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A STUDY OF CRBR OUTLET PLENUM THERMAL OSCILLATIONS DURING STEADY STATE CONDITIONS

by

J. J. Lorenz and P. A. Howard

Components Technology Division

Argonne National Laboratory

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TECHNICAL MEMORANDUM

ANL-CT-76-36
LMFBR Reactor Core Systems (UC-79e)
LMFBR Structural Materials
and Design Engineering (UC-79h)

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ABSTRACT

An experimental investigation of CRBRP outlet plenum temperature oscillations during steady state conditions was conducted. Tests were performed using water with a 1/10-scale model of the CRBRP upper plenum complete with Upper Internal Structure (UIS). The radial blanket/fuel assembly temperature difference was adjusted such that Froude number (ratio of buoyant to inertial forces) similitude of model and prototype was obtained. Temperature-time plots were obtained at 47 critical locations within the plenum. Power spectral density (PSD) analysis at particular locations was implemented to examine the frequency range of the temperature oscillations.

It was found that outlet plenum temperature oscillations in excess of 30% (peak to peak) of the fuel/blanket ΔT occur only within the clearance gap (between lower part of the UIS and top of the core) and within the UIS mixing chamber in the region above the blanket assemblies. Power spectral density analysis revealed that the oscillations were in the frequency range of 0-3 Hz (0-1.2 Hz prototype). Outside the UIS, most components were nearly at the mixed mean plenum temperature and oscillations were generally less than 10% of the fuel/blanket ΔT. Instrument post thermocouples were found to provide an accurate indication of the fuel and blanket assembly temperatures (except for the outermost blanket thermocouple which was apparently affected by the warmer recirculating fluid above the blanket region). Leakage flow at the clearance gap was found to be 7.8% (of the total flow) and 12.5% (of the total flow) for the 0.254 cm gap (nominal) and 0.508 cm gap, respectively. Doubling the leakage gap had a negligible influence on plenum temperatures; when the gap was eliminated altogether, only temperatures in the immediate neighborhood of the gap were affected.

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I. Introduction

Due to the thermal environment anticipated in the Upper Internal Structure (UIS) of the Clinch River Breeder Reactor (CRBR), the present design requires protective Inconel 718 liners on portions of the UIS structure. Upper plenum design concerns must be evaluated for both transient and steady state operation. During transient conditions, buoyancy-induced flow stratification must be considered [1-5]. Furthermore, during steady state conditions, temperature oscillations ("thermal striping") arising from the temperature mismatch of the coolant exiting from the fuel and blanket regions must be evaluated. Data supporting an early UIS design were obtained at Battelle-Columbus Laboratory [4,5]. In view of subsequent design changes, additional test data are required to verify the adequacy of the present UIS design. It is also necessary to verify certain CRBR design decisions that were made on the basis of preliminary 2-D water table tests at W-ARD [6].

A comprehensive experimental program is being conducted at ANL (under 189a CA056) to address the problem of CRBR upper plenum mixing during steady state and transient conditions. The objectives as specified in reference [7] are: 1) to measure outlet plenum thermal oscillations ("thermal striping") during steady state operation; 2) to determine the outlet plenum spatial temperature distribution for a U-1b transient event; 3) to measure thermal oscillations at the hot/cold interface as the interface advances to the top of the plenum during a U-1b transient; 4) to determine the steady state temperature distribution in the outlet plenum; 5) to determine the effect of clearance gap (between the UIS and top of the core) on outlet plenum temperatures for steady state and transient conditions; 6) to measure leakage flow through the clearance gap; and 7) to determine whether instrument post thermocouples give an accurate indication of the fuel and blanket assembly temperatures.

The steady state portion of the testing has been completed and is reported herein. Objectives 1, 4, 5, 6, and 7, were addressed. (Transient testing is in progress and will be reported in the near future). All tests were performed using water with a 1/10-scale model of the most recent CRBRP UIS design. It has previously been shown that small scale testing with water adequately simulates full scale plenum behavior [2]. In all testing Froude number (ratio of buoyant to inertial forces) similitude between model and prototype is satisfied.

II. Experimental Program

A. Facility

The facility is shown in Figure 1 and a summary of operating ranges is given in Table I. Essentially the loop is a modified version of that which was employed in previous 1/15-scale studies [3]. This modified loop was designed with the flexibility of providing pressure-induced flow, pump-induced flow, or a combination of both. Generally the loop was operated in a once-through mode.

The 0.36 m^3 blanket tank, shown in Figure 1, does not exist at the present time. Radial blanket flow during steady state conditions is derived from the 1.41 m^3 secondary tank. Fuel assembly flow is derived from the large 8.8 m^3 tank. The temperature and flowrate of both the fuel and blanket can be varied independently. During steady state operation the fuel/blanket temperature difference was set at about 38°C. Typically, the fuel and blanket flowrates were about 1.26×10^{-2} m^3/s (200 gpm) and 0.21×10^{-2} m^3/s (34 gpm) respectively.

B. Plenum Test Section

Figures 2 and 3 show the pressure vessel which was designed to readily accommodate liners and upper internal structures which simulate various outlet plenum geometries. The pressure vessel is fabricated of carbon steel with inside dimensions of 78.74 cm (dia.) by 66.04 cm high. A maximum useful diameter of 45.72 cm is provided at the plenum base to accommodate simulated large core configurations. The overall dimensions of the CRBR liner and UIS are given in Figure 2. Radial blanket flow enters the outer part of the lower cone structure via six feed lines and flows upward through an annular passage surrounding the simulated fuel assembly region. Figure 4 is a photograph of the lower cone and six feed lines for radial blanket flow. Figure 5 is a view looking down into the pressure vessel with the UIS and simulated core plate removed. A hexagonal barrier separates the fuel flow (which enters through the large central portion) from the blanket flow (which enters through six ports in the outer region). During operation the fuel and blanket flow passes upward through a simulated core plate (Figure 6) which is mounted at the plenum base.

The fully mocked-up 1/10-scale CRBRP UIS and plenum liner is shown in Figure 7. After being instrumented this entire structure is inserted into the pressure vessel. The liner was fabricated of a transparent material (Lexan) to permit visualization of the plenum flow patterns through the view port in the pressure vessel. Table II provides a description of all major plenum components; photographs are given in Figures 8 thru 12. The UIS is oriented within the plenum such that the 0° azimuth (Figure 9) is in line with the exit nozzle which is located at 1 o'clock in Figure 5.

The clearance gap between the lower part of the UIS mixing chamber and the top of the core is shown in Figures 12 and 13. Specified gap spacings are maintained by washers located between the leakage flange and plenum base. (The plenum base and top of the core lie in the same horizontal plane). As shown in the photographs and indicated in Figure 13, leakage flow is blocked over azimuthal sectors where the outer surface of the leakage flange touches the inner surface of the core barrel cap.

C. Instrumentation

Table I provides a list of instrumentation (with associated accuracy) employed in this study. Outlet plenum temperatures are recorded by 47 thermocouples at locations specified in Table III and Figures 14 thru 16. Two additional thermocouples monitor the blanket and fuel assembly temperatures. Leakage flow is measured by a differential pressure method similar to that employed by Battelle-Columbus Laboratory [4]. The system is calibrated by measuring the differential static pressure across the gap as a function of known leakage flowrates. Known leakage flowrates were obtained by capping off the chimneys in which case the leakage flow is identical to the flowrate of the fluid entering the mixing chamber. Figure 17 shows the calibration data and the pitot static tube location (also see Figure 5).

All data are recorded by an HP 2112 solid state expandable memory mini-computer and permanently stored on disk. Subsequently the data will be transferred to magnetic tape. (A tape drive has recently been obtained but has not yet been incorporated into the system).

Each channel of data is recorded at slow speed (1 sample/sec) for the first 290 sec and then at high speed (50 samples/sec) for 40.96 seconds. The purpose of the slow speed recording rate over a long time is to verify that steady state conditions have been established. The next 40.96 seconds of high speed data is the only portion of the run used for final data reduction.

D. Data Reduction

All temperatures are nondimensionalized as follows:

$$T' = \frac{T - T_B}{T_F - T_B}$$

where T is the measured temperature, and T_F and T_B are the fuel and blanket assembly exit temperatures, respectively. Values of root mean square (RMS) temperature are also dimensionless and must be multipled by $(T_F - T_B)$ to obtain the RMS temperature in degrees. Values of peak to peak oscillations referred to in the text are not the maximum peak to peak oscillations obtained from the temperature-time plots. Instead an "effective" peak to peak oscillation is calculated assuming that the fluctuation is a perfect sinusoid; i.e., peak to peak = 2 x $\sqrt{2}$ x RMS. The maximum peak to peak oscillations will, of course, exceed these "effective" values.

Times and frequencies are referred to the model. Prototype times and frequencies are calculated with the aid of the time scale ratios given in Table IV. The time scale ratio of model/prototype, τ, is defined as:

$$\tau = \frac{L_r}{V_r}$$

where V_r and L_r are the velocity and length scale ratios respectively. The frequency ratio, f_r, is simply the inverse of the time scale ratio; i.e., $f_r = \frac{V_r}{L_r}$. Viewed another way, this frequency ratio implies Strouhal number ($S = fL/V$) similitude between model and prototype; i.e., $S_r = 1 = \frac{f_r L_r}{V_r} \longrightarrow f_r = \frac{V_r}{L_r}$.

Power spectral density (PSD) distributions are calculated for thermocouples where significant oscillations were observed. A digital computer program was employed, following a procedure outlined by Newland [8]. Instead of calculating the PSD as the Fourier transform of the autocorrelation function, Newland gives an algorithm for calculating the PSD directly from the discrete Fourier transform of the data. Also, a fast Fourier transform technique is employed to enhance the efficiency of the algorithm.

The digital computer program for calculating PSDs was incorporated into the software of our mini-computer. Due to computer core storage limitations, it was not possible to process the entire 40.96 seconds worth of data (2048 data points per channel; i.e., 50 samples/sec x 40.96 sec). Instead the data were broken into two segments each 20.48 seconds (1024 data points) long. The PSDs were calculated separately for each 20.48 second segment and then averaged together. Before the averaging was effected, the two separate PSDs were in general substantially similar; the averaging merely fine tuned the PSD. The frequency range of the PSDs is 0 to 25 Hz with a resolution of .05 Hz. As a check on accuracy and consistency, the RMS values were calculated in two ways: 1) directly from the input data; and 2) as the square root of the area under the PSD plots. It was found that both methods yielded similar results. In this report the PSDs are expressed as $(RMS)^2/Hz$, where the RMS is dimensionless. To convert to $(degrees)^2/Hz$, multiply by $(T_F - T_B)^2$.

III. Experimental Results

A. Leakage Flow

Figure 18 shows the flow pattern within the mixing chamber during steady state conditions. Toward the inner fuel assembly region the coolant flows directly upward into the chimneys. In the outer fuel assembly and blanket assembly regions, the flow pattern is considerably different. Note the recirculation zone above the blanket assembly region. (Although flow visualization was not possible within the mixing chamber, the existence of a recirculation zone was confirmed in simple 2-D water table tests at W-ARD [6]. A portion of the recirculation fluid exits at the clearance gap.

Using the method described in Section II-C, leakage flow was measured for clearance gaps of 0.254 cm (nominal) and 0.508 cm. For each gap size, leakage flow was measured for different fuel/blanket assembly flowrate ratios. The results are plotted in Figure 19 as leakage flow (% of total flow) versus blanket flow (% of total flow); total flows ranged from 8.19 x 10^{-3} m^3/s (130 gpm) to 15.8 x 10^{-3} m^3/s (252 gpm). For a given gap size it can be seen that % leakage flow is a unique function of % blanket flow and this functional relationship is independent of total flow. For both gap sizes, % leakage flow increases with % blanket flow. However leakage is a stronger function of blanket flow for the larger gap. Since the curves in Figure 19 are not flat, it is apparent that the mixing chamber does not act as a perfect manifold which delivers flow to the chimneys and gap according to a simple lumped-parameter hydraulic resistance concept. (A simple hydraulic resistance model would predict a unique chimney/gap flow split for a given total flow). For nominal blanket flow conditions of 15%, the corresponding leakage flowrates for the 0.254 cm and 0.504 cm gaps are 7.8% and 12.5%, respectively.

When the lines to the differential pressure transducer were adequately bled of air bubbles and when the transducer was "behaving" properly, the estimated accuracy of leakage flow is ± 3.15 x 10^{-5} m^3/s (± 0.5 gpm). Occasionally the transducer failed to return to zero at the completion of a run when there was no leakage flow. When this occurred, the measured flowrate was discarded. Measurements of leakage flow were not extremely sensitive to the azimuthal orientation of the pressure tap orifice about the pitot tube longitudinal axis of symmetry. A maximum change of only about 5% was observed in the measured leakage flow during a 180° rotation of the probe about its axis. Among other things this implies that negligible impacting occurs, which is a necessary requirement for the measurement technique to be valid.

B. Plenum Temperatures

1. Description of Tests

A summary of runs and test parameters is given in Table IV. In most cases more than one run was conducted for a given gap in order to assess reproducibility. With the exception of run SS01, which was a "scoping" run, all thermocouples were positioned at locations specified in Table III and Figures 14-16. In run SS04, chimney exit TC's were positioned at locations denoted by "A" in Figure 16.

In all runs, the attainment of steady state was assured by examining the temperature-time plots over a sufficiently long time interval. Generally, steady state was achieved within about 30 seconds during which time data were recorded at slow speed (1 sample/sec). After steady state was verified, high speed data (50 samples/sec) were taken for the next 40.96 sec. This final 40.96 seconds of high speed data was the only portion of the run used for final data reduction.

Tables V through X summarize the results of individual runs. At the bottom of each Table, note the good agreement between the mixed mean temperature (calculated on the basis of the inlet temperatures and flowrates) and the average exit temperatures (calculated as the average of the three exit temperatures). Also, by comparing temperatures at similar locations in runs with identical gaps, it can be seen that reproducibility of the data is very good. Any small differences in temperatures can be attributed to slight variations in the % blanket flow.

2. Results for Nominal Gap

Mean temperature maps for run SS05 (typical run for 0.254 cm nominal gap) are provided in Figures 20, 21, 22; temperature-time plots over a 35 second interval are given in Figures 23-32; and power spectral densities at particular locations are plotted in Figures 33-40.

The temperature map in Figure 20 shows that the suppressor plate temperature at the plenum centerline is nearly equal to unity and decreases with increasing radial distance. The vessel liner and support columns (except TC#35) are nearly at the mixed mean plenum temperature, i.e., $T' \sim 0.85$. Table VI reveals that the RMS temperature at these locations does not exceed RMS $\approx$ 0.03; and the temperature-time plots show that the peak to peak oscillation does not exceed about 10% of the fuel/blanket ΔT. For a prototypic fuel/blanket ΔT of 66.6°C, this represents a peak to peak ΔT of only 6.6°C. Thermocouple #35, located at the bottom of the support column near the lower support plate, is influenced by leakage flow and exhibits significantly larger oscillations than observed at the previously discussed locations. From Table VI and the temperature-time plot, it is found that RMS $\approx$ 0.05 and the peak to peak oscillation is about 16% of the fuel/blanket ΔT. From the power spectral density plot for TC#35 (see Figure 38), the oscillations are seen to occur in the range 0-1 Hz. In terms of the prototype the foregoing represents a peak to peak $\Delta T \approx$ 10.6°C with frequencies in the range 0-0.4 Hz.

The three exit nozzle mean temperatures plotted in Figure 20 were measured at the nozzle center. In scoping run SS01, the nozzles were instrumented with vertical and horizontal thermocouple "rakes." It was found that no mean temperature gradients exist within the nozzles.

Figure 22 provides a temperature map of the chimney exits. Temperatures at locations "A" (see Figure 16) for run SS04 are also plotted. It can be seen that a rather modest circumferential temperature gradient is present within most chimneys. Chimneys which are totally within the fuel assembly region see mostly fuel assembly flow and hence the temperatures are equal to unity. On the other hand chimneys above the blanket/fuel interface see a mixture of fuel and blanket flow and hence a lower temperature. The largest thermal oscillations in the chimneys were observed at TC#24, but even those values were relatively small; i.e., RMS $\approx$ 0.04, peak to peak $\approx$ 12% of the ΔT (also see PSD in Figure 40).

A temperature map of the core barrel cap and inside the UIS mixing chamber is given in Figure 21. (Corresponding thermocouple locations are identified in Figure 15.) In the prototype the purpose of the instrument post thermocouples is to measure the temperature of the effluent from the respective assemblies located immediately below. Figure 21 shows that the instrument post thermocouples in the fuel and blanket regions measure the proper temperatures (except for TC#1 which measures $T' = 0.19$). Actually blanket thermocouples #4 and #7 read $T' = 0.04$ and 0.02, respectively, rather than zero. Apparently this is caused by the influence of warmer recirculating fluid in the region above the blanket assemblies, see Figure 18. The warm recirculating fluid has a much more dramatic effect on TC#1, producing a relatively large mean temperature at that location. Also, the thermal oscillations are relatively large. From Table VI, the temperature-time plots, and the PSD plot in Figure 34, the following values are obtained for TC#1: RMS = 0.097, peak to peak oscillation $\approx$ 30% of the ΔT, and the frequency range is 0-3 Hz. (Recall from Section II D that the peak to peak oscillation is calculated as $2 \times \sqrt{2} \times$ RMS. From the temperature-time plots the maximum peak to peak oscillation is nearly 40%.) In terms of the prototype, the peak to peak ΔT is about 20°C with a frequency range of 0-1.2 Hz. Oscillations of nearly the same magnitude were observed at the outermost thermocouple on the top of the mixing chamber (TC#16) and the outermost thermocouple on the instrument post top (TC#18), see Table VI and PSDs in Figures 36 and 37. At locations inboard of these, the oscillations were considerably smaller.

Relatively large oscillations were observed in the leakage gap. For example, at $\Theta = 30°$ (TC#43) where the mean is $T' = 0.38$, the peak to peak fluctuations were 30% of the ΔT. After exiting the leakage gap, the leakage flow mixes with fluid at the mixed mean plenum temperature and then impinges upon the inner surface of the core barrel cap. This mixing causes the mean fluid temperature to increase from $T' = 0.38$ at TC#43 (in the gap) to $T' = 0.58$ at TC#42 (inner surface of core barrel cap). The temperature-time plots reveal that the peak to peak oscillations at TC#42 are reduced to about 15% of the ΔT, and the PSD in Figure 39 shows that the frequency range is about 0-1 Hz. At the top center of the core barrel cap (TC#41) the mean temperature is $T' = 0.82$ and the oscillations are relatively small.

3. Comparison of Results for Different Gaps

Comparisons of mean and RMS temperatures for runs SS12 (no gap), SS05 (0.254 cm gap), and SS07 (0.508 cm gap) are given in Tables XI and XII.

At all thermocouple locations (except possibly TC#42) there is a negligible difference between data for the 0.254 cm and 0.508 cm gap. Furthermore, only at locations directly affected by leakage is there a significant difference between run SS12 (no gap) and the others. Referring to Tables XI and XII, the following locations are seen to reflect the greatest variance: TC#42, 45 (inside vertical surface of core barrel cap); TC#32, 33 (outside UIS mixing chamber skirt); and 35 (lower support plate). With zero leakage flow the temperatures at those locations tend to approach the mixed mean plenum temperature. It is also interesting to observe that the mean temperature of TC#1 (bottom of outermost blanket instrument post) increases in run SS12. Apparently this is a result of the fact that there is no gap to provide a "heat sink" for the recirculating flow in the region above the blanket assemblies.

IV. Conclusions

1) For a given clearance gap (between UIS and top of core) the leakage flow (% of total) is a unique function of blanket flow (% of total). For both the 0.254 cm gap (nominal) and 0.508 cm gap, the % leakage flow increases with % blanket flow. However, leakage flow is a stronger function of blanket flow for the larger gap. For nominal blanket flow conditions of 15%, the corresponding leakage flow was 7.8% and 12.5% for the 0.254 cm gap and 0.508 cm gap, respectively.

2) In general, outlet plenum thermal fluctuations of significant magnitude (peak to peak $\approx$ 30% of the fuel/blanket ΔT) were observed only within the UIS mixing chamber in the region above the blanket assemblies and in the leakage gap. A power spectral density analysis revealed that the oscillations were in the range of 0-3 Hz (0-1.2 Hz prototype). Oscillations at the inner surface of the core barrel cap were less severe; i.e., $\approx$ 15% of the ΔT.

3) Outside the UIS, most components were nearly at the mixed mean plenum temperature. Temperature-time plots revealed that the peak to peak oscillations at these locations do not exceed about 10% of the fuel/blanket ΔT. Oscillations at the exits of chimneys located above the blanket/fuel interface were somewhat larger but still relatively small (<12% of the fuel/blanket ΔT).

4) Instrument post thermocouples were found to provide an accurate indication of the fuel and blanket assembly temperatures (except for the outermost blanket thermocouple which measured $T' = 0.19$ instead of zero). Apparently the outermost thermocouple is affected by the warmer recirculating fluid in the region above the blanket assemblies.

5) The difference in outlet plenum temperatures for the 0.254 cm and 0.508 cm gaps was extremely small. When the gap was eliminated altogether, only temperatures in the immediate neighborhood of the gap were affected.

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Table I. Summary of Facility Operating Ranges and Accuracy

Flow:

Initial core flow - the loop flowrate is conservatively estimated at $2.52 \times 10^{-2} m^3/s$ (400 gpm) in the once-thru mode: Running time is dependent upon flowrate since upstream reservoir is fixed at 8.8 m^3. At $2.52 \times 10^{-2} m^3/s$ (400 gpm) the maximum run time is approximately five minutes. In the recirculating mode, the run time is unlimited.

Shutdown flow - A 1.44 m^3 secondary tank with a maximum flowrate of $1.38 \times 10^{-2} m^3/s$ (220 gpm) is available. If necessary this tank can be supplemented with an additional tank. At a typical shutdown flowrate of $1.88 \times 10^{-3} m^3/s$ (30 gpm) the maximum run time is about 10 minutes.

Flow Control: (Refer to Figure 1)

Fuel flow - Steady flow will be obtained by V10; coastdown by V11, V14.

Blanket flow (Steady State) - V22, V25.

Shutdown flow - V1, V2, V7.

Operating Pressures and Temperatures:

8.8 m^3 vessel:	$0\text{-}1.72 \times 10^5$ Pa	& 12°-93°C	(0-25 psi & 55-200°F)
1.41 m^3 vessel:	$0\text{-}2.06 \times 10^5$ Pa	& 12°-93°C	(0-30 psi & 55-200°F)
Model Plenum :	$0\text{-}2.75 \times 10^5$ Pa	& 12°-93°C	(0-40 psi & 55-200°F)

Density Change:

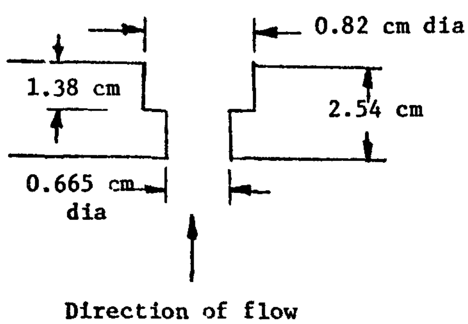
Brine - 20% NaCl by weight	$\Delta\rho/\rho$ = 13.8%
Water - 93°C to 15°C change	$\Delta\rho/\rho$ = 3.5%

Instrumentation:

Description	Range	Accuracy
Thermocouples, chromel-constantan, 0.25 mm, 10 milli-second response	0 to 93°C	± 0.55°C
Flowmeters	FM-1: 5.0×10^{-3} to $50.0 \times 10^{-3} m^3/s$	± 1% of reading
	FM-2: 8.8×10^{-4} to $88. \times 10^{-4} m^3/s$	
Differential Pressure Transducer	$0\text{-}3.15 \times 10^{-3} m^3/s$ (0-50 gpm)	$\pm 3.15 \times 10^{-5} m^3/s$ (± 0.50 gpm)
Hydrometers	.95 < sp. gr. <1.2	± .001
Multiplexer	±10 mv	± .002 mv

Table II Description of 1/10-Scale CRBR Upper Plenum Components

Component	Basic Dimensions
Plenum Vessel Liner, Figure 7	I. D.=59.30 cm Height = 58.98 cm
Exit Nozzles (3), Figure 7	I. D.= 8.89 cm
Suppressor Plate, Figure 7	59.30 cm dia.
Inlet Cone, Figure 4	
Blanket/Fuel Partition, Figure 5, 6	17.78 cm flat to flat
Chimneys (29) + webs, Figure 8.	I. D. = 2.66 cm, O.D. = 3.34 cm
Shroud Tubes (19), Figure 8	O. D. = 1.27 cm
Upper Support Plate, Figure 8	O. D. = 30.35 cm, thickness = 0.762
Lower Support Plate, Figure 8	O. D. = 30.32 cm, thickness = 1.84
Mixing Chamber, Figure 8	I. D. = 26.94 cm, height = 5.84
Lower Skirt Boundary (Leakage Flange): Figures 8, 9 . . .	
Core Barrel Cap, Figures 8, 9	I. D. = 33.57 cm, O.D. = 39.75 cm thickness = 0.762 cm
Instrument Post (98), Figures 9, 10, 11	
Support Columns (4), Figures 8.	
Shear web, Figure 8	
Simulated Core Plate, Figure 6 (also see below)	
Fuel. . . . . 217 holes	Hexagonal array/1.16 cm triangular pitch; fuel region includes 19 control assemblies and 198 fuel assemblies.
Blanket . . . . 150 holes	



Cross-section of core plate through typical flow passage

TABLE III Outlet Plenum Thermocouple Locations

Location*	Thermocouple No.
Chimney Exits, Figure 16	21-26
Leakage Gap, Figure 15	43, 46, 47
Instrumentation Post (bottom center), Figure 15	1, 3, 4, 6, 7
Instrumentation Post Top, Figure 15	18, 19, 20
Top of UIS Mixing Chamber, Figure 15	9, 16
Inside UIS Mixing Chamber Skirt (60°, in middle of skirt) Figure 14	17
Core Barrel Cap (one on inside vertical surface in center and one on top surface in center for 30° and 60° azimuths), Figures 14, 15	41, 42, 44, 45
Outside UIS Mixing Chamber Skirt Figure, 14.	
30°, 1.27 cm from bottom	32
60°, 1.27 cm from bottom	33
Support Column, Figures 14, 16	34, 35, 36-40
Vessel Liner (all at Θ = 0), Figure 14	10-15
Inside UIS Shear Web (on central chimney at Θ = 90°), Figure 14	29, 30, 31
Suppressor Plate (at Θ = 0), Figure 14	27, 28
Outlet Nozzles (one in center each nozzle), Figure 14,	
Θ = 0	5
Θ = 120°.	8
Θ = 240°.	2

* Dimensions specified here and in the Figures are model dimensions: the Figures provide radial and azimuthal locations

Table IV. Summary of Runs and Test Parameters

RUN	Gap, cm	TEMP, °C		FLOWRATE, $10^{-4} m^3/s$ (gpm)		Ratio(1) (model/prot)		
		T_B	T_F	Blanket	Fuel	Re	Fr(2)	τ(3)
SS01	0.254	14.33	58.17	19.95 (31.66)	119.35 (189.44)	0.012	1.2	0.42
SS04	0.254	14.57	50.69	21.19 (33.6)	117.51 (186.32)	0.012	1.2	0.42
SS05	0.254	14.01	56.59	21.92 (34.75)	120.28 (190.69)	0.012	1.2	0.42
SS06	0.508	14.73	52.09	21.73 (34.45)	116.47 (184.71)	0.012	1.2	0.42
SS07	0.508	14.13	54.17	21.29 (34.45)	118.61 (188.0)	0.012	1.2	0.42
SS08	0.508	14.57	53.37	22.01 (34.88)	126.49 (200.56)	0.012	1.2	0.42
SS12	0.0	15.00	55.36	20.95 (33.21)	128.15 (203.16)	0.012	1.2	0.42

Notes:

(1) Based on prototype total flow of 6.0 m^3/s (95,800 gpm) and 66.67°C fuel/blanket ΔT.

