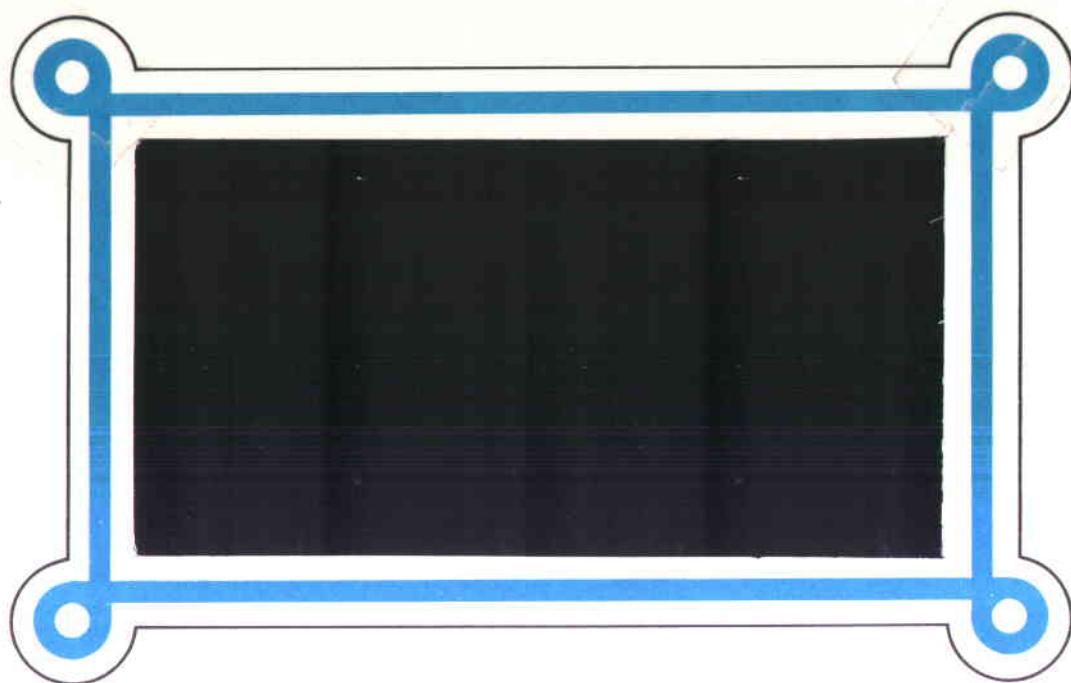


FOR
Receiver
Instrumentation

1065

cont
RCVR



SANDERS
ASSOCIATES, INC.

DEFENSIVE SYSTEMS DIVISION 95 Canal Street, Nashua, New Hampshire 03061

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SOLAR
1/4 Mw RECEIVER TEST PLANS

Revision 3

24 July 1978

Prepared for:

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Prepared by:



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SECTION 1

INTRODUCTION

Under contract to the Department of Energy (DOE), Sanders Associates, Inc. is developing a solar receiver and air heat exchanger unit (receiver) for use in advanced solar powered, electric generating plants. The function of the receiver is to absorb the concentrated solar energy focused on it by a large mirror field and transfer this energy to an airstream, where eventually it will drive an open cycle Brayton turbine powered generator. Described in this test plan is the program to measure the performance of a 1/4 Mwt model of the receiver at the solar test facility located at the Georgia Institute of Technology in Atlanta, GA. The plan for preliminary testing at Sanders Associates, Inc. prior to shipping to GIT is also included in this plan.

SECTION 2

OBJECTIVES

The objectives of this test program are as follows:

- a. Measure the efficiency of the receiver in the collection of solar energy
- b. Measure the convective heat loss associated with an open cavity air receiver
- c. Design and test a receiver concept which is scalable to larger receivers
- d. Demonstrate structural integrity of receiver design at air temperatures up to 1100°C
- e. Demonstrate a mode of operation where the outlet air temperature is held constant as insolation varies with time

SECTION 3

TEST ARTICLE

A Sanders platform will be mounted at the top of a 76 foot tower located in the center of the mirror field. On the platform are three assemblies (see Figure 3-1 block diagram) connected by 275 feet of cable to a remote control panel capable of operating the receiver from the control room at the bottom of the tower. The three platform assemblies are:

- Receiver assembly
- Burner assembly
- Cooling air assembly

3.1 PLATFORMS

The Sanders platform is approximately 4 meters square, constructed of I-beams and channels, and serves as the foundation for mounting the solar receiver assembly, burner and cooling air supply (see Figure 3-2). The weight of the hardware fully assembled is approximately 5500 kg. It will be shipped to Georgia Institute of Technology after shakedown and calibration testing at Sanders in Merrimack, NH. A separate shutter assembly, mounted on the GIT tower below the plane of the terminal concentrator, is required along with the test platform. This shutter will provide another level of safety in case of equipment malfunction.

A second test platform will be supplied by Sanders to be used during the calibration phase to obtain the flux distribution on the plane of the solar absorption panels when the terminal concentrator is in place. On top of this platform is mounted the Sanders' rotating flux rake and below it is the water-cooled terminal concentrator.

3-2

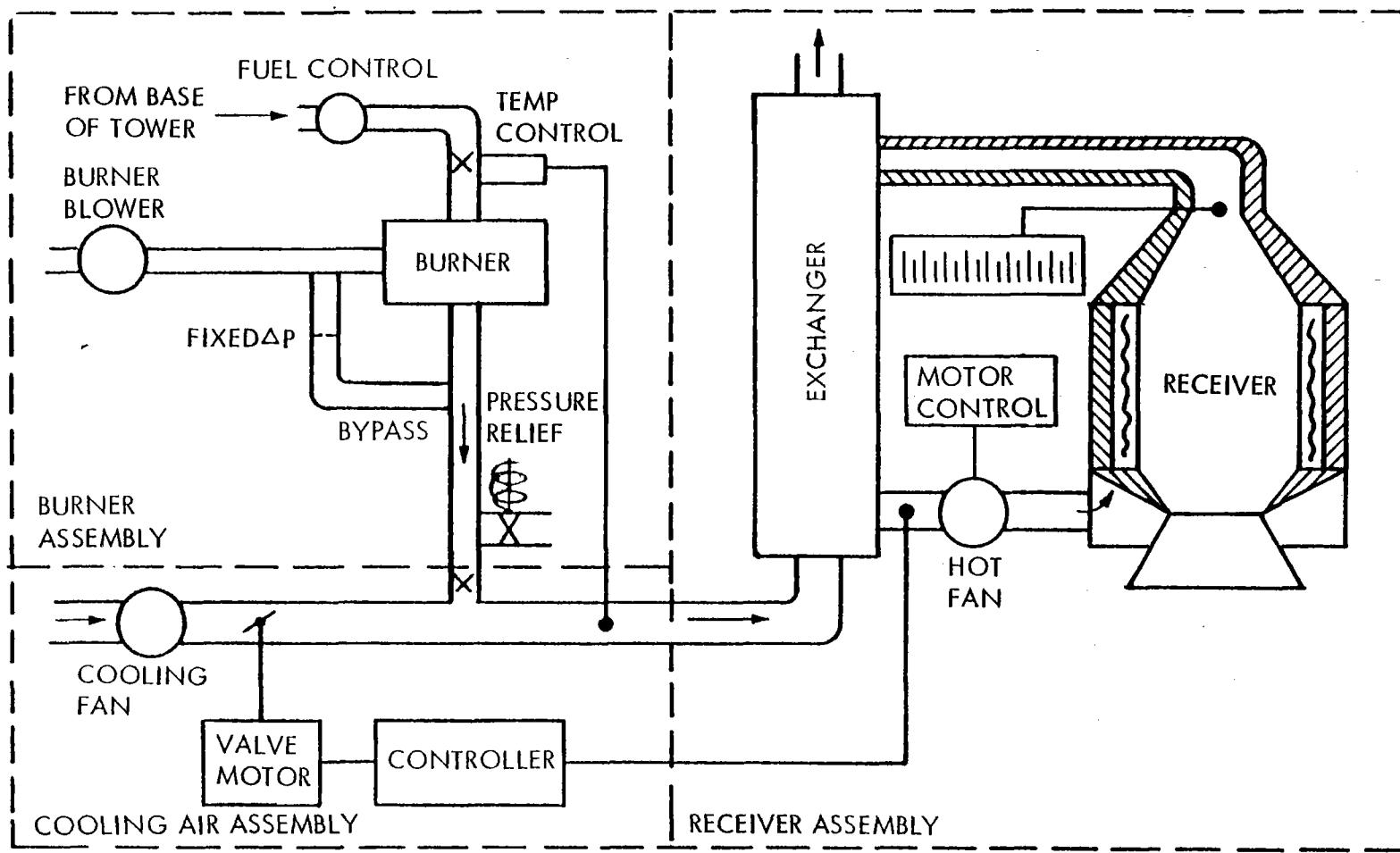


Figure 3-1. 1/4 Mwt Receiver Block Diagram

3-3

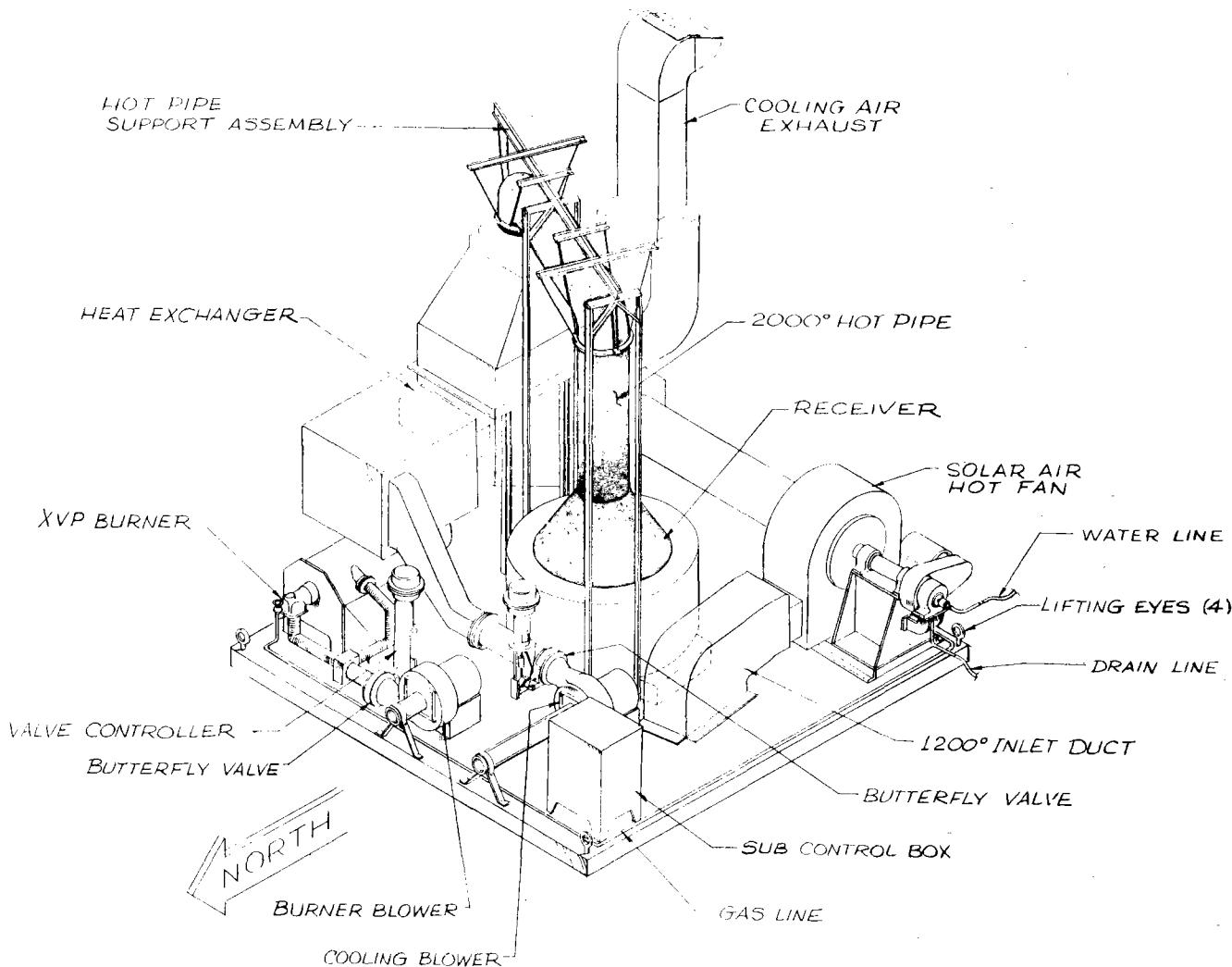


Figure 3-2. Platform

3.2 SOLAR RECEIVER ASSEMBLY

Solar energy enters the open cavity of the receiver and is absorbed in the ceramic matrix structure. Air from the high temperature fan is heated by passing through the ceramic and is then circulated to the air-to-air heat exchanger where it is cooled prior to re-entering the fan and receiver. A separate water cooling system is mounted on the platform to maintain the fan bearings at a safe operating temperature and prevent overheating of the terminal concentrator.

The inlet air temperature to the receiver is limited to 650°C by the temperature limitation on the 15 hp hot air fan. Airflow can be varied from 0.34 kg/sec to 0.57 kg/sec by controlling the speed of the fan motor. Maximum outlet temperature of the receiver is limited to approximately 1150°C.

3.3 BURNER

The gas-fired hot air supply is needed to check out the equipment prior to shipment to GIT. It will also be available at GIT for bringing the equipment up to test temperatures prior to bringing the mirror field into position (soft start).

The hot air supply consists of a gas burner, blower and controls. The output temperature of the burner is approximately 1400°C, which must be cooled by excess airflow to a maximum of 800°C prior to entering the heat exchanger. Fuel for the burner is piped from a 500/1000 pound tank on the ground. The maximum heat input to the receiver system is 440 kW.

3.4 COOLING AIR SUPPLY

The solar heat received in the ceramic matrix is removed from the receiver assembly by the cool air which passes through the heat

exchanger. Supplying the cool air is a circulating fan and a motorized flow control valve which controls the volume of ambient air passing through the heat exchanger. The airflow is controllable from 0 to 0.9 kg/sec and can be supplied simultaneously with the hot air supply.

3.5 CONTROL PANEL

The control panel is hard-wired to the platform and contains all the switches, meters, and controls needed to start up, operate, and shut down the equipment. Safety alarms and the switches for key pressures and temperatures are mounted on the control panel. Safety alarms sound when an over-temperature occurs in: (a) the bearings, (b) receiver outlet temperature, and (c) burner outlet temperature.

Further thermal analysis of receiver performance will be available from a long wavelength imaging receiver filtered to view both the front and rear surfaces of the honeycomb in the 2.75μ to 2.85μ spectral band. This unit will be mounted outside the receiver and will view its ceramic matrix through quartz windows.

3.6 FLUX RAKE

The flux rake, supplied by Sanders, will use 25 HYCAL-1112-B calorimeters mounted on a water-cooled beam to sweep out the plane of the inside of the receiver and measure the solar flux distribution and its variations throughout the day. The location of each sensor (see Section 4.1) is designed to measure the total flux coming in which can then be compared with the values measured with the Georgia Tech flux rake located just below the plane of the terminal concentrator.

The instrumentation details are described in Tables 3-1, 3-2, 3-3, and in Figure 3-2.

TABLE 3-1
INSTRUMENTATION SENSORS SANDERS FLUX RAKE

SENSOR ID	GIT CHANNEL ASSIGNED	TYPE OF SENSOR	COEFFICIENTS		FULL SCALE VOLTS	UNITS	FULL SCALE IN UNITS	COMMENTS
			STARTING VALUES	ADJUSTED FOR CALIBRATION				
CAL-1		HY-CAL	A = 0. B = 5000. C = 0.		.010	BTU/SEC-FT ²	50	
CAL-2		"	A = 0. B = 5000. C = 0.		.010	"	50	
CAL-3		"	A = 0. B = 5000. C = 0.		.010	"	50	
CAL-4		"	A = 0. B = 5000. C = 0.		.010	"	50	
CAL-5		"	A = 0. B = 5000. C = 0.		.010	"	50	
CAL-6		"	A = 0. B = 5000. C = 0.		.010	"	50	
CAL-7		"	A = 0. B = 5000. C = 0.		.010	"	50	
CAL-8		"	A = 0. B = 5000. C = 0.		.010	"	50	
CAL-9		"	A = 0. B = 5000. C = 0.		.010	"	50	
CAL-10		"	A = 0. B = 5000. C = 0.		.010	"	50	
CAL-11		"	A = 0. B = 5000. C = 0.		.010	"	50	
CAL-12		"	A = 0. B = 5000. C = 0.		.010	"	50	
CAL-13		"	A = 0. B = 5000. C = 0.		.010	"	50	
CAL-14		"	A = 0. B = 5000. C = 0.		.010	"	50	
CAL-15		"	A = 0. B = 5000. C = 0.		.010	"	50	
CAL-16		"	A = 0. B = 5000. C = 0.		.010	"	50	
CAL-17		"	A = 0. B = 5000. C = 0.		.010	"	50	
CAL-18		"	A = 0. B = 5000. C = 0.		.010	"	50	
CAL-19		"	A = 0. B = 5000. C = 0.		.010	"	50	
CAL-20		"	A = 0. B = 5000. C = 0.		.010	"	50	
CAL-21		"	A = 0. B = 5000. C = 0.		.010	"	50	
CAL-22		"	A = 0. B = 5000. C = 0.		.010	"	50	
CAL-23		"	A = 0. B = 5000. C = 0.		.010	"	50	
CAL-24		"	A = 0. B = 5000. C = 0.		.010	"	50	
CAL-25		"	A = 0. B = 5000. C = 0.		.010	"	50	

TABLE 3-2
THERMOCOUPLE CHANNELS

II. THERMOCOUPLE CHANNELS

* IS A DIFFERENTIAL PAIR: NEEDS ONE CHANNEL FOR THE TWO, NO REFERENCE JUNCTION

SENSOR ID	GIT CHANNEL ASSIGNED	TYPE OF SENSOR	COEFFICIENTS		FULL SCALE VOLTS	UNITS	FULL SCALE IN UNITS	COMMENTS
			STARTING VALUES	ADJUSTED FOR CALIBRATION				
1 - TC-1 1 - TC-2 1 - TC-3 *		THERMO-COUPLE, ALL TYPE	USE KNOWN VALUES FOR THIS TYPE TO GET INTERNAL VALUES IN DEGREES R (RANKINE)		.033913 .033913 *.026975	°R *°R	1960 1960 *0	RECEIVER IN
2 - TC-4 2 - TC-5 2 - TC-6 *		CHROMEL- ALUMEL			.053 .053 *.026575	*°R	2860 2860 *1800	RECEIVER OUT
3 - TC-7 3 - TC-8					.033913 .033913	°R	1960 1960	HOT AIR FLOW
6 - TC-9 6-TC-10					.022666 .022666		610 610	HEAT X INLET
7-TC-11 7-TC-12					.033913 .033913		1960 1960	HEAT X OUTLET
8-TC-13 8-TC-14					.053 .053		1960 1960	HEAT X TUBE
9-TC-15 9-TC-16 9-TC-17 9-TC-18 9-TC-19 9-TC-20 9-TC-21 9-TC-22 9-TC-23 9-TC-24 9-TC-25 9-TC-26 9-TC-27 9-TC-28 9-TC-29 9-TC-30 9-TC-31 9-TC-32 9-TC-33 9-TC-34					.053		2860	HONEYCOMB
10-TC-35			↓		.053	↓	610	COOLING AIR

TABLE 3-3
PRESSURE TRANSDUCERS

III. PRESSURE TRANSDUCERS

+ = Premium type, calibration to .1% to be provided (Others are 1.% Type).

SENSOR ID	GIT CHANNEL ASSIGNED	TYPE OF SENSOR	COEFFICIENTS		FULL SCALE VOLTS	UNITS	FULL SCALE IN UNITS	COMMENTS
			STARTING VALUES	ADJUSTED FOR CALIBRATION				
1-PS-1		LFE	A=0 B=1729. C=0		.060	PSF	103.7(20")	N Receiver
1-PS-2								S Inlet
1-PS-3								E
1-PS-4								W
2-PS-5								N Receiver
2-PS-6								S Outlet
2-PS-7								E
2-PS-8								W
3-PS-9		LFE	A=0 B=1729. C=0		.060		103.7	HOT
3-PS-10		+MKS	A=0 B=5.19 C=0		10.0		51.9(10")	AIR
3-PS-11		+MKS			10.0		51.9	FLOW
3-PS-12		+MKS			10.0		51.9	
3-PS-13		+MKS			10.0		51.9	
4-PS-14		LFE	A=0 B=1729. C=0		.060		103.7	COOLING AIR INLET
4-PS-15								
4-PS-16								
5-PS-17								BURNER INLET
5-PS-18								
6-PT-17								N WIND
6-PT-18								E
6-PT-19								S
6-PT-20								W
8-PS-21								HEAT
8-PS-22								X
8-PS-23								HOT
8-PS-24								FLOW
8-PS-25								

SECTION 4

OPERATION PROCEDURES

4.1 GENERAL

4.1.1 Test Platform

A test platform (see Figure 4-1) will be provided prior to receiver tests in order to calibrate the performance of the mirror field. Mounted below, the platform is the terminal concentrator surrounded by the Georgia Tech flux rake assembly. Above the platform is a Sanders flux rake, capable of measuring the flux distribution in the plane of the ceramic receiver elements. This equipment will measure the actual test conditions in order to compare them with the theoretical flux distributions assumed in the receiver design. A further objective is to make simultaneous measurements with the Sanders and Georgia Tech flux scanners so that during subsequent receiver tests, when only the GIT flux scanner is available, there is a verification of unchanging performance of the mirror field.

Operation of the flux rake requires approximately 6 gallons per minute of water flow in parallel through the rake and the terminal concentrator. A small control box operates the variable speed motor for rotating the flux arm at speeds which vary from 80 sec/rev to 360 sec/rev. A swing switch limits the arm rotation to ± 180 degrees. Position readout is provided by a 20 turn potentiometer connected to a 12 volt power supply. A calibration curve measured in situ is incorporated in the computerized data reduction procedures.

4.1.2 Receiver Platform

The three component parts of the receiver test platform are: burner assembly, cooling air assembly, and the receiver assembly.

