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CLASS 1
MARCH 1983

CORE SPRAY DESIGN METHODOLOGY CONFIRMATION TESTS

GENERAL ELECTRIC

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S. A. Sandoz
L. L. Myers
D. G. Schumacher
W. A. Sutherland
G. E. Dix

Approved: J. E. Wood
J. E. Wood, Manager
Core Methods and Analysis

NUCLEAR ENGINEERING DIVISION • GENERAL ELECTRIC COMPANY
SAN JOSE, CALIFORNIA 95125

GENERAL ELECTRIC

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UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

JAN 30 1981

General Electric Company
ATTN: Dr. G. G. Sherwood, Manager
Safety and Licensing
175 Curtner Avenue
San Jose, California 95114

Dear Dr. Sherwood:

SUBJECT: ACCEPTANCE FOR REFERENCING TOPICAL REPORT NEDO-24712
CORE SPRAY DESIGN METHODOLOGY CONFIRMATION TESTS

The Nuclear Regulatory Commission has completed its review of the General Electric Company Licensing Topical Report NEDO-27412 entitled "Core Spray Design Methodology Confirmation Tests." Although neither the report nor the transmittal letter indicated that GE was submitting it under the NRC licensing topical report program with the intent that it would be referenced in license applications, subsequent phone conversations with your representatives have so indicated. It has therefore been reviewed thereunder. The summary of our evaluation is attached.

The report provides a summary and conclusions developed from the program, the test objectives, the test facility description, identification of test parameters and test matrix, description of test operation and shakedown, the Steam Sector Test Facility (SSTF) test results compared to the pre-test prediction, description of the extension of the pre-test prediction, and test results with parameter variations.

As a result of our review we concluded the SSTF tests constitute an adequate confirmation of the GE spray distribution methodology for BWR/6 type spargers. Additional tests will be required to confirm the design methodology for other sparger designs. Further we concluded application of the methodology to actual plant configurations, including treatment of prediction uncertainties, remain unresolved.

We find the report NEDO-24712 is acceptable for referencing in licensing actions to the extent that the applicability is prescribed in the report and within the limitations stated in the attached Topical Report Evaluation.

We do not intend to repeat the review of the safety features described in the topical report and found acceptable in the attachment. Our acceptance applies only to the features described in the topical report and under the conditions discussed in the attachment.

In accordance with established procedure, it is requested that General Electric Company publish an approved version of this report, within three months of receipt of this letter. The revision is to incorporate this letter and the attached topical report evaluation following the title page and thus just in front of the abstract. The report identifications of the approved reports are to have a -A suffix.

Should Nuclear Regulatory Commission criteria or regulations change such that our conclusions as to the acceptability of the report are invalidated, General Electric Company and/or the applicants referencing the topical report will be expected to revise and resubmit their respective documentation or submit justification for the continued effective applicability of the topical report without revision of their respective documentation.

Sincerely,

R Tedesco

Robert L. Tedesco, Assistant Director
for Licensing
Division of Licensing

Enclosure:
Topical Report
Evaluation

TOPICAL REPORT EVALUATION

REPORT NUMBER AND TITLE: NEDO-24712, "Core Spray Design Methodology Confirmation Tests," August 1979.

Originating Organization: General Electric Company

Reviewed by: Reactor Systems Branch
Core Performance Branch

BACKGROUND

The core spray (CS) systems are one component of the Emergency Core Cooling System (ECCS) for all BWRs. CS systems have a nozzle or a set of nozzles arranged to distribute water over the top of the core following a postulated loss of coolant accident (LOCA). A typical BWR/6 spray sparger arrangement is shown schematically in Figure 1 where the spray from only two of many nozzles is depicted. Each fuel bundle must receive a specified minimum amount of coolant from the CS system to provide the post-LOCA spray cooling assumed in the LOCA analyses.

During tests conducted in Europe (the results of which were later confirmed by tests conducted by the General Electric Company), it was discovered that the presence of steam and/or increased pressure in and above the upper core region could adversely affect the distribution of flow from certain types of core spray nozzles.

Prior to this discovery, GE had conducted full scale spray distribution tests in air at atmospheric pressure for all BWR/2 and later designs to ensure that the necessary minimum coolant flow would be provided to each fuel bundle. Those tests were performed in a full scale test facility which used the actual core spray nozzle geometry (Spacing, type, arrangement and alignment) spraying water over a mockup of the top of the reactor core. Core spray flow into mockup "fuel bundles" was collected and measured.

Open literature data and data obtained by GE for nozzles spraying into a steam environment show that beyond a few nozzle diameters, the spray water becomes saturated provided sufficient steam is available to saturate the water. This led GE to postulate that spray water from the nozzles was influenced by the steam near the nozzle but interaction effects where the spray jets intermix is essentially hydrodynamic. Therefore, steam and hydrodynamic effects are separable.

GE proposed the following methodology for determining the spray distribution in a BWR with a steam environment:

1. Single nozzle, full scale tests are performed in steam for each spray nozzle type. The horizontal spray facility (HSF) with a collector assembly as shown in Figure 2 is used for these tests.

2. Data from the HSF are used for three purposes: (a) a "simulator" nozzle is developed which simulates, in air, the spray pattern produced by the actual nozzle in the HSF in steam, (b) the data are used to calibrate a single nozzle calculational model which can extend the HSF data base; and (c) the data are used directly as input to a multiple-nozzle model.

3. Multiple nozzle full-scale tests are conducted in air to determine nozzle-to-nozzle interaction effects on overall spray distribution patterns. These tests are conducted using the "simulator" nozzles developed as described in 2a above. These data obtained are used with the single nozzle model described in 2b above so that the model predicts spray distributions from multiple nozzles in steam.

4. A full-reactor representation of core spray distribution in steam is obtained by using the multi-nozzle model described in 3 above in conjunction with a full-scale, 360° spray test conducted in air using the "simulator" nozzles previously described.

This methodology, which is shown in Figure 3, is confirmed for the BWR/6 sparger design by the data analysis reported in NEDO-24712.

SUMMARY OF REPORT

Core spray system performance for a full-scale 30° sector of a simulated BWR/6-218 was predicted using the methodology described in the previous section and comparison tests were then run with a typical reactor steam environment in the GE Steam Sector Test Facility (SSTF) at Lynn, Massachusetts. Test results confirmed the capability of GE's core spray design methodology to predict spray distribution performance of multiple-nozzle core spray systems similar to the BWR/6 design operating in a steam environment. Pre-test predictions compare well with the test results.

Figure 4 is a schematic representation of that test section components. The upper plenum is a full-scale mockup of a 30° sector of the reference upper plenum with accurate simulation of geometric shape and shroud head curvature and height. Standpipes simulating the steam separators extend up from the shroud head. The upper and lower core spray spargers are full-scale mockups of 30° sectors of the reference HPCS and LPCS spargers with regard to size, curvature, location and nozzles. The core region simulation includes both mock fuel bundles and bypass region. The core region is full-scale in cross-section, but is approximately five feet shorter than the BWR reference due to overall facility height limitations. Fifty-eight mock fuel bundles are included in the 30^{o} sector; 42 complete bundles and 16 partial bundles having removable cover plates and baffles to simulate the 30^{o} boundary within the partial bundle. The bundles use production version hardware for channel, channel fasteners and spacerm upper tieplate, lower tieplate, and finger springs. Simulated fuel rods are included in both the upper and lower tieplate regions. Upper fuel rod simulation includes production version expansion springs, end pins, locking tab washers, hexagon nuts, and one fuel rod spacer. A steam injector tube is provided in each bundle below the upper rods to deliver the channel steam from the steam distribution manifold located outside the 30^{o} shroud wall. A weir-tube measuring device is provided in each bundle above the lower rods to measure the liquid flow. The bypass region flow area is simulated and includes dummy control rods mounted on production version fuel support castings. Leakage and flow path simulation between bundle, bypass, upper plenum, lower plenum, and guide tube is assured by using production version hardware in conjunction with accurate representations of the top fuel guide and core plate. However, there is no steam injection provided in the bypass region.

Figures 5 and 6 are representative of the comparison of pre-test predictions with test data. Although a wide uncertainty band is attached to the pre-test prediction, actual data are well within that band. Tests also showed the effects of pressure and steam upflow variations to be small below the flooding limit for counter-current flow.

REGULATORY EVALUATION

Although Staff evaluation of the results from the SSTF included many facets of the spray distribution problem, including adequacy of the flow measuring system effect of steam flow distribution, characteristics of the steam injectors, wall effects, uncertainty in aiming angle of nozzles, pressure effects, steam flow rate effects, method of data analysis and fidelity of simulation. The main points of concern were:

1. Considering the large uncertainty bands presented, can meaningful results be obtained from the tests?

2. Are the variations with pressure and steam flow as small as claimed?

3. Does a shift in the location of minimum bundle flow from single sparger tests to double sparger tests contradict results obtained from the design methodology?

Although error bands on the pre-test predictions are quite large, actual data compares very well with predicted points. Close scrutiny of the data show pressure and steam flow effects to be small but not negligible. Interaction effects obtained from air tests with simulator nozzles do predict the shift in location of minimum bundle flow from single sparger tests to double sparger tests and actually predict the correct radius for minimum bundle flow.

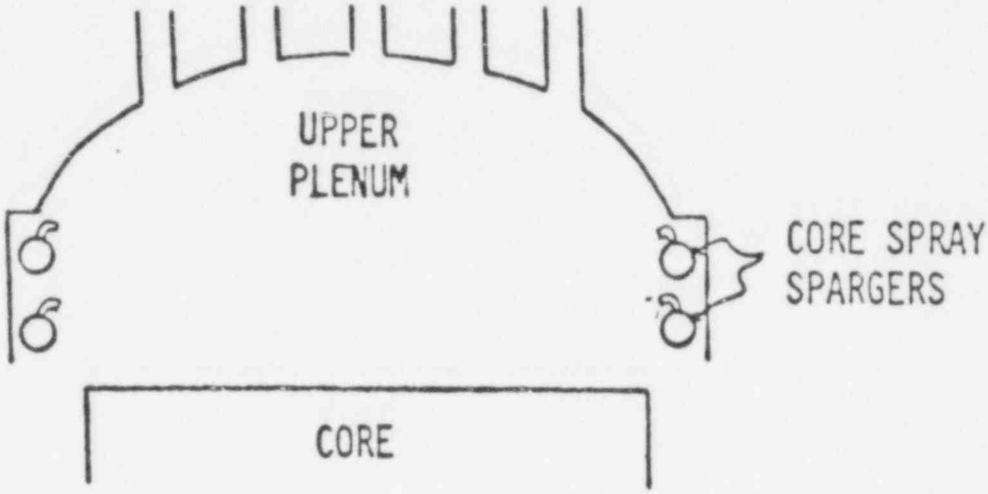
Therefore, the SSTF tests constitute a confirmation of the GE spray distribution design methodology for BWR/6 type spargers. Additional tests will be required for other sparger designs.

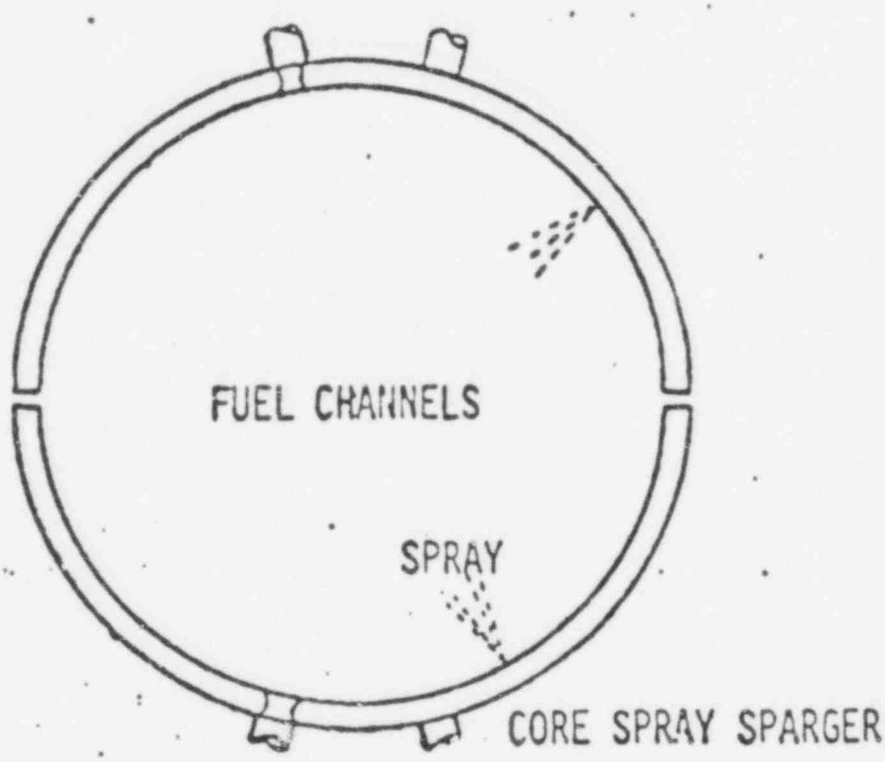
REGULATORY POSITION

The SSTF tests conducted at Lynn, Massachusetts, constitute an adequate confirmation of the GE spray distribution methodology for BWR/6 type sparger designs. Additional tests will be required to confirm the design methodology for other sparger designs. Further, application of the methodology to actual plant configurations, including treatment of prediction uncertainties, remain unresolved.

FIGURE 1

CORE SPRAY SYSTEM





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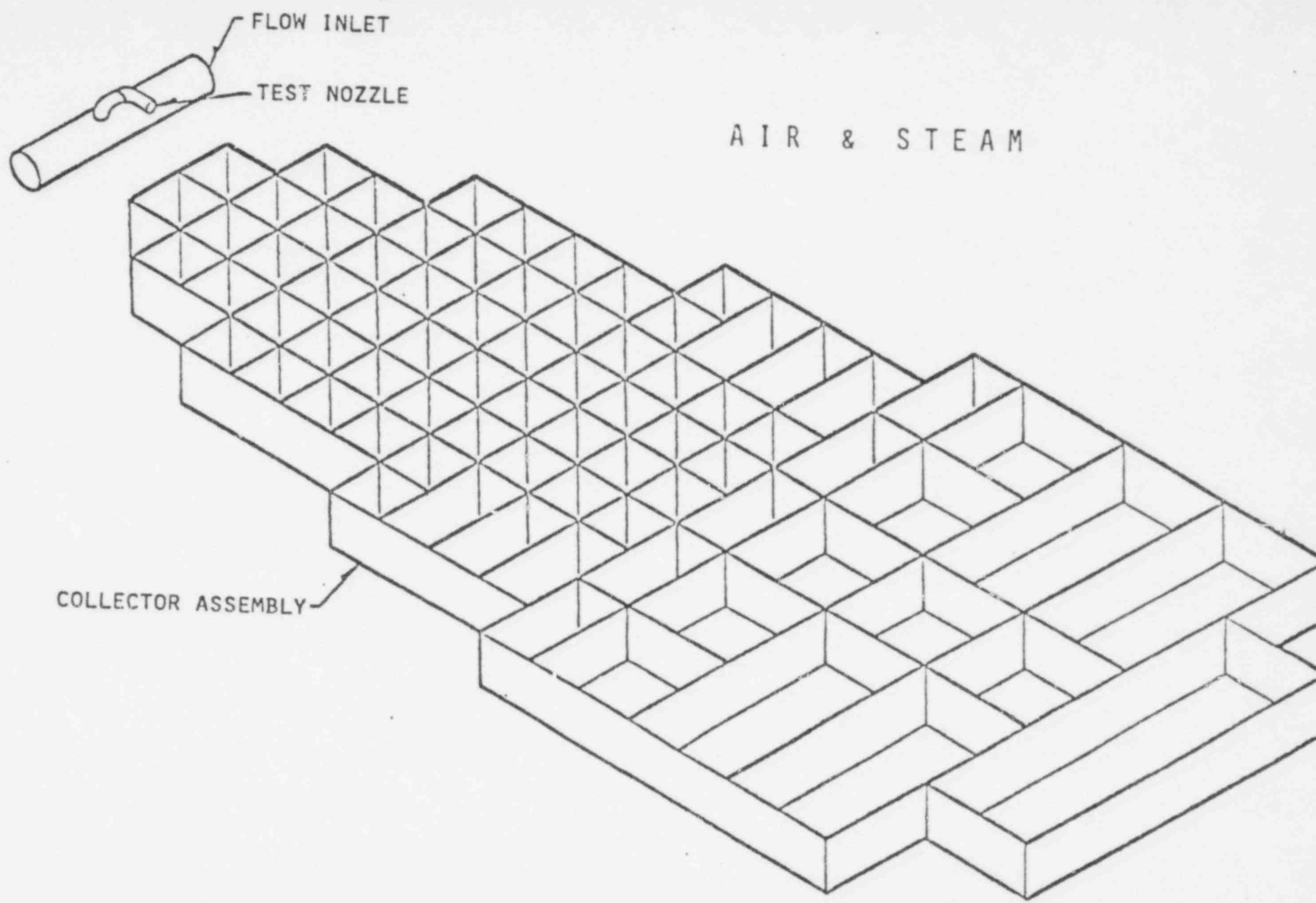
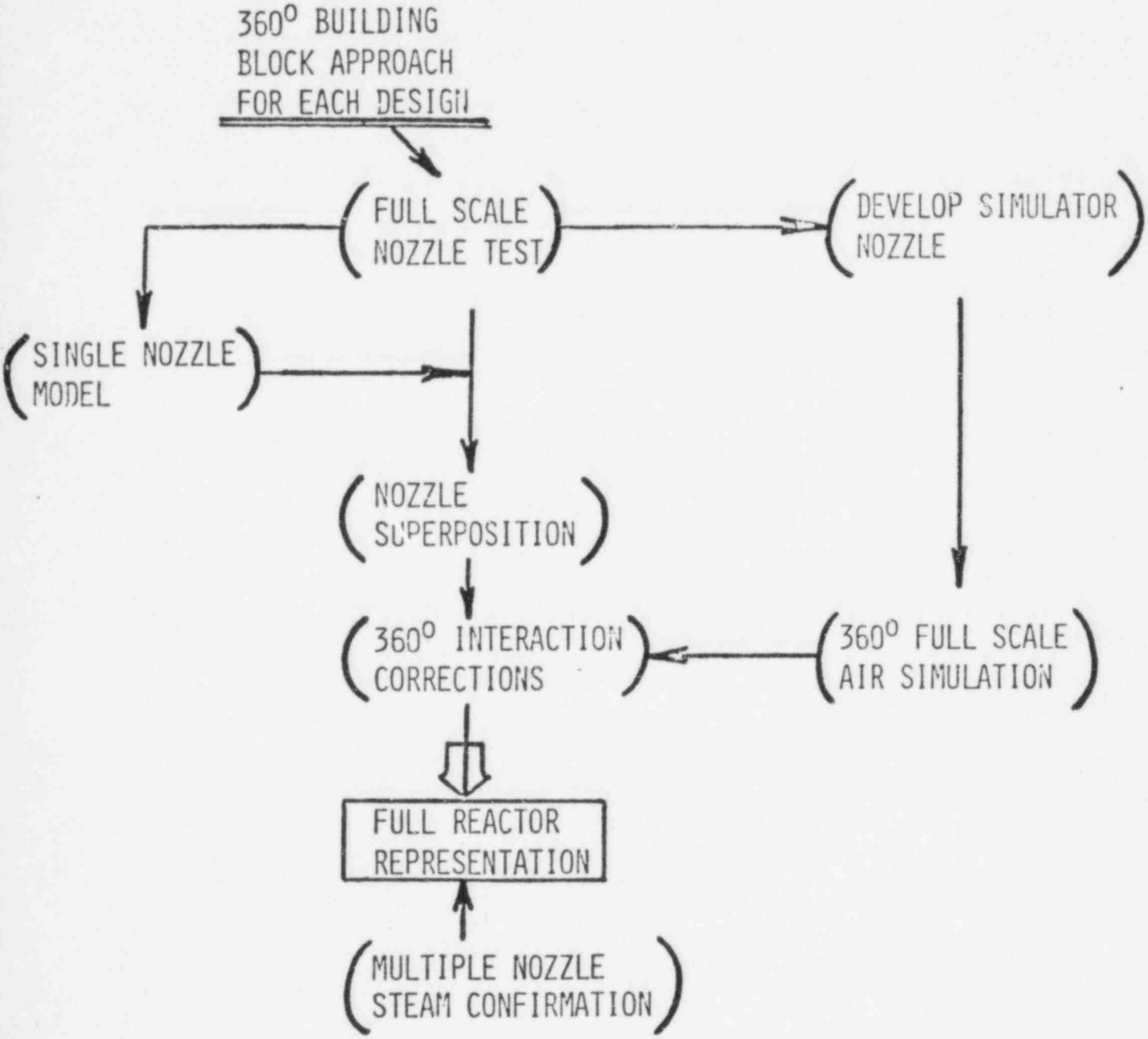


FIGURE 2

APPARATUS FOR HORIZONTAL NOZZLE TESTS

FIGURE 3

CURRENT GE CORE SPRAY PROGRAM



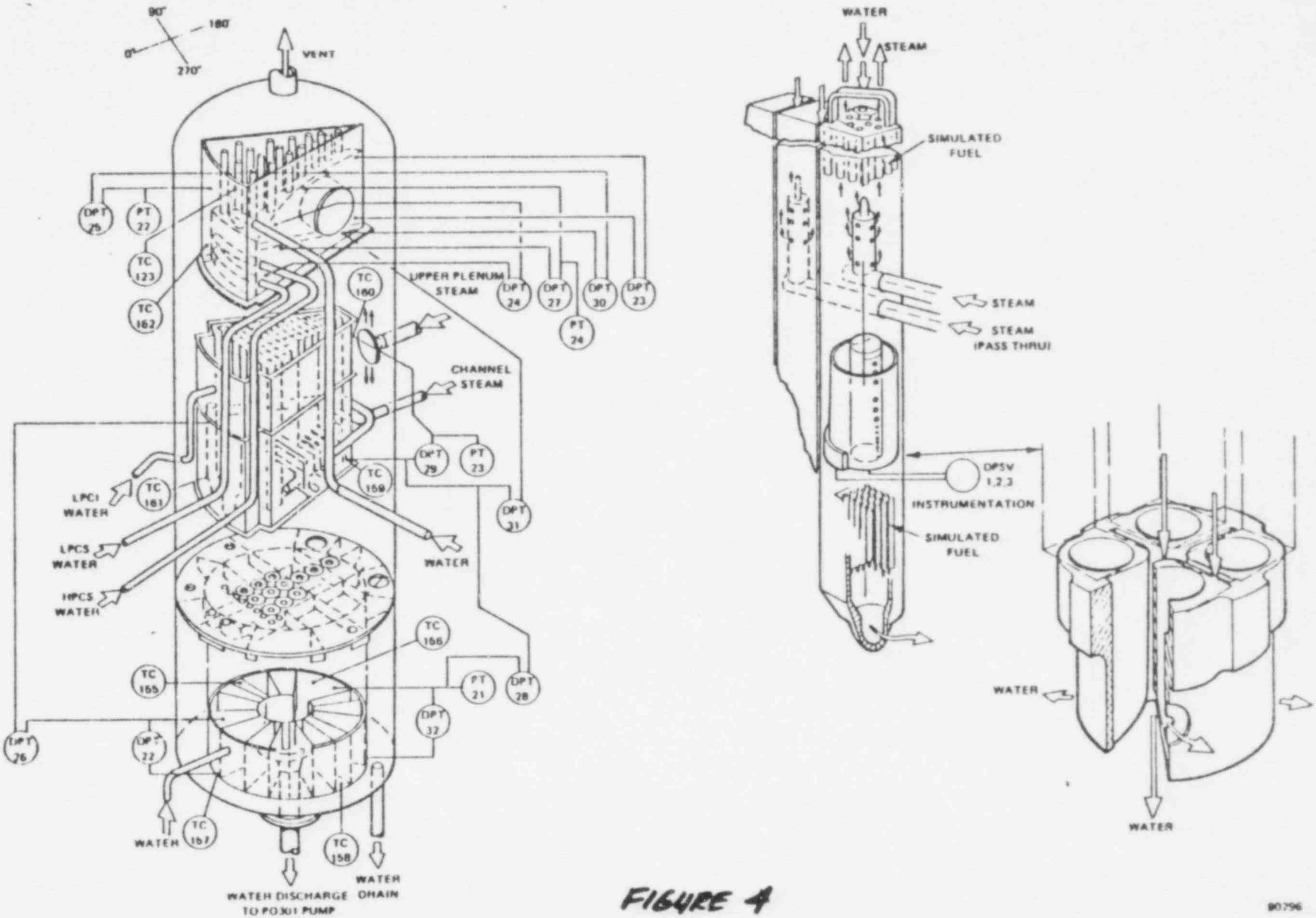


FIGURE 4

30° Steam Sector Test Section

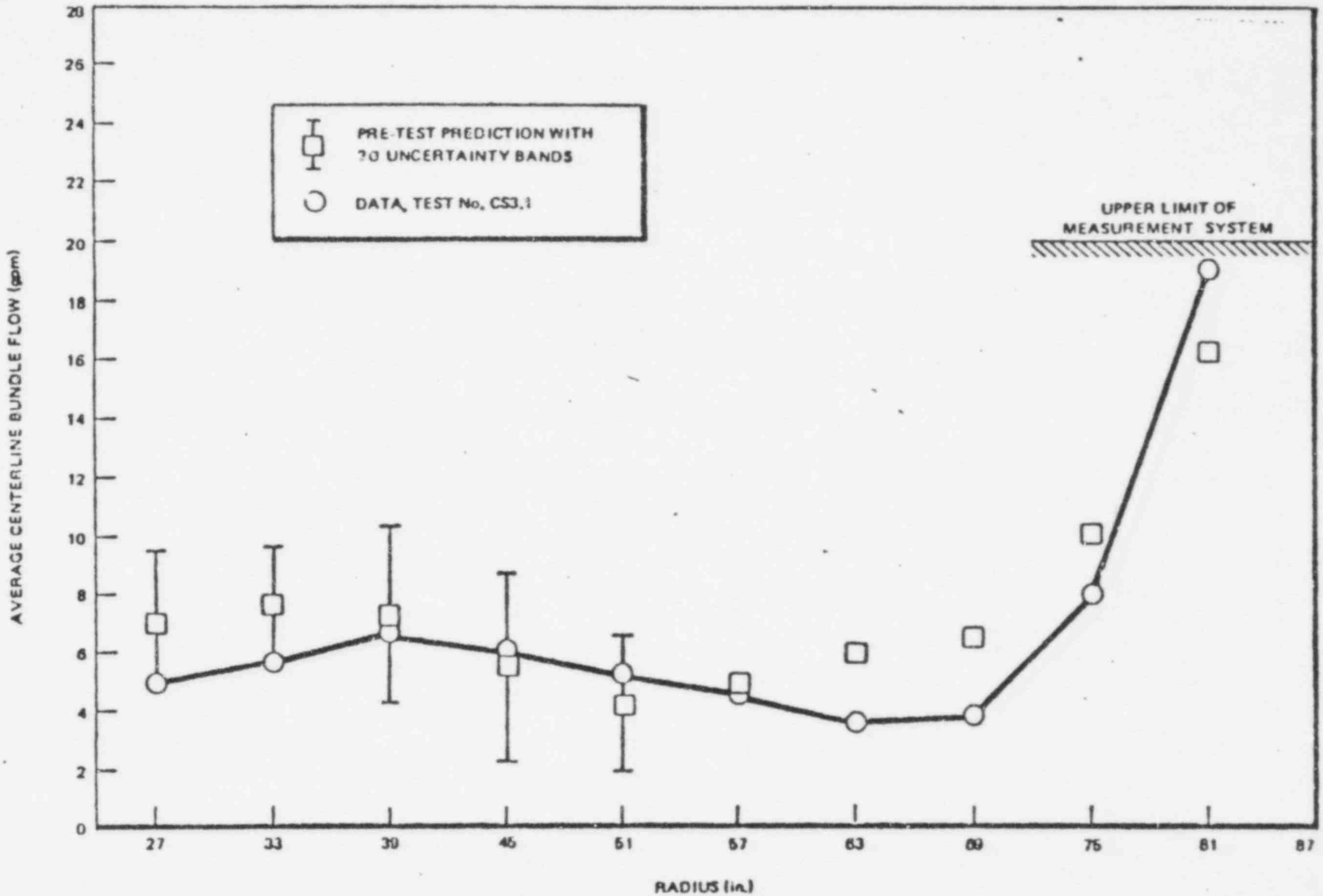


FIGURE 5

Comparison of SSTP Data to Pre-Test Prediction for LPCS Operation

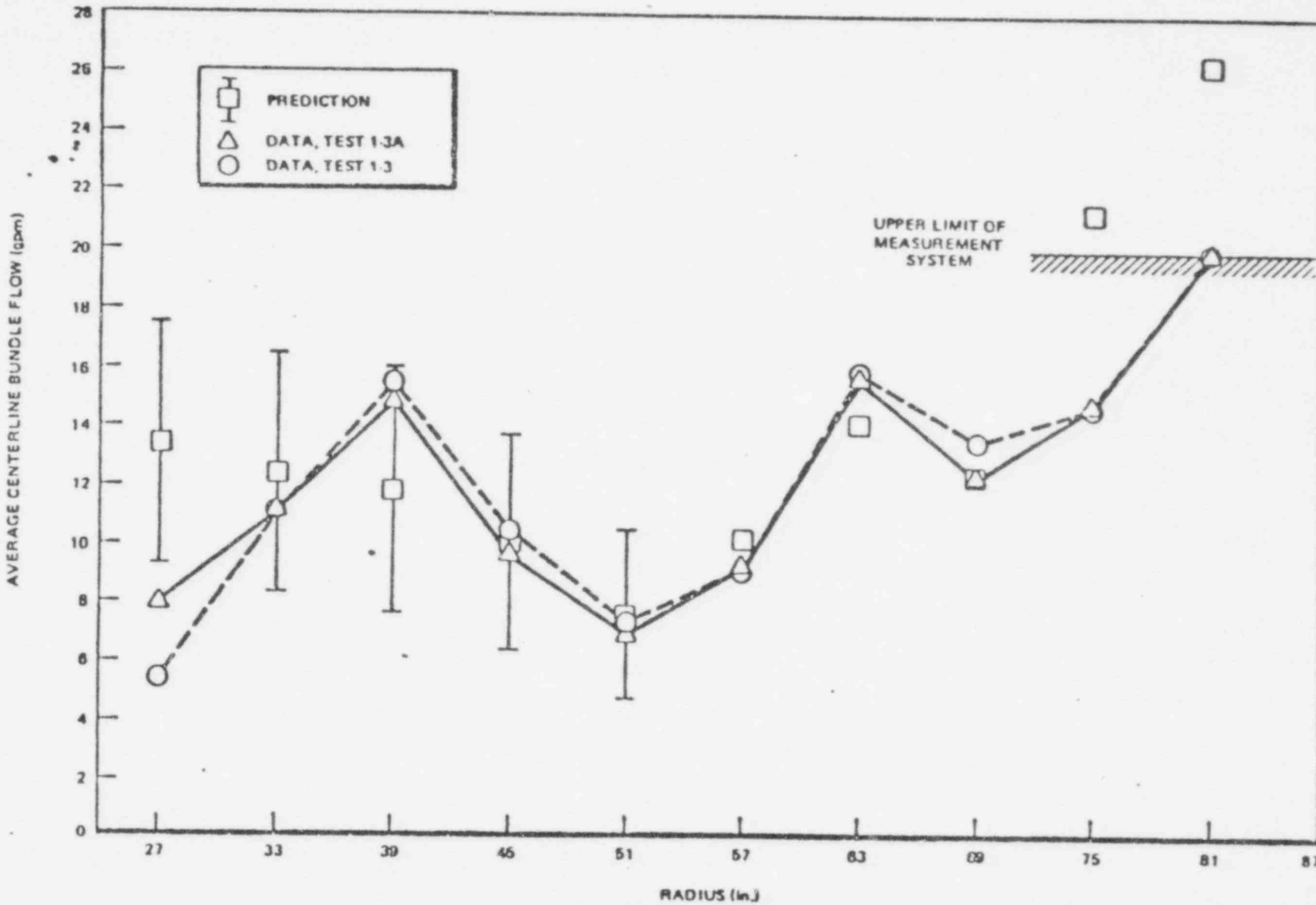


FIGURE 6

LPCS and HPCS Prediction and Comparison to Data

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ABSTRACT

Core spray system performance for a full-scale 30° sector was predicted and comparison tests then run with a typical reactor steam environment in the General Electric Steam Sector Test Facility at Lynn, Massachusetts. Test results confirmed the capability of General Electric's core spray design methodology to predict spray distribution performance of multiple-nozzle core spray systems operating in a steam environment. Core steam updraft flow variations were shown to have very little influence on the spray distribution and pressure effects were small.

ACKNOWLEDGEMENTS

The success of the Core Spray Design Methodology Confirmation Tests is due to the contributions of numerous persons during the design, fabrication, shakedown, testing, and analysis phases of the program. Mr. C. Szybalski acted as project engineer during design and construction and was responsible for coordinating the design work by Engineering and Manufacturing Services personnel at Vallecitos Nuclear Center with the technical input and reviews by San Jose personnel and for liaison with the site at Lynn during construction. Mr. J. E. Leonard as project manager for the Lynn Test Facilities was responsible for the smooth operation at the site during all phases of the program and has contributed significantly throughout the tests. On-site engineering and test operations under Mr. Leonard's direction were very ably conducted by Messrs. M. T. Carroll, M. R. Ford, G. K. Neunaber, H. Eslamy, C. M. Ralph, and D. Tagliavini. The pre-test prediction analysis and original test planning were performed by Dr. S. K. Rhow. Computer software for both data acquisition and data reduction was created by Mr. T. A. Hunter and his staff and particular acknowledgement is given to Mr. Hunter and Ms. C. J. Nakamura for their efforts during shakedown and calibration operations at the facility. Mr. D. W. Danielson contributed materially to make the bundle flow measurement system a reliable and accurate component of the system and his extra efforts during calibration of the weir system are greatly appreciated. Mr. T. Eckert, along with Mr. D. G. Schumacher, served as responsible test engineers and assured that the tests met the overall objectives of the program. A special thanks is due Ms. C. A. Tutalak for her patience with the authors during the typing, editing, reviewing, and re-typing of the manuscript.

1. SUMMARY AND CONCLUSIONS

The General Electric core spray design methodology is used to predict spray distribution performance of multiple-nozzle core spray systems operating in a steam environment. Measurements of single nozzle spray distribution in steam and measurements of single and multiple nozzle sprays in air are used to account for both thermodynamic and hydrodynamic effects. To confirm the methodology, spray performance for a full-scale 30° sector system was predicted and comparison tests then run with a typical reactor steam environment in the General Electric Steam Sector Test Facility (SSTF) at Lynn, Massachusetts.

The present report demonstrates that the pre-test prediction compares well with the test results. The data fall within the acceptance bounds defined with the pre-test predictions and, hence, confirm the capability of the methodology to predict steam environment effects on spray distribution performance. The results substantiate the key assumption of separability of thermodynamic and hydrodynamic effects. The data show that there is a very small influence on the spray distribution by core steam updraft flow variations over the realistic simulation range of this test facility. Pressure effects, as expected, are small with individual nozzle spray patterns contracting slightly due to the increased condensation, and negligible effects on the interactions among nozzles.

2. TEST OBJECTIVES

The objective of the test program was to confirm the core spray design methodology for reactor steam environments. The primary confirmation was made at system pressure of 29.5 psia and spray water temperature of 145°F. Additional objectives were to evaluate the generality of the predicted distribution through systematic sensitivity studies with varying steam updraft and system pressure, and double sparger operation. The following specific test objectives were defined.

a. To compare the multi-nozzle spray distribution measured in steam with that previously predicted with the GE methodology.

b. To evaluate system pressure effects on spray distribution.

c. To evaluate steam updraft effects on spray distribution.

d. To evaluate double sparger performance.

3. TEST FACILITY DESCRIPTION

The 30° Steam Sector Test Facility (SSTF) is located at General Electric's gas turbine/jet engine installation in Lynn, Massachusetts. Facility construction was initiated in 1977, with the first tests performed early in 1979. Following is a description of the SSTF categorized in terms of 30° sector internals, pressure vessel, control and instrumentation, facility services and loop hardware, and vapor injection simulation.

3.1 30° SECTOR INTERNALS

The 30° Sector Internals provide accurate representation of the reference BWR/6-218 (624 bundle) reactor through the use of prototypical hardware and geometry. Figure 3-1 is a schematic representation of the test section components. The upper plenum is a full-scale mockup of a 30° sector of the reference upper plenum with accurate simulation of geometric shape, and shroud head curvature and height. Standpipes simulating the steam separators extend up from the shroud head. The upper and lower core spray spargers are full-scale mockups of 30° sectors of the reference HPCS and LPCS spargers with regard to size, curvature, location and nozzles. The core region simulation includes both mock fuel bundles and bypass region. The core region is full-scale in cross-section, but is approximately five feet shorter than the BWR reference due to overall facility height limitations. Fifty-eight mock fuel bundles are included in the 30° sector; 42 complete bundles and 16 partial bundles having removable cover plates and baffles to simulate the 30° boundary within the partial bundle. The bundles utilize production version hardware for channel, channel fasteners and spacer, upper tieplate, lower tieplate, and finger springs. Simulated fuel rods are included in both the upper and lower tieplate regions. Upper fuel rod simulation includes production version expansion springs, end pins, locking tab washers, hexagon nuts, and one fuel rod spacer. A steam injector tube is provided in each bundle below the upper rods to deliver the channel steam from the steam distribution manifold located outside the 30° shroud wall. A weir-tube measuring device is provided in each bundle above the lower rods to measure the liquid flow. The bypass region flow area is simulated and includes dummy control rods mounted on production version fuel support castings. Leakage and flow path

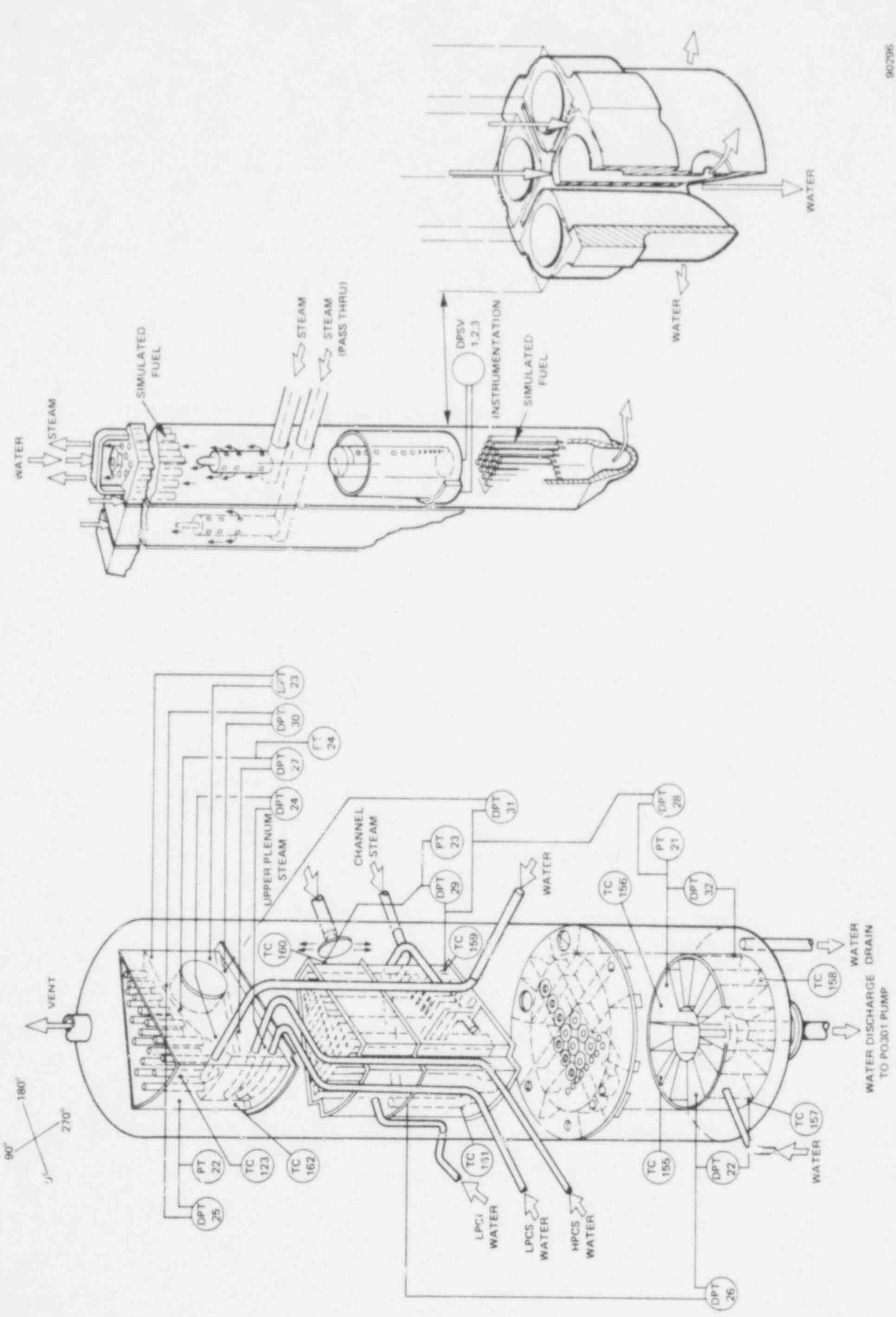

Figure 3-1. 30° Steam Sector Test Section

simulation between bundle, bypass, upper plenum, lower plenum, and guide tube is assured by using production version hardware in conjunction with accurate representations of the top fuel guide and core plate. However, there is no steam injection provided in the bypass region. Twelve volume-scaled guide tube regions are provided (one for each of the twelve centrally located side-entry fuel supports). The lower plenum volume represents the scaled volume of the reference lower plenum region outside the guide tubes.

An overview of the 30° sector core region and ECCS sparger location is shown in Figure 3-2, displaying the relationship between the fifty-eight bundles and the core spray nozzle locations. Elbows, nipples and header orifices are used to connect the spray nozzles to the spray header, as shown in Figure 3-3. The nozzle assemblies are aligned as shown in Figure 3-3, with the inclination angles and header orifices shown in Table 3-1. Figures 3-4 and 3-5 are photographs of the core region and nozzle arrangement, respectively. The relationship between the nozzle aiming and the bundle row serving as a centerline "target" is shown for each nozzle in Appendix A.

3.2 PRESSURE VESSEL

The SSTF pressure vessel (14-foot inside diameter and 27-foot inside height) serves as a pressure envelope for the 30° sector internals. The vessel is designed with numerous nozzles and penetrations to permit attaching the various process lines which service the internals and to provide routing for the various instrumentation lines and cables. The vessel is surrounded by service platforms and walkways and is serviced by a traveling overhead crane.

3.3 CONTROL AND INSTRUMENTATION

An air-conditioned control room houses the process control equipment and data acquisition system (DAS). Process instrumentation and valves are provided to monitor and control temperature, pressure and flow in the steam supply headers, water recirculation lines, ECCS lines, and vent system. Figure 3-6 is a schematic of this hardware. The DAS utilizes a Hewlett-Packard processor with 32K memory, 256 channels of multiplexer input, and a 50 megabyte disc pack. This DAS

Table 3-1

NOZZLE CONFIGURATION SPECIFICATIONS

	Nozzle Type	Nozzle Position	Inclination Angle*	Header Orifice Thread X Length x I.D., In.
Upper Sparger				
	SPRACO 2935M**	UB1, UB3, UB5	-37.°	1.00 x 1.85 x 1.00
	1 in. O.E. (street)	UB2, UB4	- 8.°	1.00 x 1.33 x 0.75
	1 in. O.E. w/nipple	UF1, UF2, UF3, UF4	-64.°	1.00 x 2.30 x 0.62
Lower Sparger				
	SPRACO 2935M**	LB1, LB3, LB5	-25.°	1.00 x 1.33 x 1.00
	1 in. O.E. (street)	LB2, LB4	- 3.°	1.00 x 1.33 x 0.75
	3/4 in. O.E. (regular)	LF1, LF2, LF3, LF4	-50.°	0.75 x 1.33 x 0.62

*Angle from the horizontal direction. A negative angle means a downward aiming (see Figure 3-3).

**SPRACO currently designates this nozzle design as 518620.

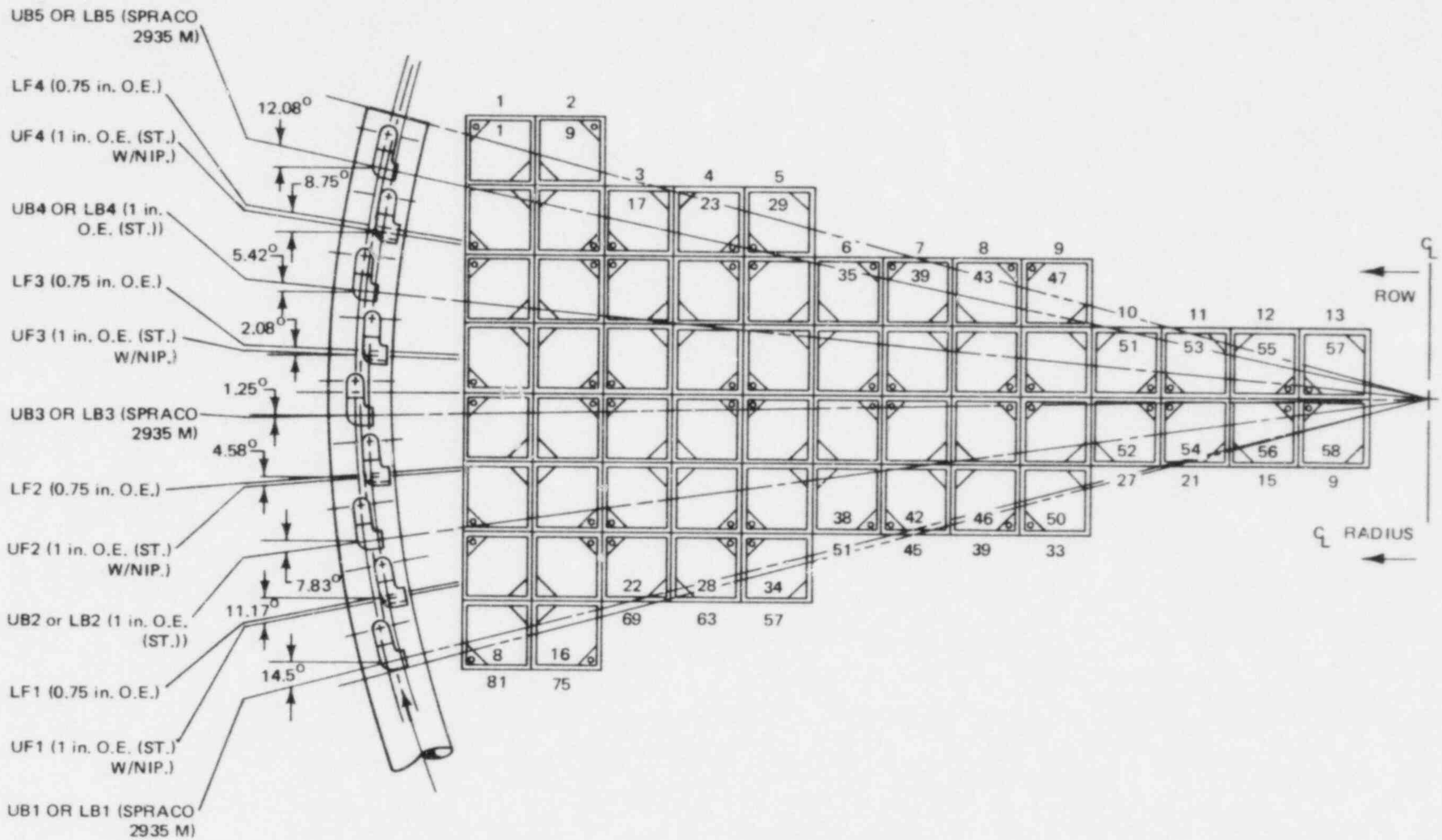

Figure 3-2. Core Spray Nozzle Location (30° SSTF)

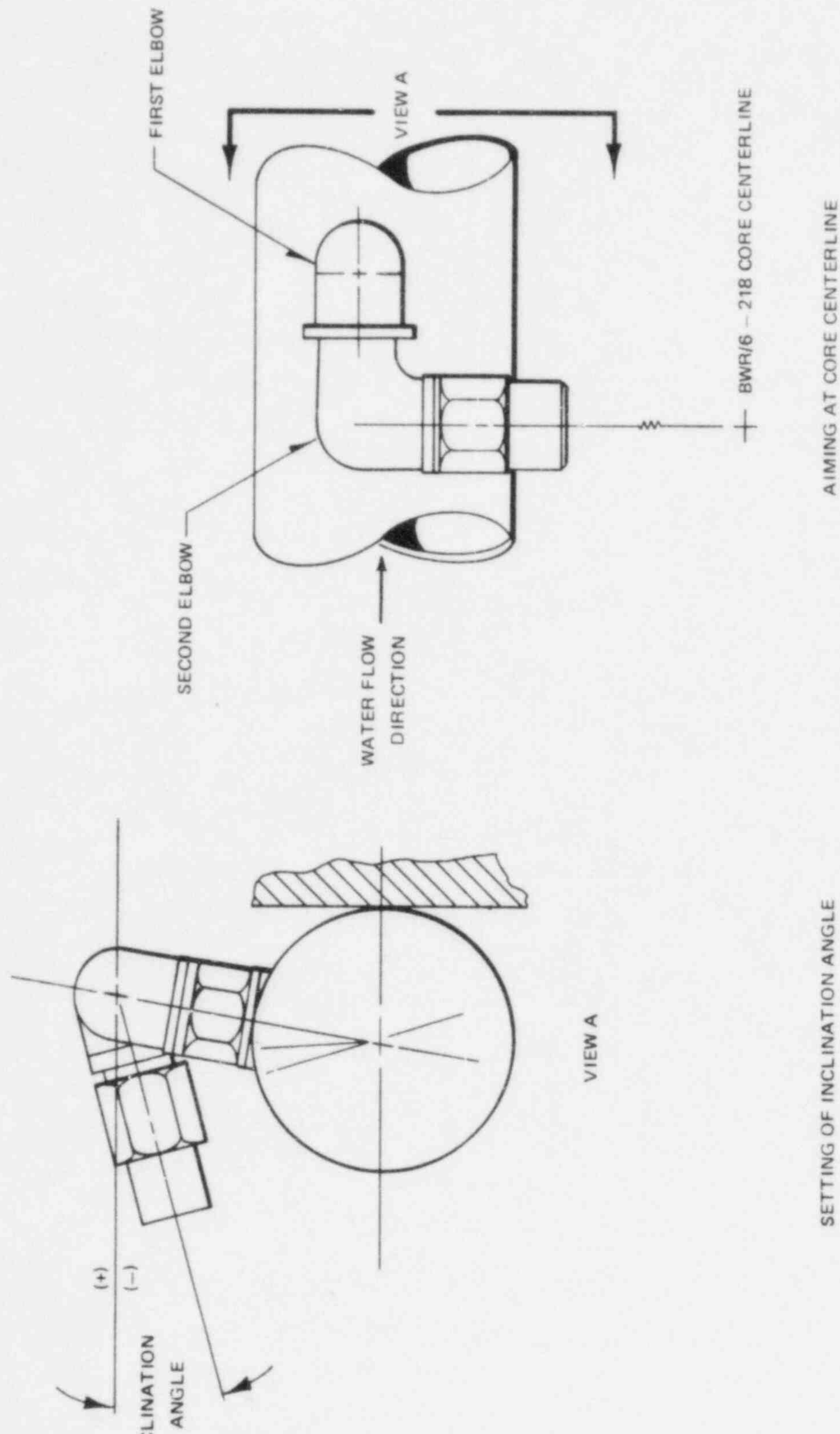

Figure 3-3. Nozzle Installation Geometry

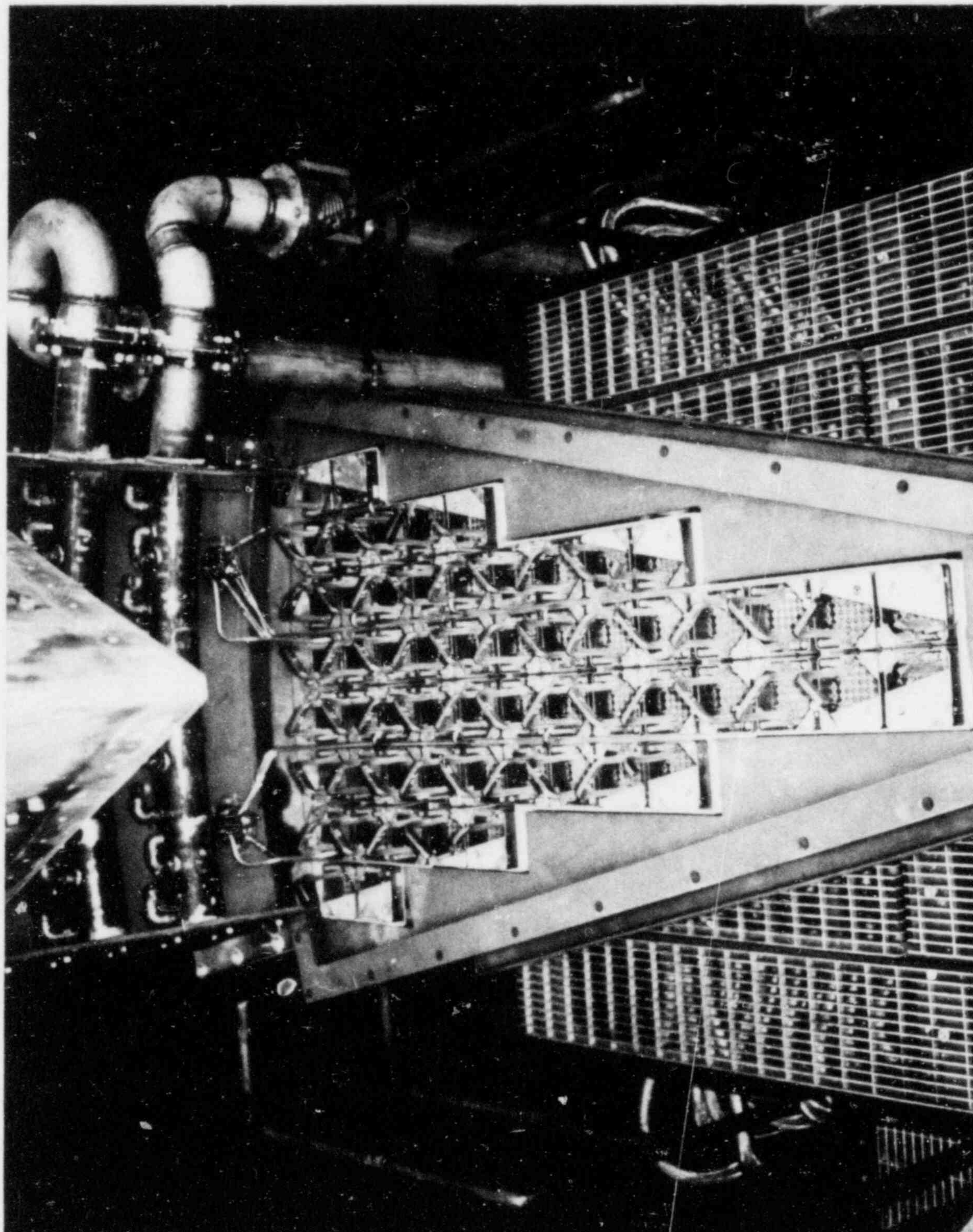

Figure 3-4. Photograph of 30° SSTF Core Region

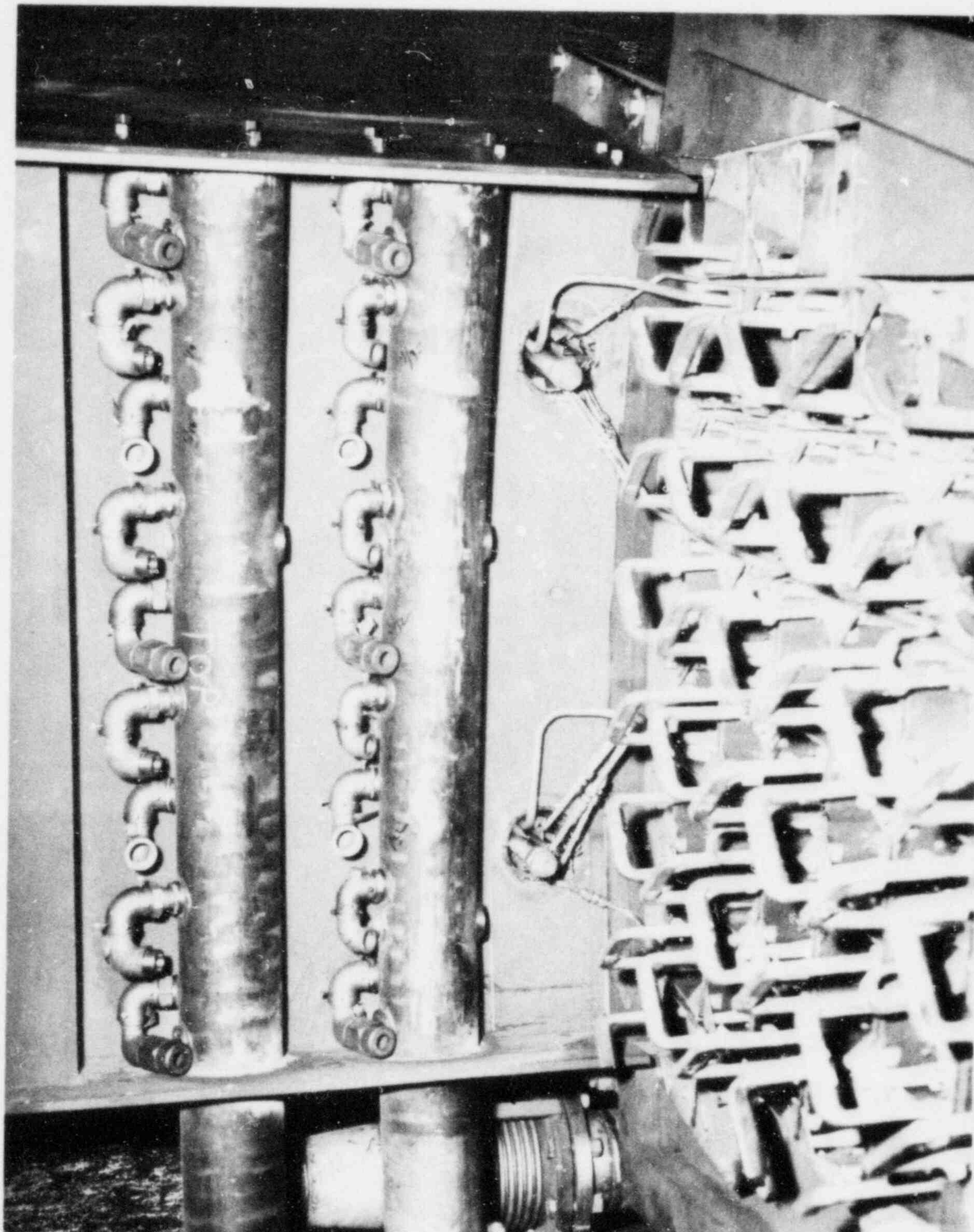

Figure 3-5. Photograph of 30° SSTF Nozzle Arrangement

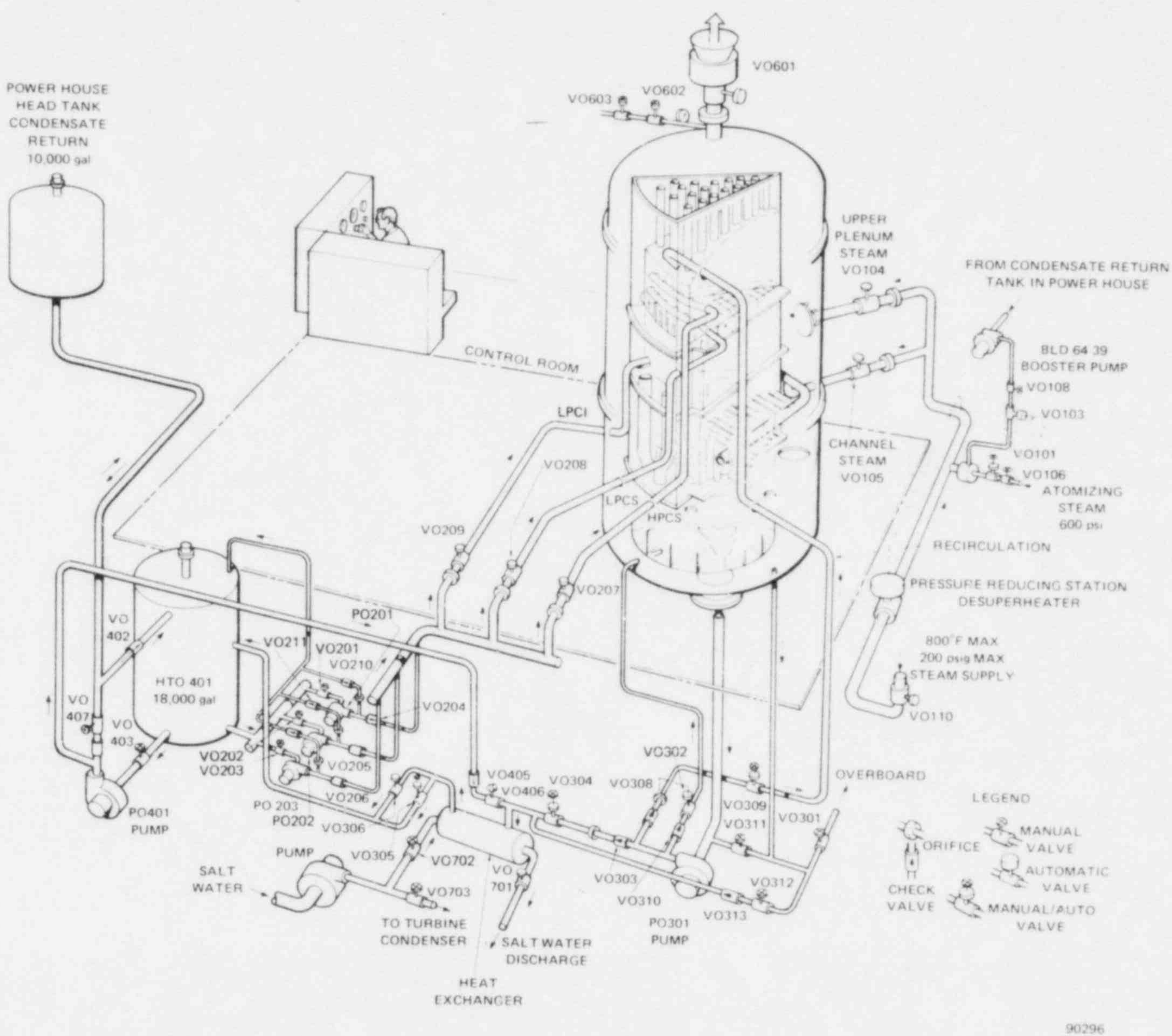

Figure 3-6. 30° Steam Sector Test Facility Loop Schematic

hardware in conjunction with the associated data acquisition and reduction software provides quick-look capability in engineering units through the use of the operator's terminal with graphics features and two color television monitors for displaying the results of on-line data handling. On-site generation of hard copy test results is provided by a Versatec printer/plotter. Permanent raw data storage is provided by a nine-track magnetic tape recorder in a format compatible with G.E.'s (San Jose) Honeywell 6000 computer for additional post-test data processing. Test instrumentation and signal conditioning include pressure and differential pressure transducers, and thermocouples as shown in Figure 3-1. The ECCS spray distribution is determined from individual bundle flow measurements provided by weir flow elements internal to each mock fuel bundle. The weir flow element (weir tube - see Figure 3-7) relates flow to the liquid level sustained in the weir element. Two precision differential pressure transducers sequentially measure the liquid level in the 58 individual weirs through a multiport scanivalve interface. Integral to the weir measurement system is a DAS-sequenced water purge subsystem which prevents flashing of the measurement line fluid. Figure 3-7 schematically depicts the principal elements of the weir tube flow measurement system.

