MARK III CONTAINMENT
HYDROGEN CONTROL OWNERS GROUP
Sam H. Hobbs, Chairman
c/o Mississippi Power and Light • P.O. Box 1640 • Jackson, Mississippi 39205
601-969-2458

October 31, 1985
HGN-058

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

Attention: Mr. Robert Bernero

Dear Mr. Bernero:

SUBJECT: Closure of Subtask 6.26 "Evaluate TVA Igniter Spray Tests"

In a February 12, 1985 meeting, the Nuclear Regulatory Commission (NRC) suggested that the Hydrogen Control Owners Group (HCOG) evaluate results of tests which indicate that igniter surface temperature may decrease in a spray environment. The NRC indicated that the Tennessee Valley Authority (TVA) had completed some tests using the Tayco igniters. These tests showed that when large amounts of water impinged on the igniter surface the igniter could no longer maintain high temperatures. This resulted in staff concerns about possible cooling of glow plug igniters. To address these concerns, HCOG developed Subtask 6.26 in Revision 2 of the Hydrogen Control Program Plan. The original intent was to investigate the results of the tests performed by TVA. However, the NRC also sponsored the Hydrogen Mitigative and Preventive Schemes Program at Sandia National Laboratories. This program involved both the GMAC model 7G glow plug igniter, used in the Mark III containment, and the Tayco helical coil igniter, used in the containment of the Sequoyah Nuclear Plant. HCOG subsequently decided that the tests performed by Sandia were more applicable to the Mark III containments and that those results should also be investigated. Subtask 6.26 was consequently expanded in Revision 3 of the Hydrogen Control Program Plan to address the evaluation of the tests performed by Sandia.

Several documents related to the TVA hydrogen ignition system were reviewed. These documents are listed in Attachment 1. The TVA tests were performed by Factory Mutual Research Corporation (FMRC) and the final report on these tests was issued in August, 1984. These tests were performed with Tayco glow coil igniters. These igniters are helical coils operating at either 120V ac or 130V ac. The Tayco igniter assembly is shown in Figure 1. The Mark III containments utilize the GMAC model 7G glow plug igniter which operates at approximately 12V ac. The glow plug igniter assembly is shown in Figure 2.

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The TVA tests were conducted in a steel-framed Lexon enclosure with a 3 ft x 3 ft cross section and a height of 5 ft. Various spray nozzles were installed at the top of the enclosure. The igniters were situated approximately 24 inches below the nozzle. Four 3/8 inch diameter inlets were installed to allow entrance of hydrogen-air mixtures. A heated water supply was provided for the spray nozzles. The water temperature of the sprays ranged from 61°F to 130°F. This arrangement is shown in Figure 3.

The TVA/FMRC test program consisted of a two phase approach. In the first phase the igniter was directly exposed to various spray fluxes to determine the critical impinging spray flux at which the coil became too cool to ignite. It was found that the maximum flux for which ignition could be achieved for the Tayco igniter operating at 130V is 0.39 gal/ft^2-min while for 120V operation it is 0.36 gal/ft^2-min.

The second phase of the program consisted of testing shielded igniters. As there had been speculation about spray diversion around the flat plate shields because of local horizontal air velocities and turbulence, these tests were conducted using a perforated cylindrical spray shield. The perforated shields used for the TVA tests had varying open areas and perforation sizes. Each shield was 3 inches in diameter and 6 inches long. Hole sizes ranged from 0.033 inches to 0.375 inches and the open areas ranged from 13% to 46% of the surface area of the shield. It was found that the shield with the least open area provided the most effective shielding from the spray up to the maximum measured spray flux of 1.8 gal/ft^2-min. Two ignition tests were conducted with a 19 x 14 5/6-inch flat plate shield. These also provided effective shielding up to the maximum measured spray flux of 1.8 gal/ft^2-min.

Sandia performed tests on both types of igniters and used solid flat plate shields above the igniters. Although Sandia has not yet published their final report discussing the results of the tests performed on both the Tayco and the GMAC model 7G igniters, several preliminary documents were provided to HCOG. These documents are listed in Attachment 2 of this letter.

Sandia had performed nine experiments to determine whether a lean (6%) hydrogen-air mixture can be ignited reliably by a cylindrical GMAC model 7G glowplug igniter in a water spray environment. These experiments were conducted in Sandia's 5m^3 variable geometry experimental system (VGES) hydrogen combustion facility.