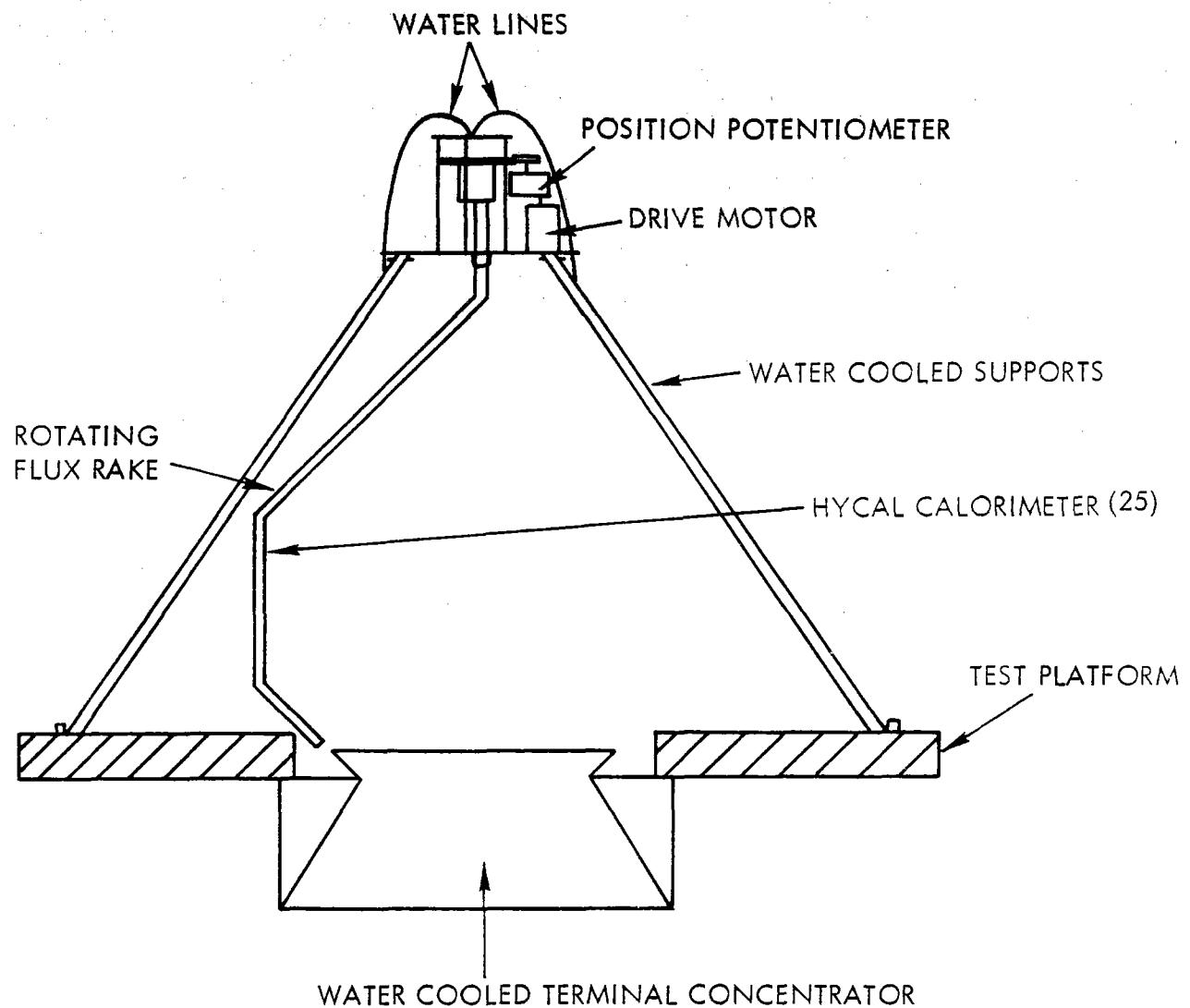


Figure 4-1. Sanders' Test Platform

Each assembly may be started and run from the control panel (Figure 4-2) as a separate system for the purposes of test, calibration, and checkout. However, when operated in conjunction with the mirror field, a detailed sequence of startup and shutdown steps are necessary. The checklists for the operation of the three components as a complete system are detailed in Tables 4-1 and 4-2; refer to Figure 4-2 for the control panel layout.

4.2 OPERATIONAL PROCEDURES

4.2.1 Test Platform

Below are the setup and operation procedures for the flux rake measurement program.

Setup:

1. Assemble rake to platform.
2. Mount terminal concentrator to platform.
3. Connect all water lines and check for flow and leaks.
4. Connect electrical leads.
5. Check operation of motor and rake.
6. Check response of each thermocouple.
7. Mount on tower and connect controls and instrumentation.
8. Operate in cold conditions.

Operation:

1. Turn power on.
2. Turn water on.
3. Check rotation flux arm through several cycles.
4. Check water flow.
5. Check instrumentation.
6. Open shutter.
7. Record flux profiles at three rotation rates:
 - a. 80 sec/scan
 - b. 160 sec/scan
 - c. 320 sec/scan

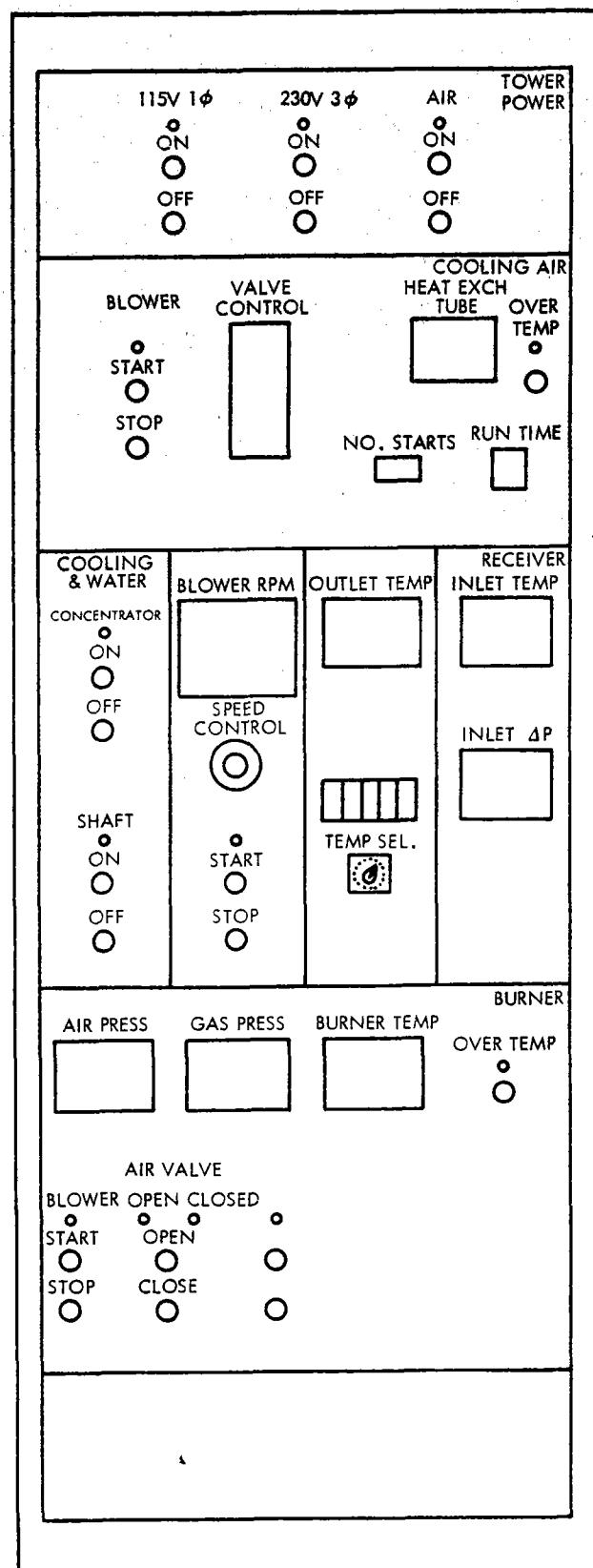


Figure 4-2. Control Console

TABLE 4-1
TURN-ON PROCEDURE

STEP	WITH SAFETY SHUTTER CLOSED	INDICATOR	CHECK
1	VISUAL SAFETY CHECK OF EQUIPMENT COMPLETE		
2	TURN <u>ON</u> TOWER POWER 115V	IND-G	
3	TURN <u>ON</u> TOWER POWER 440V	IND-G	
4	TURN <u>ON</u> COMBUSTION AIR BLOWER	IND-G	
5	OPEN COMBUSTION AIR VALVE	IND-G	
6	ENERGIZE GAS SOLENOIDS (PURGE START)	IND-G IND-R	
7	PURGE START	OUT	
	PURGE END	IND-G	
8	PRESS IGNITION <u>ON</u>	IND-G	
9	CONTROL BURNER TEMPERATURE WITH GAS VALVE CONTROL	METER TEMP.	
10	TURN ON HOT AIR BLOWER	IND-G	
11	TURN ON COOLING WATER (BLOWER) SOLENOID	IND-G	
12	TURN ON COOLING WATER (CONCENTRATOR) SOLENOID	IND-G	
13	TURN ON COOL AIR BLOWER. DO NOT EXCEED 649 ⁰ C ON HEAT EXCHANGER - ADJ BLOWER VALVE CONTROLS	IND-G TEMP.M	
14	WHEN T = 650 ⁰ C GRADUALLY OPEN HOT AIR BLOWER VALVE TO HEAT RECEIVER	T=650 ⁰ C	
15	WHEN T=650 ⁰ C TURN GAS SOLENOIDS OFF RETURN VALVE CONTROL TO CLOSED POSITION	IGN-OFF IND-CLOSED	
16	OPEN SHUTTER		
17	NOW IN <u>OPERATE</u> CONDITION		

NOTE

USE COOL AIR VALVE CONTROLS AND HOT AIR VALVE
CONTROLS TO CONTROL TEMPERATURE OF RECEIVER AND
HEAT EXCHANGER AND TO VARY MASS FLOW

TABLE 4-2
TURN-OFF PROCEDURE

STEP		INDICATOR	CHECK
1	CLOSE SAFETY SHUTTER		
2	OPEN COOL AIR VALVE FULLY OPEN		CONTROLLER
3	MONITOR ΔP METER - ADJ HOT AIR BLOWER CONTROLS TO MAINTAIN LESS THAN H_2O		ΔP METER
4	WHEN $T=260^{\circ}C$ OR LESS		
	a. SHUT OFF HOT AIR BLOWER	IND-OUT	
	b. SHUT OFF COOL AIR BLOWER	IND-OUT	
	c. RETURN HOT AIR CONTROL VALVE TO CLOSED	CONTROLLER	
	d. RETURN COOL AIR CONTROL VALVE TO CLOSED	CONTROLLER	
	e. SHUT OFF WATER SOLENOIDS	IND-OUT	
5.	TURN OFF TOWER POWER 440V		
	TURN OFF TOWER POWER 115V		
	SYSTEM IS NOW OFF		

4.2.2 Receiver Platform

The control panel contains all the signals, meters and control functions needed to operate the three independent assemblies on the receiver platform. These controls are grouped on the control console according to the assemblies they operate (see Figure 4-2 and Table 4-3). Power switches are located on the top of the console and must be turned on before any other operation can be performed.

The cooling air assembly is controlled from the second chassis in the console. Start and stop switches operate the blower and a valve control regulates the airflow needed to maintain a set temperature for the receiver air. The temperature at the critical heat exchanger is displayed, as is the number of starts and running time on the heat exchanger.

Receiver operation is controlled from the third chassis of the console. Remote control of cooling water to the hot fan shaft and the concentrator is also provided. Mass flow through the receiver is maintained by setting the speed control of the hot fan motor. Inlet and outlet receiver temperatures are displayed to aid in setting airflow. Several other critical temperatures can be selected by the operator and displayed on a digital readout.

For calibration and soft start purposes, a hot gas burner assembly can be operated from the fourth chassis. This unit requires a rigidly specified startup procedure which functions automatically once the start button is pushed. Meters and lights keep track of the various steps in the startup and shutdown sequences.

All instrumentation needed in computing receiver performance is provided by the solar facility digital data logging and computing system.

Preliminary procedures for turn on and off are presented in Tables 4-1 and 4-2.

TABLE 4-3
CONTROL PANEL INSTRUMENTATION

ASSEMBLY	ITEM	INSTRUMENTATION
Burner	Combustion air blower	ON-OFF switch, pilot light
	Combustion air valve	Open-close switches, open-close light
	Purge start	Pilot light
	Purge end	Pilot light
	Gas valve	Open-close switches, open pilot light
	Fuel valve controller	Meter, control switch
	Outlet temperature	Meter
	Air pressure	Meter
	Gas pressure	Meter
	Ignition	ON-OFF switch, pilot light
Cool Air	Over temperature	Alarm and pilot light
	Fan Motor	ON-OFF switch, pilot light
	Controller	ON switch, temperature adjust meter, mode switches
	Valve position	Open-closed
Receiver	Automatic manual mode	Pilot light
	Hot fan	ON-OFF switch, pilot light
	Valve position	Open-closed
	Controller	ON switch, meter, flow control, mode switch
	Automatic or manual mode	Pilot light

TABLE 4-3
CONTROL PANEL INSTRUMENTATION (Continued)

<u>ASSEMBLY</u>	<u>ITEM</u>	<u>INSTRUMENTATION</u>
	Temperature in	Meter
	Temperature out	Meter
	Cooling water to bearings	ON light, ON-OFF switch
	Cooling water to concentrator	ON light, ON-OFF switch
	Temperature at heat exchanger	Meter
4	Over temperature	Alarm, light
	Elapsed time indicator	Meter
	Number of hot starts	Meter
	Cooling water to bearings	ON light ON-OFF switch
	Cooling water to concentrator	ON light ON-OFF switch
	Temperature at heat exchanger	Meter
	Over temperature	Alarm, light
	Elapsed time	Meter
	Number of hot starts	Meter

SECTION 5 REQUIRED SUPPORT FACILITIES

Sanders will provide all the instrumentation and associated calibration data for the receiver and all controls for operating the solar receiver. All recorded data such as temperatures and pressures will be sent to the facility data logging equipment for processing, recording and display. Sanders understands that measurement requirements for insolation will be provided by GIT. "First-look" data reduction will also be provided and displayed in real time at the control center by the facility data logging equipment.

A separate control panel is connected to the receiver platform by about 80 meters of cable which carries all instrumentation, control signals, and controls for operating the receiver system. Sanders will provide two cables for insertion into the tower facility conduits: one contains all power lines and control and the other contains low voltage sensor lines. The only connection for electrical power will be on the tower at the fixed electrical distribution box.

There is a limitation of approximately 30 meters on the length of cable which connects the IR cameras to their respective displays. Accordingly, a "bomb shelter" is needed at the base of the tower large enough to house three or four people and a table containing two video displays. Communication between the control room tower platform and the shelter is also needed.

Sanders will need space on the ground near the tower where the complete system can be assembled and checked out using all facilities; water, power, and gas, but not necessarily data logging equipment.

SECTION 6 PERSONNEL

Sanders will provide one or two technicians and a research engineer for the total test period. These people will be responsible for the operation of all the Sanders equipment. Sanders expects Georgia Tech personnel to calibrate and operate the facility. The reduction of all insolation data, data logging, and programming and display of data are also the responsibility of GIT.

SECTION 7

TEST PLAN

7.1 TEST AT SANDERS ASSOCIATES, INC.

The program at Sanders is for the checkout and calibration of all the equipment to be sent to Georgia Institute of Technology. In addition, tests will be performed at temperatures in excess of 540°C in order to verify performance at elevated temperatures.

The following is a tentative schedule of runs to be made:

- Cooling air system operation
 - check for leaks
 - check airflow controls
 - calibrate airflow
- Hot air system operation
 - check gas supply valves
 - check for leaks
 - check airflow volume and pressure drop
 - check temperature adjustment
 - check safety features
 - connect to cooling air system and calibrate temperature controls
- Receiver assembly operation
 - check hot fan over flow (cold) range
 - add heated air and check operation
 - set inlet temperature at 540°C and measure airflow, air temperature, heat losses
 - calibrate airflow
 - check for leaks
 - check instrumentation

- check controller operation
- measure time constant for system
- measure heat loss with and without an open cavity over the range of inlet air temperatures from 480°C - 650°C and airflows of 0.35, 0.45, 0.55 kg/sec

7.2 TEST AT GEORGIA INSTITUTE OF TECHNOLOGY

Phase I - Calibration

a. Calibrate three mirror field configurations designated by Sanders as:

1. 50% (nominal 96 w/cm² at aperture, -12 cm below focal plane)
2. 75% (nominal 135 w/cm² at aperture, -12 cm below focal plane)
3. 100% (nominal 180 w/cm² at aperture, -12 cm below focal plane)

with flux rake located at the 0 and R positions of Figure 7-1.

b. Measure flux distribution at three additional stations, with mirror field configuration No. 3 (see Figure 7-1).

1. Plane of concentrator entrance - 18.54"
2. Plane of aperture - 4.76". Install terminal concentrator and Sanders flux rake
3. Vertical plane of ceramic matrix simultaneously with "R" position at several times throughout the day.

7-3

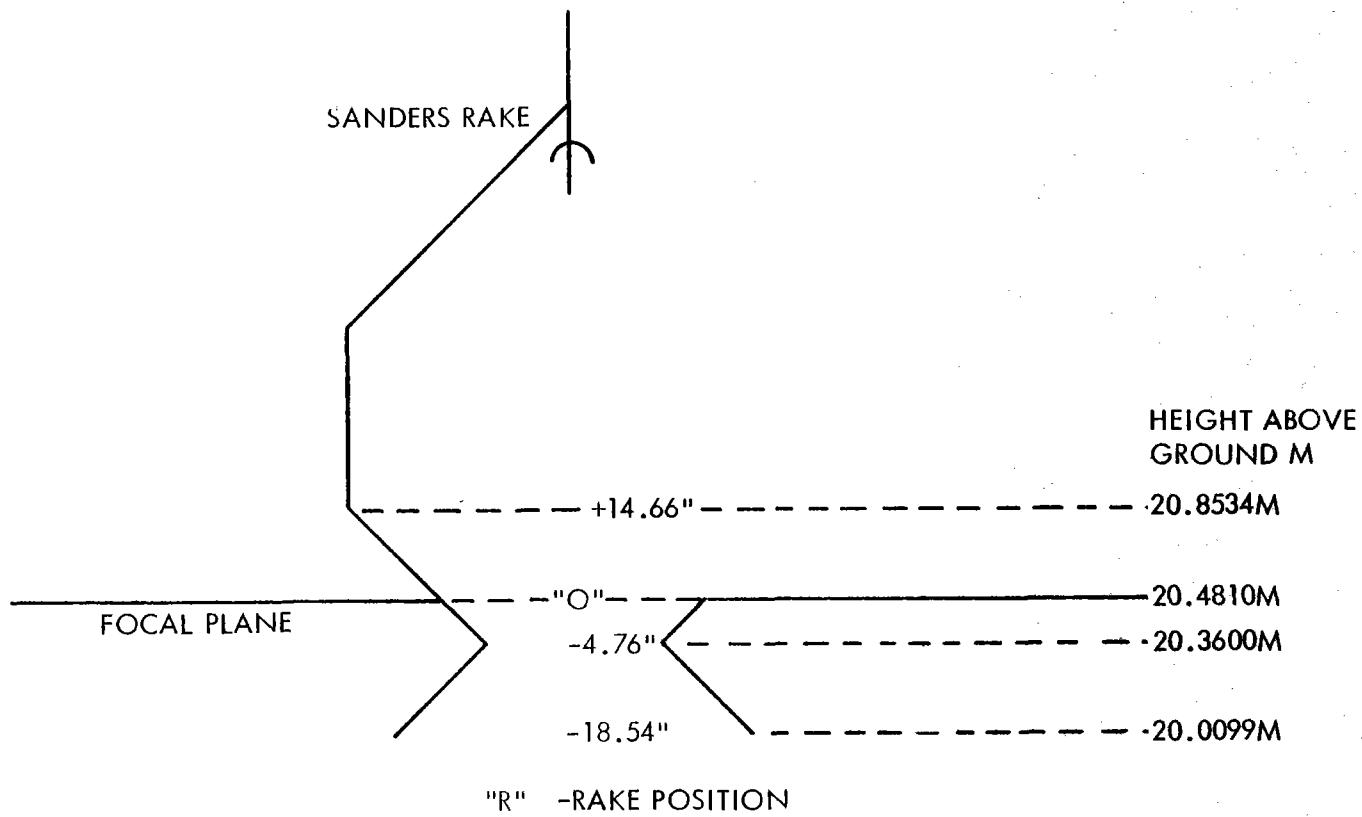


Figure 7-1. Flux Calibration Positions

Phase II - Determine Effect of Design Parameters on Efficiency

Set			Measure			
Mirror Plan	$T_{in} (^{\circ}C)$	W_a (kg/sec)	T_{out}	Ins.	ΔP_s	$T_1 ---- T_h$
1	500	0.35				
	550					
	600					
	650					
	700					
2	500	0.35 0.45				
	550					
	600					
	650					
	700					
3	500	0.35 0.45 0.55				
	550					
	600					
	650					
	700					
3	T_{in}	T_{out}	W_a	Ins.	ΔP_s	$T_1 ---- T_h$
	700	$1100^{\circ}C$		T_{out}	Ins.	ΔP_s

As required, repeat Item C-9 in Section 7.1 to measure convective and conductive heat losses of the system.

Phase III - Analyze Limits of Performance

Set			Measure
Mirror Plan	T_{in}	$^{\circ}C$	T_{out}
			$^{\circ}C$
Modified			IR Profiles, W_a , Ins., ΔP , T_1 --- T_h
C	700		1100

Display in real time (4 minute increments or less), the following performance parameters:

- mass flow - lb/sec
- inlet air temperature - $^{\circ}F$
- outlet air temperature - $^{\circ}F$
- power in - W
- efficiency - %
- ΔP at Station 3 - inches H_2O

7.3 DATA REDUCTION

7.3.1 Total Flux Determination

For the sake of error analysis, an algorithm for the total flux input to the receiver as a function of the HYCAL calorimeter readings and their displacements is provided. Calibration data received from the manufacturer is presented in Appendix I along with the appropriate correction coefficients.

At the recommended 5° reading interval, at the design rate of 80 seconds for full scan, each calorimeter will represent at most a 2° smear, which is judged not serious. If a check at a lower scan rate shows no significant difference, then we can reliably use the design rate for further measurements. With the .1% linearity, .01% repeatability of the monitor helipot, keeping $\Delta\theta_i$ to the suggested 5° is expected to be straightforward.

Since all the dimensions are assumed as in the design, the tolerances allowed on delivery will determine whether we can maintain a nominal 1% for this overall measurement. Note that errors in the local incremental area (which are 2 x linear dimension tolerances) are multiplied by an outside limit of $f_{MAX}/f_{AVERAGE}$ in the overall flux determination. Thus, with the present design of $f_{MAX}/f_{MIN} = 3:1$ (to be verified by the maps resulting from this experiment), $f_{MAX}/f_{AVERAGE} \sim 1.73$. Thus, the maximum error is $2 \times 1.73 \times \delta 1$. To be sure of a 1% error in total flux, we must have all linear dimensions within 0.3%. At the maximum radius of 24.9", this implies a 0.075" dimensional measurement accuracy.

