CALIBRATION PROCEDURES AND RESULTS

FOR A LARGE CALIBRATED HOT BOX

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ABSTRACT

This paper describes the evolution of the Owens-Corning Fiberglas Large Scale Horizontal Calibrated Hot Box known as the Thermal Research Facility described previously at the joint DOE/ASTM Insulation Conference in Tampa, Florida, 1978. The facility was constructed for experimental measurements of thermal performance of large composite horizontal building elements, as well as total building envelopes such as a one-room structure or a mobile home. This discussion summarizes the original design concepts, reviews the limitations involved with these concepts, and details the final hot box configuration. The discussion includes a detailed analysis of the limitations, with regard to power measurements and stabilization and the solutions incorporated into the final design to overcome these operational limitations. The total conditioning and measurements systems including the heating and cooling systems, the instrumentation, power measurements equipment, and data acquisition and analysis systems involved with the facility in its final design are described. The comprehensive calibration test program and the summary of results obtained are presented. The physical significance of the experimental results are explained by comparison to the mathematical model of the overall system. Details of the calibration sample used in the program are discussed also. The paper concludes with recommendations for calibration procedures for future facilities of this type.

INTRODUCTION

The Owens-Corning Fiberglas Thermal Research Facility (Figure 1) was designed and constructed between late 1976 and August of 1978. In August of 1978, the facility was fully operational from a control systems and data acquisition standpoint. The final step to achieve an accurate test facility was calibration of the metering chamber and the overall systems.

The facility consists of a primary chamber and metering chamber, each having a wide range of temperature control. The metering chamber is a highly insulated below ground pit over which the test sample is placed. The purpose of the calibration is to account for heat flow through the metering chamber surfaces and flanking loss around the sample edges. Calibration is accomplished by performing tests at a variety of conditions on a test sample of known thermal properties. Conservation of energy dictates that the difference between the measured net heat flow into the metering chamber and the heat flow through the calibration specimen calculated from the known resistance is equal to the heat loss through the metering chamber surfaces. Empirical correlation of these heat flow differences to the output of the heat flow transducers attached to the

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metering chamber surfaces provides the calibration correction equations.

Attempts to calibrate the facility continued until November of 1978. At this time it had become evident that certain modifications were necessary if the design accuracy was to be achieved. These modifications consisted of constructing a new metering chamber (Figure 3) immediately below the test sample and utilizing the original metering chamber as a surrounding thermal guard to reduce metering chamber losses. Rebuild was accomplished during the month of December 1978 and calibration resumed in January of 1979. The procedure for calibration remained essentially the same as before. The details of the evolution of the Thermal Research Facility from August 1978 to the results of the final calibration are the subject of this report.

DESCRIPTION OF ORIGINAL FACILITY

The Thermal Research Facility incorporates a below ground metering chamber with a 4.3 by 6m (14 by 20 foot) opening incorporated into the floor of a 10.7 by 21.3 by 7.6 m (35 by 70 by 25 foot) primary environmental chamber. For tests, a building section is constructed over the metering chamber opening between the two chambers. In this manner, the facility can be used to evaluate the thermal performance of horizontal elements such as roofs, attics, and floors.

The temperature in the primary chamber can be controlled to within 0.3^{o}C (0.5 ^{o}F) over a range of -46^{o} to 66^{o}C (-50^{o} to 150^{o}F). The temperature of the metering chamber can be controlled to within 0.1^{o}C (0.2^{o}F) over a range of -9.5^{o} to 66^{o}C (15^{o} to 150^{o}F). The total energy into the chamber consists of the loads due to the electrical resistance heaters, the air handler blower, lights, and any other loads which may be connected to auxiliary receptacles in the chamber. Power consumption of these loads is accurately monitored by use of electronic watt-hour transducers. The cooling system, consisting of a glycol-water solution passing through a cooling coil, is metered by measurements of the mean fluid temperature, temperature rise across the cooling coil, and fluid flow rate. During operation of the total system, the cooling capacity is controlled by manually adjusting the fluid temperature and flow rate to effectively reduce the cooling to the minimum required to maintain a given temperature condition. Reheat is provided by thermostatically monitored, SCR controlled, resistance heaters to achieve fine temperature stability.

The metering chamber was designed to limit heat flow through the walls and floor. For structural reasons, the chamber walls and floor were constructed of a 0.3m (12 in.) shell of poured reinforced concrete. Urethane foam board stock, 0.46m (18 in.) thick, was installed inside the concrete shell and covered with 16 mm (5/8 in.) gypsum board for fire protection. Around the top periphery of the chamber, a high density fiberglass surfaced foam ring was installed. This ring acts as an extension of the insulated metering chamber walls, and is used as a sample support. A much more thorough discussion of the facility design and equipment can be found in "Thermal Research Facility - A Large Calibrated Hot Box for Horizontal Building Elements"[1].

CALIBRATION SAMPLE

The calibration accuracy for a test facility of this type depends primarily upon the predictability of the thermal characteristics of the calibration test specimen. Unless the thermal performance of the specimen can be accurately predicted, correlation of the metering chamber heat loss is impossible.

