

Energy

F  
O  
S  
S  
I  
L

150  
10/3/84  
213

DR-0451-0

DOE/OR/03054-37-Annex-Vol.D  
(DE84015195)

SRC BURN TEST IN 700-hp OIL-DESIGNED BOILER

Final Technical Report

Electrostatic Precipitator Mass Train and Operating Data

Work Performed Under Contract No. AC05-78OR03054

Wheelabrator-Frye Inc.  
Coraopolis, Pennsylvania

and

International Coal Refining Company  
Allentown, Pennsylvania

Technical Information Center  
Office of Scientific and Technical Information  
United States Department of Energy



## DISCLAIMER

**This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.**

## **DISCLAIMER**

**Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.**

## DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

This report has been reproduced directly from the best available copy.

Available from the National Technical Information Service, U. S. Department of Commerce, Springfield, Virginia 22161.

Price: Printed Copy A07  
Microfiche A01

Codes are used for pricing all publications. The code is determined by the number of pages in the publication. Information pertaining to the pricing codes can be found in the current issues of the following publications, which are generally available in most libraries: *Energy Research Abstracts (ERA)*; *Government Reports Announcements and Index (GRA and I)*; *Scientific and Technical Abstract Reports (STAR)*; and publication NTIS-PR-360 available from NTIS at the above address.

**FINAL TECHNICAL REPORT:  
SRC BURN TEST IN 700-hp OIL-DESIGNED BOILER**

**Annex Volume D: Electrostatic Precipitator Mass Train  
and Operating Data**

**Wheelabrator-Frye Inc.  
Coraopolis, Pennsylvania**

**and**

**International Coal Refining Company  
Allentown, Pennsylvania**

**MASTER**

THIS PAGE  
WAS INTENTIONALLY  
LEFT BLANK

SRC TEST BURN PROGRAM  
WHEELABRATOR-FRYE INC.  
SUMMARY

The International Coal Refining Company (ICRC) is under contract from the Department of Energy (DOE) to study the technical feasibility and marketing potential of solvent-refined coal (SRC) fuels for oil-fired boiler applications. The technical aspects of the boiler fuel system conversion, combustion performance, and emission control system performance were studied through an SRC combustion test program, conducted at the Pittsburgh Energy Technology Center (PETC). Testing was conducted on the 700-hp watertube industrial boiler, designed for oil firing. Base-line data was collected by firing No. 6 fuel oil. Feasibility data were obtained by firing three types of SRC fuels: Pulverized SRC Solids, SRC Residual Oil, and SRC-Water Slurry.

The scope of work performed by the Air Pollution Control (APC) Division of Wheelabrator-Frye Inc. (WFI) and WFI Sciences was as follows: (1) provide mobile electrostatic precipitator (ESP); (2) operate and maintain the ESP; (3) provide a report on evaluation of ESP performance; (4) provide a reverse air pilot filter (PF); (5) operate and maintain the PF; (6) provide a report on evaluation of the PF performance; (7) provide equipment and personnel for assessment of particulate mass emissions at the ESP inlet and outlet and boiler outlet; (8) provide a report on particulate mass emissions data; (9) provide equipment and personnel for determination of particulate mass emissions from the existing pulse-jet baghouse (PJ); and (10) provide a report on the PJ mass emissions.

Results from the ESP evaluation report indicate that the fly ash from combustion of all three SRC fuels is easily removable by a conventional dry ESP. A relatively small collecting area is needed to collect the fly ash, but rapping reentrainment may necessitate a larger box. The pilot ESP was not set up to minimize rapping reentrainment, which was evident during the test program. Full-size units can be designed to minimize rapping reentrainment by varying the number of ESP fields, by minimizing plate height, and by using a low rapping intensity.

Results from the fabric filter feasibility evaluation report indicate that the particulate emissions from SRC fuels combustion were successfully controlled to less than  $0.01 \text{ lb}/10^6 \text{ Btu}$ , well within the particulate emission limit of the Federal Environmental Protection Agency (EPA) New Source Performance Standard (NSPS) of  $0.03 \text{ lb}/10^6 \text{ Btu}$  for electric utility steam-generating units. The amount of controlled particulate emissions from the SRC fuels combustion was equal to or less than the controlled particulate emissions from the No. 6 fuel oil combustion. Thus, the SRC Test Burn Program clearly established that the conventional fabric filters make a feasible control device for emissions from SRC-fuel-fired boilers.

Results from the boiler emission report show that the uncontrolled particulate emissions averaged  $0.92 \text{ lb}/10^6 \text{ Btu}$  for SRC Solids,  $0.20 \text{ lb}/10^6 \text{ Btu}$  for SRC Residual Oil, and  $0.91 \text{ lb}/10^6 \text{ Btu}$  for SRC-Water Slurry.

A detailed review of the findings of the Boiler Emission and Fabric Filter Studies is provided in the reports submitted by Wheelabrator-Frye Inc. and WFI Sciences for the SRC Test Burn Program.

## TABLE OF CONTENTS

	<u>Page</u>
Abstract. . . . .	vii
Executive Summary . . . . .	ix
Performance Evaluation. . . . .	xi
Introduction. . . . .	1
Nomenclature. . . . .	3
Description of Equipment. . . . .	4
Test Procedure and Methodology. . . . .	8
Discussion of Results . . . . .	23
Conclusion. . . . .	38
Appendix I - ESP Drawings	
Appendix II - No. 6 Fuel Oil Results and Graphs	
Appendix III - SRC Fuel Results and Graphs	
Appendix IV - SRC Residual Fuel Oil Results and Graphs	
Appendix V - SRC-Water Slurry Results and Graphs	
Appendix VI - V-I Data, Gas Distribution Data	

THIS PAGE  
WAS INTENTIONALLY  
LEFT BLANK

## ABSTRACT

Solvent Refined Coal (SRC) is one of the viable replacement fuels for No. 6 fuel oil in industrial and utility boilers. The Department of Energy funded the International Coal Refining Company (ICRC) to develop and to demonstrate the use of SRC as a practical fuel. Phase II of the project was to burn the SRC fuels in a 700 H.P. package boiler and to collect emission data from which air pollution control devices could be specified.

Wheelabrator-Frye Inc., APC Division was contracted by ICRC to supply and operate a pilot electrostatic precipitator (ESP). Mass emission testing was performed by WFI Sciences. Particle size tests, particle resistivity,  $SO_x$  measurements, and particulate counting tests were conducted by Southern Research Institute (SoRI).

This report is a source document covering the ESP operating data and mass emission data. The data obtained by SoRI is used by SoRI in their computer model to specify full scale design criteria.

The testing was performed with four fuel types; No. 6 fuel oil, SRC fuel, SRC residual fuel oil, and SRC-water slurry. All fuels were precipitated quite easily resulting in emission rates below the NSPS standards.

THIS PAGE  
WAS INTENTIONALLY  
LEFT BLANK

## SUMMARY

Solvent refined coal (SRC) is one of the viable replacement fuels for No. 6 fuel oil in industrial and utility boilers. The Department of Energy funded the International Coal Refining Company (ICRC) to perform a test program at the Pittsburgh Energy Technology Center (PETC) to demonstrate that the SRC fuels can be burned in an oil fired boiler and to collect flue gas emission data to design full-scale air pollution control devices. Testing was performed using a 700 H.P. package boiler between September 1982 to January 1983.

Four types of fuels were tested. Baseline tests were run with No. 6 fuel oil. Three types of SRC fuels were fired; SRC fuel, SRC residual fuel oil and SRC water slurry.

Wheelabrator-Frye, Air Pollution Control Division (WFI) was contracted to supply and to operate a pilot electrostatic precipitator (ESP). WFI Sciences, an independent WFI Division, tested the particulate mass loadings in and out of the ESP. Southern Research Institute (SoRI) performed flyash particle sizing, resistivity,  $SO_2$ - $SO_3$  concentrations in the flue gas, and other tests. This report is a source document which includes the data obtained by WFI Sciences and the ESP operating data. The data in this report along with data collected by SoRI is to be used in the SoRI computer program to specify a full-scale ESP.

The averages of the test data are shown in Table No. 1 on page xiv. The table presents the data in the most commonly used units. Both metric and English units are shown for the individual test data. The individual test data is shown by fuel type in Appendices II-V. The data does not include rapping losses, but the SoRI computer program is to compensate for this using the data collected by SoRI. The ash from all three SRC fuels is an easy application for a conventional dry ESP in

terms of flyash removal. However, there may be a problem with rapping reentrainment. In between tests when the ESP was rapped, dark puffing was evident at the stack. The reentrainment was measured by SoRI using particle counters.

The data obtained will give the SoRI computer program reliable data from which a full-scale ESP can be specified. The ash collected was high in carbon content with loss of ignition (LOI) reported to be from 70%-90% by weight. Better combustion in a larger boiler may cause the ash characteristics, such as resistivity and particulate loading, to change. More complete combustion usually lowers the LOI and particulate loading, but increases ash resistivity. Lower particulate loadings will result in increased performance. Increased ash resistivity may worsen collection efficiency if a large increase in resistivity results. The higher resistivity ash should reduce reentrainment since the particles should hold a charge and not be reentrained as easily. It is expected that better combustion will result in increased performance.

## PERFORMANCE EVALUATION

The data presented in this report include the particulate concentration at the inlet and outlet of the pilot ESP and the operating parameters of the ESP. The data does not describe the performance of a full-scale unit since rapping losses are not included.

The ESP was a three field unit with each field consisting of five gas passages with 10 inch spacing. The collecting plates were 6.5 feet tall by 6.25 feet long, resulting in an ESP total collecting area of 1218.75 ft<sup>2</sup>. The discharge electrodes were WFI's star wire which are similar to a square rod. Drawings of the ESP are shown in Appendix 1.

For each fuel type, at least one set of operating conditions was tested with the boiler at one operating condition. The primary test condition was to operate the ESP at 5000 ACFM at the inlet which resulted in a specific collecting area, SCA of 244 sq ft/1000 ACFM. This is a low SCA considering the normal range for SCA is from 200 to 700 sq ft/1000 ACFM. The power input to each field was limited to 10 milliamps which resulted in a current density of 20 nanoamps per square centimeter.

The No. 6 fuel oil tests were only run at the primary condition. The average ESP inlet loading was 0.05 lb/10<sup>6</sup> Btu with an outlet loading of 0.004 lb/10<sup>6</sup> Btu which resulted in an efficiency of 91.35%. No operating problems were encountered with the boiler or ESP.

The SRC fuel was only tested at the primary conditions of a SCA of 240 sq ft/1000 ACFM and 20 na/sq cm. Testing showed the average inlet to be 0.96 lb/10<sup>6</sup> Btu and the outlet to be 0.005 lb/10<sup>6</sup> Btu which resulted in efficiencies of 99.46%. When the SRC fuel was burned there were both boiler and ESP problems. The boiler burner had clinker buildup problems which resulted in poor burnout, CO spikes, and opacity spikes.

The poor burnout resulted in high carbon ash which caused ESP high voltage insulator fouling and partial grounding of the field. A better burnout was achieved by adding 7% total thermal input with natural gas and the insulator fouling problem was solved by adding insulator purge air. The unsteady boiler operation and opacity spikes resulted in erratic data. At the end of the best program, a new burner was designed and used. Better combustion was achieved. All the data in this report are with the original slow mix burner. No particulate testing was done with the improved fast mix burner.

The SRC residual fuel oil was burned with a steady particulate emission rate and opacity. The inlet loading average was  $0.197 \text{ lb}/10^6 \text{ Btu}$ . The primary operating condition of a SCA of  $240 \text{ sq ft}/\text{KACFM}$  and current density of  $20 \text{ na}/\text{sq cm}$  resulted in an outlet loading of  $0.002 \text{ lb}/10^6 \text{ Btu}$  with an efficiency of 99.08%. Since the amount of flyash at the ESP outlet was so small and difficult to measure, the current was lowered in each field from 10 ma to 5 ma. Contrary to theory, the outlet loading decreased to  $0.001 \text{ lb}/10^6 \text{ Btu}$  with an efficiency of 99.43%. The third condition tested was to increase the gas volume to 7000 ACFM which decreased the SCA to  $173 \text{ sq ft}/1000 \text{ ACFM}$ . The outlet loading was  $0.008 \text{ lb}/10^6 \text{ Btu}$  with an efficiency of 96.13%. The three test conditions will allow SoRI to run the computer program three times to evaluate a full-scale unit.

The SRC-water slurry burned much steadier than the SRC fuel with the emissions being more consistent. The ESP inlet ash loading was  $0.93 \text{ lb}/10^6 \text{ Btu}$  and the outlet loading was  $0.006 \text{ lb}/10^6 \text{ Btu}$  with collection of 99.34%. This performance was the same as the SRC fuel. The second condition tested was with two fields energized with the 5000 ACFM. This lowered the SCA to  $145 \text{ sq ft}/1000 \text{ ACFM}$ . The test results showed the outlet loading to increase to  $0.026 \text{ lb}/10^6 \text{ Btu}$  with an efficiency of 97.36%. These two conditions can be compared by the SoRI computer.

The SRC fuels' flyash is a relatively easy ash to collect. Low SCAs of 240 sq ft/1000 ACFM and current densities of 20 na/sq cm have given high efficiencies of 97+%. The flyash resistivities measured by SoRI show the ash to have low resistivities. Low resistivity ash of  $10^7$ - $10^9$  ohm-cm is charged and collected quite easily. A problem arises when the ash is collected and loses its charge thus being free to be reentrained. A larger SCA will possibly be required to control the reentrainment.

S U M M A R Y   O F   E S P   R E S U L T S

---

FUEL	INLET ESP (LB / 10 <sup>6</sup> Btu)	OUTLET ESP (LB / 10 <sup>6</sup> Btu)	% EFF.	SCA (SQ FT/ KACFM)	FACE VELOCITY (FT/SEC)	CURRENT DENSITY (NA / SQ CM)	SCP (WATT/ KACFM)	W (CM/ SEC)
#6 OIL	.050	.004	99.35	240	3.13	26	250	5.4
PULV SRC	.959	.005	99.46	230	3.26	21	185	11.7
RESID A	.196	.002	99.08	240	3.13	20	170	10.5
RESID B	.195	.001	99.43	240	3.13	13	95	11.8
RESID C	.209	.008	96.13	173	2.89	13	70	9.5
SLURRY A	.930	.006	99.34	220	3.41	18	150	11.9
SLURRY B	.999	.026	97.36	145	3.45	12	50	5.7

- NOTE: 1. RESID A - SRC RESIDUAL FUEL OIL. TEST CONDITION A.  
 2. SLURRY A - SRC-WATER SLURRY. TEST CONDITION A.  
 3. RESULTS ARE AVERAGES OF DATA. NO PARAMETRIC TESTS ARE INCLUDED.  
 4. ALL ABBREV. DEFINED IN NOMENCLATURE. PAGE 3.

TABLE #1: SRC FUELS SUMMARY OF RESULTS

## INTRODUCTION

The International Coal Refining Company, ICRC, was funded by the Department of Energy, DOE, to show the feasibility of using solvent refined coal (SRC) in oil fired boilers. Phase I of the program was run in August, September, October, 1980 at the Pittsburgh Energy Technology Center, PETC, and demonstrated that SRC could be burned in a small 100 HP oil designed fire tube boiler. A fabric filter field comparator was used to determine the practicality of using fabric filters as a means of air pollution control. The results of this testing were published in a report by Wheelabrator-Frye Inc., APC dated January 12, 1981.

Phase II of the program was to burn the SRC 1 fuels in a 700 HP water tube oil designed boiler. Testing was performed to evaluate the use of fabric filters and electrostatic precipitators (ESP) as air pollution control devices. This report covers the particulate emission rates without rapping at the inlet and outlet of the ESP and the performance of the ESP. This report evaluates the data obtained, but does not attempt to project design criteria for a full-size ESP. The design of a full-size unit will be done by Southern Research Institute (SoRI) using their computer program. The computer program uses the data presented in this report plus data obtained by SoRI, such as particle size and resistivity.

Phase II testing was performed at PETC between August 1982 and February 1983. The fuels tested were #6 fuel oil as a baseline, SRC fuel, SRC residual fuel oil, and SRC-water slurry. Mass train emission testing was performed by WFI Sciences and the ESP was run by the WFI ESP R&D Department.

This volume includes the text and a summary of the results. The text includes a description of the ESP and its variables, the duct layout, the test equipment, and the test methodology used. The test results are pre-

sented in both tabular and graphic form in the appendices by fuel type. The test results and the ESP operation parameters are discussed and conclusions made.

N O M E N C L A T U R E

\*\*\*\*\*

ABBREV.	DESCRIPTION	UNITS
ACFM	ACTUAL CUBIC FEET PER MINUTE	CU FT/MIN
ACMM	ACTUAL CUBIC METER PER MINUTE	CU M/MIN
BTU	BRITISH THERMAL UNIT	BTU
CM	CENTIMETER	CM
CO-2	CARBON DIOXIDE	% BY VOL
DOE	DEPARTMENT OF ENERGY	(-)
ESP	ELECTROSTATIC PRECIPITATOR	(-)
GR	GRAINS	GR
GR/ACF	GRAINS PER ACTUAL CUBIC FEET	GR/ACF
GR/SDCF	GRAINS PER STANDARD DRY CUBIC FEET	GR/SDCF
ICRC	INTERNATIONAL COAL REFINING COMPANY	(-)
I-DENS	CURRENT DENSITY	MA/SQ FT
I-DENS	CURRENT DENSITY	NA/SQ CM
KACFM	THOUSAND ACTUAL CUBIC FEET PER MINUTE	1000 ACFM
KV	KILOVOLTS	1000 VOLTS
LB	POUND	LB
LB/10 BTU	POUND PER MILLION BTU	LB/10 BTU
M	METER	M
MA	MILLIAMP	MA
MG/ACM	MILLIGRAM PER ACTUAL CUBIC METER	MG/ACM
MG/SDCM	MILLIGRAM PER STANDAR DRY CUBIC METER	MG/SDCM
NA	NANOAMPS	NA
NG/JOULE	NANOGRAMS PER JOULE	NG/JOULE
O-2	OXYGEN	% BY VOL
PETC	PITTSBURGH ENERGY TECHNOLOGY CENTER	(-)
SCA	SPECIFIC COLLECTING AREA	SQ FT/KACFM
SCP	SPECIFIC COLLECTING POWER	WATT/KACFM
SCS	SOUTHERN COMPANY SERVICES	(-)
SDCF	STANDARD DRY CUBIC FEET	SDCF
SDCM	STANDARD DRY CUBIC METER	SDCM
SEC	SECOND	SECOND
SRC	SOLVENT REFINED COAL	(-)
SRI	SOUTHERN RESEARCH INSTITUTE	(-)
SQ FT	SQUARE FEET	SQ FT
UA	MICROAMPS	UA
W	MIGRATION VELOCITY	CM/SEC
WPI	WHEELABRATOR-FRYE, INC., APC DIVISION	(-)

## DESCRIPTION OF EQUIPMENT

### Duct Layout

Flue gases emanating from the 700 HP boiler are ducted to the roof through a 24 inch diameter duct. All the gases flow through a flue gas cooler which is an air-air indirect heat exchanger. The flue gas cooler damper was regulated by a controller which monitored the temperature at the ESP inlet. During the No. 6 fuel oil testing, it was found that the flue gas could not be cooled by the cooler to the desired 300°F at the ESP inlet. The temperature was lowered minimally by partially removing the insulation from the duct between the flue gas cooler and the ESP.

The duct after the cooler was split with a Y section sending part of the gases to the ESP and the remainder to a pulse-jet baghouse. Testing verified that the characteristics of the two flue gas streams were nearly identical. The duct layout to and from the ESP is shown in Appendix I. The ductwork to the ESP was 16 inches in diameter and resulted in a gas velocity of 3580 fpm with the 5000 ACFM volume that was required for the ESP test conditions. This velocity was high enough to prevent any ash dropout. Eight test ports at the inlet and six test ports at the outlet were installed five feet apart or 3.75 diameters from each other. Normally every other port was used during the testing resulting in a 7.5 diameter distance. This minimized the disturbances caused by one sampling location on another. The flue gas was discharged through a sixty foot highstack.

### ESP Description

Drawings showing the basic layout of the ESP and the internals are shown in Appendix I.

The Wheelabrator-Frye Inc. mobile electrostatic precipitator, ESP, is a three (3) field unit complete with automatic voltage controls, rappers, vibrators, hoppers and an induced draft fan capable of 9000 ACFM at 700<sup>o</sup>F. The ESP is mounted on a trailer 8' 0" wide by 54' 6" long and 13' 6" high.

Each field consists of discharge surface (DS) pipe frames that are 5' 0" in height and 6' 3" long and have 12 wires per frame. The collecting surface (CS) plate is 6' 6" tall and consists of four interlocking strips for a length of 6' 3". The plate spacing can be varied for gas passages of 10", 12", 14", 16" 18" and 20". The SRC test program utilized five 10" gas passages which resulted in a total collecting area of 1218.75 square feet. Normal plate spacing for utilities varies between 9-12 inches depending upon ESP design.

The CS plates and DS pipe frames are of the Lurgi design. The interlocking strips of the CS plate is Lurgi's CSH design. Two standard wires are available in the pipe frames, the star wire which resembles a piece of square bar stock and the B-5 isodyn wire which resembles a large spiked saw blade. The star wire was used for the SRC program.

Each high voltage support frame is suspended from the casing with a three point insulator configuration. Each field also consists of a rapping insulator and a high voltage feed insulator. The insulators are kept clean by induced purge air and by compressed air which allows for any deposited ash to be blown off.

Each CS plate is individually bottom rapped with a rotating, falling hammer. The hammers are a modified Lurgi DS hammer that weigh 8-10 pounds. All the DS pipe frames in each field are cleaned with a side mounted Eriez P-150 vibrator. Both the CS rappers and DS vibrators are manually controlled for each field.

The ash or dust removal system consists of two trough hoppers per field with screw conveyors. The screws empty into two pyramidal hoppers which are emptied into 55 gallon drums by a vacuum system.

The required gas volume is induced with a Garden City Fan & Blower Co. RF19 fan. This fan is capable of pulling 9000 ACFM at -20" H<sub>2</sub>O at 700°F. The volume is controlled by an opposed louver damper. The specific collecting area, SCA, (ft<sup>2</sup>/1000 ACFM) and gas face velocity (ft/sec) for the ESP at 10" spacing are as follows:

<u>ACFM</u>	<u>SCA</u>	<u>Ft/Sec</u>
3000	406	1.9
5000	244	3.1
7000	174	4.3
9000	135	5.5

The automatic voltage controls are the Allen-Bradley Bulletin 1082 AVC. The transformer/rectifiers (T/R) are by Nothelfer Winding Laboratories (NWL). The controls have variable tap reactors which result in reactance of 30%, 50% or 70%. The T/Rs have variable tap transformers which are rated at 45 KV, 60 KV and 75 KV. The T/Rs also have a polarity switch for positive and negative corona. For the SRC program the T/Rs were set at 60KV with 50% reactance with negative polarity. The current density (na/cm<sup>2</sup>) for the ESP at 10" spacing is 20 na/cm<sup>2</sup> at 10 ma.

The gas distribution devices consist of an inlet nozzle with two perforated plates and an egg crate flow straightener and an outlet nozzle with one perforated plate. The gas distribution has previously been measured with a hot wire anemometer and found to be 30% RMS at the inlet and 10% RMS at the outlet with 12" spacing. The gas distribution

was measured with 10" spacing after the SRC testing and found to be 57% RMS at the inlet and 18 RMS at the outlet. The high RMS value is due to pluggage of the egg crate flow straightener. The bottom half of the egg crate had become 75% - 90% plugged during the last set of tests. The data and results of the gas distribution test are shown in Appendix VI.

## TEST PROCEDURES & METHODOLOGY

### ESP INLET

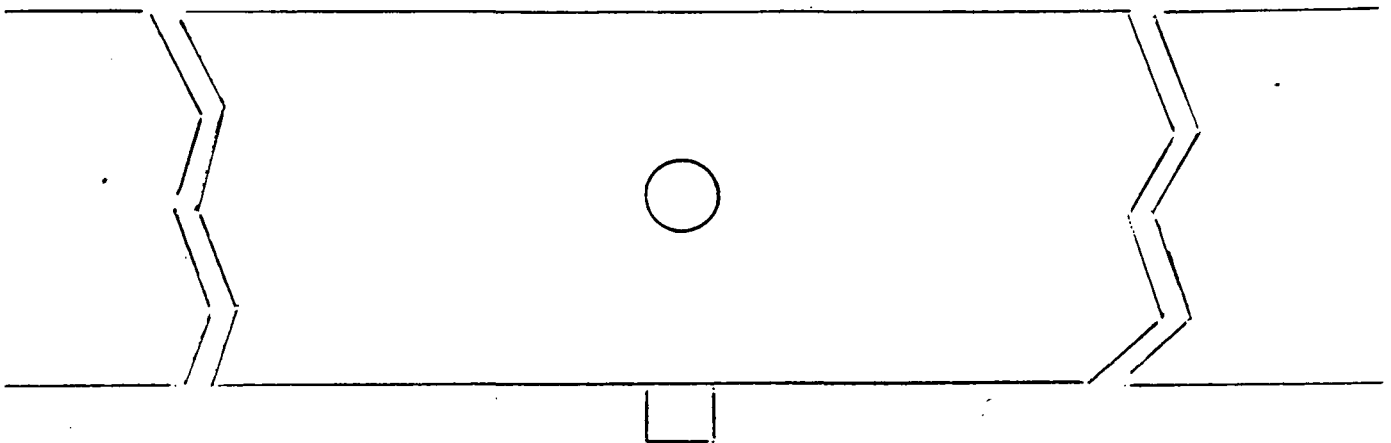
At the ESP inlet location sampling was conducted in two ports located  $90^{\circ}$  apart in the 16" I.D. circular duct (See Figure 1). The sampling train consisted of a stainless steel nozzle, an in-stack alundum thimble, an in-stack 47mm glass fiber filter, heated stainless steel probe, sample line, condenser and followed by a silica gel holder. The meter box containing the pump, calibrated dry gas meter, orifice and inclined manometer followed the sampling train. The sample train was set up as shown in Figure No. 2.

### Sampling Procedure

All sample trains were set up and run according to EPA Reference Method 17. Prior to testing, the sampling train was set up using tared filter media and then leak checked at 15"  $H_2O$  to insure it was leak free. After the sampling train was found to be leak free, ice was placed around the condenser to keep the sample gases below  $68^{\circ}F$  while testing.

The probe was then placed at the first sampling point and the velocity head ( $\Delta P$ ) was recorded, then the orifice pressure differential ( $\Delta H$ ) required to maintain an isokinetic rate of  $100 \pm 10\%$  was calculated using isokinetic sampling equations\*. This was done at each sample point. At the conclusion of the test, the sample train was leak checked at the highest vacuum attained during the test run.

\*See WFI Sciences PETC Boiler Emission Report



2 FOUR INCH SAMPLE PORTS

16" DUCT DIAMETER

8 TOTAL SAMPLE POINTS

4 TRAVERSE POINTS PER PORT

TRAVERSE POINT	PERCENT OF DUCT DIAMETER
1	6.7
2	25.0
3	75.0
4	93.3

FIGURE NO. 1

ESP INLET SAMPLE LOCATION

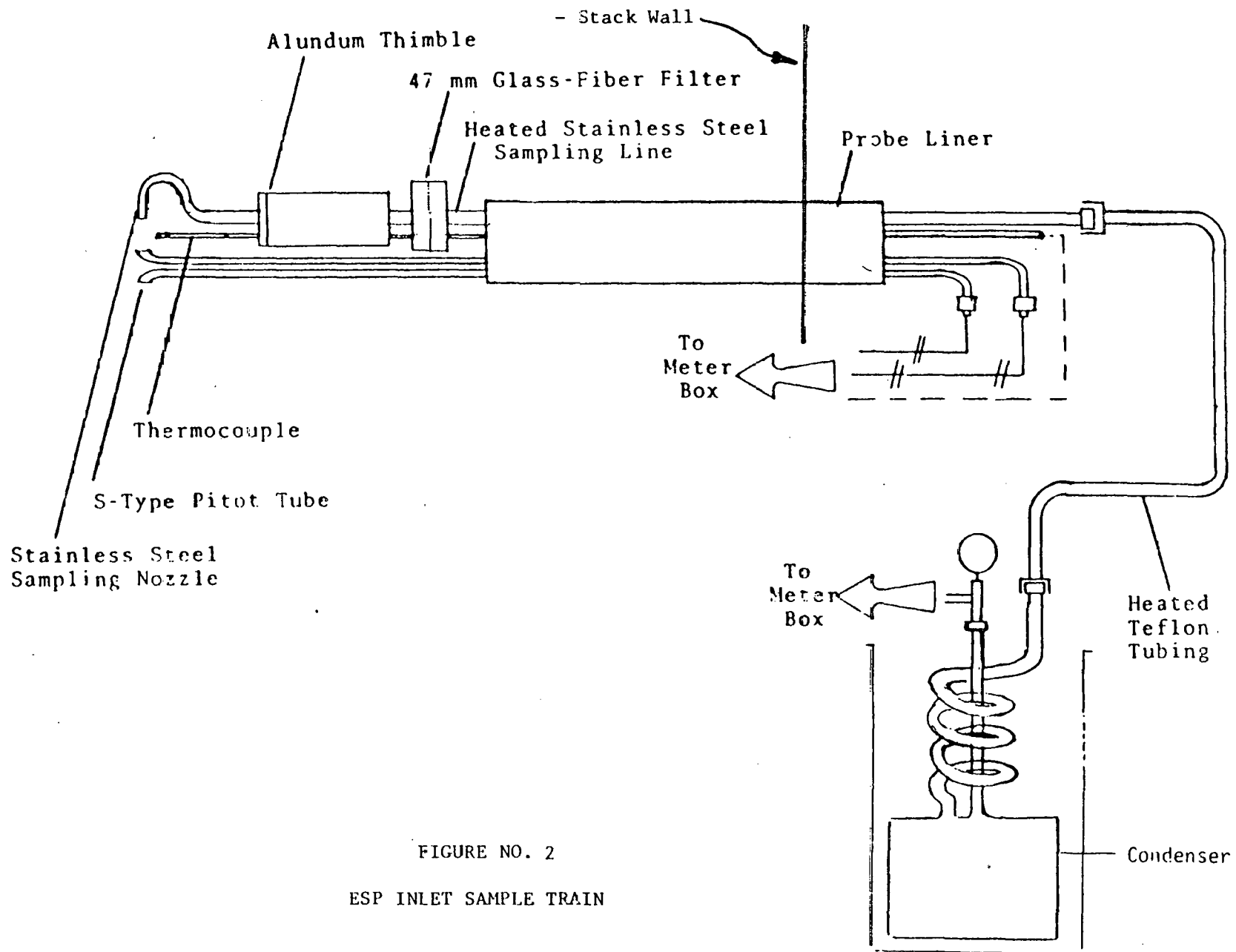


FIGURE NO. 2  
ESP INLET SAMPLE TRAIN

### Sample Recovery

At the end of the test run the sampling train was removed from the stack, leak checked and moved to the clean up area. The sample fractions were recovered as follows:

No. 1 The alundum thimble was removed from its holder, capped and placed in its identified container and labeled.

No. 2 The 47 mm glass fiber filter was removed from its holder and placed along with any loose filter fibers into its identified container and labeled.

No. 3 The nozzle rinse sample was recovered by rinsing with acetone from a wash bottle and brushing. The nozzle was rinsed until no visible particles appeared in the rinse. The sample was rinsed into a polyethylene sample bottle and labeled.

No. 4 An acetone blank was taken.

No. 5 The condensate in the condenser was measured to the nearest 1 ml and discarded.

No. 6 The silica gel was weighed to the nearest 0.5 gram for moisture determination and discarded.

### Sample Analysis

No. 1 The alundum thimble was dried in an oven at 105°C for 2 to 3 hours and cooled in a desiccator, and weighed to a constant weight.

No. 2 The 47 mm fiber glass filter was dried in an oven at 105°C for 2 to 3 hours and cooled in a desiccator and weighed to a constant weight.

No. 3 The nozzle rinse was measured and transferred to a tared 250 ml beaker and evaporated to dryness, desiccated for 24 hours and weighed to a constant weight.

No. 4 Acetone Blank The acetone blank was treated in the same manner as the nozzle rinse. A correction was then made in the rinse sample to account for any acetone contamination.

## TEST PROCEDURE & METHODOLOGY

### ESP OUTLET

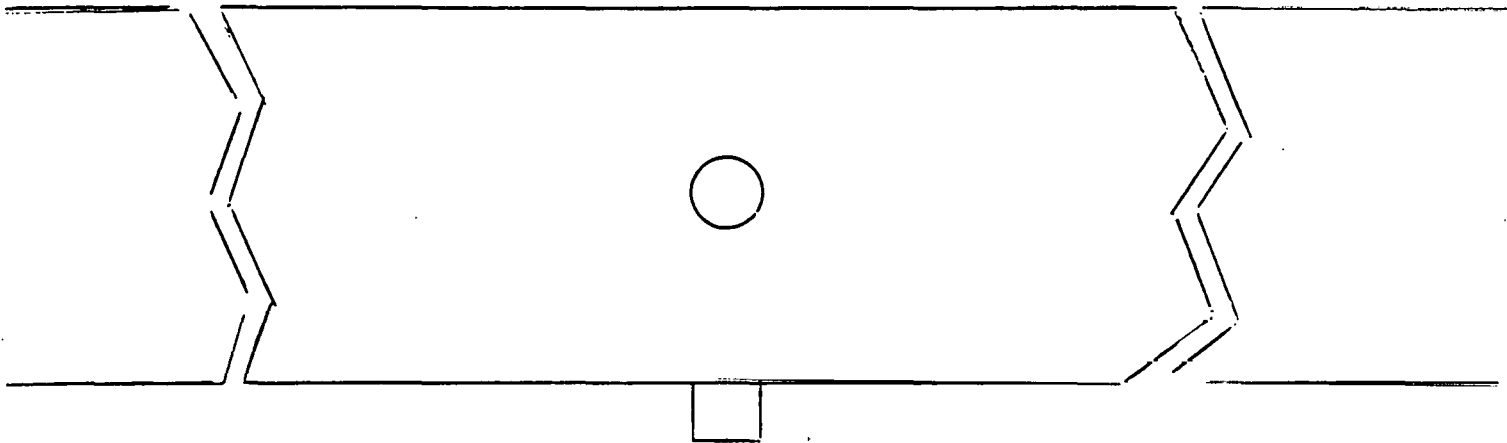
At the ESP outlet location sampling was conducted in two ports located  $90^{\circ}$  apart in the 16" I.D. circular duct (See Figure 3). The sampling train consisted of a stainless steel nozzle, and one in-stack 47 mm fiberglass filter, during the No. 6 fuel oil testing. During the remainder of the SRC test program two consecutive 47 mm filter holders were used. One contained a 47 mm Reeve Angel filter followed by another 47 mm glass fiber filter to investigate the possibility of gaseous sulfate interaction with the filter media. The filters were followed by a heated probe, sample line, condenser and a silica gel holder. The meter box containing a pump, calibrated dry gas meter, orifice and inclined manometer followed the sampling train. The sample train was set up as shown in Figure No. 4

### Sampling Procedure

All sample trains were set up and run according to EPA Reference Method 17. Prior to testing, the sampling train was set up using tared filter media and then leak checked at 15"  $H_2O$  to insure it was leak free. After the sampling train was found to be leak free, ice was placed around the condenser to keep the sample gases below  $68^{\circ}F$ --while testing.

The probe was then placed at the first sampling point and the velocity head ( $\Delta P$ ) was recorded, then the orifice pressure differential ( $\Delta H$ ) required to maintain an isokinetic rate of  $100 \pm 10\%$  was calculated using isokinetic sampling equations\*. This was done at each sample point. At the conclusion of the test

\*See WFI Sciences PETC Boiler Emission Report.



2 FOUR INCH SAMPLE PORTS

16" DUCT DIAMETER

8 TOTAL SAMPLE POINTS

4 TRAVERSE POINTS PER PORT

TRAVERSE POINT	PERCENT OF DUCT DIAMETER
1	6.7
2	25.0
3	75.0
4	93.3

FIGURE NO. 3

ESP OUTLET SAMPLE LOCATION

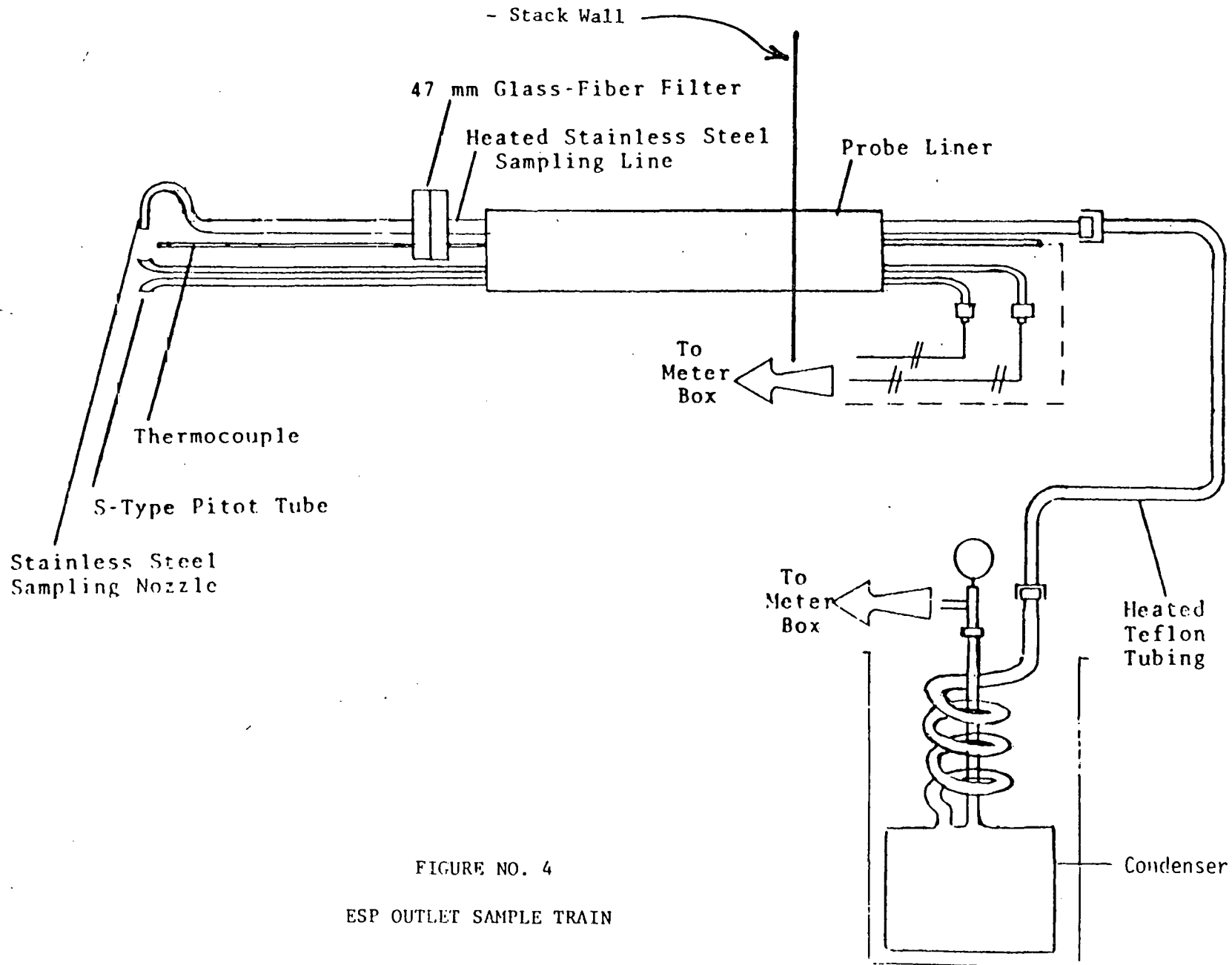


FIGURE NO. 4  
ESP OUTLET SAMPLE TRAIN

the sample train was leak checked at the highest vacuum attained during the test run.

#### Sample Recovery

At the end of the test run the sampling train was removed from the stack, leak checked and moved to the clean up area. The sample fractions were recovered as follows:

No. 1 The first 47 mm filter was removed from its holder and placed in its identified container and labeled.

No. 2 The second 47 mm glass fiber filter was removed from its holder and placed along with any loose filter fibers into its identified container and labeled.

No. 3 The nozzle rinse sample was recovered by rinsing with acetone from a wash bottle and brushing. The nozzle was rinsed until no visible particles appeared in the rinse. The sample was rinsed into a polyethylene sample bottle and labeled.

No. 4 An acetone blank was taken.

No. 5 The condensate in the condenser was measured to the nearest ml and discarded.

No. 6 The silica gel was weighed to the nearest 0.5 gram to determine moisture and discarded.