- Quantities for use in program, as based on Figure 7-2.

$$S_i = \text{array}$$

$$S_1 = 0$$

$$S_2 = 4.750$$

$$S_3 = 2 \times 4.750 = 9.5000$$

$$S_4 = 3 \times 4.750 = 14.2500$$

$$S_5$$

$$S_{16}$$

$$S_{17} = 8 \times 5.312 = 42.4960$$

$$\Delta S_i = \text{array}$$

$$\Delta S_1 = 2.24 + \frac{4.750}{2} = 4.6150$$

$$\Delta S_2 = 4.750$$

$$\Delta S_3 = 4.750$$

$$\Delta S_4 = \frac{4.750}{2} + .9756 = 3.3506$$

$$\Delta S_5 = .83 + \frac{1.940}{2} = 1.8000$$

$$\Delta S_6 \\ \Delta S_{15} \} = 1.940$$

$$\Delta S_{16} = \frac{1.940}{2} + .83 = 1.8000$$

$$\Delta S_{17} = 1.184 + \frac{5.312}{2} = 3.8400$$

} not used
in algorithm

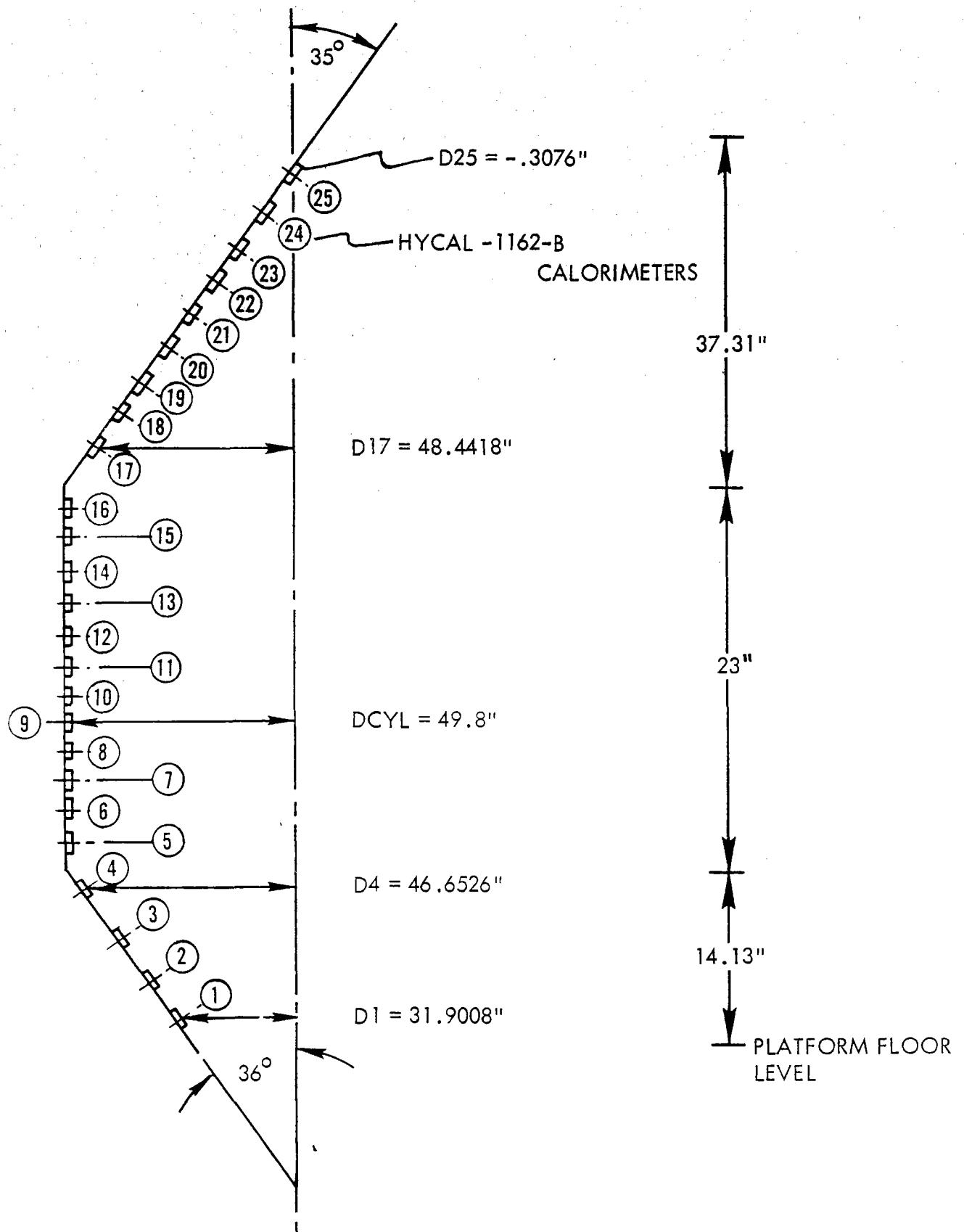


Figure 7-2. Sensor Locations

$$\begin{aligned}
 S_{18} &= 7 \times 5.312 = 37.1840 & \Delta S_{18} \\
 S_{19} &= 6 \times 5.312 = 31.8720 \\
 S_{20} &= 5 \times 5.312 = 26.5600 \\
 S_{21} &= 4 \times 5.312 = 21.2480 \\
 S_{22} &= 3 \times 5.312 = 15.9360 \\
 S_{23} &= 2 \times 5.312 = 10.6240 \\
 S_{24} &= 5.312 & \Delta S_{24} \\
 S_{25} &= 0 & \Delta S_{25} = \frac{5.312}{2} + 1.87 = 4.526
 \end{aligned}$$

$$D_1 = 2 * [24.9 - (0.976 + (3 * 4.750)) * \sin 36^\circ] \approx 31.9008$$

$$D_4 = 2 * (24.9 - 0.976 * \sin 35^\circ) \approx 46.6526$$

$$D_{CYL} = 24.90 \times 2 = 49.8000$$

$$D_{17} = 2 * (24.9 - 1.184 * \sin 35^\circ) \approx 48.4418$$

$$D_{25} = 2 * [24.9 - (1.184 + 8 \times 5.312) * \sin 35^\circ] \approx -.3076$$

$\Delta\theta_K$ = constant for all K, suggest $5^\circ = .08727$ radians

$N = \frac{2\pi}{\Delta\theta} = 72$ = number of angle readouts in sweep

(N should be an integer)

$$\frac{D_4 - D_1}{S_4 - S_1} \approx 2 * \sin 36^\circ, \quad \frac{D_{25} - D_{17}}{S_{25} - S_{17}} = 2 * \sin 35^\circ$$

$$= 1.1756 \qquad \qquad \qquad = 1.1472$$

- Algorithm for total flux in terms of calorimeter readings and dimensions.

$$\dot{Q}_{IN} = \frac{1}{144 \times 2} \sum_{\substack{i=1 \\ K=1}}^{K=N} f_i(\theta_K) * (D_1 + \frac{D_4 - D_1}{S_4 - S_1} * S_i) \Delta S_i \Delta \theta_K$$

$$+ \frac{144}{144 \times 2} \sum_{\substack{i=5 \\ K=1}}^{i=16} f_i(\theta_K) * D_{CYL} * \Delta S_i * \Delta \theta_K$$

$$+ \frac{1}{144 \times 2} \sum_{\substack{i=16 \\ K=1}}^{K=N} f_i(\theta_K) * (D_{25} + \frac{D_{25} - D_{17}}{S_{25} - S_{17}} * S_i) \Delta S_i \Delta \theta_K$$

Units

Flux values should be in BTU/sec-ft² to get \dot{Q}_{IN} in BTU/sec.

Cross Check

Set all $f_i(\theta_K) = 1$. Should get \dot{Q}_{IN} numerically equal to surface area in ft². A hand calculation gives 63.64 ft² for use in comparison with computer test runs.

NOTE

If θ_K values are well controlled so that $\Delta\theta_K$ values are all within 1%, the $\Delta\theta_K$ constant may be factored out of all three sums.

7.3.2 Data Reduction

Test data will be entered on a disc at the end of each day. A 300 BAUD phone line will write a tape at the campus computer center. This tape, when completed, will be read back and compared with the disc before any erasure of the disc data. Sanders will have a copy of this tape for later data analysis.

On-line processing will be performed directly from the disc by the computer located in the control center. The present inputs to on-line data reduction are:

- Energy input - This quantity is to be obtained from the pyroheliometer reading plus a correction factor obtained from the most recent calorimeter data. With the 3% accuracy, 0.5% repeatability of the calorimeters, this quantity dominates the overall measurement error.
- Static pressure (P_{s3}) - Barometric pressure to be supplied by facility instrumentation in units of lb/ft^2 .
- Dynamic pressure (P_{d3}) - The measuring instrument provides inches H_2O on a 0-10V scale. Its calibration needs multiplication by 5.200 to convert to lb/ft^2 (see Table 4-1 for sensor list).
- Temperatures (T_{t1}, T_{t2}, T_{t3}) - See Table 7-1 for sensor listings.

TABLE 7-1a
INSTRUMENTATION SENSORS - THERMOCOUPLES (REVISED 6/14/78)

STATION	DESCRIPTION	REFERENCE	DESCRIPTION	MAX SIGNAL MV	RESOLUTION	TEMPERATURE
1	RECEIVER INLET	150° F	TC-1 N	33.913	.01%	1500° F
	$T_{t1} = \frac{(TC-1)+(TC-2)}{2}$	150° F	TC-2 S	33.913	.01%	1500° F
		150° F	TC-3 E	26.975	.01%	1800° F
2	RECEIVER OUTLET	150° F	TC-4 S	53.000	.01%	2400° F
	$T_{t2} = \frac{(TC-4)+(TC-5)}{2}$	150° F	TC-5 N-S	53.000	.01%	2400° F
		TC-3	TC-6 E-W	26.975	.01%	1800° F
3	HOT AIRFLOW	150° F	TC-7 WALL	33.913	.01%	1500° F
	$T_{t3} = (TC-8)$	150° F	TC-8 C	33.913	.01%	1500° F
6	HEAT × AIR INLET	150° F	TC-9	22.666	.01%	150° F
		150° F	TC-10	2.666	.01%	150° F
7	HEAT × AIR OUTLET	150° F	TC-11	33.913	.01%	1500° F
		150° F	TC-12	33.913	.01%	1500° F
8	HEAT × TUBE	150° F	TC-13	53.000	.01%	1500° F
		150° F	TC-14	53.000	.01%	1500° F
9	HONEYCOMB	150° F	TC-15-34	53.000	.01%	2400° F
10	COOLING AIR	150° F	TC-35	53.00	.01%	150° F

(1) IR Camera with spectral filter 2.75μ-2.85μ

* TDIF (direct reading)

TABLE 7-1b
INSTRUMENTATION SENSORS - PRESSURE TRANSDUCERS

<u>STATION</u>	<u>DESCRIPTION</u>	<u>TYPE</u>	<u>DESIGNATION</u>	<u>MAX SIGNAL</u>	<u>RESOLUTION</u>	<u>MAX PRESSURE</u>	
1	RECEIVER INLET	N	LFE	PS-1	60 mv	1%	0-20" H ₂ O
		S	LFE	PS-2	60 mv	1%	0-20" H ₂ O
		E	LFE	PS-3	60 mv	1%	0-20" H ₂ O
		W	LFE	PS-4	60 mv	1%	0-20" H ₂ O
2	RECEIVER OUTLET	N	LFE	PS-5	60 mv	1%	0-20" H ₂ O
		S	LFE	PS-6	60 mv	1%	0-20" H ₂ O
		E	LFE	PS-7	60 mv	1%	0-20" H ₂ O
		W	LFE	PS-8	60 mv	1%	0-20" H ₂ O
3	HOT AIRFLOW	LFE	PS-9	60 mv	1%	0-20" H ₂ O	
	P _{S3} = PS-9	MKS	PS-10	10 v	0.1%	0-10" H ₂ O	
		MKS	PT-11	10 v	0.1%	0-10" H ₂ O	
	P _{D3} = PT-(11)+(12)+(13)	MKS	PT-12	10 v	0.1%	0-10" H ₂ O	
		MKS	PT-13	10 v	0.1%	0-10" H ₂ O	
	P _{t3} = P _{S3} +P _{D3}						
4	COOLING AIR INLET	LFE	PS-14	60 mv	1%	0-20" H ₂ O	
		LFE	PS-15	60 mv	1%	0-20" H ₂ O	
		LFE	PS-16	60 mv	1%	0-20" H ₂ O	
5	BURNER AIR INLET	LFE	PS-17	60 mv	1%	0-20" H ₂ O	
		LFE	PS-18	60 mv	1%	0-20" H ₂ O	

7-12

TABLE 7-1b
INSTRUMENTATION SENSORS - PRESSURE TRANSDUCERS (Continued)

PRESSURE TRANSDUCERS

<u>STATION</u>	<u>DESCRIPTION</u>	<u>TYPE</u>	<u>DESIGNATION</u>	<u>MAX SIGNAL</u>	<u>RESOLUTION</u>	<u>MAX PRESSURE</u>
6	WIND N	LFE	PT-17	60 mv	1%	0-20" H ₂ O
	WIND E	LFE	PT-18	60 mv	1%	0-20" H ₂ O
	WIND S	LFE	PT-19	60 mv	1%	0-20" H ₂ O
	WIND W	LFE	PT-20	60 mv	1%	0-20" H ₂ O
7 7-13	HEAT EXCHANGER HOT FLOW	LFE	PS-21	60 mv	1%	0-20" H ₂ O
		LFE	PS-22	60 mv	1%	0-20" H ₂ O
		LFE	PS-23	60 mv	1%	0-20" H ₂ O
		LFE	PS-24	60 mv	1%	0-20" H ₂ O
			PS-25	60 mv	1%	0-20" H ₂ O

- Temperature difference - Because of the strong position of the difference $(T_{t2} - T_{t1})$ = TDIF in the error propagation formulas, direct measurement of this quantity, independently of T_{t2} and T_{t1} is valuable (see Table 7-1 for sensor listings). The formulas used in the data reduction are listed in Table 7-2. For formulas 2, 3, 5, $R = 53.48$ matches tabulated values for air very closely. For 3 and 5, $g = 32.17$.

TABLE 7-2. PREFERRED DATA FORMULAS

 lb/ft²

$$(1) P_{t3} = P_{s3} + P_{d3}$$

 $g = 32.17$
 $R = 53.48$
 $P \text{ in } lb/ft^2 = 70.58 \times "Hg = 5.200 \times "H_2O$

 lb/ft³

$$(2) \rho = \frac{P_{t3}}{RT_{t3}}$$

All T Values in °R

 ft³/sec

$$(3) V = \sqrt{\frac{2P_{d3} T_{t3} g R}{P_{t3}}}$$

$$c_p = 0.219 + \frac{0.342}{10^4} T_{t3} - \frac{0.293}{10^8} T_{t3}^2$$

$$(4) M = \sqrt{\frac{2}{\gamma} \frac{P_{d3}}{P_{t3}}}$$

$$(4a) \left\{ \begin{array}{l} \gamma = \frac{1}{1-R/Jc_p} \\ R/J = 0.068552 \end{array} \right.$$

lb/sec

$$(5) \dot{m} = A \sqrt{\frac{2g}{R} \frac{P_{d3} P_{t3}}{T_{t3}}} \left\{ 1 + \frac{\gamma - 1}{\gamma} \frac{P_{d3}}{P_{t3}} \right\} \frac{1}{2} \frac{1 + \gamma}{1 - \gamma}$$

BTU/lb

$$(5) H_1 = T_{t1} \left[0.219 + T_{t1} \left[\frac{0.324}{2 \times 10^4} - \frac{0.293}{3 \times 10^8} T_{t1} \right] \right]$$

BTU/lb

$$(7) H_2 = T_{t2} \left[0.219 + T_{t2} \left[\frac{0.342}{2 \times 10^4} - \frac{0.293}{3 \times 10^8} T_{t2} \right] \right]$$

BTU/lb

(8)

$$\Delta H = H_2 - H_1 = (T_{t2} - T_{t1}) \left[0.219 + \frac{0.342}{2 \times 10^4} (T_{t2} + T_{t1}) - \frac{0.293}{3 \times 10^8} (T_{t2}^2 + T_{t2} T_{t1} + T_{t1}^2) \right]$$

BTU/sec

$$(9) Q_{out} = \dot{m} \Delta H$$

$$(10) n = \frac{\dot{m} \Delta H}{Q_{in}}$$

Sample Calculation

$$\text{INLET TEMP} = \frac{1140.5}{(t_{t1}-459.7)} \text{ DEG F, } = \frac{1600.2}{T_{t1}} \text{ DEG R, } = \frac{616.0}{(5T_{t1}/9-273)} \text{ DEG C, T1}$$

$$\text{OUTLET TEMP} = \frac{2000.7}{(T_{t2}-459.7)} \text{ DEG F, } = \frac{2459.7}{T_{t2}} \text{ DEG R, } = \frac{1093.5}{(5T_{t2}/9-273)} \text{ DEG C, T2}$$

$$\text{FLOW TEMP} = \frac{1196.1}{(T_{t3}-459.7)} \text{ DEG F, } = \frac{1655.8}{T_{t3}} \text{ DEG R, } = \frac{646.89}{(5T_{t3}/9-273)} \text{ DEG C, T3}$$

$$\text{OUT-IN TEMP} = \frac{859.0}{(TDIF)} \text{ DEG F, } = \frac{477.22}{(5*TDIF/9)} \text{ DEG C, TDIF}$$

$$\text{STATIC PRESSURE} = \frac{2116.0}{(P_{s3})} \text{ LB/FT}^2, = \frac{101325}{(47.88*P_{s3})} \text{ N/M}^2, = \frac{0.977 \text{ ATM}}{(P_{s3}/2116)}, P_{s3}$$

$$\text{DYNAMIC PRESSURE} = \frac{52.1}{(P_{d3})} \text{ LB/FT}^2, = \frac{250.3}{(47.88*P_{d3})} \text{ N/M}^2, \frac{.0267}{(P_{d3}/2116)},$$

ATM, PD2

(1)

$$\text{TOTAL PRESSURE} = \frac{2121.12}{(P_{t3})} \text{ LB/FT}^2, = \frac{101559.2}{(47.88*P_{t3})} \text{ N/M}^2, = \frac{0.97945}{(P_{t3}/2116)},$$

ATM, PT2,

(2)

$$\text{DENSITY} = \frac{0.2395}{(\text{RHO})} \text{ LB/FT}^3, = \frac{.38404}{(16.033 \text{ RHO})} \text{ KG/M}^3, \text{ RHO}$$

(3)

$$\text{VOLUME FLOW} = \frac{374.09}{(\text{VDOT})} \text{ FT}^3/\text{SEC}, = \frac{10.594}{(\text{VDOT}/35.31)} \text{ M}^3/\text{SEC}, \text{ VDOT}$$

(4)

$$\text{MACH NO.} = \frac{.2196}{(\text{MACH})}, \text{ MACH (see footnote (t))}$$

(4a)

$$\text{GAMMA} = \frac{1.01869}{(\text{GAMMA})}, \text{ GAMMA (see footnote (tt))}$$

(5)

$$\text{MASS FLOW} = \frac{1.31222}{(\text{MDOT})} \text{ LB/SEC}, = \frac{0.59575}{(0.454*\text{MDOT})} \text{ KG/SEC}, \text{ MDOT}$$

(6)

$$\text{ENTHALPY IN} = \frac{387.92}{(\text{H1})} \text{ BTU/LB}, \frac{901458}{(2323.8*\text{H1})} \text{ JOULES/KG}, \text{ H1}$$

(7)

$$\text{ENTHALPY OUT} = \frac{622.15}{(\text{H2})} \text{ BTU/LB}, = \frac{1445757}{(2323.8*\text{H2})} \text{ JOULES/KG}, \text{ H2}$$

(8)

$$\text{ENTHALPY DIFF} = \frac{237.23}{(\text{HDIF})} \text{ BTU/LB}, = \frac{551276}{(2323.8*\text{H2})} \text{ JOULES/KG}, \text{ HDIF}$$

(Note: This differs from 7-6. See DIF in 8)

tA (see 5) is taken as .14823 ft² for this sample calculation. Proper value will be determined after calibration test at Sanders. As default, use .7854 ft².

tt C_P = .2676

• FROM LAST CALIBRATION/PYRHELIOMETER COMBINATION

$$Q_{IN} = \frac{363.61}{(Q_{IN})} \text{ BTU/SEC, } = \frac{344.65}{(Q_{IN}/1.055)} \text{ KW, } Q_{IN}$$

(9) $Q_{OUT} = \frac{311.298}{(Q_{OUT})} \text{ BTU/SEC, } = \frac{295.069}{(Q_{OUT}/1.055)} \text{ KW, } Q_{OUT}$

(10) EFFICIENCY = $\frac{.85613}{(Q_{OUT}/Q_{IN})}$, ETA

Symbols

A - duct area (ft^2)
g - gravitational constant ($1\text{b}_m\text{-ft}/1\text{b}_f\text{-sec}^2$)
H - enthalpy (BTU/lb)
M - mach number
 \dot{m} - mass flow rate ($1\text{b}_m/\text{sec}$)
P - pressure ($1\text{b}_f/\text{ft}^2$)
Q - heat rate (BTU/hr)
R - specific gas constant ($1\text{b}_f\text{-ft}/1\text{b}_m\text{-}^0\text{R}$)
T - temperature (^0R)
V - velocity (ft/sec)
 γ - isentropic exponent for air
 η - receiver efficiency
 ρ - air density ($1\text{b}_m/\text{ft}^3$)

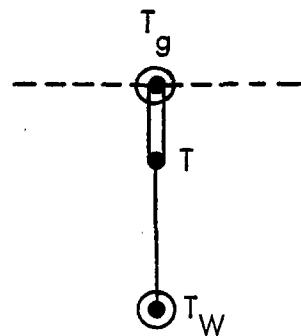
Subscripts

t₁, t₂, t₃ Total conditions at stations no. 1, 2, 3
s₁, s₂, s₃ Static conditions at stations no. 1, 2, 3
d₁, d₂, d₃ Dynamic conditions at stations no. 1, 2, 3
1, 2, 3...N Instrument numbers
IN Inlet conditions
OUT Outlet conditions

7.4 ERROR ANALYSIS

Included in the error analysis are the factors which contribute to errors, temperatures, pressure, area and solar flux.

Simple Form



$$T = \frac{h A_{t.c.} T_g + \frac{K A_x}{L} T_w}{h A_{t.c.} + \frac{K A_x}{L} T_w}$$

$$= T_g (1-n) + T_w n$$

$$\text{with } n = \frac{\frac{K A_x}{h A_{t.c.} L}}{\frac{K A_x}{h A_{t.c.} L} + 1}$$

Where:

T = thermocouple reading

T_g = gas temperature

T_w = wall temperature, which causes deviation of T from T_g if not equal to T_g

L = length of thermocouple leads

A_x = cross section of thermocouple leads/sheath

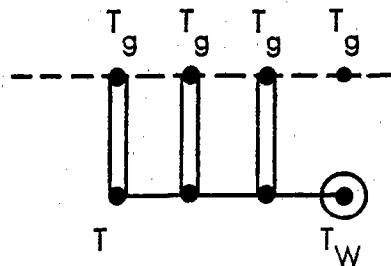
A_{t.c.} = surface area of thermocouple and/or sheath exposed to and sensitive to gas pressure

n = "conduction effectiveness" of thermocouple leads

Improved Form

Though harder to derive, a form in general use, and easy to justify, as well as leading to smaller corrections, is

$$T = T_g (1-\eta) + T_w \eta$$



$$m = \sqrt{\frac{hp}{KA_x}}$$

p = perimeter of sheath exposed
to gas temperature

L = length of leads/shield from
wall to thermocouple

$$\eta = \frac{\tanh mL}{mL}$$

Sample Numbers

$h \sim 7 \text{ BTU/h ft}^2$ (typical of exposure to 30 FPS flow velocity)

$$p = \pi \times \frac{0.0625}{12} = 0.01636 \text{ ft}$$

$$A_x = 2 \times \frac{\pi}{4} \times \left(\frac{.01}{12}\right)^2 + \pi \times \frac{0.0625}{12} \times \frac{0.010}{12} = 1.473 \times 10^{-5} \text{ ft}^2$$

$K \sim 10$ average for inconel ($K=7.5$) with 1/5 the area in highly conductive leads ($K=100$)

$$m = 27.9$$

L Inches	η
3	.1435
6	.0717
12	.0359
18	.0239

With

$$\eta = .0717$$

$$T_g = 2460^{\circ}\text{R}$$

$$T_w = 2260^{\circ}\text{R}$$

$$\begin{aligned} T &= 2460 (1 - .0717) + 2260 (.0717) \\ &= 2445.66 \end{aligned}$$

error in T_g as measured by T is

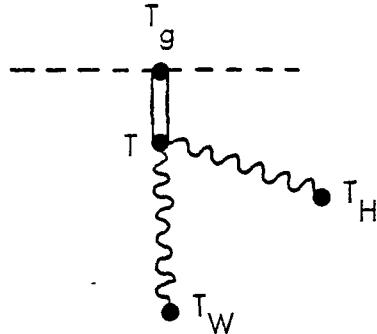
$$\varepsilon = 2460 - 2445.66 = 14.3^{\circ}$$

percent error

$$\delta\varepsilon = \frac{14.3}{2460} \times 100 = 0.58\%$$

In summary, 6" lead length or more insures conduction error is less than 0.6% when wall temperatures are as much as 200° below T_g .

Radiation Correction



General

$$\begin{aligned} T &= WAT_g + \sigma\varepsilon A \left\{ \frac{F_{t-w} \overline{(T_w^2 + T^2)} \overline{(T_w + T)}}{T_w + F_{t-h} \overline{(T_h^2 + T^2)} \overline{(T_h + T)} T_h} \right\} \\ &\quad \div hA + \sigma\varepsilon A \left\{ F_{t-w} \overline{(T_w^2 + T^2)} \overline{(T_w + T)} \right. \\ &\quad \left. + F_{t-h} \overline{(T_h^2 + T^2)} \overline{(T_h + T)} \right\} \end{aligned}$$

Assumptions

- Emissivities at wall, W, and at hot spot, H, greatly exceed value ϵ at thermocouple
- \bar{T} is a non-critical average value of T, which may be guessed with broad tolerance in calculating T and its relation to T_g .

