

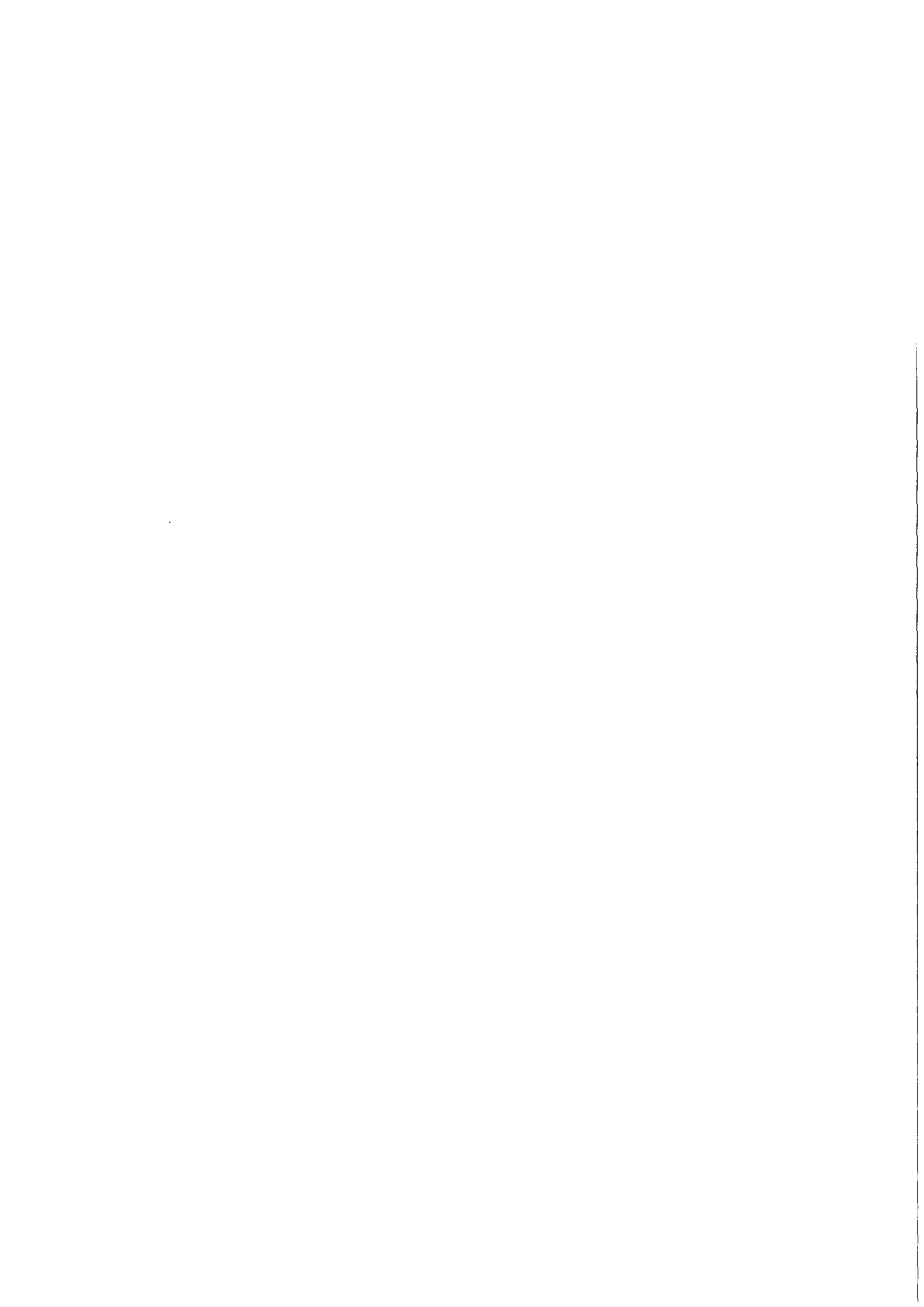
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SEFLEX Fuel Rod Simulator Effects in Flooding Experiments

**Part 2:
Unblocked Bundle Data**

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Kernforschungszentrum Karlsruhe



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Abstract

This report presents typical data and a limited heat transfer analysis from unblocked 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 blocked bundle data report (KfK 4026) an evaluation report summarizing the results of the total program (KfK 4024). These three reports conclude the SEFLEX-program.

SEFLEX - Brennstabsimulatoreffekte bei Flutexperimenten

Teil 2: Meßdaten von Experimenten mit unblockierten Bündeln

Kurzfassung

In diesem Bericht werden typische Meßergebnisse und eine begrenzte Wärmeübergangsanalyse von Flutversuchen mit unblockierten 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 blockierten Stabbündeln (KfK 4026) 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 clad 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 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 unblocked 5 x 5 REBEKA rod bundles having helium- or argon-filled gaps, i.e. data from SEFLEX test series 1 and 2.

A second data report [13] contains information about SEFLEX test series 3 and 4 performed with a 5 x 5 REBEKA rod bundle including a 90 percent flow blockage with bypass. The flow blockage was realized by artificially ballooned Zircaloy claddings at the bundle midplane of 3 x 3 rods placed in the corner of the 5 x 5 rod bundle.

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 design, and the operational procedure are briefly outlined to provide the experimental background for the present study.

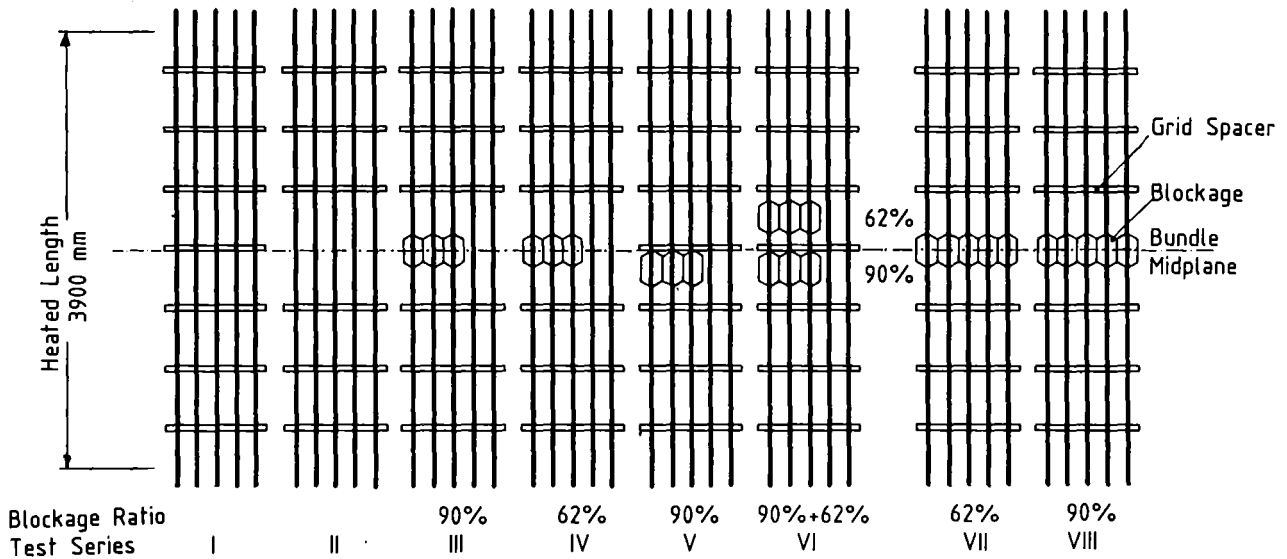
In the subsequent SEFLEX-program, for comparison forced feed reflood tests were carried out using rods with helium- or argon-filled gaps between Zircaloy-4 claddings and alumina pellets. The flow blockages were simulated by artificially ballooned Zircaloy claddings providing the same blockage geometry 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

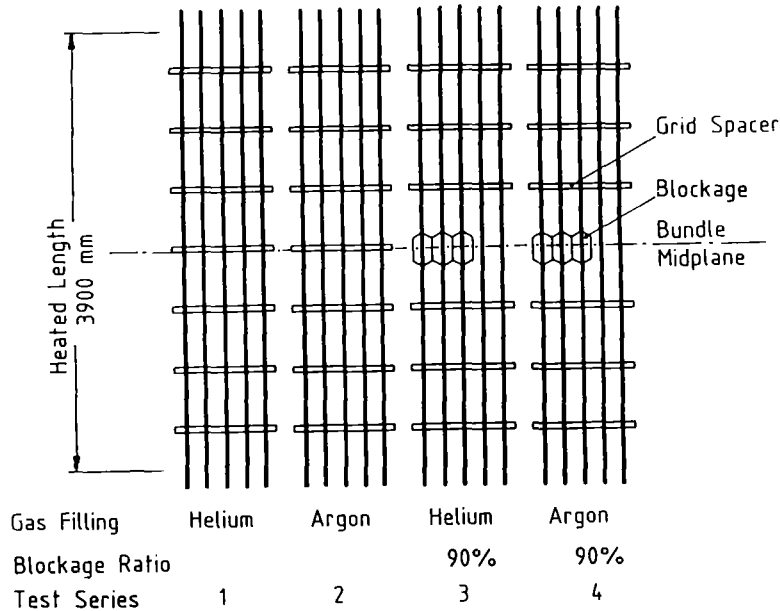
FEBA-program: Bundle geometry of test series I through VIII.
Axial arrangement of grid spacers and flow blockages.



- 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.



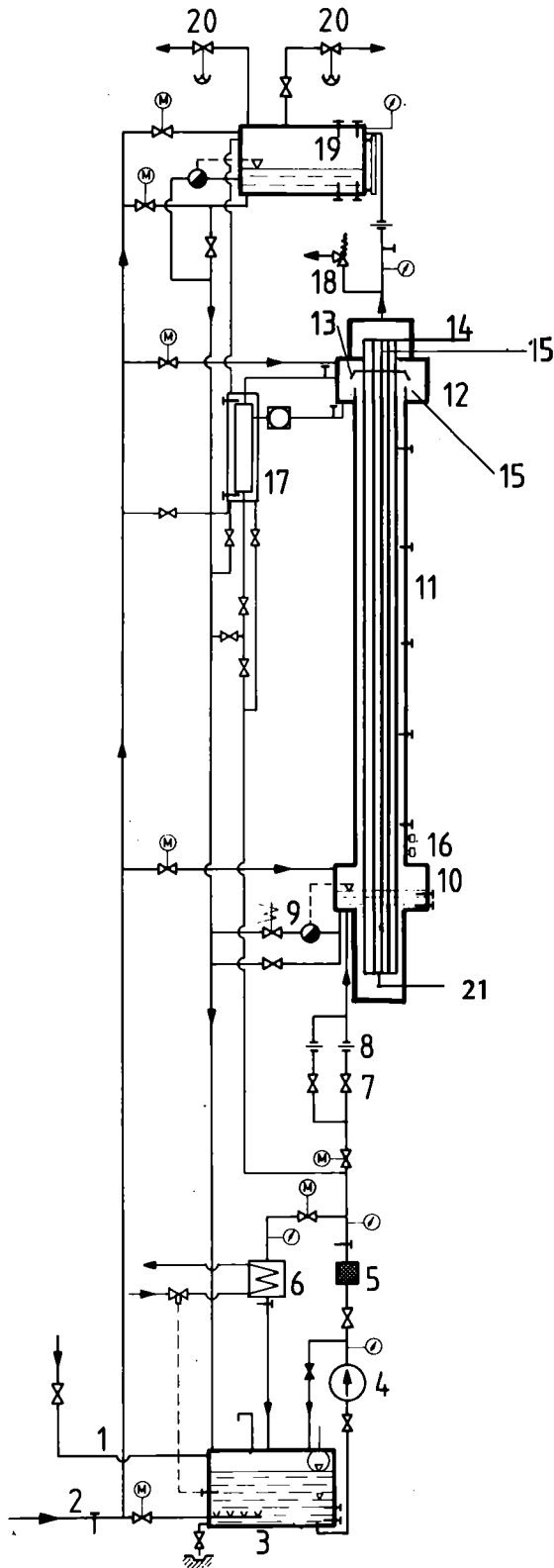
- Series 1: Rods with helium-filled gaps between Zircaloy claddings and alumina pellets; undisturbed bundle geometry with seven grid spacers. Investigation of the effects of rod clad properties, conductivity of gas filled gaps, and grid spacers. Comparison with FEBA test series I and SEFLEX test series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

The remaining characteristics of both types of fuel rod simulators are the same. Figure 5 shows an axial layout of the fuel rod simulators. The cosine power profile of the rods with a heated length of 3900 mm is approximated by seven steps of specific power. The axial power profile is 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 78.5 mm and a wall thickness of 6.5 mm. 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. Seven original PWR grid spacers without mixing vanes were installed with one at the bundle midplane (axial level 2025 mm) and others at 545 mm intervals throughout the rod assemblies. 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.

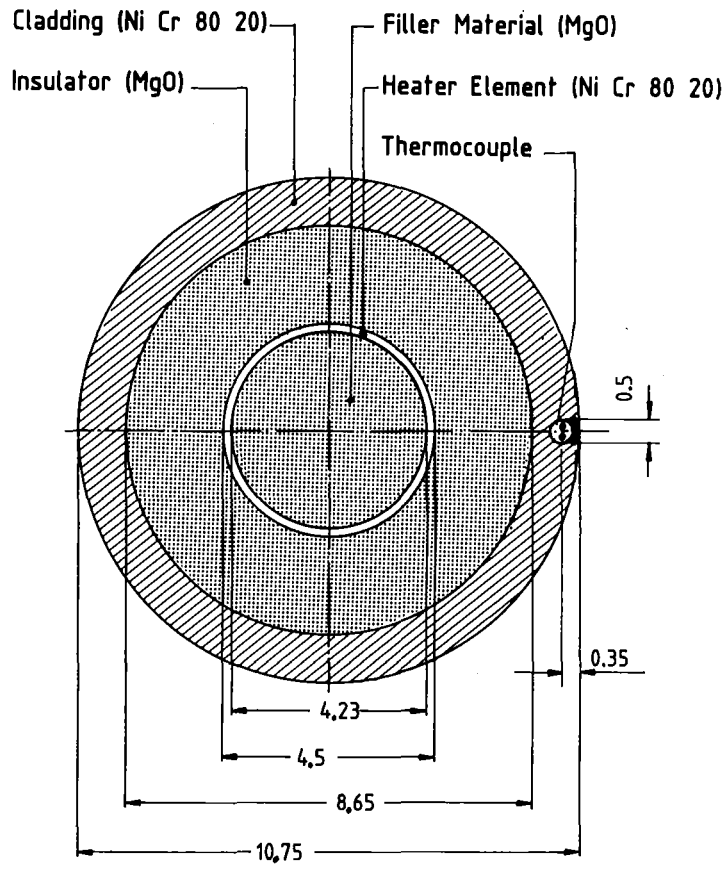


Figure 2. Cross section of a FEBA heater rod.

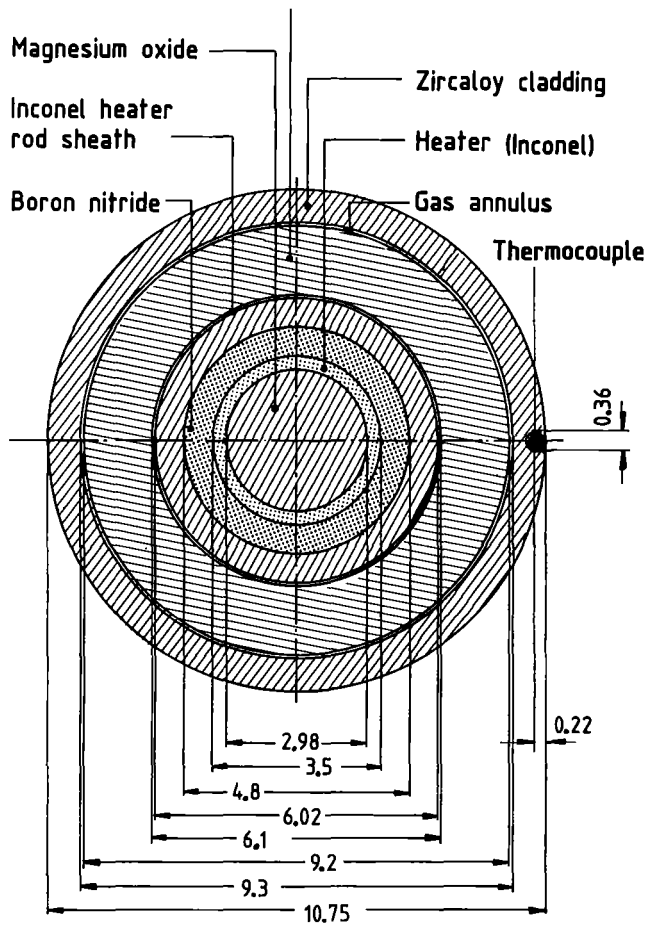


Figure 3. Cross section of a REBEKA fuel rod simulator.

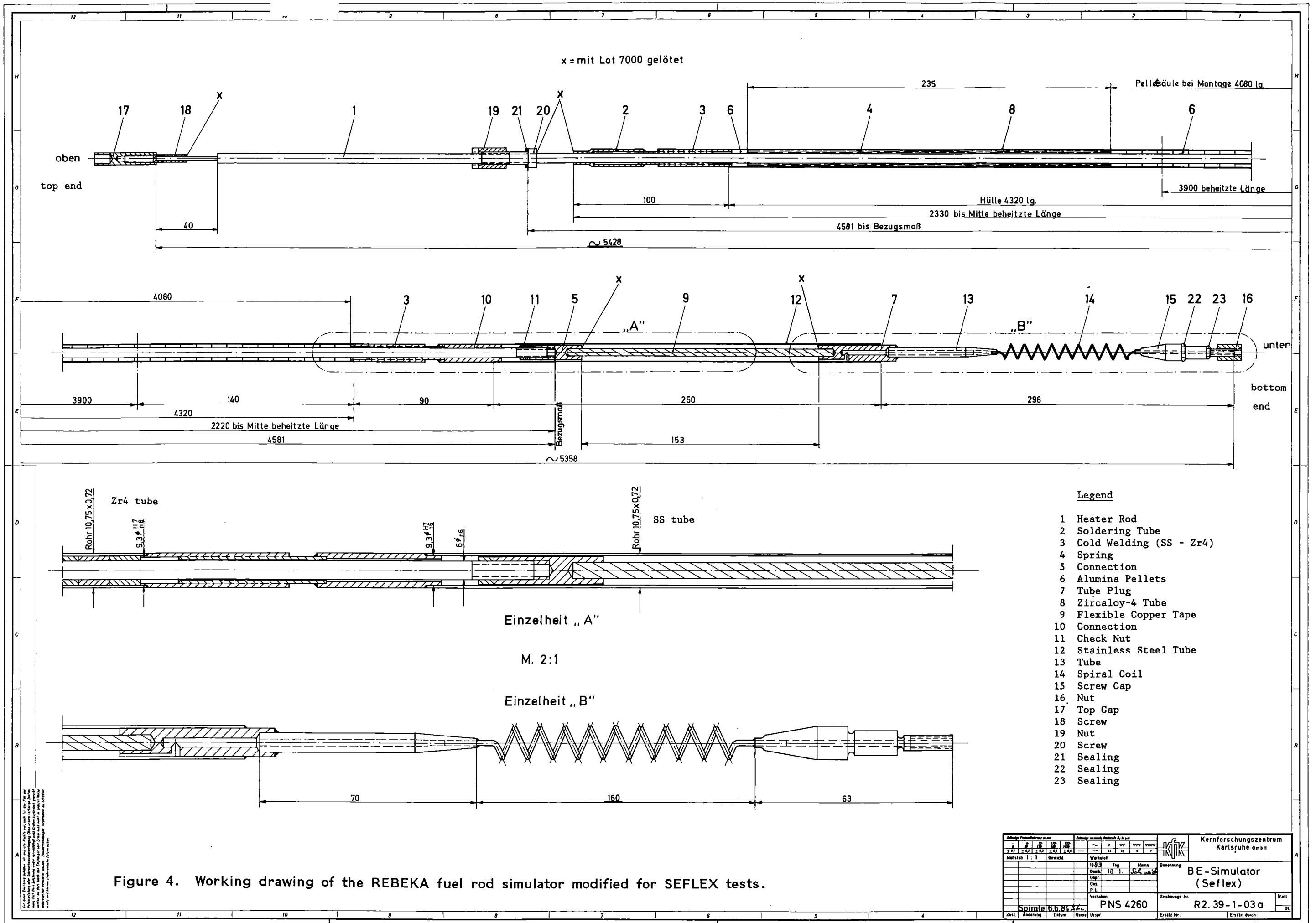


Figure 4. Working drawing of the REBEKA fuel rod simulator modified for SEFLEX tests.

Kernforschungszentrum Karlsruhe GmbH			
BE-Simulator (Seflex)			
Zeichnungs-Nr. R2.39-1-03a		Blatt BL	

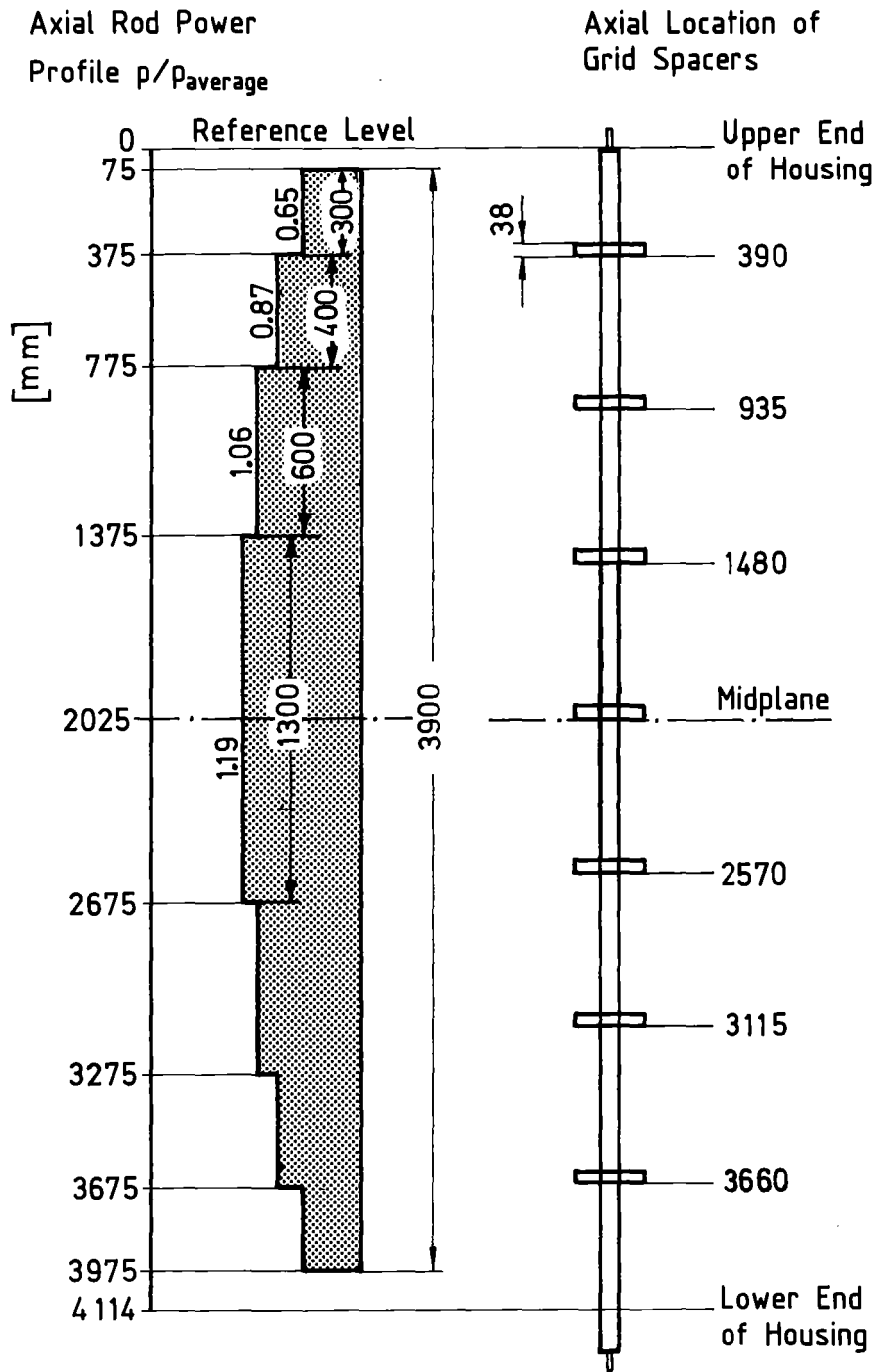


Figure 5. Axial power profile and location of grid spacers of FEBA and REBEKA rod bundles in SEFLEX.

5. Instrumentation

Most part of the SEFLEX instrumentation consisted of thermocouples (Chromel-Alumel), since cladding (TS), grid spacer (TA), fluid (TF) and housing (TK) temperatures were to be measured at various positions. Figure 6 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 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 1 and 2 summarized in Section 11.

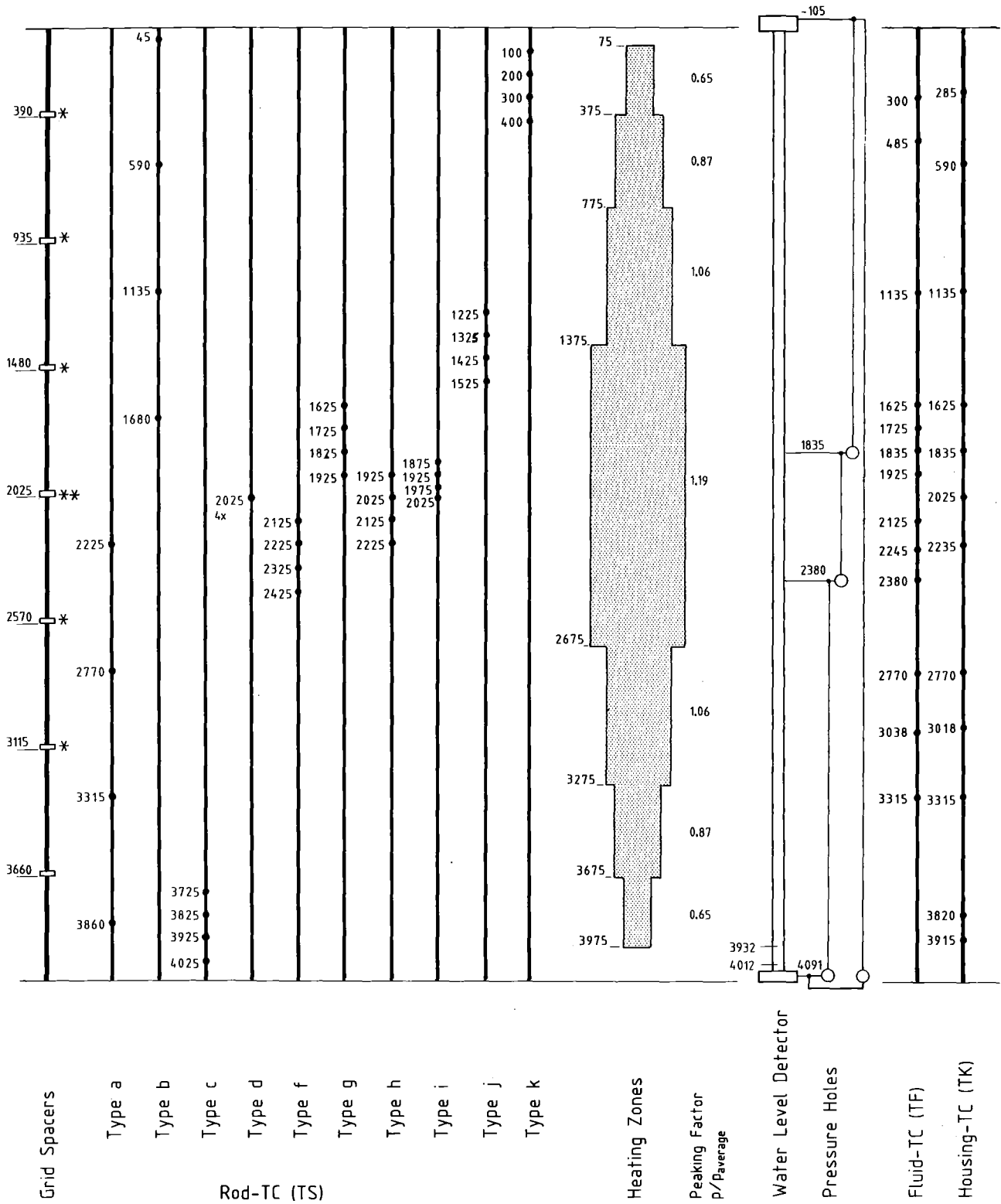
The cladding temperatures were measured with 0.36 mm sheath outer diameter thermocouples having an insulated junction. These thermocouples were embedded in grooves which were milled into the outer surface of the Zircaloy claddings. The grooves were closed by peening over to avoid any disturbance of the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

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 difference was measured along the entire bundle length. The flooding rate was measured with



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

Figure 6. Schematic diagram of SEFLEX instrumentation for unblocked rod bundle tests.

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.

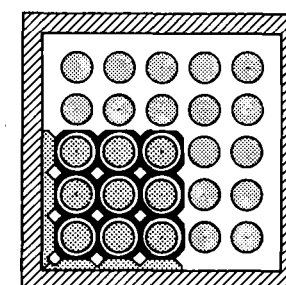
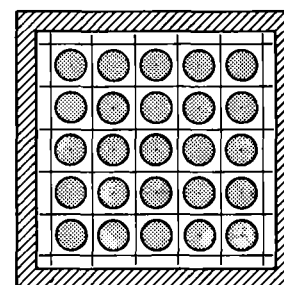
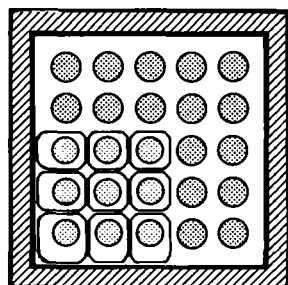
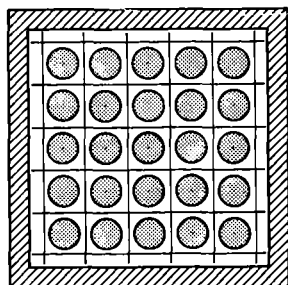
6. Test Matrix

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 flooding velocities of 3.8 and 5.8 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		
FEBA	I	218	FEBA	SS	gapless	5.8	2.1	40		
FEBA	I	214	FEBA	SS	gapless	5.8	4.1	40		
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		

7. Data Informations

For the data transfer, data management, one-dimensional heat transfer analysis and data representation the modified and supplemented HETRAP-computer code [14] was used. The PEW-computer code [15] describing the thermophysical material properties was revised to incorporate the data of helium and argon gases [16].

This data report contains a large sampling of data from five reflood tests performed with an unblocked 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 7 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 8 is to identify the main measuring positions 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 1 and 2.

It should be noted that for each test run 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 run. The same is valid for the grid spacer temperatures, fluid tempera-

tures 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 [$^{\circ}\text{C}$] of the center rod claddings in axial direction [mm].
- Flooding parameters: Flooding velocity [cm/s], system pressure [bar] measured in the buffer, feedwater temperature [$^{\circ}\text{C}$] and bundle power [kW].
- Cladding temperatures [$^{\circ}\text{C}$] 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, i.e. axial levels 2425, 2325, 2225, and 2125 mm.
Corresponding heat transfer coefficients.
- Cladding temperatures at the bundle midplane, i.e. axial level 2025 mm.
Corresponding heat transfer coefficients.
- Cladding temperatures measured immediately downstream of the bundle midplane, in the wake of the bundle midplane grid spacer, i.e. axial level 2025, 1975, 1925, and 1875 mm.
Corresponding heat transfer coefficients.
- Cladding temperatures measured downstream of the bundle midplane between two grid spacer positions, i.e. axial level 1925, 1825, 1725 and 1625 mm. Corresponding heat transfer coefficients.
- Cladding temperatures measured about the grid spacer placed next to the bundle midplane grid spacer in flow direction, i.e. axial levels 1525, 1425, 1325 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.

- Grid spacer temperatures [$^{\circ}\text{C}$] 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.

Unfortunately, the data of the pressure drop measurements along the lower bundle position, the bundle midplane, and the upper bundle portion were destroyed during the data transfer of SEFLEX test series 1 and 2.

- Coolant outlet: water carry over [kg] measured in the water collecting tank, steam temperature [$^{\circ}\text{C}$], and pressure [bar] both measured in the upper plenum.
- Axial position of the quench front [mm] as function of reflood time.

Table 4

SEFLEX-program: Main test parameters of test series 1 and 2.

SEFLEX test series 1

Rods with helium-filled gaps between Zircaloy claddings and alumina pellets; undisturbed bundle geometry with seven grid spacers.

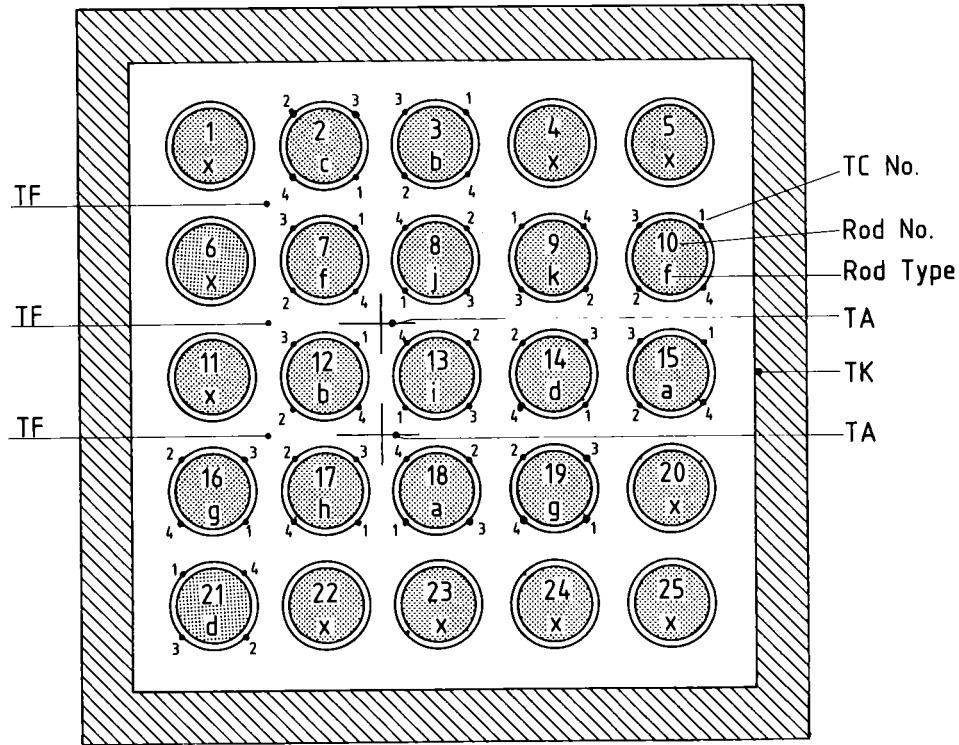
Test No.	Flooding	System Pressure bar	Feedwater Temp. ¹ °C		Bundle Power ² kW		Gap Gas Filling ³	Remarks
	Velocity cm/s		0-30 s	End	0 s	Transient		
05	3.8	2.1	45	37	200	120% ANS	Helium	Figs. 9 to 41
03	3.8	4.1	49	37	200	120% ANS	Helium	Figs. 42 to 74
06	5.8	2.1	43	36	200	120% ANS	Helium	Figs. 75 to 107
04	5.8	4.1	42	37	200	120% ANS	Helium	Figs.108 to 140
01	3.8	4.1	44	36	200	120% ANS	Helium	no data plotted
02	3.8	4.1	48	37	200	120% ANS	Helium	no data plotted

SEFLEX test series 2

Rods with argon-filled gaps between Zircaloy claddings and alumina pellets; undisturbed bundle geometry with seven grid spacers.

Test No.	Flooding	System Pressure bar	Feedwater Temp. ¹ °C		Bundle Power ² kW		Gap Gas Filling ³	Remarks
	Velocity cm/s		0-30 s	End	0 s	Transient		
07	3.8	2.1	54	53	200	120% ANS	Argon	Figs.141 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.



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

Rod Type	TC No.	Axial Level mm
f	1	2125
	2	2225
	3	2325
	4	2425
g	1	1625
	2	1725
	3	1825
	4	1925
h	1	1925
	2	2025
	3	2125
	4	2225
i	1	1875
	2	1925
	3	1975
	4	2025

Rod Type	TC No.	Axial Level mm
j	1	1225
	2	1325
	3	1425
	4	1525
k	1	100
	2	200
	3	300
	4	400
x	without TC's	

Figure 7. Radial and axial positions of cladding, grid spacer, fluid, and housing TC's for unblocked rod bundle tests.

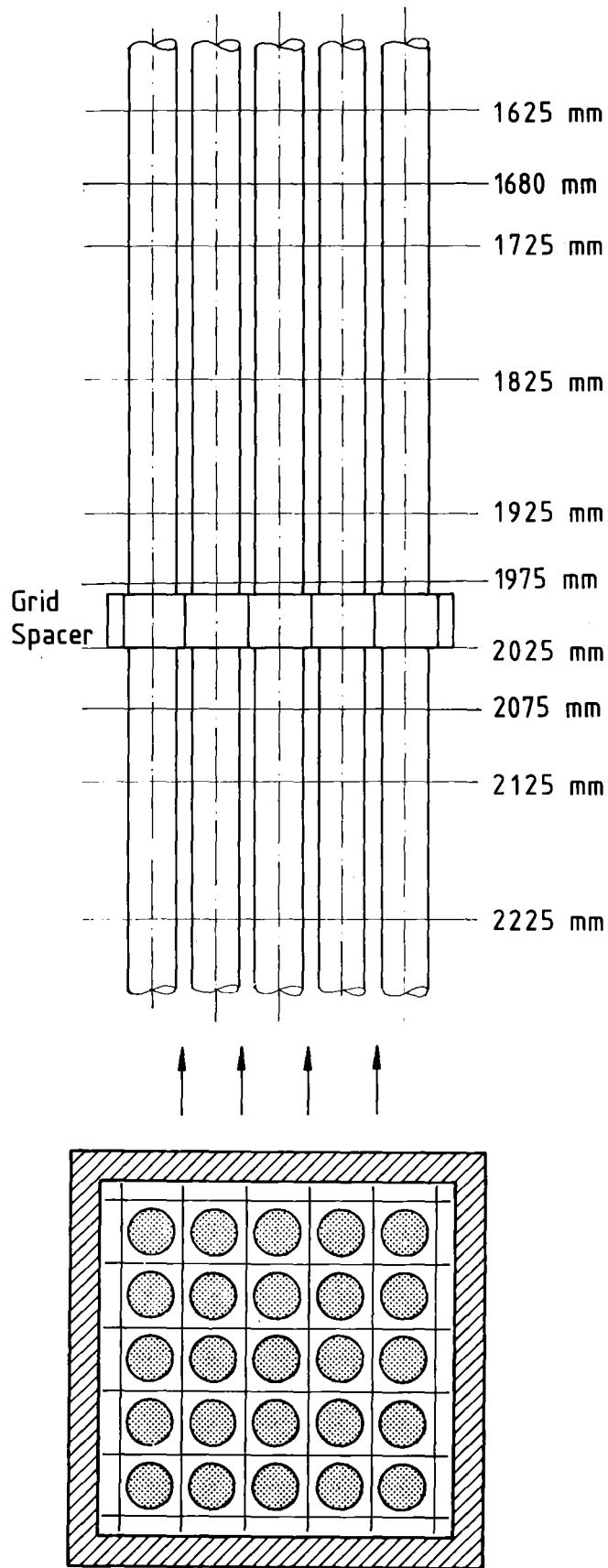


Figure 8. Sectional view of an unblocked rod bundle at the midplane.

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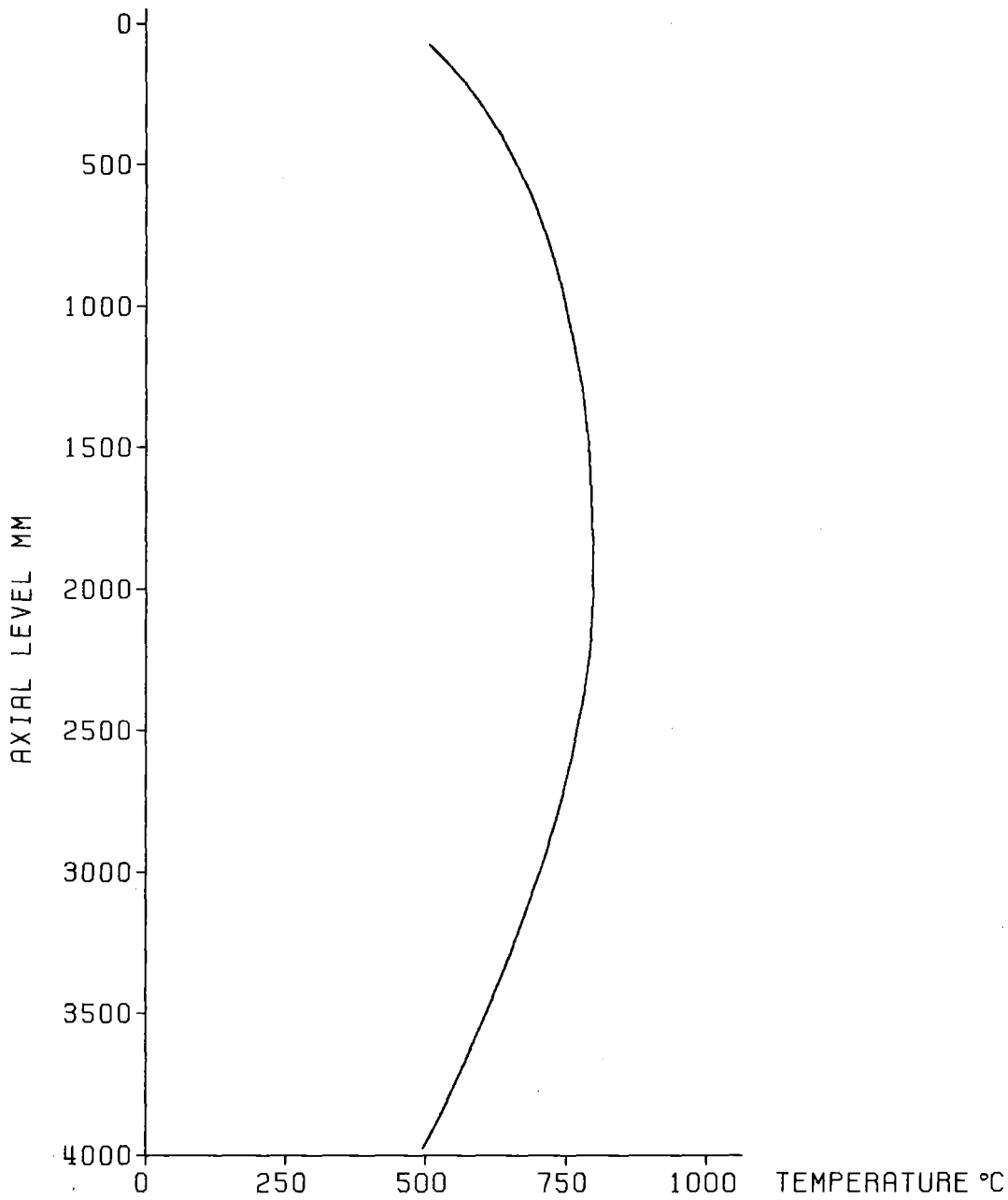
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Initial Axial Temperature Profile of Claddings
REBEKA Rods With Helium Filled Gaps

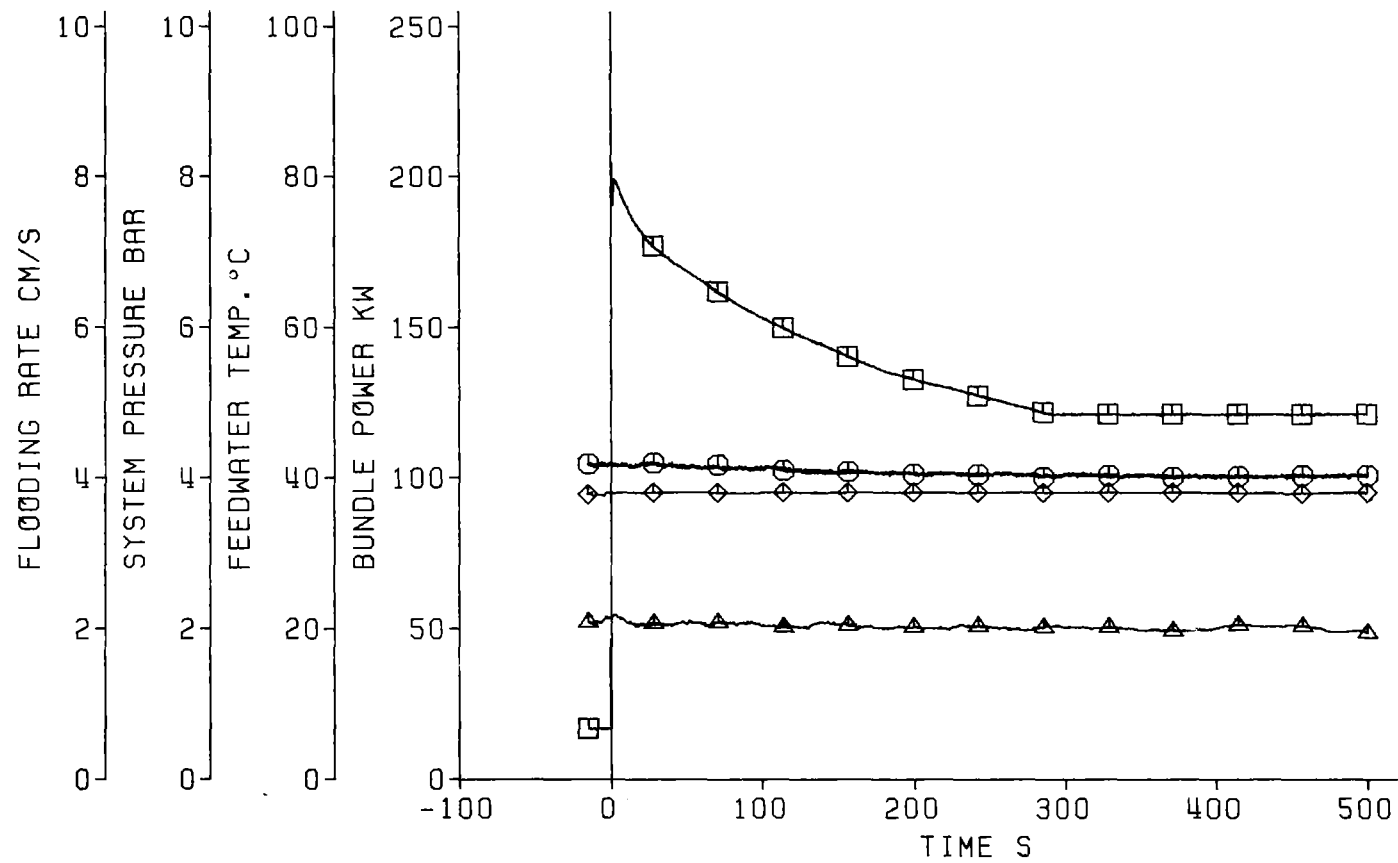


Decay Heat	120% ANS Standard
Flooding Rate (cold)	3.81 cm/s
System Pressure	2.11 bar
Feedwater Temperature	40 °C



Fig. 9 SEFLEX: 5x5 ROD BUNDLE
TEST SERIES 1, TEST-No. 05

Test Parameters:



◇ Flooding Rate
△ System Pressure
○ Feedwater Temperature
□ Bundle Power

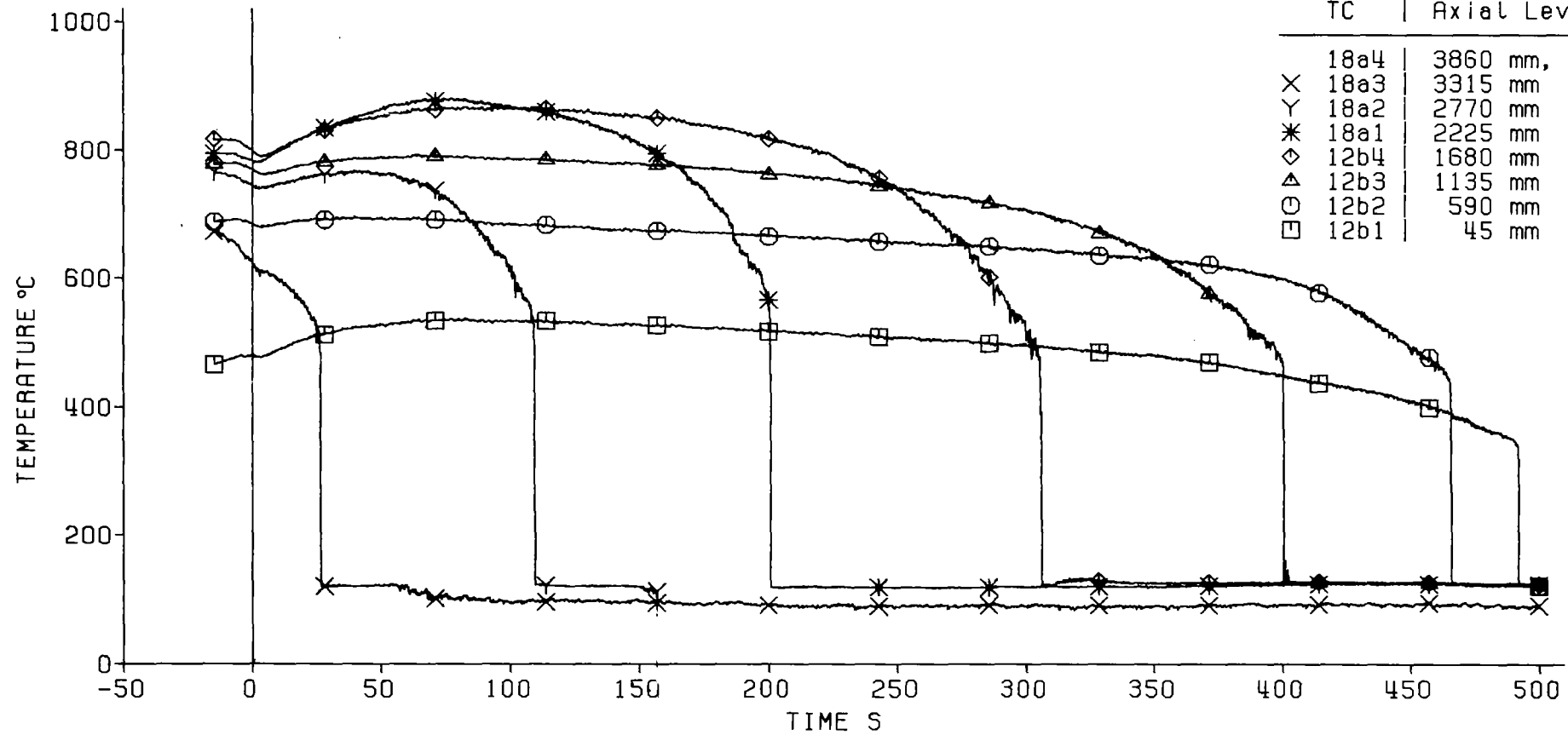
Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.81 cm/s
System Pressure 2.11 bar
Feedwater Temperature 40°C

REBEKA Rods With Helium Filled Gaps



Fig. 10 SEFLEX: 5x5 ROD BUNDLE, SERIES 1, TEST-NO. 05

Cladding Temperature

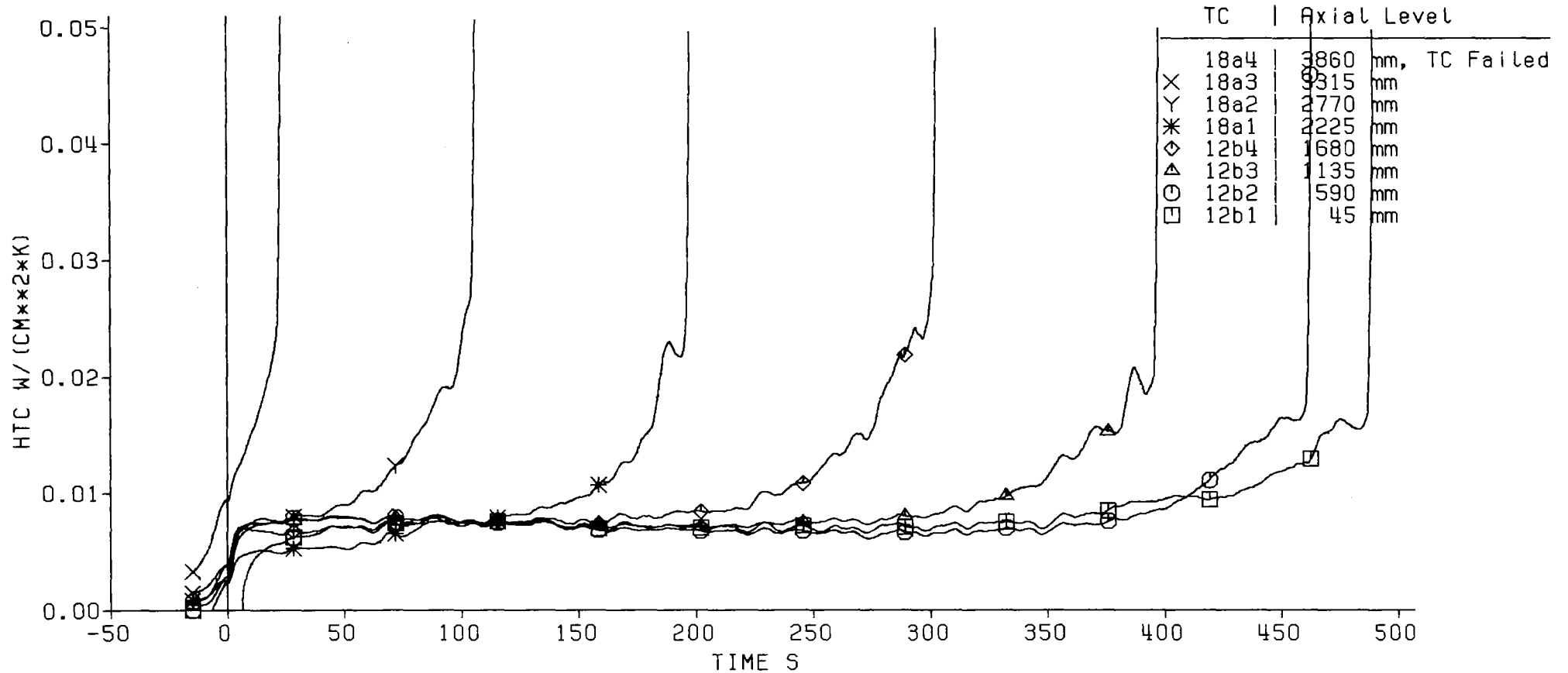


Decay Heat 120% ANS Standard
 Flooding Rate (cold) 3.81 cm/s
 System Pressure 2.11 bar
 Feedwater Temperature 40 °C

REBEKA Rods With Helium Filled Gaps



Fig. 11 SEFLEX: 5x5 ROD BUNDLE, SERIES 1, TEST-No. 05



Decay Heat
 Flooding Rate (cold)
 System Pressure
 Feedwater Temperature

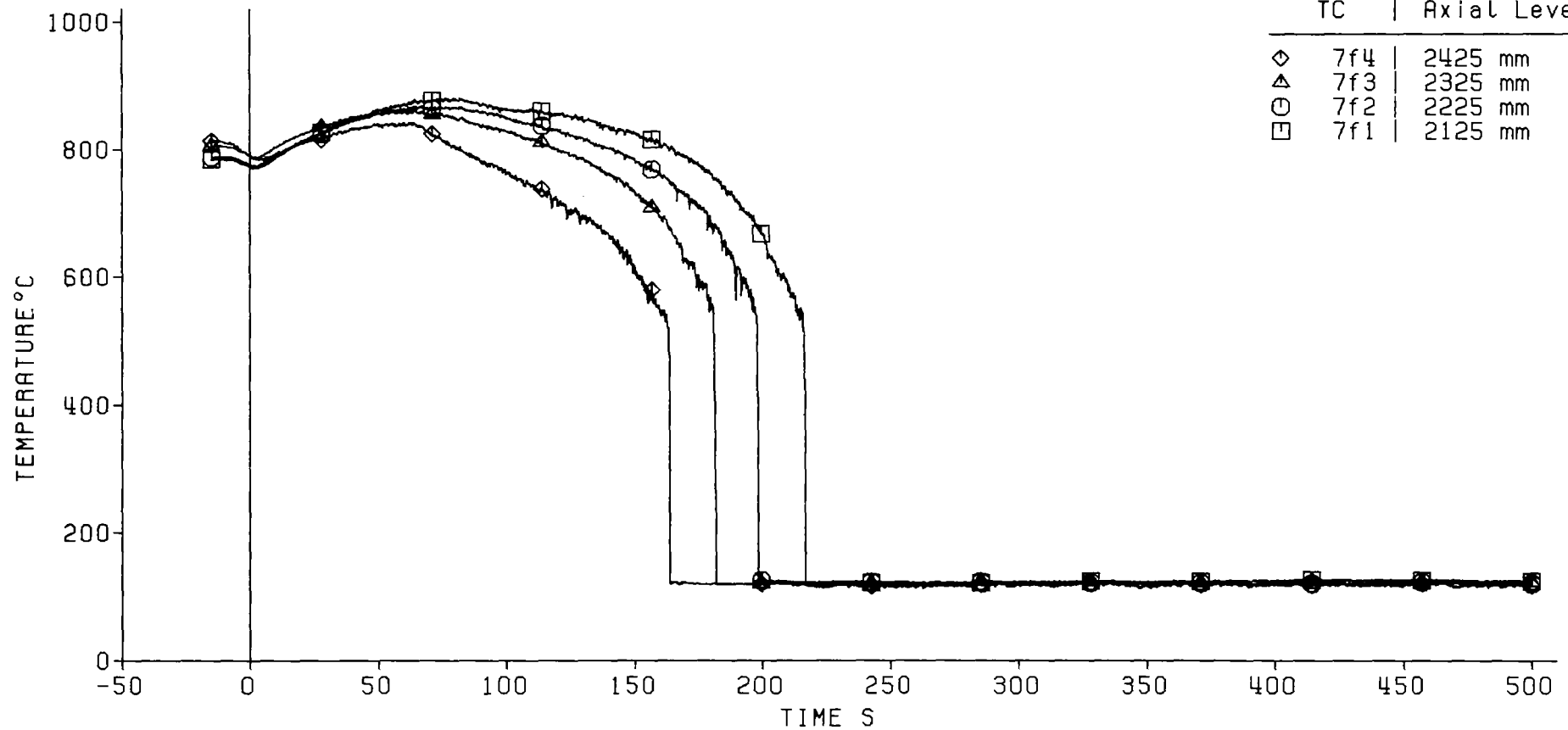
120% ANS Standard
 3.81 cm/s
 2.11 bar
 40 °C

REBEKA Rods With
 Helium Filled Gaps

KIRB

Fig. 12 SEFLEX: 5x5 ROD BUNDLE, SERIES 1, TEST-No. 05

Cladding Temperature



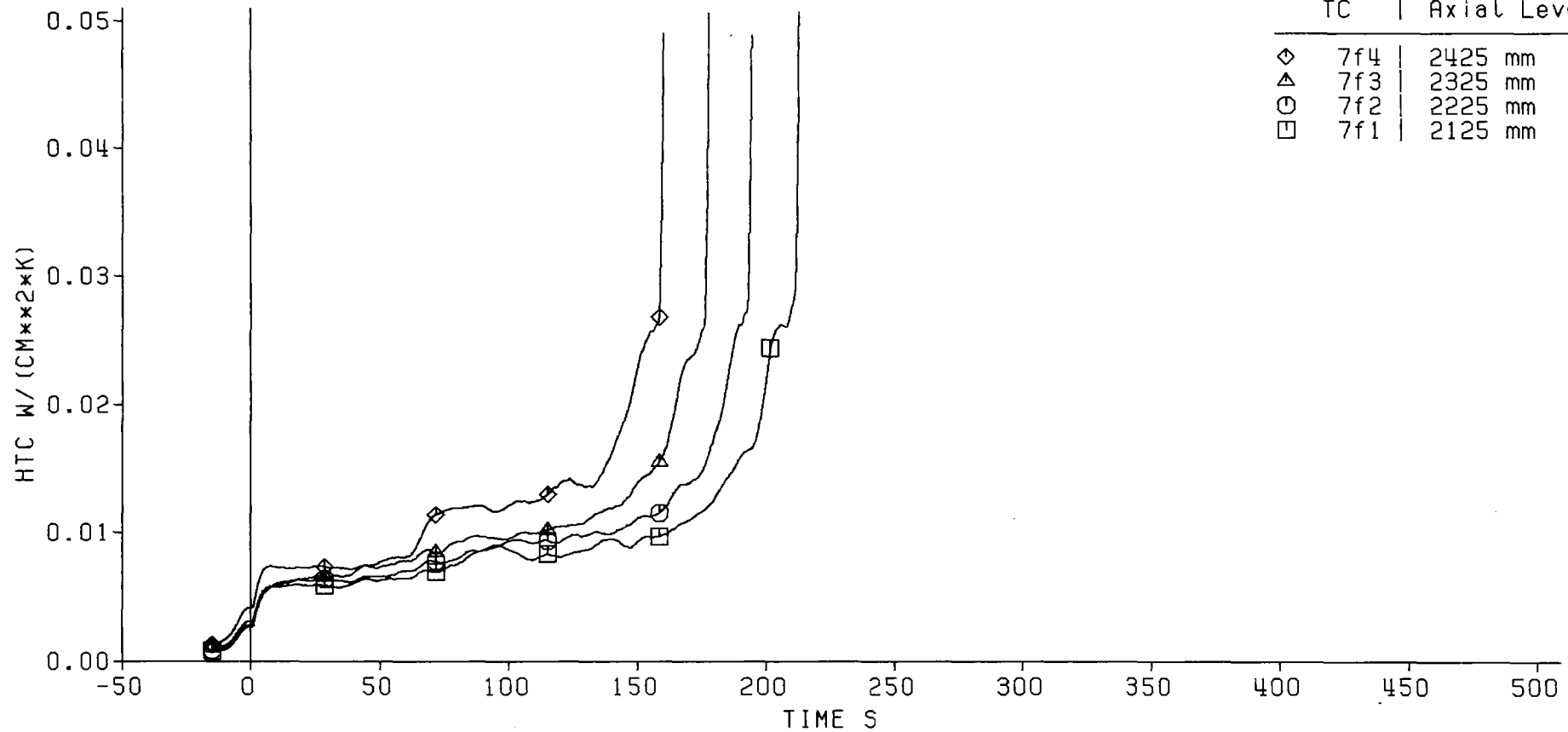
— 32 —

Decay Heat 120% ANS Standard
 Flooding Rate (cold) 3.81 cm/s
 System Pressure 2.11 bar
 Feedwater Temperature 40 °C

REBEKA Rods With Helium Filled Gaps



Fig. 13 SEFLEX: 5x5 ROD BUNDLE, SERIES 1, TEST-No. 05



Decay Heat
 Flooding Rate (cold) 3.81 cm/s
 System Pressure 2.11 bar
 Feedwater Temperature 40°C

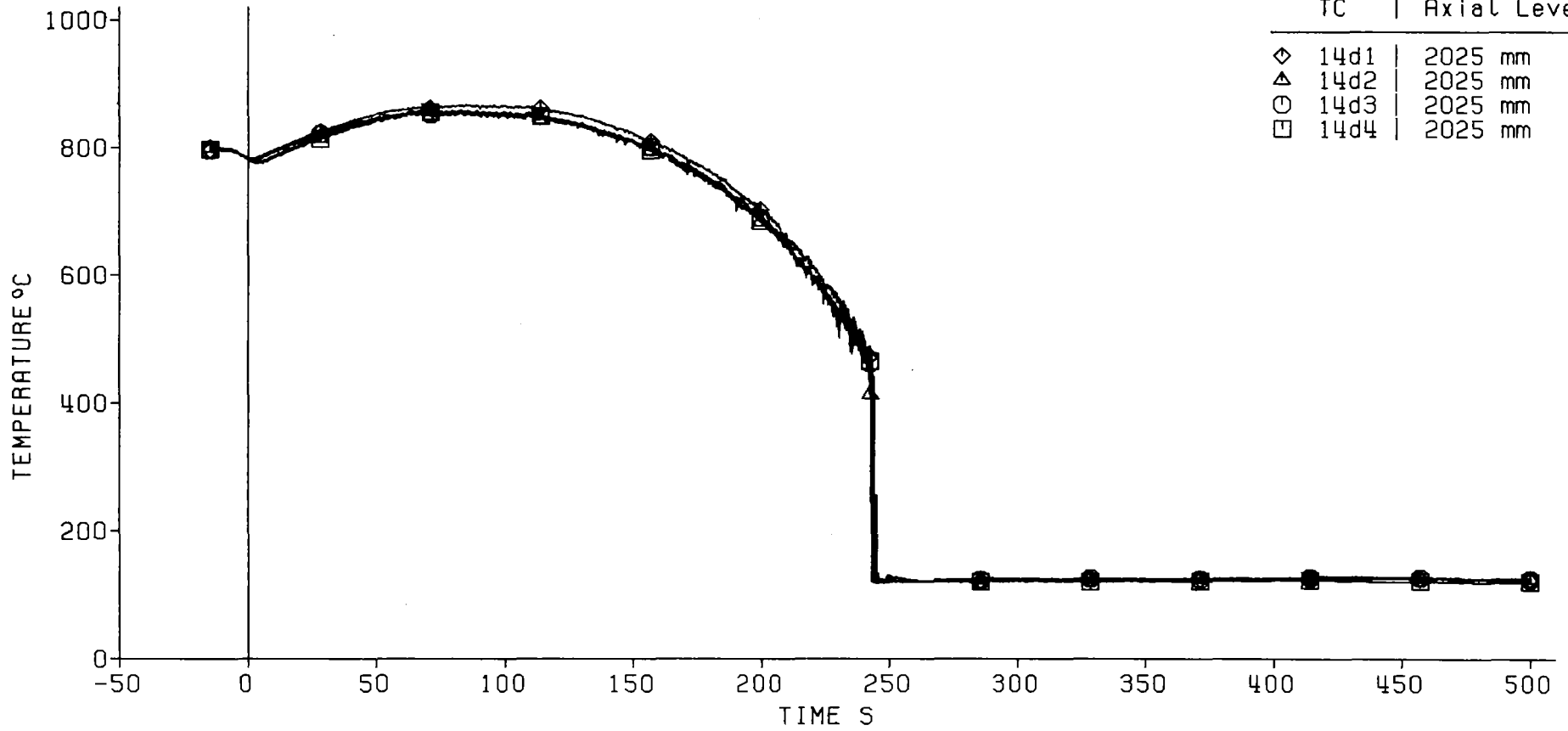
120% ANS Standard

REBEKA Rods With
 Helium Filled Gaps

KIRB

Fig. 14 SEFLEX: 5x5 ROD BUNDLE, SERIES 1, TEST-No. 05

Cladding Temperature



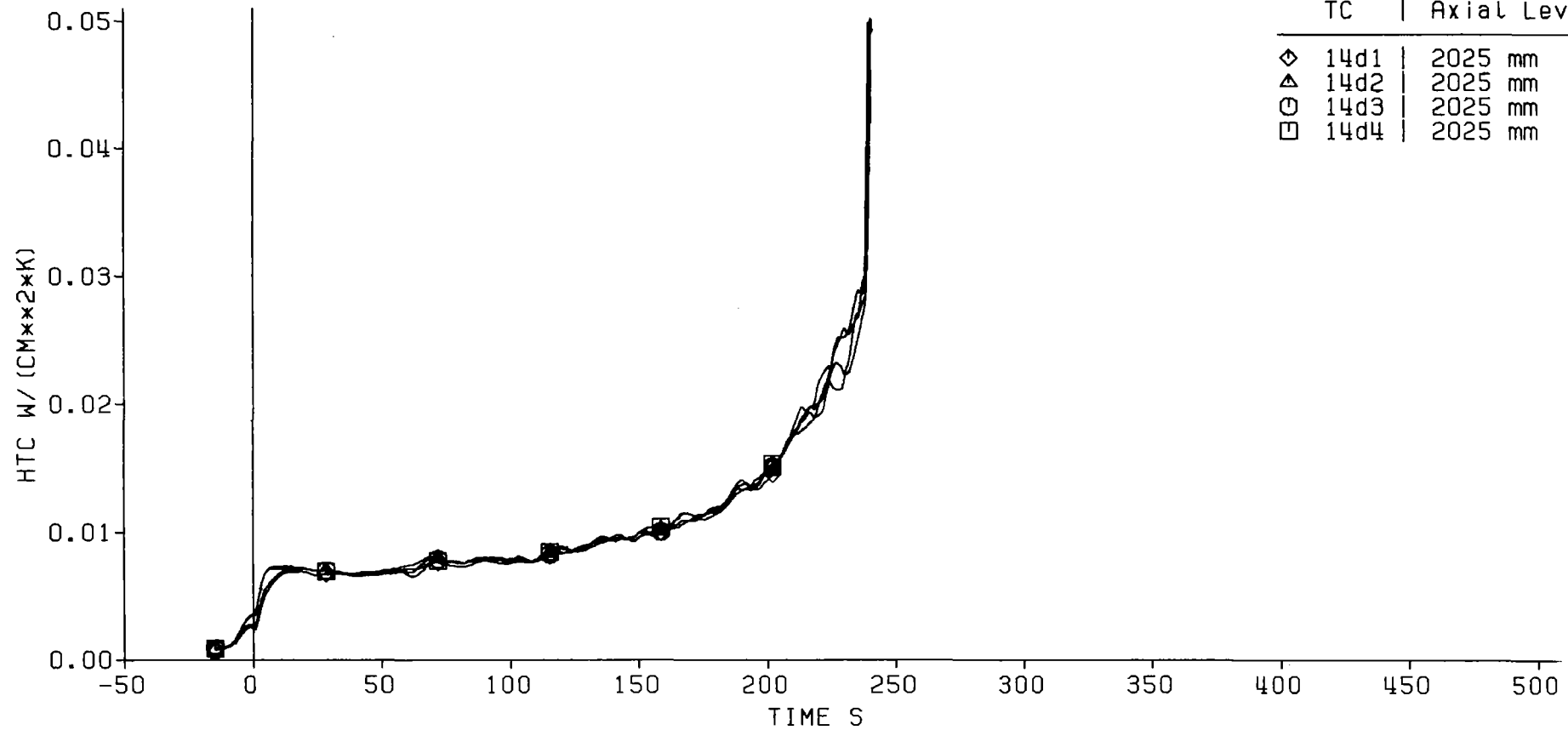
— 34 —

Decay Heat 120% ANS Standard
 Flooding Rate (cold) 3.81 cm/s
 System Pressure 2.11 bar
 Feedwater Temperature 40°C

REBEKA Rods With
 Helium Filled Gaps



Fig. 15 SEFLEX: 5x5 ROD BUNDLE, SERIES 1, TEST-No. 05



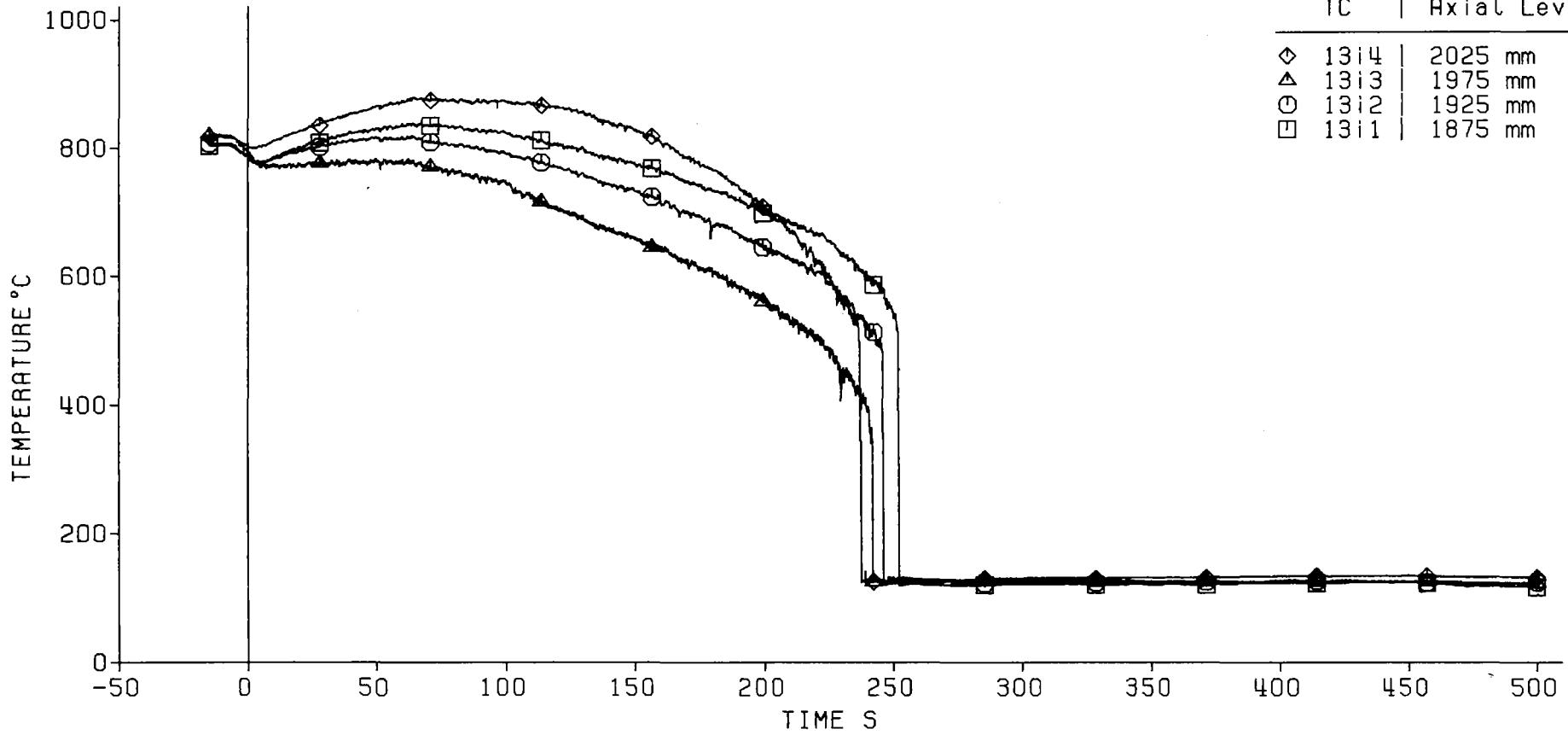
Decay Heat 120% ANS Standard
 Flooding Rate (cold) 3.81 cm/s
 System Pressure 2.11 bar
 Feedwater Temperature 40°C

REBEKA Rods With
 Helium Filled Gaps

KJK
 IRB

Fig. 16 SEFLEX: 5x5 ROD BUNDLE, SERIES 1, TEST-No. 05

Cladding Temperature

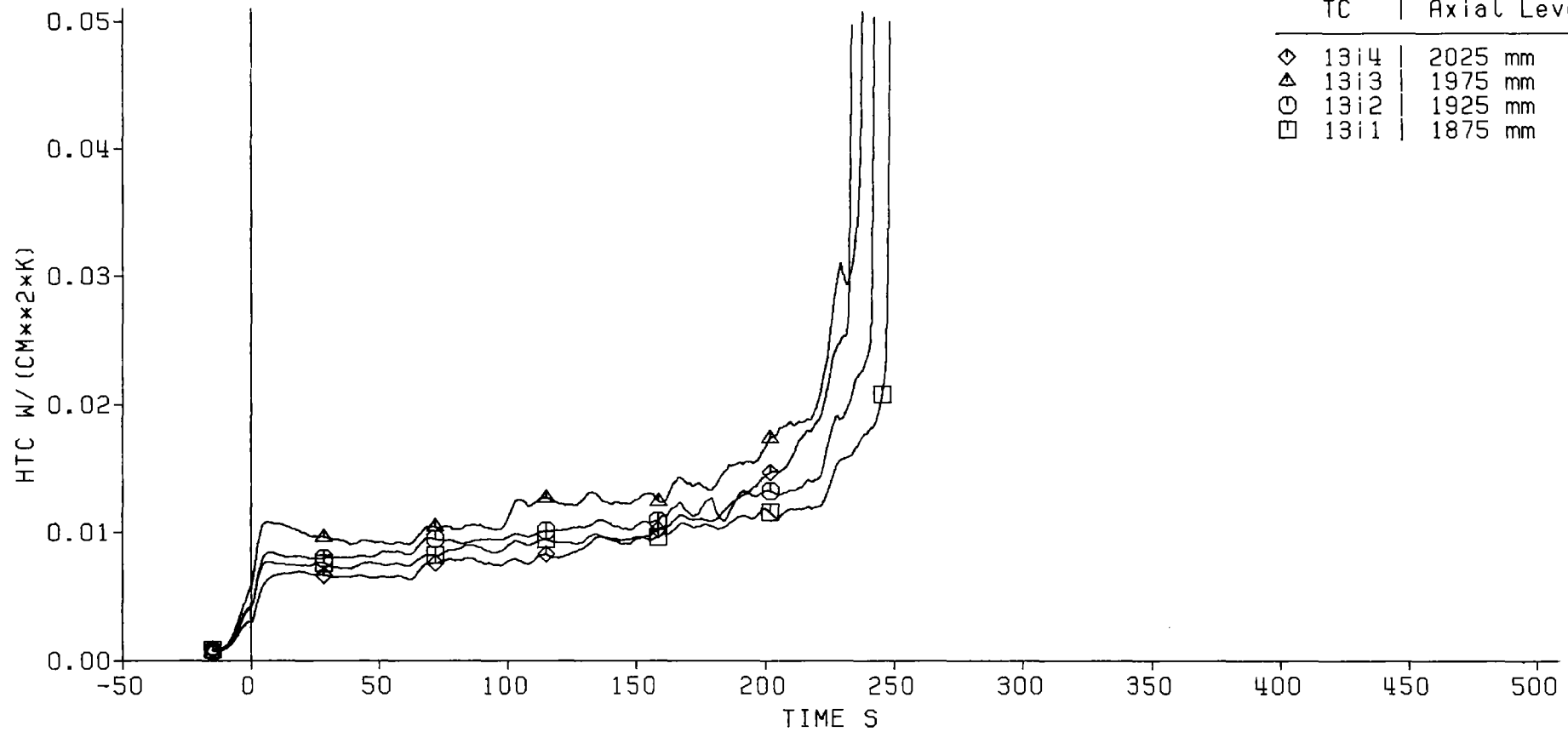


Decay Heat 120% ANS Standard
 Flooding Rate (cold) 3.81 cm/s
 System Pressure 2.11 bar
 Feedwater Temperature 40 °C

REBEKA Rods With Helium Filled Gaps



Fig. 17 SEFLEX: 5x5 ROD BUNDLE, SERIES 1, TEST-No. 05



Decay Heat
 Flooding Rate (cold) 3.81 cm/s
 System Pressure 2.11 bar
 Feedwater Temperature 40°C

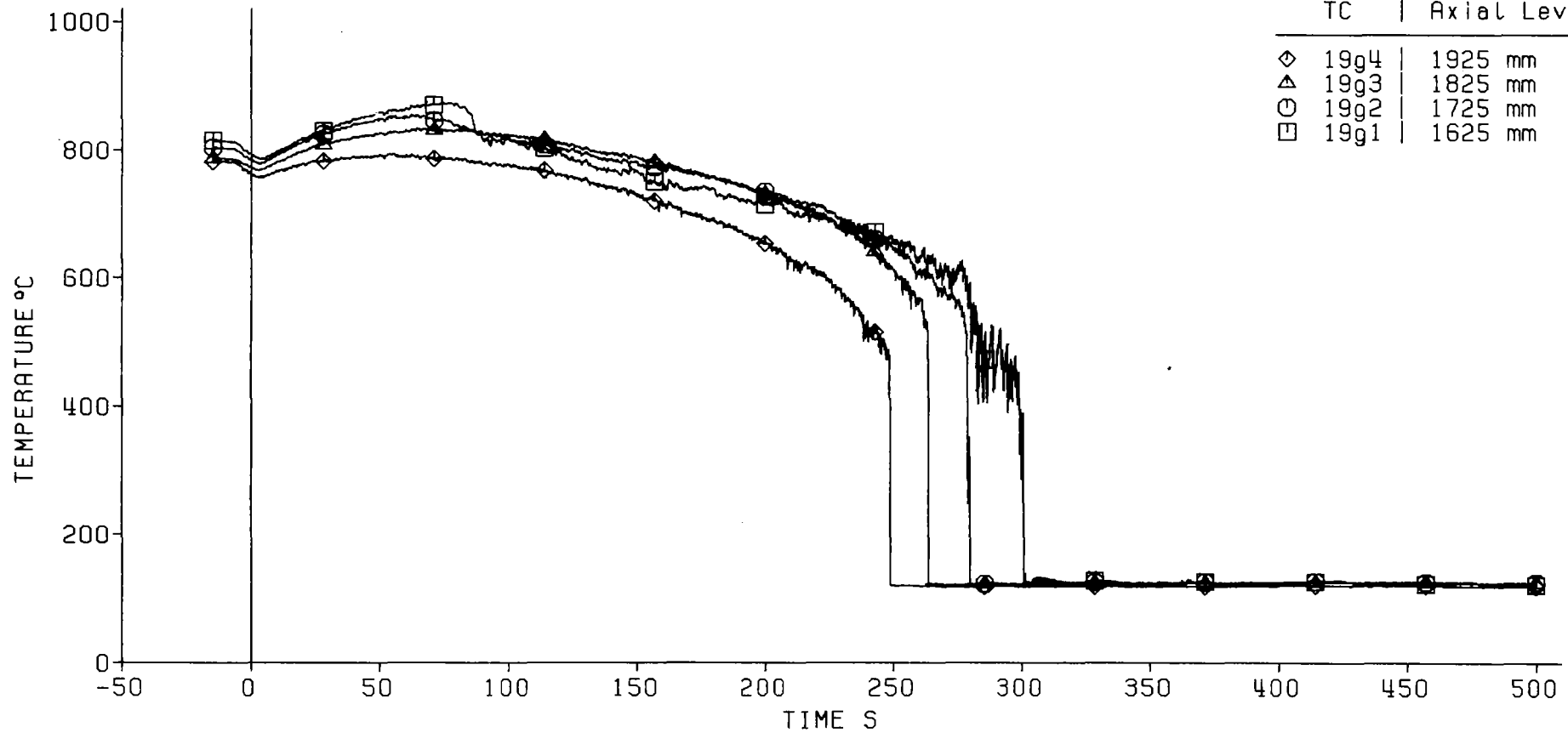
120% ANS Standard

REBEKA Rods With
 Helium Filled Gaps

KFK
 IRB

Fig. 18 SEFLEX: 5x5 ROD BUNDLE, SERIES 1, TEST-No. 05

Cladding Temperature

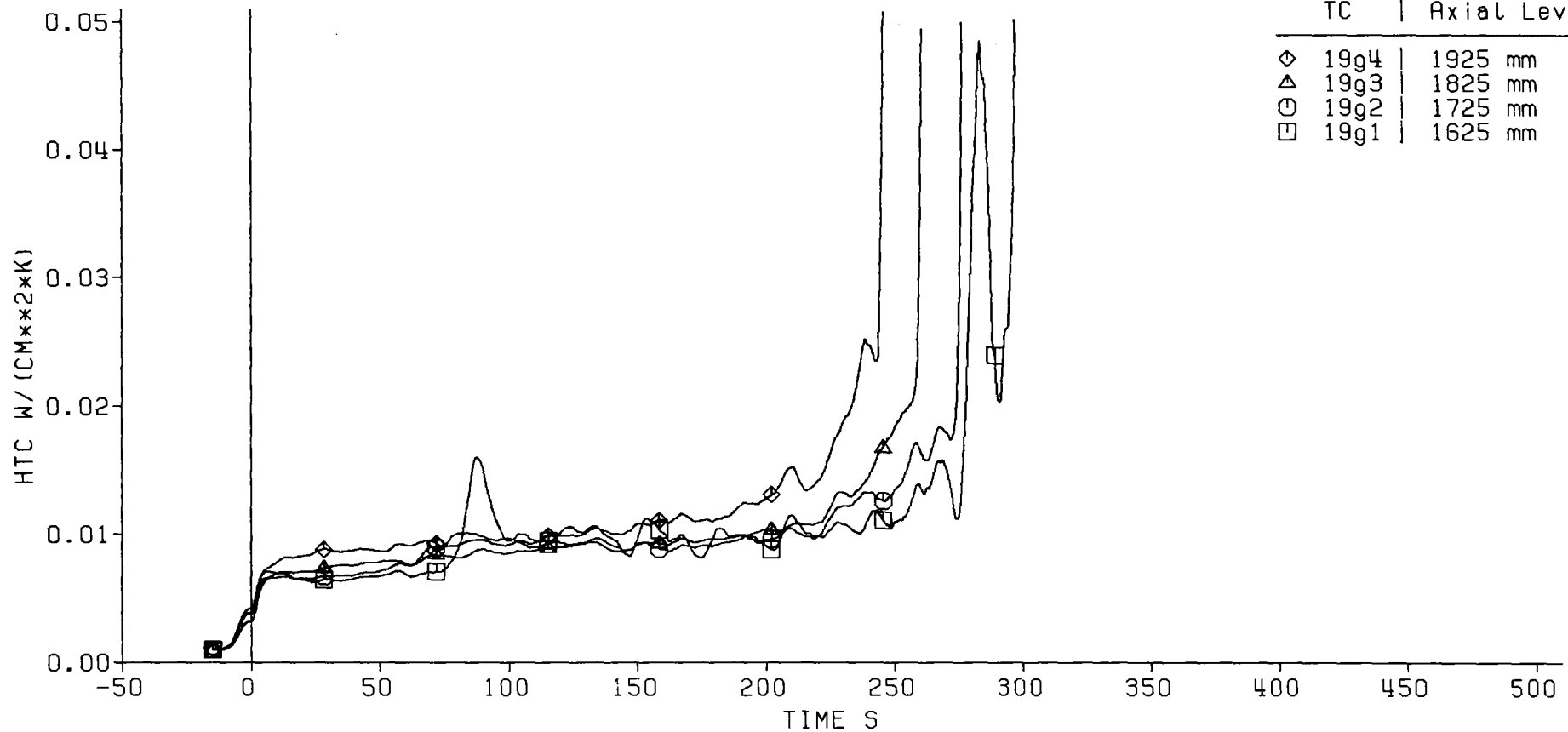


Decay Heat 120% ANS Standard
 Flooding Rate (cold) 3.81 cm/s
 System Pressure 2.11 bar
 Feedwater Temperature 40 °C