An inplace weir calibration system provides controlled and measured water flows to thirteen weir tubes selected from the 58 bundle array, allowing on-line calibration checks under pressurized operating conditions. Two portable lines allow calibration of the remaining weirs under ambient conditions. A complete description of the bundle flow measurement system, including calibration data, is available in Reference 1.

3.4 FACILITY SERVICES AND LOOP HARDWARE

The SSTF is located in the central region of an existing turbine hall, to which the necessary process equipment and loop hardware have been installed to provide the required services to the facility. Figure 3-6 is a schematic of facility and external loop hardware. A steam supply of 110,000 lbm/hr at 150 psia and 388°F is available. Steam is routed to the pressure vessel through ten-inch headers to an upper plenum supply nozzle (60,000 lbm/hr maximum) and to a

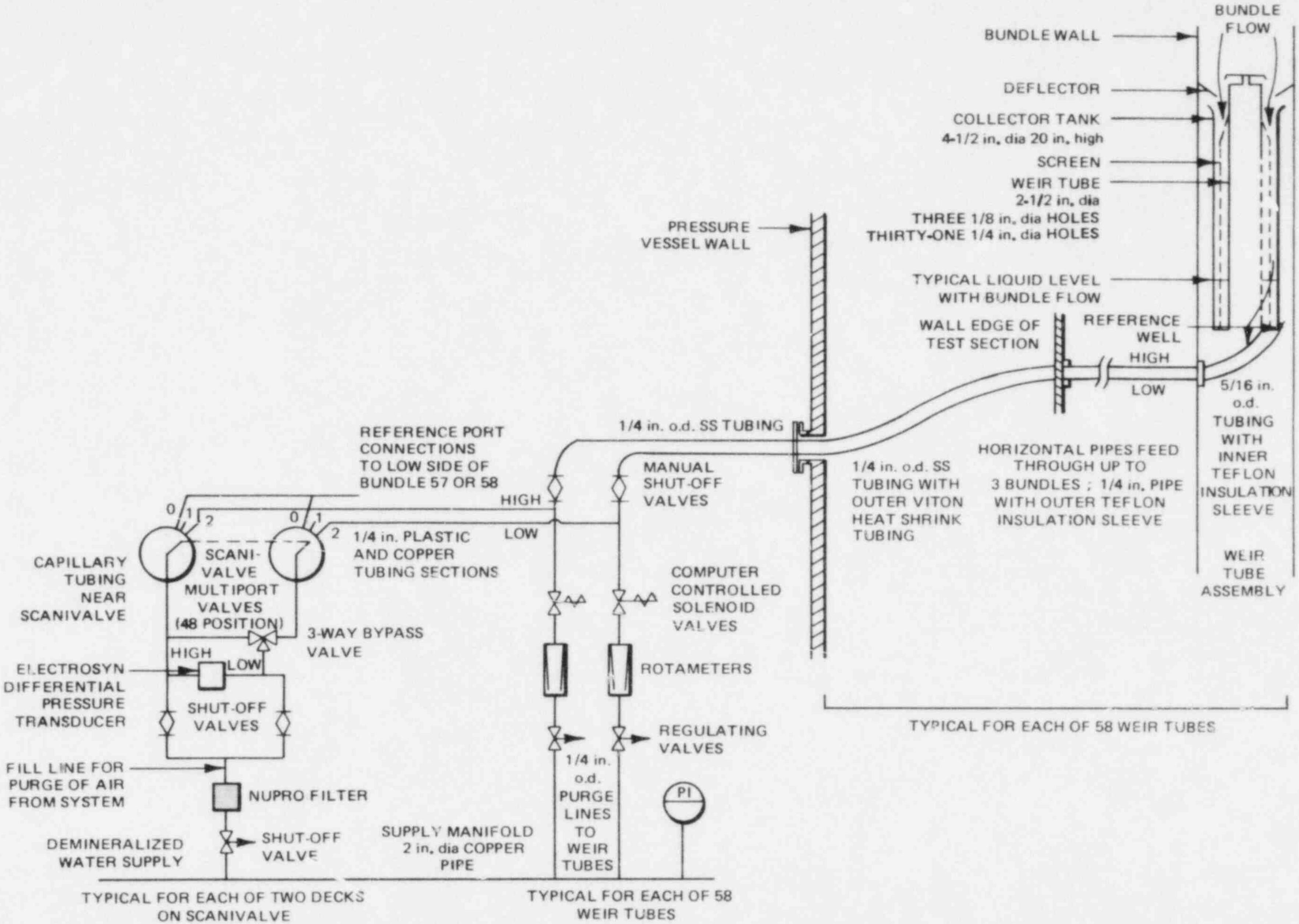

Figure 3-7. Lynn SSTF Weir Tube Flow Measurement System

mock fuel bundle supply nozzle (50,000 lbm/hr maximum). Water is supplied to the facility from a 10,000 gallon condensate tank and retained in an 18,000 gallon supply tank which is part of the ECCS water supply and recirculation loop. The temperature of the water in the tank can be controlled by recirculating through a 500 gpm heat exchanger loop. Water from the lower plenum of the test section is pumped back to the supply tank via a single pass heat exchanger unit capable of reducing the temperature of 600 gpm of loop water from 320°F to 110°F. The ECCS supply system provides flows representative of the reference BWR/6-218 reactor. The system consists of three 600 gpm pumps connected in parallel to provide up to 1800 gpm at 130 psi to the ten-inch main ECCS header. This main header in turn supplies a six-inch HPCS line with up to 533 gpm, a six-inch LPCS line with up to 533 gpm, and an eight-inch LPCI line with up to 1333 gpm. The three individual ECCS lines are routed to separate nozzles on the pressure vessel. A 12-inch steam vent located at the top of the pressure vessel is capable of handling up to 75,000 lbm/hr at 125 psi vessel pressure.

3.5 VAPOR INJECTION SIMULATION

The facility simulates vapor generation in the core, but does not simulate the flashing vapor flow in the bypass. The core steam updraft into the upper plenum is, thus, supplied by injection into each individual fuel channel, but not into the surrounding bypass region. As a result, it is expected for high steam flows that the stagnant bypass would act as an atypical sink to collect the small drops that are levitated and diverted by the high vapor velocities through the upper tieplate openings*. This phenomenon can be approximately predicted with a first order analysis (c.f. Appendix B).

The facility design with no vapor injection into the bypass region is judged acceptable. For this core spray distribution investigation the steam updraft

*In a reactor with flashing vapor updraft in the bypass, the small drops would continue to be levitated until they either coalesce and fall down or contact surfaces and run down as liquid films. For that condition, the levitated small drops would be distributed between the fuel bundles and the bypass, rather than favoring a stagnant bypass.

range for which the droplet diversion is negligible covers the full range of interest for single header operation (i.e., from zero updraft to balanced updraft/downdraft), which is the critical condition to confirm the prediction methodology. The compromise does, however, limit the methodology confirmation comparisons for two header operation to core flows below the balanced updraft/downdraft point. These conclusions are confirmed by the analysis of Appendix B and the calibration tests discussed in Section 5.

4. TEST PARAMETERS AND TEST MATRIX

The SSTF was sized to provide a spray distribution as similar to a full 360° core spray distribution as possible. Before design of the facility, tests were run in the Vallecitos Spray Facility (VSF) using sector sizes from 27° to 360°. Data from these tests are shown in Figure 4-1. These data show that spray distribution is not sensitive to sector size except for the 2 ft radial region of the central core. Since the core center region cannot be matched by any sector size short of 360°, 30° was selected for the SSTF design.

In order to properly model the vapor flow paths, walls must be used on the sides of the 30° sector. Tests were run in the VSF with and without the sector walls in place. The test results, shown in Figure 4-2, demonstrate that the influence of the walls is also confined to the center two feet of the core.

Steam can enter the reactor upper plenum from the core and/or from the steam separators, as shown in Figure 4-3. If all the steam required for condensation on the spray entered from the core, the spray flow to some bundles would be limited by the vapor updraft through the bundle upper tieplates, and the resulting measured distribution would include both core spray distribution and counter-current flow effects. Therefore, it would not be possible to determine the success or failure of the core spray methodology. The nominal test used for methodology confirmation was with balanced updraft/downdraft (i.e., half the steam required for condensation in the spray comes from the core and half down through the separators). This was achieved in the SSTF (see Figure 4-4) by injecting one-half the required steam flow into the simulated fuel bundles and allowing the remaining steam to be drawn down through the separators from the steam dome. The jet pump flow path, which would allow steam to flow from the core back through the jet pumps and annulus to the upper plenum, was closed off by raising the water level in the lower plenum to cover the jet pump exit.

The steam flow through the fuel bundles is individually set for each bundle by using appropriate orifices in the steam manifold. The steam flow through the steam separators is supplied as demanded by condensation on the spray

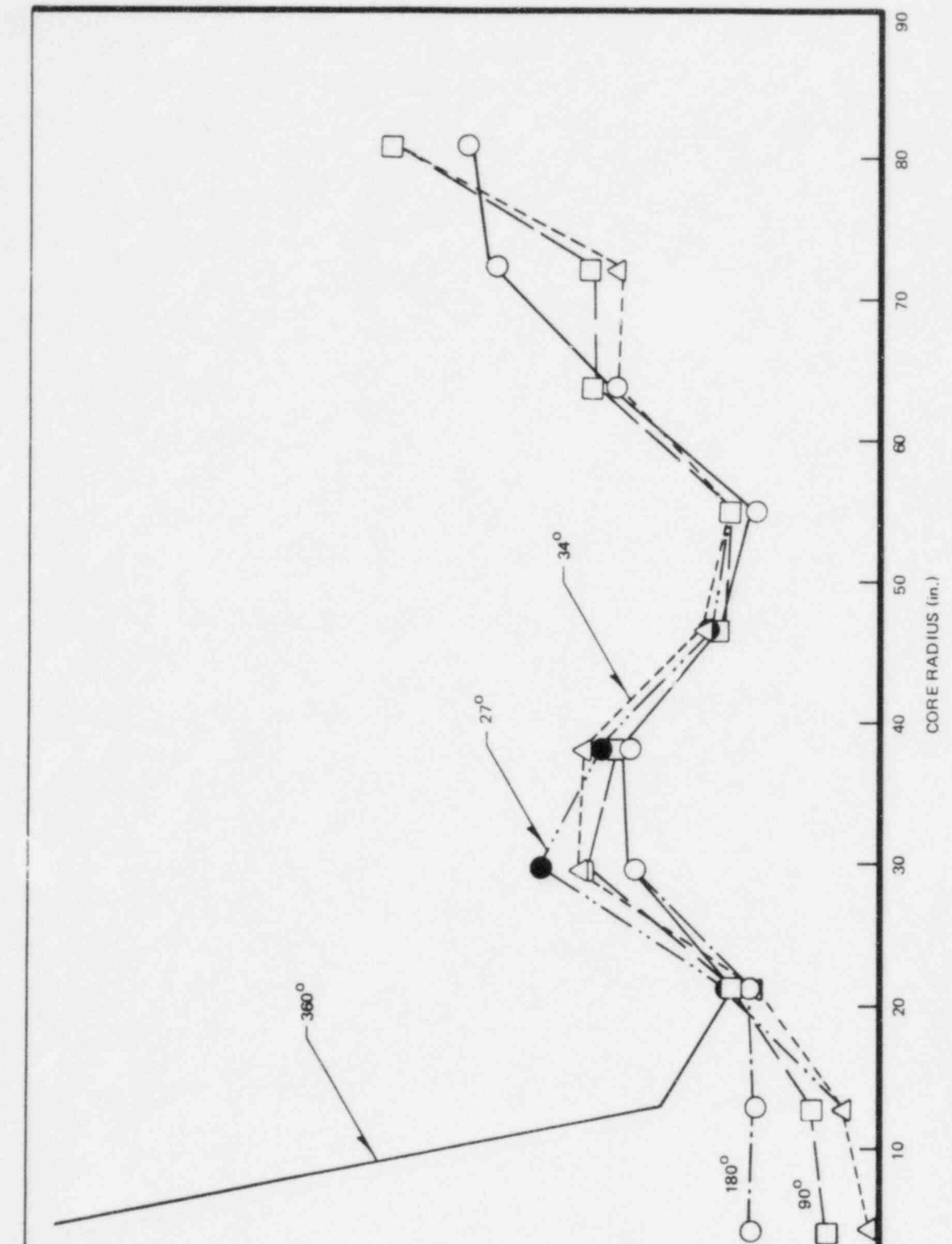

Figure 4-1. Core Spray Distribution as a Function of Sector Size For BWR/4-218 (VSF Air Tests)

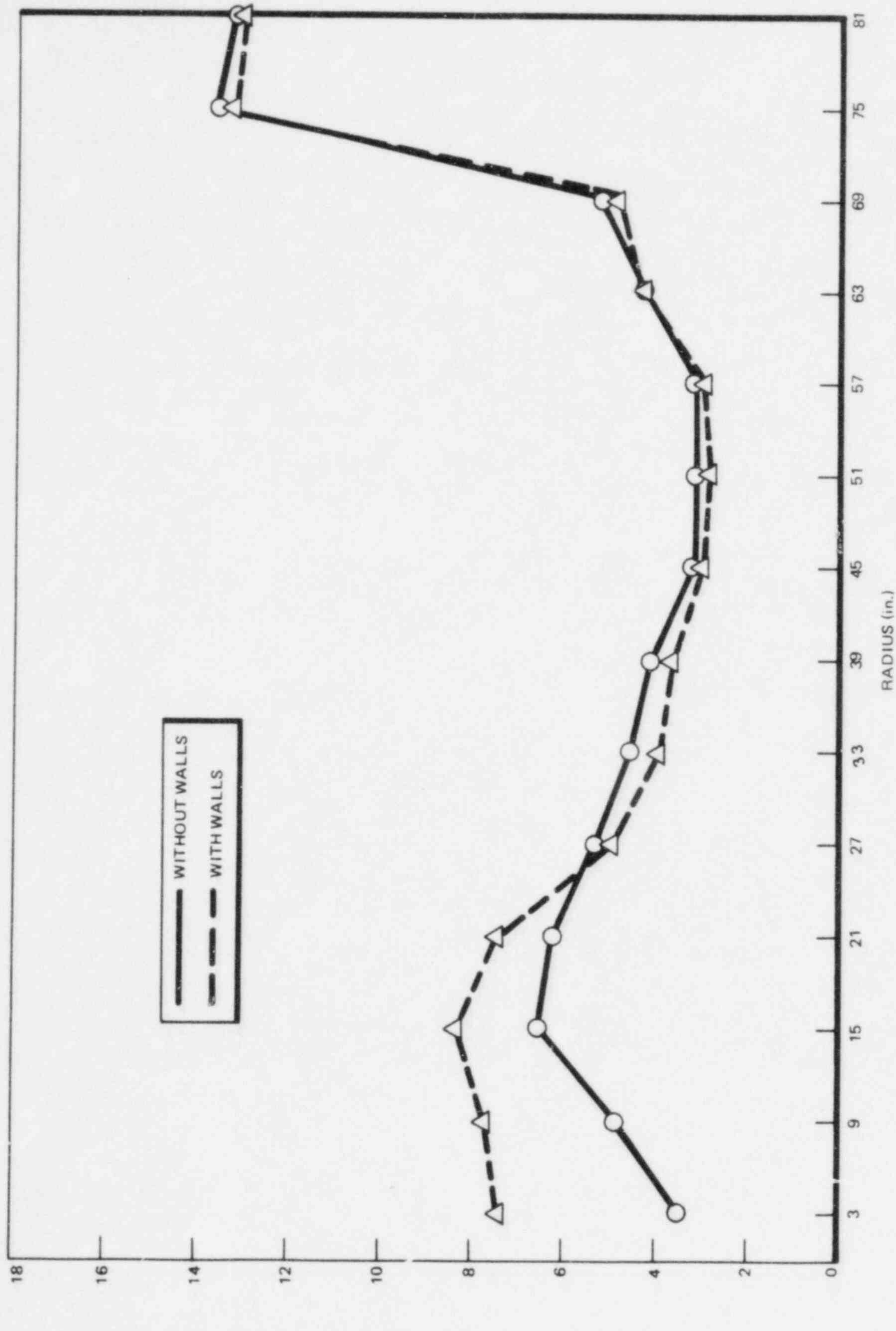

Figure 4-2. Wall Effects in a 30° Sector (VSF Tests 3-002A with Walls and 3-004A Without Walls)

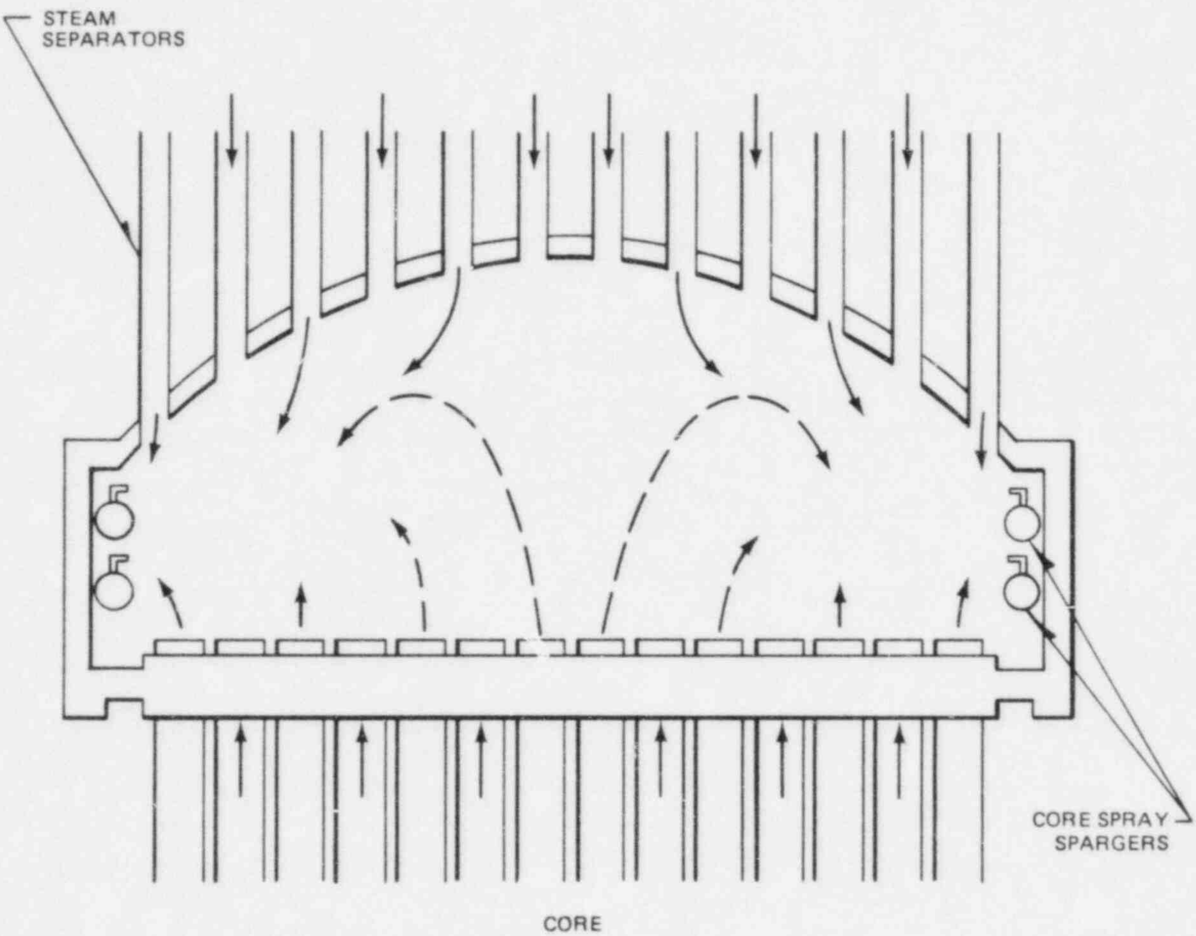

Figure 4-3. Upper Plenum Vapor Flow Paths

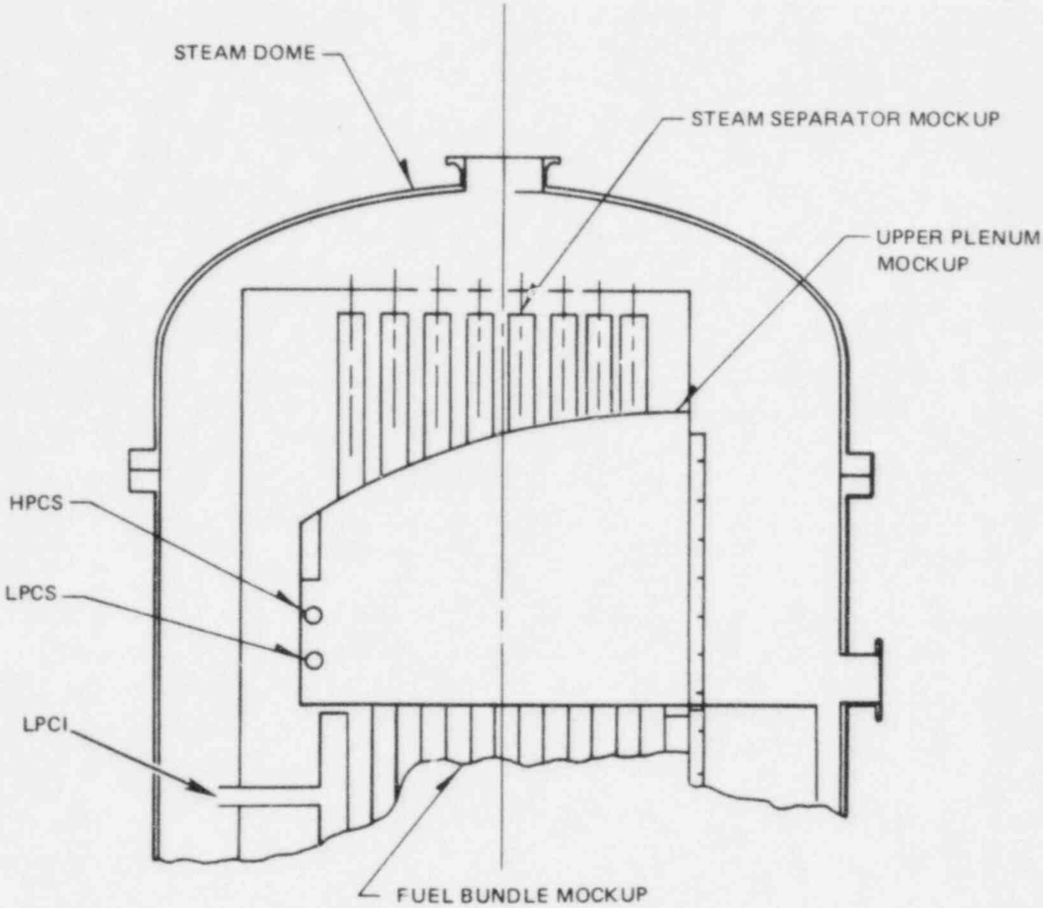

Figure 4-4. SSTF Configuration (Elevation)

to maintain steady-state pressure in the upper plenum. Therefore, only the fuel bundle steam flux can be regarded as an independent test parameter. The total steam inlet flow (sum of bundle and plenum steam) and vent flow are not independent at steady-state. The steam vent flow was nominally 10% of total steam inlet flow for the tests.

The nominal condition of zero net steam velocity in the upper plenum was met by controlling the total core steam flow at a value corresponding to half-condensing steam flow, i.e., one-half of the steam which is condensed by the spray water as determined by energy balance considerations. The balance of the steam was then free to enter the plenum through the standpipes. The calculated values of half-condensing steam flow are summarized in Table 4-1.

The fuel bundle steam flux is specified with two parameters: (1) the sum of individual fuel bundle steam flows, and (2) the profile of the fuel bundle steam flow distribution. Of these two parameters, the first parameter was an independent test parameter and the second one was fixed for all tests. The steam profile simulates expected heat generation rates in the bundles, specified from calculated bundle radial power factors. A typical BWR/6-218 (624) end-of-cycle core radial power distribution was selected. To calculate steam flows from steam manifold branches to individual bundles (full or partial) of the SSTF, the steam flow distribution was averaged circumferentially for the whole core with the radial power distribution. Then, each branch of the steam manifold was assigned a steam flow according to the core radius of its corresponding fuel bundle with adjustment for whether the bundle section is complete or partial. The steam manifold branch flows thus calculated and normalized to the average branch flow are shown in Figure 4-5.

The reference case chosen for qualifying the core spray distribution methodology utilized system conditions of 29.5 psia, spray water temperature of 145°F, and 525 gpm spray flow for each sparger in operation.

To meet the objectives of the test program, tests were performed with each spray header operating individually and with both headers operating simultaneously. A spray flow rate of 525 gpm for each operating header

Table 4-1

HALF-CONDENSING STEAM FLOWS (lbm/hr)

	Single Header	Double Header
525 gpm per Header at 145°F		
29.5 psia	14,000	28,000
44.1 psia	18,000	36,000
73.5 psia	23,000	46,000
525 gpm per Header at 185°F		
29.5 psia	8,500	17,000
44.1 psia	12,000	24,000
73.5 psia	17,000	34,000

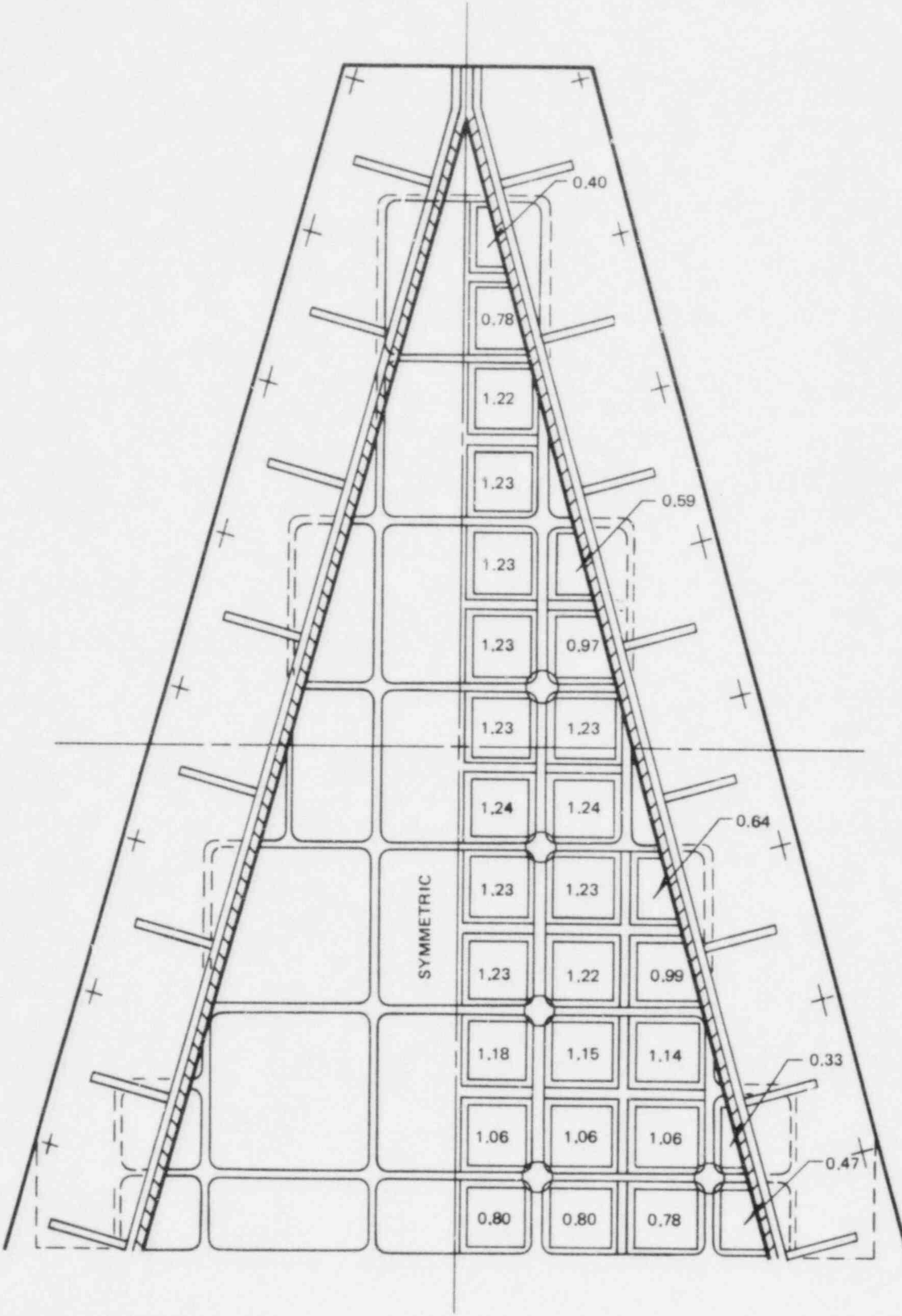

Figure 4-5. Branch Flows into Fuel Bundles Normalized to Average Branch Flow

was used for all tests. System pressures of 44.1 psia and 73.5 psia were tested in addition to the 29.5 psia reference pressure. Core steam flow rates were varied from zero to 46,000 lb/hr during the test series. In addition to updraft tests in the range of applicable flow rates, which were performed at a spray temperature of 145°F, a number of calibration tests extending beyond the applicable range of flows were performed at 185°F spray temperature to evaluate the drop diversion effect of an open bypass without steam injection. All of these tests are summarized in matrix format in Figure 4-6.

Total Core Steam Flow Rate (lb/hr)	Calibration Tests at 185°F Upper Header (HPCS)			Core Spray Distribution Tests at 145°F Upper Header (HPCS)			Lower Header (LPCS)			Double Header		
	29.5 (psia)	44.1 (psia)	73.5 (psia)	29.5 (psia)	44.1 (psia)	73.5 (psia)	29.5 (psia)	44.1 (psia)	73.5 (psia)	29.5 (psia)	44.1 (psia)	73.5 (psia)
0	CS-2F			1-1 1-1A		3-1	1-2 1-2A		3-2	1-3* 1-3A*		
14,000	CS-2A			CS-3.2*			CS-3.1*					
18,000		CS-22A			CS-30	CS-41		CS-37				
20,000	CS-2B			CS-27			CS-35					
22,500				CS-29			CS-36					
24,000		CS-22B	CS-34A		CS-31			CS-38				
25,000	CS-2C											
27,500	CS-2D											
28,000										CS-33		
30,000	CS-2E	CS-22C	CS-34B	CS-28							CS-40	CS-45
35,000			CS-34C									
36,000											CS-39	
46,000												CS-44

*Reference case tests for comparison with pre-test prediction.

Figure 4-6. Test Matrix

5. TEST OPERATION AND SHAKEDOWN

Care was taken throughout the testing to assure the quality of the data and to verify test conditions and results. Verification sheets were completed for each block of tests to ensure that the instrumentation required for the measurements were properly calibrated, that the necessary systems were operational and verified, and that required shakedown tests were performed. Any deviation noted or corrective actions taken were documented. A master instrument list and a work file provided documentation to describe the measurements made and the manner in which the measurements were displayed. Test checklist and run sheets provided assurance that the necessary actions and operations were performed prior to, during, and following each test, and that the required conditions were met by the tests. Test operation summary sheets were prepared immediately following a test to evaluate mass and heat balances, to verify selected measurements, and to check pre- and post-test conditions of selected instruments. This permitted early determination of the validity of a test and provided data for evaluation and analysis.

A number of operational checks and pretest verifications were performed during the shakedown phase of testing to satisfy operational requirements which were defined as being necessary to ensure meaningful testing in the 30° SSTF. These included instrument calibrations, test section verifications, data acquisition system checks, functional checks of flow, heat exchanger and superheater capabilities, and facility drainage and control characteristics.

Tests T1 and T4 measured the flow rates for the individual core spray nozzles on each header at 525 gpm total core spray header flow. Table 5-1 presents the measured results for the upper and lower headers as well as the specified value for each nozzle type. Specified values were obtained from earlier VSF tests. All data falls within the ±10% allowable deviation specified as an acceptance criteria.

Table 5-1

INDIVIDUAL CORE SPRAY NOZZLE FLOW RESULTS

Header Location	Nozzle Location	Nozzle Type	Specified Flow (gpm)	Measured Flow (gpm)
SSTF Test T1				
Upper	UB1	Spraco 2935M	60.2	60.4
Upper	UF1	1 inch O.E. (w/nipple)	48.1	45.9
Upper	UB2	1 inch O.E. (Street)	68.7	66.8
Upper	UF2	1 inch O.E. (w/nipple)	48.1	51.8
Upper	UB3	Spraco 2935M	60.2	61.6
Upper	UF3	1 inch O.E. (w/nipple)	48.1	49.9
Upper	UB4	1 inch O.E. (Street)	68.7	65.6
Upper	UF4	1 inch O.E. (w/nipple)	48.1	48.3
Upper	UB5	Spraco 2935M	60.2	61.0
SSTF Test T4				
Lower	LB1	Spraco 2935M	60.4	64.3
Lower	LF1	3/4 inch O.E. (regular)	47.8	48.0
Lower	LB2	1 inch O.E. (Street)	69.6	63.7
Lower	LF2	3/4 inch O.E. (regular)	47.8	48.3
Lower	LB3	Spraco 2935M	60.4	64.3
Lower	LF3	3/4 inch O.E. (regular)	47.8	49.3
Lower	LB4	1 inch O.E. (Street)	69.6	64.4
Lower	LF4	3/4 inch O.E. (regular)	47.8	49.1
Lower	LB5	Spraco 2935M	60.4	61.7

Data repeatability was verified several times during testing. Figure 5-1 shows the results of two tests performed with the lower header in an air atmosphere. These tests were separated by over two months and include the effect of nozzle removal, reinstallation, and re-aiming which occurred during that period. The demonstrated repeatability is very good.

Figure 5-2 shows data from three tests which demonstrates the negligible effect on distribution from differences in the amount of superheat of the steam environment. The three tests represent 0°F, 5°F, and 24°F superheat. These tests were all run at 29.5 psia without core steam injection.

A series of tieback tests were performed to verify the similarity of the SSTF to other facilities used in core spray distribution testing. The verification was demonstrated by comparing data taken in the SSTF with data from the VSF and the Horizontal Spray Facility (HSF) under the same test conditions. Test T10 was a spray distribution test performed in air with the sector walls and fuel channel cover plates removed. Figure 5-3 compares the SSTF lower header data from Test T10 with VSF data at identical test conditions and demonstrates the good tieback achieved.

Tests T7 and T9 were lower header tests performed in air to compare results with and without the 30° sector walls in place. Figure 5-4 shows the comparison to be very good (i.e., negligible wall effect) for Test T7 with walls and Test T9 without walls. The figure also shows the tieback to a VSF test performed with walls.

Test T11E was a spray distribution measurement test for a single SPRACO 2935M nozzle* on the upper header in a two-atmosphere steam environment. Figure 5-5 compares data from Test T11E with data from the HSF. This comparison is considered to be very good considering the measurement grid offset between the SSTF and HSF tests** and the semi-hollow spray distribution of this nozzle at some conditions in steam, which results in noticeable changes in distribution relative to small variations in measurement location.

*SPRACO currently designates this nozzle design as 518620.

**The measurement grid offset occurs because the SSTF header/bundle configuration did not permit exact duplication of the HSF positioning.

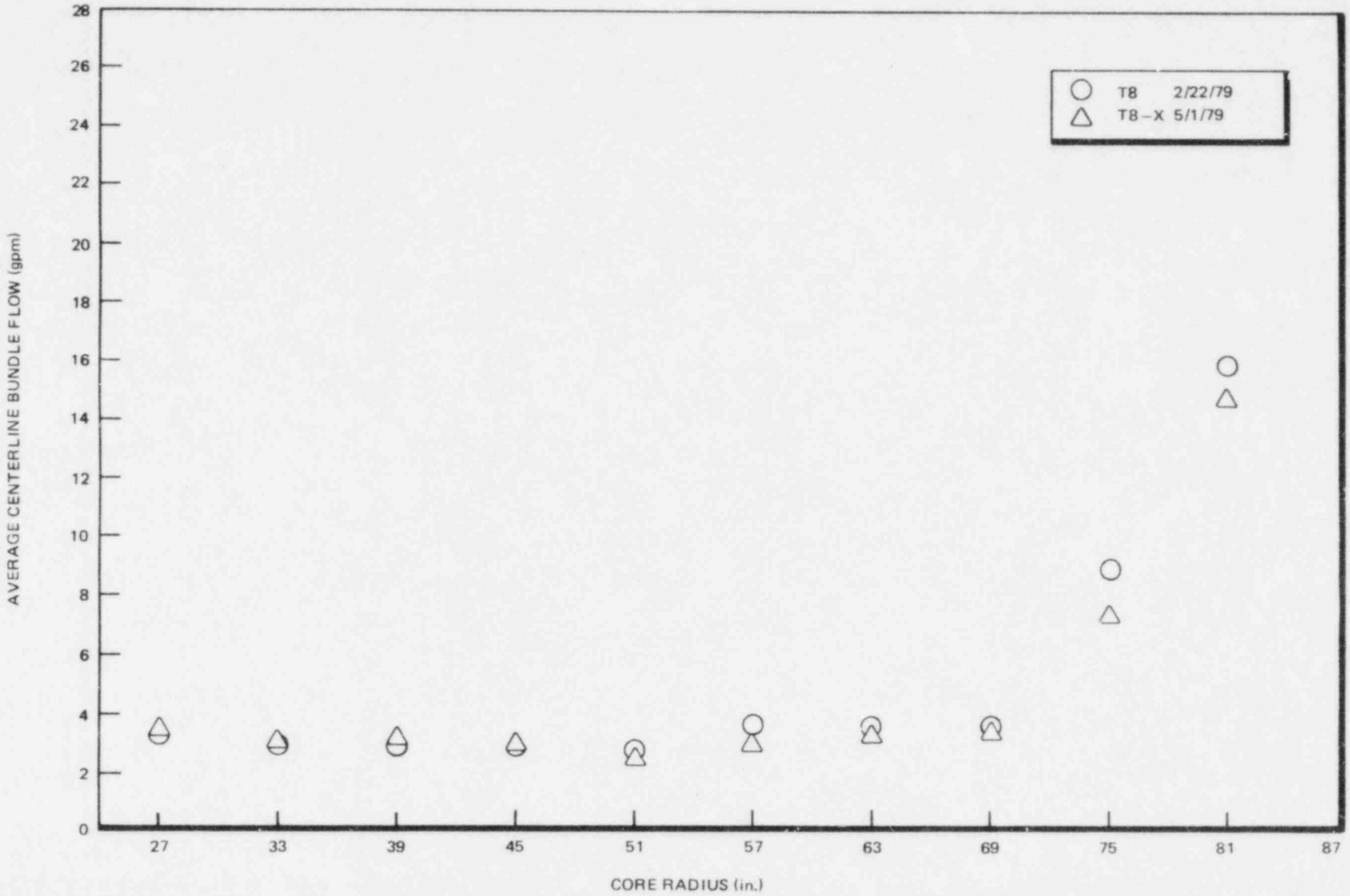

Figure 5-1. Nozzle Aiming Repeatability Check for LPCS with Reactor Nozzles in Air

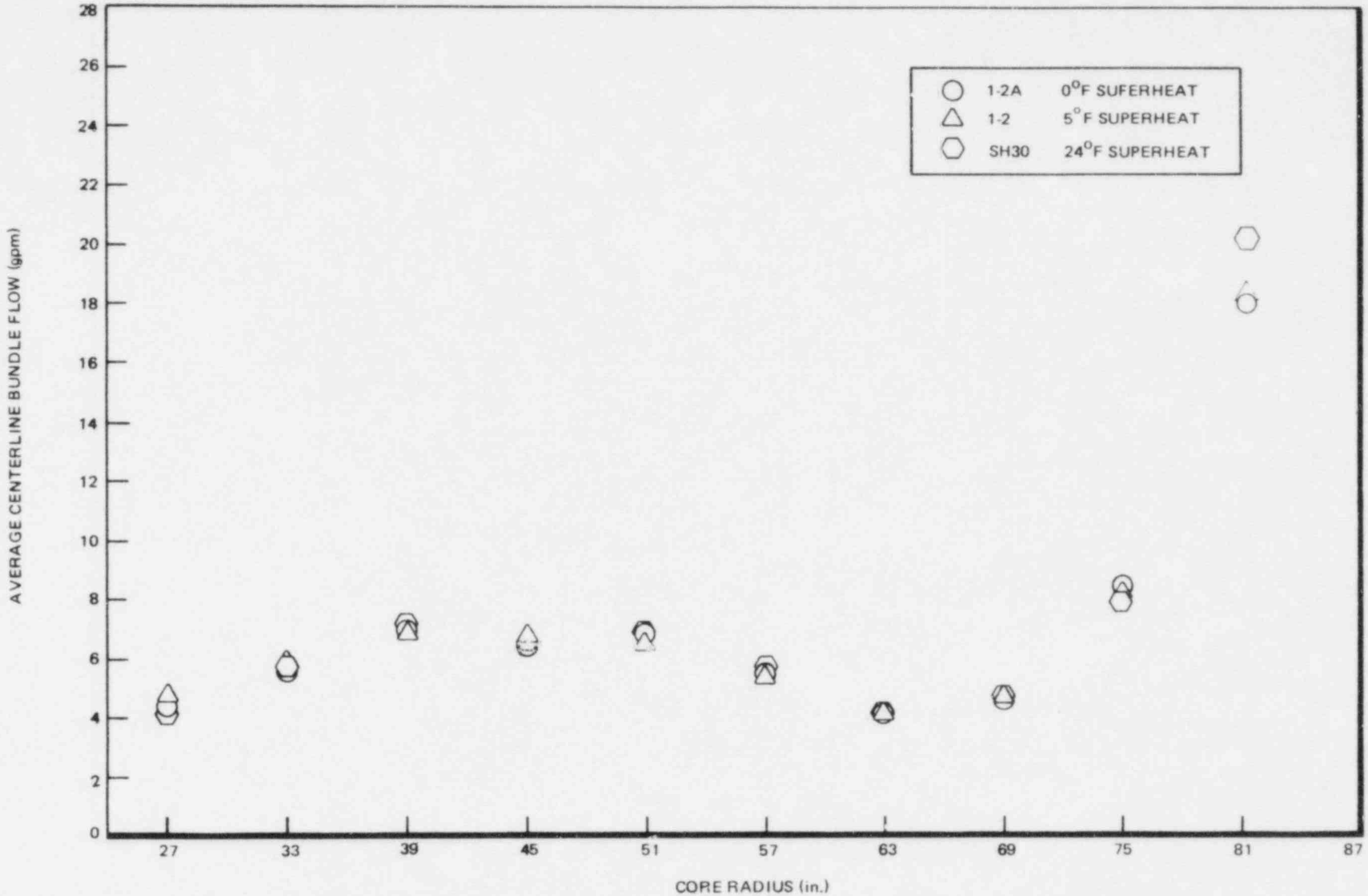

Figure 5-2. Steam Superheat Effect for LPCS

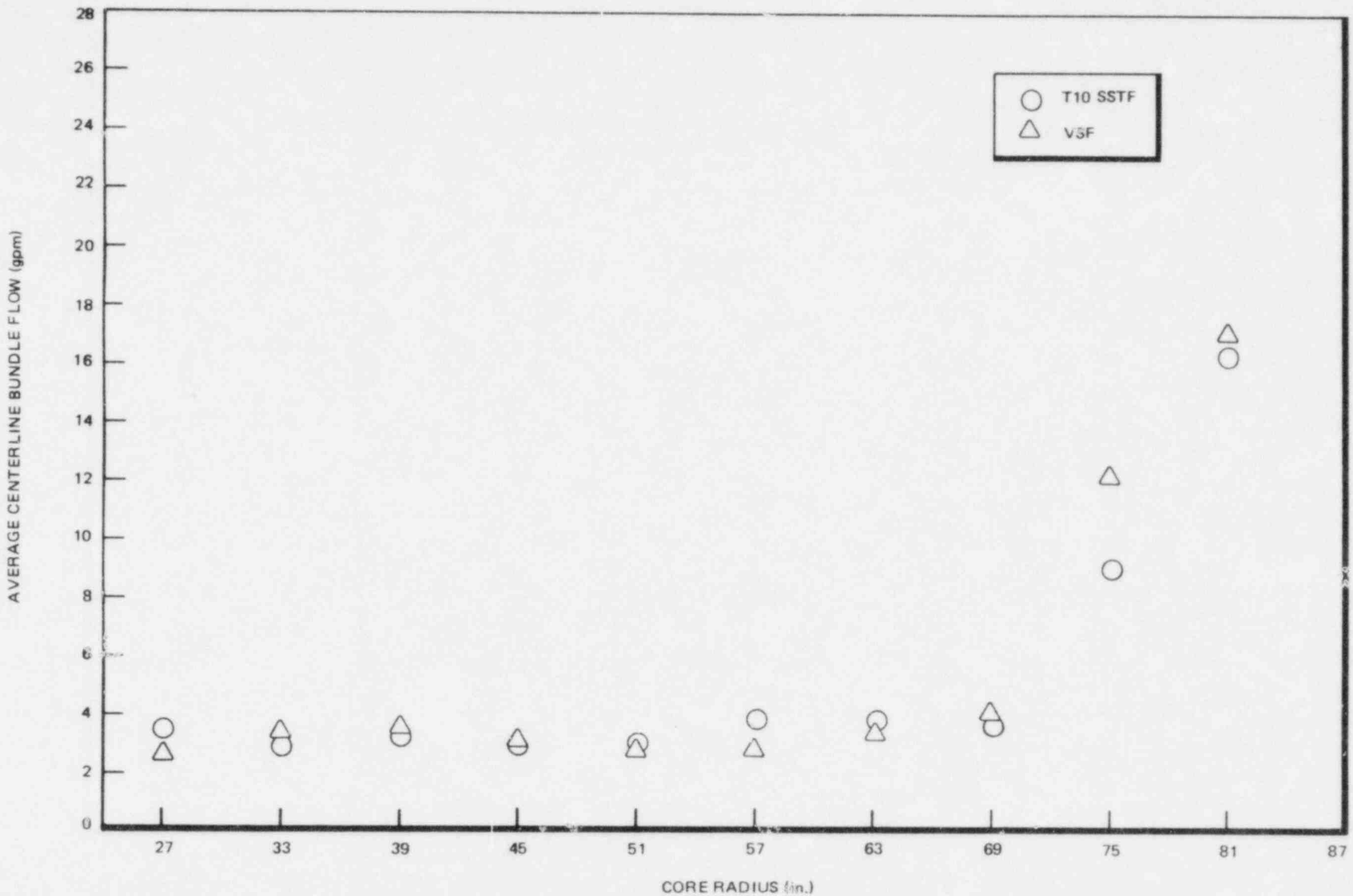

Figure 5-3. 30° Sector Spray Distribution in Air Compared to VSF for LPCS with Reactor Nozzles

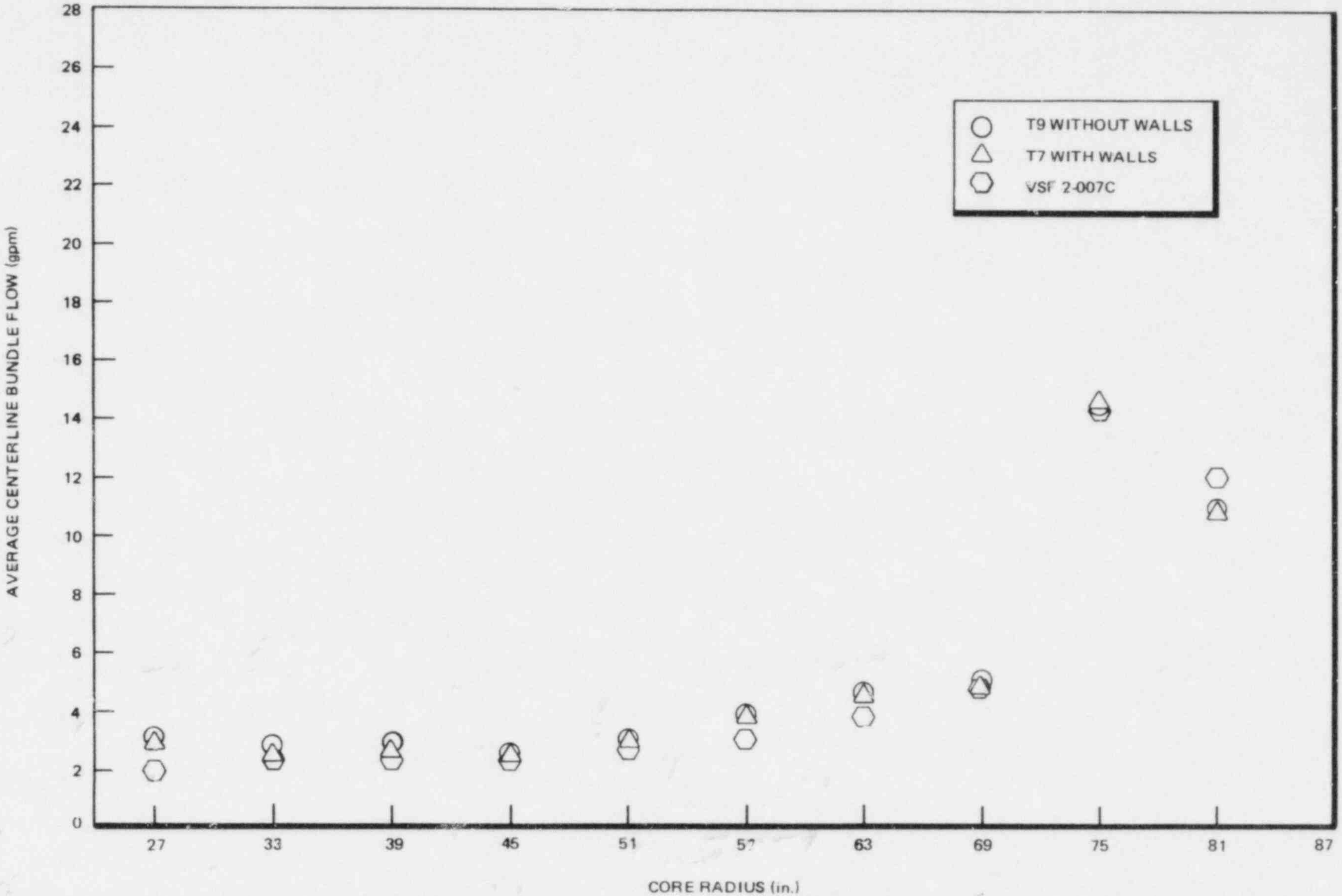

Figure 5-4. 30° Sector Spray Distribution in Air Showing Wall Effects for HPCS with Reactor Nozzles

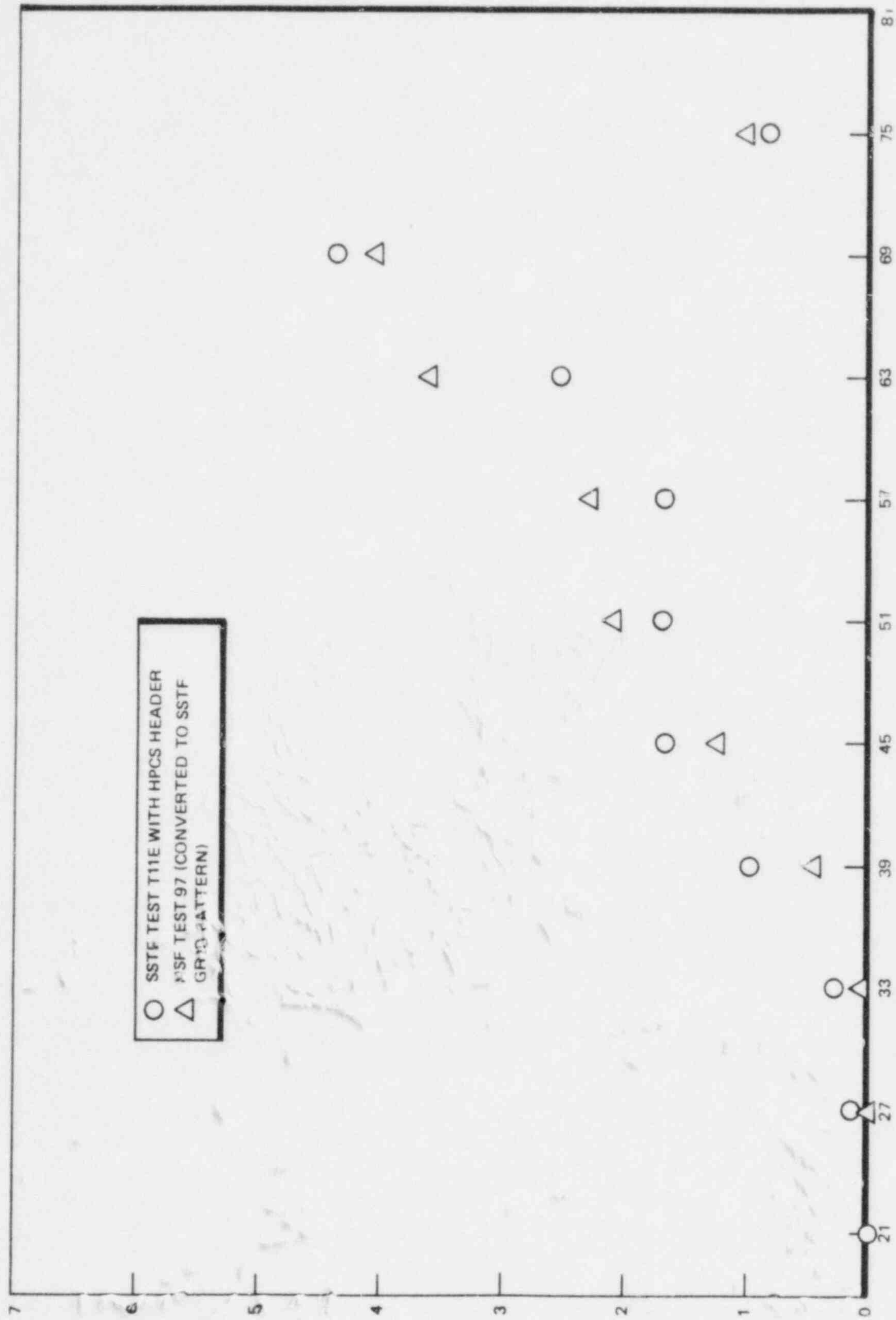

Figure 5-5. Single Nozzle Spray Distribution in Steam Compared to HSF

Drop diversion phenomena at the top of the bundles was investigated in an upper plenum geometry to evaluate the impact of having no steam flow in the bypass as discussed in Section 3. These calibration tests define the region where the facility configuration is not appropriate for methodology confirmation because of the drop diversion effect.

As expected, it was observed that high core steam flow rate resulted in a decrease in the bundle liquid downflow. The decreased bundle drainage was balanced by increased bypass drainage, with no net change in total liquid flow to the lower plenum. The open bypass without steam updraft results in spray droplets being diverted to the bypass region at high core steam flows.

Total liquid downflow data are cross-plotted in Figure 5-6 for a series of HPCS tests with different core steam flows at 29.5 psia and 185°F spray temperature. Also shown is the drop diversion estimated from a drop terminal velocity analysis described in Appendix B. The region of drop diversion is reasonably predicted by this analysis, although the calculated decrease is sharper than the measured decrease. It can be seen from this figure that for the droplet sizes present, there is a significant (>10%) drop diversion phenomena for core steam flows greater than approximately 20,000 lb/hr (corresponding to bundle flows of 400 lb/hr). Hence, core spray methodology evaluations cannot be performed in this facility for steam updraft flows above that value. As previously indicated, that only restricts evaluations for some conditions of double header operation.

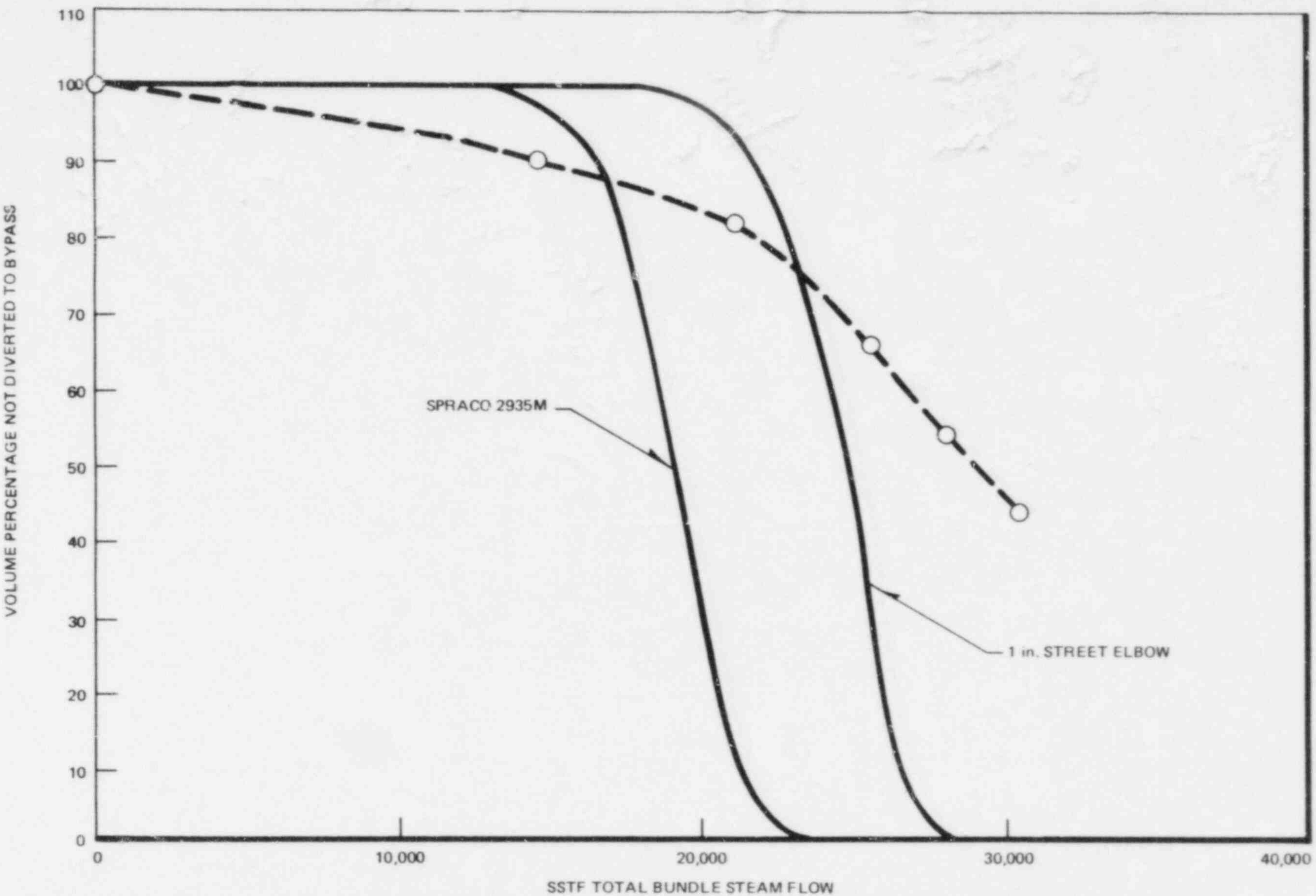

Figure 5-6. Comparison of First Order Drop Diversion Analysis to Data From Tests CS-2A Through CS-2F. Data are total flows in centerline bundles of rows 4-10 for each test, divided by the total flow in these bundles for the zero updraft test (CS-2F).