The material chosen for the calibration sample was a special production glass fiber board produced at a nominal dimension of 1.22 x 3.05 m (4 x 10 feet) to a 41 mm (1-5/8 inch) thickness and then sanded on both sides to a uniform thickness of 35mm (1-3/8 inches + 0.004"). The material had a nominal density of 16 kg/m^{3} (8.0 lbs/ft^{3}) and thermal conductivity of 0.034 W/m^{o}K (0.24 Btu-in/Hr-Ft^{2}-^{o}F). Conductivity vs. mean temperature and density curves were generated from multiple samples using standard ASTM methods. Since the fibrous glass board has a porous structure, a facing was applied to the surface for air infiltration protection. This facing, a white painted-foil-glass scrim-paper laminate, was applied using a contact adhesive. Thermal conductance tests before and after facing showed that the "facing" contribution was insignificant (less than 1/2%) with respect to the overall thermal resistance of the sample.

An aluminum grid system consisting of three 25 x 50 x 3 mm (1 x 2 x 1/8 inch) aluminum channels 6.1 m (20 feet) long was necessary to support the sample over the metering chamber. These channels were equally spaced and positioned flush with the top of the foam ring sample support and oriented with the open side towards the sample to minimize thermal contact. The three channels were supported by four 75mm (3 inch) aluminum I-Beams spanning the 4.27m (14 foot) dimension of the metering chamber which in turn were attached to the steel mounting ring built into the reinforced concrete shell of the metering chamber. The support frame which was contained entirely within the metering chamber provided a very rigid sample support with a minimum of thermal contact. With the frame in place, the sample material was then cut and fit to construct the calibration sample. The sample design allowed for an 87 mm (3-1/2 inch) overlap over the entire inside perimeter of the foam support ring. This overlap, corresponding to the width of standard "2 x 4" lumber, was chosen because the building structures to be tested were to use a "2 x 4" base plate or equivalent as the supporting interface. After sizing the material, all adjoining borders of the sample pieces were edge grooved 12mm (1/2 inch) deep and 6mm (1/4 inch) wide. Using high density glass fiber board strips 6 x 25mm (1/4 x 1 inch) as jointers, the boards were assembled over the metering chamber. The jointers provided good structural integrity to the overall specimen in addition to minimizing heat flow paths through cracks and corners. All joints, top and bottom, were then taped using 50mm (2 inch) wide tape made from the facing material. The foam support-sample interface on both the primary and metering chamber sides was sealed using silicone sealant.

INSTRUMENTATION

Instruments used included thermocouples, heat flow transducers, turbine flow meters, fluid flow temperature rise meters, and watt-hour transducers. A complete description, including specific components has been presented previously (1). Type T copper-constantan thermocouples, inert gas welded from 0.25 mm (30 Ga.) wire, are used to measure temperatures throughout the facility. By using wire from a single production run, reproduceability of temperature difference measurements improves beyond the special limits of error (+/- 3/4 F) for the wire. For the calibration sample, a total of 216 thermocouples were used to monitor the top and bottom sample surface and air temperatures. Fifty-four thermocouples were mounted directly on each sample surface with ASJ faced tape. A minimum of 100mm (4 inches) of the thermocouple lead was held in contact with the surface to prevent sensing errors. An additional 54 thermocouples were positioned above (below) each surface couple to measure the air temperature 100 mm (4 inches) from the surface. The installation practices used comply with the ASTM standard for thermocouple instrumentation of building assemblies (2).

For the heat flow determination into the metering chamber surfaces, a total of thirty heat flow transducers were used. These were strategically placed to account for the various surface constructions of the metering chamber. The chamber surfaces were divided into five areas, each representing a surface having similar heat flow behavior. These were 1) floor, 2) bottom wall, 3) top wall, 4) steel support ring, and 5) door. The transducers measured 112 x 112 mm (4-1/2 x 4-1/2 inches), and had a nominal calibration factor of 25.2 $w/m^2/mV$ (8.0 Btu/Ft^2-Hr/mV). Exact calibration factors were not determined for the transducers because the voltage produced was to be correlated in the overall heat flow balance equations. Corrections were made for changes in transducer temperature, as indicated by the internal thermocouple using manufacturers instructions.

Measurements of the metering chamber cooling system load was accomplished by accurate determination of the chilled brine flow rate, measurement of the temperature change of the fluid across the coil, and the average or mean fluid properties. The device used for fluid flow measurement was a precision turbine flowmeter, a volumetric type meter which develops a pulsed millivolt output proportional to the fluid flow volume. This low level pulsed output is then passed through a signal amplifier to obtain a pulsed 0-5 v DC output which triggers an electronic totalizer. The total number of pulses for a given time period represents the total liquid volume passing through the cooling coil during that time.

