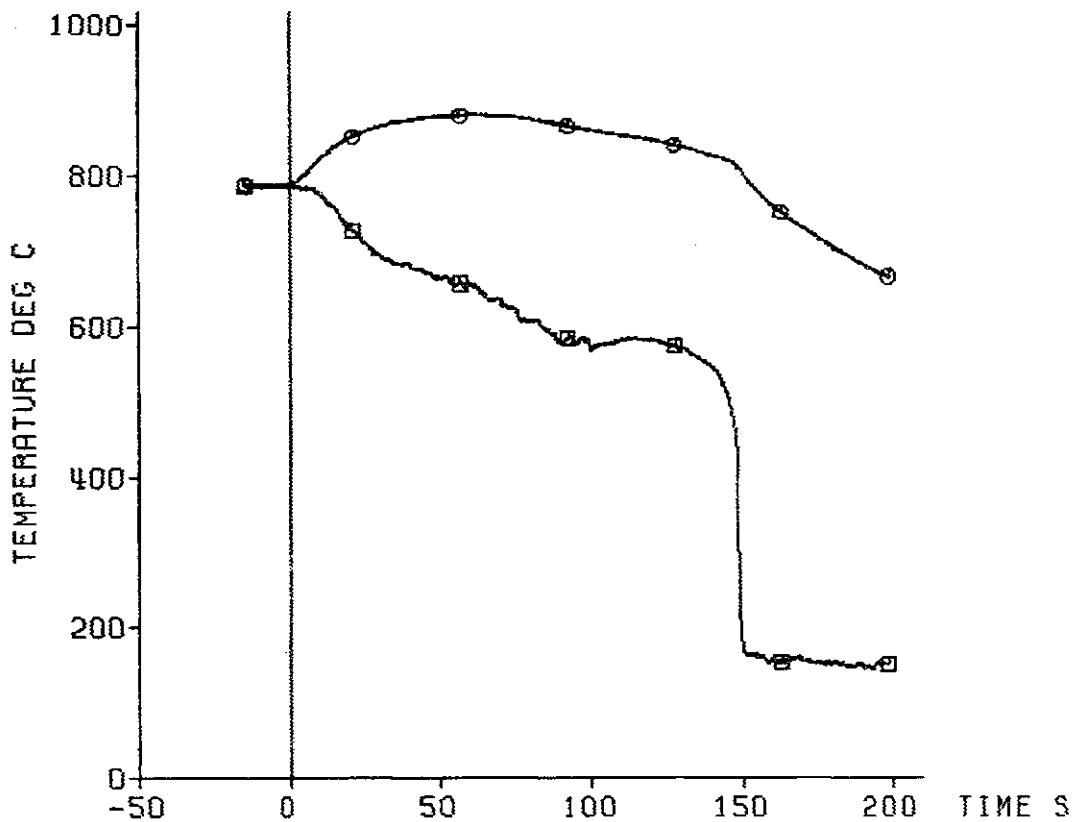
Fig. 315 FEBA: 5x5 ROD BUNDLE, TEST SERIES 3, TEST-No. 235



decay heat	120% ANS standard	blockage
flooding rate (cold)	5.71 cm/s	========
system pressure	6.21 bar	
feedwater temperature	40 deg C	

KfK KIRB

Fig. 316 FEBA: 5x5 ROD BUNDLE, TEST SERIES 3, TEST-No. 235

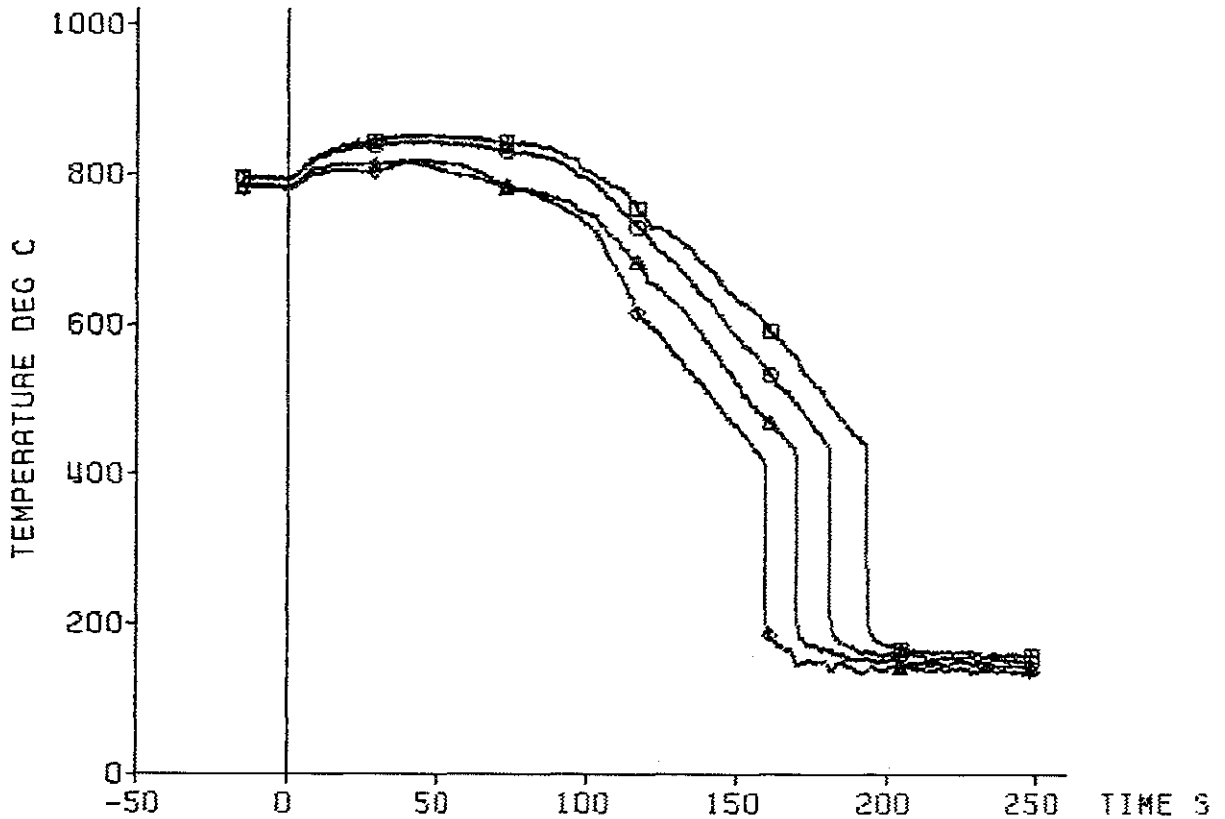


decay heat	120% ANS standard
flooding rate (cold)	5.71 cm/s
system pressure	6.21 bar
feedwater temperature	40 deg C

blockage
========

KfK IRB

Fig. 317 FEBA: 5x5 ROD BUNDLE, TEST SERIES 3, TEST-No. 235

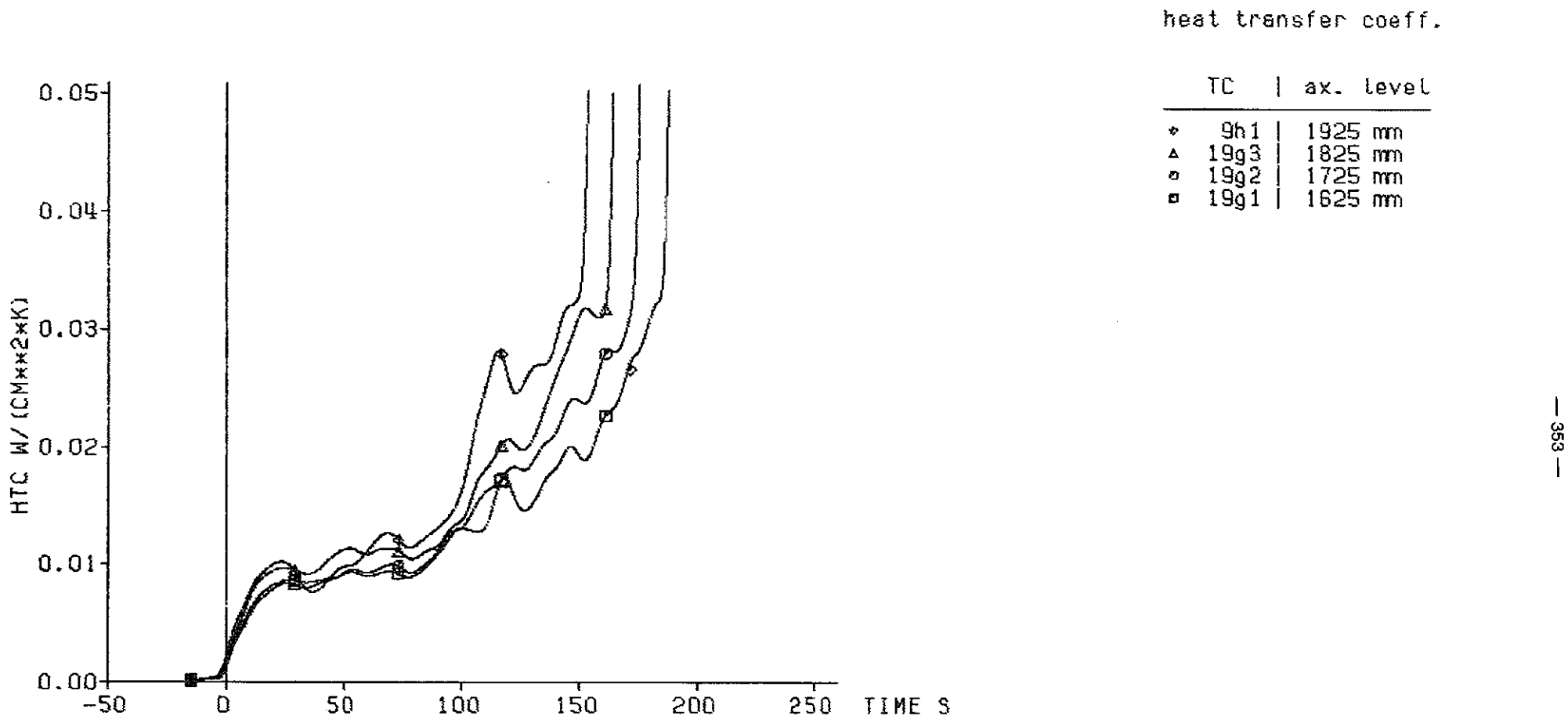


decay heat	120% ANS standard
flooding rate (cold)	5.71 cm/s
system pressure	6.21 bar
feedwater temperature	40 deg C

bypass
======

KfK KIRB

Fig. 318 FEBA: 5x5 ROD BUNDLE, TEST SERIES 3, TEST-No. 235

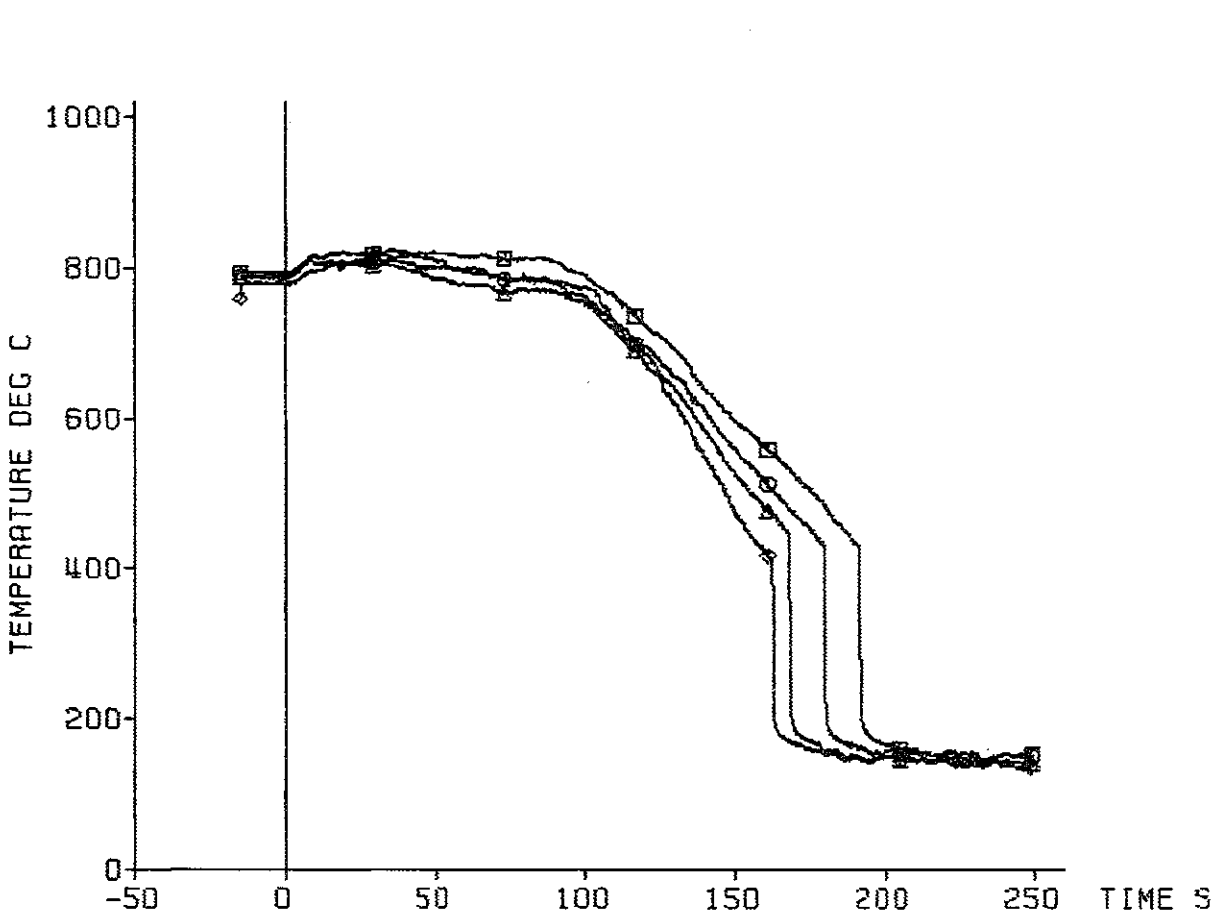


decay heat	120% ANS standard
flooding rate (cold)	5.71 cm/s
system pressure	6.21 bar
feedwater temperature	40 deg C

bypass
======

KfK IRB

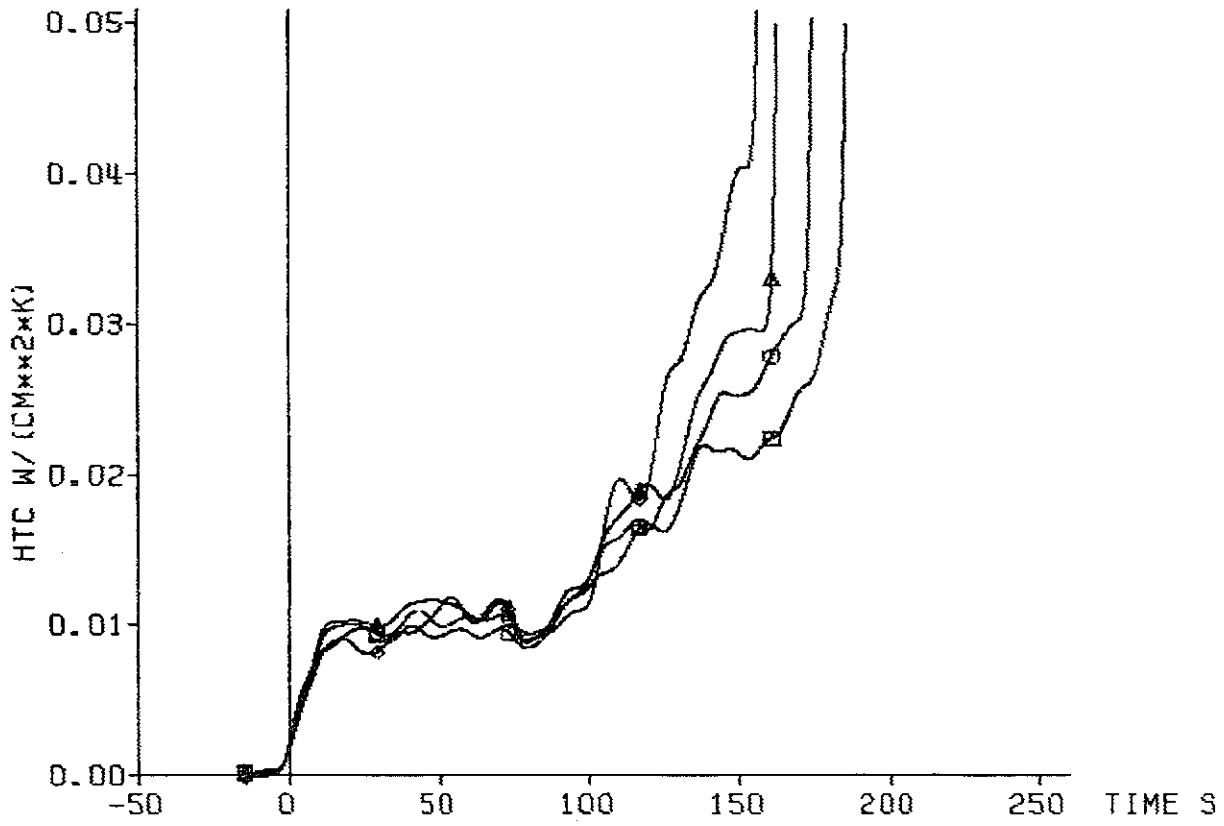
Fig. 319 FEBA: 5x5 ROD BUNDLE, TEST SERIES 3, TEST-No. 235



decay heat	120% ANS standard	blockage
flooding rate (cold)	5.71 cm/s	========
system pressure	6.21 bar	
feedwater temperature	40 deg C	

KfK IRB

Fig. 320 FEBA: 5x5 ROD BUNDLE, TEST SERIES 3, TEST-No. 235

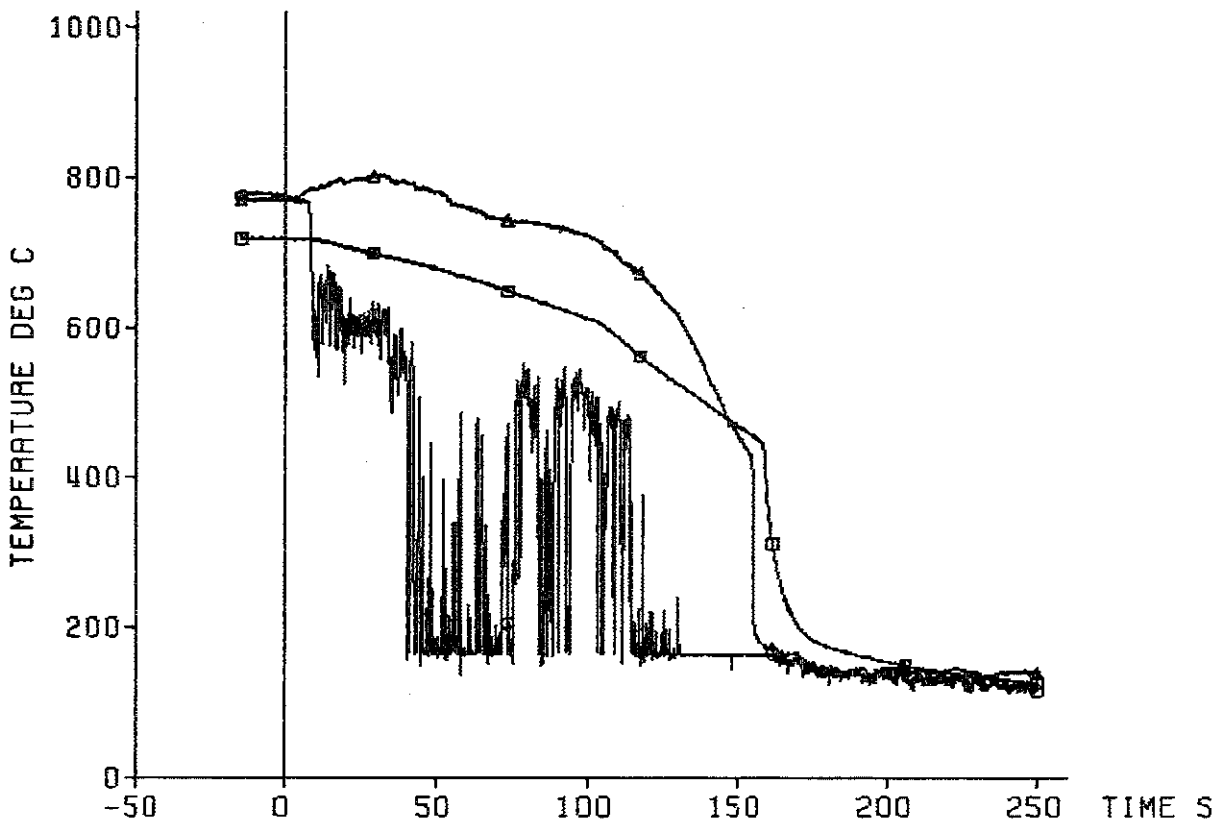


decay heat	120% ANS standard
flooding rate (cold)	5.71 cm/s
system pressure	6.21 bar
feedwater temperature	40 deg C

blockage
========

KfK IRB

Fig. 321 FEBA: 5x5 ROD BUNDLE, TEST SERIES 3, TEST-No. 235

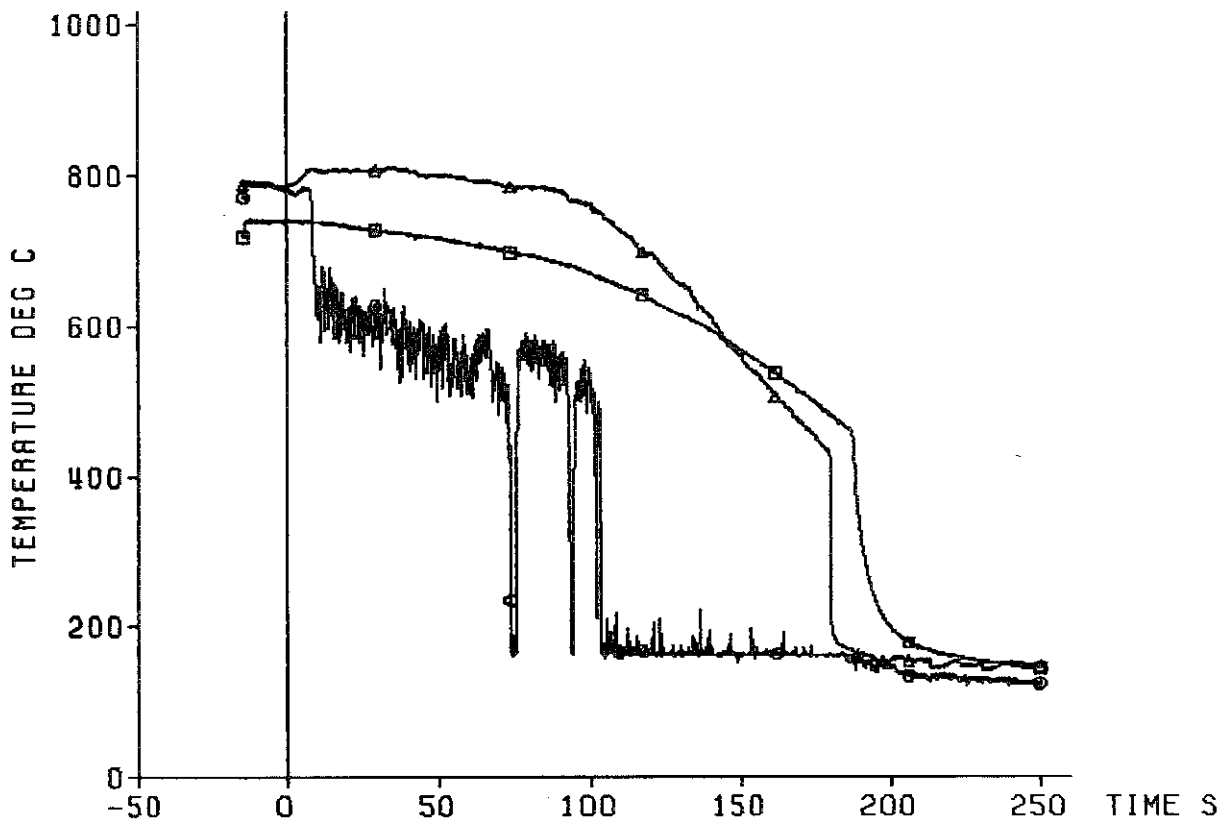


decay heat	120% ANS standard
flooding rate (cold)	5.71 cm/s
system pressure	6.21 bar
feedwater temperature	40 deg C

blockage
========

KfK IRB

Fig. 322 FEBA: 5x5 ROD BUNDLE, TEST SERIES 3, TEST-No. 235

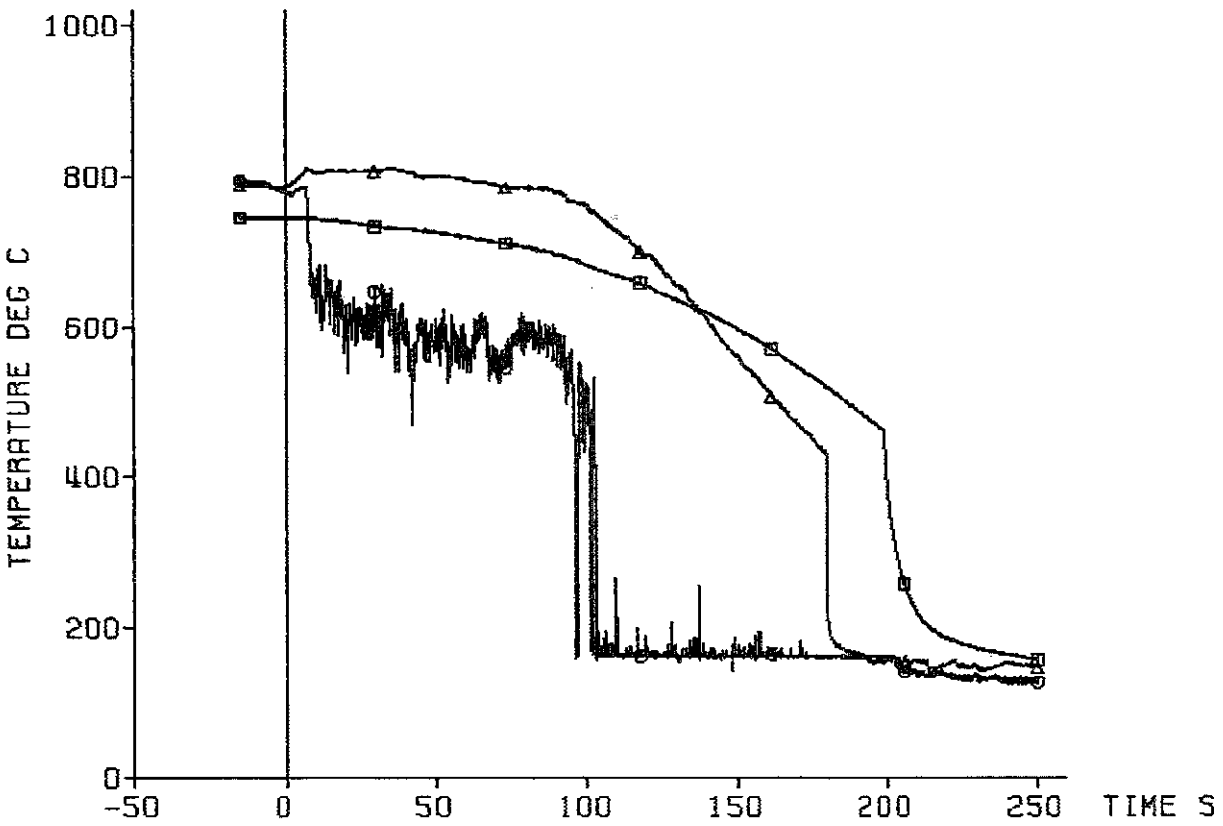


decay heat	120% ANS standard
flooding rate (cold)	5.71 cm/s
system pressure	6.21 bar
feedwater temperature	40 deg C

blockage
========

KfK IRB

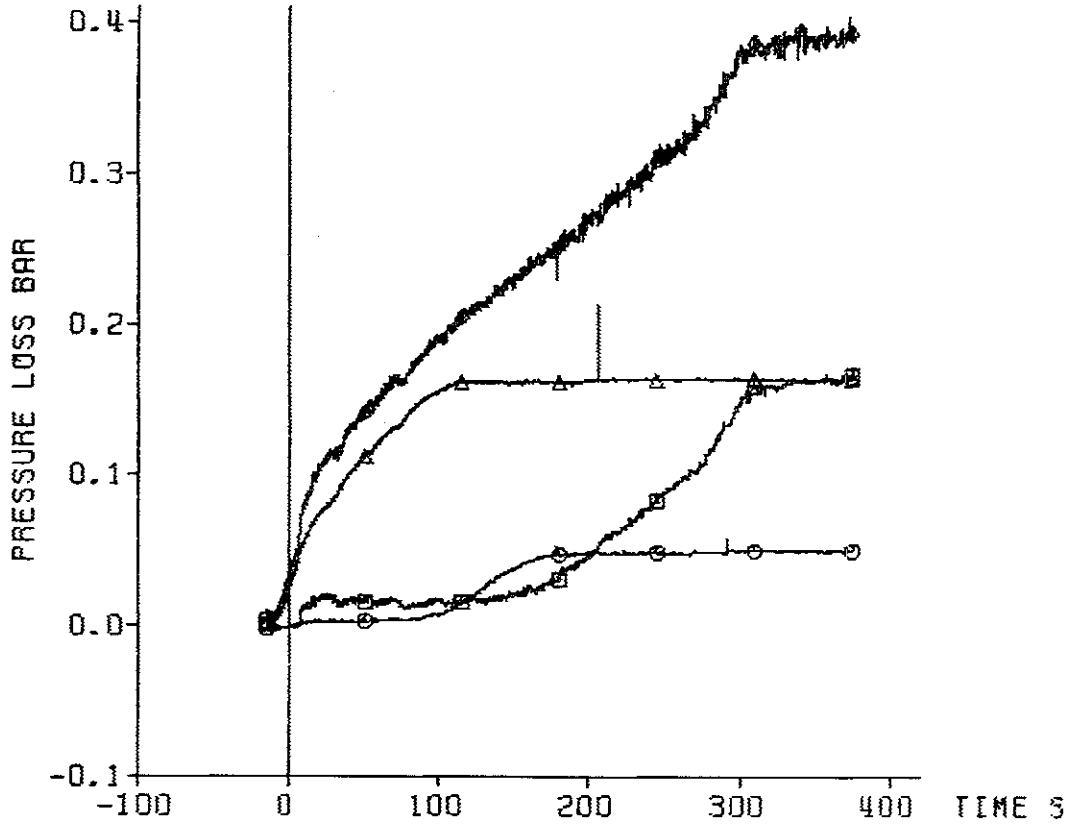
Fig. 323 FEBA: 5x5 ROD BUNDLE, TEST SERIES 3, TEST-No. 235



decay heat	120% ANS standard	blockage
flooding rate (cold)	5.71 cm/s	========
system pressure	6.21 bar	
feedwater temperature	40 deg C	

KfK IRB

Fig. 324 FEBA: 5x5 ROD BUNDLE, TEST SERIES 3, TEST-No. 235



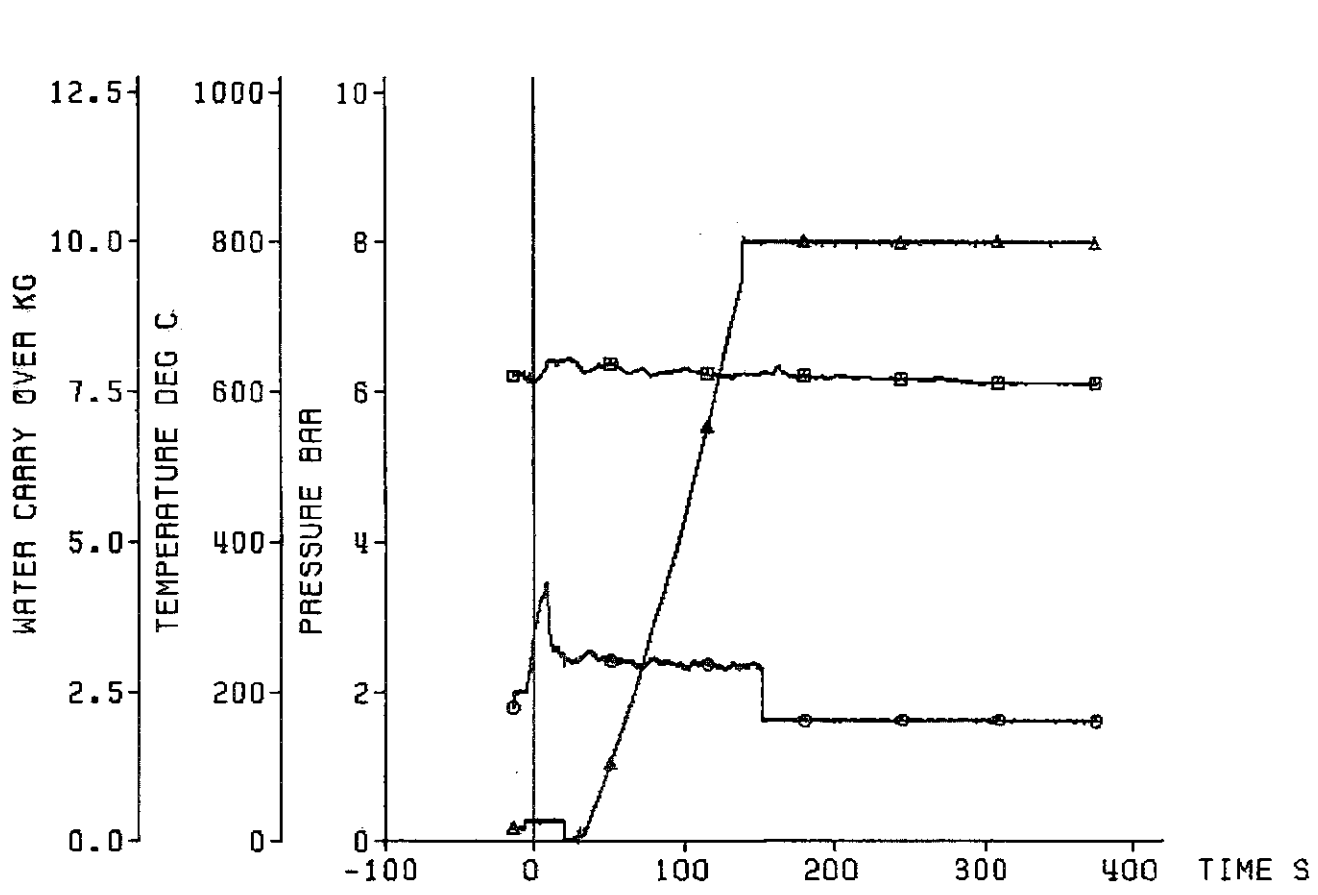
pressure loss
along the test section:

◆ total length: 4196 mm
△ lower part: 1711 mm
○ middle part: 545 mm
□ upper part: 1940 mm

decay heat	120% ANS standard
flooding rate (cold)	5.71 cm/s
system pressure	6.21 bar
feedwater temperature	40 deg C

KfK KIRB

Fig. 325 FEBA: 5x5 ROD BUNDLE, TEST SERIES 3, TEST-No. 235



decay heat	120% ANS standard
flooding rate (cold)	5.71 cm/s
system pressure	6.21 bar
feedwater temperature	40 deg C

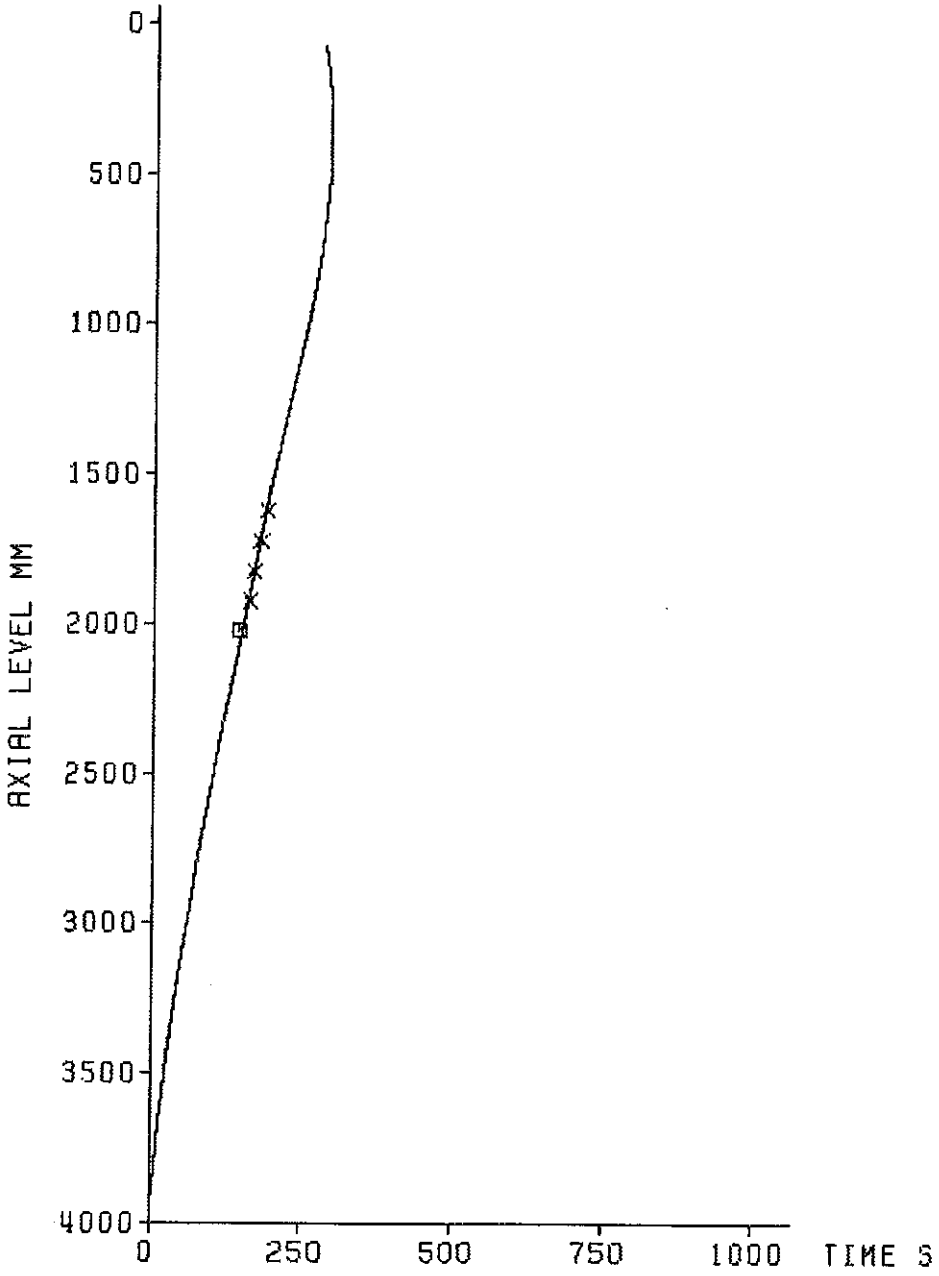
KfK IRB

Fig. 326 FEBA: 5x5 ROD BUNDLE, TEST SERIES 3, TEST-No. 235

axial position of the quench front

□ rewetting of the sleeve at the bundle midplane

× rewetting of the rod downstream of the blockage



decay heat	120% ANS standard
flooding rate (cold)	5.71 cm/s
system pressure	6.21 bar
feedwater temperature	40 deg C

KfK IRB

Fig. 327 FEBA: 5x5 ROD BUNDLE TEST SERIES 3, TEST-No. 235

TEST SERIES III

Investigation of the Effects of a 90% Flow Blockage With Bypass, Blockage at the Bundle Midplane of 3x3 Rods Placed in the Corner of the 5x5 Rod Bundle,
Without Grid Spacer at the Bundle Midplane

Channel Listing and Data Identification for Test No. 235 Through 243

Channel No.	Data Identification Type	Location	Unit	Remarks
1	Cladding Temperature	18a4.3860[1]	°C	
2	Cladding Temperature	18a3.3315	°C	
3	Cladding Temperature	18a2.2770	°C	
4	Cladding Temperature	18a1.2225	°C	
5	Cladding Temperature	12b4.1680	°C	
6	Cladding Temperature	12b3.1135	°C	
7	Cladding Temperature	12b2. 590	°C	
8	Cladding Temperature	12b1. 45	°C	
9	Cladding Temperature	17h4.2225	°C	
10	Cladding Temperature	17h3.2125	°C	
11	Cladding Temperature	17h2.2025	°C	
12	Cladding Temperature	17h1.1925	°C	
13	Fluid Temperature	TF[2] 3315	°C	
14	Fluid Temperature	TFS[3] 2380	°C	
15	Fluid Temperature	TF 1725	°C	
16	Fluid Temperature	TFS 485	°C	
17	Housing Temperature	TK[4] 3315	°C	
18	Housing Temperature	TK 2235	°C	
19	Housing Temperature	TK 1725	°C	
20	Housing Temperature	TK 590	°C	

TEST SERIES III

Channel No.	Data Identification Type	Location	Unit	Remarks
21	Fluid Temperature	Lower Plenum	°C	
22	Water Level Detector	4012	°C	Heated + Unheated TC's
23	Feedwater Temperature		°C	
24	Fluid Temperature	Upper Plenum	°C	
25	Room Temperature		°C	
26	Cladding Temperature	22f4.2425[1]	°C	
27	Cladding Temperature	22f3.2325	°C	
28	Cladding Temperature	22f2.2225	°C	
29	Cladding Temperature	22f1.2125	°C	
30	Cladding Temperature	21e4.2225	°C	
31	Cladding Temperature	21e3.2175	°C	
32	Cladding Temperature	21e2.2125	°C	
33	Cladding Temperature	21e1.2075	°C	
34	Cladding Temperature	19g4.1925	°C	
35	Cladding Temperature	19g3.1825	°C	
36	Cladding Temperature	19g2.1725	°C	
37	Cladding Temperature	19g1.1625	°C	
38	Cladding Temperature	16g4.1925	°C	
39	Cladding Temperature	16g3.1825	°C	
40	Cladding Temperature	16g2.1725	°C	
41	Cladding Temperature	16g1.1625	°C	
42	Cladding Temperature	15a4.3860	°C	
43	Cladding Temperature	15a3.3315	°C	
44	Cladding Temperature	15a2.2770	°C	
45	Cladding Temperature	15a1.2225	°C	
46	Cladding Temperature	14e4.2225	°C	
47	Cladding Temperature	14e3.2175	°C	
48	Cladding Temperature	14e2.2125	°C	
49	Cladding Temperature	14e1.2075	°C	

TEST SERIES III

Channel No.	Data Identification Type	Location	Unit	Remarks
50	Cladding Temperature	13d3.2025[1]	°C	
51	Cladding Temperature	13d2.2025	°C	
52	Cladding Temperature	13d1.2025	°C	
53	Cladding Temperature	10f4.2425	°C	
54	Cladding Temperature	10f3.2325	°C	
55	Cladding Temperature	10f2.2225	°C	
56	Cladding Temperature	10f1.2125	°C	
57	Cladding Temperature	9h4.2225	°C	
58	Cladding Temperature	9h3.2125	°C	
59	Cladding Temperature	9h2.2025	°C	
60	Cladding Temperature	9h1.1925	°C	
61	Cladding Temperature	8d4.2025	°C	
62	Cladding Temperature	8d3.2025	°C	
63	Cladding Temperature	8d2.2025	°C	
64	Cladding Temperature	8d1.2025	°C	
65	Cladding Temperature	7f4.2425	°C	
66	Cladding Temperature	7f3.2325	°C	
67	Cladding Temperature	7f2.2225	°C	
68	Cladding Temperature	7f1.2125	°C	
69	Sleeve Temperature	TH[5] 13.2025	°C	
70	Sleeve Temperature	TH 17.2025	°C	
71	Sleeve Temperature	TH 21.2025	°C	
72	----------		-	Open
73	Cladding Temperature	3b4.1680	°C	
74	Cladding Temperature	3b3.1135	°C	
75	Cladding Temperature	3b2. 590	°C	
76	Cladding Temperature	3b1. 45	°C	

TEST SERIES III

Channel No.	Data Identification Type	Location	Unit	Remarks
77	Cladding Temperature	2c4.4025[1]	°C	
78	Cladding Temperature	2c3.3925	°C	
79	Cladding Temperature	2c2.3825	°C	
80	Cladding Temperature	2c1.3725	°C	
81	Electrical Power Input	8 Rods	kW	Rods No. 1 Through 8
82	Electrical Power Input	8 Rods	kW	Rods No. 9 Through 16
83	Electrical Power Input	9 Rods	kW	Rods No. 17 Through 25
84	Housing Temperature TK[4]	4005	°C	
85	Housing Temperature TK	3915	°C	
86	Housing Temperature TK	3820	°C	
87	Housing Temperature TK	3725	°C	
88	Housing Temperature TK	3018	°C	
89	Housing Temperature TK	2770	°C	
90	Housing Temperature TK	2025	°C	
91	Housing Temperature TK	1925	°C	
92	Housing Temperature TK	1825	°C	
93	Housing Temperature TK	1625	°C	
94	Housing Temperature TK	1135	°C	
95	Housing Temperature TK	835	°C	
96	Housing Temperature TK	45	°C	
97	Fluid Temperature TF[2]	3038	°C	
98	Fluid Temperature TFS[3]	2425	°C	
99	Fluid Temperature TF	2770	°C	
100	Fluid Temperature TF	2325	°C	
101	----------		-	Open
102	----------		-	Open
103	Fluid Temperature TF	1925	°C	
104	Fluid Temperature TF	1135	°C	
105	Fluid Temperature TF	1625	°C	

TEST SERIES III

Channel No.	Data Identification Type	Location	Unit	Remarks
106	Cladding Temperature	24c4.4025[1]	°C	
107	Cladding Temperature	24c3.3925	°C	
108	Cladding Temperature	24c2.3825	°C	
109	Cladding Temperature	24c1.3725	°C	
110	Time (10 Scans/s)		s	t = 0: Start of Reflooding
111	Pressure in Lower Plenum	4091	bar	
112	Pressure in Upper Plenum	-105	bar	
113	Pressure in Buffer		bar	
114	Bundle Power		kW	Channels: 81 + 82 + 83
115	Flooding Velocity (cold)		cm/s	
116	Water Carry Over Collected		kg	Downstream of Bundle Exit
117	Pressure Diff.	1835 and -105 mm	bar	
118	Measured	2380 and 1835 mm	bar	
119	Between	4091 and 2380 mm	bar	
120	Axial Level	4091 and -105 mm	bar	Values Measured Separately

1) TC's of 0.5 mm diameter embedded in rod cladding. Measuring position: Example: rod No. = 18, type of rod instrumention = a, TC No. = 4, axial level = 3860 mm, referenced to the top flange of the bundle.

2) TF = TC's of 0.25 mm diameter (bare).
TC's placed in subchannel surrounded by rods No. 12, 17, 16 and 11.

3) TFS = TC's of 0.25 mm diameter protected by a radiation shielding.
TC's placed in subchannel surrounded by rods No. 12, 17, 16 and 11.

4) TK = TC's of 0.5 mm diameter placed in the wall of the bundle housing of of 6.5 mm thickness.

5) TH = TC's of 0.5 mm diameter embedded in sleeve. Measuring position: Example: rod No. 13, axial level = 2025 mm.

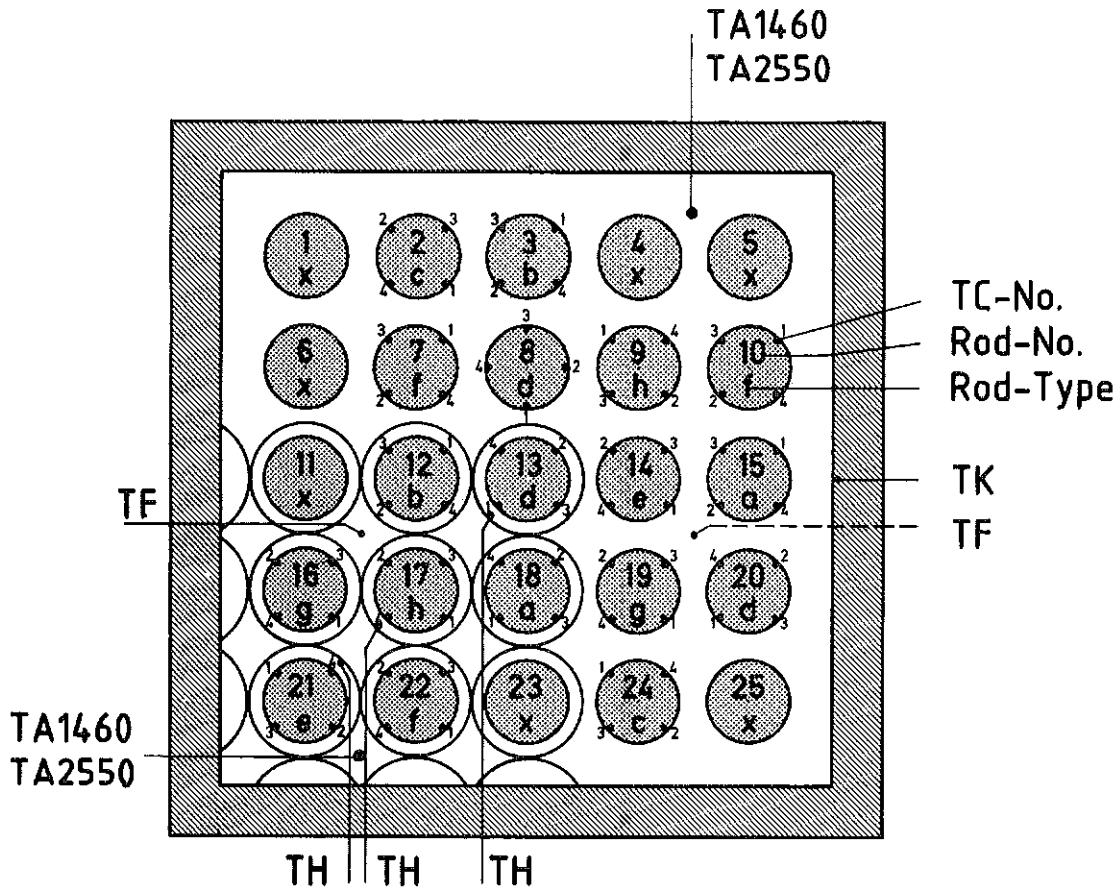
TEST SERIES IV

Test No.	Flooding Velocity (cold) cm/s	System Pressure bar	Feedwater Temp.[1] °C 0-30 s	Feedwater Temp.[1] °C End	Bundle Power[2] kW 0 s	Bundle Power[2] kW Transient	Remarks
267	2.2	4.0	69	45	200	120% ANS	Figs. 330 Through 353
262	3.8	2.0	54	43	200	120% ANS	Figs. 354 Through 377
263	3.8	3.9	61	43	200	120% ANS	Figs. 378 Through 401
268	3.8	5.9	76	44	200	120% ANS	Figs. 402 Through 425
261	5.7	2.0	57	42	200	120% ANS	Figs. 426 Through 449
264	5.8	3.9	63	41	200	120% ANS	Figs. 450 Through 473
269	5.7	5.9	73	44	200	120% ANS	Figs. 474 Through 497
272	3.0	4.0	57	41	200	120% ANS	Data Not Plotted
273	3.0	4.0	57	41	200	120% ANS	Data Not Plotted
266	3.8	3.9	125	45	200	120% ANS	Data Not Plotted
270	9.5	3.8	57	41	200	120% ANS	Data Not Plotted

1) Measured in the lower plenum

2) Decay heat transient corresponding 120% ANS Standard 40 s after shutdown of the reactor

Table 4 FEBA 5x5 rod bundle: Main test parameters of test series IV



Rod Type	TC No.	Axial Level mm
a	1	2225
	2	2770
	3	3315
	4	3860
b	1	45
	2	590
	3	1135
	4	1680
c	1	3725
	2	3825
	3	3925
	4	4025
d	1	2025
	2	2025
	3	2025
	4	2025

Rod Type	TC No.	Axial Level mm
e	1	2075
	2	2125
	3	2175
	4	2225
f	1	2125
	2	2225
	3	2325
	4	2425
g	1	1625
	2	1725
	3	1825
	4	1925
h	1	1925
	2	2025
	3	2125
	4	2225

Rod Type	TC No.	Axial Level mm
x	without TC's	

Fig. 328 5x5 rod bundle: Radial and axial location of cladding, sleeve, spacer, fluid and housing TC's for test series IV

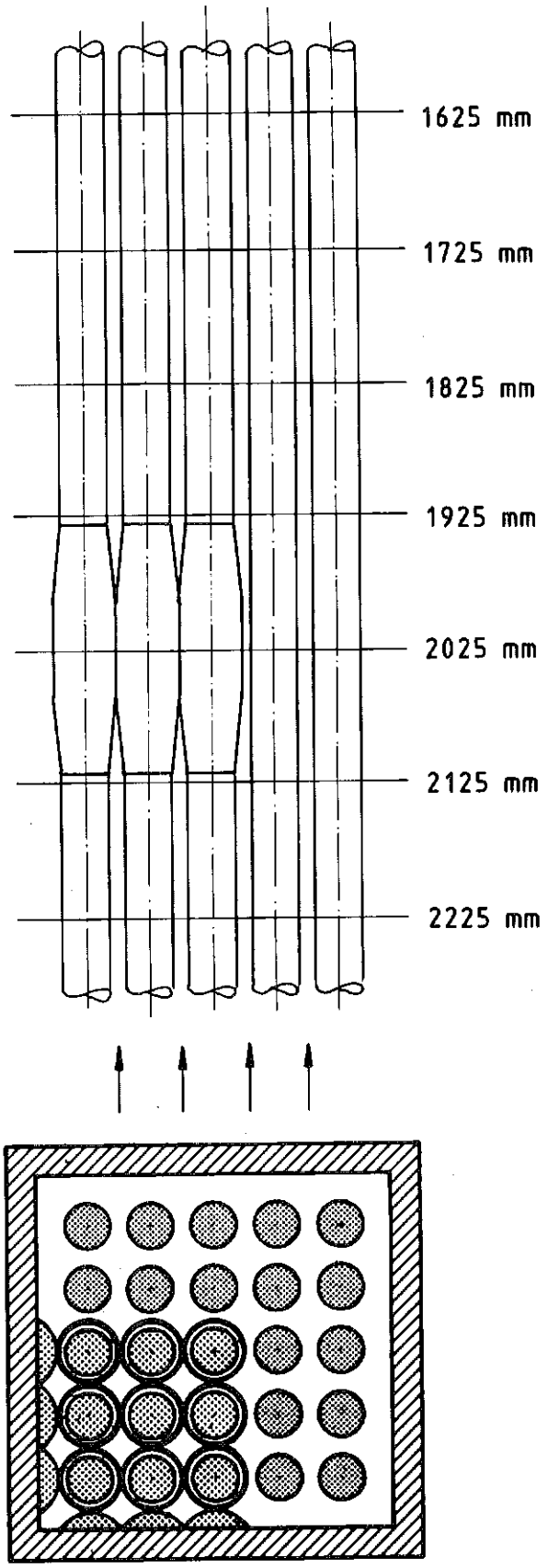
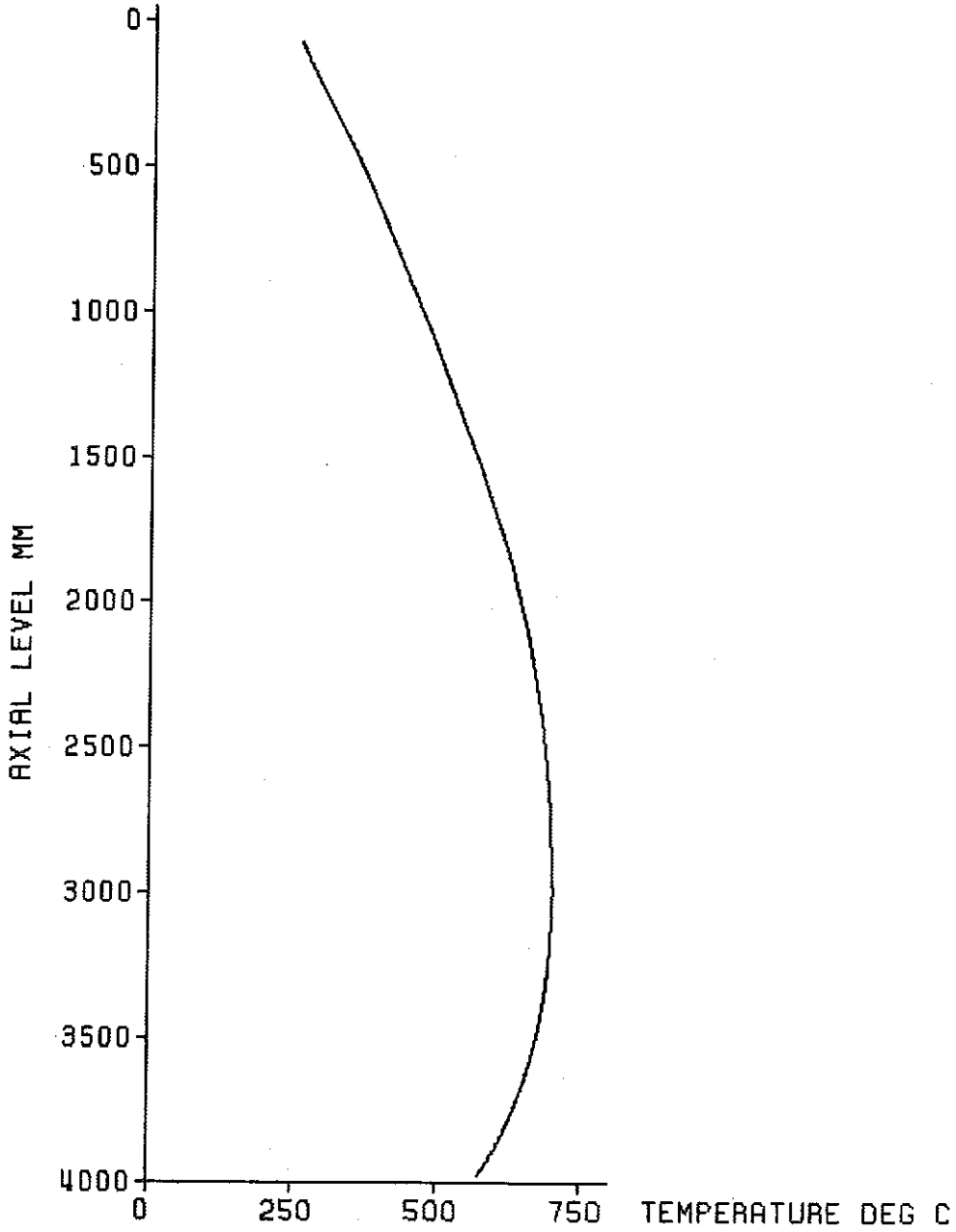


Fig. 329 5x5 rod bundle: Layout of the bundle geometry of test series IV

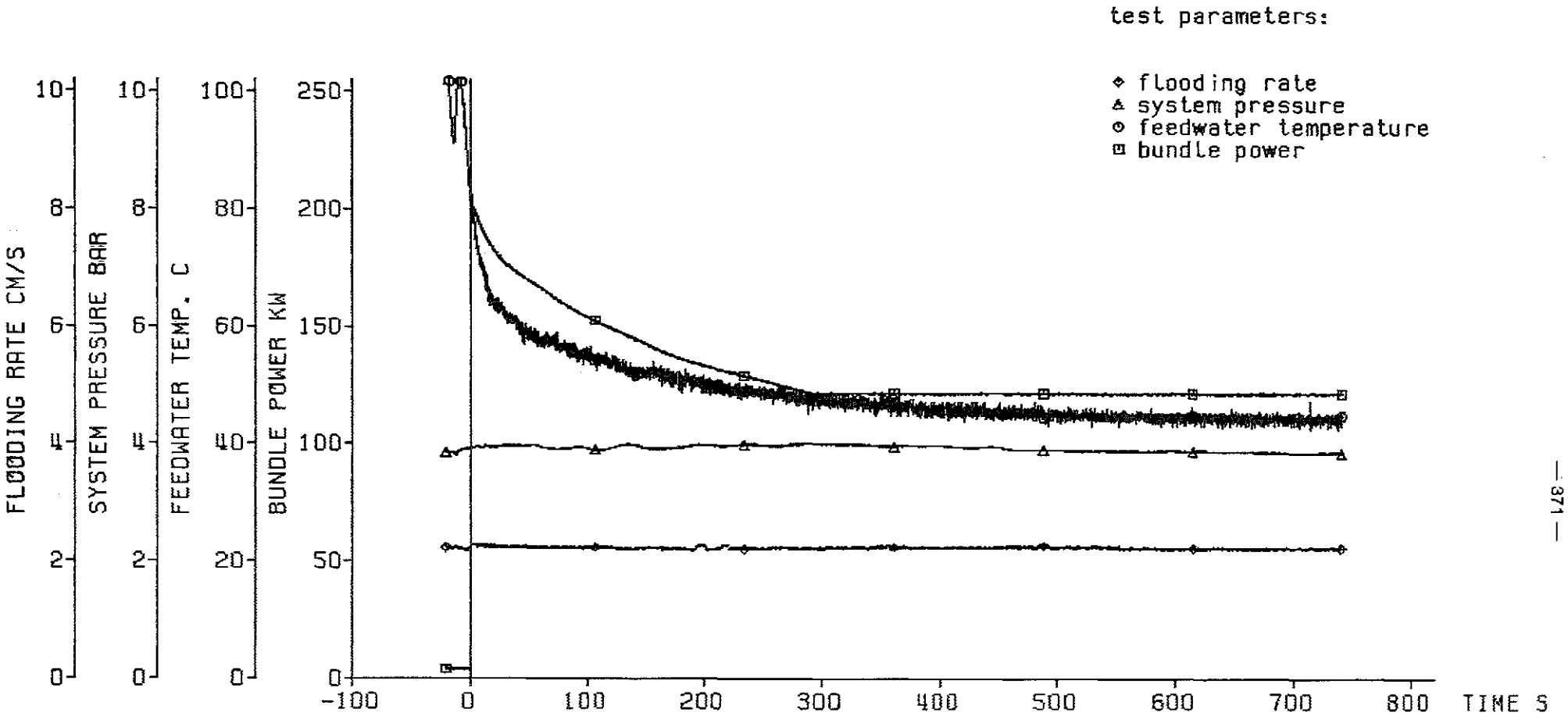
initial axial temperature profile of the cladding



decay heat	120% ANS standard
flooding rate (cold)	2.24 cm/s
system pressure	3.96 bar
feedwater temperature	40 deg C

KfK IRB

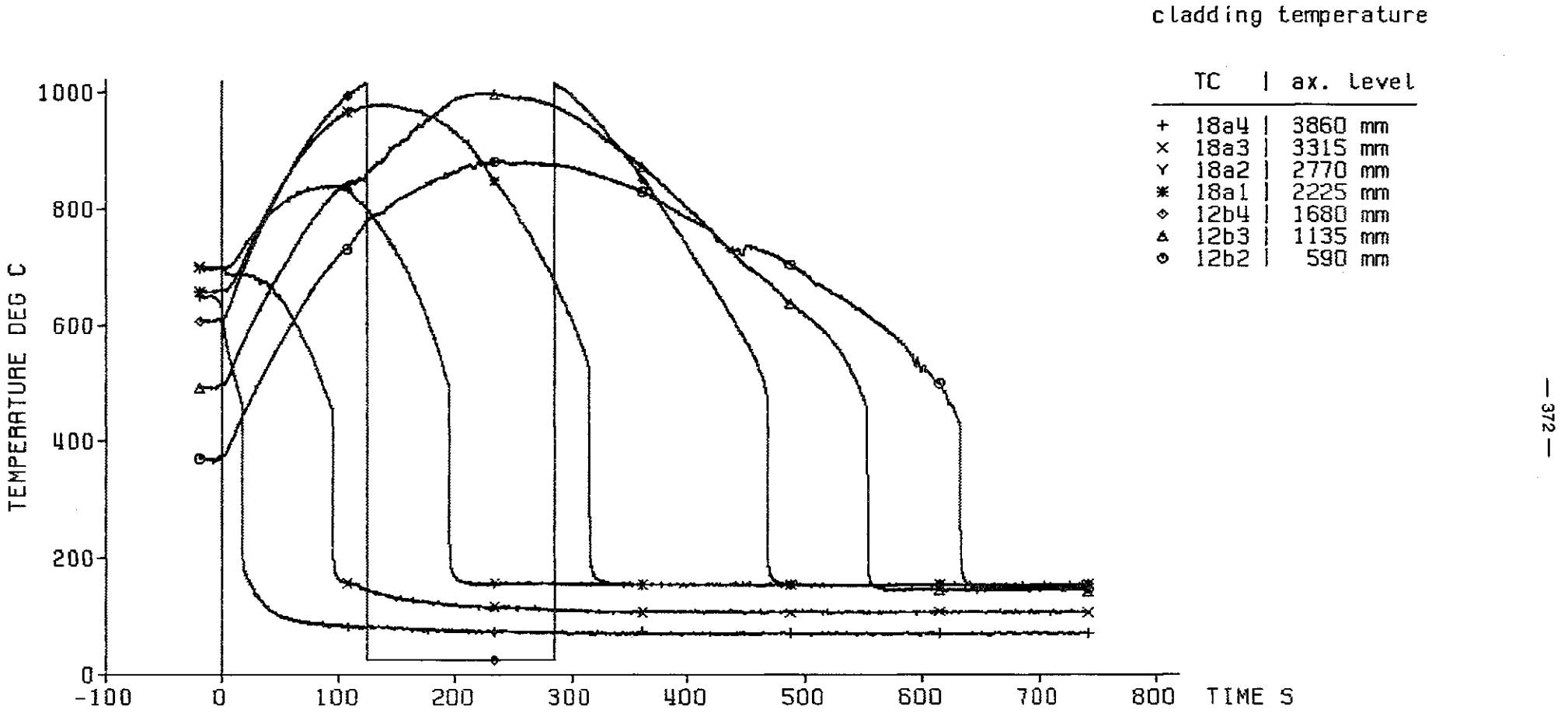
Fig. 330 FEBA: 5x5 ROD BUNDLE TEST SERIES 4, TEST-No. 267



decay heat	120% ANS standard
flooding rate (cold)	2.24 cm/s
system pressure	3.96 bar
feedwater temperature	40 deg C

KfK IRB

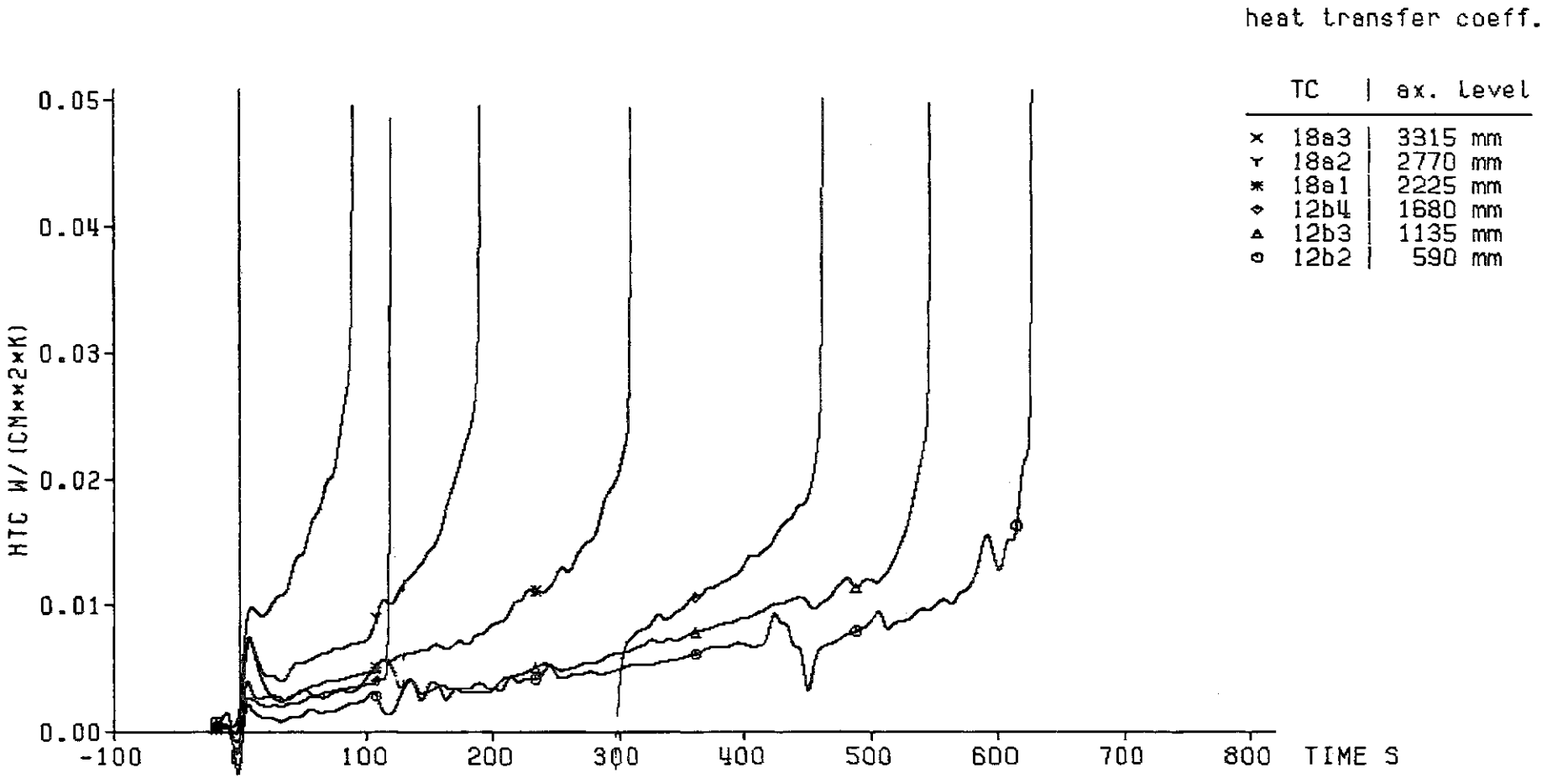
Fig. 331 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 267



decay heat	120% ANS standard
flooding rate (cold)	2.24 cm/s
system pressure	3.96 bar
feedwater temperature	40 deg C

KfK IRB

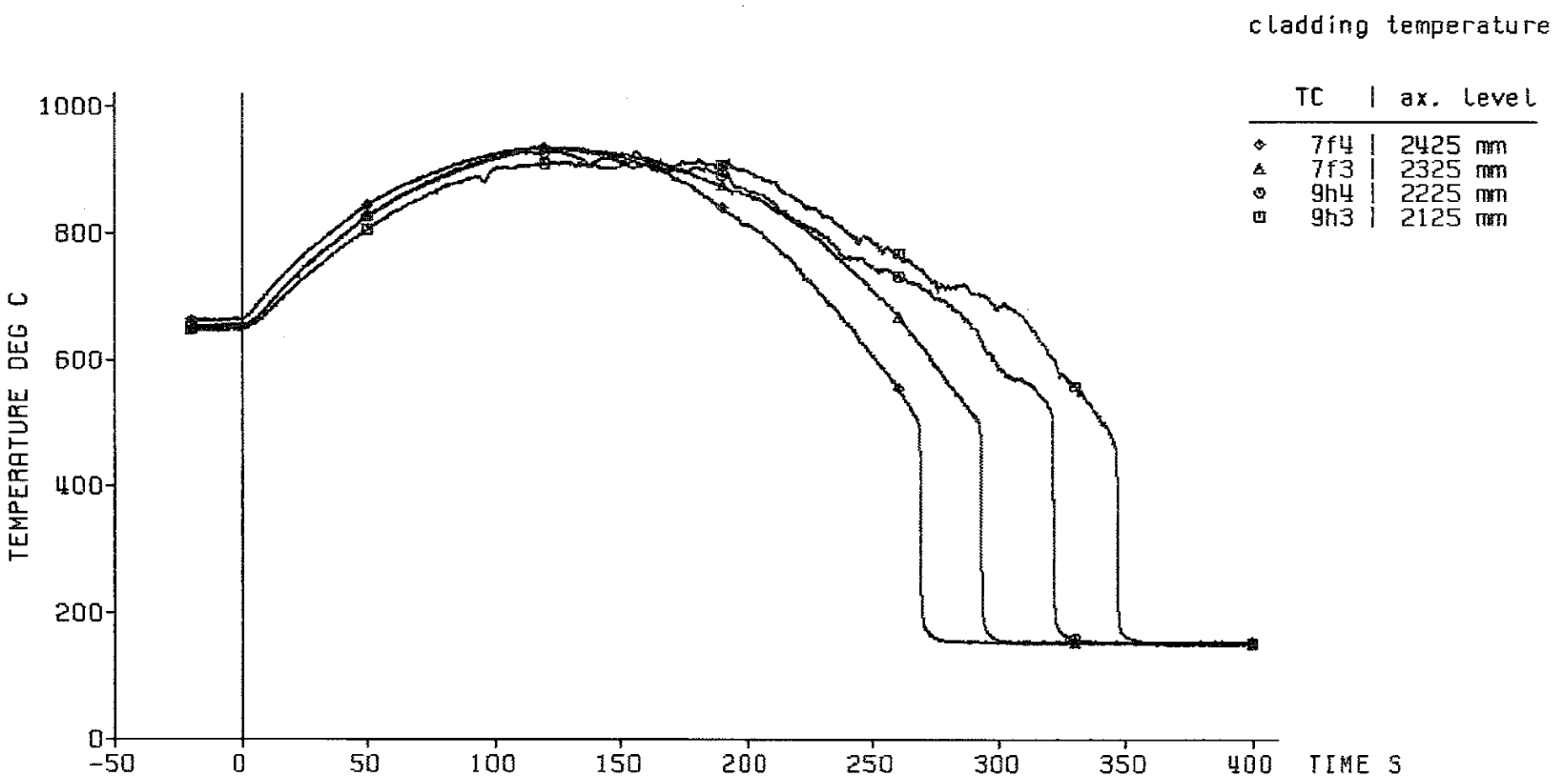
Fig. 332 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 267



decay heat	120% ANS standard
flooding rate (cold)	2.24 cm/s
system pressure	3.96 bar
feedwater temperature	40 deg C

KfK IRB

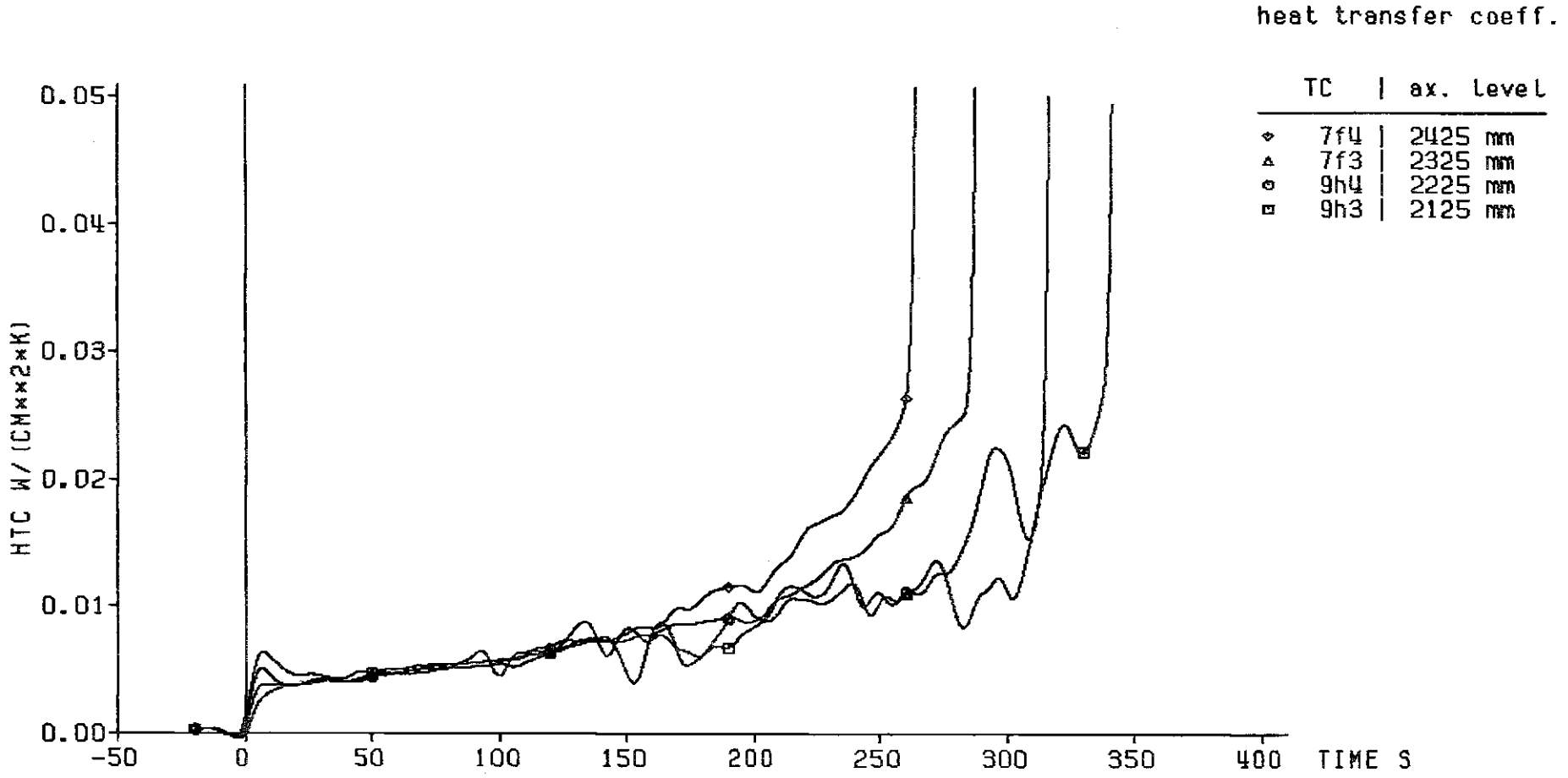
Fig. 333 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 267



decay heat	120% ANS standard	bypass
flooding rate (cold)	2.24 cm/s	======
system pressure	3.96 bar	
feedwater temperature	40 deg C	

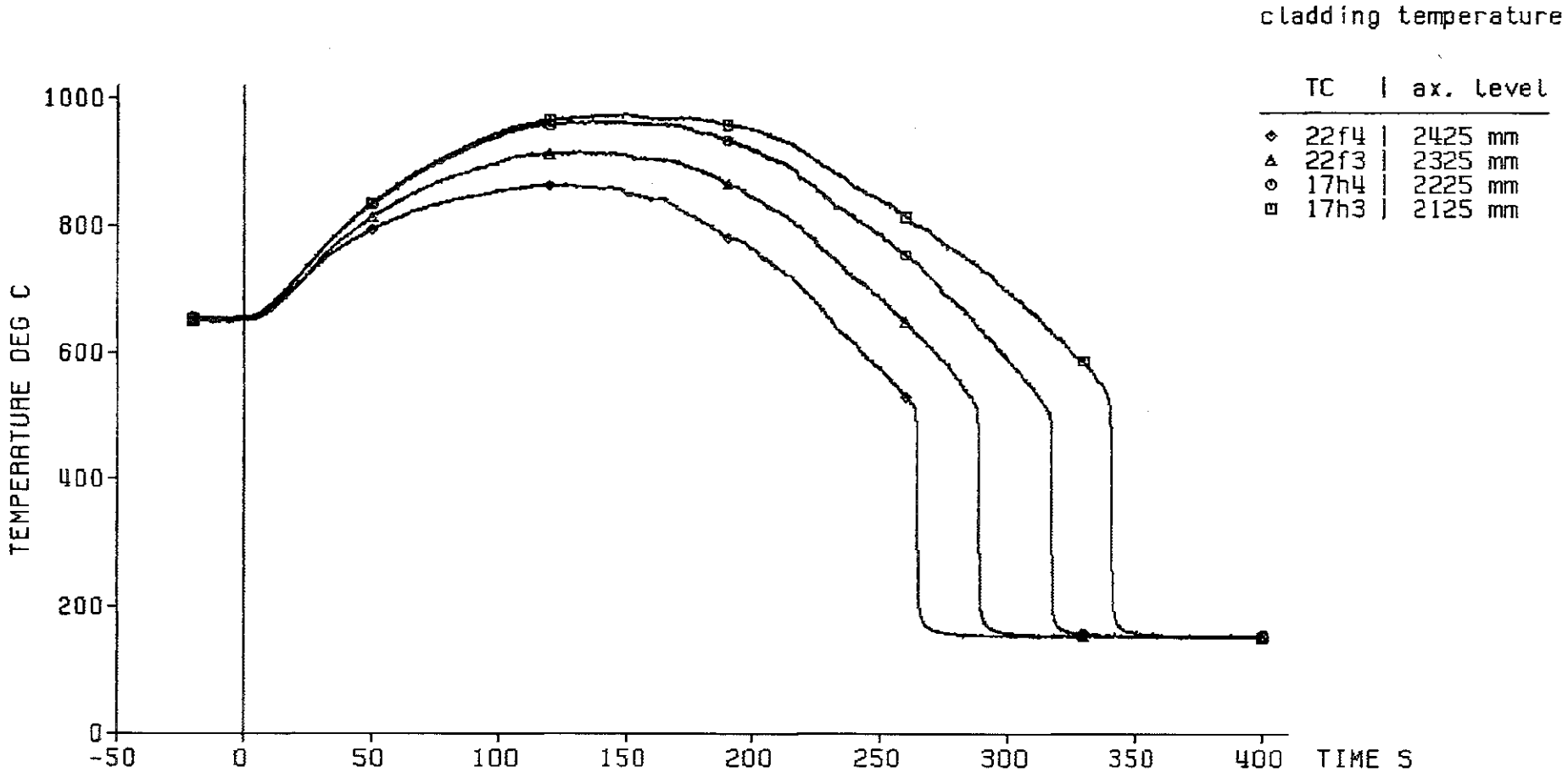
KfK IRB

Fig. 334 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 267



decay heat	120% ANS standard	bypass
flooding rate (cold)	2.24 cm/s	======
system pressure	3.96 bar	
feedwater temperature	40 deg C	