6. SSTF TEST RESULTS COMPARED TO THE PRE-TEST PREDICTION

A pretest prediction report was submitted to the NRC in April, 1979[2]. This report described the application of the core spray design methodology to the SSTF, and contained the predicted bundle flows along the test facility centerline. The method of combining single nozzle spray distributions in a steam environment with multiple nozzle interaction effects was described in this report. In addition, acceptance criteria for confirming the prediction methodology were supplied in the form of uncertainty limits. The prediction methodology would subsequently be confirmed if the appropriate fraction (95%) of the test data fell within these two-sigma uncertainty limits.

The region of the pre-test prediction is shown by the heavy line in Figure 6-1. Since the individual nozzle distribution data are a field of point functions, not a continuous function, the superposition of the contributions from all the nozzles results in a distribution calculated along a radial chord, e.g., the centerline of the 30° sector. This centerline prediction is then compared to the measured distribution, which is the average* of the flow collected by the bundles adjacent to each side of the centerline.

Flow measurement data are taken in the facility as described in Section 3. Flows are measured into all 58 full and partial bundles in the 30° sector. The flow into the bypass region is not measured directly, but the bypass water level is proportional to the total flow into the bypass.

As previously indicated, the nominal condition for comparison between pre-test predictions and data was with balanced updraft/downdraft in the tests. This is the case for the two single header comparisons discussed below. However, since this condition for two header operation resulted in updraft flows in excess of the 20,000 lb/hr droplet diversion limit established in the calibration studies of Section 5, the two-header comparison below is conducted with the zero core updraft data (i.e., unbalanced updraft/downdraft). It is subsequently demonstrated (Section 8) that variations in updraft below the droplet diversion limit have negligible effect.

*This centerline bundle average should not be confused with "radius averaging", which is taken over a full-core

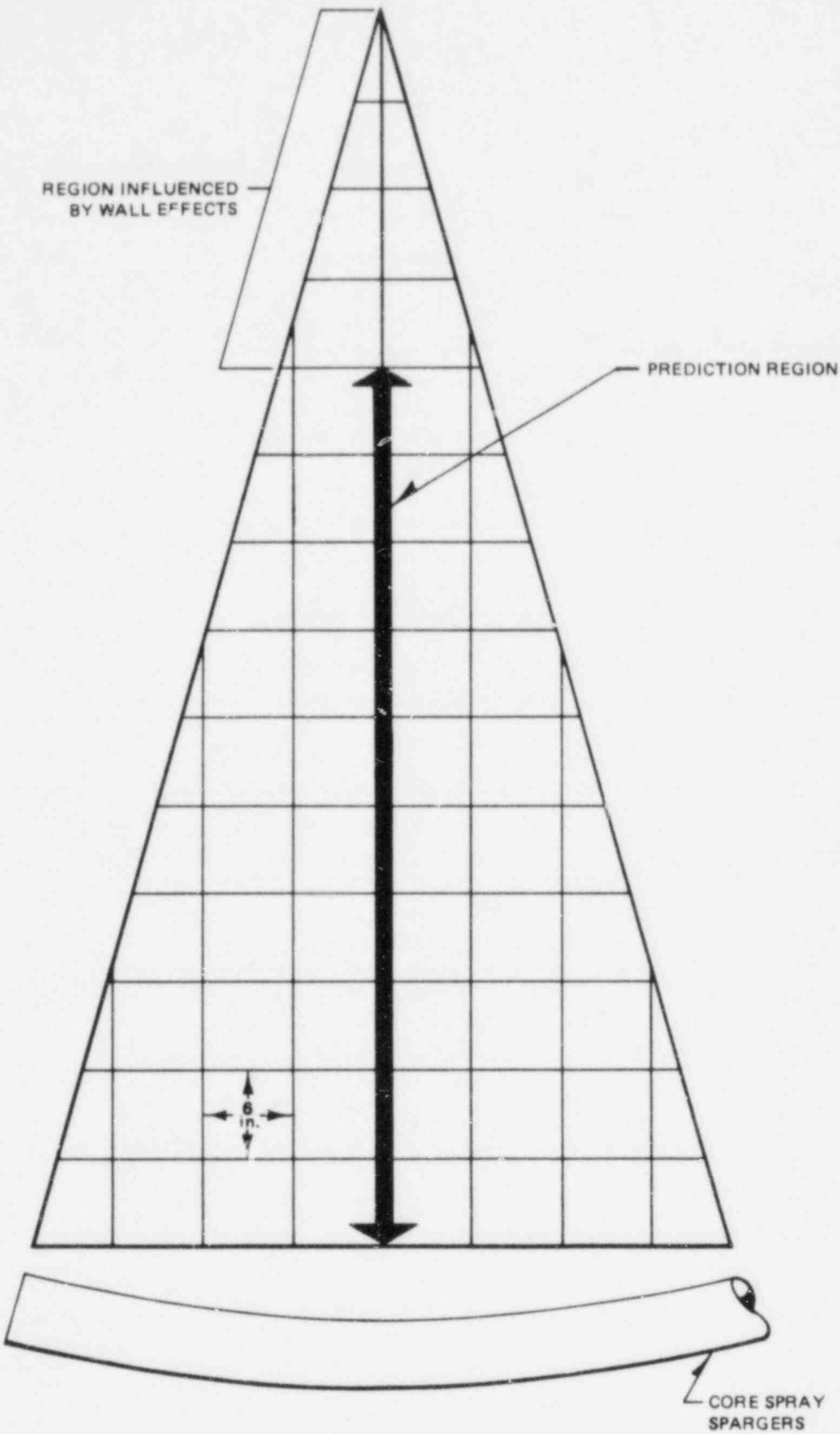

Figure 6-1. Top View of SSTF Core Mockup Showing Region of Pre-Test Prediction

LPCS - The centerline-averaged data are plotted in Figure 6-2 along with the pre-test prediction and the 2σ uncertainty bands. The centerline-average data points all fall within the uncertainty bands associated with confirmation of the methodology. The individual bundle flows are shown in Figure C-15. An examination of Figure C-15 shows that flows for two individual bundles fall outside the bands.*

HPCS - The centerline averaged data are plotted in Figure 6-3 along with the pre-test prediction and the 2σ uncertainty bands. The individual bundle flows are shown in Figure C-16. As described in the Pre-Test Prediction report[2], the prediction could not be performed within 45 inches of the center due to the lack of single nozzle data for one nozzle. These data were subsequently obtained in the SSTF and the prediction extended to within 27 inches of the center. This extended prediction is discussed in Section 7. The centerline average data points all fall within the uncertainty bands associated with confirmation of the methodology as do all of the individual bundle measurements in Figure C-16.

HPCS and LPCS - The centerline-averaged data are plotted in Figure 6-4 along with the pre-test prediction and the 2σ uncertainty bands. The individual bundle flows are shown in Figures C-5 and C-6. Results fall well within the confirmation acceptance bands for the two points supplied (see Section 7 for more complete comparison).

The close agreement between the predicted and measured spray distribution satisfy the criteria for confirmation of the methodology and assumptions.

*The uncertainty bands supplied with the pre-test prediction are appropriate for the centerline bundle average; bands for individual bundle flows are somewhat larger.

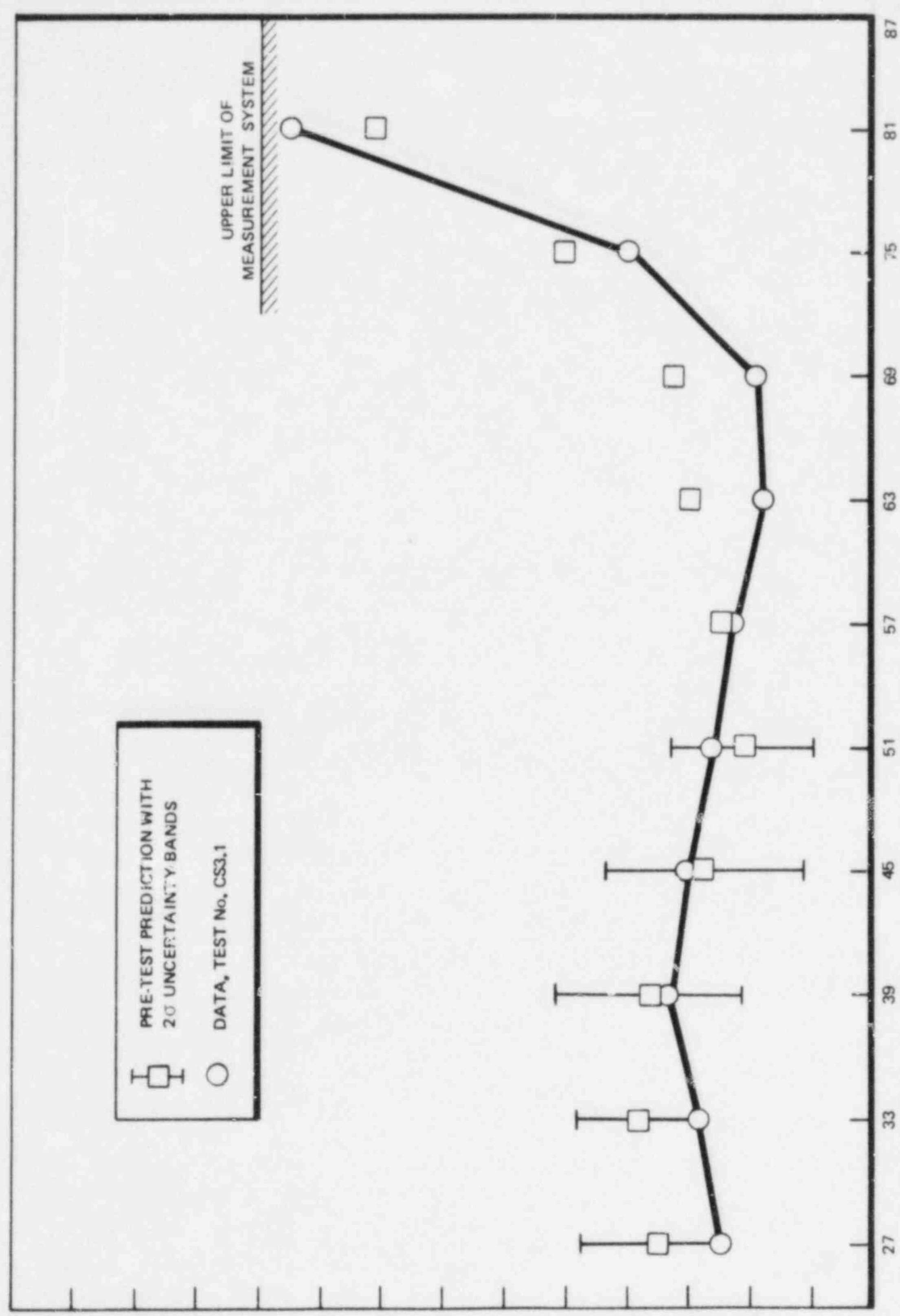

Figure 6-2. Comparison of SSTF Data to Pre-Test Prediction for LPCS Operation

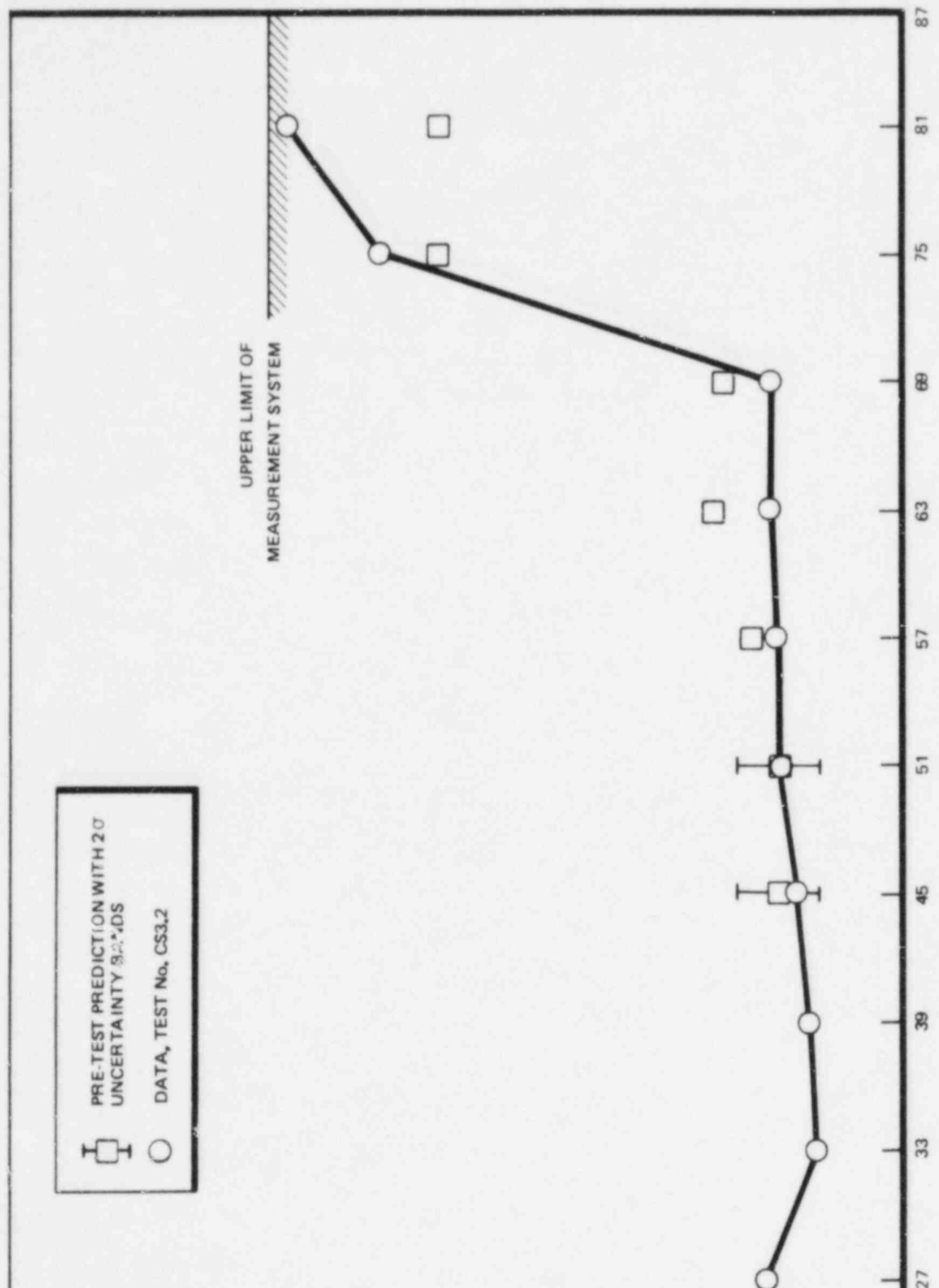

Figure 6-3. Comparison of SSTF Data to Pre-Test Prediction for HPCS Operation

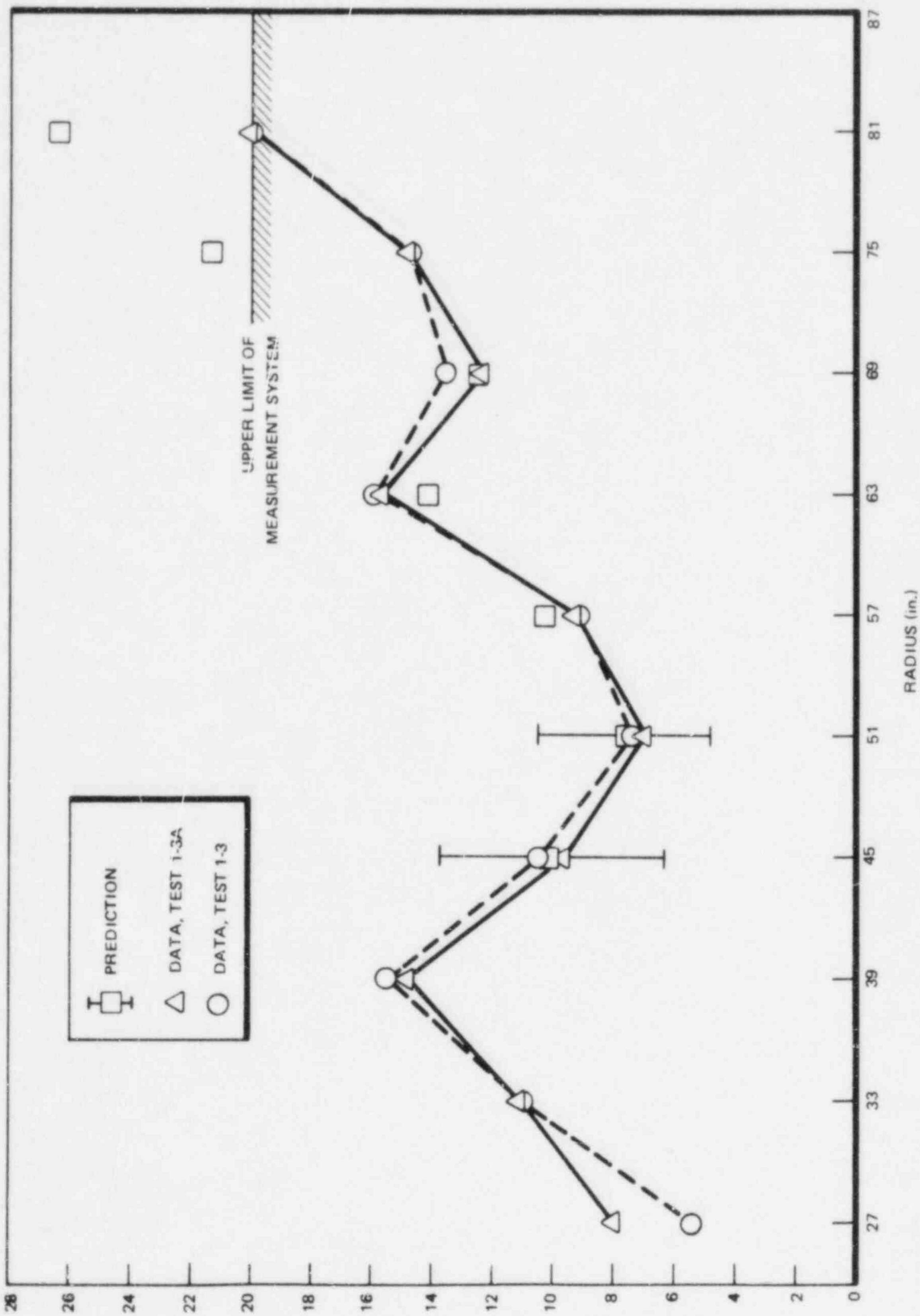

Figure 6-4. Comparison of SSTF Data to Pre-Test Prediction for LPCS and HPCS Operation

7. EXTENSION OF THE PRE-TEST PREDICTION

HPCS - The pre-test prediction for the HPCS did not include the points at 27, 33 and 39 inches because a single nozzle test for the 1 inch street elbow could not be run in the HSF. In order to extend the prediction, single nozzle tests of this nozzle were performed in the SSTF. The test results for the two different nozzle positions are shown in Figure 7-1 and 7-2. These data were used to extend the pre-test prediction and the resulting extension is shown in Figure 7-3, along with the test data. As with the other points, the new prediction values agree with the 30° SSTF data and further confirm the prediction methodology.

HPCS and LPCS - The pre-test prediction for both HPCS and LPCS together also did not include the points at 27, 33 and 39 inches because of the missing single nozzle test data. The new single nozzle data in Figures 7-1 and 7-2 were also used to extend the double sparger prediction. The additional points are shown in Figure 7-4, along with the test data presented earlier. Again, although the updraft/downdraft is unbalanced, the prediction methodology is further confirmed by these comparisons.

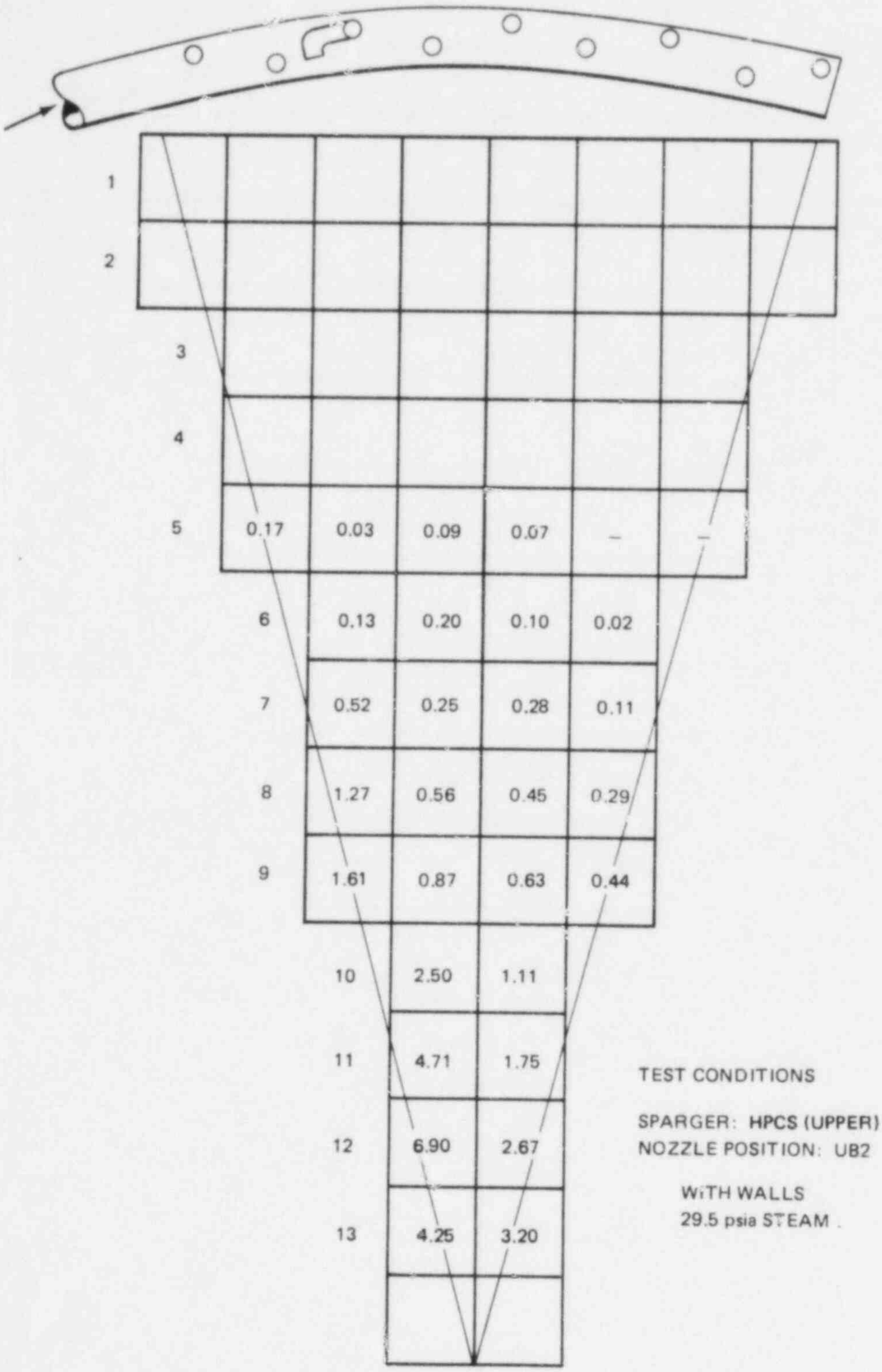

Figure 7-1. 30° SSTF 1 Inch O.E. (ST) Single Nozzle Test in 2 Atm. Steam Test Results - Test T14

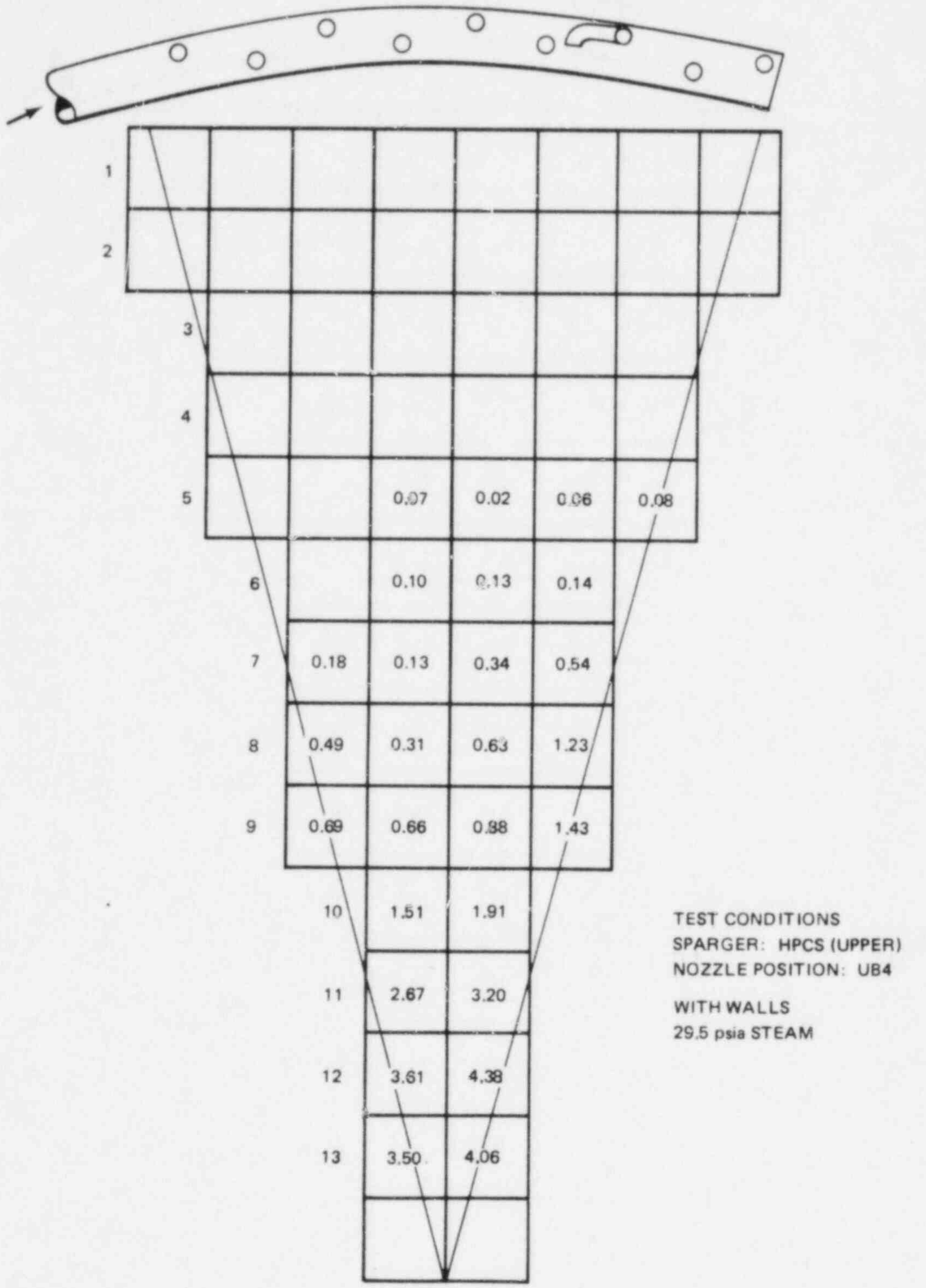

Figure 7-2. 30° SSTF 1 Inch O.E. (ST) Single Nozzle Test in 2 Atm. Steam Test Results - Test T12A

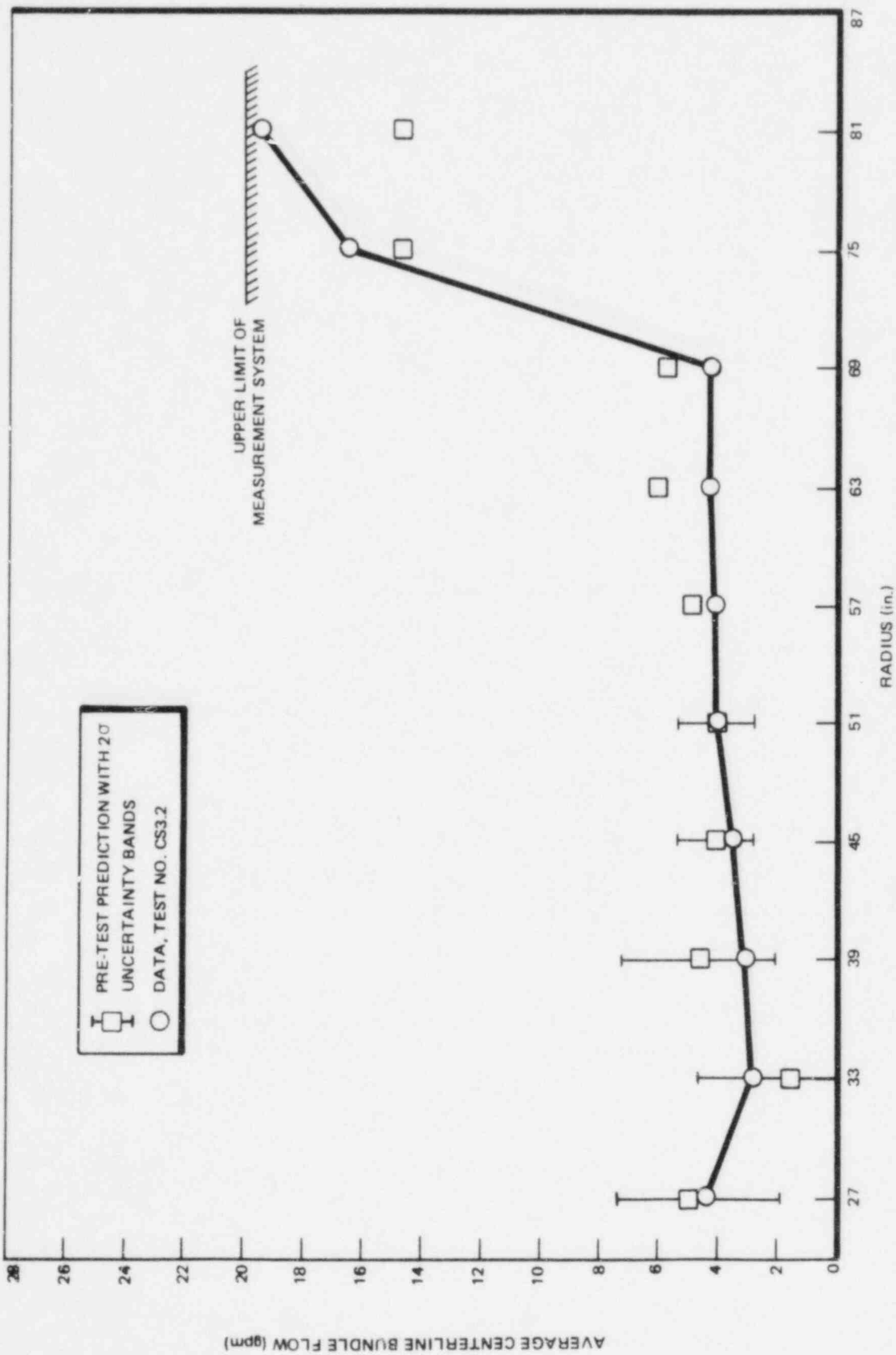

Figure 7-3. Comparison of SSTF Data to Extended Prediction for HPCS Operation

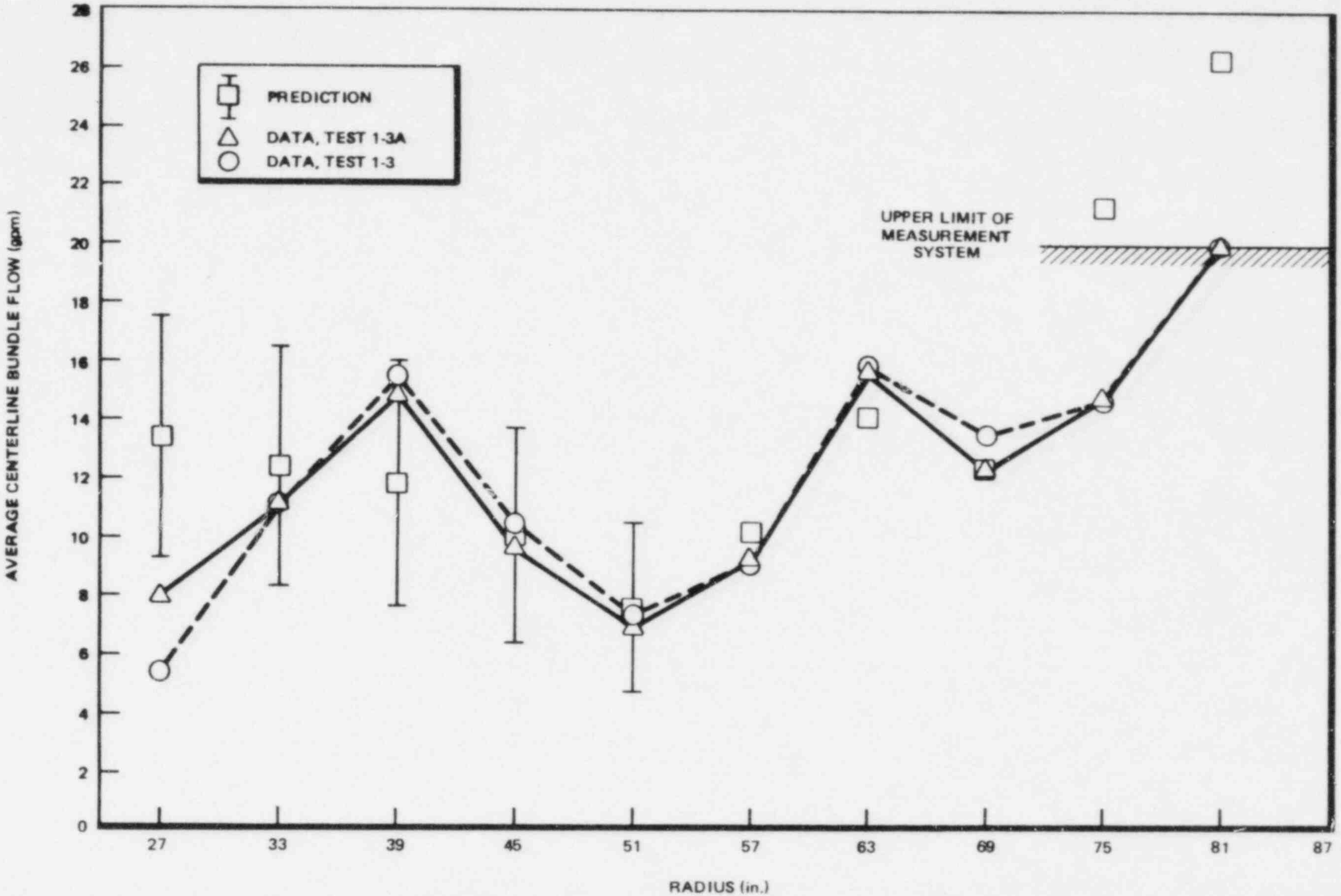

Figure 7-4. Extension of the LPCS and HPCS Prediction and Comparison to Data

8. TEST RESULTS WITH PARAMETRIC VARIATIONS

The effect of core steam updraft on spray distribution, in the region where the methodology is applicable, is shown in Figure 8-1 for a series of HPCS tests at 29.5 psia and 145°F spray temperature. As expected from the earlier calibration studies (c.f., Section 5), there is a negligible effect of core steam up to approximately 20,000 lb/hr. Beyond that value, the present facility cannot be used for distribution prediction confirmation.

The effect of changes in system pressure on core spray distribution was investigated by performing parametric tests at system pressures of 29.5 psia (2 atm), 44.1 psia (3 atm), and 73.5 psia (5 atm). Test results are shown in Figure 8-2. The distribution was not significantly affected, although pressure did have the anticipated effects on the magnitude of the distribution at specific locations.

The small changes in the distribution which did occur are caused by the increased condensation effects near the nozzle face. Increased condensation causes more contraction of the spray cones, leading to higher flows in the centers of the spray cones and lower flows around the edges. The influence of these changes on the data shown in Figure 8-2 can be better understood by examining Figure 8-3. The regions of coverage by each nozzle type are shown, and the influence of a pressure increase is sketched as a dashed line. The pressure increase causes an increased spray flow where the Spraco nozzle is centered (rows 3, 4 and 5) and a somewhat smaller increase where the 1 inch street elbow is centered (row 10). A decrease in flow occurs in the region between spray peaks (rows 7 and 8)*. A review of Figure 8-2 shows that the 30° sector data is compatible with these expected single nozzle trends. Because the pressure trends shown in the sector data result from pressure effects on the individual nozzle patterns, it can be concluded that the interaction effects among the nozzles are not sensitive to pressure. Therefore, calculated spray distributions can be used over a range of pressures.

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*The actual BWR/6 reactor core spray designs compensate for this potential low zone by staggered aiming of the 1 inch Street Elbow nozzles.

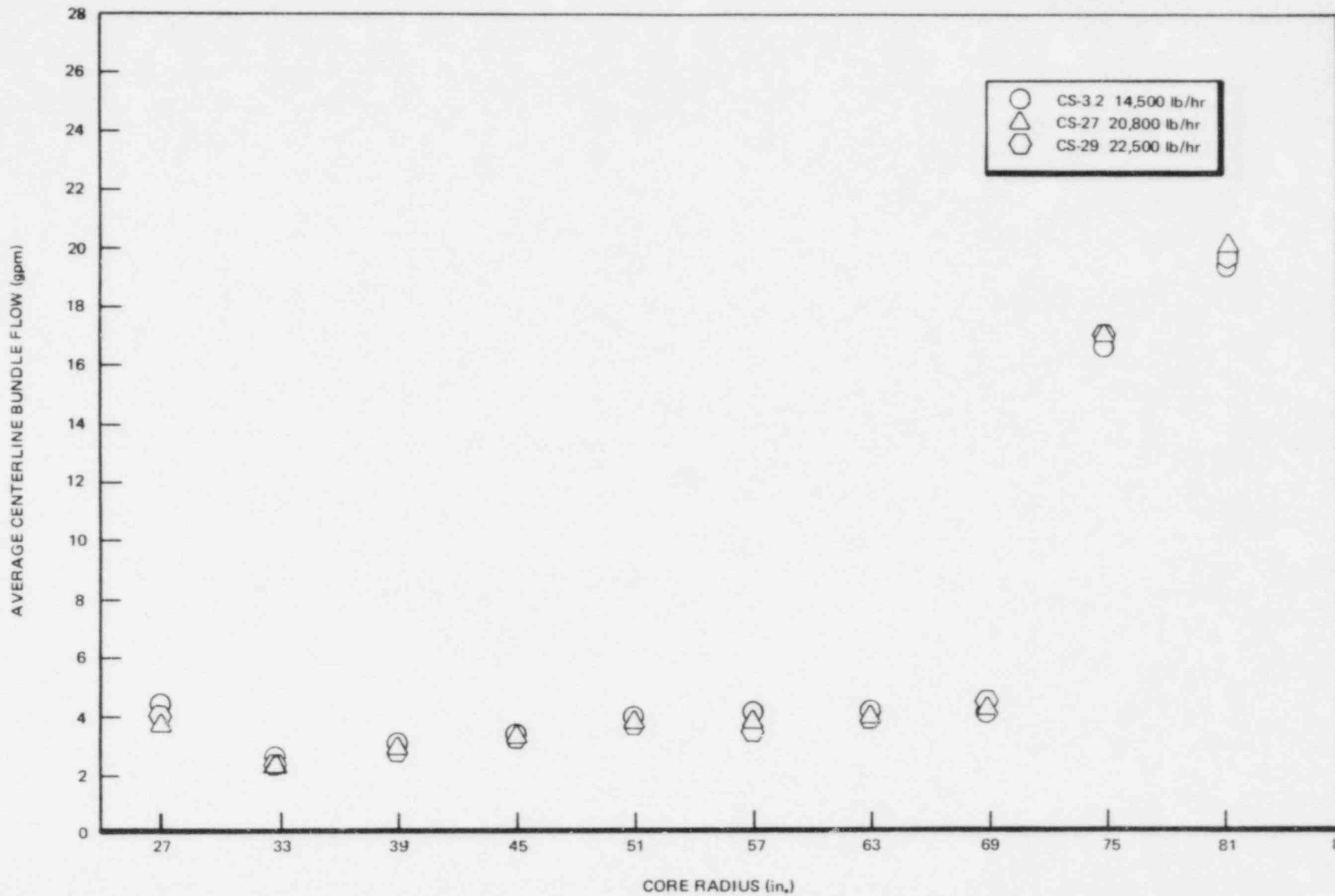


Figure 8-1. Steam Updraft Effect on Spray Distribution for HPCS

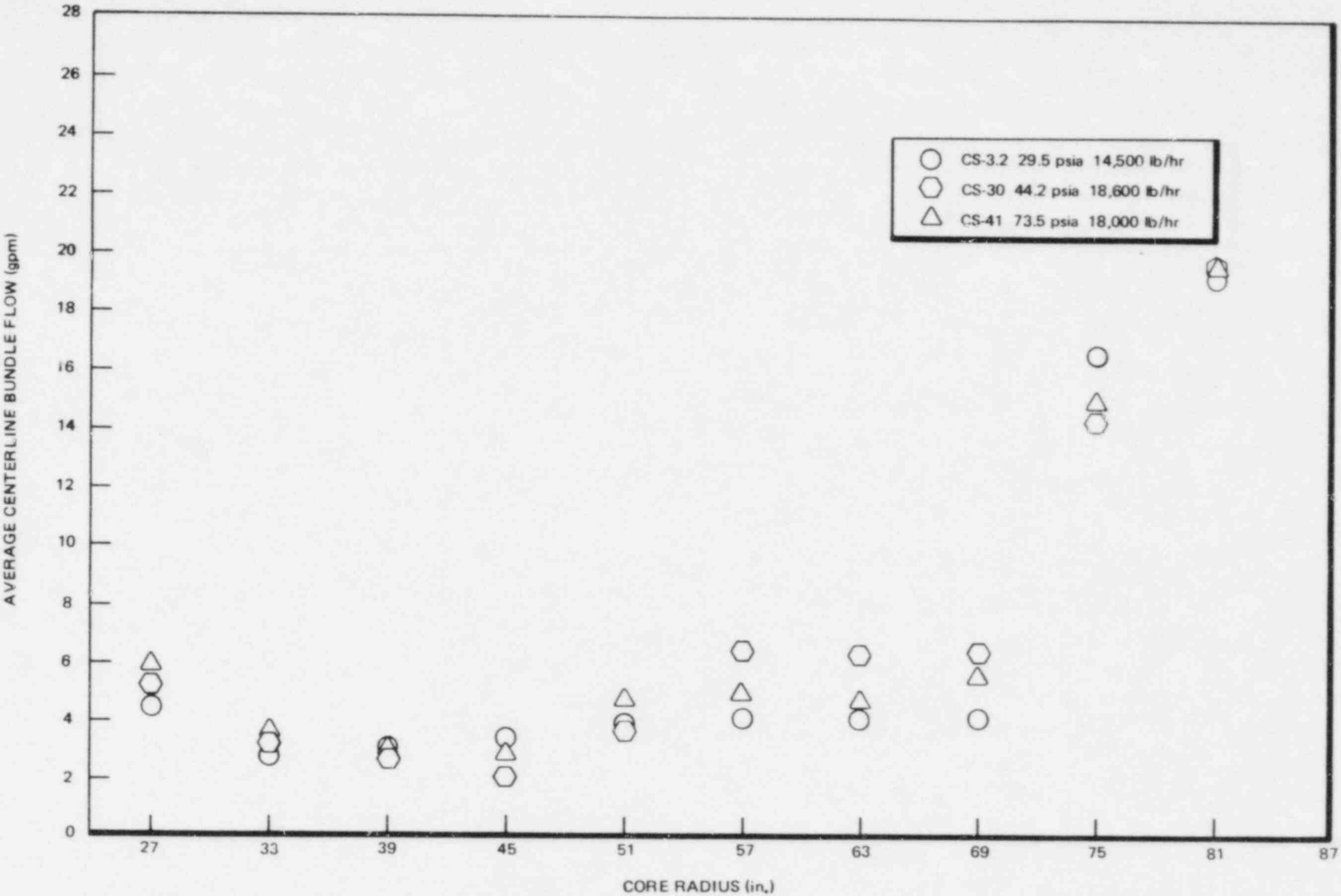


Figure 8-2. System Pressure Effect on Spray Distribution for HPCS

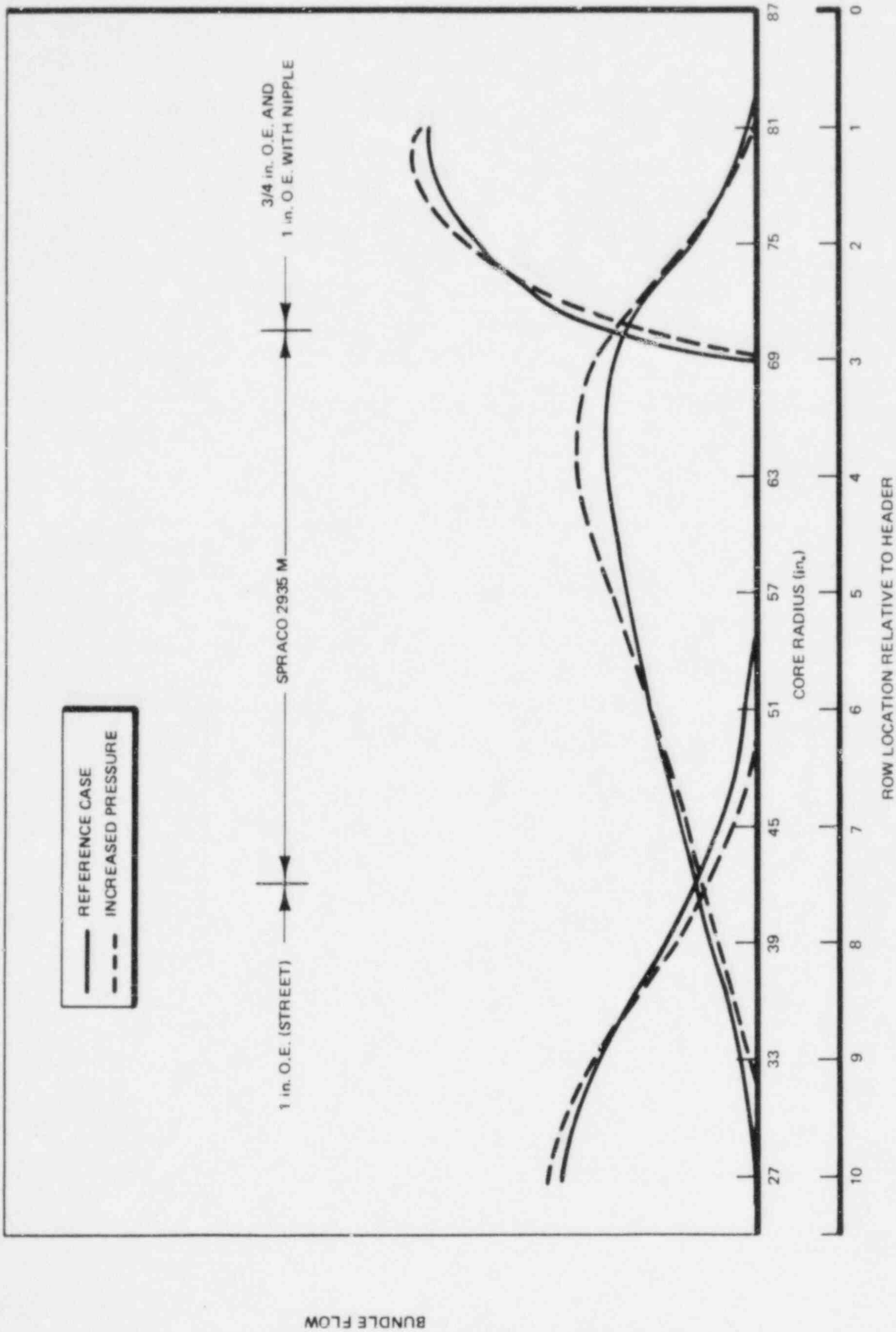


Figure 8-3. Individual Nozzle Distribution Regions

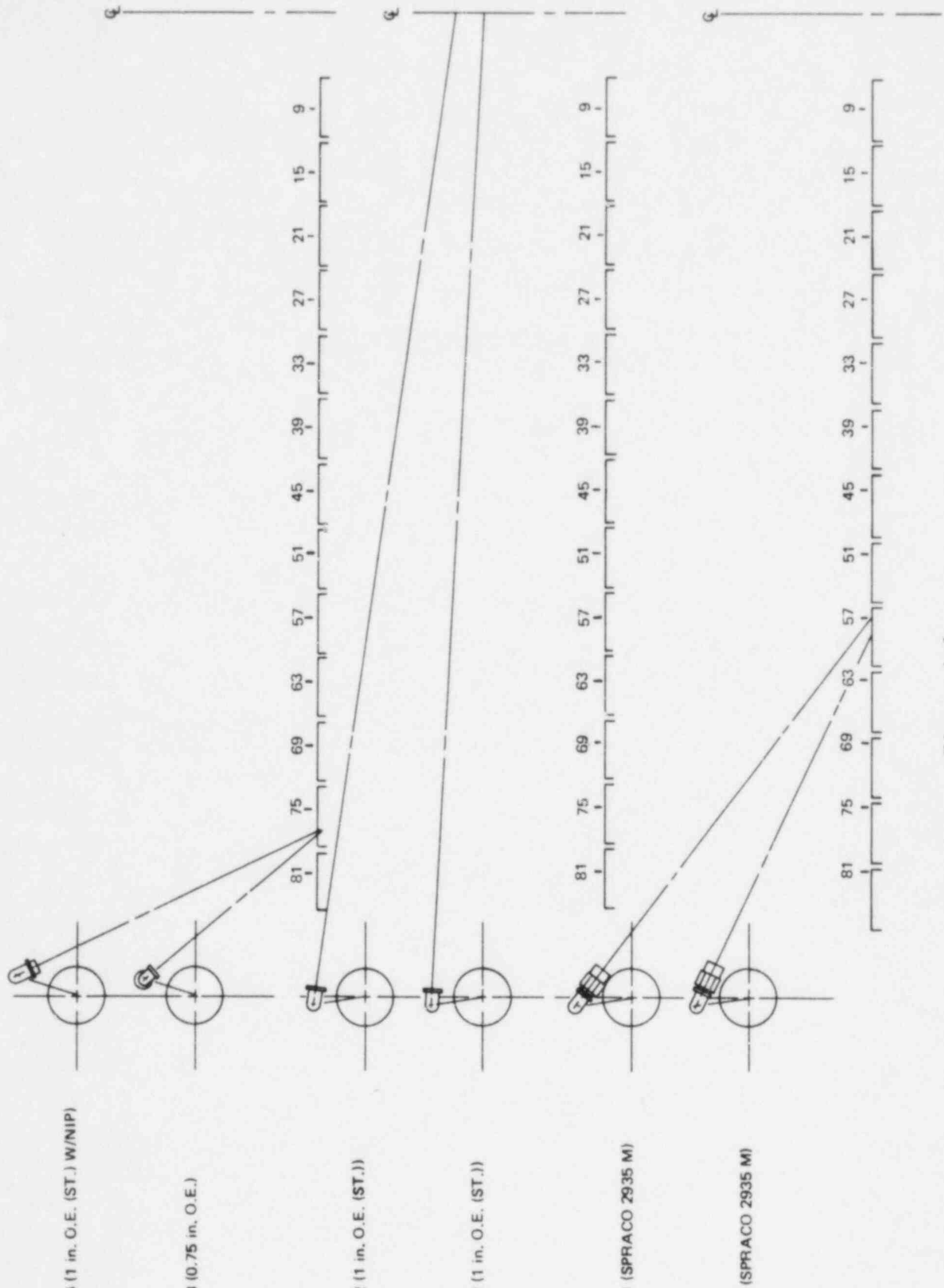
9. REFERENCES

1. NEDO-24706, "Lynn SSTF Bundle Flow Measurement System Description and Calibration", D. W. Danielson, August 1979.

2. Letter report, "Pre-Test Prediction for SSTF Core Spray Tests", S.K. Rhow and S. A. Sandoz, April 1979. (included as Appendix D to this document).

Appendix A

NOZZLE INSTALLATION CONFIGURATION


UF4 (1 in. O.E. (ST.) W/NIP)
LF4 (0.75 in. O.E.)
UB2 (1 in. O.E. (ST.))
LB2 (1 in. O.E. (ST.))
UB1 (SPRACO 2935 M)
LB1 (SPRACO 2935 M)
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15
21
27
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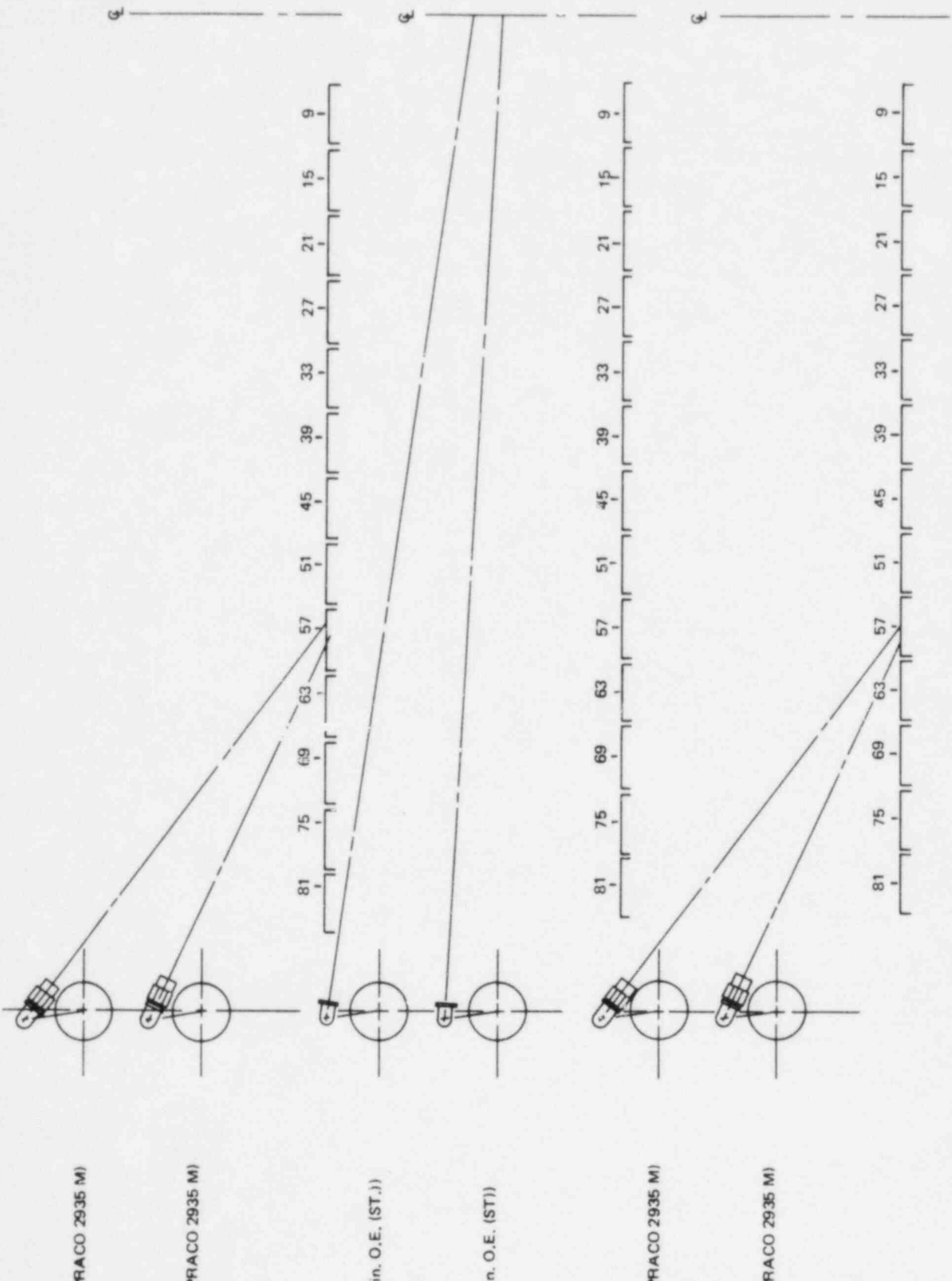
69
75
81

Figure A-1.


UB5(SPRACO 2935 M)
LB5 (SPRACO 2935 M)
UB4 (1 in. O.E. (ST.))
LB4 (1 in. O.E. (ST))
UB3 (SPRACO 2935 M)
LB3 (SPRACO 2935 M)
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81

Figure A-2.

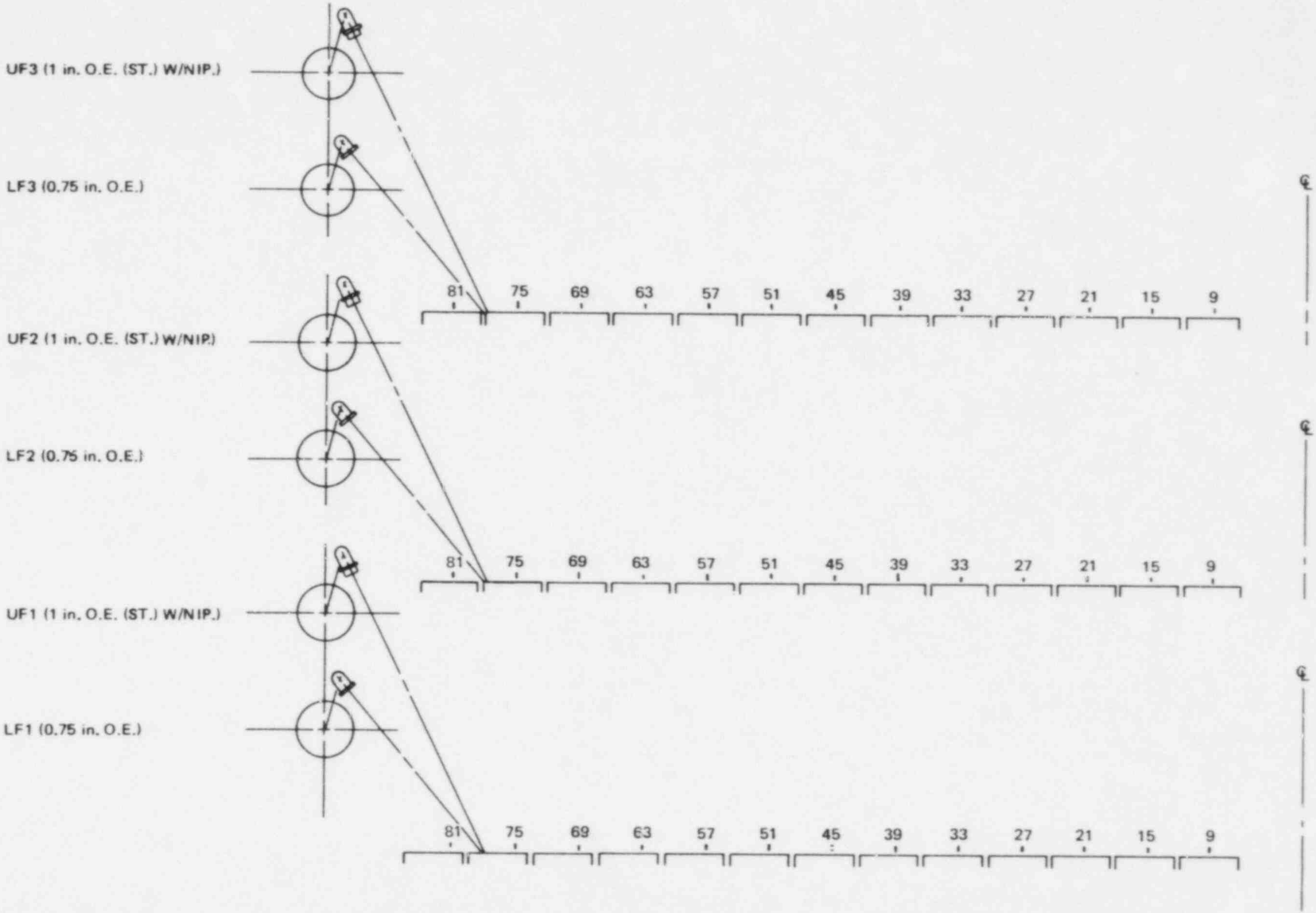
UF3 (1 in. O.E. (ST.) W/NIP.)
LF3 (0.75 in. O.E.)
UF2 (1 in. O.E. (ST.) W/NIP.)
LF2 (0.75 in. O.E.)
UF1 (1 in. O.E. (ST.) W/NIP.)
LF1 (0.75 in. O.E.)
81 75 69 63 57 51 45 39 33 27 21 15 9
81 75 69 63 57 51 45 39 33 27 21 15 9
81 75 69 63 57 51 45 39 33 27 21 15 9
℄
℄
℄

Figure A-3.

Appendix B

VAPOR FLOW EFFECTS ON DROP TRAJECTORIES VERY NEAR THE BUNDLE UPPER TIEPLATE

Steam injection in the simulated fuel bundles in the SSTF produces substantial vapor velocities (~10-30 ft/sec) upward through the bundle upper tieplates (UTP). After the steam leaves the UTP, its velocity is reduced by a factor of three due to the larger available flow area in the upper plenum. Because of the larger local velocity near the tieplate, the trajectories of smaller spray drops may be influenced during tests with steam injection. In particular, if the local steam velocity exceeds the drop's terminal velocity, the drop can be suspended or moved upward. This movement will be of limited extent for all but the smallest drops, since the steam velocity is so much smaller in the upper plenum. As soon as the drop moves to a level of lower steam velocity, it will begin to fall again.

In a reactor with updraft in both fuel bundles and bypass, this local drop movement might lead to some minor redistribution of spray flow. The drops could bounce around above the core until they collide with other drops (which yield drops large enough to fall against the vapor velocity at the tieplate) or some solid surface, allowing them to pass through the bundle tieplates.