REBEKA Rods With Helium Filled Gaps



Fig. 19 SEFLEX: 5x5 ROD BUNDLE, SERIES 1, TEST-No. 05



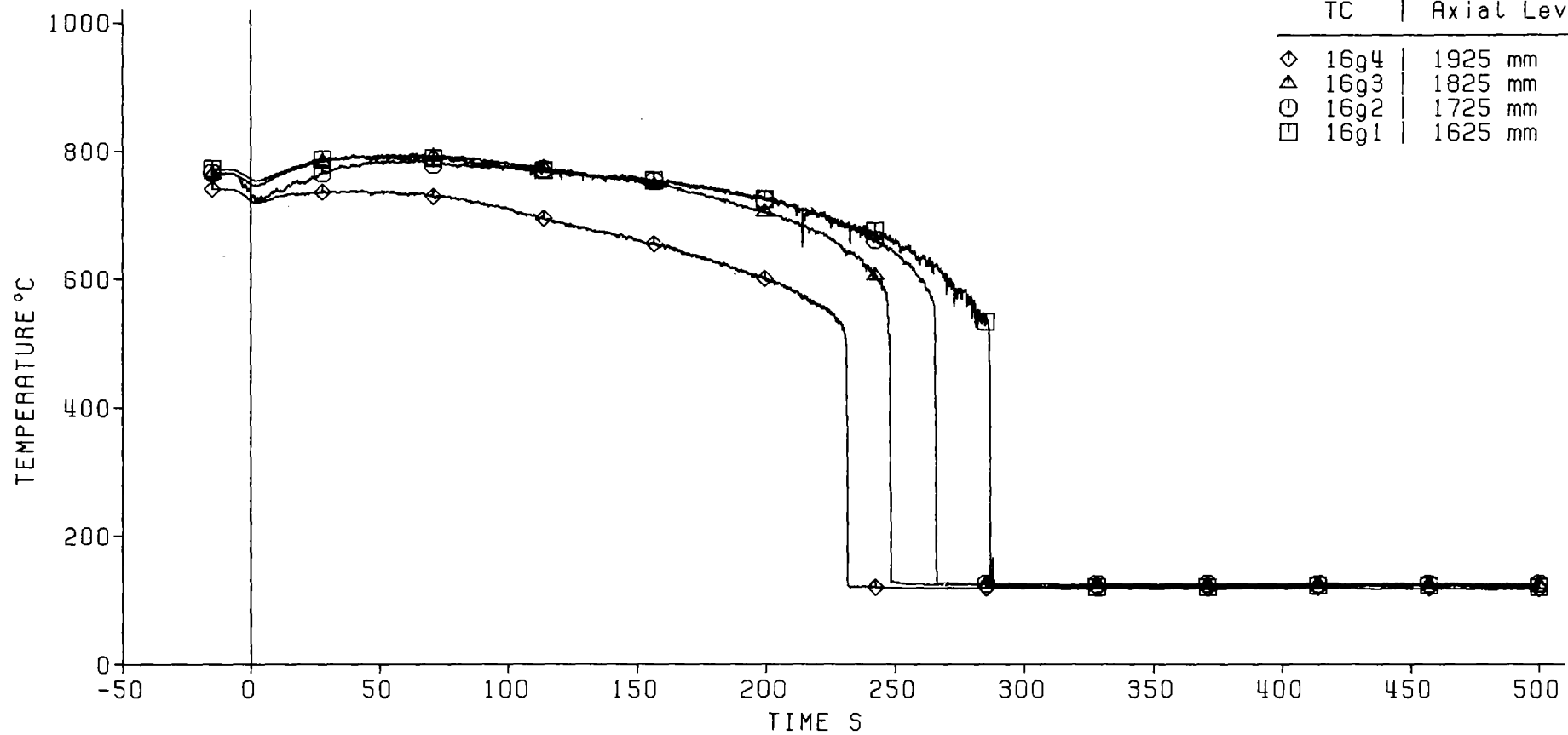
Decay Heat 120% ANS Standard
 Flooding Rate (cold) 3.81 cm/s
 System Pressure 2.11 bar
 Feedwater Temperature 40°C

REBEKA Rods With
 Helium Filled Gaps



Fig. 20 SEFLEX: 5x5 ROD BUNDLE, SERIES 1, TEST-No. 05

Cladding Temperature

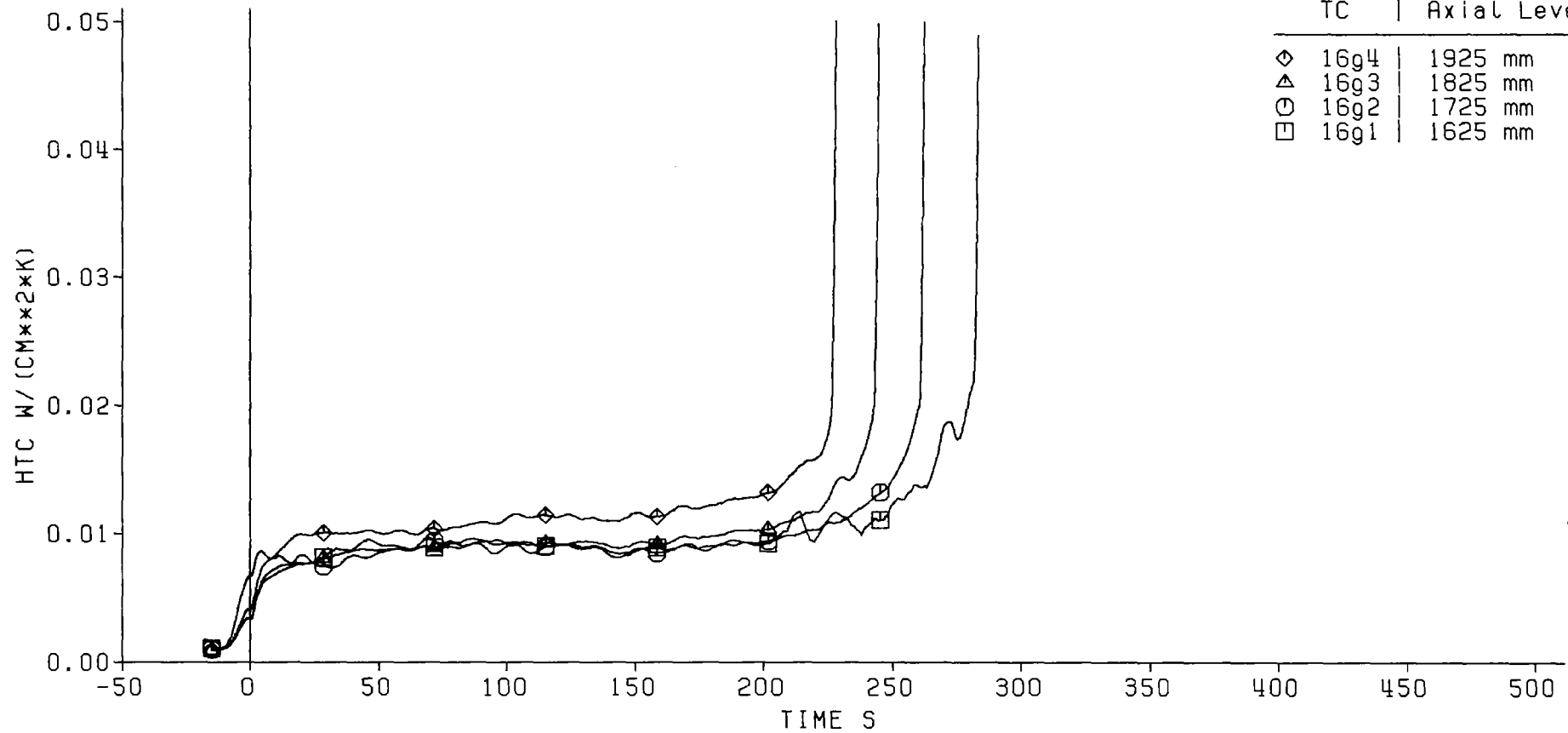


Decay Heat 120% ANS Standard
 Flooding Rate (cold) 3.81 cm/s
 System Pressure 2.11 bar
 Feedwater Temperature 40°C

REBEKA Rods With Helium Filled Gaps



Fig. 21 SEFLEX: 5x5 ROD BUNDLE, SERIES 1, TEST-No. 05



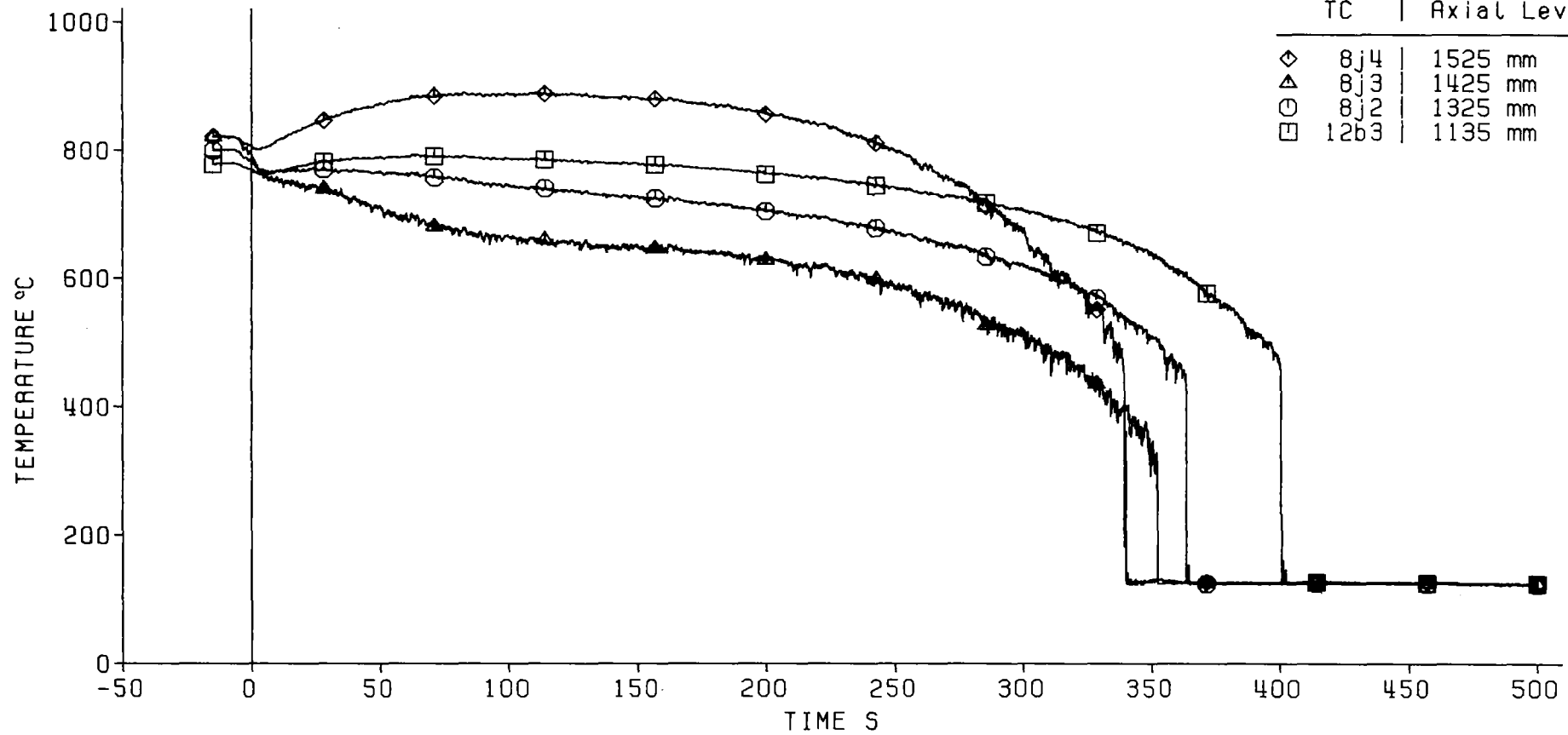
Decay Heat 120% ANS Standard
 Flooding Rate (cold) 3.81 cm/s
 System Pressure 2.11 bar
 Feedwater Temperature 40°C

REBEKA Rods With
 Helium Filled Gaps

KJK
 IRB

Fig. 22 SEFLEX: 5x5 ROD BUNDLE, SERIES 1, TEST-No. 05

Cladding Temperature

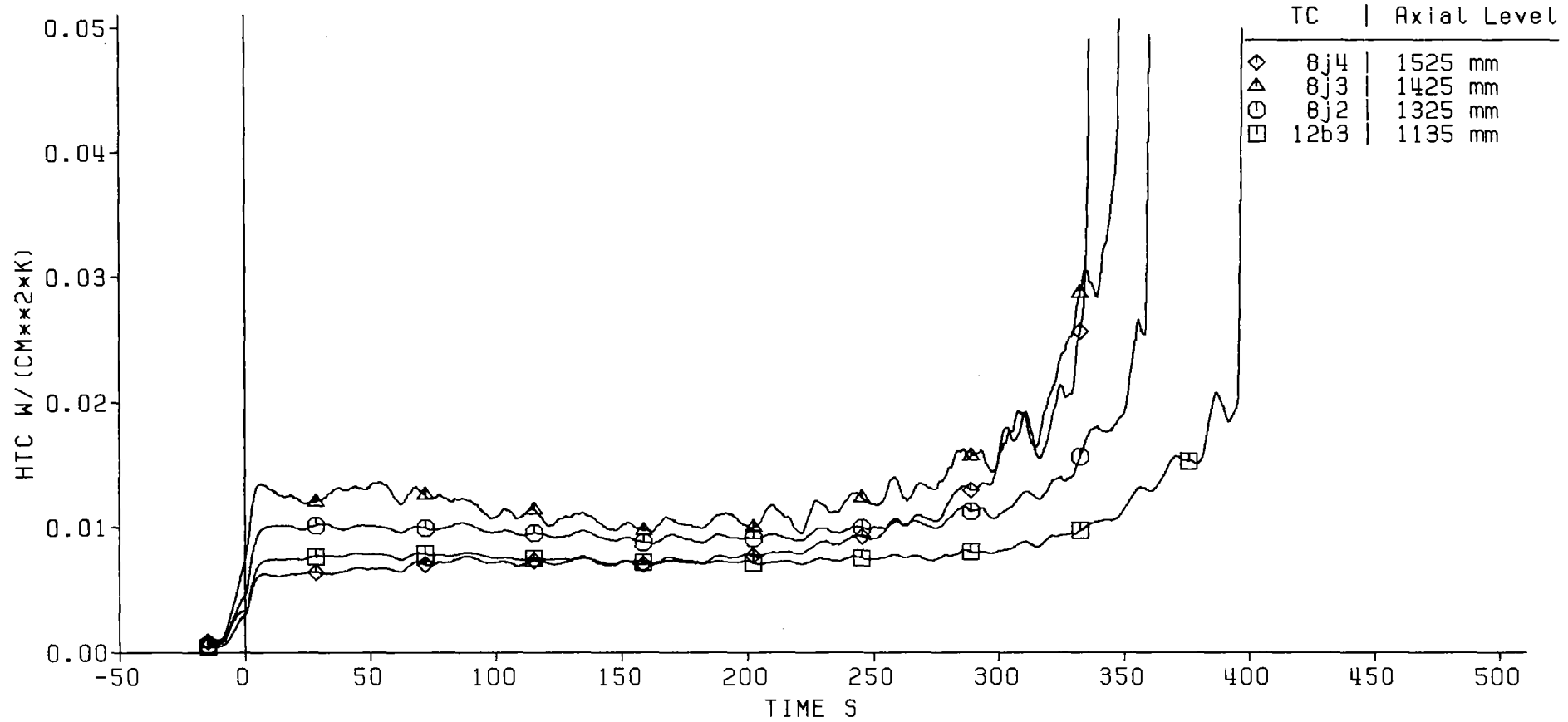


Decay Heat 120% ANS Standard
 Flooding Rate (cold) 3.81 cm/s
 System Pressure 2.11 bar
 Feedwater Temperature 40°C

REBEKA Rods With Helium Filled Gaps



Fig. 23 SEFLEX: 5x5 ROD BUNDLE, SERIES 1, TEST-No. 05



Decay Heat
 Flooding Rate (cold) 3.81 cm/s
 System Pressure 2.11 bar
 Feedwater Temperature 40°C

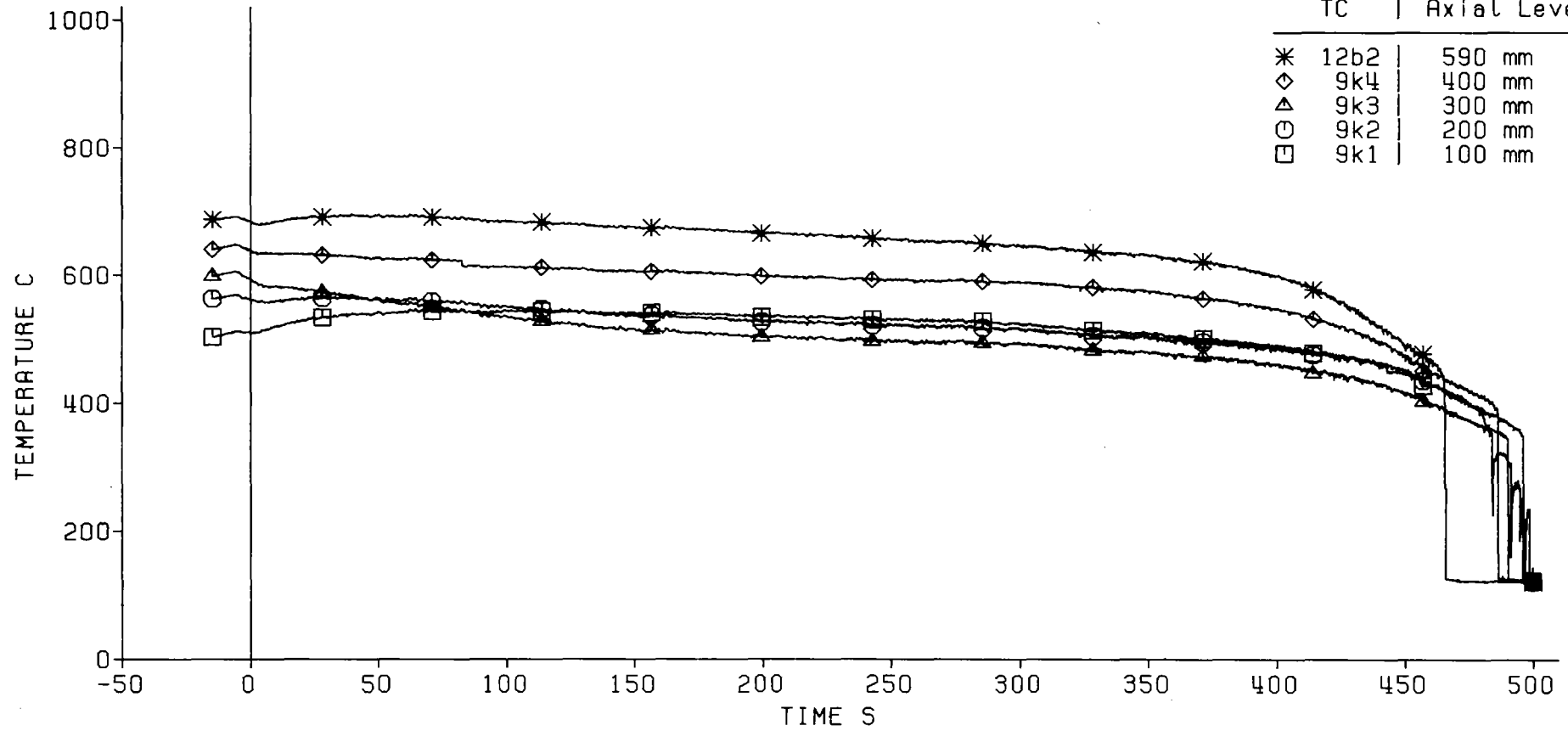
120% ANS Standard

REBEKA Rods With
 Helium Filled Gaps

KIK
 IRB

Fig. 24 SEFLEX: 5x5 ROD BUNDLE, SERIES 1, TEST-No. 05

Cladding Temperature

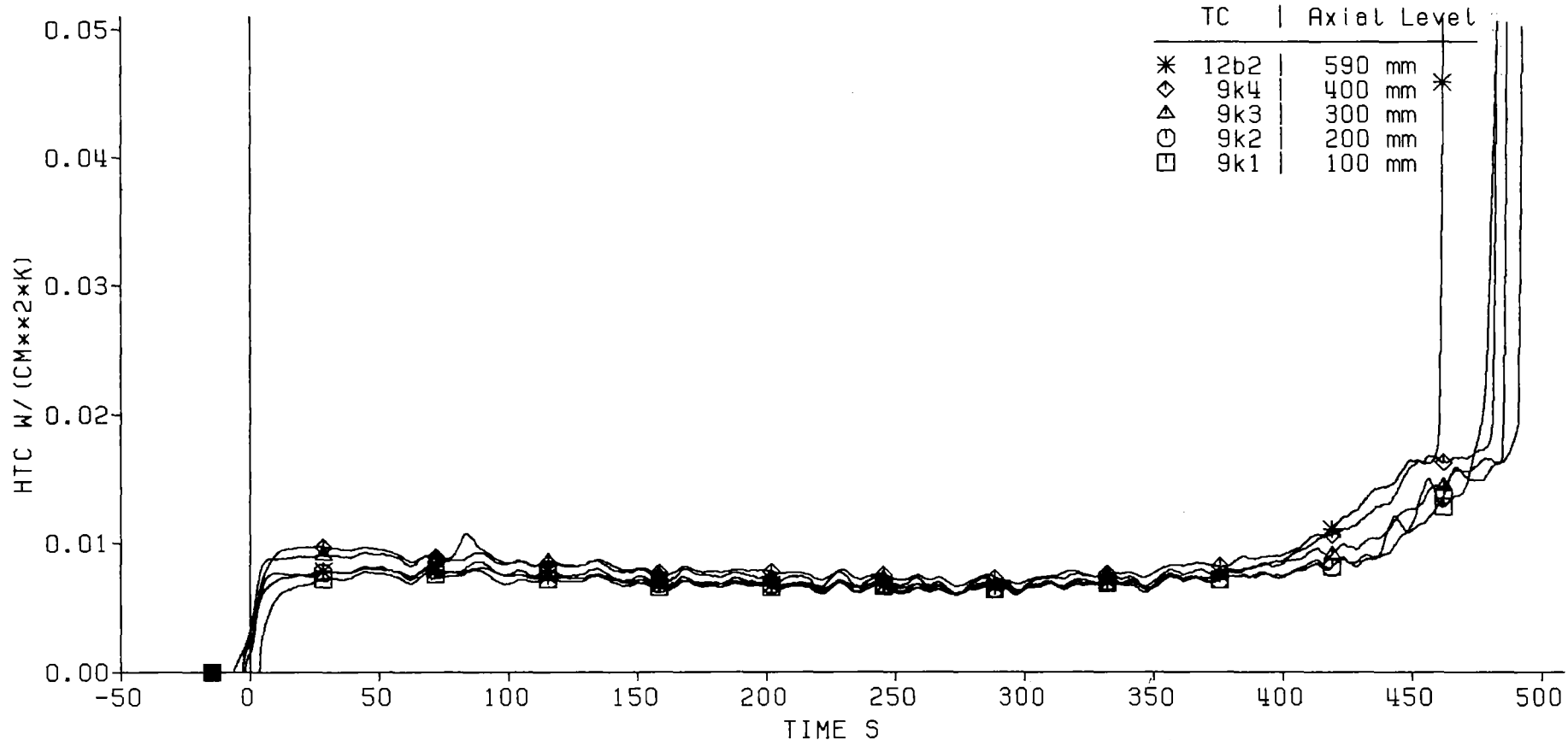


Decay Heat 120% ANS Standard
 Flooding Rate (cold) 3.81 cm/s
 System Pressure 2.11 bar
 Feedwater Temperature 40°C

REBEKA Rods With Helium Filled Gaps



Fig. 25 SEFLEX: 5x5 ROD BUNDLE, SERIES 1, TEST-No. 05



Decay Heat
Flooding Rate (cold)
System Pressure
Feedwater Temperature

120% ANS Standard
3.81 cm/s
2.11 bar
40°C

REBEKA Rods With
Helium Filled Gaps

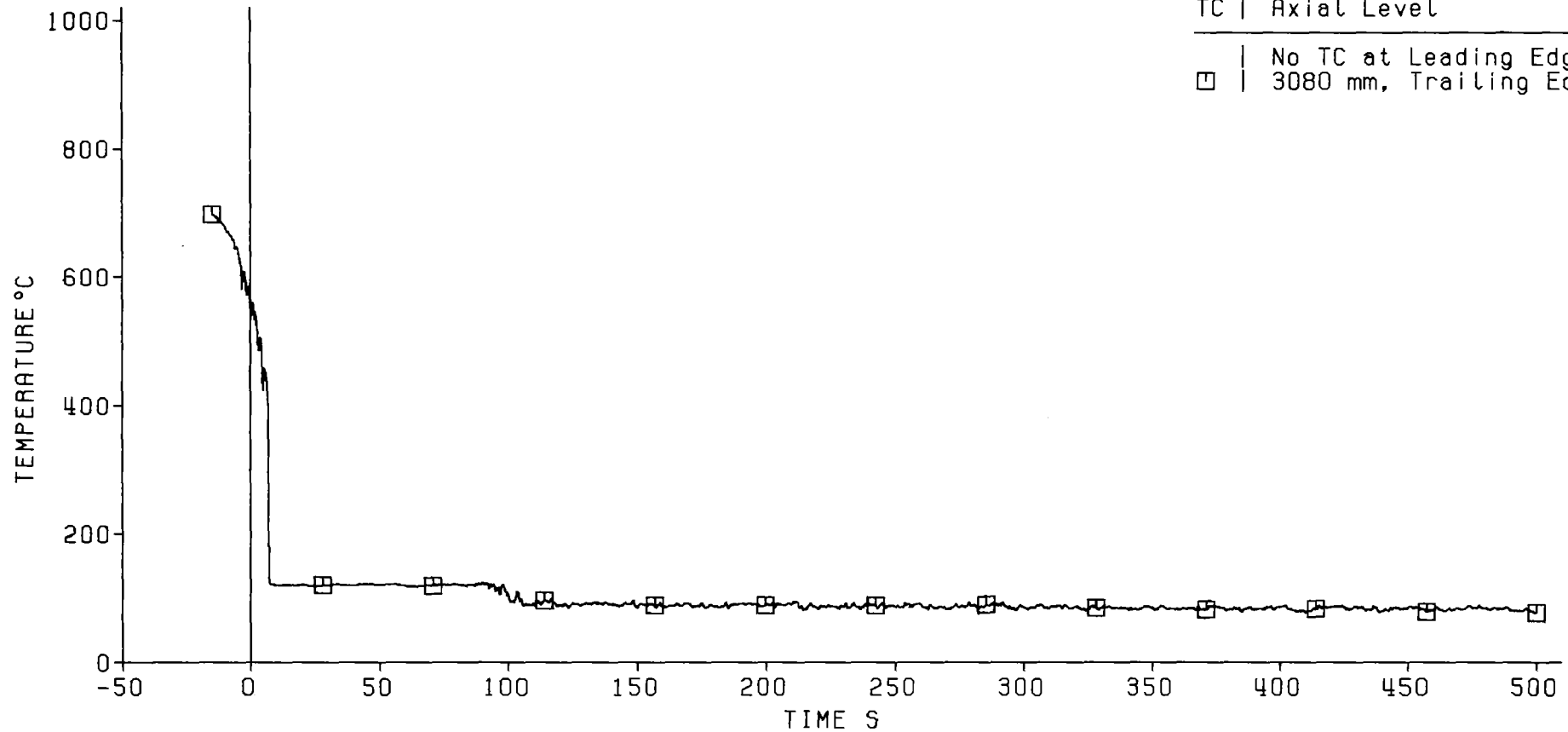


Fig. 26 SEFLEX: 5x5 ROD BUNDLE, SERIES 1, TEST-No. 05

Grid Spacer Temperature

TC | Axial Level

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



Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.81 cm/s
System Pressure 2.11 bar
Feedwater Temperature 40°C

REBEKA Rods With Helium Filled Gaps

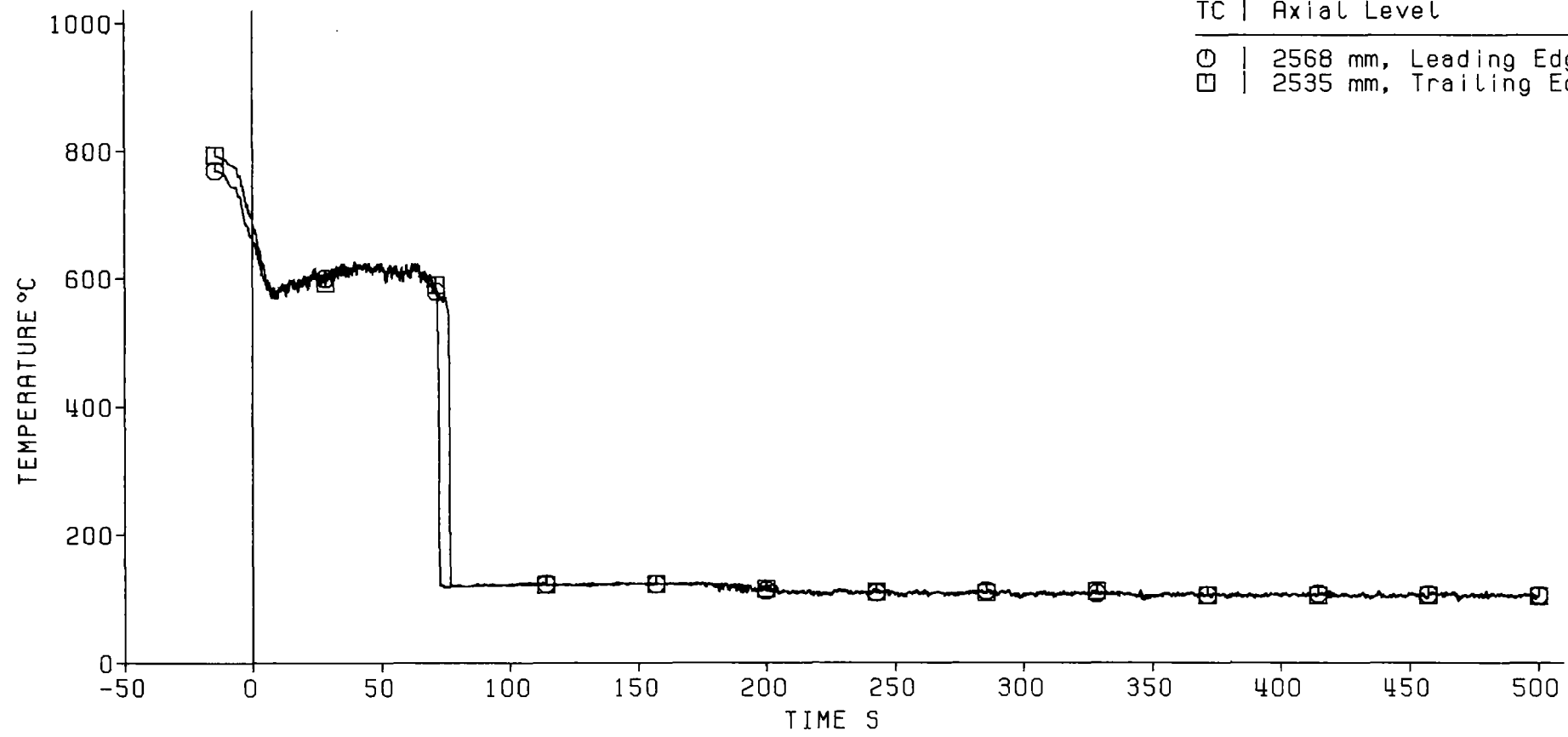


Fig. 27 SEFLEX: 5x5 ROD BUNDLE, SERIES 1, TEST-No. 05

Grid Spacer Temperature

TC | Axial Level

○ | 2568 mm, Leading Edge
□ | 2535 mm, Trailing Edge



Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.81 cm/s
System Pressure 2.11 bar
Feedwater Temperature 40 °C

REBEKA Rods With Helium Filled Gaps

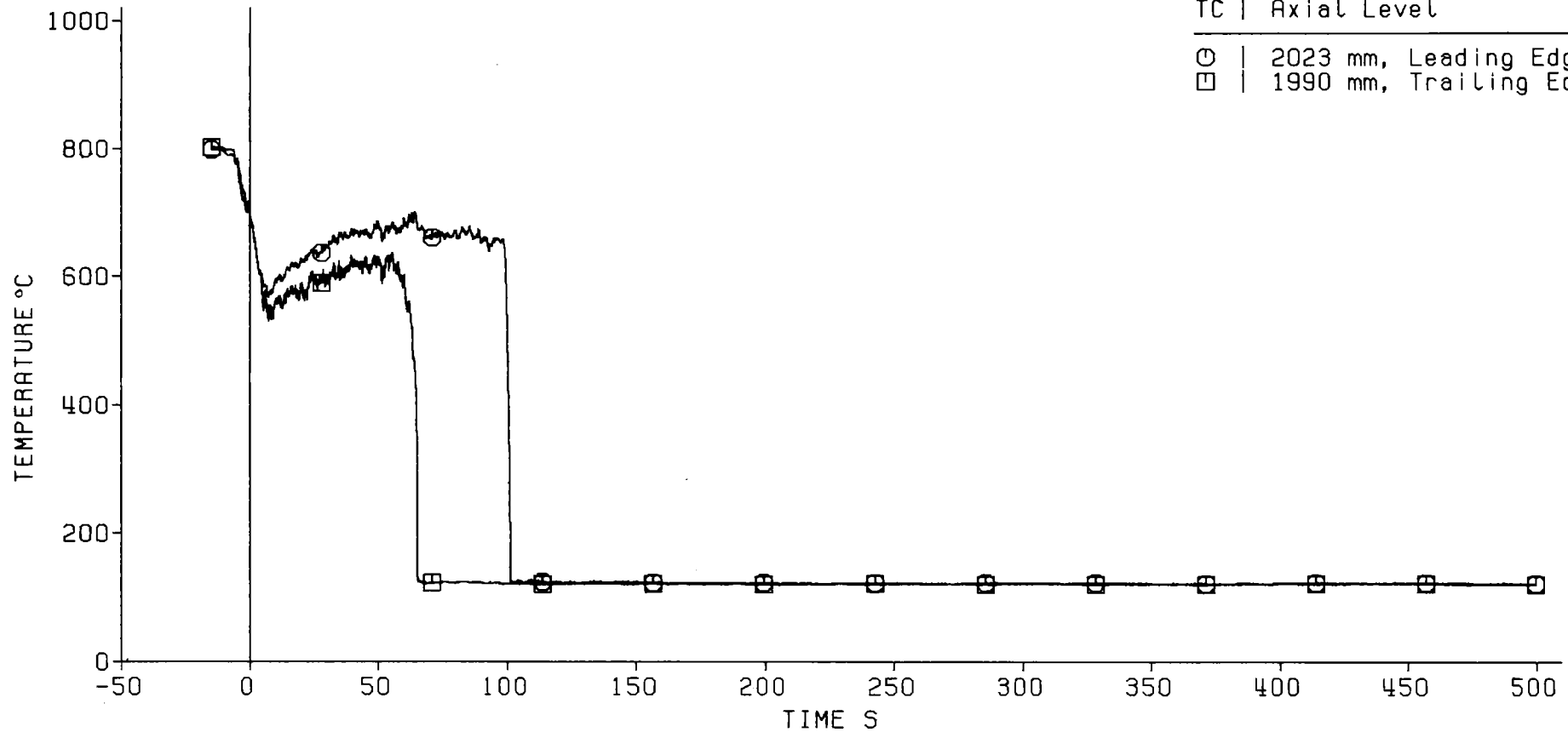


Fig. 28 SEFLEX: 5x5 ROD BUNDLE, SERIES 1, TEST-No. 05

Grid Spacer Temperature

TC | Axial Level

- | 2023 mm, Leading Edge
- | 1990 mm, Trailing Edge



Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.81 cm/s
System Pressure 2.11 bar
Feedwater Temperature 40°C

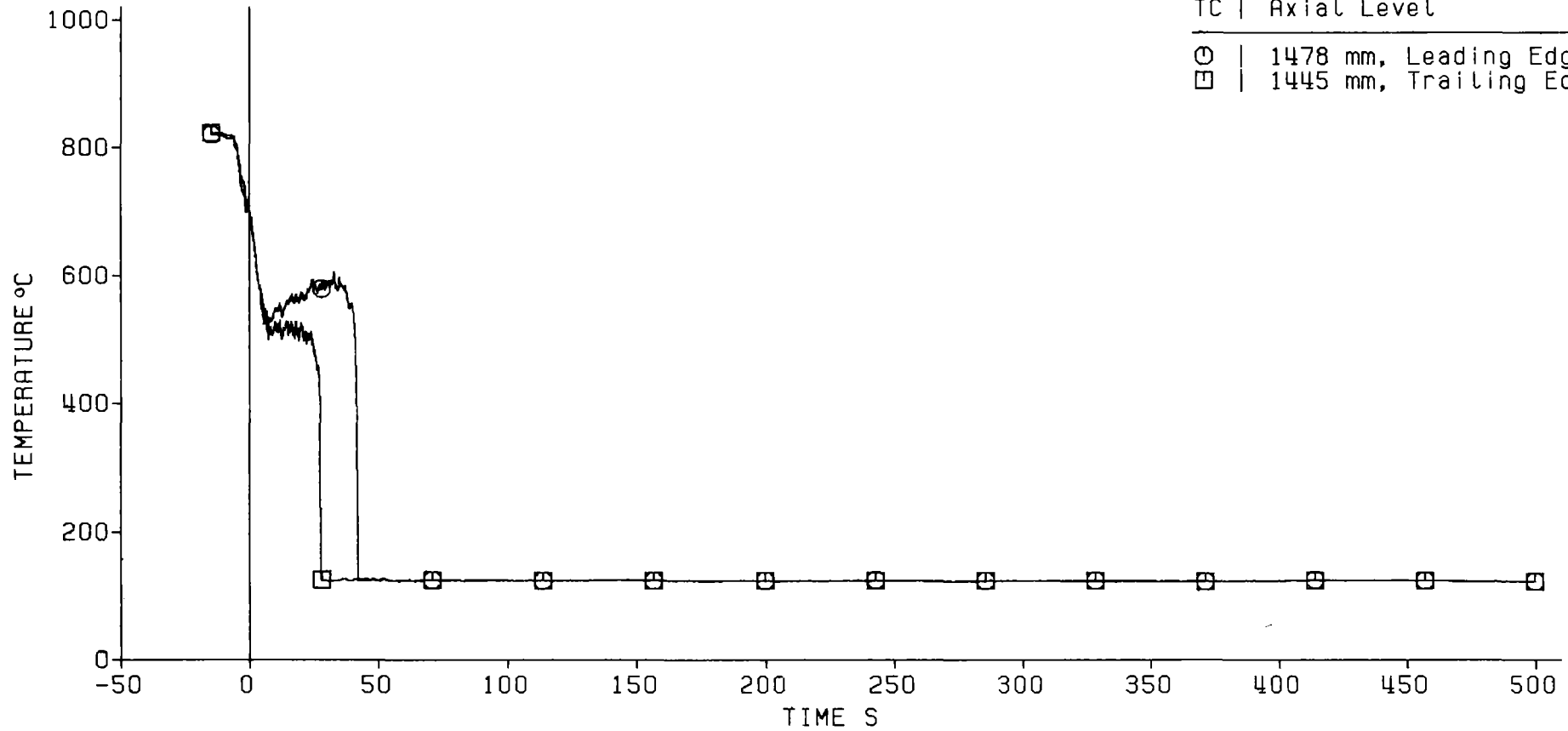
REBEKA Rods With
Helium Filled Gaps



Fig. 29 SEFLEX: 5x5 ROD BUNDLE, SERIES 1, TEST-No. 05

TC | Axial Level

○ | 1478 mm, Leading Edge
□ | 1445 mm, Trailing Edge



Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.81 cm/s
System Pressure 2.11 bar
Feedwater Temperature 40°C

REBEKA Rods With Helium Filled Gaps

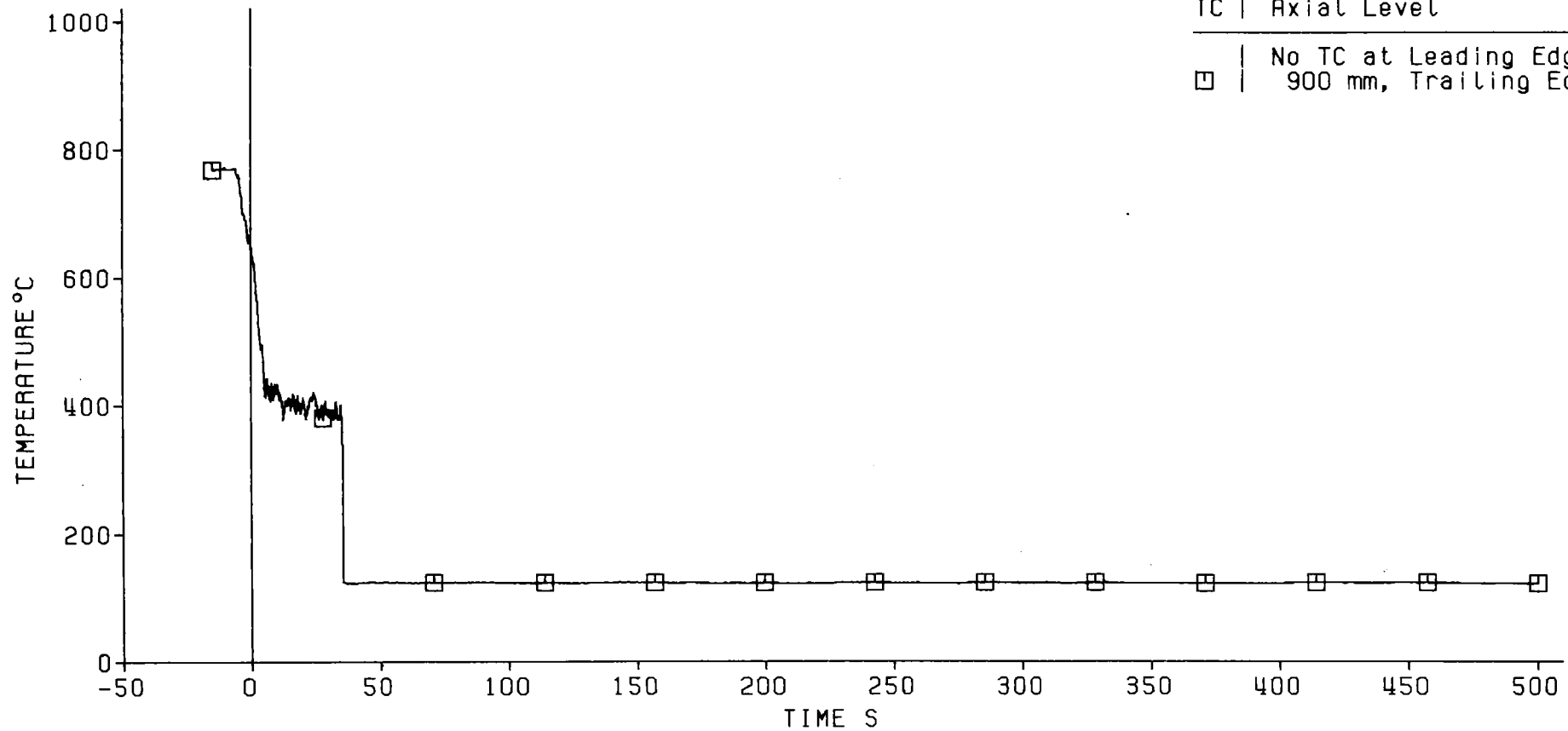


Fig. 30 SEFLEX: 5x5 ROD BUNDLE, SERIES 1, TEST-No. 05

Grid Spacer Temperature

TC | Axial Level

□ | No TC at Leading Edge
□ | 900 mm, Trailing Edge



— 50 —

Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.81 cm/s
System Pressure 2.11 bar
Feedwater Temperature 40°C

REBEKA Rods With
Helium Filled Gaps

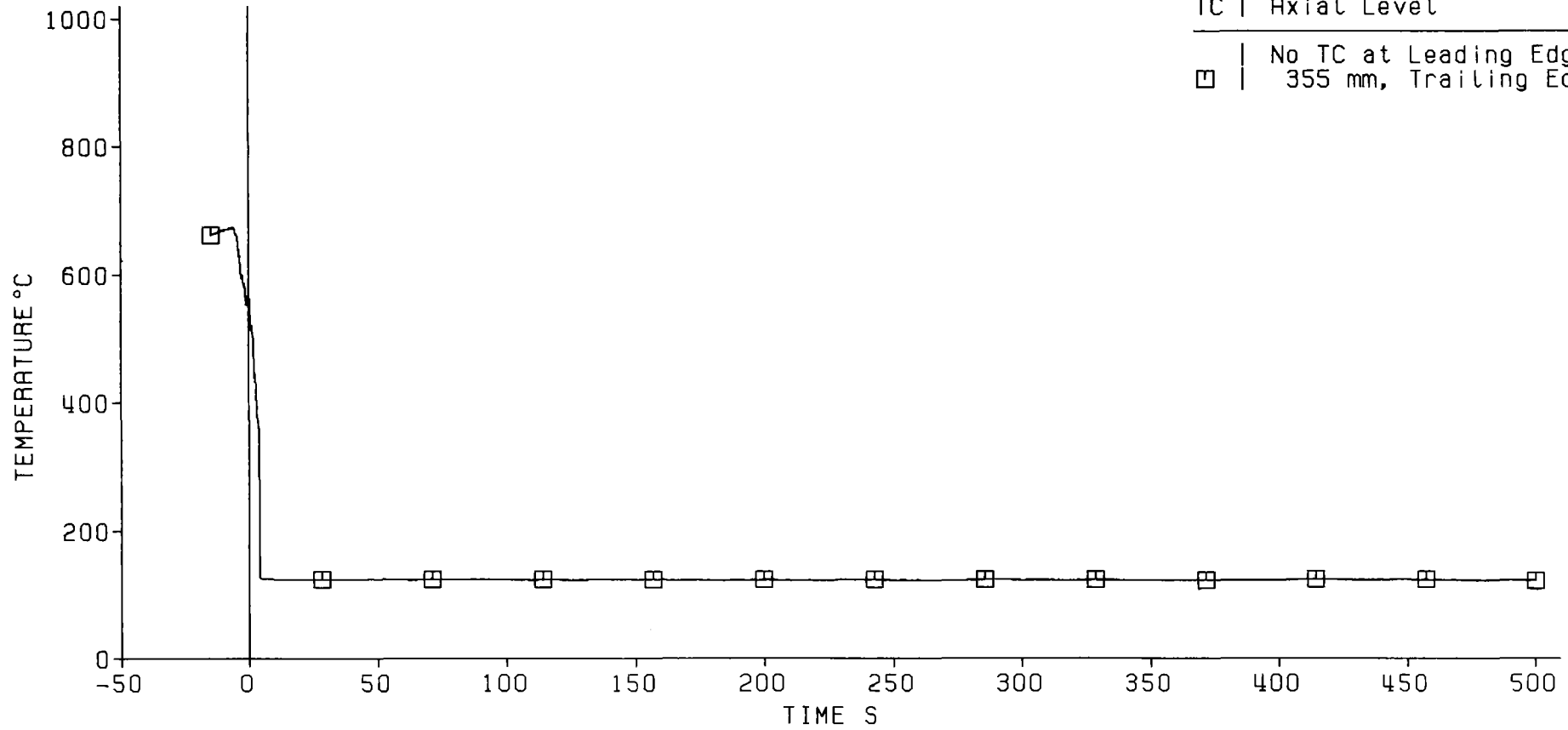


Fig. 31 SEFLEX: 5x5 ROD BUNDLE, SERIES 1, TEST-No. 05

Grid Spacer Temperature

TC | Axial Level

□ | No TC at Leading Edge
□ | 355 mm, Trailing Edge



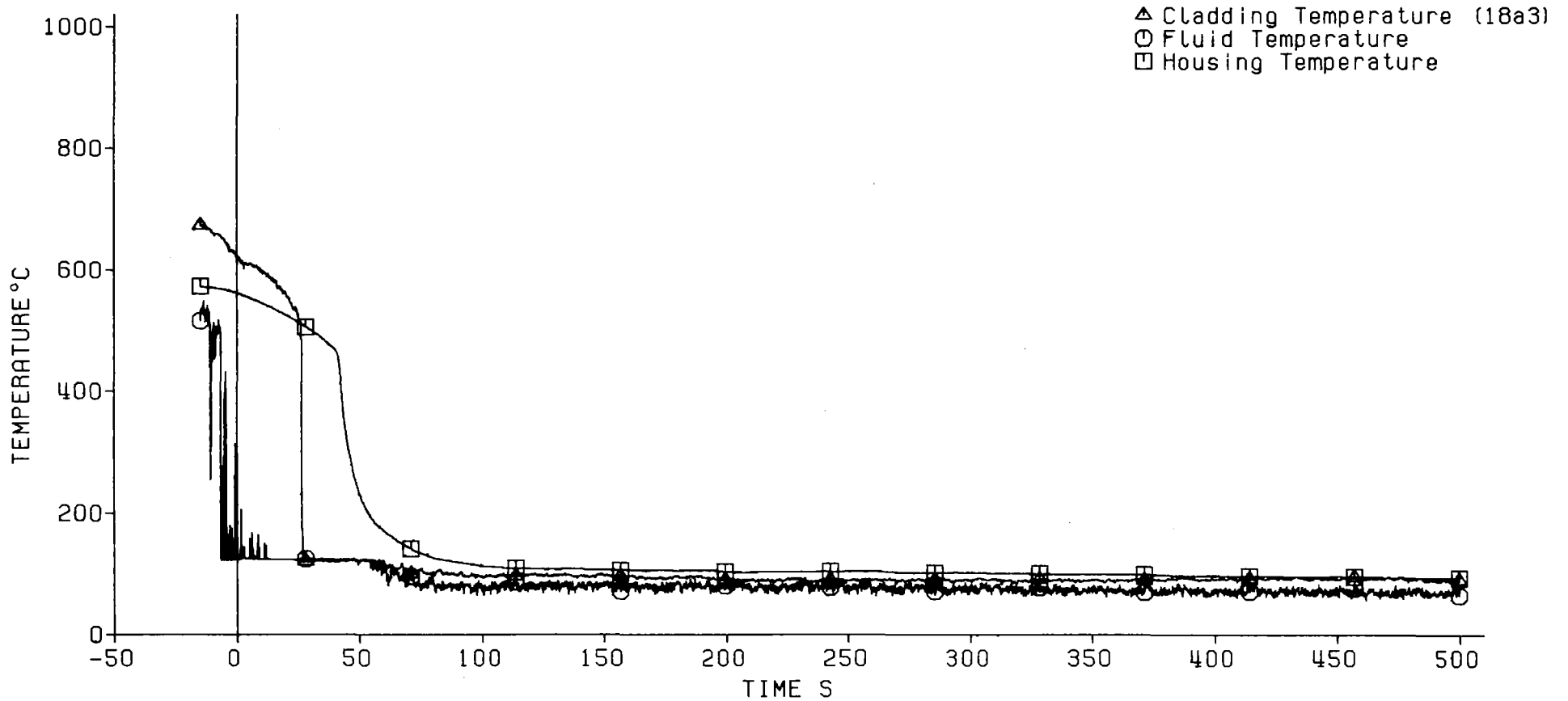
Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.81 cm/s
System Pressure 2.11 bar
Feedwater Temperature 40°C

REBEKA Rods With
Helium Filled Gaps



Fig. 32 SEFLEX: 5x5 ROD BUNDLE, SERIES 1, TEST-No. 05

Axial Level: 3315 mm



— 52 —

Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.81 cm/s
System Pressure 2.11 bar
Feedwater Temperature 40°C

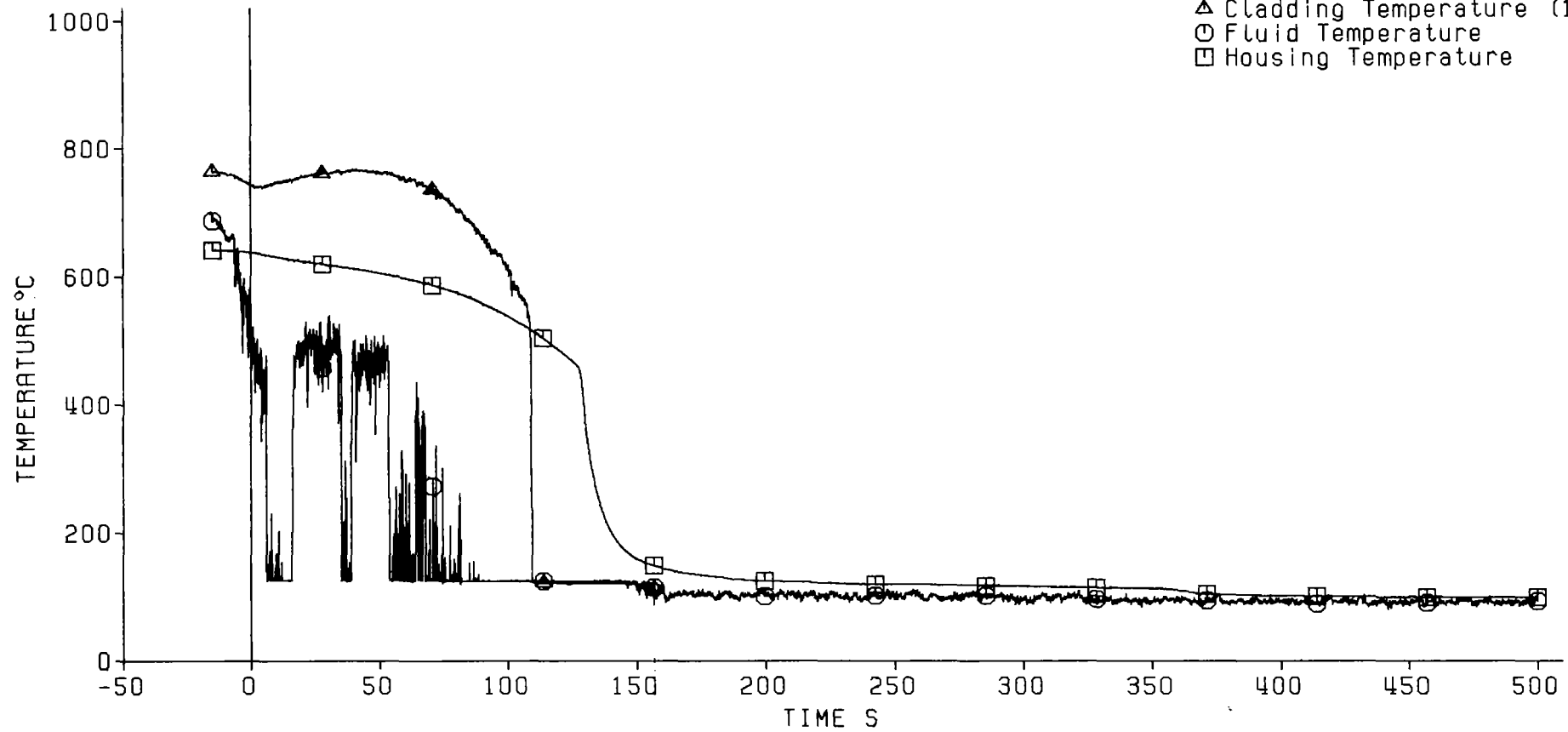
REBEKA Rods With Helium Filled Gaps



Fig. 33 SEFLEX: 5x5 ROD BUNDLE, SERIES 1, TEST-No. 05

Axial Level: 2770 mm

△ Cladding Temperature (18a2)
○ Fluid Temperature
□ Housing Temperature



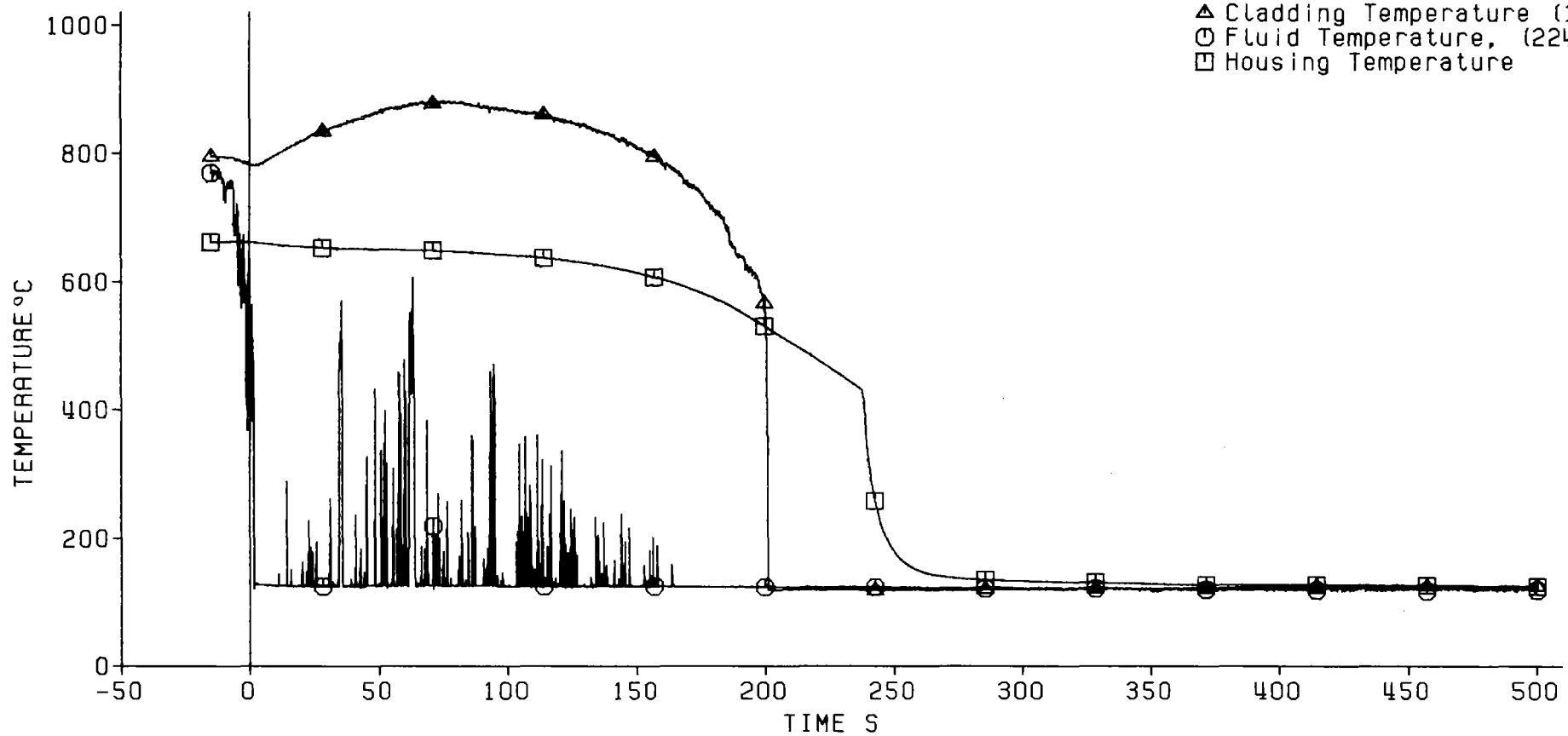
Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.81 cm/s
System Pressure 2.11 bar
Feedwater Temperature 40°C

REBEKA Rods With
Helium Filled Gaps



Fig. 34 SEFLEX: 5x5 ROD BUNDLE, SERIES 1, TEST-No. 05

Axial Level: 2225 mm



— 54 —

Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.81 cm/s
System Pressure 2.11 bar
Feedwater Temperature 40 °C

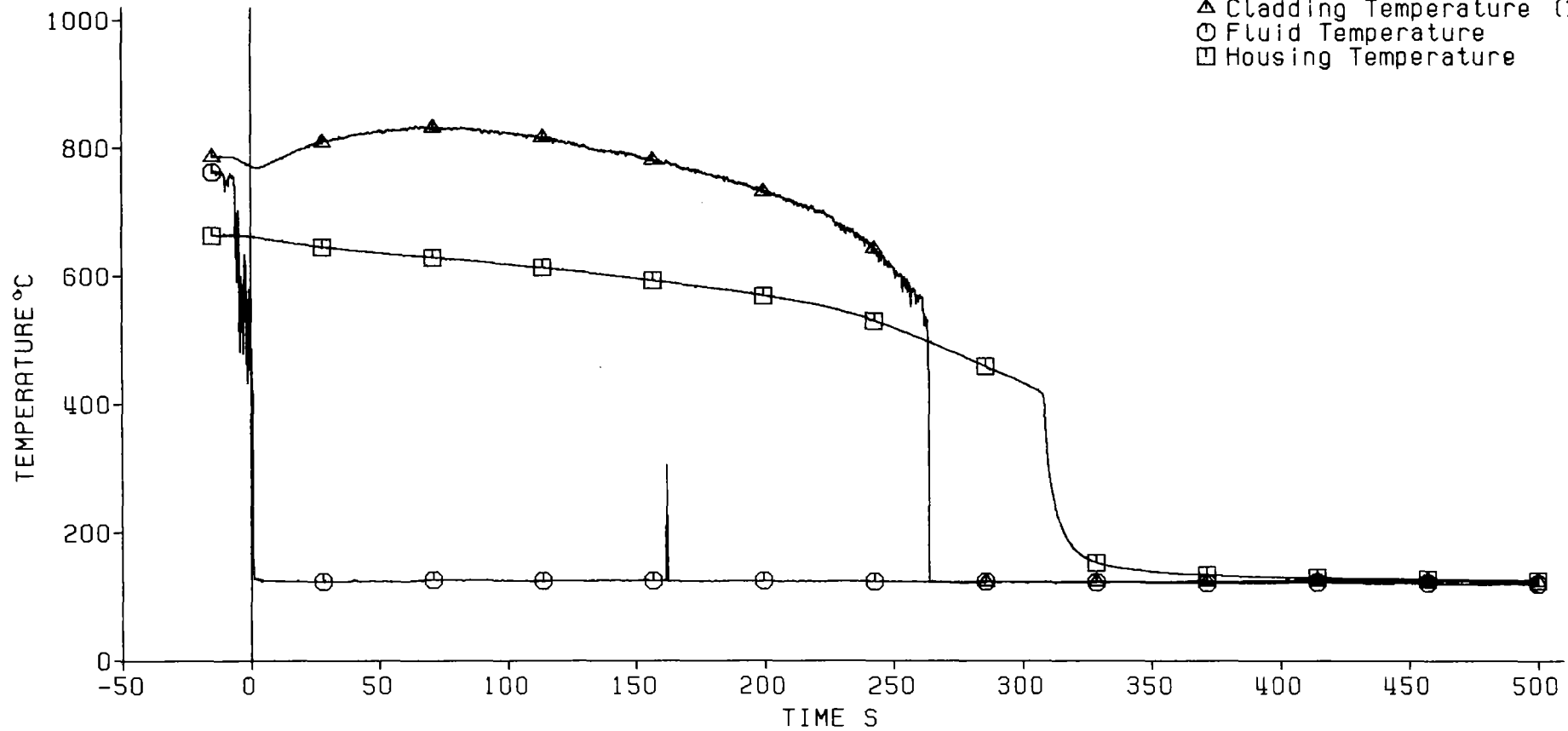
REBEKA Rods With
Helium Filled Gaps



Fig. 35 SEFLEX: 5x5 ROD BUNDLE, SERIES 1, TEST-NO. 05

Axial Level: 1825 mm

△ Cladding Temperature (19g3)
○ Fluid Temperature
□ Housing Temperature



Decay Heat
Flooding Rate (cold) 3.81 cm/s
System Pressure 2.11 bar
Feedwater Temperature 40°C

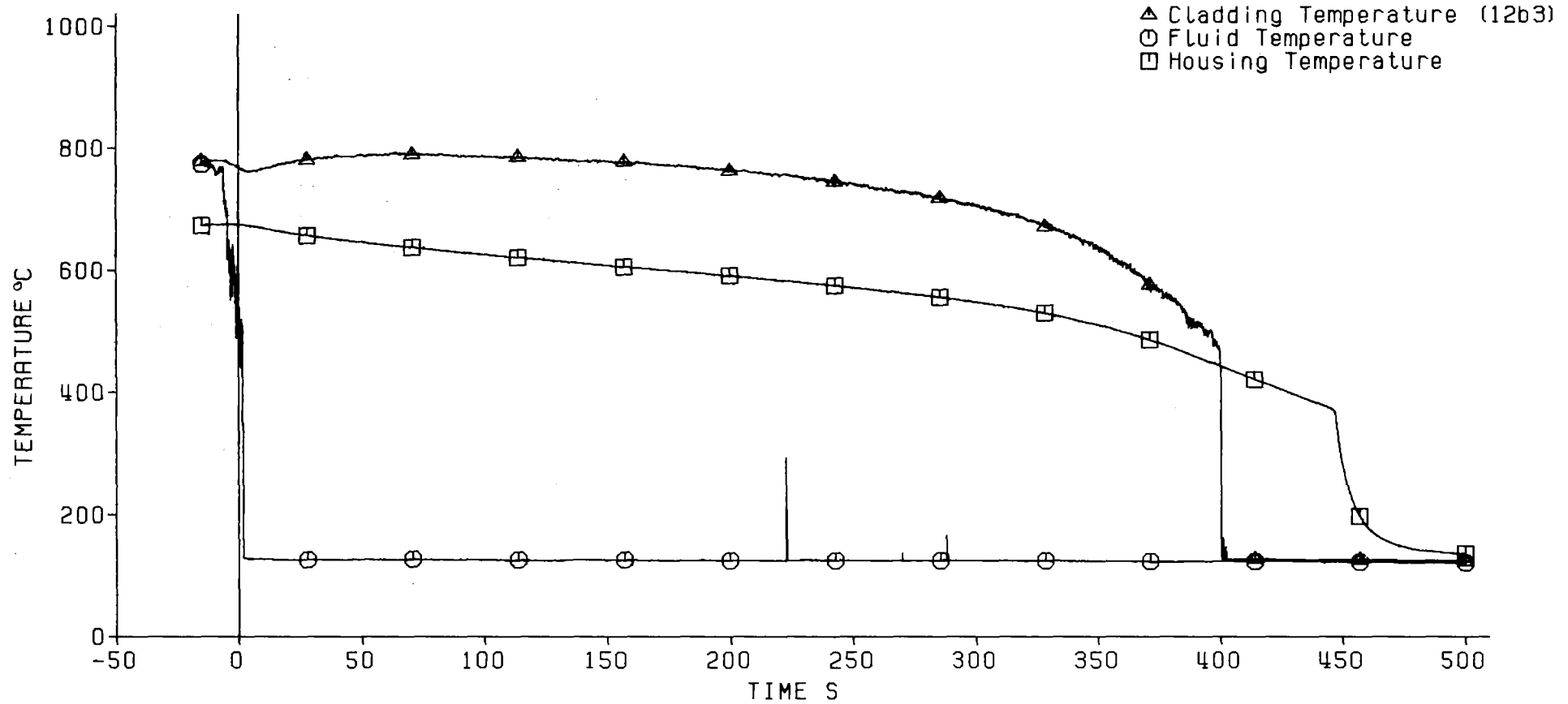
120% ANS Standard

REBEKA Rods With Helium Filled Gaps



Fig. 36 SEFLEX: 5x5 ROD BUNDLE, SERIES 1, TEST-No. 05

Axial Level: 1135 mm



Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.81 cm/s
System Pressure 2.11 bar
Feedwater Temperature 40°C

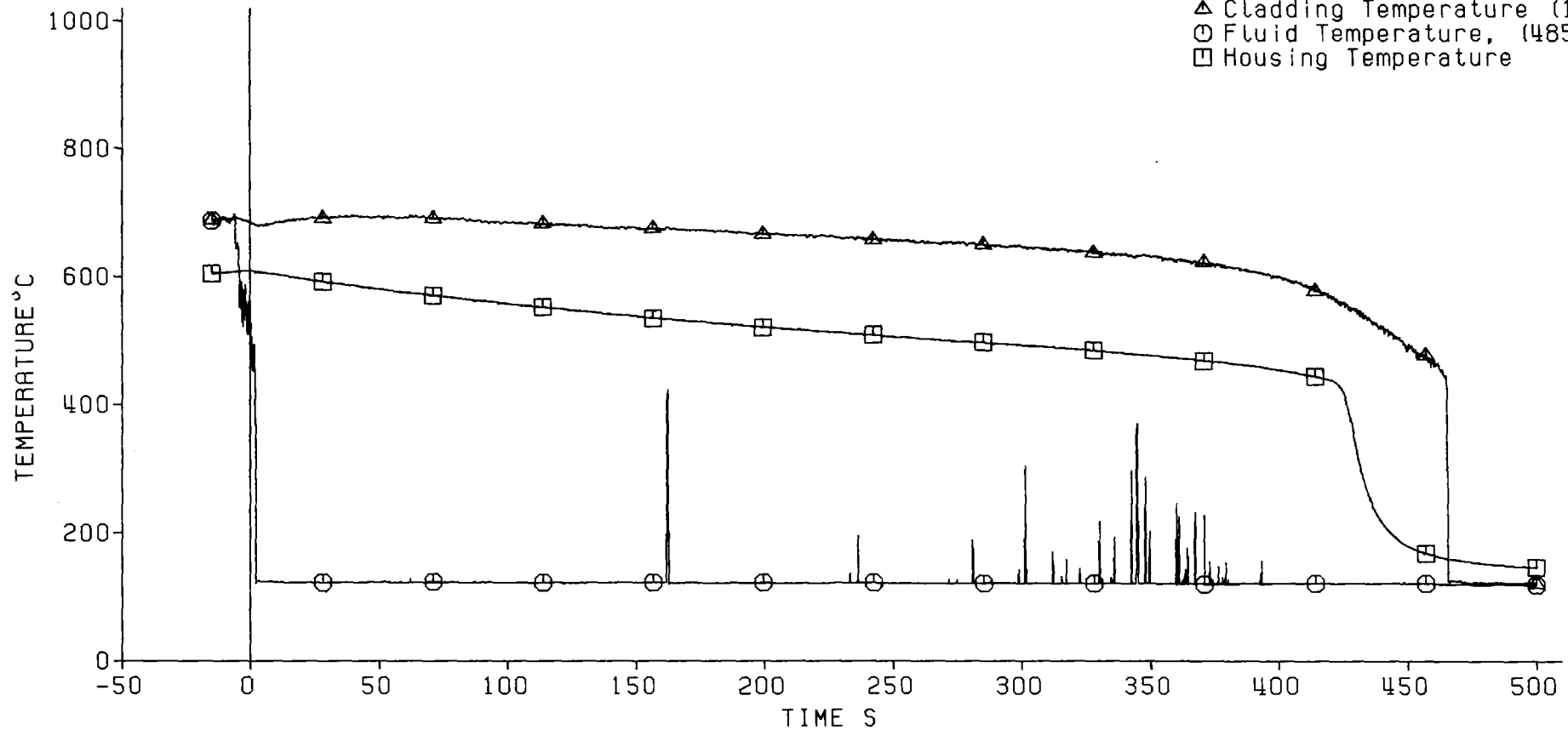
REBEKA Rods With
Helium Filled Gaps



Fig. 37 SEFLEX: 5x5 ROD BUNDLE, SERIES 1, TEST-NO. 05

Axial Level: 590 mm

△ Cladding Temperature (12b2)
○ Fluid Temperature, (485 mm)
□ Housing Temperature



Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.81 cm/s
System Pressure 2.11 bar
Feedwater Temperature 40 °C

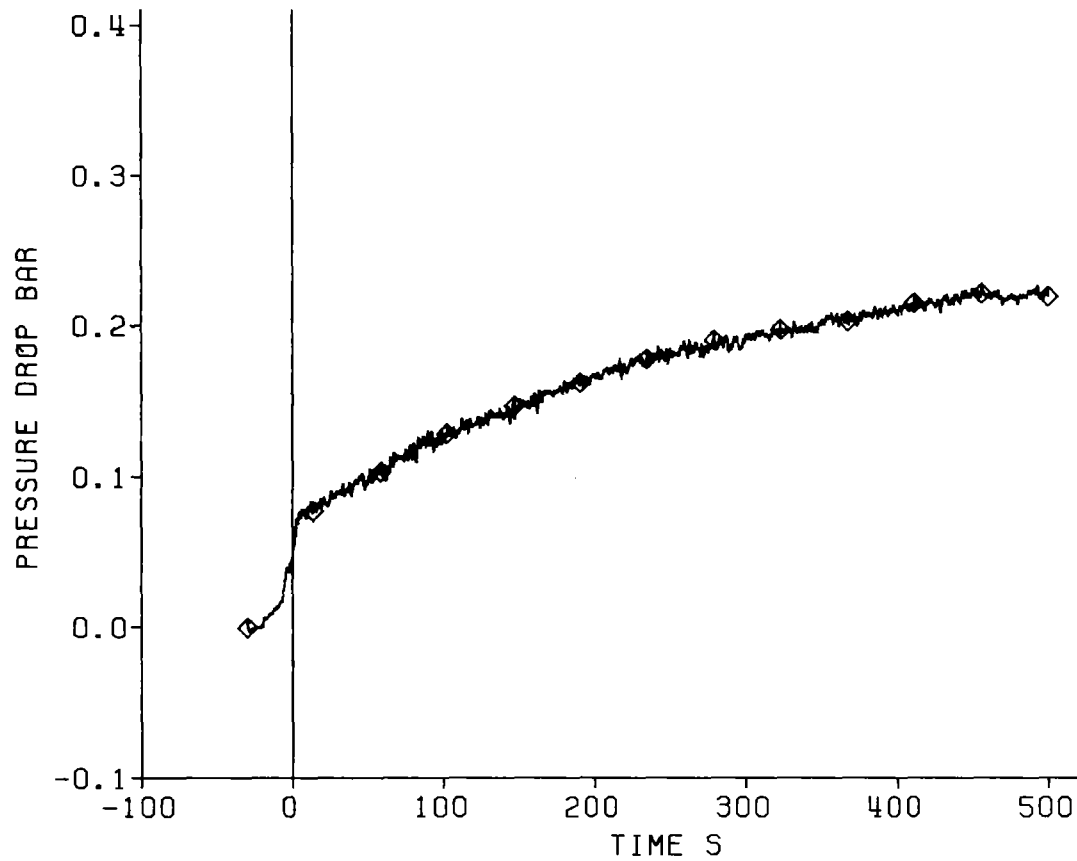
REBEKA Rods With
Helium Filled Gaps



Fig. 38 SEFLEX: 5x5 ROD BUNDLE, SERIES 1, TEST-No. 05

Pressure Drop
Along the Test Section:

◇ Total Length: 4196 mm



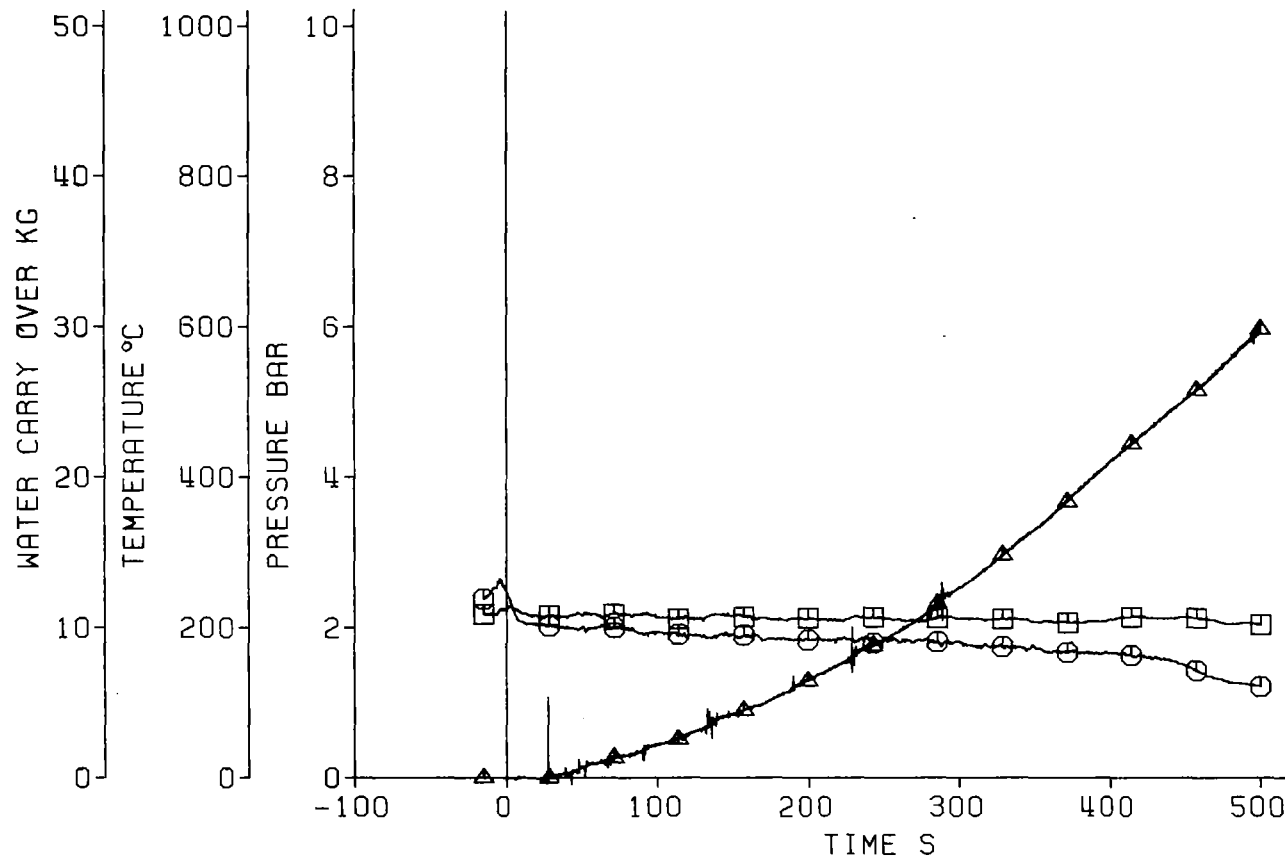
Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.81 cm/s
System Pressure 2.11 bar
Feedwater Temperature 40°C

REBEKA Rods With
Helium Filled Gaps



Fig. 39 SEFLEX: 5x5 ROD BUNDLE, SERIES 1, TEST-No. 05

Coolant Outlet Conditions:



△ Water Carry Over
○ Coolant Temperature
□ Coolant Pressure

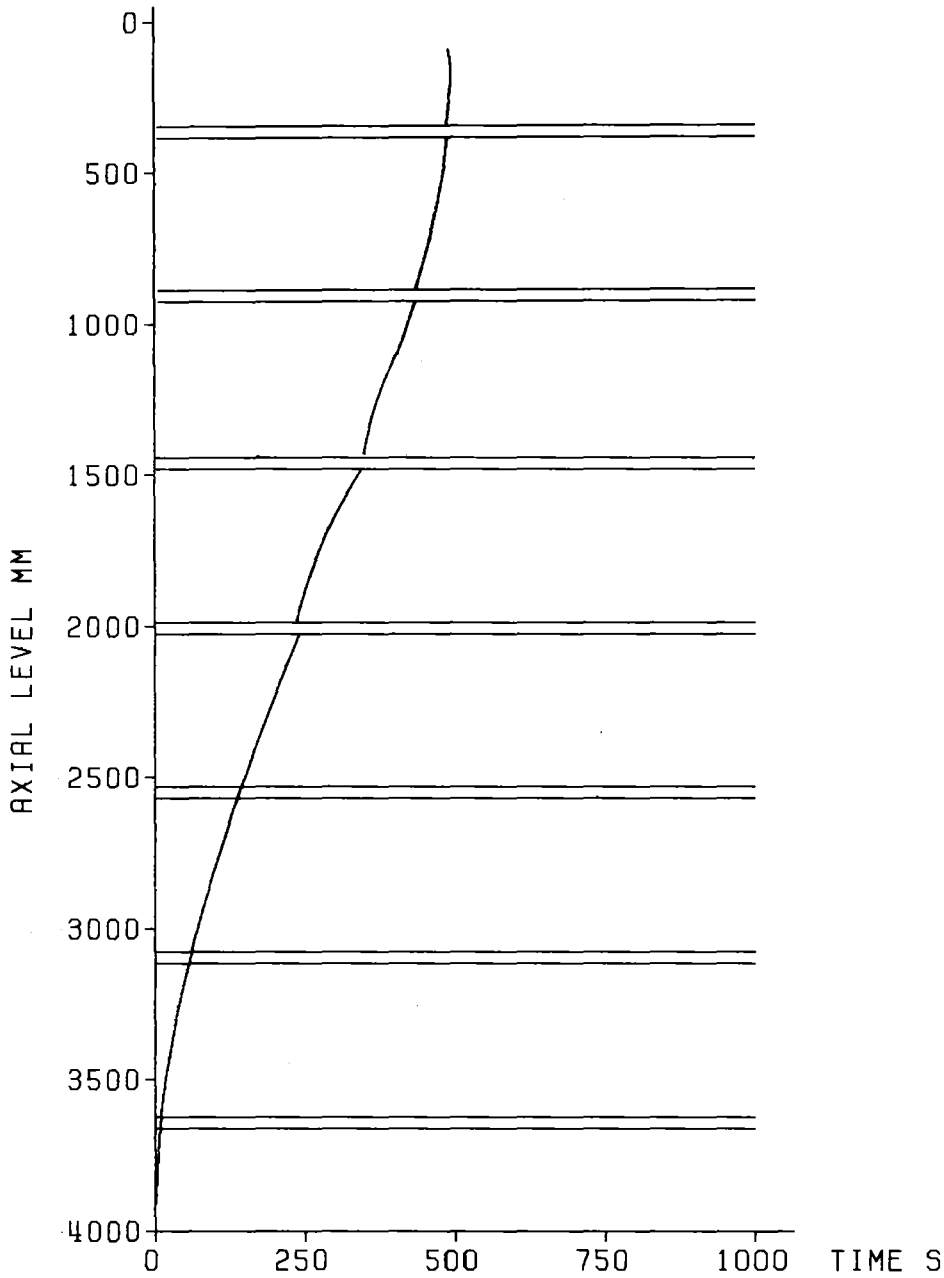
Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.81 cm/s
System Pressure 2.11 bar
Feedwater Temperature 40 °C

REBEKA Rods With
Helium Filled Gaps



Fig. 40 SEFLEX: 5x5 ROD BUNDLE, SERIES 1, TEST-NO. 05

Axial Position of Quench Front
Rebeka Rods With Helium Filled Gaps

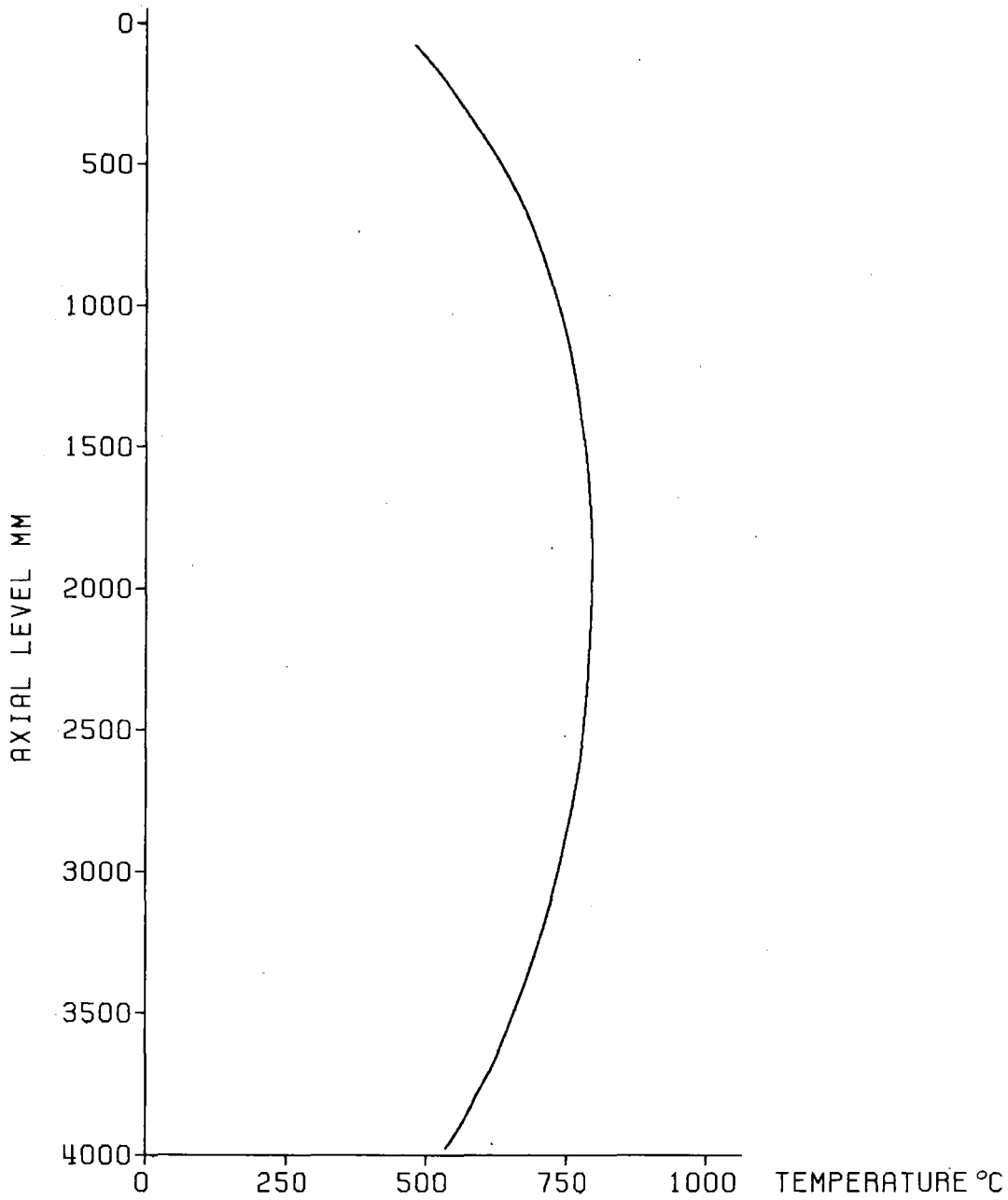


Decay Heat	120% ANS Standard
Flooding Rate (cold)	3.81 cm/s
System Pressure	2.11 bar
Feedwater Temperature	40°C