Fig. 335 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 267

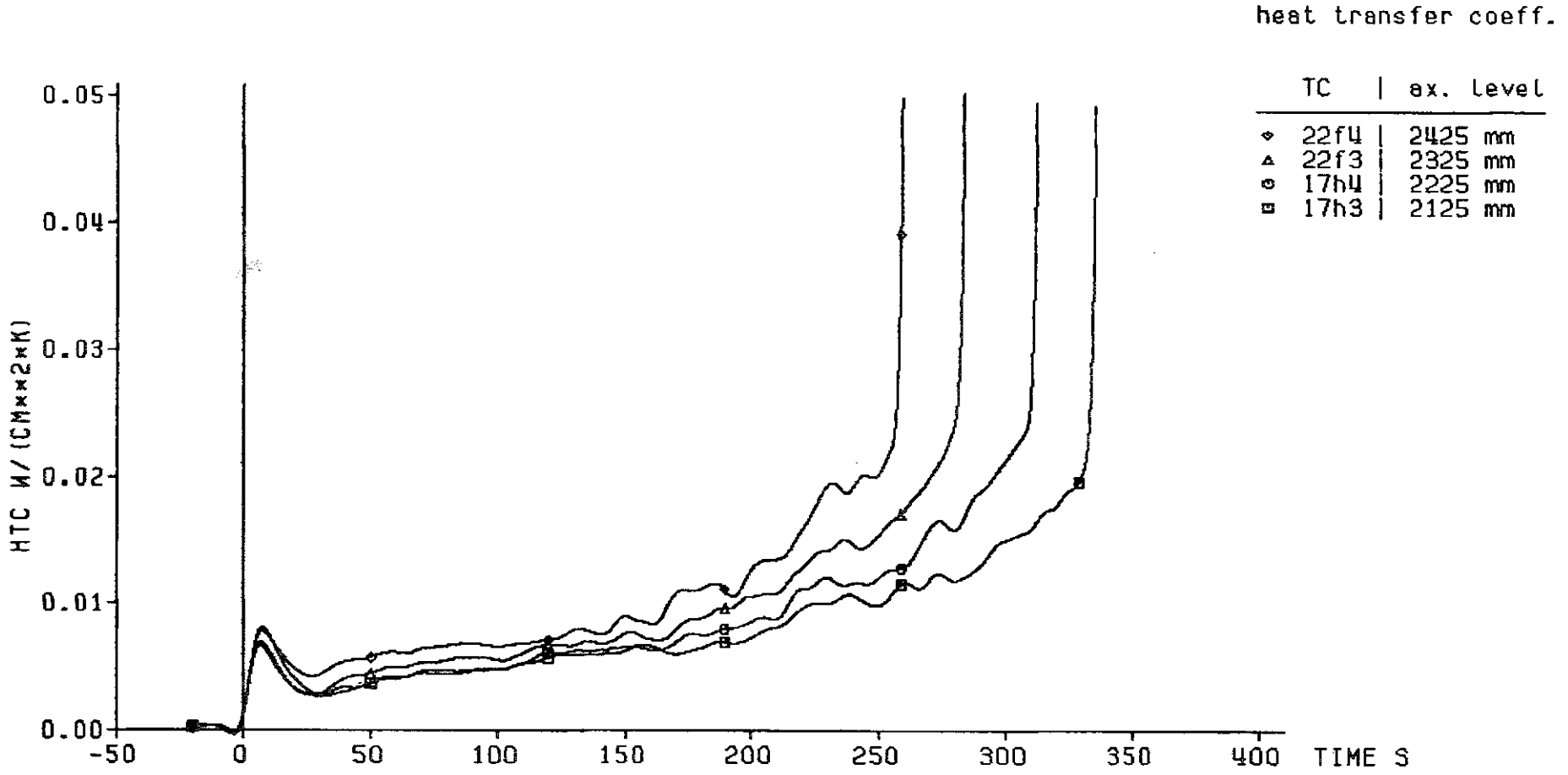


decay heat 120% ANS standard
flooding rate (cold) 2.24 cm/s
system pressure 3.96 bar
feedwater temperature 40 deg C

blockage
========

KfK IRB

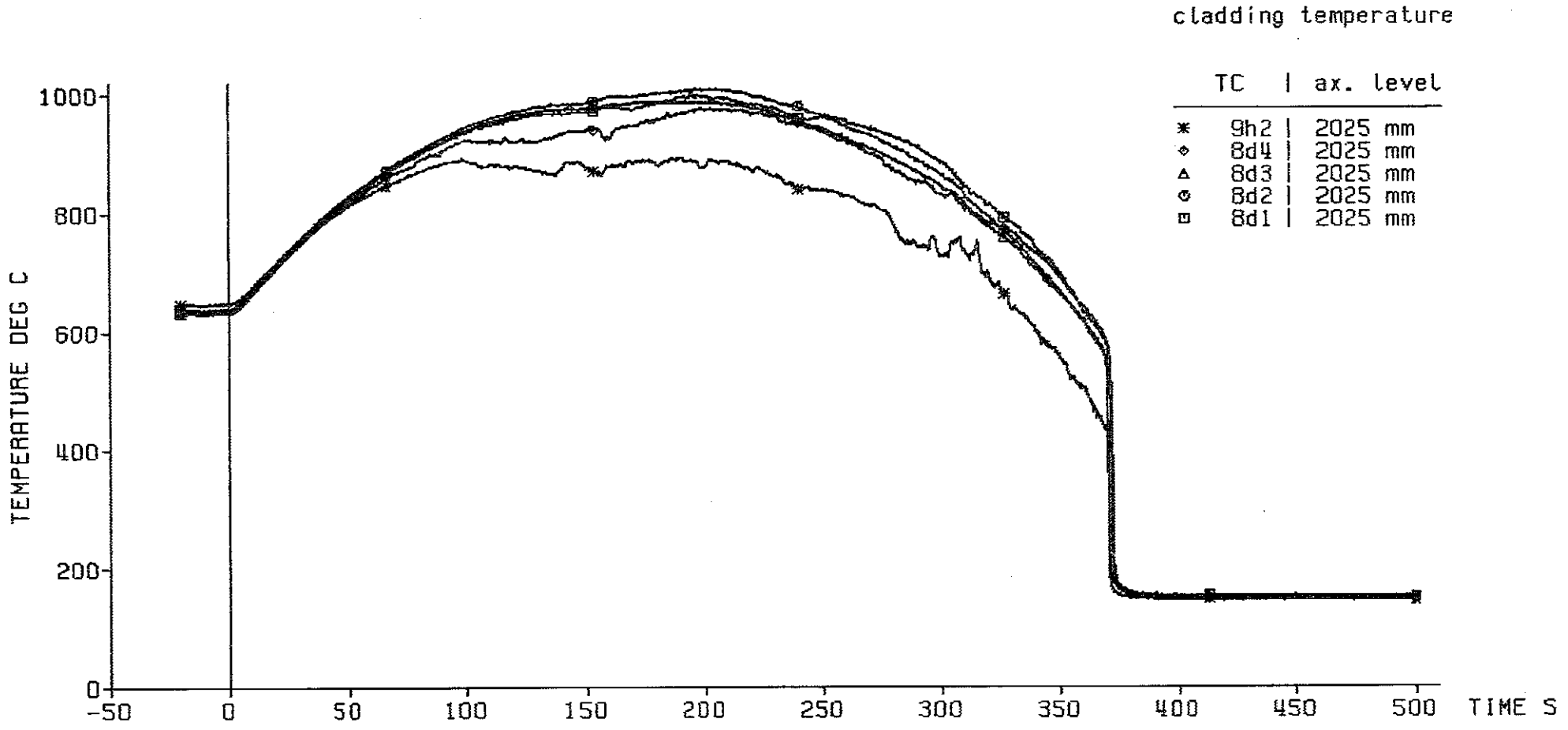
Fig. 336 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 267



decay heat	120% ANS standard	blockage
flooding rate (cold)	2.24 cm/s	========
system pressure	3.96 bar	
feedwater temperature	40 deg C	

KfK IRB

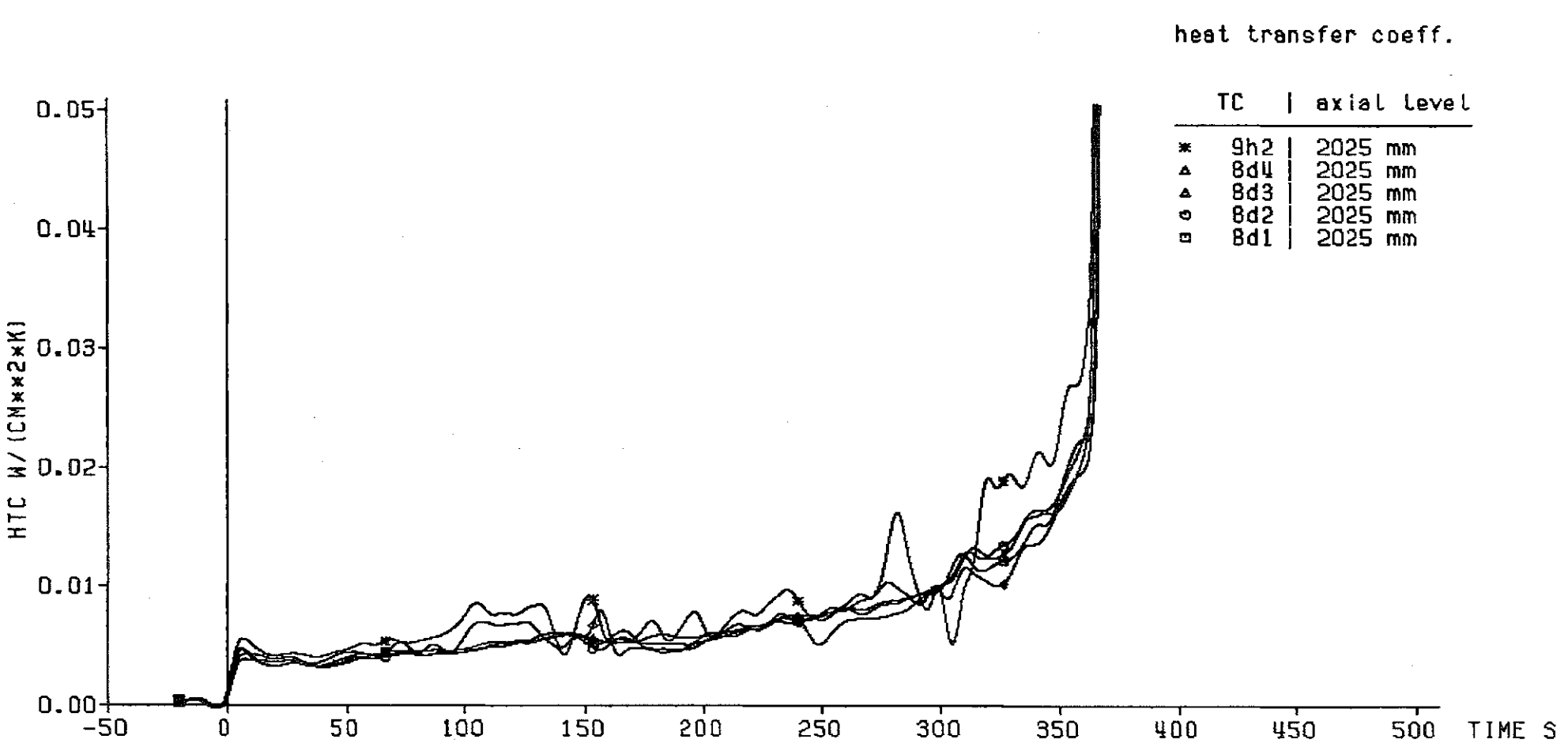
Fig. 337 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 267



decay heat	120% ANS standard	bypass
flooding rate (cold)	2.24 cm/s	======
system pressure	3.96 bar	
feedwater temperature	40 deg C	

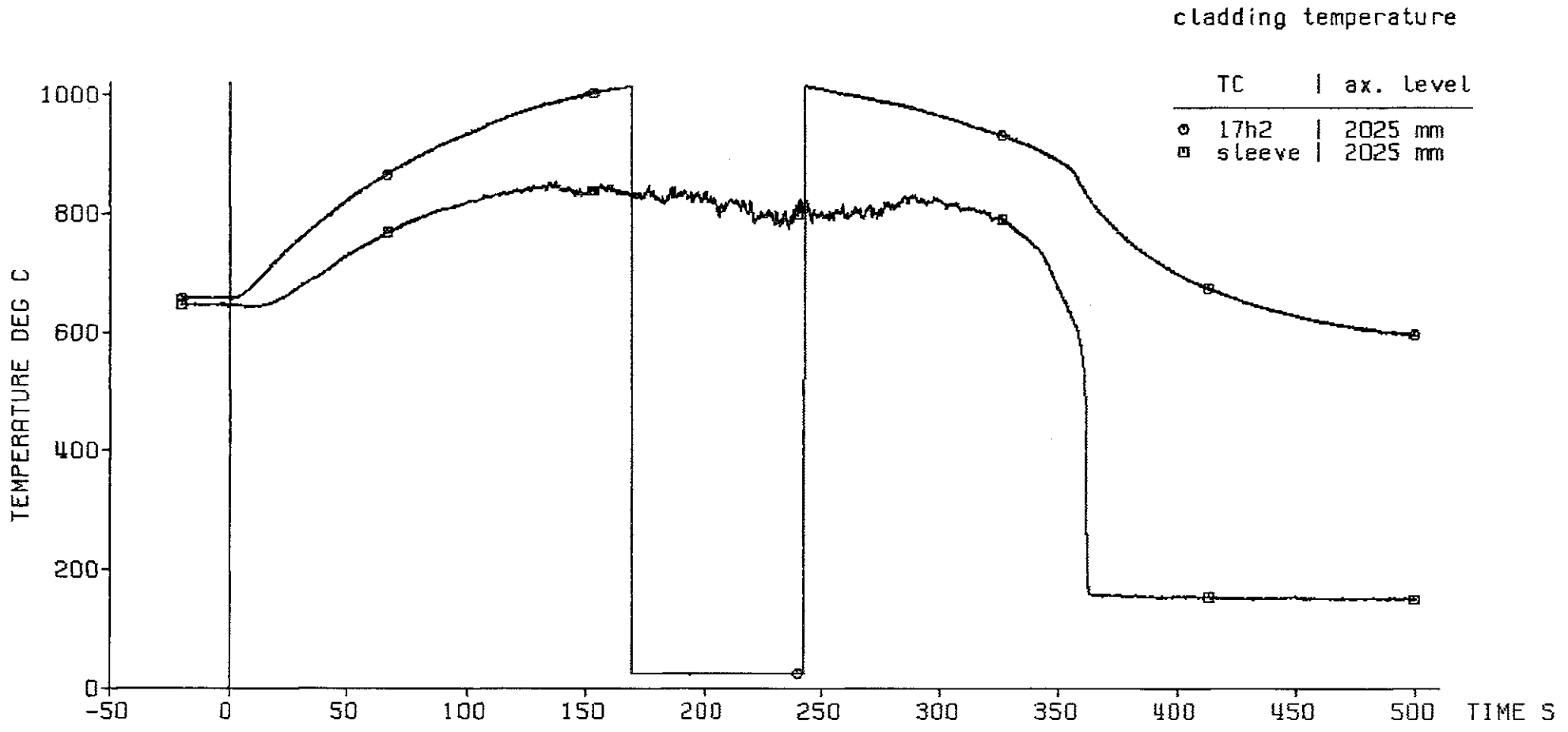
KfK IRB

Fig. 338 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 267



decay heat	120% ANS standard	bypass
flooding rate (cold)	2.24 cm/s	======
system pressure	3.96 bar	
feedwater temperature	40 deg C	

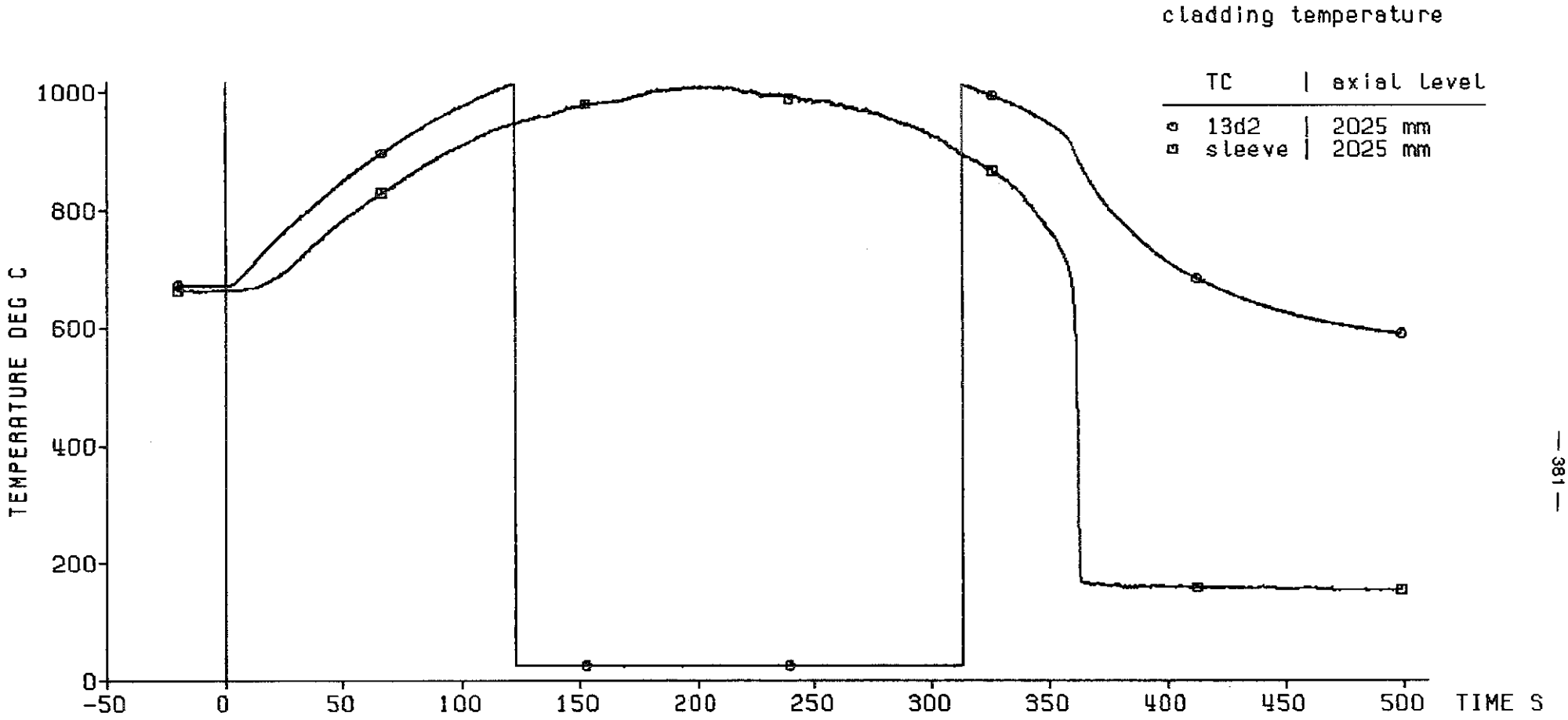
Fig. 339 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 267



decay heat	120% ANS standard	blockage
flooding rate (cold)	2.24 cm/s	========
system pressure	3.96 bar	
feedwater temperature	40 deg C	

KfK IRB

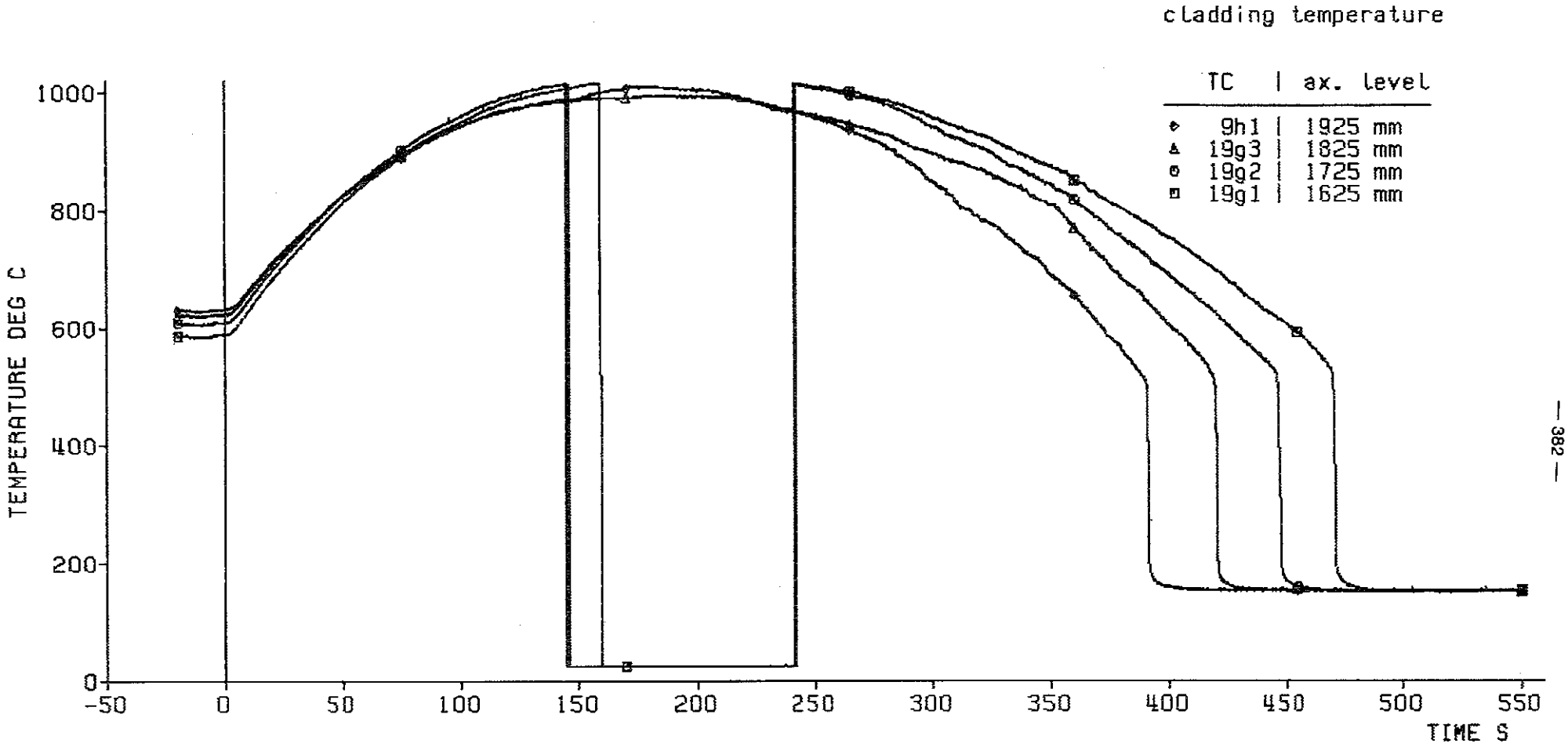
Fig. 340 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 267



decay heat	120% ANS standard	blockage
flooding rate (cold)	2.24 cm/s	========
system pressure	3.96 bar	
feedwater temperature	40 deg C	

KfK IRB

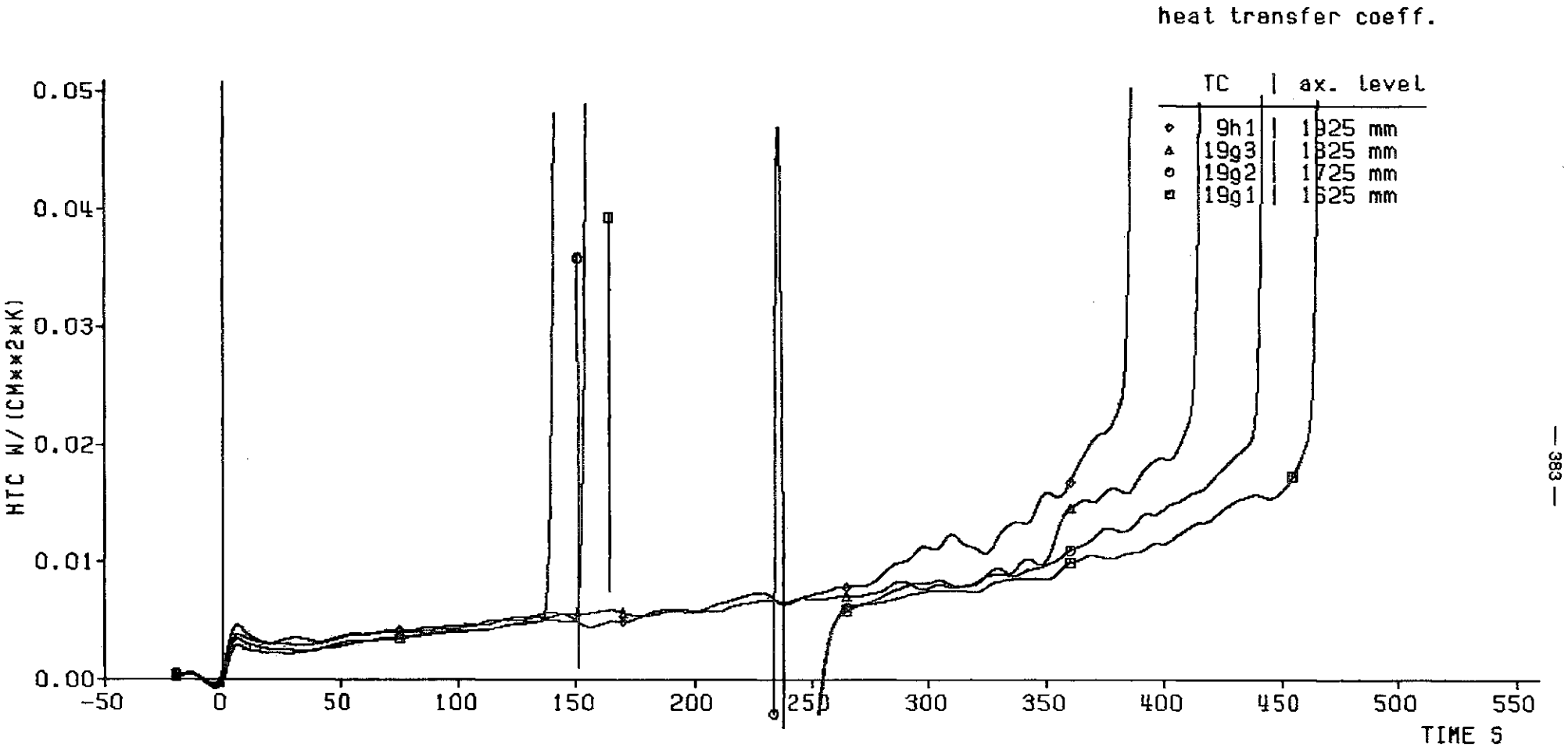
Fig. 341 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 267



decay heat	120% ANS standard	bypass
flooding rate (cold)	2.24 cm/s	======
system pressure	3.96 bar	
feedwater temperature	40 deg C	

KfK KIRB

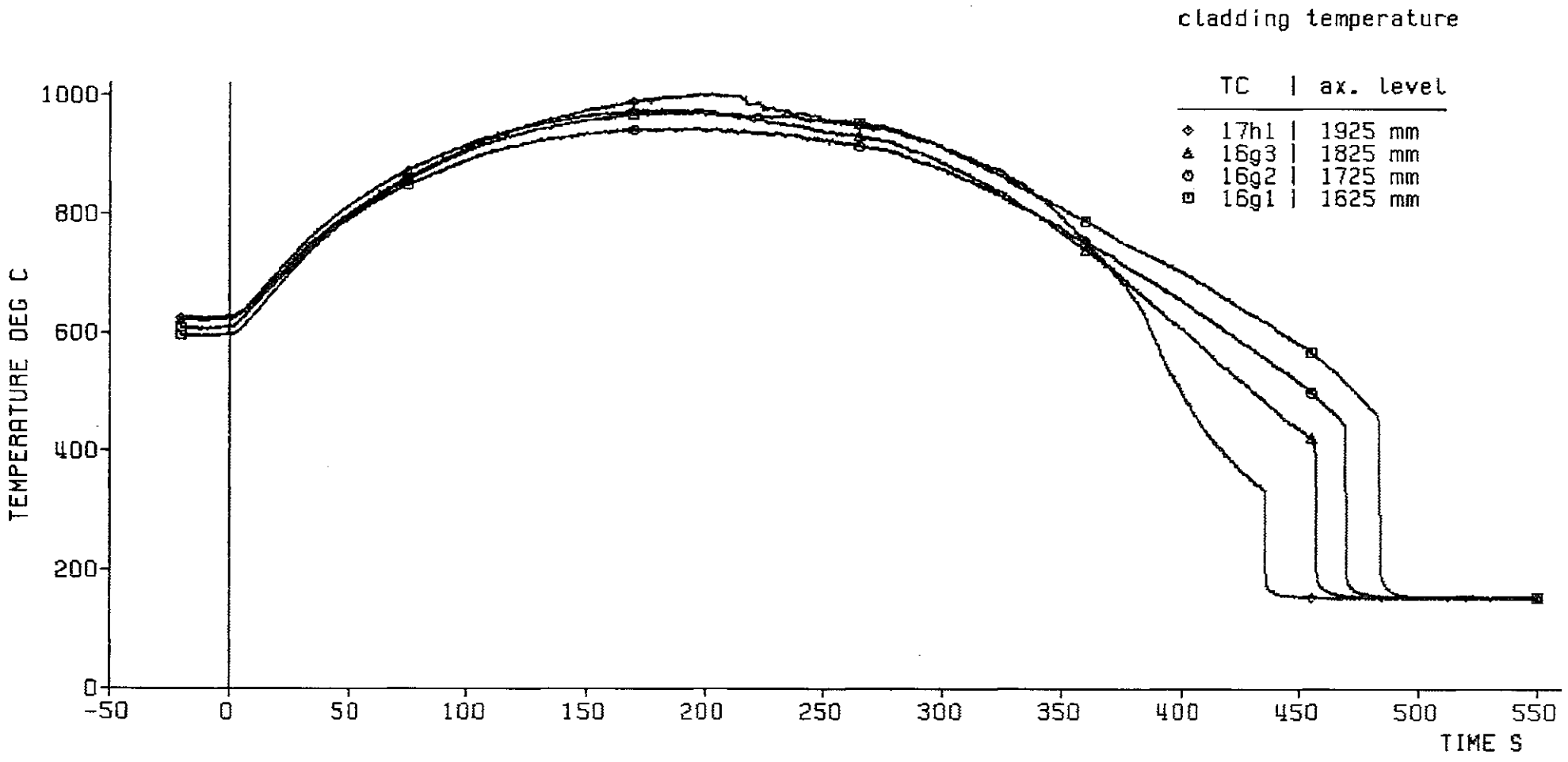
Fig. 342 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 267



decay heat	120% ANS standard	bypass
flooding rate (cold)	2.24 cm/s	======
system pressure	3.96 bar	
feedwater temperature	40 deg C	

KfK IRB

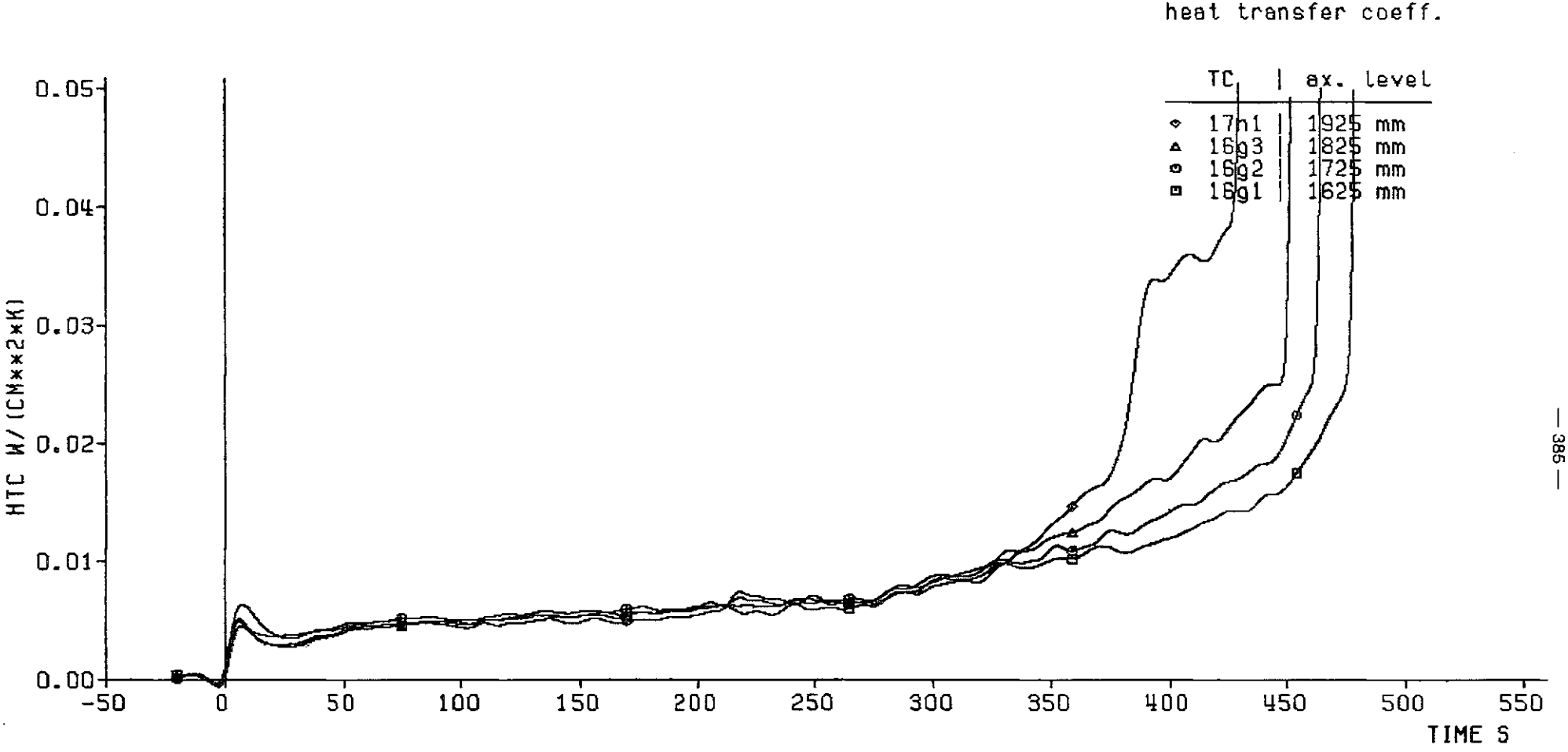
Fig. 343 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 267



decay heat	120% ANS standard	blockage
flooding rate (cold)	2.24 cm/s	========
system pressure	3.96 bar	
feedwater temperature	40 deg C	

KfK IRB

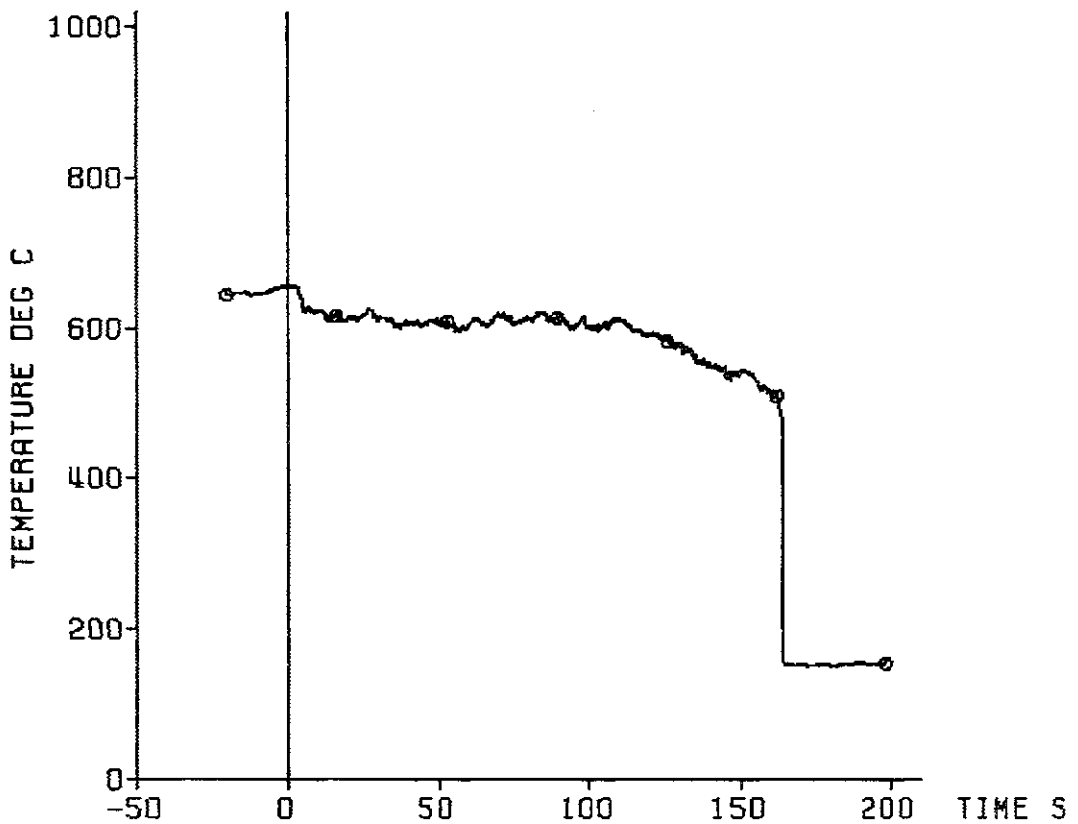
Fig. 344 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 267



decay heat	120% ANS standard	blockage
flooding rate (cold)	2.24 cm/s	========
system pressure	3.96 bar	
feedwater temperature	40 deg C	

KfK IRB

Fig. 345 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 267



decay heat	120% ANS standard
flooding rate (cold)	2.24 cm/s
system pressure	3.96 bar
feedwater temperature	40 deg C

KfK IRB

Fig. 346 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 267

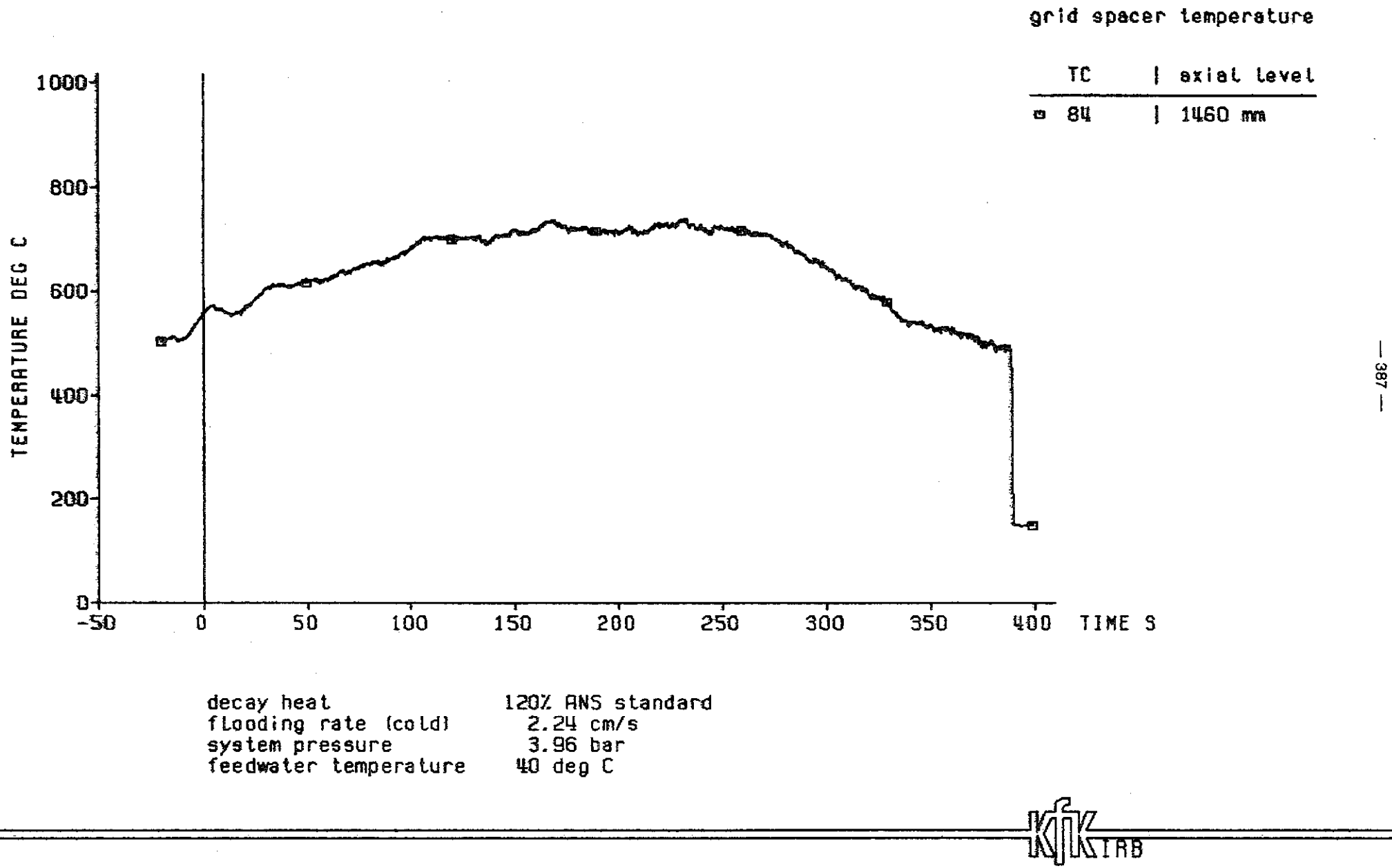
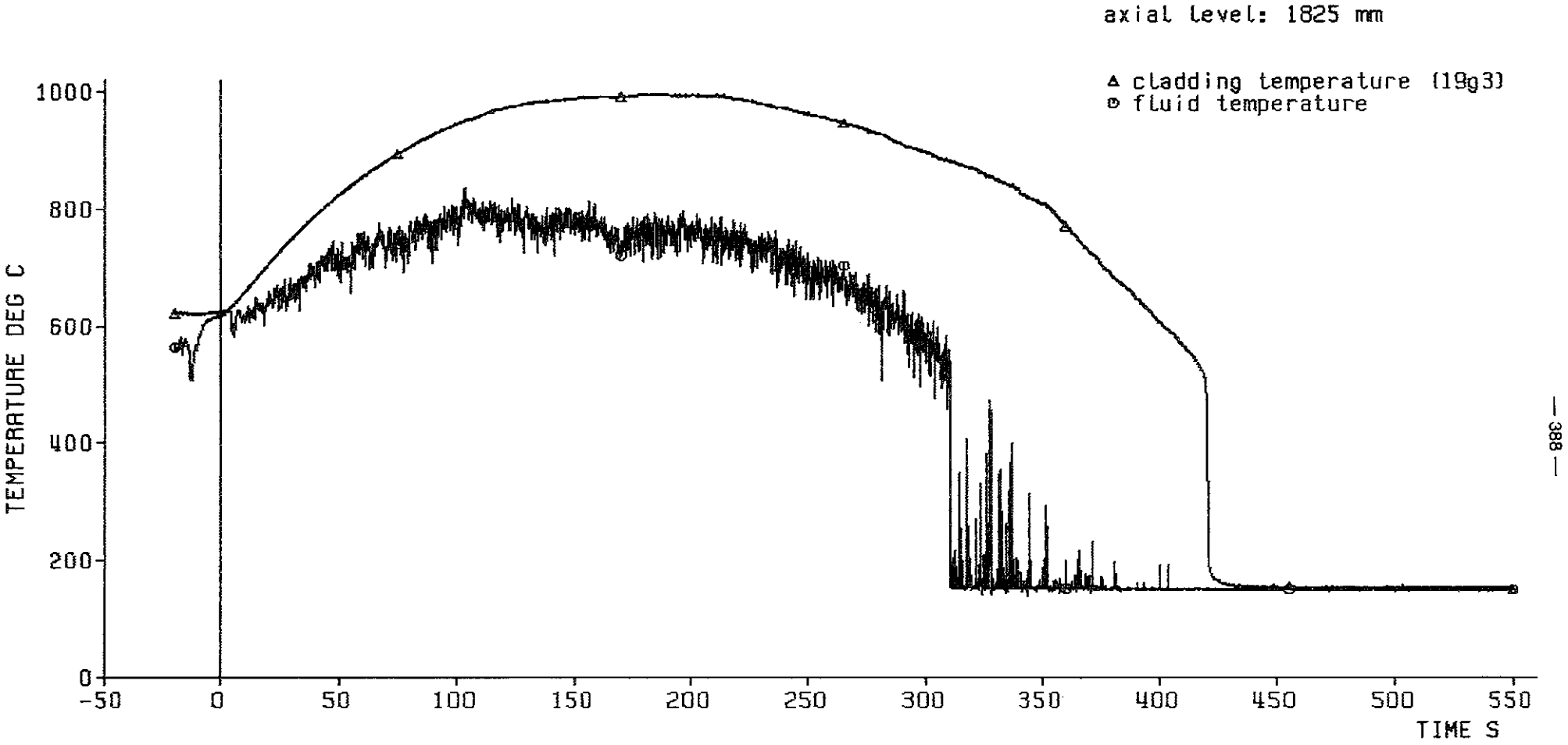


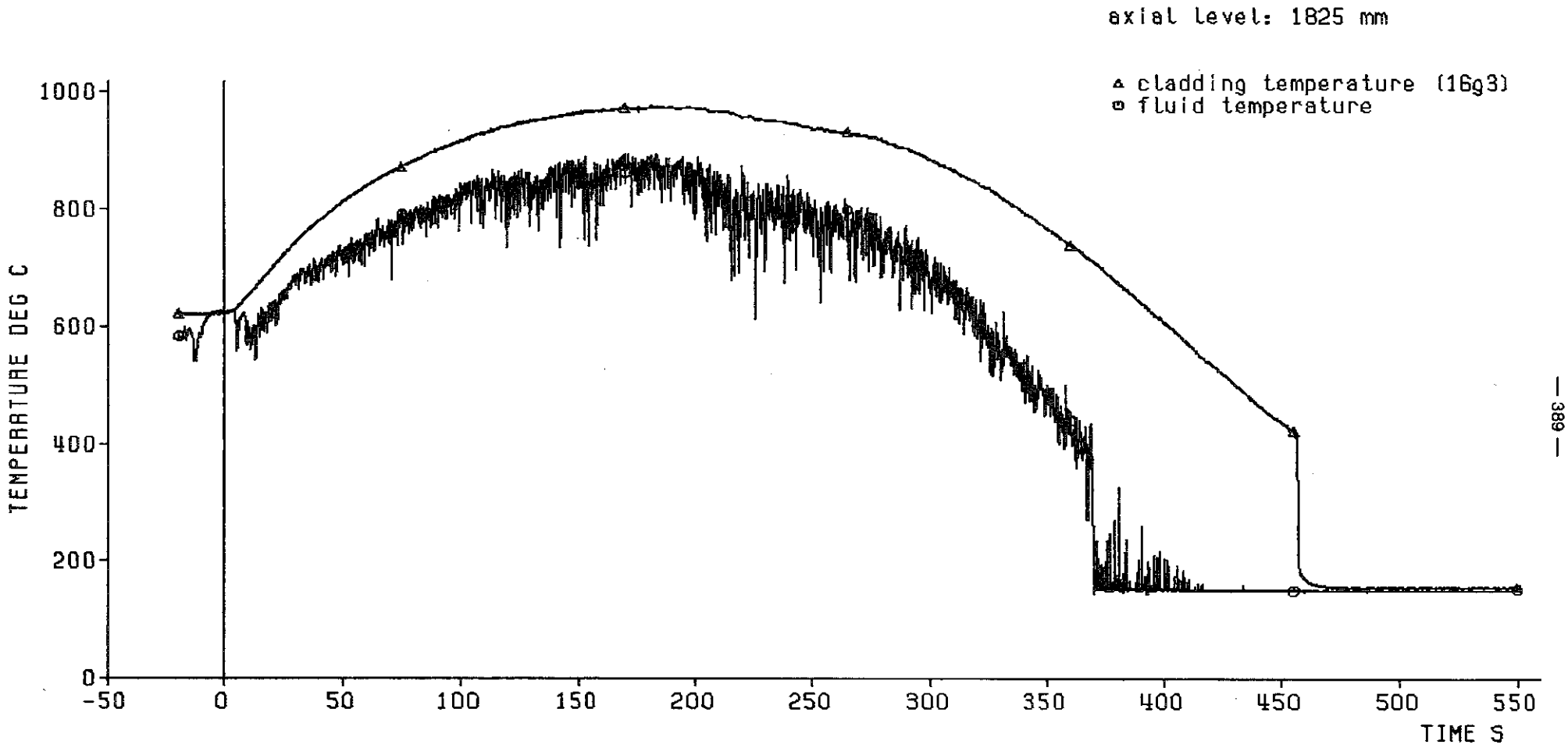
Fig. 347 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 267



decay heat	120% ANS standard	bypass
flooding rate (cold)	2.24 cm/s	======
system pressure	3.96 bar	
feedwater temperature	40 deg C	

KfK IRB

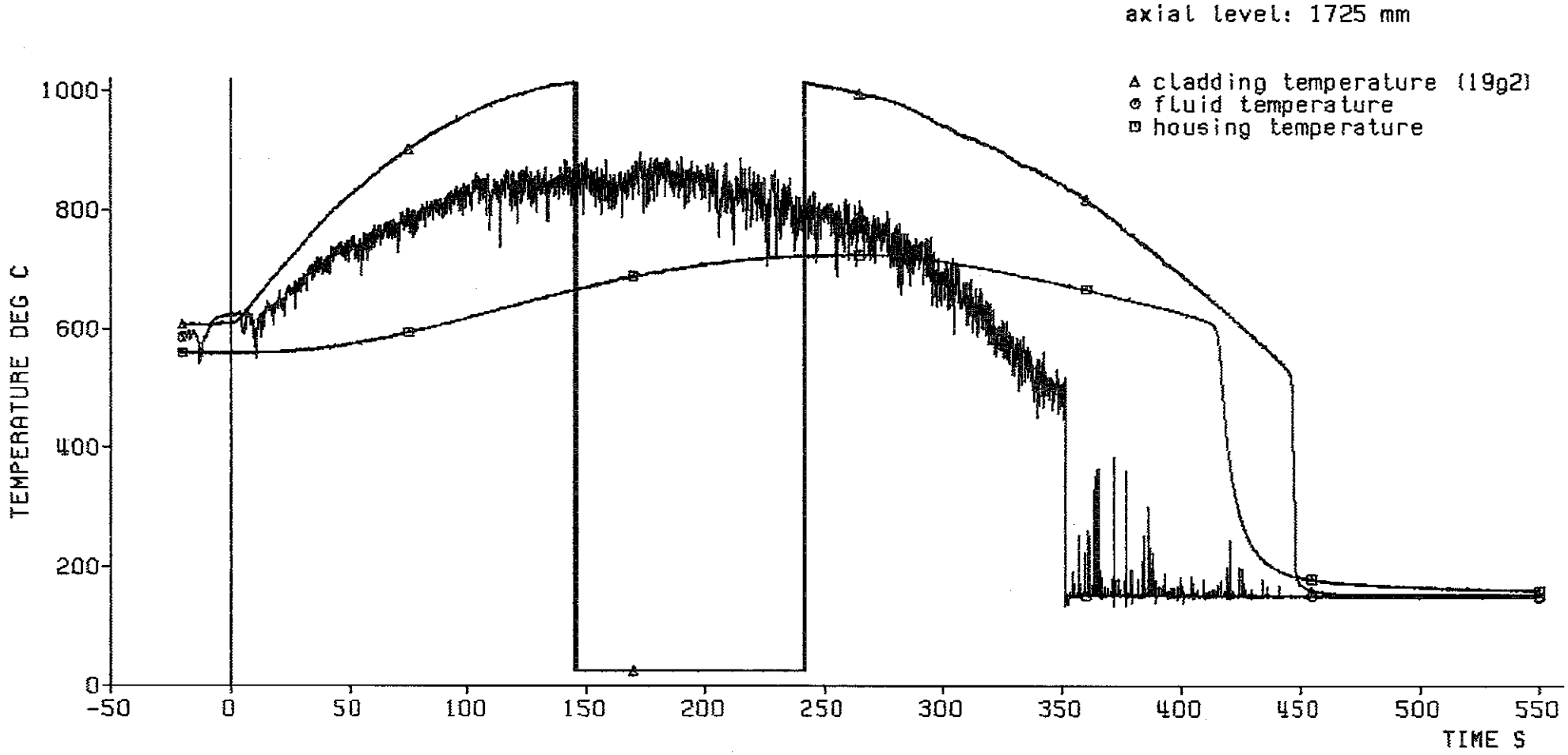
Fig. 348 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 267



decay heat	120% ANS standard	blockage
flooding rate (cold)	2.24 cm/s	========
system pressure	3.96 bar	
feedwater temperature	40 deg C	

KfK IRB

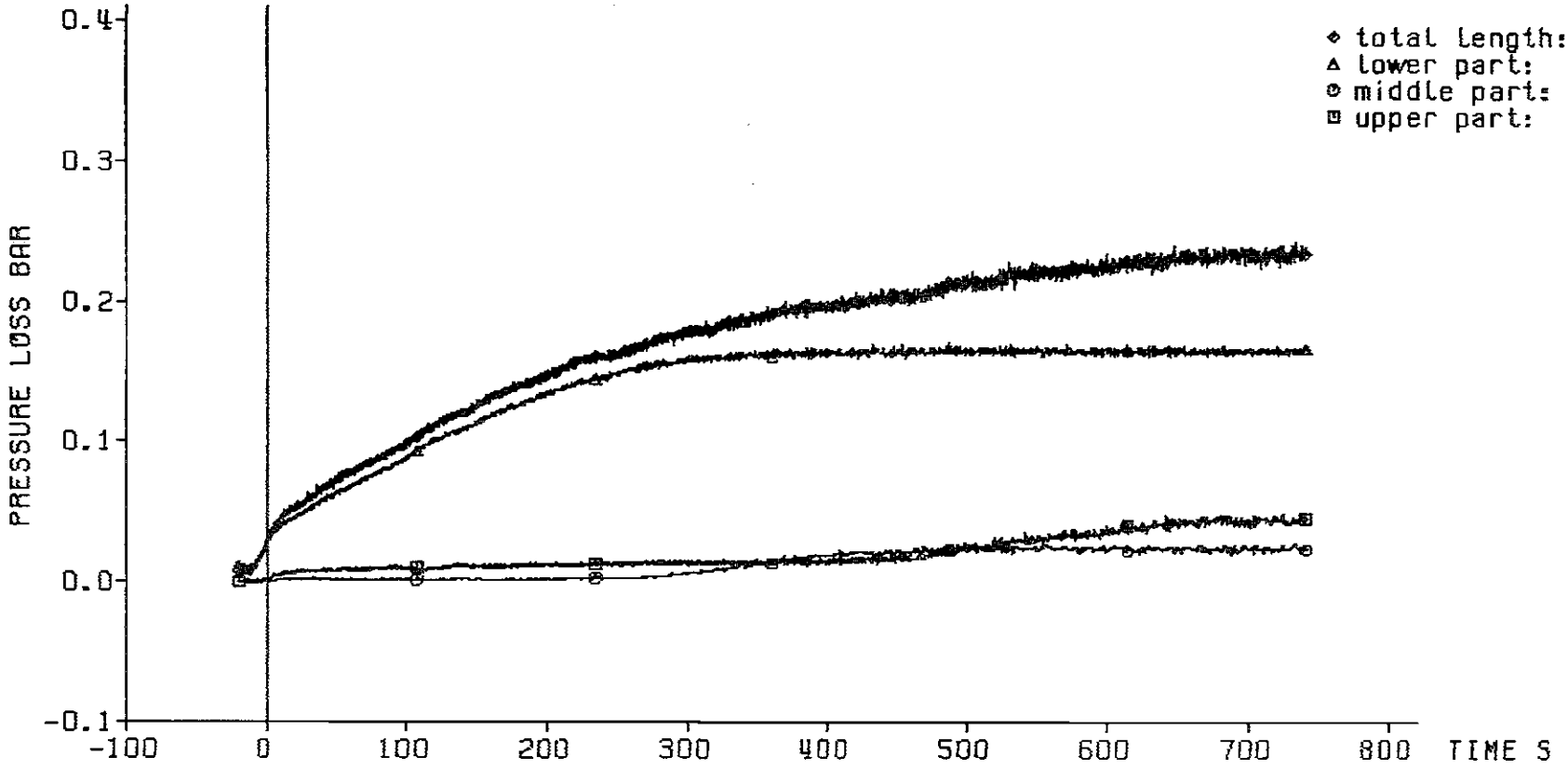
Fig. 349 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 267



decay heat	120% ANS standard	bypass
flooding rate (cold)	2.24 cm/s	======
system pressure	3.96 bar	
feedwater temperature	40 deg C	

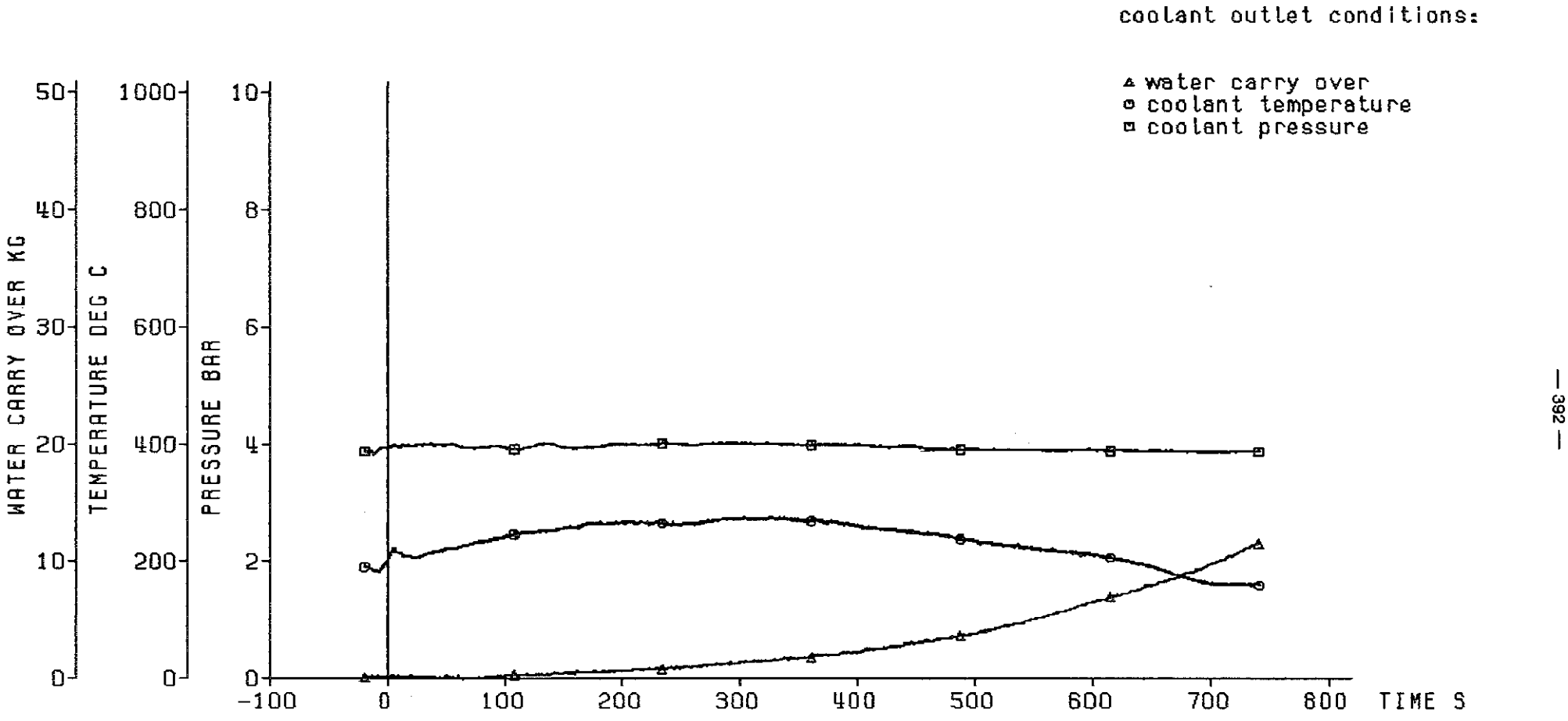
KfK IRB

Fig. 350 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 267



decay heat	120% ANS standard
flooding rate (cold)	2.24 cm/s
system pressure	3.96 bar
feedwater temperature	40 deg C

Fig. 351 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 267



decay heat	120% ANS standard
flooding rate (cold)	2.24 cm/s
system pressure	3.96 bar
feedwater temperature	40 deg C

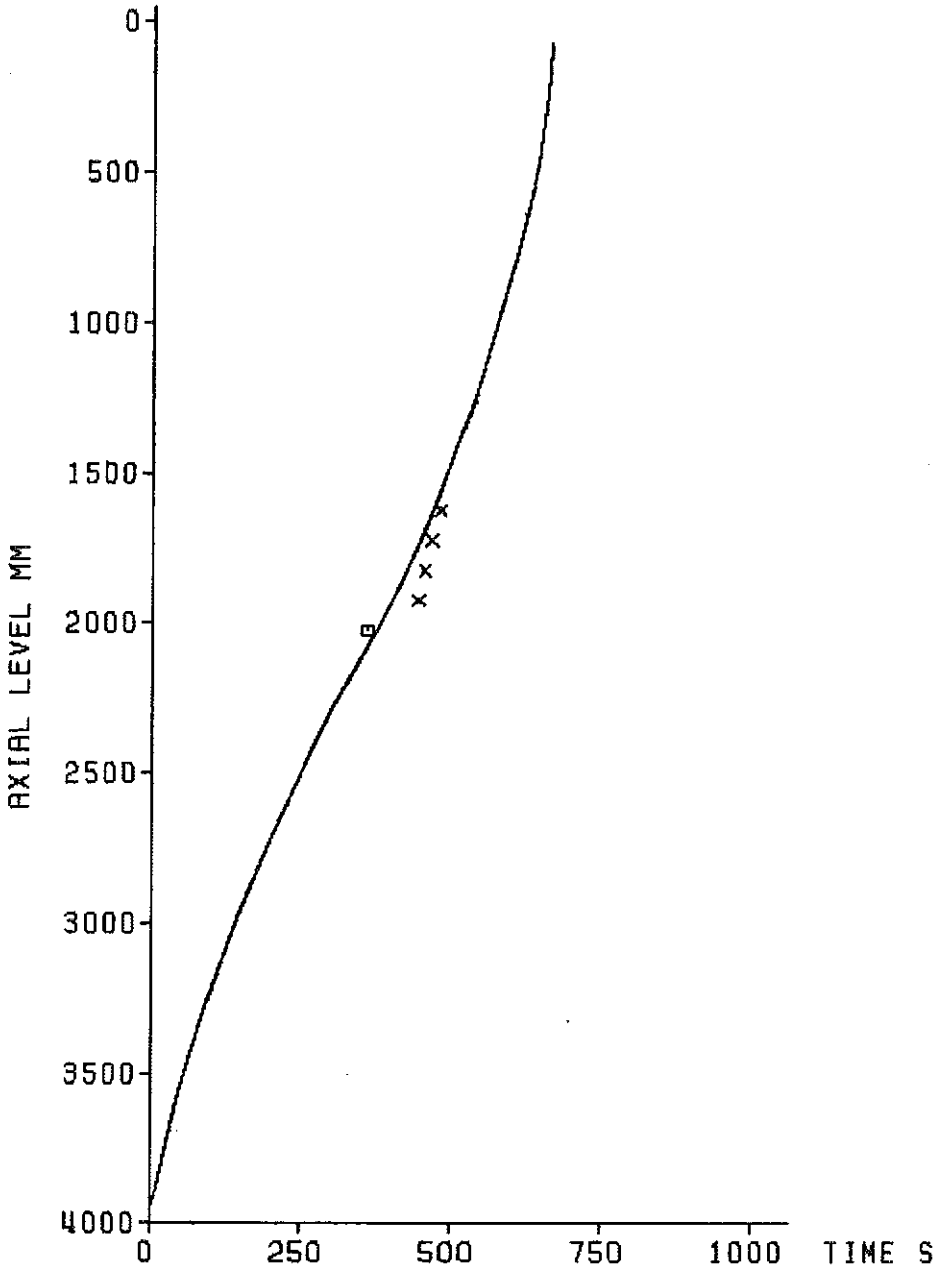
KfK IRB

Fig. 352 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 267

axial position of the quench front

⊡ rewetting of the sleeve at the bundle midplane

× rewetting of the rod downstream of the blockage

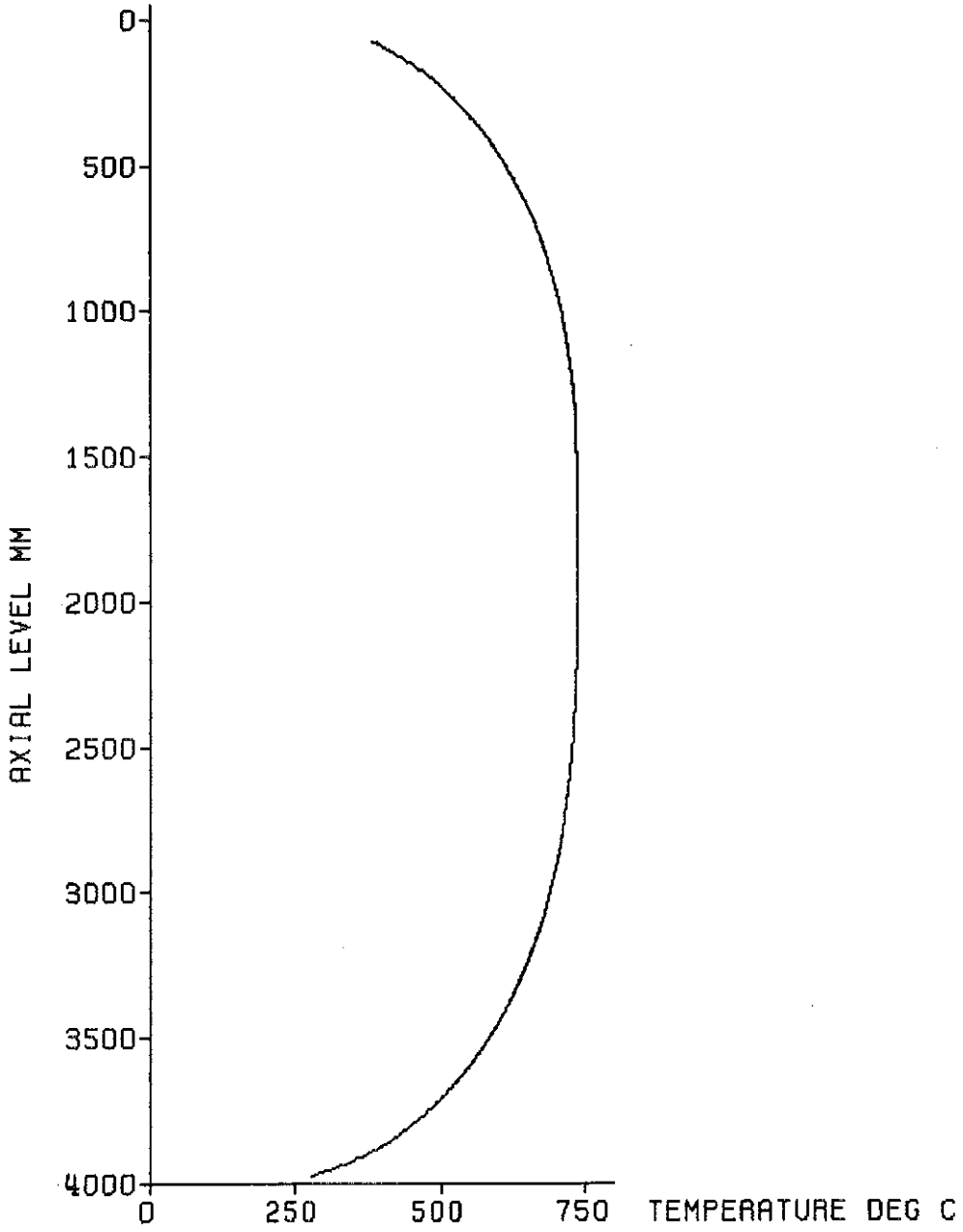


decay heat	120% ANS standard
flooding rate (cold)	2.24 cm/s
system pressure	3.96 bar
feedwater temperature	40 deg C

KfK IRB

Fig. 353 FEBA: 5x5 ROD BUNDLE TEST SERIES 4, TEST-No. 267

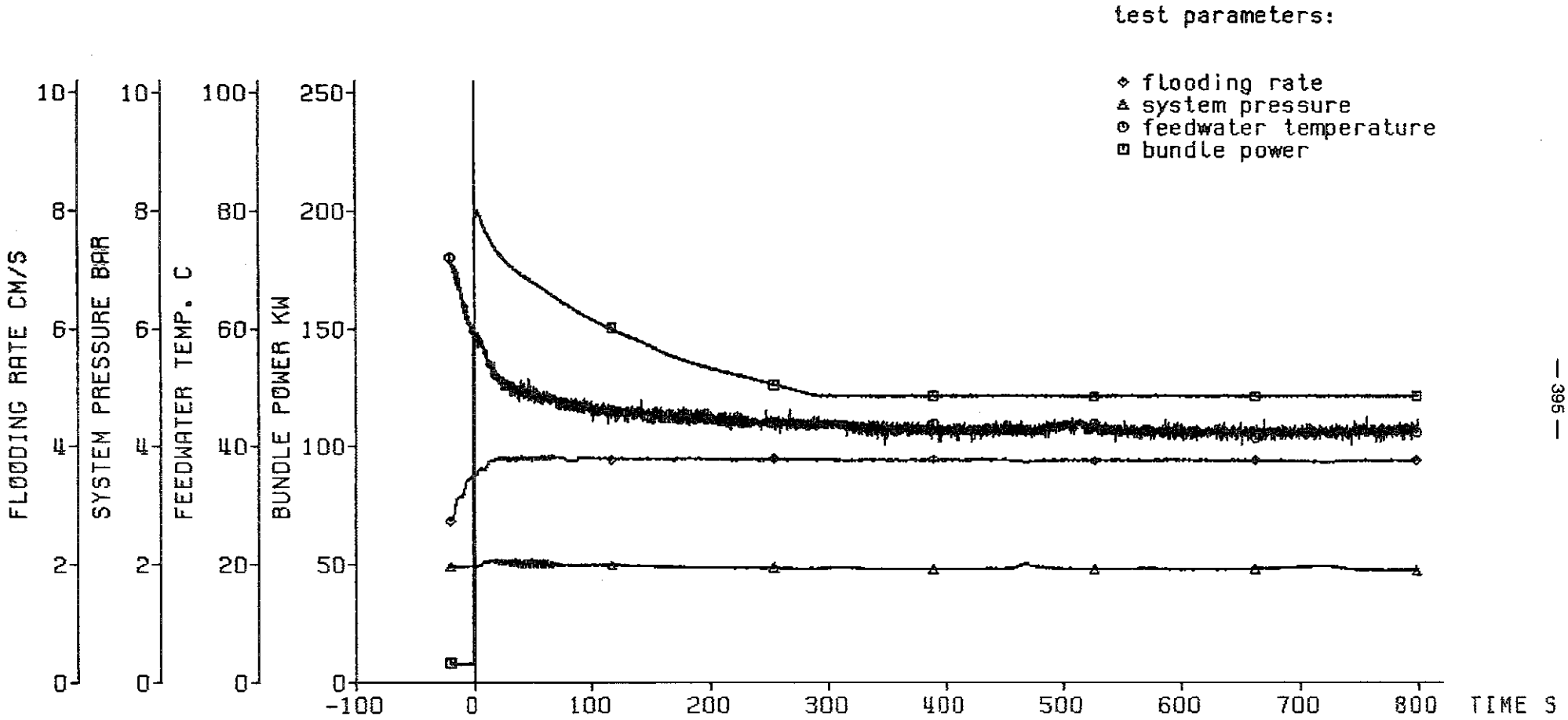
initial axial temperature profile of the cladding



decay heat	120% ANS standard
flooding rate (cold)	3.80 cm/s
system pressure	1.98 bar
feedwater temperature	40 deg C

KfK IRB

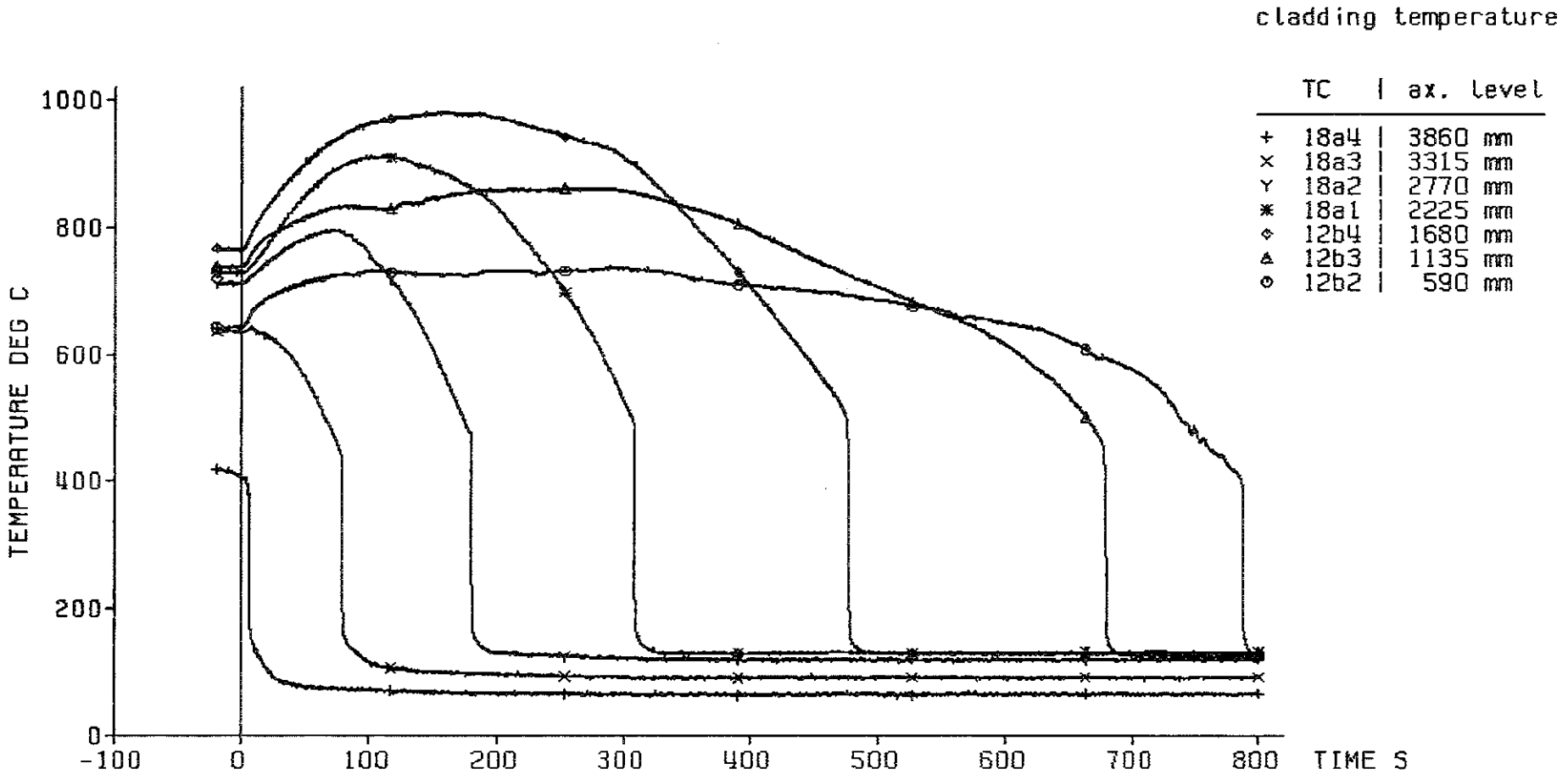
Fig. 354 FEBA: 5x5 ROD BUNDLE TEST SERIES 4, TEST-No. 262



decay heat	120% ANS standard
flooding rate (cold)	3.80 cm/s
system pressure	1.98 bar
feedwater temperature	40 deg C

KfK IRB

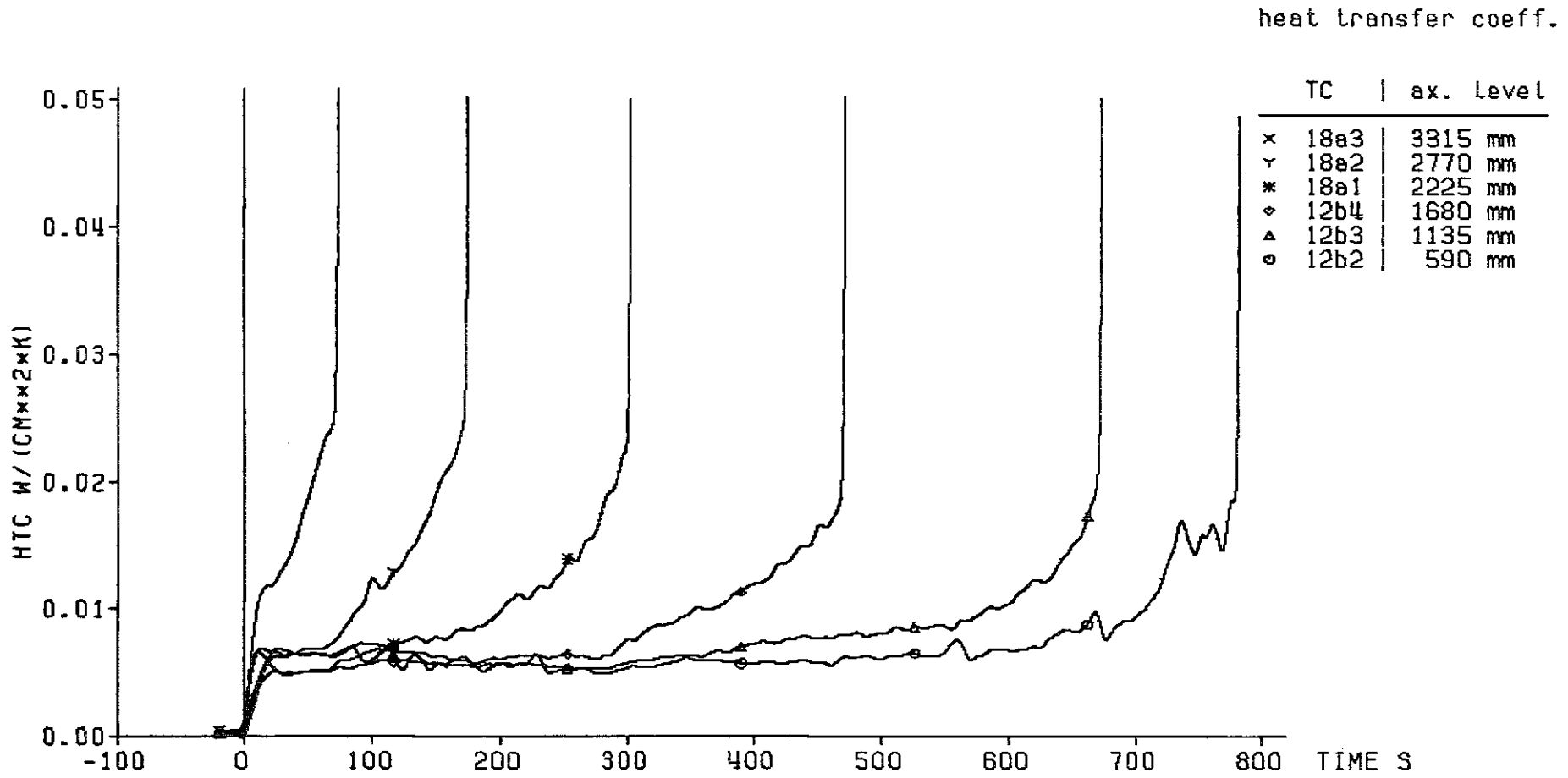
Fig. 355 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 262



decay heat	120% ANS standard
flooding rate (cold)	3.60 cm/s
system pressure	1.98 bar
feedwater temperature	40 deg C

KfK IRB

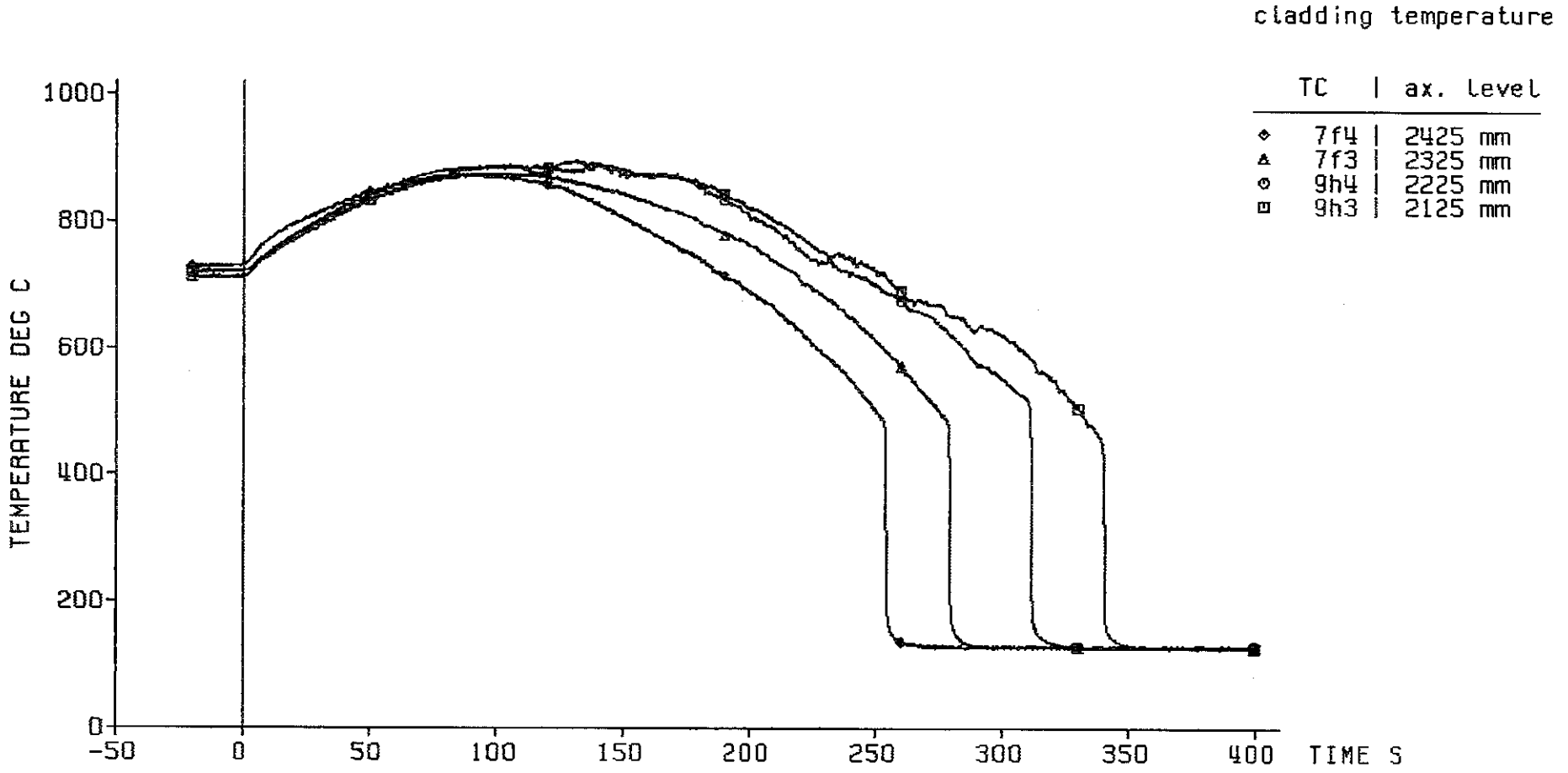
Fig. 356 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 262



decay heat	120% ANS standard
flooding rate (cold)	3.80 cm/s
system pressure	1.98 bar
feedwater temperature	40 deg C

KfK IRB

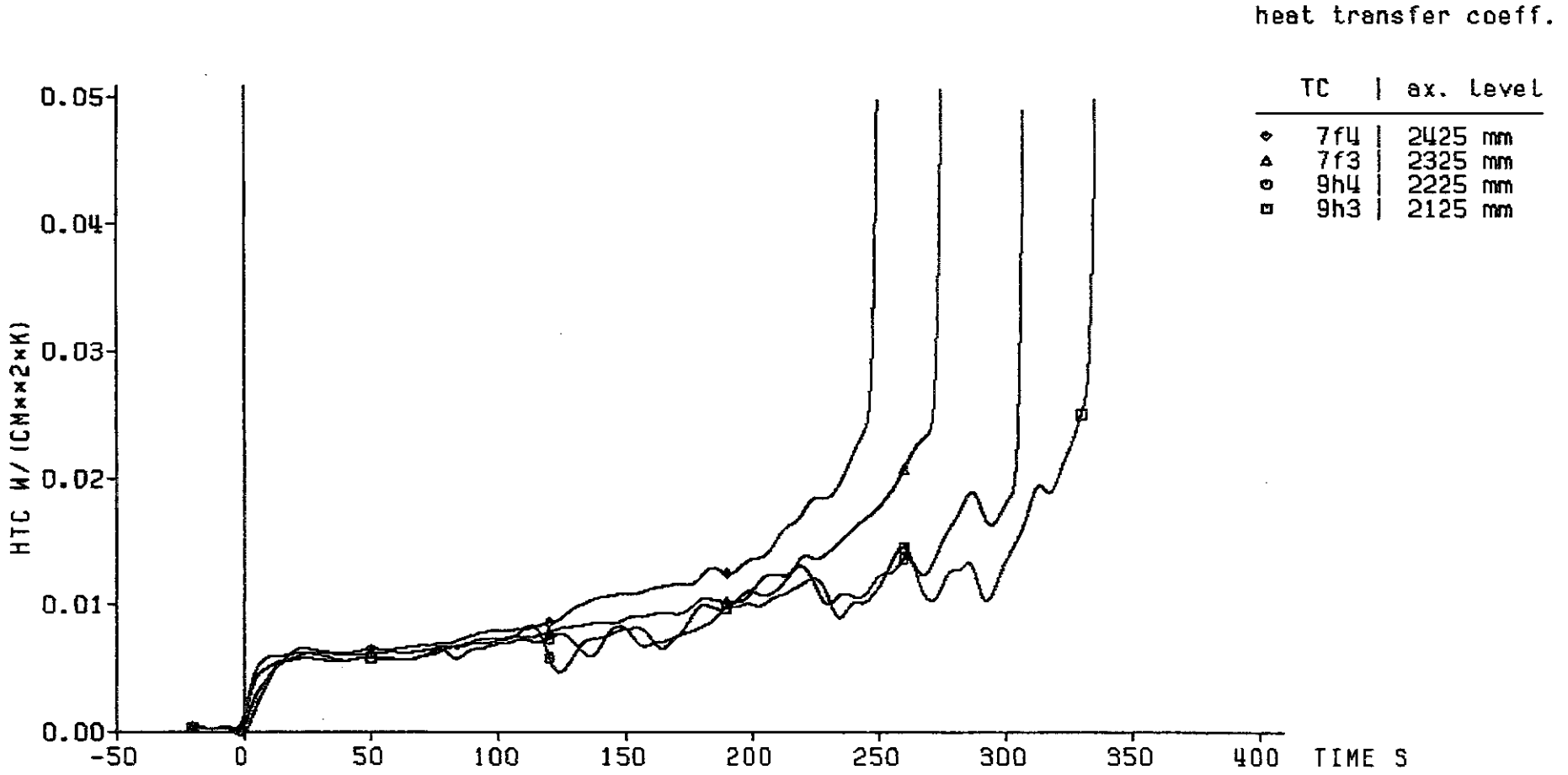
Fig. 357 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 262



decay heat	120% ANS standard	bypass
flooding rate (cold)	3.80 cm/s	======
system pressure	1.98 bar	
feedwater temperature	40 deg C	