In present experiment, there is no significant area at T_h .

Using the form

$$T = T_g (1 - \eta_R) + T_w \eta_R$$

for the radiation correction, and defining m_R and η_R as follows

$$m_R = \frac{\sigma \epsilon F (T_w^2 + T^2)}{h} \frac{(T_w + T)}{(T_w + T)}$$

$$\eta_R = \frac{m}{1+m}$$

$$m = \frac{1.73 \times 10^{-9} \times .3 \times 1.0}{7} \times \frac{(2460^2 + 2460^2)}{(2460 + 2460)}$$

$$= \frac{4.42}{7} = .63$$

$$\eta_R = .38$$

Since

$$\frac{\delta T}{T} = \frac{T_w - T_g}{T_g} \eta_R$$

Then

$$\frac{\delta T}{T} = < .5\% \text{ if } T_w - T_g < \frac{T_g}{\eta} (\frac{\delta T}{T}) = 32^0$$

When a larger temperature difference occurs, either a radiation shield or a suitable adjustment for T_w in data reduction will be needed.

$$T_g = \frac{T - \eta_R T_w}{1 - \eta_R} \sim T + \eta_R (T - T_w) + \dots$$

In summary, the thermocouples will be so located that they can not directly view either the solar flux or solar heated parts of the receiver.

Within the limits of the above analysis, we expect a temperature error to be primarily random, of $\pm 15^0$, or 0.6% in the absolute temperature. For the temperature difference, $T_2 - T_1$, which requires no reference junction, $\pm 4^0$ or 0.2% of the difference is the expected error.

Pressures

The critical values of dynamic pressures will all be measured with instruments rated to $\pm 0.1\%$. The static pressure will be measured as the barometric pressure, probably to far better than 0.1%.

Cross Sectional Area

While random errors in area can be kept under 0.2% with reasonable caution (based on $\pm .010$ inch dimensions), the systematic error in this quantity will dominate (to be discussed).

Energy Flux Input

The basic random error of the HYCAL calorimeters is stated at 0.5%. Since the flux measurement is not at the desired location (at the mouth of the receiver aperture), and must be referred to another flux measurement made during a separate calibration phase, a $\pm 0.7\%$ repeatability or random error is the best that can be assigned to this measurement.

Systematic Errors

Temperature - None are expected if the probes are properly placed following preliminary experiments, and if radiation and lead conduction corrections can be safely ignored, as discussed above under random errors, and by the theoretical results of the Appendix.

Pressure - No significant systematic errors are expected in pressure as read at the probe. For the assumed mass flow formula, error will result from the fact that the pressure profile will be inhomogeneous across the duct. An independent calibration experiment is planned to calculate the mass flows based on the observed profile of dynamic pressure. Discrepancies from the assumed formula will be resolved by: (a) choice of the point at which pressure will be measured during (non-calibration) runs, and (b) use of an effective value for cross sectional area differing from the true dimensions. This will, crudely, account for the ineffectiveness of the boundary layer zone in the mass flow formula.

Since the velocity profile depends on the square root of the measured pressures, the pressure profile accuracy is improved by a factor of 2. Since, however, the measurement depends on a separate calibration, the random error or repeatability is degraded. We anticipate at 3% consistency in pressure probe measurement and averaging, thus a $\pm 1.5\%$ mass flow systematic error. A repeatability of $\pm 0.5\%$ is expected to provide a generous allowance for the random errors in the separate calibration.

Energy Flux Input

The calibration accuracy of $\pm 3\%$ for the calorimeters, based on the best NBS traceable calibration available, imposes the strongest limit on the overall experimental accuracy.

Error Propagation Formulas

Outside Limit Form:

$$\delta\eta = \delta Q_{in} + 1/2 \left(\delta P_{d3} + \delta P_{s3} + \delta T_3 \right) + \delta(T_2 - T_1) + \delta A$$

Gaussian Form

$$\sigma\eta = \sqrt{\sigma Q_{in}^2 + 1/4 \left(\sigma P_{d3}^2 + \sigma P_{s3}^2 + \sigma T_3^2 \right) + \sigma(T_2 - T_1)^2 + \sigma A^2}$$

Numerical Values

Using the random errors, discussed above in the Gaussian error propagation, we get a repeatability for the experiment as follows:

$$\sigma_\eta = \sqrt{(.5)^2 + 1/4 (0.1^2 + 0.1^2 + .6^2) + (.2)^2 + (.2)^2}$$

= 0.65 percent repeatability

Using the outside limit form, we get a worst case repeatability of

$$\sigma_\eta = .5 + 1/2 (0.1 + 0.1 + 0.6) + 0.2 + 0.2$$

= 1.3 percent repeatability - worst case

For the systematic errors, where we can only justify use of the worst case error propagation, we must use the $\pm 3\%$ error inherent in the flux calibration - the best level for which NBS certification is available for light flux. We must also use the expected mass flow error of 1.5% in place of the cross sectional area of the duct (which is the quantity to be adjusted in the calibration experiment). Thus,

$$\sigma_\eta = 3.0 + 1/2 (0.1 + 0.1 + 0.6) + 0.2 + 1.5$$

= 5.1 percent error - systematic

Thus, we anticipate an overall measurement accuracy of $\pm 5\%$, repeatable to 0.7% in standard deviation to 1.3% as an outside limit.

SECTION 8

SAFETY

Factors of prime consideration in evaluating the safety of the receiver test program are the dangers arising from fires and exposure to hot parts. Propane gas for the heater is the only combustible material which will be on the tower. It will be supplied to the gas control system from a tank on the ground which maintains a pressurized flow of propane at 10 psig. Should a leak develop on the tower, the fuel supply can be shut off completely from the ground.

There is a danger to personnel working on the receiver before it has been properly cooled. Therefore, the cooling air system and the hot fan in the receiver assembly are used to cool parts prior to allowing workmen on the tower.

8.1 PRELIMINARY SAFETY STATEMENT

8.1.1 Gas - Fuel (Propane)

1. The gas (propane) tank at base of tower has a ten-pound pressure regulator and a manual shut-off valve.
2. The piping to the burner includes dual solenoid shut-off valves with a solenoid vent valve between.
3. Built into the gas control system are safety features which will cause burner shutdown and stop gas flow. They are as follows:
 - a. High gas pressure
 - b. Low gas pressure
 - c. Pilot failure to light
 - d. Over temperature
 - e. Burner or pilot light cannot be ignited until purge cycle is complete

NOTE

See attachment A for NFPA code summary.

8.1.2 Electrical

1. The 440V line is protected by heaters in magnetic contactors in all three (3) blower motor starters. 110V lines will be protected by fusing as required.
2. All electrical wiring will be in conduits.
3. All electrical equipment susceptible to weather will be housed in protective enclosures.
4. All electrical controls will be so interlocked that, in the event of a power failure, all systems shut down and will not self-start when power is returned.
5. All critical functions are monitored at Sanders' control panel by meters or indicators, and during operation indicate status of the system.
6. All power to Sanders' system (tower) will be controlled (ON/OFF) from a Sanders control console.
7. All power to Sanders' control console issues from the tower.

NOTE

This is relatively low current as it is used for controls and indicators only.

8. The control to defocus mirrors or close the shutter in the event of an emergency shutdown is to be provided by GIT.

9. There will be a written procedure/checklist detailing the startup, operate, and shutdown procedures. This checklist is to be followed step-by-step, and any deviation from the list is only to be by agreement between Sanders personnel and GIT personnel, except under emergency conditions.

ATTACHMENT A
NFPA CODE SUMMARY

NFPA CODE SUMMARY

Direct Fired Furnaces and Ovens:

- 1) Standard No. 86 applies to new, or alteration or extension of existing equipment. All equipment over 150,000 BTU/Hour is covered by this standard.
- 2) NFPA No. 86 is subdivided into three classifications:
 - Class A — Furnaces and ovens operating substantially at atmospheric pressure, and temperature below 1400°F (760°C).
 - Class B — Furnaces or ovens operating at or above atmospheric pressure and above 1400°F (760°C).
 - Class C — Furnaces and ovens with explosion hazard due to flammable atmosphere, including vacuum furnaces.
NOTE: NFPA Classification A also covers bakery ovens.
- 3) All systems with an input greater than 400,000 BTU/Hour require double safety shutoff valve and vent valve.
NOTE: Pilot systems greater than 400,000 BTU/Hour, located upstream of main safety shutoff valve, must use three valve systems.
- 4) All systems must have manual reset high temperature limit controls in addition to any normal temperature control used.
- 5) Limit switches shall include high gas and low gas (manual reset), low oil temperature, and combustion air.
- 6) All furnaces and ovens shall have flame supervision on each operating burner whenever below 1400°F (760°C). Flame supervision is recommended during startup of furnaces operating over 1400°F (760°C) continuously.
- 7) Purge ventilation is required to allow a minimum of four furnace or oven air changes. Doors must be interlocked when natural ventilation is the source of purge air.
- 8) Combustion air blower should be interlocked to prevent start until after purge is completed, unless using second safety shutoff valve. Failure or shutdown of ventilation fan motors must recycle purge.
- 9) Trial for ignition time for pilots or main burner shall not exceed 15 seconds. Exception to this interval must be justified by the determination that 25% of the lower explosive limit is not exceeded under the most extreme operating conditions. This time shall not exceed 60 seconds.
- 10) Ignition may not automatically recycle after flame out.

ATTACHMENT B
CALIBRATION OF HYCAL CALORIMETERS

ATTACHMENT B
CALIBRATION OF HYCAL CALORIMETERS

For use in GIT's data reduction system, the individual calibration curves furnished must be converted to coefficients of a polynomial in the FLUX-VOLTAGE relationship. We require the coefficients A, B, C, etc. in $F = A + BV + CV^2 + \dots$. Using a TALOS digitizer and PDP-11, we have produced a file of V, F pairs (about 11 pairs) for each sensor in a form suitable for regression analysis to determine A, B, C, ... The V values are in volts, and the F values in BTU/SEC-FT². The calorimeter number is part of the filename, thus FILE 3.DAT refers to calorimeters #3, etc.

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3.97382E-03, 1.87829E+01
4.97490E-03, 2.36252E+01
5.99606E-03, 2.87349E+01
6.97259E-03, 3.37926E+01
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3.99949E-03, 1.79037E+01
4.99131E-03, 2.25639E+01
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3.99113E-03, 1.76795E+01
4.99510E-03, 2.23548E+01
6.00327E-03, 2.71001E+01
6.98371E-03, 3.19876E+01
7.98538E-03, 3.65527E+01
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3.98534E-03, 2.02001E+01
4.98681E-03, 2.54002E+01
5.98753E-03, 3.09014E+01
6.97048E-03, 3.64645E+01
7.95873E-03, 4.23382E+01
8.96138E-03, 4.83008E+01

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4.97844E-03, 2.09156E+01

4.98681E-03, 2.54002E+01
5.98753E-03, 3.09014E+01
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.TY FILE8.DAT

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7.95580E-03, 3.78904E+01
8.97696E-03, 4.29914E+01
9.99793E-03, 4.79619E+01

CERTIFICATE OF CALIBRATION

"THE TEMPERATURE PEOPLE"
HY-CAL ENGINEERING
 12100 Los Nietos Road • Santa Fe Springs, California 90670

DATE 6-28-78

CUSTOMER Sanders

P.O. NO. 780772

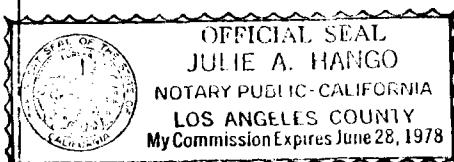
INST. TYPE Calorimeter

MODEL C-1112-BX-50-300

ABSORPTIVITY .89

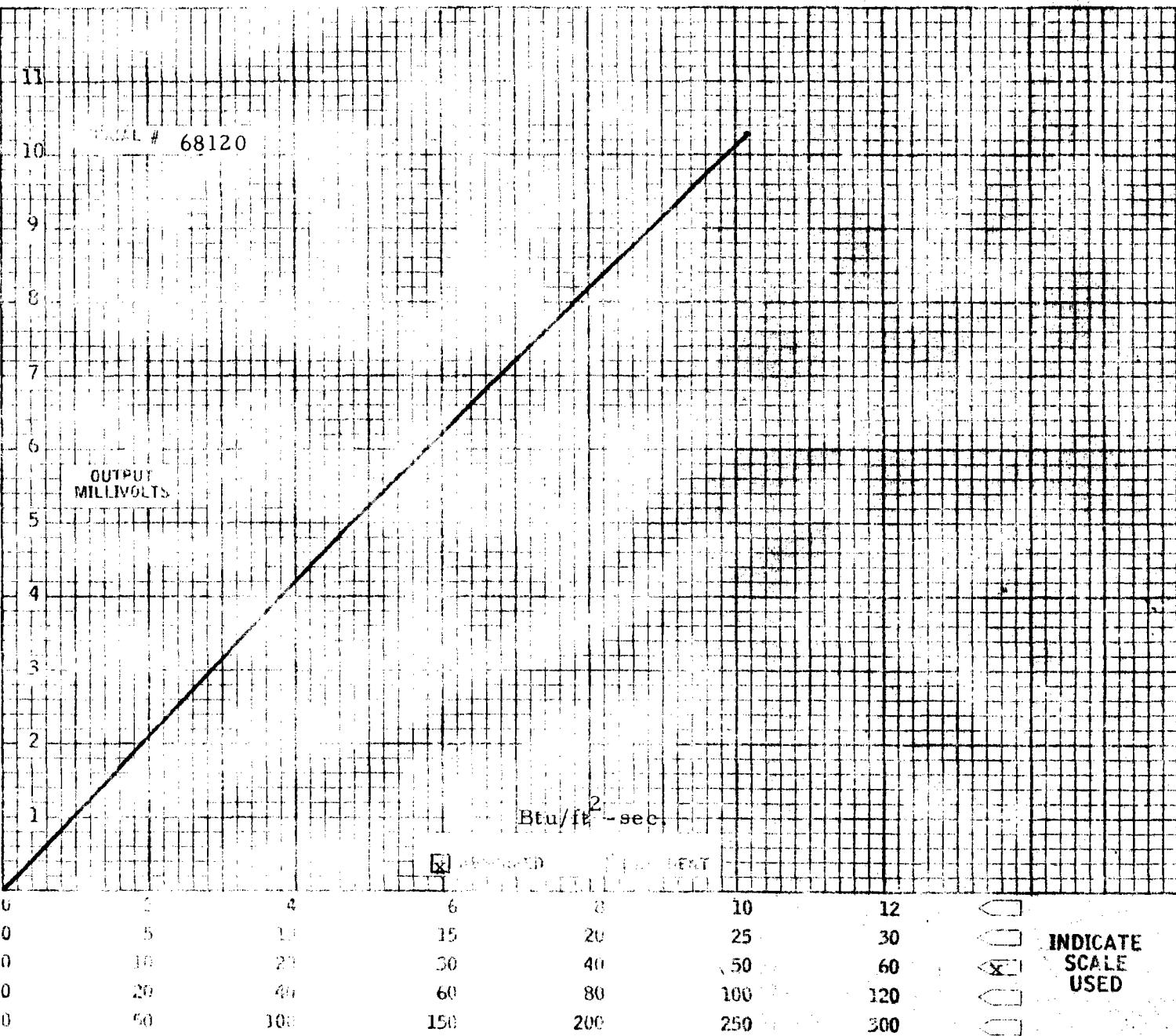
CERTIFIED RECORD OF CALIBRATION
 DATA ON THE INSTRUMENT LISTED ABOVE.
 THE DATA WAS OBTAINED AT HY-CAL
 ENGINEERING'S THERMAL TEST FACILITY.

REFERENCE STANDARD 43592

TESTED BY *JLH*Q.C. APPROVAL *HC**13*

SUBSCRIBED AND SWORN TO
 BEFORE ME THIS 28th DAY

OF June 19 78



CERTIFICATE OF CALIBRATION

HY-CUT ENGINEER INC.
101808 कालापांडी, सूनारा २०१५ • २० जूलाई २०१६



DATE १५.६.१६

CUSTOMER

SERIAL # ३००१

TESTED BY _____

MODEL _____

ABSORBILITY _____

PRECISION STANDARDS

CERTIFIED RECORD OF CALIBRATION
DATA OF THE INSTRUMENT
ABOVE THE DATA WAS OBTAINED IN
HY-DAF ENGINEER'S THERMAL FUX
FACTORY

OUTPUT
MILLIWATTS

REFERENCE INSTRUMENT

TESTED BY _____

O.C. APPROVAL

SUBSCRIBED AND SIGNED TO
BEFORE ME THIS 16 DAY
OF June 2016

USED	100	200	300	400	500	600	800	1000	1200	1500	2000	3000
SCAFF	0	0	0	0	0	0	0	0	0	0	0	0
MICRATE	0	0	0	0	0	0	0	0	0	0	0	0
ABSORBED	0	1	2	3	4	5	6	7	8	9	10	15
INIDEW	0	0	0	0	0	0	0	0	0	0	0	0

CERTIFICATE OF CALIBRATION

THE TEMPERATURE PEOPLE

THE ENGINEERING

TECHNOLOGY CORP. • Santa Fe Springs, California 90670

DATE 6-28-78

CUSTOMER Sanders

F.C. NO. 780772

INST. TYPE Calorimeter

MODEL C-1112-BX-50-300

ABSORPTIVITY .89

CERTIFIED RECORD OF CALIBRATION
DATA ON THE INSTRUMENT DESCRIBED
ABOVE THE DATA WAS OBTAINED IN
MY AL ENGINEERING'S IN-SITE FLUX
FACTORY.

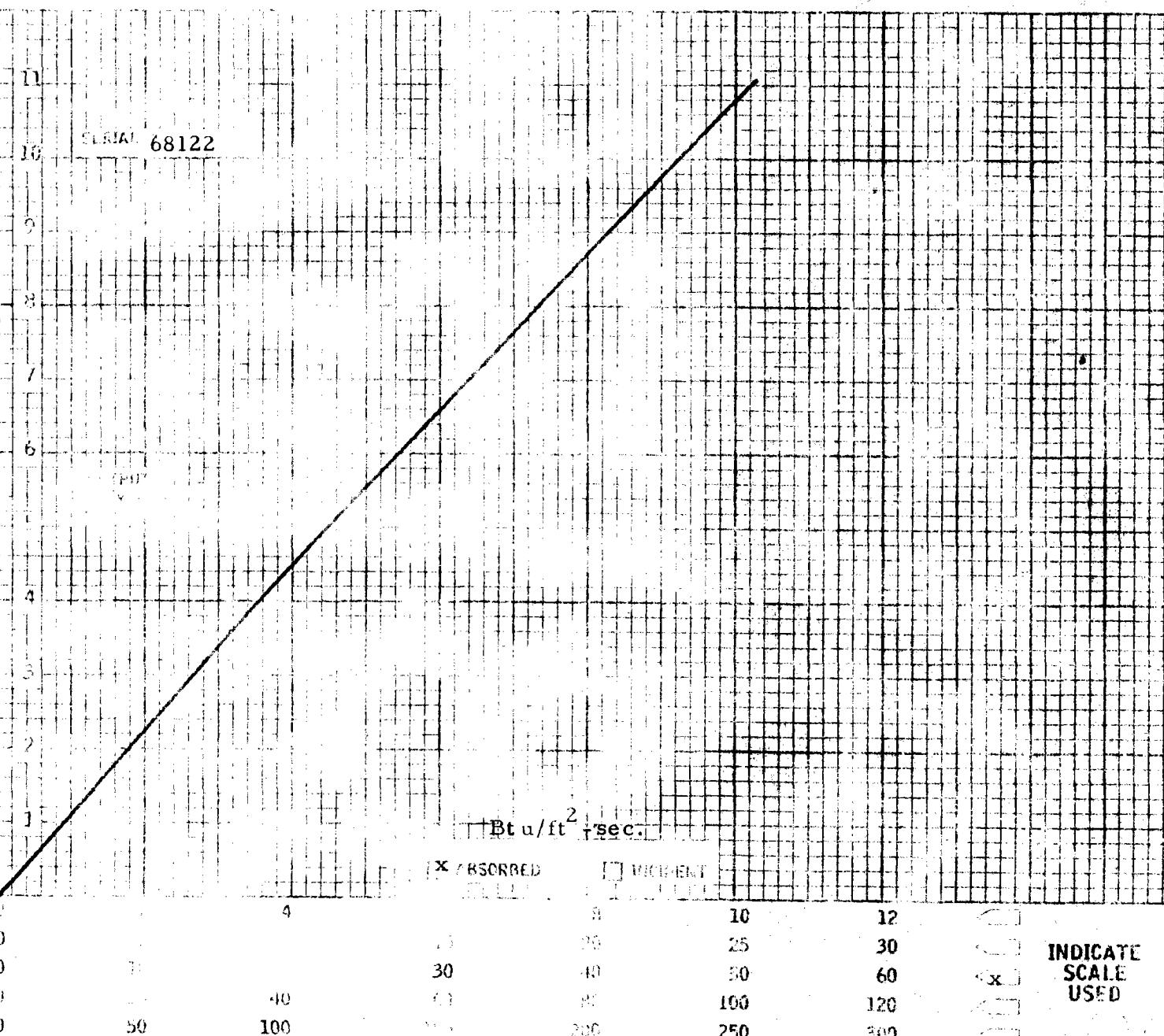
REFERENCE STANDARD 43592

TESTED 7/28/78

Q.C. APPROVED



SUBSCRIBED AND SWORN TO
BEFORE ME THIS 28th Day
OF JUNE 1978

INDICATE
SCALE
USED

CERTIFICATE OF CALIBRATION

THE TEMPERATURE PEOPLE

HY-CAL ENGINEERING
12105 Los Nietos Road • Santa Fe Springs, California 90670

DATE 6-28-78

CUSTOMER Sanders

P. O. NO. 780772

INST TYPE Calorimeter

MODEL C-1112-BX-50-300

ABSORPTIVITY 89

CERTIFIED RECORD OF CALIBRATION
DATA ON THE INSTRUMENT DESCRIBED
ABOVE. THE DATA WAS OBTAINED IN
HY-CAL ENGINEERING'S THERMAL FLUX
FACILITY.

B-13

REFERENCE STANDARD 43592

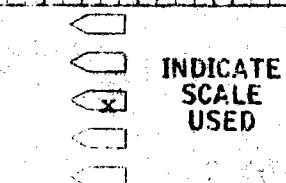
TESTED BY *T. S. Z.*

O.C. APPROVAL

HC
13SUBSCRIBED AND SWORN TO
BEFORE ME THIS 28th DAY

OF JUNE, 1978.

