PRE-TEST PREDICTIONS
FOR BWR/4-218 SSTF
CORE SPRAY TESTS

by

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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 determined from air environment measurements. This report presents the pre-test predictions of the spray distribution for the BWR/4-218 core spray system in the SSTF at Lynn, Massachusetts.

A key assumption in the prediction method is that the condensation effects in a steam environment and the hydrodynamic effects can be treated separately. This separability assumption was previously confirmed for the BWR/6 core spray configuration by the measured flow density in SSTF matching the pretest predicted distribution within the expected uncertainty.[1,2] It is expected that this separability assumption will be further confirmed for the BWR/4 core spray configuration by the agreement of the SSTF data with the pretest prediction presented here.

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 previously undertook multiple nozzle tests to provide a confirmation of the assumption that thermodynamic and hydrodynamic phenomena are separable. Such tests were conducted in 1979 for a BWR/6 spray system geometry, and successfully confirmed the prediction methodology.

Due to interest expressed by NRC and EPRI, the cooperatively funded BWR Refill/Reflood Program was planned to include a second core spray distribution test series, using a spray system geometry like that of existing BWR/4 reactors. The second confirmation of the prediction methodology will demonstrate that the method is applicable to different spray system geometries.

III. SSTF CORE SPRAY SYSTEM REFERENCE DESIGN

The original design basis of the SSTF was to accurately mock up a 30° sector of a BWR/6-218 upper plenum and core. For BWR/4-218 testing, the facility has been modified by the addition of a BWR/4-218 lower sparger, and by the removal of the fuel bundle handles from the edge row of bundles (which are not present in BWR/4-218 reactors). The sparger segment has seven nozzle assemblies. This is less than a full 30° segment (8-2/3 nozzles) because of facility hardware constraints. This results in less than full reactor flow for the 30° sector. However, this compromise is acceptable since the purpose of the current studies is to verify the separability assumption in a multiple nozzle experiment that is generally similar to a BWR/4 hardware configuration. Seven nozzles are sufficient for this methodology confirmation and verification of the separability assumption. The nozzles used are the 1" VNC 9/16 and the Spraco 3101, which alternate on the BWR/4-218 spargers. The nozzles are mounted exactly as specified for the BWR/4-218 plant designs. Further details about the hardware in the test facility can be found in References 2 and 3.

IV. TEST CONDITIONS

The system conditions for the pre-test prediction and the associated tests are:

System Pressure: 29.5 psia
ECCS Flow Rate: 375 gpm
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 confirguration provides the correct flow areas so that vapor velocities will be typical. One-half of the steam needed for condensation on the spray will be supplied through the core steam injectors. The remaining steam will be drawn down into the upper plenum through the steam separators. Enough steam will be supplied to the steam dome above the separators to accommodate the spray condensation needs and maintain a constant system pressure. 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).

