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SEFLEX
Fuel Rod Simulator Effects in Flooding Experiments

Part 3:
Blocked Bundle Data

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Abstract

This report presents typical data and a limited heat transfer analysis from blocked bundle reflood tests of an experimental thermal-hydraulic program conducted to investigate Fuel Rod Simulator Effects in Flooding Experiments (SEFLEX-program). Full-length bundles of 5 x 5 fuel rod simulators having a gas-filled gap between the Zircaloy cladding and the alumina pellets were tested in the test rig designed for the earlier Flooding Experiments with Blocked Arrays (FEBA-program). The 5 x 5 FEBA rod bundle tests were performed with gapless heater rods widely used for reflood tests. These rods have a close thermal contact between the stainless steel cladding and the electric insulation material. A comparison of the SEFLEX data with the reference data of FEBA obtained under identical initial and reflood conditions shows the influence of different fuel rod simulators on the thermal-hydraulic behavior during forced feed bottom reflooding of unblocked and blocked arrays. Compared to bundles of gapless rods, bundles of rods with Zircaloy claddings and a gas filled gap between claddings and pellets, which more closely represent the features that exist in an actual fuel rod geometry, produced higher quench front velocities, enhanced removal of stored heat in the rods, reduced peak cladding temperatures, increased grid spacer effects and absolutely unproblematic coolability of 90 percent blockages with bypass. The data offer the opportunity for further validation of computer codes to make realistic predictions of safety margins during a loss-of-coolant accident in a pressurized water reactor.

This report is accompanied by a separate unblocked bundle data report (KfK 4025) and an evaluation report summarizing the results of the total program (KfK 4024). These three reports conclude the SEFLEX-program.

SEFLEX - Brennstabsimulatoreffekte bei Flutexperimenten

Teil 3: Meßdaten von Experimenten mit blockierten Bündeln

Kurzfassung

In diesem Bericht werden typische Meßergebnisse und eine begrenzte Wärmeübergangsanalyse von Flutversuchen mit blockierten Bündeln vorgestellt, die im Rahmen des SEFLEX-Programmes (Brennstabsimulatoreffekte in Flutexperimenten) gewonnen wurden. Stabbündel voller Länge bestehend aus 5 x 5 Brennstabsimulatoren mit gasgefülltem Spalt zwischen dem Zircaloy-Hüllrohr und den Aluminiumoxid-Pellets wurden in dem Prüfstand geflutet, der für das vorher durchgeführte FEBA-Programm (Flutexperimente mit blockierten Anordnungen) verwendet worden war. Die FEBA-Versuche wurden mit Bündeln aus 5 x 5 "spaltlosen" Stäben durchgeführt, wie sie gewöhnlich für Flutversuche verwendet werden. Diese Stäbe haben einen engen thermischen Kontakt zwischen dem Hüllrohr aus Edelstahl und dem elektrischen Isolatorwerkstoff. Ein Vergleich der SEFLEX-Daten mit den FEBA-Referenzdaten, die unter den gleichen Anfangs- und Flutbedingungen erzielt wurden, zeigt den Einfluß unterschiedlicher Brennstabsimulatoren auf das thermohydraulische Verhalten beim Zwangsfluten der unblockierten und blockierten Stabanordnungen von unten. Im Vergleich zu Bündeln aus spaltlosen Stäben führen Bündel aus Stäben mit Zircaloy-Hüllrohren und mit gasgefülltem Spalt zwischen Hüllrohr und Pellets, die weitgehend die Merkmale eines aktuellen Brennstabes haben, zu höheren Geschwindigkeiten der Benetzungsfront, einer verbesserten Abfuhr der in den Stäben gespeicherten Wärme, niedrigeren Maximaltemperaturen der Hüllrohre, erhöhten Effekten der Abstandshalter und absolut unproblematischer Kühlbarkeit von 90 % Blockaden mit Bypass. Die Daten eröffnen die Möglichkeit zum weiteren Befähigungsnachweis von Rechenprogrammen, den Sicherheitsabstand während eines Kühlmittelverluststörfalles realistisch zu bestimmen.

Zu diesem Bericht gehören ein getrennter Bericht mit Meßdaten von Experimenten mit unblockierten Stabbündeln (KfK 4025) und ein Auswertungsbericht, in dem die Ergebnisse des gesamten Programmes zusammengefaßt sind (KfK 4024). Mit diesen drei Berichten ist das SEFLEX-Programm abgeschlossen.

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1. Introduction

During in pile tests such as the OECD Halden Reactor Project, it was observed that nuclear fuel rods [1], which are characterized by heat generating fuel pellets stacked in a Zircaloy tube with a radial gap between pellets and cladding, were quenched substantially earlier than SEMISCALE electrically heated rods with a close contact between filler material and stainless steel cladding [2], [3]. In the same project, REBEKA fuel rod simulators with a gas filled gap between alumina pellets and Zircaloy-4 cladding simulated closely the actual fuel rod behavior [4] during a loss-of-coolant accident (LOCA). The REBEKA rods were designed and used to study the plastic deformation behavior of pressurized Zircaloy-4 cladded fuel rod simulators in the REBEKA test program [5].

Apart from the OECD Halden Reactor Project, the influence of thermal properties of different cladding materials on the heat transfer and rewetting behavior was observed in experiments using single rods or tubes of stainless steel and Zircaloy, respectively, under falling film and bottom reflood conditions [6]. Similar bench-type reflood experiments [7] were carried out with a 4-rod bundle to study the quench behavior of stainless steel and Zircaloy claddings. However, in most bottom reflooding experiments the real fuel rods were simulated by conventional heater rods with stainless steel claddings which are in close contact with the filler material. Under these conditions the thermal-hydraulic phenomena were examined in experiments such as FEBA [8], FLECHT-SEASET [9], THETIS [10] and others. The objectives of all these bundle tests have been to provide experimental reflood heat transfer and two-phase flow data in simulated pressurized water reactor (PWR) geometries for postulated LOCA conditions. The measured data have been used to develop and validate physical models to describe basic heat transfer effects and local thermal-hydraulic phenomena at grid spacers and flow blockages. These models have been incorporated into computer codes providing qualified analytical tools for the prediction of realistic parameters as cladding temperature, vapor temperature, or quench front velocity and consequently safety margins for unblocked and blocked rod bundle configurations.

Thus applicability of these data have been subject to question because of uncertainties regarding the ability of gapless heater rods to simulate the thermal response of nuclear fuel rods. Therefore, the objective of the

SEFLEX-program (Fuel Rod Simulator Effects in Flooding Experiments) has been to quantify differences in the thermal-hydraulic behavior of two different fuel rod simulator designs (FEBA and REBEKA) on the basis of two-phase flow and heat transfer phenomena in unblocked and blocked bundle tests.

The experimental data from the FEBA tests [11] using heater rods without gap between filler material and stainless steel cladding served as a reference data base. For comparison forced feed bottom reflood tests were performed using the FEBA test facility and 5 x 5 REBEKA rod bundles with flow blockage and bypass of the same dimensions instead of 5 x 5 FEBA rod bundles.

Details of the SEFLEX-program as well as a comparison of typical transients measured and evaluated from gapped REBEKA and gapless FEBA rod bundles without and with flow blockage are presented in a separate evaluation report [12]. The information presented in the following is a broader sampling of data selected from tests with a 5 x 5 REBEKA rod bundle including a 90 percent flow blockage with bypass. The flow blockage was realized by artifically balloonned Zircaloy claddings at the bundle midplane of 3 x 3 rods placed in the corner of the 5 x 5 rod bundle. For test series 3 the gaps were filled with helium. For test series 4 an argon filling was provided.

A second data report [13] contains information about SEFLEX test series 1 and 2 performed with a 5 x 5 REBEKA rod bundle of undisturbed geometry.

On request all measured SEFLEX data are available on tapes from KfK.

2. Background

To study the reflood behavior of rod bundles composed of fuel rod simulators of different design, data from FEBA test series [11] served as reference data base. For this program solid type (gapless) rods were employed and the flow blockages were simulated by steel sleeves attached to the rods. Separate effect tests were carried out in eight test series with the objective to measure and to evaluate thermal-hydraulic behavior of grid spacers and of unblocked versus blocked bundle geometries with and without bypass. The bundle configurations tested are listed in Table 1. The reflood conditions were systematically repeated from series to series to isolate the different effects. In the following section of this report, the test facility, the heater rod and blockage designs, and the operational procedure are briefly outlined to provide the experimental background for the present study.

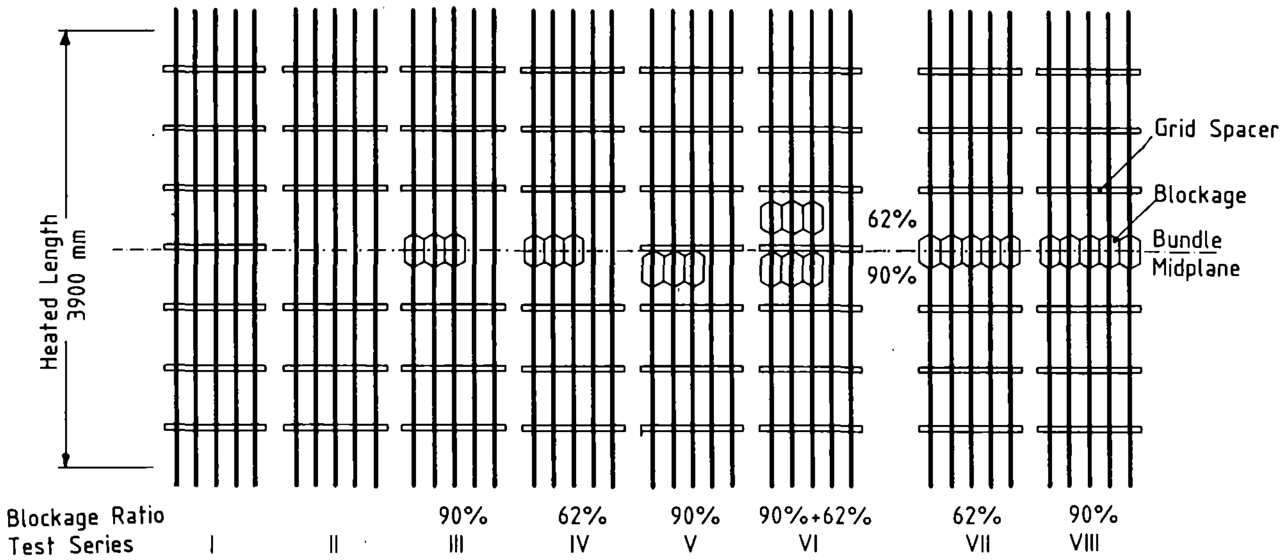
In the subsequent SEFLEX-program, for comparison forced feed reflood tests were carried out using rods with helium- or argon-filled gaps between Zircaloy-4 claddings and alumina pellets. The flow blockages were simulated by artificially ballooned Zircaloy claddings providing the same blockage geometry as for the FEBA experiments. Separate effect tests were carried out in four test series to measure and to evaluate the influence of four major factors on the reflood heat transfer and rod quenching:

- rod clad properties
- conductivity of the gap between pellets and cladding
- grid spacers
- flow blockages.

The bundle configurations tested are listed in Table 2. The SEFLEX tests were conducted using REBEKA rod bundles in the FEBA test facility to minimize the influence of the boundary conditions of different test rigs. The initial and reflood conditions selected for the FEBA-program were repeated as close as experimentally possible for the comparison of the differences in the behavior of the two rod designs on the basis of two-phase flow and heat transfer phenomena of SEFLEX test series 1 through 4 and FEBA test series I and III.

Table 1

FEBA-program: Bundle geometry of test series I through VIII.
Axial arrangement of grid spacers and flow blockages.



Series I: Baseline tests with undisturbed bundle geometry; seven grid spacers.

Series II: Investigation of the effects of a grid spacer; 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 3 x 3 rods placed in the corner of the 5 x 5 rod bundle; without grid spacer at the bundle midplane.

Series IV: Investigation of the effects of a 62% flow blockage with bypass; blockage at the bundle midplane of 3 x 3 rods placed in the corner of the 5 x 5 rod bundle; without grid spacer at the bundle midplane.

Series V: Investigation of the effects of a 90% flow blockage with bypass combined with grid spacer effects; blockage immediately upstream of the bundle midplane at 3 x 3 rods placed in the corner of the 5 x 5 rod bundle; grid spacer at the bundle midplane.

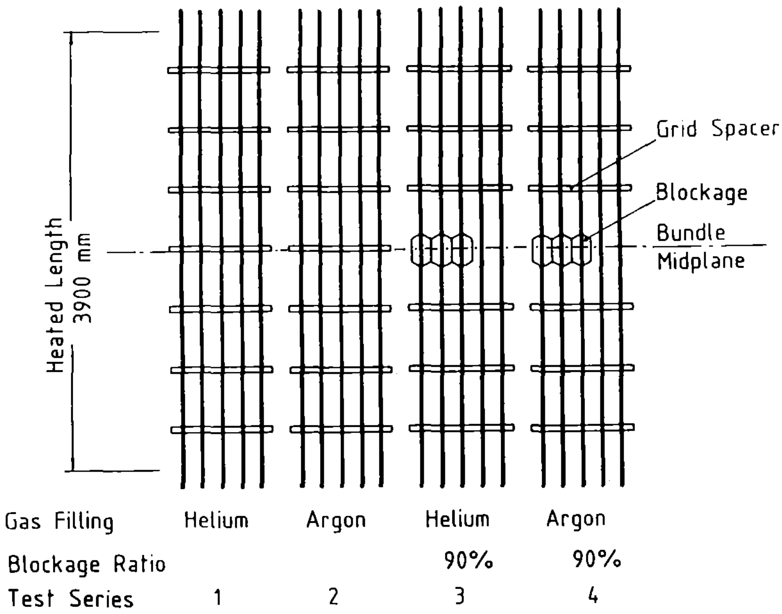
Series VI: Investigation of the effects of 90% and 62% flow blockages with bypass combined grid spacer effects; 90% flow blockage immediately upstream of the bundle midplane; 62% flow blockage immediately downstream of the bundle midplane; both blockages at the same 3 x 3 rods placed in the corner of the 5 x 5 rod bundle; grid spacer at the bundle midplane.

Series VII: Investigation of the effects of a 62% flow blockage without bypass; blockage at the bundle midplane of all rods of the 5 x 5 rod bundle.

Series VIII: Investigation of the effects of a 90% flow blockage without bypass; blockage at the bundle midplane of all rods of the 5 x 5 rod bundle.

Table 2

SEFLEX-program: Bundle geometry of test series 1 through 4.
Axial arrangement of grid spacers and flow blockages.



Series 1: Rods with helium-filled gaps between Zircaloy claddings and alumina pellets; undisturbed bundle geometry with seven grid spacers.
Investigation of the effects of rod clad properties, conductivity of gas filled gaps, and grid spacers.
Comparison with FEBA test series I and SEFLEX test series 2.

Series 2: Rods with argon-filled gaps between Zircaloy claddings and alumina pellets; undisturbed bundle geometry with seven grid spacers.
Investigation of the effects of rod clad properties, conductivity of gas filled gaps, and grid spacers.
Comparison with FEBA test series I and SEFLEX test series 1.

Series 3: Rods with helium-filled gaps between Zircaloy claddings and alumina pellets; 90% flow blockage with bypass; blockage at the bundle midplane of 3 x 3 rods placed in the corner of the 5 x 5 rod bundle; without grid spacer at the bundle midplane.
Investigation of the effects of rod clad properties, conductivity of gas filled gaps, grid spacers, and flow blockage.
Comparison with FEBA test series III and SEFLEX test series 4.

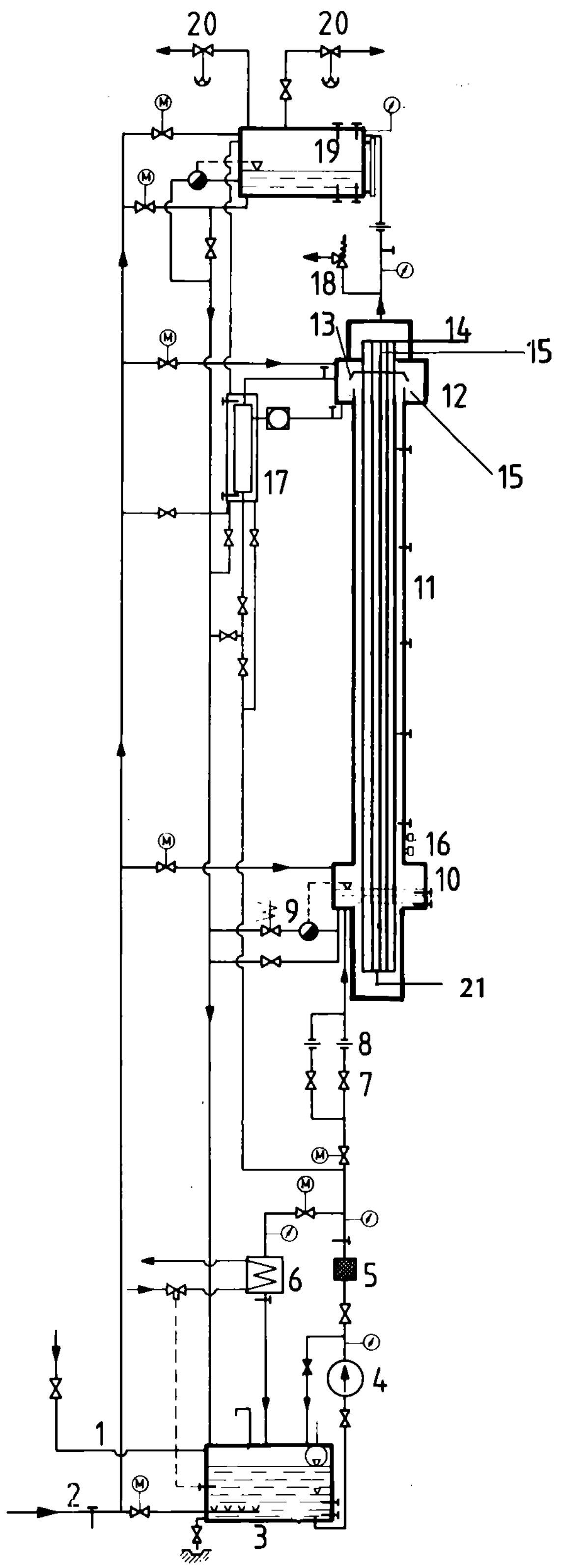
Series 4: Rods with argon-filled gaps between Zircaloy claddings and alumina pellets; 90% flow blockage with bypass; blockage at the bundle midplane of 3 x 3 rods placed in the corner of the 5 x 5 rod bundle; without grid spacer at the bundle midplane.
Investigation of the effects of rod clad properties, conductivity of gas filled gaps, grid spacers, and flow blockage.
Comparison with FEBA test series III and SEFLEX test series 3.

3. Test Loop

Figure 1 shows schematically the FEBA test facility with its main components. It is a forced flow bottom injection 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 fuel rod simulators. Entrained water droplets are transported upwards by the steam flow and may impinge on the steam water separator (13) placed above the test assembly. The liquid separated from the steam 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) and the back pressure control valve (10) to the atmosphere. 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.

For the performance of the FEBA test series [8], the heater rod instrumentation, which was completely embedded in the rod claddings, did exit from the lower end of the rod assembly as did the electric power connections for the heater rods. However, the instrumentation of the sleeve blockages was led to the top end of the housing such that the lead outs attached to the rod surfaces did not influence the two-phase mixture rising from the bottom.

For the performance of the SEFLEX test series, the heater rod instrumentation (15) and the electric power connections (14) for the heater rods were led out from the upper plenum (12). Therefore, the upper plenum (12) and the steam water separator (13) were modified as well as the lower plenum (10) where the REBEKA fuel rod simulators were filled with helium or argon gas, respectively (21). These modifications are described in the evaluation report [12].



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
21 Filling Gas Supply

Figure 1. FEBA test loop used for SEFLEX tests.

4. Test Section Design

Fuel rod simulators of PWR dimensions were used to simulate the nuclear fuel rods. Figure 2 shows the cross section of a gapless FEBA 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 (magnesium oxide), and then encapsulated in the clad of NiCr 80 20 which has a wall thickness of 1.0 mm. In contrast to a nuclear fuel rod with a Zircaloy cladding and a gas filled gap, this heater rod is a solid type widely used for thermal-hydraulic tests. A close thermal contact between cladding and filler material results from swaging of the rods.

Figure 3 shows the cross section of a REBEKA fuel rod simulator. This fuel rod simulator consists of an electrically heated rod of 6.0 mm outer diameter placed in the center of annular alumina pellets simulating fuel pellets. As for a nuclear rod, the pellets are encapsulated in the Zircaloy tube with a wall thickness of 0.725 mm. By pressurization of the rod with filling gas the gap between pellets and cladding is filled with helium or argon, respectively, to study the influence of the gap conductivity on the reflood behavior. The thickness of the Zircaloy cladding, the helium filling and the nominal gap width of 0.05 mm of a REBEKA rod are identical to a nuclear fuel rod at the beginning of life time. Heater rod and alumina pellets represent about 110 percent of the heat capacity of fuel pellets. The heat conductivity of argon corresponds roughly to that of the fission gas mixed with the helium after high fuel burn up.

Figure 4 shows a working drawing of a REBEKA fuel rod simulator of nominal geometry modified for the SEFLEX tests. Figure 5 shows a working drawing of REBEKA fuel rod simulators with artifically ballooned claddings as well as the instrumentation of the individual simulator types with thermocouples in axial and circumferential directions. The instrumention is described in detail in Section 5. To model a 90 percent flow blockage with bypass according to the corresponding FEBA blocked bundle configuration of test series III, three types of artificially ballooned Zircaloy claddings with different outer shape were produced. This was necessary to avoid side wall blockages as used for the FEBA tests. The cross sections of simulator type a and f, shown in Figure 5, indicate the geometries of regular ballooned rods and ballooned rods placed at the housing wall of the 3 x 3 rod cluster, respectively. A third type of simulator was used to constrict the coolant subchannel in the corner of the housing (see cross section of rod No. 21 shown in Figure 10). The required outer shape of the ballooned Zircaloy claddings was produced in a furnace by heating up the pressurized cylindrical tubes placed in correspondingly shaped molds. Subsequently, the ballooned claddings were cooled down very slowly to avoid any bursting or collapsing.

Figure 6 shows a sectional view of the rod bundle with coplanar 90 percent flow blockage and bypass investigated in the SEFLEX test series 3 and 4. The flow blockage was placed symmetrically to the bundle midplane (axial level 2025 mm) generating a local coolant channel constriction of nine subchannels of the 3 x 3 rod cluster. The balloons had an axial extension of 180 mm including the conical ends. The length of the 90 percent flow channel constriction amouted to 65 mm.

For comparison the coplanar 90 percent blockage configuration with bypass used for the FEBA tests is shown in Figure 7. Hollow sleeves of stainless steel were used to simulate ballooned rods. The sleeves were attached to the rods. For the simulation of the heat resistance between pellets and lifted cladding a gap of 0.8 mm width filled with stagnant steam was provided between the outer surface of the FEBA rod and the inner surface of the sleeve. In addition, side plate devices were placed between the sleeves of the peripheral rods and the housing walls for constriction of the coolant subchannels between the 3 x 3 rod cluster and the housing.

The outer shapes of the blockages, i. e. the geometry and the surface exposed to the coolant, were the same for both, the SEFLEX and FEBA arrays. However, the heat capacities and the radial compositions underneath the cooled surfaces were different from each other.

The remaining characteristics of both types of fuel rod simulators were the same. Figure 8 shows an axial layout of the fuel rod simulators. The cosine power profile of the rods with a heated length of 3900 mm were approximated by seven steps of specific power. The axial power profile was flat with a peak-to-average ratio of 1.19.

The 5 x 5 FEBA and 5 x 5 REBEKA rod bundles, respectively, were placed in a square stainless steel (AISI 316 Ti) shroud having an inner edge length of

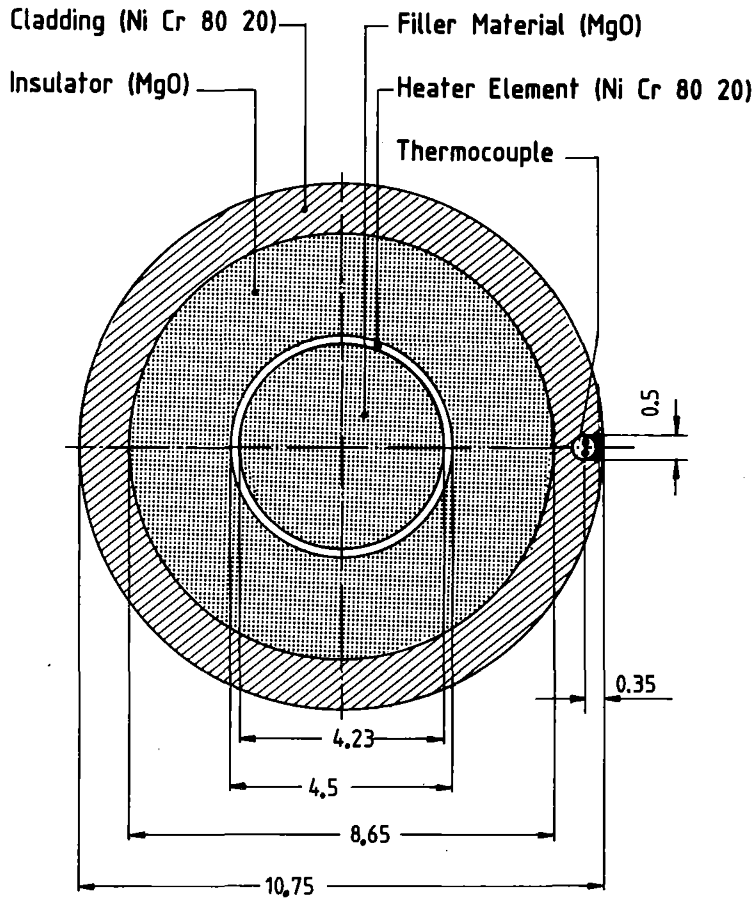


Figure 2. Cross section of a FEBA heater rod.

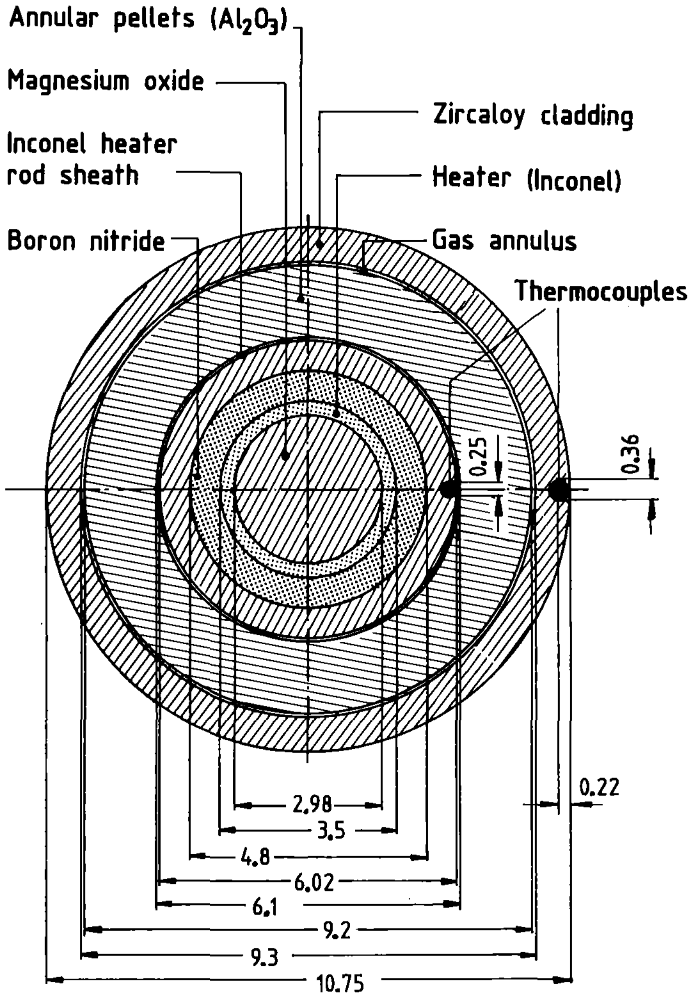


Figure 3. Cross section of a REBEKA fuel rod simulator.

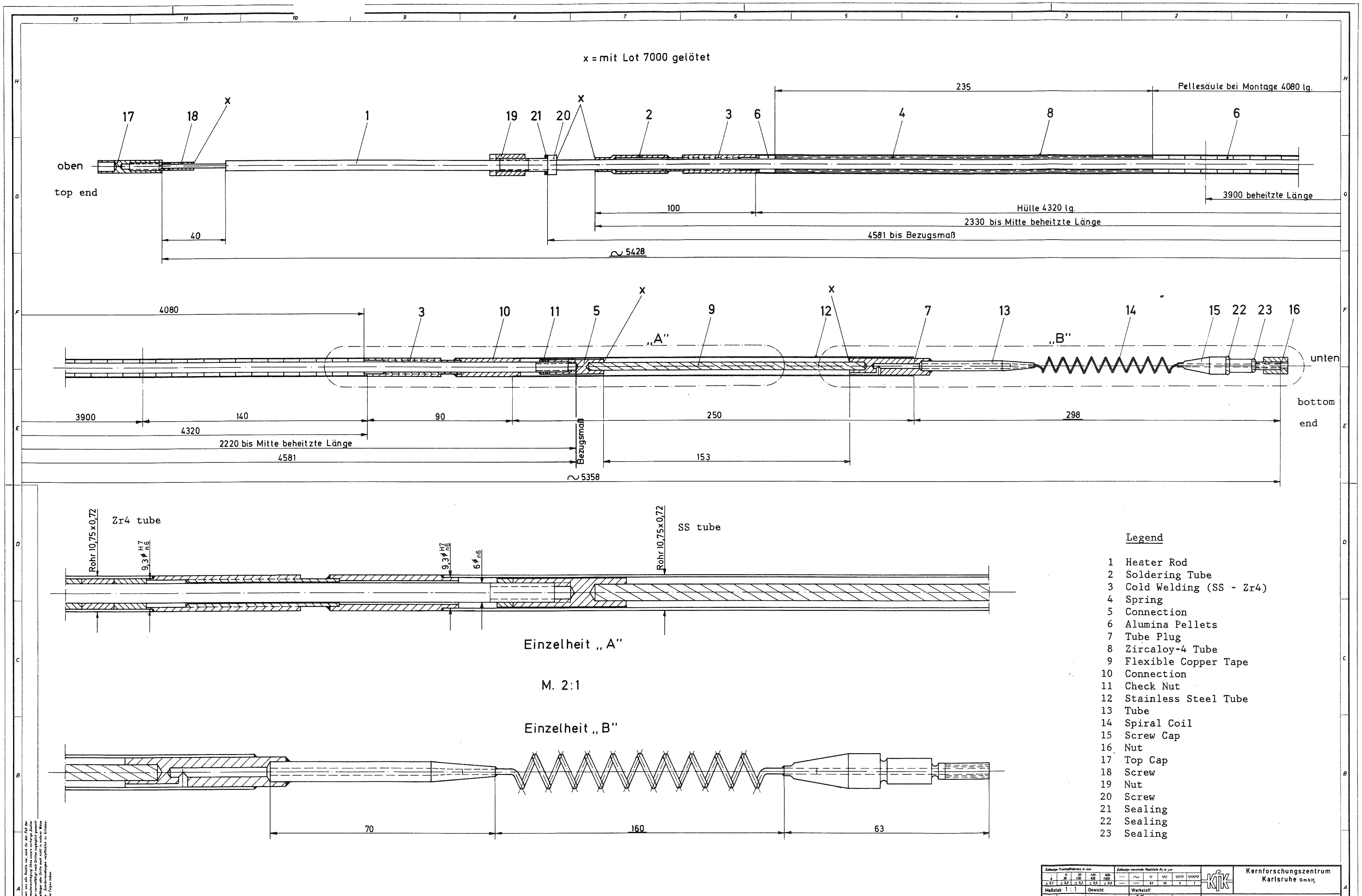
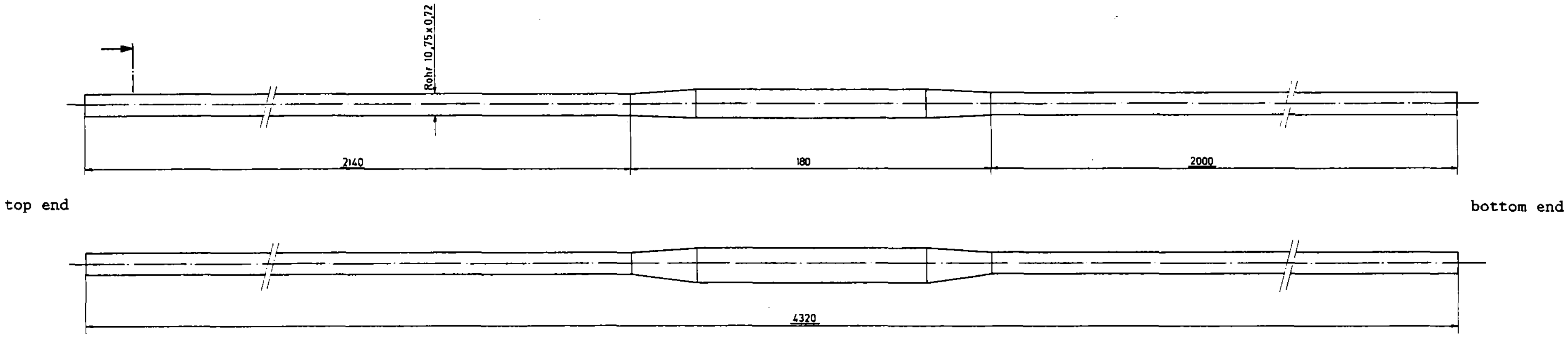
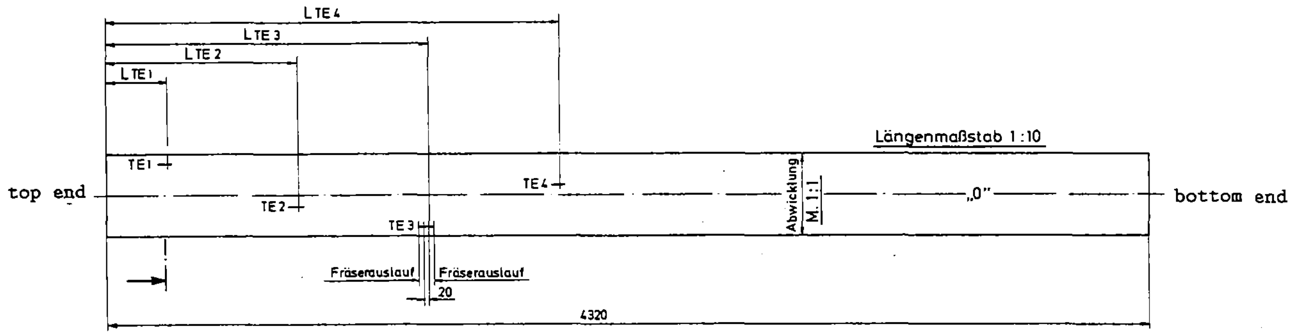


Figure 4. Working drawing of the REBEKA fuel rod simulator modified for SEFLEX tests.





Stückzahl	Simulator Typ	LTE1	LTE2	LTE3	LTE4	Blockade	Heizleiter Typ
1	a	2430	2975	3520	4065	——	
1	a	2430	2975	3520	4065	R2.39-2-23	a
1	b	250	795	1340	1885	——	
1	b	250	795	1340	1885	R2.39-2-23	b
1	f	2330	2430	2530	2630	——	
1	f	2330	2430	2530	2630	R2.39-2-24	
1	g	1830	1930	2030	2130	——	
1	g	1830	[1930]	[2030]	[2130]	R2.39-2-24	
1	j	1430	1530	1630	1730	——	
1	k	305	405	505	605	——	
2	l	2130	2180	2230	2280	——	l
2	l	[2130]	2180	2230	2280	R2.39-2-23	l

[ ] nicht fräsen, nur anreißen

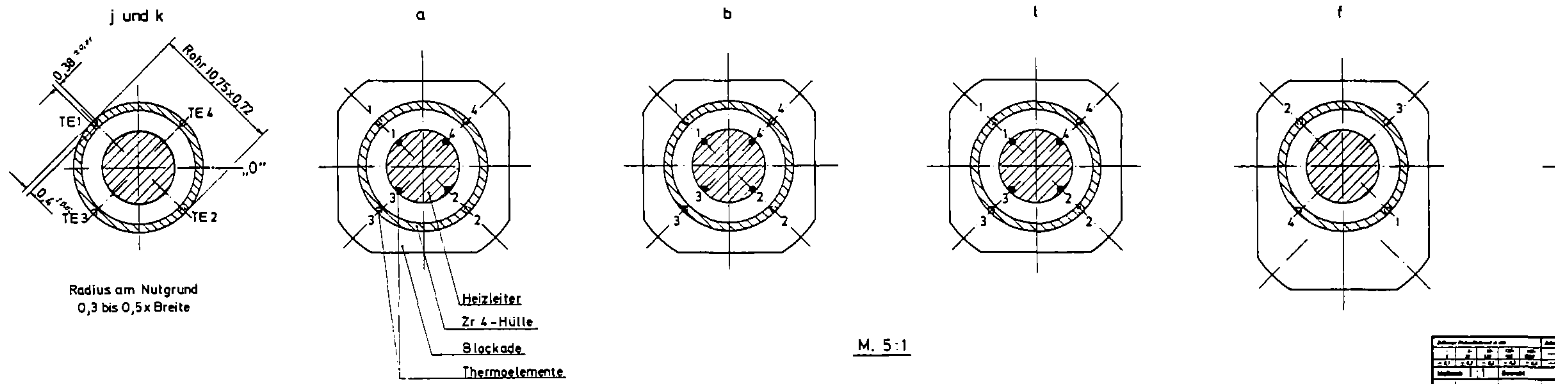


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Figure 5. Working drawing of ballooned REBEKA fuel rod simulators with instrumentation used for SEFLEX tests.

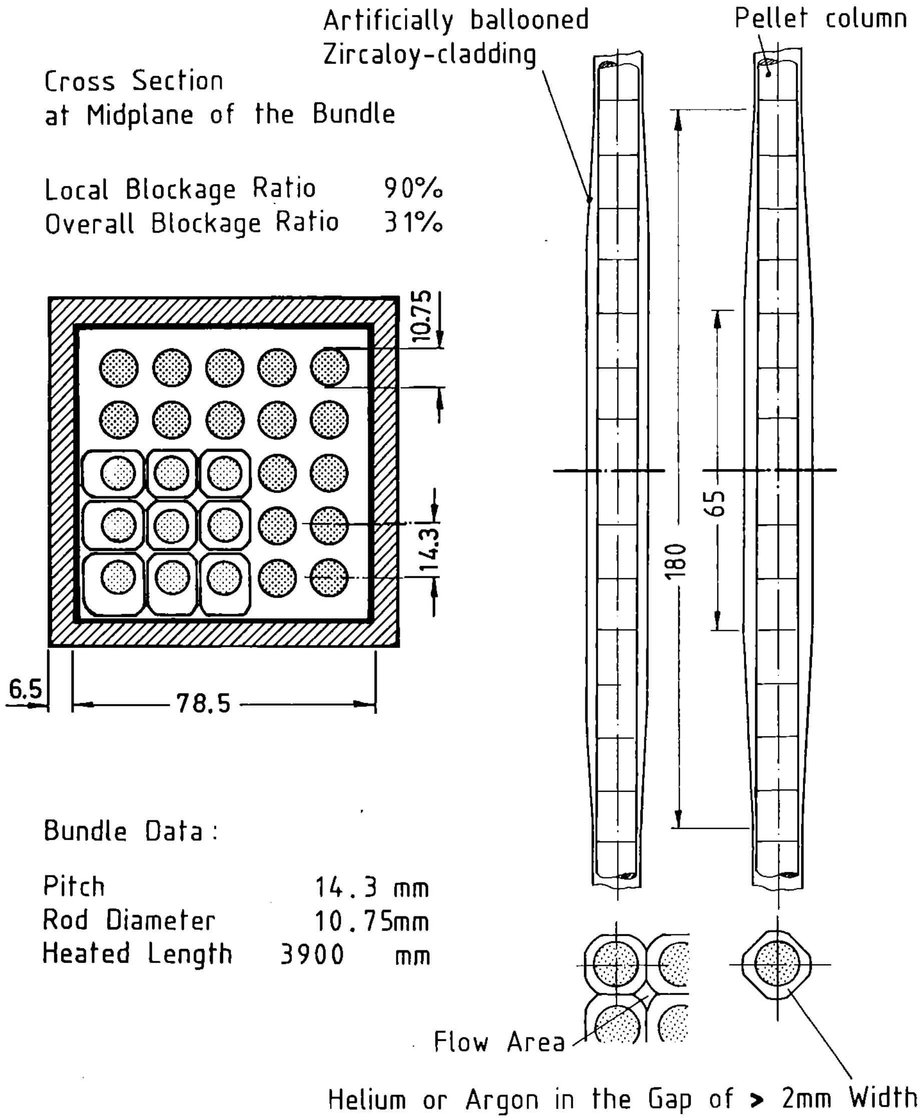


Figure 6. Sectional view of the 90 percent blockage with bypass realized for SEFLEX tests.

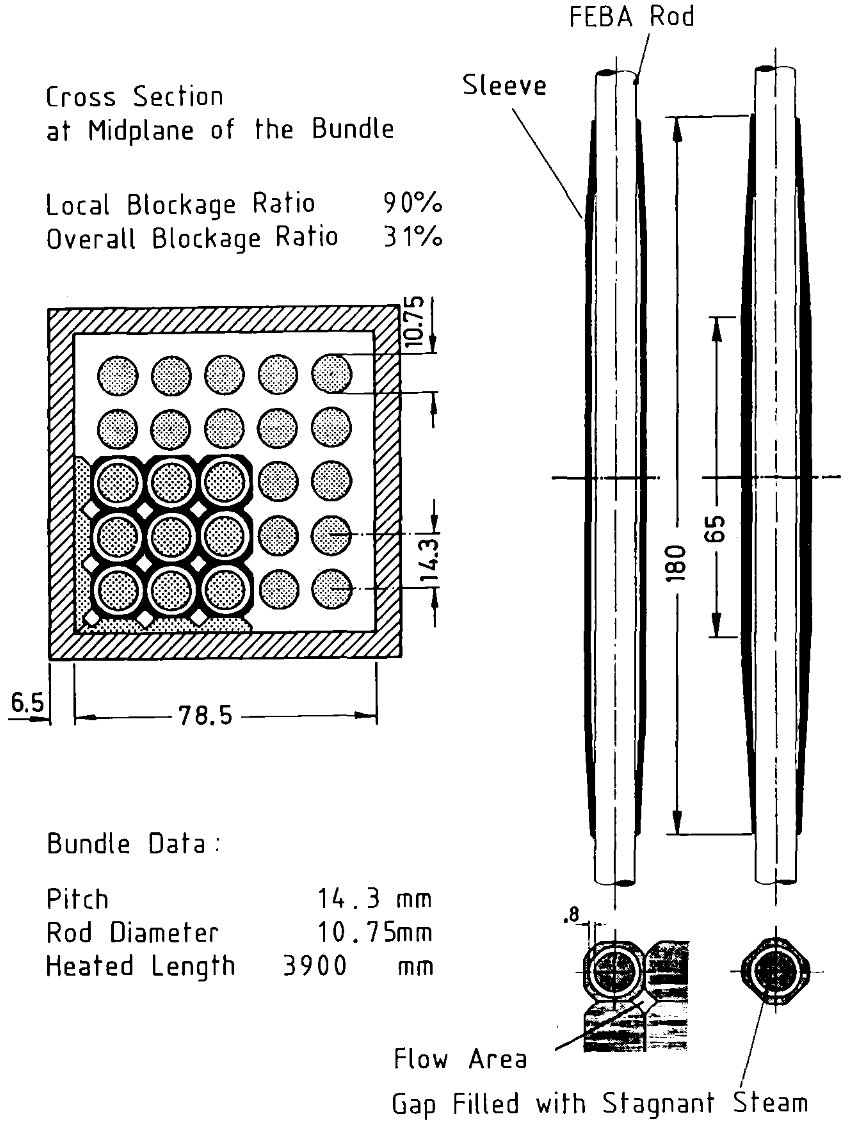


Figure 7. Sectional view of the 90 percent blockage with bypass realized for FEBA tests.

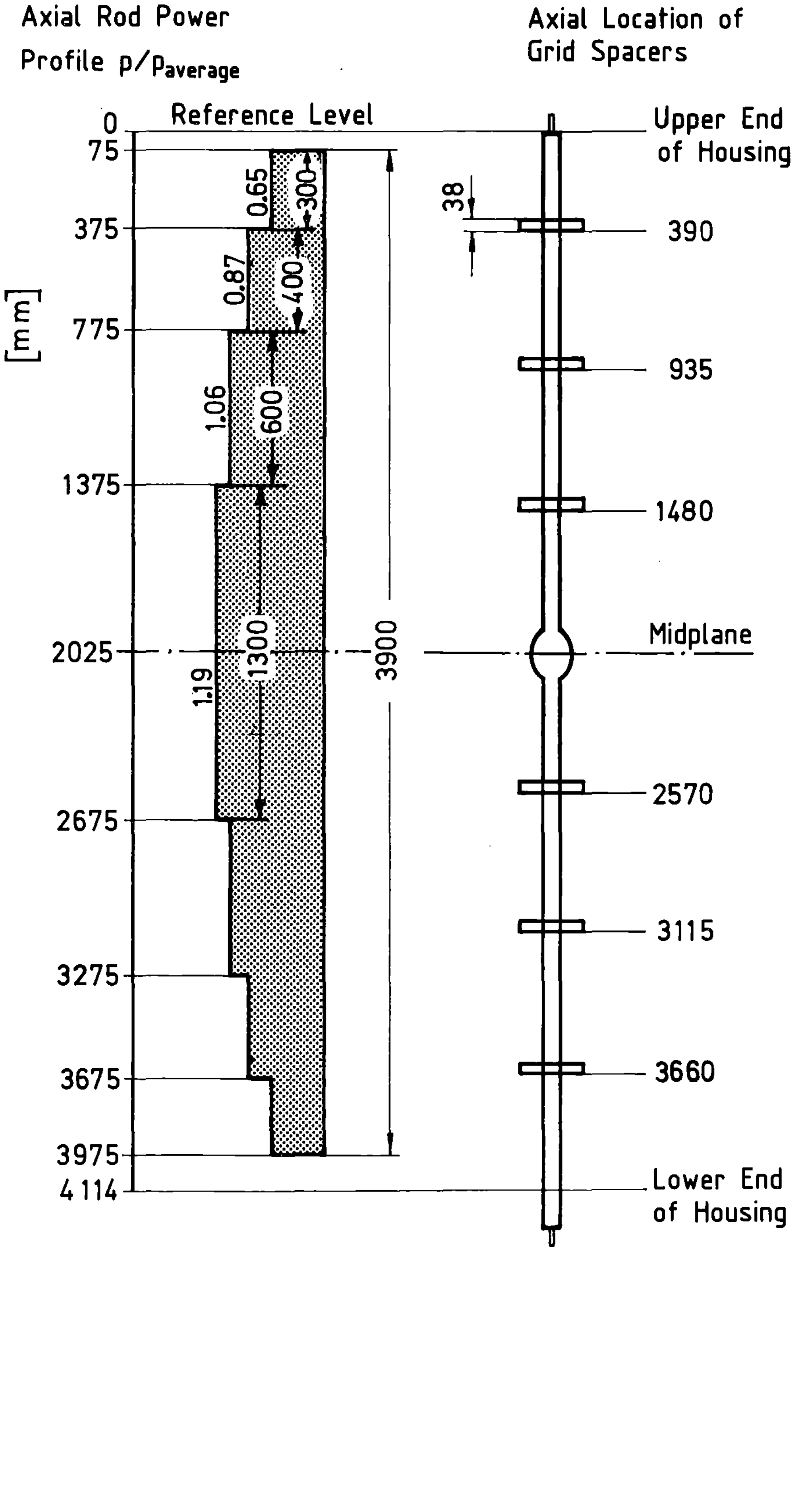


Figure 8. Axial power profile and location of flow blockage and grid spacers of FEBA and REBEKA rods used for SEFLEX tests.

78.5 mm and a wall thickness of 6.5 mm as shown in Figures 6 and 7. The housing was insulated at the outside to reduce the heat losses to the environment. The heater rods were bolted to the top flange of the test section. The upper end of the housing represented the reference or zero level for the axial measuring positions. Six original PWR grid spacers without mixing vanes were installed symmetrically to the blockage at the bundle midplane (axial level 2025 mm) at 545 mm intervals throughout the rod assemblies, i. e. no grid spacer was placed at the bundle midplane. The grid spacers of 38 mm height were attached to the rods by friction. They were sliding in the shroud in the case of different thermal extension of shroud and rod bundles in axial direction. At the lower bundle end, the individual rods were allowed moving in axial direction independently from each other as well as relative to the housing during temperature changes.

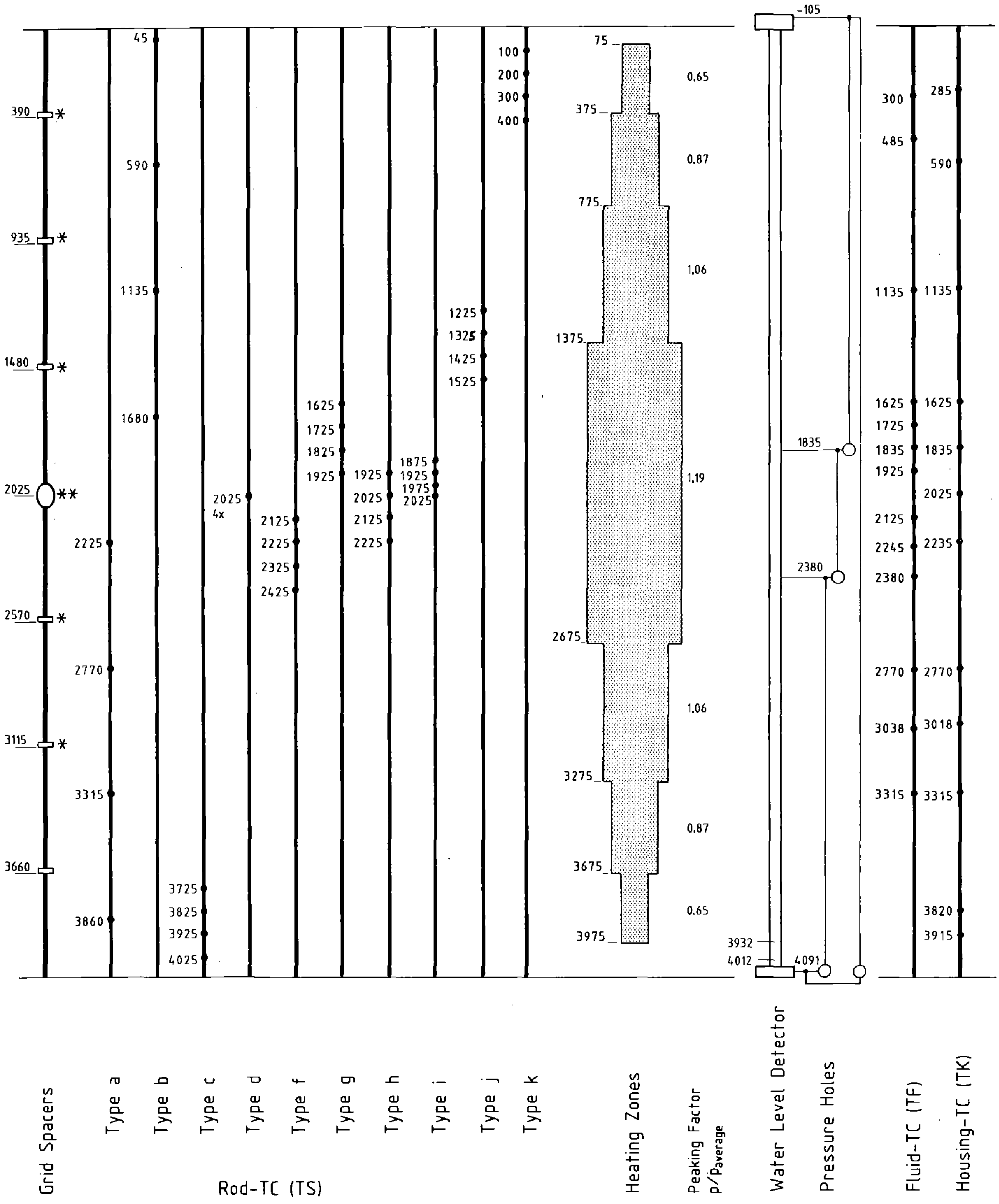
5. Instrumentation

Most part of the SEFLEX instrumentation consisted of thermocouples (Chromel-Alumel), since cladding (TS), heater sheath (TZ), grid spacer (TA), fluid (TF) and housing (TK) temperatures were to be measured at various positions. Figure 9 shows a schematic diagram of the axial levels of the thermocouples, the pressure and the differential pressure measuring positions. This diagram enables to relate the measuring positions to the blockage and the grid spacer positions as well as to the different specific power zones. Additional informations can be taken from the computer channel listing for SEFLEX test series 3 and 4 summarized in Section 11.

The cladding temperatures were measured with 0.36 mm sheath outer diameter thermocouples having an insulated junctions. These thermocouples were embedded in grooves of 20 mm length, which were milled into the outer surface of the Zircaloy claddings. The short grooves were closed by peening over to avoid any disturbance of the coolant flow.

The lead outs were attached to the outer surface of the Zircaloy claddings by very small and thin straps of Zircaloy which were spot welded to the claddings. For the instrumentation of the ballooned portion of the claddings the same method was applied with the difference that the thermocouple tips were not embedded in grooves but also were attached to the rods by using straps. This external instrumentation was necessary with respect to the reduced wall thickness of the balloons. A separate effects experiment program [17] conducted in the LOFT Test Support Facility (LTSF) at the Idaho National Engineering Laboratory (INEL) with REBEKA fuel rod simulators to evaluate the effect of cladding external thermocouples on the quench behavior indicated: "Cladding external thermocouples have a negligible effect on the cooldown rate and quench behavior of a REBEKA fuel rod simulator over the range of LOCA-type, high pressure thermal-hydraulic reflood conditions examined."

As shown in Figures 3 and 5, the heater rods placed in the center of the alumina pellets were instrumented for the conduction of SEFLEX test series 3 and 4. The temperature of the heater rod sheath with an outer diameter of 6.02 mm was measured with 0.25 mm sheath outer diameter thermocouples having insulated junctions. These thermocouples were embedded in grooves which were milled into the outer surface of the Inconel rod sheath. The grooves were



* Grid spacer instrumented
** Location of 90% blockage in series 3 and 4

Figure 9. Schematic diagram of SEFLEX instrumentation for blocked rod bundle tests.

closed by peening over to keep the thermocouples at the provided measuring positions and to maintain the geometry of the alumina pellets. The leads were led out at the top end of the rod bundle close to the insulated connections of the electrical rod power supply.

The grid spacer temperatures were measured with 0.5 mm outer sheath diameter thermocouples having insulated junctions. The tips of these thermocouples were placed each at about 2 mm from the leading and the trailing edges, respectively, of the grid spacers. The thermocouples were attached to the grid spacers by very small and thin straps of Zircaloy which were spot welded to the surface of the 0.38 mm thin grid spacer sheetings. The leads were led via trailing edge to the peripheral subchannels to avoid as far as possible any disturbance of the coolant flow.

The fluid temperatures were measured with unshielded thermocouples of 0.25 mm outer sheath diameter. The junctions protruded into the center of the individual bundle subchannels. The ability of such fluid thermocouples for measuring steam temperature is demonstrated in Ref. [8].

The housing temperatures were measured with 0.5 mm outer sheath diameter thermocouples placed from the outside close to the inner surface of the 6.5 mm thick housing wall.

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 portion of the bundle as well as along the bundle midplane. The flooding rate was measured with a turbo-flowmeter. The amount of water carried over was measured continuously by a pressure transducer at the water collecting tank.

All data were recorded with a scan frequency of 10 cycles per second using NEFF amplifiers, a PDP-11 mini-computer and disks for fast data recording.

6. Test Matrix

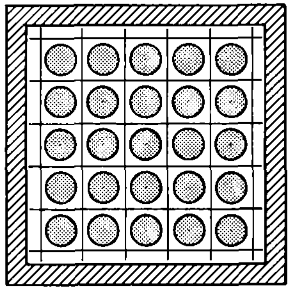
The main test parameters varied are shown in Table 3:

- Bundle geometry
- Gap gas filling
- Flooding rate given as flooding velocity, i.e. the velocity of the rising water level in the cold bundle
- System pressure.

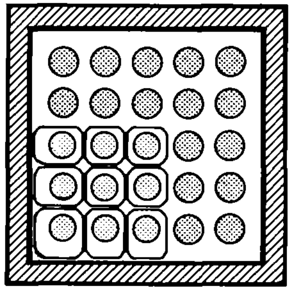
For the comparison of the reflood behavior of the two rod bundles consisting of either 5 x 5 FEBA or 5 x 5 REBEKA fuel rod simulators, the SEFLEX tests were carried out for a flooding velocity of 3.8 cm/s (in the cold bundle) and system pressures of 2.1 and 4.1 bar. The test operational procedures were also similar. For about two hours prior to reflood, the bundle was heated in an essentially stagnant steam environment to the desired initial temperature level using a low rod power. The power input was stepped up, when the rising water level reached the bottom end of the heated bundle length, to about 200 kW and decreased corresponding to the 120 percent ANS decay heat transient 40 seconds after reactor shutdown. Flooding velocity, system pressure, and feed-water temperature were kept constant during each test. The internal gas pressure was controlled to about 1 bar overpressure with respect to the system pressure.

Table 3

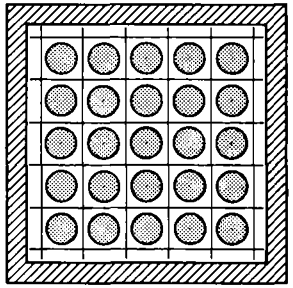
Test matrix of the SEFLEX-program



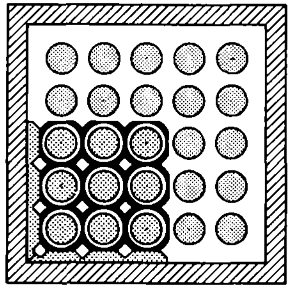
SEFLEX-Program
Test Series 1 and 2



SEFLEX-Program
Test Series 3 and 4
90% Blockage
Ballooned claddings



FEBA-Program
Test Series I



FEBA-Program
Test Series III
90% Blockage
Sleeve blockages

Program	Test Series	Test-No.	Rod Design	Cladding Material	Gap Gas Filling	Flooding Velocity cm/s	System Pressure bar	Feedwater Temperature °C	Reference Tests FEBA-Test	SEFLEX-Test
SEFLEX	1	05	REBEKA	Zircaloy	Helium	3.8	2.1	40	No. 223	No. 07
SEFLEX	1	03	REBEKA	Zircaloy	Helium	3.8	4.1	40	No. 216	
SEFLEX	1	06	REBEKA	Zircaloy	Helium	5.8	2.1	40	No. 218	
SEFLEX	1	04	REBEKA	Zircaloy	Helium	5.8	4.1	40	No. 214	
SEFLEX	2	07	REBEKA	Zircaloy	Argon	3.8	2.1	40	No. 223	No. 05
FEBA	I	223	FEBA	SS	gapless	3.8	2.1	40		No. 05 and 07
FEBA	I	216	FEBA	SS	gapless	3.8	4.1	40		No. 03
FEBA	I	218	FEBA	SS	gapless	5.8	2.1	40		No. 06
FEBA	I	214	FEBA	SS	gapless	5.8	4.1	40		No. 04
SEFLEX	3	32	REBEKA	Zircaloy	Helium	3.8	2.1	40	No. 241	
SEFLEX	3	35	REBEKA	Zircaloy	Helium	3.8	4.1	40	No. 239	
SEFLEX	4	33	REBEKA	Zircaloy	Argon	3.8	2.1	40	No. 241	
SEFLEX	4	34	REBEKA	Zircaloy	Argon	3.8	4.1	40	No. 239	
FEBA	III	241	FEBA	SS	gapless	3.8	2.1	40		No. 32 and 33
FEBA	III	239	FEBA	SS	gapless	3.8	4.1	40		No. 34 and 35

7. Data Informations

For the data transfer, data management, one-dimensional heat transfer analysis and data representation the modified and supplemented HETRAP-computer code [15] was used. The PEW-computer code [16] describing the thermophysical material properties was revised to incorporate the data of helium and argon gases [17].

This data report contains a large sampling of data from four reflood tests performed with a blocked bundle of 5 x 5 REBEKA fuel rod simulators with helium- and argon gas filled gaps, respectively, between the Zircaloy claddings and alumina pellets. The test conditions and results are described by the following tables, figures, plots and computer channel listings:

a) Summary and comment table.
Table 4 gives an overlook over the individual test runs, i.e. flooding velocity, system pressure, feedwater temperature, bundle power transient, gas filling.

b) Information figure for identification of rod bundle measuring position.
The upper part of Figure 10 shows the cross sectional geometry at the bundle midplane, the rod numbers, the type of rod instrumentation, the thermocouple numbers, the fluid thermocouples (TF), the housing thermocouples (TK), and the grid spacer thermocouples (TA).
The axial positions of the cladding instrumentation are listed in the lower part of the figure.

c) Layout of the bundle geometry.
The main purpose of Figure 11 is to identify the main measuring positions at the blockage, in the bypass, and in the vicinity, i. e. upstream and downstream of the bundle midplane, axial level 2025 mm. Again, it is to point out that all axial levels are referenced to the upper end of the housing (zero level).

d) Data plots of test series 3 and 4.
It should be noted that for each test run Zircaloy cladding temperatures versus reflood time were plotted which were measured at identical rods and elevations, respectively, if the measurement did not fail during the test

Table 4

SEFLEX-program: Main test parameters of test series 3 and 4.

SEFLEX test series 3

Rods with helium-filled gaps between Zircaloy claddings and alumina pellets. 90% flow blockage with bypass; blockage at the bundle midplane of 3 x 3 rods placed in the corner of the 5 x 5 rod bundle; without grid spacer at the bundle midplane.

Test No.	Flooding Velocity cm/s	System Pressure bar	Feedwater Temp.[1] °C		Bundle Power[2] kW		Gap Gas Filling[3]	Remarks
			0-30 s	End	0 s	Transient		
32	3.8	2.1	41	40	200	120% ANS	Helium	Figs. 12 to 51
35	3.8	4.1	52	42	200	120% ANS	Helium	Figs. 52 to 91

SEFLEX test series 4

Rods with argon-filled gaps between Zircaloy claddings and alumina pellets. 90% flow blockage with bypass; blockage at the bundle midplane of 3 x 3 rods placed in the corner of the 5 x 5 rod bundle; without grid spacer at the bundle midplane.

Test No.	Flooding Velocity cm/s	System Pressure bar	Feedwater Temp.[1] °C		Bundle Power[2] kW		Gap Gas Filling[3]	Remarks
			0-30 s	End	0 s	Transient		
33	3.8	2.1	44	41	200	120% ANS	Argon	Figs. 92 to 131
34	3.8	4.1	52	43	200	120% ANS	Argon	Figs.132 to 171

1) Measured in the lower plenum.
2) Decay heat transient corresponding to 120% ANS Standard 40 s after shut-down of the reactor.
3) The pressure of the gas filling depends on the system pressure. An over-pressure of 1 bar was selected for the gas filling.

run. The same is valid for the Inconel heater sheath temperatures, the grid spacer temperatures, fluid temperatures 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 temperature profile [°C] of the center rod claddings in axial direction [mm].
- Flooding parameters: Flooding velocity [cm/s], system pressure [bar] measured in the buffer, feedwater temperature [°C] and bundle power [kW].
- Cladding temperatures [°C] measured at fixed levels of 345 mm downstream of the leading edge of each grid spacer, i.e. axial levels 3860, 3315, 2770, 2225, 1680, 1135, 590, and 45 mm.

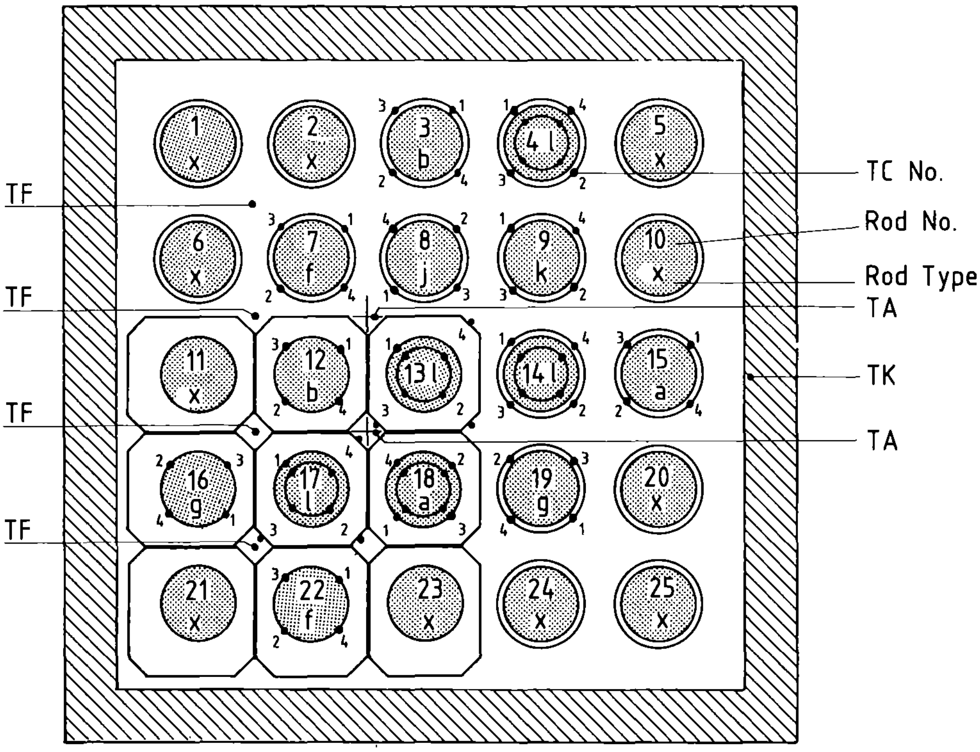
  Heat transfer coefficient [W/cmK] corresponding to the afore mentioned cladding temperatures.

  The heat transfer coefficients are the results of one-dimensional analyses and they are related to the saturation temperature corresponding to the system pressure. In contrast to all other data plotted in this report, a smoothing routine 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 the 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 for both the bypass region and the blocked region, i.e. axial levels 2425, 2325, 2225, and 2125 mm.

  Corresponding heat transfer coefficients.
- Cladding temperatures in the vicinity of the bundle midplane for both the bypass region and the blocked region, i. e. 2075, 2025, 1975 and 1925 mm.

  Corresponding heat transfer coefficients.
- Cladding temperatures measured downstream of the bundle midplane for both the bypass region and the blocked region, i.e. axial levels 1925, 1825, 1725 and 1625 mm.

  Corresponding heat transfer coefficients.
- Cladding temperatures measured about the grid spacer placed next to the



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
f	1	2125
	2	2225
	3	2325
	4	2425

Rod Type	TC No.	Axial Level mm
g	1	1625
	2	1725
	3	1825
	4	1925
j	1	1225
	2	1325
	3	1425
	4	1525
k	1	100
	2	200
	3	300
	4	400

Rod Type	TC No.	Axial Level mm
l	1	1925
	2	1975
	3	2025
	4	2075
x	without TC's	

Figure 10. Radial and axial positions of cladding, heater sheath, grid spacer, fluid and housing TC's for blocked rod bundle tests.

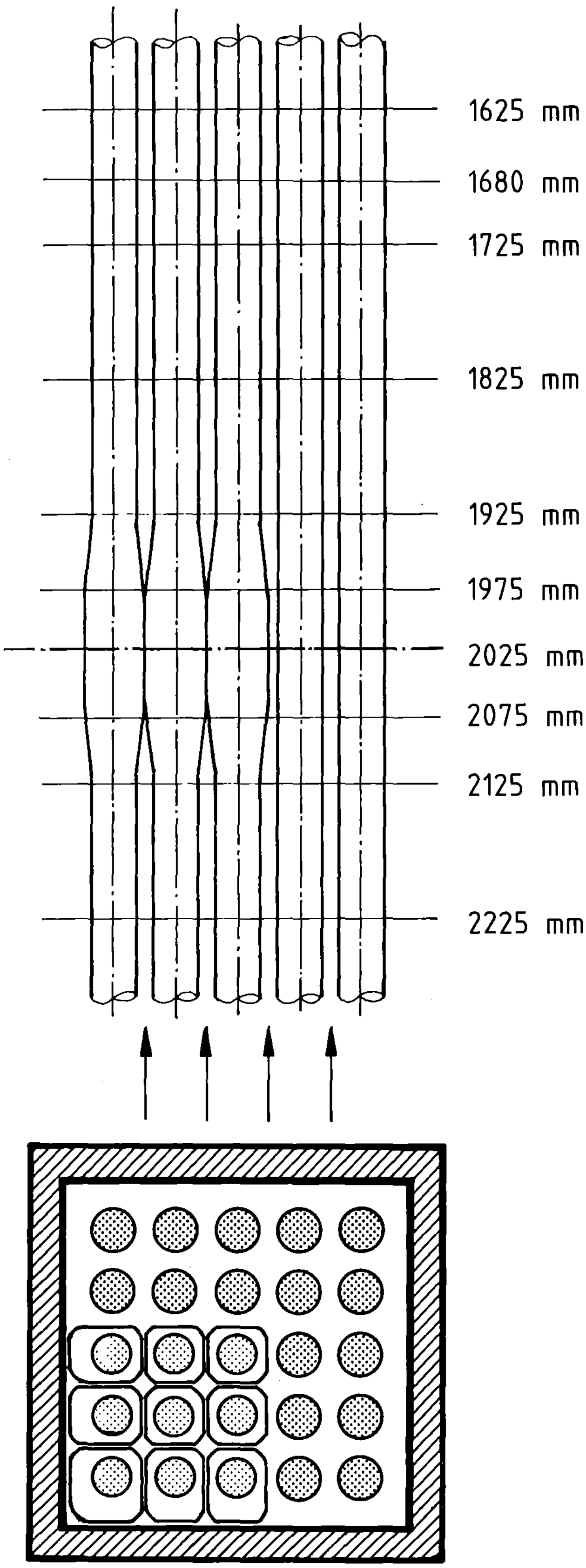


Figure 11. Sectional view of a blocked rod bundle at the midplane.

bundle midplane in flow direction, i.e. axial levels 1525, 1425, 1325, 1225 and 1135 mm.
Corresponding heat transfer coefficients.

- Cladding temperatures measured in the upper most bundle portion, i.e. axial levels 590, 400, 300, 200 and 100 mm.
  Corresponding heat transfer coefficients.
- Cladding and heater sheath temperatures measured at and downstream of the bundle midplane for both the bypass region and the blocked region, i. e. axial levels 2025 and 1925 mm.
- Grid spacer temperatures [°C] measured at the leading and trailing edges, respectively, in case of instrumentation of both positions.
- Cladding, fluid, and housing temperatures measured at the same axial positions.
- Pressure drop [bar] along the entire bundle length, the lower portion of the bundle, the bundle midplane, and the upper portion of the bundle.
- Coolant outlet: water carry over [kg] measured in the water collecting tank, steam temperature [°C], and pressure [bar] both measured in the upper plenum.
- Axial position of the quench front [mm] as function of reflood time for the bundle portion upstream of the bundle midplane. For the upper most portion of the rod bundle, a data scattering of the quench times has been observed even for the FEBA tests. It is assumed that this more pronounced effect arising in the SEFLEX tests results from the influence of the blockage and possibly from the instrumentation. Therefore, the quench times of the individual TC's are marked by symbols only instead of a solid curve.

Note: Test No. 35 of test series 3 and test No. 34 of test series 4 are limited in their validity because of heater rod failures:

a) Test No. 35
   Rod No. 13 failed from beginning of the test.
   Rod No. 17 failed during the test after 190 s reflood time.
   Shut off of power supply after 330 s reflood time.

b) Test No. 34
   Rod No. 13 failed during the test after 225 s reflood time.

8. References

[1] C. Vitanza et al.:
"Blowdown/Reflood Tests With Nuclear Heated Rods, (IFA-511.2)."
OECD Halden Reactor Project, HPR 248, May 1980.

[2] T. Johnsen and C. Vitanza:
"Blowdown/Reflood Tests With SEMISCALE Heaters, (IFA-511.3, Data Collection)."
OECD Halden Reactor Project, HWR 17, May 1981.

[3] T. Johnsen and C. Vitanza:
"Results of LOCA Tests With SEMISCALE Heaters, (IFA-511.5)."
OECD Halden Reactor Project, HPR 313, May 1984.

[4] C. Vitanza and T. Johnsen:
"Results of Blowdown/Reflood Tests With REBEKA Electric Simulators, (IFA-511.4, Cycle 2)."
OECD Halden Reactor Project, HWR 85, May 1983.

[5] F.J. Erbacher:
"Interaction Between Fuel Clad Ballooning and Thermal-Hydraulics in a LOCA."
KfK 3880, Vol. 1, December 1984, pp. 299-310.

[6] B.D.G. Pigott and R.B. Duffey:
"The Quenching of Irradiated Fuel Pins."
Nuclear Engineering and Design, Vol. 32, 1975, pp. 182-190.

[7] V.K. Dhir and I. Catton:
"Reflood Experiments With a 4-Rod Bundle."
EPRI NP-1277, December 1979.

[8] P. Ihle and K. Rust:
"FEBA - Flooding Experiments With Blocked Arrays, Evaluation Report."
KfK 3657, March 1984.

[9] M.J. Loftus et al.:
"PWR FLECHT-SEASET, 21-Rod Bundle Flow Blockage Task, Data and Analysis Report."
NUREG/CR-2444, EPRI NP-2014, WCAP-9992, Vol. 1 and 2, September 1982.

[10] K.G. Pearson and L.A. Cooper:
"Reflood Heat Transfer in Severely Blocked Fuel Assemblies."
NUREG/CP-0060, December 1984, pp. 643-671.

[11] P. Ihle and K. Rust:
"FEBA - Flooding Experiments With Blocked Arrays, Data Report 1: Test Series I Through IV."
KfK 3658, March 1984.

"FEBA - Flooding Experiments With Blocked Arrays, Data Report 2: Test Series V Through VIII."
KfK 3659, March 1984.

[12] P. Ihle and K. Rust:
"SEFLEX - Fuel Rod Simulator Effects in Flooding Experiments,
Part 1: Evaluation Report."
KfK 4024, March 1986.

[13] P. Ihle and K. Rust:
"SEFLEX - Fuel Rod Simulator Effects in Flooding Experiments,
Part 2: Unblocked Bundle Data."
KfK 4025, March 1986.

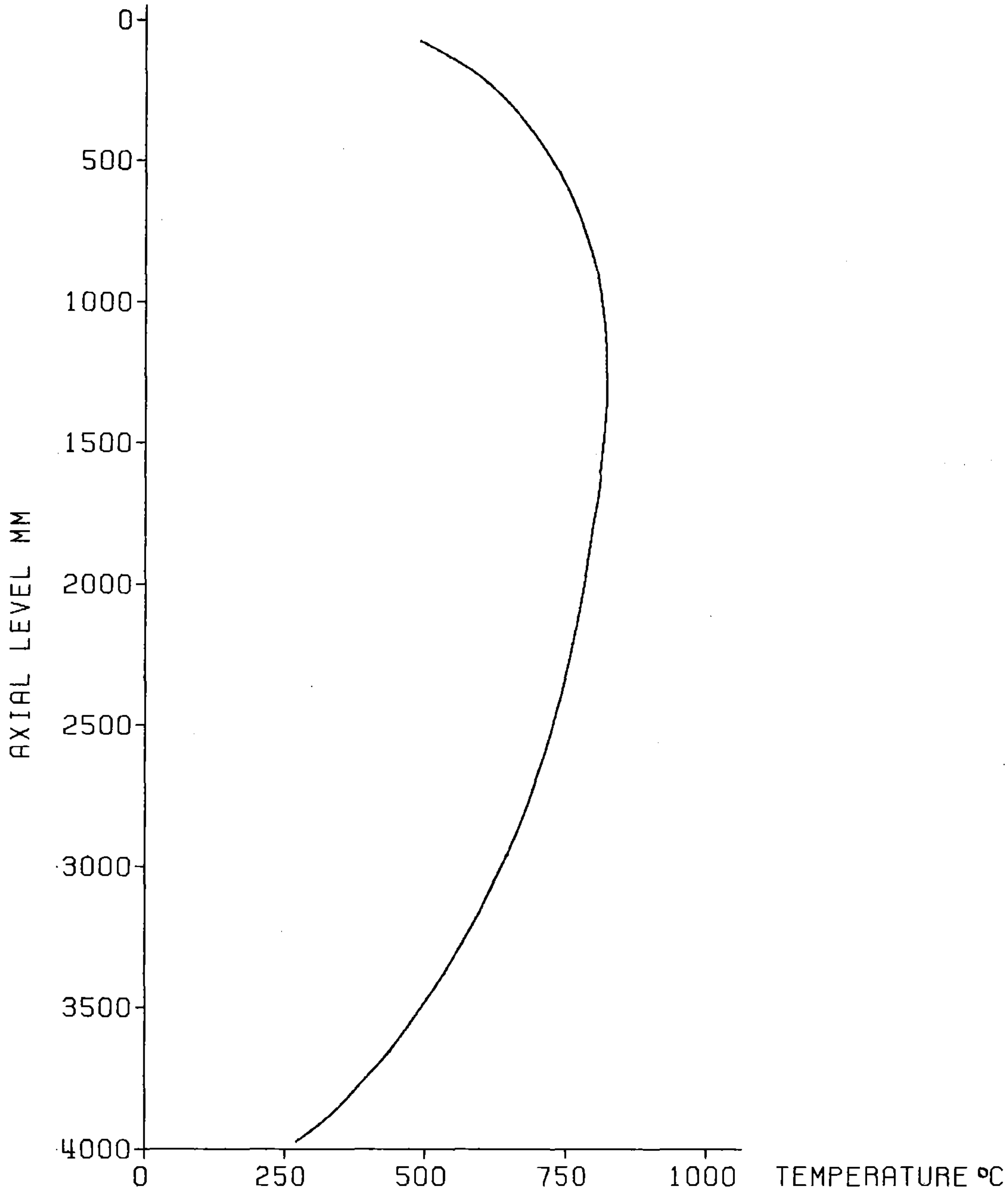
[14] R.C. Gottula:
"Effects of Cladding Surface Thermocouples and Electrical Heater Rod
Design on Quench Behavior."
NUREG/CR-2691, EGG-2186, February 1984.

[15] S. Malang:
"HETRAP - A Heat Transfer Analysis Program."
ORNL-TM-4555, September 1974.

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

[17] N.B. Vargaftik:
"Tables on the Thermophysical Properties of Liquids and Gases."
John Wiley & Sons, Inc., New York 1975.