S/N 68123

OUTPUT
MILLIVOLTS1
2
3
4
5
6
7
8
9
10
11Btu/ ft^2 -sec.EXPOSED INCIDENTDIRECT DIFFUSEREFLECTED TRANSMITTED REFRACTED SCATTERED REFLECTED TRANSMITTED REFRACTED SCATTERED 0 2 4 6 8 10 12
0 5 10 15 20 25 30
0 10 20 30 40 50 60
0 20 40 60 80 100 120
0 50 100 150 200 250 300

CERTIFICATE OF CALIBRATION

"THE TEMPERATURE PEOPLE"
TL ENGINEERING

100 Los Natos Road • Santa Fe Springs, California 90670

DATE 6-28-78

TESTER
Sanders

F.D. NO. 780772

INSTRUMENT Calorimeter

MODEL C-1112-BX-50-300

ABSORPTIVITY .89

CERTIFIED RECORD OF CALIBRATION
DATA ON THE INSTRUMENT LISTED
ABOVE. THE DATA WAS OBTAINED IN
HYDRAULIC ENGINEERING TEST FACILITY

B - 14

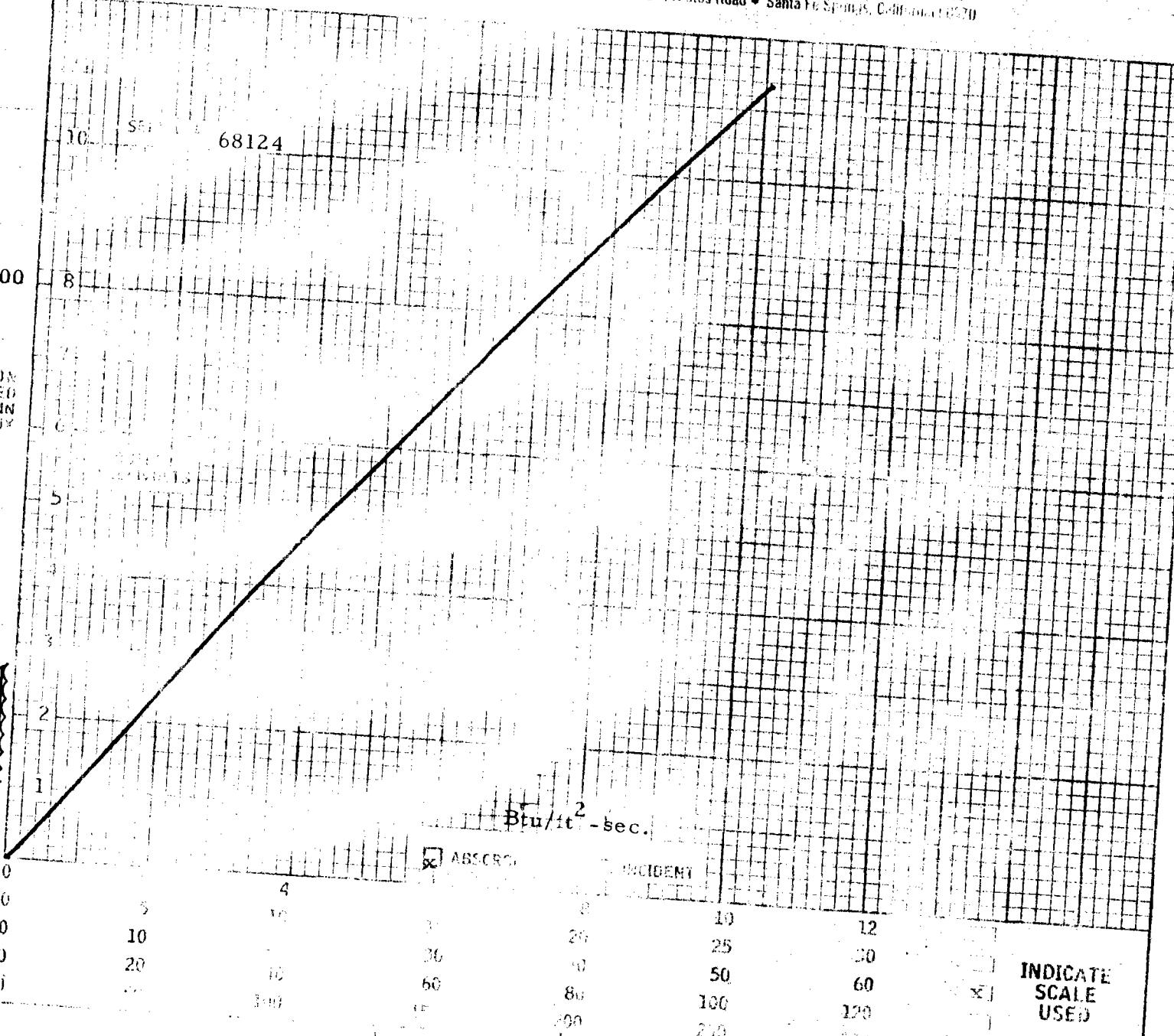
REFERENCE STANDARD 43592

TESTED BY / 235



SUBSCRIBED AND SWEARN TO
BEFORE ME THIS 28th DAY
OF JUNE 1978

66 235-57



CERTIFICATE OF CALIBRATION

THE TEMPERATURE PEOPLE

CAL ENGINEERING

10000 State Road • Santa Fe Springs, California 90670

DATE 6-28-78
 CUSTOMER Sanders
 P. O. NO. 780772
 INST. TYPE Calorimeter
 MODEL C-1112-BX-50-300

ABSORPTIVITY .89

CERTIFIED RECORD OF CALIBRATION
 DATA ON THE INSTRUMENT DESCRIBED
 ABOVE. THE DATA WAS OBTAINED AT
 HY-CAL ENGINEERING'S TEST FACILITY.

REFERENCE STANDARD #43592

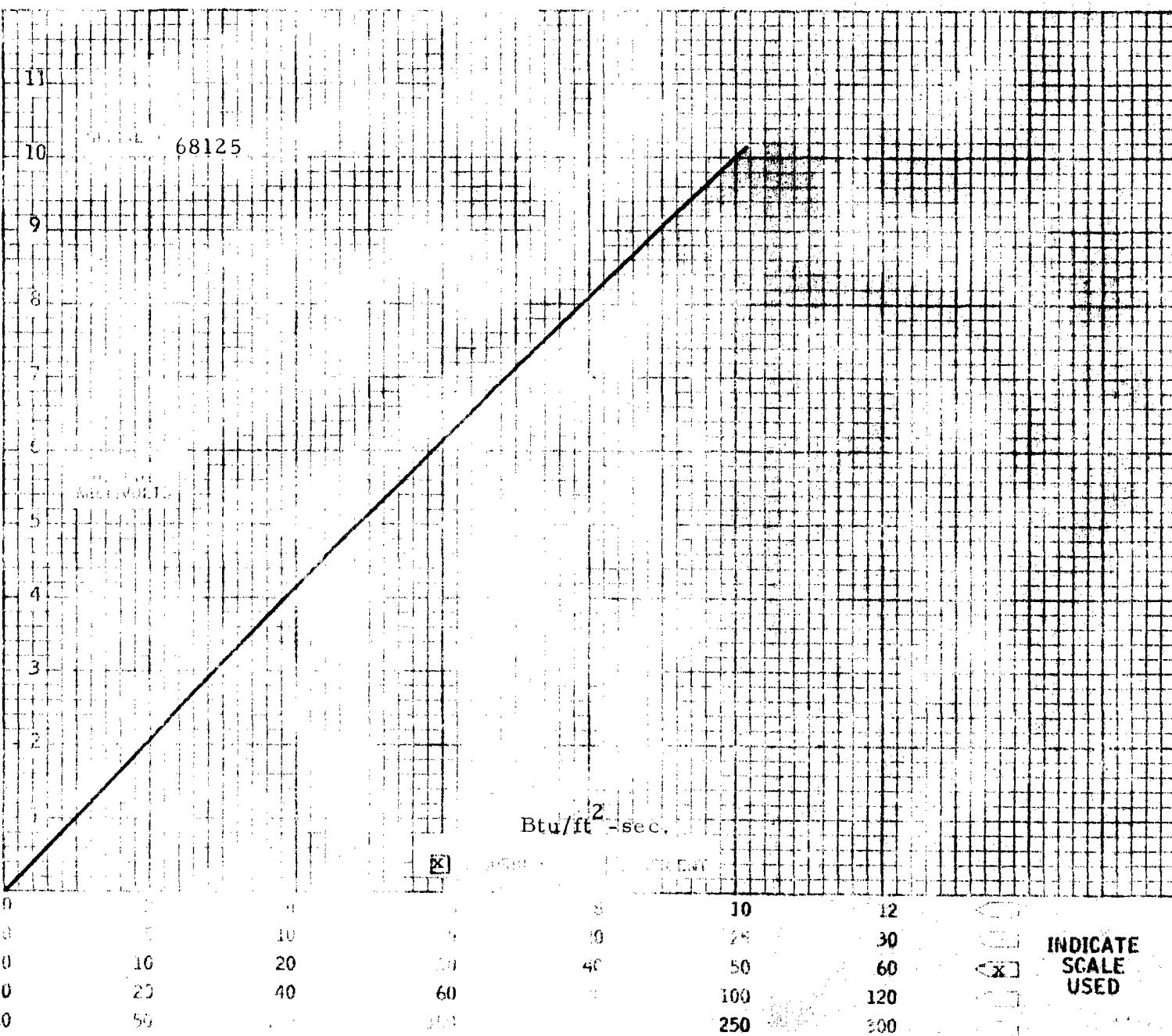
TESTED BY J. Hango

Q.C. APPROVAL



SUBSCRIBED AND SWORN TO
 BEFORE ME THIS 28th day

OF JUNE 1978



CERTIFICATE OF CALIBRATION

THE TEMPERATURE PEOPLE

HY-CAL ENGINEERING

100 Los Nictos Road • Santa Fe Springs, California 90670

DATE 6-28-78

CUSTOMER Sanders

P.O. NO. 780772

INST. TYPE Calorimeter

MODEL C-1112-BX-50-300

ABSORPTIVITY .89

CERTIFIED RECORD OF CALIBRATION
DATA ON THE INSTRUMENT NUMBERED AS
ABOVE. THE DATA WAS DETERMINED IN
HY-CAL ENGINEERING'S THIRTY-FIVE
FACILITY.

REFERENCE STANDARD 43592

TESTED BY J. A. Hango

Q.C. APPROVAL HC

13



SUBSCRIBED AND SWORN TO
BEFORE ME THIS 28th DAY

OF June 1978

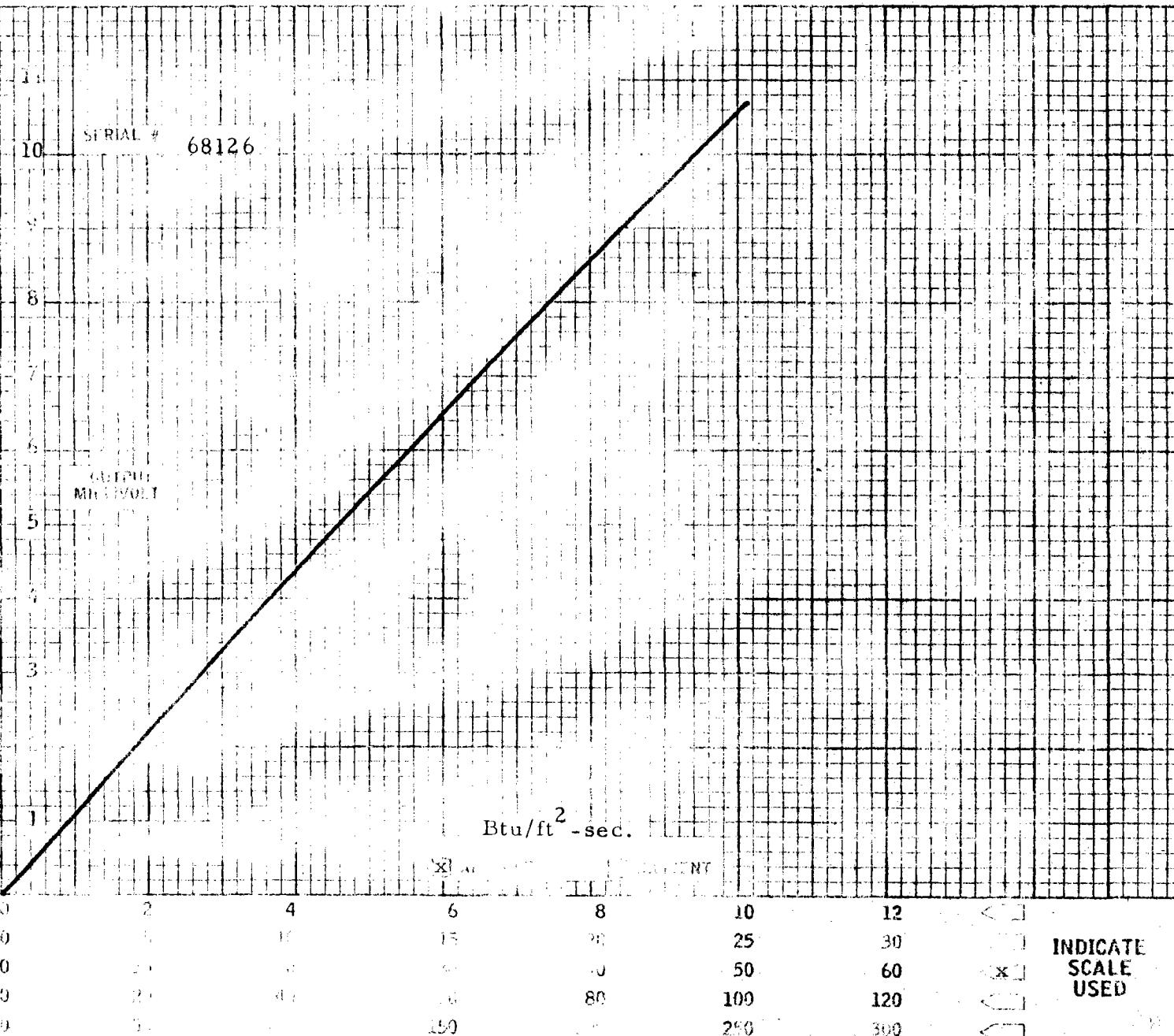
Subscribed and sworn to before me this 28th day of June 1978

Subscribed and sworn to before me this 28th day of June 1978

Subscribed and sworn to before me this 28th day of June 1978

Subscribed and sworn to before me this 28th day of June 1978

S. H. 205-57



CERTIFICATE OF CALIBRATION



THE TEMPERATURE PEOPLE

PYROCAL ENGINEERING

10000 Road • Santa Fe Springs, California 90670

DATE 6-28-78

CUSTOMER Sanders

P.O. NO. 780772

TEST TYPE Calorimeter

MODEL C-1112-BX-50-300

ABSORPTIVITY .89

CERTIFIED RECORD OF OPERATION
DATA OF THE EQUIPMENT DESCRIBED
ABOVE, INC., WAS OBTAINED IN
BY USE OF PYROCAL'S THERMAL FLUX
FACTORY

REFERENCE STANDARD 43592

TESTED BY *T.S.*

Q.C APPROVED

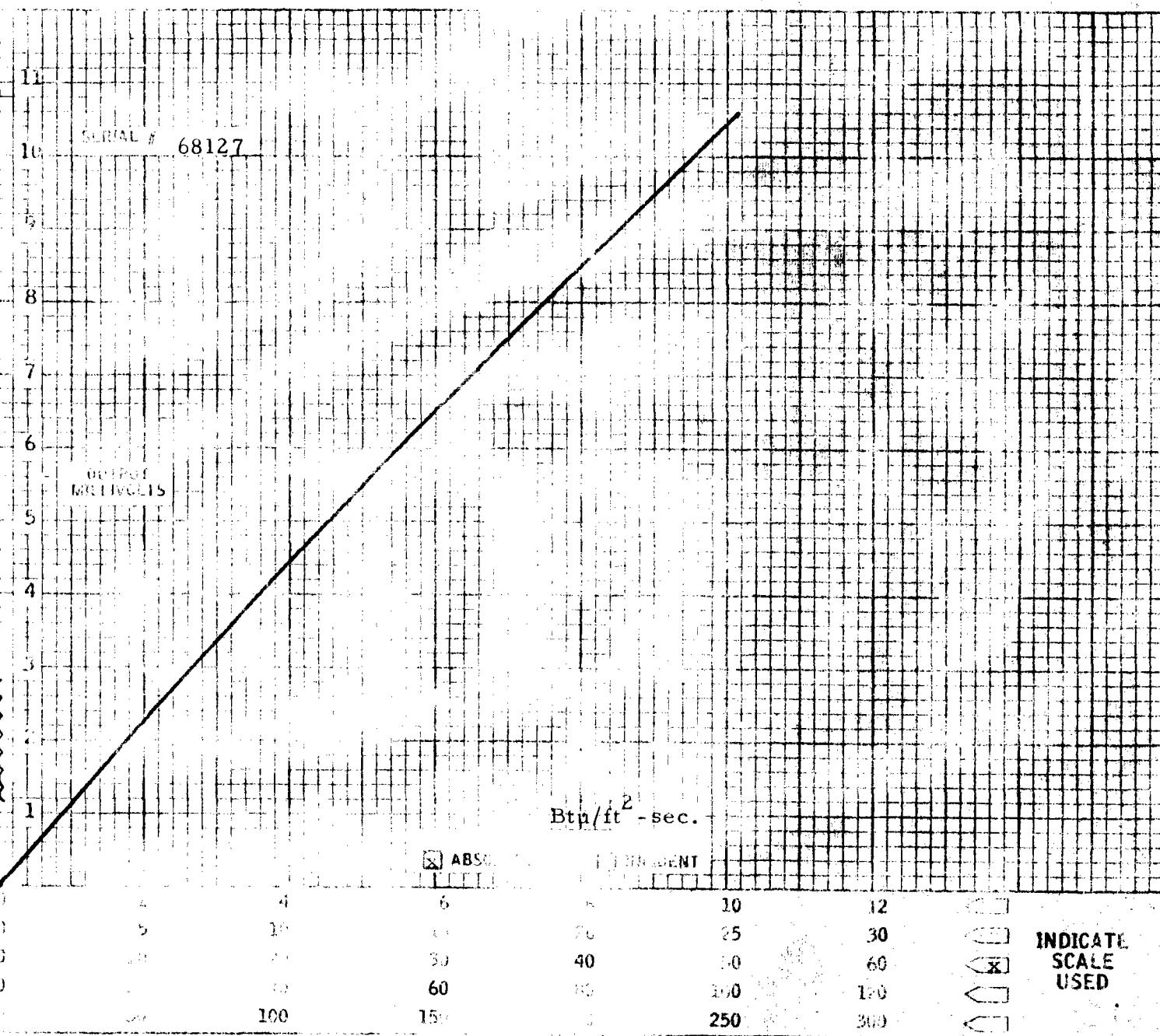


OFFICIAL SEAL
JULIE A. HANGO
NOTARY PUBLIC - CALIFORNIA
LOS ANGELES COUNTY
My Commission Expires June 28, 1978

SUBSCRIBED AND SWORN TO

BEFORE ME on the 28th

OF JUNE 1978

*Subscribed and sworn to**on the 28th day of June 1978**before me by**John Doe**for the purpose of**issuing a certificate of calibration**for a Pyrocal instrument**model C-1112-BX-50-300*

CERTIFICATE OF CALIBRATION

THE TEMPERATURE PEOPLE®

HY-LAL ENGINEERING

17105 Los Nietos Road • Santa Fe Springs, California 90670

DATE 6-28-78

CUSTOMER Sanders

P.O. NO. 780772

INST. TYPE Calorimeter

MODEL C-1112-BX-50-300

ABSORPTIVITY .89

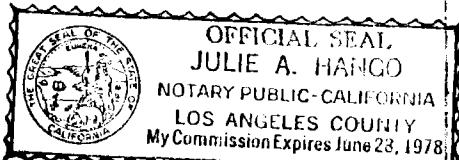
CERTIFIED RECORD OF CALIBRATION
 DATA ON THE INSTRUMENT DESCRIBED
 ABOVE, THE DATA WAS OBTAINED IN
 HY-LAL ENGINEERING'S THIRTY (30)
 FACILITY.

REFERENCE STANDARD 43592

TESTED BY J. S. D.

Q.C. APPROVAL

(HC)



SUBSCRIBED AND SWORN TO

BEFORE ME THIS 28th DAY

OF JUNE 1978

IN THE CITY OF LOS ANGELES

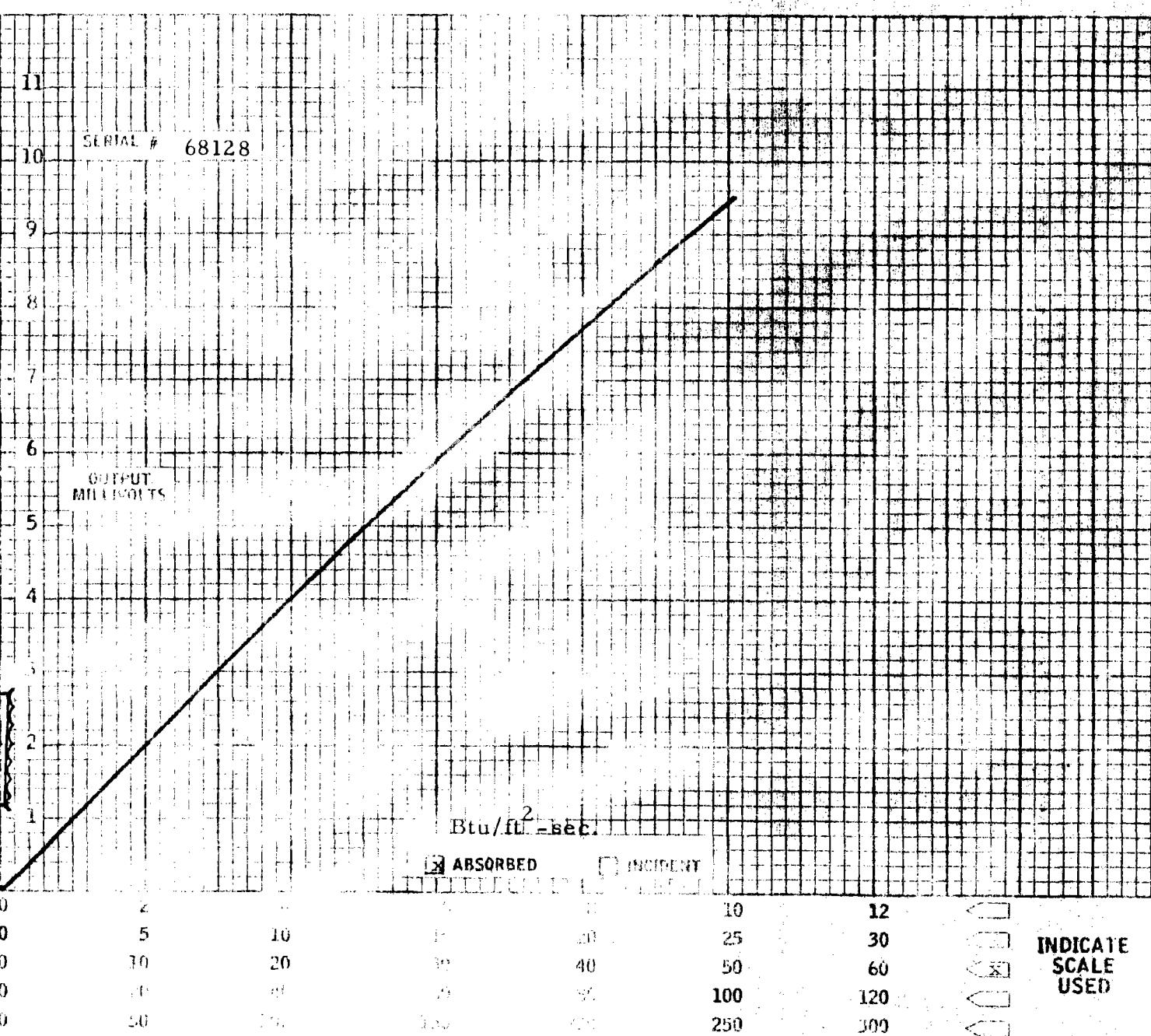
STATE OF CALIFORNIA

ON BEHALF OF THE PEOPLE

I AM A NOTARY PUBLIC

IN THE STATE OF CALIFORNIA

AND I AM SWORN TO THE TRUTH



CERTIFICATE OF CALIBRATION

THE TEMPERATURE PEOPLE

HY-CAL ENGINEERING
1214 W. 10th Street • Santa Fe Springs, California 90670

DATE 6-28-78

CUSTOMER Sanders

P.O. NO. 780772

INSTL. TYPE Calorimeter

MODEL C-1112-BX-50-300

ABSORPTIVITY .89

CERTIFIED RECORD OF CALIBRATION
 DATA ON THE INSTRUMENT DESCRIBED
 ABOVE. THE DATA WAS TRANSFERRED
 BY CAL ENGINEERING'S TEST FACILITY.