The fluid temperature rise across the coil was measured using a differential temperature transducer, a thermocouple device having a millivolt output proportional to the temperature difference between the inlet and outlet streams. A thermocouple probe mounted directly upstream on the "cold" side of the differential temperature transducer is used to measure fluid mean temperature. Because the temperature rise transducer sensitivity is proportional to the mean fluid temperature it must be corrected using the transducer manufacturer's supplied calibration curves. The fluid used was a 50% ethylene glycol-water solution concentration controlled to within 1%. From the known concentration, the specific properties (specific gravity, specific heat) of the fluid can then be calculated using the glycol manufacturer's data as a function of mean fluid temperature.

The measurement of electrical power consumption within the metering chamber was made with solid state watt-hour transducers which provide a digital signal directly proportional to energy consumption. A counter totalizes the counts over a specified time period to determine power consumption. These transducers were connected to all metering chamber input devices - electrical resistance heaters, blower, lights, and receptacles.

DATA ACQUISITION

This complex instrumentation system requires a computer controlled data system for efficient operation. The data acquisition system used included signal conditioning to provide analog outputs from the different scanners, digitizers or totalizing units, a scanner controlled by the computer and a mass storage device for the data. A schematic of this system is presented in Figure 2.

The voltage output devices (thermocouples, heat flow transducers, differential temperature transducer), are connected through a multiplexing scanner to a high precision integrating digital voltmeter. When a specified channel is called, the signal is multiplexed through a relay connecting the leads to the voltmeter. During this switching operation for the thermocouple channels, a reference junction compensation voltage is applied to the signal to automatically reference the thermocouple to a $0^{\circ}C$ ($32^{\circ}F$) base temperature. The transducer output voltages are scanned similarly but with no bias voltage. The scanner output voltages are then digitized by an integrating digital voltmeter with 6-place resolution.

The power consumption transducers and the cooling liquid flow meter outputs both are in the form of a contact closure. These outputs are recorded using totalizing counters capable of one million counts at a rate of 10kHz. They automatically reset to zero beyond one million counts. The link between the counters and computer is an EIA RS232 communications link established using ASCII character strings.

The control/storage device is a FORTRAN programmable 16 bite mini computer. The computer program used for calibration consists of subroutines which perform a number of different functions. These include operational and communication subroutines which permit the computer to communicate with the various instruments such as the scanners and totalizing counters. An internal timekeeping system allows the computer to read instrumentation values at the desired frequency. The remaining subroutines convert data values to engineering units. The computer then performs computational functions to produce a printout summary of the data values and store the data for more detailed processing.

In the calibration tests performed, the test print increment was chosen as one hour. However, due to slight fluctuations in the temperatures, it was necessary to read some instrumentation outputs more frequently. All thermocouple channels were read at five minute intervals and then averaged for the one hour test increment. Since the brine temperature also fluctuated periodically, one-minute scans of the brine temperature and coil temperature rise values were made to obtain accurate cooling load data.

PRE-CALIBRATION

Before any actual calibration tests were performed, an overall system inspection was made. Each component and subsystem in the facility was first checked for proper installation. Initial calibration established the accuracy of each component either as it was installed or after installation. The use of commercial components was beneficial as they can normally be purchased with factory calibration within the design accuracy limits.

The heat flow transducers were uncalibrated, as the wall heat flux versus meter output would be determined by the calibration tests. The watt-hour transducers were checked for accuracy using a watt-hour meter standard traceable to NBS. The flow meter was checked by passing a weighed quantity of fluid through the meter, recording the counts and comparing the results with the factory calibration. All equipment was within the limits prescribed.

One component that required extensive on-site calibration was the temperature scanning system. Although factory adjusted, the scanner reference compensation and digital voltmeter zero and range required readjustment after initial operation. The compensation adjustment was simplified by using an ice-point cell and adjusting the output of the scanner to read zero. The digital voltmeter was checked by comparison to established voltage standards. Internal zero and calibration systems were used for routine checkout.

ORIGINAL FACILITY CALIBRATION PROCEDURE

To calibrate the facility, the heat losses through the metering chamber surfaces as a function of chamber temperature must be determined. With the calibration sample in place, a known temperature differential can be applied to the sample and the net metering chamber heat flow measured. The difference between the calculated sample heat flow and the total measured energy into the metering chamber is then the amount of heat flow through the metering chamber surfaces. By performing tests at numerous temperature combinations, the metering chamber heat losses can be empirically correlated to the heat flow transducer outputs.

DISCUSSION - INITIAL CALIBRATION

Analysis of the original calibration tests showed that the facility as originally designed would not provide the desired test accuracy under all conditions of contemplated use. The major problem was significant heat loss through the metering chamber surfaces relative to the sample heat loss.

A second problem was temperature stabilization. Long term transients associated with the thermally thick walls and shifting ground temperatures could not be substantially reduced. A 14°C (25°F) change in metering chamber temperature required approximately 100 hours to reach 1% equilibrium. Although the problem was recognized during the design, the magnitude was greater than expected.