(2) Modified Froude number (or Richardson number), $Fr = \frac{\Delta\rho L g}{\rho V^2}$, where Δρ is based on on the fuel/ blanket ΔT.

(3) τ ≡ time scale.

Table V Summary of Results for Run SS04

DATA SET NAME SS04 DATE CALCULATED 6/7/76
T_F =50.69C (123.24F) T_B =14.54C (58.18F)
5/14/76 CRBR
WATER ONLY
.254 CM (.1 INCH) GAP

TC # 1	MEAN TEMP = .20264	RMS = .99213E-01
TC # 2	MEAN TEMP = .84218	RMS = .14266E-01
TC # 3	MEAN TEMP = .99729	RMS = .24086E-02
TC # 4	MEAN TEMP = .04065	RMS = .41839E-01
TC # 5	MEAN TEMP = .85379	RMS = .86018E-02
TC # 6	MEAN TEMP = .99833	RMS = .24880E-02
TC # 7	MEAN TEMP = .03458	RMS = .30488E-01
TC # 8	MEAN TEMP .85493	RMS = .12092E-01
TC # 9	MEAN TEMP = .88746	RMS = .13842E-01
TC # 10	MEAN TEMP = .82506	RMS = .17961E-01
TC # 11	MEAN TEMP = .85210	RMS = .91621E-02
TC # 12	MEAN TEMP = .85408	RMS = .99453E-02
TC # 13	MEAN TEMP = .85108	RMS = .11429E-01
TC # 14	MEAN TEMP = .85106	RMS = .15392E-01
TC # 15	MEAN TEMP = .85813	RMS = .24845E-01
TC # 16	MEAN TEMP = .54827	RMS = .67999E-01
TC # 17	MEAN TEMP = .73306	RMS = .18301E-01
TC # 18	MEAN TEMP = .53140	RMS = .75367E-01
TC # 19	MEAN TEMP = .80099	RMS = .24199E-01
TC # 20	MEAN TEMP = .86881	RMS = .18595E-01
TC # 21	MEAN TEMP = .77283	RMS = .31996E-01
TC # 22	MEAN TEMP =1.00019	RMS = .18612E-02
TC # 23	MEAN TEMP = .97190	RMS = .34585E-02
TC # 24	MEAN TEMP = .77331	RMS = .26564E-01
TC # 25	MEAN TEMP =1.00335	RMS = .23934E-02
TC # 26	MEAN TEMP = .55680	RMS = .21566E-01
TC # 27	MEAN TEMP = .98657	RMS = .22890E-02
TC # 28	MEAN TEMP = .94573	RMS = .20631E-01
TC # 29	MEAN TEMP = .94148	RMS = .84565E-02
TC # 30	MEAN TEMP = .93437	RMS = .54779E-02
TC # 31	MEAN TEMP = .96630	RMS = .74077E-02
TC # 32	Inoperative	
TC # 33	Inoperative	
TC # 34	Inoperative	
TC # 35	Inoperative	
TC # 36	MEAN TEMP = .96970	RMS = .83386E-02
TC # 37	MEAN TEMP = .84080	RMS = .21239E-01
TC # 38	MEAN TEMP = .84025	RMS = .15991E-01
TC # 39	MEAN TEMP = .85070	RMS = .15247E-01
TC # 40	MEAN TEMP = .85483	RMS = .11847E-01
TC # 41	MEAN TEMP = .81961	RMS = .25407E-01
TC # 42	MEAN TEMP = .59399	RMS = .48955E-01
TC # 43	MEAN TEMP = .41162	RMS = .99066E-01
TC # 44	MEAN TEMP = .83339	RMS = .17541E-01
TC # 45	MEAN TEMP = .63401	RMS = .47840E-01
TC # 46	MEAN TEMP = .60093	RMS = .72618E-01
TC # 47	MEAN TEMP = .62315	RMS = .31019E-01

MEAN BLANKET FLOW = .2119E-02 CUBIC METERS PER SEC. RMS = .11392E-04
MEAN TOTAL FLOW = .1387E-01 CUBIC METERS PER SEC. RMS = .10460E-03
MEAN LEAKAGE = .1082E-02 CUBIC METERS PER SEC. RMS = .38862E-04
AVERAGE EXIT TEMP = .8503 MIXED MEAN = .8472

Table VI Summary of Results for Run SS05

DATA SET NAME SS05 DATE CALCULATED 6/7/76
T_F =56.59C (133.87F) T_B =14.01C (57.22F)
5/19/76
CRBR, WATER ONLY
.254 CM (.1 INCH) GAP

TC # 1	MEAN TEMP = .19367	RMS =	.96992E-01
TC # 2	MEAN TEMP = .83287	RMS =	.13157E-01
TC # 3	MEAN TEMP = .99589	RMS =	.17052E-02
TC # 4	MEAN TEMP = .03683	RMS =	.37503E-01
TC # 5	MEAN TEMP = .84909	RMS =	.11130E-01
TC # 6	MEAN TEMP = .99632	RMS =	.20859E-02
TC # 7	MEAN TEMP = .02226	RMS =	.20360E-01
TC # 8	MEAN TEMP = .85275	RMS =	.13066E-01
TC # 9	MEAN TEMP = .88619	RMS =	.13918E-01
TC # 10	MEAN TEMP = .82635	RMS =	.22009E-01
TC # 11	MEAN TEMP = .84999	RMS =	.87042E-02
TC # 12	MEAN TEMP = .85016	RMS =	.10865E-01
TC # 13	MEAN TEMP = .84723	RMS =	.12869E-01
TC # 14	MEAN TEMP = .84654	RMS =	.16054E-01
TC # 15	MEAN TEMP = .26432	RMS =	.31073E-01
TC # 16	MEAN TEMP = .53745	RMS =	.64823E-01
TC # 17	MEAN TEMP = .72029	RMS =	.21097E-01
TC # 18	MEAN TEMP = .52713	RMS =	.69174E-01
TC # 19	MEAN TEMP = .79629	RMS =	.26835E-01
TC # 20	MEAN TEMP = .86573	RMS =	.19655E-01
TC # 21	MEAN TEMP = .70656	RMS =	.34396E-01
TC # 22	MEAN TEMP = .99833	RMS =	.18987E-02
TC # 23	MEAN TEMP = .99439	RMS =	.23686E-02
TC # 24	MEAN TEMP = .70167	RMS =	.40047E-01
TC # 25	MEAN TEMP = .98528	RMS =	.31658E-02
TC # 26	MEAN TEMP = .60981	RMS =	.26190E-01
TC # 27	MEAN TEMP = .98491	RMS =	.17912E-02
TC # 28	MEAN TEMP = .95429	RMS =	.17704E-01
TC # 29	MEAN TEMP = .92411	RMS =	.11461E-01
TC # 30	MEAN TEMP = .90573	RMS =	.44796E-02
TC # 31	MEAN TEMP = .96782	RMS =	.10377E-01
TC # 32	MEAN TEMP = .69939	RMS =	.30399E-01
TC # 33	MEAN TEMP = .70447	RMS =	.33120E-01
TC # 34	MEAN TEMP = .83380	RMS =	.34770E-01
TC # 35	MEAN TEMP = .67837	RMS =	.54509E-01
TC # 36	MEAN TEMP = .97027	RMS =	.58447E-02
TC # 37	MEAN TEMP = .85198	RMS =	.27396E-01
TC # 38	MEAN TEMP = .84350	RMS =	.17484E-01
TC # 39	MEAN TEMP = .85531	RMS =	.12150E-01
TC # 40	MEAN TEMP = .85513	RMS =	.11763E-01
TC # 41	MEAN TEMP = .32479	RMS =	.17831E-01
TC # 42	MEAN TEMP = .58436	RMS =	.50648E-01
TC # 43	MEAN TEMP = .38401	RMS =	.99564E-01
TC # 44	MEAN TEMP = .82997	RMS =	.18342E-01
TC # 45	MEAN TEMP = .61879	RMS =	.47279E-01
TC # 46	MEAN TEMP = .57352	RMS =	.77927E-01
TC # 47	MEAN TEMP = .61066	RMS =	.30404E-01

MEAN BLANKET FLOW = .2192E-02 CUBIC METERS PER SEC. RMS = .18220E-04
MEAN TOTAL FLOW = .1422E-01 CUBIC METERS PER SEC. RMS = .12507E-03
MEAN LEAKAGE = Inoperative
AVERAGE EXIT TEMP = .8449 MIXED MEAN = .8459

Table VII Summary of Results for Run SS06

DATA SET NAME SS06 DATE CALCULATED 6/7/76
T_F =52.09C (125.76F) T_B =14.73C (58.51F)
5/21/76
CRBR WATER ONLY
.508 CM (.2 INCH) GAP

TC	#	1	MEAN TEMP	=	.18735	RMS	=	.10514E+00
TC	#	2	MEAN TEMP	=	.85549	RMS	=	.15231E-01
TC	#	3	MEAN TEMP	=	.99627	RMS	=	.22083E-02
TC	#	4	MEAN TEMP	=	.08594	RMS	=	.73406E-01
TC	#	5	MEAN TEMP	=	.85290	RMS	=	.10900E-01
TC	#	6	MEAN TEMP	=	.99463	RMS	=	.48349E-02
TC	#	7	MEAN TEMP	=	.01554	RMS	=	.11351E-01
TC	#	8	MEAN TEMP	=	.83475	RMS	=	.19157E-01
TC	#	9	MEAN TEMP	=	.90049	RMS	=	.12601E-01
TC	#	10	MEAN TEMP	=	.79414	RMS	=	.20008E-01
TC	#	11	MEAN TEMP	=	.85574	RMS	=	.84245E-02
TC	#	12	MEAN TEMP	=	.85777	RMS	=	.10060E-01
TC	#	13	MEAN TEMP	=	.85626	RMS	=	.10201E-01
TC	#	14	MEAN TEMP	=	.86091	RMS	=	.14602E-01
TC	#	15	MEAN TEMP	=	.87807	RMS	=	.18257E-01
TC	#	16	MEAN TEMP	=	.56747	RMS	=	.49020E-01
TC	#	17	MEAN TEMP	=	.73915	RMS	=	.20986E-01
TC	#	18	MEAN TEMP	=	.45081	RMS	=	.63391E-01
TC	#	19	MEAN TEMP	=	.82239	RMS	=	.23197E-01
TC	#	20	MEAN TEMP	=	.37984	RMS	=	.15211E-01
TC	#	21	MEAN TEMP	=	.76931	RMS	=	.30707E-01
TC	#	22	MEAN TEMP	=	.99966	RMS	=	.20129E-02
TC	#	23	MEAN TEMP	=	.99658	RMS	=	.23260E-02
TC	#	24	MEAN TEMP	=	.76920	RMS	=	.33857E-01
TC	#	25	MEAN TEMP	=	.98505	RMS	=	.38846E-02
TC	#	26	MEAN TEMP	=	.62359	RMS	=	.29445E-01
TC	#	27	MEAN TEMP	=	.98449	RMS	=	.23940E-02
TC	#	28	MEAN TEMP	=	.94275	RMS	=	.21051E-01
TC	#	29	MEAN TEMP	=	.92655	RMS	=	.15058E-01
TC	#	30	MEAN TEMP	=	.89394	RMS	=	.21318E-01
TC	#	31	MEAN TEMP	=	.95034	RMS	=	.19521E-01
TC	#	32	MEAN TEMP	=	.71079	RMS	=	.35020E-01
TC	#	33	MEAN TEMP	=	.68756	RMS	=	.37206E-01
TC	#	34	MEAN TEMP	=	.79732	RMS	=	.37387E-01
TC	#	35	MEAN TEMP	=	.68271	RMS	=	.71539E-01
TC	#	36	MEAN TEMP	=	.96674	RMS	=	.84140E-02
TC	#	37	MEAN TEMP	=	.87920	RMS	=	.18433E-01
TC	#	38	MEAN TEMP	=	.83515	RMS	=	.12426E-01
TC	#	39	MEAN TEMP	=	.83499	RMS	=	.14121E-01
TC	#	40	MEAN TEMP	=	.82699	RMS	=	.16462E-01
TC	#	41	MEAN TEMP	=	.80754	RMS	=	.18274E-01
TC	#	42	MEAN TEMP	=	.36397	RMS	=	.64842E-01
TC	#	43	MEAN TEMP	=	.40949	RMS	=	.95681E-01
TC	#	44	MEAN TEMP	=	.82622	RMS	=	.18927E-01
TC	#	45	MEAN TEMP	=	.62266	RMS	=	.57966E-01
TC	#	46	MEAN TEMP	=	.61149	RMS	=	.77069E-01
TC	#	47	MEAN TEMP	=	.54943	RMS	=	.44067E-01

MEAN BLANKET FLOW = .2173E-02 CUBIC METERS PER SEC. RMS = .26688E-04
MEAN TOTAL FLOW = .1382E-01 CUBIC METERS PER SEC. RMS = .11578E-03
MEAN LEAKAGE = Inoperative
AVERAGE EXIT TEMP = .8477 MIXED MEAN = .8428

Table VIII Summary of Results for Run SS07

DATA SET NAME SS07 DATE CALCULATED 6/7/76
T_F =54.17C (129.50F) T_B =14.13C (57.43F)
5/25/76
CRBR, WATER ONLY
.508 CM (.2 INCH) GAP

TC #	1	MEAN TEMP =	.20716	RMS =	.95222E-01
TC #	2	MEAN TEMP =	.84966	RMS =	.17504E-01
TC #	3	MEAN TEMP =	.99583	RMS =	.22116E-02
TC #	4	MEAN TEMP =	.08335	RMS =	.62439E-01
TC #	5	MEAN TEMP =	.85599	RMS =	.12707E-01
TC #	6	MEAN TEMP =	.99410	RMS =	.42635E-02
TC #	7	MEAN TEMP =	.01436	RMS =	.10890E-01
TC #	8	MEAN TEMP =	.83879	RMS =	.17692E-01
TC #	9	MEAN TEMP =	.90139	RMS =	.11890E-01
TC #	10	MEAN TEMP =	.80640	RMS =	.29279E-01
TC #	11	MEAN TEMP =	.85655	RMS =	.82418E-02
TC #	12	MEAN TEMP =	.85826	RMS =	.90894E-02
TC #	13	MEAN TEMP =	.85706	RMS =	.10400E-01
TC #	14	MEAN TEMP =	.85934	RMS =	.16531E-01
TC #	15	MEAN TEMP =	.87994	RMS =	.18832E-01
TC #	16	MEAN TEMP =	.56781	RMS =	.52579E-01
TC #	17	MEAN TEMP =	.73515	RMS =	.22376E-01
TC #	18	MEAN TEMP =	.46249	RMS =	.57685E-01
TC #	19	MEAN TEMP =	.82232	RMS =	.22748E-01
TC #	20	MEAN TEMP =	.87938	RMS =	.16031E-01
TC #	21	MEAN TEMP =	.76968	RMS =	.31608E-01
TC #	22	MEAN TEMP =	.99892	RMS =	.17044E-02
TC #	23	MEAN TEMP =	.99588	RMS =	.22964E-02
TC #	24	MEAN TEMP =	.77223	RMS =	.34983E-01
TC #	25	MEAN TEMP =	.98461	RMS =	.35428E-02
TC #	26	MEAN TEMP =	.62260	RMS =	.30438E-01
TC #	27	MEAN TEMP =	.98475	RMS =	.21285E-02
TC #	28	MEAN TEMP =	.94846	RMS =	.16293E-01
TC #	29	MEAN TEMP =	.92595	RMS =	.15600E-01
TC #	30	MEAN TEMP =	.89866	RMS =	.15656E-01
TC #	31	MEAN TEMP =	.95770	RMS =	.17212E-01
TC #	32	MEAN TEMP =	.70625	RMS =	.34516E-01
TC #	33	MEAN TEMP =	.70202	RMS =	.42217E-01
TC #	34	MEAN TEMP =	.79639	RMS =	.40344E-01
TC #	35	MEAN TEMP =	.69163	RMS =	.66495E-01
TC #	36	MEAN TEMP =	.96573	RMS =	.83384E-02
TC #	37	MEAN TEMP =	.87362	RMS =	.17867E-01
TC #	38	MEAN TEMP =	.83047	RMS =	.14746E-01
TC #	39	MEAN TEMP =	.83061	RMS =	.17602E-01
TC #	40	MEAN TEMP =	.82230	RMS =	.23021E-01
TC #	41	MEAN TEMP =	.80481	RMS =	.23509E-01
TC #	42	MEAN TEMP =	.38400	RMS =	.71428E-01
TC #	43	MEAN TEMP =	.39015	RMS =	.95894E-01
TC #	44	MEAN TEMP =	.82187	RMS =	.20726E-01
TC #	45	MEAN TEMP =	.63935	RMS =	.52981E-01
TC #	46	MEAN TEMP =	.62158	RMS =	.72236E-01
TC #	47	MEAN TEMP =	.54262	RMS =	.42346E-01

MEAN BLANKET FLOW = .2129E-02 CUBIC METERS PER SEC. RMS = .14409E-04
MEAN TOTAL FLOW = .1399E-01 CUBIC METERS PER SEC. RMS = .90349E-04
MEAN LEAKAGE = .1822E-02 CUBIC METERS PER SEC. RMS = .77485E-04
AVERAG EXIT TEMP = .8481 MIXED MEAN = .8478

Table IX Summary of Results for Run SS08

DATA SET NAME SS08 DATE CALCULATED 6/7/76
T_F=53.37C (128.06F) T_B=14.57C (58.23F)
5/27/76
.508 CM (.2 INCH) GAP
CRBR WATER ONLY

TC # 1	MEAN TEMP =	.21113	RMS =	.99996E-01
TC # 2	MEAN TEMP	.85589	RMS	.14167E- [illegible]
TC # 3	MEAN TEMP =	.99627	RMS =	.21561E-02
TC # 4	MEAN TEMP =	.09402	RMS =	.63673E-01
TC # 5	MEAN TEMP =	.85367	RMS =	.10124E-01
TC # 6	MEAN TEMP =	.99462	RMS =	.40967E-02
TC # 7	MEAN TEMP =	.02161	RMS =	.17253E-01
TC # 8	MEAN TEMP =	.85300	RMS =	.15544E-01
TC # 9	MEAN TEMP =	.90410	RMS =	.12474E-01
TC # 10	MEAN TEMP =	.82095	RMS =	.30856E-01
TC # 11	MEAN TEMP =	.85579	RMS =	.79985E-02
TC # 12	MEAN TEMP =	.25648	RMS =	.94522E-02
TC # 13	MEAN TEMP =	.85676	RMS =	.95317E-02
TC # 14	MEAN TEMP =	.86374	RMS =	.15121E-01
TC # 15	MEAN TEMP =	.87825	RMS =	.13811E-01
TC # 16	MEAN TEMP =	.57295	RMS =	.54330E-01
TC # 17	MEAN TEMP =	.73400	RMS =	.26868E-01
TC # 18	MEAN TEMP =	.48359	RMS =	.56873E-01
TC # 19	MEAN TEMP =	.83198	RMS =	.19549E-01
TC # 20	MEAN TEMP =	.38854	RMS =	.14557E-01
TC # 21	MEAN TEMP =	.77054	RMS =	.35065E-01
TC # 22	MEAN TEMP =	.99965	RMS =	.19714E-02
TC # 23	MEAN TEMP =	.99621	RMS =	.22253E-02
TC # 24	MEAN TEMP =	.78379	RMS =	.31294E-01
TC # 25	MEAN TEMP =	.98604	RMS =	.36416E-02
TC # 26	MEAN TEMP =	.63163	RMS =	.28327E-01
TC # 27	MEAN TEMP =	.98538	RMS =	.21073E-02
TC # 28	MEAN TEMP =	.94840	RMS =	.19939E-01
TC # 29	MEAN TEMP =	.94182	RMS =	.93692E-02
TC # 30	MEAN TEMP =	.90631	RMS =	.20834E-01
TC # 31	MEAN TEMP =	.94325	RMS =	.20589E-01
TC # 32	MEAN TEMP -	.70751	RMS =	.48494E-01
TC # 33	MEAN TEMP =	.69075	RMS =	.56986E-01
TC # 34	MEAN TEMP =	.83172	RMS =	.38077E-01
TC # 35	MEAN TEMP =	.68953	RMS =	.81765E-01
TC # 36	MEAN TEMP =	.96856	RMS =	.74385E-02
TC # 37	MEAN TEMP =	.87609	RMS =	.20254E-01
TC # 38	MEAN TEMP =	.84090	RMS =	.16573E-01
TC # 39	MEAN TEMP =	.84962	RMS =	.16321E-01
TC # 40	MEAN TEMP =	.35057	RMS =	.16932E-01
TC # 41	MEAN TEMP =	.81918	RMS =	.29511E-01
TC # 42	MEAN TEMP =	.43064	RMS =	.57602E-01
TC # 43	MEAN TEMP =	.39809	RMS =	.80718E-01
TC # 44	MEAN TEMP =	.83605	RMS =	.25751E-01
TC # 45	MEAN TEMP =	.83431	RMS =	.23417E-01
TC # 46	MEAN TEMP =	.67280	RMS =	.51455E-01
TC # 47	MEAN TEMP =	.55419	RMS =	.40329E-01

MEAN BLANKET FLOW = .2201E-02 CUBIC METERS PER SEC. RMS = .19612E-05
MEAN TOTAL FLOW = .1485E-01 CUBIC METERS PER SEC. RMS = .99774E-04
MEAN LEAKAGE = .1940E-02 CUBIC METERS PER SEC. RMS = .83219E-04
AVERAGE EXIT TEMP = .8542 MIXED MEAN = .8518

Table X. Summary of Results for Run SS12

DATA SET NAME SS12 DATE CALCULATED 6/7/76
T_F =55.36C (131.65F) T_B =15.00C (59.00F)
5/27/76
CRBR WATER ONLY
NO GAP

TC #	MEAN TEMP =	RMS =
1	.29527	.11766E+00
2	.84964	.99374E-02
3	.99663	.21149E-02
4	.06849	.67834E-01
5	.86228	.69846E-02
6	.99689	.24415E-02
7	.00717	.65109E-02
8	.86254	.90963E-02
9	.86312	.18082E-01
10	.85268	.83869E-02
11	.85414	.10553E-01
12	.85619	.11210E-01
13	.85510	.10830E-01
14	.85501	.16561E-01
15	.87325	.19943E-01
16	.52899	.55543E-01
17	.67859	.30685E-01
18	.57758	.47309E-01
19	.77659	.26333E-01
20	.82253	.24356E-01
21	.64969	.37669E-01
22	.99914	.18548E-02
23	.99722	.21484E-02
24	.66347	.31864E-01
25	.99228	.30889E-02
26	.62161	.19769E-01
27	.98573	.18257E-02
28	.93578	.25945E-01
29	.95175	.10831E-01
30	.92449	.25321E-01
31	.98535	.14709E-01
32	.83776	.20759E-01
33	.83747	.20327E-01
34	.86107	.95417E-02
35	.85217	.95254E-02
36	.96406	.95343E-02
37	.86402	.25135E-01
38	.29472	.18057E-02
39	.85727	.17190E-01
40	.86541	.92683E-02
41	.84271	.18390E-01
42	.76989	.25973E-01
43	—	—
44	.84699	.16040E-01
45	.78554	.27419E-01
46	—	—
47	—	—