Fig. 41 SEFLEX: 5x5 ROD BUNDLE
TEST SERIES 1, TEST-No. 05

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

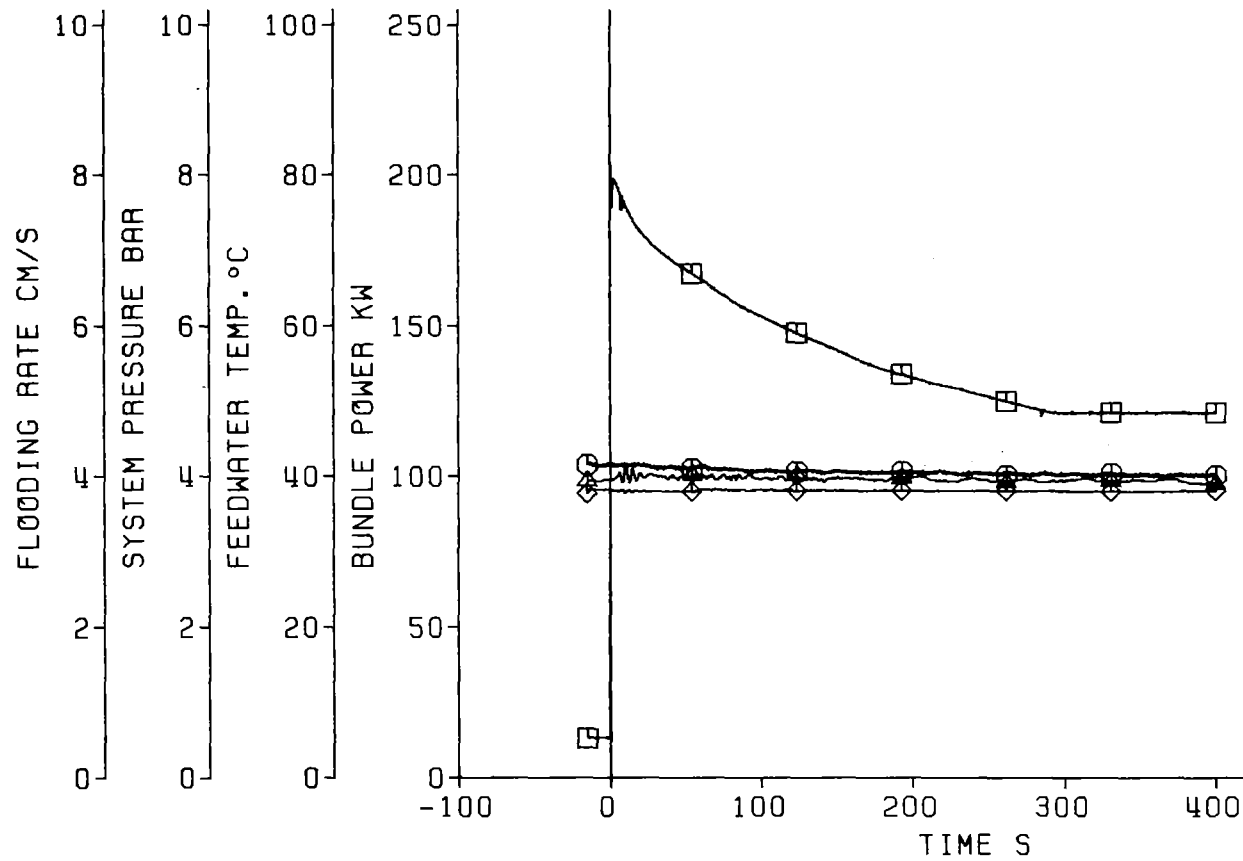


Decay Heat	120% ANS Standard
Flooding Rate (cold)	3.81 cm/s
System Pressure	4.04 bar
Feedwater Temperature	40°C



Fig. 42 SEFLEX: 5x5 ROD BUNDLE
TEST SERIES 1, TEST-No. 03

Test Parameters:



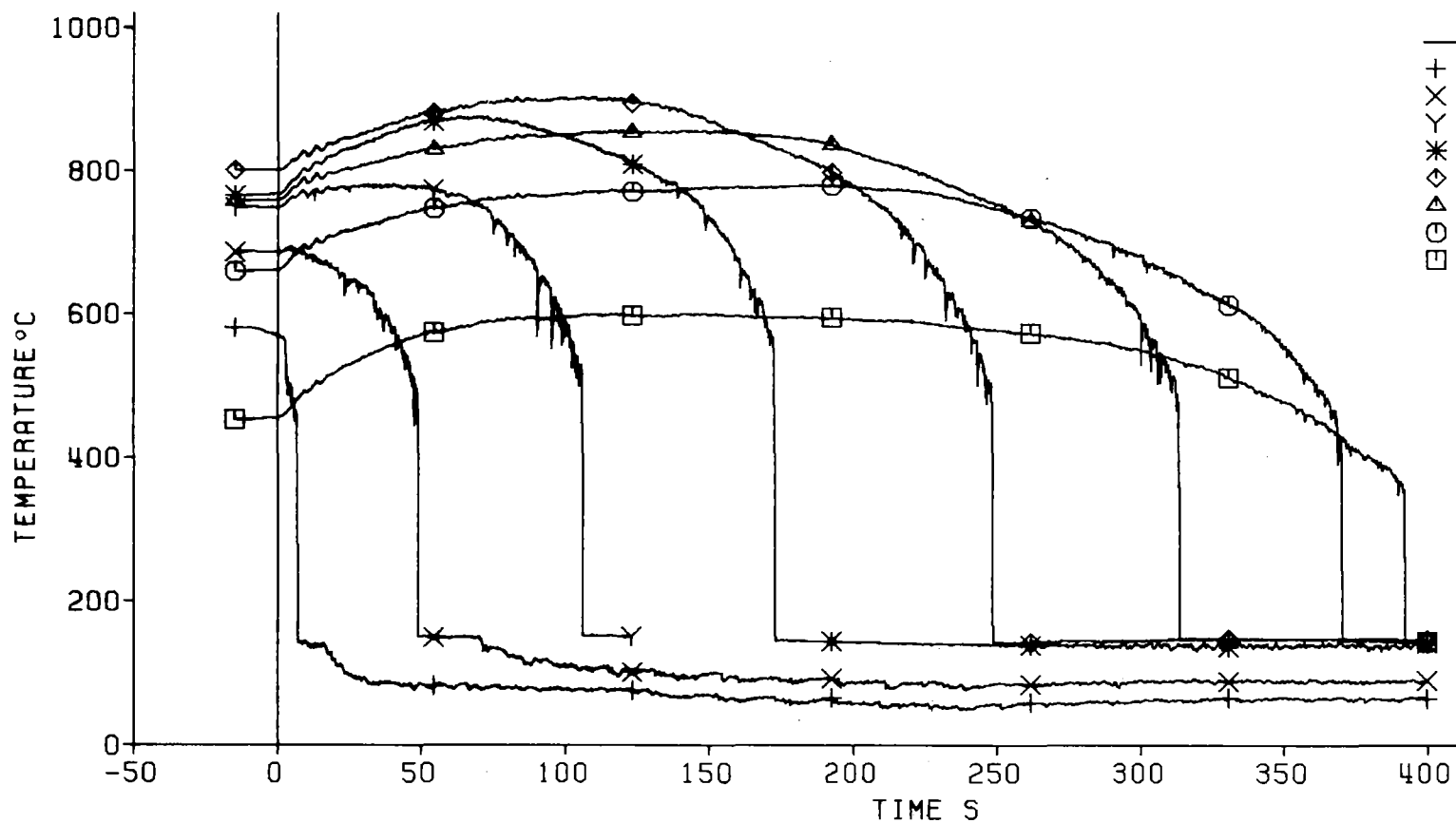
Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.81 cm/s
System Pressure 4.04 bar
Feedwater Temperature 40°C

REBEKA Rods With
Helium Filled Gaps



Fig. 43 SEFLEX: 5x5 ROD BUNDLE, SERIES 1, TEST-No. 03

Cladding Temperature

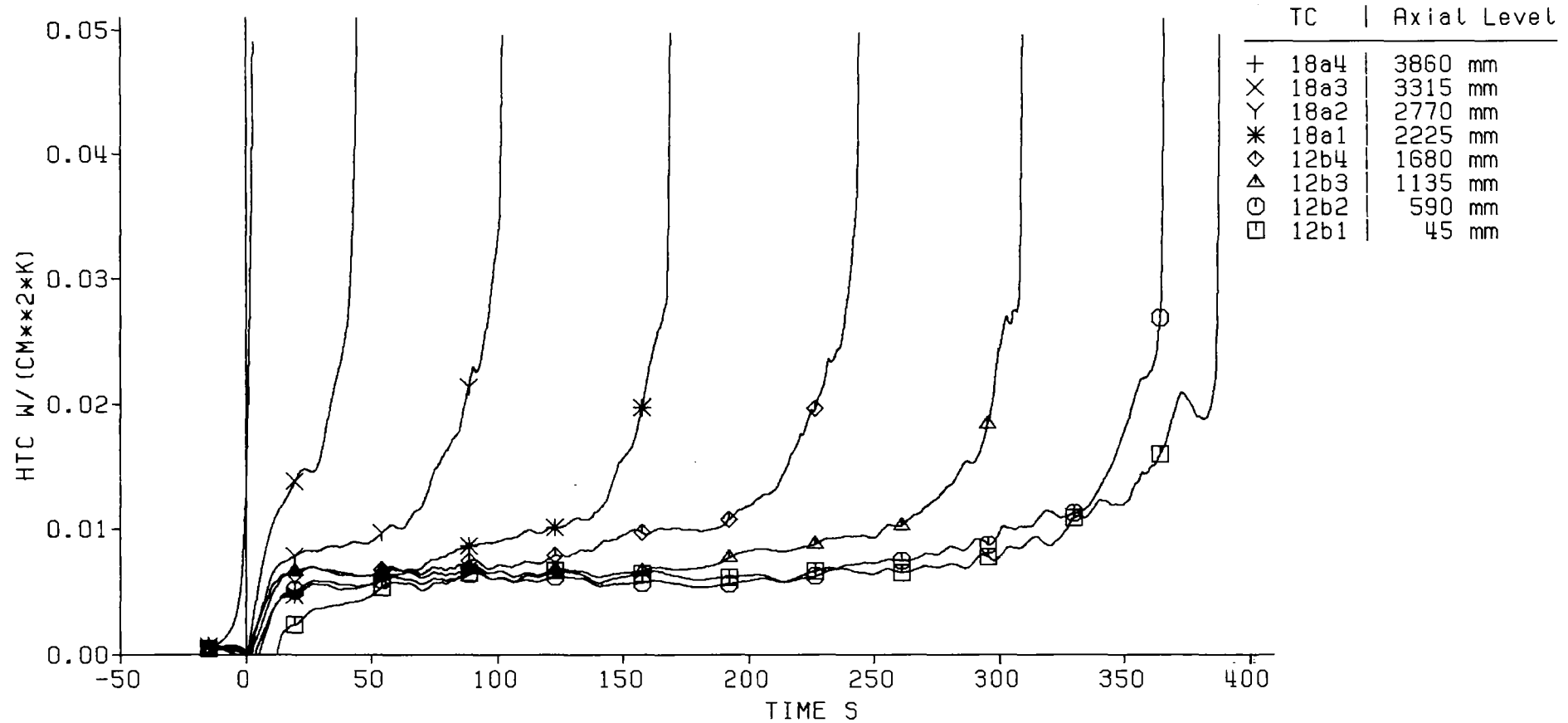


Decay Heat 120% ANS Standard
 Flooding Rate (cold) 3.81 cm/s
 System Pressure 4.04 bar
 Feedwater Temperature 40°C

REBEKA Rods With
 Helium Filled Gaps



Fig. 44 SEFLEX: 5x5 ROD BUNDLE, SERIES 1, TEST-No. 03



Decay Heat
 Flooding Rate (cold) 3.81 cm/s
 System Pressure 4.04 bar
 Feedwater Temperature 40°C

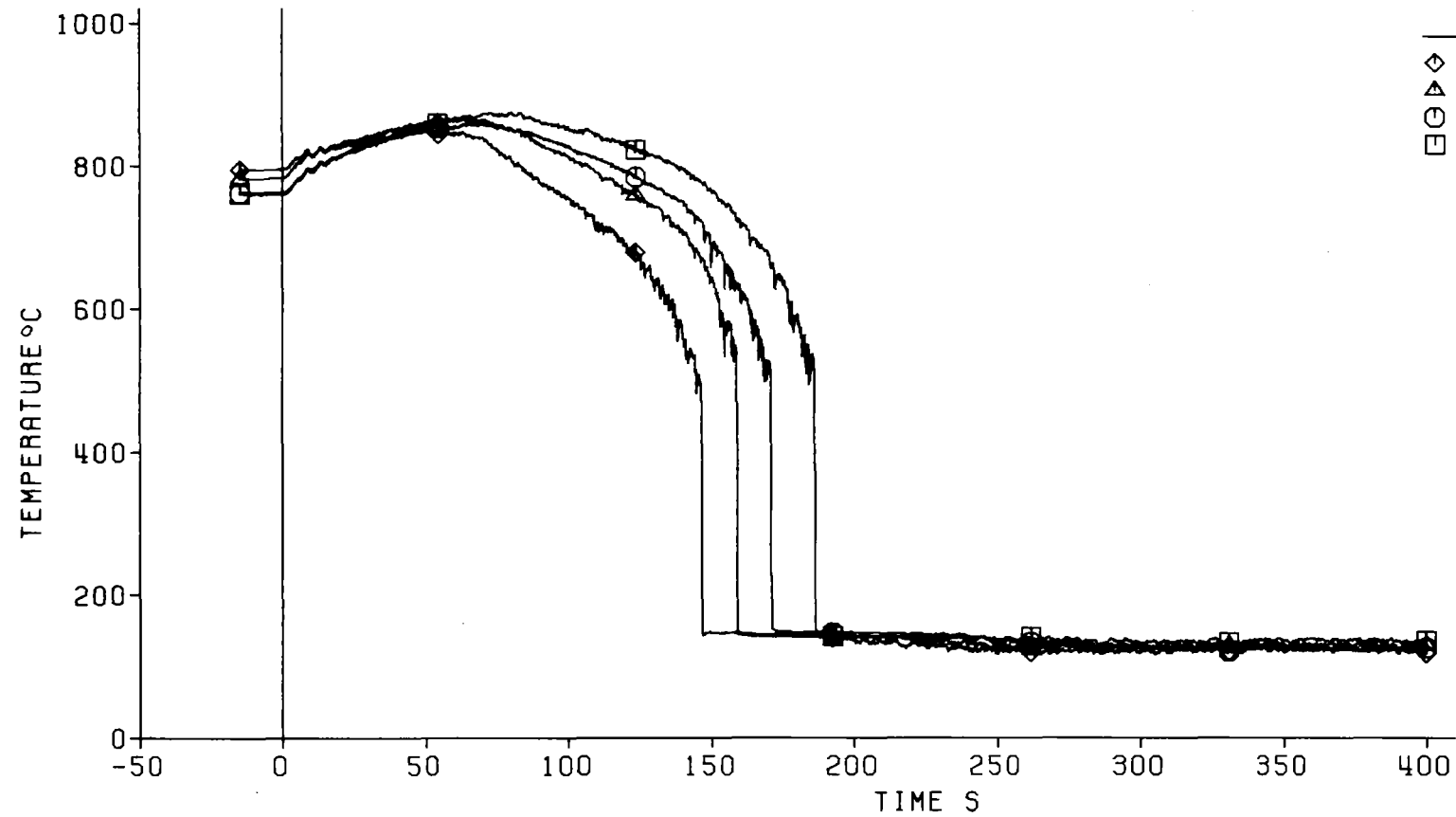
120% ANS Standard

REBEKA Rods With
 Helium Filled Gaps

KIRB

Fig. 45 SEFLEX: 5x5 ROD BUNDLE, SERIES 1, TEST-No. 03

Cladding Temperature

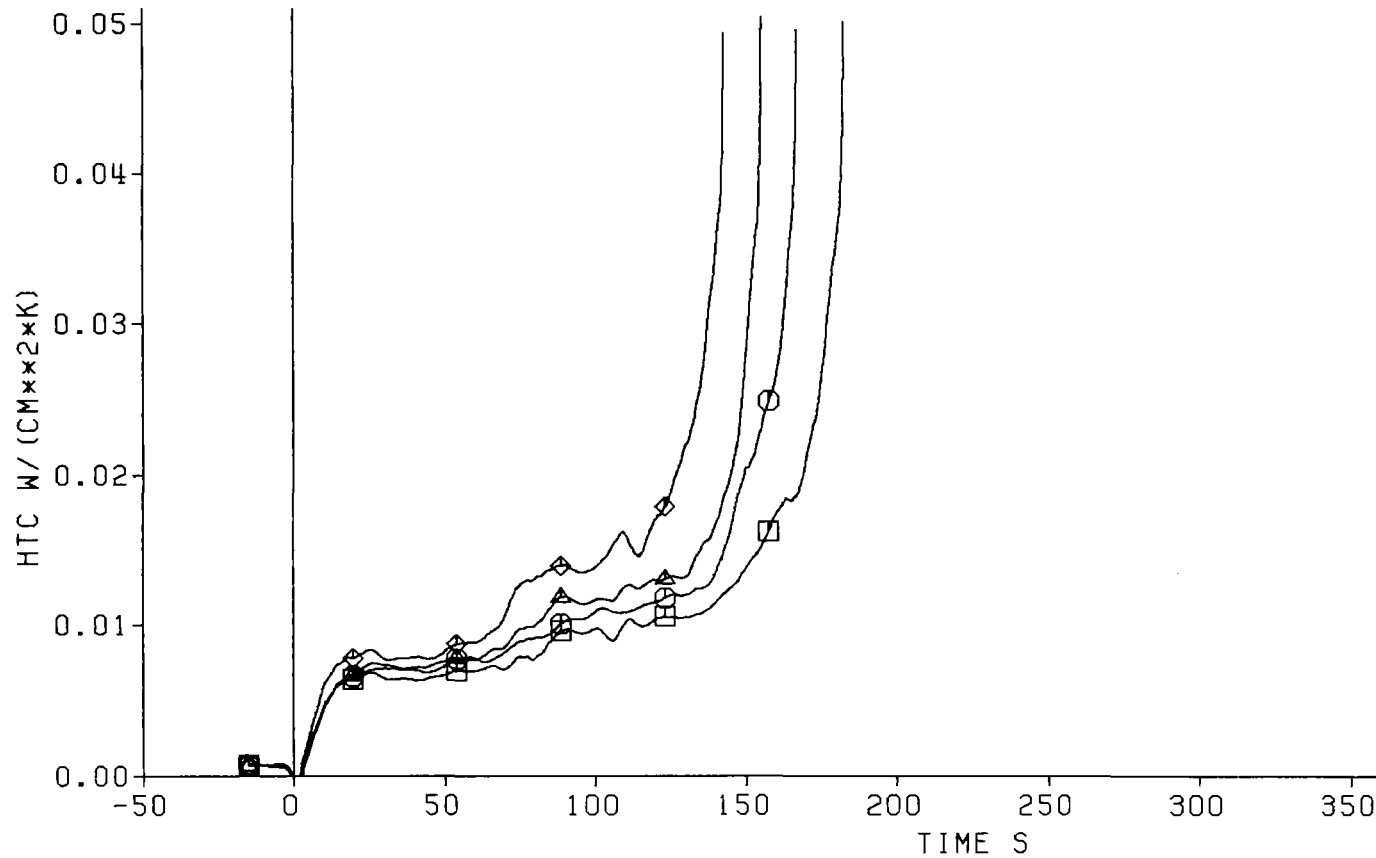


Decay Heat 120% ANS Standard
 Flooding Rate (cold) 3.81 cm/s
 System Pressure 4.04 bar
 Feedwater Temperature 40°C

REBEKA Rods With Helium Filled Gaps



Fig. 46 SEFLEX: 5x5 ROD BUNDLE, SERIES 1, TEST-No. 03



TC	Symbol	Axial Level
7f4	◇	2425 mm
7f3	△	2325 mm
7f2	○	2225 mm
7f1	□	2125 mm

Decay Heat
 Flooding Rate (cold) 3.81 cm/s
 System Pressure 4.04 bar
 Feedwater Temperature 40 °C

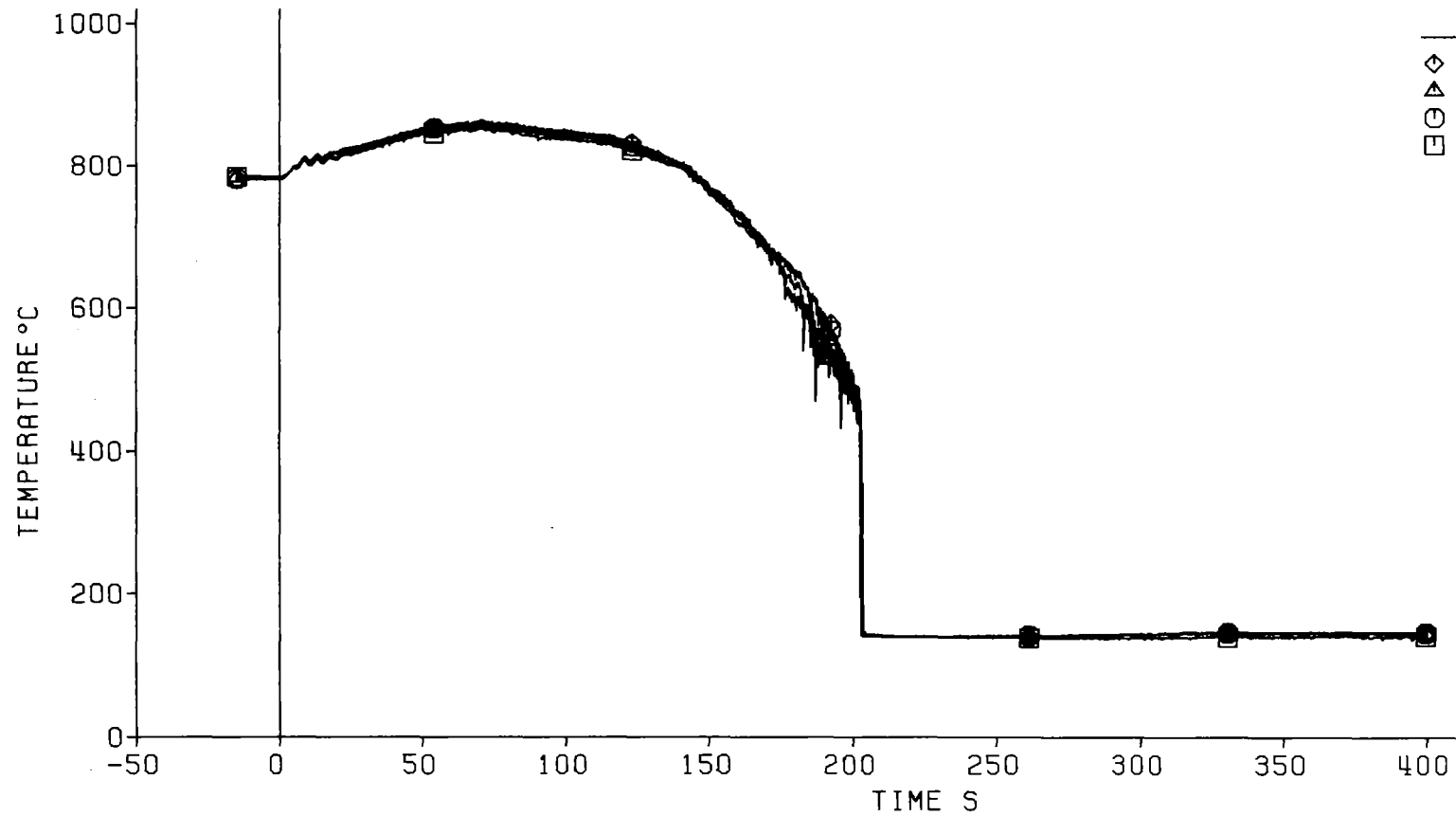
120% ANS Standard

REBEKA Rods With Helium Filled Gaps



Fig. 47 SEFLEX: 5x5 ROD BUNDLE, SERIES 1, TEST-No. 03

Cladding Temperature



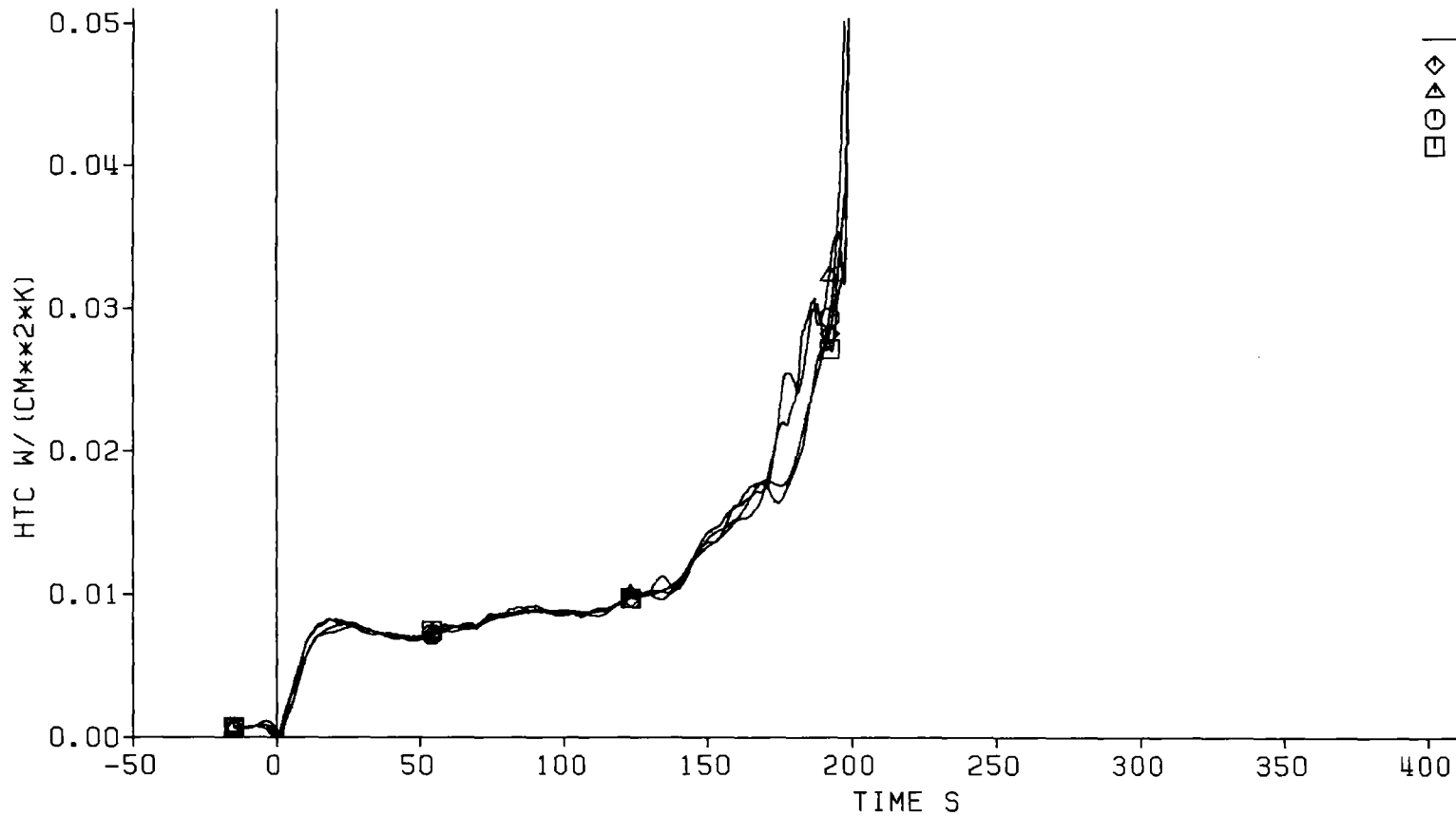
TC	Axial Level
◇ 14d1	2025 mm
△ 14d2	2025 mm
○ 14d3	2025 mm
□ 14d4	2025 mm

Decay Heat 120% ANS Standard
 Flooding Rate (cold) 3.81 cm/s
 System Pressure 4.04 bar
 Feedwater Temperature 40°C

REBEKA Rods With Helium Filled Gaps



Fig. 48 SEFLEX: 5x5 ROD BUNDLE, SERIES 1, TEST-No. 03



TC	Axial Level
◇ 14d1	2025 mm
△ 14d2	2025 mm
○ 14d3	2025 mm
□ 14d4	2025 mm

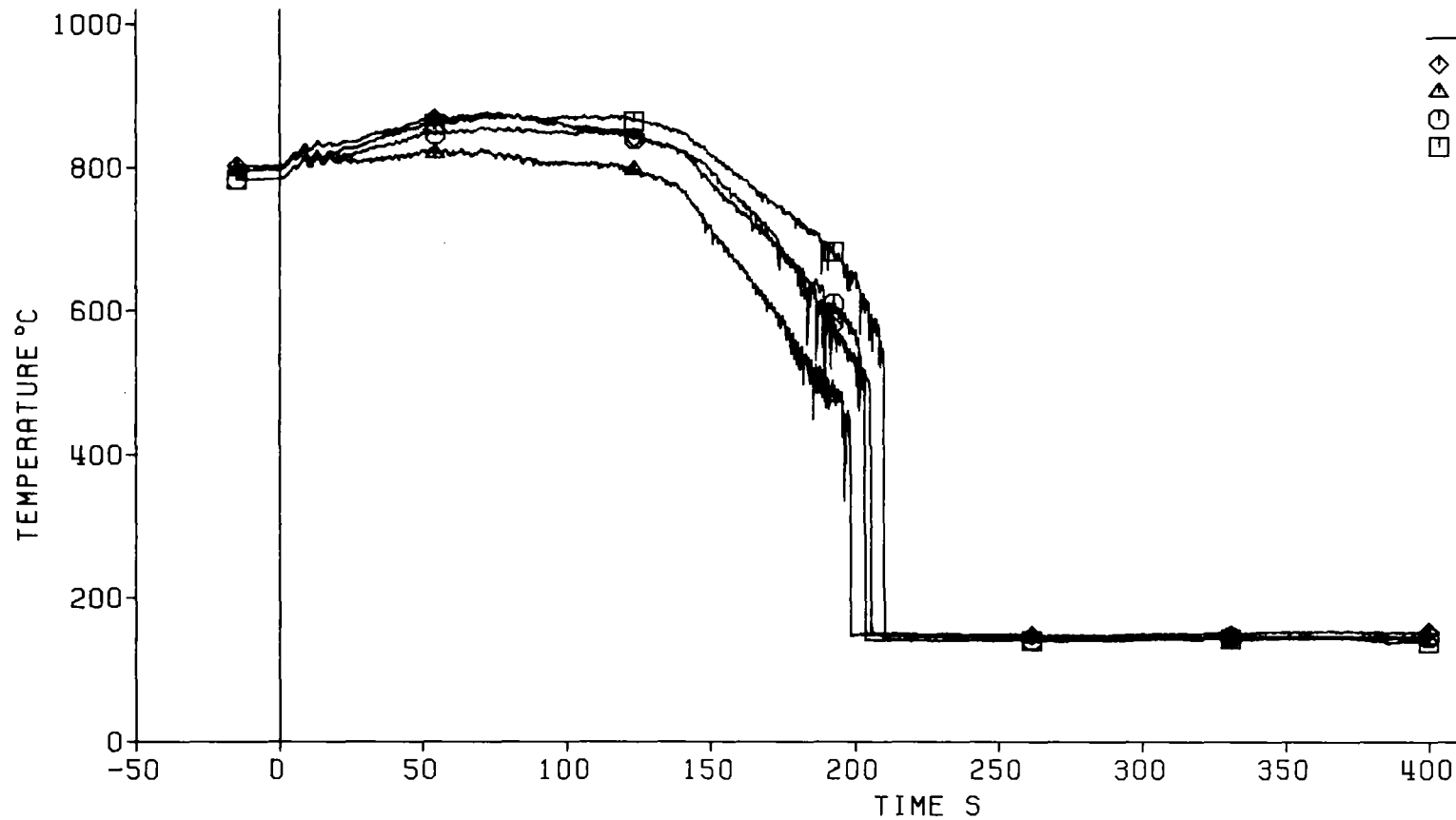
Decay Heat 120% ANS Standard
 Flooding Rate (cold) 3.81 cm/s
 System Pressure 4.04 bar
 Feedwater Temperature 40°C

REBEKA Rods With Helium Filled Gaps



Fig. 49 SEFLEX: 5x5 ROD BUNDLE, SERIES 1, TEST-No. 03

Cladding Temperature

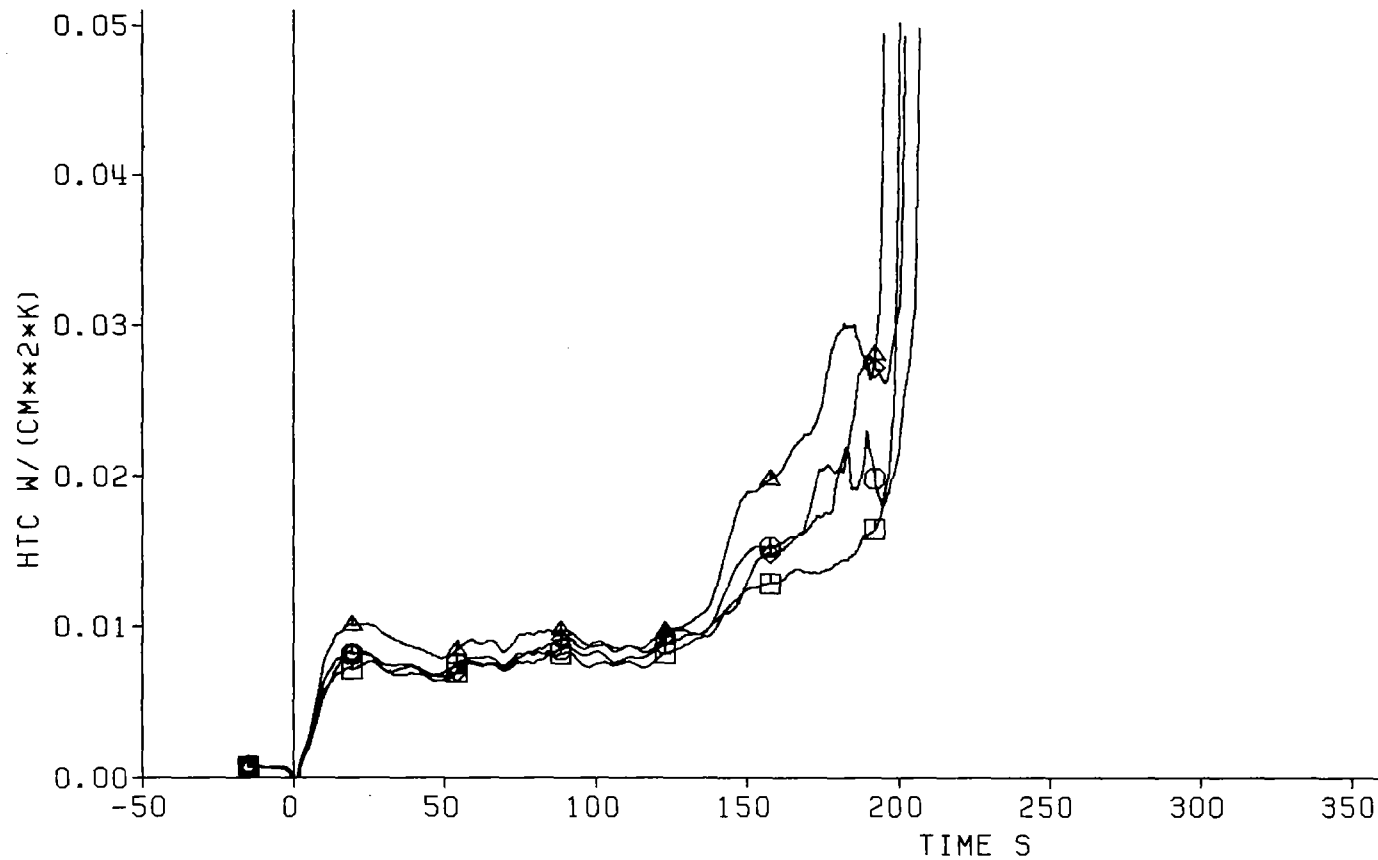


Decay Heat 120% ANS Standard
 Flooding Rate (cold) 3.81 cm/s
 System Pressure 4.04 bar
 Feedwater Temperature 40 °C

REBEKA Rods With
 Helium Filled Gaps



Fig. 50 SEFLEX: 5x5 ROD BUNDLE, SERIES 1, TEST-No. 03



TC	Axial Level
◇ 13i4	2025 mm
△ 13i3	1975 mm
○ 13i2	1925 mm
□ 13i1	1875 mm

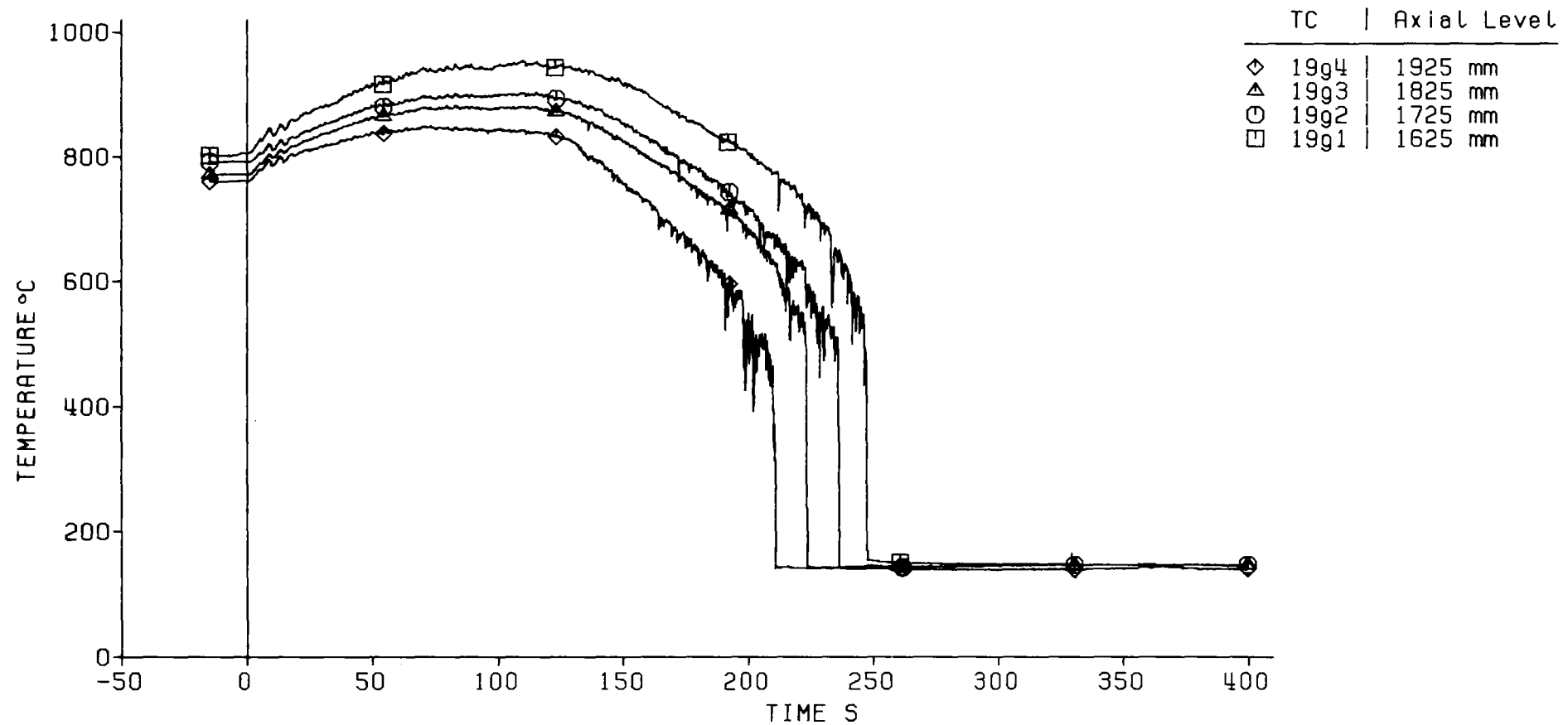
Decay Heat 120% ANS Standard
 Flooding Rate (cold) 3.81 cm/s
 System Pressure 4.04 bar
 Feedwater Temperature 40 °C

REBEKA Rods With Helium Filled Gaps



Fig. 51 SEFLEX: 5x5 ROD BUNDLE, SERIES 1, TEST-NO. 03

Cladding Temperature



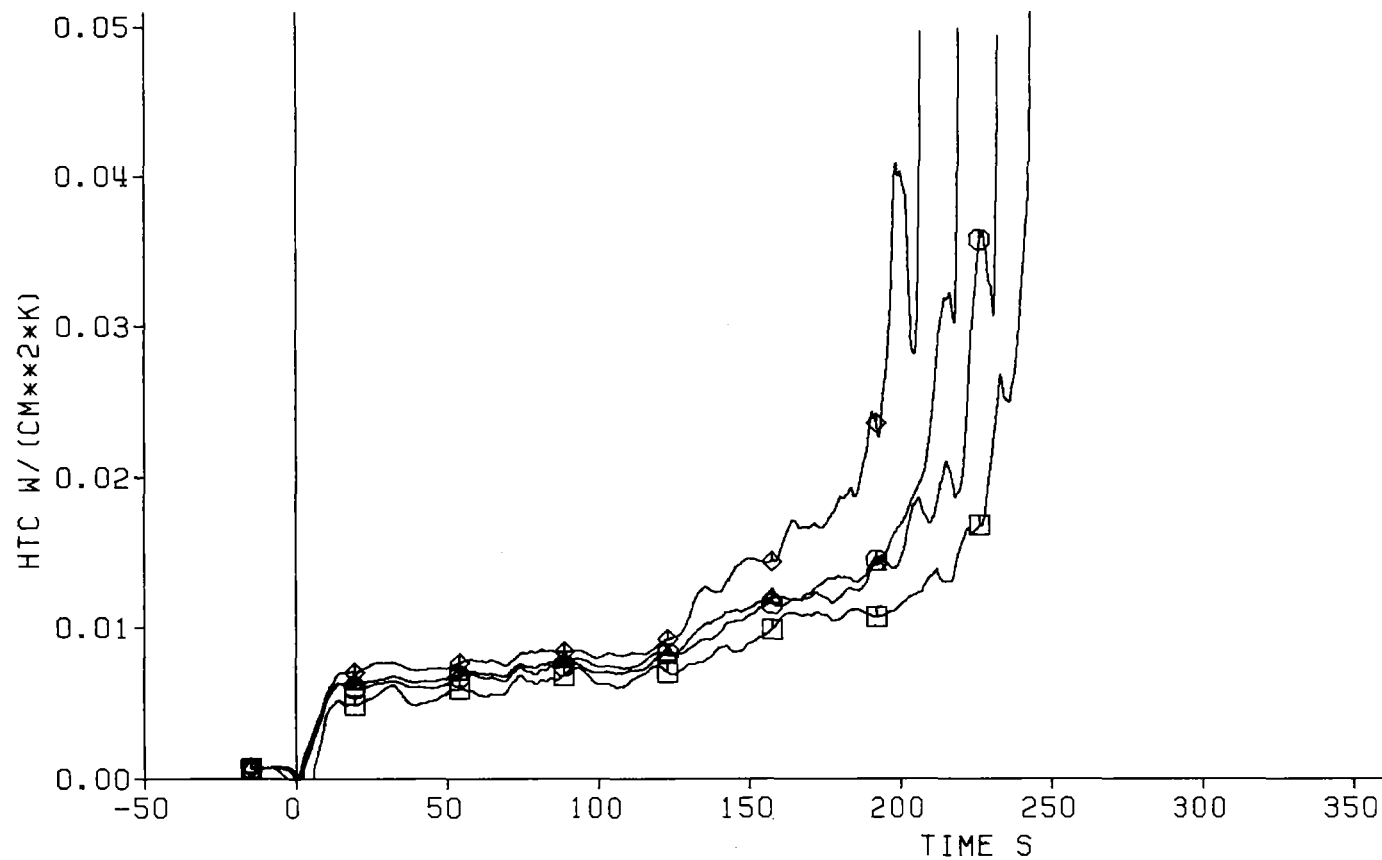
— 72 —

Decay Heat 120% ANS Standard
 Flooding Rate (cold) 3.81 cm/s
 System Pressure 4.04 bar
 Feedwater Temperature 40 °C

REBEKA Rods With Helium Filled Gaps



Fig. 52 SEFLEX: 5x5 ROD BUNDLE, SERIES 1, TEST-No. 03



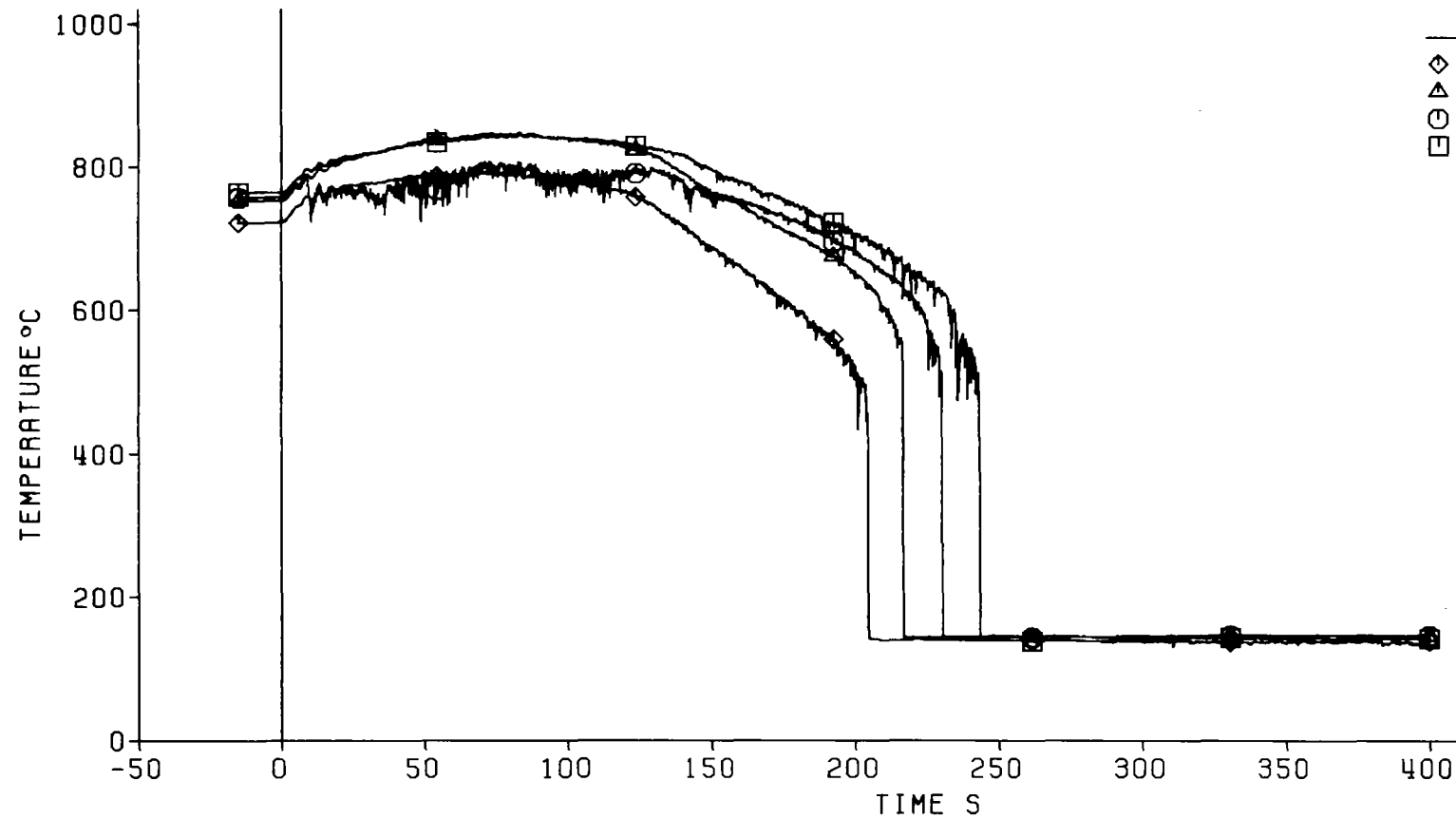
Decay Heat 120% ANS Standard
 Flooding Rate (cold) 3.81 cm/s
 System Pressure 4.04 bar
 Feedwater Temperature 40 °C

REBEKA Rods With
 Helium Filled Gaps

KJK
 IRB

Fig. 53 SEFLEX: 5x5 ROD BUNDLE, SERIES 1, TEST-No. 03

Cladding Temperature



— 74 —

Decay Heat
 Flooding Rate (cold) 3.81 cm/s
 System Pressure 4.04 bar
 Feedwater Temperature 40 °C

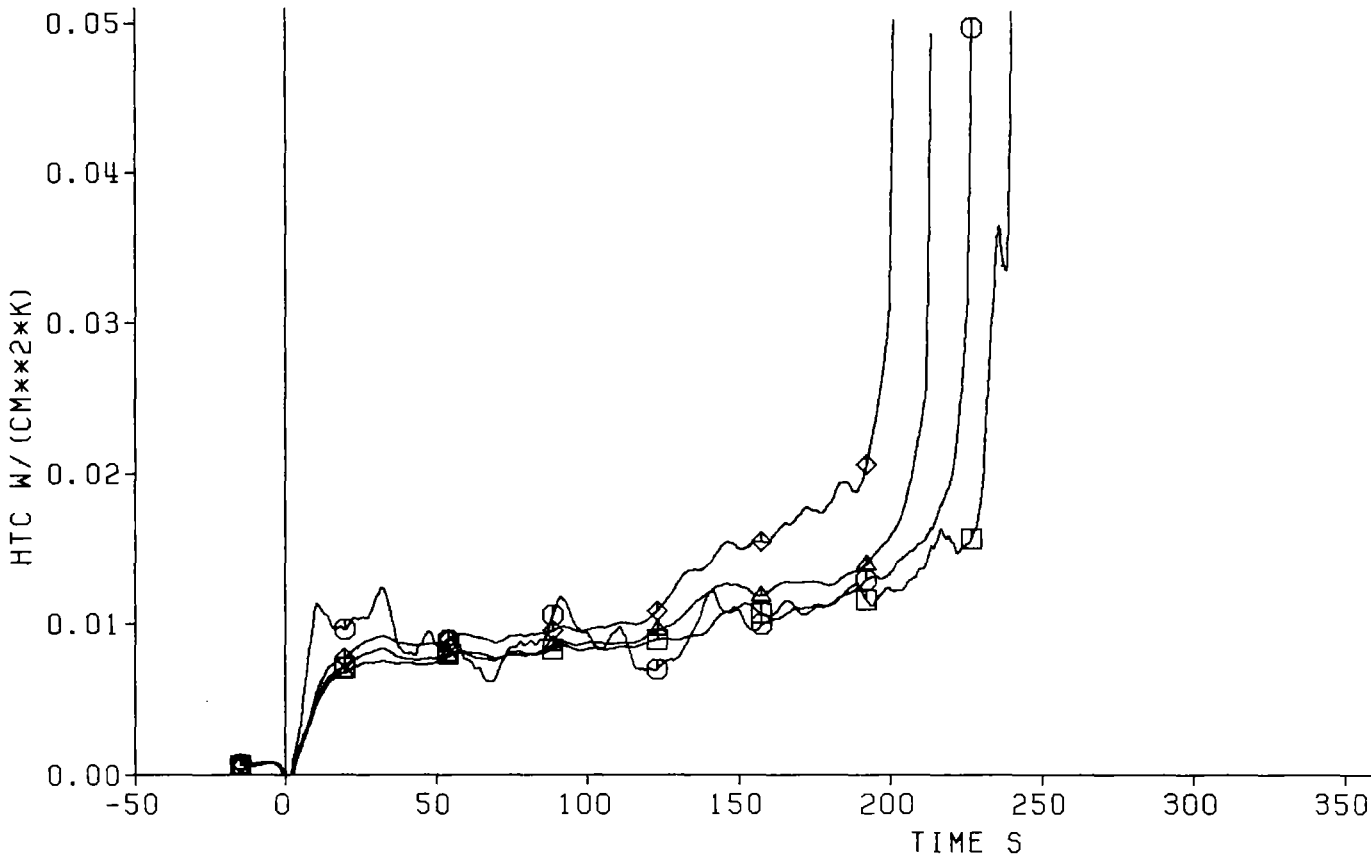
120% ANS Standard

REBEKA Rods With Helium Filled Gaps



Fig. 54 SEFLEX: 5x5 ROD BUNDLE, SERIES 1, TEST-No. 03

TC	Axial Level
◇	16g4 1925 mm
△	16g3 1825 mm
○	16g2 1725 mm
□	16g1 1625 mm



— 75 —

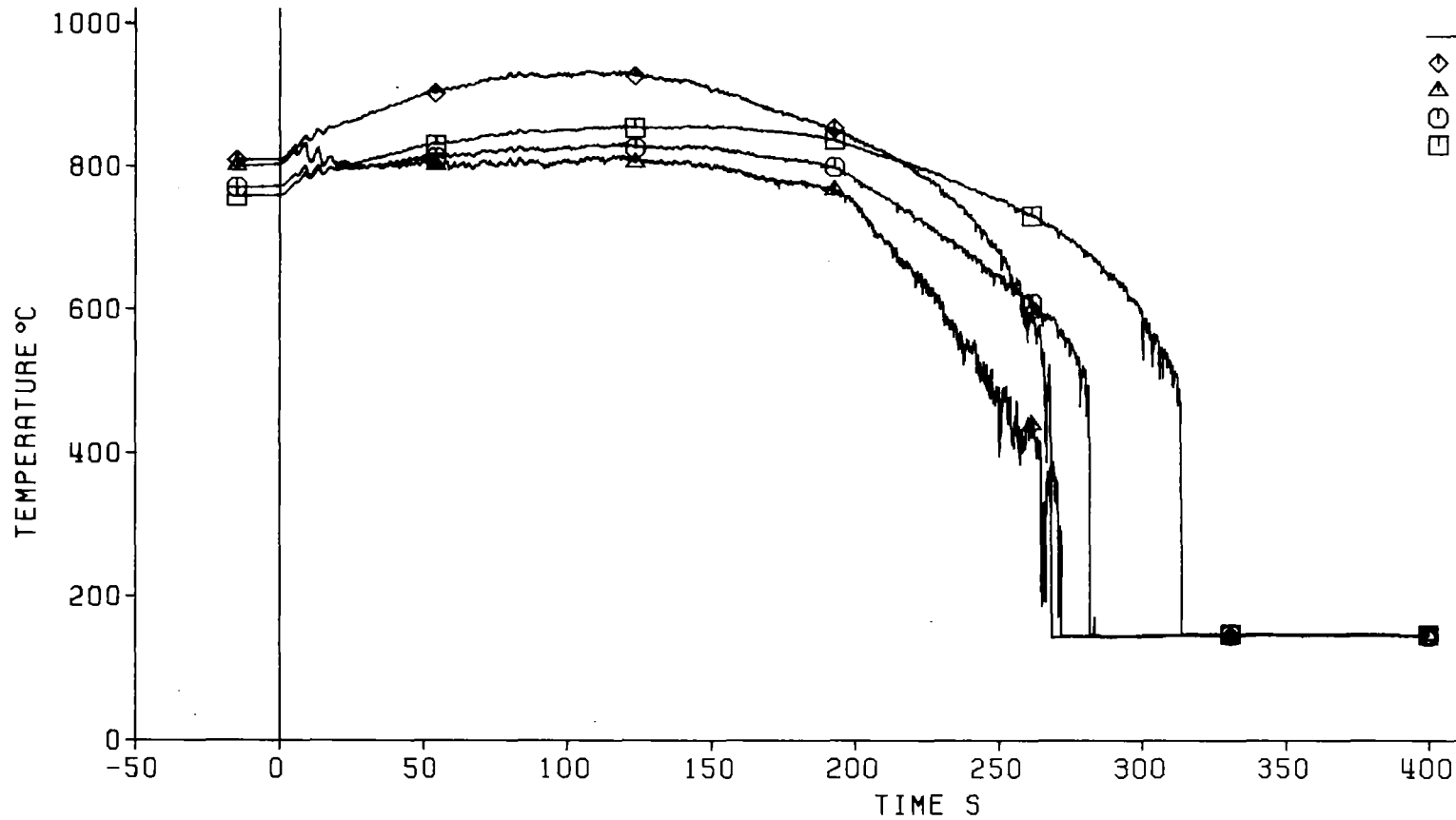
Decay Heat	120% ANS Standard	REBEKA Rods With
Flooding Rate (cold)	3.81 cm/s	Helium Filled Gaps
System Pressure	4.04 bar	
Feedwater Temperature	40°C	



Fig. 55 SEFLEX: 5x5 ROD BUNDLE, SERIES 1, TEST-No. 03

Cladding Temperature

TC	Axial Level
◇	8j4 1525 mm
△	8j3 1425 mm
○	8j2 1325 mm
□	12b3 1135 mm

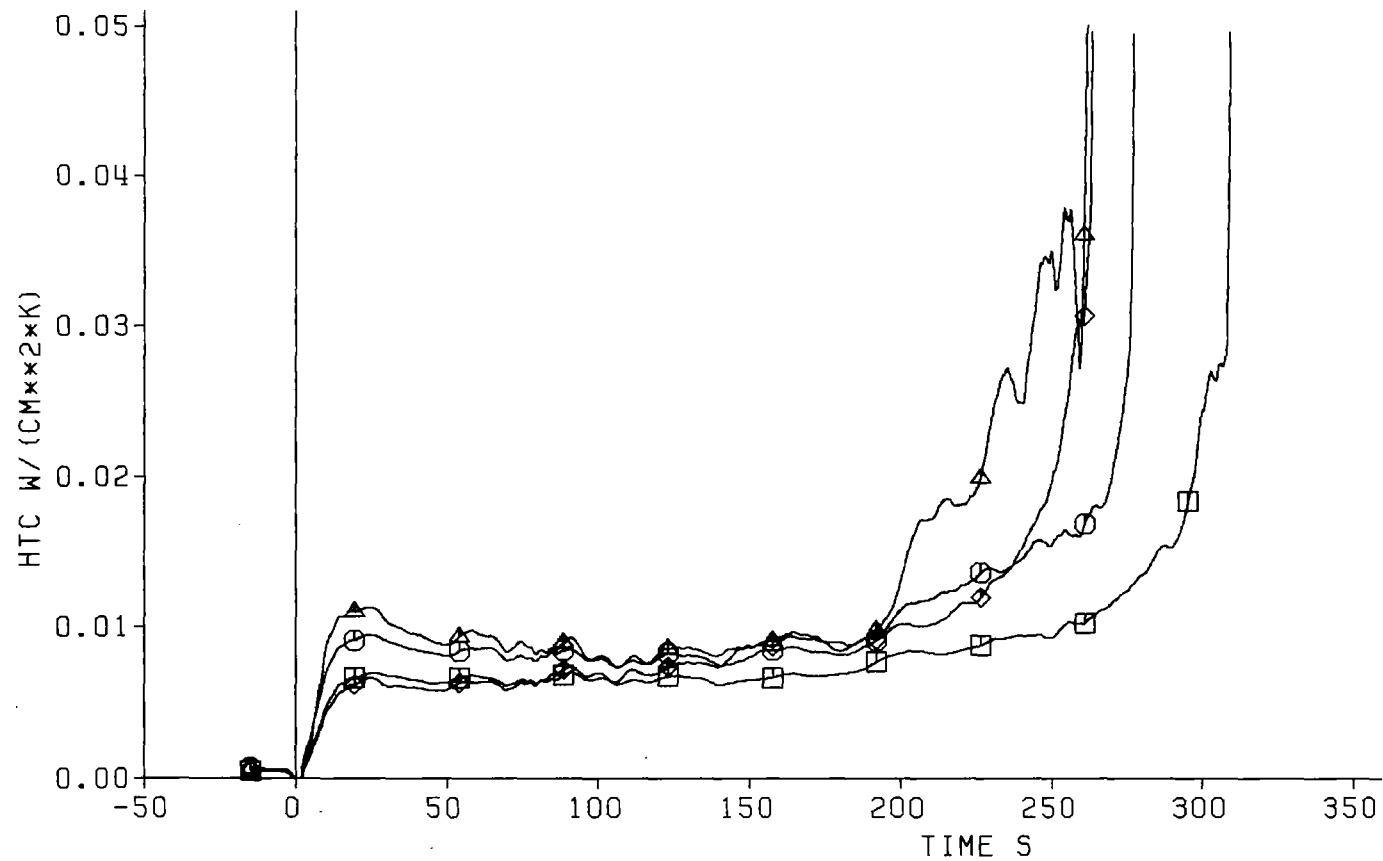


Decay Heat 120% ANS Standard
 Flooding Rate (cold) 3.81 cm/s
 System Pressure 4.04 bar
 Feedwater Temperature 40°C

REBEKA Rods With Helium Filled Gaps



Fig. 56 SEFLEX: 5x5 ROD BUNDLE, SERIES 1, TEST-No. 03



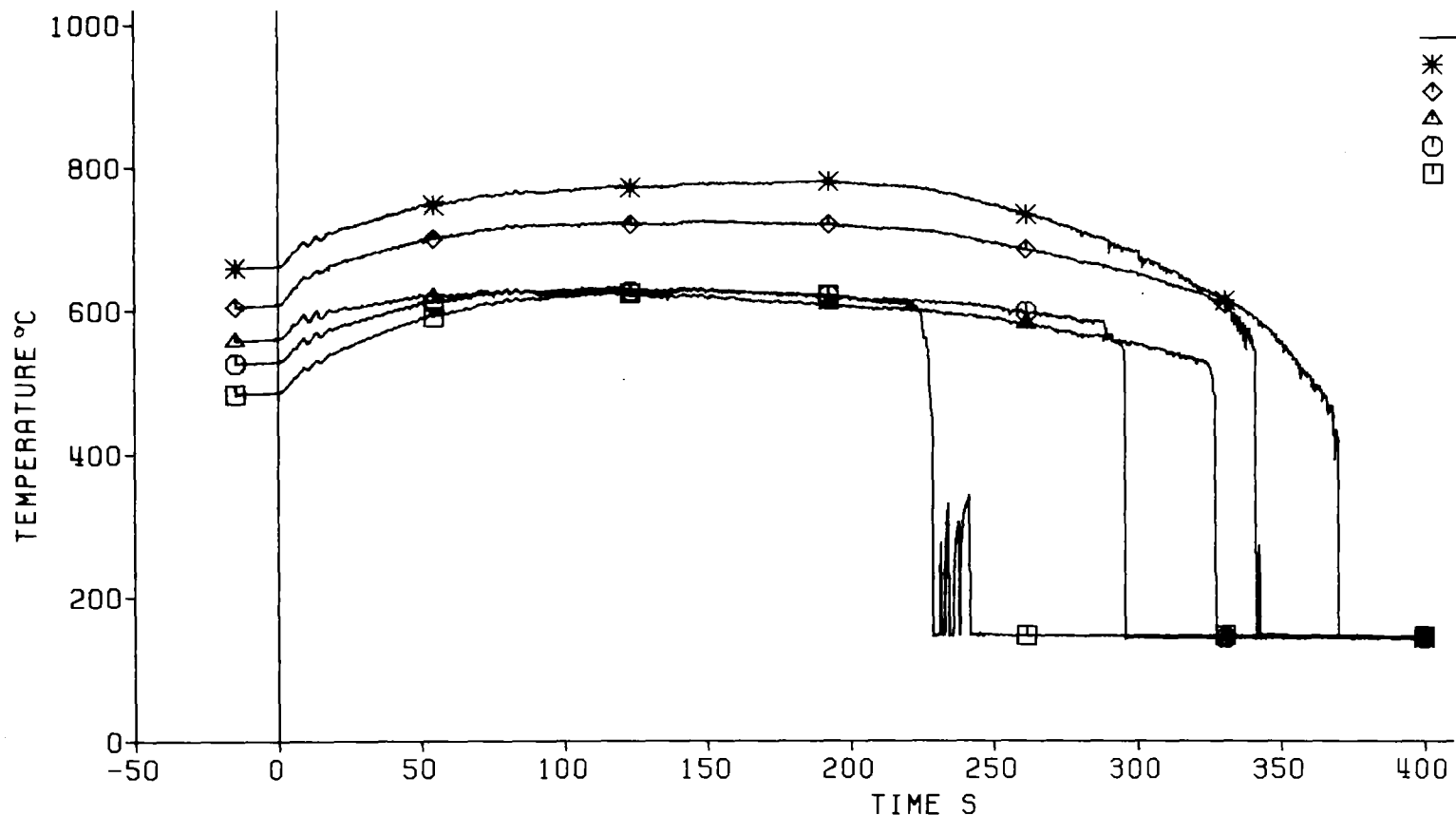
Decay Heat 120% ANS Standard
 Flooding Rate (cold) 3.81 cm/s
 System Pressure 4.04 bar
 Feedwater Temperature 40 °C

REBEKA Rods With
 Helium Filled Gaps

KfK
 IRB

Fig. 57 SEFLEX: 5x5 ROD BUNDLE, SERIES 1, TEST-No. 03

Cladding Temperature

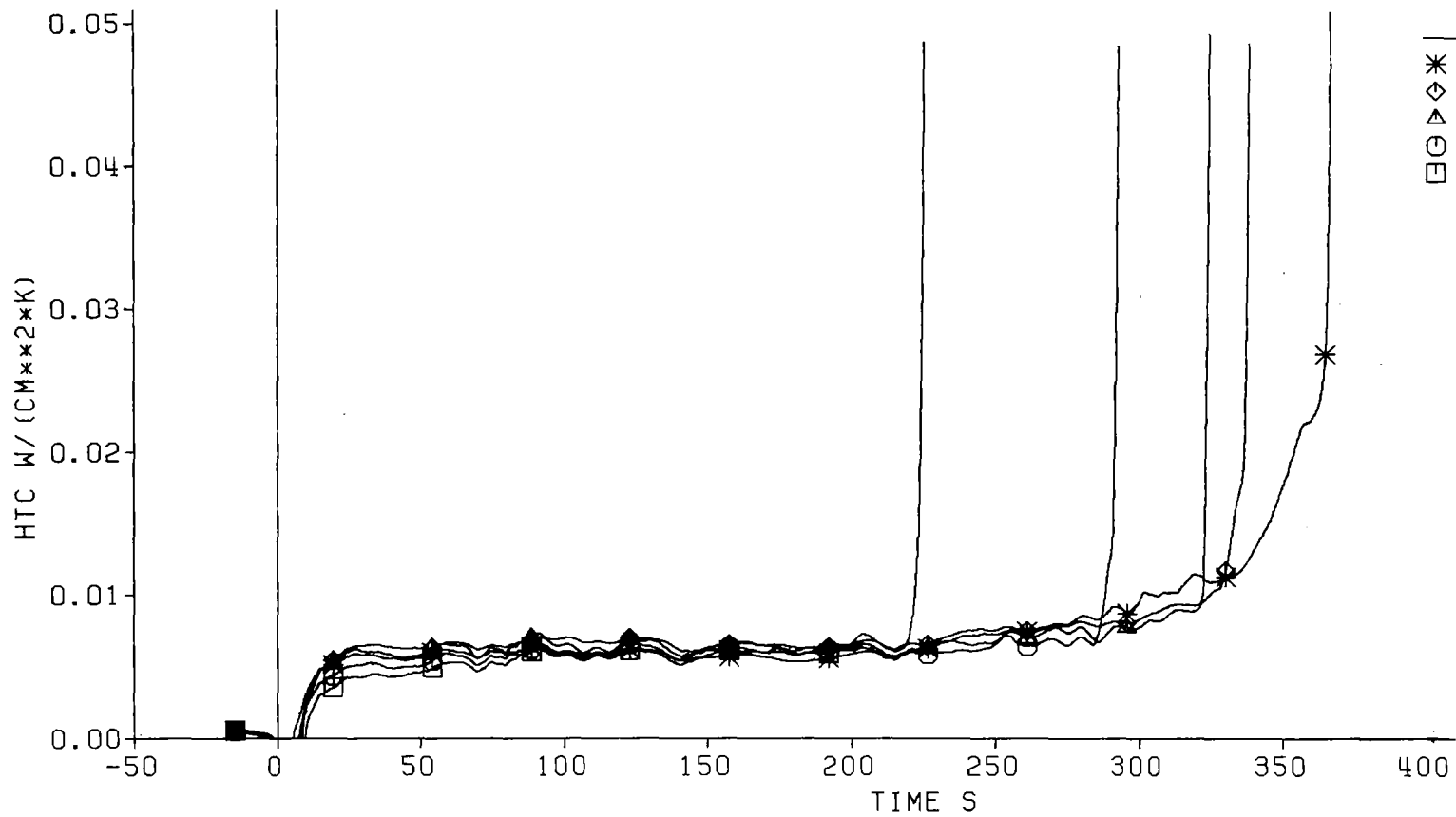


Decay Heat 120% ANS Standard
 Flooding Rate (cold) 3.81 cm/s
 System Pressure 4.04 bar
 Feedwater Temperature 40 °C

REBEKA Rods With Helium Filled Gaps



Fig. 58 SEFLEX: 5x5 ROD BUNDLE, SERIES 1, TEST-No. 03



Decay Heat 120% ANS Standard
 Flooding Rate (cold) 3.81 cm/s
 System Pressure 4.04 bar
 Feedwater Temperature 40°C

REBEKA Rods With
 Helium Filled Gaps

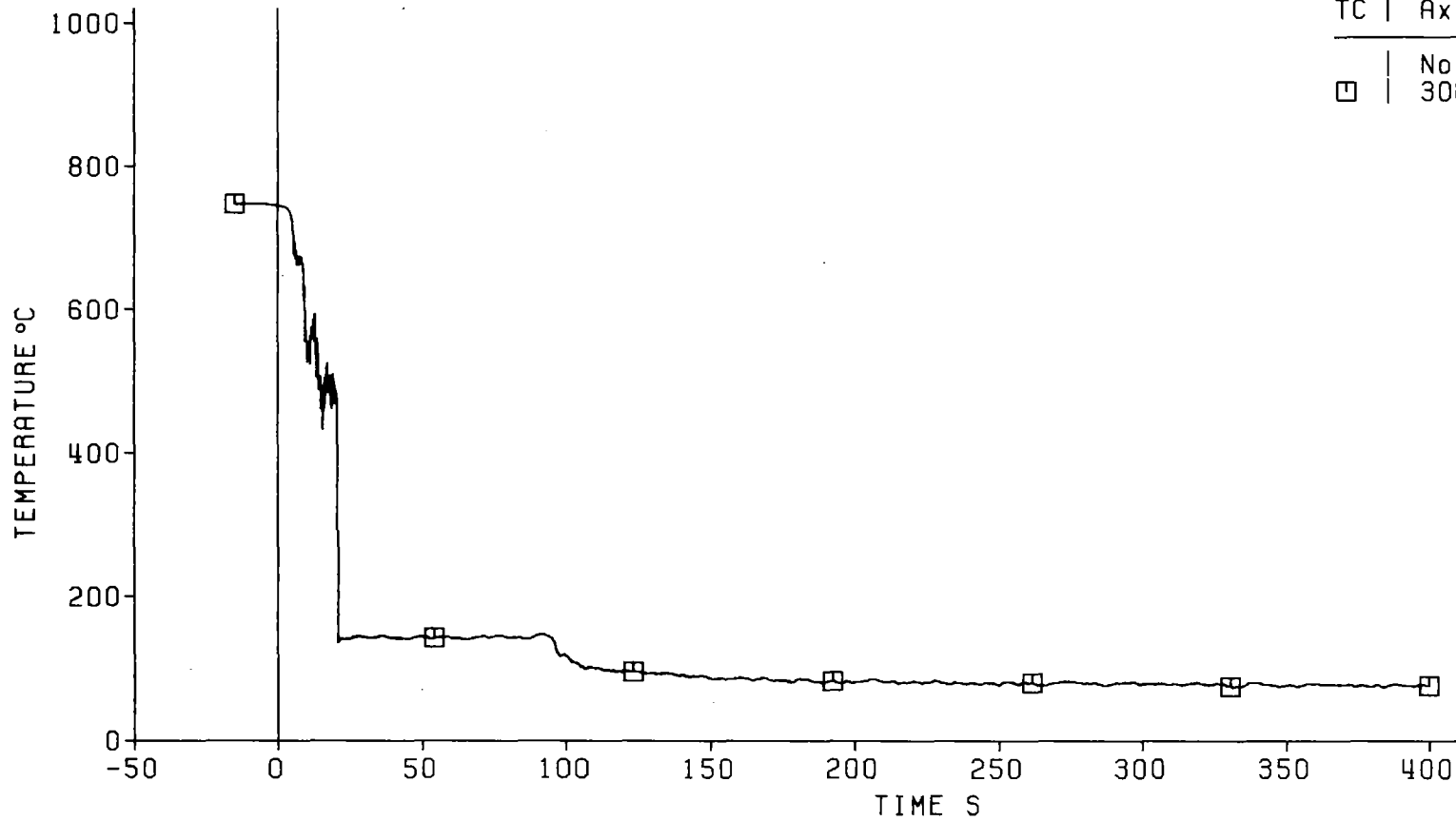


Fig. 59 SEFLEX: 5x5 ROD BUNDLE, SERIES 1, TEST-NO. 03

Grid Spacer Temperature

TC | Axial Level

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



Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.81 cm/s
System Pressure 4.04 bar
Feedwater Temperature 40°C

REBEKA Rods With
Helium Filled Gaps

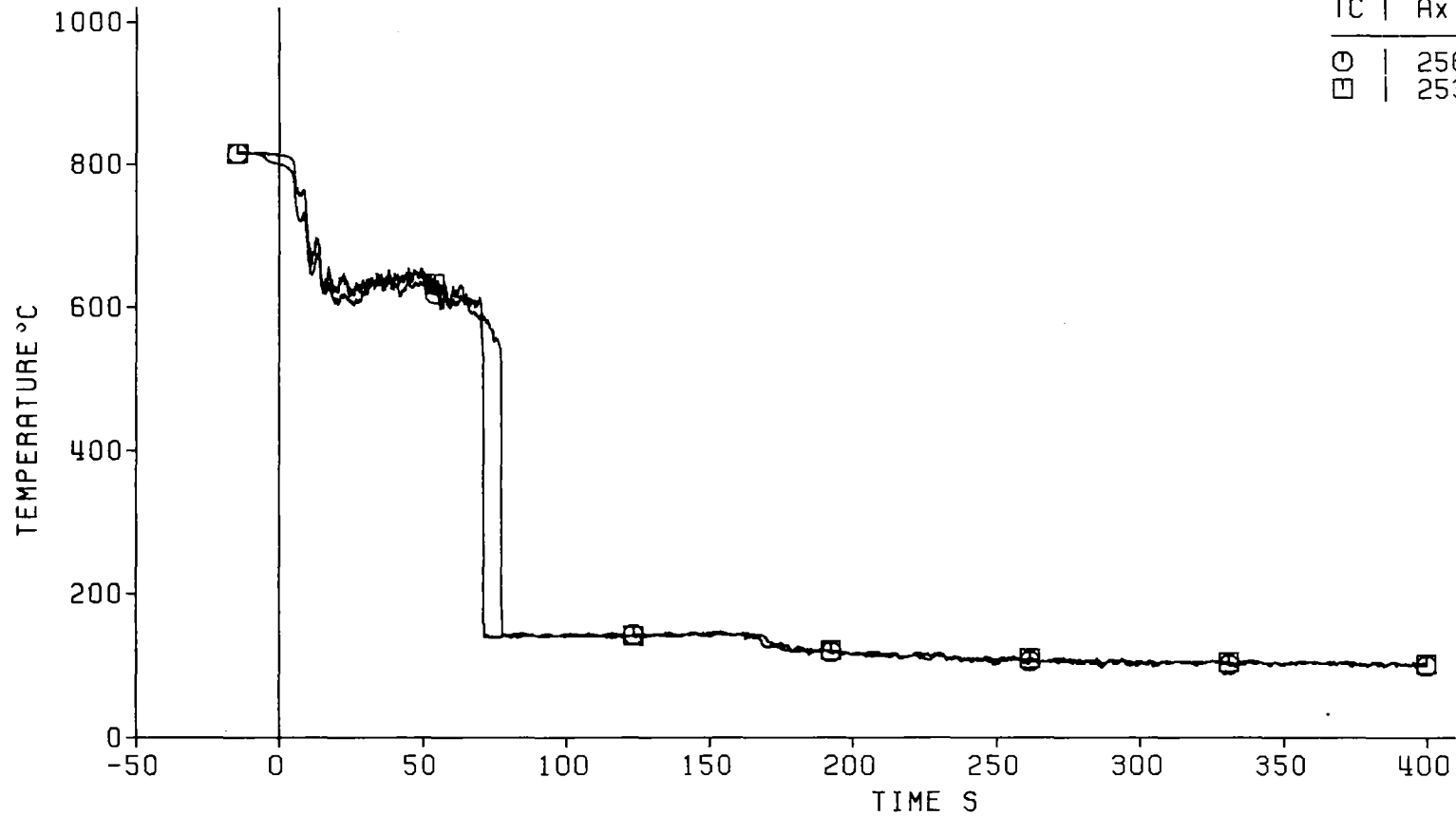


Fig. 60 SEFLEX: 5x5 ROD BUNDLE, SERIES 1, TEST-No. 03

Grid Spacer Temperature

TC | Axial Level

○ | 2568 mm, Leading Edge
□ | 2535 mm, Trailing Edge



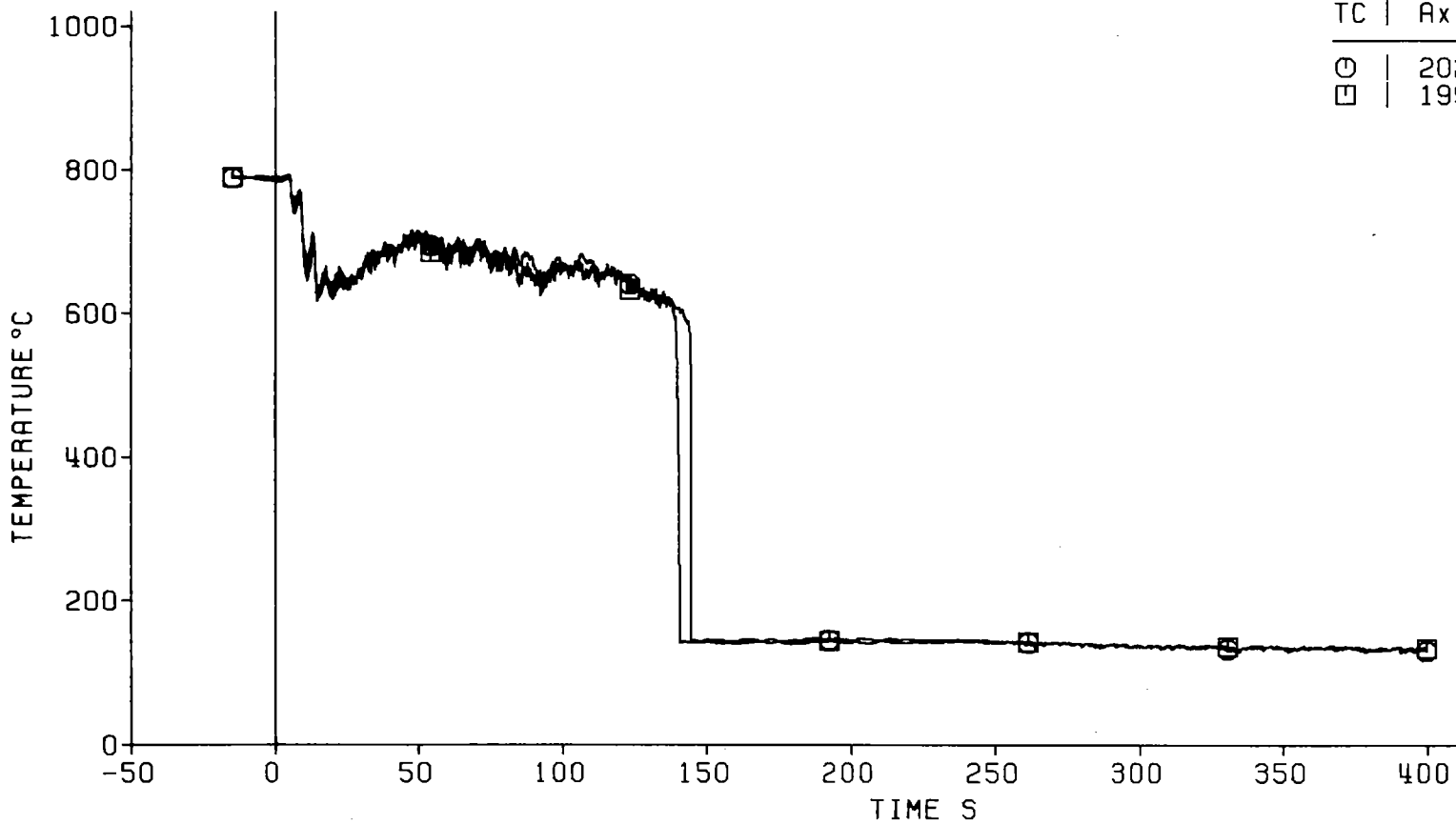
Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.81 cm/s
System Pressure 4.04 bar
Feedwater Temperature 40 °C

REBEKA Rods With
Helium Filled Gaps



Fig. 61 SEFLEX: 5x5 ROD BUNDLE, SERIES 1, TEST-No. 03

Grid Spacer Temperature



TC | Axial Level
○ | 2023 mm, Leading Edge
□ | 1990 mm, Trailing Edge

Decay Heat 120% ANS Standard REBEKA Rods With Helium Filled Gaps
Flooding Rate (cold) 3.81 cm/s
System Pressure 4.04 bar
Feedwater Temperature 40°C

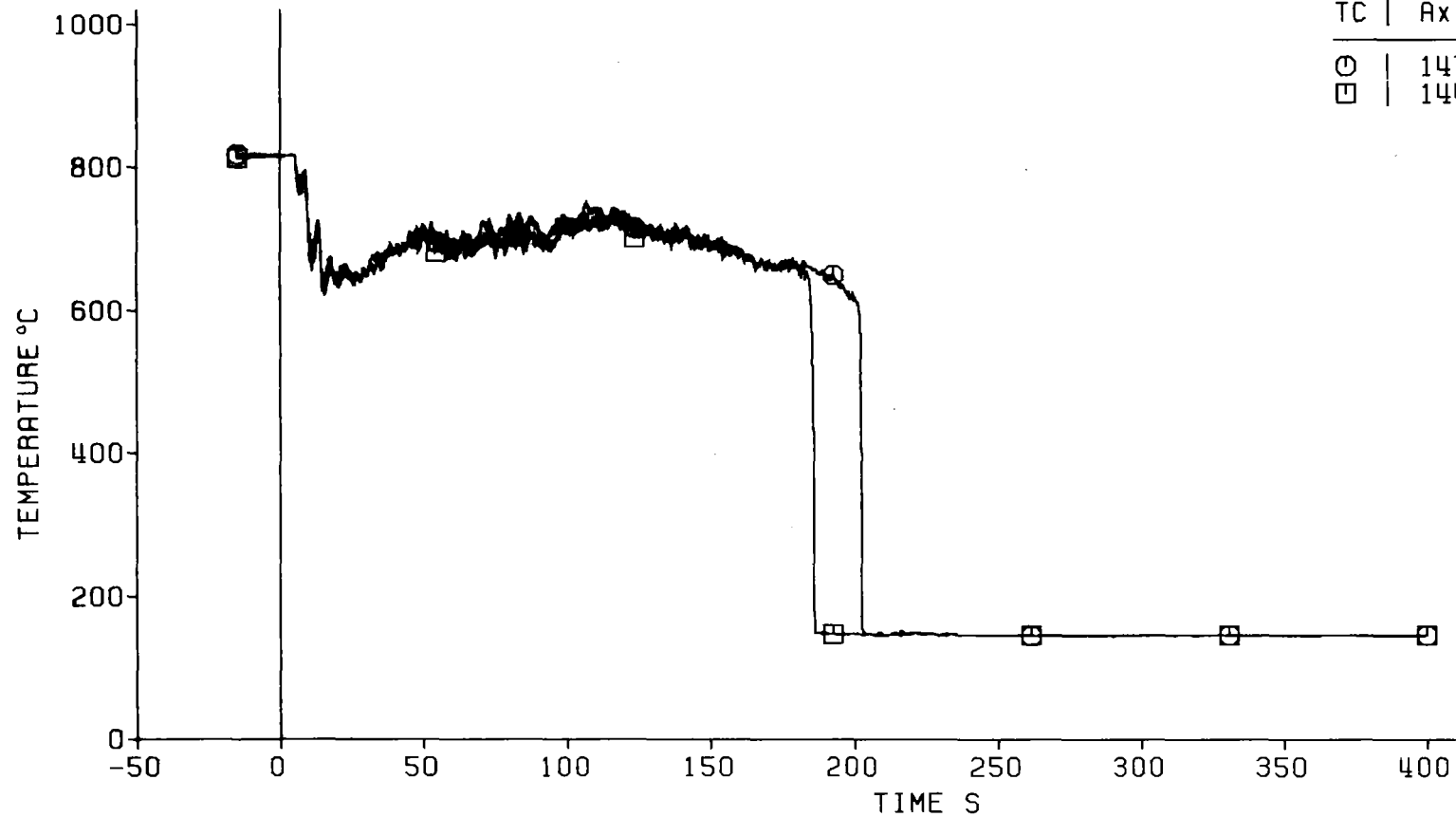


Fig. 62 SEFLEX: 5x5 ROD BUNDLE, SERIES 1, TEST-NO. 03

Grid Spacer Temperature

TC | Axial Level

⊙ | 1478 mm, Leading Edge
□ | 1445 mm, Trailing Edge



Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.81 cm/s
System Pressure 4.04 bar
Feedwater Temperature 40°C