KfK IRB

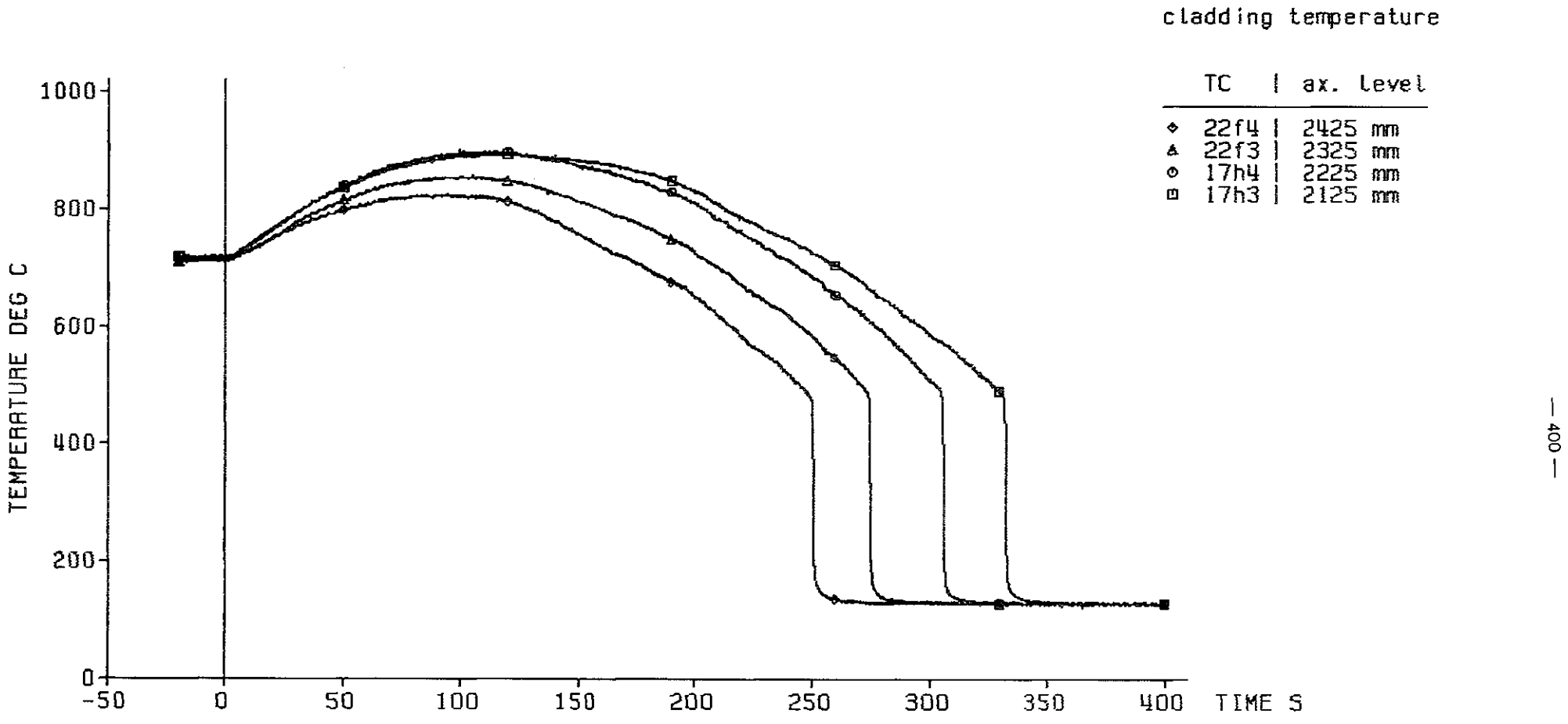
Fig. 358 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 262



decay heat	120% ANS standard	bypass
flooding rate (cold)	3.80 cm/s	======
system pressure	1.98 bar	
feedwater temperature	40 deg C	

KfK IRB

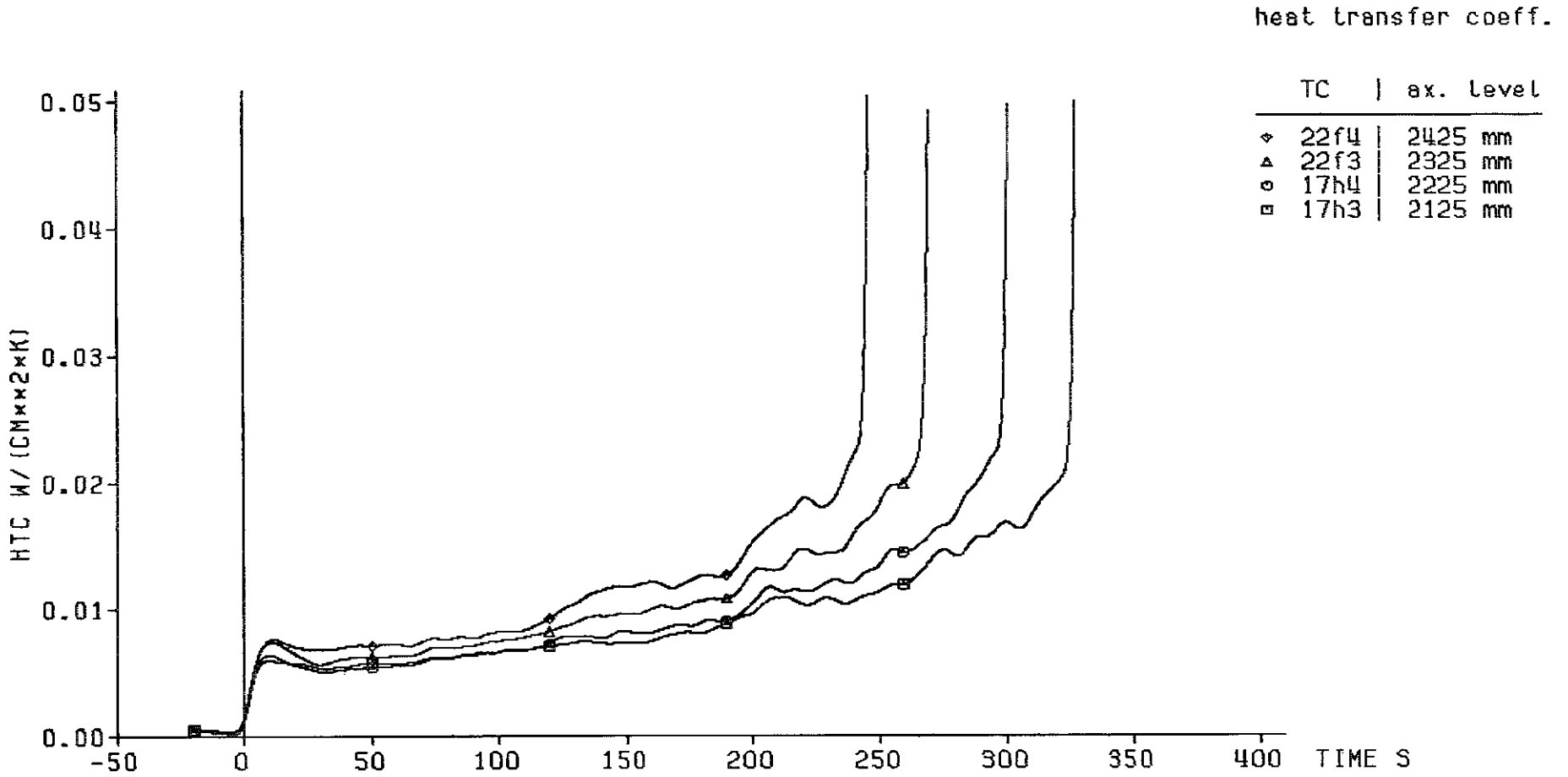
Fig. 359 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 262



decay heat	120% ANS standard	blockage
flooding rate (cold)	3.80 cm/s	========
system pressure	1.98 bar	
feedwater temperature	40 deg C	

KfK KIRB

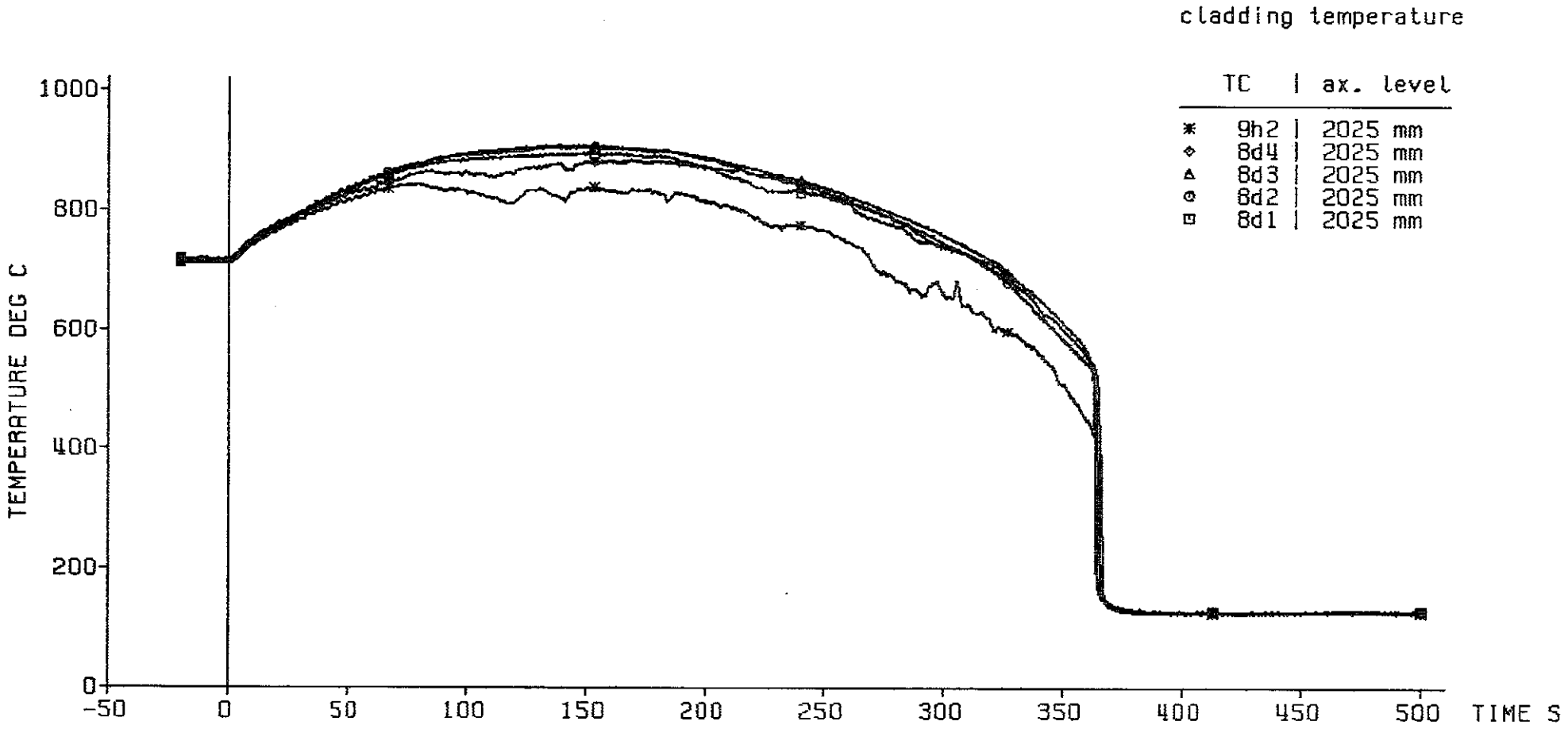
Fig. 360 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 262



decay heat	120% ANS standard	blockage
flooding rate (cold)	3.80 cm/s	========
system pressure	1.98 bar	
feedwater temperature	40 deg C	

KfK IRB

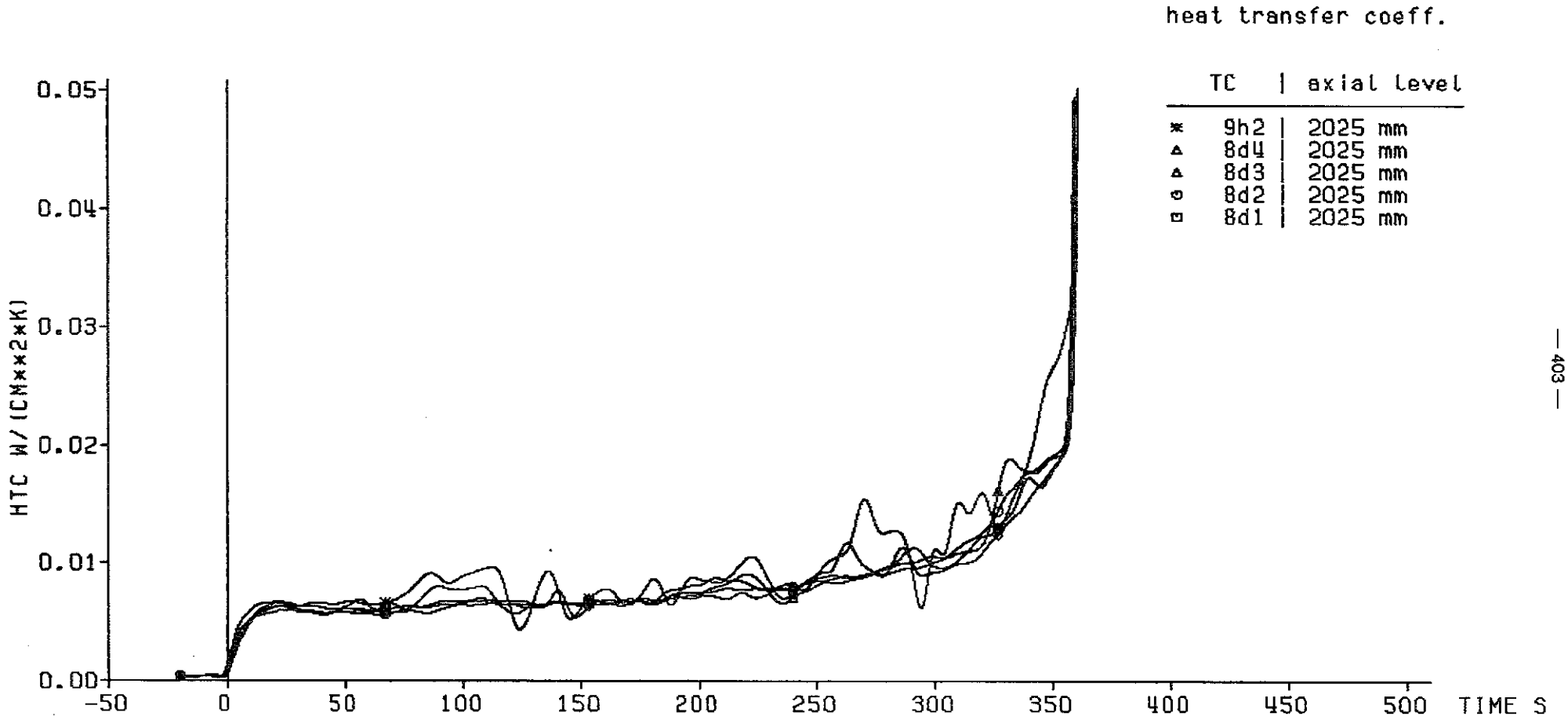
Fig. 361 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 262



decay heat	120% ANS standard	bypass
flooding rate (cold)	3.80 cm/s	======
system pressure	1.98 bar	
feedwater temperature	40 deg C	

KfK IRB

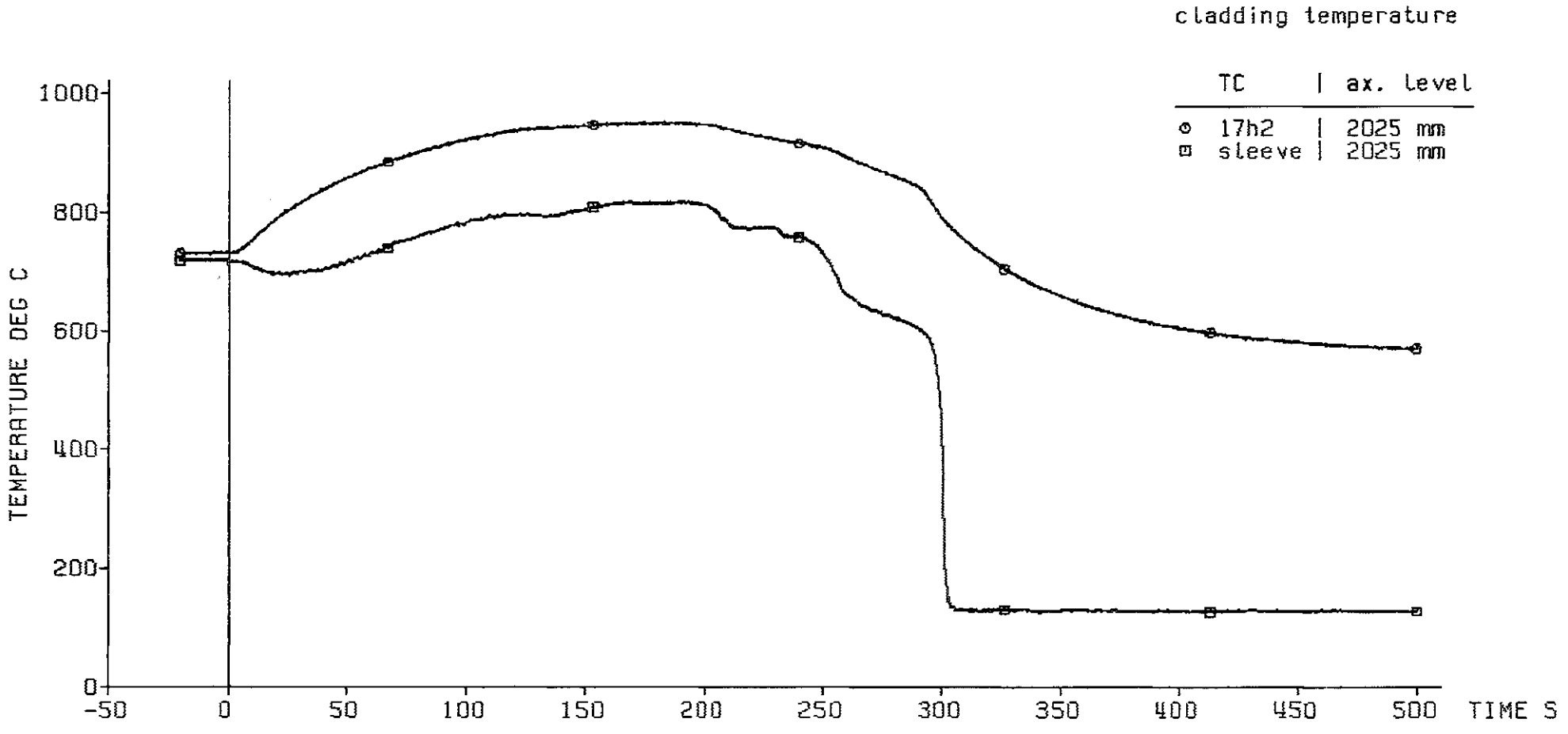
Fig. 362 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 262



decay heat	120% ANS standard	bypass
flooding rate (cold)	3.80 cm/s	======
system pressure	1.98 bar	
feedwater temperature	40 deg C	

KfK IRB

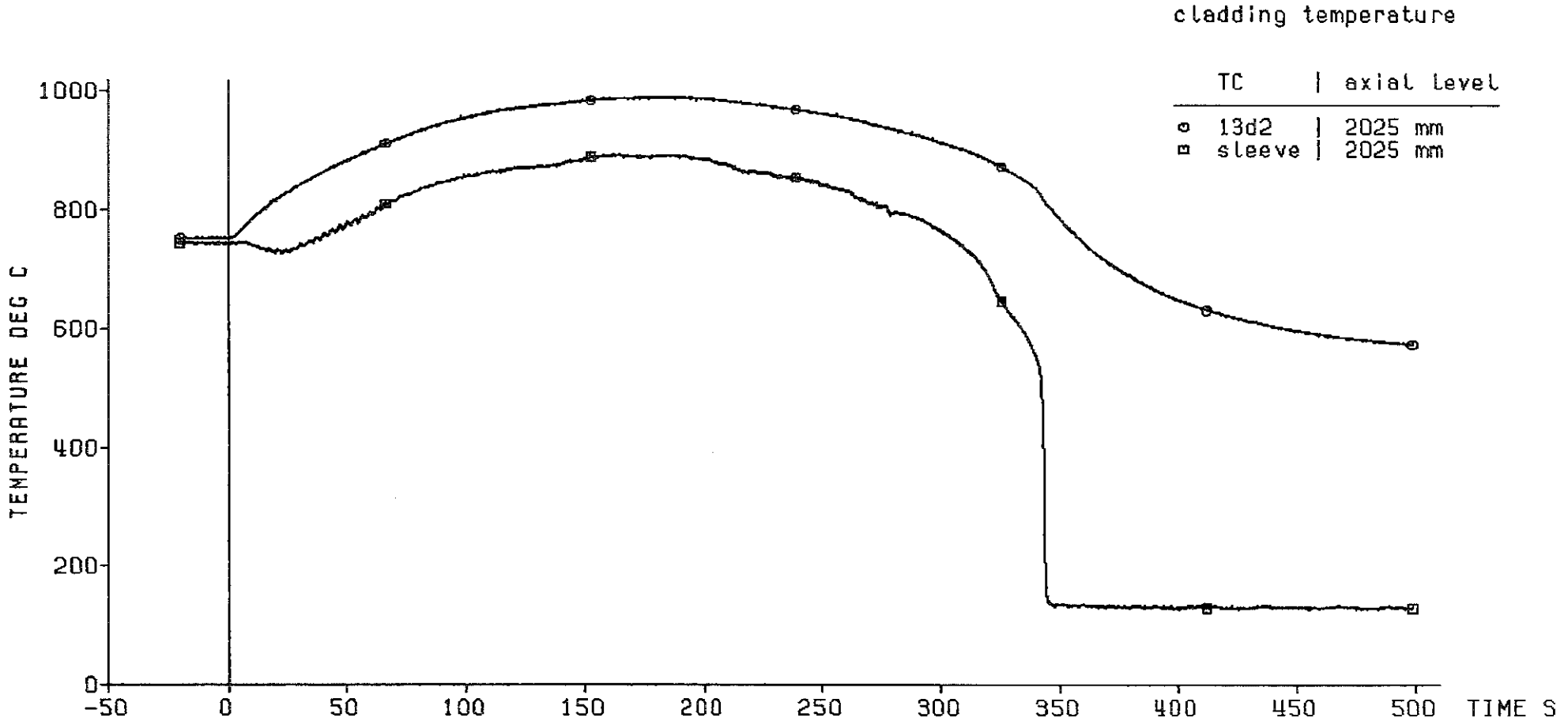
Fig. 363 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 262



decay heat	120% ANS standard	blockage
flooding rate (cold)	3.80 cm/s	========
system pressure	1.98 bar	
feedwater temperature	40 deg C	

KfK IRB

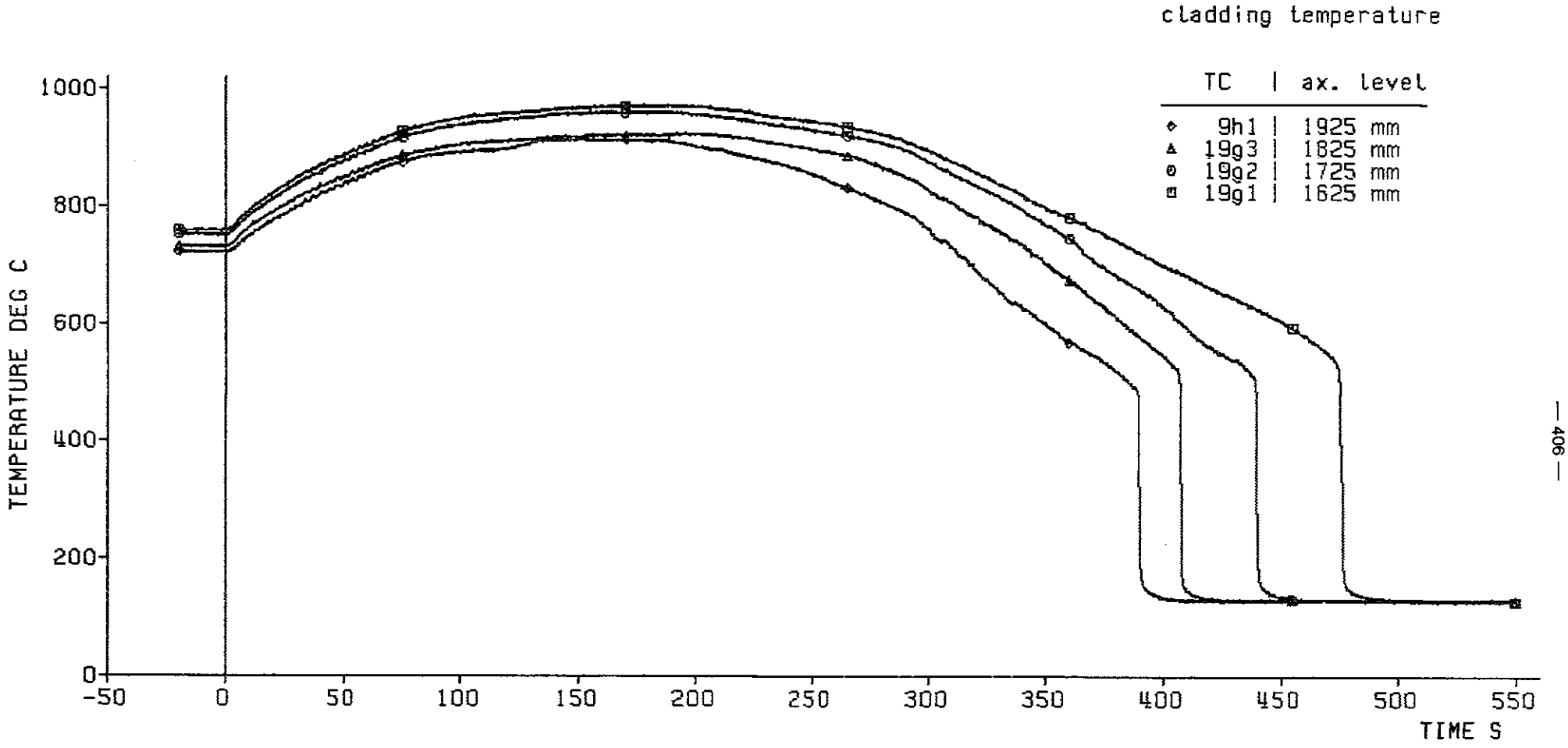
Fig. 364 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 262



decay heat	120% ANS standard	blockage
flooding rate (cold)	3.80 cm/s	========
system pressure	1.98 bar	
feedwater temperature	40 deg C	

KfK IRB

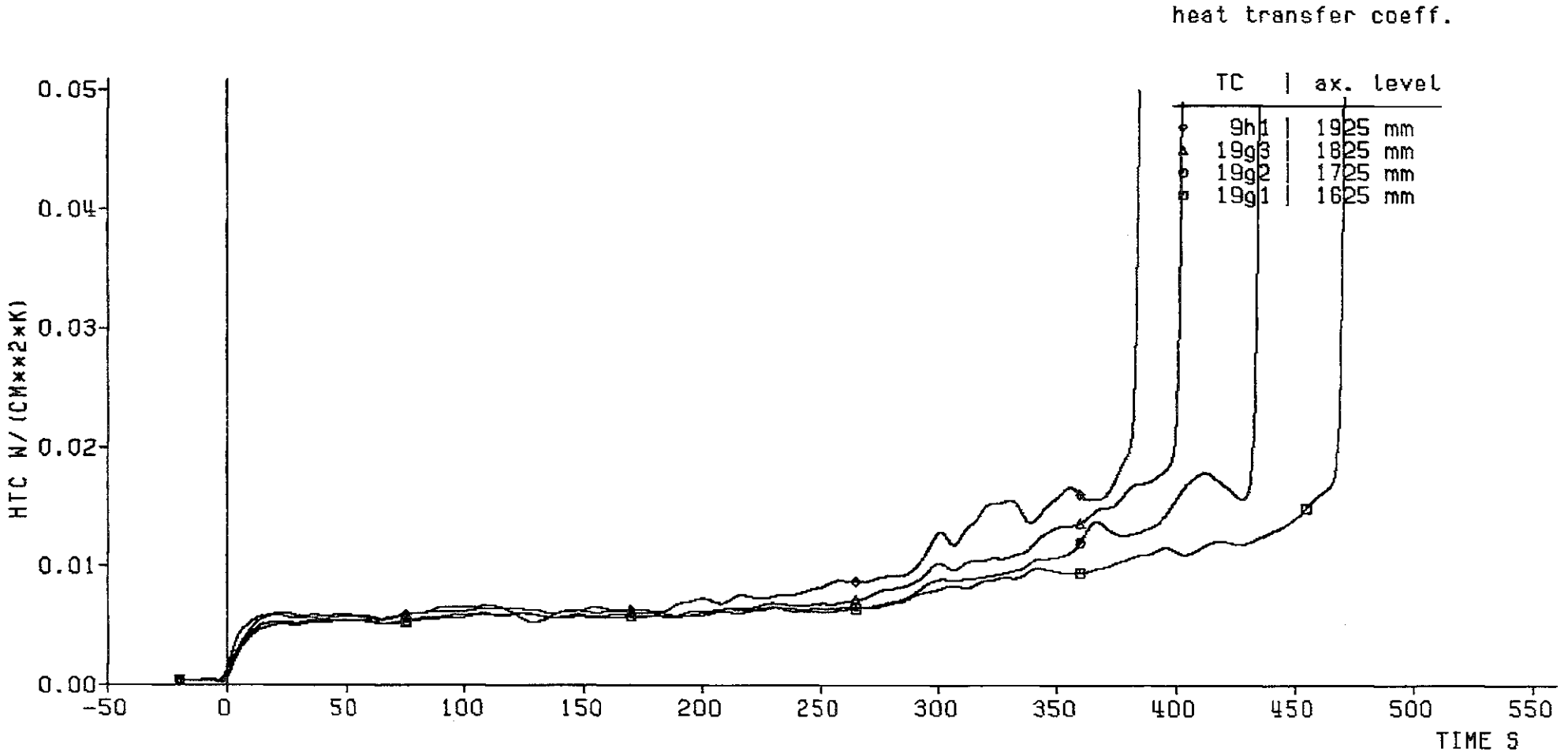
Fig. 365 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 262



decay heat	120% ANS standard	bypass
flooding rate (cold)	3.80 cm/s	======
system pressure	1.98 bar	
feedwater temperature	40 deg C	

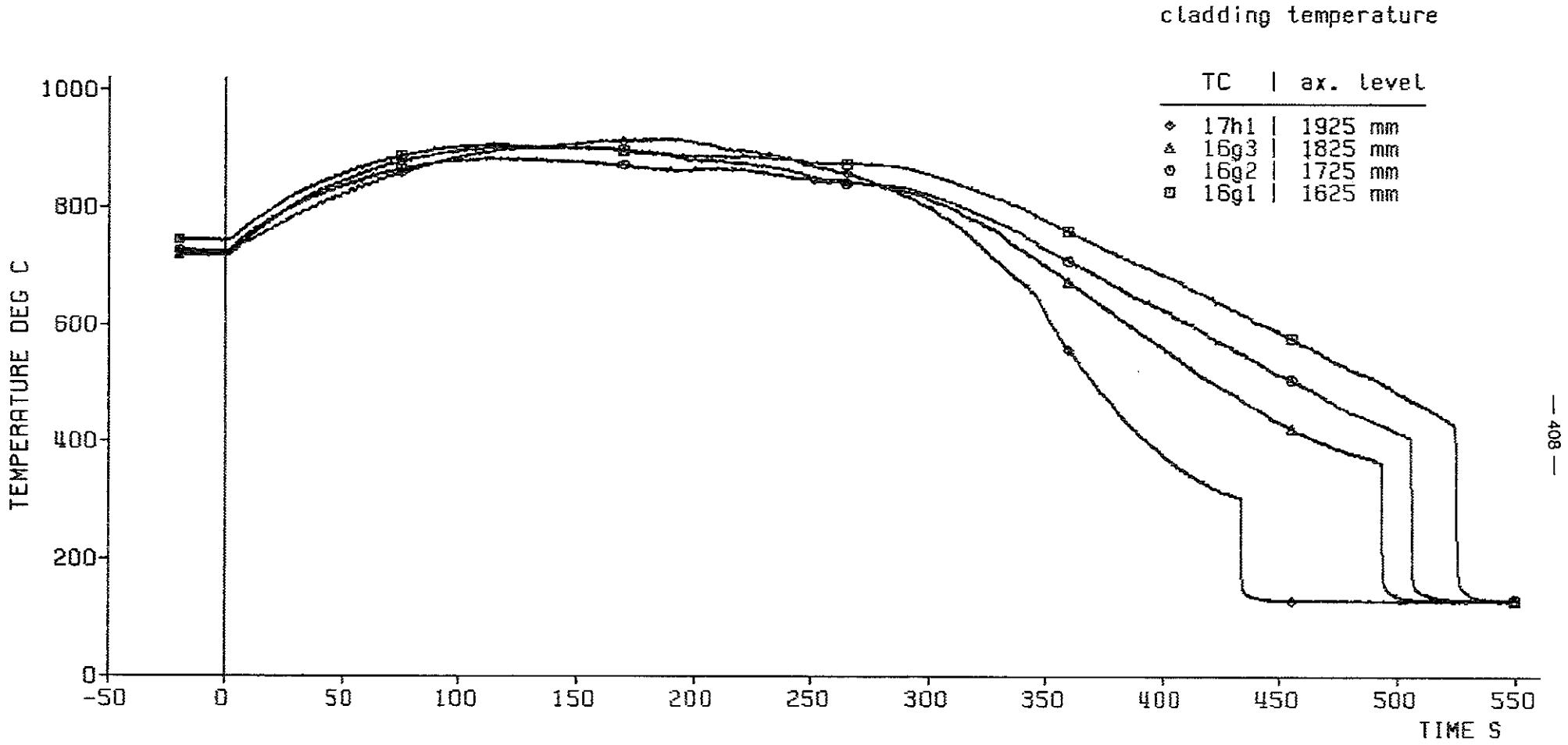
KfK IRB

Fig. 366 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 262



decay heat	120% ANS standard	bypass
flooding rate (cold)	3.80 cm/s	======
system pressure	1.98 bar	
feedwater temperature	40 deg C	

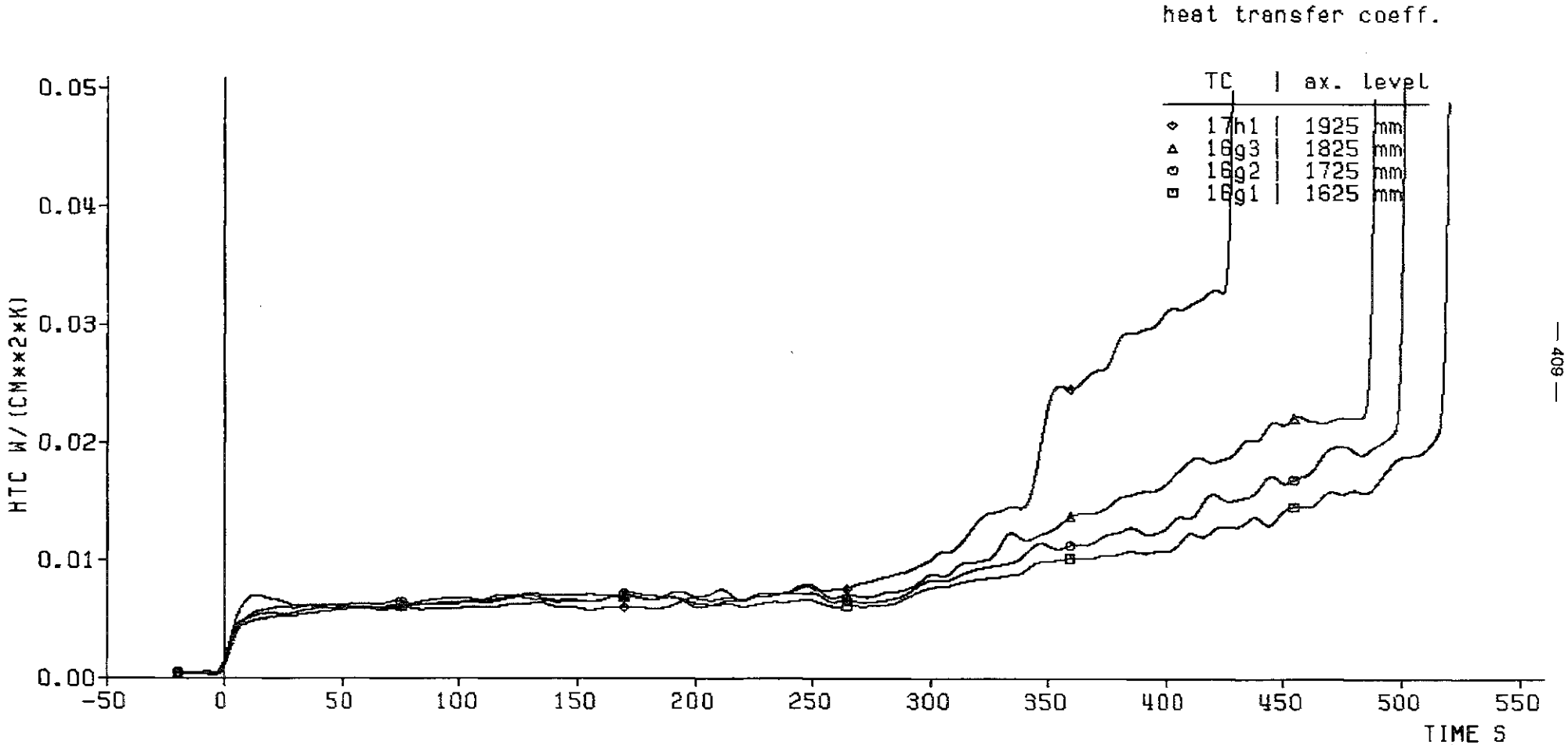
Fig. 367 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 262



decay heat	120% ANS standard	blockage
flooding rate (cold)	3.80 cm/s	========
system pressure	1.98 bar	
feedwater temperature	40 deg C	

KfK IRB

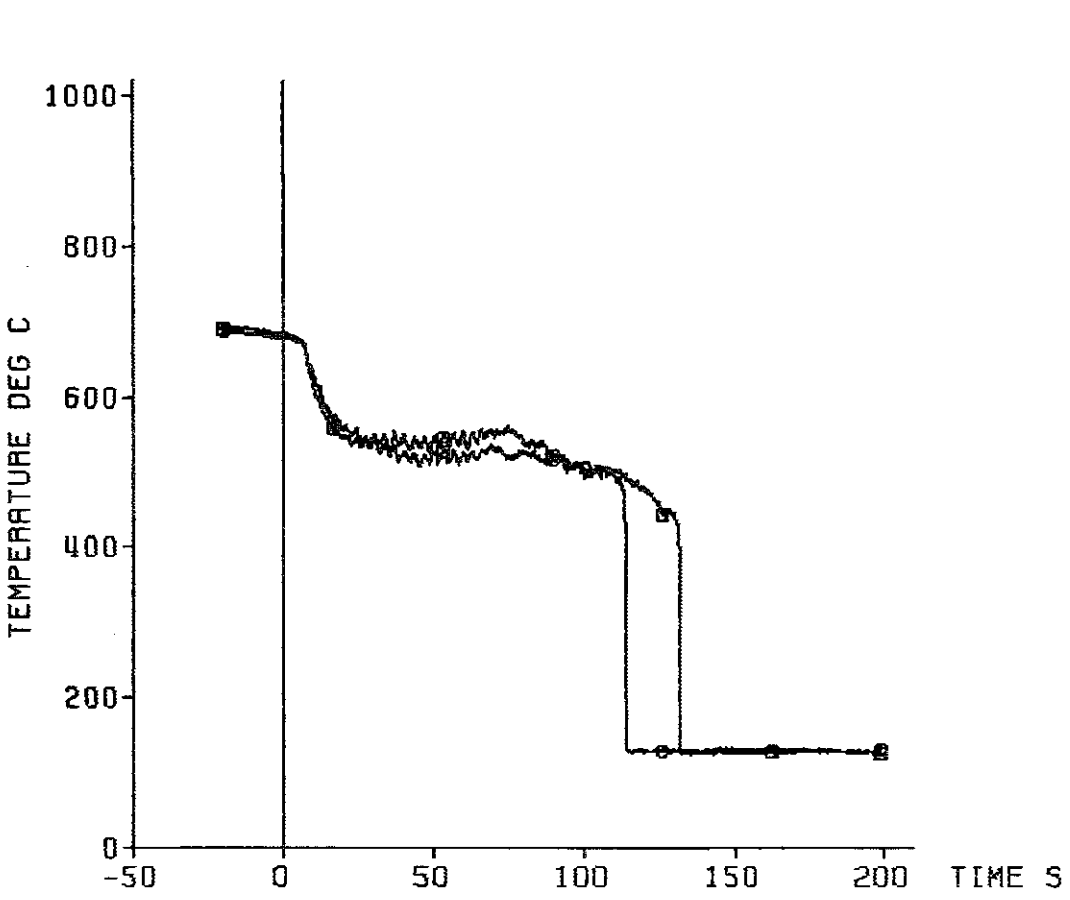
Fig. 368 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 262



decay heat	120% ANS standard	blockage
flooding rate (cold)	3.80 cm/s	========
system pressure	1.98 bar	
feedwater temperature	40 deg C	

KfK IRB

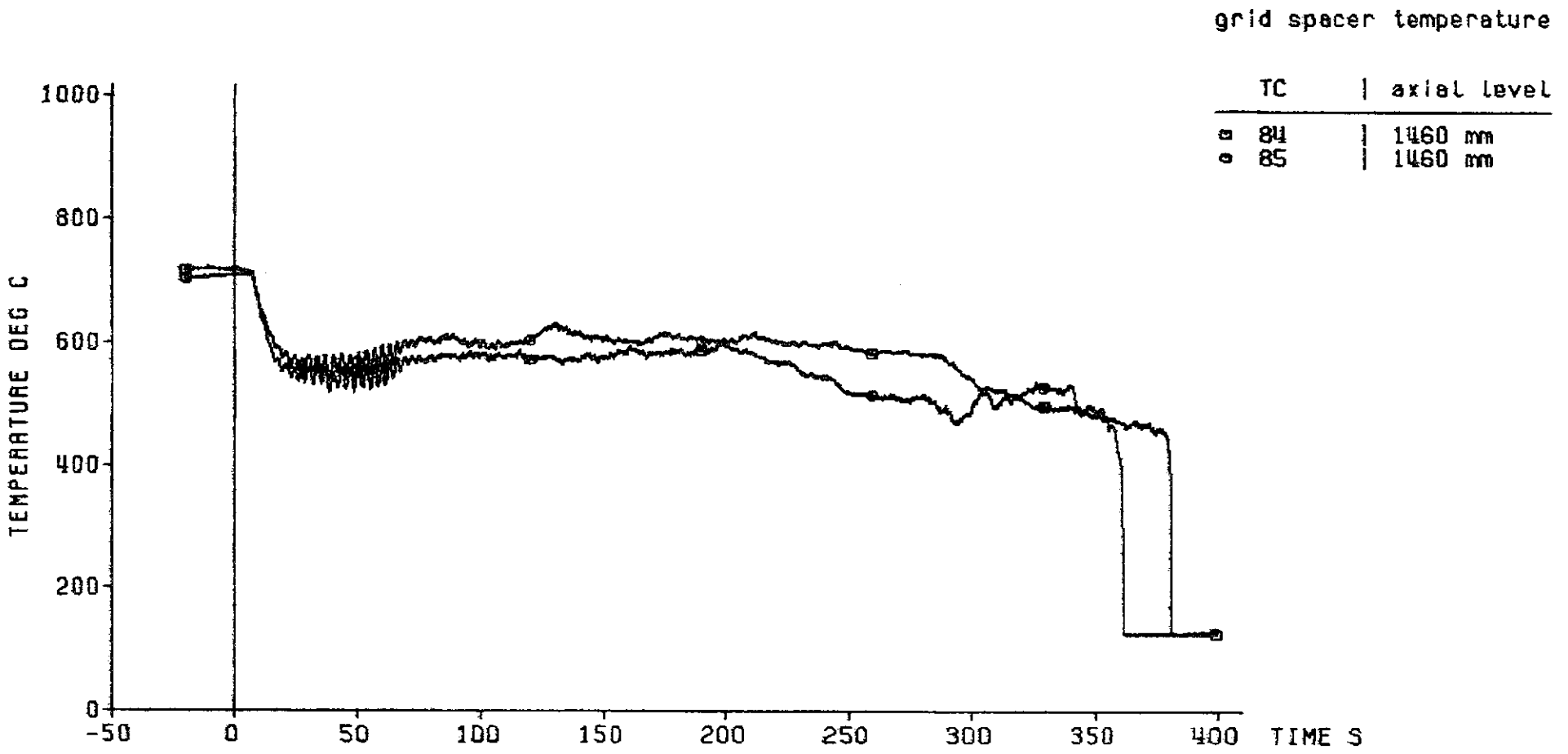
Fig. 369 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 262



decay heat	120% ANS standard
flooding rate (cold)	3.80 cm/s
system pressure	1.98 bar
feedwater temperature	40 deg C

KfK IRB

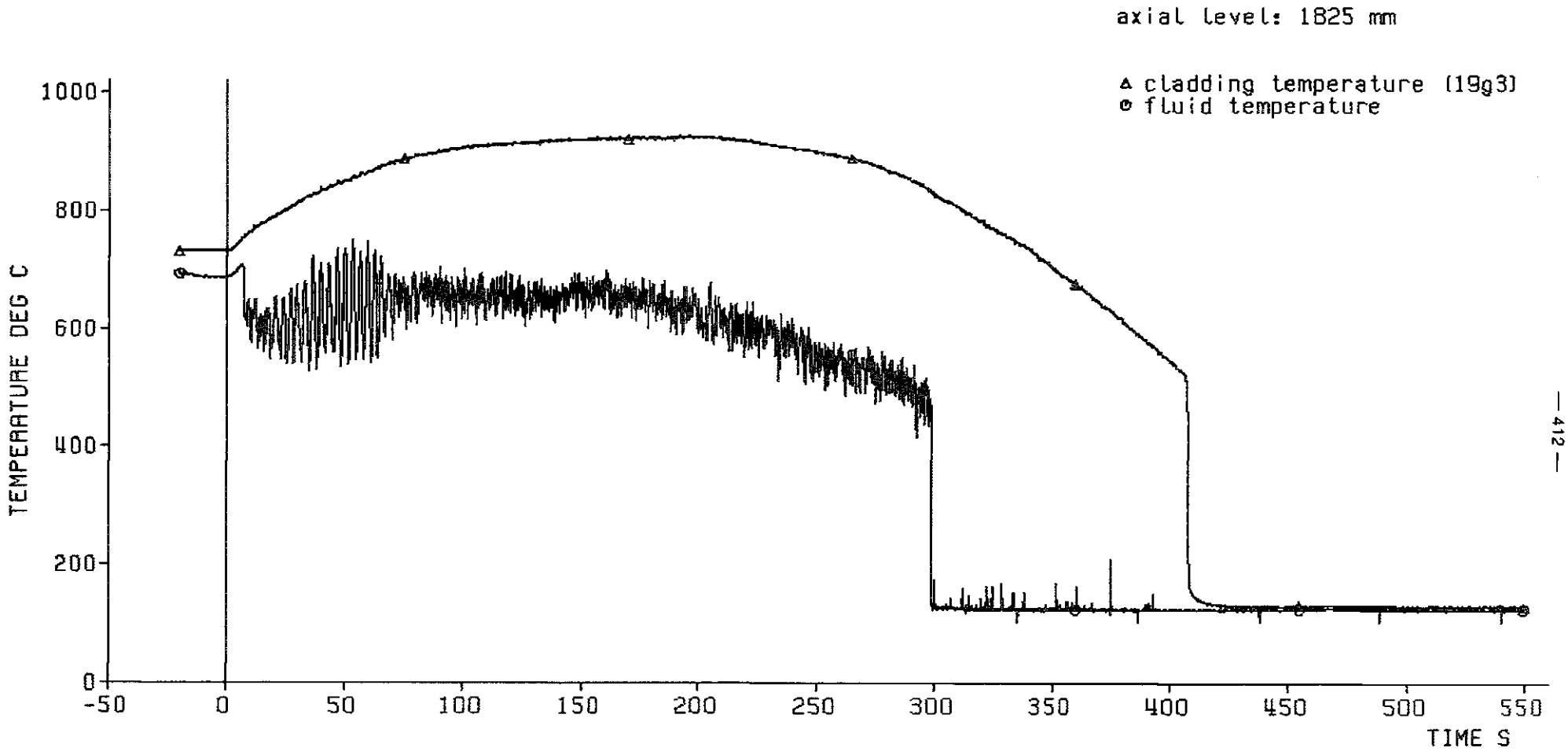
Fig. 370 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 262



decay heat	120% ANS standard
flooding rate (cold)	3.80 cm/s
system pressure	1.98 bar
feedwater temperature	40 deg C

KfK IRB

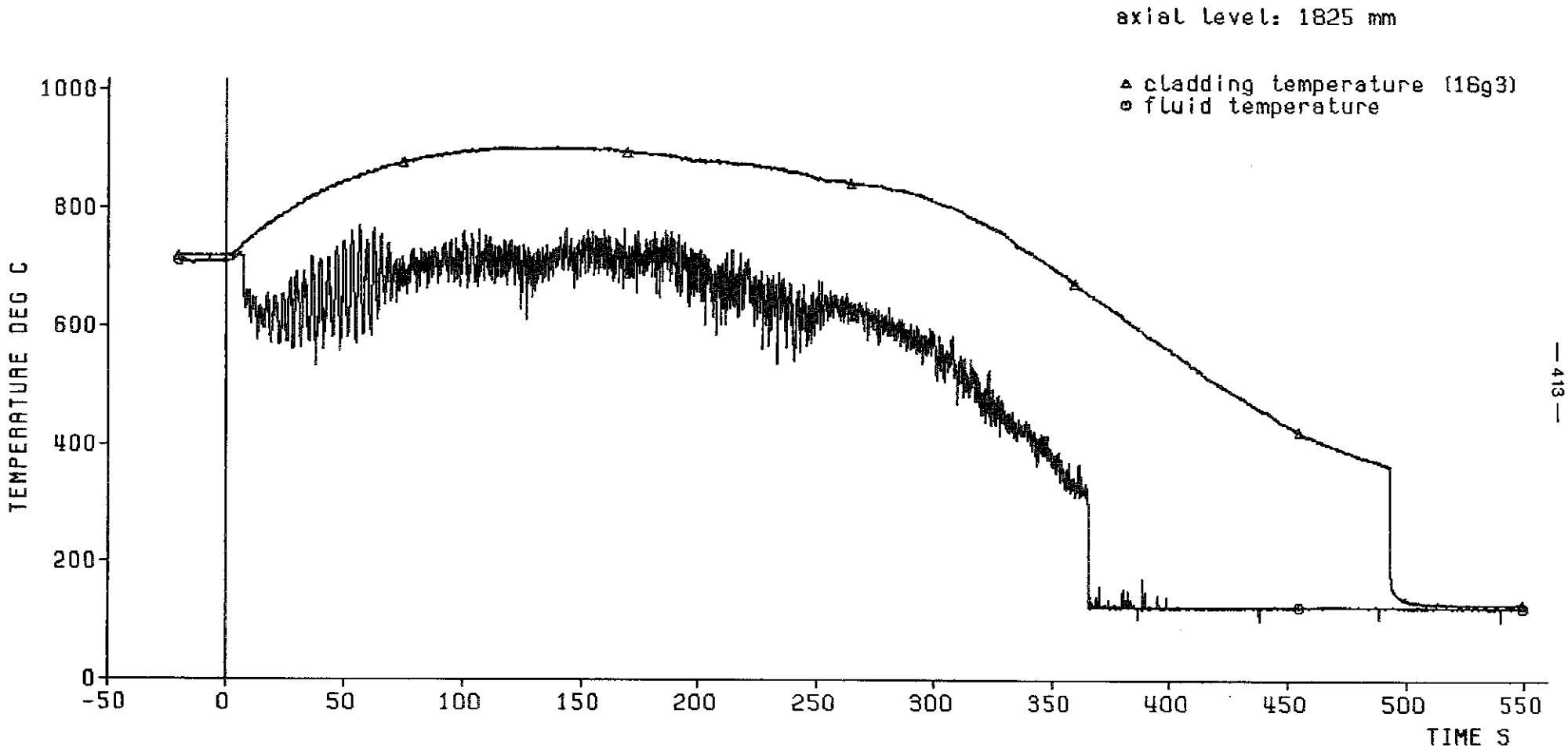
Fig. 371 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 262



decay heat	120% ANS standard	bypass
flooding rate (cold)	3.60 cm/s	======
system pressure	1.98 bar	
feedwater temperature	40 deg C	

KfK IRB

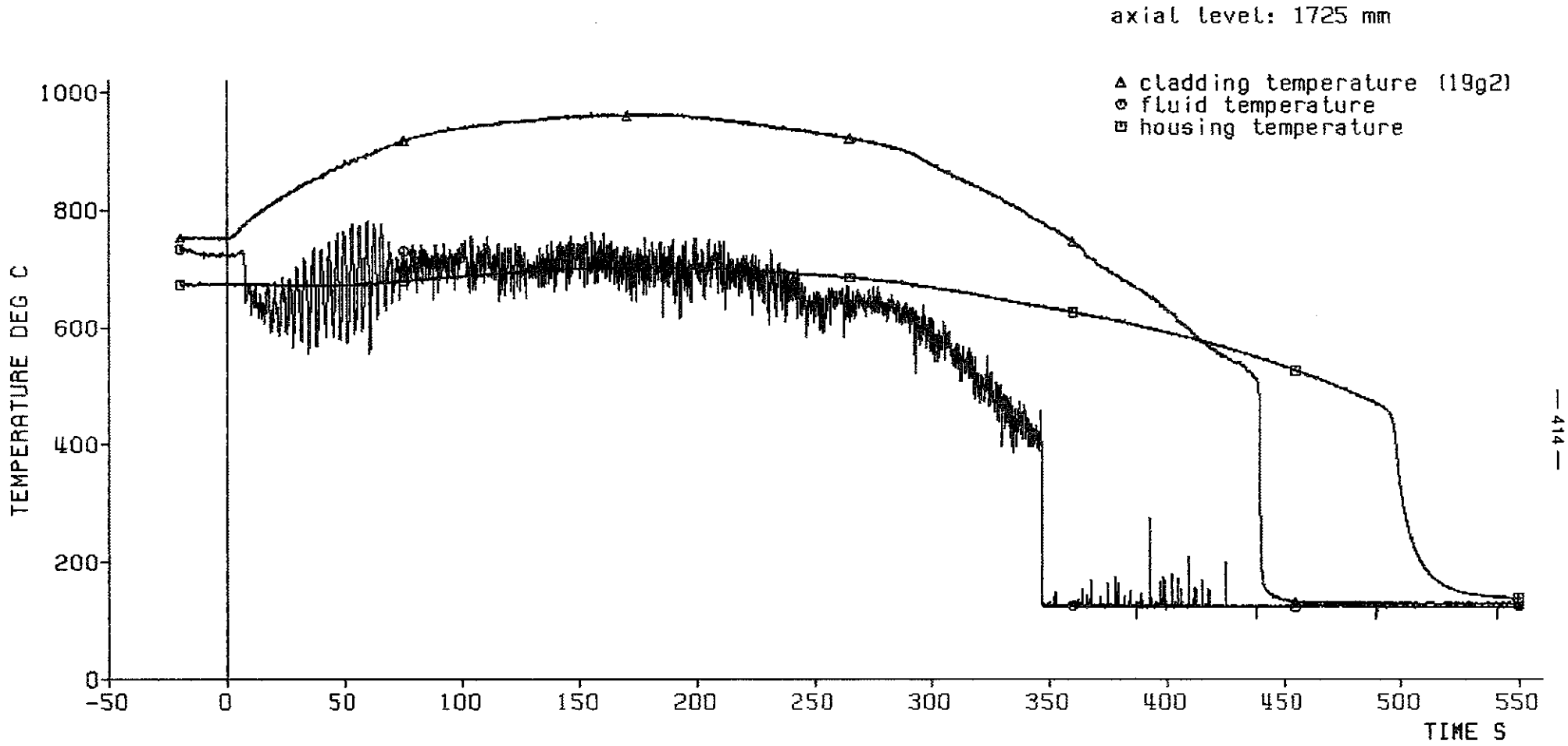
Fig. 372 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 262



decay heat	120% ANS standard	blockage
flooding rate (cold)	3.80 cm/s	========
system pressure	1.98 bar	
feedwater temperature	40 deg C	

KfK IRB

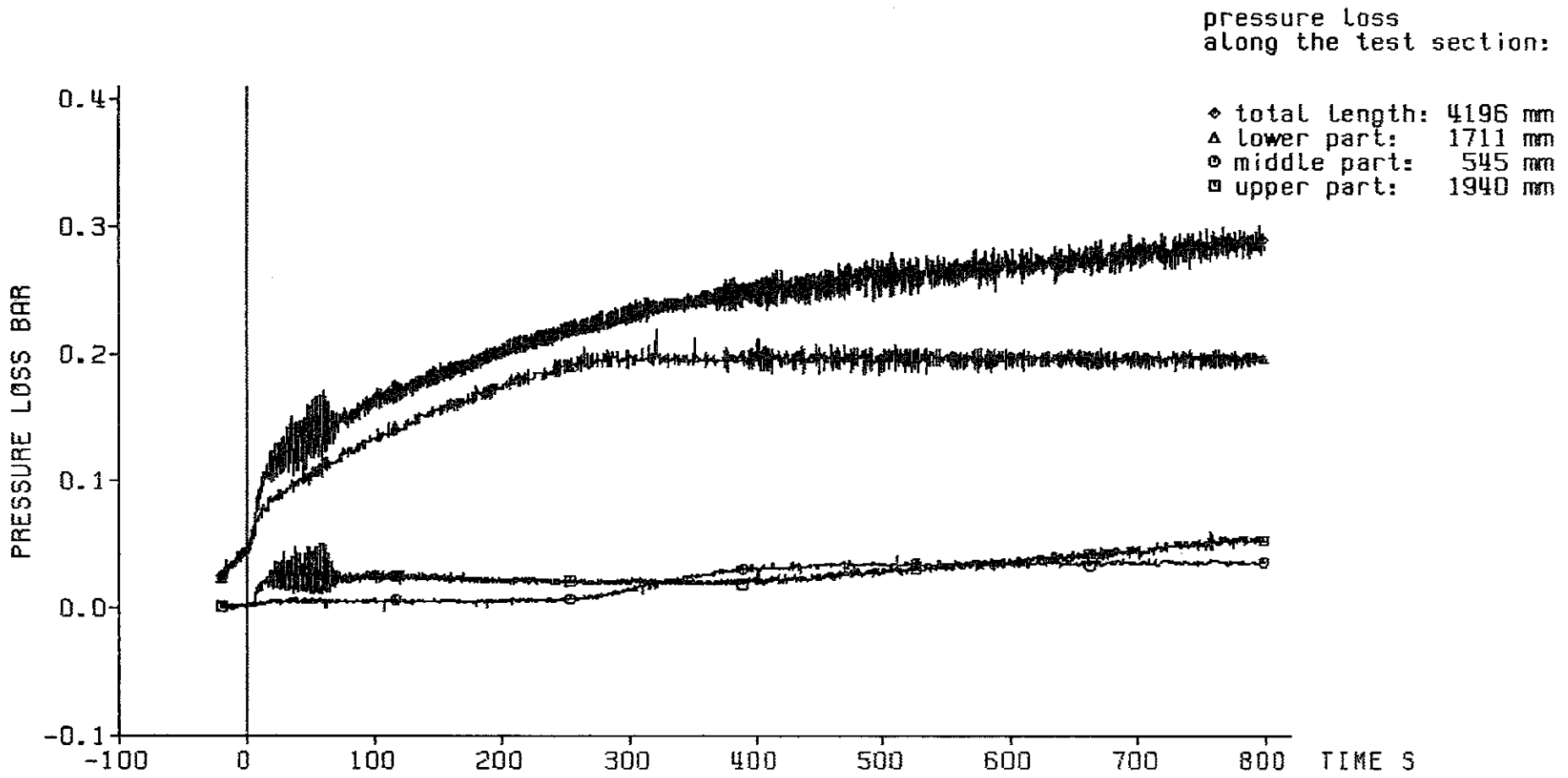
Fig. 373 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 262



decay heat	120% ANS standard	bypass
flooding rate (cold)	3.80 cm/s	======
system pressure	1.98 bar	
feedwater temperature	40 deg C	

KfK IRB

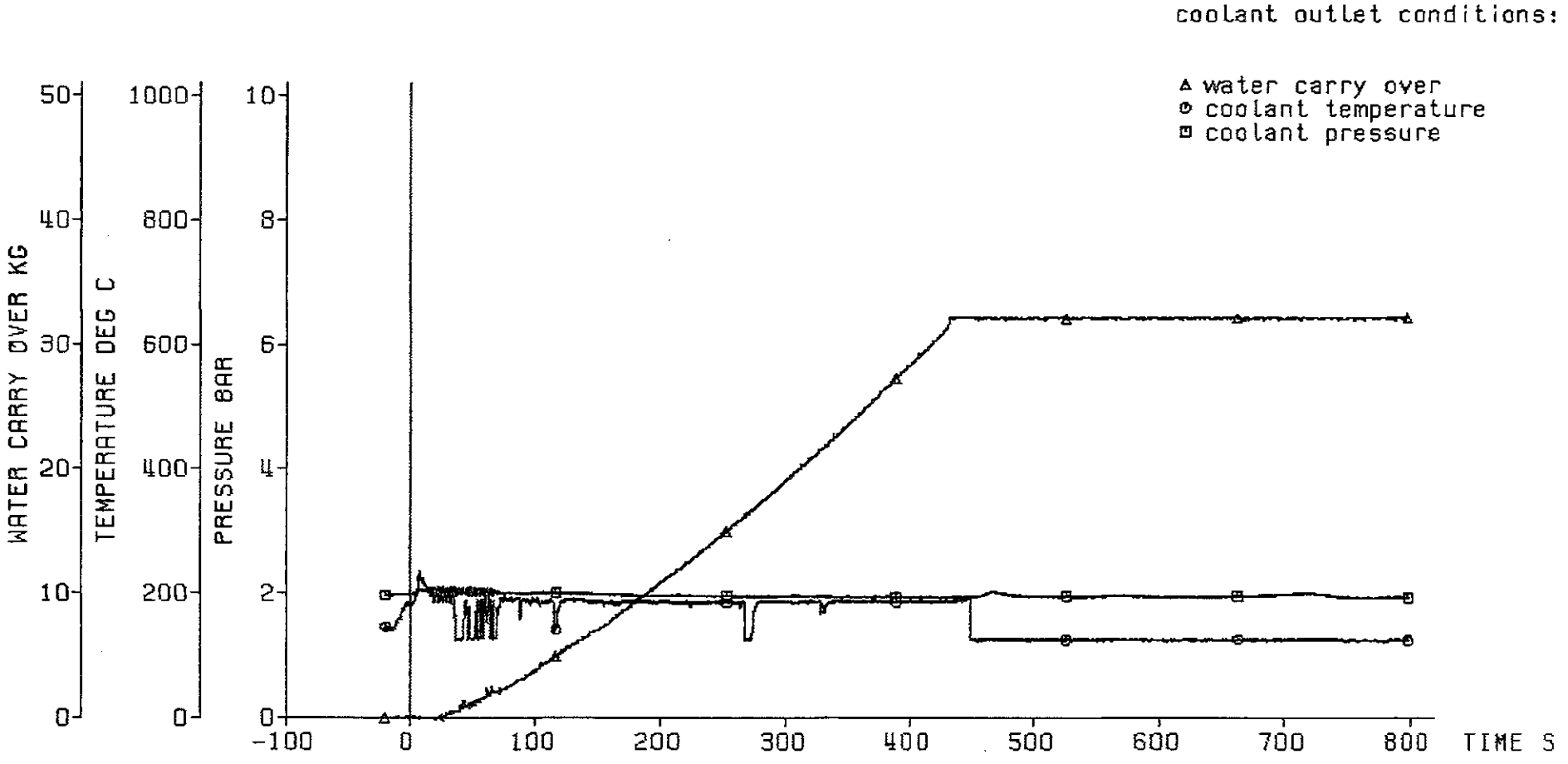
Fig. 374 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 262



decay heat	120% ANS standard
flooding rate (cold)	3.80 cm/s
system pressure	1.98 bar
feedwater temperature	40 deg C

KfK KIRB

Fig. 375 FEBA: 5x5 RØD BUNDLE, TEST SERIES 4, TEST-No. 262



decay heat	120% ANS standard
flooding rate (cold)	3.80 cm/s
system pressure	1.98 bar
feedwater temperature	40 deg C

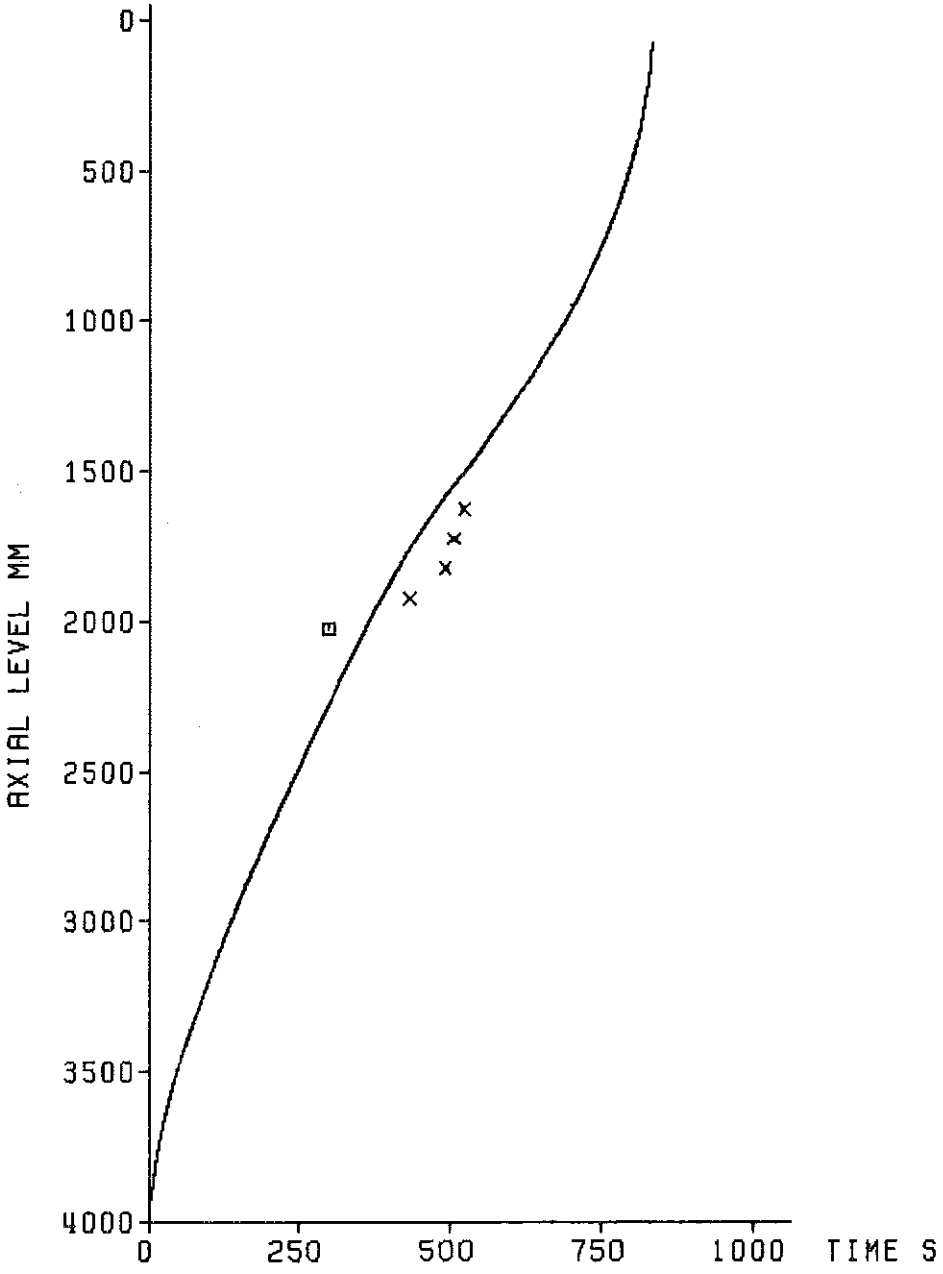
KfK IRB

Fig. 376 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 262

axial position of the quench front

⊡ rewetting of the sleeve at the bundle midplane

× rewetting of the rod downstream of the blockage

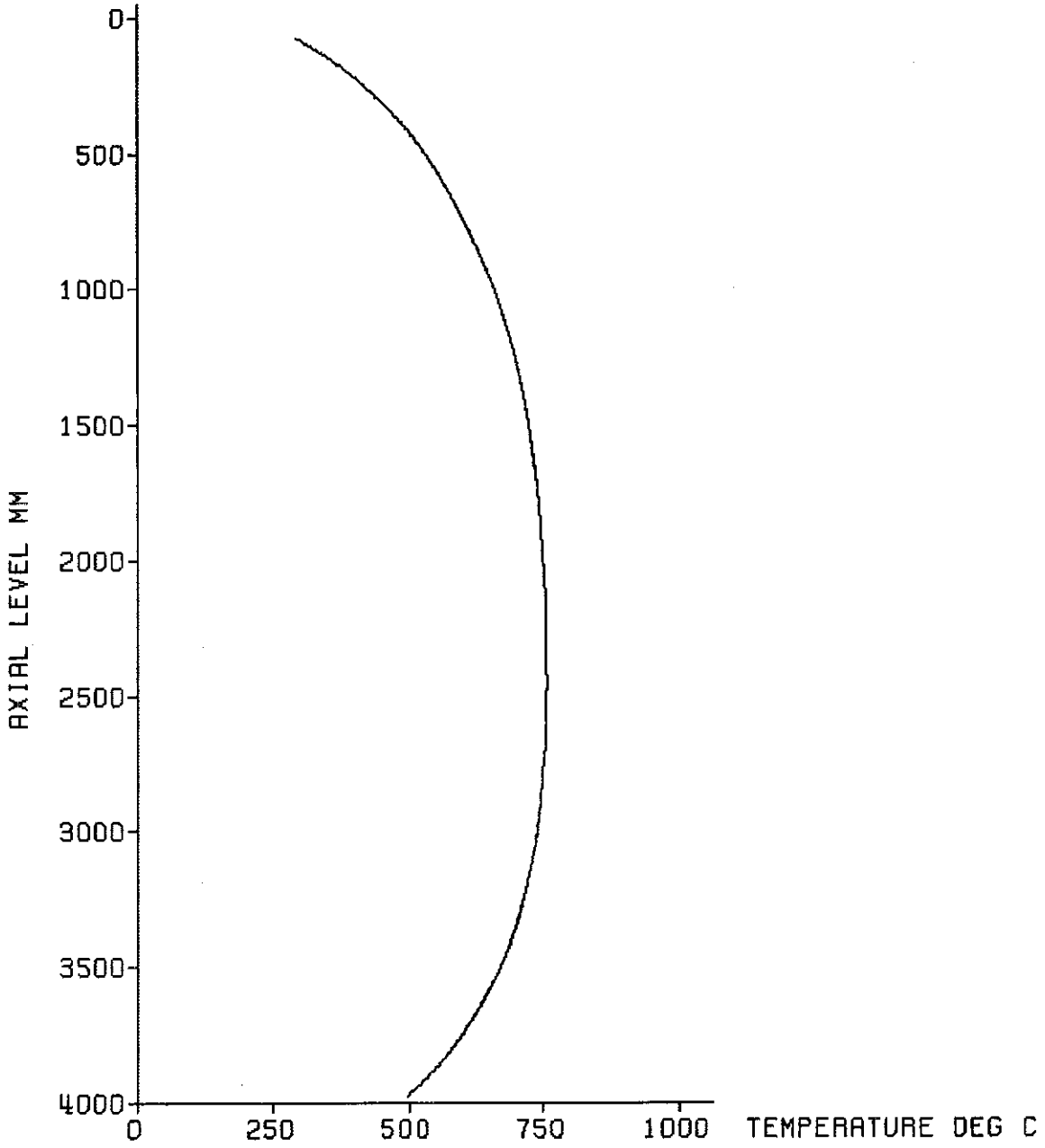


decay heat	120% ANS standard
flooding rate (cold)	3.80 cm/s
system pressure	1.98 bar
feedwater temperature	40 deg C

KfK IRB

Fig. 377 FEBA: 5x5 ROD BUNDLE TEST SERIES 4, TEST-No. 262

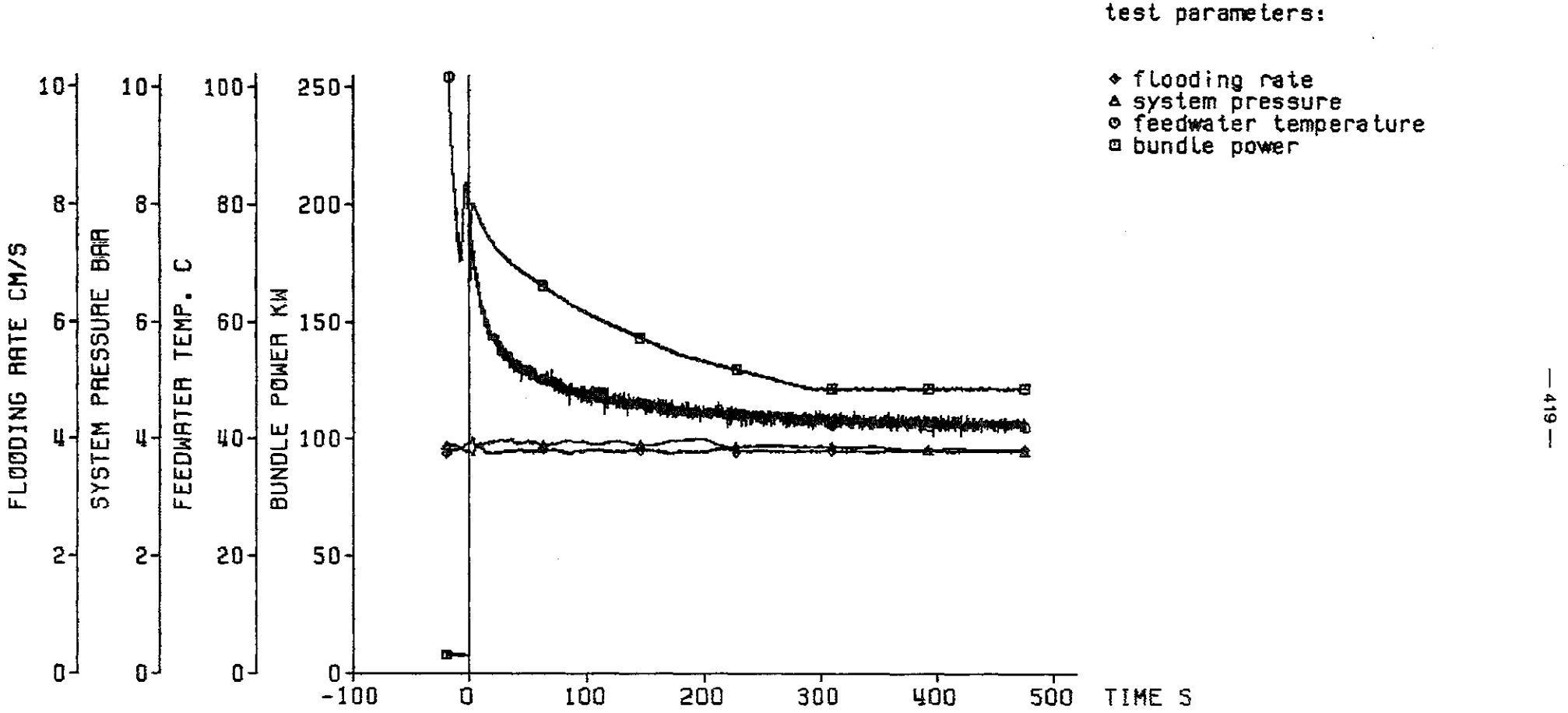
initial axial temperature profile of the cladding



decay heat	120% ANS standard
flooding rate (cold)	3.80 cm/s
system pressure	3.94 bar
feedwater temperature	40 deg C

KfK IRB

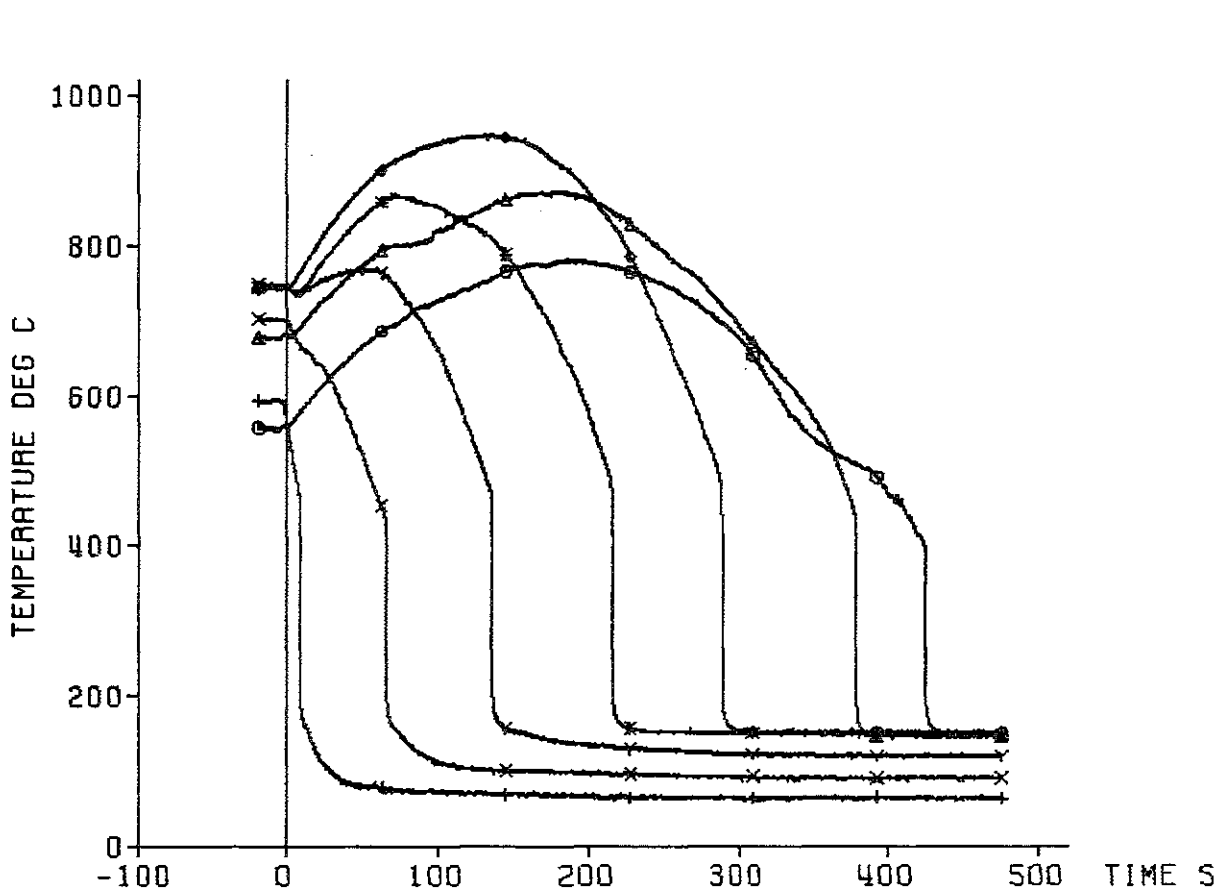
Fig. 378 FEBA: 5x5 ROD BUNDLE TEST SERIES 4, TEST-No. 263



decay heat	120% ANS standard
flooding rate (cold)	3.80 cm/s
system pressure	3.94 bar
feedwater temperature	40 deg C

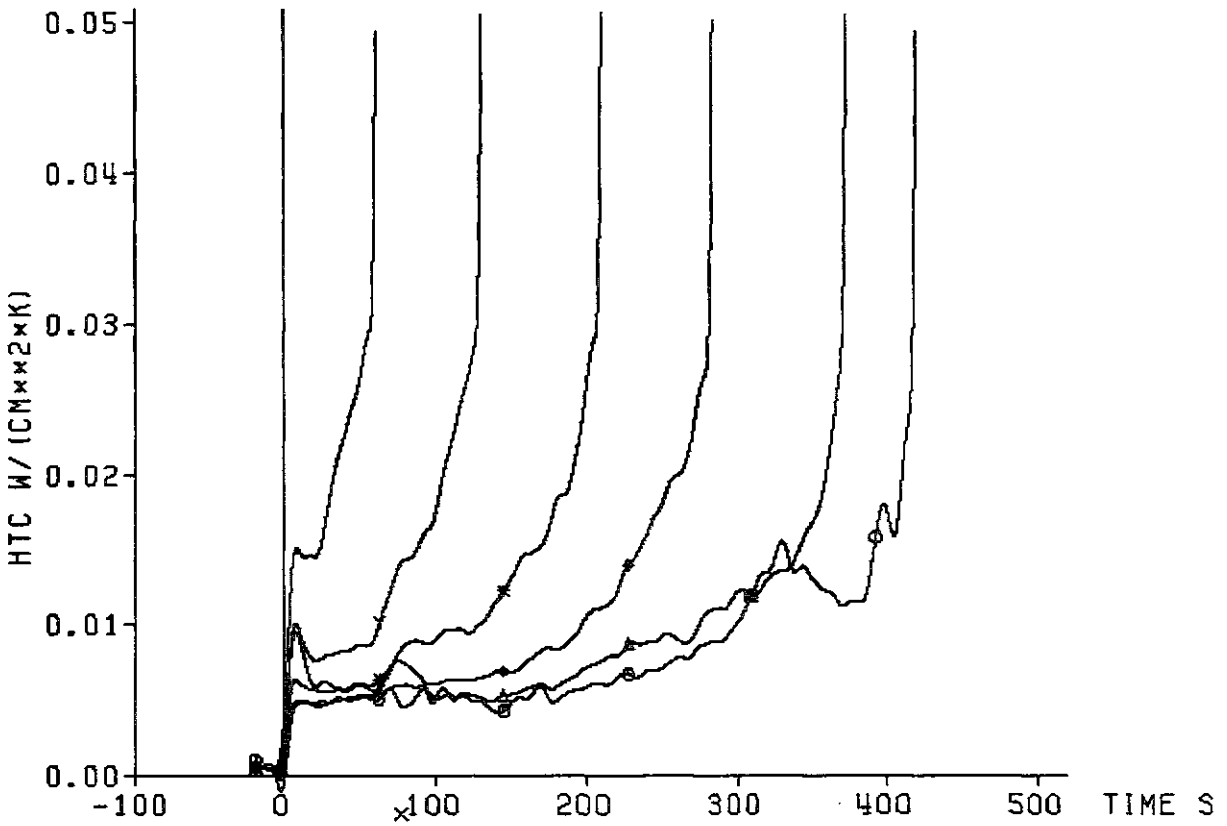
KfK IRB

Fig. 379 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 263



decay heat	120% ANS standard
flooding rate (cold)	3.80 cm/s
system pressure	3.94 bar
feedwater temperature	40 deg C

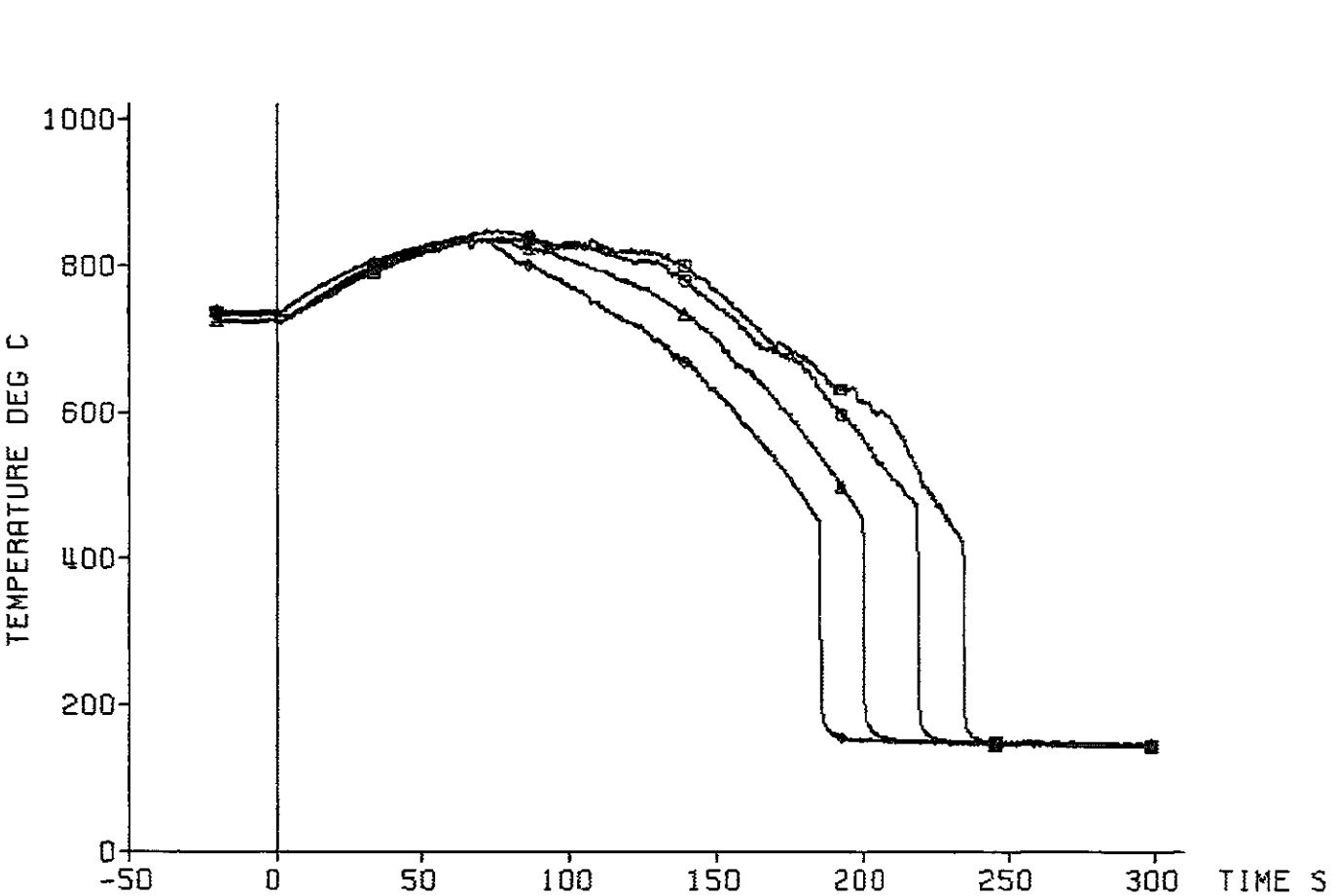
Fig. 380 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 263



decay heat	120% ANS standard
flooding rate (cold)	3.80 cm/s
system pressure	3.94 bar
feedwater temperature	40 deg C