The Spraco model 1108-1214 solid cone nozzle was used to simulate a spray flux of 38.3 l/m^2-min (0.915 gal/ft^2-min). It should be noted that this spray flux is representative of the spray in a Mark III containment with both spray trains operating. The spray was first examined in a calm indoor location to characterize the drop diameter distribution, flux, and drop velocities. A fan capable of inducing horizontal gas flows of up to 6 m/sec (20 ft/sec) was placed next to the igniter. The arrangement of the fan, nozzle, igniter, and spray shield in the VGES facility is shown in Figure 4.

These experiments were performed in four modes:

1. Spray off, spray shield off, and fan off
2. Spray on, spray shield off and fan off
3. Spray on and spray shield on, and fan off, and
4. Spray on, spray shield on, and fan on

The Spraco nozzle was mounted on the centerline of the chamber and pointed downward. The glowplug igniter was mounted directly below the nozzle. The igniter and nozzle were placed 1.22 m and 3.0 m above the bottom of the chamber, respectively. This separation was selected by measuring the water flux at various positions and interpolating the location of the igniter to provide the needed spray flux. Sandia indicated that this could result in approximately a 10% error in the determination of the spray coverage. The mounting of the spray shield and the igniter are shown schematically in Figure 5.

It should be noted that some parameters used by Sandia are not prototypical of the Mark II containments. For example, Sandia introduced hydrogen into the compartment before energizing the igniter. Another item to be noted is that in Figure 5, the igniter and spray shield mounting configuration used by Sandia is such that the spray shield is placed 8 inches above the igniter and extends 4 inches beyond the base of the igniter, thus providing more effective coverage of the area near the igniter. Another difference in parameters between Sandia and the Mark III containments concerns the drop size distribution between the two spray nozzles. The Spraco model 1108-1214 solid cone nozzle used by Sandia to simulate the required spray flux was found to have a peak drop diameter distribution approximately 90 microns larger than the Spraco model 1713 hollow cone nozzle used in the Mark III containments. However, the distributions of the two nozzles are similar. Also, in most tests Sandia operated the igniter at a voltage of 14 V ac while the Mark III containment igniters are operated at 12 V ac.

Sandia conducted tests to determine the threshold flux of both shielded and unshielded igniters. It was found that the shielded glow plug igniter in a spray flux of up to 38.3 l/m^2-min (0.915 gal/ft^2-min). The experiments to determine the threshold flux of unshielded igniters in a quiescent atmosphere were conducted with the igniters operating at 10.4, 12, and 14 V ac. It was found that the unshielded glowplug igniter, operating at 12 V ac, had a threshold flux between 25 and 29 l/m^2-min (0.6 and 0.7 gal/ft^2-min). At that flux a temperature of 1500°F, which is higher than the required ignition temperature, was maintained by the igniter.

The NRC staff had concerns about whether a flat plate shield above the igniter would allow it to operate even when exposed to a horizontal flow of gas that might drive spray droplets beneath the plate. Consequently, Sandia simulated horizontal gas flow by use of the previously mentioned fan. Initial reports indicated that shielded glowplug igniters in a spray environment would operate even with horizontal gas flow up to 5.9 m/s (19 ft/sec). A later report updated the original results and indicated that sufficient surface

temperatures for ignition were maintained in horizontal gas flows up to 10 m/s (33 ft/sec). Although HCOG has not made definitive horizontal velocity measurements in the Quarter Scale Test Facility (WSTF) preliminary estimates indicate that the horizontal component of the velocity is much smaller and thus would not have a significant effect on the operability of the igniter.

Since the tests performed by TVA did not include the GMAC model 7G glowplug, HCOG has concluded that the TVA sponsored tests are not applicable to the Mark III containments. Sandia demonstrated that the shielded glowplug igniters can operate under spray fluxes comparable to those found in a prototypical containment. Igniters in the Mark III containment are either shielded with flat plate shields or located such that direct spray impingement does not occur, thus Sandia's tests demonstrated the operability of these igniters in the Mark III containment even with containment sprays in operation.

This letter constitutes closure of Subtask 6.26, "Evaluate TVA Igniter Spray Tests" by the HCOG.

This submittal was compiled by HCOG from the best information available for submittal to the Nuclear Regulatory Commission. The submittal is believed to be complete and accurate, but it is not submitted on any specific plant docket. The information contained in this letter and its attachments should not be used for evaluation of any specific plant unless the information has been endorsed by the appropriate member utility. HCOG members may individually reference this letter in whole or in part as being applicable to their specific plants.