Additional difficulties existed with the large magnitudes of the heating and cooling quantities associated with the commercial HVAC equipment used to condition the metering chamber. These could not be reduced to an acceptable level by the existing control capability. In some cases, this resulted in a net heat input equalling the difference between a large heating load and large cooling load, thus compromising the accuracy of net heating and cooling load measurement.

Aided by the results of our preliminary calibration attempts and additional mathematical analysis of the system based upon those results, we determined that extensive redesign of the metering chamber was necessary before calibration could proceed.

METERING CHAMBER MODIFICATION

The major modification was to incorpore into the original metering chamber a smaller metering chamber (Figure 3) having a separate heating and cooling system. The original chamber was then to act as a controlled thermal guard to minimize heat losses through the new metering chamber surfaces. This modification changes the operational configuration from a classic calibrated hot box to a hybrid guarded-calibrated hot box.

The new metering chamber was constructed so that its upper dimension was identical to the original chamber. The sides tapered in at an angle of 0.78 radians (45°) to a depth of 0.6 m (2 ft.) below the test sample. The new chamber enclosure was constructed of two layers of 25mm (1 inch) thick high density fiberglass duct board glued to a 18 mm (3/4 inch) plywood backing for strength. The duct board was faced on each surface with an airtight, glass-reinforced, painted foil. The entire structure was supported with a 100 x 100mm (4 x 4 inch) wooden framework. After installation, all foil seams and joints were sealed using silicone sealant and painted foil faced tape.

An improved, independent heating and cooling system was designed and constructed for this new metering chamber based upon the experience gained during the initial calibration work. The prime concern was to minimize the air blower power dissipation, provide very fine control of the heating and cooling loads, and design the overall system so that when negative sample temperature differential tests were performed, the cooling requirement would be eliminated whenever possible.

The cooling system consists of a small and large cooling coil, staged together so that they could be used separately or together as required. The flow rate of the fluid was reduced to 16-130ml/s (0.25-2.0 gal/min.). The heat extraction of the fluid was accomplished by use of a heat-exchanger plumbed into the existing guard cooling system. A 150 l. (40 gal.) reservoir reduced the fluid temperature fluctuations. The fluid temperature was controlled by throttling the amount of fluid passing through the heat-exchanger. Water was substituted for the ethylene-glycol solution because metering box temperatures below $10^{\circ}C$ ($50^{\circ}F$) had been eliminated from the testing schedule. By using water as the fluid, thermophysical properties characterization was more precise.

This cooling system design eliminated all of the problems discovered in the previous system. All control adjustments were now manually activated. This mode of operation requires more attention, however, this is a necessity from an accuracy standpoint to minimize cooling capacity at each test condition. The instrumentation of the cooling system remained the same, with the exception of the flow meter sizing.

The heating system now consists of seven banks of four exposed heating elements wired to yield 660 watts (2250 Btu/hr) each at 1/4 rated wattage. A thermistor temperature controller monitors the metering chamber temperature and activates the heating elements as required to maintain the set point. The method of monitoring energy consumption remained unchanged.

The heating and cooling systems are completely enclosed in an insulated sheet metal housing. The air distribution system uses a squirrel-cage blower unit sized to provide approximately one air exchange per minute within the metering chamber. The air distribution system consists of linear air diffusers running lengthwise along each side, fed through a round glass fiber duct.

The overall system can control the metering chamber temperature over a range of 10° to $65^{\circ}C$ (50° to $150^{\circ}F$) to within $0.1^{\circ}C$ ($0.2^{\circ}F$). The original metering chamber temperature, now designated as the outside guard temperature, has similar control. Thus, the temperature differential across the guard (metering chamber surface) can effectively be controlled to less than $0.2^{\circ}C$ ($0.4^{\circ}F$). The metering chamber losses were thus reduced (Figure 4) and the long-term transients as seen by the metering chamber, were effectively eliminated.

FINAL CALIBRATION

The basic calibration procedure as previously described remained unchanged for the modified chamber. The heat transfer through the guard, although now small, must be determined. The majority of heat loss is now concentrated at the small area near the sample-support interface (Figure 5). In most cases, the support sees the same temperature differential as the sample and may be the source of significant heat loss in spite of its high insulation level.

The metering chamber guard was instrumented with twelve heat flow transducers evenly distributed over its surface and installed between the insulation board and plywood to eliminate short-term transients from air currents. The entire guard was assumed to have uniform heat flow, therefore the twelve transducer outputs are simply averaged and applied to the total guard area.

The first calibration tests were performed using heating only, thus only negative sample temperature differences could exist (primary chamber colder than metering chamber). An overall heat balance of the system is:

$$Q_{in} = Q_{out} = Q_{sample} + Q_{support} + Q_{guard} \tag{1}$$

where Q_{in} is the sum of the heat supplied to the heater and the blower.

Defining:

$$\begin{aligned} Q_{correction} &= Q_{in} - Q_{sample} \\ &= Q_{support} + Q_{guard} \end{aligned} \tag{2}$$

$Q_{correction}$ is the desired heat flow quantity to be obtained from the calibration. Thus, by performing a number of tests and varying the sample temperature differential, sample mean temperature and guard temperature differential, a correlation can be made between the required heating correction values and the physically significant parameters of the metering chamber.