KfK IRB

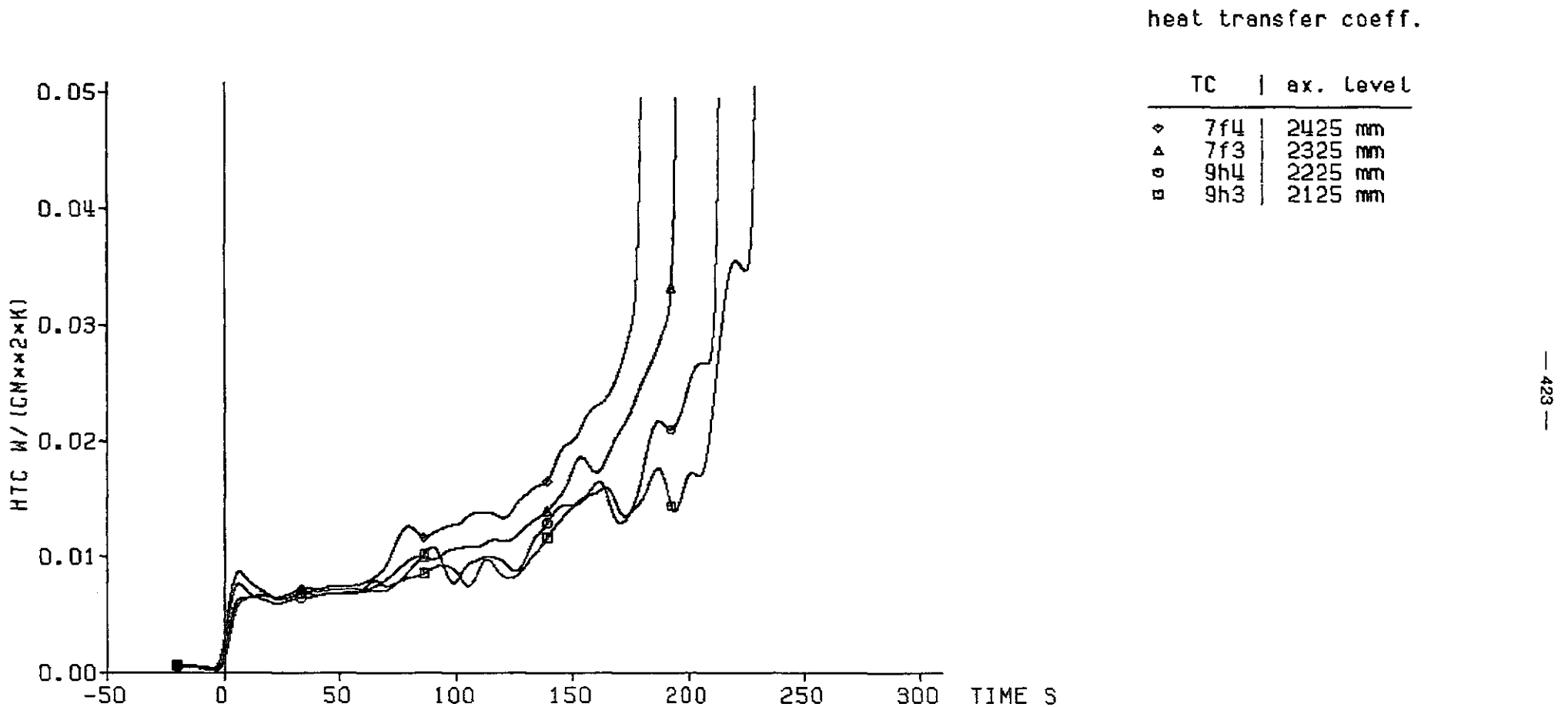
Fig. 381 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 263



decay heat	120% ANS standard	bypass
flooding rate (cold)	3.80 cm/s	======
system pressure	3.94 bar	
feedwater temperature	40 deg C	

KfK IRB

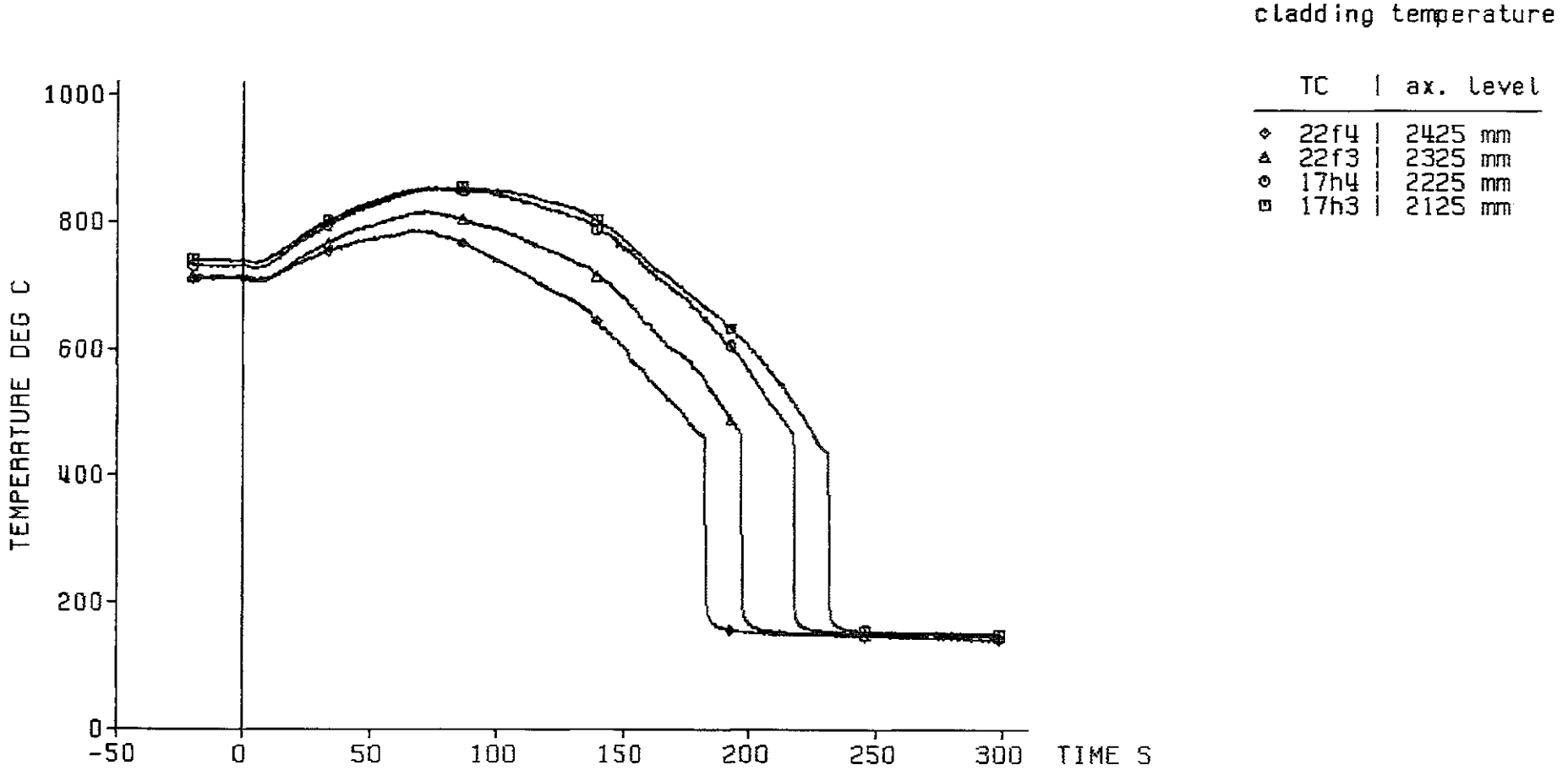
Fig. 382 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 263



decay heat	120% ANS standard	bypass
flooding rate (cold)	3.80 cm/s	======
system pressure	3.94 bar	
feedwater temperature	40 deg C	

KfK IRB

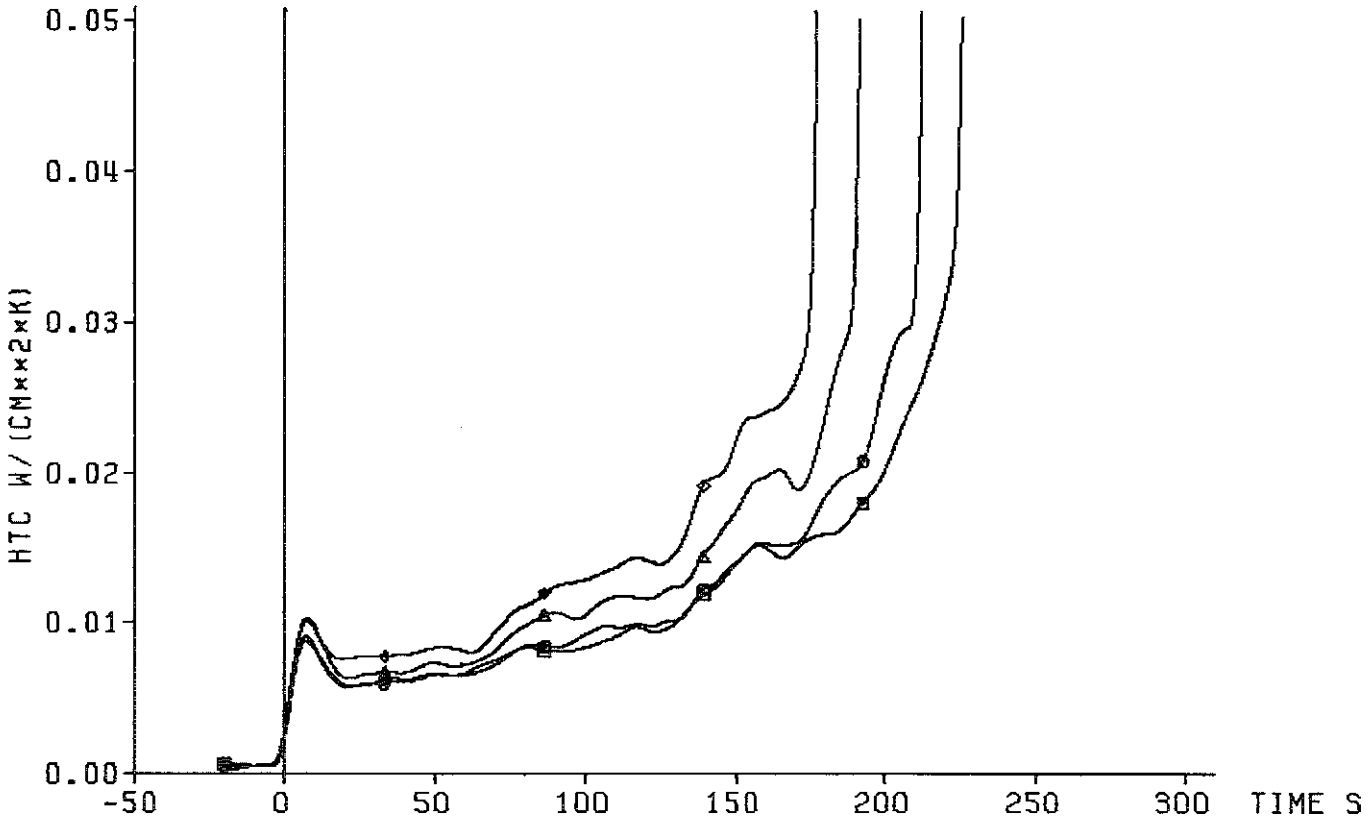
Fig. 383 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 263



decay heat	120% ANS standard	blockage
flooding rate (cold)	3.80 cm/s	========
system pressure	3.94 bar	
feedwater temperature	40 deg C	

KfK IRB

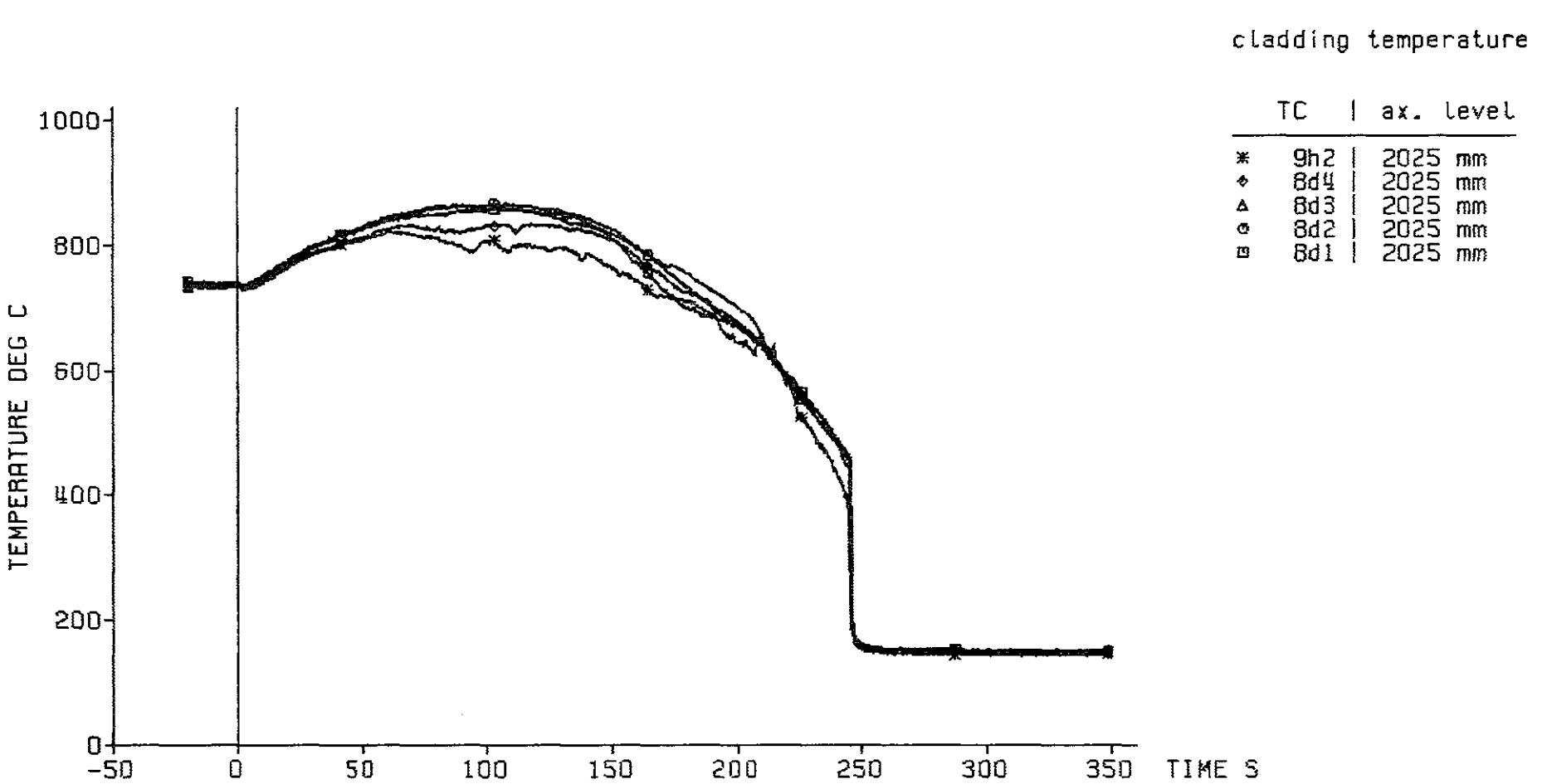
Fig. 384 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 263



decay heat	120% ANS standard	blockage
flooding rate (cold)	3.80 cm/s	========
system pressure	3.94 bar	
feedwater temperature	40 deg C	

KfK IRB

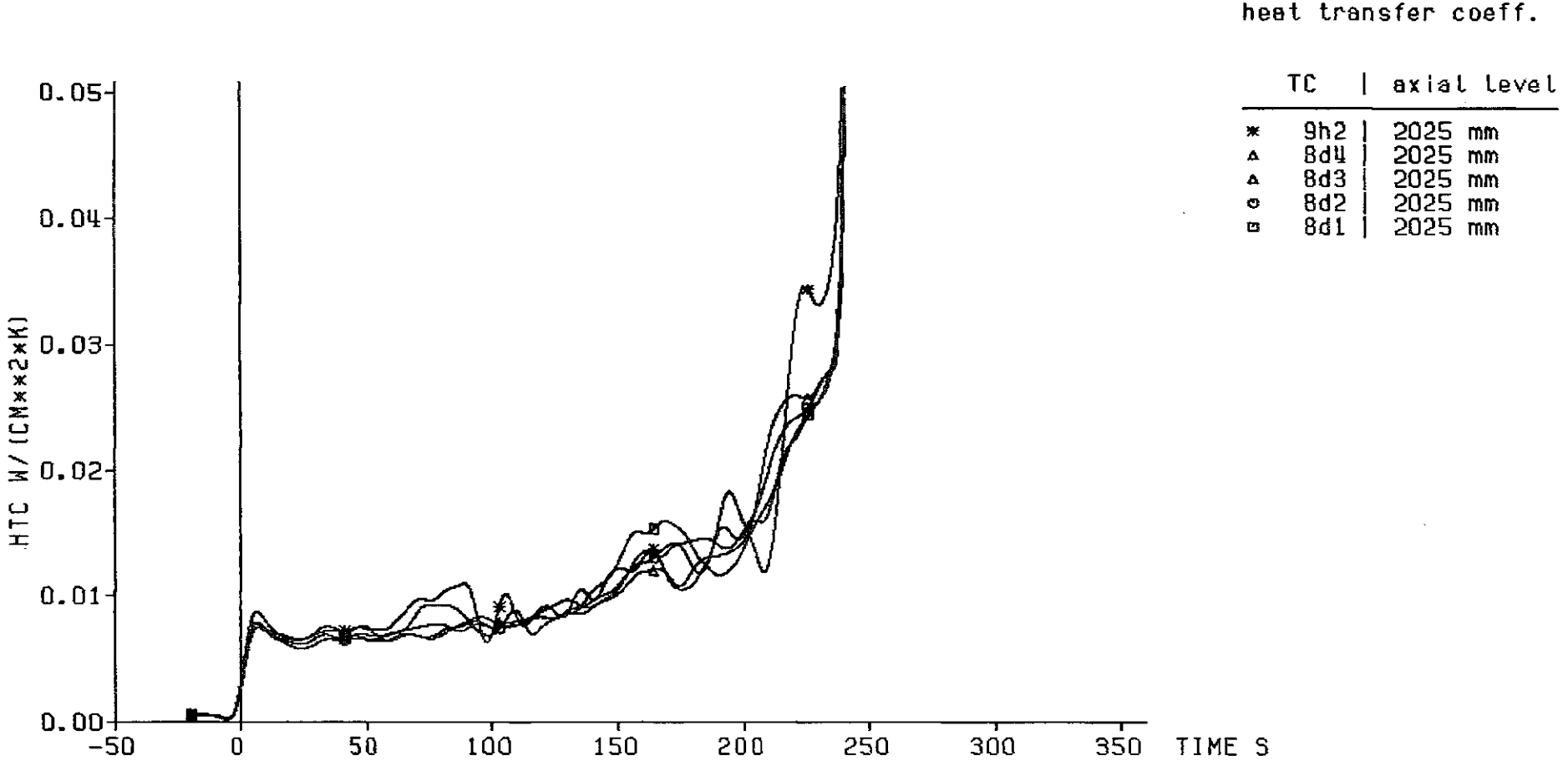
Fig. 385 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 263



decay heat	120% ANS standard	bypass
flooding rate (cold)	3.80 cm/s	======
system pressure	3.94 bar	
feedwater temperature	40 deg C	

KfK IRB

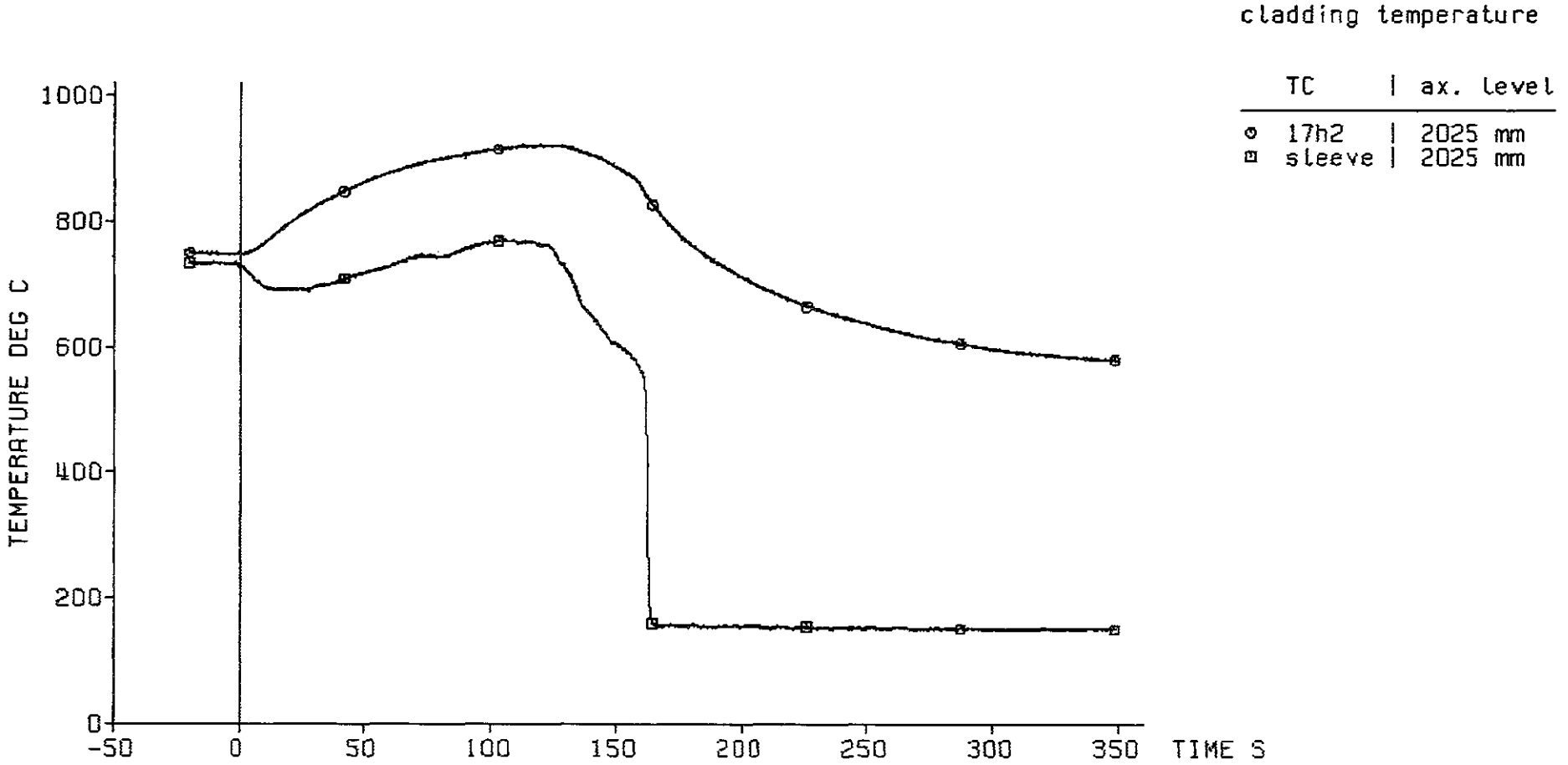
Fig. 386 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 263



decay heat	120% ANS standard	bypass
flooding rate (cold)	3.80 cm/s	======
system pressure	3.94 bar	
feedwater temperature	40 deg C	

KfK IRB

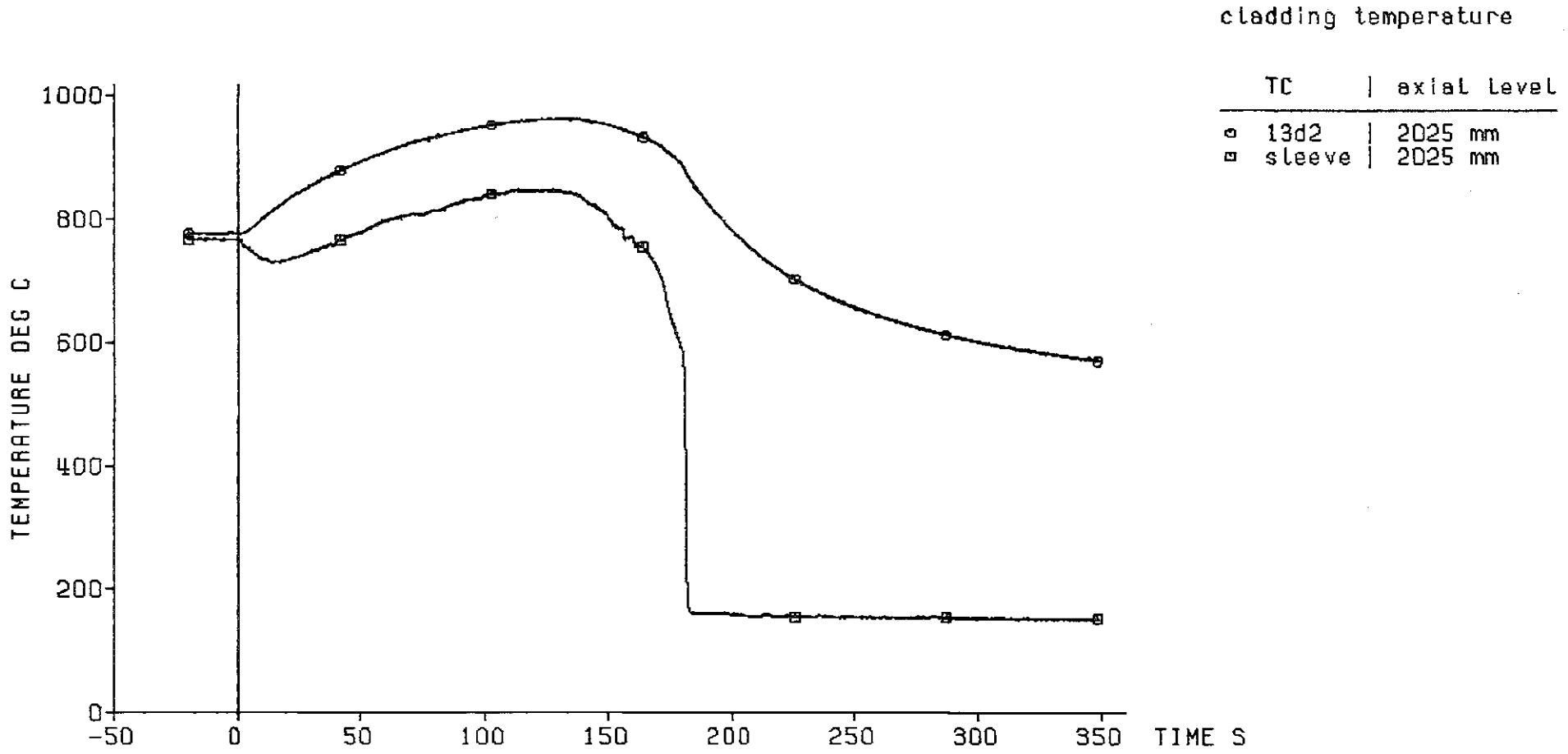
Fig. 387 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 263



decay heat	120% ANS standard	blockage
flooding rate (cold)	3.80 cm/s	========
system pressure	3.94 bar	
feedwater temperature	40 deg C	

KfK IRB

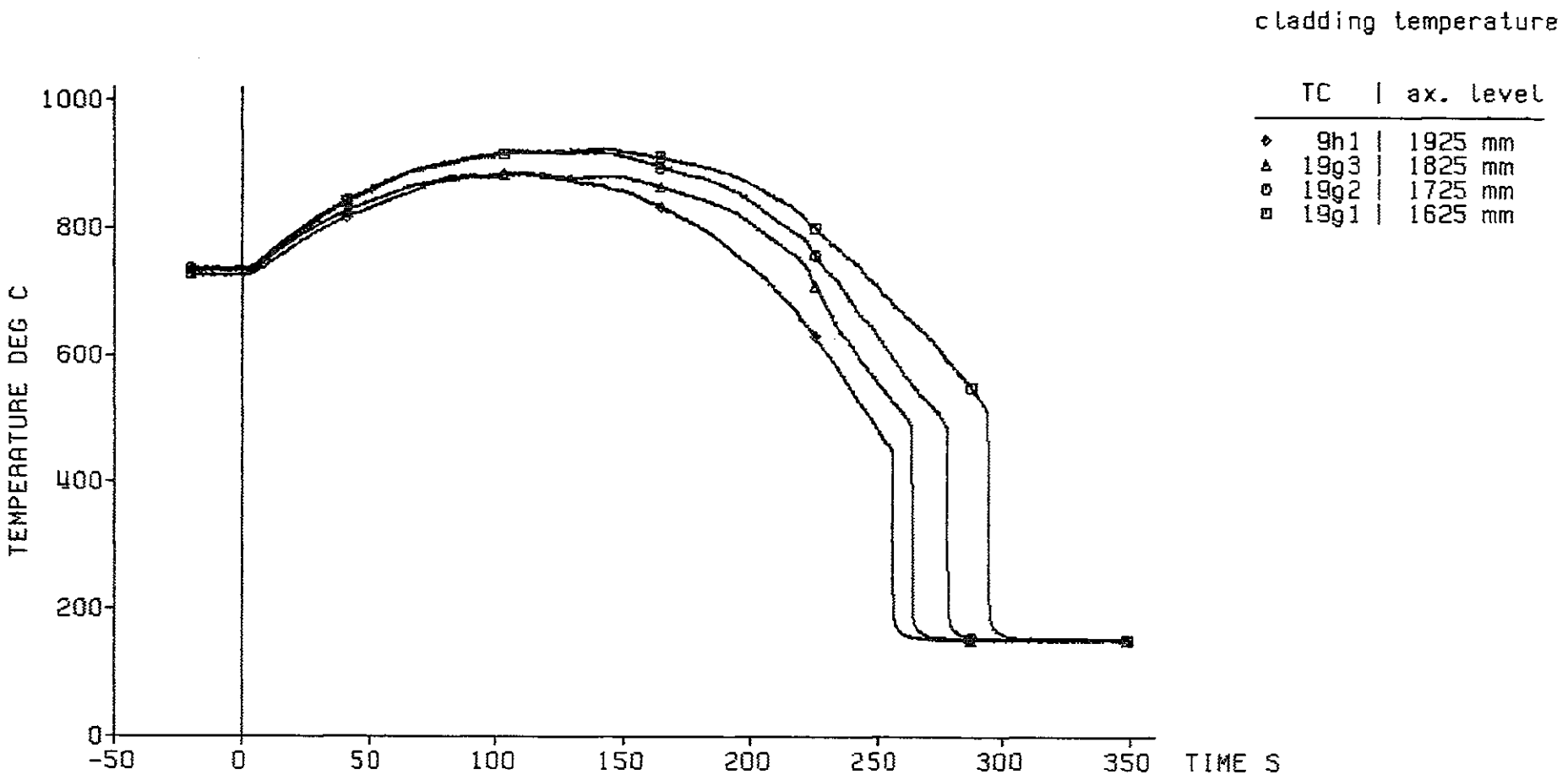
Fig. 388 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 263



decay heat	120% ANS standard	blockage
flooding rate (cold)	3.80 cm/s	========
system pressure	3.94 bar	
feedwater temperature	40 deg C	

KfK IRB

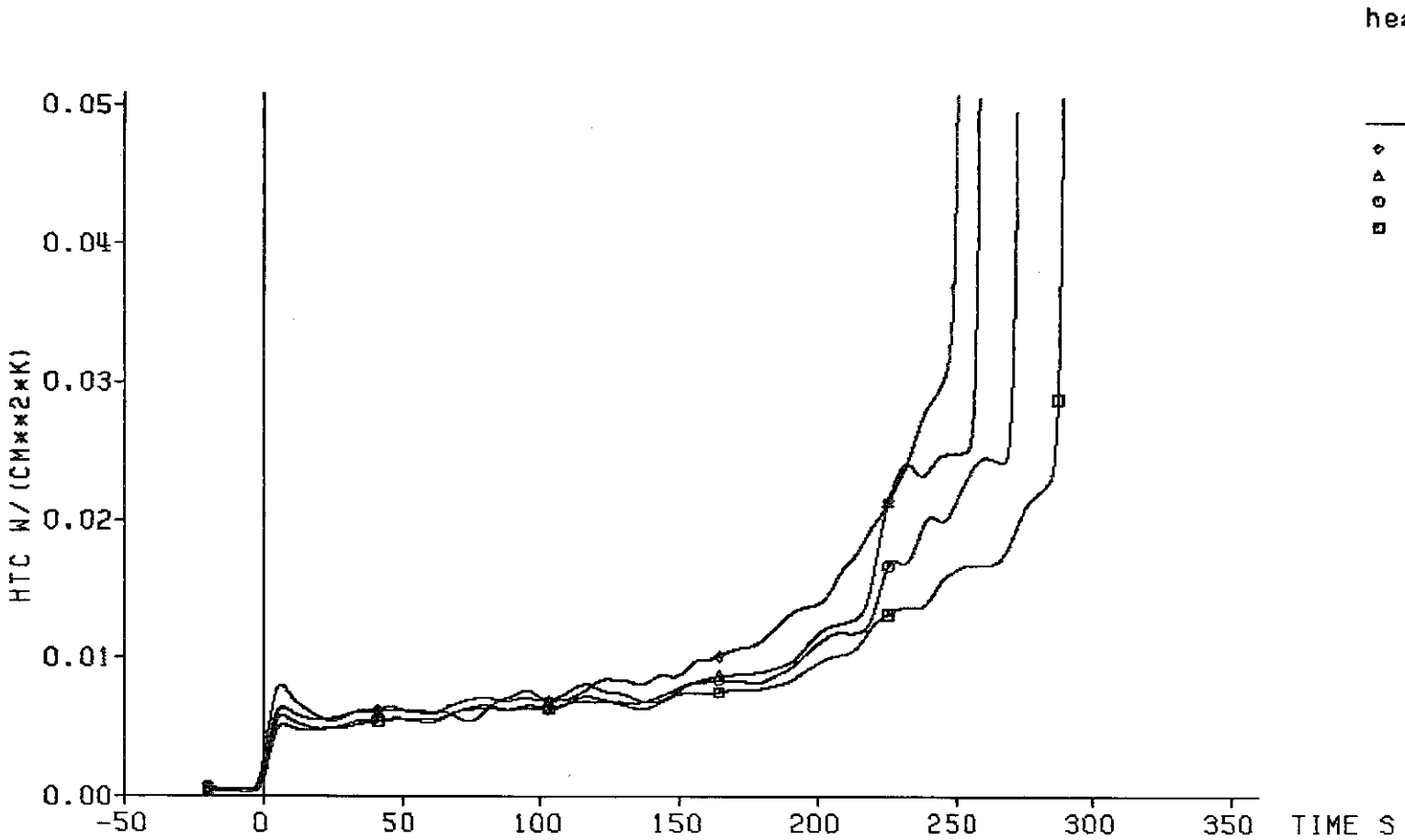
Fig. 389 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 263



decay heat	120% ANS standard	bypass
flooding rate (cold)	3.80 cm/s	======
system pressure	3.94 bar	
feedwater temperature	40 deg C	

KfK IRB

Fig. 390 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 263

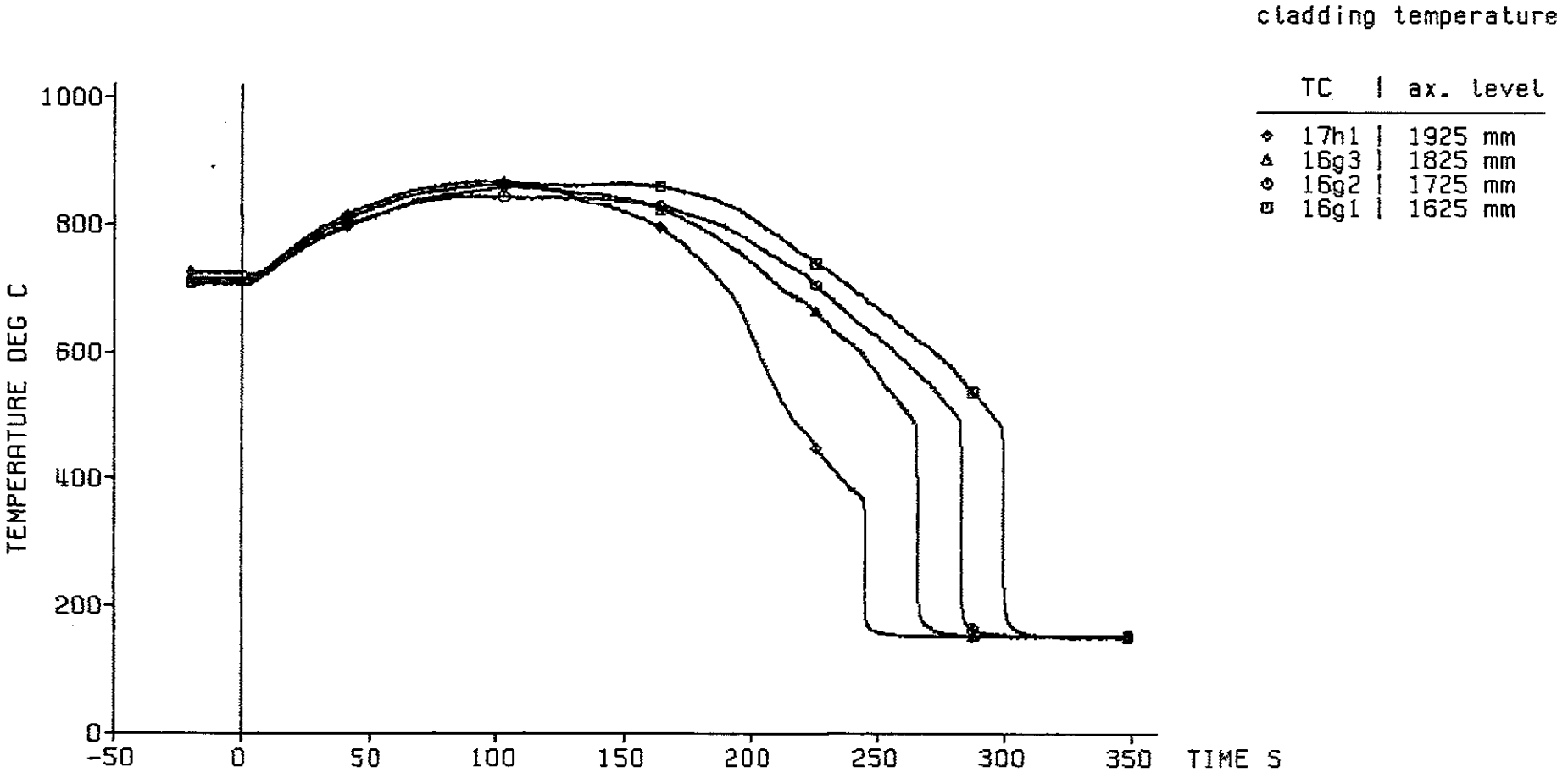


decay heat 120% ANS standard
flooding rate (cold) 3.80 cm/s
system pressure 3.94 bar
feedwater temperature 40 deg C

bypass
======

KfK IRB

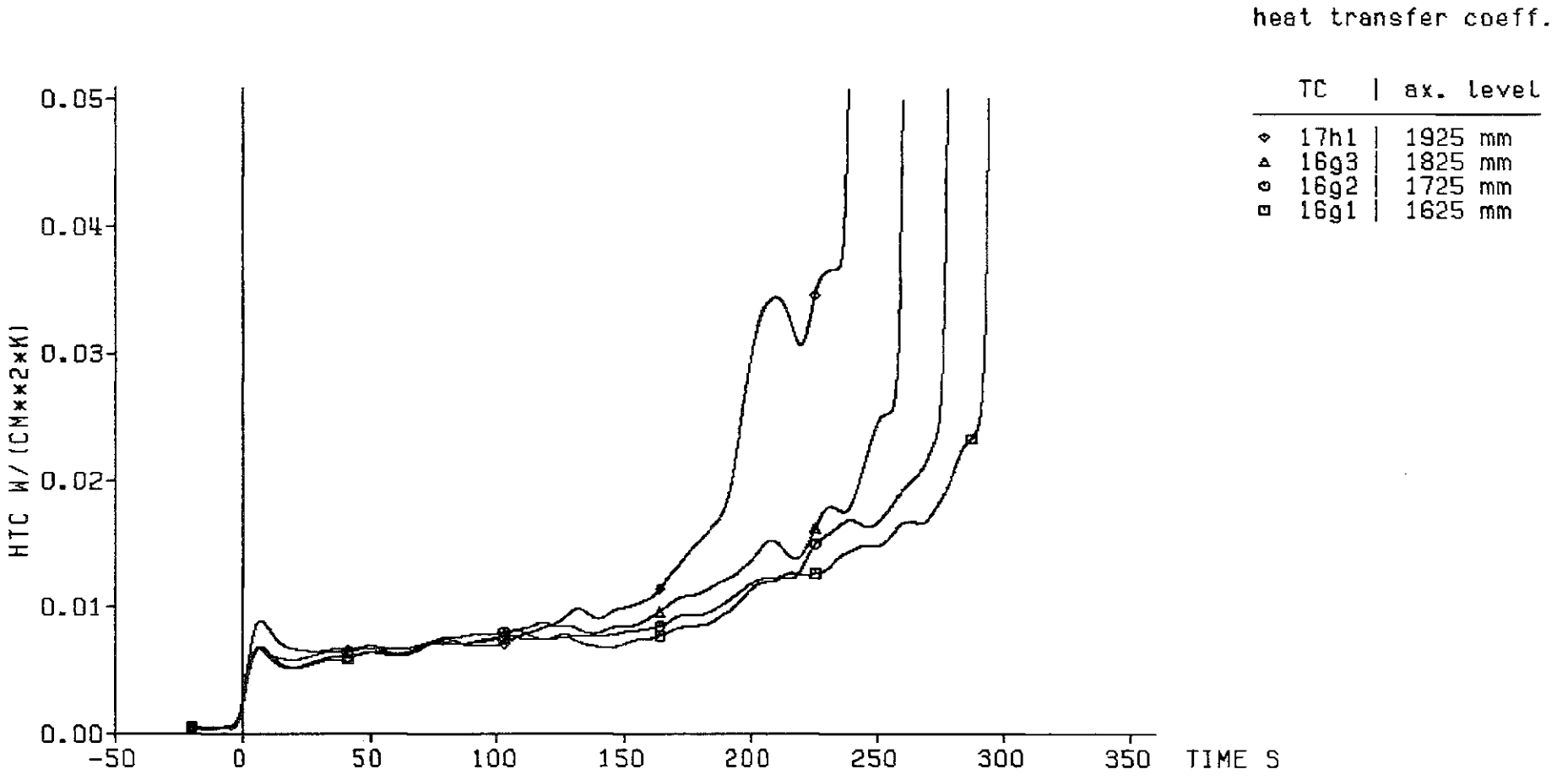
Fig. 391 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 263



decay heat	120% ANS standard	blockage
flooding rate (cold)	3.80 cm/s	========
system pressure	3.94 bar	
feedwater temperature	40 deg C	

KfK IRB

Fig. 392 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 263



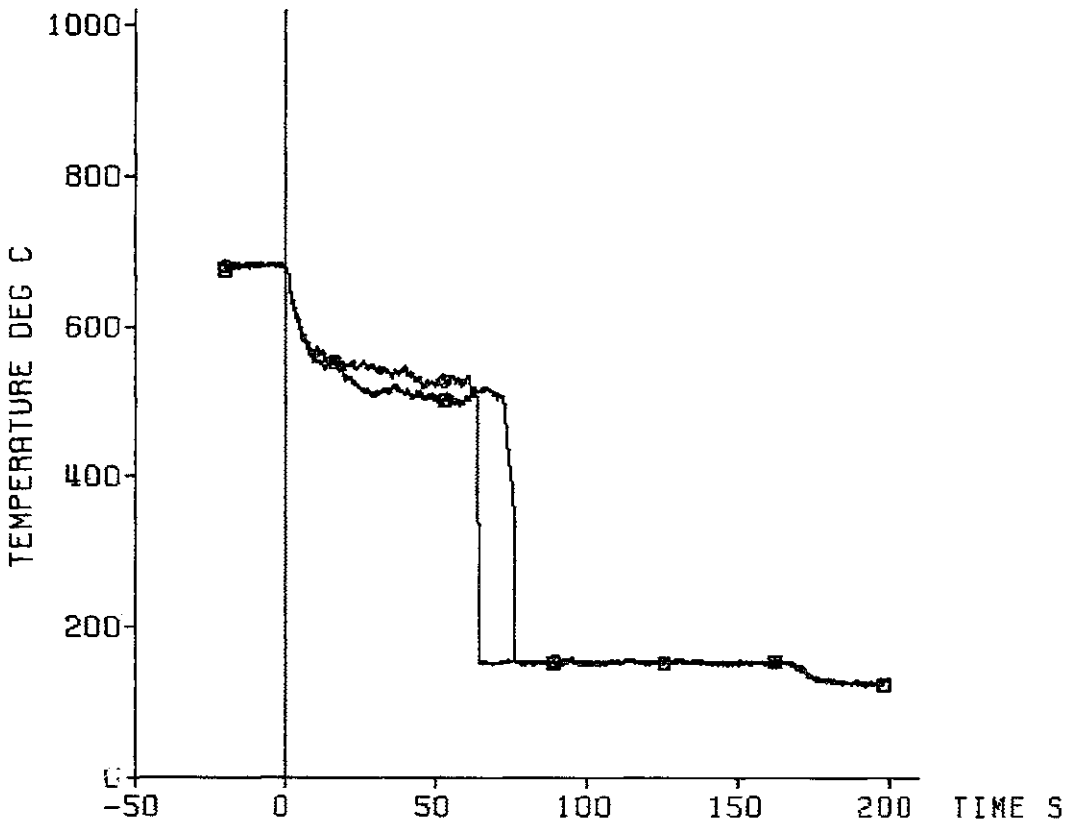
decay heat	120% ANS standard	blockage
flooding rate (cold)	3.80 cm/s	========
system pressure	3.94 bar	
feedwater temperature	40 deg C	

KfK IRB

Fig. 393 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 263

grid spacer temperature

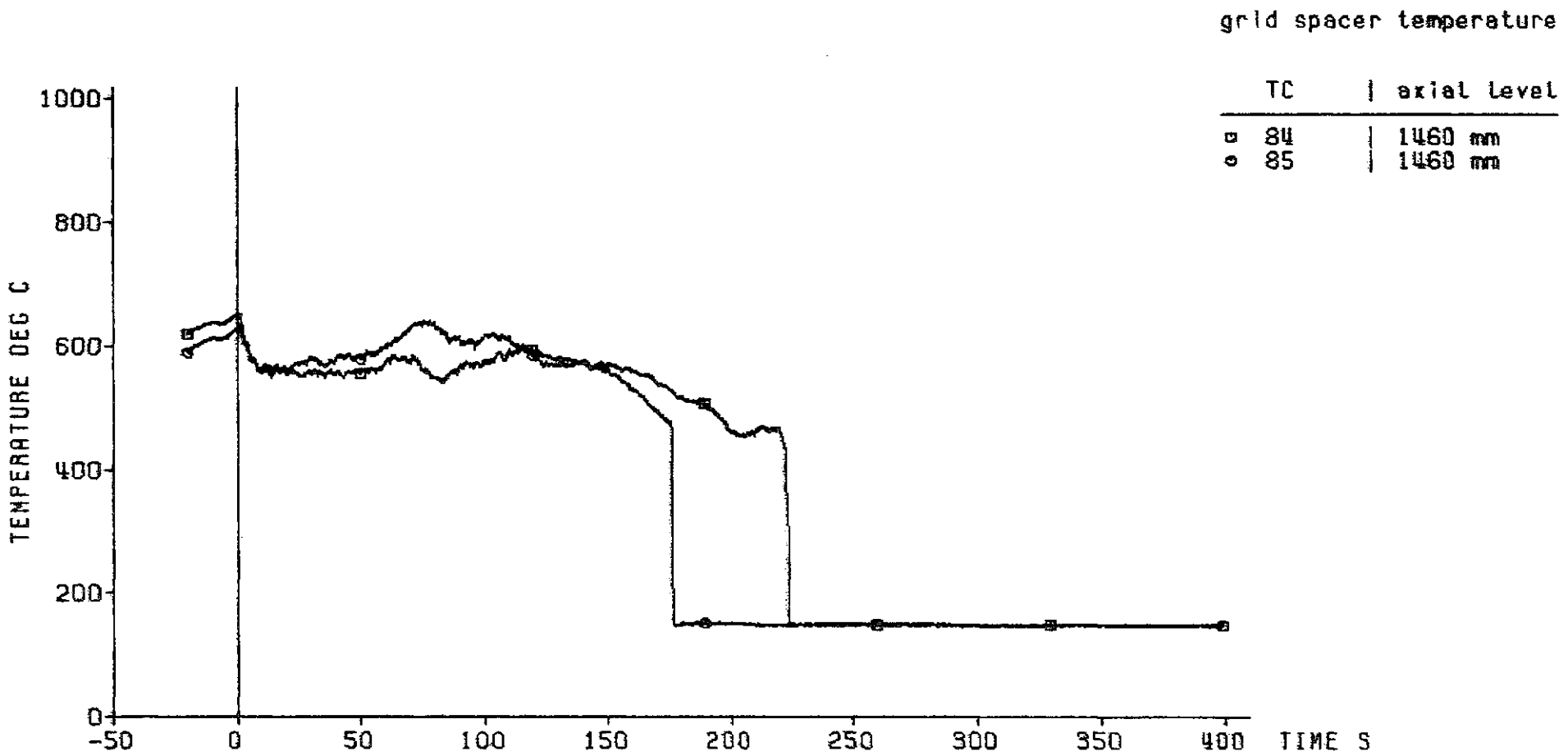
	TC	axial level
▫	86	2550 mm
◦	87	2550 mm



decay heat	120% ANS standard
flooding rate (cold)	3.80 cm/s
system pressure	3.94 bar
feedwater temperature	40 deg C

KfK IRB

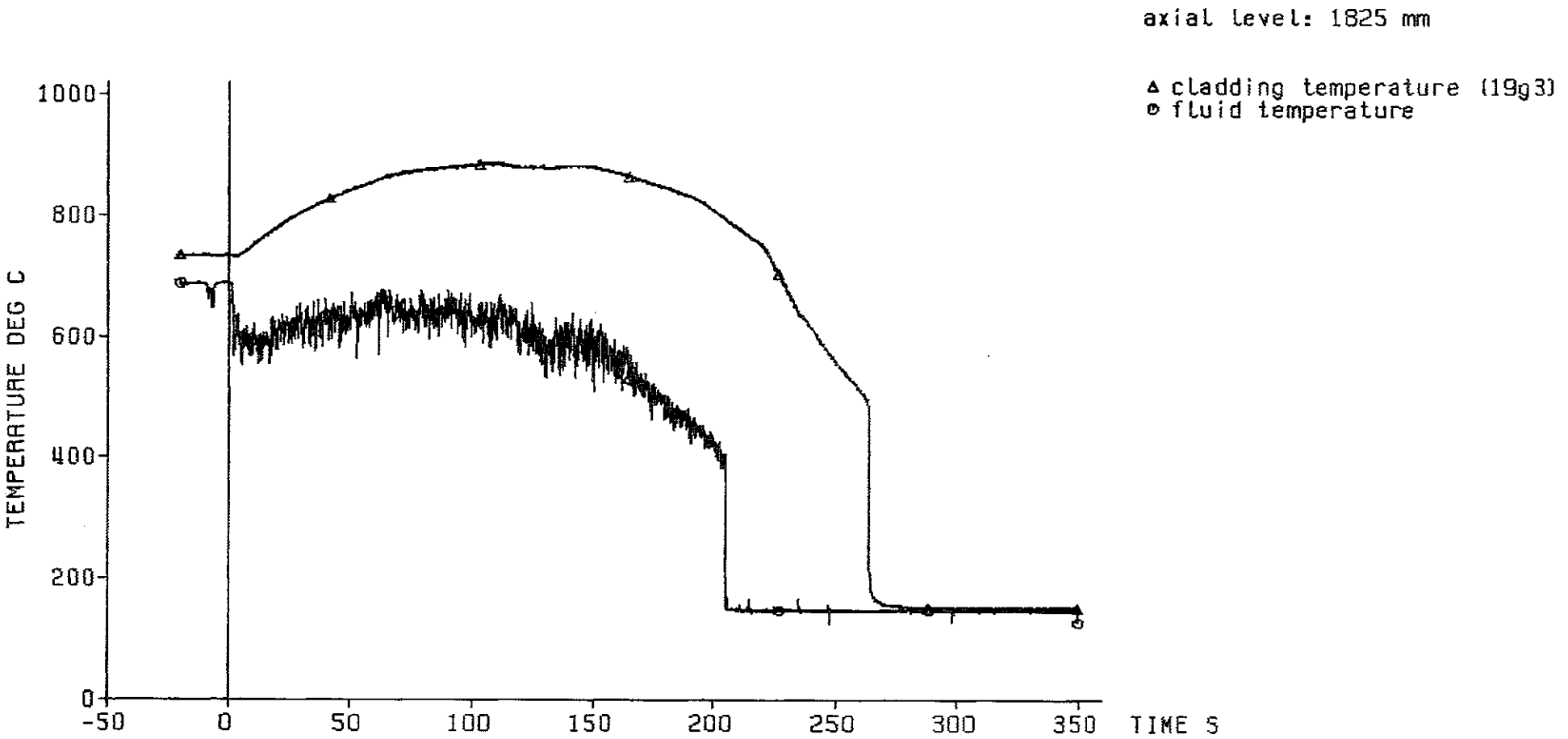
Fig. 394 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 263



decay heat	120% ANS standard
flooding rate (cold)	3.80 cm/s
system pressure	3.94 bar
feedwater temperature	40 deg C

KfK IRB

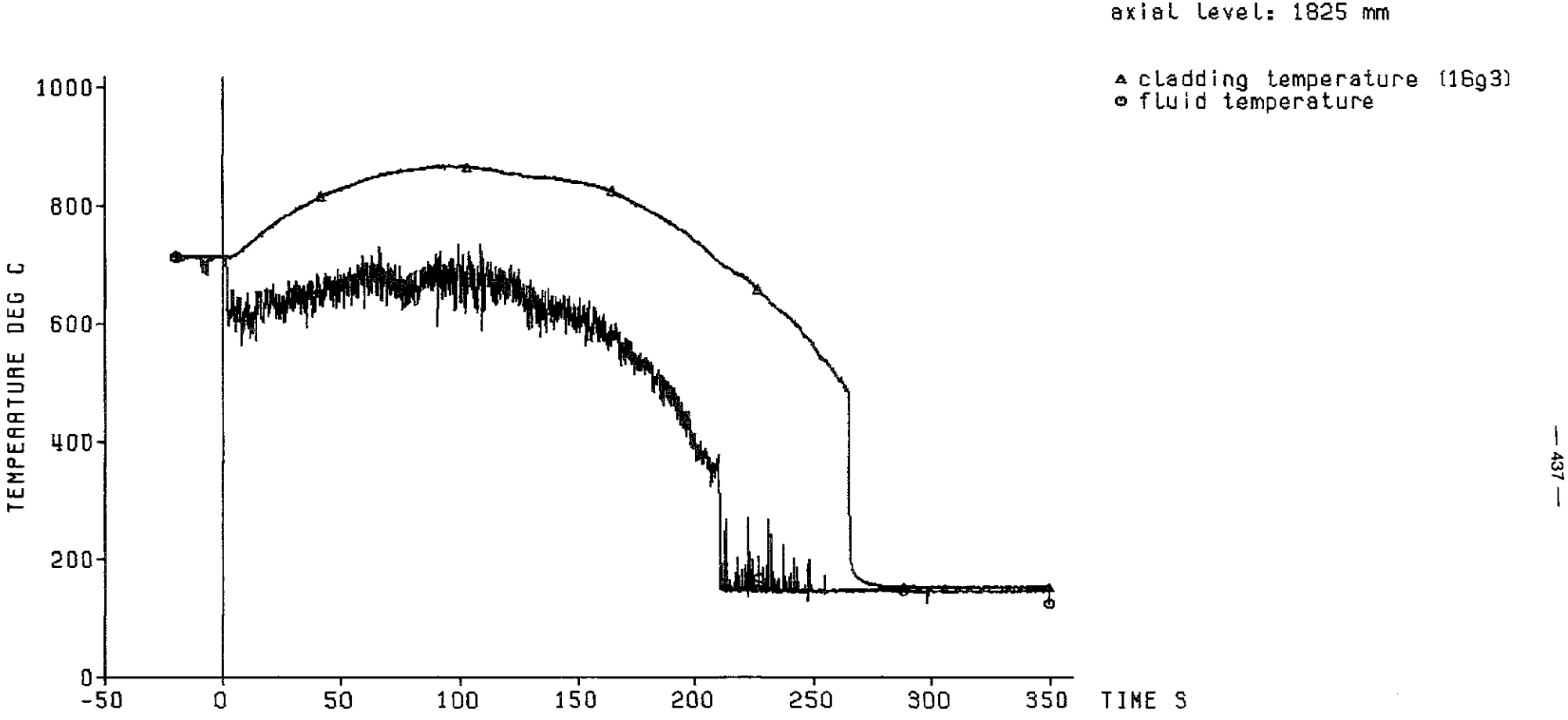
Fig. 395 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 263



decay heat	120% ANS standard	bypass
flooding rate (cold)	3.80 cm/s	======
system pressure	3.94 bar	
feedwater temperature	40 deg C	

KfK IRB

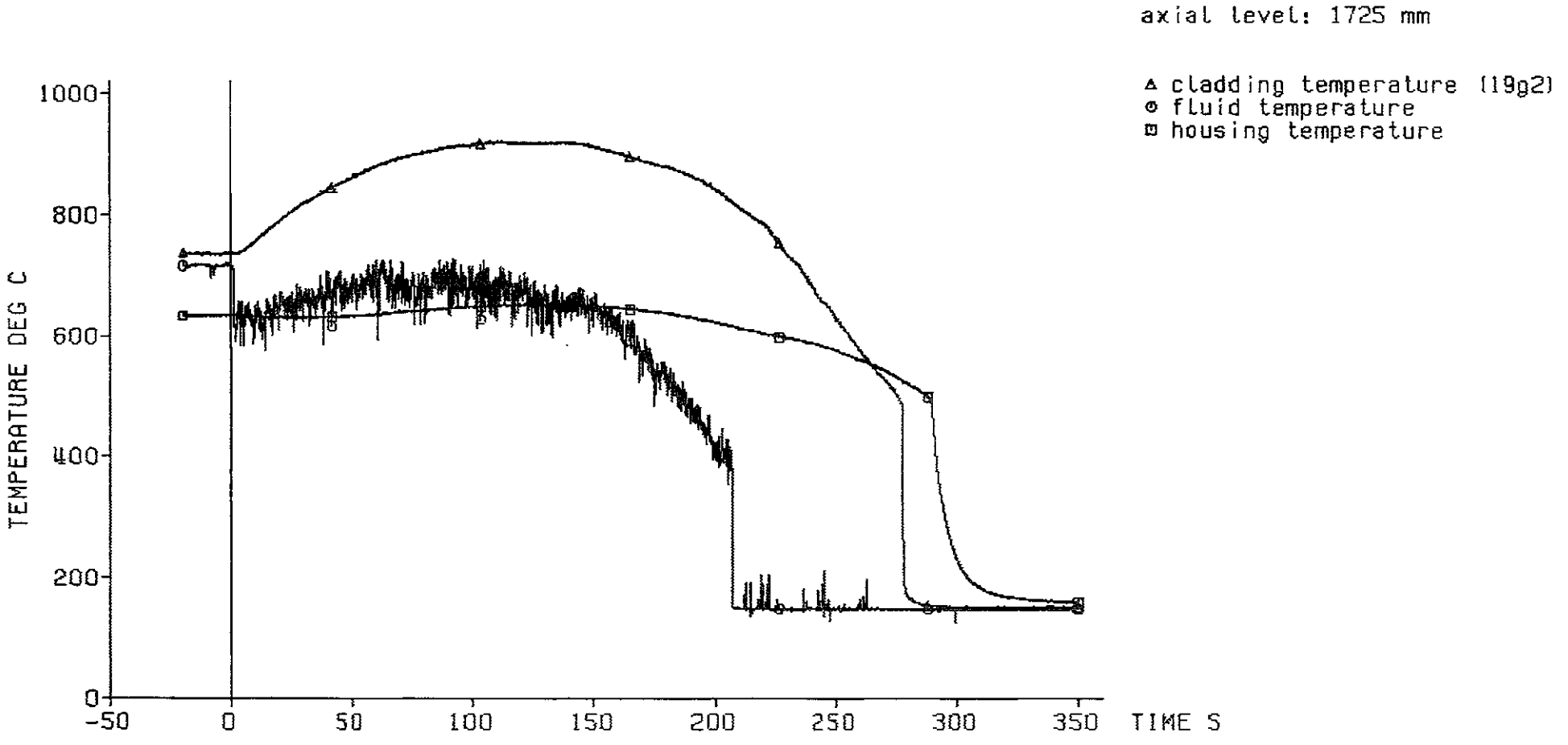
Fig. 396 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 263



decay heat	120% ANS standard	blockage
flooding rate (cold)	3.80 cm/s	========
system pressure	3.94 bar	
feedwater temperature	40 deg C	

KfK IRB

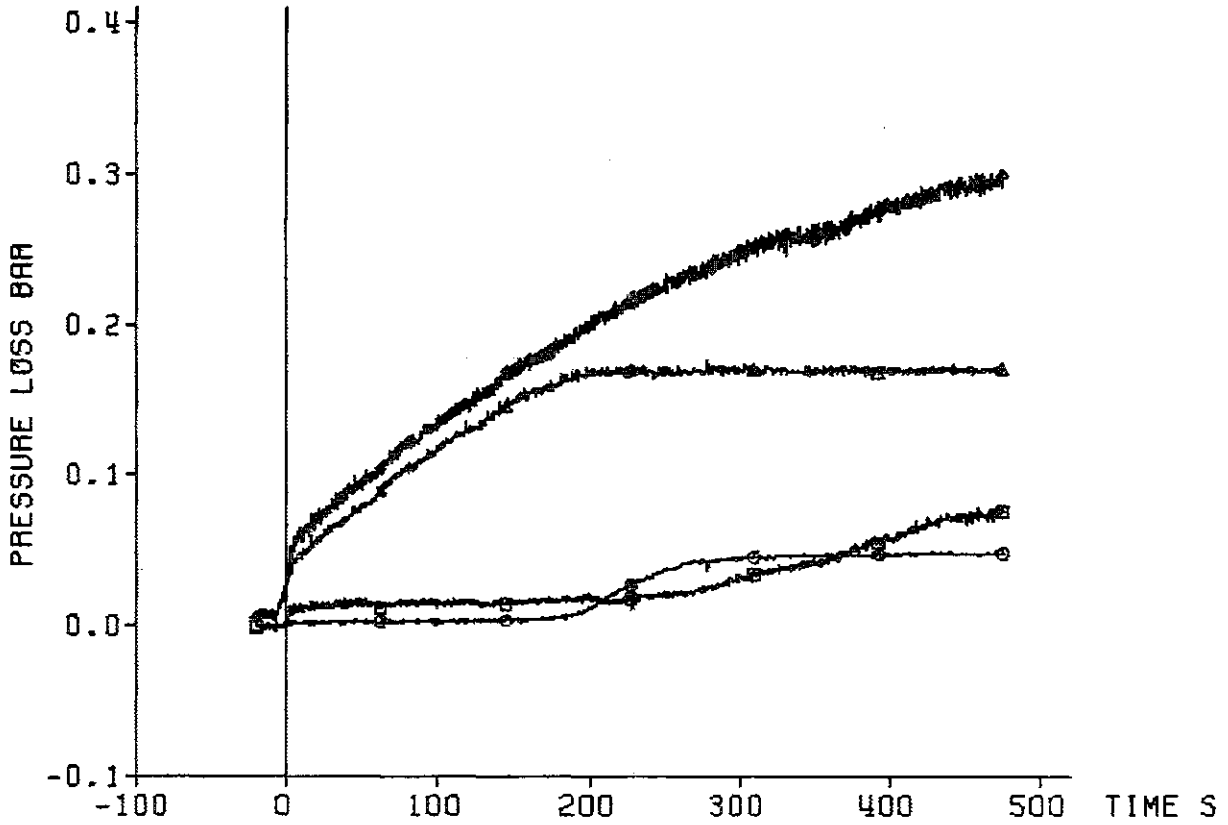
Fig. 397 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 263



decay heat	120% ANS standard	bypass
flooding rate (cold)	3.80 cm/s	======
system pressure	3.94 bar	
feedwater temperature	40 deg C	

KfK IRB

Fig. 398 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 263



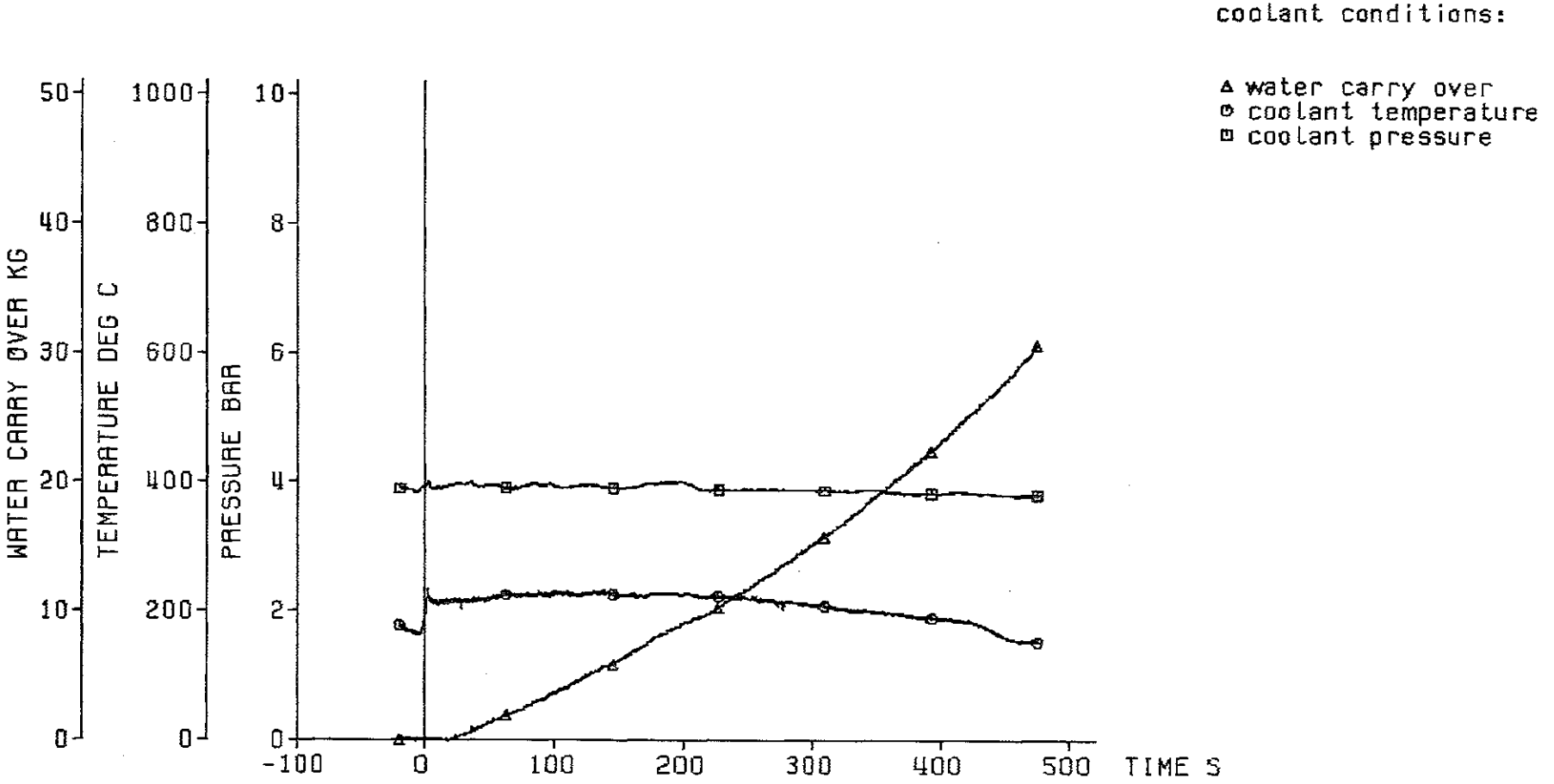
pressure loss
along the test section:

◆ total length: 4196 mm
▲ lower part: 1711 mm
⊙ middle part: 545 mm
⊡ upper part: 1940 mm

decay heat	120% ANS standard
flooding rate (cold)	3.80 cm/s
system pressure	3.94 bar
feedwater temperature	40 deg C

KfK KIRB

Fig. 399 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 263



decay heat	120% ANS standard
flooding rate (cold)	3.80 cm/s
system pressure	3.94 bar
feedwater temperature	40 deg C

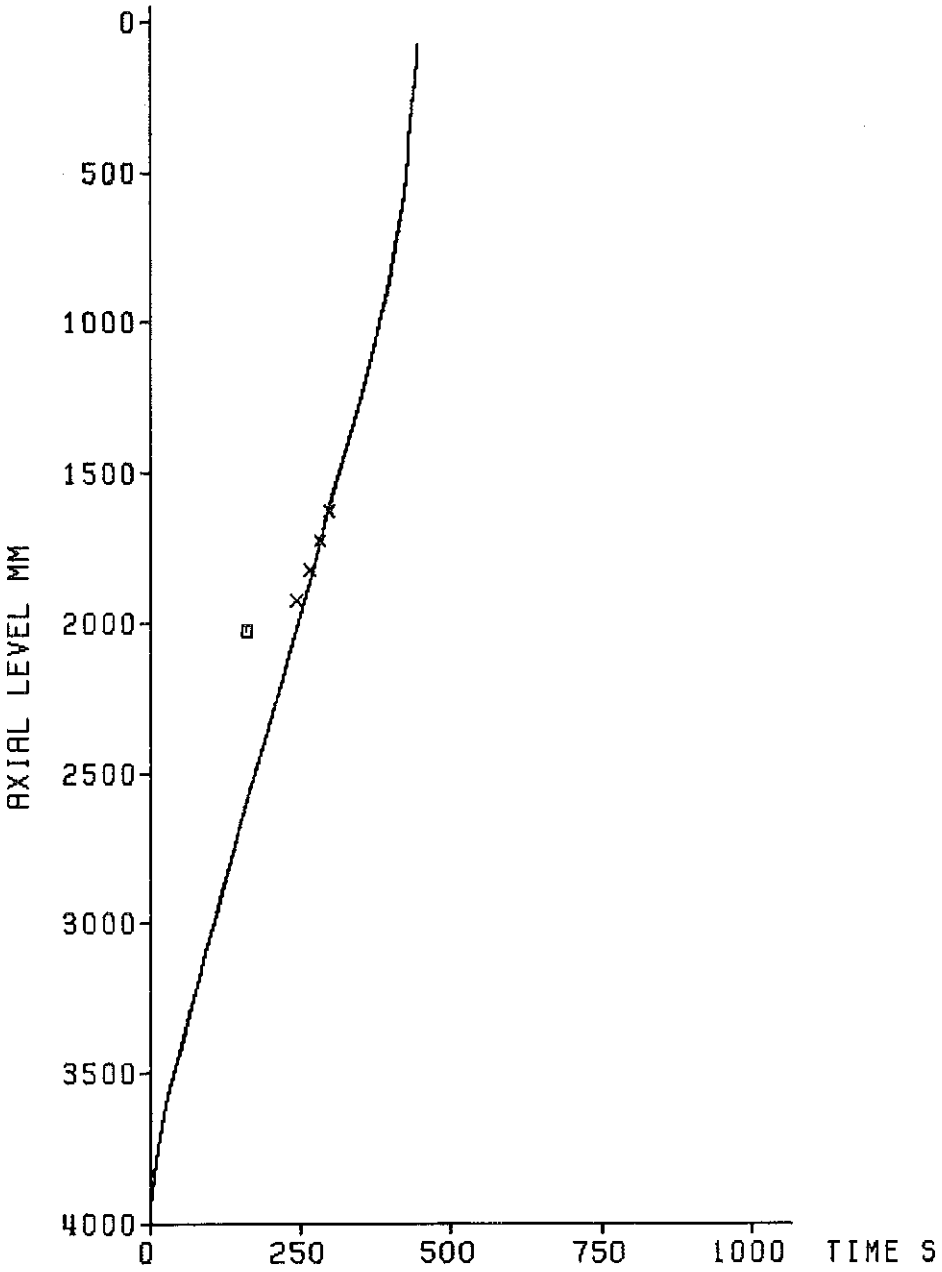
KfK IRB

Fig. 400 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 263

axial position of the quench front

▣ rewetting of the sleeve at the bundle midplane

× rewetting of the rod downstream of the blockage

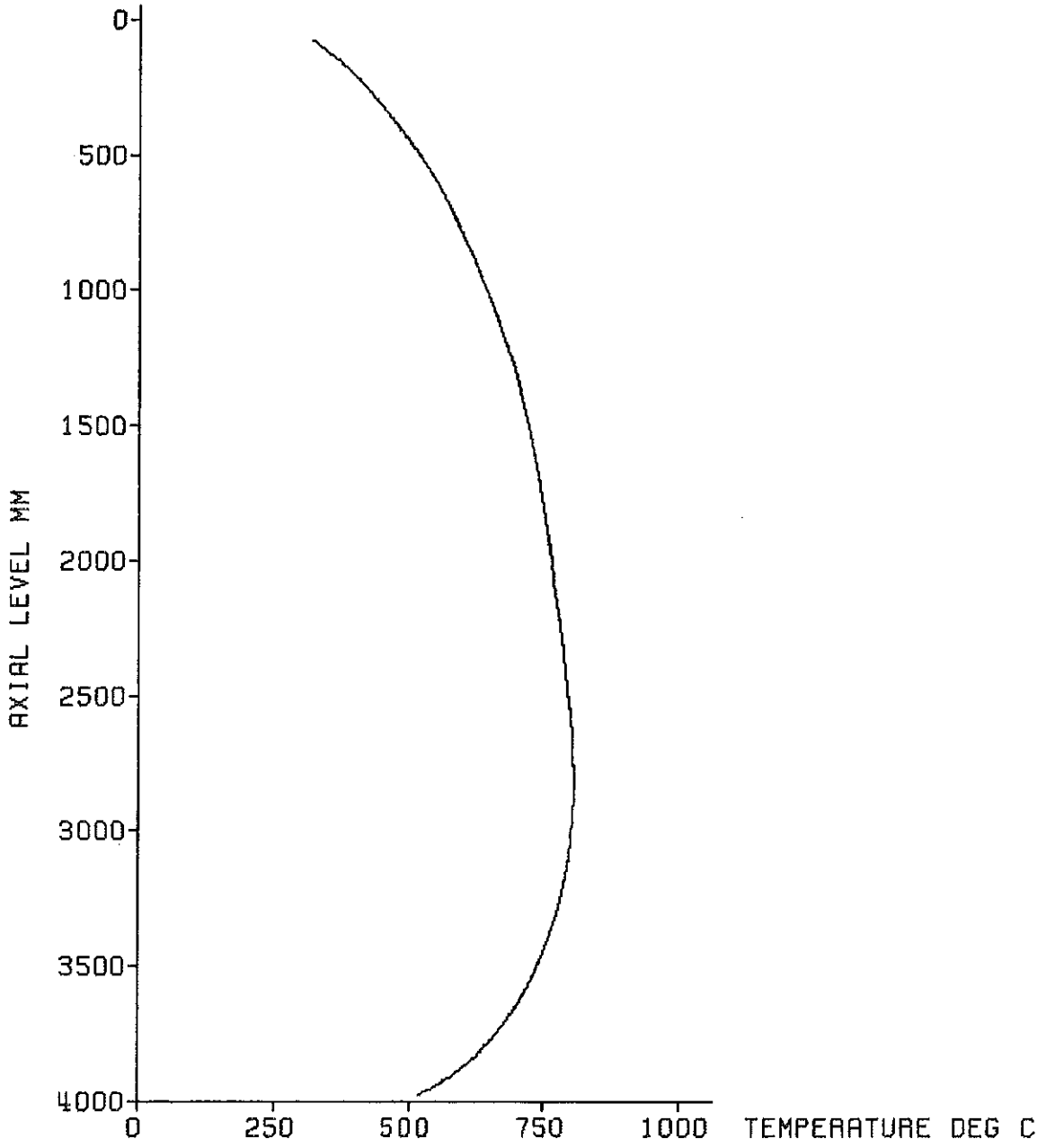


decay heat	120% ANS standard
flooding rate (cold)	3.80 cm/s
system pressure	3.94 bar
feedwater temperature	40 deg C

KfK IRB

Fig. 401 FEBA: 5x5 ROD BUNDLE TEST SERIES 4, TEST-No. 263

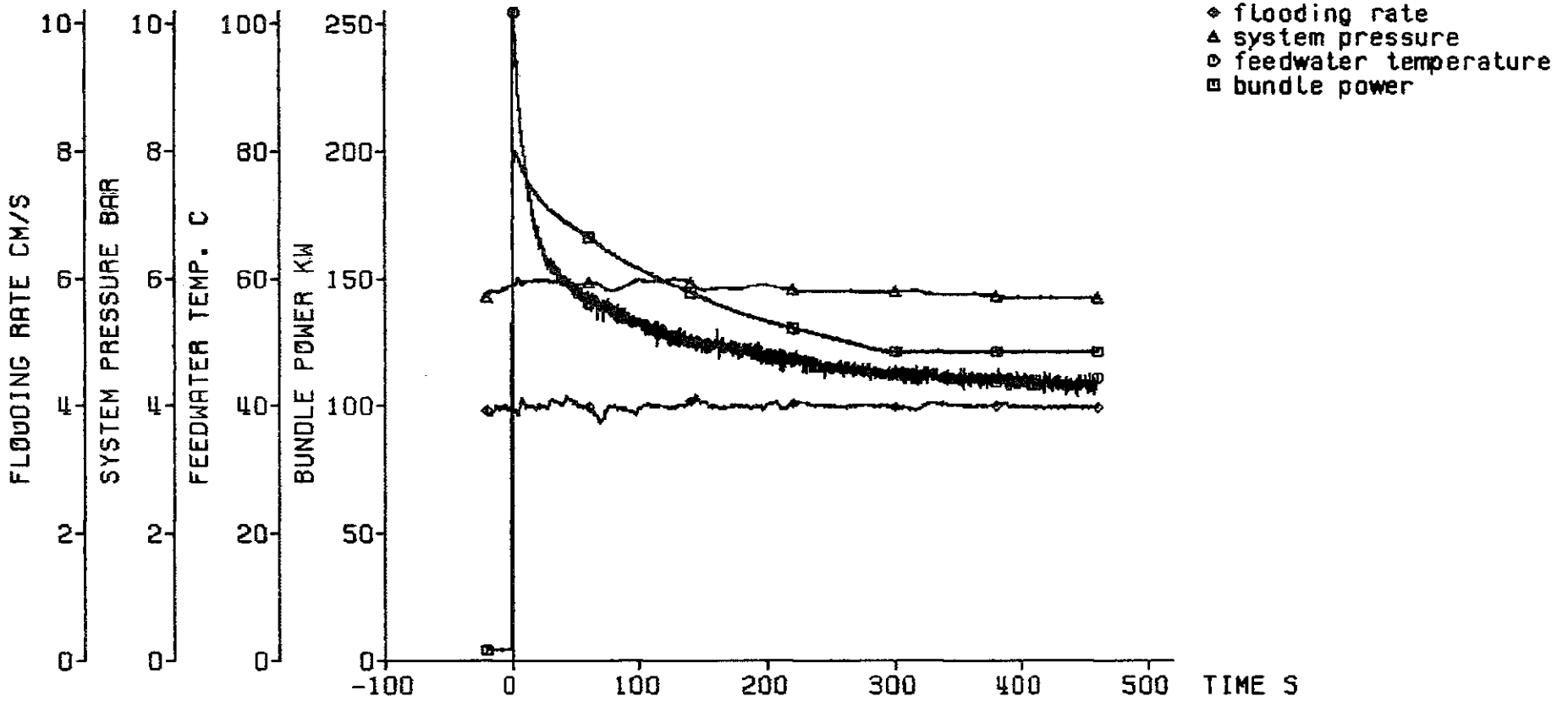
initial axial temperature profile of the cladding



decay heat	120% ANS standard
flooding rate (cold)	3.80 cm/s
system pressure	5.90 bar
feedwater temperature	40 deg C

KfK IRB

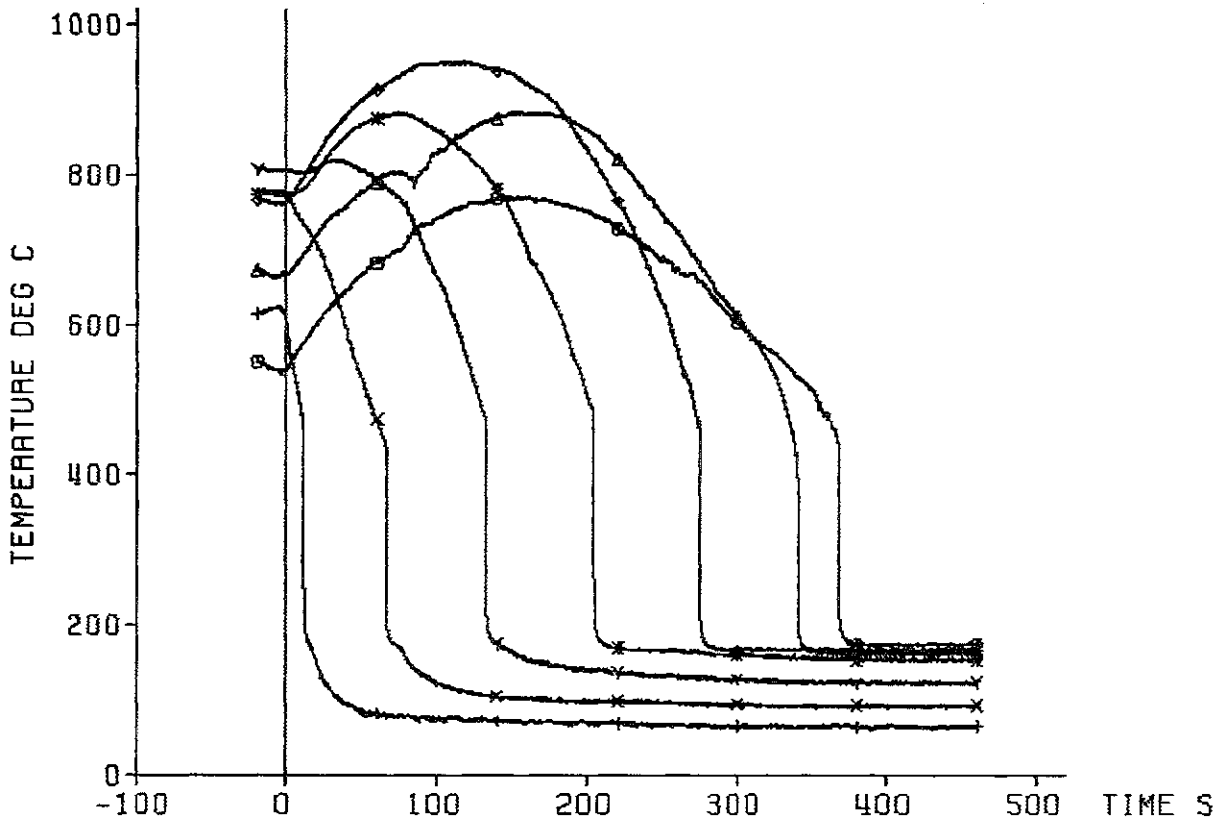
Fig. 402 FEBA: 5x5 ROD BUNDLE TEST SERIES 4, TEST-No. 268



decay heat	120% ANS standard
flooding rate (cold)	3.80 cm/s
system pressure	5.90 bar
feedwater temperature	40 deg C