Very truly yours,

Sam H Hobbs

Sam H. Hobbs

SHH:bms
Attachment

cc: Mr. Carl R. Stahle (w/a)
Hydrogen Control Project Manager
U. S. Nuclear Regulatory Commission
Office of Nuclear Reactor Regulation
Washington, D. C. 20555

Mr. Charles G. Tinkler (w/a)
Containment Systems Branch
Office of Nuclear Reactor Regulation
Washington, D. C 20555

Sandia National Laboratories
Attention: John C. Cummings
Organization 1512
P. O. Box 5800
Albuquerque, New Mexico 87185

Attachment 1

TVA Documents Reviewed

(1) "Executive Summary Report on the Adequacy of the Permanent Hydrogen Mitigation System for the Sequoyah and Watts Bar Nuclear Plants" Tennessee Valley Authority, September, 1982.

(2) "Safety Evaluation Report related to the Operation of Sequoyah Nuclear Plant, Units 1 and 2, Supplement 6" U. S. Nuclear Regulatory Commission, December, 1982.

(3) "Hydrogen Combustion Initiated by a Tayco Igniter in a Spray Environment Part 1: Test Program Description", Final Report, Zalosh and Chaffee, August, 1984.

(4) "Hydrogen Combustion Initiated by a Tayco Igniter in a Spray Environment Part 2: Combustion Data", Final Report, Zalosh and Chaffee, August, 1984.

Attachment 2

Preliminary Documents Provided by
Sandia National Laboratories

(1) "Test Plan to Check Tayco Igniter Operability in a Water Spray Environment," memorandum, Nelson and Berman to Worthington, March 18, 1983.

(2) "Operability of a Tayco Igniter in a Water Spray Environment", memorandum, Nelson, Benedick and Prassinos to Worthington, January 26, 1984.

(3) "Operability of a General Motors AC 7G Glowplug Igniter in a Water Spray Environment," memorandum, Nelson, Benedick and Prassinos to Worthington, March 7, 1984.

(4) "Third Interim Report on the Operability of Hydrogen Igniters in a Water Spray Environment" memorandum, Nelson to Worthington, June 11, 1984.

(5) "Mitigation of Damaging Effects of Hydrogen Combustion in Nuclear Power Plants" by Lloyd S. Nelson and Marshall Berman, in Proceedings of the Eleventh Water Reactor Safety Research Information Meeting, National Bureau of Standards, Gaithersburg, Maryland, October 24-28, 1983, U. S. Nuclear Regulatory Commission, Washington, D. C., NUREG/CP-0048, Vol. 3, pp. 422-444.

(6) "Reduction of the Damaging Effects of Hydrogen Combustion in Nuclear Power Plants" by Lloyd S. Nelson and Marshall Berman in Designing for Hydrogen in Nuclear Power Plants, a collection of reports presented at the Joint ASME/ANS Nuclear Engineering Conference, Portland, Oregon, August 5-8, 1984, The American Society of Mechanical Engineers, New York, N. Y., pp 45-53.

(7) "Behavior of Hydrogen Igniters During Operation of Water Sprays in Containment" by Lloyd S. Nelson, in Proceedings of the Twelfth Water Reactor Safety Research Information Meeting, National Bureau of Standards, Gaithersburg, Maryland, October 22-26, 1984, NUREG/CP-0058, U. S. Nuclear Regulatory Commission, Washington, D. C., Vol. 3, pp. 371-387.