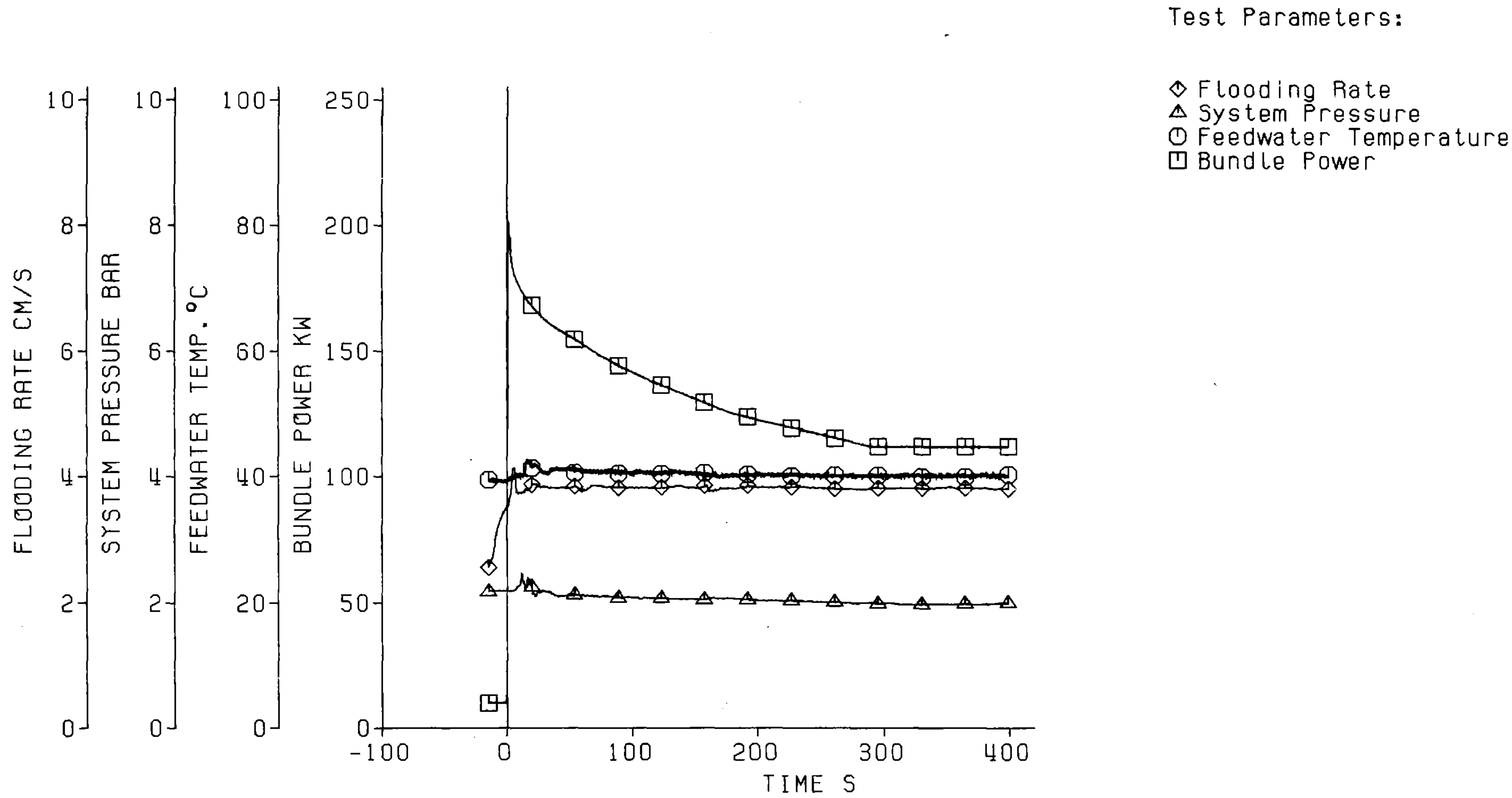
Initial Axial Temperature Profile of Claddings
REBEKA Rods With Helium Filled Gaps



Decay Heat	120% ANS Standard
Flooding Rate (cold)	3.82 cm/s
System Pressure	2.01 bar
Feedwater Temperature	40 °C

KfK IRB

Fig. 12 SEFLEX: 5x5 RØD BUNDLE
TEST SERIES 3, TEST-No. 32

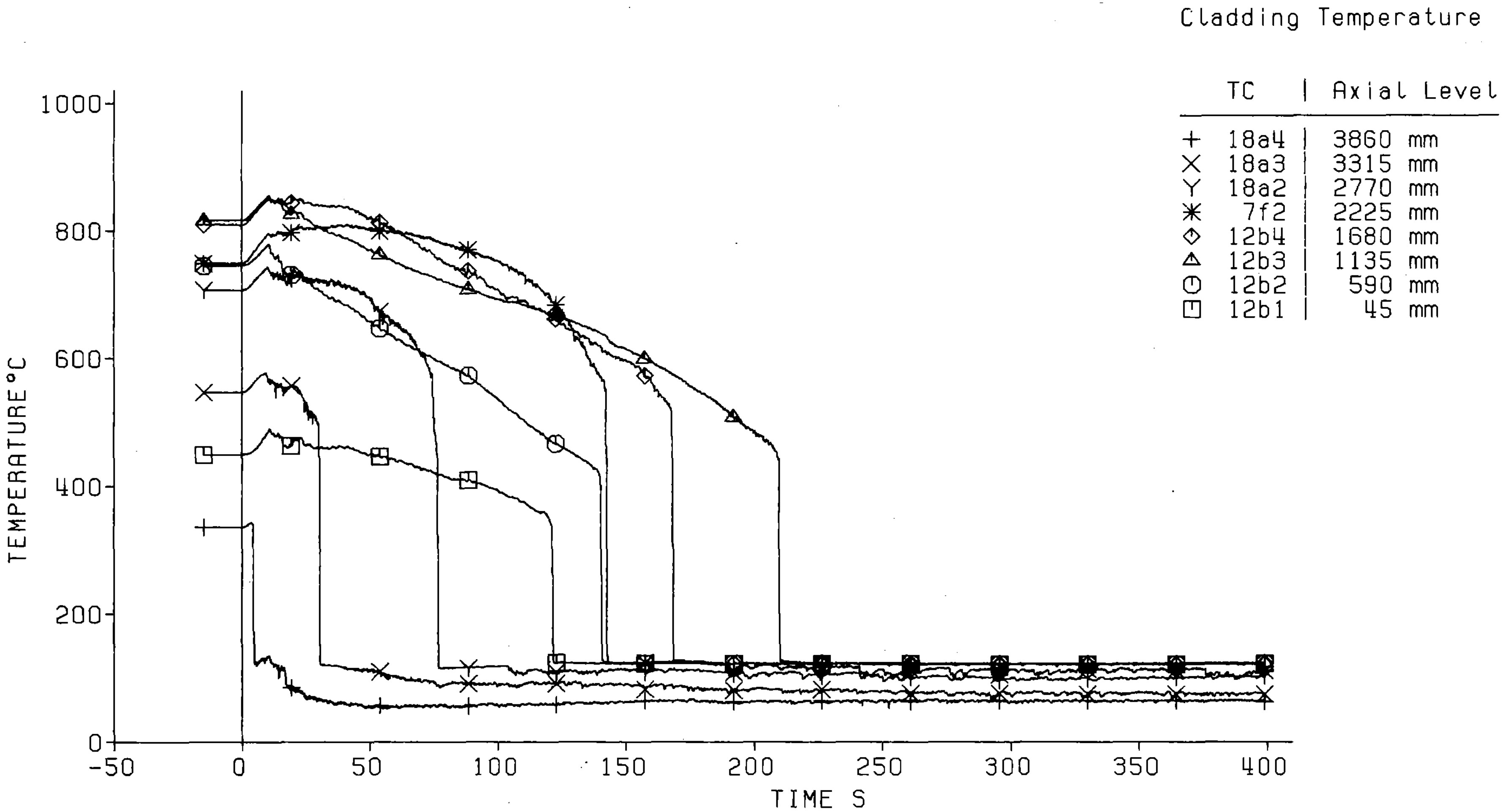


Decay Heat	120% ANS Standard
Flooding Rate (cold)	3.82 cm/s
System Pressure	2.01 bar
Feedwater Temperature	40°C

REBEKA Rods With
Helium Filled Gaps

KfK IRB

Fig. 13 SEFLEX: 5x5 RØD BUNDLE, SERIES 3, TEST-No. 32

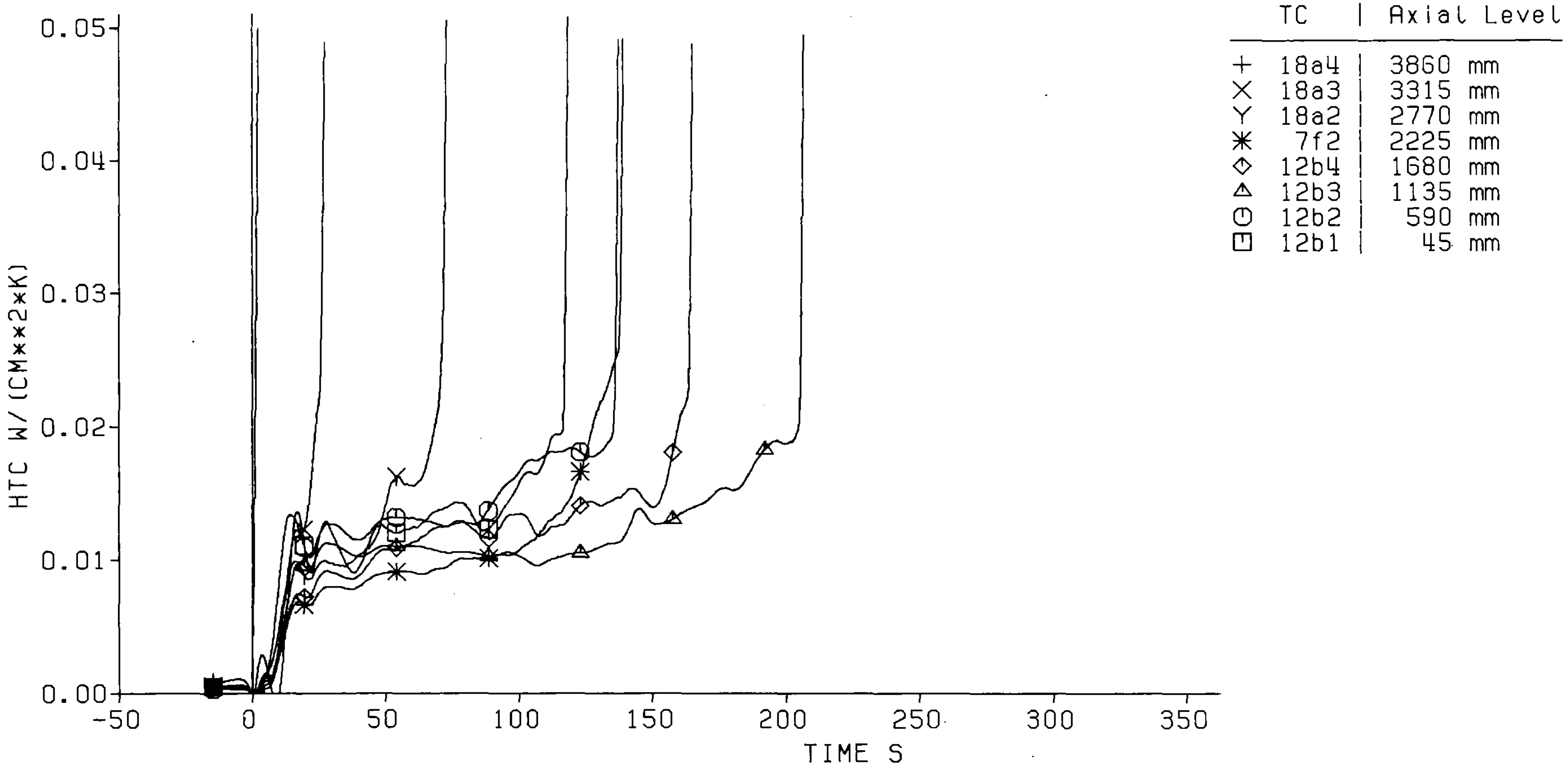


Decay Heat	120% ANS Standard
Flooding Rate (cold)	3.82 cm/s
System Pressure	2.01 bar
Feedwater Temperature	40 °C

REBEKA Rods With Helium Filled Gaps

KfK IRB

Fig. 14 SEFLEX: 5x5 RØD BUNDLE, SERIES 3, TEST-No. 32

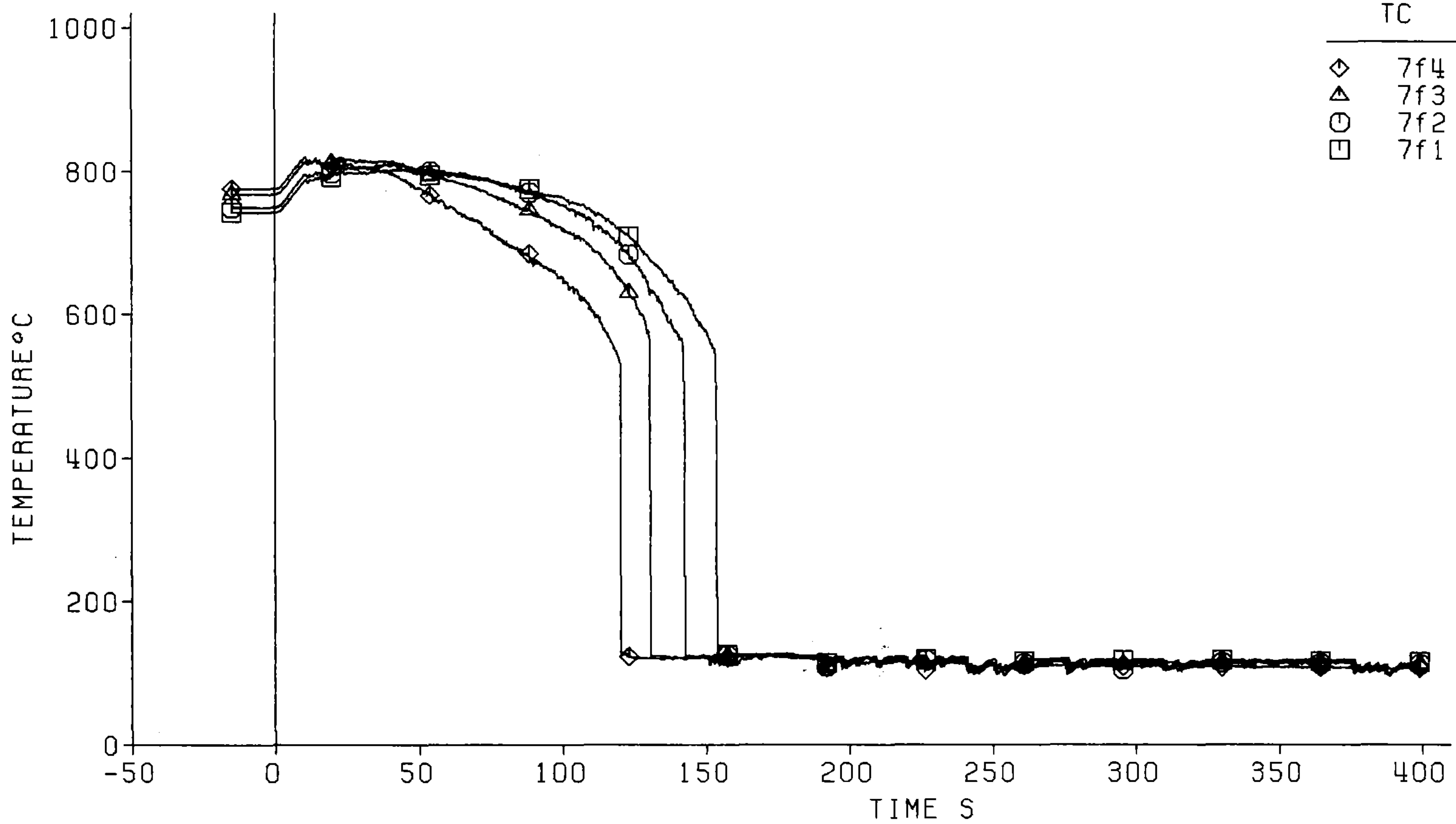


Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.82 cm/s
System Pressure 2.01 bar
Feedwater Temperature 40°C

REBEKA Rods With
Helium Filled Gaps

KfK IRB

Fig. 15 SEFLEX: 5x5 RØD BUNDLE, SERIES 3, TEST-No. 32



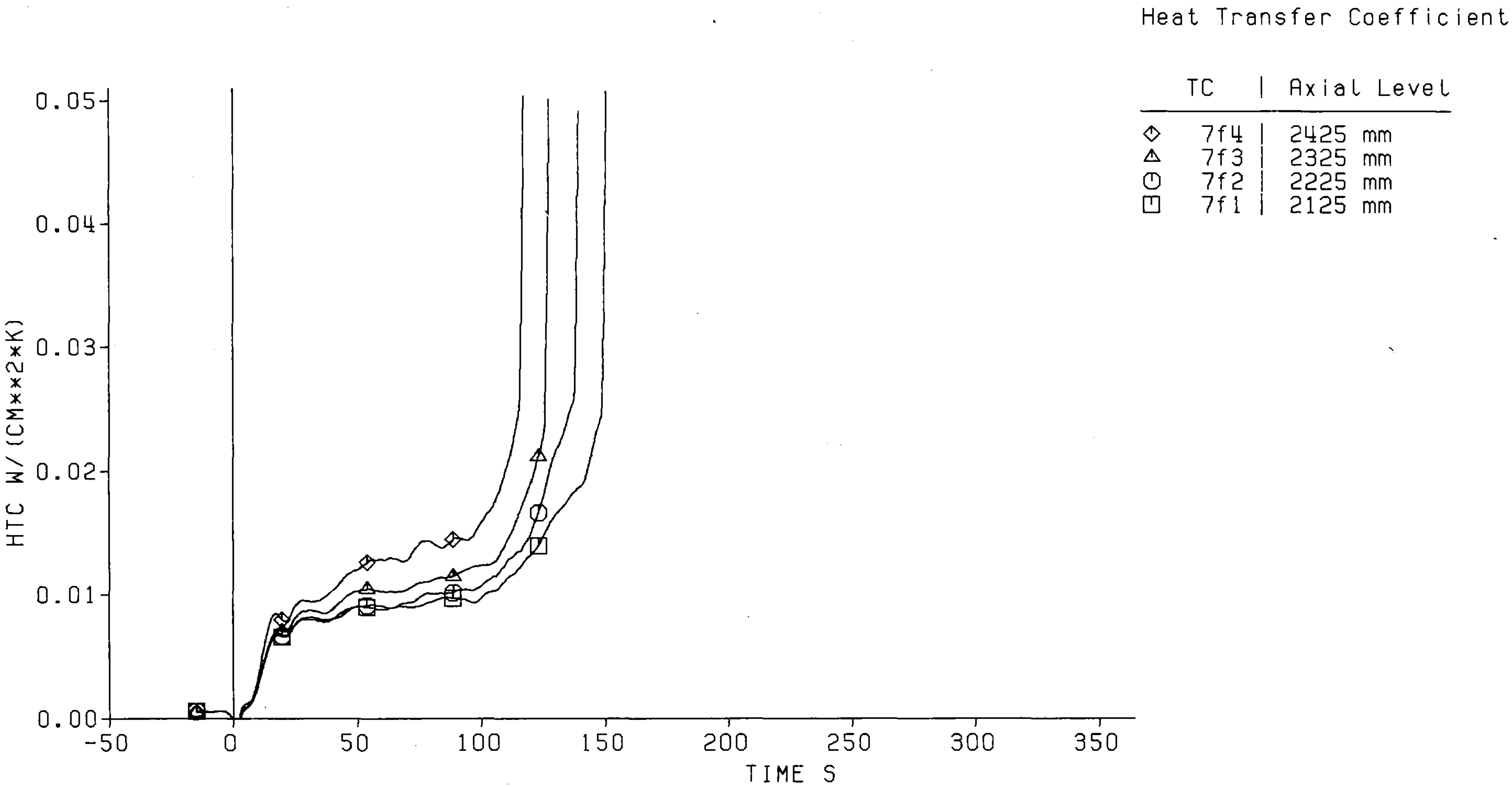
Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.82 cm/s
System Pressure 2.01 bar
Feedwater Temperature 40 °C

REBEKA Rods With
Helium Filled Gaps

Bypass
======

KfK IRB

Fig. 16 SEFLEX: 5x5 RØD BUNDLE, SERIES 3, TEST-No. 32



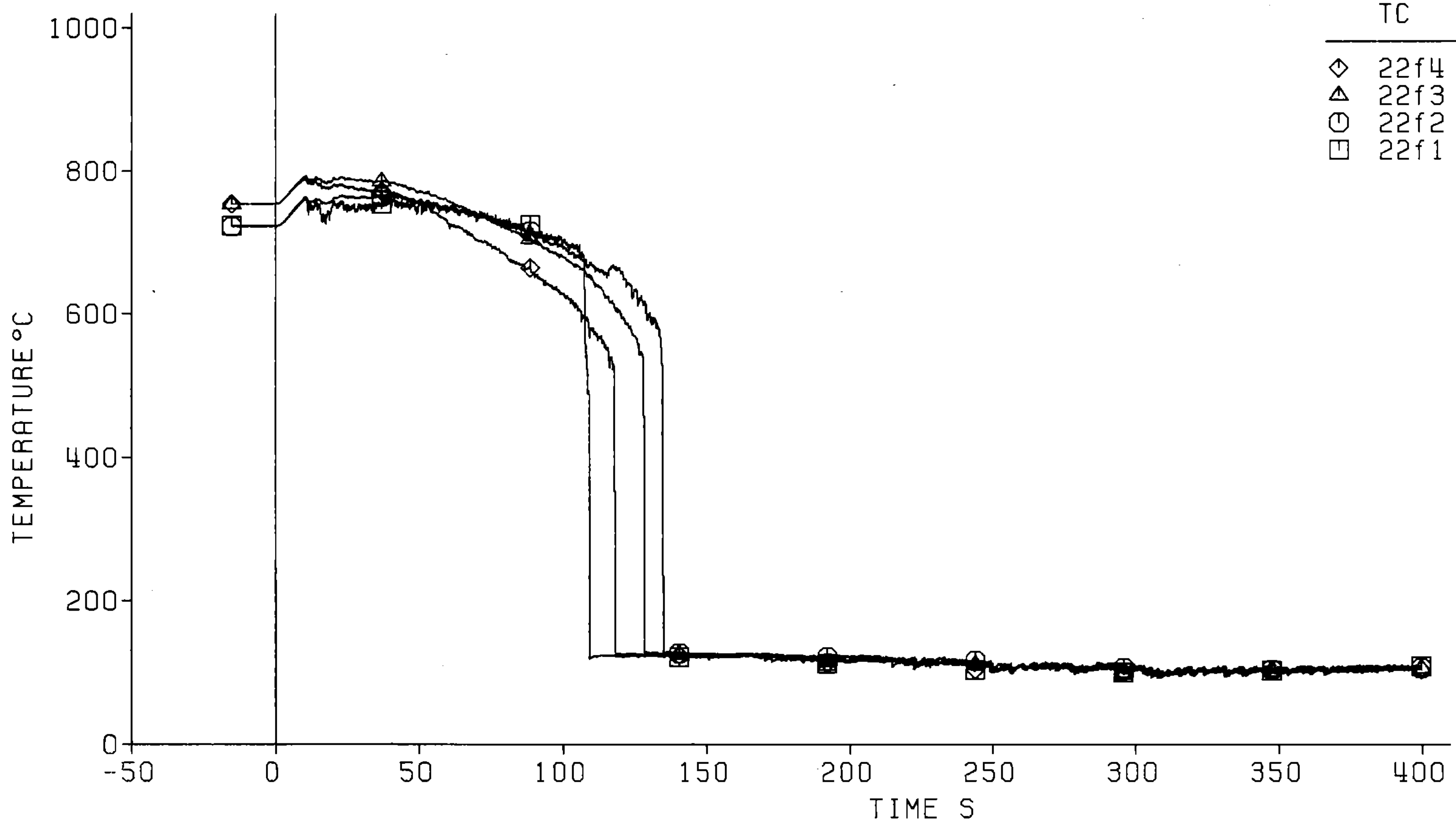
Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.82 cm/s
System Pressure 2.01 bar
Feedwater Temperature 40°C

REBEKA Rods With
Helium Filled Gaps

Bypass
======

KfK IRB

Fig. 17 SEFLEX: 5x5 RØD BUNDLE, SERIES 3, TEST-No. 32



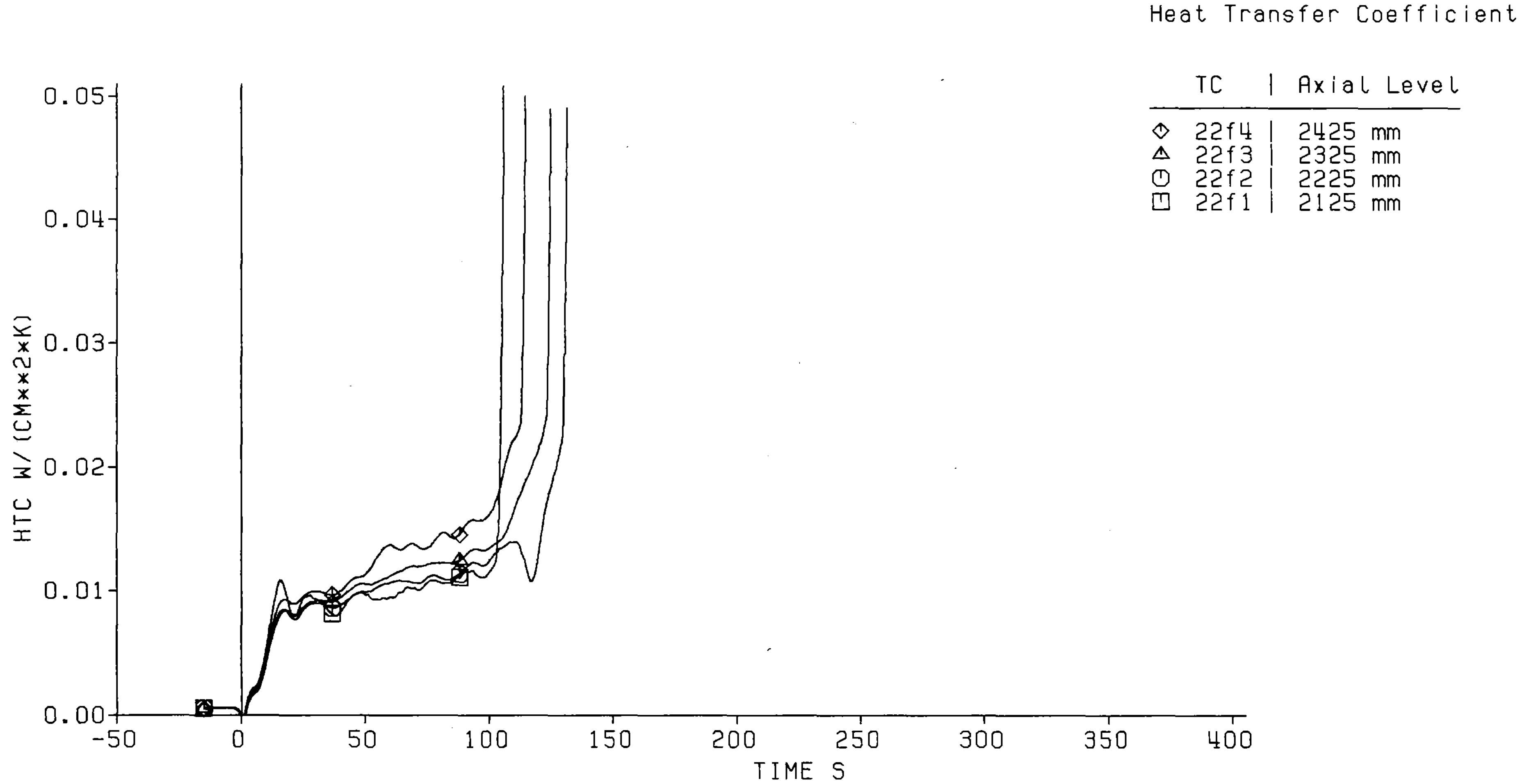
Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.82 cm/s
System Pressure 2.01 bar
Feedwater Temperature 40 °C

REBEKA Rods With
Helium Filled Gaps

Blockage
========

KfK IRB

Fig. 18 SEFLEX: 5x5 RØD BUNDLE, SERIES 3, TEST-No. 32



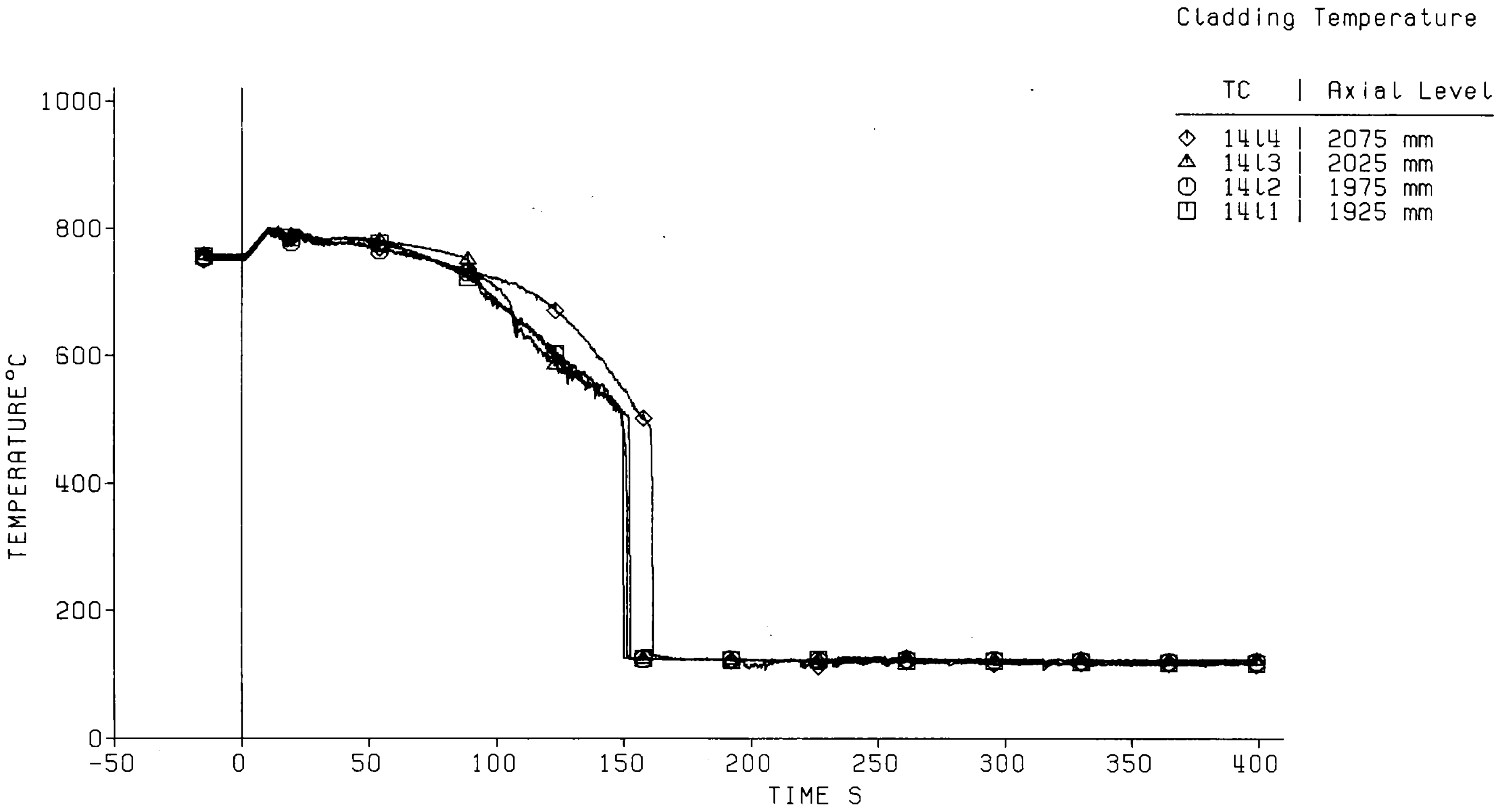
Decay Heat	120% ANS Standard
Flooding Rate (cold)	3.82 cm/s
System Pressure	2.01 bar
Feedwater Temperature	40 °C

REBEKA Rods With
Helium Filled Gaps

Blockage
========

KfK IRB

Fig. 19 SEFLEX: 5x5 RØD BUNDLE, SERIES 3, TEST-No. 32



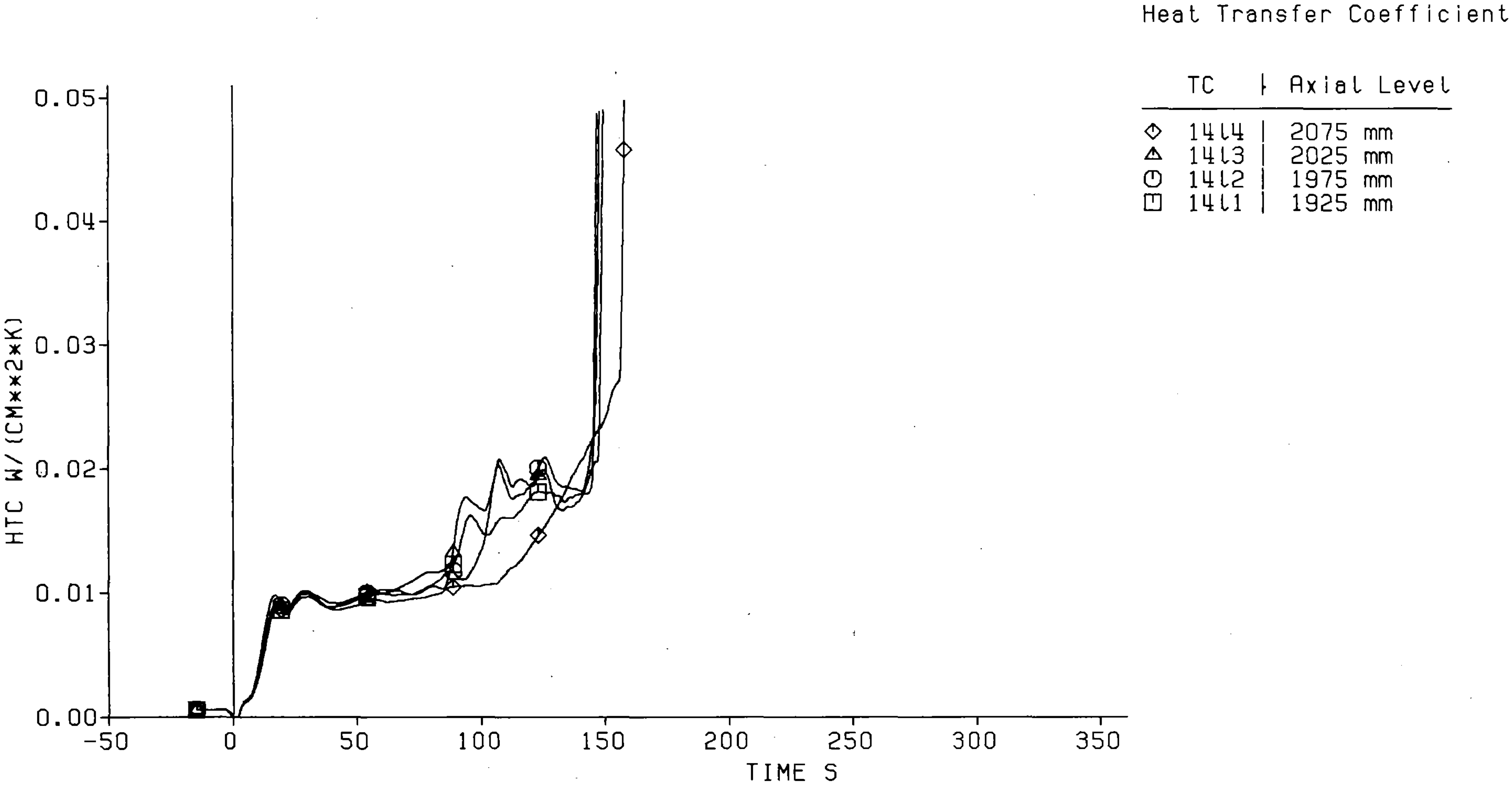
Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.82 cm/s
System Pressure 2.01 bar
Feedwater Temperature 40°C

REBEKA Rods With
Helium Filled Gaps

Bypass
======

KfK IRB

Fig. 20 SEFLEX: 5x5 RØD BUNDLE, SERIES 3, TEST-No. 32



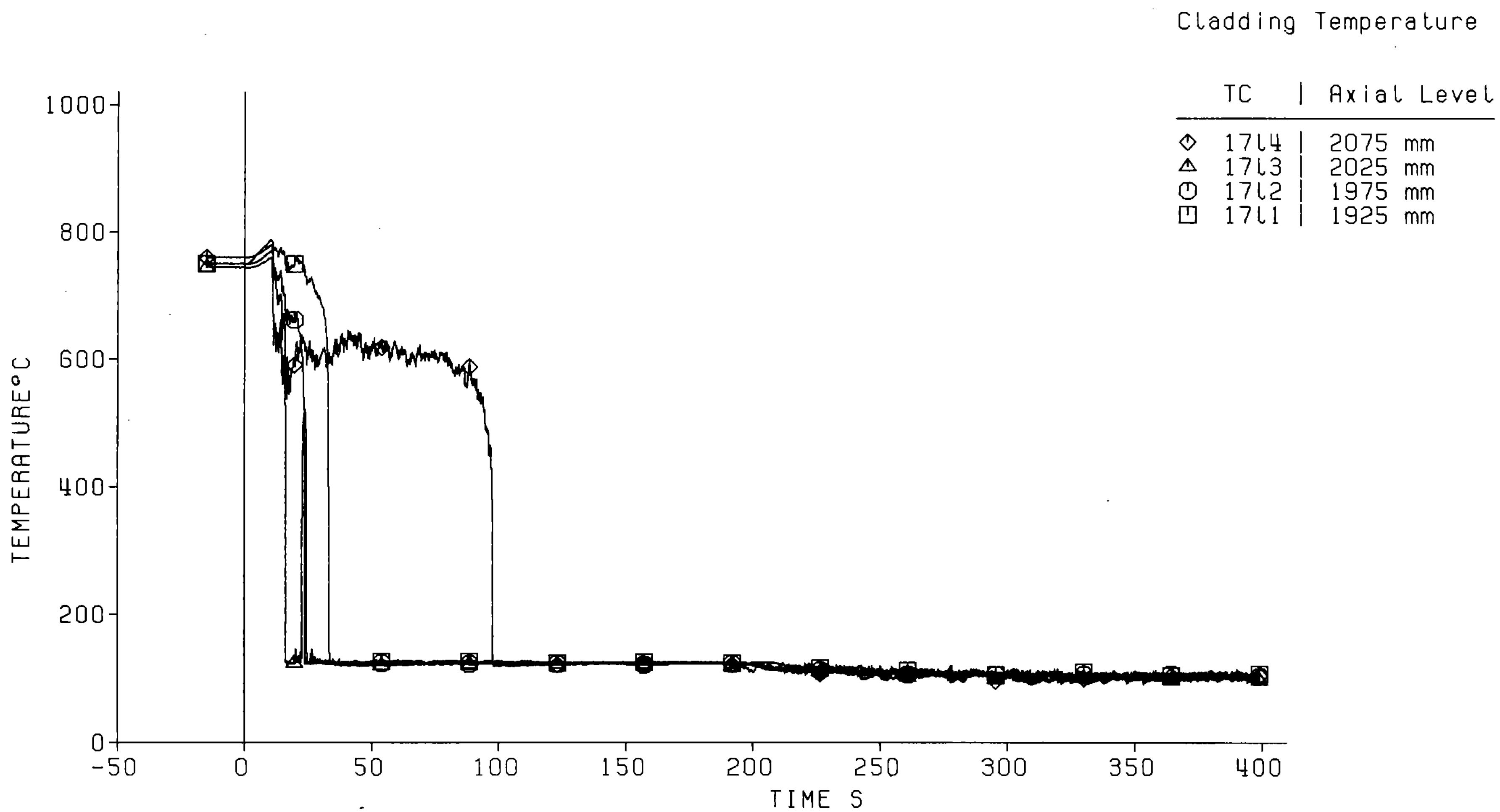
Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.82 cm/s
System Pressure 2.01 bar
Feedwater Temperature 40°C

REBEKA Rods With
Helium Filled Gaps

Bypass
======

KfK IRB

Fig. 21 SEFLEX: 5x5 RØD BUNDLE, SERIES 3, TEST-No. 32



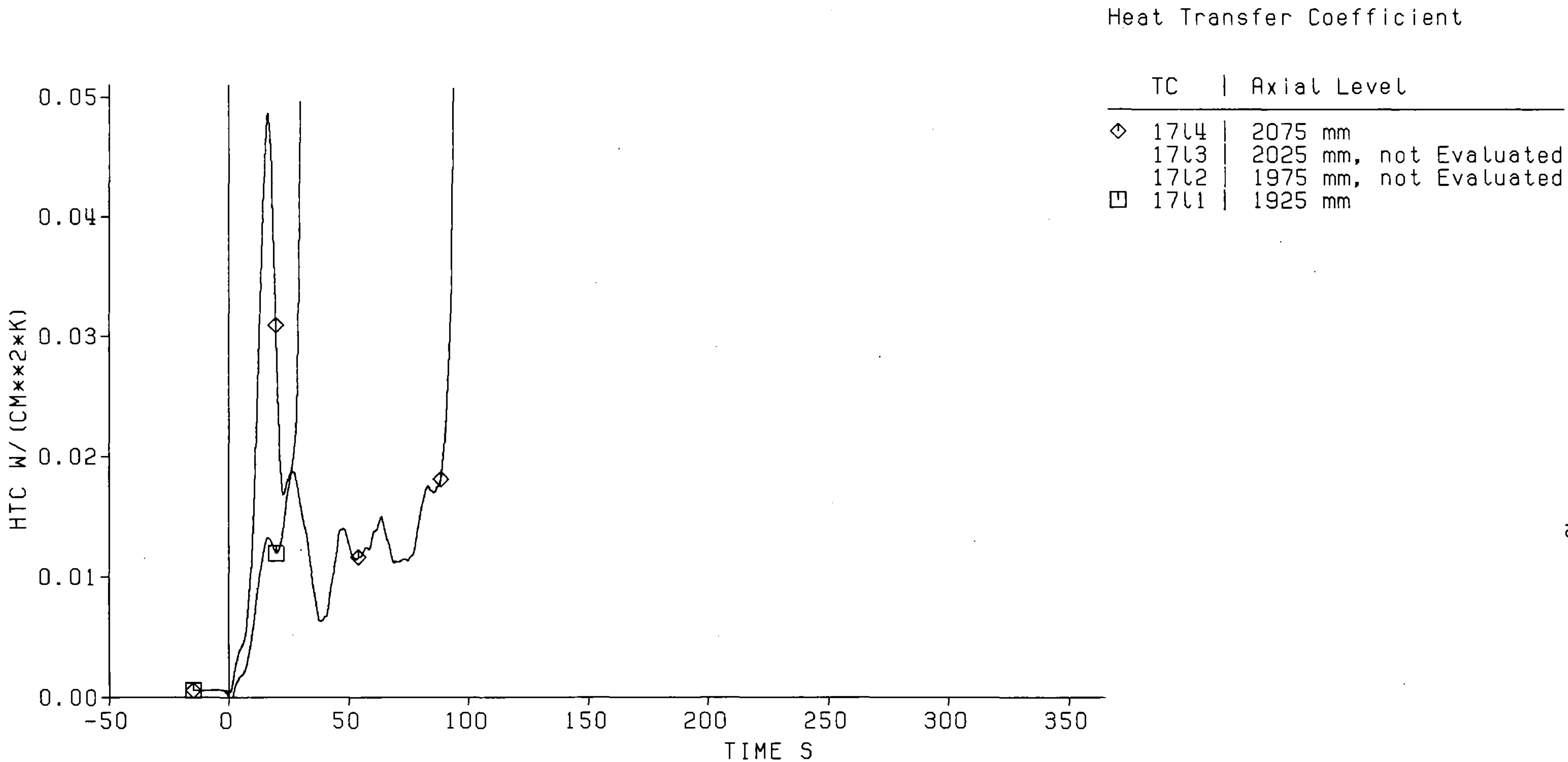
Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.82 cm/s
System Pressure 2.01 bar
Feedwater Temperature 40°C

REBEKA Rods With
Helium Filled Gaps

Blockage
========

KfK IRB

Fig. 22 SEFLEX: 5x5 RØD BUNDLE, SERIES 3, TEST-No. 32



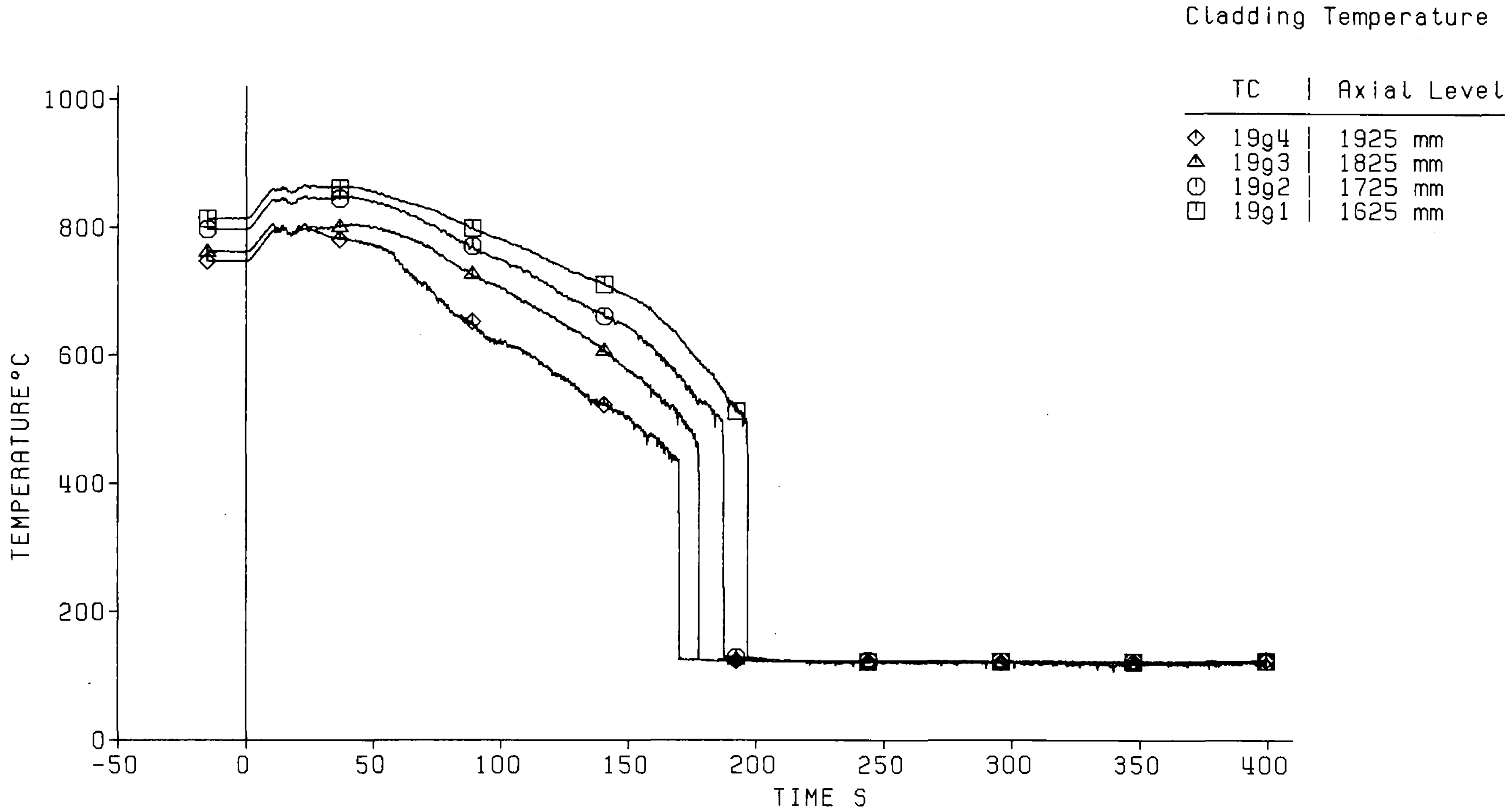
Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.82 cm/s
System Pressure 2.01 bar
Feedwater Temperature 40°C

REBEKA Rods With Helium Filled Gaps

Blockage
========

KfK IRB

Fig. 23 SEFLEX: 5x5 RØD BUNDLE, SERIES 3, TEST-No. 32



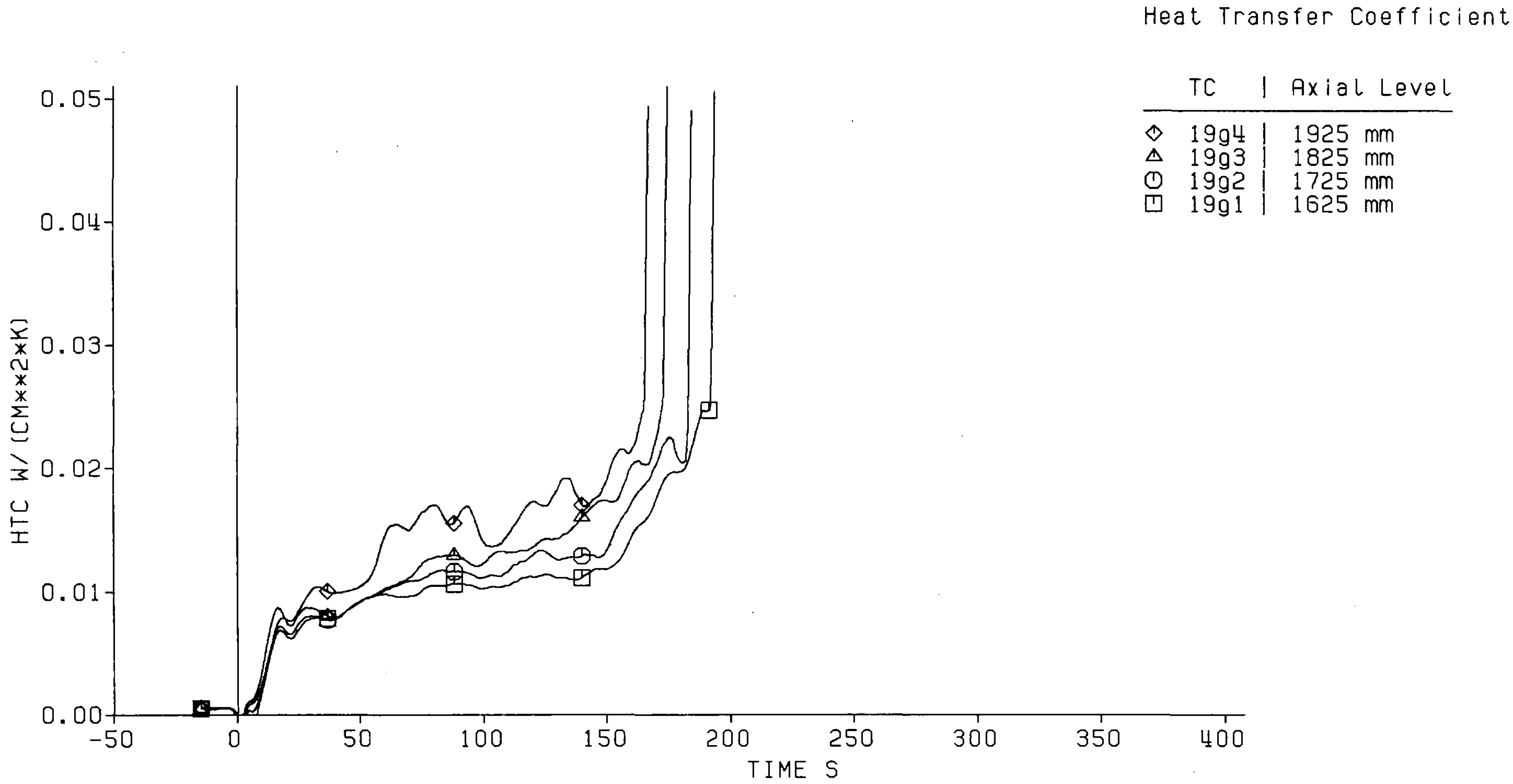
Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.82 cm/s
System Pressure 2.01 bar
Feedwater Temperature 40 °C

REBEKA Rods With
Helium Filled Gaps

Bypass
======

KfK IRB

Fig. 24 SEFLEX: 5x5 RØD BUNDLE, SERIES 3, TEST-No. 32



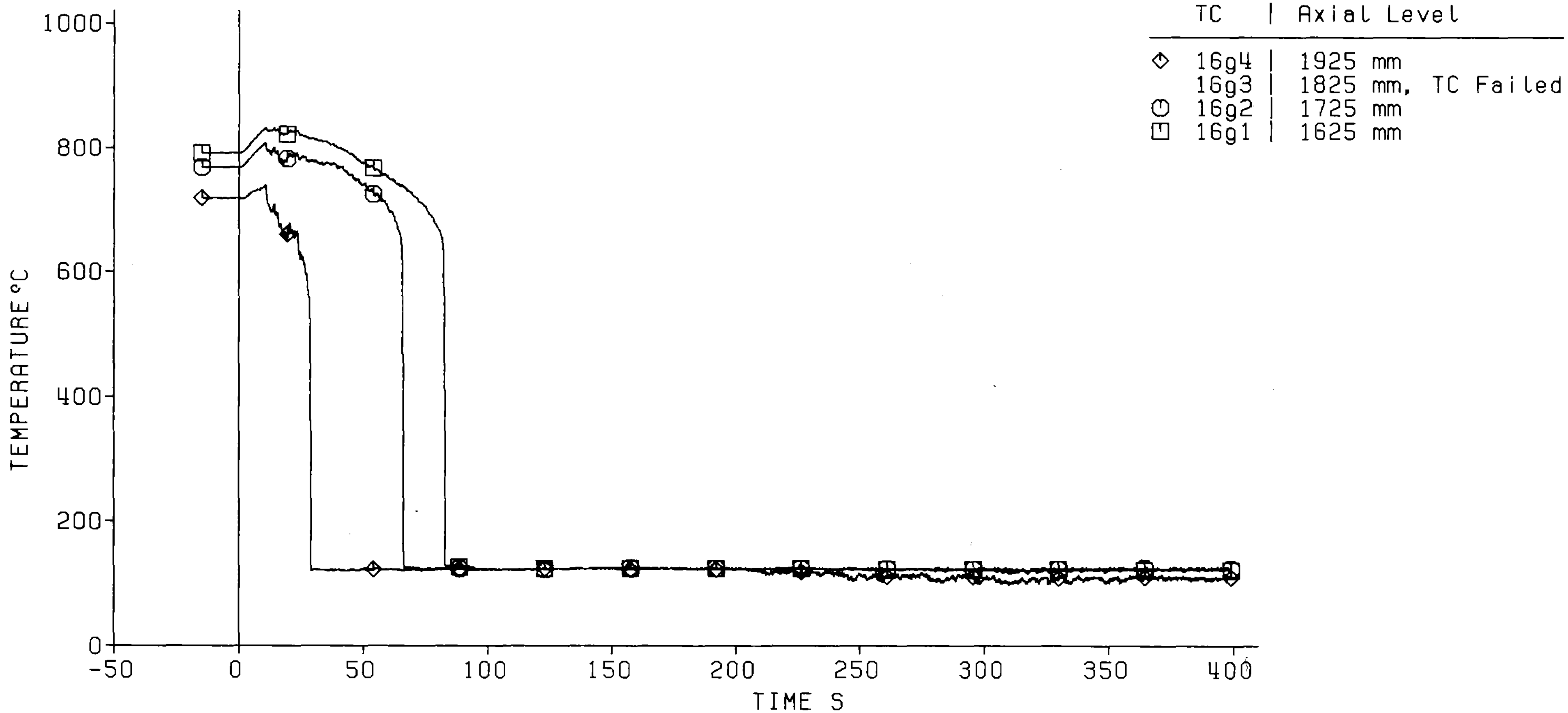
Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.82 cm/s
System Pressure 2.01 bar
Feedwater Temperature 40°C

REBEKA Rods With
Helium Filled Gaps

Bypass
======

KfK IRB

Fig. 25 SEFLEX: 5x5 RØD BUNDLE, SERIES 3, TEST-No. 32



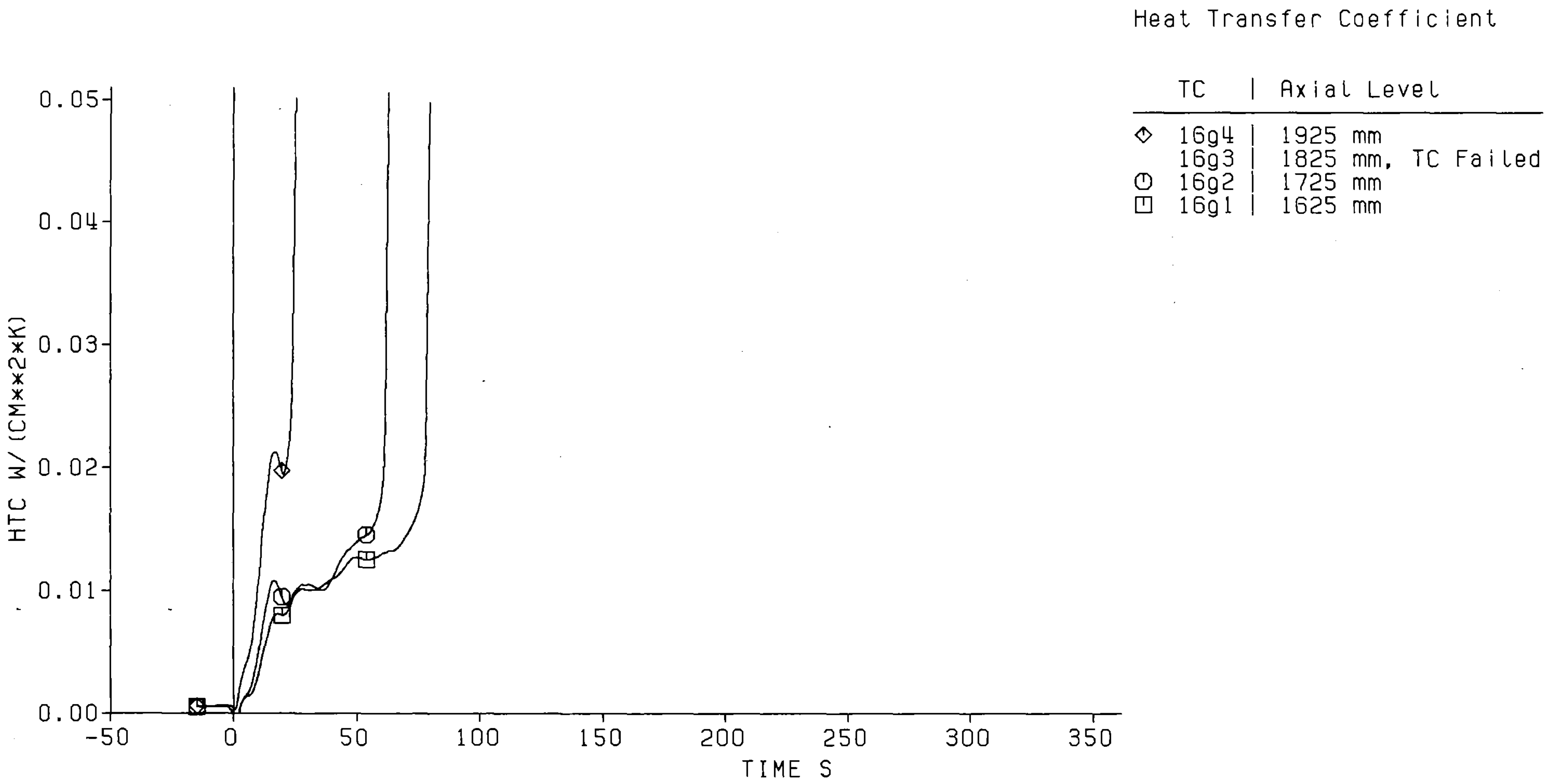
Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.82 cm/s
System Pressure 2.01 bar
Feedwater Temperature 40 °C

REBEKA Rods With
Helium Filled Gaps

Blockage
========

KfK IRB

Fig. 26 SEFLEX: 5x5 RØD BUNDLE, SERIES 3, TEST-No. 32



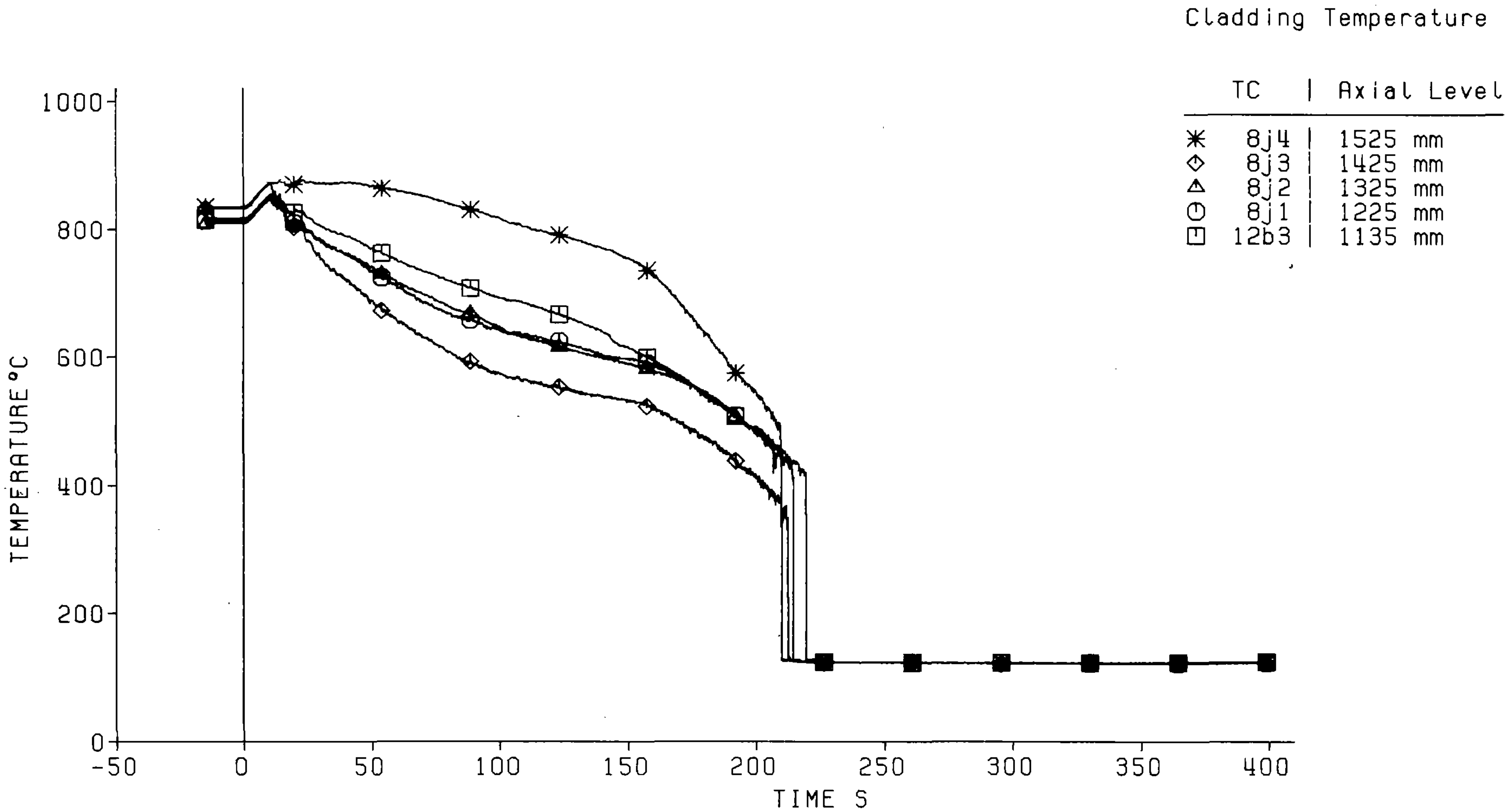
Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.82 cm/s
System Pressure 2.01 bar
Feedwater Temperature 40°C

REBEKA Rods With Helium Filled Gaps

Blockage

KfK IRB

Fig. 27 SEFLEX: 5x5 RØD BUNDLE, SERIES 3, TEST-No. 32

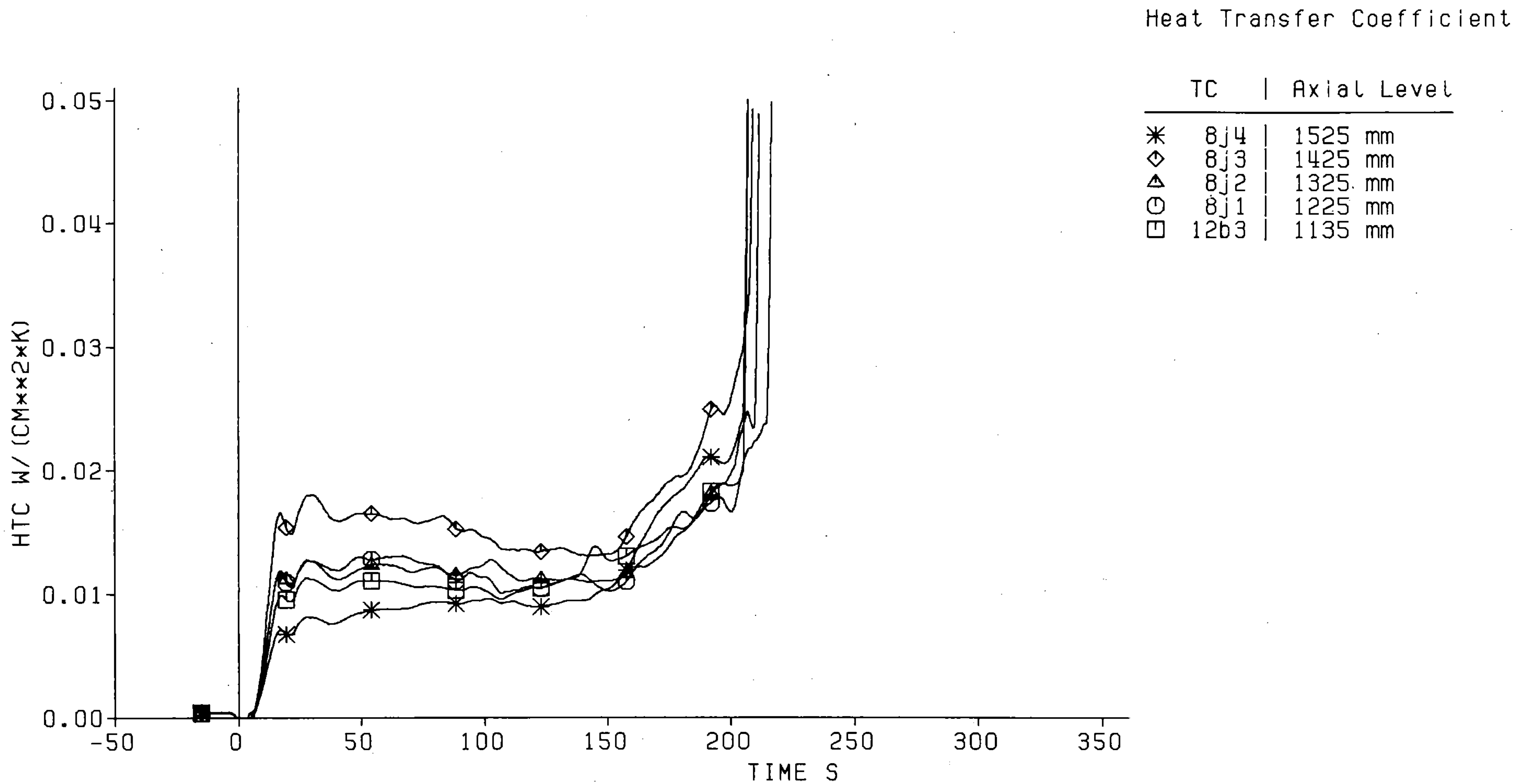


Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.82 cm/s
System Pressure 2.01 bar
Feedwater Temperature 40°C

REBEKA Rods With
Helium Filled Gaps

KfK IRB

Fig. 28 SEFLEX: 5x5 RØD BUNDLE, SERIES 3, TEST-No. 32

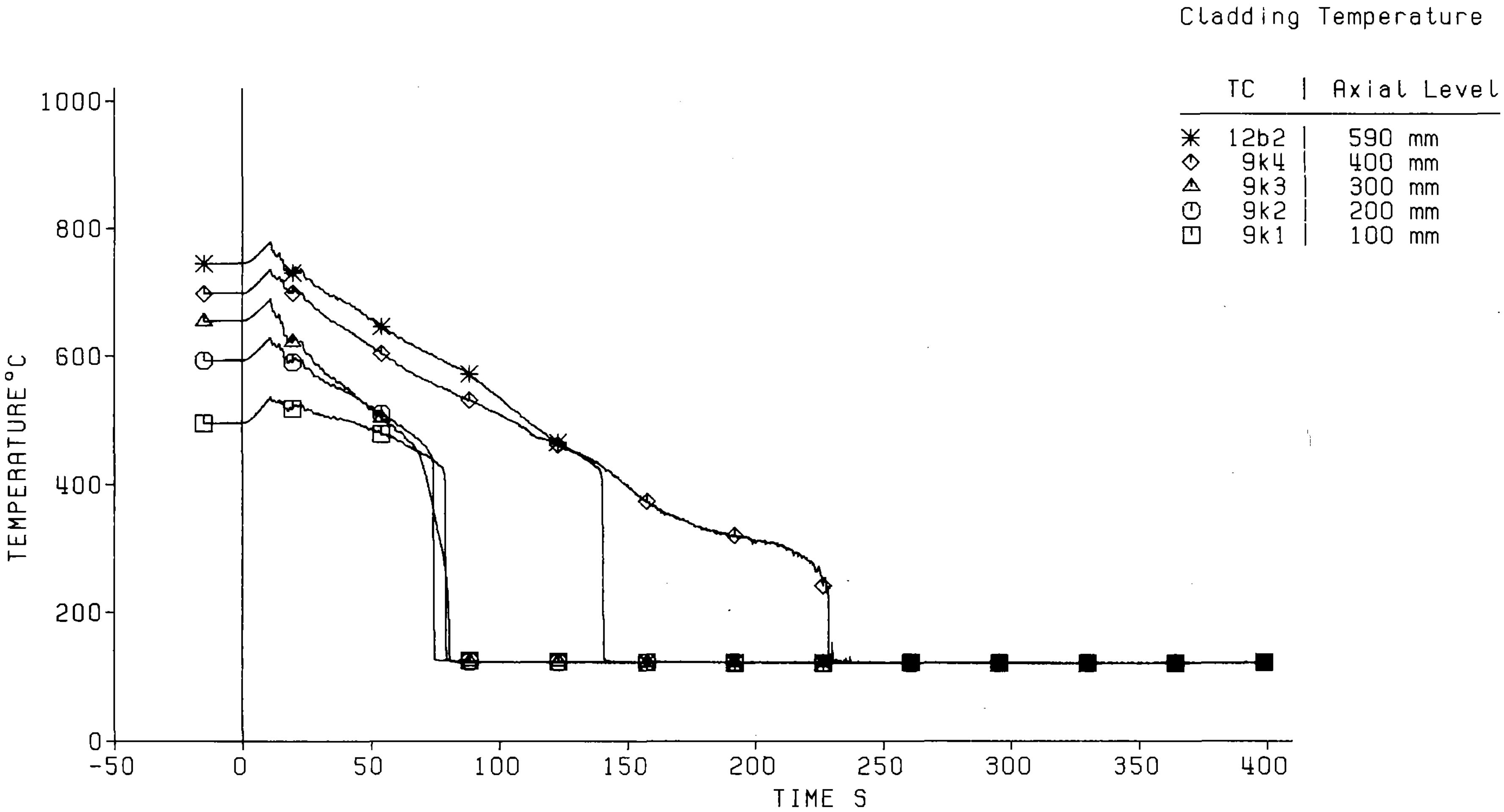


Decay Heat	120% ANS Standard
Flooding Rate (cold)	3.82 cm/s
System Pressure	2.01 bar
Feedwater Temperature	40°C

REBEKA Rods With Helium Filled Gaps

KfK IRB

Fig. 29 SEFLEX: 5x5 RØD BUNDLE, SERIES 3, TEST-No. 32

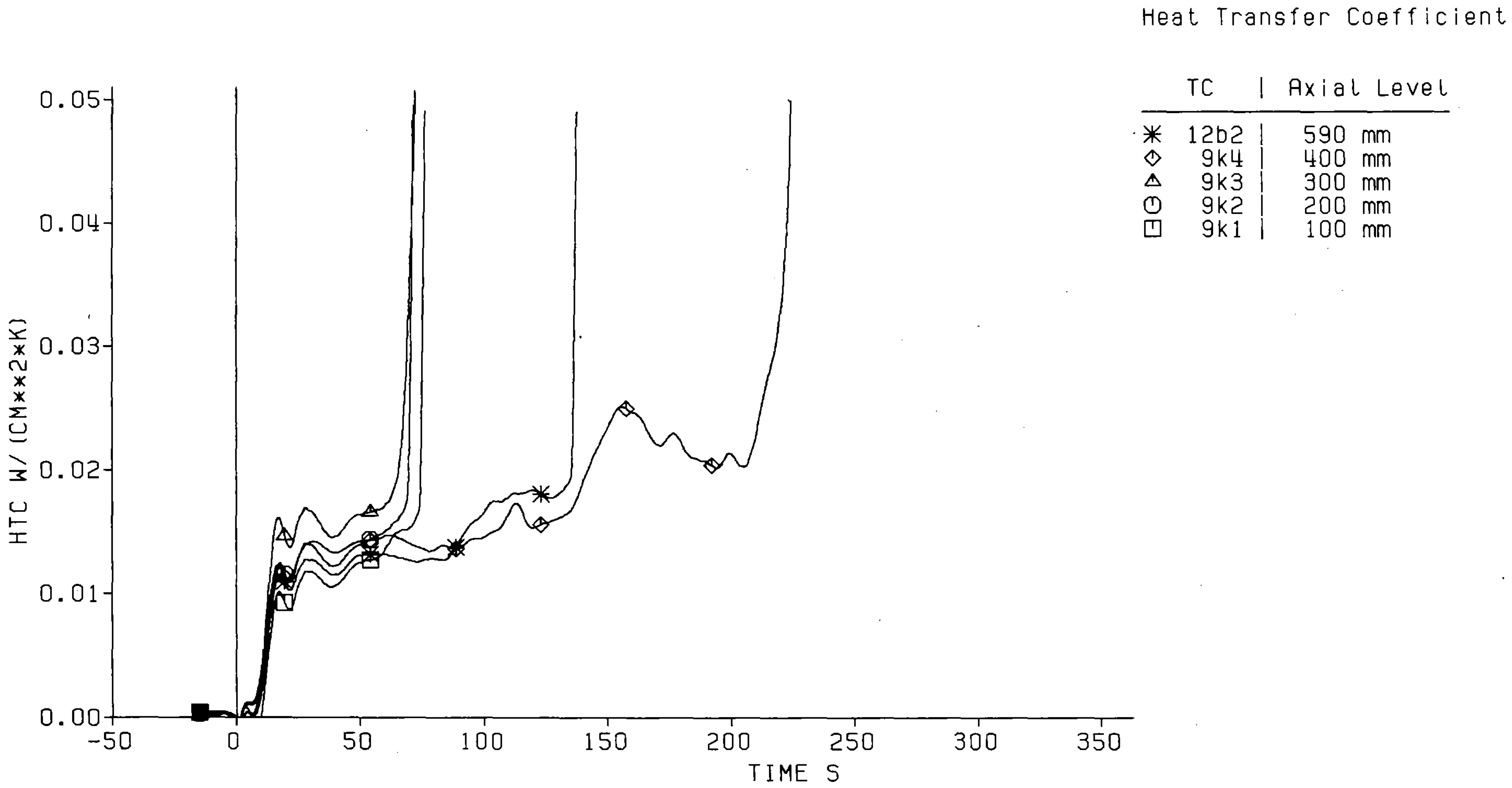


Decay Heat	120% ANS Standard
Flooding Rate (cold)	3.82 cm/s
System Pressure	2.01 bar
Feedwater Temperature	40°C

REBEKA Rods With
Helium Filled Gaps

KfK IRB

Fig. 30 SEFLEX: 5x5 RØD BUNDLE, SERIES 3, TEST-No. 32

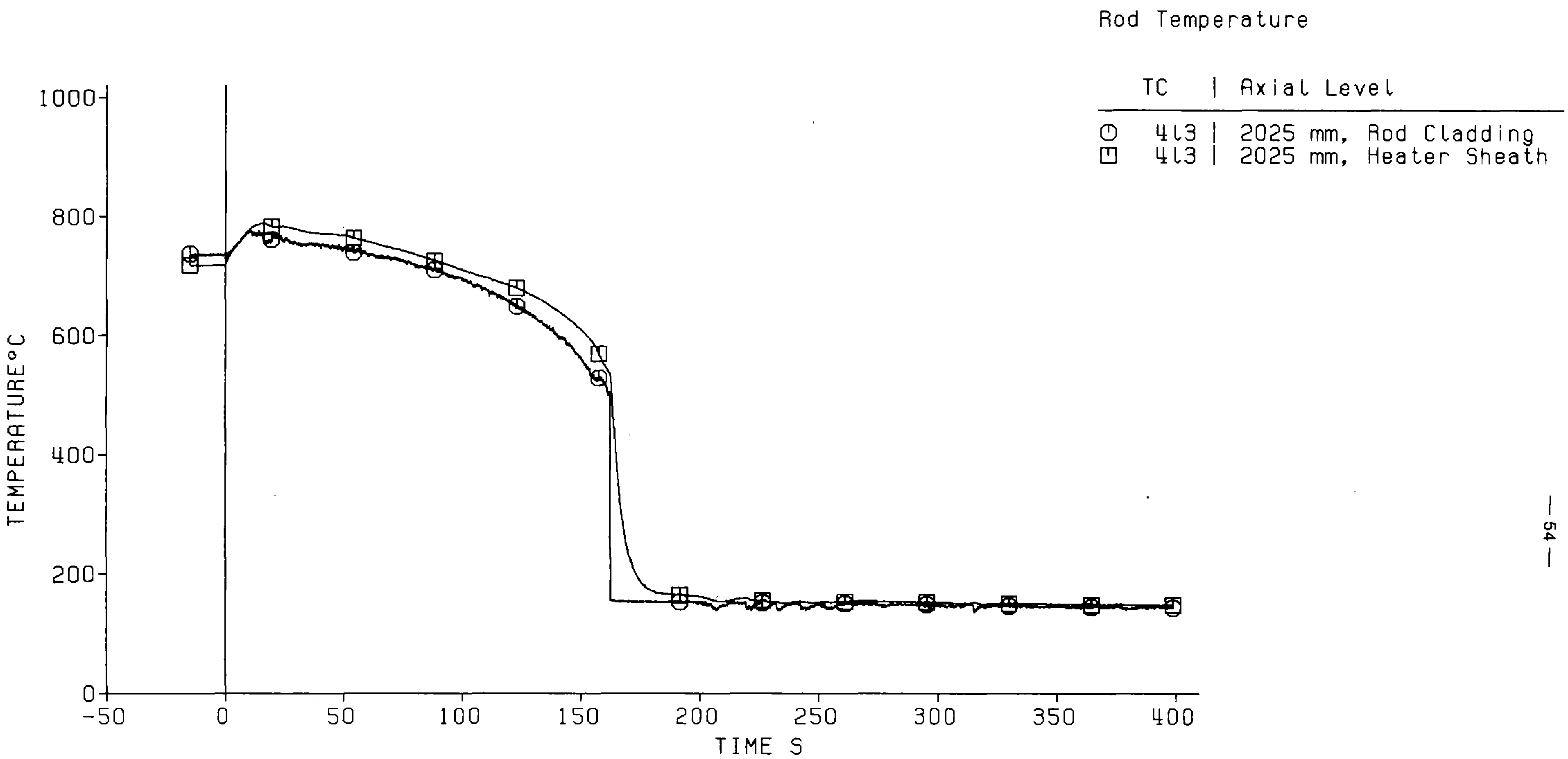


Decay Heat	120% ANS Standard
Flooding Rate (cold)	3.82 cm/s
System Pressure	2.01 bar
Feedwater Temperature	40°C

REBEKA Rods With
Helium Filled Gaps

KfK IRB

Fig. 31 SEFLEX: 5x5 RØD BUNDLE, SERIES 3, TEST-No. 32



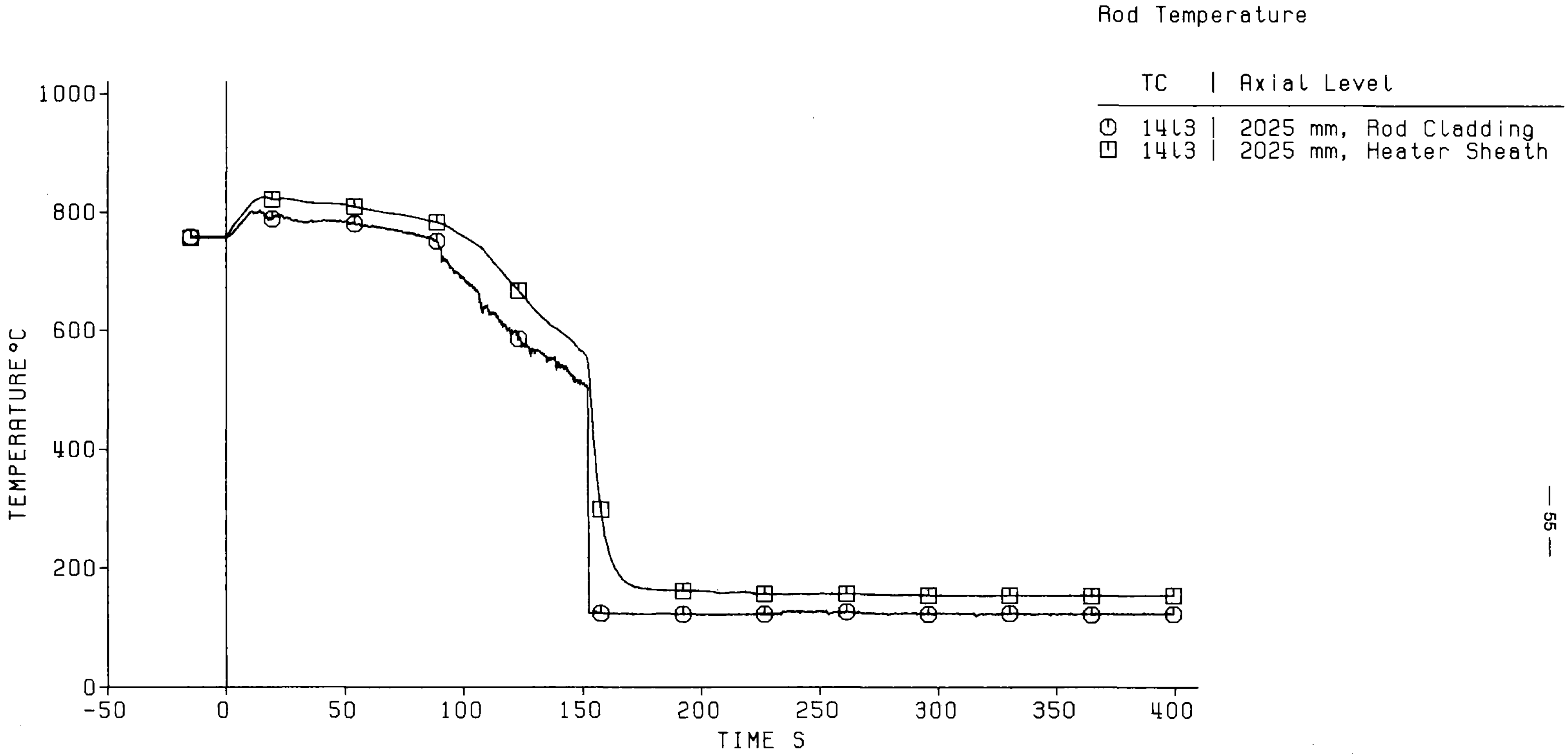
Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.82 cm/s
System Pressure 2.01 bar
Feedwater Temperature 40°C

REBEKA Rods With
Helium Filled Gaps

Bypass
======

KfK IRB

Fig. 32 SEFLEX: 5x5 RØD BUNDLE, SERIES 3, TEST-No. 32



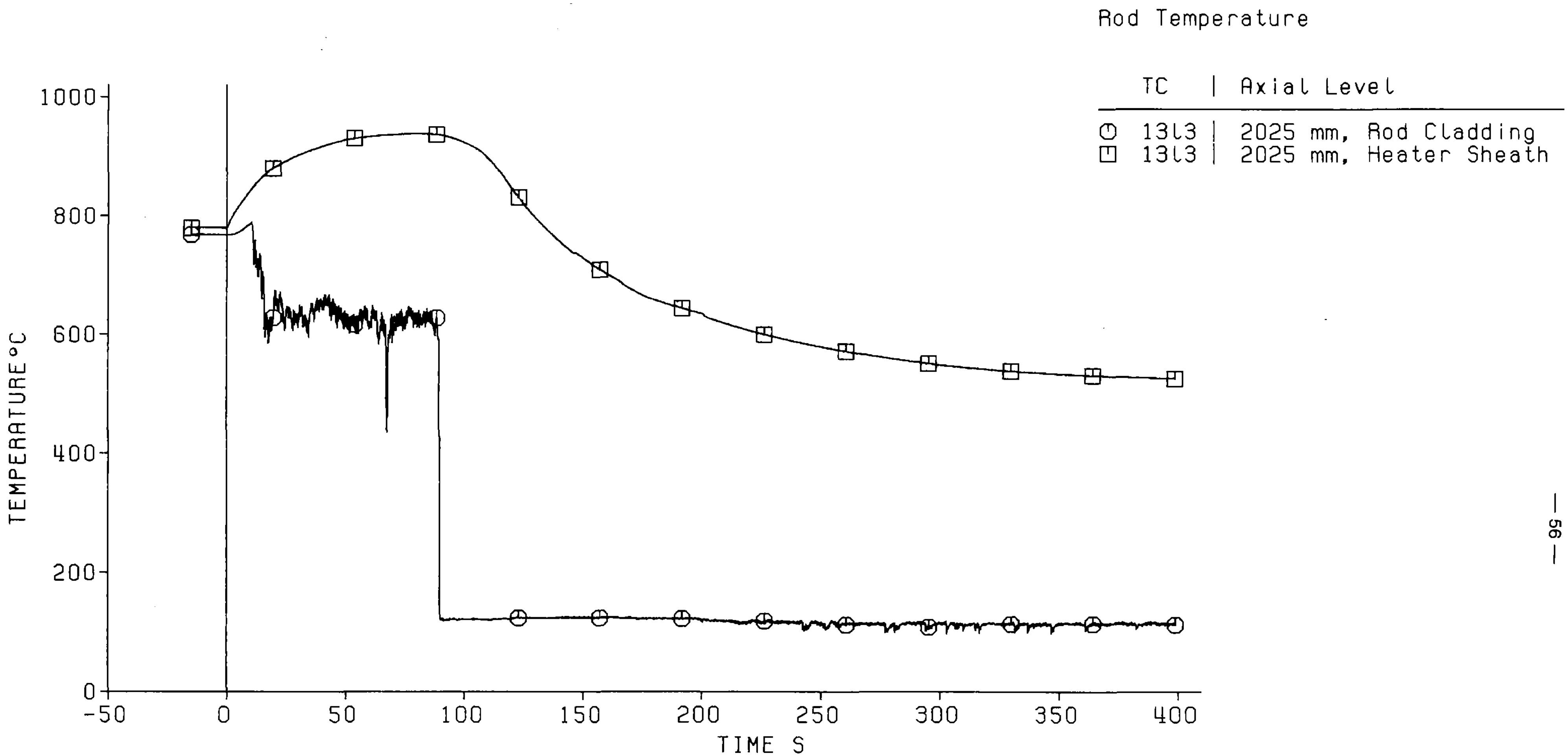
Decay Heat	120% ANS Standard
Flooding Rate (cold)	3.82 cm/s
System Pressure	2.01 bar
Feedwater Temperature	40 °C

REBEKA Rods With
Helium Filled Gaps

Bypass
======

KfK IRB

Fig. 33 SEFLEX: 5x5 RØD BUNDLE, SERIES 3, TEST-No. 32



Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.82 cm/s
System Pressure 2.01 bar
Feedwater Temperature 40°C

REBEKA Rods With
Helium Filled Gaps

Blockage
========

KfK IRB

Fig. 34 SEFLEX: 5x5 RØD BUNDLE, SERIES 3, TEST-No. 32

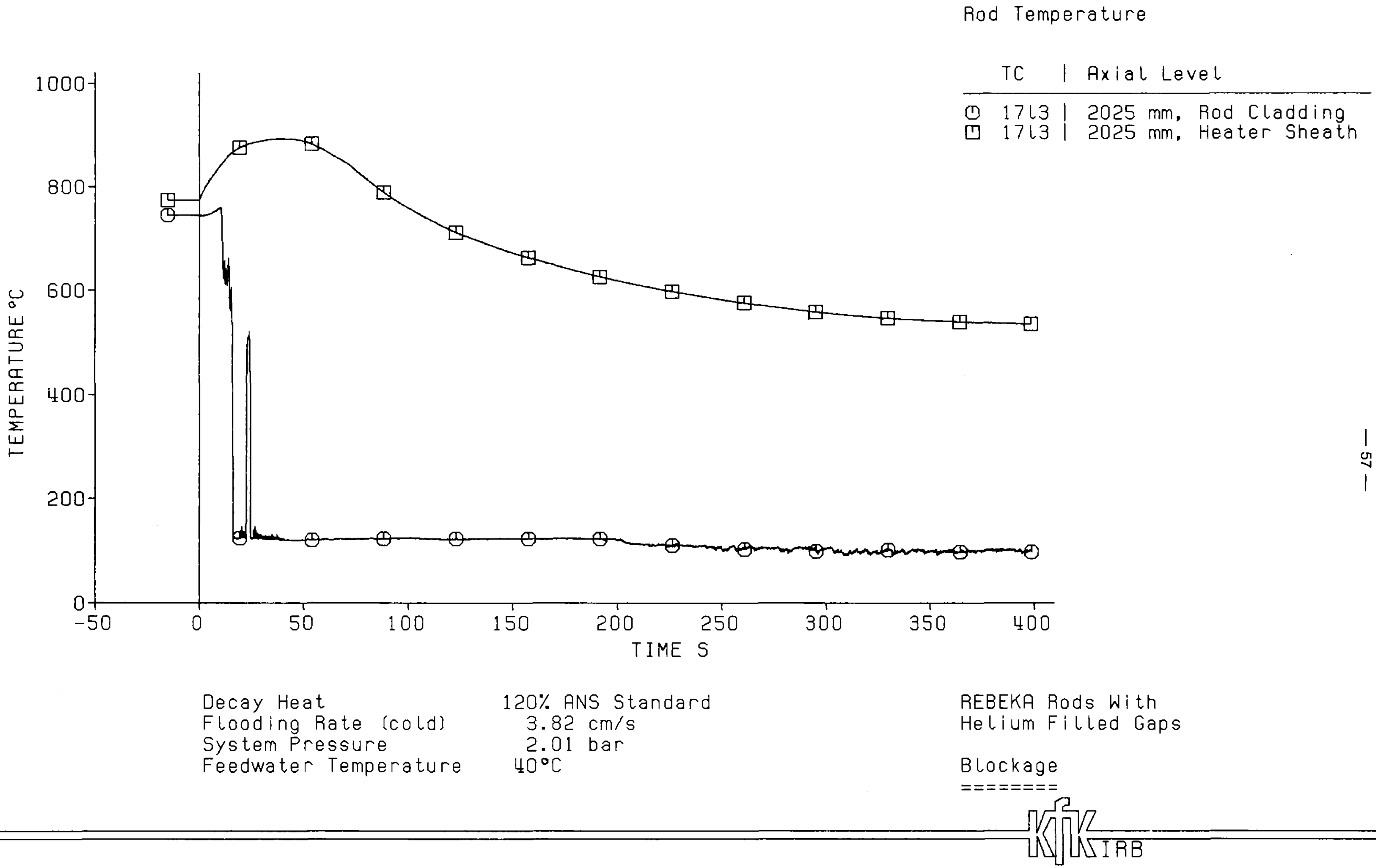


Fig. 35 SEFLEX: 5x5 RØD BUNDLE, SERIES 3, TEST-No. 32

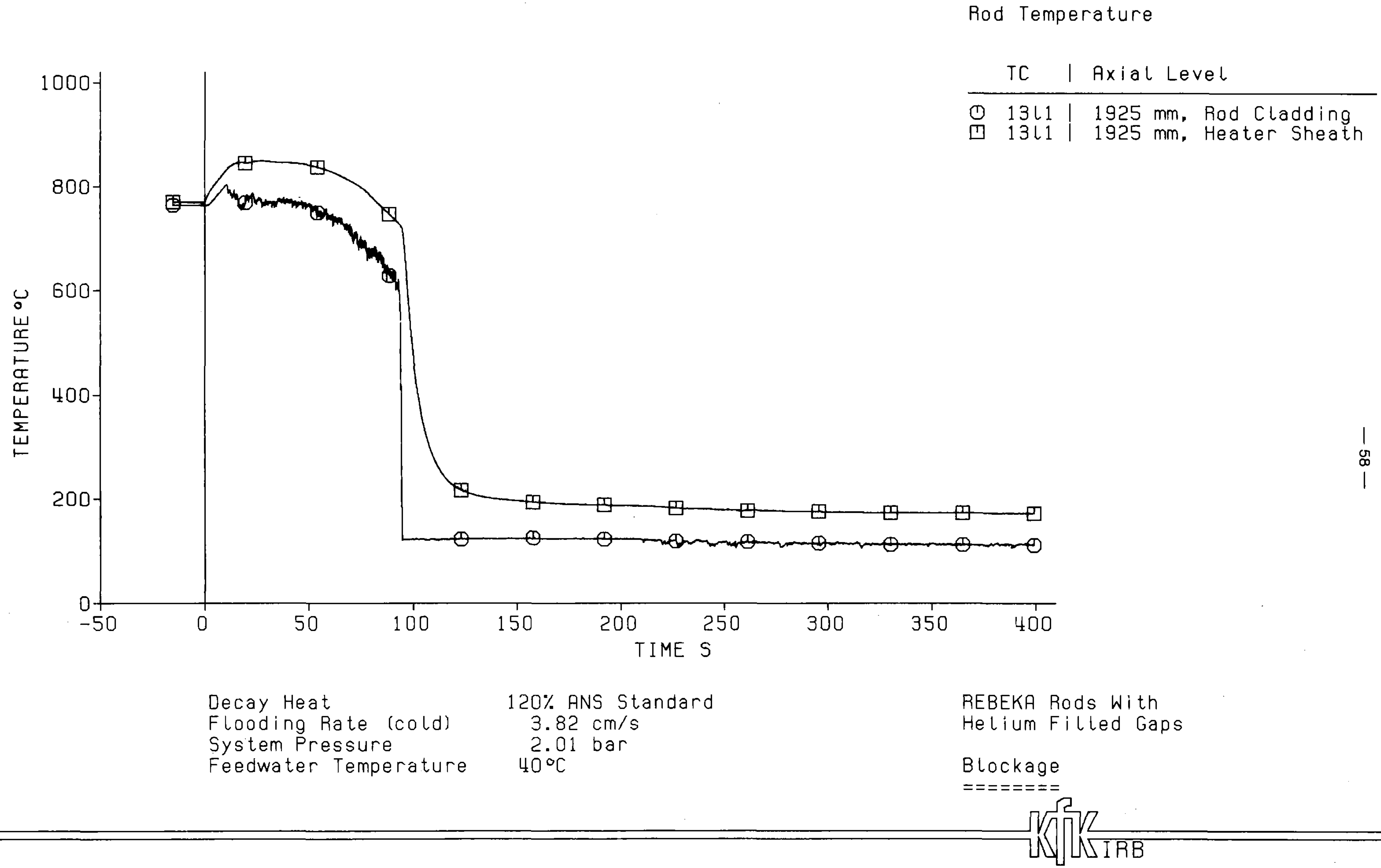
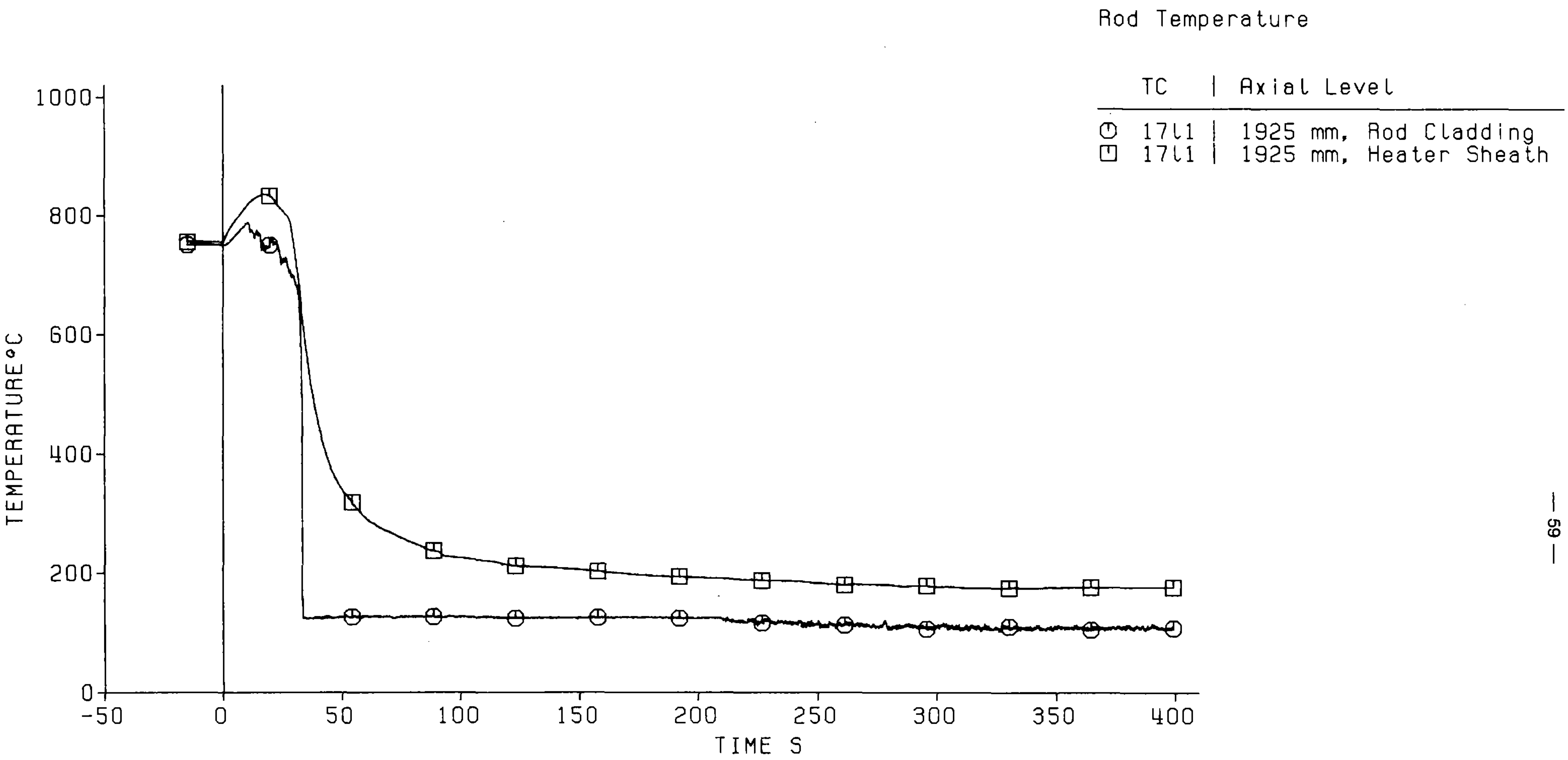


Fig. 36 SEFLEX: 5x5 RØD BUNDLE, SERIES 3, TEST-No. 32



Decay Heat	120% ANS Standard
Flooding Rate (cold)	3.82 cm/s
System Pressure	2.01 bar
Feedwater Temperature	40°C