KfK IRB

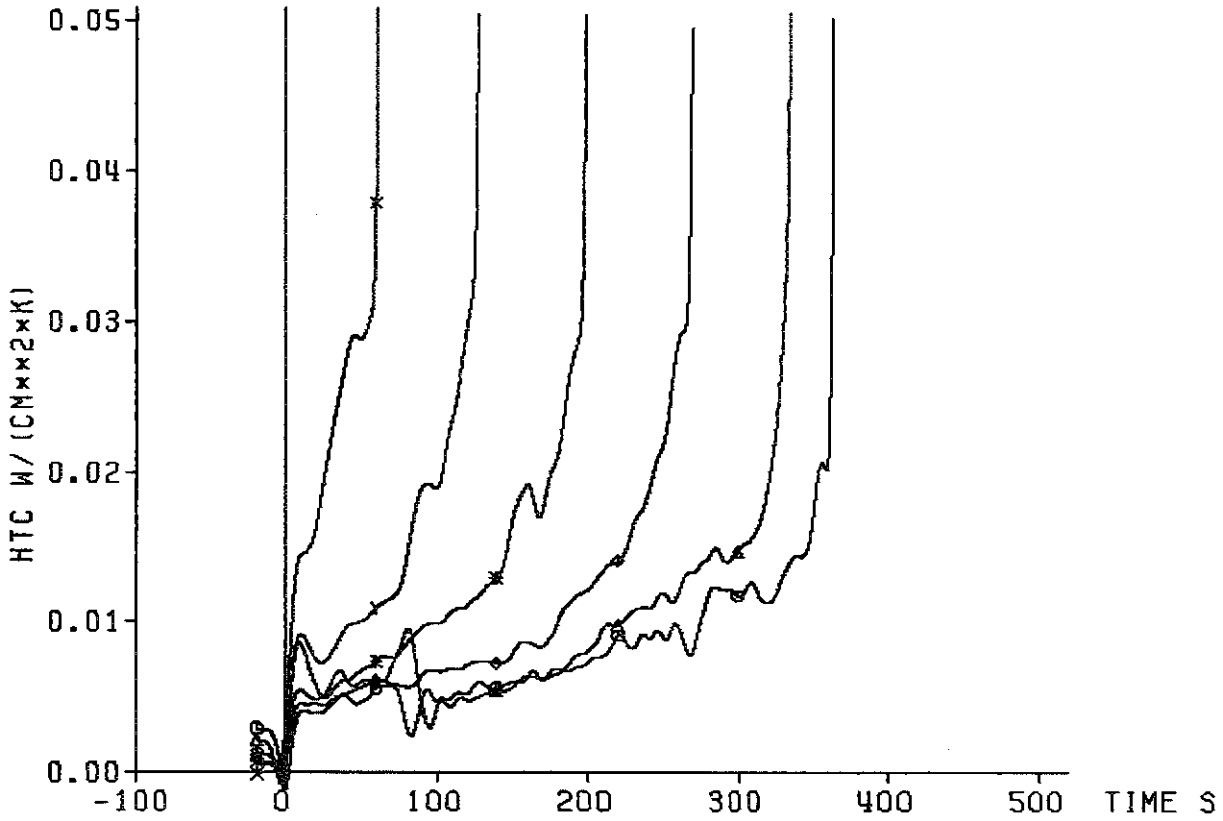
Fig. 403 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 268



decay heat	120% ANS standard
flooding rate (cold)	3.60 cm/s
system pressure	5.90 bar
feedwater temperature	40 deg C

KfK IRB

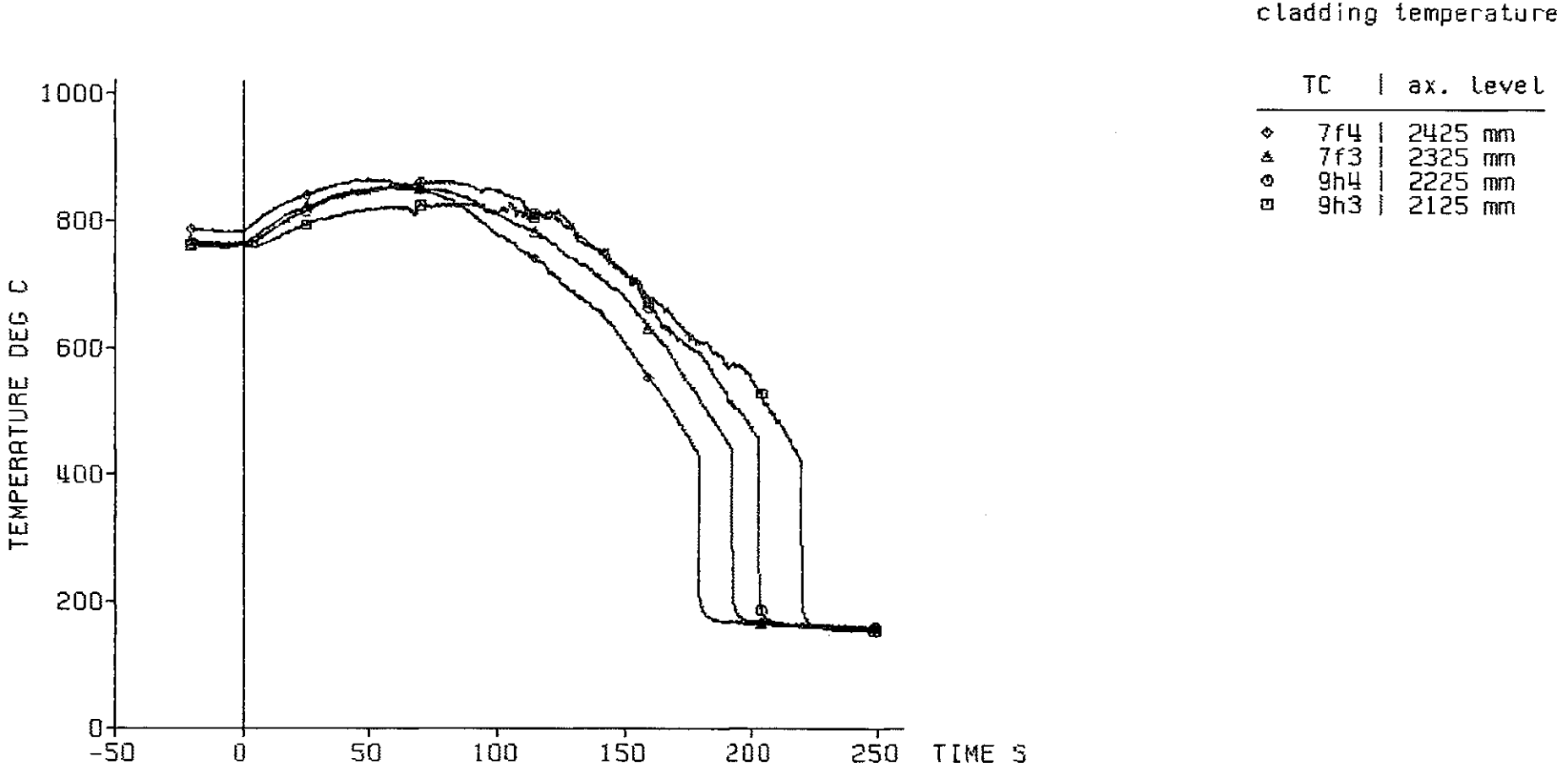
Fig. 404 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 268



decay heat	120% ANS standard
flooding rate (cold)	3.80 cm/s
system pressure	5.90 bar
feedwater temperature	40 deg C

KfK IRB

Fig. 405 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 268

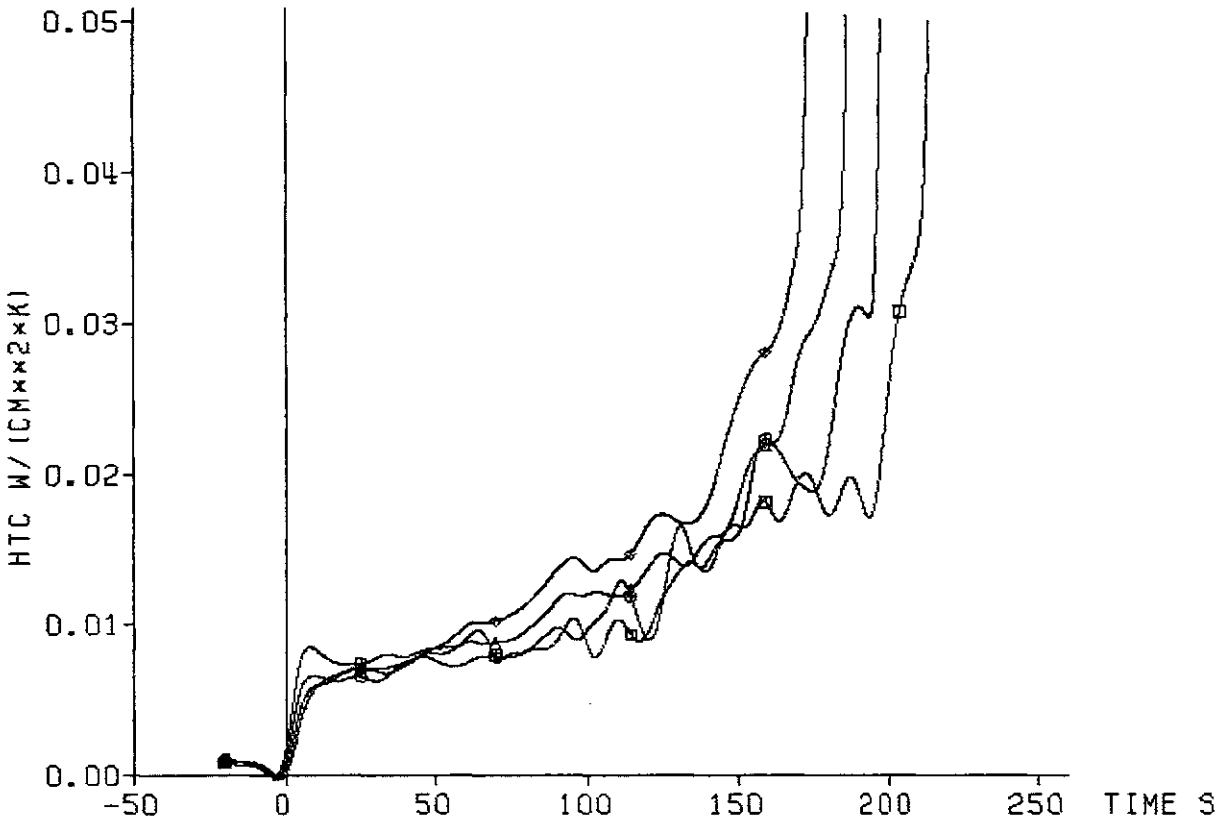


decay heat	120% ANS standard
flooding rate (cold)	3.80 cm/s
system pressure	5.90 bar
feedwater temperature	40 deg C

bypass
======

KfK IRB

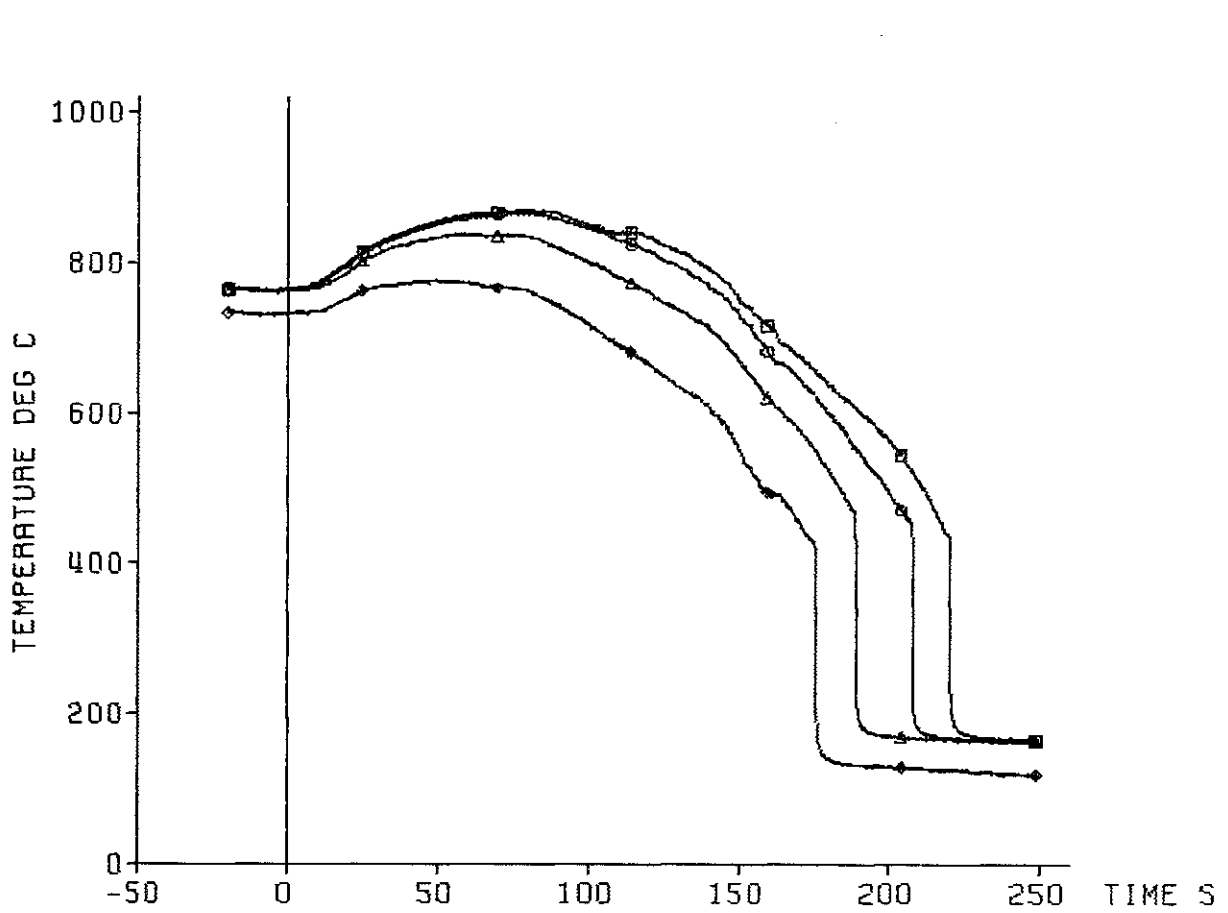
Fig. 406 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 268



decay heat	120% ANS standard
flooding rate (cold)	3.80 cm/s
system pressure	5.90 bar
feedwater temperature	40 deg C

bypass
======

Fig. 407 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 268

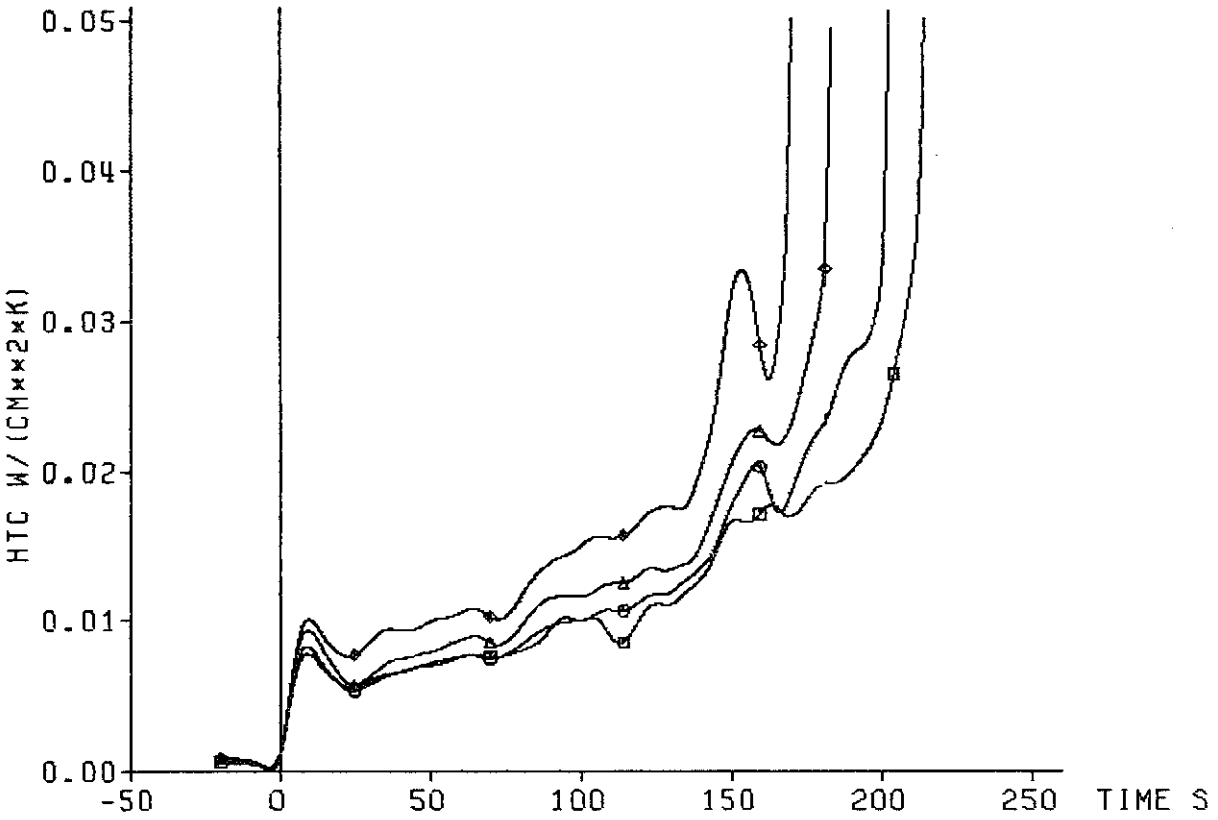


decay heat	120% ANS standard
flooding rate (cold)	3.80 cm/s
system pressure	5.90 bar
feedwater temperature	40 deg C

blockage
========

KfK IRB

Fig. 408 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 268

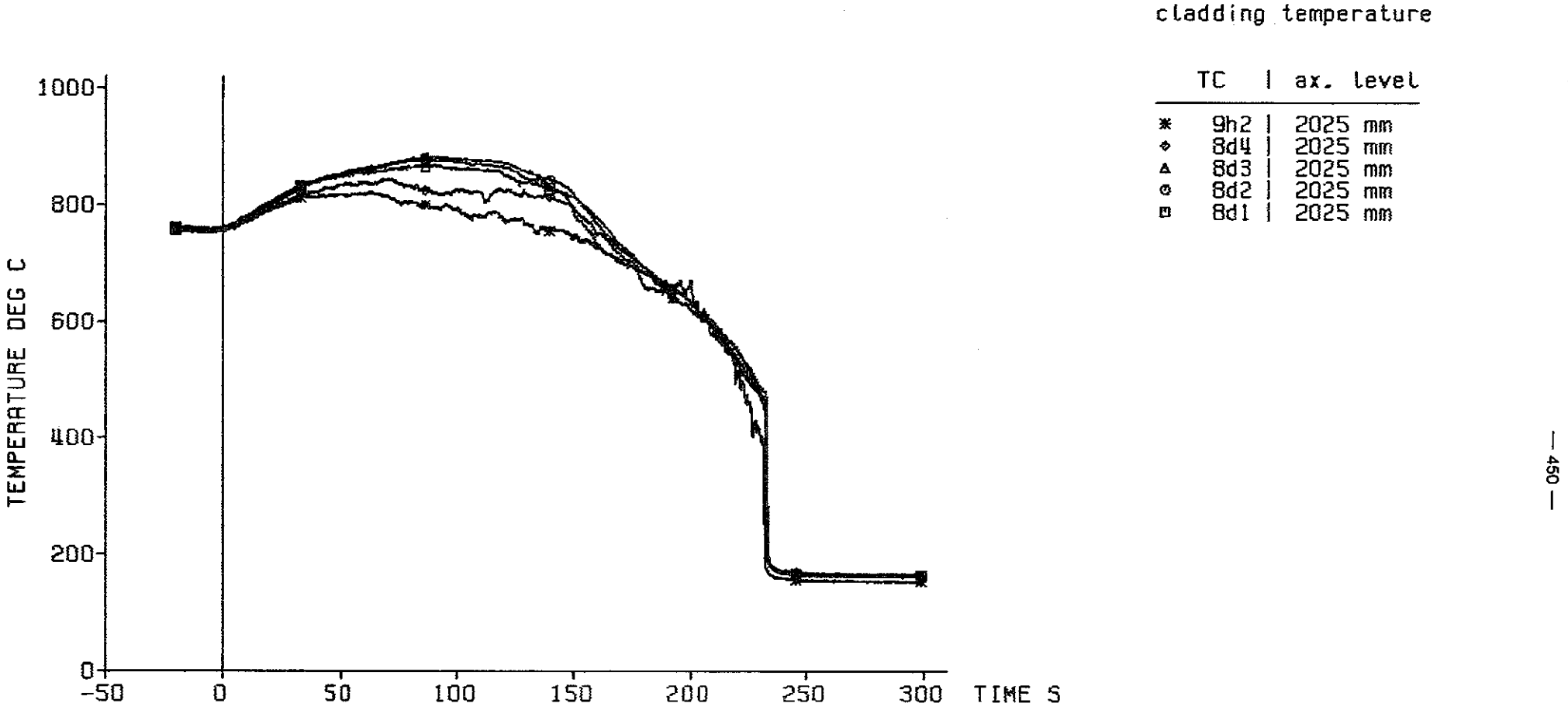


decay heat	120% ANS standard
flooding rate (cold)	3.80 cm/s
system pressure	5.90 bar
feedwater temperature	40 deg C

blockage
========

KfK IRB

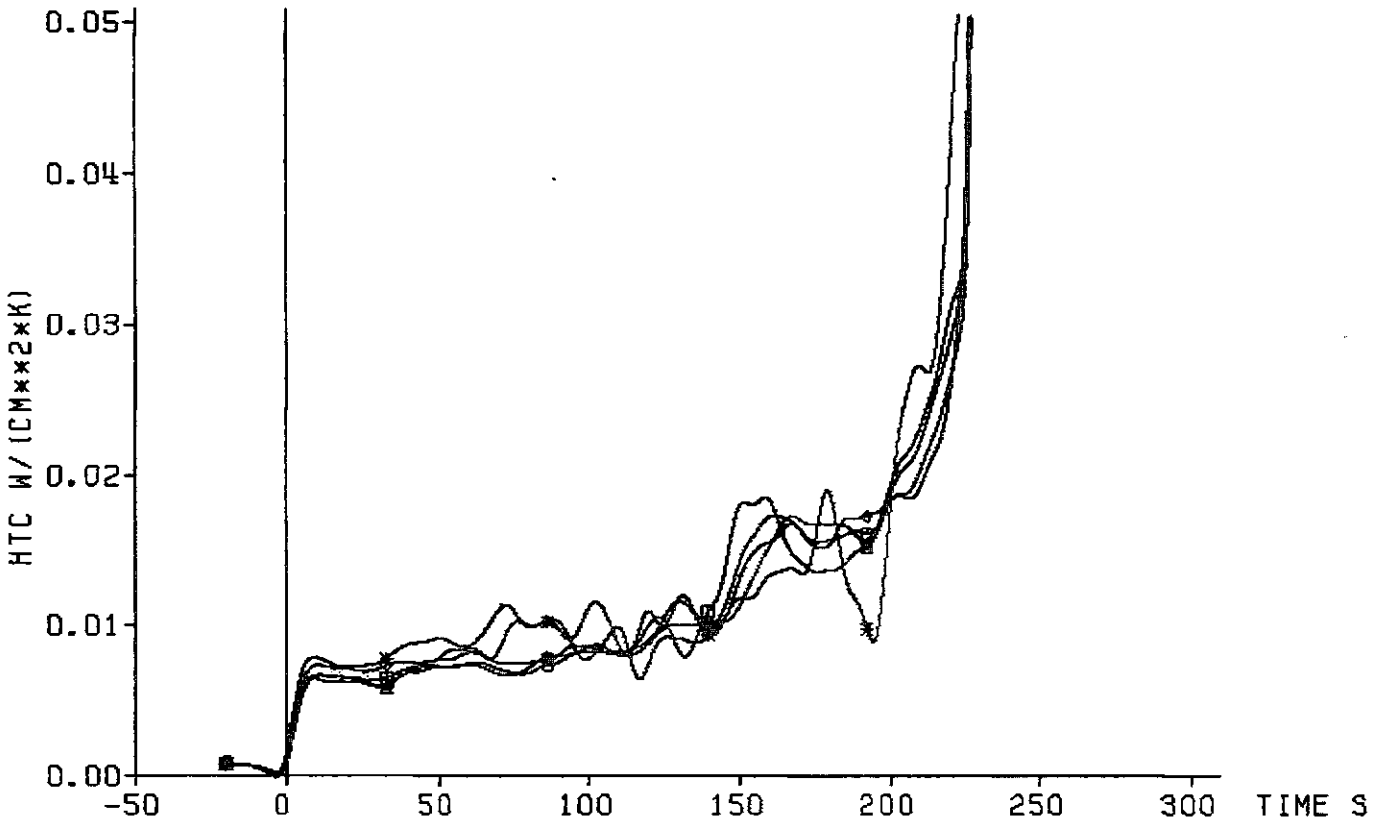
Fig. 409 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 268



decay heat	120% ANS standard	bypass
flooding rate (cold)	3.80 cm/s	======
system pressure	5.90 bar	
feedwater temperature	40 deg C	

KfK IRB

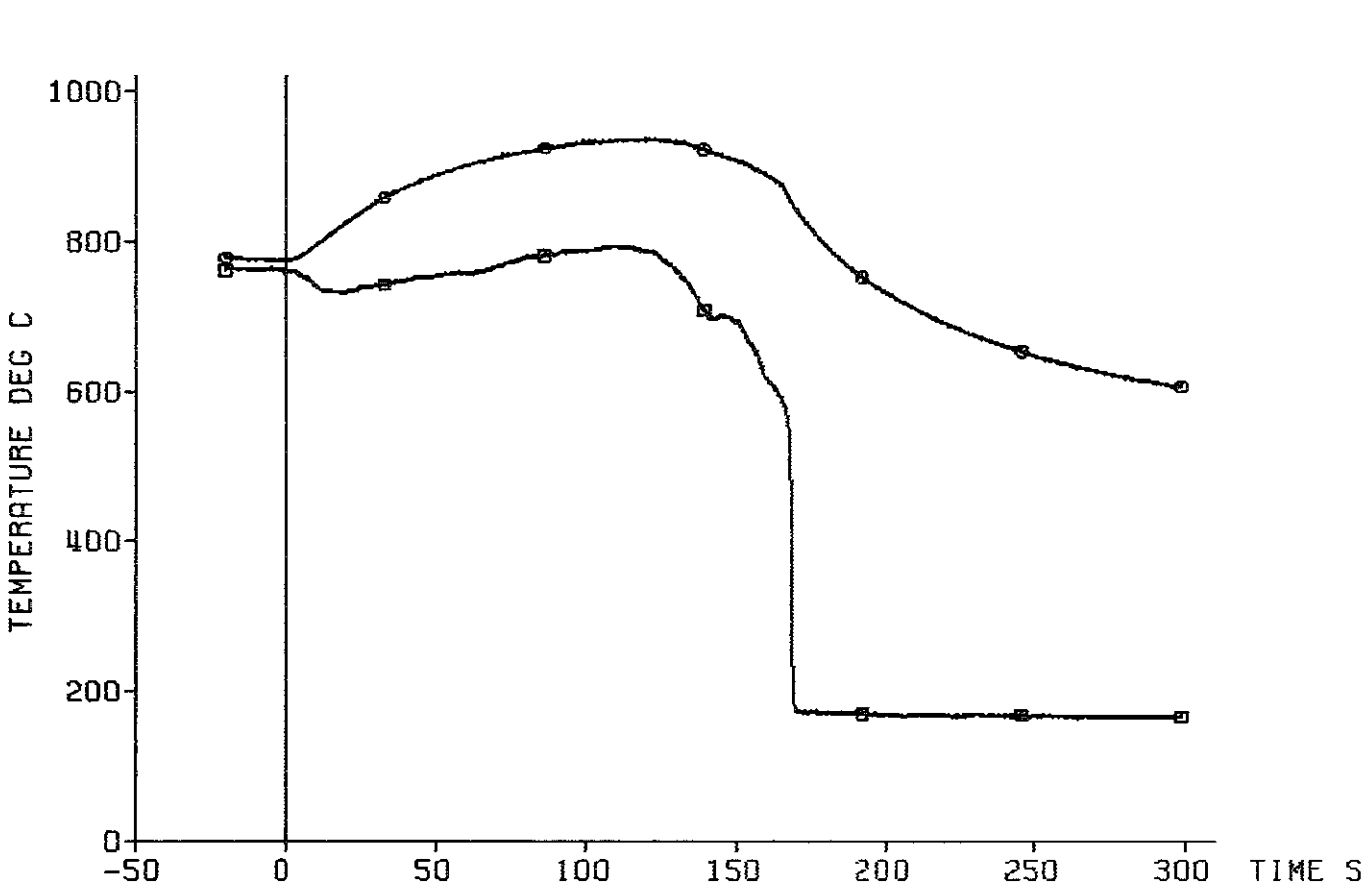
Fig. 410 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 268



decay heat	120% ANS standard	bypass
flooding rate (cold)	3.80 cm/s	======
system pressure	5.90 bar	
feedwater temperature	40 deg C	

KfK IRB

Fig. 411 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 268

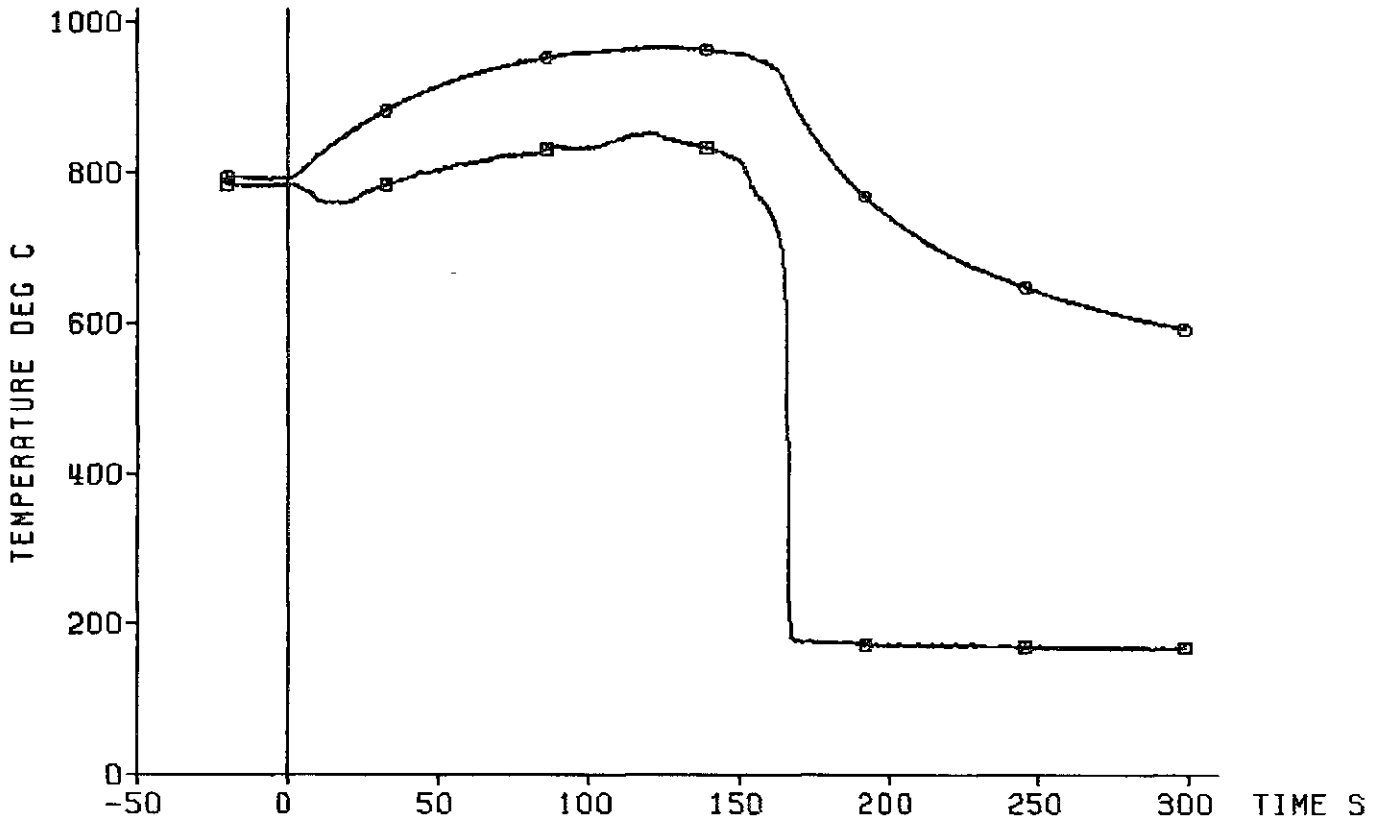


decay heat	120% ANS standard
flooding rate (cold)	3.80 cm/s
system pressure	5.90 bar
feedwater temperature	40 deg C

blockage
========

KfK IRB

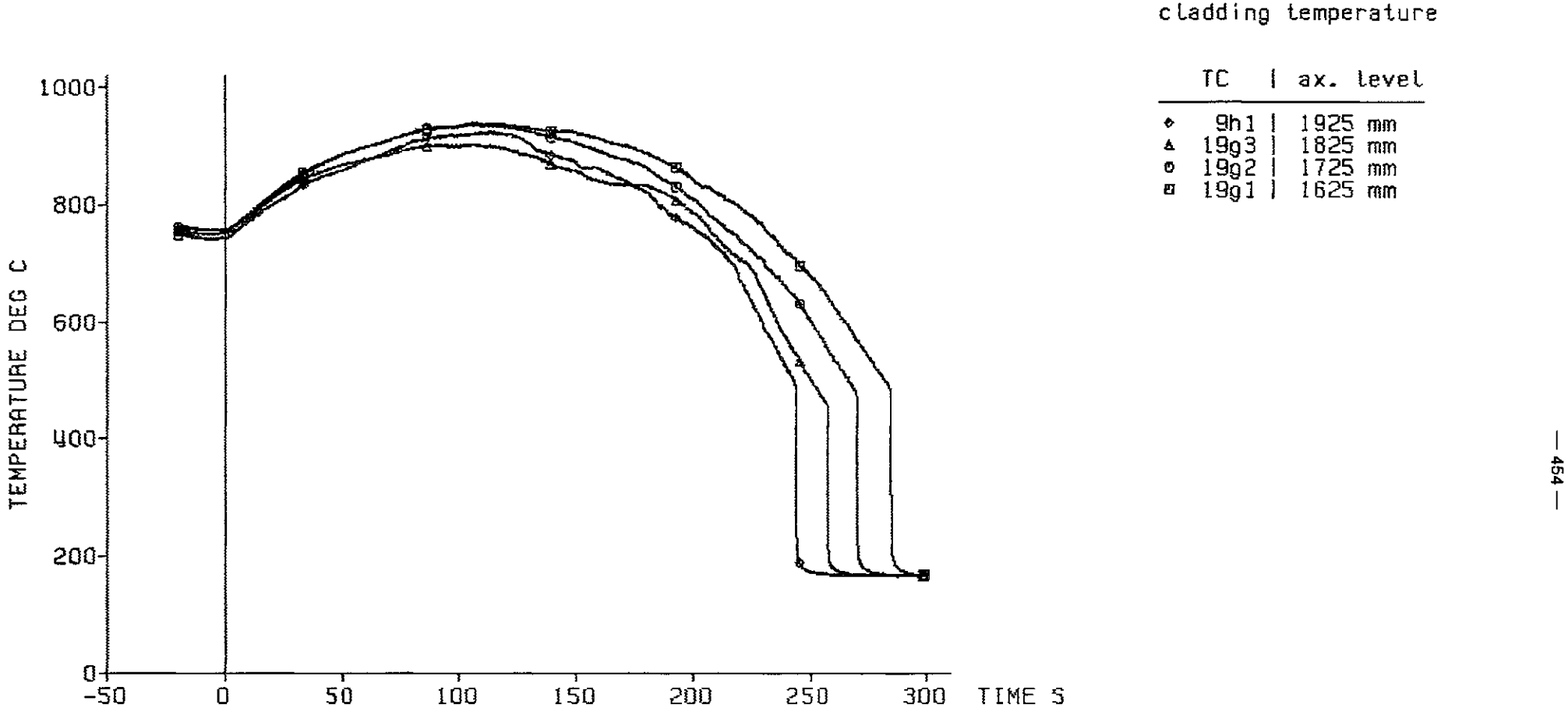
Fig. 412 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 268



decay heat	120% ANS standard	blockage
flooding rate (cold)	3.80 cm/s	========
system pressure	5.90 bar	
feedwater temperature	40 deg C	

KfK IRB

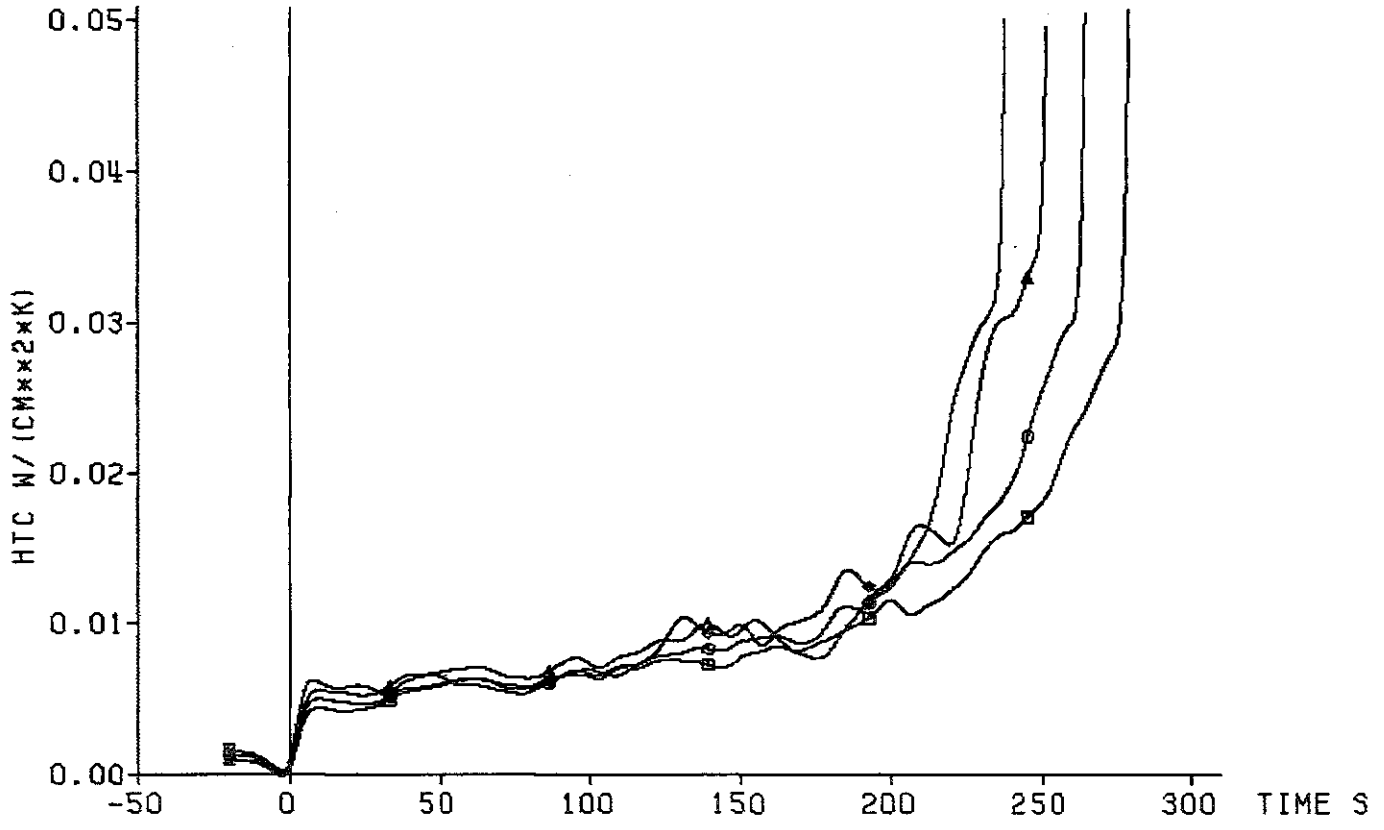
Fig. 413 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 268



decay heat	120% ANS standard	bypass
flooding rate (cold)	3.80 cm/s	======
system pressure	5.90 bar	
feedwater temperature	40 deg C	

KfK IRB

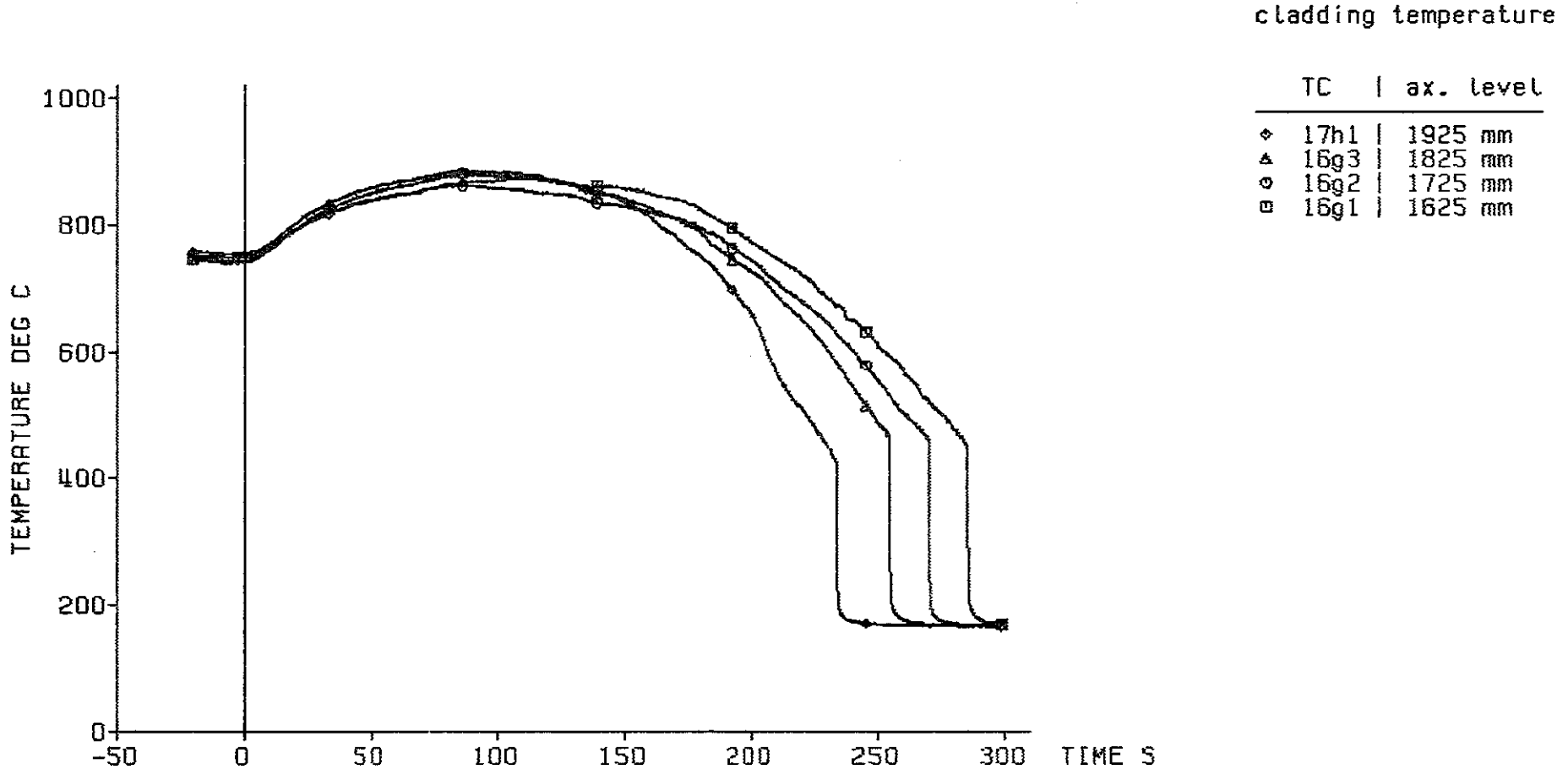
Fig. 414 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 268



decay heat	120% ANS standard	bypass
flooding rate (cold)	3.80 cm/s	======
system pressure	5.90 bar	
feedwater temperature	40 deg C	

KfK IRB

Fig. 415 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 268

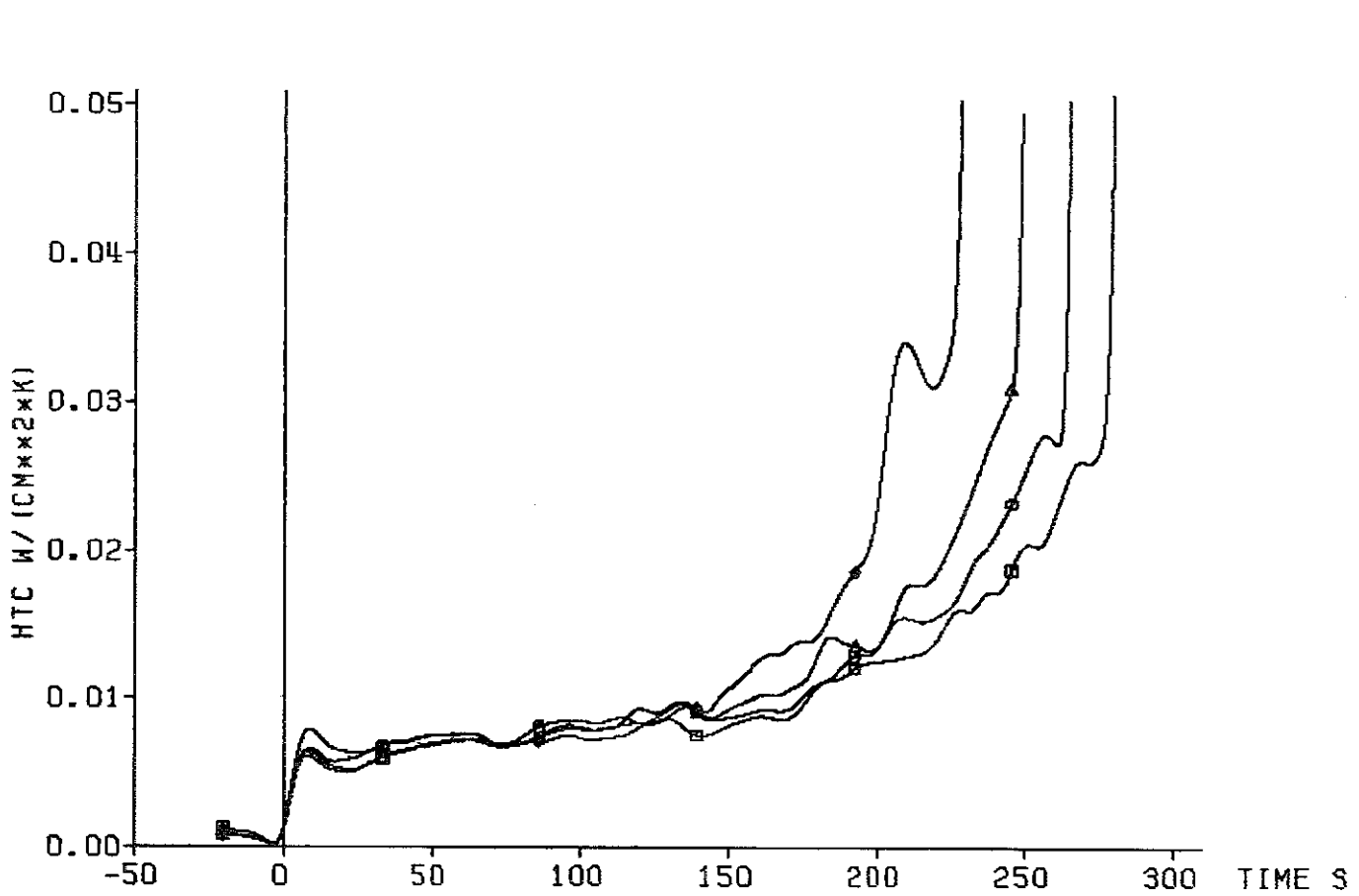


decay heat	120% ANS standard
flooding rate (cold)	3.80 cm/s
system pressure	5.90 bar
feedwater temperature	40 deg C

blockage
========

KfK KIRB

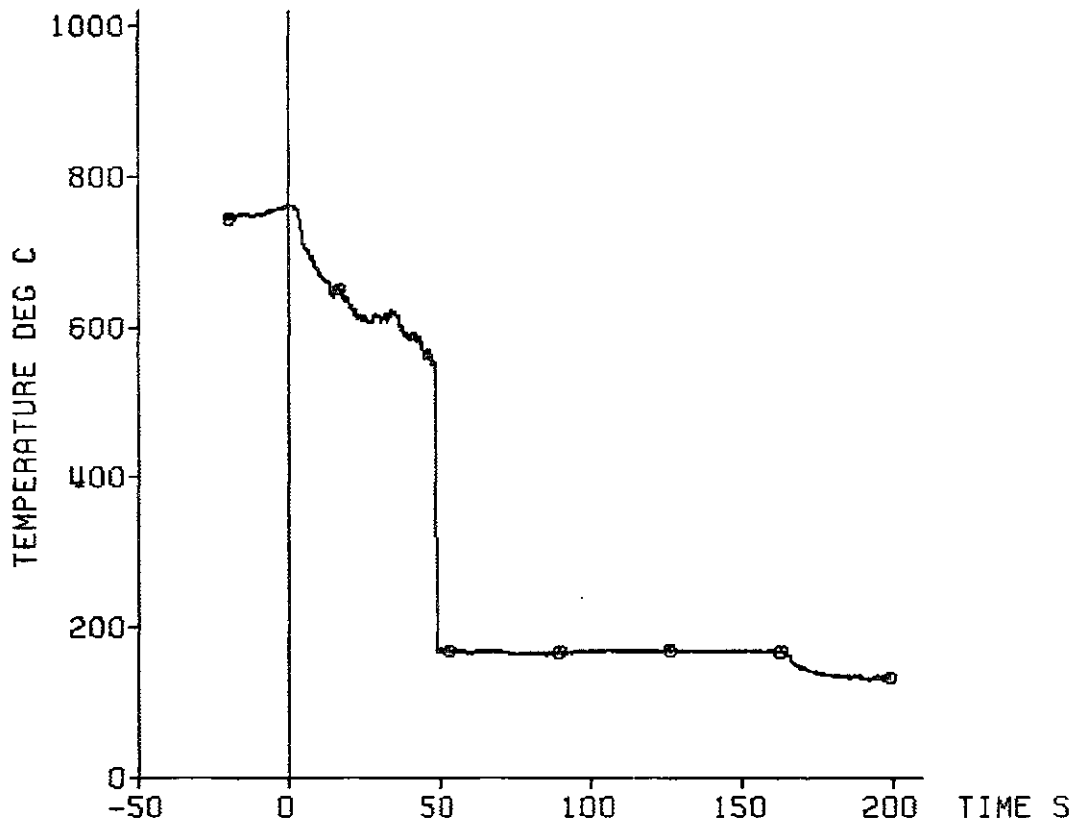
Fig. 416 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 268



decay heat	120% ANS standard
flooding rate (cold)	3.80 cm/s
system pressure	5.90 bar
feedwater temperature	40 deg C

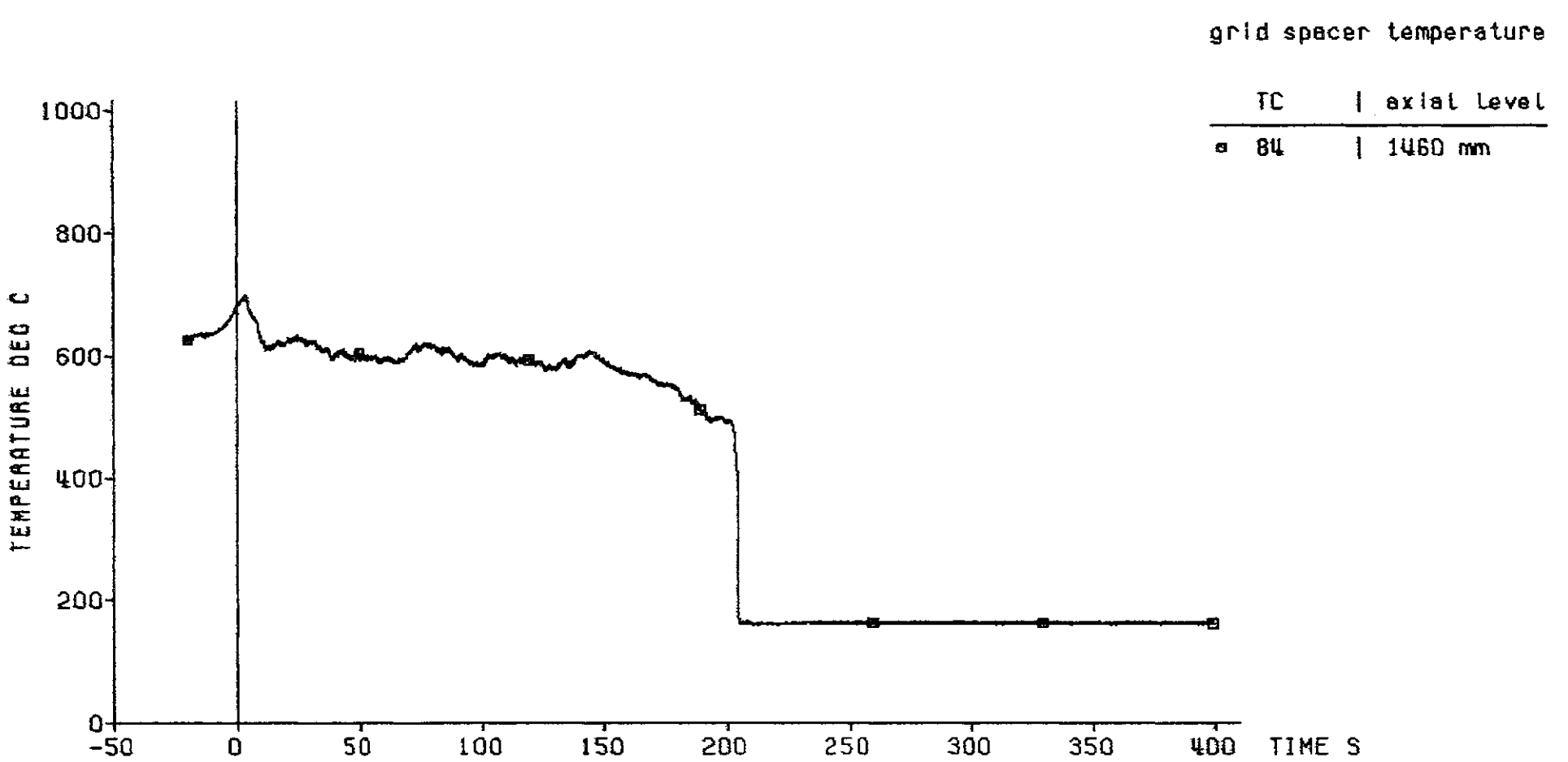
blockage
========

Fig. 417 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 268



decay heat	120% ANS standard
flooding rate (cold)	3.84 cm/s
system pressure	5.96 bar
feedwater temperature	40 deg C

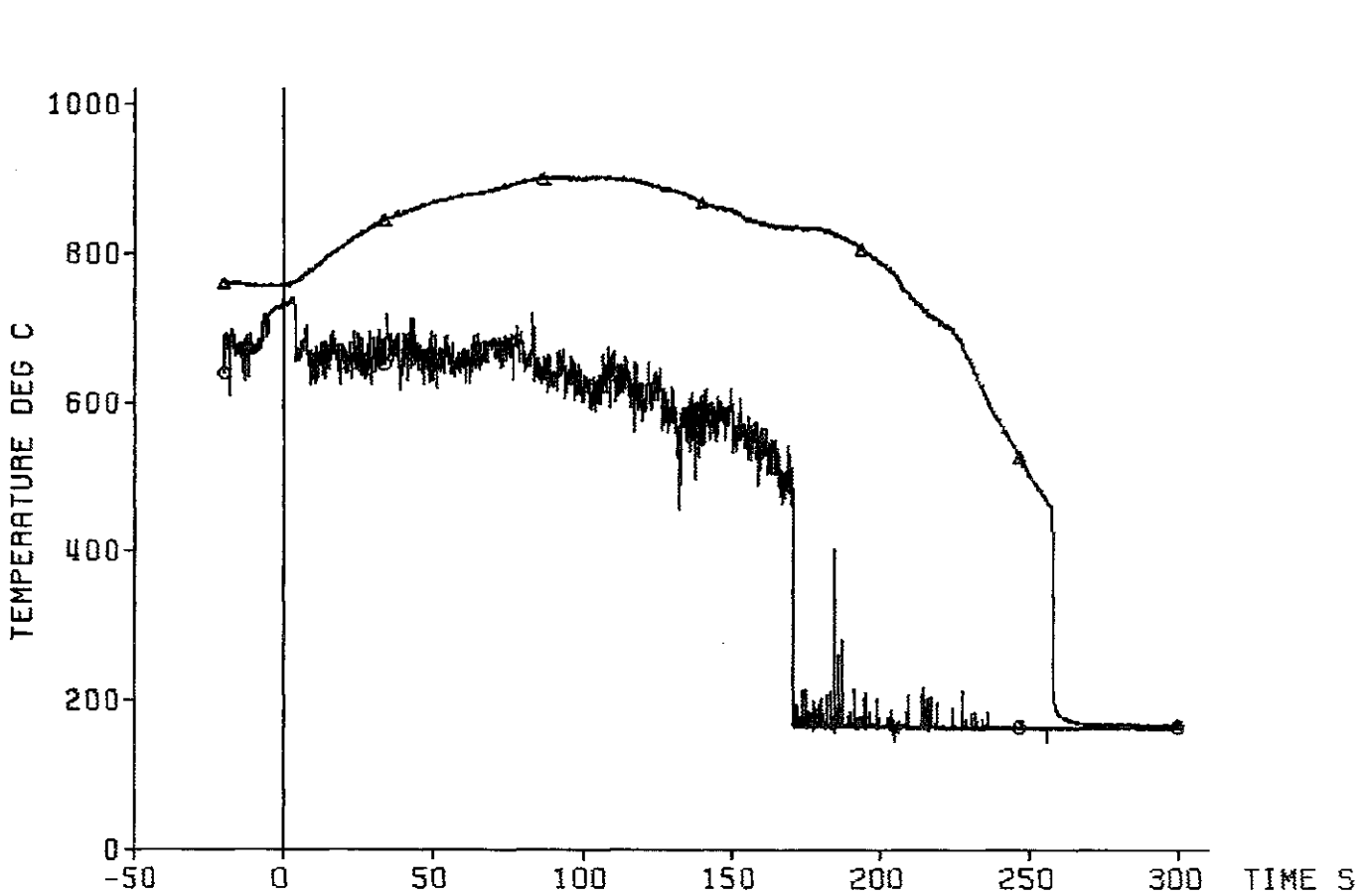
Fig. 418 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 268



decay heat 120% ANS standard
flooding rate (cold) 3.84 cm/s
system pressure 5.96 bar
feedwater temperature 40 deg C

KfK IRB

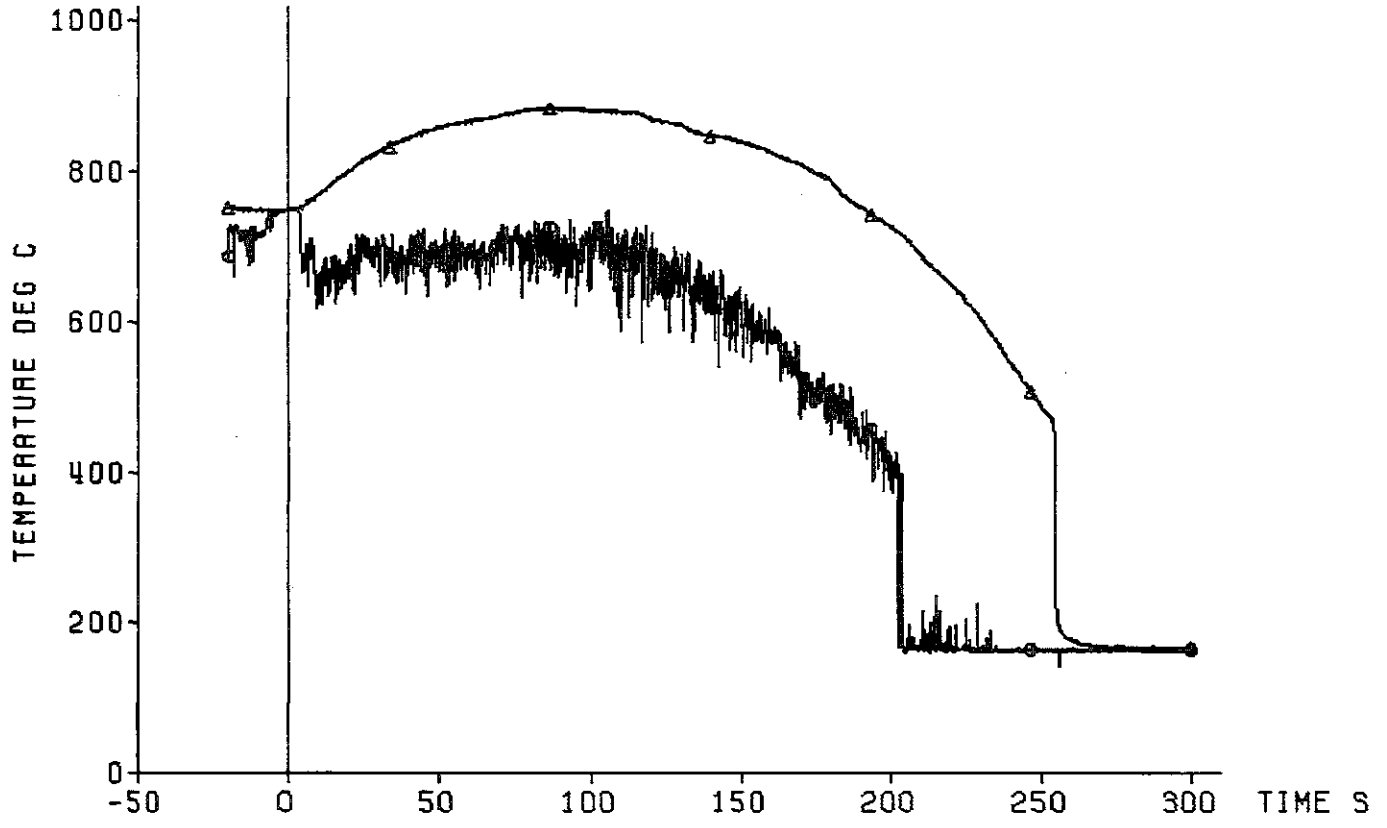
Fig. 419 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 268



decay heat	120% ANS standard	bypass
flooding rate (cold)	3.80 cm/s	======
system pressure	5.90 bar	
feedwater temperature	40 deg C	

KfK IRB

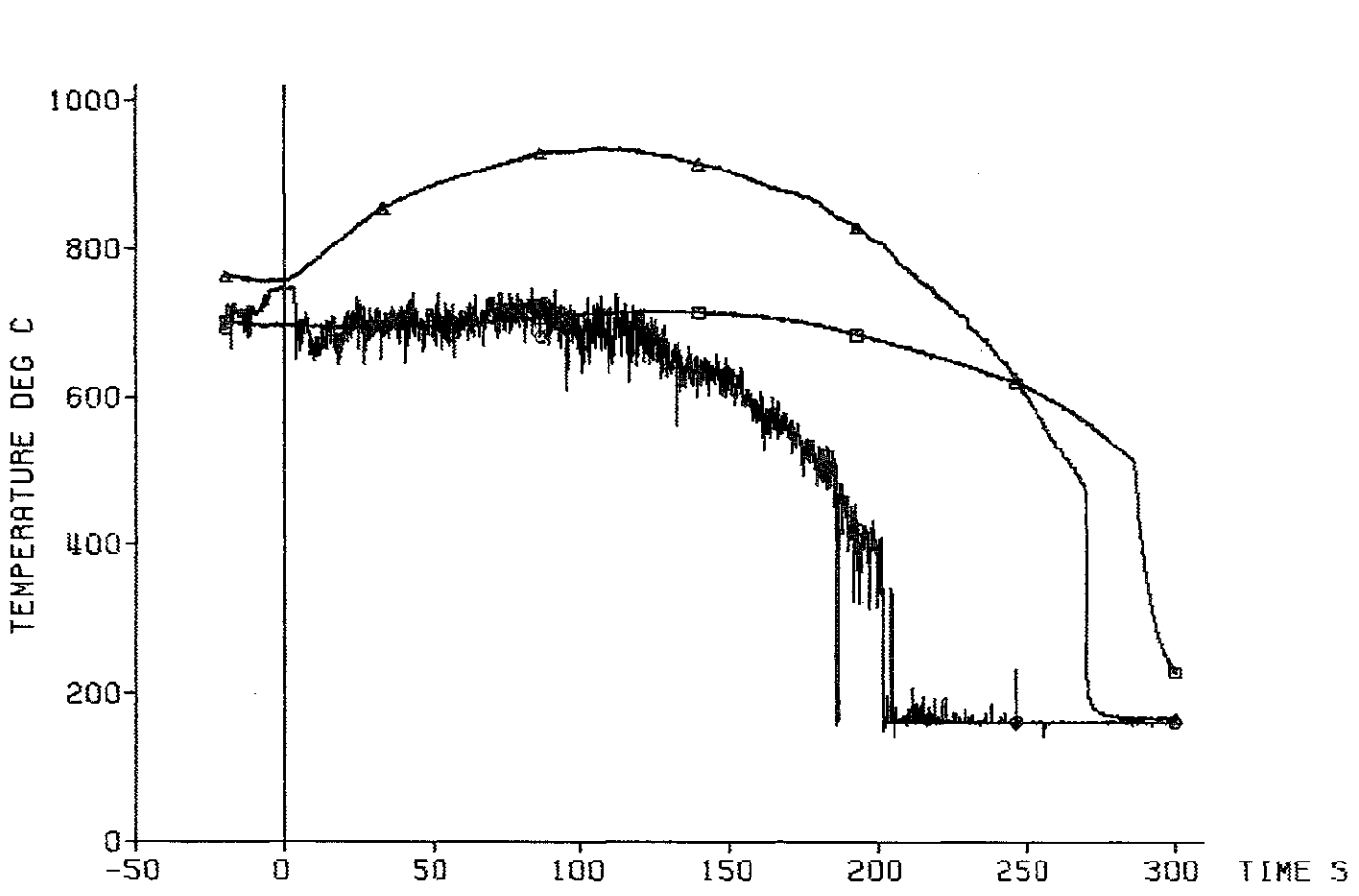
Fig. 420 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 268



decay heat	120% ANS standard	blockage
flooding rate (cold)	3.60 cm/s	========
system pressure	5.90 bar	
feedwater temperature	40 deg C	

KfK IRB

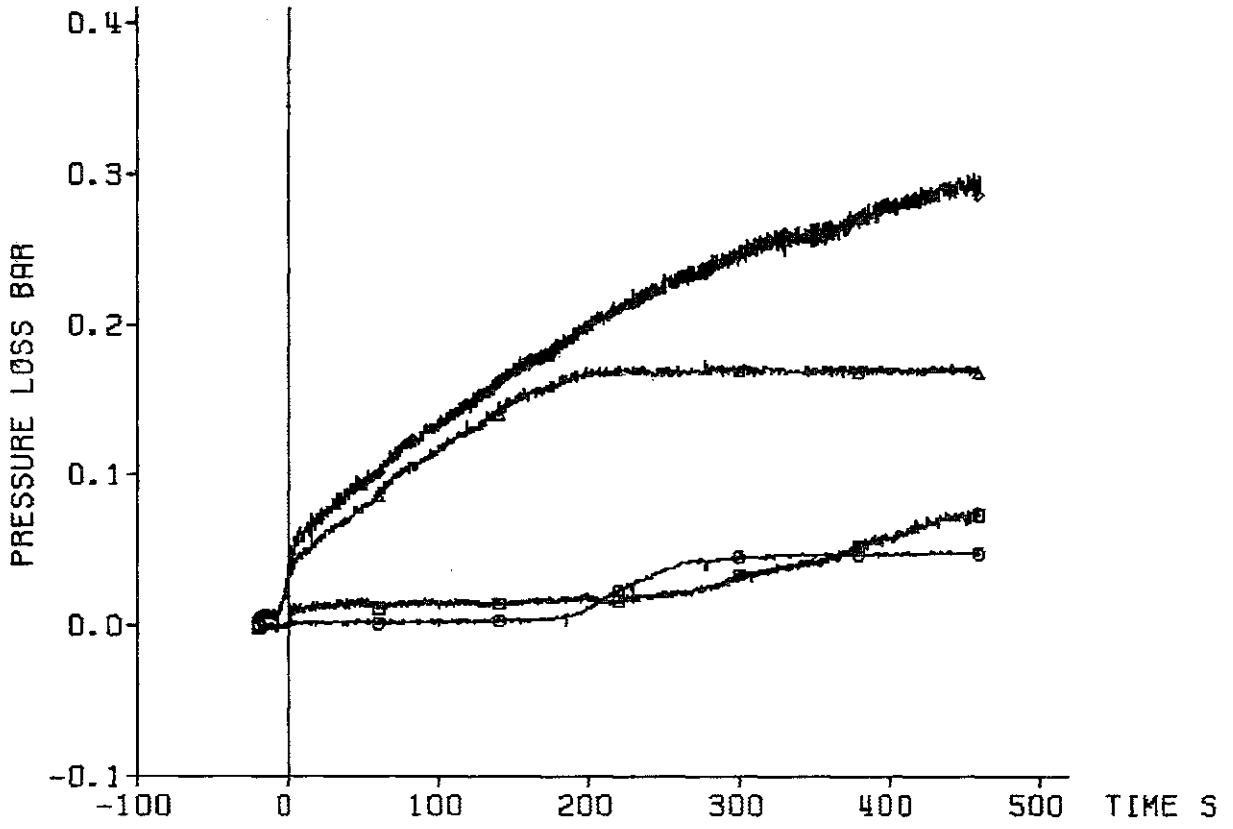
Fig. 421 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 268



decay heat	120% ANS standard	bypass
flooding rate (cold)	3.80 cm/s	======
system pressure	5.90 bar	
feedwater temperature	40 deg C	

KfK ITRB

Fig. 422 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 268



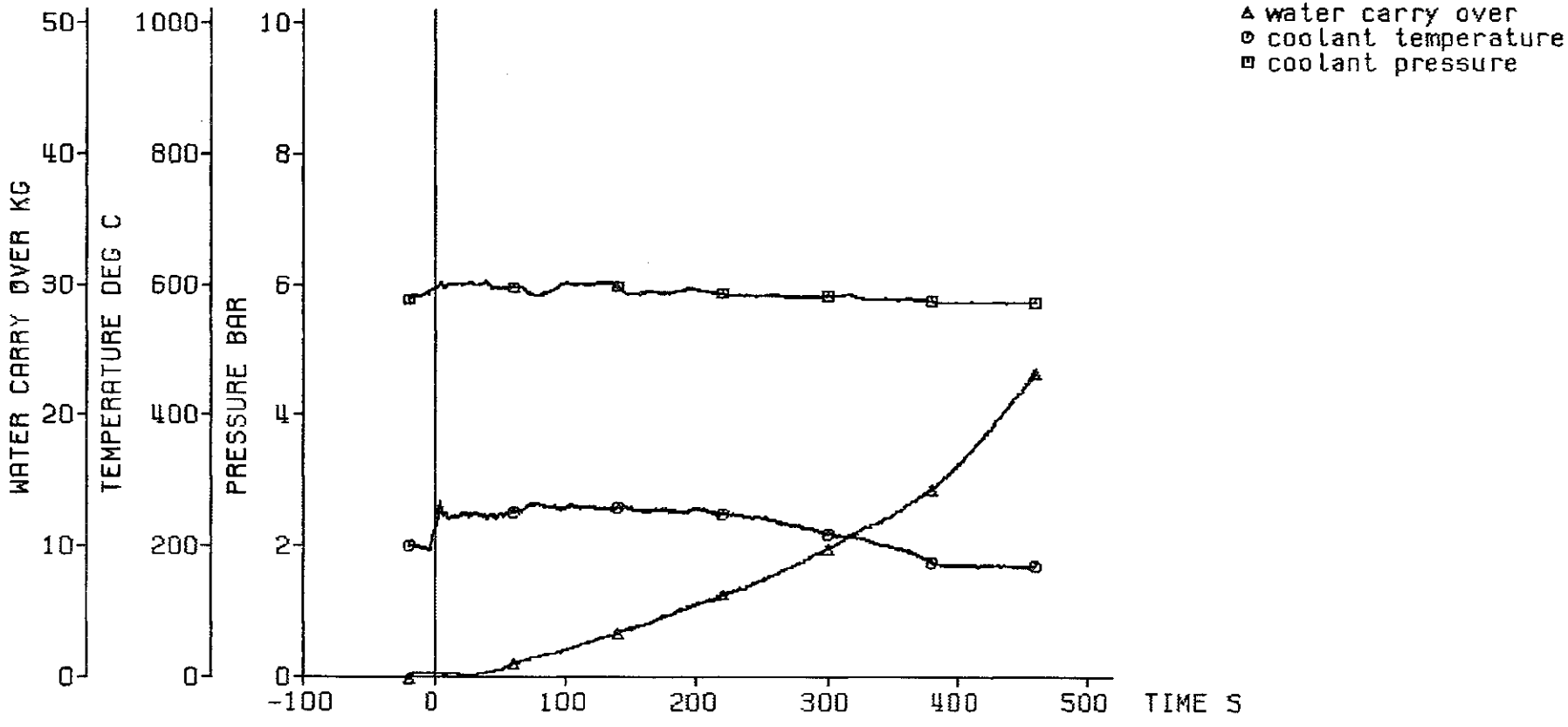
pressure loss
along the test section:

◇ total length: 4196 mm
△ lower part: 1711 mm
○ middle part: 545 mm
□ upper part: 1940 mm

decay heat	120% ANS standard
flooding rate (cold)	3.80 cm/s
system pressure	5.90 bar
feedwater temperature	40 deg C

KfK KIRB

Fig. 423 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 268



decay heat	120% ANS standard
flooding rate (cold)	3.80 cm/s
system pressure	5.90 bar
feedwater temperature	40 deg C

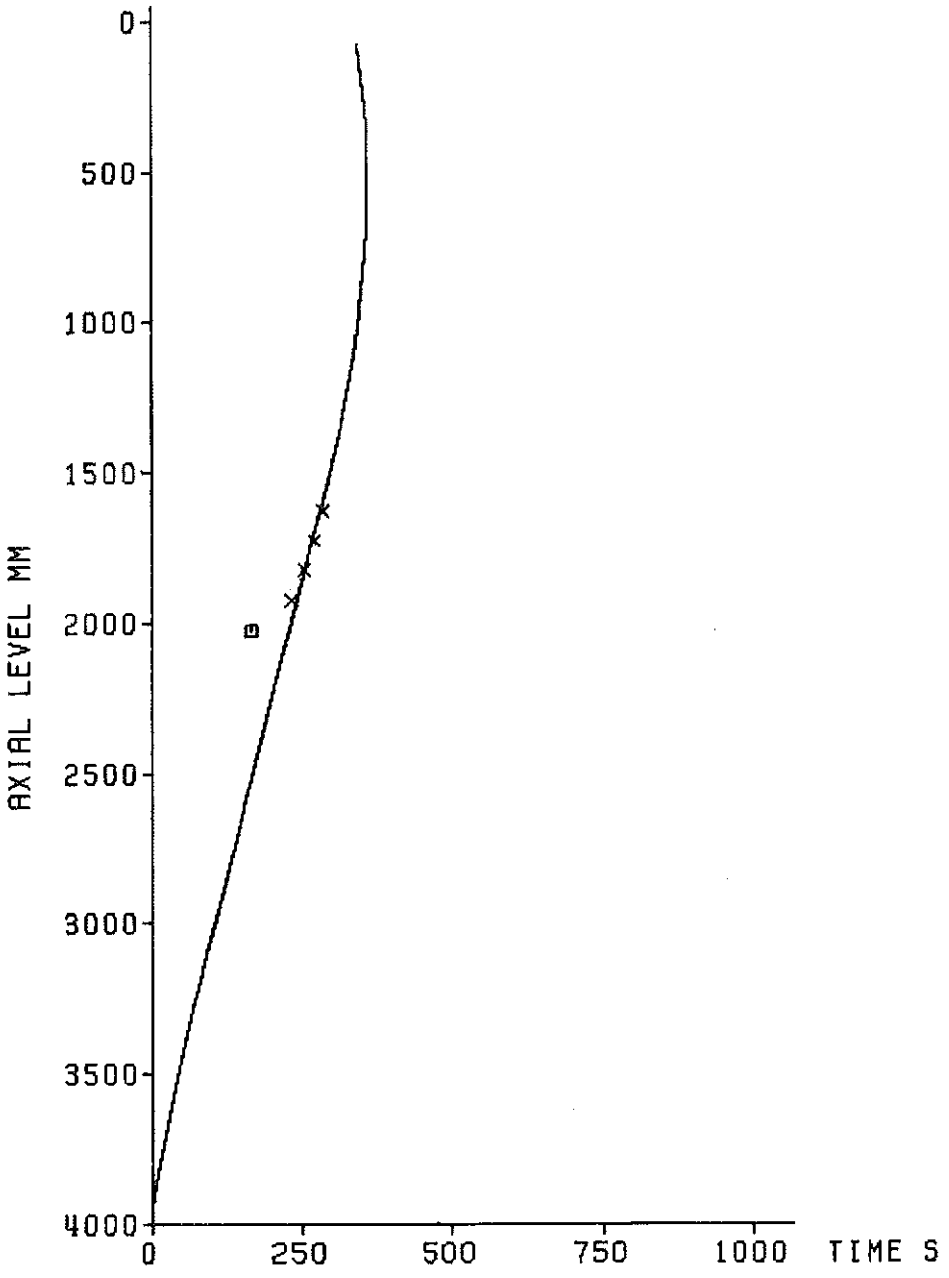
KfK IRB

Fig. 424 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 268

axial position of the quench front

⊡ rewetting of the sleeve at the bundle midplane

× rewetting of the rod downstream of the blockage

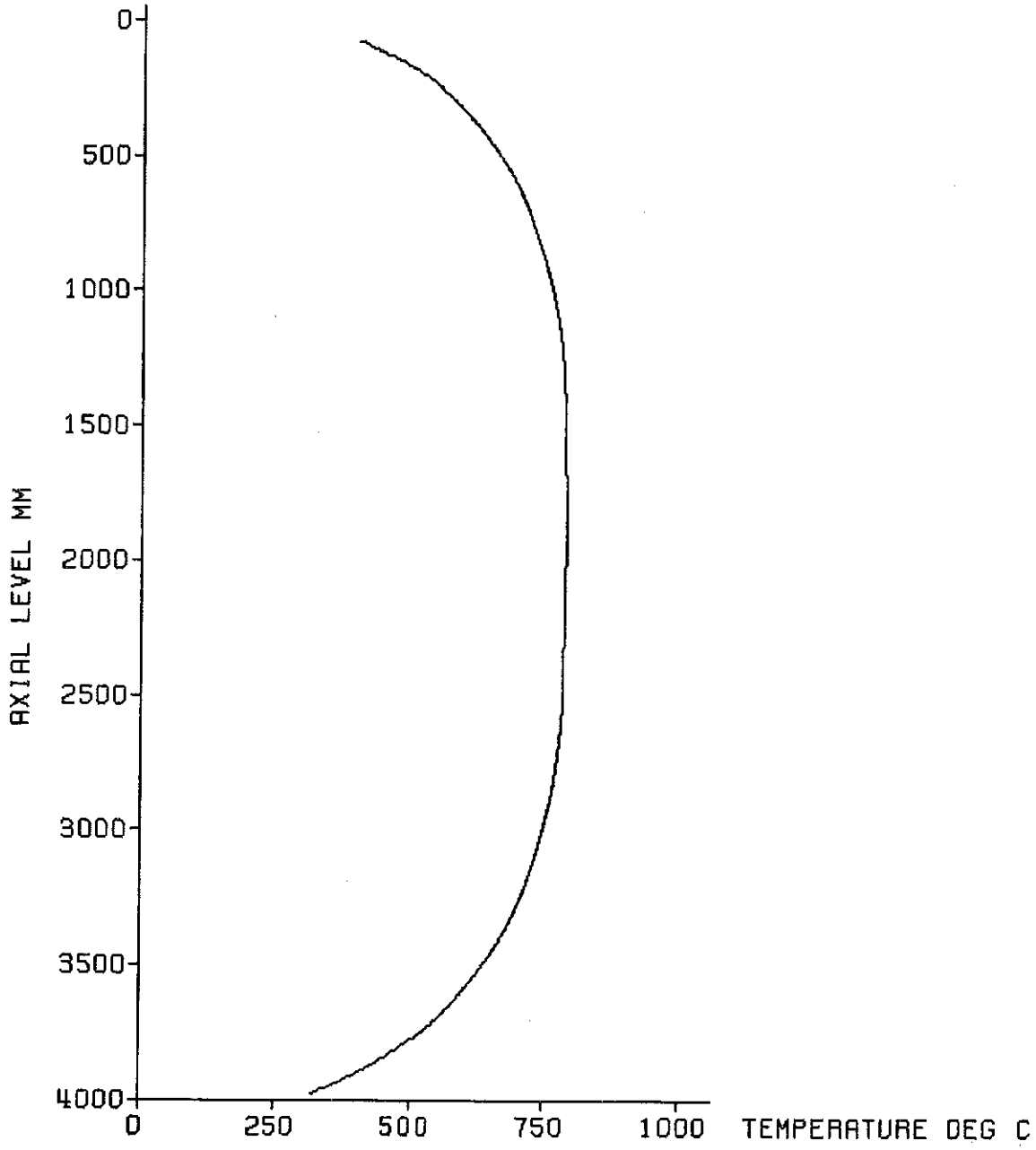


decay heat	120% ANS standard
flooding rate (cold)	3.80 cm/s
system pressure	5.90 bar
feedwater temperature	40 deg C

KfK IRB

Fig. 425 FEBA: 5x5 ROD BUNDLE
TEST SERIES 4, TEST-No. 268

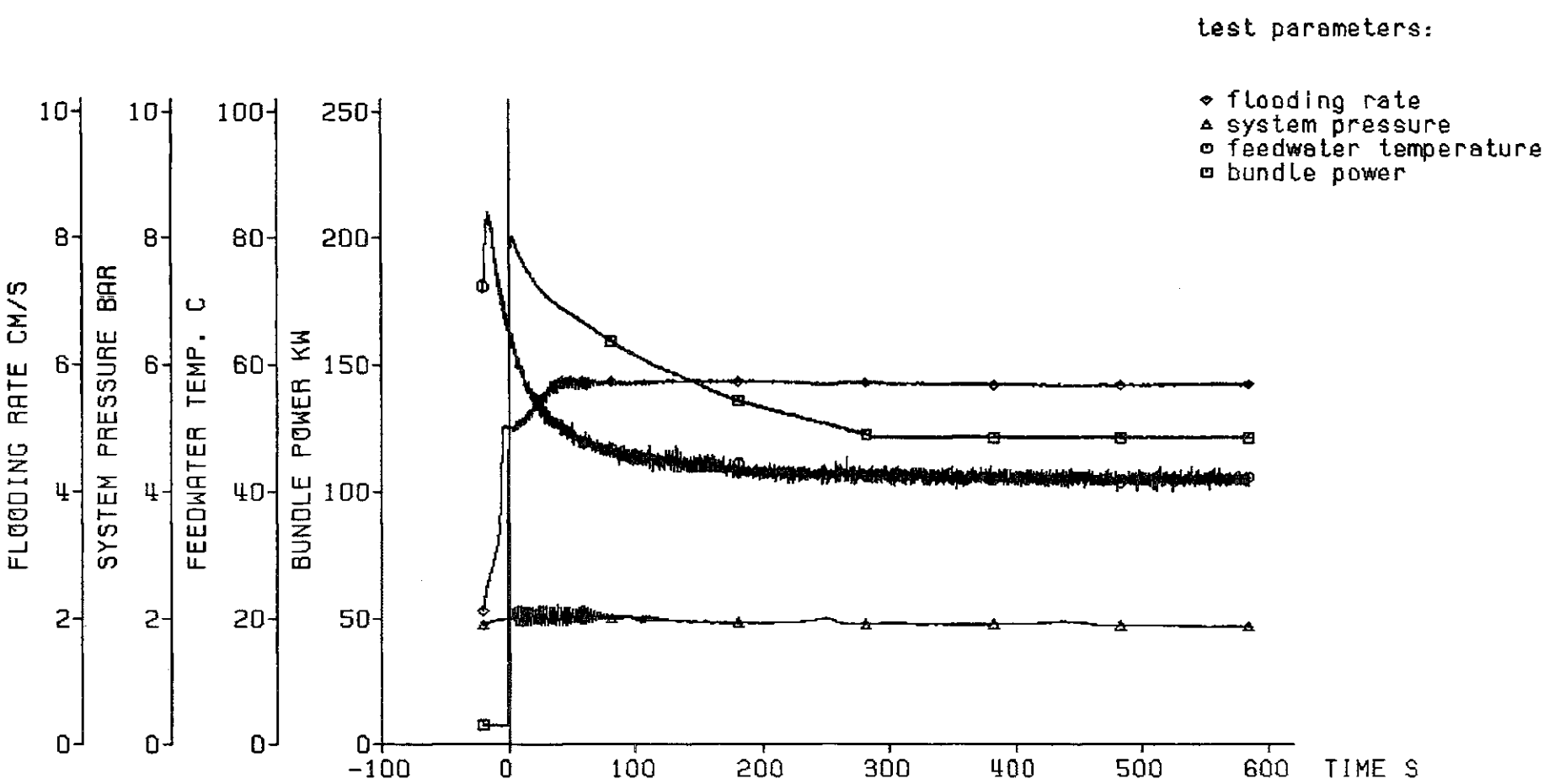
Initial axial temperature profile of the cladding



decay heat	120% ANS standard
flooding rate (cold)	5.68 cm/s
system pressure	1.98 bar
feedwater temperature	40 deg C