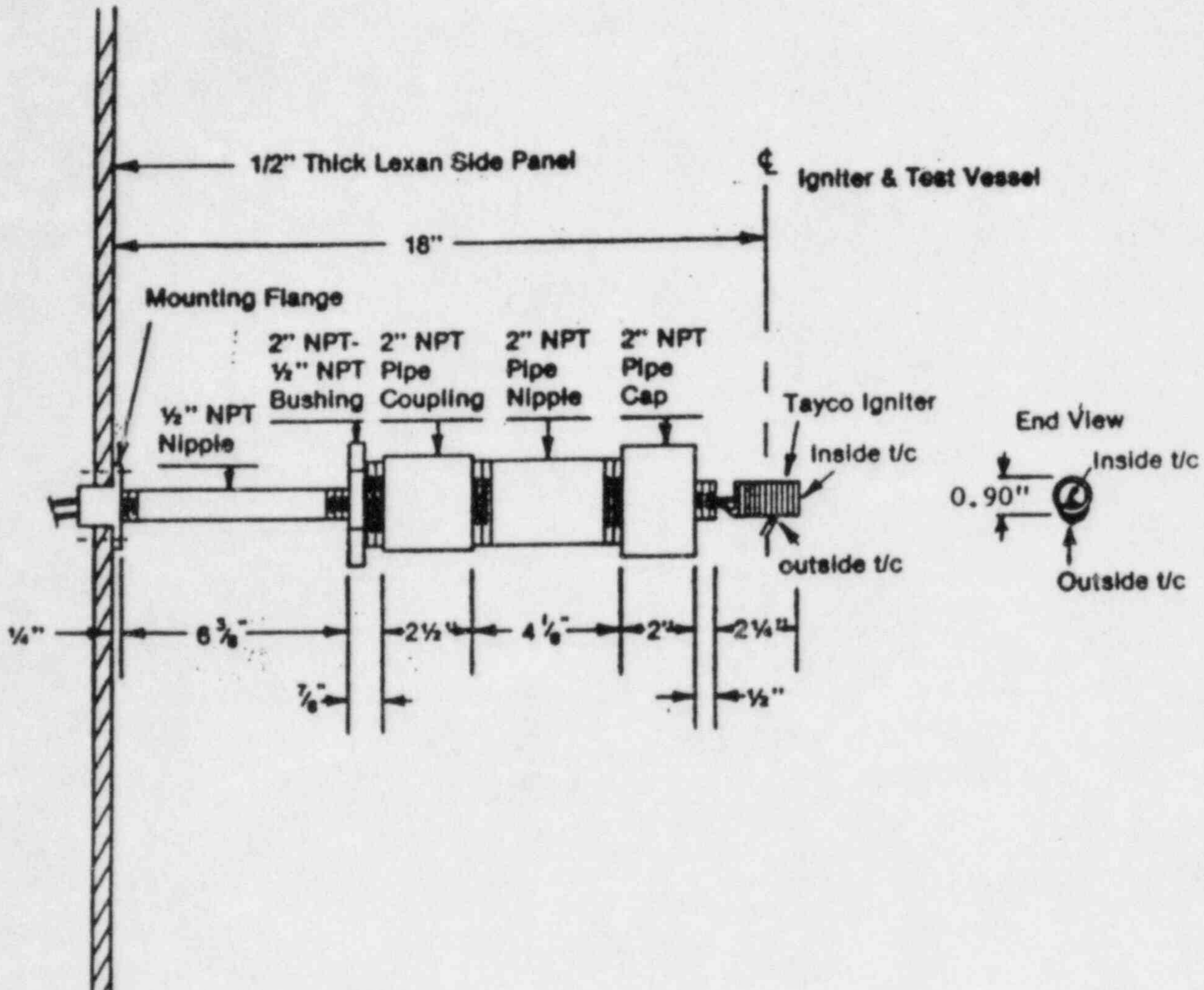


FIGURE 1

TAYCO IGNITER MOUNTING FOR TVA TESTS

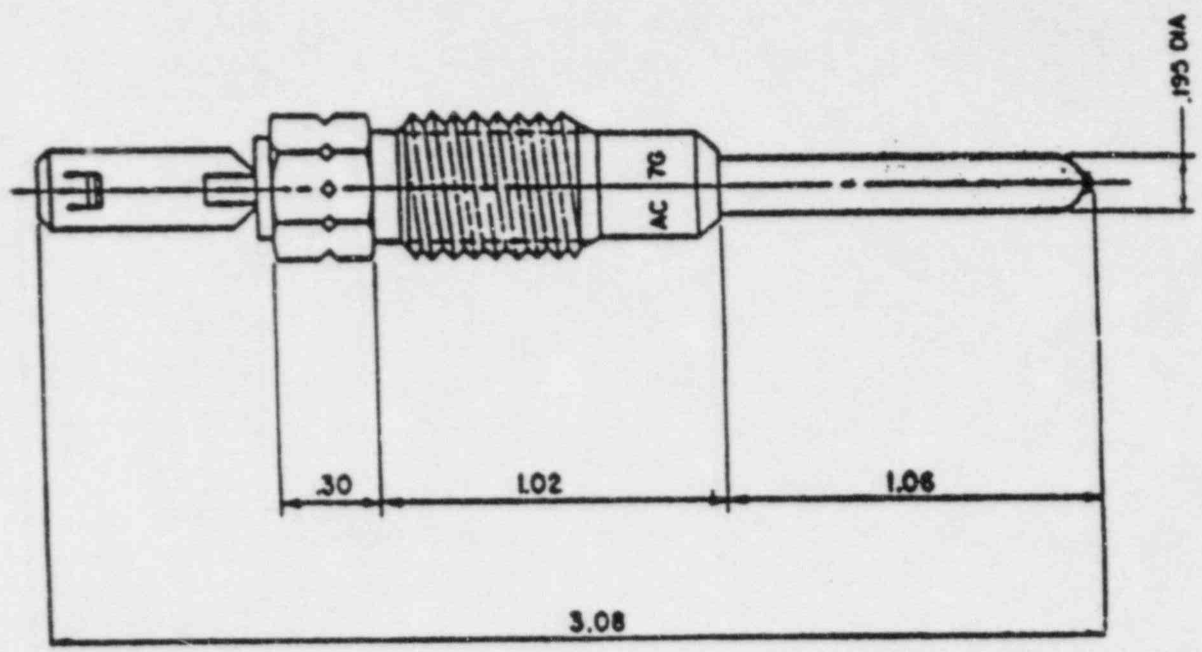


FIGURE 2

CONSTRUCTION OF THE GENERAL MOTORS AC 7G GLOW PLUG.
DIMENSIONS ARE IN INCHES.