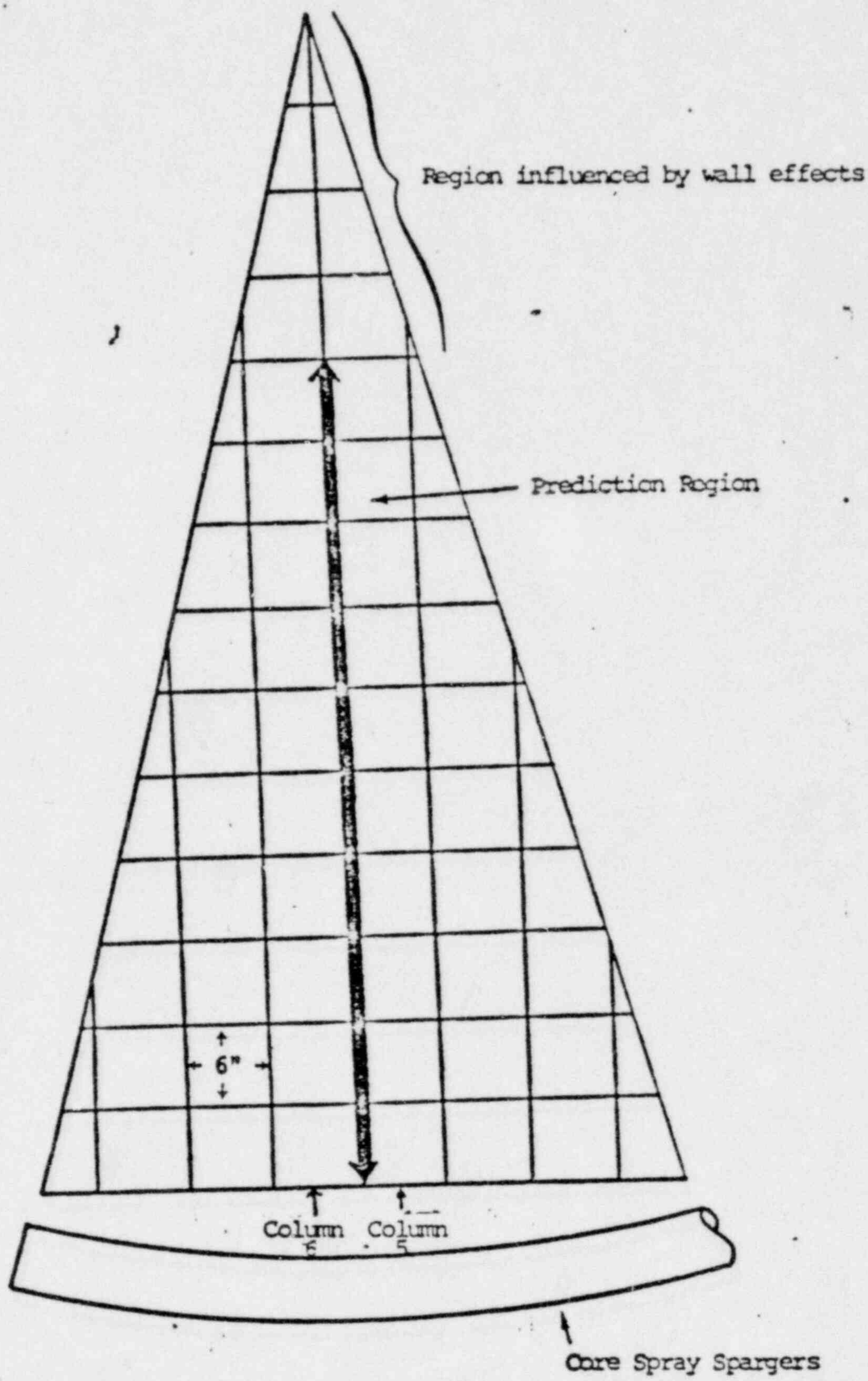


FIGURE 1

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

V. CORE SPRAY METHODOLOGY AND SSTF PRE-TEST PREDICTION

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

Predicted spray flow in SSTF in steam = Superposition of single nozzle spray flows in steam + Multiple nozzle Interaction factor

where

Multiple nozzle Interaction factor = Measured spray flow for SSTF in air with simulator nozzles - Superposition of single nozzle spray flows for simulators in air

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.

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

N = Total number of spray nozzles.

The terms G and $\sum_{i=i}^{N} g_i$ 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). The resulting MIE for the SSTF BWR/4-218 mockup as a function of radius is shown in Figure 2.

The MIE is then combined with $\sum_{i=i}^{N} f_i$, 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 individual centerline bundles in columns 5 and 6 (see Figure 1 for location of columns) are shown in Table I and plotted in Figures 3 and 4.

