DOE/CS/40008-T5

BRAYTON-CYCLE HEAT RECOVERY SYSTEM CHARACTERIZATION PROGRAM

MASTER

GLASS-FURNACE FACILITY TEST PLAN

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ALPHA
Alpha Glass, Inc.

SUMMARY

This Glass Furnace Test Facility Plan has been prepared under Subtask A8.1.1 of the Phase 1 Program Plan - Brayton-Cycle Heat Recovery System Characterization Program. It describes the Test Requirements, Test Methods, and the facility to be implemented at the Glass Containers Plant, in Vernon, California.

The test approach has been selected to fulfill the requirements stated in the AiResearch Program Document, Materials Selection and Coupon Test Plan, Report No. 80-17123, August 10, 1980. Representatives of AiResearch and the NASA Lewis Laboratory have reviewed and provided support to the development of the Test Facility approach. Glass Container Corporation Engineering and Plant Personnel have reviewed and approved this plan for considerations of plant operation and safety factors.

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1.0 INTRODUCTION

Alpha Glass, Inc., in cooperation with AiResearch Manufacturing Company of California and Oak Ridge National Laboratories, is developing, under contract to the Department of Energy, a system to recover waste heat and produce electricity and preheated combustion air from the exhaust gases of an industrial glass furnace. The approach is to use a subatmospheric turbocompressor in a Brayton-cycle system. As a part of the Phase 1 effort, materials will be selected and tested under conditions simulating use in a glass plant. One set of materials will be tested in a laboratory test environment at AiResearch and another set will be tested at the Glass Containers Corporation Glass Plant in Vernon, California using the effluent gases of one of the furnaces located there. That furnace produces more than 200 tons per day of container glass on a continuous basis and is typical in size and product of the majority of glass container plants. The AiResearch program document, "Materials Selection and Coupon Test Plan", Report No. 80-17123, August 10, 1980 (Reference 1) stipulates the materials to be tested and the general operating parameters for both the materials testing at AiResearch and at the operational furnace. This facility plan has been prepared under Subtask A8.1.1 (Reference 2) and defines the test configuration, instrumentation, access and controls to support the operational furnace tests.

2.0 OPERATIONAL FURNACE TEST REQUIREMENTS

Glass furnace effluent gases are cooled as they pass from an operational regenerated glass container furnace through the checkers and exhaust ducts, then through the turbine, heat exchanger, and compressor. As the gases cool, sodium sulphate and other constituents are removed from the vapor phase by condensation, and chemical reaction (corrosion) may occur with the materials of the Brayton-cycle system. The hot corrosion potential and changing state of these flue gases have been assessed by AiResearch to provide a basis for the material selection and testing at the operational furnace. The most important criterion in the definition of the operational furnace test method is that it simulate all service conditions as well as possible with the constraints given. The most significant constraint in the operational furnace test is the requirement to interface the test facility with the furnace without adversely affecting the glass production which makes glass 24 hours a day, seven days a week.

The operational furnace tests to be performed under Task 8 of the Phase 1 statement of work will contain two principal elements: (a) a heat exchanger module test and (b) coupon material tests for selected temperature regimes.

2.1 HEAT EXCHANGER MODULE REQUIREMENTS

To determine the effect of condensate, a plate and fin heat exchanger module that will have been used in the model SAS program will be furnished by AiResearch to Alpha for testing at the operational furnace test facility. The module will be made from Type 409 stainless steel brazed with AMS 4777 alloy. A print of the module configuration has been delivered to Alpha from AiResearch. The module will be installed in a separate glass plant test unit. The test unit will be operated to provide a gradient across the heat exchanger test sample from the maximum available temperature of the flue gases (which is about 1000^{o}F) to approximately ambient temperature. Periodically, the module will be removed from the test rig and a section of fin will be removed and examined. The module will then be reinstalled in the test rig. At the end of the test program, the module will be sectioned and metallurgically examined to determine the effect of sulphuric acid condensation on the unit. If possible, the test setup may use the cyclic cleaning method, to be developed in the model SAS program, to prevent plugging. This cleaning system will be furnished by AiResearch.

2.2 MATERIAL COUPON TEST REQUIREMENTS

Coupon materials will be placed in the waste gas stream for exposure at three desired exposure temperatures:

- 1550^{o}F -- Maximum turbine nozzle temperature
- 1350^{o}F -- Maximum turbine wheel temperature and potential overheating temperature for heat exchanger.
- 1100^{o}F -- Maximum heat exchanger temperature at temperature at maximum-stress region of turbine wheel.