REBEKA Rods With
Helium Filled Gaps

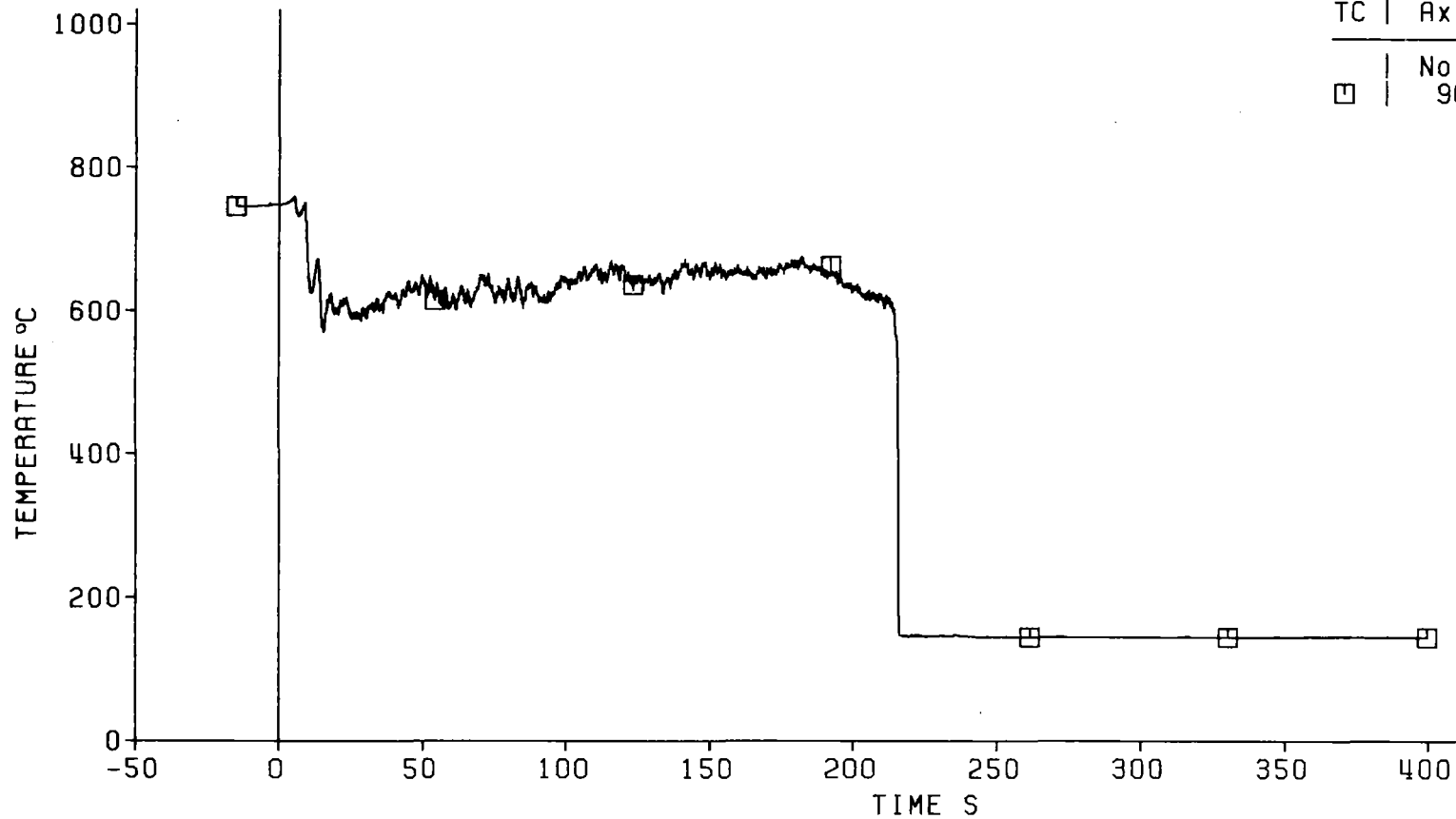


Fig. 63 SEFLEX: 5x5 ROD BUNDLE, SERIES 1, TEST-No. 03

Grid Spacer Temperature

TC | Axial Level

□ | No TC at Leading Edge
□ | 900 mm, Trailing Edge



Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.81 cm/s
System Pressure 4.04 bar
Feedwater Temperature 40°C

REBEKA Rods With
Helium Filled Gaps

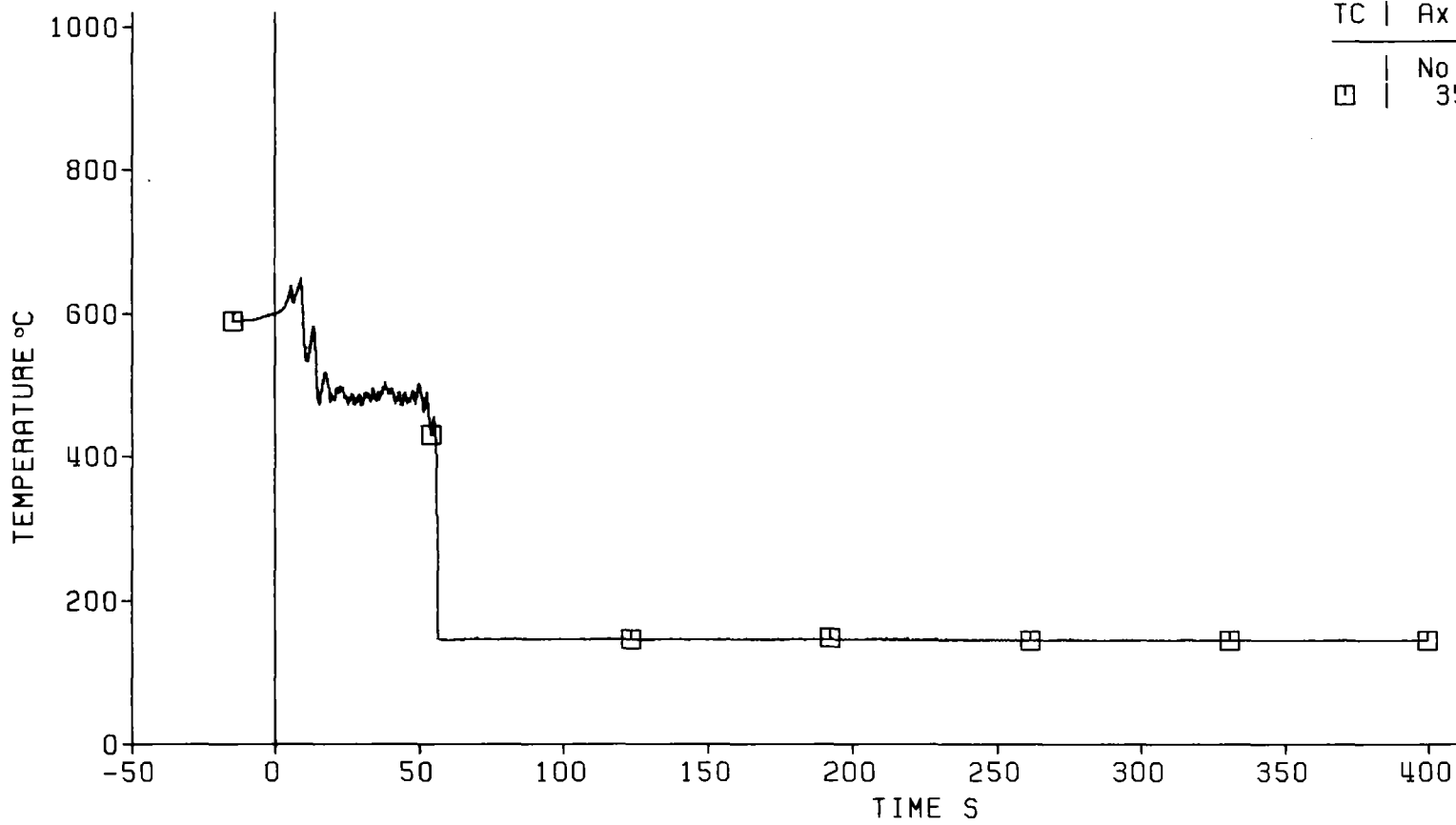


Fig. 64 SEFLEX: 5x5 ROD BUNDLE, SERIES 1, TEST-No. 03

Grid Spacer Temperature

TC | Axial Level

□ | No TC at Leading Edge
□ | 355 mm, Trailing Edge



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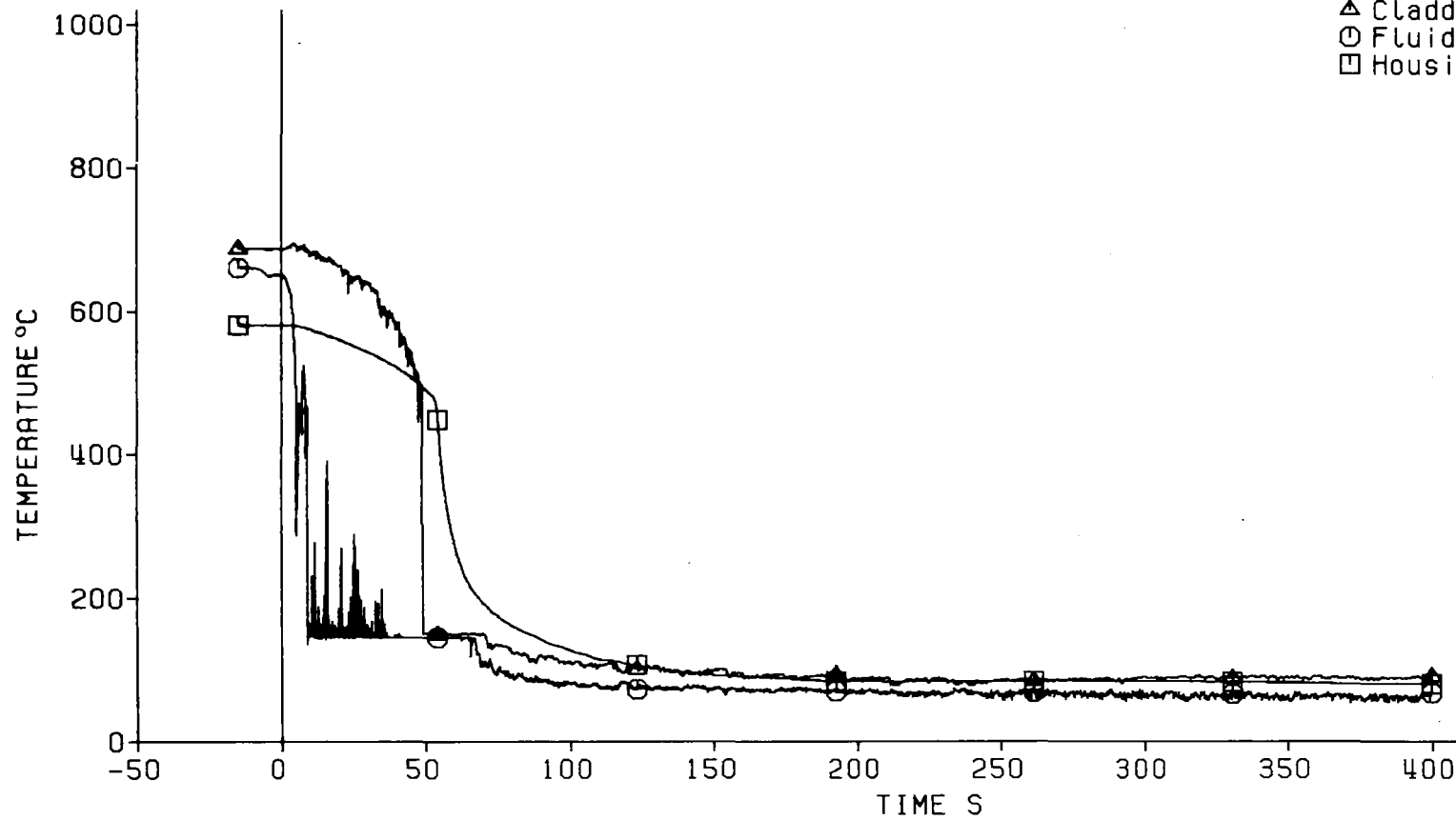
Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.81 cm/s
System Pressure 4.04 bar
Feedwater Temperature 40°C

REBEKA Rods With Helium Filled Gaps



Fig. 65 SEFLEX: 5x5 ROD BUNDLE, SERIES 1, TEST-NO. 03

Axial Level: 3315 mm



△ Cladding Temperature (18a3)
○ Fluid Temperature
□ Housing Temperature

Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.81 cm/s
System Pressure 4.04 bar
Feedwater Temperature 40°C

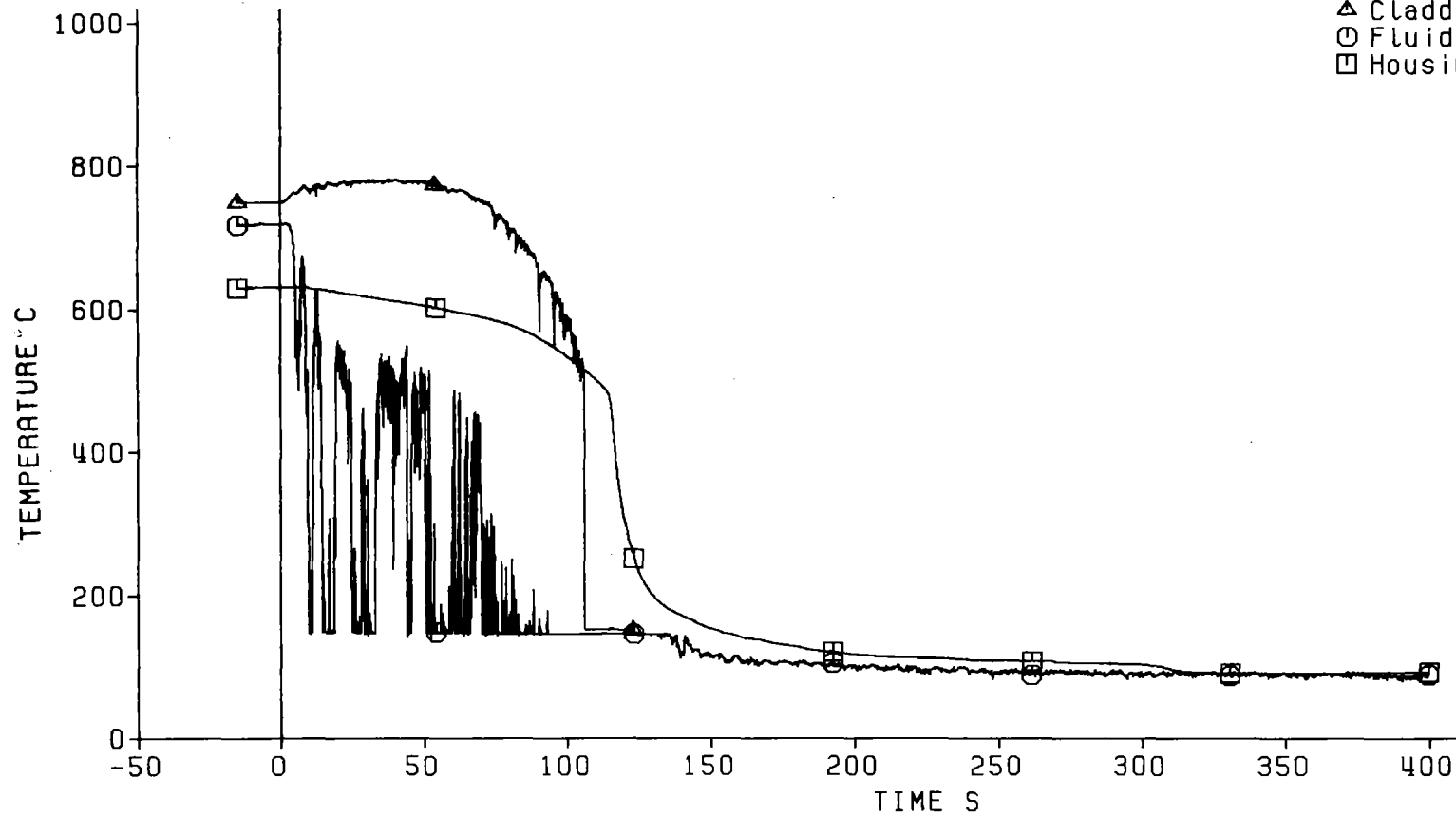
REBEKA Rods With
Helium Filled Gaps



Fig. 66 SEFLEX: 5x5 ROD BUNDLE, SERIES 1, TEST-NO. 03

Axial Level: 2770 mm

△ Cladding Temperature (18a2)
○ Fluid Temperature
□ Housing Temperature



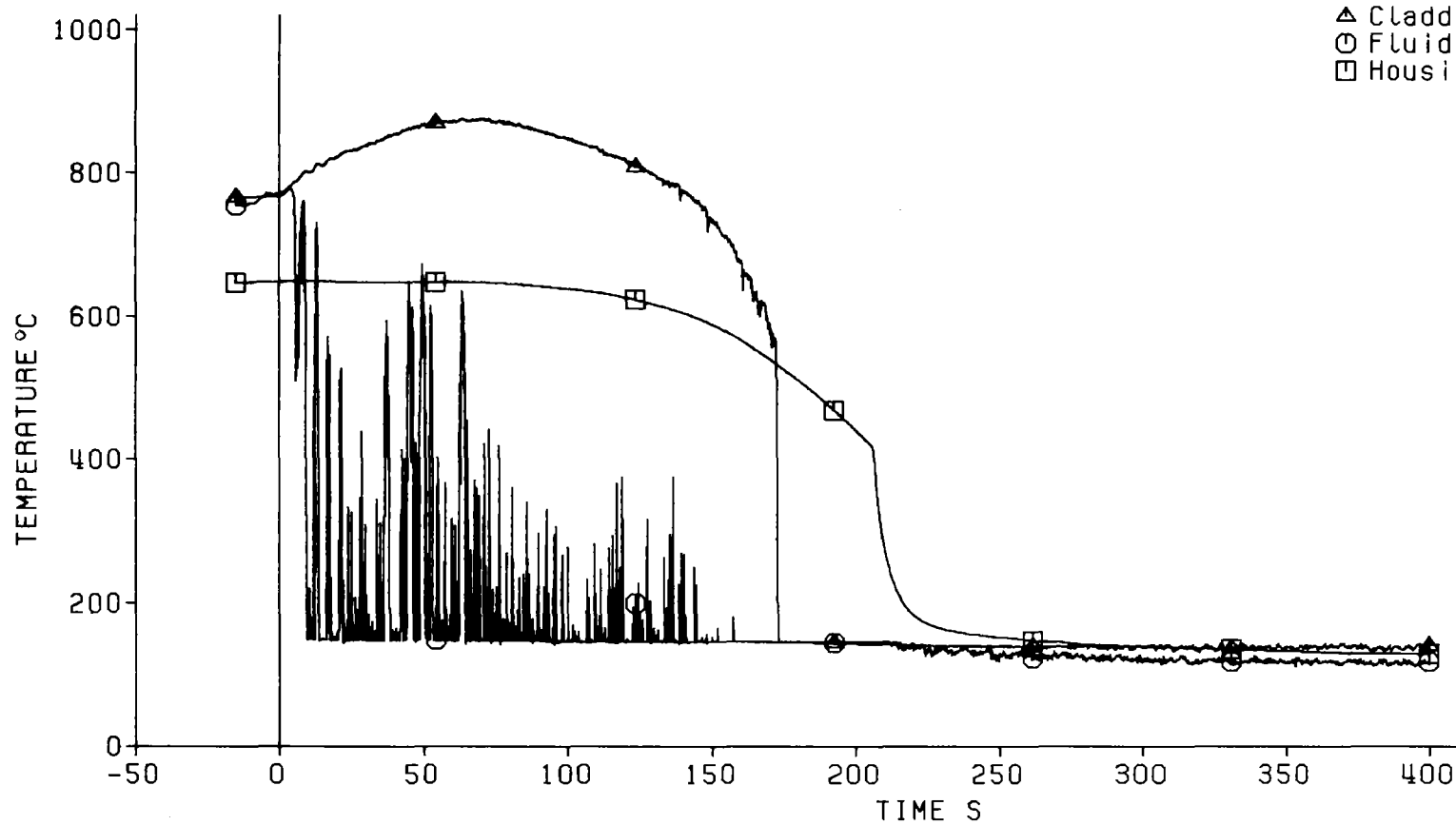
Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.81 cm/s
System Pressure 4.04 bar
Feedwater Temperature 40°C

REBEKA Rods With
Helium Filled Gaps



Fig. 67 SEFLEX: 5x5 ROD BUNDLE, SERIES 1, TEST-No. 03

Axial Level: 2225 mm



△ Cladding Temperature (18a1)
○ Fluid Temperature, (2240 mm)
□ Housing Temperature

Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.81 cm/s
System Pressure 4.04 bar
Feedwater Temperature 40°C

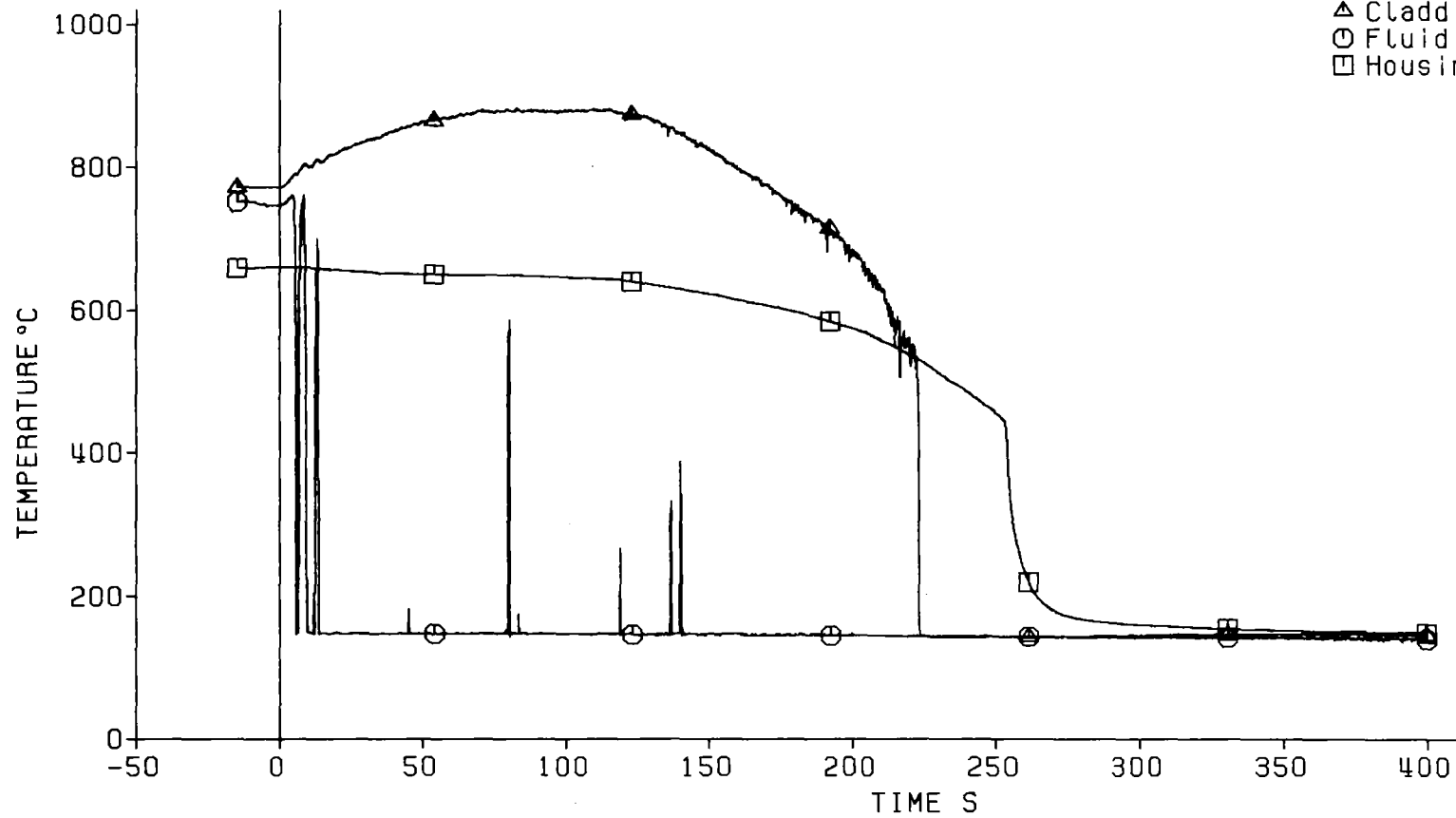
REBEKA Rods With
Helium Filled Gaps



Fig. 68 SEFLEX: 5x5 ROD BUNDLE, SERIES 1, TEST-No. 03

Axial Level: 1825 mm

△ Cladding Temperature (19g3)
○ Fluid Temperature
□ Housing Temperature



Decay Heat
Flooding Rate (cold)
System Pressure
Feedwater Temperature

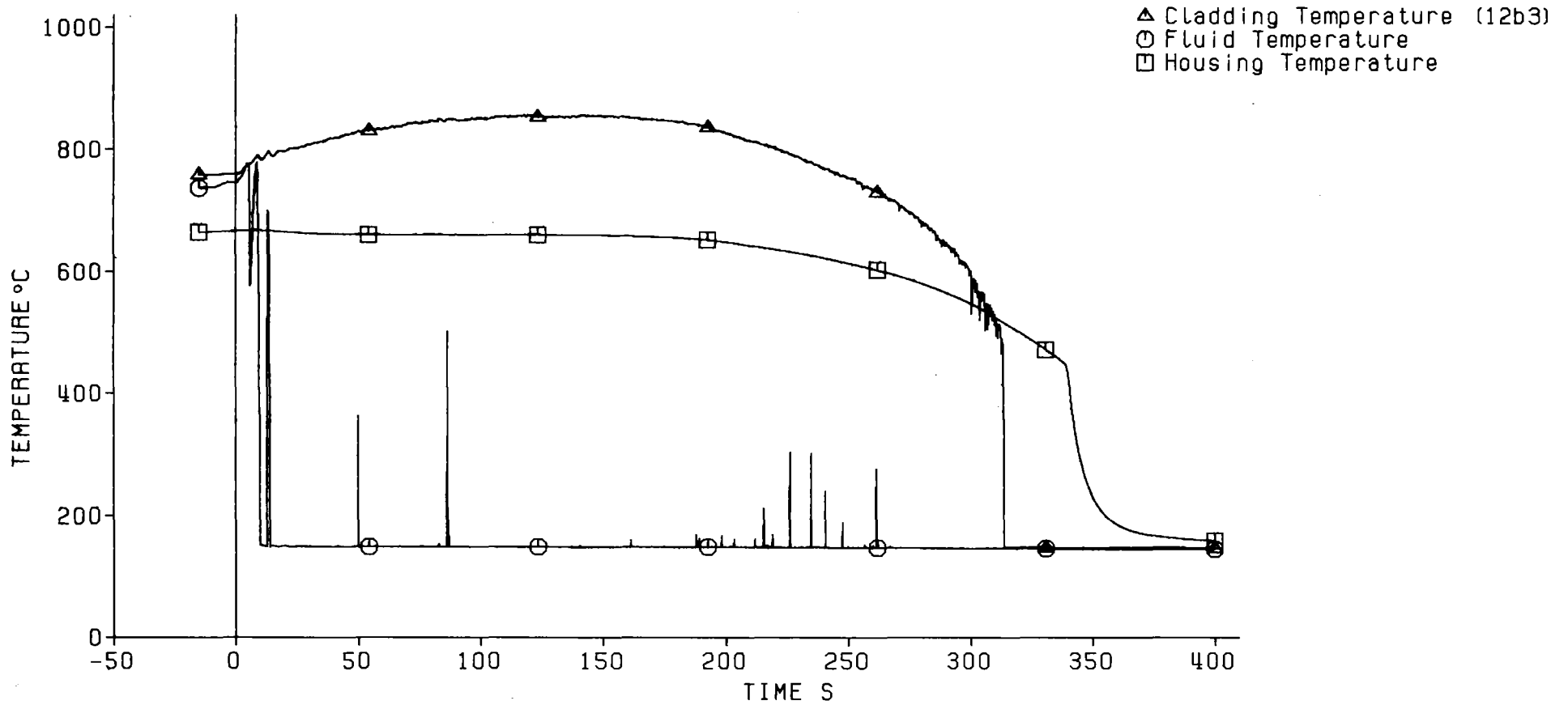
120% ANS Standard
3.81 cm/s
4.04 bar
40°C

REBEKA Rods With
Helium Filled Gaps



Fig. 69 SEFLEX: 5x5 ROD BUNDLE, SERIES 1, TEST-No. 03

Axial Level: 1135 mm



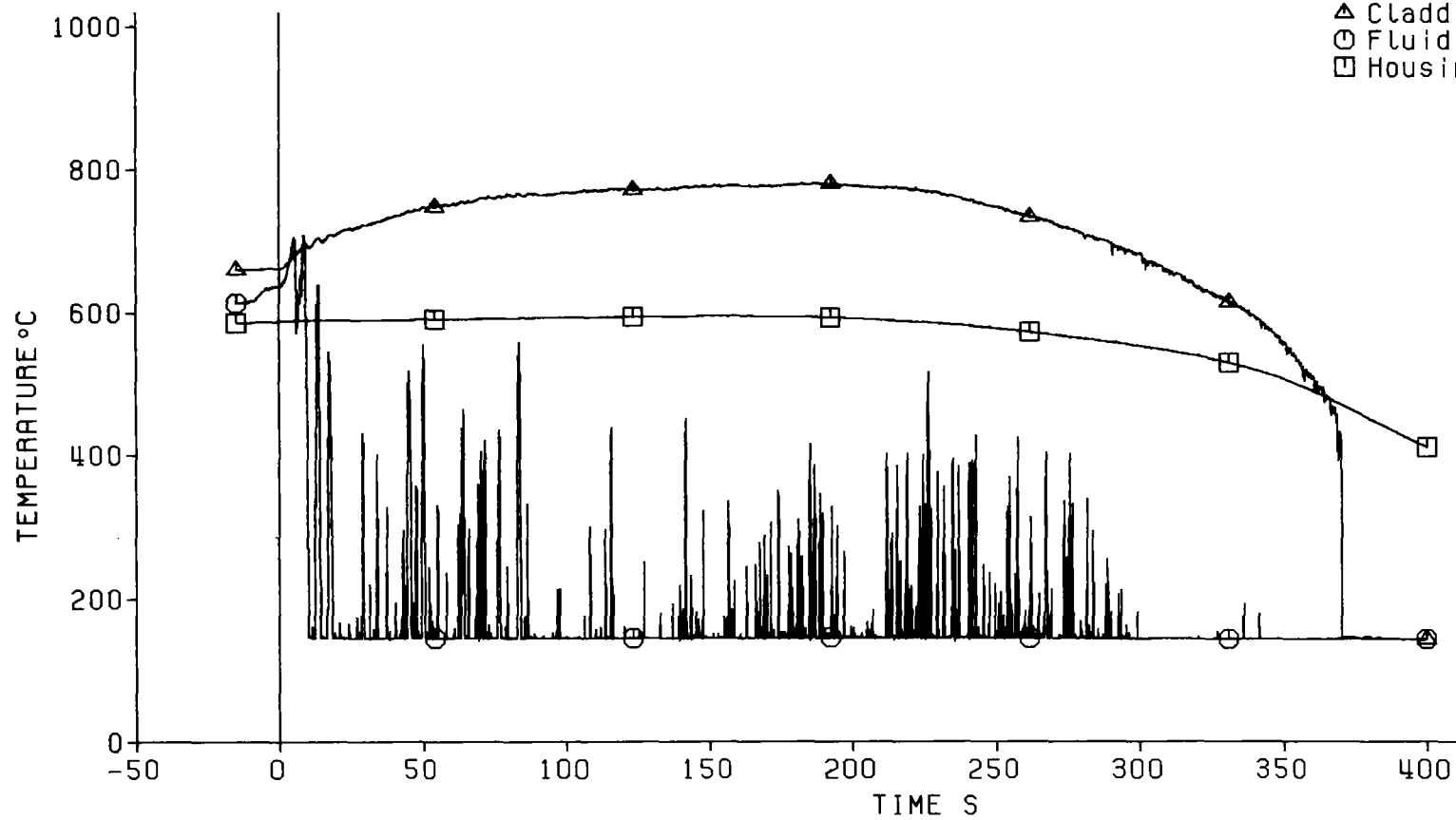
Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.81 cm/s
System Pressure 4.04 bar
Feedwater Temperature 40°C

REBEKA Rods With Helium Filled Gaps



Fig. 70 SEFLEX: 5x5 ROD BUNDLE, SERIES 1, TEST-No. 03

Axial Level: 590 mm



Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.81 cm/s
System Pressure 4.04 bar
Feedwater Temperature 40 °C

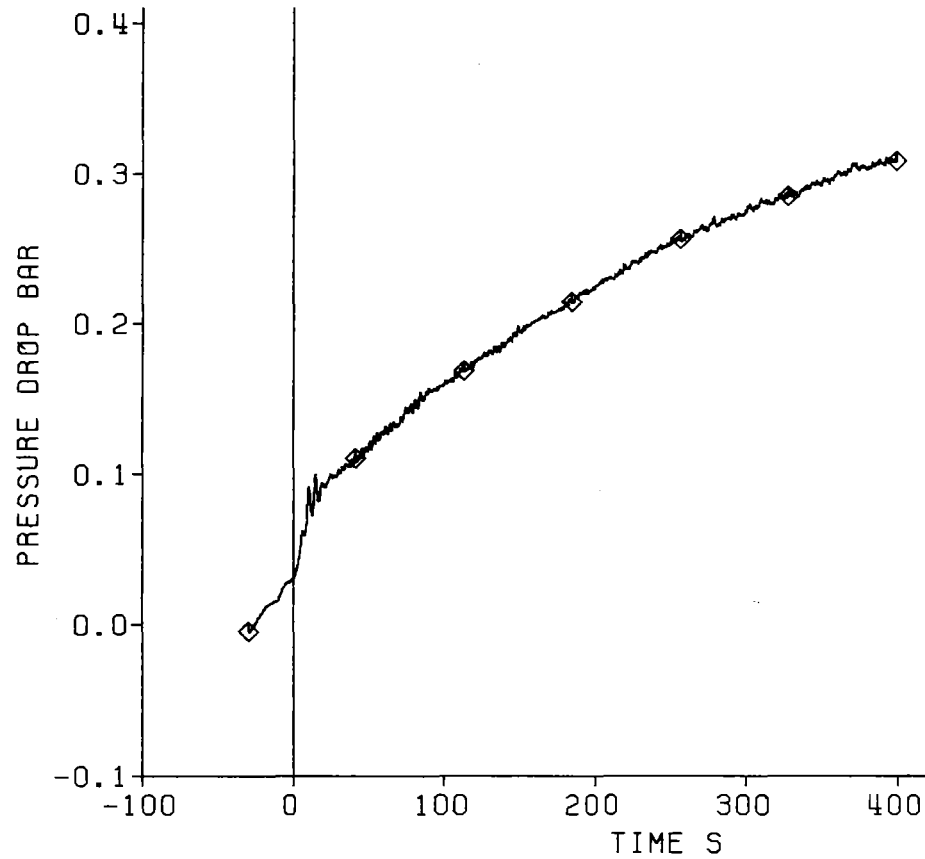
REBEKA Rods With Helium Filled Gaps



Fig. 71 SEFLEX: 5x5 ROD BUNDLE, SERIES 1, TEST-NO. 03

Pressure Drop
Along the Test Section:

◇ Total Length: 4196 mm



Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.81 cm/s
System Pressure 4.04 bar
Feedwater Temperature 40°C

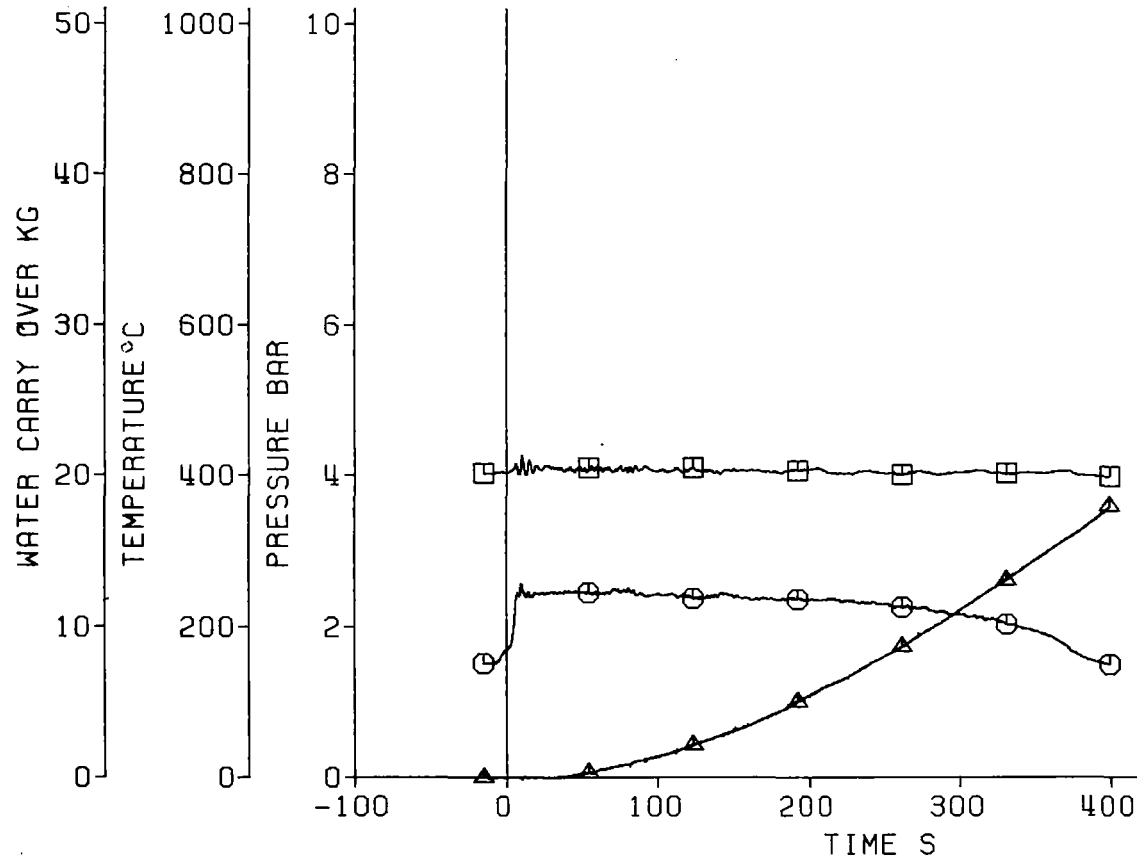
REBEKA Rods With
Helium Filled Gaps

KTR IRB

Fig. 72 SEFLEX: 5x5 ROD BUNDLE, SERIES 1, TEST-NO. 03

Coolant Outlet Conditions:

△ Water Carry Over
○ Coolant Temperature
□ Coolant Pressure



Decay Heat
Flooding Rate (cold)
System Pressure
Feedwater Temperature

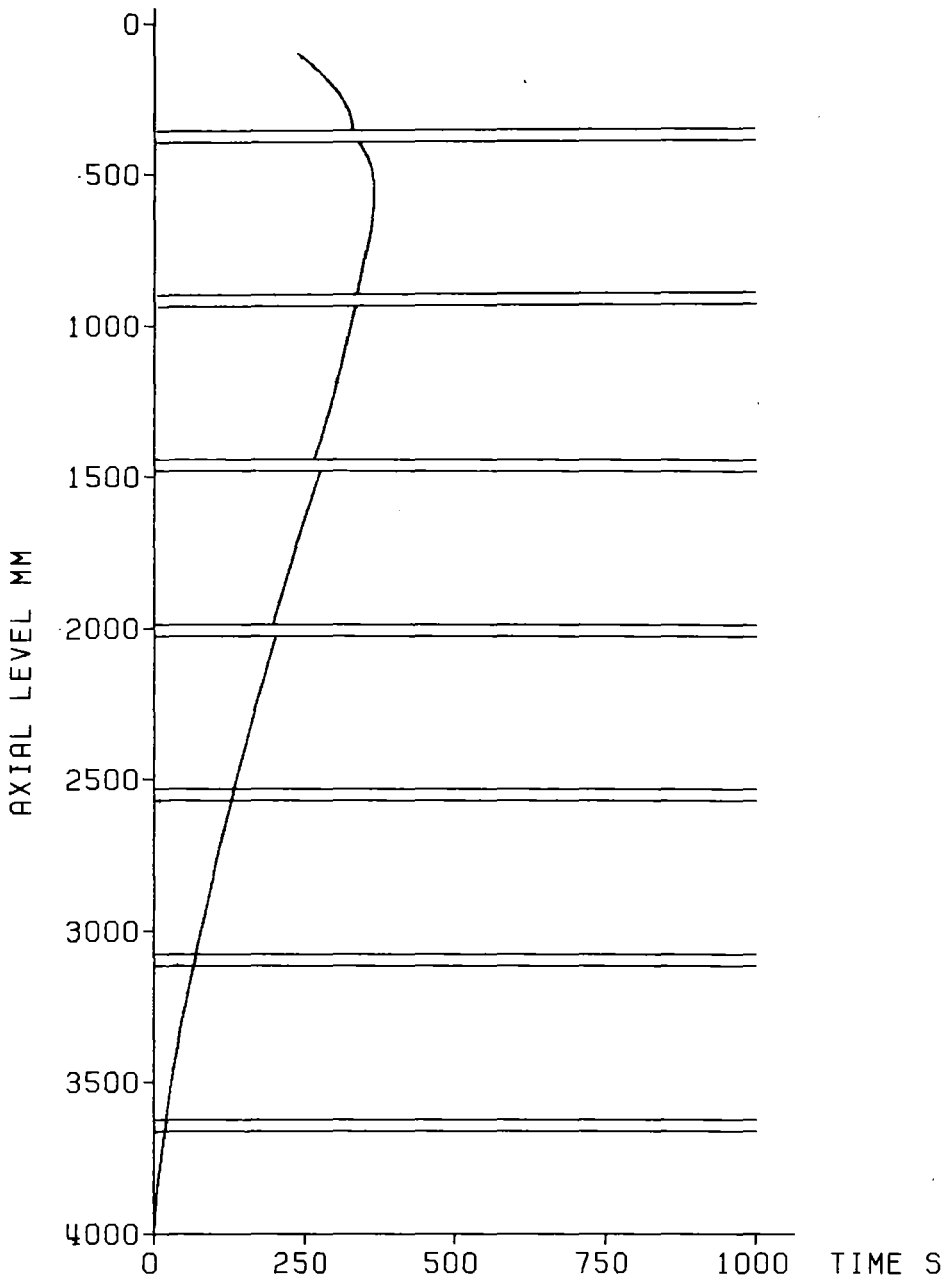
120% ANS Standard
3.81 cm/s
4.04 bar
40°C

REBEKA Rods With
Helium Filled Gaps



Fig. 73 SEFLEX: 5x5 ROD BUNDLE, SERIES 1, TEST-NO. 03

Axial Position of Quench Front
Rebeka Rods With Helium Filled Gaps

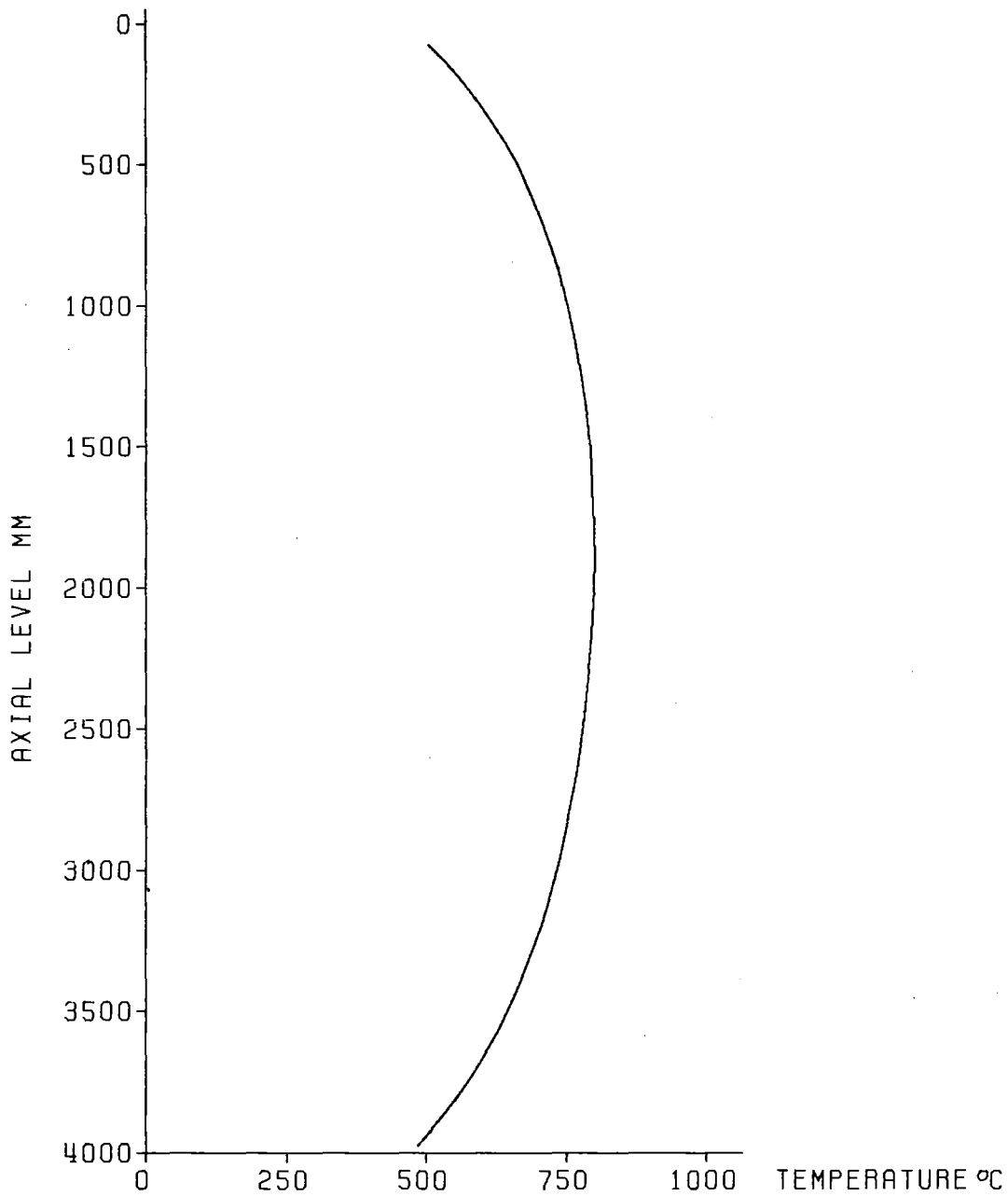


Decay Heat	120% ANS Standard
Flooding Rate (cold)	3.81 cm/s
System Pressure	4.04 bar
Feedwater Temperature	40 °C



Fig. 74 SEFLEX: 5x5 ROD BUNDLE
TEST SERIES 1, TEST-No. 03

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

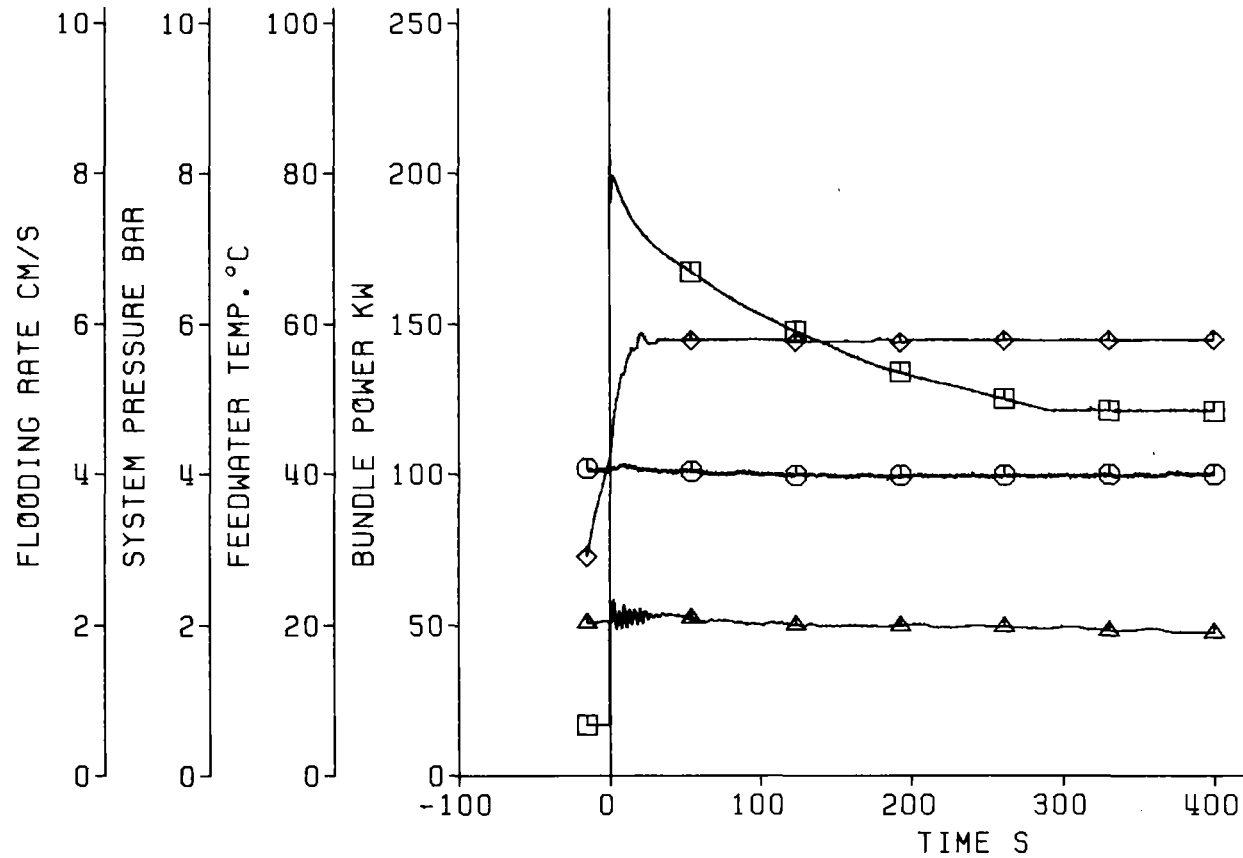


Decay Heat	120% ANS Standard
Flooding Rate (cold)	5.79 cm/s
System Pressure	2.09 bar
Feedwater Temperature	40°C

KIK IRB

Fig. 75 SEFLEX: 5x5 ROD BUNDLE
TEST SERIES 1, TEST-No. 06

Test Parameters:



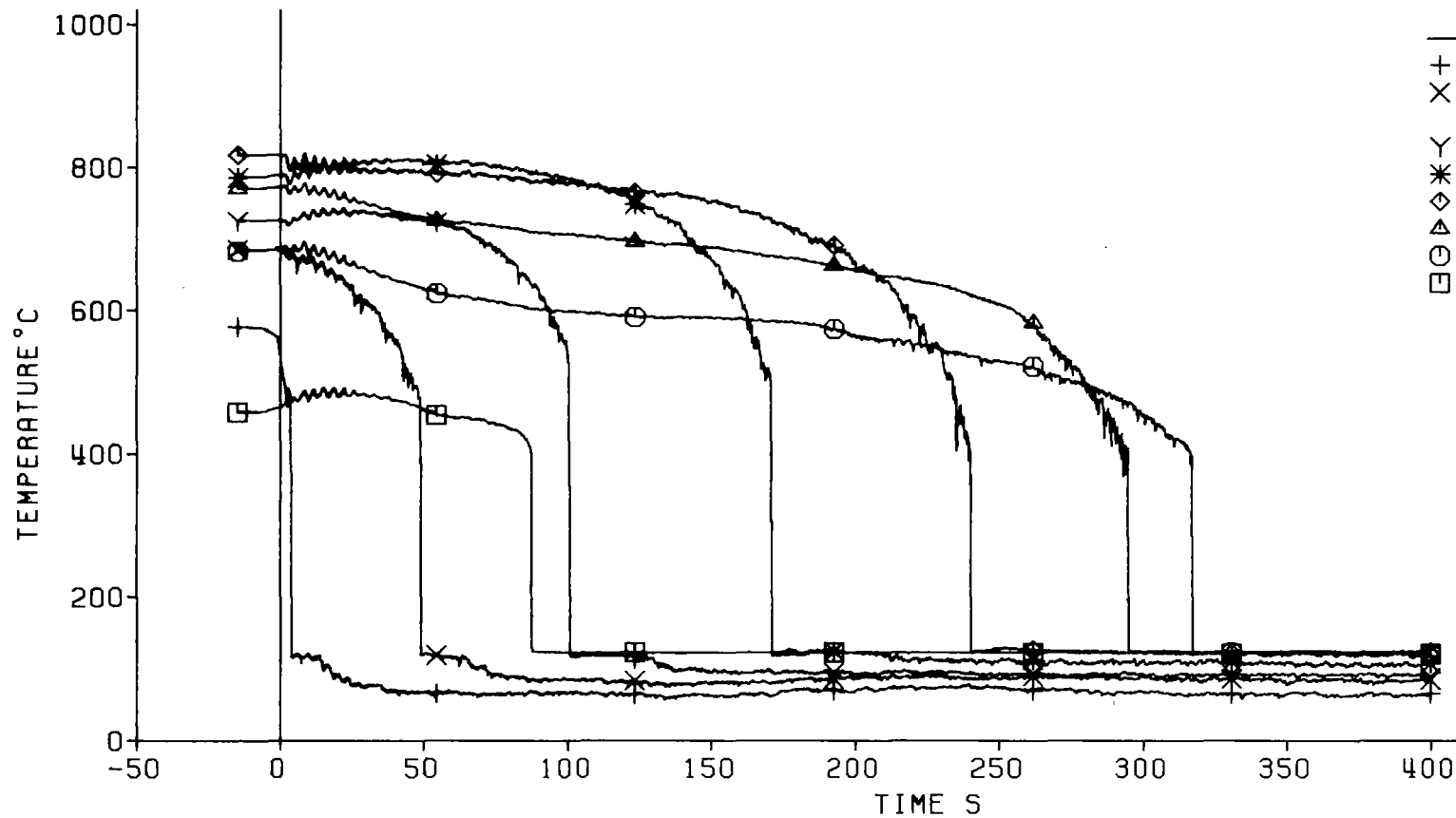
Decay Heat 120% ANS Standard
Flooding Rate (cold) 5.79 cm/s
System Pressure 2.09 bar
Feedwater Temperature 40°C

REBEKA Rods With
Helium Filled Gaps



Fig. 76 SEFLEX: 5x5 ROD BUNDLE, SERIES 1, TEST-NO. 06

Cladding Temperature



TC	Axial Level
+	18a4 3860 mm
X	18a3 3315 mm
Y	18a2 2770 mm, TC Failed
*	18a1 2225 mm
◇	12b4 1680 mm
△	12b3 1135 mm
⊙	12b2 590 mm
□	12b1 45 mm

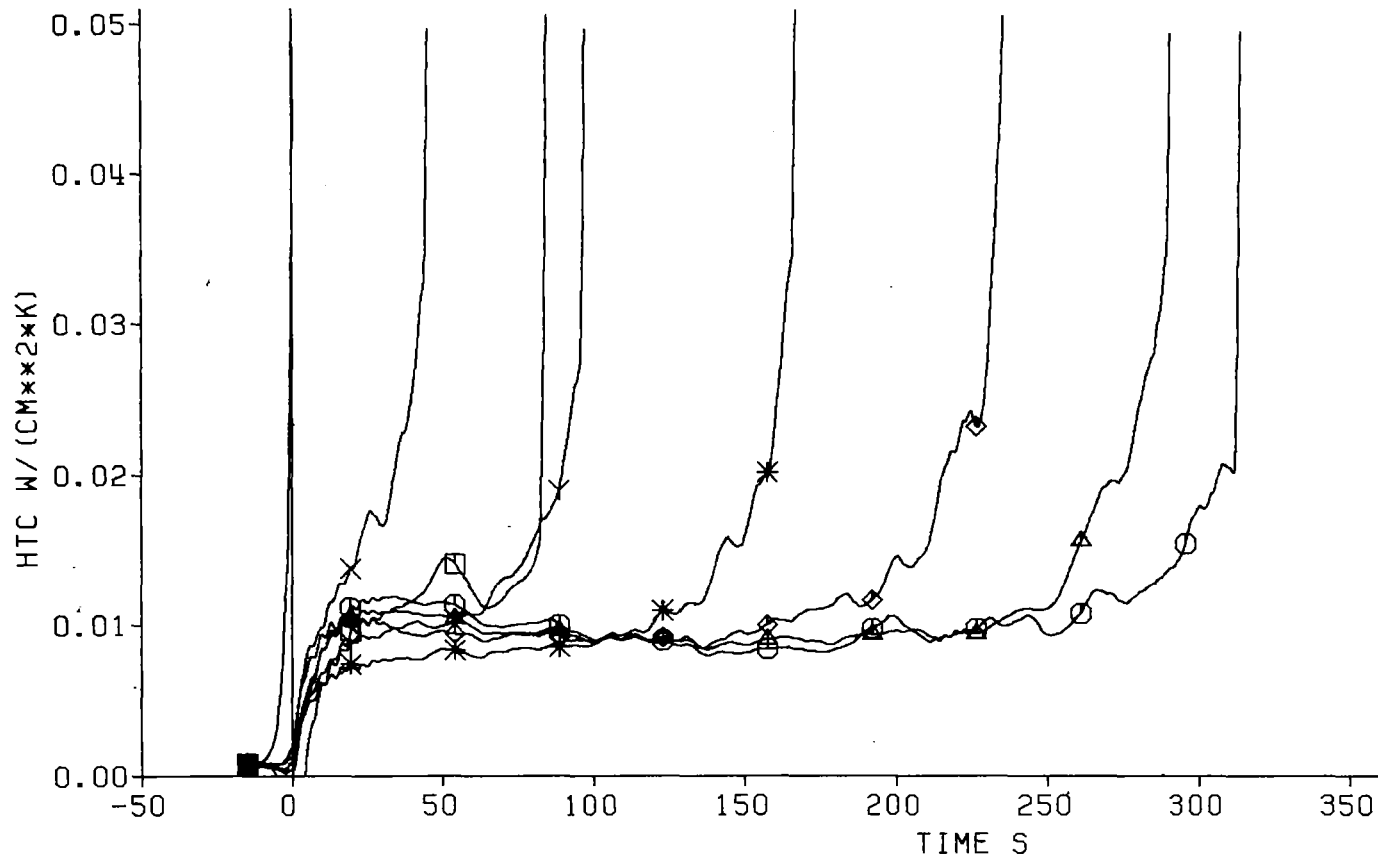
Decay Heat 120% ANS Standard
 Flooding Rate (cold) 5.79 cm/s
 System Pressure 2.09 bar
 Feedwater Temperature 40 °C

REBEKA Rods With
 Helium Filled Gaps



Fig. 77 SEFLEX: 5x5 ROD BUNDLE, SERIES 1, TEST-NO. 06

Heat Transfer Coefficient



TC	TC	Axial Level
+	18a4	3860 mm
X	18a3	3315 mm
Y	18a2	2770 mm, TC Failed
*	18a1	2225 mm
◇	12b4	1680 mm
△	12b3	1135 mm
○	12b2	590 mm
□	12b1	45 mm

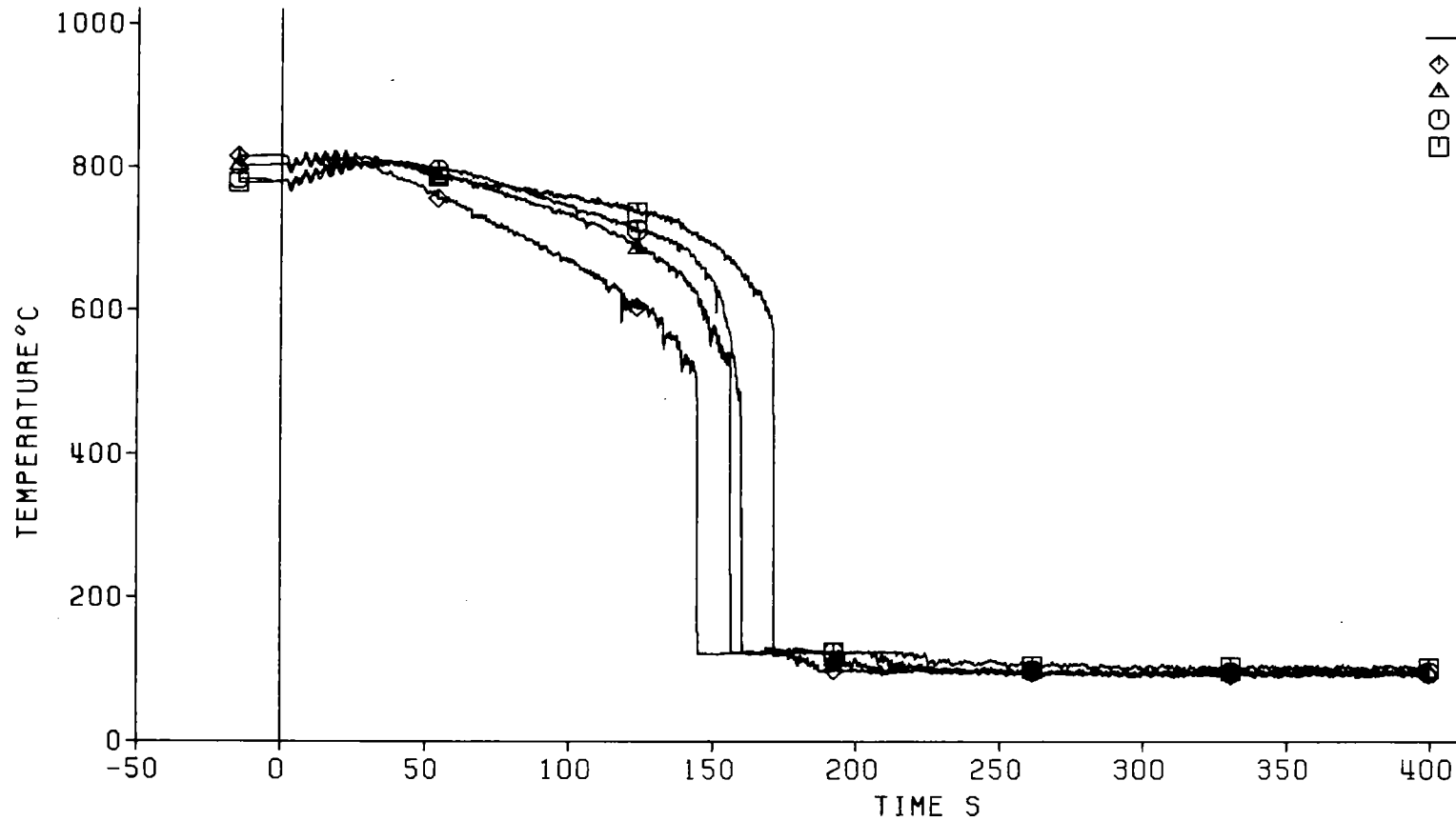
Decay Heat 120% ANS Standard
 Flooding Rate (cold) 5.79 cm/s
 System Pressure 2.09 bar
 Feedwater Temperature 40°C

REBEKA Rods With Helium Filled Gaps



Fig. 78 SEFLEX: 5x5 ROD BUNDLE, SERIES 1, TEST-No. 06

Cladding Temperature



- 100 -

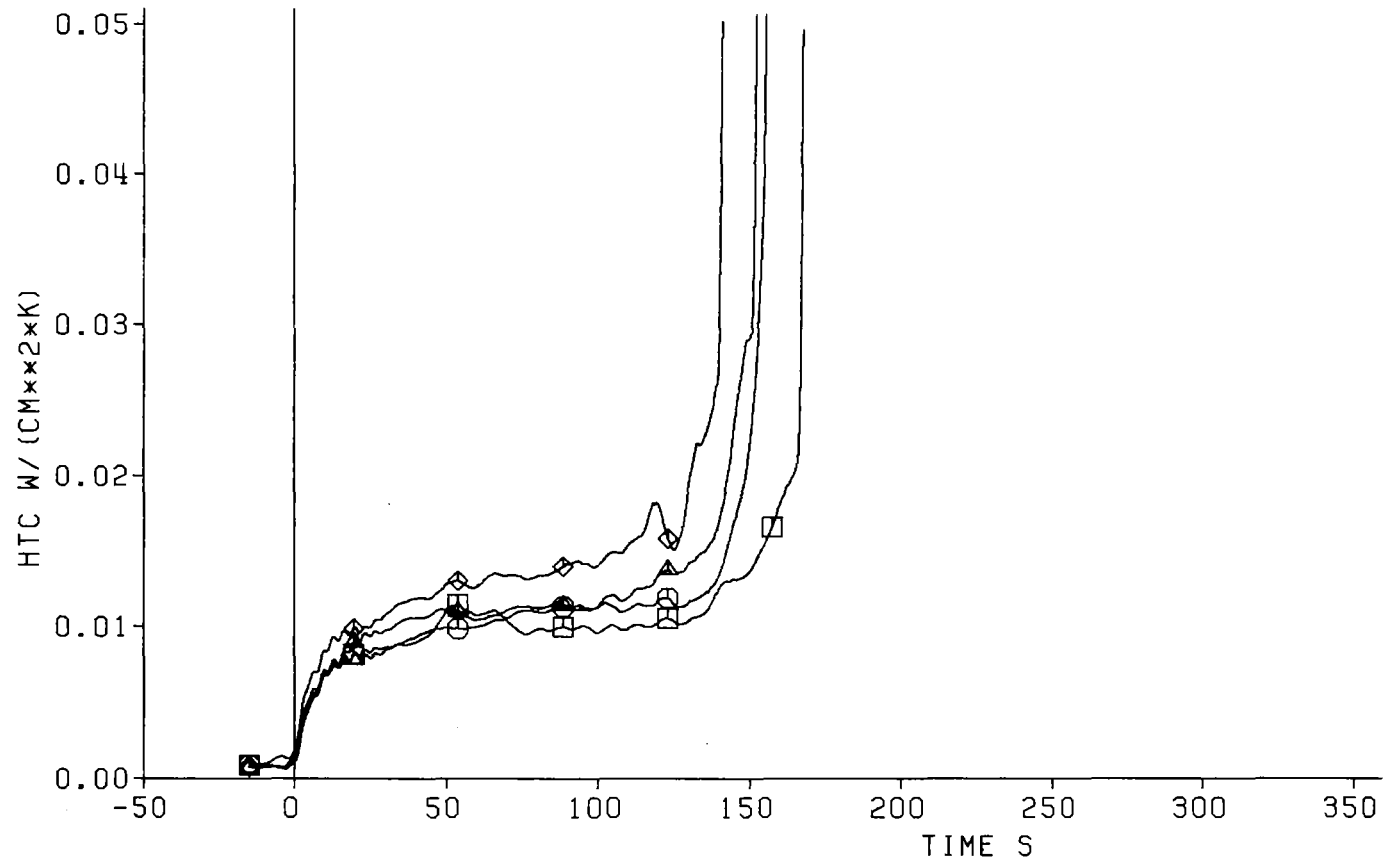
Decay Heat 120% ANS Standard
 Flooding Rate (cold) 5.79 cm/s
 System Pressure 2.09 bar
 Feedwater Temperature 40 °C

REBEKA Rods With
 Helium Filled Gaps



Fig. 79 SEFLEX: 5x5 ROD BUNDLE, SERIES 1, TEST-No. 06

TC	Axial Level
◇	7f4 2425 mm
△	7f3 2325 mm
○	7f2 2225 mm
□	7f1 2125 mm



Decay Heat
 Flooding Rate (cold) 5.79 cm/s
 System Pressure 2.09 bar
 Feedwater Temperature 40 °C

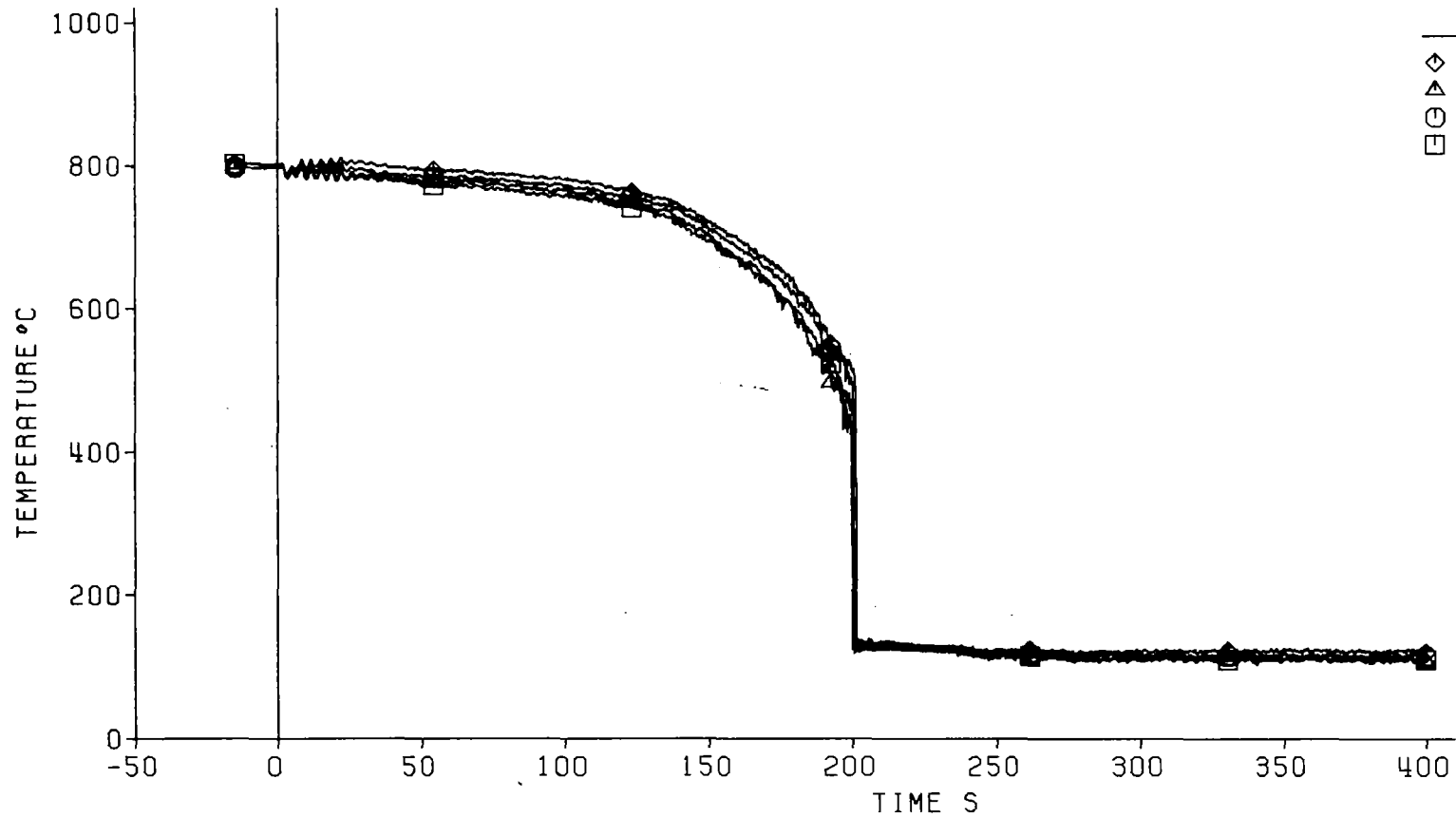
120% ANS Standard

REBEKA Rods With
 Helium Filled Gaps



Fig. 80 SEFLEX: 5x5 ROD BUNDLE, SERIES 1, TEST-No. 06

Cladding Temperature



Decay Heat
 Flooding Rate (cold)
 System Pressure
 Feedwater Temperature

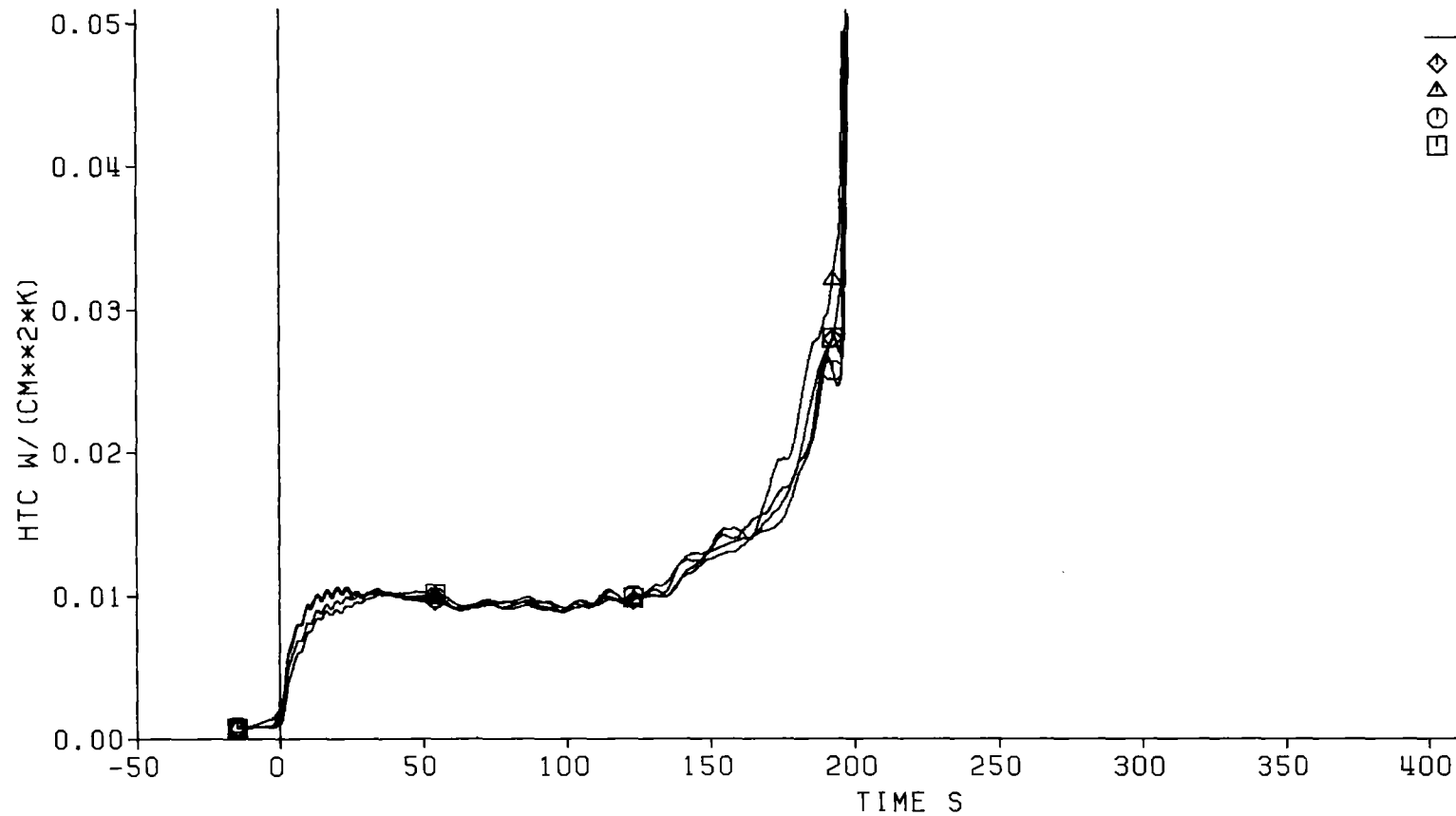
120% ANS Standard
 5.79 cm/s
 2.09 bar
 40 °C

REBEKA Rods With
 Helium Filled Gaps



Fig. 81 SEFLEX: 5x5 ROD BUNDLE, SERIES 1, TEST-No. 06

Heat Transfer Coefficient



TC	Axial Level
◇ 14d1	2025 mm
△ 14d2	2025 mm
○ 14d3	2025 mm
□ 14d4	2025 mm

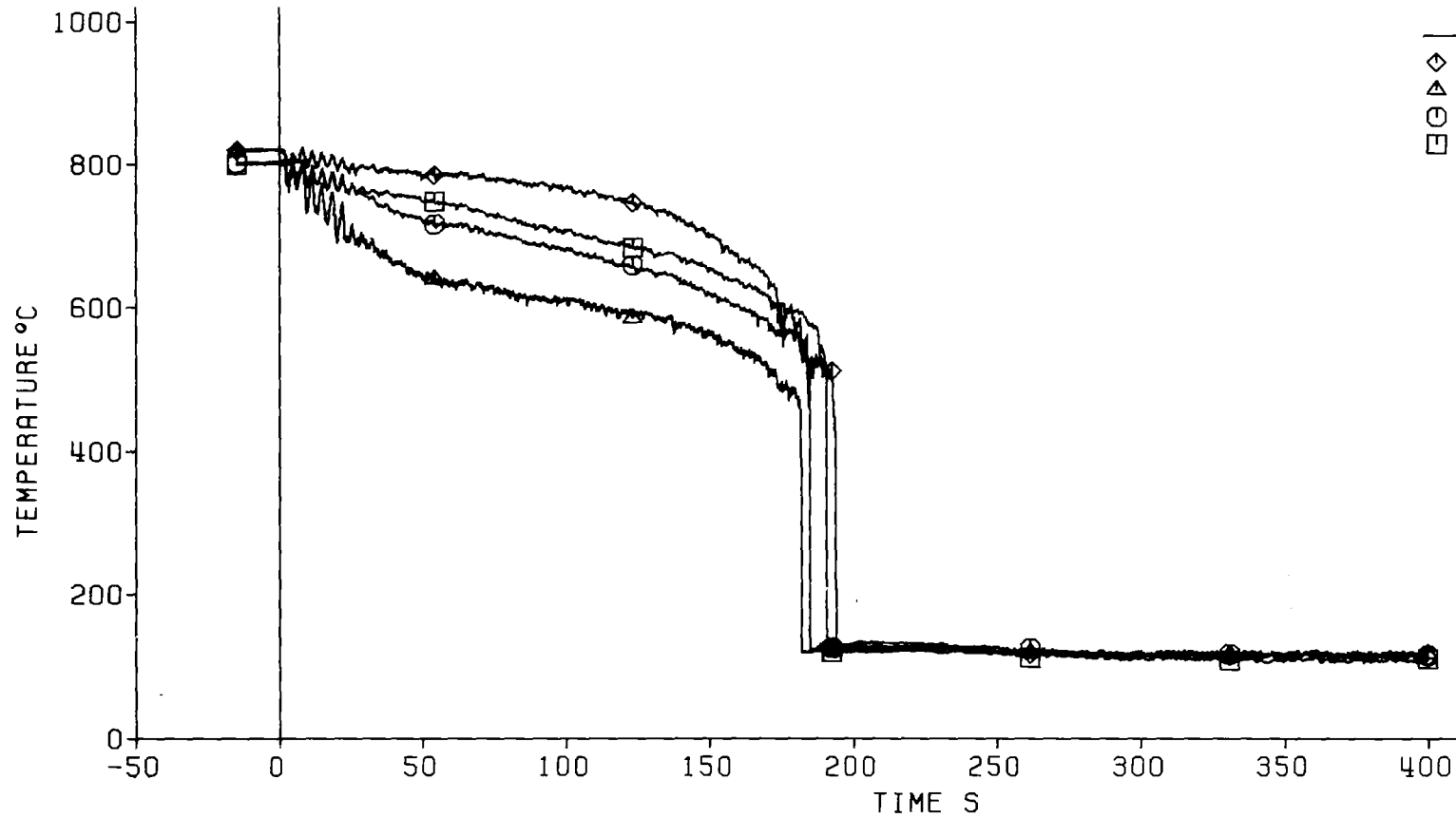
Decay Heat 120% ANS Standard
 Flooding Rate (cold) 5.79 cm/s
 System Pressure 2.09 bar
 Feedwater Temperature 40 °C

REBEKA Rods With
 Helium Filled Gaps



Fig. 82 SEFLEX: 5x5 ROD BUNDLE, SERIES 1, TEST-No. 06

TC	Axial Level
◇ 13i4	2025 mm
△ 13i3	1975 mm
○ 13i2	1925 mm
□ 13i1	1875 mm

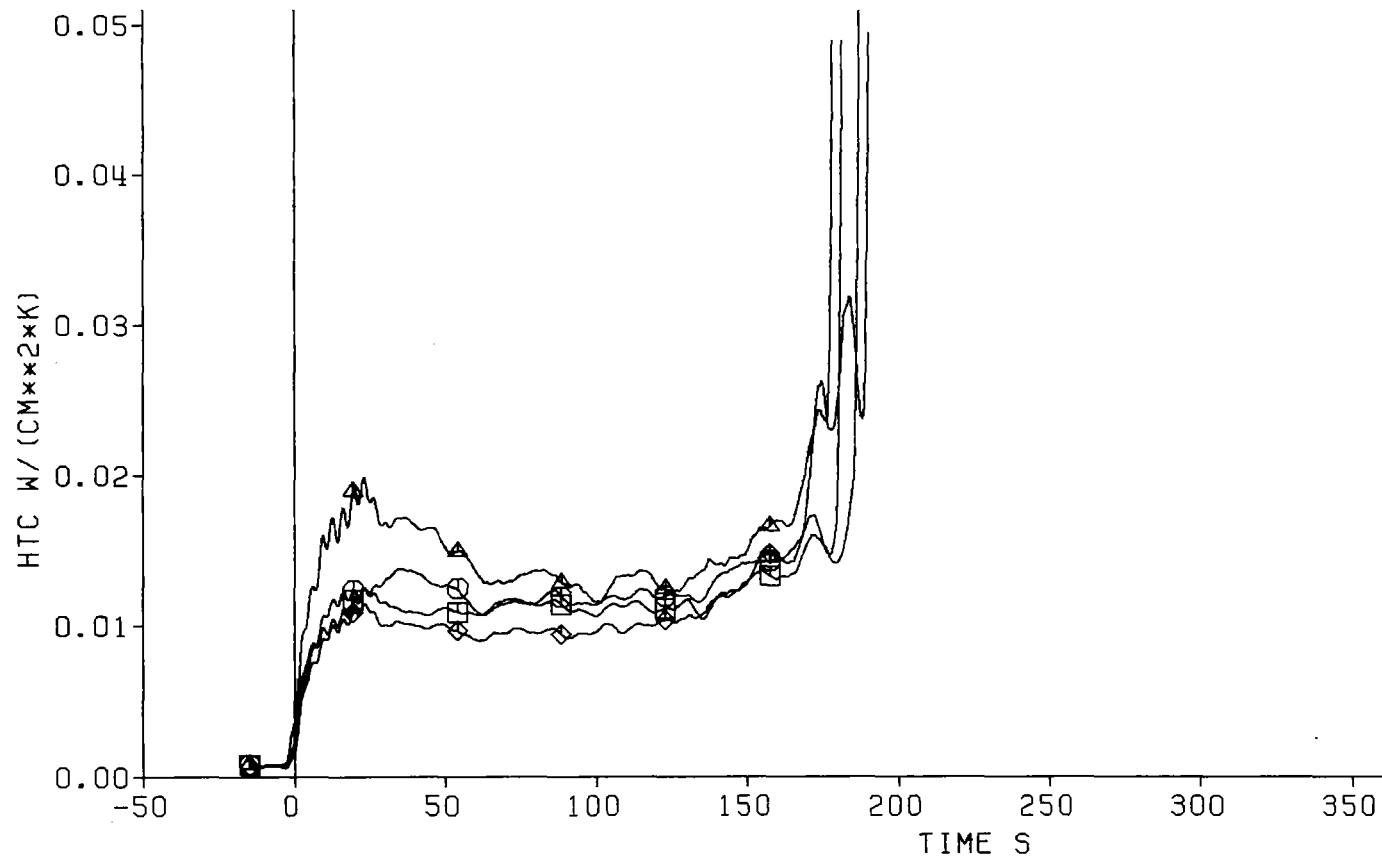


Decay Heat 120% ANS Standard
 Flooding Rate (cold) 5.79 cm/s
 System Pressure 2.09 bar
 Feedwater Temperature 40 °C

REBEKA Rods With
 Helium Filled Gaps



Fig. 83 SEFLEX: 5x5 ROD BUNDLE, SERIES 1, TEST-No. 06



TC	Axial Level
◇ 1314	2025 mm
△ 1313	1975 mm
○ 1312	1925 mm
□ 1311	1875 mm

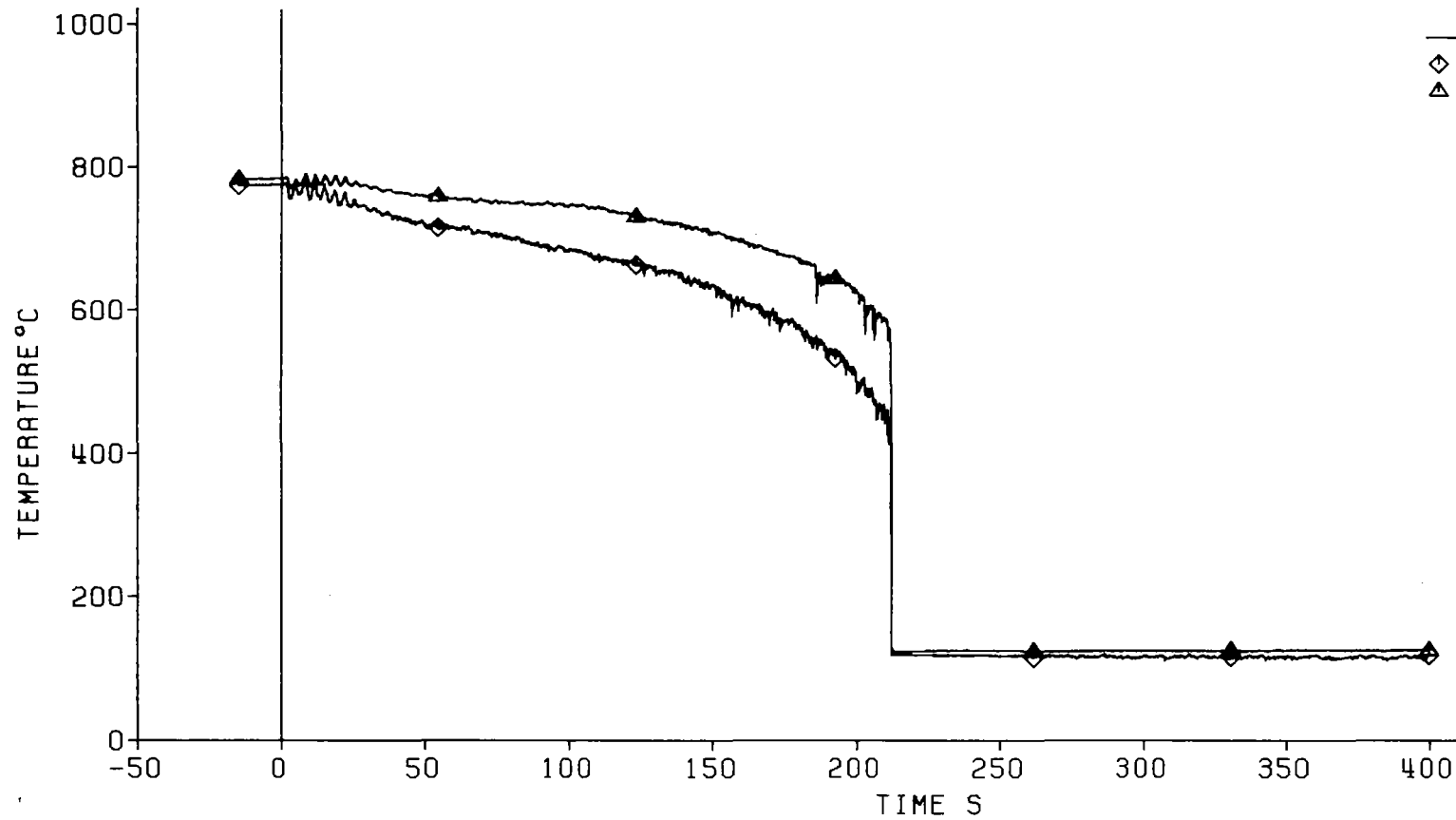
Decay Heat 120% ANS Standard
 Flooding Rate (cold) 5.79 cm/s
 System Pressure 2.09 bar
 Feedwater Temperature 40°C