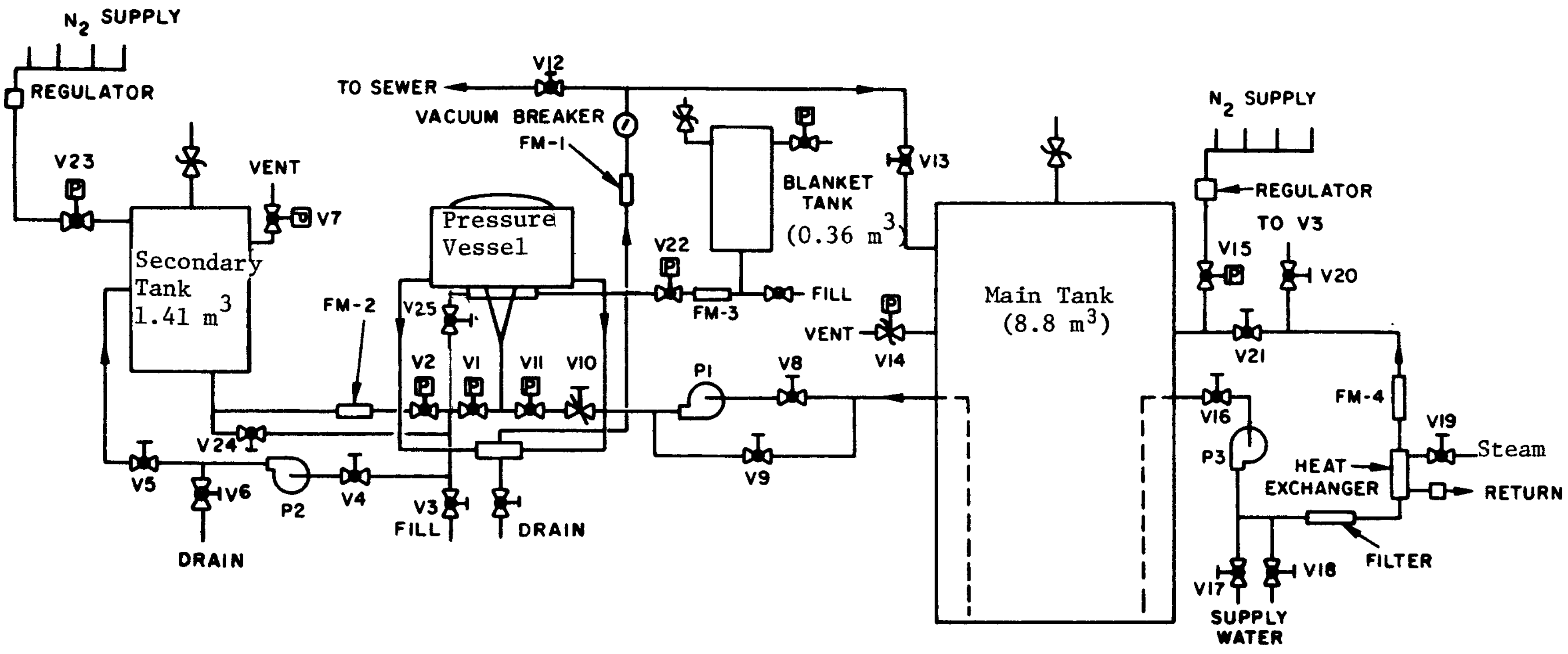
MEAN **BLANKET** FLOW = .2095E-02 CUBIC METERS PER SEC. RMS = .17093E-04
MEAN TOTAL FLOW = .1491E-01 CUBIC METERS PER SEC. RMS = .67688E-04
MEAN LEAKAGE = **0** CUBIC METERS PER SEC. RMS = **0**
AVERAGE EXIT TEMP = .8582 MIXED MEAN = .8595

Table XI Comparison of Mean Temperatures for Different Gaps

	SS12 NO GAP	SSØ5 .254 CM	SSØ7 .5Ø8 CM
TC # 1	.29527	.19367	.2Ø716
TC # 2	.84964	.83287	.84966
TC # 3	.99663	.99589	.99583
TC # 4	.Ø6849	.Ø3683	.Ø8335
TC # 5	.86228	.849Ø9	.85599
TC # 6	.99689	.99632	.9941Ø
TC # 7	.ØØ717	.Ø2226	.Ø1436
TC # 8	.86254	.85275	.83879
TC # 9	.86312	.88619	.9Ø139
TC # 10	.85268	.82635	.8Ø64Ø
TC # 11	.85414	.84999	.85655
TC # 12	.85619	.85Ø16	.85826
TC # 13	.8551Ø	.84723	.857Ø6
TC # 14	.855Ø1	.84654	.85934
TC # 15	.87325	.86432	.[illegible]7994
TC # 16	.52899	.53745	.56781
TC # 17	.67659	.72Ø29	.73515
TC # 18	.57758	.52713	.46249
TC # 19	.77659	.79629	.82232
TC # 20	.82253	.86573	.87938
TC # 21	.64969	.7Ø656	.76968
TC # 22	.99914	.99833	.99892
TC # 23	.9[illegible]722	.99439	.99588
TC # 24	.66347	.7Ø167	.77223
TC # 25	.99228	.98528	.98461
TC # 26	.62161	.6Ø981	.6226Ø
TC # 27	.98573	.98491	.98475
TC # 28	.93578	.95429	.94846
TC # 29	.95175	.92411	.92595
TC # 30	.92449	.9Ø573	.89866
TC # 31	.98535	.96782	.9577Ø
TC # 32	.83776	.69939	.7Ø625
TC # 33	.83747	.7Ø447	.7Ø2Ø2
TC # 34	.861Ø7	.8338Ø	.79639
TC # 35	.85217	.67837	.69163
TC # 36	.964Ø6	.97Ø27	.96573
TC # 37	.86[illegible]2	.85198	.87362
TC # 38	.29472	.8435Ø	.83Ø47
TC # 39	.85727	.85531	.83Ø61
TC # 40	.86541	.85513	.8223Ø
TC # 41	.84271	.82479	.8Ø481
TC # 42	.76989	.58436	.384ØØ
TC # 43	—	.384Ø1	.39Ø15
TC # 44	.84699	.82997	.82187
TC # 45	.78554	.61879	.63935
TC # 46	—	.57352	.62158
TC # 47	—	.61Ø66	.54262

Table XII. Comparison of RMS Temperatures for Different Gaps

	SS12 NO GAP	SSØ5 .254 CM	SSØ7 .5Ø8 CM
TC # 1	.11766E+ØØ	.96992E-Ø1	.95222E-Ø1
TC # 2	.99374E-Ø2	.13157E-Ø1	.175Ø4E-Ø1
TC # 3	.21149E-Ø2	.17Ø52E-Ø2	.22116E-Ø2
TC # 4	.67834E-Ø1	.375Ø3E-Ø1	.62439E-Ø1
TC # 5	.69846E-Ø2	.1113ØE-Ø1	.127Ø7E-Ø1
TC # 6	.24415E-Ø2	.2Ø859E-Ø2	.42635E-Ø2
TC # 7	.651Ø9E-Ø2	.2Ø36ØE-Ø1	.1Ø89ØE-Ø1
TC # 8	.9Ø963E-Ø2	.13Ø66E-Ø1	.17692E-Ø1
TC # 9	.18Ø82E-Ø1	.13918E-Ø1	.1189ØE-Ø1
TC # 10	.83869E-Ø2	.22ØØ9E-Ø1	.29279E-Ø1
TC # 11	.1Ø553E-Ø1	.87Ø42E-Ø2	.82418E-Ø2
TC # 12	.1121ØE-Ø1	.1Ø865E-Ø1	.9Ø894E-Ø2
TC # 13	.1Ø83ØE-Ø1	.12869E-Ø1	.1Ø4ØØE-Ø1
TC # 14	.16561E-Ø1	.16Ø54E-Ø1	.16531E-Ø1
TC # 15	.19943E-Ø1	.31Ø73E-Ø1	.18832E-Ø1
TC # 16	.55543E-Ø1	.64823E-Ø1	.52579E-Ø1
TC # 17	.3Ø685E-Ø1	.21Ø97E-Ø1	.22376E-Ø1
TC # 18	.473Ø9E-Ø1	.69174E-Ø1	.57685E-Ø1
TC # 19	.26333E-Ø1	.26835E-Ø1	.22748E-Ø1
TC # 20	.24356E-Ø1	.19655E-Ø1	.16Ø31E-Ø1
TC # 21	.37669E-Ø1	.34396E-Ø1	.316Ø8E-Ø1
TC # 22	.18548E-Ø2	.18987E-Ø2	.17Ø44E-Ø2
TC # 23	.21484E-[illegible]	.23686E-Ø2	.22964E-Ø2
TC # 24	.31864E-Ø1	.4ØØ47E-Ø1	.34983E-Ø1
TC # 25	.3Ø889E-Ø2	.31658E-Ø2	.35428E-Ø2
TC # 26	.19769E-Ø1	.2619ØE-Ø1	.3Ø438E-Ø1
TC # 27	.18257E-Ø2	.17912E-Ø2	.21285E-Ø2
TC # 28	.25945E-Ø1	.177Ø4E-Ø1	.16293E-Ø1
TC # 29	.1Ø831E-Ø1	.11461E-Ø1	.156ØØE-Ø1
TC # 30	.25321E-Ø1	.44796E-Ø2	.15656E-Ø1
TC # 31	.147Ø9E-Ø1	.1Ø377E-Ø1	.17212E-Ø1
TC # 32	.2Ø759E-Ø1	.3Ø399E-Ø1	.34516E-Ø1
TC # 33	.2Ø327E-Ø1	.3312ØE-Ø1	.42217E-Ø1
TC # 34	.95417E-Ø2	.3477ØE-Ø1	.4Ø344E-Ø1
TC # 35	.95254E-Ø2	.545Ø9E-Ø1	.66495E-Ø1
TC # 36	.95343E-Ø2	.58447E-Ø2	.83384E-Ø2
TC # 37	.25135E-Ø1	.27396E-Ø1	.17867E-Ø1
TC # 38	.18Ø57E-Ø2	.17484E-Ø1	.14746E-Ø1
TC # 39	.1719ØE-Ø1	.1215ØE-Ø1	.176Ø2E-Ø1
TC # 40	.92683E-Ø2	.11763E-Ø1	.23Ø21E-Ø1
TC # 41	.1839ØE-Ø1	.17831E-Ø1	.235Ø9E-Ø1
TC # 42	.25973E-Ø1	.5Ø648E-Ø1	.71428E-Ø1
TC # 43	—	.99564E-Ø1	.95894E-Ø1
TC # 44	.16Ø4ØE-Ø1	.18342E-Ø1	.2Ø726E-Ø1
TC # 45	.27419E-Ø1	.47279E-Ø1	.52981E-Ø1
TC # 46	—	.77927E-Ø1	.72236E-Ø1
TC # 47	—	.3Ø4Ø4E-Ø1	.42346E-Ø1



P1:	25-HP MAIN FLOW, 400 GPM ($2.52 \times 10^{-2} m^3/s$)
P2:	1-HP RECIRCULATE
P3:	1/2 HP RECIRCULATE
FM-1:	80-800 GPM ($5.0 \times 10^{-3} m^3/s$)
FM-2:	14-140 GPM (8.8×10^{-4} - $88. \times 10^{-4} m^3/s$)
FM-3:	2-20 GPM (1.25×10^{-4} - $12.57 \times 10^{-4} m^3/s$)
FM-4:	0-20 GPM ($0\text{-}12.57 \times 10^{-4} m^3/s$)

V1:	7.62 cm PNEUMATIC
V2:	5.08 cm PNEUMATIC
V3:	3.67 cm GLOBE,MANUAL
V4-V5:	3.67 cm BALL,MANUAL
V6:	3.67 cm GATE,MANUAL
V7:	5.08 cm BALL,PNEUMATIC
V8-V9:	10.16 cm GATE,MANUAL
V10:	10.16 cm BUTTERFLY,MANUAL
V11:	10.16 cm PNEUMATIC
V12-V13:	10.16 cm GATE, MANUAL
V14:	10.16 cm BUTTERFLY,PNEUMATIC
V15,V22-V23:	3.67 cm BALL, PNEUMATIC
V16-V21:	1.90 cm GATE,MANUAL
V24:	5.08 cm BALL, PNEUMATIC
V25:	7.62 cm BALL, PNUEMATIC

Figure 1. 1/10-Scale Outlet Plenum Mixing Test Facility

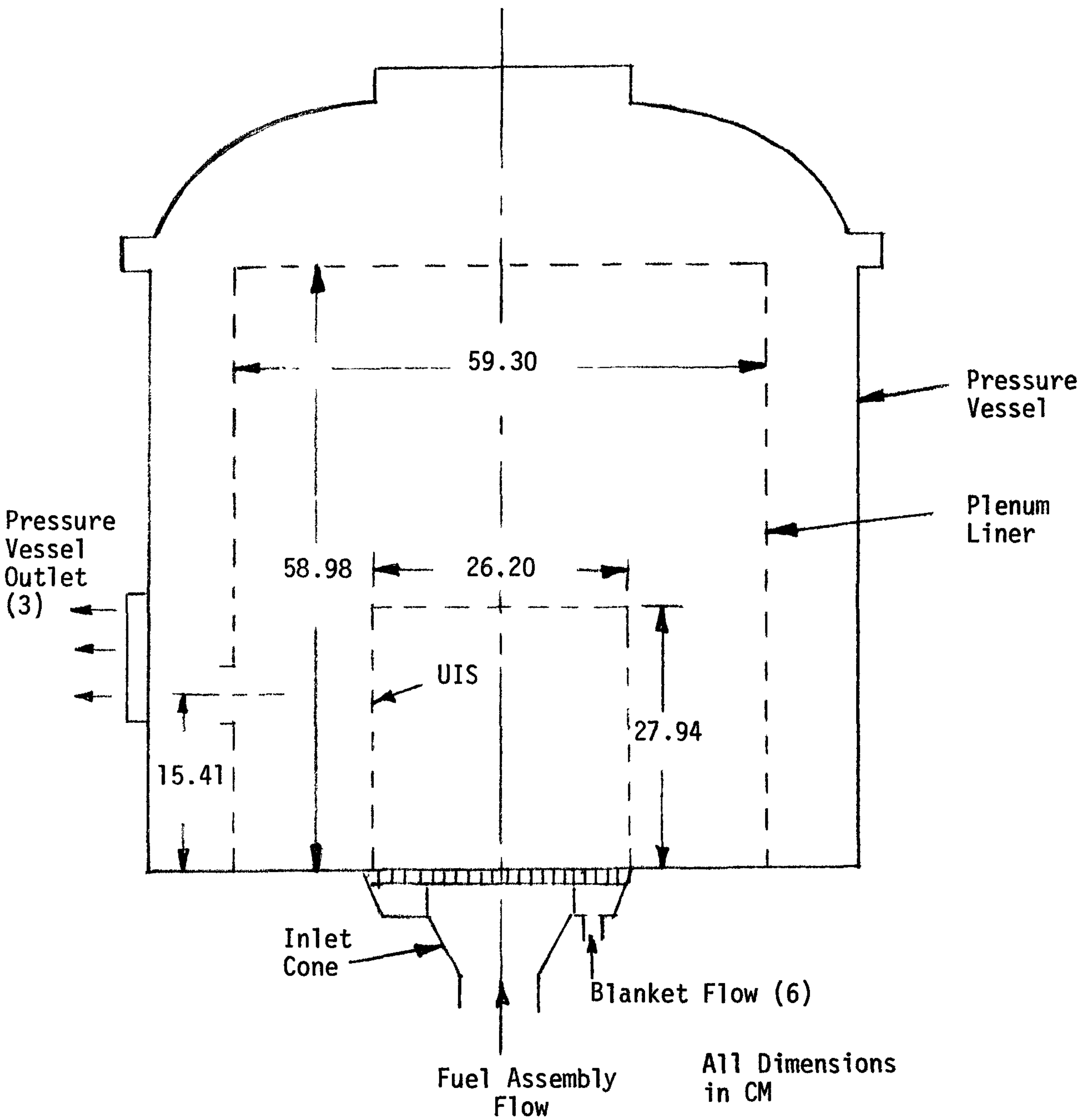


Figure 2. Sketch of Pressure Vessel and Basic Plenum Components

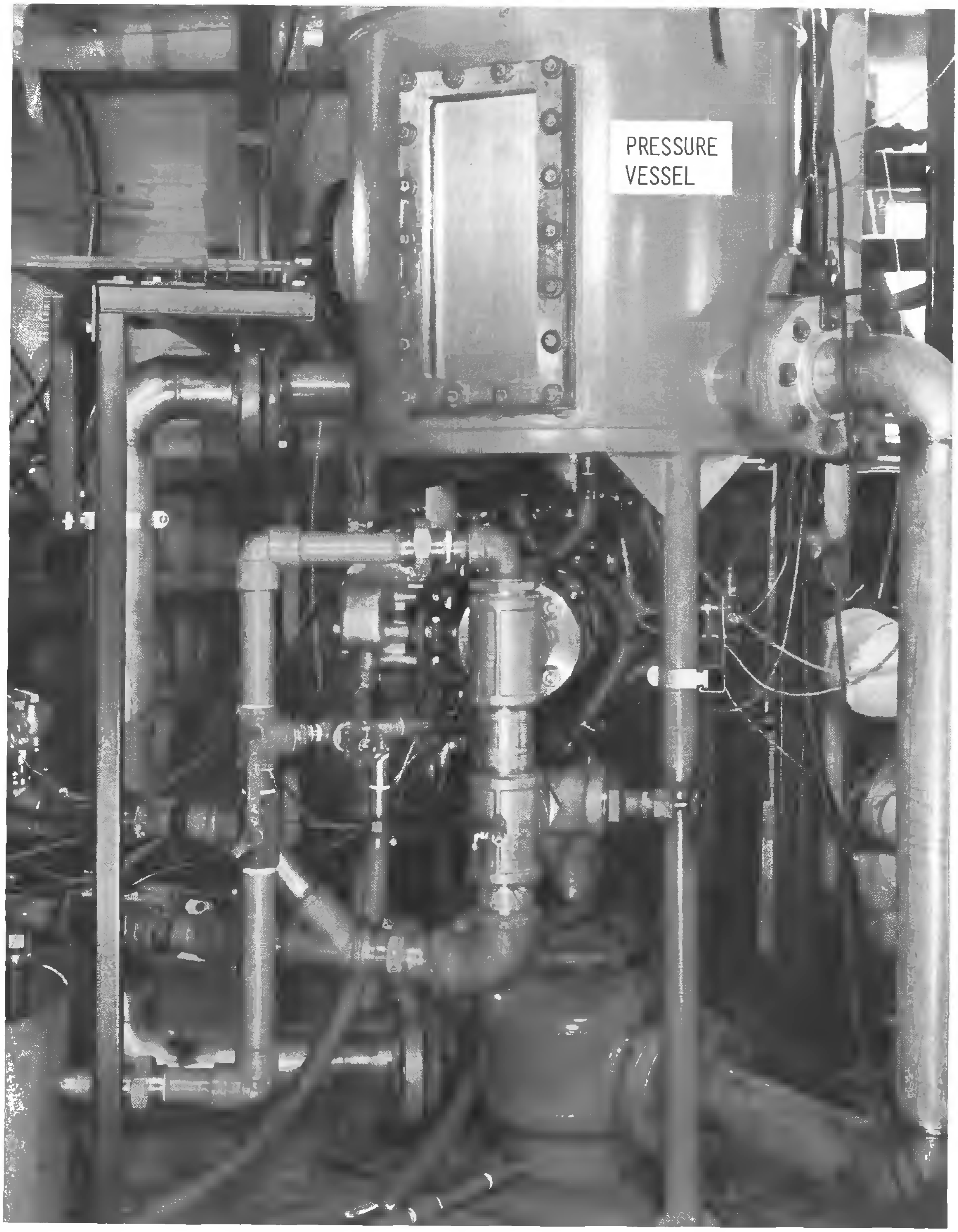


Figure 3. Photograph of Pressure Vessel

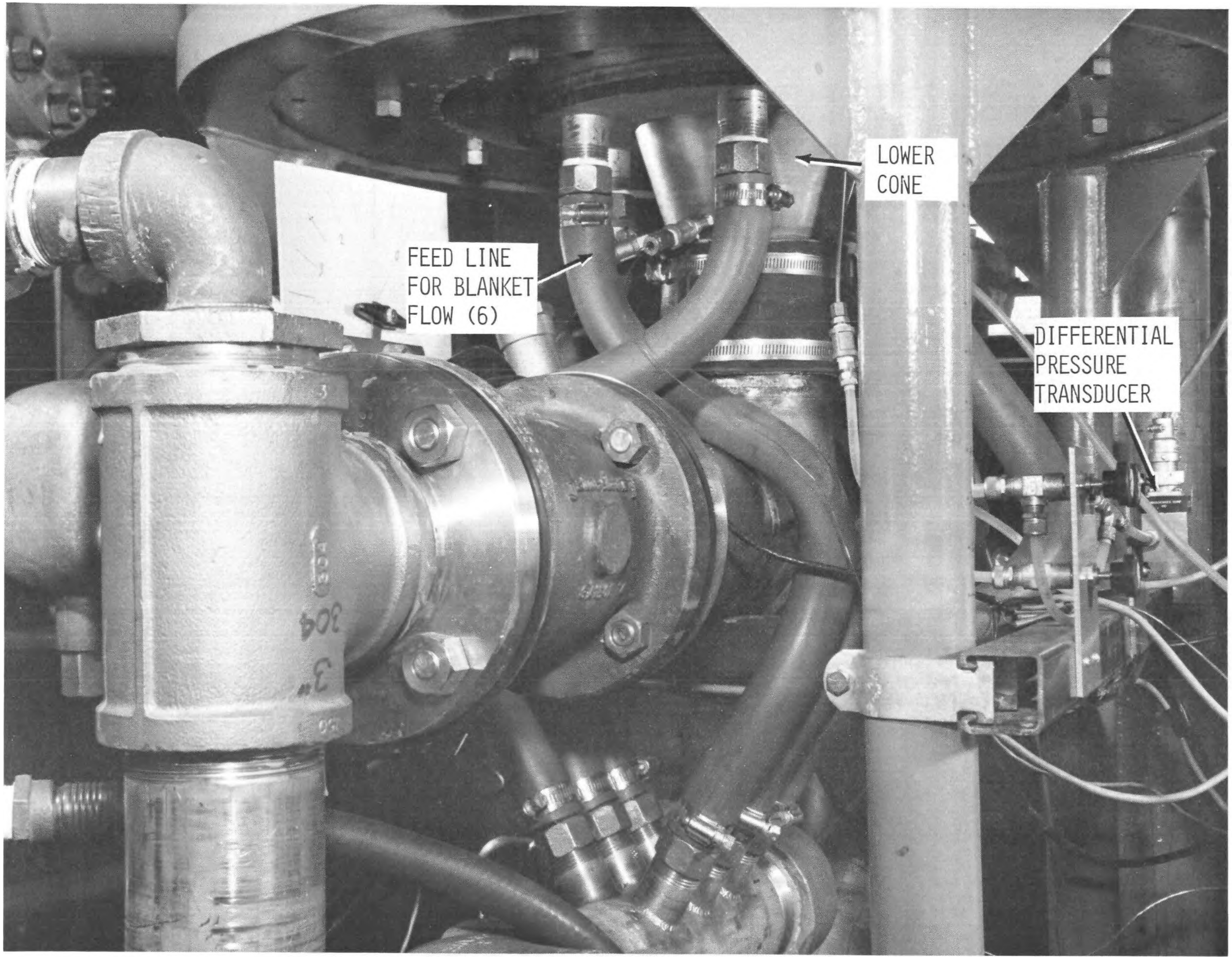


Figure 4. Lower Cone and Radial Blanket Feed Lines

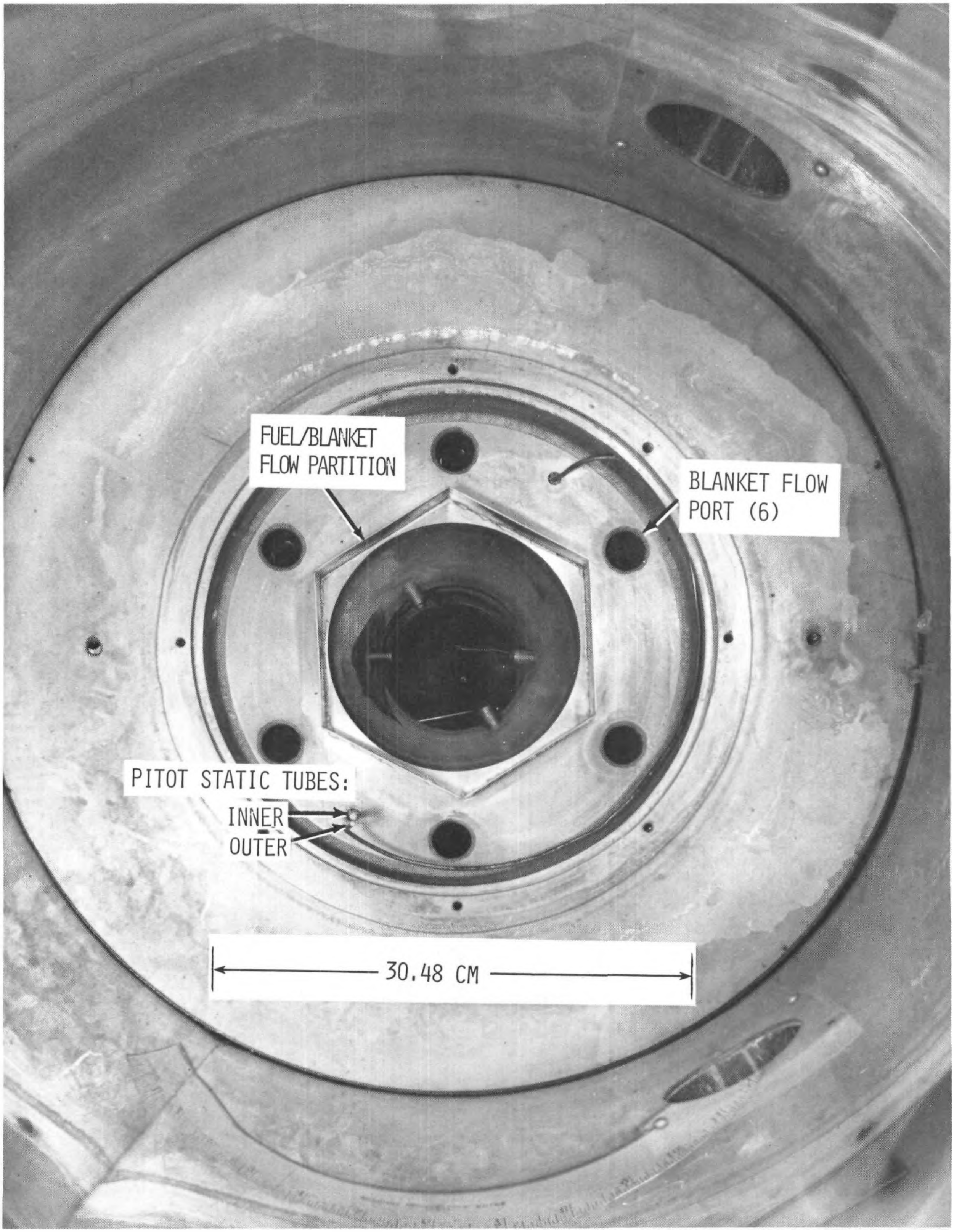


Figure 5. View Looking Down into Pressure Vessel with Simulated Core Plate Removed