AiResearch will provide sample coupons that have been prepared and grouped by sample type and duration of test. Table 2-1 shows the maximum number of samples and test duration for each temperature. AiResearch will measure, weigh and provide thermocouples secured to a number of selected specimens (maximum number thermocoupled shown in Table 2-1).

The test coupons will be placed in a suitable test environment that is controlled to provide the sample temperatures shown in Table 2-1. Gas temperatures immediately surrounding the samples should be within 50^{o}F of the coupon temperature. In addition to the temperature, the environment should simulate the furnace exhaust gas composition and particle size distribution expected from a full-size furnace with the Brayton-cycle system installed. Therefore, particle and gas composition shall be measured immediately upstream of the test coupons. The results of this analysis shall closely match the values obtained by Truesdail Laboratory (Reference 3). The particle composition from this Truesdail test is shown in Table 2-2 of Reference 4, and the gas composition is shown in Table 2-6 of Reference 5. If there is a significant difference between the analyses upstream of the coupons and the baseline Truesdail results, the baseline test shall be repeated at the same location after the operational reversal valve. AiResearch shall approve any planned gas sampling plans to verify the composition and may participate in the sampling.

2.3 MODEL SAS TEST REQUIREMENTS

Provision shall be made in the Glass Furnace Test Facility for providing the test environment for the SAS Model System, should it be desired to test this system at this facility at a later date.

3.0 OPERATIONAL FURNACE ENVIRONMENT

The Glass Container Corporation plant is located at 3601 South Santa Fe, in Vernon, California. Two regenerated container furnaces are in this plant and are in operation on a full time basis, except during holidays (such as Thanksgiving or Christmas) when they do not produce glass nor enough energy is supplied to keep the glass suitably viscous.

The test facility will employ the waste gases from Furnace Number 2, which is almost identical to the other furnace (Number 1) in size and operational

TABLE 2-1

MATERIAL COUPON TEST PLANT

	NUMBER OF COUPONS AT TEMPERATURE		
	1550°F	1350°F	1100°F
EXPOSURE TIME			
20 DAYS	7 Coupons (Type B)*	12 Coupons (Type A & B)	12 Coupons (Type A & B)
50 DAYS	7 Coupons (Type B)	5 Coupons (Type A)	12 Coupons (Type A & B)
UP TO 210 DAYS	7 Coupons (Type B)	12 Coupons (Type A & B)	12 Coupons (Type A & B)
MAXIMUM THERMOCOUPLES INSTRUMENTED	9 K Type	15 K Type	18 K Type

*These types are defined in "Materials Selection and Coupon Test Plan, 80-17123, as the following but may be substituted.

TYPE A

Steel	Braze	Coating
409	AMS 4777	None
409	J-8300	None
409	AMS 4777	Aluminide
444	AMS 4777	None
430	AMS 4777	None

TYPE B

Alloy	Coating
IN-713LL	None
IN-738	None
IN-738	Al
IN-738	PT-Al
IN-792	None
IN-792	Al
IN-792	PT-1

characteristics. Figure 3-1 is a simplified sketch of the furnace showing the relationship of the melt tank, two checkers (regenerators), the flues passing to the reversing valve, and then out to the exhaust stack. The exhaust gases normally exit through a scrubber, but the stack is maintained and used in the event the environmental equipment is down for maintenance.

The test areas of interest include the bottom of the checkers, the switching valve and access to the top of the flues all of which are located in the basement level of the plant. The access port to obtain the waste gases for the heat exchanger module and material coupon tests is shown in Figure 3-1. A floor plan of the basement area is shown with dimensions in Figure 3-2. The space available for the test units and instrumentation is generally restricted to that area in front of the left and right checkers. A protective fence has been installed around that area before the right checker which makes it more desireable for a test area.