REFERENCE STANDARD 43592

TESTED BY / 28/78

N.C. APPROVAL



OFFICIAL SEAL
 JULIE A. HANGO
 NOTARY PUBLIC - CALIFORNIA
 LOS ANGELES COUNTY
 My Commission Expires June 28, 1978

SUBSCRIBED AND SWORN TO

BEFORE ME THIS 28th DAY

OF JUNE 1978

IN THE CITY OF SANTA FE SPRINGS

COUNTY OF LOS ANGELES

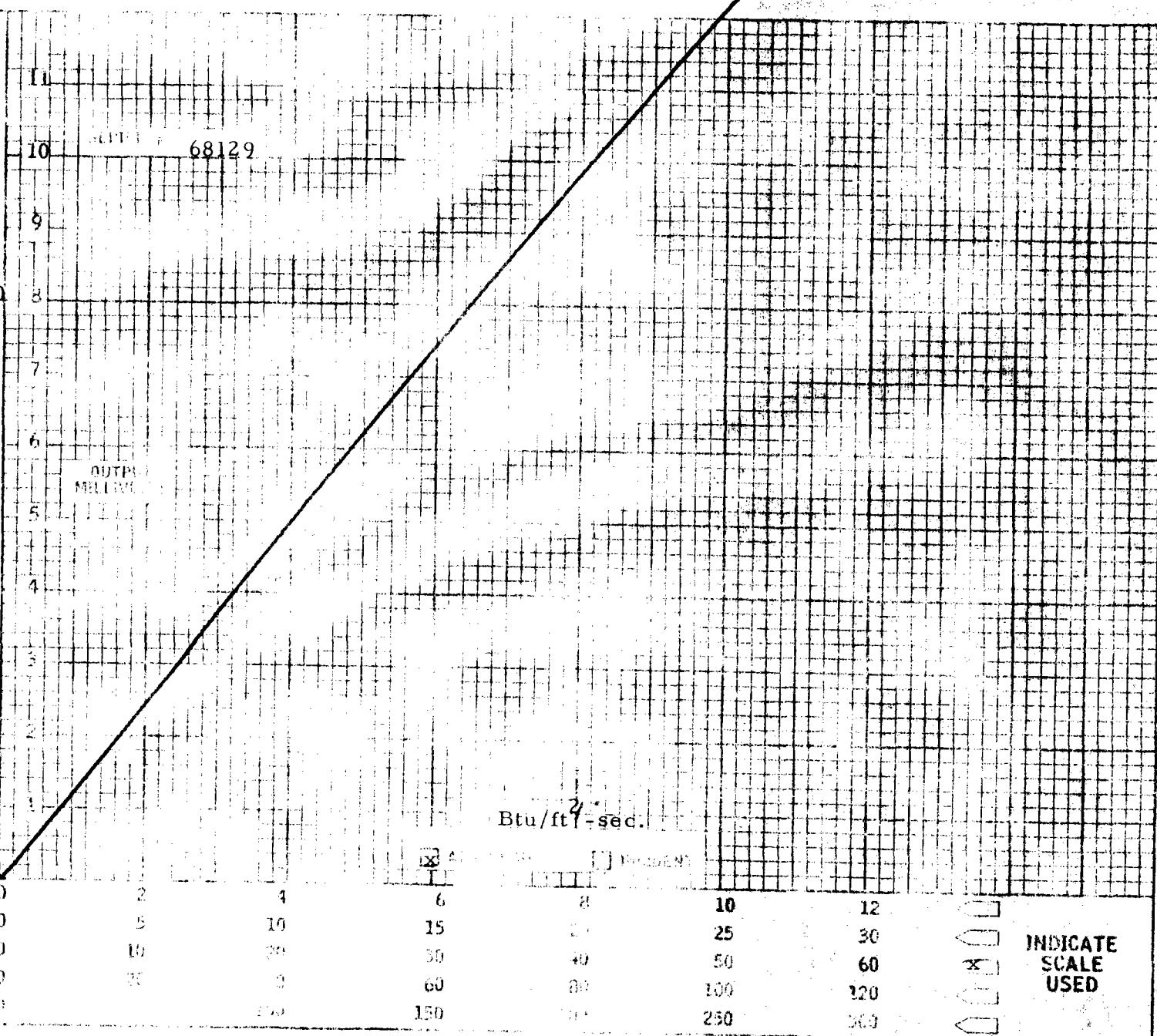
STATE OF CALIFORNIA

I am a Notary Public in the State of California

My Commission Expires June 28, 1978

I am a Notary Public in the State of California

My Commission Expires June 28, 1978



CERTIFICATE OF CALIBRATION

THE TEMPERATURE PEOPLE

WACO ENGINEERING

17105 Franklin Blvd. • Santa Fe Springs, California 90670

DATE 6-28-78

CUSTOMER Sanders

P.O. NO. 780772

TEST TYPE Calorimeter

MODEL C-1112-BX-50-300

ABSORBANCE .89

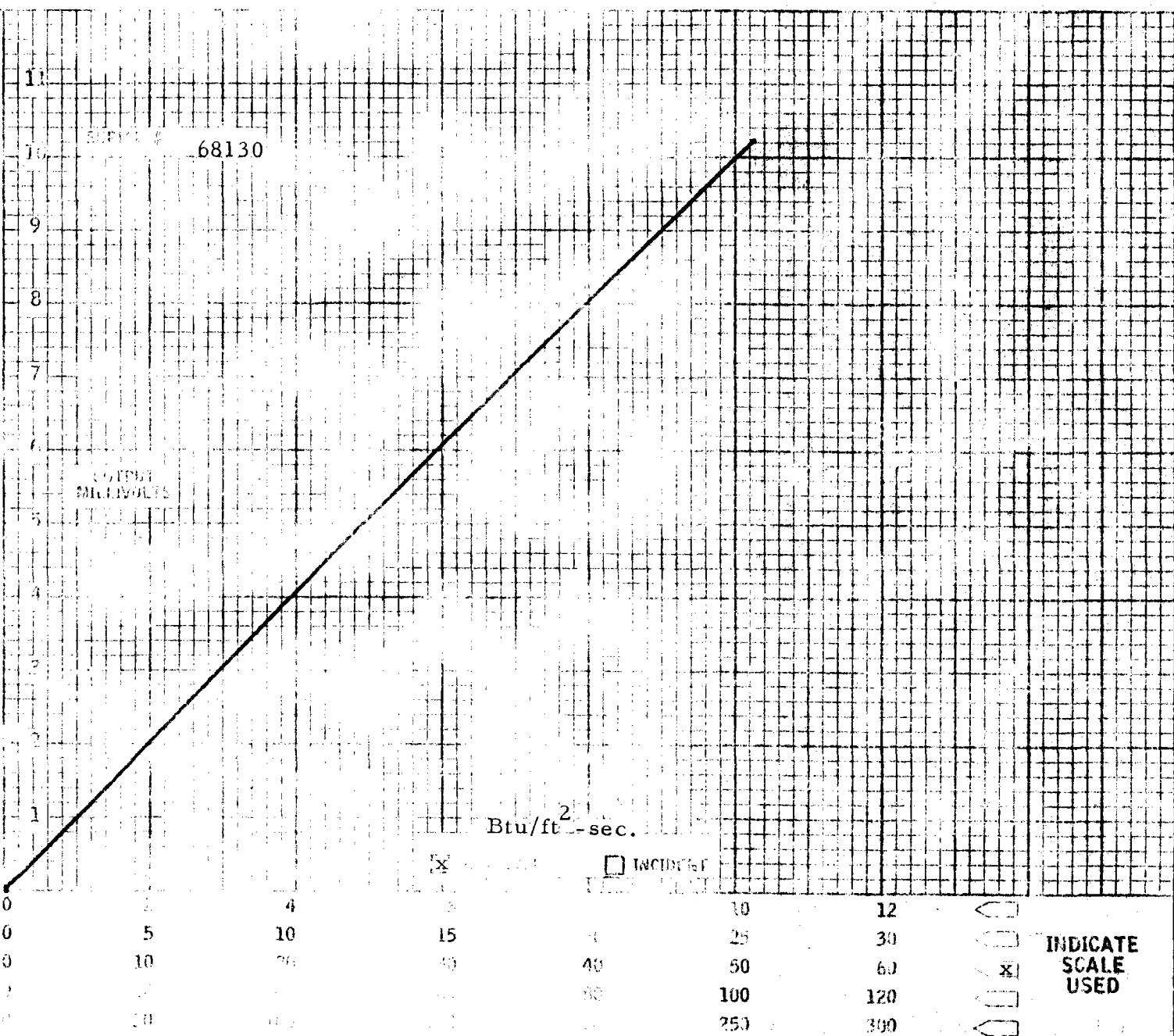
CERTIFIED RECORD OF CALIBRATION
DATA ON THE INSTRUMENT INDICATED
ABOVE. THE DATA WAS OBTAINED
BY THE ENGR. DEPT. OF THE WACO
FACILITY.

REFERENCE STANDARD 43592

TESTED BY J. Hango

SIGHTING AND SHOOTING
BEFORE THE 28th

On June 1978



CERTIFICATE OF CALIBRATION

"THE TEMPERATURE PEOPLE"

HIL ENGINEERING

15000 N. Dietos Road • Santa Fe Springs, California 90735

DATE 6-28-78

CUSTOMER Sanders

P.O. NO 780772

INST. TYPE Calorimeter

MODEL C-1112-BX-50-300

ABSORPTIVITY .89

CERTIFIED RECORD OF CALIBRATION
 DATA ON THE INSTRUMENT INDICATED
 ABOVE. THE DATA WAS OBTAINED IN
 HY CAL ENGINEERING'S THERMAL FLUX
 FACILITY.

B-21

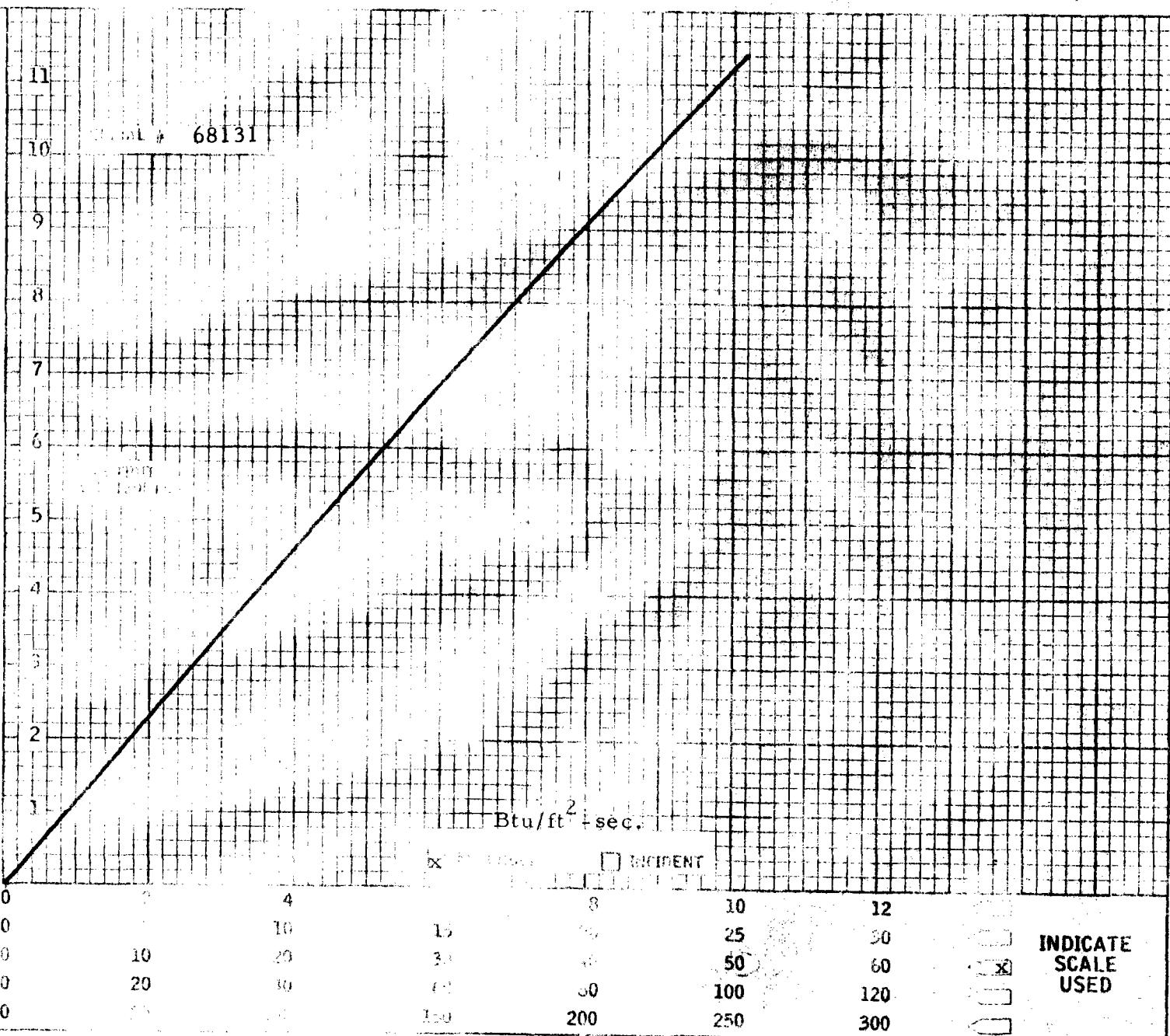
REFERENCE STANDARD 43592

TESTED BY *J. A. Hango*Q.C. APPROVAL *(HC)*

SUBSCRIBED AND SWORN TO

BEFORE ME THIS 28th

OF June 19 78



CERTIFICATE OF CALIBRATION

"THE TEMPERATURE PEOPLE"

HY-CAL ENGINEERING

12915 Bellanca Road • Santa Fe Springs, California 90670

DATE 6-28-78

CUSTOMER Sanders

P.O. NO. 780772

INST. TYPE Calorimeter

MODEL C-1112-BX-50-300

ABSORBIVITY .89

CERTIFIED RECORD OF CALIBRATION
DATA ON THE INSTRUMENT IDENTIFIED
ABOVE. THE DATA WAS OBTAINED IN
HY-CAL ENGINEERING'S THERMAL FLUX
FACTORY.

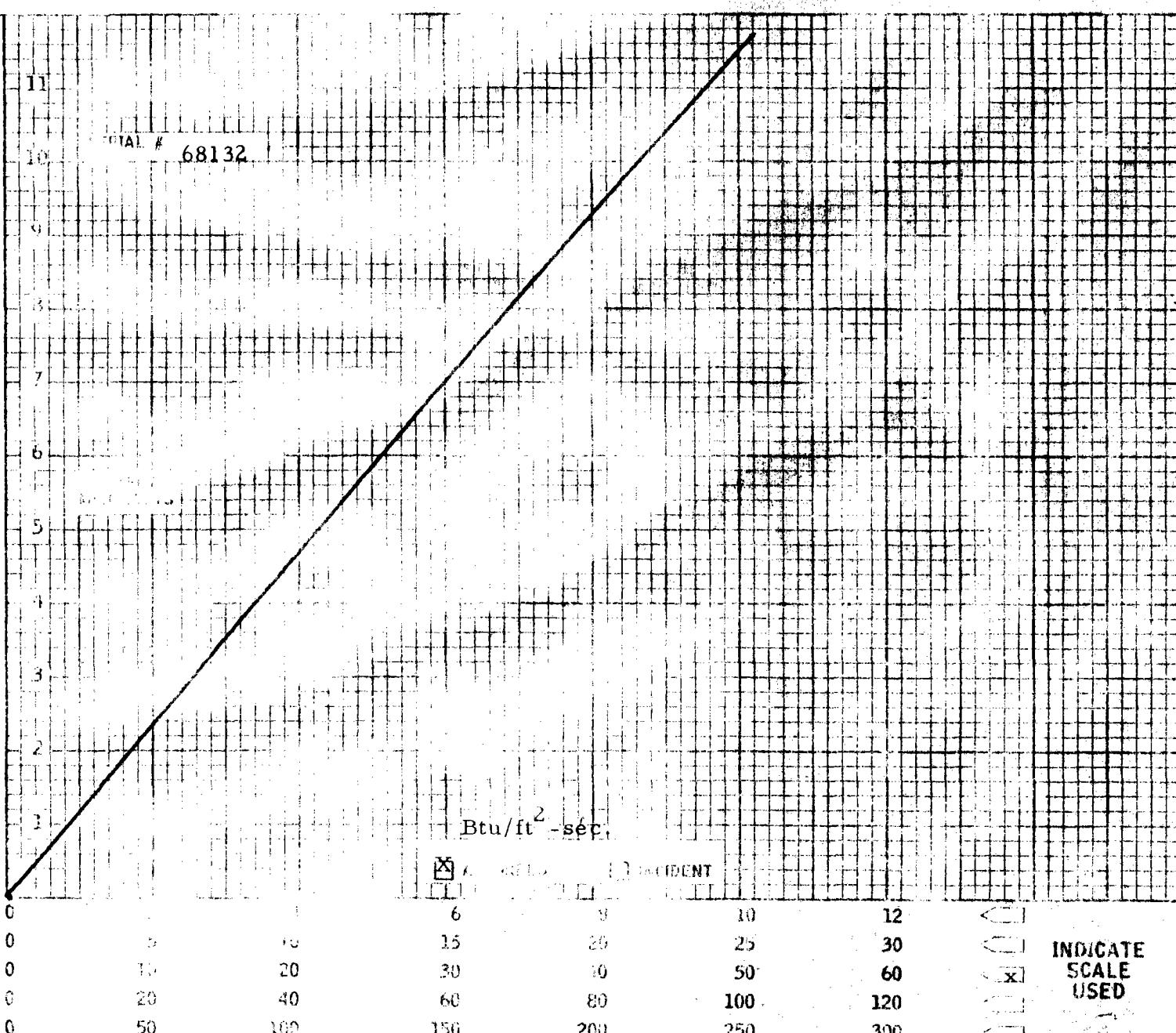
REFERENCE STANDARD 43592

TESTED BY J. S. (22)

Q.C. APPROVAL (13)

SUBSCRIBED AND SWORN TO
BEFORE ME THIS 28th DAY

UPON June 29, 1978



CERTIFICATE OF CALIBRATION

THE TEMPERATURE PEOPLE™

HOT & COLD ENGINEERING

12101 Las Cielos Road • Santa Fe Springs, California 90670

79

DATE 6-28-78

CUSTOMER Sanders

P.O. NO. 780772

INST. TYPE Calorimeter

MODEL C-1112-BX-50-300

ABSORPTIVITY .89

CERTIFIED RECORD OF CALIBRATION
DATA IN THE INSTRUMENT INDEX
AND THE DATA WAS OBTAINED
HY-CAL ENGINEERING'S TEST FACILITY.

B-23

REFERENCE STANDARD 43592

TESTED ON 7/3/78

(HC)
13

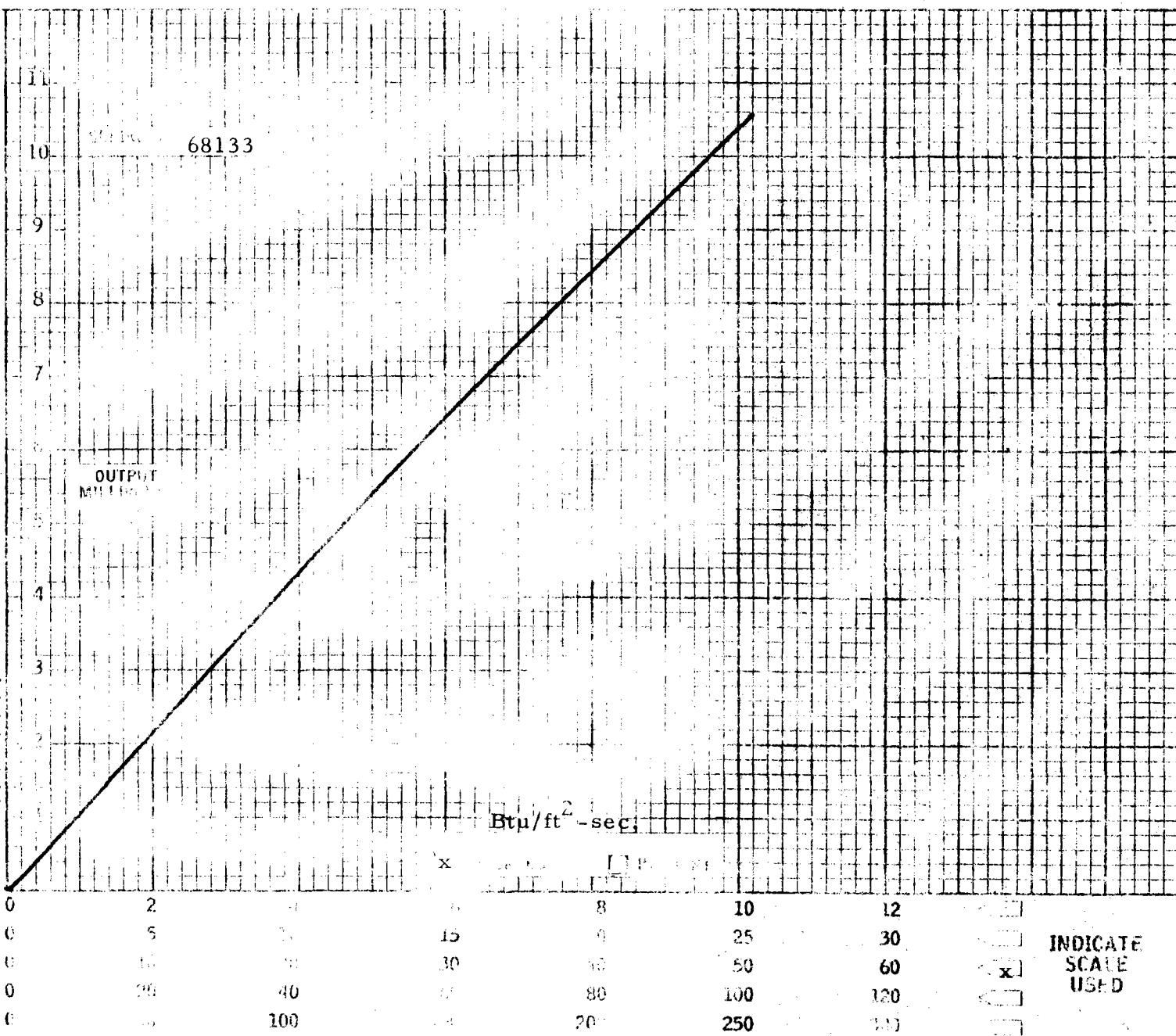
Q.C. APPROVAL



OFFICIAL SEAL
JULIE A. HANGO
NOTARY PUBLIC - CALIFORNIA
LOS ANGELES COUNTY
My Commission Expires June 28, 1978

SUBSCRIBED AND SWORN TO
BEFORE ME THIS 28th DAY

OF JUNE, 1978



CERTIFICATE OF CALIBRATION

THE TEMPERATURE PEOPLE
SIMPSON ENGINEERING
11111 Santa Fe Springs Road • Santa Fe Springs, California 90670

DATE 6-28-78

CUSTOMER Sanders

P.O. NO. 780772

INST. TYPE Calorimeter

~~MODEL C-1112-BX-50-300~~

ABSORPTIVITY _____. 89

CERTIFIED RECORD OF CALIBRATION
DATA ON THE INSTRUMENT DESCRIBED
ABOVE. THE DATA WAS OBTAINED IN
HY-CAL ENGINEERING'S THERMAL FLUX
FACILITY.