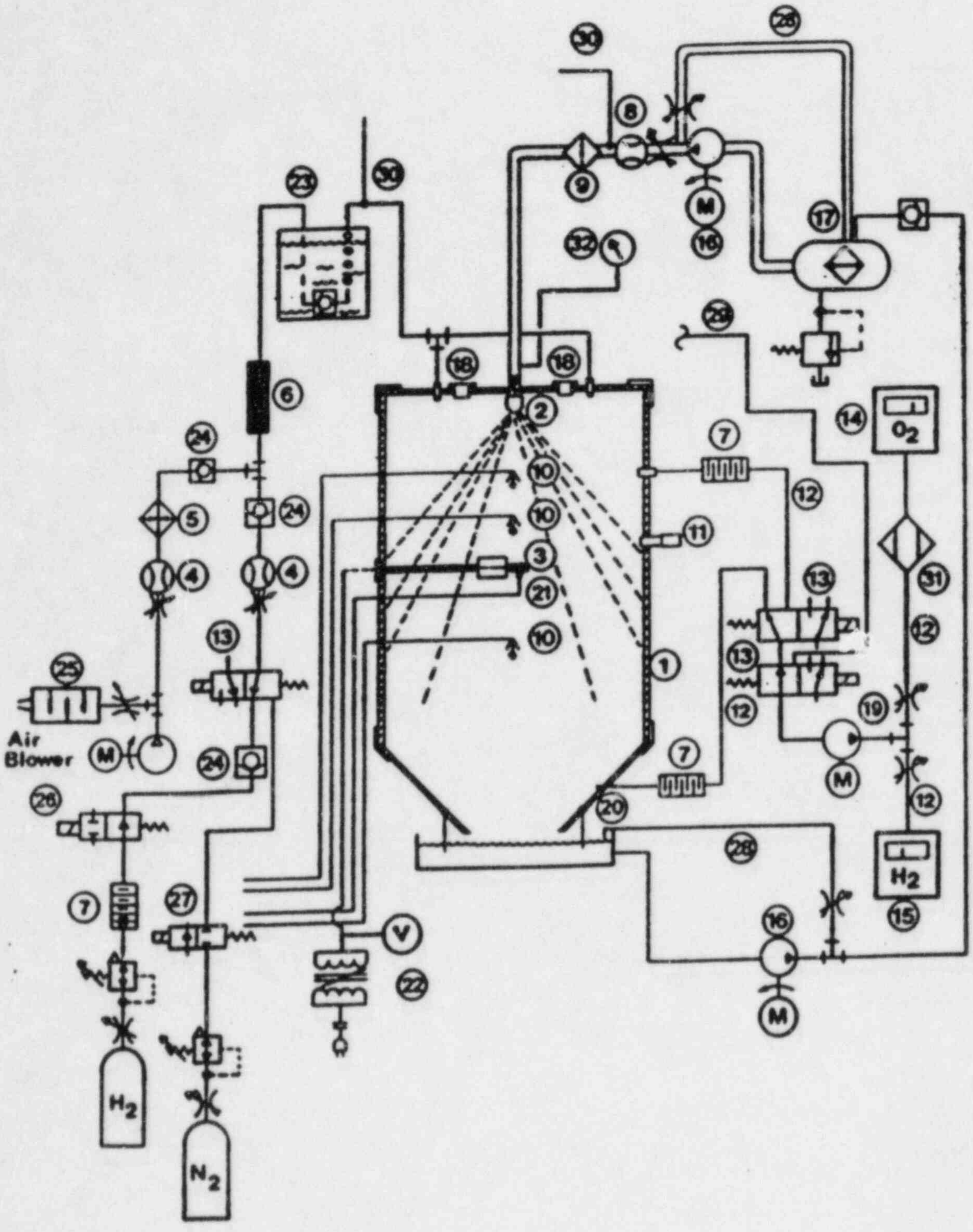


FIGURE 3

HYDROGEN IGNITER TEST SCHEMATIC

FIGURE 3 (LIST OF COMPONENTS)

Item No.	Description
1	3'x3'x5' Lexan Test Enclosure
2	Spray Nozzles: SPRACO 11-260, Spraying Systems 3/8HH15, 3/8HH24W, 1/2HH35W
3	Tayco Igniter (120-130 VAC)
4	Rotameter
5	Flow-through Air Heater
6	Hydrogen-Air Mixer
7	Flash Arresters
8	Water Flow Meter
9	Filter
10	Thermocouple with spray shield
11	Pressure Transducer (0-15 psig Data Instruments)
12	Gas Sampling Line
13	3-Way Solenoid Valve
14	Oxygen Analyzer (Servomex Type A250)
15	Hydrogen Analyzer (Beckman Model 7C)
16	Water Pump
17	Water Heating Tank (82 gal)
18	Vent Disks
19	Gas Sampling Pump
20	Rubber Flaps
21	Igniter Surface Thermocouples (2)
22	0-290 VAC Variable Transformer and Voltmeter
23	Hydraulic Flashback Arrester
24	Check Valve
25	Muffler
26	Normally open Solenoid Valve
27	Normally closed Solenoid Valve
28	Water Bypass Line
29	Test Room Sampling Line
30	Air and Water Thermocouples
31	Desiccator
32	Pressure Gage