REBEKA Rods With
Helium Filled Gaps

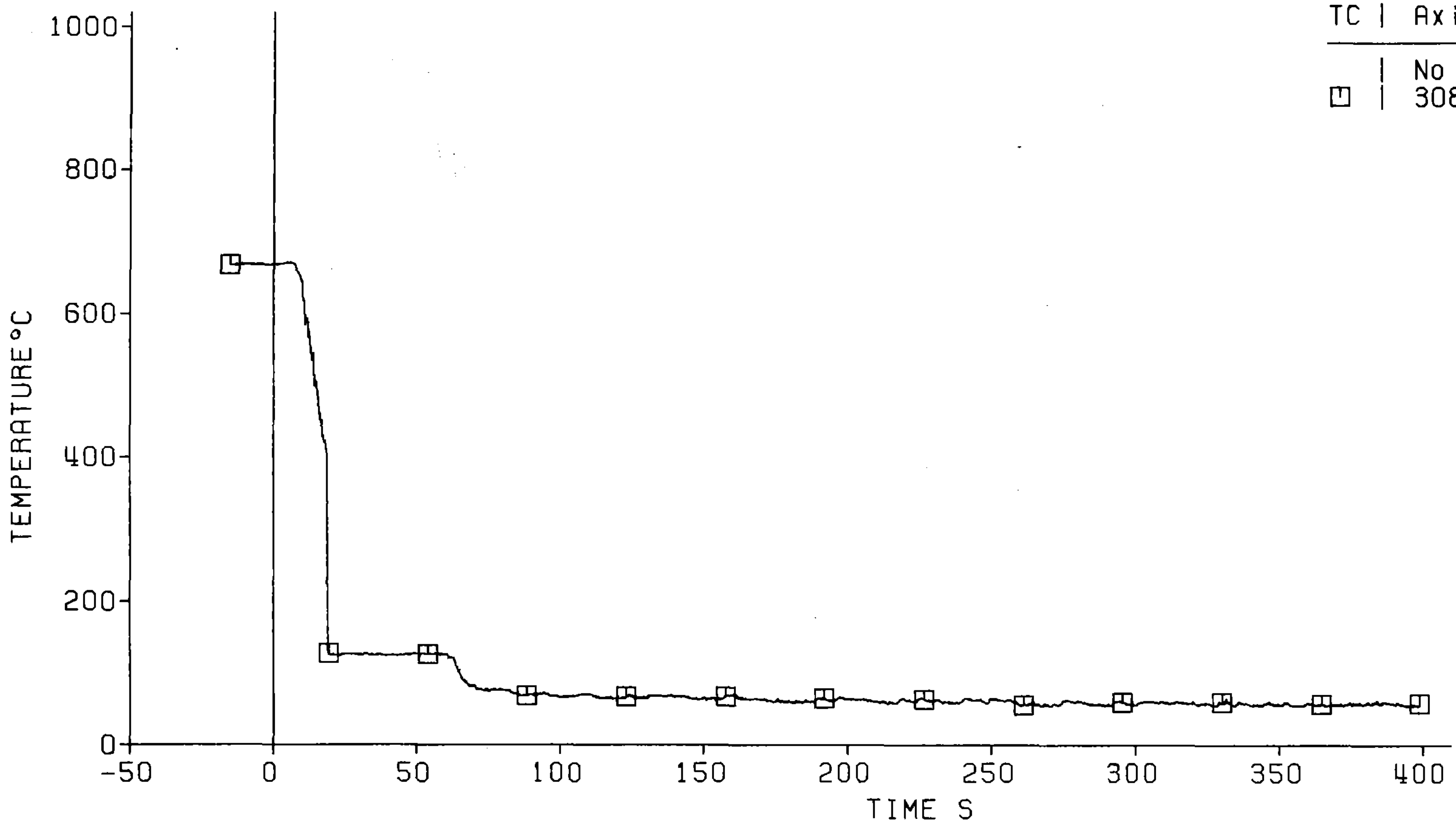
Blockage
========

Fig. 37 SEFLEX: 5x5 RØD BUNDLE, SERIES 3, TEST-No. 32

Grid Spacer Temperature

TC | Axial Level

| No TC at Leading Edge
□ | 3080 mm, Trailing Edge

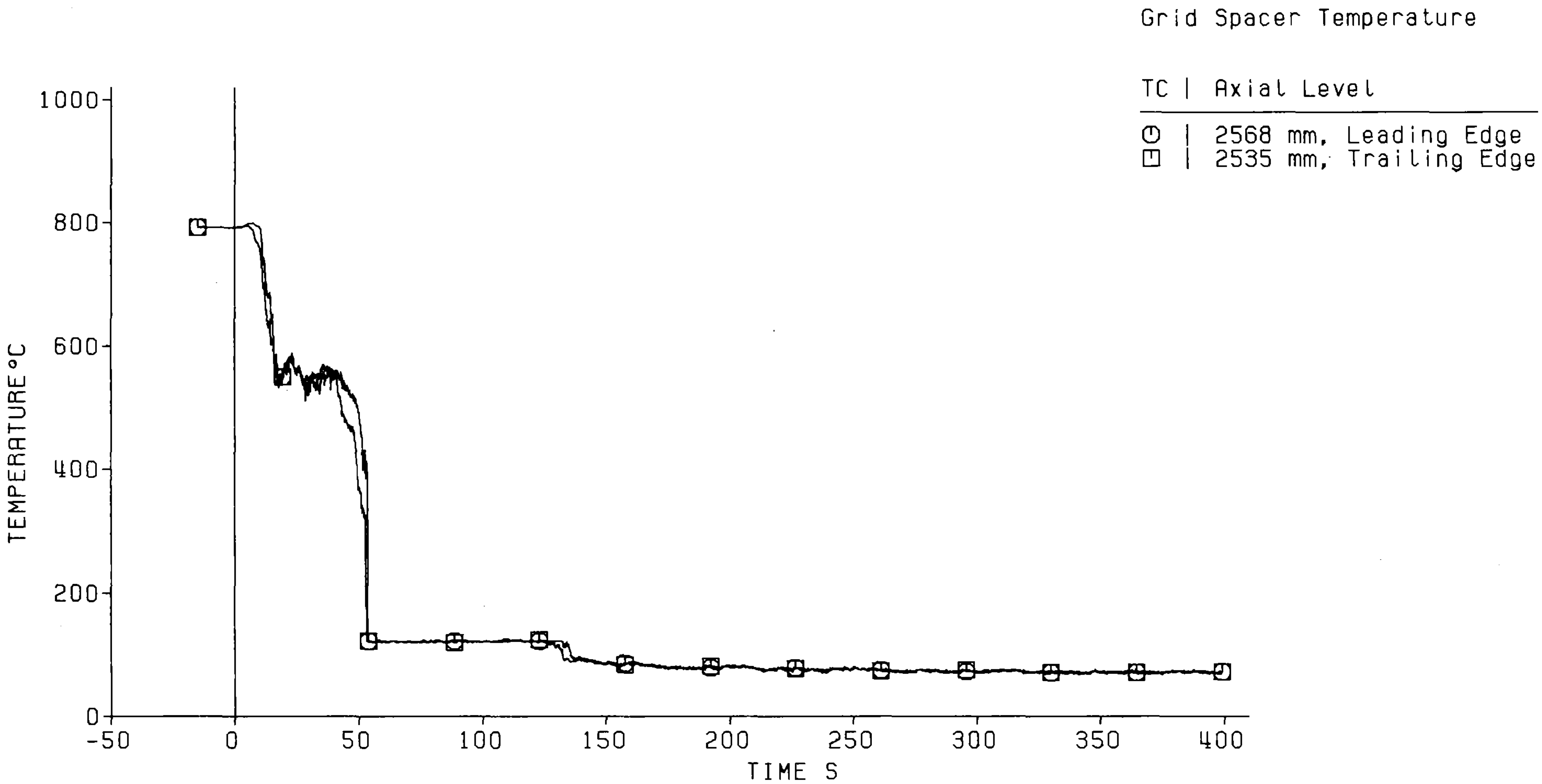


Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.82 cm/s
System Pressure 2.01 bar
Feedwater Temperature 40°C

REBEKA Rods With
Helium Filled Gaps

KfK IRB

Fig. 38 SEFLEX: 5x5 RØD BUNDLE, SERIES 3, TEST-No. 32

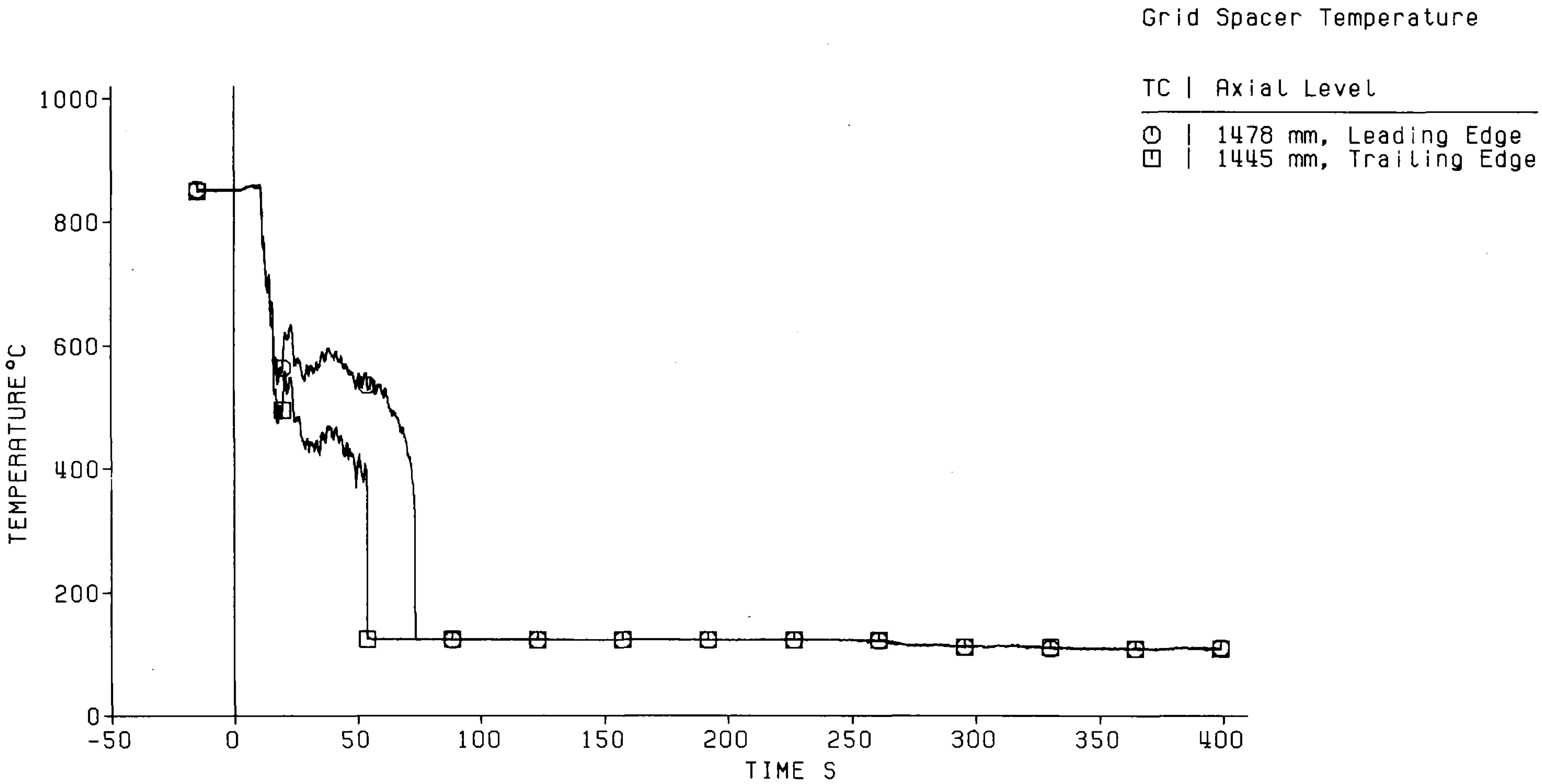


Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.82 cm/s
System Pressure 2.01 bar
Feedwater Temperature 40 °C

REBEKA Rods With Helium Filled Gaps

KfK IRB

Fig. 39 SEFLEX: 5x5 RØD BUNDLE, SERIES 3, TEST-No. 32

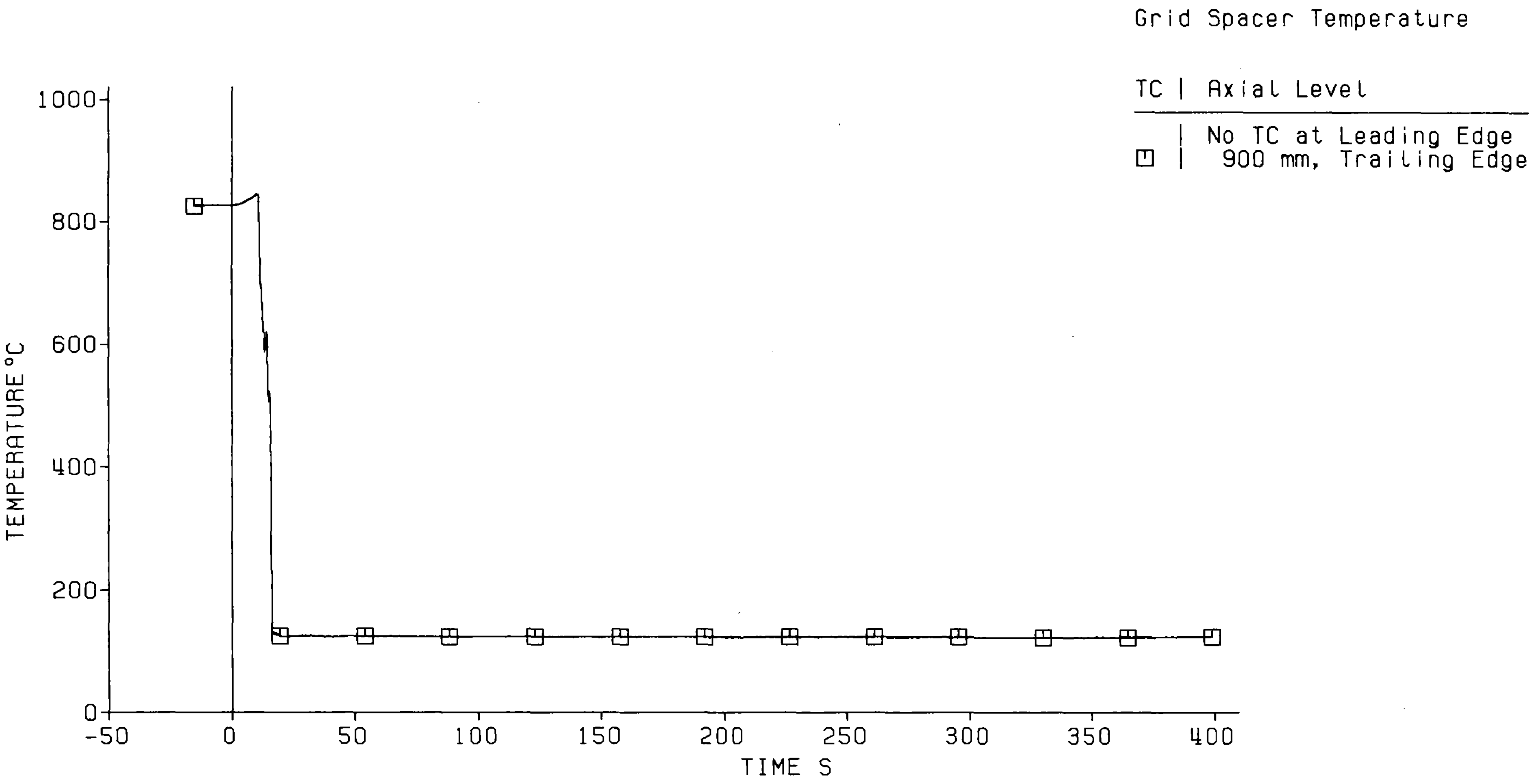


Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.82 cm/s
System Pressure 2.01 bar
Feedwater Temperature 40 °C

REBEKA Rods With
Helium Filled Gaps

KfK IRB

Fig. 40 SEFLEX: 5x5 RØD BUNDLE, SERIES 3, TEST-No. 32

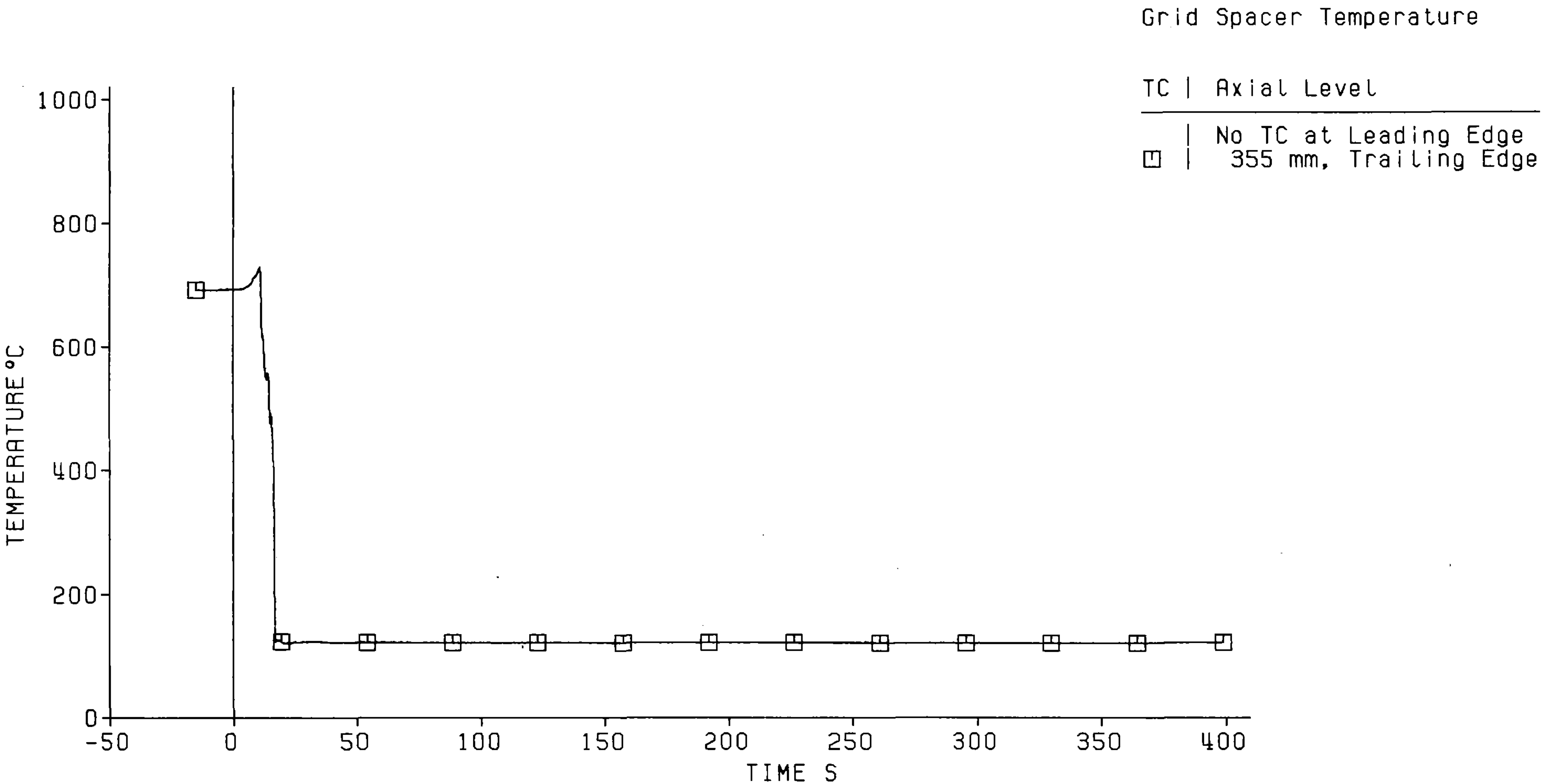


Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.82 cm/s
System Pressure 2.01 bar
Feedwater Temperature 40°C

REBEKA Rods With
Helium Filled Gaps

KfK IRB

Fig. 41 SEFLEX: 5x5 RØD BUNDLE, SERIES 3, TEST-No. 32

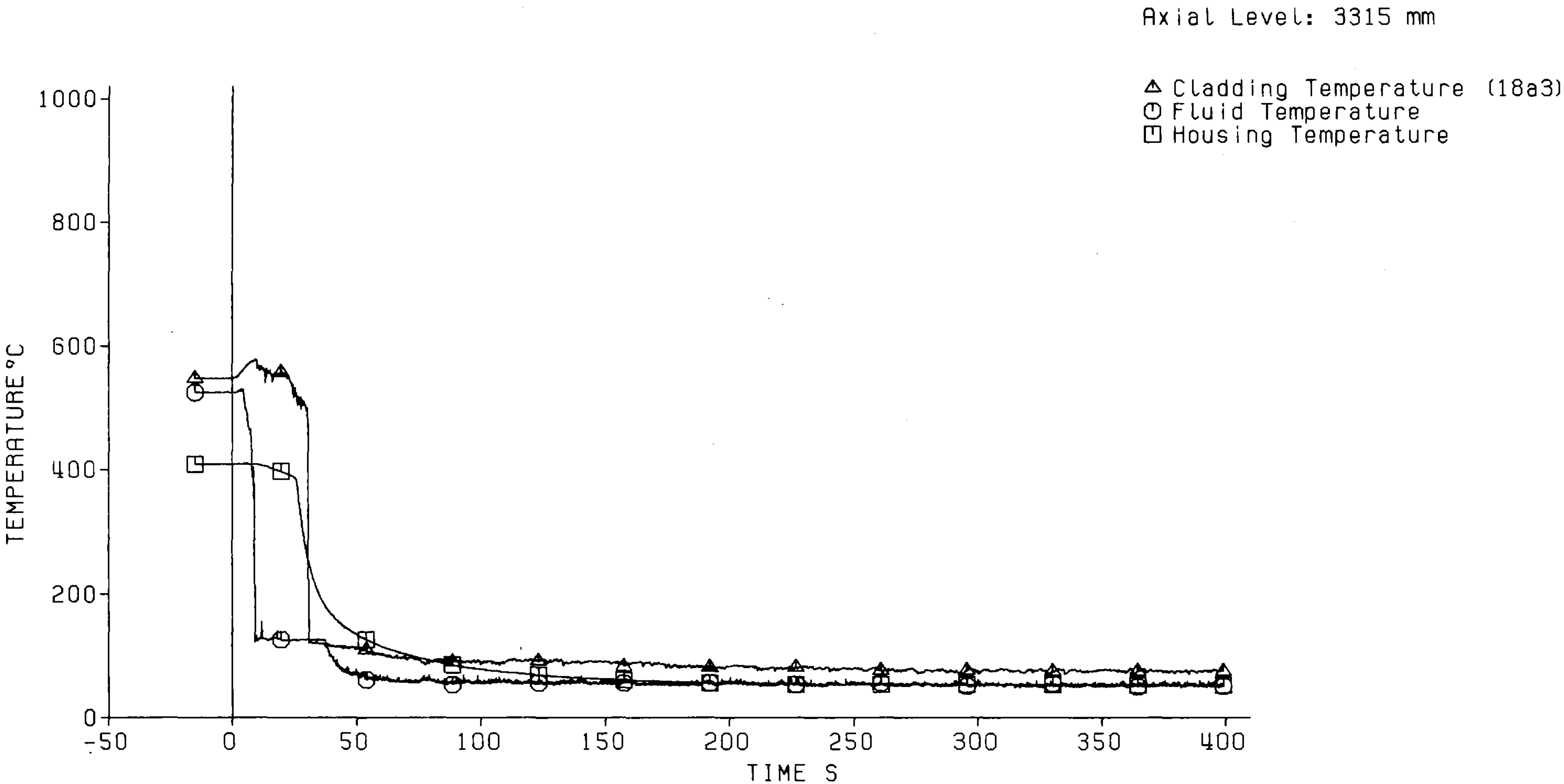


Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.82 cm/s
System Pressure 2.01 bar
Feedwater Temperature 40°C

REBEKA Rods With
Helium Filled Gaps

KfK IRB

Fig. 42 SEFLEX: 5x5 RØD BUNDLE, SERIES 3, TEST-No. 32



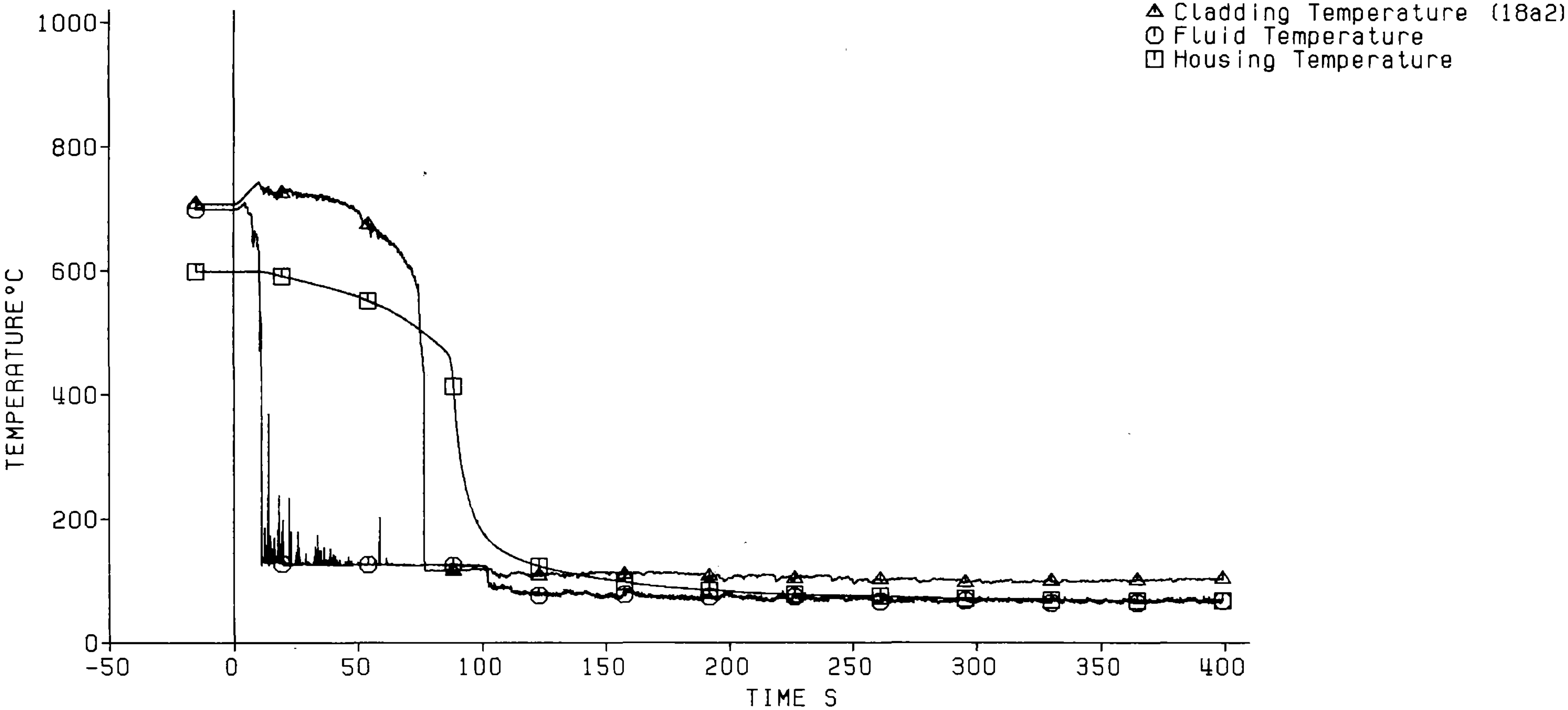
Decay Heat	120% ANS Standard
Flooding Rate (cold)	3.82 cm/s
System Pressure	2.01 bar
Feedwater Temperature	40°C

REBEKA Rods With
Helium Filled Gaps

KfK IRB

Fig. 43 SEFLEX: 5x5 RØD BUNDLE, SERIES 3, TEST-No. 32

Axial Level: 2770 mm

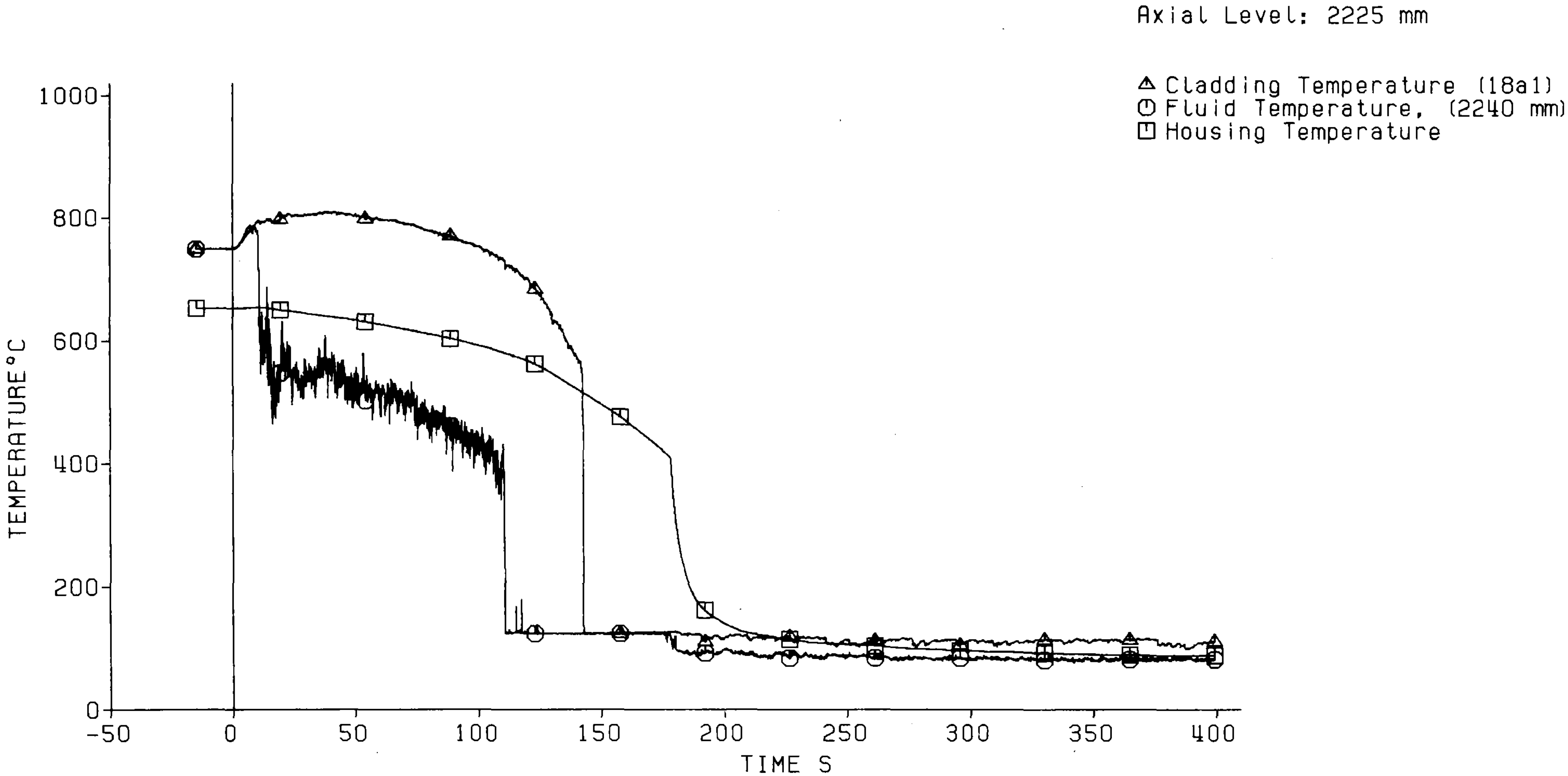


Decay Heat	120% ANS Standard
Flooding Rate (cold)	3.82 cm/s
System Pressure	2.01 bar
Feedwater Temperature	40°C

REBEKA Rods With
Helium Filled Gaps

KfK IRB

Fig. 44 SEFLEX: 5x5 RØD BUNDLE, SERIES 3, TEST-No. 32

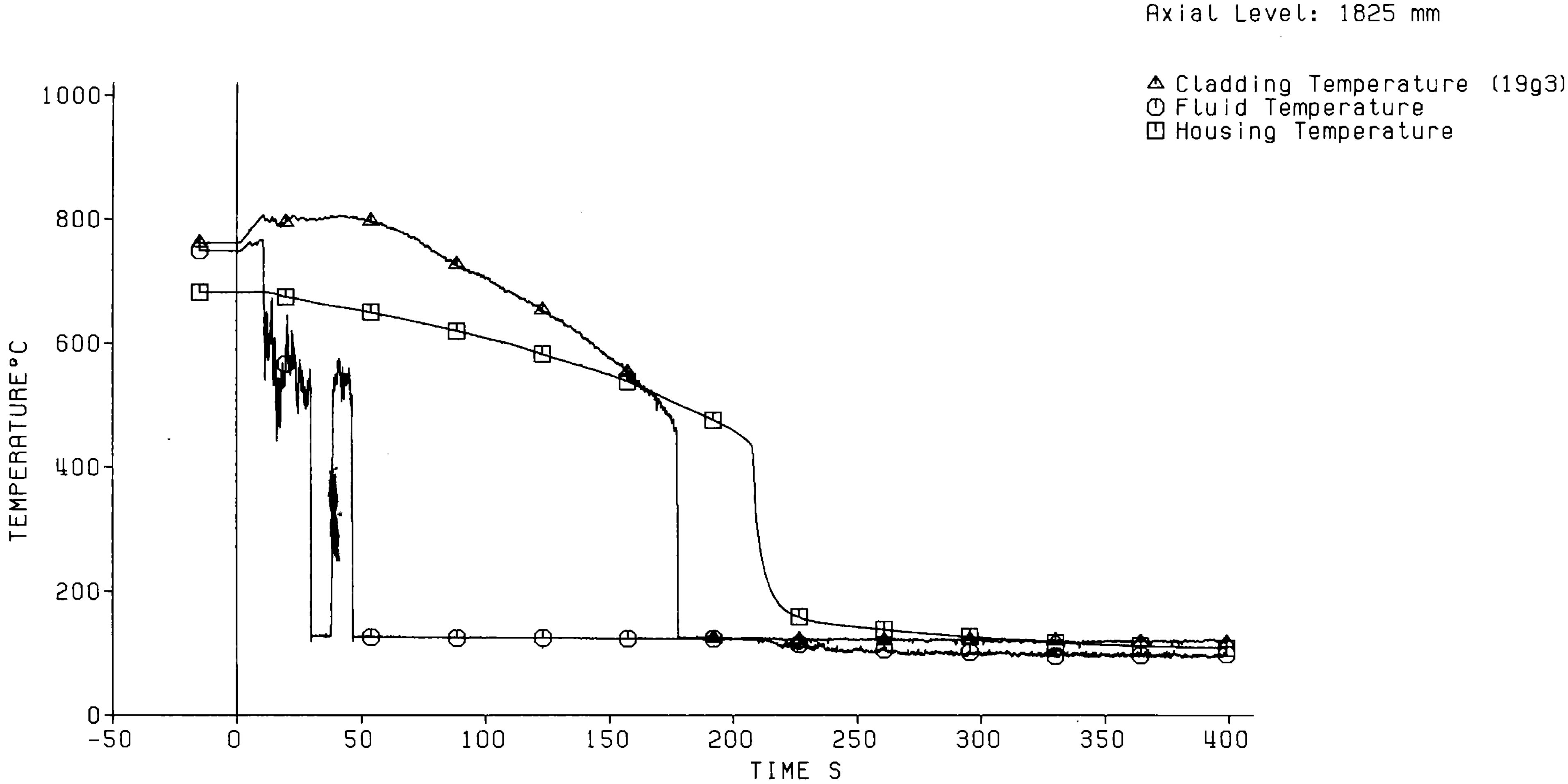


Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.82 cm/s
System Pressure 2.01 bar
Feedwater Temperature 40°C

REBEKA Rods With
Helium Filled Gaps

KfK IRB

Fig. 45 SEFLEX: 5x5 RØD BUNDLE, SERIES 3, TEST-No. 32

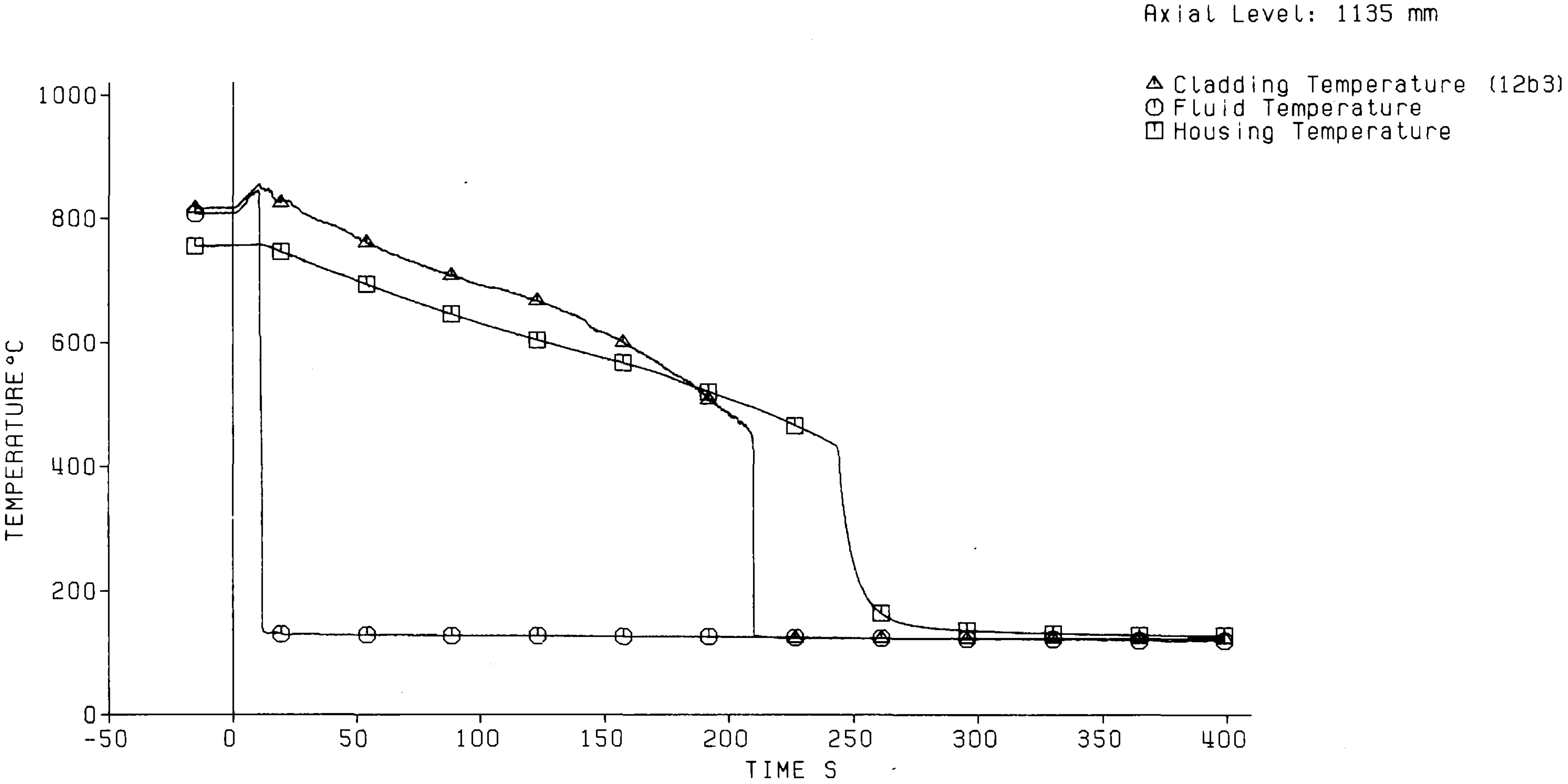


Decay Heat	120% ANS Standard
Flooding Rate (cold)	3.82 cm/s
System Pressure	2.01 bar
Feedwater Temperature	40°C

REBEKA Rods With
Helium Filled Gaps

KfK IRB

Fig. 46 SEFLEX: 5x5 RØD BUNDLE, SERIES 3, TEST-No. 32

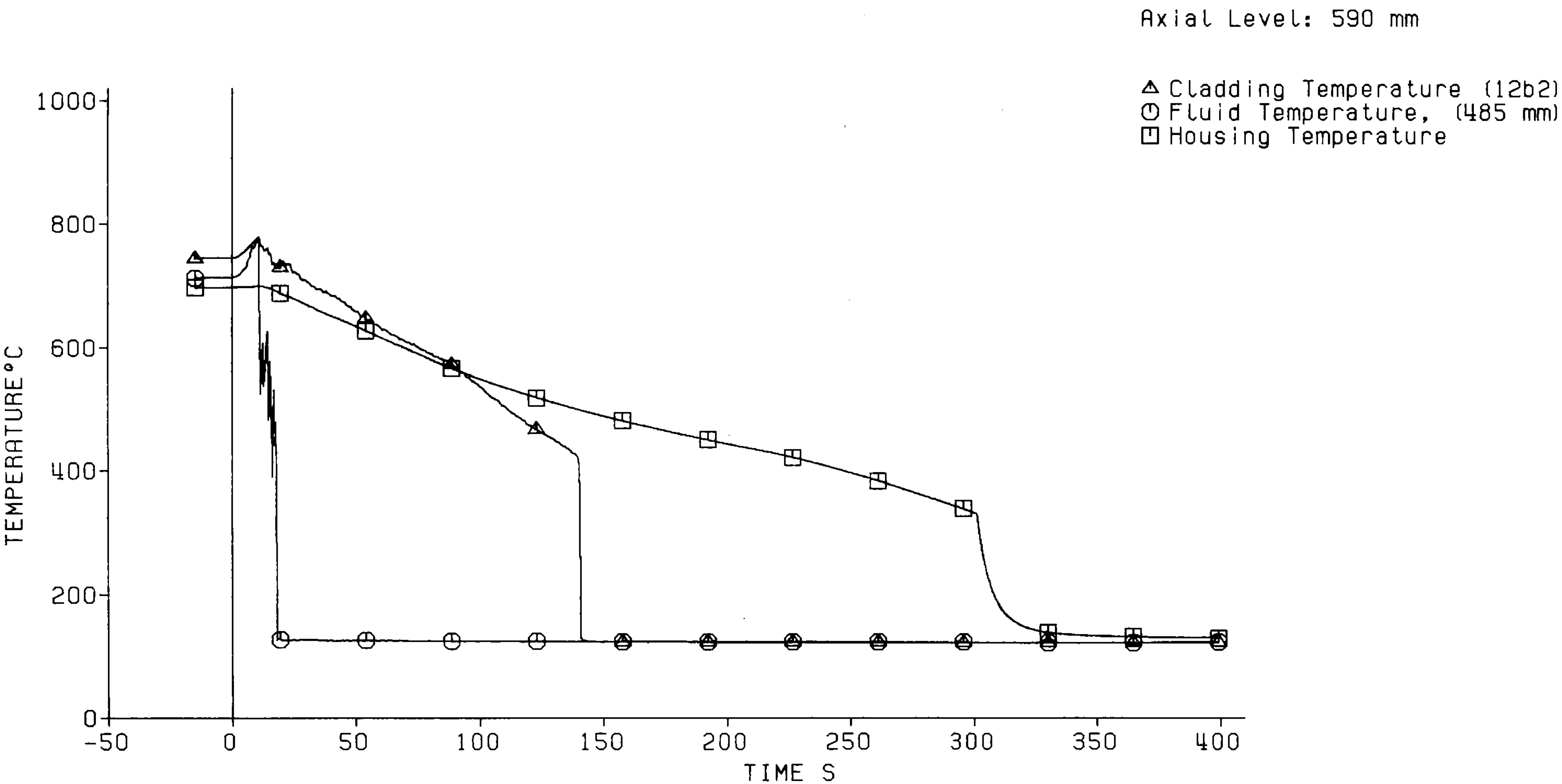


Decay Heat	120% ANS Standard
Flooding Rate (cold)	3.82 cm/s
System Pressure	2.01 bar
Feedwater Temperature	40°C

REBEKA Rods With
Helium Filled Gaps

KfK IRB

Fig. 47 SEFLEX: 5x5 RØD BUNDLE, SERIES 3, TEST-No. 32

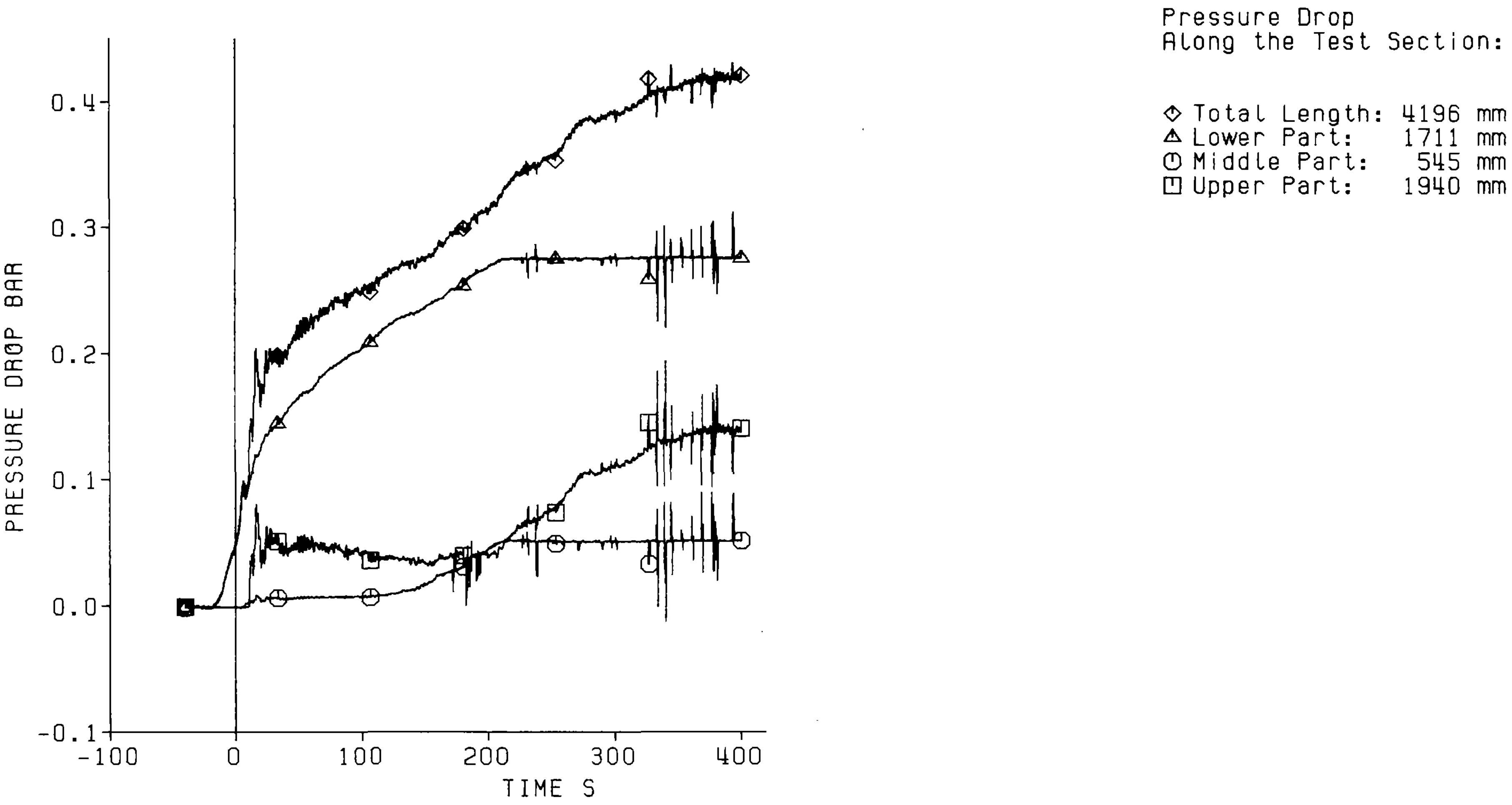


Decay Heat	120% ANS Standard
Flooding Rate (cold)	3.82 cm/s
System Pressure	2.01 bar
Feedwater Temperature	40°C

REBEKA Rods With
Helium Filled Gaps

KfK IRB

Fig. 48 SEFLEX: 5x5 RØD BUNDLE, SERIES 3, TEST-No. 32

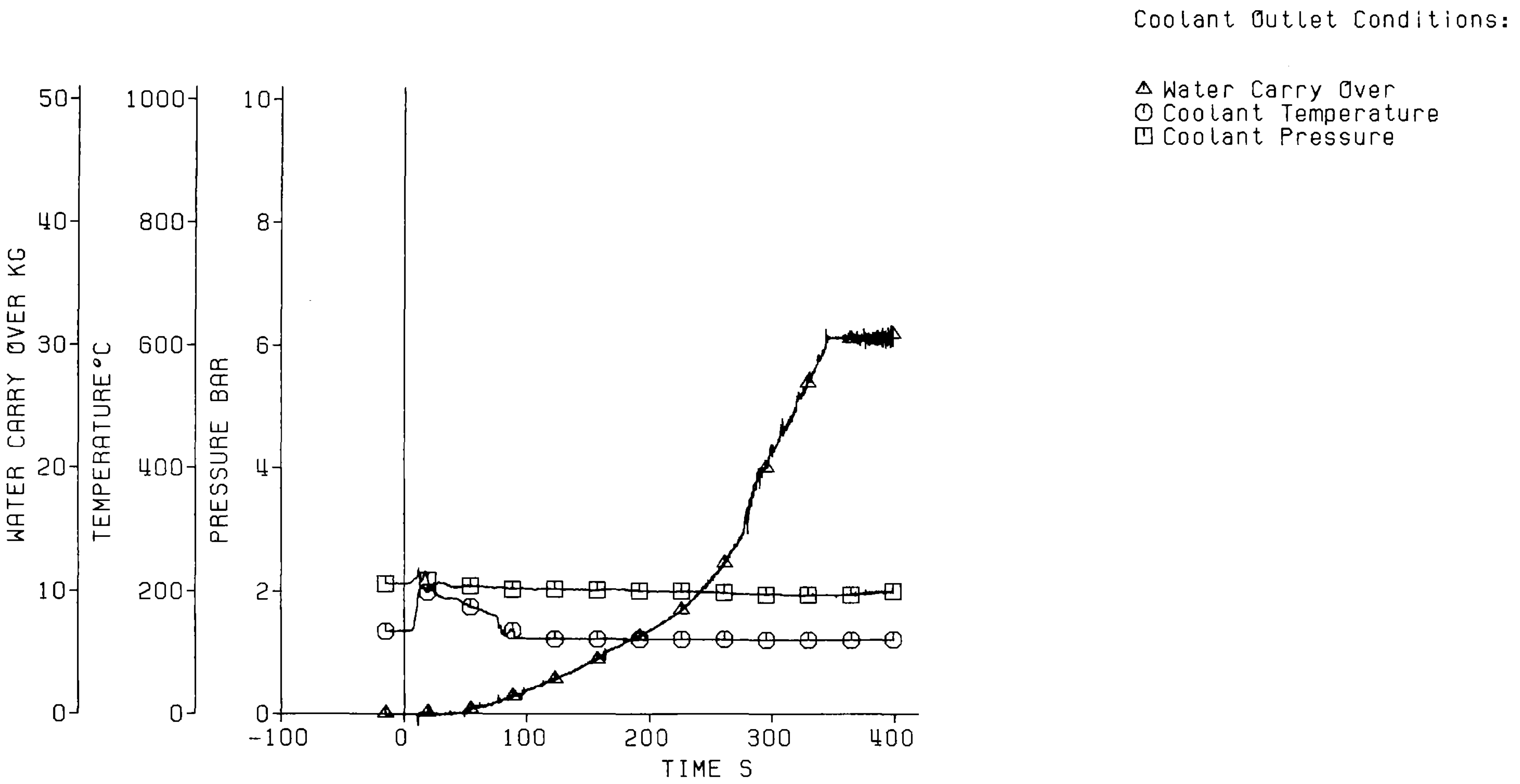


Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.82 cm/s
System Pressure 2.01 bar
Feedwater Temperature 40°C

REBEKA Rods With
Helium Filled Gaps

KfK IRB

Fig. 49 SEFLEX: 5x5 ROD BUNDLE, SERIES 3, TEST-No. 32

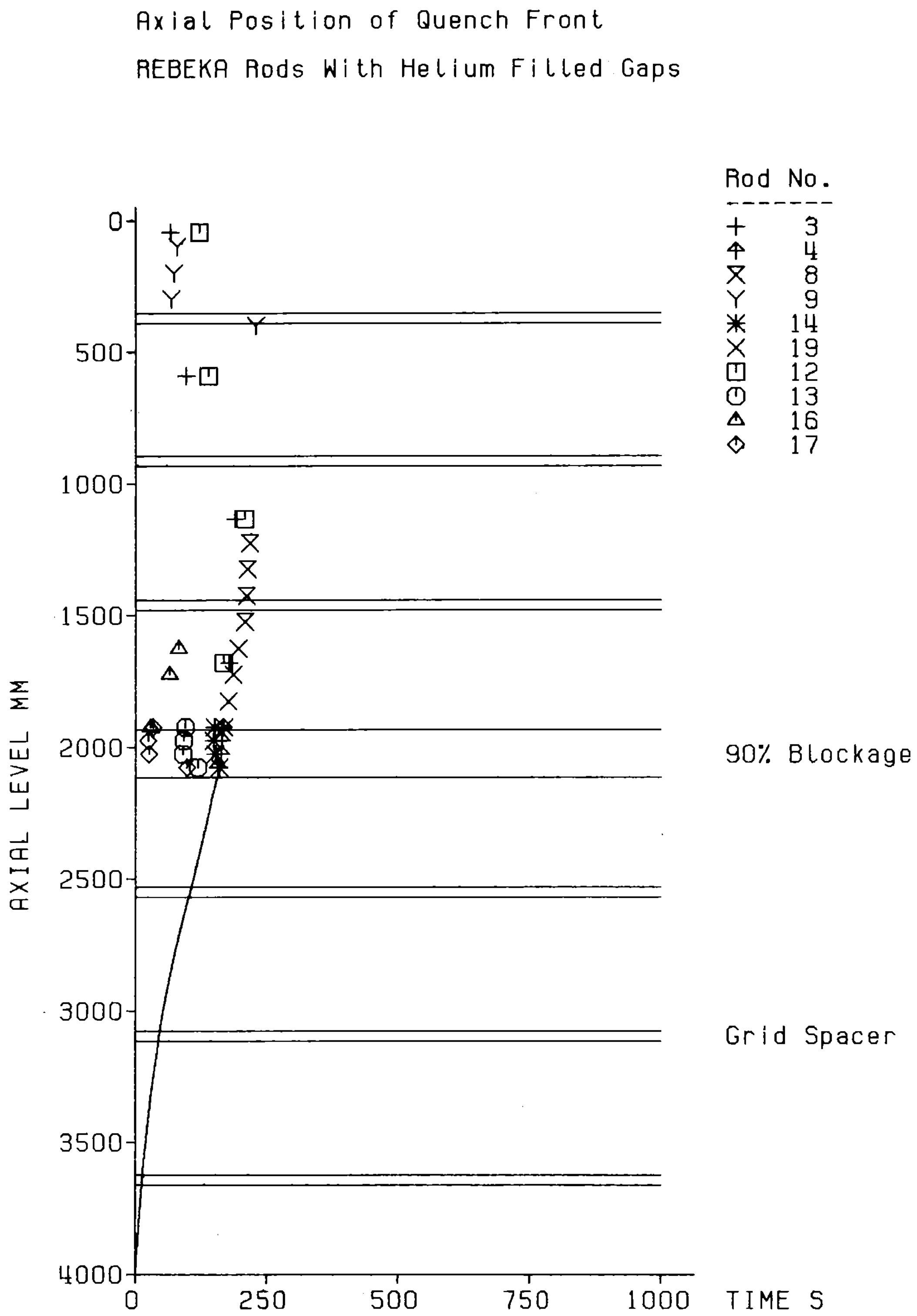


Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.82 cm/s
System Pressure 2.01 bar
Feedwater Temperature 40°C

REBEKA Rods With
Helium Filled Gaps

KfK IRB

Fig. 50 SEFLEX: 5x5 ROD BUNDLE, SERIES 3, TEST-No. 32



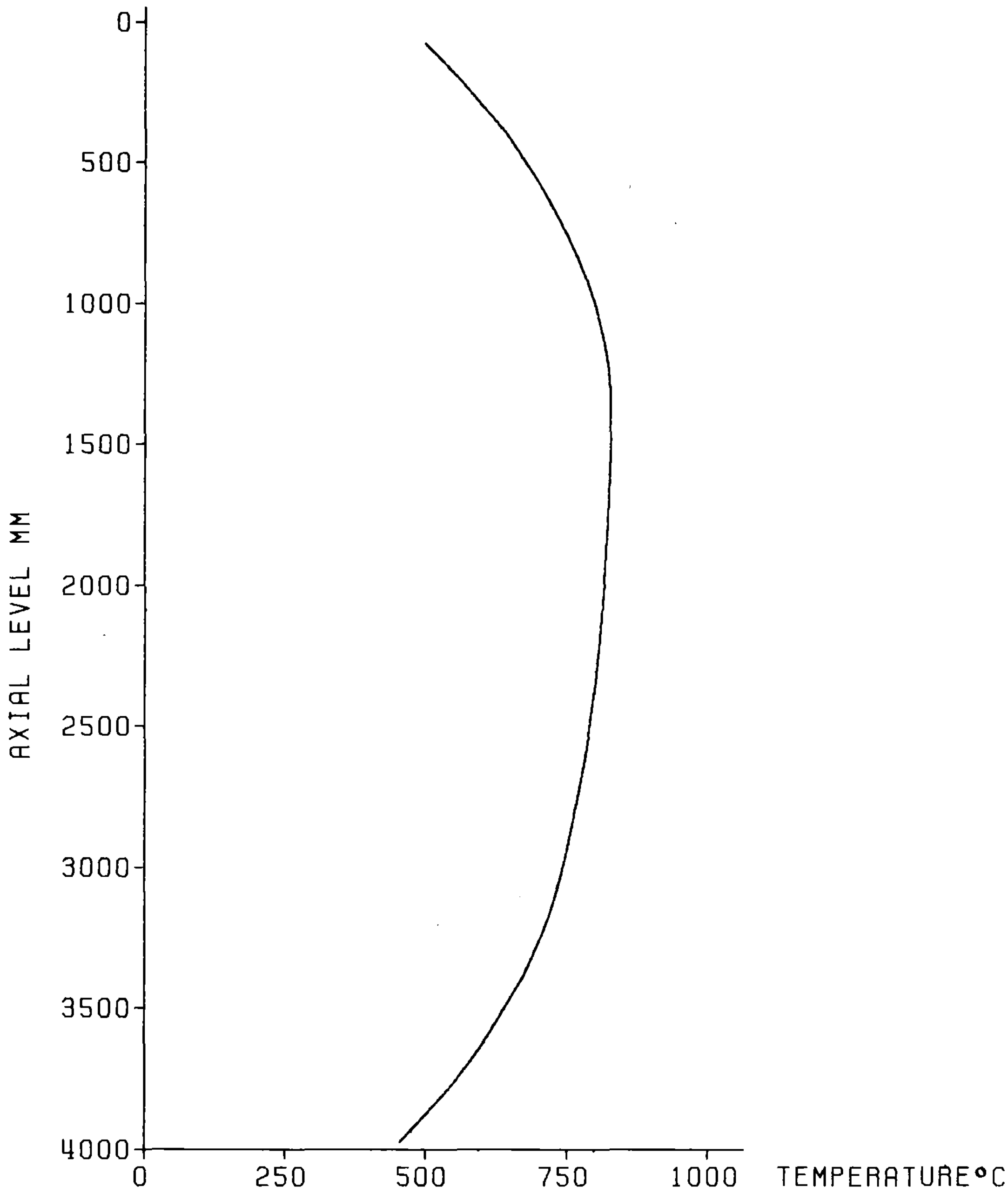
Decay Heat	120% ANS Standard
Flooding Rate (cold)	3.82 cm/s
System Pressure	2.01 bar
Feedwater Temperature	40 °C

KfK IRB

Fig. 51 SEFLEX: 5x5 RØD BUNDLE
TEST SERIES 3, TEST-No. 32

Initial Axial Temperature Profile of Claddings

REBEKA Rods With Helium Filled Gaps

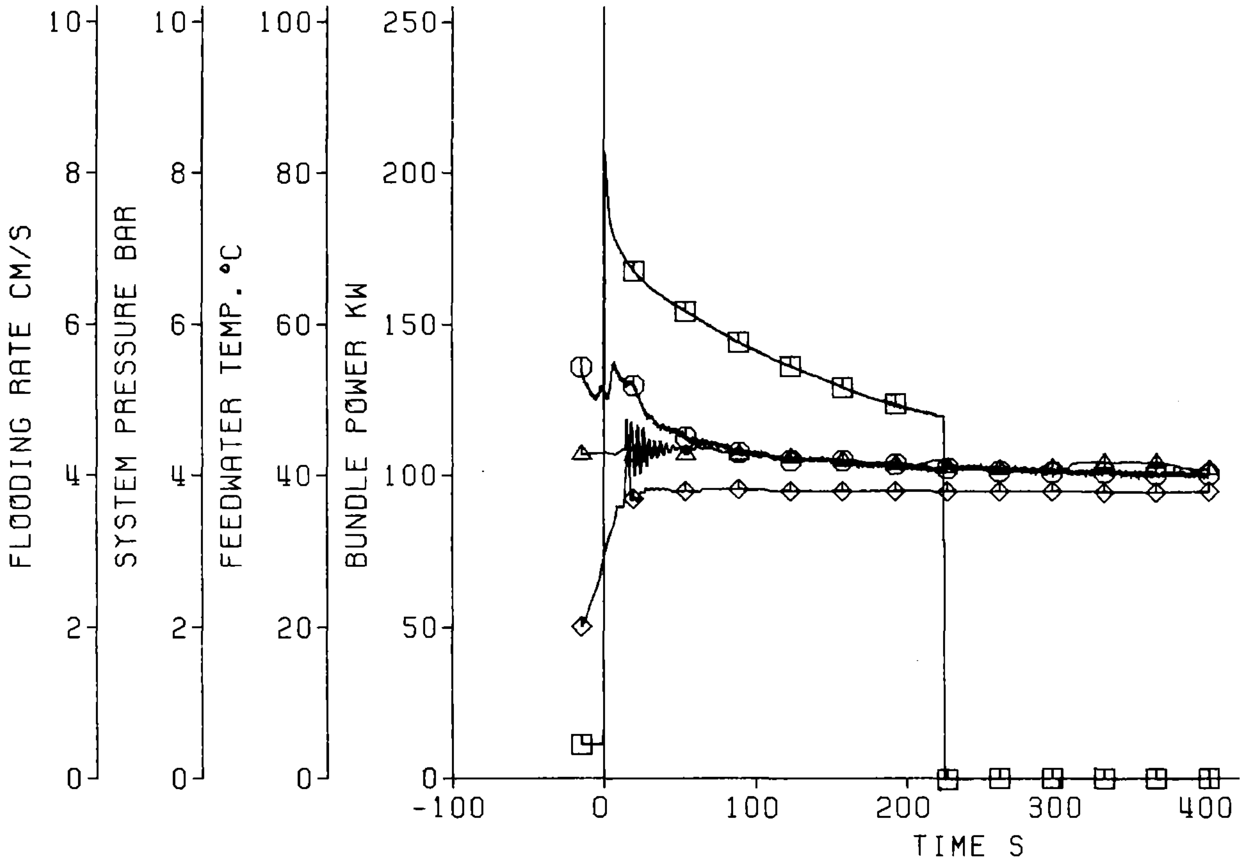


Decay Heat	120% ANS Standard
Flooding Rate (cold)	3.80 cm/s
System Pressure	4.20 bar
Feedwater Temperature	43°C

KfK IRB

Fig. 52 SEFLEX: 5x5 RØD BUNDLE
TEST SERIES 3, TEST-No. 35

Test Parameters:

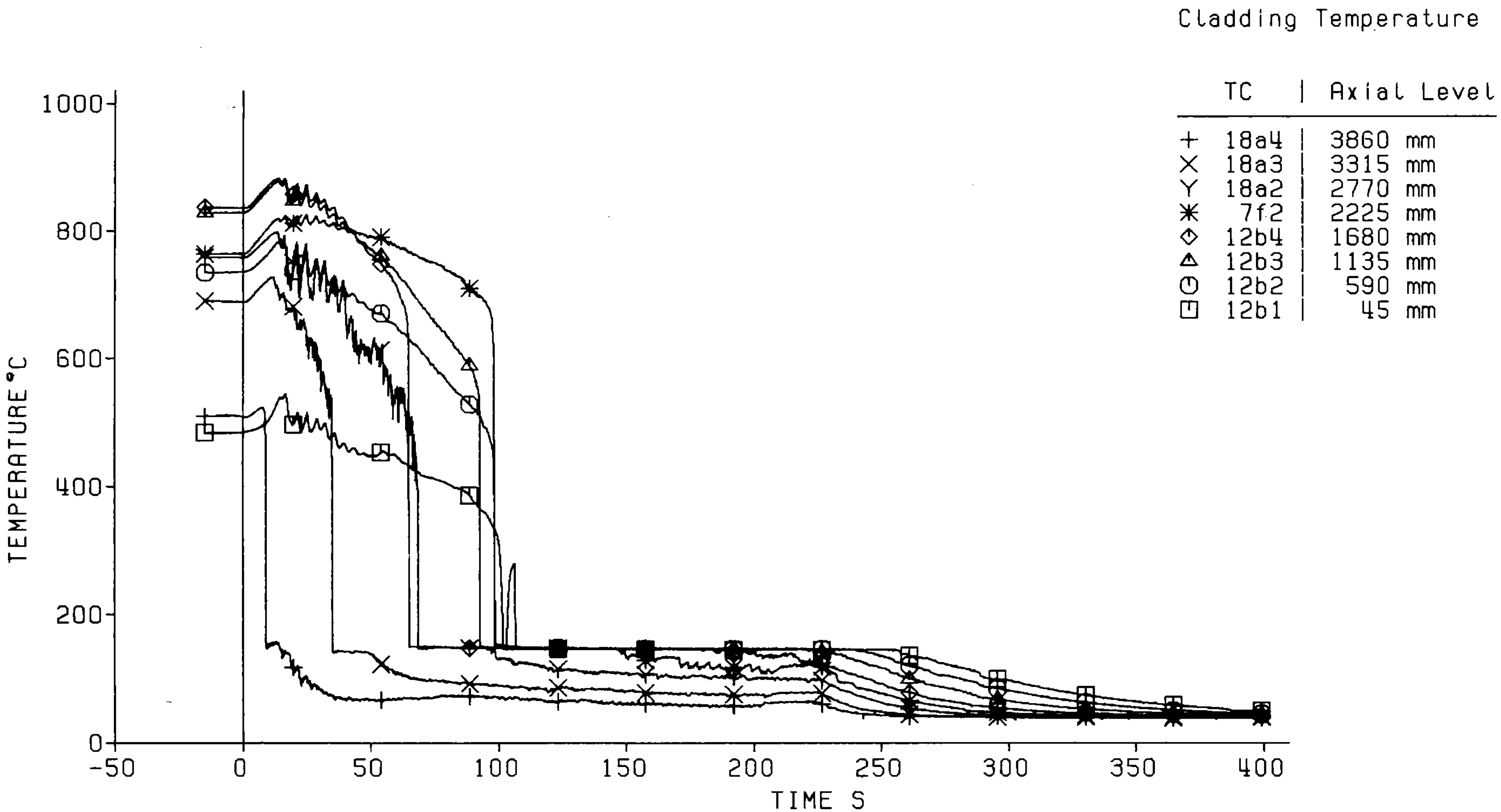


Decay Heat	120% ANS Standard
Flooding Rate (cold)	3.80 cm/s
System Pressure	4.20 bar
Feedwater Temperature	43°C

REBEKA Rods With
Helium Filled Gaps

KfK IRB

Fig. 53 SEFLEX: 5x5 RØD BUNDLE, SERIES 3, TEST-No. 35

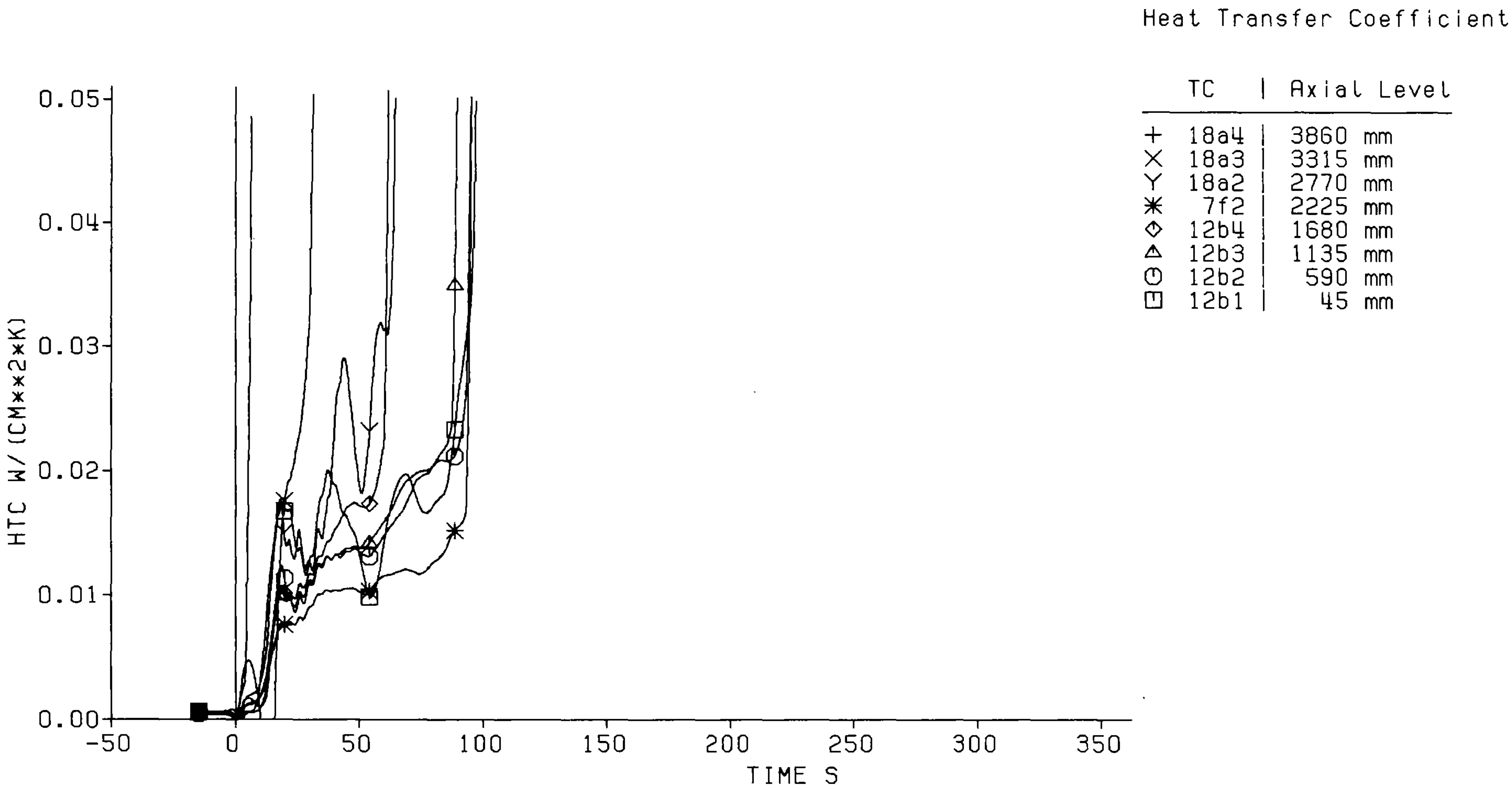


Decay Heat	120% ANS Standard
Flooding Rate (cold)	3.80 cm/s
System Pressure	4.20 bar
Feedwater Temperature	43°C

REBEKA Rods With
Helium Filled Gaps

KfK IRB

Fig. 54 SEFLEX: 5x5 RØD BUNDLE, SERIES 3, TEST-No. 35

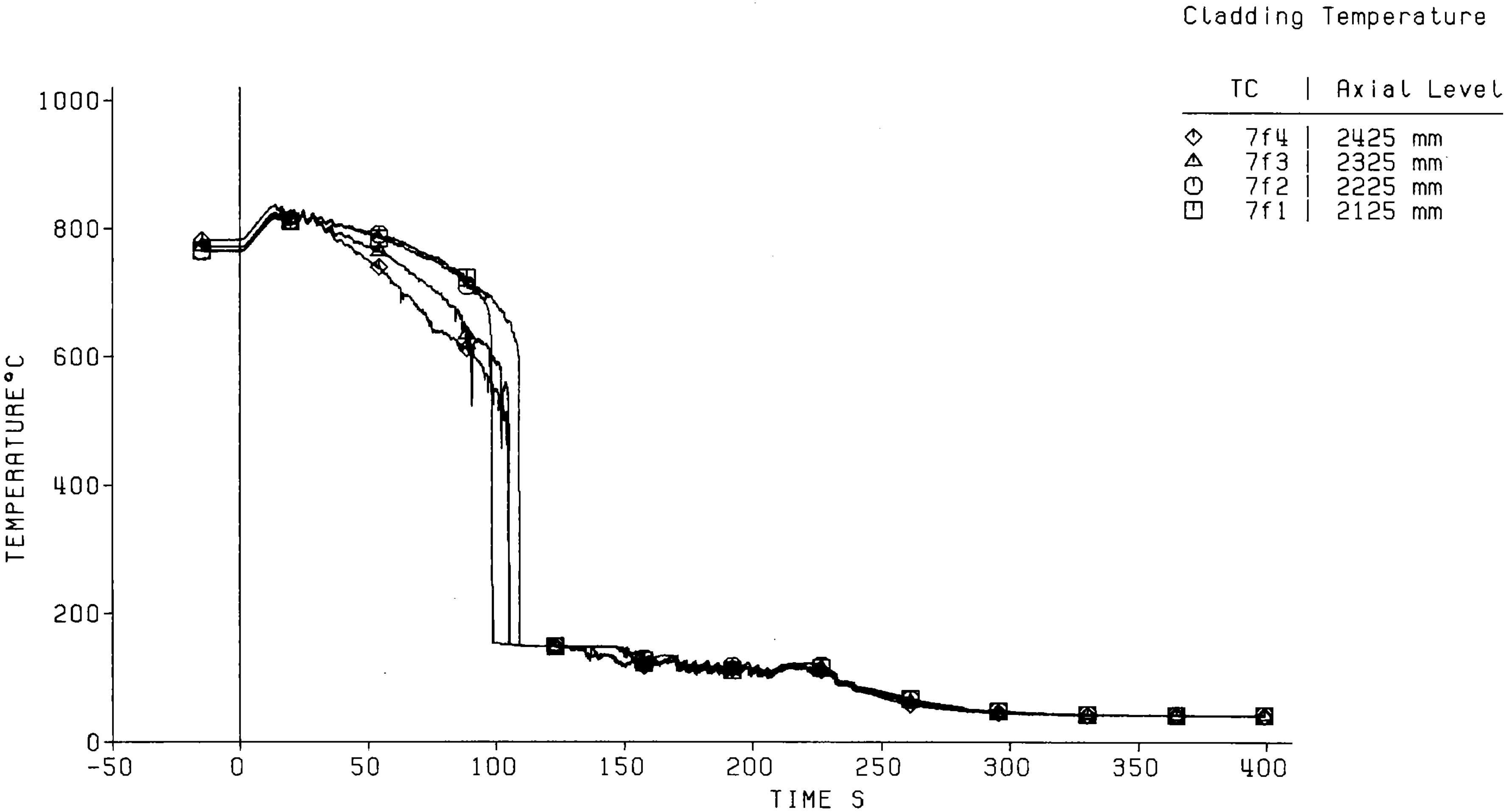


Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.80 cm/s
System Pressure 4.20 bar
Feedwater Temperature 43°C

REBEKA Rods With
Helium Filled Gaps

KfK IRB

Fig. 55 SEFLEX: 5x5 RØD BUNDLE, SERIES 3, TEST-No. 35



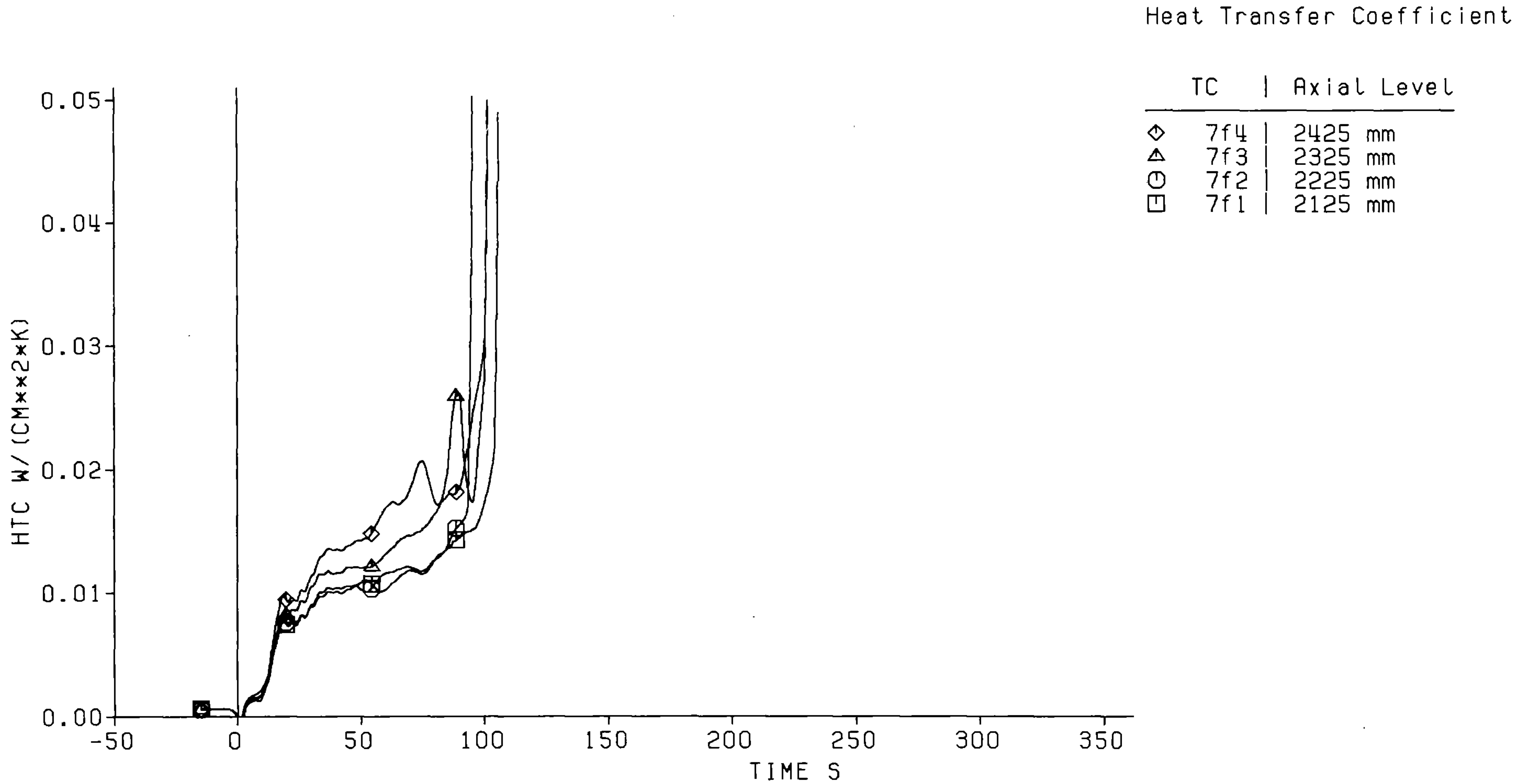
Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.80 cm/s
System Pressure 4.20 bar
Feedwater Temperature 43 °C

REBEKA Rods With Helium Filled Gaps

Bypass
======

KfK IRB

Fig. 56 SEFLEX: 5x5 RØD BUNDLE, SERIES 3, TEST-No. 35



Decay Heat	120% ANS Standard
Flooding Rate (cold)	3.80 cm/s
System Pressure	4.20 bar
Feedwater Temperature	43°C

REBEKA Rods With
Helium Filled Gaps

Bypass
======

KfK IRB

Fig. 57 SEFLEX: 5x5 RØD BUNDLE, SERIES 3, TEST-No. 35

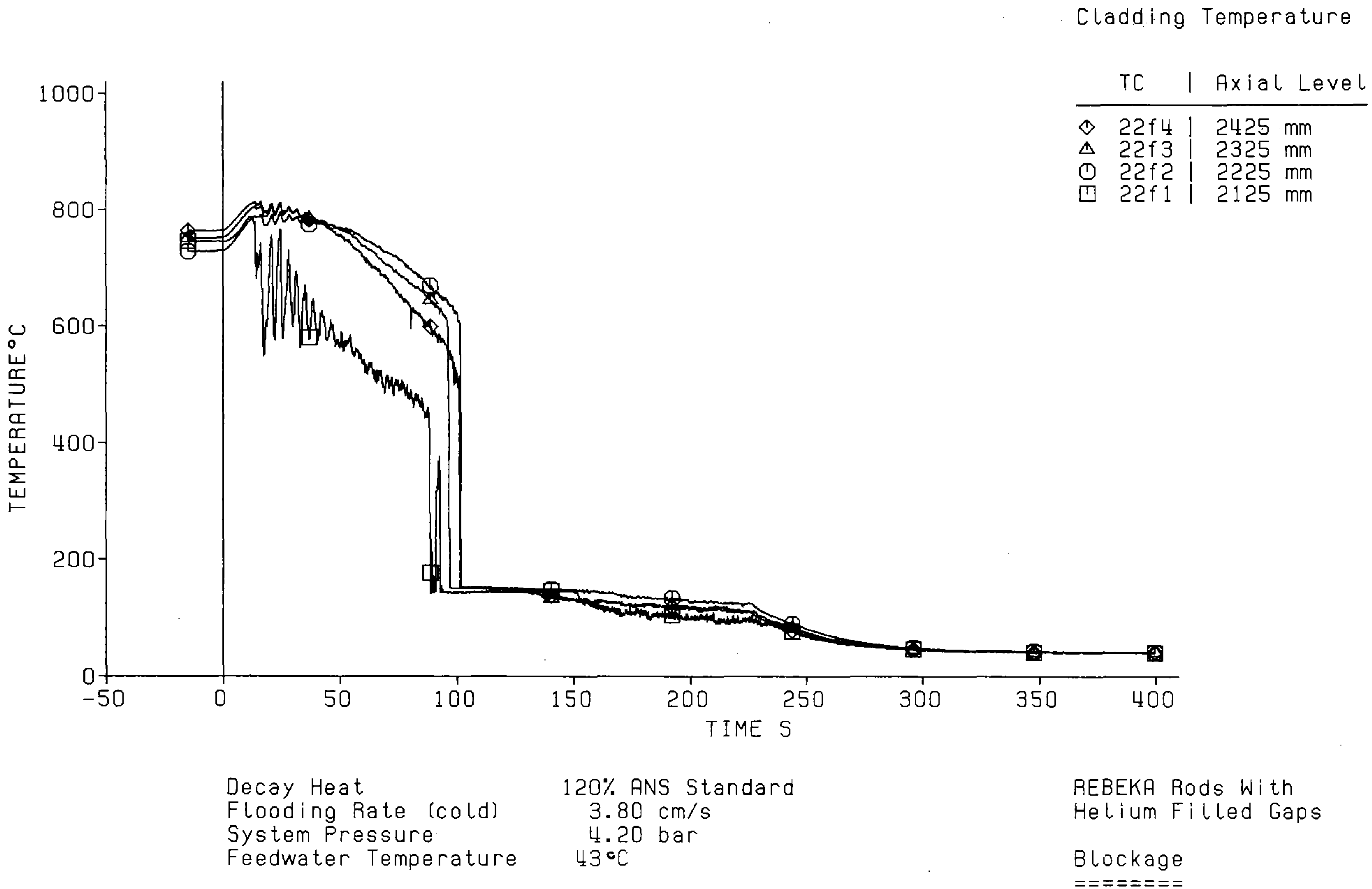
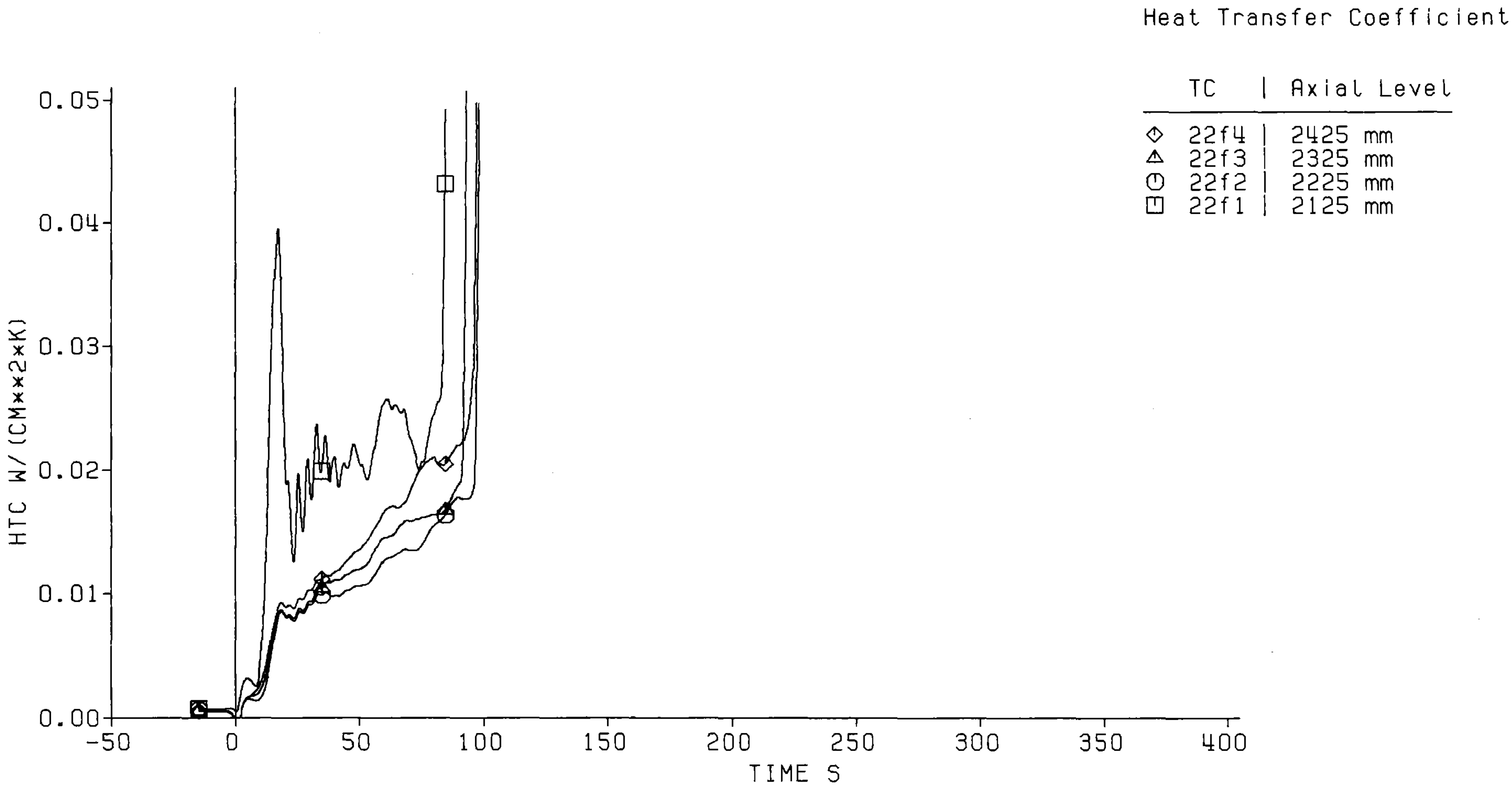


Fig. 58 SEFLEX: 5x5 RØD BUNDLE, SERIES 3, TEST-No. 35



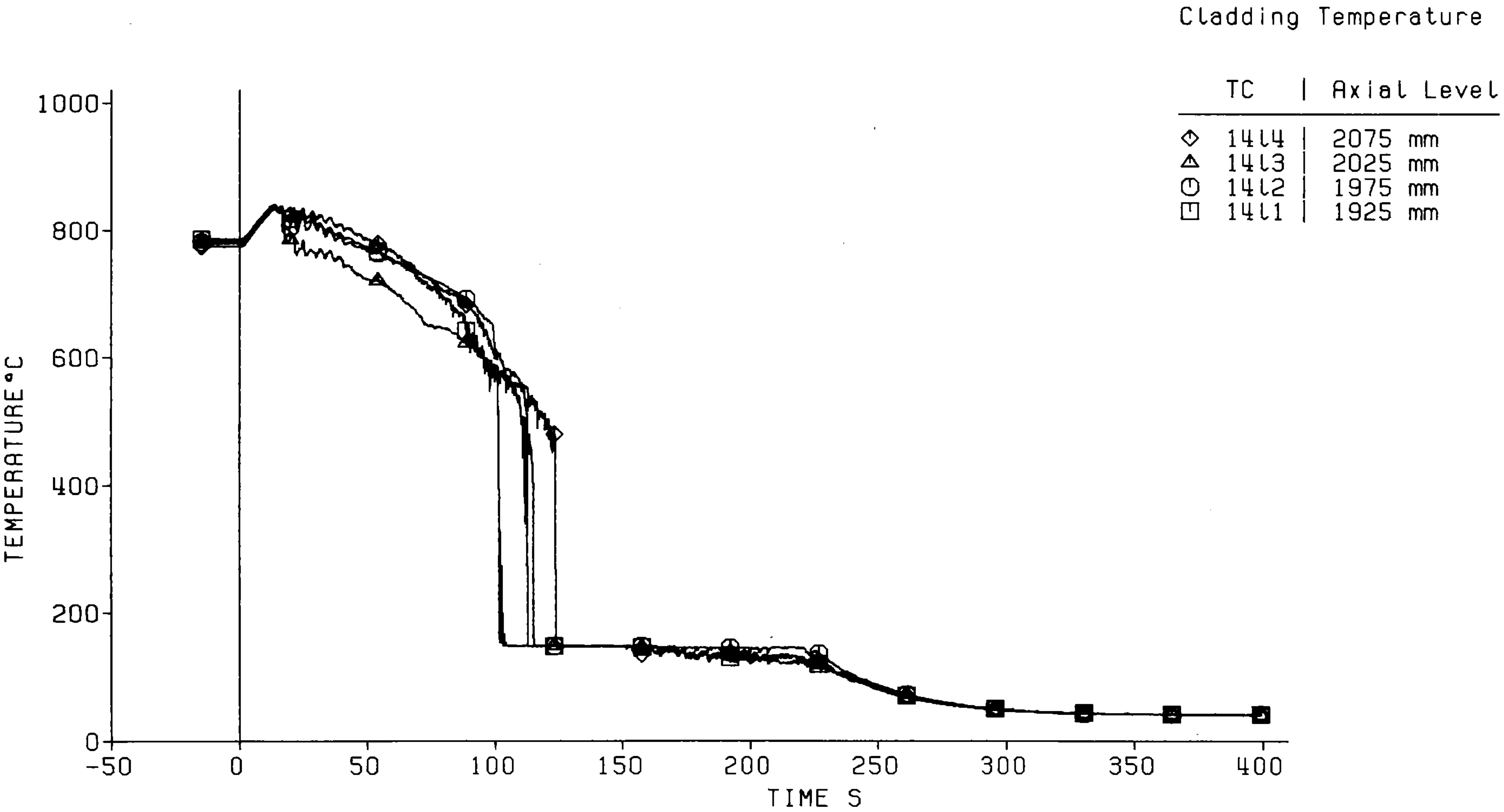
Decay Heat	120% ANS Standard
Flooding Rate (cold)	3.80 cm/s
System Pressure	4.20 bar
Feedwater Temperature	43°C