#### Sample Analysis

No. 1 The first 47 mm filter was dried in an oven at 105°C for 2 to 3 hours and cooled in a desiccator and weighed to a constant weight.

No. 2 The second 47 mm fiber glass filter was dried in an oven at 105°C for 2 to 3 hours and cooled in a desiccator and weighed to a constant weight.

No. 3 The nozzle rinse was measured and transferred to a tared 250 ml beaker and evaporated to dryness, desiccated for 24 hours and weighed to a constant weight.

No. 4 The acetone blank was treated in the same manner as the nozzle rinse. A correction was then made in the rinse sample to account for any acetone contamination.

## EQUIPMENT CALIBRATION

Sample Meter System - The sample meter system--consisting of the pump, vacuum guage, valves, orifice meter, and dry gas meter--was initially calibrated by stringent laboratory methods before it was used in the field. After the initial acceptance, the calibration was rechecked. The recheck provides a method that can be used more often and with less effort to ensure that the calibration has not changed. When the quick check indicates that the calibration factor has changed, the tester must again use the complete calibration procedure to obtain a new calibration factor. After recalibration, the metered sample volume is multiplied by either the initial or the recalibrated calibration factor--that is, the one that yields the lower gas volume for each test run.

Before initial calibration of the metering system, a leak check was conducted. The meter system must be leak free. Both positive (pressure) and negative (vacuum) leak checks were performed.

### Temperature Gauges

Impinger Thermometer - Thermometer used to measure temperature of the gas leaving the impinger train was initially compared with a mercury-in-glass thermometer which meets ASTM E-1 No. 63C or 63F specifications.

Dry Glass Thermometers - The thermometers used to measure the metered gas sample temperature were initially compared with a mercury-in-glass thermometer as above, using a similar procedure.

Stack Temperature Sensor - The stack temperature sensor was calibrated before field use. Each sensor was uniquely marked for identification. The calibration was performed over the range of temperatures anticipated during actual sampling. For temperatures up to 450°C (761°F), a reference mercury-in-glass thermometer was used.

Probe Nozzle - Probe nozzles were calibrated before initial use in the field. Using a micrometer, the ID of the nozzle was measured to the nearest 0.025 mm (0.001 in.). Three measurements were made using measured diameters each time to obtain the average. The difference between the high and the low numbers did not exceed 0.1 mm (0.004 in.).

Type-S Pitot Tube - The pitot tubes were calibrated using the calibration system setup recommended in EPA Method No. 2 (See Figure No. 5). The calibration procedure was as follows: One leg of the Type S pitot tube was marked with an "A" and the other with a "B." To obtain calibration data for either the A or B sides, a manometer was filled with clean fluid of the proper density. All pitot lines and fittings were leak checked, repaired, or replaced, if necessary.

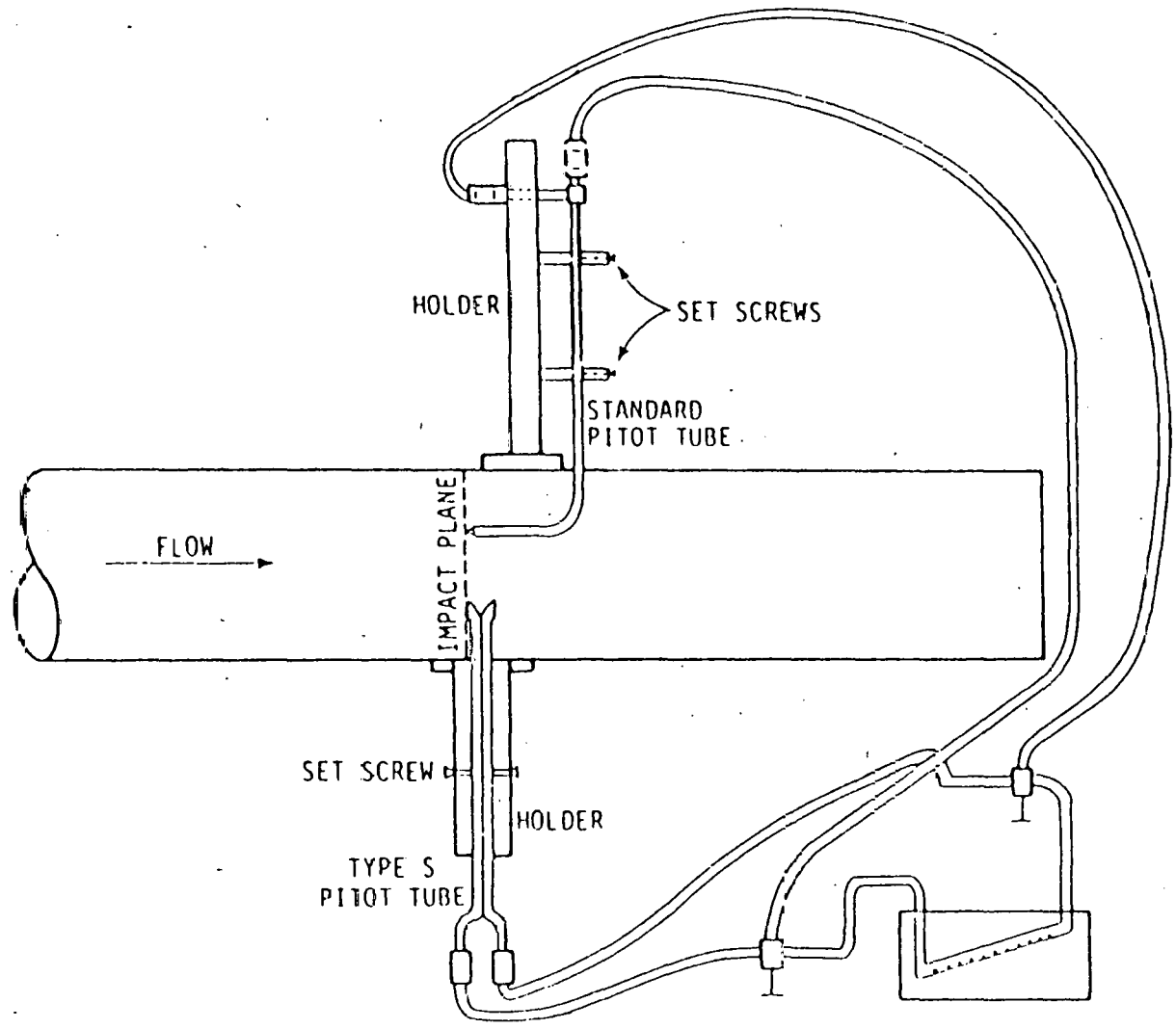


Figure No. 5 Pitot tube calibration set-up.

The inclined manometer was leveled and zeroed. The calibration system I.D. fan was turned on to allow the flow to stabilize.

The standard type pitot tube was positioned near the center of the duct, and the entry port sealed with a rag or duct tape. The pitot tube was checked to insure it was properly aligned and perpendicular to the duct.

The I.D. fan speed was adjusted to give the desired velocity head, as measured by the standard pitot tube and the  $\Delta p_{std}$  was recorded on a data form.

The Type S pitot tube was then connected to the manometer. The Type S tube was inserted and located at the same point in the duct as that measured by the standard tube.

The Type S tube was aligned with leg A facing directly upstream. The velocity head ( $\Delta p_s$ ) was read and recorded on the data form. The Type S tube was removed from the duct, and disconnected from the manometer.

The procedure was repeated until three sets of velocity head measurements for each pitot tube were obtained.

If necessary, the complete procedure was repeated with leg B of the Type S pitot tube facing upstream.

The Type S pitot tube coefficient,  $C_{p(S)}$ , was calculated for each set of measurements, using the equation below.

$$C_{p(S)} = C_{p(std)} \sqrt{\frac{\Delta p_{std}}{\Delta p_S}}$$

where:

- $C_{p(S)}$  = Type S pitot tube coefficient
- $C_{p(std)}$  = Standard pitot tube coefficient (use 0.99 if coefficient is unknown and tube is designed according to guidelines in Section 1.7 of the EPA method)
- $\Delta p_{std}$  = Velocity head measured by the standard pitot tube, cm (in.)  $H_2O$ .
- $\Delta p_S$  = Velocity head measured by the Type S pitot tube, cm (in.)  $H_2O$ .

## DISCUSSION OF RESULTS

### General Test Results Analysis

The test data and results for each fuel type are included in this volume as separate appendices.

The test numbering system includes preliminary tests, tests with steady-state boiler, and WFI Sciences test numbers. The WFI Sciences test numbers are the numbers in parentheses. This number would be used if one were to look at the field data in Appendices II-V of this report. The ESP parametric tests run during the boiler testing are designated by "P". The ESP tests run under steady-state conditions are designated by a number only. It is this data that is discussed and graphed. The dates and times of each test are included so that the mass train data can be referenced to other data collected by other contractors.

Flue gas characteristics are listed by test number and include orsat data, gas temperatures, and moisture content. The orsat data measured the oxygen and carbon dioxide at the inlet and outlet of the ESP. No carbon monoxide data was collected by WFI Sciences since this measurement is not necessary to determine the molecular weight of the flue gas. CO readings at the boiler were recorded and can be found in the boiler report. Gas temperatures are presented in both metric and English units. The moisture in the flue gas was measured by the condensation method described in the Test Procedure and Methodology.

The gas volumes are presented in actual and standard conditions for both English and metric units. The in-leakage across the ESP was calculated by two methods. One method was to find the difference between the standard dry volumes in and out of the ESP. The other method was to calculate in-leakage using the oxygen data. The oxygen method is the more accurate measurement since volumes include pitot error.

The mass emission data is presented in six ways. In English units the loadings are presented in gr/ACF, gr/SDCF, and lb/10<sup>6</sup> Btu. In metric units the data is presented in mg/ACM, mg/SDCM, and NG/Joule. The test isokinetics are presented to show that the sampling rates were within the 100% ± 10% range. Some preliminary tests were below 90% due to plugged filters which prevented the required gas volume from being sampled.

The ESP data presented includes power readings and terms used to describe ESP operation. The power readings are the average of each test. Specific collecting area, current density, specific corona power, and migration velocity are calculated to describe the ESP operating conditions.

Graphs were made to show the relationships between the ESP outlet loadings, efficiency, and migration velocity versus gas volume, SCA, current density, and specific corona power. The graphs are shown in the appendix for that particular fuel type.

This data and results are only for the testing done on the ESP. No rapping of either the discharge or collecting electrodes were done during the tests. Rapping would increase outlet particulate loadings and decrease the efficiency and migration velocity. The data presented here is to be used by the SORI computer model.

#### ESP Operating Nomenclature and Definitions

There are many terms used to describe the operating conditions of an ESP. The amount of gas to be cleaned and the size of the ESP are related in terms of specific collecting area (SCA). The gas volume is stated in ACFM, actual cubic feet per minute. Sometimes the gas volume is corrected to standard temperature and pressure without moisture and is known as SDCFM, standard dry cubic feet per minute. The collecting area of an ESP is the total surface area of all the collecting plates. SCA is defined as square feet of collecting area per 1000 ACFM. SCA will vary from 200 to 700 sq ft/KACFM depending upon the fuel type. A hard to collect ash may require a SCA of 700 sq ft/KACFM in order to meet emission limits. The No. 6 oil and SRC fuels were tested with a SCA of 244 sq ft/1000 ACFM.

In addition to the gas volume, the amount of power input to an ESP

will affect its performance. ESP power is the secondary d.c. voltage and current output of the transformer-rectifier. The DC voltage is rated in KV, kilovolts, and the current in ma, milliamps. One way to describe power is in terms of current density. Current density is defined as either nanoamps per square cm, na/sq cm, or milliamps per square foot, ma/sq.ft. Another way to describe power is by specific corona power, watts per 1000 ACFM.

The migration velocity, W, is often used to describe the collection characteristic of a particular type of fly ash. The Duestch-Anderson equation is:

$$\text{eff} = 1 - e^{\frac{-WA}{Q}}$$

where eff = ESP efficiency

W = migration velocity

A = total collecting area

Q = volumetric flow rate

solving for W

$$W = -\ln(1-\text{eff}) (Q/A)$$

The equation shows the migration velocity to be a function of the efficiency, collection area, and the volumetric flow rate. Ideally, the migration velocity is constant as the other variables change. The only other variable not considered by the Deutsch-Anderson equation is the power input which should increase the value of W as the efficiency increases with increased power.

### General Observations

The performance of an ESP in many cases can be determined by observing the ESP power readings and the stack plume. When the ESP stack was clear, the power readings were good in all three fields. Good power can be thought as 30-50 KV with 5-10 ma. A high KV with very little current, ma, indicates an ash buildup on either the discharge or collecting electrodes. This inhibits corona generation and decreases the ESP performance. The general mode of operation during the testing at PETC was to rap the collecting plates and vibrate the discharge electrodes before or between tests. During the tests the KV would increase as the ash would buildup on the wires and plates, especially in the first twenty minutes. The first field showed the largest increase in KV since the most ash is collected in that field. The third field may not show any increase because of very little ash entering that field. The ESP power readings in Volumes II-IV show this to generally be true. This trend does not appear to be correct for some tests with the SRC fuels, but this was due to insulator fouling.

Insulator fouling is when a layer of ash is desposited on the insulator. The layer of ash acts as a conductor when high voltage is applied to the field. The secondary current is then going across the insulator instead of into the field. The current leakage across the insulator can be detected by secondary current meter fluctuation and by a distorted waveshape on the oscilloscope. Current leakage or tracking of the insulators causes the corona field to be collapsed for one-half cycle or 1/120

second or more and this deteriorates the ESP performance. To help prevent this tracking, the ESP KV power levels were reduced to just below tracking voltages. This resulted in first field KVs lower than second field KVs.

The severity of the insulator tracking depends upon the resistivity of the fly ash. The lower the resistivity, the easier it is for tracking to occur. The average power readings shown in Appendix II show relatively high KVs of 45-50 at 10 ma for No. 6 fuel oil and there were no problems with insulator tracking. When the SRC fuel, whose ash has low resistivity and high carbon content, was burned, there was a tracking problem. The first field KVs are 4-5 KV lower than the second field when they should have been a few KV higher due to increased ash loadings. The SRC residual fuel oil was the worst case with the first field operating at 25-30 KV and the second field operating at 37-39 KV.

Several modifications were made to the ESP insulator system in order to minimize the insulator tracking. The layout of the insulators for each field is shown on page 3 of Appendix I. Originally the insulators were attached to a gas tight casing out of the gas stream. When the tracking occurred with the pulverized SRC, shrouds and vent holes were added to the insulators. This purge air was to keep the insulators clean, but increased the percent inleakage from 10% to 30%. After a couple of days of operation, the insulator tracking problem still existed. A compressor was added to the purge system so that the insulators could be blown clean when necessary. This helped but another compressor was used

to give adequate purge pressure and air flow. Even with all the modifications, the insulators would still start to track after a day or two of operation. This necessitated shutting down the ESP, opening the top access doors, and cleaning the insulators.

The inleakage with the purge air modifications was 20%-30%. This is a large amount but does not bias the results significantly. When the ash resistivity is low,  $10^7 - 10^8$  ohm-cm, dilution and cooling will not change the resistivity or the ESP performance to any extent. If the resistivity had been high,  $10^{12} - 10^{13}$  ohm-cm, then the dilution air would have changed the resistivity. Resistivity is normally a bell-shaped curve with  $10^{12} - 10^{13}$  at the top and  $10^7 - 10^8$  at the bottom where small operating changes have a small effect on resistivity. When comparing the emissions data, the gr/ACF and gr/SDCF include the air inleakage while the lb/ $10^6$  Btu corrects for inleakage. Therefore, the emissions will be analyzed on a lb/ $10^6$  Btu basis.

#### Stack Opacity

An opacity monitor had originally been installed in the outlet nozzle of the ESP. The opacity probe had an enclosed reflector in the gas stream which was purged with a blower. The purge was ineffective and the lense kept getting dirty from dusty ambient air and resulted in erroneous opacity measurements. It was also found that the probe had sagged inside the ESP causing misalignment of the probe reflector. The use of the monitor was stopped. When all fields were in operation, the stack was clear. The opacity should be considered to be 0%-3% which is invisible to the eye.

## No. 6 Fuel Oil

The first fuel burned was the No. 6 fuel oil. These tests were baseline tests to which the SRC fuels could be referenced to. A total of fifteen tests were run with eleven of these tests at one boiler condition.

All of the tests run with the No. 6 oil were run at one ESP condition. The flue gas volume to the ESP was set at 5000 ACFM at 340-370<sup>o</sup>F. This resulted in a SCA of 230-240 sq ft./1000 ACFM. The power input to the ESP was set with each of the three fields operating at 10 ma. The secondary voltages for the first field were 44-50 KV and 35-42 KV for the second and third fields. This resulted in a current density of 26 na/sq. cm. and a specific corona power of 230-250 watts/1000 ACFM.

The mass train testing showed the ESP inlet loadings to consistently be between 0.045 - 0.053 lb/10<sup>6</sup> Btu. The outlet particulate loading varied from 0.003 - 0.006 lb/10<sup>6</sup> Btu with an average of 0.0039 lb/10<sup>6</sup> Btu. The efficiency of the ESP was 91%-92%. The average migration velocity, W, was 5.4 cm/sec. The graphs in Appendix II show the data as a function of gas volume and power. Since only one ESP test condition was run, the graphs are limited in scale ranges and the data appears to have a large scatter. For example, the graph of lb/10<sup>6</sup> Btu out versus SCA cover the 200-300 SCA range while the typical range for SCA is from 200-700 sq. ft./1000 ACFM. On the larger scale, the scatter would appear to be minimal.

## SRC Fuel

One set of ESP conditions were tested with the pulverized SRC fuel. A steady-state boiler operation could not be achieved due to boiler burner clinkering, fluctuating CO and opacity, and occasional 90% opacity spikes. Natural gas was burned with the SRC and accounted for 7% of the total thermal input. The gas helped to stabilize the flame, but boiler CO and opacity conditions were still erratic. The ESP test parameters were a gas volume of 5000-5400 ACFM which result in a SCA of 220-240 sq ft/1000 ACFM and a current density of 20-23 na/sq cm.

The inlet particulate loading varied from 0.7 to 1.4 lb/10<sup>6</sup> Btu. The wide range is due to the unstable burning of SRC which resulted in increased grain loadings. The lower numbers are probably more indicative of a good burn, but this is not documented.

The ESP outlet loadings varied from 0.003 to 0.026 lb/10<sup>6</sup> Btu with efficiencies of 99.0% to 99.7%. This wide range of data was also due to an unstable boiler with large opacity spikes. The opacity spikes are more noticeable at the outlet since the ESP can not recover from rapid changes in particulate loading. When an opacity spike would occur, the KV would drop and the ma would rise as though there was an ash ground. After a few minutes the power would resume its normal levels. One or two spikes are enough to invalidate a test. Tests #1, 2, 3, 5, and 11 have large outlet loadings and are considered invalid. The large loadings may have been from the opacity spikes or from nozzle scrapings when inserting or removing the sampling probe.

The migration velocity averaged 11.7 cm/sec without the invalid tests. This value is about the same as the other SRC fuels.

#### SRC Residual Fuel Oil

With the boiler at steady-state, three different modes of ESP operation were tested. Tests #1-5 were with a gas volume of 5000 ACFM with the ESP fields set at 10 ma except for field #1 which ran at maximum power with 3-5 ma due to insulator tracking. Tests #6-10 were at the same 5000 ACFM, but with a lower current of 5 ma per field. The last three tests were run at 7000 ACFM with the fields set at 5 ma. The boiler was run at a steady state mode.

The results of the tests are shown in Appendix IV tables and graphs. The inlet loading to the ESP ranged from 0.13 - 0.23 lb/10<sup>6</sup> Btu. Test #1 and 2 had low loadings of 0.13 - 0.14 lb/10<sup>6</sup> Btu. The average inlet loading without those two tests was 0.208 lb/10<sup>6</sup> which is four times the amount of #6 oil ash. The outlet loadings with the SRC residual fuel oil ash were lower than the #6 oil loadings. With an SCA of 240 sq ft/1000 ACFM and a current density of 20 na/sq cm the outlet loadings ranged from 0.0005 - 0.003 lb/10<sup>6</sup> Btu. The migration velocity was calculated to be 10.5 cm/sec. The amount of particulate collected on the filter paper was small and the accuracy of the test was questionable. The current density was lowered to 13 na/sq cm to theoretically lower the efficiency. The opposite happened, the efficiency increased from 99.0% to 99.4% with outlet loadings of 0.0002 - 0.002 lb/10<sup>6</sup> Btu. The migration velocity increased from 10.5 to 11.8 cm/sec. This indicates that the ESP was overpowered at 20 na/sq cm. The lower particulate loadings with a current density 13 na/sq cm are about

the same as those with 20 na/sq cm when one considers the accuracy of measuring loadings this small.

The biggest change in ESP performance came with the increase in gas flow rate or a decrease in SCA. With SCA of 173 and a current density of 13 na/sq cm. The outlet loadings increased to 0.007 - 0.009 lb/10<sup>6</sup> Btu. The efficiencies were 96%, and the migration velocity dropped to 9.5 cm/sec.

The graphs show the three ESP operating conditions with the two 5000 ACFM conditions having similar loadings and efficiencies. The two sets of data that can be used for the SoRI computer model would be the 7000 ACFM, 173 sq ft/1000 ACFM SCA with a current density of 13 na/sq cm and the 5000 ACFM, 240 sq ft/1000 ACFM SCA with the 13 na/sq cm current density.

#### SRC-Water Slurry

Two data points that could be used by the SoRI computer model were obtained from the slurry testing. Three ESP test conditions were tested, but one of the conditions consisted of only two tests whose results varied greatly. The primary test conditions were a gas volume of 5300 ACFM, an SCA of 220 sq ft/1000 ACFM, and a current density of 18 na/sq cm. Seven tests were run at this condition, but two of the tests showed high particulate loadings and are not included in the averaging of the data. The five runs counted were no.'s 1, 2, 5, 7, and 8. The second condition was to operate the ESP with only the last two fields energized, runs 9, 11, and 12. With two fields energized at 5300 ACFM, the SCA

was 145 sq sf/1000 ACFM and the current density was 12 na/sq cm.

The inlet particulate loading averaged  $0.96 \text{ lb}/10^6 \text{ Btu}$  which is about the same as the SRC fuel. This ash did have a grayish tint compared to the SRC fuel ash which was black. The tint was assumed to be due to the additive Lomar D which is a wetting agent. The voltage-current (V-I) data for the slurry was quite different from the SRC fuel and is discussed in the V-I section of this discussion.

The outlet emission rates for the 200 SCA at 18 na/sq cm were from 0.003-0.008 lb/mmbtu with two tests at 0.0192 and  $0.0155 \text{ lb}/10^6 \text{ Btu}$ . The ESP efficiency was 99.3% with a migration velocity of 11.9 cm/sec. The two high loading tests are not considered typical and the data is not included in the averages. When the first field was de-energized, the emission rate increased to  $0.026 \text{ lb}/10^6 \text{ Btu}$  with an efficiency of 97.3%. The migration velocity dropped from 11.9 to 5.7 cm/sec.

#### Rapping and Reentrainment

The fly ash of all four fuels tested was easily cleaned from the plates and wires. The buildup of ash was a problem only when the unit was allowed to cool below the dewpoint during either a boiler or an ESP downtime. The ease of rapping was to be expected with the low resistivity ash. Low resistivity particles tend to lose their charge at the collecting plate more readily than high resistivity particles.

The ease of rapping will be a problem for rapping reentrainment.

The ash was light and was reentrained quite easily. The rapping reentrainment was measured by SoRI using particle counters. This data is to be used by SoRI in their computer model in sizing a full-scale unit.

#### V-I Data and Curves (Appendix VI)

The V-I (voltage-current) data describes the electrical characteristics of the ESP and of the flue gas. The voltage is the secondary or ESP voltage which is measured in KV. The current is the secondary current resulting from corona generation. As an increasing voltage is applied to an isolated electrode or wire, a corona field will form. Within the corona field there is a flow of electrons or current. The higher the applied voltage, the higher the corona current until sparkover voltages are reached.

Without any gas flow through the ESP there exists V-I data for air, known as an airload. This data is dependent upon the ESP electrode configuration and spacing. Corona fields occur most readily around sharp objects. As a result the V-I characteristics for a round or star wire are different than the V-I characteristics of a barbed discharge electrode. A round wire will require more KV than a barbed wire for the same corona current.

Different discharge electrode configurations are best suited for different applications. A spiked or barbed electrode results in a strong localized corona which is good for high dust loadings. A round or star wire generates a corona along the entire electrode. This re-

sults in better corona coverage and is good with light dust loadings. Both the No. 6 oil and SRC fuels are low in ash, and thus, the star type wire was chosen for this particular application. A drawing of the star wire is included in Appendix I.

For a given electrode configuration, different flue gas characteristics will effect the V-I data. Ash loading, ash resistivity, flue gas moisture, and temperature will effect the V-I properties. Generally, the first field will have a higher voltage KV for the same current, ma, than the other fields due to increased loadings. The V-I curves in Appendix VI show this to be true. The type of fuel burned determines the flue gas characteristics and the V-I data.

The V-I data for the No. 6 oil shows that fields #2 and #3 V-I curves are basically the same. The field #1 curve is located to the lower right. This indicates that most of the ash is being collected in the first field since the second and third field curves are the same. The variation of the two curves at the higher current levels is probably due to some variation in one of the fields such as electrode spacing, ash buildup, or metering inaccuracy.

The V-I data for the pulverized SRC shows the three fields to have the same curves with little variation. This is due to the nature of the ash which is low resistivity and high carbon. The ash conducts so easily that the amount of ash has little effect on the V-I characteristics.

The SRC residual oil V-I data shows the three fields to be similar with a small shift in position for the three fields. This data is typical of a low mass loading.

The SRC-water slurry V-I data shows three distinctly different curves for the three fields. The nature of the fuel accounts for the differences. The addition of water or moisture flattens and shifts the curves down and to the right. This fuel also contains a wetting agent called Lomar-D which also affects the V-I data in its own way which is unknown.

## CONCLUSION

The data obtained from the ESP testing will be a good base for the SoRI computer program to specify a full-scale ESP. At least one good data point was obtained for each of the SRC fuels. Additional data points were obtained for the SRC residual oil and SRC-water slurry. This data was obtained under different ESP conditions with one boiler condition. The additional data will allow SoRI to run two programs for the two fuels to see if the full-size ESP specifications are similar.

The ESP operation during the testing was quite smooth with the exception of the insulator fouling. There were no problems with sparking within the fields. The ash removal indicated that most of the flyash was collected in the first field. The insulator fouling is a design problem of the pilot ESP and should not be a concern in a full-scale ESP. The insulator fouling did limit the performance of the first field, but this is accounted for in the ESP power variables.

The flyash characteristics may change with more complete combustion. The ash carbon content was high with 80 - 90% loss of ignition with the small 700 H.P. boiler. More complete combustion in a utility boiler could change the particle resistivity and size distribution which will change the ESP performance. Performance could be either better or worse.

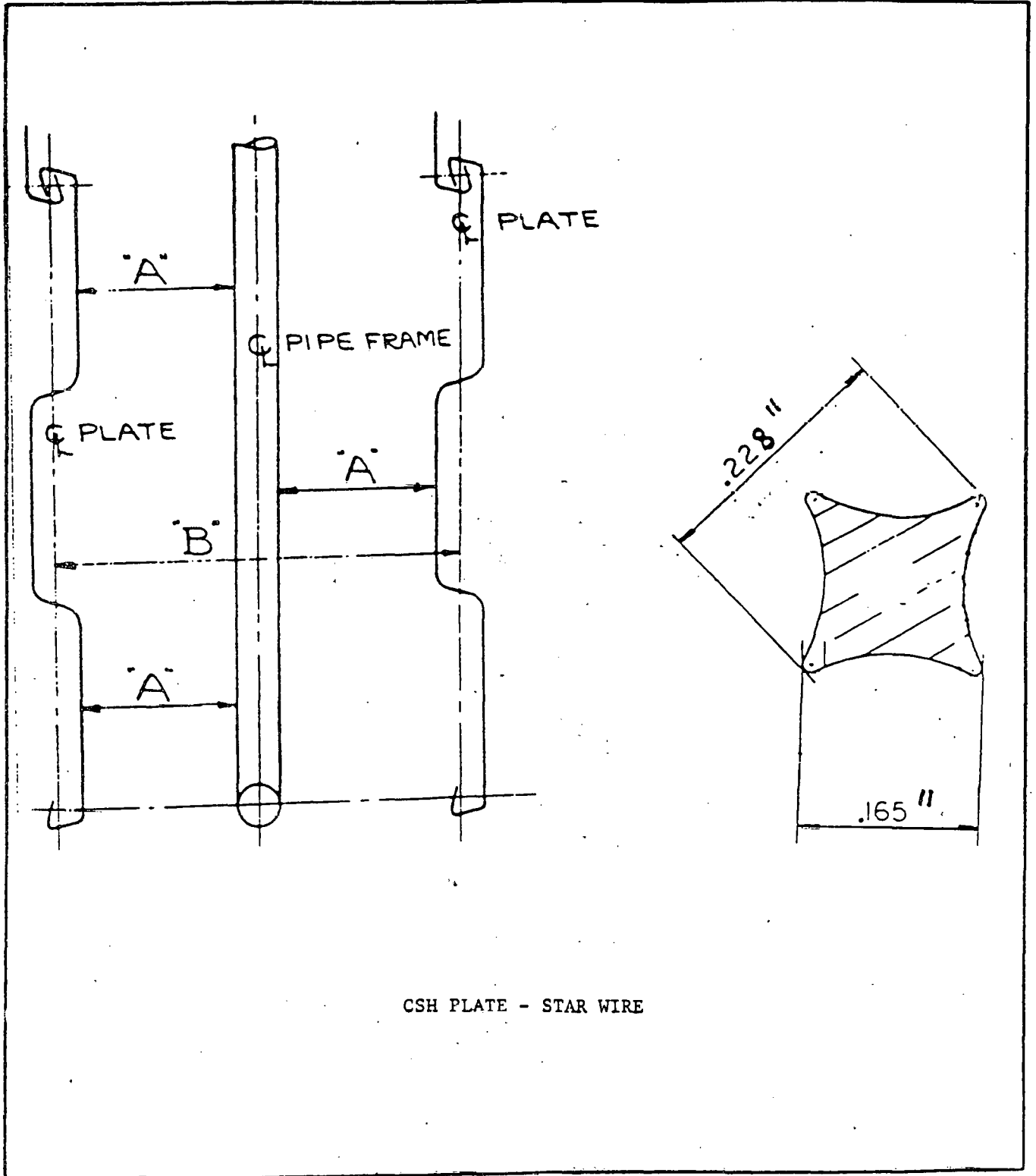
APPENDIX I

ESP DRAWING AND DUCT LAYOUT









CSH PLATE - STAR WIRE

CUSTOMER \_\_\_\_\_ PROJECT NO. \_\_\_\_\_

APPLICATION \_\_\_\_\_ SHEET \_\_\_\_\_ OF \_\_\_\_\_

PREPARED BY \_\_\_\_\_ DATE \_\_\_\_\_

CHECKED BY \_\_\_\_\_ DATE \_\_\_\_\_



APPENDIX II

#6 Fuel Oil Test Results and Graphs

	Page
<u>TESTING DATA</u>	
Date, Time, Orsat, Gas Temperature, Moisture . . . . .	1
Gas Volume, In-leakage . . . . .	2
Mass Emission Rates - English . . . . .	3
Mass Emission Rate - Metric . . . . .	4
ESP Operating Data and Results . . . . .	5
 <u>GRAPHS</u>	
LB/10 <sup>6</sup> Btu Out Versus ACFM In . . . . .	6
LB/10 <sup>6</sup> Btu Out Versus SCA . . . . .	7
LB/10 <sup>6</sup> Btu Out Versus Current Density . . . . .	8
LB/10 <sup>6</sup> Btu Out Versus Specific Corona Power . . . . .	9
% Efficiency Versus ACFM In . . . . .	10
% Efficiency Versus SCA . . . . .	11
% Efficiency Versus Current Density . . . . .	12
% Efficiency Versus Specific Corona Power . . . . .	13
W Versus SCA . . . . .	14
W Versus Current Density . . . . .	15
W Versus Specific Corona Power . . . . .	16

P E T C - S R C

M A S S T R A I N D A T A

( 4 6 O I L F I R E D )

TEST NO	DATE (1982)	TIME START	TIME END	--ORSAT DATA (% VOL)--				----GAS TEMPERATURE----				--MOISTURE--	
				O2IN	CO2IN	O2OUT	CO2OUT	IN	OUT	IN	OUT	IN	OUT
(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(F)	(F)	(C)	(C)	(%)	(%)
P1(1)	8-26	10:55	13:10	3.4	14.4	5.6	11.4	346	283	174	139	11.2	10.2
P2(2)	8-26	13:46	15:53	3.4	14	5.3	11	352	290	178	143	13.1	12.7
P3(3)	8-27	10:00	12:06	3.2	14.4	5	12.4	340	290	171	143	13	11.7
P4(4)	8-27	12:42	14:49	3.2	14.6	4.9	12.6	348	290	176	143	12.3	12
1(5)	8-30	9:16	11:26	3.2	13.6	4.8	13.2	335	289	168	143	12.6	10.8
2(6)	8-30	12:45	14:53	3.4	13.8	5	12	344	291	173	144	13	11.5
3(7)	8-31	8:30	10:38	3.7	14	5.4	11.8	345	290	174	143	13.4	11.3
4(8)	NO	TEST	BOILER	LOST	FIRE			NA	NA	NA	NA	NA	
5(9)	8-31	15:54	18:00	3.5	14	5	13	366	308	186	153	13.2	11.6
6(10)	9-1	8:30	10:38	3.5	14	5.1	12.6	358	303	181	151	13.5	12.4
7(11)	9-1	12:32	17:38	3.4	14	5	12.6	374	310	190	154	13.7	13.2
8(12)	9-2	8:34	10:41	3.5	14	5.1	12.2	355	300	179	149	12.5	12.2
9(13)	9-2	12:33	14:44	3.4	14.2	5.2	12.6	362	305	183	152	13.5	12.3
10(14)	9-3	7:10	9:17	3.8	13.4	5.4	12.6	362	304	183	151	12.7	11.7
11(15)	9-3	10:36	12:49	3.4	13.8	5.3	12.6	374	313	190	156	13.4	11.6

I-II

P E T E - B R C I M A S S T R A I N D A T A ( 0 6 O I L F I R E D )

TEST NO.	G A S V O L U M E								% IN-LEAK (SDCFM)	% IN-LEAK (0-2)
	IN (ACFM)	OUT (ACFM)	IN (SDCFM)	OUT (SDCFM)	IN (ACMM)	OUT (ACMM)	IN (SDCMM)	OUT (SDCMM)		
P1(1)	4119	4241	2253	2541	116.7	120.1	63.8	74.8	17.22	14.38
P2(2)	4203	4270	2233	2562	119	120.9	63.2	72.6	14.73	12.18
P3(3)	4766	4503	2545	2716	135	127.5	72.1	76.9	6.72	11.32
P4(4)	4738	4509	2526	2719	134.2	127.7	71.5	77	7.64	10.63
1(5)	4960	4769	2699	2735	140.5	135.1	76.4	83.1	8.74	9.94
2(6)	5289	4900	2833	2984	149.8	138.8	80.2	84.5	5.33	10.06
3(7)	5083	4786	2701	2918	144	135.5	76.5	82.6	8.03	10.97
4(8)	NA	NA	NA	NA	NA	NA	NA	NA	NA	
5(9)	5100	4813	2648	2859	144.4	136.3	75	81	7.97	9.43
6(10)	4925	4732	2603	2792	139.5	134	73.7	79.1	7.26	10.13
7(11)	5189	5033	2687	2915	147	142.5	76.1	82.6	8.49	10.06
8(12)	5068	4890	2664	2888	143.5	138.5	75.4	81.8	8.41	10.13
9(13)	5127	4816	2646	2820	145.2	136.4	74.9	79.9	6.58	11.46
10(14)	5355	5181	2787	3059	151.7	146.7	78.9	86.6	9.76	10.32
11(15)	5426	4686	2759	2738	153.7	132.7	78.1	77.5	-0.76	12.18

P E T C - S R C      T E S T   E M I S S I O N   R A T E S      ( # 6   O I L   F I R E D )

TEST NO.	----GR/ACF.-----			----GR/SDCF-----			Lbs/10 <sup>6</sup> Btu (F-91.05)--			TEST	
	IN	OUT	%	IN	OUT	%	IN	OUT	%	ISO	KINETICS
	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(%IN)	(%OUT)
P1(1)	.0154	.0006	96.10	.0282	.001	96.45	.044	.0019	95.68	87.2	97.6
P2(2)	.0159	.0009	94.34	.03	.0015	95.00	.0468	.0026	94.44	88.4	95.6
P3(3)	.0151	.0018	88.08	.0283	.0029	89.75	.0436	.005	88.53	93.4	103.2
P4(4)	.0151	NA	NA	.0284	NA	NA	.0437	NA	NA	93.6	104.9
1(5)	.0153	.001	93.46	.0281	.0016	94.31	.0434	.0028	93.55	91.7	98.6
2(6)	.0162	.0022	86.42	.0303	.0037	87.79	.0472	.0063	86.65	90.6	99.3
3(7)	.0153	.0015	90.20	.0287	.0024	91.64	.0456	.0043	90.57	93	98.7
4(8)		NA	NA		NA	NA		NA	NA		
5(9)	.0146	.0011	92.47	.028	.0019	93.21	.044	.0033	92.50	93.2	100.7
6(10)	.0173	.0018	89.60	.0327	.003	90.83	.0512	.0052	89.84	88.2	93.6
7(11)	.0162	.0012	92.59	.0312	.0022	92.95	.0487	.0037	92.40	93.5	98.3
8(12)	.0237	.0012	94.94	.0451	.0021	95.34	.0708	.0037	94.77	92.6	102
9(13)	.0153	.0011	92.81	.0297	.0019	93.60	.0463	.0033	92.87	94.1	102.4
10(14)	.0165	.0014	91.52	.0316	.0023	92.72	.0505	.0042	91.68	90.8	101
11(15)	.0152	.0011	92.76	.03	.0019	93.67	.0468	.0033	92.95	91	100.9

P E T C - B R C T E S T E M I S S I O N R A T E S ( 0 6 O I L F I R E D )

TEST NO.	---MG/ACH---			---MG/BDCH---			---MG/JOULE---			TEST ISOKINETICS	
	IN	OUT	%	IN	OUT	%	IN	OUT	%	(%IN)	(%OUT)
P1(1)	35.2	1.4	96.02	64.5	2.3	96.43	18.9	.8	93.77	87.2	97.4
P2(2)	34.4	2.1	94.23	48.4	3.4	93.04	20.1	1.1	94.53	88.4	95.6
P3(3)	34.5	4.1	88.12	64.8	6.6	89.81	18.7	2.2	88.24	93.4	103.2
P4(4)	34.5	NA	NA	65	NA	NA	18.8	NA	NA	93.4	104.9
1(5)	35	2.3	93.43	64.3	3.7	94.25	18.7	1.2	93.58	91.7	98.6
2(6)	37.1	5	86.52	69.3	8.5	87.73	20.3	2.7	86.70	90.6	99.3
3(7)	35	3.4	90.29	65.7	5.5	91.63	19.4	1.8	90.82	93	98.7
4(8)	0	NA	NA	0	NA	NA	0	NA	NA		
5(9)	33.4	2.5	92.51	64.1	4.3	93.29	18.9	1.5	92.06	93.2	100.7
6(10)	39.6	4.1	89.65	74.8	6.9	90.78	22	2.2	90.00	88.2	93.6
7(11)	37.1	2.7	92.72	71.4	5	93.00	20.9	1.6	92.34	93.5	98.3
8(12)	54.2	2.7	95.02	103.2	4.8	95.35	30.4	1.6	94.74	92.6	102
9(13)	35	2.5	92.86	68	4.3	93.68	19.9	1.4	92.96	94.1	102.4
10(14)	37.8	3.2	91.53	72.3	5.3	92.67	21.7	1.8	91.71	90.8	101
11(15)	34.8	2.5	92.82	68.6	4.3	93.73	20.1	1.4	93.03	91	100.9

P E T C - S R C      E S P   D A T A   &   R E S U L T S   ( # 6   O I L   F I R E D )