REBEKA Rods With
 Helium Filled Gaps

KTR IRB

Fig. 84 SEFLEX: 5x5 ROD BUNDLE, SERIES 1, TEST-No. 06

Cladding Temperature



TC	Axial Level
◇ 19g4	1925 mm
△ 19g3	1825 mm
19g2	1725 mm, TC Failed
19g1	1625 mm, TC Failed

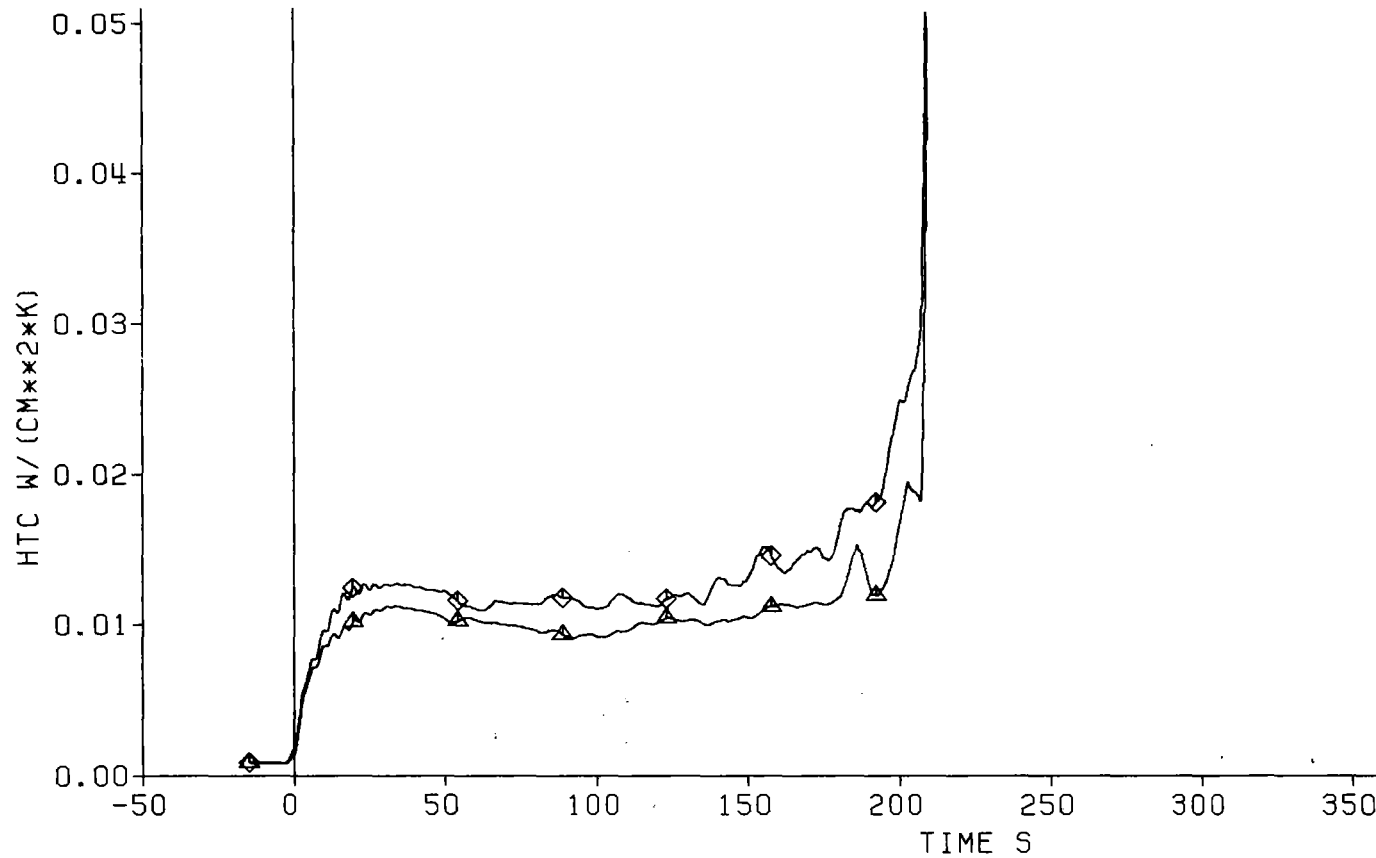
Decay Heat 120% ANS Standard
 Flooding Rate (cold) 5.79 cm/s
 System Pressure 2.09 bar
 Feedwater Temperature 40°C

REBEKA Rods With
 Helium Filled Gaps



Fig. 85 SEFLEX: 5x5 ROD BUNDLE, SERIES 1, TEST-No. 06

Heat Transfer Coefficient



TC	Axial Level
◇ 19g4	1925 mm
△ 19g3	1825 mm
19g2	1725 mm, TC Failed
19g1	1625 mm, TC Failed

Decay Heat 120% ANS Standard
 Flooding Rate (cold) 5.79 cm/s
 System Pressure 2.09 bar
 Feedwater Temperature 40°C

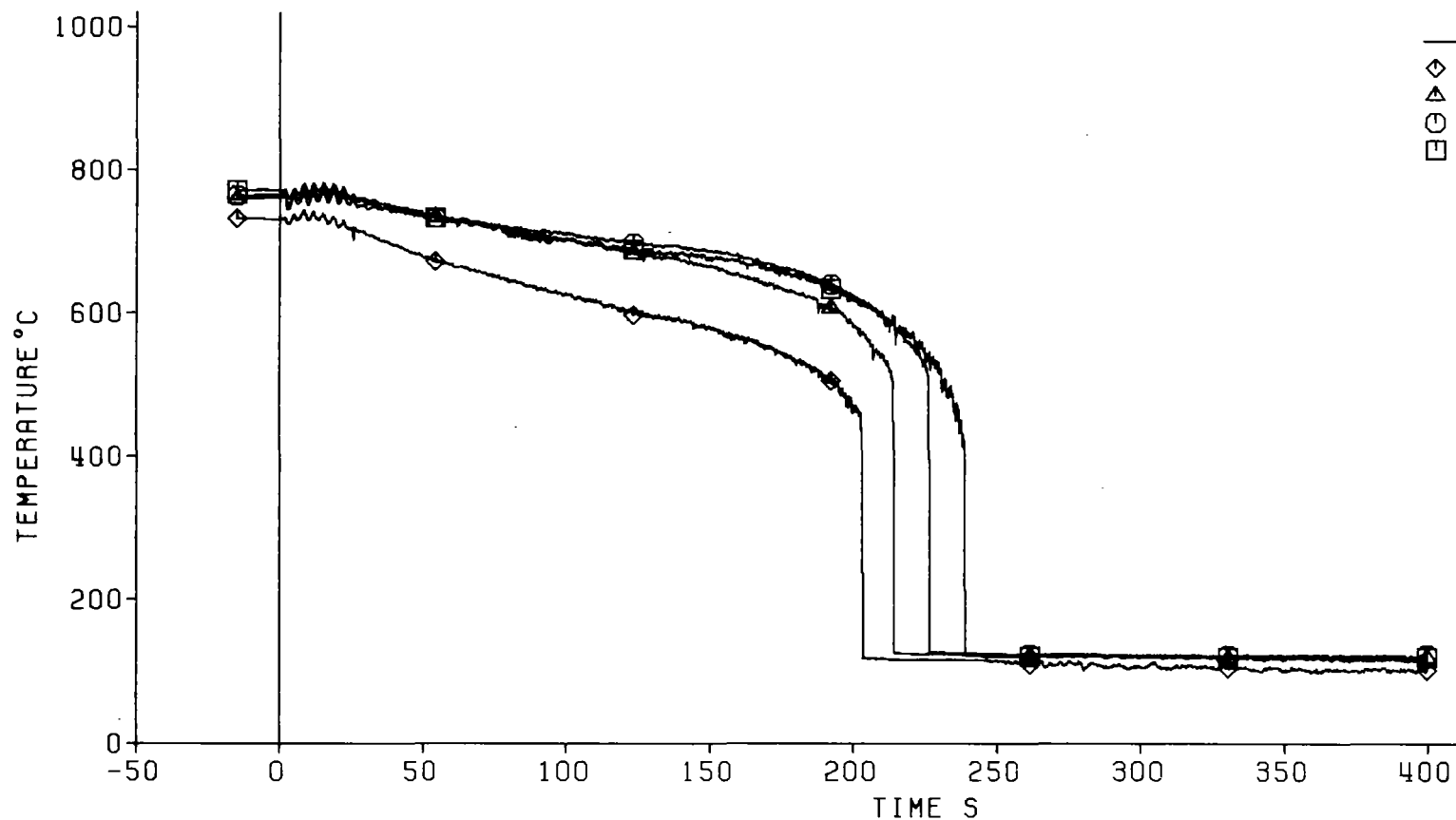
REBEKA Rods With Helium Filled Gaps



Fig. 86 SEFLEX: 5x5 ROD BUNDLE, SERIES 1, TEST-No. 06

Cladding Temperature

TC	Axial Level
◇	16g4 1925 mm
△	16g3 1825 mm
○	16g2 1725 mm
□	16g1 1625 mm

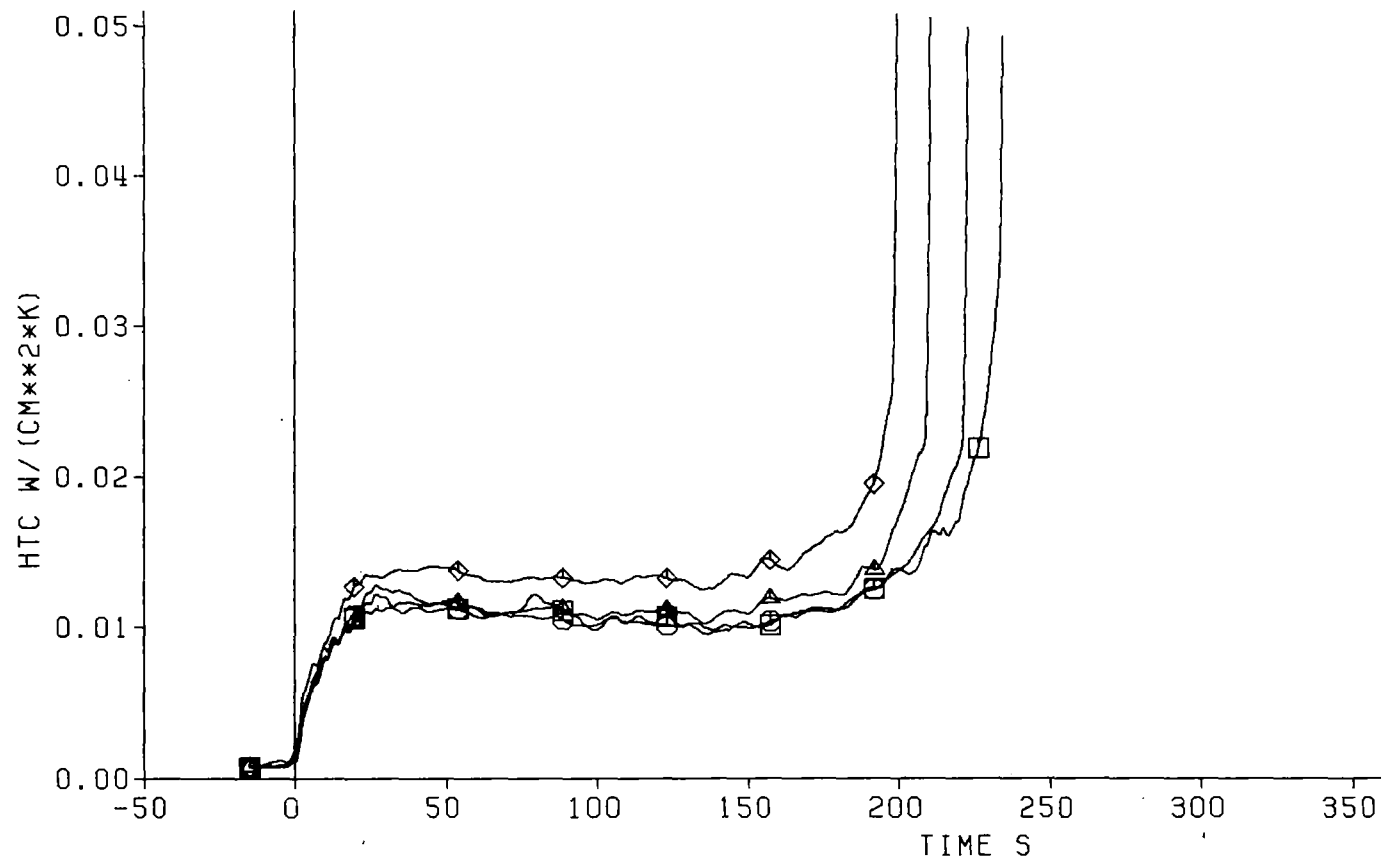


Decay Heat 120% ANS Standard
 Flooding Rate (cold) 5.79 cm/s
 System Pressure 2.09 bar
 Feedwater Temperature 40°C

REBEKA Rods With
 Helium Filled Gaps



Fig. 87 SEFLEX: 5x5 ROD BUNDLE, SERIES 1, TEST-No. 06



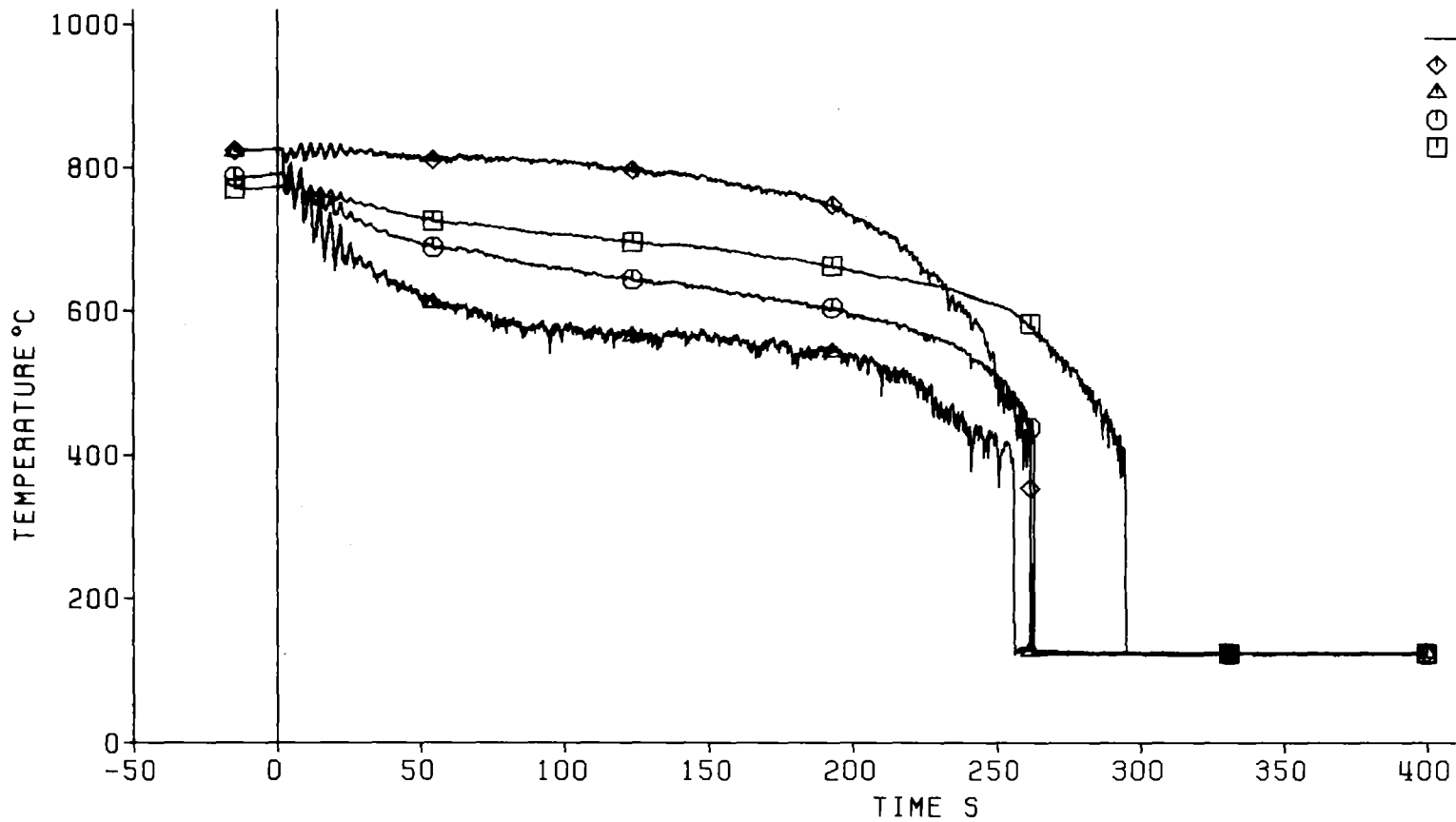
Decay Heat 120% ANS Standard
 Flooding Rate (cold) 5.79 cm/s
 System Pressure 2.09 bar
 Feedwater Temperature 40°C

REBEKA Rods With
 Helium Filled Gaps

KFK
 IRB

Fig. 88 SEFLEX: 5x5 ROD BUNDLE, SERIES 1, TEST-No. 06

Cladding Temperature

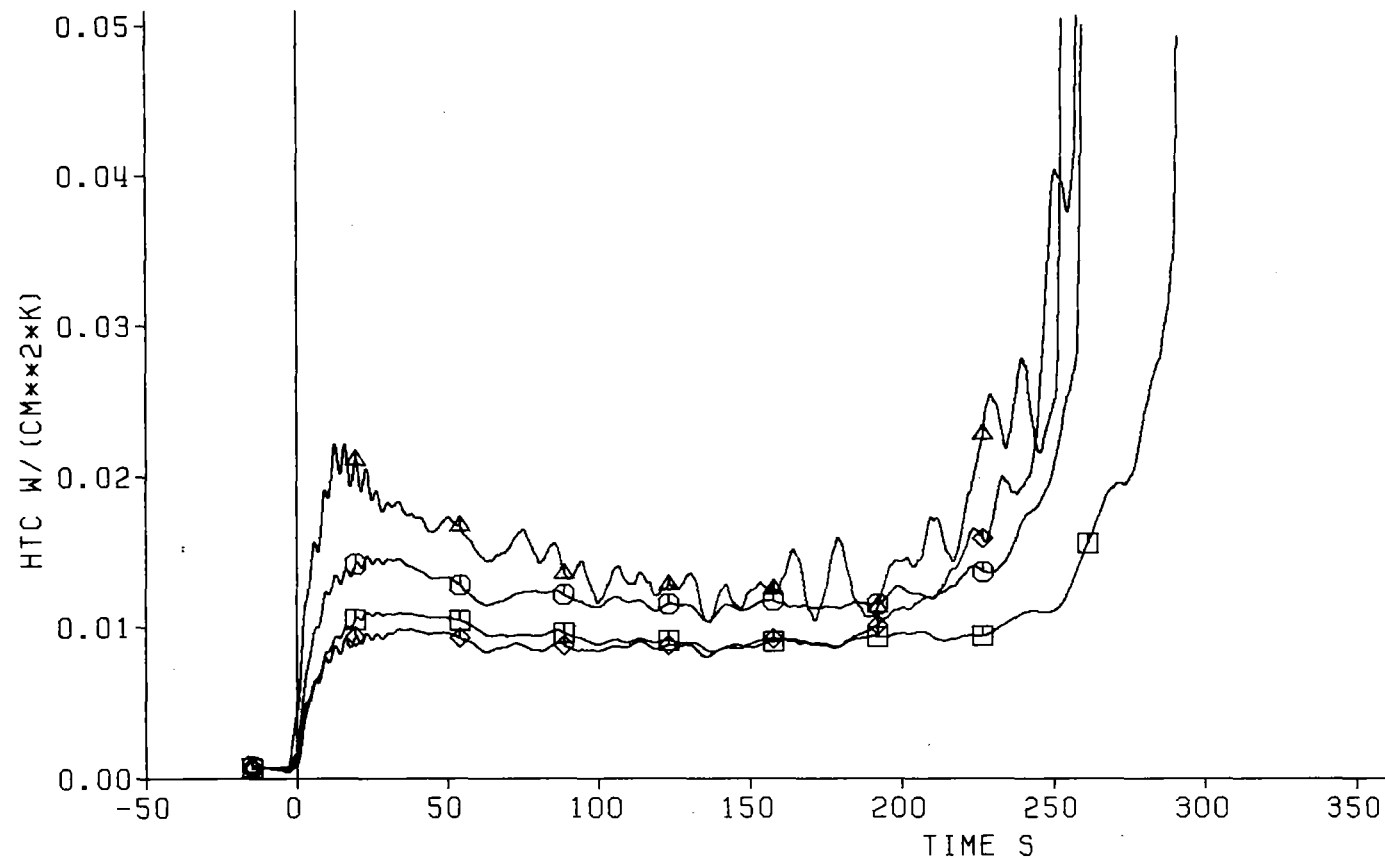


Decay Heat 120% ANS Standard
 Flooding Rate (cold) 5.79 cm/s
 System Pressure 2.09 bar
 Feedwater Temperature 40 °C

REBEKA Rods With
 Helium Filled Gaps



Fig. 89 SEFLEX: 5x5 ROD BUNDLE, SERIES 1, TEST-NO. 06



TC	Axial Level
◇	8j4 1525 mm
△	8j3 1425 mm
○	8j2 1325 mm
□	12b3 1135 mm

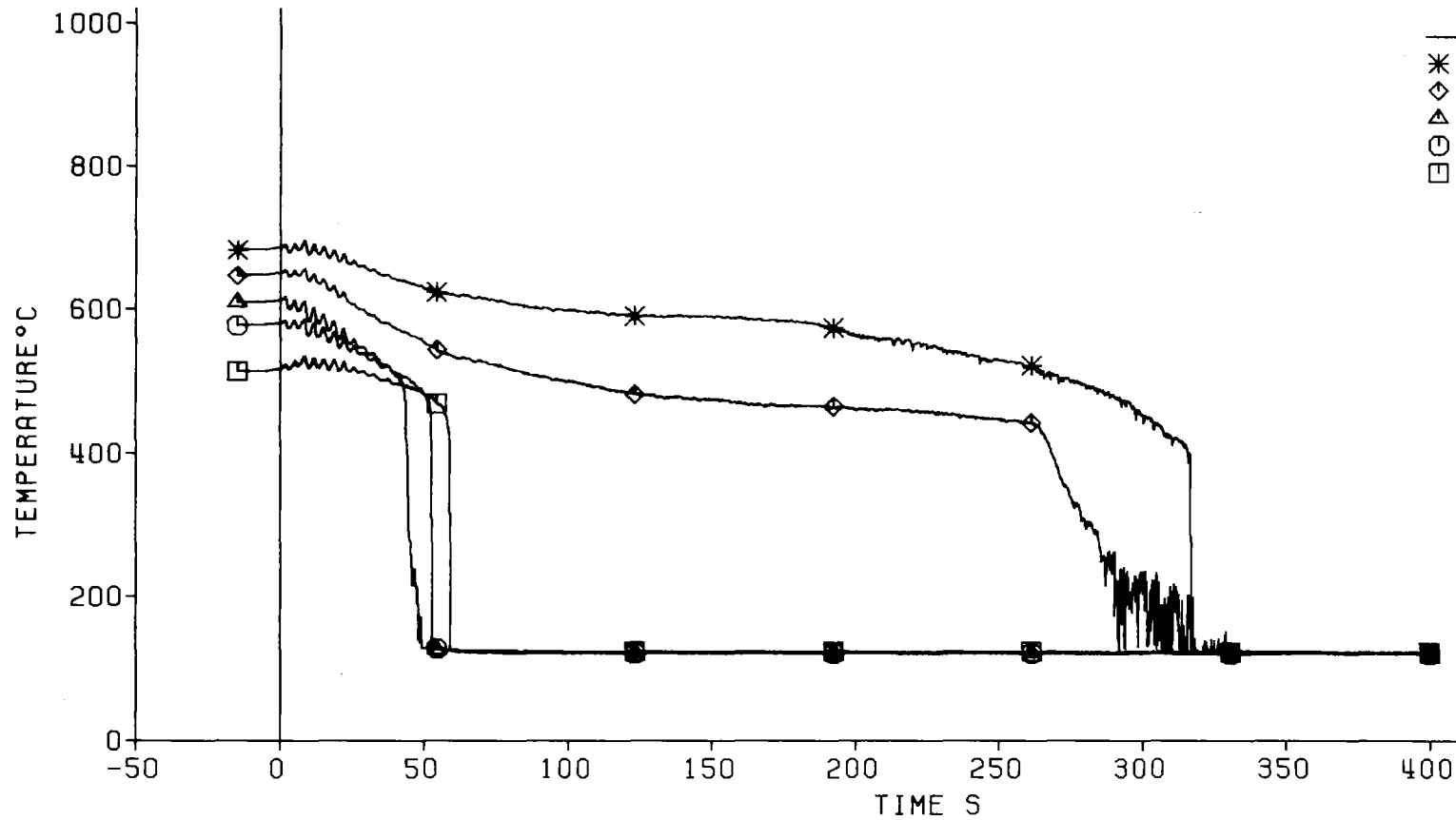
Decay Heat 120% ANS Standard
 Flooding Rate (cold) 5.79 cm/s
 System Pressure 2.09 bar
 Feedwater Temperature 40°C

REBEKA Rods With
 Helium Filled Gaps

KIK
 IRB

Fig. 90 SEFLEX: 5x5 ROD BUNDLE, SERIES 1, TEST-No. 06

Cladding Temperature

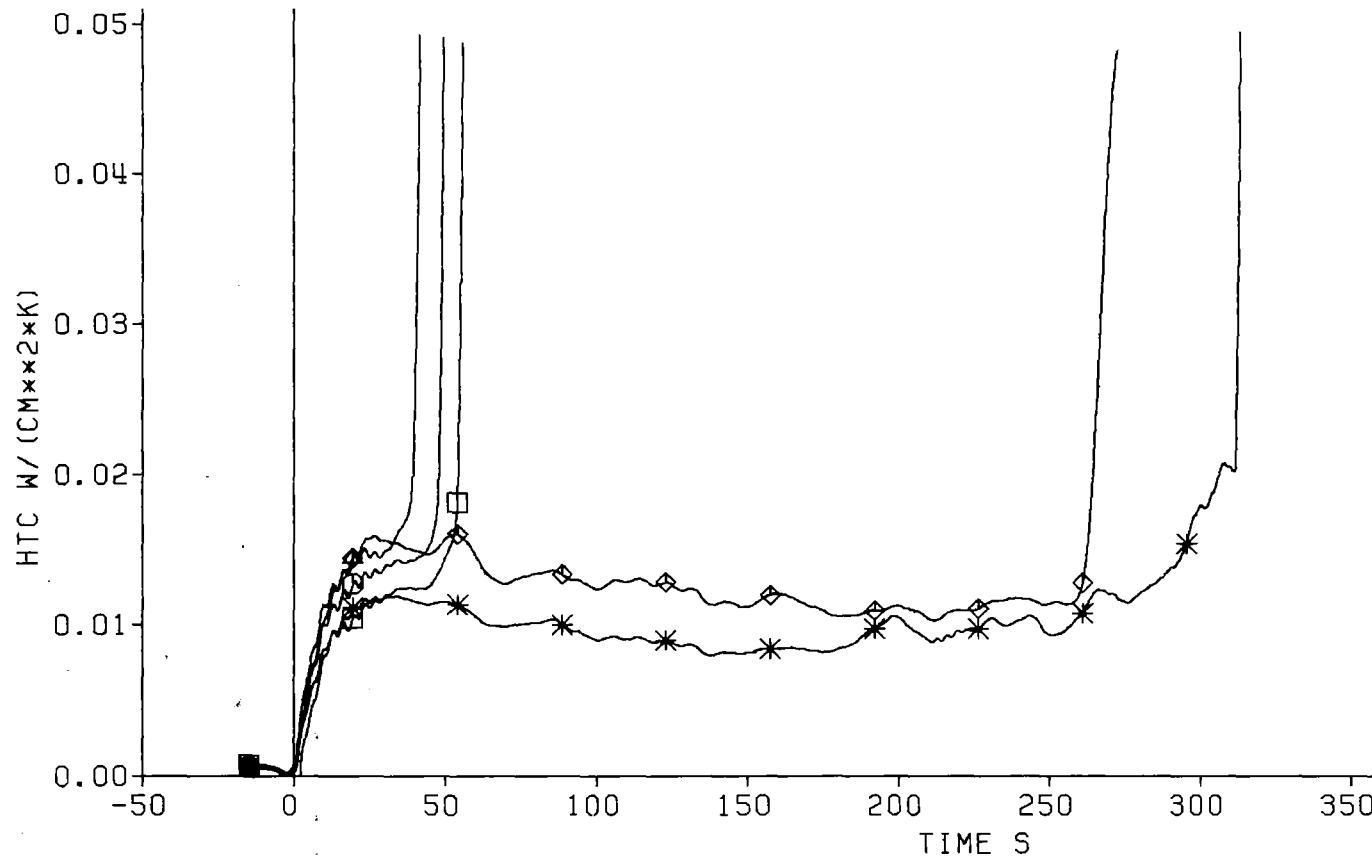


Decay Heat 120% ANS Standard
 Flooding Rate (cold) 5.79 cm/s
 System Pressure 2.09 bar
 Feedwater Temperature 40 °C

REBEKA Rods With Helium Filled Gaps



Fig. 91 SEFLEX: 5x5 ROD BUNDLE, SERIES 1, TEST-No. 06



TC	Axial Level
* 12b2	590 mm
◇ 9k4	400 mm
△ 9k3	300 mm
○ 9k2	200 mm
□ 9k1	100 mm

Decay Heat 120% ANS Standard
 Flooding Rate (cold) 5.79 cm/s
 System Pressure 2.09 bar
 Feedwater Temperature 40 °C

REBEKA Rods With Helium Filled Gaps

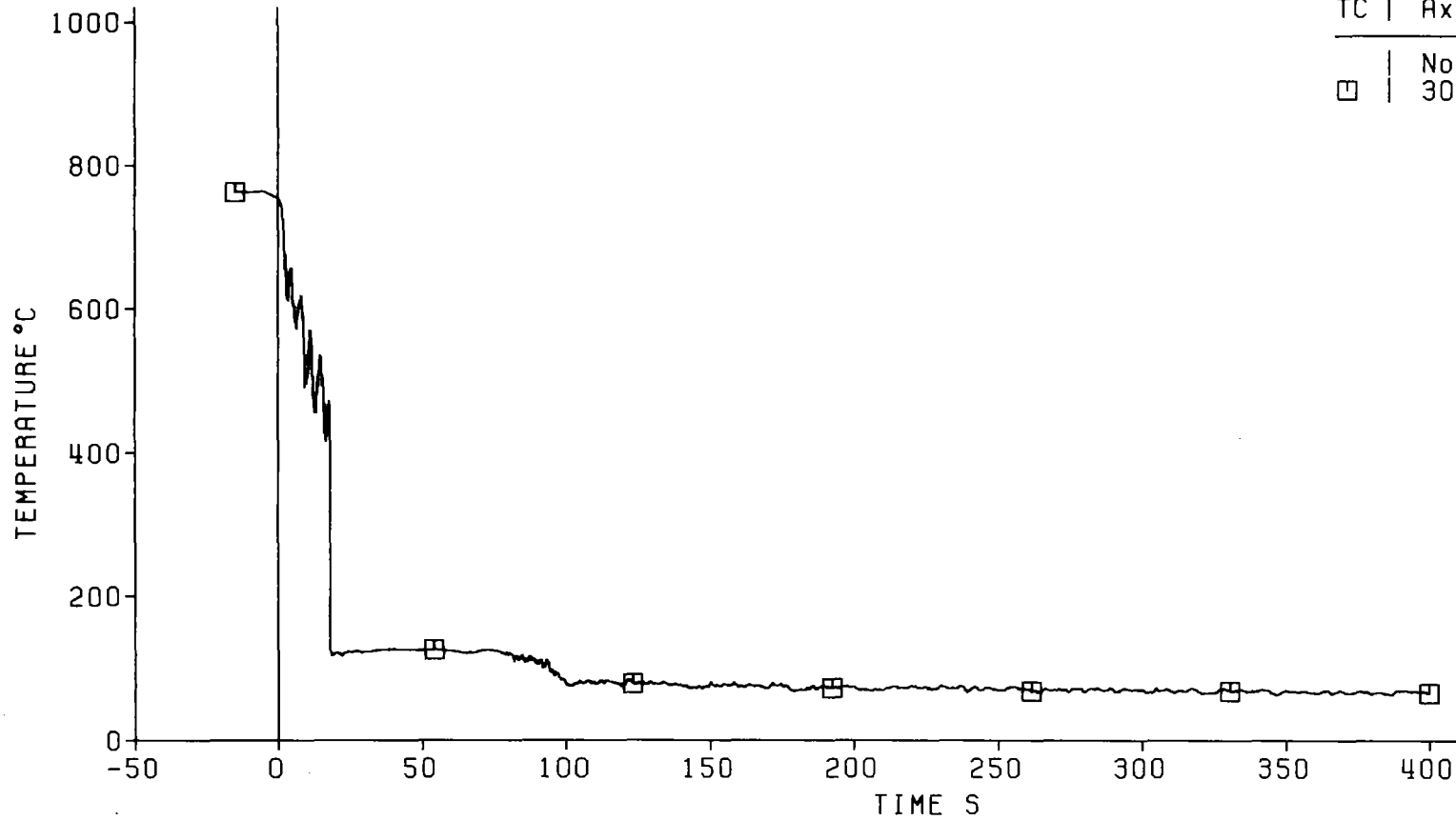


Fig. 92 SEFLEX: 5x5 ROD BUNDLE, SERIES 1, TEST-No. 06

Grid Spacer Temperature

TC | Axial Level

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



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Decay Heat 120% ANS Standard
Flooding Rate (cold) 5.79 cm/s
System Pressure 2.09 bar
Feedwater Temperature 40 °C

REBEKA Rods With
Helium Filled Gaps

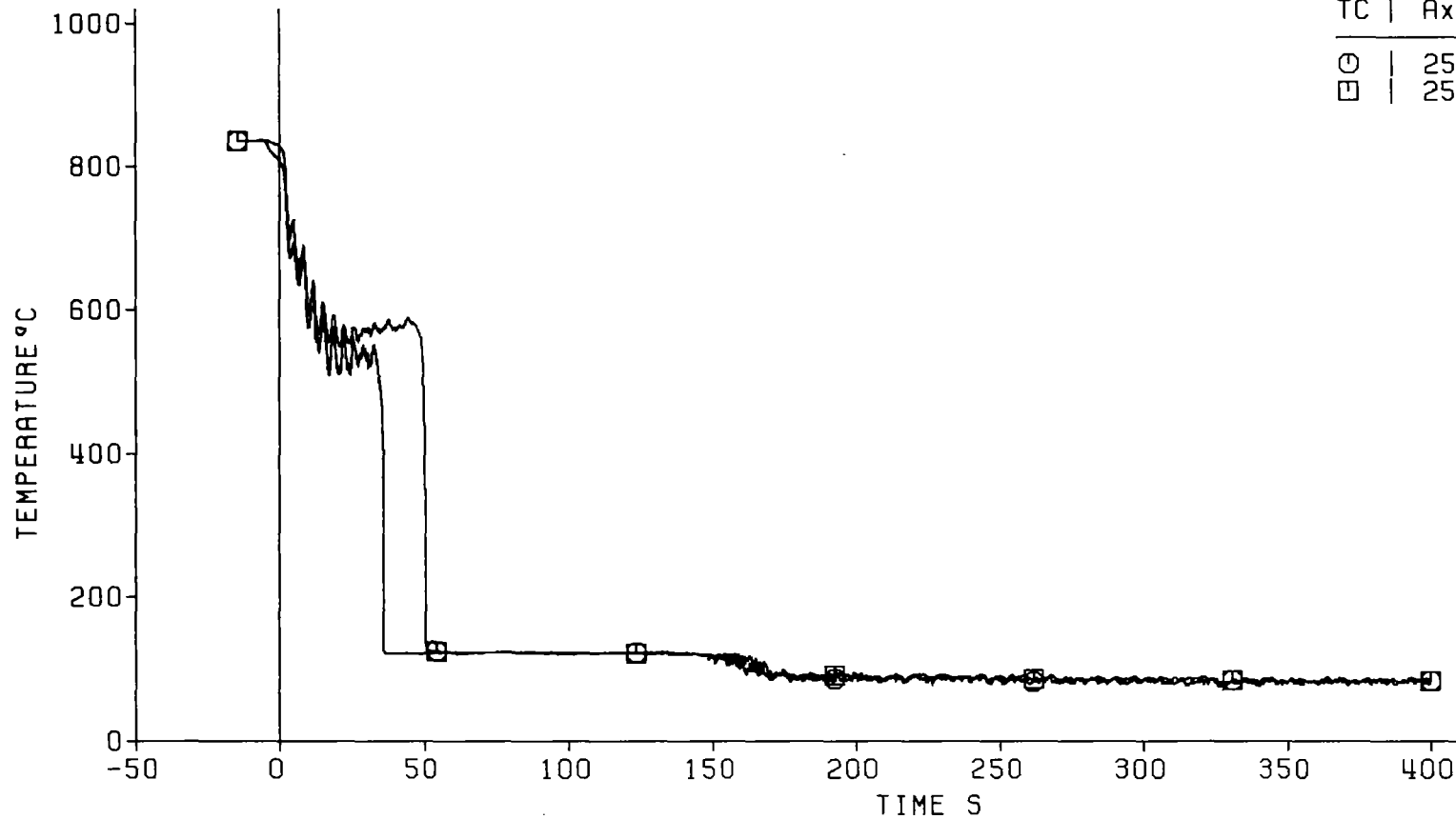


Fig. 93 SEFLEX: 5x5 ROD BUNDLE, SERIES 1, TEST-No. 06

Grid Spacer Temperature

TC | Axial Level

⊙ | 2568 mm, Leading Edge
⊠ | 2535 mm, Trailing Edge



Decay Heat 120% ANS Standard
Flooding Rate (cold) 5.79 cm/s
System Pressure 2.09 bar
Feedwater Temperature 40°C

REBEKA Rods With
Helium Filled Gaps

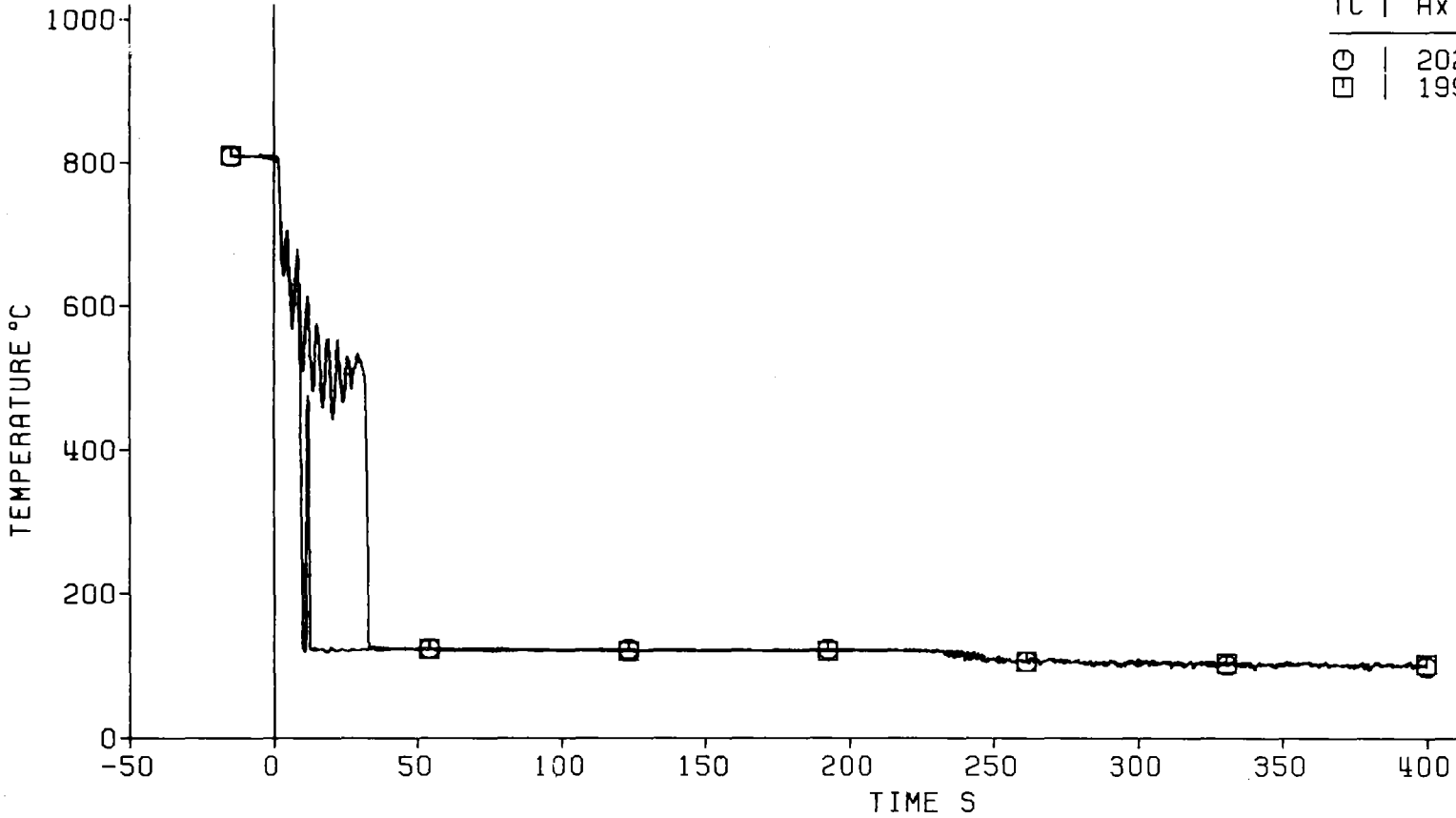


Fig. 94 SEFLEX: 5x5 ROD BUNDLE, SERIES 1, TEST-No. 06

Grid Spacer Temperature

TC | Axial Level

- | 2023 mm, Leading Edge
- | 1990 mm, Trailing Edge



Decay Heat 120% ANS Standard
Flooding Rate (cold) 5.79 cm/s
System Pressure 2.09 bar
Feedwater Temperature 40°C

REBEKA Rods With Helium Filled Gaps

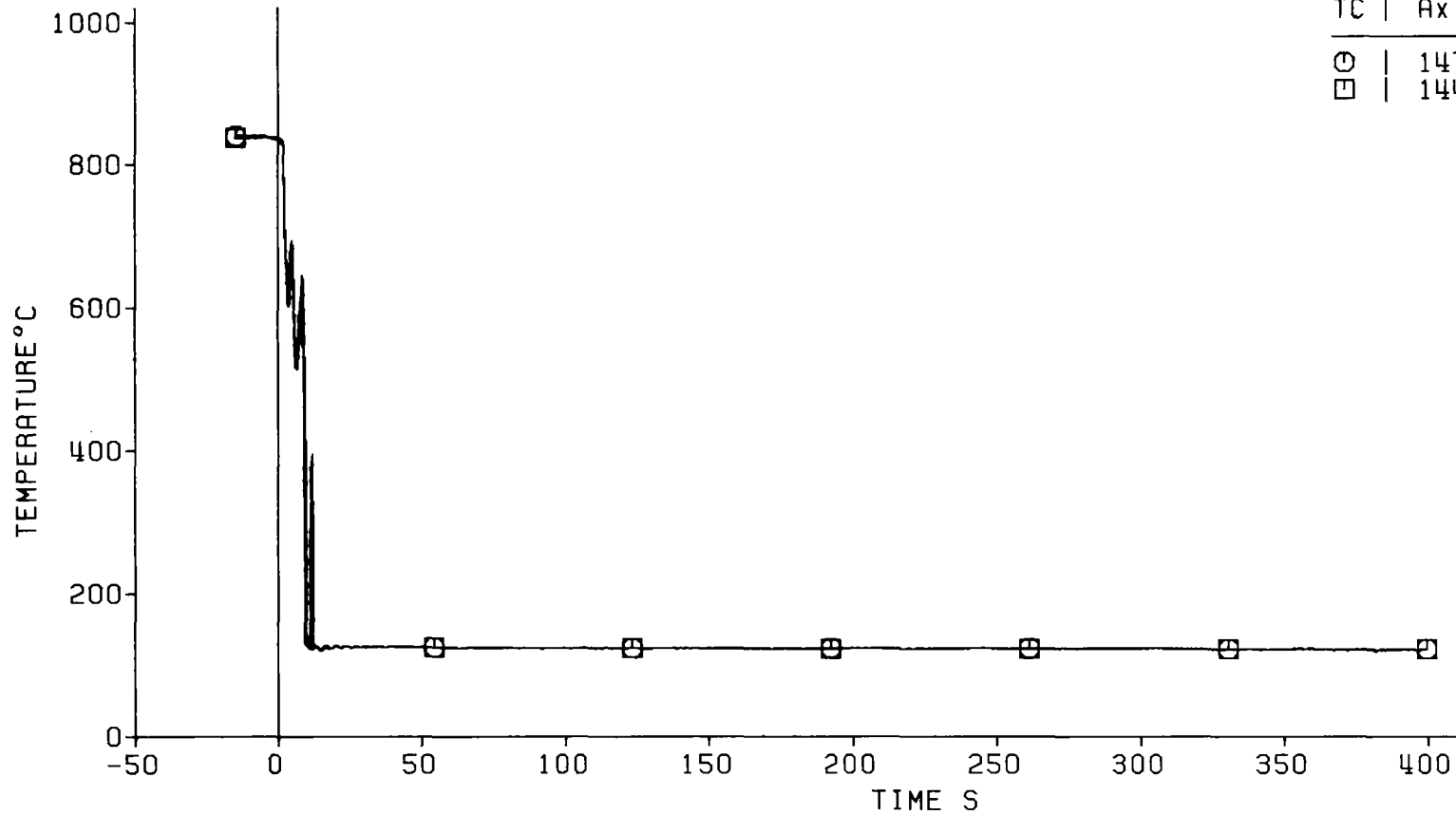


Fig. 95 SEFLEX: 5x5 ROD BUNDLE, SERIES 1, TEST-No. 06

Grid Spacer Temperature

TC | Axial Level

○ | 1478 mm, Leading Edge
□ | 1445 mm, Trailing Edge



Decay Heat 120% ANS Standard
Flooding Rate (cold) 5.79 cm/s
System Pressure 2.09 bar
Feedwater Temperature 40 °C

REBEKA Rods With Helium Filled Gaps

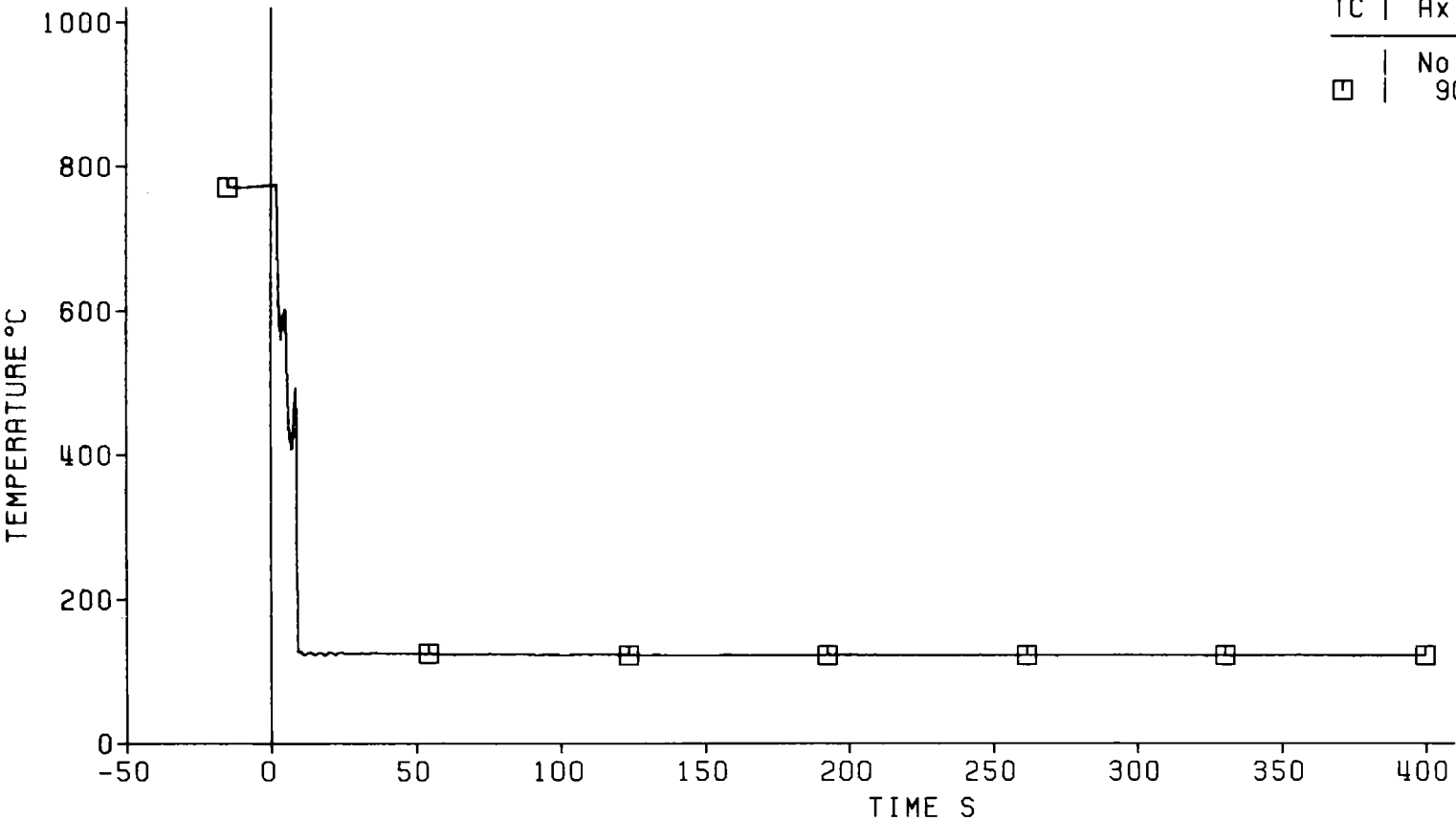


Fig. 96 SEFLEX: 5x5 ROD BUNDLE, SERIES 1, TEST-No. 06

Grid Spacer Temperature

TC | Axial Level

□ | No TC at Leading Edge
□ | 900 mm, Trailing Edge



Decay Heat	120% ANS Standard	REBEKA Rods With
Flooding Rate (cold)	5.79 cm/s	Helium Filled Gaps
System Pressure	2.09 bar	
Feedwater Temperature	40°C	

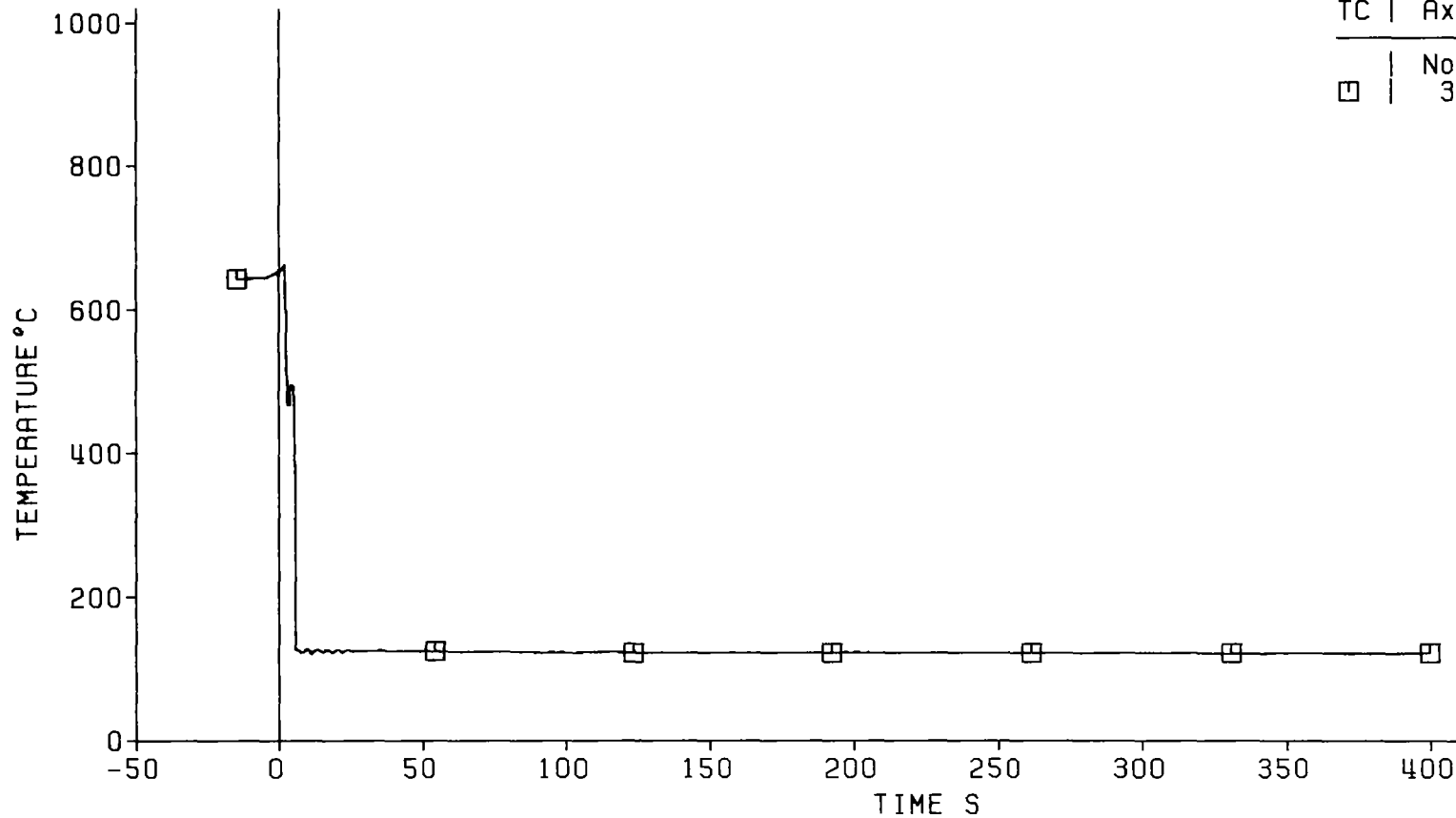


Fig. 97 SEFLEX: 5x5 ROD BUNDLE, SERIES 1, TEST-No. 06

Grid Spacer Temperature

TC | Axial Level

□ | No TC at Leading Edge
□ | 355 mm, Trailing Edge



Decay Heat 120% ANS Standard
Flooding Rate (cold) 5.79 cm/s
System Pressure 2.09 bar
Feedwater Temperature 40°C

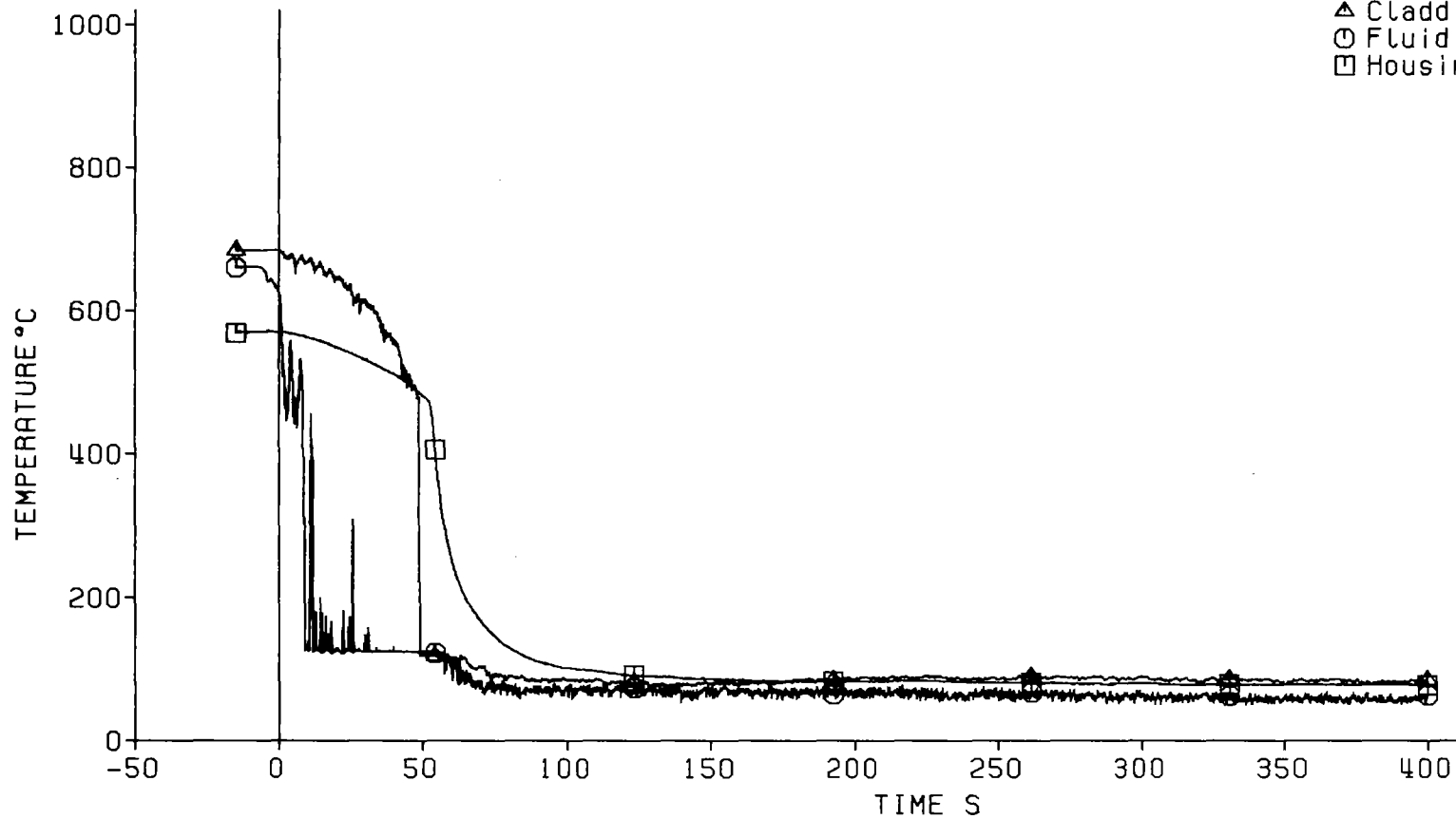
REBEKA Rods With
Helium Filled Gaps



Fig. 98 SEFLEX: 5x5 ROD BUNDLE, SERIES 1, TEST-No. 06

Axial Level: 3315 mm

▲ Cladding Temperature (18a3)
○ Fluid Temperature
□ Housing Temperature



Decay Heat 120% ANS Standard
Flooding Rate (cold) 5.79 cm/s
System Pressure 2.09 bar
Feedwater Temperature 40°C

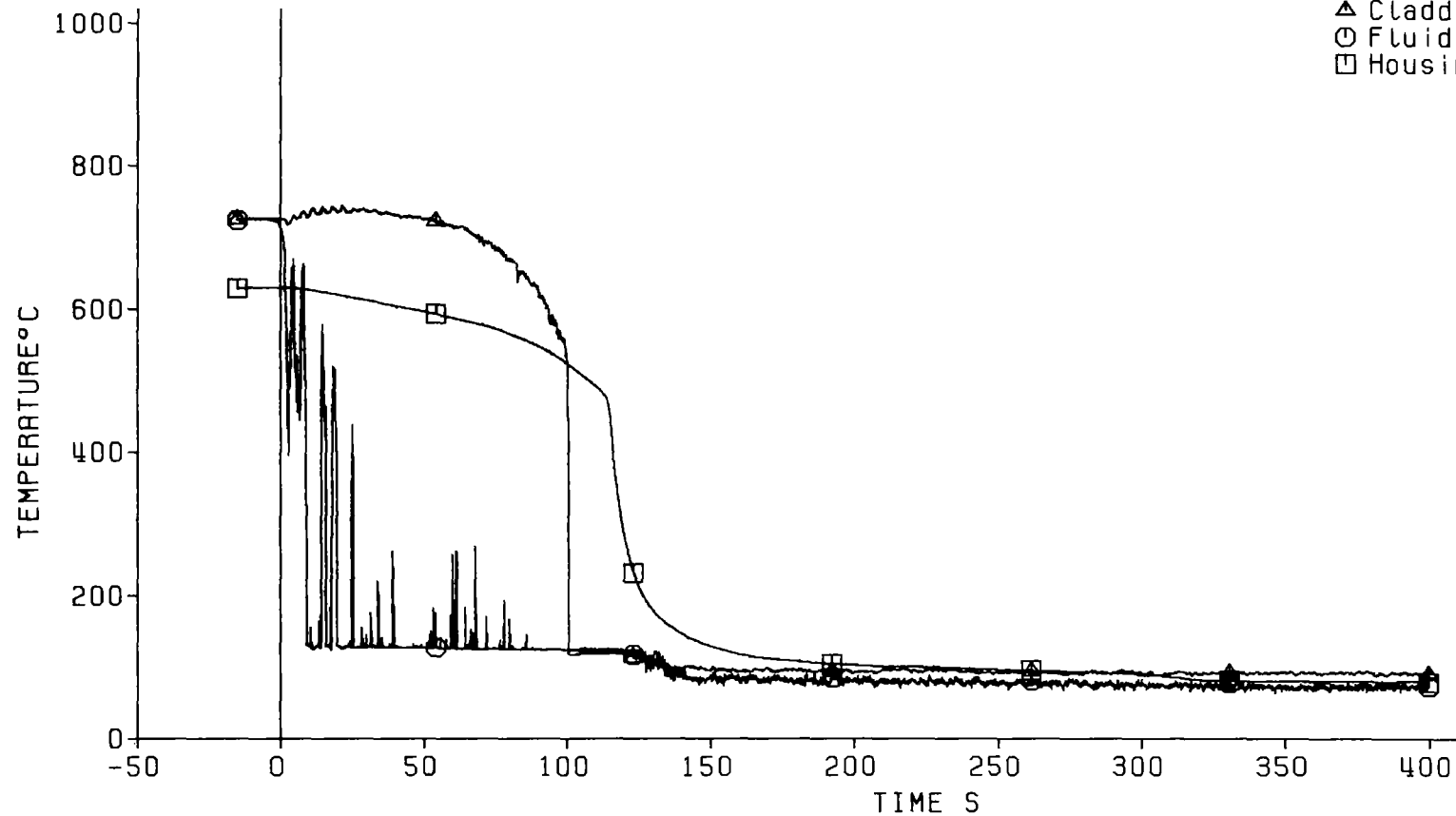
REBEKA Rods With
Helium Filled Gaps

KJK
IRB

Fig. 99 SEFLEX: 5x5 ROD BUNDLE, SERIES 1, TEST-No. 06

Axial Level: 2770 mm

▲ Cladding Temperature (15a2)
○ Fluid Temperature
□ Housing Temperature



Decay Heat 120% ANS Standard
Flooding Rate (cold) 5.79 cm/s
System Pressure 2.09 bar
Feedwater Temperature 40°C

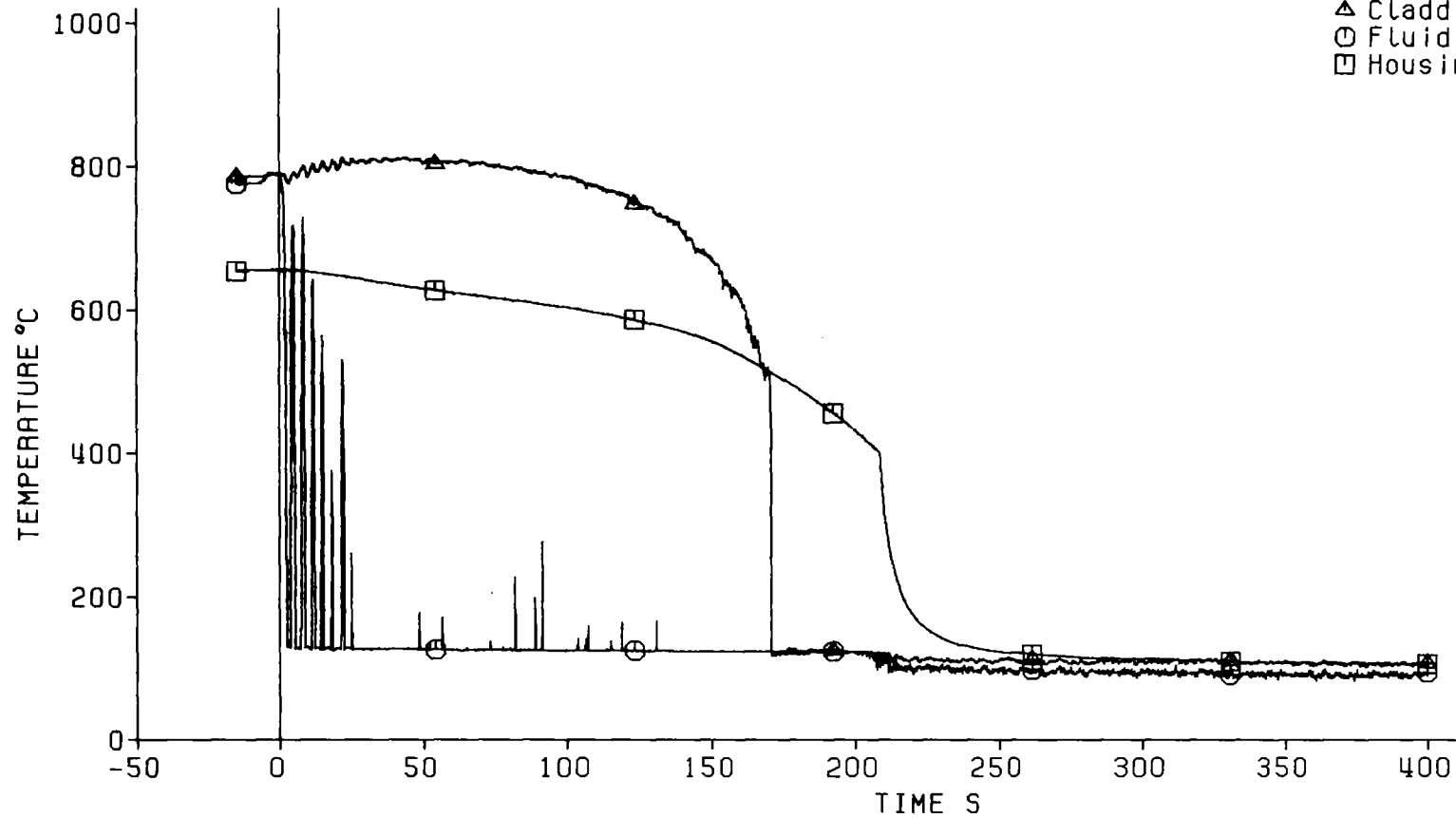
REBEKA Rods With
Helium Filled Gaps



Fig. 100 SEFLEX: 5x5 ROD BUNDLE, SERIES 1, TEST-No. 06

Axial Level: 2225 mm

△ Cladding Temperature (18a1)
○ Fluid Temperature, (2240 mm)
□ Housing Temperature



Decay Heat
Flooding Rate (cold) 5.79 cm/s
System Pressure 2.09 bar
Feedwater Temperature 40°C

120% ANS Standard

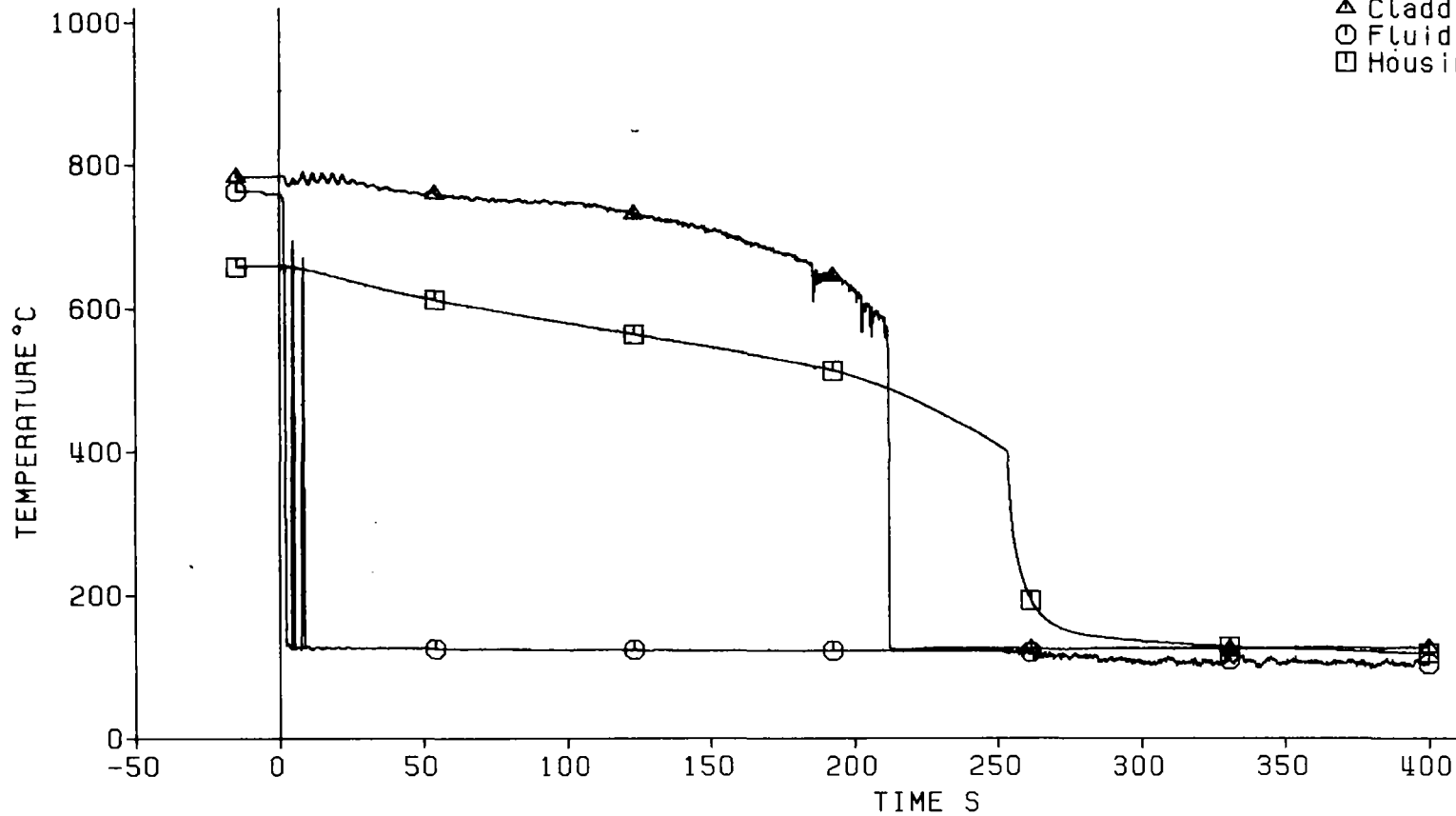
REBEKA Rods With
Helium Filled Gaps



Fig. 101 SEFLEX: 5x5 ROD BUNDLE, SERIES 1, TEST-No. 06

Axial Level: 1825 mm

△ Cladding Temperature (19g3)
○ Fluid Temperature
□ Housing Temperature



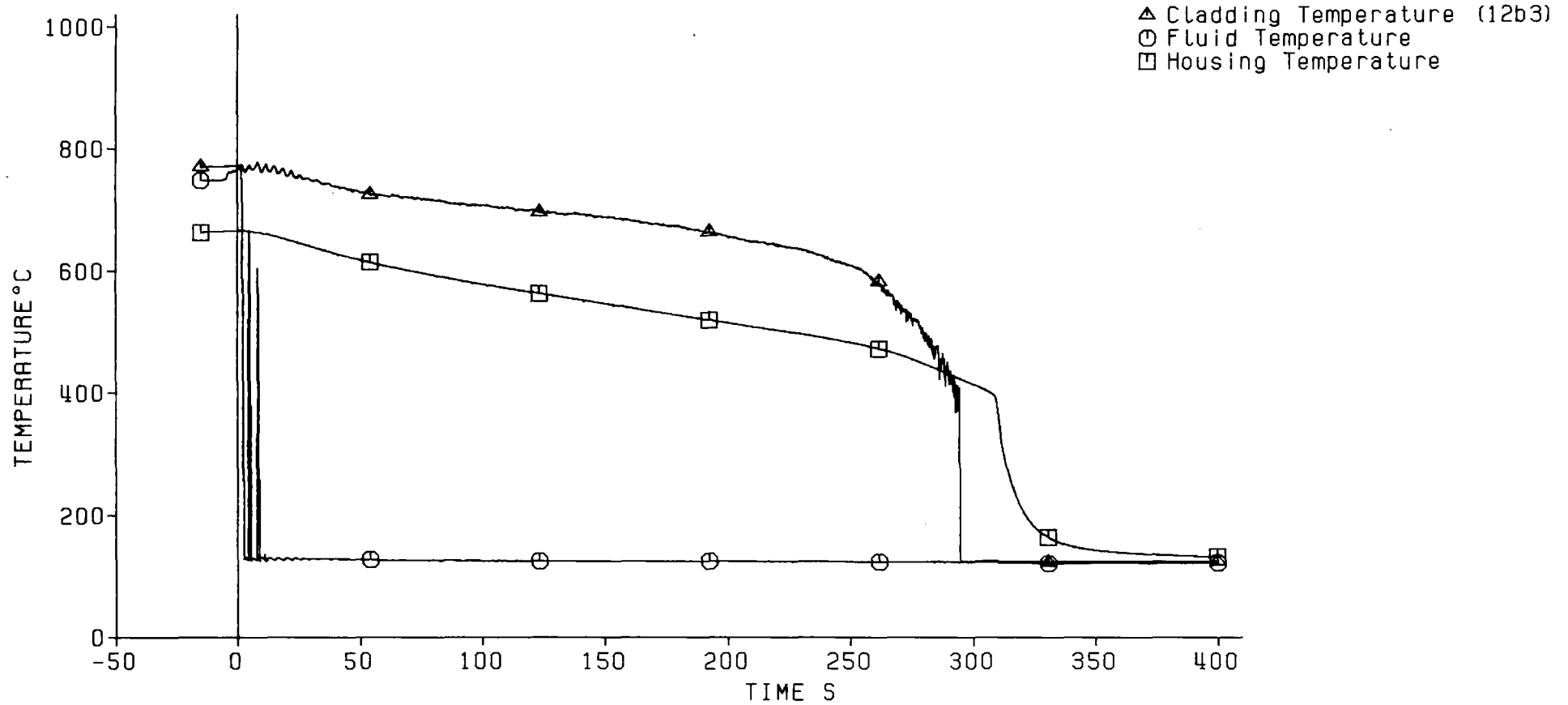
Decay Heat 120% ANS Standard
Flooding Rate (cold) 5.79 cm/s
System Pressure 2.09 bar
Feedwater Temperature 40°C

REBEKA Rods With
Helium Filled Gaps



Fig. 102 SEFLEX: 5x5 ROD BUNDLE, SERIES 1, TEST-No. 06

Axial Level: 1135 mm



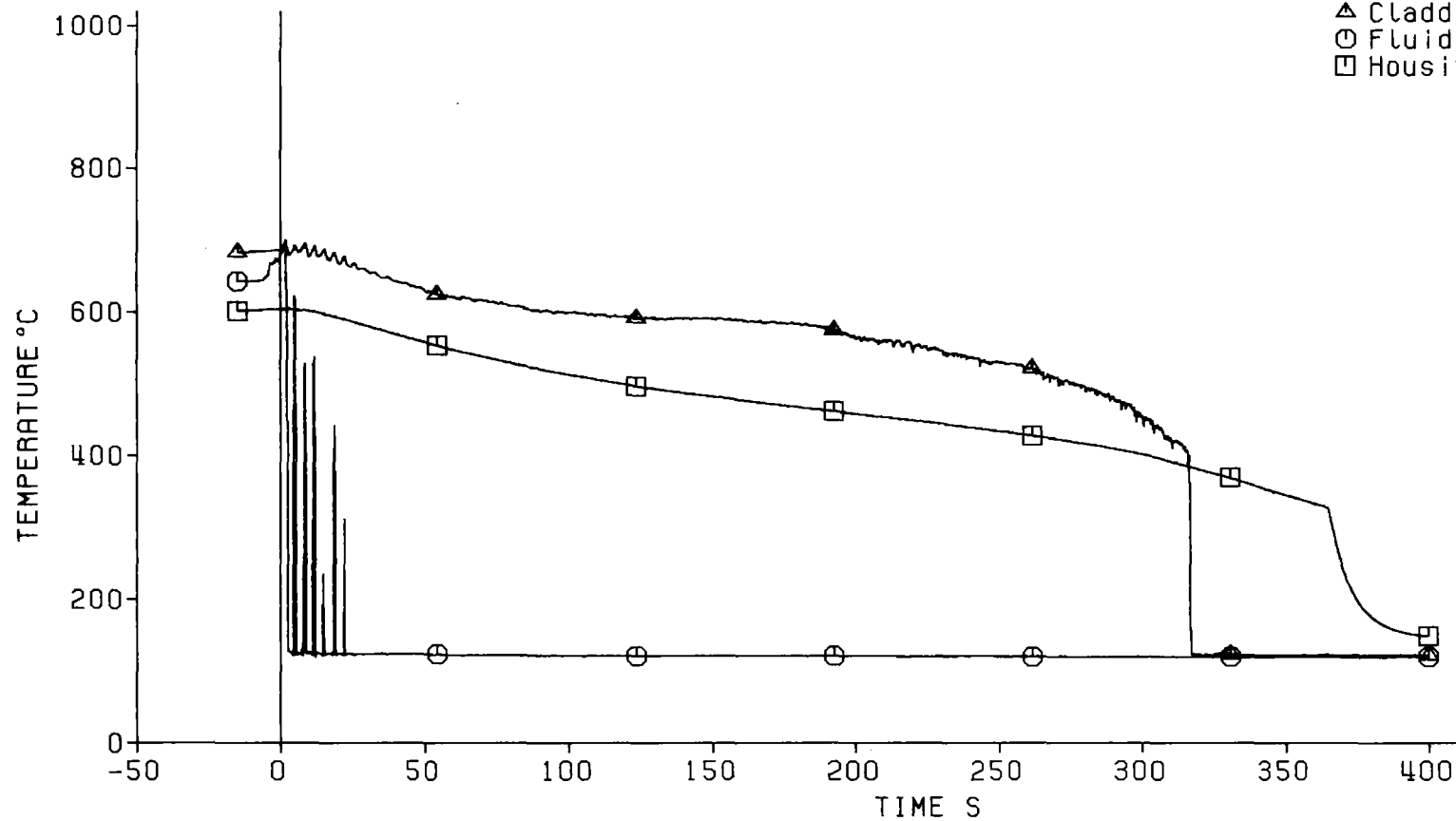
Decay Heat 120% ANS Standard
Flooding Rate (cold) 5.79 cm/s
System Pressure 2.09 bar
Feedwater Temperature 40°C

REBEKA Rods With Helium Filled Gaps



Fig. 103 SEFLEX: 5x5 ROD BUNDLE, SERIES 1, TEST-No. 06

Axial Level: 590 mm



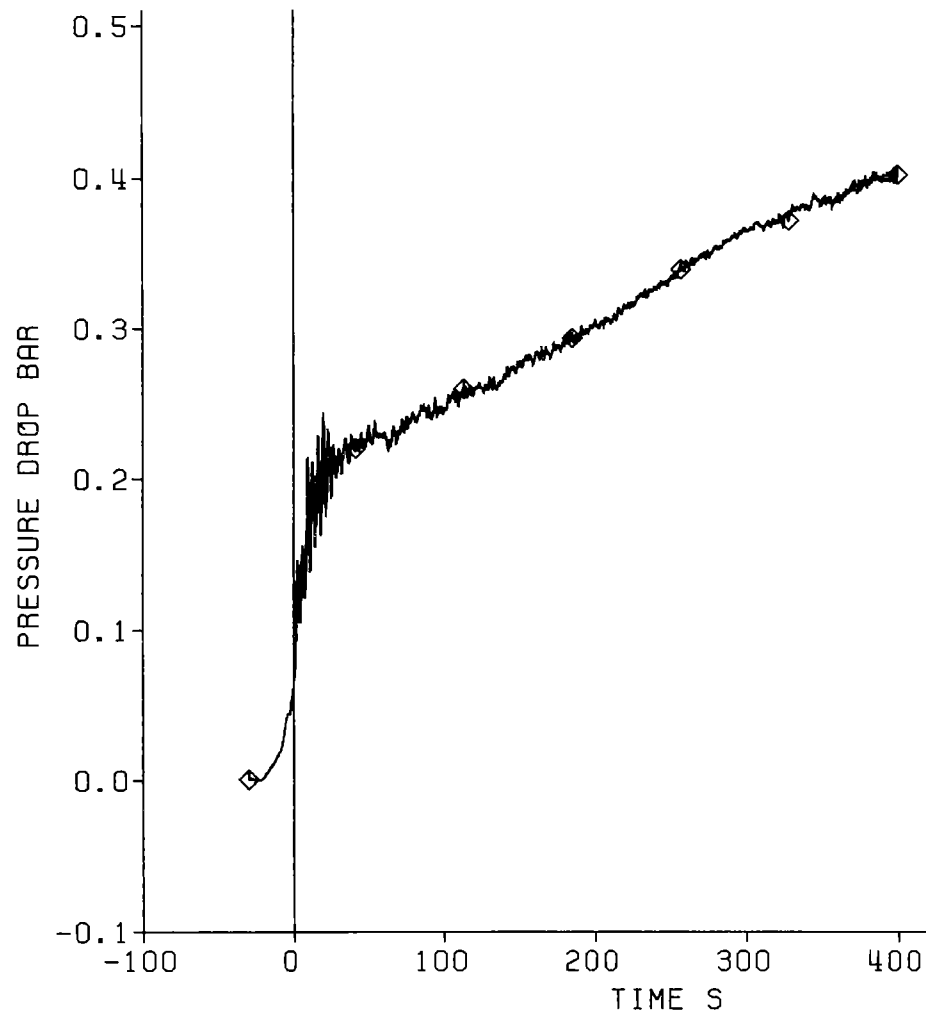
△ Cladding Temperature (12b2)
○ Fluid Temperature, (485 mm)
□ Housing Temperature

Decay Heat 120% ANS Standard
Flooding Rate (cold) 5.79 cm/s
System Pressure 2.09 bar
Feedwater Temperature 40°C

REBEKA Rods With
Helium Filled Gaps

KIK IRB

Fig. 104 SEFLEX: 5x5 ROD BUNDLE, SERIES 1, TEST-No. 06



Pressure Drop
Along the Test Section:

◇ Total Length: 4196 mm

Decay Heat	120% ANS Standard
Flooding Rate (cold)	5.79 cm/s
System Pressure	2.09 bar
Feedwater Temperature	40 °C