KfK IRB

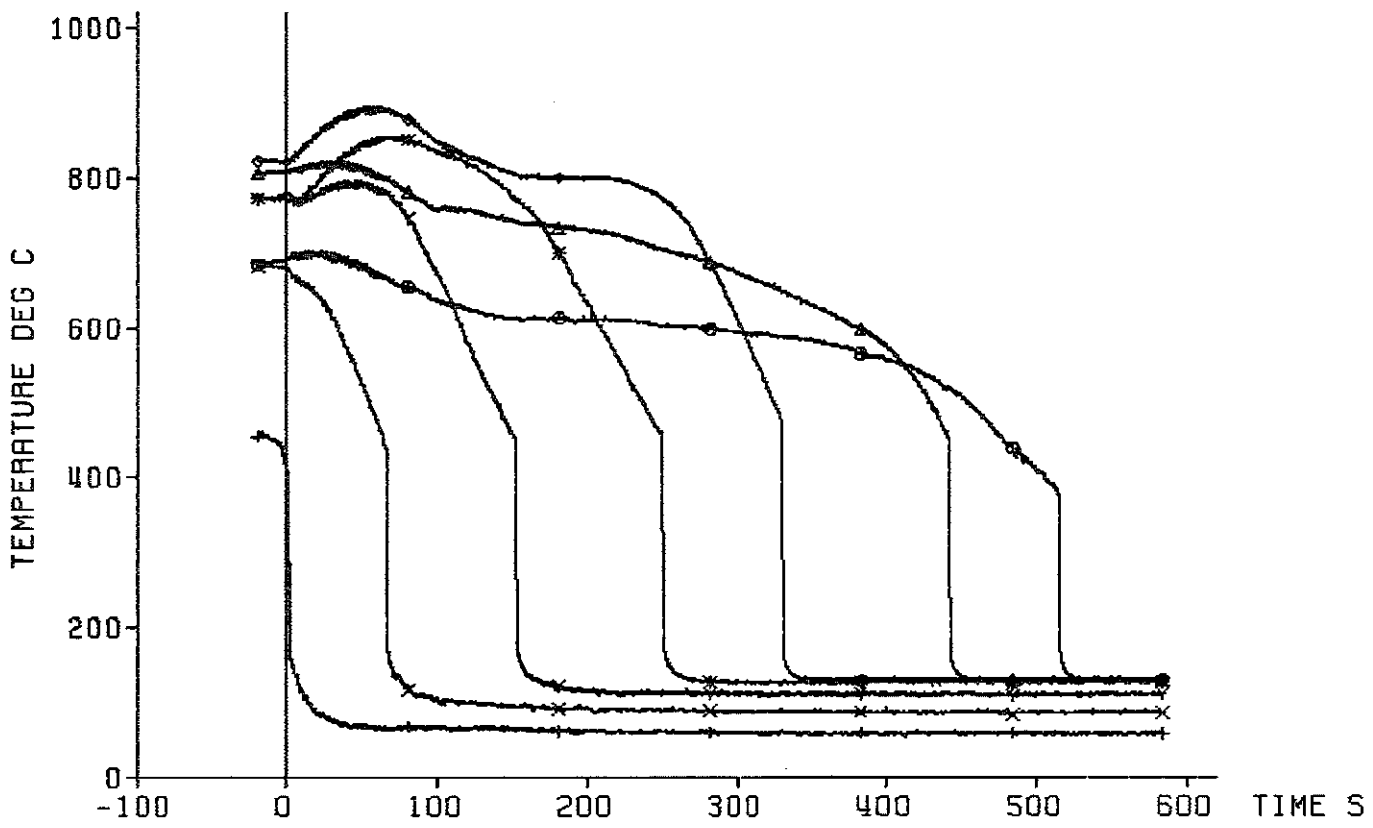
Fig. 426 FEBA: 5x5 ROD BUNDLE TEST SERIES 4, TEST-No. 261



decay heat	120% ANS standard
flooding rate (cold)	5.68 cm/s
system pressure	1.98 bar
feedwater temperature	40 deg C

KfK IRB

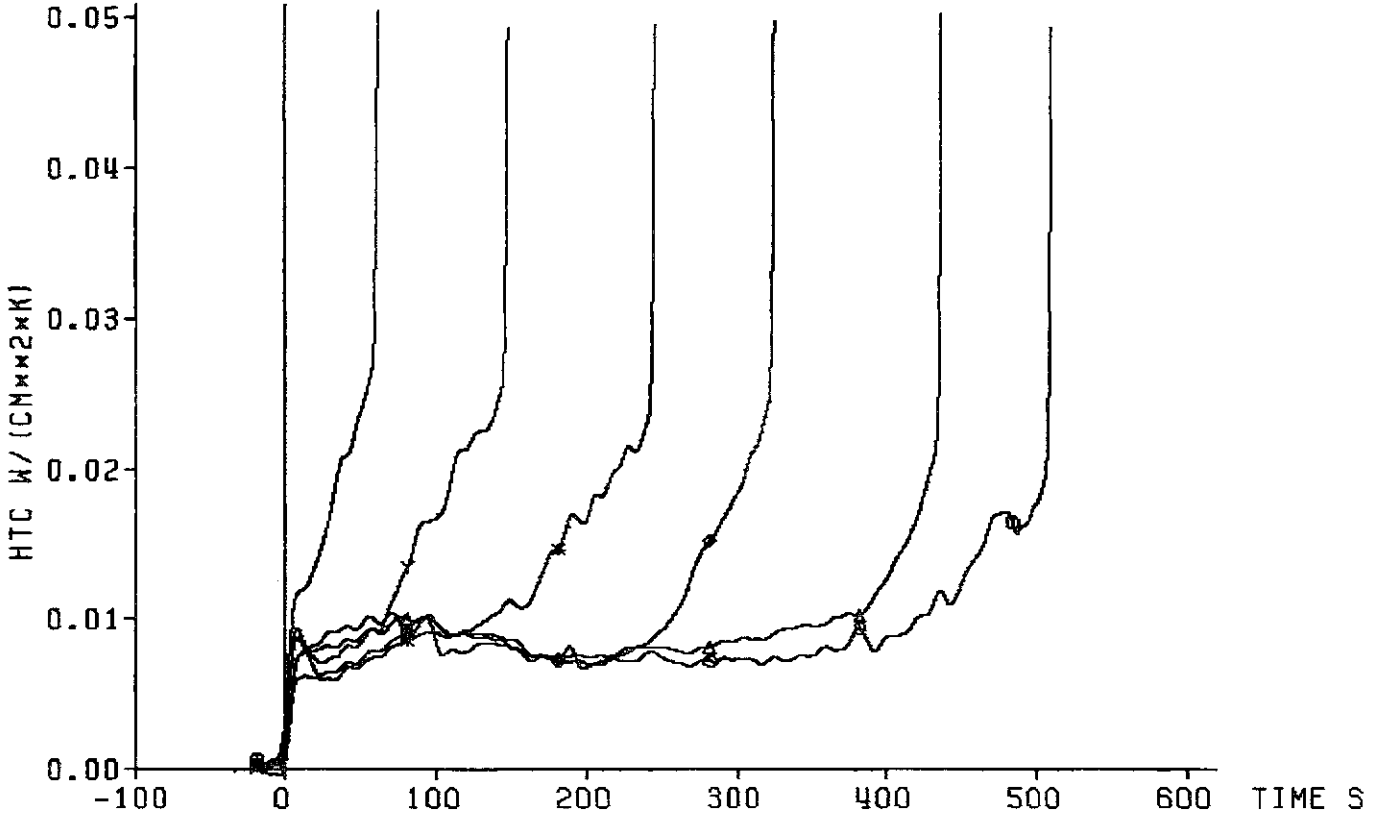
Fig. 427 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 261



decay heat	120% ANS standard
flooding rate (cold)	5.68 cm/s
system pressure	1.98 bar
feedwater temperature	40 deg C

KfK IRB

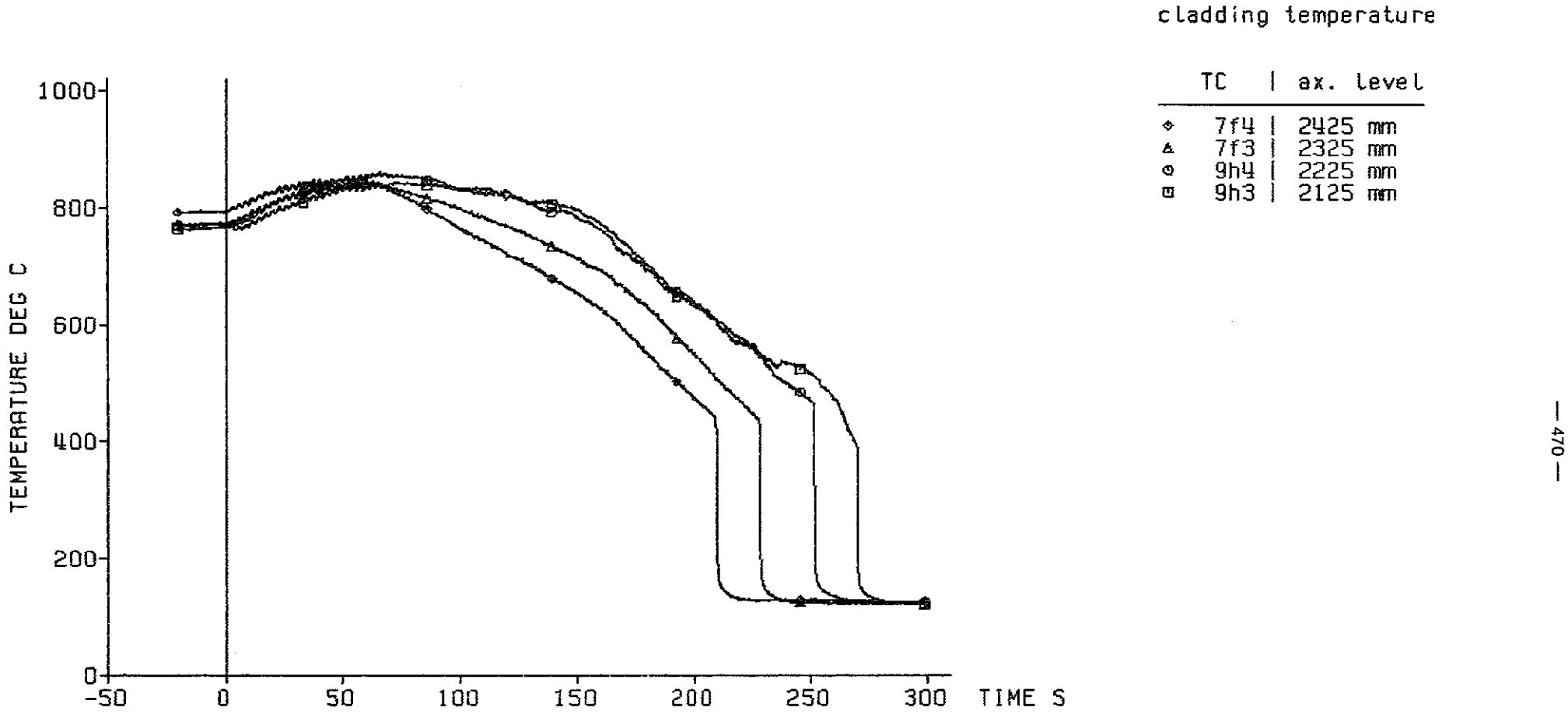
Fig. 428 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 261



decay heat	120% ANS standard
flooding rate (cold)	5.68 cm/s
system pressure	1.98 bar
feedwater temperature	40 deg C

KfK IRB

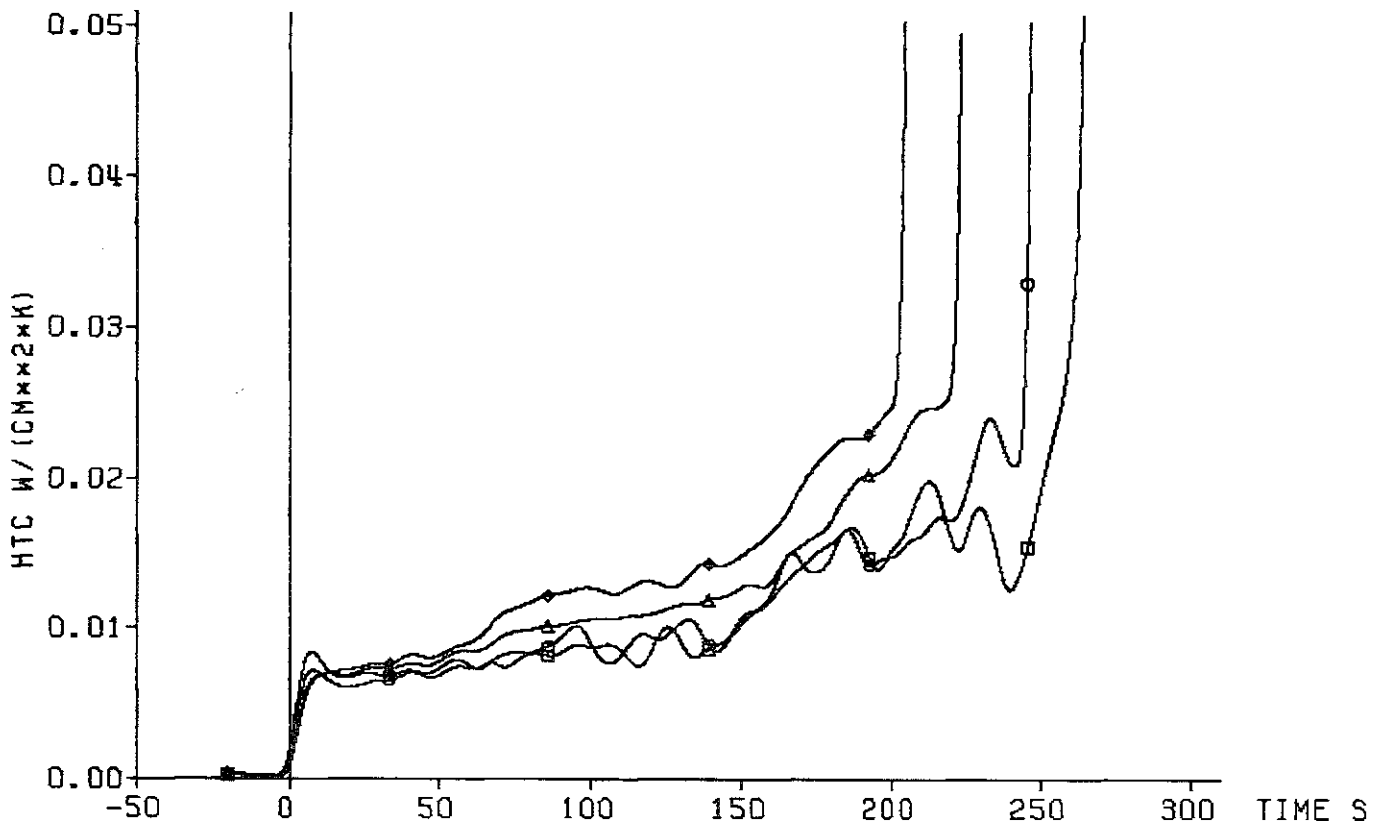
Fig. 429 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 261



decay heat	120% ANS standard	bypass
flooding rate (cold)	5.68 cm/s	======
system pressure	1.98 bar	
feedwater temperature	40 deg C	

KfK IRB

Fig. 430 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 261

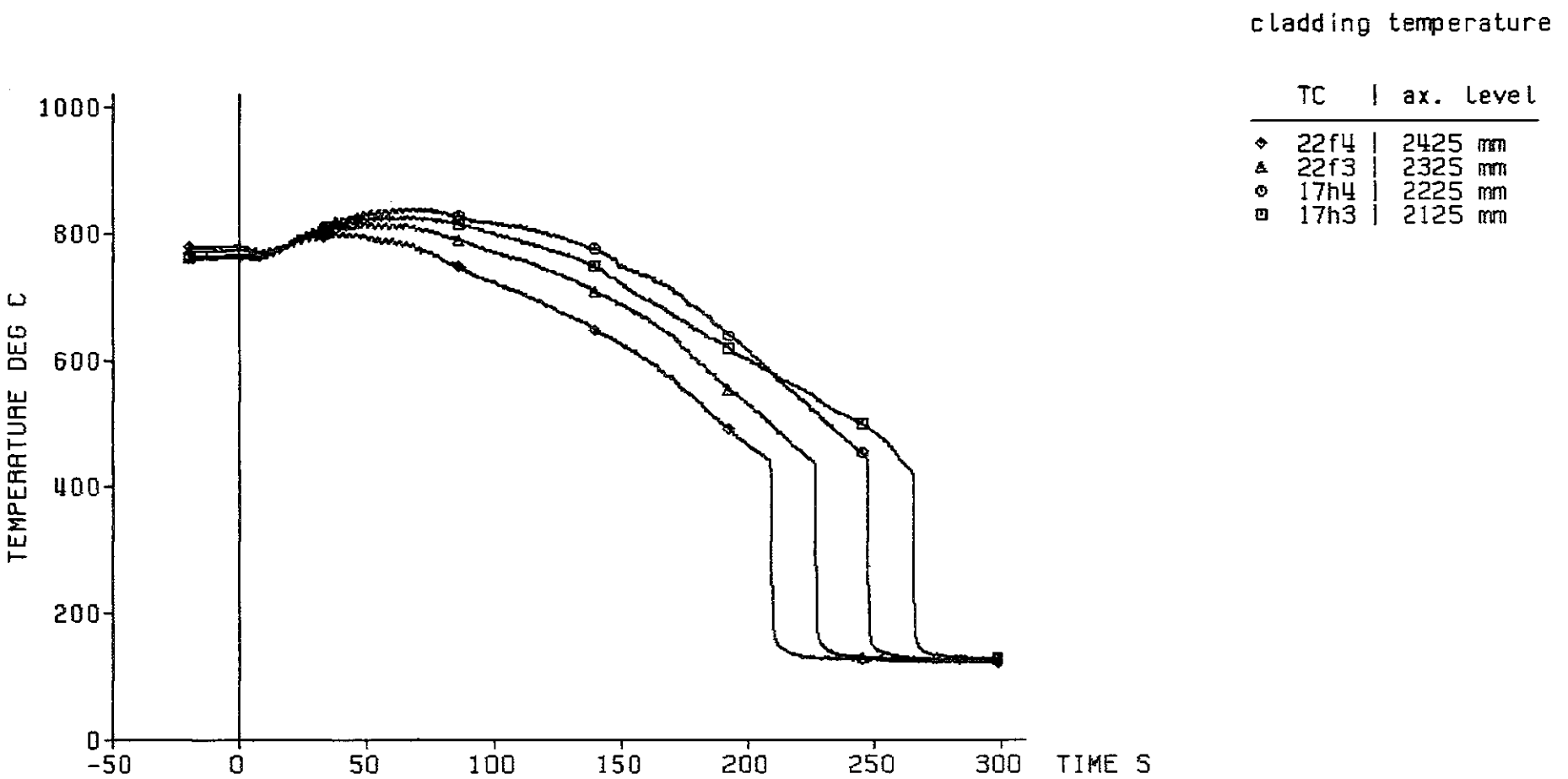


decay heat	120% ANS standard
flooding rate (cold)	5.68 cm/s
system pressure	1.98 bar
feedwater temperature	40 deg C

bypass
======

KfK IRB

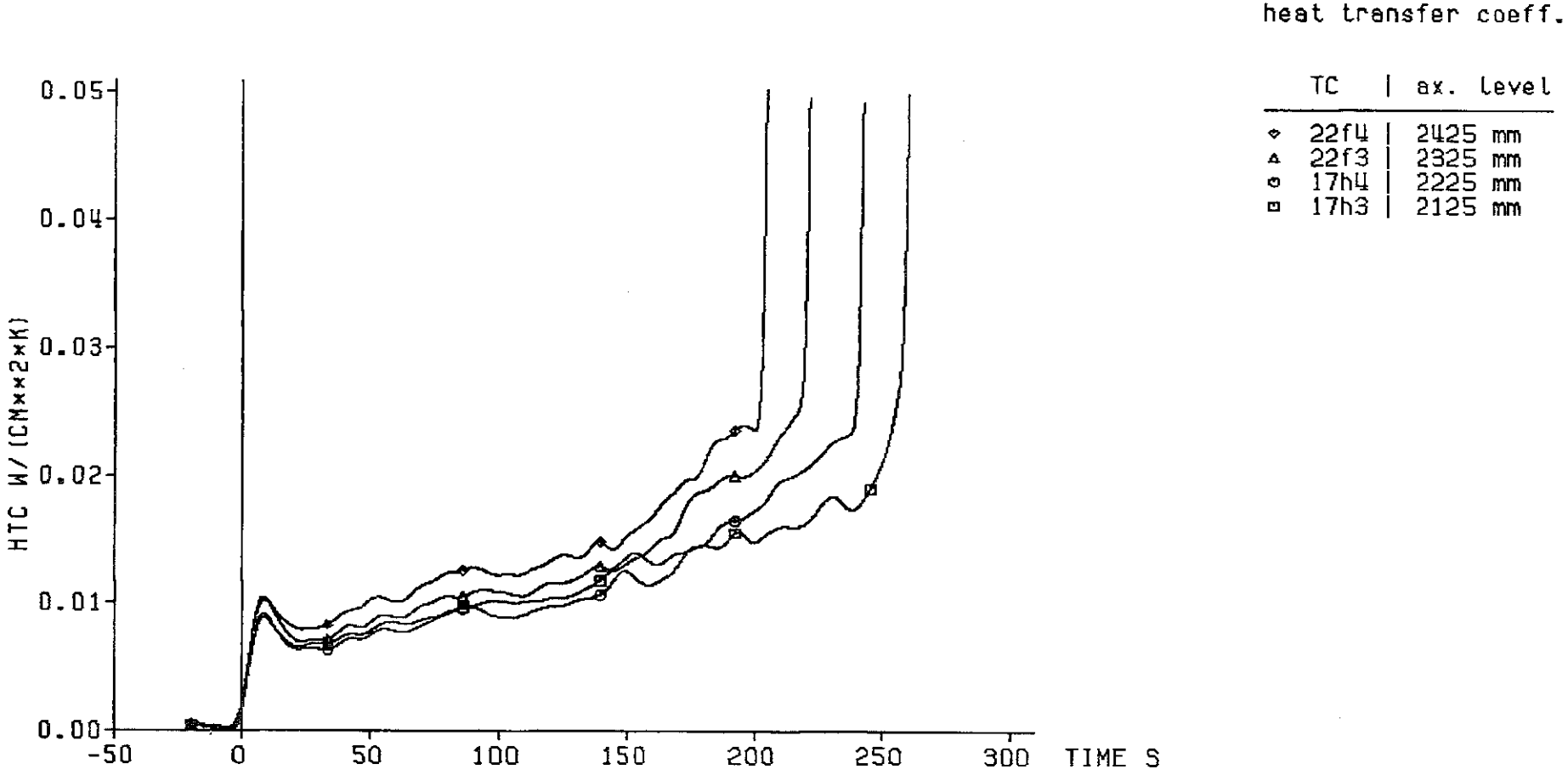
Fig. 431 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 261



decay heat	120% ANS standard	blockage
flooding rate (cold)	5.68 cm/s	========
system pressure	1.98 bar	
feedwater temperature	40 deg C	

KfK IRB

Fig. 432 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 261

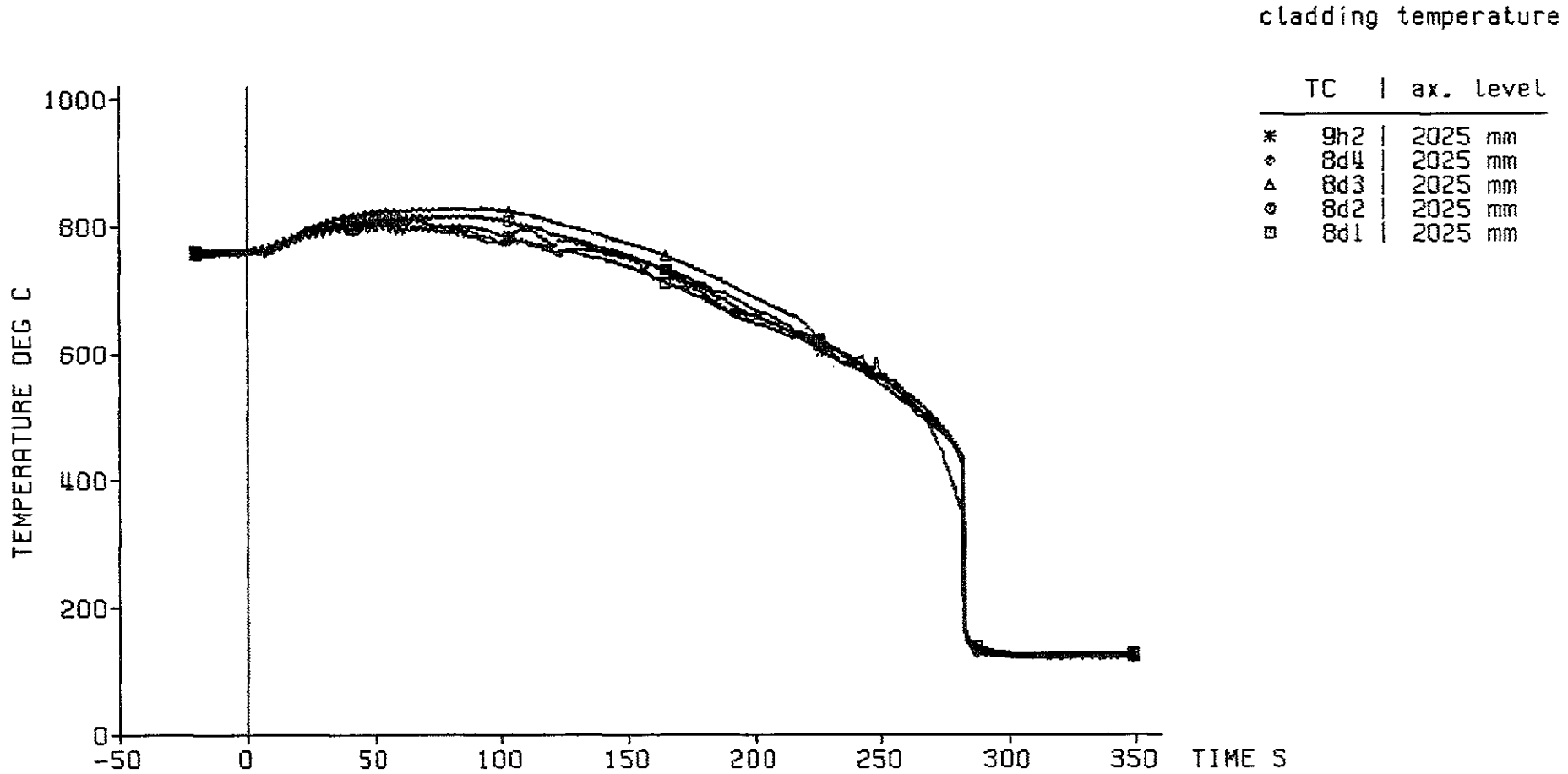


decay heat	120% ANS standard
flooding rate (cold)	5.68 cm/s
system pressure	1.98 bar
feedwater temperature	40 deg C

blockage
========

KfK IRB

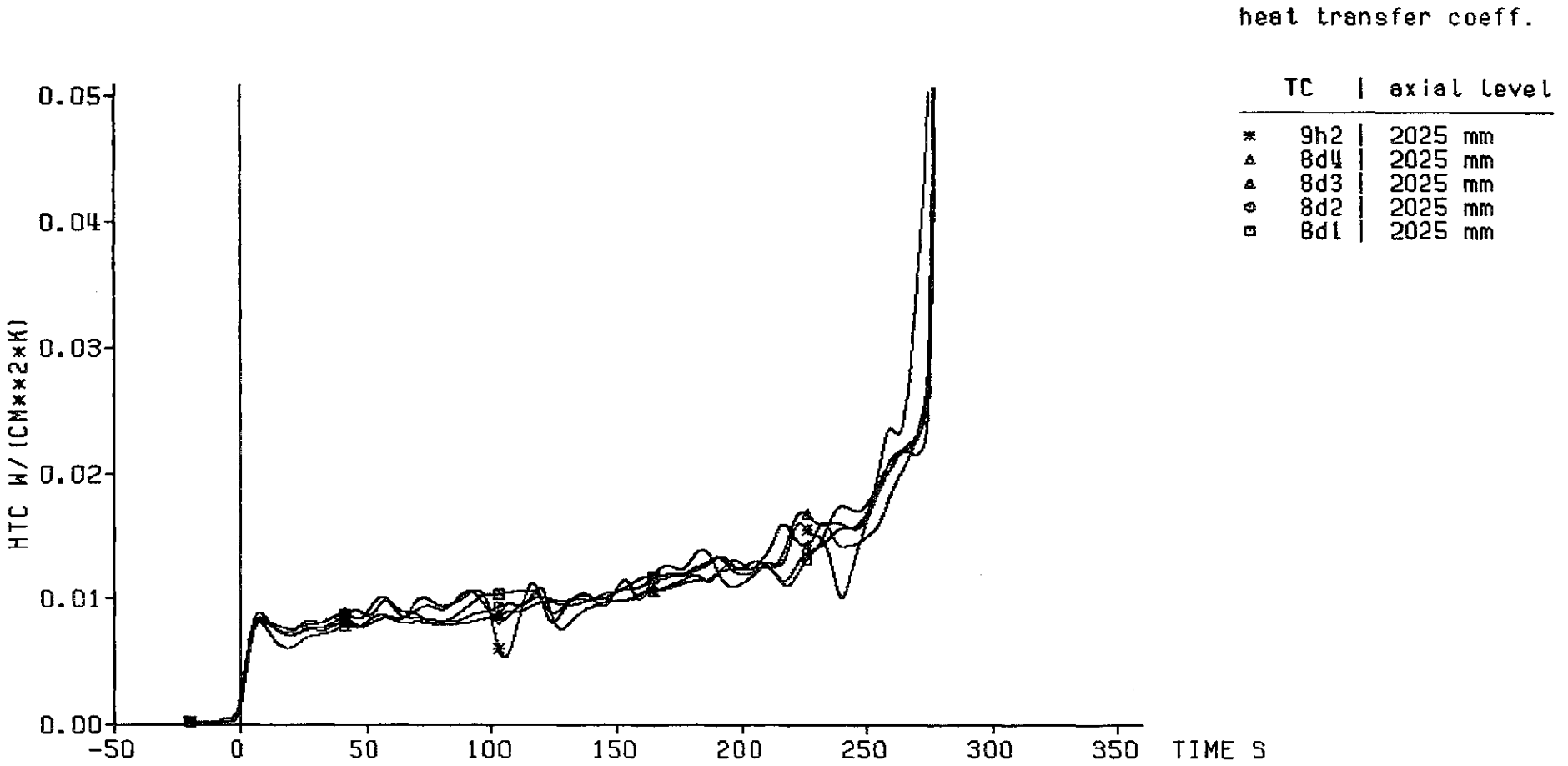
Fig. 433 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 261



decay heat	120% ANS standard	bypass
flooding rate (cold)	5.68 cm/s	======
system pressure	1.98 bar	
feedwater temperature	40 deg C	

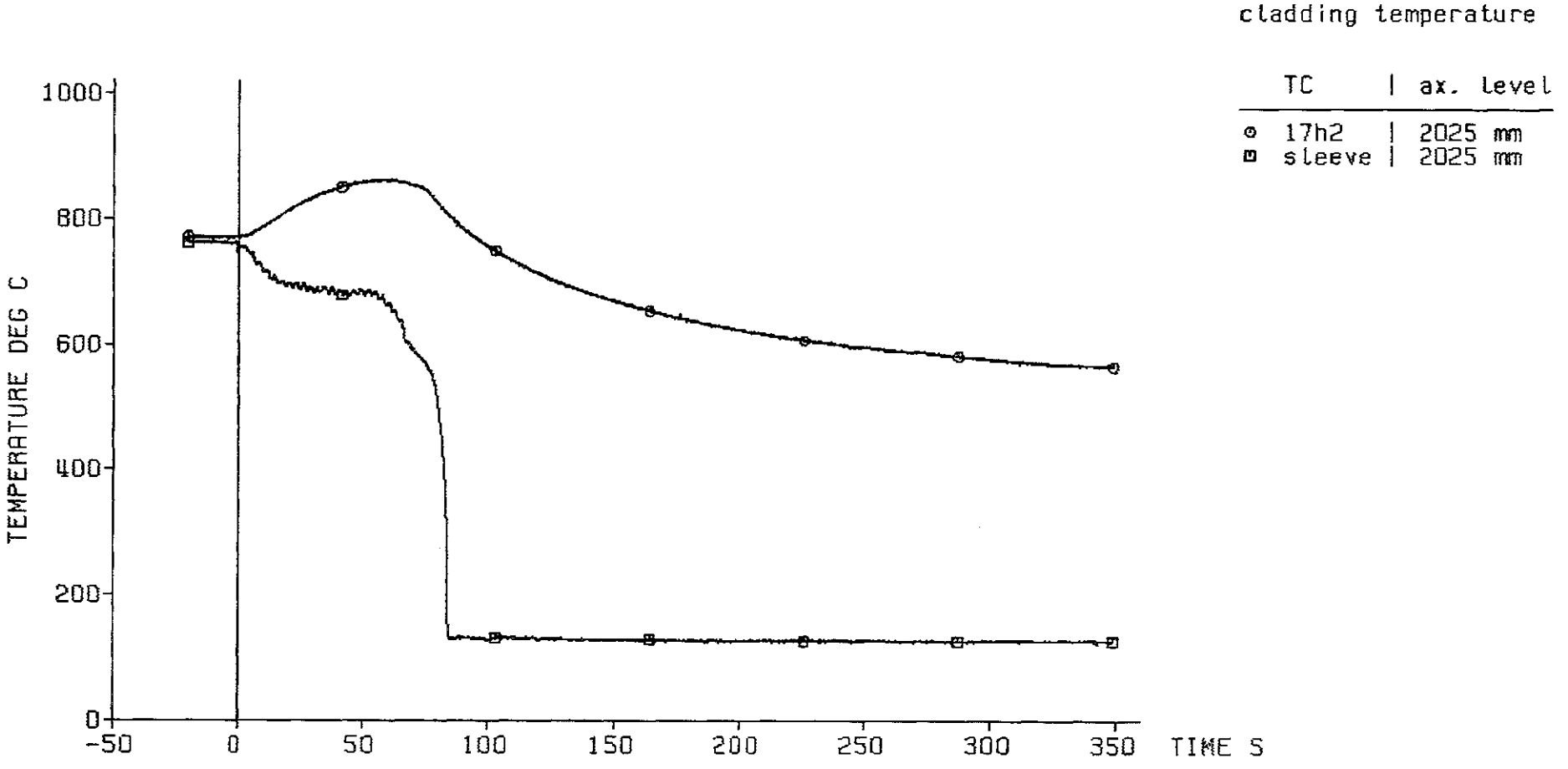
KfK IRB

Fig. 434 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 261



decay heat	120% ANS standard	bypass
flooding rate (cold)	5.68 cm/s	======
system pressure	1.98 bar	
feedwater temperature	40 deg C	

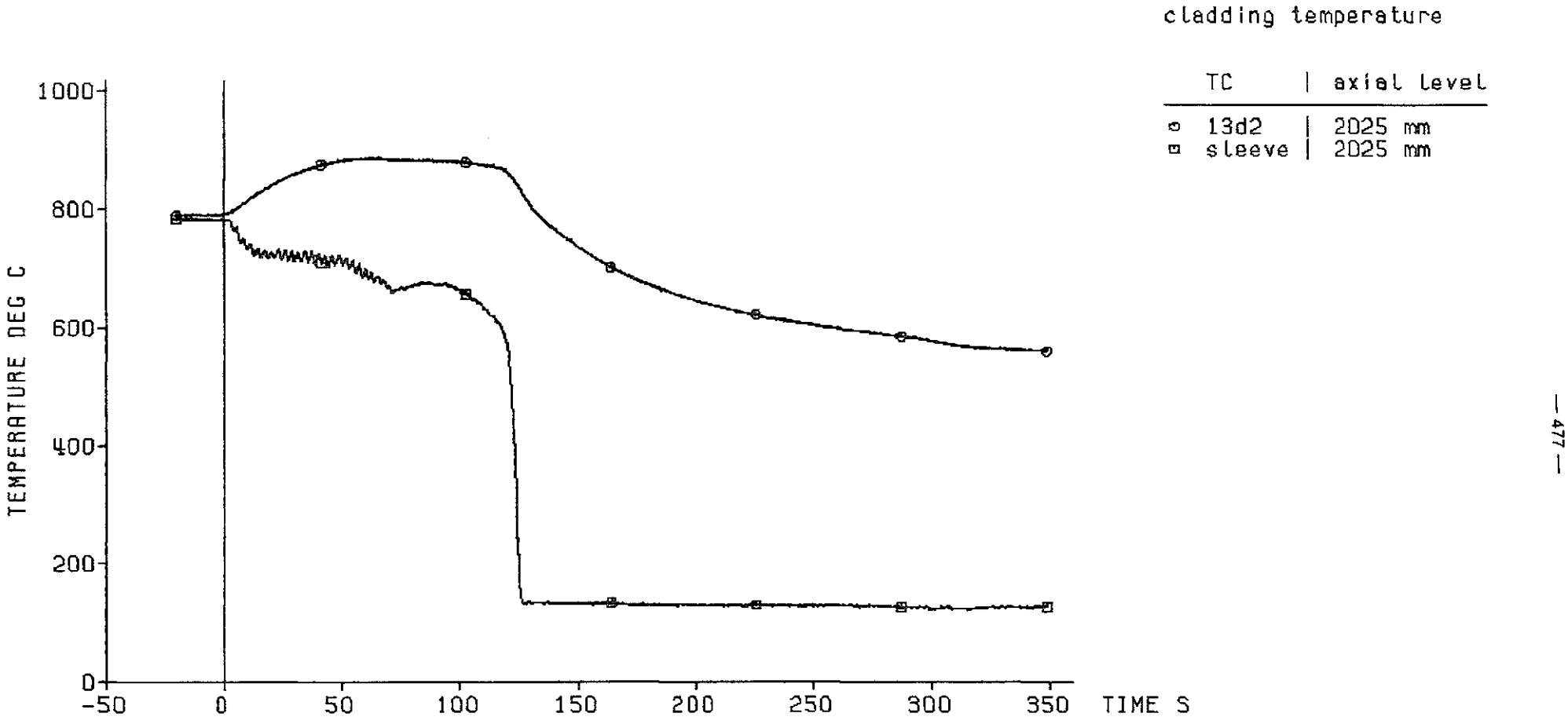
Fig. 435 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 261



decay heat	120% ANS standard	blockage
flooding rate (cold)	5.68 cm/s	========
system pressure	1.98 bar	
feedwater temperature	40 deg C	

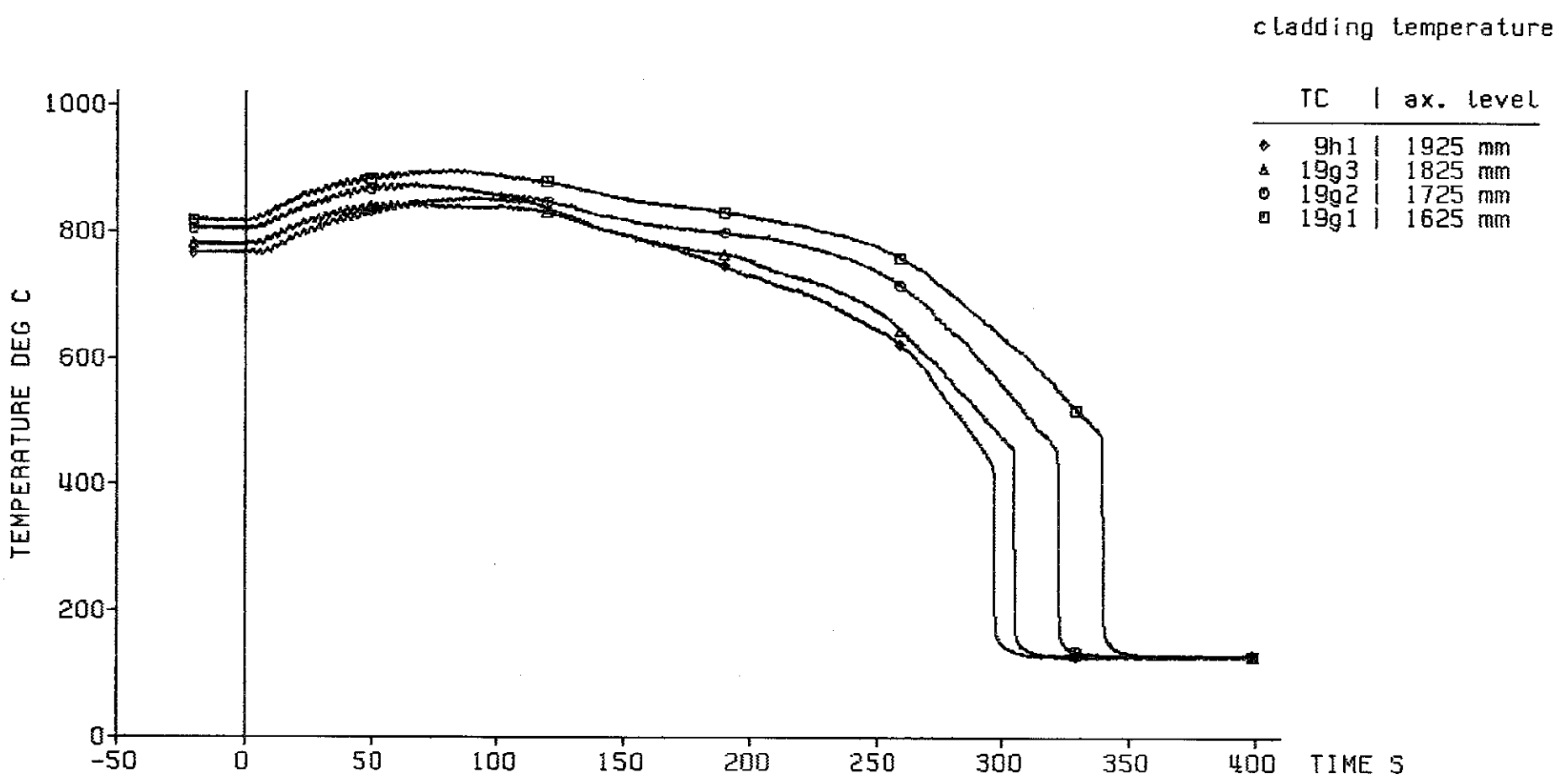
KfK KIRB

Fig. 436 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 261



decay heat	120% ANS standard	blockage
flooding rate (cold)	5.68 cm/s	========
system pressure	1.98 bar	
feedwater temperature	40 deg C	

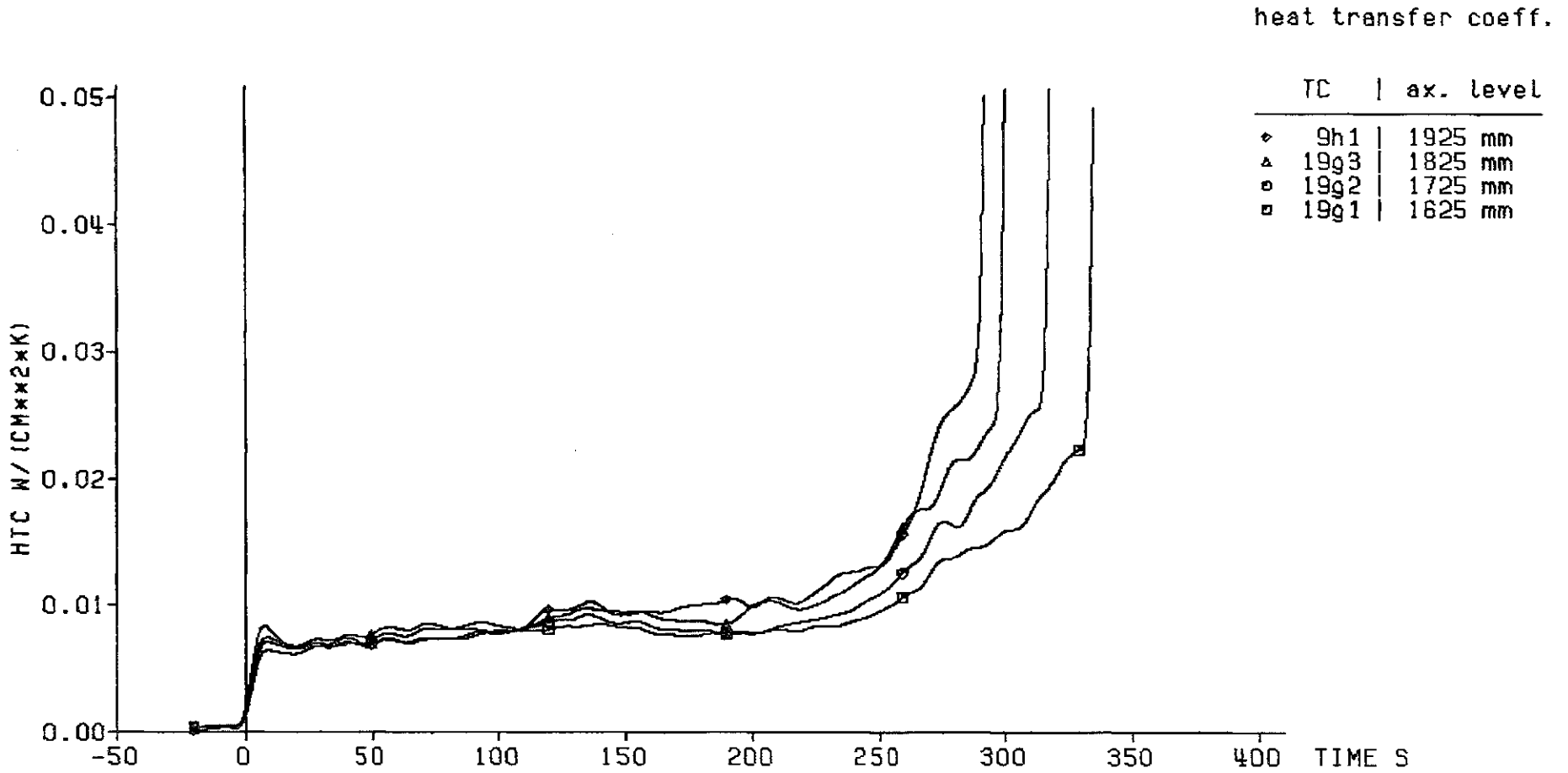
Fig. 437 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 261



decay heat	120% ANS standard	bypass
flooding rate (cold)	5.68 cm/s	======
system pressure	1.98 bar	
feedwater temperature	40 deg C	

KfK KIRB

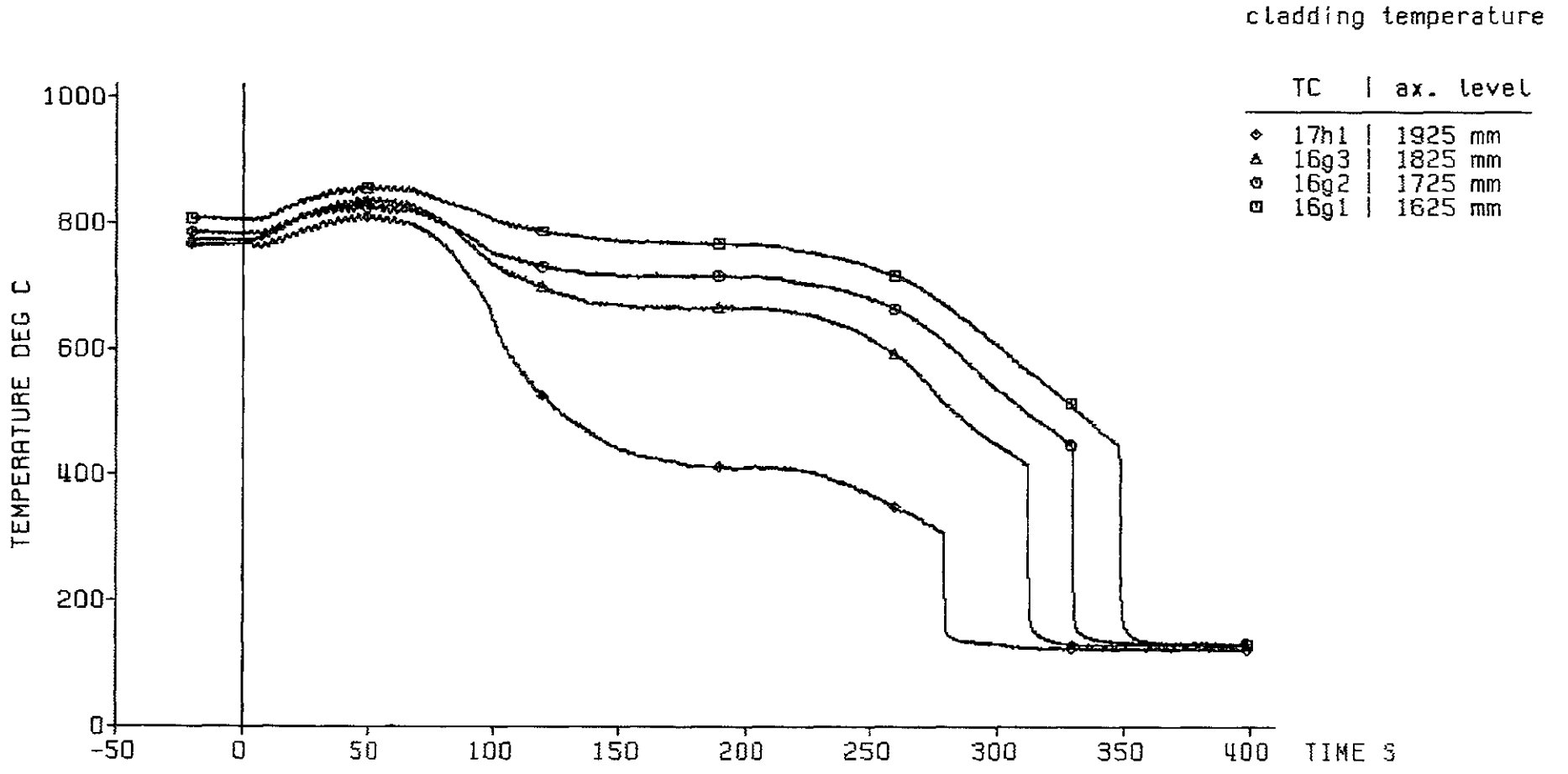
Fig. 438 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 261



decay heat	120% ANS standard	bypass
flooding rate (cold)	5.68 cm/s	======
system pressure	1.98 bar	
feedwater temperature	40 deg C	

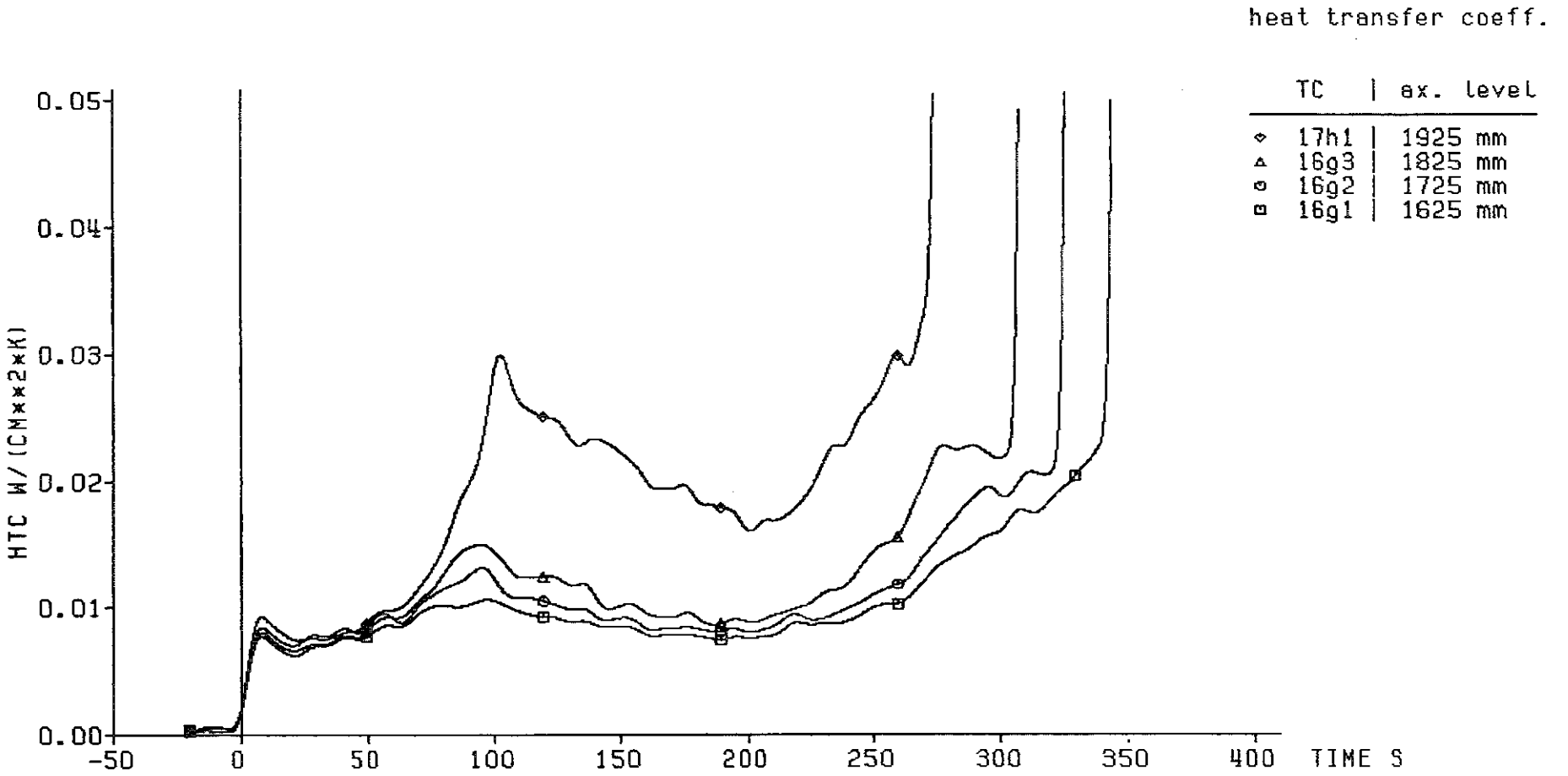
KfK IRB

Fig. 439 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 261



decay heat	120% ANS standard	blockage
flooding rate (cold)	5.68 cm/s	========
system pressure	1.98 bar	
feedwater temperature	40 deg C	

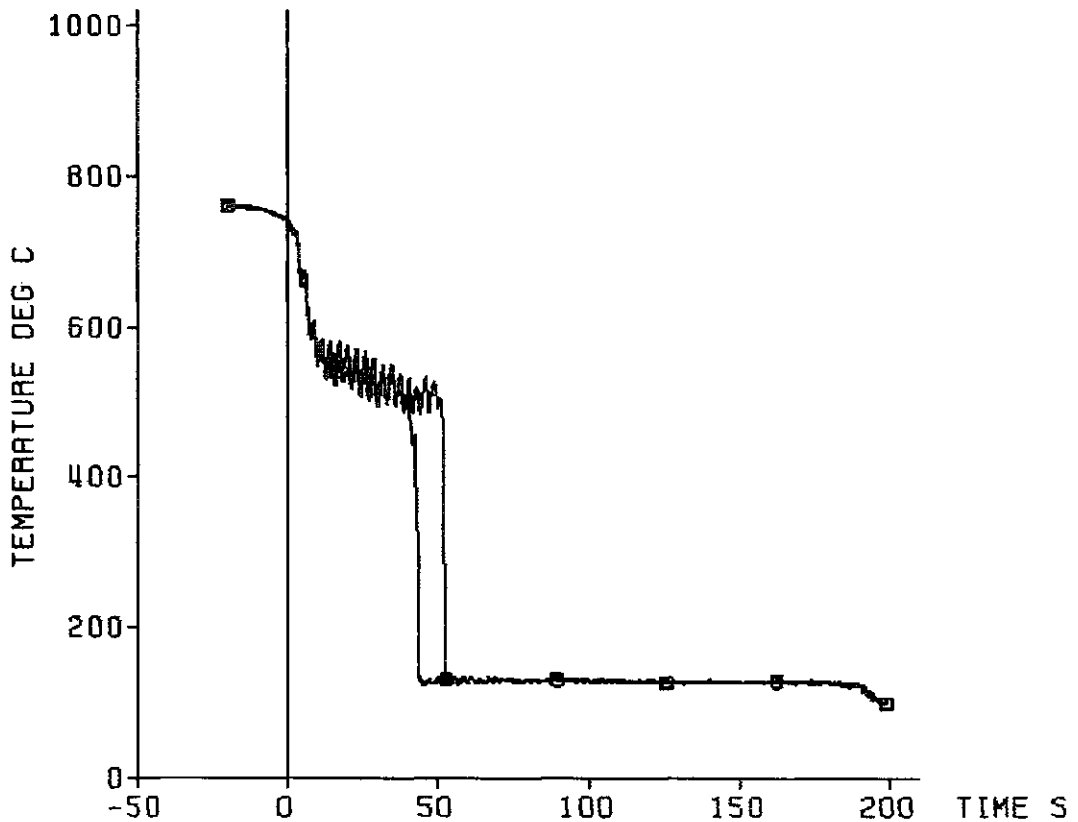
Fig. 440 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 261



decay heat	120% ANS standard	blockage
flooding rate (cold)	5.68 cm/s	========
system pressure	1.98 bar	
feedwater temperature	40 deg C	

KfK IRB

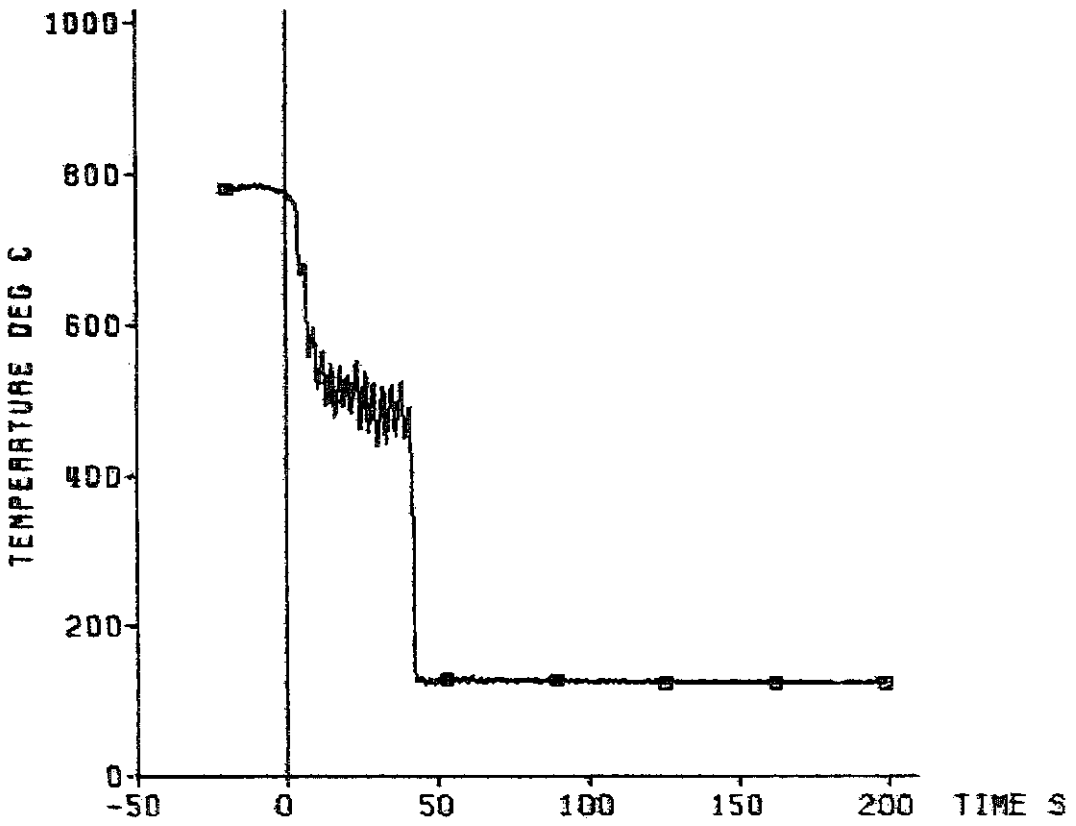
Fig. 441 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 261



decay heat	120% ANS standard
flooding rate (cold)	5.68 cm/s
system pressure	1.98 bar
feedwater temperature	40 deg C

KfK IRB

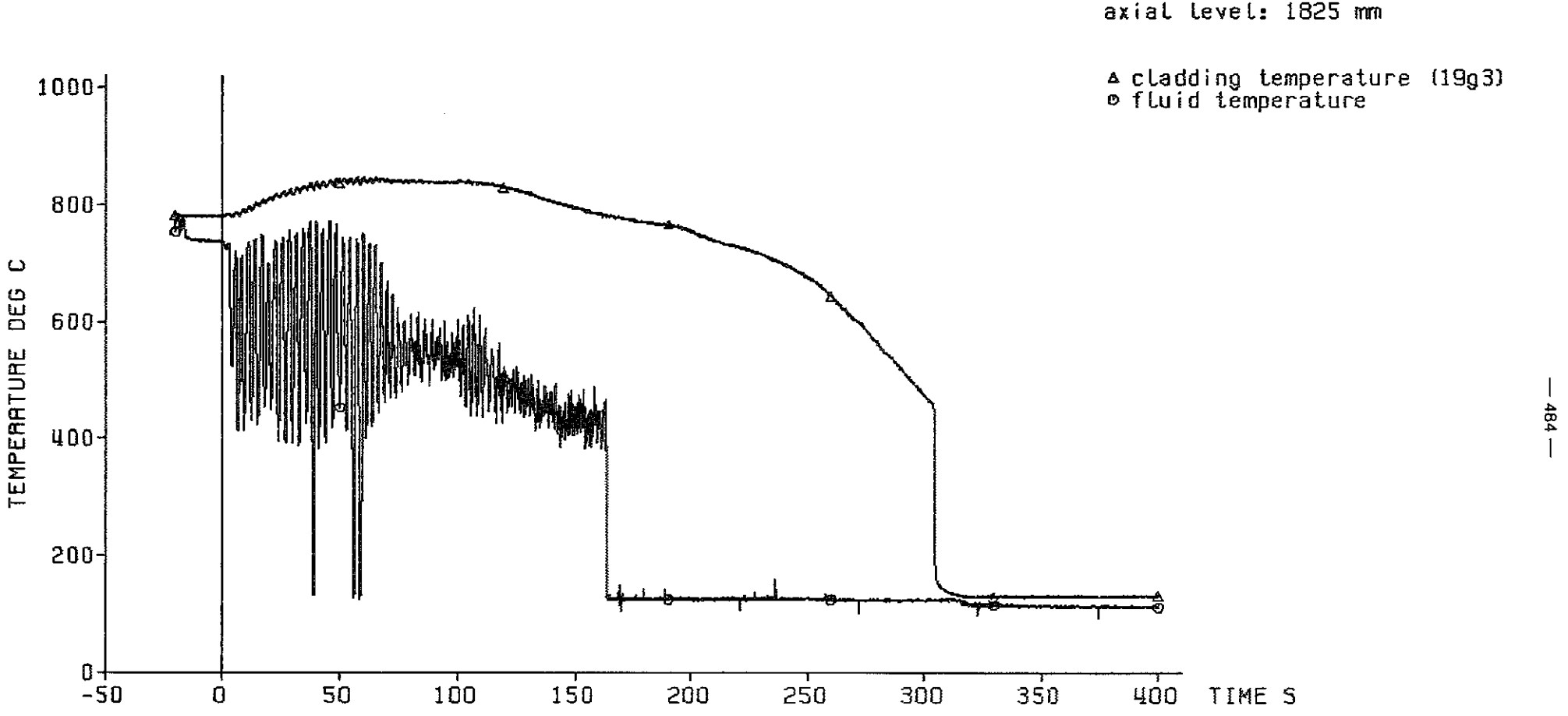
Fig. 442 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 261



decay heat	120% ANS standard
flooding rate (cold)	5.68 cm/s
system pressure	1.98 bar
feedwater temperature	40 deg C

KfK KTRB

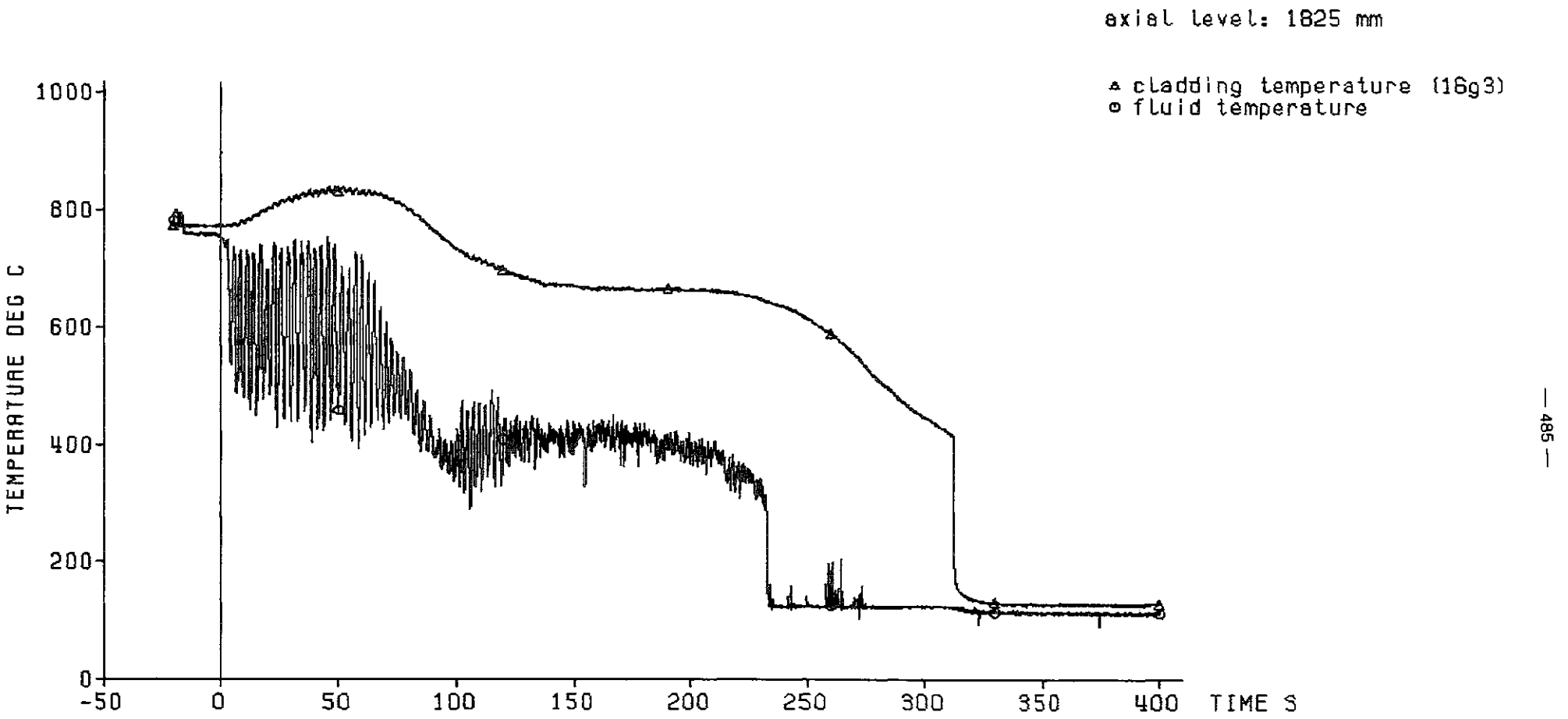
Fig. 443 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 261



decay heat	120% ANS standard	bypass
flooding rate (cold)	5.68 cm/s	======
system pressure	1.98 bar	
feedwater temperature	40 deg C	

KfK IRB

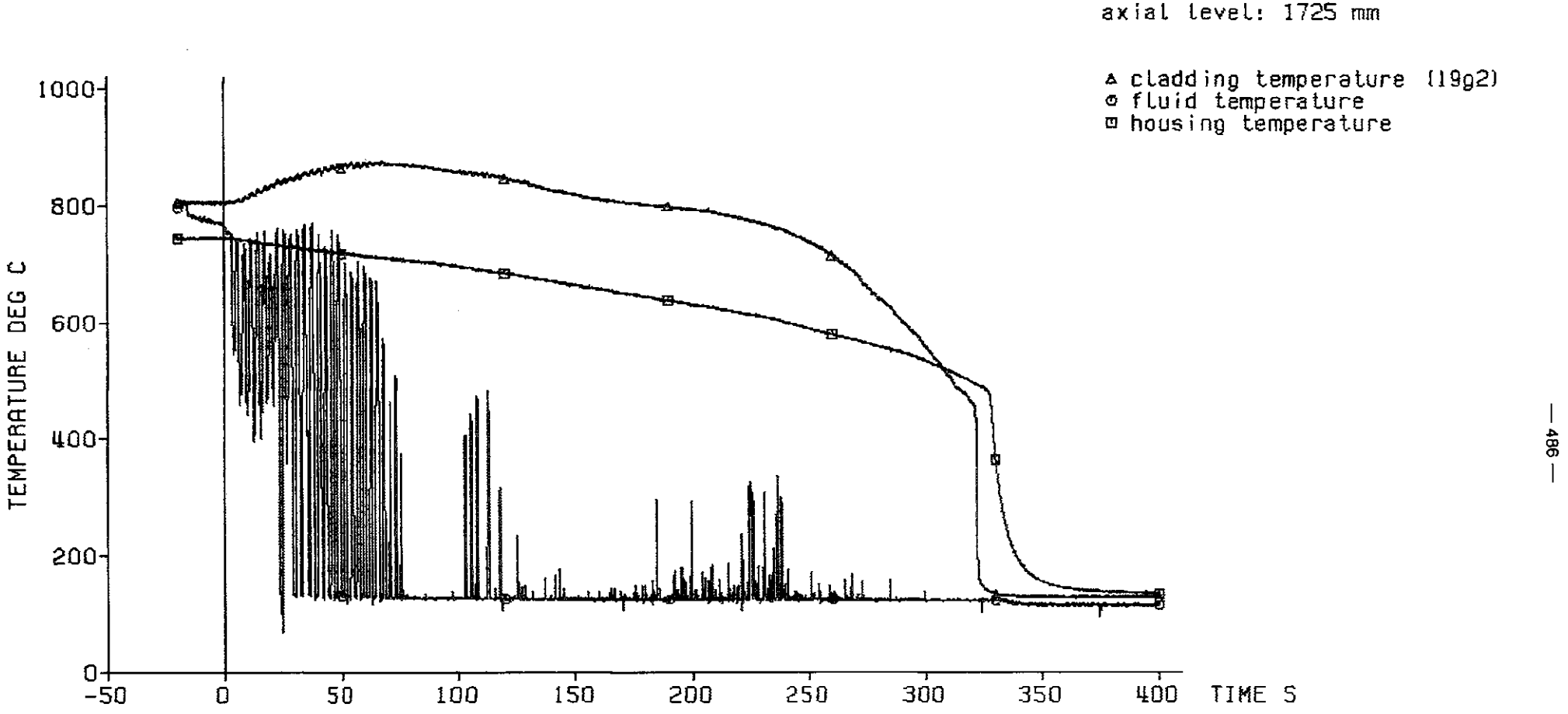
Fig. 444 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 261



decay heat	120% ANS standard	blockage
flooding rate (cold)	5.68 cm/s	========
system pressure	1.98 bar	
feedwater temperature	40 deg C	

KfK IRB

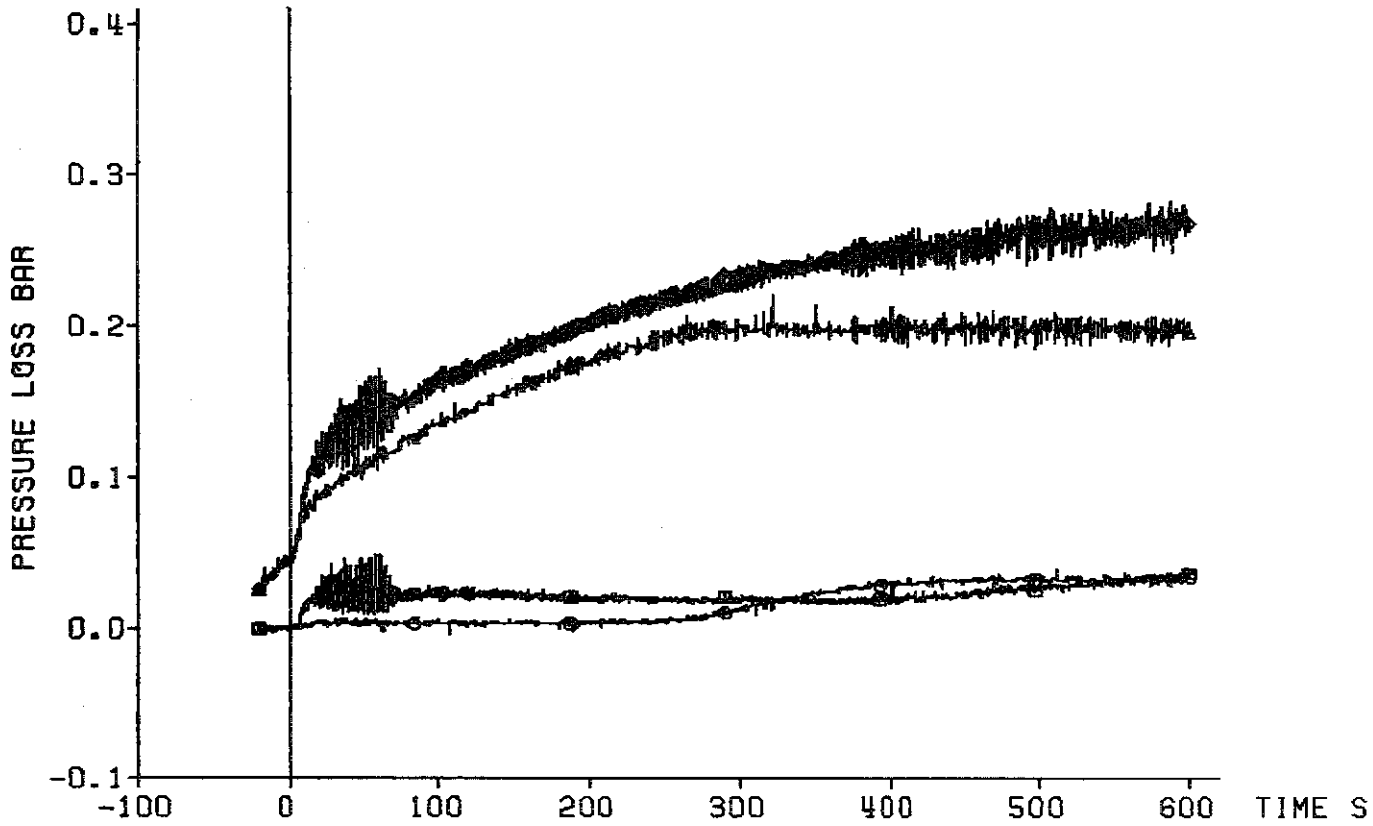
Fig. 445 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 261



decay heat	120% ANS standard	bypass
flooding rate (cold)	5.68 cm/s	======
system pressure	1.98 bar	
feedwater temperature	40 deg C	

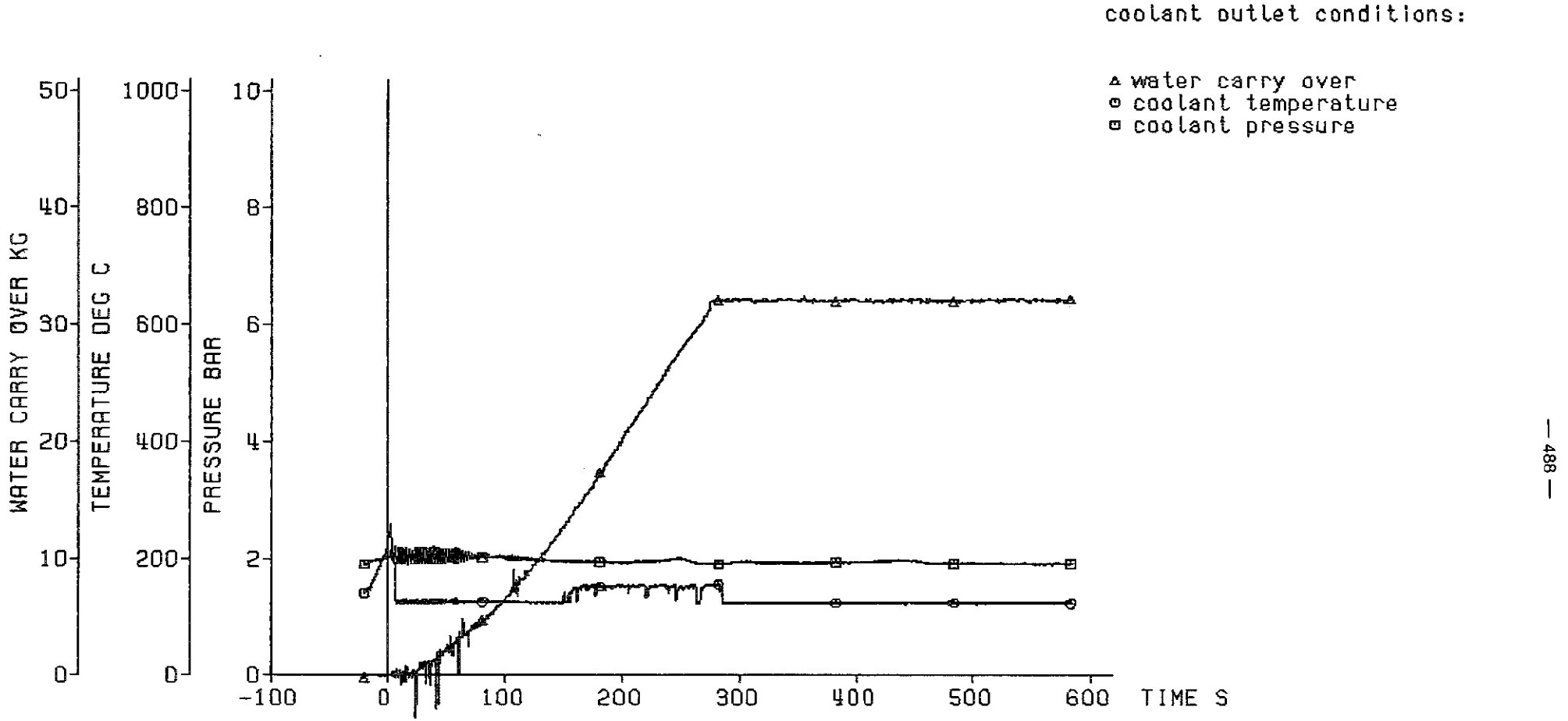
KfK IRB

Fig. 446 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 261



decay heat	120% ANS standard
flooding rate (cold)	5.68 cm/s
system pressure	1.98 bar
feedwater temperature	40 deg C

Fig. 447 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 261



decay heat	120% ANS standard
flooding rate (cold)	5.68 cm/s
system pressure	1.98 bar
feedwater temperature	40 deg C

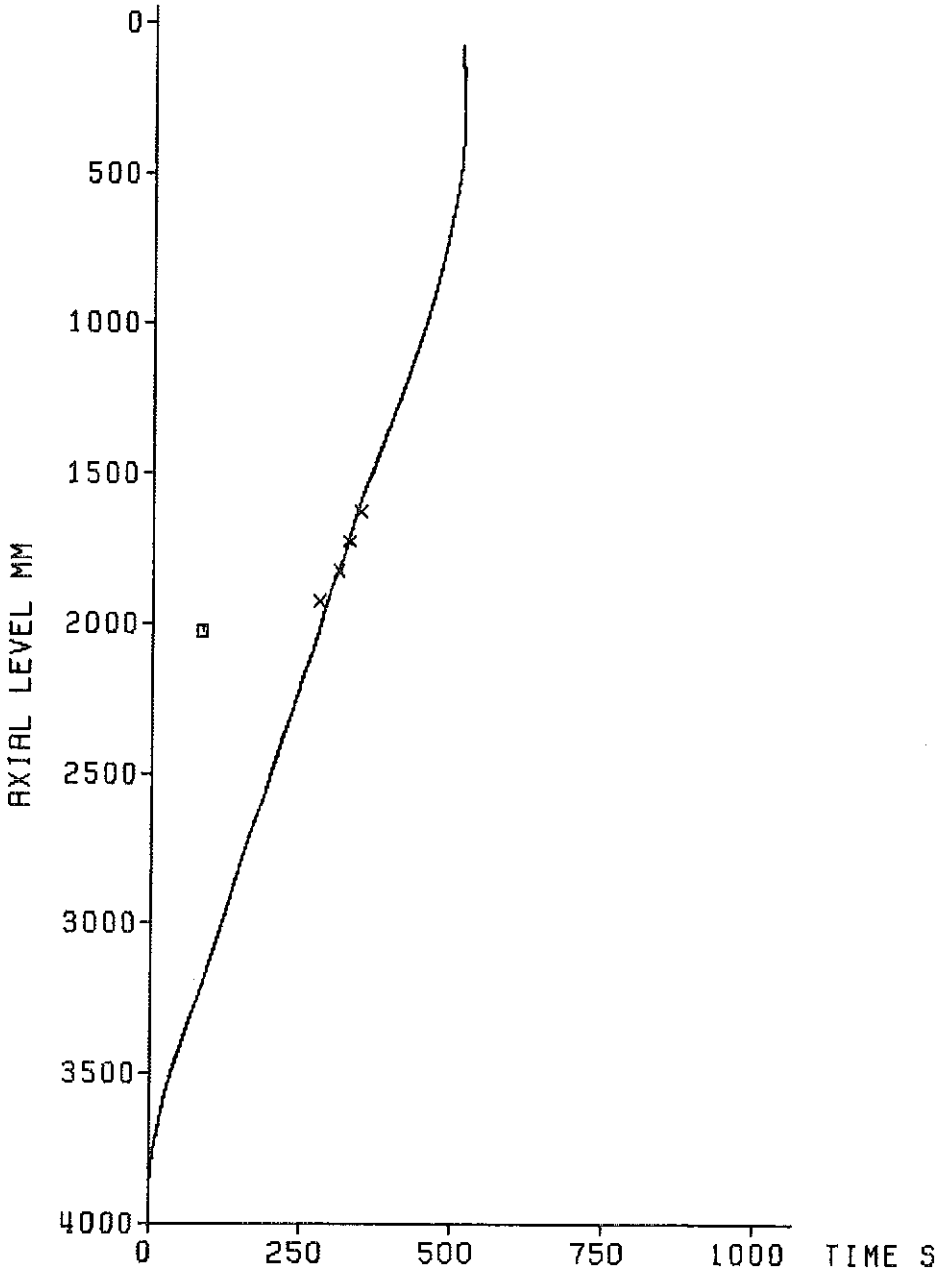
KfK IRB

Fig. 448 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 261

axial position of the quench front

▫ rewetting of the sleeve at the bundle midplane

× rewetting of the rod downstream of the blockage

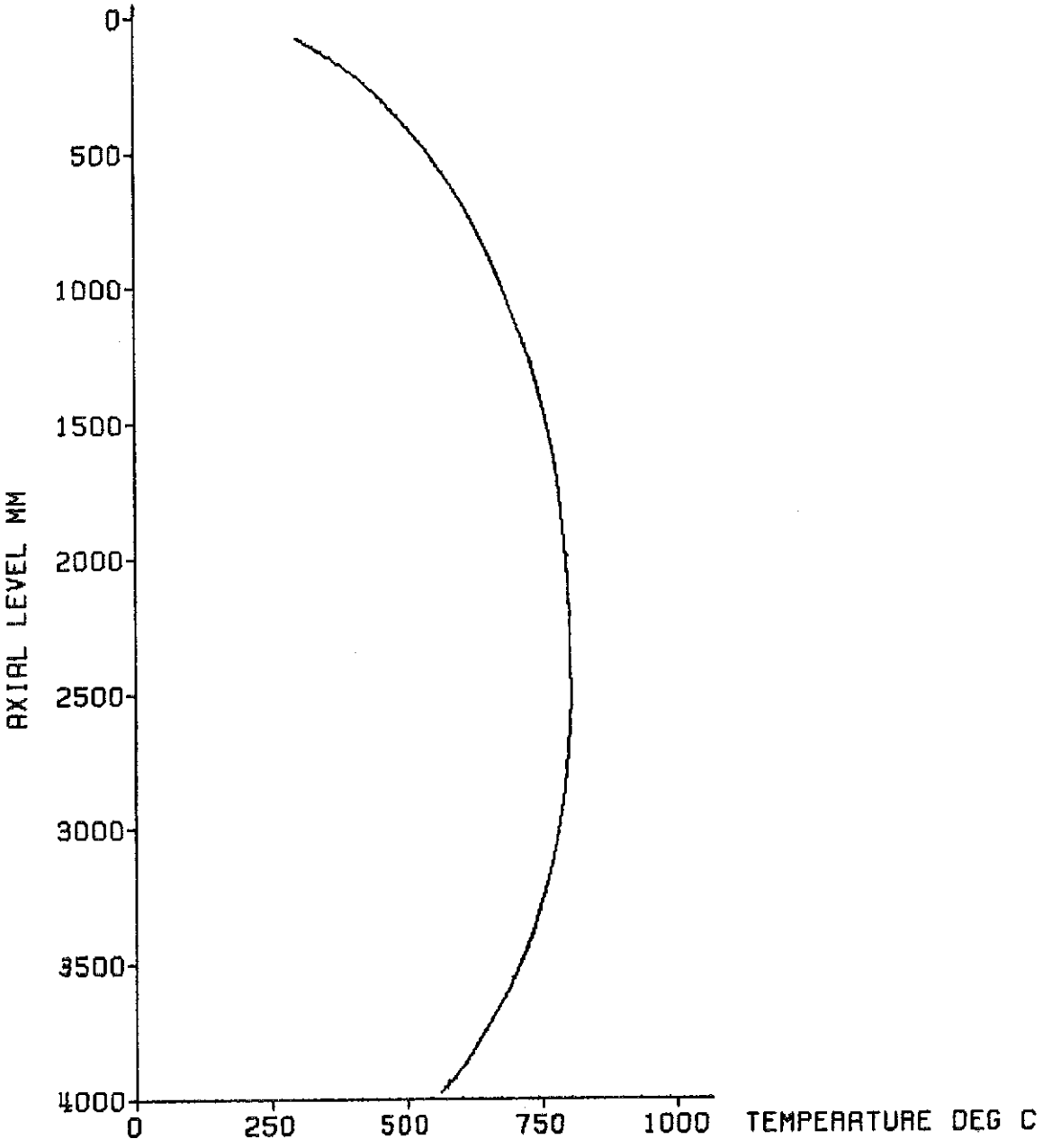


decay heat	120% ANS standard
flooding rate (cold)	5.68 cm/s
system pressure	1.98 bar
feedwater temperature	40 deg C