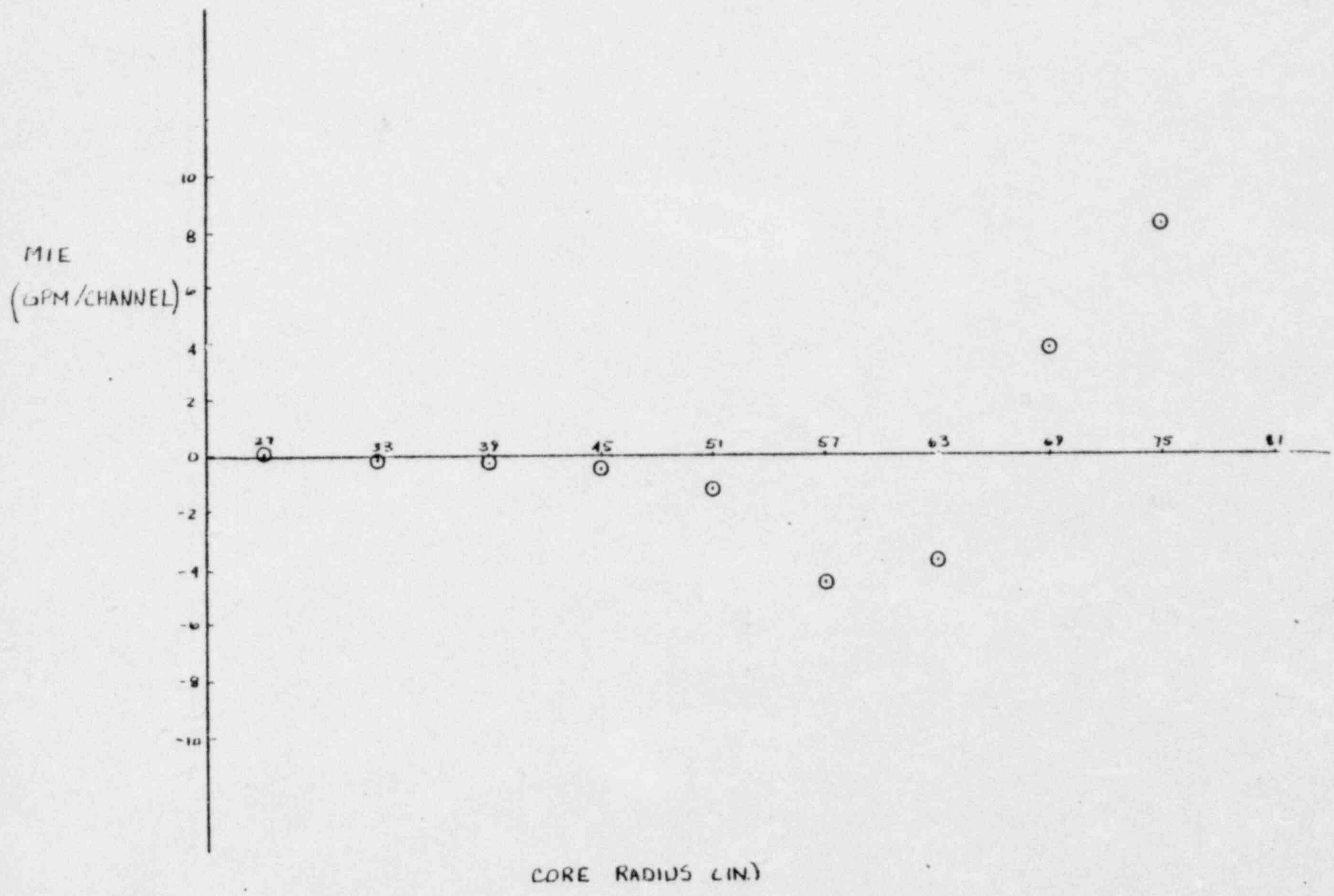
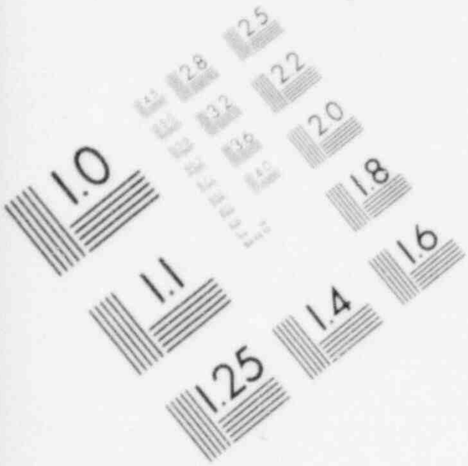