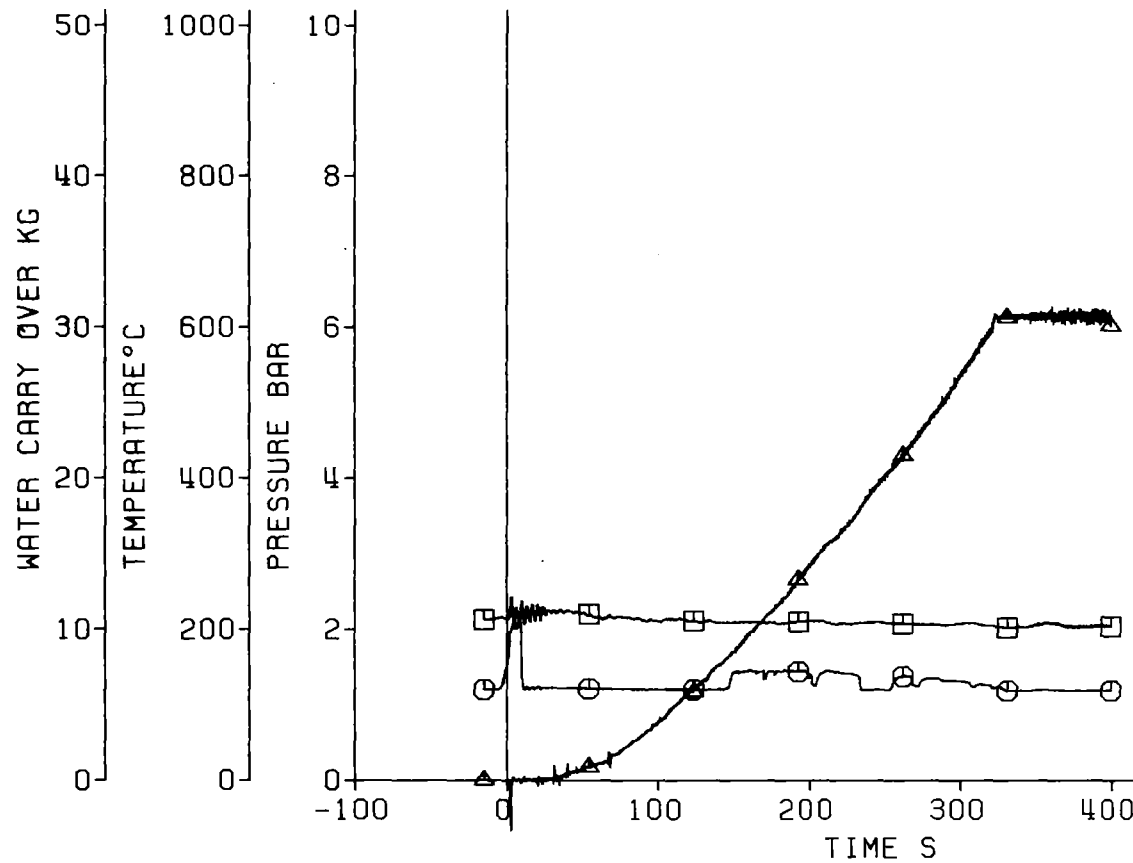
REBEKA Rods With
Helium Filled Gaps

KJK_{IRB}

Fig. 105 SEFLEX: 5x5 ROD BUNDLE, SERIES 1, TEST-No. 06

Coolant Outlet Conditions:

△ Water Carry Over
○ Coolant Temperature
□ Coolant Pressure



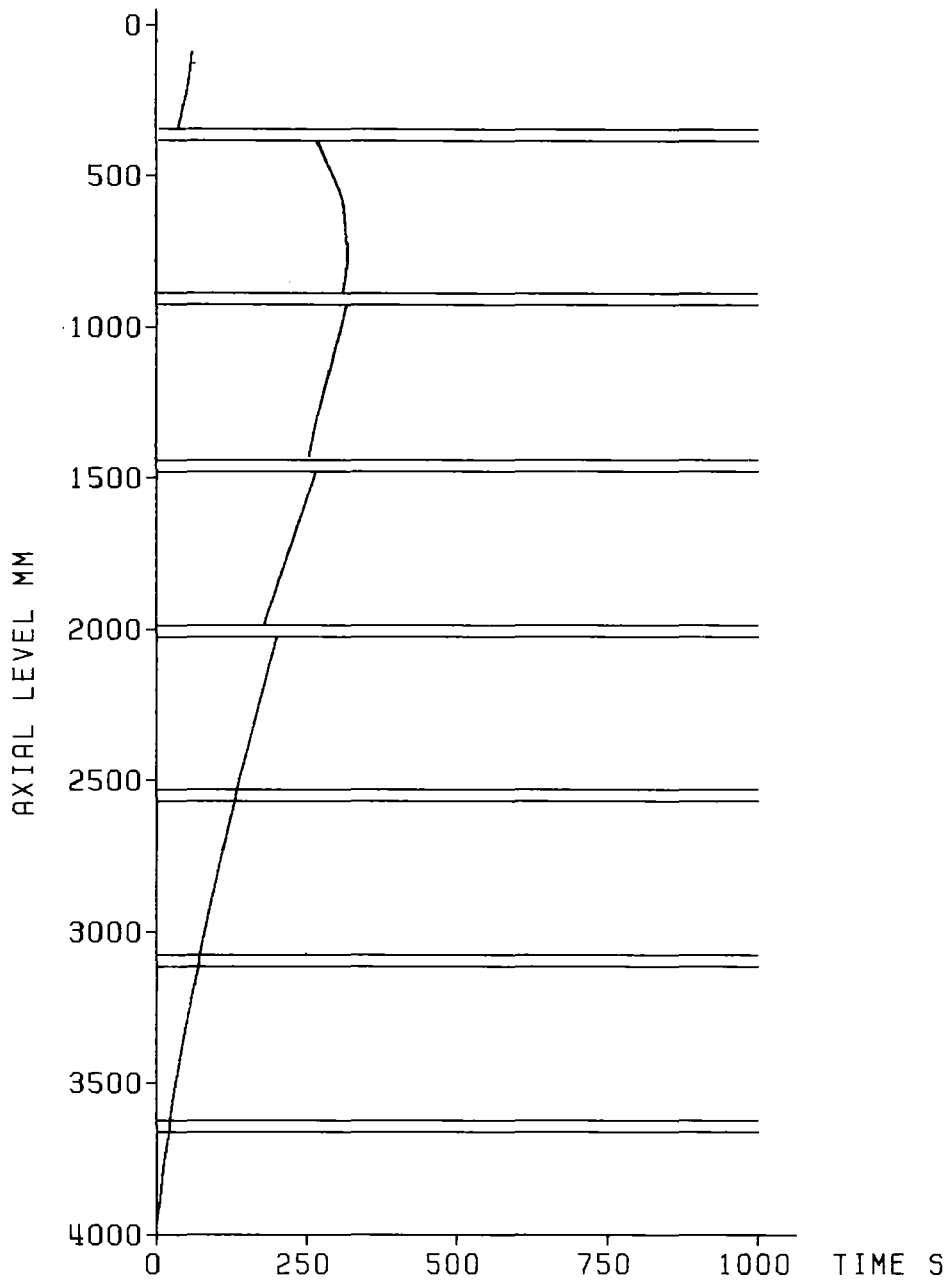
Decay Heat 120% ANS Standard
Flooding Rate (cold) 5.79 cm/s
System Pressure 2.09 bar
Feedwater Temperature 40 °C

REBEKA Rods With
Helium Filled Gaps



Fig. 106 SEFLEX: 5x5 ROD BUNDLE, SERIES 1, TEST-NO. 06

Axial Position of Quench Front
Rebeka Rods With Helium Filled Gaps

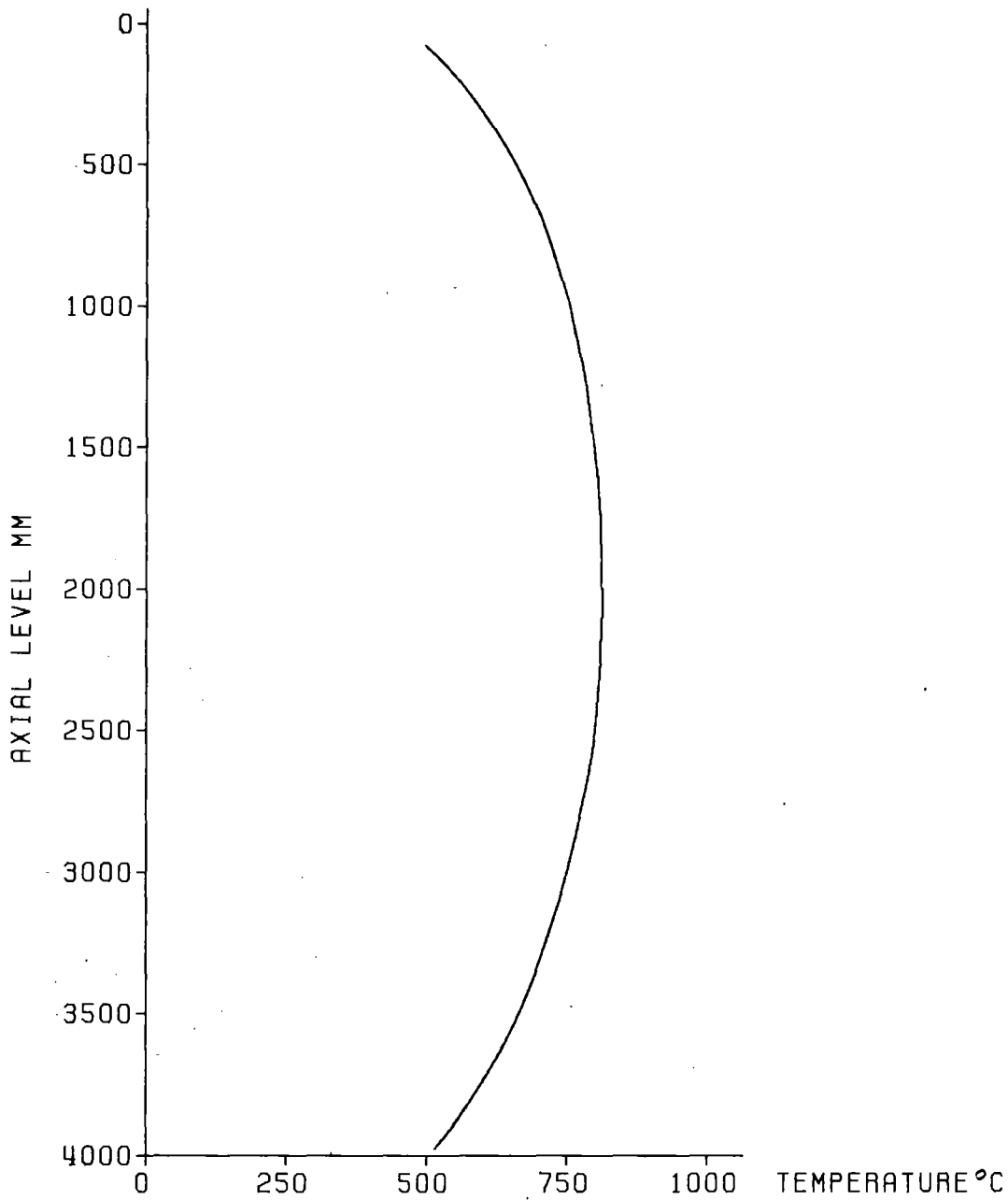


Decay Heat	120% ANS Standard
Flooding Rate (cold)	5.79 cm/s
System Pressure	2.09 bar
Feedwater Temperature	40°C



Fig. 107 SEFLEX: 5x5 ROD BUNDLE
TEST SERIES 1, TEST-No. 06

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

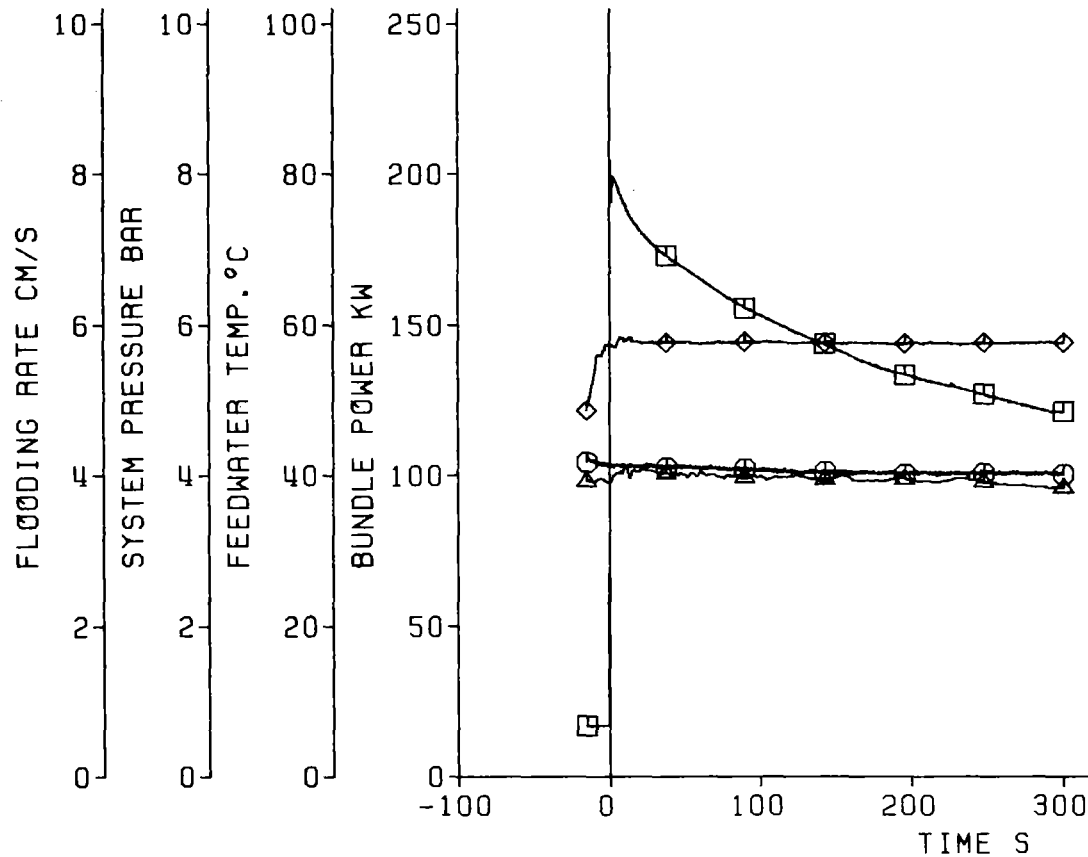


Decay Heat	120% ANS Standard
Flooding Rate (cold)	5.77 cm/s
System Pressure	4.01 bar
Feedwater Temperature	40°C



Fig. 108 SEFLEX: 5x5 ROD BUNDLE
TEST SERIES 1, TEST-No. 04

Test Parameters:



- ◇ Flooding Rate
- △ System Pressure
- Feedwater Temperature
- Bundle Power

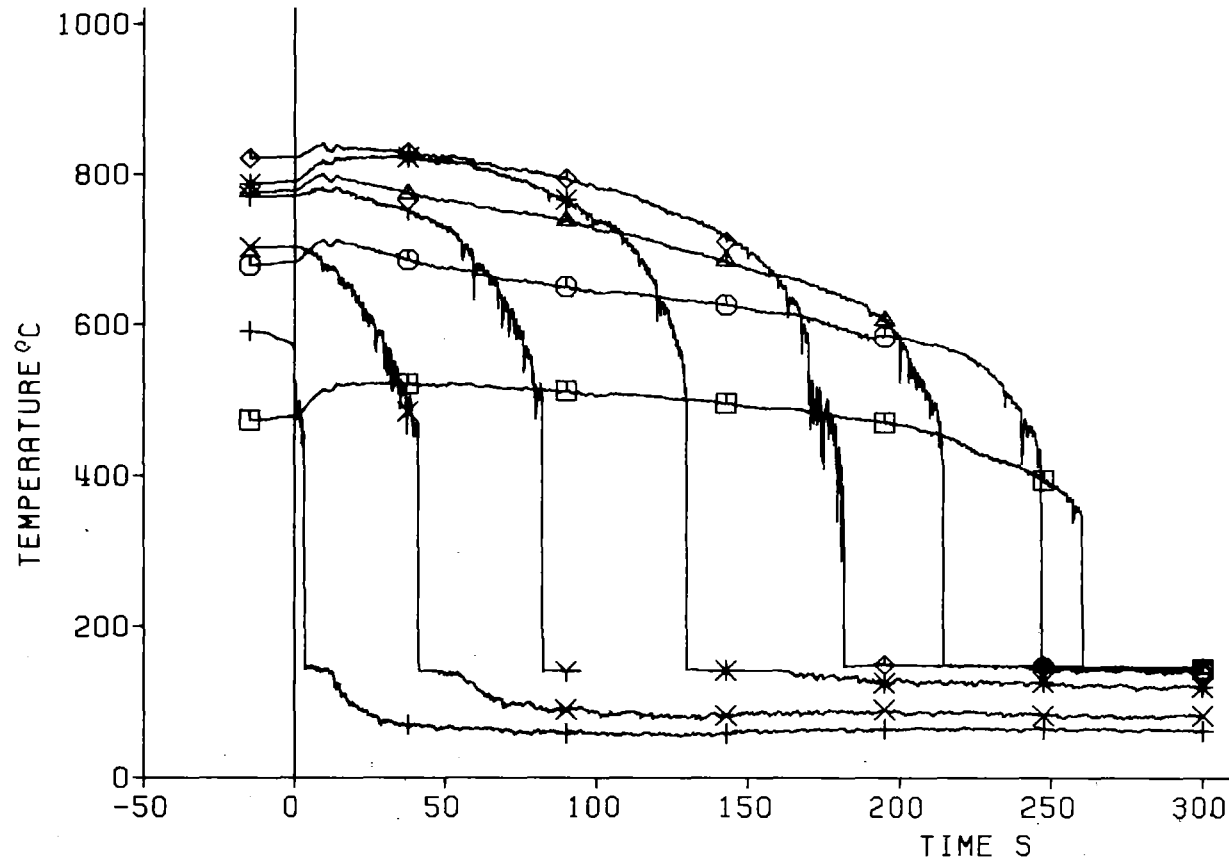
Decay Heat 120% ANS Standard
 Flooding Rate (cold) 5.77 cm/s
 System Pressure 4.01 bar
 Feedwater Temperature 40 °C

REBEKA Rods With
 Helium Filled Gaps



Fig. 109 SEFLEX: 5x5 ROD BUNDLE, SERIES 1, TEST-No. 04

Cladding Temperature



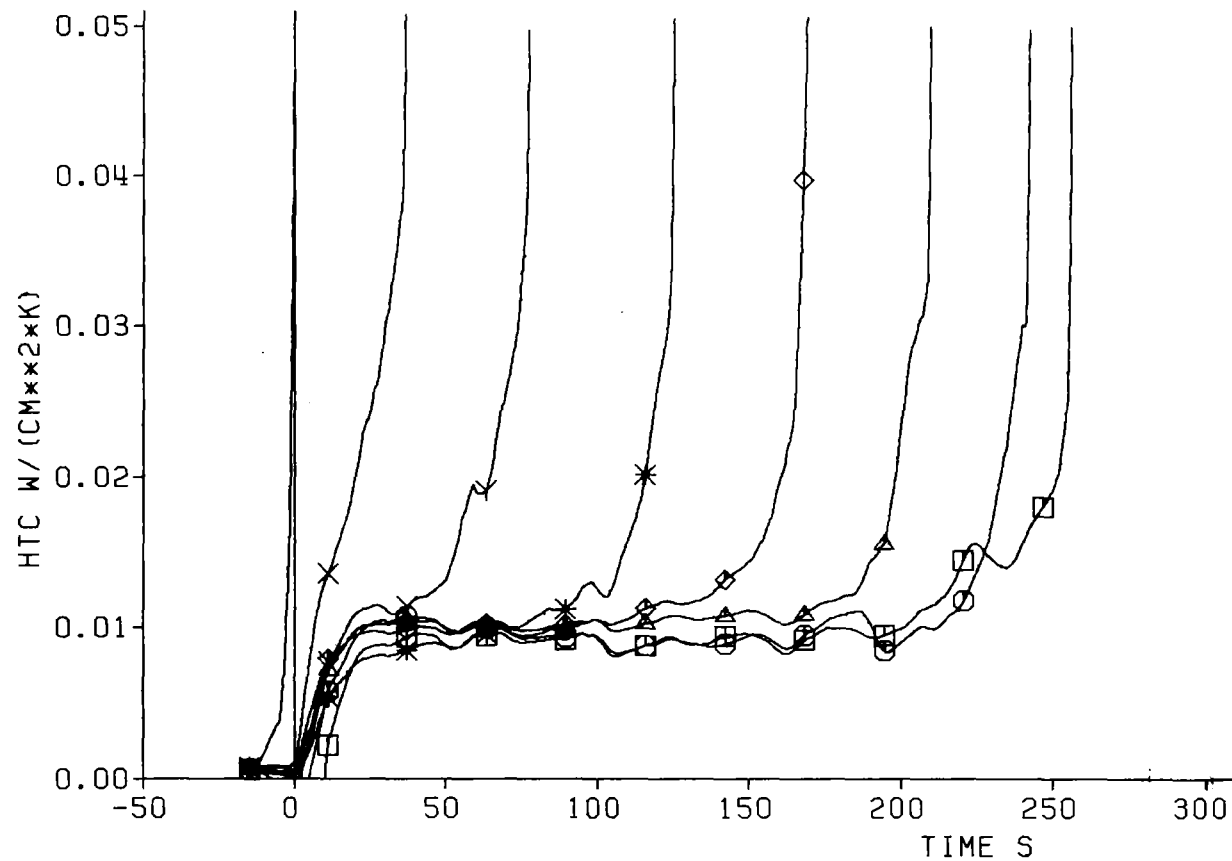
TC	Axial Level
+	18a4 3860 mm
X	18a3 3315 mm
Y	18a2 2770 mm
*	18a1 2225 mm
◇	12b4 1680 mm
△	12b3 1135 mm
⊙	12b2 590 mm
□	12b1 45 mm

Decay Heat 120% ANS Standard
 Flooding Rate (cold) 5.77 cm/s
 System Pressure 4.01 bar
 Feedwater Temperature 40°C

REBEKA Rods With
 Helium Filled Gaps



Fig. 110 SEFLEX: 5x5 ROD BUNDLE, SERIES 1, TEST-No. 04



TC	TC	Axial Level
+	18a4	3860 mm
X	18a3	3315 mm
Y	18a2	2770 mm
*	18a1	2225 mm
◇	12b4	1680 mm
△	12b3	1135 mm
○	12b2	590 mm
□	12b1	45 mm

Decay Heat
 Flooding Rate (cold) 120% ANS Standard
 System Pressure 5.77 cm/s
 Feedwater Temperature 4.01 bar
 40 °C

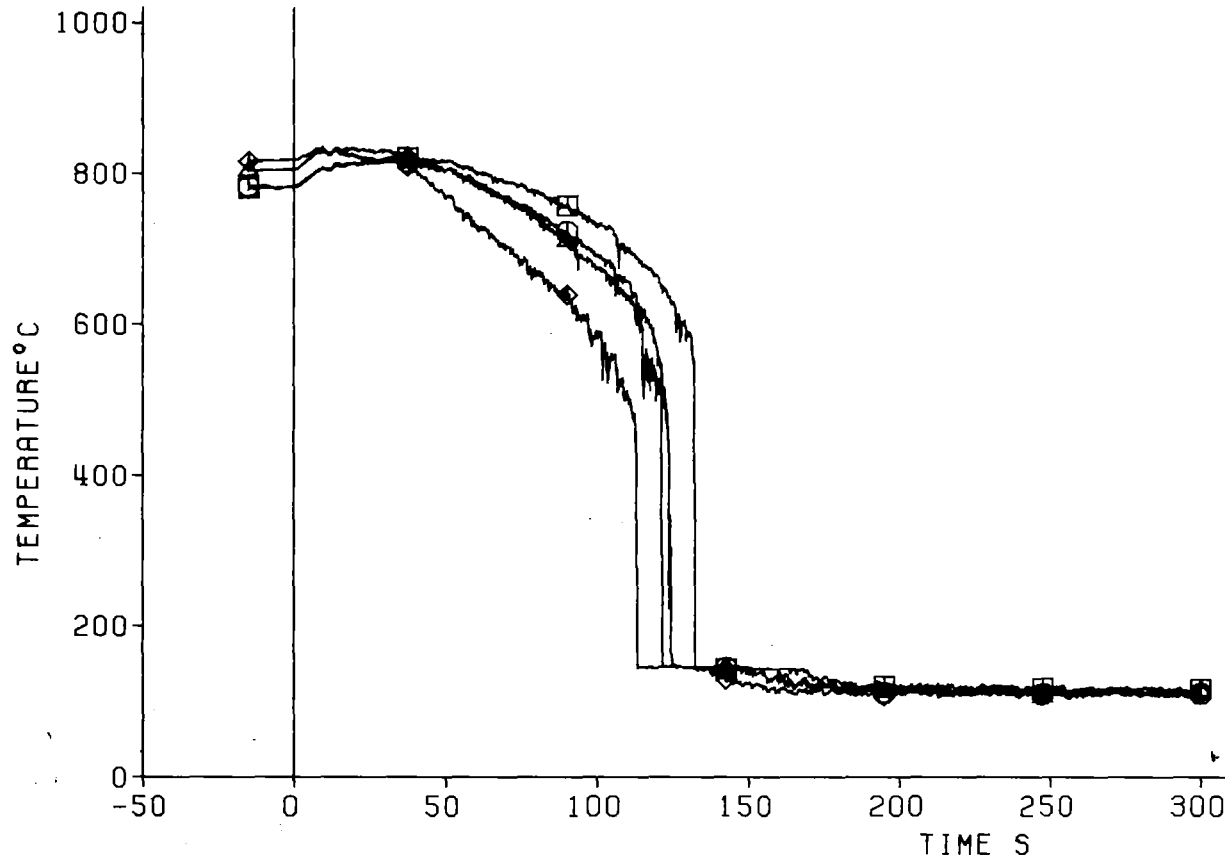
REBEKA Rods With
 Helium Filled Gaps



Fig. 111 SEFLEX: 5x5 ROD BUNDLE, SERIES 1, TEST-NO. 04

Cladding Temperature

TC	Axial Level
◇	7f4 2425 mm
△	7f3 2325 mm
○	7f2 2225 mm
□	7f1 2125 mm



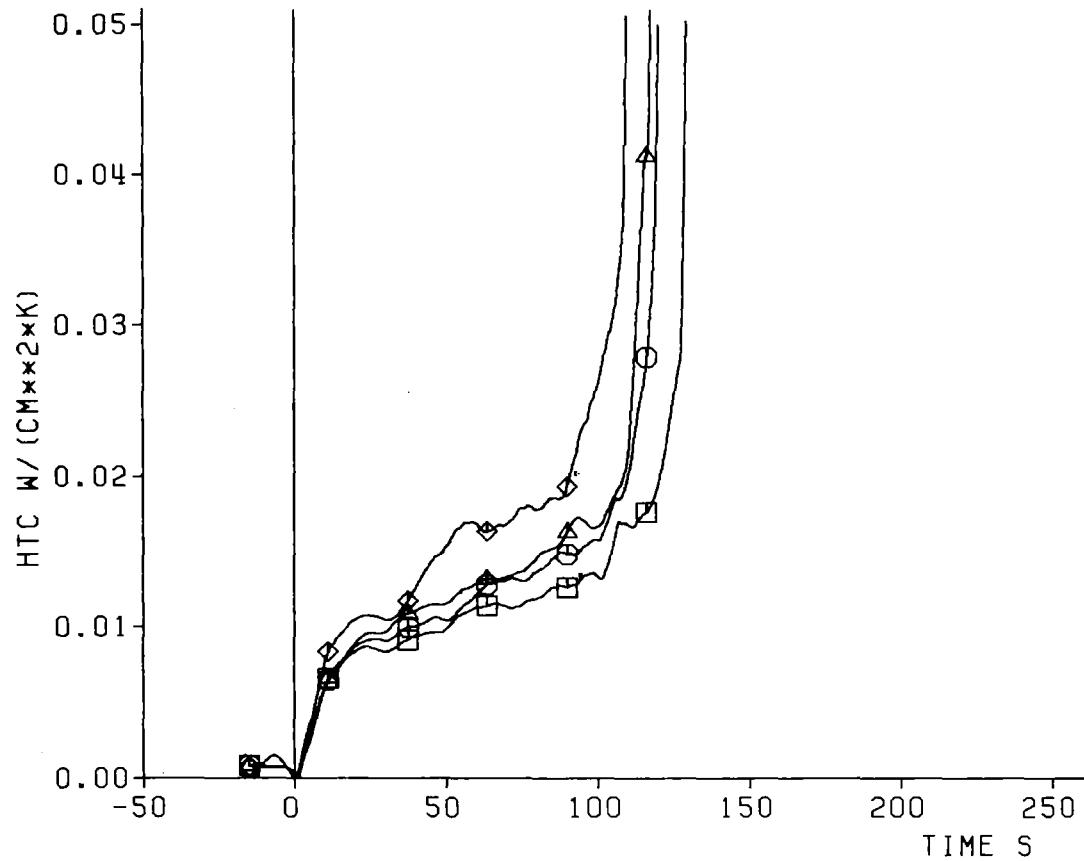
Decay Heat
 Flooding Rate (cold) 5.77 cm/s
 System Pressure 4.01 bar
 Feedwater Temperature 40 °C

120% ANS Standard

REBEKA Rods With Helium Filled Gaps



Fig. 112 SEFLEX: 5x5 ROD BUNDLE, SERIES 1, TEST-No. 04



TC	Axial Level
◇	7f4 2425 mm
△	7f3 2325 mm
○	7f2 2225 mm
□	7f1 2125 mm

Decay Heat 120% ANS Standard
 Flooding Rate (cold) 5.77 cm/s
 System Pressure 4.01 bar
 Feedwater Temperature 40°C

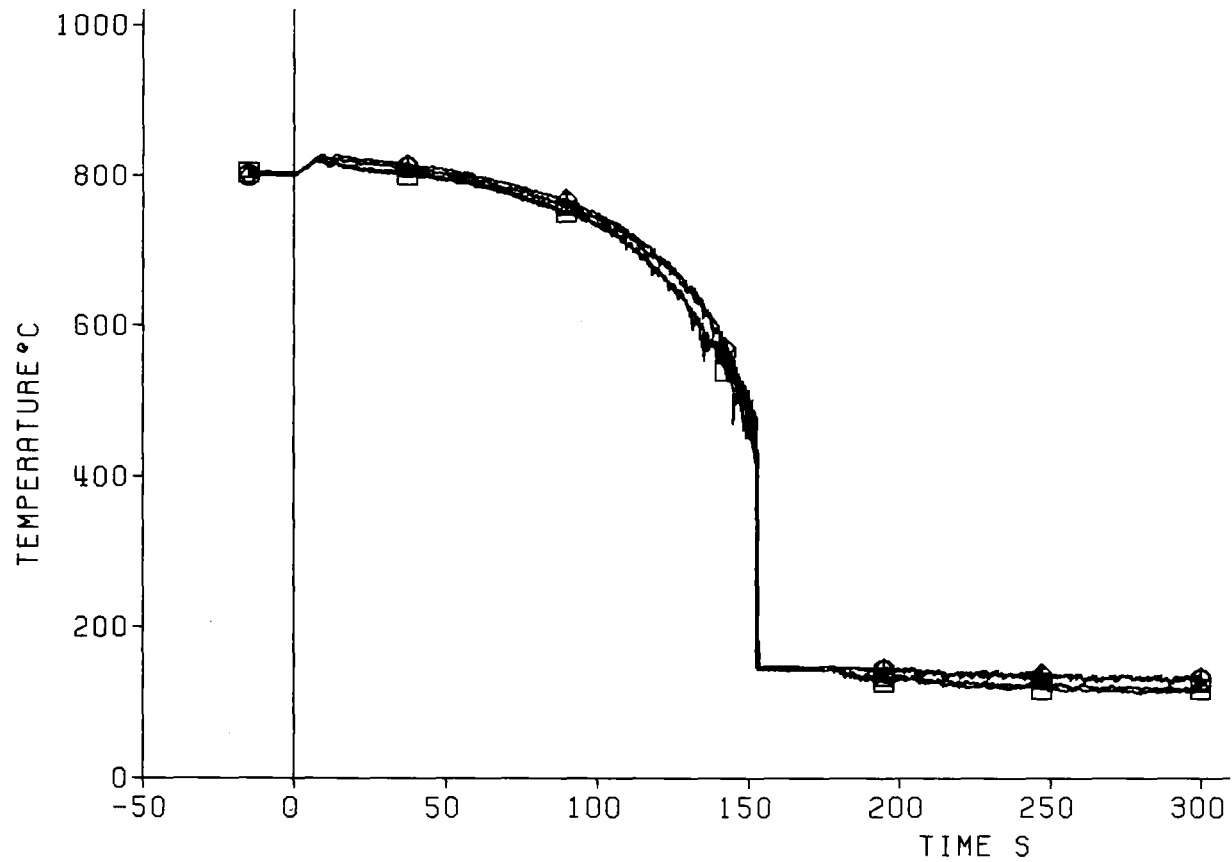
REBEKA Rods With Helium Filled Gaps



Fig. 113 SEFLEX: 5x5 ROD BUNDLE, SERIES 1, TEST-No. 04

Cladding Temperature

TC	Axial Level
◇ 14d1	2025 mm
△ 14d2	2025 mm
○ 14d3	2025 mm
□ 14d4	2025 mm

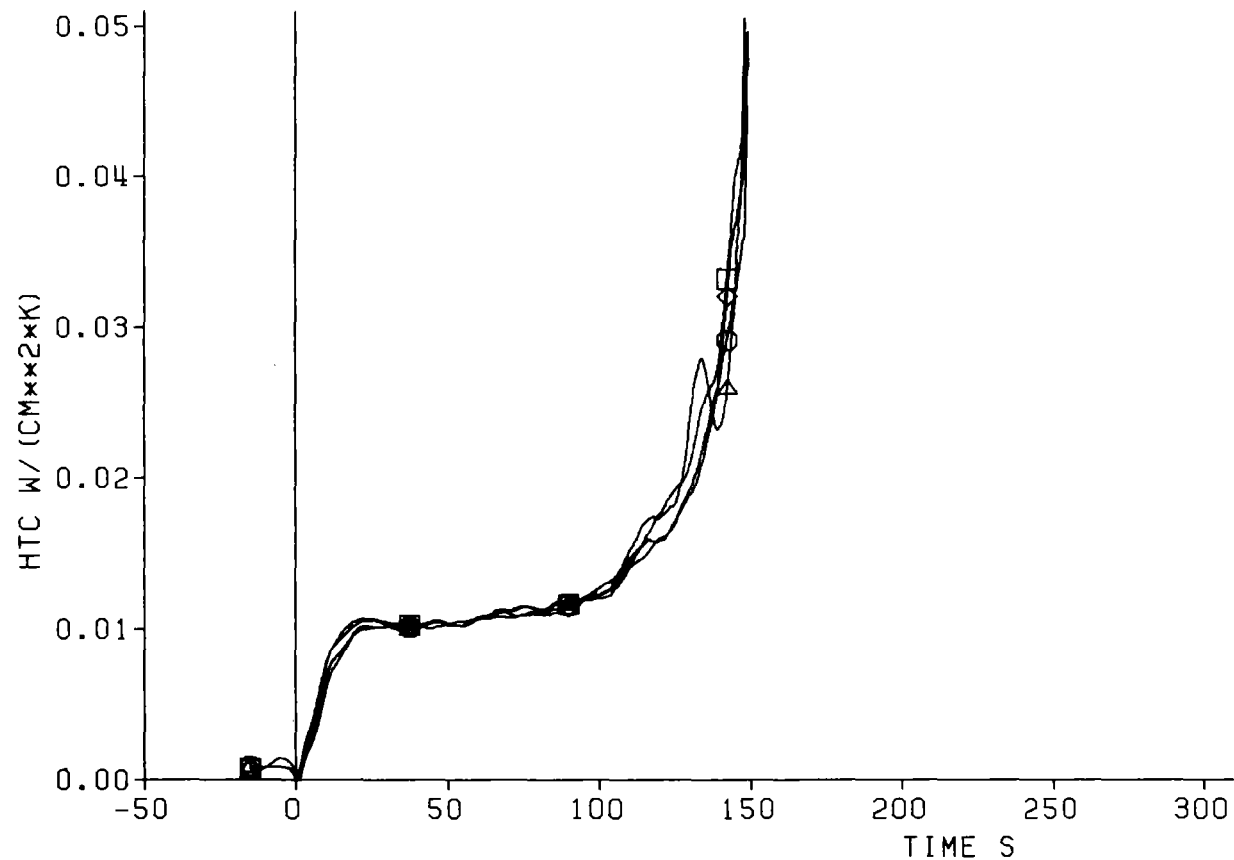


Decay Heat 120% ANS Standard
 Flooding Rate (cold) 5.77 cm/s
 System Pressure 4.01 bar
 Feedwater Temperature 40 °C

REBEKA Rods With
 Helium Filled Gaps



Fig. 114 SEFLEX: 5x5 ROD BUNDLE, SERIES 1, TEST-No. 04



TC	Axial Level
◇ 14d1	2025 mm
△ 14d2	2025 mm
○ 14d3	2025 mm
□ 14d4	2025 mm

Decay Heat 120% ANS Standard
 Flooding Rate (cold) 5.77 cm/s
 System Pressure 4.01 bar
 Feedwater Temperature 40 °C

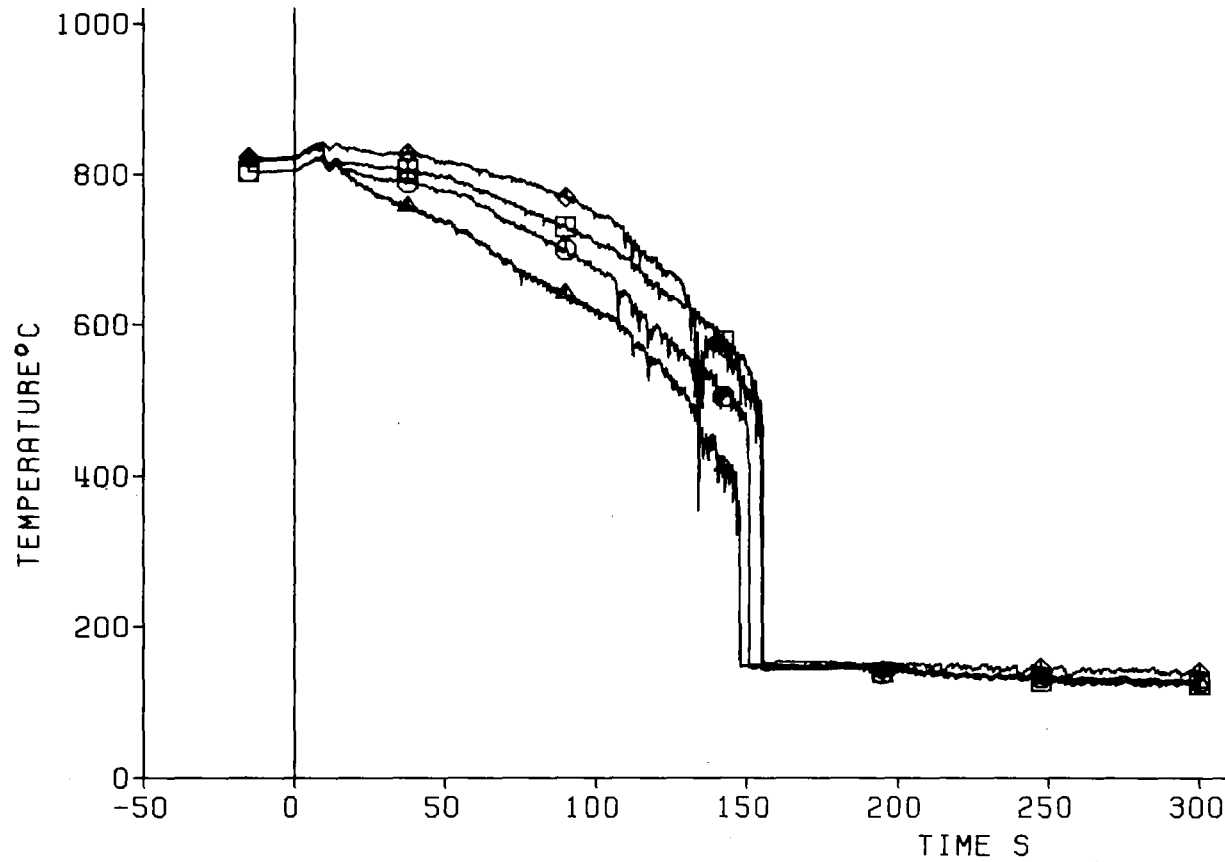
REBEKA Rods With
 Helium Filled Gaps

KIK
 TRB

Fig. 115 SEFLEX: 5x5 ROD BUNDLE, SERIES 1, TEST-NO. 04

Cladding Temperature

TC	Axial Level
◇ 13i4	2025 mm
△ 13i3	1975 mm
○ 13i2	1925 mm
□ 13i1	1875 mm

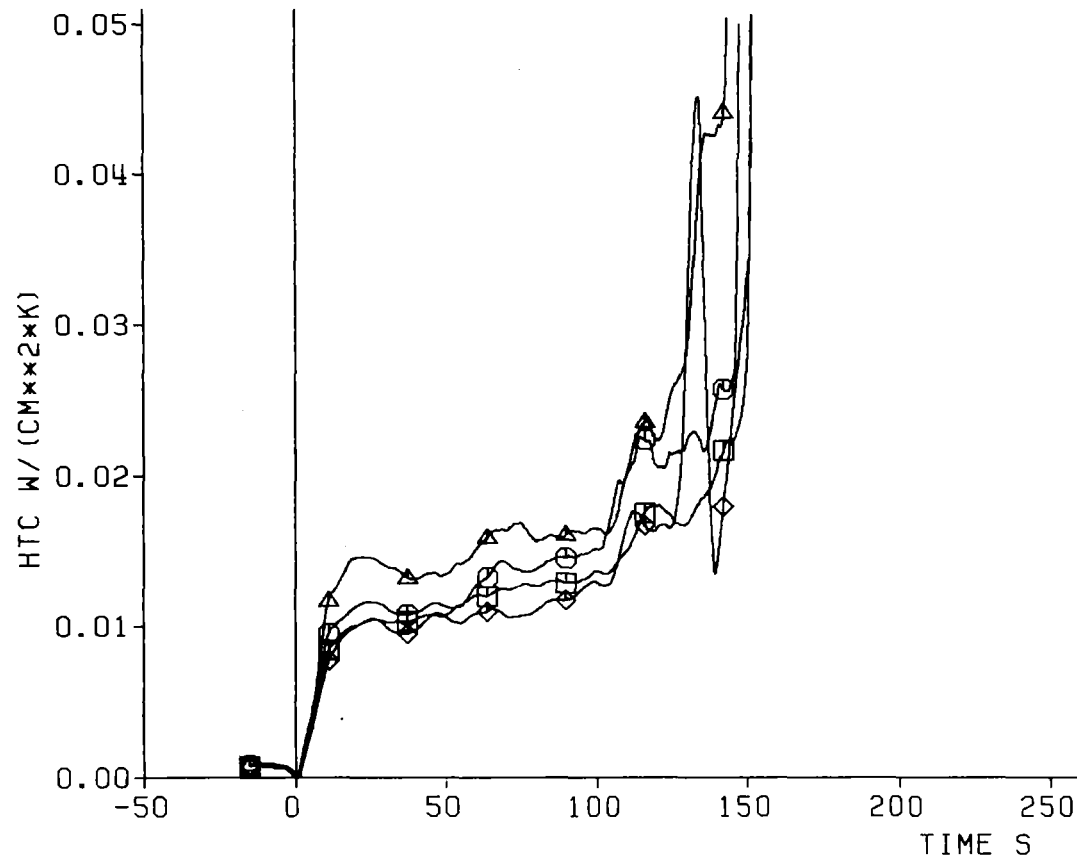


Decay Heat 120% ANS Standard
 Flooding Rate (cold) 5.77 cm/s
 System Pressure 4.01 bar
 Feedwater Temperature 40°C

REBEKA Rods With
 Helium Filled Gaps



Fig. 116 SEFLEX: 5x5 ROD BUNDLE, SERIES 1, TEST-No. 04



TC	Axial Level
◇ 13i4	2025 mm
△ 13i3	1975 mm
○ 13i2	1925 mm
□ 13i1	1875 mm

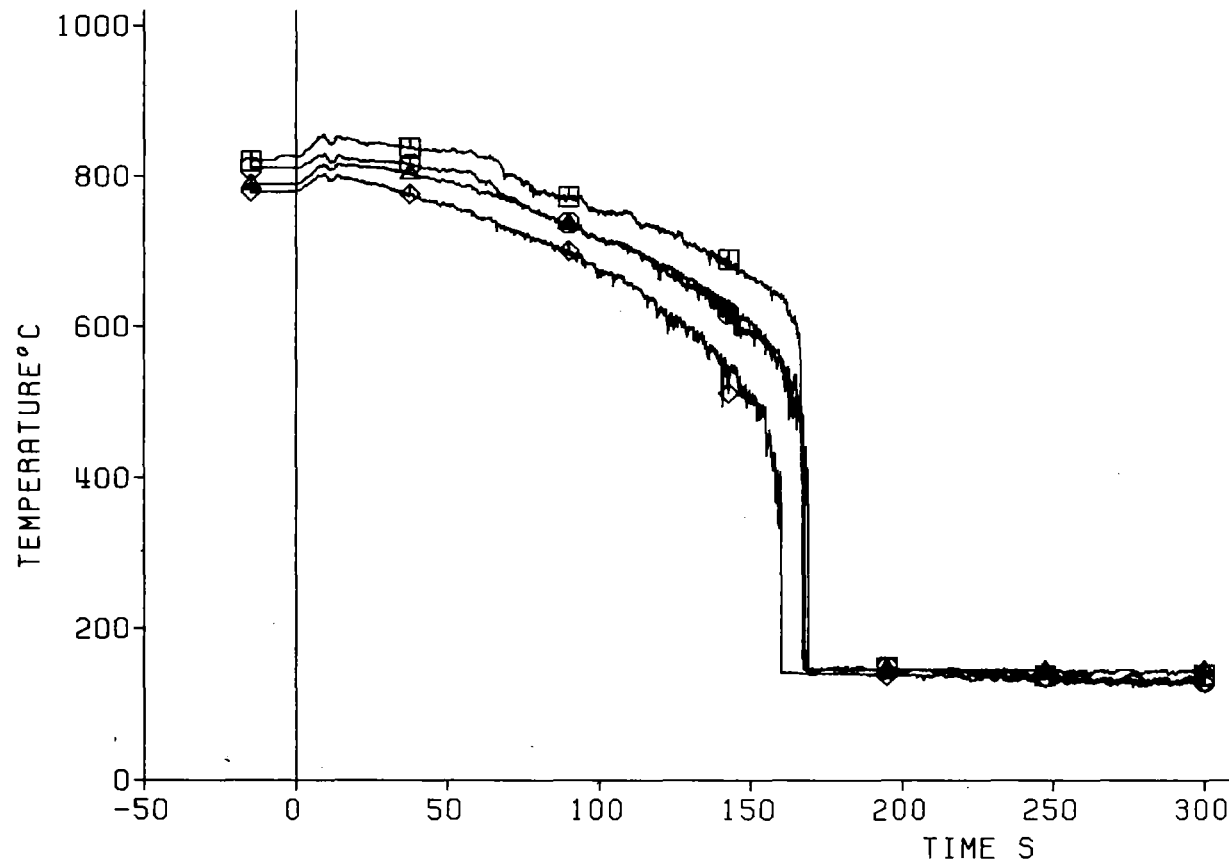
Decay Heat 120% ANS Standard
 Flooding Rate (cold) 5.77 cm/s
 System Pressure 4.01 bar
 Feedwater Temperature 40°C

REBEKA Rods With
 Helium Filled Gaps



Fig. 117 SEFLEX: 5x5 ROD BUNDLE, SERIES 1, TEST-No. 04

Cladding Temperature



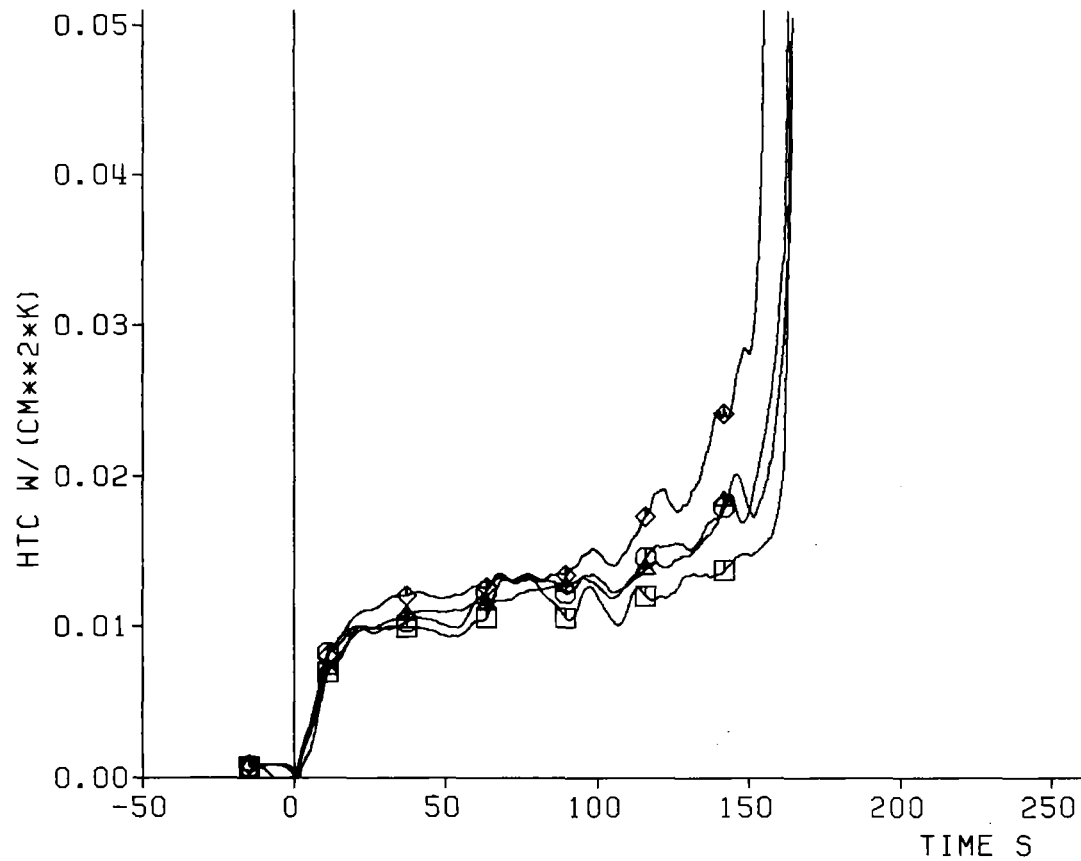
TC	Axial Level
◇ 19g4	1925 mm
△ 19g3	1825 mm
○ 19g2	1725 mm
□ 19g1	1625 mm

Decay Heat 120% ANS Standard
 Flooding Rate (cold) 5.77 cm/s
 System Pressure 4.01 bar
 Feedwater Temperature 40°C

REBEKA Rods With Helium Filled Gaps



Fig. 118 SEFLEX: 5x5 ROD BUNDLE, SERIES 1, TEST-No. 04



TC	Axial Level
◇	19g4 1925 mm
△	19g3 1825 mm
○	19g2 1725 mm
□	19g1 1625 mm

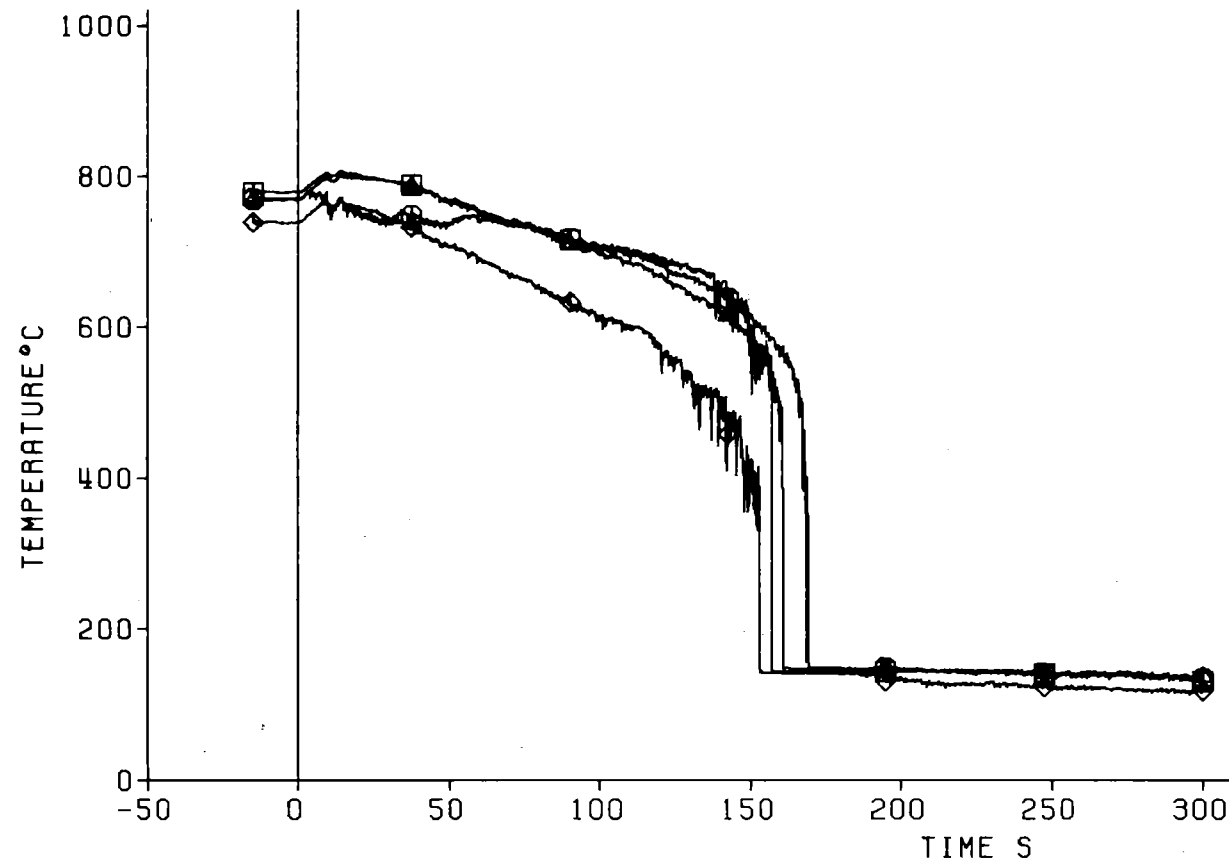
Decay Heat 120% ANS Standard
 Flooding Rate (cold) 5.77 cm/s
 System Pressure 4.01 bar
 Feedwater Temperature 40°C

REBEKA Rods With
 Helium Filled Gaps

KIK
 IRB

Fig. 119 SEFLEX: 5x5 ROD BUNDLE, SERIES 1, TEST-NO. 04

Cladding Temperature



TC	Axial Level
◇ 16g4	1925 mm
△ 16g3	1825 mm
○ 16g2	1725 mm
□ 16g1	1625 mm

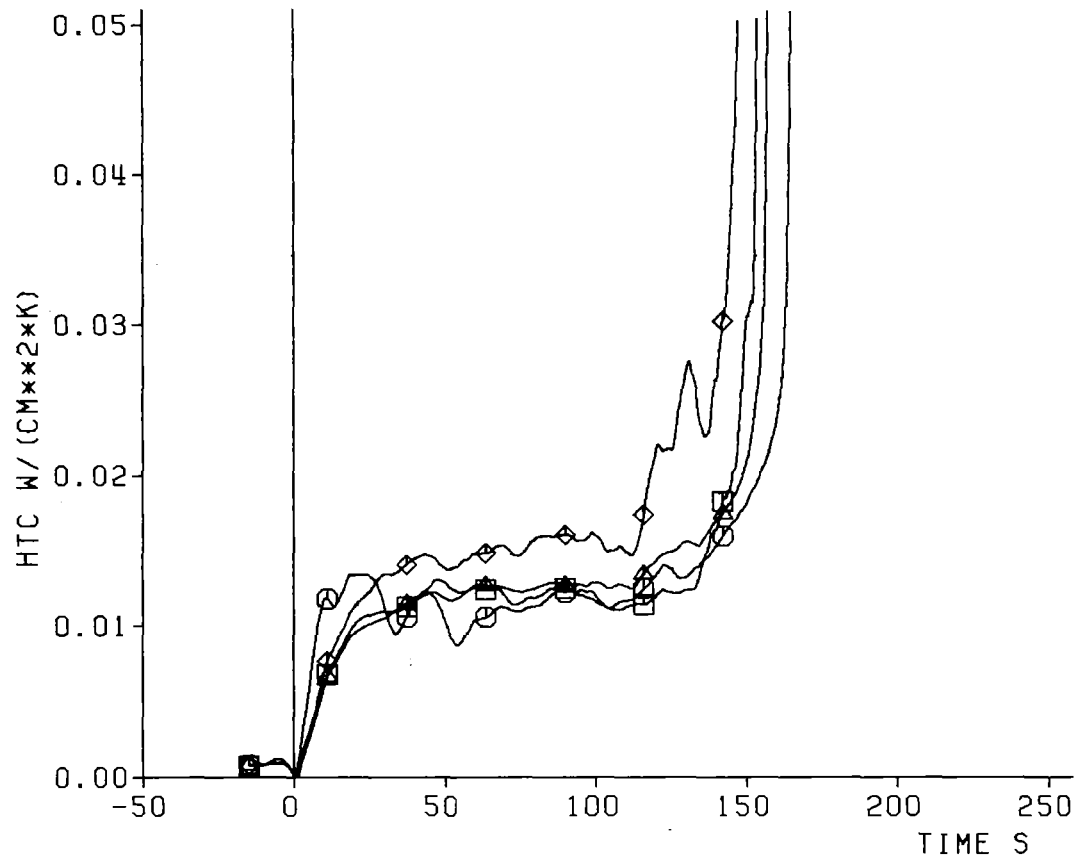
Decay Heat 120% ANS Standard
 Flooding Rate (cold) 5.77 cm/s
 System Pressure 4.01 bar
 Feedwater Temperature 40°C

REBEKA Rods With
 Helium Filled Gaps



Fig. 120 SEFLEX: 5x5 ROD BUNDLE, SERIES 1, TEST-No. 04

Heat Transfer Coefficient



TC	Axial Level
◇	16g4 1925 mm
△	16g3 1825 mm
○	16g2 1725 mm
□	16g1 1625 mm

Decay Heat 120% ANS Standard
 Flooding Rate (cold) 5.77 cm/s
 System Pressure 4.01 bar
 Feedwater Temperature 40°C

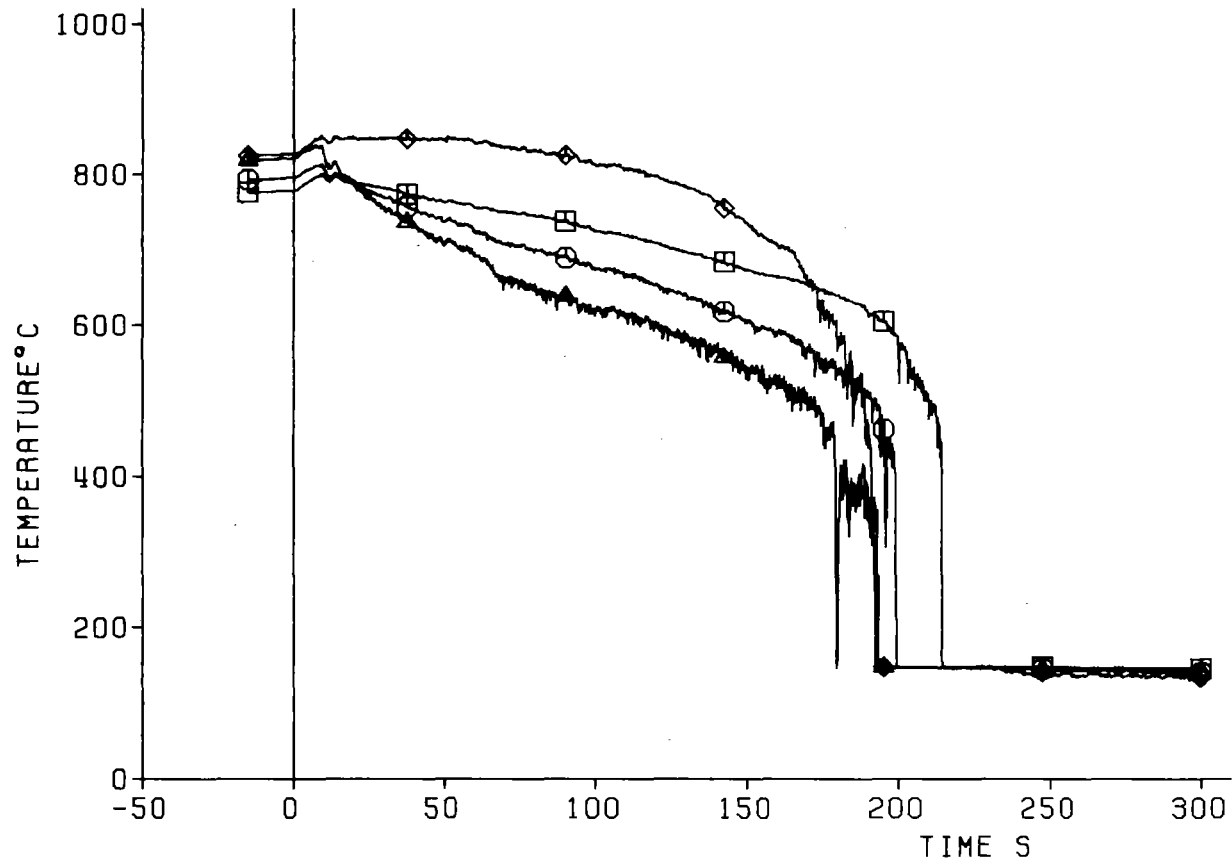
REBEKA Rods With
 Helium Filled Gaps



Fig. 121 SEFLEX: 5x5 ROD BUNDLE, SERIES 1, TEST-No. 04

Cladding Temperature

TC	Axial Level
◇	8j4 1525 mm
△	8j3 1425 mm
○	8j2 1325 mm
□	12b3 1135 mm

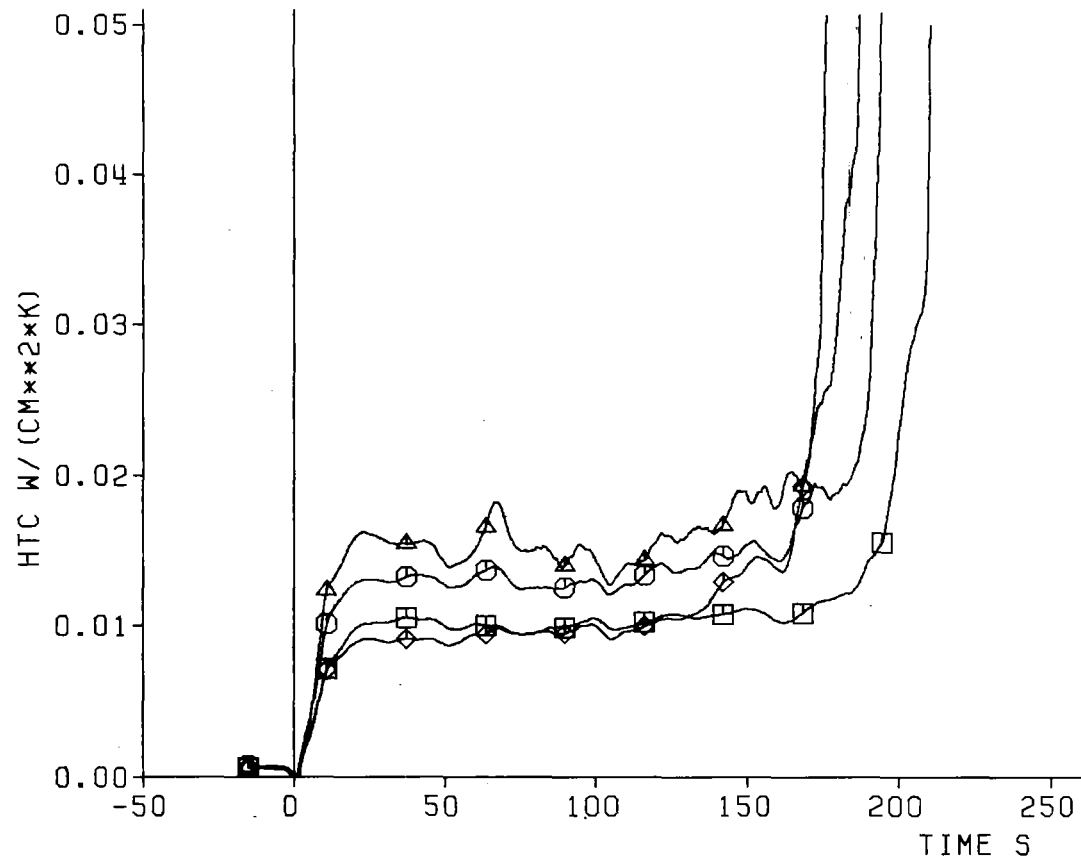


Decay Heat 120% ANS Standard
 Flooding Rate (cold) 5.77 cm/s
 System Pressure 4.01 bar
 Feedwater Temperature 40°C

REBEKA Rods With
 Helium Filled Gaps



Fig. 122 SEFLEX: 5x5 ROD BUNDLE, SERIES 1, TEST-No. 04



TC	Axial Level
◇	8j4 1525 mm
△	8j3 1425 mm
○	8j2 1325 mm
□	12b3 1135 mm

Decay Heat 120% ANS Standard
 Flooding Rate (cold) 5.77 cm/s
 System Pressure 4.01 bar
 Feedwater Temperature 40°C

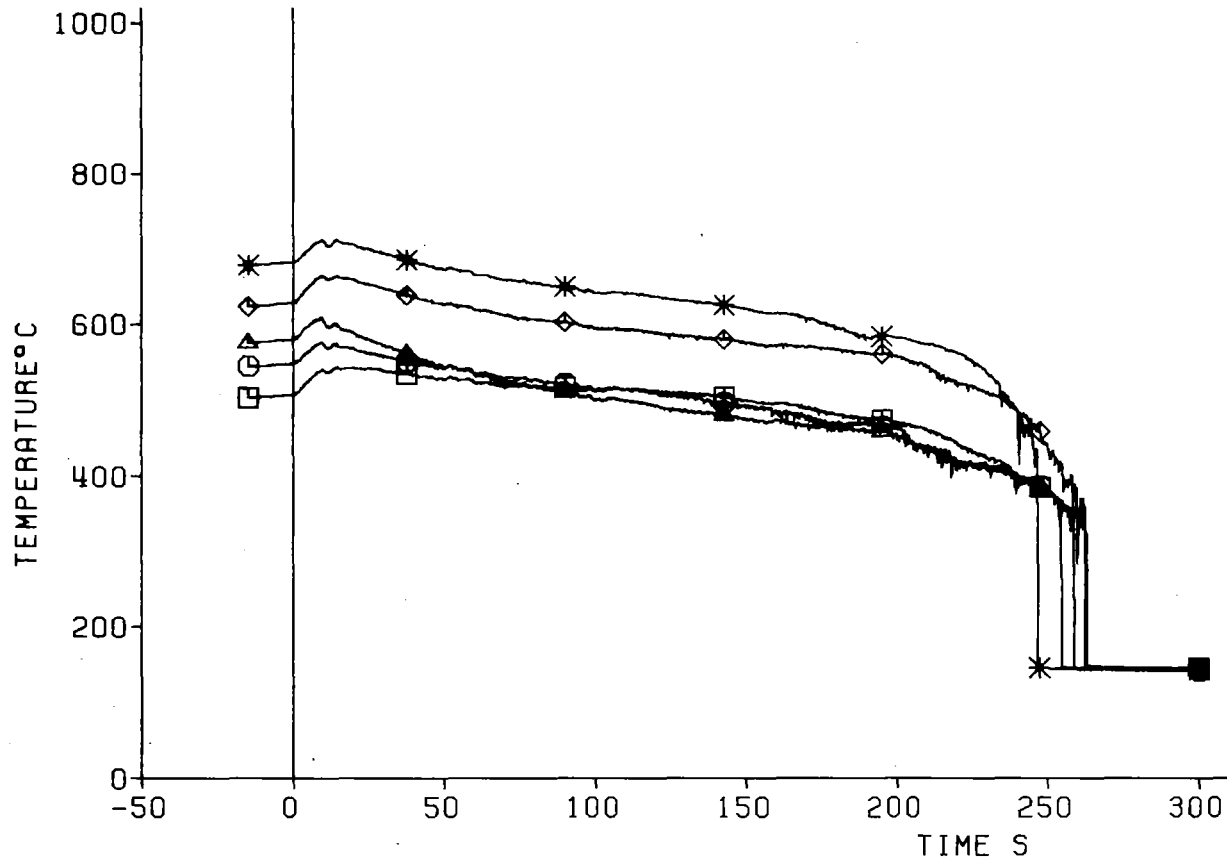
REBEKA Rods With
 Helium Filled Gaps

KIRB

Fig. 123 SEFLEX: 5x5 ROD BUNDLE, SERIES 1, TEST-No. 04

Cladding Temperature

TC	Axial Level
* 12b2	590 mm
◇ 9k4	400 mm
△ 9k3	300 mm
○ 9k2	200 mm
□ 9k1	100 mm

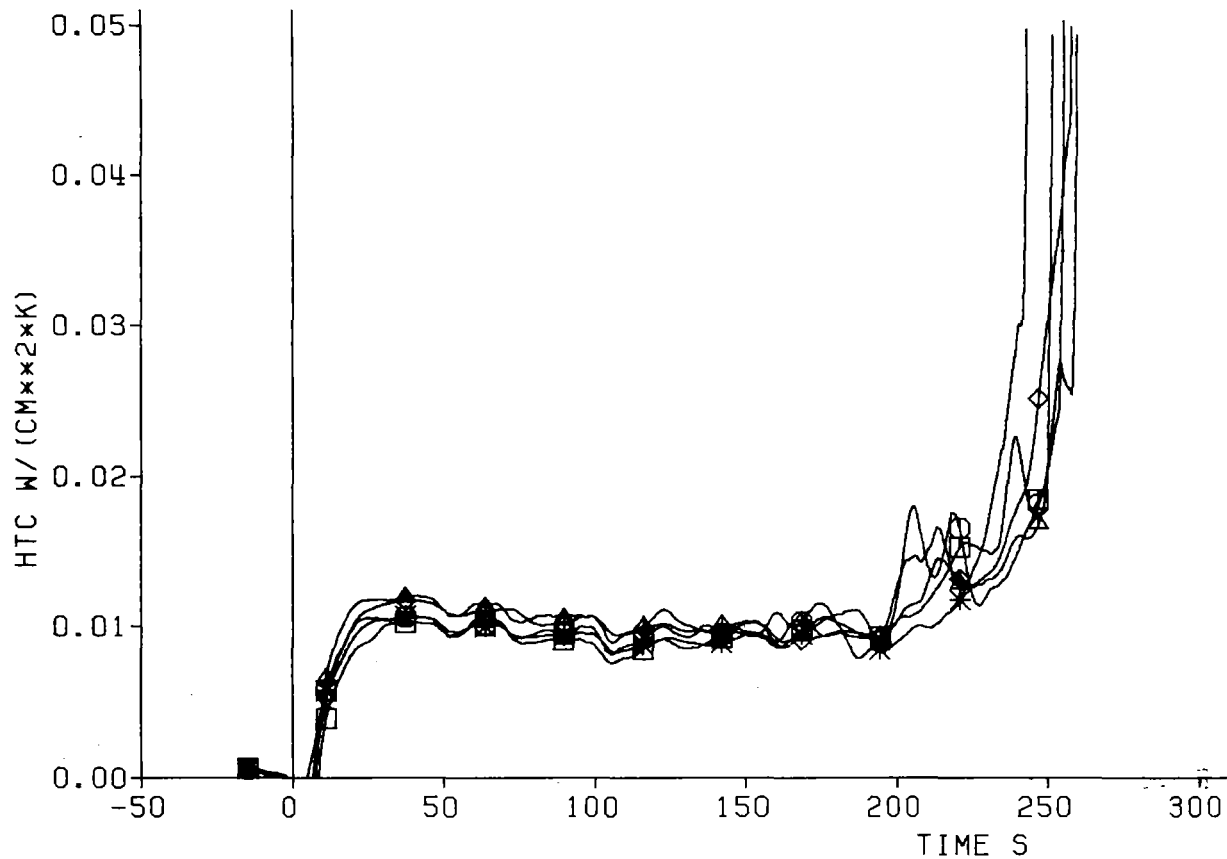


Decay Heat 120% ANS Standard
 Flooding Rate (cold) 5.77 cm/s
 System Pressure 4.01 bar
 Feedwater Temperature 40°C

REBEKA Rods With Helium Filled Gaps



Fig. 124 SEFLEX: 5x5 ROD BUNDLE, SERIES 1, TEST-No. 04



TC	Axial Level
*	12b2 590 mm
◇	9k4 400 mm
△	9k3 300 mm
○	9k2 200 mm
□	9k1 100 mm

Decay Heat 120% ANS Standard
 Flooding Rate (cold) 5.77 cm/s
 System Pressure 4.01 bar
 Feedwater Temperature 40°C

REBEKA Rods With
 Helium Filled Gaps

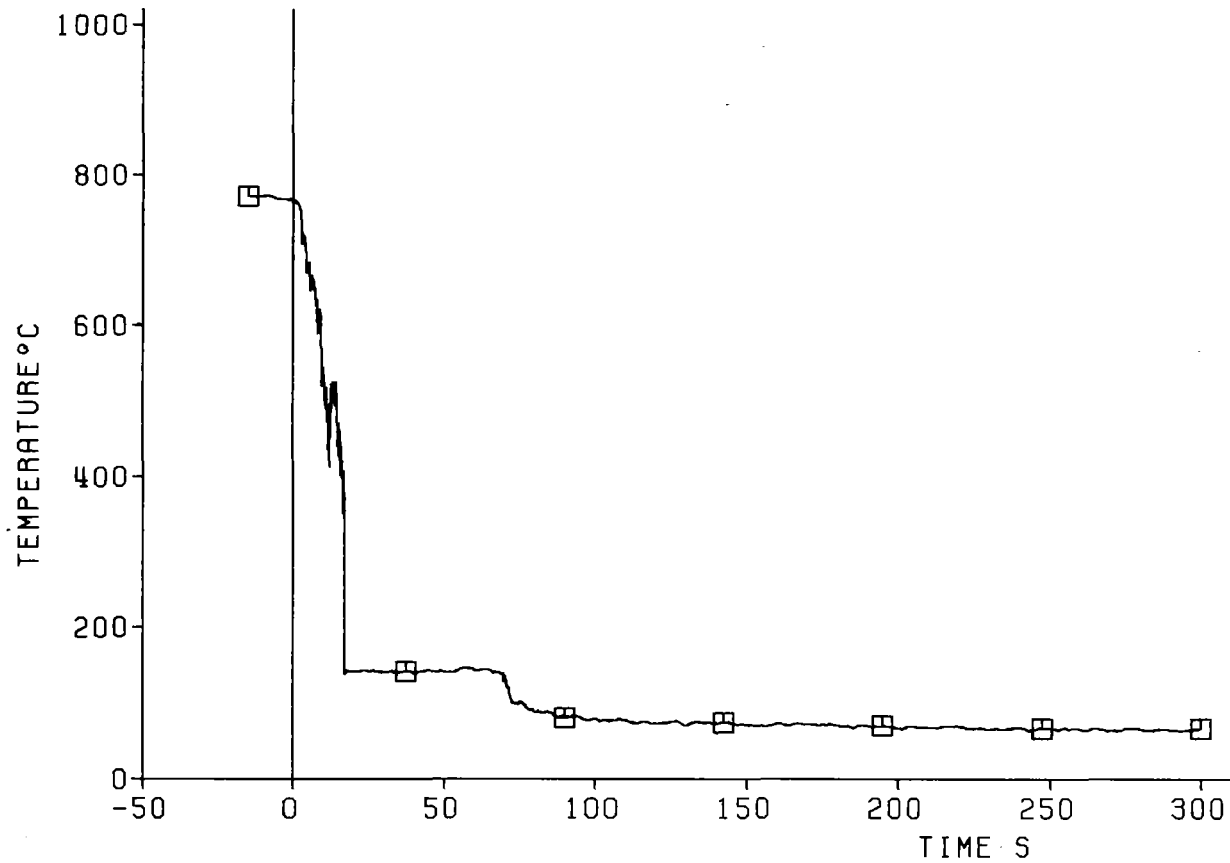


Fig. 125 SEFLEX: 5x5 ROD BUNDLE, SERIES 1, TEST-No. 04

Grid Spacer Temperature

TC | Axial Level

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



Decay Heat 120% ANS Standard
Flooding Rate (cold) 5.77 cm/s
System Pressure 4.01 bar
Feedwater Temperature 40°C

REBEKA Rods With
Helium Filled Gaps

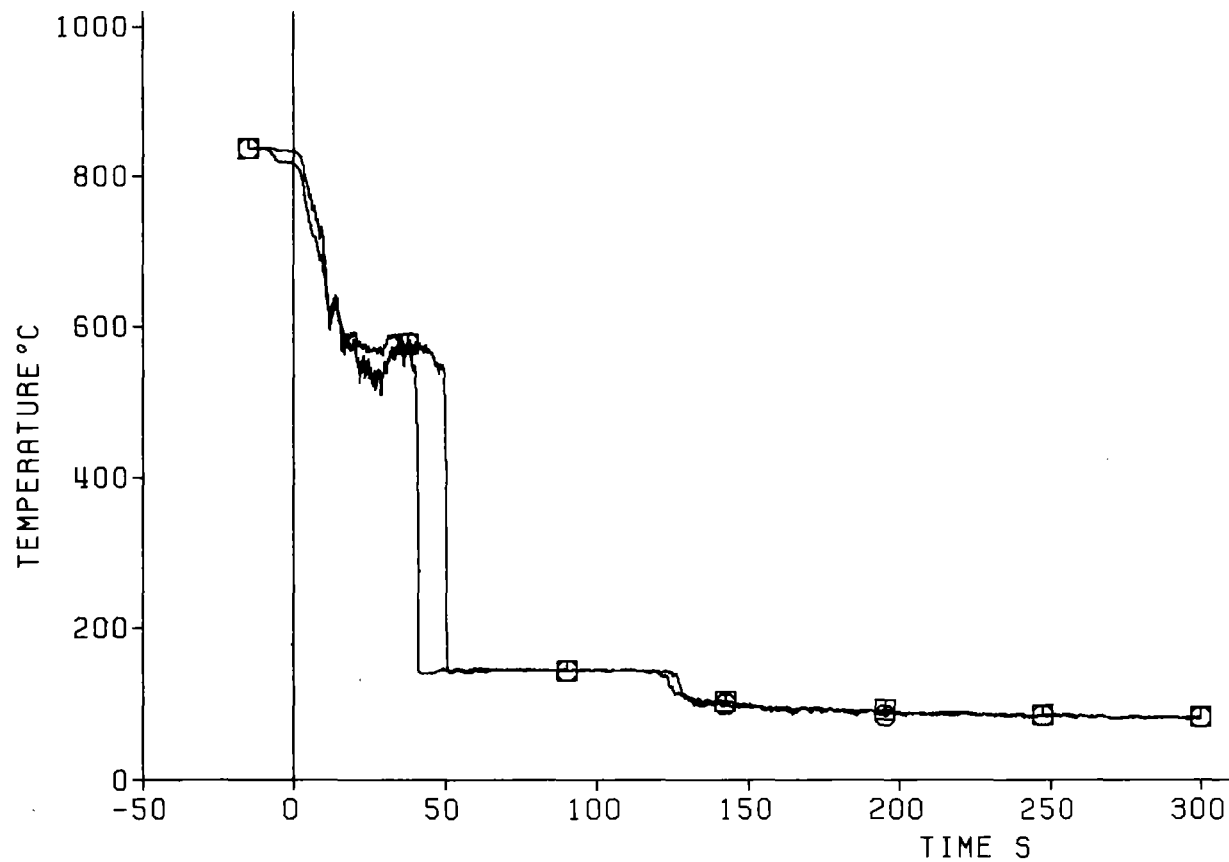


Fig. 126 SEFLEX: 5x5 ROD BUNDLE, SERIES 1, TEST-No. 04

Grid Spacer Temperature

TC | Axial Level

○ | 2568 mm, Leading Edge
□ | 2535 mm, Trailing Edge



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Decay Heat 120% ANS Standard
Flooding Rate (cold) 5.77 cm/s
System Pressure 4.01 bar
Feedwater Temperature 40°C

REBEKA Rods With Helium Filled Gaps

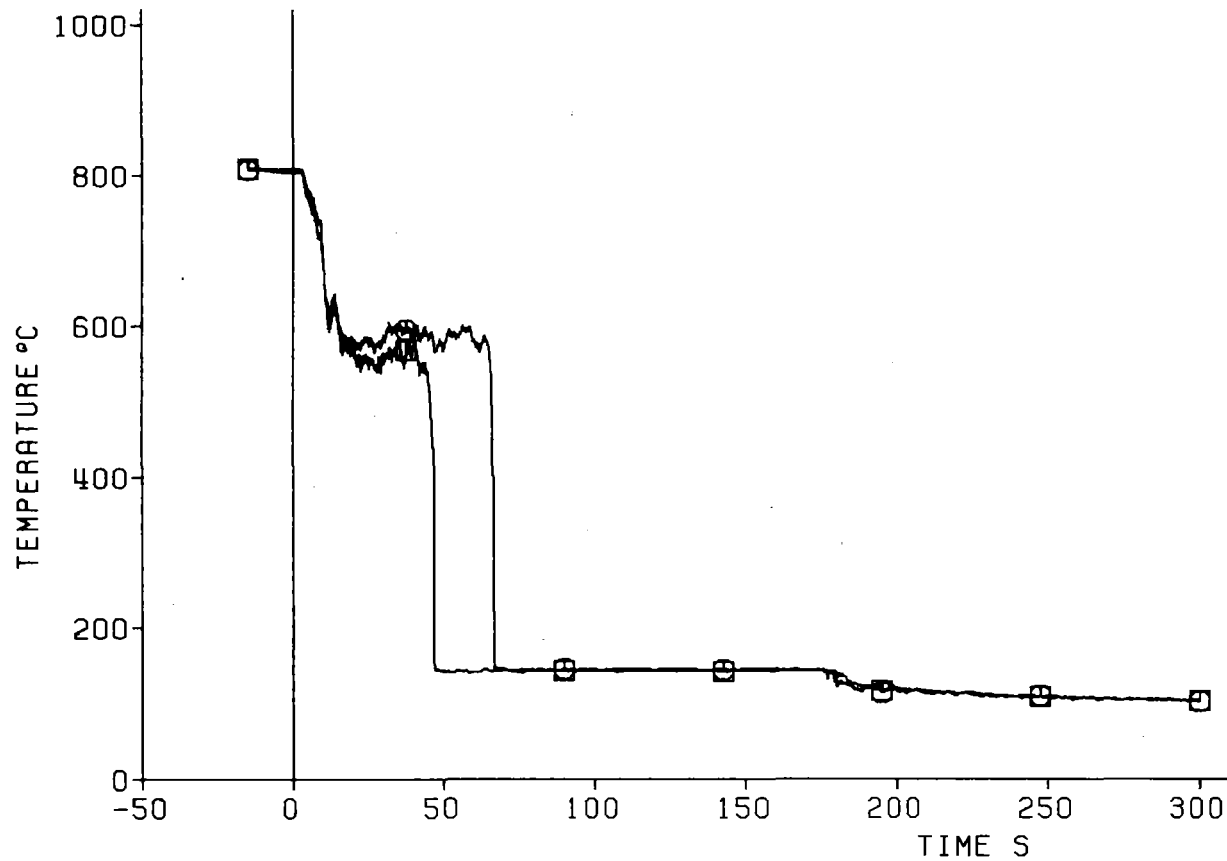


Fig. 127 SEFLEX: 5x5 ROD BUNDLE, SERIES 1, TEST-NO. 04

Grid Spacer Temperature

TC | Axial Level

- | 2023 mm, Leading Edge
- | 1990 mm, Trailing Edge



Decay Heat 120% ANS Standard
Flooding Rate (cold) 5.77 cm/s
System Pressure 4.01 bar
Feedwater Temperature 40°C

REBEKA Rods With
Helium Filled Gaps

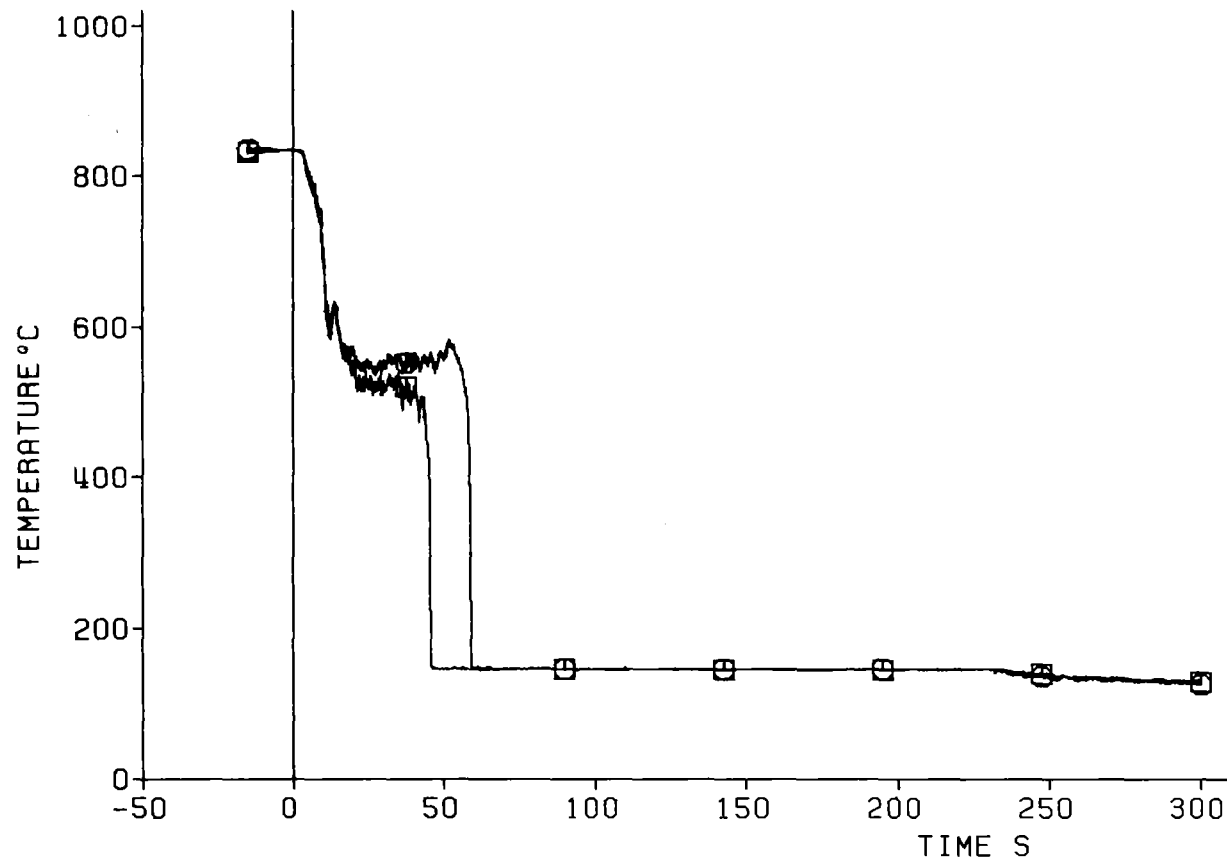


Fig. 128 SEFLEX: 5x5 ROD BUNDLE, SERIES 1, TEST-No. 04

Grid Spacer Temperature

TC | Axial Level

○ | 1478 mm, Leading Edge
□ | 1445 mm, Trailing Edge



Decay Heat 120% ANS Standard
Flooding Rate (cold) 5.77 cm/s
System Pressure 4.01 bar
Feedwater Temperature 40°C