A total of twelve tests were performed in the heating only mode (Figure 6). The sample temperature differential and sample mean temperature were varied from -4^{o} to $52^{o}C$ (25^{o} to $125^{o}F$). The guard temperature differential was varied from -0.5^{o} to $+0.5^{o}C$ (-1.0^{o} to $+1.0^{o}F$). A correction factor could then be statistically derived from the data collected as a function of physically significant parameters yet to be determined.

To determine these parameters, a mathematical model of the system was developed. The two areas of concern were the guard and the sample-guard-support interface.

For the model of the guard, a general correlation exists for the average voltage output of the heat flow transducers and the heat transfer through the guard. Using the nominal sensitivity provided with the transducers $0.0252\ W/m^2/mV$ ($0.008\ Btu/Ft^2\text{-}Hr/mV$) and a guard area of $29m^2$ ($315\ Ft^2$) the predicted heat transfer through the guard is simply:

$$\begin{aligned} Q_{guard} &= \text{Transducer sensitivity x area} \\ &= (0.008\ Btu/Ft^2\text{-}Hr/Mv) \times (315\ Ft^2) \\ &= 2.520\ Btu/Hr \text{ per uV reading} \end{aligned} \tag{3}$$

The foam support-sample-guard interface was modeled using a two-dimensional finite element analysis modeling program. The results of the analysis showed the heat flow through the guard and support portion of this surface to be only about 2.5% of that for the calibration sample for a metering chamber temperature of $24^{o}C$ ($75^{o}F$) and primary chamber temperature of $7^{o}C$ ($45^{o}F$). For a $0.5^{o}C$ ($1.0^{o}F$) air-to-air sample temperature differential, a heat transfer rate of 12 watts (40 Btu/Hr) is predicted. This assumes "still air" surface coefficients.

Thus, the model predicts the heat transfer through the interface as a function of the air to air sample temperature difference to be:

$$\begin{aligned} Q_{interface} &= (0.025)(40\ Btu/Hr) \text{ for a unit temperature difference} \\ &= \Delta T \text{ in Btu/Hr for the general case where the temperature difference is } \Delta T\ (^{o}F) \end{aligned} \tag{4}$$

Further correction of equation (4) for the predicted variation in conductivity of the support with the mean temperature in ^{o}F yields:

$$Q_{interface} = (.863 + .0023\ T_m)\Delta T \tag{5}$$

where:

T_m = mean temperature of support (^{o}F)
ΔT = the air-to-air temperature difference across the support (^{o}F)

Combining Eq. (3) and Eq. (5) yields the total $Q_{correction}$ factor as derived from the model:

$$Q_{correction} = (.863 + .0023\ T_m)\Delta T + 2.52\ (EMF) \tag{6}$$

where:

$Q_{correction}$ = heat transfer through guard and interface in Btu/Hr
T_m = mean temperature of support (^{o}F)
ΔT = air-to-air temperature differential across calibration sample (^{o}F)
EMF = average heat flow transducer output in uV

Note that the temperature differential, air-to-air, across the calibration sample is the same as that for the support. Also, the mean support temperature can be assumed equal to the mean sample temperature for purpose of this analysis with no significant change in accuracy.

From the analysis above, the physically significant parameters were found to be the sample temperature difference (ΔT), the product of the sample mean temperature and sample temperature difference ($\Delta T \times T_m$) and the transducer output in uV (EMF). Using these parameters as independent variables, a multiple linear regression was performed on the calibration test results. From the regression analysis, the heating correction factor equation was determined to be the following:

$$\text{or}\quad Q_{correction} = 3.137 - (1.367 + .00813T_m)\Delta T + 2.04\ (EMF) \tag{7}$$

This regression provided agreement between the experimental results for the calibration sample theoretical prediction within a maximum of 2.5% for all data points and to within 1.5% for the majority of test points.

This calibration factor can be assumed to be valid in all cases of negative or positive sample temperature differences, since the heat flow behavior of the guard or foam support is independent of direction. Based on this assumption, the cooling system was then calibrated against the heating system with the heating correction factor incorporated into the data analysis.

For the tests involving heating and cooling, the primary chamber, metering chamber, and outside guard were all set to $24^{o}C$ ($75^{o}F$). A total of ten tests were performed at a range of cooling loads achieved by varying the cooling fluid flow rate and mean temperature. In two of the tests the primary chamber temperature was increased so that a sample temperature differential existed (Figure 6). For the eight cases with no differential, the heating load should exactly equal the cooling load. The difference measured between these two values was determined at each condition and calculated as a percentage. These results are presented in Figure 7.

Analysis off these results reveals an overall systematic error of approximately 4% with a standard deviation of less than 1% in the nominal cooling load. This cooling correction was then incorporated into the computer's data reduction program to correct the test results.