REBEKA Rods With
Helium Filled Gaps

Blockage
========

KfK IRB

Fig. 59 SEFLEX: 5x5 RØD BUNDLE, SERIES 3, TEST-No. 35



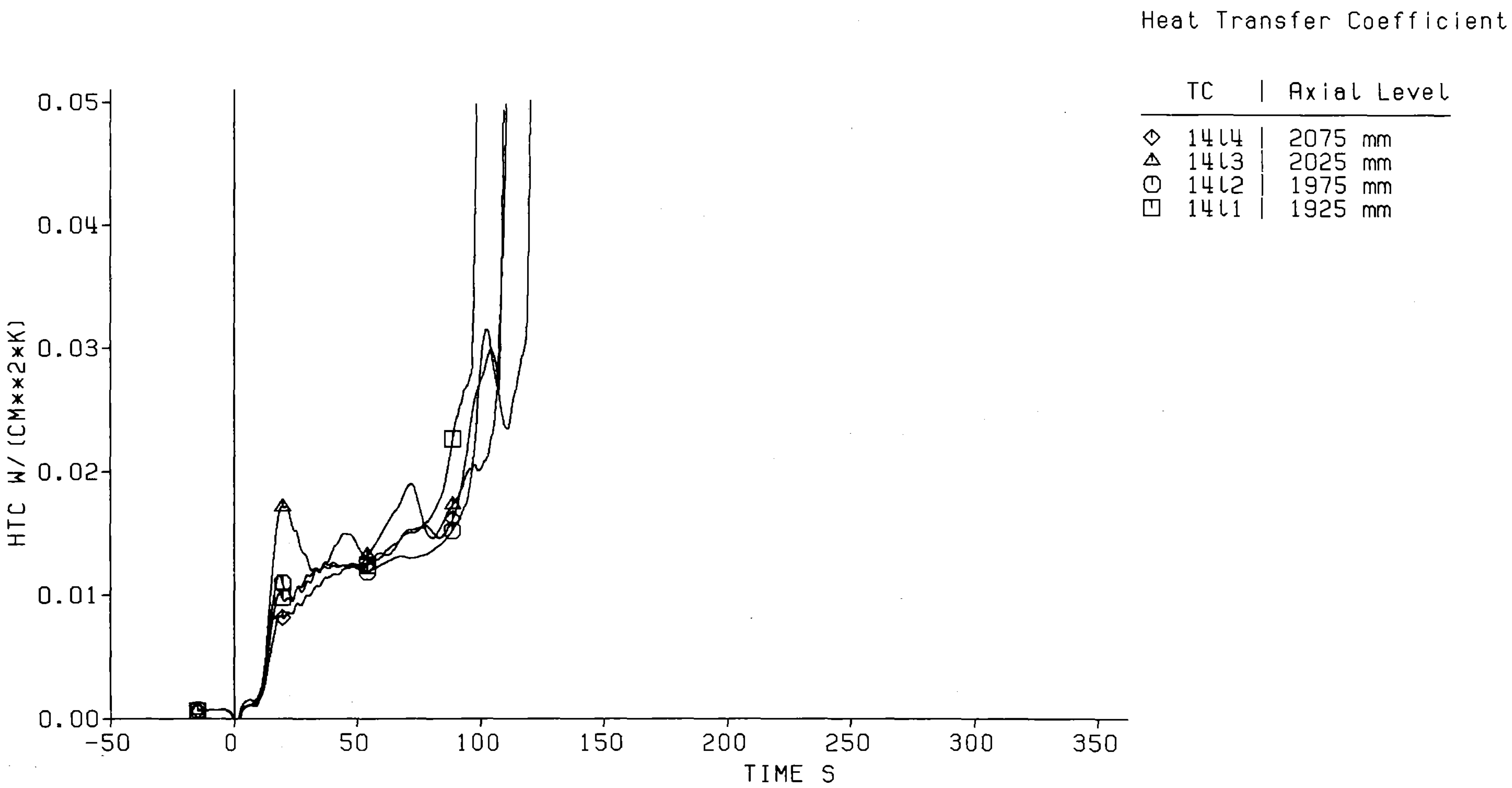
Decay Heat	120% ANS Standard
Flooding Rate (cold)	3.80 cm/s
System Pressure	4.20 bar
Feedwater Temperature	43°C

REBEKA Rods With
Helium Filled Gaps

Bypass
======

KfK IRB

Fig. 60 SEFLEX: 5x5 RØD BUNDLE, SERIES 3, TEST-No. 35



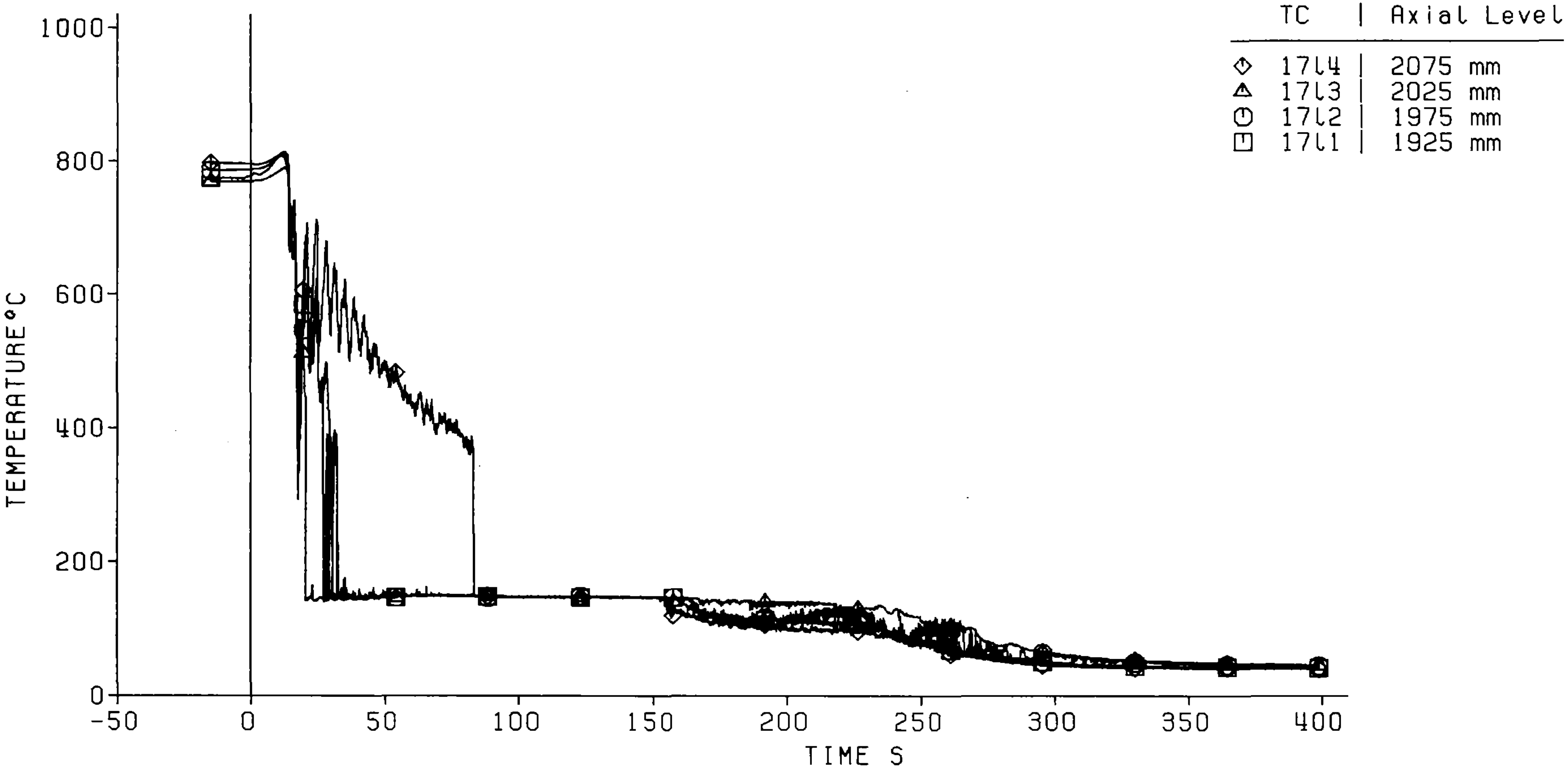
Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.80 cm/s
System Pressure 4.20 bar
Feedwater Temperature 43°C

REBEKA Rods With
Helium Filled Gaps

Bypass
======

KfK IRB

Fig. 61 SEFLEX: 5x5 RØD BUNDLE, SERIES 3, TEST-No. 35



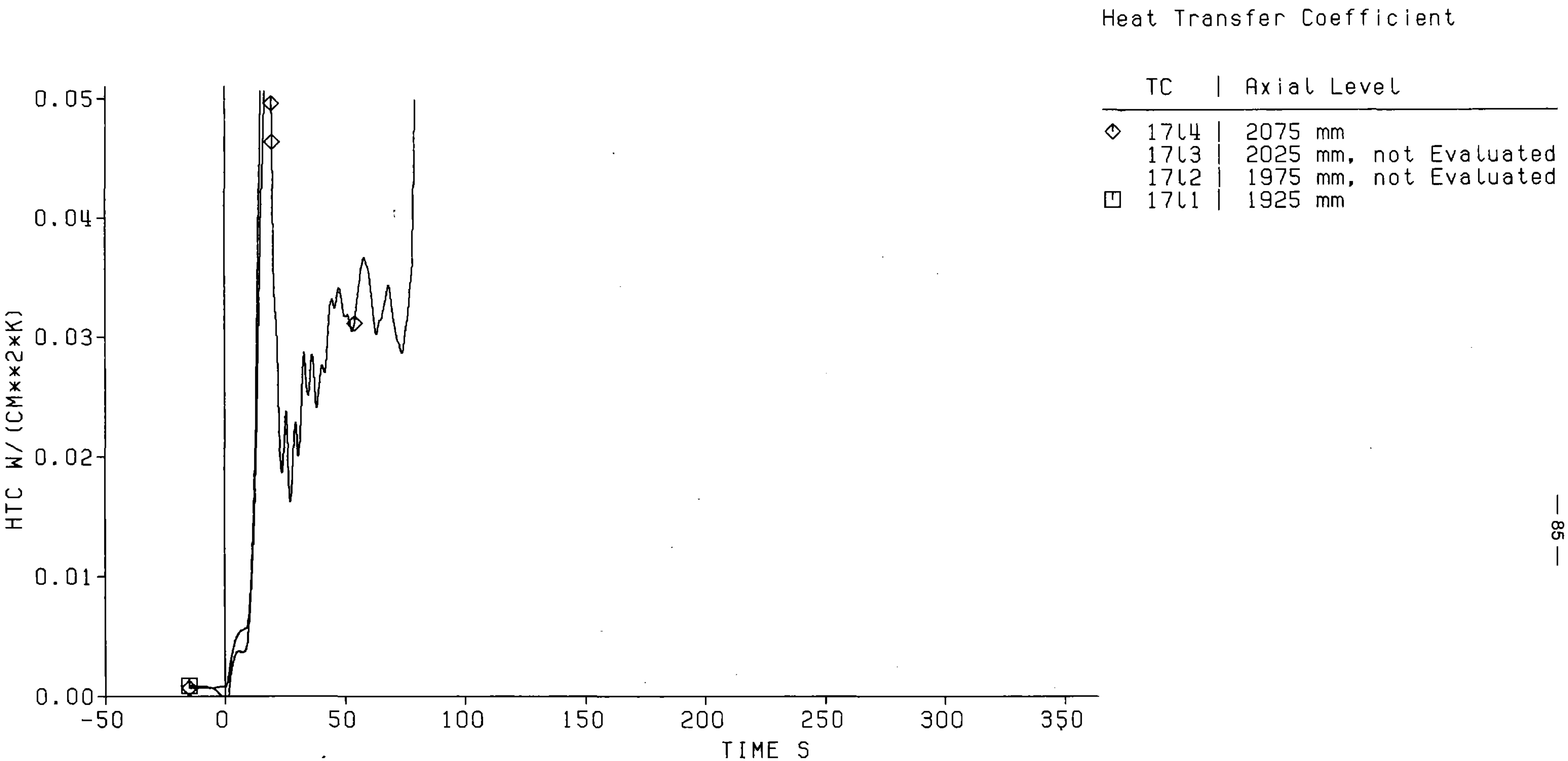
Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.80 cm/s
System Pressure 4.20 bar
Feedwater Temperature 43°C

REBEKA Rods With
Helium Filled Gaps

Blockage
========

KfK IRB

Fig. 62 SEFLEX: 5x5 RØD BUNDLE, SERIES 3, TEST-No. 35



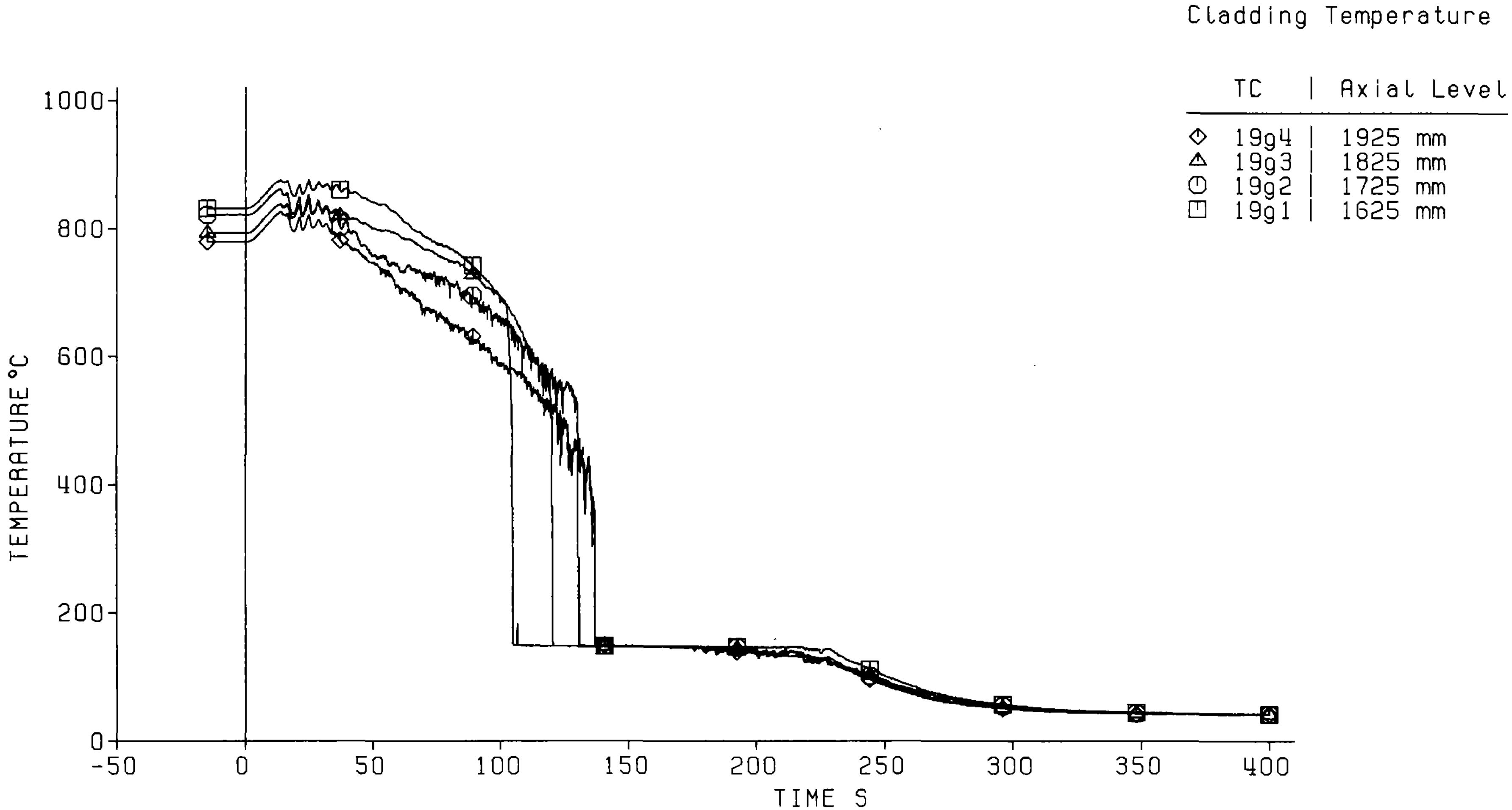
Decay Heat	120% ANS Standard
Flooding Rate (cold)	3.80 cm/s
System Pressure	4.20 bar
Feedwater Temperature	43°C

REBEKA Rods With
Helium Filled Gaps

Blockage
========

KfK IRB

Fig. 63 SEFLEX: 5x5 RØD BUNDLE, SERIES 3, TEST-No. 35

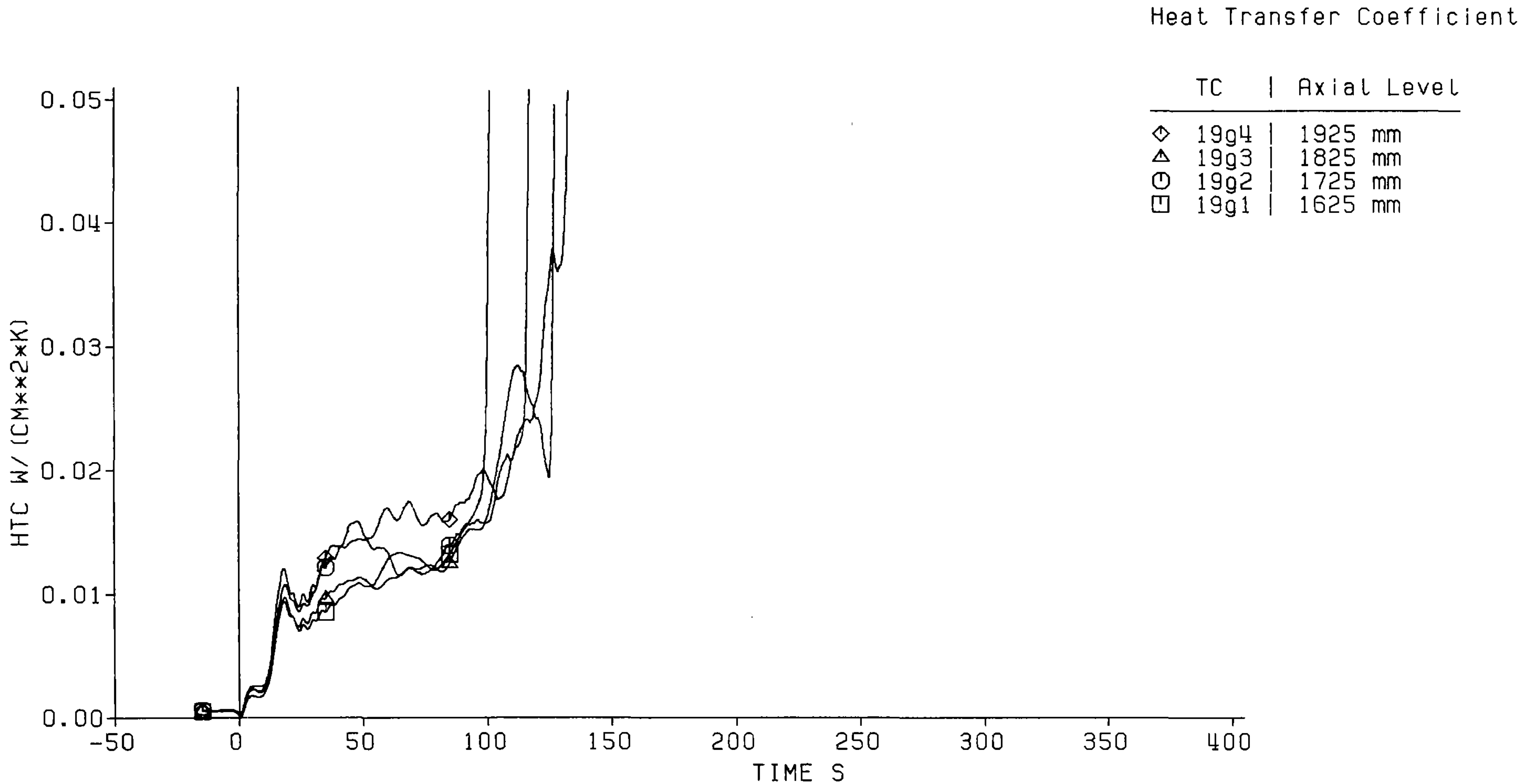


Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.80 cm/s
System Pressure 4.20 bar
Feedwater Temperature 43°C

REBEKA Rods With
Helium Filled Gaps

Bypass
======

Fig. 64 SEFLEX: 5x5 RØD BUNDLE, SERIES 3, TEST-No. 35



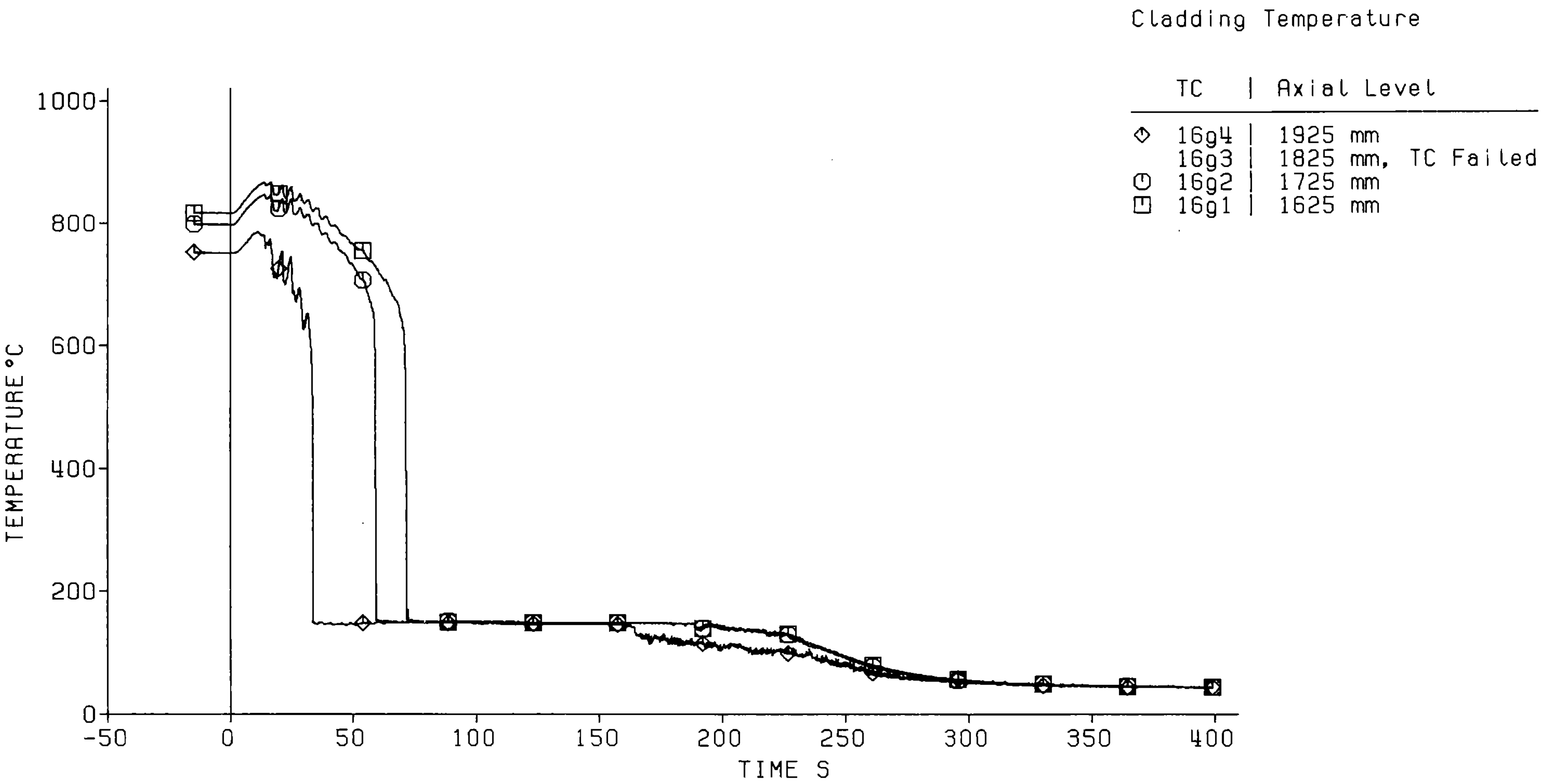
Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.80 cm/s
System Pressure 4.20 bar
Feedwater Temperature 43°C

REBEKA Rods With
Helium Filled Gaps

Bypass
======

KfK IRB

Fig. 65 SEFLEX: 5x5 RØD BUNDLE, SERIES 3, TEST-No. 35



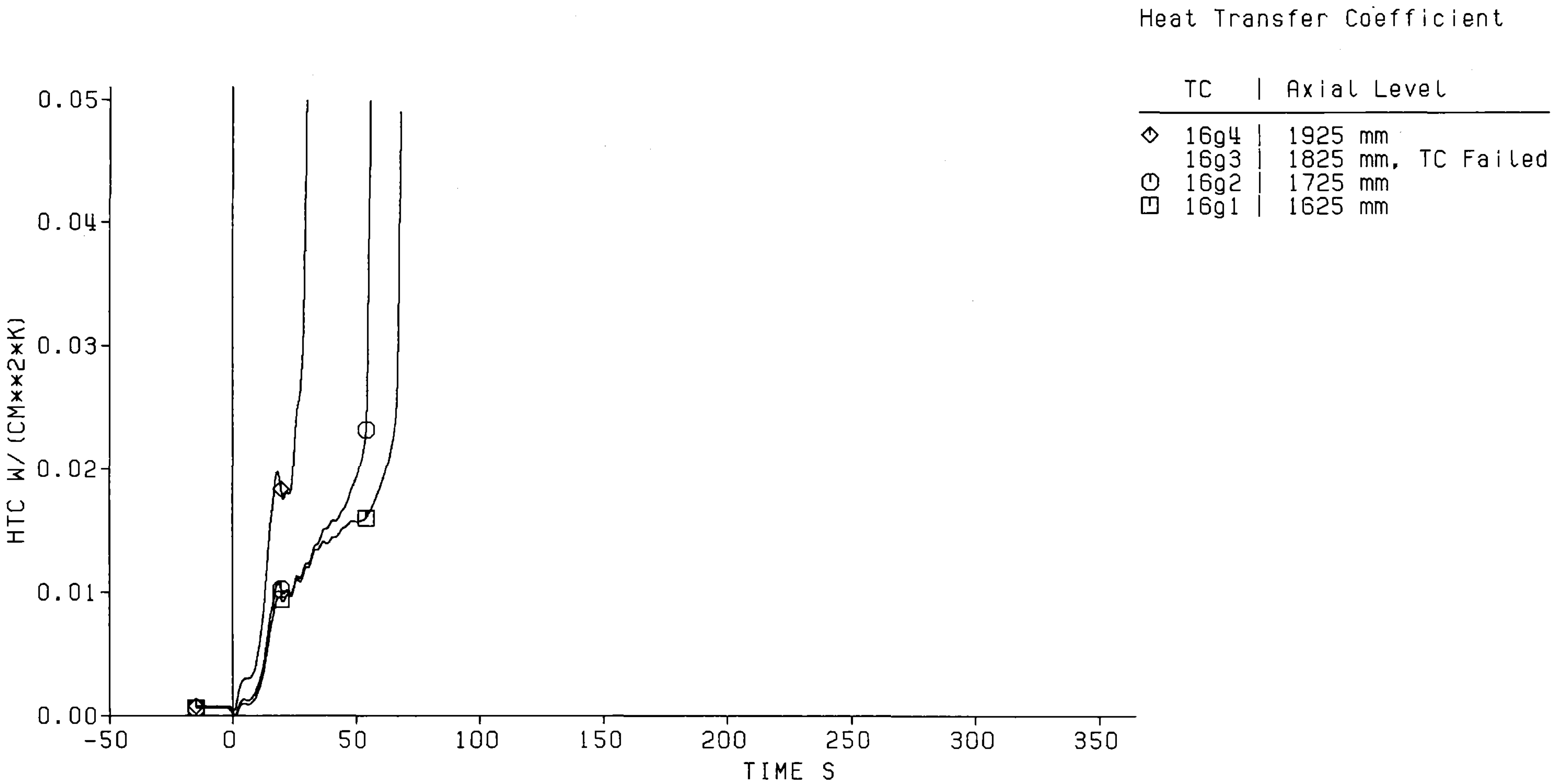
Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.80 cm/s
System Pressure 4.20 bar
Feedwater Temperature 43 °C

REBEKA Rods With
Helium Filled Gaps

Blockage
========

KfK IRB

Fig. 66 SEFLEX: 5x5 RØD BUNDLE, SERIES 3, TEST-No. 35



Decay Heat	120% ANS Standard
Flooding Rate (cold)	3.80 cm/s
System Pressure	4.20 bar
Feedwater Temperature	43°C

REBEKA Rods With
Helium Filled Gaps

Blockage
========

KfK IRB

Fig. 67 SEFLEX: 5x5 RØD BUNDLE, SERIES 3, TEST-No. 35

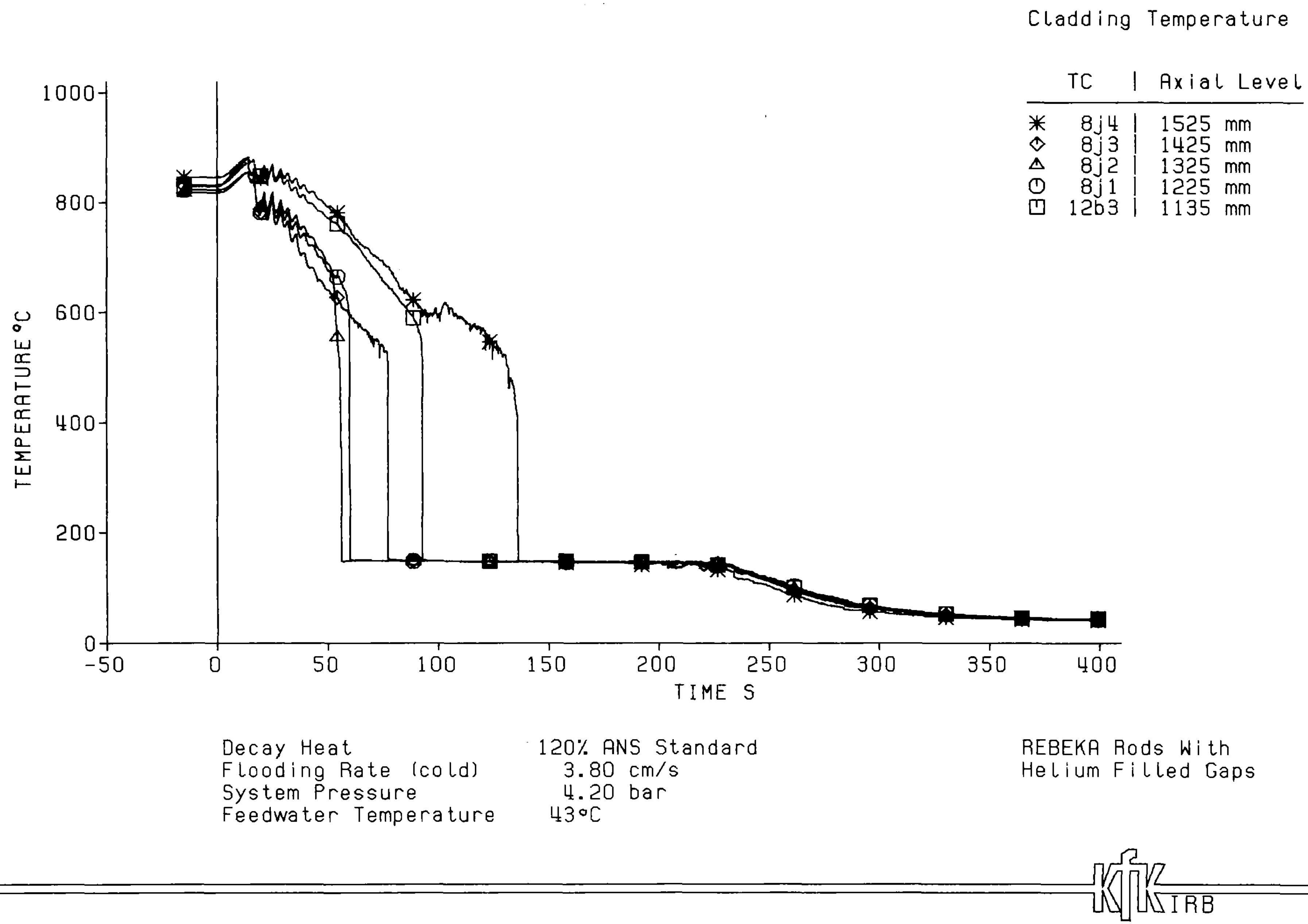
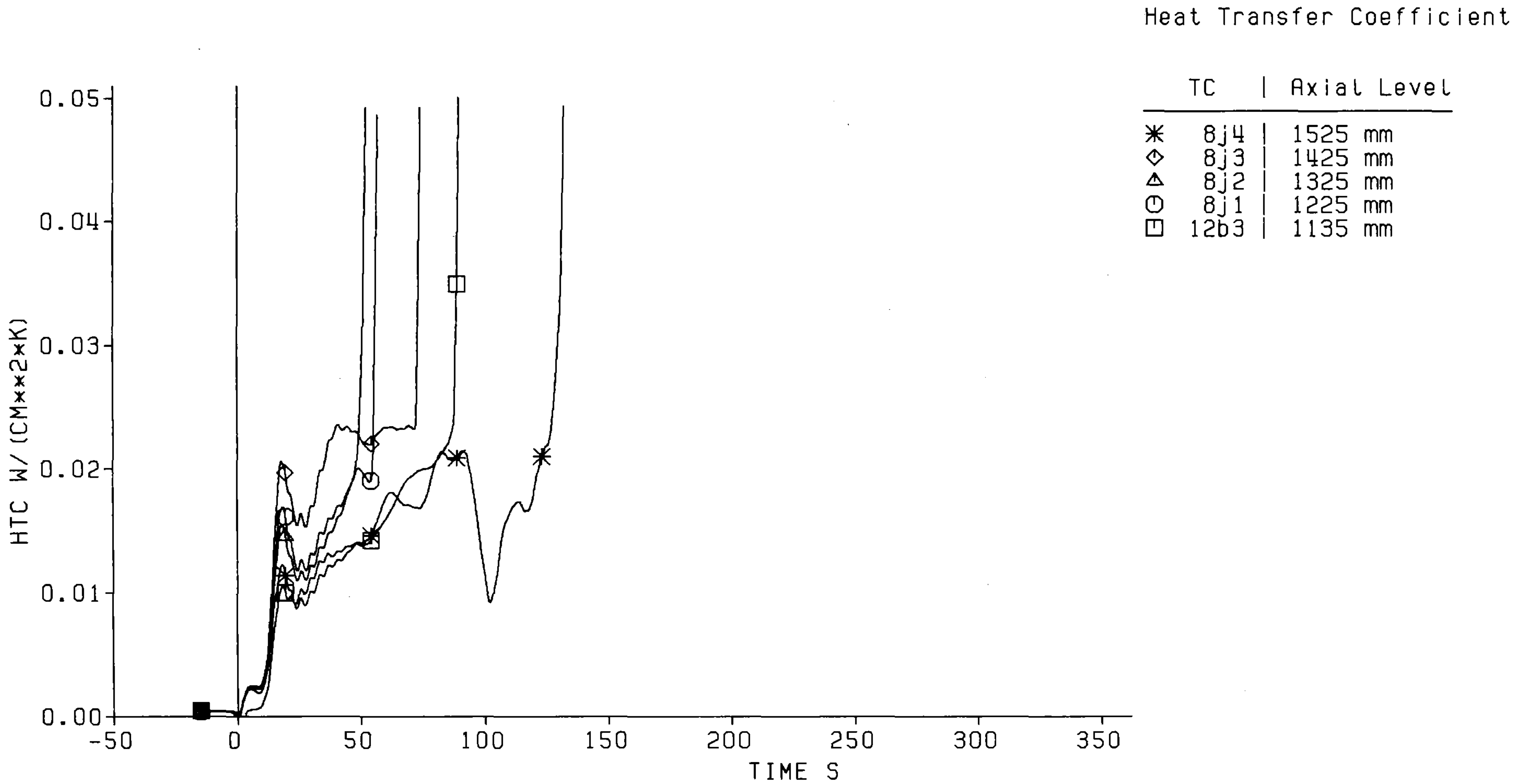


Fig. 68 SEFLEX: 5x5 RØD BUNDLE, SERIES 3, TEST-No. 35

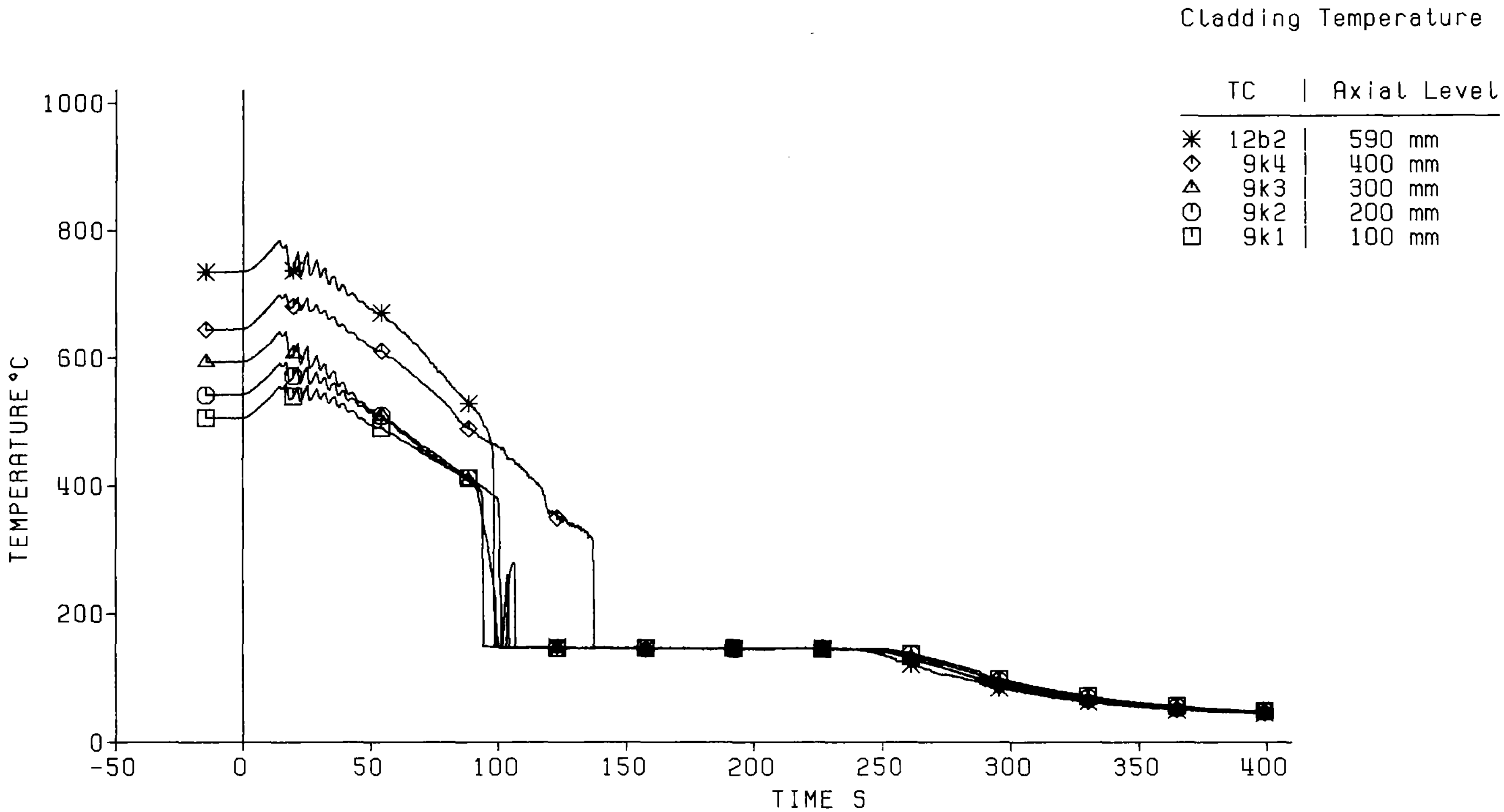


Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.80 cm/s
System Pressure 4.20 bar
Feedwater Temperature 43°C

REBEKA Rods With
Helium Filled Gaps

KfK IRB

Fig. 69 SEFLEX: 5x5 RØD BUNDLE, SERIES 3, TEST-No. 35

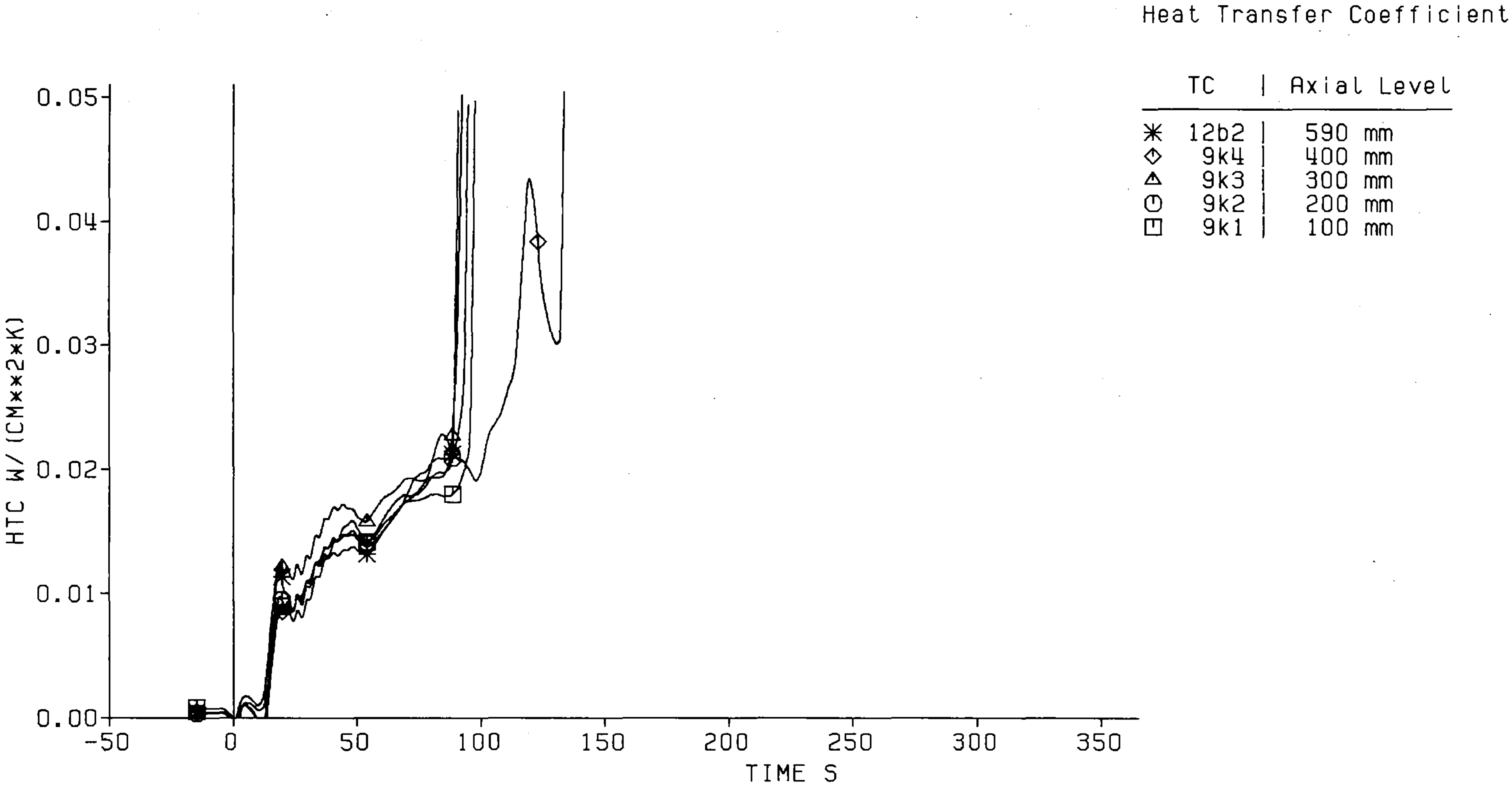


Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.80 cm/s
System Pressure 4.20 bar
Feedwater Temperature 43 °C

REBEKA Rods With
Helium Filled Gaps

KfK IRB

Fig. 70 SEFLEX: 5x5 RØD BUNDLE, SERIES 3, TEST-No. 35

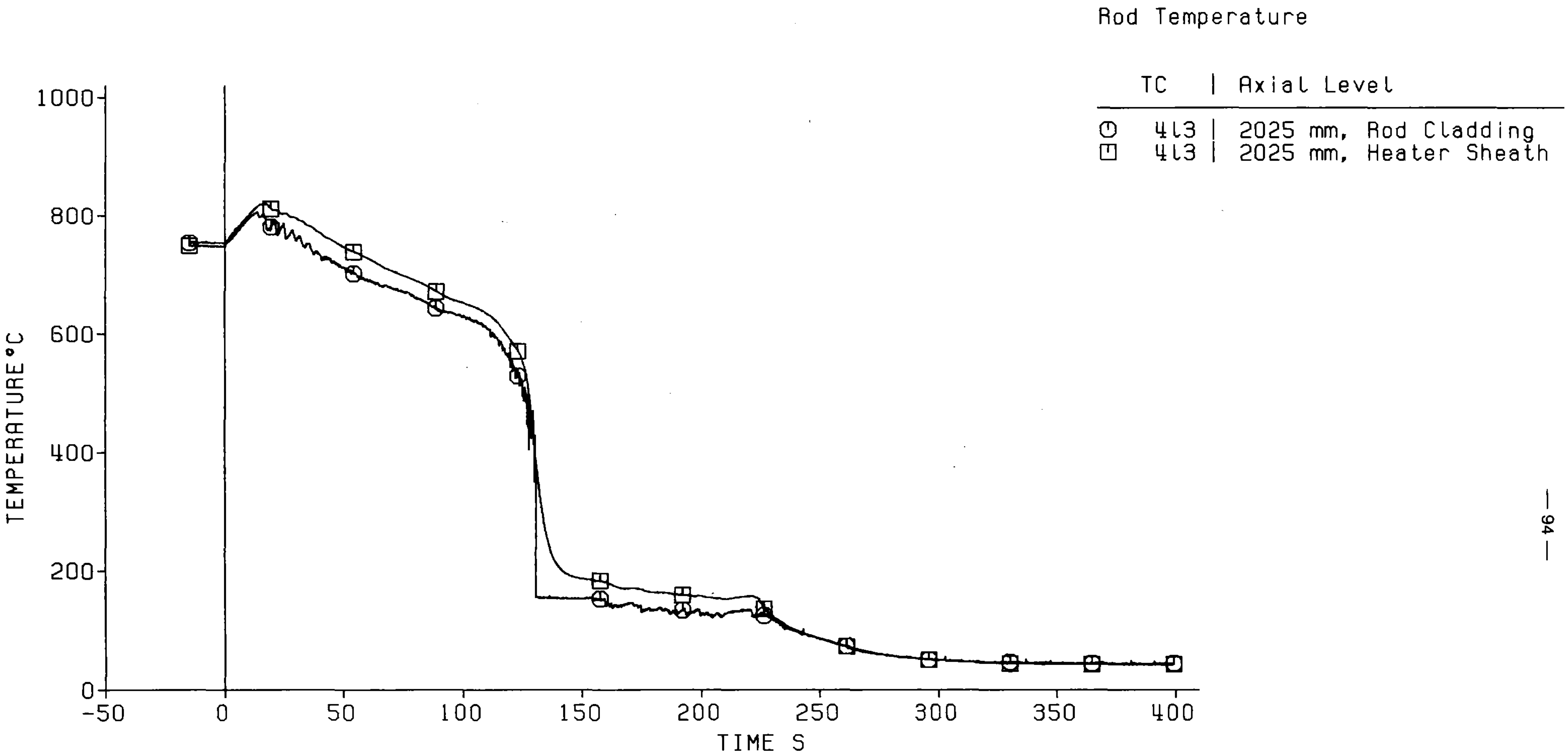


Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.80 cm/s
System Pressure 4.20 bar
Feedwater Temperature 43 °C

REBEKA Rods With
Helium Filled Gaps

KfK IRB

Fig. 71 SEFLEX: 5x5 RØD BUNDLE, SERIES 3, TEST-No. 35



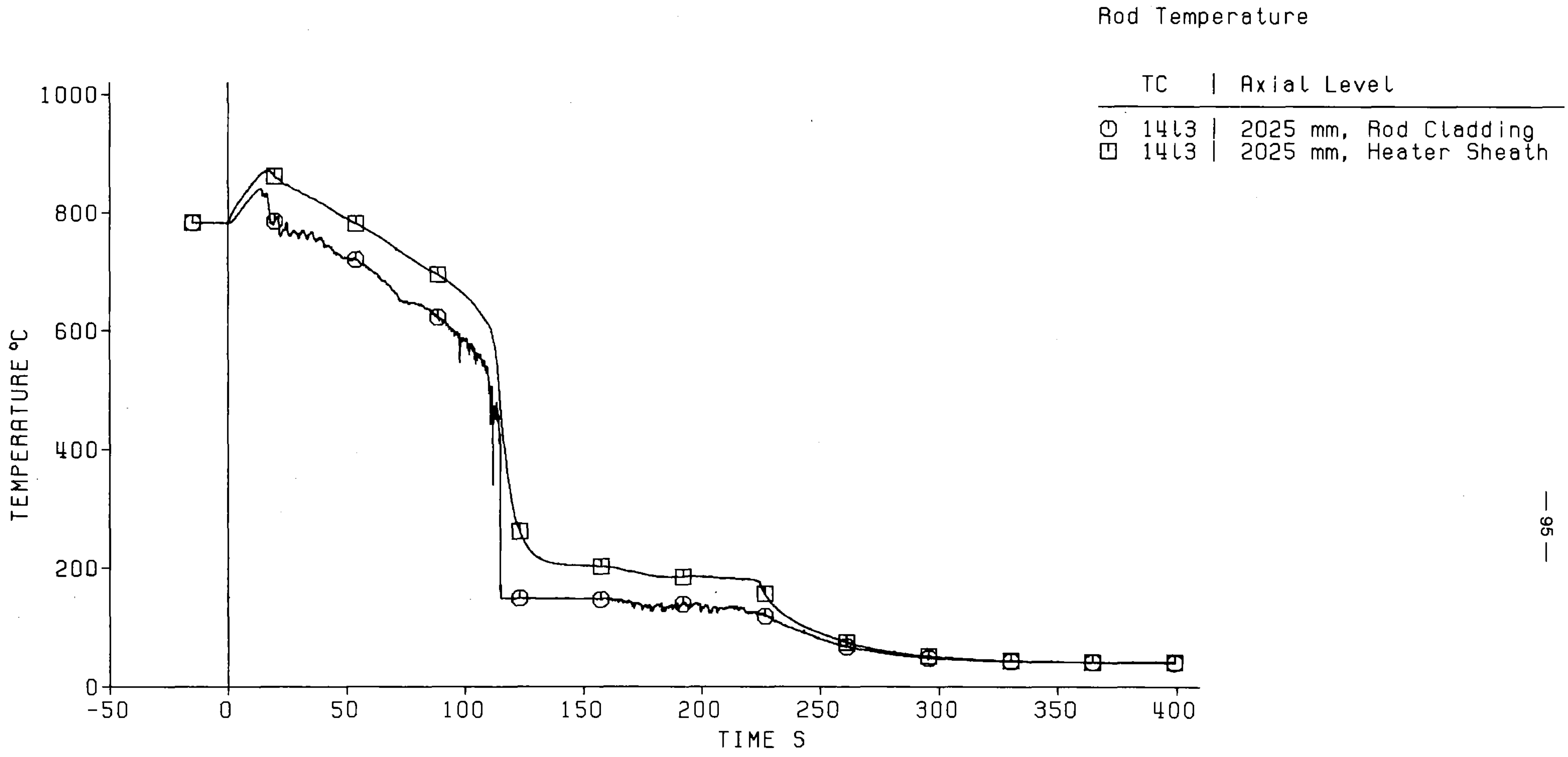
Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.80 cm/s
System Pressure 4.20 bar
Feedwater Temperature 43°C

REBEKA Rods With
Helium Filled Gaps

Bypass
======

KfK IRB

Fig. 72 SEFLEX: 5x5 RØD BUNDLE, SERIES 3, TEST-No. 35



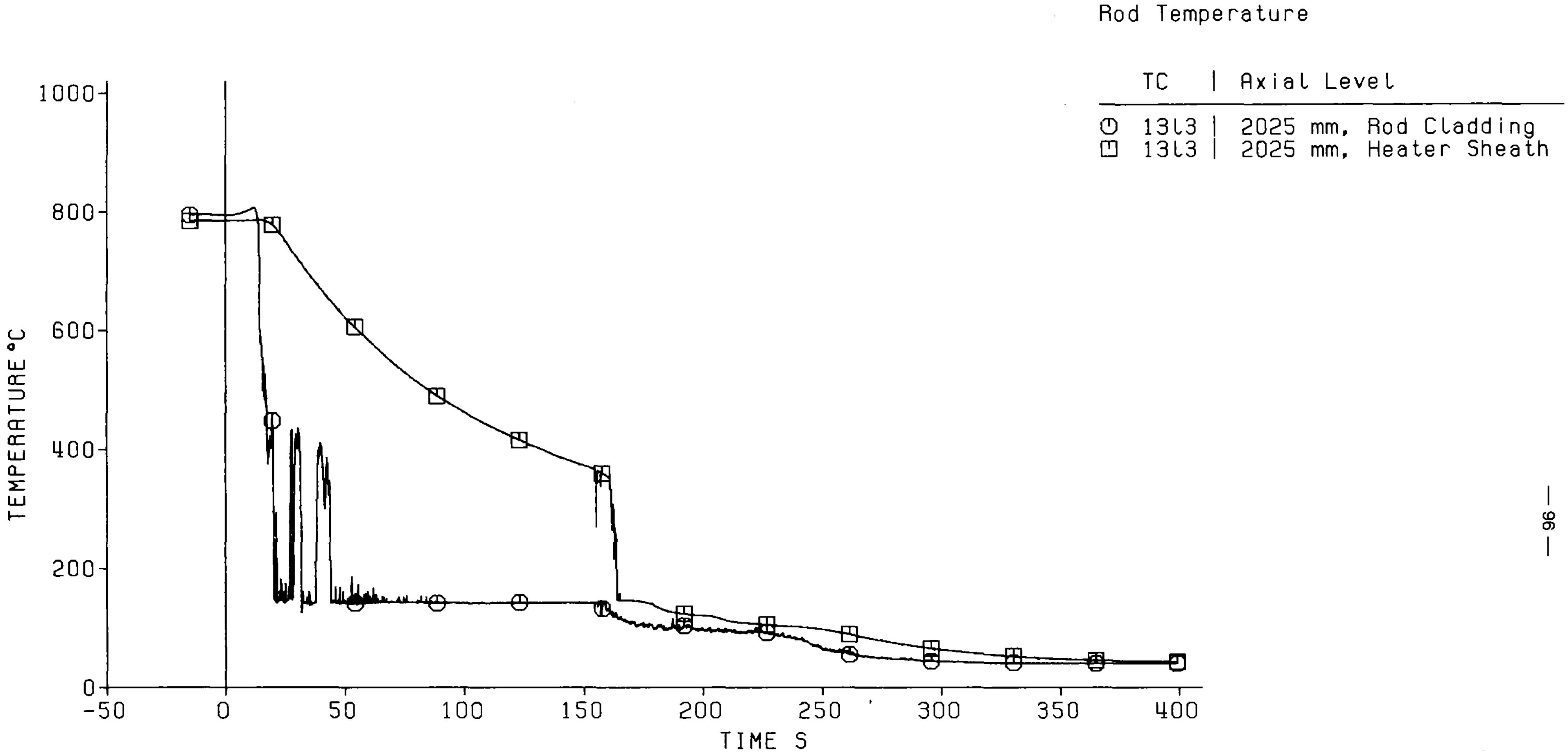
Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.80 cm/s
System Pressure 4.20 bar
Feedwater Temperature 43°C

REBEKA Rods With
Helium Filled Gaps

Bypass
======

KfK IRB

Fig. 73 SEFLEX: 5x5 RØD BUNDLE, SERIES 3, TEST-No. 35



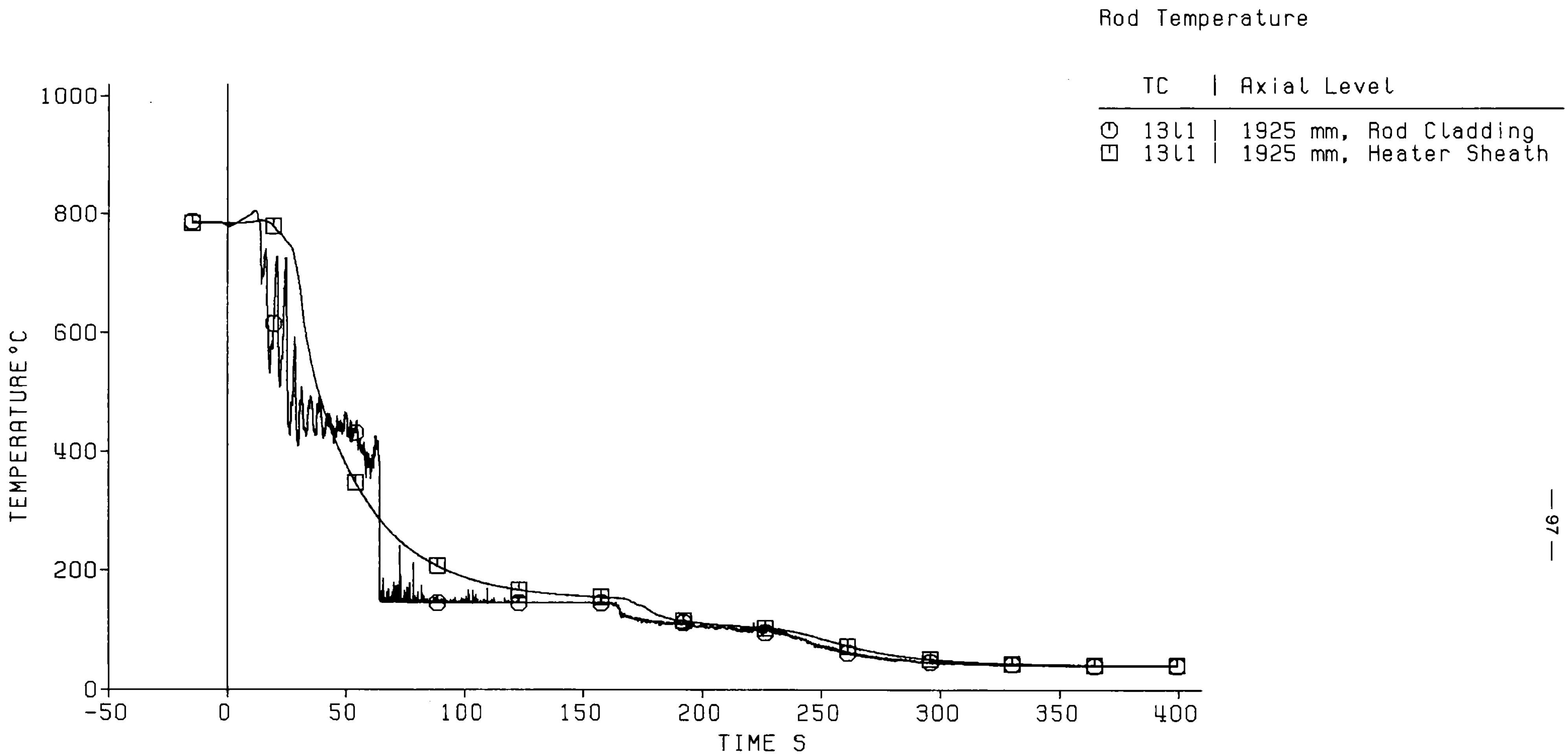
Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.80 cm/s
System Pressure 4.20 bar
Feedwater Temperature 43°C

REBEKA Rods With Helium Filled Gaps

Blockage
========

KfK IRB

Fig. 74 SEFLEX: 5x5 RØD BUNDLE, SERIES 3, TEST-No. 35



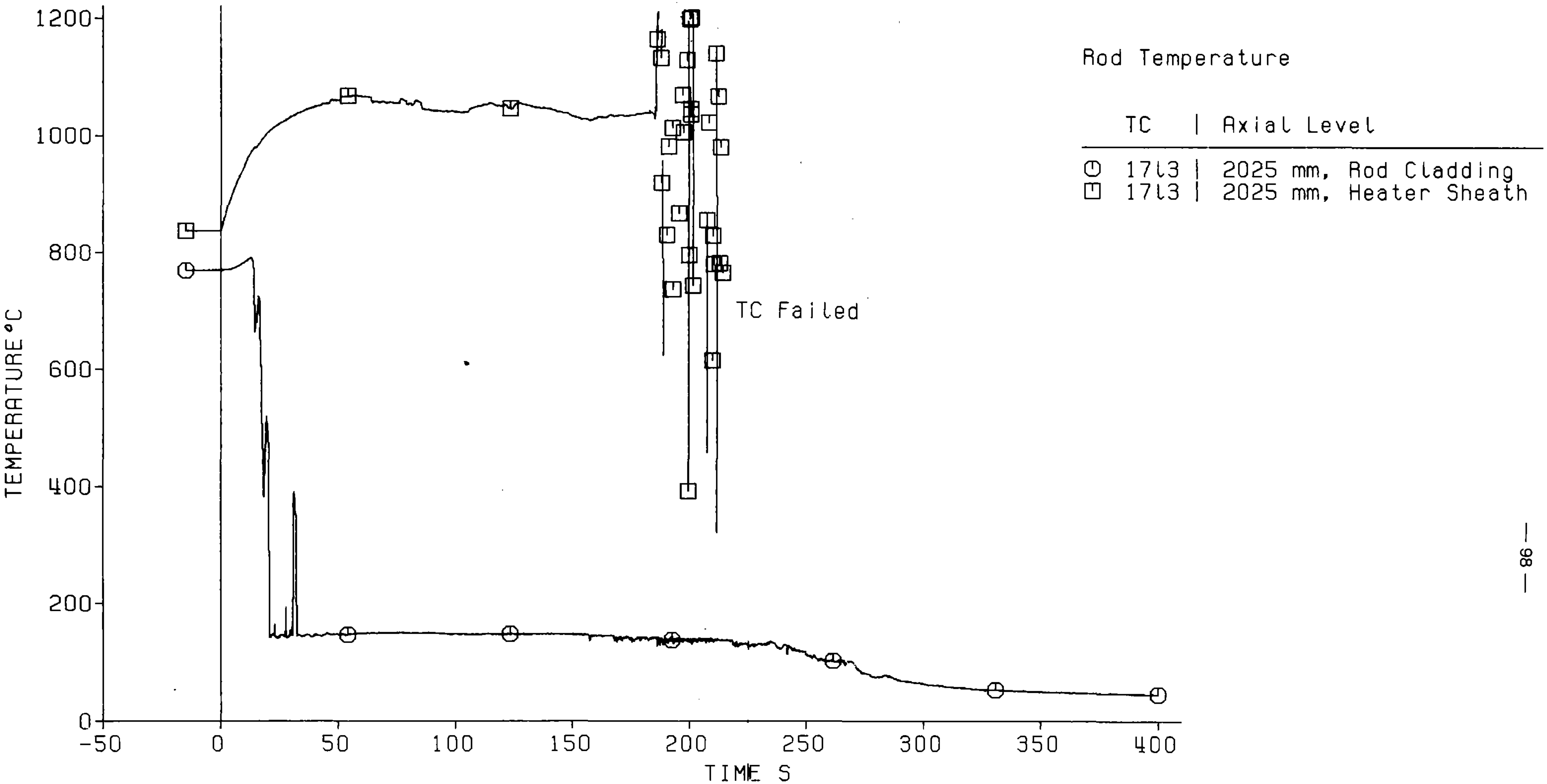
Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.80 cm/s
System Pressure 4.20 bar
Feedwater Temperature 43°C

REBEKA Rods With
Helium Filled Gaps

Blockage
========

KfK IRB

Fig. 75 SEFLEX: 5x5 RØD BUNDLE, SERIES 3, TEST-No. 35



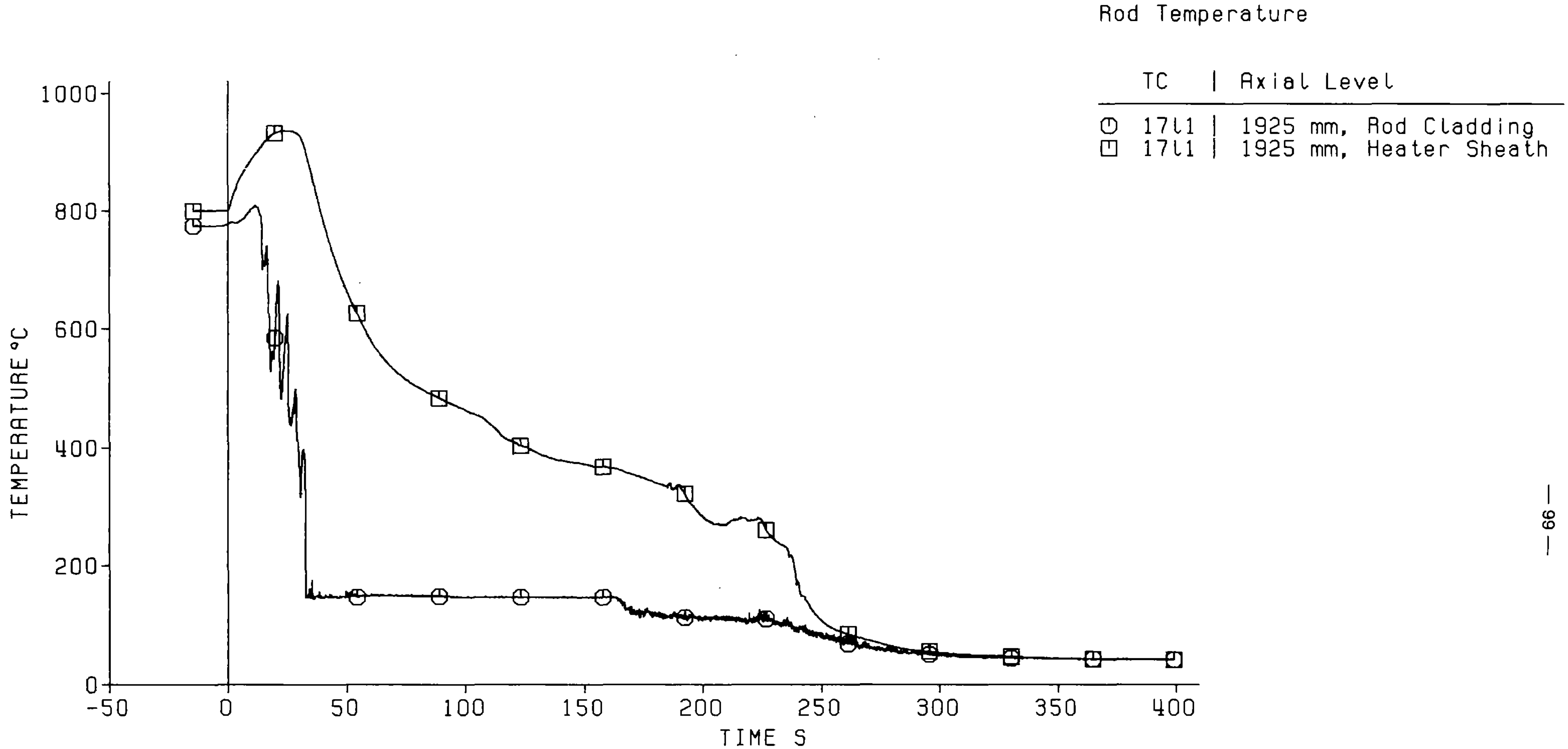
Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.80 cm/s
System Pressure 4.20 bar
Feedwater Temperature 43 °C

REBEKA Rods With
Helium Filled Gaps

Blockage
========

KfK IRB

Fig. 76 SEFLEX: 5x5 ROD BUNDLE, SERIES 3, TEST-No. 35



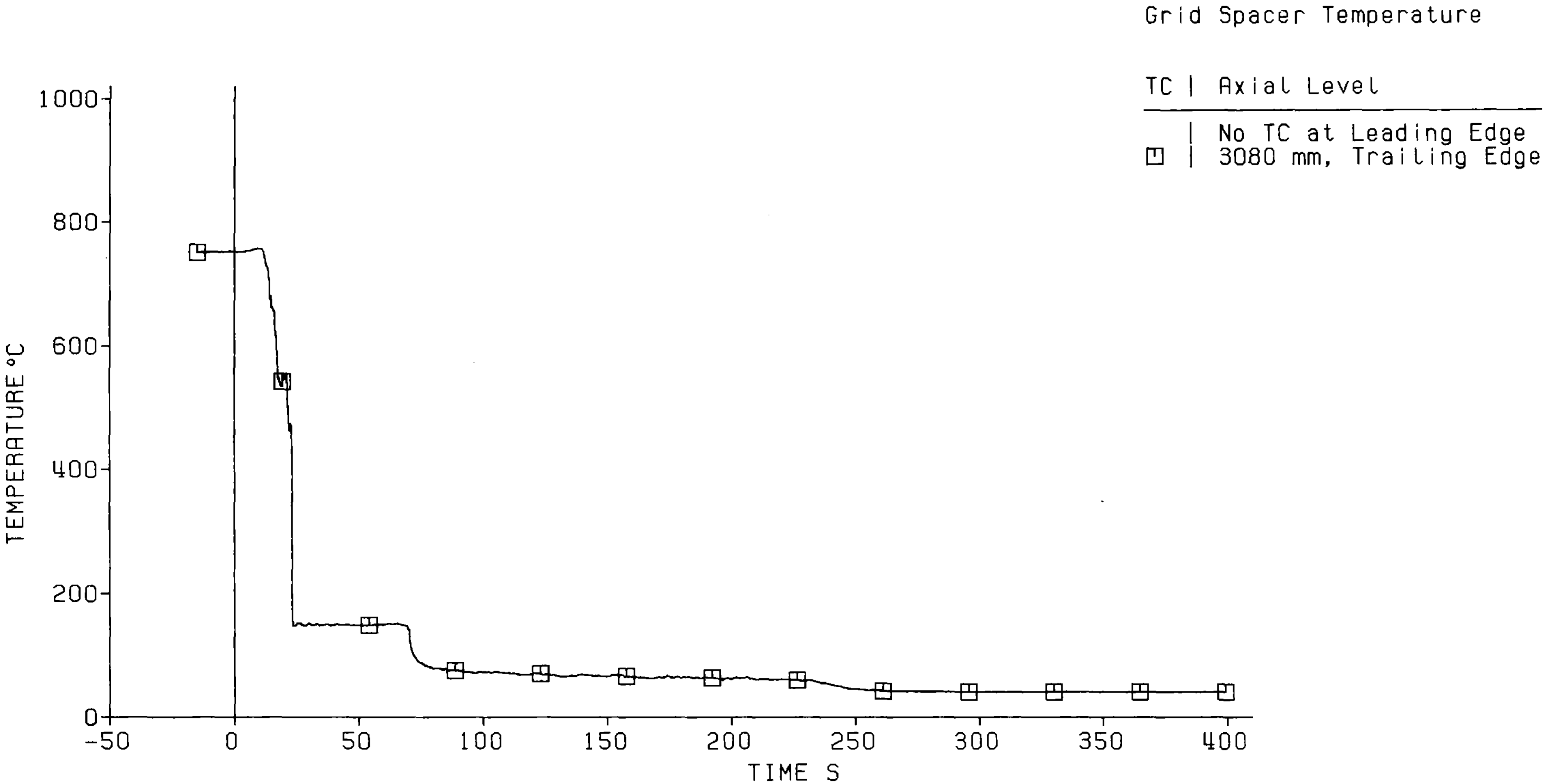
Decay Heat	120% ANS Standard
Flooding Rate (cold)	3.80 cm/s
System Pressure	4.20 bar
Feedwater Temperature	43°C

REBEKA Rods With
Helium Filled Gaps

Blockage
========

KfK IRB

Fig. 77 SEFLEX: 5x5 RØD BUNDLE, SERIES 3, TEST-No. 35

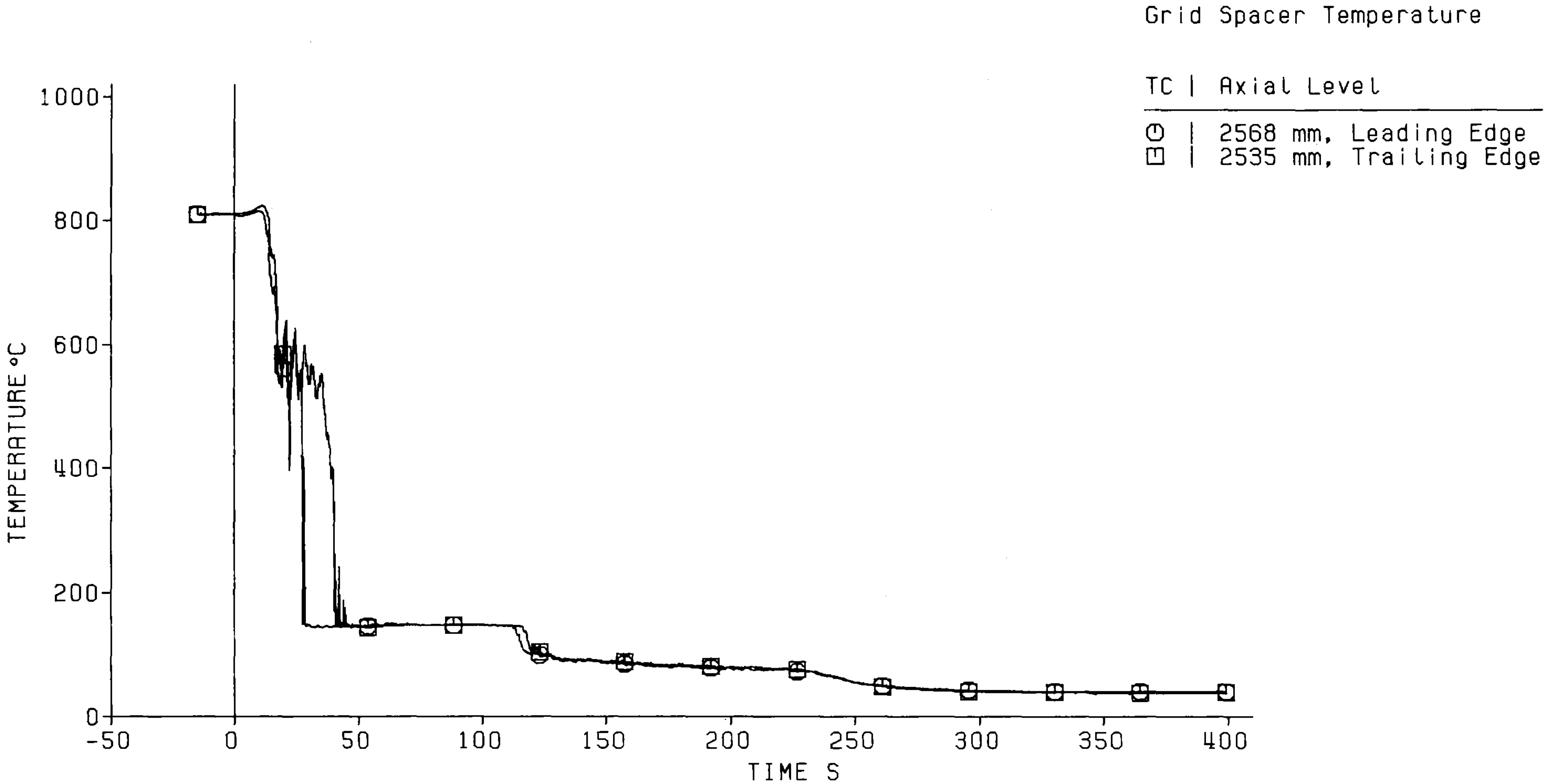


Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.80 cm/s
System Pressure 4.20 bar
Feedwater Temperature 43 °C

REBEKA Rods With
Helium Filled Gaps

KfK IRB

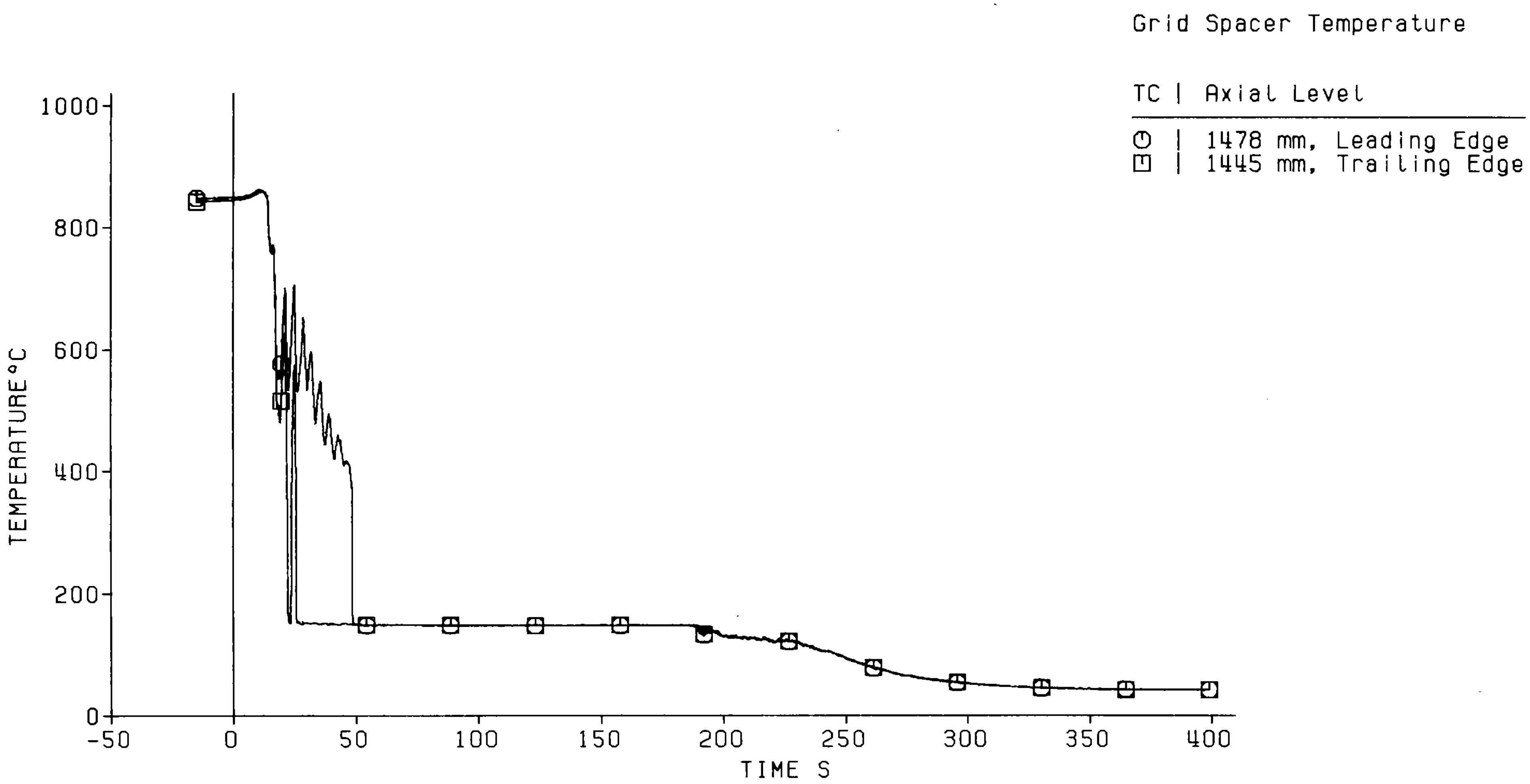
Fig. 78 SEFLEX: 5x5 RØD BUNDLE, SERIES 3, TEST-No. 35



Decay Heat	120% ANS Standard	REBEKA Rods With
Flooding Rate (cold)	3.80 cm/s	Helium Filled Gaps
System Pressure	4.20 bar	
Feedwater Temperature	43°C	

KfK IRB

Fig. 79 SEFLEX: 5x5 RØD BUNDLE, SERIES 3, TEST-No. 35

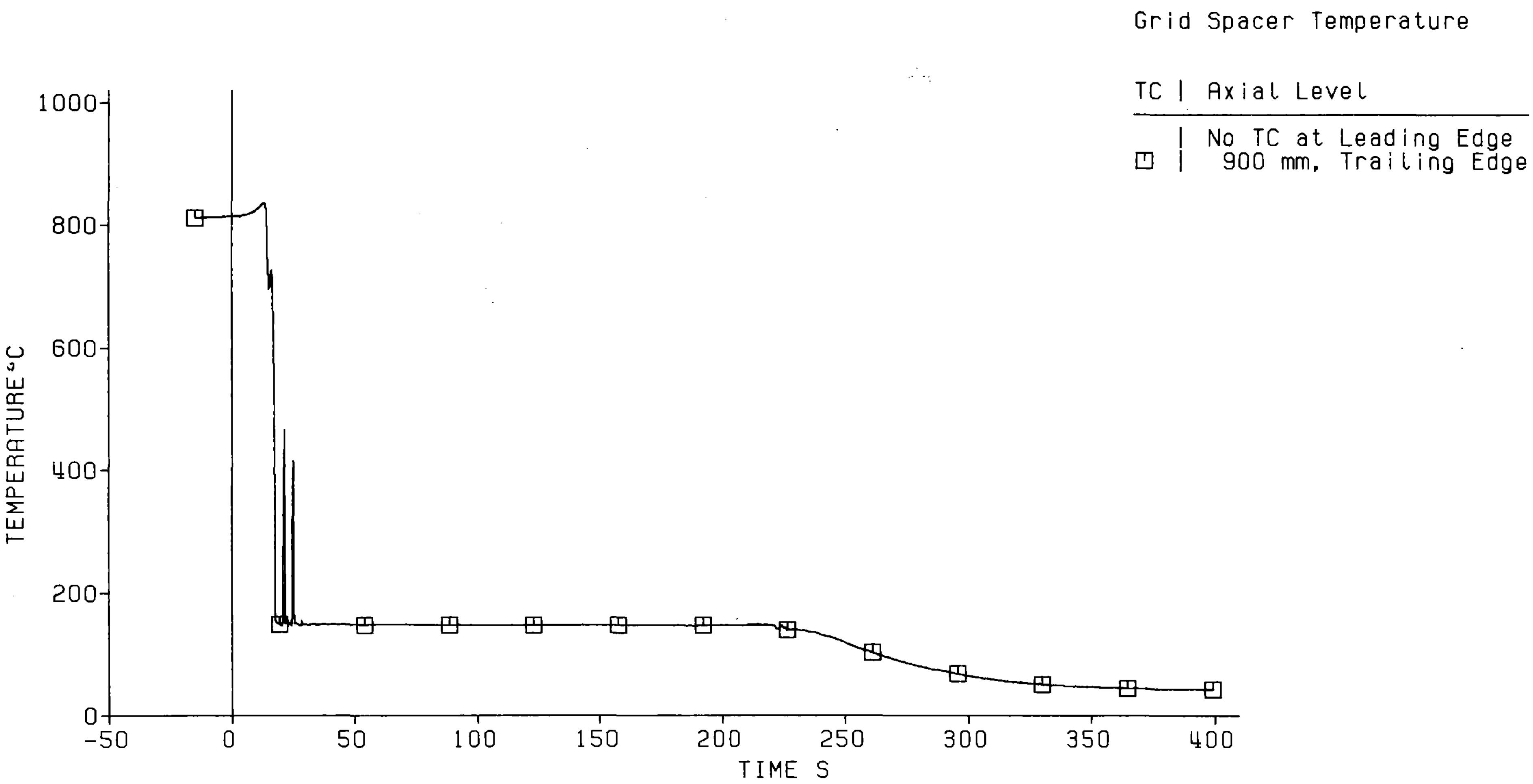


Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.80 cm/s
System Pressure 4.20 bar
Feedwater Temperature 43 °C

REBEKA Rods With Helium Filled Gaps

KfK IRB

Fig. 80 SEFLEX: 5x5 RØD BUNDLE, SERIES 3, TEST-No. 35

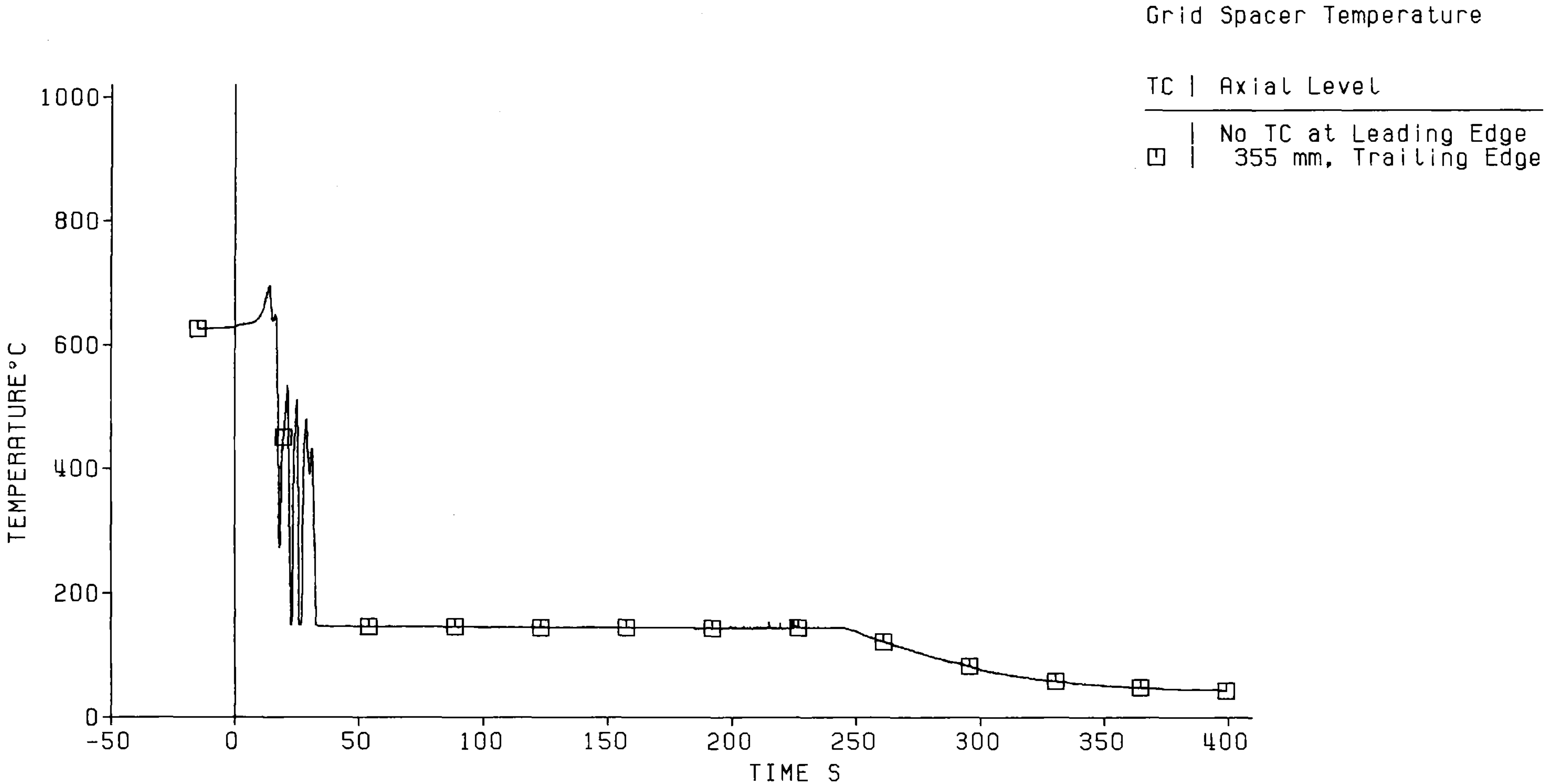


Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.80 cm/s
System Pressure 4.20 bar
Feedwater Temperature 43 °C

REBEKA Rods With
Helium Filled Gaps

KfK IRB

Fig. 81 SEFLEX: 5x5 RØD BUNDLE, SERIES 3, TEST-No. 35

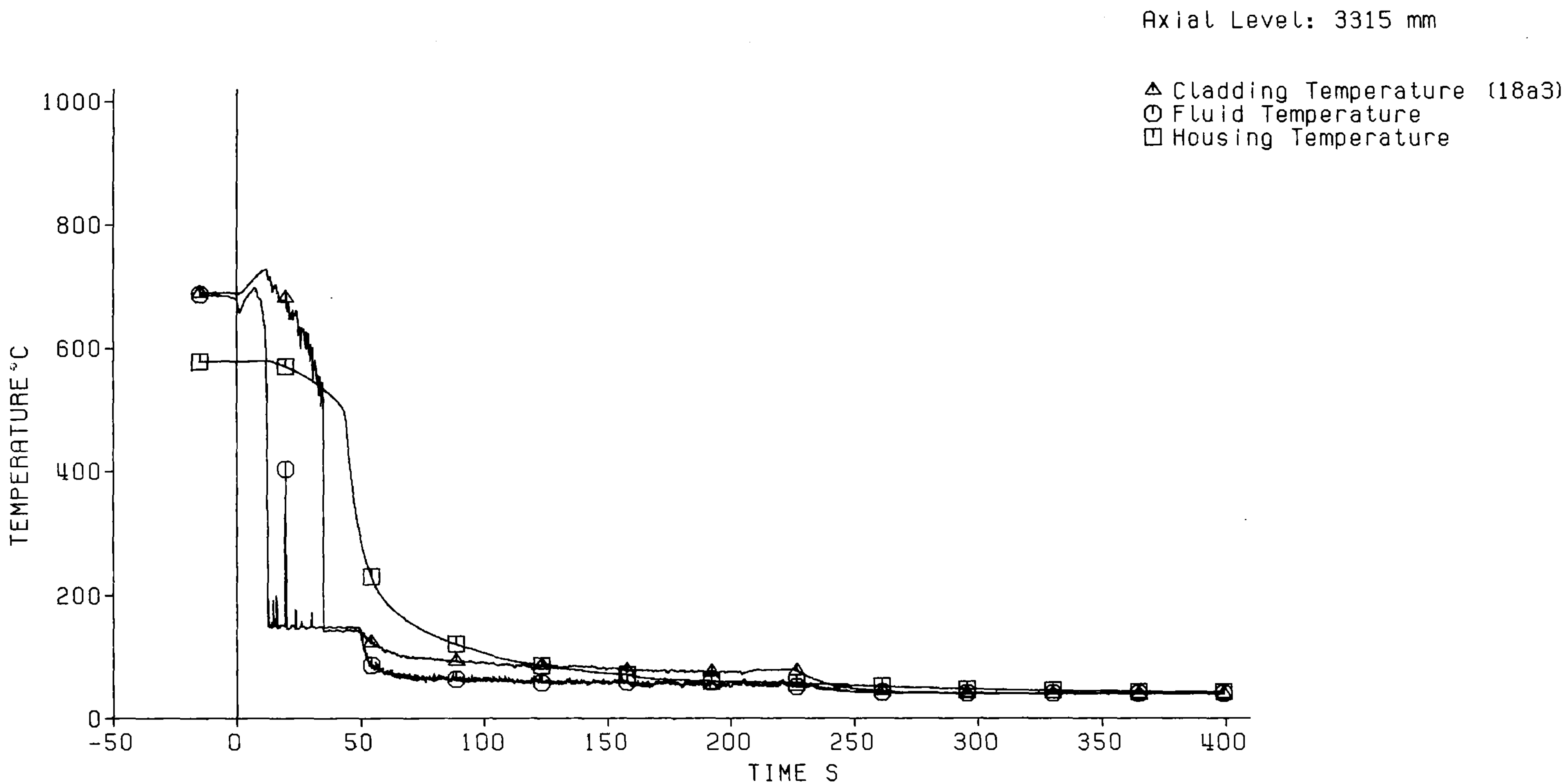


Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.80 cm/s
System Pressure 4.20 bar
Feedwater Temperature 43 °C