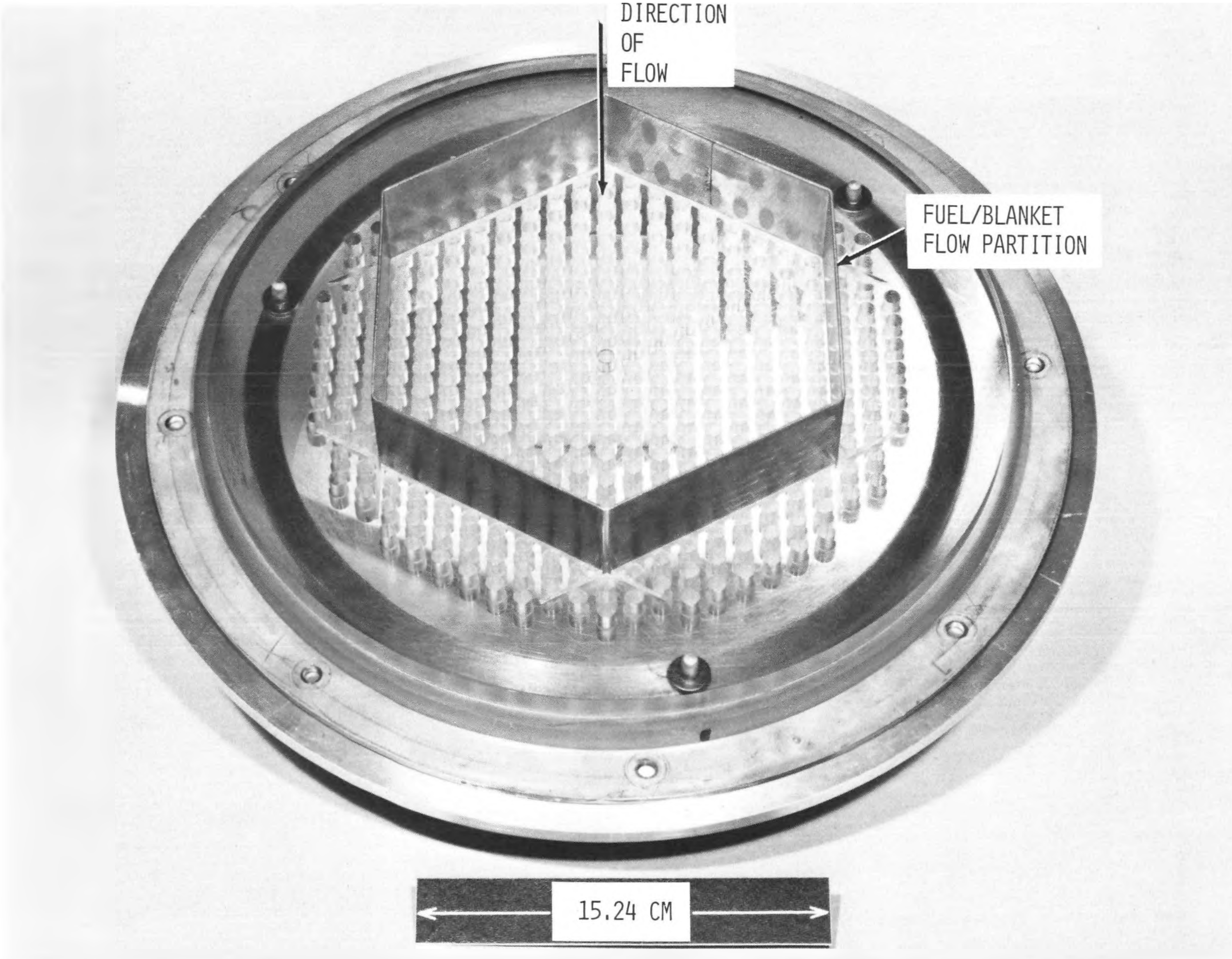


Figure 6. Simulated Core Plate with Fuel/Blanket Flow Partition Attached

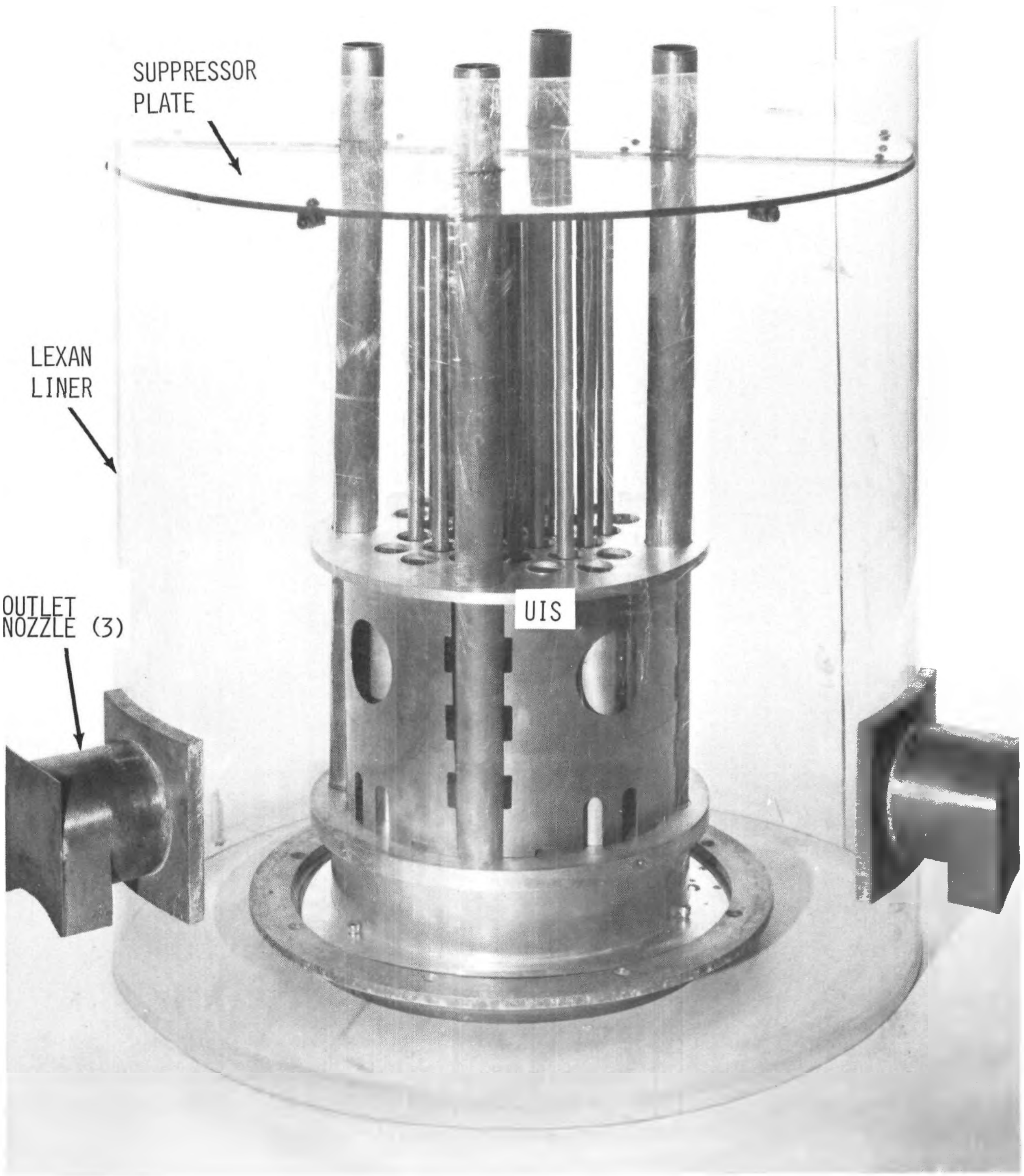


Figure 7. Fully Mocked-up 1/10-Scale CRBR UIS and Plenum Liner

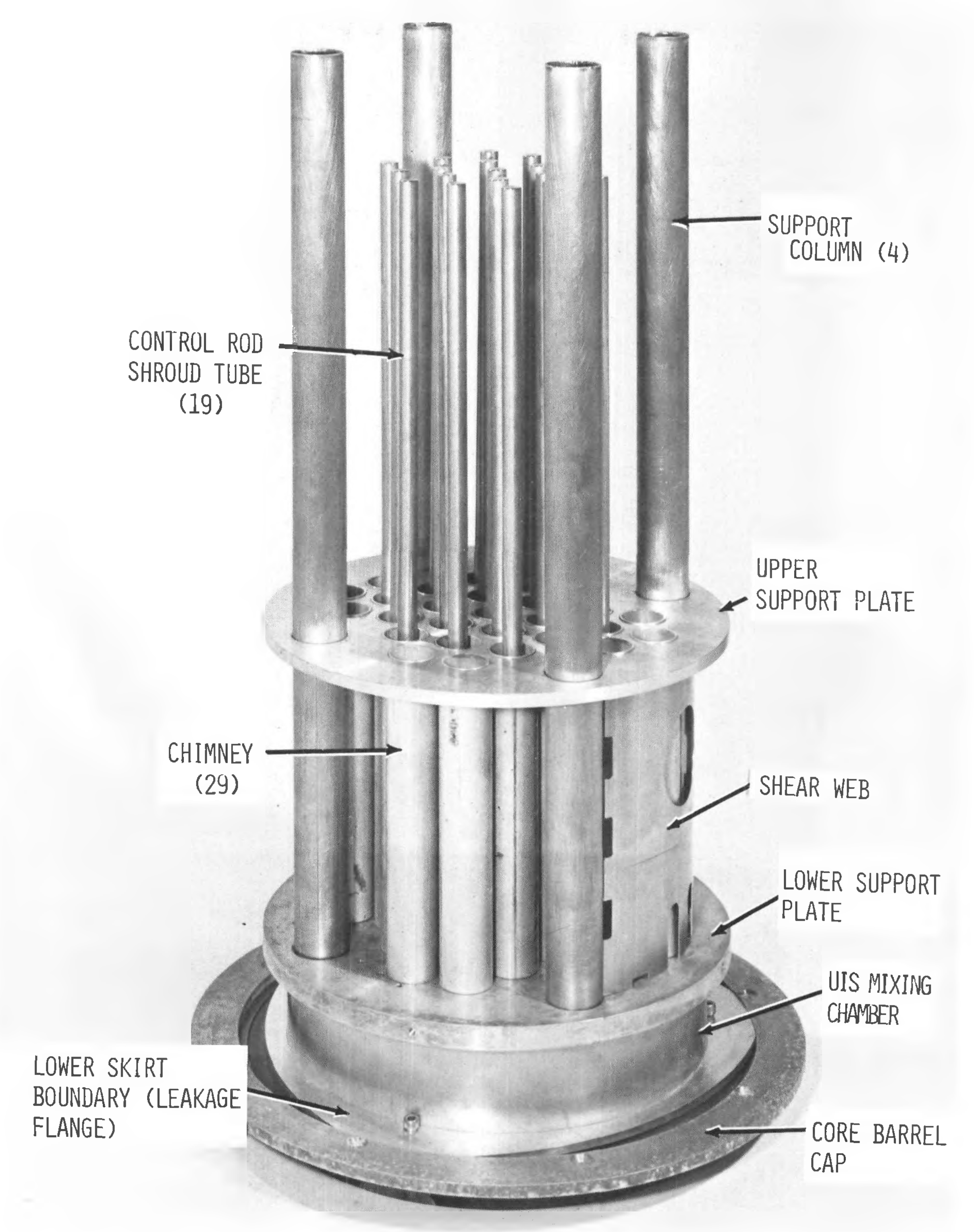


Figure 8. UIS with Portion of Shear Web Removed to Show Chimneys

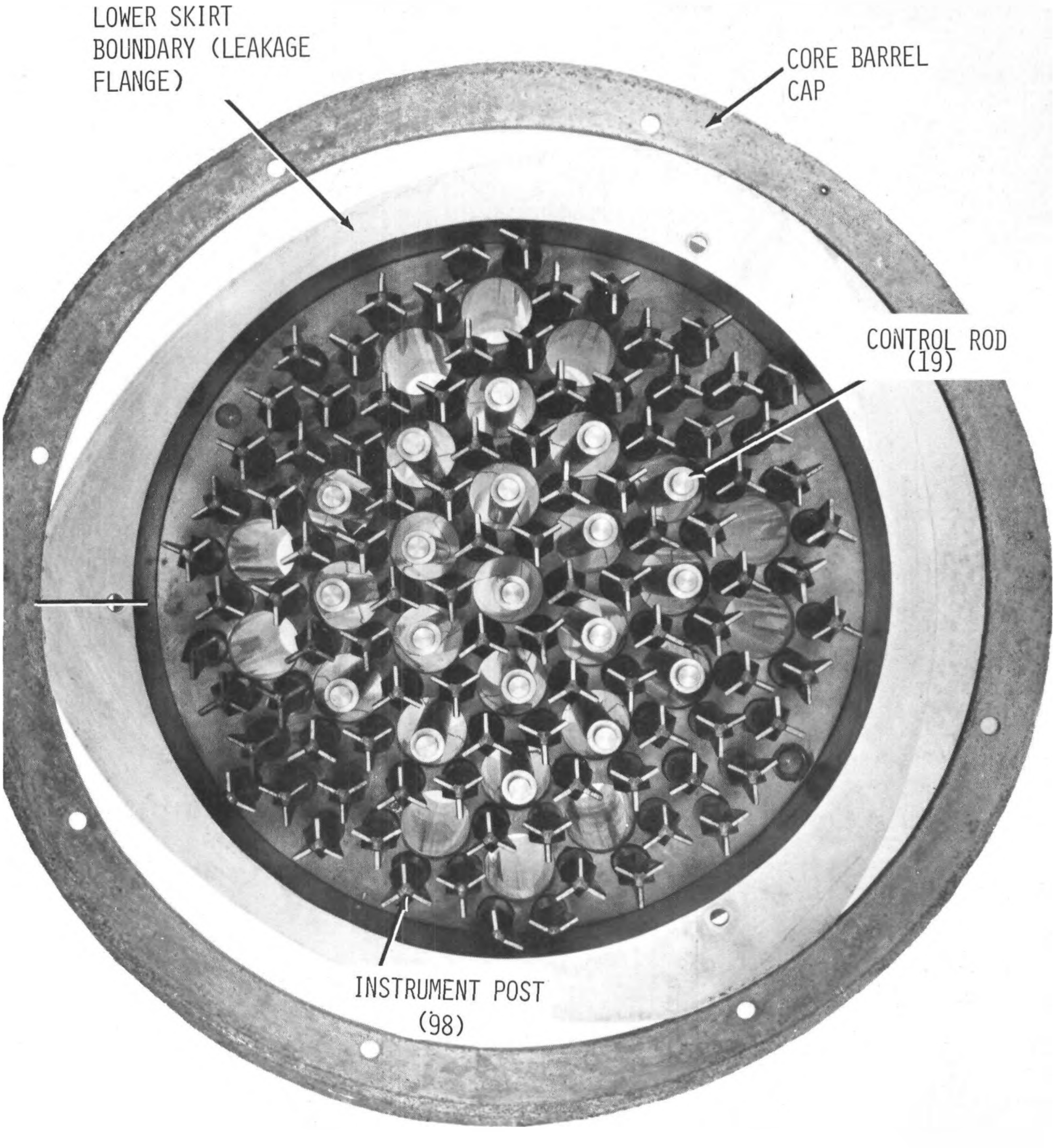


Figure 9. View Looking Into Mixing Chamber from Below; the 0° Azimuth is Represented by the Line at 9 O'Clock