FIGURE 2 - INTERACTION EFFECT (MIE) FOR COLUMNS 5 AND 6 BUNDLES IN THE SSTF (BWR/4-218)

IMAGE EVALUATION
TEST TARGET (MT-3)



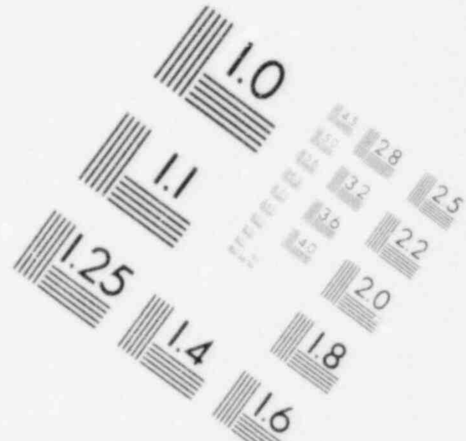
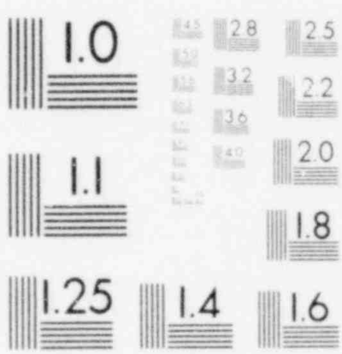


IMAGE EVALUATION TEST TARGET (MT-3)



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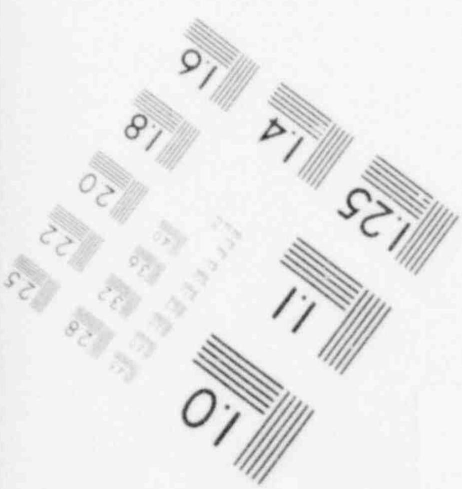

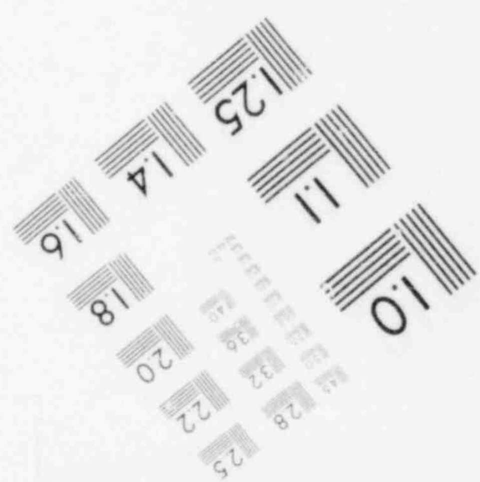

TABLE I

BWR/4-218 SSTF PRE-TEST PREDICTION

Distance From Apex to Bundle Centerline	Lower Header (gpm/bundle) Column 5	Column 6
27	0.48	0.70
33	0.70	0.84
39	1.47	1.43
45	3.32	2.68
51	7.31	6.01
57	11.06	8.74
63	18.34	15.98
69	23.24	21.02
75	16.28	15.02