REBEKA Rods With
Helium Filled Gaps

KfK IRB

Fig. 82 SEFLEX: 5x5 RØD BUNDLE, SERIES 3, TEST-No. 35

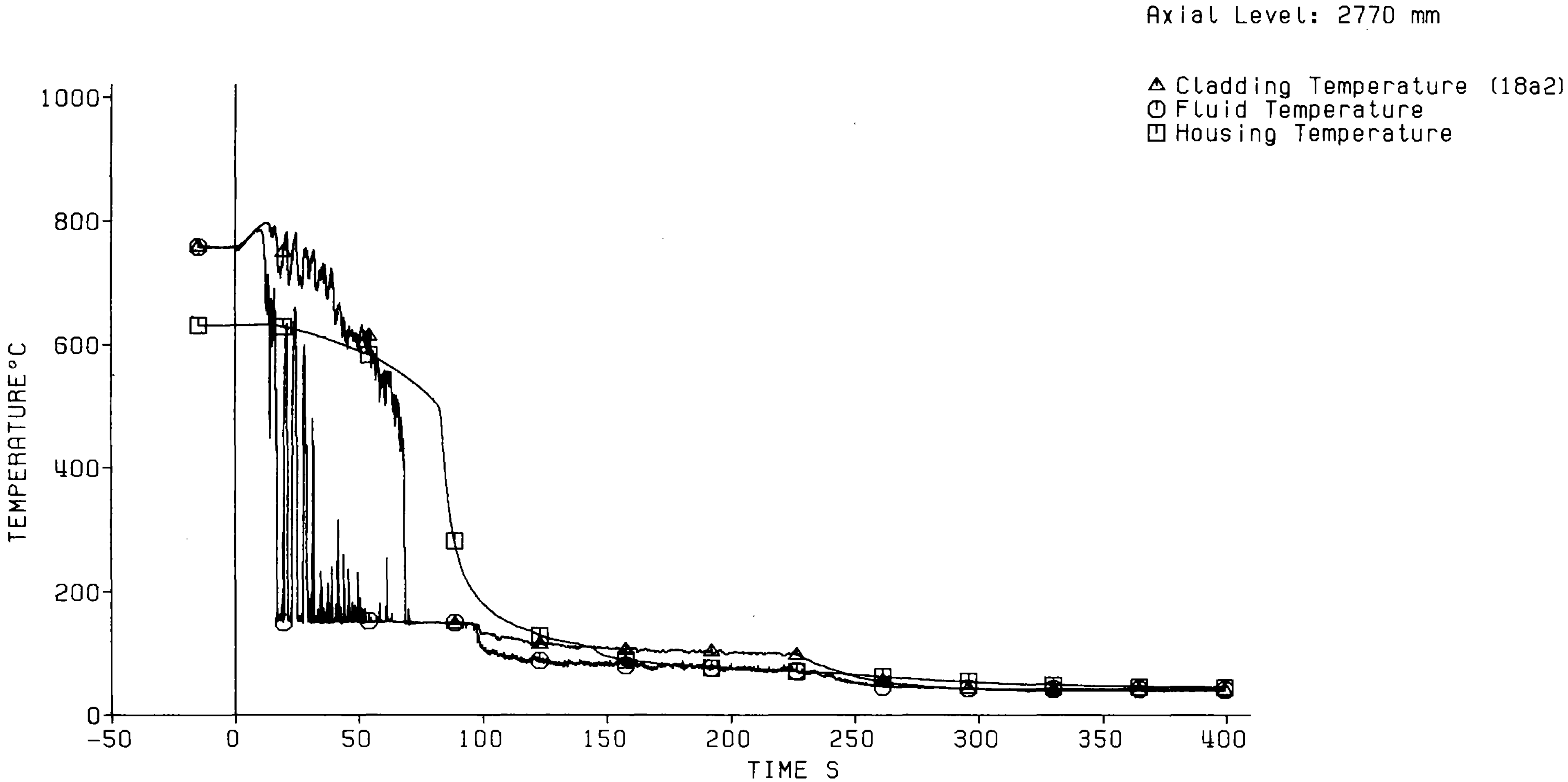


Decay Heat	120% ANS Standard
Flooding Rate (cold)	3.80 cm/s
System Pressure	4.20 bar
Feedwater Temperature	43 °C

REBEKA Rods With
Helium Filled Gaps

KfK IRB

Fig. 83 SEFLEX: 5x5 RØD BUNDLE, SERIES 3, TEST-No. 35

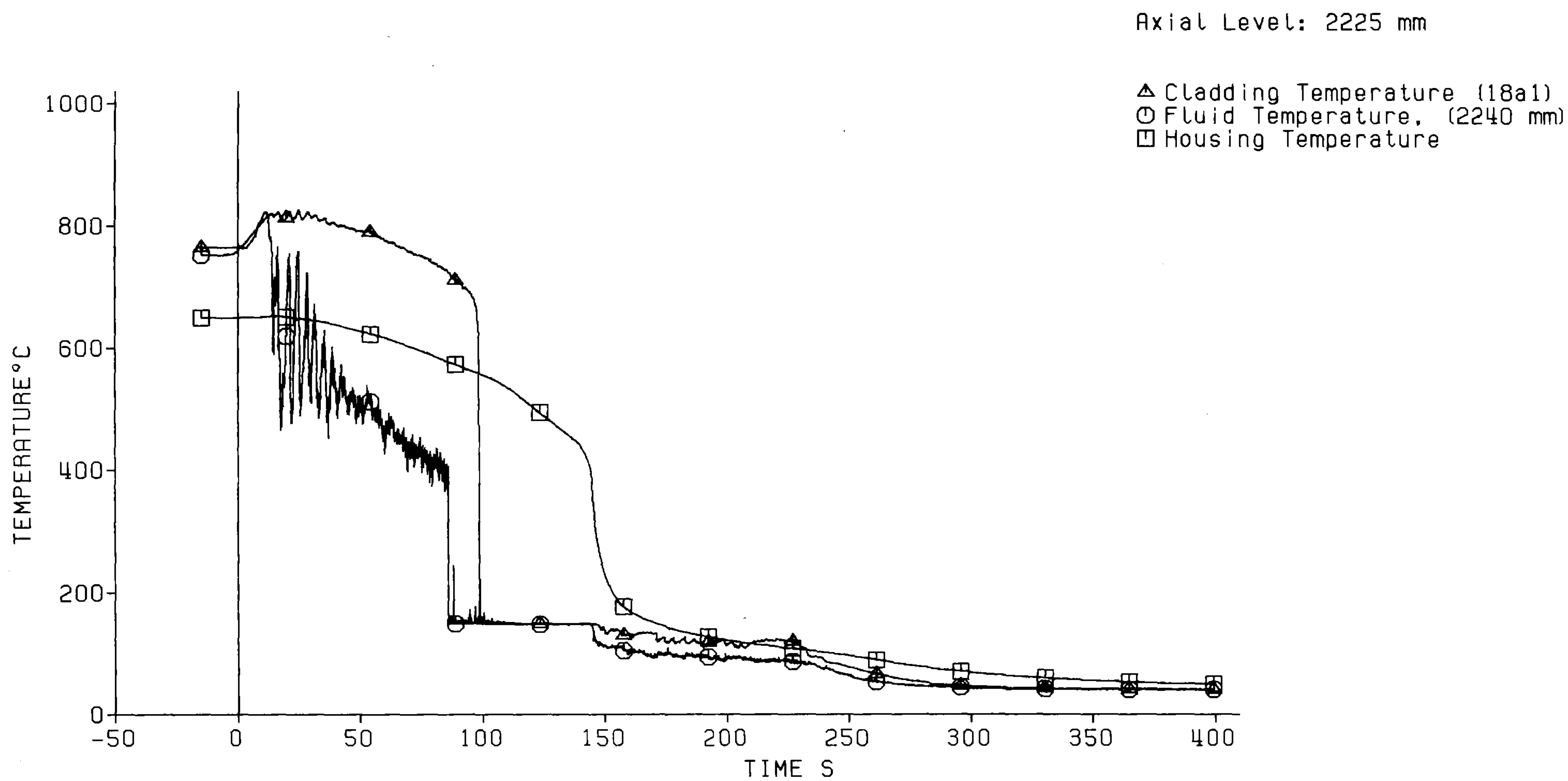


Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.80 cm/s
System Pressure 4.20 bar
Feedwater Temperature 43°C

REBEKA Rods With
Helium Filled Gaps

KfK IRB

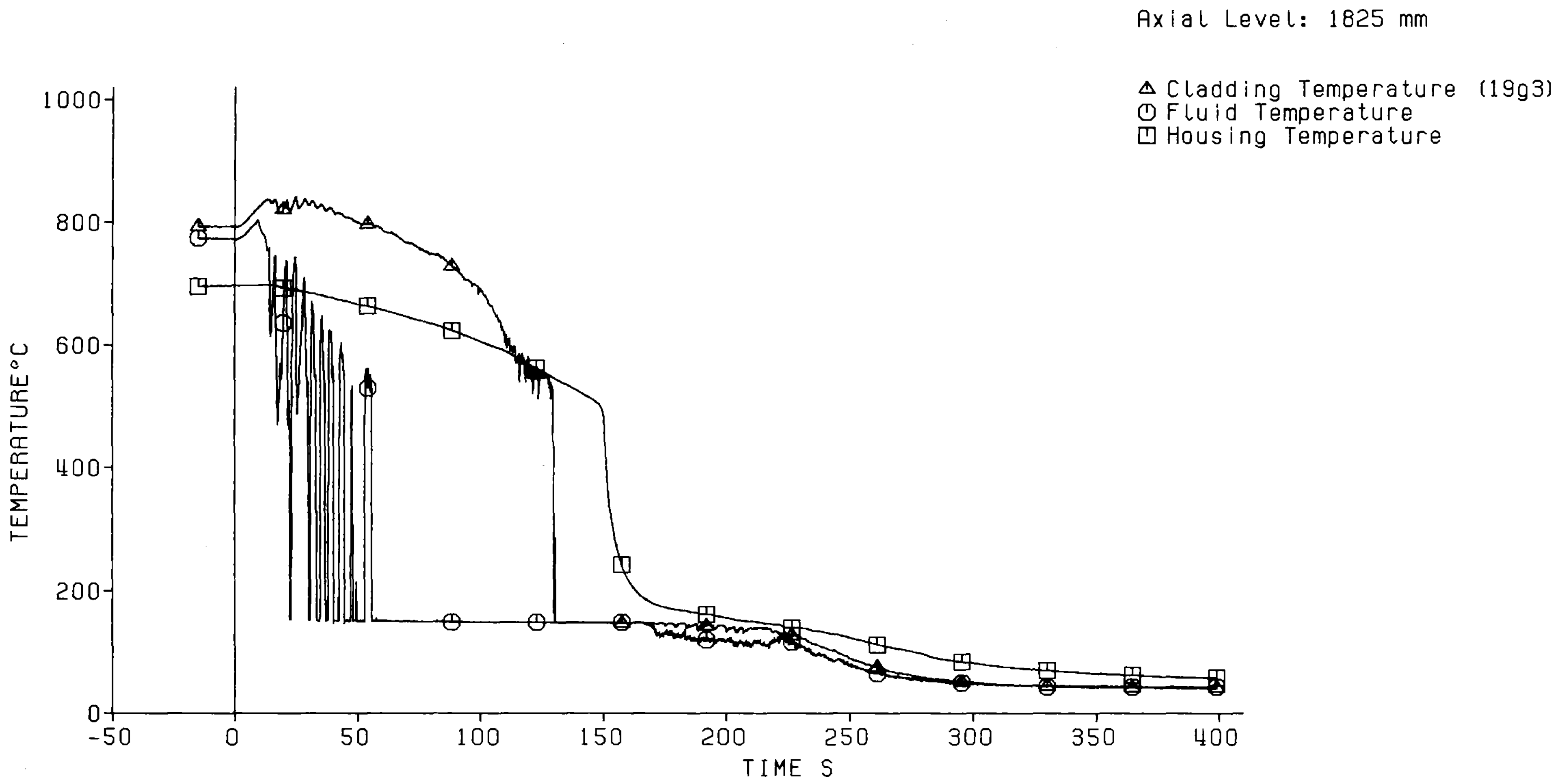
Fig. 84 SEFLEX: 5x5 RØD BUNDLE, SERIES 3, TEST-No. 35



Decay Heat	120% ANS Standard	REBEKA Rods With
Flooding Rate (cold)	3.80 cm/s	Helium Filled Gaps
System Pressure	4.20 bar	
Feedwater Temperature	43°C	

KfK IRB

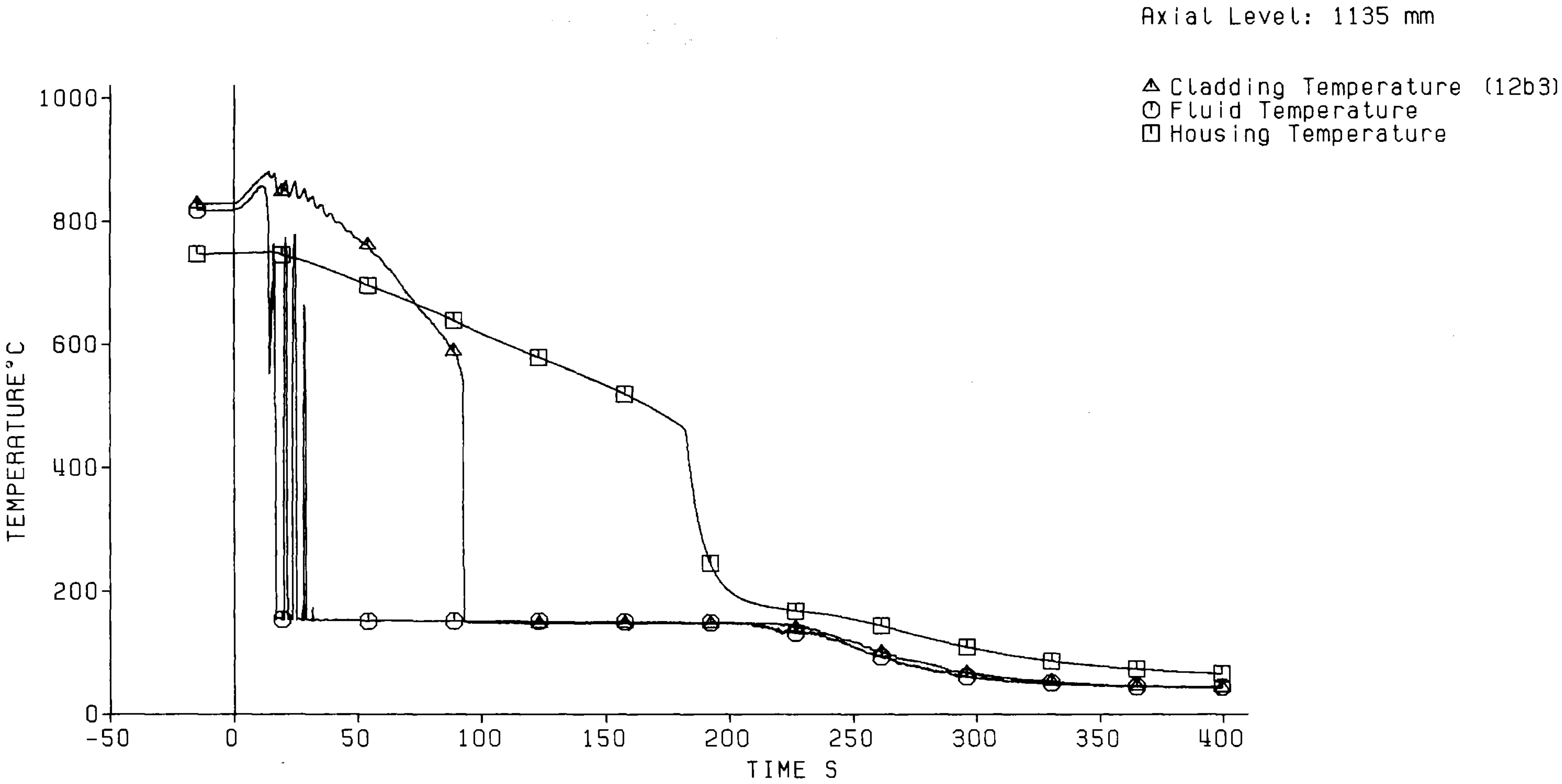
Fig. 85 SEFLEX: 5x5 RØD BUNDLE, SERIES 3, TEST-No. 35



Decay Heat	120% ANS Standard	REBEKA Rods With
Flooding Rate (cold)	3.80 cm/s	Helium Filled Gaps
System Pressure	4.20 bar	
Feedwater Temperature	43°C	

KfK IRB

Fig. 86 SEFLEX: 5x5 RØD BUNDLE, SERIES 3, TEST-No. 35

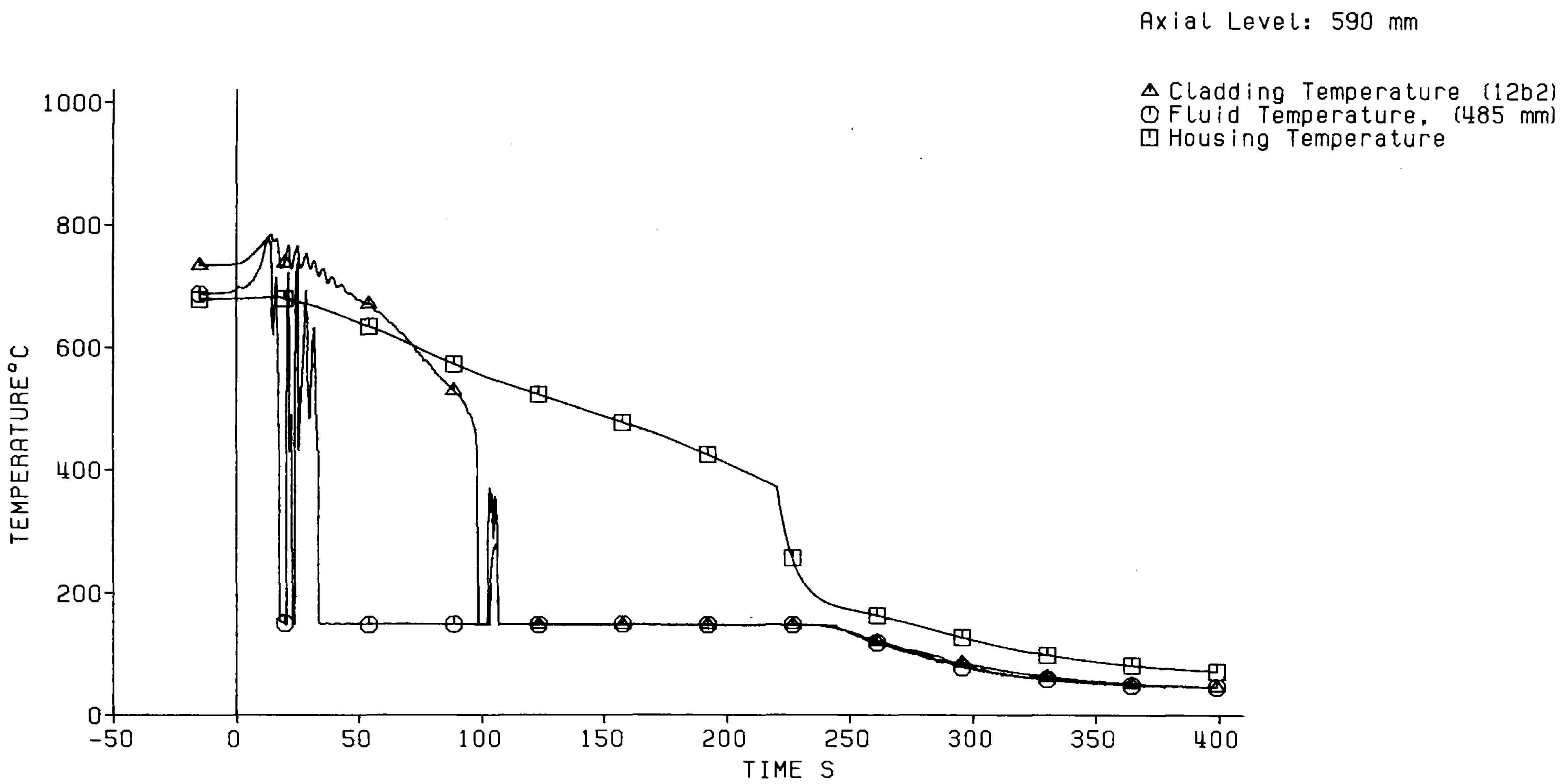


Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.80 cm/s
System Pressure 4.20 bar
Feedwater Temperature 43°C

REBEKA Rods With
Helium Filled Gaps

KfK IRB

Fig. 87 SEFLEX: 5x5 RØD BUNDLE, SERIES 3, TEST-No. 35

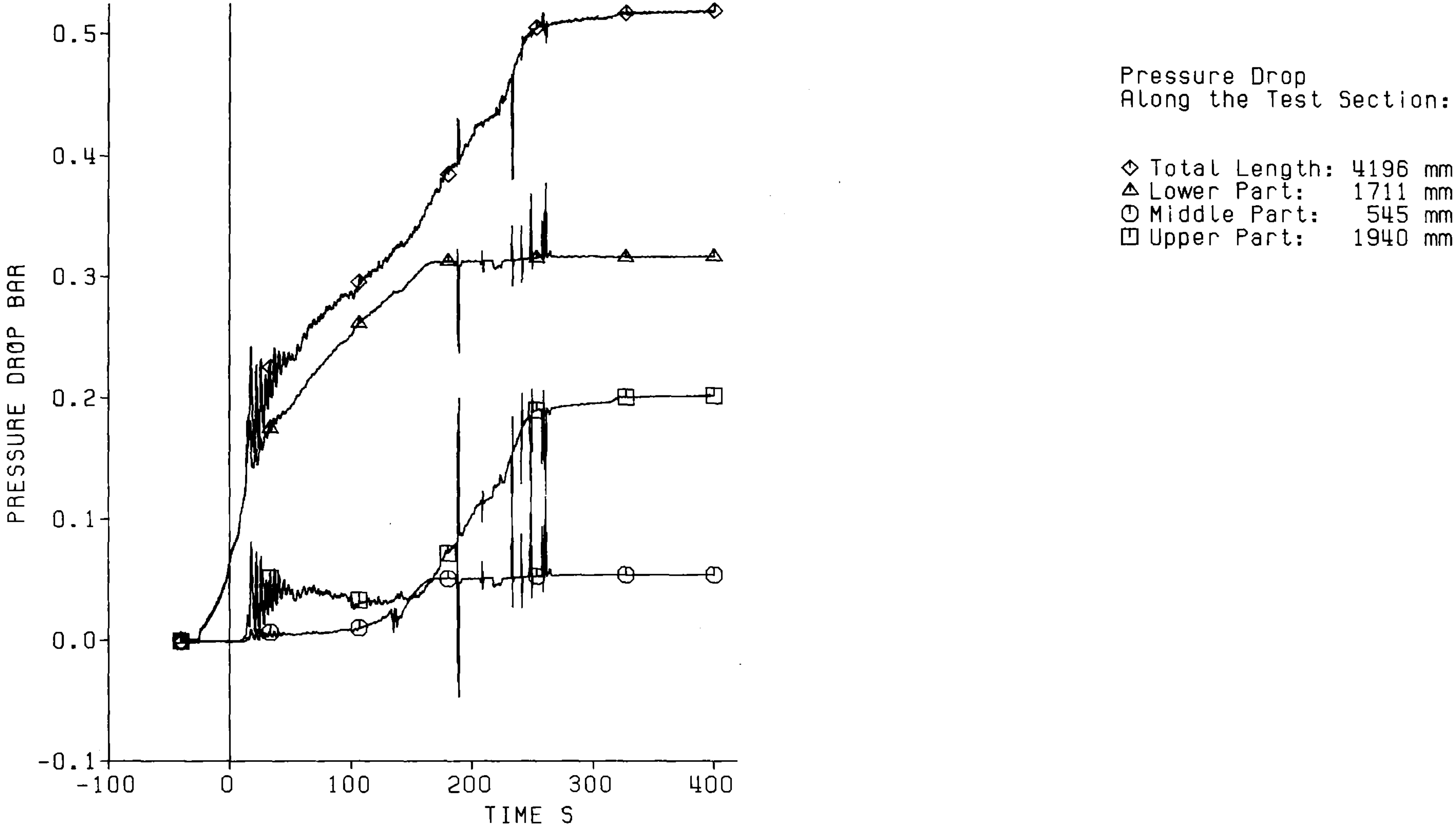


Decay Heat	120% ANS Standard
Flooding Rate (cold)	3.80 cm/s
System Pressure	4.20 bar
Feedwater Temperature	43°C

REBEKA Rods With
Helium Filled Gaps

KfK IRB

Fig. 88 SEFLEX: 5x5 RØD BUNDLE, SERIES 3, TEST-No. 35



Decay Heat	120% ANS Standard
Flooding Rate (cold)	3.80 cm/s
System Pressure	4.20 bar
Feedwater Temperature	43°C

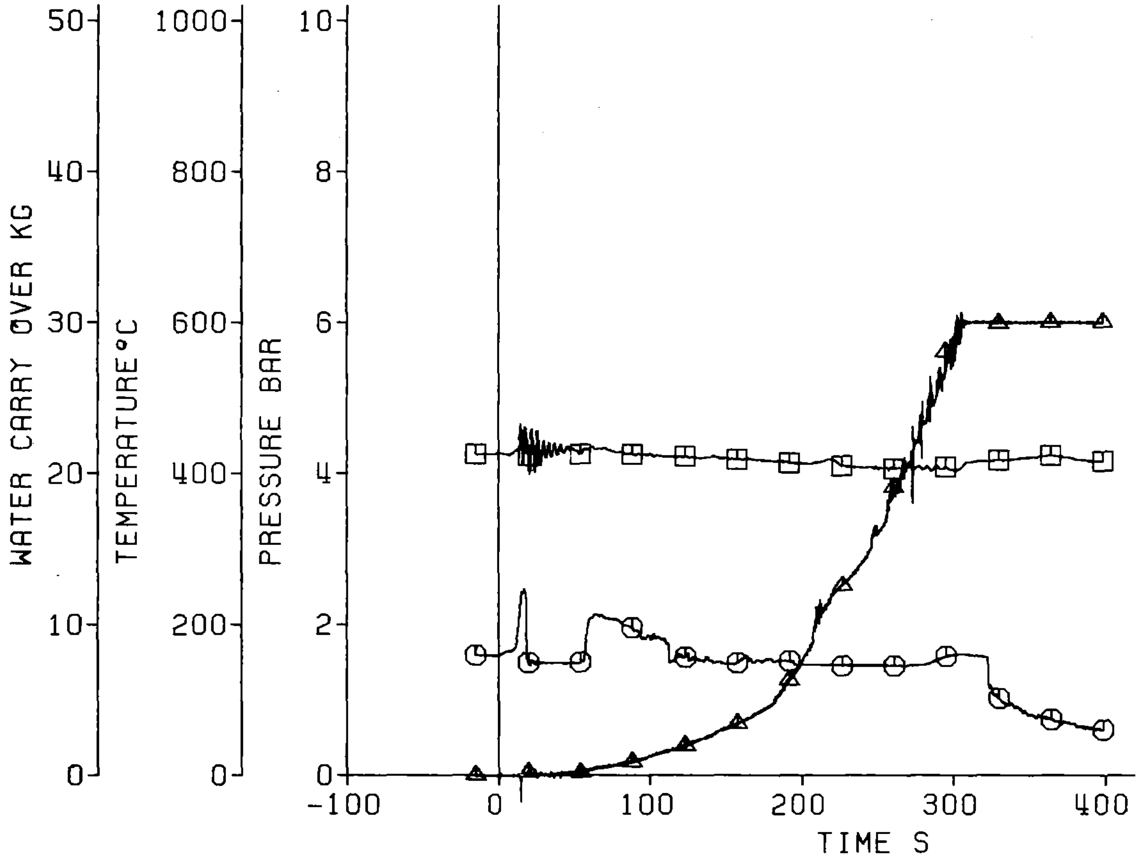
REBEKA Rods With
Helium Filled Gaps

KfK IRB

Fig. 89 SEFLEX: 5x5 RØD BUNDLE, SERIES 3, TEST-No. 35

Coolant Outlet Conditions:

△ Water Carry Over
○ Coolant Temperature
□ Coolant Pressure



Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.80 cm/s
System Pressure 4.20 bar
Feedwater Temperature 43°C

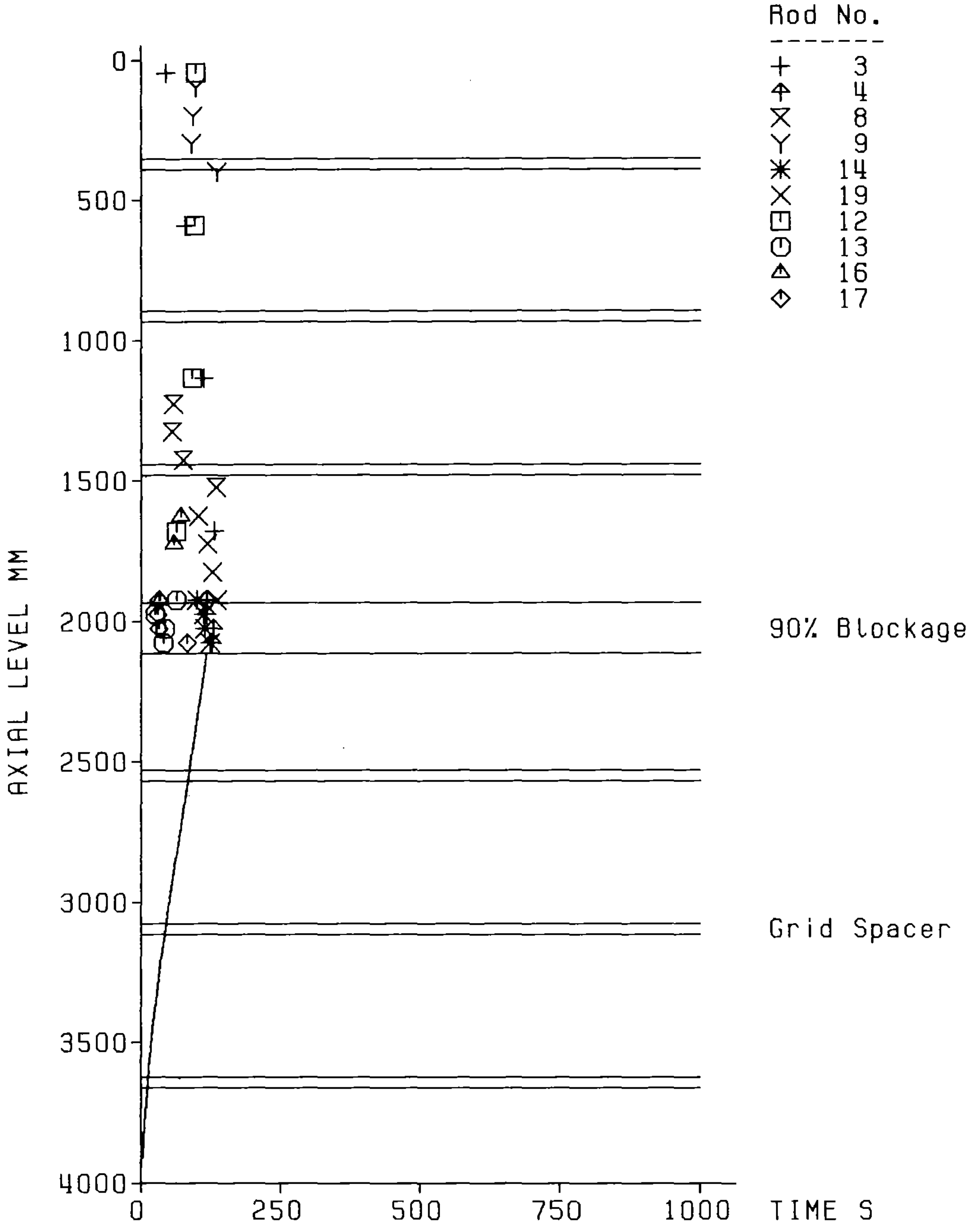
REBEKA Rods With
Helium Filled Gaps

KfK IRB

Fig. 90 SEFLEX: 5x5 ROD BUNDLE, SERIES 3, TEST-No. 35

Axial Position of Quench Front

REBEKA Rods With Helium Filled Gaps



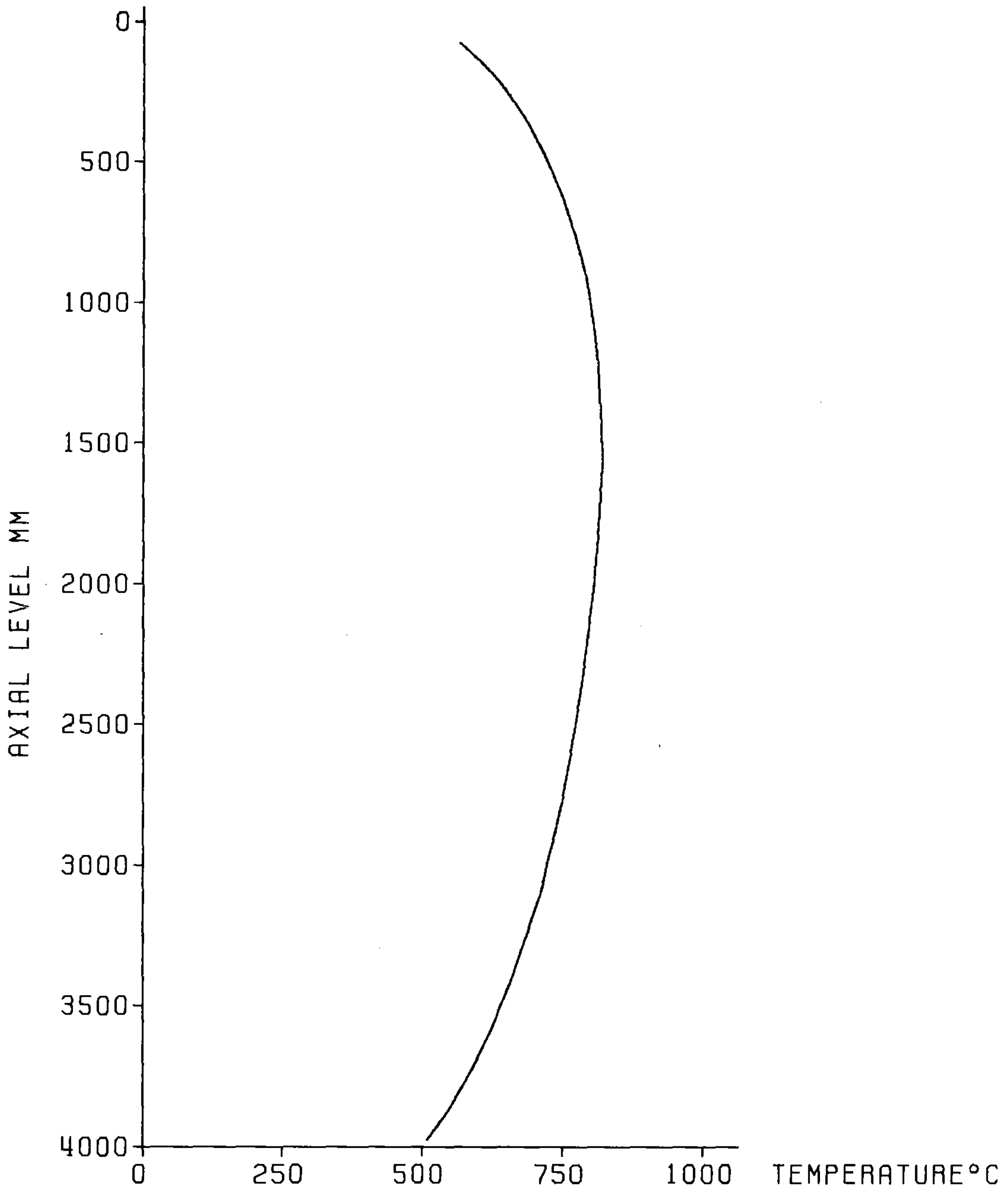
Decay Heat	120% ANS Standard
Flooding Rate (cold)	3.80 cm/s
System Pressure	4.20 bar
Feedwater Temperature	43°C

KfK IRB

Fig. 91 SEFLEX: 5x5 RØD BUNDLE
TEST SERIES 3, TEST-No. 35

Initial Axial Temperature Profile of Claddings

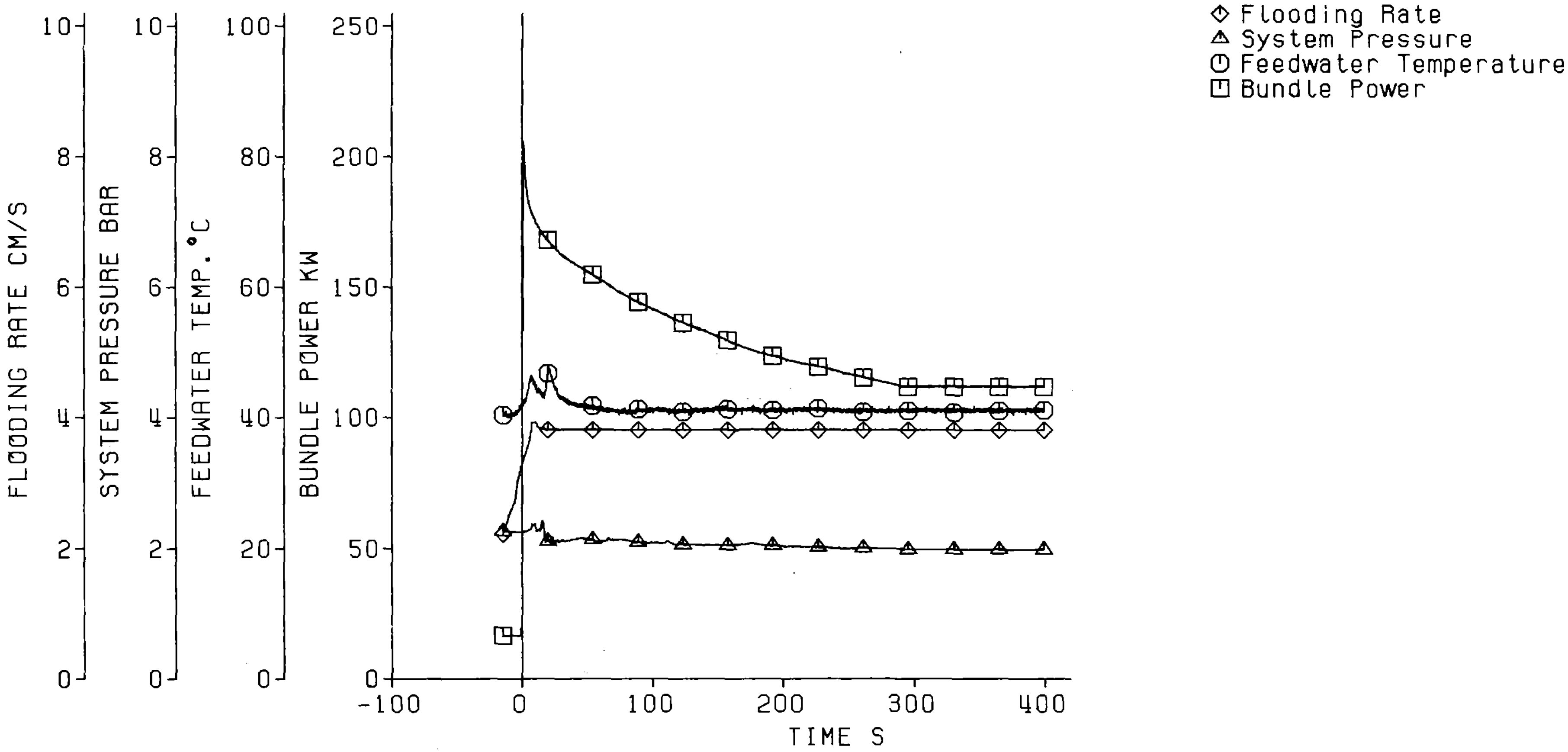
REBEKA Rods With Argon Filled Gaps



Decay Heat	120% ANS Standard
Flooding Rate (cold)	3.81 cm/s
System Pressure	2.05 bar
Feedwater Temperature	41°C

KfK IRB

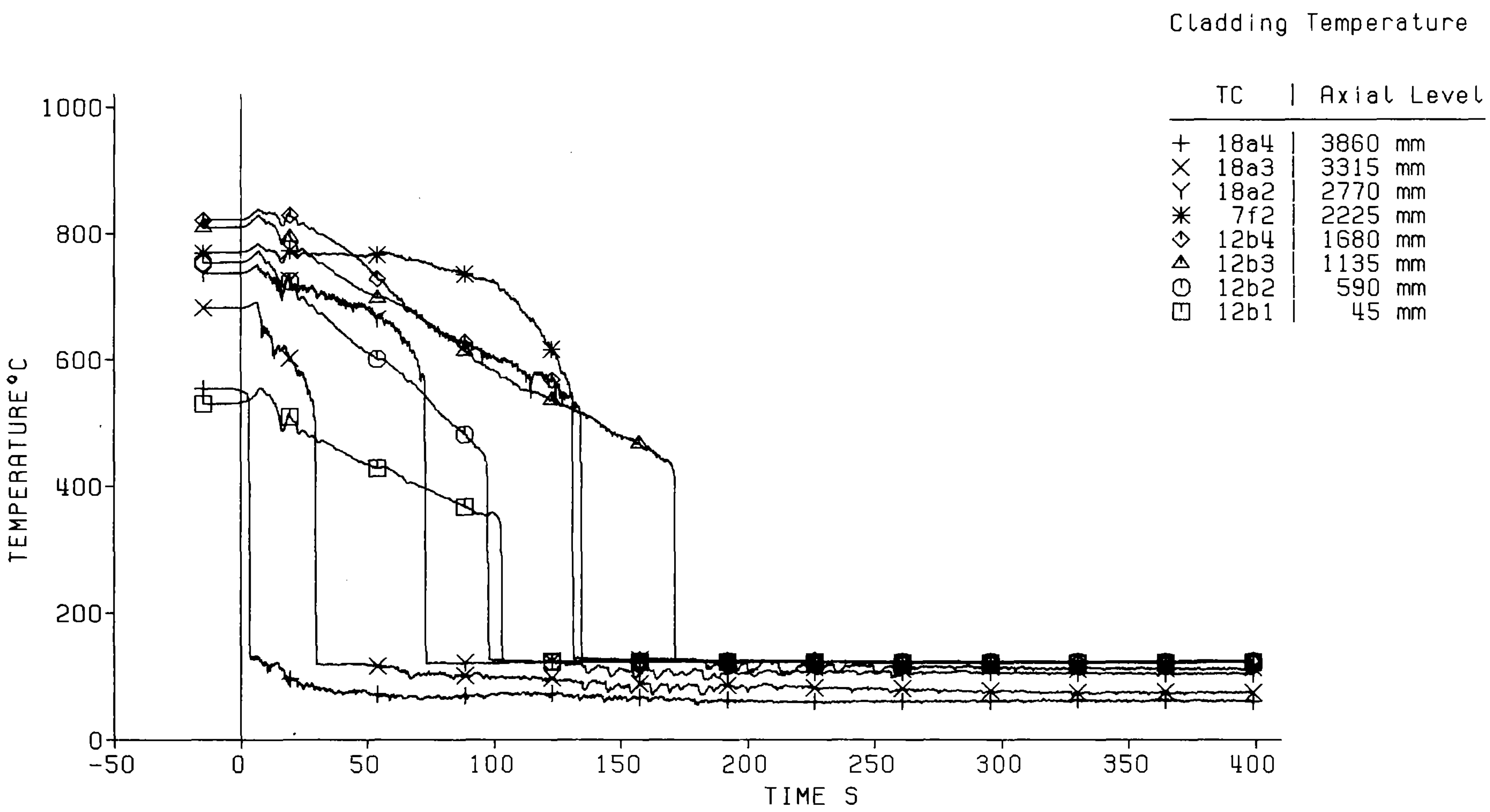
Fig. 92 SEFLEX: 5x5 RØD BUNDLE
TEST SERIES 4, TEST-No. 33



Decay Heat	120% ANS Standard	REBEKA Rods With Argon Filled Gaps
Flooding Rate (cold)	3.81 cm/s	
System Pressure	2.05 bar	
Feedwater Temperature	41°C	

KfK IRB

Fig. 93 SEFLEX: 5x5 RØD BUNDLE, SERIES 4, TEST-No. 33

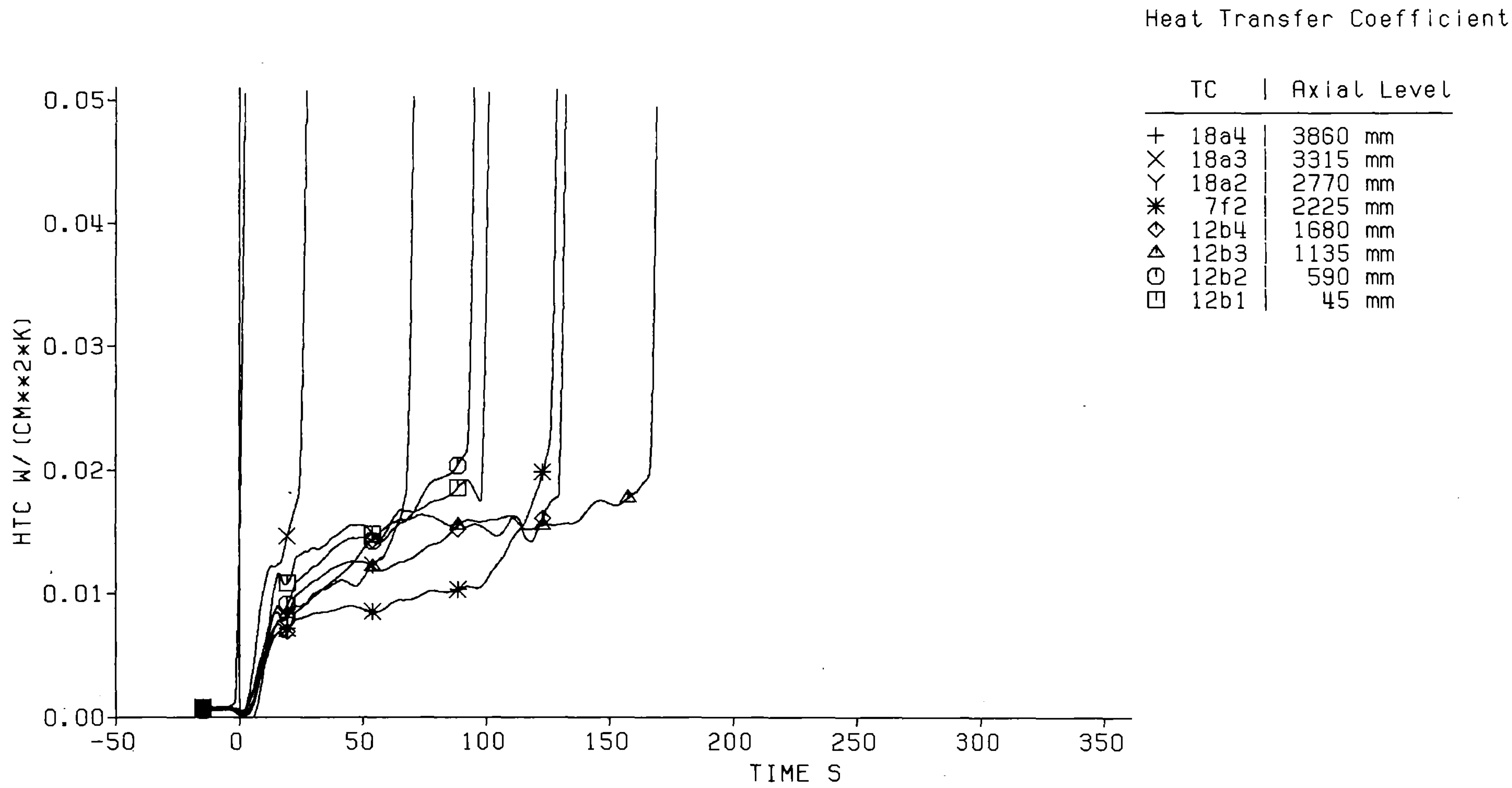


Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.81 cm/s
System Pressure 2.05 bar
Feedwater Temperature 41°C

REBEKA Rods With
Argon Filled Gaps

KfK IRB

Fig. 94 SEFLEX: 5x5 RØD BUNDLE, SERIES 4, TEST-No. 33

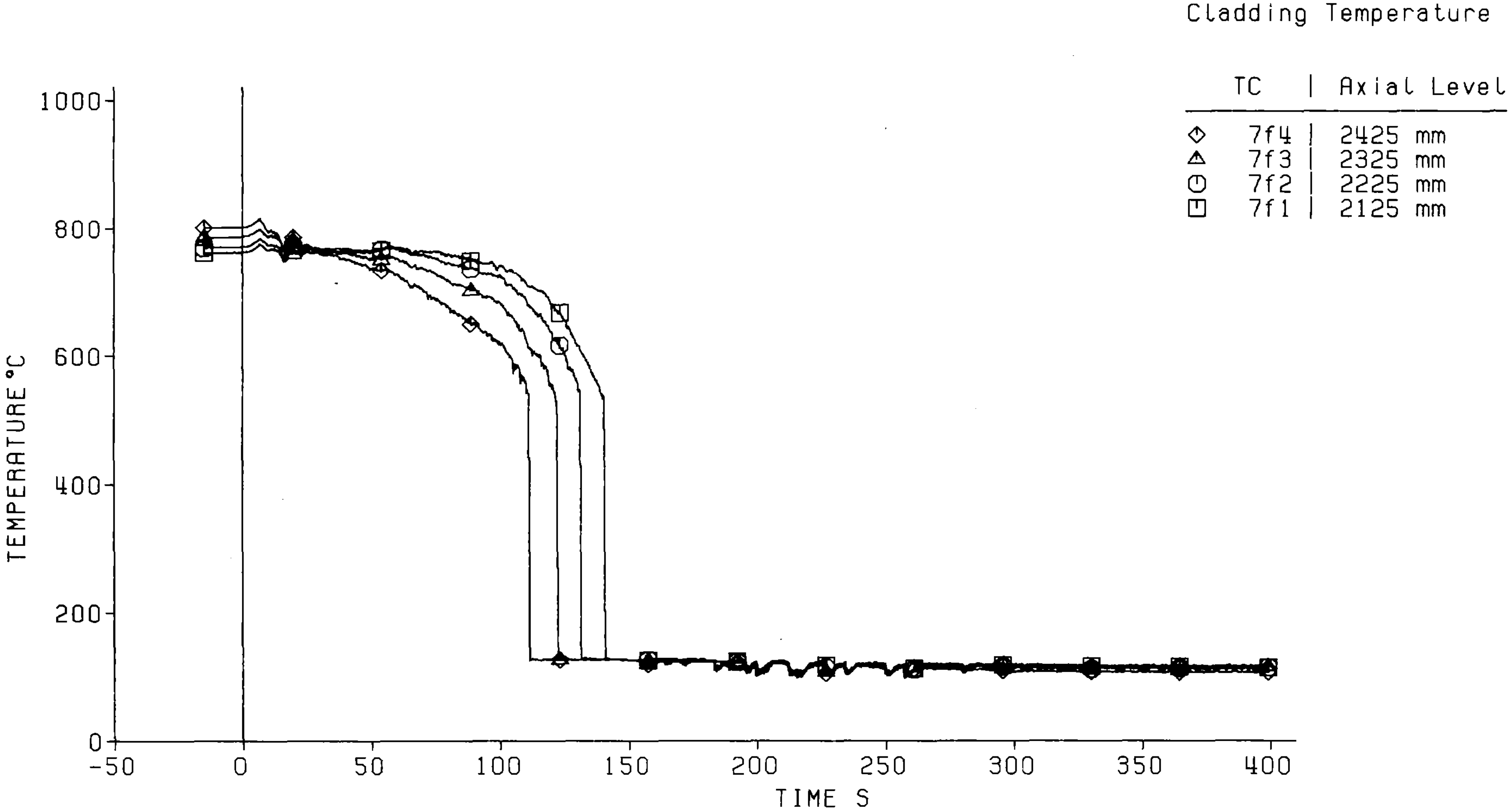


Decay Heat	120% ANS Standard
Flooding Rate (cold)	3.81 cm/s
System Pressure	2.05 bar
Feedwater Temperature	41°C

REBEKA Rods With
Argon Filled Gaps

KfK IRB

Fig. 95 SEFLEX: 5x5 RØD BUNDLE, SERIES 4, TEST-No. 33



Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.81 cm/s
System Pressure 2.05 bar
Feedwater Temperature 41°C

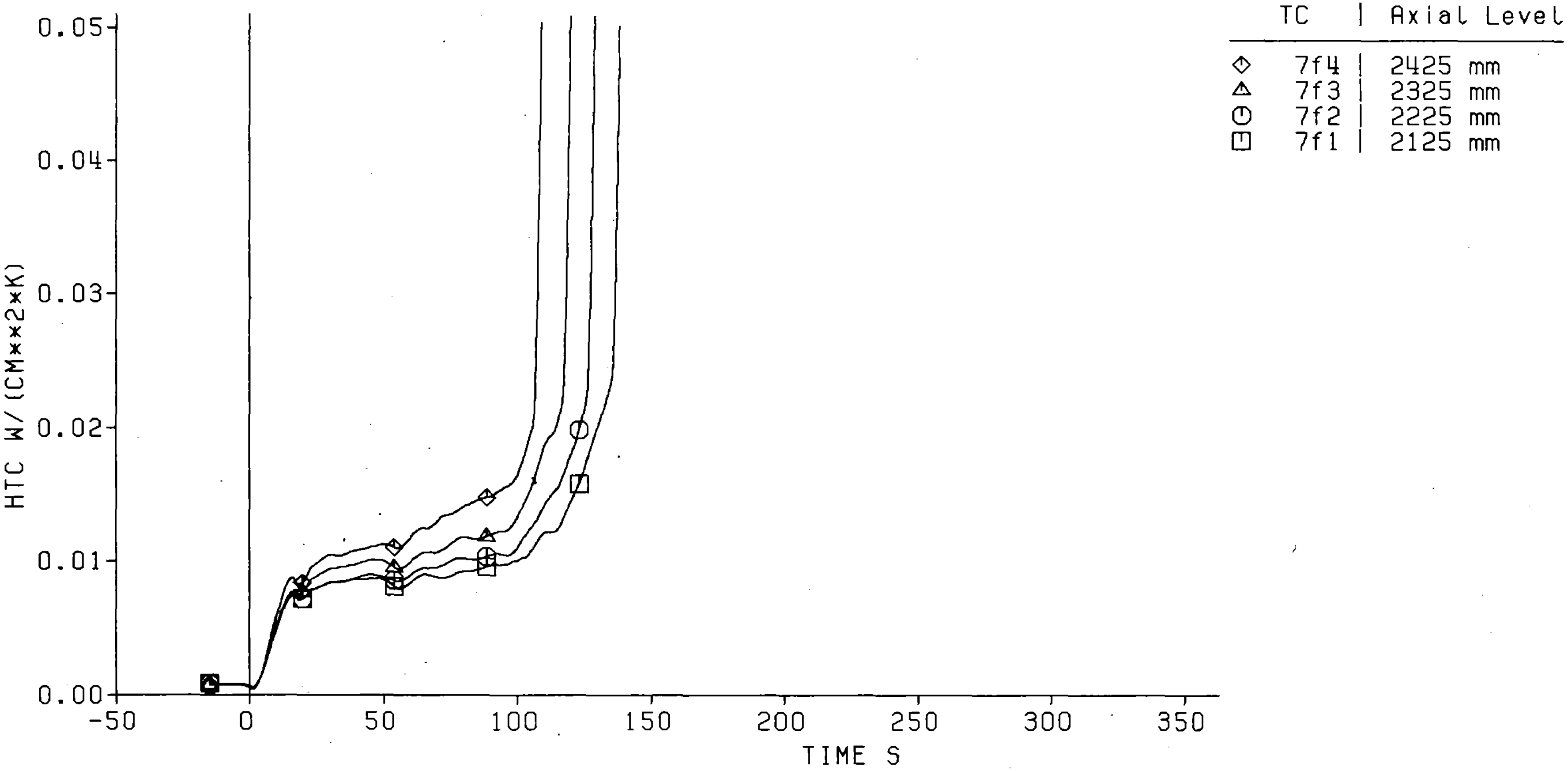
REBEKA Rods With
Argon Filled Gaps

Bypass
======

KfK IRB

Fig. 96 SEFLEX: 5x5 RØD BUNDLE, SERIES 4, TEST-No. 33

Heat Transfer Coefficient



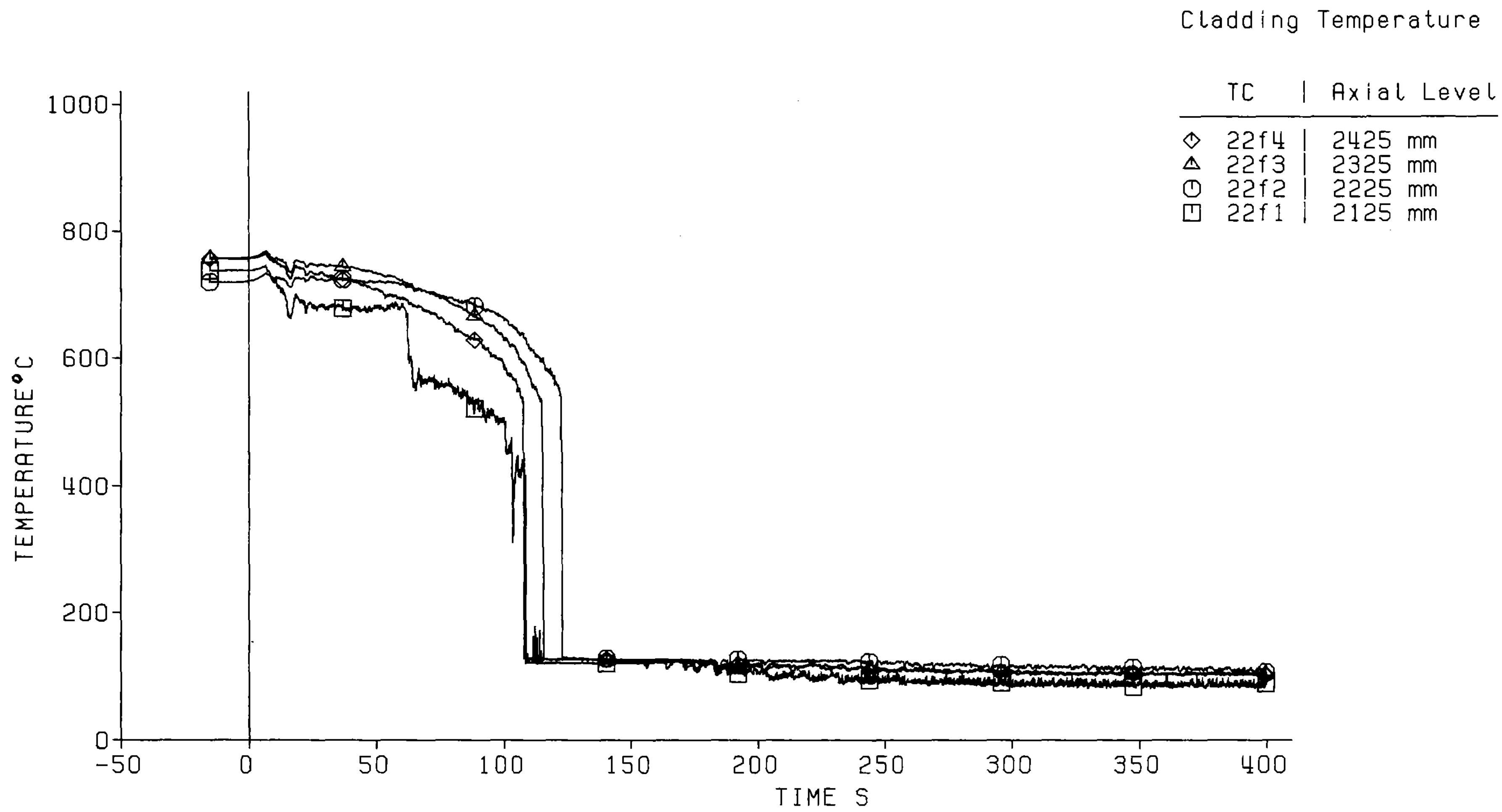
Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.81 cm/s
System Pressure 2.05 bar
Feedwater Temperature 41°C

REBEKA Rods With
Argon Filled Gaps

Bypass
======

KfK IRB

Fig. 97 SEFLEX: 5x5 RØD BUNDLE, SERIES 4, TEST-No. 33



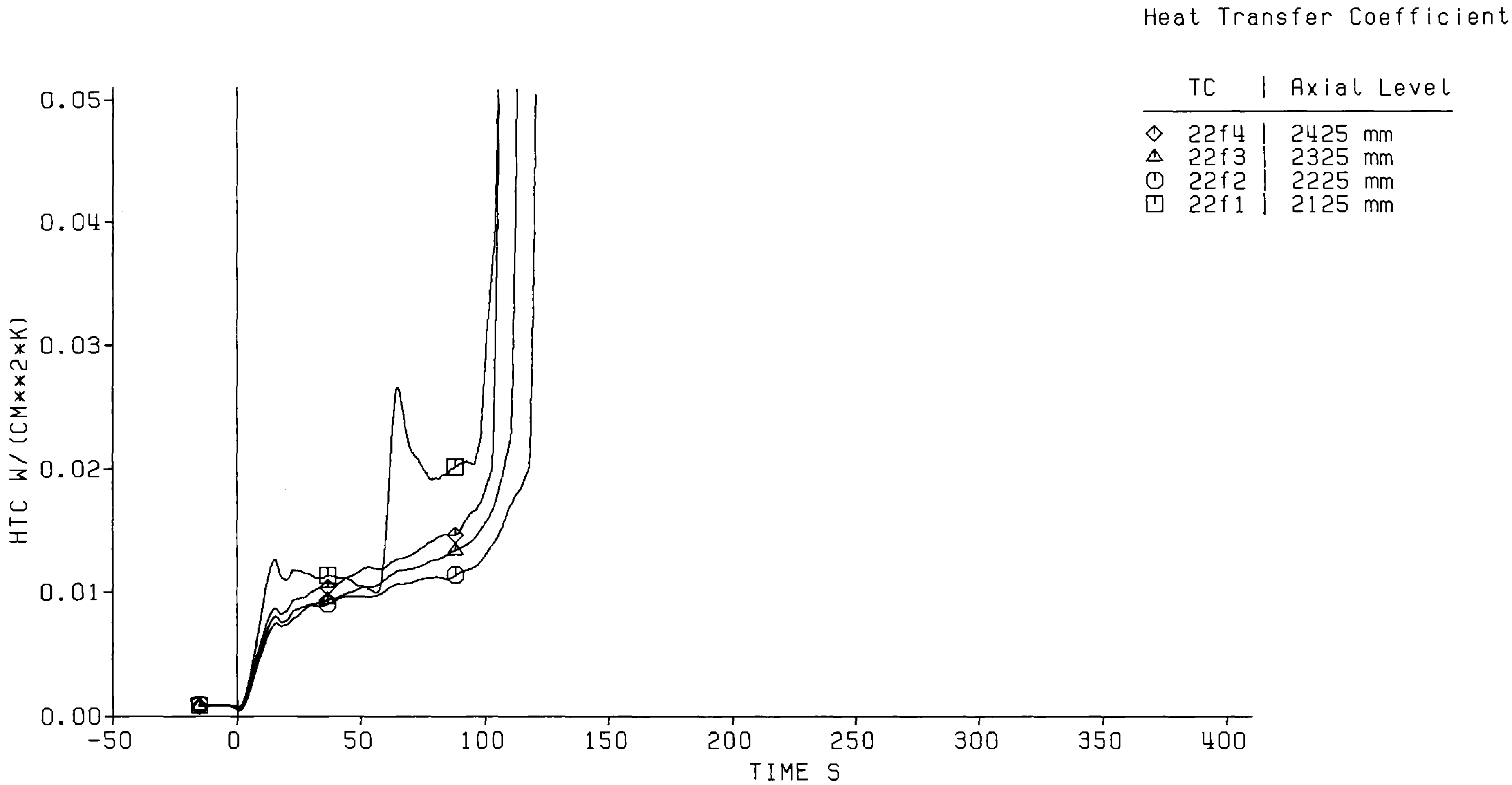
Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.81 cm/s
System Pressure 2.05 bar
Feedwater Temperature 41°C

REBEKA Rods With
Argon Filled Gaps

Blockage
========

KfK IRB

Fig. 98 SEFLEX: 5x5 RØD BUNDLE, SERIES 4, TEST-No. 33



Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.81 cm/s
System Pressure 2.05 bar
Feedwater Temperature 41°C

REBEKA Rods With
Argon Filled Gaps

Blockage
========

KfK IRB

Fig. 99 SEFLEX: 5x5 RØD BUNDLE, SERIES 4, TEST-No. 33

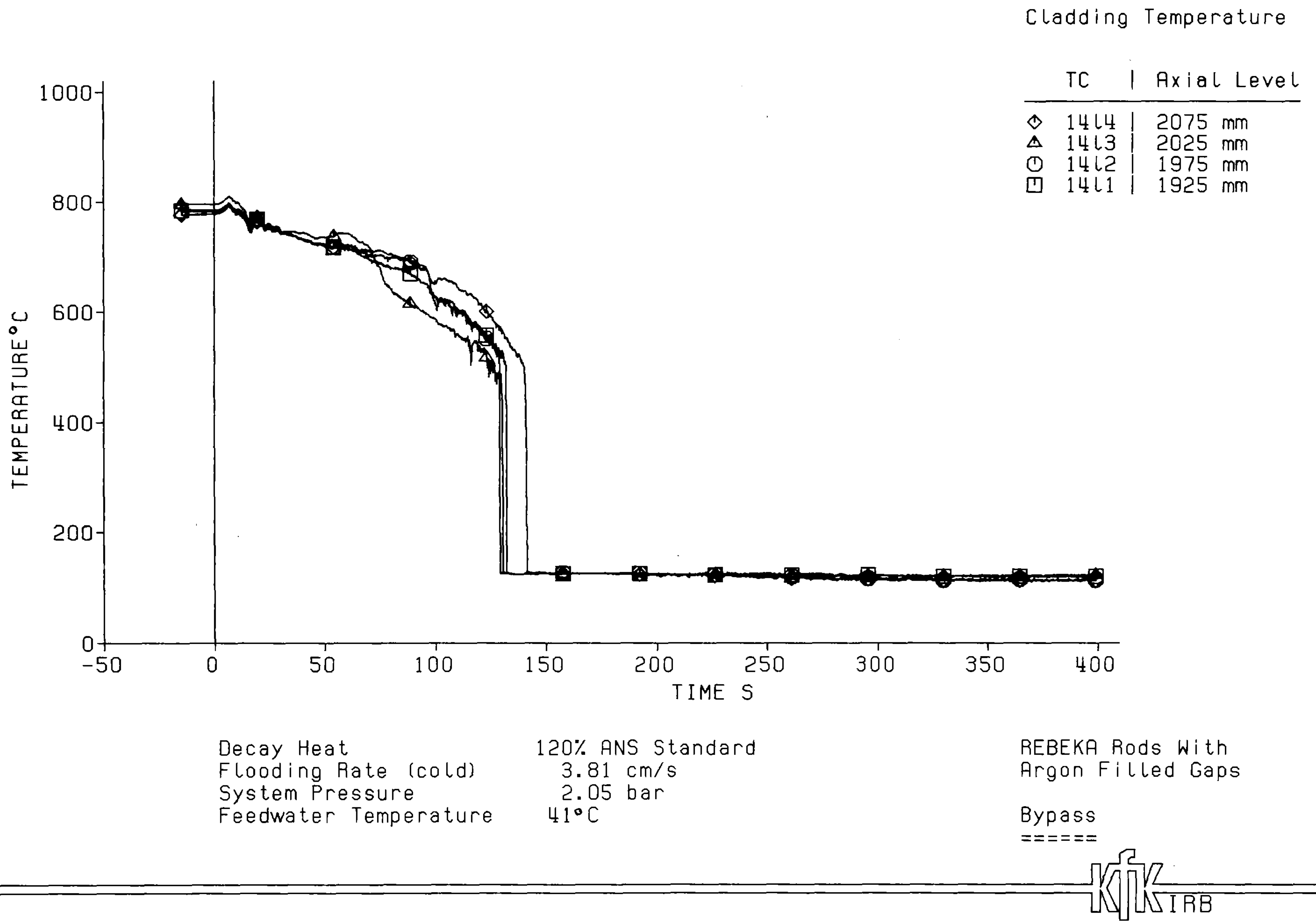
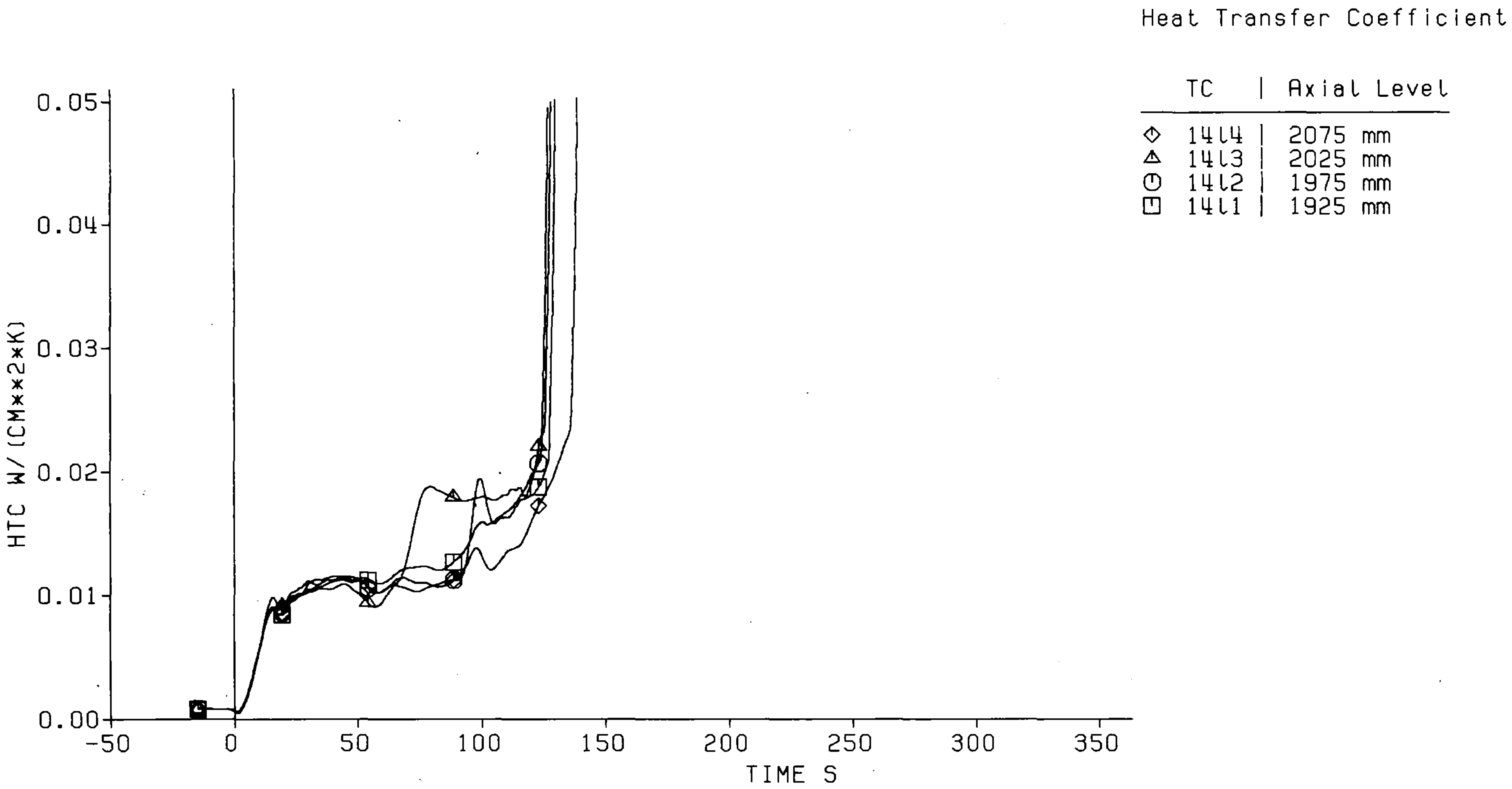


Fig. 100 SEFLEX: 5x5 RØD BUNDLE, SERIES 4, TEST-No. 33



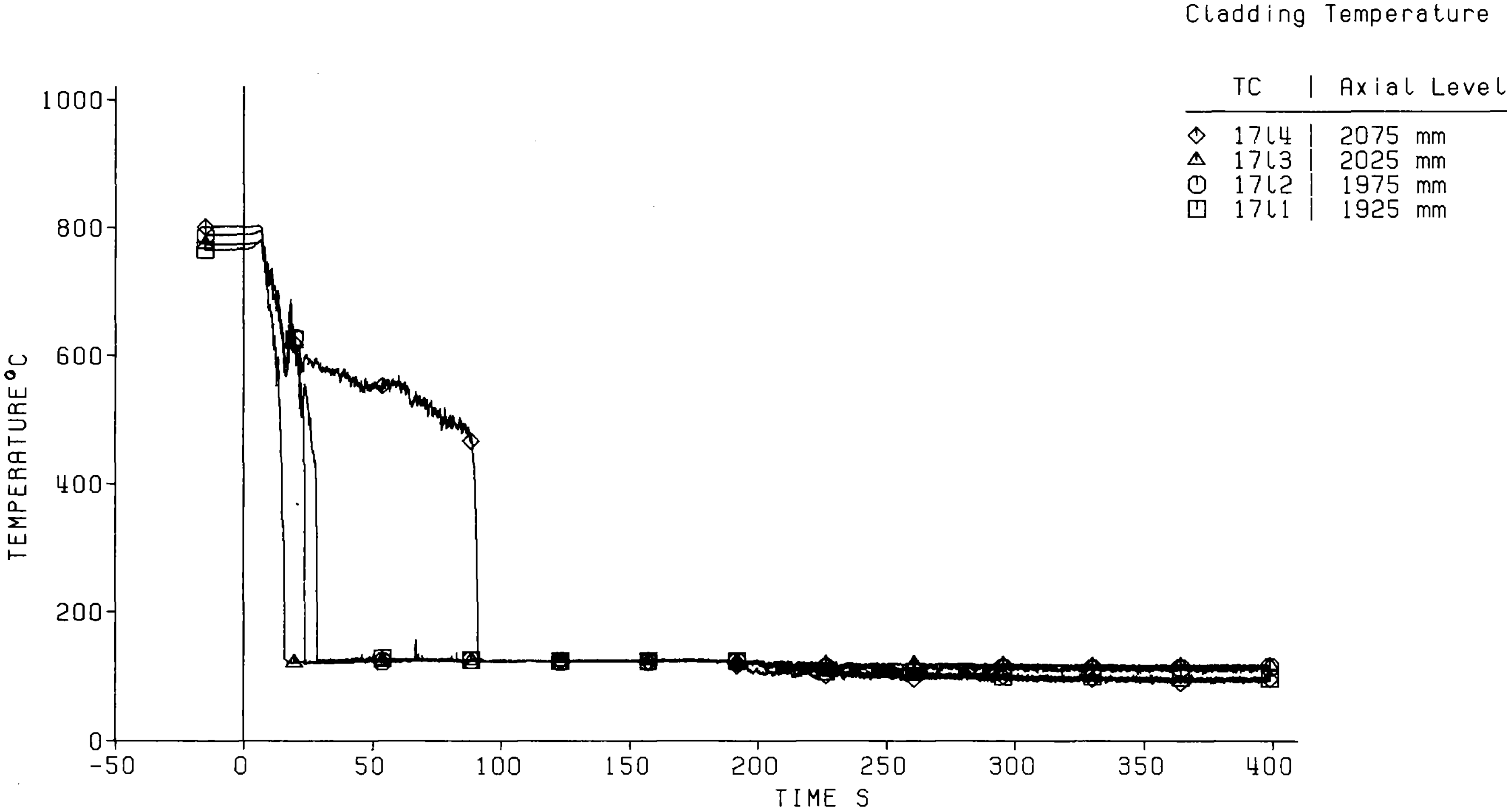
Decay Heat	120% ANS Standard
Flooding Rate (cold)	3.81 cm/s
System Pressure	2.05 bar
Feedwater Temperature	41°C

REBEKA Rods With
Argon Filled Gaps

Bypass
======

KfK IRB

Fig. 101 SEFLEX: 5x5 RØD BUNDLE, SERIES 4, TEST-No. 33



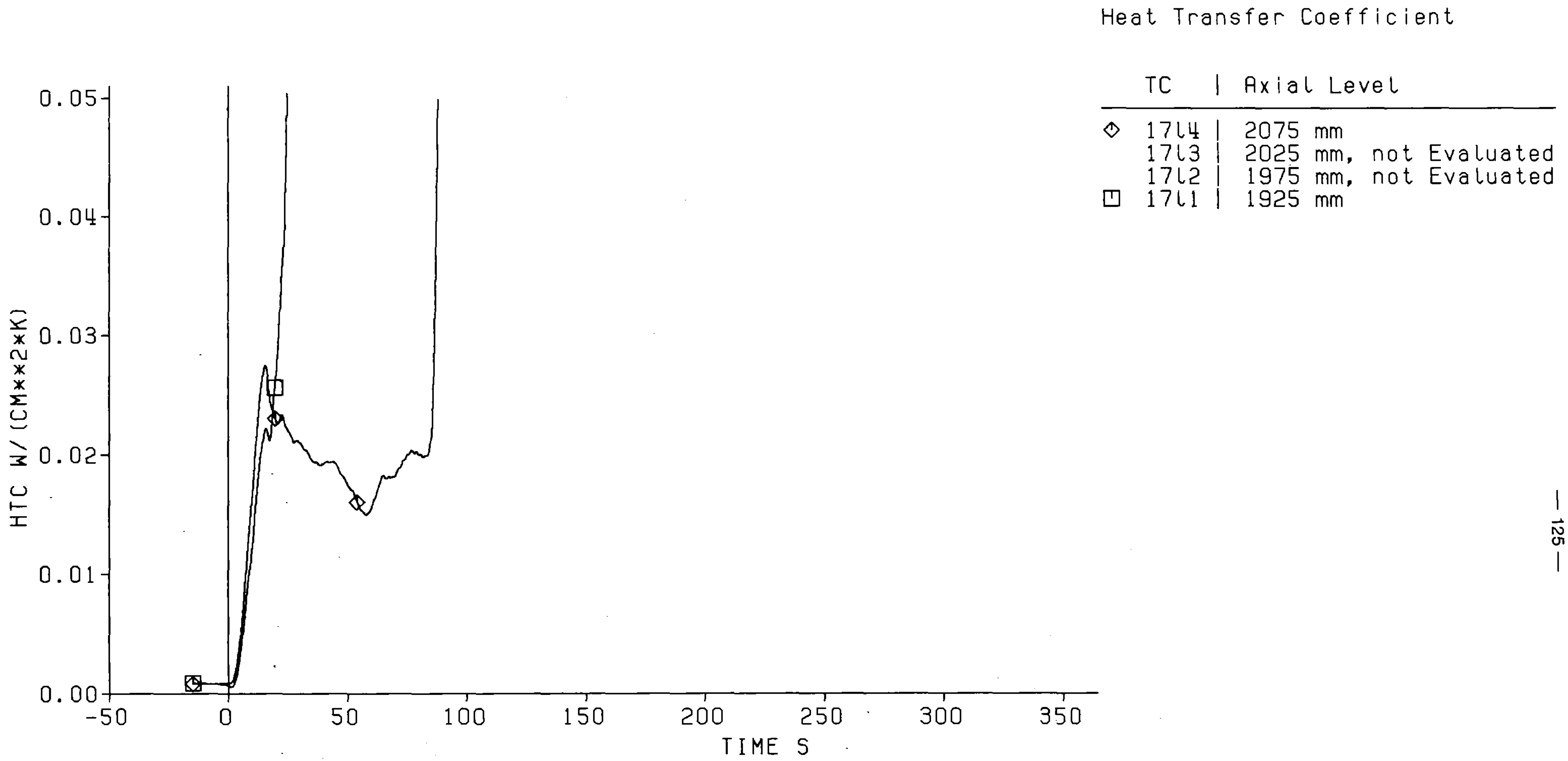
Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.81 cm/s
System Pressure 2.05 bar
Feedwater Temperature 41°C

REBEKA Rods With
Argon Filled Gaps

Blockage
========

KfK IRB

Fig. 102 SEFLEX: 5x5 RØD BUNDLE, SERIES 4, TEST-No. 33



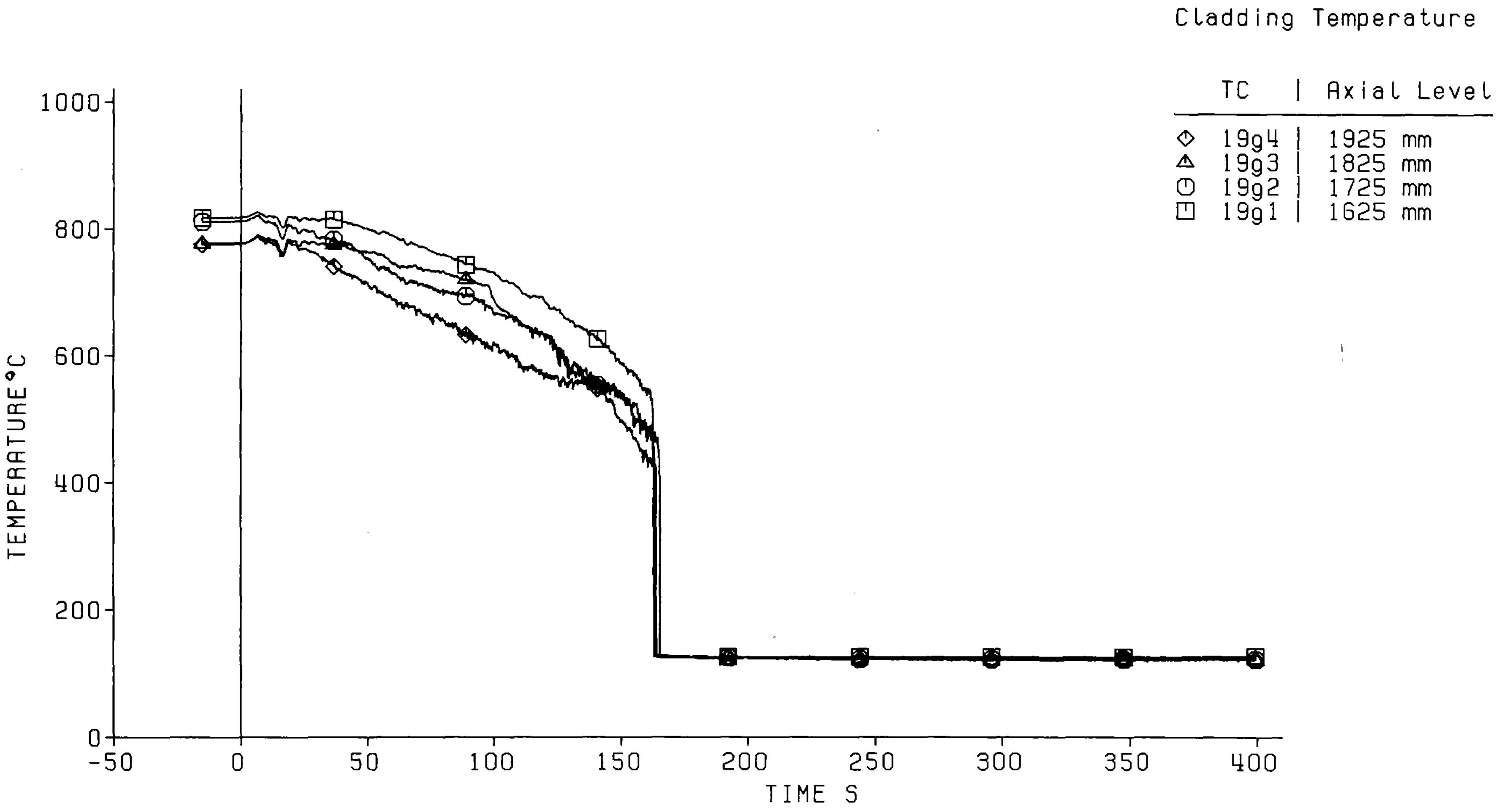
Decay Heat	120% ANS Standard
Flooding Rate (cold)	3.81 cm/s
System Pressure	2.05 bar
Feedwater Temperature	41°C

REBEKA Rods With
Argon Filled Gaps

Blockage
========

KfK IRB

Fig. 103 SEFLEX: 5x5 RØD BUNDLE, SERIES 4, TEST-No. 33



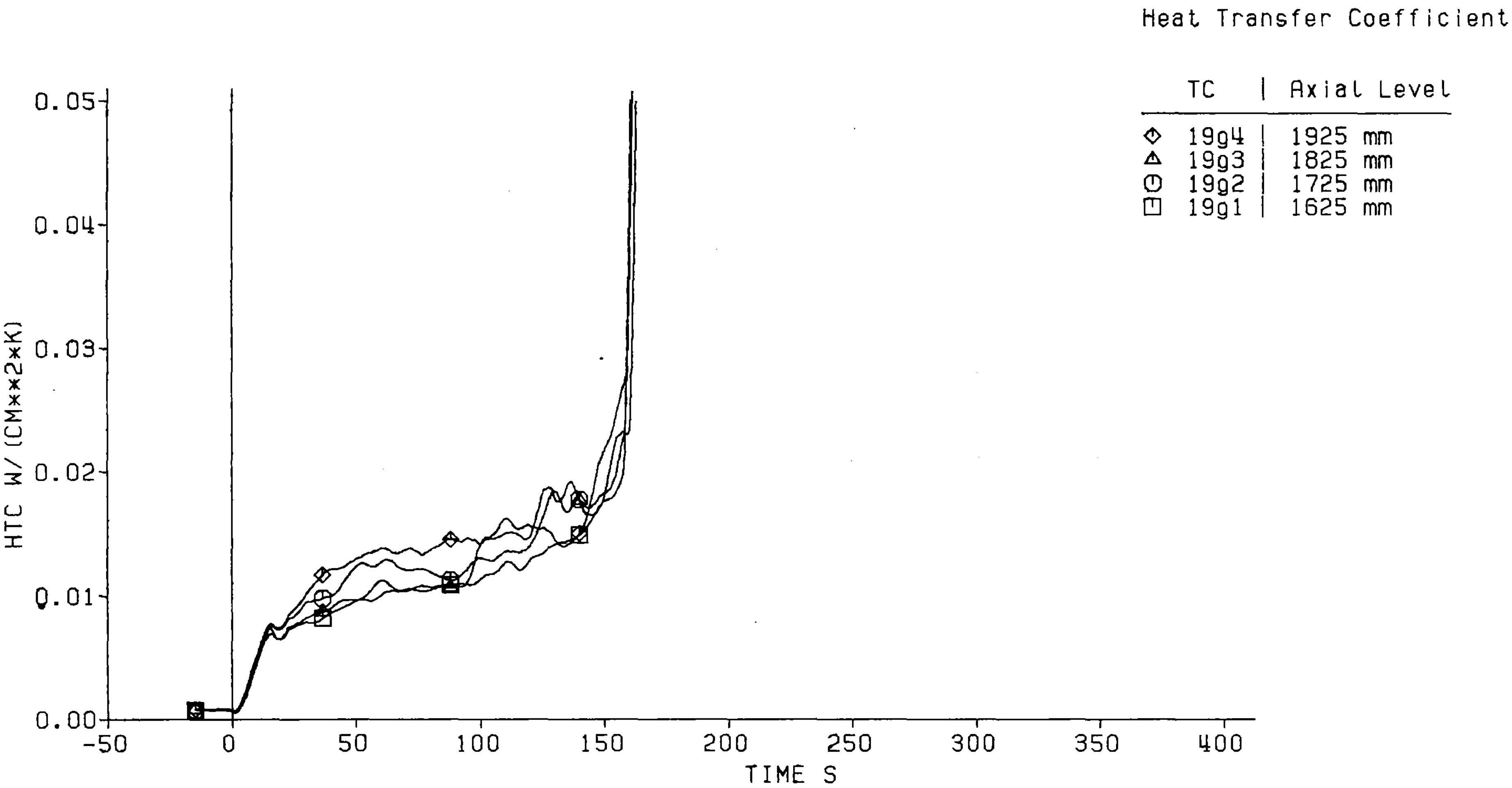
Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.81 cm/s
System Pressure 2.05 bar
Feedwater Temperature 41°C

REBEKA Rods With
Argon Filled Gaps

Bypass
======

KfK IRB

Fig. 104 SEFLEX: 5x5 RØD BUNDLE, SERIES 4, TEST-No. 33



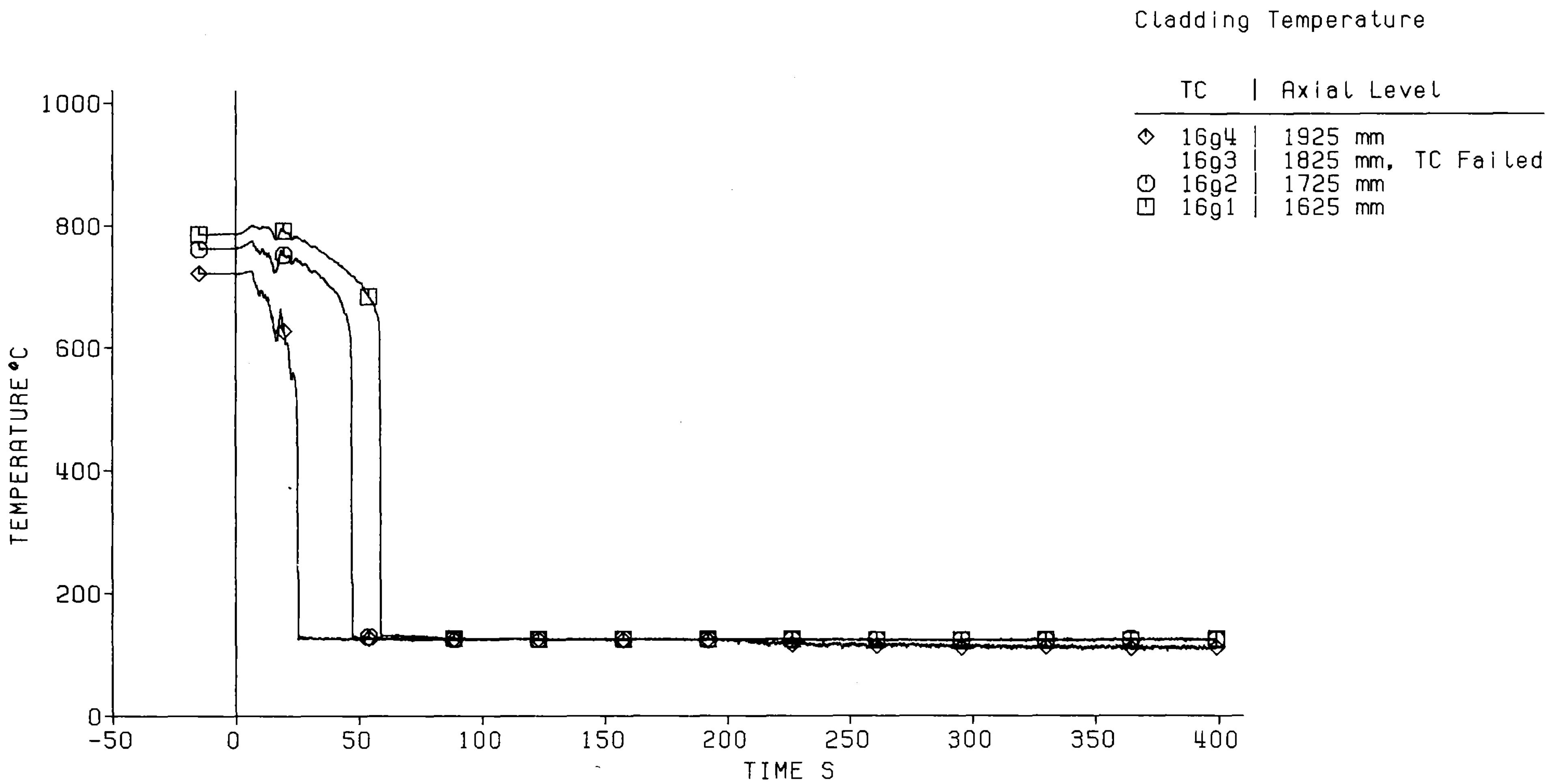
Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.81 cm/s
System Pressure 2.05 bar
Feedwater Temperature 41°C