REFERENCE STANDARD 43592

TESTED BY

Q. C. APPROVAL

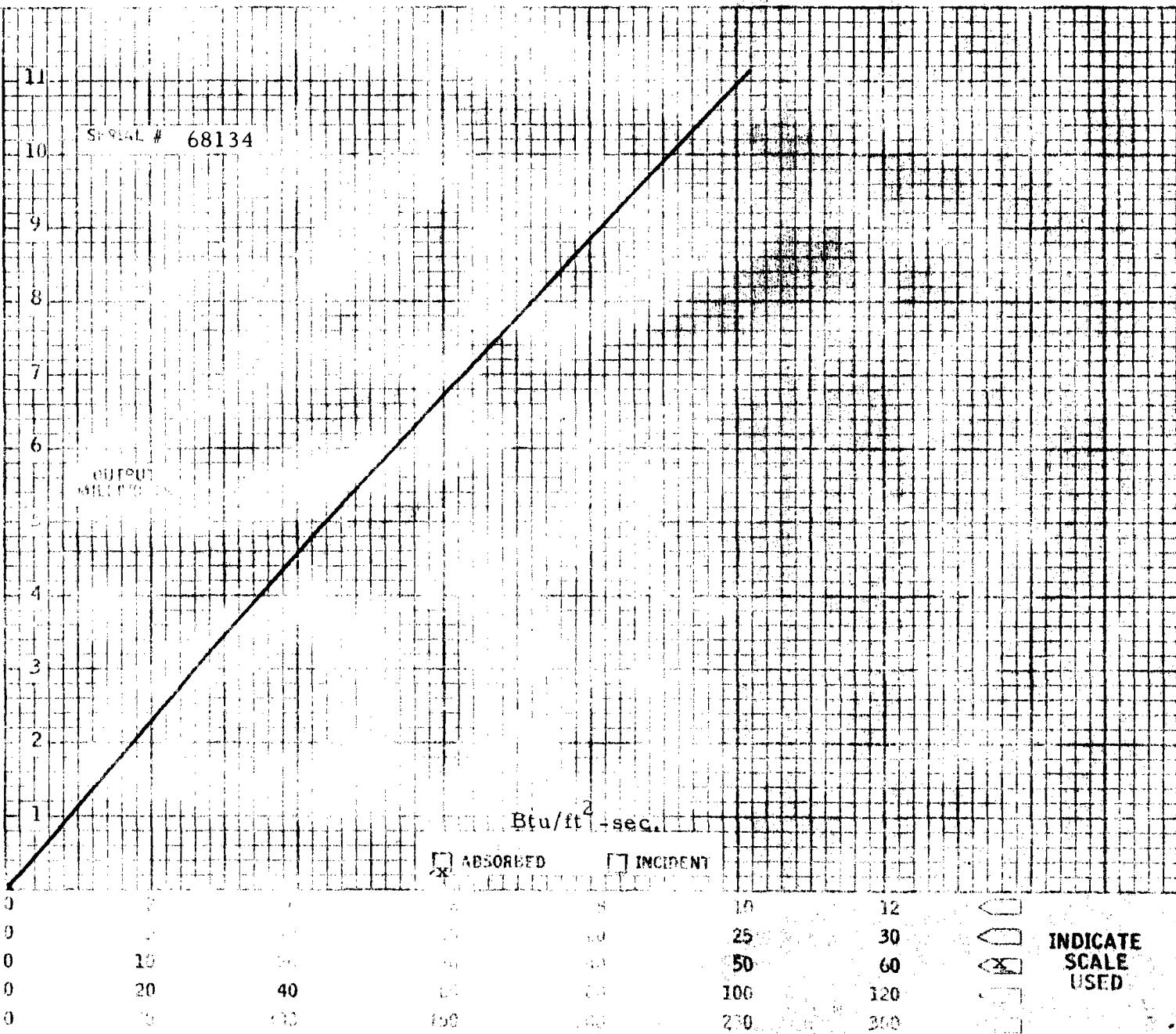


The image shows the official seal of Julie A. Hango. It consists of a rectangular border containing the following text:

OFFICIAL SEAL
JULIE A. HANGO
NOTARY PUBLIC - CALIFORNIA
LOS ANGELES COUNTY
Commission Expires June 23, 1927

The text is arranged in five lines, with "NOTARY PUBLIC - CALIFORNIA" centered between "JULIE A. HANGO" and "LOS ANGELES COUNTY". The entire seal is enclosed in a thin black border.

SUBSCRIBED AND SWORN TO
BEFORE ME THIS 28th
OF June 1878



**INDICATE
SCALE
USED**

CERTIFICATE OF CALIBRATION



"THE TEMPERATURE PEOPLE"

HY-CAL ENGINEERING
 12095 Las Flores Road • Santa Fe Springs, California 90670

DATE 6-28-78

CUSTOMER Sanders

P.O. NO. 780772

INST. TYPE Calorimeter

MODEL C-1112-BX-50-300

ABSORPTIVITY .89

CERTIFIED RECORD OF CALIBRATION
 DATA ON THE INSTRUMENT DESCRIBED
 ABOVE. THE DATA WAS OBTAINED IN
 HY-CAL ENGINEERING'S THERMAL TEST
 FACILITY.

REFERENCE STANDARD 43592

TESTED BY J. A. Hango

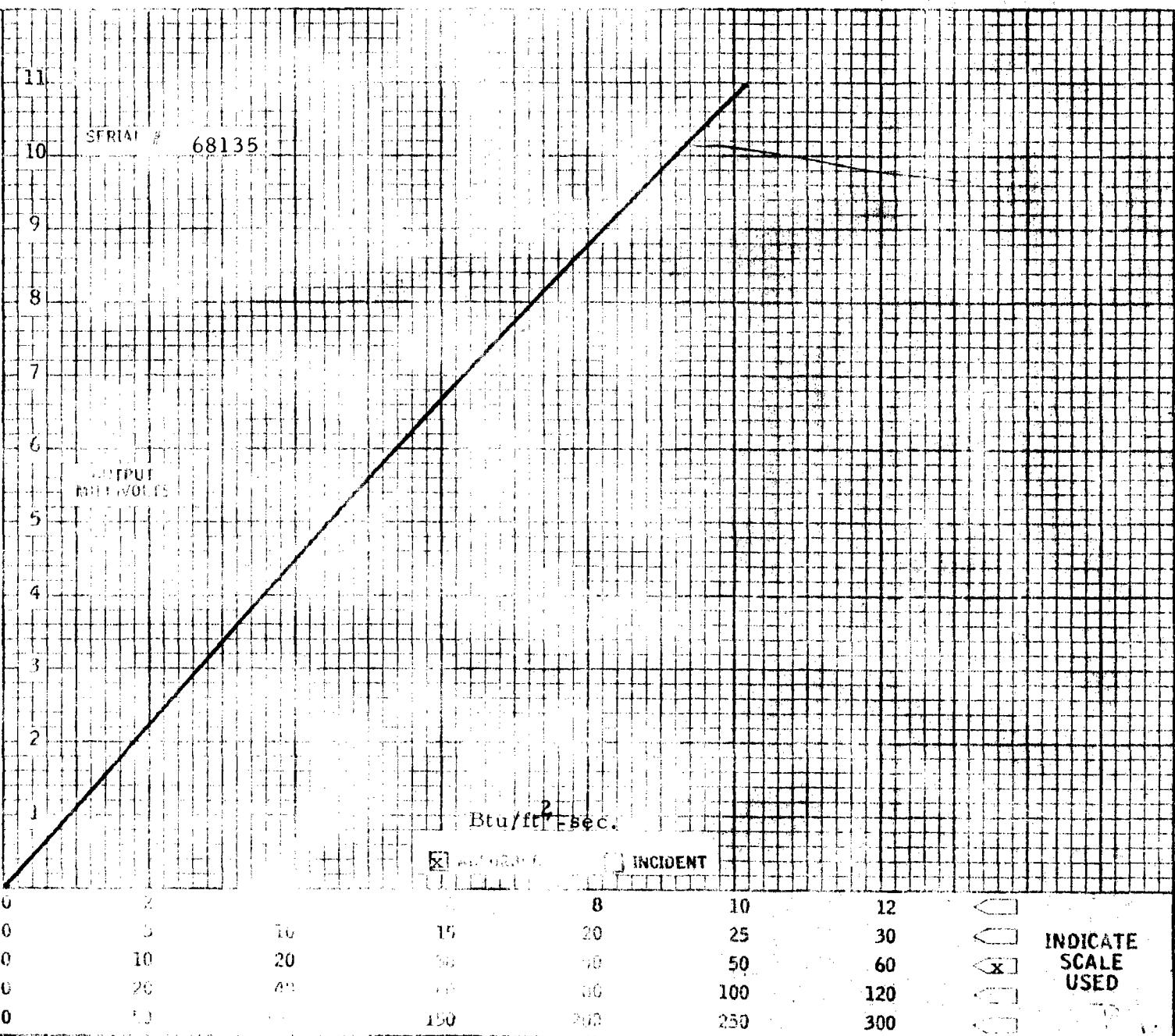
Q.C. APPROVAL MC 13



SUBSCRIBED AND SWORN TO

BEFORE ME THIS 28th DAY

OF June 78



CERTIFICATE OF CALIBRATION

"THE TEMPERATURE PEOPLE"

HY CAL ENGINEERING

12105 Los Nogales Road • Santa Fe Springs, California 90670

DATE 6-28-78

CUSTOMER Sanders

P. O. NO. 780772

INST. TYPE Calorimeter

MODEL C-1112-BX-50-300

ABSORPTIVITY .89

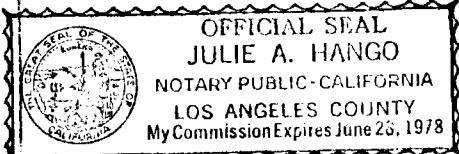
CERTIFIED RECORD OF CALIBRATION
 DATA ON THE INSTRUMENT DESCRIBED
 ABOVE. THE DATA WAS OBTAINED IN
 HY CAL ENGINEERING'S THERMAL FLUX
 FACILITY

REFERENCE STANDARD 43592

TESTED BY

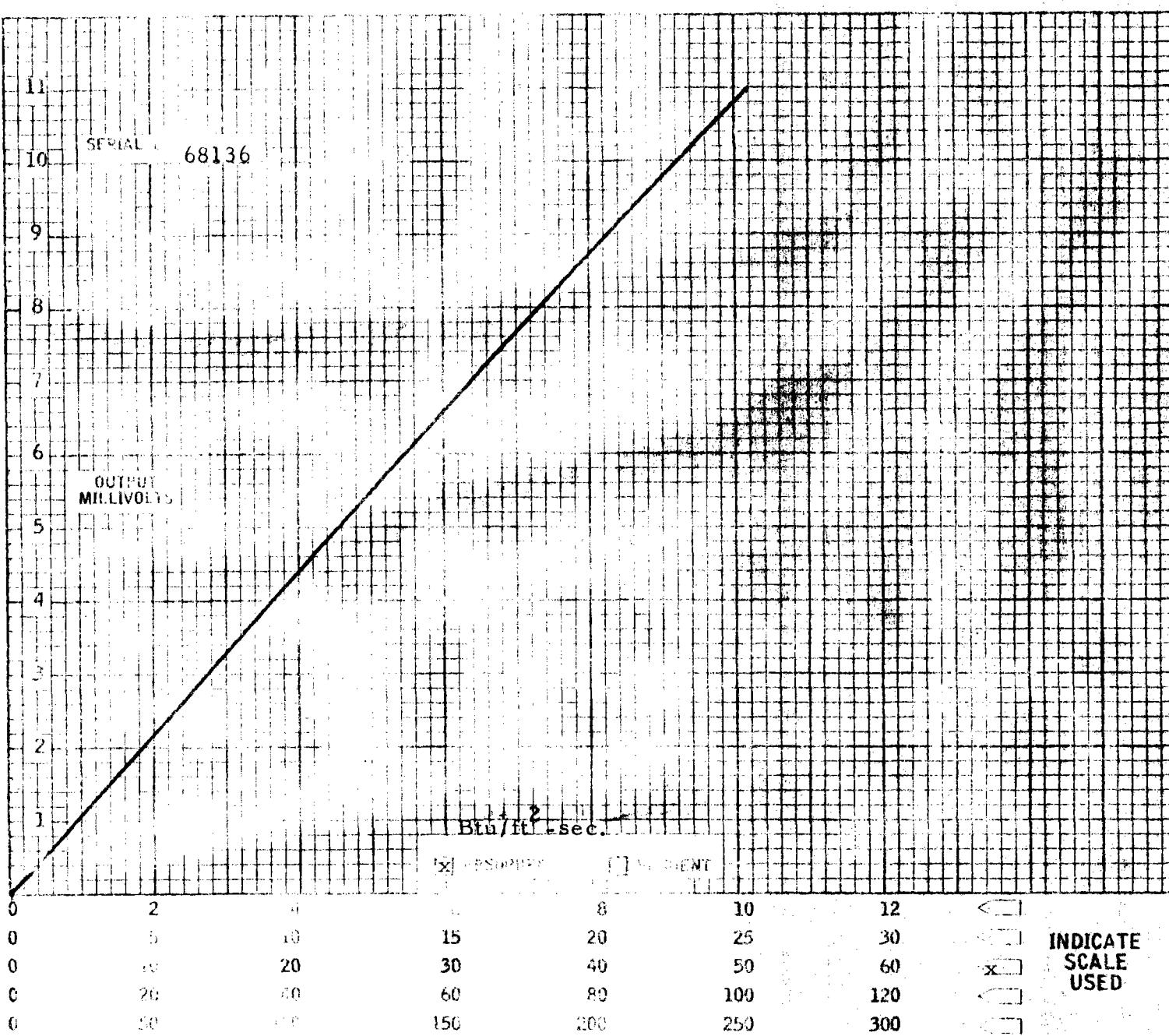


Q. C. APPROVAL



SUBSCRIBED AND SWORN TO
 BEFORE ME THIS 28th DAY

OF JUNE 19, 1978



ABSORPTIVITY

REFLECTANCE

CALIBRATION

ACCURACY

STABILITY

LINEARITY

SIGNAL NOISE

RESPONSE

SIGNAL STRENGTH

SIGNAL SMOOTHING

SIGNAL ATTENUATION

SIGNAL AMPLIFICATION

SIGNAL INTEGRATION

 INDICATE
SCALE
USED

CERTIFICATE OF CALIBRATION

"THE TEMPERATURE PEOPLE"

HY-CAL ENGINEERING

1100 Los Nester Road • Santa Fe Springs, California 90670

DATE 6-28-78

CUSTOMER Sanders

P.O. NO. 780772

INST. TYPE Calorimeter

MODEL C-1112-BX-50-300

ABSORBTIVITY .89

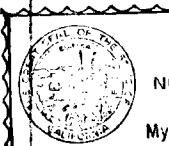
CERTIFICATE RELATING TO CALIBRATION DATA ON THE INSTRUMENT DESCRIBED ABOVE. THE DATA WAS OBTAINED IN HY-CAL ENGINEERING'S THERMAL FLUX FACILITY.

REFERENCE STANDARD 43592

TESTED BY J. A. Hango

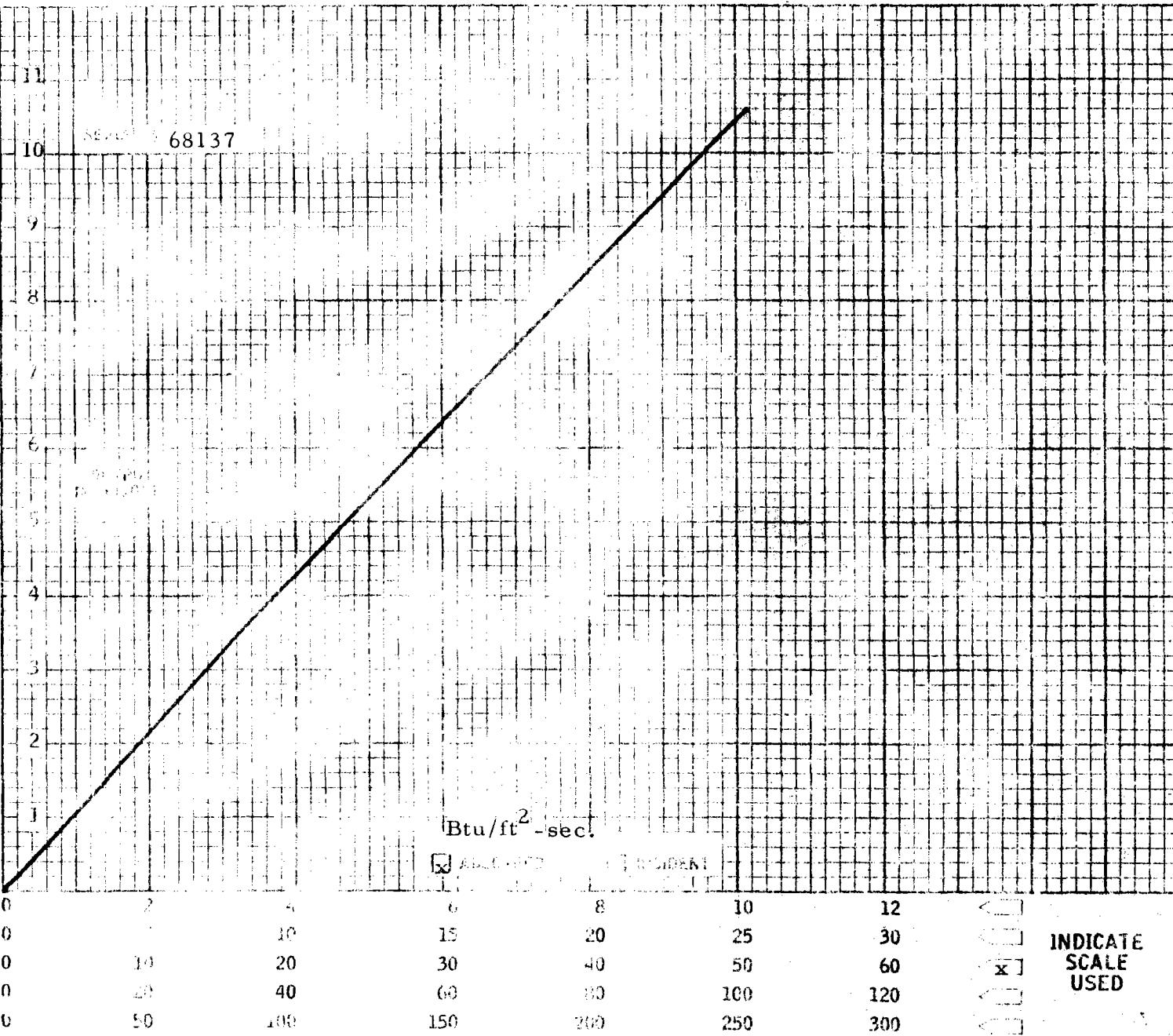


Q.C. APPROVAL



OFFICIAL SEAL
JULIE A. HANGO
NOTARY PUBLIC - CALIFORNIA
LOS ANGELES COUNTY
My Commission Expires June 28, 1978

SUBSCRIBED AND SWEORN TO
BEFORE ME THIS 28th DAY
OF June 1978



CERTIFICATE OF CALIBRATION

"THE TEMPERATURE PEOPLE"

MECH ENGINEERING

17151 - 1/2 Mile Road • Santa Fe Springs, California 90670

DATE 6-28-78

CUSTOMER Sanders

P.O. NO. 780772

INSTL. TYPE Calorimeter

MODEL C-1112-BX-50-300

ABSORPTIVITY .89

CERTIFIED RECORD OF CALIBRATION
 DATA ON THE INSTRUMENT IS SHOWN ABOVE.
 THE DATA WAS OBTAINED IN
 HY-CAL ENGINEERING'S THERMAL FLUX
 FACILITY.

REFERENCE STANDARD 43592

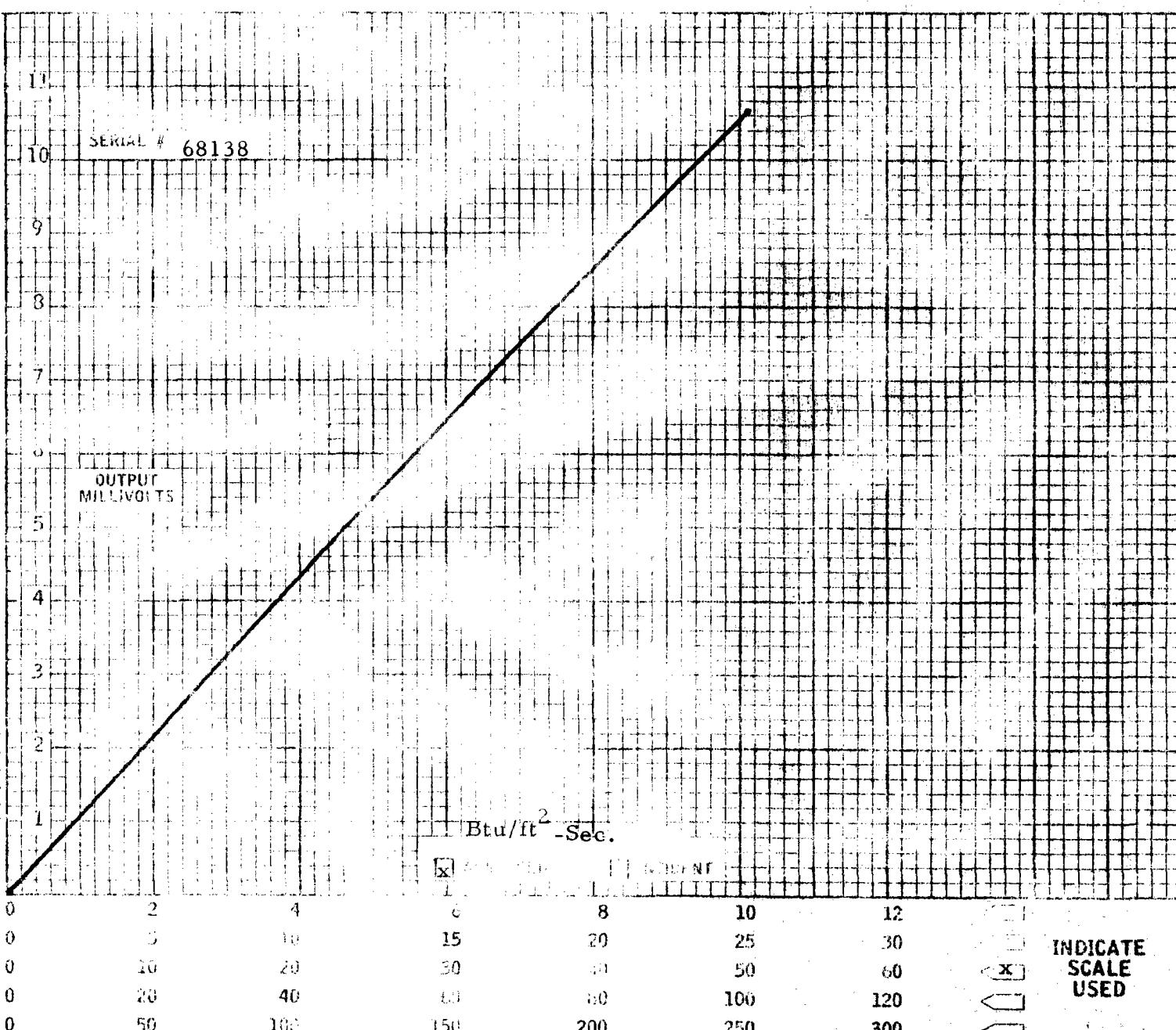
TESTED BY J. S. Z.



OFFICIAL SEAL
 JULIE A. HANGO
 NOTARY PUBLIC - CALIFORNIA
 LOS ANGELES COUNTY
 My Commission Expires June 28, 1978

SUBSCRIBED AND SWORN TO
 BEFORE ME THIS 28th DAY

OF June 19 78



ABSORPTIVITY GAIN/LOSS

INSTRUMENTATION ATTACHMENT

CALIBRATION ADJUSTMENT

OTHER

INDICATE
SCALE
USED

CERTIFICATE OF CALIBRATION

"THE TEMPERATURE PEOPLE"

CAL ENGINEERING

1105 Los Nietos Road • Santa Fe Springs, California 90670

DATE 6-28-78

CUSTOMER Sanders

P.O. NO. 780772

INST. TYPE Calorimeter

MODEL C-1112-BX-50-300

ABSORPTIVITY .89

CERTIFIED RECORD OF CALIBRATION
DATA ON THE INSTRUMENT DESCRIBED
ABOVE. THE DATA WAS OBTAINED IN
NY-CAL ENGINEERING'S THERMAL FLUX
FACILITY.