TEST NO.	-- E S P   A V E R A G E   P O W E R --						ESP	SP PWR	CURR	I-DENS	I-DENS	SCA	W	W-K
	KV1	MA1	KV2	MA2	KV3	MA3	POWER (WATT/ (WATT) KACFM)		AVE	(MA/ SQ FT)	(NA/ SQ CM)	(SQ FT /KACFM)	(CM/ SEC)	(CM/ SEC)
	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
P1(1)	46.9	19.4	40.3	25.4	45.8	30	3405	827	24.9	.0613	65.98	294	5.39	16.93
P2(2)	48.7	20	40.3	24.7	45.8	30	3342	795	24.9	.0613	65.98	290	5.09	14.78
P3(3)	43.7	10	36.1	10	36.7	10	1164	244	10	.0246	26.48	254	4.29	9.24
P4(4)	45.3	9.46	37	9.7	37	9.9	1155	244	9.69	.0239	25.73	257	NA	NA
1(5)	44.2	9.96	35.2	10.1	36.6	10.1	1164	235	10	.0246	26.48	246	5.70	15.72
2(6)	46.9	9.9	35.4	10	37.1	10.5	1206	228	10.1	.0249	26.80	230	4.45	8.99
3(7)	47.5	10	36.9	10	36.5	10	1209	238	10	.0246	26.48	240	5.02	11.87
4(8)							NA	NA	NA	NA	NA	NA	NA	NA
5(9)	47.1	10	38.6	10.2	38.2	10	1247	245	10.1	.0249	26.80	239	5.49	14.18
6(10)	46.2	9.4	38.6	9.93	38.2	10	1199	243	9.78	.0241	25.94	247	4.69	10.69
7(11)	47.7	9.67	40.2	9.5	42.1	9.6	1248	241	9.59	.0236	25.40	235	5.37	14.34
8(12)	44.8	9.98	36.8	10	41.4	10	1229	243	9.99	.0246	26.48	240	6.23	18.38
9(13)	46.8	10	37.7	10	41.8	10	1263	246	10	.0246	26.48	238	5.63	14.84
10(14)	49.1	10	41.4	10	43.6	10	1341	250	10	.0246	26.48	228	5.56	13.87
11(15)	50.1	10	41.4	10	43.6	10	1351	249	10	.0246	26.48	225	5.98	15.82

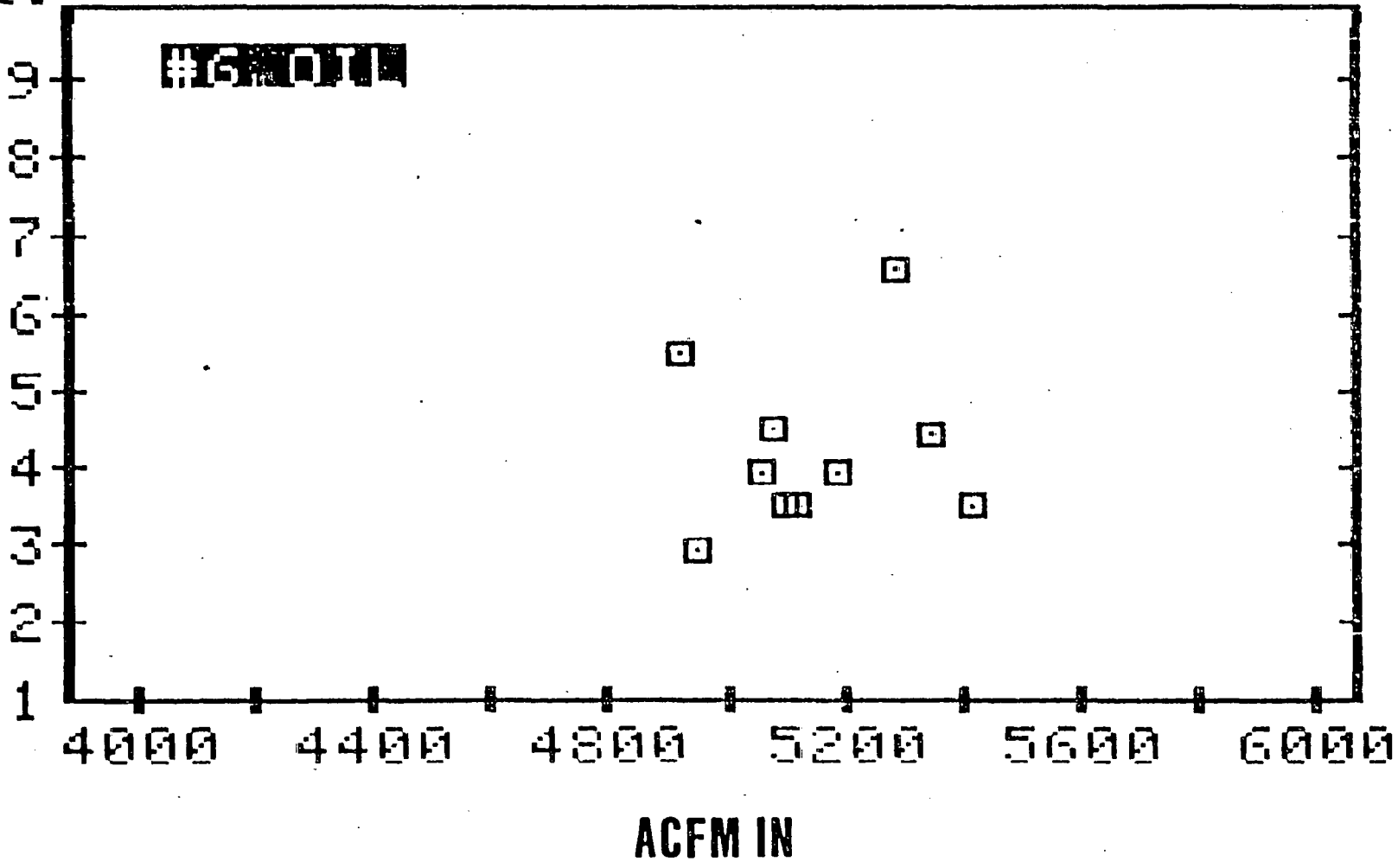
11-5

# LB/10<sup>6</sup> BTU OUT vs. ACFM IN

1E-3

#6 OUT

10<sup>6</sup> BTU OUT

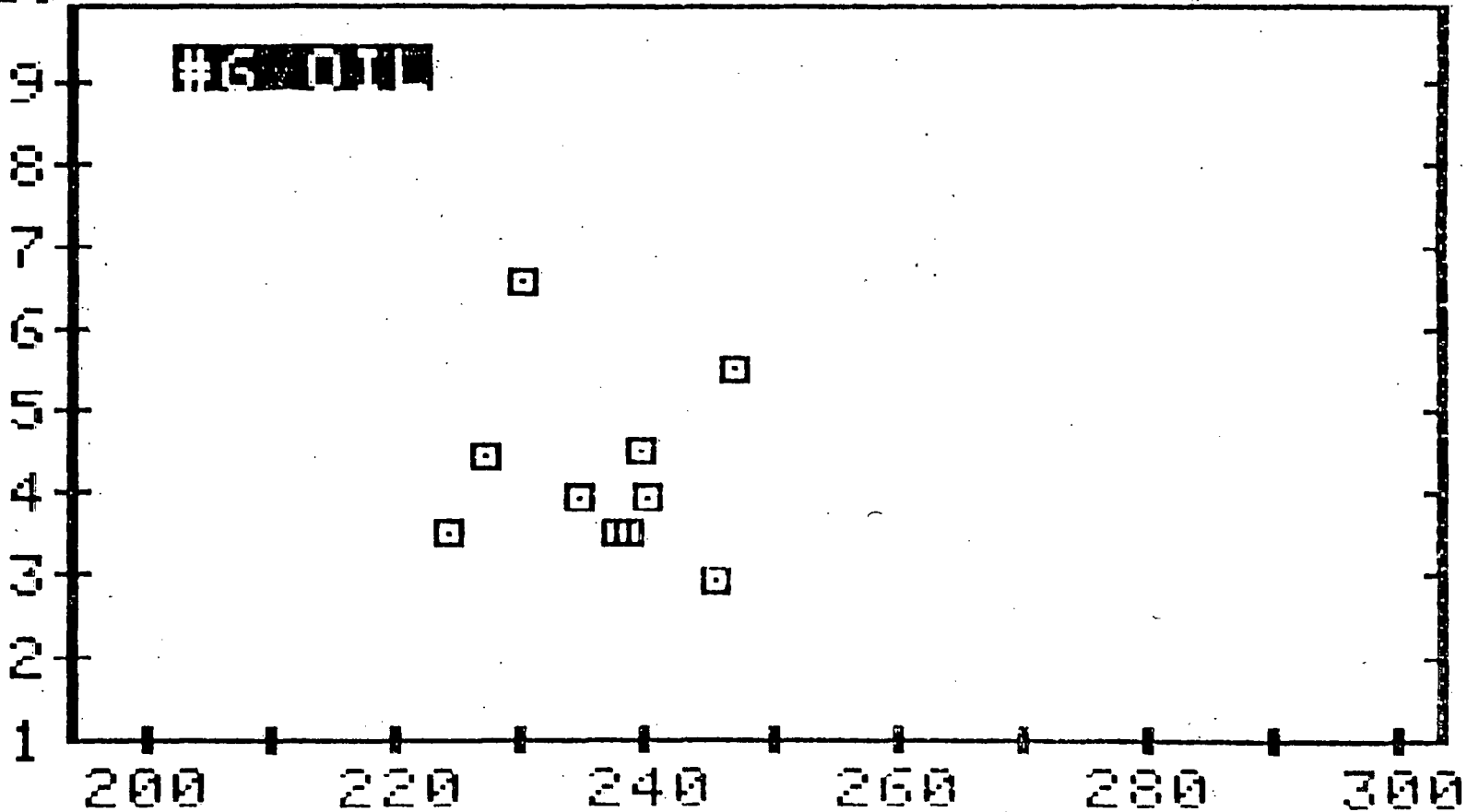


# LB/10<sup>6</sup> BTU OUT vs. SCA

1E-3

#6 OUT

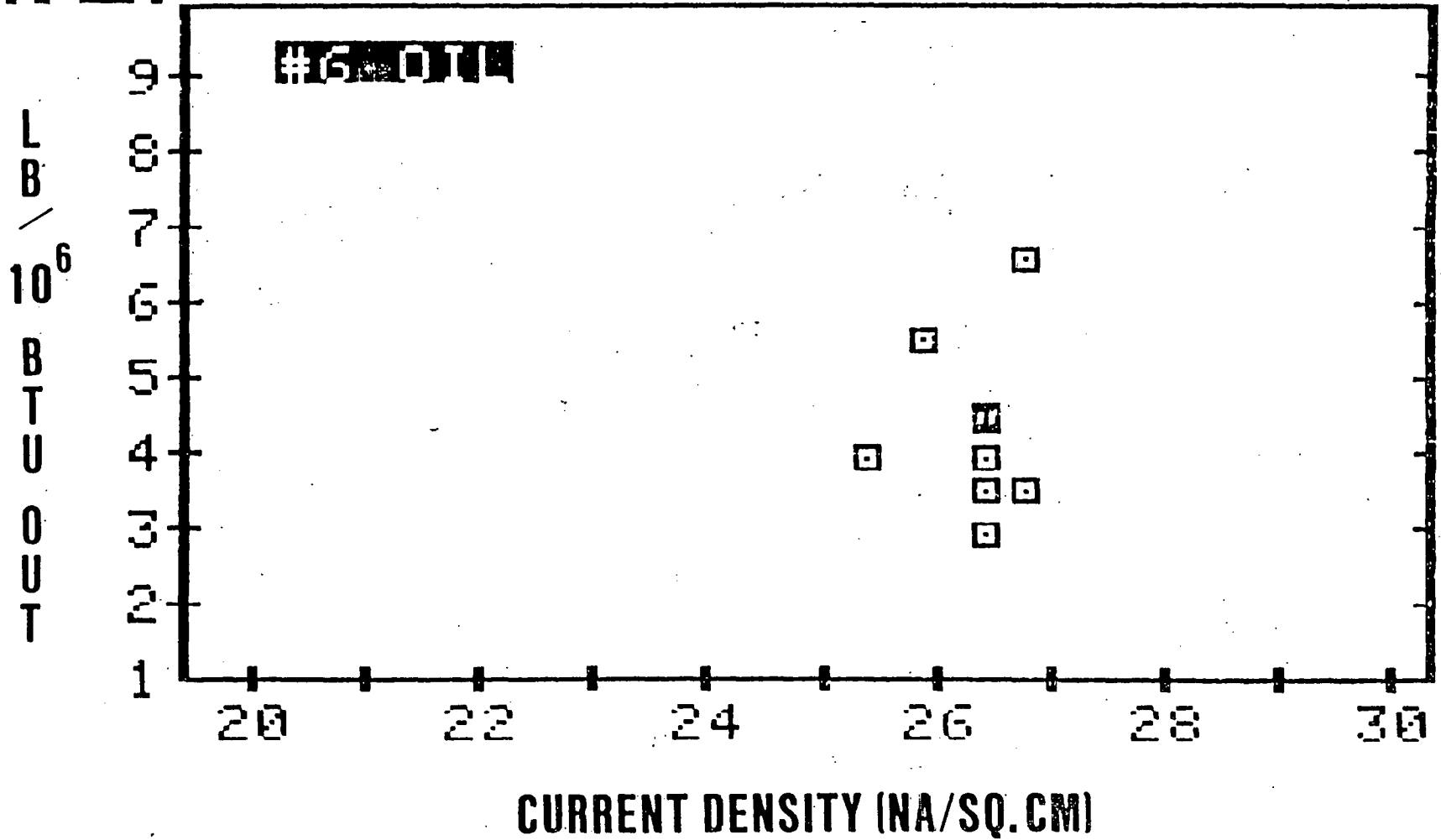
LB / 10<sup>6</sup> BTU OUT



SCA - SPECIFIC COLLECTING AREA  
(SQ.FT./1000 ACFM)

# LB/10<sup>6</sup> BTU OUT vs. CURRENT DENSITY

1E-3

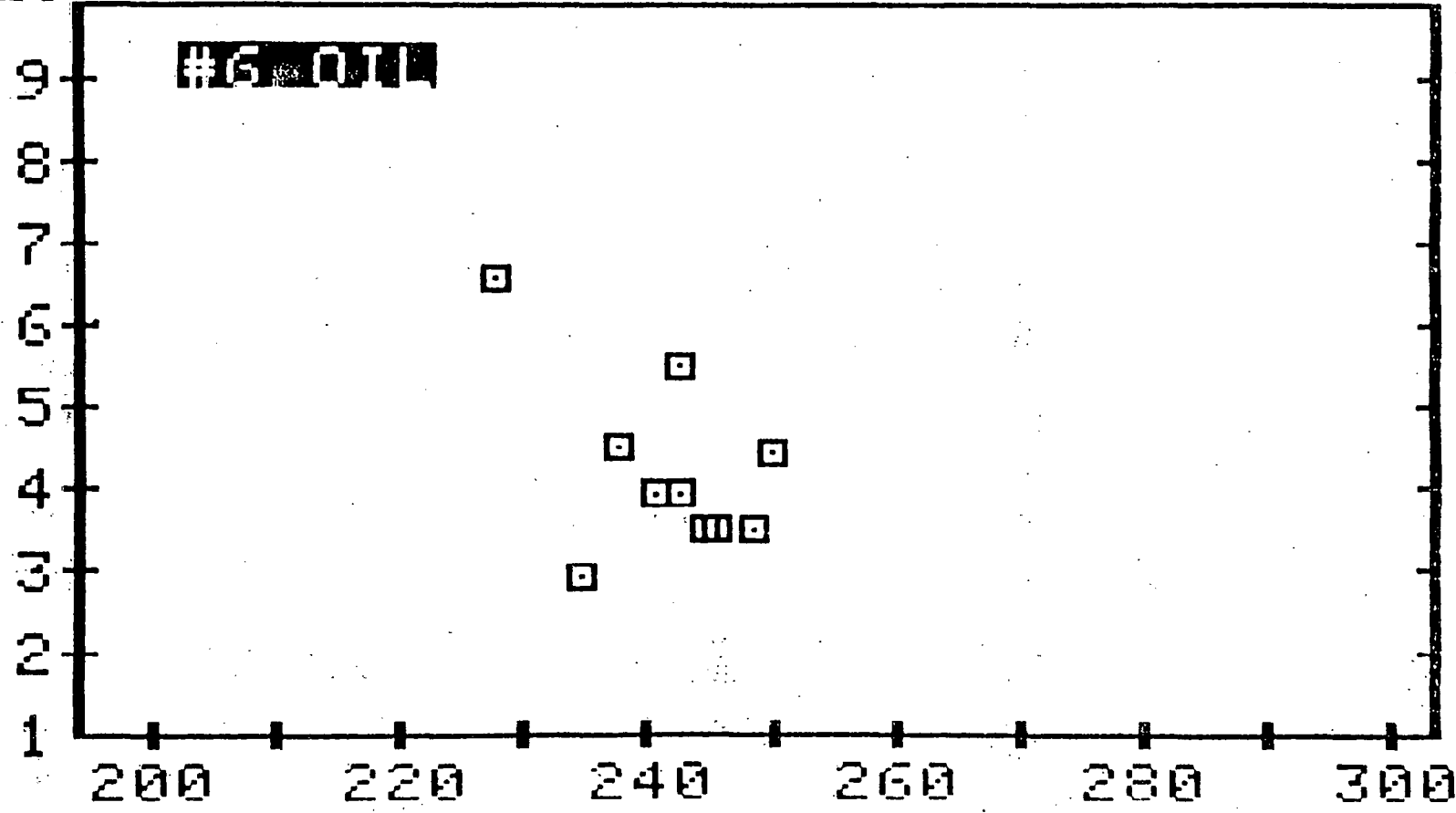


# LB/10<sup>6</sup> BTU vs. SPECIFIC CORONA POWER

FE-8

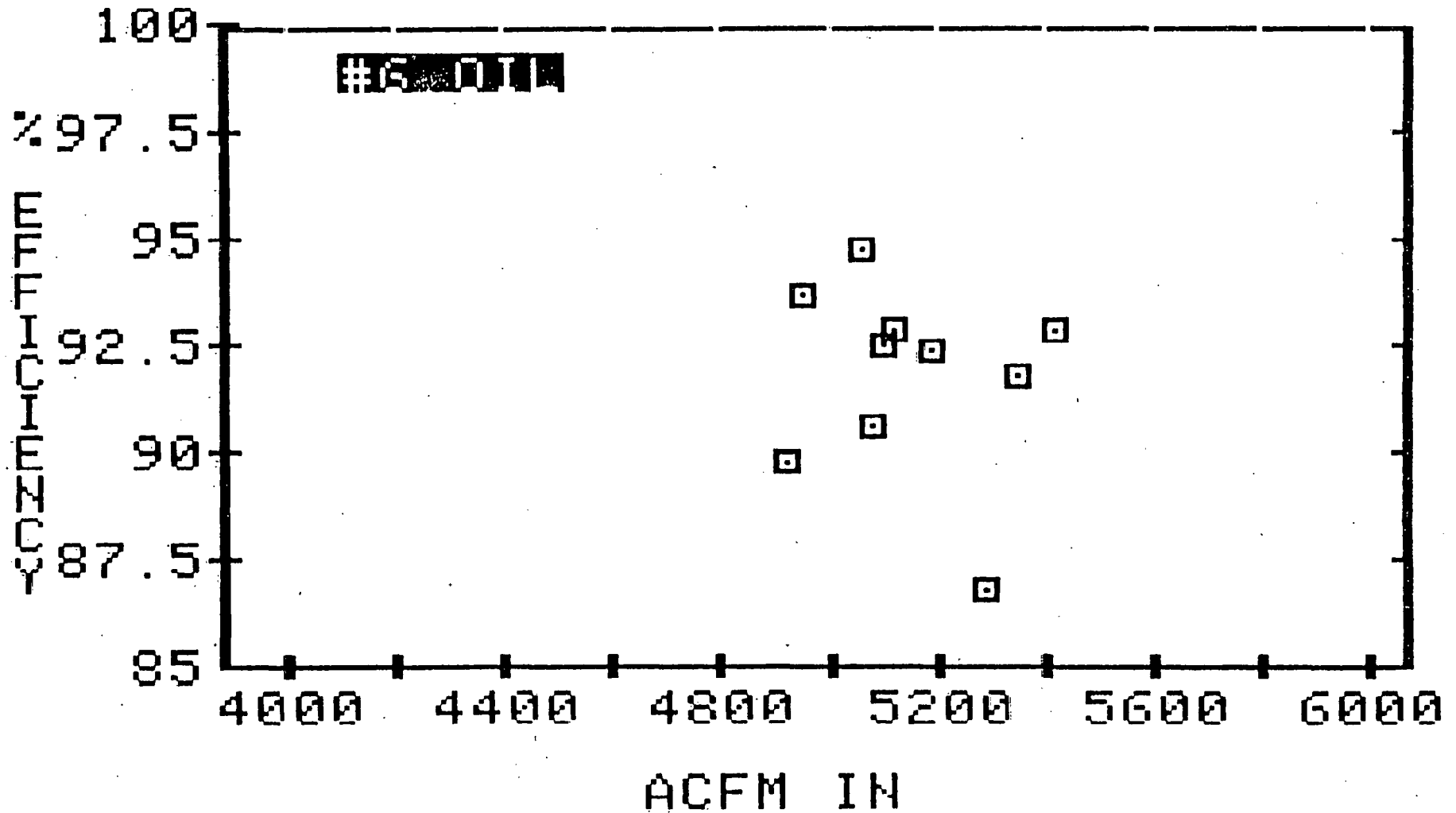
#6 QTL

BTU / 10<sup>6</sup> LB

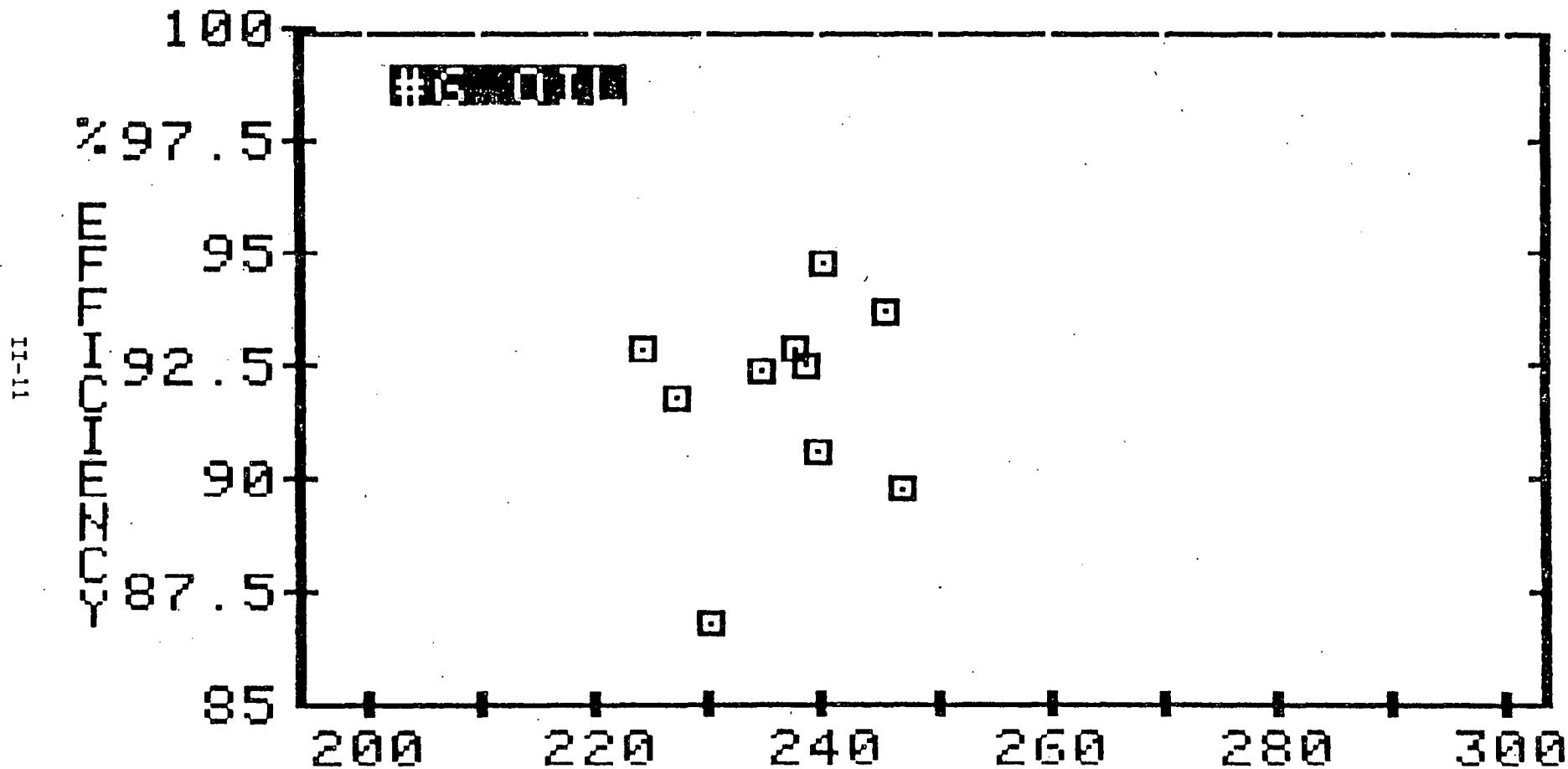


SPECIFIC CORONA POWER  
(WATTS/1000 ACFM)

# % EFFICIENCY VS ACFM IN

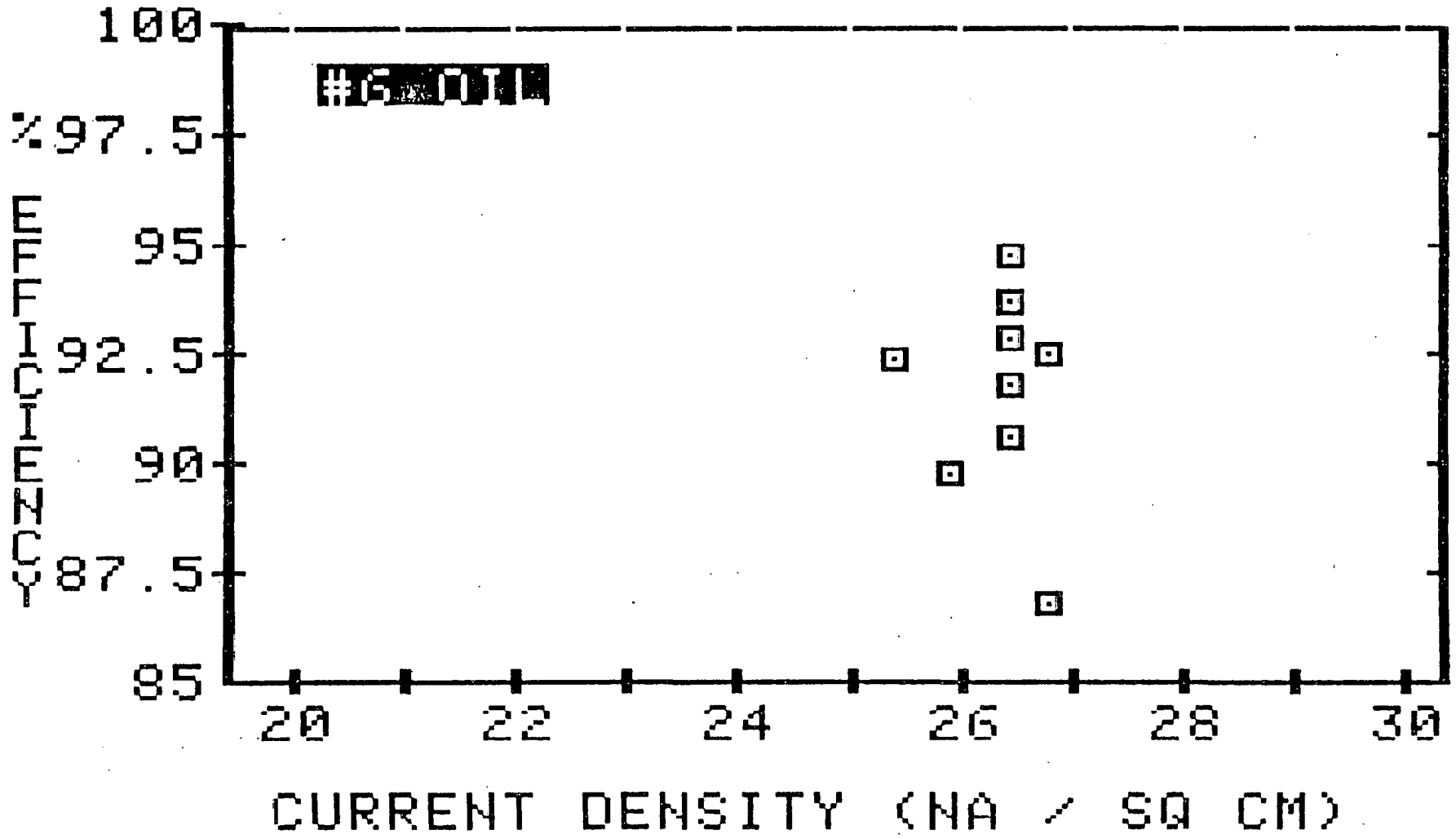


# % EFFICIENCY VS SCA

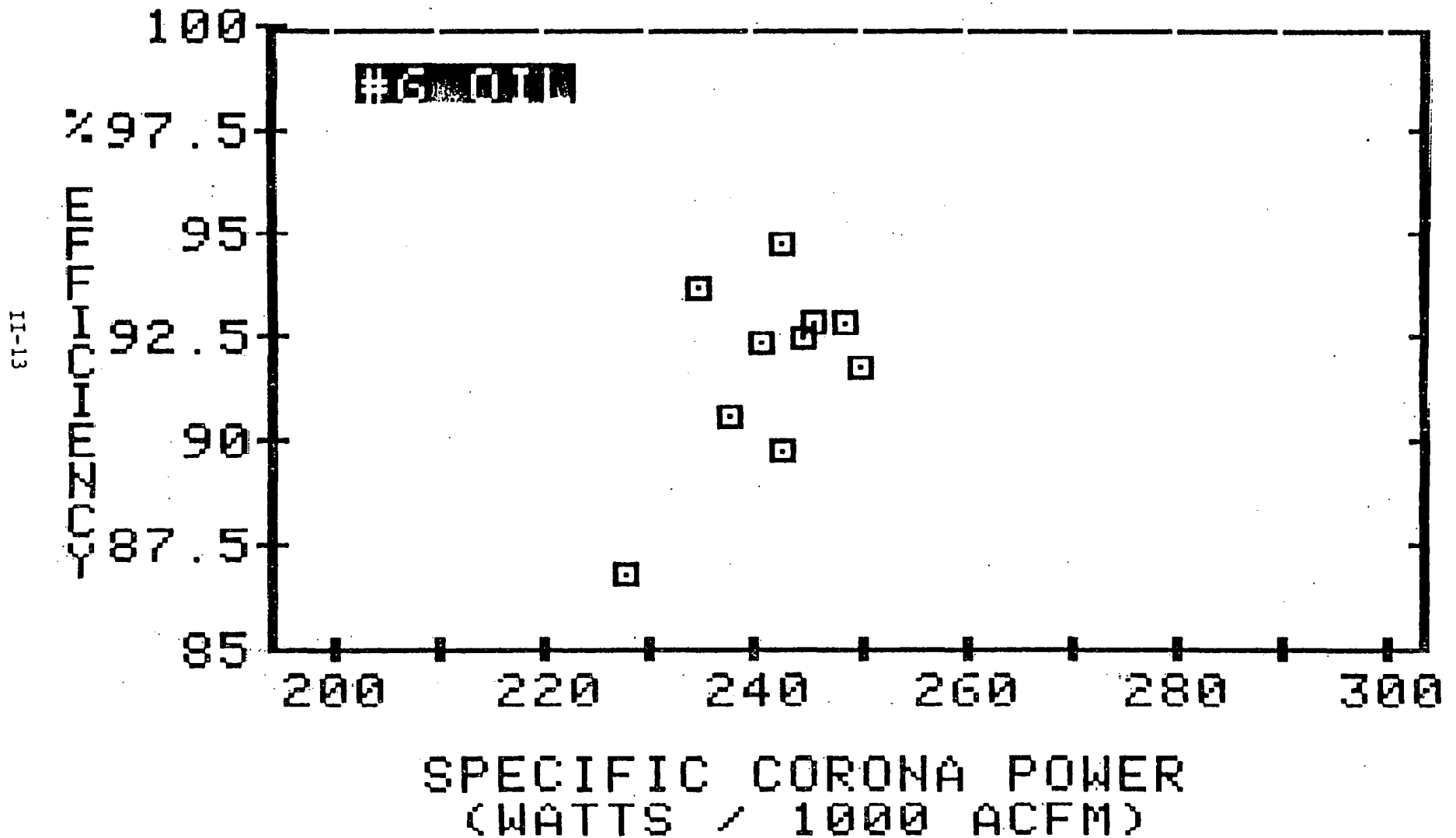


SCA - SPECIFIC COLLECTING AREA  
(SQ FT / 1000 ACFM)

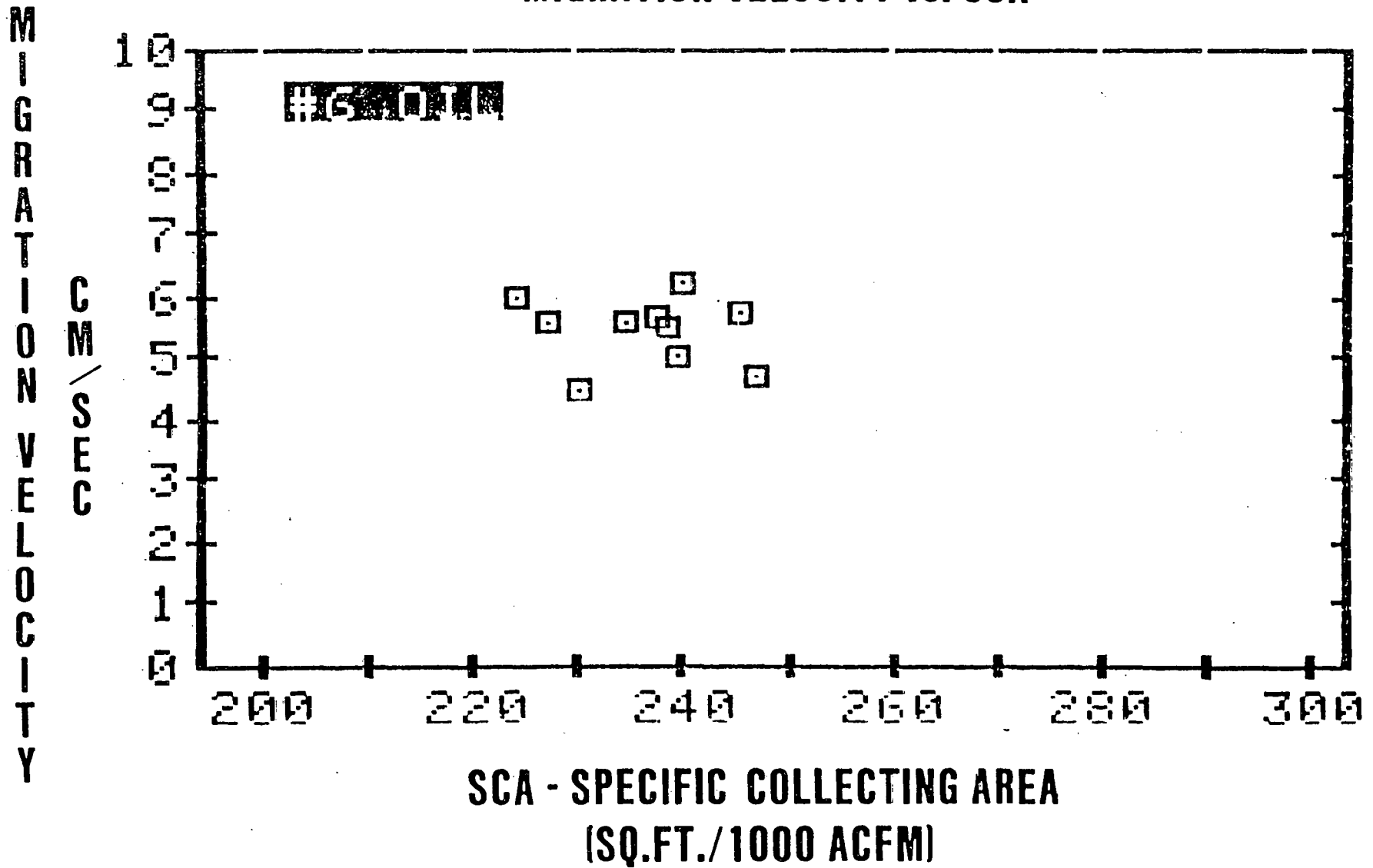
# % EFFICIENCY VS CURRENT DENSITY



# % EFF VS SPECIFIC CORONA POWER



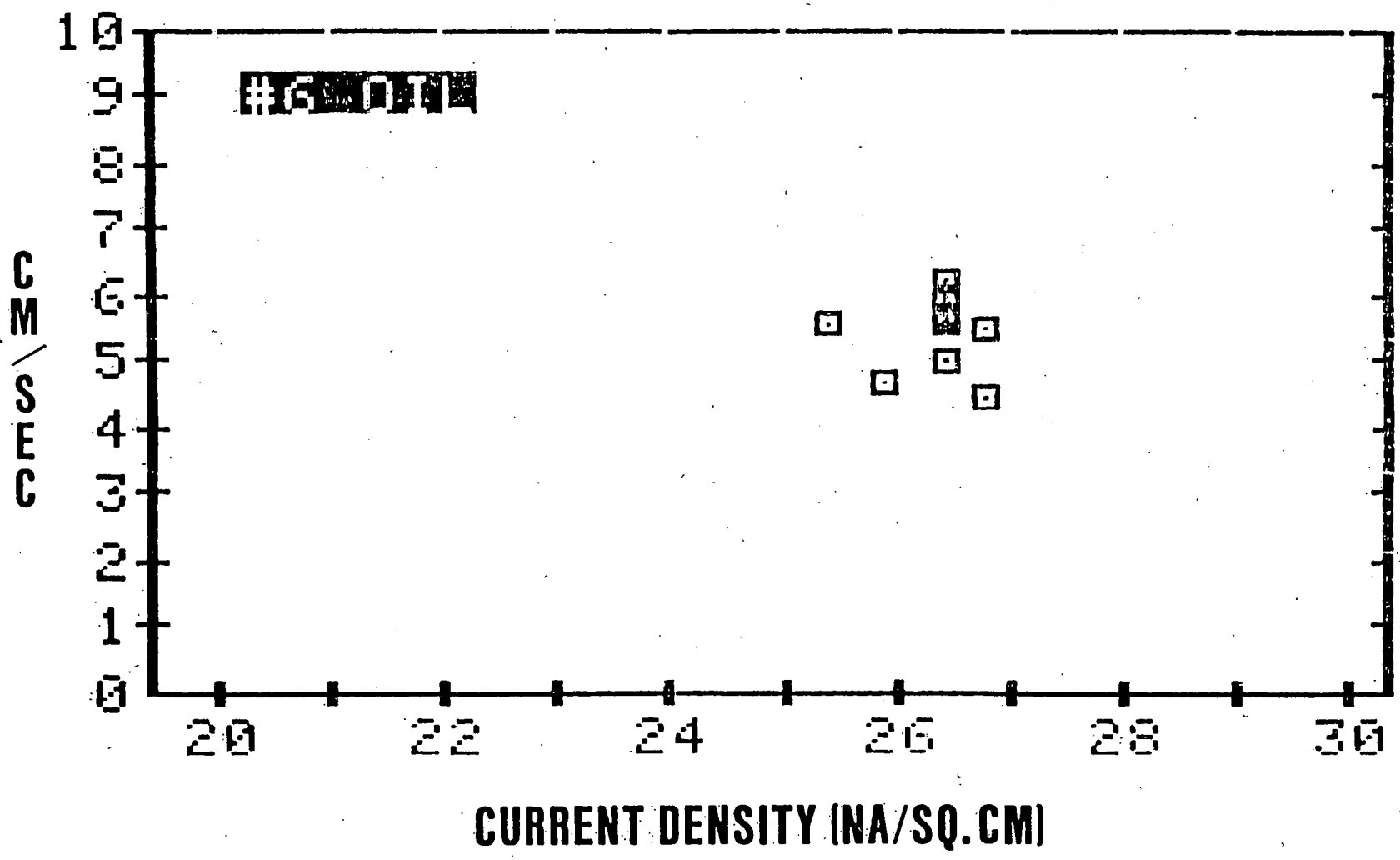
# MIGRATION VELOCITY vs. SCA



II-14

# MIGRATION VELOCITY vs. CURRENT DENSITY

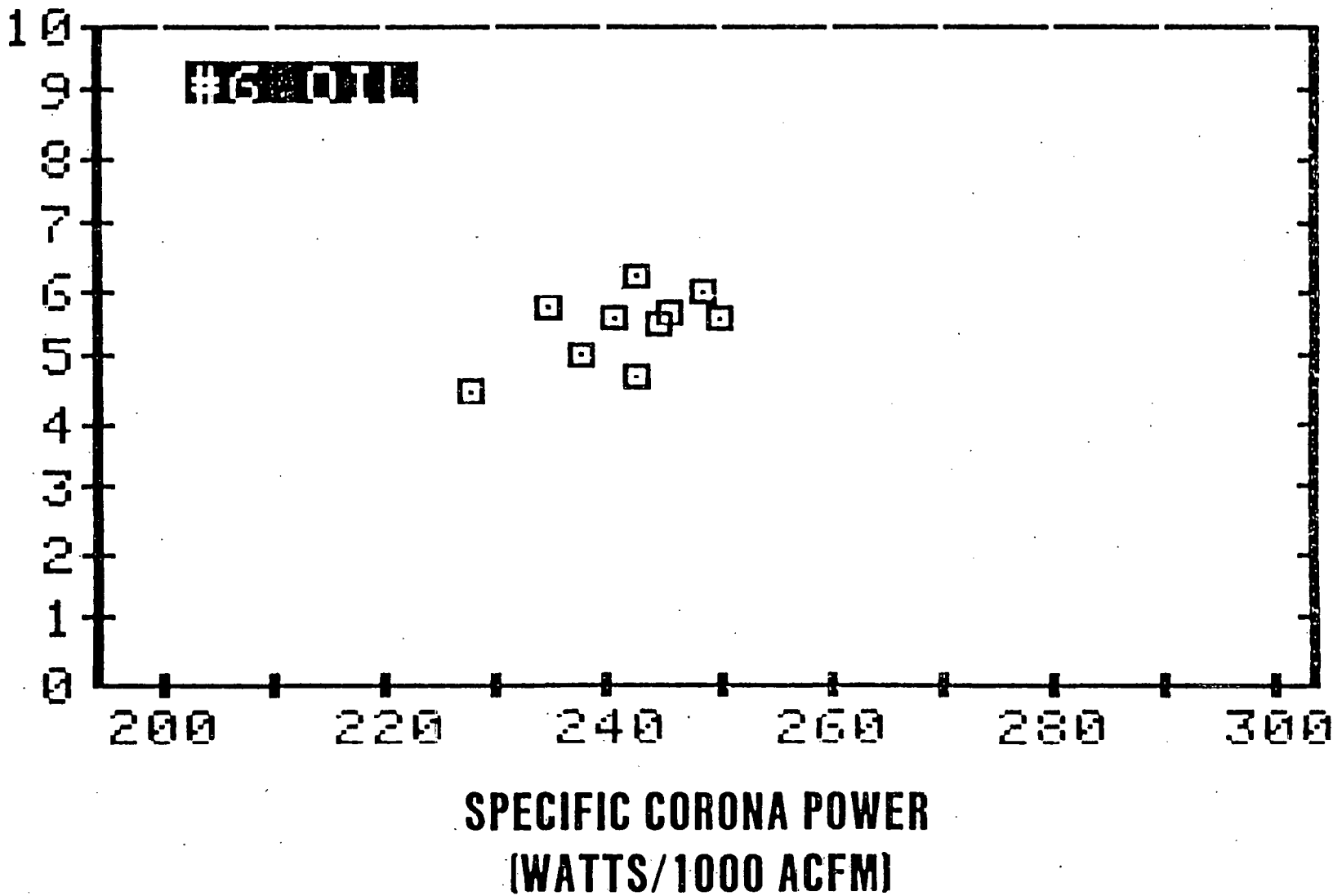
MIGRATION VELOCITY



CURRENT DENSITY (mA/SQ.CM)