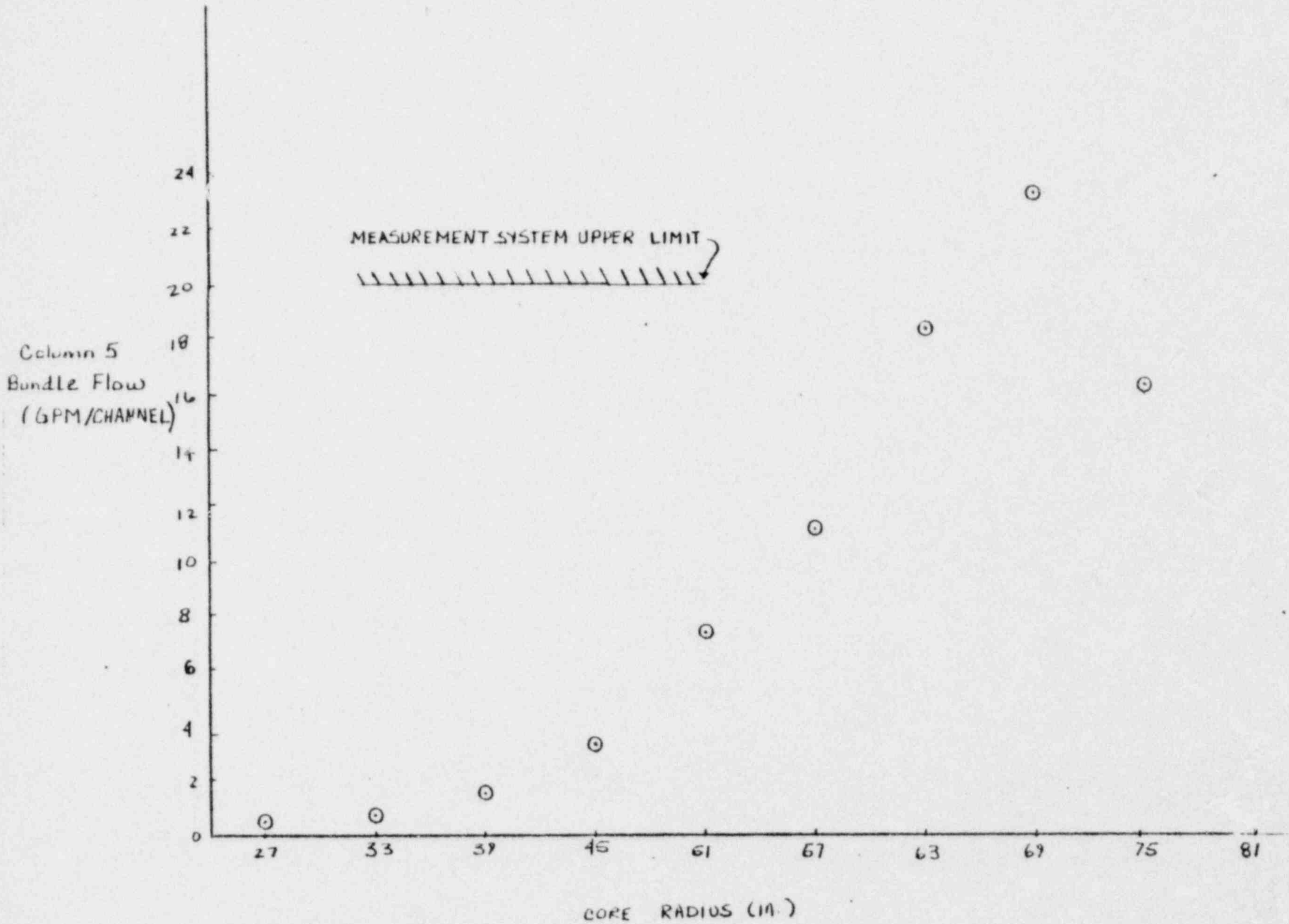

FIGURE 3 - PREDICTED FLOWS FOR COLUMN 5 BUNDLES IN THE SSTF

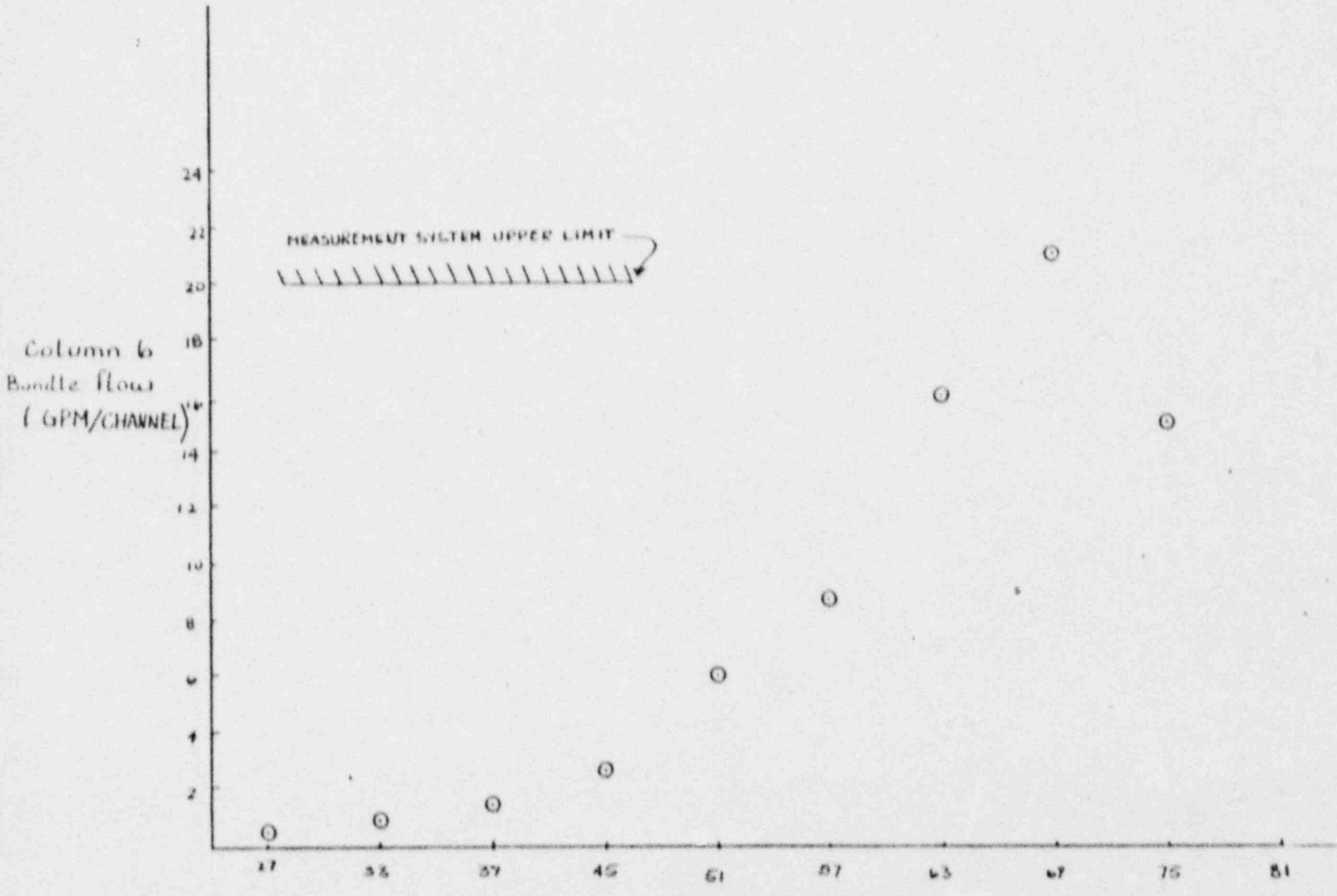

FIGURE 4 - PREDICTED FLOWS FOR COLUMN 6 BUNDLES IN THE SSTF

VI. COMPARISON WITH SSTF DATA

The data from SSTF tests will be compared with the predicted flows of Figures 3 and 4 on an individual bundle basis.

NOMENCLATURE

Symbol	Description
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 nozzle air test.
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.

REFERENCES

1. NEDO-24797, *Pre-Test Prediction for SSTF Core Spray Tests*, S.K. Rhow and S.A. Sandoz, April, 1979.

2. NEDO-24712, *Core Spray Design Methodology Confirmation Tests*, S.A. Sandoz, L.L. Myers, D.G. Schumacher, W.A. Sutherland, and G.E. Dix, August, 1979.

3. ETP 514.8005, *Task 4.2 - Core Spray Distribution Experimental Task Plan*, T. Eckert, BWR Refill/Reflood Program, Contract #NRC-04-79-184 (January, 1980).