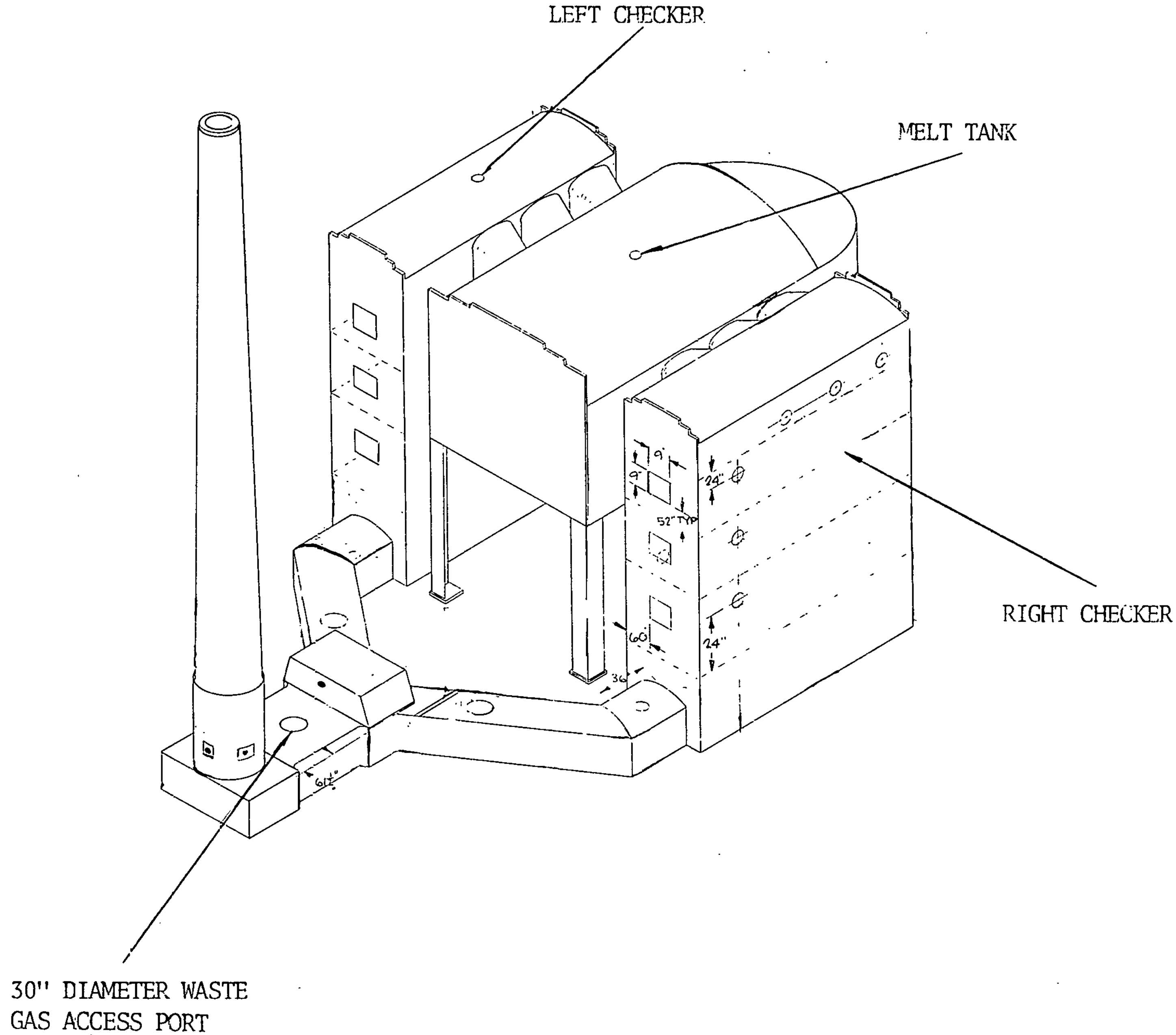
4.0 TEST FACILITY APPROACH

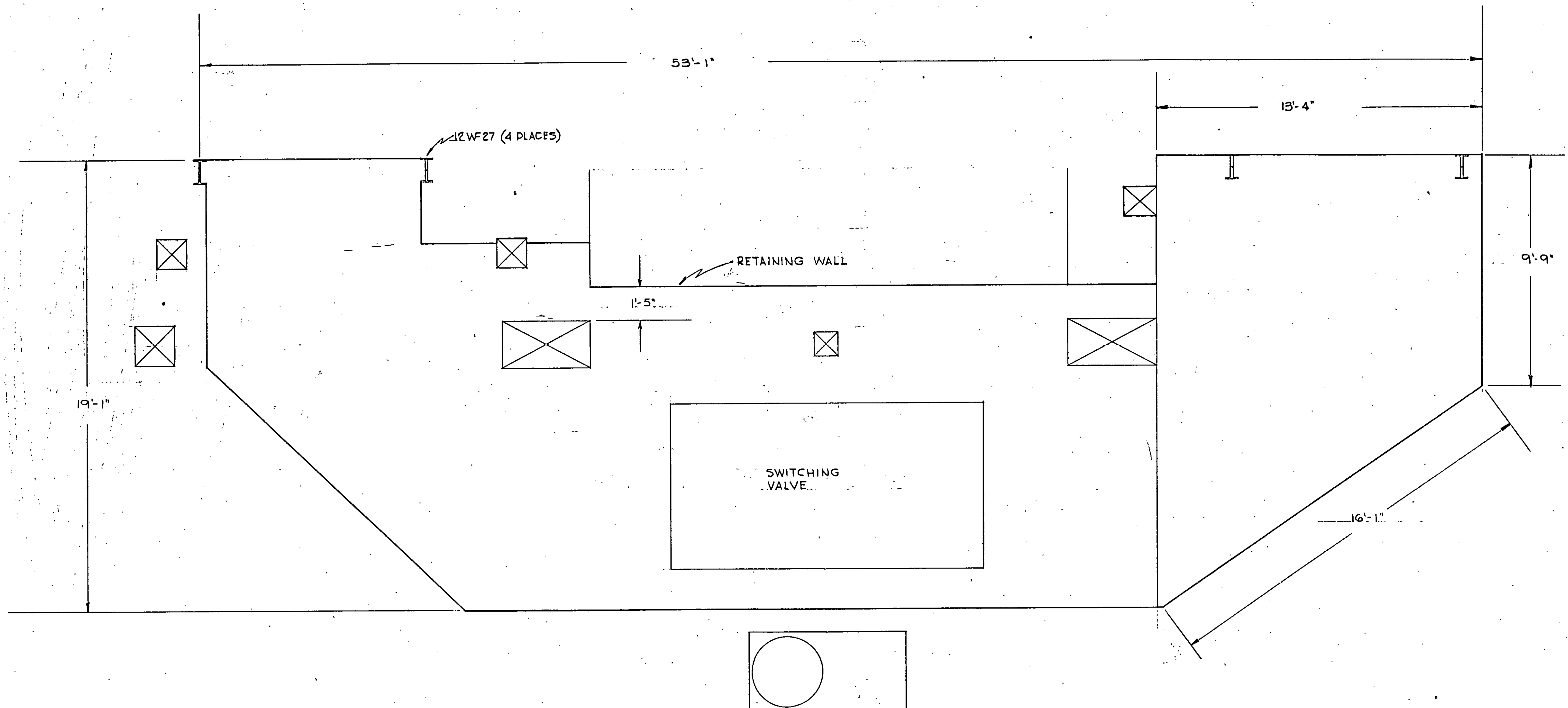
4.1 DISCUSSION OF ALTERNATIVES

Two methods have been examined for the facility design approach to obtain waste gases from the operational furnace for the material coupon and heat exchanger tests. Technical risk, test equipment availability, impact on furnace operations, reliability, availability and cost were the principal considerations that were evaluated in the selection of the test approach.

The first method considered takes the waste gases from the top of the left and right checkers where they are at 2800°F, draws the gases down by means of a fan through a specially designed reversing valve that is slaved to the operational furnace switching valve, and runs them into the test chambers. In this alternative, the gases must be cooled down by a combination of radiation through the ducting that leads from the top of the checkers to the switching valve, and by the introduction of two high temperature heat exchangers to control the gas temperature to about 1600°F prior to entry into the switching valve. The temperature of the gases would have to be further conditioned to achieve the test condition requirements of 1550°F, 1350°F and 1100°F in each test chamber. With a cursory

FIGURE 3-1 LAYOUT OF VERNON FURNACE




53'-1"
13'-4"
12WF27 (4 PLACES)
RETAINING WALL
1'-5"
9'-9"
19'-1"
SWITCHING VALVE
16'-1"

look, this approach appears straighforward and practical. However, a more detailed analysis revealed significant difficulty and risk in the implementation. The ducting to survive in temperatures up to 2800^{O}F must be lined with a ceramic fiber material and covered with metal. Construction and fitting such ducting is costly and difficult. In addition, it is possible that the velocity of the gases (about 1,000 cfm) would cause the lining to spall off and contaminate the gas flow. For these reasons, this method was discarded in favor of the other alternative.