KfK IRB

Fig. 449 FEBA: 5x5 ROD BUNDLE TEST SERIES 4, TEST-No. 261

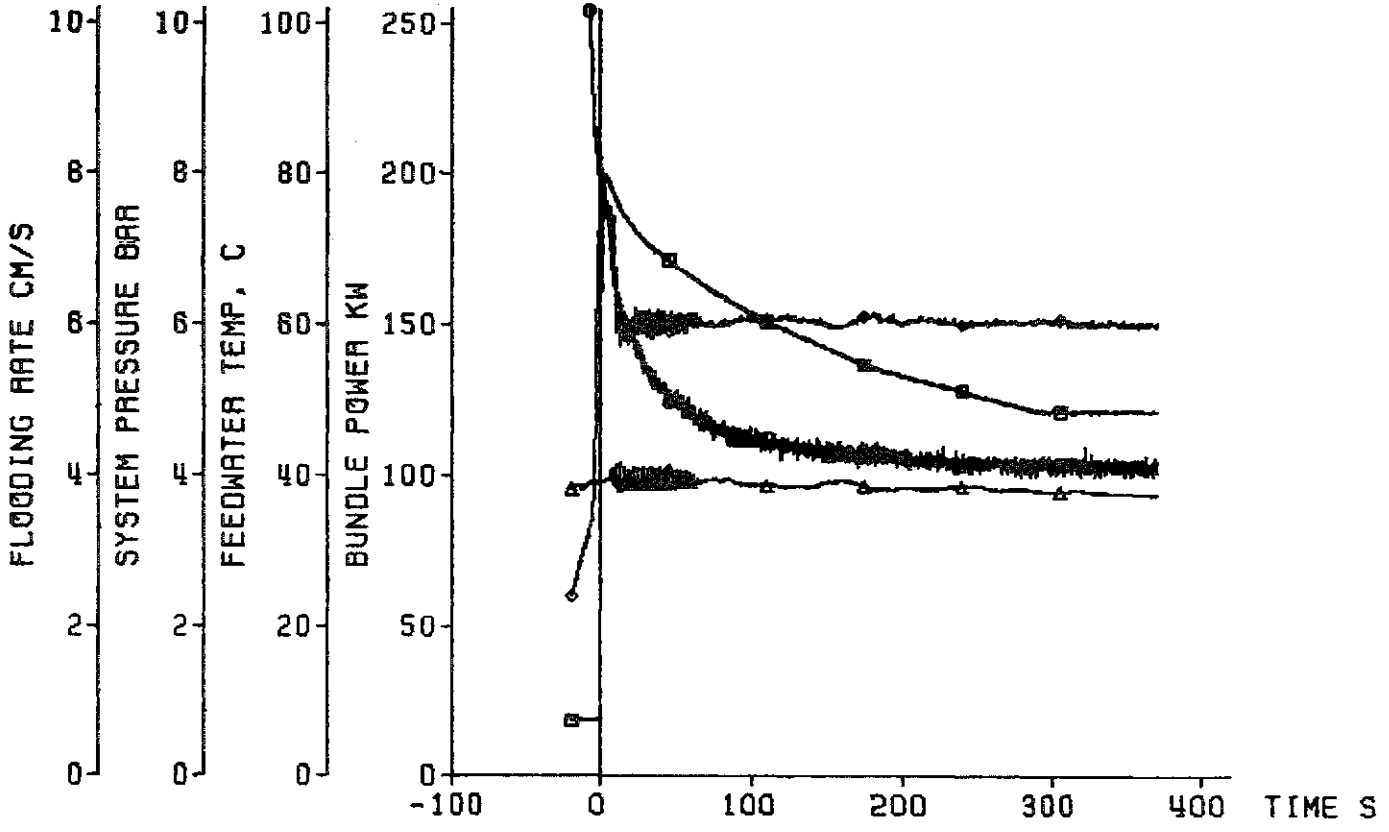
Initial axial temperature profile of the cladding



decay heat	120% ANS standard
flooding rate (cold)	5.80 cm/s
system pressure	3.89 bar
feedwater temperature	40 deg C

KfK IRB

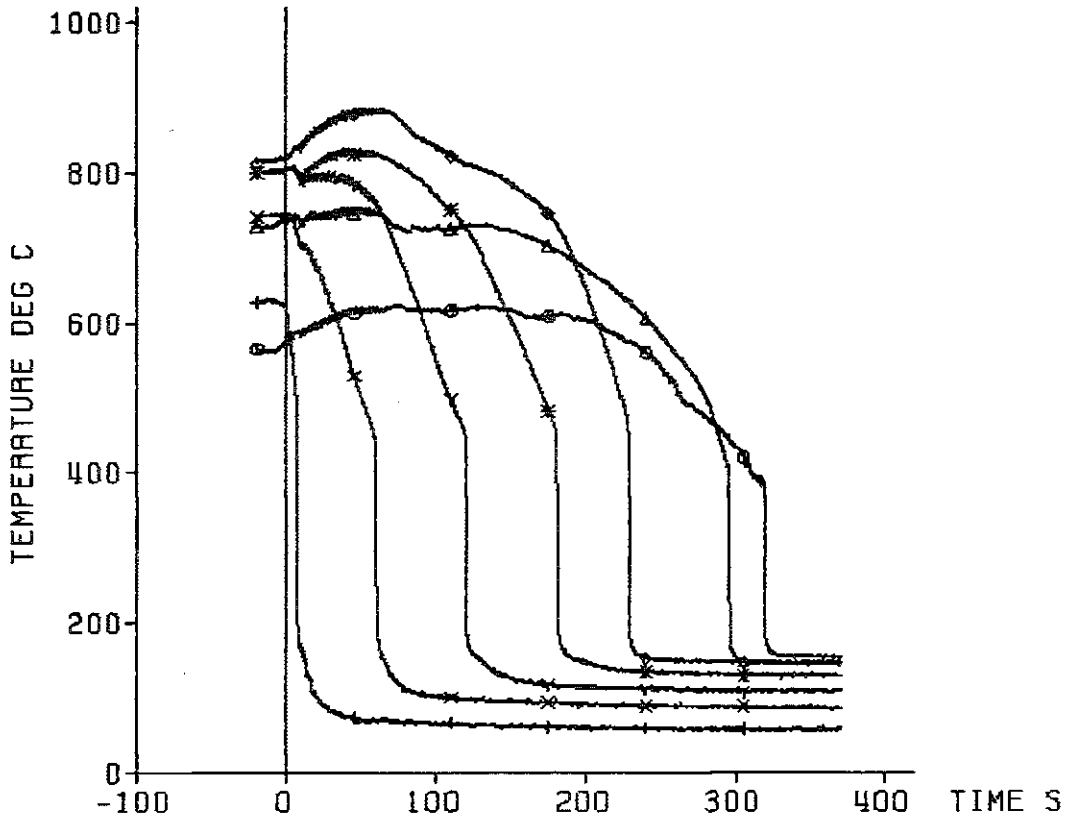
Fig. 450 FEBA: 5x5 ROD BUNDLE TEST SERIES 4, TEST-No. 264



decay heat	120% ANS standard
flooding rate (cold)	5.80 cm/s
system pressure	3.89 bar
feedwater temperature	40 deg C

KfK IRB

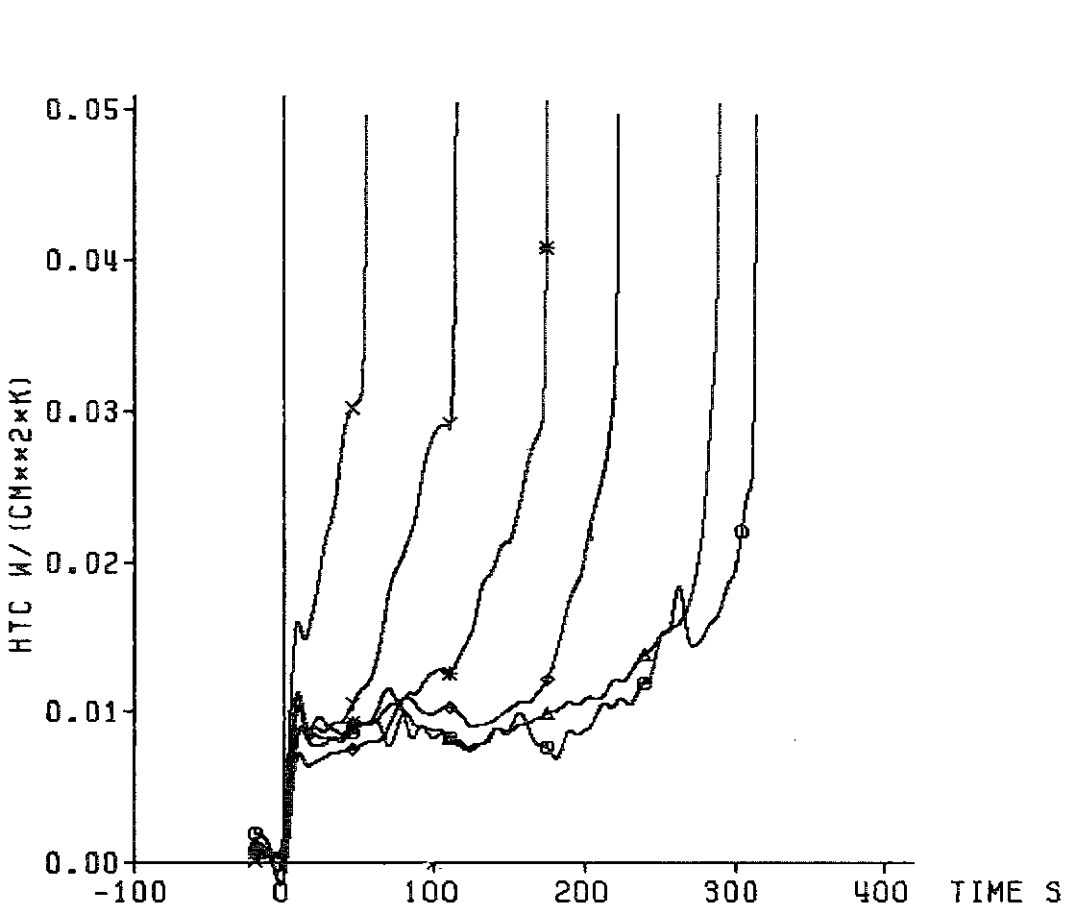
Fig. 451 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 264



decay heat	120% ANS standard
flooding rate (cold)	5.80 cm/s
system pressure	3.89 bar
feedwater temperature	40 deg C

KfK IRB

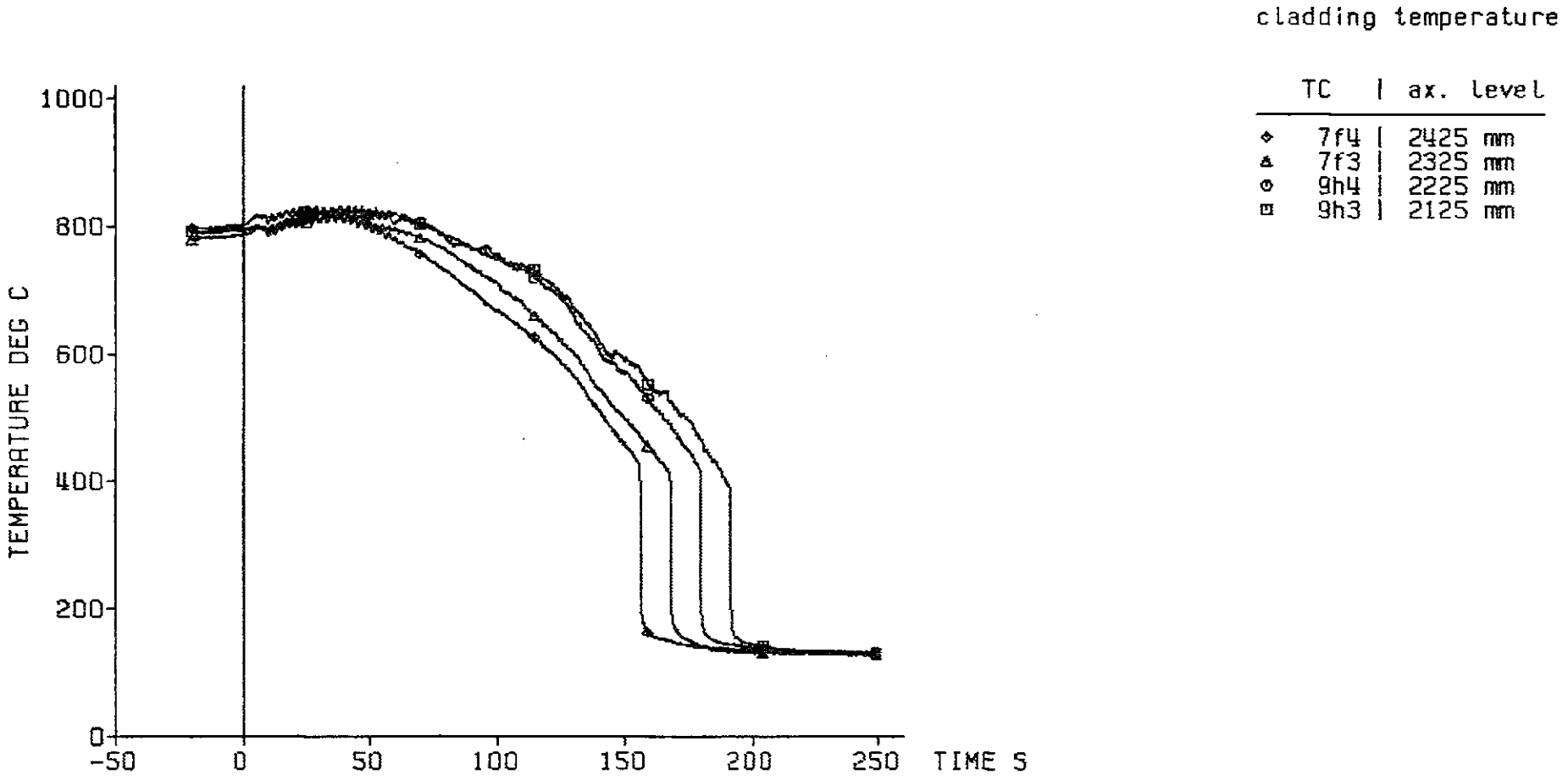
Fig. 452 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 264



decay heat	120% ANS standard
flooding rate (cold)	5.80 cm/s
system pressure	3.89 bar
feedwater temperature	40 deg C

KfK IRB

Fig. 453 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 264

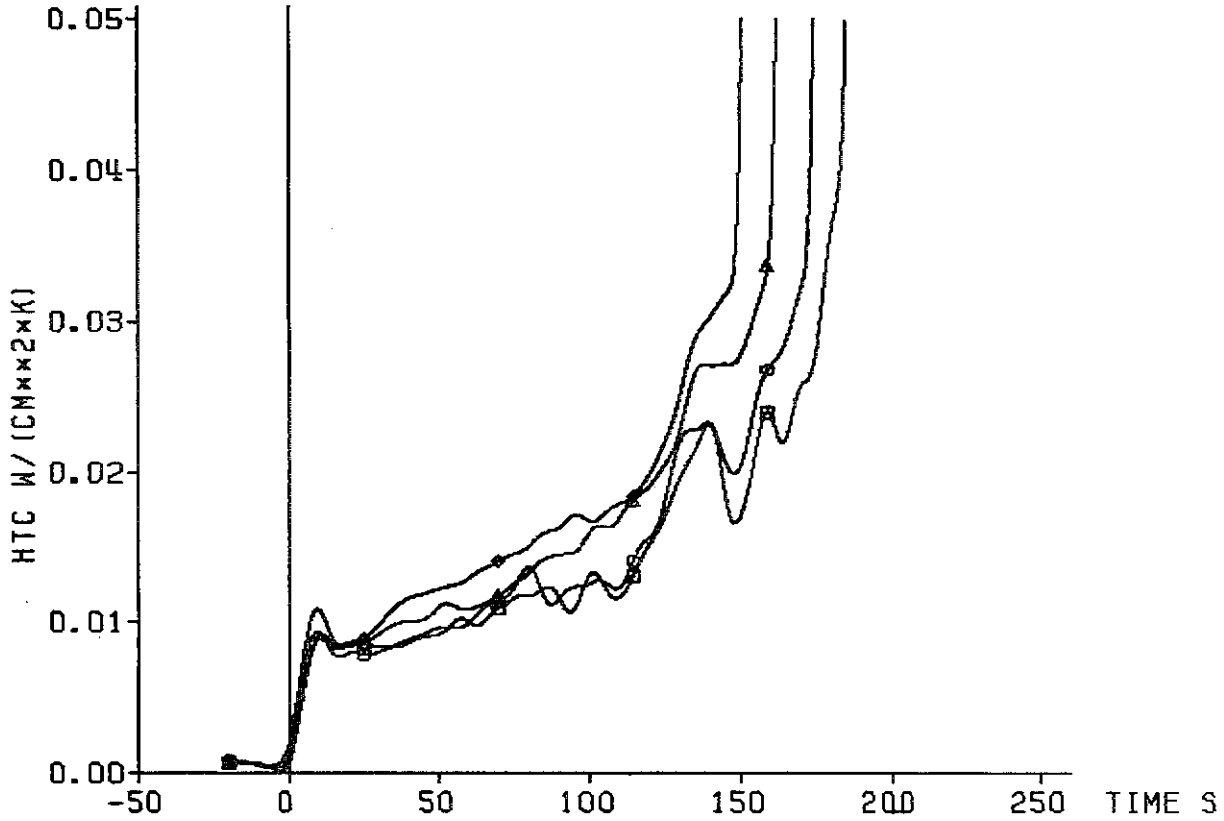


decay heat	120% ANS standard
flooding rate (cold)	5.80 cm/s
system pressure	3.89 bar
feedwater temperature	40 deg C

bypass
======

KfK KIRB

Fig. 454 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 264

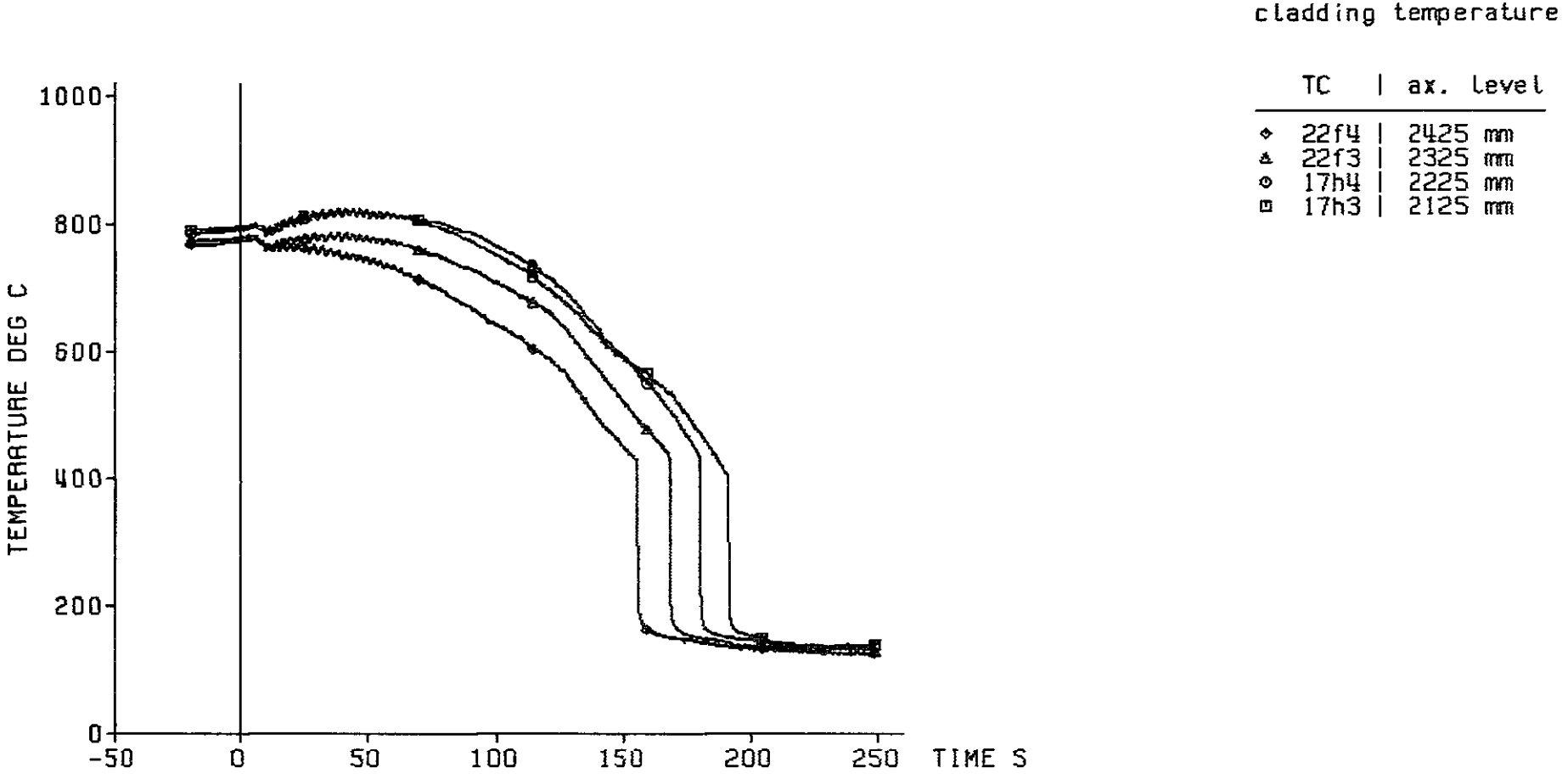


decay heat	120% ANS standard
flooding rate (cold)	5.80 cm/s
system pressure	3.89 bar
feedwater temperature	40 deg C

bypass
======

KfK IRB

Fig. 455 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 264

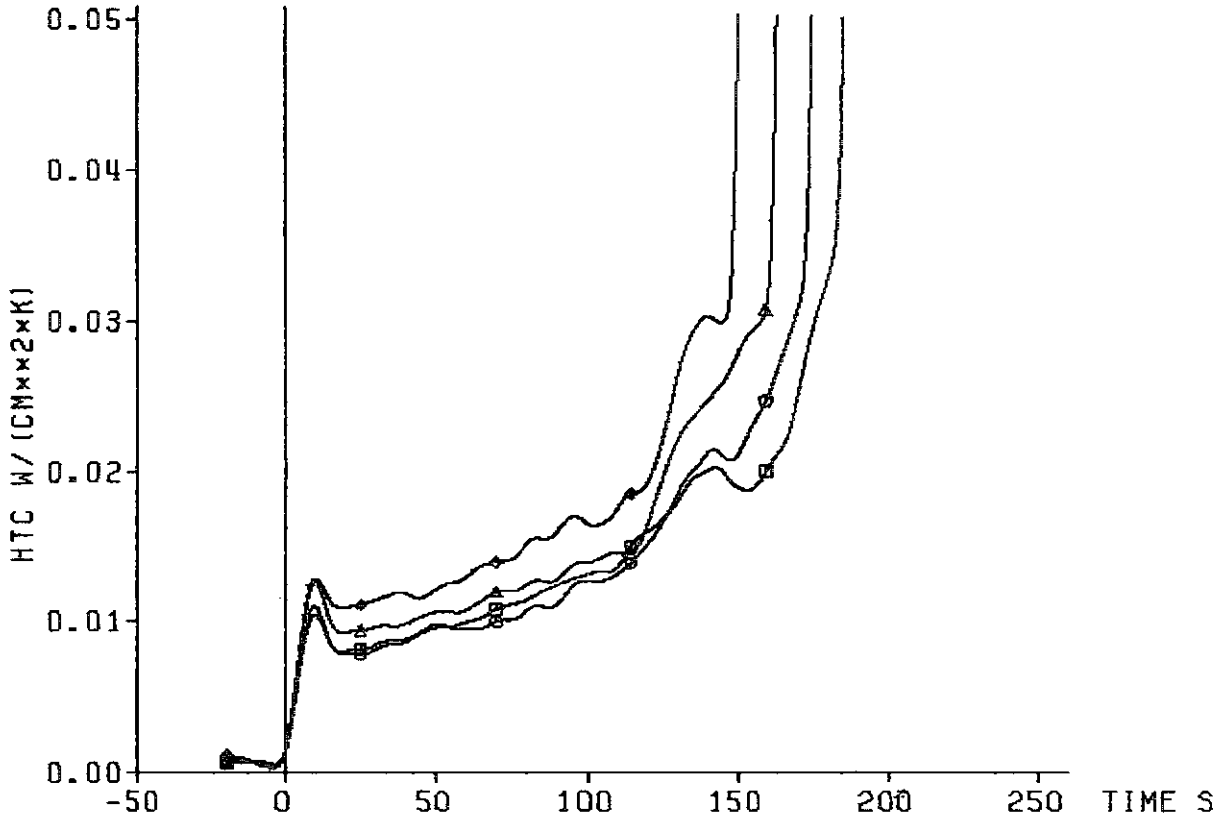


decay heat	120% ANS standard
flooding rate (cold)	5.80 cm/s
system pressure	3.89 bar
feedwater temperature	40 deg C

blockage
========

KfK KIRB

Fig. 456 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 264

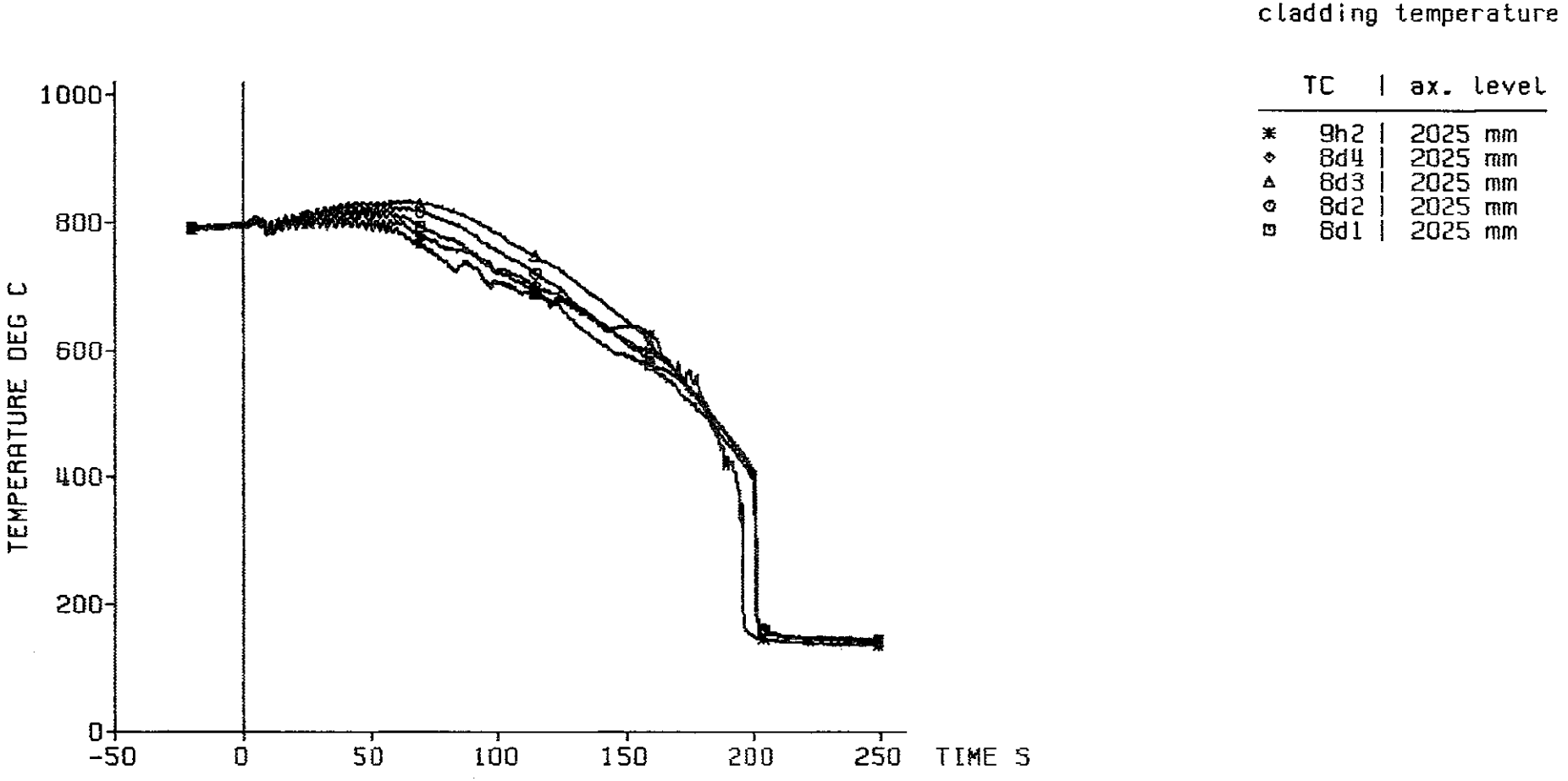


decay heat	120% ANS standard
flooding rate (cold)	5.80 cm/s
system pressure	3.89 bar
feedwater temperature	40 deg C

blockage
========

KfK IRB

Fig. 457 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 264

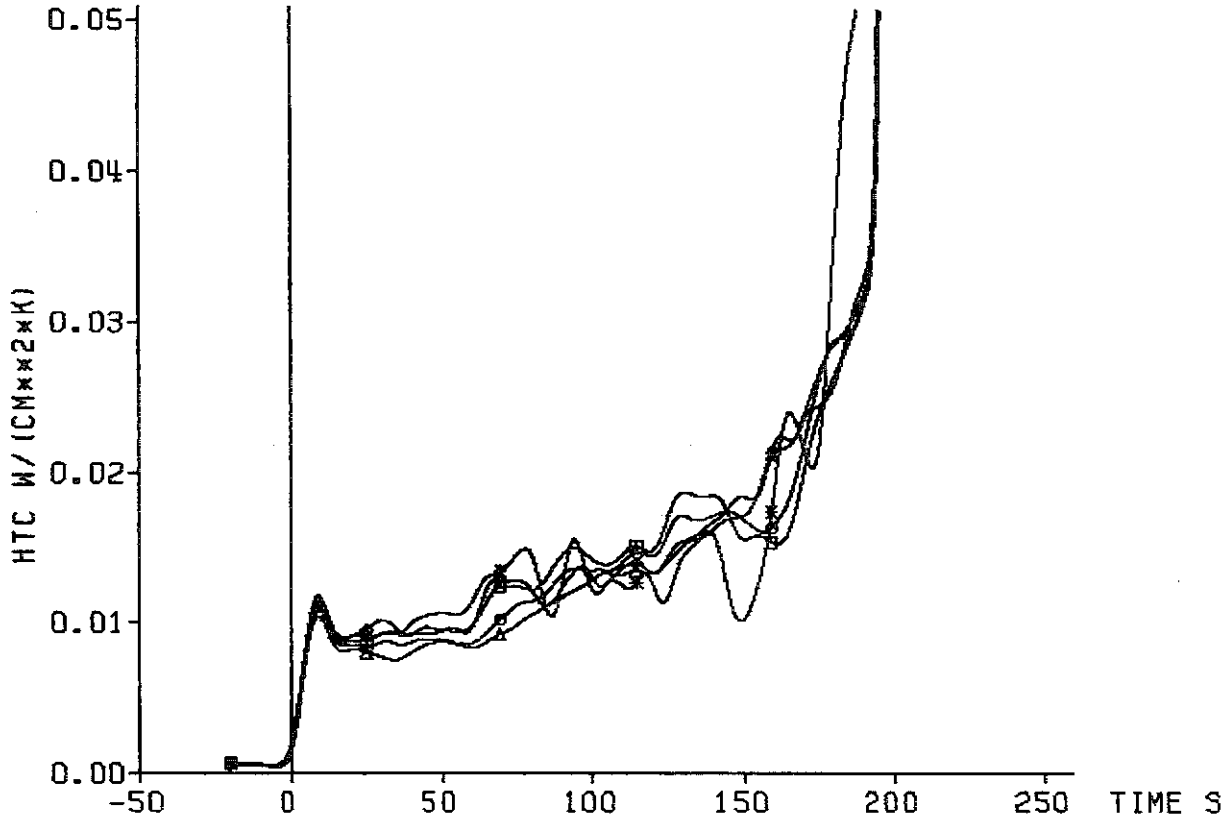


decay heat	120% ANS standard
flooding rate (cold)	5.80 cm/s
system pressure	3.89 bar
feedwater temperature	40 deg C

bypass
======

KfK IRB

Fig. 458 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 264



decay heat	120% ANS standard
flooding rate (cold)	5.80 cm/s
system pressure	3.89 bar
feedwater temperature	40 deg C

bypass
======

KfK IRB

Fig. 459 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 264

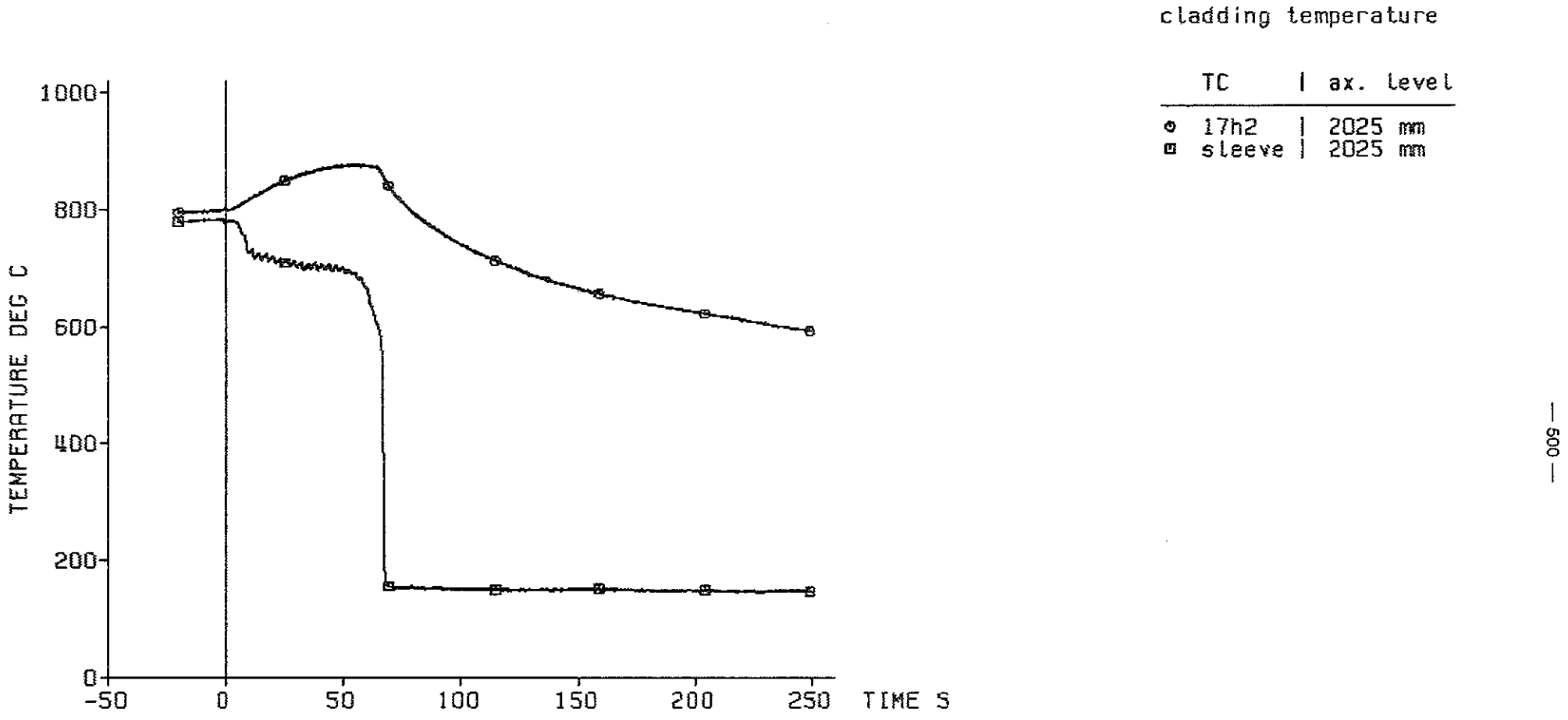
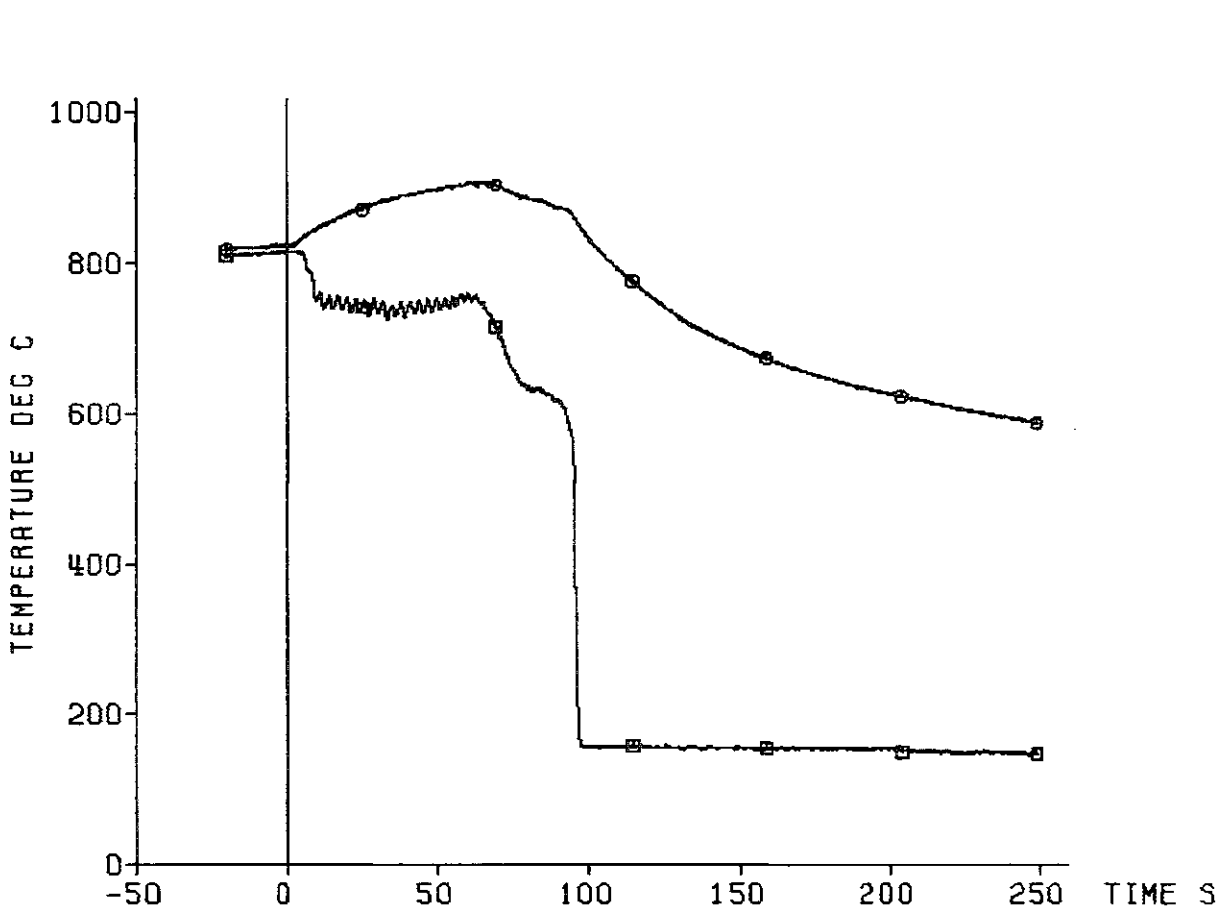


Fig. 460 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 264

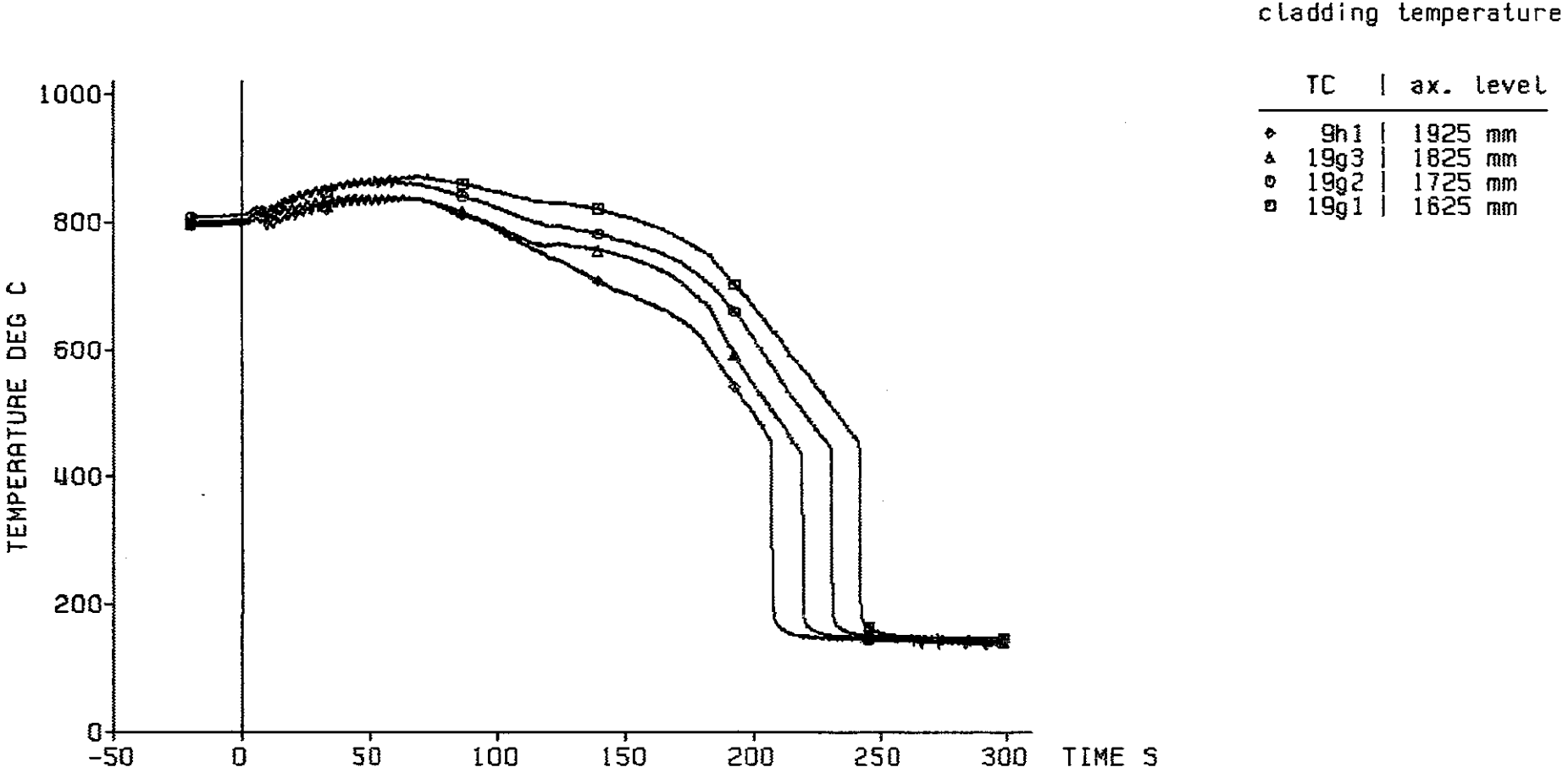


decay heat	120% ANS standard
flooding rate [cold]	5.80 cm/s
system pressure	3.89 bar
feedwater temperature	40 deg C

blockage
========

KfK IRB

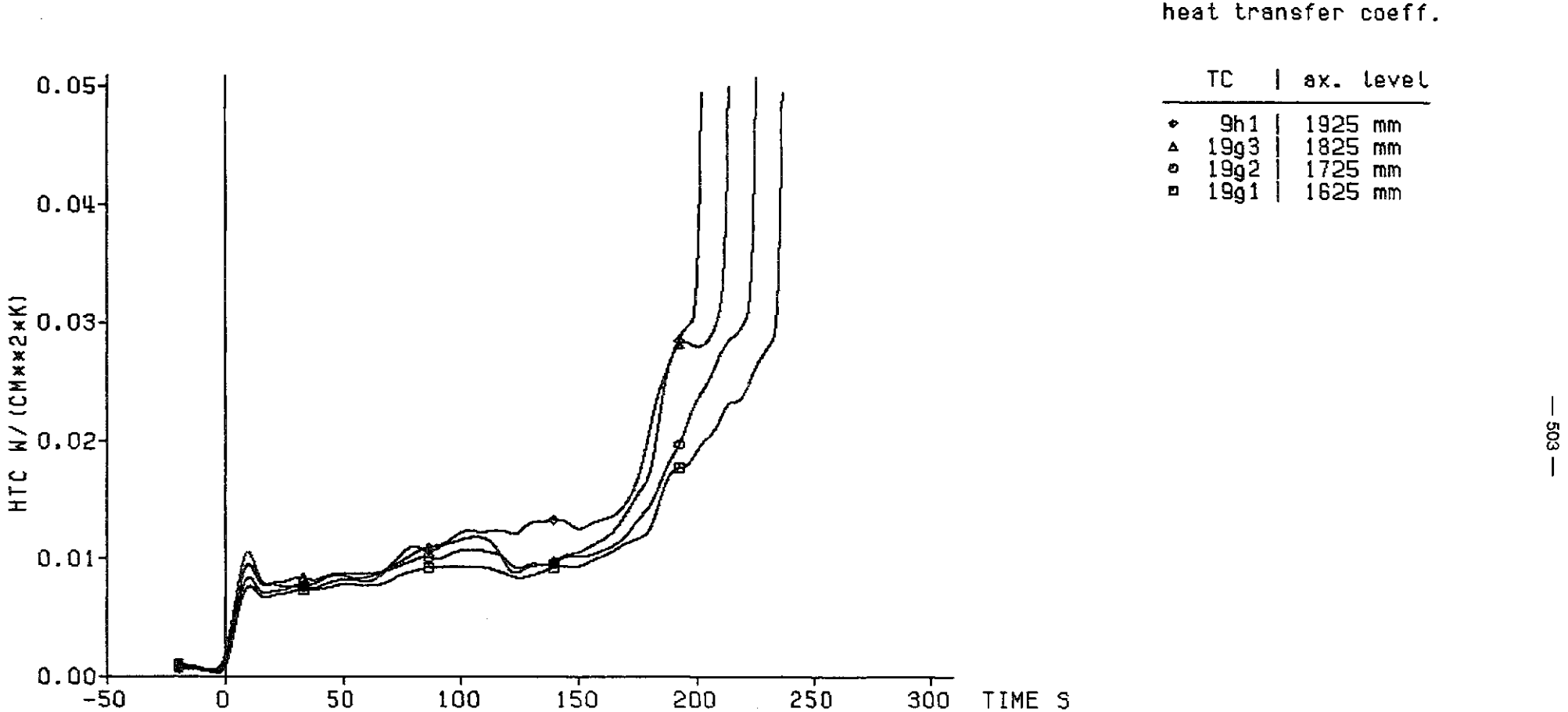
Fig. 461 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 264



decay heat	120% ANS standard	bypass
flooding rate (cold)	5.80 cm/s	======
system pressure	3.89 bar	
feedwater temperature	40 deg C	

KfK IRB

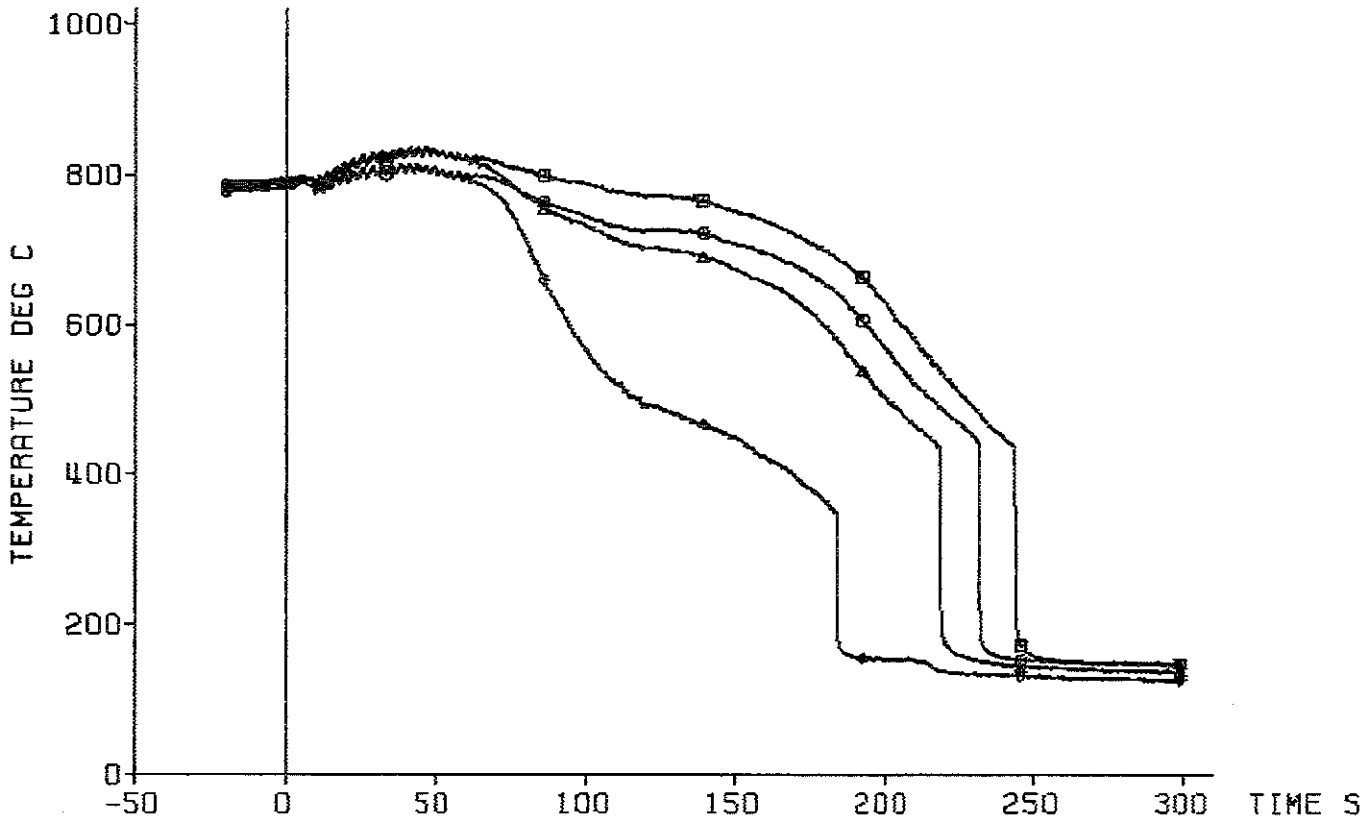
Fig. 462 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 264



decay heat	120% ANS standard	bypass
flooding rate (cold)	5.80 cm/s	======
system pressure	3.89 bar	
feedwater temperature	40 deg C	

KfK IRB

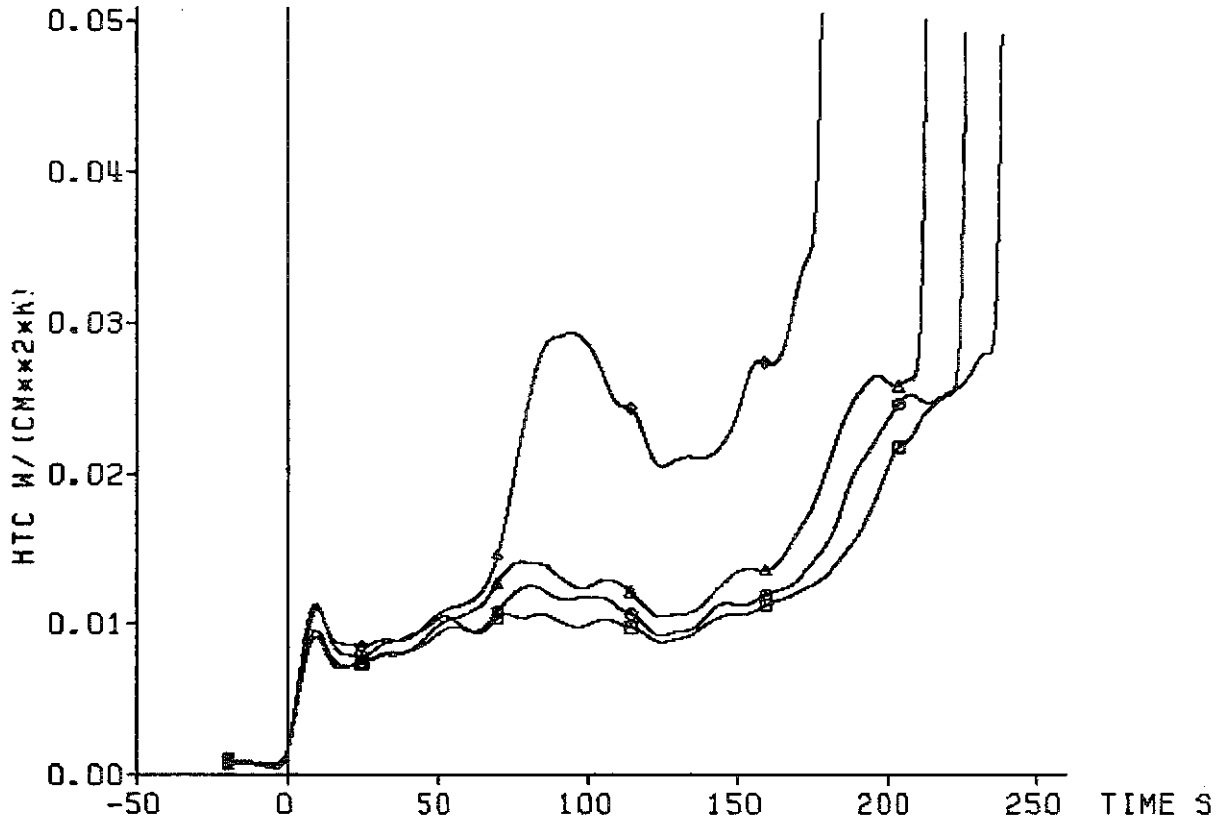
Fig. 463 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 264



decay heat	120% ANS standard	blockage
flooding rate (cold)	5.60 cm/s	========
system pressure	3.89 bar	
feedwater temperature	40 deg C	

KfK KIRB

Fig. 464 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 264

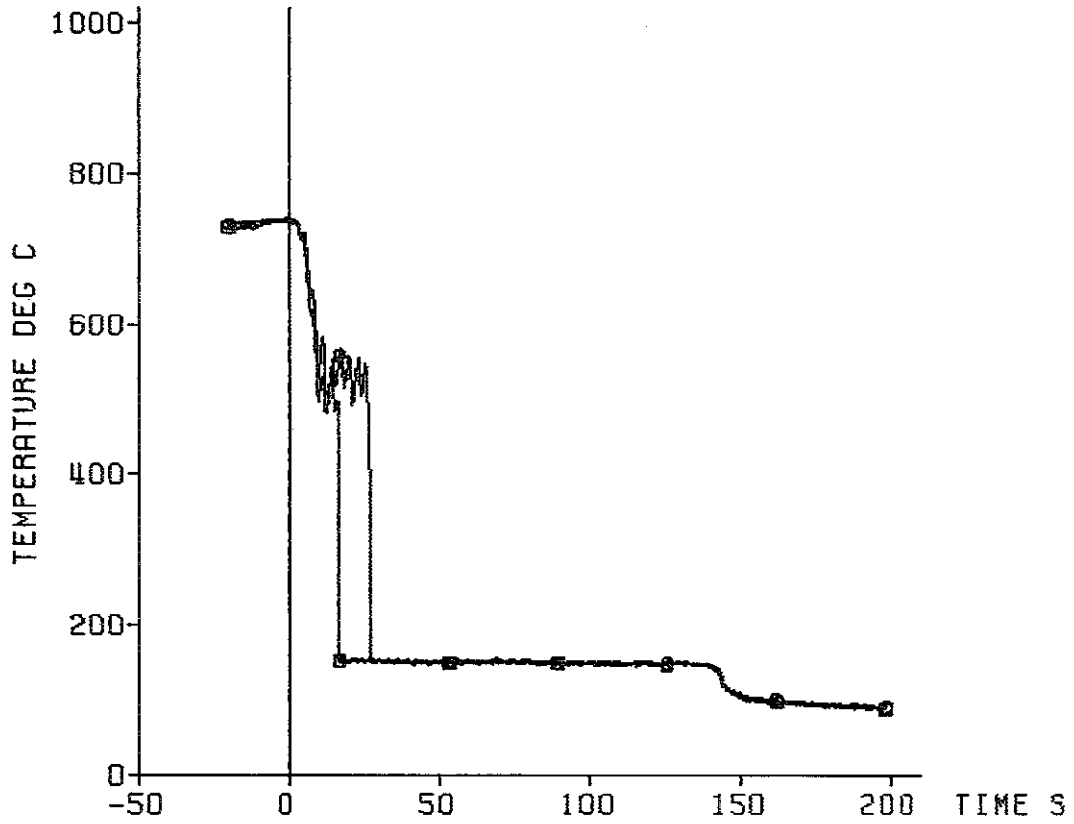


decay heat	120% ANS standard
flooding rate (cold)	5.80 cm/s
system pressure	3.89 bar
feedwater temperature	40 deg C

blockage
========

KfK IRB

Fig. 465 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 264



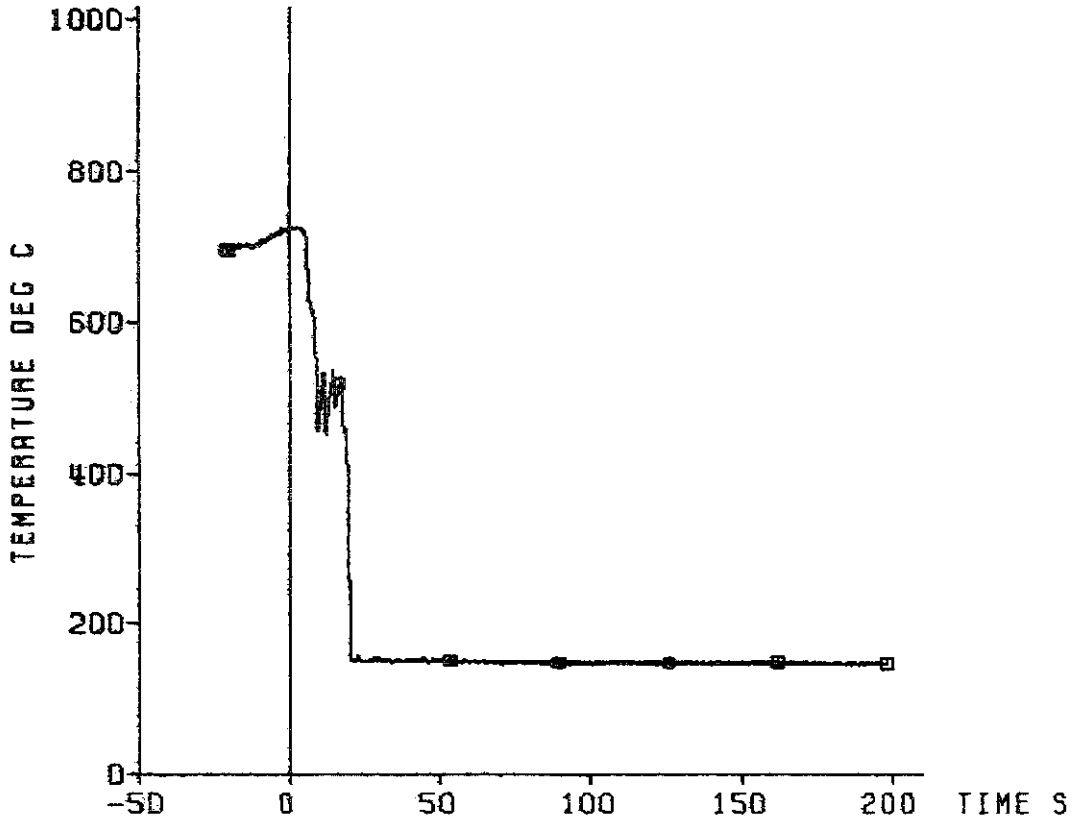
decay heat	120% ANS standard
flooding rate (cold)	5.80 cm/s
system pressure	3.89 bar
feedwater temperature	40 deg C

KfK KIRB

Fig. 466 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 264

grid spacer temperature

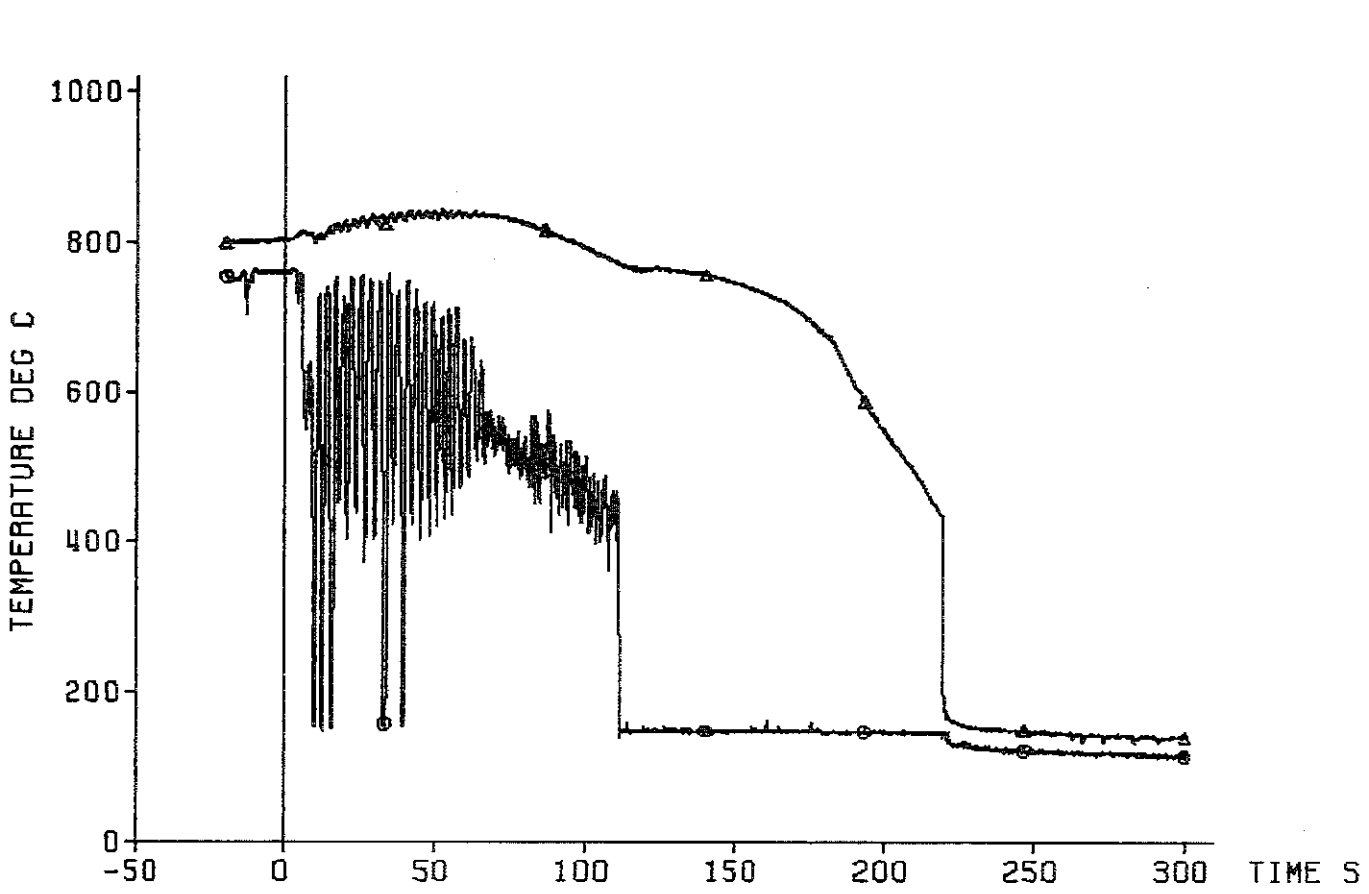
TC	axial level
▫ 84	1460 mm



decay heat	120% ANS standard
flooding rate (cold)	5.80 cm/s
system pressure	3.89 bar
feedwater temperature	40 deg C

KfK IRB

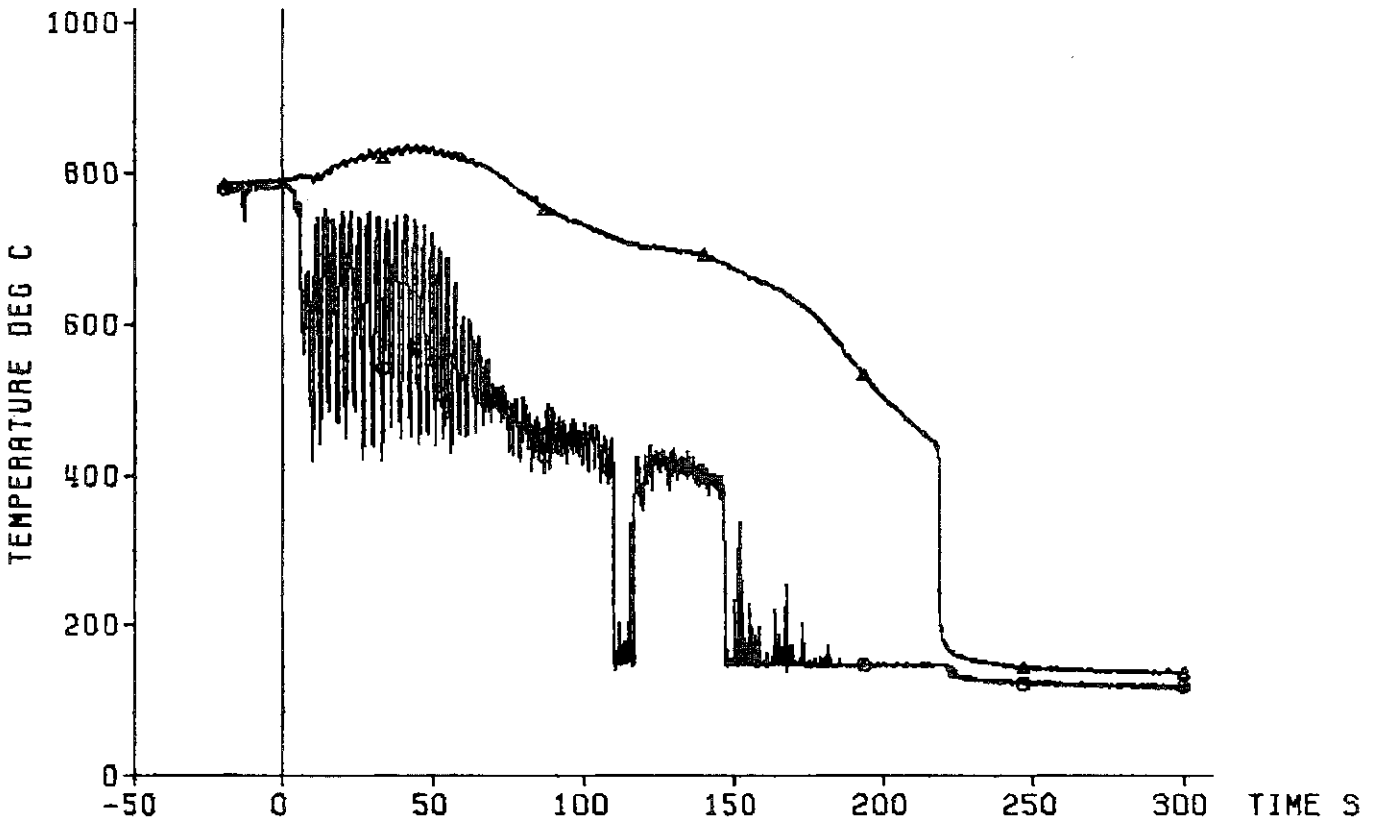
Fig. 467 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 264



decay heat	120% ANS standard	bypass
flooding rate (cold)	5.80 cm/s	======
system pressure	3.89 bar	
feedwater temperature	40 deg C	

KfK IRB

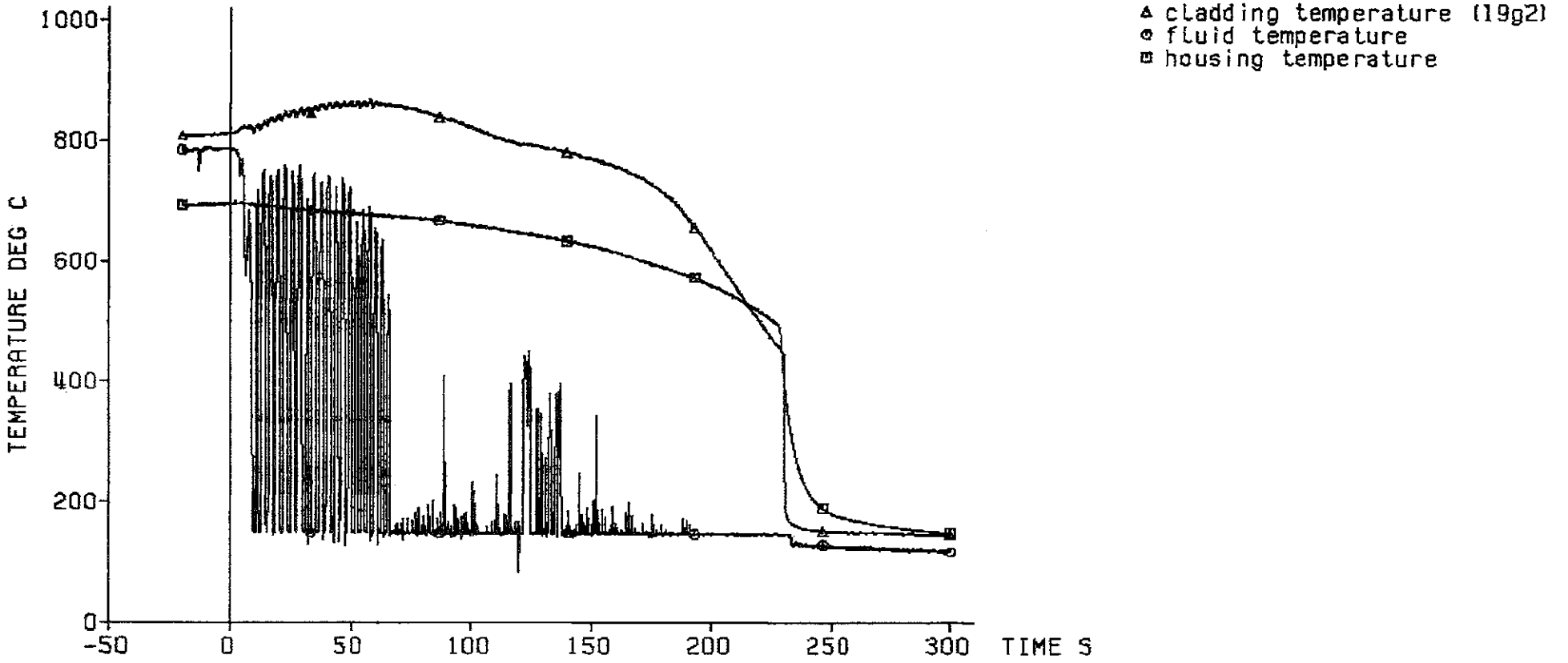
Fig. 468 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 264



decay heat	120% ANS standard	blockage
flooding rate (cold)	5.80 cm/s	========
system pressure	3.89 bar	
feedwater temperature	40 deg C	

KfK IRB

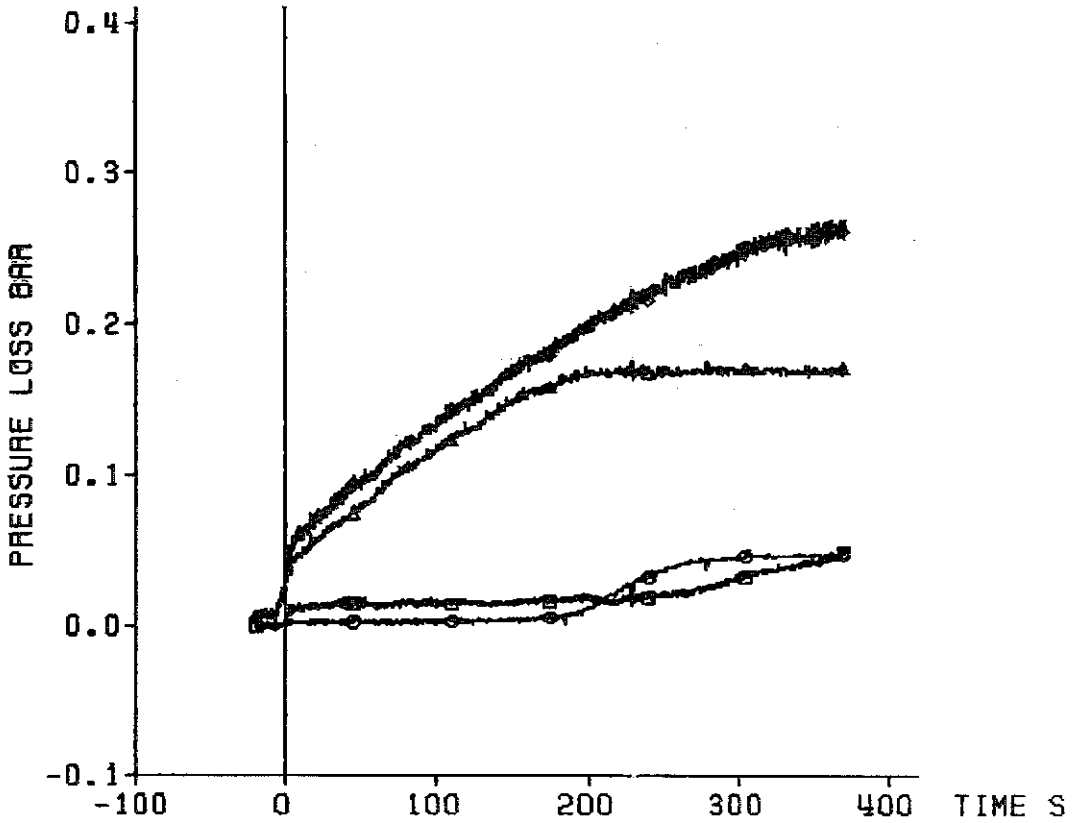
Fig. 469 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 264



decay heat	120% ANS standard	bypass
flooding rate (cold)	5.80 cm/s	======
system pressure	3.89 bar	
feedwater temperature	40 deg C	

KfK IRB

Fig. 470 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 264



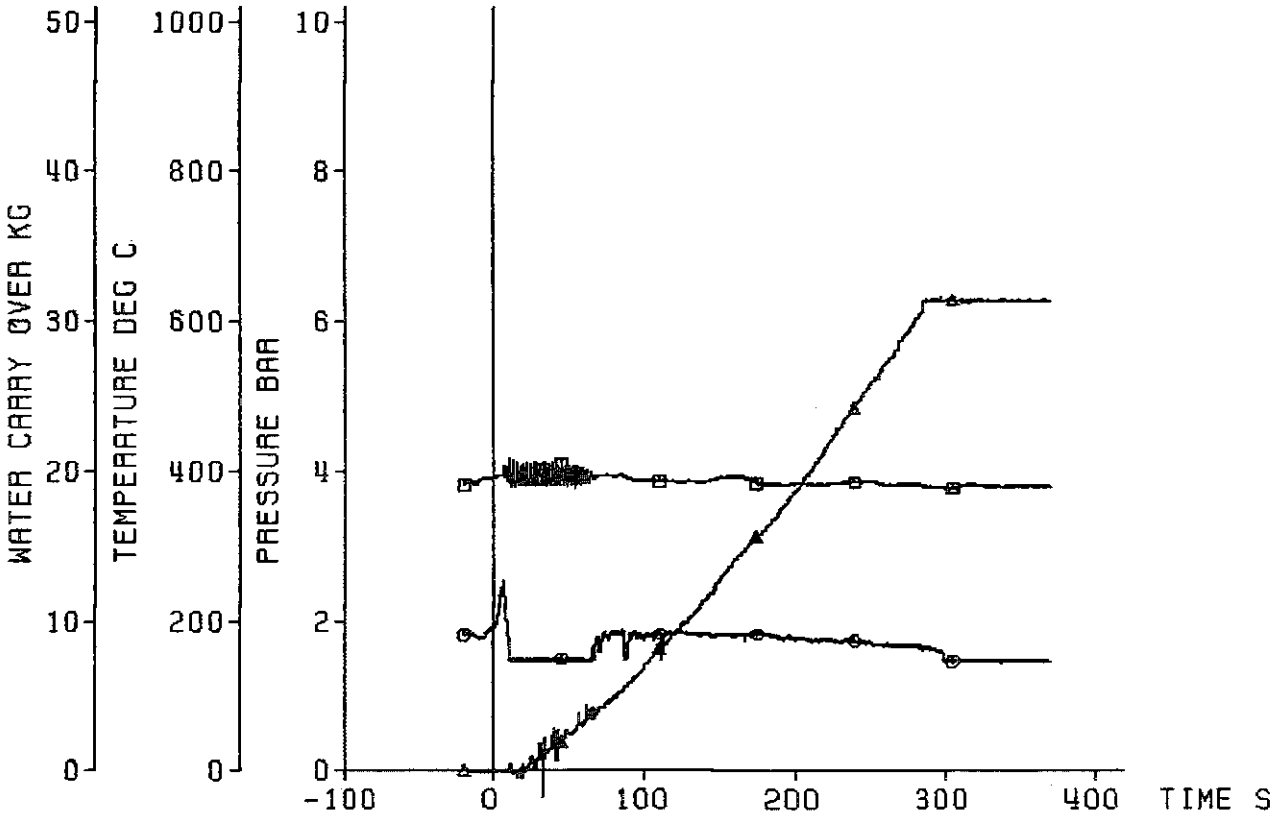
pressure loss
along the test section:

◇ total length: 4196 mm
△ lower part: 1711 mm
○ middle part: 545 mm
□ upper part: 1940 mm

decay heat	120% ANS standard
flooding rate (cold)	5.80 cm/s
system pressure	3.89 bar
feedwater temperature	40 deg C

KfK IRB

Fig. 471 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 264



decay heat	120% ANS standard
flooding rate (cold)	5.80 cm/s
system pressure	3.89 bar
feedwater temperature	40 deg C

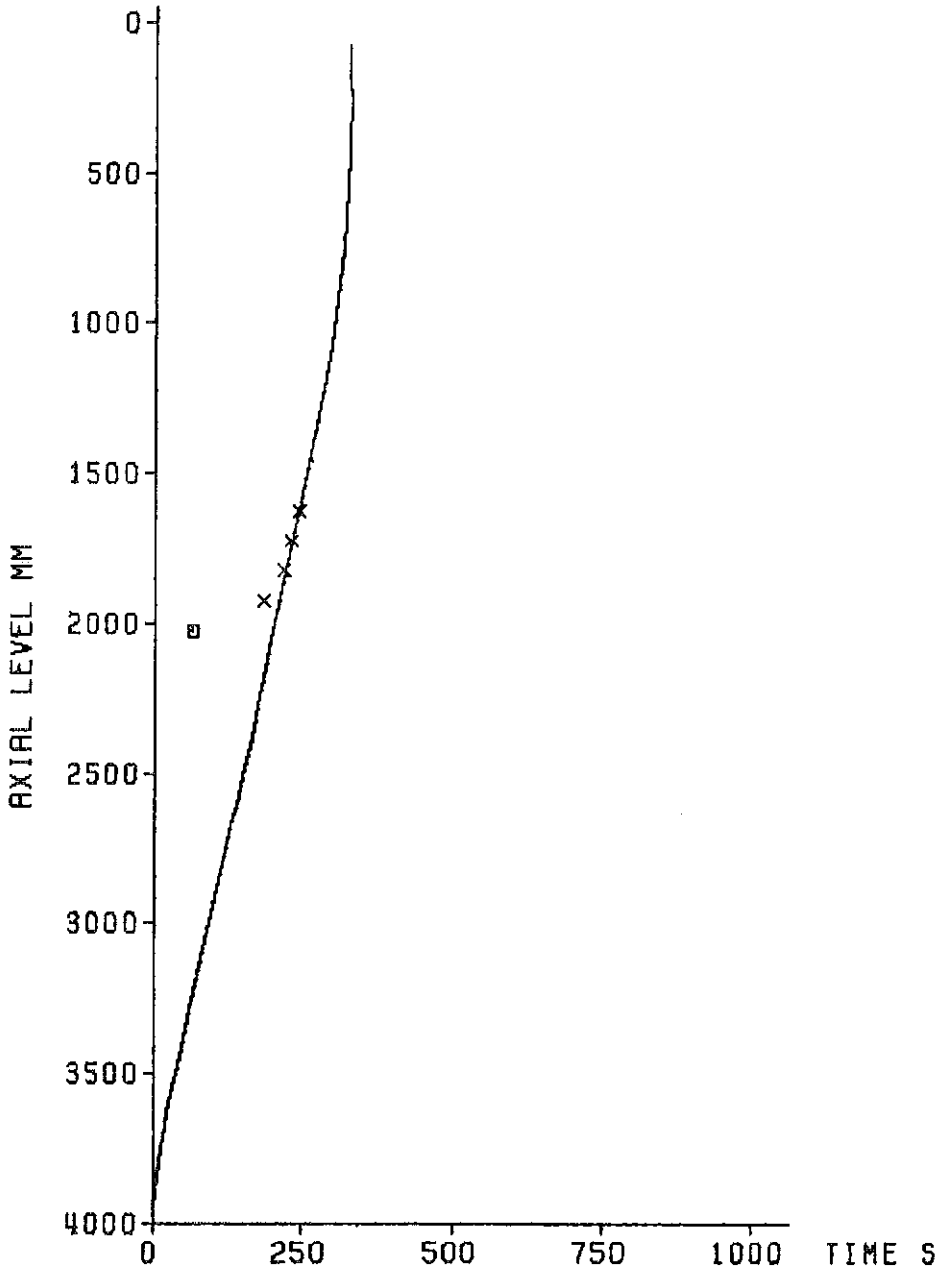
KfK IRB

Fig. 472 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 264

axial position of the quench front

⊡ rewetting of the sleeve at the bundle midplane

× rewetting of the rod downstream of the blockage

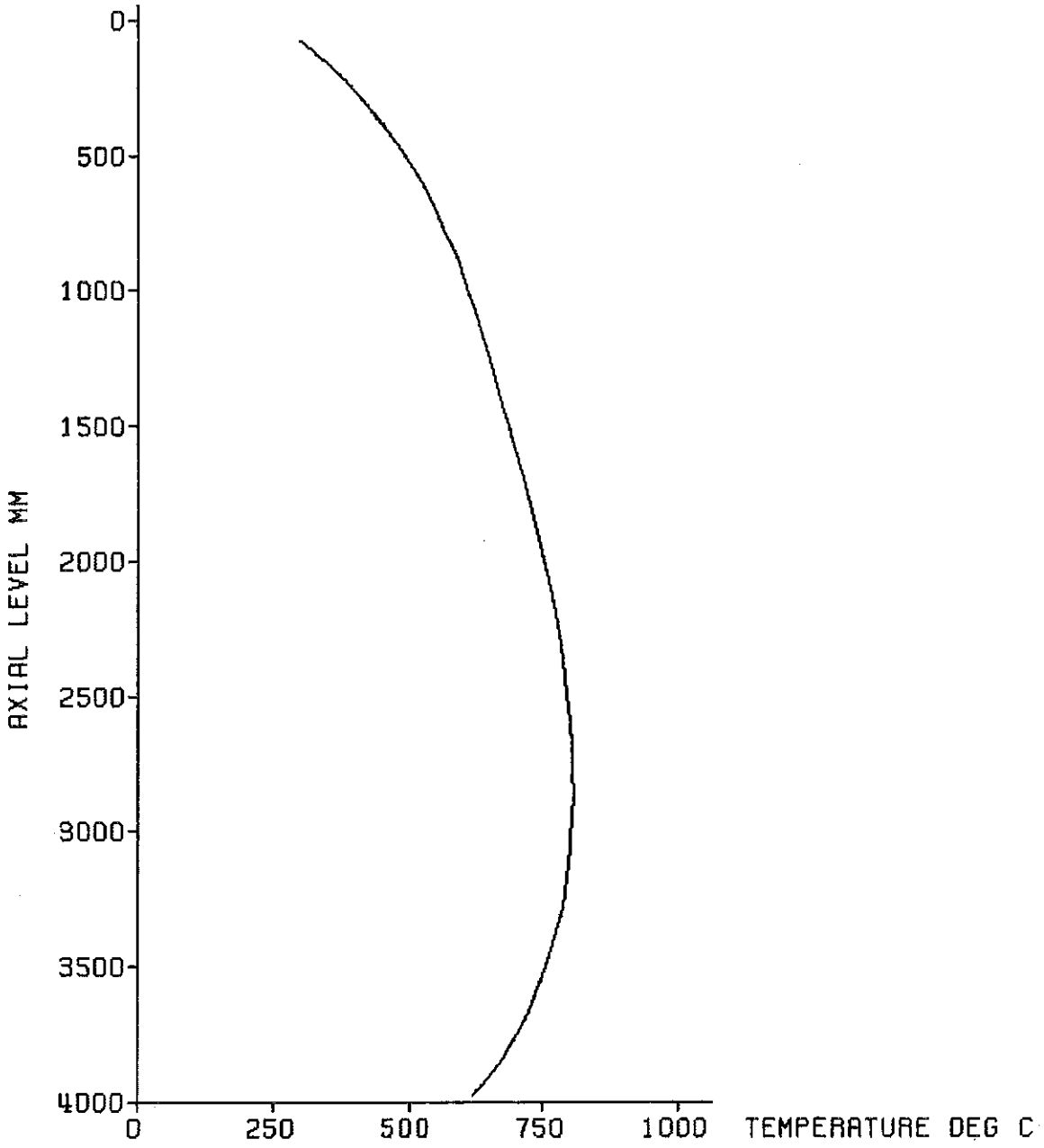


decay heat	120% ANS standard
flooding rate (cold)	5.80 cm/s
system pressure	3.89 bar
feedwater temperature	40 deg C