MIGRATION VELOCITY  
CM/SEC

### MIGRATION VELOCITY vs. SPECIFIC CORONA POWER



APPENDIX III

SRC Fuel Test Results and Graphs

	Page
<u>TESTING DATA</u>	
Date, Time, Orsat, Gas Temperature, Moisture . . . . .	1
Gas Volume, In-leakage . . . . .	2
Mass Emission Rates - English . . . . .	3
Mass Emission Rate - Metric . . . . .	4
ESP Operating Data and Results . . . . .	5
 <u>GRAPHS</u>	
LB/10 <sup>6</sup> Btu Out Versus ACFM In . . . . .	6
LB/10 <sup>6</sup> Btu Out Versus SCA . . . . .	7
LB/10 <sup>6</sup> Btu Out Versus Current Density . . . . .	8
LB/10 <sup>6</sup> Btu Out Versus Specific Corona Power . . . . .	9
% Efficiency Versus ACFM In . . . . .	10
% Efficiency Versus SCA . . . . .	11
% Efficiency Versus Current Density . . . . .	12
% Efficiency Versus Specific Corona Power . . . . .	13
W Versus SCA . . . . .	14
W Versus Current Density . . . . .	15
W Versus Specific Corona Power . . . . .	16

P E T C - B R C

M A S S T R A I N D A T A ( P U L V. B R C F I R E D )

TEST NO	DATE (1982)	TIME START	TIME END	--ORSAT DATA (% VOL)--				----GAS TEMPERATURE----				--MOISTURE--	
				O2IN	CO2IN	O2OUT	CO2OUT	IN	OUT	IN	OUT	IN	OUT
(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(F)	(F)	(C)	(C)	(%)	(%)
P1(1)	10-29	11:13	13:24	4.6	14	6.6	12	299	252	148	122	6.5	4.8
P2(2)	10-29	18:40	20:08	5.8	13.6	8.4	11	315	267	157	131	5.9	5
P3(3)	11-1	13:37	15:58	6.5	11.7	9	9.7	300	242	149	117	7.4	6.4
P4(4)	11-1	17:22	19:58	6.2	12.3	8.9	10.1	300	247	149	119	4.2	5.5
P5(5)	11-3	15:48	17:19	6.4	12.4	9.8	9.3	300	245	149	118	8.3	5.7
P6(6)	11-4	11:46	13:51	6.6	12.2	9.8	8.6	299	229	148	109	5.2	5.2
1(7)	11-15	9:28	11:34	6.4	12.2	8.4	10.2	302	229	150	109	4.7	4.8
2(8)	11-15	17:55	19:58	7.2	11	10.6	8.6	301	230	149	110	4.9	4.4
3(9)	11-16	8:43	11:09	7.2	11.2	10	8.8	295	228	146	109	5.8	4.4
4(10)	11-16	16:34	16:56	7.2	11.2	10	8.8	306	235	152	113	10	5.8
5(11)	11-16	18:41	20:47	8.4	11.6	11.4	8.6	297	225	147	107	5.5	4.7
6(12)	11-17	8:39	10:44	7	12.4	10.4	8	299	233	148	112	6.2	5.5
7(13)	11-17	14:34	16:39	7.2	12.2	10.4	9.2	300	237	149	114	6.8	5.1
8(14)	11-18	14:17	16:22	8	11.4	10	8.6	299	242	148	117	4.9	5.8
9(15)	11-18	17:01	19:05	7.4	11	10.4	8.4	306	243	152	117	6.1	5.7
10(16)	11-19	8:59	11:04	6.6	11.8	10	8.8	299	233	148	112	7	5.3
11(17)	11-19	11:41	11:55	6.6	11.8	10	8.8	305	242	152	117	4.6	6.4
12(18)	11-19	12:41	14:58	7.2	11.4	9.4	9.4	300	238	149	114	7.2	5
13(19)	11-19	15:36	17:32	6.4	12	9.2	9.4	300	238	149	114	6.2	4.7

I-III

P E T C - S R C M A S S T R A I N D A T A ( P U L V B R C F I R E D )

TEST NO.	-----G A S V O L U M E-----								% IN- LEAK (SDCFM)	% IN- LEAK (O-2)
	IN (ACFM)	OUT (ACFM)	IN (SDCFM)	OUT (SDCFM)	IN (ACMM)	OUT (ACMM)	IN (SDCMM)	OUT (SDCMM)		
P1(1)	4752	4890	2909	3385	134.6	138.5	82.4	95.9	16.34	13.99
P2(2)	4535	5285	2745	3567	128.4	149.7	77.7	101	29.95	20.80
P3(3)	3877	4864	2346	3345	109.8	137.7	66.4	94.7	42.58	21.01
P4(4)	4623	5632	2888	3885	130.9	159.5	81.8	110	34.52	22.50
P5(5)	4533	5686	2705	3907	128.4	161	76.4	110.6	44.44	30.63
P6(6)	4814	5633	2956	3982	136.3	159.5	83.7	112.8	34.71	28.83
1(7)	5253	5755	3265	4155	148.8	163	92.5	117.7	27.26	16.00
2(8)	5479	6340	3415	4584	155.2	179.5	96.7	129.8	34.23	33.01
3(9)	5441	6277	3373	4537	154.1	177.8	95.5	128.5	34.51	25.69
4(10)	5164	6345	3017	4460	146.2	179.7	85.4	126.3	47.83	25.69
5(11)	4684	5822	3123	4199	132.7	164.9	88.4	118.9	34.45	31.58
6(12)	5801	6127	3315	4340	141.6	173.5	93.9	122.9	30.92	32.38
7(13)	5272	6107	3212	4317	149.3	173	91	122.3	34.40	30.48
8(14)	5096	6077	3124	4241	144.3	172.1	88.5	120.1	35.76	18.35
9(15)	5387	6425	3310	4482	152.6	182	93.7	126.9	35.41	28.57
10(16)	5450	6132	3325	4367	154.3	173.7	94.2	123.7	31.34	31.19
11(17)	5360	6328	3092	4392	151.8	179.2	87.6	124.4	42.04	31.19
12(18)	5475	6216	3358	4394	155.1	176	95.1	124.4	30.85	19.13
13(19)	5568	6136	3418	4355	157.7	173.8	96.8	123.3	27.41	23.93

P E T C - B R C I T E S T E M I S S I O N R A T E S ( P U L V. S R C F I R E D )

TEST NO.	----GR/ACF-----			----GR/SDCF-----			Lbs/10 <sup>6</sup> Btu(F=94.10)-			TEST ISOKINETICS	
	IN	OUT	%	IN	OUT	%	IN	OUT	%	(%IN)	(%OUT)
	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)		
P1(1)	.5482	.1914	65.09	.8955	.304	66.05	1.5959	.6175	61.31	108.7	115.1
P2(2)	.3801	.0113	97.03	.6279	.0168	97.32	1.2079	.0391	96.76	102.5	102.2
P3(3)	.2304	.0031	98.65	.3809	.0045	98.82	.7687	.009	98.83	110.3	99.7
P4(4)	.3405	.002	99.41	.5453	.0029	99.47	1.0777	.0069	99.36	95.7	101.5
P5(5)	.2899	.0047	98.38	.4857	.0069	98.58	.9731	.0181	98.14	109	98.6
P6(6)	.2915	.0412	85.87	.4746	.0583	87.72	.9642	.1526	84.17	104.6	102.7
1(7)	.3508	.0035	99.00	.5446	.0048	99.15	1.131	.0112	99.01	98.4	101.9
2(8)	.2211	.0053	97.60	.3548	.0073	97.94	.7525	.0207	97.25	102.4	97.3
3(9)	.2521	.009	96.43	.4068	.0125	96.93	1.0838	.0266	97.55	98.9	98.3
4(10)	.3151	.0032	98.98	.5393	.0046	99.15	1.434	.0098	99.32	103.8	98.9
5(11)	.2877	.0054	98.12	.4316	.0075	98.26	1.0029	.023	97.71	96.9	97.6
6(12)	.3213	.0013	99.60	.4847	.0019	99.61	1.0126	.0053	99.48	95.7	97.5
7(13)	.2614	.0019	99.27	.4291	.0027	99.37	.91	.0075	99.18	103.6	97.5
8(14)	.2514	.0009	99.64	.4101	.0013	99.68	.9234	.0035	99.62	102.2	101.9
9(15)	.2206	.0013	99.41	.359	.0019	99.47	.7725	.0052	99.33	102.4	98.6
10(16)	.2637	.0008	99.72	.4648	.0011	99.76	.9442	.0029	99.69	101.2	98.8
11(17)	.276	.0042	98.68	.4784	.006	98.75	.9718	.016	98.35	95.7	102.2
12(18)	.2528	.0011	99.56	.4142	.0016	99.61	.8739	.004	99.54	102.5	98.1
13(19)	.2166	.001	99.54	.3529	.0014	99.60	.707	.0034	99.52	102.9	98.7

III-3

P E T C - S R C      T E S T   E M I S S I O N   R A T E S   ( P U L V .   B R C   F I R E D )

TEST NO.	---MG/ACM---			---MG/SDCM---			-----NG/JOULE-----			TEST	
	IN	OUT	%	IN	OUT	%	IN	OUT	%	ISOKINETICS	
	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(%IN)	(%OUT)
P1(1)	1254	437.92	65.09	2049	695.55	66.05	686	265.53	61.31	108.7	115.1
P2(2)	870	25.85	97.03	1437	38.44	97.32	519	16.81	96.76	102.5	102.2
P3(3)	527	7.09	98.65	871	10.30	98.82	311	3.87	98.83	110.3	99.7
P4(4)	779	4.58	99.41	1248	6.64	99.47	453	2.97	99.36	95.7	101.5
P5(5)	663	10.75	98.38	1111	15.79	98.58	418	7.78	98.14	109	98.6
P6(6)	667	94.27	85.87	1086	133.39	87.72	415	65.62	84.17	104.6	102.7
1(7)	803	8.01	99.00	1292	10.98	99.15	486	4.82	99.01	98.4	101.9
2(8)	506	12.13	97.60	812	16.70	97.94	324	8.90	97.25	102.4	97.3
3(9)	577	20.59	96.43	931	28.60	96.93	466	11.44	97.55	98.9	98.3
4(10)	721	7.32	98.98	1234	10.52	99.15	617	4.21	99.32	103.8	98.9
5(11)	658	12.36	98.12	988	17.16	98.26	431	9.89	97.71	96.9	97.6
6(12)	735	2.97	99.60	1109	4.35	99.61	436	2.28	99.48	95.7	97.5
7(13)	598	4.35	99.25	982	6.18	99.37	391	3.23	99.18	103.4	97.5
8(14)	575	2.06	99.64	938	2.97	99.68	397	1.51	99.62	102.2	101.9
9(15)	505	2.97	99.41	821	4.35	99.47	332	2.24	99.33	102.4	98.6
10(16)	649	1.83	99.72	1063	2.52	99.76	406	1.25	99.69	101.2	98.8
11(17)	631	9.61	98.48	1095	13.73	98.75	418	6.88	98.35	95.7	102.2
12(18)	578	2.52	99.55	948	3.66	99.61	376	1.72	99.54	102.5	98.1
13(19)	456	2.29	99.54	807	3.20	99.60	304	1.46	99.52	102.9	98.7

III-4

P E T C - S R C . E S P D A T A & R E S U L T S ( P U L V S R C F I R E D )

TEST NO.	-- E S P A V E R A G E P O W E R --						ESP	SP PWR	CURR	I-DENS	I-DENS	SCA	W	W-K
	KVE	MA1	KV2	MA2	KV3	MA3	POWER (WATT/ KACFM)	AVE	(MA/ SQ FT)	(NA/ SQ CM)/KACFM)	(SQ FT	(CM/ SEC)	(CM/ SEC)	
	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	
P1(1)	5.3	32.9	7.9	21.8	10.5	22.1	581	122	25.9	.0638	68.68	156	1.88	1.79
P2(2)	13	9.9	20.1	8.9	38.8	5.5	528	116	8.1	.0199	21.42	269	6.48	22.24
P3(3)	19.1	8.3	35.1	11	36.7	10.1	908	234	9.8	.0241	25.94	314	7.19	32.03
P4(4)	10.3	10	29.2	8.5	38.9	9.9	729	158	9.5	.0234	25.19	264	9.74	49.26
P5(5)	19	6.5	29.6	4.3	31.9	4.6	381	84	5.1	.0126	13.56	269	7.53	29.99
P6(6)	13.9	8	24.5	5.5	12.9	9.3	315	65	7.6	.0187	20.13	253	3.70	6.82
1(7)	33.8	4.6	39.9	7	46.1	10	899	171	7.2	.0177	19.05	232	10.12	46.73
2(8)	40	5.2	43.6	10	46.3	10	1110	203	8.4	.0207	22.28	222	8.21	29.49
3(9)	35.2	6.3	39.6	10.4	42.7	10.4	1073	197	9	.0222	23.90	224	8.41	31.19
4(10)	37.1	4	42.8	10	45.8	10	1037	201	8	.0197	21.21	236	10.74	53.61
5(11)	39.4	6.1	40.8	9.9	43.4	10.6	1107	236	8.9	.0219	23.57	260	7.37	27.83
6(12)	28.3	5.4	37.4	5.7	41.7	7.8	688	138	6.2	.0153	16.47	244	10.96	57.62
7(13)	36.6	4.7	40.7	10	43.4	10	1012	192	8.2	.0202	21.74	231	10.56	50.70
8(14)	36.7	6.4	40.7	10	42.2	10	1066	209	8.8	.0217	23.36	239	11.85	66.14
9(15)	36.3	5.9	40.2	5.9	42.3	10	1040	193	8.6	.0212	22.82	226	11.24	56.26
10(16)	37.9	6.1	40.6	9.9	41.4	10	1051	193	8.7	.0214	23.04	224	13.15	76.17
11(17)	28.7	5.5	40.5	10	42	10	982	183	8.5	.0209	22.50	227	9.17	37.65
12(18)	30.7	4	39.9	9.4	41.9	10	924	169	7.8	.0192	20.67	223	12.30	66.34
13(19)	37.2	4.8	40.2	9.7	42.4	10	995	179	8.2	.0202	21.74	219	12.40	66.23

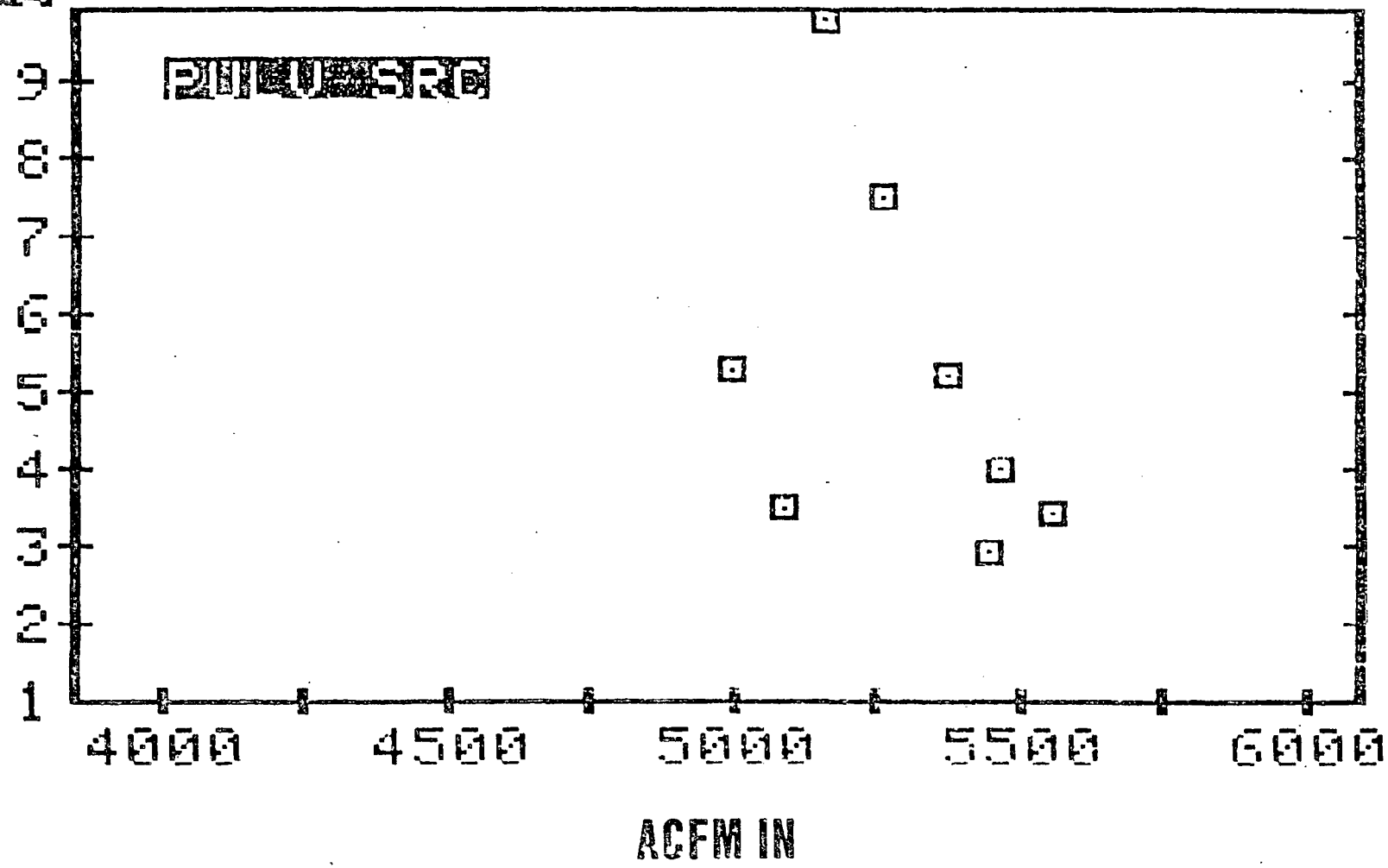
III-5

# LB/10<sup>6</sup> BTU OUT vs. ACFM IN

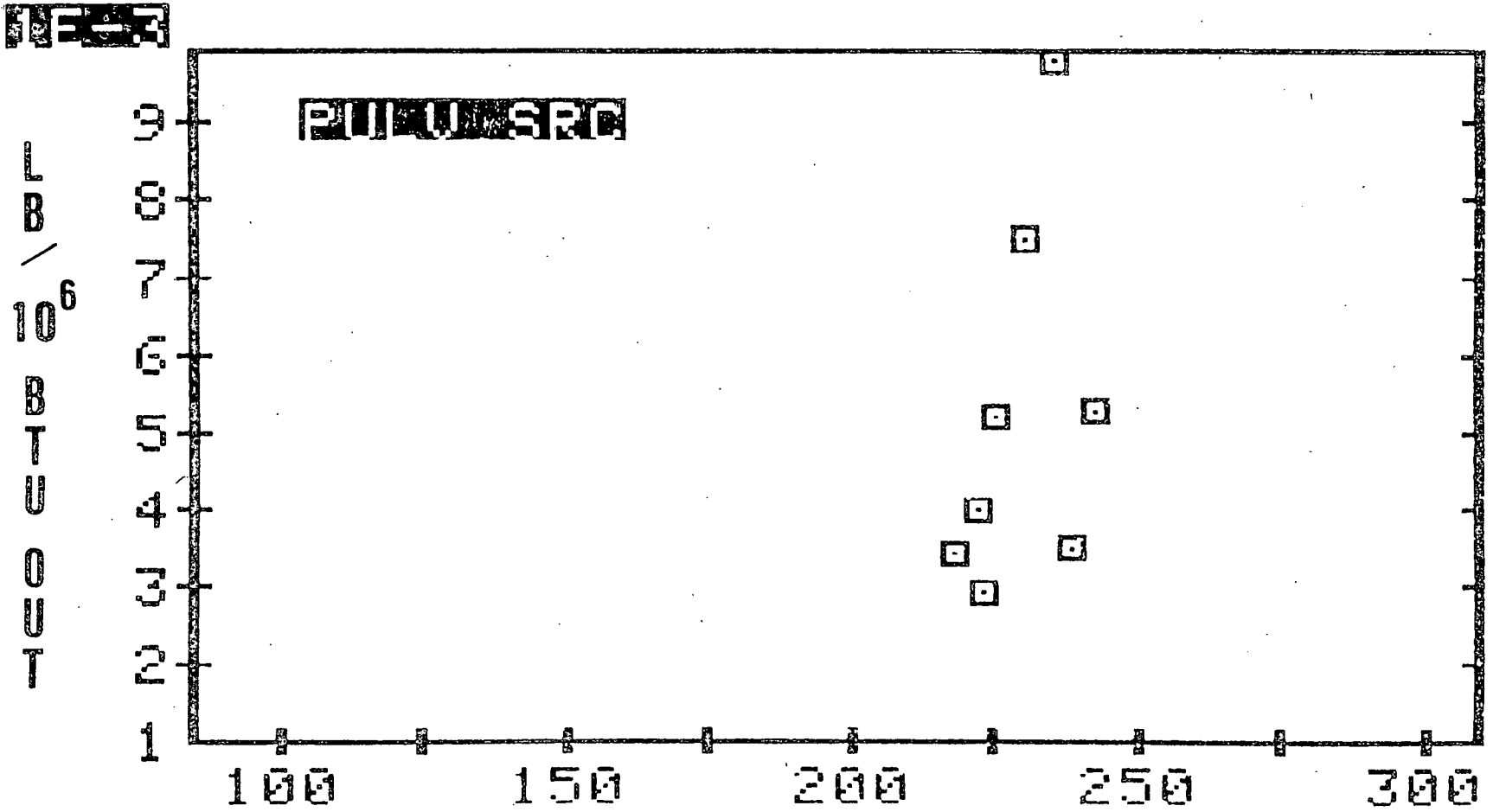
FIG. 3

PHILVSRG

10<sup>6</sup> BTU OUT



# LB/10<sup>6</sup> BTU OUT vs. SCA



SCA - SPECIFIC COLLECTING AREA  
(SQ.FT./1000 ACFM)

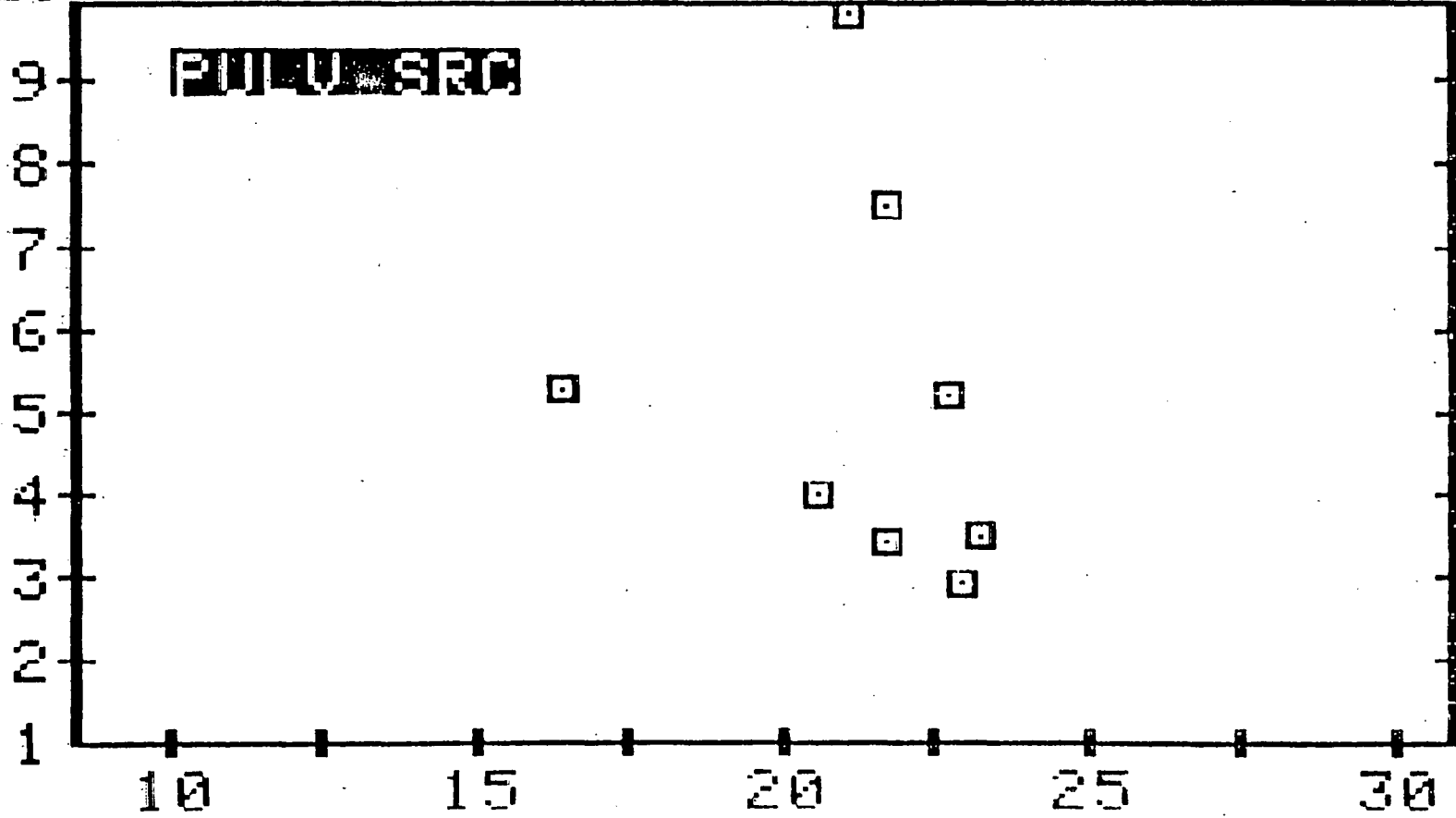
# LB/10<sup>6</sup> BTU OUT vs. CURRENT DENSITY

1E-3

PULV ARC

8-III

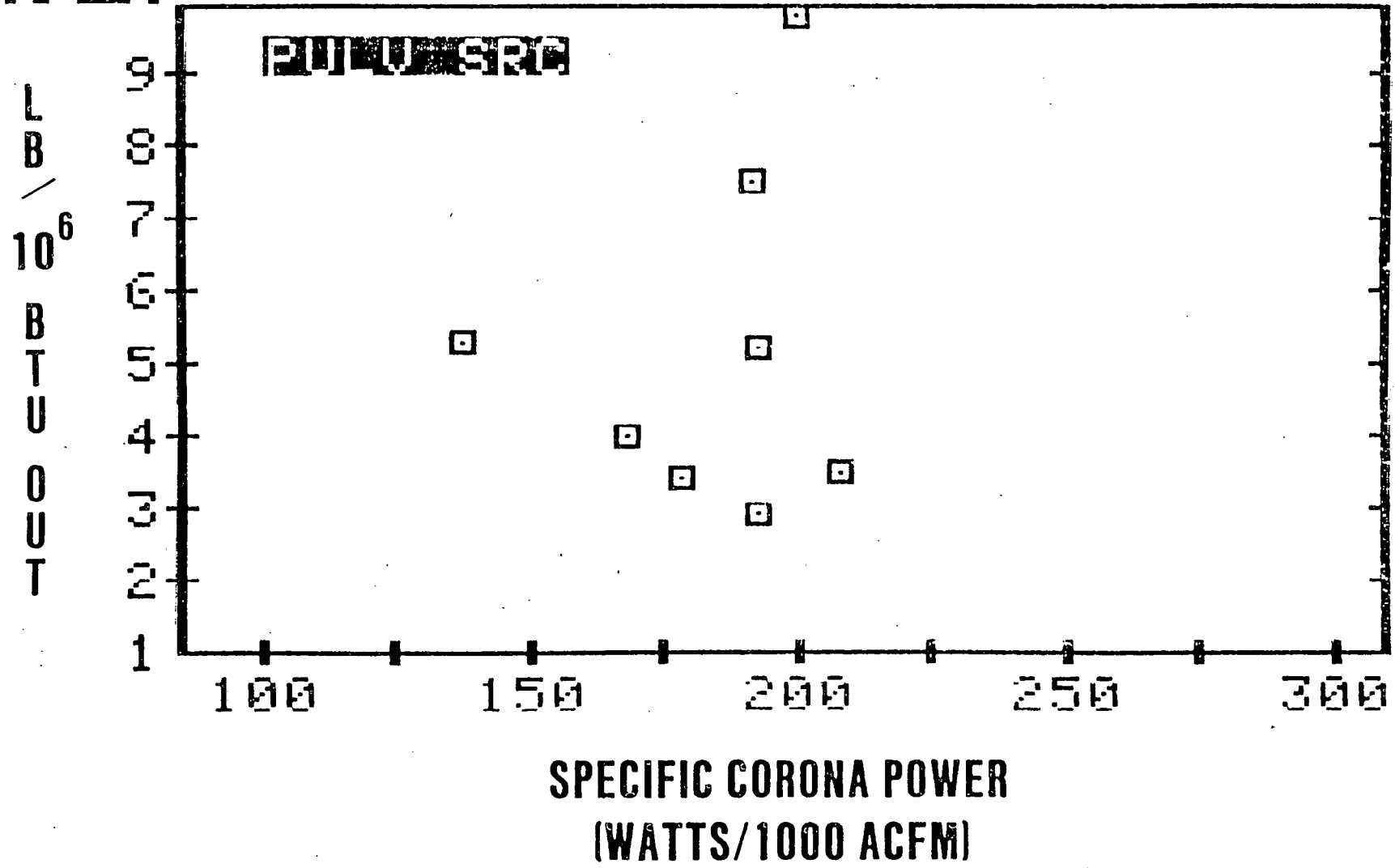
LB / 10<sup>6</sup> BTU OUT



CURRENT DENSITY (MA/SQ.CM)

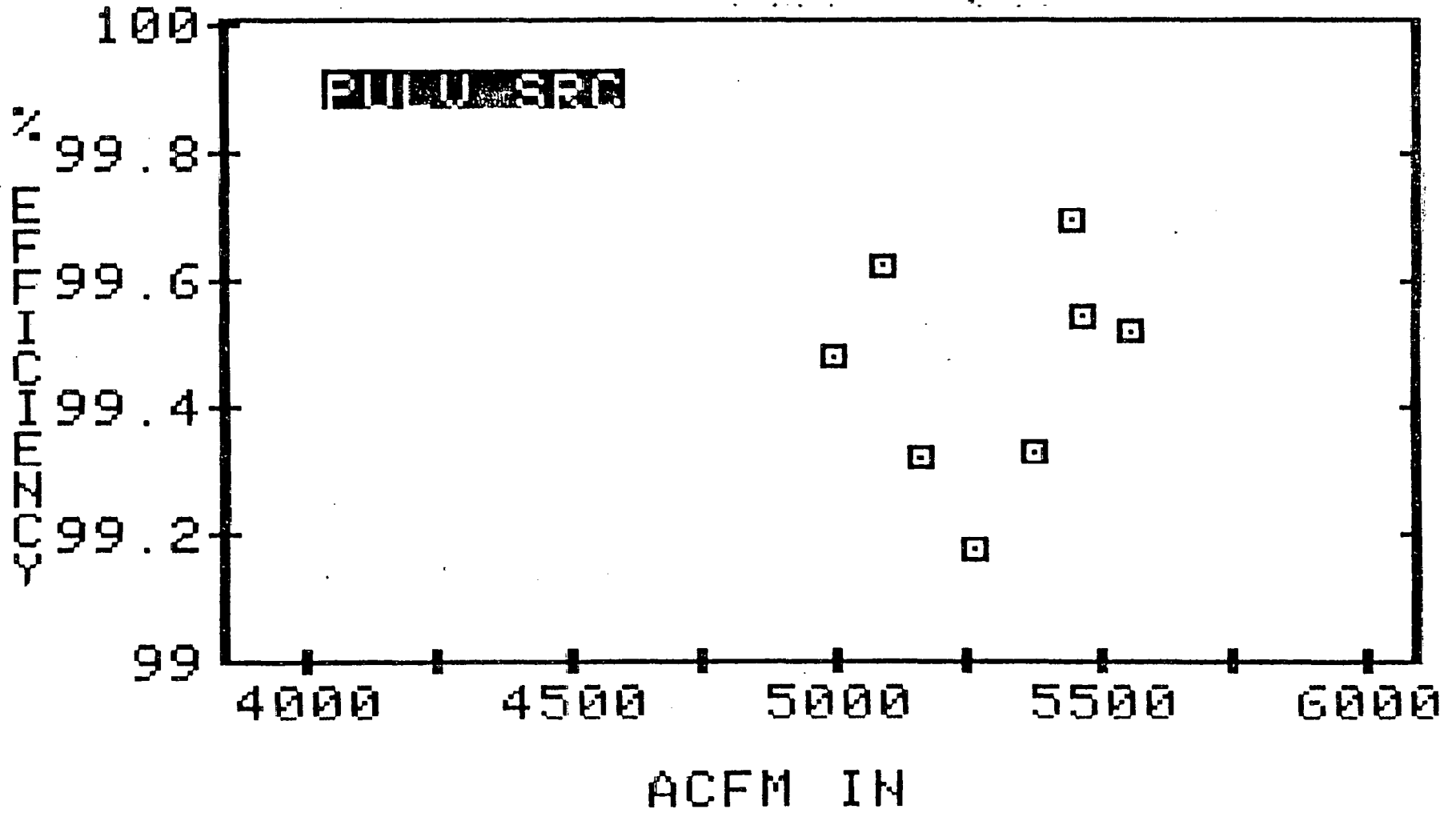
# LB/10<sup>6</sup> BTU vs. SPECIFIC CORONA POWER