The alternative method selected consists of taking the gases out of the flue downstream from the operational furnace switching valve for both the material coupon and heat exchanger module tests. The temperature of the gases at the point of access is about 1,000^{O}F which requires a process to heat them up prior to entering the material test chambers. This method is more susceptible to achieving accurate temperature control on a consistent basis, and has the least potential adverse affects on the furnace pressures which must be maintained constant for good glass production.

4.2 DESCRIPTION OF TEST METHOD

Figure 4.1 is a schematic of the test rig to be employed for the material coupon and heat exchanger test at the operational glass furnace. The advanced component test rig (in the switching valve) is also shown because it is integrated with the other tests but is described in a separate test plan. For identification purposes, the material coupon tests are designated Test #1 and the heat exchanger test is designated Test #2.

For Test #1, the gases are drawn from the existing exhaust furnace duct (located downstream from the switching valve) at a rate of 1000 cfm by a fan rated at 6000 cfm. The 8" diameter intact duct is inserted 3' down into the furnace exhaust flue with the open duct facing into the main exhaust flow. The test duct running from the intake valve to the test boxes will contain a group of cartridge heaters (see detail in Figure 4.2) which will heat up the gas to 1100^{O}F in Test Box 1, 1350^{O}F in Test Box #2 and 1550^{O}F in Test Box 3. The dimensions of each box are 2' x 2' x 2'. Each box has a ceramic lining to eliminate contamination,