Figure 10. Oblique View of Mixing Chamber from Below

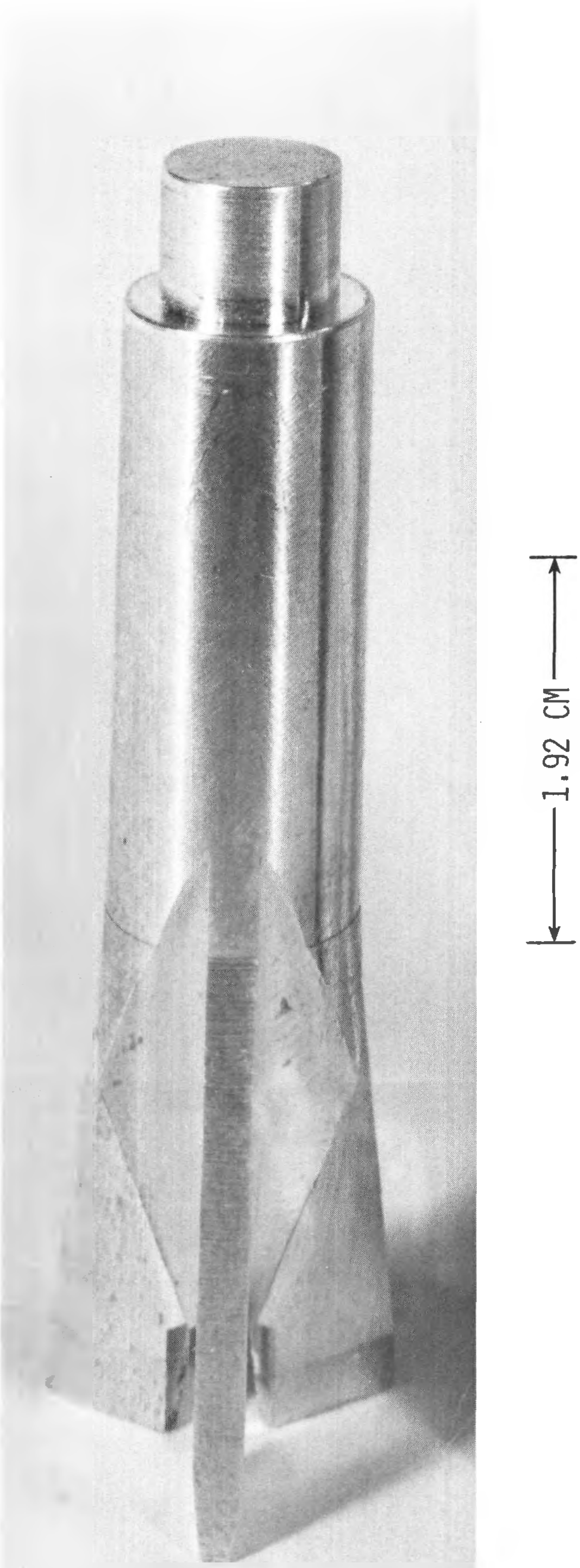


Figure 11. Close-up of Instrument Post

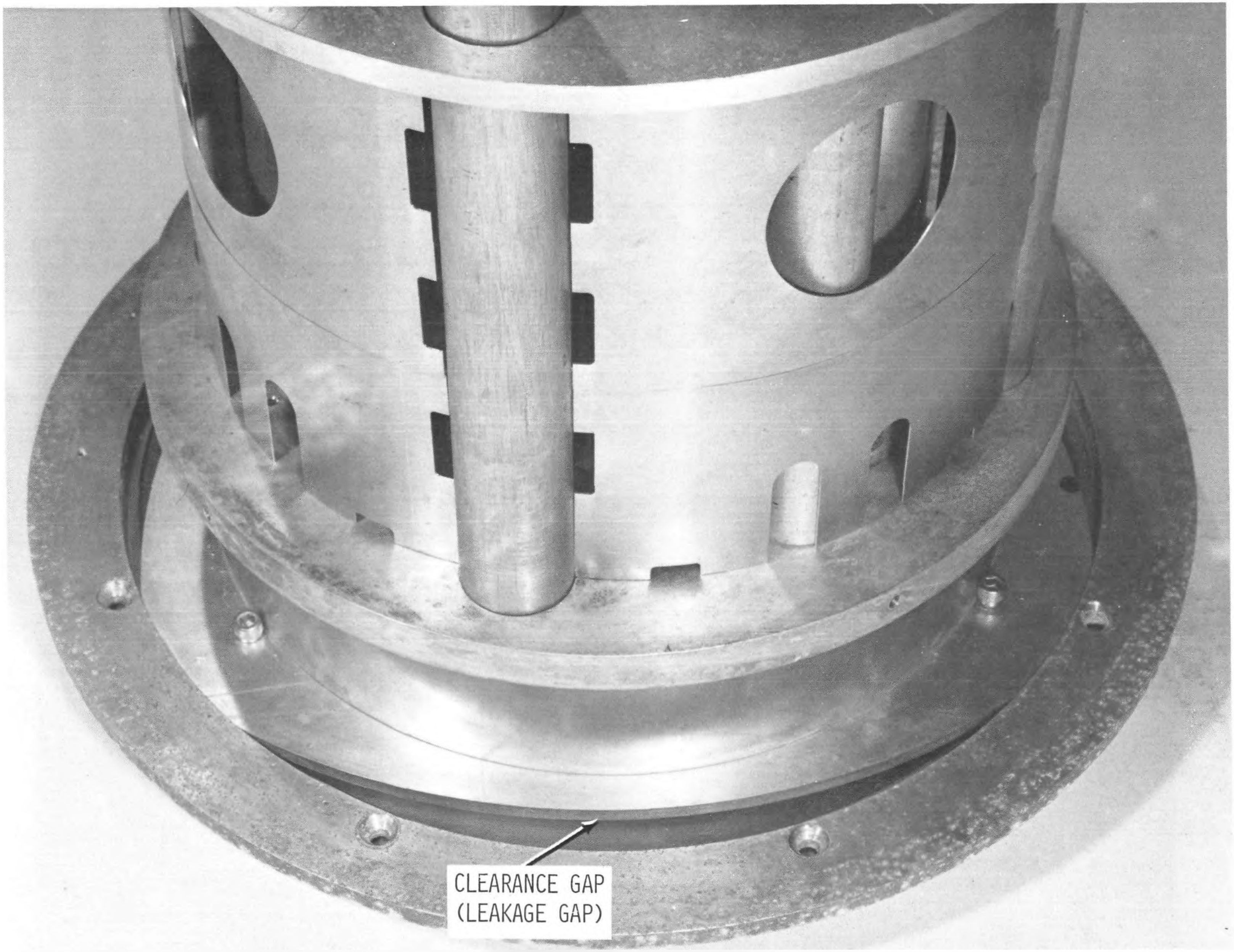


Figure 12. Photograph of Leakage Gap

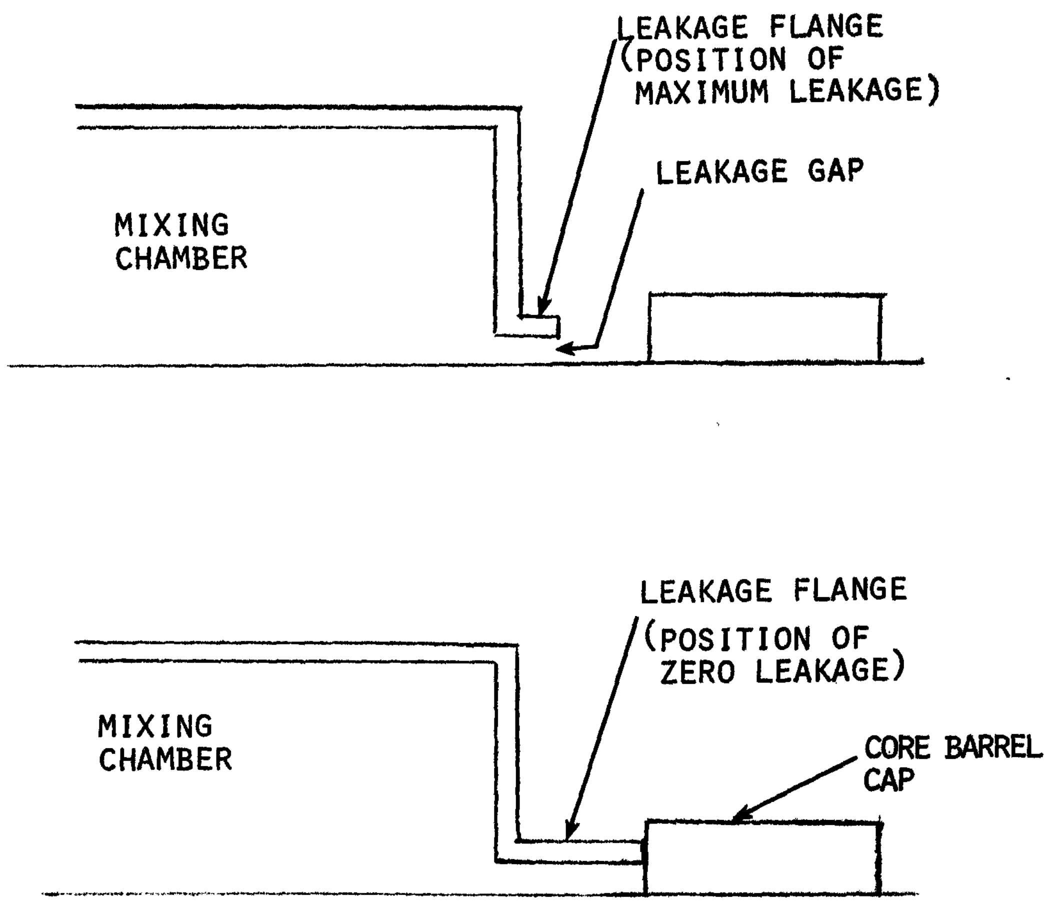
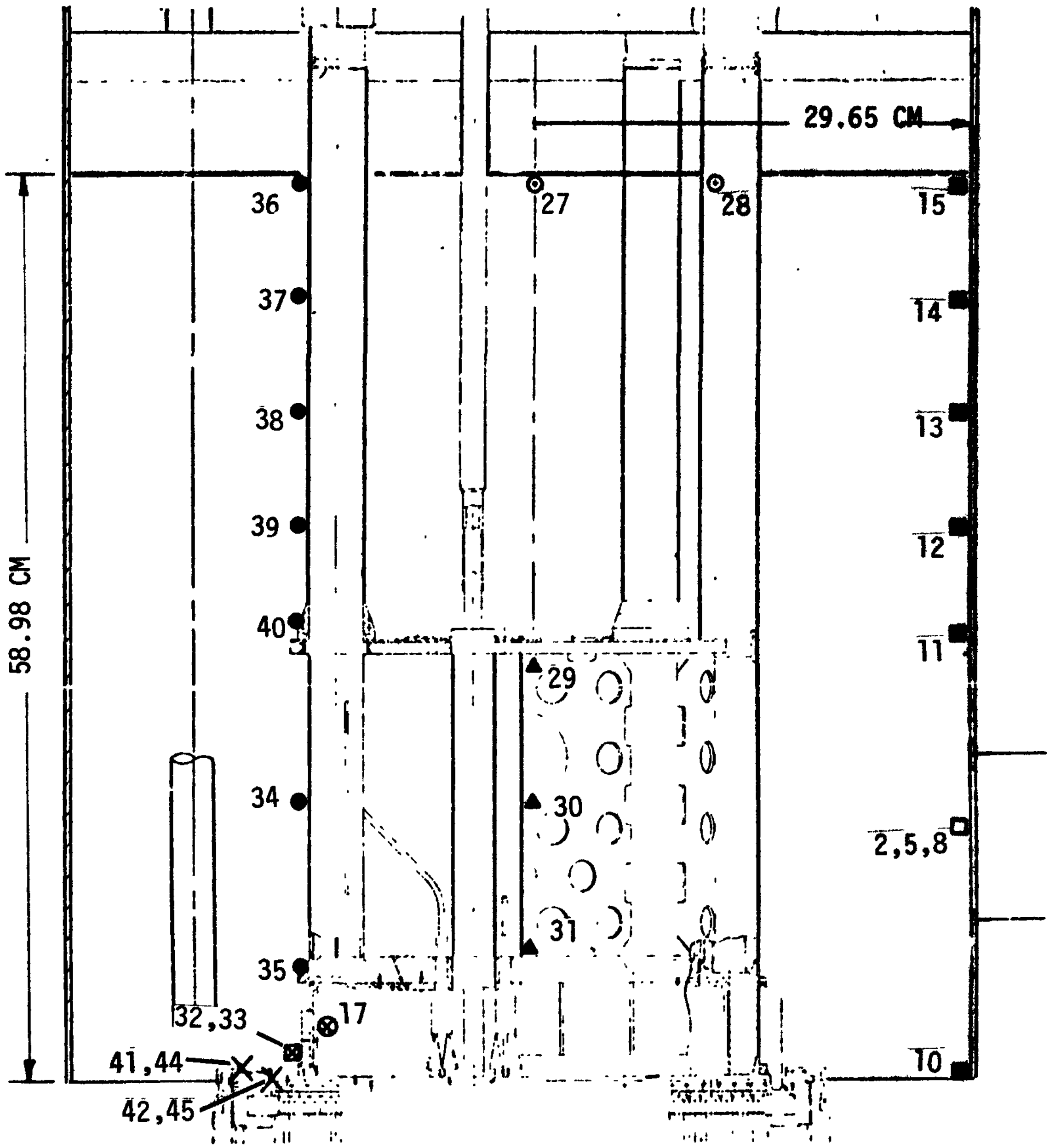


Figure 13. Leakage Flange at Zero and Maximum Leakage Positions



⊗ Inside UIS Mixing Chamber Skirt
● Support Columns
■ Vessel Liner
▲ Inside of Shear Web
X Core Barrel Cap
⊙ Suppressor Plate
⊠ Outside UIS Mixing Chamber Skirt
□ Exit Nozzle Center

Figure 14. Outlet Plenum Thermocouple Map

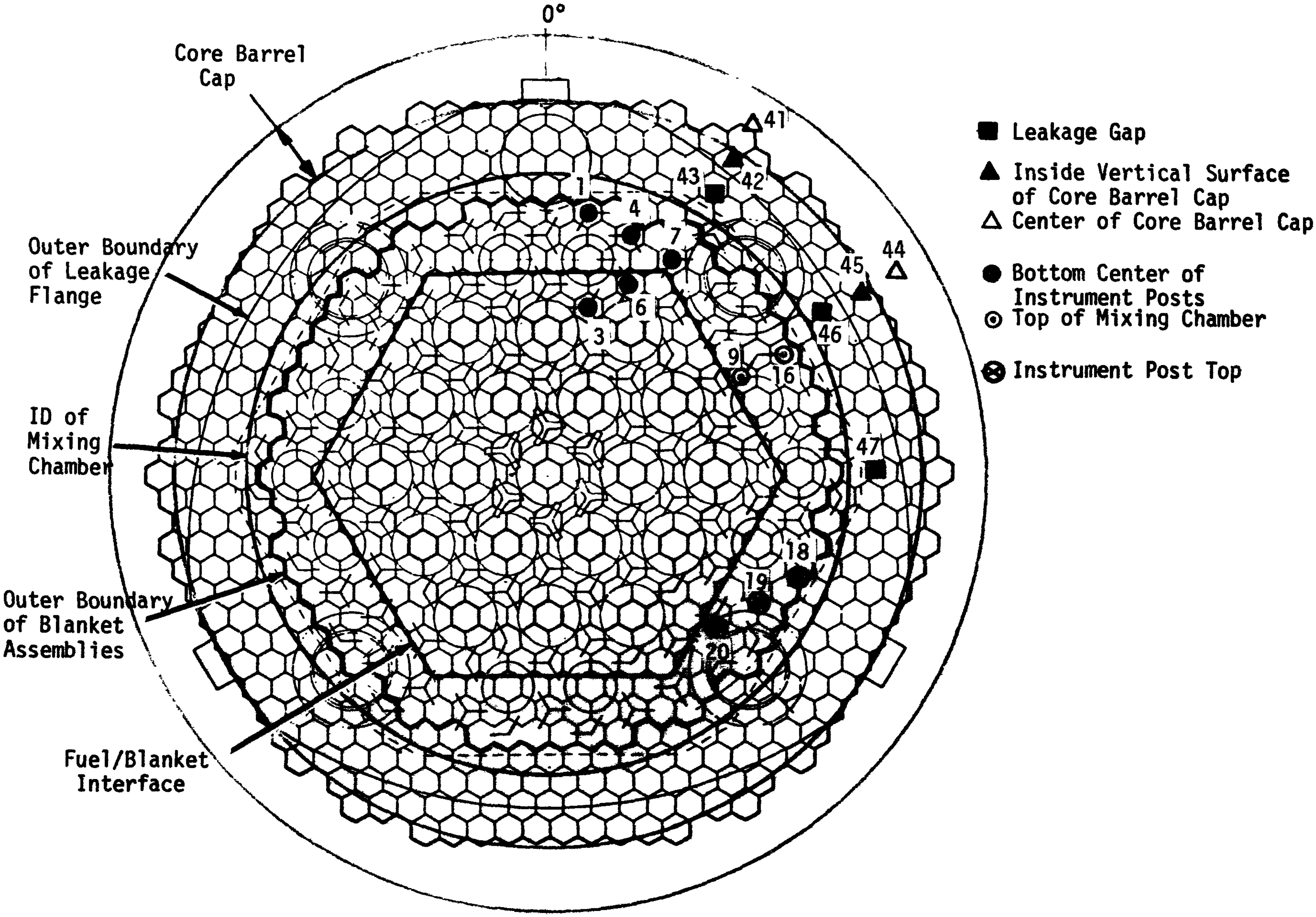


Figure 15. Outlet Plenum Thermocouple Map

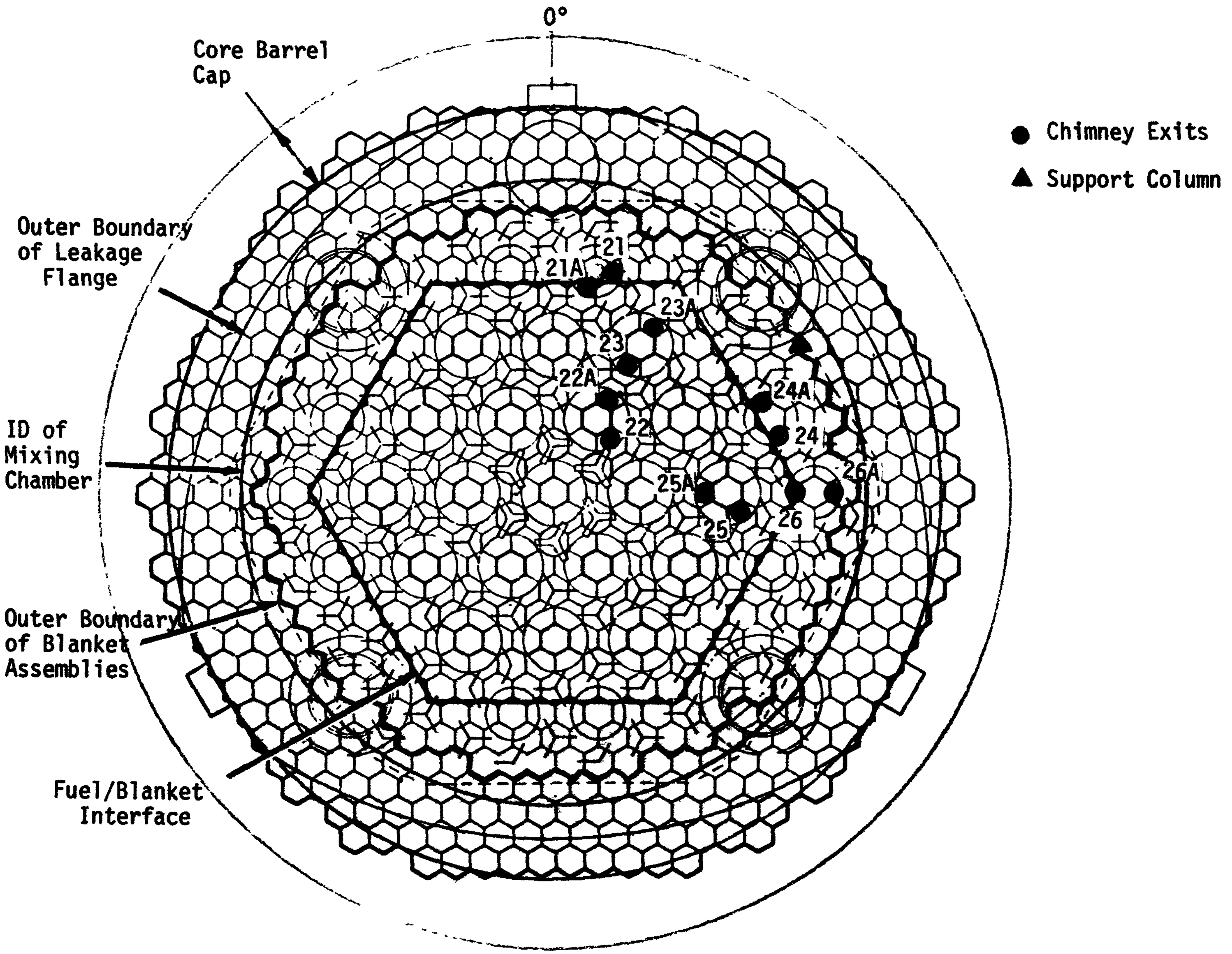


Figure 16. Outlet Plenum Thermocouple Map (TC Numbers Followed by "A" Pertain to Run SS04 only)