9-6  
E-3

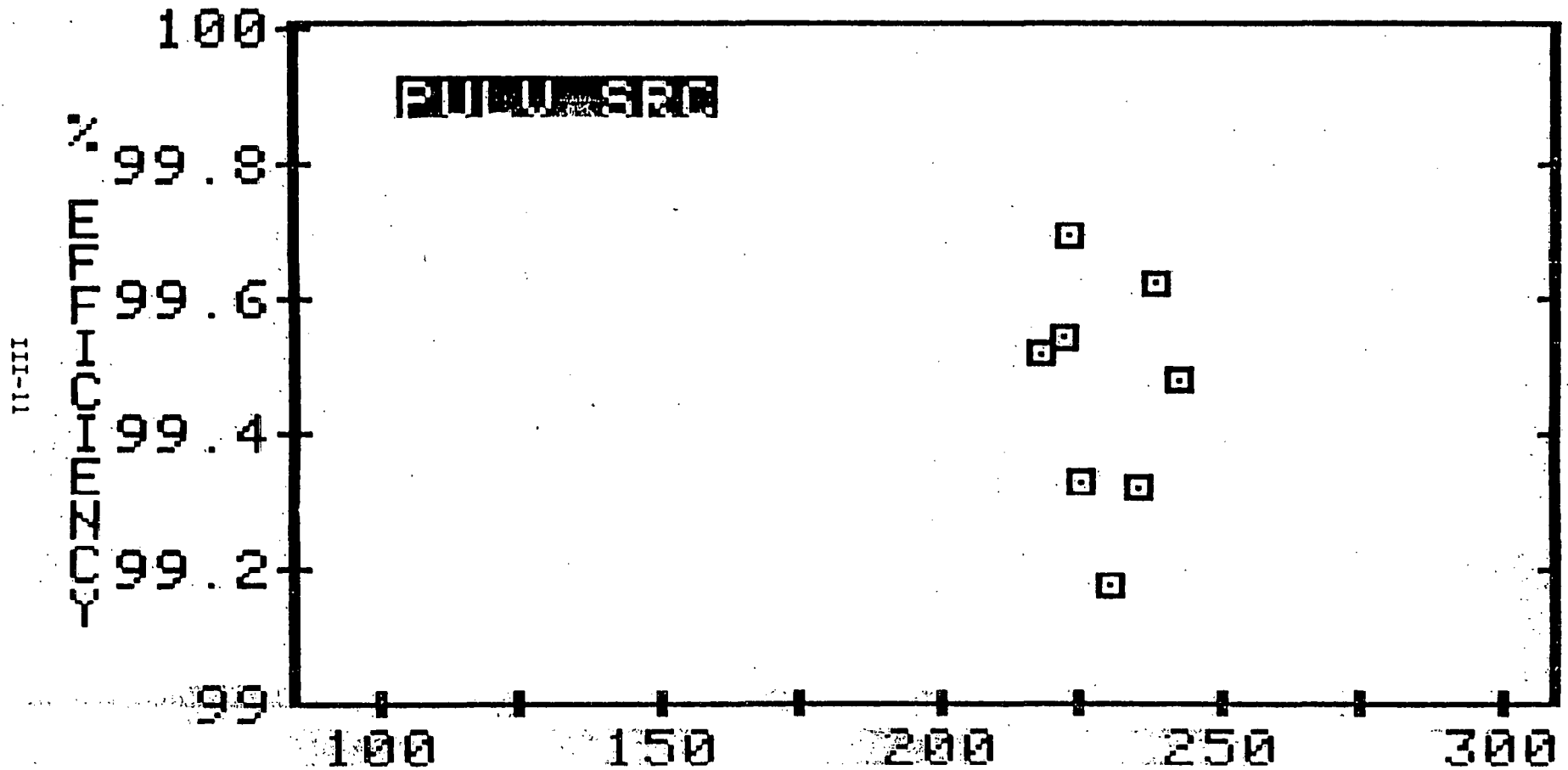


# % EFFICIENCY VS ACFM IN

III-10

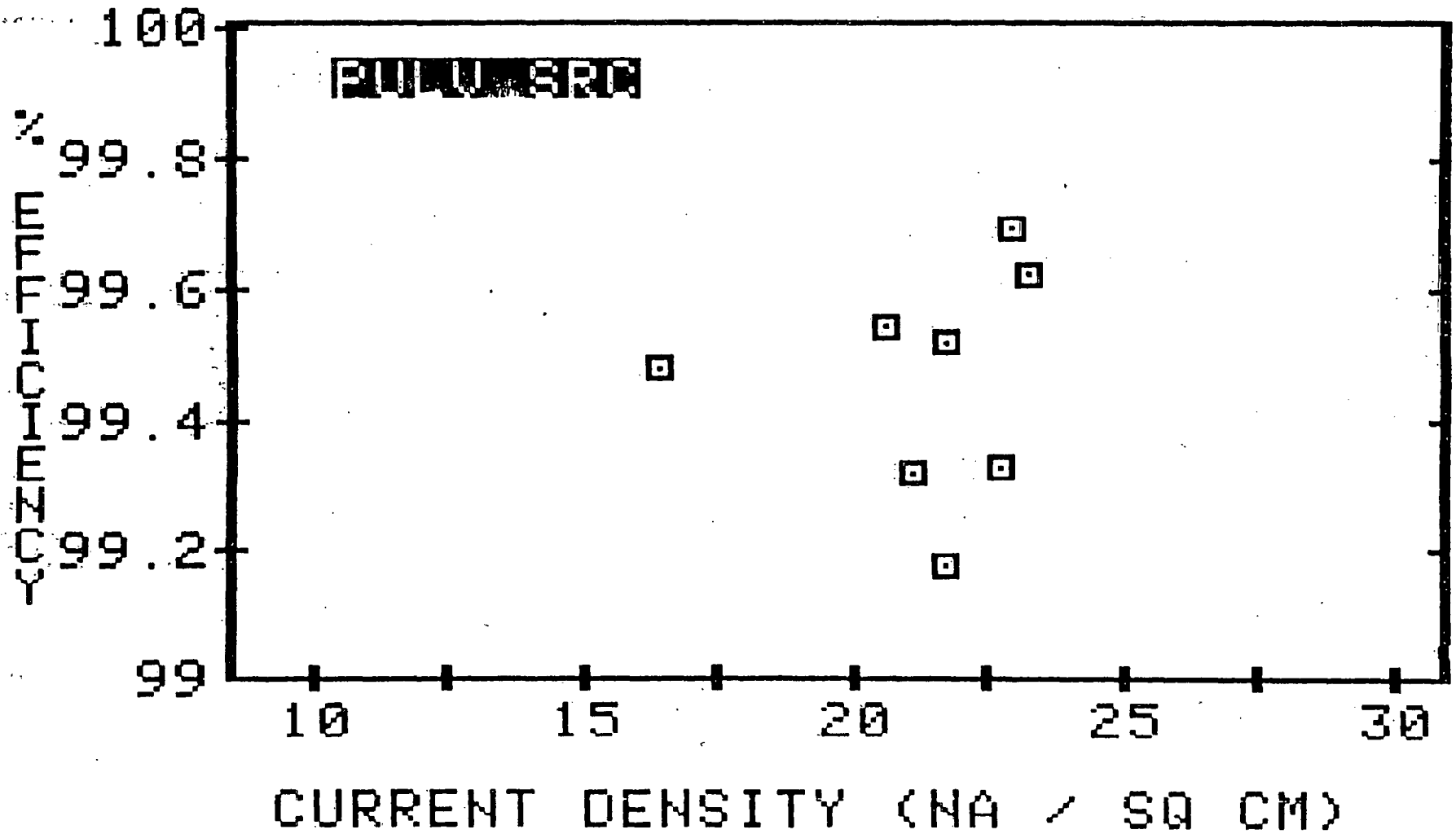


# % EFFICIENCY VS SCA



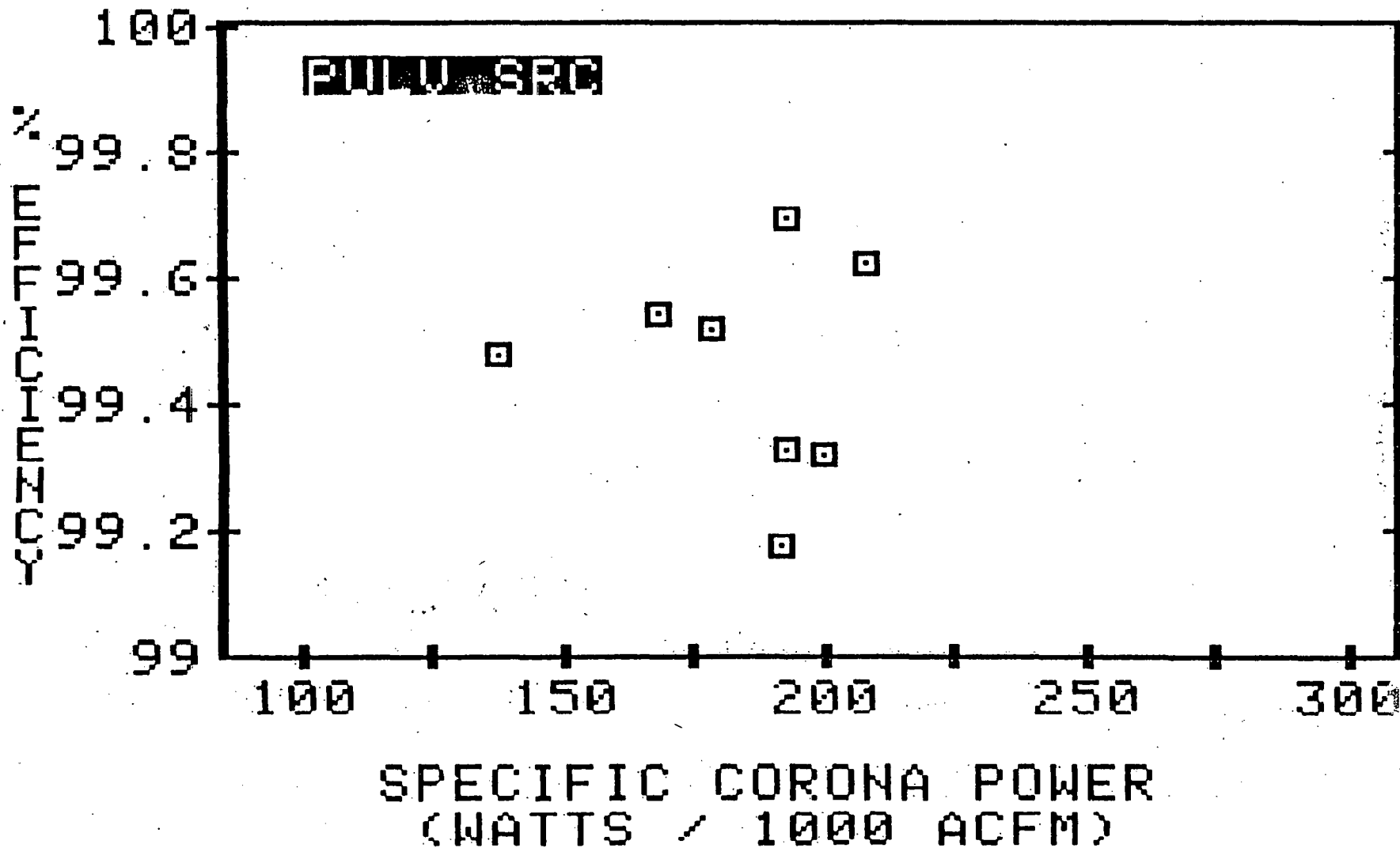
SCA - SPECIFIC COLLECTING AREA  
(SQ FT / 1000 ACFM)

# % EFFICIENCY VS CURRENT DENSITY



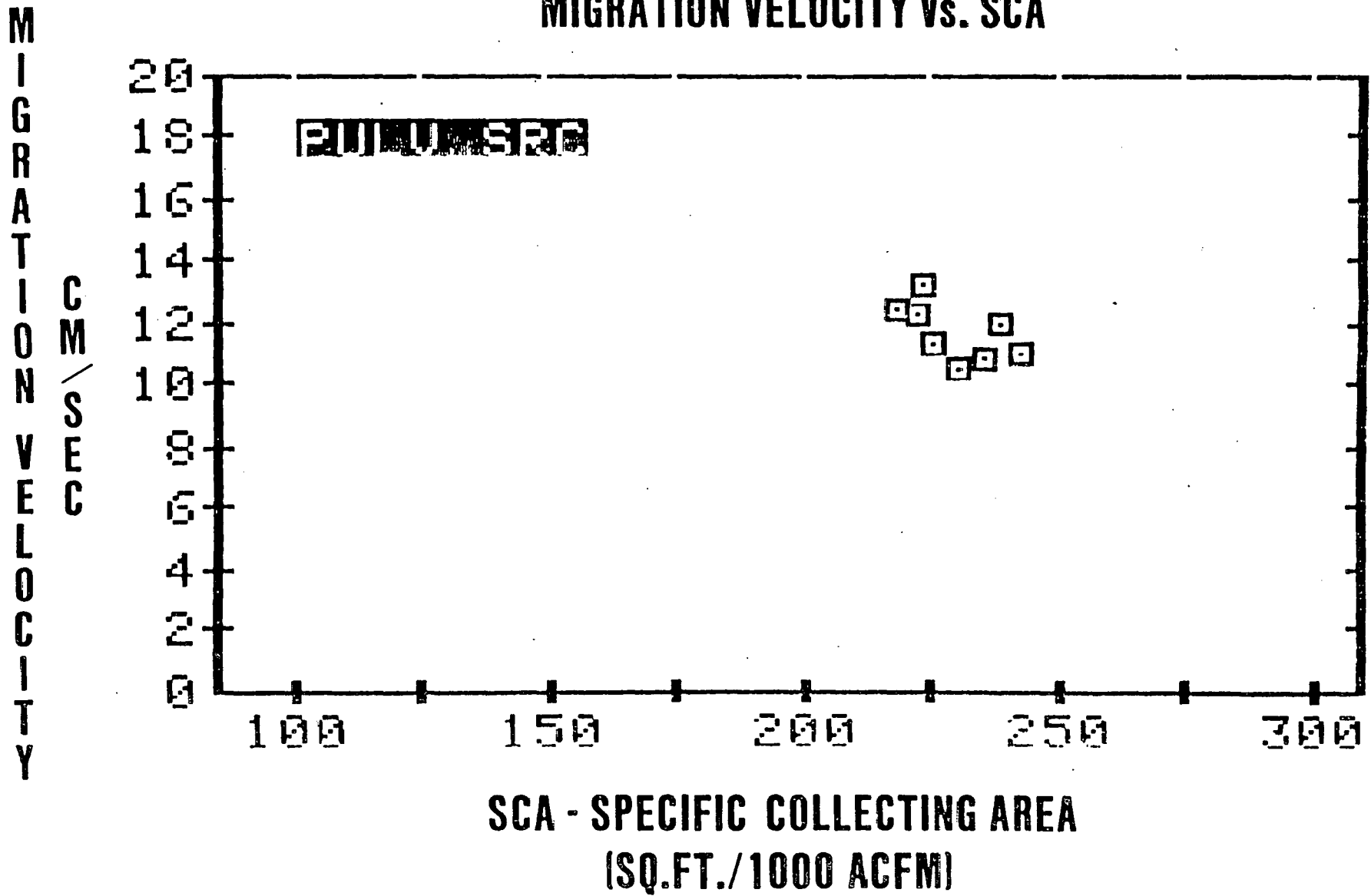
III-12

# EFFICIENCY VS SPECIFIC CORONA POWER



# MIGRATION VELOCITY vs. SCA

71-111

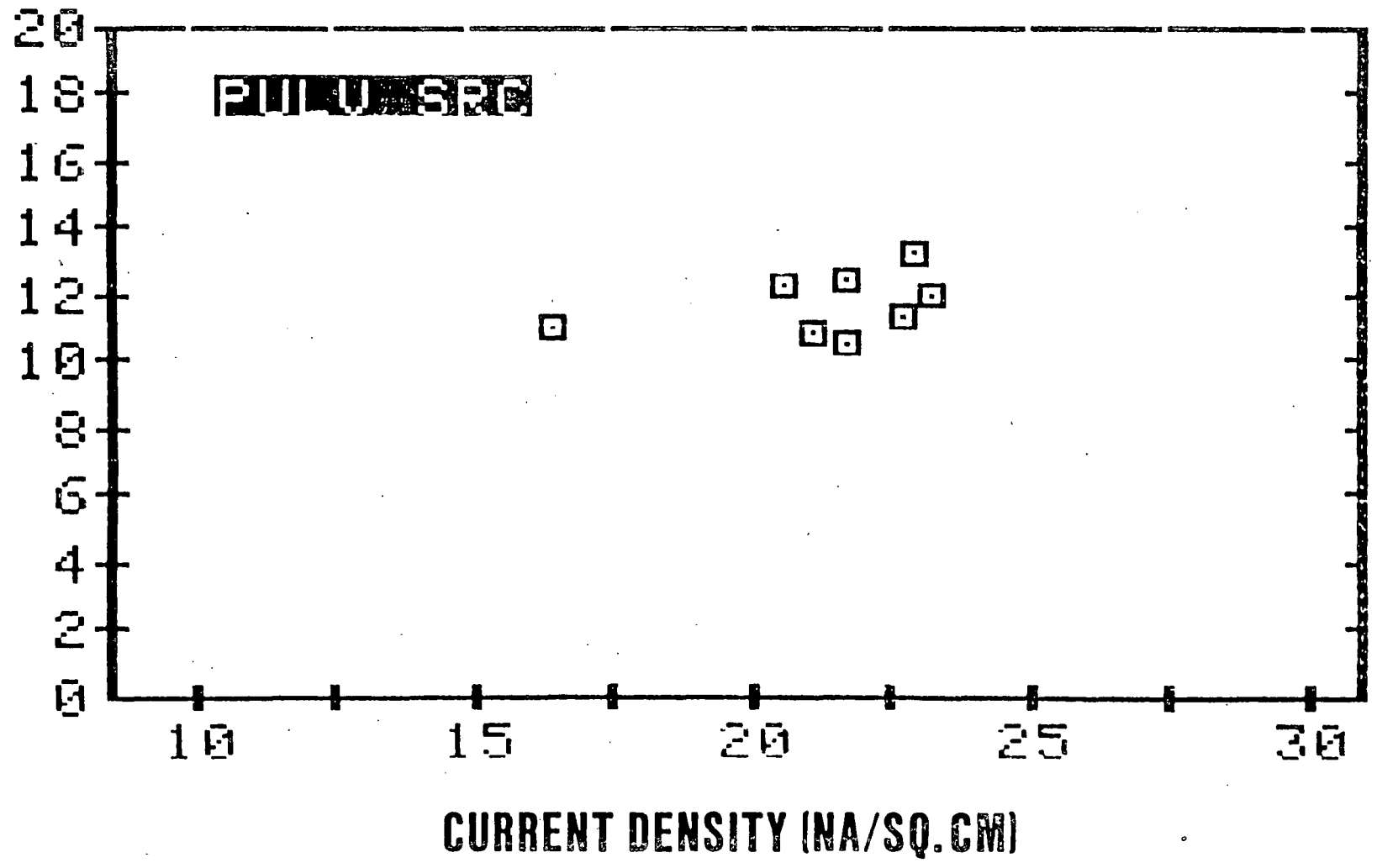


III-15

MIGRATION VELOCITY

CM/SEC

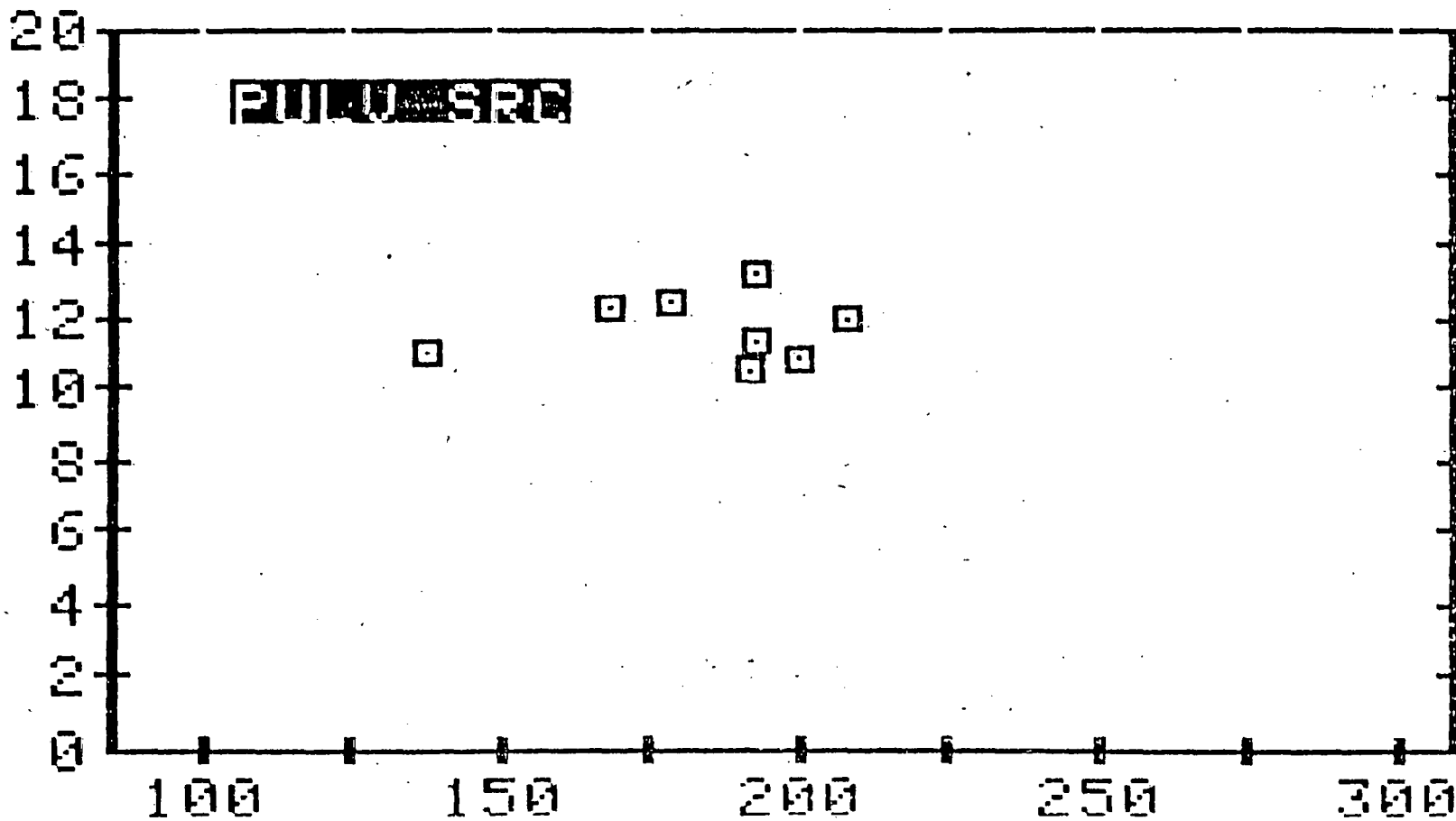
### MIGRATION VELOCITY vs. CURRENT DENSITY



MIGRATION VELOCITY

CM/SEC

## MIGRATION VELOCITY vs. SPECIFIC CORONA POWER

SPECIFIC CORONA POWER  
(WATTS/1000 ACFM)

APPENDIX IV

SRC Residual Fuel Oil Test Results and Graphs

	Page
<u>TESTING DATA</u>	
Date, Time, Orsat, Gas Temperature, Moisture . . . . .	1
Gas Volume, In-leakage . . . . .	2
Mass Emission Rates - English . . . . .	3
Mass Emission Rate - Metric . . . . .	4
ESP Operating Data and Results . . . . .	5
 <u>GRAPHS</u>	
LB/10 <sup>6</sup> Btu Out Versus ACFM In . . . . .	6
LB/10 <sup>6</sup> Btu Out Versus SCA . . . . .	7
LB/10 <sup>6</sup> Btu Out Versus Current Density . . . . .	8
LB/10 <sup>6</sup> Btu Out Versus Specific Corona Power . . . . .	9
% Efficiency Versus ACFM In . . . . .	10
% Efficiency Versus SCA . . . . .	11
% Efficiency Versus Current Density . . . . .	12
% Efficiency Versus Specific Corona Power . . . . .	13
W Versus SCA . . . . .	14
W Versus Current Density . . . . .	15
W Versus Specific Corona Power. . . . .	16

P E T C - S R C

## M A S S T R A I N D A T A ( R E S I D . O I L F I R E D )

TEST NO	DATE (1982)	TIME START	TIME END	--ORSAT DATA (% VOL)--				----GAS		TEMPERATURE----		--MOISTURE--	
				O2IN	CO2IN	O2OUT	CO2OUT	IN	OUT	IN	OUT	IN	OUT
(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(F)	(F)	(C)	(C)	(%)	(%)
P1(20)	12-8	10:07	12:16	4.6	14.4	8.2	10.2	296	227	147	108	9.4	8.8
P2(21)	12-8	14:56	17:05	3.2	15	7	11	291	235	144	113	10.2	7.9
P3(22)	12-9	9:56	11:24	5.2	13.4	9.2	9.4	294	233	146	112	9.1	7.9
P4(23)	12-9	13:33	15:39	7	12	9.2	9.8	301	234	149	112	8.6	7.4
P5(24)	12-10	11:43	13:50	5.2	13.6	7.6	11	293	223	145	106	9.1	8.1
P6(25)	12-10	15:58	18:03	5.2	13.6	6	12.6	299	232	148	111	9.6	7.9
1(26)	12-13	11:10	13:19	5.4	13	7.4	11.2	296	228	147	109	8.9	7.3
2(27)	12-13	14:10	16:18	5	13	7	12	303	230	151	110	9.5	8
3(28)	12-14	9:56	12:03	6	12.4	8.2	9.8	298	235	148	113	9.7	8.3
4(29)	12-14	13:02	15:12	4	14	7.2	11	300	238	149	114	9.7	8.3
5(30)	12-14	15:55	18:00	6.8	12.2	7.6	11	304	244	151	118	10.2	8.4
6(31)	12-15	8:45	10:52	6.8	12	7.6	11	297	238	147	114	9.5	8
7(32)	12-15	11:30	13:38	4	14	6.4	12.6	293	242	145	117	9.8	8.6
8(33)	12-15	14:04	15:16	4.2	14	7.2	11.2	300	240	149	116	9.4	8.6
9(34)	12-16	8:40	10:47	4	14	6.6	11.6	300	241	149	116	9	8.5
10(35)	12-16	11:29	13:34	3.6	14.4	4.2	14	300	240	149	116	11.2	8.3
11(36)	12-17	9:06	11:12	4.6	13.8	5.8	12.8	300	253	149	123	11.6	8.7
12(37)	12-17	11:39	13:44	3.6	15	6	12.4	300	254	149	123	9.5	8.7
13(38)	12-17	14:26	16:32	3.8	14.4	5.6	13	300	254	149	123	9.6	9

T-AT

P E T C - S R C      M A S S   T R A I N   D A T A   ( R E B I D   O I L   F I R E D )

TEST NO.	G A S   V O L U M E								% IN- LEAK (%)	% IN- LEAK (0-2)
	IN (ACFM)	OUT (ACFM)	IN (SDCFM)	OUT (SDCFM)	IN (ACMM)	OUT (ACMM)	IN (SDCMM)	OUT (SDCMM)		
P1(20)	4827	5158	2930	3622	136.7	146.1	83	102.6	23.62	28.35
P2(21)	4749	5166	2886	3624	135.1	146.3	81.7	102.6	25.57	27.34
P3(22)	4979	5364	3010	3730	141	151.9	85.2	105.6	23.92	34.19
P4(23)	5037	5250	3033	3670	142.6	148.7	85.9	103.9	21.00	18.80
P5(24)	5064	5431	3012	3776	143.4	153.8	85.3	106.9	25.37	18.05
P6(25)	4972	5588	2921	3842	140.8	158.3	82.7	108.8	31.53	5.37
1(26)	5059	5767	3038	4028	143.3	163.3	86	114.1	32.59	14.81
2(27)	5122	5478	3033	3789	145.1	155.1	85.9	107.3	24.93	14.39
3(28)	4921	5642	2895	3850	139.4	159.8	82	109	32.99	17.32
4(29)	5491	5620	3222	3818	155.5	159.2	91.2	108.1	18.50	23.36
5(30)	5334	5744	3097	3866	151.1	162.7	87.7	109.5	24.83	6.02
6(31)	4843	5861	2869	3992	137.7	166	81.3	113.1	39.14	6.02
7(32)	5104	5584	3021	3758	144.5	158.1	85.6	106.4	24.40	16.55
8(33)	5279	5642	3108	3807	149.5	159.8	88	107.8	22.49	21.90
9(34)	5072	5599	2981	3747	143.6	158.6	84.4	106.1	25.70	18.18
10(35)	5138	5689	2947	3821	145.5	161.1	83.5	108.2	29.66	3.59
11(36)	7052	7482	4114	4970	199.7	211.9	116.5	140.8	20.81	7.95
12(37)	7009	7483	4184	4977	198.5	211.9	118.5	140.9	18.95	16.11
13(38)	7042	7764	4194	5142	199.4	219.9	118.8	145.6	22.60	11.76

IV-2

P E T C - S R C I T E S T E M I S S I O N R A T E S ( R E S I D . O I L F I R E D )

TEST NO.	----GR/ACF ----			----GR/SDCF ----			Lbs/10 <sup>6</sup> Btu (F-93.86)--			TEST	
	IN (-)	OUT (-)	% (-)	IN (-)	OUT (-)	% (-)	IN (-)	OUT (-)	% (-)	ISOKINETICS (%IN) (%OUT)	
P1(20)	.1093	.0014	98.72	.18	.002	98.89	.3182	.0045	98.59	103	89
P2(21)	.0834	.0012	98.56	.1378	.0017	98.77	.2244	.0037	98.35	97.5	98.7
P3(22)	.0617	.0004	99.35	.102	.0006	99.41	.1871	.0015	99.20	103.3	97.7
P4(23)	.042	.0003	99.29	.0697	.0004	99.43	.1444	.001	99.31	99.8	95.9
P5(24)	.0544	.0005	99.08	.0915	.0007	99.23	.1679	.0016	99.05	101.1	93.4
P6(25)	.053	.0007	98.68	.0902	.001	98.89	.1655	.0019	98.85	103	94.9
1(26)	.0431	.0007	98.38	.0717	.0011	98.47	.1333	.0023	98.27	100.9	95.9
2(27)	.0437	.0002	99.56	.0772	.0002	99.74	.1398	.0005	99.64	99.3	93.4
3(28)	.0781	.0009	98.85	.1327	.0013	99.02	.2566	.003	98.83	100.6	95.7
4(29)	.0742	.0006	99.19	.1264	.001	99.21	.2156	.002	99.07	101.9	95.6
5(30)	.0666	.0002	99.70	.1147	.0003	99.74	.2344	.001	99.57	101.1	95.8
6(31)	.056	.0002	99.64	.0949	.0003	99.68	.1941	.0006	99.69	105	96.3
7(32)	.06	.0005	99.17	.1014	.0008	99.21	.1728	.0016	99.07	101.3	96.6
8(33)	.0602	.0007	98.84	.1022	.0011	98.92	.1763	.0023	98.70	103.5	95.5
9(34)	.0733	.0002	99.73	.1246	.0002	99.84	.2125	.0005	99.76	99.7	95.9
10(35)	.0756	.0002	99.74	.1318	.0002	99.85	.2195	.0002	99.91	103.8	96.8
11(36)	.0719	.0026	96.38	.1233	.0039	96.84	.2179	.0075	96.56	103.9	96.9
12(37)	.0712	.0024	96.63	.1192	.0036	96.98	.1985	.007	96.47	102.1	94.9
13(38)	.0694	.0032	95.39	.1165	.0048	95.88	.1963	.0091	95.36	102.1	96.9

IV-3

P E T C - S R C . T E S T E M I S S I O N R A T E S ( S R C R E S I D O I L F I R E D )

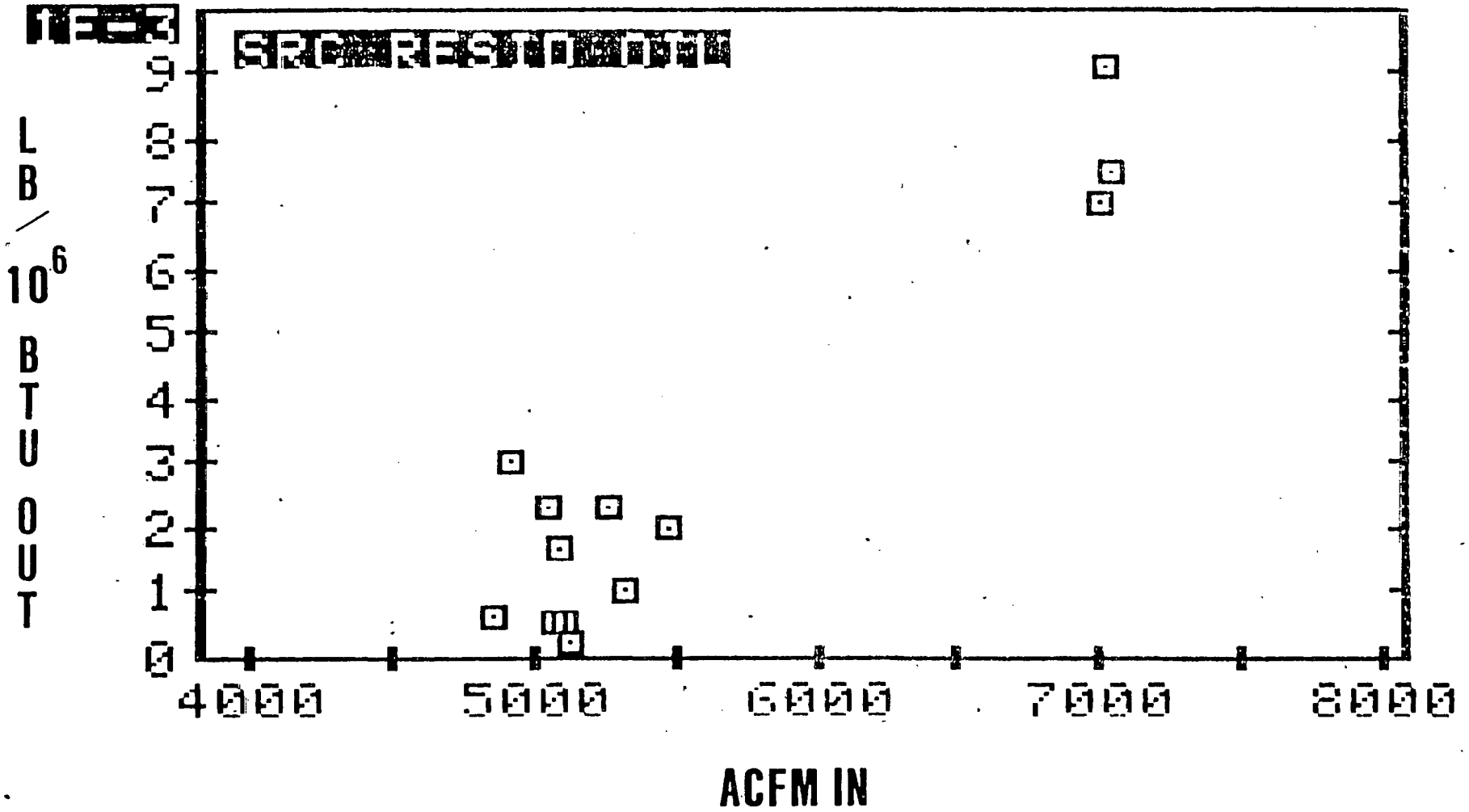
TEST NO.	---MG/ACM---			---MG/SDCM---			---MG/JOULE---			TEST	
	IN (-)	OUT (-)	% (-)	IN (-)	OUT (-)	% (-)	IN (-)	OUT (-)	% (-)	(%IN)	(%OUT)
P1(20)	250	3.20	98.72	412	4.38	98.89	137	1.94	98.59	103	89
P2(21)	191	2.75	98.56	315	3.89	98.77	96	1.59	98.35	97.5	98.7
P3(22)	141	0.92	99.35	233	1.37	99.41	80	0.65	99.20	103.3	97.7
P4(23)	96	0.69	99.29	159	0.92	99.43	62	0.43	99.31	99.8	95.9
P5(24)	124	1.14	99.08	209	1.60	99.23	72	0.69	99.05	101.1	93.4
P6(25)	121	1.60	98.68	206	2.29	98.89	71	0.82	98.85	103	94.9
1(26)	99	1.60	98.38	164	2.52	98.47	57	0.99	98.27	100.9	95.9
2(27)	105	0.46	99.56	177	0.46	99.74	60	0.22	99.64	99.3	93.4
3(28)	179	2.06	98.85	304	2.97	99.02	110	1.29	98.83	100.6	95.7
4(29)	170	1.37	99.19	289	2.29	99.21	93	0.86	99.07	101.9	95.6
5(30)	152	0.46	99.70	262	0.69	99.74	101	0.43	99.57	101.1	95.8
6(31)	128	0.46	99.64	217	0.69	99.68	83	0.26	99.69	105	96.3
7(32)	137	1.14	99.17	232	1.83	99.21	74	0.69	99.07	101.3	96.6
8(33)	138	1.60	98.84	234	2.52	98.92	76	0.99	98.70	103.5	95.5
9(34)	168	0.46	99.73	285	0.46	99.84	91	0.22	99.76	99.7	95.9
10(35)	173	0.46	99.74	302	0.46	99.85	94	0.09	99.91	103.8	96.8
11(36)	165	5.95	96.38	282	8.92	96.84	94	3.23	96.56	103.9	96.9
12(37)	163	5.49	96.63	273	8.24	96.98	95	3.01	96.47	102.1	94.9
13(38)	159	7.32	95.39	267	10.98	95.88	94	3.91	95.36	102.1	96.9

P E T C - S R C    E S P   D A T A   &   R E S U L T S   ( R E S I D   O I L   F I R E D )

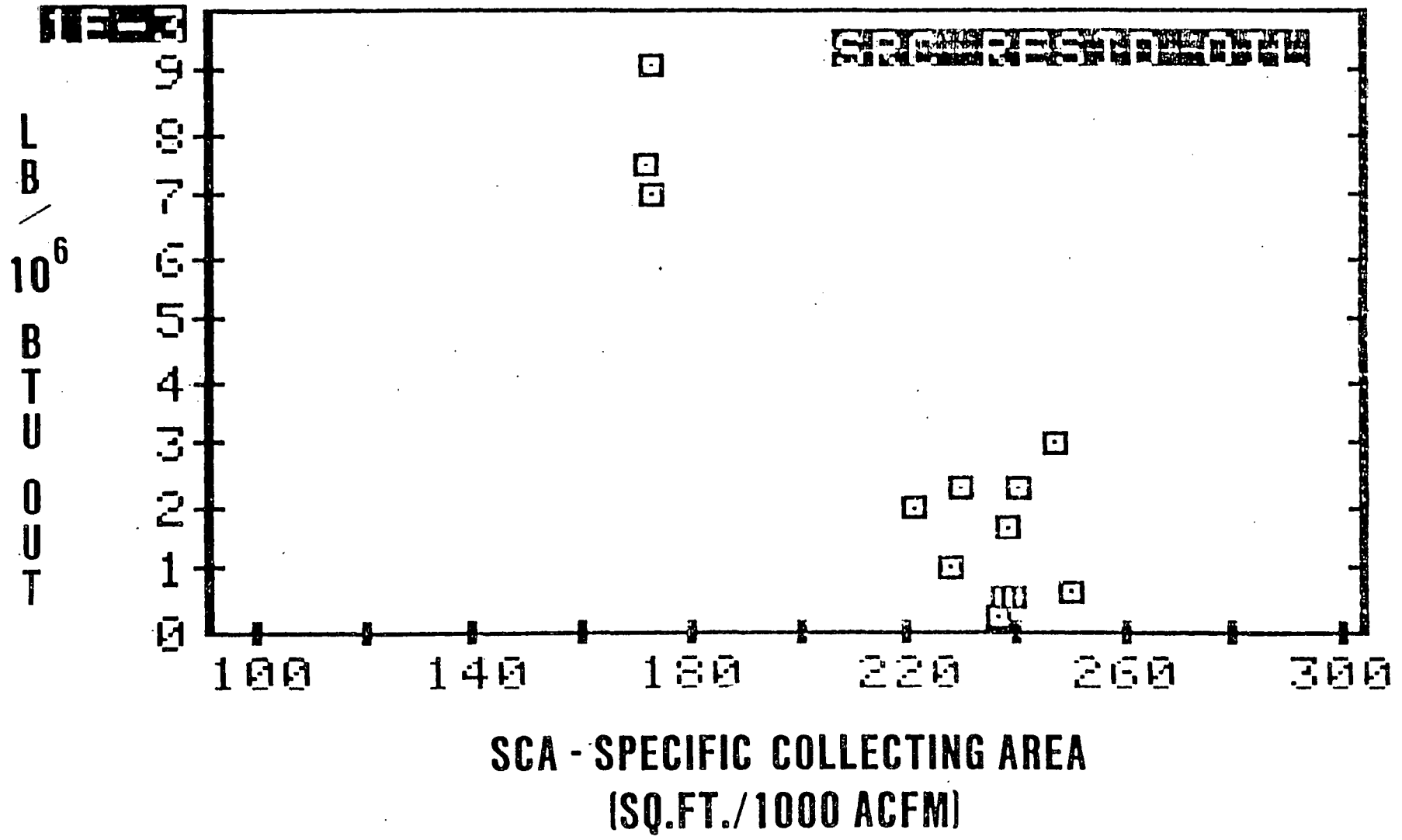
TV-5

TEST NO.	--- E S P    A V E R A G E    P O W E R ---						ESP	SP PWR	CURR	I-DENS	I-DENS	SCA	W	W-K
	KV1	MA1	KV2	MA2	KV3	MA3	POWER (WATT/		AVE	(MA/	(NA/	(SQ FT	(CM/	(CM/
							(WATT) KACFM)		(MA)	SQ FT)	SQ CM)/KACFM)	SEC)	SEC)	
P1(20)	32.4	10.1	36.7	9.54	35.2	9.91	1028	213	9.84	.0243	24.14	252	8.55	34.34
P2(21)	33.4	10.7	35.2	10	35.6	10	1065	223	10.2	.0251	27.02	254	8.19	33.71
P3(22)	40.9	10	38.6	10	36	10	1155	232	10	.0244	24.48	245	10.04	48.41
P4(23)	37.5	5.03	34.7	5	31.3	5	519	103	5.01	.0123	13.24	242	10.47	52.19
P5(24)	40.5	10	37.4	10	34.9	10	1128	223	10	.0244	24.48	241	9.85	45.94
P6(25)	31.4	5.29	39.4	10	34.9	10	910	183	8.43	.0208	22.39	245	9.29	41.60
1(26)	26.2	3	39.4	10	37.1	10.1	848	168	7.71	.019	20.45	241	8.59	34.98
2(27)	26.4	2.5	39.7	10	37.1	10	834	163	7.5	.0185	19.91	238	12.05	68.04
3(28)	25.2	5	39	10	36	10	874	178	8.33	.0205	22.07	248	9.15	40.84
4(29)	25.7	5	39.8	10	36.5	10	891	162	8.33	.0205	22.07	222	10.74	50.41
5(30)	28	4.55	40	10	37.1	10	898	168	8.18	.0201	21.64	228	12.16	64.53
6(31)	23.7	3.21	37.1	5	34.3	5	433	89	4.4	.0108	11.63	251	11.74	68.00
7(32)	22.2	3.64	37.6	5	33.7	5	434	85	4.55	.0112	12.04	239	9.99	46.90
8(33)	24.4	4.9	37.6	5	34	5	477	90	4.97	.0122	13.13	231	9.58	41.48
9(34)	26.2	5.29	38	5	34.4	5	500	99	5.1	.0126	13.56	240	12.82	77.77
10(35)	27.1	5.43	37.5	5	34.6	5	508	99	5.14	.0127	13.67	237	15.02	105.36
11(36)	30.4	5.53	38.6	5	32.5	5	523	74	5.18	.0128	13.78	173	9.90	33.37
12(37)	23.4	4.43	39.2	5	33.6	5	468	67	4.81	.0118	12.70	174	9.77	32.66
13(38)	21.5	4.67	38.7	5	32.9	5	459	65	4.89	.012	12.92	173	9.02	27.73