FIGURE 4.1 OPERATIONAL FURNACE TEST SETUP

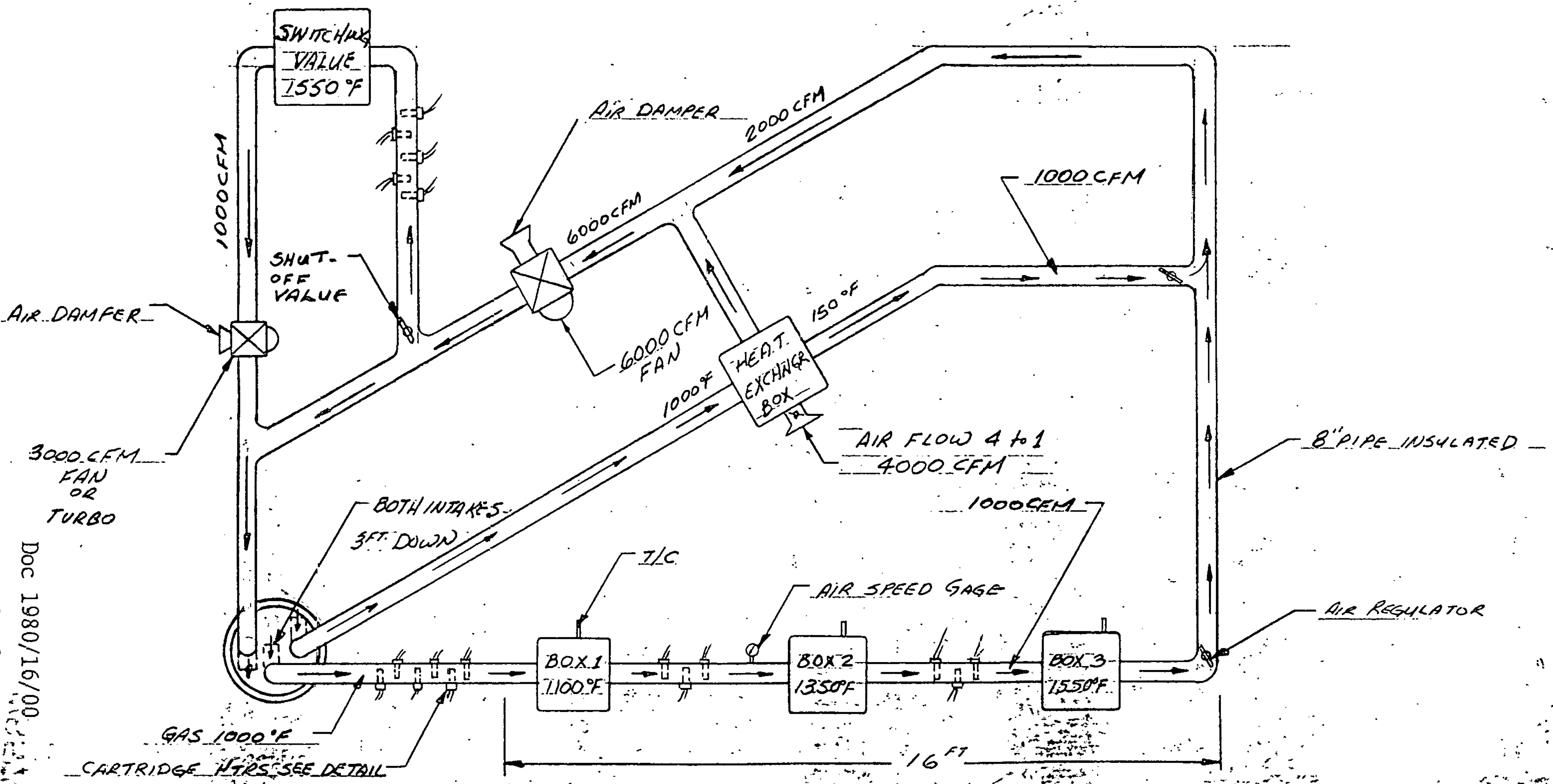
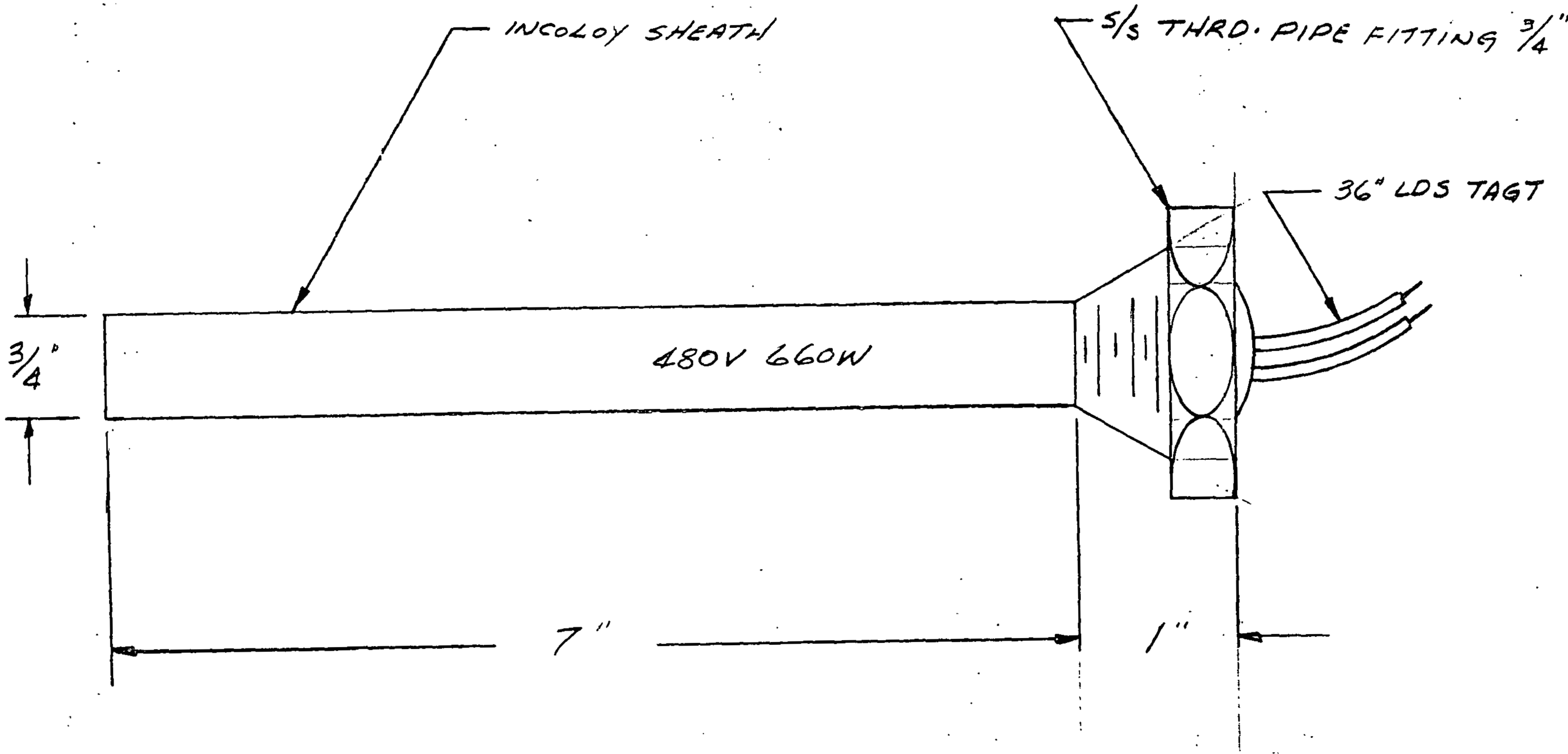