In the current configuration of SSTF, where no steam injection is present in the bypass, levitated drops can readily fall into the bypass region adjacent to the fuel bundles. As the steam updraft increases, more and more spray could be diverted into the adjacent bypass through this mechanism.

Although the exact amount of flow diversion into the bypass is difficult to evaluate, a first order approximation can be found by assuming that all droplets that are small enough to be levitated by the steam velocity through the tieplates are ultimately diverted and deposited into the bypass. This should provide an upper bound on the diversion since droplet coalescence and impact with hardware surfaces should allow some fraction of these small levitated drops to enter the fuel bundles.

This first-order analysis has been performed for 29.5 psia with drop size distributions that were calculated for two of the three nozzle types used in SSTF, using correlations reported by Mugele[B-1,B-2], as illustrated in Figure B-1. Drop terminal velocity as a function of drop size is available in data obtained by Lane and Green and described in Reference B-3. Assuming this drop terminal velocity equals the steam velocity through the UTP, an equivalent bundle steam flow to levitate a drop of a specific size can be calculated. Combined with the drop size distribution information, the volume percentage of the spray which could be diverted into the bypass as a function of total SSTF bundle steam flow can be calculated, and is shown in Figure B-2. This curve was calculated with the vapor velocities, and is therefore only directly applicable, for rows 4-10 on the sector centerline. Other bundle locations in the sector have lower steam flows and will levitate a correspondingly smaller percentage of the spray.

The calibration tests discussed in Section 5 are reproduced in Figure B-3, with the predictions of Figure B-2. The calibration data suggest that the actual droplet distribution includes a larger fraction of both small droplets (i.e., the diversion starts at slightly lower steam velocity than predicted) and large droplets. However, the discrepancies for higher steam velocities may be due to coalescence of the levitated drops rather than larger drops produced at the spray nozzles. Despite these minor deviations, the first-order analysis presented here provides a rather good description of the controlling phenomena, and indicates that a facility modification to include bypass steam injection would be required to obtain meaningful data at high steam flows for comparison with the prediction methodology. Such comparisons are not judged to be necessary for the methodology confirmation.

References

B-1 Mugele, R. A., Evans, H. D., "Droplet Size Distribution in Sprays" Industrial and Engineering Chemistry, Vol. 43, No. 6, Page 1317, June 1951.

B-2 Mugele, R. A., "Maximum Stable Droplets in Dispersoids", AIChE Journal, Vol. 6, No. 1, Page 3, March 1960.

B-3 Brodkey, R. S., "The Phenomena of Fluid Motions", Addison-Wesley Publishing Co., 1967, Page 584.

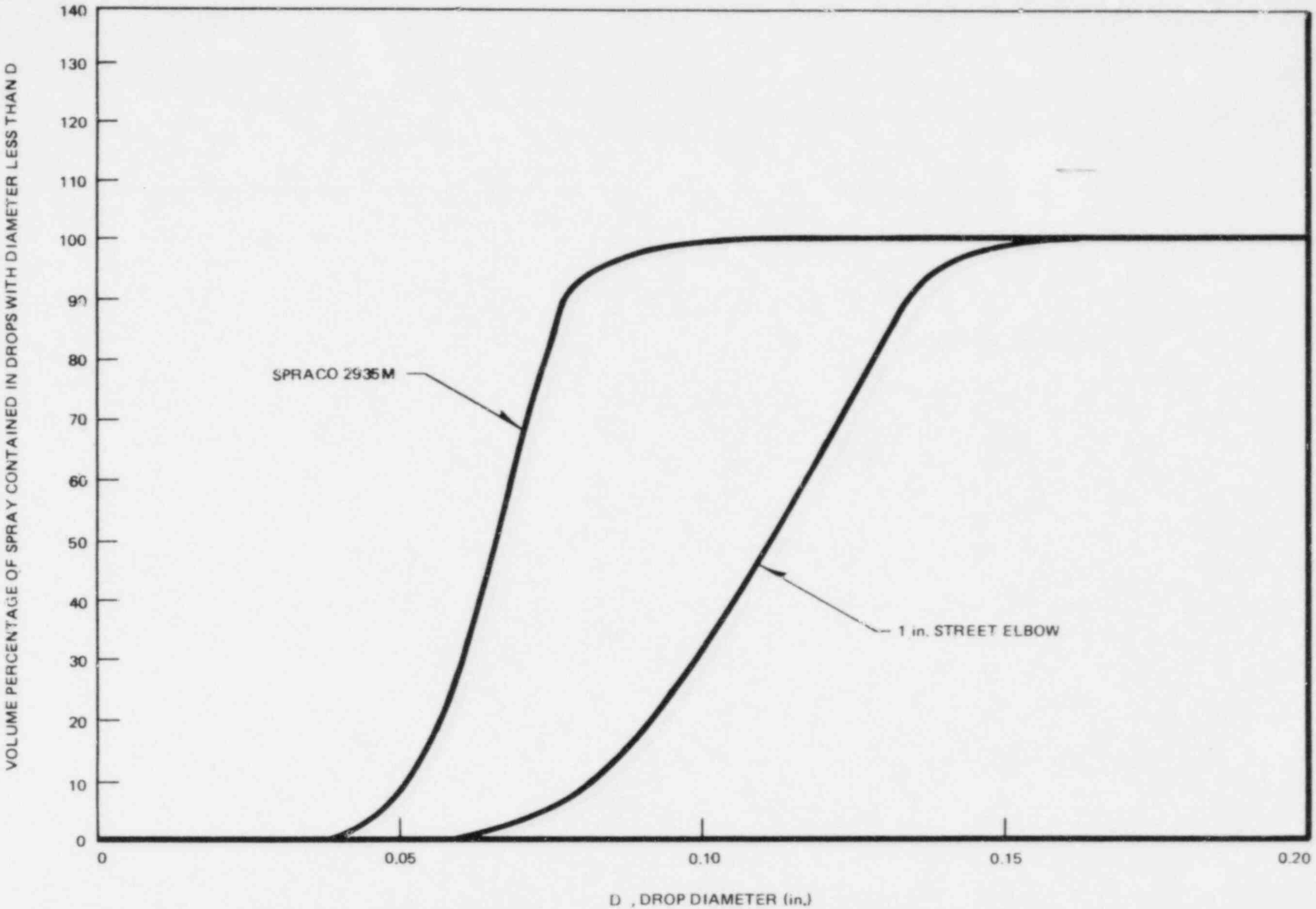

Figure B-1. Drop Size Distributions for Two Core Spray Nozzles Based on Mugele's Correlation

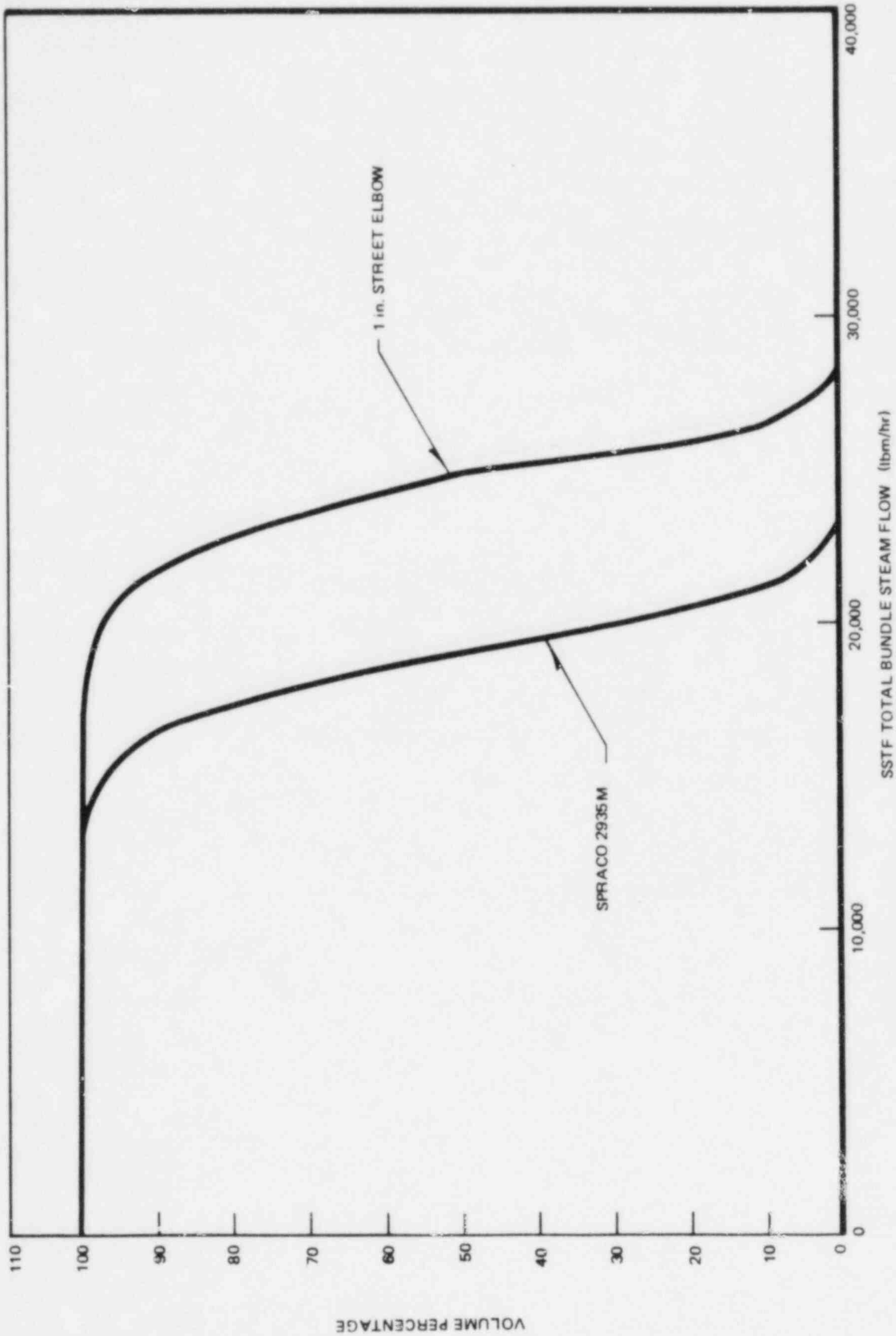

Figure B-2. Percentage of Spray Contained in Drops With Terminal Velocity Greater Than the Updraft Velocity Through the Upper Tie Plate

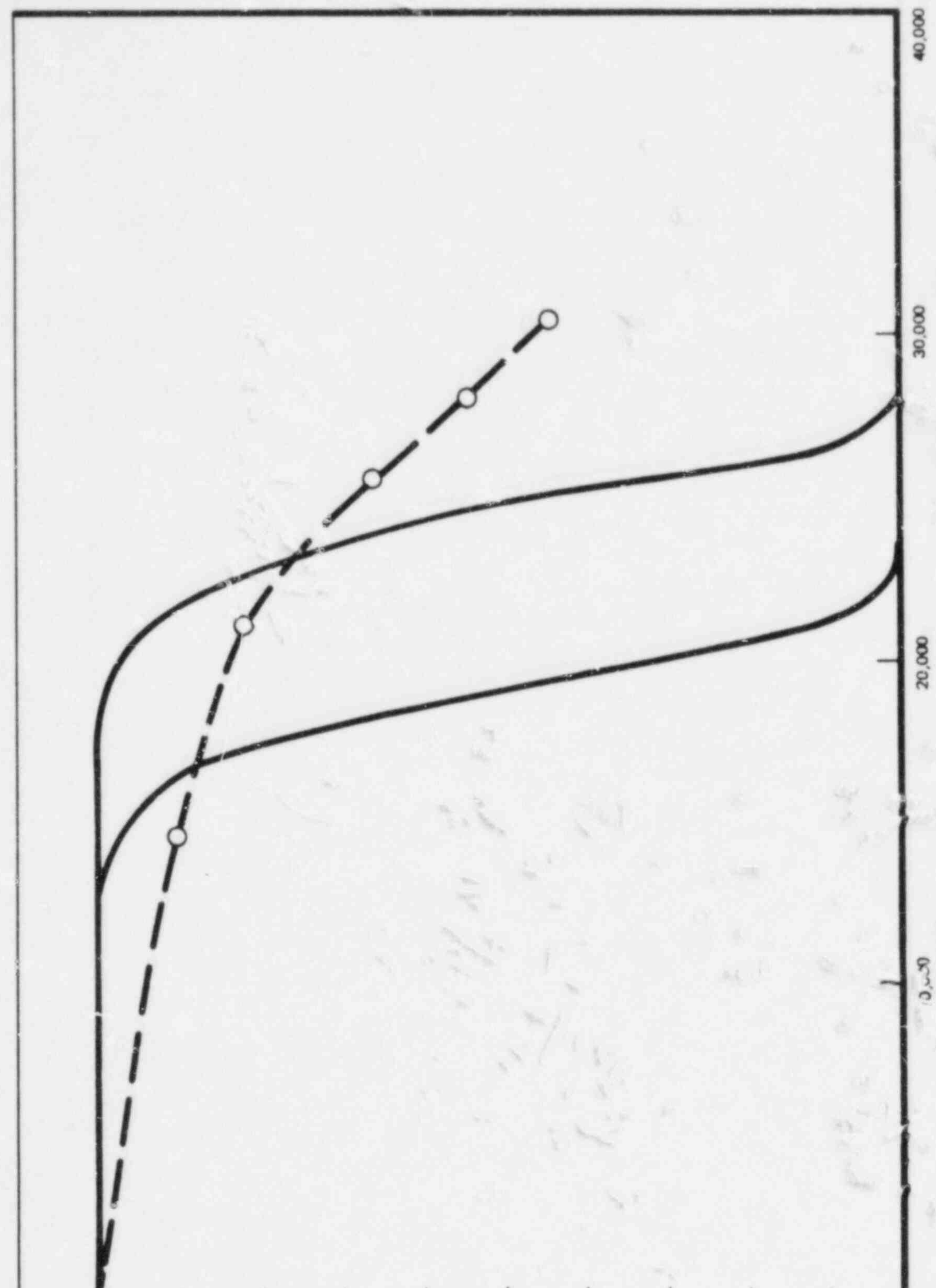

Figure B-3. Comparison of First-Order Prediction for Drop Diversion to Calibration Data from Section 5.

Appendix C

CORE FLOW MAPS FOR TEST RUNS

This Appendix contains core flow maps for all test runs listed in the test matrix. The individual bundle flow is shown for each position in units of gpm per bundle.

Figure	Run	Figure	Run
C-1	1-1	C-20	CS-27
C-2	1-1A	C-21	CS-28
C-3	1-2	C-22	CS-29
C-4	1-2A	C-23	CS-30
C-5	1-3	C-24	CS-31
C-6	1-3A	C-25	CS-33
C-7	3-1	C-26	CS-34A
C-8	3-2	C-27	CS-34B
C-9	CS-2A	C-28	CS-34C
C-10	CS-2B	C-29	CS-35
C-11	CS-2C	C-30	CS-36
C-12	CS-2D	C-31	CS-37
C-13	CS-2E	C-32	CS-38
C-14	CS-2F	C-33	CS-39
C-15	CS-3.1	C-34	CS-40
C-16	CS-3.2	C-35	CS-41
C-17	CS-22A	C-36	CS-44
C-18	CS-22B	C-37	CS-45
C-19	CS-22C		

LINE1= MEAN VALUE [GPM]
LINE2= MAXIMUM VALUE
LINE3= MINIMUM VALUE
LINE4= STD. DEVIATION

\\\\\-PARTIAL BUNDLES

* FLOW OUTSIDE OF INSTRUMENT RANGE

	1	2	3	4	5	6	7	8	9	10
1		4.9785	12.9618	14.2300	>20 GPM*	>20 GPM*	11.1435	8.6885	2.1448	
1		5.1567	13.3066	15.0987			11.5890	9.2991	2.4594	
1		4.7481	12.4505	13.7869			10.8088	8.1405	2.0071	
1		.1016	.2415	.3025			.2226	.3372	.1257	
2		3.3645	16.0834	10.8924	13.1171	15.3718	11.5560	14.8240	1.5888	
2		3.5954	17.5242	11.7172	13.7811	16.0976	12.4012	15.5040	1.7669	
2		3.1754	15.2850	10.4110	12.6971	14.5943	10.8074	14.6[illegible]5	1.4215	
2		.1130	.6201	.3325	.2932	.4383	.3909	.4319	.0784	
3			6.6382	5.5003	3.1749	5.1446	6.2757	3.8958		
3			7.0518	5.7698	3.3342	5.3457	6.6168	4.0549		
3			6.4597	5.2688	3.0201	4.8912	5.9916	3.8112		
3			.1364	.1172	.0874	.1221	.1639	.0683		
4			10.4088	8.2259	1.9761	5.5086	6.3252	6.9738		
4			10.8526	8.6071	2.0683	6.0446	6.6557	7.1624		
4			10.1079	7.9665	1.8496	5.1924	5.9149	6.7986		
4			.1833	.1828	.0476	.2081	.2057	.1920		
5			10.0792	9.4097	2.8138	5.4066	5.5998	7.0582		
5			10.3679	9.7922	2.9895	5.7318	5.8379	7.5697		
5			9.6364	8.9805	2.7201	5.2304	5.2672	6.6381		
5			.2114	.2635	.0701	.1177	.1504	.2084		
6				5.8811	4.5457	4.2859	4.4721			
6				7.2520	4.8546	4.7118	4.7795			
6				4.9320	4.3402	3.7625	4.2685			
6				.5525	.1266	.2426	.1209			
7				3.1115	2.8087	3.1737	4.8804			
7				3.2068	2.9915	3.5289	5.1553			
7				2.9890	2.6891	2.8683	4.7058			
7				.0612	.0862	.1728	.0968			
8				4.4080	3.6528	2.5952	3.6899			
8				4.8218	5.8111	2.9635	4.0207			
8				3.9027	3.3092	2.2829	3.2767			
8				.2167	.1276	.2148	.1680			
9				4.5219	5.1652	3.2584	2.3181			
9				4.8583	5.4215	3.4965	2.5448			
9				4.1405	4.8543	2.9587	2.1068			
9				.2172	.1802	.1561	.0769			
10					8.0250	5.4144				
10					8.6322	5.6529				
10					7.6538	5.1552				
10					.2453	.1847				
11					10.5[illegible]	5.0775				
11					10.85[illegible]	5.1555				
11					10.0644	4.9659				
11					.2037	.0595				
12					8.3684	4.6526				
12					9.2132	4.9661				
12					7.7340	3.9847				
12					.4323	.2634				
13					3.2561	1.7610				
13					3.7625	1.9334				
13					2.7788	1.5878				
13					.2910	.1046				
14										
14										
14										
14										

Figure C-1. Core Flow Map; Run 1-1

LINE1= MEAN VALUE [GPM]
LINE2= MAXIMUM VALUE
LINE3= MINIMUM VALUE
LINE4= STD. DEVIATION

\\\\\\-PARTIAL BUNDLES

* FLOW OUTSIDE OF INSTRUMENT RANGE

	1	2	3	4	5	6	7	8	9	10
1		5.0467 5.2185 4.8489 .0886	13.0394 14.5810 11.7812 .7280	13.9818 14.4123 13.4115 .3298	>20 GPM *	>20 GPM *	10.8346 11.7795 10.5055 .3417	8.0900 8.7678 7.6693 .3030	2.6198 2.8882 2.3686 .1594	
2		4.0055 4.4873 3.5924 .2721	15.8805 17.0277 15.2061 .5138	10.8242 11.6268 10.3276 .3268	13.4130 14.1435 12.4981 .5151	15.5826 16.0087 15.0208 .3075	11.6392 12.6967 10.6837 .7100	14.3934 14.9643 13.7725 .3285	1.7972 1.8826 1.7192 .0500	
3			6.1071 6.6739 5.8228 .2304	5.4521 5.7341 5.3506 .0827	3.2072 3.3646 3.0199 .0888	5.1461 5.3894 4.7882 .1383	6.6237 6.8537 6.4024 .1379	3.9836 4.2101 3.7579 .1184		
4			10.2594 10.5455 9.9832 .1799	8.4744 9.1150 8.1405 .2572	2.0940 2.1996 1.9982 .0506	5.8815 6.2009 5.6567 .1776	6.4931 6.6763 6.2466 .1213	7.0919 7.2356 6.8749 .1141		
5			10.2568 10.8982 9.6484 .3860	9.8963 10.4633 9.4248 .4004	3.4732 3.7252 3.2058 .1193	5.8484 6.0449 5.3883 .1497	5.4861 5.8611 5.2930 .1636	7.3182 7.5195 7.0336 .1192		
6				6.0100 6.2853 5.6702 .1946	4.6833 5.0867 4.4599 .1683	4.2737 4.7034 3.9281 .2287	4.6204 4.8256 4.3519 .1319			
7				3.1397 3.6920 2.6928 .2899	2.6213 2.7982 2.4795 .0726	2.7757 3.0199 2.6069 .1176	4.7099 4.8632 4.4965 .0948			
8				4.3266 4.5233 4.1695 .0973	3.4940 3.6571 3.2943 .1223	2.5617 2.9611 2.2293 .1846	3.3302 3.5566 3.1349 .1235			
9				4.6834 4.9224 4.4517 .1395	5.1647 5.5035 4.7889 .1984	3.4320 3.5924 3.3008 .0839	2.2227 2.3690 2.0787 .0758			
10					8.3905 8.7260 8.0729 .1411	5.3844 5.5422 4.9744 .1527				
11					10.5799 10.8975 10.3710 .1079	5.1612 5.7345 4.6413 .2207				
12					8.1524 8.7671 7.7495 .2433	4.8374 5.1245 4.7918 .2748				
13					3.2210 3.5597 2.9288 .1596	1.7084 1.8580 1.4826 .0913				
14										

Figure C-2. Core Flow Map; Run 1-1A

LINE1= MEAN VALUE [GPM]
LINE2= MAXIMUM VALUE
LINE3= MINIMUM VALUE
LINE4= STD. DEVIATION

\\\\\\-PARTIAL BUNDLES   * FLOW OUTSIDE OF INSTRUMENT RANGE

	1	2	3	4	5	6	7	8	9	10
1		8.2160	>20 GPM*	>20 GPM*	16.6230	>20 GPM*	>20 GPM*	16.3605	.2868	
1		8.8649			17.3417			17.2878	.3891	
1		7.7777			16.1319			15.5690	.2618	
1		.3207			.3073			.5539	.0175	
2		2.9938	8.7147	9.1258	9.5894	6.8105	6.5980	7.5659	1.0945	
2		3.4084	9.4551	9.5146	9.7120	7.0562	7.2076	7.7788	1.1780	
2		2.7217	8.1082	8.7184	9.4959	6.5402	5.9687	7.3346	1.0273	
2		.2146	.3227	.2002	.0739	.1459	.3440	.1109	.0386	
3			7.6236	7.0299	2.9504	5.7142	6.3689	3.5979		
3			8.2266	7.4526	3.0522	6.0883	6.7772	3.8153		
3			7.6559	6.7626	2.8395	5.4636	5.6872	3.3118		
3			.3867	.2143	.0512	.1556	.3155	.1595		
4			7.5609	9.6164	2.6314	5.1908	4.9538	5.8736		
4			7.9808	10.0384	2.7221	5.3504	5.1575	6.1275		
4			7.6156	9.4093	2.5494	5.0826	4.6781	5.5407		
4			.2491	.1281	.0536	.0776	.1377	.1602		
5			7.9164	10.3268	4.1325	6.3220	4.5608	6.4346		
5			8.4393	10.5470	4.3545	6.5229	4.8613	6.6427		
5			7.4956	10.0604	3.9687	6.1661	4.3183	6.2443		
5			.2445	.1241	.1180	.1042	.1438	.0911		
6				8.3550	7.8429	4.9991	5.2387			
6				9.0094	8.0661	5.3831	5.6194			
6				7.7788	7.6137	4.7138	5.0828			
6				.3444	.1135	.1965	.1237			
7				7.1131	8.0514	5.0755	5.2475			
7				7.4155	8.2732	5.2325	5.5021			
7				6.7774	7.8186	4.8973	5.0077			
7				.1817	.1123	.0840	.1233			
8				8.2982	8.5423	4.9455	4.8583			
8				8.7598	8.9452	5.5283	5.0823			
8				7.8998	8.1915	4.5300	4.6251			
8				.2585	.1917	.2748	.1080			
9				5.2783	7.3198	4.1159	2.1501			
9				5.9173	7.7384	4.3538	2.2690			
9				4.4409	6.7630	3.6965	1.9841			
9				.3498	.2899	.1977	.0664			
10					5.9365	3.3158				
10					6.8169	3.5434				
10					5.3068	3.1190				
10					.3795	.1040				
11					3.1[illegible]	1.7000				
11					3.6306	1.8387				
11					2.8398	1.5674				
11					.1836	.0611				
12					1.6169	.7400				
12					2.1436	.8197				
12					1.2816	.6826				
12					.2478	.0432				
13					.4164	.3284				
13					.4998	.3501				
13					.3092	.2841				
13					.0370	.0162				
14										
14										
14										
14										

Figure C-3. Core Flow Map; Run 1-2

LINE1= MEAN VALUE [GPM]
LINE2= MAXIMUM VALUE
LINE3= MINIMUM VALUE
LINE4= STD. DEVIATION

\\\\\\-PARTIAL BUNDLES

* FLOW OUTSIDE OF INSTRUMENT RANGE

	1	2	3	4	5	6	7	8	9	10
1		7.9458 8.3993 7.6301 .2221	>20 GPM	>20 GPM	16.0230 16.9682 15.2673 .4635	>20 GPM	>20 GPM	15.8895 17.3746 14.5782 .6671	.3014 .3451 .2796 .0172	
2		8.0323 8.4620 7.7809 .1810	8.6004 9.0051 8.0917 .2410	8.0836 8.5220 7.6706 .2725	9.8908 10.1587 9.5546 .1786	6.7551 6.9532 6.4810 .1531	6.0727 6.8367 5.5051 .3477	7.3437 7.6304 7.0715 .1419	1.0619 1.1282 .9982 .0406	
3			7.8241 8.1148 7.4706 .1870	6.3763 6.5181 6.1633 .0970	2.9217 3.0513 2.8101 .0759	6.1072 6.5979 5.7744 .2247	6.6885 7.3500 6.2863 .2593	3.5893 3.7936 3.2312 .1345		
4			8.0297 8.3567 7.6304 .2092	9.4913 9.8082 9.3069 .1253	2.7845 3.0206 2.5510 .1337	5.2806 5.6200 5.0876 .1436	5.1118 5.4066 4.9598 .1155	5.5603 5.8907 5.4663 .1060		
5			8.3964 9.0996 7.7108 .4564	10.2961 10.6425 9.9407 .1882	4.7517 5.1077 4.5240 .1750	6.2367 6.4395 6.0462 .1261	4.6347 4.7765 4.4881 .0882	6.1699 6.3995 6.0068 .1061		
6				8.0430 8.7685 7.7103 .2828	8.5406 9.1306 8.2145 .2752	5.0548 6.0157 4.5596 .4110	5.1213 5.3148 4.9012 .1259			
7				7.1651 7.3901 6.7953 .1542	8.1018 8.4215 7.7637 .1972	4.5399 4.8133 4.4168 .1092	5.1629 5.3528 4.9754 .1105			
8				8.0664 8.6041 7.7912 .2170	8.8239 9.2588 8.5451 .2050	4.9425 5.0842 4.6295 .1207	4.5539 4.9611 4.4254 .1175			
9				4.9891 5.1820 4.6670 .1409	7.1910 7.7230 6.4788 .3023	3.9121 4.0662 3.7928 .0778	1.9697 2.0543 1.8586 .0545			
10					5.6497 6.2067 5.2191 .2873	3.0793 3.3931 2.8899 [illegible]				
11					2.7087 3.1752 2.3853 .2110	1.4592 1.6529 1.2879 .1173				
12					1.0844 1.2734 .9742 .0675	.5871 .6443 .5181 .0335				
13					.3647 .4740 .3036 .0567	.2814 .3343 .2110 .0350				
14										

Figure C-4. Core Flow Map; Run 1-2A

LINE1= MEAN VALUE [GPM]
LINE2= MAXIMUM VALUE
LINE3= MINIMUM VALUE
LINE4= STD. DEVIATION

\\\\\ - PARTIAL BUNDLES

* FLOW OUTSIDE OF INSTRUMENT RANGE

	1	2	3	4	5	6	7	8	9	10
1		17.6721 19.5477 16.7466 .6765	>20 GPM*	>20 GPM*	>20 GPM*	>20 GPM*	>20 GPM*	>20 GPM*	1.0627 1.1983 .9818 .0566	
2		5.1369 5.7725 4.7212 .2892	18.7249 21.0316 17.8414 .7853	14.0087 15.2983 13.6901 .4872	14.6630 15.5680 14.1374 .3966	14.6942 15.7085 13.8641 .5716	13.2157 14.1429 12.5358 .4191	18.1113 19.5483 17.5085 .4780	1.4384 1.6143 1.3468 .0531	
3			10.5506 16.9595 9.6531 .3116	>20 GPM*	9.4690 9.9536 8.9803 .2400	17.4760 18.3823 16.4169 .4901	17.6916 18.5039 15.9983 .4162	5.1192 5.3624 4.9430 .1197		
4			>20 GPM*	>20 GPM*	13.6536 14.5146 13.2925 .3089	18.0308 19.5018 15.9185 .7905	16.8458 18.0371 16.0093 .5323	>20 GPM*		
5			15.9336 16.9995 14.6795 .5286	13.3191 14.5256 12.4314 .5569	9.1300 9.5680 8.7298 .2426	9.1009 9.6888 8.3330 .3842	10.7455 12.8917 9.3977 .8236	>20 GPM*		
6				7.3347 8.2365 6.4707 .5836	10.5820 11.1990 9.4278 .4830	4.0957 5.1550 3.5030 .4867	6.6756 6.9394 6.5358 .1171			
7				10.1776 10.7369 9.5680 .3764	14.2034 15.3834 13.0844 .5209	6.7498 8.1948 6.0416 .5461	5.9188 6.3363 5.3618 .2453			
8				16.4835 18.0346 15.2983 .6894	>20 GPM*	10.9117 11.5253 10.3113 .3197	6.1741 6.4177 5.8640 .1424			
9				8.5394 9.1524 7.8281 .6556	12.8550 13.3925 12.0423 .3270	9.4180 10.9155 8.6891 .5780	3.3206 3.6529 2.9692 .1782			
10					5.9729 7.2249 4.7565 .5834	4.8411 5.4367 4.2105 .3233				
11					1.40 1.5852 1.2155 .1077	.9380 1.1284 .8213 .0787				
12					.2249 .2825 .1600 .0176	.2930 .3833 .2166 .0387				
13					.0129 .0448 -.0413 .0205	.2221 .2850 .1446 .0312				
14										

Figure C-5. Core Flow Map; Run 1-3

LINE1= MEAN VALUE [GPM]
LINE2= MAXIMUM VALUE
LINE3= MINIMUM VALUE
LINE4= STD. DEVIATION

\\\\\-PARTIAL BUNDLES   * FLOW OUTSIDE OF INSTRUMENT RANGE

	1	2	3	4	5	6	7	8	9	10
1		16.5606							1.0569	
1		17.1675	>20 GPM*	>20 GPM*	>20 GPM*	>20 GPM*	>20 GPM*	>20 GPM*	1.1457	
1		15.7191							.9831	
1		.4194							.0424	
2		5.3164		13.4683	15.4373	14.2145	13.1710	18.3866	1.3953	
2		5.7490	>20 GPM*	14.2011	16.5985	14.8584	14.3179	20.0249	1.5461	
2		4.9977		13.0122	14.2602	13.7264	12.5065	17.7029	1.2886	
2		.1904		.3034	.6919	.3328	.4765	.6211	.0676	
3			9.5796	18.5573	8.5610	16.8378	17.2627	5.1386		
3			10.1164	19.6142	8.7711	17.4938	17.8344	5.4309		
3			8.8943	17.8896	8.1574	16.0458	16.9986	4.9040		
3			.3708	.4459	.1461	.3838	.2167	.1230		
4					13.6791	17.1676	16.4082			
4			>20 GPM*	>20 GPM*	14.2020	17.9586	17.3165	>20 GPM*		
4					13.2645	16.5361	15.6597			
4					.2575	.4153	.5521			
5			15.7309	14.5759	10.0478	8.5677	12.3168			
5			16.5626	16.0428	10.5054	8.9660	12.8140	>20 GPM*		
5			15.8311	13.5154	9.5202	8.2180	11.9035			
5			.7633	.7878	.2766	.1678	.3036			
6				6.6545	9.8716	3.9260	6.3623			
6				7.2323	10.5566	4.1716	6.6004			
6				6.0942	9.4730	3.6269	6.0874			
6				.2734	.3014	.1555	.1540			
7				8.8546	13.0072	6.3814	5.5752			
7				9.1025	13.8845	6.6398	5.8931			
7				8.4426	12.4093	6.0175	5.2405			
7				.1567	.4127	.1726	.1569			
8				15.6438	19.2256	10.4171	5.7480			
8				16.4995	20.5483	10.8558	6.1663			
8				14.7481	18.1583	9.8250	5.5928			
8				.4663	.6586	.2532	.1709			
9				8.2133	13.1186	9.3515	3.3635			
9				9.1859	14.4822	11.9971	4.1422			
9				7.6323	12.3598	8.6472	2.9510			
9				.4084	.6564	.8637	.2987			
10					8.6060	7.1050				
10					10.0297	8.6736				
10					7.5923	6.5457				
10					.6006	.6363				
11					3.4375	2.8375				
11					4.6591	3.1066				
11					2.8110	1.5254				
11					.5190	.5008				
12					1.0694	.9832				
12					1.5257	1.5806				
12					.7911	.5740				
12					.2118	.2896				
13					.4248	.4717				
13					.6417	.8938				
13					.2600	.2234				
13					.1103	.1970				
14										
14										
14										
14										

Figure C-6. Core Flow Map; Run 1-3A

LINE1= MEAN VALUE [GPM]
LINE2= MAXIMUM VALUE
LINE3= MINIMUM VALUE
LINE4= STD. DEVIATION

\\\\\-PARTIAL BUNDLES

* FLOW OUTSIDE OF INSTRUMENT RANGE

	1	2	3	4	5	6	7	8	9	10
1		3.5297	>20 GPM*	16.?334	>20 GPM*	>20 GPM*	13.5741	12.5906	2.8222	
1		6.0526		17.?319			14.2131	13.5077	2.9285	
1		5.2262		15.2465			12.9667	11.9364	2.1911	
1		.1943		.5939			.3142	.3789	.1903	
2		3.1681	16.5189	9.6514	10.8277	13.9122	10.7839	14.0390	1.3456	
2		3.4443	18.1906	10.1746	11.2767	14.9541	11.3691	14.5508	1.7348	
2		2.8956	15.4419	9.2509	10.3458	13.1890	10.3445	13.4024	1.4250	
2		.1358	.8423	.2299	.2699	.4638	.2780	.2881	.0780	
3			8.6795	7.5316	4.6156	6.9744	7.8204	5.0038		
3			9.3383	7.8320	4.9574	7.3862	8.1447	5.2263		
3			8.1433	7.3861	4.2864	6.6393	7.5585	4.8335		
3			.3372	.1206	.1917	.2002	.1507	.0938		
4			>20 GPM*	9.7063	4.6377	8.5714	9.1856	9.9100		
4				10.1033	5.0348	9.2734	9.6004	10.1675		
4				9.2557	4.4690	7.8501	8.7793	9.6696		
4				.2419	.1058	.3560	.2573	.1386		
5			14.5088	4.9211	5.7448	7.3291	8.3036	7.9410		
5			15.9067	5.1103	6.0118	7.5985	8.7363	8.1918		
5			13.8287	4.6479	5.3805	6.9686	7.8499	7.7230		
5			.3363	.1272	.1531	.1979	.2047	.1359		
6				1.6118	4.2973	2.8251	4.4146			
6				1.7028	4.6101	3.0529	4.7237			
6				1.4846	4.0331	2.5938	4.1627			
6				.0554	.1478	.1212	.1341			
7				2.1936	4.0485	2.6704	2.5437			
7				2.3924	4.3099	2.7725	2.7414			
7				1.8928	3.8386	2.5352	2.3866			
7				.1143	.1429	.0685	.0981			
8				4.9141	6.5213	3.7356	2.9100			
8				5.2262	7.0102	4.1047	3.0884			
8				4.6552	6.2692	3.5595	2.6798			
8				.1605	.1850	.1340	.1015			
9				4.8660	8.4611	4.3520	2.3776			
9				5.1111	8.8809	4.8446	2.6502			
9				4.5437	7.8923	3.9266	2.1373			
9				.1389	.2616	.2836	.1497			
10					9.4844	5.8607				
10					9.9065	6.1872				
10					8.8658	5.5433				
10					.2823	.1791				
11					[illegible]	4.0041				
11					[illegible]	4.3165				
11					6.8995	3.6971				
11					.3191	.1332				
12					2.5161	2.1707				
12					2.7421	2.4726				
12					2.2003	1.8553				
12					.1194	.1864				
13					.6794	.6253				
13					.8119	.6806				
13					.5406	.5713				
13					.0670	.6245				
14										
14										
14										
14										

Figure C-7. Core Flow Map; Run 3-1

LINE1= MEAN VALUE [GPM]
LINE2= MAXIMUM VALUE
LINE3= MINIMUM VALUE
LINE4= STD. DEVIATION

\\\\\-PARTIAL BUNDLES * FLOW OUTSIDE OF INSTRUMENT RANGE

	1	2	3	4	5	6	7	8	9	10
1		10.1280 10.8116 9.3439 .4161	>20GPM*	>20GPM*	18.1918 19.3520 17.3114 .6135	>20GPM*	>20GPM*	18.8829 20.0637 17.3263 .7844	.5110 .5640 .4945 .0163	
2		2.4531 2.6546 2.1486 .1462	6.7069 7.5178 6.1115 .2787	6.4400 7.3151 5.6975 .4018	9.3561 9.6344 8.9733 .1577	6.6764 7.0687 6.4161 .1542	4.2900 4.7662 3.9492 .2034	6.5236 6.8220 6.2558 .1463	1.0885 1.2109 1.0194 .0417	
3			11.5062 11.9401 10.9950 .2371	8.2793 9.1489 7.6443 .3822	6.2029 7.3146 5.6193 .3838	9.4471 10.3517 8.6709 .5216	9.1505 9.4308 8.8260 .1418	5.9072 6.2328 5.7080 .1362		
4			18.5274 19.8391 17.5952 .4687	12.6326 13.6056 11.0598 .7247	7.6617 8.0649 7.1917 .2761	8.0632 8.5842 7.6451 .2834	8.6556 8.9977 8.3600 .1485	7.5129 7.7302 7.3091 .1038		
5			15.7855 16.4894 15.3139 .3077	9.8045 10.3998 9.3234 .2779	10.1018 10.8569 9.5610 .3206	6.1456 6.5194 5.7086 .1310	7.9283 8.2329 7.6886 .1461	7.9858 8.2396 7.6456 .1550		
6				7.5608 8.0227 6.9458 .2891	10.2323 10.7656 9.5444 .3584	4.0299 4.2163 3.8242 .1183	7.4610 7.7731 7.0992 .1892			
7				5.0527 5.4621 4.6581 .2015	8.1554 9.1494 7.6448 .3908	5.8335 6.0547 5.5013 .1425	4.9646 5.1538 4.6516 .1527			
8				2.9367 3.6851 2.6243 .2054	6.3895 7.0578 5.9889 .3087	5.3674 5.5941 5.1929 .0945	2.7653 3.0913 2.5628 .1282			
9				1.0231 1.1572 .8985 .0701	2.8079 3.2550 2.6224 .1746	2.9274 3.3137 2.6841 .1855	1.1556 1.2110 1.0526 .0506			
10					1.1666 1.4431 1.0881 .0853	.9511 1.0196 .8791 .0385				
11					[illegible] [illegible] .2708 .0201	.2432 .2811 .1864 .0169				
12					.0043 .0324 -.0267 .0141	.1111 .1360 .0551 .0195				
13					-.0640 -.0421 -.1069 .0158	.0776 .1090 -.0033 .0273				
14										

Figure C-8. Core Flow Map; Run 3-2

LINE1= MEAN VALUE [GPM]
LINE2= MAXIMUM VALUE
LINE3= MINIMUM VALUE
LINE4= STD. DEVIATION

\\\\\\-PARTIAL BUNDLES

* FLOW OUTSIDE OF INSTRUMENT RANGE

	1	2	3	4	5	6	7	8	9	10
1		5.2122	9.7384	13.1108	16.8468	18.0658	8.8601	6.6065	1.8949	
1		5.3687	10.1468	13.6003	17.4135	18.8173	9.3798	6.8250	2.1134	
1		5.0684	9.3442	12.7125	16.0403	17.4178	8.4418	6.4406	1.8107	
1		.0806	.2038	.2599	.3630	.4801	.2460	.1047	.0676	
2		4.1970	14.1877	14.1222	17.0199	17.9639	12.7646	12.3341	1.8777	
2		4.3425	15.0296	15.0603	17.8729	18.6384	14.2655	12.7408	2.0046	
2		4.0947	12.6929	13.3228	16.4822	17.3725	11.8003	11.9043	1.8066	
2		.0733	.6002	.3945	.3779	.3495	.6405	.2221	.0439	
3			6.6647	5.9868	3.1340	5.2217	6.5713	4.9036		
3			6.9124	6.1870	3.2918	5.4247	6.7991	5.3112		
3			6.4913	5.6892	3.0035	5.0074	6.3782	4.5651		
3			.0847	.1064	.0730	.0657	.1027	.1826		
4			7.3678	6.4697	2.2511	5.0721	5.1884	6.4833		
4			7.5995	6.6624	2.3860	5.2006	5.4193	6.5769		
4			7.2129	6.2739	2.1425	4.8622	5.0099	6.3060		
4			.0767	.1119	.0589	.0723	.1083	.0693		
5			5.8462	7.0375	2.7757	4.2304	3.7543	6.7121		
5			5.9700	7.1667	3.0152	4.3677	3.8667	6.8544		
5			5.7045	6.8522	2.6805	4.1158	3.6274	6.5432		
5			.0598	.1062	.0705	.0681	.0521	.0873		
6				4.9305	3.8336	3.4038	3.1995			
6				5.0787	3.9864	3.4931	3.3352			
6				4.7466	3.6728	3.2623	3.0729			
6				.0965	.0832	.0565	.0642			
7				4.6847	2.7720	3.7243	3.9115			
7				4.9064	2.8603	3.8319	4.0347			
7				4.4322	2.6472	3.5927	3.7876			
7				.1172	.0524	.0563	.0613			
8				4.0056	3.1360	3.6653	4.2351			
8				4.1843	3.2634	3.7570	4.4257			
8				3.8290	3.0049	3.4865	4.0290			
8				.0704	.0563	.0736	.0847			
9				2.6212	2.6619	2.7458	2.1698			
9				2.7349	2.8202	2.8138	2.2969			
9				2.5286	2.5491	2.6344	2.0555			
9				.0495	.0649	.0481	.0676			
10					3.2979	3.2242				
10					3.4801	3.3843				
10					3.1206	3.0887				
10					.0901	.0793				
11					5.4142	3.7532				
11					5.6747	3.8653				
11					5.1125	3.5874				
11					.1496	.0785				
12					7.7212	5.4326				
12					7.9199	5.5596				
12					7.3356	5.2026				
12					.1385	.1100				
13					8.5084	4.8492				
13					8.8519	5.1094				
13					8.0211	4.5560				
13					.2091	.1359				
14										
14										
14										
14										

Figure C-9. Core Flow Map; Run CS-2A

LINE1= MEAN VALUE [GPM]
LINE2= MAXIMUM VALUE
LINE3= MINIMUM VALUE
LINE4= STD. DEVIATION

\\\\\\-PARTIAL BUNDLES * FLOW OUTSIDE OF INSTRUMENT RANGE

	1	2	3	4	5	6	7	8	9	10
1		5.0898 5.2396 4.9628 .0646	9.0937 9.5628 8.6620 .2395	12.0926 12.3313 11.8940 .1432	16.2264 17.6709 15.8524 .4171	16.6959 17.1065 16.2697 .2449	8.2087 8.4546 7.8568 .2017	6.1938 6.3866 5.9292 .1205	2.0326 2.2931 1.8598 .1165	
2		3.6891 3.8044 3.6000 .0565	12.[illegible]665 13.[illegible]805 12.[illegible]946 .4114	14.5923 15.5563 14.1549 .3779	18.3676 19.2221 17.6658 .3939	16.6395 17.5815 16.1640 .4019	11.8698 12.7986 10.9702 .4763	12.2090 13.0647 11.8715 .2870	1.8951 2.0993 1.7748 .0778	
3			6.5126 6.7624 6.[illegible]822 .1041	6.1423 6.2807 5.9729 .0673	2.8984 3.0573 2.8097 .0611	5.1710 5.3646 4.9890 .0966	6.2836 6.4747 6.1318 .1034	5.0400 5.3292 4.7673 .1488		
4			7.4442 7.6261 7.2716 .0958	5.8938 6.0197 5.7120 .0754	2.2844 2.4065 2.1621 .0489	4.3721 4.5113 4.2574 .0691	5.0516 5.1799 4.8850 .0847	6.2347 6.3978 6.0562 .0932		
5			5.1091 5.2396 5.0164 .0602	6.1649 6.2475 6.0151 .0724	2.7636 2.8828 2.6132 .0657	3.8893 4.0983 3.7815 .0886	3.5899 3.7177 3.4823 .0561	6.6329 6.7525 6.4423 .0756		
6				3.8944 3.9835 3.7764 .0473	3.9053 4.0759 3.7942 .0695	3.0972 3.2518 2.9662 .0657	2.9602 3.0277 2.8702 .0482			
7				3.6987 3.7871 3.6162 .0402	2.7669 2.8790 2.6648 .0506	3.0799 3.1877 2.9349 .0618	3.1164 3.2319 3.0060 .0676			
8				3.8516 3.9466 3.7400 .0499	2.7192 2.8042 2.6527 .0353	2.9249 3.0533 2.8359 .0622	3.3131 3.6001 3.3599 .0699			
9				2.4176 2.5495 2.2692 .0623	2.3987 2.6264 2.2272 .1014	2.3330 2.4528 2.2320 .0582	2.1080 2.2049 2.0201 .0455			
10					2.7709 2.8925 2.6512 .0370	2.9482 3.1395 2.8240 .0338				
11					4.5876 4.7307 4.3331 .1066	3.0620 3.2058 2.8866 .1018				
12					6.8884 7.0864 6.6628 .1193	4.9471 5.1819 4.6243 .1394				
13					7.6427 7.8446 7.4169 .0957	4.5800 4.7159 4.4892 .0769				
14										

Figure C-10. Core Flow Map; Run CS-2B

LINE1= MEAN VALUE [GPM]
LINE2= MAXIMUM VALUE
LINE3= MINIMUM VALUE
LINE4= STD. DEVIATION

\\\\\-PARTIAL BUNDLES

* FLOW OUTSIDE OF INSTRUMENT RANGE

	1	2	3	4	5	6	7	8	9	10
1		4.7698	9.2791	11.1068	15.1588	17.2036	8.3057	6.4939	1.8612	
1		4.9468	9.7369	11.527[illegible]	15.6801	18.3075	8.6598	6.7720	2.0538	
1		4.6169	8.6272	10.6726	14.6511	15.4100	7.9825	6.2376	1.7571	
1		.0977	.3032	.2505	.3808	.4705	.1691	.1405	.0782	
2		3.2599	13.3490	13.3484	>20 GPM	16.1821	11.3512	12.8152	1.6241	
2		3.3791	14.2783	13.7759		17.2679	12.7561	13.3332	1.7296	
2		3.1430	12.5045	12.4227		15.1919	10.6645	12.1687	1.5289	
2		.0598	.5210	.3401		.5995	.6266	.3283	.0356	
3			6.1791	5.3759	3.3237	4.7468	5.6071	5.2127		
3			6.4384	5.6326	3.4810	4.9926	5.8710	5.4845		
3			5.8303	5.2522	3.1865	4.4033	5.3816	4.9563		
3			.1523	.0905	.0753	.1169	.1379	.1311		
4			6.8283	6.1202	1.7705	4.1145	5.1807	5.4573		
4			7.0436	6.3711	1.8607	4.1902	5.3322	5.6342		
4			6.5439	5.9461	1.7196	3.9758	5.0347	5.2932		
4			.1183	.1045	.0356	.0568	.0767	.0923		
5			4.8444	6.3914	1.7984	3.3811	2.9839	5.8569		
5			4.9833	6.6387	1.8897	3.4772	3.1901	5.9843		
5			4.7259	6.2120	1.7014	3.2446	2.8758	5.6782		
5			.0673	.1091	.0458	.0640	.0748	.0919		
6				4.5041	2.7103	2.8503	2.7992			
6				4.6278	2.8112	2.9995	2.9046			
6				4.3745	2.5700	2.7238	2.7198			
6				.0715	.0678	.0651	.0482			
7				3.9166	1.9423	2.8399	2.8737			
7				4.0326	2.0510	2.9062	2.9771			
7				3.7894	1.8500	2.7238	2.6994			
7				.0569	.0606	.0510	.0731			
8				3.8668	1.8912	2.3829	2.9968			
8				3.9490	1.9890	2.5704	3.1830			
8				3.7766	1.7453	2.0764	2.7868			
8				.0423	.0596	.1159	.0889			
9				2.2976	1.8287	1.5746	2.2348			
9				2.4090	1.8919	1.6892	2.3170			
9				2.1112	1.7242	1.4946	2.1002			
9				.0684	.0344	.0471	.0547			
10					2.3902	2.5258				
10					2.5075	2.7041				
10					2.2296	2.3543				
10					.0734	.1004				
11					4.0551	2.5852				
11					4.3364	2.6747				
11					3.8103	2.4401				
11					.1254	.0585				
12					6.6408	4.2943				
12					6.8596	4.4452				
12					6.3612	3.9079				
12					.1236	.1127				
13					7.1308	5.5293				
13					7.3025	5.7973				
13					6.5742	5.3100				
13					.1842	.0979				
14										
14										
14										
14										

Figure C-11. Core Flow Map; Run CS-2C

LINE1= MEAN VALUE [GPM]
LINE2= MAXIMUM VALUE
LINE3= MINIMUM VALUE
LINE4= STD. DEVIATION

\\\\\-PARTIAL BUNDLES

* FLOW OUTSIDE OF INSTRUMENT RANGE

	1	2	3	4	5	6	7	8	9	10
1		4.6060	9.4581	10.6287	14.4236	17.1566	8.2444	6.5901	1.8604	
1		4.7659	9.7855	11.2107	15.1412	17.6528	8.6276	6.9294	1.9334	
1		4.4042	9.0397	10.2879	13.8049	16.6747	7.9074	6.3930	1.7350	
1		.0811	.2212	.2228	.3192	.2597	.1934	.1545	.0522	
2		3.4257	14.5241	13.4234	>20GPM*	16.5008	10.8935	13.0102	1.6901	
2		3.6032	16.0406	14.1701		17.4723	12.1158	13.4997	1.8020	
2		3.3064	13.2374	12.8332		15.5643	10.1497	12.5192	1.6514	
2		.0705	.8034	.4087		.5947	.4703	.2828	.0536	
3			6.1867	5.1337	3.4227	4.7403	5.6158	5.2778		
3			6.4035	5.3716	3.5832	5.0719	5.7978	5.4892		
3			5.8711	4.9560	3.2534	4.5892	5.3848	5.0368		
3			.1131	.0976	.0828	.1244	.1110	.1190		
4			6.5632	6.0484	1.4772	3.8964	5.0667	5.1822		
4			6.7404	6.1440	1.6092	4.0868	5.2232	5.4111		
4			6.3957	5.9132	1.3821	3.6660	4.9268	4.9576		
4			.0934	.0637	.0638	.1041	.0715	.1018		
5			4.7154	6.2422	1.4757	2.9646	2.6553	5.6856		
5			4.8754	6.4110	1.5706	3.0846	2.7568	5.8363		
5			4.5472	6.1009	1.3861	2.8629	2.5496	5.4543		
5			.0877	.0983	.0416	.0609	.0572	.1122		
6				4.4796	2.1639	2.4188	2.5148			
6				4.6667	2.3705	2.5785	2.7225			
6				4.3059	2.0198	2.2958	2.2325			
6				.1018	.0967	.0783	.1176			
7				3.6312	1.7422	2.6307	2.6560			
7				3.7578	1.8041	2.7262	2.7622			
7				3.4550	1.6416	2.4633	2.5523			
7				.0834	.0377	.0798	.0497			
8				3.3369	1.3390	1.7339	2.6920			
8				3.5423	1.4606	1.8304	2.8516			
8				3.1172	1.2282	1.5812	2.5791			
8				.0938	.0737	.0598	.0729			
9				1.6646	1.3034	1.0369	1.7938			
9				1.7213	1.4421	1.0903	1.8730			
9				1.5665	1.1596	.9816	1.6838			
9				.0357	.0698	.0263	.0437			
10					1.8760	1.8736				
10					2.0478	1.9319				
10					1.7553	1.7855				
10					.0826	.0377				
11					3.5431	1.9739				
11					3.8136	2.1122				
11					3.3097	1.8093				
11					.1097	.0656				
12					3.3490	3.6884				
12					3.5315	3.9129				
12					3.1560	3.4298				
12					.1199	.1237				
13					6.7560	5.9981				
13					7.1158	6.2418				
13					6.4620	5.6260				
13					.1620	.1853				
14										
14										
14										
14										

Figure C-12. Core Flow Map; Run CS-2D

LINE1= MEAN VALUE [GPM]
LINE2= MAXIMUM VALUE
LINE3= MINIMUM VALUE
LINE4= STD. DEVIATION

\\\\\\-PARTIAL BUNDLES

* FLOW OUTSIDE OF INSTRUMENT RANGE

	1	2	3	4	5	6	7	8	9	10
1		4.5002 4.7695 4.2986 .0960	9.5307 9.9635 9.0461 .2553	10.3306 10.7719 9.8711 .2304	13.4968 14.0455 12.9063 .3163	17.0921 18.5281 15.6799 .7239	8.1838 8.5526 7.8339 .2005	6.4563 6.8192 6.2055 .1591	1.7851 1.9557 1.6677 .0578	
2		3.5504 3.6414 3.4405 .0519	15.4833 16.5670 13.7411 .7600	13.4731 14.2908 12.6383 .3742	>20 GPM*	16.6110 17.6811 15.5763 .5925	11.3958 13.3564 10.5936 .6967	12.7849 13.5620 12.3291 .3257	1.5426 1.6066 1.4479 .0546	
3			6.0741 6.4463 5.8378 .1626	4.3701 4.7013 4.0129 .1656	3.5469 3.7893 3.3208 .1127	4.8348 5.1892 4.5555 .1643	5.5680 5.8400 5.3504 .1295	5.0029 5.3431 4.8163 .1217		
4			6.4522 6.6285 6.2455 .0865	5.8801 6.1113 5.6494 .0956	1.0762 1.2155 .9581 .0657	3.5457 3.[illegible]74 3.[illegible]84 .1372	4.8584 5.1148 4.6746 .1087	4.8857 5.0305 4.7390 .0832		
5			4.5645 4.6966 4.4419 .0460	6.1536 6.4928 5.7620 .1923	1.0474 1.1498 .9905 .0421	2.6430 2.7437 2.5047 .0674	2.2348 2.5810 2.0598 .1232	5.5749 5.7632 5.4587 .0712		
6				4.4781 4.6699 4.2735 .1175	1.7761 1.8716 1.6366 .0746	1.8282 2.0085 1.7196 .0609	2.1079 2.2343 1.9968 .0692			
7				3.1239 3.2927 2.9119 .0861	1.5642 1.6885 1.4295 .0574	1.9559 2.0593 1.8124 .0570	2.4211 2.5555 2.2979 .0682			
8				2.6487 2.6883 2.5417 .0377	1.2383 1.3227 1.1586 .0357	.9938 1.0601 .9111 .0413	2.5169 2.7003 2.3507 .0894			
9				1.1143 1.1468 1.0657 .0190	.8790 1.0137 .8145 .0431	.6669 .6950 .6281 .0155	1.3839 1.4682 1.2716 .0514			
10					1.7677 1.8512 1.6655 .0511	1.5718 1.8112 1.3544 .1151				
11					2.8545 3.0868 2.6874 .0701	1.7738 1.8594 1.6710 .0483				
12					3.9387 4.0736 3.7278 .0877	3.7593 3.9849 3.5695 .1084				
13					6.3858 6.5819 6.1610 .1221	6.1165 6.5228 5.8487 .1849				
14										

Figure C-13. Core Flow Map; Run CS-2E

LINE1= MEAN VALUE [GPM]
LINE2= MAXIMUM VALUE
LINE3= MINIMUM VALUE
LINE4= STD. DEVIATION

\\\\\\-PARTIAL BUNDLES   * FLOW OUTSIDE OF INSTRUMENT RANGE

	1	2	3	4	5	6	7	8	9	10
1		5.0821 5.2216 4.9976 .0609	10.1423 10.6336 9.7301 .2113	13.2250 13.7733 12.6726 .2881	17.8360 18.5089 17.2282 .3269	19.1814 19.9697 18.5650 .3881	9.3991 9.8074 9.1383 .1462	6.8189 7.1378 6.6367 .1222	1.9667 2.1966 1.8367 .0835	
2		4.2451 4.3826 4.0620 .0624	14.5785 16.0940 13.6648 .5836	13.4654 13.7617 12.8605 .1864	15.5233 16.1863 14.5349 .3953	16.2558 17.1234 15.4837 .4152	12.7328 14.6300 11.6681 .6433	13.8894 14.3614 13.1085 .3314	1.7649 1.8817 1.7107 .0353	
3			6.6238 6.7638 6.4560 .0678	6.3251 6.4654 6.1931 .0623	3.2146 3.3595 3.1014 .0590	5.2342 5.3544 5.1260 .0581	6.4386 6.6130 6.3062 .0760	4.3566 4.5697 4.1698 .1068		
4			7.6109 7.7615 7.4881 .0664	7.2698 7.4142 7.1383 .0657	2.5886 2.6474 2.5016 .0418	5.5959 5.7779 5.4765 .0832	5.4893 5.6482 5.3859 .0707	6.6795 6.8174 6.5437 .0682		
5			6.4831 6.5842 6.2784 .0748	8.3930 8.5192 8.2002 .0723	3.2347 3.3406 3.0816 .0643	5.0336 5.1895 4.8886 .0784	4.7105 4.8353 4.5071 .0759	7.0411 7.2836 6.8610 .1073		
6				5.8774 6.0598 5.6812 .1000	4.1939 4.4596 3.9908 .1068	3.9301 4.0789 3.7655 .0679	4.0725 4.2067 3.9567 .0585			
7				4.3089 4.5441 4.1155 .1059	3.3747 3.5501 3.1820 .0852	3.8805 4.0438 3.7655 .0751	5.1246 5.2544 4.9900 .0628			
8				3.7601 3.8881 3.6189 .0600	2.9716 3.1368 2.7886 .0945	3.1231 3.2916 2.9414 .0849	4.4991 4.7249 4.3207 .1030			
9				3.1895 3.3017 3.0446 .0789	2.8616 2.9174 2.6707 .0588	2.7205 2.8166 2.5782 .0662	2.4706 2.6471 2.3554 .0873			
10					4.8968 5.1514 4.4199 .1742	3.9900 4.1881 3.7283 .1041				
11					8.0295 8.3794 7.7515 .1518	5.0440 5.2998 4.8105 .1153				
12					10.3413 10.7562 9.9867 .2206	6.5875 6.7092 6.2414 .1313				
13					8.6485 9.3027 7.9860 .2993	4.3137 4.5939 4.0663 .1456				
14										

Figure C-14. Core Flow Map; Run CS-2F

LINE1= MEAN VALUE [GPM]
LINE2= MAXIMUM VALUE
LINE3= MINIMUM VALUE
LINE4= STD. DEVIATION

\\\\\\-PARTIAL BUNDLES

* FLOW OUTSIDE OF INSTRUMENT RANGE

	1	2	3	4	5	6	7	8	9	10
1		8.6350 9.1740 8.3750 .2169	>20.*	>20.*	17.9828 19.1150 17.4100 .3157	>20.*	>20.*	16.4926 17.5536 15.7599 .5142	.3501 .4008 .3139 .0194	
2		8.2528 3.8200 2.8716 .2693	9.0549 9.7492 8.3539 .3281	10.2689 11.1403 9.5459 .3910	9.0004 9.3902 8.6108 .2094	6.8909 7.3549 6.6195 .1745	6.8672 7.7995 5.9999 .4605	7.4528 7.9010 7.0425 .1891	1.1849 1.2702 1.1157 .0581	
3			7.7037 8.5212 6.7268 .4970	6.3821 7.0455 5.8446 .3618	2.7366 2.8531 2.6132 .0688	4.9946 5.3893 4.6386 .1699	6.2627 7.0360 5.5105 .4366	3.9603 4.6020 3.4373 .2865		
4			7.2134 7.9375 6.5243 .4310	8.6673 9.0049 8.1977 .1841	2.6473 2.7681 2.5031 .0737	4.6526 4.9401 4.3486 .1499	4.9154 5.2740 4.5038 .2046	5.7134 6.1167 5.3118 .1990		
5			7.6637 8.2949 7.0072 .3108	9.2211 9.5406 8.8793 .1669	3.6030 3.9493 3.3737 .1345	5.6262 5.9458 5.1827 .1654	4.1191 4.6165 3.8018 .2112	6.5704 7.0521 5.9246 .2523		
6				7.8543 8.1877 7.5245 .1753	5.7736 6.0372 5.4274 .1374	4.7210 4.9822 4.3642 .1735	5.1800 5.5808 4.5280 .2594			
7				6.3147 6.7236 5.9599 .2167	6.7114 7.2569 6.2814 .2077	5.3426 5.9578 5.0553 .2156	4.5595 4.9134 4.1072 .1827			
8				7.7094 8.3060 7.1721 .2762	7.4717 8.0299 7.0846 .2559	5.8256 6.1424 5.3458 .1948	5.1882 5.8534 4.6598 .1127			
9				5.1624 5.5475 4.9128 .1548	7.2157 7.5214 6.6187 .2082	4.0559 4.2127 3.7930 .1060	2.4345 2.5848 2.1616 .0049			
10					6.1603 6.4785 5.4883 .2367	3.6491 3.9346 3.3851 .1598				
11					4.4180 4.7505 3.9618 .1781	2.2124 2.3923 2.0144 .0831				
12					5.5398 5.7024 5.1298 .1331	1.5762 1.6660 1.4687 .0590				
13					2.0516 2.3491 1.6926 .1722	.8074 .8651 .6899 .0408				
14										