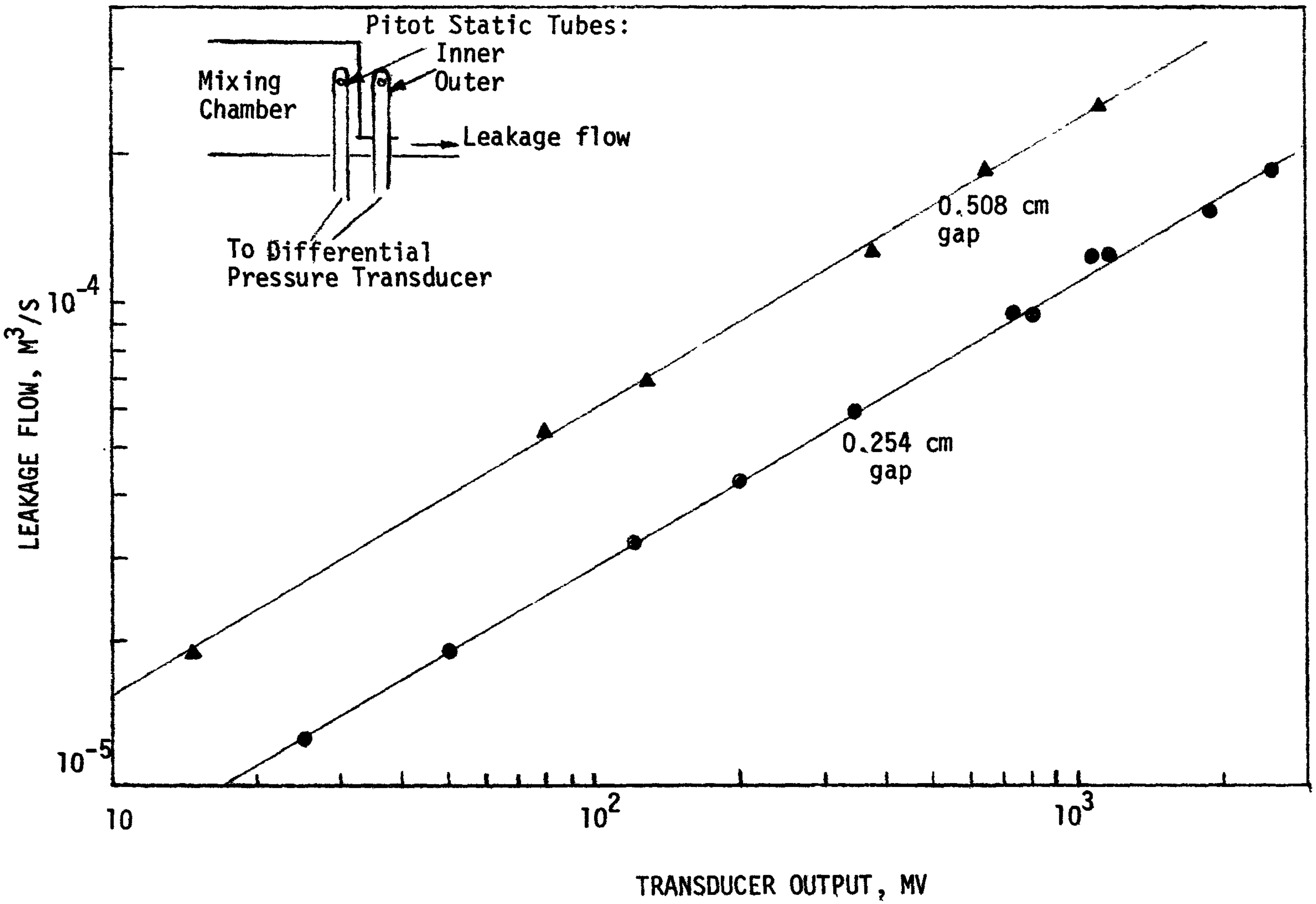


Figure 17. Calibration Curves for Leakage Flow

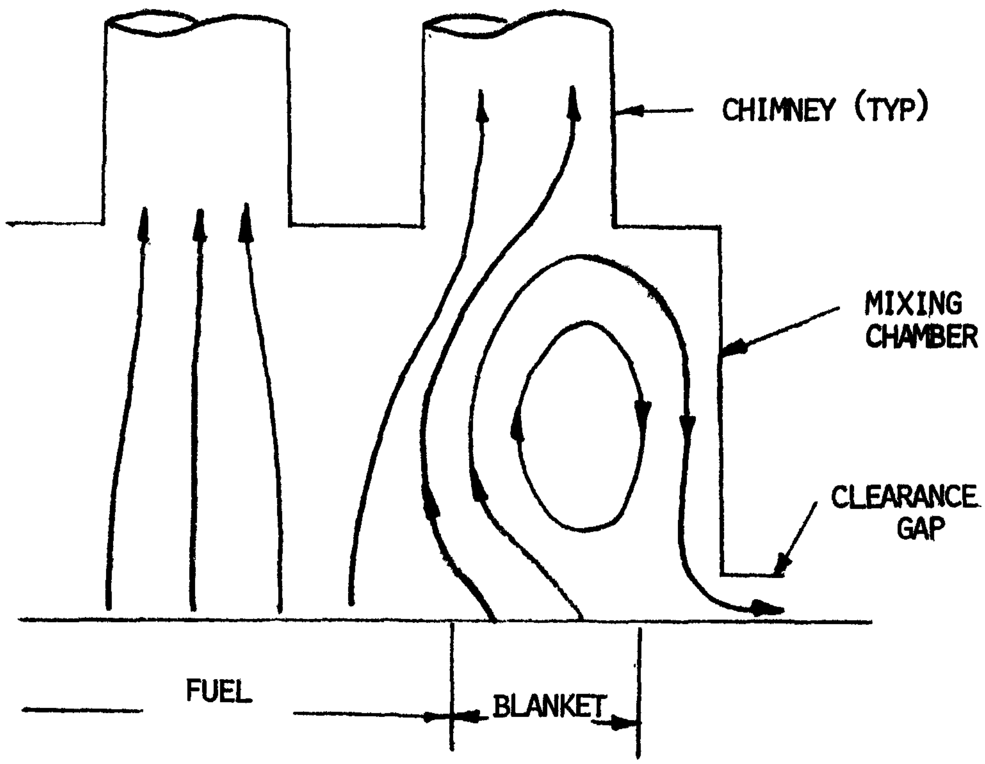


Figure 18. Flow Pattern Within UIS Mixing Chamber

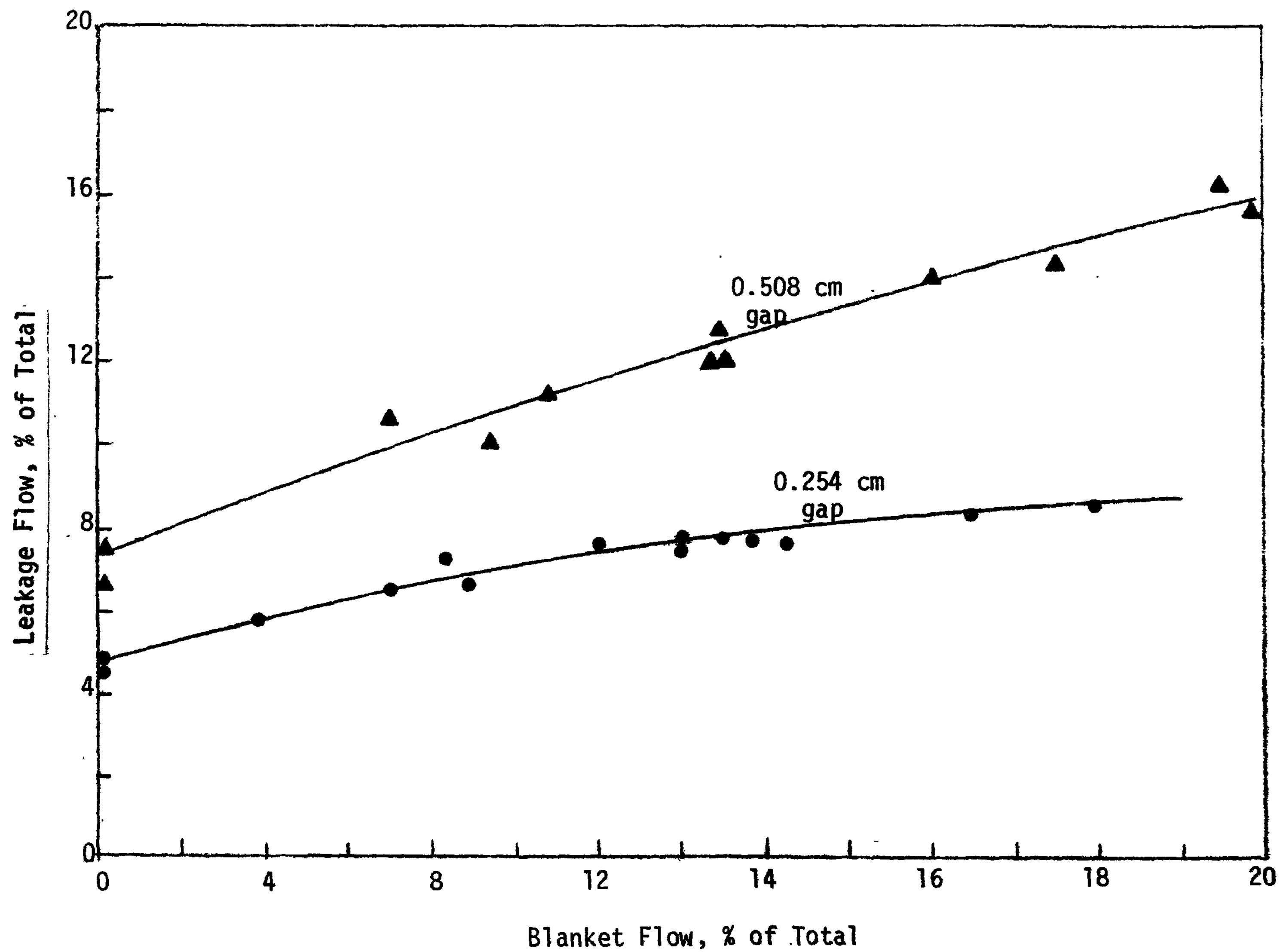


Figure 19. Effect of Blanket Flow on Leakage Flow for Different Gaps

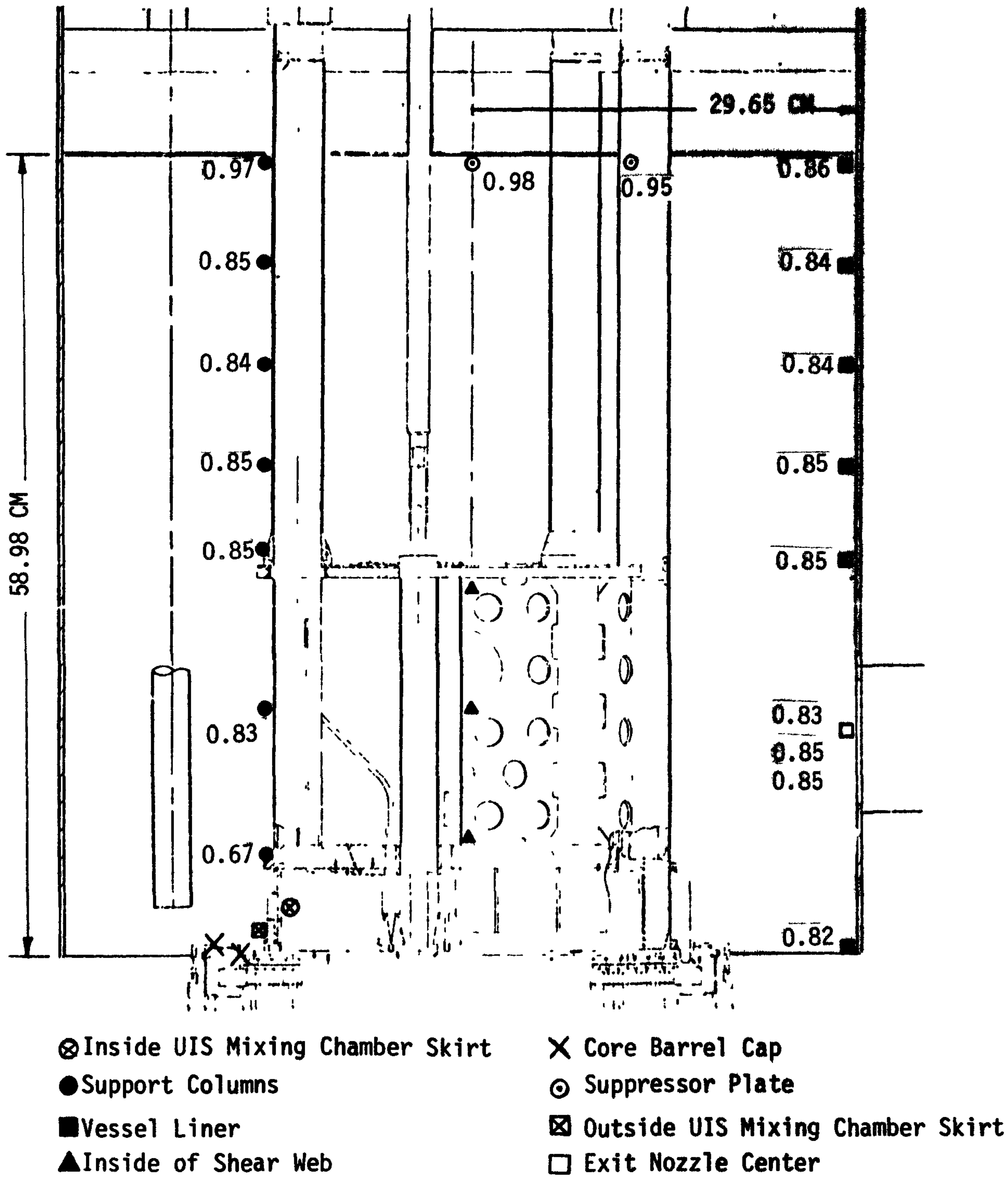


Figure 20. Mean Temperature Map for SS05

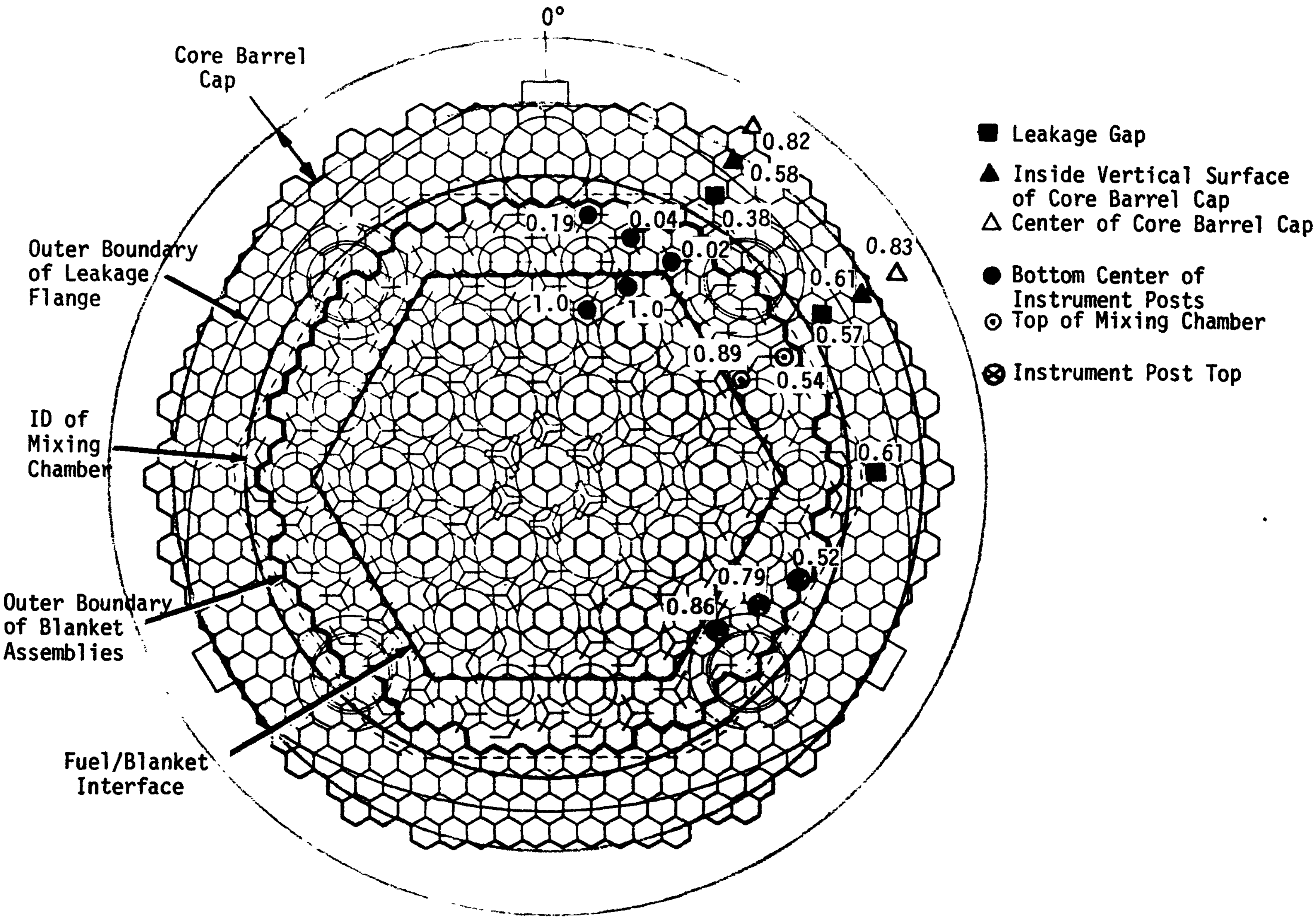


Figure 21. Mean Temperature Map for SS05

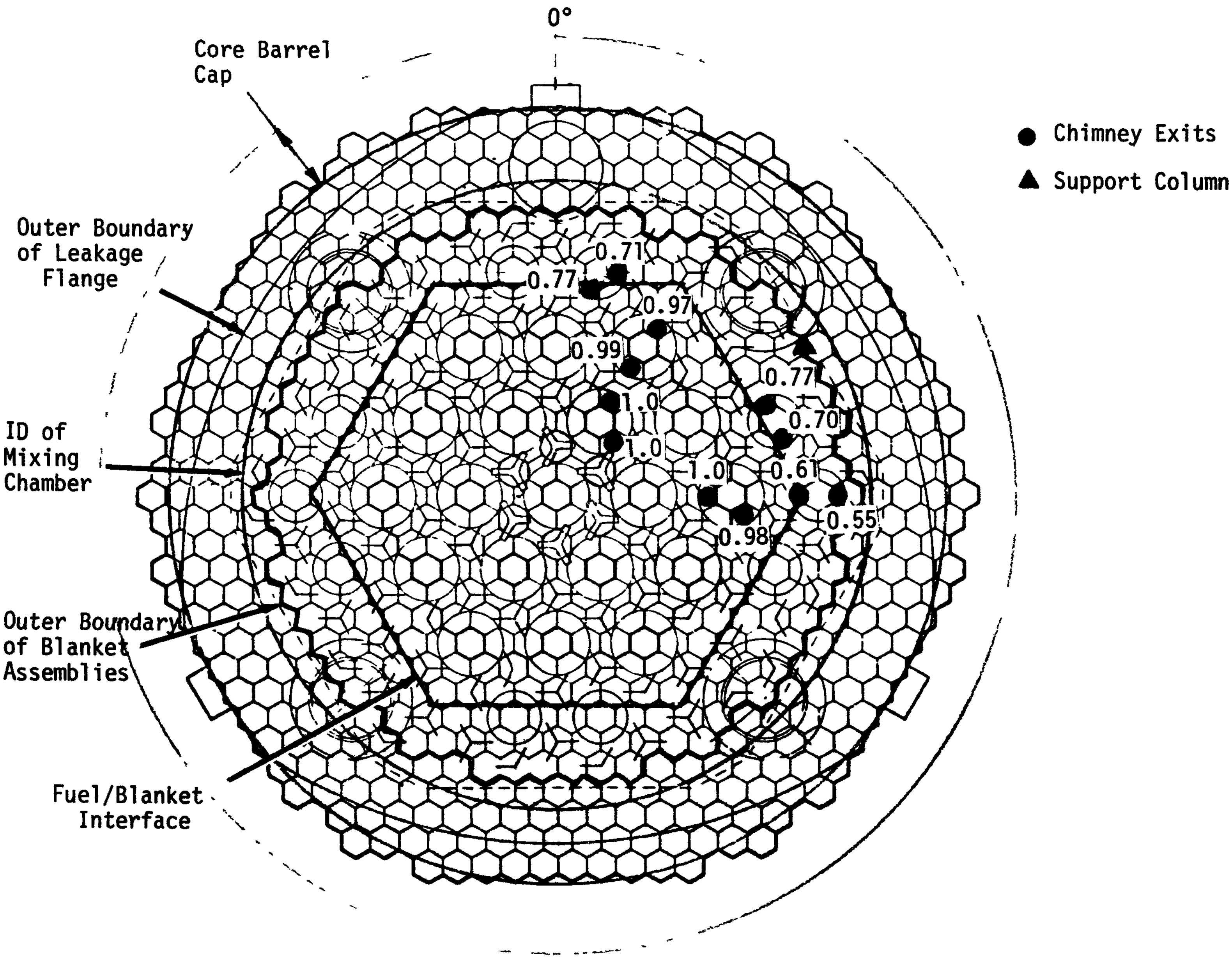


Figure 22. Mean Temperature Map for Chimney Exit with Nominal Gap

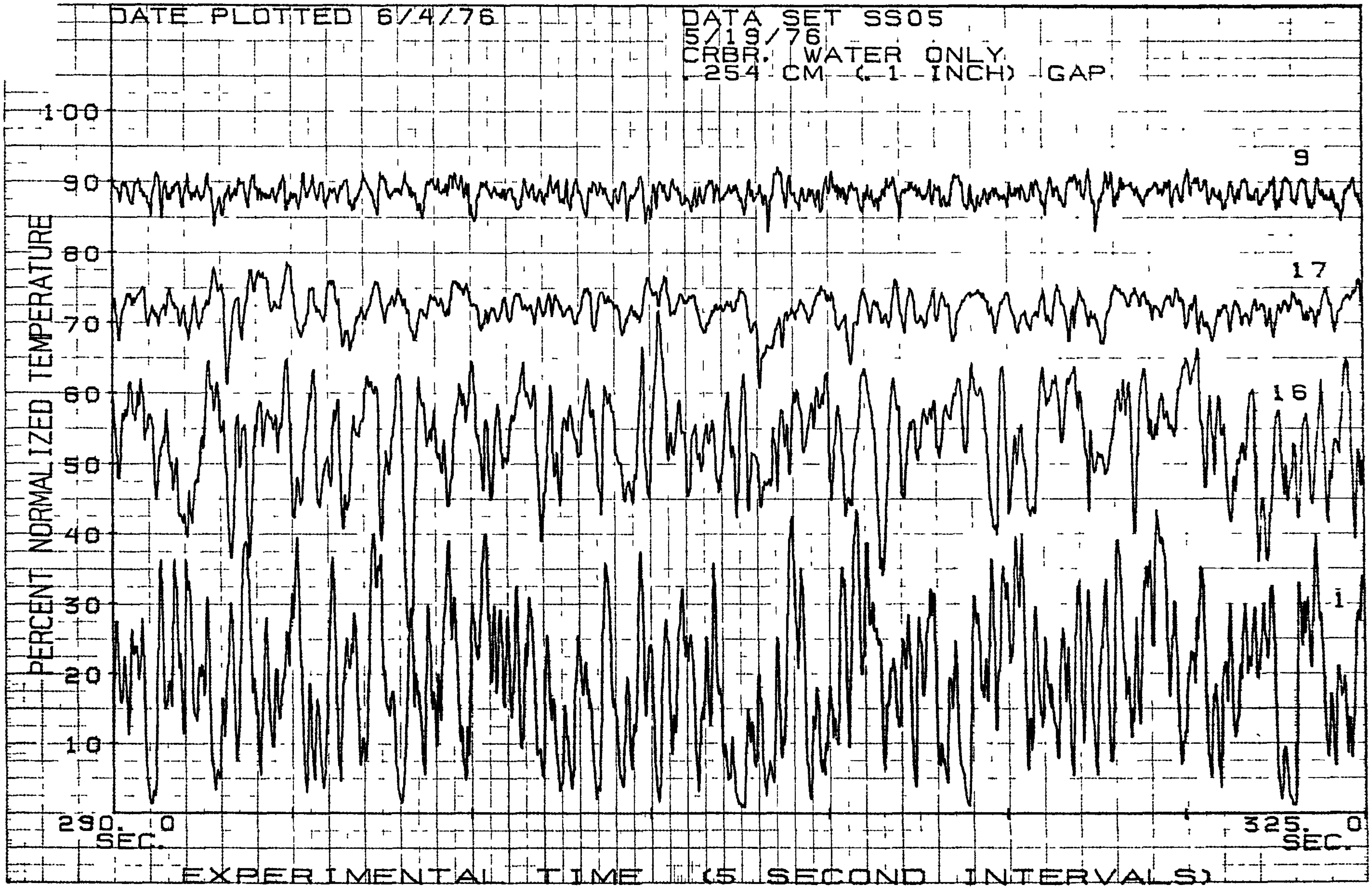


Figure 23. Steady State Temperature-Time Plots

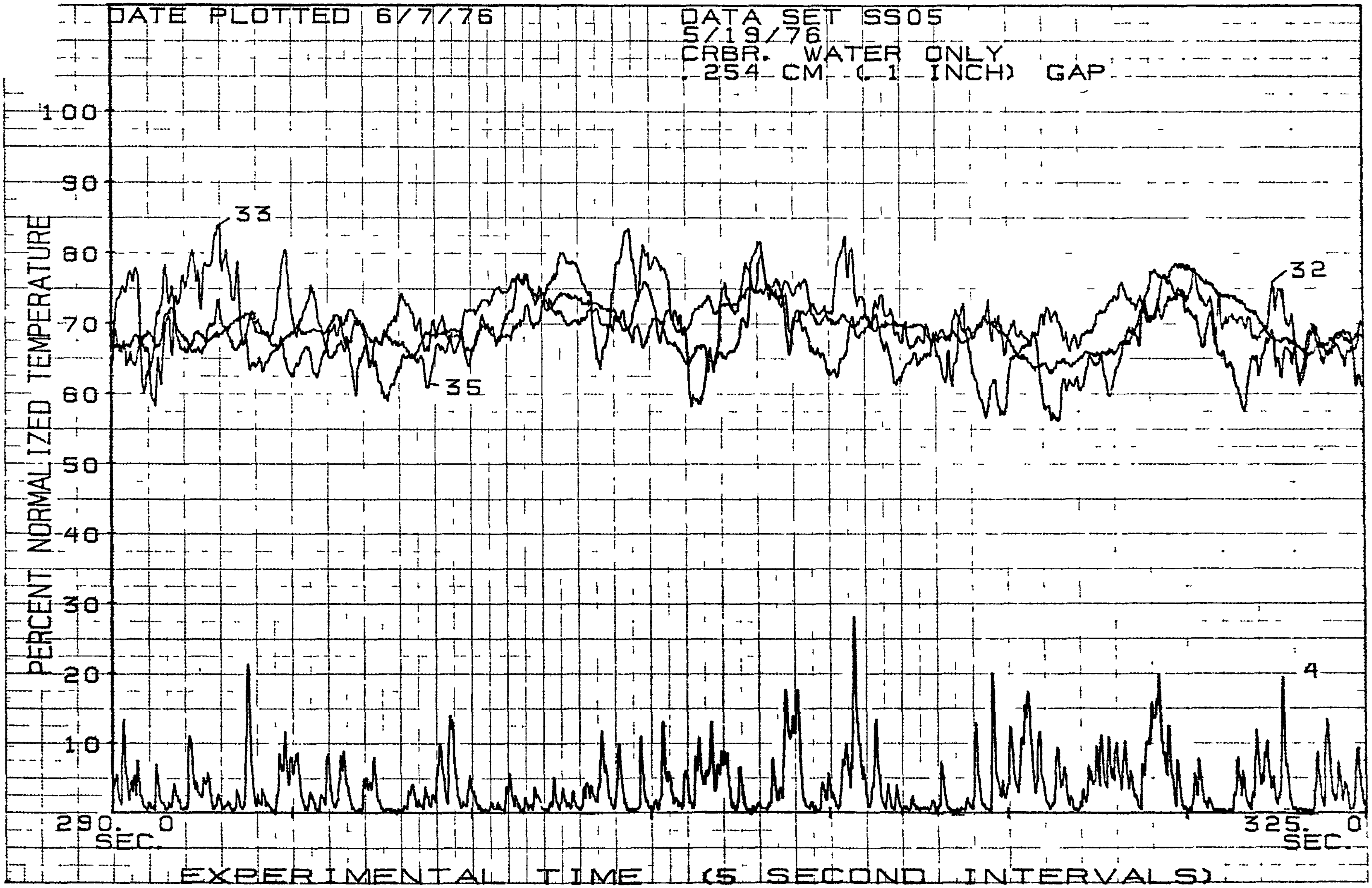


Figure 24. Steady State Temperature-Time Plots

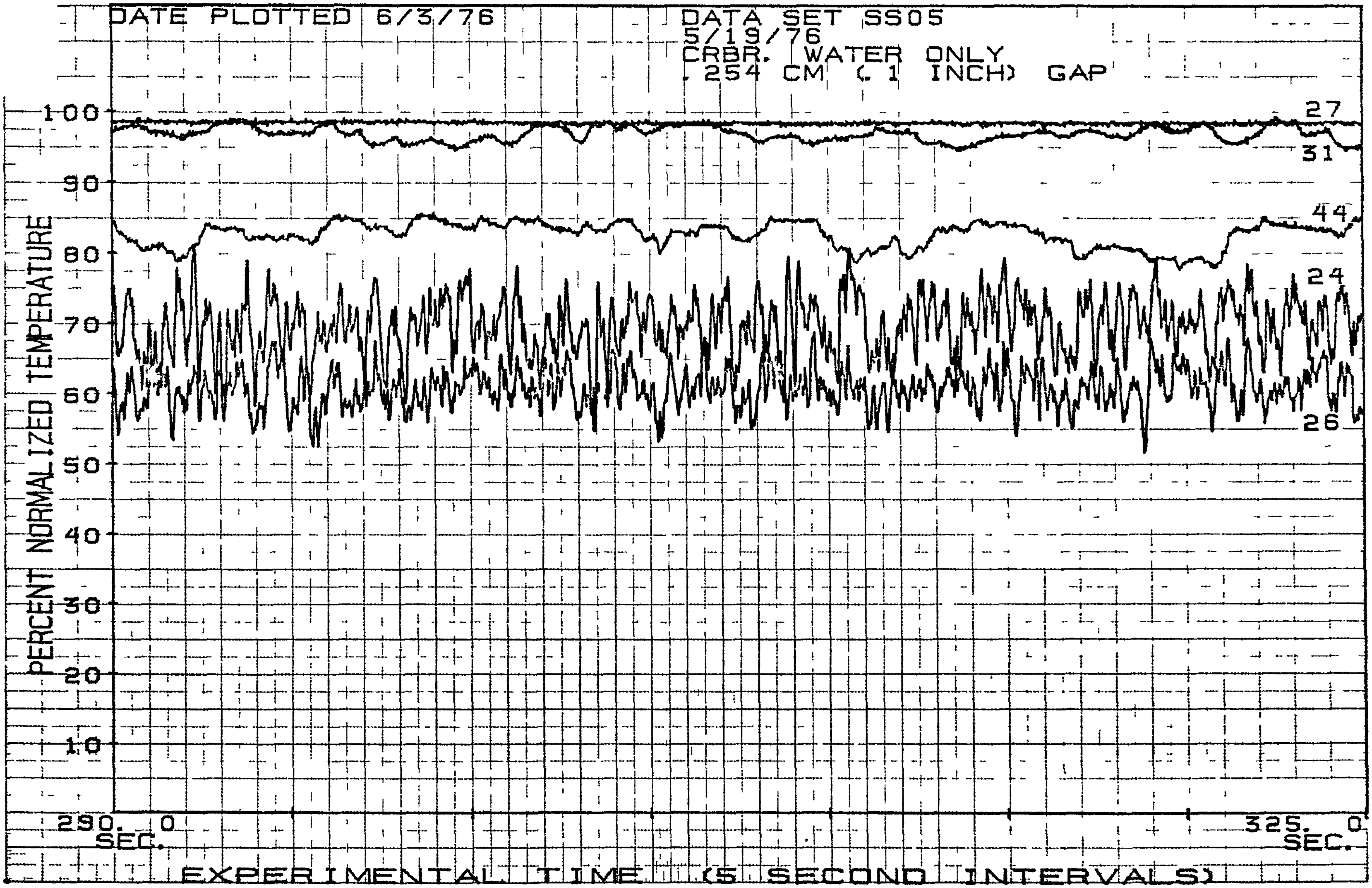