FIGURE 4.2 DETAIL OF CARTRIDGE HEATERS



and is air tight and fully insulated to prevent heat loss. All heat exchangers have controllers and sensors to maintain temperatures with ±50°F of required test temperatures in the test boxes. All test boxes will contain thermocouples for monitoring the ambient air temperature and there is an air guage in the system to read air speed.

Computation of the air velocity in each test box is as follows:

1100°F air in Box #1

25.4 lbs of air/min ÷ 60 cubic ft./sec. = 42 ÷ 8 = .052 velocity ft/sec.

1350°F air in Box #2

21.9 lbs of air/min ÷ 60 cubic ft./sec. = 36 ÷ 8 = .045 velocity ft/sec.

1550°F air in Box #3

19.7 lbs of air/min ÷ 60 cubic ft./sec. = 32 ÷ 8 = .041 velocity ft/sec.

Computation of the required electrical energy to maintain each test box at required temperature is as follows:

Test Box #1

$$\frac{1000 \text{ cfm} \times 60 \times .0192 \times .260 \times 100^{\circ}\text{F}}{3412 = 1 \text{ btu}} = 8.7\text{kw} \times 20\% = 11 \text{ kw}$$

Test Box #2

$$\frac{1000 \text{ cfm} \times 60 \times .0192 \times .260 \times 250^{\circ}\text{F}}{3412} = 21.9 \text{ kw} \times 20\% = 26 \text{ kw}$$

Test Box #3

$$\frac{1000 \text{ cfm} \times 60 \times .0192 \times .260 \times 200^{\circ}\text{F}}{3412} = 17.5 \text{ kw} \times 20\% = 21 \text{ kw}$$

Heat Exchanger #1: 11 kw @ 480v 3Ø
Heat Exchanger #2: 26 kw @ 480v 3Ø - Totaling 58 kw/7 lamps
Heat Exchanger #3: 21 kw @ 480v 3Ø

All duct piping will be insulated to hold respectful temperatures for control and safety purposes. The gases will be returned via exhaust ducting to the intake valve located after the operational switching valve. The exhaust duct opening will be positioned in the large flue so as not to disturb the gases around the intake ducts.

For Test #2, Heat Exchanger Module Test, the waste gases will be drawn from the same flue opening as in Test #1 by means of a separate 8" diameter duct. The gases will be taken at available temperature (approximately 1000^{o}F) at 1000 cfm through the heat exchanger test box containing a plate fin module to be furnished by AiResearch, and exit at approximately 150^{o}F to be dumped back into the exhaust ducting. The heat exchanger will have a cross flow of air of 4:1 (4000 to 1000 cfm) for cooling with an adjustable air valve and air gauge. Thermocouples will be provided at entrance and exit of gas ducts to read ambient temperatures.