KfK IRB

Fig. 473 FEBA: 5x5 ROD BUNDLE TEST SERIES 4, TEST-No. 264

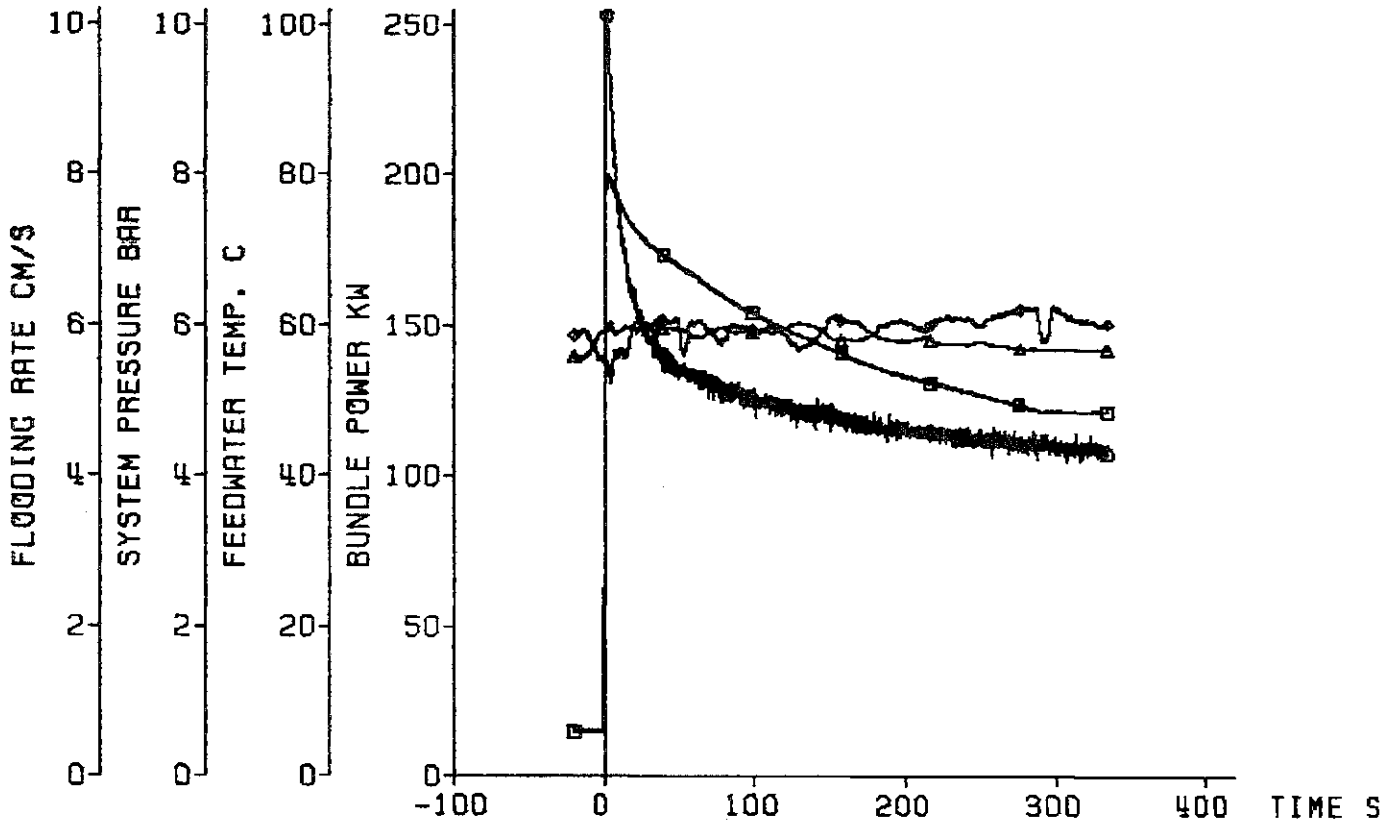
Initial axial temperature profile of the cladding



decay heat	120% ANS standard
flooding rate (cold)	5.66 cm/s
system pressure	5.89 bar
feedwater temperature	40 deg C

KfK IRB

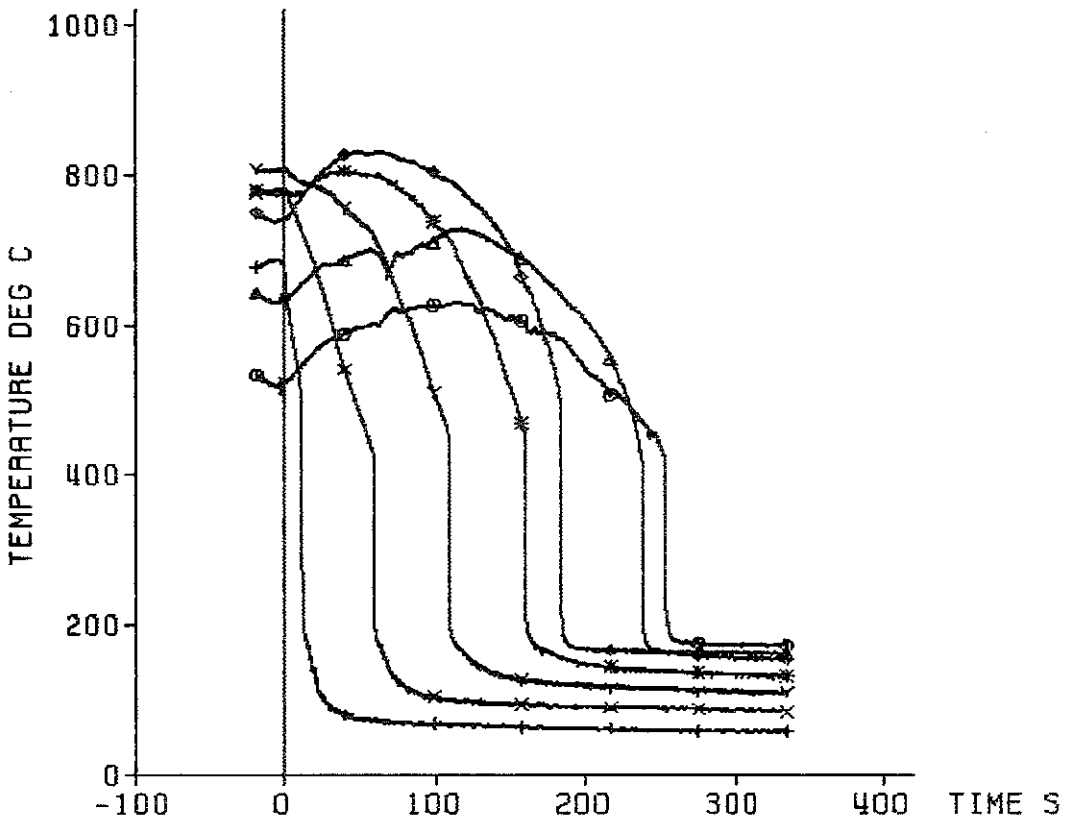
Fig. 474 FEBA: 5x5 ROD BUNDLE TEST SERIES 4, TEST-No. 269



decay heat	120% ANS standard
flooding rate (cold)	5.66 cm/s
system pressure	5.89 bar
feedwater temperature	40 deg C

KfK IRB

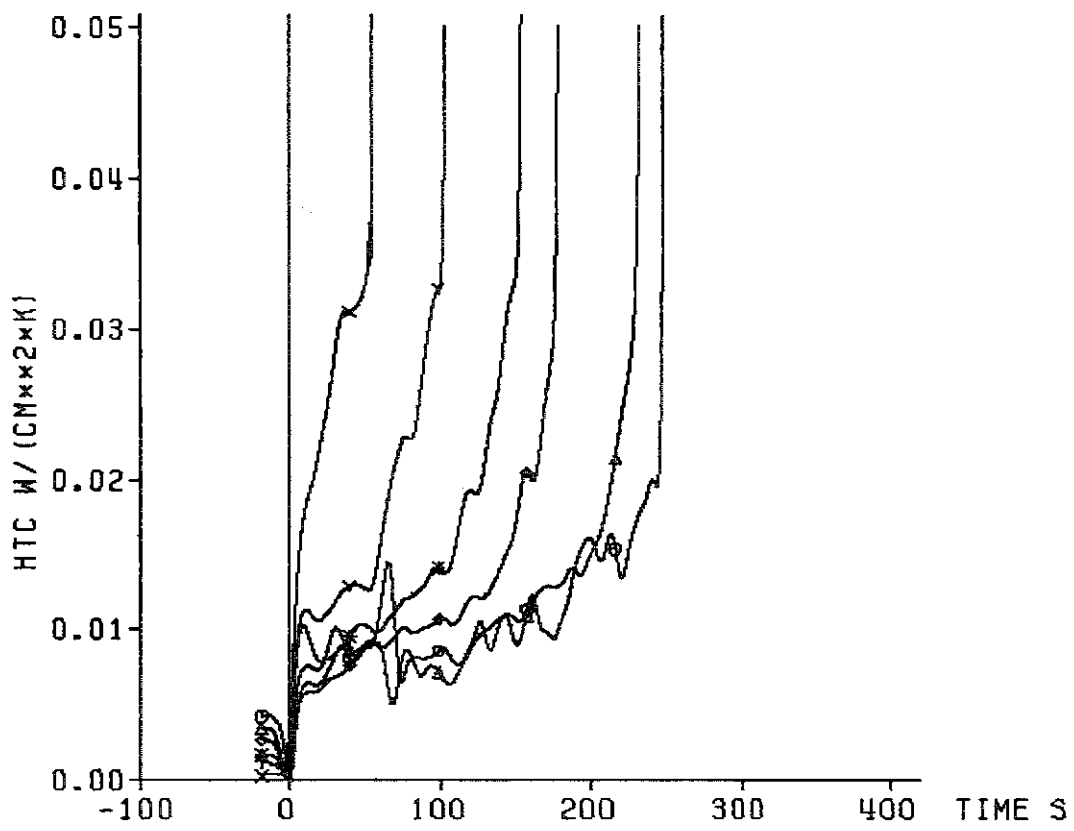
Fig. 475 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 269



decay heat	120% ANS standard
flooding rate (cold)	5.66 cm/s
system pressure	5.89 bar
feedwater temperature	40 deg C

KfK IRB

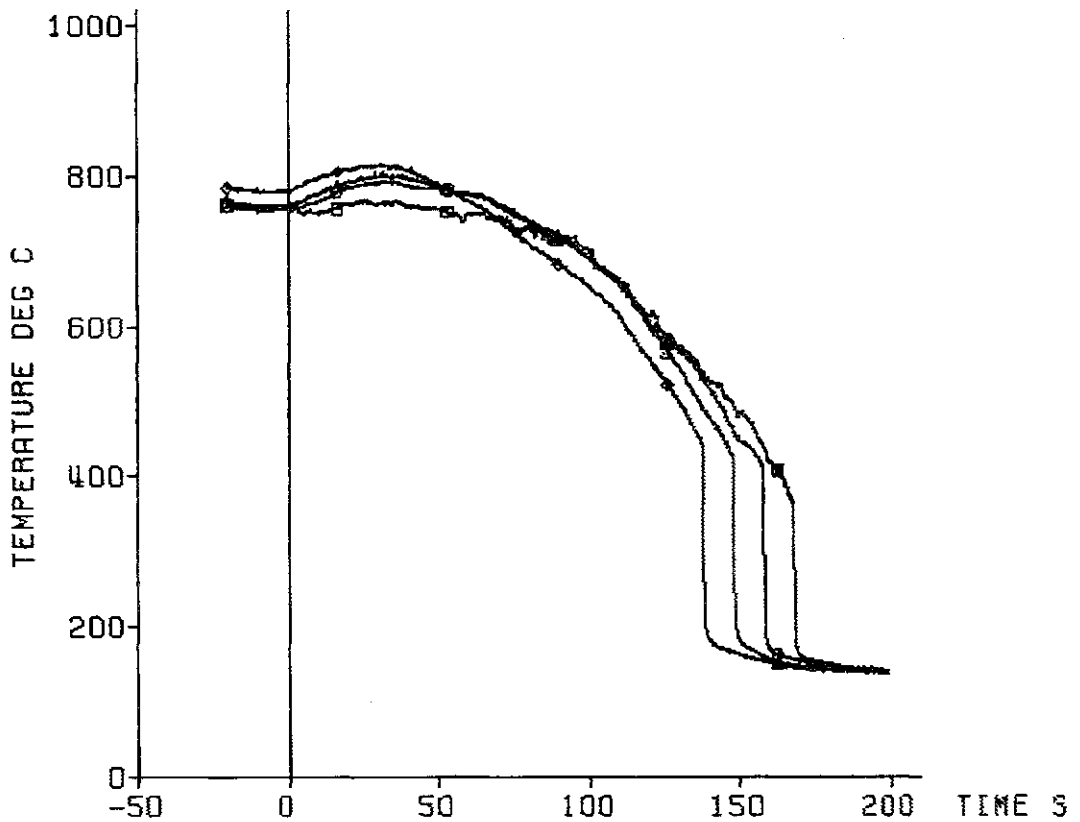
Fig. 476 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 269



decay heat	120% ANS standard
flooding rate (cold)	5.66 cm/s
system pressure	5.89 bar
feedwater temperature	40 deg C

KfK IRB

Fig. 477 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 269

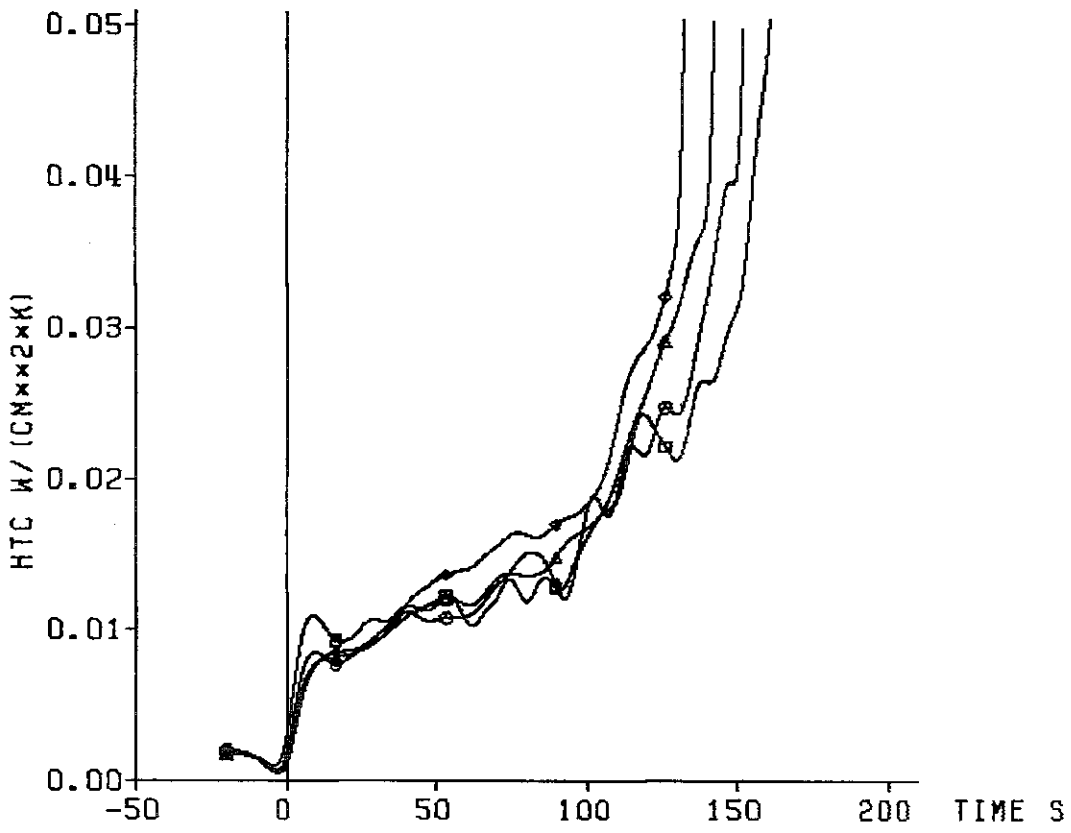


decay heat	120% ANS standard
flooding rate (cold)	5.66 cm/s
system pressure	5.89 bar
feedwater temperature	40 deg C

bypass
======

KfK IRB

Fig. 478 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 269

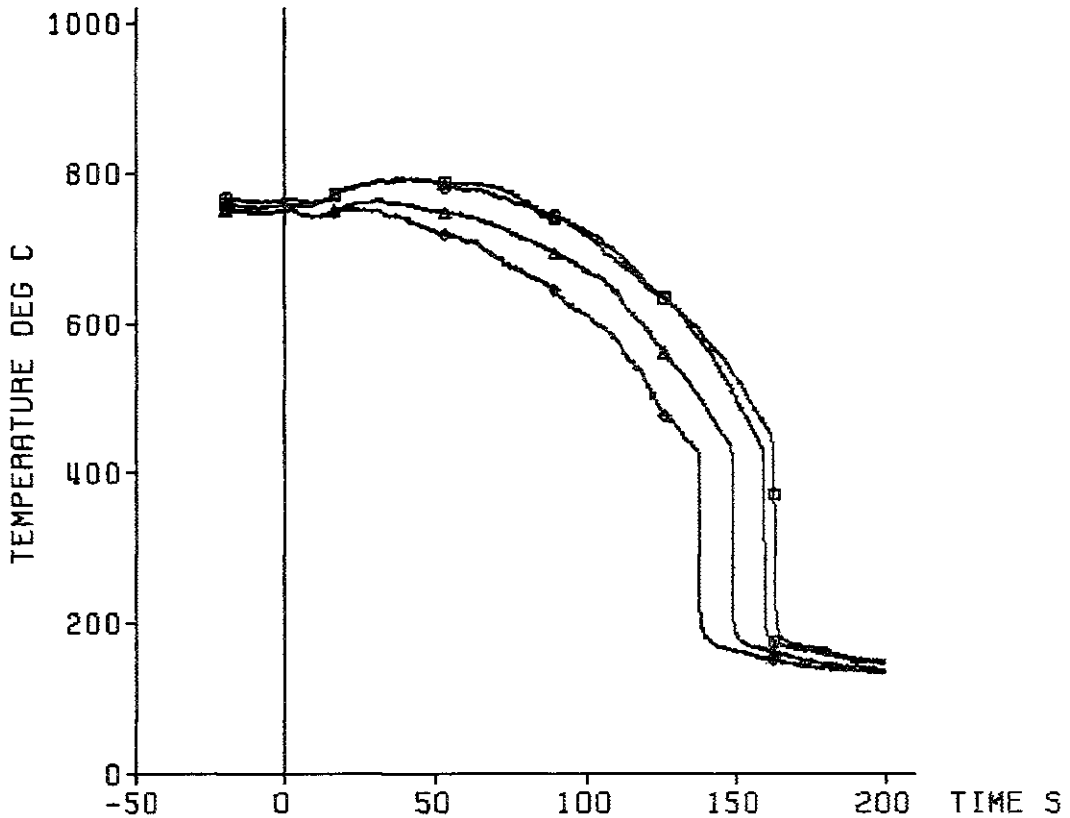


decay heat	120% ANS standard
flooding rate (cold)	5.66 cm/s
system pressure	5.89 bar
feedwater temperature	40 deg C

bypass
======

KfK IRB

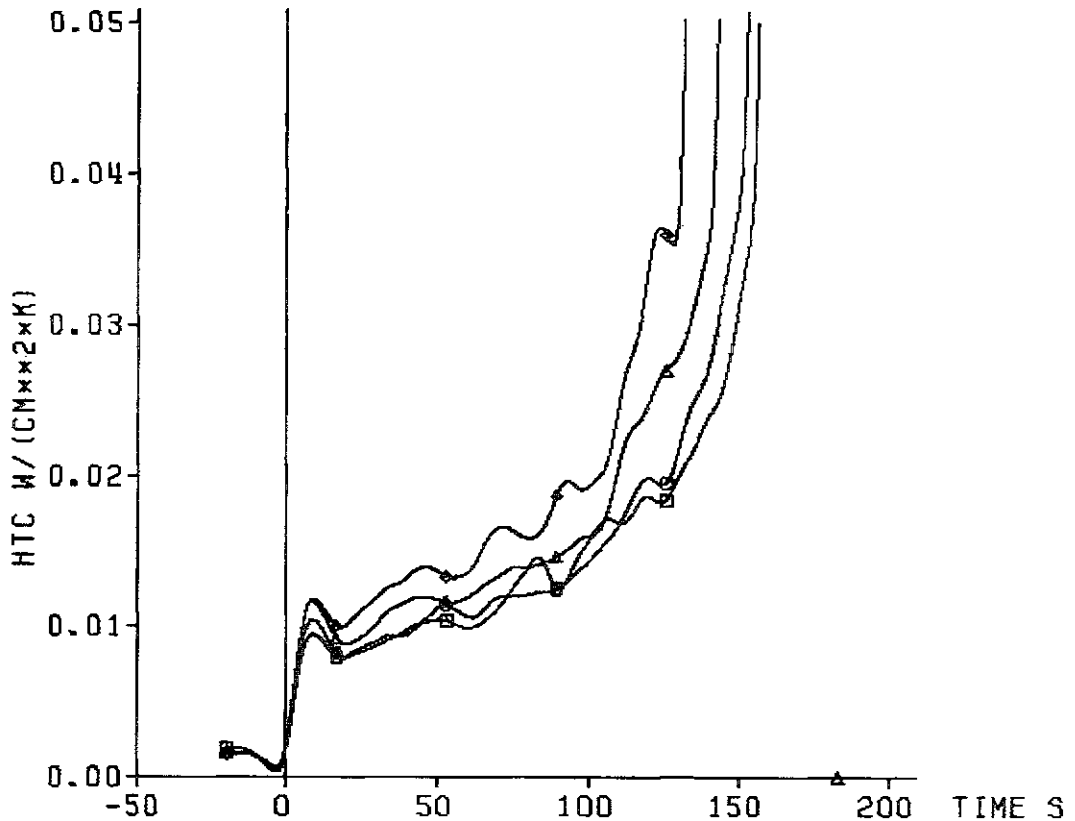
Fig. 479 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 269



decay heat	120% ANS standard	blockage
flooding rate (cold)	5.66 cm/s	========
system pressure	5.89 bar	
feedwater temperature	40 deg C	

KfK IRB

Fig. 480 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 269

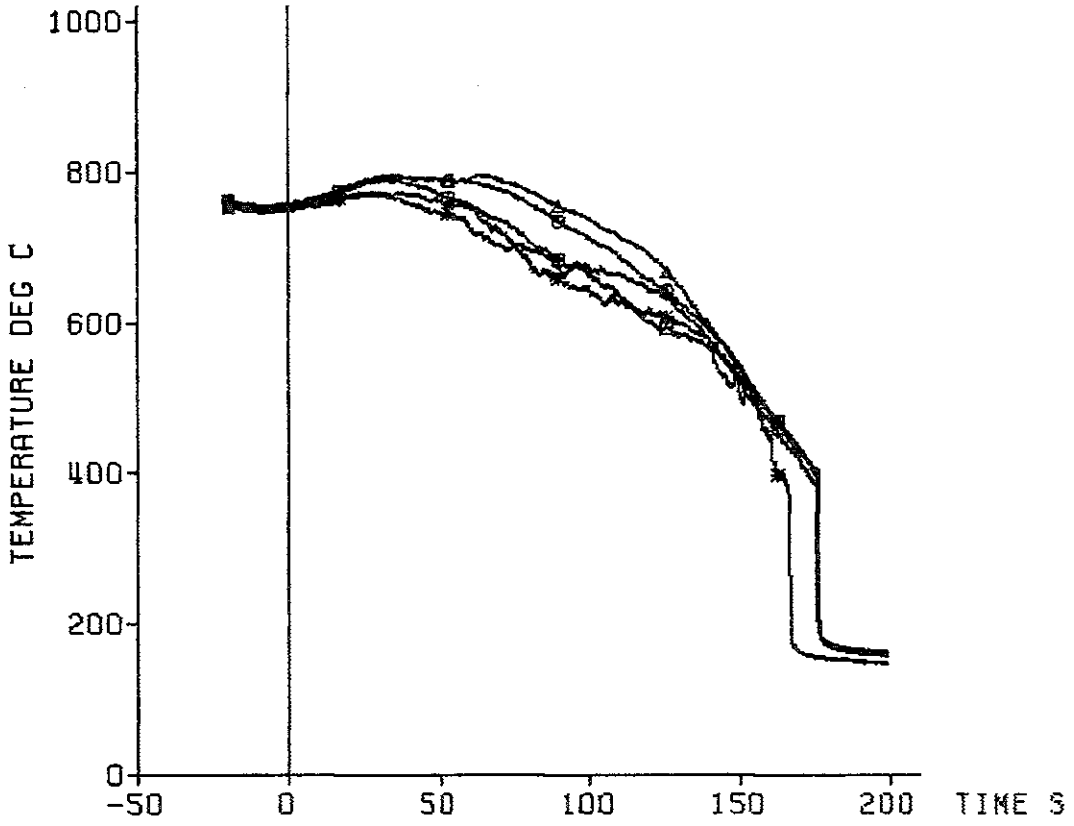


decay heat	120% ANS standard
flooding rate (cold)	5.66 cm/s
system pressure	5.89 bar
feedwater temperature	40 deg C

blockage
========

KfK IRB

Fig. 481 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 269

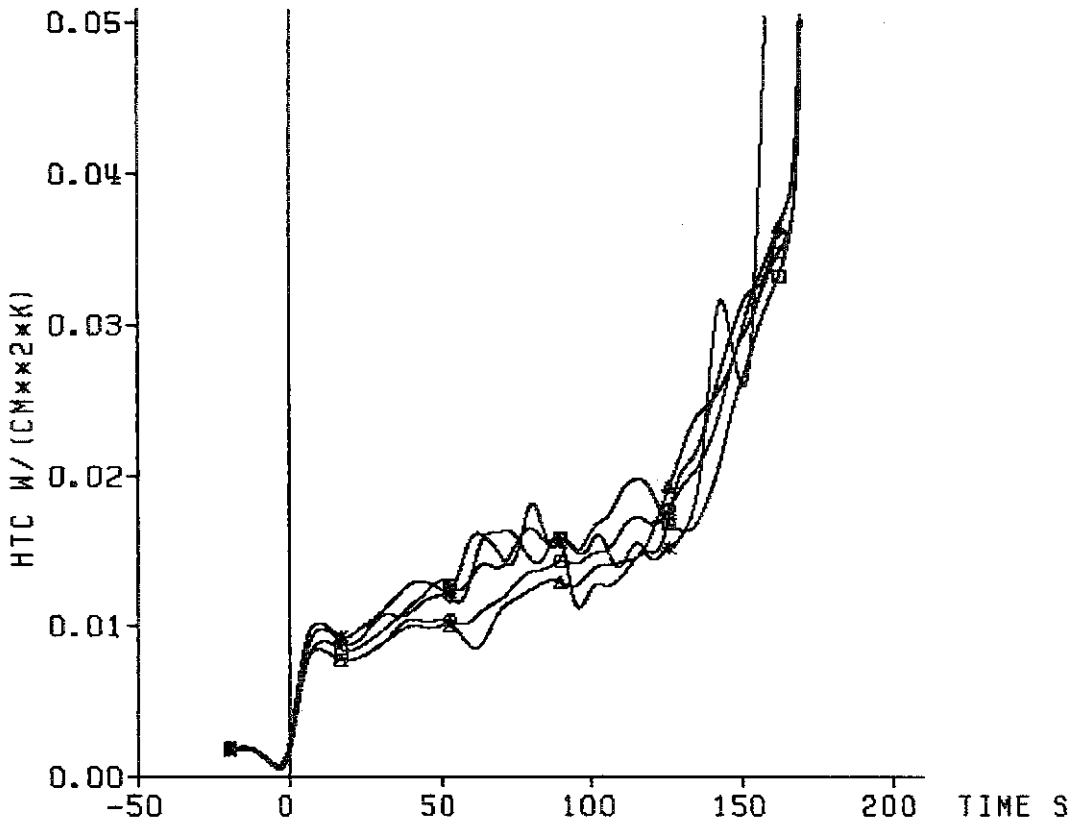


decay heat	120% ANS standard
flooding rate (cold)	5.66 cm/s
system pressure	5.89 bar
feedwater temperature	40 deg C

bypass
======

KfK IRB

Fig. 482 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 269

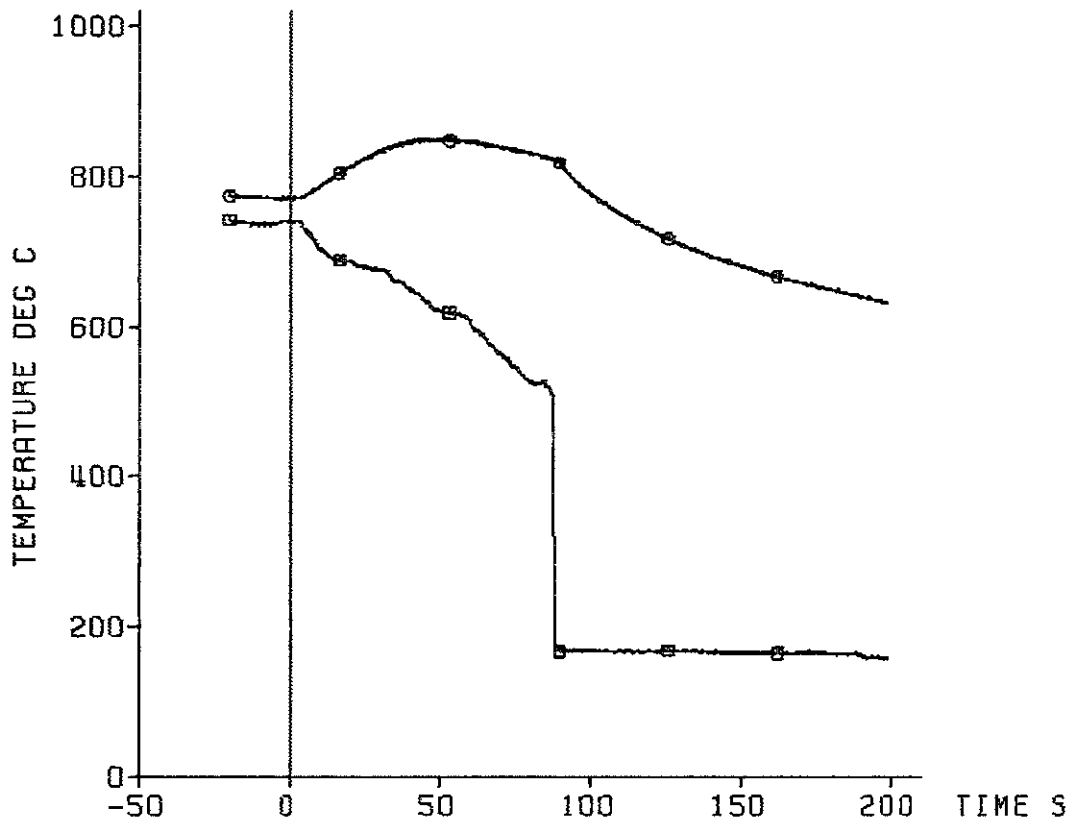


decay heat	120% ANS standard
flooding rate (cold)	5.66 cm/s
system pressure	5.89 bar
feedwater temperature	40 deg C

bypass
======

KfK IRB

Fig. 483 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 269

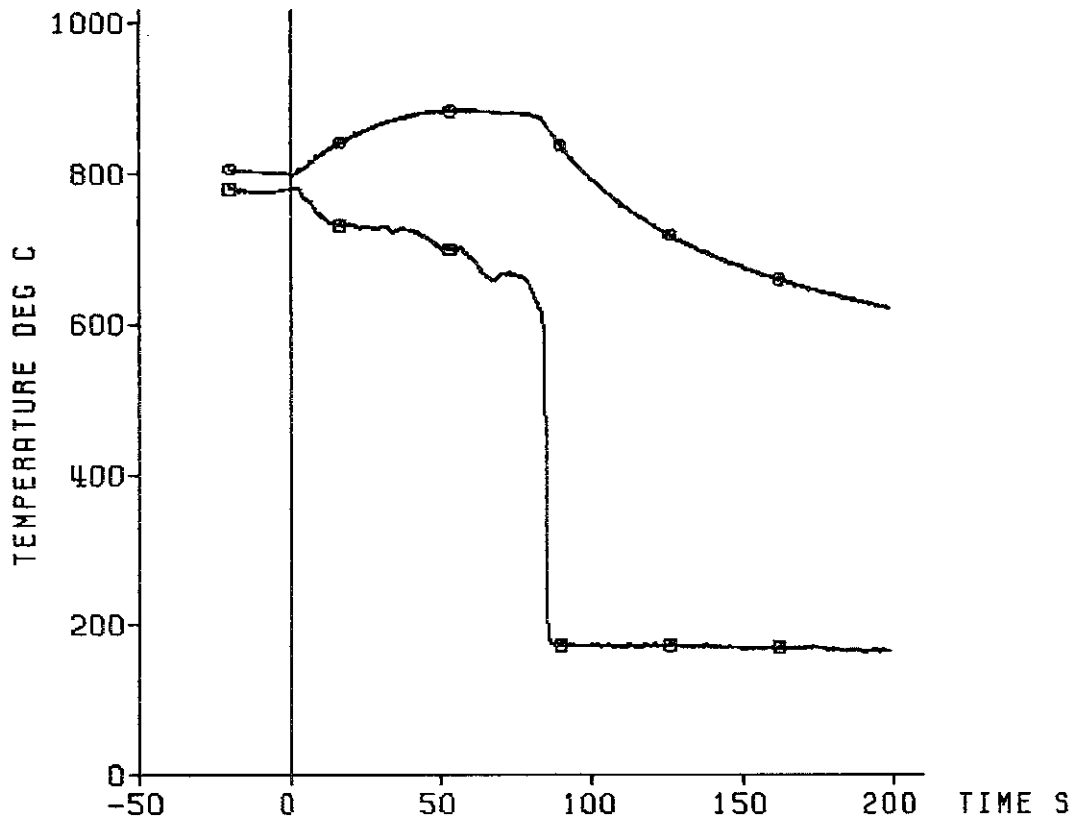


decay heat	120% ANS standard
flooding rate (cold)	5.66 cm/s
system pressure	5.89 bar
feedwater temperature	40 deg C

blockage
========

KfK IRB

Fig. 484 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 269

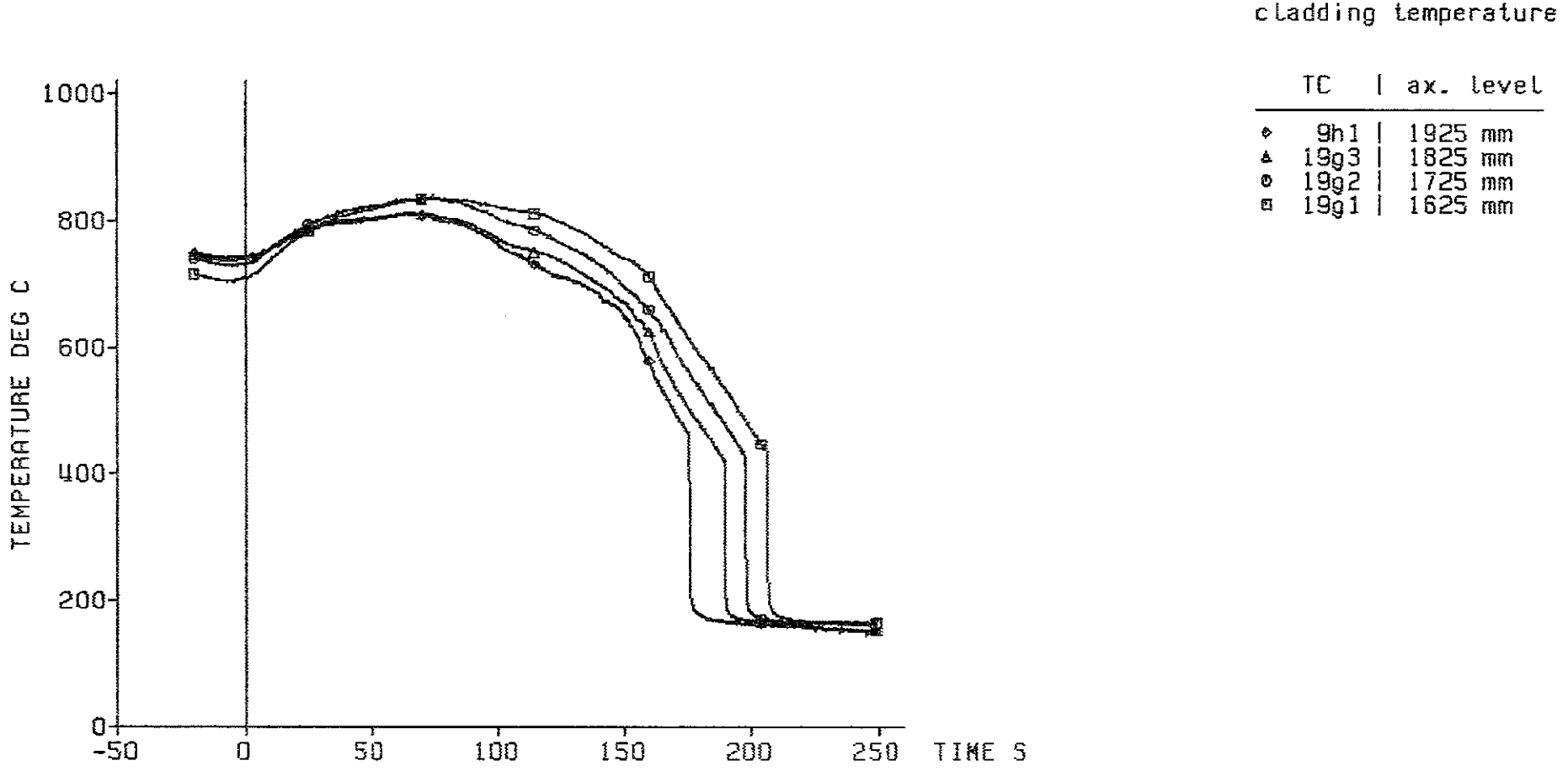


decay heat	120% ANS standard
flooding rate (cold)	5.66 cm/s
system pressure	5.89 bar
feedwater temperature	40 deg C

blockage
========

KfK IRB

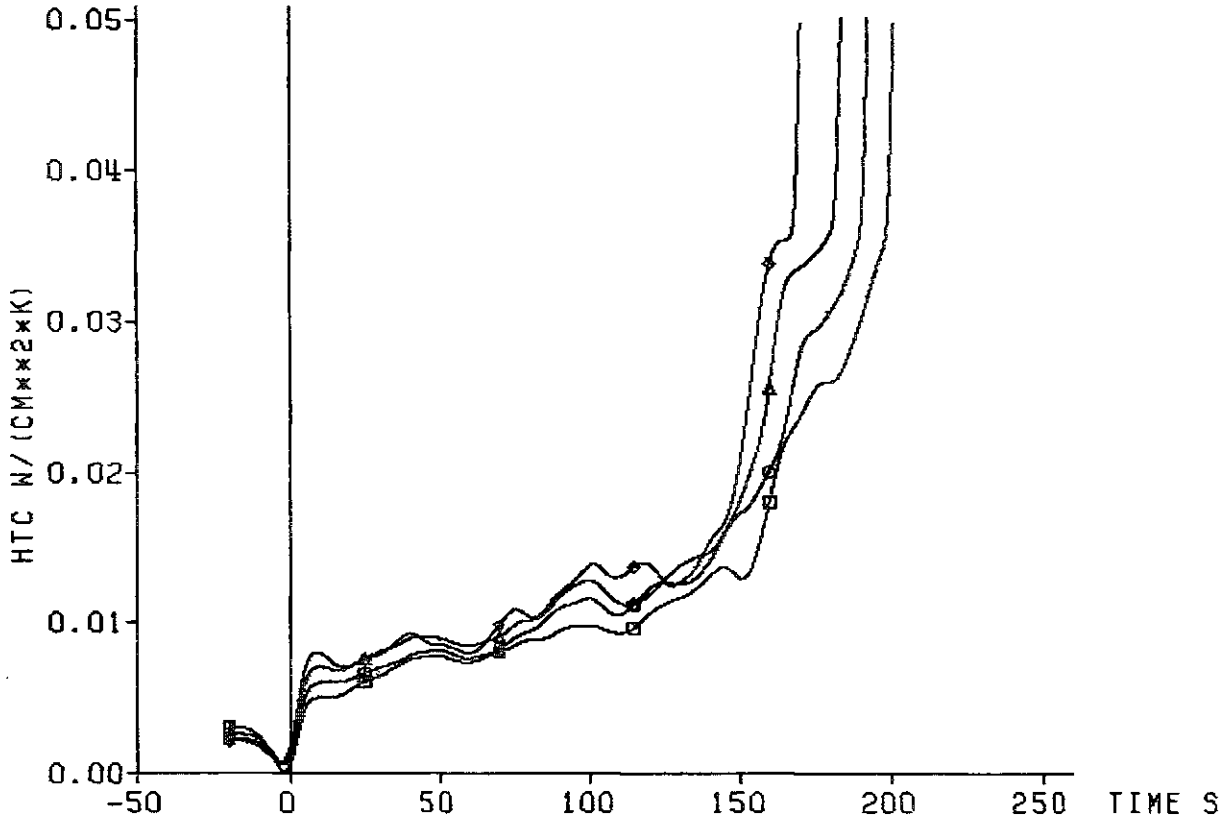
Fig. 485 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 269



decay heat	120% ANS standard	bypass
flooding rate (cold)	5.66 cm/s	======
system pressure	5.89 bar	
feedwater temperature	40 deg C	

KfK IRB

Fig. 486 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 269

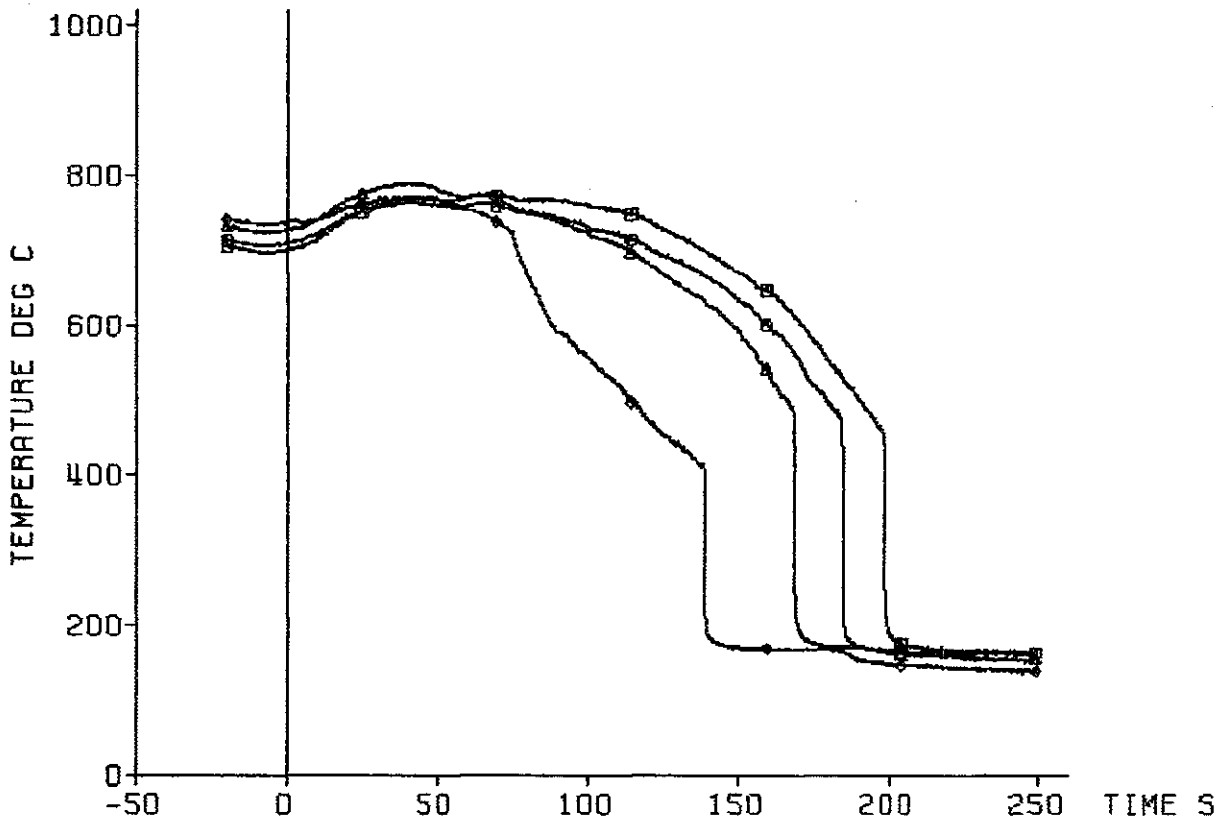


decay heat	120% ANS standard
flooding rate (cold)	5.66 cm/s
system pressure	5.89 bar
feedwater temperature	40 deg C

bypass
======

KfK IRB

Fig. 487 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 269

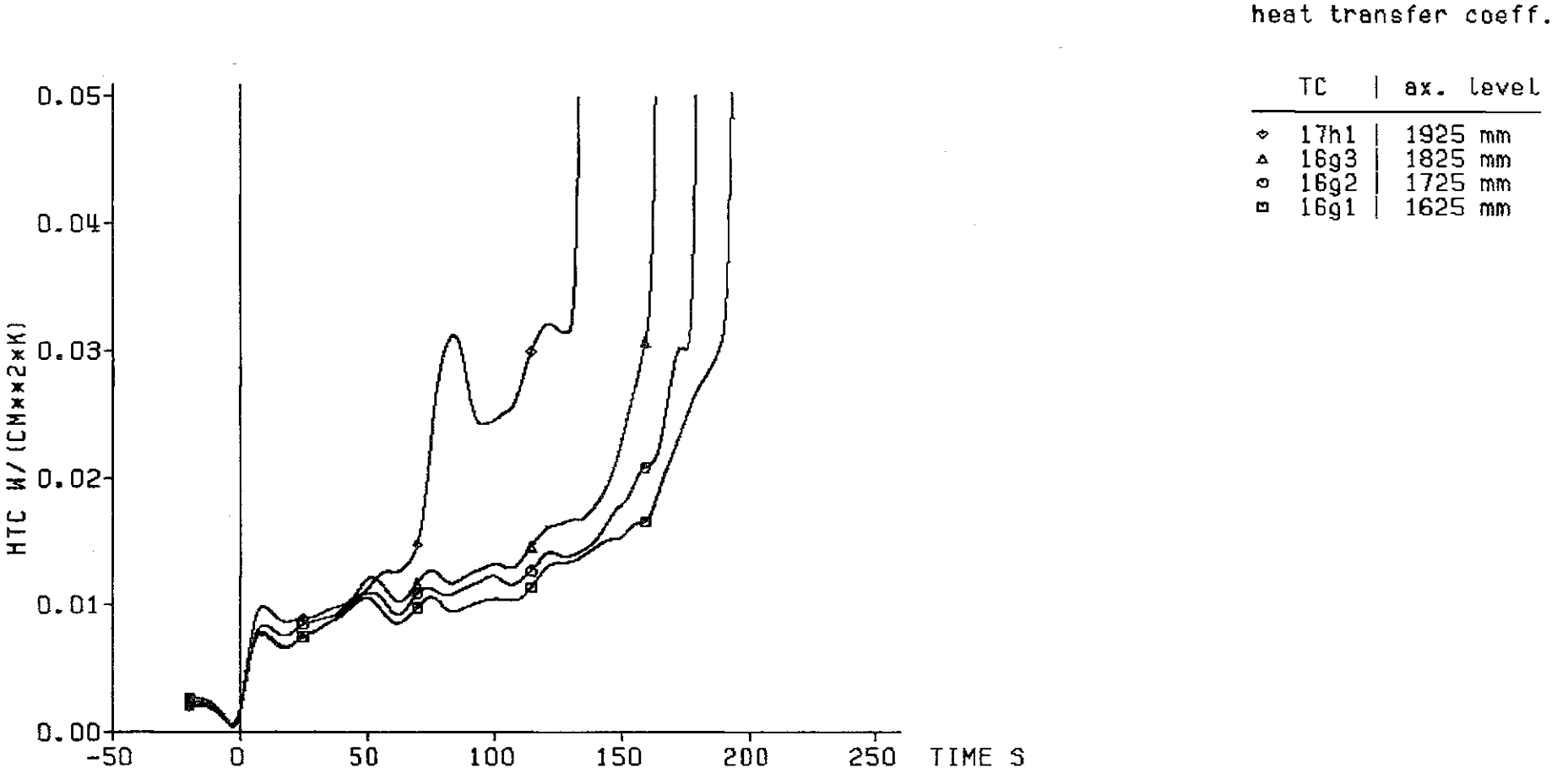


decay heat	120% ANS standard
flooding rate (cold)	5.66 cm/s
system pressure	5.89 bar
feedwater temperature	40 deg C

blockage
========

KfK IRB

Fig. 488 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 269

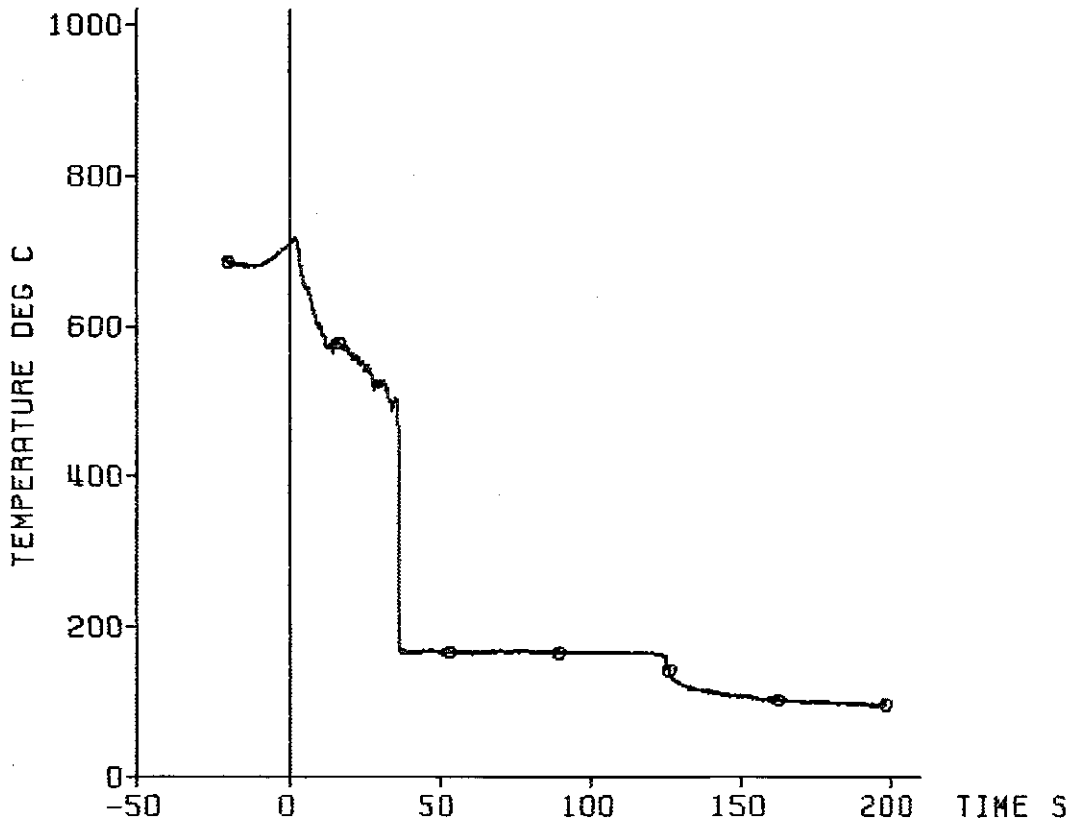


decay heat	120% ANS standard
flooding rate (cold)	5.66 cm/s
system pressure	5.89 bar
feedwater temperature	40 deg C

blockage
========

KfK IRB

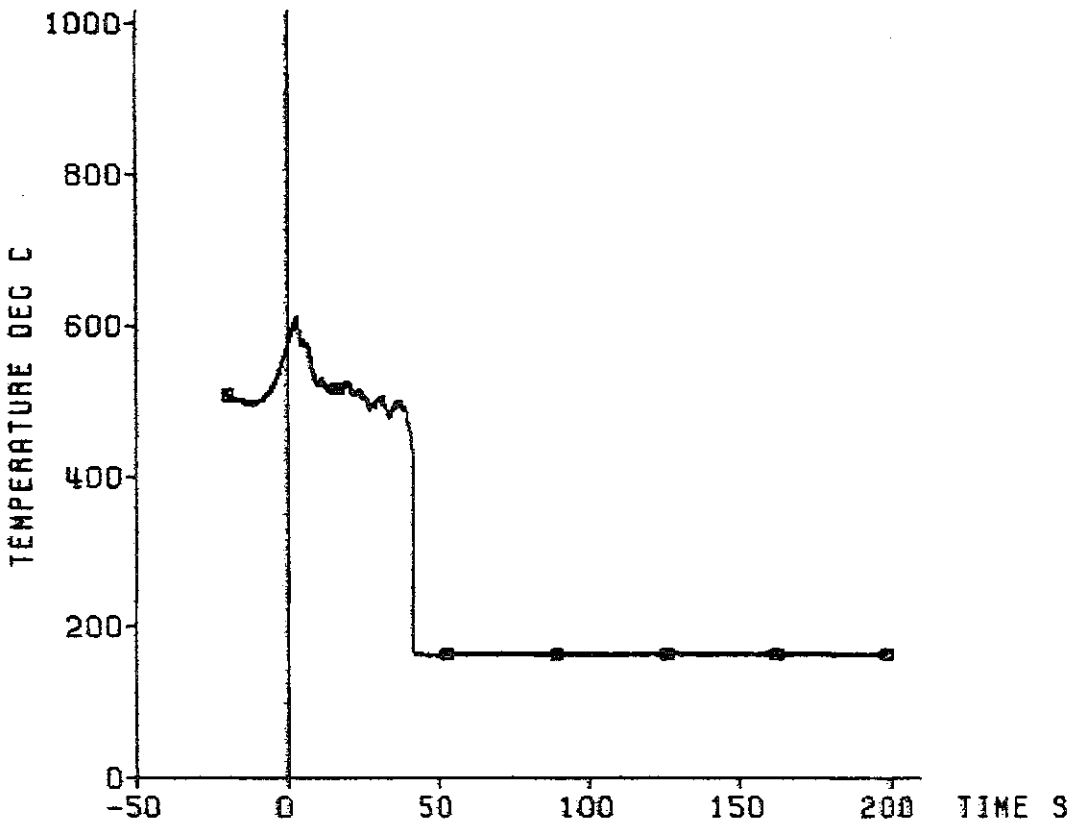
Fig. 489 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 269



decay heat	120% ANS standard
flooding rate (cold)	5.66 cm/s
system pressure	5.89 bar
feedwater temperature	40 deg C

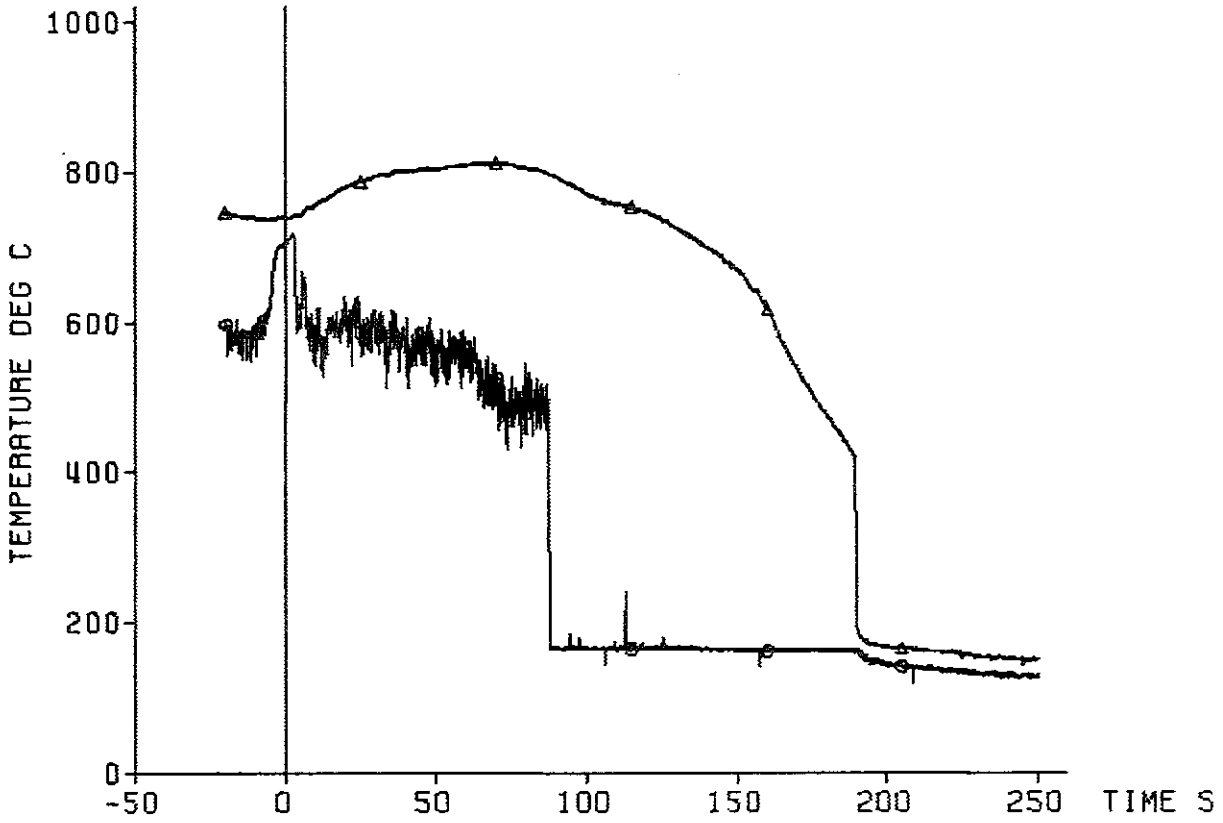
KfK IRB

Fig. 490 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 269



decay heat	120% ANS standard
flooding rate (cold)	5.66 cm/s
system pressure	5.89 bar
feedwater temperature	40 deg C

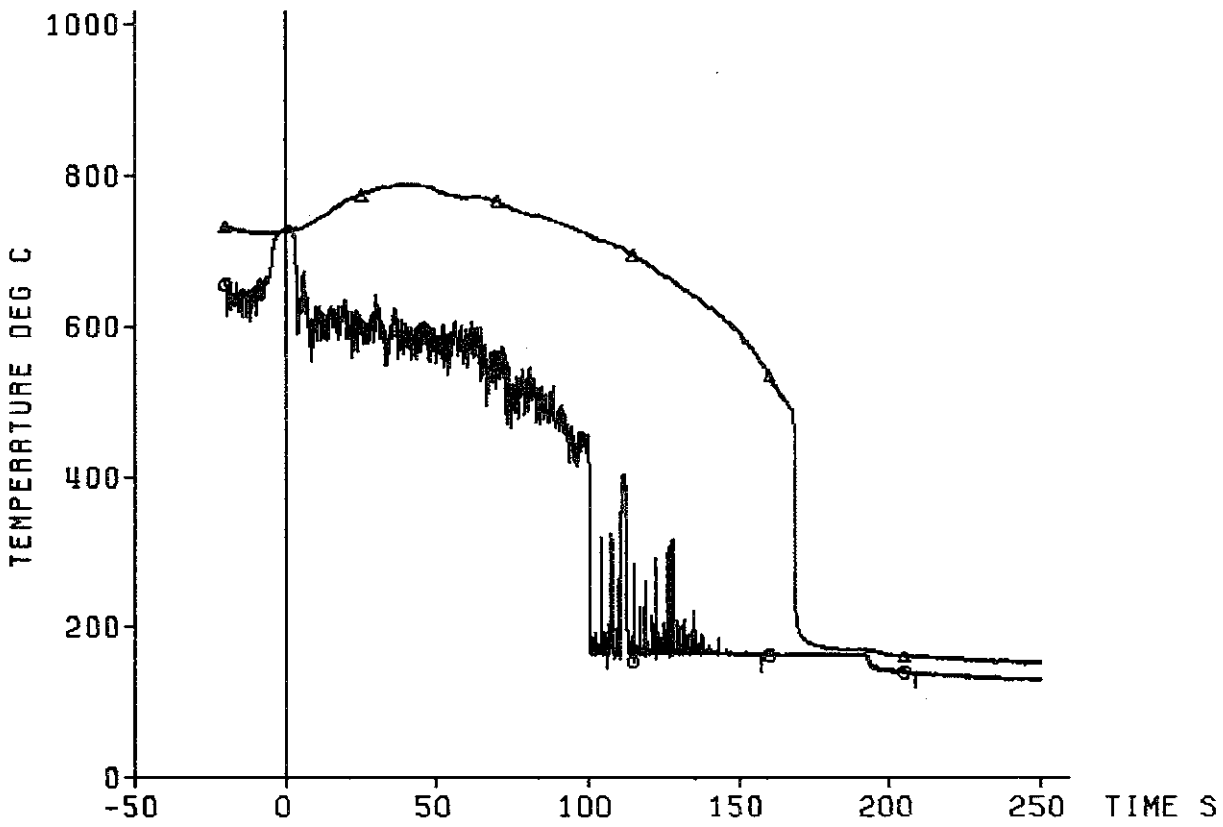
Fig. 491 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 269



decay heat	120% ANS standard	bypass
flooding rate (cold)	5.66 cm/s	======
system pressure	5.89 bar	
feedwater temperature	40 deg C	

KfK IRB

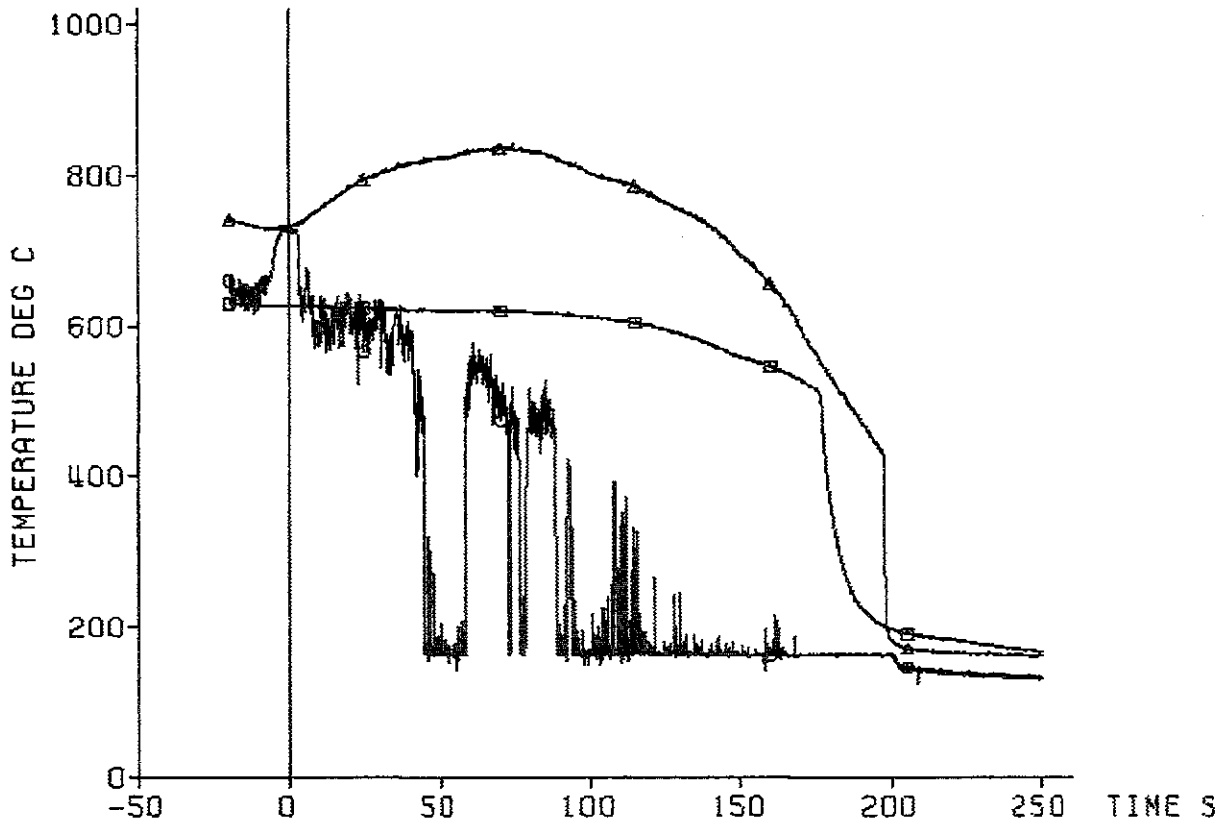
Fig. 492 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 269



decay heat	120% ANS standard	blockage
flooding rate (cold)	5.66 cm/s	========
system pressure	5.89 bar	
feedwater temperature	40 deg C	

KfK IRB

Fig. 493 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 269

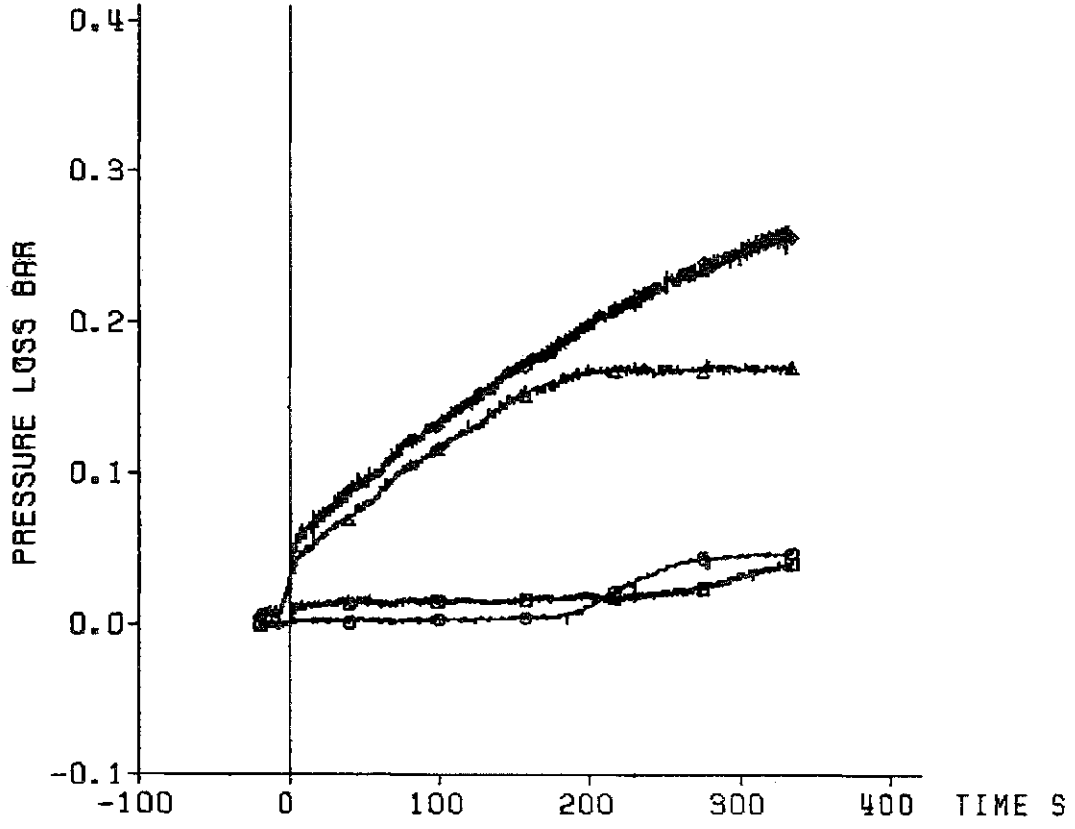


decay heat	120% ANS standard
flooding rate (cold)	5.66 cm/s
system pressure	5.89 bar
feedwater temperature	40 deg C

bypass
======

KfK KTRB

Fig. 494 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 269



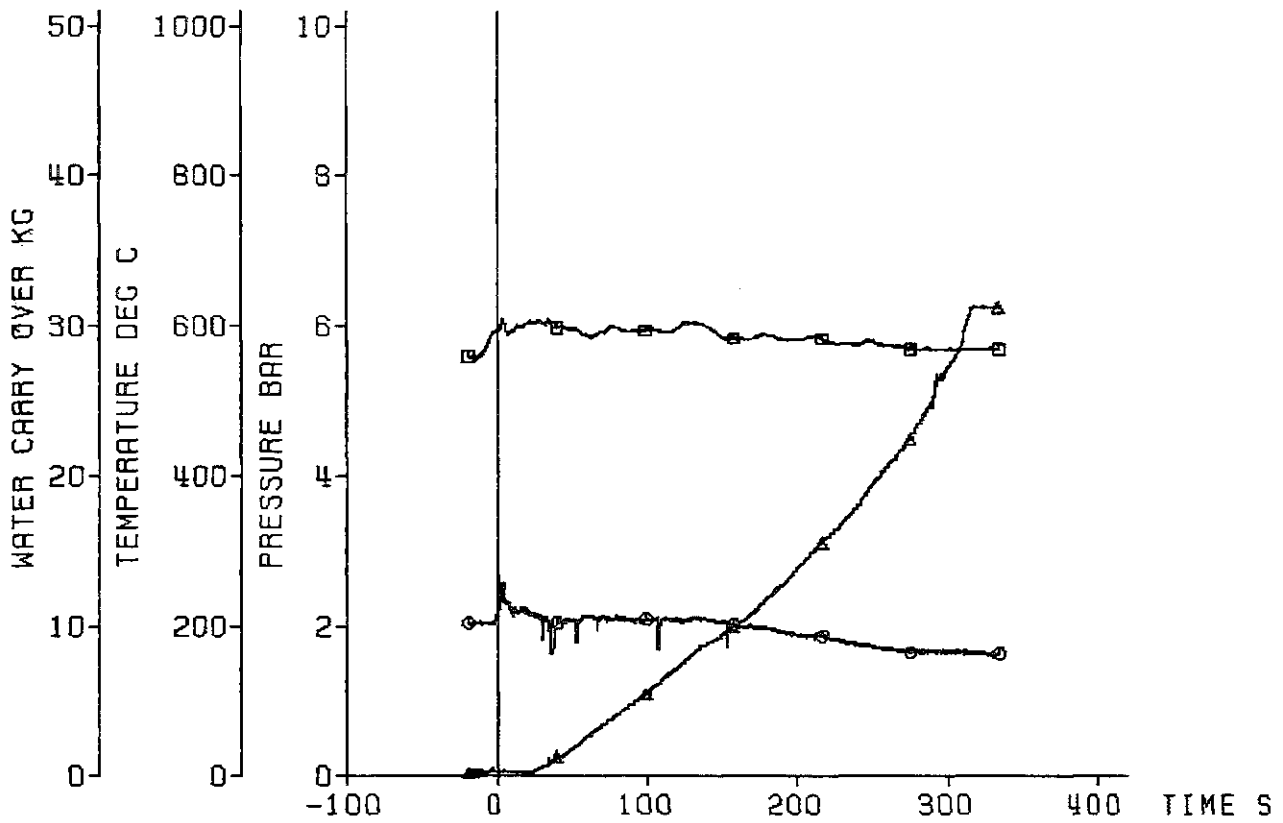
pressure loss
along the test section:

◇ total length: 4196 mm
△ lower part: 1711 mm
○ middle part: 545 mm
□ upper part: 1940 mm

decay heat	120% ANS standard
flooding rate (cold)	5.66 cm/s
system pressure	5.89 bar
feedwater temperature	40 deg C

KfK IRB

Fig. 495 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 269



decay heat	120% ANS standard
flooding rate (cold)	5.66 cm/s
system pressure	5.89 bar
feedwater temperature	40 deg C

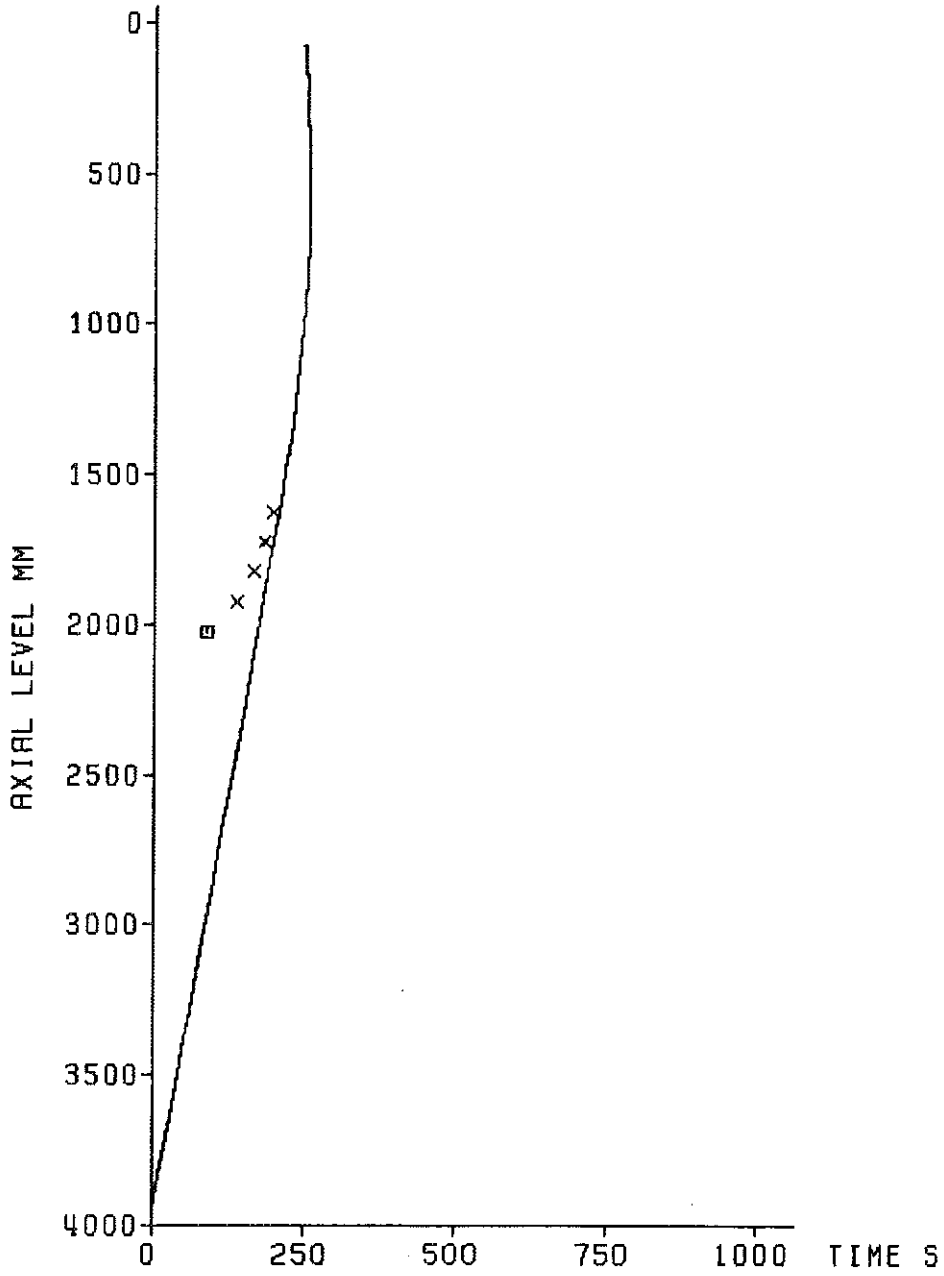
KfK IRB

Fig. 496 FEBA: 5x5 ROD BUNDLE, TEST SERIES 4, TEST-No. 269

axial position of the quench front

⊡ rewetting of the sleeve at the bundle midplane

× rewetting of the rod downstream of the blockage



decay heat	120% ANS standard
flooding rate (cold)	5.66 cm/s
system pressure	5.89 bar
feedwater temperature	40 deg C

KfK IRB

Fig. 497 FEBA: 5x5 ROD BUNDLE TEST SERIES 4, TEST-No. 269

TEST SERIES IV

Investigation of the Effects of a 62% Flow Blockage With Bypass, Blockage at the Bundle Midplane of 3x3 Rods Placed in the Corner of the 5x5 Rod Bundle, Without Grid Spacer at the Bundle Midplane

Channel Listing and Data Identification for Test No. 261 Through 273

Channel No.	Data Identification Type	Location	Unit	Remarks
1	Cladding Temperature	18a4.3860[1]	°C	
2	Cladding Temperature	18a3.3315	°C	
3	Cladding Temperature	18a2.2770	°C	
4	Cladding Temperature	18a1.2225	°C	
5	Cladding Temperature	12b4.1680	°C	
6	Cladding Temperature	12b3.1135	°C	
7	Cladding Temperature	12b2. 590	°C	
8	Cladding Temperature	12b1. 45	°C	
9	Cladding Temperature	17h4.2225	°C	
10	Cladding Temperature	17h3.2125	°C	
11	Cladding Temperature	17h2.2025	°C	
12	Cladding Temperature	17h1.1925	°C	
13	Fluid Temperature	TF[2] 3315	°C	
14	Fluid Temperature	TF[2] 2380	°C	
15	Fluid Temperature	TF[2] 1725	°C	
16	Fluid Temperature	TF[2] 485	°C	
17	Housing Temperature	TK[4] 3315	°C	
18	Housing Temperature	TK 2235	°C	
19	Housing Temperature	TK 1725	°C	
20	Housing Temperature	TK 590	°C	

TEST SERIES IV

Channel No.	Data Identification Type	Location	Unit	Remarks
21	Fluid Temperature	Lower Plenum	°C	
22	Water Level Detector	4012	°C	Heated + Unheated TC's
23	Feedwater Temperature		°C	
24	Fluid Temperature	Upper Plenum	°C	
25	Room Temperature		°C	
26	Cladding Temperature	22f4.2425[1]	°C	
27	Cladding Temperature	22f3.2325	°C	
28	Cladding Temperature	22f2.2225	°C	
29	Cladding Temperature	22f1.2125	°C	
30	Cladding Temperature	21e4.2225	°C	
31	Cladding Temperature	21e3.2175	°C	
32	Cladding Temperature	21e2.2125	°C	
33	Cladding Temperature	21e1.2075	°C	
34	Cladding Temperature	19g4.1925	°C	
35	Cladding Temperature	19g3.1825	°C	
36	Cladding Temperature	19g2.1725	°C	
37	Cladding Temperature	19g1.1625	°C	
38	Cladding Temperature	16g4.1925	°C	
39	Cladding Temperature	16g3.1825	°C	
40	Cladding Temperature	16g1.1625	°C	
41	Cladding Temperature	16g2.1725	°C	
42	Cladding Temperature	15a4.3860	°C	
43	Cladding Temperature	15a3.3315	°C	
44	Cladding Temperature	15a2.2770	°C	
45	Cladding Temperature	15a1.2225	°C	
46	Cladding Temperature	14e4.2225	°C	
47	Cladding Temperature	14e3.2175	°C	
48	Cladding Temperature	14e2.2125	°C	
49	Cladding Temperature	14e1.2075	°C	

TEST SERIES IV

Channel No.	Data Identification Type	Location	Unit	Remarks
50	Cladding Temperature	13d3.2025[1]	°C	
51	Cladding Temperature	13d2.2025	°C	
52	Cladding Temperature	13d1.2025	°C	
53	Cladding Temperature	10f4.2425	°C	
54	Cladding Temperature	10f3.2325	°C	
55	Cladding Temperature	10f2.2225	°C	
56	Cladding Temperature	10f1.2125	°C	
57	Cladding Temperature	9h4.2225	°C	
58	Cladding Temperature	9h3.2125	°C	
59	Cladding Temperature	9h2.2025	°C	
60	Cladding Temperature	9h1.1925	°C	
61	Cladding Temperature	8d4.2025	°C	
62	Cladding Temperature	8d3.2025	°C	
63	Cladding Temperature	8d2.2025	°C	
64	Cladding Temperature	8d1.2025	°C	
65	Cladding Temperature	7f4.2425	°C	
66	Cladding Temperature	7f3.2325	°C	
67	Cladding Temperature	7f2.2225	°C	
68	Cladding Temperature	7f1.2125	°C	
69	Sleeve Temperature	TH[5] 13.2025	°C	
70	Sleeve Temperature	TH 17.2025	°C	
71	Sleeve Temperature	TH 21.2025	°C	TC Failed
72	----------		-	Open
73	Cladding Temperature	3b4.1680	°C	
74	Cladding Temperature	3b3.1135	°C	
75	Cladding Temperature	3b2. 590	°C	
76	Cladding Temperature	3b1. 45	°C	

TEST SERIES IV

Channel No.	Data Identification Type	Location	Unit	Remarks
77	Grid Temperature TA[6]	1460	°C	
78	Grid Temperature TA[7]	1460	°C	TC Failed After Test 267
79	Grid Temperature TA[6]	2550	°C	TC Failed After Test 268
80	Grid Temperature TA[7]	2550	°C	
81	Electrical Power Input	8 Rods	kW	Rods No. 1 Through 8
82	Electrical Power Input	8 Rods	kW	Rods No. 9 Through 16
83	Electrical Power Input	9 Rods	kW	Rods No. 17 Through 25
84	Housing Temperature TK[4]	3915	°C	
85	Housing Temperature TK	3564	°C	
86	Cladding Temperature	2c4.4025[1]	°C	
87	Cladding Temperature	2c3.3925	°C	
88	Cladding Temperature	2c2.3825	°C	
89	Cladding Temperature	2c1.3725	°C	
90	Cladding Temperature	24c4.4025	°C	
91	Cladding Temperature	24c3.3925	°C	
92	Cladding Temperature	24c2.3825	°C	
93	Cladding Temperature	24c1.3725	°C	
94	Cladding Temperature	20d4.2025	°C	
95	Cladding Temperature	20d3.2025	°C	
96	Cladding Temperature	20d2.2025	°C	
97	Cladding Temperature	20d1.2025	°C	
98	Fluid Temperature TF[2]	3038	°C	
99	Fluid Temperature TF[2]	2770	°C	
100	Fluid Temperature TF[3]	2245	°C	
101	Fluid Temperature TF[2]	2210	°C	
102	Fluid Temperature TF[3]	2045	°C	
103	Fluid Temperature TF[2]	1825	°C	
104	Fluid Temperature TF[3]	1825	°C	

TEST SERIES IV

Channel No.	Data Identification Type	Location	Unit	Remarks
105	Fluid Temperature TF[2]	2770	°C	TC of 0.5 mm Diameter
106	Fluid Temperature TF[2]	2770	°C	TC of 1.0 mm Diameter
107	Fluid Temperature TF[2]	3038	°C	TC of 0.5 mm Diameter
108	Fluid Temperature TF[2]	3315	°C	TC of 0.5 mm Diameter
109	Fluid Temperature TF[2]	3315	°C	TC of 1.0 mm Diameter
110	Time (10 Scans/s)		s	t = 0: Start of Reflooding
111	Pressure in Lower Plenum	4091	bar	
112	Pressure in Upper Plenum	-105	bar	
113	Pressure in Buffer		bar	
114	Bundle Power		kW	Channels: 81 + 82 + 83
115	Flooding Velocity (cold)		cm/s	
116	Water Carry Over Collected		kg	Downstream of Bundle Exit
117	Pressure Diff.	1835 and -105 mm	bar	
118	Measured	2380 and 1835 mm	bar	
119	Between	4091 and 2380 mm	bar	
120	Axial Level	4091 and -105 mm	bar	Values Measured Separately

1) TC's of 0.5 mm diameter embedded in rod cladding. Measuring position: Example: rod No. = 18, type of rod instrumention = a, TC No. = 4, axial level = 3860 mm, referenced to the top flange of the bundle.

2) TF = TC's of 0.25 mm diameter (bare).
TC's placed in subchannel surrounded by rods No. 12, 17, 16 and 11.

3) TF = TC's of 0.25 mm diameter (bare).
TC's placed in subchannel surrounded by rods No. 15, 20, 19 and 14.

4) TK = TC's of 0.5 mm diameter placed in the wall of the bundle housing of of 6.5 mm thickness.

TEST SERIES IV

5) TH = TC's of 0.5 mm diameter embedded in sleeve. Measuring position: Example: rod No. 13, axial level = 2025 mm.

6) TA = TC's of 0.5 mm diameter placed at the grid spacer in subchannel surrounded by housing and rods No. 21 and 22.

7) TA = TC's of 0.5 mm diameter placed at the grid spacer in subchannel surrounded by housing and rods No. 4 and 5.