Figure C-15. Core Flow Map; Run CS-3.1

LINE1= MEAN VALUE [GPM]
LINE2= MAXIMUM VALUE
LINE3= MINIMUM VALUE
LINE4= STD. DEVIATION

\\\\\ - PARTIAL BUNDLES * FLOW OUTSIDE OF INSTRUMENT RANGE

	1	2	3	4	5	6	7	8	9	10
1		5.9303	11.7921	15.1578	19.0587	> 20.*	10.6740	7.8056	2.5792	
1		6.3260	12.7920	16.0899	19.8134		11.2203	8.3583	2.8702	
1		5.6776	11.2294	14.6935	17.9932		10.2797	7.3802	2.3941	
1		.1556	.4618	.3535	.3718		.2266	.1949	.1210	
2		4.3055	15.3376	14.6450	15.8936	17.2049	12.8210	13.4891	1.9500	
2		4.6063	16.8888	15.8821	16.5292	18.2746	13.5130	14.3283	2.1140	
2		4.1092	14.6350	13.7795	15.3837	16.3776	11.9630	12.9195	1.8581	
2		.1042	.5815	.5608	.2178	.4145	.4060	.3264	.0506	
3			6.9476	5.1486	2.8556	5.3365	6.4065	4.8733		
3			7.2757	5.3947	2.9804	5.5885	6.7367	5.4367		
3			6.6559	4.9762	2.7637	5.2066	6.2365	4.4996		
3			.1511	.1183	.0663	.0999	.1323	.2044		
4			10.2601	6.5037	2.2599	6.0008	5.9021	7.2402		
4			10.4971	6.7565	2.4201	6.4009	6.2652	7.5722		
4			9.9455	6.2499	2.0944	5.7449	5.6562	6.9372		
4			.1426	.1207	.0840	.1581	.1551	.1445		
5			9.5869	8.4349	2.5415	5.5869	4.8789	7.8642		
5			9.8852	8.9765	2.7173	5.7667	5.1375	8.0915		
5			9.2242	8.0047	2.3971	5.4190	4.5490	7.5832		
5			.1584	.2141	.0789	.1023	.1354	.1266		
6				4.9095	3.3240	4.5074	3.8911			
6				5.0881	3.5078	4.6956	4.1367			
6				4.6113	3.0171	4.2606	3.6454			
6				.1107	.1181	.1158	.1191			
7				2.8851	2.7656	4.0370	4.3482			
7				3.0465	2.9618	4.1985	4.6611			
7				2.6506	2.5635	3.8054	4.1128			
7				.0940	.0912	.0974	.1349			
8				3.4689	2.9156	3.1968	4.2762			
8				3.6914	3.1075	3.3633	4.5823			
8				3.2279	2.6404	2.9464	4.0370			
8				.1047	.1077	.1019	.1230			
9				2.9283	2.8723	2.6624	2.3478			
9				3.1772	3.0157	2.8199	2.5021			
9				2.5640	2.6437	2.4946	2.1112			
9				.1410	.0971	.0766	.0958			
10					4.8177	4.0525				
10					5.0099	4.2615				
10					4.2476	3.7321				
10					[illegible]	[illegible]				
11					7.8009	4.6527				
11					8.2734	5.0368				
11					7.4110	4.3018				
11					.2041	.1334				
12					10.9117	6.2071				
12					11.4009	6.4402				
12					10.3313	5.8627				
12					.2641	.1185				
13					9.3357	4.1104				
13					9.9342	4.4835				
13					8.6258	3.7645				
13					.0894	.1162				
14										
14										
14										
14										

Figure C-16. Core Flow Map; Run CS-3.2

LINE1= MEAN VALUE [GPM]
LINE2= MAXIMUM VALUE
LINE3= MINIMUM VALUE
LINE4= STD. DEVIATION

\\\\\\-PARTIAL BUNDLES

* FLOW OUTSIDE OF INSTRUMENT RANGE

	1	2	3	4	5	6	7	8	9	10
1		4.8202 5.1299 4.8705 .1209	12.8130 13.4689 12.1092 .3456	13.2909 14.0376 12.7934 .3078	19.8799 20.7057 19.2819 .3674	>20 GPM*	10.0056 10.6056 9.5549 .2716	7.7296 8.1128 7.4383 .1533	1.8433 2.0298 1.7525 .0545	
2		3.8760 4.0533 3.7705 .0729	>20 GPM*	12.1816 12.8545 11.7095 .2821	16.6083 17.4738 15.9462 .3409	17.2171 18.1383 16.6621 .4608	13.4833 14.4655 12.5250 .6905	13.3768 13.9694 12.7273 .3095	1.7032 1.8432 1.5183 .0883	
3			5.8849 6.1154 5.6525 .1101	5.3829 5.5738 5.1493 .0942	3.7575 4.2748 3.6037 .0976	5.6301 5.9399 5.5084 .0979	5.2898 5.5054 5.1615 .0985	5.0857 5.3961 4.8977 .1282		
4			8.9840 9.1669 8.7564 .1071	8.3171 8.6365 8.1046 .1153	2.1091 2.2492 1.9584 .0677	6.0751 6.4811 5.8122 .1056	5.6308 5.8945 5.3961 .1467	7.2857 7.5578 7.0794 .1388		
5			7.8102 7.9545 7.6483 .0919	10.0674 10.3692 9.8811 .1166	2.2266 2.3457 2.0477 .0696	5.4838 5.6761 5.3291 .0924	4.5058 4.7097 4.2387 .1464	7.2490 7.5302 7.1263 .0962		
6				6.9152 7.1324 6.7014 .1082	3.7136 3.8655 3.5149 .0896	4.7163 4.8357 4.5001 .0948	3.7137 3.9766 3.4822 .1212			
7				4.2029 4.5918 3.9254 .1436	3.0983 3.3182 2.9214 .0919	4.0996 4.2053 3.9209 .0747	4.3410 4.6995 4.0727 .1204			
8				3.8215 3.9908 3.6772 .0811	2.9049 2.9774 2.6936 .0756	2.8037 2.9317 2.5957 .0760	4.1440 4.2673 3.9014 .0919			
9				2.8599 3.1239 2.6279 .1041	2.3567 2.5705 2.0335 .1282	1.9935 2.1010 1.8704 .0614	1.8497 1.9828 1.7113 .0462			
10					3.5461 3.8578 3.2428 .1529	3.0389 3.1801 2.8540 .0898				
11					6.0293 6.2175 5.6370 .1566	3.1687 3.2659 2.8732 .0936				
12					8.2334 8.5796 7.8345 .1203	5.1582 5.3177 4.7528 .1198				
13					8.9376 9.2362 8.4162 .1917	3.9575 4.0794 3.7314 .0611				
14										

Figure C-17. Core Flow Map; Run CS-22A

LINE1= MEAN VALUE [GPM]
LINE2= MAXIMUM VALUE
LINE3= MINIMUM VALUE
LINE4= STD. DEVIATION

\\\\\-PARTIAL BUNDLES

* FLOW OUTSIDE OF INSTRUMENT RANGE

	1	2	3	4	5	6	7	8	9	10
1		4.7474	12.7664	12.7167	19.0117	*	9.6365	7.6473	1.8931	
1		4.9850	13.4309	13.3877	19.7340	>20 GPM	10.1259	8.0399	2.1400	
1		4.5386	12.2146	12.1949	18.2762		9.2691	[illegible]	1.7798	
1		.1209	.3384	.2768	.3450		.2136		.0922	
2		3.1076	18.5662	11.9349	17.9246	17.3576	12.7268	13.9303	1.7247	
2		3.2972	19.8052	12.6105	18.6742	18.1533	14.1864	14.8566	1.9206	
2		3.0364	17.6956	11.5791	17.3580	16.2962	11.8386	13.2137	1.5640	
2		.0703	.4991	.2477	.3624	.5248	.5494	.4237	.0776	
3			5.3984	4.8383	3.8323	5.9507	5.0933	4.5530		
3			5.6197	5.1553	3.9586	6.2999	5.3965	4.9420		
3			5.2379	4.5060	3.6098	5.6731	4.9430	4.3436		
3			.0953	.1349	.0832	.1667	.1049	.1325		
4			8.6537	7.6714	1.9076	6.2241	5.1636	6.6140		
4			9.0528	7.9124	2.0307	6.7650	5.4010	6.8481		
4			8.6434	7.4709	1.8125	5.8984	4.9837	6.4864		
4			.1169	.1136	.0554	.2314	.1061	.1047		
5			7.0591	9.6227	1.7865	5.1526	3.8972	6.8176		
5			7.2795	9.8330	1.9223	5.4123	4.1691	7.0598		
5			6.8668	9.3843	1.7057	4.8762	3.6405	6.6214		
5			.1026	.1199	.0562	.1314	.1181	.1118		
6				7.4920	2.9316	4.8601	3.2454			
6				7.6540	3.1474	5.1769	3.5218			
6				7.1393	2.7307	4.6534	2.9878			
6				.1197	.0972	.1163	.1415			
7				5.1337	2.7999	4.1857	3.9093			
7				5.2914	2.9912	4.3189	4.1510			
7				4.9891	2.6141	4.0301	3.6496			
7				.0823	.0924	.0809	.1215			
8				4.0221	2.8356	2.8758	4.0595			
8				4.1761	2.9819	3.0307	4.2844			
8				3.9225	2.6656	2.6574	3.8376			
8				.0632	.0781	.0861	.1037			
9				2.7619	1.9424	1.9718	1.7455			
9				2.8768	2.0627	2.0764	1.8109			
9				2.5722	1.7833	1.8486	1.5903			
9				.0768	.0559	.0554	.0505			
10					2.7789	2.9226				
10					2.9566	3.1189				
10					2.6168	2.7019				
10					.0833	.0802				
11					5.2300	2.7987				
11					5.3772	2.9435				
11					4.9607	2.5688				
11					.0893	.0699				
12					7.3611	4.8991				
12					7.7050	5.1358				
12					7.0723	4.4187				
12					.1525	.1204				
13					8.2501	4.0962				
13					8.5444	4.3077				
13					7.9038	3.6920				
13					.1591	.1216				
14										
14										
14										
14										

Figure C-18. Core Flow Map; Run CS-22B

LINE1= MEAN VALUE [GPM]
LINE2= MAXIMUM VALUE
LINE3= MINIMUM VALUE
LINE4= STD. DEVIATION

\\\\\\-PARTIAL BUNDLES

* FLOW OUTSIDE OF INSTRUMENT RANGE

	1	2	3	4	5	6	7	8	9	10
1 1 1 1		4.6065 4.6414 4.3068 .0892	12.3267 12.8348 11.8912 .2353	11.9044 12.5089 11.5320 .2653	18.1302 18.8668 17.1482 .3832	>20 GPM*	9.0276 9.4549 8.6582 .2586	7.3768 7.7282 7.0176 .1836	1.8167 2.0355 1.7117 .0700	
2 2 2 2		2.8523 3.0487 2.1594 .0846	18.0760 19.9105 18.1165 .5204	11.7344 12.2683 11.0299 .2902	>20 GPM*	17.1530 17.9067 16.3114 .4588	12.3402 13.4155 10.9554 .6533	13.8766 14.5793 13.1756 .3702	1.5121 1.7275 1.8756 .0819	
3 3 3 3			4.8826 5.2065 4.6079 .1495	4.0583 4.3719 3.8586 .1240	3.6753 3.8924 3.4765 .1019	5.5701 5.8733 5.2925 .1315	4.8610 5.0600 4.6500 .0936	4.7325 5.0657 4.4250 .1826		
4 4 4 4			8.4713 8.6931 8.1606 .1366	7.1253 7.4703 6.8791 .1516	1.7340 1.7914 1.6736 .0381	5.3082 5.5158 5.0539 .1287	4.9473 5.1779 4.7266 .1047	6.2544 6.4979 6.0241 .1340		
5 5 5 5			6.3652 6.5253 6.1055 .0875	9.1330 9.4390 8.8070 .1747	1.1379 1.1963 1.0768 .0317	4.5288 4.8075 4.3577 .1150	3.1233 3.3396 2.8859 .1231	6.5958 6.9113 6.3529 .1427		
6 6 6 6				7.2904 7.4642 7.1070 .0951	1.9691 2.0975 1.8152 .0682	4.3623 4.5490 4.0042 .1474	2.8474 3.0248 2.6775 .0742			
7 7 7 7				5.2337 5.6018 4.8821 .1748	1.8654 1.9464 1.7469 .0598	4.0176 4.1426 3.8240 .0753	3.0874 3.2107 2.8514 .0897			
8 8 8 8				3.8242 3.9325 3.6515 .0916	1.8893 1.9379 1.7883 .0474	2.4804 2.6316 2.3133 .0784	3.0837 3.2874 2.7378 .1004			
9 9 9 9				2.4975 2.6840 2.3485 .0702	1.6725 1.8610 1.4689 .0930	1.4443 1.5508 1.2509 .0622	2.0344 2.1504 1.8682 .0600			
10 10 10 10					1.8472 1.9314 1.7366 .0461	2.6709 2.9276 2.4385 .1222				
11 11 11 11					4.1405 4.3364 3.9413 .0860	2.4613 2.6968 2.2549 .0984				
12 12 12 12					6.3238 6.4529 6.0669 .0763	4.4374 4.6682 4.1665 .1205				
13 13 13 13					7.3423 7.5558 6.0169 .1501	5.1706 5.3602 4.9912 .0749				
14 14 14 14										

Figure C-19. Core Flow Map; Run CS-22C

LINE1= MEAN VALUE [GPM]
LINE2= MAXIMUM VALUE
LINE3= MINIMUM VALUE
LINE4= STD. DEVIATION

\\\\\-PARTIAL BUNDLES

* FLOW OUTSIDE OF INSTRUMENT RANGE

	1	2	3	4	5	6	7	8	9	10
1		5.7940	11.7727	14.4605	>20GPM*	>20GPM*	8.9720	6.6033	2.4515	
1		6.1045	12.7108	15.5565			9.6639	7.0418	2.8140	
1		5.4972	10.7515	14.0366			8.5523	6.4228	2.2312	
1		.1558	.4670	.3201			.2751	.1508	.1462	
2		4.1744	15.1585	14.0095	15.8488	18.0925	12.1050	12.6589	2.0894	
2		4.3955	17.1969	15.4752	16.5589	19.5164	12.7989	13.4665	2.2809	
2		4.0386	14.0928	12.7901	14.9320	16.9196	11.3683	12.1851	1.9631	
2		.0834	.7561	.5647	.3769	.6860	.4340	.3572	.0698	
3			6.7474	4.8443	2.8744	5.4236	6.4177	5.4764		
3			7.0138	5.0672	3.0477	5.6763	6.7073	5.7528		
3			6.4756	4.6897	2.7381	5.2923	6.2082	5.2931		
3			.1515	.0972	.0842	.0985	.1309	.1214		
4			9.3848	5.8499	2.0585	5.7796	5.5497	7.0504		
4			9.8790	6.1049	2.2036	6.0262	5.8551	7.3497		
4			9.3818	5.5667	1.9461	5.5636	5.2081	6.7586		
4			.1427	.1311	.0658	.1232	.1467	.1564		
5			8.4728	7.7228	2.1289	5.3582	4.2665	7.8354		
5			8.7519	8.1391	2.2913	5.6614	4.4852	8.0629		
5			8.1198	7.2334	2.0014	5.1678	3.9856	7.5893		
5			.1391	.2220	.0802	.1206	.1334	.1073		
6				5.0810	2.9540	4.5385	3.2258			
6				5.3206	3.1532	4.7761	3.5185			
6				4.8367	2.7728	4.2309	3.0218			
6				.1378	.1110	.1257	.1082			
7				3.3024	2.6450	3.7910	3.8767			
7				3.4760	2.8120	3.9171	4.0864			
7				3.0514	2.4235	3.6076	3.6299			
7				.1120	.0981	.0864	.1058			
8				3.2444	2.8581	2.8600	4.4445			
8				3.3971	2.9865	3.0763	4.6287			
8				2.9769	2.5863	2.6487	4.1562			
8				.0959	.0897	.1202	.1189			
9				2.6189	2.3739	2.2251	2.1165			
9				2.7754	2.5604	2.3866	2.2526			
9				2.4250	2.0854	2.0371	1.8631			
9				.0835	.1272	.0895	.0827			
10					3.7866	3.5655				
10					3.9385	3.8121				
10					3.4938	3.2338				
10										
11					6.4784	3.7949				
11					6.7269	3.9542				
11					5.9959	3.4344				
11					.1622	.1157				
12					9.7271	5.5937				
12					10.0925	5.9532				
12					9.3005	5.1483				
12					.1737	.2192				
13					9.7677	4.2201				
13					10.1975	4.4994				
13					9.6828	3.8143				
13					.2014	.1798				
14										
14										
14										
14										

Figure C-20. Core Flow Map; Run CS-27

LINE1 = MEAN VALUE [GPM]
LINE2 = MAXIMUM VALUE
LINE3 = MINIMUM VALUE
LINE4 = STD. DEVIATION

\\\\\\ - PARTIAL BUNDLES

	1	2	3	4	5	6	7	8	9	10
1		5.0935	10.9949	13.6129	18.4786	>20 GPM *	8.1411	7.0467	2.2283	
1		5.3393	11.5558	14.8531	19.6268		8.5705	7.8677	2.4913	
1		4.9437	10.5429	13.0777	17.6576		7.8831	6.6993	2.0488	
1		.0855	.2672	.4401	.4005		.1786	.2947	.0986	
2		3.6474	16.1224	11.4834	17.8983	>20 GPM *	11.2023	13.6664	1.6687	
2		3.9064	17.2219	12.3067	18.8753		12.8123	14.8295	1.8678	
2		3.4628	14.8754	10.9075	16.7197		10.2651	12.6938	1.5012	
2		.1141	.5864	.4499	.6138		.5034	.4922	.0585	
3			5.2824	4.1186	3.2760	5.7637	5.2702	4.2685		
3			5.6057	4.6255	3.5423	6.0684	5.6825	4.5569		
3			4.8237	3.8344	3.0189	5.5303	5.0467	3.9763		
3			.1803	.2284	.1258	.1374	.1423	.1321		
4			7.9449	6.4442	1.0807	4.3098	4.7072	5.4630		
4			8.1843	6.8196	1.1703	4.7051	5.1477	5.8002		
4			7.6794	6.1551	.9780	4.0502	4.1260	5.1587		
4			.1372	.1789	.0490	.1834	.2512	.1685		
5			6.3804	8.3975	.8293	3.2212	2.3714	6.8367		
5			6.5735	8.7202	.9514	3.7872	2.6579	7.1640		
5			6.1871	8.0346	.7403	2.9543	2.1777	6.5795		
5			.1066	.1750	.0522	.2171	.1191	.1424		
6				6.9812	1.5615	2.6916	2.4639			
6				7.3916	1.9110	3.0223	2.6284			
6				6.6577	1.2239	2.4534	2.1975			
6				.2003	.1234	.1515	.1094			
7				4.1376	1.2314	2.5977	2.7381			
7				4.6718	1.3406	2.8360	2.9776			
7				3.6492	1.1399	2.2579	2.4298			
7				.2123	.0573	.1363	.1078			
8				2.3951	1.1756	1.7448	2.3938			
8				2.5873	1.3522	1.8457	2.7222			
8				2.0394	1.0348	1.5939	2.1502			
8				.1059	.0818	.0661	.1528			
9				1.5862	1.2912	1.0013	1.6075			
9				1.6883	1.5178	1.0653	1.8172			
9				1.4322	1.1176	.9290	1.4582			
9				.0587	.0957	.0332	.0893			
10					1.9014	2.6412				
10					2.0623	2.8871				
10					1.6987	2.2952				
10					.0999	.1398				
11					3.9486	2.5790				
11					4.2268	2.7959				
11					3.7036	2.3500				
11					.1038	.0973				
12					5.3911	4.5797				
12					5.6400	4.9711				
12					5.0055	4.1595				
12					.1651	.1755				
13					7.1962	6.5269				
13					7.5952	6.7975				
13					6.7310	6.1762				
13					.1981	.1253				
14										
14										
14										
14										

Figure C-21. Core Flow Map; Run CS-28

LINE1= MEAN VALUE [GPM]
LINE2= MAXIMUM VALUE
LINE3= MINIMUM VALUE
LINE4= STD. DEVIATION

\\\\\\-PARTIAL BUNDLES

* FLOW OUTSIDE OF INSTRUMENT RANGE

	1	2	3	4	5	6	7	8	9	10
1		3.4336	12.2638	14.6685	19.6145	>20 GPM*	9.1503	6.8344	2.1706	
1		5.8042	13.1547	15.4469	20.0937		9.7212	7.1231	2.4046	
1		[illegible].2762	11.7405	13.9929	19.0085		8.2866	6.6600	2.0234	
1		.1321	.4273	.4168	.2711		.3733	.1078	.0952	
2		4.0256	16.3886	12.2075	15.9265	18.1639	12.3408	12.8670	1.9132	
2		4.2204	17.7633	12.7039	16.5854	19.1916	13.3952	13.2631	2.0968	
2		3.9041	15.3625	11.6331	15.5714	17.1236	11.6703	12.3409	1.8181	
2		.0745	.6351	.2773	.2751	.5940	.4936	.2638	.0625	
3			6.3494	5.1288	3.3028	5.7459	5.9057	5.3938		
3			6.7872	5.3768	3.4717	5.9554	6.2895	5.5731		
3			6.1718	4.9229	3.1457	5.6067	5.5286	5.2290		
3			.1518	.1017	.0891	.1630	.2006	.0951		
4			8.8633	6.3566	1.8688	5.8490	5.4131	6.7876		
4			9.0965	6.5832	1.9975	6.0738	5.6678	6.9671		
4			8.5781	6.1196	1.7781	5.6125	5.2176	6.5734		
4			.1309	.0996	.0563	.1234	.1161	.0830		
5			7.7214	8.0909	1.8075	5.0310	3.8169	7.2919		
5			7.9643	8.3947	1.9031	5.2155	3.9908	7.4046		
5			7.4959	7.8355	1.6907	4.8748	3.6444	7.0031		
5			.0972	.1452	.0528	.0893	.0944	.1083		
6				6.1566	2.9919	4.3241	3.0446			
6				6.4248	3.0944	4.6331	3.2248			
6				5.8130	2.8394	4.1289	2.8100			
6				.1657	.0646	.1221	.1067			
7				4.3006	2.8615	3.6616	4.0046			
7				4.6712	2.9751	3.8505	4.2024			
7				5.9905	2.7246	3.4421	3.6387			
7				.1673	.0642	.0980	.1444			
8				3.5598	2.9512	2.6538	4.4851			
8				3.8043	3.1533	2.7707	4.7492			
8				3.2994	2.7424	2.5045	4.2347			
8				.1193	.1006	.0678	.1176			
9				2.[illegible]2	2.5346	2.1432	2.0622			
9				2.9043	2.8385	2.4159	2.2301			
9				2.5709	2.2518	1.9633	1.8907			
9				.0972	.1438	.1035	.0690			
10					4.0582	3.8065				
10					4.4007	4.1011				
10					3.7333	3.4737				
10					.1651	.1592				
11					6.8060	3.9376				
11					7.0394	4.1377				
11					6.5007	3.6799				
11					.1410	.1109				
12					9.2348	6.1620				
12					9.5535	6.4247				
12					8.9418	5.8926				
12					.1325	.1751				
13					9.1030	4.7679				
13					9.5755	4.9895				
13					8.5456	4.4679				
13					.2291	.1234				
14										
14										
14										
14										

Figure C-22. Core Flow Map; Run CS-29

LINE1= MEAN VALUE [GPM]
LINE2= MAXIMUM VALUE
LINE3= MINIMUM VALUE
LINE4= STD. DEVIATION

\\\\\-PARTIAL BUNDLES

* FLOW OUTSIDE OF INSTRUMENT RANGE

	1	2	3	4	5	6	7	8	9	10
1		5.4066 5.7563 5.2231 .1495	16.0304 17.0824 15.3948 .4638	15.8496 16.7945 15.2727 .4176	>20GPM *	>20 GPM *	11.3099 11.9120 10.7765 .2460	9.0389 9.5041 8.6469 .1950	2.3688 2.7639 2.0696 .1105	
2		3.9501 4.1428 3.7523 .1022	17.3052 18.9166 15.7670 .7890	11.0194 11.6680 10.3906 .3068	13.8249 14.7509 13.0408 .4410	15.9823 16.9253 15.0289 .4720	12.1923 12.8283 11.5247 .3330	14.4376 15.0764 13.8632 .2142	1.8018 1.9578 1.6202 .0687	
3			6.8223 7.2997 6.5577 .1846	4.9257 5.1615 4.7044 .1225	4.0467 4.2596 3.8658 .0952	6.9165 7.0954 6.6573 .1103	6.0841 6.3667 5.8287 .1384	5.1005 5.5614 4.8736 .1664		
4			13.8537 14.4052 13.3492 .2687	7.7726 7.9877 7.4637 .1394	2.5439 2.7023 2.3502 .0873	6.7104 7.0834 6.4855 .1608	6.5297 6.8003 6.2565 .1574	7.7478 8.0856 7.5599 .1226		
5			12.3606 12.6276 11.9812 .1582	6.8870 7.2939 6.6187 .1682	3.3496 3.5903 3.1878 .0926	6.4846 6.9481 6.1562 .1850	5.2746 5.7133 5.0684 .1702	7.2218 7.4175 6.9767 .1299		
6				4.5092 4.6932 4.2888 .1032	4.7302 4.9909 4.2774 .1488	4.6860 5.0016 4.3000 .1979	4.7302 4.9527 4.3546 .1607			
7				2.5334 2.6303 2.3680 .0663	2.8141 3.0344 2.6549 .0941	2.8953 3.1573 2.7160 .1243	4.3282 4.6379 4.0838 .1431			
8				3.5922 3.9422 3.6275 .0779	3.6563 3.8785 3.3568 .1368	2.5139 2.6125 2.3318 .0699	3.6533 3.4268 2.8044 .1532			
9				3.7552 3.9963 3.4783 .1027	4.7372 5.2124 4.2748 .2633	2.5850 2.8374 2.1984 .1400	1.8714 1.9461 1.7726 .0491			
10					7.2251 7.5934 6.8497 [illegible]	4.5418 5.0687 4.0994 [illegible]				
11					9.2547 9.6634 8.8797 .1692	4.3276 4.6755 4.0127 .1643				
12					9.2686 9.7829 8.6231 .3506	5.3303 5.6082 5.0239 .1899				
13					6.0124 6.3427 5.4174 .2082	2.7697 2.9287 2.5268 .1114				
14										

Figure C-23. Core Flow Map; Run CS-30

LINE1= MEAN VALUE [GPM]
LINE2= MAXIMUM VALUE
LINE3= MINIMUM VALUE
LINE4= STD. DEVIATION

\\\\\\-PARTIAL BUNDLES

* FLOW OUTSIDE OF INSTRUMENT RANGE

	1	2	3	4	5	6	7	8	9	10
1		5.2048	14.2759	15.6034			10.0961	7.9670	2.0747	
1		5.4851	15.0475	16.4034	>20GPM*	>20GPM*	10.7977	8.4172	2.1762	
1		5.0268	13.7055	15.0242			9.5447	7.6719	1.9166	
1		.0968	.3552	.3593			.3092	.1813	.1263	
2		4.0214		11.1585	14.2842	16.9078	12.5623	13.9920	1.7432	
2		4.2209	>20GPM*	11.9923	15.0480	18.0925	14.1367	14.7912	1.8920	
2		3.8602		10.6492	13.6998	16.2101	11.5421	13.2783	1.5908	
2		.0904		.3755	.3475	.5000	.6569	.3778	.0749	
3			6.1207	4.5502	3.7526	6.5036	5.4383	5.1399		
3			6.5402	4.8795	3.9738	6.7340	5.7149	5.4181		
3			5.9099	4.2475	3.6284	6.3657	5.2538	4.9162		
3			.1295	.1510	.0885	.1021	.1129	.1150		
4			12.2759	7.2839	2.1460	6.9752	5.7636	7.7203		
4			12.7744	7.6160	2.3953	7.5105	6.0675	7.9270		
4			11.8490	6.9152	1.9271	6.6117	5.2912	7.5109		
4			.2100	.1915	.1180	.2163	.1988	.1006		
5			11.3553	7.3666	2.6772	5.8837	4.6424	7.6375		
5			11.8919	7.7633	2.8296	6.2081	4.9155	7.8878		
5			10.8758	6.8923	2.5354	5.6103	4.3626	7.3865		
5			.2007	.2112	.0839	.1741	.1501	.1254		
6				4.7873	4.4118	4.5180	4.2777			
6				4.9888	4.6519	4.8407	4.5048			
6				4.5080	4.0657	4.2544	3.8895			
6				.1294	.1565	.1551	.1438			
7				2.7069	2.6279	2.6950	4.3475			
7				2.8905	2.7711	2.8299	4.5790			
7				2.5350	2.4196	2.5357	4.1019			
7				.0852	.0967	.0756	.1223			
8				3.1836	2.6313	2.1807	3.2741			
8				3.3761	2.8321	2.3873	3.5112			
8				2.9812	2.4480	1.9797	2.9878			
8				.0875	.0931	.0922	.1423			
9				2.8619	3.3936	1.9664	1.7388			
9				3.1098	3.7140	2.1277	1.8195			
9				2.6219	3.0829	1.7842	1.6124			
9				.1183	.1277	.0763	.0570			
10					5.4612	3.8650				
10					5.9094	4.0661				
10					5.1019	3.6123				
10					.2001	.0937				
11					8.0820	3.6175				
11					8.3329	3.8504				
11					7.7146	3.2434				
11					.1700	.1290				
12					9.1894	5.4298				
12					9.5160	5.7674				
12					8.7516	5.0678				
12					.2247	.1548				
13					7.3450	3.8121				
13					7.8803	3.9596				
13					7.1639	3.5428				
13					.1688	.1111				
14										
14										
14										
14										

Figure C-24. Core Flow Map; Run CS-31

LINE1= MEAN VALUE [GPM]
LINE2= MAXIMUM VALUE
LINE3= MINIMUM VALUE
LINE4= STD. DEVIATION

\\\\\-PARTIAL BUNDLES   * FLOW OUTSIDE OF INSTRUMENT RANGE

	1	2	3	4	5	6	7	8	9	10
1		16.1070 17.8687 15.6067 .4764	>20 GPM*	>20 GPM*	>20 GPM*	>20 GPM*	>20 GPM*	>20 GPM*	1.2570 1.6782 1.1199 .1329	
2		6.1930 6.5433 5.6236 .2293	>20 GPM*	12.1495 13.1095 11.2489 .5095	16.4704 17.3136 15.3106 .5409	14.5815 15.4213 14.1845 .3308	10.3118 11.7427 9.0862 .6668	18.2313 19.0107 17.1303 .5357	1.8785 2.0162 1.7913 .0569	
3			8.4035 9.1674 7.8102 .3214	16.3369 17.4042 15.4678 .4410	6.3278 6.5560 6.0934 .1236	10.5036 11.4488 9.3329 .7442	18.6603 19.6659 17.2559 .7805	4.6231 5.0578 4.3118 .1915		
4			>20 GPM*	>20 GPM*	8.6189 9.0437 8.3199 .1661	12.1645 12.7425 11.6937 .2588	13.9455 15.0866 13.3332 .4294	>20 GPM*		
5			16.5851 17.6028 15.0839 .6581	12.9020 15.2242 11.6402 1.1044	9.4946 9.9605 8.8110 .2217	9.4574 9.7411 8.9902 .1221	10.4316 10.8169 10.0362 .2104	14.5566 16.1867 12.9473 .8541		
6				4.0833 4.4774 3.7676 .2027	7.5067 7.9987 7.1148 .2405	3.5244 3.8824 3.2734 .1749	9.7885 10.1421 9.5871 .1445			
7				2.7666 2.8938 2.6284 .0699	6.8861 7.1648 6.4966 .1794	2.8640 3.0160 2.6478 .0985	3.9702 4.2506 3.6018 .1603			
8				6.7164 7.0516 6.6552 .1856	9.2140 9.6245 8.7504 .2424	3.6374 3.8460 3.4025 .1308	3.2615 3.4703 3.0076 .1567			
9				7.7939 7.9873 7.5761 .0970	13.5596 14.2114 12.6811 .4748	3.6904 3.9005 3.3976 .1197	3.4238 3.5792 3.1687 .0997			
10					10.2988 10.8001 9.9331 .2107	6.3317 6.7416 5.9195 .2603				
11					5.0615 5.4700 4.4766 .2722	4.2008 4.4062 3.9341 .1144				
12					4.6993 5.1136 4.[illegible]807 .1931	5.4003 5.5909 5.1014 .1672				
13					5.1908 5.5074 4.9595 .1047	5.2343 5.4627 4.7817 .1599				
14										

Figure C-25. Core Flow Map; Run CS-33

LINE1= MEAN VALUE [GPM]
LINE2= MAXIMUM VALUE
LINE3= MINIMUM VALUE
LINE4= STD. DEVIATION

\\\\\\-PARTIAL BUNDLES

* FLOW OUTSIDE OF INSTRUMENT RANGE

	1	2	3	4	5	6	7	8	9	10
1		5.0766	15.1507	14.1860	>20GPM*	>20 GPM*	11.4960	9.3891	1.7822	
1		5.2275	15.6773	15.0112			12.2337	9.5652	2.0233	
1		4.9586	14.4266	13.5444			11.1911	9.0574	1.4663	
1		.0733	.3556	.3328			.2737	.1171	.1305	
2		3.8699	>20 GPM*	10.6837	15.8006	17.1526	13.3014	13.7776	1.3745	
2		4.0106		10.8875	16.7650	18.1439	14.9298	14.3658	1.6111	
2		3.7596		10.4787	15.1907	15.6681	12.6820	13.3388	1.2163	
2		.0710		.1193	.3969	.6226	.5179	.3138	.1041	
3			6.8852	4.8009	4.7536	6.7535	5.2815	4.8305		
3			7.3932	5.0376	5.0434	6.9468	5.5189	5.1344		
3			6.6325	4.4960	4.5119	6.4589	5.0921	4.5920		
3			.1883	.1523	.1278	.1219	.1164	.1435		
4			12.3796	9.1682	2.7700	7.1603	6.0240	8.8598		
4			12.6241	9.4287	2.8808	7.9769	6.5970	9.5267		
4			12.0109	8.8714	2.5703	6.7885	5.3774	8.5886		
4			.1667	.1668	.0760	.3128	.3043	.2307		
5			10.3819	9.8757	3.0529	6.6104	5.1040	7.5142		
5			10.6407	10.6503	3.2676	6.7751	5.3969	7.8716		
5			10.1941	9.4454	2.8738	6.3302	4.5932	7.3390		
5			.1142	.2285	.0951	.1181	.2128	.0918		
6				5.4697	4.7721	5.6377	4.4636			
6				5.7202	4.9190	5.9105	4.6762			
6				5.1753	4.5332	5.4413	4.2952			
6				.1843	.1166	.1136	.1074			
7				2.5949	2.2668	3.6020	4.4414			
7				2.7422	2.4527	3.8734	4.6353			
7				2.3812	2.0265	3.3490	4.1922			
7				.1018	.1323	.1320	.1236			
8				3.2769	1.6405	2.0837	3.3477			
8				3.4217	1.7421	2.2122	3.6597			
8				3.1184	1.5550	1.9193	3.1045			
8				.0783	.0495	.0779	.1217			
9				2.6634	1.8533	1.7241	1.7849			
9				2.7507	1.9809	1.7985	1.8694			
9				2.5065	1.7518	1.6329	1.7202			
9				.0582	.0650	.0432	.0361			
10					3.2235	2.7466				
10					3.5518	2.8602				
10					2.9795	2.6070				
10					.1726	.0709				
11					5.4176	2.7472				
11					5.6854	2.8769				
11					5.2179	2.6232				
11					.1375	.0800				
12					7.5765	5.3965				
12					7.8236	5.6114				
12					7.1377	5.0654				
12					.1931	.1312				
13					6.9304	4.4506				
13					7.2260	4.6571				
13					6.5076	4.1634				
13					.2263	.1496				
14										
14										
14										
14										

Figure C-26. Core Flow Map; Run CS-34A

LINE1= MEAN VALUE [GPM]
LINE2= MAXIMUM VALUE
LINE3= MINIMUM VALUE
LINE4= STD. DEVIATION

\\\\\\-PARTIAL BUNDLES

* FLOW OUTSIDE OF INSTRUMENT RANGE

	1	2	3	4	5	6	7	8	9	10
1		4.9695	15.3128	13.7332	>20GPM*	>20 GPM*	11.0202	9.3570	1.1224	
1		5.1131	16.2796	14.1788			11.6846	9.7829	2.1056	
1		4.9213	14.4954	13.0566			10.4483	9.1917	1.4241	
1		.0578	.4848	.3460			.3191	.2112	.1556	
2		3.3321	>20GPM*	10.6089	16.8799	17.1499	12.9202	13.9733	1.4624	
2		3.3151		10.9831	17.4642	18.5667	14.8155	14.4893	1.6583	
2		3.2412		10.2151	16.2385	16.0602	11.9115	13.4555	1.3115	
2		.0807		.2545	.3713	.6273	.7207	.2945	.1018	
3			6.1086	4.2124	4.6473	6.6083	5.0968	4.5282		
3			6.6347	4.4606	4.8911	6.8679	5.3259	4.9413		
3			5.4915	3.9362	4.3638	6.4210	4.8645	4.2526		
3			.2625	.1399	.1254	.1245	.1154	.1915		
4			12.1568	9.0078	2.6272	7.1627	5.7252	8.[illegible]		
4			12.4266	9.4325	2.7871	7.5502	6.1625	8.7616		
4			11.7668	8.7487	2.4816	6.8733	5.3793	8.2171		
4			.1828	.2107	.0754	.2163	.2026	.1737		
5			9.9477	9.9381	2.4630	6.4330	4.2367	7.1691		
5			10.3746	10.1998	2.7179	6.8184	4.5941	7.3838		
5			9.6788	9.6670	2.2731	6.0097	3.8944	6.[illegible]782		
5			.1768	.1657	.1164	.2091	.1888	[illegible]		
6				6.2166	4.0309	6.4244	3.9798			
6				6.4721	4.2699	6.5851	4.1848			
6				5.7609	3.8618	6.2273	3.7804			
6				.2068	.1013	.0944	.1169			
7				2.8301	1.8984	3.9161	4.1403			
7				2.9657	2.0009	4.0921	4.3076			
7				2.6812	1.7454	3.5914	3.9348			
7				.0588	.0631	.1216	.0692			
8				3.3771	1.4118	1.9902	3.2601			
8				3.4921	1.6246	2.2131	3.4492			
8				3.2196	1.1698	1.8694	3.3724			
8				.0861	.1019	.0916	.1044			
9				2.6268	1.3973	1.4788	1.5248			
9				2.7207	1.5874	1.6335	1.6266			
9				2.4777	1.2327	1.3750	1.4269			
9				.0612	.0877	.0749	.0625			
10					2.7335	2.5895				
10					2.8208	2.7661				
10					2.5434	2.3674				
10					.0745	.1163				
11					5.0260	2.5966				
11					5.2977	2.6872				
11					4.7222	2.4414				
11					.1415	.0668				
12					7.1949	5.2593				
12					7.6233	5.4623				
12					6.8594	5.1453				
12					.1970	.0917				
13					6.5024	4.7804				
13					6.7880	5.1261				
13					6.2710	4.3158				
13					.1662	.1519				
14										
14										
14										
14										

Figure C-27. Core Flow Map; Run CS-34B

LINE1= MEAN VALUE [GPM]
LINE2= MAXIMUM VALUE
LINE3= MINIMUM VALUE
LINE4= STD. DEVIATION

\\\\\-PARTIAL BUNDLES

* FLOW OUTSIDE OF INSTRUMENT RANGE

	1	2	3	4	5	6	7	8	9	10
1		\\\\\ 4.9853 5.1927 4.7716 .1140	15.3716 15.9563 14.5004 .3745	13.2657 13.6118 12.5827 .2799	>20GPM *	>20GPM *	10.7360 11.5422 9.8715 .3798	9.2611 9.5707 8.8536 .2038	\\\\\ 1.8130 2.0258 1.5784 .1373	
2		\\\\\ 3.0766 3.1762 2.9788 .0662	>20 GPM *	10.3288 10.7111 9.7382 .2259	17.5592 18.4562 15.9133 .6104	17.6204 18.4348 16.3909 .5356	12.6663 13.8662 11.6656 .6539	14.2929 15.0383 13.5698 .3827	\\\\\ 1.4770 1.6832 1.3320 .0713	
3		\\\\\	5.3376 5.6499 5.0669 .1506	3.6114 3.7934 3.4370 .0795	4.2810 4.5522 4.1437 .1040	6.5371 6.9533 6.1425 .1795	4.9697 5.1735 4.7135 .1199	4.2818 4.6358 4.0314 .1603		
4			\\\\\ 11.9706 12.2704 11.7219 .1355	8.5194 9.0513 8.1676 .2245	1.9839 2.1141 1.8539 .0679	6.8426 7.2839 6.3501 .2323	4.9781 5.5366 4.6903 .2131	\\\\\ 7.6776 7.8903 7.3541 .1645		
5			\\\\\ 9.2447 9.4281 8.9998 .1111	10.3856 10.5664 10.1115 .1352	1.8866 1.9499 1.6106 .0846	6.3070 6.7820 5.8532 .1980	3.2473 3.5766 3.0032 .1375	\\\\\ 6.8821 7.0194 6.7338 .0702		
6				6.8384 7.1922 6.5531 .1903	3.2207 3.7917 2.9262 .2130	6.4226 6.7458 5.9925 .1979	3.4205 3.7831 3.1167 .1905			
7				3.2668 3.5378 3.0643 .1308	1.8346 1.9234 1.6983 .0524	4.0899 4.2407 3.9122 .1025	3.6562 3.9008 3.4339 .1359			
8				\\\\\ 3.5780 3.7030 3.4247 .0743	1.3320 1.5122 1.2260 .0690	1.8913 1.9725 1.8204 .0426	\\\\\ 3.0759 3.2717 2.9090 .1031			
9				\\\\\ 2.6728 2.7843 2.4791 .0655	1.2035 1.3507 1.1065 .0591	1.3167 1.4374 1.2395 .0405	\\\\\ 1.6008 1.7468 1.4277 .0779			
10					2.5847 2.8216 2.3966 .1084	2.5758 2.7359 2.3682 .1050				
11					4.9844 5.1829 4.5731 .1624	2.5662 2.7516 2.3542 .1149				
12					\\\\\ 6.8013 7.1834 6.4634 .1394	\\\\\ 5.4036 5.6223 5.1089 .1320				
13					\\\\\ 6.2946 6.5903 6.0735 .1262	\\\\\ 5.2464 5.5217 5.0101 .1240				
14										

Figure C-28. Core Flow Map; Run CS-34C

LINE1= MEAN VALUE [GPM]
LINE2= MAXIMUM VALUE
LINE3= MINIMUM VALUE
LINE4= STD. DEVIATION

\\\\\\-PARTIAL BUNDLES

* FLOW OUTSIDE OF INSTRUMENT RANGE

	1	2	3	4	5	6	7	8	9	10
1		8.0108 8.3989 7.6878 .1775	>20 GPM *	>20GPM *	8.9688 19.7834 18.4843 .3251	>20 GPM *	>20 GPM *	15.0986 15.9939 14.7196 .3145	.5621 .6182 .5005 .0286	
2		4.1046 4.6687 3.9160 .1782	10.5414 11.4956 9.9224 .5123	12.3017 13.0420 11.6998 .4584	9.7905 10.0683 9.3905 .1610	7.1643 7.7622 6.8234 .2623	9.5865 10.3994 8.9997 .3200	8.3678 8.7573 8.0392 .1878	1.5553 1.7048 1.4408 .0639	
3			7.5653 7.8719 7.2428 .1798	6.3462 6.6260 6.0794 .1177	2.6142 2.7443 2.4491 .0615	5.0934 5.3050 4.8851 .1133	5.3089 5.5901 5.1382 .1187	3.3557 3.5488 3.1458 .1197		
4			6.5286 6.7693 6.3423 .1095	8.1803 8.3961 7.9895 .1029	2.5631 2.6605 2.4556 .0541	4.5932 4.8172 4.3693 .1040	4.4231 4.8649 4.1741 .1707	5.6772 5.8862 5.3848 .1193		
5			7.0297 7.2202 6.8299 .1123	8.2865 8.5024 8.0580 .1098	2.9409 3.1326 2.8183 .0729	5.2861 5.4100 5.0639 .0822	3.9028 4.1429 3.6888 .1277	7.1725 7.3810 6.9865 .0841		
6				7.1453 7.5020 6.7995 .1687	4.0459 4.1881 3.8629 .0836	4.0867 4.2497 3.8946 .0700	4.8915 5.2712 4.4443 .2139			
7				5.3144 5.5475 5.0569 .1108	5.2169 5.5877 4.8995 .1796	4.8870 5.1303 4.5391 .1550	3.8509 3.9818 3.5954 .1021			
8				7.3894 7.6962 7.0330 .1665	5.4898 5.8050 5.0344 .1893	5.4320 5.5801 5.0913 .1128	5.2648 5.4686 5.0854 .1017			
9				5.6696 5.8174 5.4372 .0962	6.4368 6.8647 5.9223 .2072	4.0489 4.1689 3.8516 .0856	2.8393 2.9571 2.6765 .0698			
10					5.2558 5.3786 5.0404 [illegible]	4.0425 4.2041 3.8089 [illegible]				
11					5.0117 5.3064 4.6001 .1584	2.4432 2.6559 2.1945 .0884				
12					6.1027 6.2724 5.5848 .1643	2.5323 2.6748 2.2953 .0940				
13					5.3969 5.6056 4.8571 .1443	1.8755 1.9858 1.6929 .0659				
14										

Figure C-29. Core Flow Map; Run CS-35

LINE1= MEAN VALUE [GPM]
LINE2= MAXIMUM VALUE
LINE3= MINIMUM VALUE
LINE4= STD. DEVIATION

\\\\\\-PARTIAL BUNDLES

* FLOW OUTSIDE OF INSTRUMENT RANGE

	1	2	3	4	5	6	7	8	9	10
1		8.9800	>20 GPM *	>20 GPM *	17.5265	>20 GPM *	>20 GPM *	15.7399	.4239	
1		9.8050			18.2118			16.3498	.4710	
1		8.7363			16.7266			14.7510	.3872	
1		.1989			.4406			.5072	.0284	
2		2.8719	8.7057	7.3089	9.6396	7.4081	6.1443	7.5278	1.3713	
2		2.9378	9.0279	7.6311	9.8444	7.6196	6.8930	7.7783	1.4659	
2		2.6518	8.1300	7.0053	9.3779	7.0717	5.1017	7.0734	1.2218	
2		.0722	.2518	.1437	.1329	.1442	.4860	.1664	.1113	
3			7.5746	6.1852	2.6460	5.2088	6.5604	3.9199		
3			7.8471	6.4539	2.7814	5.5164	6.7941	4.1666		
3			7.3363	5.8673	2.4555	4.9803	6.3681	3.6674		
3			.1648	.1391	.0765	.1655	.1202	.1317		
4			6.5206	9.7028	2.2643	4.4426	4.9919	5.1332		
4			6.6430	9.9672	2.3482	4.6482	5.2124	5.4440		
4			6.3567	9.3719	2.1570	4.2782	4.7280	4.8715		
4			.0920	.1521	.0536	.1071	.1373	.1489		
5			7.2555	9.7416	2.8368	4.9636	3.0350	5.9935		
5			7.4292	9.9963	3.0121	5.1996	3.1964	6.1843		
5			7.0778	9.6110	2.7032	4.5951	2.8784	5.7585		
5			.1112	.0889	.0789	.1599	.1075	.1075		
6				8.0107	4.2370	3.0594	4.2215			
6				8.2653	4.5355	3.2274	4.4615			
6				7.8300	4.0596	2.9397	3.7042			
6				.1175	.1308	.0770	.1448			
7				5.5395	5.8369	4.5285	3.0288			
7				5.7111	6.1547	4.7328	3.2029			
7				5.4452	5.5712	4.2954	2.9108			
7				.0803	.1782	.1132	.0838			
8				7.0533	6.3177	5.1388	4.5047			
8				7.3582	6.6084	5.2911	4.6996			
8				6.8804	6.0203	4.9172	4.3199			
8				.1193	.1727	.0864	.1020			
9				5.5507	7.0654	4.1200	2.9863			
9				5.8288	7.3648	4.3221	3.0663			
9				5.4107	6.6910	3.7223	2.9058			
9				.1151	.1954	.1561	.0436			
10					5.5454	4.7378				
10					5.8473	5.0418				
10					5.2030	4.5155				
11					4.4398	3.0134				
11					4.7952	3.0783				
11					4.1768	2.8541				
11					.1683	.0593				
12					4.1918	2.6876				
12					4.3936	2.8412				
12					4.1176	2.5957				
12					.0540	.0518				
13					3.6814	1.8749				
13					3.9273	1.9950				
13					3.5481	1.8191				
13					.0911	.0419				
14										

Figure C-30. Core Flow Map; Run CS-36

LINE1= MEAN VALUE [GPM]
LINE2= MAXIMUM VALUE
LINE3= MINIMUM VALUE
LINE4= STD. DEVIATION

\\\\\-PARTIAL BUNDLES * FLOW OUTSIDE OF INSTRUMENT RANGE

	1	2	3	4	5	6	7	8	9	10
1		9.5497 9.9529 9.1954 .2385	>20 GPM *	>20GPM *	18.3032 19.0702 16.6645 .6955	>20GPM *	>20 GPM *	18.7483 20.1978 17.4774 .8300	.3397 .4015 .3136 .0285	
2		2.4241 2.8336 2.1907 .1536	7.7000 8.2427 7.1895 .3304	6.4475 7.3154 6.0999 .2514	9.0239 9.3457 8.6340 .1887	7.3576 7.7394 7.1451 .1796	4.9400 5.5801 4.2815 .3687	7.2016 7.4958 6.8641 .1836	1.1211 1.3264 .9765 .0816	
3			10.4109 10.6835 9.9833 .2039	6.0339 6.3002 5.8259 .1461	4.0373 4.1963 3.8746 .0877	6.6448 7.0290 6.2717 .2059	7.7203 7.8919 7.5340 .1095	5.3647 5.6075 5.1797 .1215		
4			11.2115 11.7894 10.2789 .4257	11.1370 11.5883 10.6971 .2840	4.1618 4.5082 3.8582 .1680	5.7575 6.3427 5.3593 .2981	6.0420 6.4752 5.3916 .2648	6.0487 6.3433 5.5549 .1349		
5			11.2786 11.6139 10.8263 .2590	11.4016 12.1131 10.9571 .2528	6.5664 6.7484 6.2401 .1351	5.8714 6.4459 5.4996 .2323	4.5927 5.0843 4.1946 .2201	6.6977 7.1154 6.3962 .1597		
6				9.1173 9.3946 8.3706 .2744	9.4466 9.9353 9.0814 .1900	4.3231 4.6803 4.1309 .1380	6.2578 6.5626 5.8896 .1668			
7				6.0265 6.3252 5.7438 .1641	8.2562 8.7144 7.8544 .2597	5.4169 5.6224 5.2016 .1175	4.2982 4.6378 4.0070 .1824			
8				6.3656 6.8318 6.0895 .1715	8.0302 8.3309 7.5584 .2225	5.1247 5.3017 4.8854 .1085	4.0161 4.3118 3.6597 .1700			
9				3.7679 4.0071 3.4602 .1427	6.5747 7.0338 6.0785 .2980	4.1085 4.3791 3.9461 .1133	1.9762 2.0594 1.9029 .0458			
10					5.4499 5.8234 4.9455	3.3039 3.5223 3.0164				
11					2.8927 3.0436 2.6687 .1031	1.7197 1.8467 1.5636 .0824				
12					1.7382 1.9130 1.4761 .1311	.8516 .9690 .7349 .0682				
13					.8280 .9442 .6949 .0789	.4860 .5418 .4361 .0242				
14										

Figure C-31. Core Flow Map; Run CS-37

LINE1= MEAN VALUE [GPM]
LINE2= MAXIMUM VALUE
LINE3= MINIMUM VALUE
LINE4= STD. DEVIATION

\\\\\-PARTIAL BUNDLES

* FLOW OUTSIDE OF INSTRUMENT RANGE

	1	2	3	4	5	6	7	8	9	10
1		9.5970			18.8027			18.0009	.6249	
1		9.9965	>20GPM*	>20 GPM*	19.4932	>20 GPM*	>20GPM*	19.2527	.7085	
1		9.2379			17.4819			16.8788	.5391	
1		.2057			.6302			.7259	.0828	
2		2.5531	7.8905	6.5288	9.6808	7.1484	5.4761	7.6342	1.7036	
2		2.9284	8.6150	6.8825	9.9930	7.3436	6.2510	7.8942	1.9399	
2		2.3294	7.4732	6.1396	9.4743	6.9882	4.6946	7.3380	1.5129	
2		.1822	.3096	.1898	.1270	.1028	.4621	.1490	.1093	
3			9.7463	5.5536	3.7687	6.7177	7.1971	4.1552		
3			10.1136	5.8666	3.9816	7.0709	7.3762	4.4944		
3			9.5392	5.2419	3.5617	6.0352	6.9423	3.7981		
3			.1698	.1798	.1181	.2970	.1229	.1733		
4			10.3428	10.4851	3.9727	6.2502	5.0787	5.3426		
4			10.7222	10.8363	4.1082	6.6623	5.5073	5.6956		
4			10.0683	9.8553	3.7884	5.7120	4.6015	4.9755		
4			.2030	.2731	.0934	.2774	.2538	.1584		
5			10.3703	9.9754	5.6523	5.9090	3.3593	6.2525		
5			10.6483	10.6830	5.9303	6.6464	3.9090	6.9567		
5			10.0777	9.4542	5.1631	5.3458	2.8077	5.7669		
5			.1474	.2603	.1763	.4093	.2721	.2684		
6				8.1831	7.0418	4.1720	5.1568			
6				8.4928	7.4031	4.3857	5.5775			
6				7.8104	6.8014	3.9881	4.6902			
6				.2273	.2034	.1124	.2825			
7				5.2852	6.9[illegible]71	5.3367	3.2468			
7				5.5138	7.[illegible]309	5.6618	3.4414			
7				5.0568	6.8089	5.0132	2.9723			
7				.1302	.1191	.2017	.1389			
8				6.4068	6.4960	5.4447	3.9286			
8				6.5586	6.7563	6.1887	4.1283			
8				6.2459	6.1603	4.9992	3.7313			
8				.0720	.1689	.3050	.0913			
9				4.[illegible]888	6.0811	4.1974	2.0349			
9				4.7388	6.4363	4.5266	2.1408			
9				4.1874	5.6076	3.9113	1.9290			
9				.1581	.2321	.1997	.0638			
10					5.1868	3.9199				
10					5.7857	4.2044				
10					4.9086	3.7335				
10					.2011	.1510				
11					3.8833	1.9494				
11					4.1042	2.1614				
11					3.7501	1.8223				
11					.1079	.0820				
12					3.2832	1.7204				
12					3.6368	1.8516				
12					2.9397	1.5489				
12					.1830	.0864				
13					2.6312	1.0066				
13					2.7844	1.1165				
13					2.4549	.8678				
13					.1042	.0644				
14										
14										
14										
14										

Figure C-32. Core Flow Map; Run CS-38

LINE1= MEAN VALUE [GPM]
LINE2= MAXIMUM VALUE
LINE3= MINIMUM VALUE
LINE4= STD. DEVIATION

\\\\\-PARTIAL BUNDLES

* FLOW OUTSIDE OF INSTRUMENT RANGE

	1	2	3	4	5	6	7	8	9	10
1		>20GPM*	>20GPM*	>20GPM*	>20GPM*	>20GPM*	>20GPM*	>20GPM*	1.0091 2.0013 1.7985 .0466	
2		5.1860 5.3848 5.0054 .0947	15.0490 16.2934 13.2746 .8276	9.3461 9.8004 8.6388 .2847	13.4148 13.8629 12.3498 .3773	12.7102 13.5709 11.9145 .4103	9.1489 9.9050 7.9398 .5089	14.1347 14.8871 13.2375 .4870	2.0814 2.2367 1.9926 .0596	
3			15.5824 17.9711 14.1132 1.1363	14.7782 16.2714 13.6461 .6668	7.9349 8.1778 7.5788 .1870	17.3641 18.6788 15.3921 1.0534	>20GPM*	4.3663 4.7233 4.1621 .1483		
4			>20GPM*	16.3505 17.4599 14.7364 .8134	11.3503 11.7901 10.7657 .2724	11.9771 12.3106 11.5182 .2441	13.3300 14.1864 12.7140 .4137	15.8984 17.2130 14.2840 .7941		
5			12.4062 12.8660 11.7623 .3012	6.4427 6.9945 5.9997 .3013	10.1861 10.6539 9.8679 .2261	6.9814 7.3701 6.6096 .2289	10.8238 11.0570 10.6052 .1314	11.4257 12.4026 11.1543 .1904		
6				2.9762 3.0911 2.8368 .0703	5.6865 6.0492 5.3432 .2145	2.1330 2.3127 1.9904 .0862	8.3383 8.6727 8.0973 .1664			
7				3.8607 4.1336 3.5701 .1509	7.8817 8.2664 7.3735 .3127	2.4658 2.7499 2.1714 .1806	2.3166 2.5066 2.1899 .0868			
8				7.5412 7.7442 7.2675 .1219	9.8296 10.3318 9.4624 .2903	3.8652 4.1870 3.5866 .2147	3.0776 3.5227 2.7916 .1905			
9				6.1482 6.5461 5.8437 .1739	10.4127 11.4367 9.6747 .4314	3.6378 3.9124 3.3602 .1416	2.9755 3.1461 2.8531 .0852			
10					5.8976 6.4479 5.4033 .3474	4.9747 5.2675 4.5789 .2023				
11					3.7574 3.9627 3.4414 .1844	4.3861 4.7541 4.0828 .1542				
12					6.0651 6.4437 5.7447 .2287	8.3617 8.9969 8.0897 .2089				
13					8.5075 8.9973 8.1854 .2606	8.3824 8.8755 7.9702 .2904				
14										

Figure C-33. Core Flow Map; Run CS-39

LINE1= MEAN VALUE [GPM]
LINE2= MAXIMUM VALUE
LINE3= MINIMUM VALUE
LINE4= STD. DEVIATION

\\\\\\-PARTIAL BUNDLES

* FLOW OUTSIDE OF INSTRUMENT RANGE

	1	2	3	4	5	6	7	8	9	10
1		>20GPM*	>20GPM*	>20 GPM*	>20 GPM*	>20GPM*	>20 GPM*	>20GPM*	1.9616	
1									2.1089	
1									1.7500	
1									.1016	
2		4.9169	14.6299	11.0804	11.9355	13.4262	9.3961	14.1299	1.9313	
2		5.0834	15.8453	11.5950	12.4582	13.8525	9.9958	14.8312	1.9940	
2		4.7864	13.7254	10.6734	11.3674	13.0344	8.7229	13.5125	1.8409	
2		.0941	.5325	.2800	.3479	.2252	.4272	.4053	.0430	
3			>20 GPM*	18.0270	9.1065	>20GPM*	>20GPM*	4.8960		
3				19.3159	9.5312			5.4182		
3				16.9459	8.5833			4.5744		
3				.6675	.2640			.2674		
4			12.2547	>20 GPM*	14.3611	14.4492	17.6737	18.0627		
4			16.6065		15.0449	14.9526	18.7455	19.1592		
4			8.9689		13.8217	13.7701	16.8539	17.2241		
4			2.0044		.3726	.3283	.5031	.5558		
5			13.8680	8.0611	11.7495	6.2740	13.7872	16.9073		
5			14.5933	8.4987	12.3594	6.6119	14.3583	17.8629		
5			13.1866	7.7232	11.1088	6.0164	13.2392	16.7910		
5			.4304	.2386	.3300	.1927	.3344	.6130		
6				6.3932	9.9278	2.0753	7.6905			
6				6.7472	10.5659	2.2302	8.1819			
6				5.9662	9.3008	1.9150	7.3718			
6				.2494	.3763	.0867	.1262			
7				8.1293	13.7597	3.0482	4.2372			
7				8.6724	14.9926	3.3290	4.4928			
7				7.7079	12.8727	2.8751	4.0116			
7				.2492	.5134	.1261	.1139			
8				10.7411	16.5757	6.7085	5.5593			
8				11.4880	17.5901	7.1324	5.8540			
8				10.3077	15.8532	6.3478	5.0062			
8				.2945	.4842	.2017	.1672			
9				6.8947	12.5631	7.8745	4.5019			
9				7.3718	13.1761	8.4622	4.9184			
9				6.5847	11.4897	7.3830	4.3153			
9				.2477	.5398	.2708	.1543			
10					6.7728	5.9525				
10					7.1959	6.2910				
10					6.3716	5.5818				
10					.2628	.2066				
11					3.4245	2.9734				
11					3.5447	3.1731				
11					3.2418	2.8156				
11					.0811	.0822				
12					4.4577	3.0133				
12					4.9072	3.2800				
12					4.1386	2.7582				
12					.1828	.1472				
13					4.1909	1.9493				
13					4.4992	2.0893				
13					3.9201	1.7813				
13					.1572	.0830				
14										
14										
14										
14										