CONCLUSIONS

Owens-Corning Fiberglas has successfully designed, constructed, and calibrated a heat transfer research facility which operates within the guideline test method proposed by ASTM (2). The heating calibration tests show that heating only mode tests can be performed within 2.5%. When cooling is involved, overall test accuracy is within 3% for all tests in the range of temperatures and heat flows examined in this study.

Based upon early calibration attempts, many important details were identified as requiring further consideration before accurate calibration could be achieved. These details include the following:

1) Extraneous heat losses must be reduced to an acceptable level and unwanted transients eliminated. Heat transfer analysis will aid in proper design.

2) Equipment must be properly sized and operational techniques developed to minimize heating and cooling loads at each test condition.

3) The data acquisition system, including each component and sub-system must be checked and calibrated to insure that accurate data is acquired. All calculational procedures must also be checked to ensure accurate data reduction.

4) The calibration sample material must be accurately characterized before it can be constructed and tested.

REFERENCES

(1) "Thermal Research Facility - A Large Calibrated Hot Box for Horizontal Building Elements", J. R. Mumaw, Research Supervisor, Owens-Corning Fiberglas Corporation, Granville, Ohio 43023, Presented at the DOE/ASTM Conference in Tampa, Florida, 1978.

(2) "Standard Test Method for Thermal Performance of Building Assemblies by Means of a Calibrated Hot Box", C-XXX-XX, Subcommittee C16.30, American Society for Testing and Materials, Draft 6, Sept., 1979.

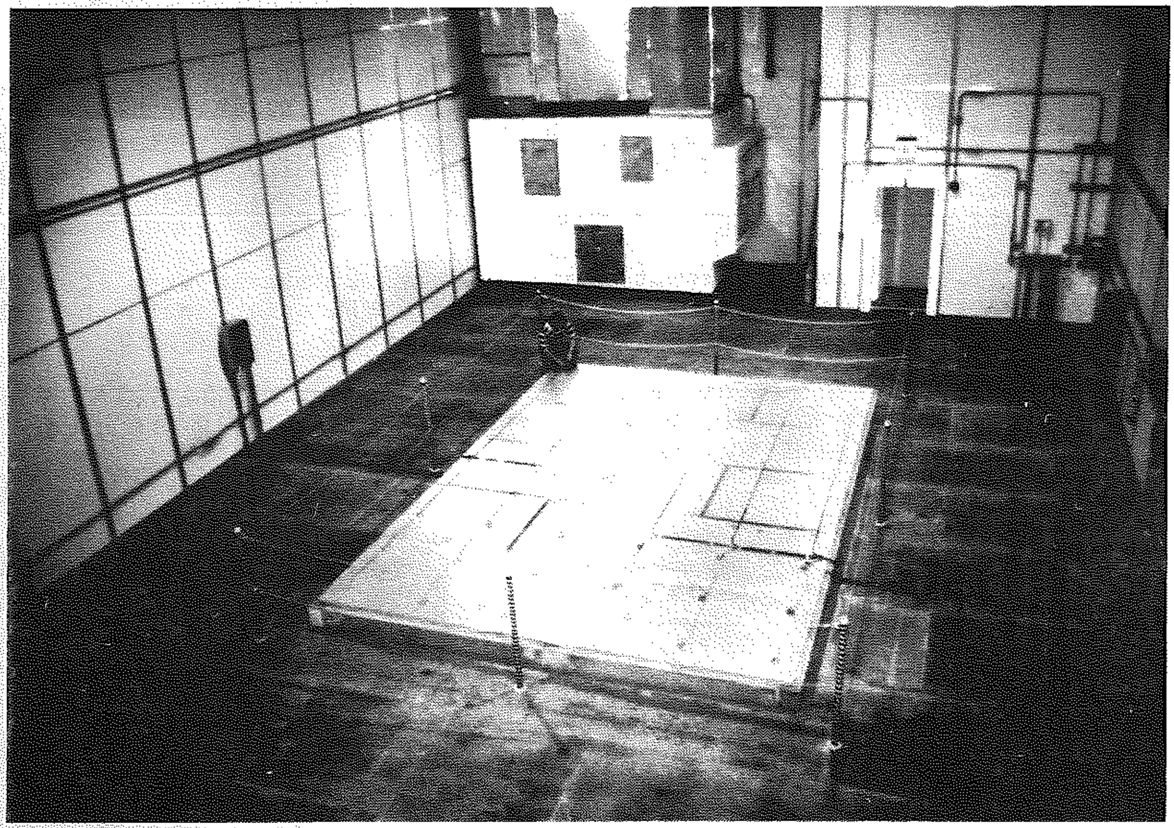

Fig. 1 Thermal research facility - shown with calibration sample installed over metering chamber