REBEKA Rods With
Argon Filled Gaps

Bypass
======

KfK IRB

Fig. 105 SEFLEX: 5x5 RØD BUNDLE, SERIES 4, TEST-No. 33



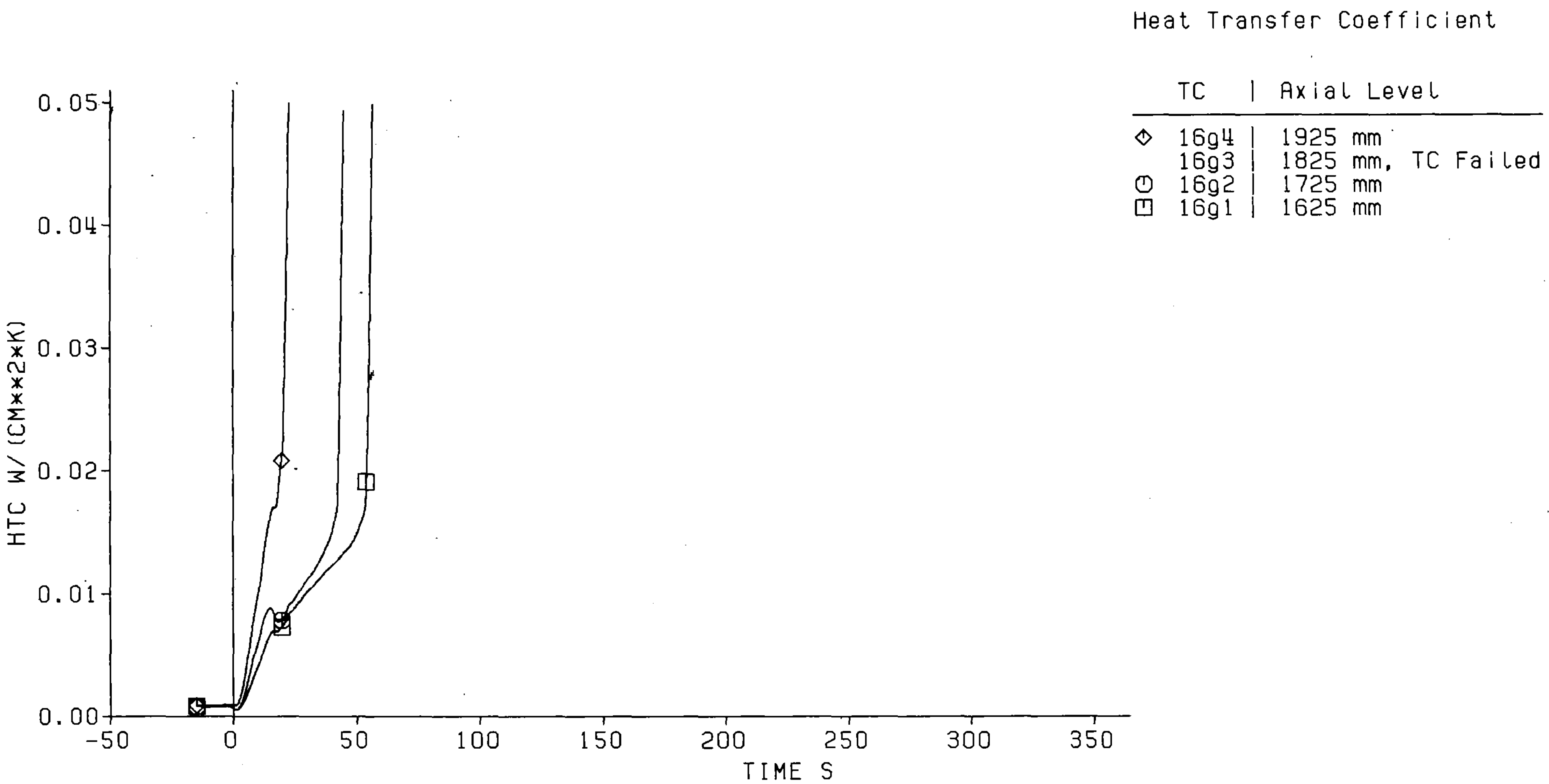
Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.81 cm/s
System Pressure 2.05 bar
Feedwater Temperature 41° C

REBEKA Rods With Argon Filled Gaps

Blockage
========

KfK IRB

Fig. 106 SEFLEX: 5x5 RØD BUNDLE, SERIES 4, TEST-No. 33



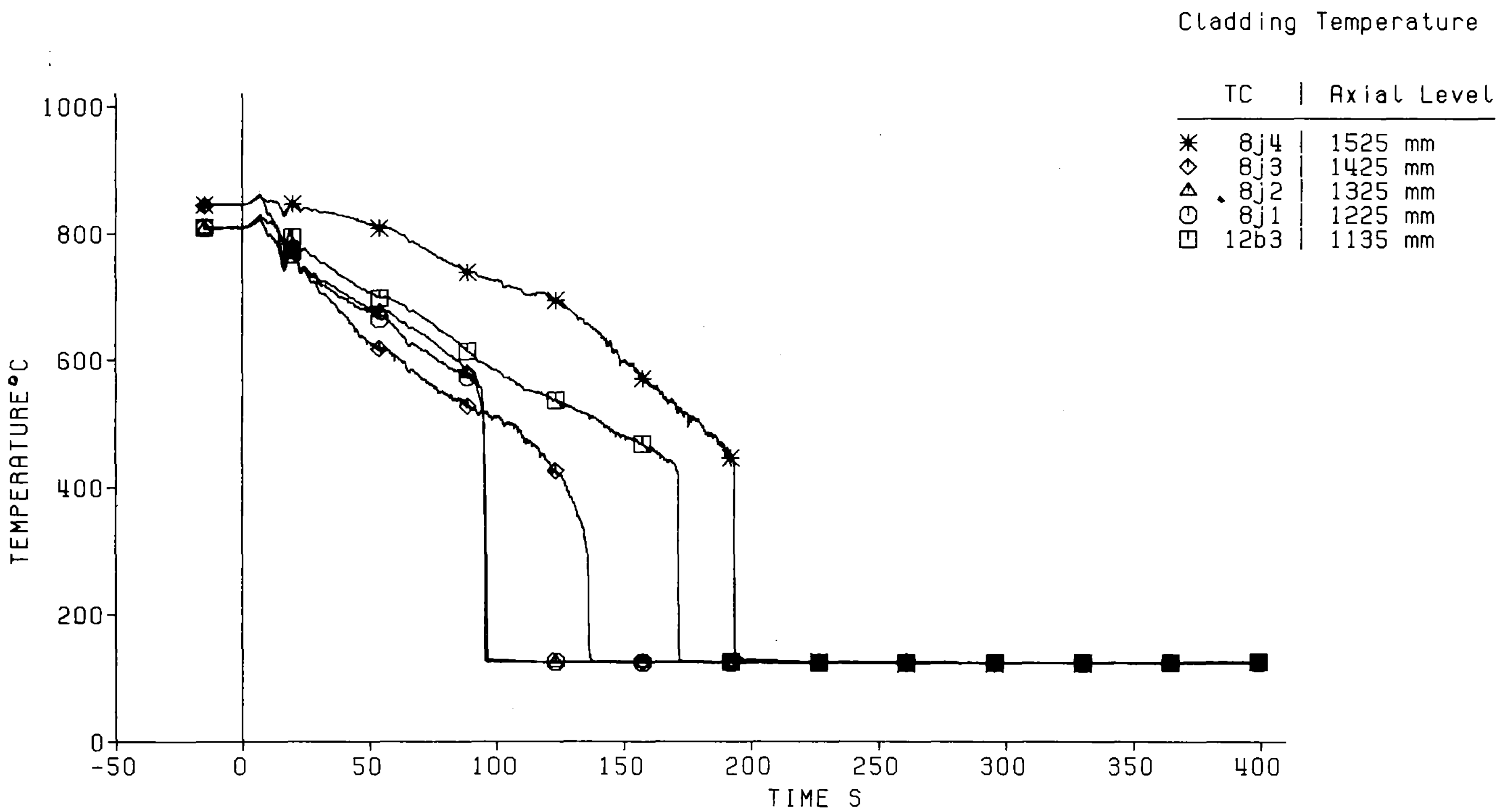
Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.81 cm/s
System Pressure 2.05 bar
Feedwater Temperature 41°C

REBEKA Rods With
Argon Filled Gaps

Blockage
========

KfK IRB

Fig. 107 SEFLEX: 5x5 RØD BUNDLE, SERIES 4, TEST-No. 33

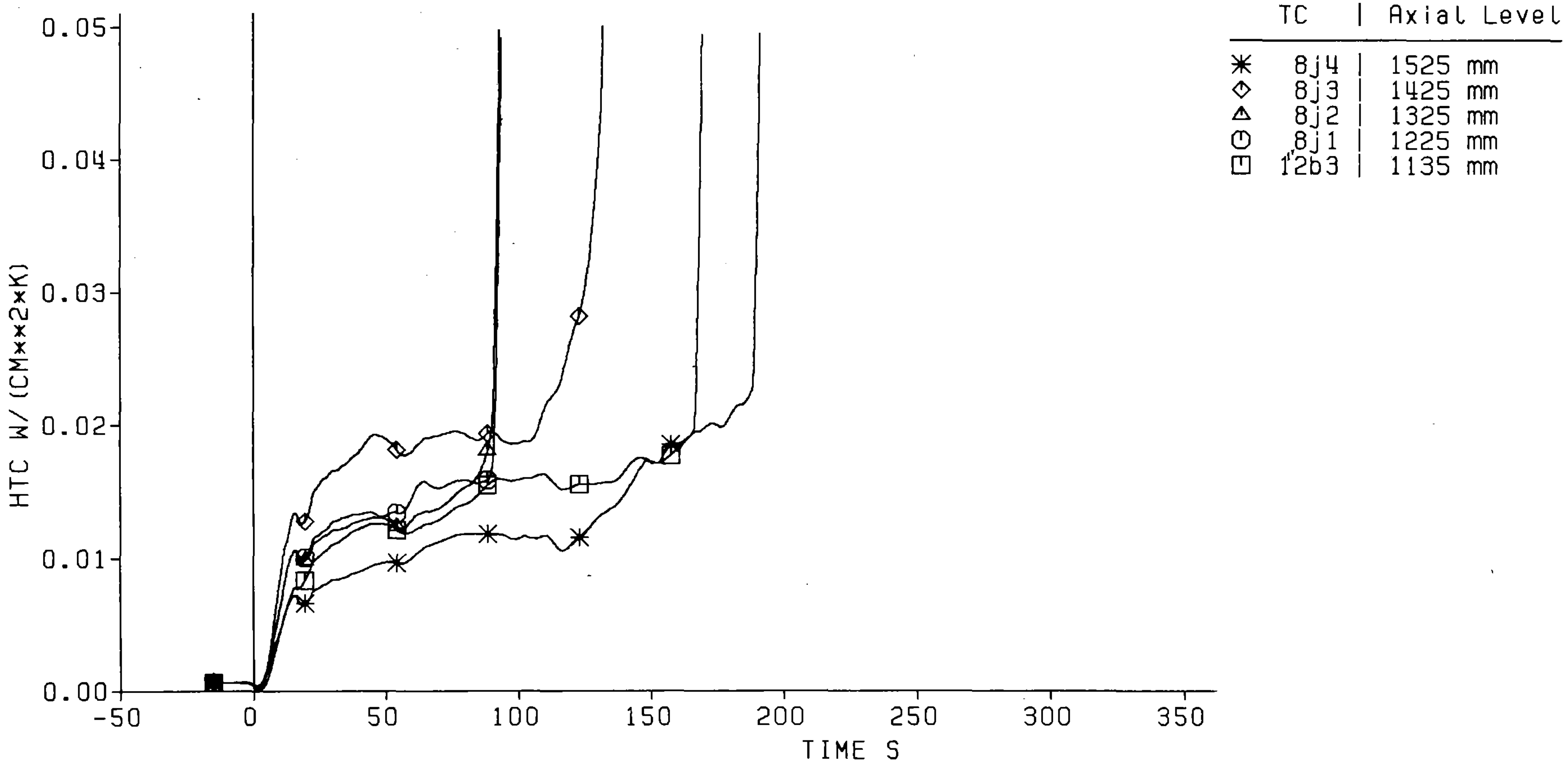


Decay Heat	120% ANS Standard
Flooding Rate (cold)	3.81 cm/s
System Pressure	2.05 bar
Feedwater Temperature	41°C

REBEKA Rods With
Argon Filled Gaps

KfK IRB

Fig. 108 SEFLEX: 5x5 RØD BUNDLE, SERIES 4, TEST-No. 33

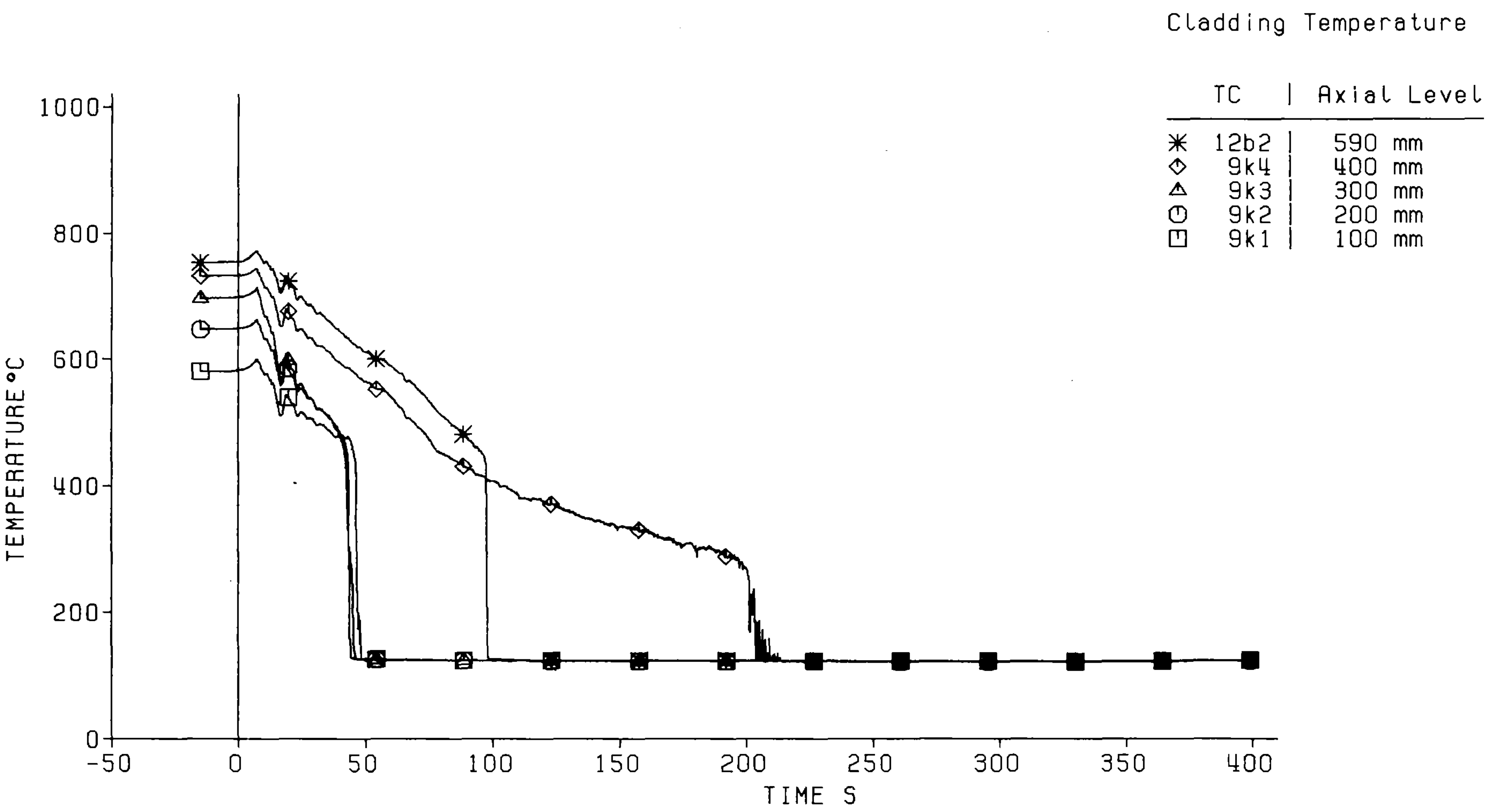


Decay Heat	120% ANS Standard
Flooding Rate (cold)	3.81 cm/s
System Pressure	2.05 bar
Feedwater Temperature	41° C

REBEKA Rods With
Argon Filled Gaps

KfK IRB

Fig. 109 SEFLEX: 5x5 RØD BUNDLE, SERIES 4, TEST-No. 33

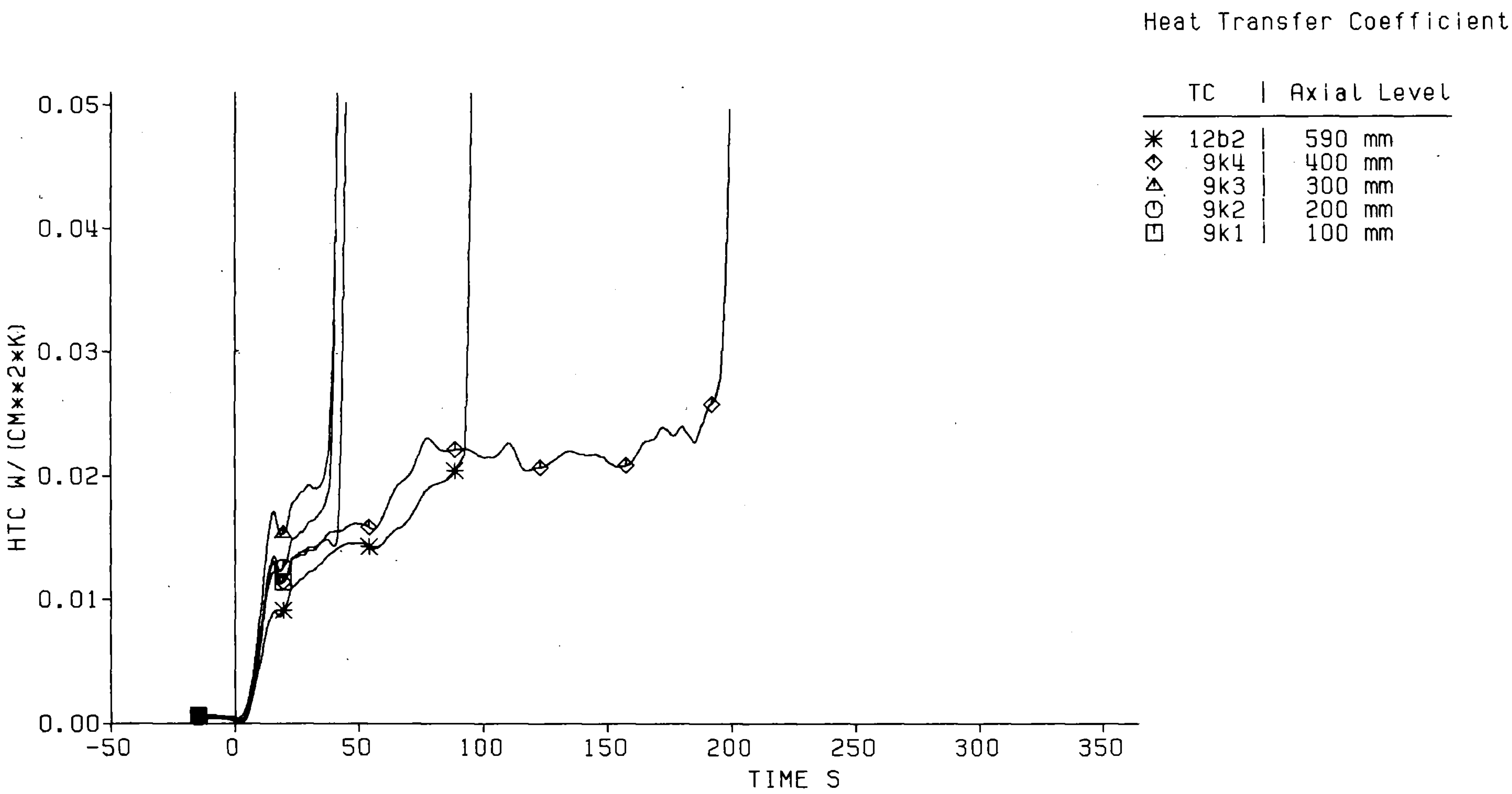


Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.81 cm/s
System Pressure 2.05 bar
Feedwater Temperature 41°C

REBEKA Rods With
Argon Filled Gaps

KfK IRB

Fig. 110 SEFLEX: 5x5 RØD BUNDLE, SERIES 4, TEST-No. 33

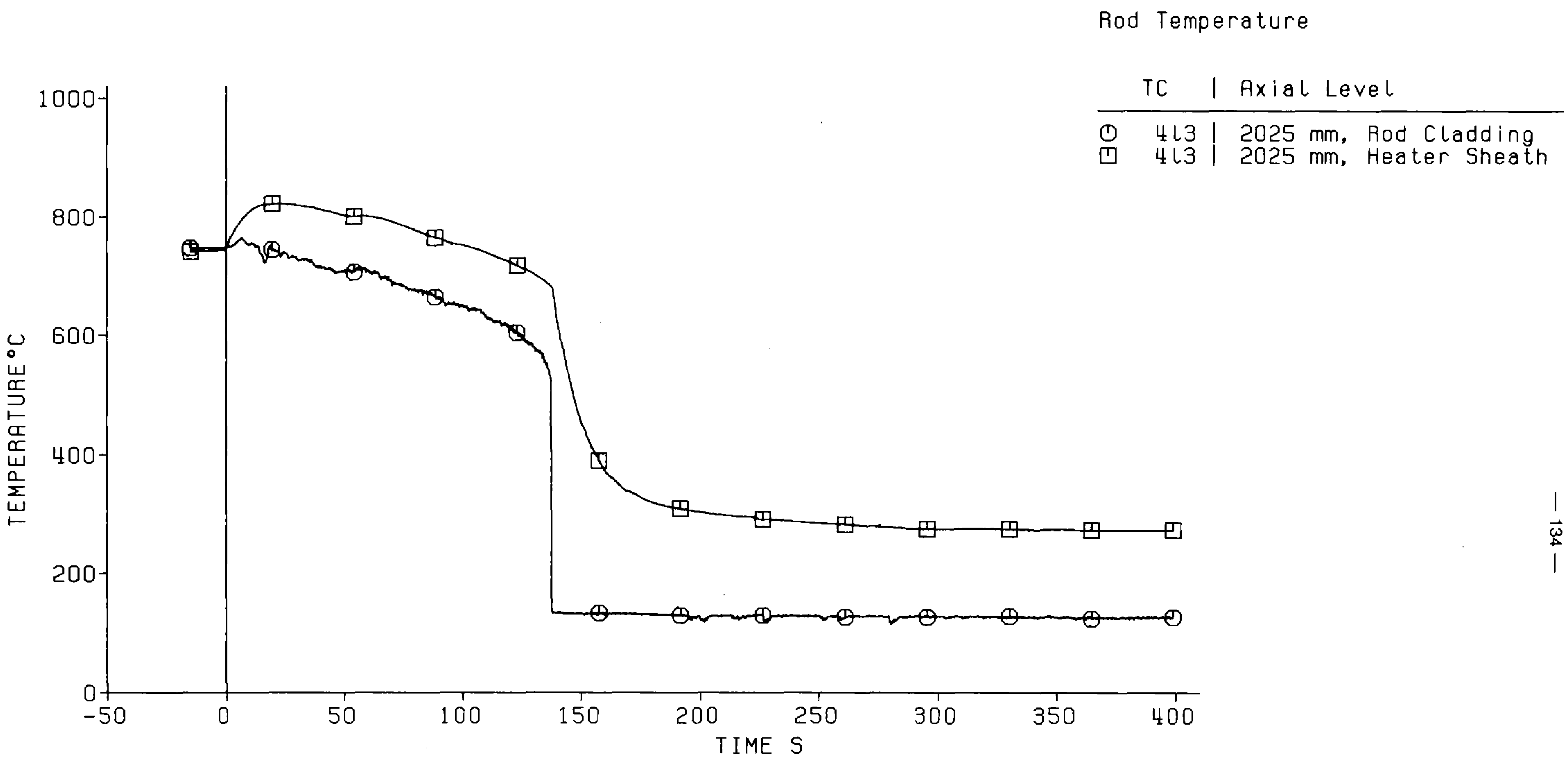


Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.81 cm/s
System Pressure 2.05 bar
Feedwater Temperature 41°C

REBEKA Rods With
Argon Filled Gaps

KfK IRB

Fig. 111 SEFLEX: 5x5 RØD BUNDLE, SERIES 4, TEST-No. 33



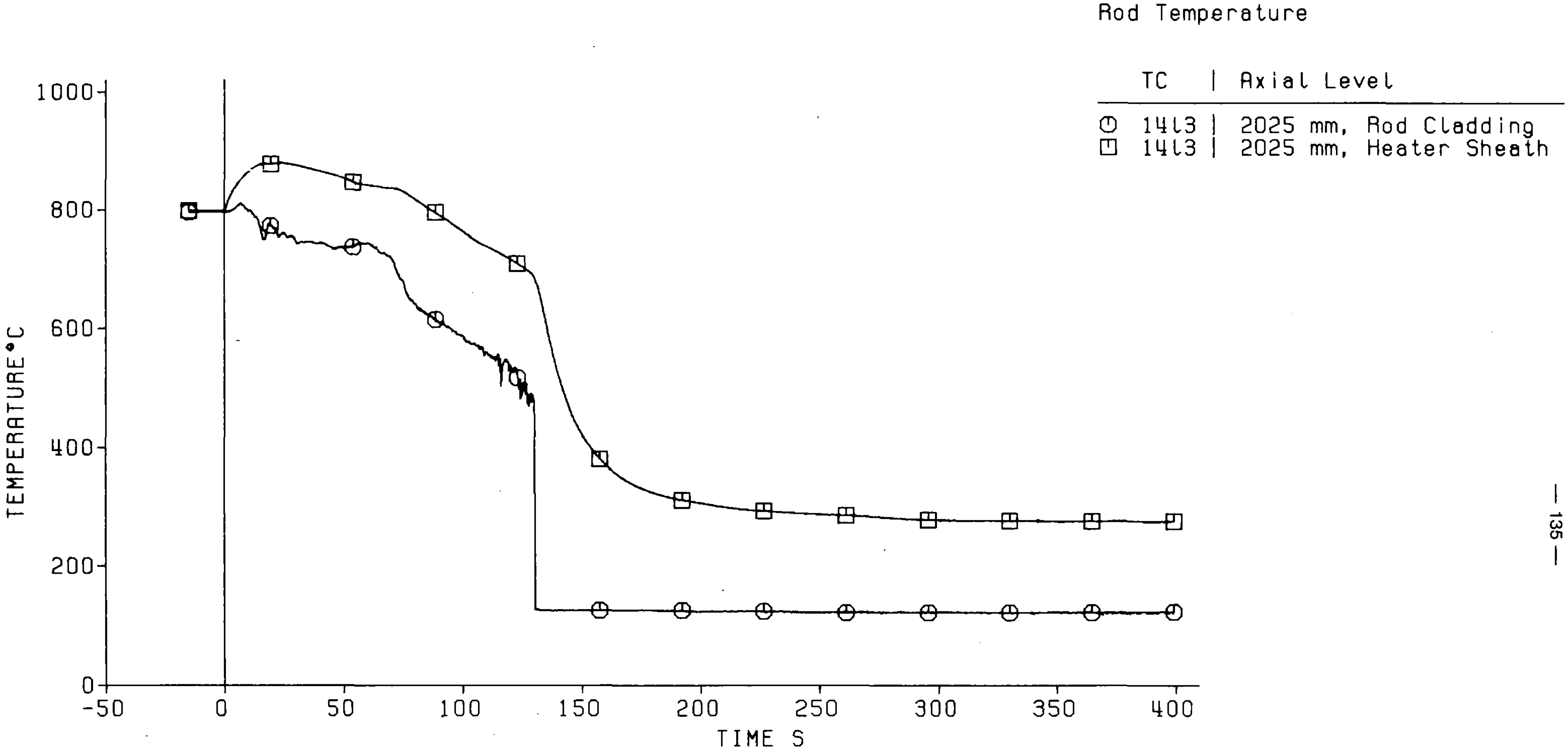
Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.81 cm/s
System Pressure 2.05 bar
Feedwater Temperature 41°C

REBEKA Rods With
Argon Filled Gaps

Bypass
======

KfK IRB

Fig. 112 SEFLEX: 5x5 RØD BUNDLE, SERIES 4, TEST-No. 33



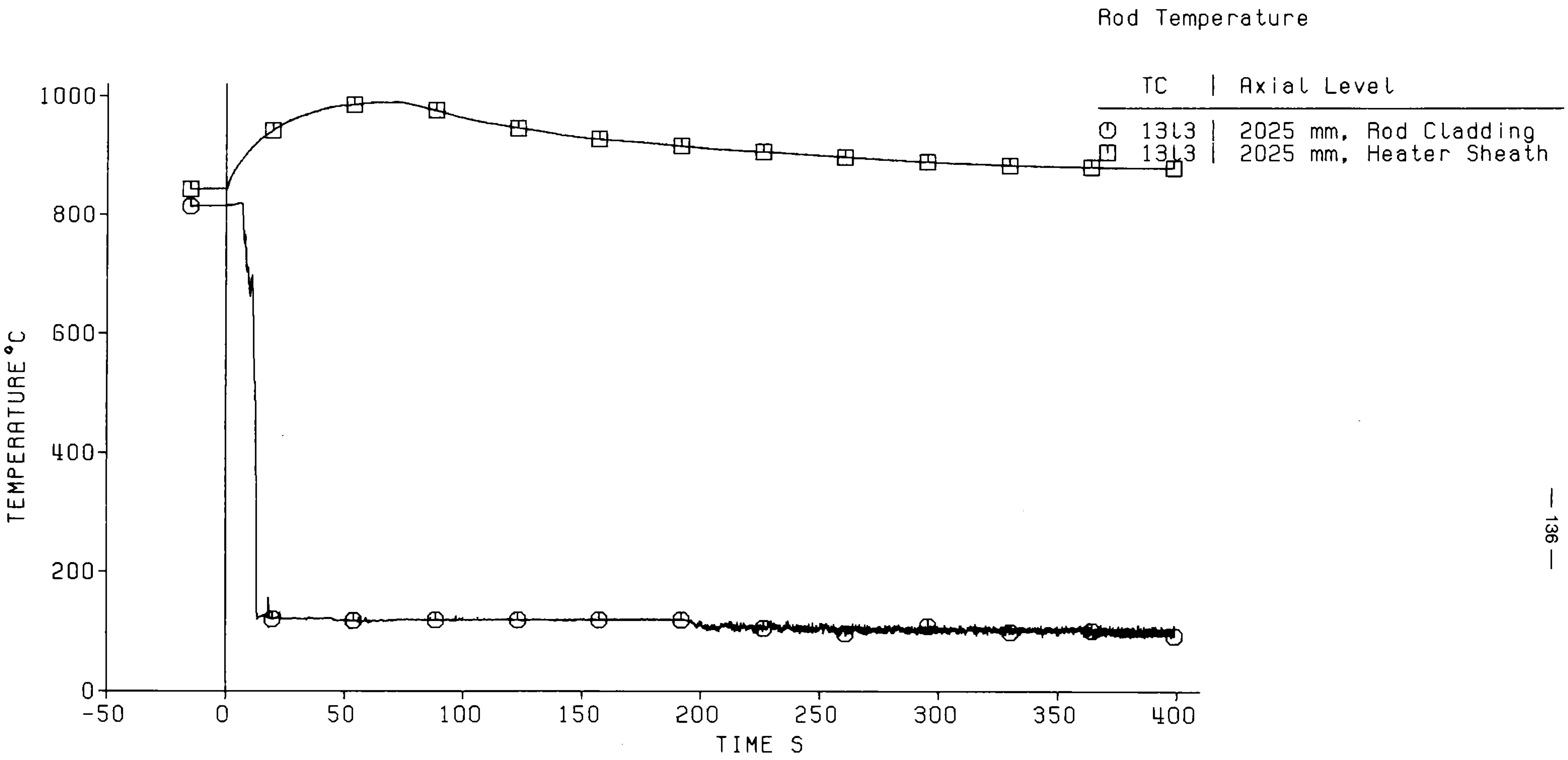
Decay Heat	120% ANS Standard
Flooding Rate (cold)	3.81 cm/s
System Pressure	2.05 bar
Feedwater Temperature	41°C

REBEKA Rods With
Argon Filled Gaps

Bypass
======

KfK IRB

Fig. 113 SEFLEX: 5x5 RØD BUNDLE, SERIES 4, TEST-No. 33



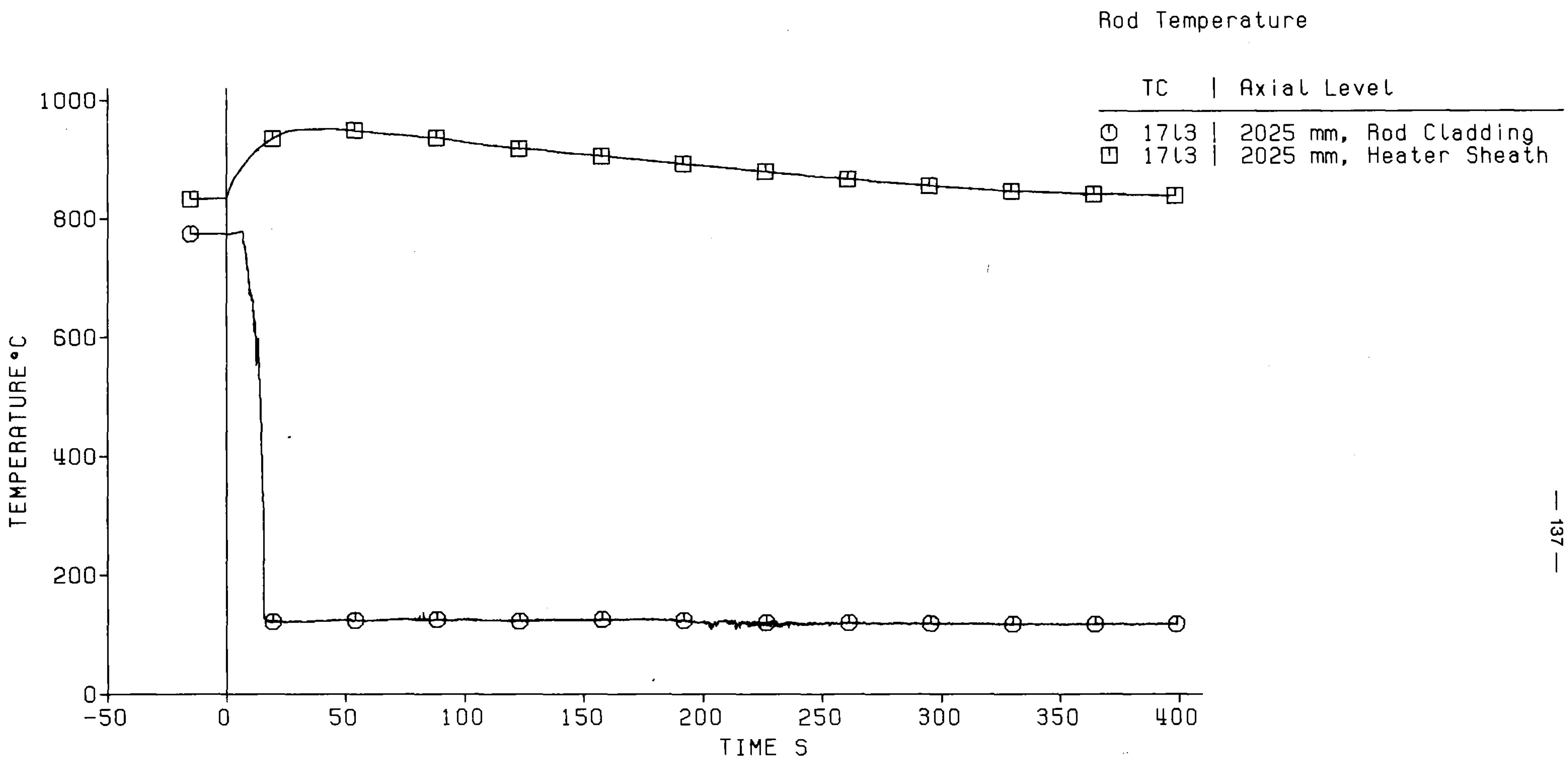
Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.81 cm/s
System Pressure 2.05 bar
Feedwater Temperature 41°C

REBEKA Rods With
Argon Filled Gaps

Blockage
========

KfK IRB

Fig. 114 SEFLEX: 5x5 RØD BUNDLE, SERIES 4, TEST-No. 33



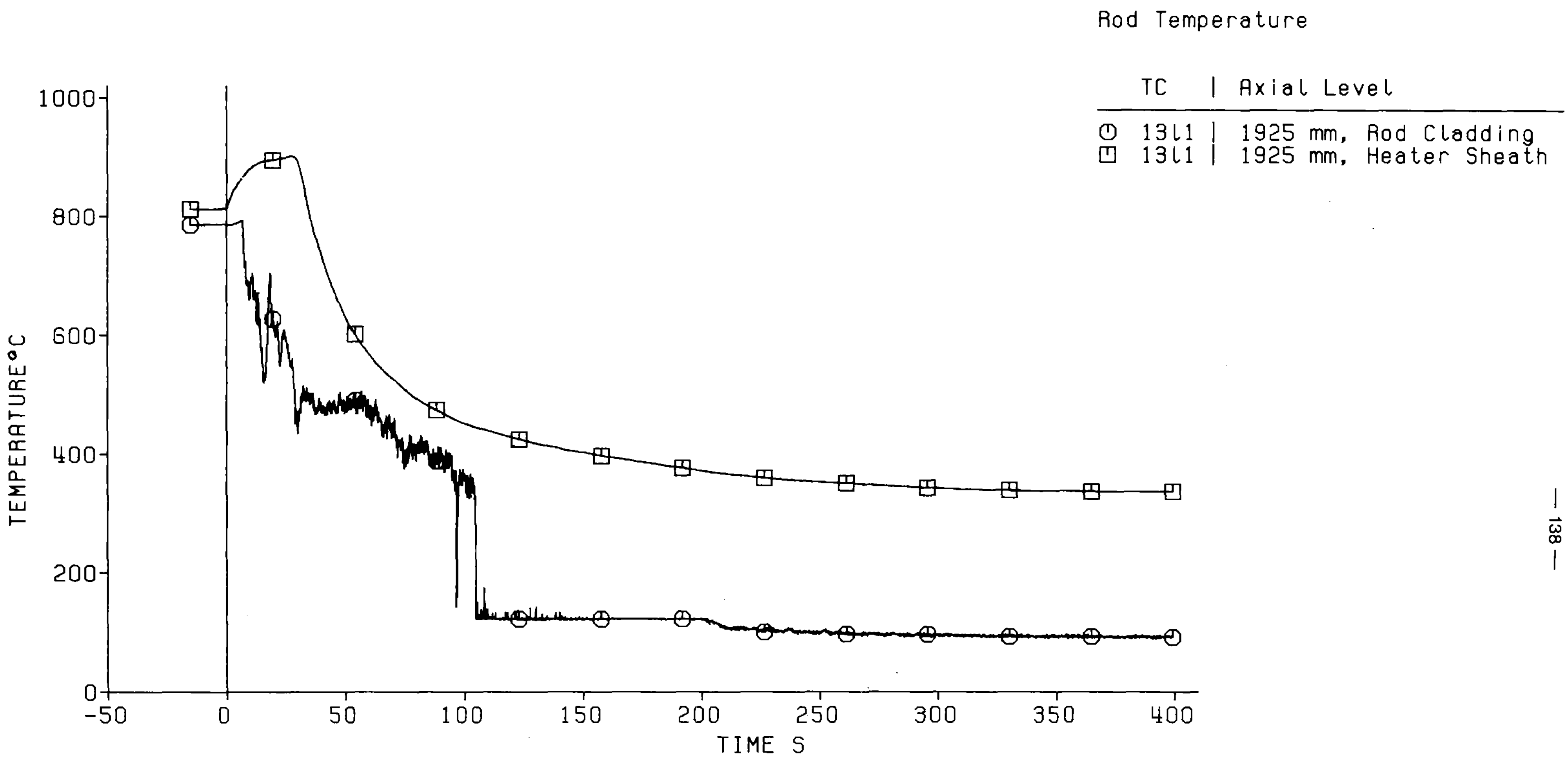
Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.81 cm/s
System Pressure 2.05 bar
Feedwater Temperature 41°C

REBEKA Rods With
Argon Filled Gaps

Blockage
========

KfK IRB

Fig. 115 SEFLEX: 5x5 ROD BUNDLE, SERIES 4, TEST-No. 33



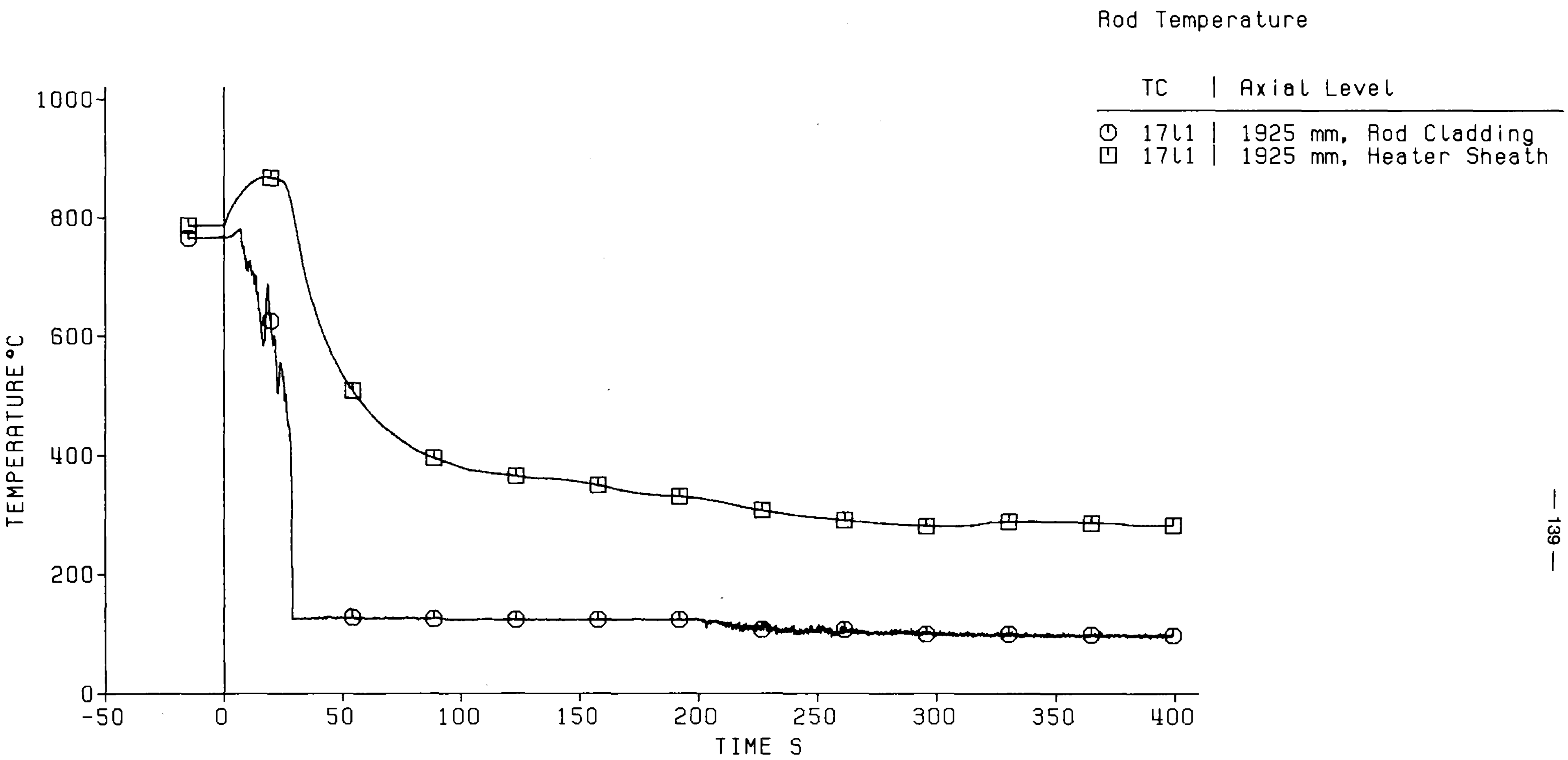
Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.81 cm/s
System Pressure 2.05 bar
Feedwater Temperature 41°C

REBEKA Rods With
Argon Filled Gaps

Blockage
========

KfK IRB

Fig. 116 SEFLEX: 5x5 RØD BUNDLE, SERIES 4, TEST-No. 33



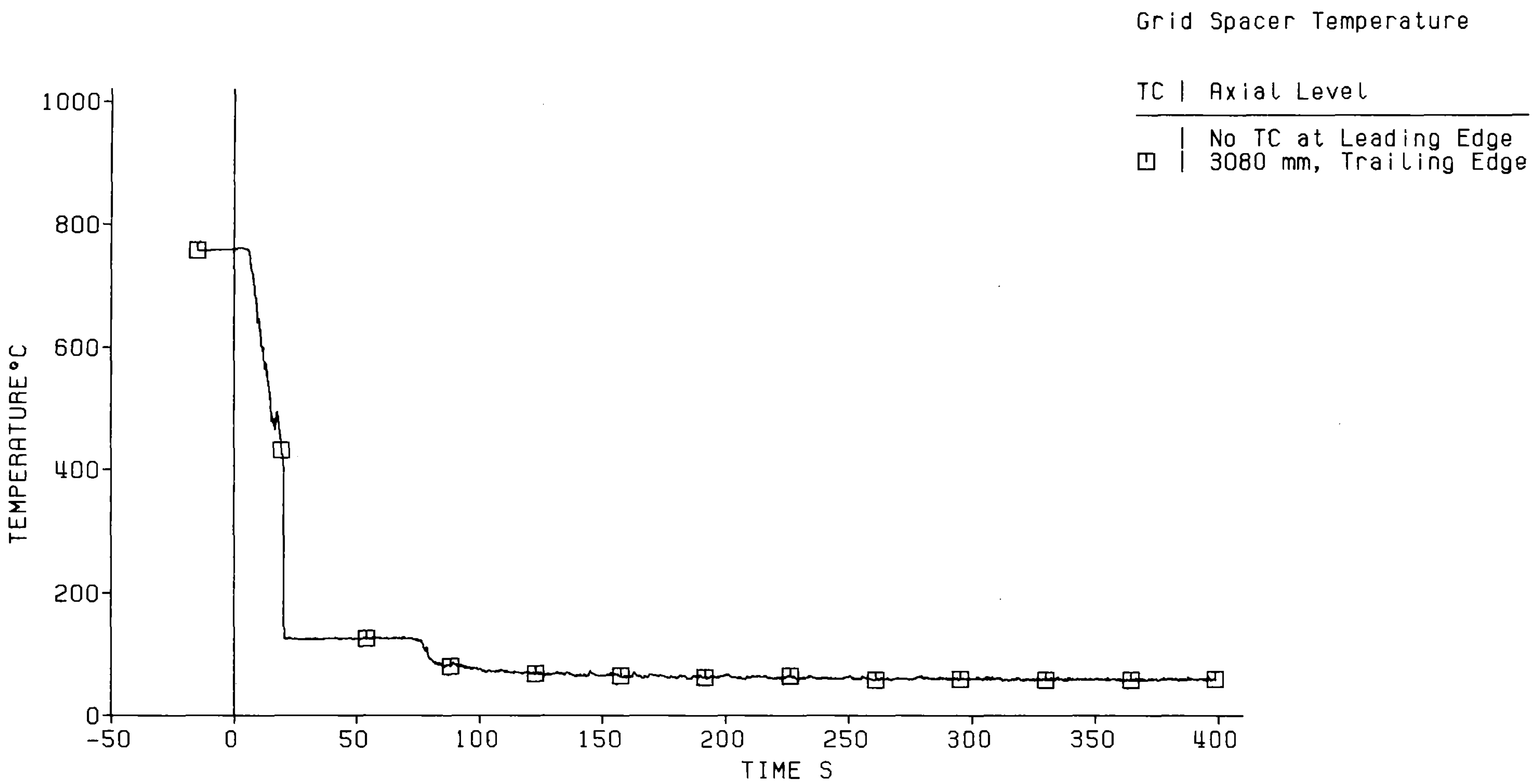
Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.81 cm/s
System Pressure 2.05 bar
Feedwater Temperature 41°C

REBEKA Rods With
Argon Filled Gaps

Blockage
========

KfK IRB

Fig. 117 SEFLEX: 5x5 RØD BUNDLE, SERIES 4, TEST-No. 33

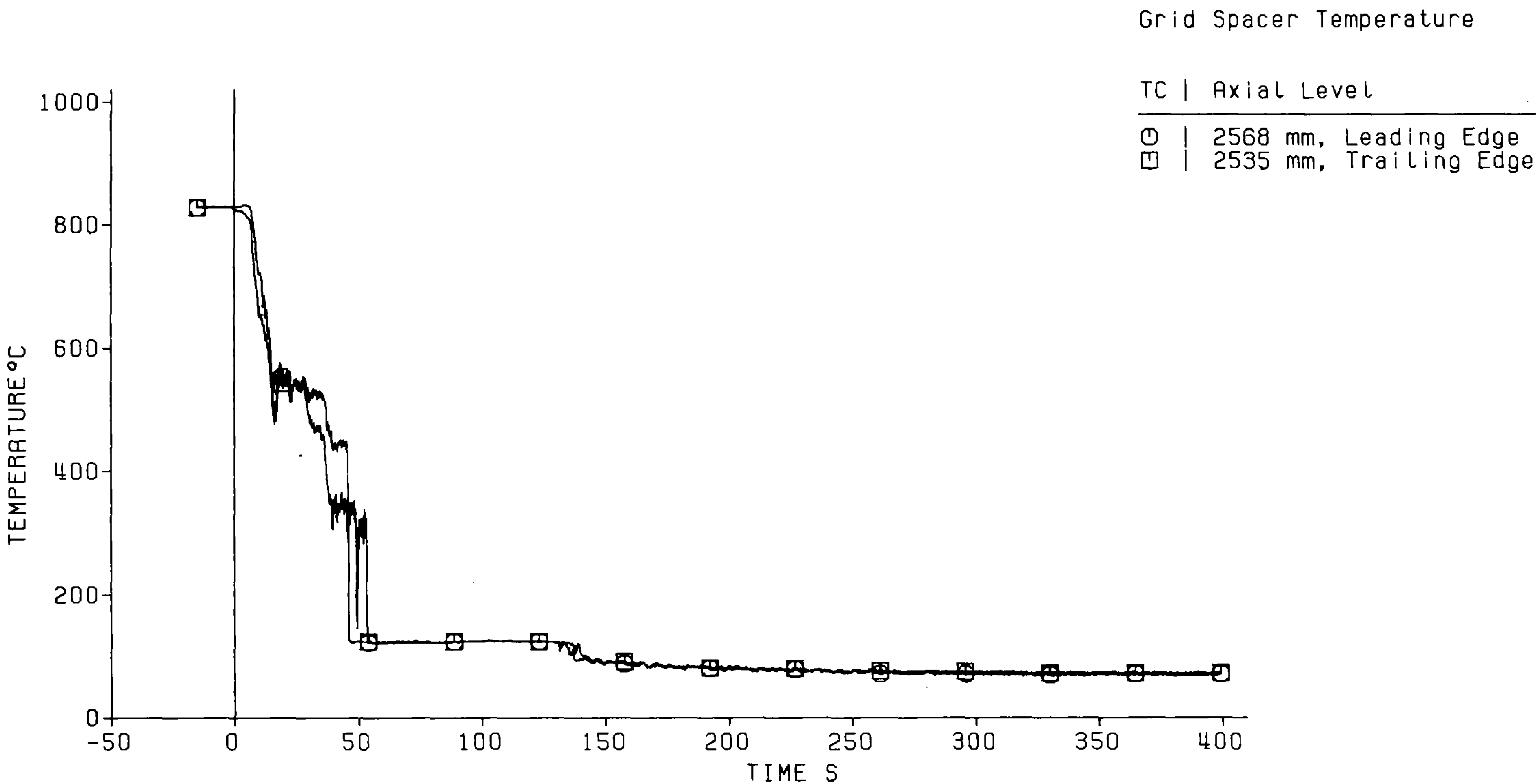


Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.81 cm/s
System Pressure 2.05 bar
Feedwater Temperature 41°C

REBEKA Rods With
Argon Filled Gaps

KfK IRB

Fig. 118 SEFLEX: 5x5 RØD BUNDLE, SERIES 4, TEST-No. 33

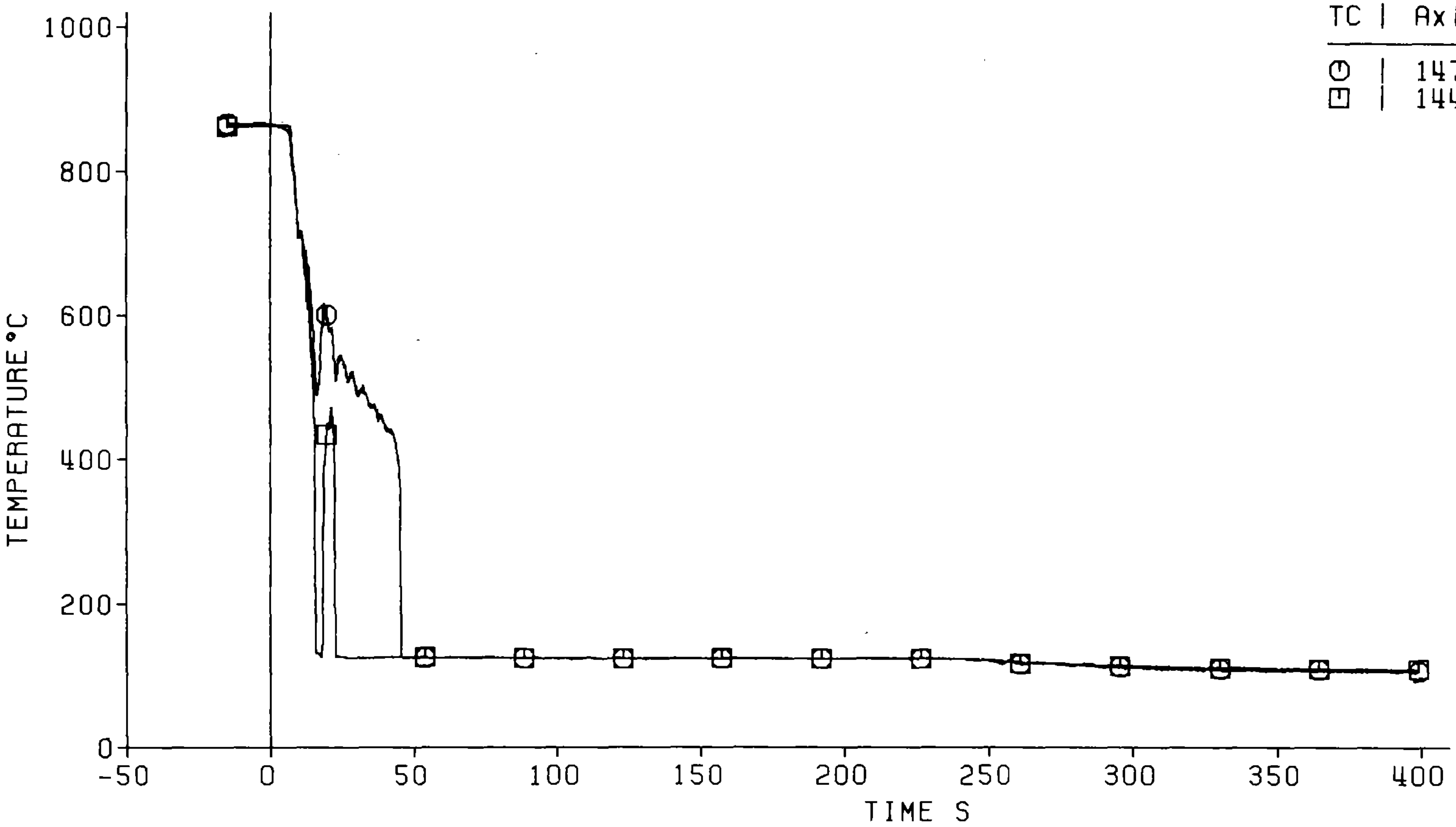


Decay Heat	120% ANS Standard
Flooding Rate (cold)	3.81 cm/s
System Pressure	2.05 bar
Feedwater Temperature	41° C

REBEKA Rods With
Argon Filled Gaps

KfK IRB

Fig. 119 SEFLEX: 5x5 RØD BUNDLE, SERIES 4, TEST-No. 33

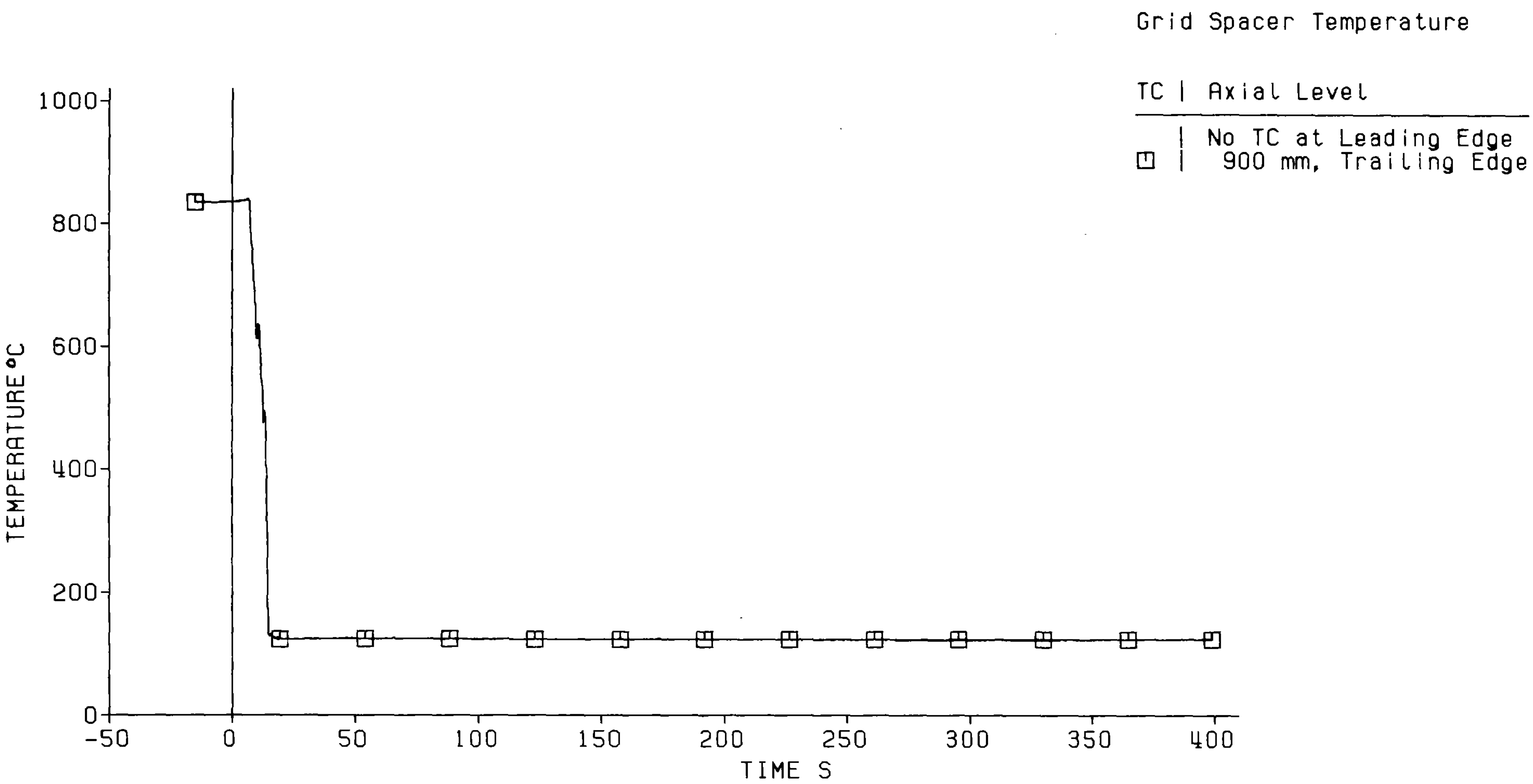


Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.81 cm/s
System Pressure 2.05 bar
Feedwater Temperature 41°C

REBEKA Rods With
Argon Filled Gaps

KfK IRB

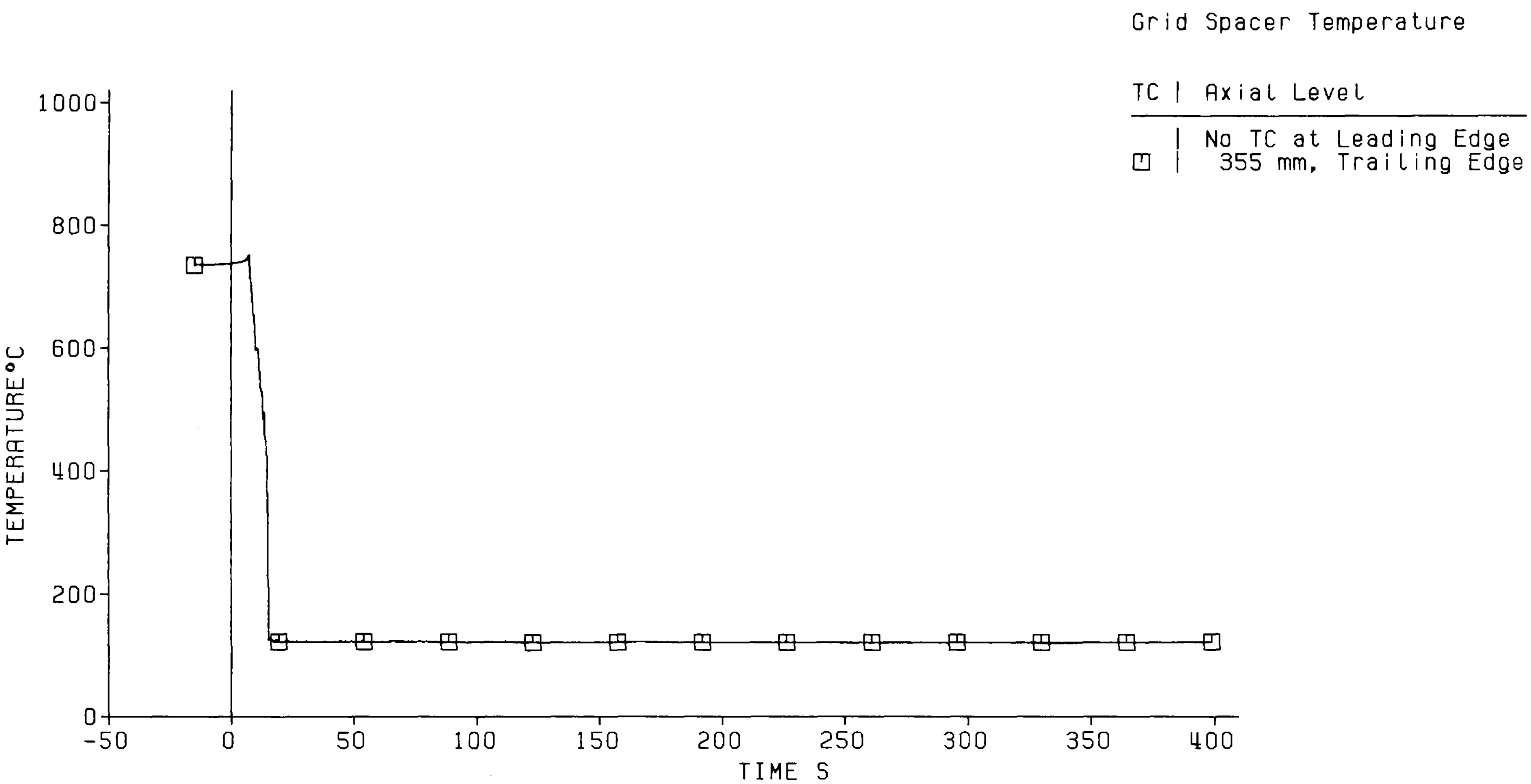
Fig. 120 SEFLEX: 5x5 RØD BUNDLE, SERIES 4, TEST-No. 33



Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.81 cm/s
System Pressure 2.05 bar
Feedwater Temperature 41° C

REBEKA Rods With
Argon Filled Gaps

Fig. 121 SEFLEX: 5x5 ROD BUNDLE, SERIES 4, TEST-No. 33

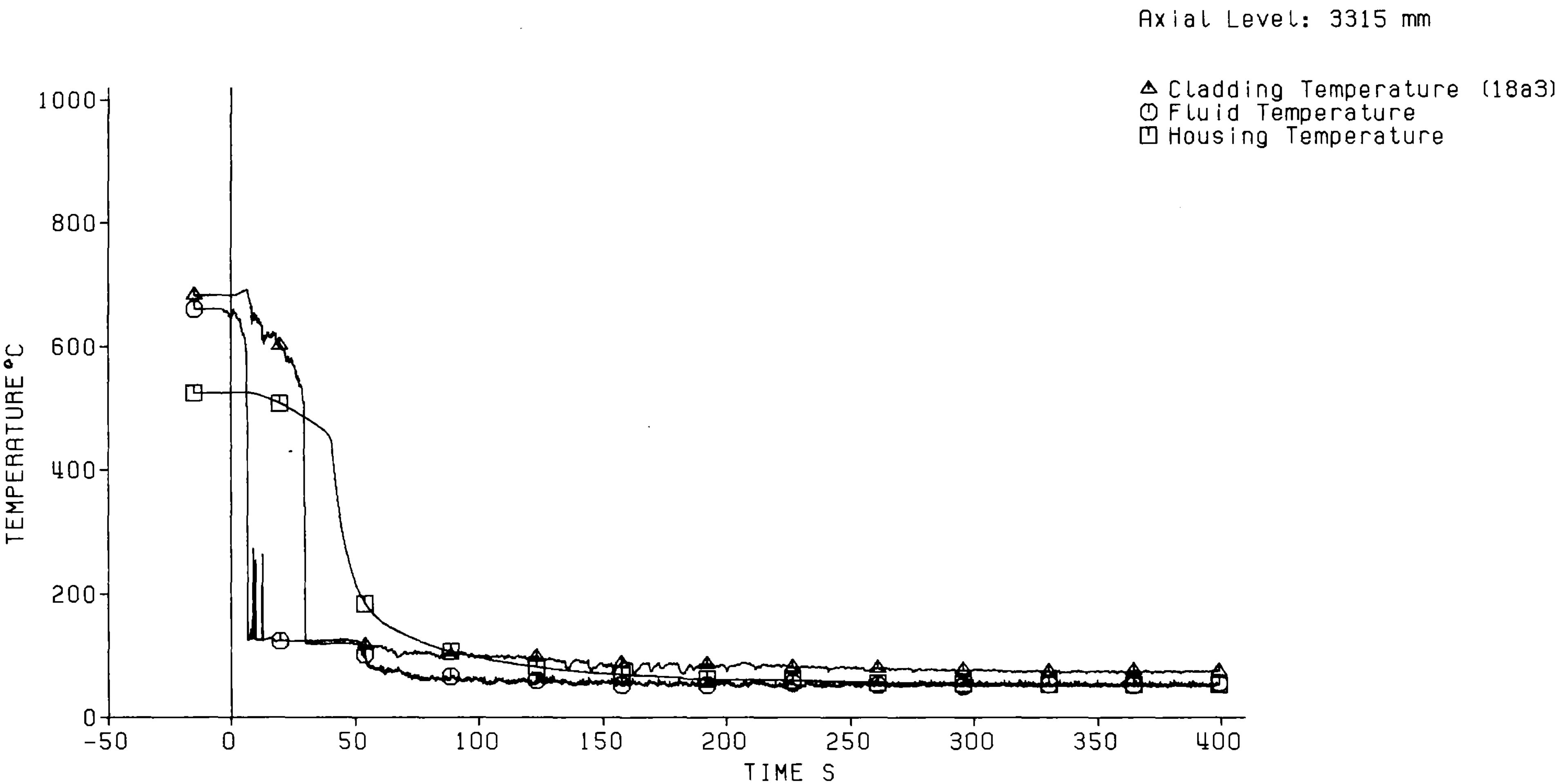


Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.81 cm/s
System Pressure 2.05 bar
Feedwater Temperature 41°C

REBEKA Rods With
Argon Filled Gaps

KfK IRB

Fig. 122 SEFLEX: 5x5 RØD BUNDLE, SERIES 4, TEST-No. 33

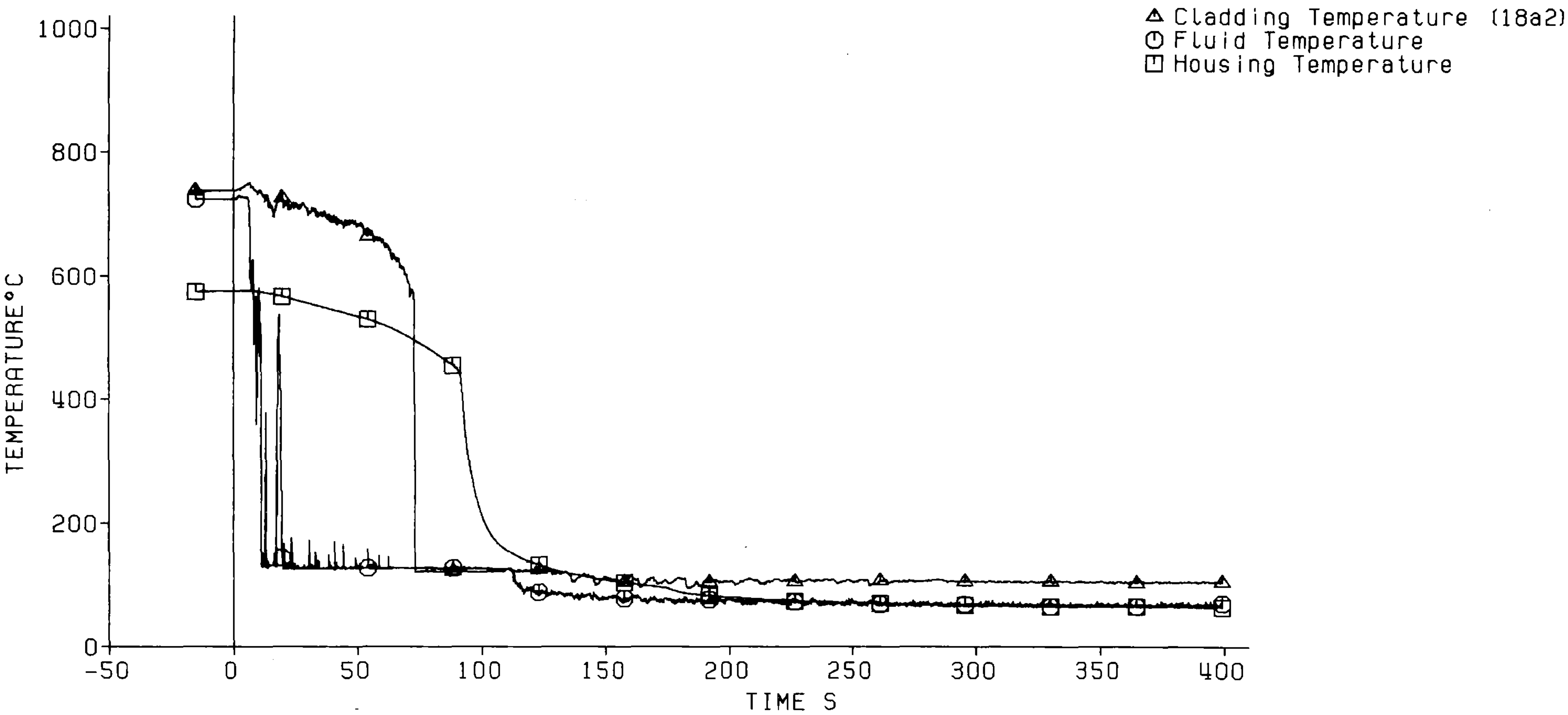


Decay Heat	120% ANS Standard	REBEKA Rods With
Flooding Rate (cold)	3.81 cm/s	Argon Filled Gaps
System Pressure	2.05 bar	
Feedwater Temperature	41°C	

KfK IRB

Fig. 123 SEFLEX: 5x5 RØD BUNDLE, SERIES 4, TEST-No. 33

Axial Level: 2770 mm

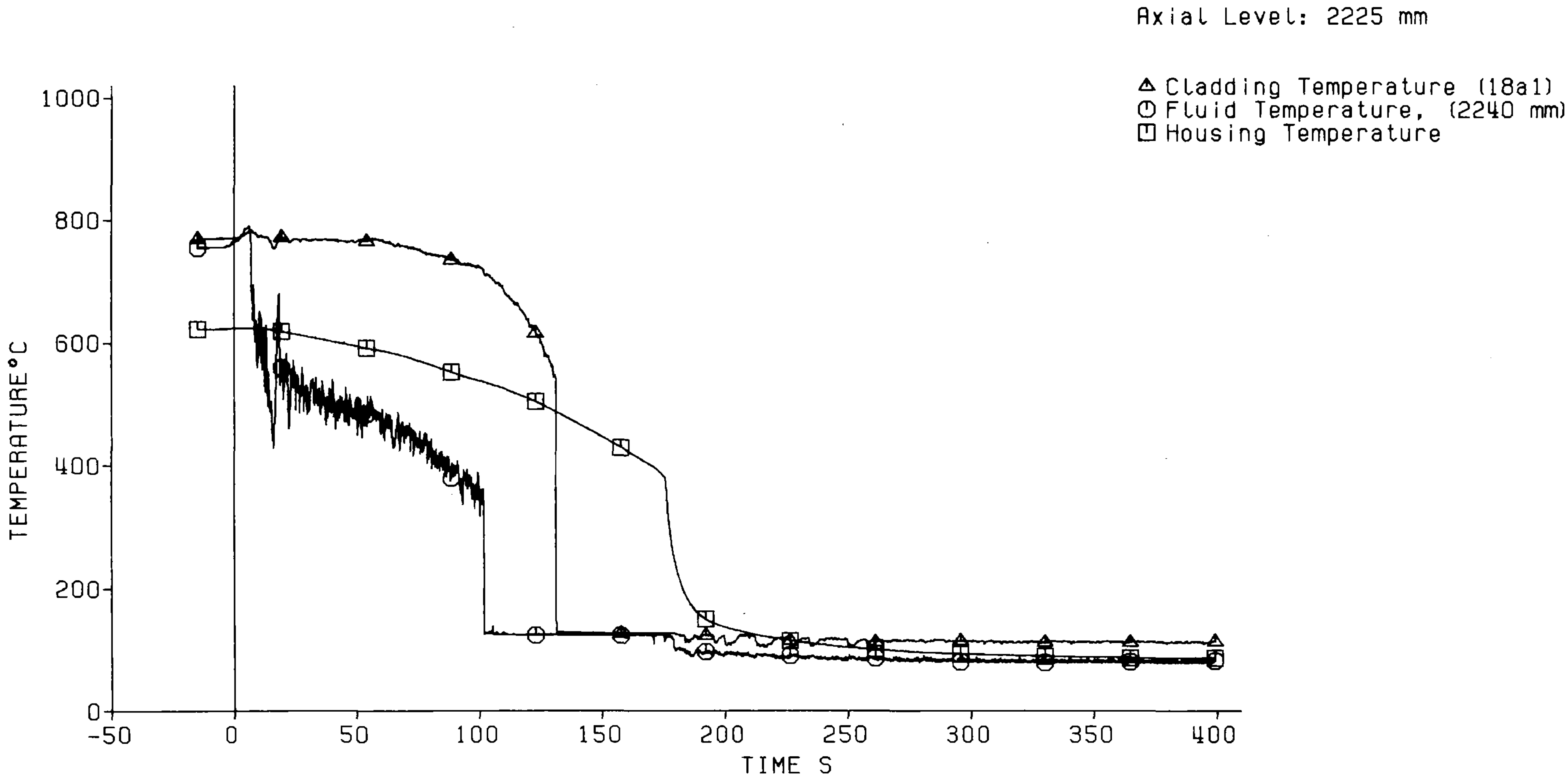


Decay Heat	120% ANS Standard
Flooding Rate (cold)	3.81 cm/s
System Pressure	2.05 bar
Feedwater Temperature	41°C

REBEKA Rods With
Argon Filled Gaps

KfK IRB

Fig. 124 SEFLEX: 5x5 RØD BUNDLE, SERIES 4, TEST-No. 33

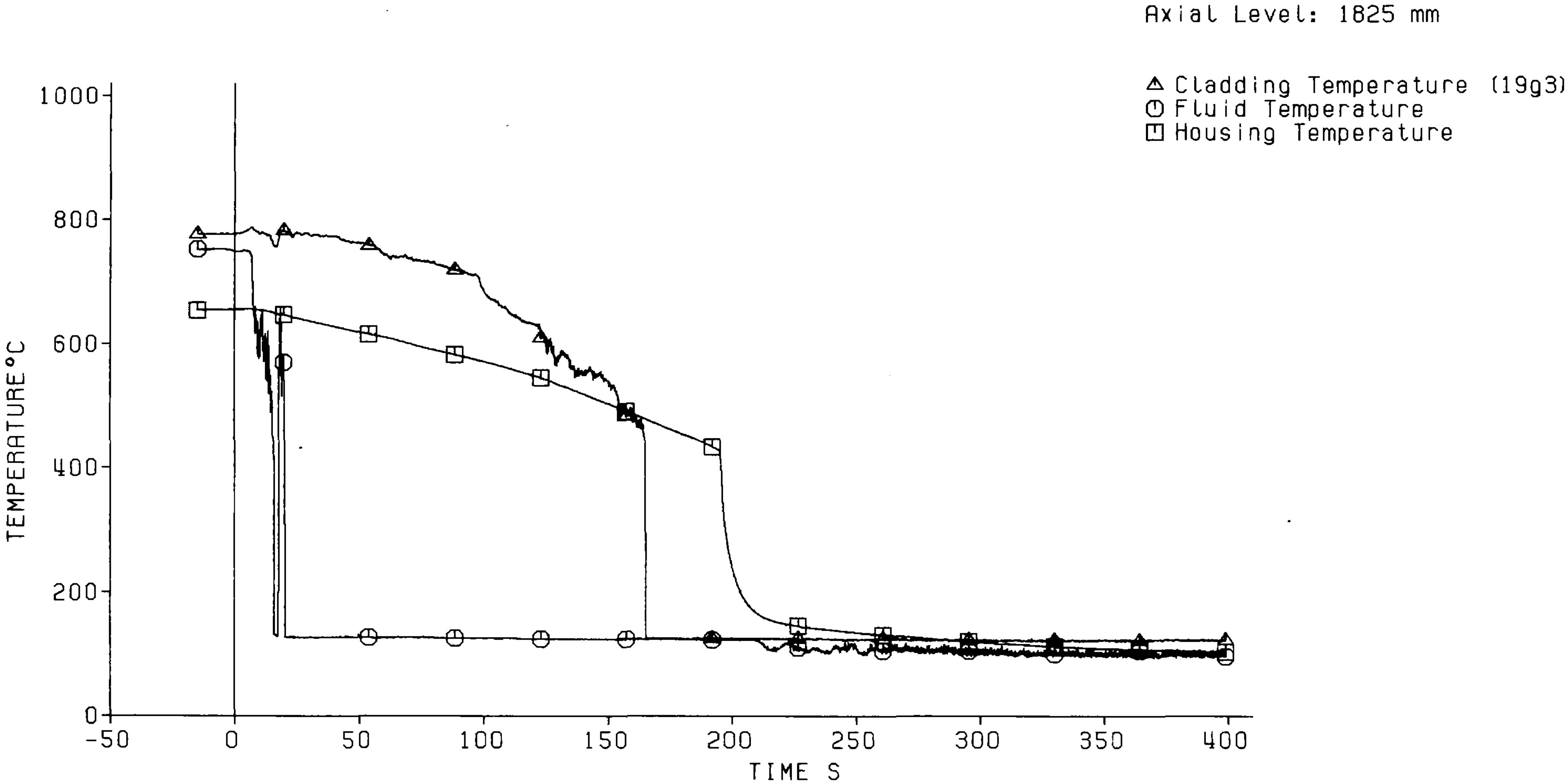


Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.81 cm/s
System Pressure 2.05 bar
Feedwater Temperature 41°C

REBEKA Rods With
Argon Filled Gaps

KfK IRB

Fig. 125 SEFLEX: 5x5 RØD BUNDLE, SERIES 4, TEST-No. 33



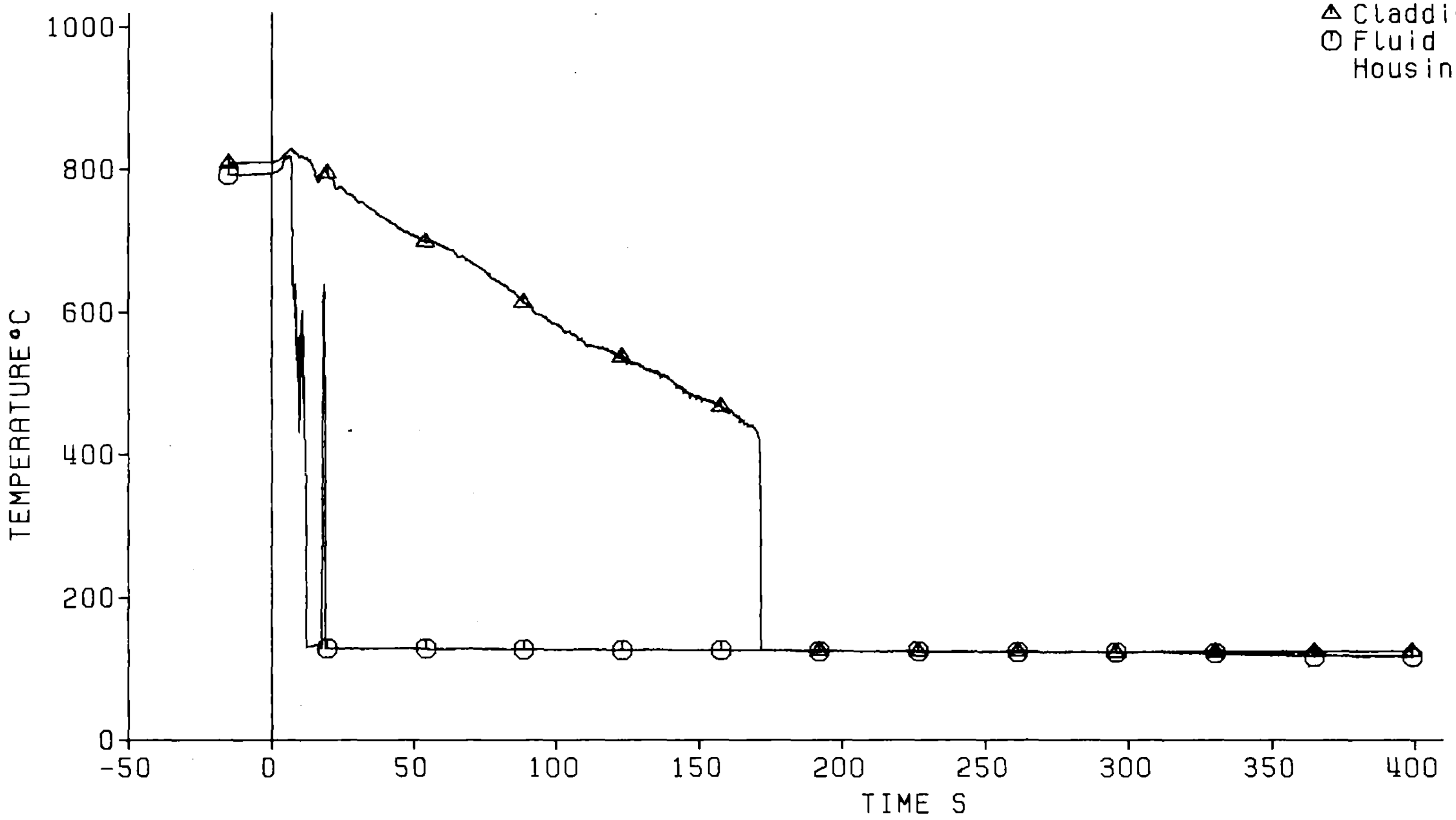
Decay Heat	120% ANS Standard
Flooding Rate (cold)	3.81 cm/s
System Pressure	2.05 bar
Feedwater Temperature	41°C

REBEKA Rods With
Argon Filled Gaps

KfK IRB

Fig. 126 SEFLEX: 5x5 RØD BUNDLE, SERIES 4, TEST-No. 33

Axial Level: 1135 mm

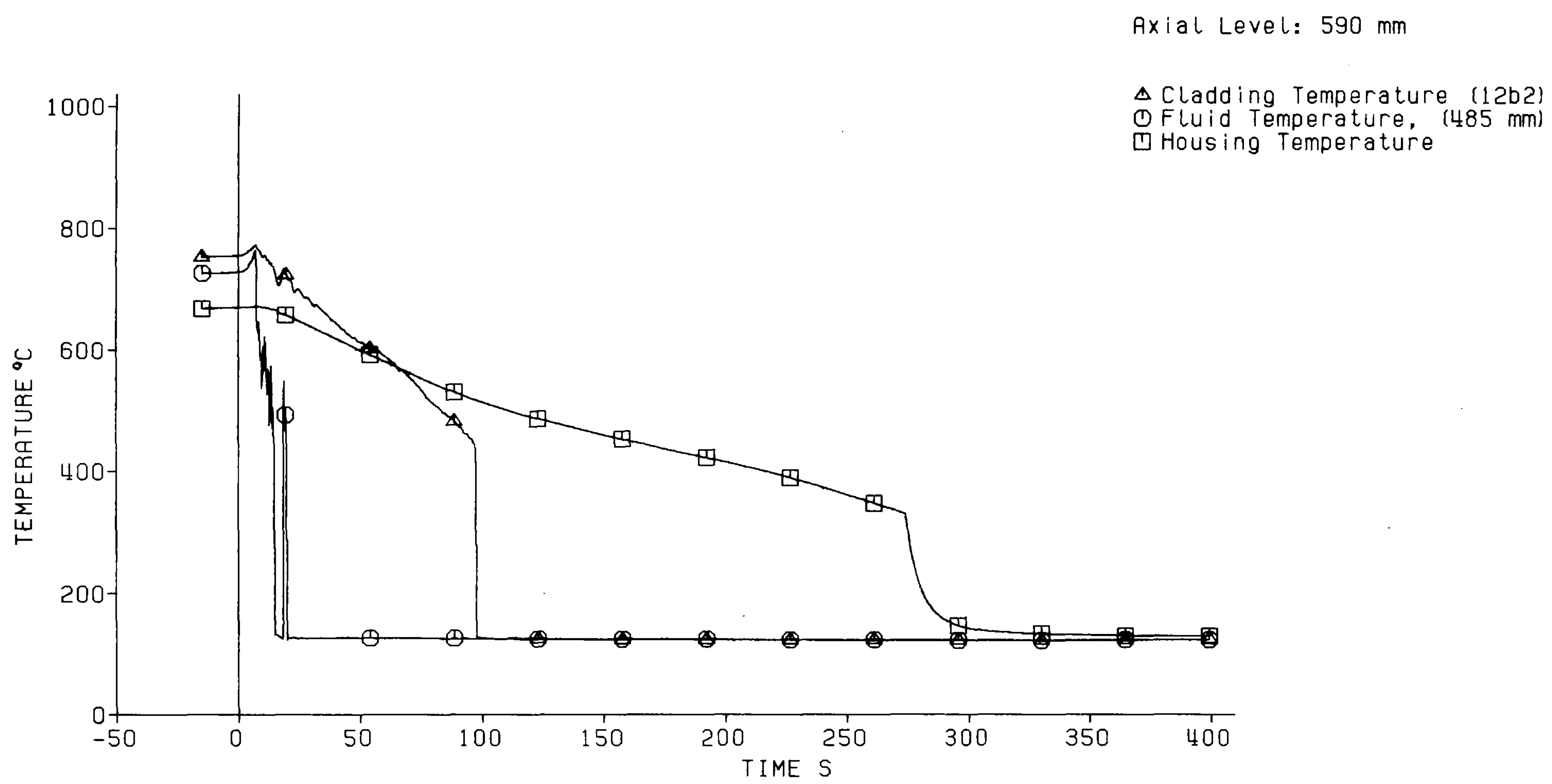


Decay Heat	120% ANS Standard
Flooding Rate (cold)	3.81 cm/s
System Pressure	2.05 bar
Feedwater Temperature	41°C