# LB/10<sup>6</sup> BTU OUT vs. ACFM IN

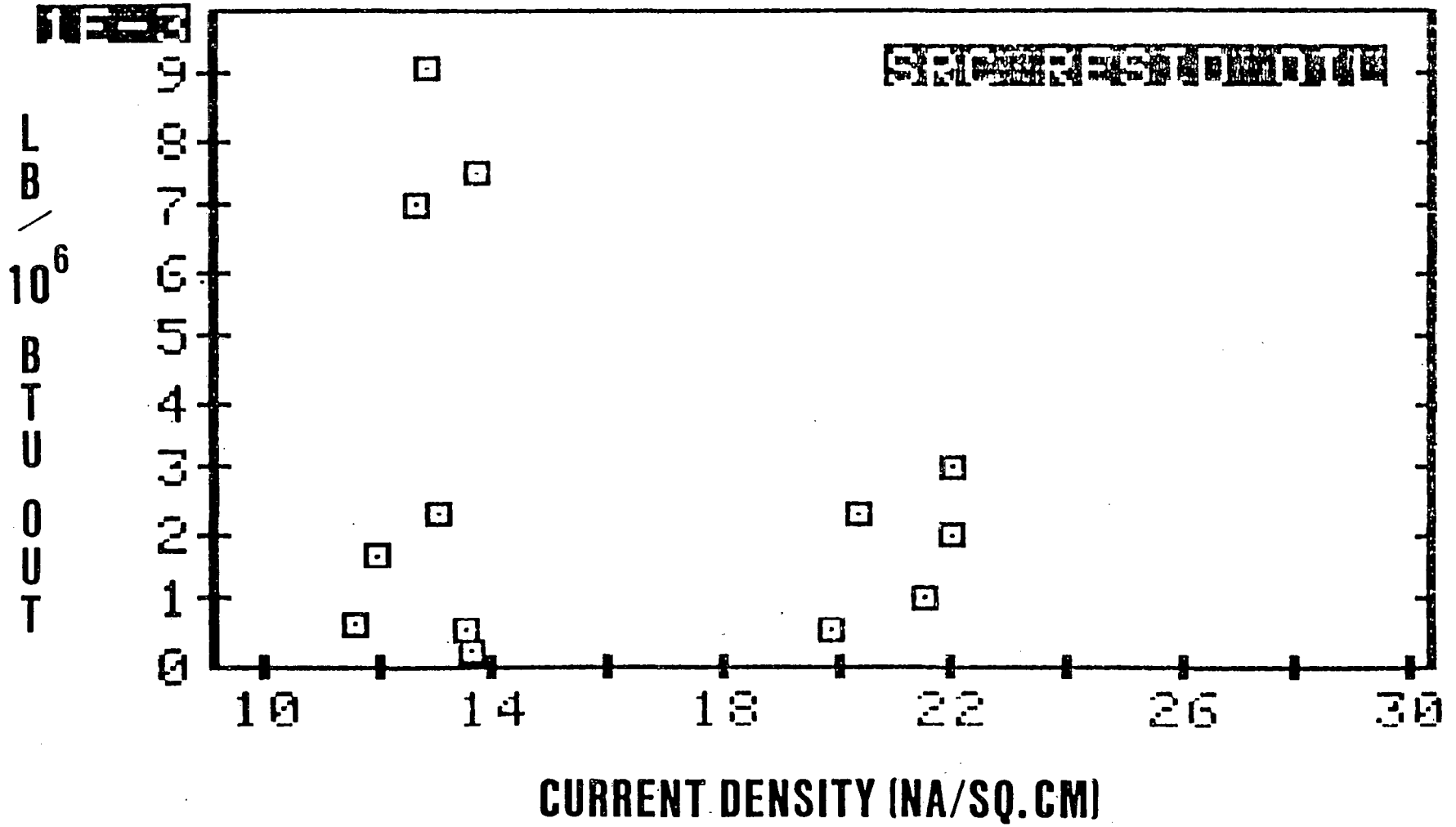


# LB/10<sup>6</sup> BTU OUT vs. SCA

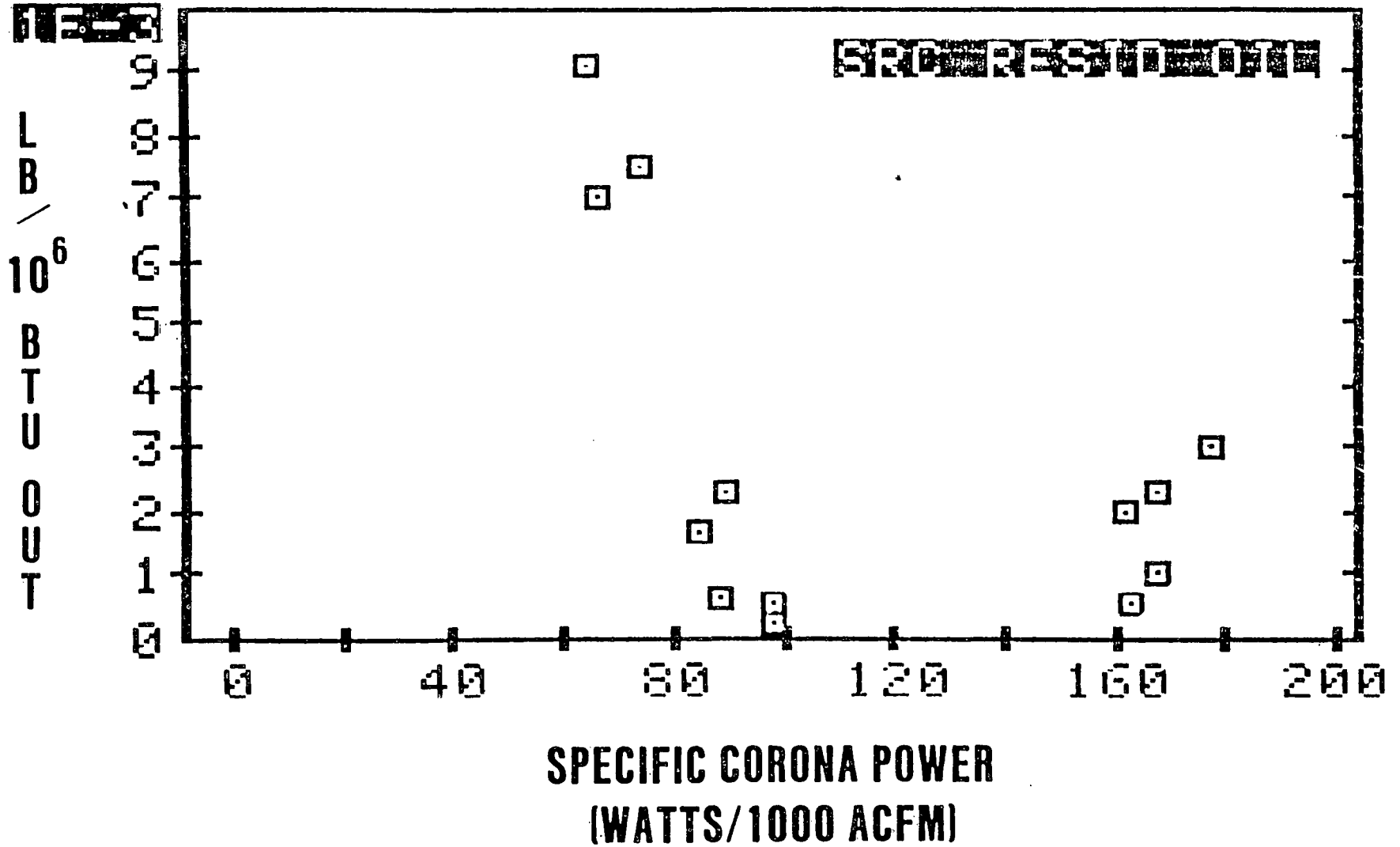


# LB/10<sup>6</sup> BTU OUT vs. CURRENT DENSITY

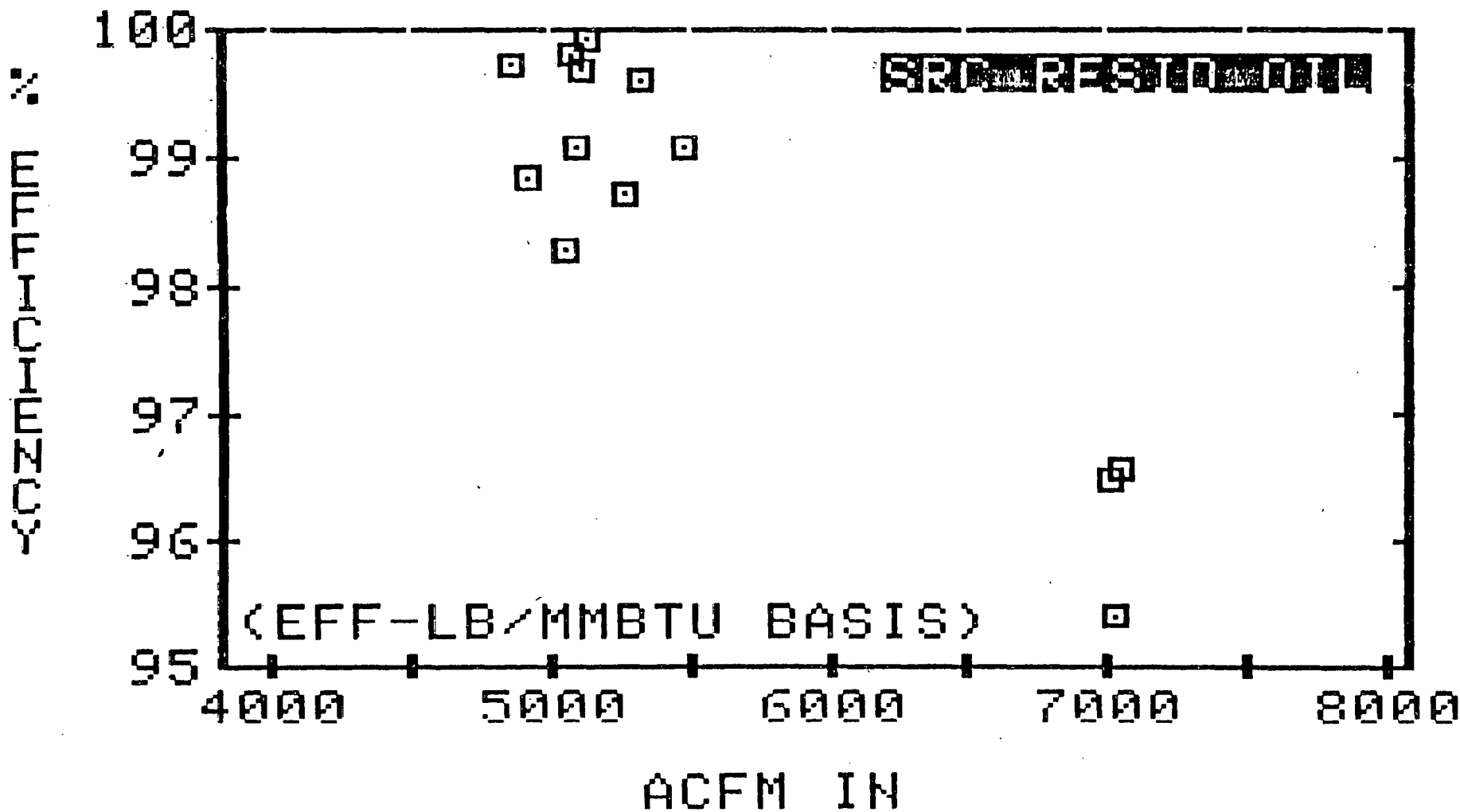
IV-8



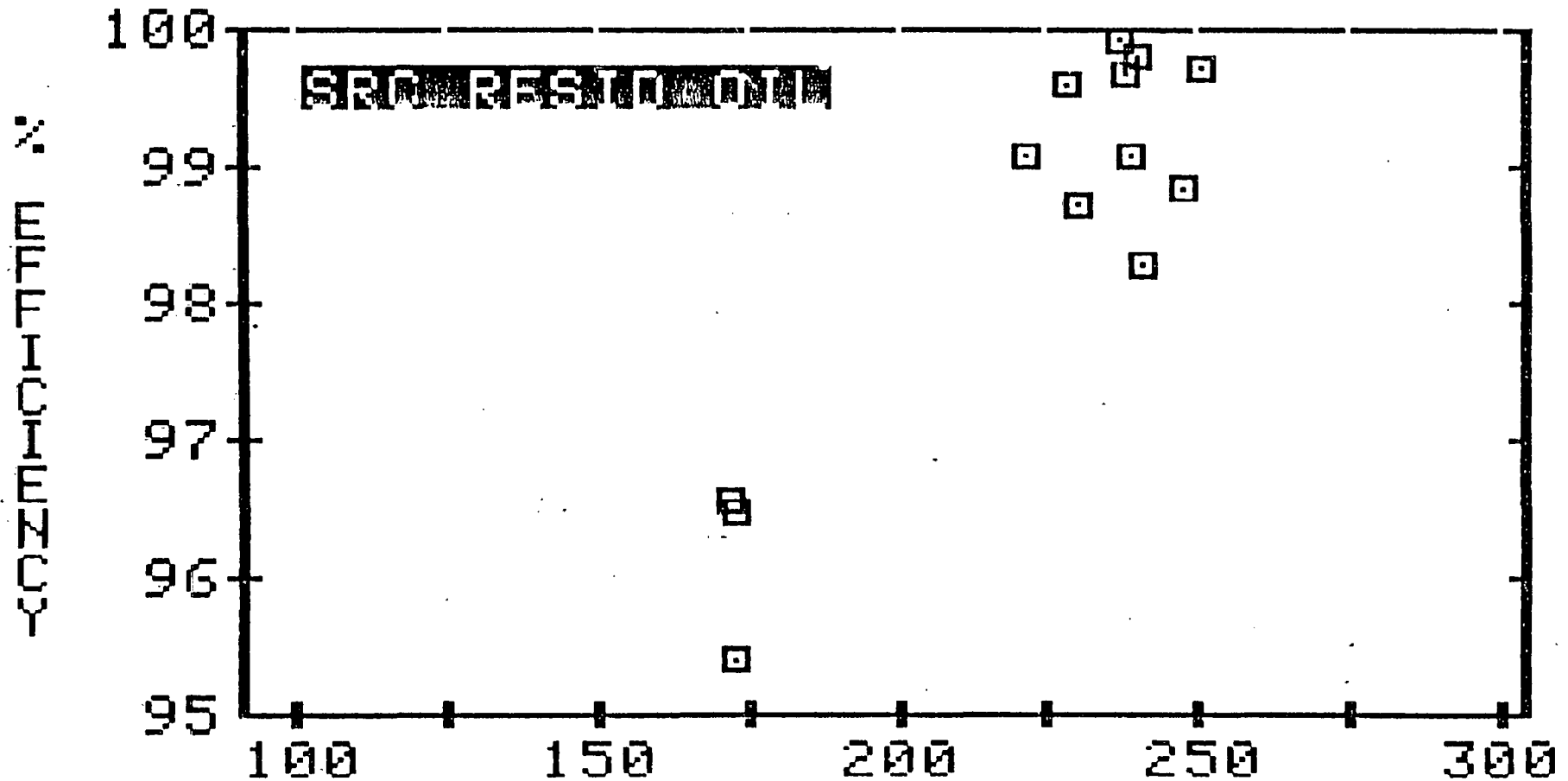
# LB/10<sup>6</sup> BTU vs. SPECIFIC CORONA POWER



# % EFFICIENCY VS ACFM IN

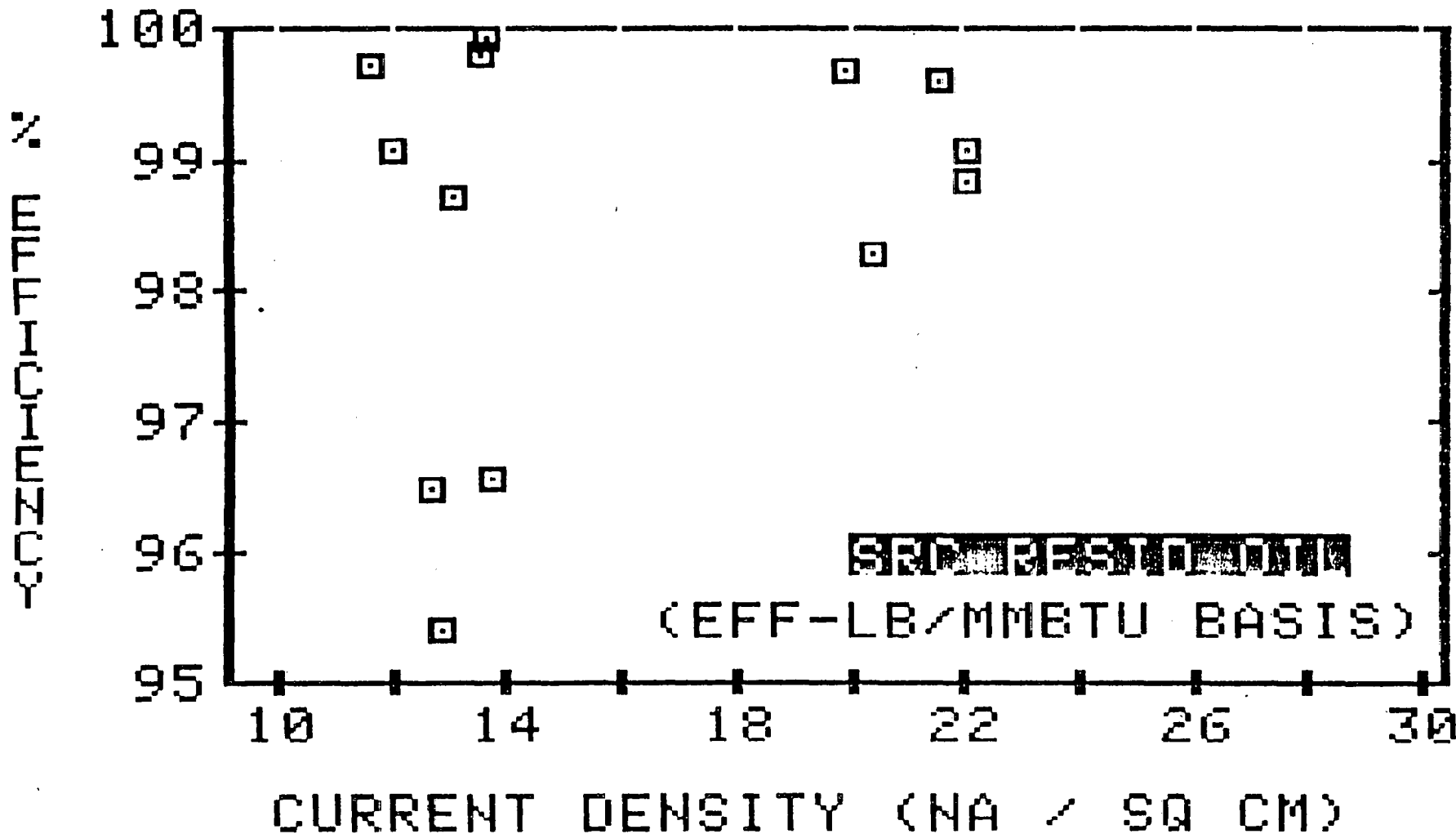


# % EFFICIENCY VS SCA

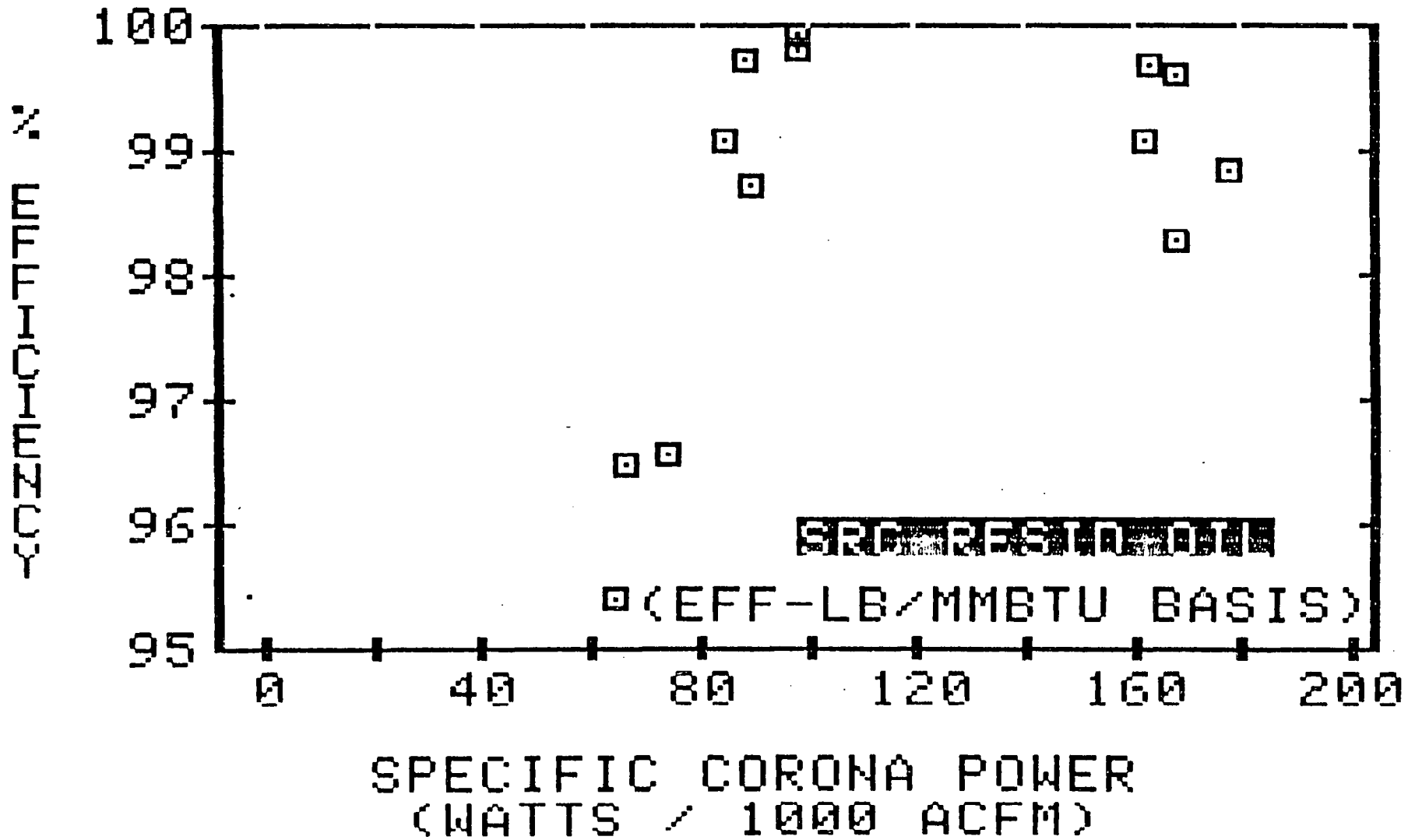


SCA - SPECIFIC COLLECTING AREA  
(SQ FT / 1000 ACFM)

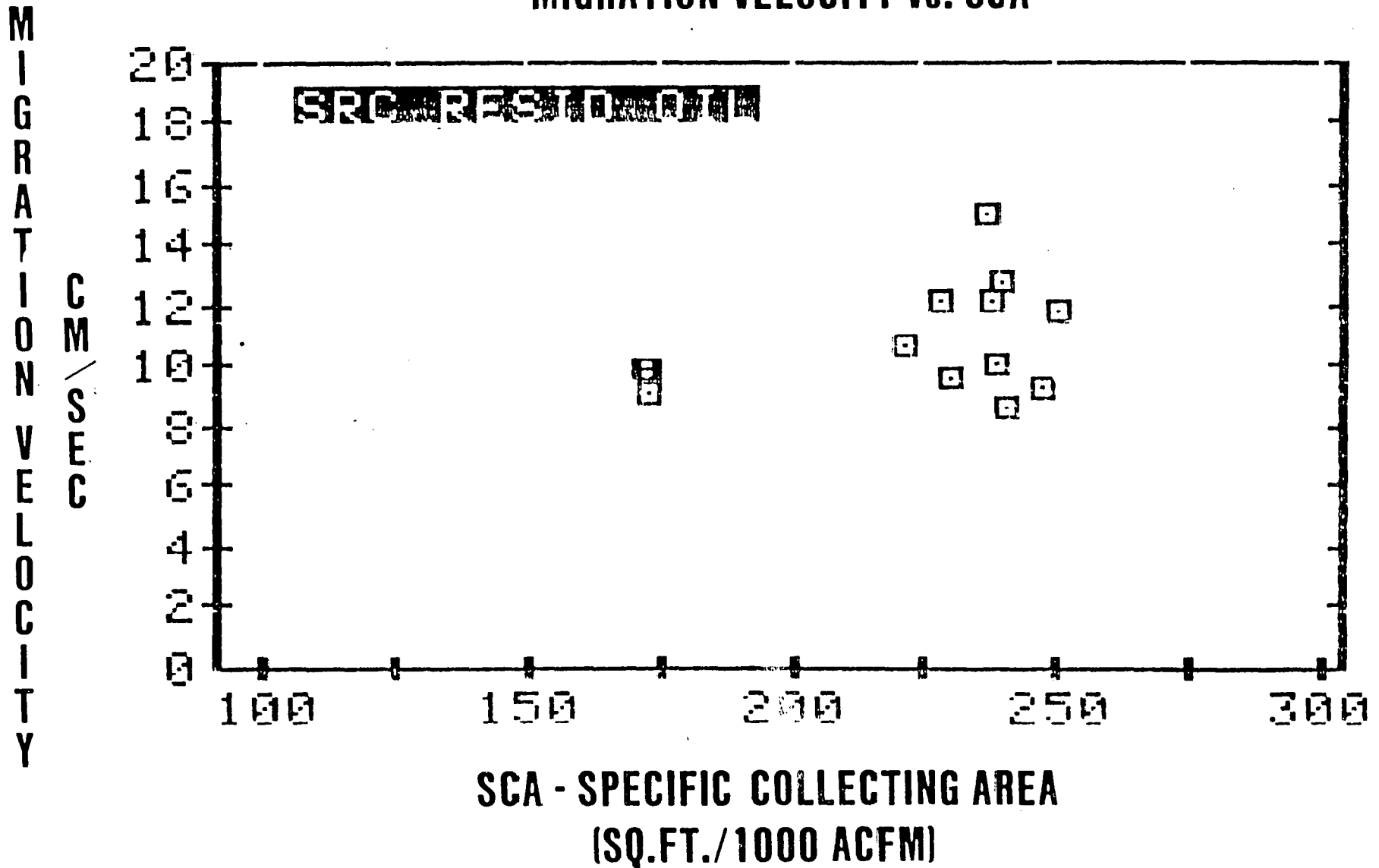
# % EFFICIENCY VS CURRENT DENSITY



# % EFF VS SPECIFIC CORONA POWER



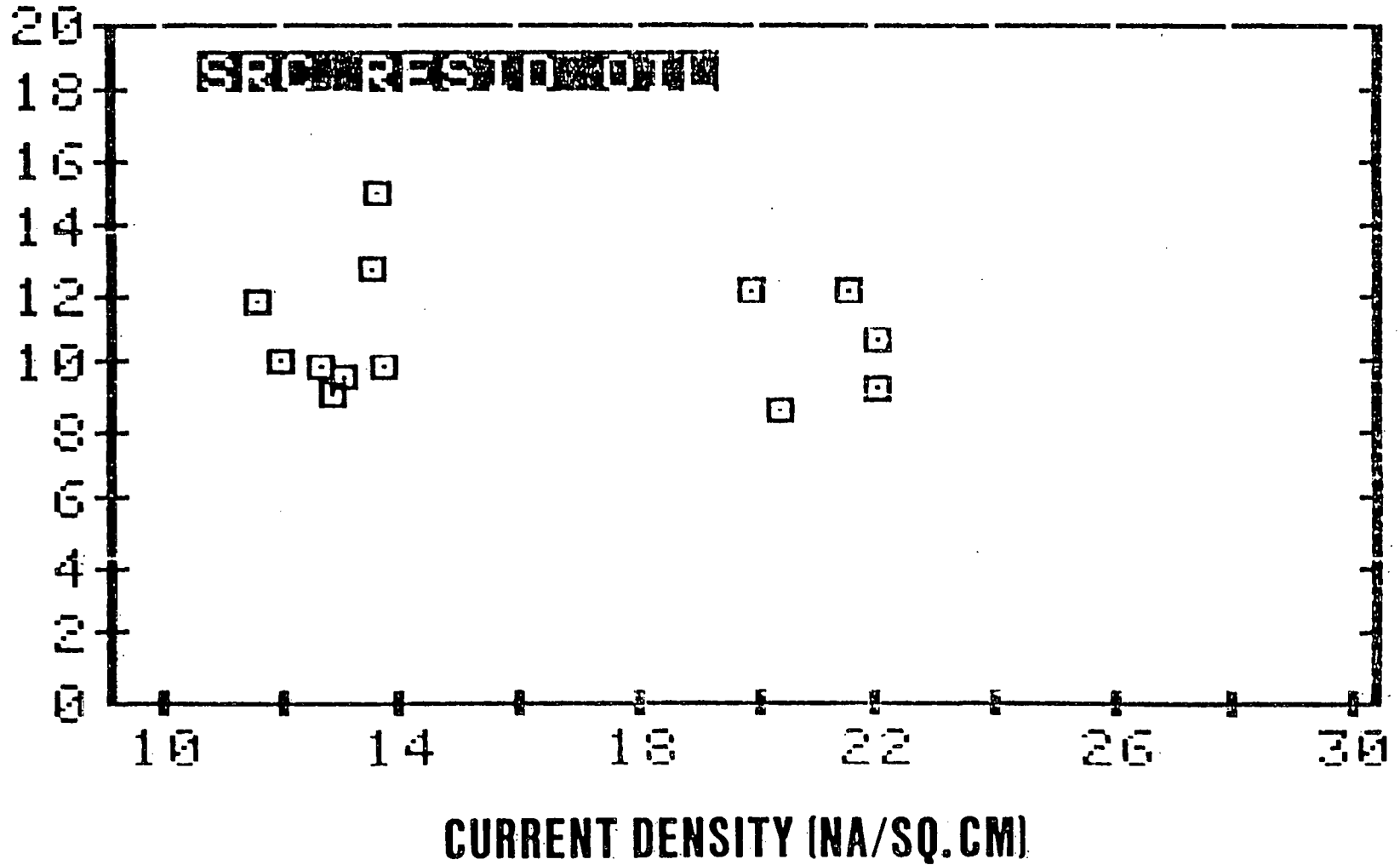
# MIGRATION VELOCITY vs. SCA



MIGRATION VELOCITY

CM/SEC

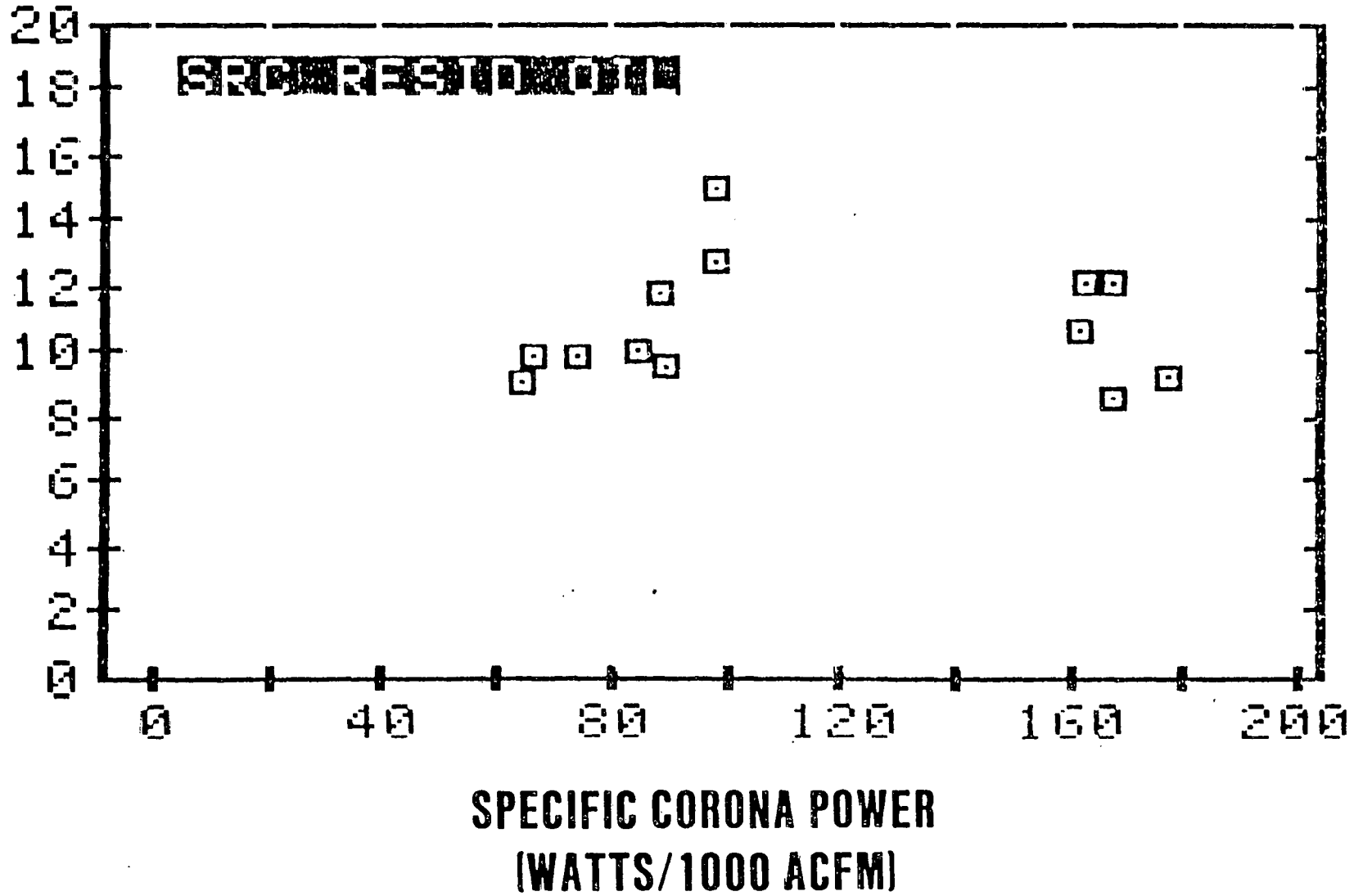
## MIGRATION VELOCITY vs. CURRENT DENSITY



M I G R A T I O N V E L O C I T Y

C M / S E C

### MIGRATION VELOCITY vs. SPECIFIC CORONA POWER



APPENDIX V

SRC - Water Slurry Test Results And Graphs

	Page
<u>TESTING DATA</u>	
Date, Time, Orsat, Gas Temperature, Moisture . . . . .	1
Gas Volume, In-leakage . . . . .	2
Mass Emission Rates - English . . . . .	3
Mass Emission Rate - Metric . . . . .	4
ESP Operating Data and Results . . . . .	5
 <u>GRAPHS</u>	
LB/10 <sup>6</sup> Btu Out Versus ACFM In . . . . .	6
LB/10 <sup>6</sup> Btu Out Versus SCA . . . . .	7
LB/10 <sup>6</sup> Btu Out Versus Current Density . . . . .	8
LB/10 <sup>6</sup> Btu Out Versus Specific Corona Power . . . . .	9
% Efficiency Versus ACFM In . . . . .	10
% Efficiency Versus SCA . . . . .	11
% Efficiency Versus Current Density . . . . .	12
% Efficiency Versus Specific Corona Power . . . . .	13
W Versus SCA . . . . .	14
W Versus Current Density . . . . .	15
W Versus Specific Corona Power. . . . .	16

P E T C - S R C

M A S S T R A I N D A T A ( S R C - W A T E R F I R E D )

TEST NO	DATE (1982)	TIME START	TIME END	--ORSAT DATA (% VOL)--				----GAS TEMPERATURE----				--MOISTURE--	
				O2IN	CO2IN	O2OUT	CO2OUT	IN	OUT	IN	OUT	IN	OUT
(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(F)	(F)	(C)	(C)	(%)	(%)
P1(39)	1-5	10:00	11:11	4	13.6	8.5	9	300	233	149	112	12.2	9.9
P2(40)	1-6	8:40	9:46	4.4	14	7	11.4	296	229	147	109	11.4	10.6
P3(41)	1-6	11:27	12:27	4.5	14.6	6.4	10.8	300	235	149	113	11.9	10.7
P4(42)	1-7	9:00	10:24	4.4	13.6	8.6	10.2	301	234	149	112	12.1	10.1
P5(43)	1-7	11:15	12:40	4.2	13.6	8	11.2	298	242	148	117	12.2	10.1
P6(44)	1-7	15:30	16:30	3.8	12.8	7.8	11.2	300	240	149	116	12	10.8
P7(45)	1-10	8:50	10:55	9	9.8			270		132		11.2	
P8(46)	1-10	12:53	14:55	5	11			270		132		11.9	
1(47)	1-11	8:45	10:50	4.4	12.8	8.4	10.2	303	236	151	113	10.9	10.2
2(48)	1-11	11:30	13:32	4.4	13.8	8.8	9.2	300	240	149	116	11.5	10.1
3(49)	1-11	14:15	16:18	4.6	13	8.8	11.2	307	244	153	118	11.5	10.1
4(50)	1-12	8:50	10:55	4.2	13.8	7.2	11.4	301	235	149	113	10.1	8.9
5(51)	1-12	12:03	14:08	3.8	13.2	6.8	11.4	301	235	149	113	10.2	9.8
6(52)	1-12	14:37	16:43	4.8	13.2	7.2	10.8	301	240	149	116	11.7	8.8
7(53)	1-13	7:52	9:58	4.4	13.6	7.6	10.2	300	240	149	116	11.5	9.2
8(54)	1-13	10:41	12:22	4.6	13.2	7.6	11.2	299	240	148	116	11.6	10.9
9(55)	1-13	12:49	14:14	4	13	7.4	10.8	301	240	149	116	12.8	11.8
10(56)	1-14	8:21	10:26	4.8	13.2	7.4	10	298	240	148	116	11.5	9.6
11(57)	1-14	11:25	13:07	4.2	14	7.4	10	301	240	149	116	11.7	9.9
12(58)	1-14	13:34	14:59	4.6	12.8	7	11.2	301	240	149	116	12.3	9.5

T-A

P E T C - B R C M A S S T R A I N D A T A ( B R C - W A T E R F I R E D )

G A S V O L U M E

TEST NO.	IN	OUT	IN	OUT	IN	OUT	IN	OUT	% IN-LEAKAGE	
	(ACFM)	(ACFM)	(SDCFM)	(SDCFM)	(ACMM)	(ACMM)	(SDCMM)	(SDCMM)	(SDCFM)	(O-2)
P1(39)	5088	5411	2949	3800	144.1	158.9	83.5	107.6	28.86	36.29
P2(40)	5396	5593	3120	3749	152.8	158.4	88.4	106.2	20.16	18.71
P3(41)	5413	5824	3213	3867	159	164.9	91	109.5	20.35	13.10
P4(42)	5555	5925	3137	3881	157.3	167.8	88.8	109.9	23.72	34.15
P5(43)	5439	6017	3077	3949	154	170.4	87.1	111.8	28.34	29.46
P6(44)	5532	5756	3126	3758	156.7	163	88.5	106.4	20.22	30.53
P7(45)	5709		3443		161.7		98.1			
P8(46)	6015		3623		170.3		102.6			
1(47)	5701	5895	3234	3863	161.5	166.9	91.6	109.4	19.45	32.00
2(48)	5600	5973	3169	3898	158.6	169.2	89.7	110.4	23.00	36.36
3(49)	5441	6054	3051	3928	154.1	171.4	86.4	111.2	40.74	34.71
4(50)	5046	5660	2989	3827	142.9	160.3	84.6	108.4	28.04	21.90
5(51)	5304	5738	3146	3841	150.2	162.5	89.1	108.8	22.09	21.28
6(52)	5334	5705	3105	3834	151.1	161.6	87.9	108.6	23.48	17.52
7(53)	5523	5804	3176	3882	156.4	164.4	89.9	109.9	21.23	24.06
8(54)	5659	5679	3247	3727	160.3	160.8	91	105.5	14.78	22.56
9(55)	5645	5740	3188	3729	159.9	162.6	90.3	105.6	16.97	25.19
10(56)	5338	5686	3034	3738	151.2	161	85.9	105.9	23.20	19.16
11(57)	5558	5563	3140	3646	157.4	157.5	88.9	103.3	16.11	23.70
12(58)	5584	5533	3134	3641	158.1	156.7	88.8	103.1	16.18	17.27

P E T C - S R C    T E S T    E M I S S I O N    R A T E S    ( S R C - W A T E R    F I R E D )