Figure C-34. Core Flow Map; Run CS-40

LINE1= MEAN VALUE [GPM]
LINE2= MAXIMUM VALUE
LINE3= MINIMUM VALUE
LINE4= STD. DEVIATION

\\\\\\-PARTIAL BUNDLES   * FLOW OUTSIDE OF INSTRUMENT RANGE

Row	1	2	3	4	5	6	7	8	9	10
1		[illegible].2938	15.6747	17.4687			12.2349	10.6616	2.1141	
1		6.5721	16.5261	18.4683	>20 GPM*	>20 GPM*	13.1337	11.1635	2.6184	
1		6.0632	14.7493	16.9604			11.5497	10.2630	1.9429	
1		.1082	.4570	.3299			.4333	.2630	.1877	
2		3.8739	16.9349	11.1704	12.9667	15.5520	12.9135	15.6218	1.4388	
2		4.0117	18.4058	11.7229	14.0067	17.1480	13.6492	16.7998	1.6867	
2		3.6938	15.2227	10.5198	12.1764	14.7948	12.2627	14.8352	1.2632	
2		.0822	.8610	.3267	.4219	.5975	.4409	.4697	.0957	
3			7.7136	4.9141	4.8592	7.8815	6.2221	5.1438		
3			8.1504	5.1634	5.0340	8.2163	6.4721	5.3399		
3			7.2735	4.5904	4.6220	7.6519	6.0430	4.9942		
3			.2566	.1617	.0967	.1198	.0968	.0926		
4			18.5890	7.9255	4.0612	8.4346	6.4918	[illegible].2578		
4			19.0835	8.5106	4.2350	8.9197	6.8799	8.6118		
4			18.6545	7.5358	3.8763	7.6485	6.2537	7.8778		
4			.2876	.2568	.1048	.2636	.1597	.1809		
5			12.5237	6.2129	6.3272	6.5794	6.8483	8.3607		
5			13.0151	6.4863	6.5906	6.8345	7.3780	[illegible].8562		
5			11.5559	5.5042	5.6928	6.2762	6.3904	8.0339		
5			.3948	.2304	.2235	.1569	.2596	.2206		
6				2.6535	4.6218	2.7691	5.4554			
6				2.8369	4.8173	3.0198	5.6535			
6				2.5319	4.3645	2.6449	5.1512			
6				.0775	.1441	.0975	.1353			
7				1.4712	2.0739	2.1736	2.7694			
7				1.5849	2.2424	2.3339	2.9040			
7				1.3164	1.8461	1.9828	2.6223			
7				.0600	.1119	.1028	.0798			
8				3.3129	3.0344	2.3402	2.5962			
8				3.5691	3.3292	2.5429	2.7305			
8				3.0838	2.7733	2.1732	2.4882			
8				.1298	.1355	.0998	.0697			
9				3.2315	4.3339	2.2173	1.7216			
9				3.4166	4.7526	2.4086	1.8457			
9				3.0195	3.8324	1.9993	1.6082			
9				.0935	.2441	.1012	.0553			
10					6.6585	3.7583				
10					7.1509	4.0036				
10					6.1301	3.4732				
10					.2975	.1506				
11					8.5597	3.2736				
11					8.9194	3.6641				
11					8.1484	2.8582				
11					.2043	.2396				
12					[illegible].0102	[illegible].2012				
12					9.4094	5.4636				
12					8.5816	4.9998				
12					.2731	.0985				
13					6.0350	2.8849				
13					6.4322	3.0388				
13					5.4638	2.5378				
13					.2103	.1510				
14										
14										
14										
14										

Figure C-35. Core Flow Map; Run CS-41

LINE1= MEAN VALUE [GPM]
LINE2= MAXIMUM VALUE
LINE3= MINIMUM VALUE
LINE4= STD. DEVIATION

\\\\\\-PARTIAL BUNDLES * FLOW OUTSIDE OF INSTRUMENT RANGE

	1	2	3	4	5	6	7	8	9	10
1		>20 GPM*	>20 GPM*	>20 GPM*	>20GPM*	>20 GPM*	>20 GPM*	>20 GPM*	2.2093 2.6602 1.9005 .2204	
2		6.1390 6.6091 5.7119 .2160	12.4843 13.6209 10.7431 .6487	10.1939 11.0876 9.4665 .3926	14.0485 15.8322 13.0494 .7375	13.1525 14.1296 12.2990 .4979	8.6340 10.0096 7.1102 .7955	12.5705 13.8875 11.6019 .5176	1.8088 2.0972 1.6568 .1917	
3			>20GPM*	12.9817 15.5084 11.2893 1.0730	9.4184 10.3210 8.8814 .4065	18.8677 21.2327 16.4106 1.3009	>20GPM*	4.5578 5.3980 3.8583 .4026		
4			>20 GPM*	10.5046 12.3217 9.2911 .8872	14.0348 15.0348 13.3073 .4542	12.2580 13.0513 11.3786 .4927	12.2822 12.9916 11.4892 .4076	16.2929 17.8671 14.5526 .8064		
5			10.1521 10.8417 9.7841 .2913	4.1977 4.8657 3.8290 .2718	9.2880 9.6834 8.4000 .3305	4.0190 4.3665 3.6422 .2159	10.3290 10.7734 9.7664 .2828	11.9275 13.6274 10.0781 .9645		
6				1.8771 2.1703 1.6453 .1534	6.5539 6.9934 6.0789 .2822	2.7596 3.1581 2.3299 .2001	4.8851 5.2485 4.3368 .2310			
7				4.7888 5.0083 4.4106 .1445	8.2647 9.1992 7.2755 .4986	2.7314 3.0081 2.3121 .1804	1.8240 1.9267 1.6845 .0582			
8				7.4226 7.8536 7.1877 .1785	8.5469 9.2383 7.7534 .4439	3.8711 4.6657 3.2782 .3109	4.0210 4.3384 3.6764 .1576			
9				6.4999 7.0401 6.0977 .2626	8.4032 9.0882 7.6506 .4338	3.8471 4.0561 3.3916 .1666	3.4557 3.7642 3.0124 .1882			
10					4.7809 5.0652 4.4283 .1380	4.3877 4.8399 3.8757 .3251				
11					5.7710 6.1465 4.9308 .2702	6.4293 6.8194 5.9849 .2230				
12					8.8997 9.4733 8.3607 .2797	10.0081 10.3584 9.3605 .3093				
13					9.4113 10.1229 8.7751 .3755	7.6785 8.1756 7.2429 .2451				
14										

Figure C-36. Core Flow Map; Run CS-44

LINE1= MEAN VALUE [GPM]
LINE2= MAXIMUM VALUE
LINE3= MINIMUM VALUE
LINE4= STD. DEVIATION

\\\\\-PARTIAL BUNDLES

* FLOW OUTSIDE OF INSTRUMENT RANGE

	1	2	3	4	5	6	7	8	9	10
1		>20 GPM*	>20 GPM*	>20 GPM*	>20 GPM*	>20 GPM*	>20 GPM*	>20 GPM*	2.1607 2.0078 1.9293 .1599	
2		5.2401 5.5987 5.0170 .1025	12.1811 13.2711 11.4802 .5200	13.5676 14.1071 13.0073 .2428	12.1170 13.5293 11.5097 .5569	15.3576 16.7755 14.8808 .4225	9.8735 10.4373 9.5227 .2755	12.6404 13.6460 12.3231 .2673	1.5098 1.9113 1.2857 .1501	
3			>20 GPM*	>20 GPM*	14.9088 15.9915 14.2180 .4618	>20 GPM*	>20 GPM*	5.8751 6.5328 5.2358 .3703		
4			>20 GPM*	18.3230 19.1280 17.4058 .5043	17.2146 18.3576 15.9523 .6415	11.9779 13.3052 11.3196 .5270	19.3883 21.1224 18.2254 1.0086	>20 GPM*		
5			11.6539 11.9196 10.2511 .4829	9.2558 10.0374 8.6006 .3929	12.8416 13.5542 11.7983 .3952	3.6822 4.0305 3.4279 .1686	12.0582 12.7493 11.1749 .4250	>20 GPM*		
6				10.4439 11.2873 9.4349 .5132	16.1709 17.2601 14.6805 .7341	2.2161 2.5606 1.9515 .1629	4.3050 4.9331 3.8544 .3234			
7				10.8499 11.3101 10.0507 .3647	18.6995 19.8785 17.2544 .6808	4.3577 4.9150 3.8860 .3212	3.9740 4.3042 3.4770 .1873			
8				11.9707 12.8317 11.0190 .3103	17.8713 18.7646 16.7769 .5070	7.8282 8.4171 7.0167 .4220	6.3551 6.6986 5.9765 .1480			
9				5.8067 6.4051 5.1272 .3267	11.1234 12.3162 9.8452 .5938	7.5877 8.0707 7.1543 .2576	3.9479 4.2630 3.6172 .1643			
10					6.0596 6.3735 5.5961 .2246	3.0963 3.5861 2.7261 .1896				
11					2.6658 2.9350 2.3339 .1317	1.3297 1.6490 1.1260 .1168				
12					.9614 1.1151 .8090 .0816	.8461 1.0458 .7212 .0654				
13					.5286 .5760 .4710 .0223	.4766 .5438 .4173 .0232				
14										

Figure C-37. Core Flow Map; Run CS-45

Appendix D

PRE-TEST PREDICTION FOR STEAM SECTOR TEST FACILITY CORE SPRAY TESTS

GENERAL ELECTRIC

NUCLEAR ENERGY

PROJECTS DIVISION

AJL-23-79

GENERAL ELECTRIC COMPANY, 175 CURTNER AVE., SAN JOSE, CALIFORNIA 95125

MC 682, (408) 925-3217

April 17, 1979

U. S. Nuclear Regulatory Commission
Office of Nuclear Reactor Regulation
Washington, D. C. 20555

Attention: D. G. Eisenhut
Assistant Director For Operational Technology
Division of Operating Reactors

R. L. Tedesco
Assistant Director for Reactor Safeguards
Division of Systems Safety

Gentlemen:

SUBJECT: REQUEST FOR ADDITIONAL INFORMATION ON GENERAL ELECTRIC CORE SPRAY DISTRIBUTION PROGRAM

Reference: Meeting Summary Progress Report on Confirmation of Core Spray Distribution in a Steam Environment, 11/28/78 - R. Woods (NRC), distributed 12/6/78

As noted in the reference, GE agreed to provide the acceptance criteria for test results from the Lynn core spray test facility before significant testing is begun. Accordingly, the Pretest Prediction For SSTF (Sector Steam Test Facility) Core Spray Tests is attached for your information. It is planned to commence combined steam and spray testing in the facility on April 19, 1979.

If you require any additional information, please contact the undersigned.

Very truly yours,

A. J. Levine, Manager
Project Licensing Unit I
Safety and Licensing Operation

AJL:gmm/416

Attachment

cc: R. Woods (NRC)
L. S. Gifford (GE-Bethesda) (w/o att.)

bcc: (All w/o att.)
G. E. Dix
L. E. Schnebly
E. P. Stroupe
R. N. Woldstad
R. E. Engel
R. L. Gridley
S. A. Sandoz
J. E. Wood
D. L. Fischer

AJL:gmm/416

File 2.1.1

GENERAL ELECTRIC
Nuclear Technology Department
San Jose, California

cc: JD Duncan
T. Eckert
Y. Eljas
DL Fischer
J. Jacobson
LE Schnebly
DG Schumacher
CM Shields
CH Solanas
WA Sutherland
JE Wood

April 13, 1979

To: A. J. Levine, Mananger
Projects Licensing I

Subject: SSTF PRE-TEST PREDICTION

Attached is the SSTF Pre-test Prediction. This document is the answer to NRC Question 1a) as described in EWA SAL-02-35, Rev. A.

S. A. Sandoz, Technical Leader
Thermal Development
M/C 583, Ext. 55356

/kc

Attachment

PRE-TEST PREDICTION FOR SSTF CORE SPRAY TESTS

By

S. K. Rhow

S. A. Sandoz

PRE-TEST PREDICTION FOR SSTF CORE SPRAY TESTS

APPROVALS:

J. E. Wood, Manager
Nuclear Core Technology

4/13/79

D. L. Fischer, Manager
Nuclear Engineering

for 4/12/79

J. Jacobson, Manager
Reactor Design

CONTENTS

I - SUMMARY

Performance of multiple nozzle core spray systems in a steam environment is predicted by superposition of single nozzle spray distributions that are measured in a steam environment, and corrected for multiple nozzle interaction effects that are measured in an air environment. This report presents the spray distribution predicted for the core spray systems in the SSTF at Lynn, Massachusetts.

A key assumption in the analysis method is that the condensation effects in a steam environment and the hydrodynamic effects of multiple nozzle interactions can be handled independently. This separability assumption is to be confirmed by the measured flow density distribution in SSTF being similar to the predicted distribution, and, particularly, by the measured flow density in the "far region" confirming the predicted value within the expected uncertainty. Uncertainty limits are determined by summing the uncertainty in the prediction and the test measurements. The uncertainty (i.e., variance) is the sum of the variances of the component parts in the analysis method (i.e., single nozzle distribution in a steam environment, single simulator nozzle distribution in an air environment, and multiple nozzle distribution in an air environment). The pre-test prediction, its uncertainty limits, and the method of evaluating the separability assumption are presented herein.

II - BACKGROUND

General Electric has developed a method to account for steam environment effects in the design of core spray systems for Boiling Water Reactors. Measurements of single nozzle spray distribution in steam, and measurements of single and multiple nozzle sprays in air, account for both thermodynamic and hydrodynamic effects. Although multiple nozzle tests in steam are not needed in using the method for design applications, General Electric undertook such a multiple nozzle test to provide a final confirmation of the assumption that thermodynamic and hydrodynamic phenomena are separable.

In 1977 G.E. began construction of a Steam Sector Test Facility (SSTF) at a G.E. site in Lynn, Massachusetts. In discussions held with the NRC, January 19, 1978, it was agreed that this test would provide sufficient confirmation of the core spray design methodology. Subsequently, NRC requested that the test results be predicted in advance of the first steam sector tests. This report provides those predictions. Also included are the associated uncertainties in the region far from the nozzles where the assumption of thermodynamic separability has the greatest influence.

III - SSTF CORE SPRAY SYSTEM

REFERENCE DESIGN

The core spray sparger used in the SSTF is a design configuration which was specified at the time the SSTF design was frozen. Single nozzle steam tests, simulator development, simulator sector tests in air, and the associated analysis, were carried out with this design.

IV - SSTF CONFIGURATION AND

TEST CONDITIONS

The SSTF can be used in three operation modes of Spray Systems: High Pressure Core Spray (HPCS) only, Low Pressure Core Spray (LPCS) only, and both HPCS and LPCS. The system conditions for the pre-test prediction and the associated tests are:

System Pressure:	29.5 psia
ECCS Flow Rate:	525 gpm (each system)
ECCS Water Temperature:	145°F

To accommodate steam condensation by the spray water, steam can flow into the upper plenum through both the core region mock-up and steam separator mockup. The tests are conducted with the 30° sector walls in place. This configuration provides the correct flow areas so that vapor velocities will be typical.

Prediction of the radial flow distribution is made along the sector centerline to allow comparison for the greatest radial distance. However, because wall effects become significant near the apex of the sector, no prediction is made in this region (c.f., Figure 1).

V - CORE SPRAY METHODOLOGY AND SSTF PRE-TEST PREDICTION

Core spray flow rate at a particular fuel bundle location is calculated as follows:

$$\begin{pmatrix}\text{Predicted spray}\\ \text{flow in SSTF}\\ \text{in steam}\end{pmatrix} = \begin{pmatrix}\text{Superposition of}\\ \text{single nozzle spray}\\ \text{flows in steam}\end{pmatrix} + \begin{pmatrix}\text{Multiple nozzle}\\ \text{Interaction factor}\end{pmatrix}$$

where

$$\begin{pmatrix}\text{Multiple nozzle}\\ \text{Interaction factor}\end{pmatrix} = \begin{pmatrix}\text{Measured spray flow}\\ \text{for SSTF in air with}\\ \text{simulator nozzles}\end{pmatrix} - \begin{pmatrix}\text{Superposition of}\\ \text{single nozzle spray}\\ \text{flows for simulators}\\ \text{in air}\end{pmatrix}$$

This relationship can be expressed in briefer form algebraically:

$$F = \sum_{i=1}^{N} f_i + G - \sum_{i=1}^{N} g_i \qquad (1)$$

where F = Predicted flow in steam in SSTF

G = Flow measurement in air in SSTF

f_i = Flow measurement to this fuel bundle from single nozzle at location i in steam test

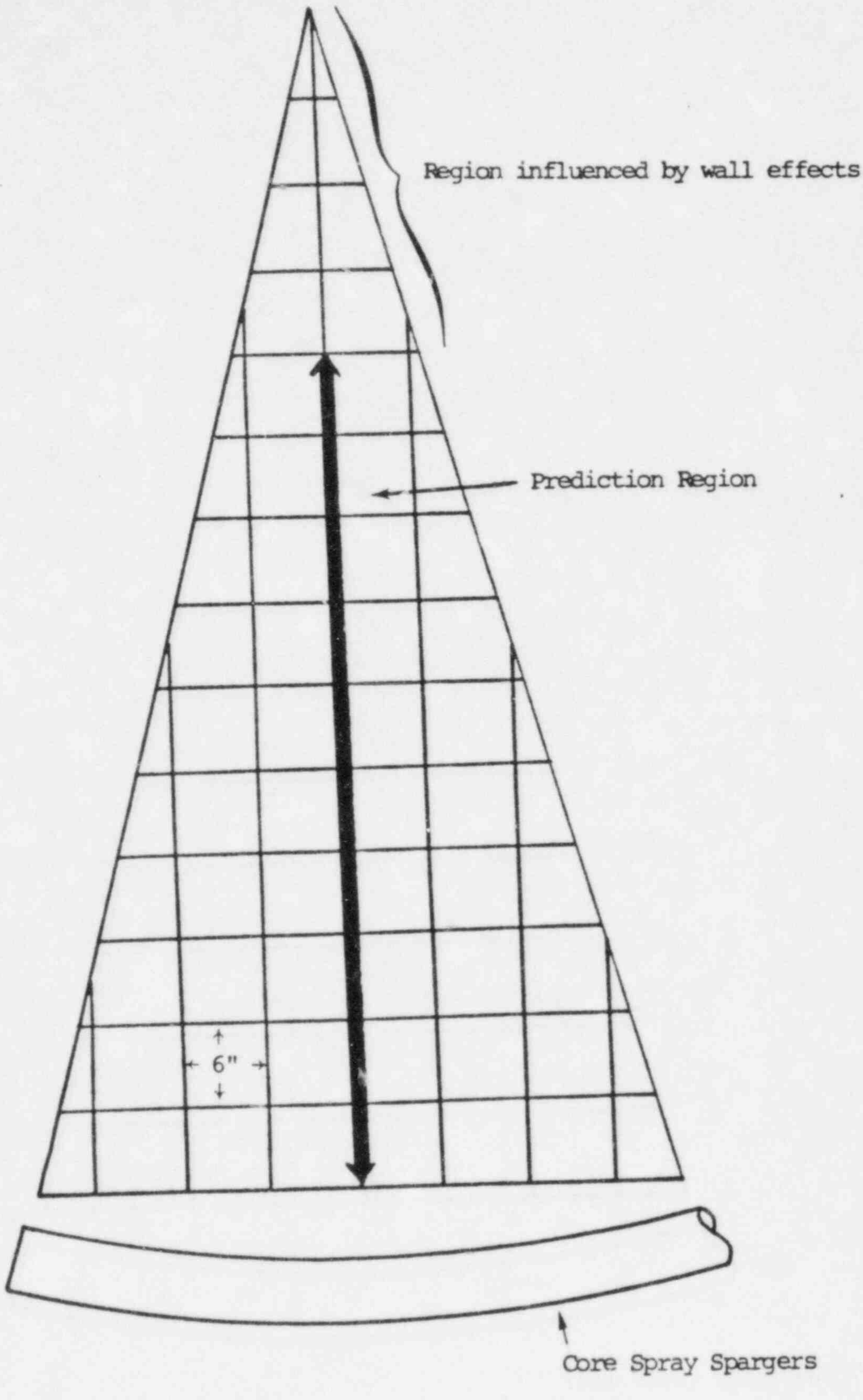

FIGURE 1

TOP VIEW OF SSTF CORE MOCKUP SHOWING REGION OF PRE-TEST PREDICTION

g_i = Flow measurement to this fuel bundle from simulator nozzle at location i in air.

N = Total number of spray nozzles.

The terms G and $\sum_{i=1}^{N} g_i$ are obtained from multiple and single nozzle tests with simulators in air. Row-by-row comparison of the two terms provides quantification of the hydrodynamic effects of multiple nozzles (i.e., the multiple nozzle interaction factor, or MIE). It was found that the interaction of the nozzles used in this design configuration is not only relatively small compared to the bundle flows, but is also smaller than the standard deviation of the flow prediction uncertainty.

The MIE is then combined with $\sum_{i=1}^{N} f_i$, the single nozzle tests in steam that include the thermodynamic effects, to obtain F, the bundle flow predicted for SSTF in steam. The predicted flows for the centerline bundles are shown in Table I and plotted in Figures 2, 3 and 4. Predicted flows for the bundles at 27, 33, and 39 inches are only shown for the LPCS because single nozzle data is not presently available for the 1" street elbow nozzle on the HPCS due to HSF limitations.

VI-COMPARISON WITH SSTF DATA

The data from SSTF tests will be compared with the predicted flow by summing the measured flow into the bundles on either side of the sector centerline, dividing by two, and comparing with the values listed in Table I for the corresponding radial position.

TABLE I

SSTF PRETEST PREDICTION

Distance From Apex To Bundle Centerline	HPCS GPM/ Bundle	LPCS GPM/ Bundle	HPCS & LPCS GPM/ Bundle
27 in.		7.1	
33		7.6	
39		7.3	
45	4.0	5.5	10.0
51	4.0	4.2	7.6
57	4.8	4.9	10.2
63	6.1	6.0	14.1
69	5.7	6.5	12.4
75	14.7	10.1	21.3
81	14.7	16.3	26.4

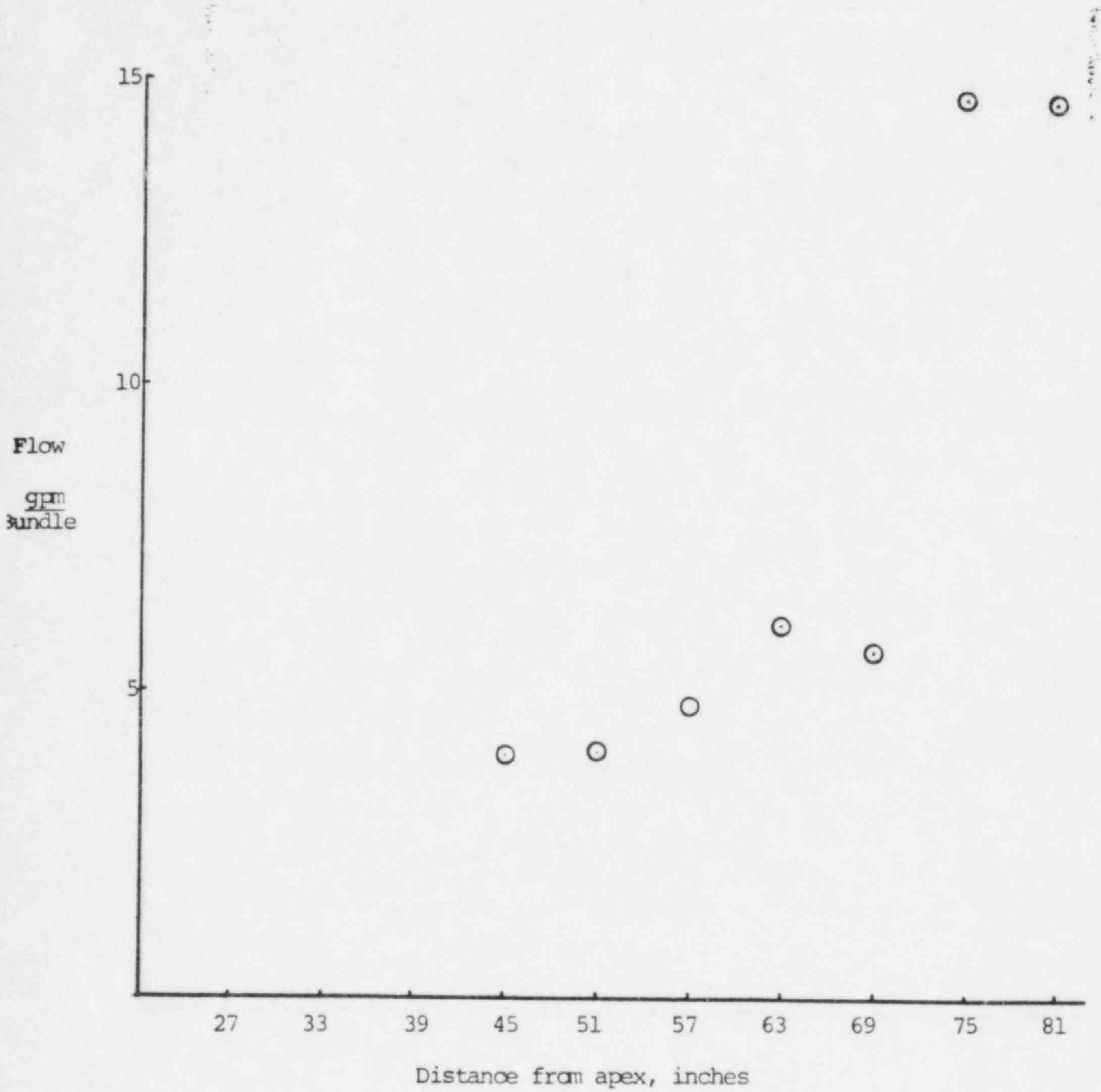

FIGURE 2 - Predicted Bundle Flows for HPCS

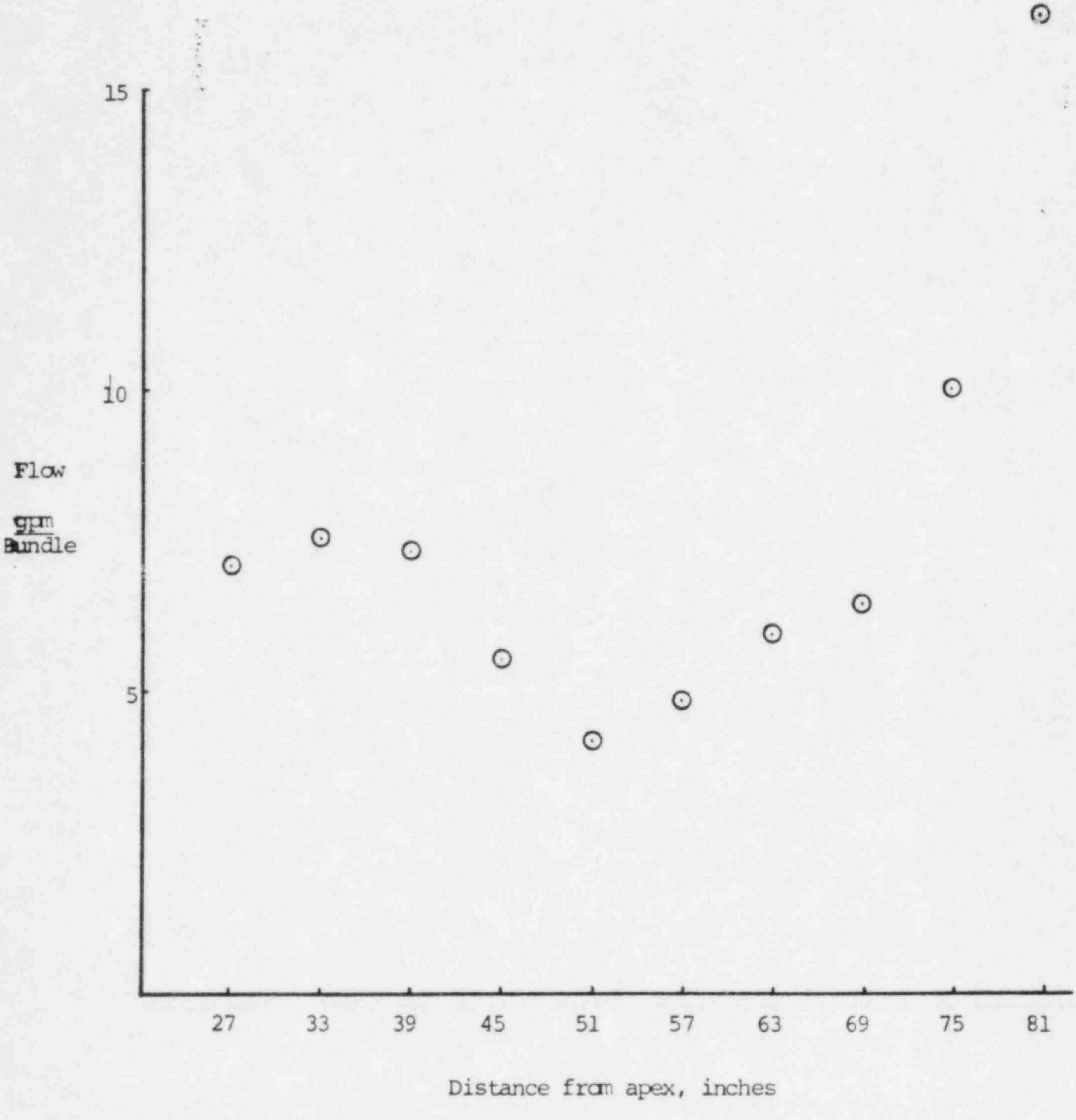

FIGURE 3 - Predicted Bundle Flows for LPCS

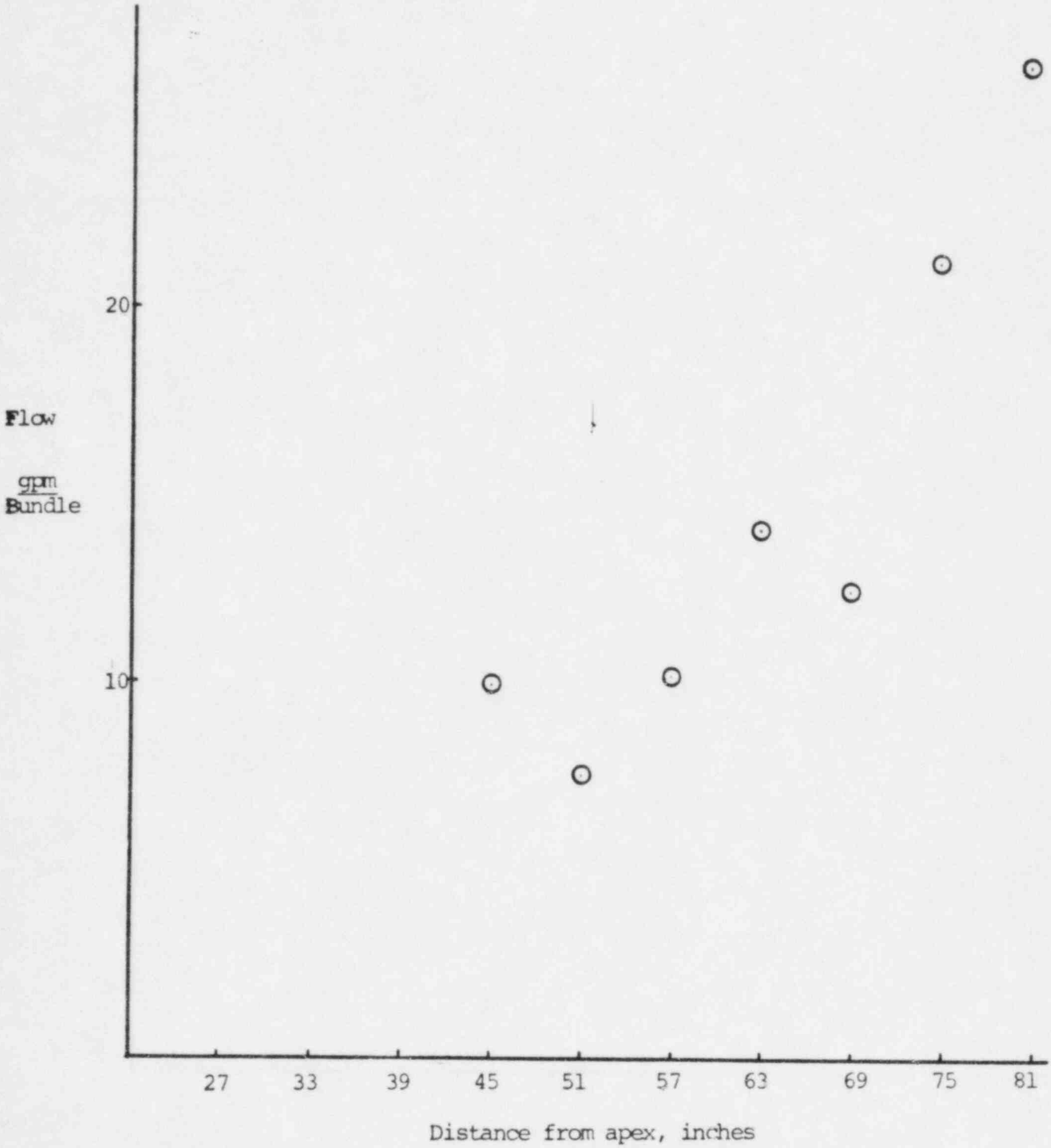

FIGURE 4 - Predicted Bundle Flows for Operation of Both HPCS and LPCS

VII - SEPARABILITY OF THERMODYNAMIC AND HYDRODYNAMIC EFFECTS

An assumption made in developing the core spray design methodology is that the thermodynamic effects can be separated from the hydrodynamic effects because the thermodynamic effects (i.e., steam condensation) occur very close to the spray nozzles. This assumption allows the multiple nozzle hydrodynamic effects to be determined empirically in air tests, and the thermodynamic effects to be determined empirically in single nozzle steam tests.

Thermodynamic effects can influence the spray distribution in two ways: By changing the initial spray shape at the nozzle outlet, or by creating a strong vapor flow which displaces the spray after it leaves the nozzle. In either instance, the distribution will be most strongly affected far from the nozzle. Therefore, although it is appropriate that the pre-test predictions are consistent with the measurements for all bundles, the bundles at the limits of nozzle droplet trajectories are most sensitive for evaluation of the separability assumption. The approximate contributions of the three types of nozzles for the LPCS are illustrated as a function of radius in Figure 5. From Figure 5, the limiting droplet trajectories for the 3/4-inch open elbow nozzles fall in the radius range of 69 to 81 inches. The SPRACO 2935 nozzles' limiting droplet trajectories fall in the range of 33 to 75 inches. Similarly, the effective limiting range for the 1-inch street elbow nozzles is 27 to 51 inches (the actual limiting droplet trajectories for these nozzles are at and beyond the apex; however, the effective limits in the SSTF are sufficient to evaluate the separability assumption).

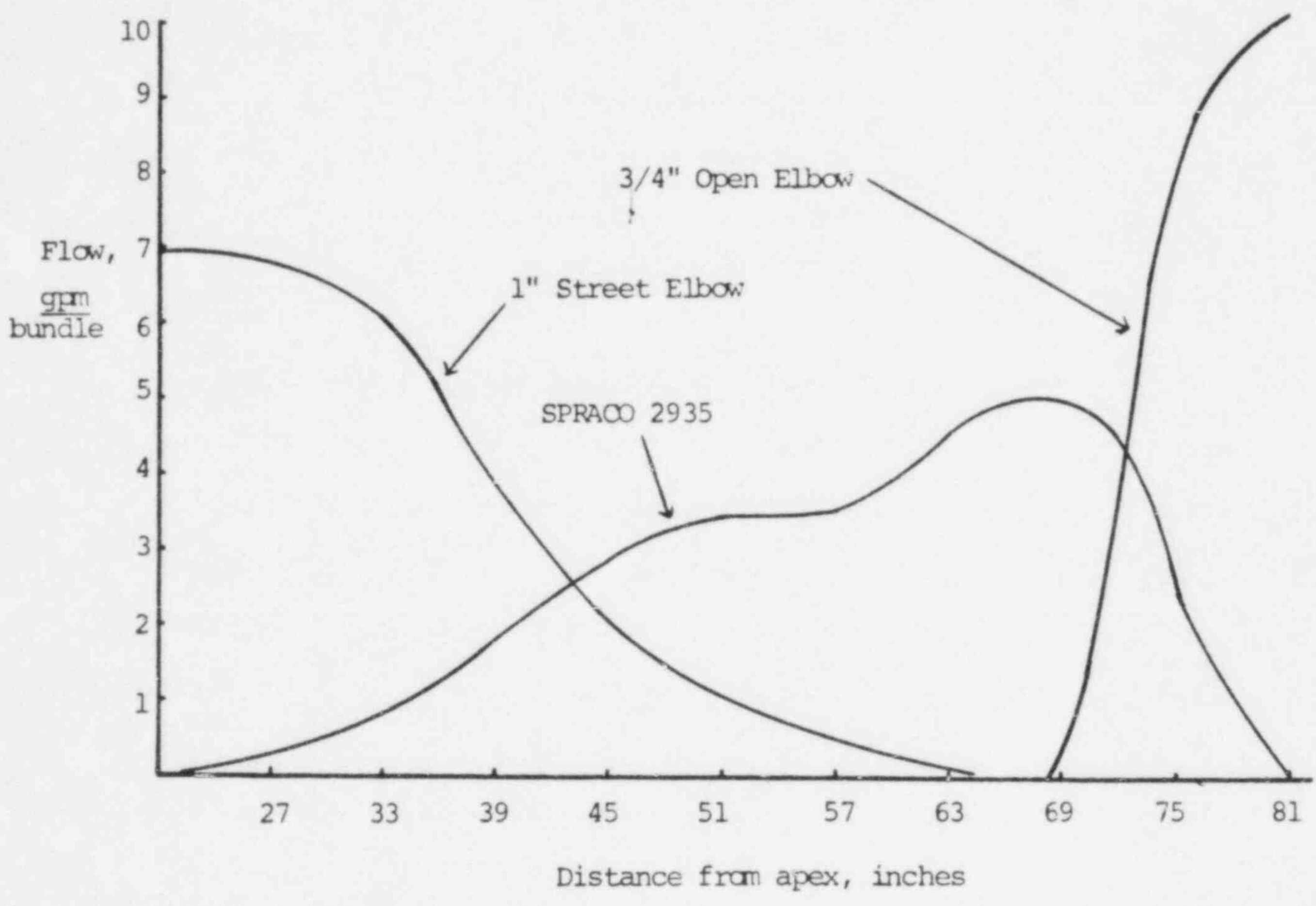

FIGURE 5

Flow contribution vs. distance for different nozzle types used on the LPCS

The droplet trajectories of the 3/4-inch open elbow nozzles are very short and thus not sensitive to interaction effects. Therefore, the bundles near the core spray header are of little value for assessing the separability assumption. However, the limiting ranges for both the SPRACO 2935 nozzles and the 1-inch street elbow nozzles are important for evaluating the separability. Therefore, the separability assumption will be evaluated by direct comparison of the pre-test predictions of Table II over the combined range of 27 to 51 inches. The applicability of the separability assumption will be judged by comparing deviations between measurements and predictions with the uncertainty analysis for the same range, as listed in Table A-III of the attached appendix.

NOMENCLATURE

Symbol	Description
b_x	Systematic measurement error in the quantity x.
C_n	Flow distribution function parameters.
e_x	Random measurement error in the quantity x.
F	Flow density at a particular location in SSTF for the 30° sector steam test.
f_i	Flow density at a particular location from nozzle i, measured in a single nozzle steam test.
G	Flow density at a particular location in SSTF, measured during a 30° sector test using simulator nozzles in air.
g_i	Flow density at a particular location from simulator nozzle i, measured in a single nozzle air test.
H	Flow density measured at a particular location in SSTF for the 30° sector steam test.
i	Index indicating specific nozzle location in SSTF.
N	Total number of nozzles.
X^1	True value of the quantity x.
Var{X}	Variance of quantity X, $=\sigma^2\{X\}$.
Cor{X,Y}	Correlation of quantities X and Y; $= \frac{\text{Covariance }\{X,Y\}}{\sigma\{X\}\sigma\{Y\}}$
σ{X}	Standard deviation of quantity X.

APPENDIX

UNCERTAINTY ANALYSIS FOR PRETEST PREDICTION

As is the case in all experimental work, many variables do not remain constant in the tests that are the basis for the predicted flow in this analysis. There are hardware manufacturing and installation tolerances, system parameter variations, and measurement uncertainties. These variations lead to differences between the predicted flow, F, and the flow measured in SSTF, H. Knowledge about the magnitude of these variations can be used to calculate an estimated uncertainty in the quantity (F-H).

The measured value of a particular flow, W, can be expressed as:

$$W = W^1 + b_W + e_W \qquad \text{(A-1)}$$

where W^1 = true value of the flow

b_W = systematic measurement bias in W

e_W = random measurement error in W

The difference between F and H can be expressed as:

$$F - H = \sum_{i=1}^{N} (f_i^1 + b_{f_i} + e_{f_i}) + G^1 + b_G + e_G - \sum_{i=1}^{N} (g_i^1 + b_{g_i} + e_{g_i}) - (H^1 + b_H + e_H) \qquad \text{(A-2)}$$

Since f_i and g_i are both determined from Horizontal Spray Facility (HSF) data, and are approximately the same magnitude, any systematic measurement error from the facility will tend to cancel itself (that is, $b_{f_i} - b_{g_i} \simeq 0$ for i = 1 to N). Similarly, G and H are both determined in SSTF and systematic measurement error there will cancel itself also ($b_G - b_H \simeq 0$).

Because independent data sets are used, the influence of uncertainties on the difference between F and H is determined by summing the variances of the individual terms.

$$\mathrm{Var}\{F-H\} = \mathrm{Var}\{\sum_{i=1}^{N} f_i\} + \mathrm{Var}\{G\} + \mathrm{Var}\{\sum_{i=1}^{N} g_i\} + \mathrm{Var}\{H\} \qquad \text{(A-3)}$$

For the purposes of this analysis, $\mathrm{Var}\{\sum_{i=1}^{N} f_i\}$ is assumed equal to $\mathrm{Var}\{\sum_{i=1}^{N} g_i\}$. Since the nozzles and spray distributions contributing to the two terms are very similar, and the data are obtained in the same test facility using the same methods, this is an appropriate assumption. Testing experience in HSF has shown no differences in variance between air and steam tests.

Similarly, Var{G} is assumed equal to Var{H}. This assumption is based on the same arguments. Although SSTF has not yet been operated in steam, no differences in measurement uncertainty are expected between its operating characteristics in air and in steam.

Each of the individual terms, such as Var{G}, contains contributions from many sources. Some of these terms result from true variations in the flow distribution and others are caused by uncertainty in the measurement of the flow. As long as the contributions come from statistically independent sources, the variance caused by each source can simply be added to that caused by every other source. This is the case for all sources of Var{G} and Var{H}. However, it is not the case for all sources of $\mathrm{Var}\{\sum_{i=1}^{N} f_i\}$ and $\mathrm{Var}\{\sum_{i=1}^{N} g_i\}$. Because each nozzle type appears more than once, data from a single nozzle test in HSF is used more than once in the calculation of $\sum_{i=1}^{N} f_i$ and $\sum_{i=1}^{N} g_i$. Therefore, wherever the spray patterns of two or more nozzles of the same type overlap, the contributions to the variance come from the same single nozzle test and so are not statistically independent. For example, for two such flows, the variance is obtained as the sum of the variances and the covariances of the sources:

$$Var\{f_1 + f_2\} = Var\{f_1\} + Var\{f_2\} + 2\ Cor\{f_1, f_2\}\{\{Var\{f_1\}\ Var\{f_2\}\}^{1/2} \qquad (A-4)$$

Because most of the factors leading to changes in flow will produce corresponding changes in all flows at the same distance from the nozzle, flows at this distance will be highly positively correlated. Therefore, rather than performing the lengthy covariance calculation, the covariances for SSTF have been bounded by the reasonable assumption $Cor\{f_1, f_2\} = 1$.

It should be noted that there are many substantive differences between this uncertainty analysis and an uncertainty analysis which would be performed for a reactor application. Therefore uncertainty bounds shown herein cannot be applied directly to reactor core spray systems.

VARIANCE OF MEASURED PARAMETERS

The standard deviations of parameters measured in tests (pressure, flow rate, etc.) have been determined from evaluation of measurement data. The influence of the parameter variation on spray distribution is also determined experimentally through the use of vertical single nozzle test data where these parameters were varied.

The values used for the sensitivity analysis to determine the uncertainty in f_i are shown in Table A-I. In the analysis, more than one parameter in Table A-I may influence a specific characteristic of the spray distribution. For example, variation in both nozzle geometry and nozzle flow rate influence the peak height

TABLE A-I

EXPERIMENTAL PARAMETERS

Variable	Mean Value	Standard Deviation
System Pressure	29.5 psia	1 psia
Spray Water Temperature	145°F	2.5°F
Header Spray Flow	525 gpm	10 gpm
Nozzle Flow Rates	as specified	2 gpm
Nozzle Aiming Angles	as specified	1/2 degree
Nozzle Dimensions	as specified	Variable, depending on dimension 0.005-0.04 inches, typical

of the spray distribution. Since the variations occur independently, the combined variance is calculated by adding the separate contributions of each parameter:

$$\mathrm{Var}\{C_n\} = \left(\frac{\partial C_n}{\partial x_1}\right)^2 \mathrm{Var}\{X_1\} + \left(\frac{\partial C_n}{\partial x_2}\right)^2 \mathrm{Var}\{X_2\} + \ldots$$

where X_i = physical parameter being varied

C_n = flow distribution function parameter.

To calculate variance for the single nozzle distribution function f_i, the single nozzle model (SNAP) was used to determine a base case. Input coefficients were perturbed the amounts shown in Table A-II. The difference between the base case and the perturbed case are used to determine the variances of the flow to each channel. Once the local variances for individual parameters for each nozzle type are known, they are combined to provide calculated variances for f_i. This combination is performed by GENUS, the global superposition model, in the same way it is used to calculate flow distributions.

In addition to variations in the spray distribution due to hardware tolerance and flow parameter uncertainty, measurement uncertainty is also taken into account. Again, measurement uncertainty is statistically independent from other uncertainties, so the variance due to measurement uncertainty can be added to the variances from other sources. The contribution of measurement uncertainty is different in different test facilities.

Single nozzle tests are performed in HSF. Flow density is determined by measuring the time required to fill a known volume. Calibration of this measurement system has shown that the standard deviation of the reading is 3%.

The SSTF bundle mockups contain weir tubes to measure flow. These weir

TABLE A-II

SINGLE NOZZLE MODEL PARAMETERS

Parameter	Standard Deviation
Nozzle Flow Rate	2 gpm
Distribution Function	
- Peak flow density	5% of value
- Cone width	5% of value
- Pattern spread	0.005 inches
- Skew (includes pattern asymmetry and aiming angle variation)	0.01 inches

tubes are designed so that flow through the tube can be related to the water column height within it. This water column height is measured with a pressure transducer. Calibration of these devices shows that the standard deviation of measurement uncertainty is 5% of the reading.

DEVIATION IN SIMULATION

The core spray design methodology incorporates the assumption that multiple-nozzle interaction effects in steam are equivalent to multiple-nozzle interaction effects (MIE) in air. The methodology would still be adequate with a "less-than-perfect" equivalence of MIE in steam and air. Therefore it is appropriate to allow a modest deviation in the interaction effect for an acceptable confirmation of the methodology.

This is addressed in the uncertainty analysis by first calculating the multiple-nozzle interaction effect, and then determining the mean absolute value ($|\overline{MIE}|$), for the predicted bundles. Then 25% of this mean, squared, is added to the variance obtained in equation A-3. With the small interaction effect obtained, this term represents a small change in the total variance.

TOTAL UNCERTAINTY ANALYSIS RESULTS

The above uncertainty calculations have been performed at the predicted bundle locations to be used for evaluating the separability assumption. The resulting one and two σ limits are shown in Table A-III. The primary sources of uncertainty for these points are the uncertainty in nozzle flow rate and flow distribution skew. Other components contributed very small additional uncertainty.

This uncertainty calculation is an estimate of the actual uncertainty. Knowledge of the actual uncertainty may be improved through further testing in SSTF.

TABLE A-III

Distance From Apex To Bundle Centerline	HPCS σ	HPCS 2σ	LPCS σ	LPCS 2σ	HPCS & LPCS σ	HPCS & LPCS 2σ
27	1.4	2.8	1.2	2.4	2.1	4.1
33	1.5	3.1	1.0	2.0	2.1	4.1
39	1.3	1.6	1.5	3.0	2.1	4.2
45	0.7	1.3	1.6	3.2	1.8	3.7
51	0.6	1.3	1.2	2.3	1.5	2.9

Appendix E

ADDITIONAL INFORMATION REQUESTS

"CORE SPRAY DESIGN METHODOLOGY CONFIRMATION TESTS"

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

FEB 1 1980

MEMORANDUM FOR: Paul S. Check, Chief, Reactor Safety Branch
Division of Operating Reactors

FROM: Ledyard B. Marsh, Reactor Safety Branch
Division of Operating Reactors

THRU: Vincent W. Panciera, Section Leader, Reactor Safety Branch, Division of Operating Reactors

SUBJECT: SUMMARY OF MEETING WITH GENERAL ELECTRIC COMPANY REGARDING STEAM EFFECTS ON BWR CORE SPRAY DISTRIBUTION

Representatives of the NRC staff and the General Electric Company met on November 15, 1979, in Bethesda, Maryland, to discuss GE's plans in the subject area and responses to several staff questions. A summary of the meeting, an attendance list, the staff's questions, GE's categorization of the staff questions, and copies of the presentation slides are attached.

Ledyard B. Marsh
Reactor Safety Branch
Division of Operating Reactors

Enclosures:
As stated

cc: See attached list

ATTENDANCE LIST, NOVEMBER 15, 1979

CORE SPRAY DISTRIBUTION MEETING

V. Panciera	NRC/DOR
L. B. Marsh	NRC/DOR
W. Hodges	NRC/DSS
R. Frahm	NRC/DSS
R. Woods	NRC/I&E
J. Alai	GE
G. Dix	GE
L. Rodriguez	GE

Summary of Meeting with GE to discuss

Steam effects on Core Spray Distribution

The meeting was requested by GE to discuss their progress to date, and to give their responses to several staff questions generated during the review of GE's August, 1979 report "Core Spray Design Methodology Tests."

GE briefly reviewed their testing and analyses in their efforts to investigate and model the effects of steam on BWR core spray. Single and multinozzle tests in a full scale mockup of a BWR-6 upper plenum in an air environment were conducted at the Valicitos, California facility, More recently, multinozzle tests in a full scale mockup of a 30° sector of a BWR-6 upper plenum in various steam environments were conducted. These tests have been performed by GE in developing models and techniques to predict core spray distribution in typical post LOCA environments.

This phase of the overall effort to ensure adequate BWR post LOCA fuel spray cooling has been called by GE the "methodology" phase. Once the methodology is developed and accepted, each BWR licensee must ensure acceptable fuel cooling by applying the methodology to their particular plant design. This phase of the effort will be the final step in assuring adequate core spray in steam environments, and has been called the "application" phase.

The staff's questions from its review of the GE report "Core Spray Design Methodology Tests", which had been informally given to GE previously, were tentatively grouped (by GE) into two categories (corresponding to the two phases): those pertaining to the methodology being used by GE in developing models and techniques to predict BWR core spray in a steam environment and those pertaining to the application of the methodology to individual reactors in assuring acceptable fuel performance in LOCA situations. The staff's questions and their categorization are attached.

GE was prepared to discuss only their responses to the staff's methodology questions, and stated that the application questions would be addressed during that phase of the overall effort. It was GE's contention that by acceptably answering the staff's methodology questions and by presenting corroborating data, the GE methodology for predicting BWR core spray in a steam environment would be substantiated.

The staff stated that if all methodology questions were acceptably answered, then the general methodology would be accepted. However, the staff stated that the separation of the questions into two groups might be oversimplifying the contents of the questions. For example, certain questions may appear to be "application" type questions, but their response may bring to light questions concerning the validity of the overall methodology.

GE responded that the methodology itself should be justifiable, independent of specific application questions, but if methodology concerns arose during the responses to application questions, those concerns would be answered.

GE then presented their responses to the staff's methodology questions. The staff noted that GE's methodology report and their responses to the staff's questions were given in terms of flow density (gpm/bundle) at certain core radii, but no data was given for the bundle predicted flowrates. Since acceptance of the methodology depends on how well the technique predicts individual bundle flowrates, the staff requested that questions pertaining to predicted or actual bundle flowrate be answered with bundle by bundle data, not with flow densities.

Additionally, the staff requested GE to document the information presented on the slides shown at the meeting, as well as the accompanying explanation.

GE requested, and the staff agreed to formally ask both the methodology questions being discussed at the meeting and the application questions which would be addressed at a later date. These questions (attached) had been previously given to GE informally. The staff concluded that the following questions, however, had been acceptably addressed at the meeting and would not be formally asked and did not require any further response: 1a, 5a, 7, 9, and 11.

GE requested, and the staff agreed to send GE a letter, when all methodology questions have been acceptably answered, stating our acceptance of their techniques. The staff stated that acceptance of the GE methodology depends on satisfactorily responding to the methodology questions referred to above, as well as any other methodology type questions which may arise in our review of GE's responses.

MEETING SUMMARY DISTRIBUTION

*H. Denton
*E. Case
W. Russell
*D. Eisenhut
R. Tedesco
B. Grimes
L. Shao
P. Check
D. Crutchfield
A. Schwencer
D. Ziemann
G. Lainas
V. Noonan
G. Knighton
T. Ippolito
D. Brinkman
K. Kniel
Z. Rosztoczy
D. Fieno
T. Novak
*R. Silver
*S. Nowicki
*J. Shea
*P. O'Conner
*T. Wambach
H. Thornburg
K. Seyfrit
S. Bryan
E. Jordan
*ORB 3-PMs
*C. Berlinger
*M. Aycock
OELD
OI&E (3)
OSD (3)
R. Fraley, ACRS (16)
TERA
Docket Files
NRC PDR
Local PDR
NRR Reading File
RS Reading File
Receptionist, Bethesda
Attendees

L. Gifford, GE, Bethesda
J. Alai, GE, San Jose
L. Rodriguez, GE, San Jose
S. Sandoz, GE, San Jose
G. Sherwood, GE, San Jose
A. Levine, GE, San Jose
W. Hodges
R. Frahm
R. Woods
L. Marsh

*Denotes person to receive a copy of slides

ADDITIONAL INFORMATION REQUESTS -
CORE SPRAY DESIGN METHODOLOGY CONFIRMATION TESTS -
August 1979

QUESTION 1

With regard to the core spray distribution data taken at Lynn and presented in this report:

a) Explain how the measured individual bundle (or partial bundle) flow rates were used to calculate the (average) bundle flow vs. core radius data presented in your report. Include a table and/or figure showing which bundles (or portions of bundles) were used to determine the spray flows presented in your report for core radii of 27", 33", 39", 45", 51", 57", 63", 69", 75" and 81" respectively.

b) Explain how the data presented (average spray flow vs. radius) can be interpreted by the reader to allow determination of the conservatively bounding minimum spray flow that was actually measured in the Lynn facility for any individual bundle at each given radius ($\geq$27"). If the data as presented cannot be used for this purpose (i.e., if you cannot state, for example, that "in all cases the minimum was within (x%) of the average") then you must present new figures for each case used in your confirmation of the GE-core-spray-distribution methodology, showing minimum bundle core spray flow measured at each radius (for radii $\geq$27").

c) Indicate the uncertainty that should be applied to the measured minimum bundle flow rates due to bundle flow measurement errors, calibration errors, total sparger flow uncertainty, etc.

QUESTION 1a - RESPONSE

Although this question was answered during the November 15, 1979 meeting, the answer is repeated here to clarify the bundle locations discussed in other responses.

Predicted average for the center two bundles is compared with the average of measurements from the center two bundles, for all radial locations (see Figure 1A).

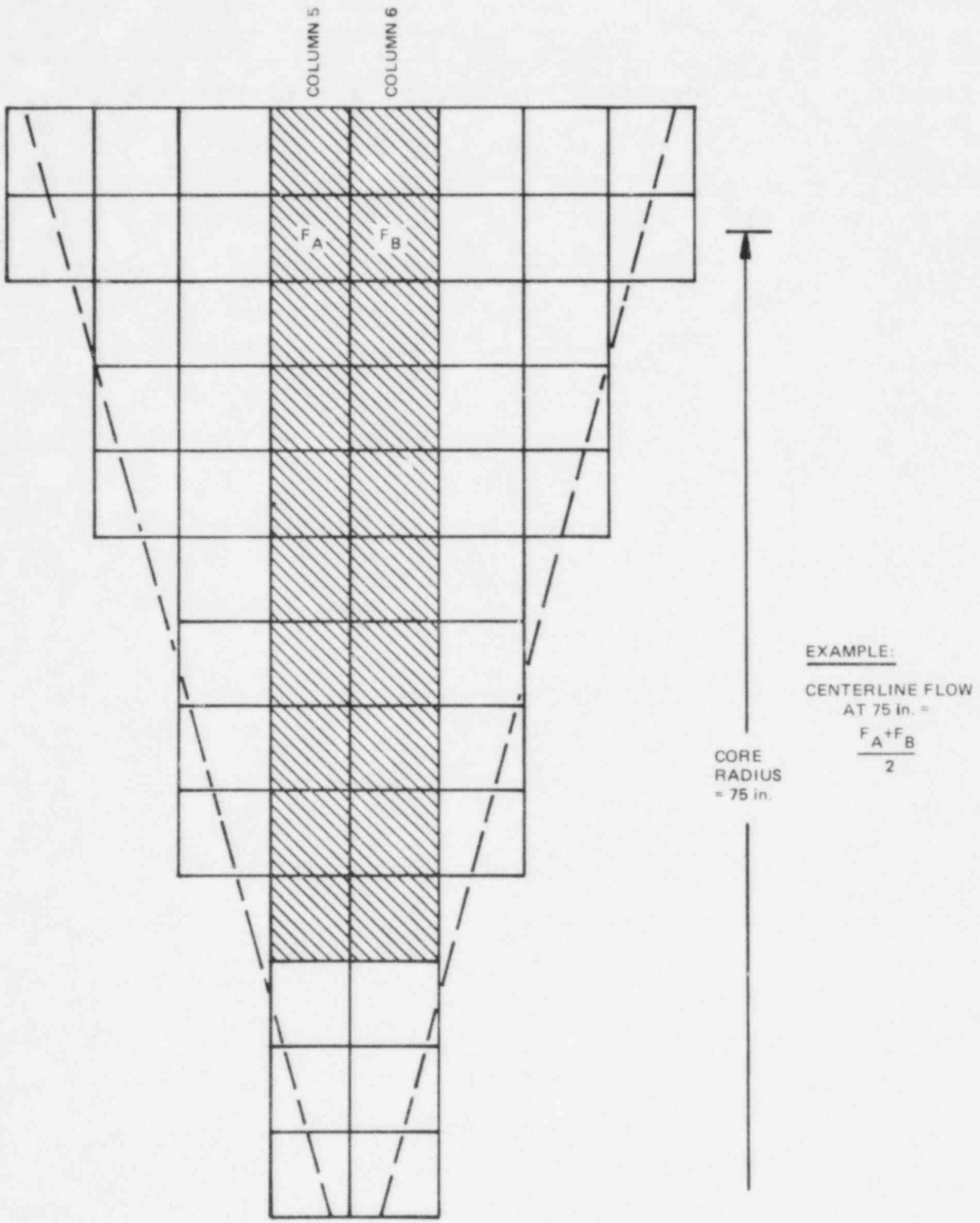

Figure 1A. Calculation of Centerline Bundle Flows

QUESTION 1b - RESPONSE

Previously, flow density prediction and data for two bundles across the centerline were averaged as shown in Figure 1A.

Shown here are the SSTF predictions and SSTF data compared for each individual bundles of these two columns. The uncertainty bands shown along with the predicted flows are increased by a factor $\sqrt{2}$ from the bands shown with the centerline-average predictions. This factor is the adjustment required due to the use of single bundle flows instead of the average of two bundles.

The results are presented in Figures 1B through 1G as plots of flow per bundle along columns 5 and 6 of Figure 1A. These results show little difference between the center average and single bundle comparisons. The predictions are also matched, i.e., 95% of the SSTF data is within the 2σ error bands of the prediction curve. Two comparison points on one double header curve, Figure 1G, are beyond the 2σ limit but within the 3σ limit.