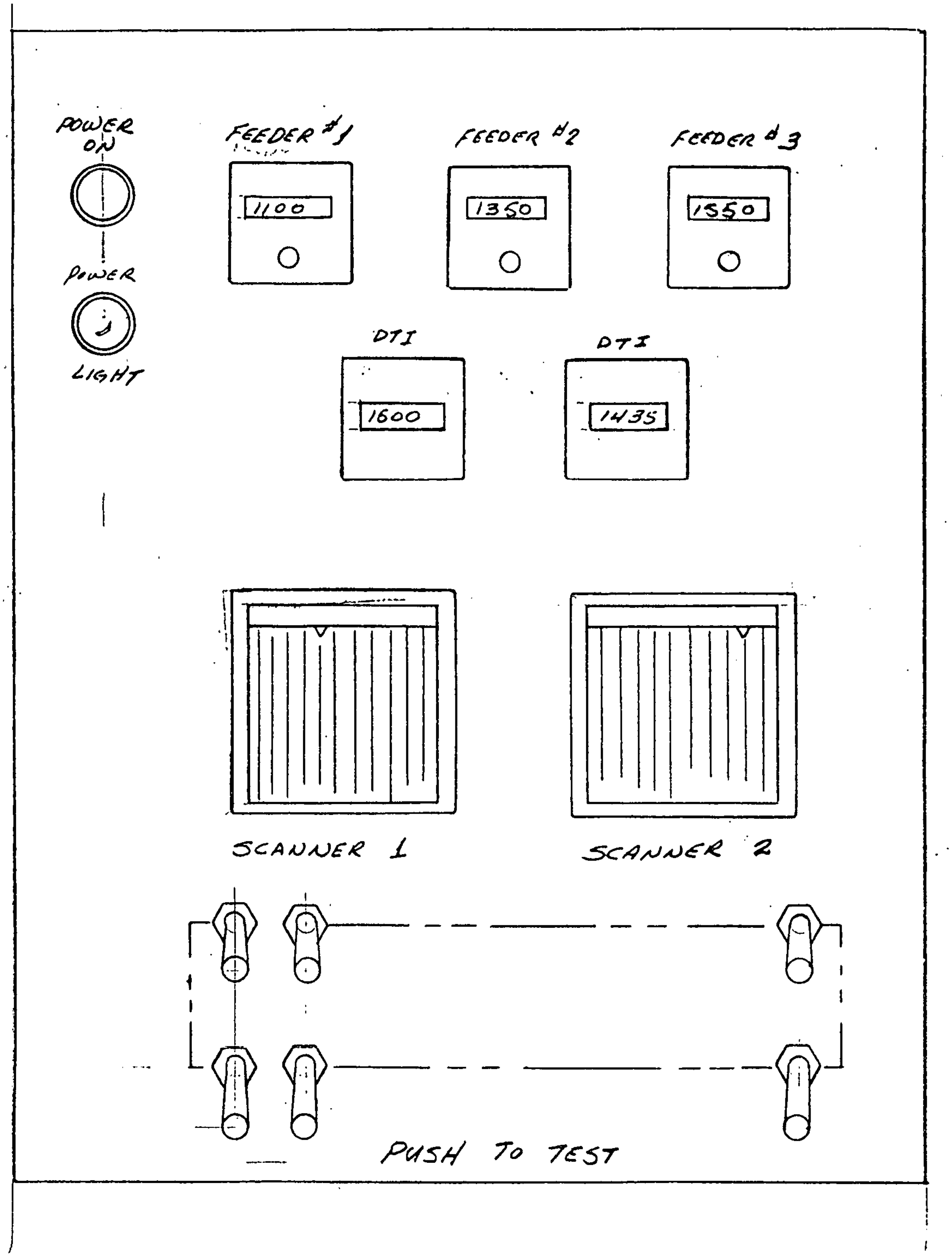
4.3 INSTRUMENTATION

Figure 4.3 illustrates the instrumentation panel which will be used to monitor input/output temperatures in the ducting, as well as the temperatures in boxes #1, 2 and 3. Thermocouple readings of selected materials in these boxes and of the cross section of the heat exchanger module will be recorded with identification on a constant basis by means of stamp recorders and are identified as Scanners 1 and 2. The scanners are speedomax 250 series multipoint recorders. Each recorder can read and record from 2 to 30 points. The time per point setting can be set from 1 to 180 seconds.

4.4 SCHEDULE

The ducting which connects with the operational furnace flue can only be installed while the furnace is idling during a holiday period. The next available downtime at the Glass Container Corporation Vernon Furnace is November 25, 1980. The material purchases, construction and installation are therefore keyed to accomplish the hookup at that time. After installation, a shakedown period of two weeks has been allocated to make sure that temperatures and flows conform with test requirements before installing the test materials.

FIGURE 4.3 TEMPERATURE READOUT INSTRUMENTATION



REFERENCES

1. "Materials Selection and Coupon Test Plan", Report No. 80-17123, AiResearch Manufacturing Company of California, August 10, 1980.
2. "Phase 1 Program Plan - Brayton-cycle Heat Recovery System Characterization Program", Report No. 79-16411, Rev. 2, AiResearch Manufacturing Company of California, December 17, 1979.
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4. Lowell, C.E., NASA Lewis Research Center, Private communication, April 18, 1980.
5. "Flue Gas Characterization Literature Search", Report No. 80-16900, AiResearch Manufacturing Company of California, March 19, 1980.