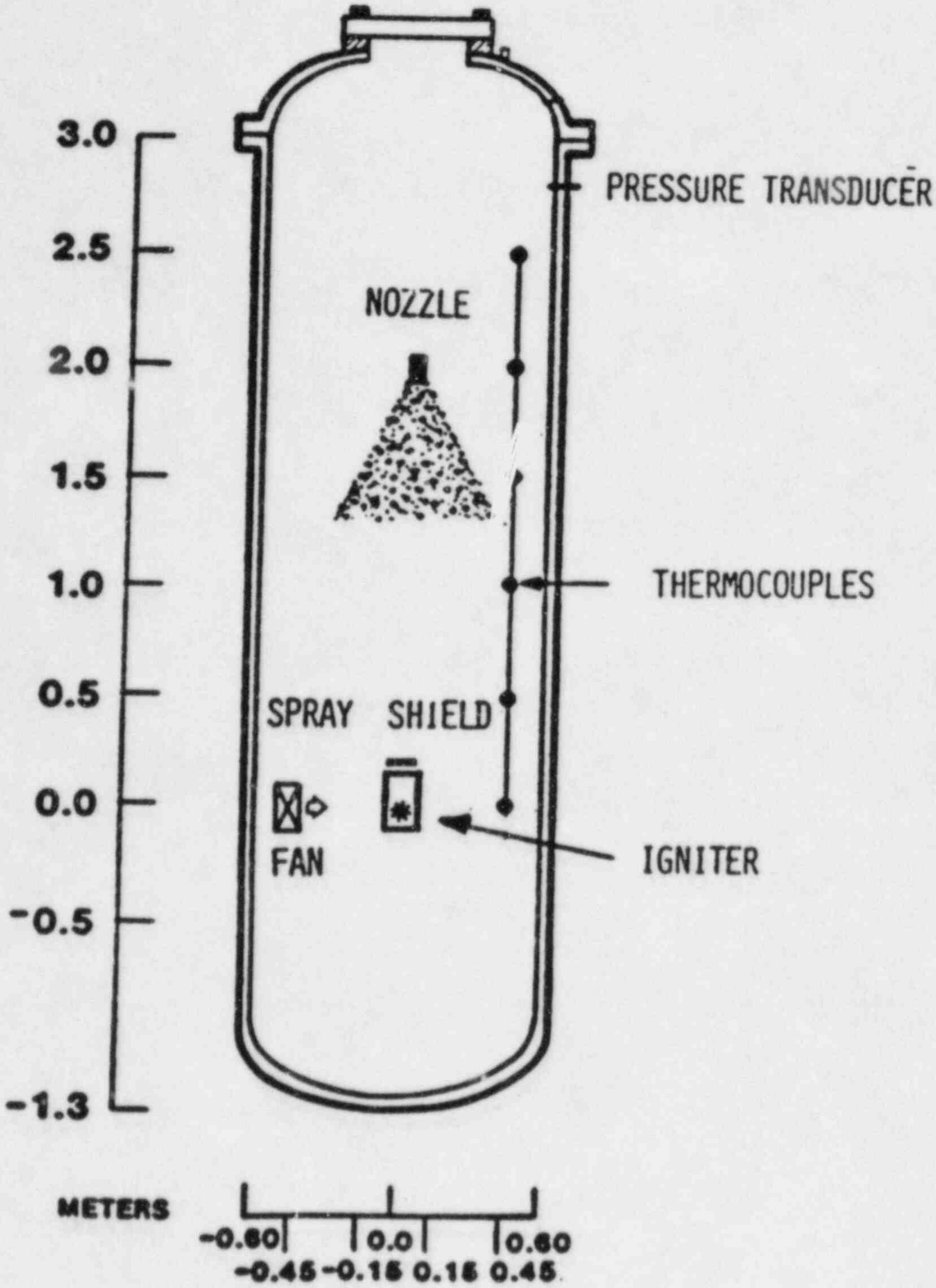
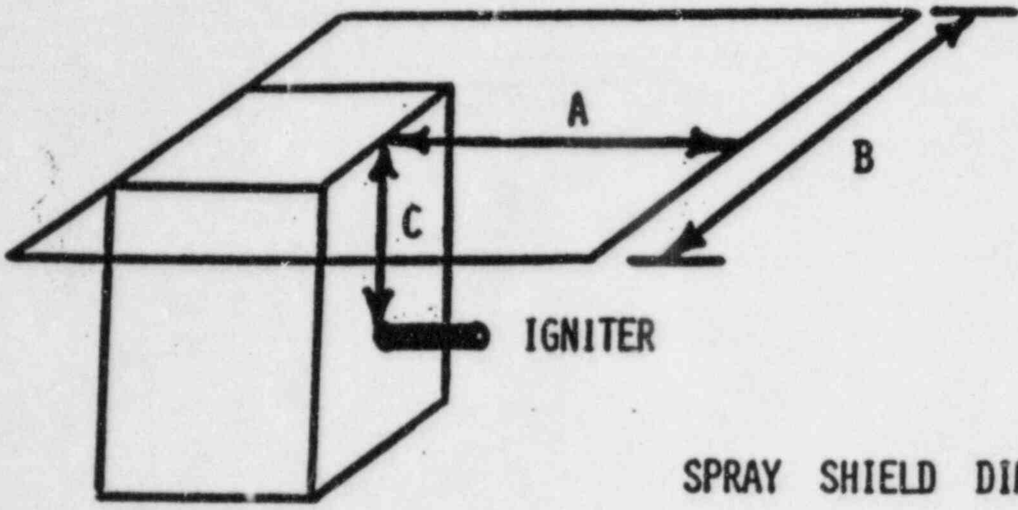


FIGURE 4

SCHEMATIC DIAGRAM OF THE VGES COMBUSTION CHAMBER AS USED TO TEST OPERABILITY OF IGNITERS IN A WATER SPRAY ENVIRONMENT.



SPRAY SHIELD DIMENSIONS

	A	B	C
GENERAL MOTORS AC 7G	10 CM	15 CM	20 CM
	4 IN	6 IN	8 IN

FIGURE 5

SCHEMATIC DIAGRAM OF THE PLACEMENT AND DIMENSIONS OF THE SPRAY SHIELD IN RELATION TO THE GENERAL MOTORS AC 7G IGNITER AS USED IN THE TESTS OF IGNITER OPERABILITY IN A WATER SPRAY ENVIRONMENT.