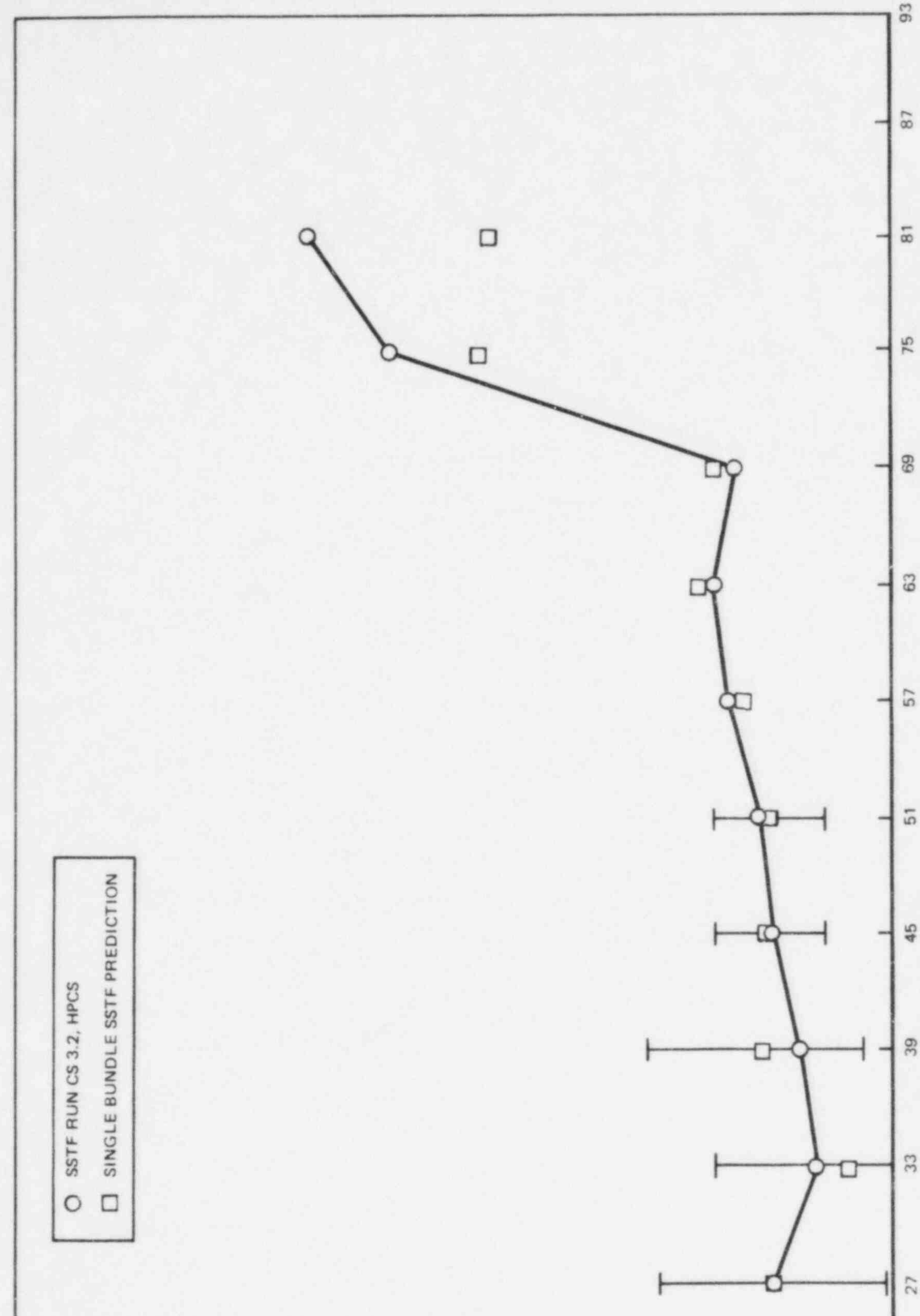

Figure 1B. Comparison of Prediction and SSTF Test for the HPCS, Column 6

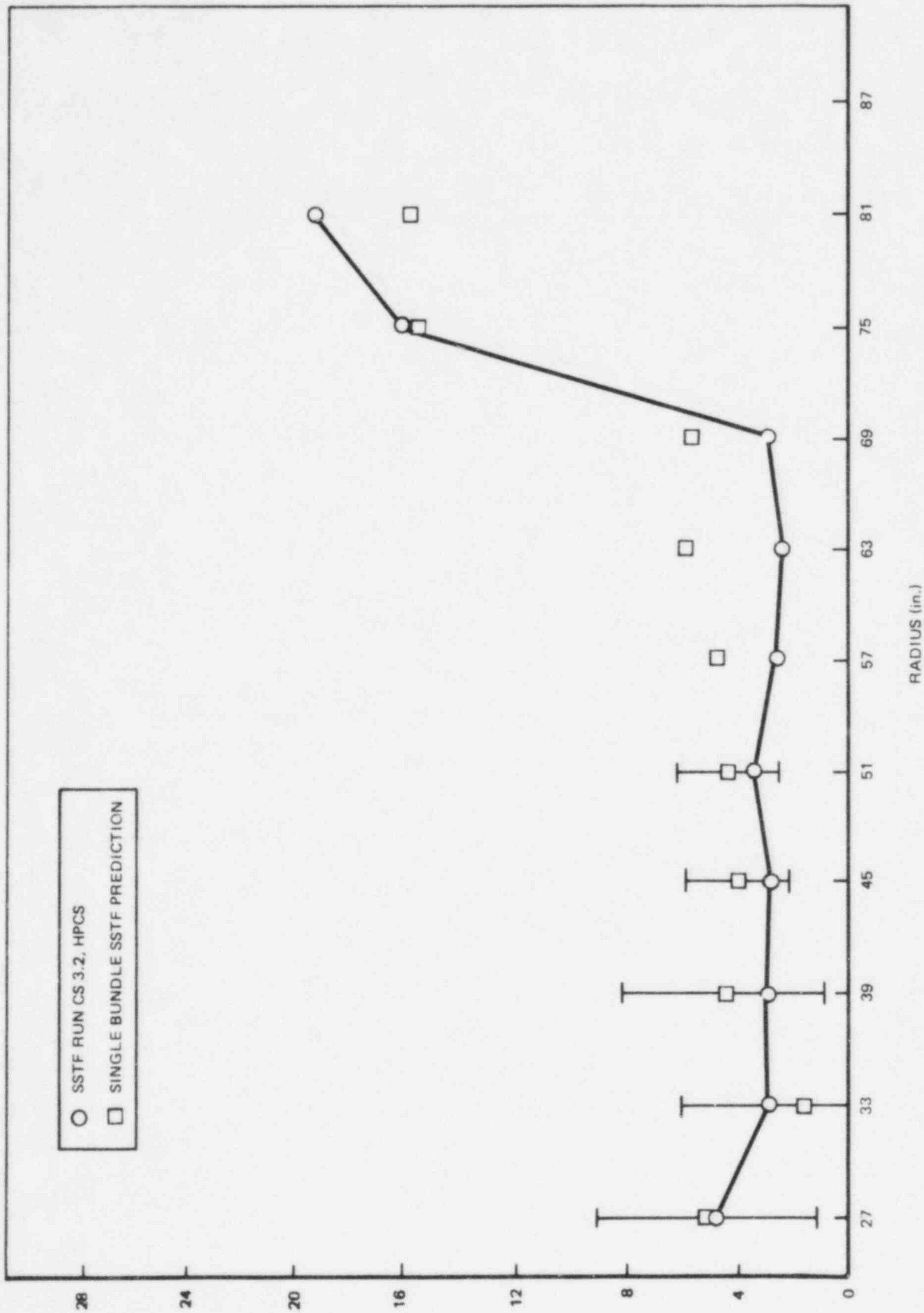

Figure 1C. Comparison of Prediction and SSTF Test for the HPCS, Column 5

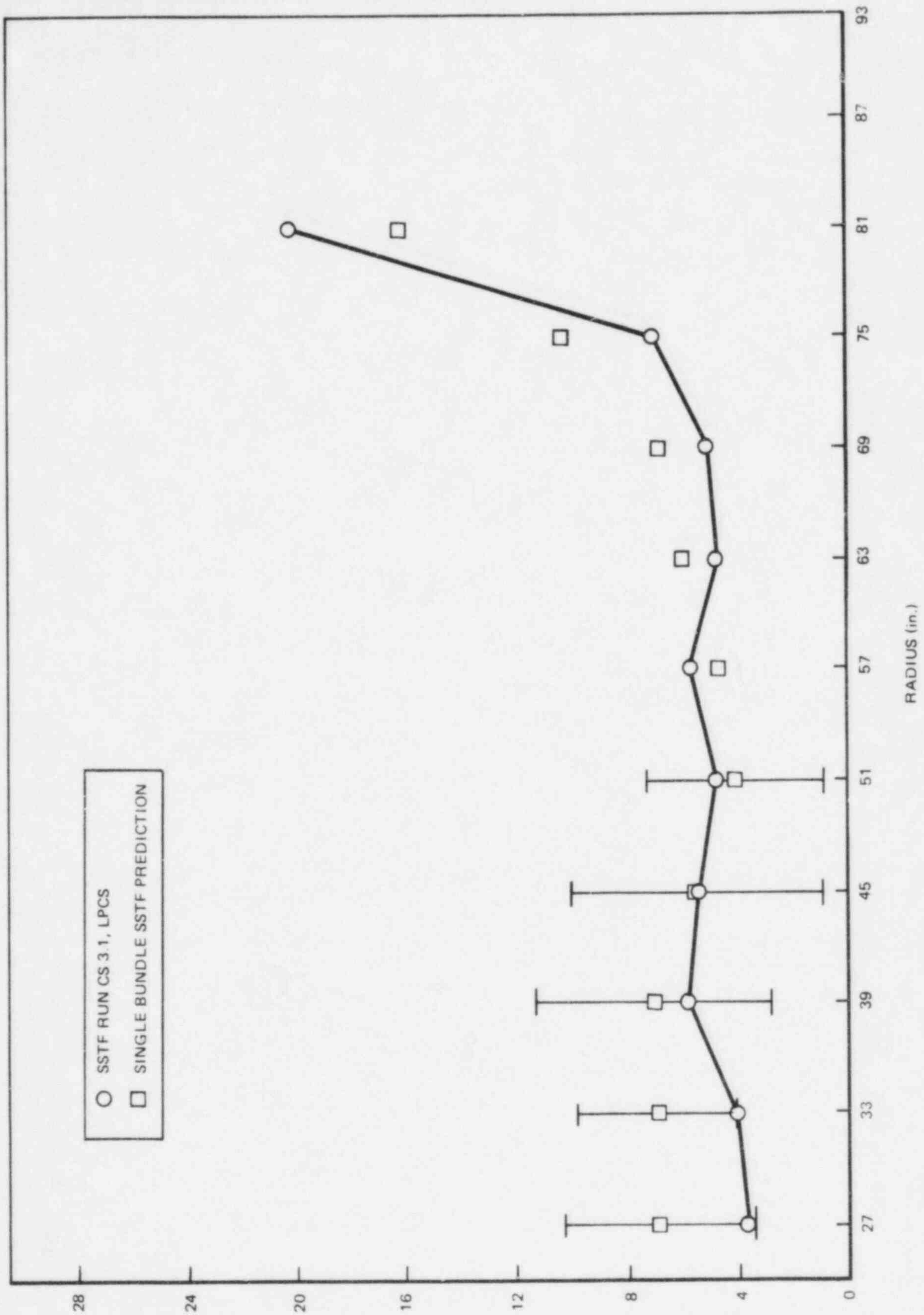

Figure 1D. Comparison of Prediction and SSTF for the LPCS, Column 6

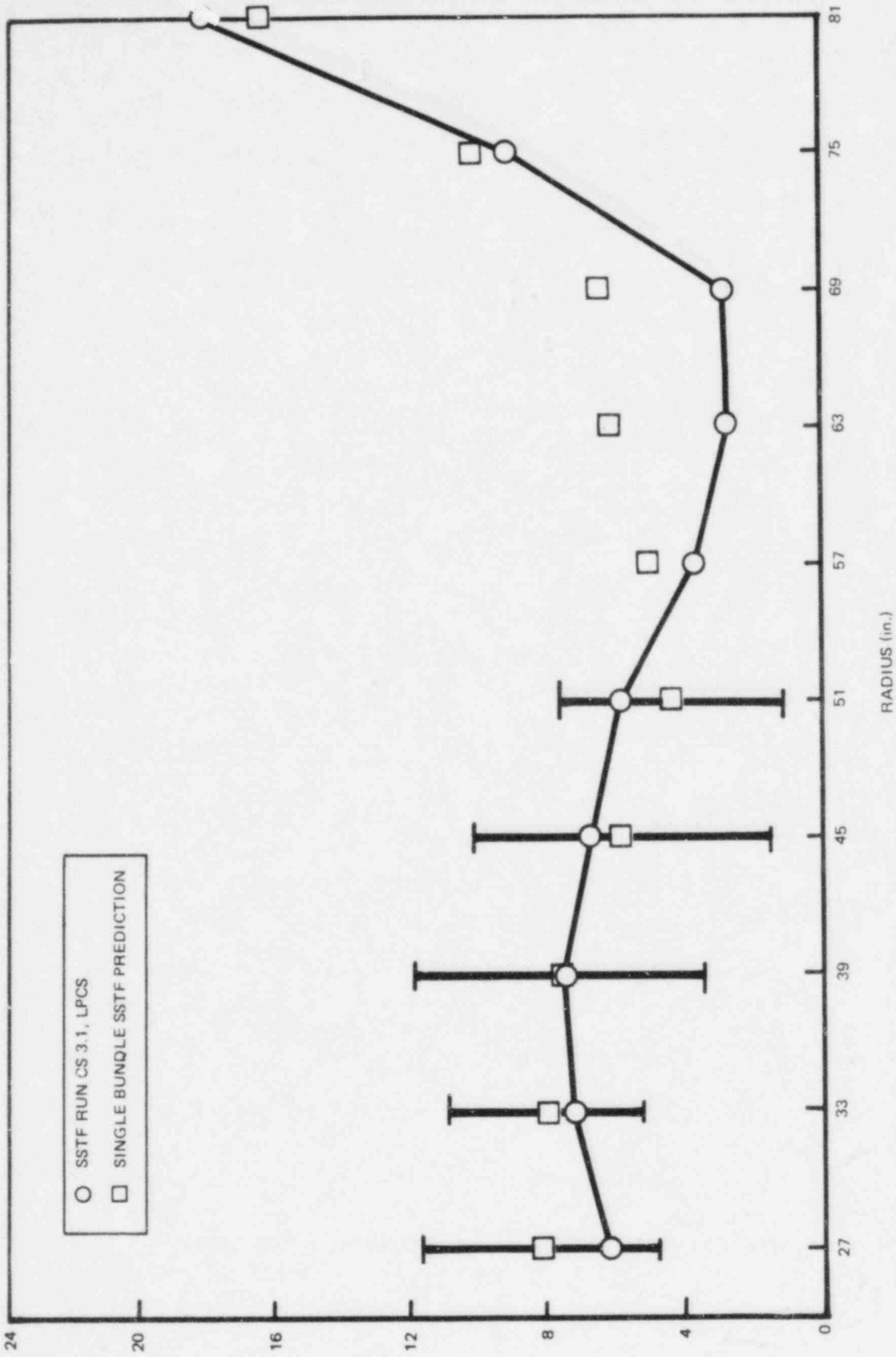

Figure 1E. Comparison of Prediction and SSTF Test for the LPCS, Column 5

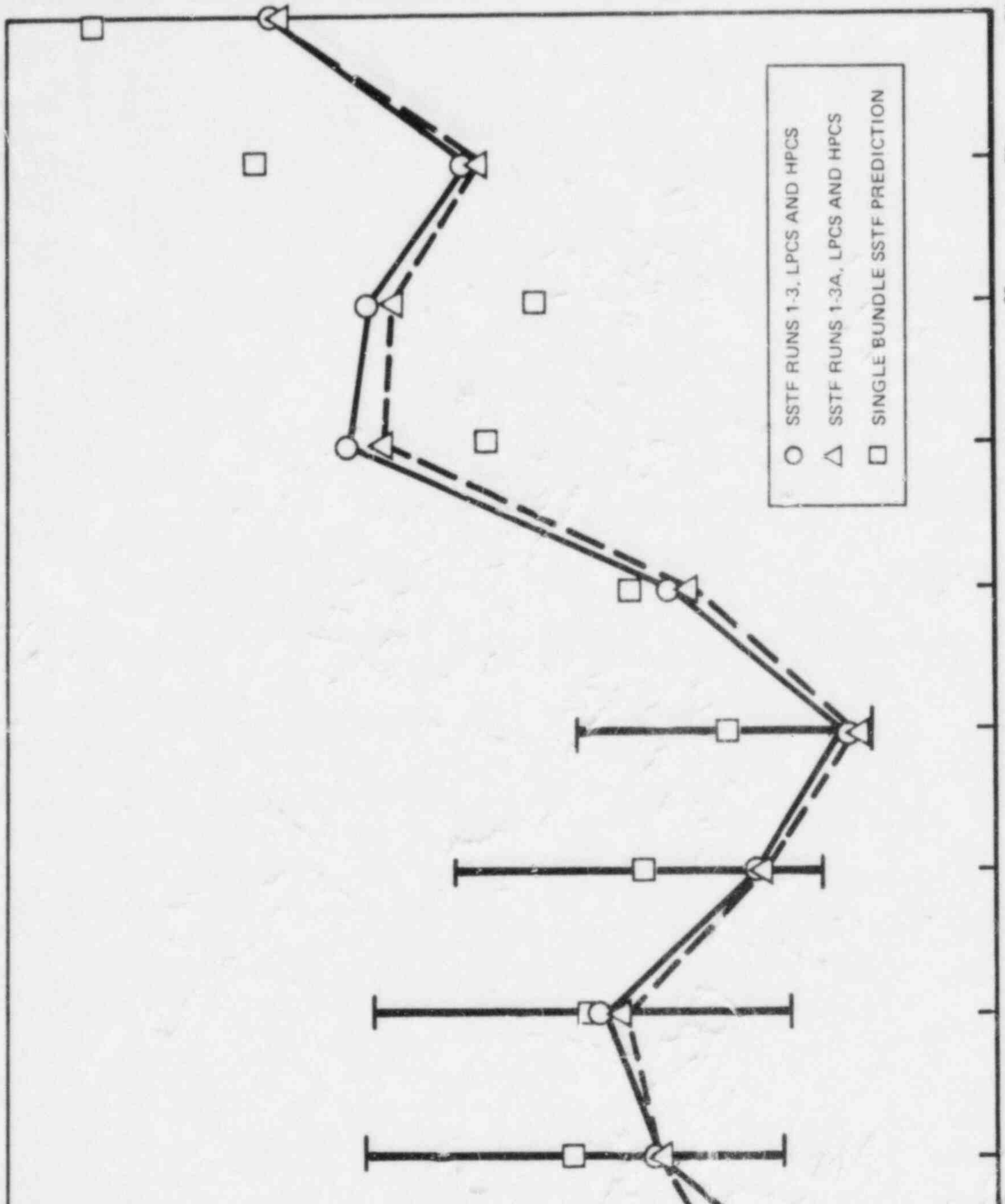

Figure 1F. Comparison of Prediction and SSTF Test for the Double Header, Column 6

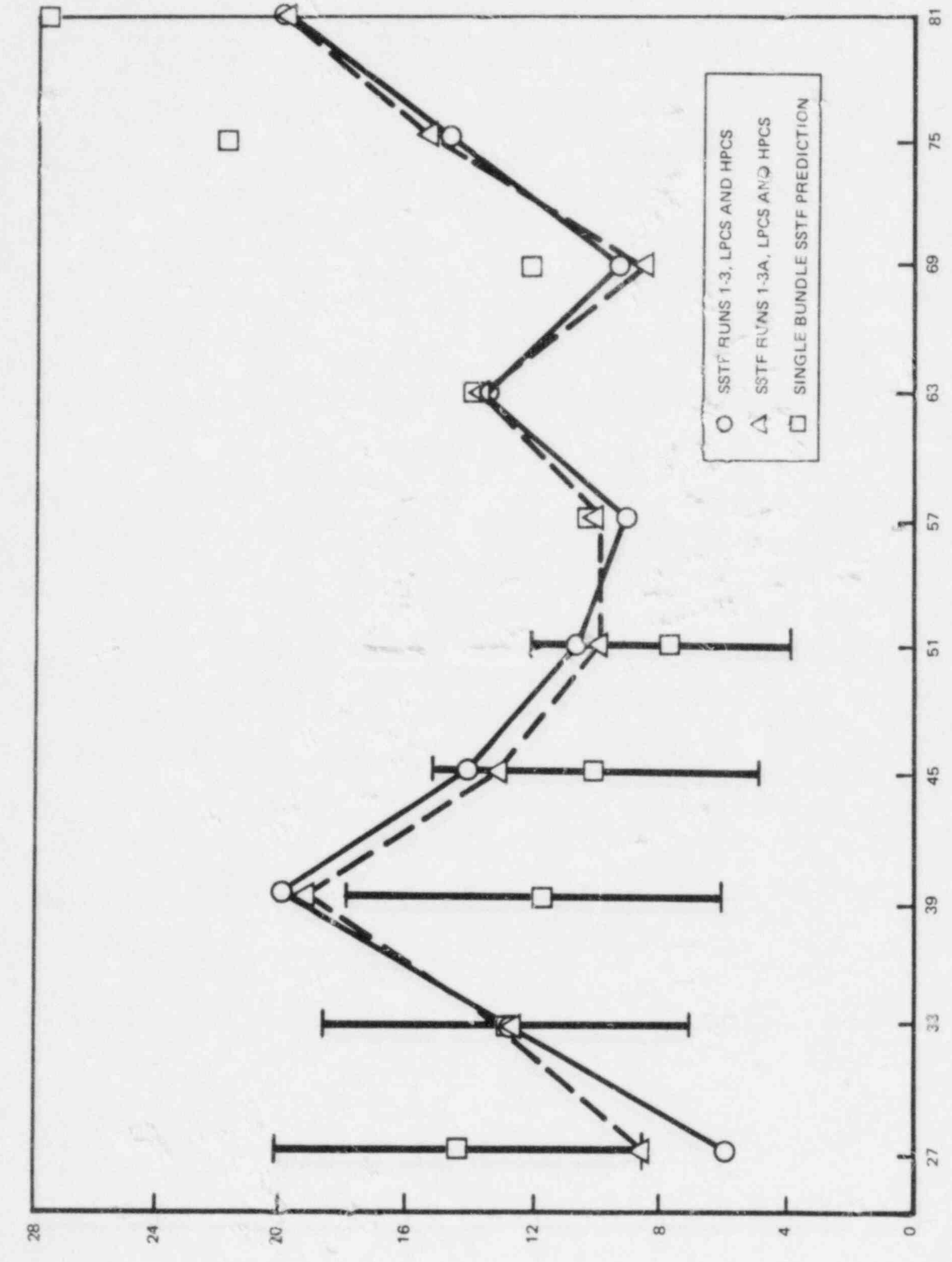

Figure 1G. Comparison of Prediction and SSTF Test for the Double Header, Column 5

QUESTION 1c - RESPONSE

All appropriate uncertainties in SSTF were included in the error bands submitted with the pre-test prediction. As described in the prediction report,* each of the potential sources of error was evaluated, the magnitude of the error quantified, and the influence on measured bundle flow calculated. The sources evaluated included both hardware installation variations and measurement errors in experimental parameters.

The influence of any particular parameter must be evaluated locally at each bundle location. The local differences in influence are the cause of the different-sized uncertainty bands at different radial locations. In general, individual nozzle aiming angle and flow skew produce the largest uncertainties. Since these variations are present in the same magnitude in all four sets of test data involved (single nozzle tests in steam, simulator single nozzle tests in air, 30° sector simulator tests in air, and 30° sector tests in steam), the SSTF 30° sector tests in steam contribute about one-fourth of the total variance at each bundle location. This value includes all sources of error.

One component of this error is the random uncertainty in the bundle flow measurements at SSTF. This uncertainty is about 5% of the measured flow. Calibration errors in the weir tube readings result in systematic error rather than a random one. As discussed in the pre-test prediction report, systematic errors were excluded from the uncertainty bands because they subtract out in the analysis. The standard deviation of the total measurement uncertainty was determined** to be 8% over the range 1 to 20 gpm.

*S. K. Rhow and S. A. Sandoz, "Pre-Test Prediction for SSTF Core Spray Tests" (Appendix D of this document).

**D. W. Danielson, "Lynn SSTF Bundle Flow Measurement System Description and Calibration," General Electric Company, August 1979 (NEDO-24706).

QUESTION 2

With regard to the GE spray distribution methodology and its confirmation by the Lynn tests for 218" I.D. BWR/6 plants:

a) State the spray flows for one CS system and for two CS system operation that GE believes would be the minimum present in any bundle following any size LOCA under all conditions when LOCA analyses take credit for core spray cooling.

b) Describe in detail all steps in the derivation of the minimum values presented in 2-a. For example, are the flows presented the mean values of "GE methodology superposition" calculations less 2-sigma?

c) Describe how differences between the predicted post-LOCA conditions and test or calculational conditions assumed or measured in 2-b are accounted for, including but not necessarily limited to:

   1) post-LOCA pressures outside the range where HSF (and/or Lynn) tests were performed (i.e., you used 29.5 psia, but credit is taken for spray cooling up to ≈150 psia);

   2) spray temperatures outside the range tested, or a combination of post-LOCA pressure and spray temperature different from any combination tested.

QUESTION 2 - RESPONSE

It was agreed that this question would be answered during the specific plant application phase of the overall core spray effort. The answer to this question was not deemed necessary for approval of the methodology.

QUESTION 3

a) Compare the minimum measured flows (#1-b less the uncertainty stated in #1-c) to the minimum flows stated in #2-a, and compare both to the BWR/6 - 218" minimum design spray flow of 3.25 gpm per bundle.

b) If any of the values presented above are less than 3.25 gpm, explain how you will justify acceptability of the spray cooling coefficients assumed in the 218" BWR/6 ECCS "Appendix K" analyses, which are based on FLECHT tests with 3.25 gpm supplied to the electrically heated single bundle.

Provide a schedule for any new tests (FLECHT, etc.) you may propose.

QUESTION 3 - RESPONSE

It was agreed that this question would be answered during the specific plant application phase of the overall core spray effort. The answer to this question was not deemed necessary for approval of the methodology.

QUESTION 4

With regard to application of the GE superposition methodology to plant sizes other than 218" (where Lynn results are not available for direct comparison, i.e., 238" BWR/6 or 251" BWR/4, etc.), and considering the differences between the Lynn results discussed above and the "superposition methodology" results (including measurement uncertainty subtracted from the Lynn results), quantitatively discuss how much reduction will be applied to the minimum channel flow calculated for such plants by applying the GE superposition methodology.

QUESTION 4 - RESPONSE

The General Electric core spray distribution methodology combines superimposed single nozzle spray distribution in steam with interaction factors obtained from multiple-nozzle tests in air. The key assumption inherent in this method is that the multiple-nozzle air tests can give an interaction effect which is correct for steam. This approach is valid because most of the condensation of steam on the spray occurs very near the spray nozzle.

Experimental results demonstrating this fact are contained in the response to Question 12-2.

Away from the nozzle, where the interactions between sprays occur, the spray water is at or near saturation temperature. Therefore, the interactions are only hydrodynamic and can be simulated in air tests.

The objective of the tests at Lynn was to demonstrate that the core spray methodology successfully predicts multiple nozzle spray performance in steam. This successful demonstration confirms the assumption of separability of thermodynamic and hydrodynamic effects.

Since the confirmed assumption of separability of thermodynamic and hydrodynamic effects is based on the general result of condensation effects occurring very near to spray nozzles, the confirmation is equally valid for the spray systems of other plant designs. Therefore, with specific full scale air tests and single nozzle steam tests for the particular reactor design, the prediction methodology can be applied with the same confidence.

QUESTION 5

On the morning of July 5, 1979 an NRC staff member (R. Woods) witnessed two representative tests at the Lynn facility. He noted and commented on the fact that certain low-flow bundle locations did not appear to benefit significantly from operation of two spargers as opposed to one sparger (the spray flow to those locations remained essentially the same for a one and for a two sparger steam test). Since justification for continued operation of BWRs pending completion of final testing (which includes Lynn testing) partially relies on the minimum-bundle-spray-flow margin believed to be present due to 2 sparger operation, Woods' observation would appear to be a significant result of the Lynn testing. However, your report does not specifically mention these results and does not present data in sufficient detail to verify or refute the observation.

a) Accordingly, provide core flow maps (in the format of Figures C-1 through C-37) for all spray distribution tests performed to date. Also provide an index which indicates the groups of tests (i.e., two or more) that have comparable steam flow, spray flow, and temperature conditions and which involve one sparger and then both spargers operating together (indicate the series run the morning of July 5, 1979). Provide a test matrix for the additional figures containing the information on page 25 of your report. The only such series now in your report are Figures C-1, C-3 and C-5 (for upper, lower, and both spargers at 29.5 psia, no core steam flow, and 145°F), and Figures C-2, C-4, C-6 which apparently represent a repeat of those tests. For position x=6, y-6, both of those series show less flow for two sparger operation than for either sparger operating alone.

b) Quantitatively comment on the apparent failure of the superposition principle for one and two sparger operation.

QUESTION 5a - REPONSE

Data from all of the 30° sector tests conducted in steam in the SSTF are included in Appendix C of this confirmation report. The test conditions in these tests are summarized in the test matrix in Figure 4-6 (p. 4-10) of this report. The test series run on July 5, 1979 was CS-41, CS-44, and CS-45 (CS-41 and CS-45 were witnessed by R. Woods). The tests shown in the matrix are reported in Figures C-1 through C-37 and are cross-referenced on p. C-1. There are no additional series of tests other than those reported in C1 through C6 which form a series for upper, lower, and both spargers.

QUESTION 5b - RESPONSE

The GE methodology is based on superposition modified by full-scale interaction effects. When calculating double sparger performance, simulator nozzle tests are conducted with both spargers operating and a double sparger interaction factor is developed. This double sparger interaction factor was used to develop the pre-test prediction for double sparger performance. In particular, it can be noted that for the position in question (x=6, y=6), the predicted flow matches the measured flow very well (see Figure 5A). Further, while the minimum location for both spargers is not necessarily at the same location as the individual spargers, the double sparger minimum flow is approximately twice the single sparger minimum flows (see Figure 5B). This is consistent with previous double sparger observations.

DOUBLE SPARGER OPERATION

PREDICTION OF DOUBLE SPARGER DISTRIBUTION
REQUIRES DOUBLE SPARGER INTERACTION EFFECT

AT R = 51 inches IN TESTS 1-1, 1-2, 1-3:

TEST	SPARGER	PREDICTED FLOW (gpm)	MEASURED FLOW (gpm)
1-1	HPCS	4.0 ± 1.3	$\frac{4.55 + 4.29}{2} = 4.4$
1-2	LPCS	4.2 ± 2.2	$\frac{7.84 + 5.0}{2} = 6.4$
1-3	BOTH	7.7 ± 3.6	$\frac{10.5 + 4.10}{2} = 7.3$

Figure 5A. Double Sparger Operation

SINGLE VERSUS DOUBLE SPARGERS

TEST	SPARGER	LOCATION	FLOW (gpm)
1-1	HPCS	(4, 5)	2.0
1-2	LPCS	(4, 5)	2.6
1-3	BOTH	(6, 6)	4.1

Figure 5B. Minimum Bundle Flows

QUESTION 6

With respect to the steam flow and flow paths used during the Lynn tests, you state that the maximum steam flow that can be provided to the fuel bundles without "significant" droplet diversion is around 20,000 lb/hr. We note, however, that such a steam flow rate corresponds to a decay heat removal (due to vaporization) of only about 2% of full core power. Credit is taken for core spray cooling under conditions when decay heat is at least 5% and/or significant depressurization (flashing) is still occurring. We are therefore concerned that the steam flow regime investigated at Lynn is not representative of postulated post-LOCA conditions. Accordingly, please justify the acceptability of the steam flow and steam flow paths in the Lynn facility regarding ability of that facility to conservatively represent predicted post-LOCA conditions, including but not necessarily limited to the following:

a) Qualitatively explain why the "balanced steam flow" condition (equal steam flows through "fuel" bundle and upper plenum/steam separators) represents the worst case for methodology confirmation.

b) Quantitatively, for 29.5 psi pressure and 145°F spray flow (or similar conditions where you obtained extensive data) provide a plot of minimum spray flow measured in any channel (R≥27") as a function of core steam flow. On the same plot, indicate any data points you obtained with different steam flow splits (i.e., not "balanced" between fuel and separators). Indicate the range of core steam flow expected during times when credit is taken for core spray cooling, including all sizes and locations of postulated LOCAs.

c) Explain the basis of the statement on page 3-12 that "The facility design with no vapor injection into the bypass region is judged acceptable."

d) Justify the conservatism of the steam flow distribution selected for the tests, since other parallel channel steam flow rates (not necessarily even in the same direction) result in the same ΔP and may yield a lower minimum single channel spray flow.

QUESTION 6 - RESPONSE

Core steam flow in a reactor would vary with time and system conditions following a LOCA. From CCFL considerations, flow limiting effects will influence the highest bundle spray flows ($\geq$16 gpm) for core vaporization conditions at a "Lynn equivalent" of 20,000 lb/hr core steam injection. Higher core steam flows during earlier transient periods would produce CCFL effects in bundles and cause them to receive lower spray down flows. For higher core steam flows, the upper plenum flow regime would be dominated more by CCFL effects, and core cooling would result primarily from the flowing steam.

Test results and analyses demonstrate that reduced liquid down flow in the bundles due to CCFL at higher steam flows is more than compensated for by increased convective cooling from this higher steam flow. Engineering analysis of single-phase steam flow in a fuel bundle, using standard convection heat transfer correlations, show that the convective steam cooling is equivalent to Appendix K spray cooling heat transfer for a "Lynn equivalent" steam updraft of 22,000 lbm/hr. This calculation assumed no spray water entering the top of the fuel bundle.

Therefore, Lynn core spray tests covered the full range of updrafts where the addition of spray water is required to maintain the heat transfer assumed in licensing models. In addition, as detailed below in the responses to specific questions 6a through 6d, the insensitivity of core spray capability to steam updraft can be extrapolated well beyond the 20,000 lb/hr limits of the Lynn facility.

QUESTION 6a - RESPONSE

The GE core spray methodology provides a best estimate of the spray distribution. The multiple nozzle steam experiments at Lynn were intended to evaluate the adequacy of the key assumptions in the model, i.e., the separability of thermodynamic and hydrodynamic effects. While it was not entirely necessary to have exact reactor conditions in order to evaluate that assumption, it was considered appropriate to make the test conditions reasonably representative. Since the tests evaluate a best estimate prediction method, rather than provide bounding flow values for reactor application, the approach of selecting worst case conditions is not appropriate. The question of conservative application of this best estimate core spray prediction methodology should be addressed in the context of the entire reactor licensing basis. The "balanced steam flow" condition was selected as a representative case for methodology confirmation. Single nozzle analysis indicated that the distribution would not be sensitive to steam flow. This is illustrated in Figure 6A1 by results of drop trajectory calculations which demonstrate this lack of sensitivity for drop sizes and velocities typical of reactor LOCA conditions. Lynn sensitivity study test results (see Figures 6A2 and 6A3) confirmed that the distribution is not sensitive to the steam flow conditions. Therefore, the conditions tested are quite representative, and the confirmation of the separability assumption is applicable over the full range of postulated LOCA core spray conditions.

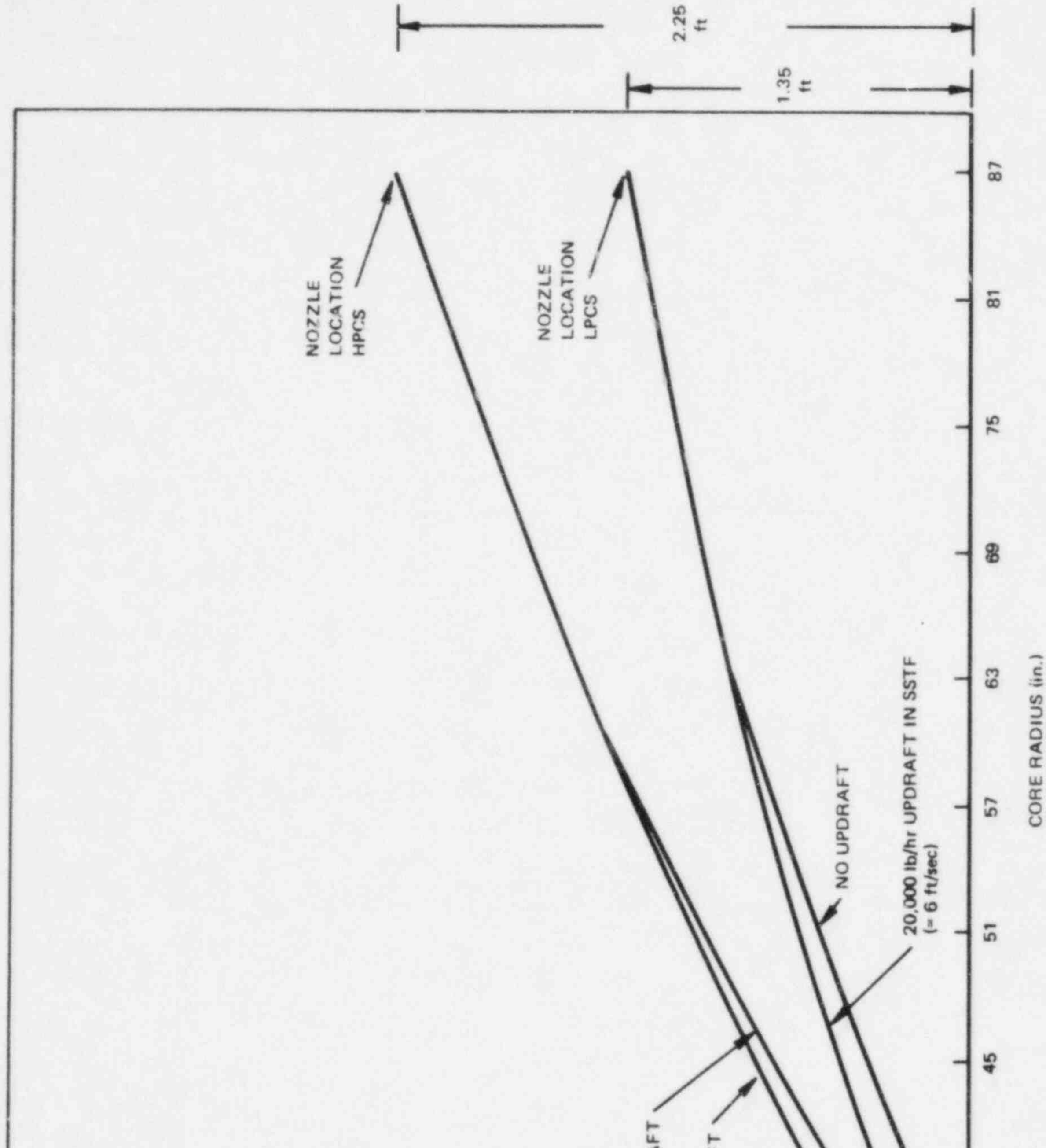

Figure 6A1. Influence of Updraft on Spray Trajectories

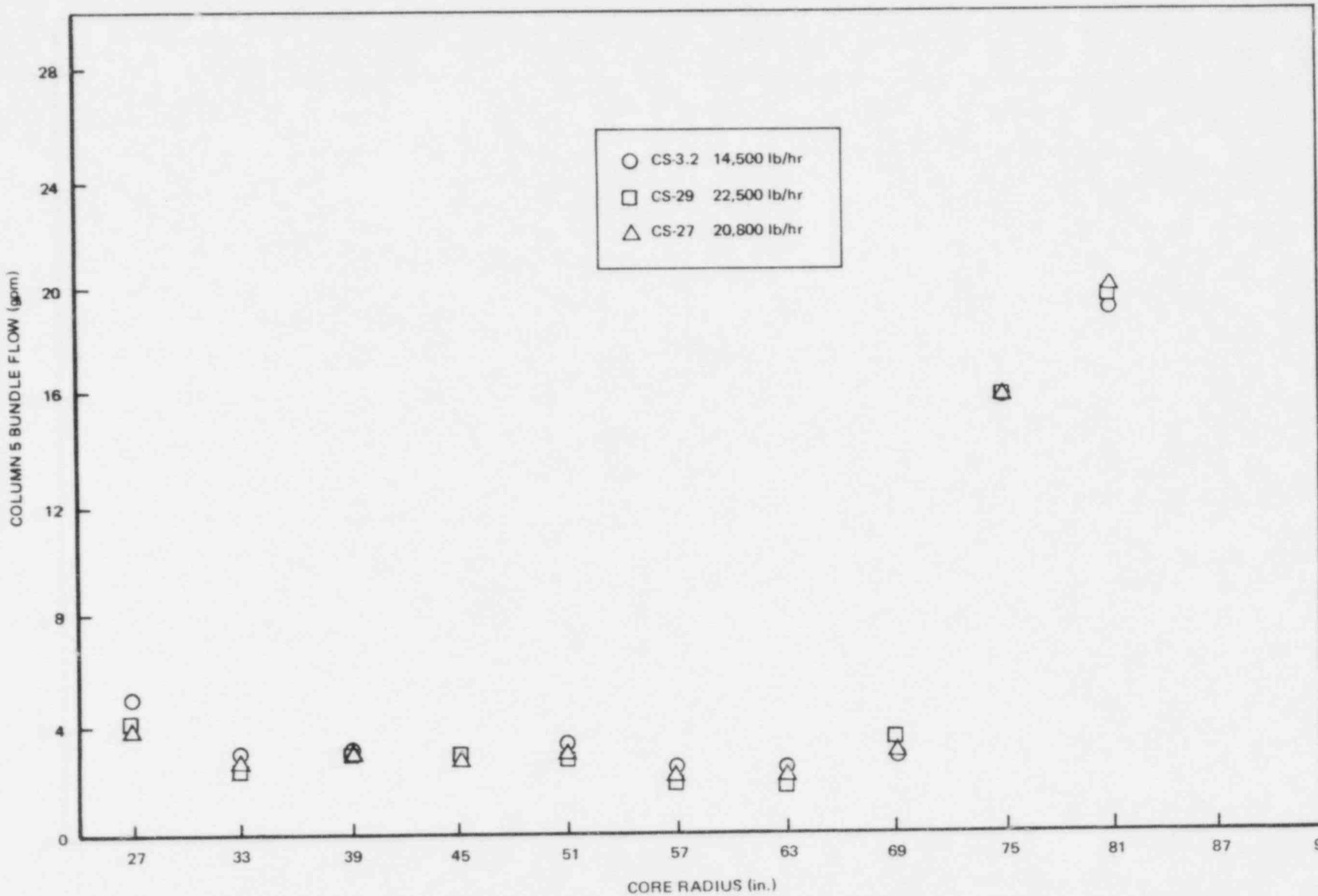

Figure 6A2. Steam Updraft Effect on Spray Distribution for HPCS

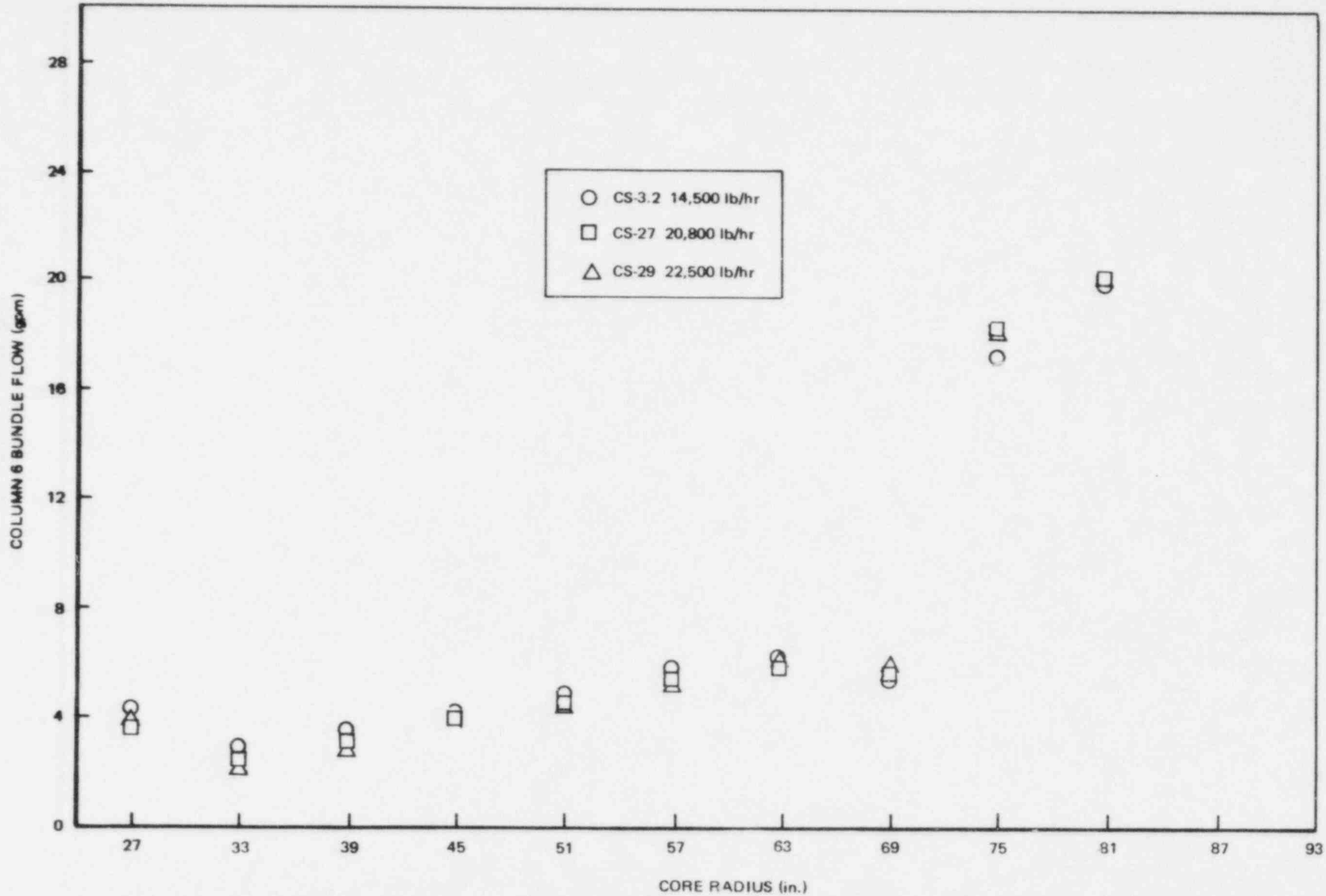

Figure 6A3. Steam Updraft Effect on Spray Distribution for HPCS

QUESTION 6b - RESPONSE

The bundles adjacent to the centerline in a 30° sector are the ones most representative of 360° results. The requested minimum individual bundle flows for varying core steam flow rates are illustrated in Figure 6B. Note that the "balanced" split between core and separator steam flows is represented by the single point along the core steam scale. The other values represent different steam flow splits (i.e., total steam flow constant for fixed spray flow and temperature).

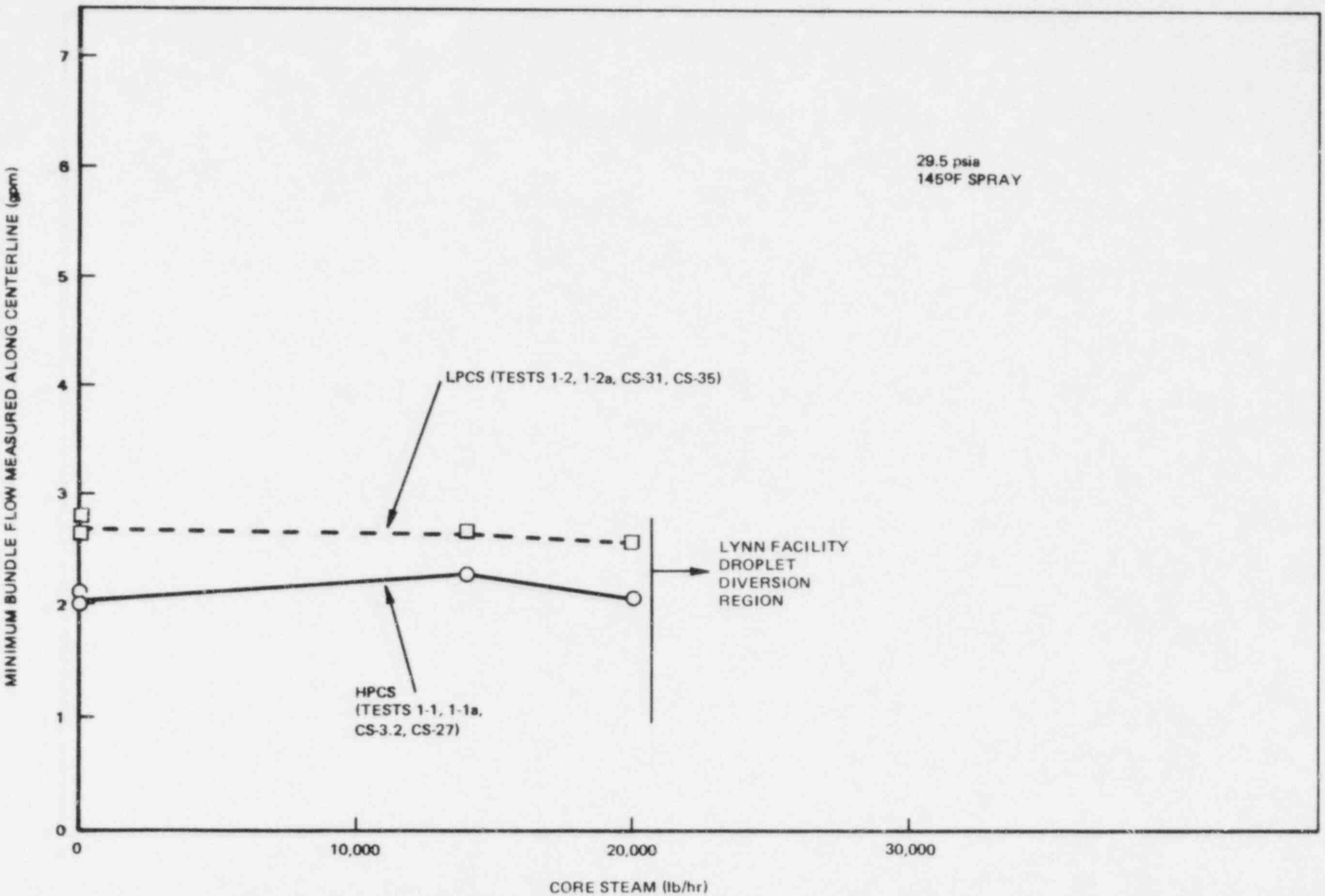

Figure 6B. Steam Updraft Effect

QUESTION 6c - RESPONSE

The facility design with no vapor injection in the bypass was judged acceptable because the region of negligible droplet diversion extended from zero to 20,000 lbm/hr steam injection. This updraft range encompasses the region of interest for core spray methodology confirmation, as discussed above.

QUESTION 6d - RESPONSE

The selection of a typical steam flow profile is appropriate to have representative conditions for confirmation tests. However, since the core spray methodology is a best estimate model, it is not necessary to demonstrate bounding results for all parameters, unless they are shown to have a significant effect on the test results. Calculation with the single nozzle model indicated that the distribution would not be sensitive to steam updraft effects. Therefore, a single representative radial profile was selected for steam injection for all Lynn tests. The lack of sensitivity observed in the Lynn tests (see Figures 6A2 and 6A3) confirms this approach.

QUESTION 7

State the location of the "steam vent" (p. 4-6) and describe how flow out the steam vent was controlled and/or measured.

QUESTION 7 - RESPONSE

The steam vent is at the top of the pressure vessel. Steam injected into the core region was controlled and measured with an orifice as an independent parameter. All of this steam passes into the upper plenum and is condensed. Steam into the steam dome region was controlled and measured with an orifice as an independent parameter. Some of this steam is drawn down the stand pipes where it is condensed. The remaining steam flows up the vent. The vent flow is controlled to maintain system pressure and is measured with an orifice (Figure 7).

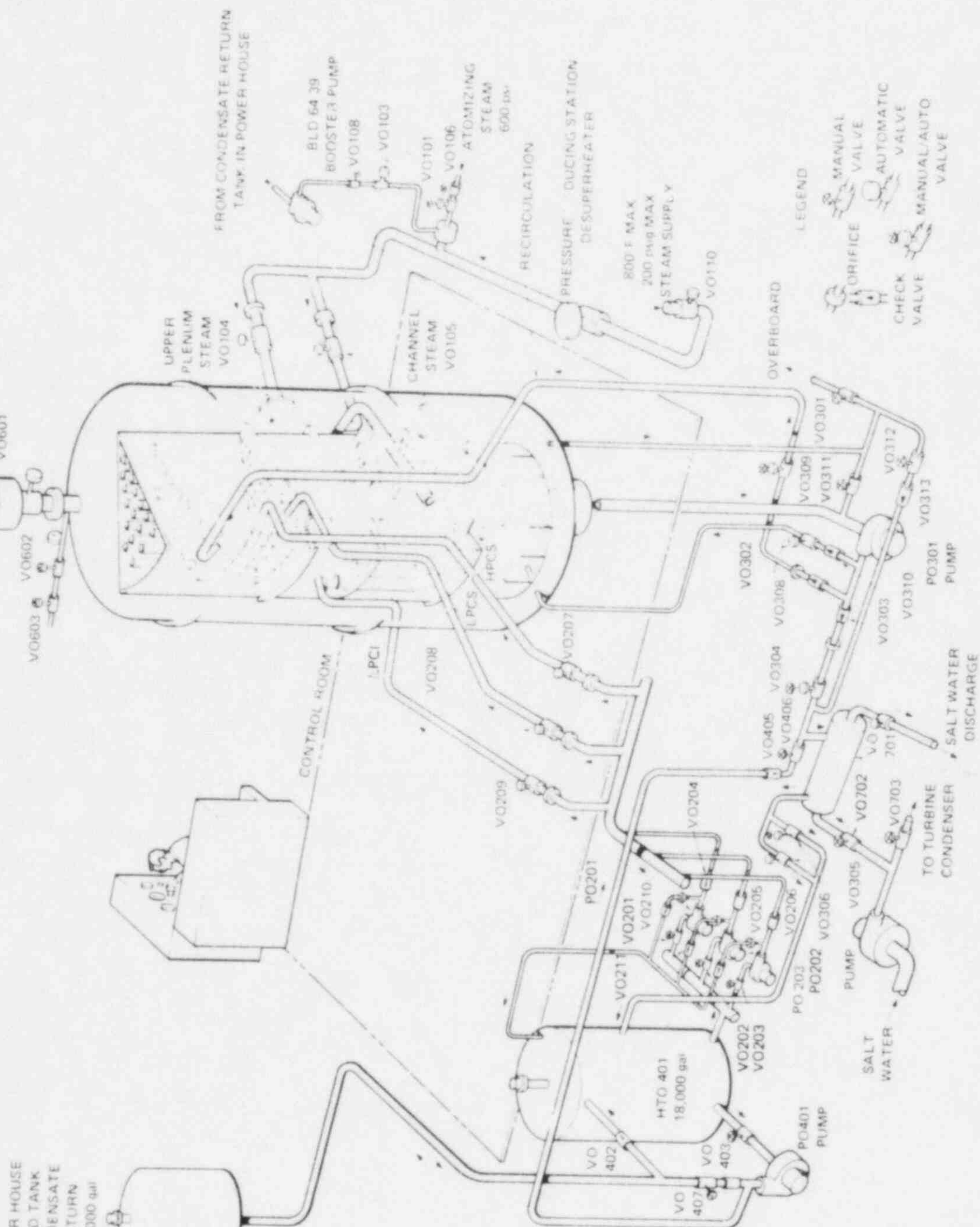

Figure 7. 30° Steam Sector Test Facility Loop Schematic

QUESTION 8

On page 5-8, Figure 5-5, centerline flows at Lynn vs. HSF are compared. However, other parameters such as nozzle spread (transverse to flow direction), azimuthal asymmetry, etc., may also be significant and may be different at Lynn compared to the HSF. Provide data to show that the other parameters were not significantly different.

QUESTION 8 - RESPONSE

The single nozzle tests in steam were conducted in SSTF primarily for the purpose of testing the facility's performance. The centerline flows are compared to assess any significant facility problems. As indicated by Figure 5-5 of the confirmation report,* single nozzles operated in the Lynn facility produce generally similar distributions to those from HSF tests (as expected). More complete comparisons with conditions closely matched between the two facilities confirm that the complete detail of the single nozzle distributions match well (as was required to achieve the excellent comparison with the multi-nozzle steam results).

Direct comparison of the flow measurements in the two facilities is complicated somewhat by different nozzle-to-collector positioning in the two facilities. Because of these differences, the following parameters are used to characterize single nozzle flow distribution: pattern area, center of gravity, width, length, and skew. These parameters are defined in Figure 8. The results for the comparisons of the SPRACO 2935 runs at HSF and SSTF, as shown in Table 1, indicate good agreement of the nozzle characterizations for the two facilities.

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*S. A. Sandoz, L. L. Myers, D. G. Schumacher, W. A. Sutherland, and G. E. Dix, "Core Spray Design Methodology Confirmation Tests", General Electric Company, August 1979 (NEDO-24712).

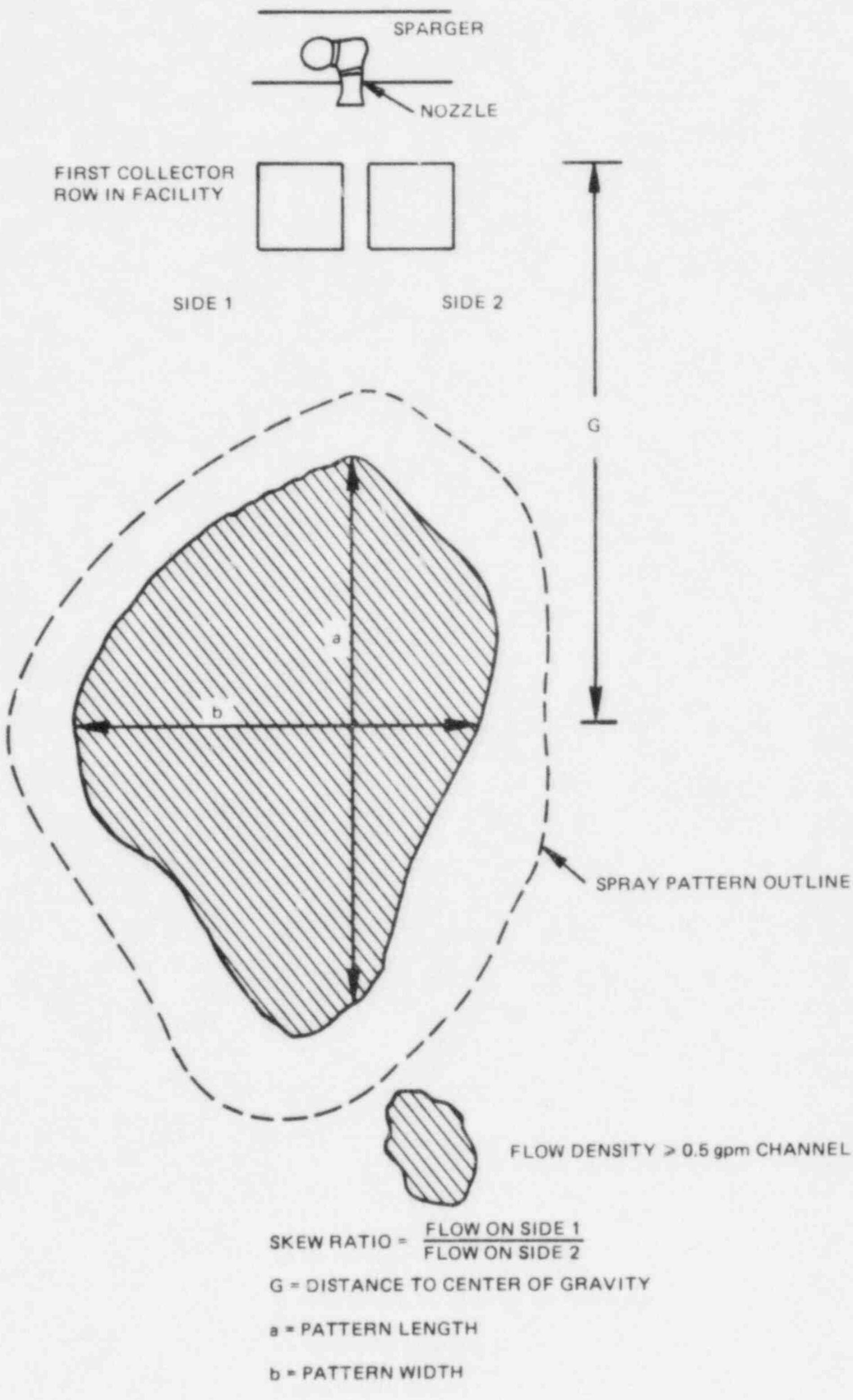

Figure 8. Parameters for the Characterization of a Flow Pattern

Table 1

COMPARISON OF S2935 PATTERNS AT HSF AND SSTF

	HSF 7801-97	SSTF T11E
Pattern Area	6.5 square feet	7.5 square feet
Center of Gravity (distance from edge of first collector row)	3.92 feet	4.71 feet
Breadth	30 inches	36 inches
Length	42 inches	42 inches
Skew Ratio	1.2	1.23

QUESTION 9

Explain the effects of running the calibration tests (p. 4-10) at a spray temperature different from the spray distribution tests (185°F vs 145°F resp.).

QUESTION 9 - RESPONSE

The calibration tests were run to evaluate the updraft drop diversion region in The Lynn Facility (cf. p. 5-9). The spray temperature was maximized in those tests in order to minimize condensation effects in the upper plenum: 185°F was the facility limit. There is little effect of this spray temperature difference on spray distribution for the same steam updraft (Figure 9).