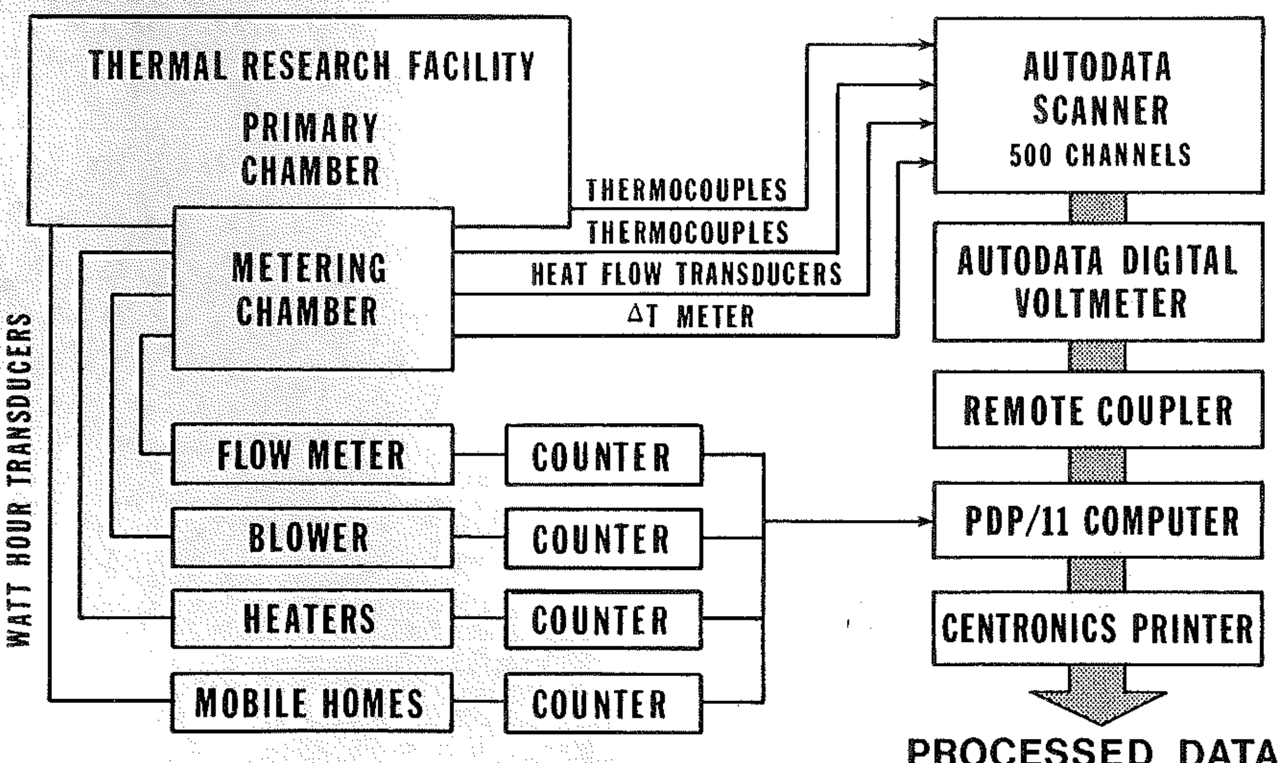

Fig. 2 Instrumentation and data acquisition

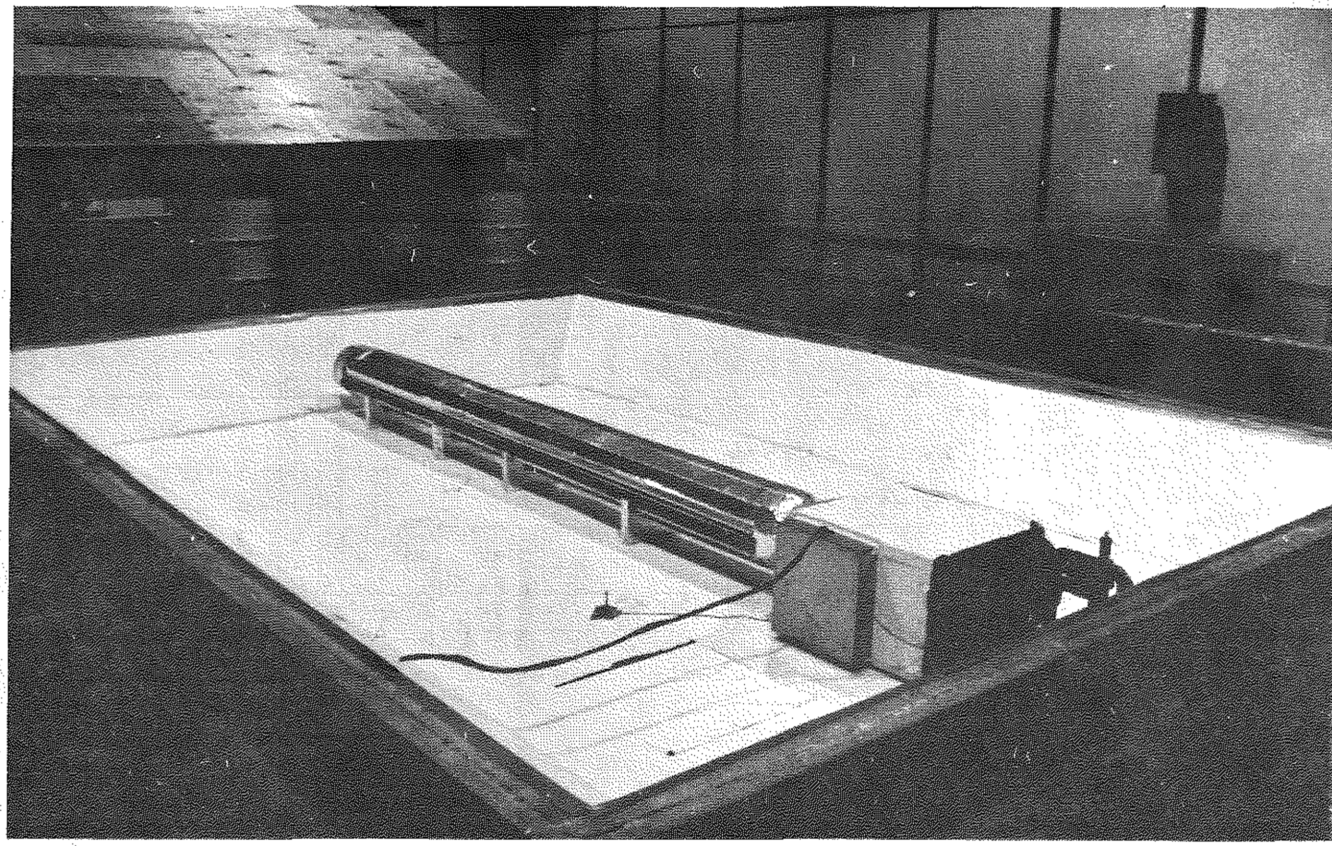

Fig. 3 Modified metering chamber - assumes a metering chamber temperature of 24°C (75 F)