REBEKA Rods With
Argon Filled Gaps

KfK IRB

Fig. 127 SEFLEX: 5x5 RØD BUNDLE, SERIES 4, TEST-No. 33

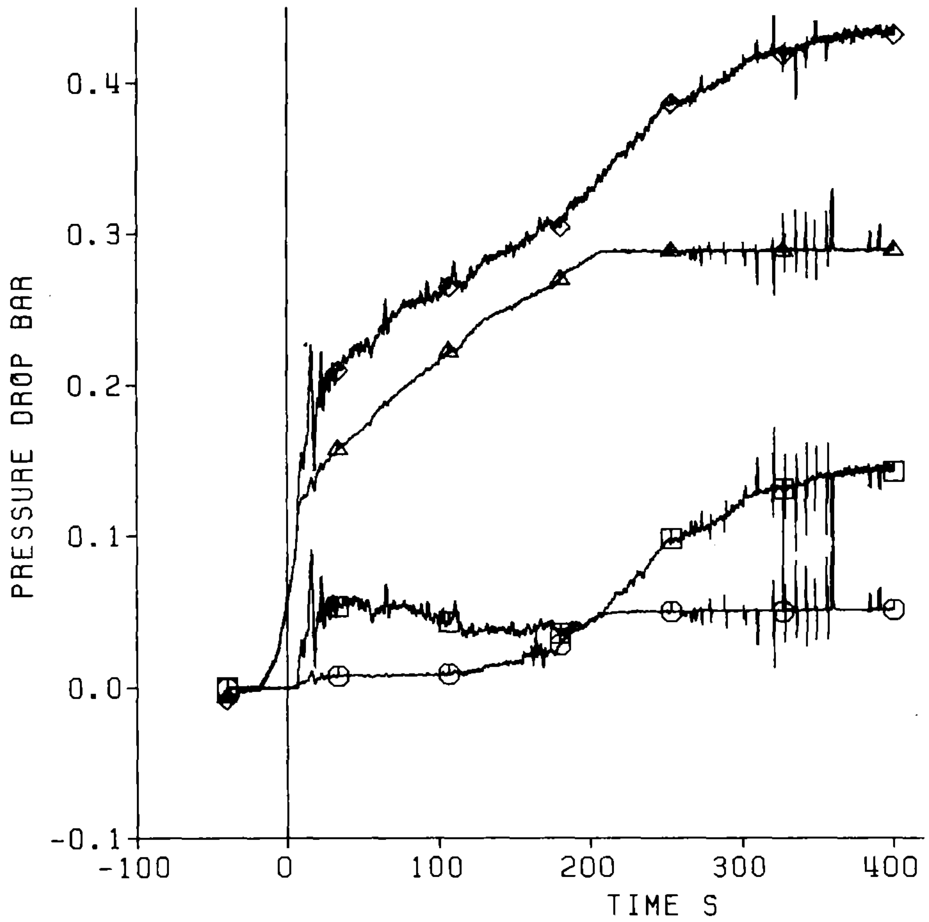


Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.81 cm/s
System Pressure 2.05 bar
Feedwater Temperature 41°C

REBEKA Rods With
Argon Filled Gaps

KfK IRB

Fig. 128 SEFLEX: 5x5 RØD BUNDLE, SERIES 4, TEST-No. 33



Pressure Drop
Along the Test Section:

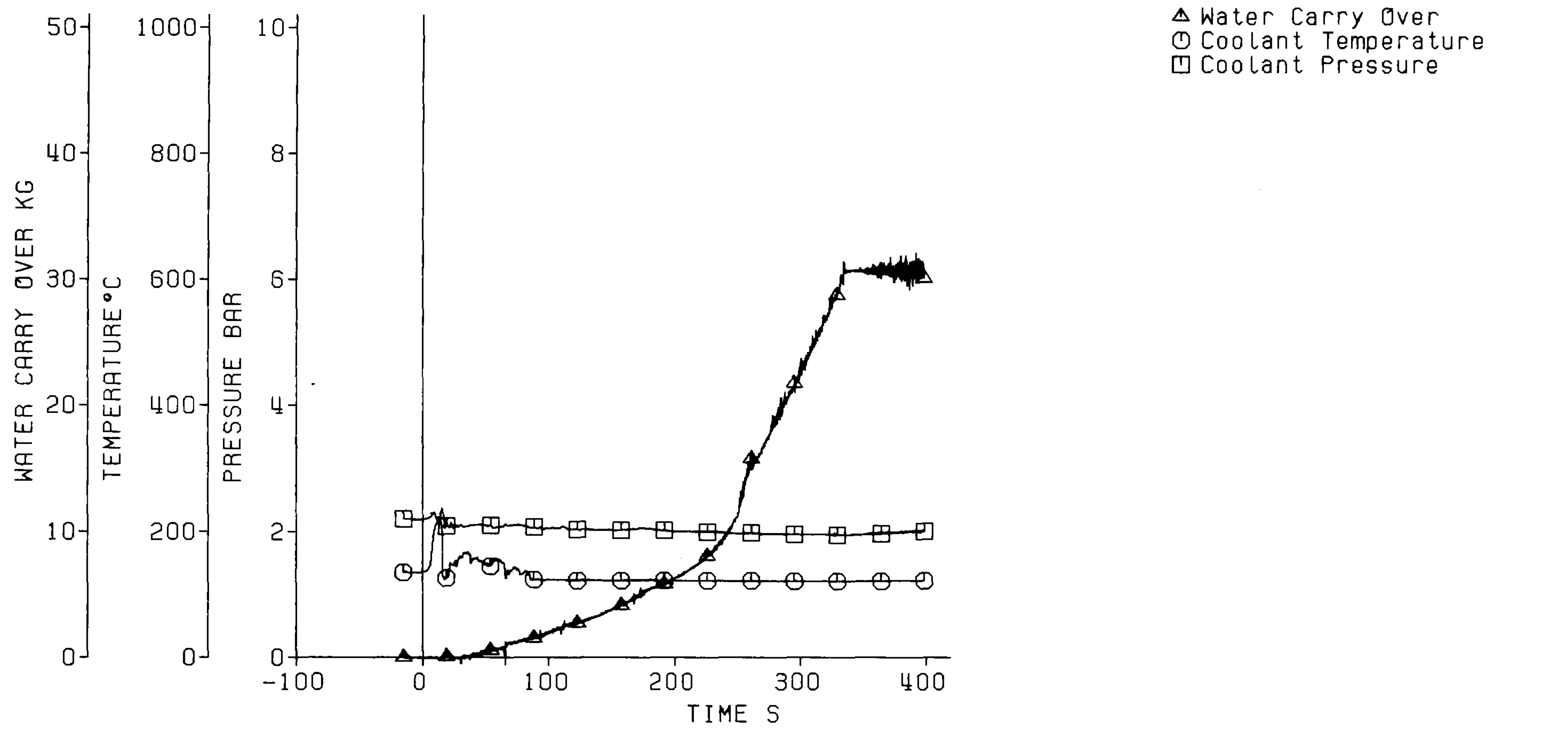
◇ Total Length: 4196 mm
△ Lower Part: 1711 mm
○ Middle Part: 545 mm
□ Upper Part: 1940 mm

Decay Heat	120% ANS Standard
Flooding Rate (cold)	3.81 cm/s
System Pressure	2.05 bar
Feedwater Temperature	41°C

REBEKA Rods With
Argon Filled Gaps

KfK IRB

Fig. 129 SEFLEX: 5x5 ROD BUNDLE, SERIES 4, TEST-No. 33



Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.81 cm/s
System Pressure 2.05 bar
Feedwater Temperature 41°C

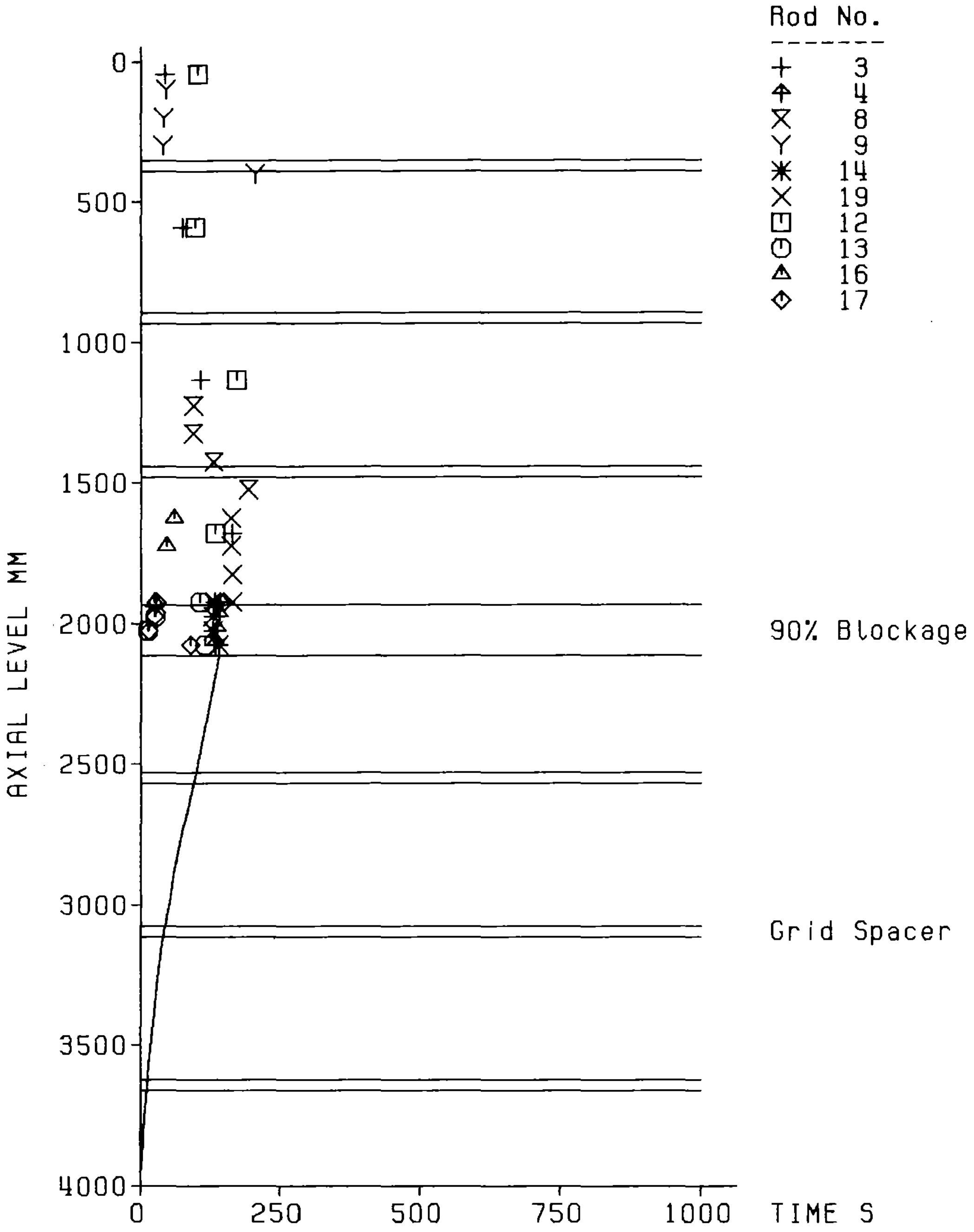
REBEKA Rods With
Argon Filled Gaps

KfK IRB

Fig. 130 SEFLEX: 5x5 RØD BUNDLE, SERIES 4, TEST-No. 33

Axial Position of Quench Front

REBEKA Rods With Argon Filled Gaps



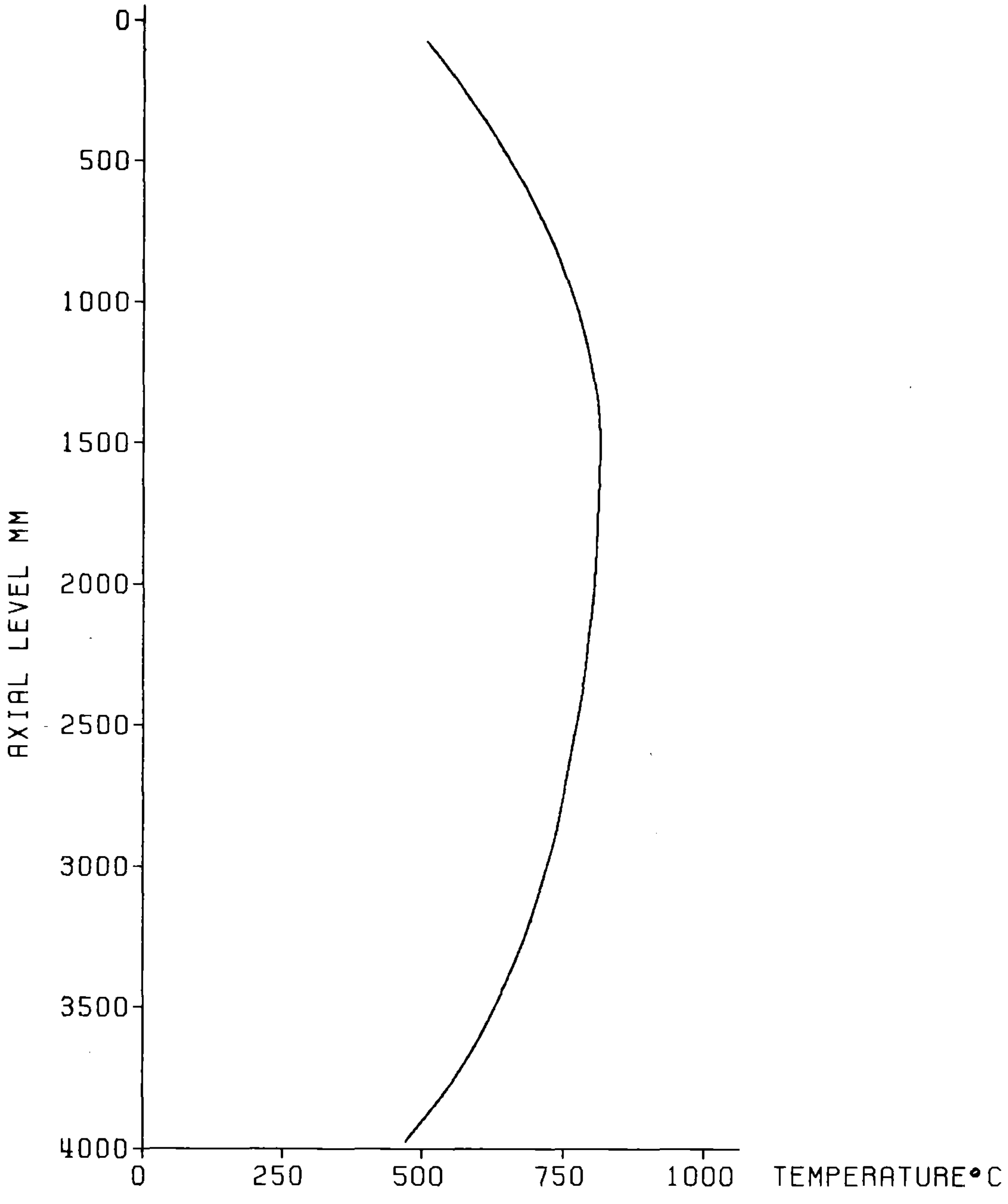
Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.81 cm/s
System Pressure 2.05 bar
Feedwater Temperature 41°C

KfK IRB

Fig. 131 SEFLEX: 5x5 ROD BUNDLE TEST SERIES 4, TEST-No. 33

Initial Axial Temperature Profile of Claddings

REBEKA Rods With Argon Filled Gaps

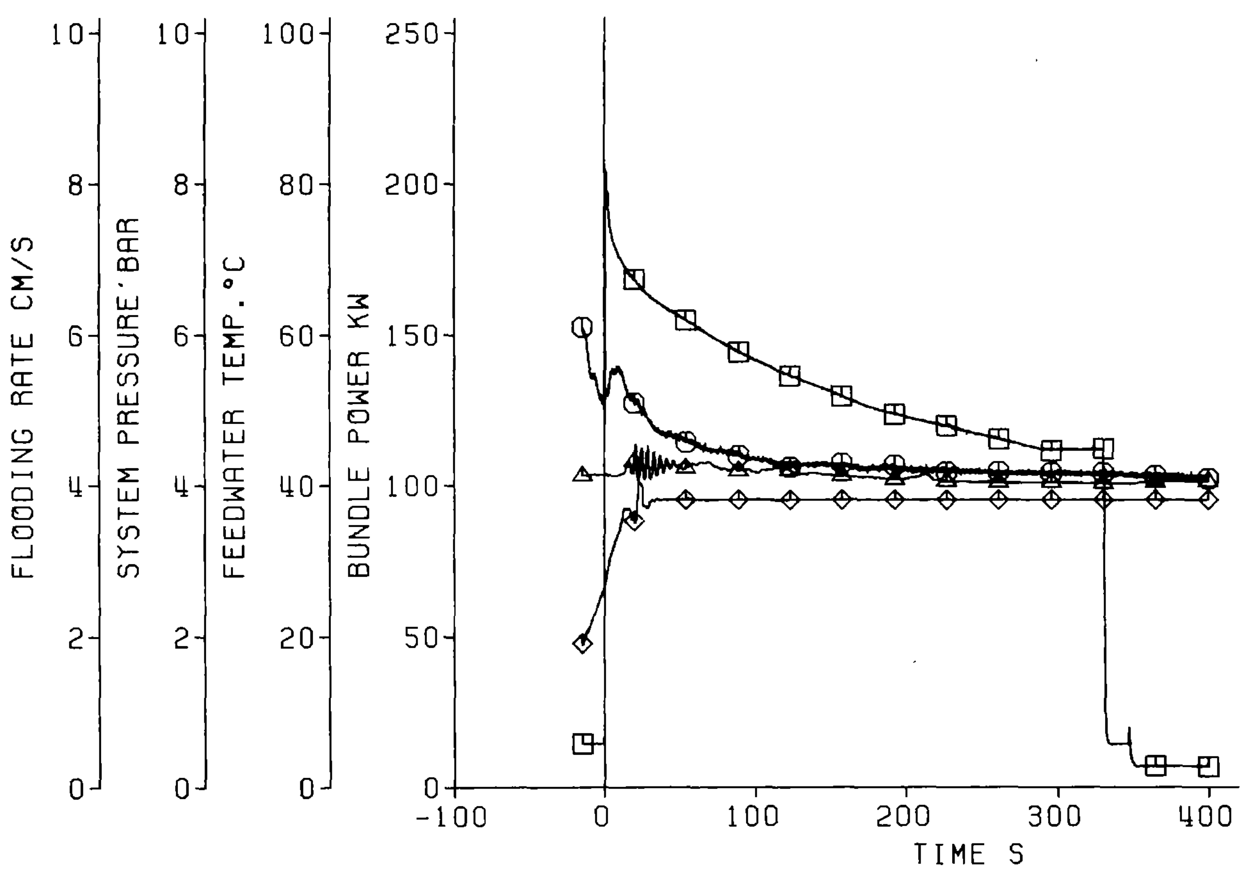


Decay Heat	120% ANS Standard
Flooding Rate (cold)	3.80 cm/s
System Pressure	4.15 bar
Feedwater Temperature	44°C

KfK IRB

Fig. 132 SEFLEX: 5x5 ROD BUNDLE
TEST SERIES 4, TEST-No. 34

Test Parameters:

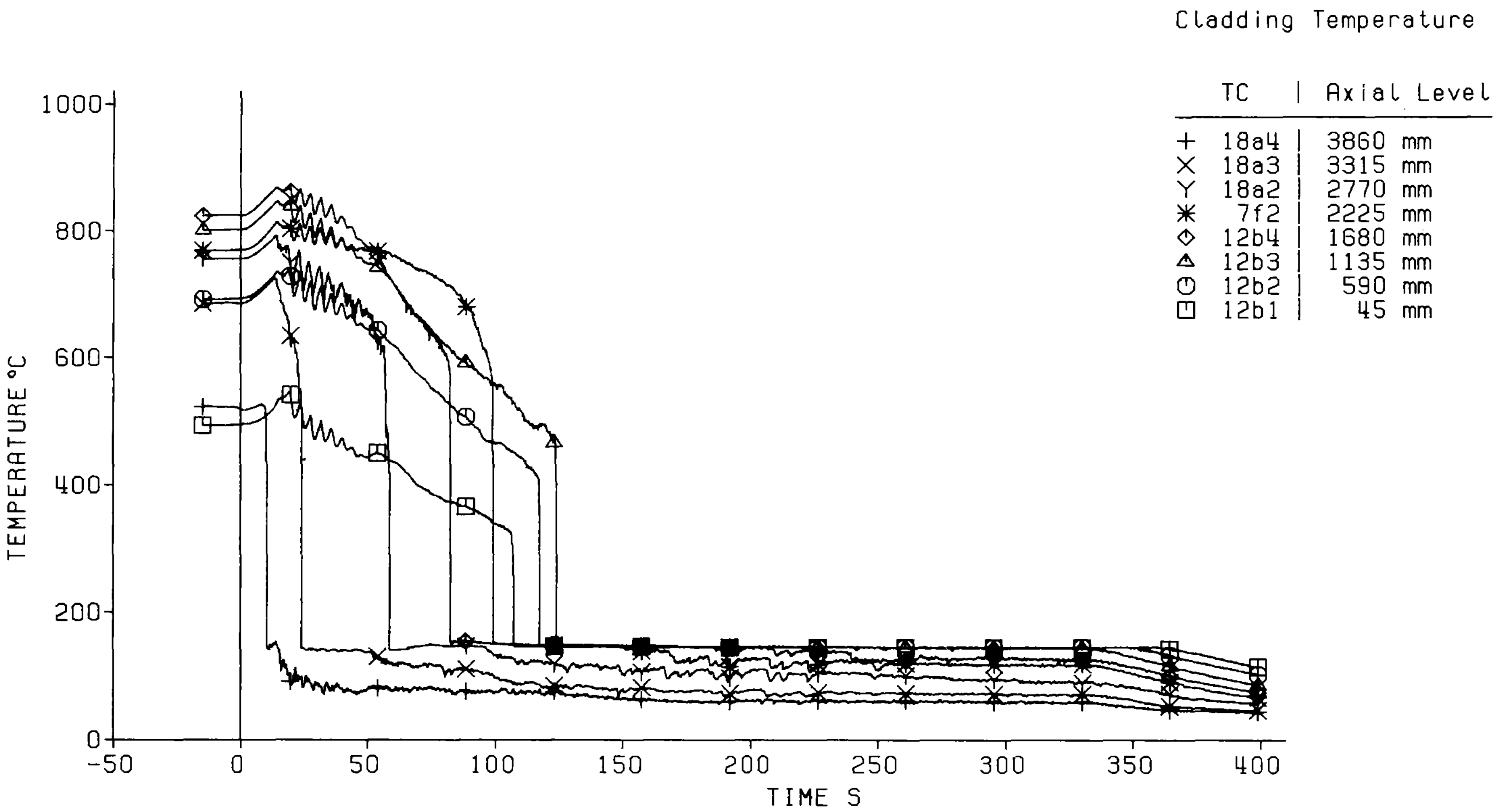


Decay Heat	120% ANS Standard
Flooding Rate (cold)	3.80 cm/s
System Pressure	4.15 bar
Feedwater Temperature	44°C

REBEKA Rods With
Argon Filled Gaps

KfK IRB

Fig. 133 SEFLEX: 5x5 RØD BUNDLE, SERIES 4, TEST-No. 34

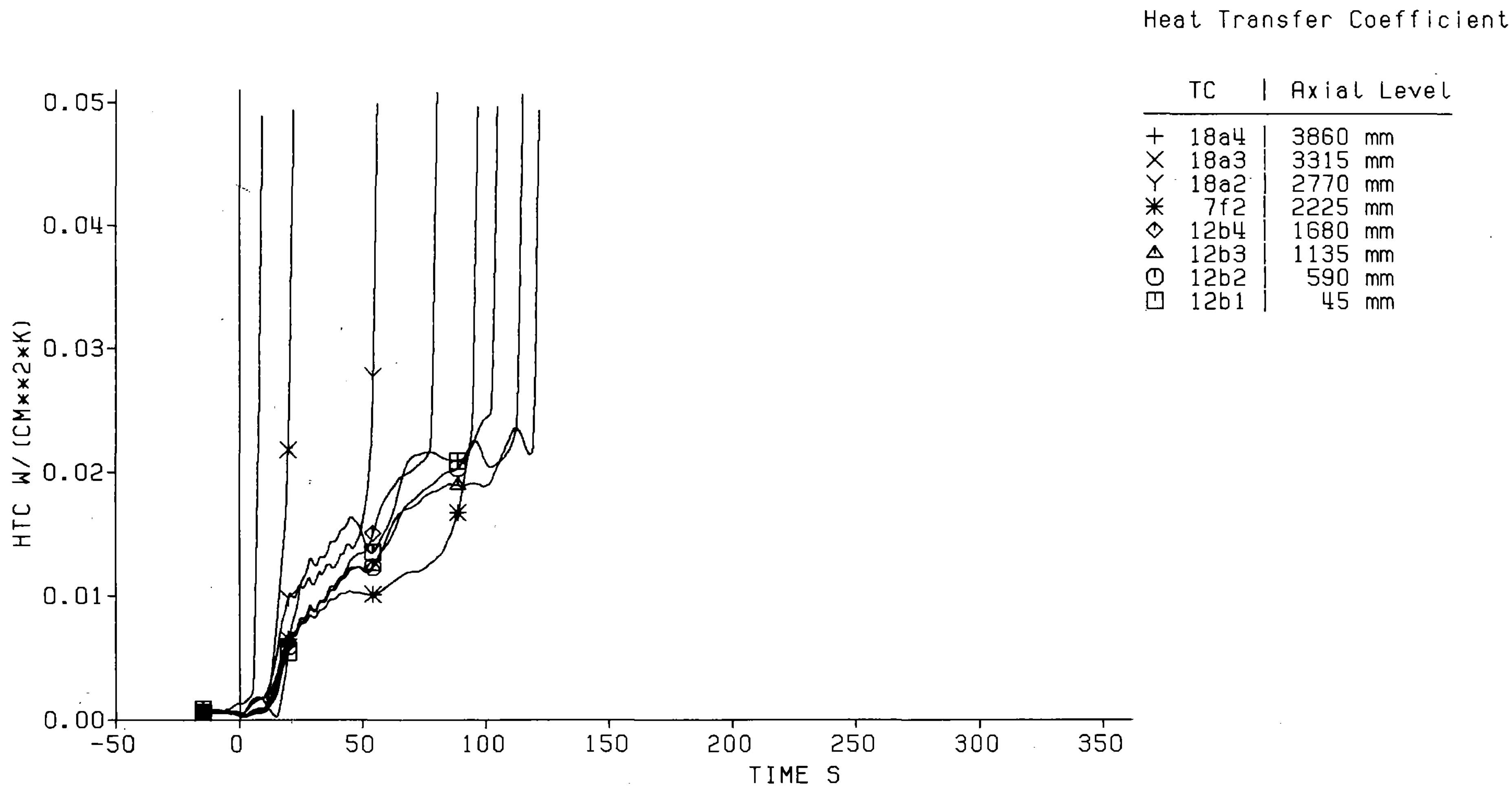


Decay Heat	120% ANS Standard
Flooding Rate (cold)	3.80 cm/s
System Pressure	4.15 bar
Feedwater Temperature	44°C

REBEKA Rods With
Argon Filled Gaps

KfK IRB

Fig. 134 SEFLEX: 5x5 RØD BUNDLE, SERIES 4, TEST-No. 34

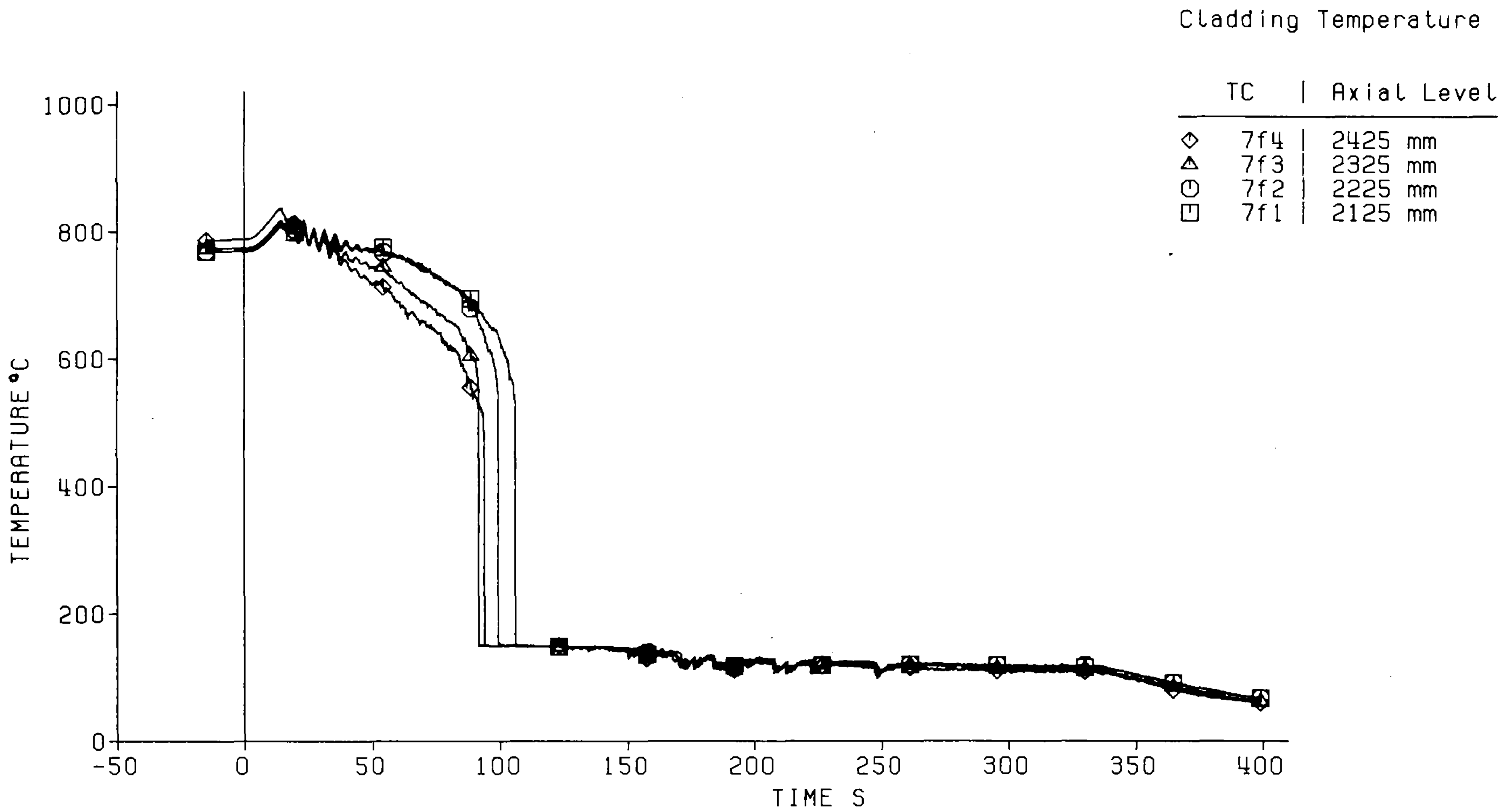


Decay Heat	120% ANS Standard
Flooding Rate (cold)	3.80 cm/s
System Pressure	4.15 bar
Feedwater Temperature	44°C

REBEKA Rods With
Argon Filled Gaps

KfK IRB

Fig. 135 SEFLEX: 5x5 RØD BUNDLE, SERIES 4, TEST-No. 34



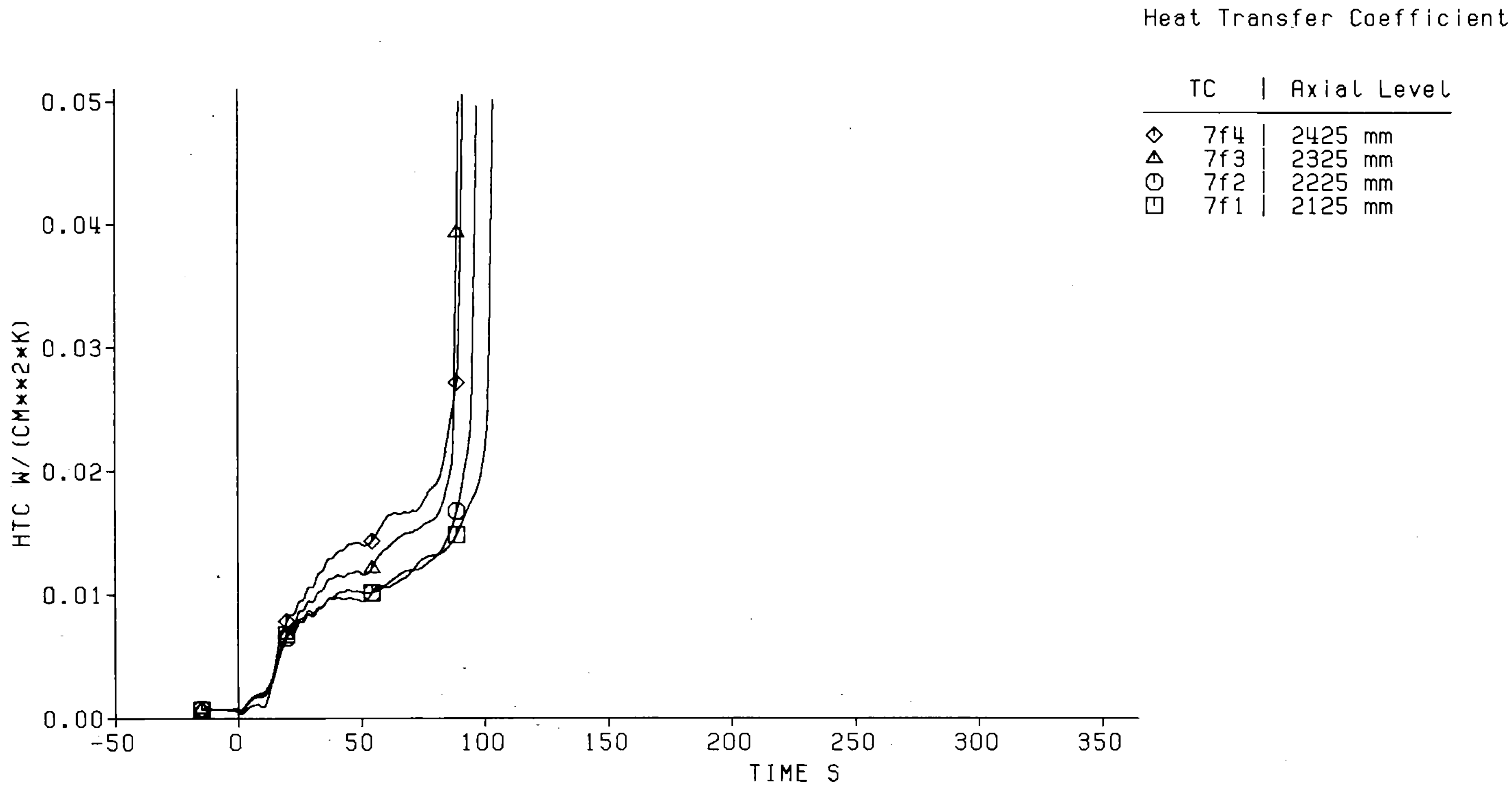
Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.80 cm/s
System Pressure 4.15 bar
Feedwater Temperature 44°C

REBEKA Rods With
Argon Filled Gaps

Bypass
======

KfK IRB

Fig. 136 SEFLEX: 5x5 RØD BUNDLE, SERIES 4, TEST-No. 34



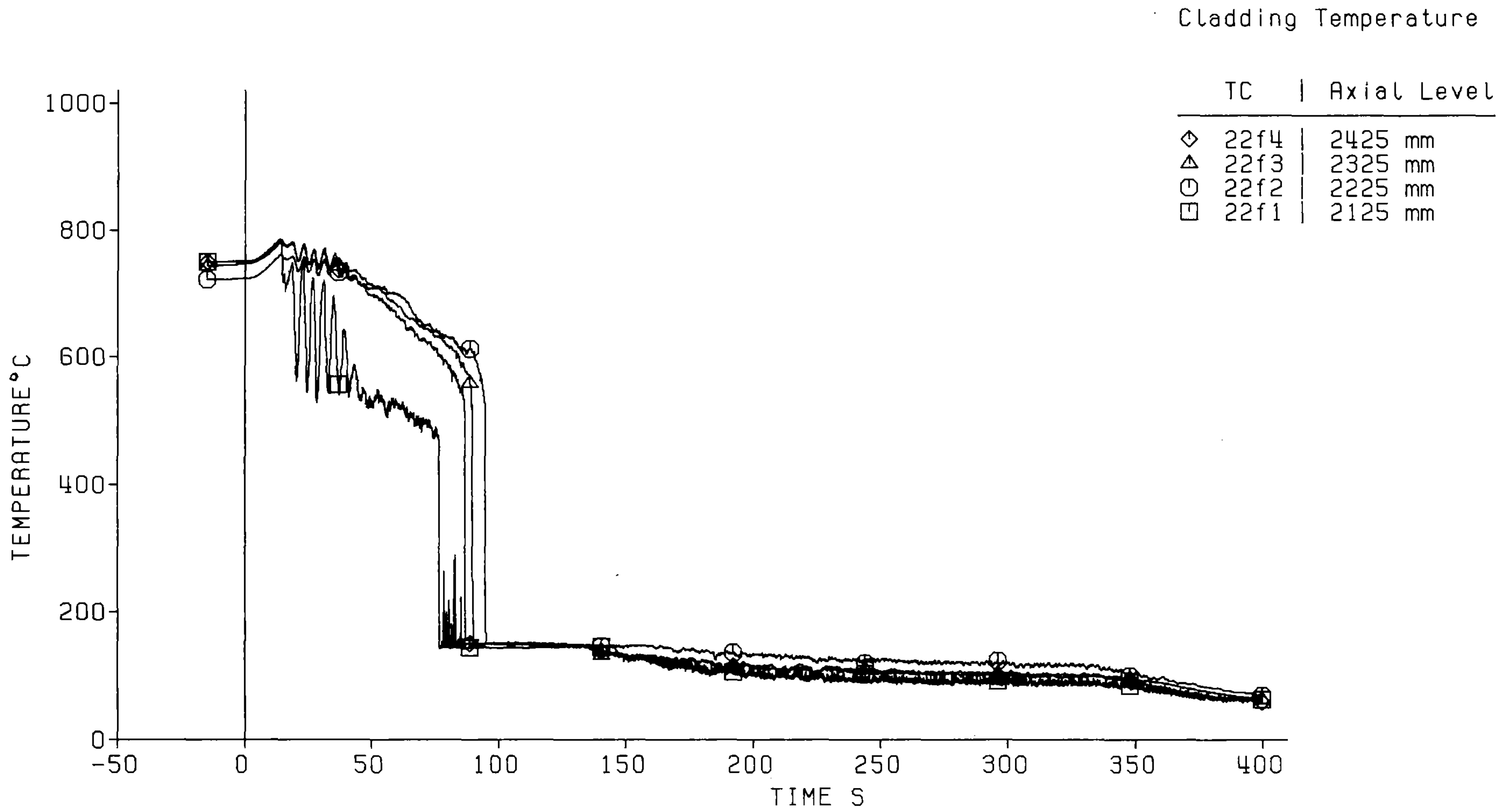
Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.80 cm/s
System Pressure 4.15 bar
Feedwater Temperature 44°C

REBEKA Rods With Argon Filled Gaps

Bypass
======

KfK IRB

Fig. 137 SEFLEX: 5x5 RØD BUNDLE, SERIES 4, TEST-No. 34



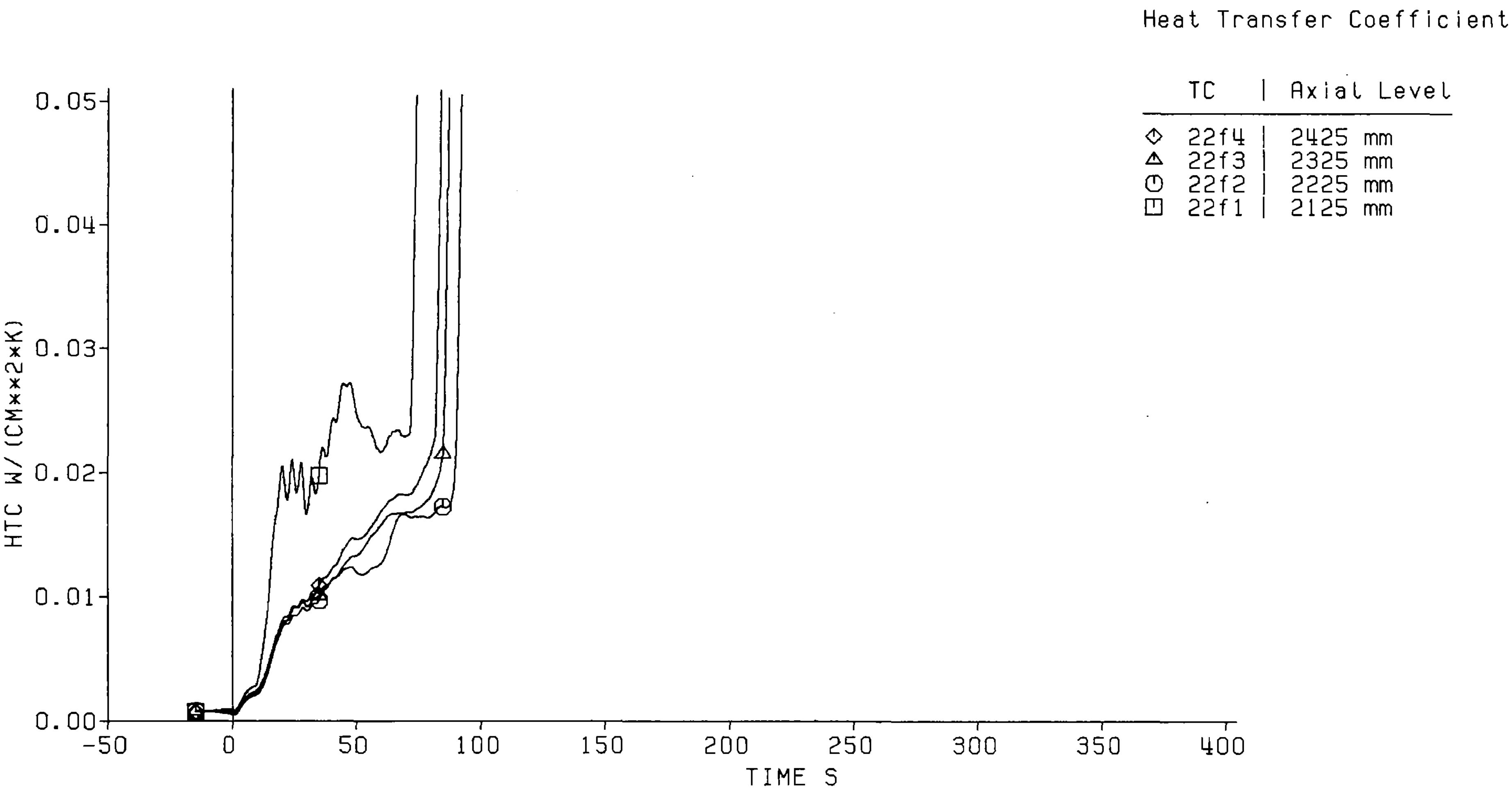
Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.80 cm/s
System Pressure 4.15 bar
Feedwater Temperature 44°C

REBEKA Rods With
Argon Filled Gaps

Blockage
========

KfK IRB

Fig. 138 SEFLEX: 5x5 RØD BUNDLE, SERIES 4, TEST-No. 34



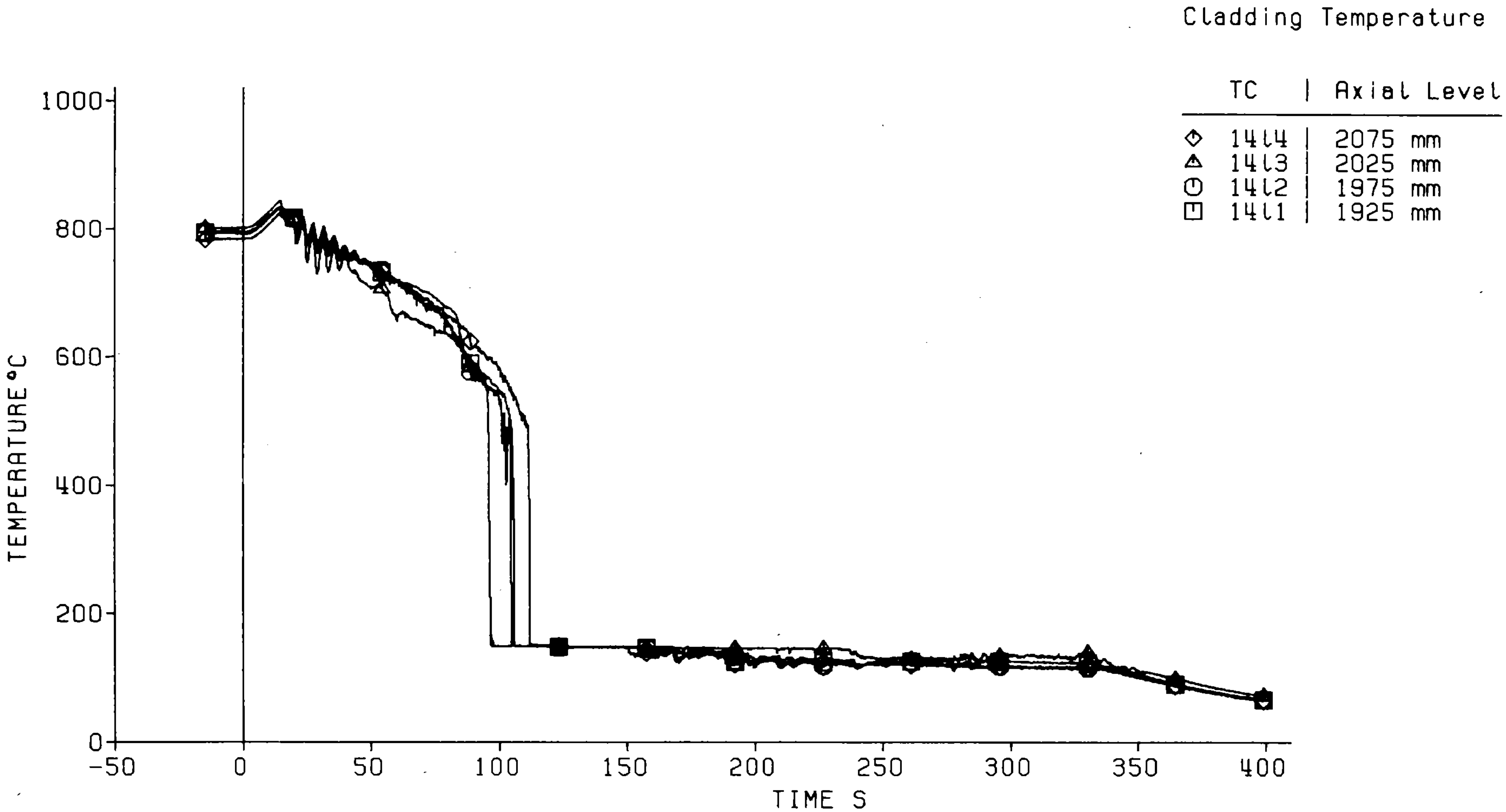
Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.80 cm/s
System Pressure 4.15 bar
Feedwater Temperature 44°C

REBEKA Rods With
Argon Filled Gaps

Blockage
========

KfK IRB

Fig. 139 SEFLEX: 5x5 RØD BUNDLE, SERIES 4, TEST-No. 34



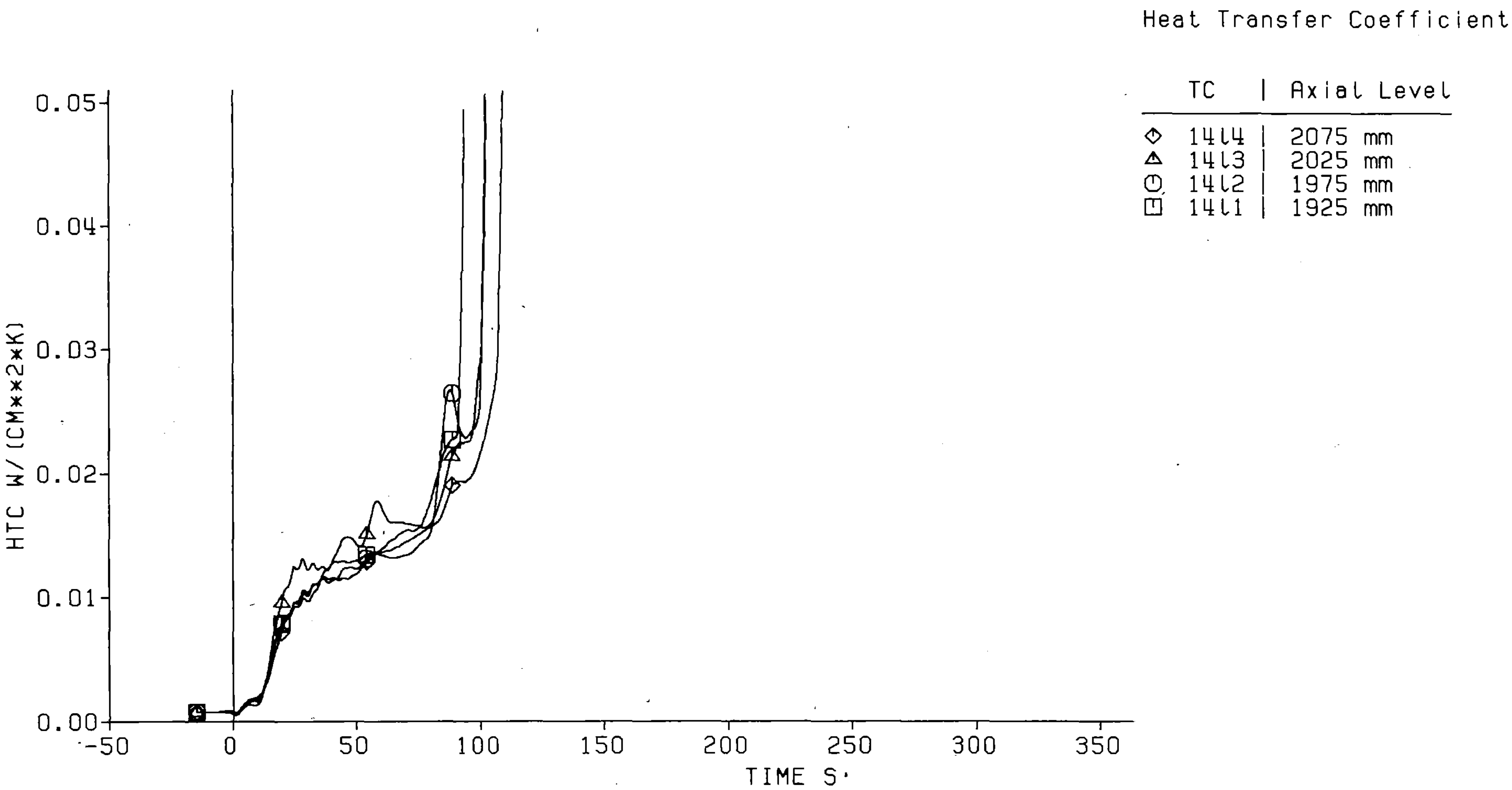
Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.80 cm/s
System Pressure 4.15 bar
Feedwater Temperature 44°C

REBEKA Rods With
Argon Filled Gaps

Bypass
======

KfK IRB

Fig. 140 SEFLEX: 5x5 RØD BUNDLE, SERIES 4, TEST-No. 34



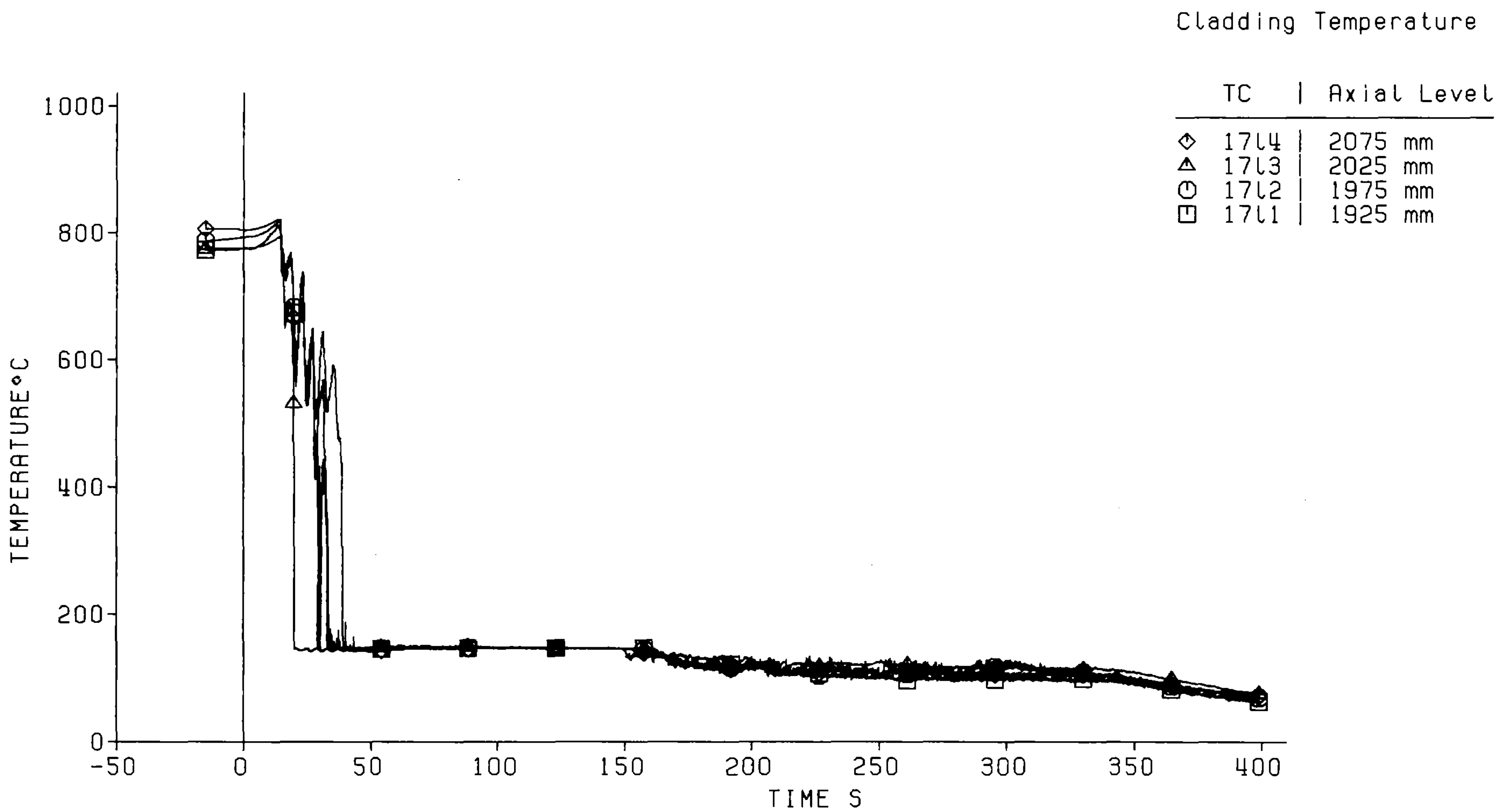
Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.80 cm/s
System Pressure 4.15 bar
Feedwater Temperature 44°C

REBEKA Rods With
Argon Filled Gaps

Bypass
======

KfK IRB

Fig. 141 SEFLEX: 5x5 RØD BUNDLE, SERIES 4, TEST-No. 34



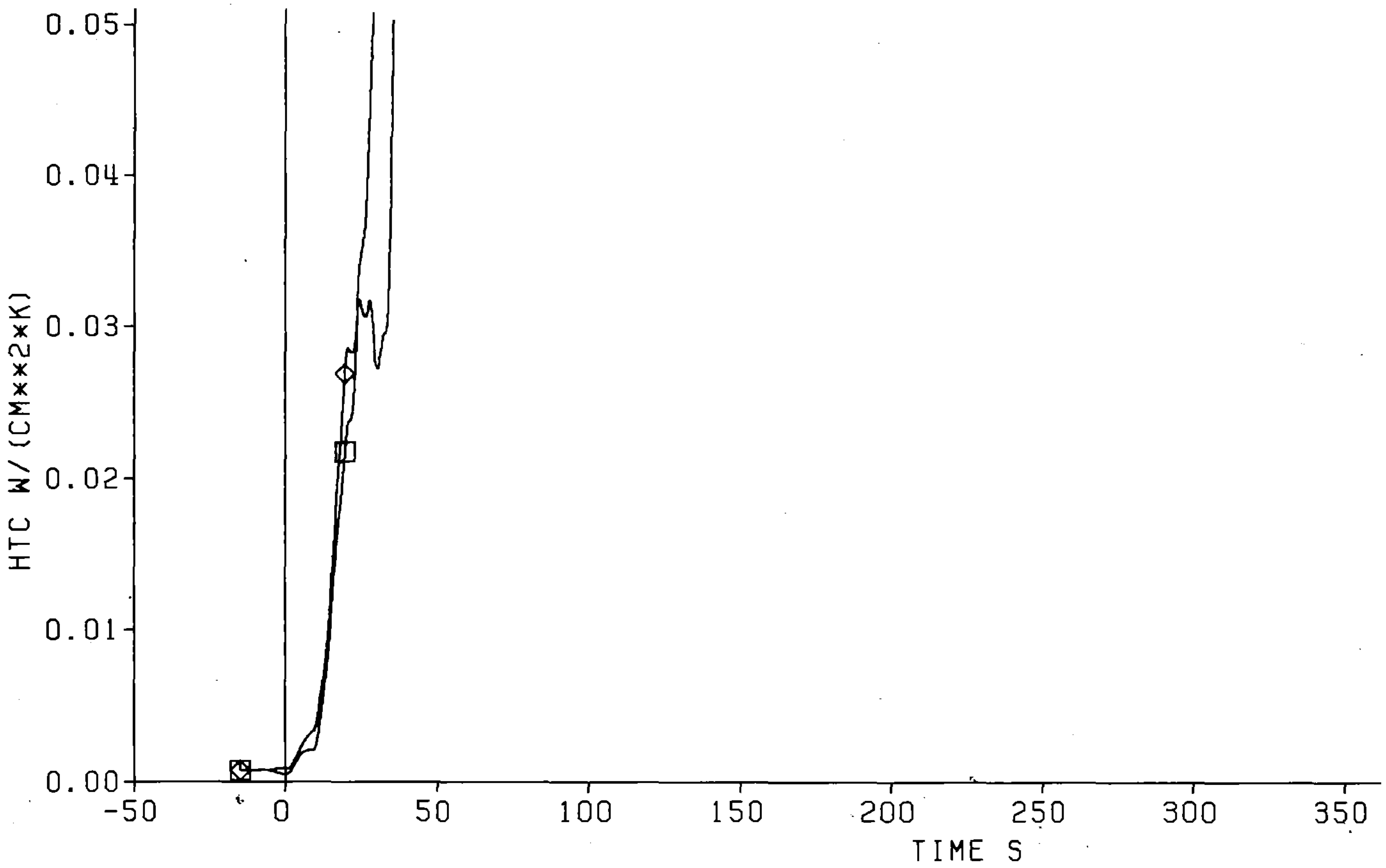
Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.80 cm/s
System Pressure 4.15 bar
Feedwater Temperature 44°C

REBEKA Rods With
Argon Filled Gaps

Blockage
========

KfK IRB

Fig. 142 SEFLEX: 5x5 RØD BUNDLE, SERIES 4, TEST-No. 34

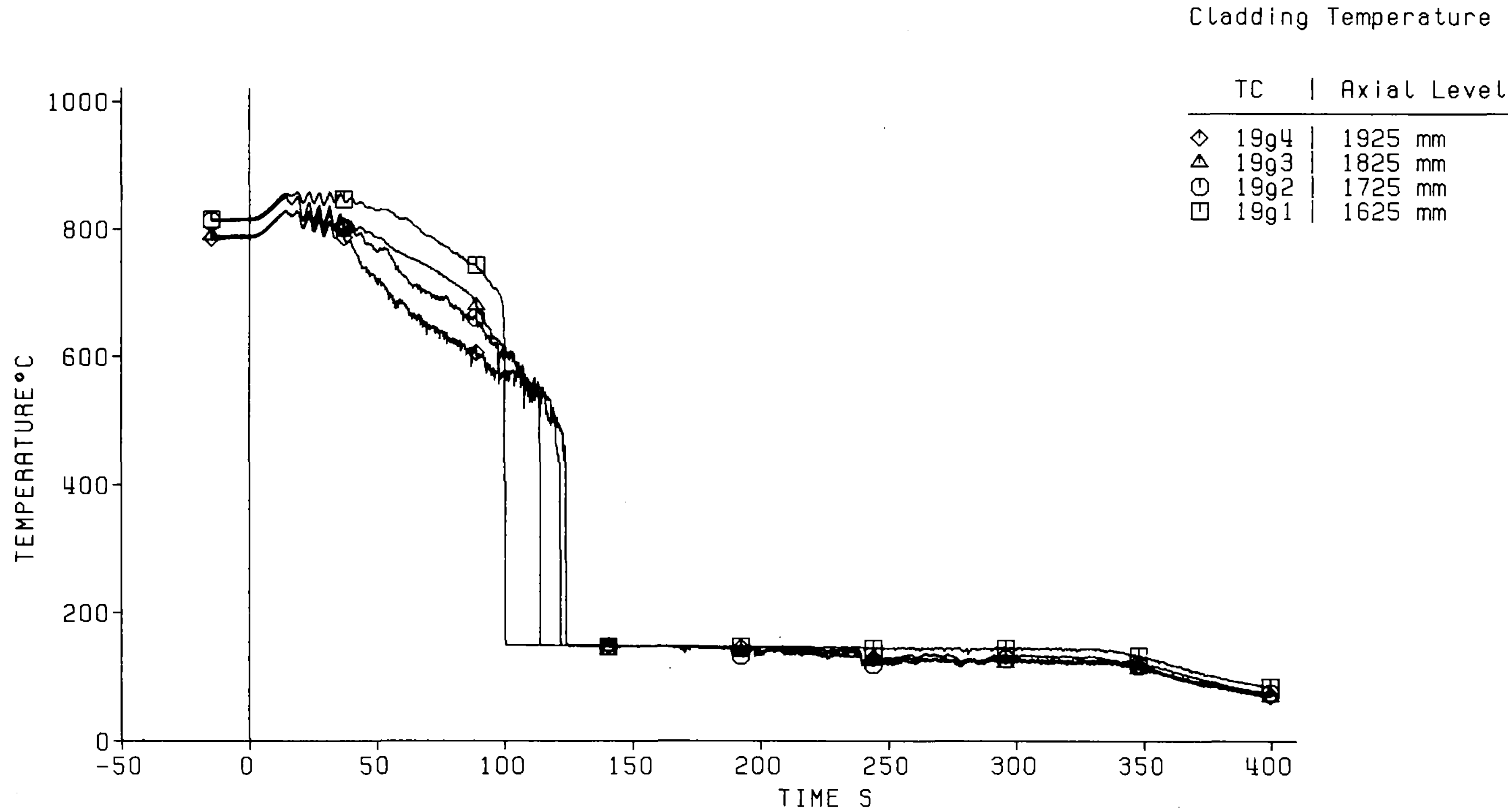


Decay Heat	120% ANS Standard
Flooding Rate (cold)	3.80 cm/s
System Pressure	4.15 bar
Feedwater Temperature	44 °C

REBEKA Rods With
Argon Filled Gaps

Blockage
========

Fig. 143 SEFLEX: 5x5 RØD BUNDLE, SERIES 4, TEST-No. 34



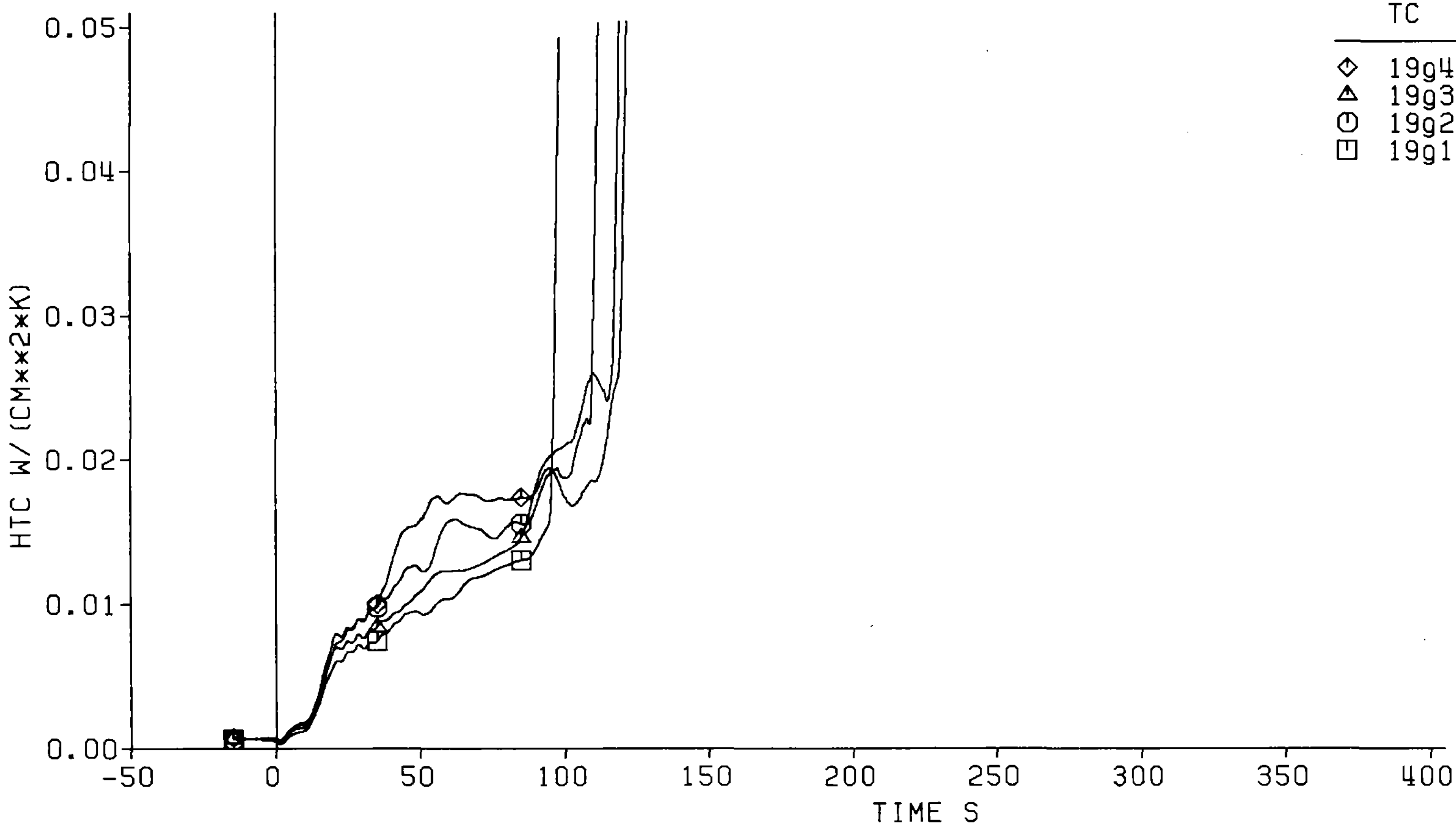
Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.80 cm/s
System Pressure 4.15 bar
Feedwater Temperature 44°C

REBEKA Rods With
Argon Filled Gaps

Bypass
======

KfK IRB

Fig. 144 SEFLEX: 5x5 RØD BUNDLE, SERIES 4, TEST-No. 34



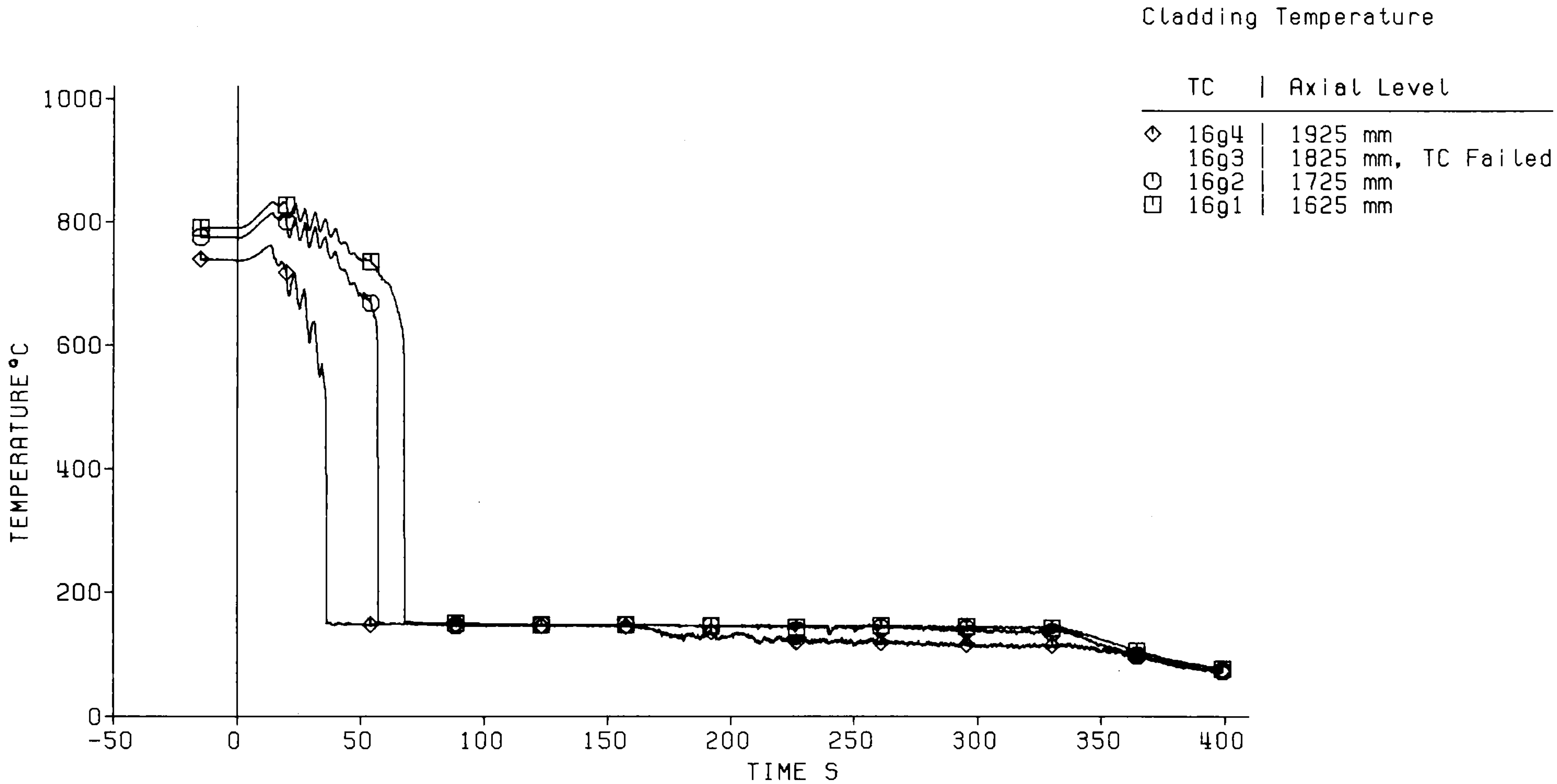
Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.80 cm/s
System Pressure 4.15 bar
Feedwater Temperature 44°C

REBEKA Rods With
Argon Filled Gaps

Bypass
======

KfK IRB

Fig. 145 SEFLEX: 5x5 RØD BUNDLE, SERIES 4, TEST-No. 34



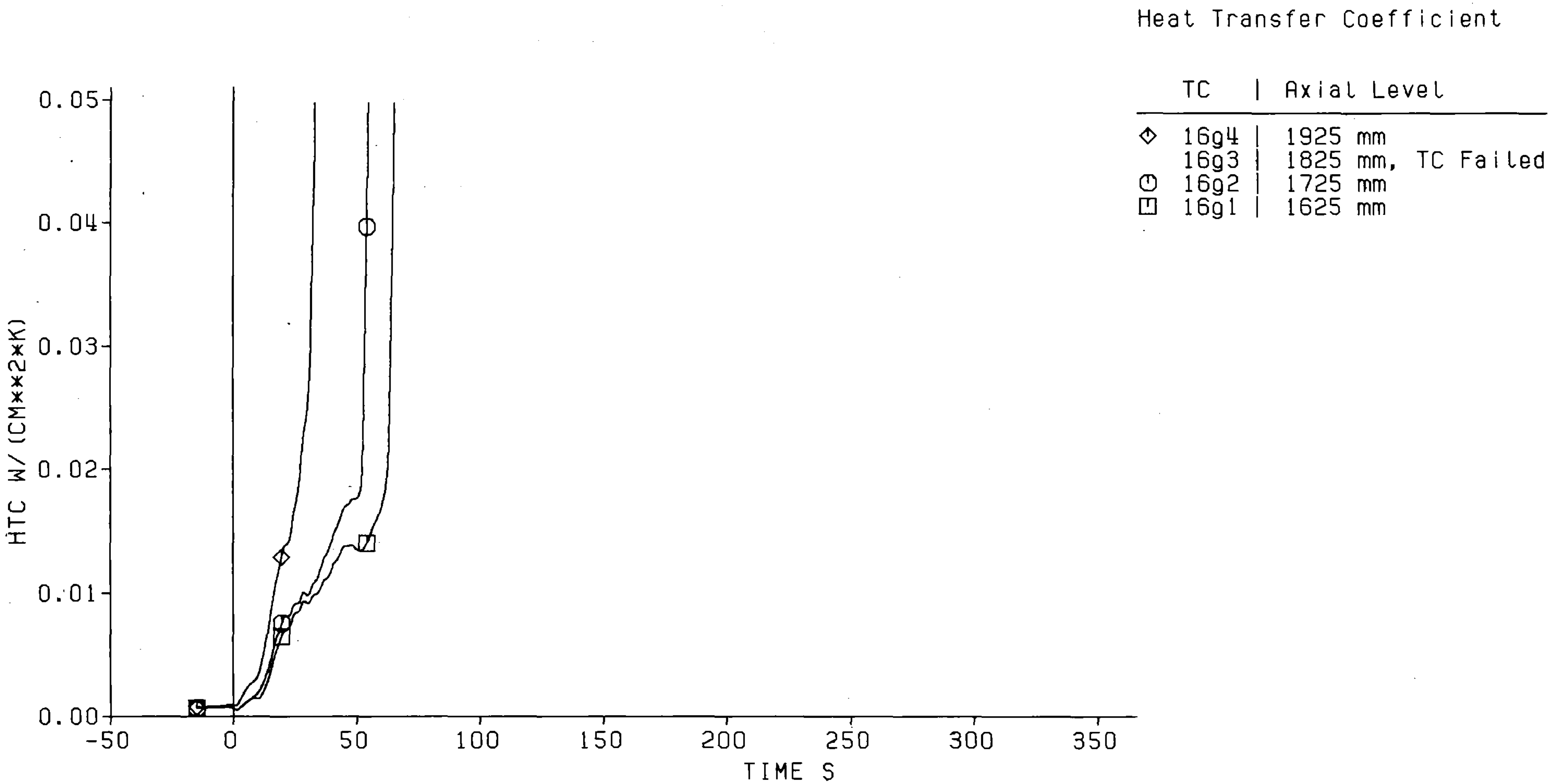
Decay Heat	120% ANS Standard
Flooding Rate (cold)	3.80 cm/s
System Pressure	4.15 bar
Feedwater Temperature	44°C

REBEKA Rods With
Argon Filled Gaps

Blockage
========

KfK IRB

Fig. 146 SEFLEX: 5x5 RØD BUNDLE, SERIES 4, TEST-No. 34



Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.80 cm/s
System Pressure 4.15 bar
Feedwater Temperature 44°C

REBEKA Rods With
Argon Filled Gaps

Blockage
========

Fig. 147 SEFLEX: 5x5 RØD BUNDLE, SERIES 4, TEST-No. 34

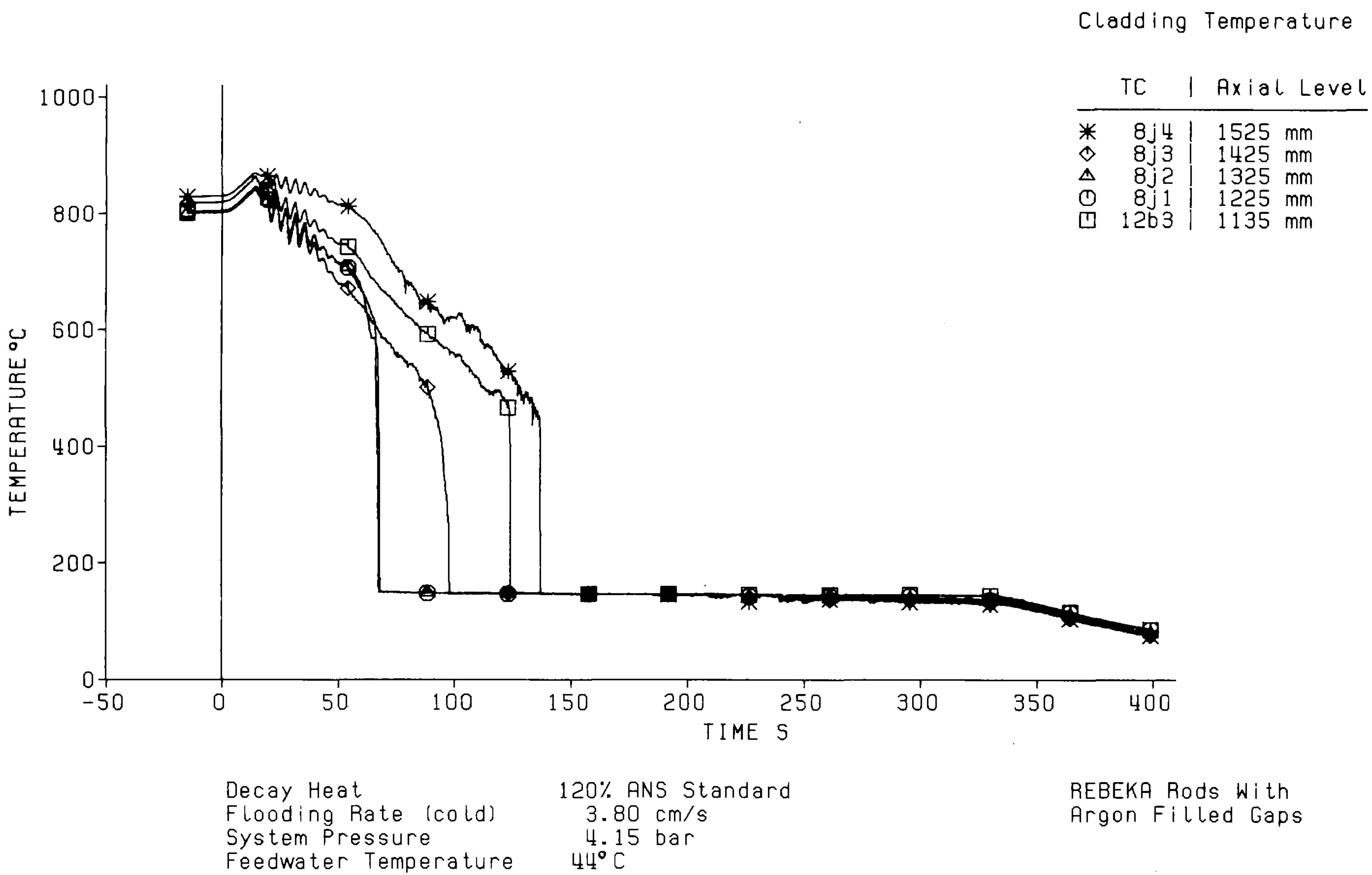
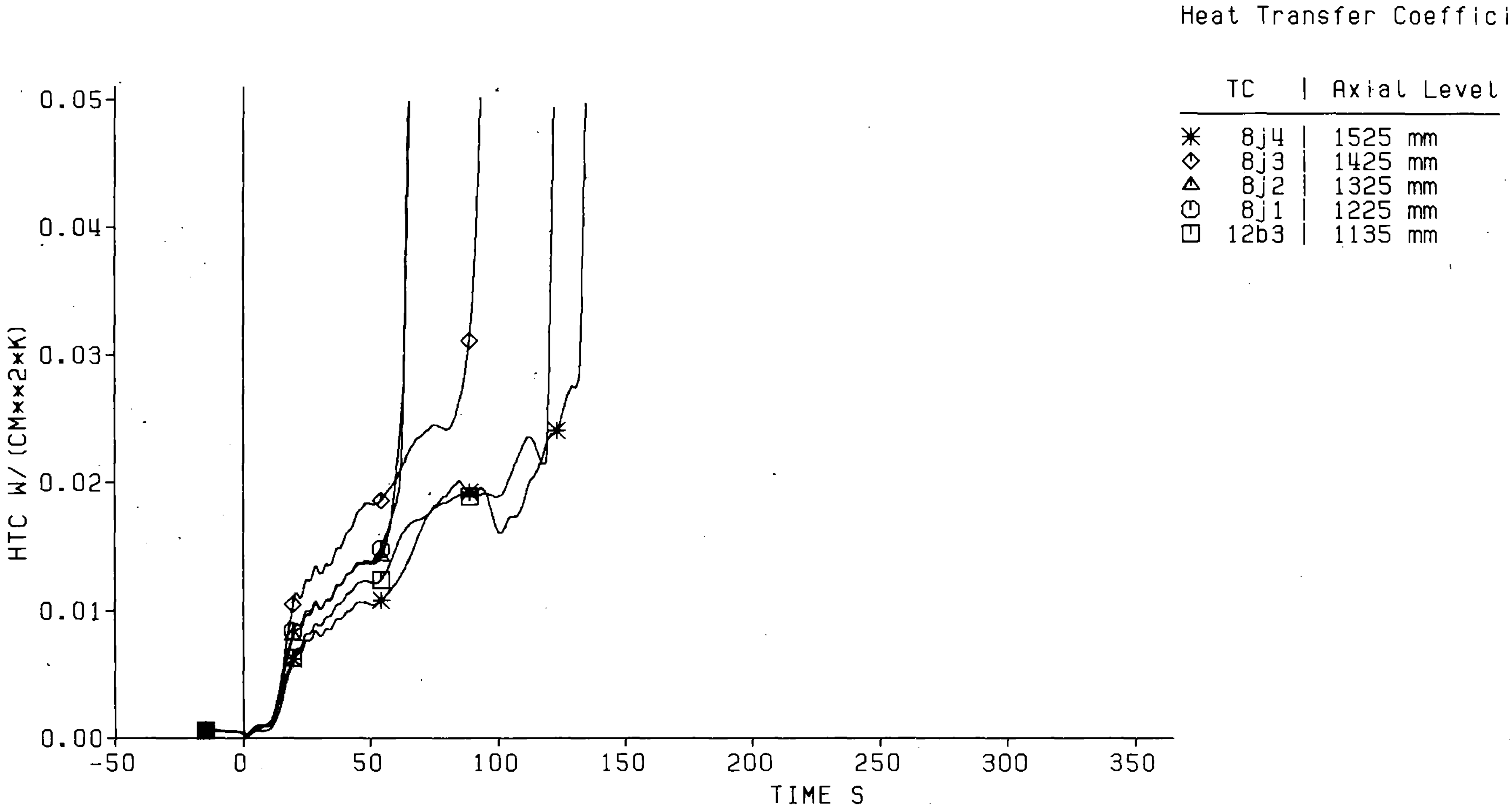


Fig. 148 SEFLEX: 5x5 RØD BUNDLE, SERIES 4, TEST-No. 34

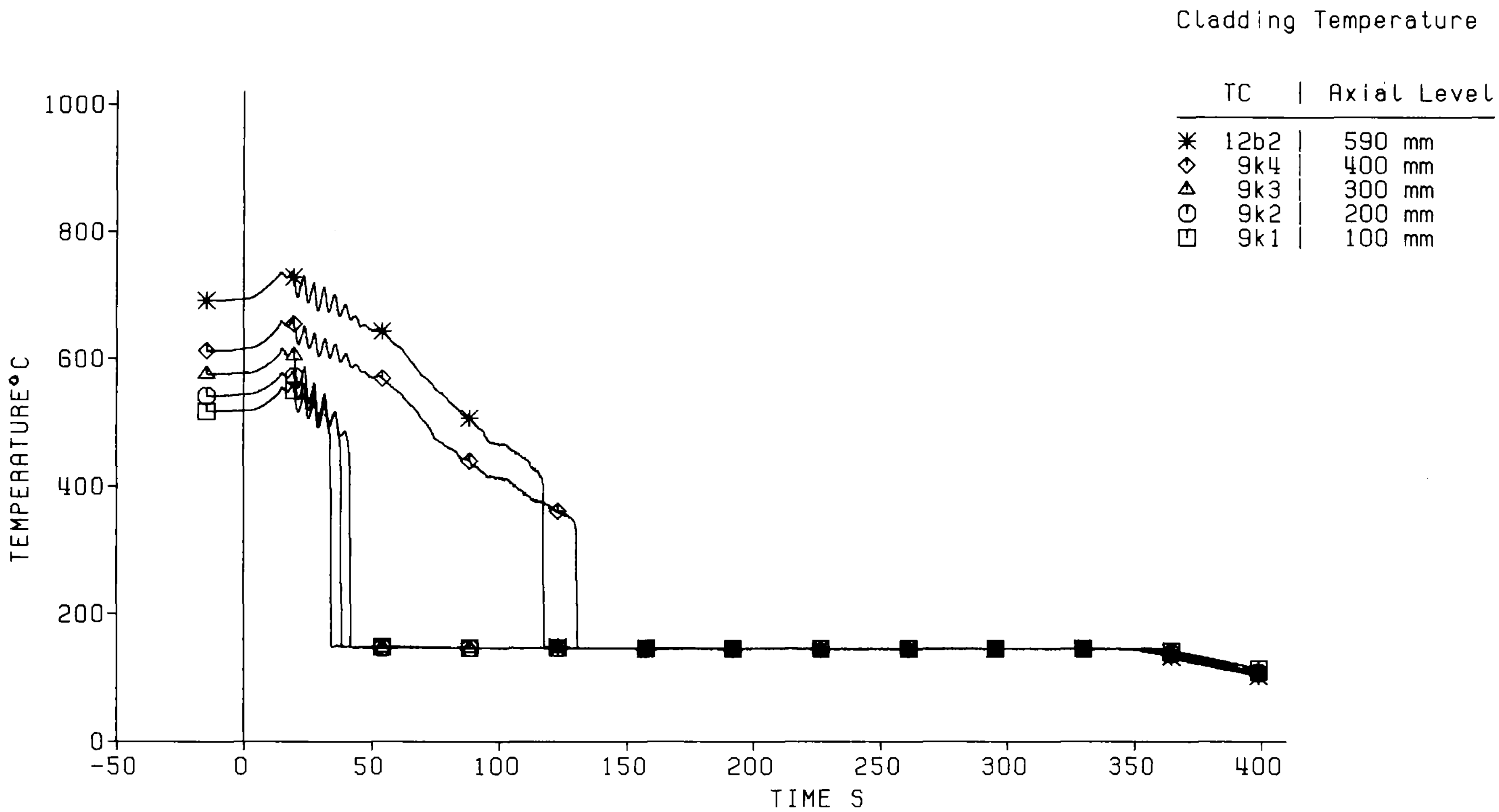


Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.80 cm/s
System Pressure 4.15 bar
Feedwater Temperature 44°C

REBEKA Rods With Argon Filled Gaps

KfK IRB

Fig. 149 SEFLEX: 5x5 RØD BUNDLE, SERIES 4, TEST-No. 34

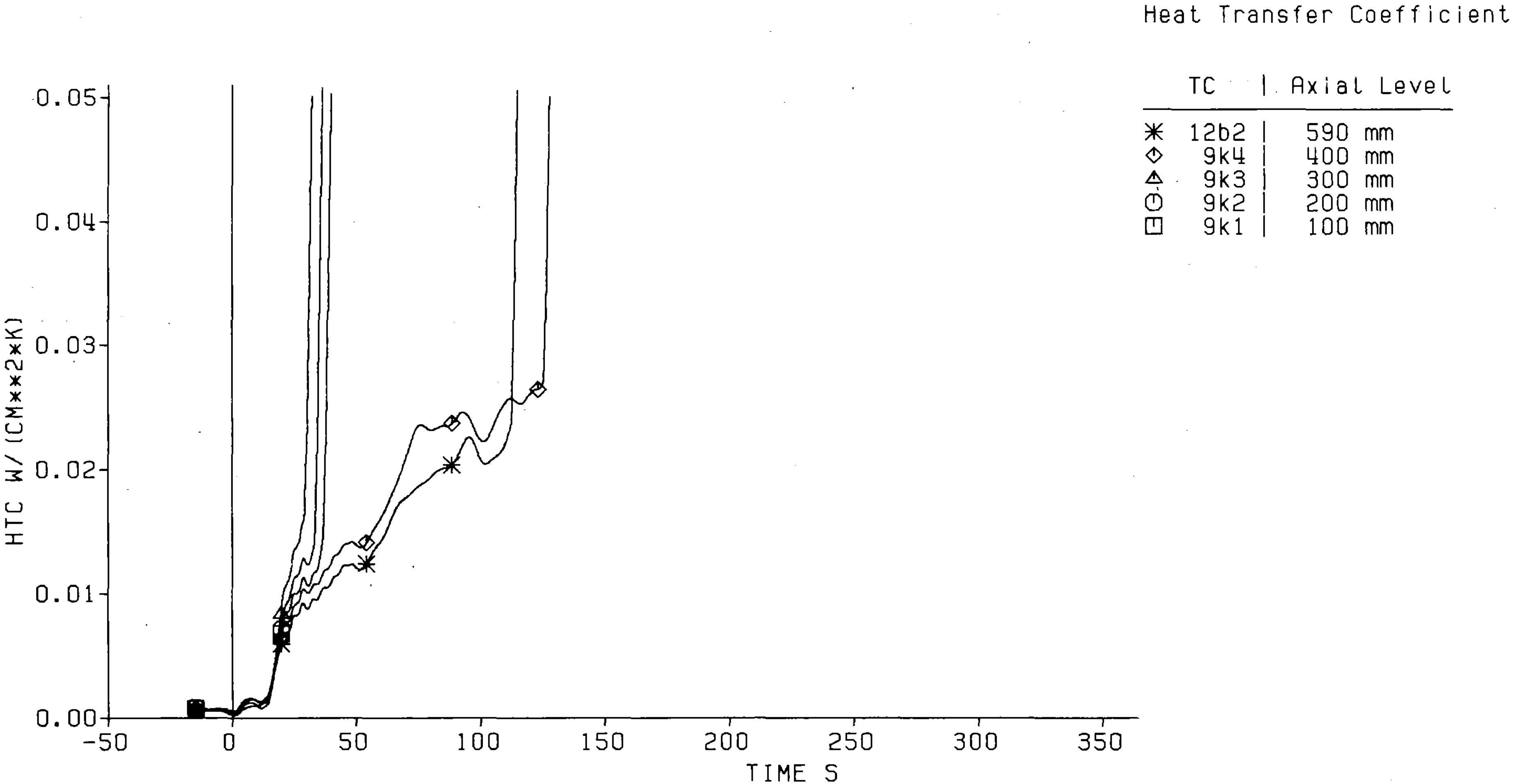


Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.80 cm/s
System Pressure 4.15 bar
Feedwater Temperature 44°C