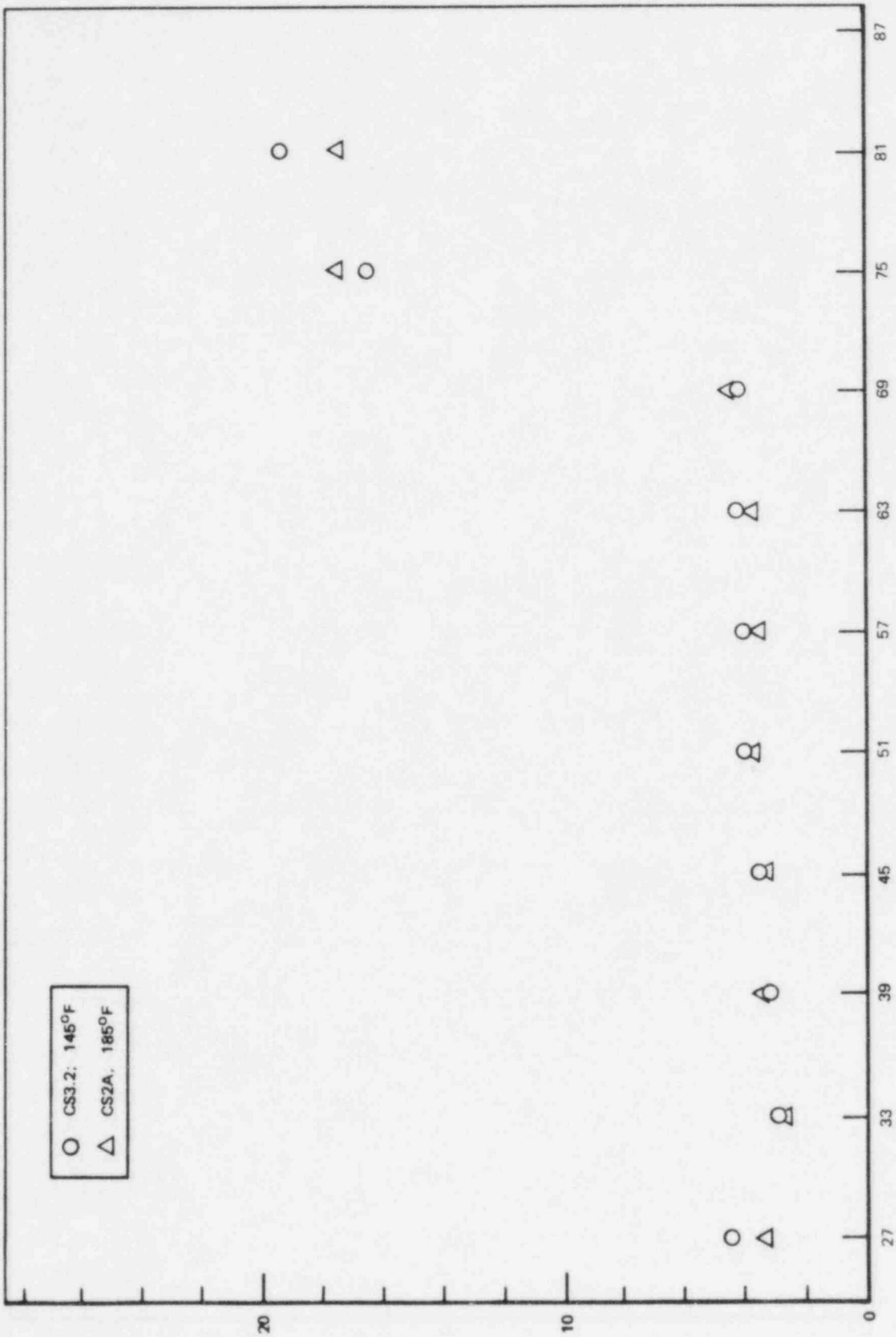

Figure 9. Temperature Effect

QUESTION 10

Provide the vertical axis' scale for Figure 8-3, pg. 8-4.

QUESTION 10 - RESPONSE

Figure 8-3 is for illustrative purposes to assist in the explanation in the text. The curves at 29.5 psia came from actual calculations, as shown on the attached Figure 10. The higher pressure curves were sketched from past experience with high pressure testing. No calculations exist for these exact nozzle configurations at higher pressure.

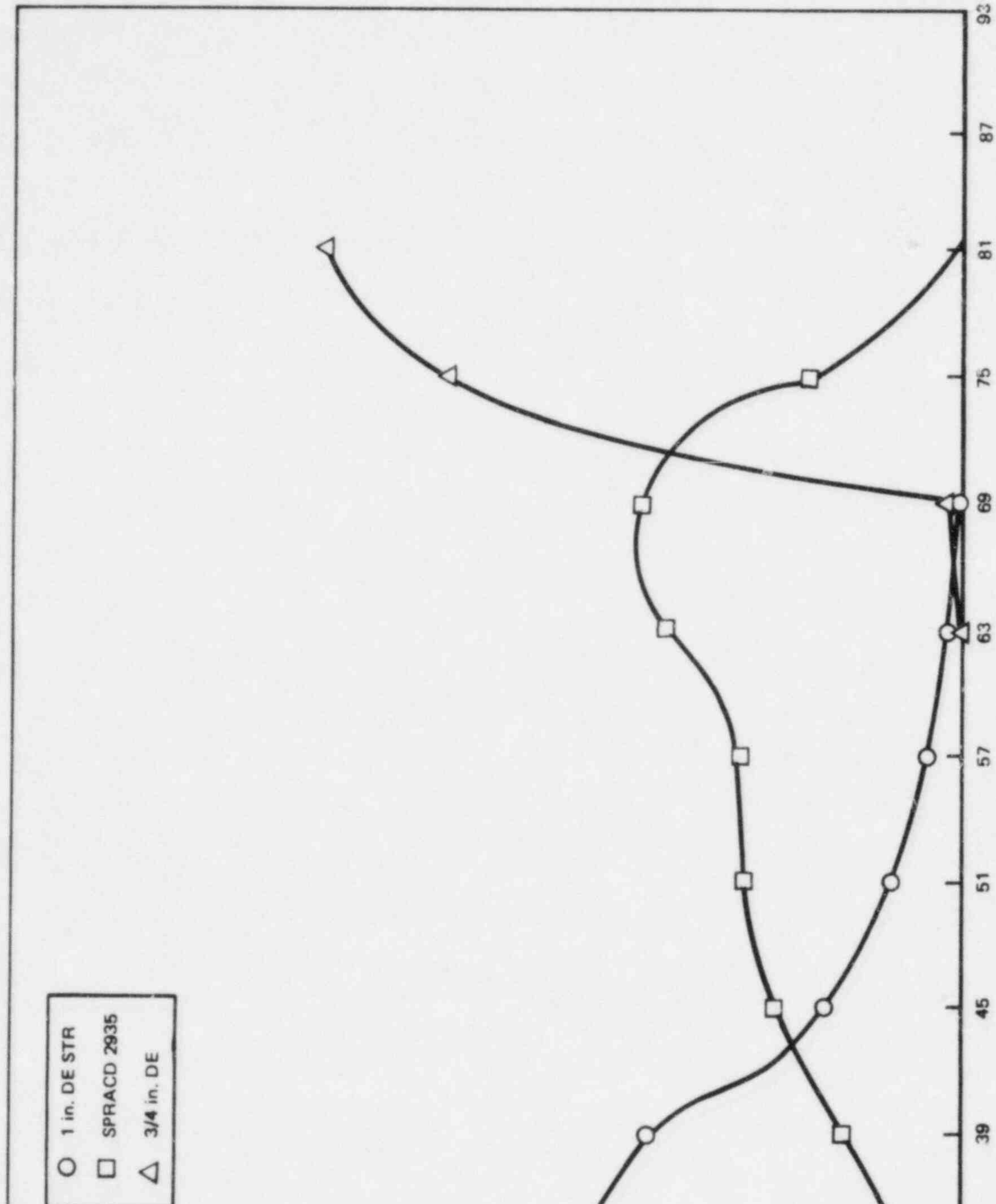

Figure 10. Genus Superposition Calculation for the LPCS in SSTF

QUESTION 11

Justify conservatism of the 30° sector minimum spray flow results compared to the full 360° geometry in view of Figure 4-2, which shows considerably more flow to some bundles for a 27° sector compared to a full 360° geometry (also see question #(12)-9) below).

QUESTION 11 - CLARIFICATION

The 30° sector experiment is not intended to define minimum spray flows for a 360° geometry. The 30° sector can provide representative results that are appropriate for evaluating the core spray methodology prediction capability. The sector air tests (Figure 11) demonstrate that the spray distribution along the center of a 27° sector is sufficiently representative of 360° results that comparisons between steam data and predictions for such a sector would be expected to identify any deficiencies with the prediction method.

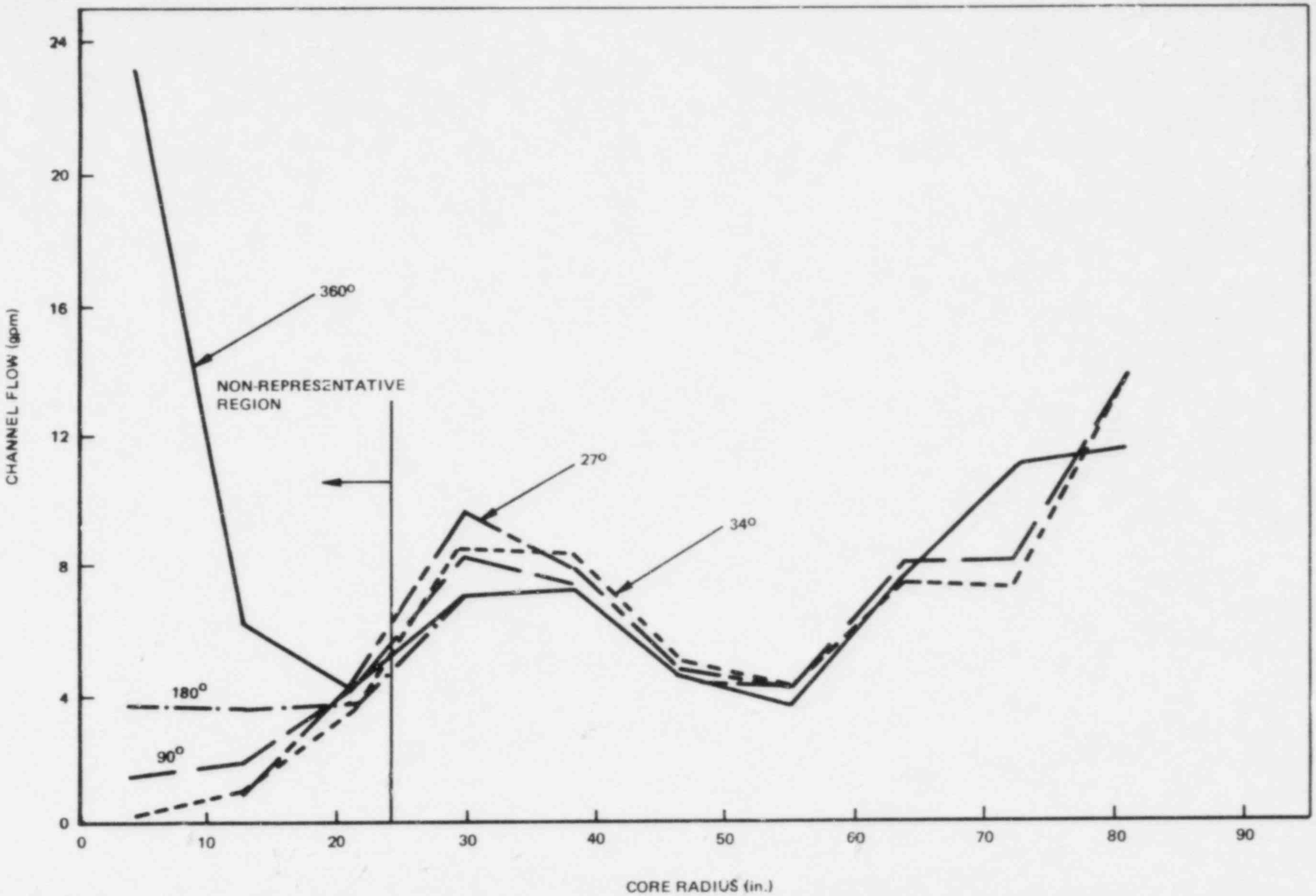

Figure 11. Core Spray Distribution as a Function of Sector Size For BWR/4-218 (VSF Air Tests)

QUESTION 12

Answers to several questions in a February 3, 1978 NRC letter* to GE were deferred until Lynn results became available. These deferred questions are listed below with the original number, and should be answered now that Lynn results are available.

*Letter from D. G. Eisenhut (NRC) to G. G. Sherwood (GE), "Request for Additional Information on GE Core Spray Distribution Program", February 3, 1978.

QUESTION 12-2

(1/19/78) Provide copies of the references cited by Dr. Sandoz at the 1/19/78 meeting regarding size of the steam condensing region surrounding a nozzle. Describe why GE believes that this data is appropriate for application to a BWR spray system (e.g., that the geometry, spray flow rates, subcooling, and steam pressures are similar in the referenced tests and in BWR's following a postulated LOCA). Please include pictures of typical BWR single nozzle spray patterns in steam.

QUESTION 12-2 - RESPONSE

The references cited in the January 19, 1978 presentation were as follows:

S. Weinberg, "Heat Transfer to Low Pressure Sprays of Water in a Steam Atmosphere," Institute of Mechanical Engineers Proceedings, 1952, Vol. 1B, No. 7, p. 240.

S. G. Simpson and S. Lynn, "Vacuum-Spray Stripping of Sparingly Soluble Gases from Aqueous Solutions," AIChE Journal, 1977, Vol. 23, No. 5, pp. 666-673.

Two other references are also available which apply to spray systems:

Y. Takahashi, M. Masuda, K. Aikawa and M. Tahara, "A Basic Study of Mixture Type Steam Condensers," Mitsubishi Heavy Industries Technical Report, 1972, Vol. 9, No. 1, p. 15-20.

A. Lekić, "Direct Contact Condensation of Vapour on a Spray of Subcooled Drops," Ph.D. dissertation, University of Waterloo, Ontario, Canada, 1976.

The information in the Lekić thesis agrees with the other references; however, Dr. Lekić did not obtain temperature measurements close enough to the spray nozzles to be in the high condensation rate zone.

A list of additional references on condensation rates are shown in Table 12-2-1.

A summary of the parameter ranges covered by data in the literature is shown in Table 12-2-2, along with comparable ranges for BWR spray systems. Although the entire flow rate range is not covered by open literature data, it has been covered in General Electric's own tests where no sensitivity to flow rate has been observed. In addition, the literature show lack of sensitivity to nozzle flow rate (Figure 8 of Simpson and Lynn and Figures 17 and 21 of Weinberg). A similar lack of sensitivity to system pressure is shown in Weinberg's data, which was taken over a range of 25 to 65 psia. Takahashi's data, with pressures as low as 1.5 psia, is shown to be quite comparable to Weinberg's in Figure 12 of the Takahashi paper.

The literature data brackets the expected BWR operating conditions for the other parameters shown. Because of the closeness of test conditions for the published data and for BWR spray systems, the BWR core spray is expected to operate with similar condensation rates.

Quantitative information on these condensation rates can be obtained from the attached papers. Three sets of data from these papers have been reproduced in Figures 12-2-1 and 12-2-2. These curves show measured temperatures of the spray water as a function of distance from the nozzle.

This impact of the very high near-nozzle condensation rates on spray distribution can be seen in Figures 12-2-3 and 12-2-4. Figure 12-2-3 shows a 1-in. VNC 14/16 before and after the abrupt cone narrowing has occurred. Quantitative information about this nozzle is included in NEDO-20566-3.*

Figure 12-2-4 shows a Spraying System 1-1/2H30 nozzle spraying into air and steam. The "necking" of the spray in steam as it exits the nozzle can be observed by comparing the two photographs. Quantitative information about this nozzle's performance is included in NEDO-24164.**

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*"Effect of Steam Environment on BWR Core Spray Distribution," General Electric Company, April 1977 (NEDO-20566-3).

**"Evaluation of the Dresden I Core Spray Sparger Performance in a Steam Environment," General Electric Company, December 1978 (NEDO-24164).

Figures 12-2-3 and 12-2-4 provide clear visual evidence that the influence of condensation on spray distribution happens in the region very near the nozzle exit.

Table 12-2-1

CONDENSATION RATE REFERENCES

G. G. Brucker and E. M. Sparrow, "Direct Contact Condensation of Steam Bubbles in Water at High Pressure," Int. J. Heat Mass Transfer, Vol. 20, pp. 371-381, 1977.

D. Hasson, D. Luss, and U. Navon, "An Experimental Study of Steam Condensation on a Laminar Water Sheet," Int. J. Heat Mass Transfer, Vol. 7, pp. 983-1001, 1964.

D. Hasson, D. Luss, and R. Peck, "Theoretical Analysis of Vapour Condensation on Laminar Liquid Jets," Int. J. Heat Mass Transfer, Vol. 7, pp. 969-981, 1964.

E. Kulic and E. Rhodes, "Direct Contact Condensation from Air-Steam Mixtures on a Single Droplet," Can Jl. of Chem. Engr., Vol. 55, p. 131, April 1977.

K. Miyazaki, I. Nakajima, T. Fujii-e, and T. Suita, "Condensing Heat Transfer in Steam-Water Condensing-Injector," Jl. of Nucl. Science and Technology, 10 (7), p. 411, July 1973.

Table 12-2-2

CONDENSATION RATE PARAMETER RANGE

Parameter	BWR Core Spray	Literature Data Base
Spray Flow (gpm)	10 - 90	0.4 - 44
System Pressure (psia)	15 - 120	1.5 - 65
Spray Temperature (°F)	100 - 180	50 - 200
Nozzle Pressure Drop (psi)	10 - 35	5 - 50
Nozzle Diameter (in.)	0.22 - 1.08	0.04 - 1.57

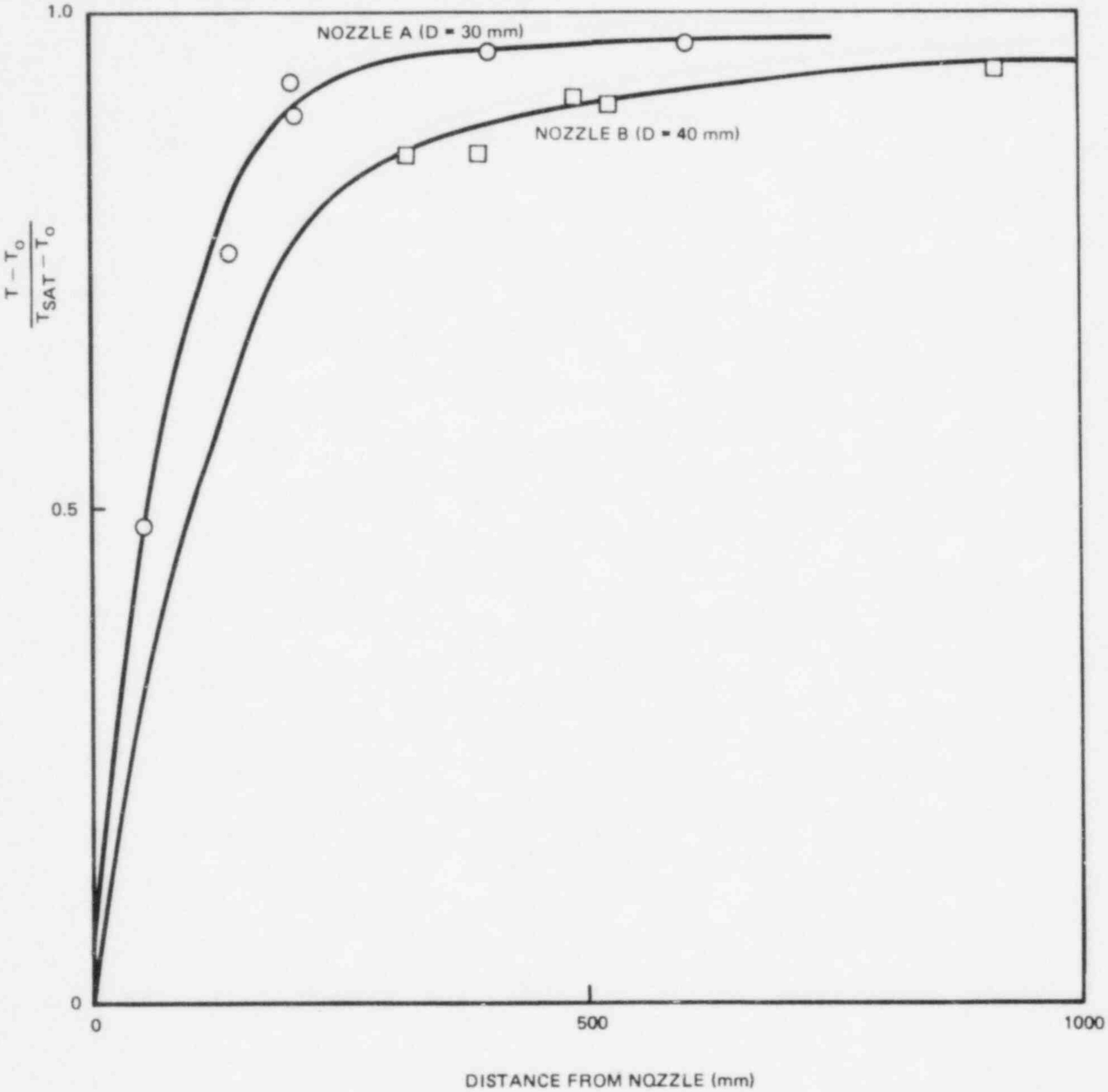
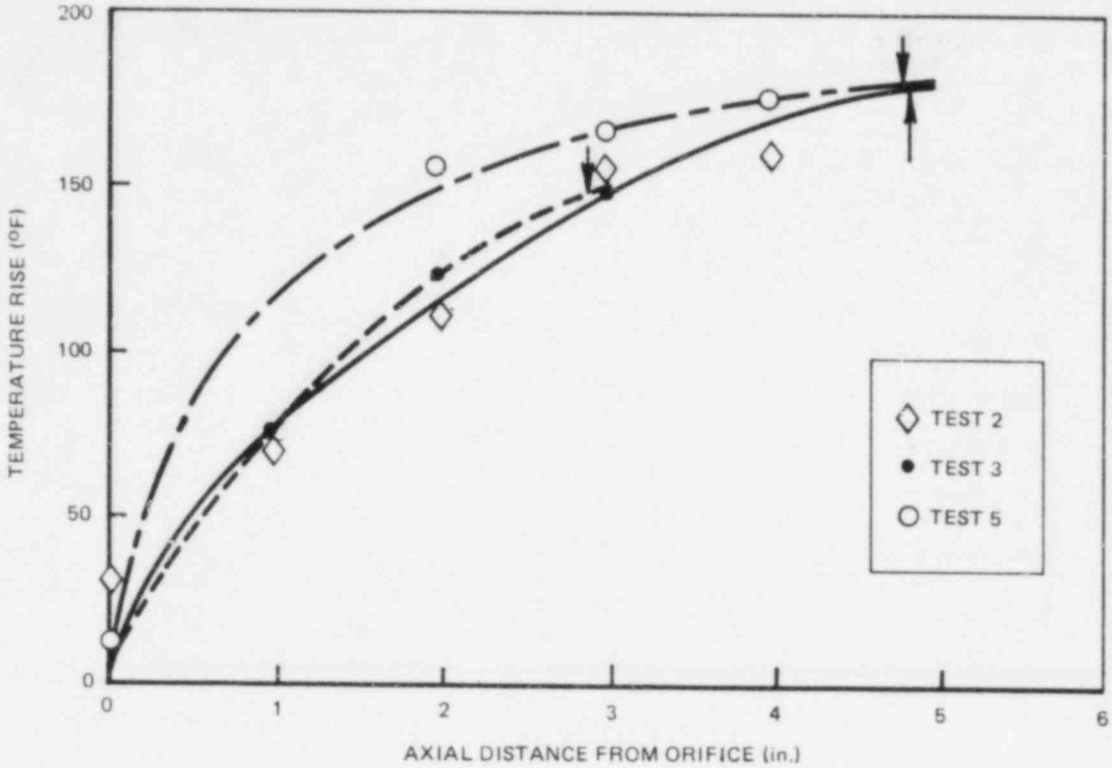


Figure 12-2-1. Replot of Figure 12 from Takahashi, et al., Showing Temperature Rise in a Spray as a Function of Distance From the Nozzle



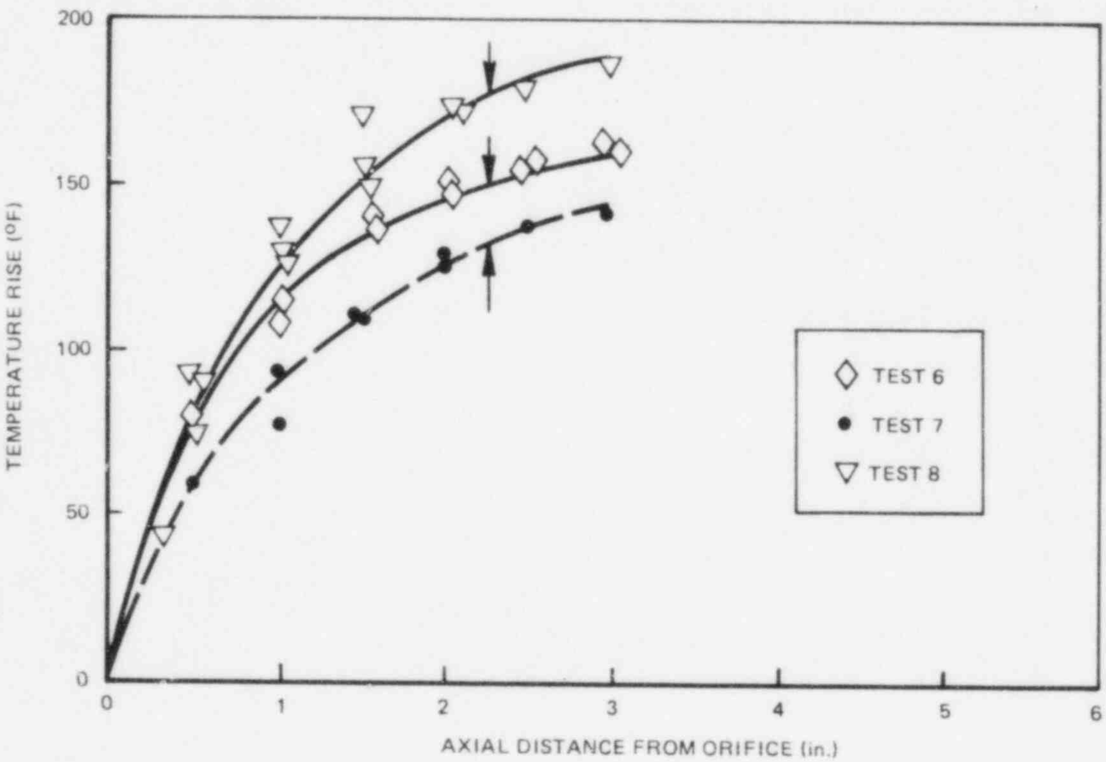
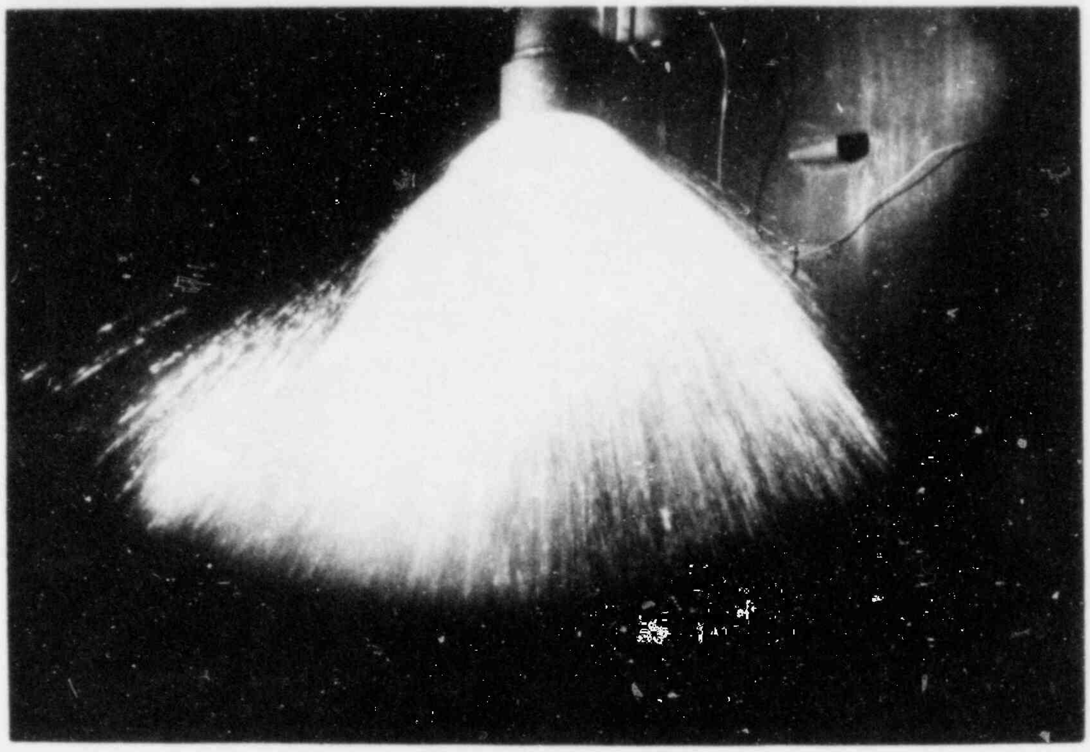
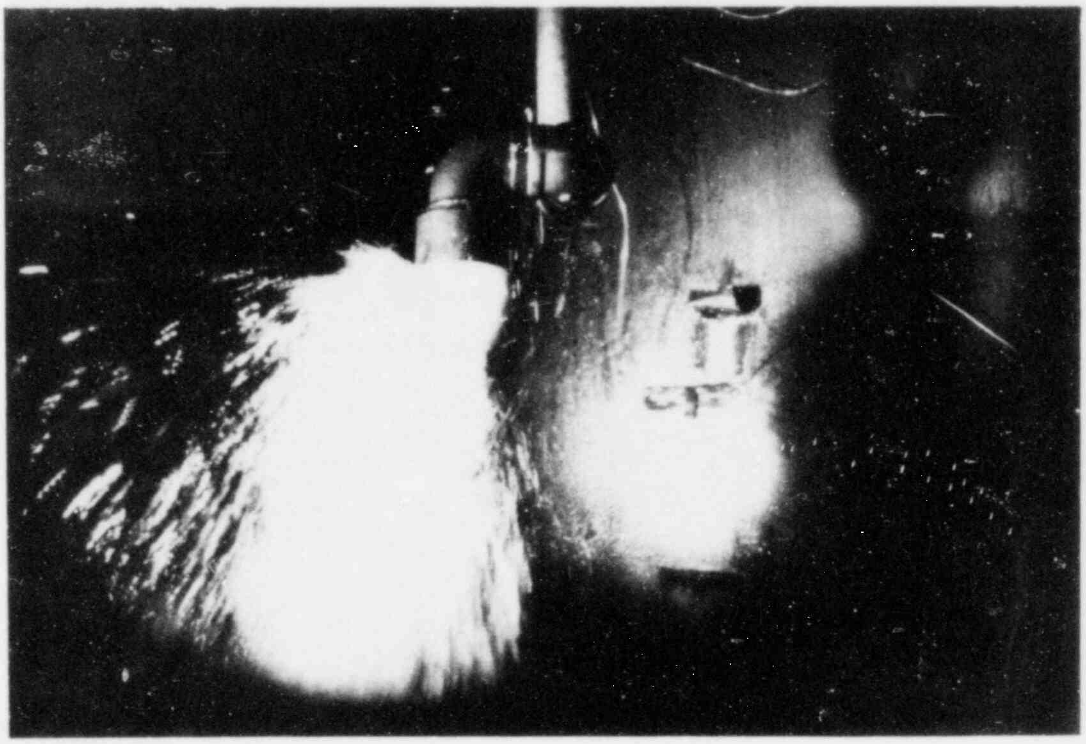


Figure 12-2-2. Weinberg's Data Showing Temperature Rise in the Film Phase of a Spray



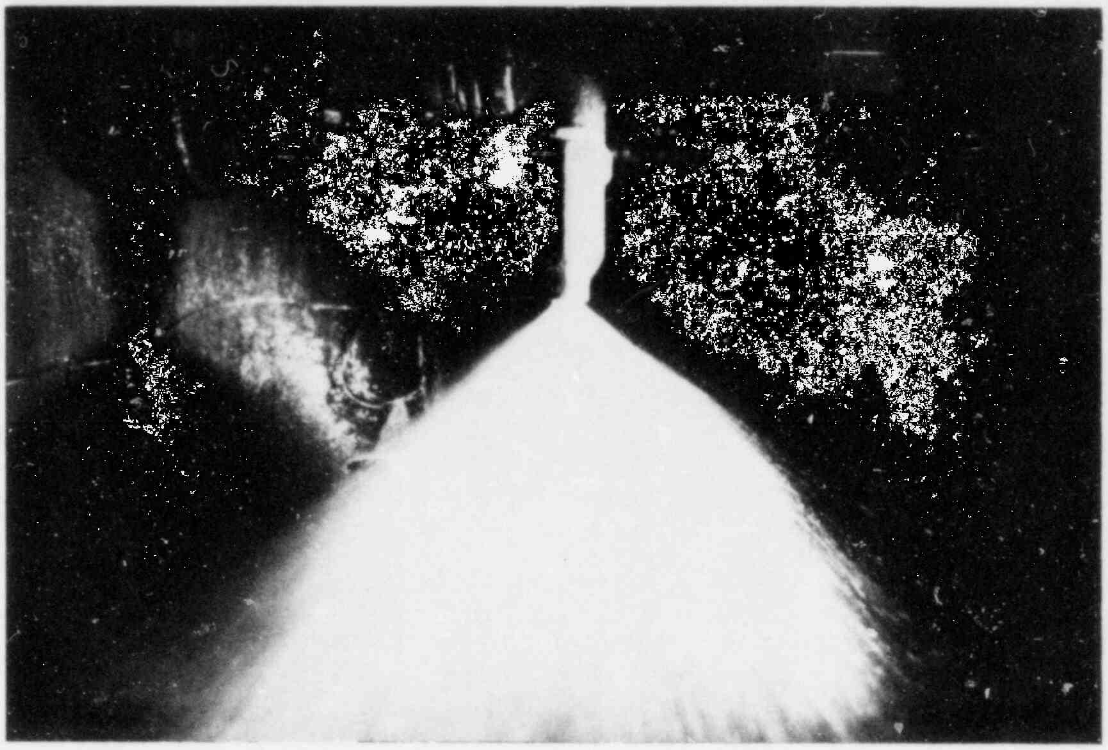
Water Temperature = 95°F
Flow Rate = 55 gpm
Environment = steam, 15 psia

Figure 12-2-3A. 1-in. VNC 14/16 with Open Cone



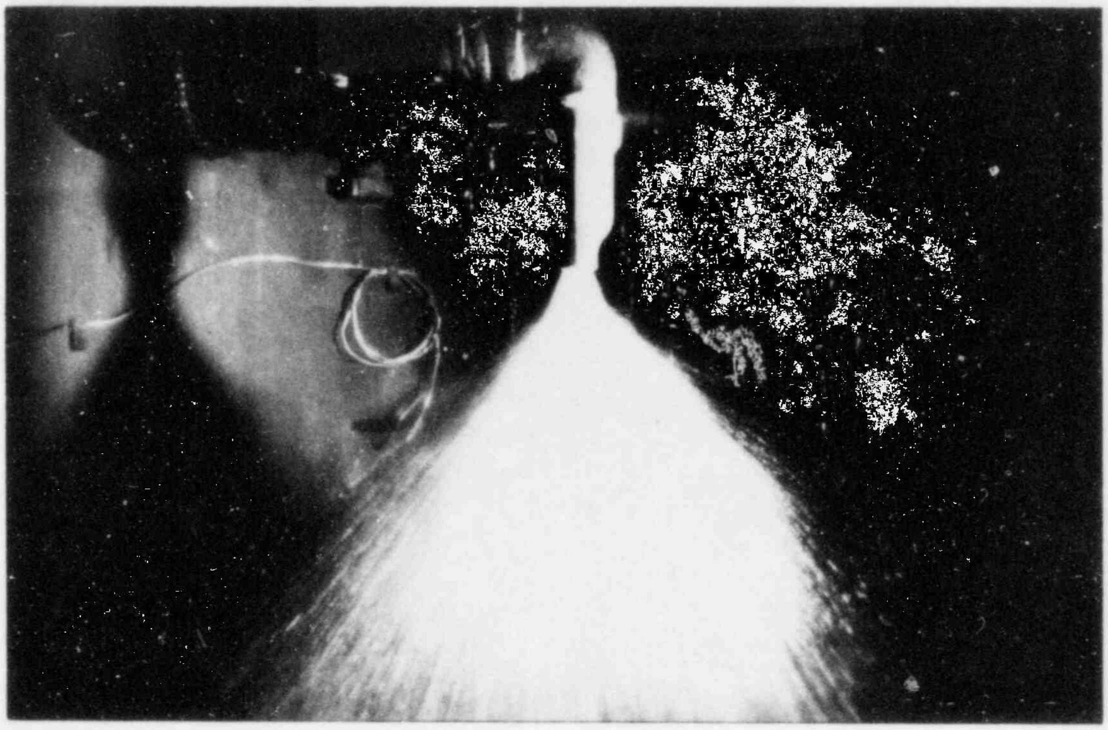
Water Temperature = 95°F
Flow Rate = 55 gpm
Environment = steam, 44 psia

Figure 12-2-3B. 1-in. VNC 14/16 with Narrowed Cone



Water Temperature = 95°F
Flow Rate = 40 gpm
Environment = air, 15 psia

Figure 12-2-4A. 1-1/2H30 Nozzle



Water Temperature = 95°F
Flow Rate = 40 gpm
Environment = steam, 15 psia

Figure 12-2-4B. 1-1/2H30 Nozzle

QUESTION 12-5

(1/19/78) We have heard several presentations regarding test programs to be accomplished at the Lynn, Massachusetts full scale 30°-sector steam test facility. Each presentation has emphasized investigation of either core spray (CS) distribution or counter-current-flow-limiting (CCFL) phenomena. In reality, the two are closely coupled. Please provide a written description regarding how the facility will be utilized to investigate the closely coupled relationship of CS and CCFL phenomena.

QUESTION 12-5 - RESPONSE

The core spray distribution methodology defines how the core spray water would be distributed over the top of the reactor when a steam environment exists in the upper plenum. The CCFL-related system response with core spray will be studied in the Lynn facility under realistic blowdown/refill transient conditions. The plan for these coupled experiments is identified in the BWR Refill-Reflood program contract (work scope), and is further defined in the 30° sector task plan* of that program.

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*D. G. Schumacher, "BWR-Refill-Reflood Program Task 4.4 - CCFL/Refill System Effects Tests (30° Sector) Experimental Task Plan," April 1981 (GEAP-24893).

QUESTION 12-6

(1/19/78) Quantify the expected effects of the smaller amount of steam condensation that is expected to occur in the "hydrodynamic" region. Why does GE expect that this condensation will not invalidate the "separability" hypothesis? (The January 19 meeting disclosed that approximately 25% of the total condensation is expected in this region.)

QUESTION 12-6 - RESPONSE

As discussed in the 1/19/78 meeting and Question 12-2 response, most of the condensation occurs in the film region near the nozzle exit, before the breakup of the spray into drops. Therefore, very little condensation occurs on the droplets in the "hydrodynamic" region.

Quantification of the amount of steam condensation in the hydrodynamic region is best seen by examination of typical data in Figure 12-6. This figure shows that the condensation rate, beyond a few diameters from the nozzle, is relatively slow. Therefore, the local steam velocities induced by condensation in the hydrodynamic region are very small and have negligible influence on spray drop trajectories. This conclusion is reinforced by the successful methodology confirmation tests.

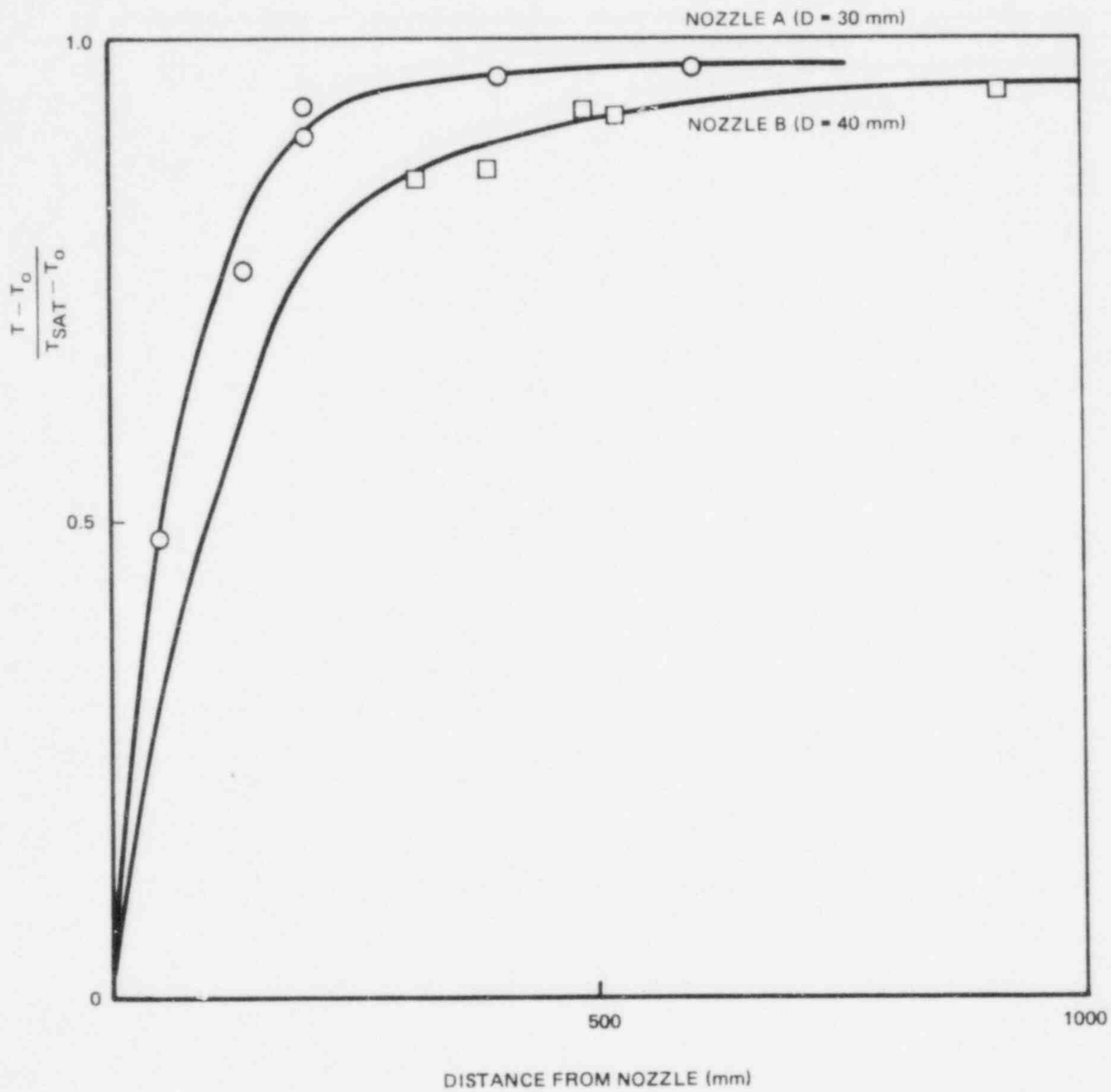

Figure 12-6. Temperature Rise in a Spray as a Function of Distance from the Nozzle

QUESTION 12-7

(1/19/78) What air updraft velocities will be utilized in future Vallecitos air-water full scale tests to simulate steam velocities in the post-LOCA environment? Justify the conservatism of the simulation, including magnitude and direction of the air flow with respect to predicted steam magnitude and direction following a LOCA.

QUESTION 12-7 - RESPONSE

The core spray distribution is not sensitive to updraft, as shown by calculations with the single nozzle model and by the Lynn sensitivity tests. Therefore, no updraft is used in the Vallecitos full scale air tests with simulator nozzles. The successful Lynn confirmation verifies the adequacy of this approach.

QUESTION 12-9

(12/15/77) Provide documentation regarding why GE believes steam and water flow patterns in the Lynn 30° test facility will adequately represent the flow patterns that might be present in a full 360° reactor upper plenum following a LOCA. Include discussion of tests both with and without the "pie-shaped baffle" in place. (Answer to this question should be included in or coordinated with your answer to Question 11 above.)

QUESTION 12-9 - RESPONSE

The fuel channels and separator standpipes force axisymmetric axial flows across the boundaries of the BWR upper plenum (see Figure 12-9A). The flow patterns within the upper plenum are controlled by the interactions of these boundary flows and the core spray coolant flows with the confining geometry of the reactor plenum. These controlling features have been reproduced in the Lynn steam sector facility (see Figure 12-9B). The similarity in flow patterns that result from the axisymmetric upper plenum conditions has been illustrated by the similar core spray distribution results obtained in different sector sizes with air (see Figure 12-9C). The effects of including pie-shaped baffle walls in the sector was to increase the apex flow somewhat (as expected), but not to significantly change the region over which the sector adequately represents full 360° results.

The observation that most of the spray trajectory in a steam environment also occurs under "hydrodymamic" (i.e., negligible condensation) conditions leads to the conclusion that the 30° sector will similarly provide an adequate representation of 360° flow patterns for steam environments.

The test results, with and without walls, are shown in Figure 12-9D for each individual bundle. Examination of these data show that presence of the walls does not affect the skew of the spray, which further confirms the adequacy of the 30° sector.

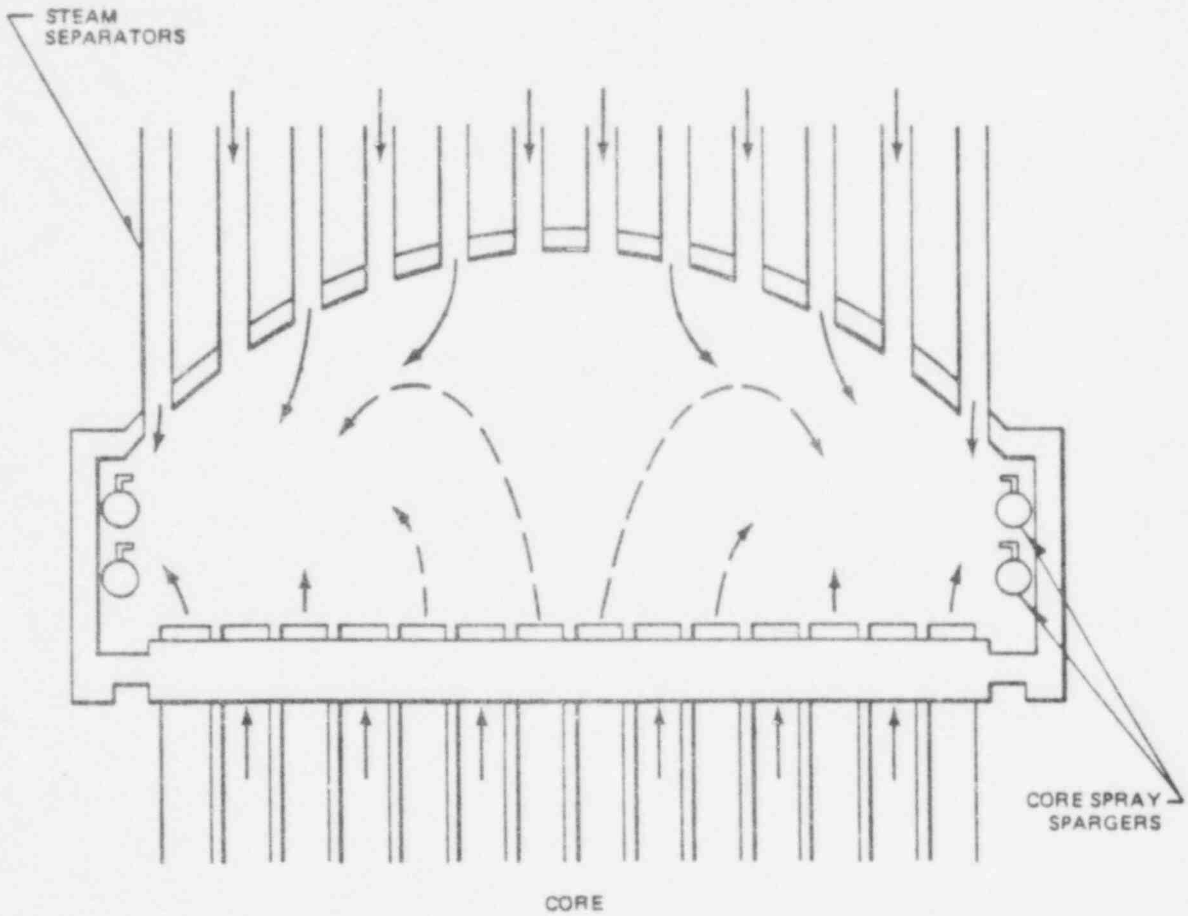

Figure 12-9A. Upper Plenum Vapor Flow Paths

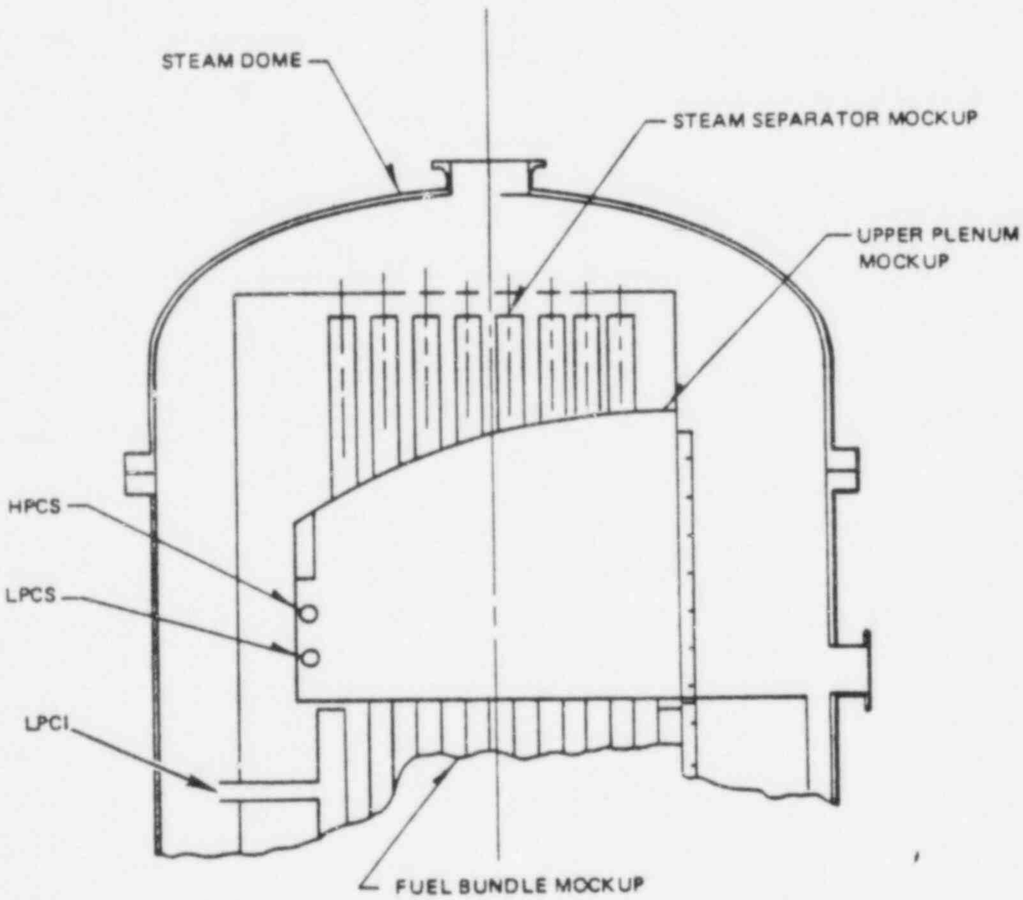

Figure 12-9B. SSTF Configuration (Elevation)

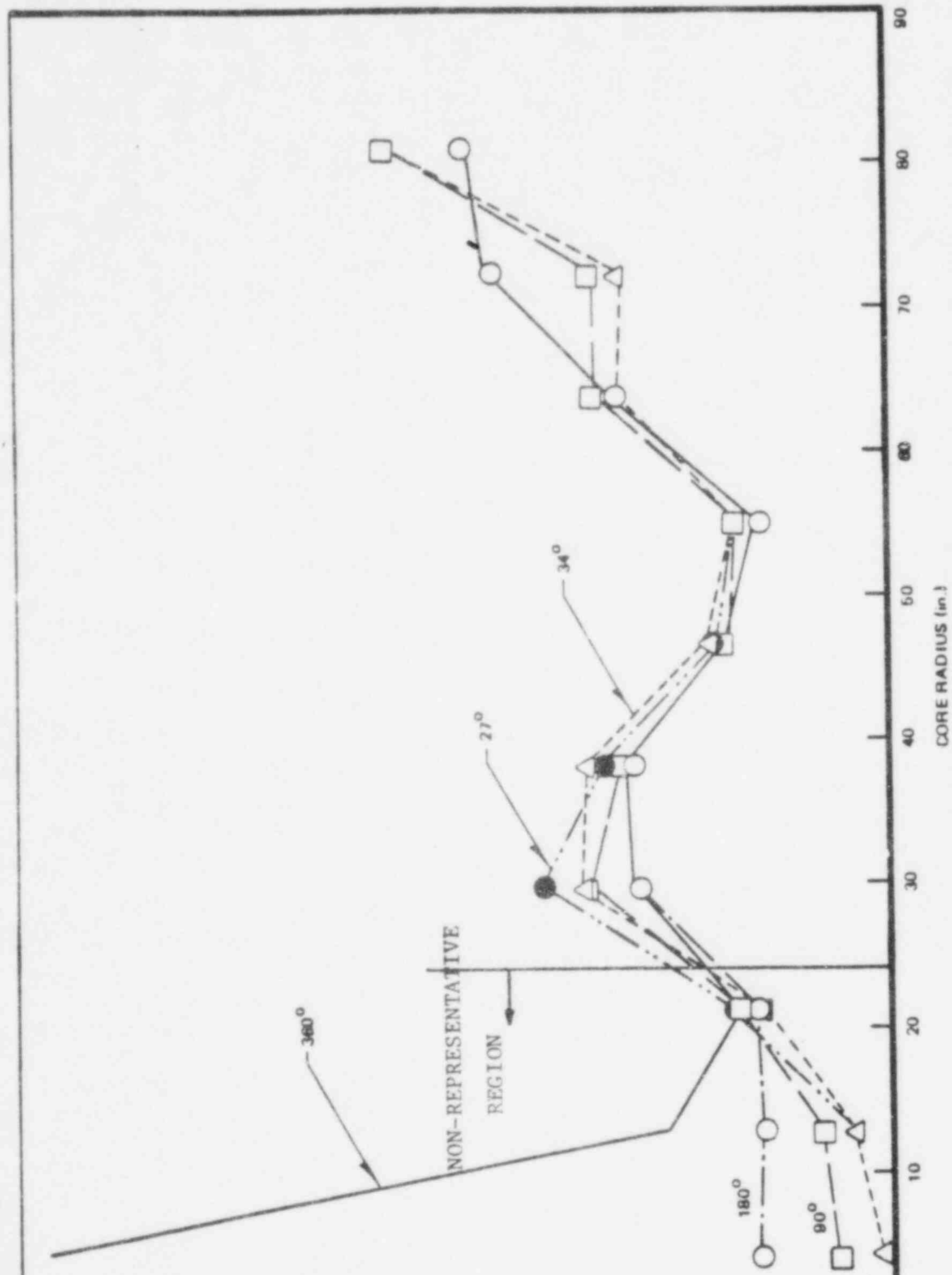

Figure 12-9C. Core Spray Distribution as a Function of Sector Size For BWR/4-218 (VSF Air Tests)

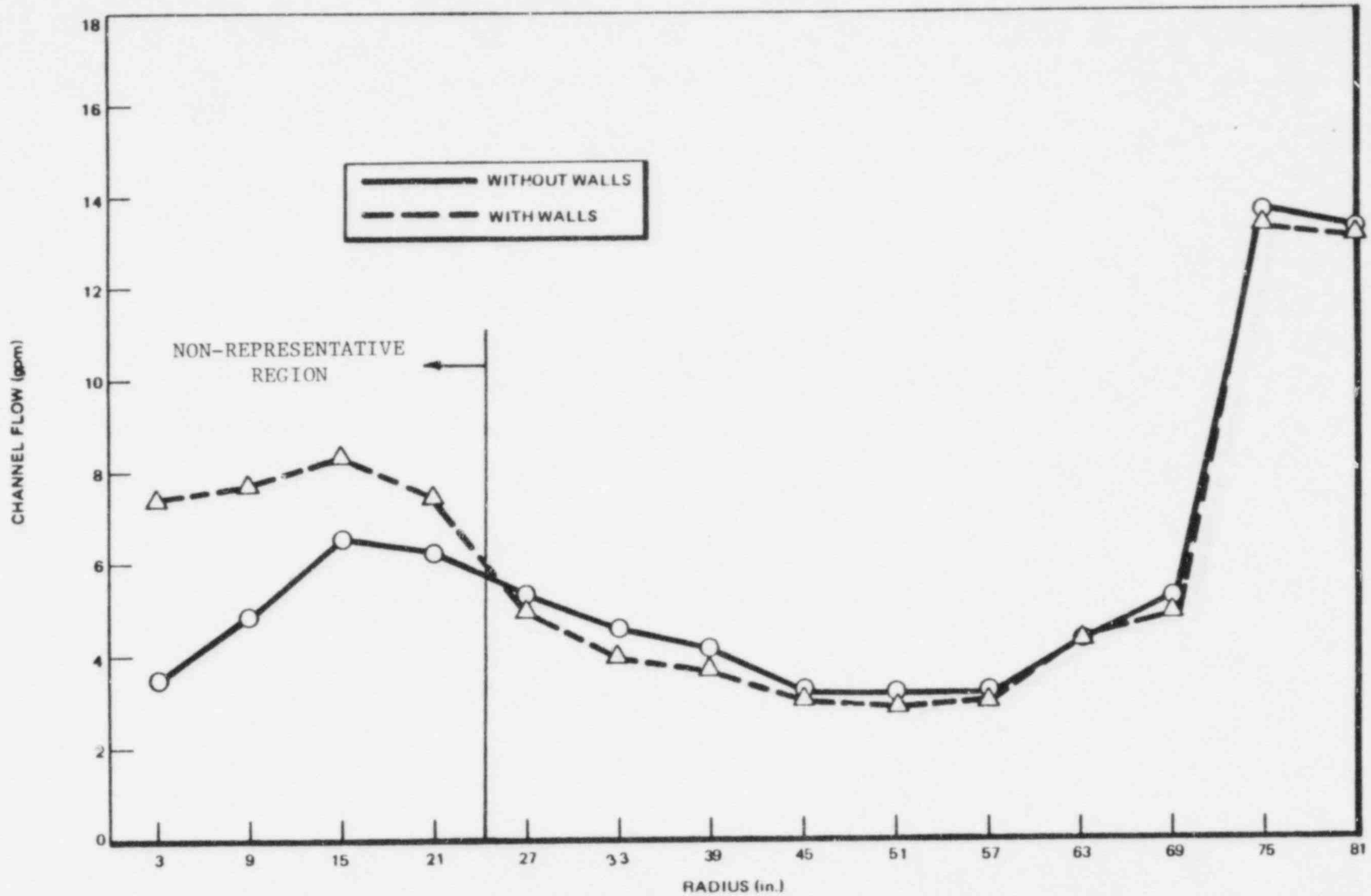

Figure 12-9D. Wall Effects in a 30° Sector (VSF Tests 3-002A with Walls and 3-004A Without Walls)

QUESTION 12-11

(12/15/77) Provide the "CCFL delay vs. zero spray coefficient" tradeoff results (discussed in slides SCR-5 through SCR-8 (12/15/77)) for the sizes and types of jet-pump BWR plants whose results were not presented at the 12/15/77 meeting, and for the second most limiting break location for "LPCI-Modified" BWR's.

QUESTION 12-11 - RESPONSE

It was agreed that this question would be answered during the specific plant application phase of the overall core spray effort. The answer to this question was not deemed necessary for approval of the methodology.

QUESTION 12-12

(Previous number 1-C, 9/2/77) The proposed tests do not include possible effects due to the different steam qualities that might be present under various conditions. Water droplets entrained in the steam may change the interaction of the steam and the spray cone. Describe how GE plans to quantify such possible effects experimentally and/or analytically.

QUESTION 12-12 - RESPONSE

For spray cooling conditions of a hypothetical BWR-LOCA, the relatively low vapor velocities produce few entrained droplets from the fuel bundles. Previous experiments* with single fuel bundle simulations have demonstrated that CCFL results from both heated rod bundles and adiabatic steam injection bundles match quite well. Since these CCFL results are expected to be sensitive to entrained droplets from the fuel bundle, it can be concluded that the entrained droplets are adequately simulated with adiabatic bundles used in Lynn. The spray itself provides the primary source of droplets entrained in the complex upper plenum flow field. These reactor simulation effects are directly included in the Lynn sector data through use of realistic reactor mock-up and bundle simulation hardware and realistic spray operating conditions. Therefore, the Lynn facility provides the desired realistic evaluation of the core spray prediction methodology.

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*D. D. Jones and S. S. Dua, "Saturated Counter-Current Flow Characteristics of a BWR Upper Tieplate," General Electric Company, July 1978 (NEDO-20566-4-P).

QUESTION 12-17

(Previous number 11, 9/2/77) Justify your assumption that one-half of the "Appendix K" quoted core spray heat transfer coefficients can be used when spray flow to a bundle is below minimum design flow. You should provide results of experimental spray heat transfer coefficient measurements taken at lower spray flows. Also, you should quantitatively demonstrate that actual penetration of the assumed (lower) flow into the bundle is consistent with your CCFL data and correlations, under all conditions predicted by your ECCS calculations where this assumption of lower heat transfer coefficients is made.

QUESTION 12-17 RESPONSE

It was agreed that this question will be answered during the specific plant application phase of the overall core spray effort. The answer to this question was not deemed necessary for approval of the methodology.

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