TEST NO.	----GR/ACF-----			----GR/SDCF-----			--LB/ (F=96.42)--			TEST	
	IN	OUT	%	IN	OUT	%	IN	OUT	%	ISOKINETICS	
	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(%IN)	(%OUT)
P1(39)	.3197	.0207	93.53	.5316	.0305	94.47	.9441	.0713	92.45	99.3	90.7
P2(40)	.3519	.0326	90.74	.6089	.0494	91.89	1.0673	.1028	90.37	104.1	95.3
P3(41)	.3641	.0132	96.37	.6362	.0197	96.90	1.1218	.0396	96.47	104.2	99.8
P4(42)	.2992	.0014	99.53	.5297	.0021	99.60	.9287	.005	99.46	102.9	99
P5(43)	.3894	.002	99.49	.6882	.0031	99.55	1.193	.0084	99.30	102.8	98.7
P6(44)	.414	.0013	99.69	.7385	.0021	99.72	1.2493	.0046	99.63	105.6	96.3
P7(45)	.396			.6528			1.1052			97.6	
P8(46)	.4615			.7662			1.2896			98.8	
1(47)	.3134	.0013	99.59	.5323	.002	99.64	.9683	.0047	99.51	103.3	99.6
2(48)	.3582	.0008	99.78	.6331	.0013	99.79	1.11	.003	99.73	102.2	99.6
3(49)	.3679	.0022	99.40	.6562	.0034	99.48	1.1645	.0081	99.30	101.9	98.2
4(50)	.2941	.0062	97.89	.4965	.0091	98.17	.86	.0192	97.77	102.7	99.9
5(51)	.2914	.0021	99.28	.4913	.0031	99.37	.831	.0063	99.24	100.6	100.2
6(52)	.2865	.0043	98.50	.4923	.0064	98.70	.8844	.0136	98.46	101.9	99.4
7(53)	.29	.0022	99.24	.5043	.0032	99.37	.884	.007	99.21	99.7	100.1
8(54)	.2793	.0025	99.10	.4819	.0038	99.21	.8552	.0083	99.03	100.5	102.7
9(55)	.3124	.0078	97.50	.5531	.0121	97.81	.9468	.026	97.25	99.3	102.3
10(56)	.3068	.0047	98.47	.5396	.0072	98.67	.9696	.0155	98.40	103.4	100.9
11(57)	.3302	.0078	97.64	.5844	.0119	97.96	1.0122	.0253	97.48	102.2	101.2
12(58)	.3286	.0087	97.35	.5855	.0132	97.75	1.0389	.0276	97.34	105.1	100.7

P E T C - B R C . T E S T E M I S S I O N R A T E S ( S R C - W A T E R F I R E D )

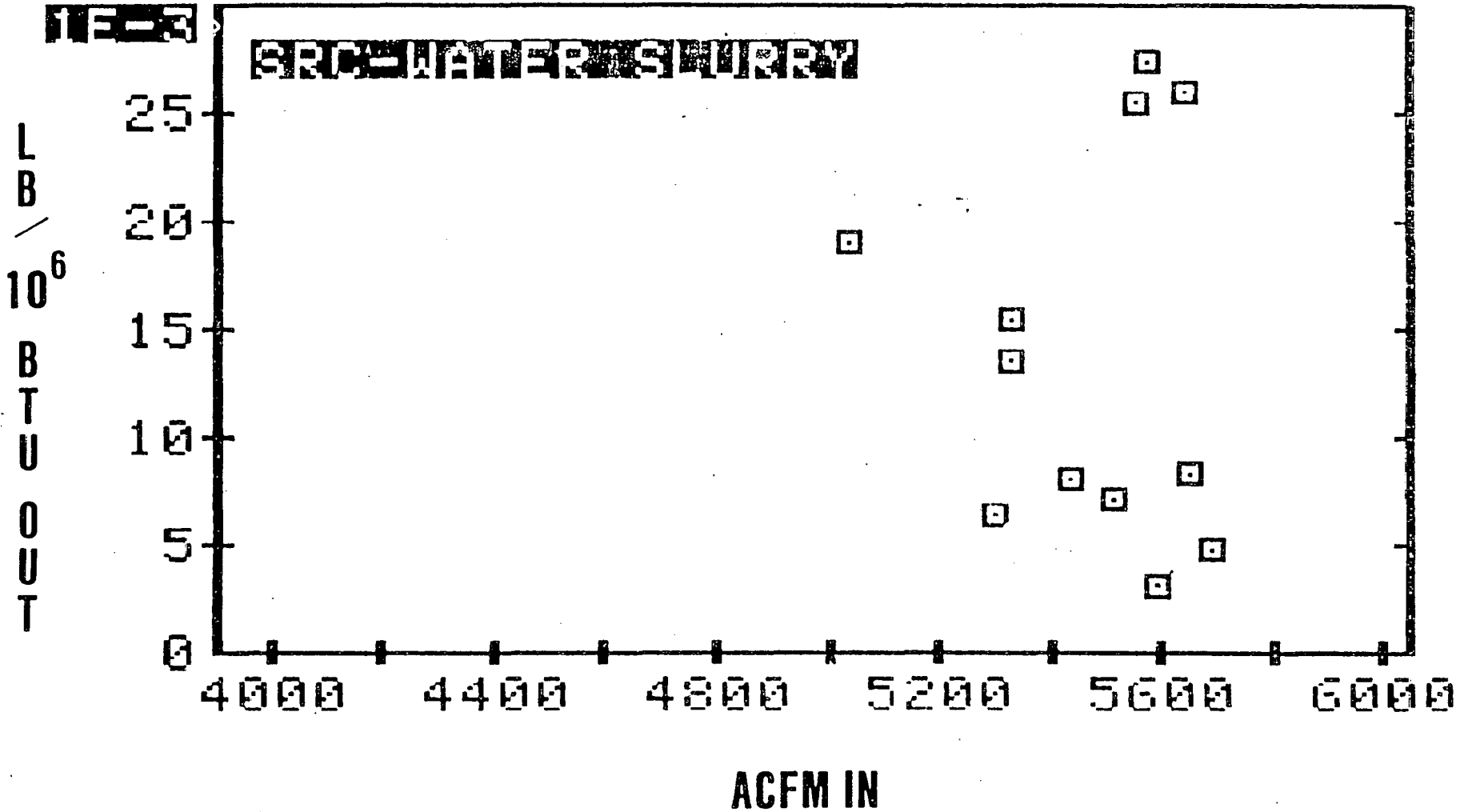
TEST NO.	---MG/ACH---			---MG/SDCM---			---MG/JOULE---			TEST	
	IN (-)	OUT (-)	% (-)	IN (-)	OUT (-)	% (-)	IN (-)	OUT (-)	% (-)	ISOKINETICS (%IN) (%OUT)	
P1(39)	731	47	93.53	1262	70	94.47	406	31	92.43	99.5 90.7	
P2(40)	803	75	90.74	1393	113	91.89	459	44	90.37	104.1 95.3	
P3(41)	833	30	96.37	1456	45	96.90	482	17	96.47	104.2 99.8	
P4(42)	685	3	99.53	1212	5	99.60	399	2	99.46	102.9 99	
P5(43)	891	5	99.49	1575	7	99.53	513	4	99.30	102.8 98.7	
P6(44)	947	3	99.69	1690	5	99.72	537	2	99.63	105.6 96.3	
P7(45)	904			1494			475			97.4	
P8(46)	1056			1753			555			98.8	
1(47)	717	3	99.59	1264	5	99.64	413	2	99.51	103.3 99.6	
2(48)	820	2	99.78	1449	3	99.79	477	1	99.73	102.2 99.6	
3(49)	842	5	99.40	1501	8	99.48	501	3	99.30	101.9 98.2	
4(50)	673	14	97.89	1136	21	98.17	370	8	97.77	102.7 99.9	
5(51)	667	5	99.28	1124	7	99.37	357	3	99.24	100.6 100.2	
6(52)	654	10	98.50	1126	15	98.70	380	6	98.46	101.9 99.4	
7(53)	664	5	99.24	1154	7	99.37	389	3	99.21	99.7 100.1	
8(54)	639	6	99.10	1103	9	99.21	368	4	99.03	100.5 102.7	
9(55)	715	18	97.50	1265	28	97.81	407	11	97.25	99.3 102.3	
10(56)	702	11	98.47	1235	16	98.67	417	7	98.40	103.4 100.9	
11(57)	755	18	97.64	1337	27	97.96	435	11	97.48	102.2 101.2	
12(58)	752	20	97.35	1340	30	97.75	447	12	97.34	105.1 100.7	

P E T C - S R C E S P D A T A & R E S U L T S ( S R C - W A T E R F I R E D ) I R E D )

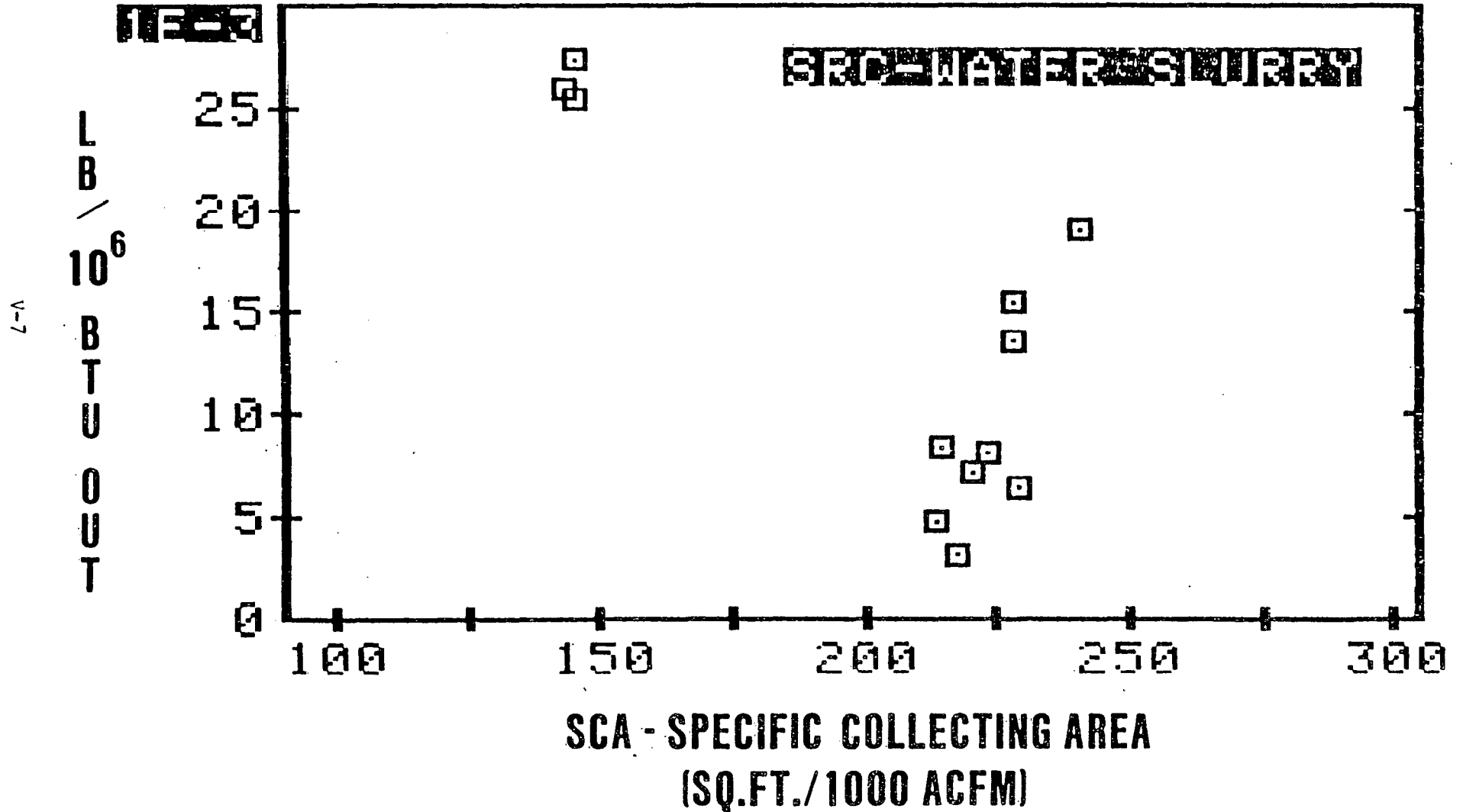
TEST NO.	--- E S P A V E R A G E P O W E R ---						ESP	SP PWR	CURR	I-DENS	I-DENS	SCA	W	W-K
	KV1	MA1	KV2	MA2	KV3	MA3	POWER (WATT/ (WATT) KACFM)	(MA)	(MA/ SQ FT)	(NA/ SQ CM)/KACFM)	(BQ FT)	(CM/ SEC)	(CM/ SEC)	
P1(39)	0	0	42.1	4.36	0	0	91.9	18	4.36	.0036	3.88	80	1.83	4.72
P2(40)	0	0	36.3	3	14	7.2	81.9	15	5.1	.0084	9.04	151	3.51	8.21
P3(41)	0	0	37.8	3.06	24.2	2.69	88.9	16	2.87	.0047	5.06	145	5.21	17.43
P4(42)	30.4	9.13	44.7	8.45	38.2	9.83	618	111	9.14	.0225	24.22	219	12.12	63.42
P5(43)	31.7	6.75	47.5	9.37	39.9	8.9	1012	186	8.34	.0205	22.07	224	11.23	55.62
P6(44)	30.1	7.7	46.2	7.76	40.2	10	979	177	8.49	.0209	22.50	220	12.94	72.66
P7(45)	0	0	0	0	0	0	0	0	0	0	0.00	213	0.00	0.00
P8(46)	0	0	0	0	0	0	0	0	0	0	0.00	203	0.00	0.00
1(47)	42	4.38	40.8	8.4	33.3	9.66	848	149	7.48	.0184	19.81	214	12.68	67.69
2(48)	43.2	3.67	41.9	9.71	33.6	10	906	162	7.8	.0192	20.67	218	13.82	81.88
3(49)	36.8	3.93	43.3	5	32.7	4.93	519	95	4.62	.0114	12.27	224	11.26	55.91
4(50)	25.1	5.25	47.8	5.33	39.4	9.88	780	155	6.82	.0168	18.08	242	7.99	30.38
5(51)	42.4	4.6	45.1	4.6	41.9	9.84	815	154	6.35	.0156	16.79	230	10.78	52.55
6(52)	40.4	4.47	43.9	4.28	36.8	4.5	533	100	4.42	.0109	11.73	228	9.29	38.78
7(53)	34.5	4	49.8	6.63	40.8	9.43	854	155	6.69	.0165	17.76	221	11.13	53.78
8(54)	32.2	4	47.8	5	42.7	9.48	773	137	6.16	.0152	16.36	215	10.93	50.61
9(55)	0	0	46	4	44.4	10	251	44	7	.0115	12.38	144	5.64	20.29
10(56)	46.2	8.29	43.5	10.3	34.1	10	1175	220	9.54	.0235	25.30	228	9.21	38.11
11(57)	0	0	45.8	3.82	39.3	9.64	278	50	6.73	.011	11.84	146	5.69	20.94
12(58)	0	0	41.6	3	44.9	9.55	332	59	6.28	.0103	11.09	146	5.63	20.45

V-5

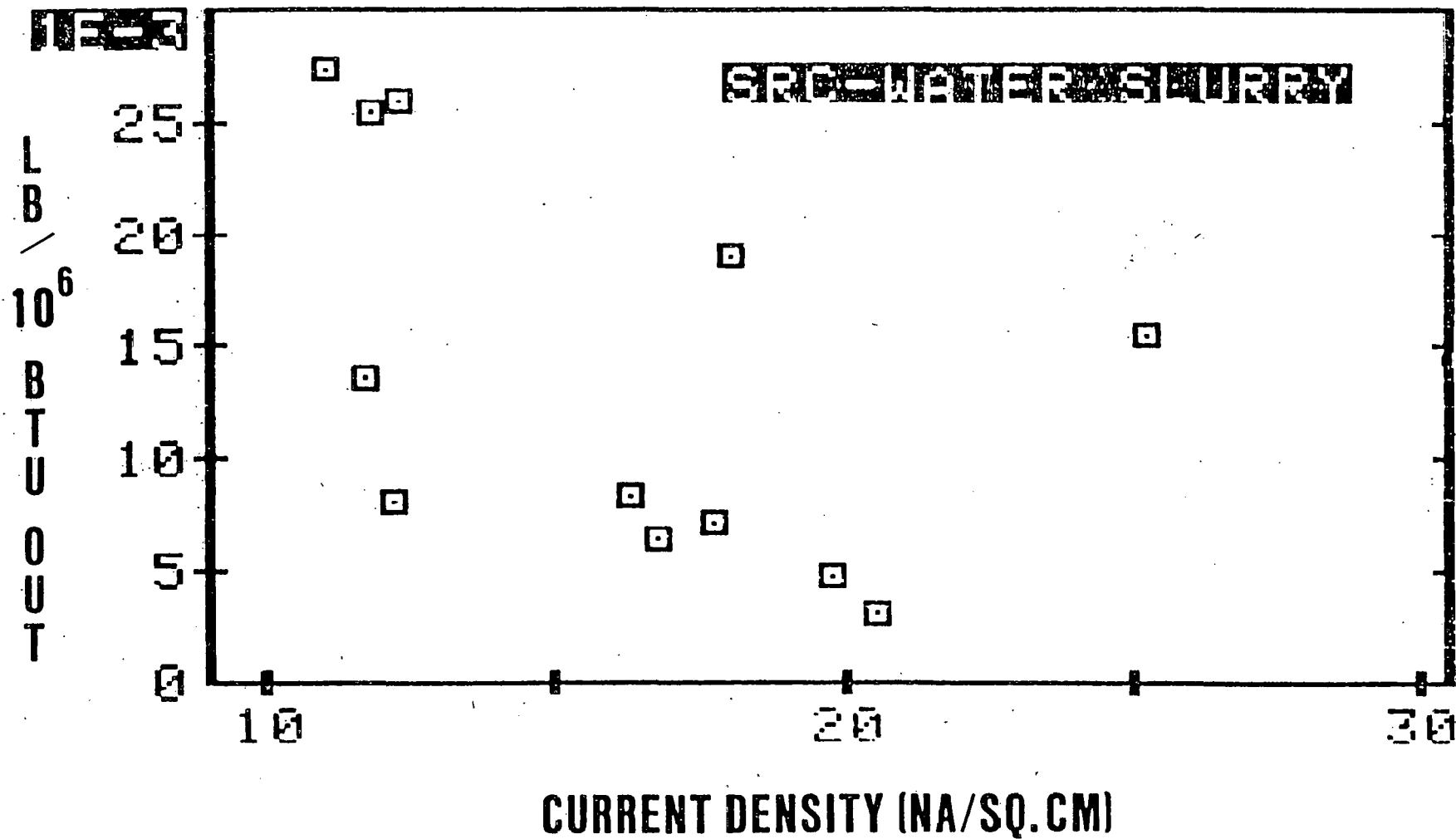
# LB/10<sup>6</sup> BTU OUT vs. ACFM IN



# LB/10<sup>6</sup> BTU OUT vs. SCA

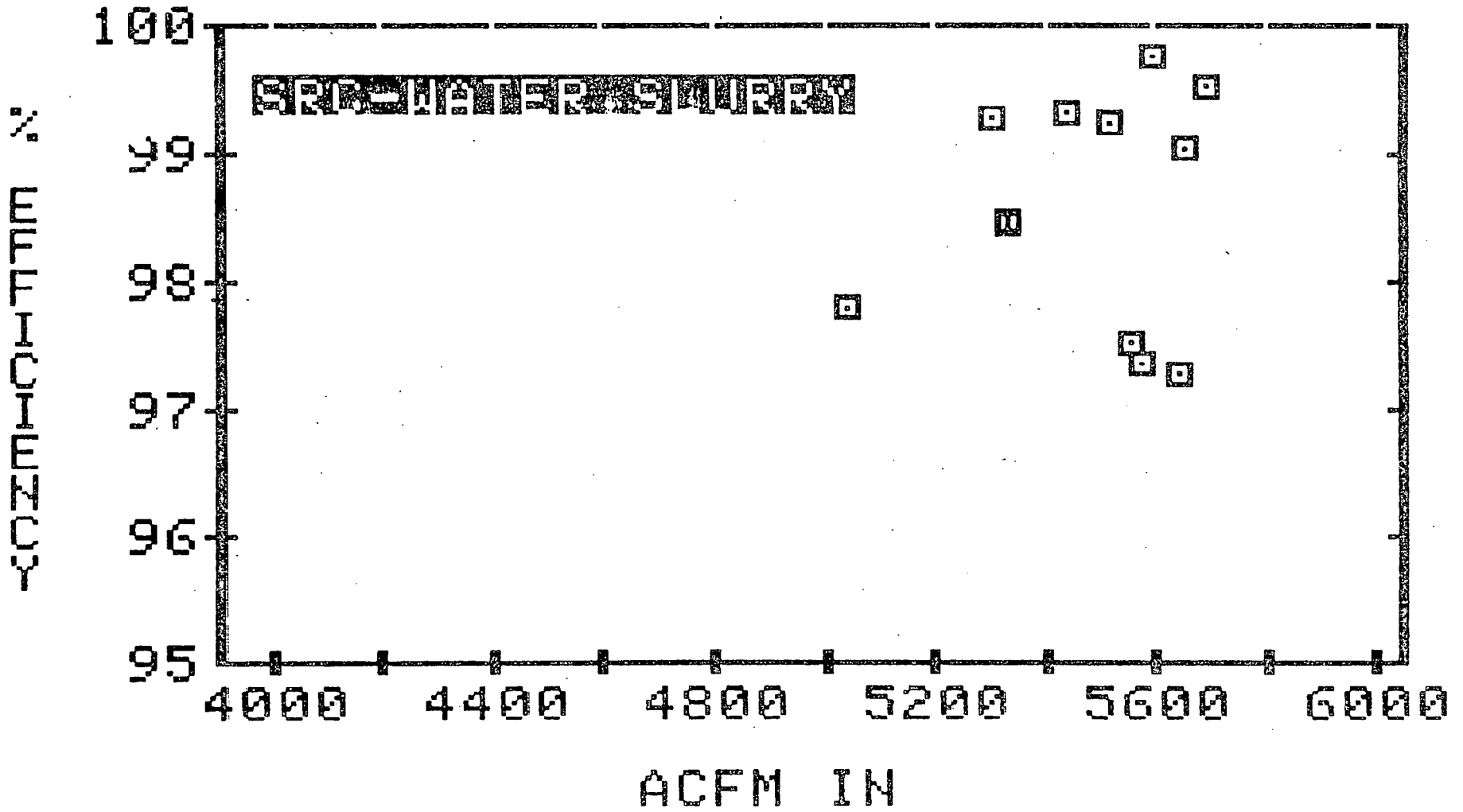


# LB/10<sup>6</sup> BTU OUT vs. CURRENT DENSITY

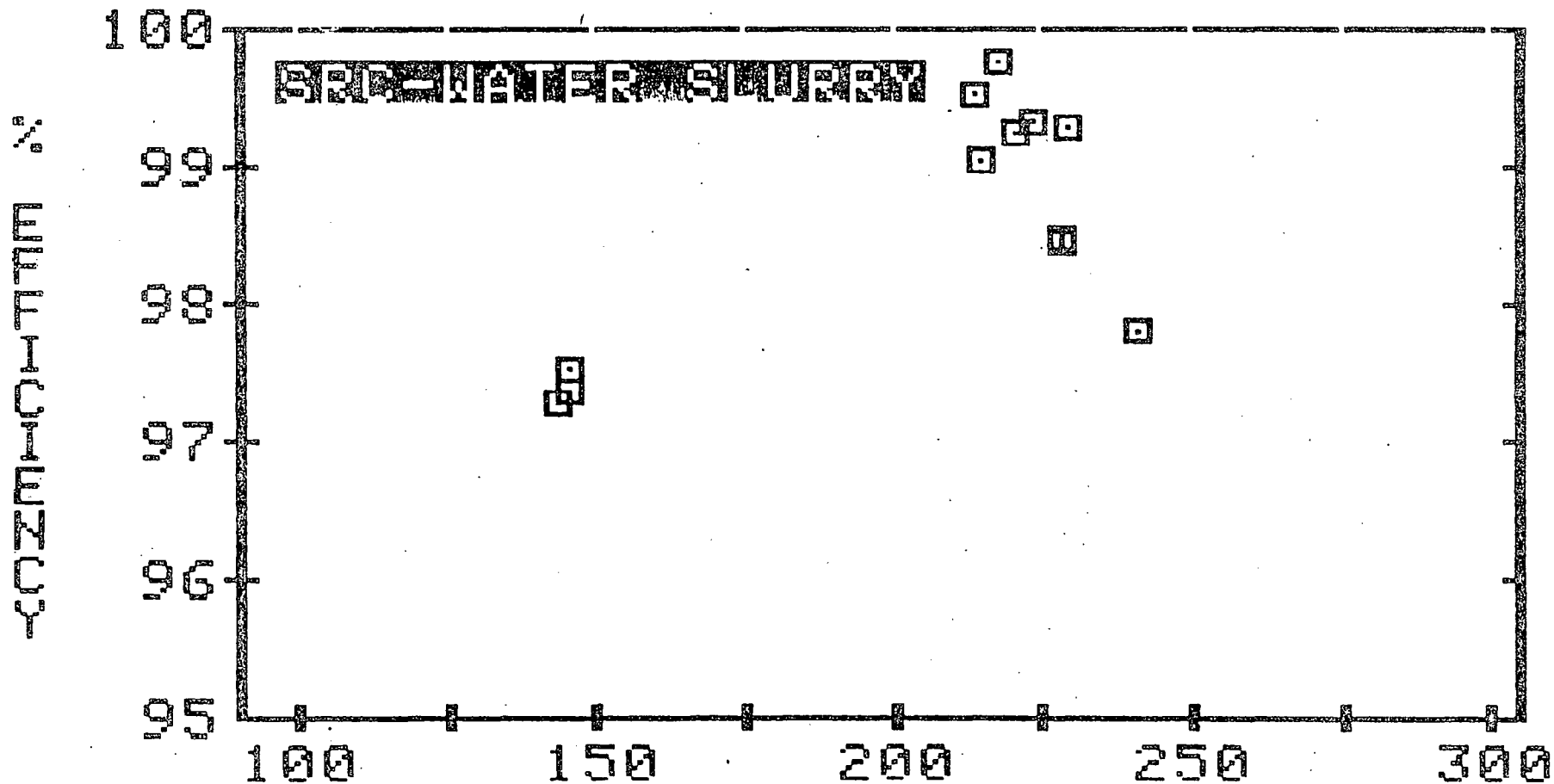




# % EFFICIENCY VS ACFM IN

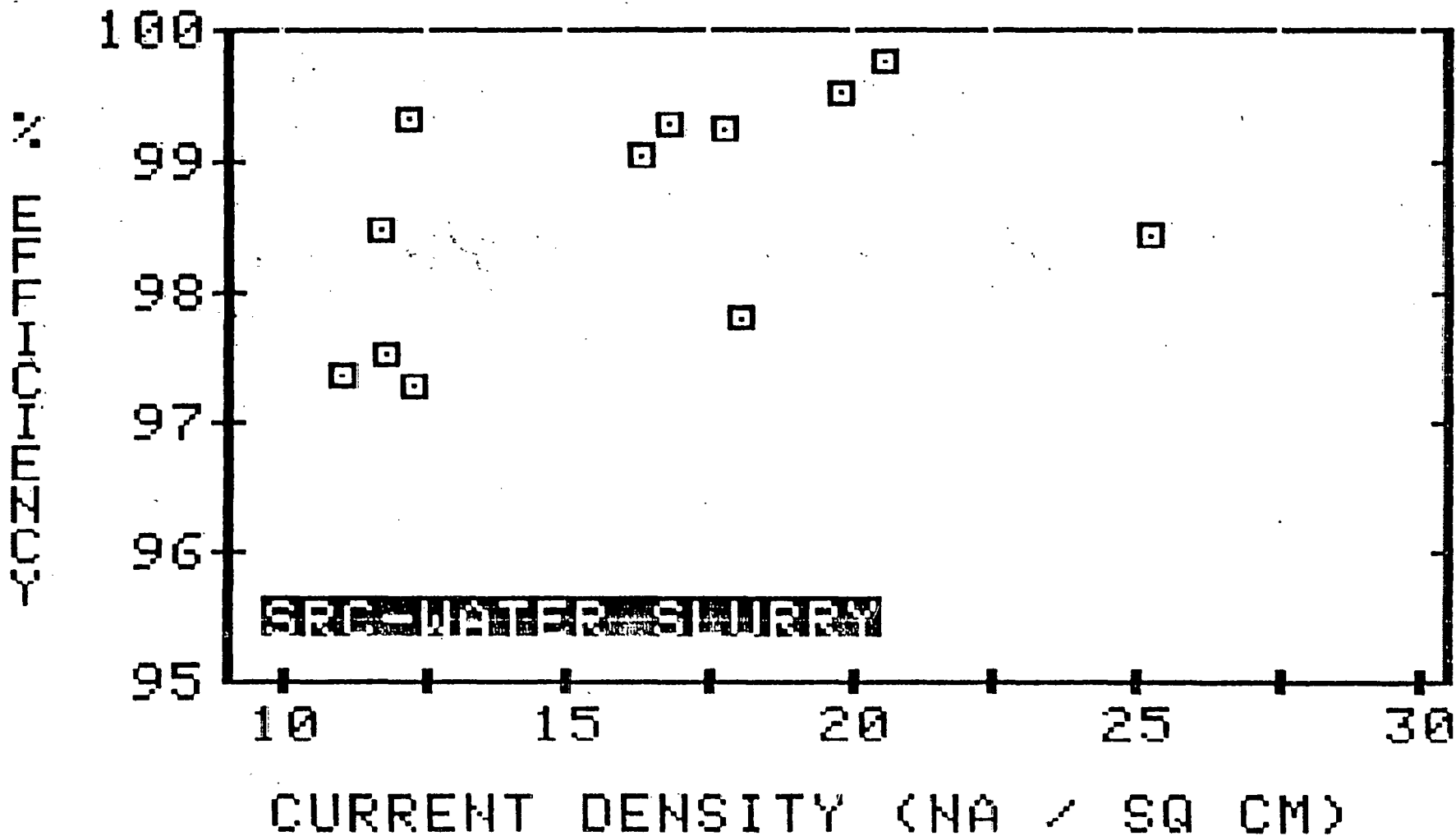


# % EFFICIENCY VS SCA

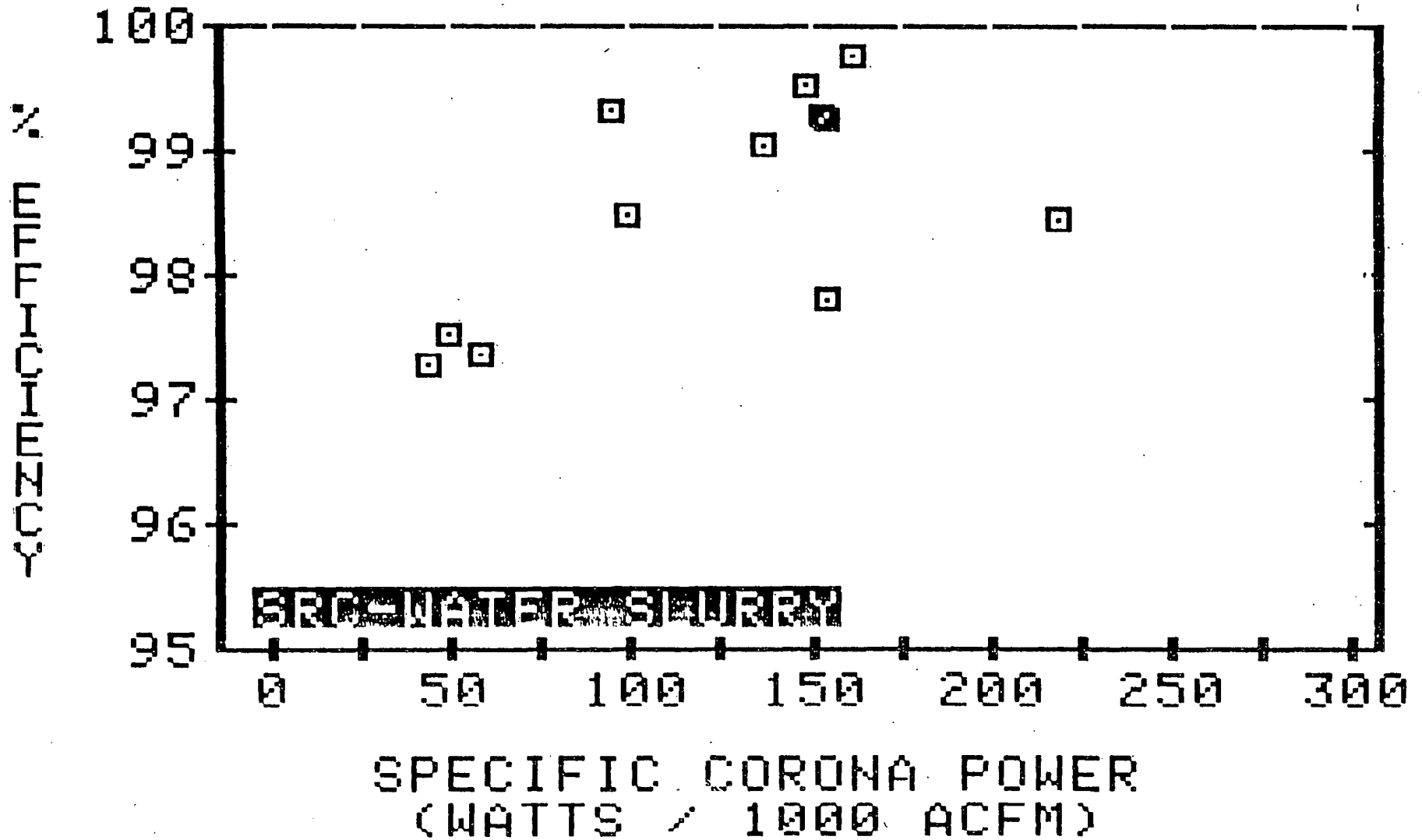


SCA - SPECIFIC COLLECTING AREA  
(SQ FT / 1000 ACFM)

# % EFFICIENCY VS CURRENT DENSITY

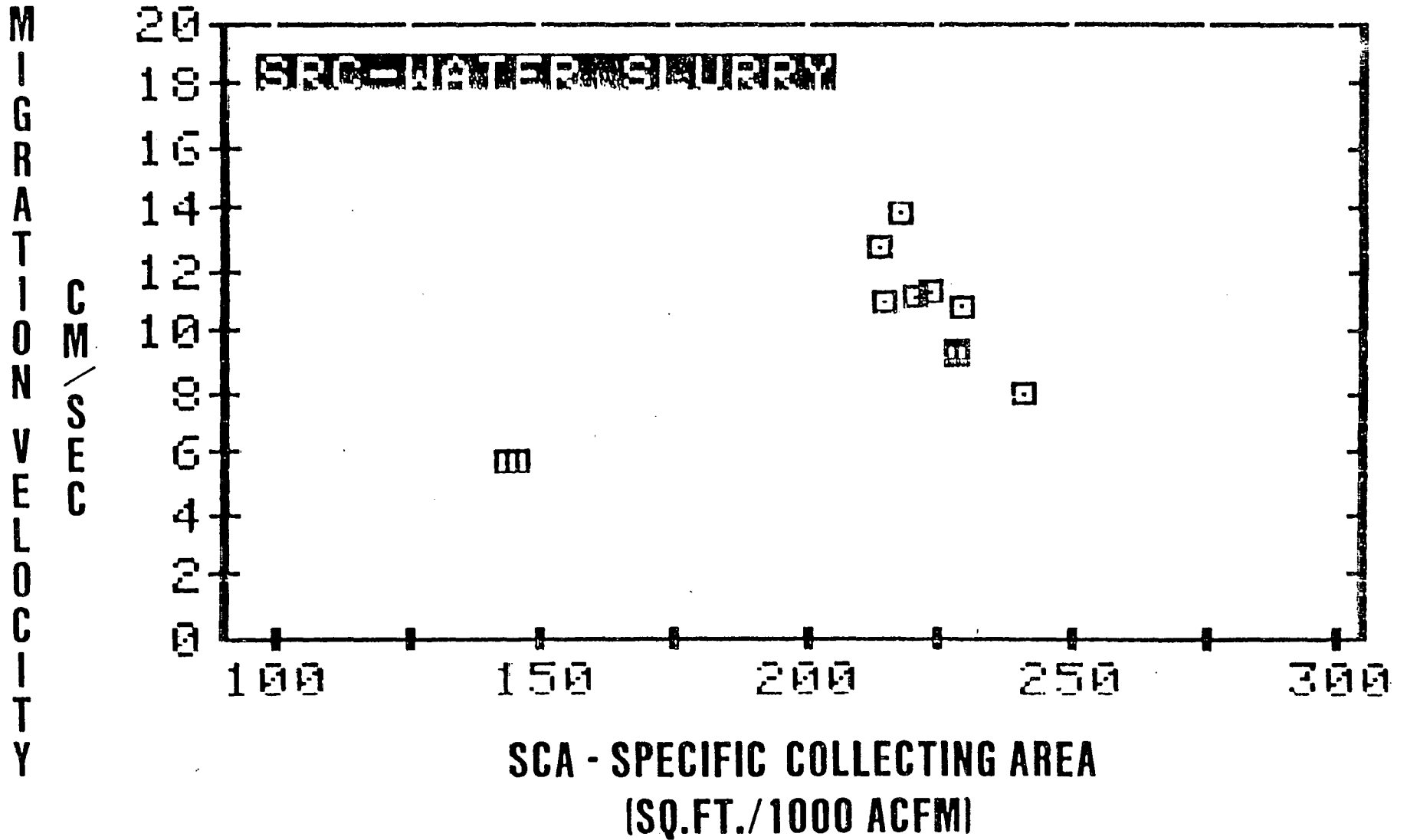


# % EFF VS SPECIFIC CORONA POWER



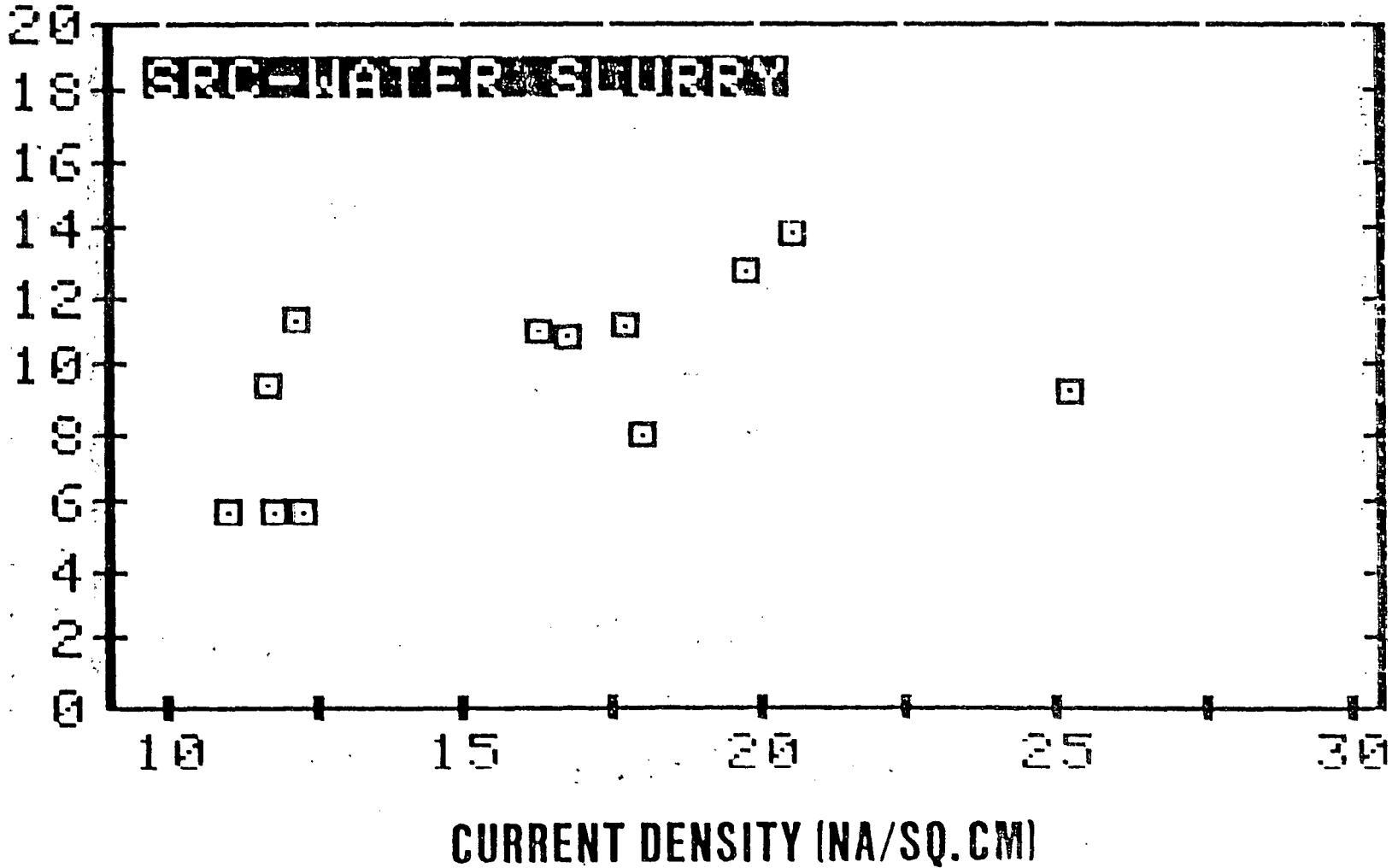
# MIGRATION VELOCITY vs. SCA

v-14-A



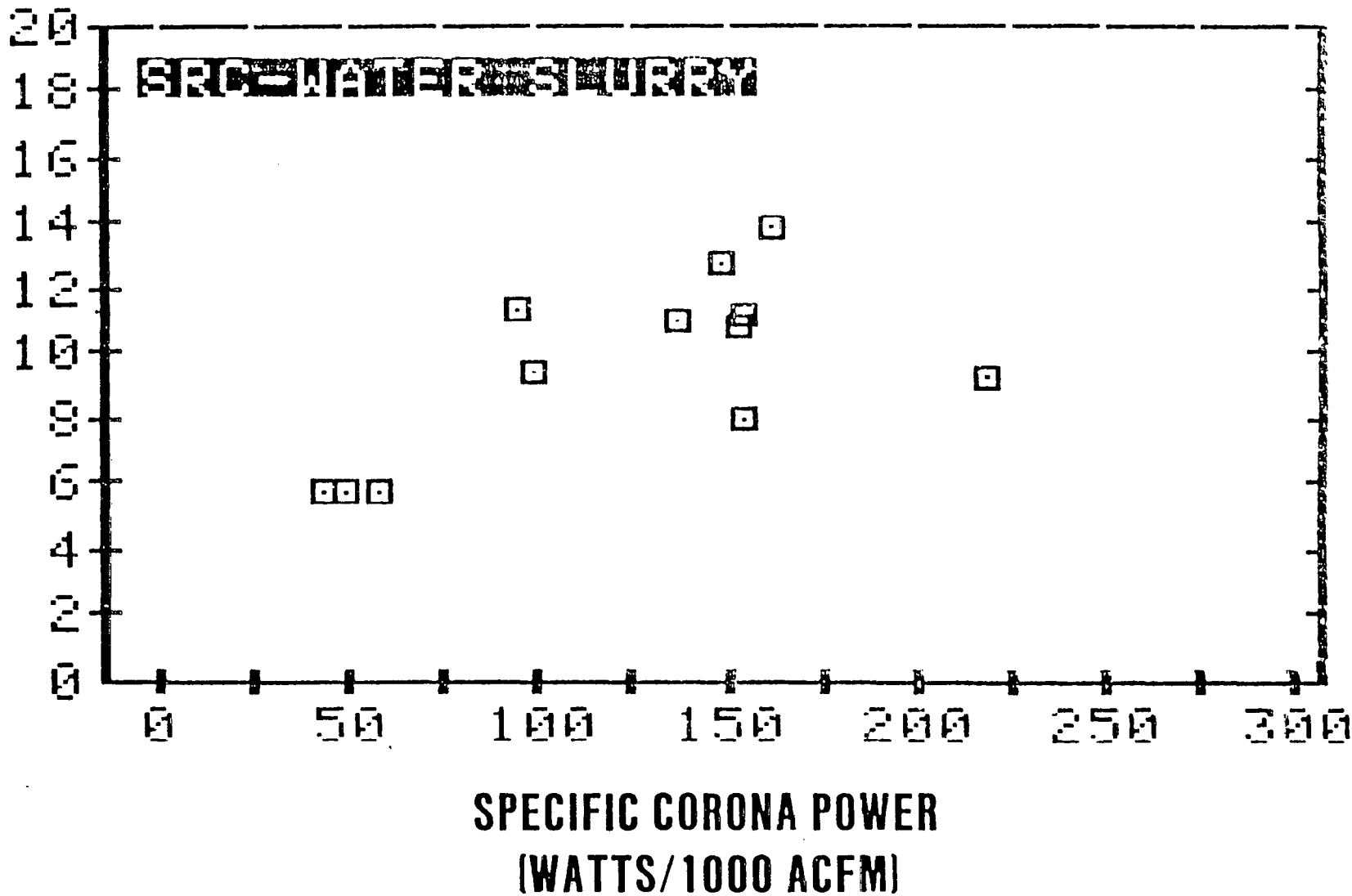
# MIGRATION VELOCITY vs. CURRENT DENSITY