Figure 25. Steady State Temperature-Time Plots

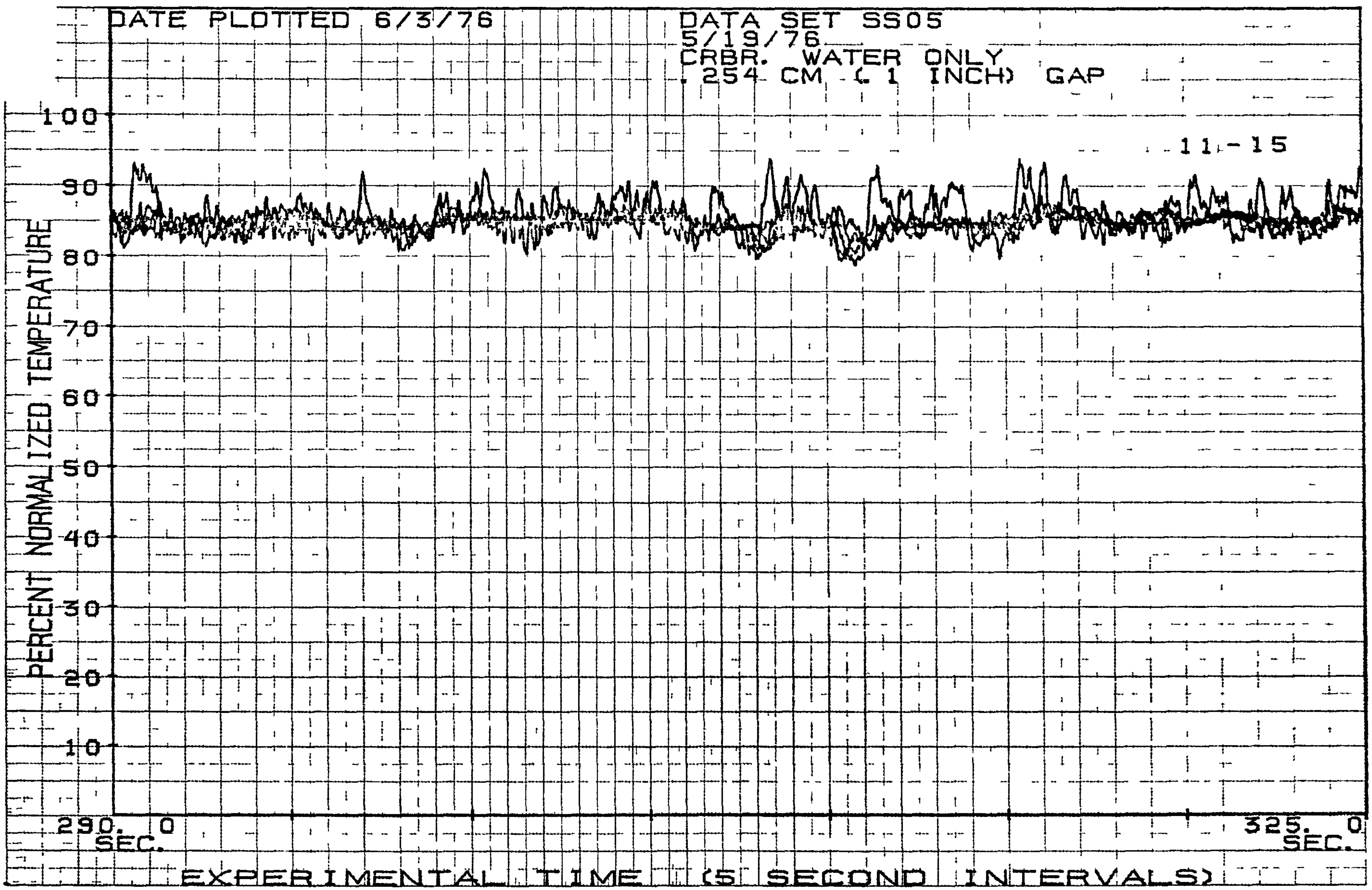


Figure 26. Steady State Temperature-Time Plots

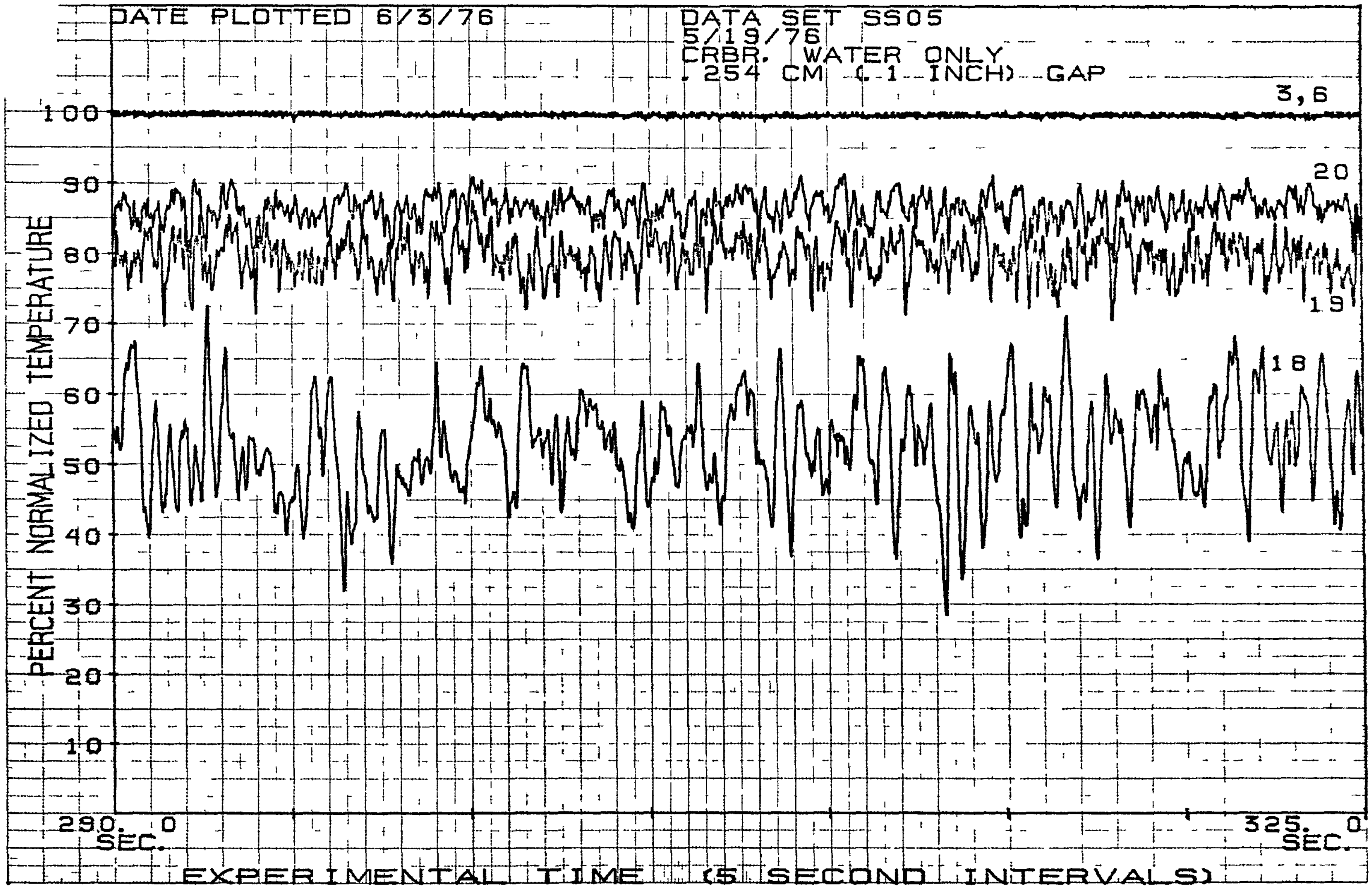


Figure 27. Steady State Temperature-Time Plots

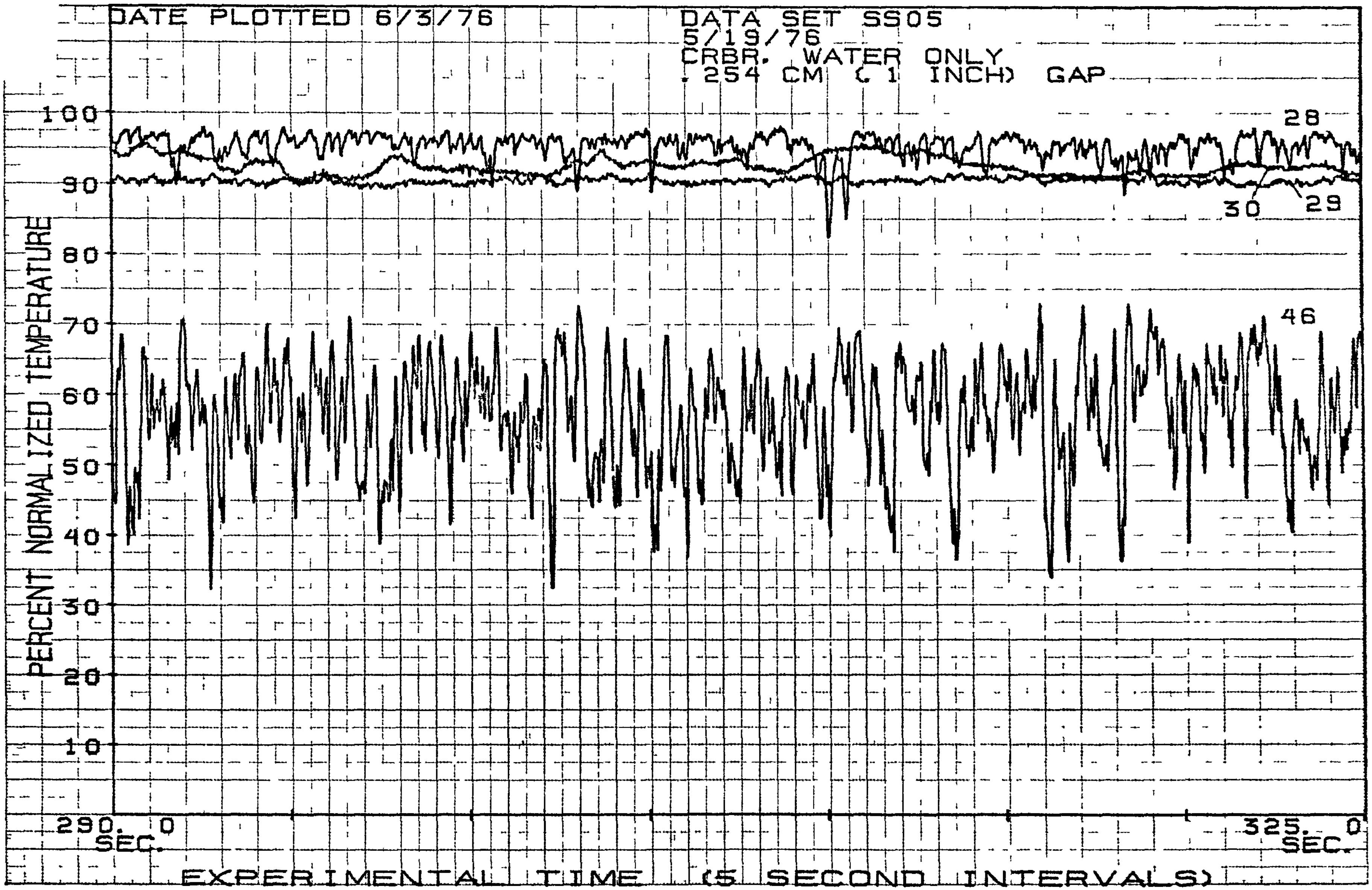


Figure 28. Steady State Temperature-Time Plots

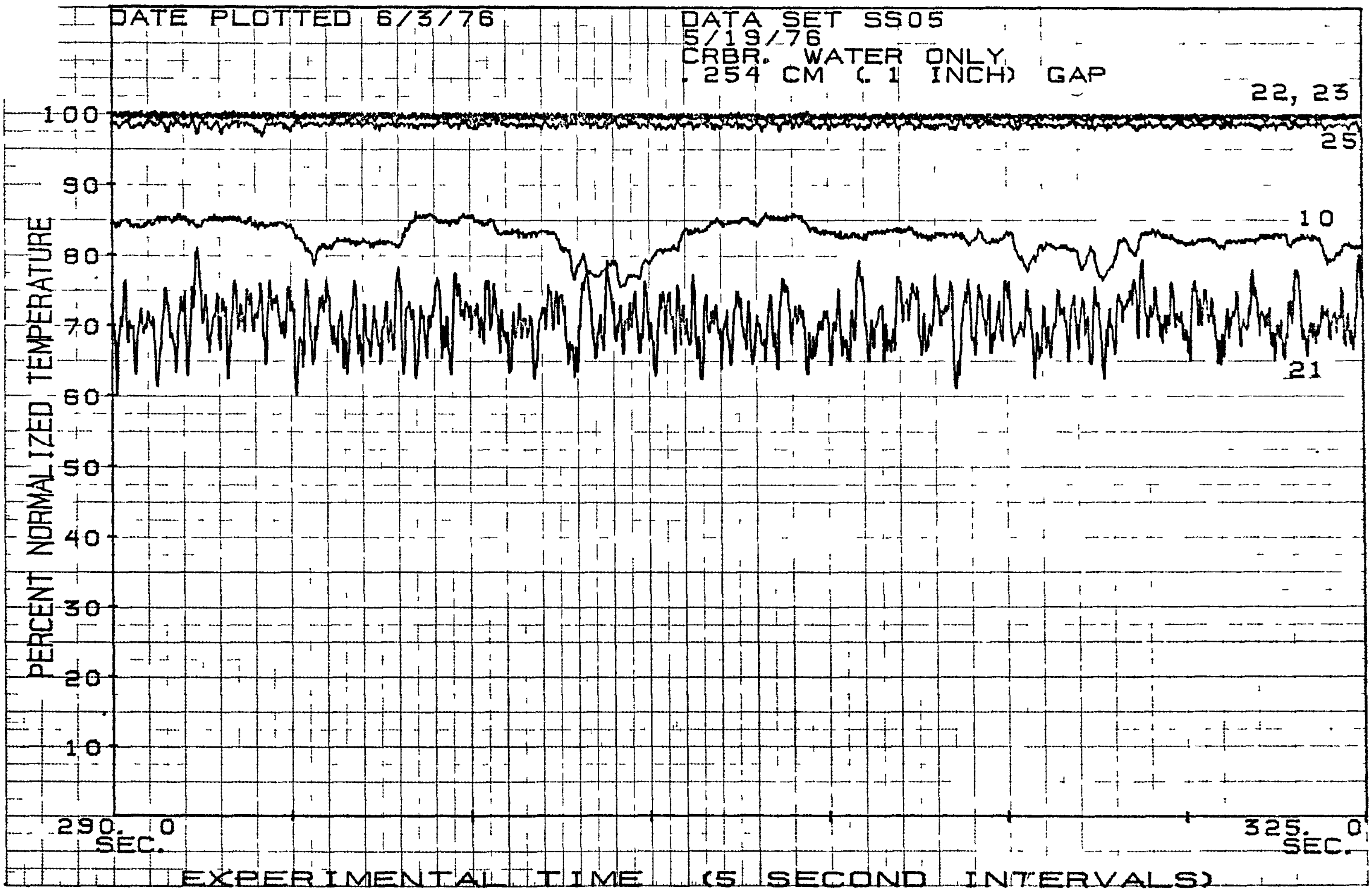


Figure 29. Steady State Temperature-Time Plots

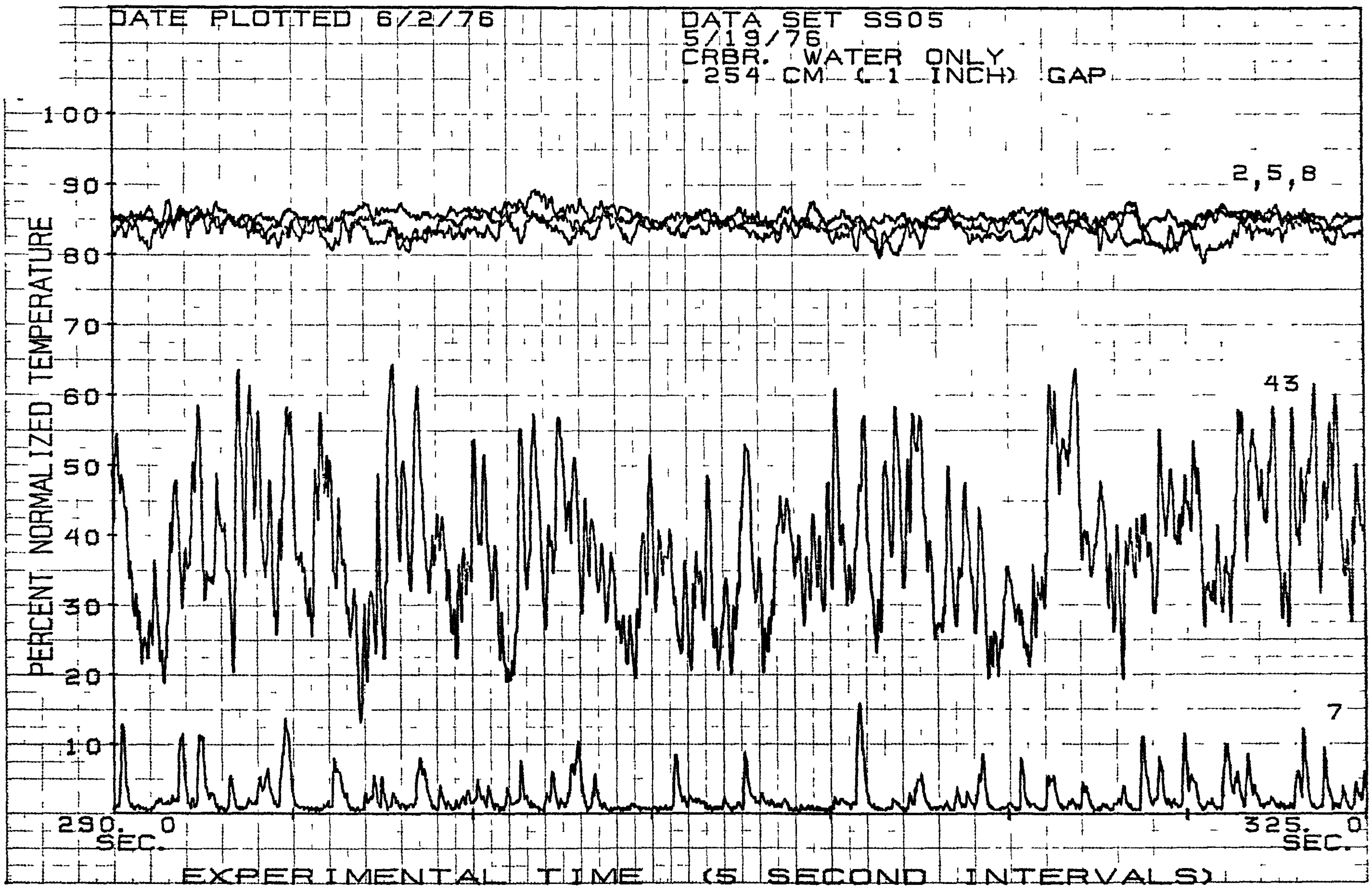


Figure 30. Steady State Temperature-Time Plots

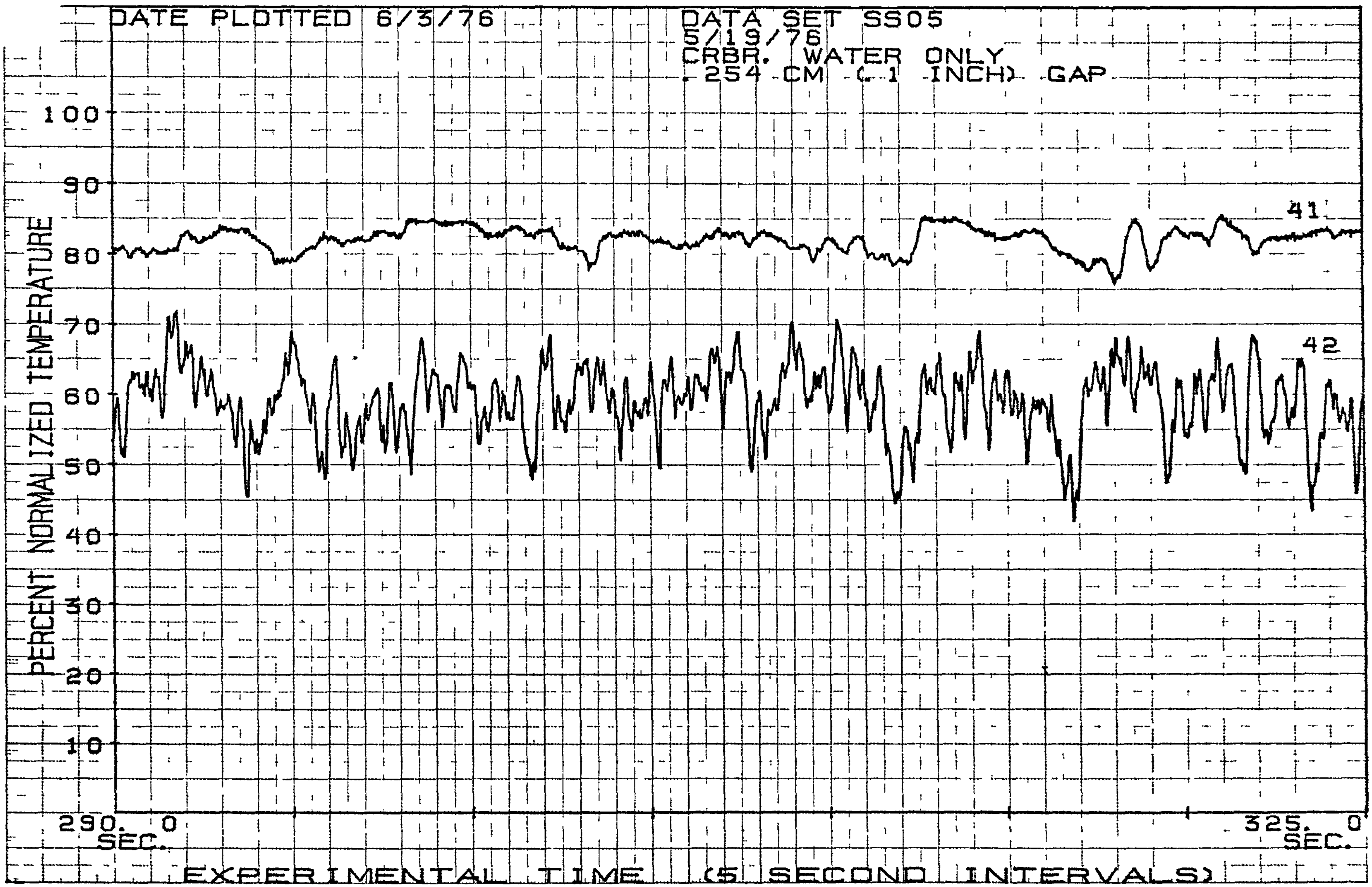


Figure 31. Steady State Temperature-Time Plots

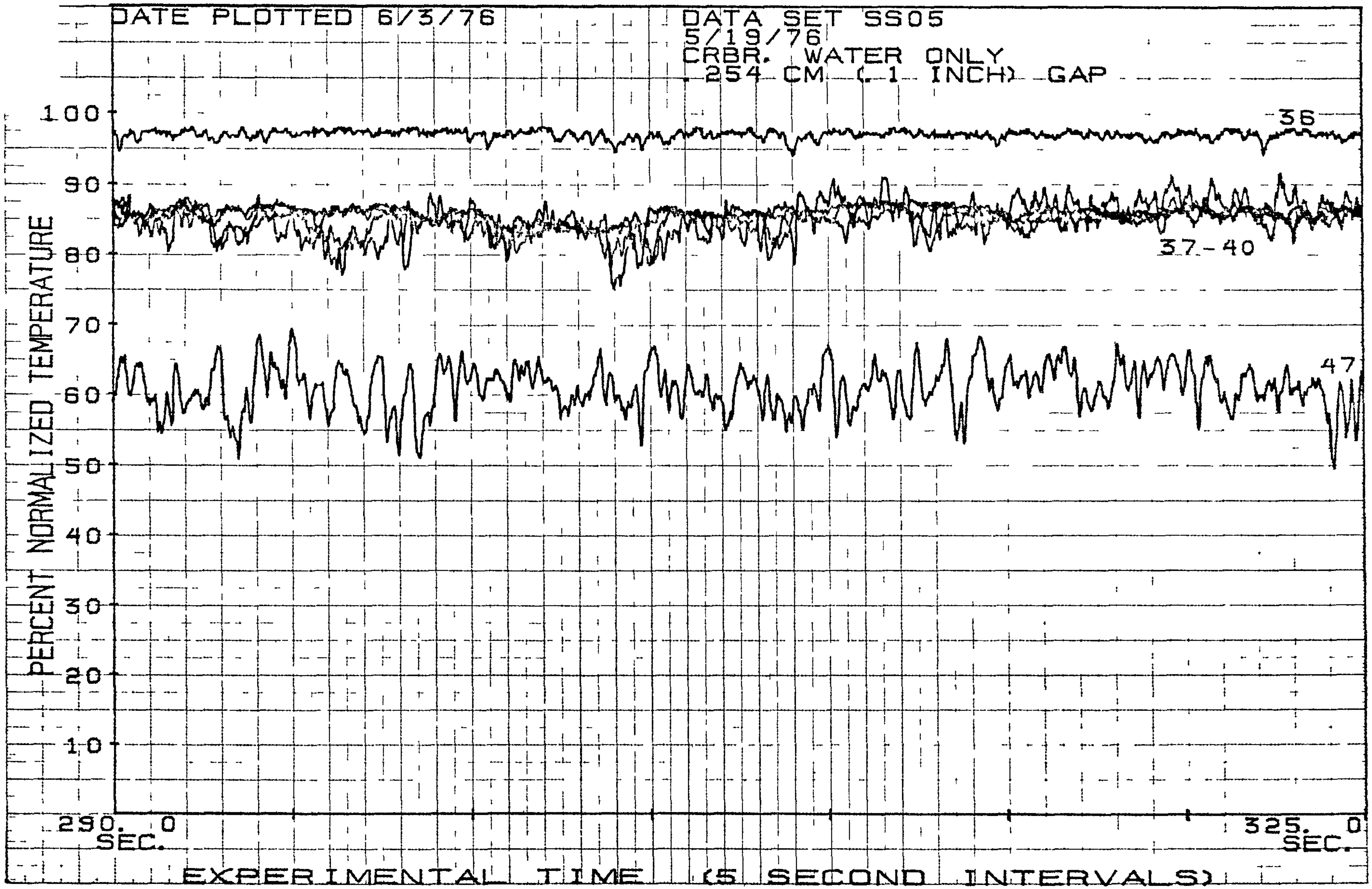


Figure 32. Steady State Temperature-Time Plots

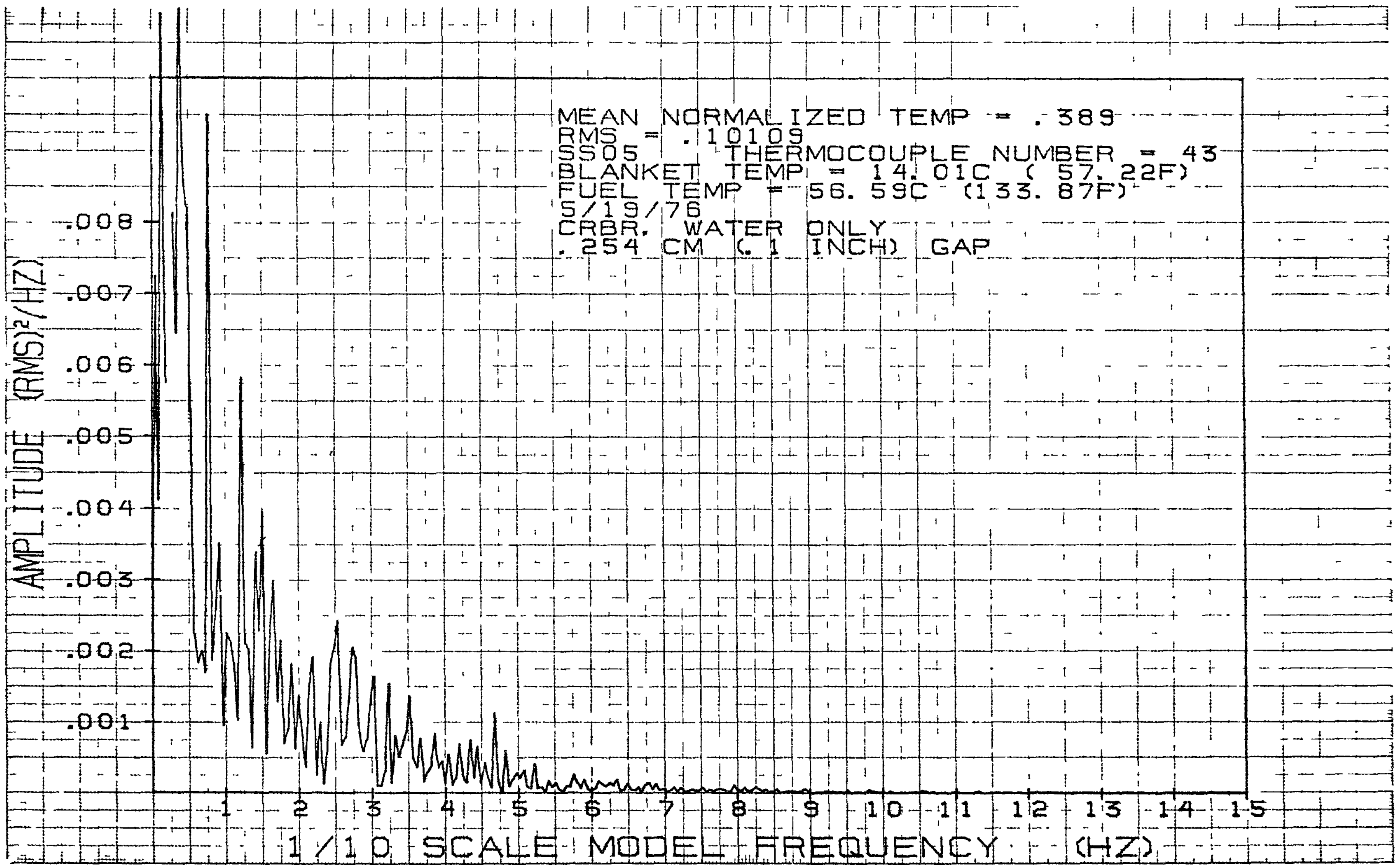


Figure 33. Power Spectral Density Plot for TC #43.