REFERENCE STANDARD 43592

TESTED BY J.S. 29

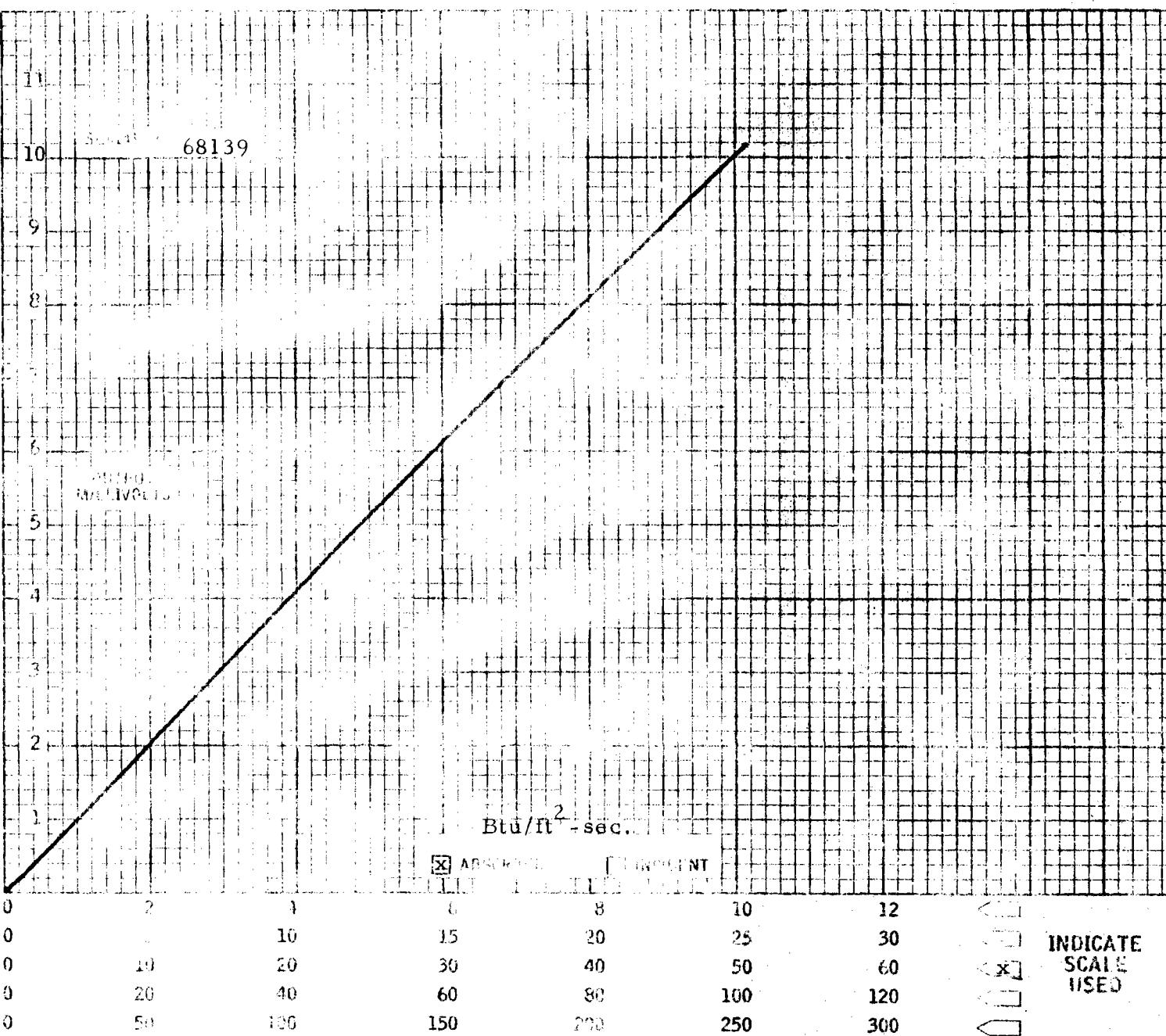
(HC)

G.C. APPROVAL 13



SUBSCRIBED AND SWORN TO
BEFORE ME THIS 28th DAY

OF June 1978



CERTIFICATE OF CALIBRATION

"THE TEMPERATURE PEOPLE"

HY-CAL ENGINEERING

12105 Los Nogales Road • Santa Fe Springs, California 90870

DATE 6-28-78

CUSTOMER Sanders

P.O. NO. 780772

INST. TYPE Calorimeter

MODEL LC-1112-BX-50-300

ABSORPTIVITY .89

CERTIFIED RECORD OF CALIBRATION
 DATA ON THE EQUIPMENT DESCRIBED
 ABOVE. THE DATA WAS OBTAINED AT
 HY-CAL ENGINEERING'S THERMAL TEST
 FACILITY.

REFERENCE STANDARD 43592

TESTED BY J. S. S.

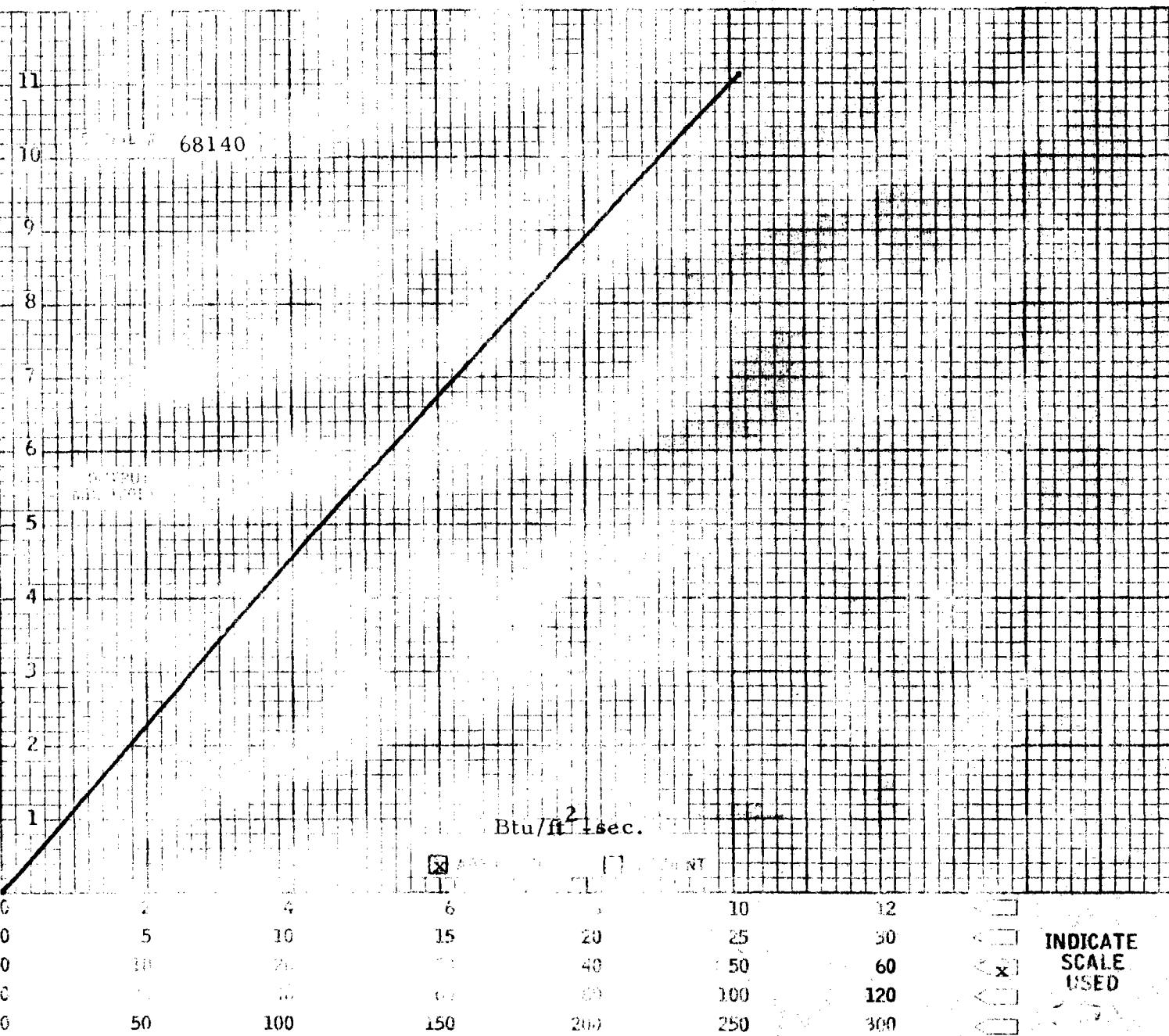


Q.C. APPROVAL

B-30



SUBSCRIBED AND SIGNED THIS
 BEFORE THE 28th day
 OF June 1978



CERTIFICATE OF CALIBRATION

THE TEMPERATURE PEOPLE



1200 E. Santa Ana • Santa Fe Springs, California 90670

DATE 6-28-78

CUSTOMER Sanders

P.G. #O. 780772

INST. TYPE Calorimeter

MODEL C-1112-BX-50-300

ABSORPTIVITY .89

CERTIFIED RECORD OF CALIBRATION
DATE 6-28-78 FOR THE DESCRIBED
ABOVE INSTRUMENT TESTED AT THE
INDUSTRIAL ENGINEERING'S CALIBRATION
FACILITY.

B-31

REFERENCE STANDARD 43592

TESTED BY 16526

Q.C. APPROVAL

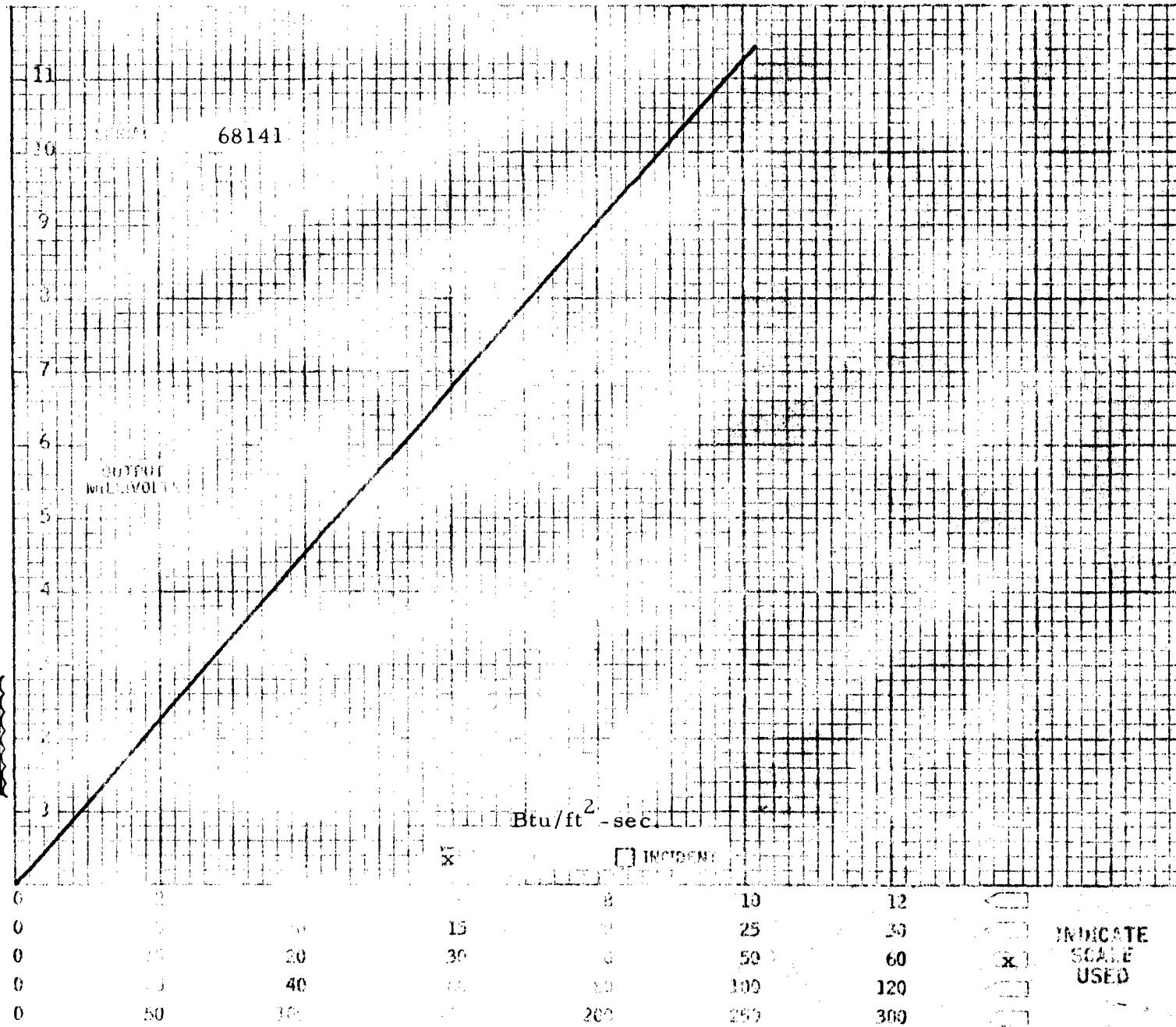


SUBSCRIBED AND SWORN

BEFORE ME THIS 28th

OF JUNE 19 78

IN THE CITY OF SANTA FE SPRINGS



CERTIFICATE OF CALIBRATION



DATE 6-28-78

CUSTOMER Sanders

P. O. NO. 780772

INST. TYPE Calorimeter

MODEL C-1112-BX-50-300

ABSORPTIVITY .89

CERTIFIED RECORD OF CALIBRATION
DATA ON THE INSTRUMENT DESCRIBED
ABOVE. THE DATA WAS OBTAINED IN
HY-CAL ENGINEERING'S THERMAL FACILITY.

B - 32

REFERENCE STANDARD 43592

TESTED BY J. S. Z.

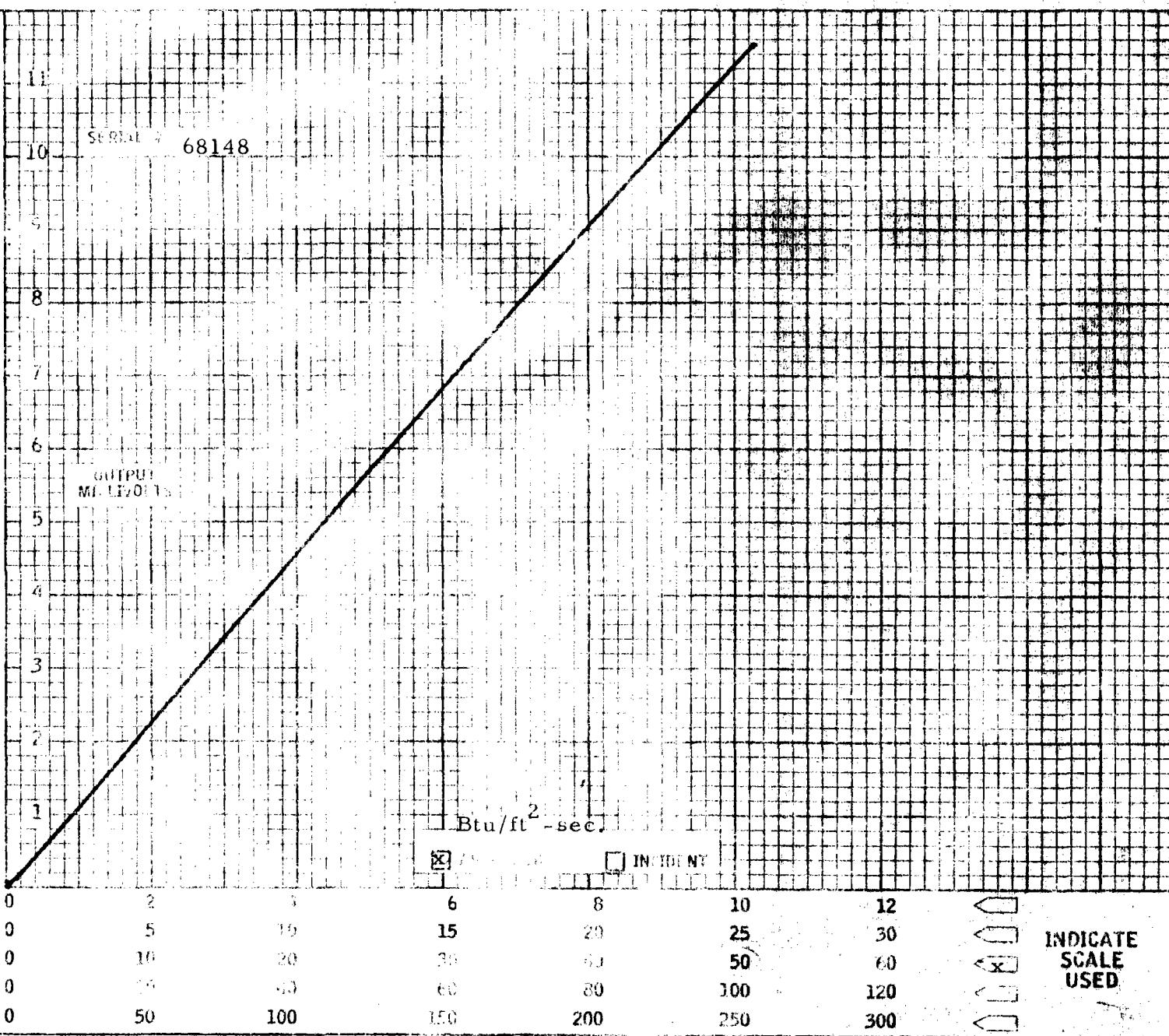
(HC)
13

Q. C. APPROVAL



SUBSCRIBED AND SWORN TO
BEFORE ME THIS 28th DAY

OF JUNE 1978



CERTIFICATE OF CALIBRATION

"THE TEMPERATURE PEOPLE"

HY-CAL ENGINEERING

P.O. Box 780772 • Santa Fe Springs, California 90670

DATE 6-28-78

CUSTOMER Sanders

P. O. NO. 780772

INST. TYPE Calorimeter

MODEL C-1112-BX-50-300

ABSORBIVITY .89

CERTIFIED RECORD OF CALIBRATION
 DATA ON THE INSTRUMENT DESCRIBED
 ABOVE. THE DATA WAS OBTAINED IN
 HY-CAL ENGINEERING'S THERMAL TEST
 FACILITY.

REFERENCE STANDARD D-43592

TESTED BY J. S. A.

Q. C. APPROVAL

HC
IS

SUBSCRIBED AND SWORN TO
 BEFORE ME THIS 28th DAY

OF June 1978

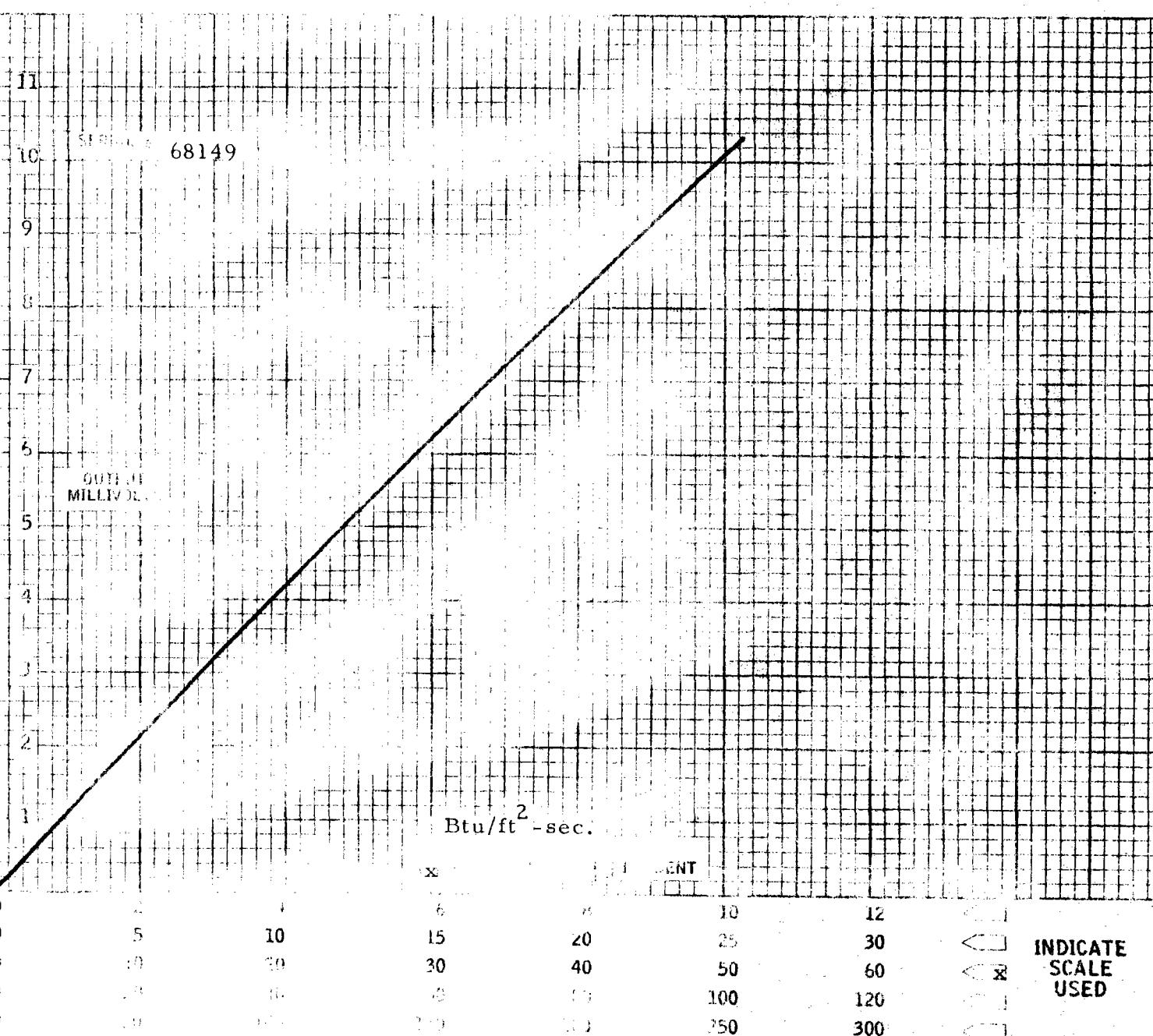
IN THE CITY OF LOS ANGELES

STATE OF CALIFORNIA

AND THE YEAR OF OUR LORD ONE THOUSAND NINETEEN SEVENTY EIGHT

I am a Notary Public in the State of California

and my Commission Expires June 23, 1973



CERTIFICATE OF CALIBRATION

'THE TEMPERATURE PEOPLE'

HY-CAL ENGINEERING

10011 Pacific Coast Highway • Santa Fe Springs, California 90670

DATE 6-28-78

CUSTOMER Sanders

P. O. NO. 780772

INST. TYPE Calorimeter

MODEL C-1112-BX-50-300

ABSORPTIVITY .89

CERTIFIED RECORD OF CALIBRATION
DATA ON THE INSTRUMENT DESCRIBED
ABOVE. THE DATA WAS OBTAINED IN
HY-CAL ENGINEERING'S THERMAL FLUX
FACILITY.

REFERENCE STANDARD 43592

TESTED BY *J. S. S.*

(HC)

Q. C. APPROVAL *13*

OFFICIAL SEAL
JULIE A. HANGO
NOTARY PUBLIC - CALIFORNIA
LOS ANGELES COUNTY
My Commission Expires June 28, 1978

SUBSCRIBED AND SWORN TO
BEFORE ME THIS 28th DAY

OF June 1978