MIGRATION VELOCITY  
CM/SEC



MIGRATION VELOCITY  
M/SEC

### MIGRATION VELOCITY vs. SPECIFIC CORONA POWER



APPENDIX VI

V-I DATA AND CURVES  
GAS DISTRIBUTION DATA

P E T C - S R C 1

V - I D A T A

( G A S L O A D )

	FIELD #1			FIELD #2			FIELD #3		
DATE: 8/20/82	KVM1	KVA1	MA1	KVM2	KVA2	MA2	KVM3	KVA3	MA3
TIME	----	----	----	----	----	----	----	----	----
FUEL AIR		0	0		0	0		0	0
ACFM ?	30	29.7	2	28	25.8	2	24	28.3	2
SPACING- 10"	32	31.7	3	34	31.3	5	28	30.5	5
T-R	38	37.6	10	39	35.9	10	37	40.3	10
POL. NEG.	42	41.6	15	42	38.6	15	40	43.6	15
RATING-60KV	46	45.5	20	44	40.5	20	42	45.8	20
REACT. = 50%	48	47.5	25	48	44.2	25	44	48	25
	50	49.5	30	50	46	30	46	50.1	30
	52	51.5	35	52	47.8	35	48	52.3	35
	56	55.4	40	54	49.7	40	50	54.5	40
				58	53.4	45	52	56.7	45
				58	53.4	50	56	61	50

NOTES:

-----  
KVM IS METER READING

KVA IS CORRECTED VALUE

FIELD #1 = 0.99

FIELD #2 = 0.92

FIELD #3 = 1.09

I-IA

P E T C - S R C 1

V - I D A T A

( C A S L O A D )

	FIELD #1			FIELD #2			FIELD #3		
DATE..8-30-82	KVM1	KVA1	MA1	KVM2	KVA2	MA2	KVM3	KVA3	MA3
TIME..17:35	----	----	----	----	----	----	----	----	----
FUEL.. #6 OIL	22	21.8	0	22	20.2	0	22	14	0
ACFM..5290	37.5	37.1	2	29	26.7	2	25	17.3	2
TEMP..290	42.5	41.1	4	34.5	31.7	4	28	30.5	4
	45	44.6	6	37	34	6	30.5	33.2	6
SPACING= 10"	47	45.5	8	39	35.9	8	32.5	35.4	8
T-R	49	49.5	10	40	36.8	10	34	37.1	10
POL..NEG.	50.5	50	15	43	39.6	15	36	39.2	15
RATING=60KV				44.5	40.9	20	38.5	41	20
REACT. = 50%				46.5	42.8	25	40.5	44.1	25
				47.5	43.7	30	42	45.8	30
				49	45.1	35	44.5	48.5	35
				50	46	40	46	50.1	40
				52	47.8	45			
				52.5	48.3	50			

NOTES:

-----  
KVM IS METER READING

KVA IS CORRECTED VALUE

CORRECTION FACTORS:

FIELD #1 = 0.99

FIELD #2 = 0.92

FIELD #3 = 1.09

OTHER FIELDS WERE SET AT 10 MA.

VI-2

P E T C - S R C 1      V - I   D A T A      ( G A S L O A D )

	FIELD #1			FIELD #2			FIELD #3		
	KVM1	KVA1	MA1	KVM2	KVA2	MA2	KVM3	KVA3	MA3
DATE . 11-19-82									
TIME . 0830	---	---	---	---	---	---	---	---	---
FUEL . PULV SRC		0	0		0	0		0	0
ACFM . 5450	32.5	32.2	2	34	31.3	2	26.5	28.9	2
TEMP . 299	38	37.6	4	39	35.9	4	32	34.9	4
	40	39.6	6	41.5	38.2	6	35.5	38.7	6
SPACING- 10"	41	40.6	8	43	39.6	8	37	40.3	8
T-R				44.5	40.9	10	38.5	42	10
POL . NEG				46	42.3	15	40.5	44.1	15
RATING-60KV				48	44.2	20	42	45.8	20
REACT . = 50%							44	48	25
							45.5	49.6	30

NOTES:

KVM IS METER READING

KVA IS CORRECTED VALUE

CORRECTION FACTORS:

FIELD #1 = 0.99

FIELD #2 = 0.92

FIELD #3 = 1.09

P E T C - S R C 1

V - I D A T A

(G A S L O A D)

	FIELD #1			FIELD #2			FIELD #3		
DATE ..12-10-82	KVM1	KVA1	MA1	KVM2	KVA2	MA2	KVM3	KVA3	MA3
TIME .....	-----	-----	-----	-----	-----	-----	-----	-----	-----
FUEL RESID OIL		0	0		0	0		0	0
ACFM ..5000	31	30.7	2	31.5	29	2	23	25.1	2
TEMP ..295	34.5	34.2	4	36	33.1	4	27	29.4	4
	37	36.6	6	37.5	34.5	6	29.5	32.2	6
SPACING- 10"	39	38.6	8	39.5	36.3	8	31	33.8	8
T-R	40	39.6	10	41	37.7	10	32.5	35.4	10
POL ..NEC.	43.5	43.1	15	44	40.5	15	35.5	38.7	15
RATING-60KV				45	41.4	20	37.5	40.9	20
REACT. = 50%				47.5	43.7	25	40	43.6	25
							41.5	45.2	30
							43.5	47.4	35
							44	48	40
							45.5	49.6	45

NOTES:

KVM IS METER READING

KVA IS CORRECTED VALUE

CORRECTION FACTORS:

FIELD #1 = 0.99

FIELD #2 = 0.92

FIELD #3 = 1.09

VI-4

P E T C - S R C I      V - I   D A T A      ( G A S L O A D )

	FIELD #1			FIELD #2			FIELD #3		
DATE . . . 1-11-83	KVM1	KVA1	MA1	KVM2	KVA2	MA2	KVM3	KVA3	MA3
TIME . . . 10:55	-----	-----	-----	-----	-----	-----	-----	-----	-----
FUEL . . . SRC-WATER		0	0		0	0		0	0
ACFM . . . 5700	38	37.6	2	35	32.2	2	23.5	25.6	2
TEMP . . . 300	43.5	45	4	39	35.9	4	26	28.3	4
	48	47.5	6	42	38.6	6	28	30.5	6
SPACING = 10"				44	40.5	8	30	32.7	8
T-R				47	43.2	10	30.5	33.2	10
POL . . . NEG.				49	45.1	15	34	37.1	15
RATING = 60KV				50.5	46.5	20	36	39.2	20
REACT . . . 50%							38	41.4	25
							40	43.6	30
							42	45.8	35

NOTES:

-----  
 KVM IS METER READING  
 KVA IS CORRECTED VALUE

CORRECTION FACTORS:

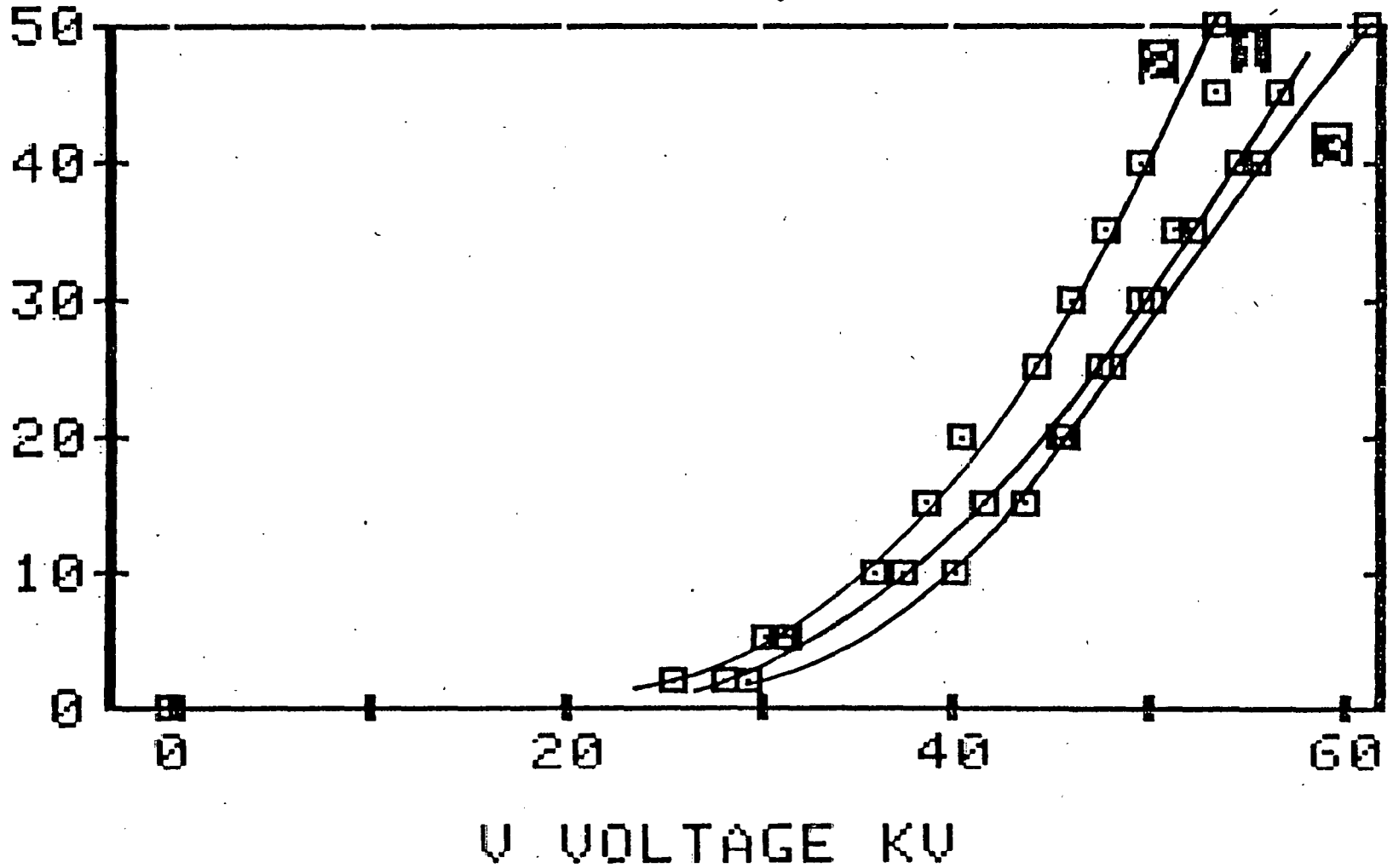
FIELD #1 = 0.99  
 FIELD #2 = 0.92  
 FIELD #3 = 1.09

VI-5

# V-I AIRLOAD

9-1A

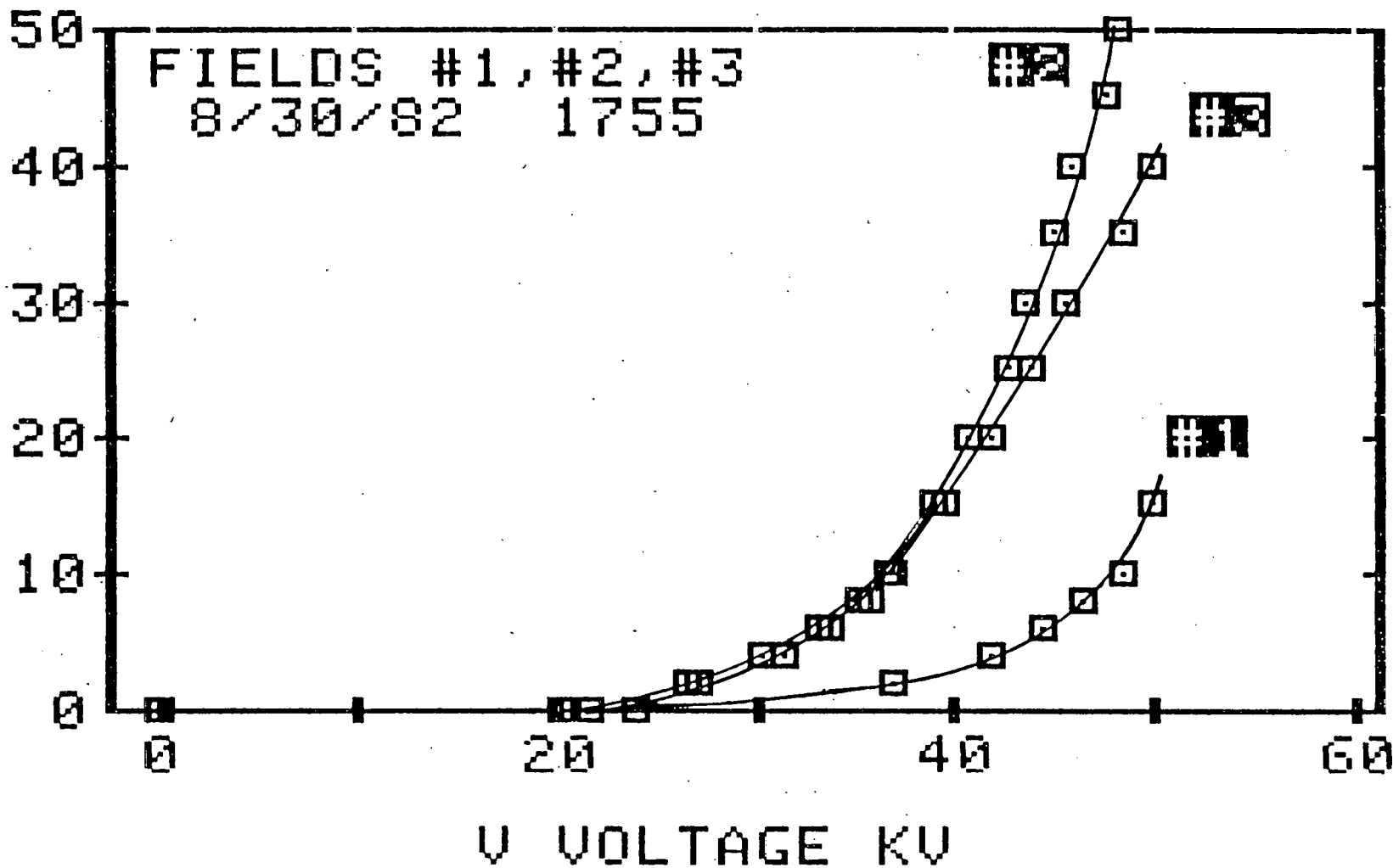
DE - 12M703C0 I



# V-I GASLOAD #6 OIL

DE - IZMROCO I

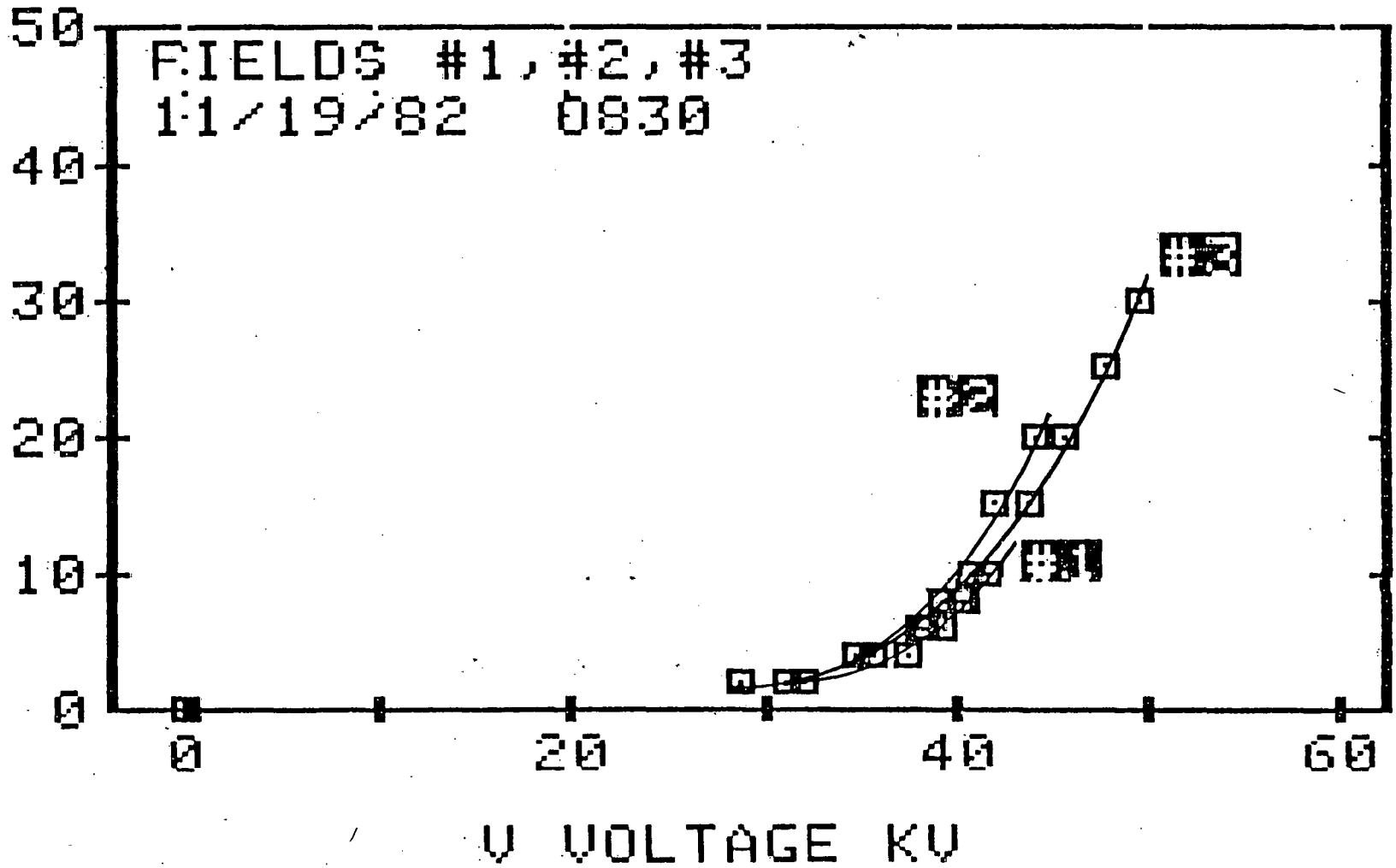
L-7



# V-I GASLOAD PULV SRC

8-1A

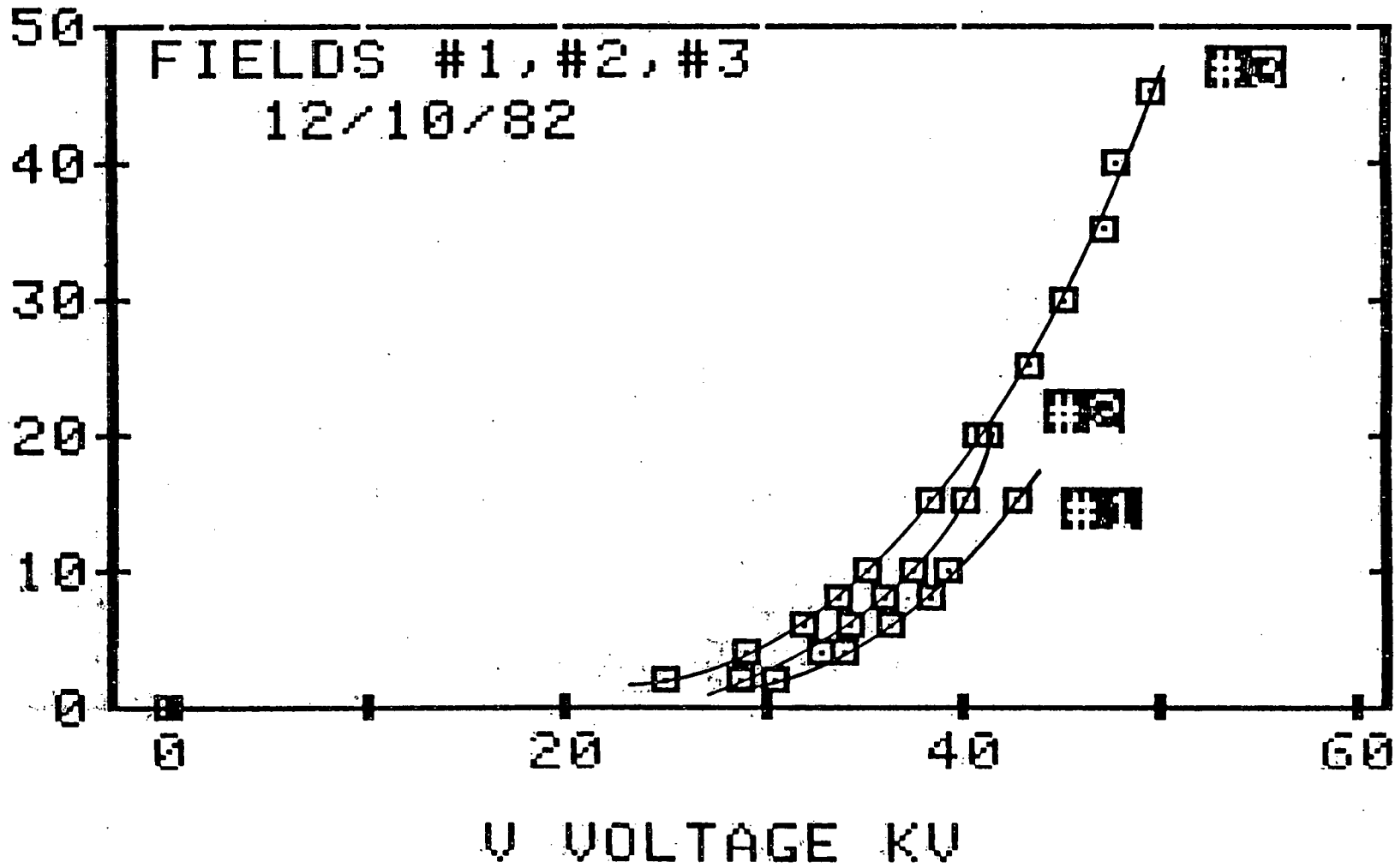
DE - 12M7000 I



# V-I GASLOAD SRC RESID OIL

6-1A

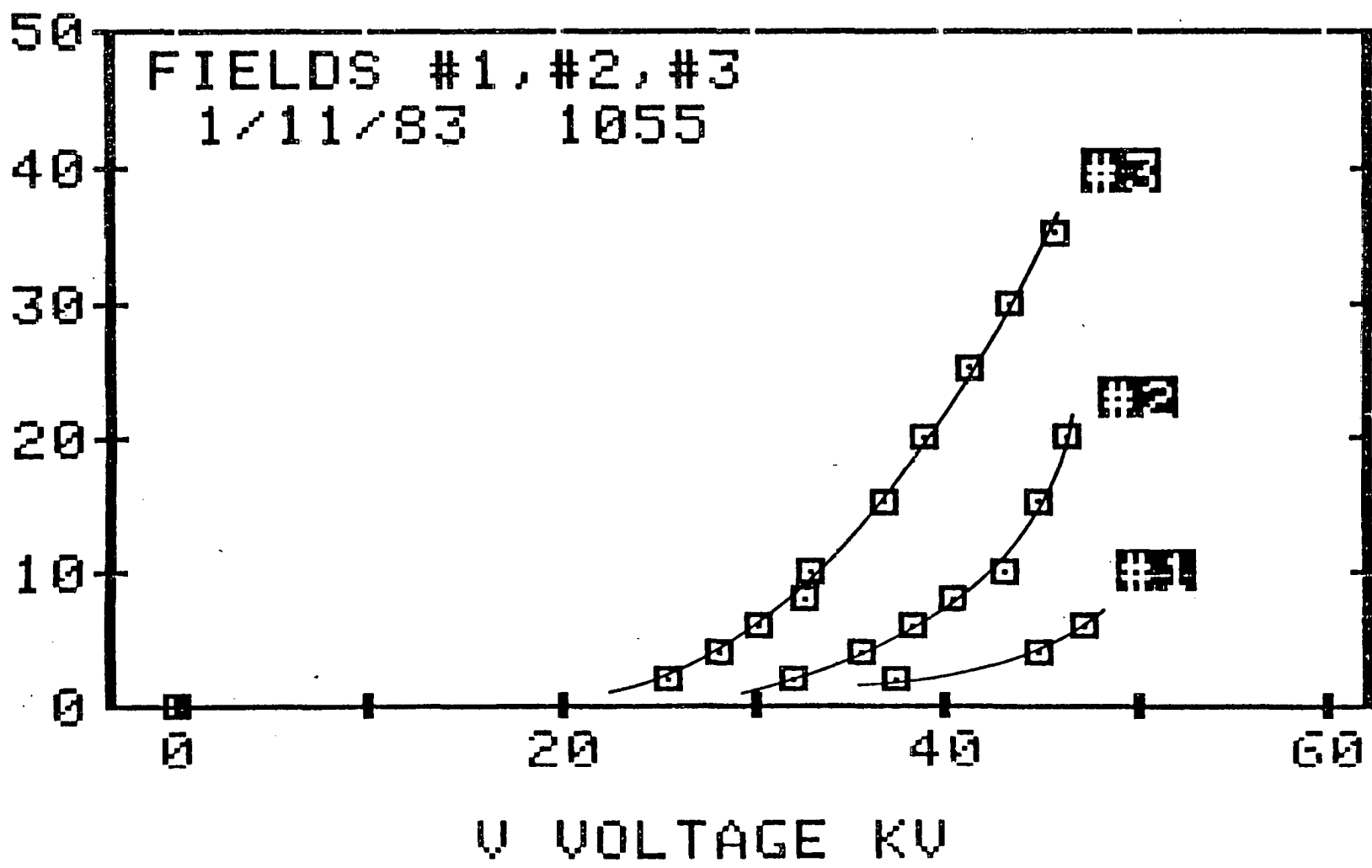
DE - TEMPERATURE



# V-I GASLOAD SRC-WATER

VI-1A

DE - IZM77C0 I



ESP GAS DISTRIBUTION 10" SPACING

DATE 2/4/83 RUN # AVE FLOW. ? ACFM. TEMP. 25 F

----- E S P I N L E T -----

TEST	(DOOR)*****D A T A P O I N T ***** (WALL)										ORIGIN
PORT	1	2	3	4	5	6	7	8	9	10	WAVED
F(TOP)	307	323	370	290	230	227	283	373	320	303	303
E	323	407	450	480	473	403	373	413	453	563	434
D	243	367	400	440	480	437	400	387	413	490	408
C	303	283	117	127	120	113	127	173	183	147	169
B	180	76.7	76.7	103	110	76.7	73.3	76.7	80	110	96.3
A(BOTTOM)	46.7	60	123	143	187	150	86.7	157	110	107	117
COLUMN AVE	237	253	256	264	267	234	224	263	260	287	254. TOTAL AVE

57.0 % RMS

----- E S P O U T L E T -----

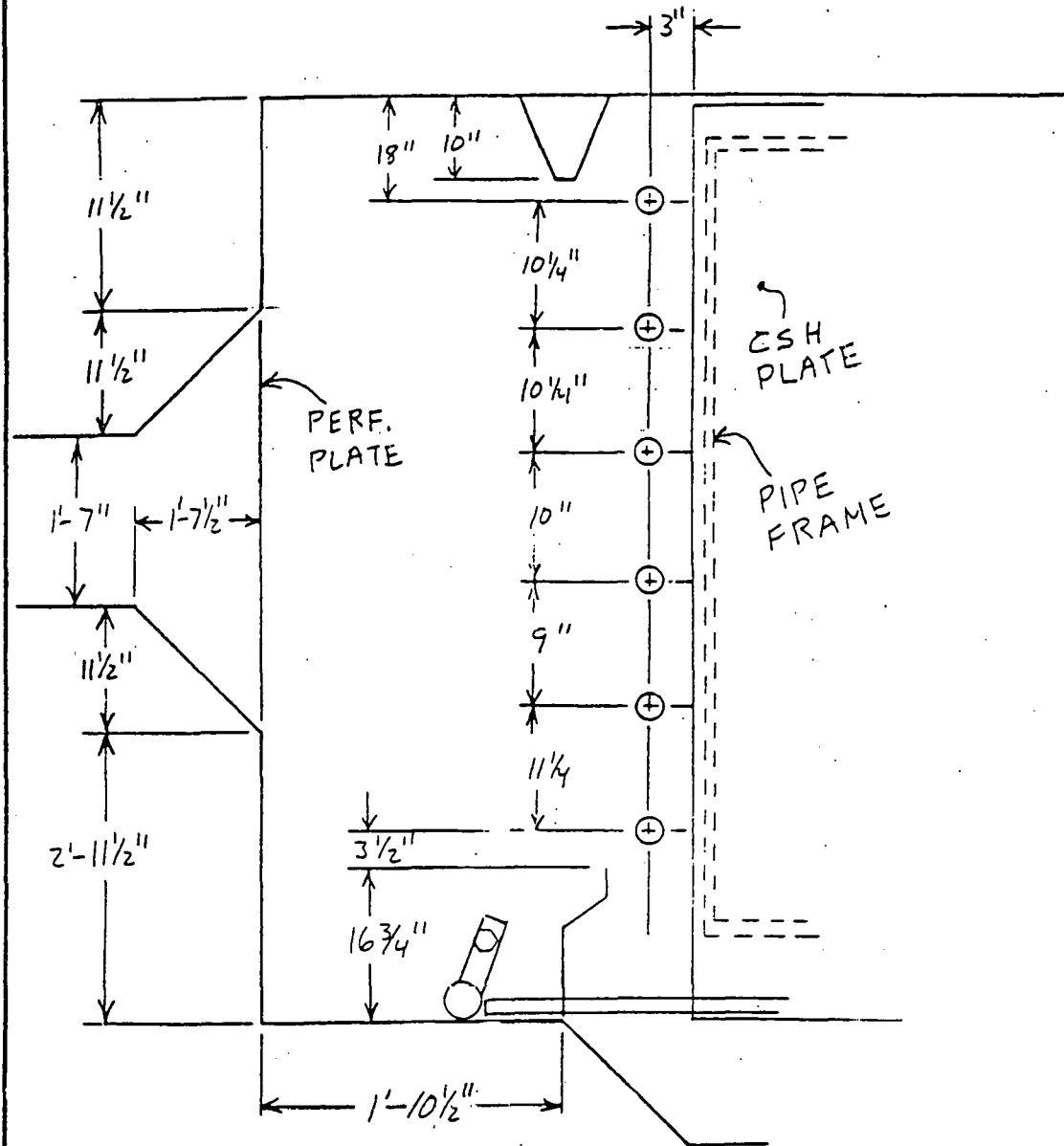
TEST	(DOOR)*****D A T A P O I N T ***** (WALL)										
PORT	1	2	3	4	5	6	7	8	9	10	
F(TOP)	170	270	297	287	280	280	287	270	237	193	267
E	277	260	317	297	313	300	307	280	233	200	278
D	180	290	330	307	323	297	303	283	213	197	282
C	253	290	303	297	277	293	300	283	243	193	273
B	233	230	267	267	277	260	273	250	237	210	249
A(BOTTOM)	177	180	193	173	187	173	177	173	193	197	182
COLUMN AVE	247	253	284	271	276	267	274	257	226	198	255. TOTAL AVE

17.9 % RMS

VI-11



# ESP OUTLET NOZZLE



CUSTOMER ESP Gas Distribution PROJECT NO. \_\_\_\_\_

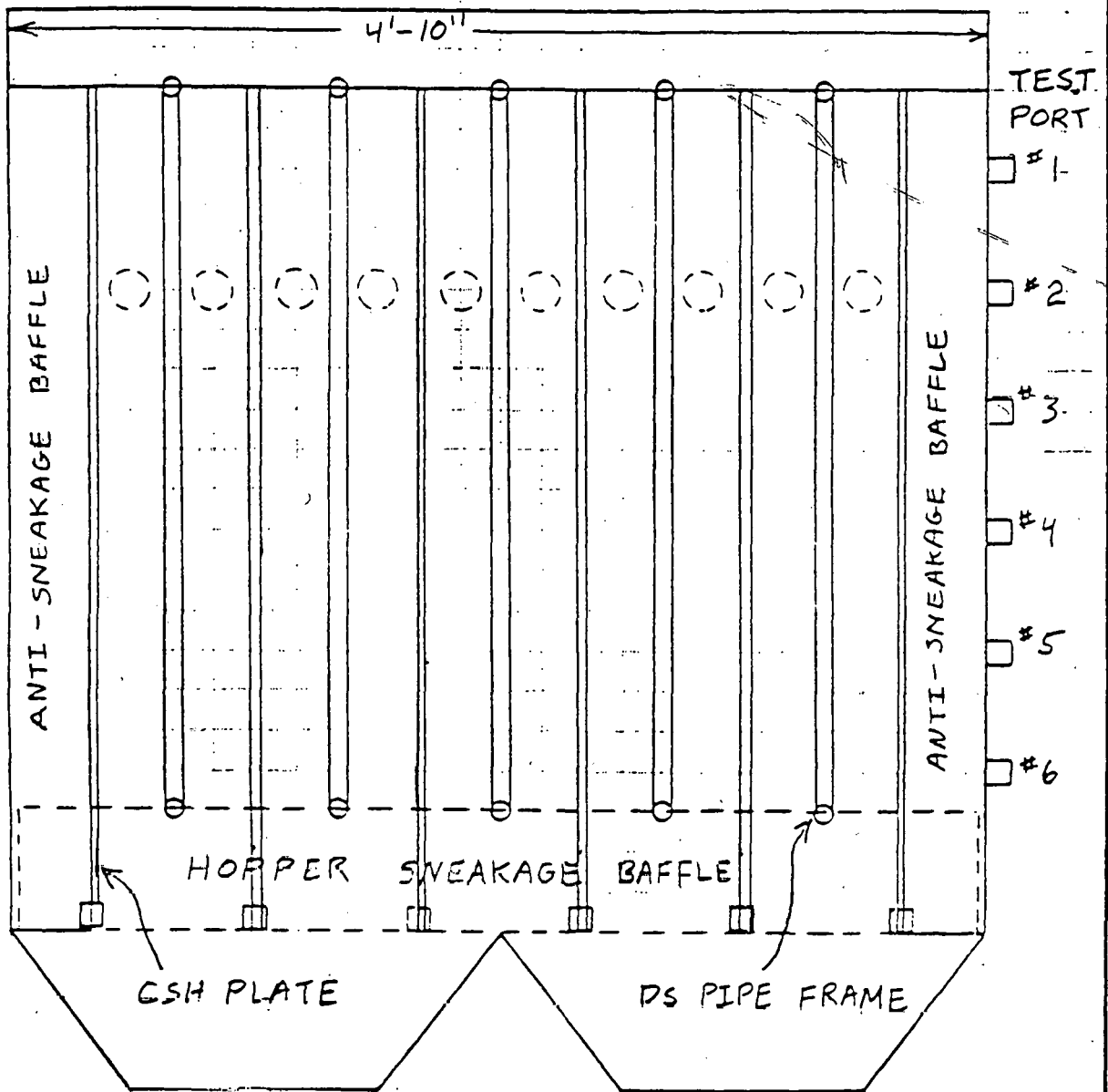
APPLICATION Outlet Nozzle SHEET \_\_\_\_\_ OF \_\_\_\_\_

PREPARED BY J. Shover DATE 10/14/82

CHECKED BY \_\_\_\_\_ DATE \_\_\_\_\_



# ESP PLATE-WIRE SPACING



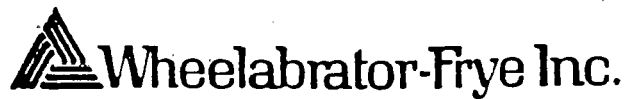
FIVE 10" GAS PASSAGES

CUSTOMER ESP - Gas Distribution PROJECT NO. \_\_\_\_\_

APPLICATION 10" Gas Passages SHEET \_\_\_\_\_ OF \_\_\_\_\_

PREPARED BY J. Shaw DATE 10/14/82

CHECKED BY \_\_\_\_\_ DATE \_\_\_\_\_



VI-14

U. S. GOVERNMENT PRINTING OFFICE: 1984-746-081/10161

W-2776