REBEKA Rods With
Helium Filled Gaps

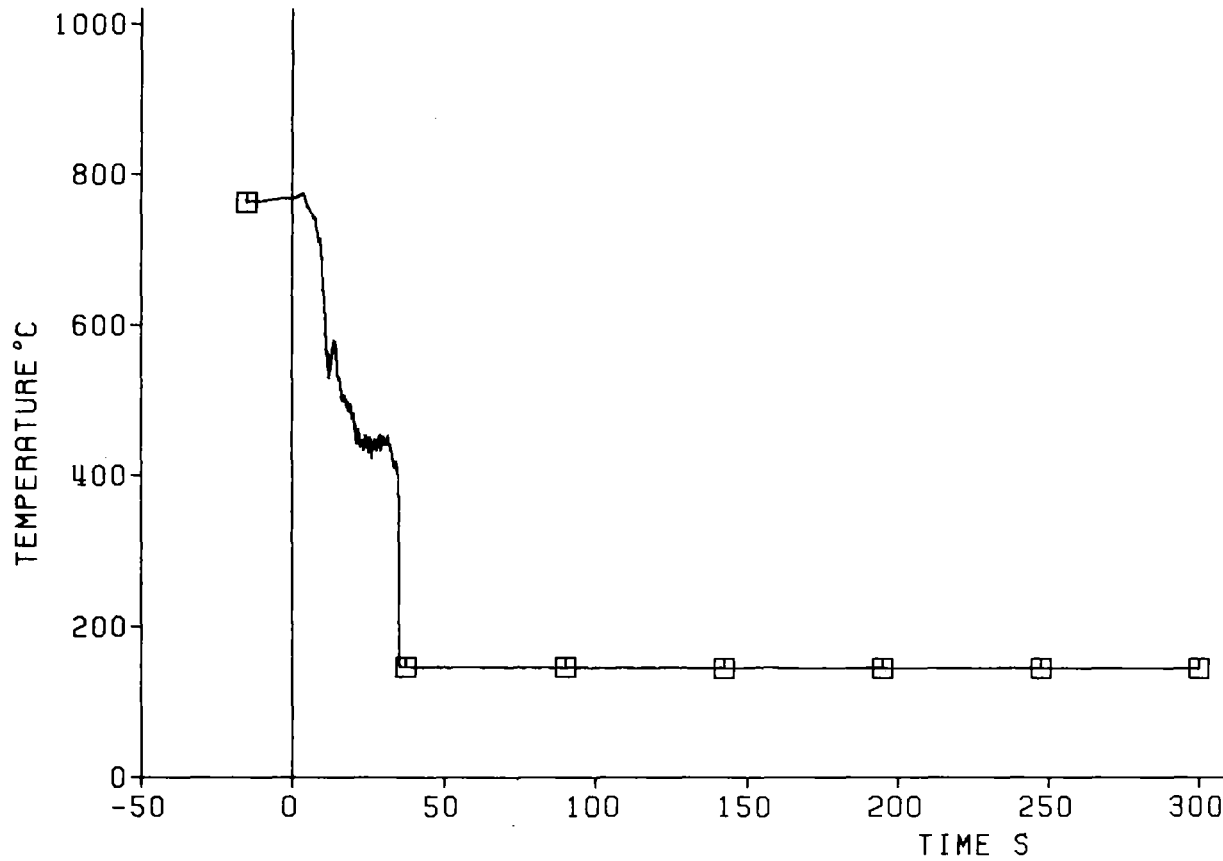


Fig. 129 SEFLEX: 5x5 ROD BUNDLE, SERIES 1, TEST-No. 04

Grid Spacer Temperature

TC | Axial Level

□ | No TC at Leading Edge
□ | 900 mm, Trailing Edge



Decay Heat 120% ANS Standard
Flooding Rate (cold) 5.77 cm/s
System Pressure 4.01 bar
Feedwater Temperature 40°C

REBEKA Rods With
Helium Filled Gaps

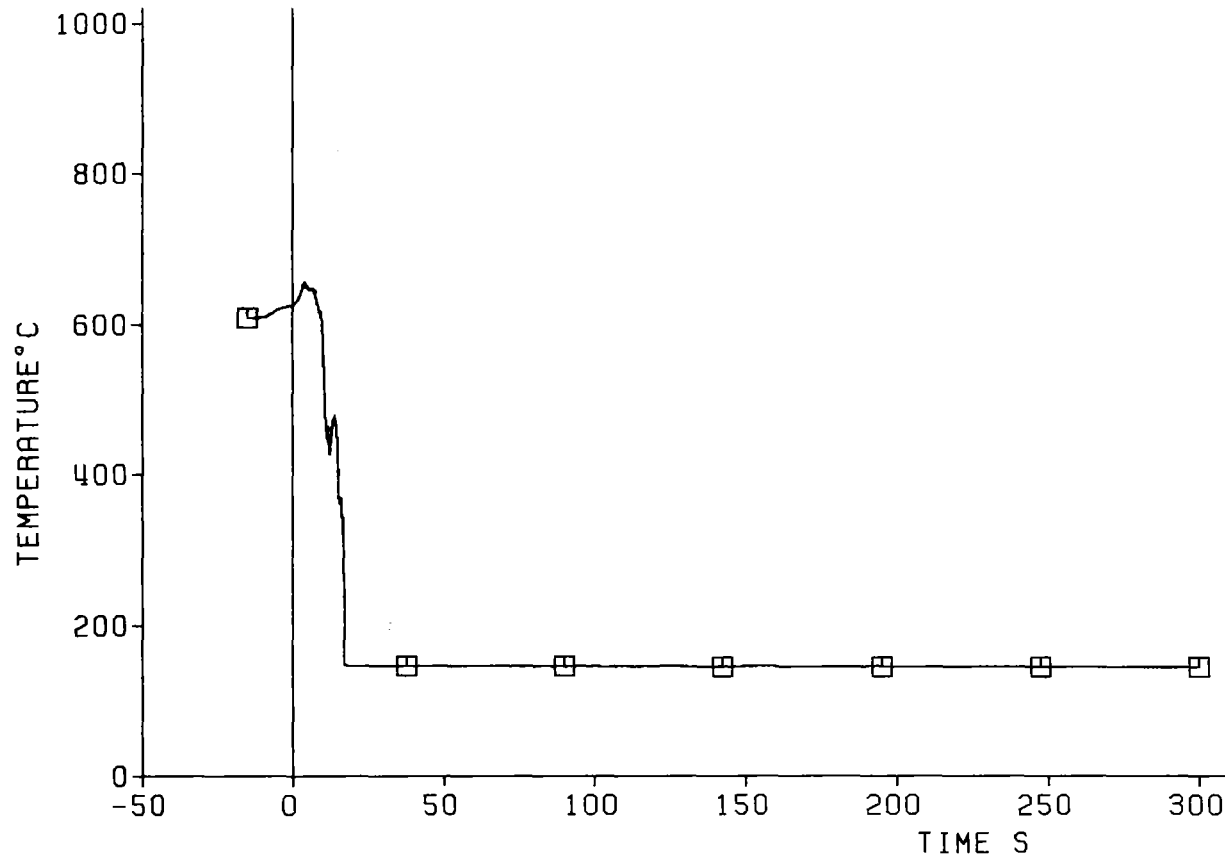


Fig. 130 SEFLEX: 5x5 ROD BUNDLE, SERIES 1, TEST-No. 04

Grid Spacer Temperature

TC | Axial Level

□ | No TC at Leading Edge
□ | 355 mm, Trailing Edge



Decay Heat 120% ANS Standard
Flooding Rate (cold) 5.77 cm/s
System Pressure 4.01 bar
Feedwater Temperature 40°C

REBEKA Rods With
Helium Filled Gaps

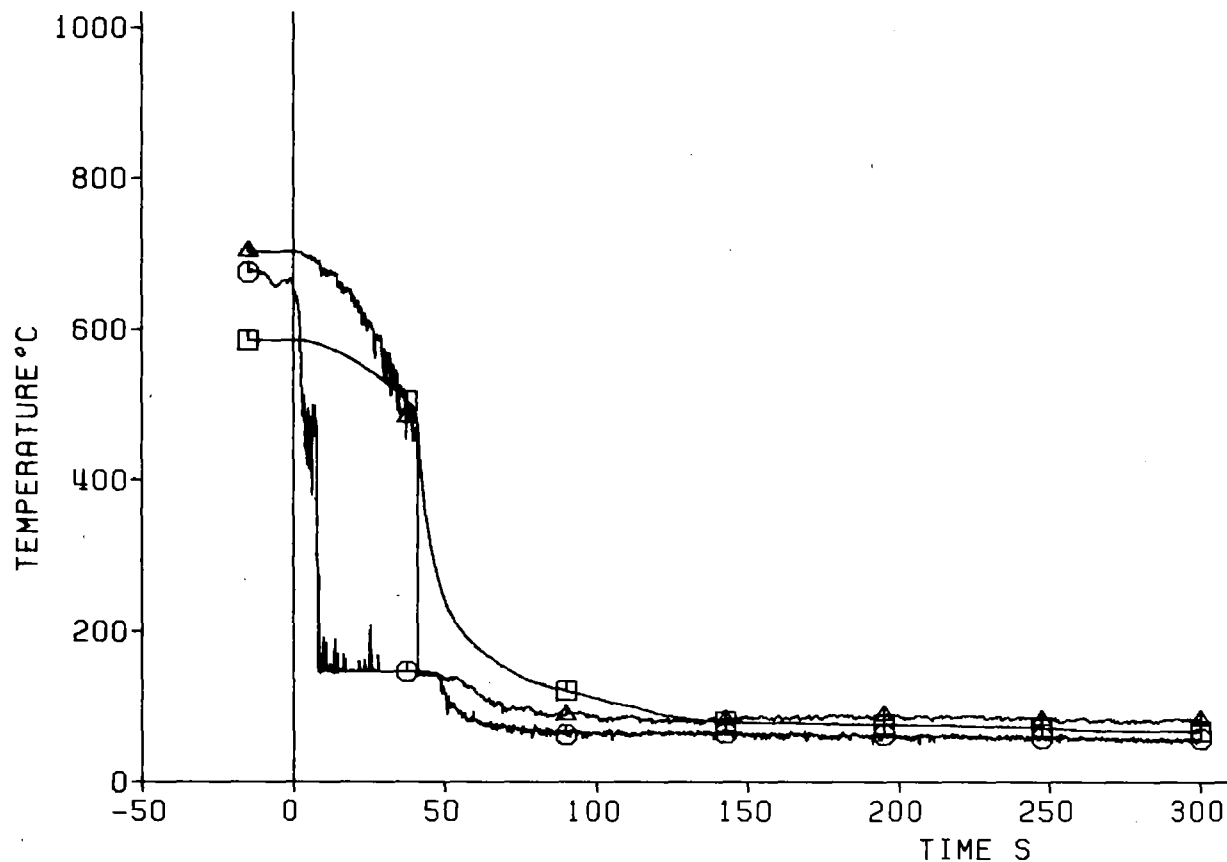
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Fig. 131 SEFLEX: 5x5 ROD BUNDLE, SERIES 1, TEST-No. 04

Axial Level: 3315 mm

△ Cladding Temperature (18a3)
○ Fluid Temperature
□ Housing Temperature



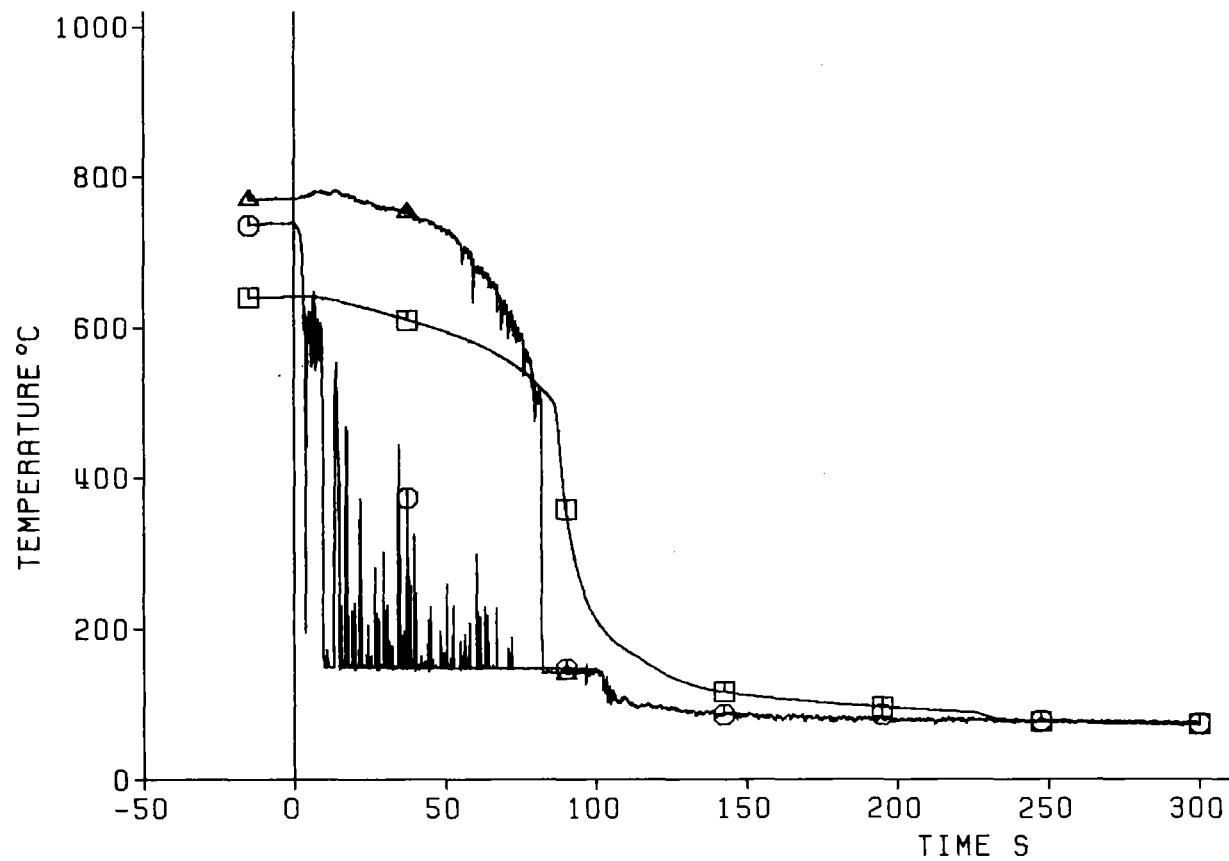
Decay Heat 120% ANS Standard
Flooding Rate (cold) 5.77 cm/s
System Pressure 4.01 bar
Feedwater Temperature 40°C

REBEKA Rods With
Helium Filled Gaps



Fig. 132 SEFLEX: 5x5 ROD BUNDLE, SERIES 1, TEST-No. 04

Axial Level: 2770 mm



△ Cladding Temperature (18a2)
○ Fluid Temperature
□ Housing Temperature

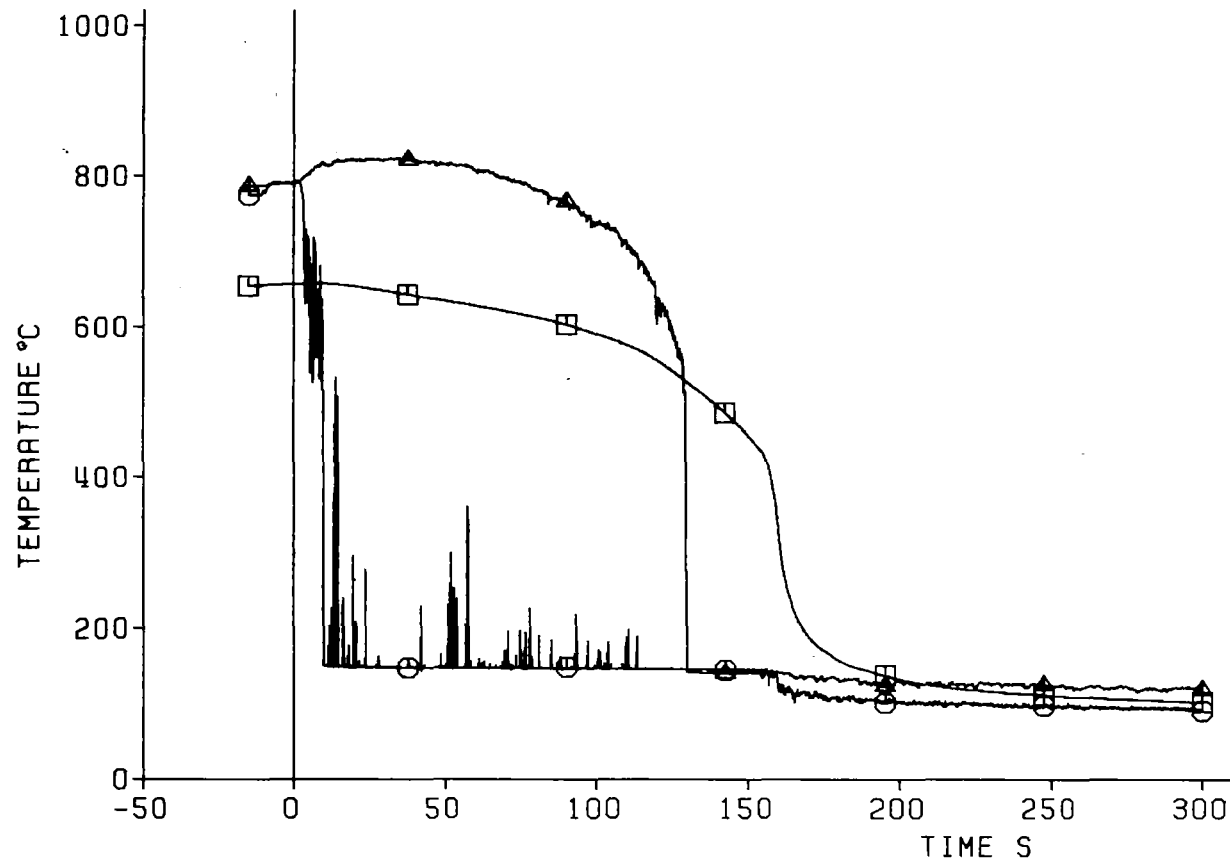
Decay Heat 120% ANS Standard
Flooding Rate (cold) 5.77 cm/s
System Pressure 4.01 bar
Feedwater Temperature 40°C

REBEKA Rods With
Helium Filled Gaps



Fig. 133 SEFLEX: 5x5 ROD BUNDLE, SERIES 1, TEST-No. 04

Axial Level: 2225 mm



▲ Cladding Temperature (18a1)
○ Fluid Temperature, (2240 mm)
□ Housing Temperature

Decay Heat
Flooding Rate (cold) 5.77 cm/s
System Pressure 4.01 bar
Feedwater Temperature 40 °C

120% ANS Standard

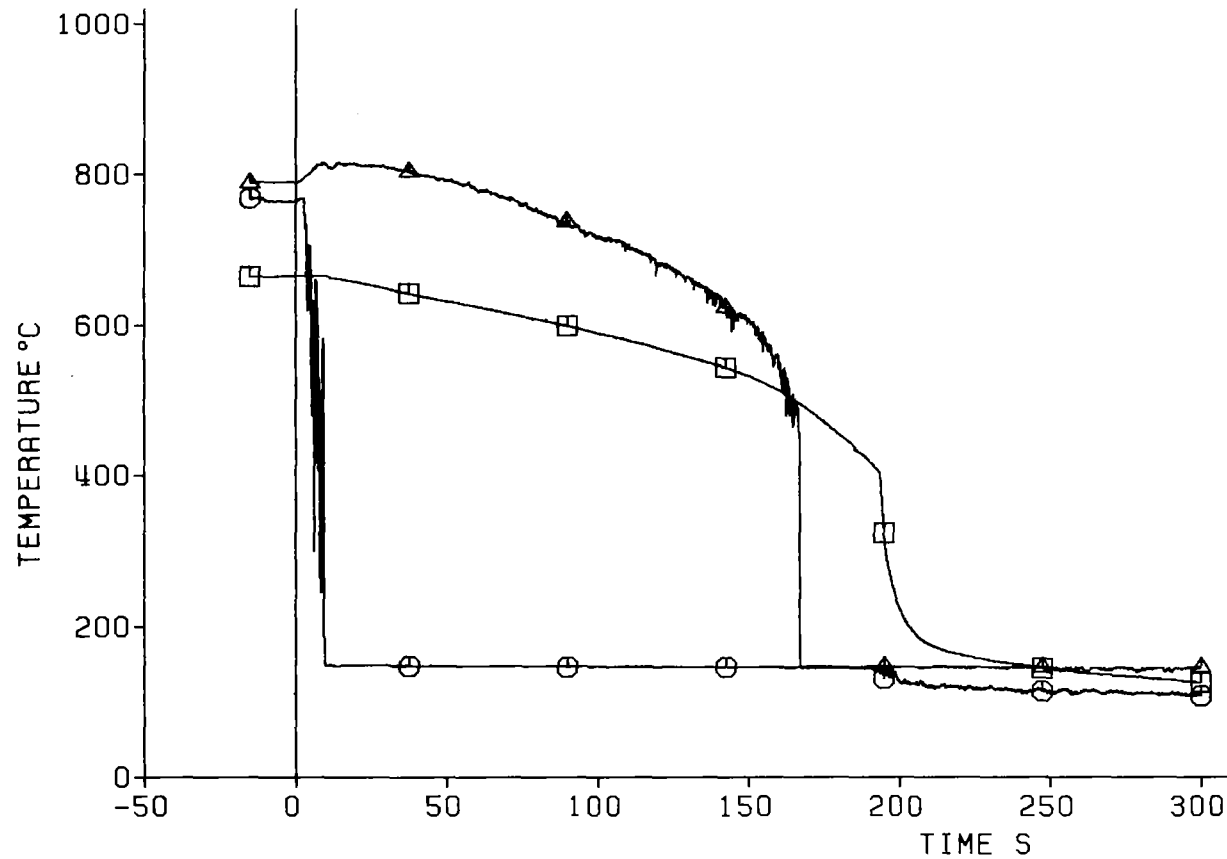
REBEKA Rods With
Helium Filled Gaps

KfK
IRB

Fig. 134 SEFLEX: 5x5 ROD BUNDLE, SERIES 1, TEST-No. 04

Axial Level: 1825 mm

△ Cladding Temperature (19g3)
○ Fluid Temperature
□ Housing Temperature



Decay Heat
Flooding Rate (cold) 5.77 cm/s
System Pressure 4.01 bar
Feedwater Temperature 40°C

120% ANS Standard

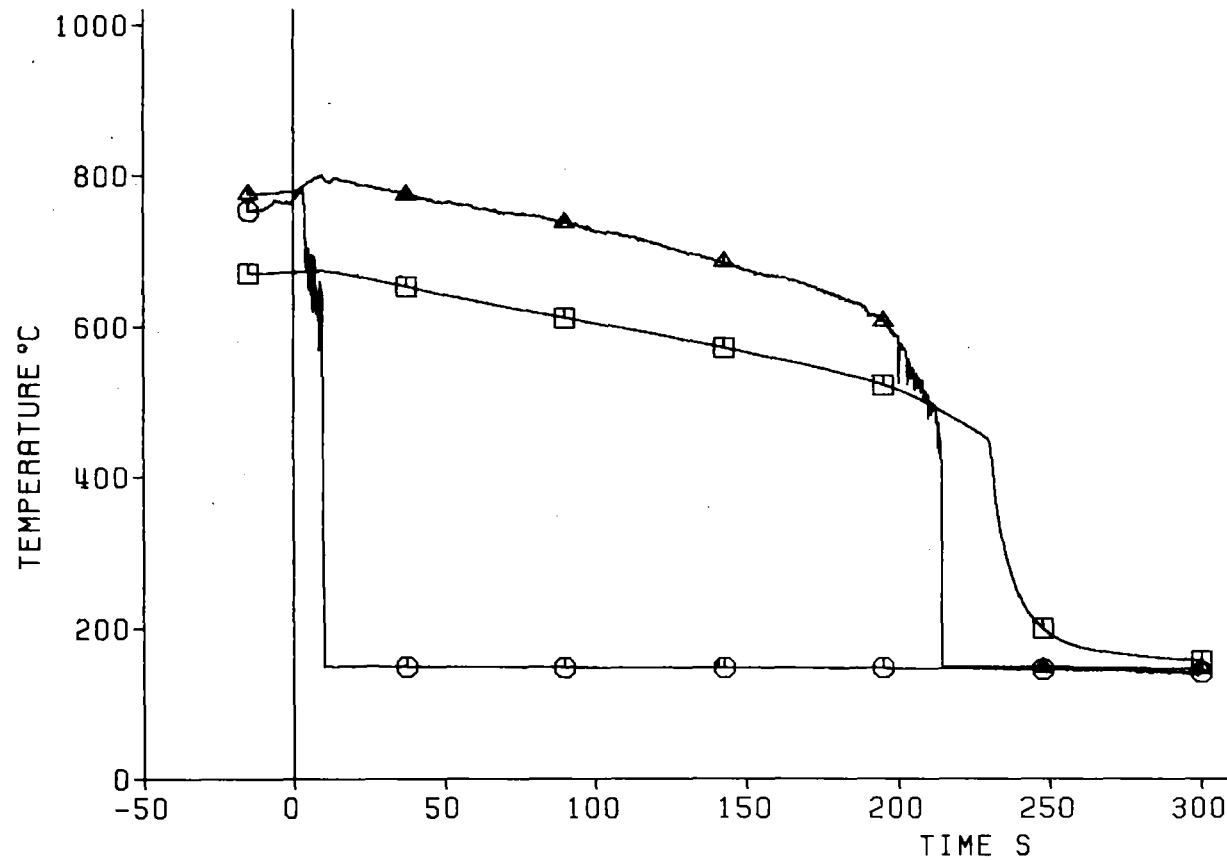
REBEKA Rods With
Helium Filled Gaps

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Fig. 135 SEFLEX: 5x5 ROD BUNDLE, SERIES 1, TEST-No. 04

Axial Level: 1135 mm



▲ Cladding Temperature (12b3)
○ Fluid Temperature
□ Housing Temperature

Decay Heat
Flooding Rate (cold) 120% ANS Standard
System Pressure 5.77 cm/s
Feedwater Temperature 4.01 bar
40°C

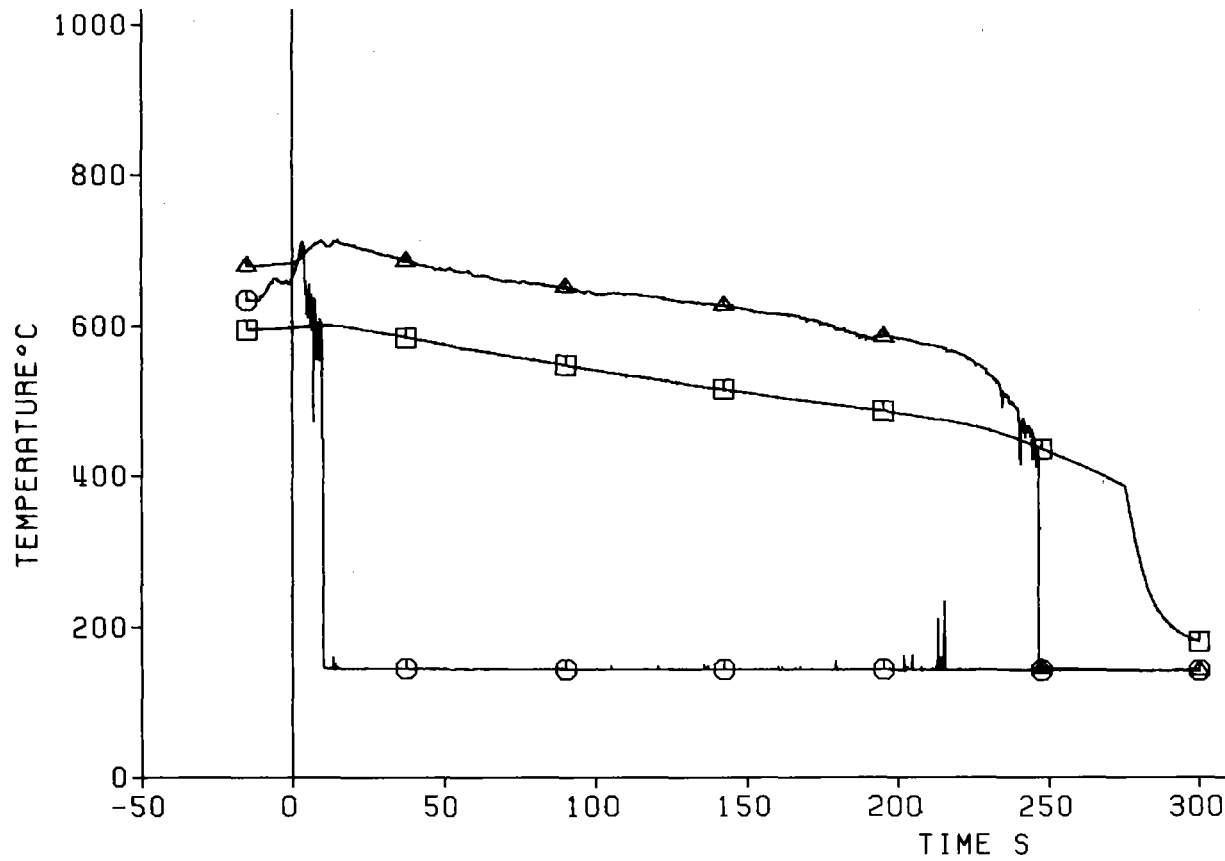
REBEKA Rods With
Helium Filled Gaps



Fig. 136 SEFLEX: 5x5 ROD BUNDLE, SERIES 1, TEST-NO. 04

Axial Level: 590 mm

△ Cladding Temperature (12b2)
○ Fluid Temperature, (485 mm)
□ Housing Temperature



Decay Heat 120% ANS Standard
Flooding Rate (cold) 5.77 cm/s
System Pressure 4.01 bar
Feedwater Temperature 40°C

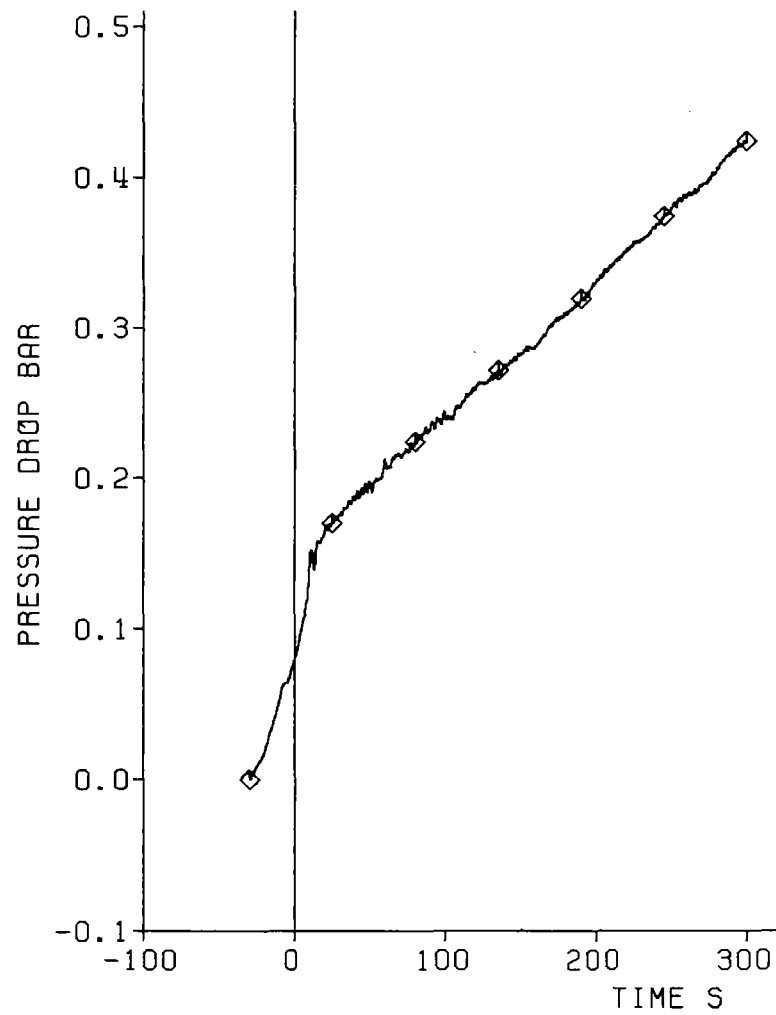
REBEKA Rods With Helium Filled Gaps



Fig. 137 SEFLEX: 5x5 ROD BUNDLE, SERIES 1, TEST-No. 04

Pressure Drop
Along the Test Section:

◇ Total Length: 4196 mm



Decay Heat 120% ANS Standard
Flooding Rate (cold) 5.77 cm/s
System Pressure 4.01 bar
Feedwater Temperature 40°C

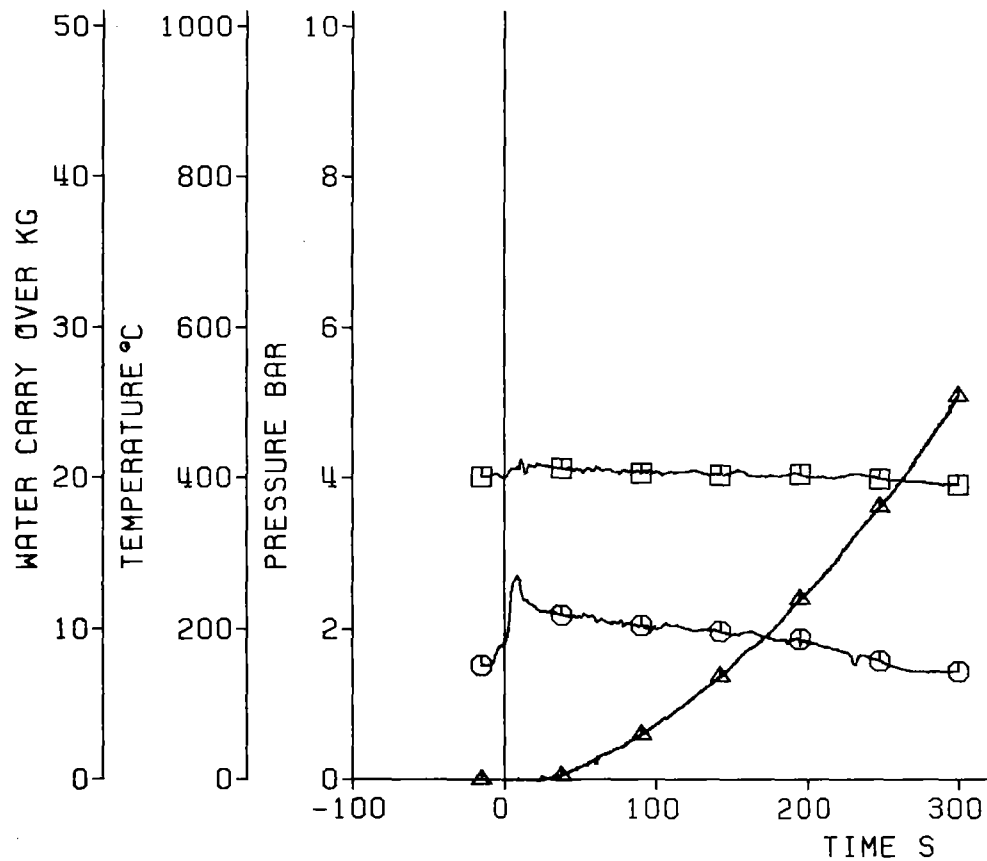
REBEKA Rods With
Helium Filled Gaps

KfK
IRB

Fig. 138 SEFLEX: 5x5 ROD BUNDLE, SERIES 1, TEST-No. 04

Coolant Outlet Conditions:

△ Water Carry Over
○ Coolant Temperature
□ Coolant Pressure



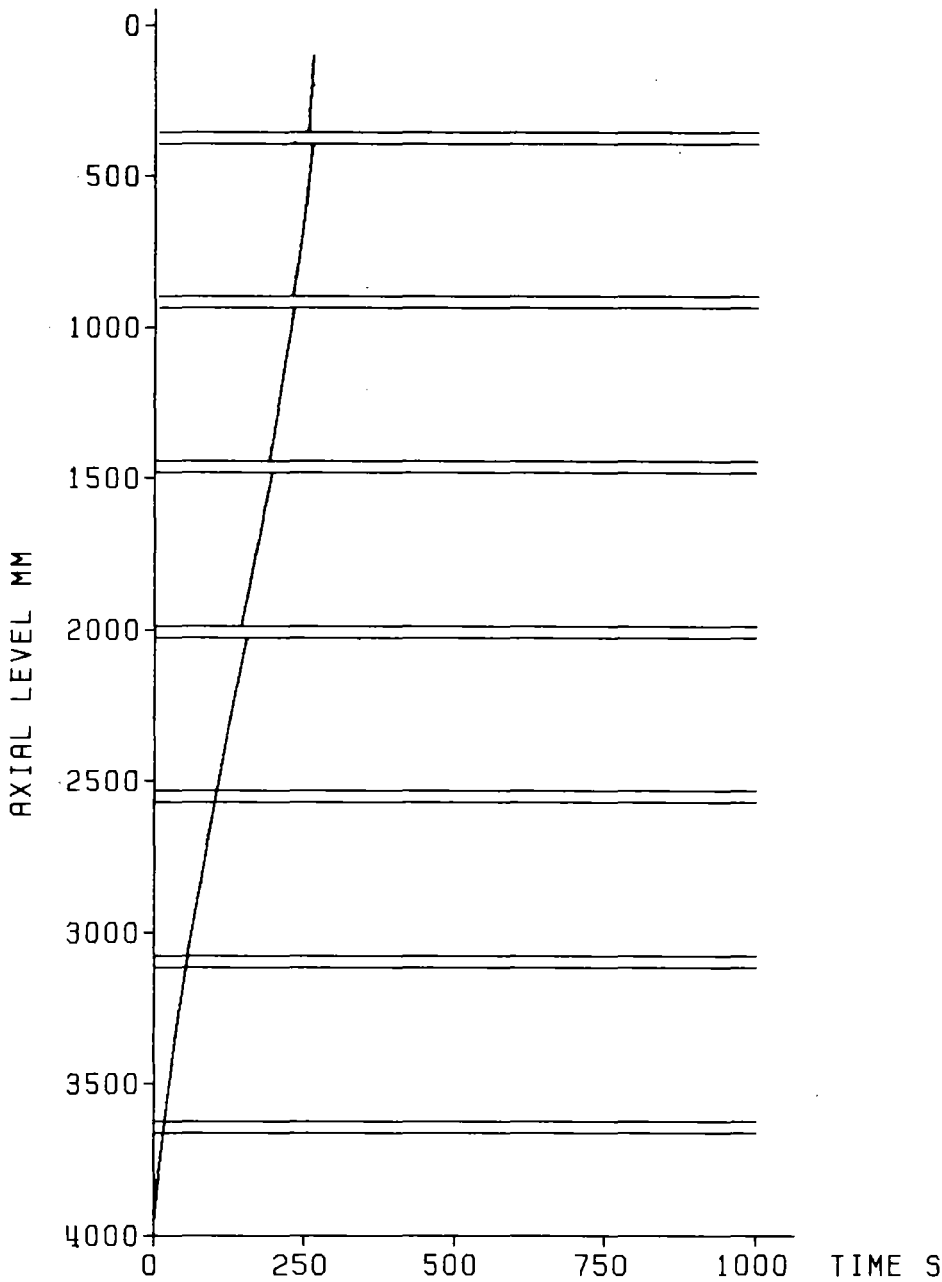
Decay Heat 120% ANS Standard
Flooding Rate (cold) 5.77 cm/s
System Pressure 4.01 bar
Feedwater Temperature 40°C

REBEKA Rods With
Helium Filled Gaps



Fig. 139 SEFLEX: 5x5 ROD BUNDLE, SERIES 1, TEST-No. 04

Axial Position of Quench Front
Rebeka Rods With Helium Filled Gaps

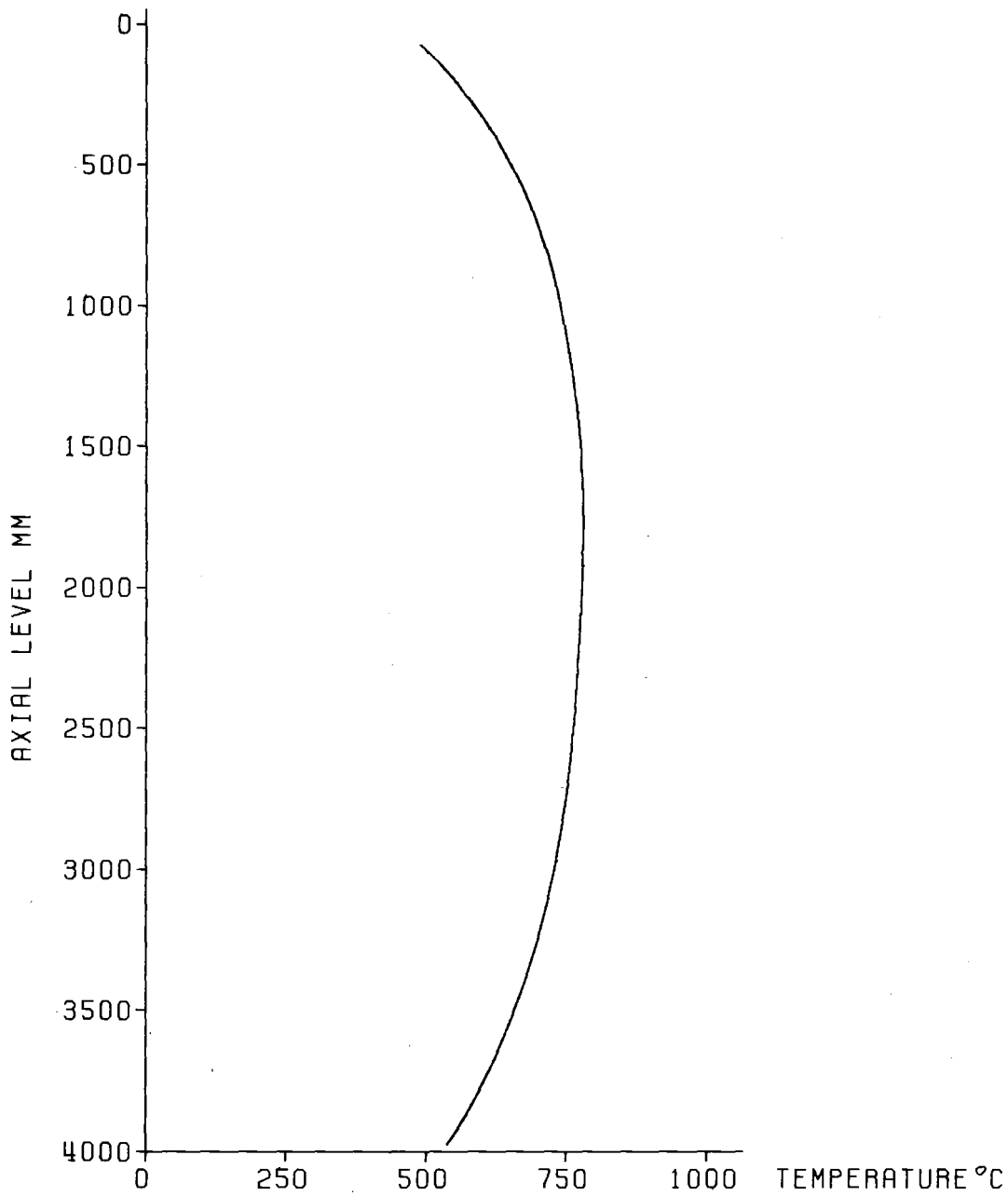


Decay Heat	120% ANS Standard
Flooding Rate (cold)	5.77 cm/s
System Pressure	4.01 bar
Feedwater Temperature	40°C

KIK IRB

Fig. 140 SEFLEX: 5x5 ROD BUNDLE
TEST SERIES 1, TEST-No. 04

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



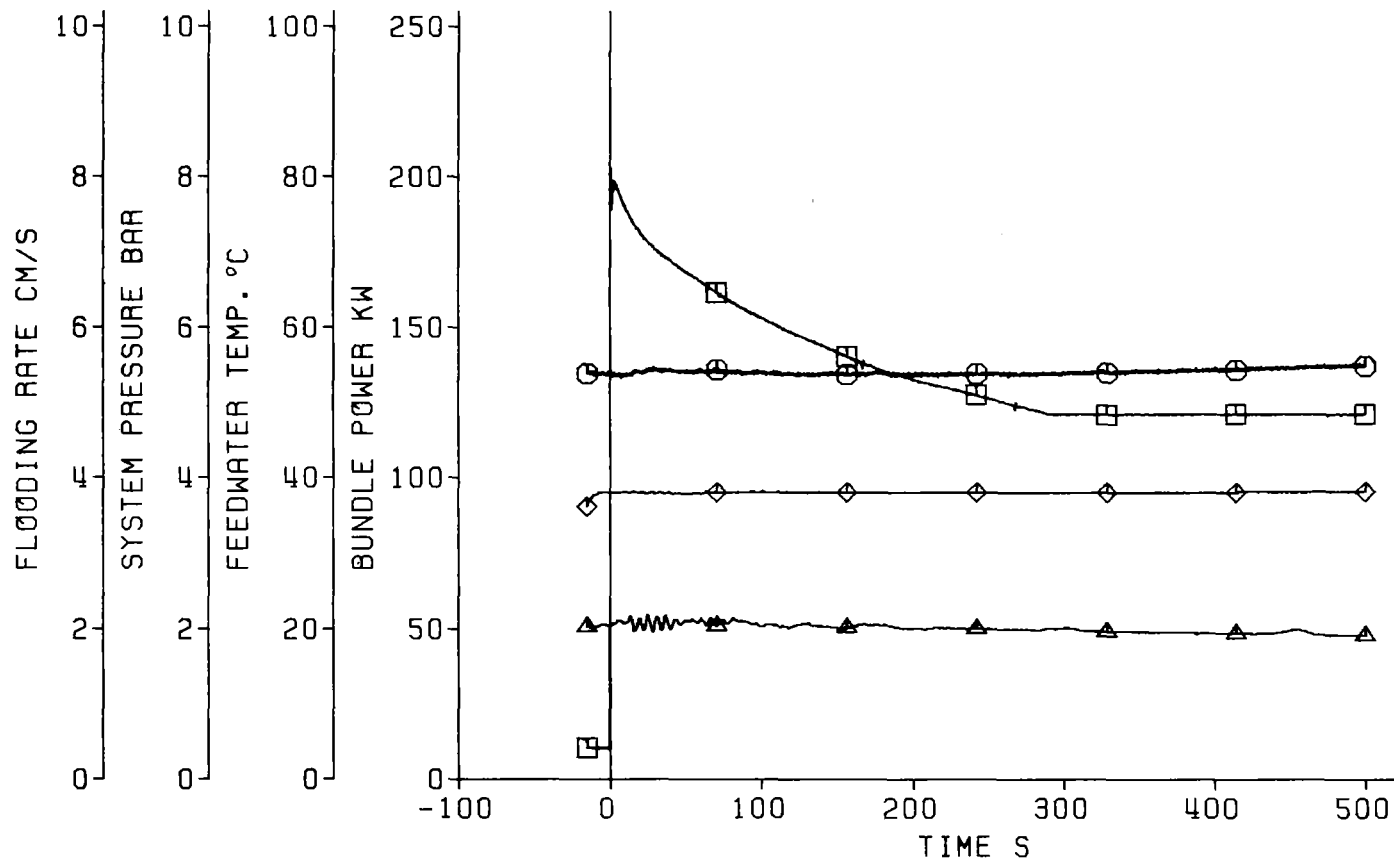
Decay Heat	120% ANS Standard
Flooding Rate (cold)	3.81 cm/s
System Pressure	2.12 bar
Feedwater Temperature	54°C

KIK IRB

Fig. 141 SEFLEX: 5x5 ROD BUNDLE
TEST SERIES 2, TEST-No. 07

Test Parameters:

- ◇ Flooding Rate
- △ System Pressure
- Feedwater Temperature
- Bundle Power

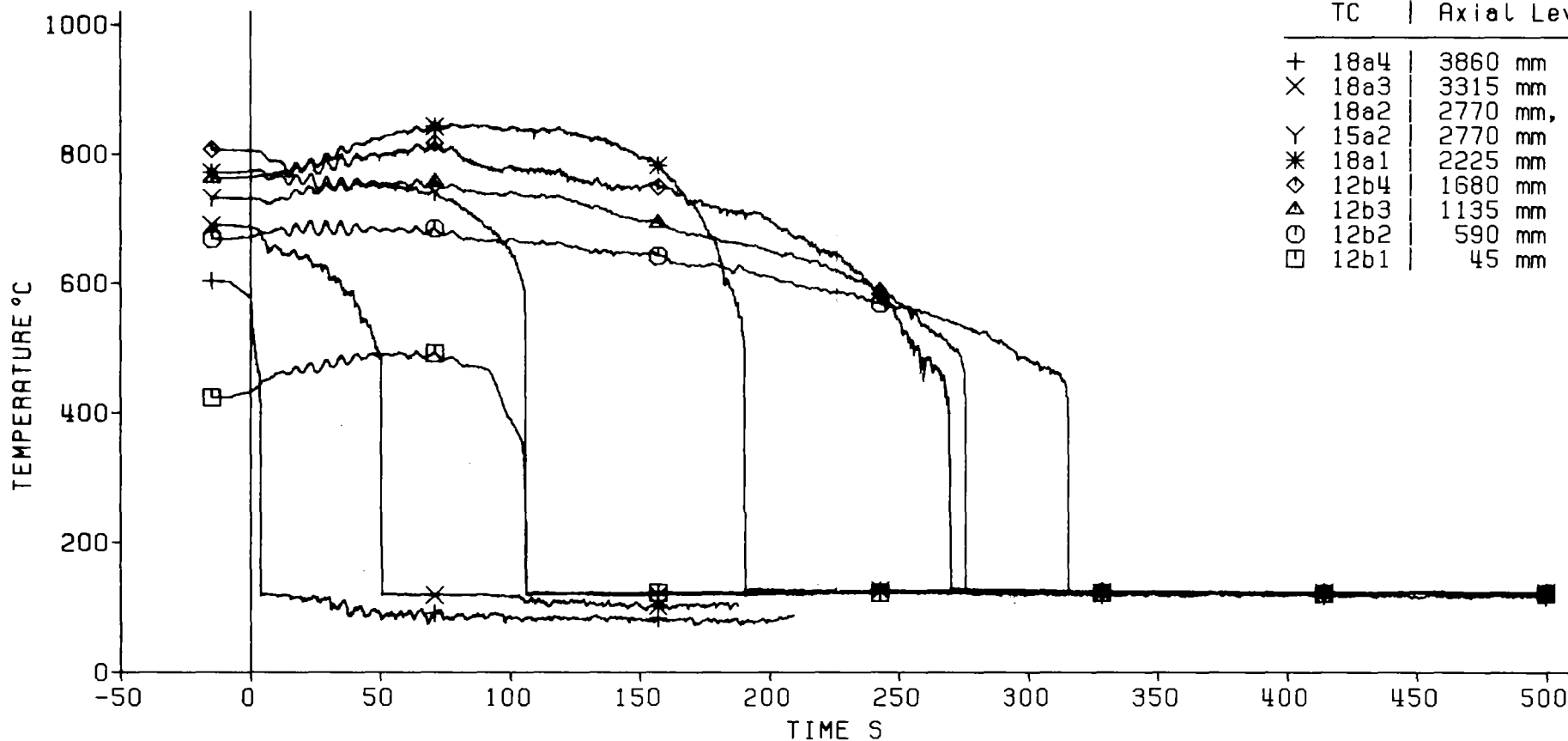


Decay Heat 120% ANS Standard
 Flooding Rate (cold) 3.81 cm/s
 System Pressure 2.12 bar
 Feedwater Temperature 54 °C

REBEKA Rods With Argon Filled Gaps



Fig. 142 SEFLEX: 5x5 ROD BUNDLE, SERIES 2, TEST-No. 07



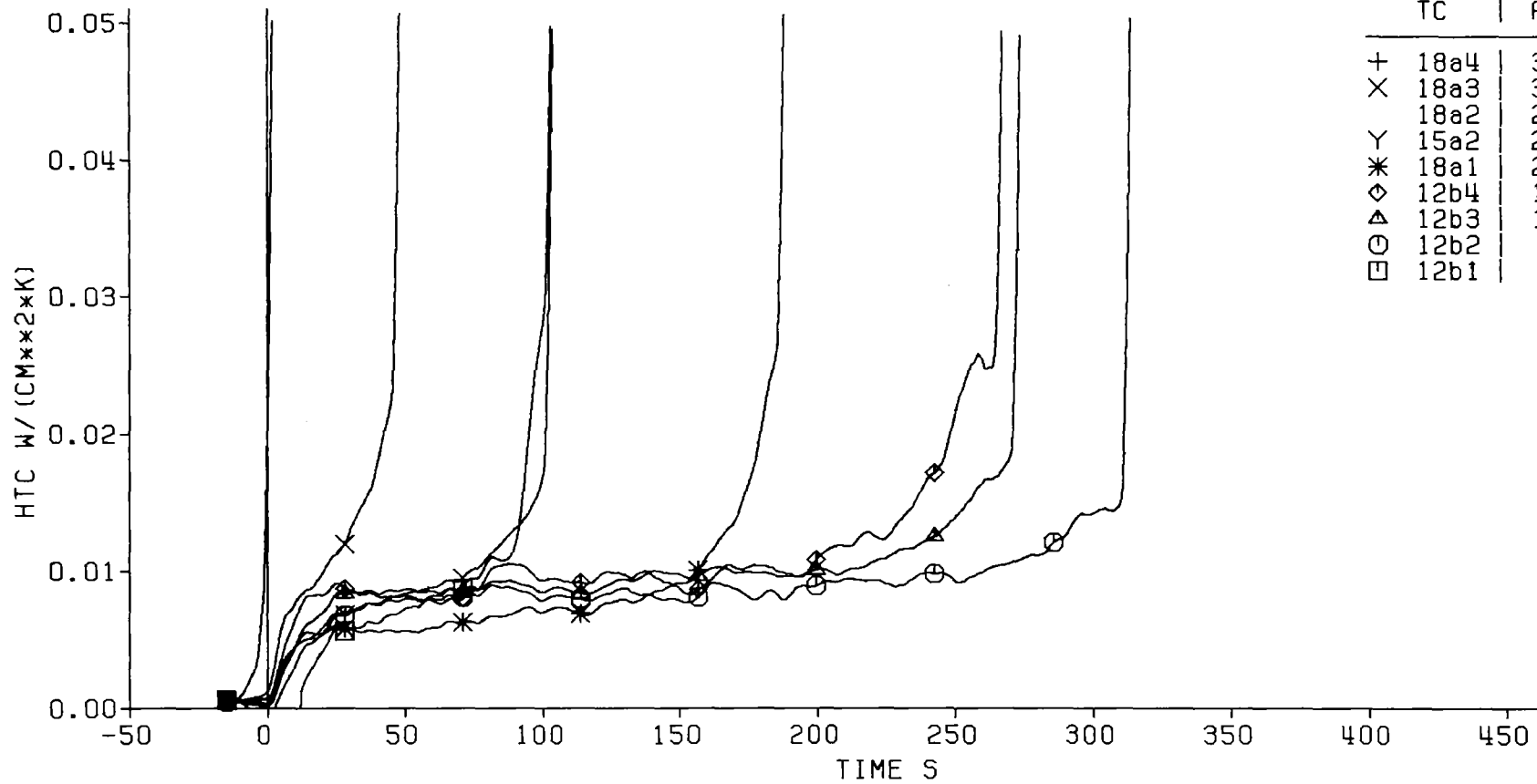
Decay Heat 120% ANS Standard
 Flooding Rate (cold) 3.81 cm/s
 System Pressure 2.12 bar
 Feedwater Temperature 54°C

REBEKA Rods With Argon Filled Gaps



Fig. 143 SEFLEX: 5x5 ROD BUNDLE, SERIES 2, TEST-No. 07

Heat Transfer Coefficient



TC	TC	Axial Level
+	18a4	3860 mm
X	18a3	3315 mm
	18a2	2770 mm, TC Failed
Y	15a2	2770 mm
*	18a1	2225 mm
◇	12b4	1680 mm
△	12b3	1135 mm
○	12b2	590 mm
□	12b1	45 mm

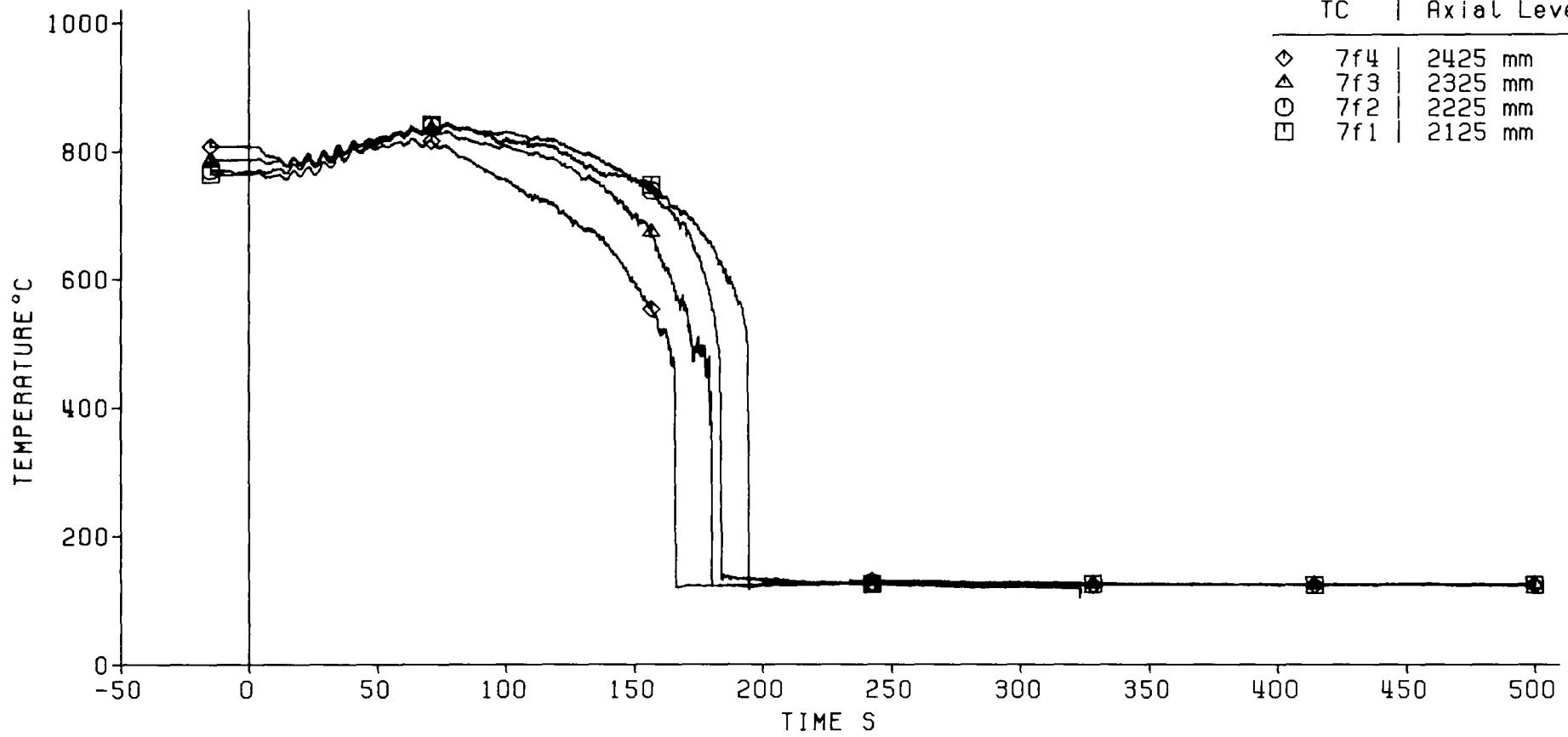
Decay Heat 120% ANS Standard
 Flooding Rate (cold) 3.81 cm/s
 System Pressure 2.12 bar
 Feedwater Temperature 54°C

REBEKA Rods With
 Argon Filled Gaps



Fig. 144 SEFLEX: 5x5 ROD BUNDLE, SERIES 2, TEST-No. 07

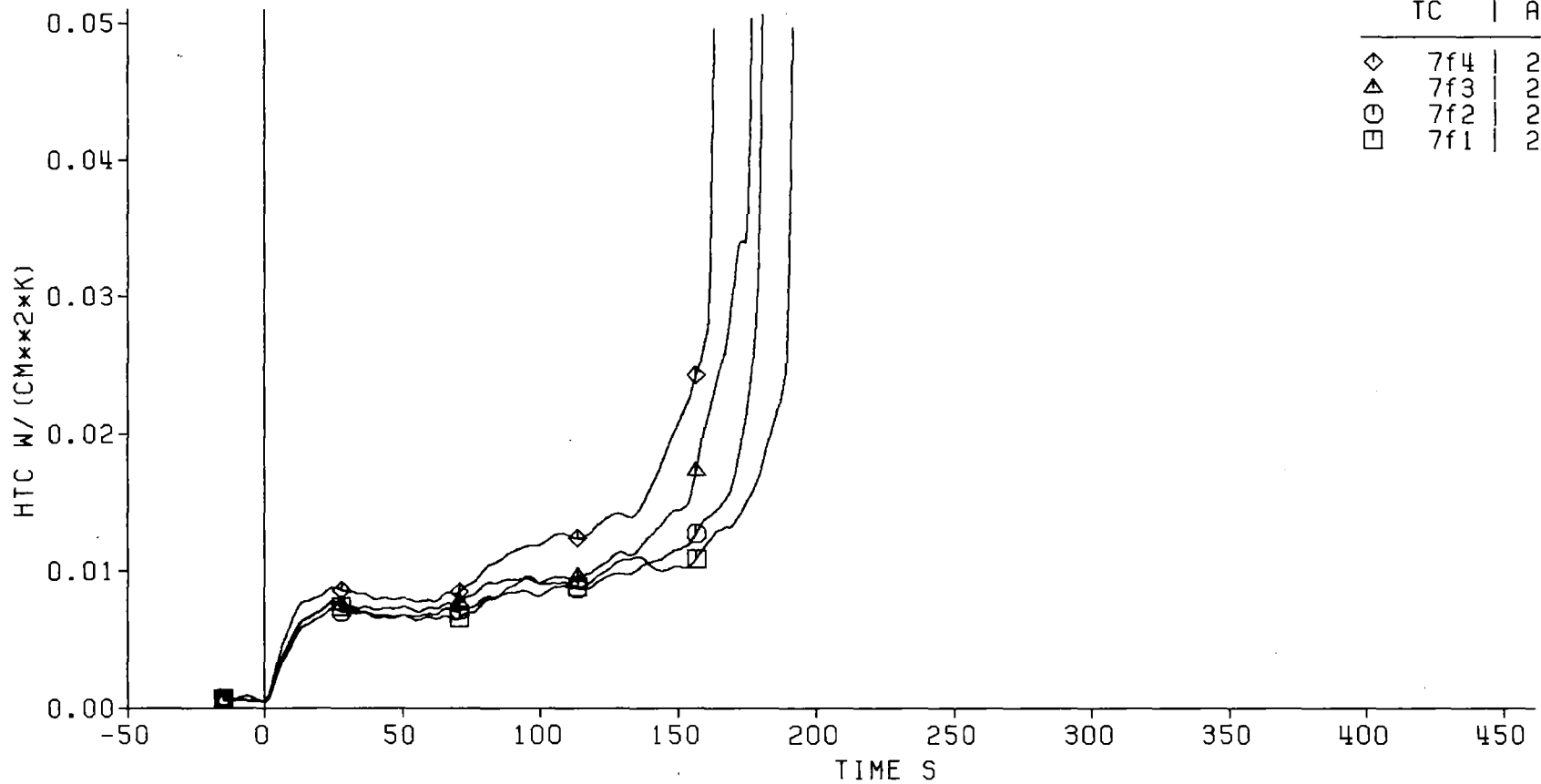
Cladding Temperature



Decay Heat 120% ANS Standard REBEKA Rods With Argon Filled Gaps
 Flooding Rate (cold) 3.81 cm/s
 System Pressure 2.12 bar
 Feedwater Temperature 54°C



Fig. 145 SEFLEX: 5x5 ROD BUNDLE, SERIES 2, TEST-No. 07



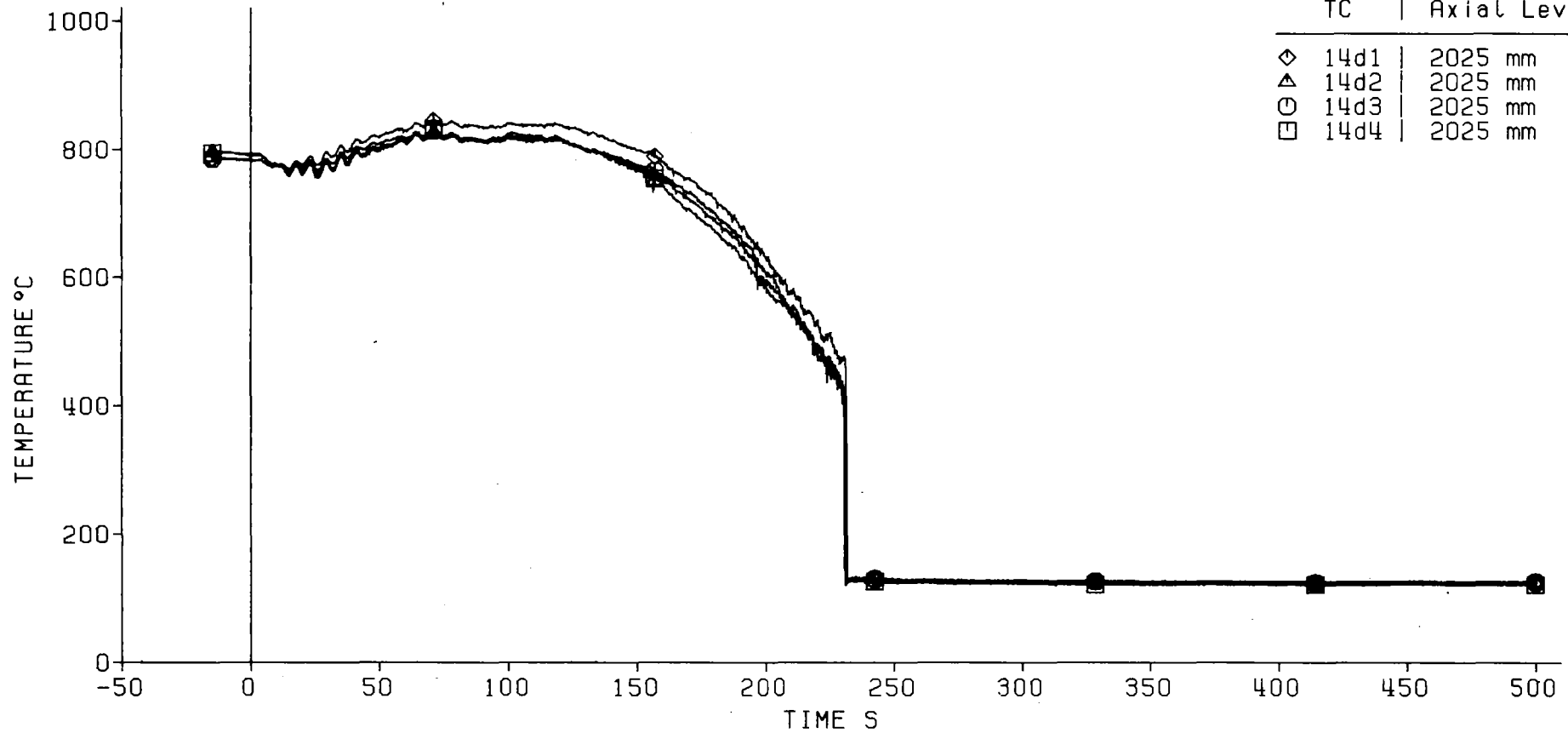
Decay Heat 120% ANS Standard
 Flooding Rate (cold) 3.81 cm/s
 System Pressure 2.12 bar
 Feedwater Temperature 54°C

REBEKA Rods With
 Argon Filled Gaps



Fig. 146 SEFLEX: 5x5 ROD BUNDLE, SERIES 2, TEST-No. 07

Cladding Temperature



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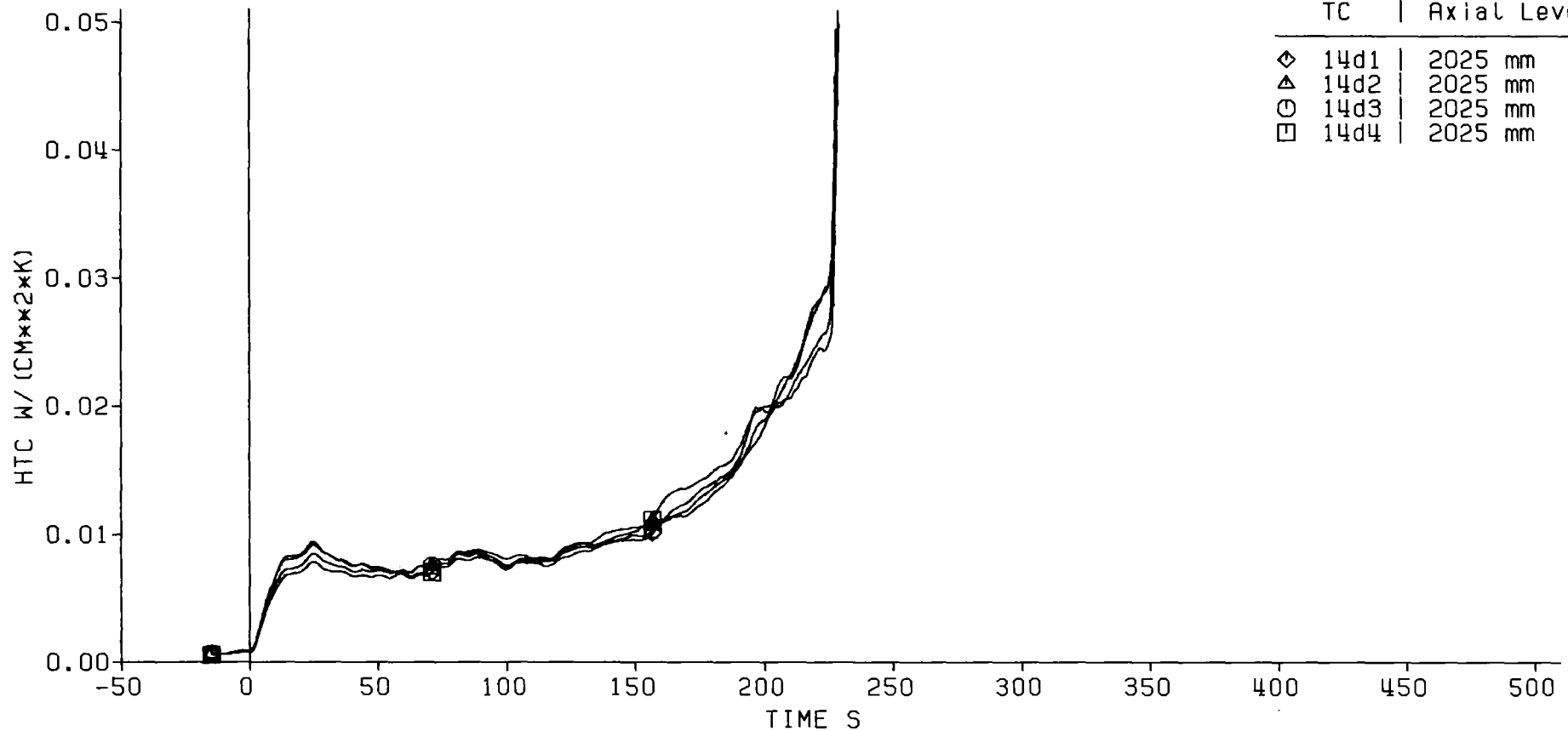
Decay Heat 120% ANS Standard
 Flooding Rate (cold) 3.81 cm/s
 System Pressure 2.12 bar
 Feedwater Temperature 54°C

REBEKA Rods With
 Argon Filled Gaps



Fig. 147 SEFLEX: 5x5 ROD BUNDLE, SERIES 2, TEST-No. 07

Heat Transfer Coefficient



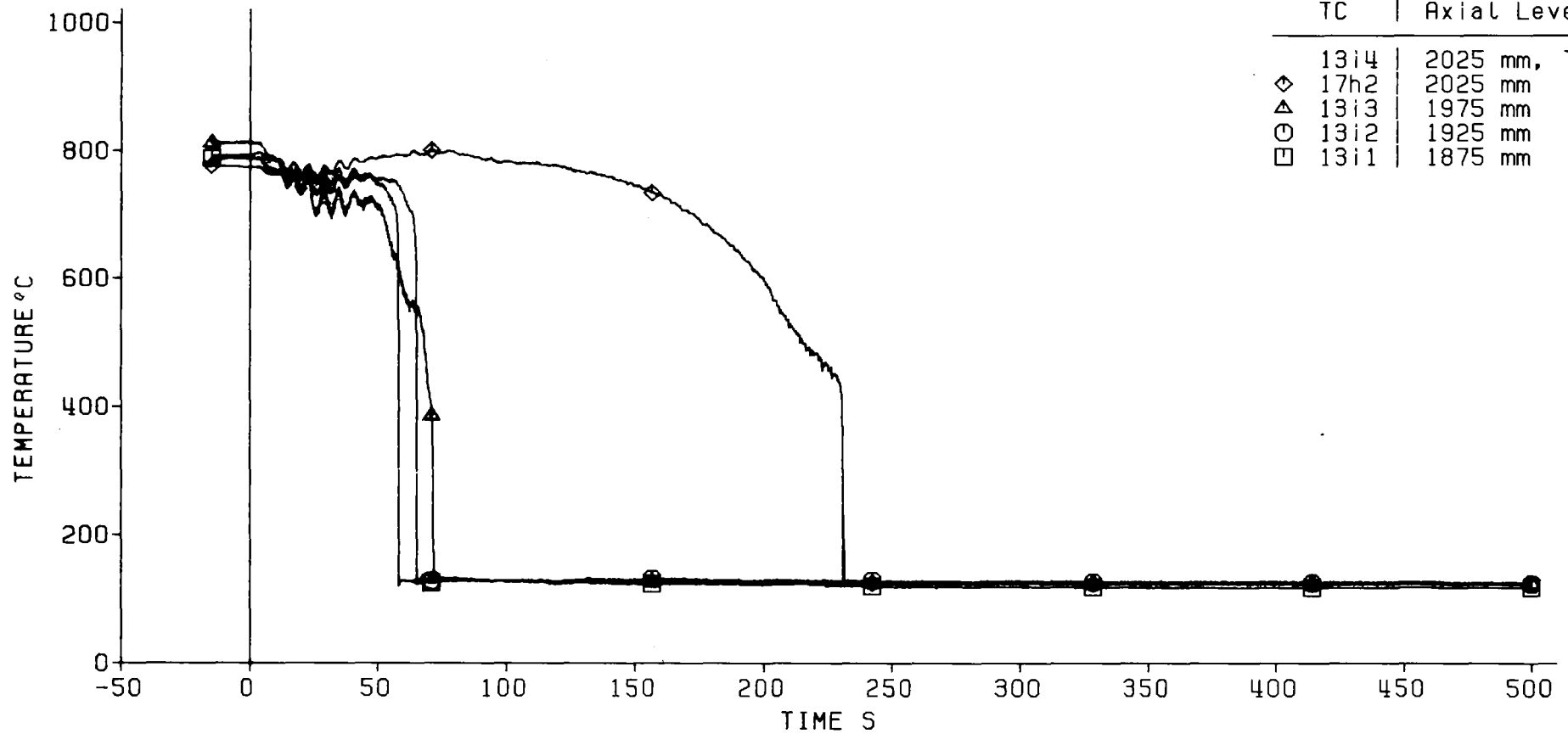
Decay Heat 120% ANS Standard
 Flooding Rate (cold) 3.81 cm/s
 System Pressure 2.12 bar
 Feedwater Temperature 54°C

REBEKA Rods With
 Argon Filled Gaps



Fig. 148 SEFLEX: 5x5 ROD BUNDLE, SERIES 2, TEST-No. 07

Cladding Temperature



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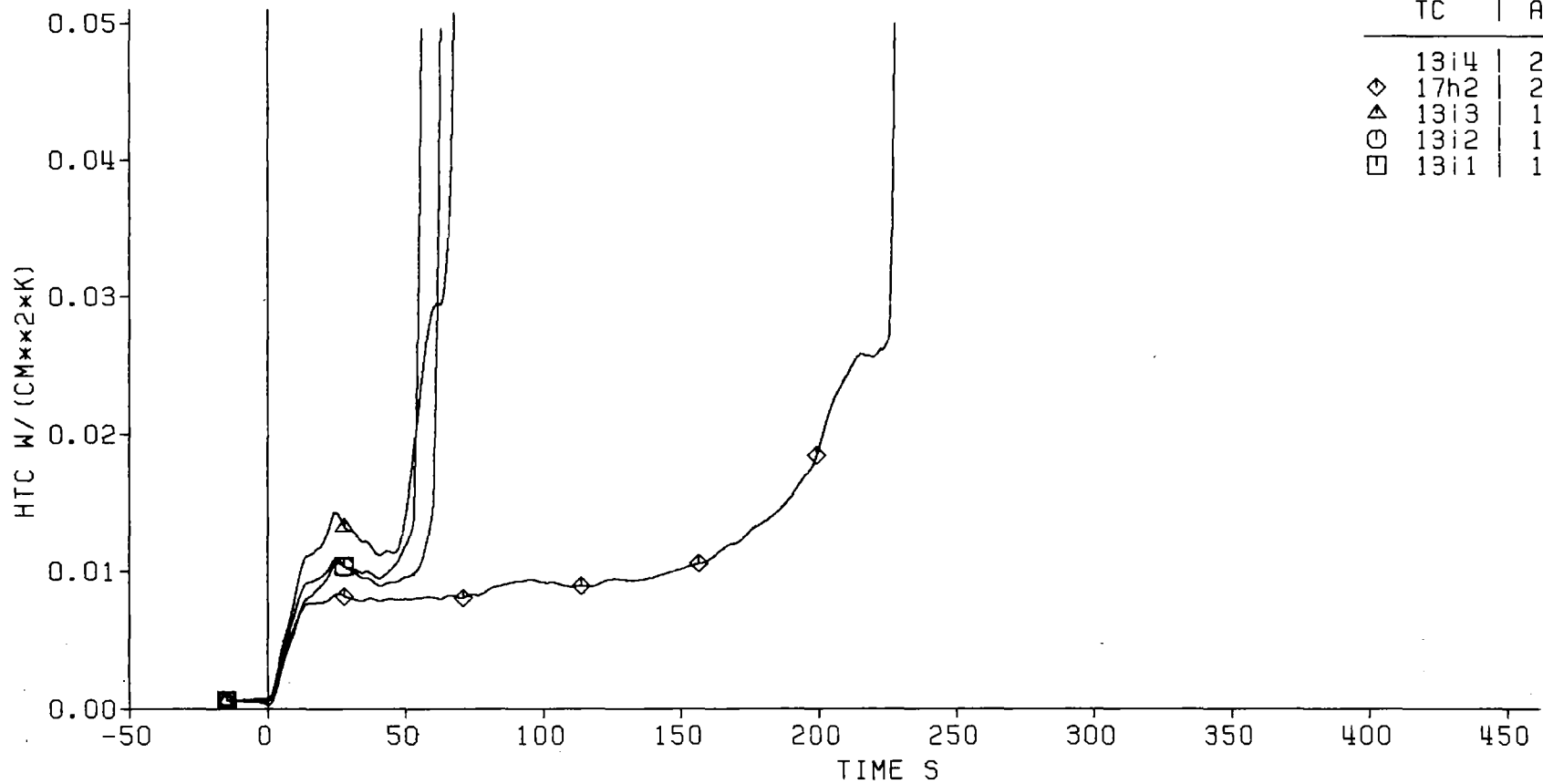
Decay Heat 120% ANS Standard
 Flooding Rate (cold) 3.81 cm/s
 System Pressure 2.12 bar
 Feedwater Temperature 54°C

REBEKA Rods With Argon Filled Gaps



Fig. 149 SEFLEX: 5x5 ROD BUNDLE, SERIES 2, TEST-No. 07

Heat Transfer Coefficient



TC	Axial Level
13i4	2025 mm, TC Failed
◇ 17h2	2025 mm
△ 13i3	1975 mm
○ 13i2	1925 mm
□ 13i1	1875 mm

Decay Heat 120% ANS Standard
 Flooding Rate (cold) 3.81 cm/s
 System Pressure 2.12 bar
 Feedwater Temperature 54°C

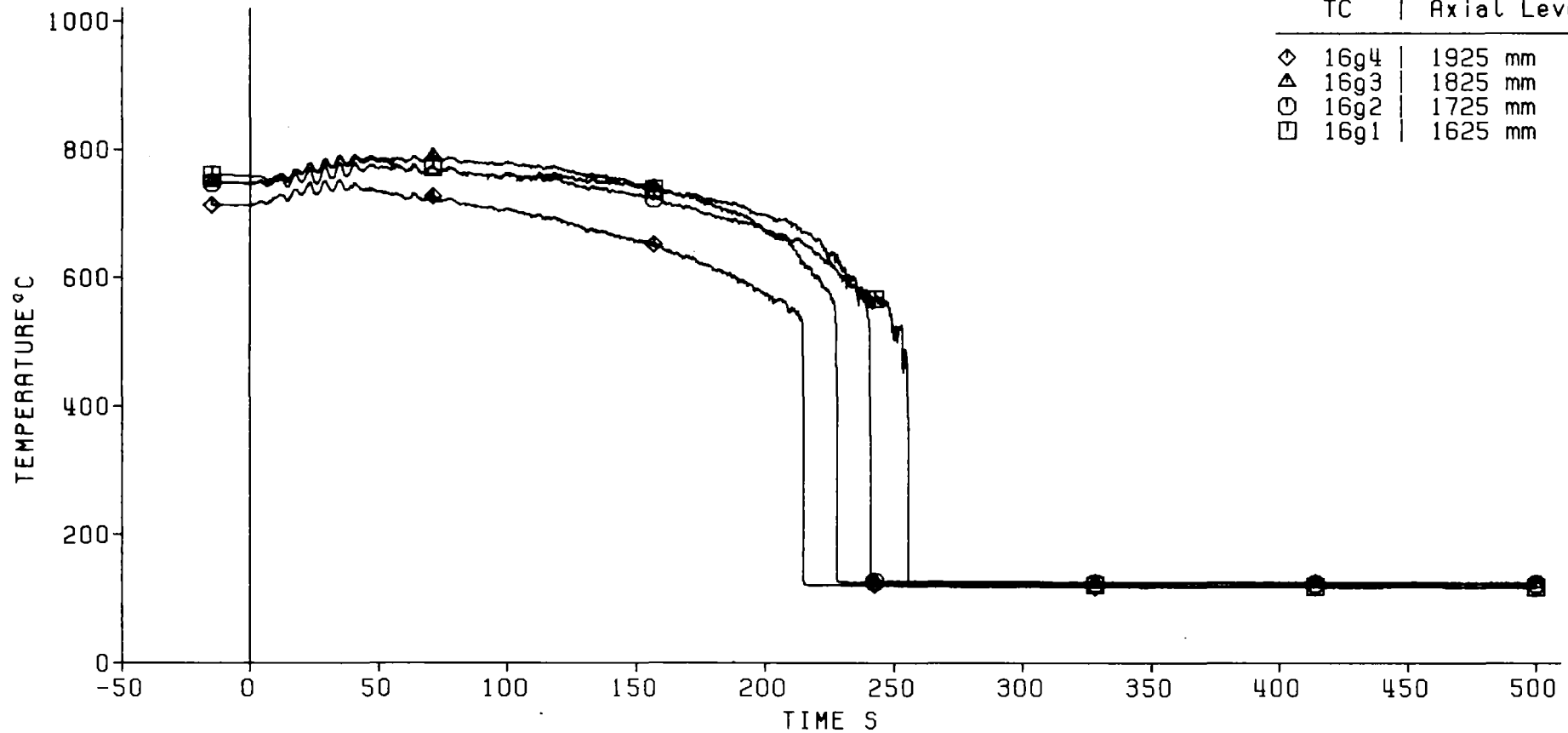
REBEKA Rods With Argon Filled Gaps



Fig. 150 SEFLEX: 5x5 ROD BUNDLE, SERIES 2, TEST-No. 07

Cladding Temperature

TC	Axial Level
◇	16g4 1925 mm
△	16g3 1825 mm
○	16g2 1725 mm
□	16g1 1625 mm



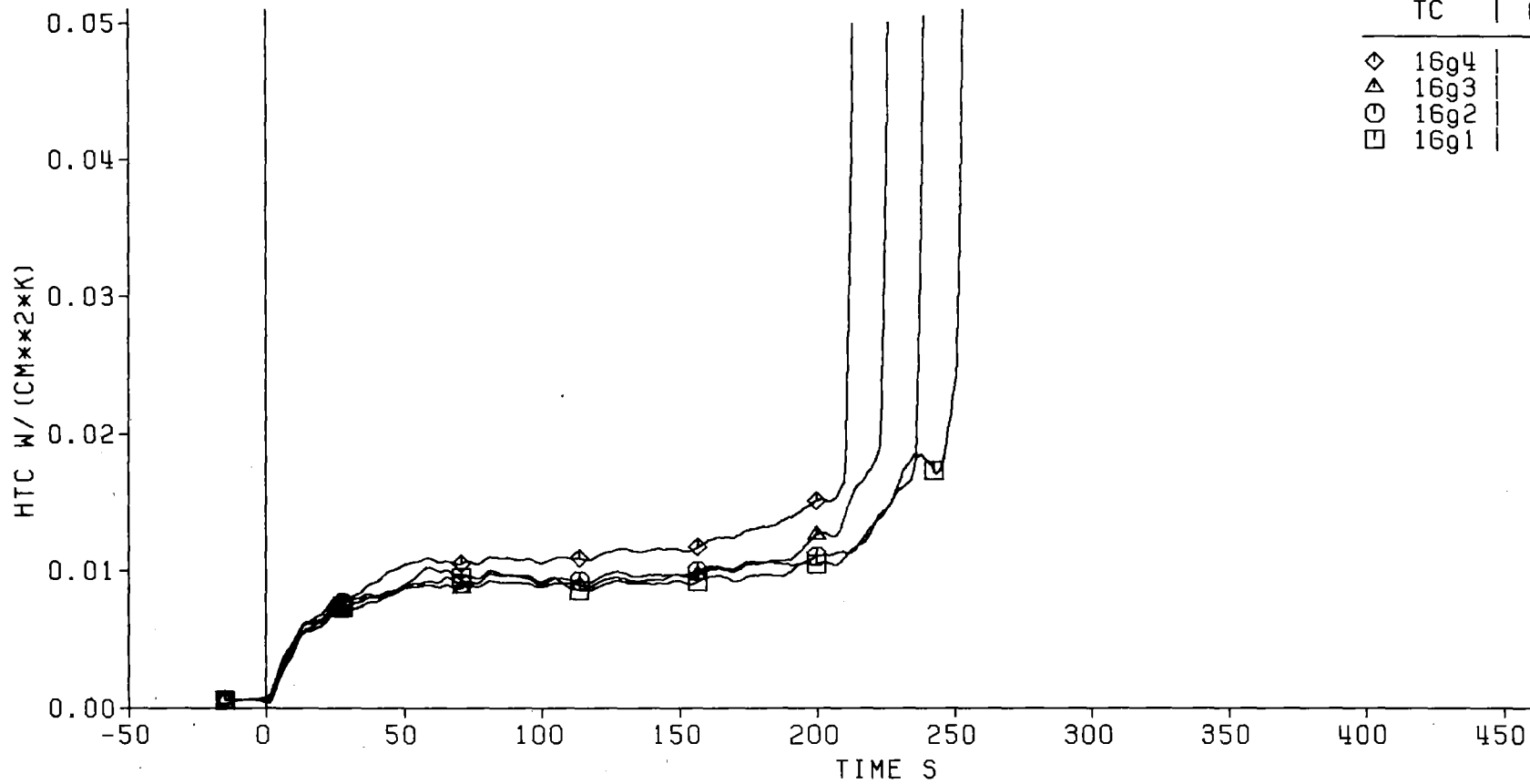
Decay Heat 120% ANS Standard
 Flooding Rate (cold) 3.81 cm/s
 System Pressure 2.12 bar
 Feedwater Temperature 54°C