REBEKA Rods With
Argon Filled Gaps

KfK IRB

Fig. 150 SEFLEX: 5x5 RØD BUNDLE, SERIES 4, TEST-No. 34

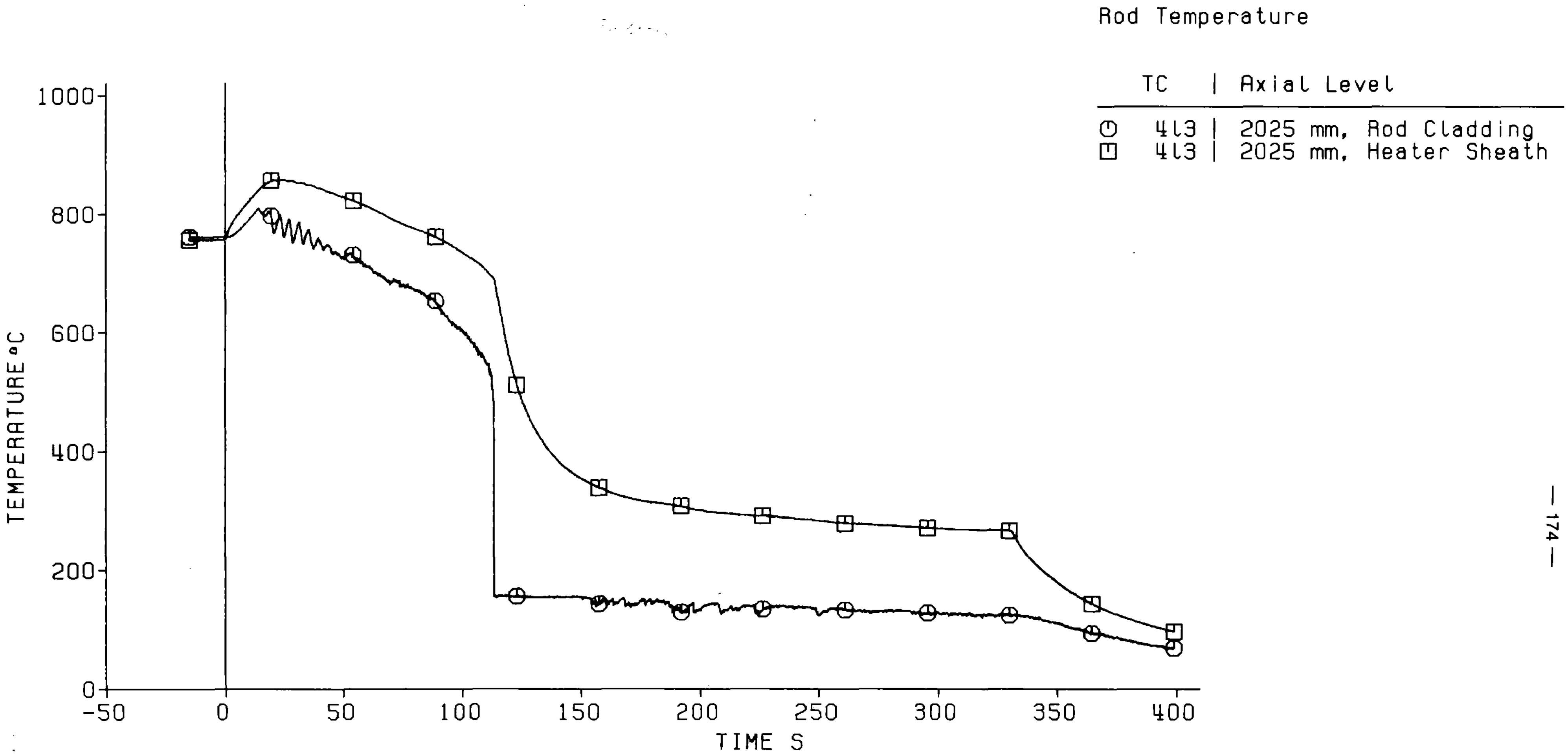


Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.80 cm/s
System Pressure 4.15 bar
Feedwater Temperature 44°C

REBEKA Rods With
Argon Filled Gaps

KfK IRB

Fig. 151 SEFLEX: 5x5 RØD BUNDLE, SERIES 4, TEST-No. 34



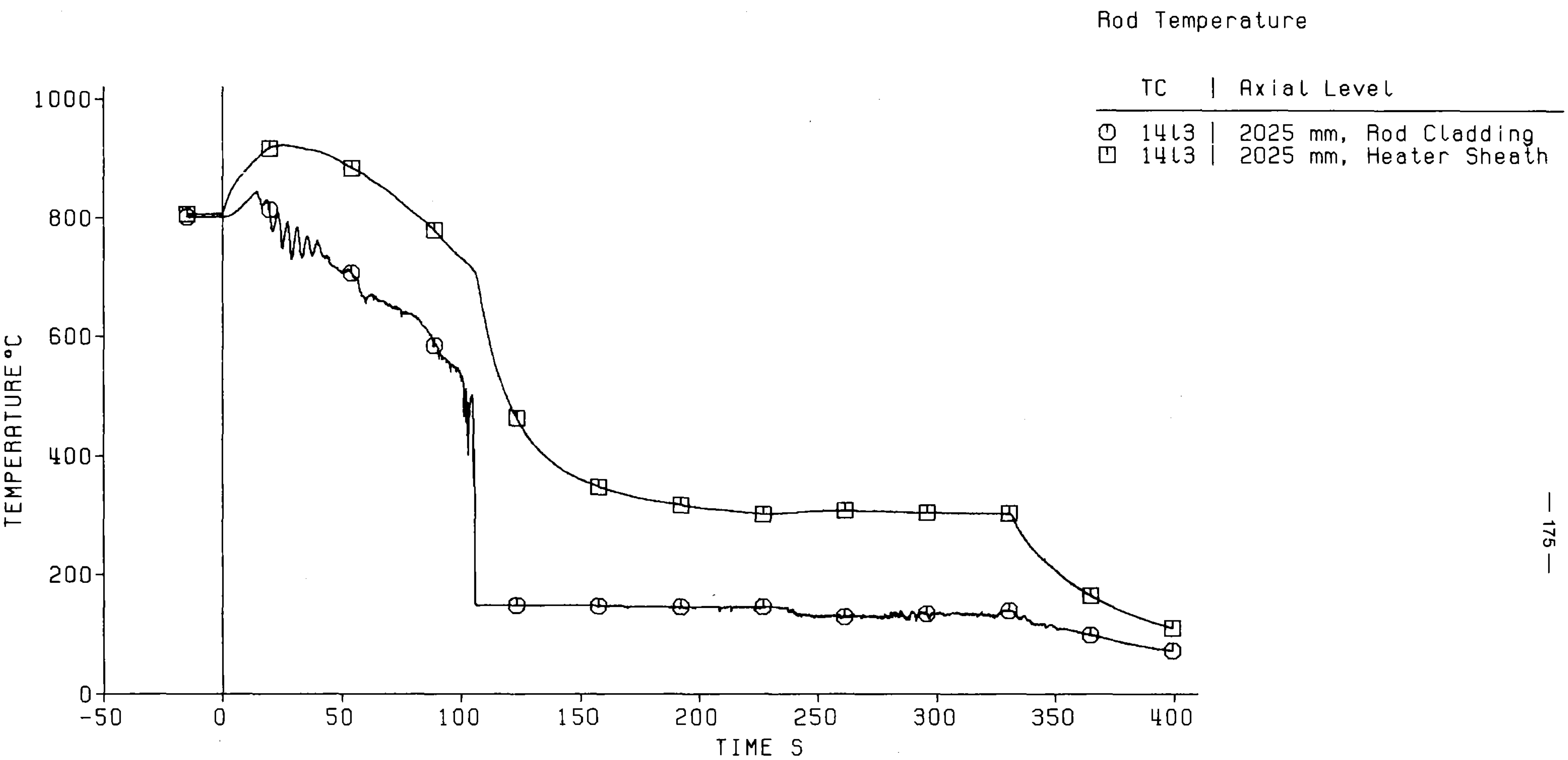
Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.80 cm/s
System Pressure 4.15 bar
Feedwater Temperature 44°C

REBEKA Rods With
Argon Filled Gaps

Bypass
======

KfK IRB

Fig. 152 SEFLEX: 5x5 RØD BUNDLE, SERIES 4, TEST-No. 34



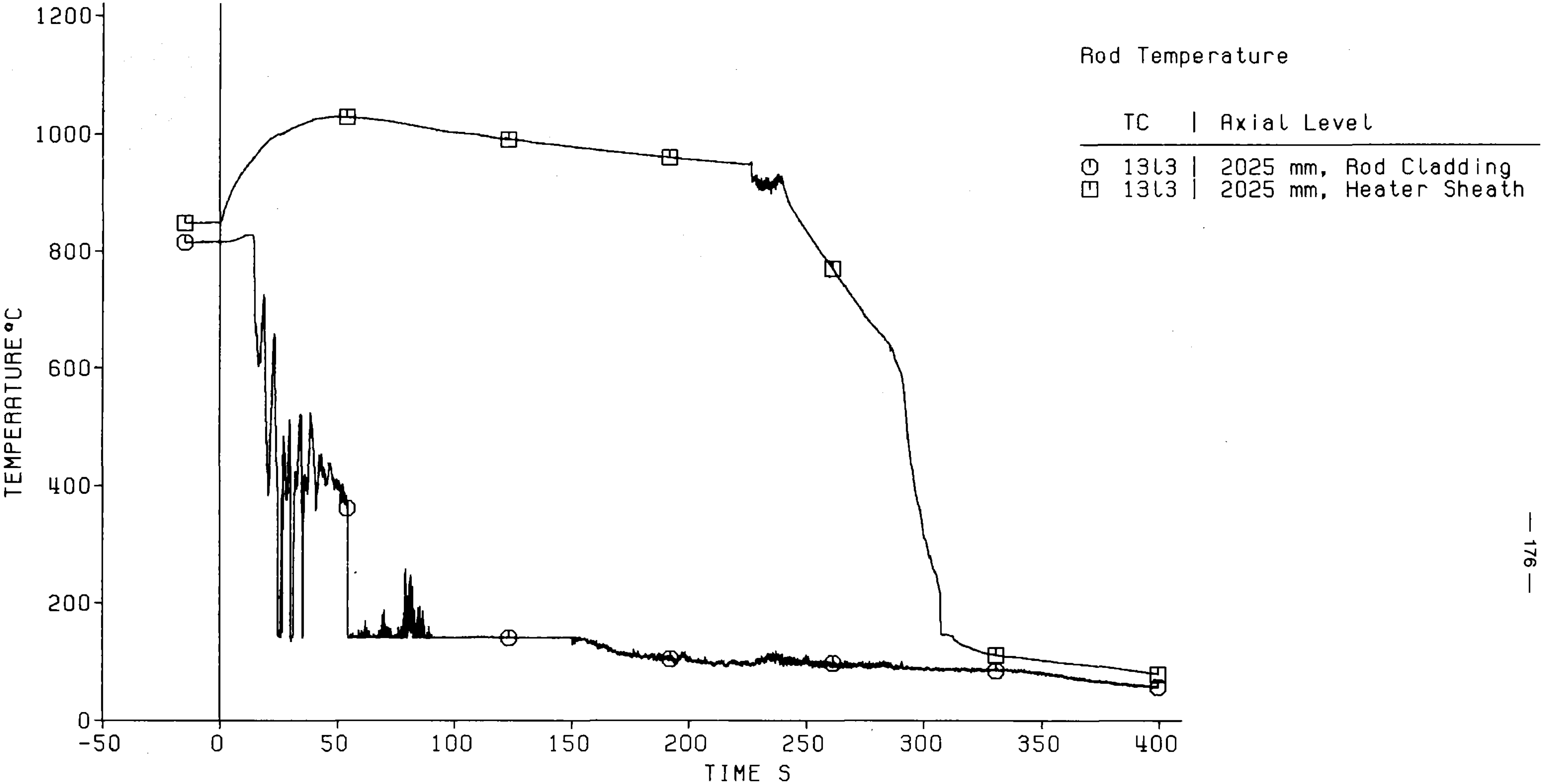
Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.80 cm/s
System Pressure 4.15 bar
Feedwater Temperature 44°C

REBEKA Rods With
Argon Filled Gaps

Bypass
======

KfK IRB

Fig. 153 SEFLEX: 5x5 RØD BUNDLE, SERIES 4, TEST-No. 34



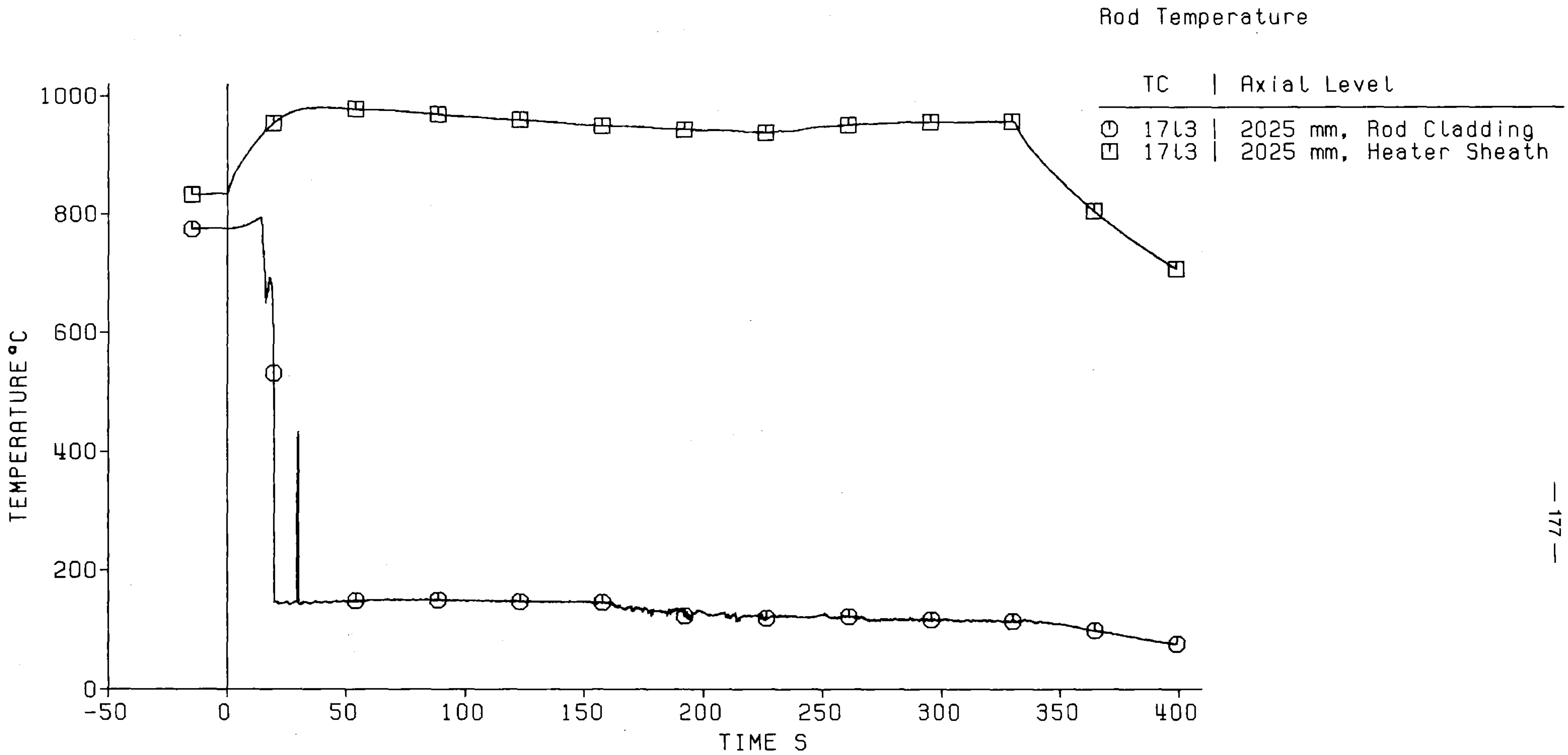
Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.80 cm/s
System Pressure 4.15 bar
Feedwater Temperature 44°C

REBEKA Rods With
Argon Filled Gaps

Blockage
========

KfK IRB

Fig. 154 SEFLEX: 5x5 RØD BUNDLE, SERIES 4, TEST-No. 34



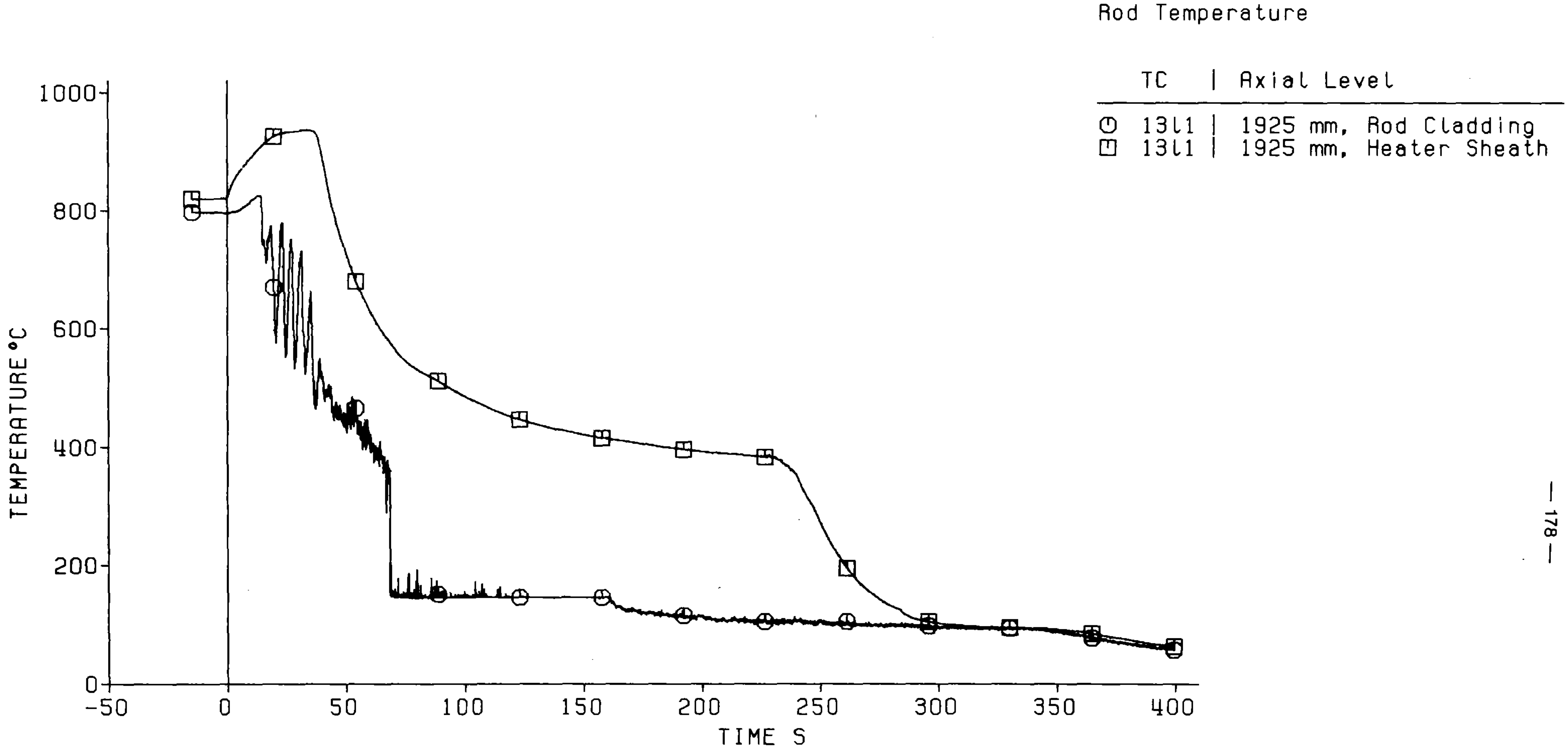
Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.80 cm/s
System Pressure 4.15 bar
Feedwater Temperature 44°C

REBEKA Rods With
Argon Filled Gaps

Blockage
========

KfK IRB

Fig. 155 SEFLEX: 5x5 RØD BUNDLE, SERIES 4, TEST-No. 34



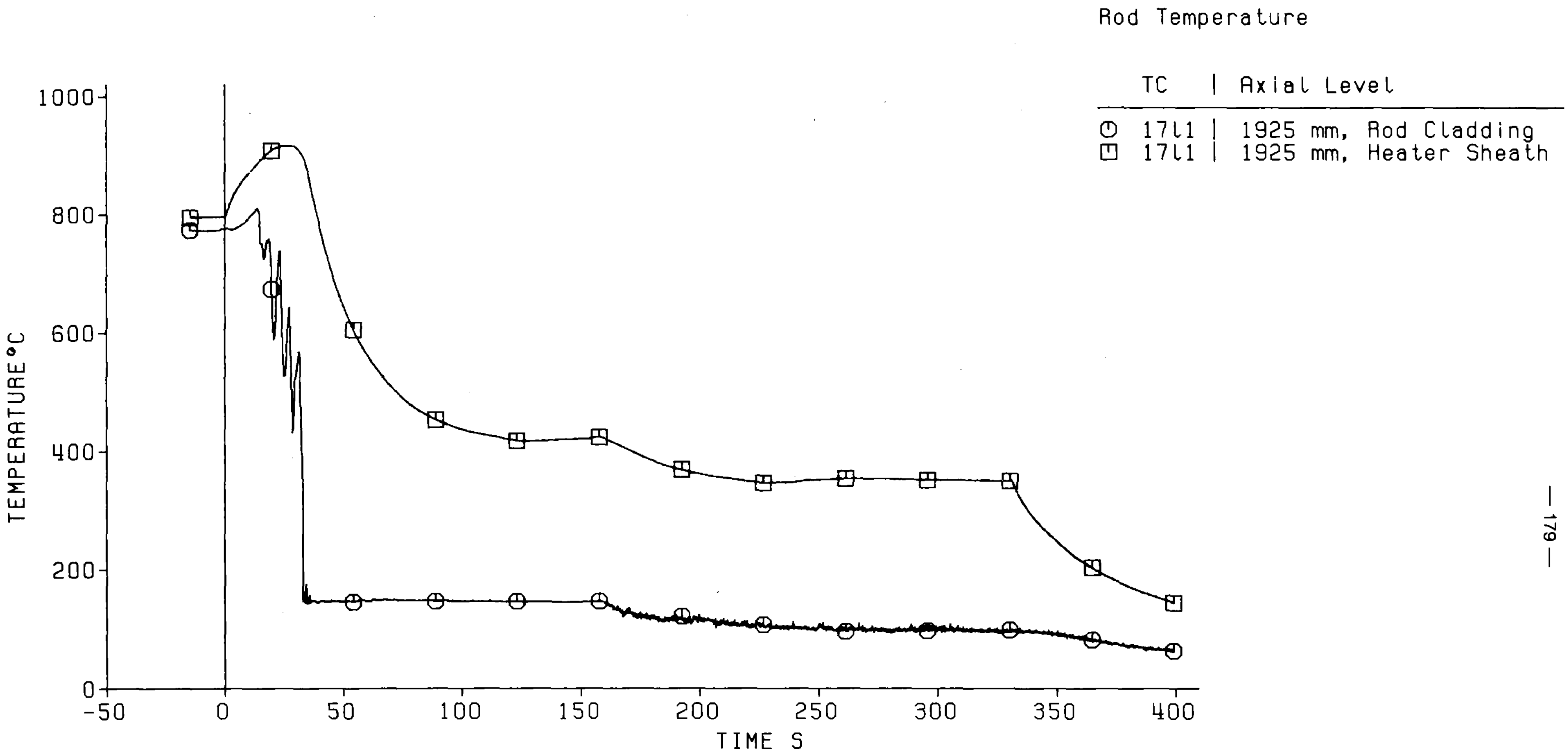
Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.80 cm/s
System Pressure 4.15 bar
Feedwater Temperature 44°C

REBEKA Rods With
Argon Filled Gaps

Blockage
========

KfK IRB

Fig. 156 SEFLEX: 5x5 RØD BUNDLE, SERIES 4, TEST-No. 34

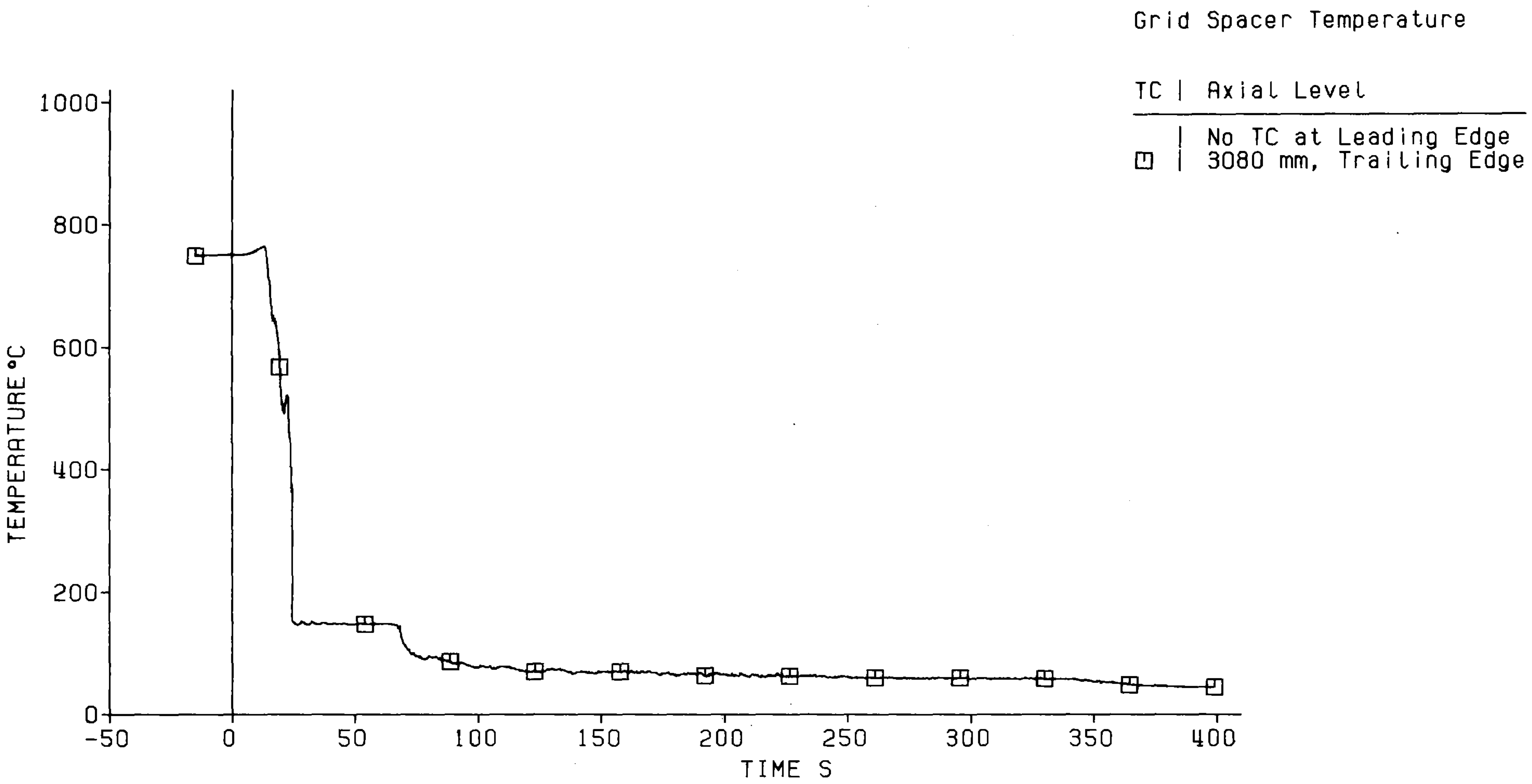


Decay Heat	120% ANS Standard
Flooding Rate (cold)	3.80 cm/s
System Pressure	4.15 bar
Feedwater Temperature	44° C

REBEKA Rods With
Argon Filled Gaps

Blockage
========

Fig. 157 SEFLEX: 5x5 RØD BUNDLE, SERIES 4, TEST-No. 34

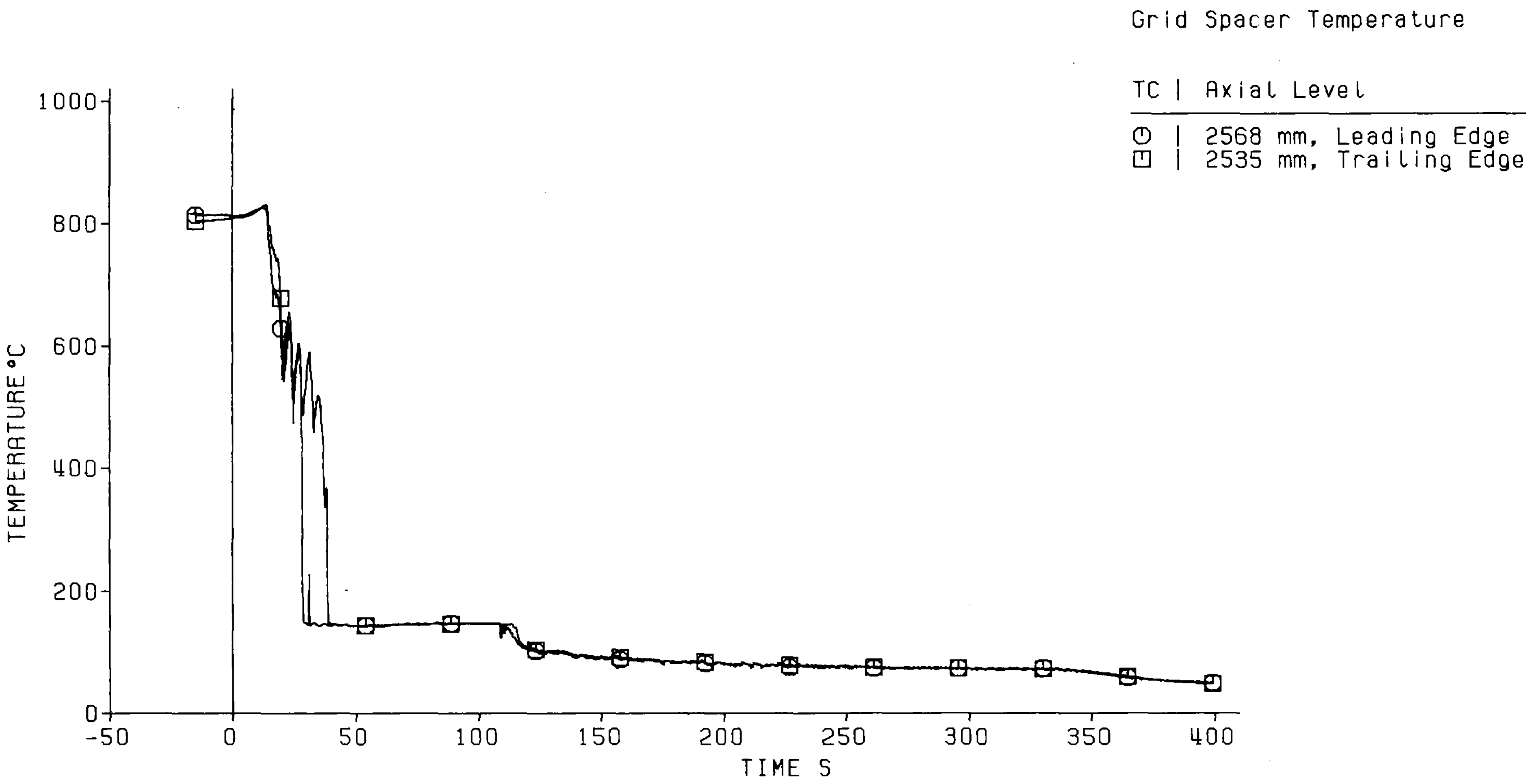


Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.80 cm/s
System Pressure 4.15 bar
Feedwater Temperature 44°C

REBEKA Rods With
Argon Filled Gaps

KfK IRB

Fig. 158 SEFLEX: 5x5 RØD BUNDLE, SERIES 4, TEST-No. 34

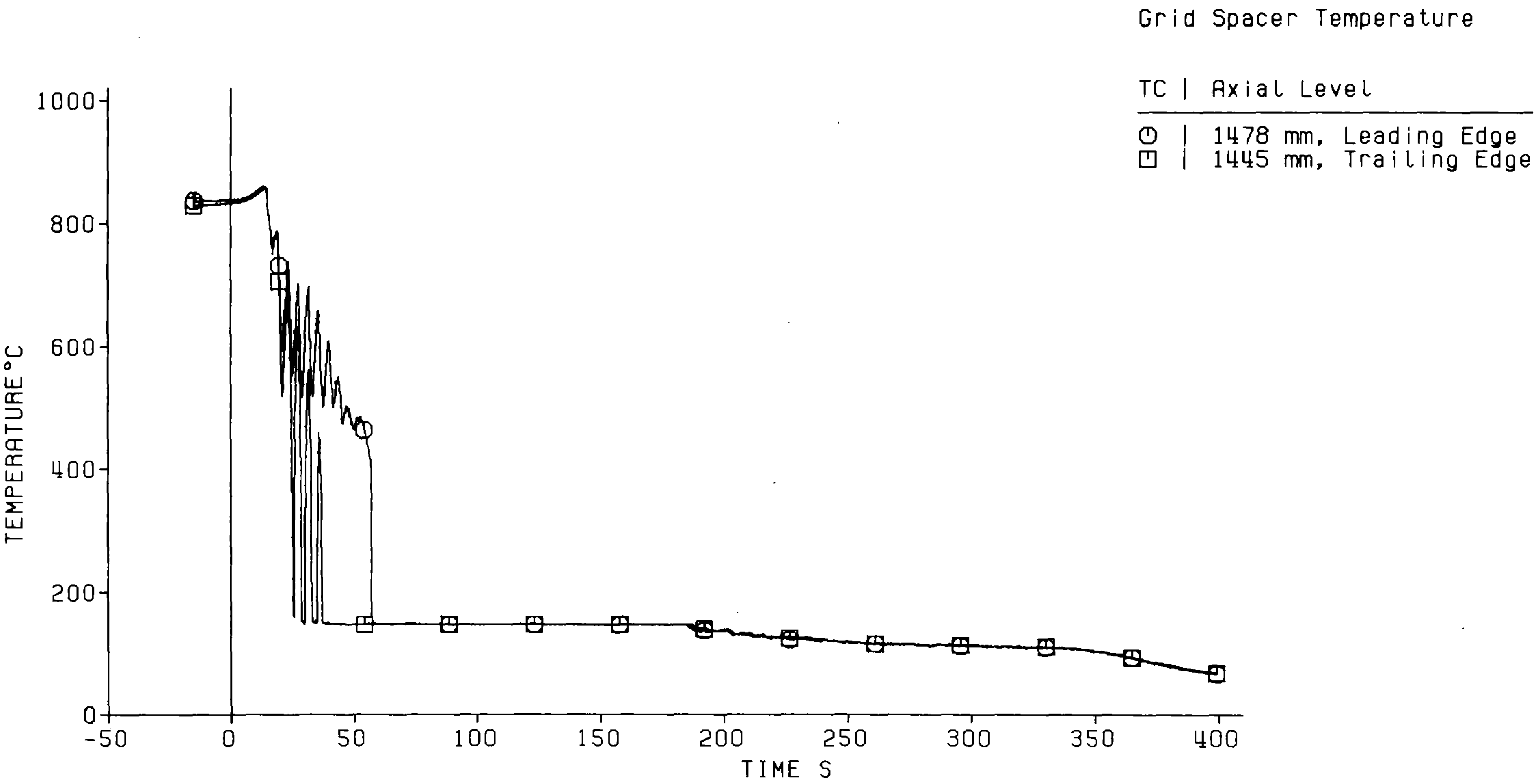


Decay Heat	120% ANS Standard
Flooding Rate (cold)	3.80 cm/s
System Pressure	4.15 bar
Feedwater Temperature	44°C

REBEKA Rods With
Argon Filled Gaps

KfK IRB

Fig. 159 SEFLEX: 5x5 RØD BUNDLE, SERIES 4, TEST-No. 34

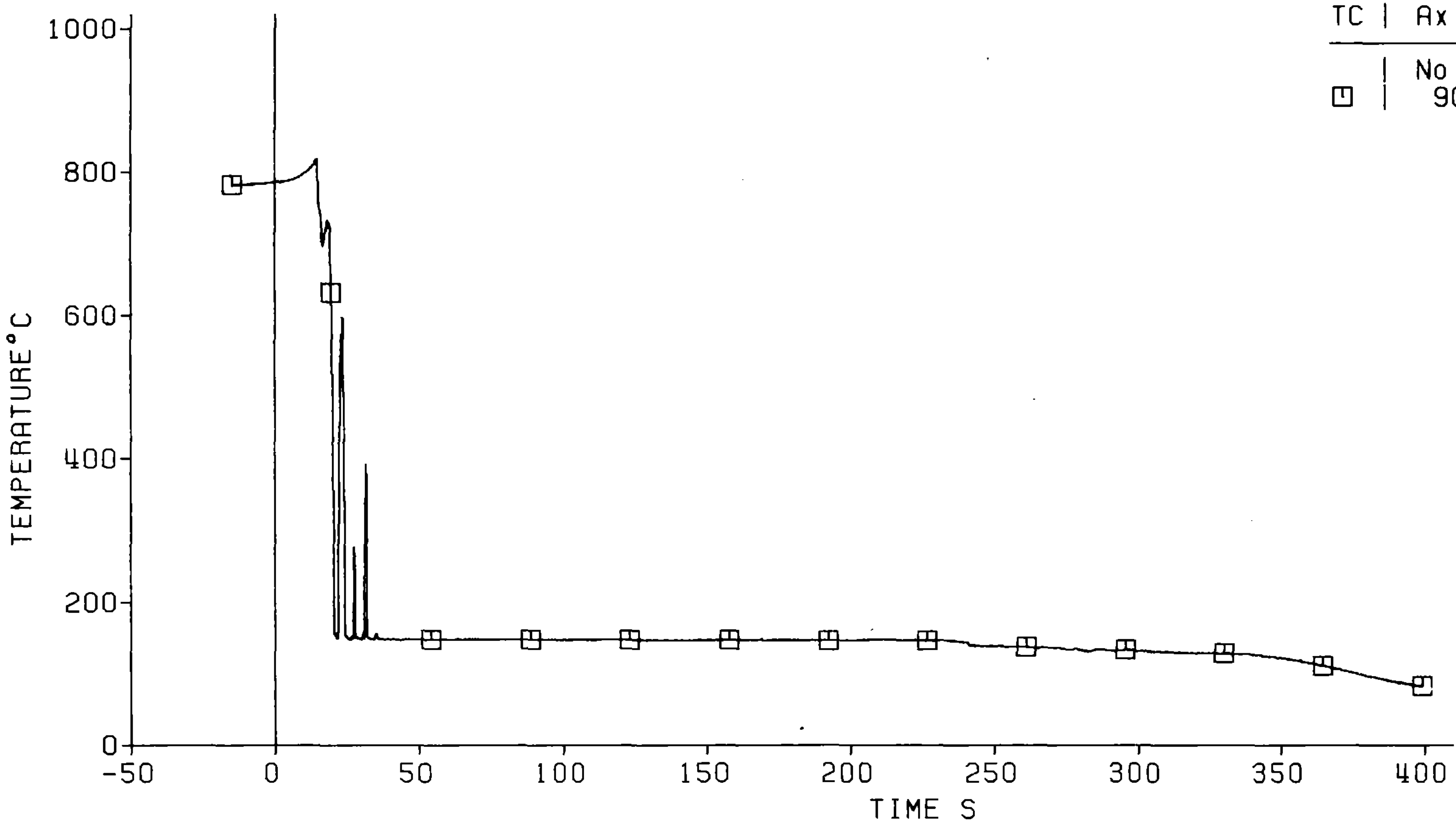


Decay Heat	120% ANS Standard
Flooding Rate (cold)	3.80 cm/s
System Pressure	4.15 bar
Feedwater Temperature	44°C

REBEKA Rods With
Argon Filled Gaps

KfK IRB

Fig. 160 SEFLEX: 5x5 RØD BUNDLE, SERIES 4, TEST-No. 34

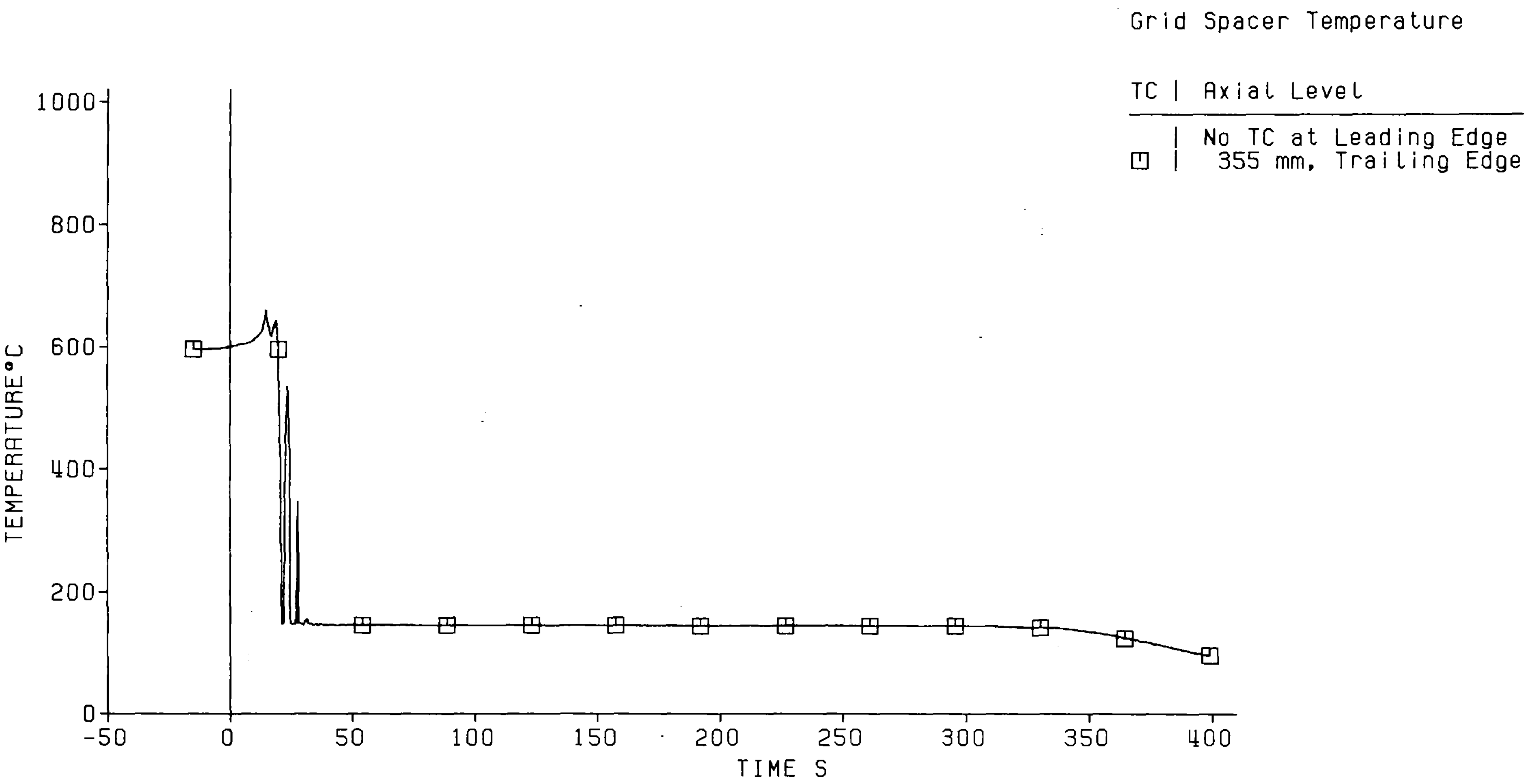


Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.80 cm/s
System Pressure 4.15 bar
Feedwater Temperature 44°C

REBEKA Rods With
Argon Filled Gaps

KfK IRB

Fig. 161 SEFLEX: 5x5 RØD BUNDLE, SERIES 4, TEST-No. 34

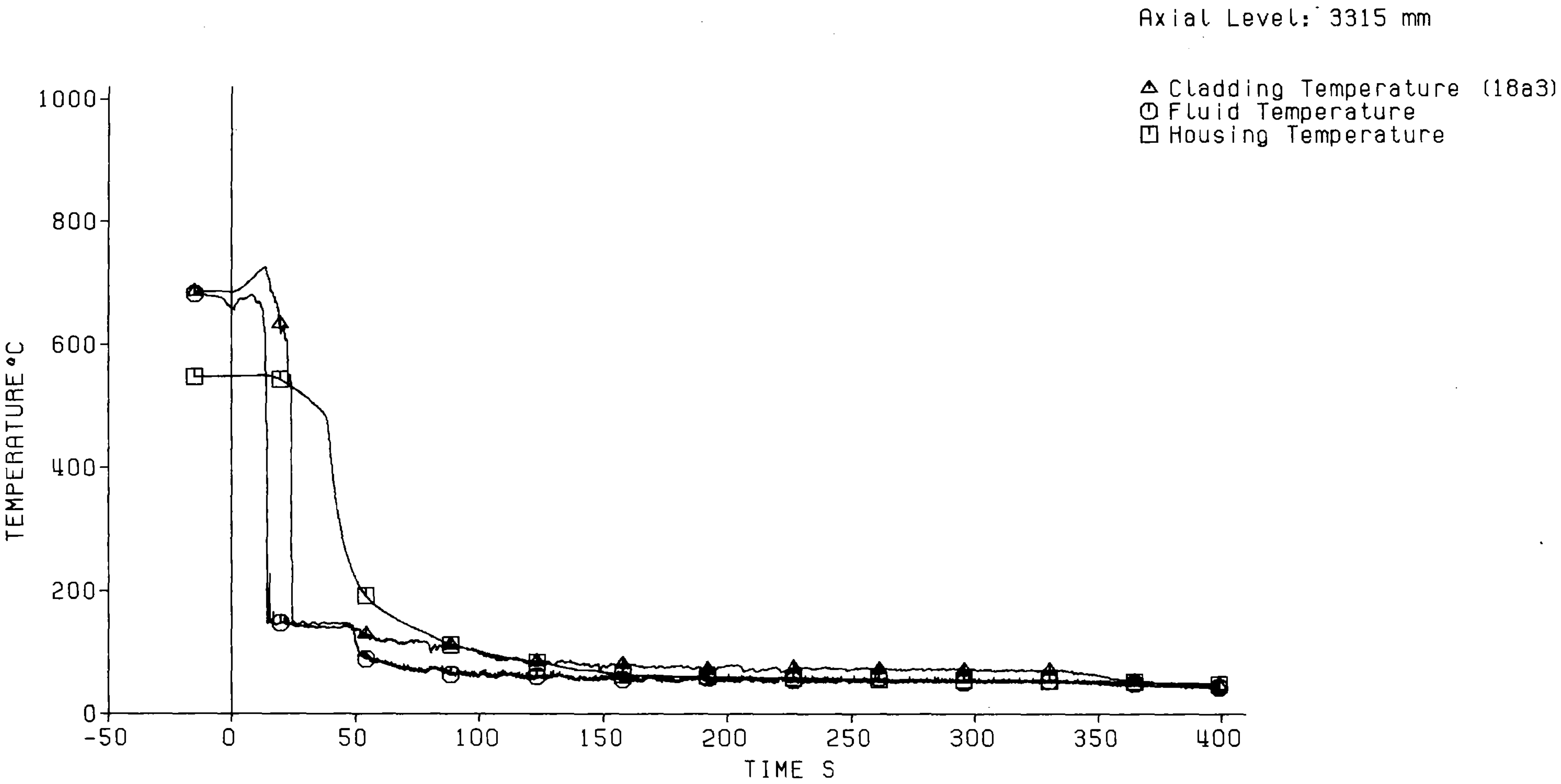


Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.80 cm/s
System Pressure 4.15 bar
Feedwater Temperature 44°C

REBEKA Rods With
Argon Filled Gaps

KfK IRB

Fig. 162 SEFLEX: 5x5 RØD BUNDLE, SERIES 4, TEST-No. 34

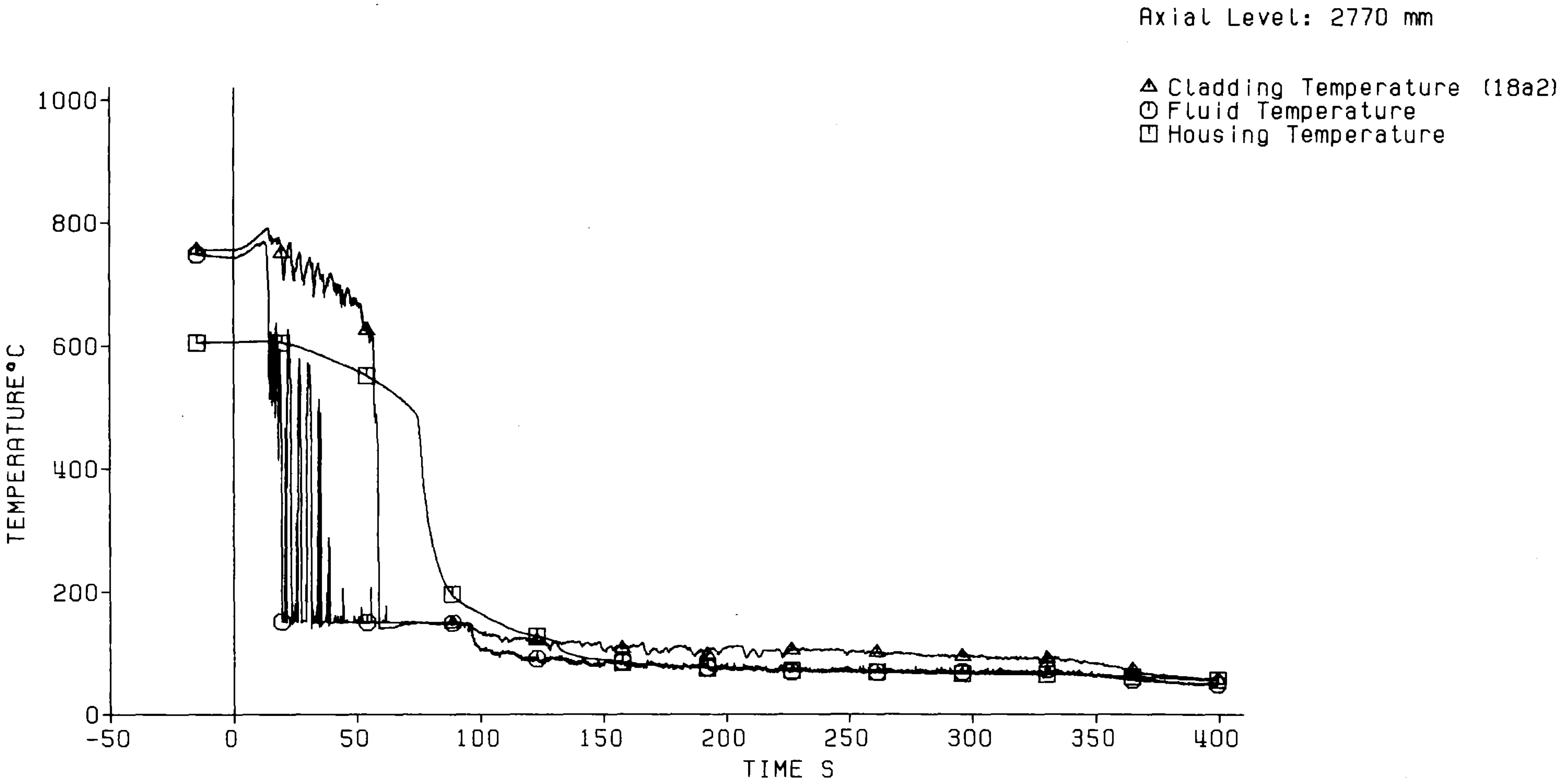


Decay Heat	120% ANS Standard
Flooding Rate (cold)	3.80 cm/s
System Pressure	4.15 bar
Feedwater Temperature	44°C

REBEKA Rods With
Argon Filled Gaps

KfK IRB

Fig. 163 SEFLEX: 5x5 ROD BUNDLE, SERIES 4, TEST-No. 34

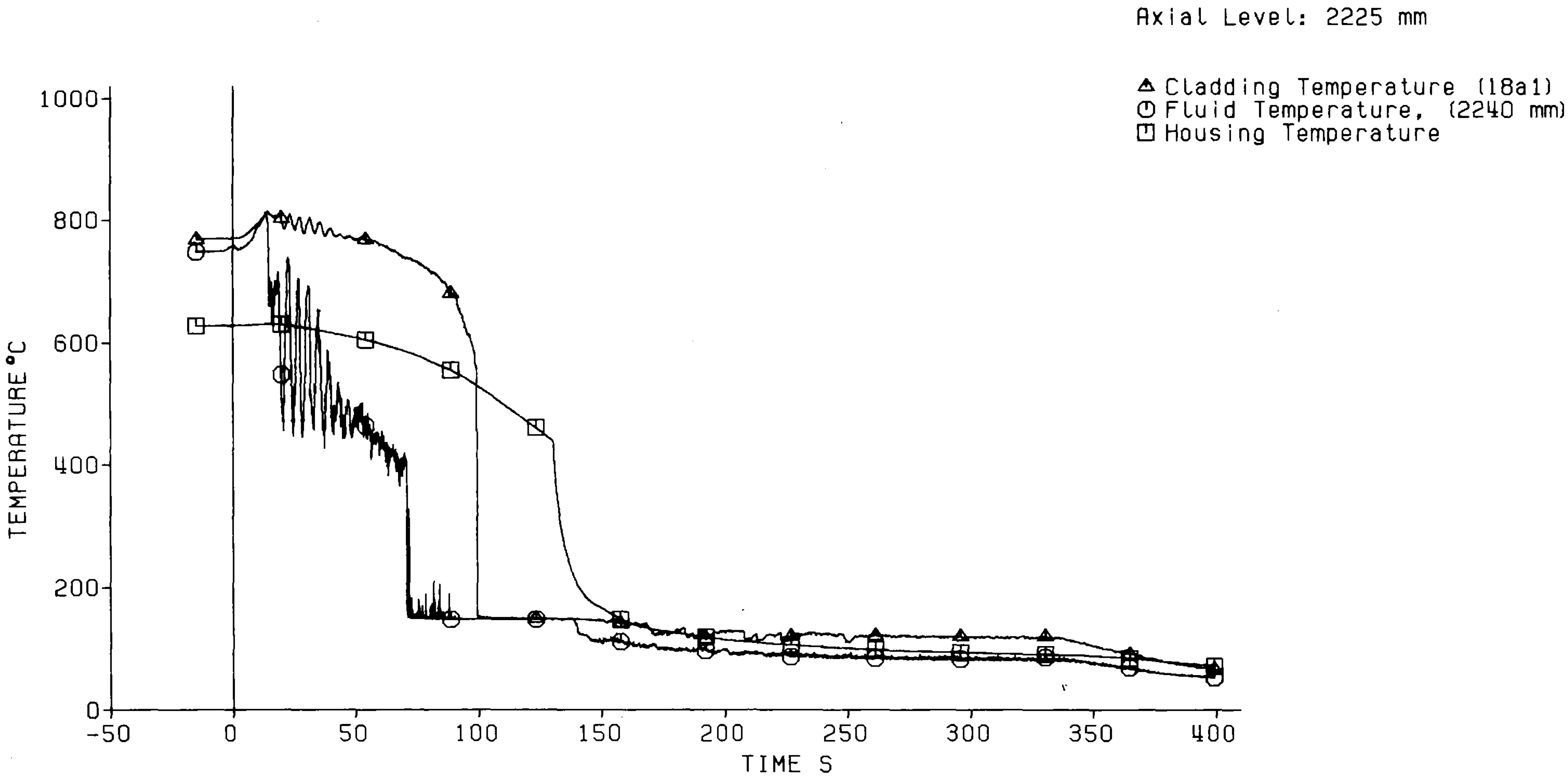


Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.80 cm/s
System Pressure 4.15 bar
Feedwater Temperature 44 °C

REBEKA Rods With
Argon Filled Gaps

KfK IRB

Fig. 164 SEFLEX: 5x5 RØD BUNDLE, SERIES 4, TEST-No. 34

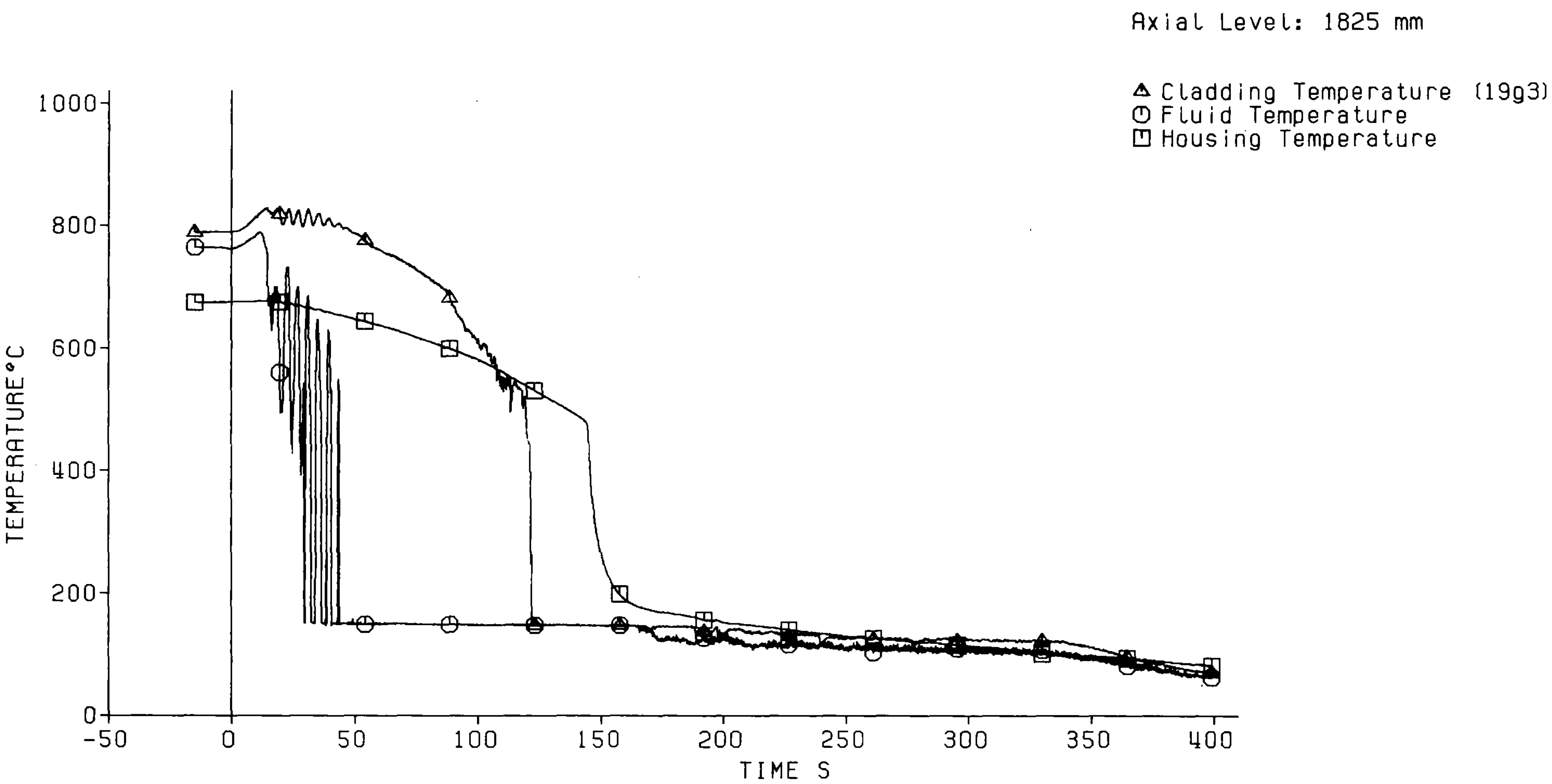


Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.80 cm/s
System Pressure 4.15 bar
Feedwater Temperature 44°C

REBEKA Rods With
Argon Filled Gaps

KfK IRB

Fig. 165 SEFLEX: 5x5 RØD BUNDLE, SERIES 4, TEST-No. 34

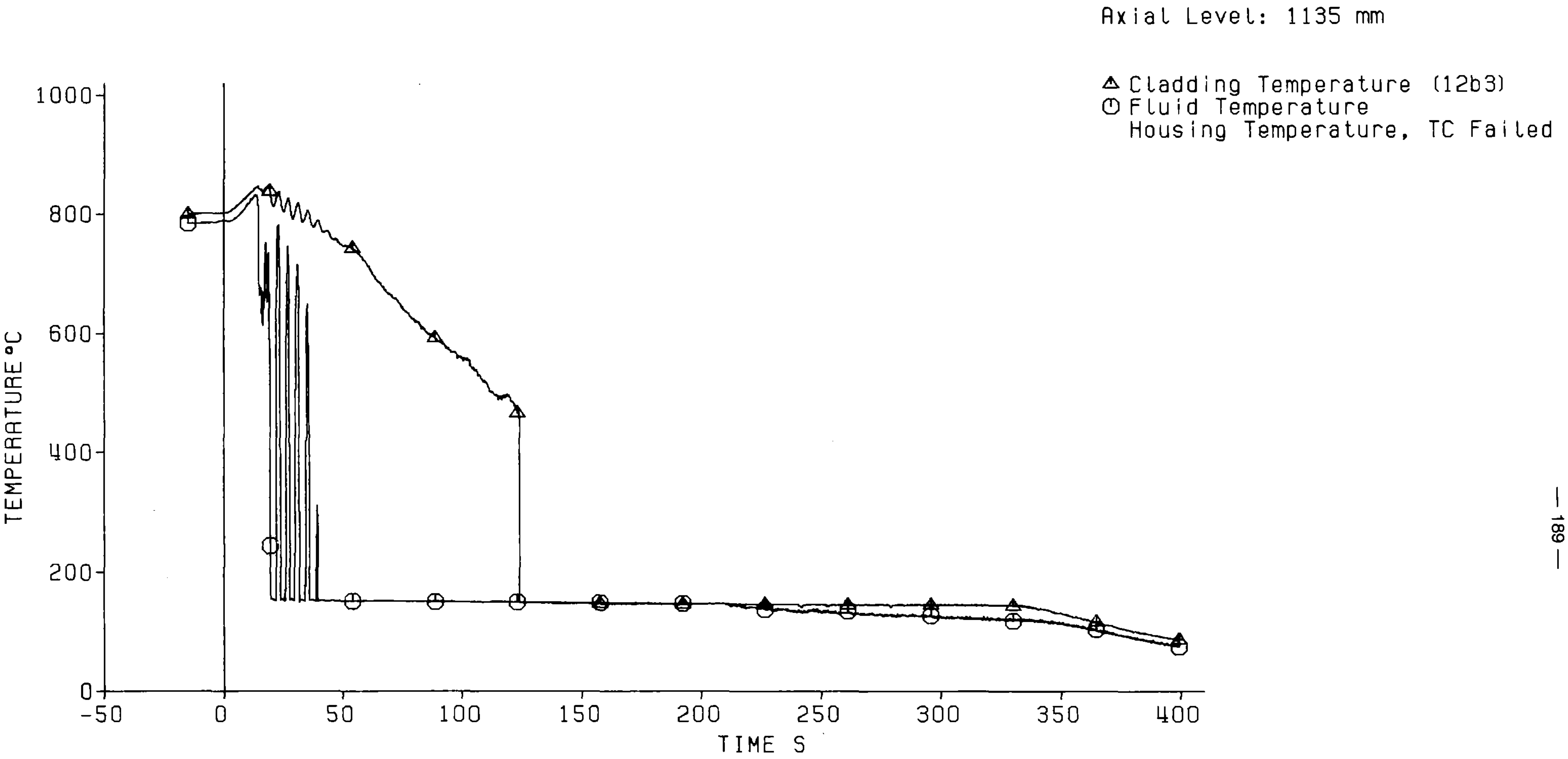


Decay Heat	120% ANS Standard
Flooding Rate (cold)	3.80 cm/s
System Pressure	4.15 bar
Feedwater Temperature	44°C

REBEKA Rods With
Argon Filled Gaps

KfK IRB

Fig. 166 SEFLEX: 5x5 RØD BUNDLE, SERIES 4, TEST-No. 34

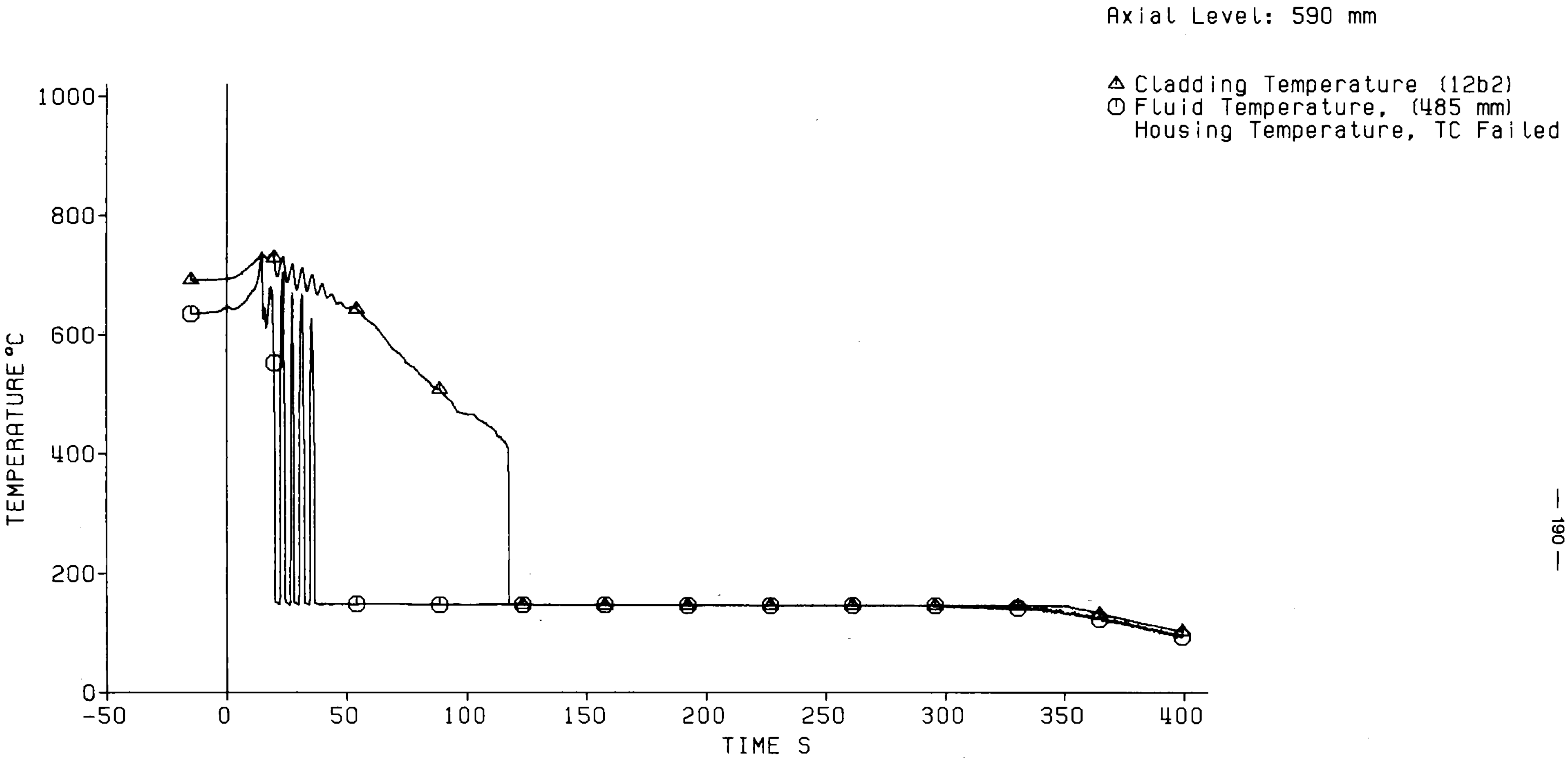


Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.80 cm/s
System Pressure 4.15 bar
Feedwater Temperature 44°C

REBEKA Rods With
Argon Filled Gaps

KfK IRB

Fig. 167 SEFLEX: 5x5 RØD BUNDLE, SERIES 4, TEST-No. 34

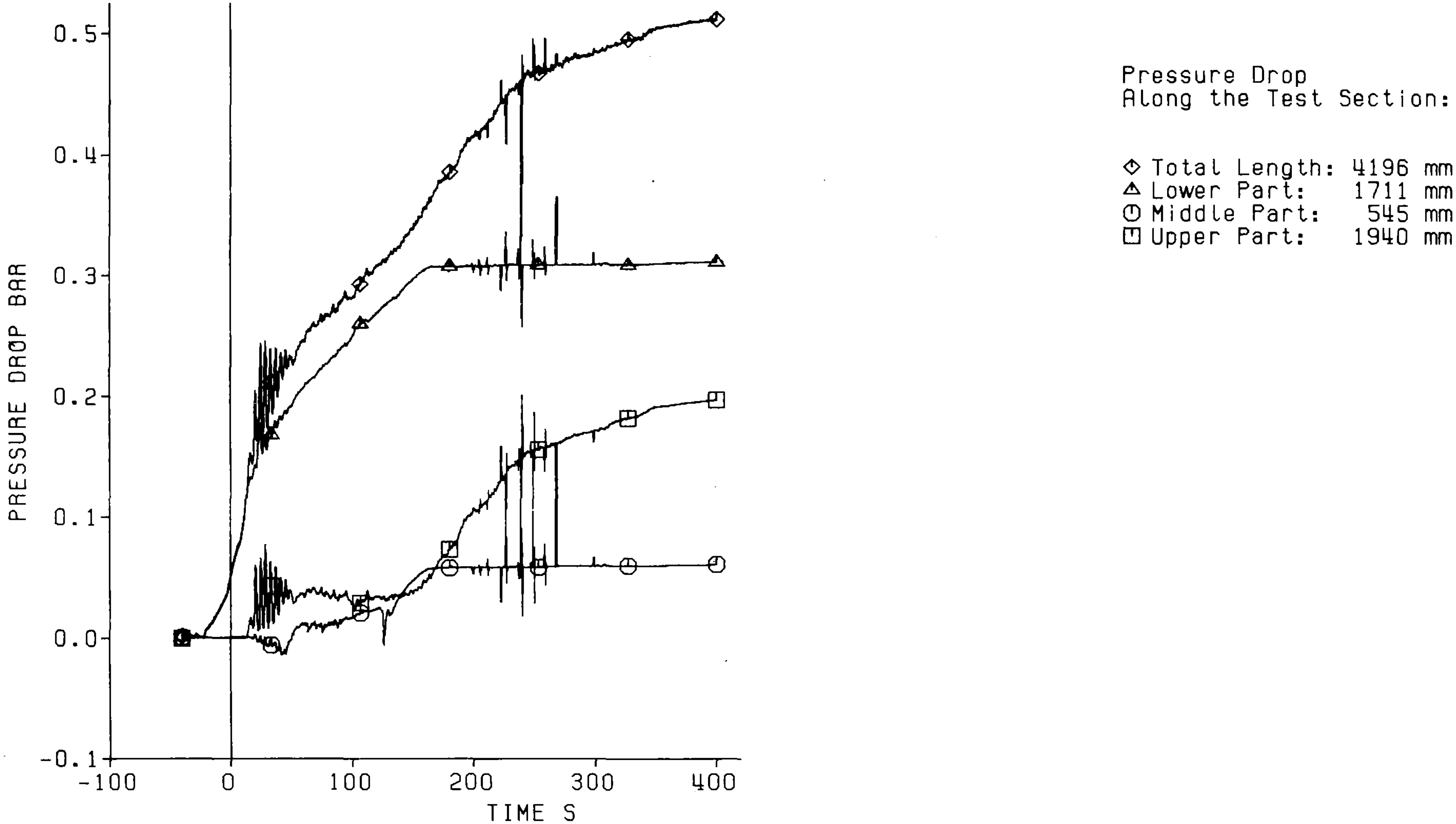


Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.80 cm/s
System Pressure 4.15 bar
Feedwater Temperature 44°C

REBEKA Rods With
Argon Filled Gaps

KfK IRB

Fig. 168 SEFLEX: 5x5 RØD BUNDLE, SERIES 4, TEST-No. 34



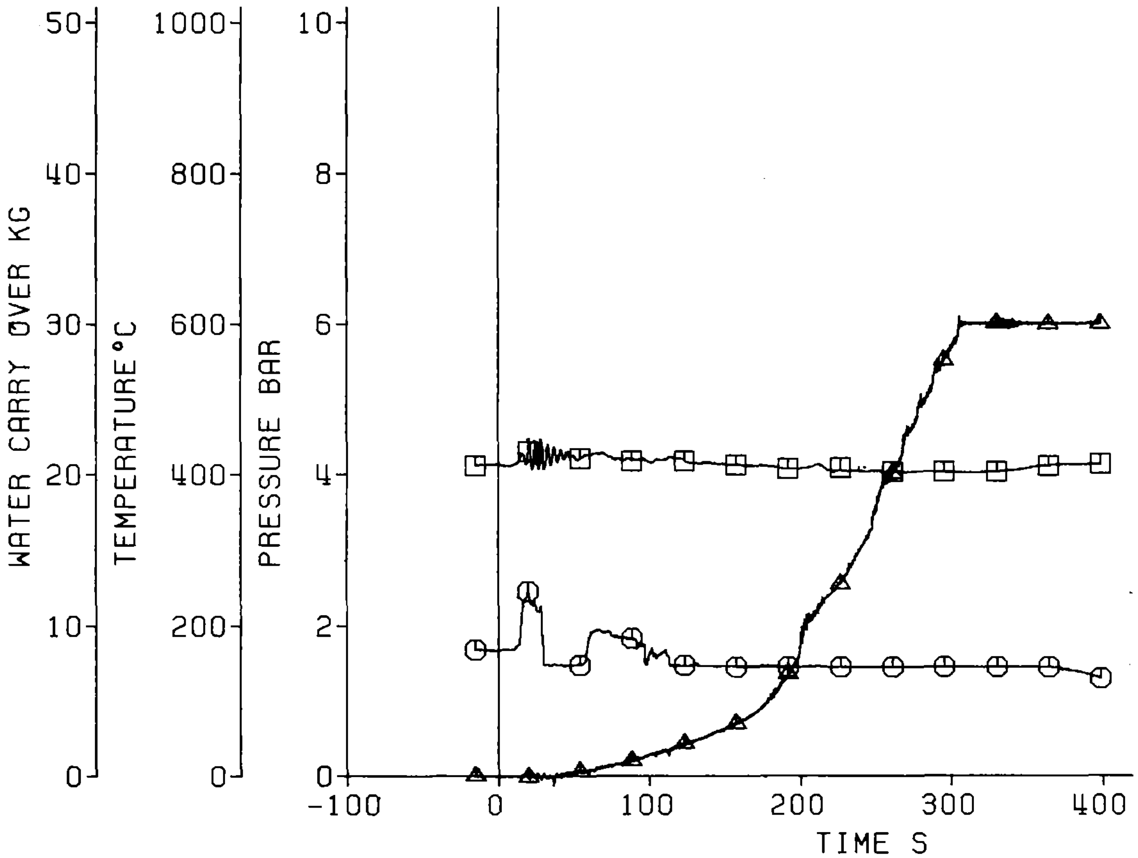
Decay Heat	120% ANS Standard
Flooding Rate (cold)	3.80 cm/s
System Pressure	4.15 bar
Feedwater Temperature	44°C

REBEKA Rods With
Argon Filled Gaps

KfK IRB

Fig. 169 SEFLEX: 5x5 RØD BUNDLE, SERIES 4, TEST-No. 34

Coolant Outlet Conditions:



Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.80 cm/s
System Pressure 4.15 bar
Feedwater Temperature 44°C

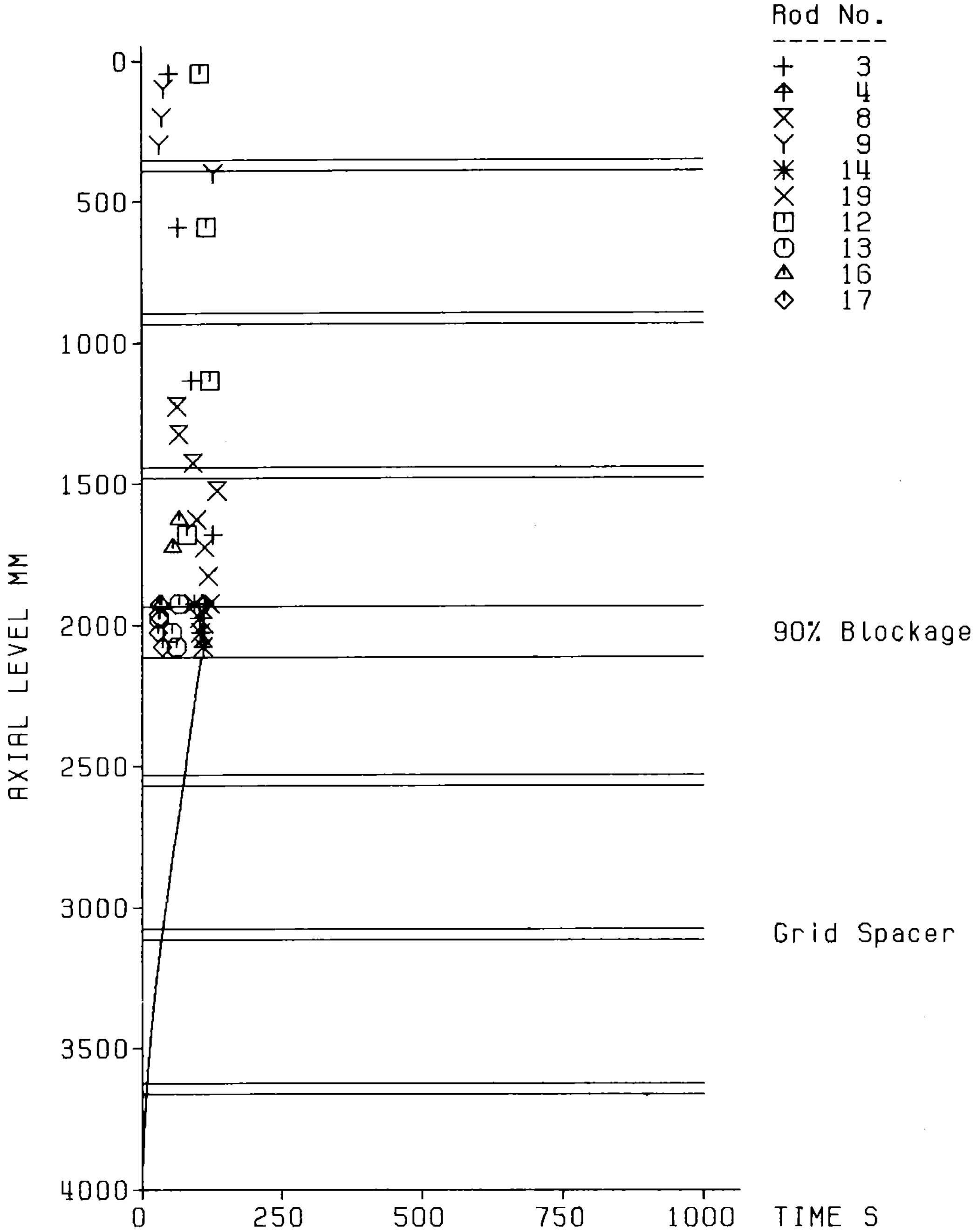
REBEKA Rods With
Argon Filled Gaps

KfK IRB

Fig. 170 SEFLEX: 5x5 ROD BUNDLE, SERIES 4, TEST-No. 34

Axial Position of Quench Front

REBEKA Rods With Argon Filled Gaps



Decay Heat	120% ANS Standard
Flooding Rate (cold)	3.80 cm/s
System Pressure	4.15 bar
Feedwater Temperature	44 °C

KfK IRB

Fig. 171 SEFLEX: 5x5 ROD BUNDLE
TEST SERIES 4, TEST-No. 34

SEFLEX PROGRAM: TEST SERIES 3 and 4

Test series 3, test No. 32 and 35: Rods with helium-filled gaps between Zircaloy claddings and alumina pellets; 90% flow blockage with bypass; blockage at the bundle midplane of 3 x 3 rods placed in the corner of the 5 x 5 rod bundle; without grid spacer at the bundle midplane.

Test series 4, test No. 33 and 34: Rods with argon-filled gaps between Zircaloy claddings and alumina pellets; 90% flow blockage with bypass; blockage at the bundle midplane of 3 x 3 rods placed in the corner of the 5 x 5 rod bundle; without grid spacer at the bundle midplane.

Channel listing and data identification for test No. 32 through 35

Channel	Data Identification		Unit	Remarks
No.	Type	Location		
1	Time (10 Scans/s)		s	t = 0: Start of Reflooding
2	Cladding Temperature	3.b.1. 45[1]	°C	
3	Cladding Temperature	3.b.2. 590	°C	
4	Cladding Temperature	3.b.3.1135	°C	
5	Cladding Temperature	3.b.4.1680	°C	
6	Cladding Temperature	4.1.1. 45	°C	
7	Cladding Temperature	4.1.2. 590	°C	
8	Cladding Temperature	4.1.3.1135	°C	
9	Cladding Temperature	4.1.4.1680	°C	
10	Cladding Temperature	7.f.1.2125	°C	
11	Cladding Temperature	7.f.2.2225	°C	
12	Cladding Temperature	7.f.3.2325	°C	
13	Cladding Temperature	7.f.4.2425	°C	
14	Cladding Temperature	8.j.1.1225	°C	
15	Cladding Temperature	8.j.2.1325	°C	
16	Cladding Temperature	8.j.3.1425	°C	
17	Cladding Temperature	8.j.4.1525	°C	

SEFLEX PROGRAM: TEST SERIES 3 and 4

Channel	Data Identification		Unit	Remarks
No.	Type	Location		
18	Cladding Temperature	9.k.1. 100[1]	°C	
19	Cladding Temperature	9.k.2. 200	°C	
20	Cladding Temperature	9.k.3. 300	°C	
21	Cladding Temperature	9.k.4. 400	°C	
22	Cladding Temperature	12.b.1. 45	°C	
23	Cladding Temperature	12.b.2. 590	°C	
24	Cladding Temperature	12.b.3.1135	°C	
25	Cladding Temperature	12.b.4.1680	°C	
26	Cladding Temperature	13.1.1.1925	°C	
27	Cladding Temperature	13.1.2.1975	°C	
28	Cladding Temperature	13.1.3.2025	°C	
29	Cladding Temperature	13.1.4.2075	°C	
30	Cladding Temperature	14.1.1.1925	°C	
31	Cladding Temperature	14.1.2.1975	°C	
32	Cladding Temperature	14.1.3.2025	°C	
33	Cladding Temperature	14.1.4.2075	°C	
34	Cladding Temperature	15.a.1.2225	°C	
35	Cladding Temperature	15.a.2.2770	°C	
36	Cladding Temperature	15.a.3.3315	°C	
37	Cladding Temperature	15.a.4.3860	°C	
38	Cladding Temperature	16.g.1.1625	°C	
39	Cladding Temperature	16.g.2.1725	°C	
40	Cladding Temperature	16.g.3.1825	°C	32[9], 33[9], 34[9], 35[9]
41	Cladding Temperature	16.g.4.1925	°C	
42	Cladding Temperature	17.1.1.1925	°C	
43	Cladding Temperature	17.1.2.1975	°C	
44	Cladding Temperature	17.1.3.2025	°C	
45	Cladding Temperature	17.1.4.2075	°C	

SEFLEX PROGRAM: TEST SERIES 3 and 4

Channel No.	Data Identification Type	Location	Unit	Remarks
46	Cladding Temperature	18.a.1.2225[1]	°C	33[9], 34[9], 35[9]
47	Cladding Temperature	18.a.2.2770	°C	
48	Cladding Temperature	18.a.3.3315	°C	
49	Cladding Temperature	18.a.4.3860	°C	
50	Cladding Temperature	19.g.1.1625	°C	
51	Cladding Temperature	19.g.2.1725	°C	
52	Cladding Temperature	19.g.3.1825	°C	
53	Cladding Temperature	19.g.4.1925	°C	
54	Cladding Temperature	22.f.1.2125	°C	
55	Cladding Temperature	22.f.2.2225	°C	
56	Cladding Temperature	22.f.3.2325	°C	
57	Cladding Temperature	22.f.4.2425	°C	
58	Heater Sheath Temp.	4.1.2.1975	°C	32[9], 33[9], 34[9], 35[9]
59	Heater Sheath Temp.	4.1.3.2025	°C	
60	Heater Sheath Temp.	13.1.1.1925	°C	
61	Heater Sheath Temp.	13.1.2.1975	°C	
62	Heater Sheath Temp.	13.1.3.2025	°C	
63	Heater Sheath Temp.	13.1.4.2075	°C	32[9], 33[9], 34[9], 35[9]
64	Heater Sheath Temp.	14.1.1.1925	°C	32[9], 33[9], 34[9], 35[9]
65	Heater Sheath Temp.	14.1.2.1975	°C	32[9], 33[9], 34[9], 35[9]
66	Heater Sheath Temp.	14.1.3.2025	°C	
67	Heater Sheath Temp.	17.1.1.1925	°C	
68	Heater Sheath Temp.	17.1.2.1975	°C	35[9]
69	Heater Sheath Temp.	17.1.3.2025	°C	35[9]
70	Grid Spacer Temp.	TA[2] 355 mm	°C	
71	Grid Spacer Temp.	TA[2] 900 mm	°C	
72	Grid Spacer Temp.	TA[2] 1445 mm	°C	

SEFLEX PROGRAM: TEST SERIES 3 and 4

Channel No.	Data Identification Type	Location	Unit	Remarks
73	Fluid Temperature	TF[4] 1925 mm	°C	
74	Grid Spacer Temp.	TA[2] 2535 mm	°C	
75	Grid Spacer Temp.	TA[2] 3080 mm	°C	
76	Grid Spacer Temp.	TA[3] 1478 mm	°C	
77	Fluid Temperature	TF[4] 2125 mm	°C	
78	Grid Spacer Temp.	TA[3] 2568 mm	°C	
79	Fluid Temperature	TF[6] 300 mm	°C	
80	Fluid Temperature	TF[5] 485 mm	°C	
81	Fluid Temperature	TF[5] 1135 mm	°C	
82	Fluid Temperature	TF[5] 1625 mm	°C	
83	Fluid Temperature	TF[5] 1725 mm	°C	
84	Fluid Temperature	TF[7] 1825 mm	°C	
85	Fluid Temperature	TF[5] 1925 mm	°C	
86	Fluid Temperature	TF[5] 2240 mm	°C	
87	Fluid Temperature	TF[5] 2380 mm	°C	
88	Fluid Temperature	TF[5] 2770 mm	°C	
89	Fluid Temperature	TF[5] 3038 mm	°C	
90	Fluid Temperature	TF[5] 3315 mm	°C	
91	Housing Temperature	TK[8] 283 mm	°C	
92	Housing Temperature	TK 590 mm	°C	34[9]
93	Housing Temperature	TK 1135 mm	°C	33[9], 34[9]
94	Housing Temperature	TK 1625 mm	°C	
95	Housing Temperature	TK 1825 mm	°C	
96	Housing Temperature	TK 2025 mm	°C	
97	Housing Temperature	TK 2235 mm	°C	
98	Housing Temperature	TK 2770 mm	°C	
99	Housing Temperature	TK 3018 mm	°C	
100	Housing Temperature	TK 3315 mm	°C	
101	Housing Temperature	TK 3820 mm	°C	

SEFLEX PROGRAM: TEST SERIES 3 and 4

Channel No.	Data Identification: Type	Location	Unit	Remarks
102	Housing Temperature	TK[8] 3915 mm	°C	
103	Temperature at Power Input		°C	
104	Heater Sheath Temp.	17.1.4.2075	°C	
105	Heater Sheath Temp.	18.a.1.2225	°C	
106	Heater Sheath Temp.	18.a.2.2770	°C	
107	Heater Sheath Temp.	18.a.3.3315	°C	
108	Fluid Temperature at Orifice		°C	
109	Fluid Temperature in Lower Plenum		°C	
110	Fluid Temperature in Upper Plenum		°C	
111	Feedwater Temperature		°C	
112	Room Temperature		°C	
113	Electrical Power Input	9 Rods	kW	Rods No. 1 to 9
114	Electrical Power Input	8 Rods	kW	Rods No. 10 to 17
115	Electrical Power Input	8 Rods	kW	Rods No. 18 to 25
116	Water Level Detector	4012 mm	°C	Heated and Unheated TC's
117	Water Level Detector	3932 mm	°C	Heated and Unheated TC's
118	System Pressure in Buffer		bar	
119	Flooding Velocity (cold bundle)		cm/s	
120	Pressure in Upper Plenum	-105 mm	bar	
121	Pressure in Lower Plenum	4091 mm	bar	
122	Bundle Power		kW	Channels: 113 + 114 + 115
123	Water Carry Over Collected		kg	Downstream of Bundle Exit

SEFLEX PROGRAM: TEST SERIES 3 and 4

Channel No.	Data Identification Type	Location	Unit	Remarks
124	Pressure Diff.	1835 and -105 mm	bar	
125	Pressure Diff.	2380 and 1835 mm	bar	
126	Pressure Diff.	4091 and 2380 mm	bar	
127	Pressure Diff.	4091 and -105 mm	bar	

1) TC's of 0.36 mm diameter embedded in rod cladding. Measuring position Example: rod No. = 3, type of rod instrumention = b, TC No. = 1, Axial level = 45 mm, referenced to the top flange of the bundle.

2) TA = TC's of 0.5 mm diameter brazed on surface of grid spacer at trailing edge. Measuring position: Example: Axial level = 355 mm. Subchannel surrounded by rods No. 8, 13, 12 and 7.

3) TA = TC's of 0.5 mm diameter brazed on surface of grid spacer at leading edge. Measuring position: Example: Axial level = 1478 mm. Subchannel surrounded by rods No. 13, 18, 17 and 12.

4) TF = TC's of 0.25 mm diameter (bare) placed in subchannel surrounded by rods No. 17, 22, 21 and 16.

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

6) TF = TC's of 0.25 mm diameter (bare) placed in subchannel surrounded by rods No. 7, 12, 11 and 6.

7) TF = TC's of 0.25 mm diameter (bare) placed in subchannel surrounded by rods No. 2, 7, 6 and 1.

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

9) TC failed in test No.