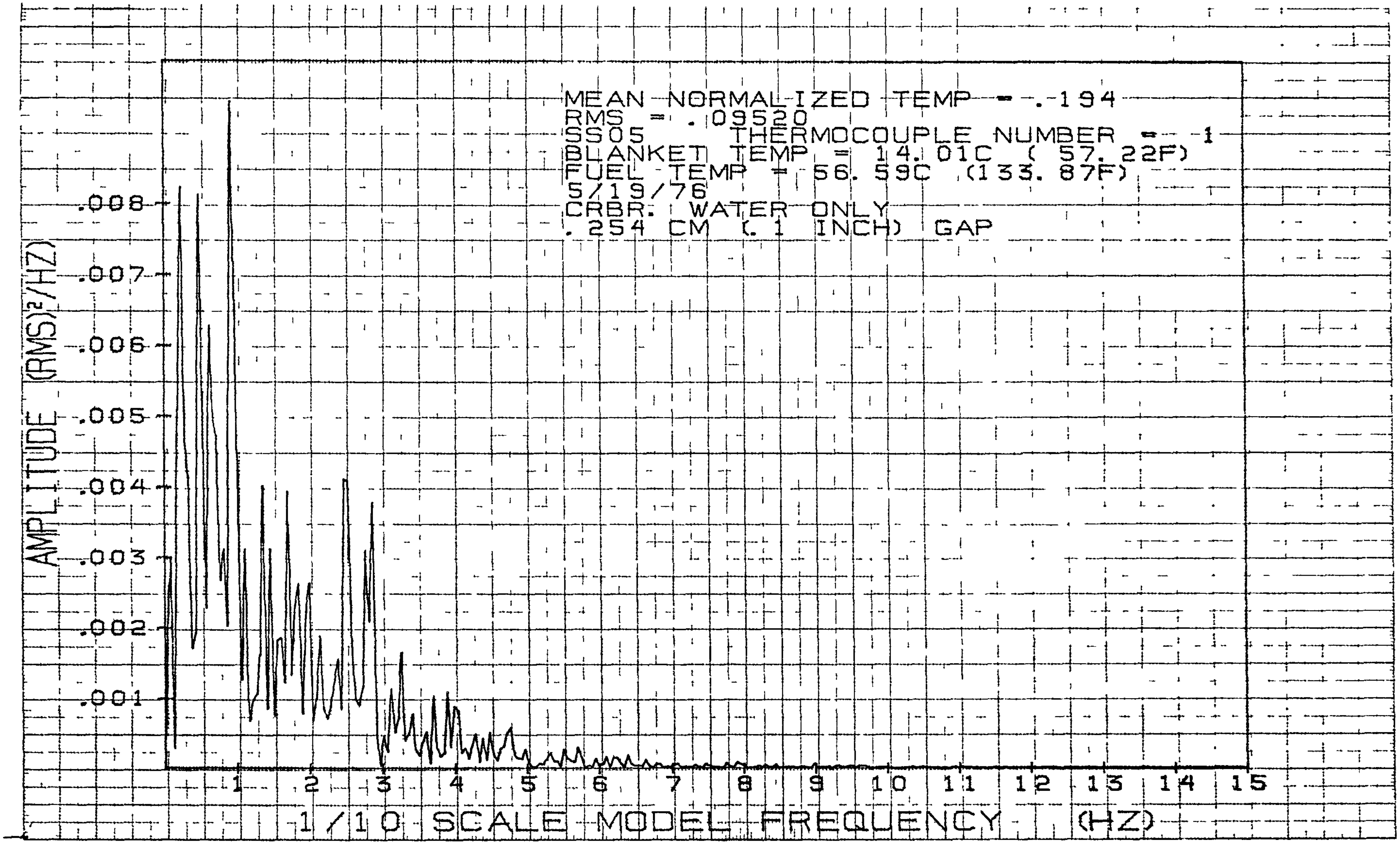


Figure 34. Power Spectral Density Plot for TC #1

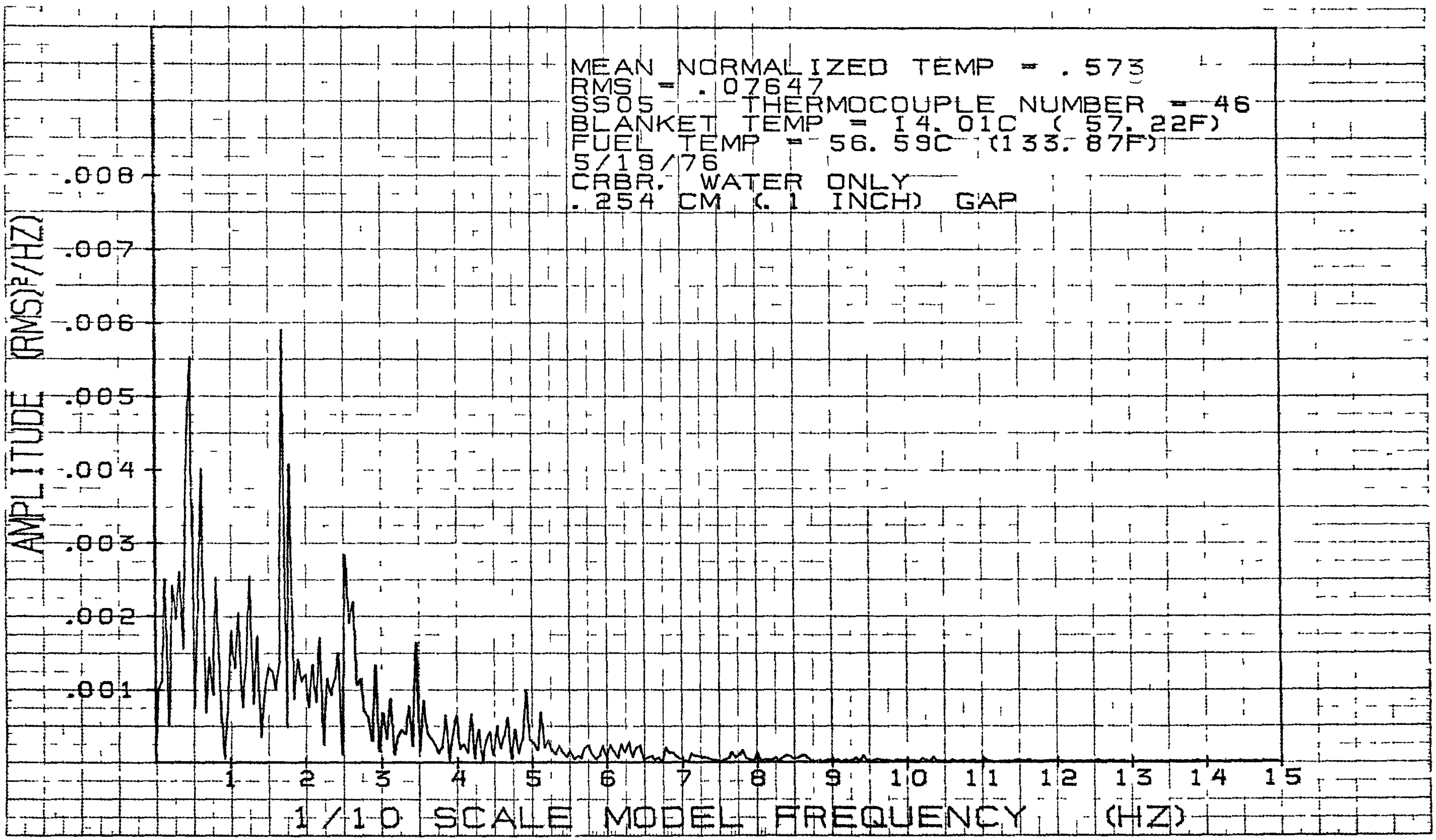


Figure 35. Power Spectral Density Plot for TC #46

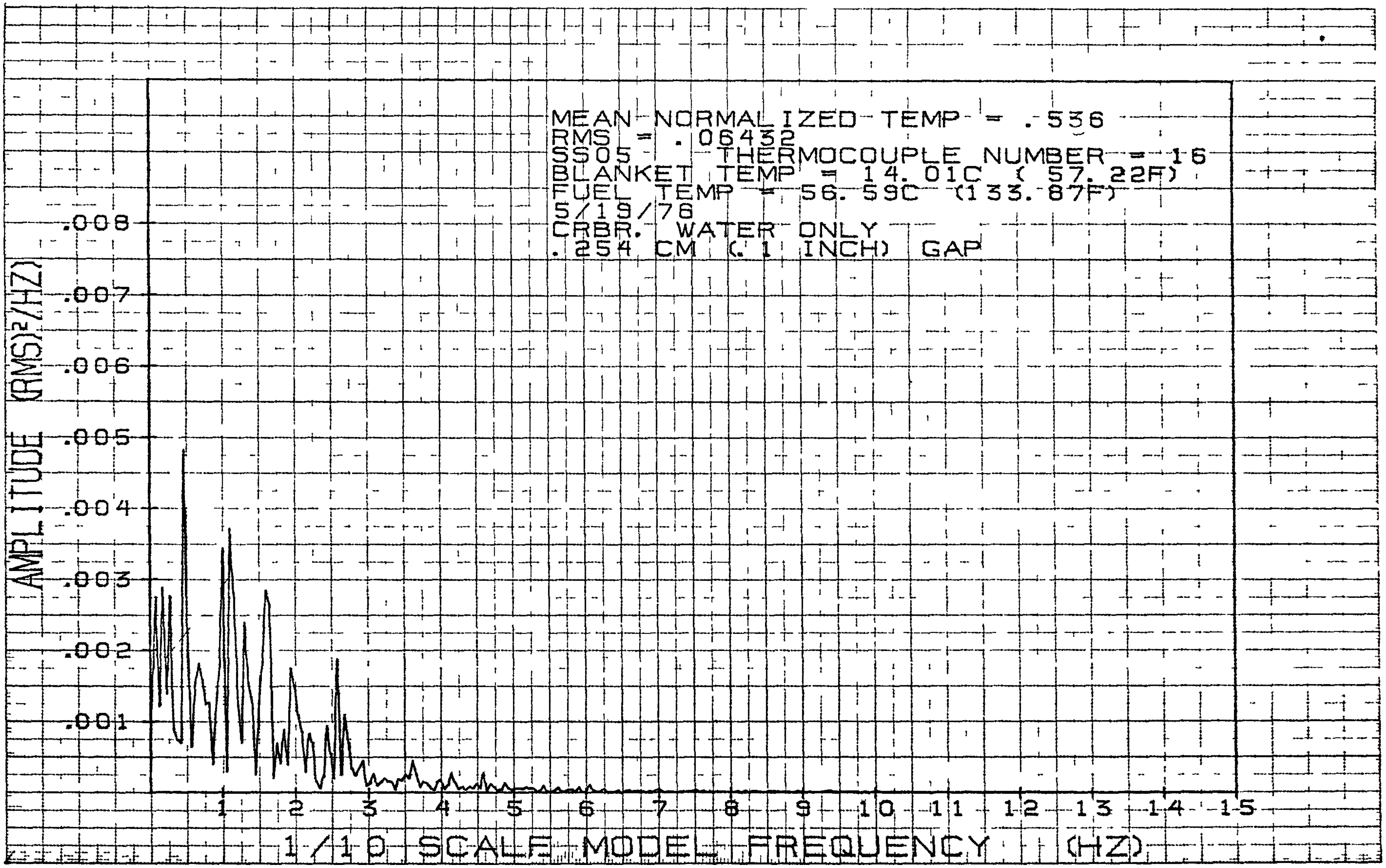


Figure 36. Power Spectral Density Plot for TC #16

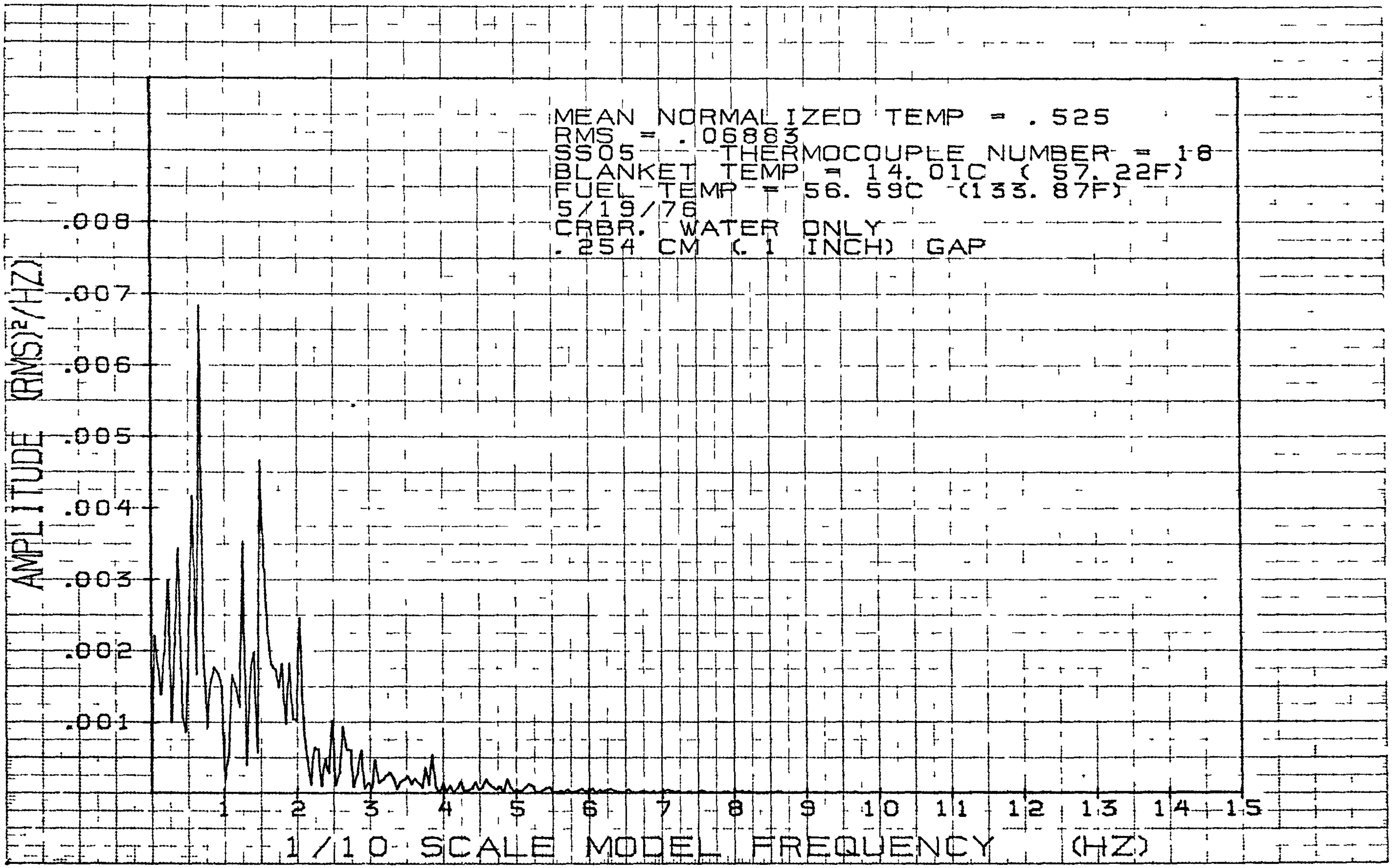


Figure 37. Power Spectral Density Plot for TC #18

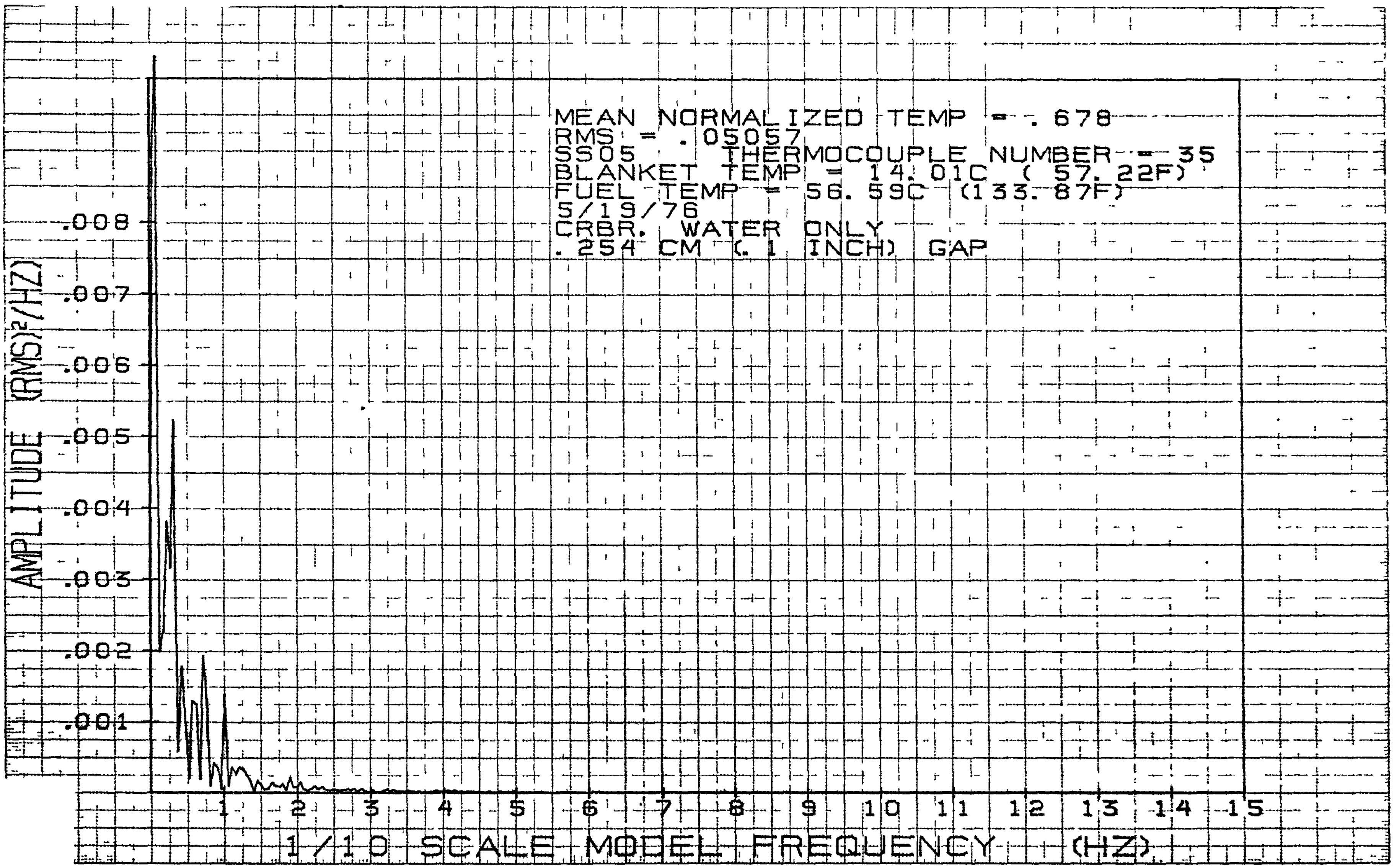


Figure 38. Power Spectral Density Plot for TC #35

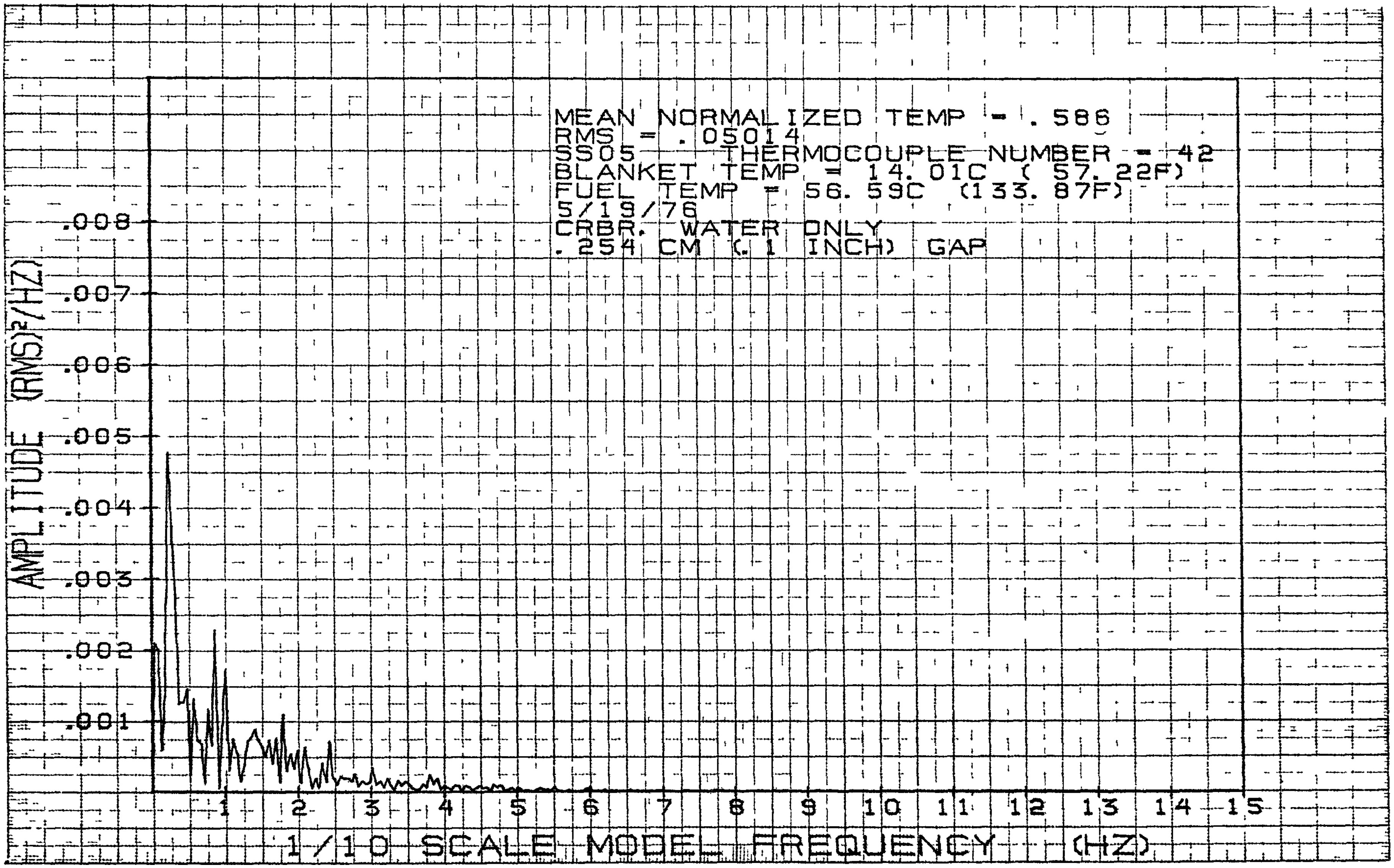


Figure 39. Power Spectral Density Plot for TC #42

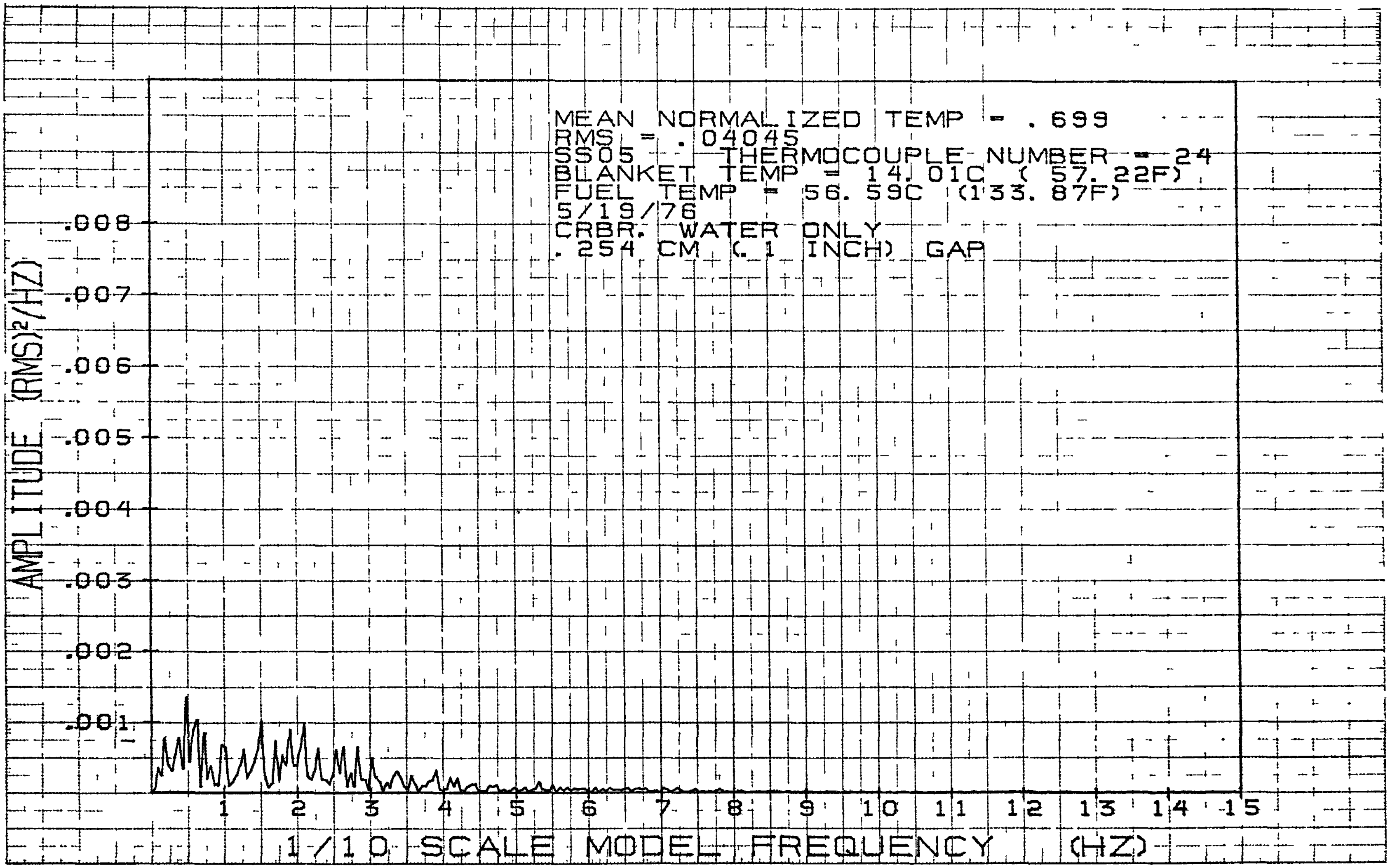


Figure 40. Power Spectral Density Plot for TC #24