REBEKA Rods With
 Argon Filled Gaps



Fig. 151 SEFLEX: 5x5 ROD BUNDLE, SERIES 2, TEST-No. 07

Heat Transfer Coefficient



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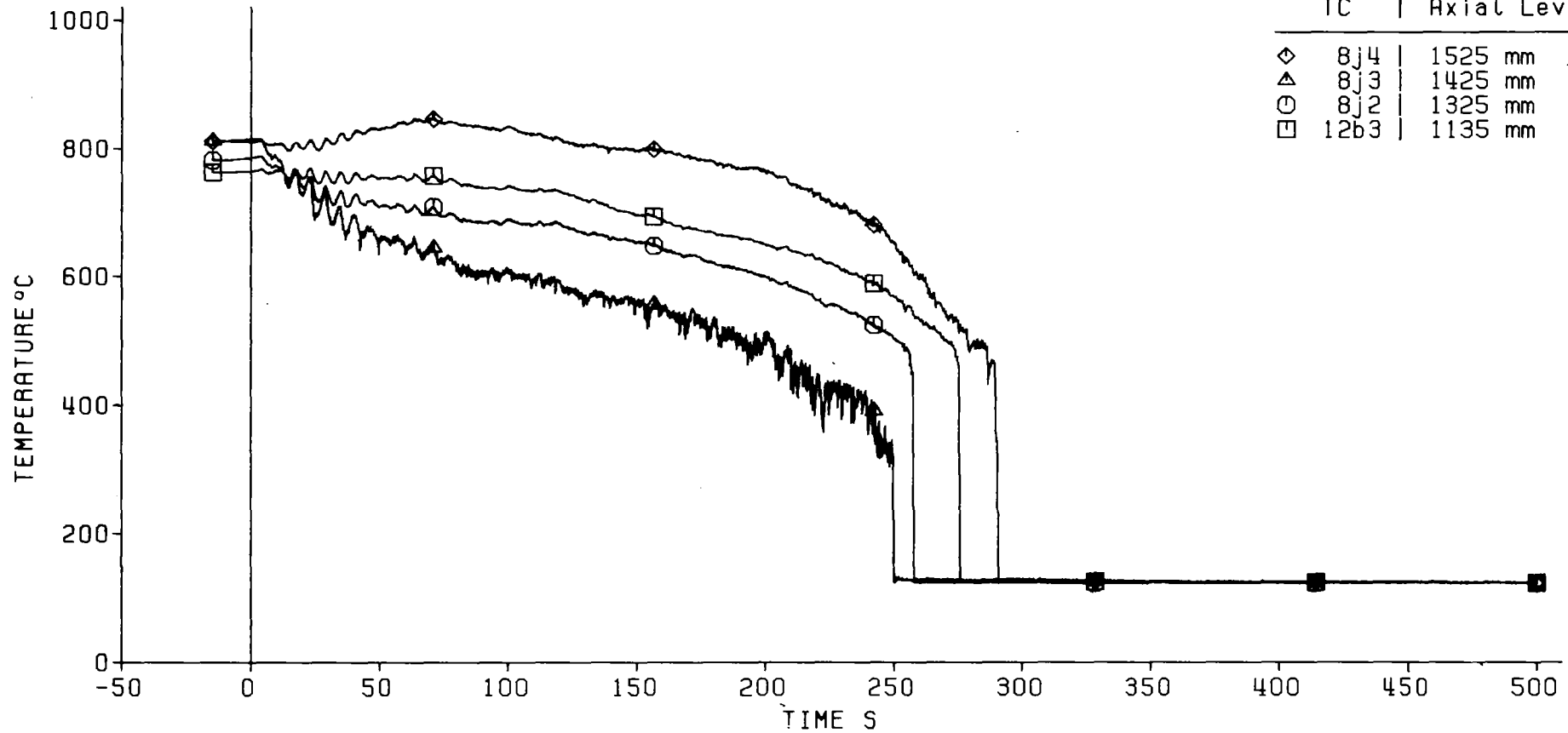
Decay Heat	120% ANS Standard	REBEKA Rods With
Flooding Rate (cold)	3.81 cm/s	Argon Filled Gaps
System Pressure	2.12 bar	
Feedwater Temperature	54°C	



Fig. 152 SEFLEX: 5x5 ROD BUNDLE, SERIES 2, TEST-No. 07

Cladding Temperature

TC	Axial Level
◇	8j4 1525 mm
△	8j3 1425 mm
○	8j2 1325 mm
□	12b3 1135 mm

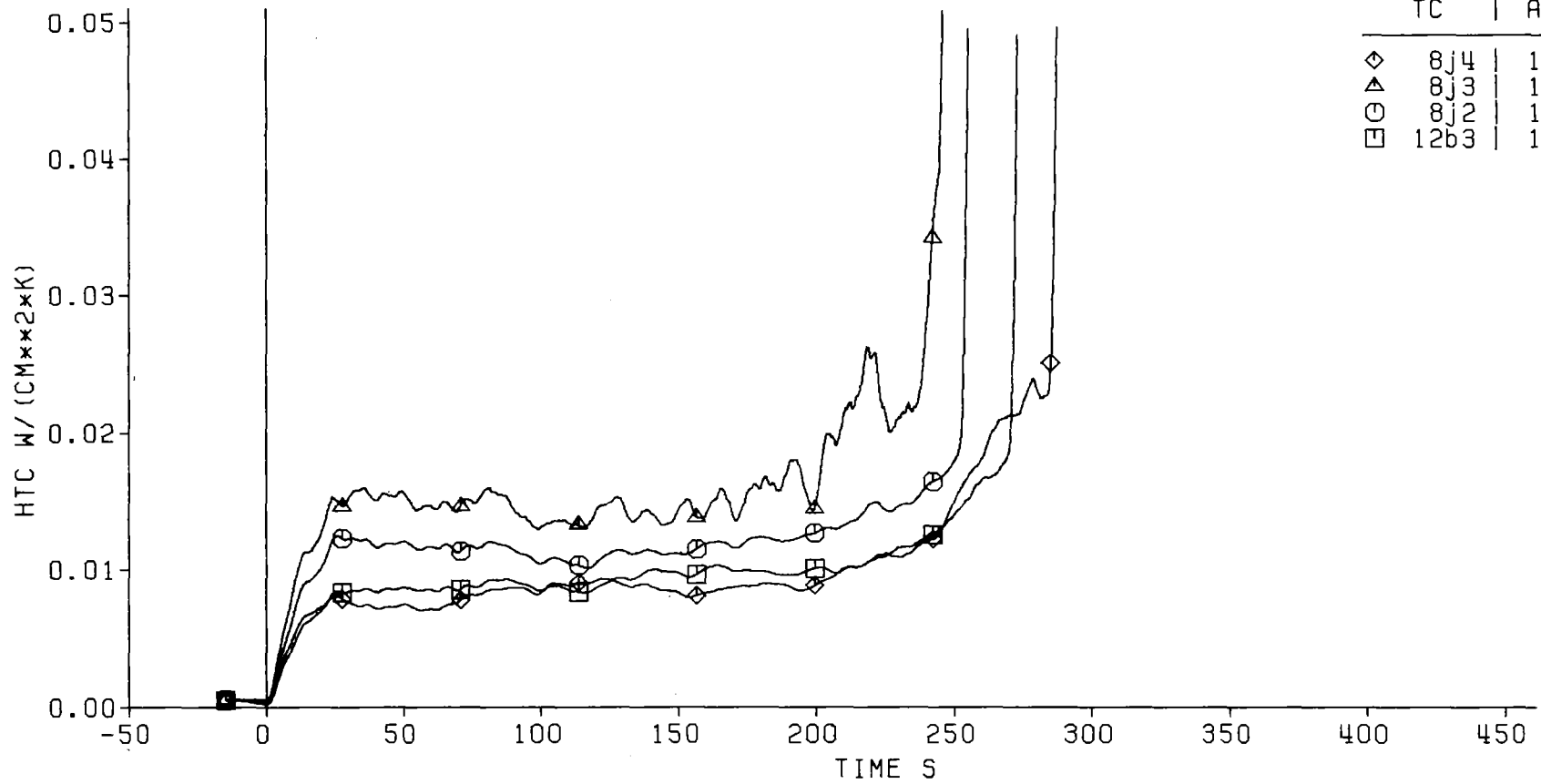


Decay Heat 120% ANS Standard
 Flooding Rate (cold) 3.81 cm/s
 System Pressure 2.12 bar
 Feedwater Temperature 54°C

REBEKA Rods With
 Argon Filled Gaps



Fig. 153 SEFLEX: 5x5 ROD BUNDLE, SERIES 2, TEST-No. 07



Decay Heat 120% ANS Standard
 Flooding Rate (cold) 3.81 cm/s
 System Pressure 2.12 bar
 Feedwater Temperature 54°C

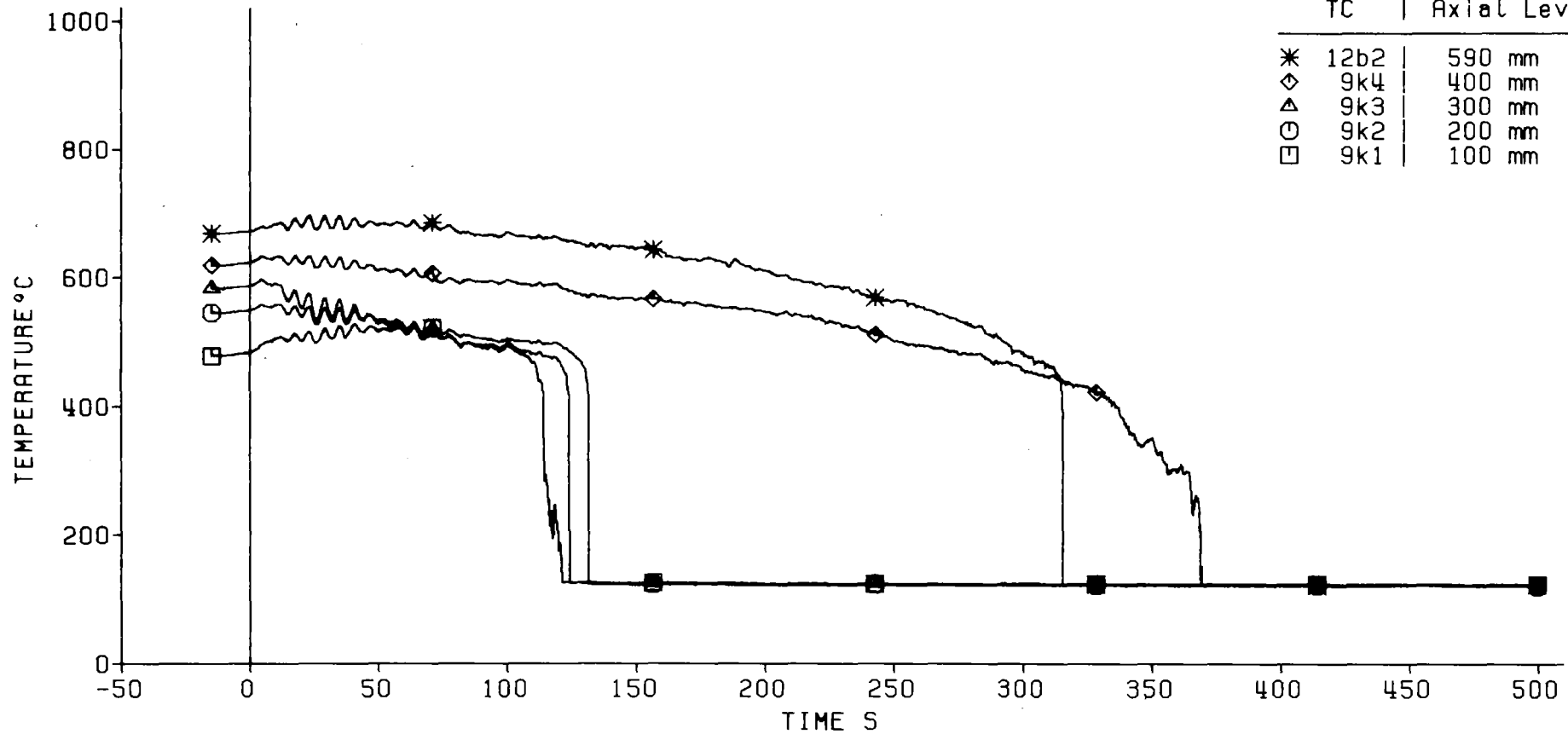
REBEKA Rods With
 Argon Filled Gaps



Fig. 154 SEFLEX: 5x5 ROD BUNDLE, SERIES 2, TEST-No. 07

Cladding Temperature

TC	Axial Level
* 12b2	590 mm
◇ 9k4	400 mm
△ 9k3	300 mm
○ 9k2	200 mm
□ 9k1	100 mm



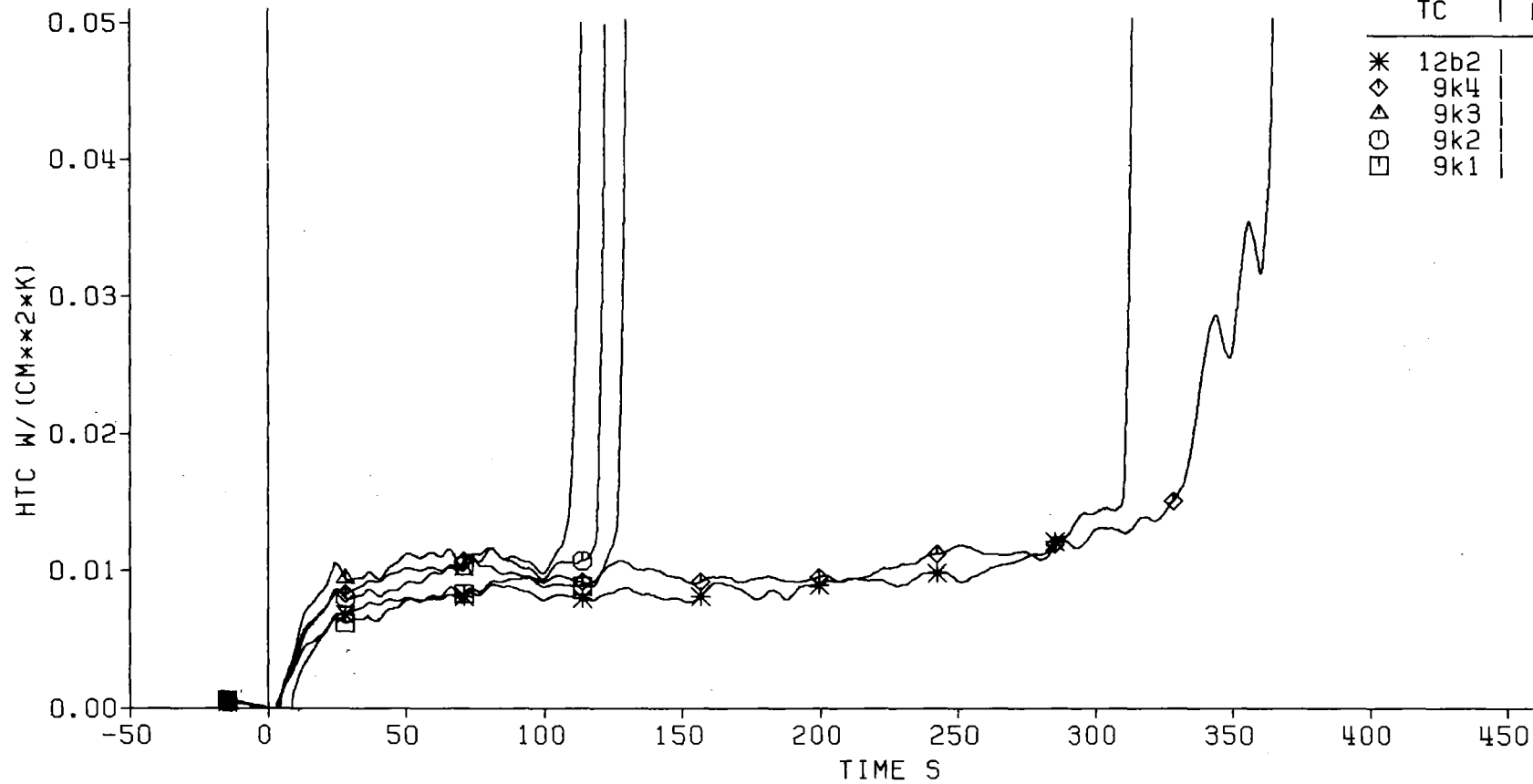
Decay Heat 120% ANS Standard
 Flooding Rate (cold) 3.81 cm/s
 System Pressure 2.12 bar
 Feedwater Temperature 54°C

REBEKA Rods With
 Argon Filled Gaps



Fig. 155 SEFLEX: 5x5 ROD BUNDLE, SERIES 2, TEST-No. 07

Heat Transfer Coefficient



Decay Heat 120% ANS Standard
 Flooding Rate (cold) 3.81 cm/s
 System Pressure 2.12 bar
 Feedwater Temperature 54°C

REBEKA Rods With Argon Filled Gaps

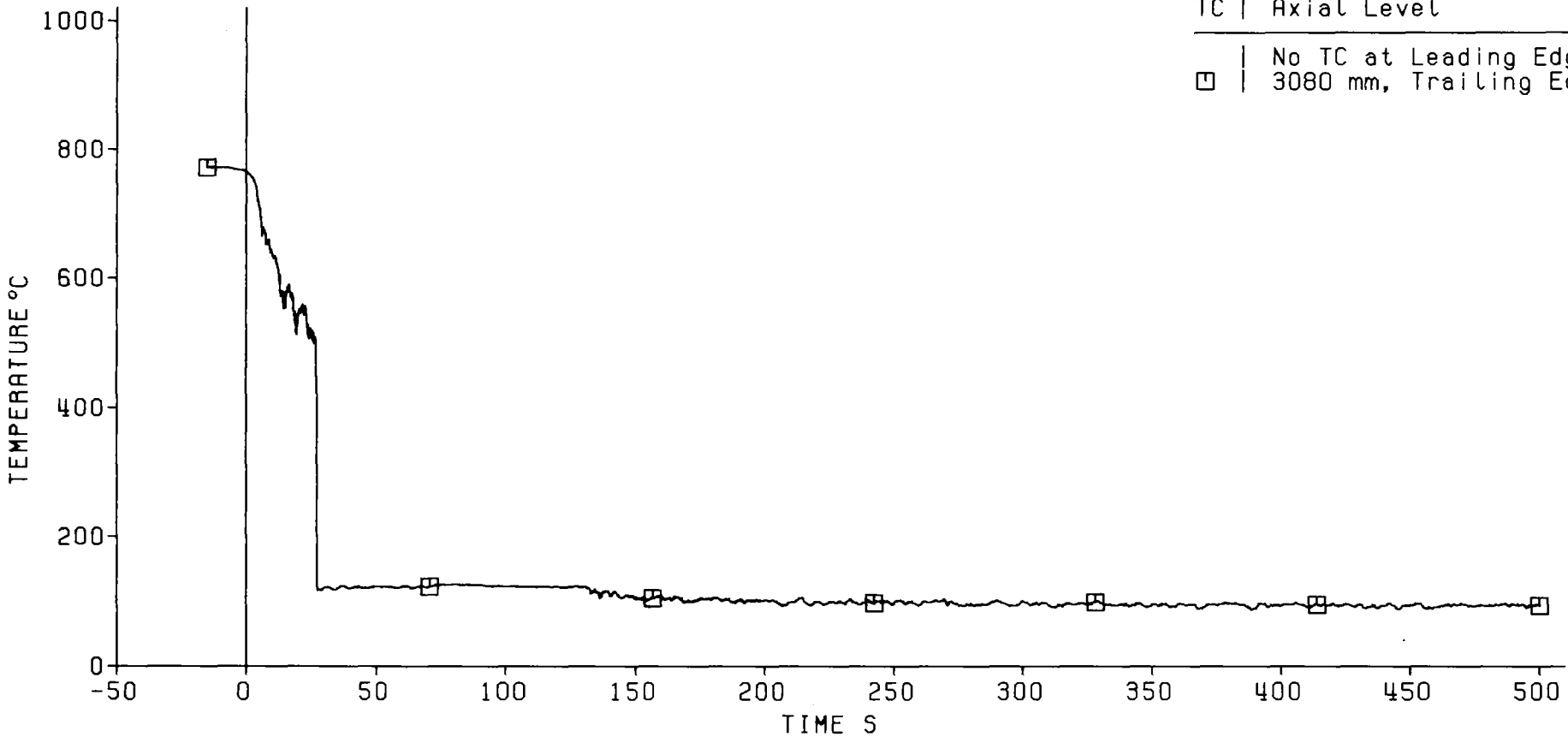


Fig. 156 SEFLEX: 5x5 ROD BUNDLE, SERIES 2, TEST-No. 07

Grid Spacer Temperature

TC | Axial Level

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



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Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.81 cm/s
System Pressure 2.12 bar
Feedwater Temperature 54°C

REBEKA Rods With Argon Filled Gaps

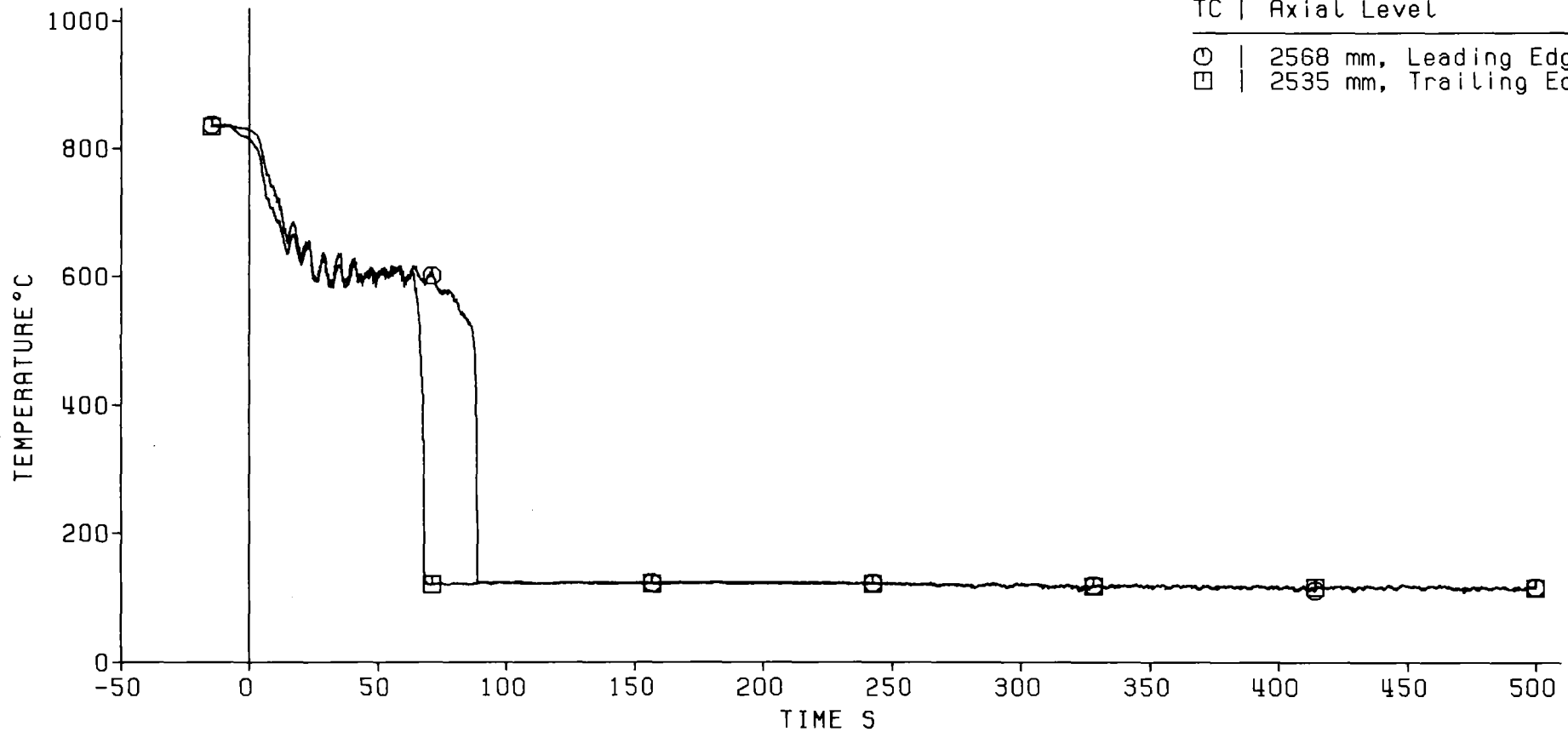


Fig. 157 SEFLEX: 5x5 ROD BUNDLE, SERIES 2, TEST-No. 07

Grid Spacer Temperature

TC | Axial Level

- ⊙ | 2568 mm, Leading Edge
- ⊠ | 2535 mm, Trailing Edge



Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.81 cm/s
System Pressure 2.12 bar
Feedwater Temperature 54°C

REBEKA Rods With
Argon Filled Gaps

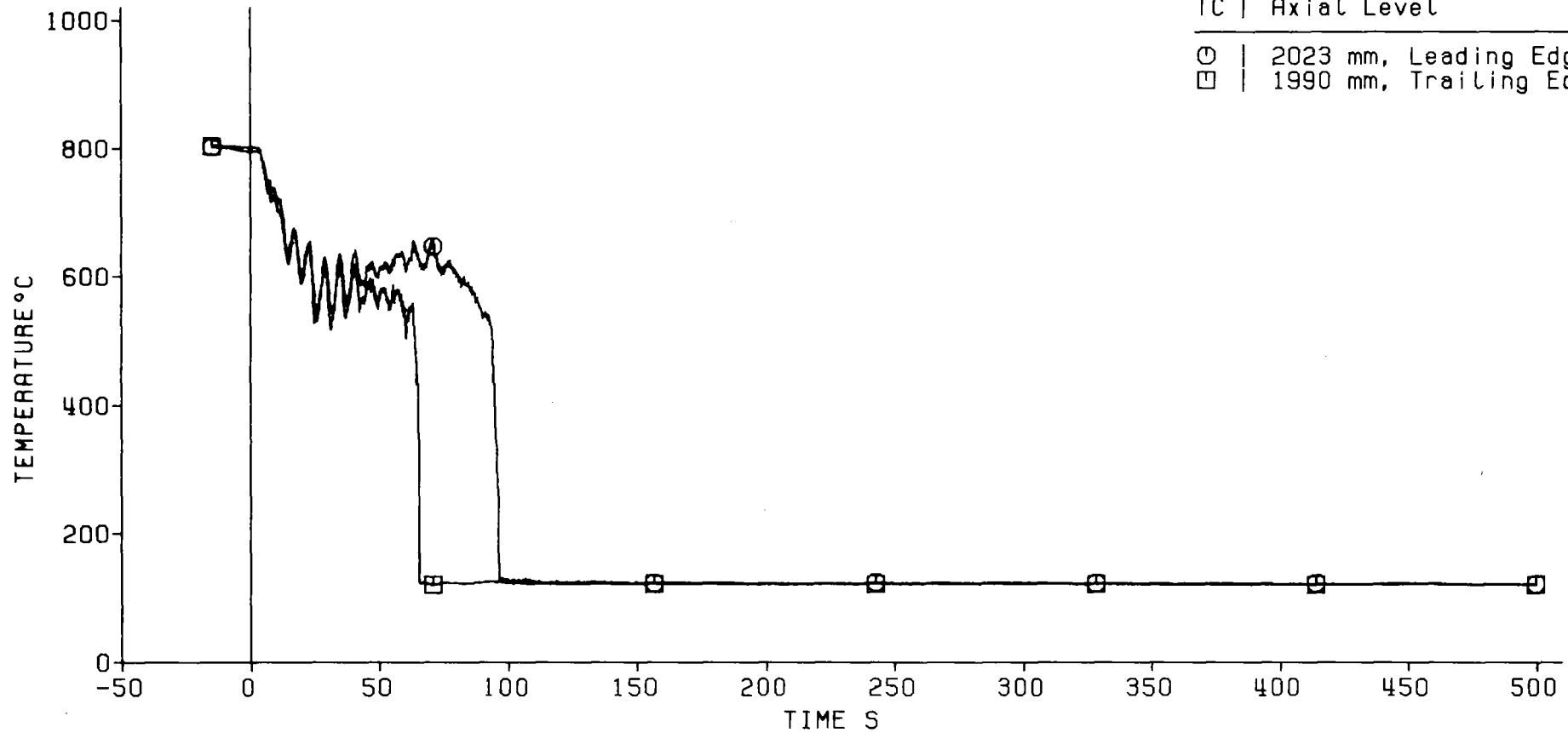


Fig. 158 SEFLEX: 5x5 ROD BUNDLE, SERIES 2, TEST-No. 07

Grid Spacer Temperature

TC | Axial Level

○ | 2023 mm, Leading Edge
□ | 1990 mm, Trailing Edge



Decay Heat
Flooding Rate (cold)
System Pressure
Feedwater Temperature

120% ANS Standard
3.81 cm/s
2.12 bar
54°C

REBEKA Rods With
Argon Filled Gaps

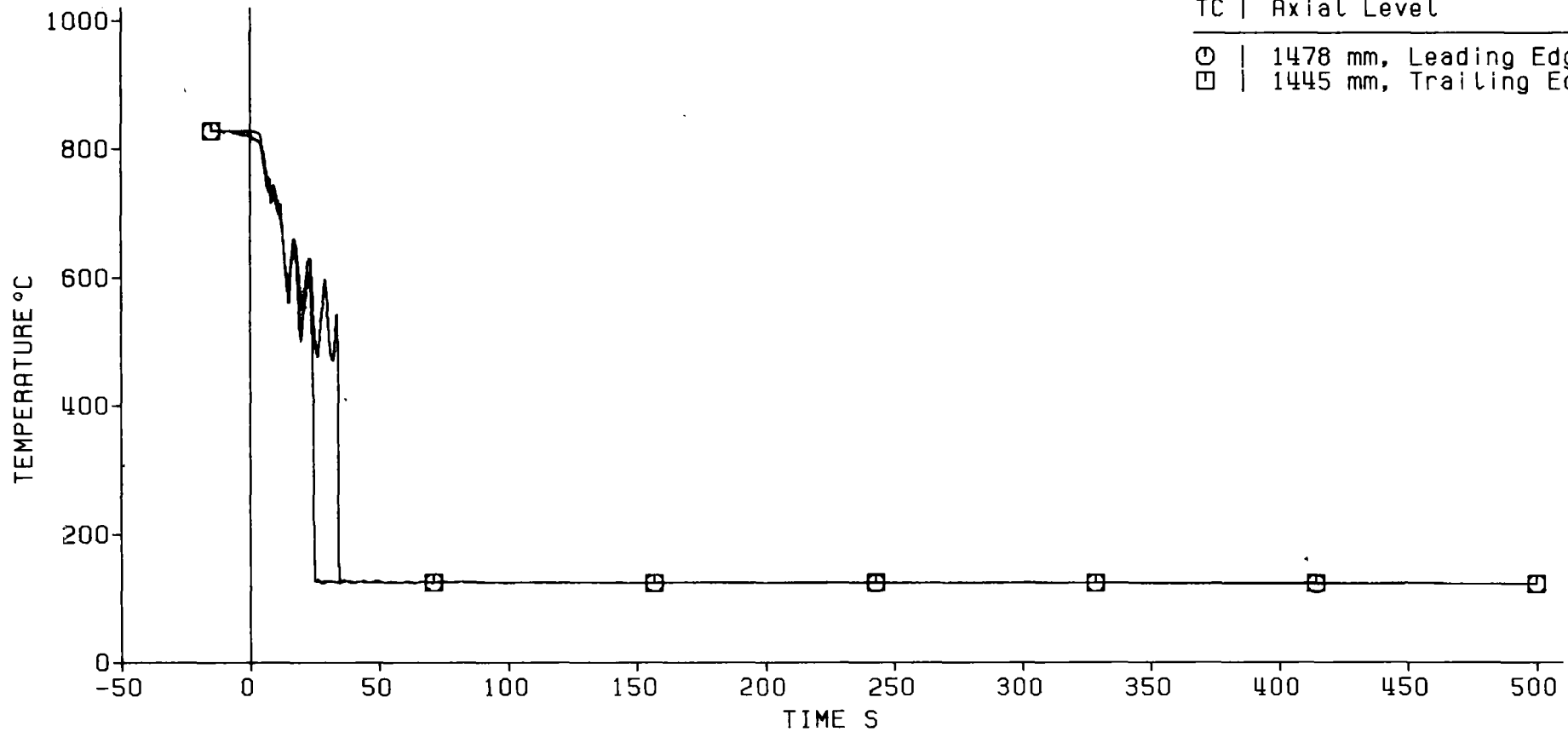


Fig. 159 SEFLEX: 5x5 ROD BUNDLE, SERIES 2, TEST-No. 07

Grid Spacer Temperature

TC | Axial Level

- ⊙ | 1478 mm, Leading Edge
- ⊠ | 1445 mm, Trailing Edge



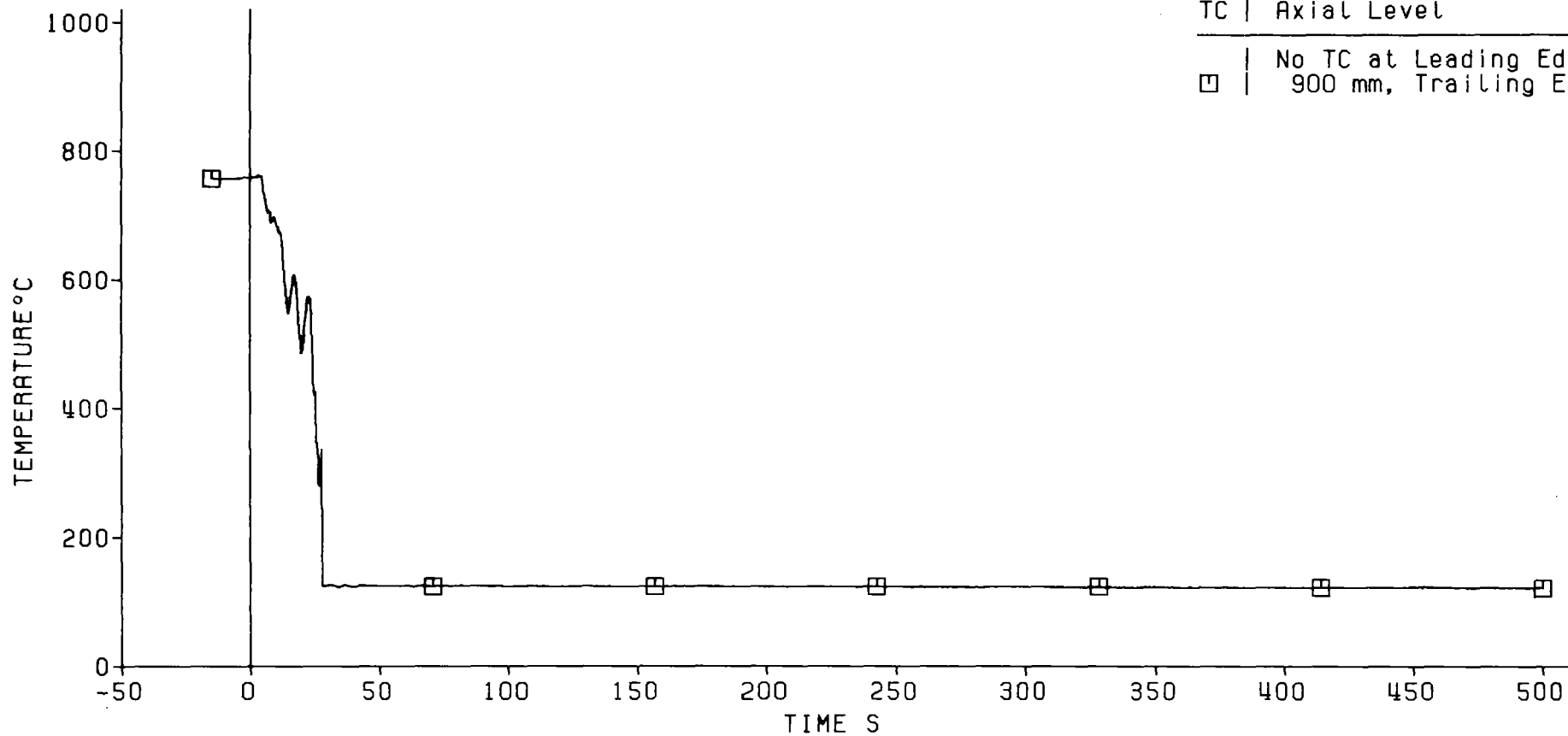
Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.81 cm/s
System Pressure 2.12 bar
Feedwater Temperature 54°C

REBEKA Rods With
Argon Filled Gaps



Fig. 160 SEFLEX: 5x5 ROD BUNDLE, SERIES 2, TEST-No. 07

Grid Spacer Temperature



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Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.81 cm/s
System Pressure 2.12 bar
Feedwater Temperature 54°C

REBEKA Rods With
Argon Filled Gaps

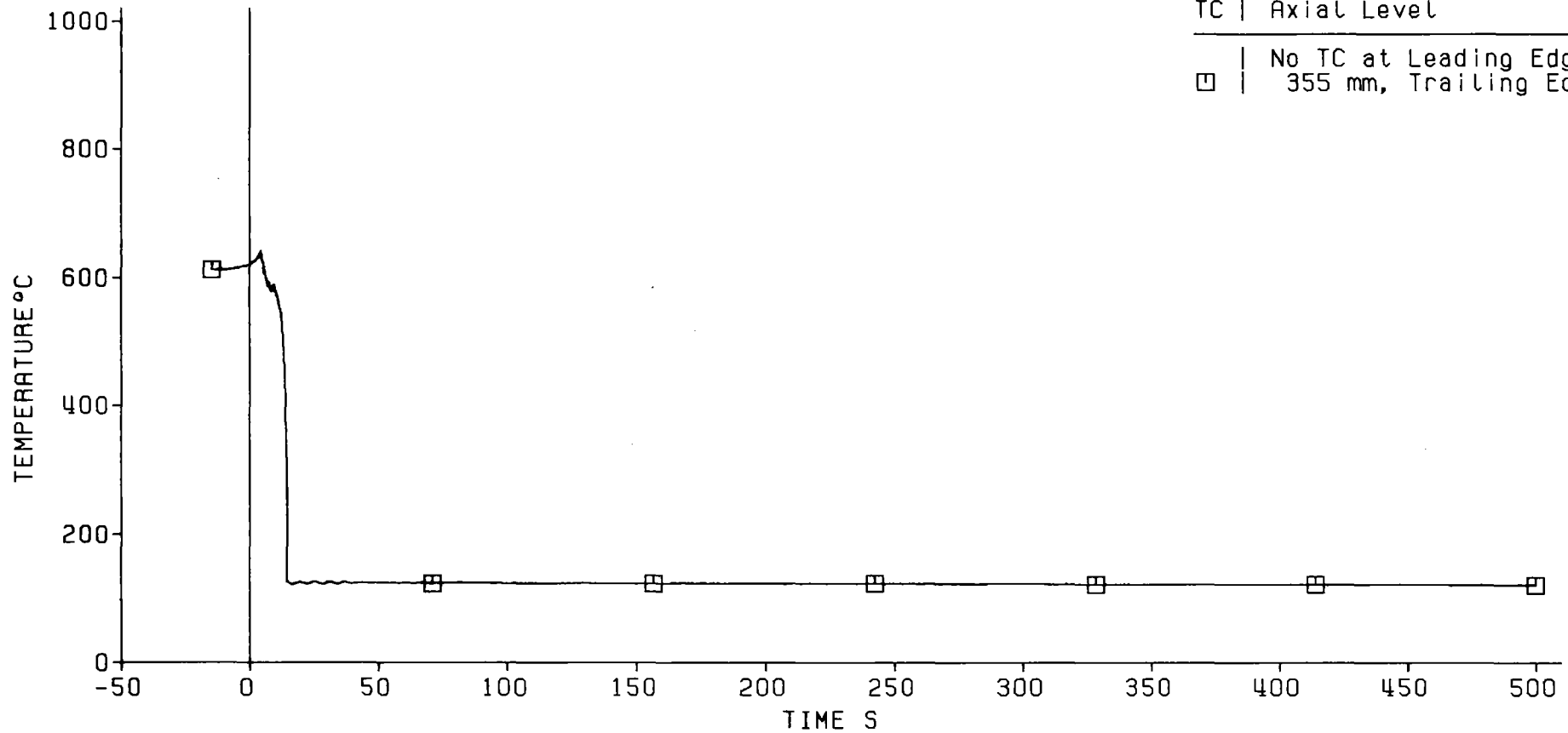


Fig. 161 SEFLEX: 5x5 ROD BUNDLE, SERIES 2, TEST-No. 07

Grid Spacer Temperature

TC | Axial Level

□ | No TC at Leading Edge
□ | 355 mm, Trailing Edge



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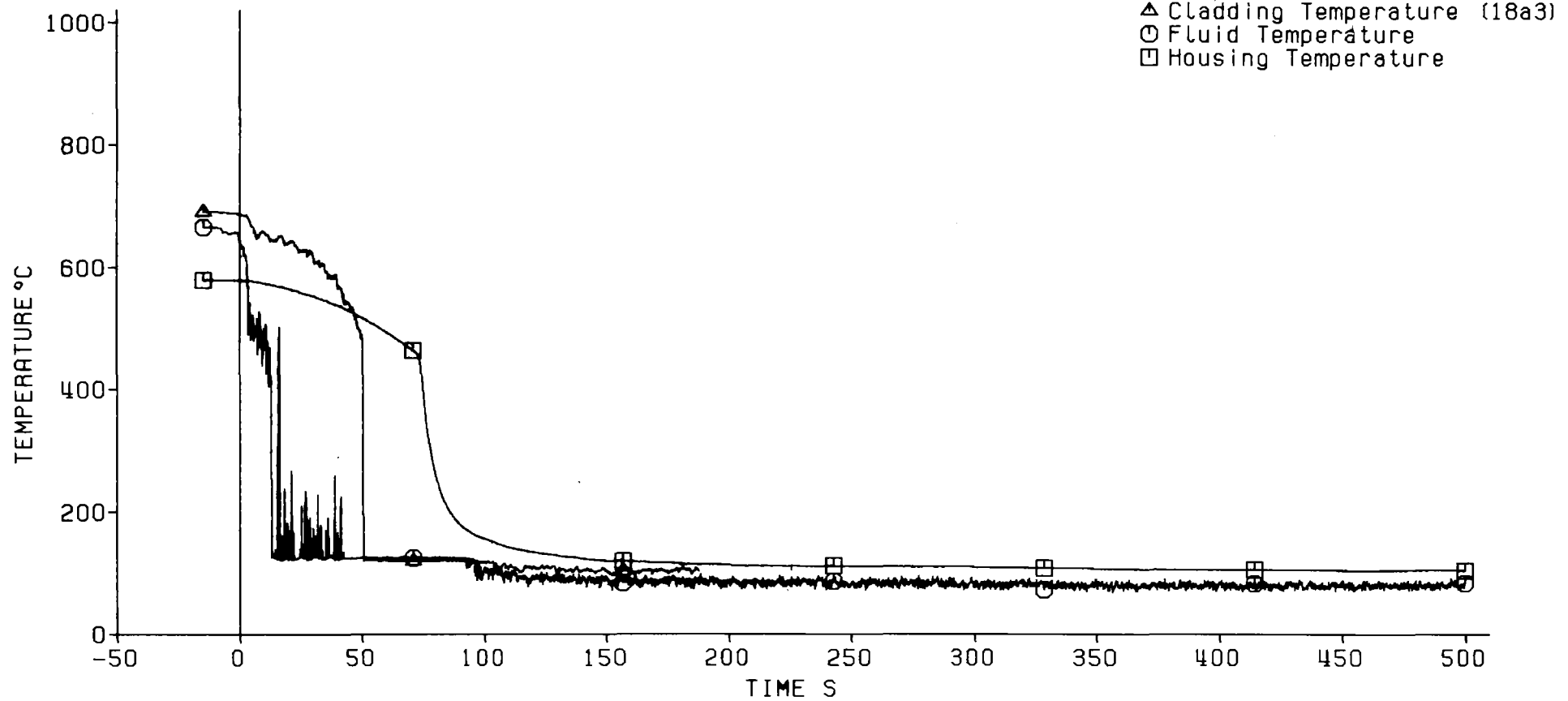
Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.81 cm/s
System Pressure 2.12 bar
Feedwater Temperature 54°C

REBEKA Rods With
Argon Filled Gaps



Fig. 162 SEFLEX: 5x5 ROD BUNDLE, SERIES 2, TEST-No. 07

Axial Level: 3315 mm



Decay Heat
Flooding Rate (cold)
System Pressure
Feedwater Temperature

120% ANS Standard
3.81 cm/s
2.12 bar
54°C

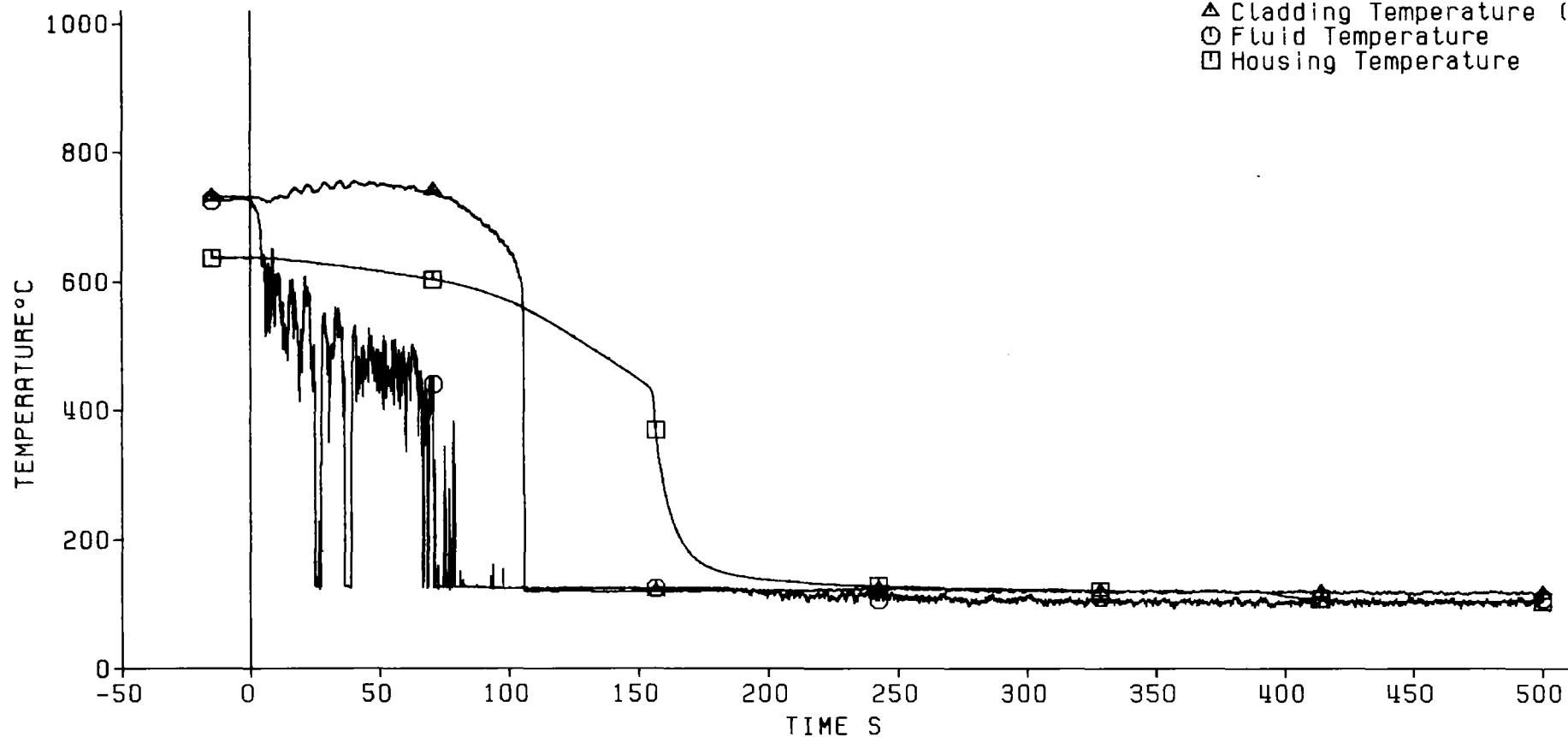
REBEKA Rods With
Argon Filled Gaps



Fig. 163 SEFLEX: 5x5 ROD BUNDLE, SERIES 2, TEST-No. 07

Axial Level: 2770 mm

△ Cladding Temperature (15a2)
○ Fluid Temperature
□ Housing Temperature



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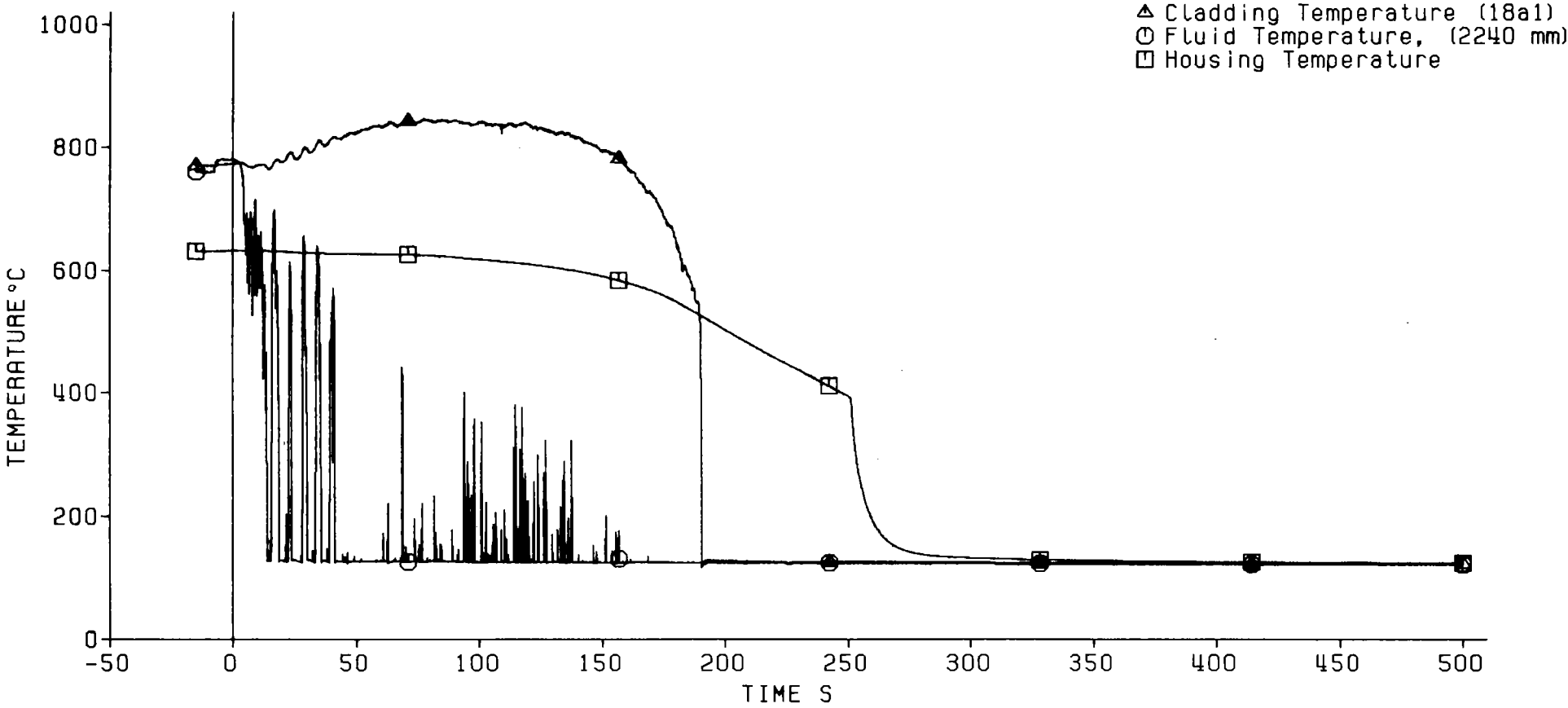
Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.81 cm/s
System Pressure 2.12 bar
Feedwater Temperature 54°C

REBEKA Rods With
Argon Filled Gaps



Fig. 164 SEFLEX: 5x5 ROD BUNDLE, SERIES 2, TEST-No. 07

Axial Level: 2225 mm



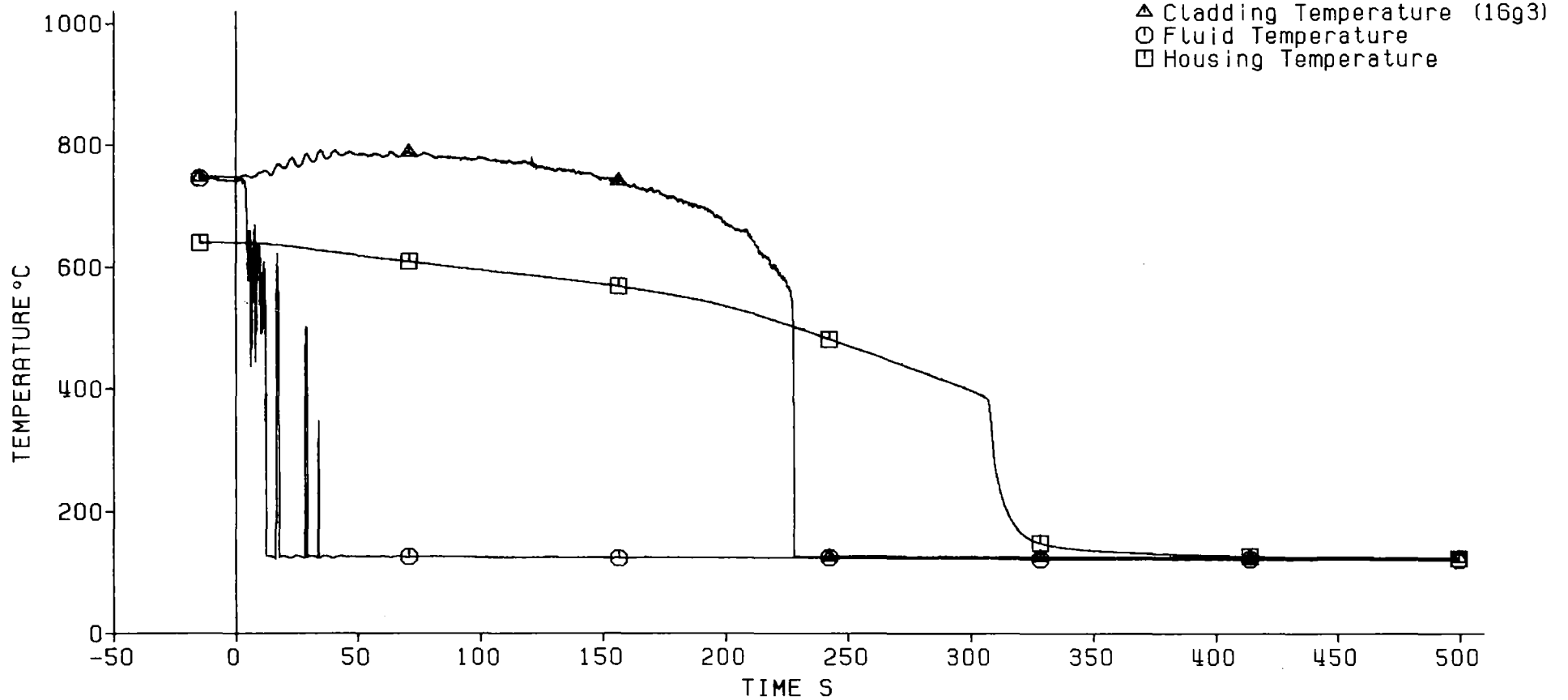
188

Decay Heat	120% ANS Standard	REBEKA Rods With
Flooding Rate (cold)	3.81 cm/s	Argon Filled Gaps
System Pressure	2.12 bar	
Feedwater Temperature	54°C	



Fig. 165 SEFLEX: 5x5 ROD BUNDLE, SERIES 2, TEST-No. 07

Axial Level: 1825 mm



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Decay Heat
Flooding Rate (cold)
System Pressure
Feedwater Temperature

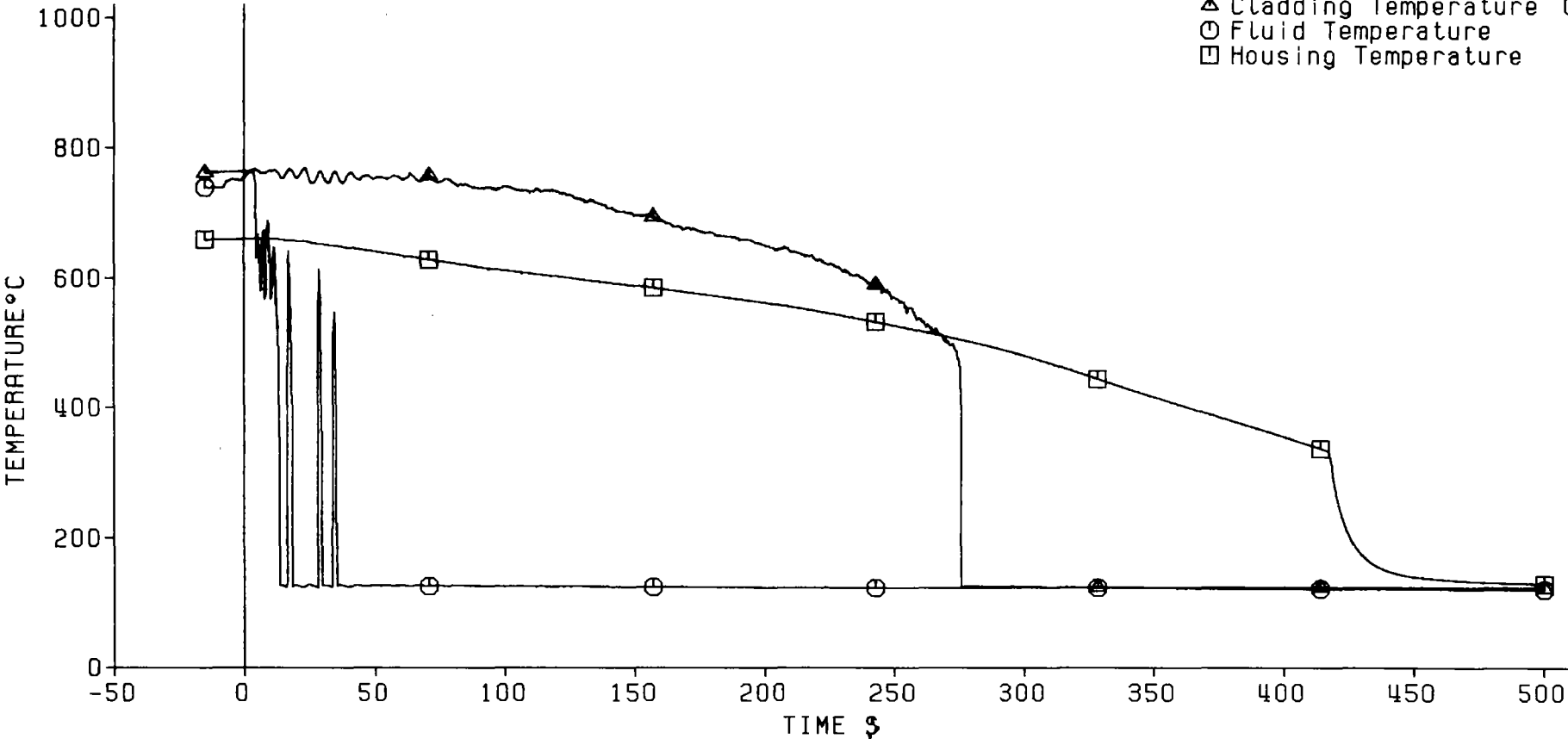
120% ANS Standard
3.81 cm/s
2.12 bar
54°C

REBEKA Rods With
Argon Filled Gaps



Fig. 166 SEFLEX: 5x5 ROD BUNDLE, SERIES 2, TEST-No. 07

Axial Level: 1135 mm



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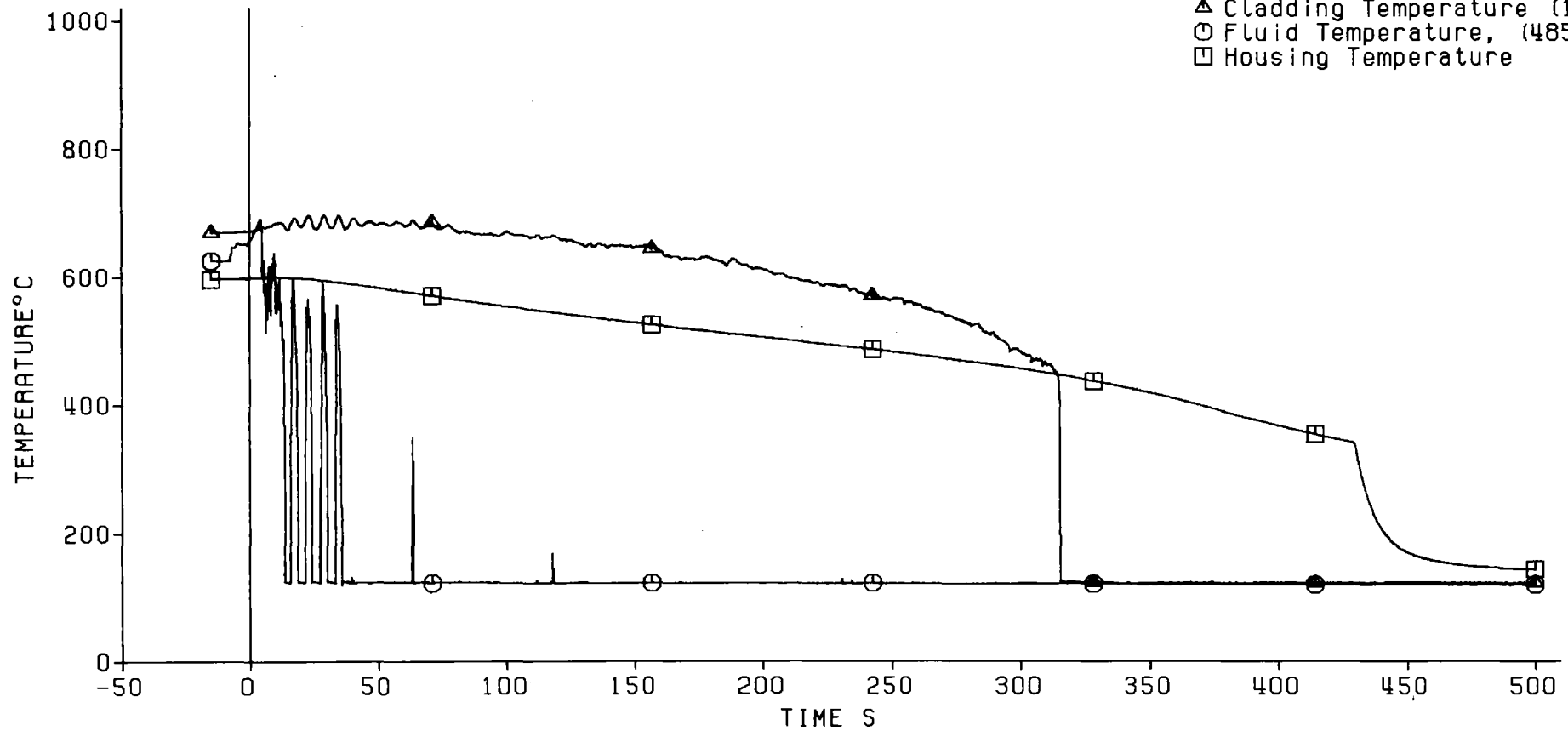
Decay Heat 120% ANS Standard REBEKA Rods With Argon Filled Gaps
Flooding Rate (cold) 3.81 cm/s
System Pressure 2.12 bar
Feedwater Temperature 54°C



Fig. 167 SEFLEX: 5x5 ROD BUNDLE, SERIES 2, TEST-No. 07

Axial Level: 590 mm

△ Cladding Temperature (12b2)
○ Fluid Temperature, (485 mm)
□ Housing Temperature



Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.81 cm/s
System Pressure 2.12 bar
Feedwater Temperature 54°C

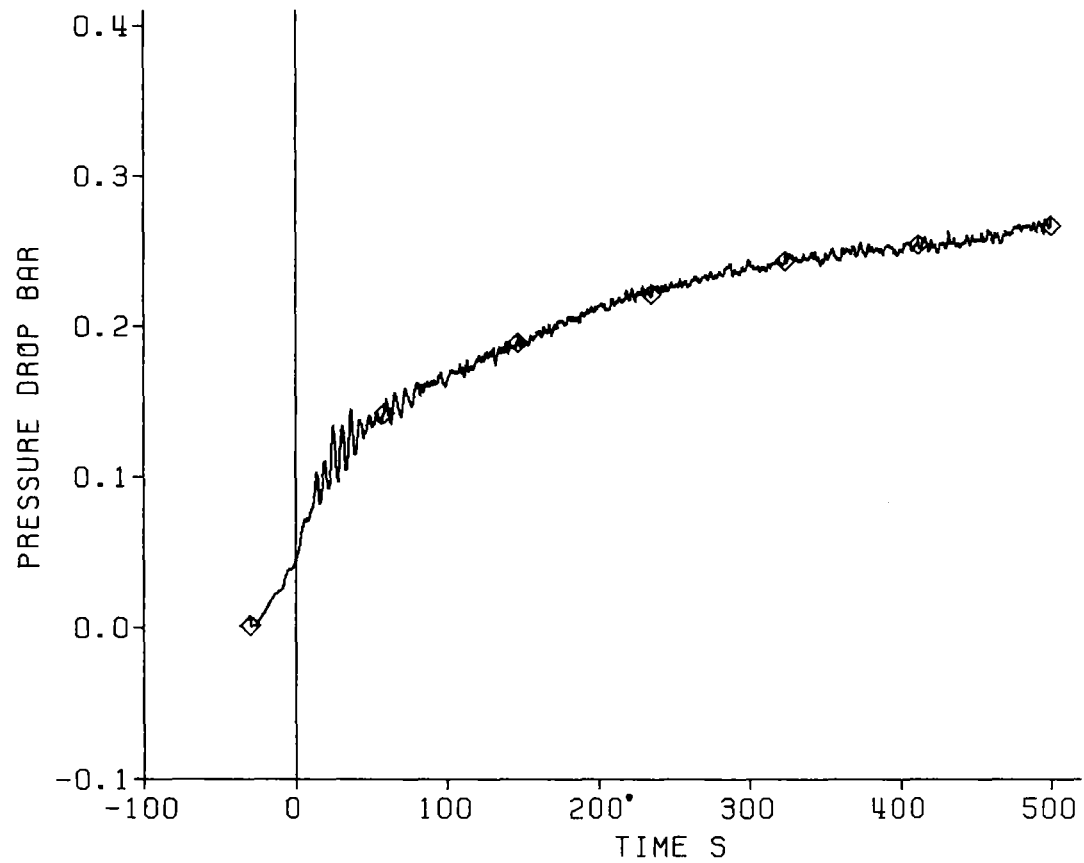
REBEKA Rods With
Argon Filled Gaps



Fig. 168 SEFLEX: 5x5 ROD BUNDLE, SERIES 2, TEST-No. 07

Pressure Drop
Along the Test Section:

◇ Total Length: 4196 mm



Decay Heat	120% ANS Standard
Flooding Rate (cold)	3.81 cm/s
System Pressure	2.12 bar
Feedwater Temperature	54°C

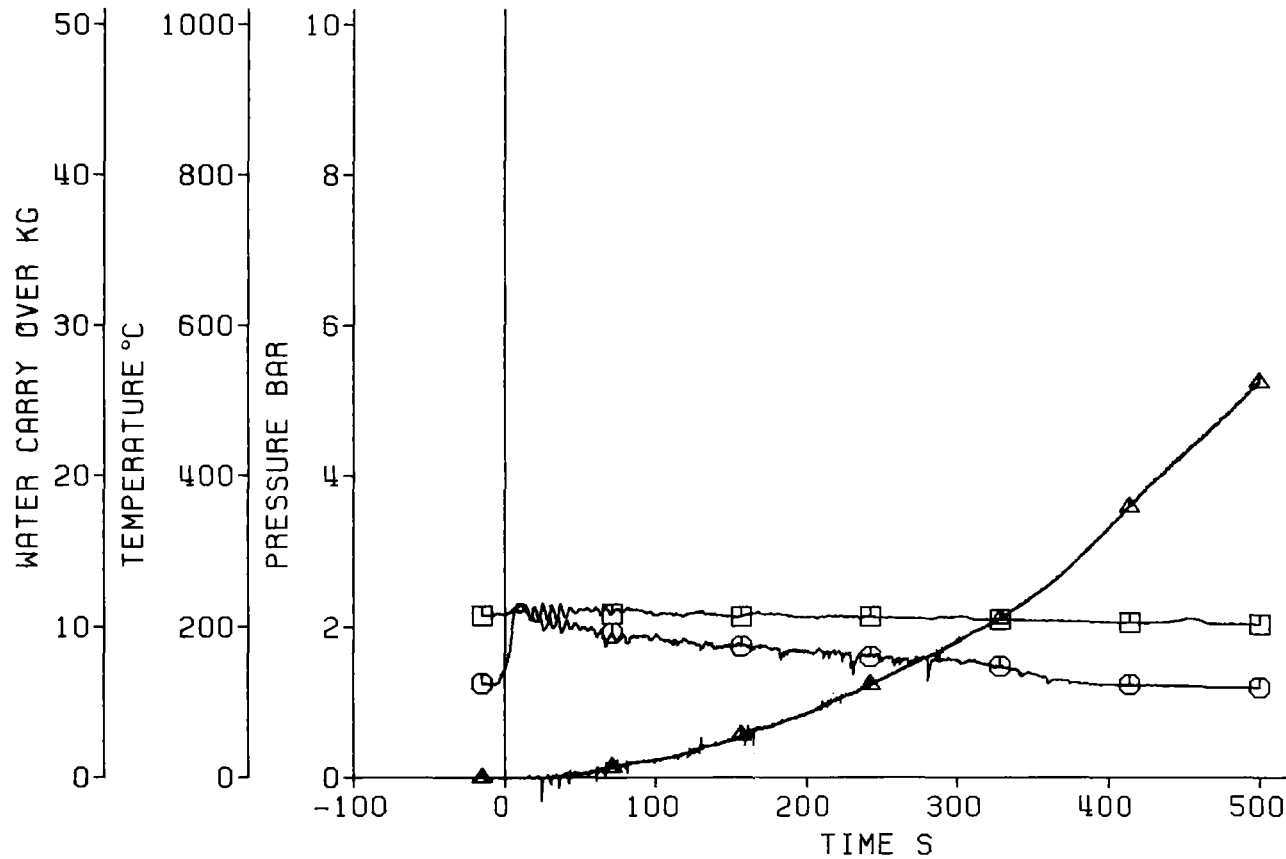
REBEKA Rods With
Argon Filled Gaps



Fig. 169 SEFLEX: 5x5 ROD BUNDLE, SERIES 2, TEST-No. 07

Coolant Outlet Conditions:

△ Water Carry Over
○ Coolant Temperature
□ Coolant Pressure



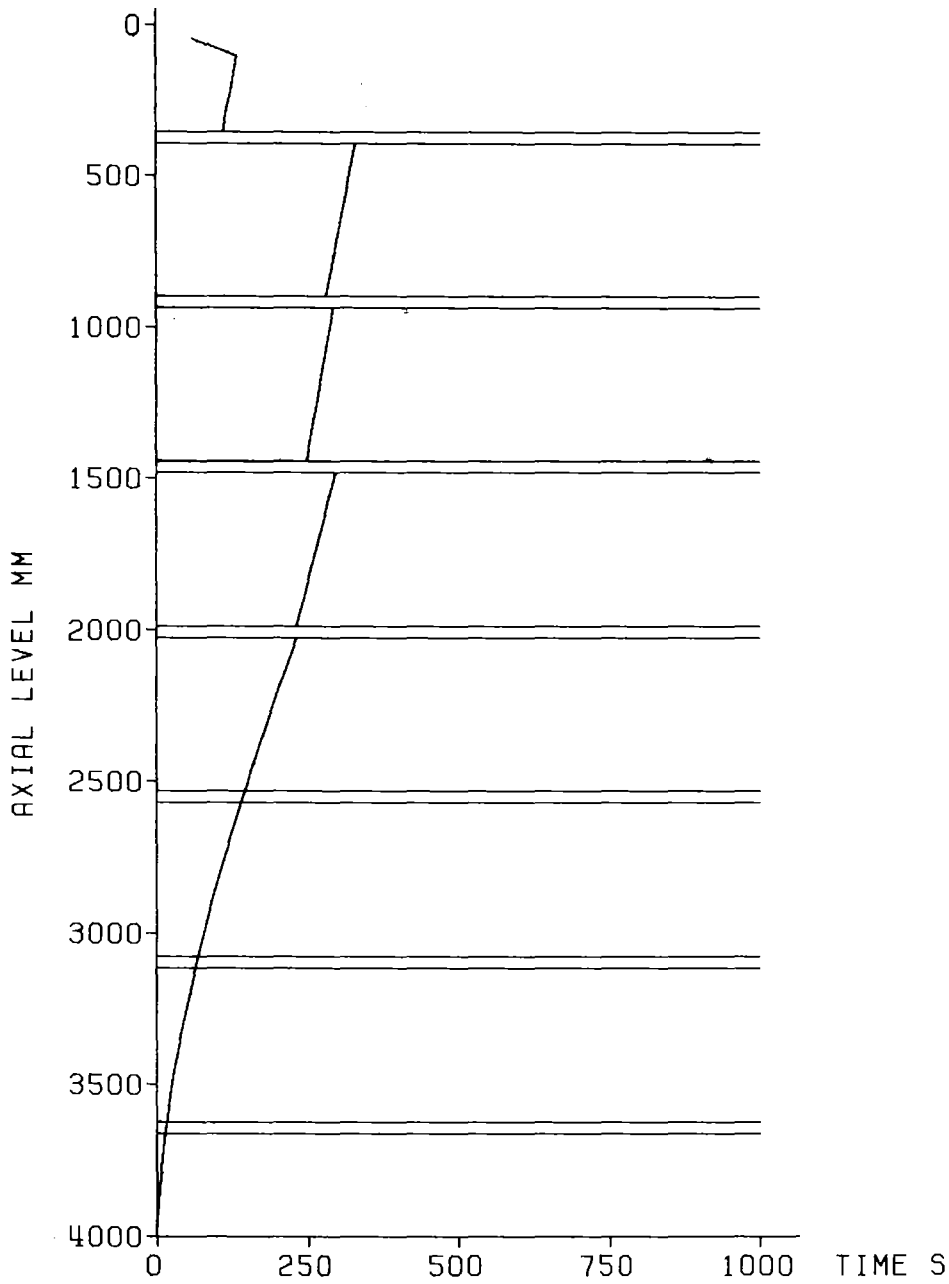
Decay Heat 120% ANS Standard
Flooding Rate (cold) 3.81 cm/s
System Pressure 2.12 bar
Feedwater Temperature 54°C

REBEKA Rods With
Argon Filled Gaps



Fig. 170 SEFLEX: 5x5 ROD BUNDLE, SERIES 2, TEST-No. 07

Axial Position of Quench Front
REBEKA Rods With Argon Filled Gaps



Decay Heat	120% RNS Standard
Flooding Rate (cold)	3.81 cm/s
System Pressure	2.12 bar
Feedwater Temperature	54°C



Fig. 171 SEFLEX: 5x5 ROD BUNDLE
TEST SERIES 2, TEST-No. 07

SEFLEX PROGRAM: TEST SERIES 1 and 2

Test series 1, test No. 01 through 06: Rods with helium-filled gaps between between Zircaloy claddings and alumina pellets; undisturbed bundle geometry with seven grid spacers.

Test series 2, test No. 07: Rods with argon-filled gaps between Zircaloy claddings and alumina pellets; undisturbed bundle geometry with seven grid spacers.

Channel listing and data identification for test No. 01 through 07

Channel No.	Data Identification		Unit	Remarks
	Type	Location		
1	Time (10 Scans/s)		s	t = 0: Start of Reflooding
2	Cladding Temperature	2.c.1.3725 ¹	°C	
3	Cladding Temperature	2.c.2.3825	°C	
4	Cladding Temperature	2.c.3.3925	°C	
5	Cladding Temperature	2.c.4.4025	°C	
6	Cladding Temperature	3.b.1. 45	°C	
7	Cladding Temperature	3.b.2. 590	°C	
8	Cladding Temperature	3.b.3.1135	°C	
9	Cladding Temperature	3.b.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	03 to 07 ⁹
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 1 and 2

Channel No.	Data Identification		Unit	Remarks
	Type	Location		
18	Cladding Temperature	9.k.1. 100	°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	10.f.1.2125 ¹	°C	
23	Cladding Temperature	10.f.2.2225	°C	
24	Cladding Temperature	10.f.3.2325	°C	
25	Cladding Temperature	10.f.4.2425	°C	
26	Cladding Temperature	12.b.1. 45	°C	
27	Cladding Temperature	12.b.2. 590	°C	
28	Cladding Temperature	12.b.3.1135	°C	
29	Cladding Temperature	12.b.4.1680	°C	
30	Cladding Temperature	13.i.1.1875	°C	
31	Cladding Temperature	13.i.2.1925	°C	
32	Cladding Temperature	13.i.3.1975	°C	07 ⁸
33	Cladding Temperature	13.i.4.2025	°C	07 ⁹
34	Cladding Temperature	14.d.1.2025	°C	
35	Cladding Temperature	14.d.2.2025	°C	
36	Cladding Temperature	14.d.3.2025	°C	
37	Cladding Temperature	14.d.4.2025	°C	
38	Cladding Temperature	15.a.1.2225	°C	
39	Cladding Temperature	15.a.2.2770	°C	
40	Cladding Temperature	15.a.3.3315	°C	
41	Cladding Temperature	15.a.4.3860	°C	
42	Cladding Temperature	16.g.1.1625	°C	
43	Cladding Temperature	16.g.2.1725	°C	
44	Cladding Temperature	16.g.3.1825	°C	
45	Cladding Temperature	16.g.4.1925	°C	

SEFLEX PROGRAM: TEST SERIES 1 and 2

Channel No.	Data Identification		Unit	Remarks
	Type	Location		
46	Cladding Temperature	17.h.1.1925	°C	
47	Cladding Temperature	17.h.2.2025	°C	
48	Cladding Temperature	17.h.3.2125	°C	
49	Cladding Temperature	17.h.4.2225	°C	
50	Cladding Temperature	18.a.1.2225 ¹	°C	
51	Cladding Temperature	18.a.2.2770	°C	01 to 05 ⁸ , 06 and 07 ⁹
52	Cladding Temperature	18.a.3.3315	°C	07 ⁸
53	Cladding Temperature	18.a.4.3860	°C	07 ⁸
54	Cladding Temperature	19.g.1.1625	°C	02 to 05 ⁸ , 06 and 07 ⁹
55	Cladding Temperature	19.g.2.1725	°C	05 ⁸ , 06 and 07 ⁹
56	Cladding Temperature	19.g.3.1825	°C	07 ⁹
57	Cladding Temperature	19.g.4.1925	°C	06 ⁸ , 07 ⁹
58	Cladding Temperature	21.d.1.2025	°C	
59	Cladding Temperature	21.d.2.2025	°C	
60	Cladding Temperature	21.d.3.2025	°C	
61	Cladding Temperature	21.d.4.2025	°C	
62	Grid Spacer Temp.	TA ² 355 mm	°C	
63	Grid Spacer Temp.	TA ² 900 mm	°C	
64	Grid Spacer Temp.	TA ² 1445 mm	°C	
65	Grid Spacer Temp.	TA ² 1990 mm	°C	
66	Grid Spacer Temp.	TA ² 2535 mm	°C	
67	Grid Spacer Temp.	TA ² 3080 mm	°C	01 ⁹
68	Grid Spacer Temp.	TA ³ 1478 mm	°C	
69	Grid Spacer Temp.	TA ³ 2023 mm	°C	
70	Grid Spacer Temp.	TA ³ 2568 mm	°C	
71	Fluid Temperature	TF ⁴ 300 mm	°C	04 to 07 ⁹
72	Fluid Temperature	TF ⁵ 485 mm	°C	
73	Fluid Temperature	TF ⁵ 1135 mm	°C	
74	Fluid Temperature	TF ⁵ 1625 mm	°C	

SEFLEX PROGRAM: TEST SERIES 1 and 2

Channel No.	Data Identification		Unit	Remarks
	Type	Location		
75	Fluid Temperature	TF ⁵ 1725 mm	°C	02 to 06 ⁹
76	Fluid Temperature	TF ⁶ 1825 mm	°C	
77	Fluid Temperature	TF ⁵ 1925 mm	°C	
78	Fluid Temperature	TF ⁵ 2240 mm	°C	
79	Fluid Temperature	TF ⁵ 2380 mm	°C	
80	Fluid Temperature	TF ⁵ 2770 mm	°C	
81	Fluid Temperature	TF ⁵ 3038 mm	°C	
82	Fluid Temperature	TF ⁵ 3315 mm	°C	
83	Housing Temperature	TK ⁷ 283 mm	°C	04 to 06 ⁹ 02 and 03 ⁹
84	Housing Temperature	TK 590 mm	°C	
85	Housing Temperature	TK 1135 mm	°C	
86	Housing Temperature	TK 1625 mm	°C	
87	Housing Temperature	TK 1825 mm	°C	
88	Housing Temperature	TK 2025 mm	°C	
89	Housing Temperature	TK 2235 mm	°C	
90	Housing Temperature	TK 2770 mm	°C	
91	Housing Temperature	TK 3018 mm	°C	
92	Housing Temperature	TK 3315 mm	°C	
93	Housing Temperature	TK 3820 mm	°C	
94	Housing Temperature	TK 3915 mm	°C	
95	Temperature at Power Input		°C	
96	Fluid Temperature at Orifice		°C	
97	Fluid Temperature in Lower Plenum		°C	
98	Fluid Temperature in Upper Plenum		°C	
99	Feedwater Temperature		°C	
100	Room Temperature		°C	
101	Electrical Power Input	9 Rods	kW	Rod No. 1 to 9
102	Electrical Power Input	8 Rods	kW	Rod No. 10 to 17
103	Electrical Power Input	8 Rods	kW	Rod No. 18 to 25

SEFLEX PROGRAM: TEST SERIES 1 and 2

Channel No.	Data Identification		Unit	Remarks
	Type	Location		
104	Water Level Detector	4012 mm	°C	Heated and Unheated TC's
105	Water Level Detector	3932 mm	°C	Heated and Unheated TC's
106	System Pressure in Buffer		bar	
107	Flooding Velocity (cold bundle)		cm/s	
108	Pressure in Upper Plenum	-105 mm	bar	
109	Pressure in Lower Plenum	4091 mm	bar	
110	Bundle Power		kW	Channels: 101 + 102 + 103
111	Water Carry Over Collected		kg	Downstream of Bundle Exit
112	Pressure Diff.	4091 and -105 mm	bar	

- 1) TC's of 0.36 mm diameter embedded in rod cladding. Measuring position Example: rod No. = 2, type of rod instrumentation = c, TC No. = 1, Axial level = 3725 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. 13, 18, 17 and 12.
- 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. 8, 13, 12 and 7.
- 4) TF = TC's of 0.25 mm diameter (bare) placed in subchannel surrounded by rods No. 7, 12, 11 and 6.
- 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. 2, 7, 6 and 1.
- 7) TK = TC's of 0.5 mm diameter placed in the wall of the bundle housing of 6.5 mm thickness.
- 8) TC failed partly in test No.
- 9) TC failed in test No.