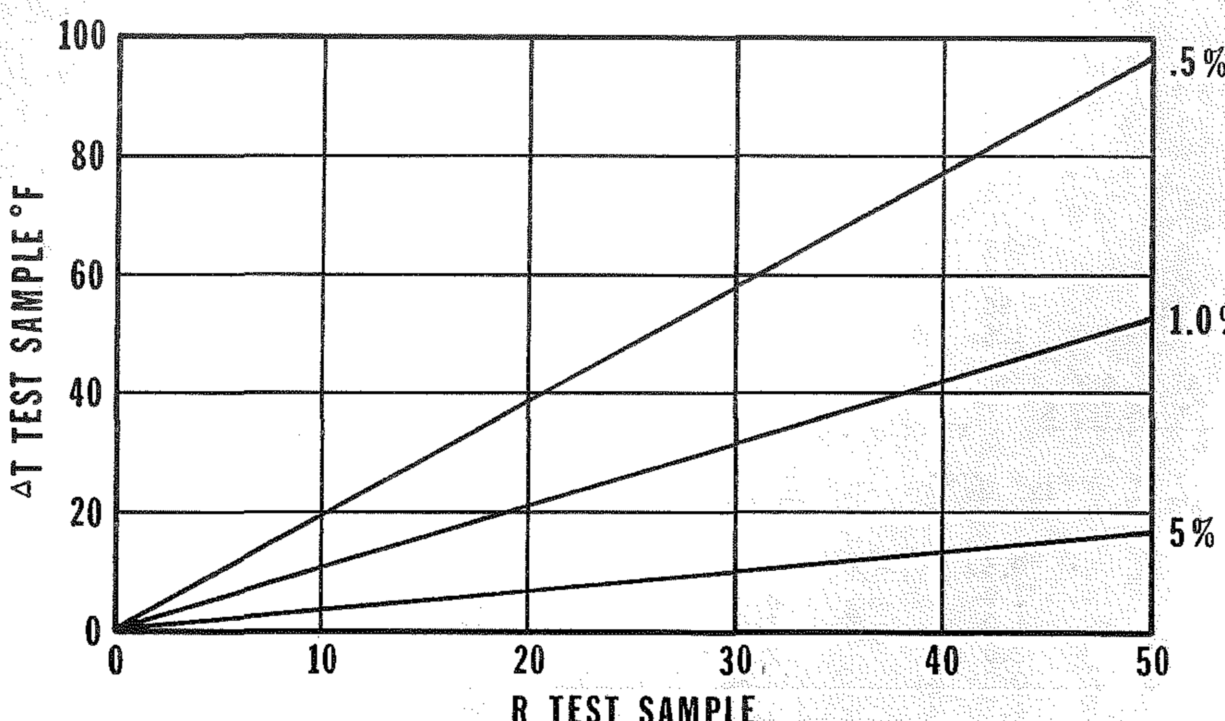

Fig. 4 Percent guard losses vs sample losses for modified metering chamber: assumes conductivity of guard of 0.20 Btu-in./hr-ft^2-°F, guard area of 29 m^2 (315 ft^2), guard temperature differential of 0.2°C (o.4 F)

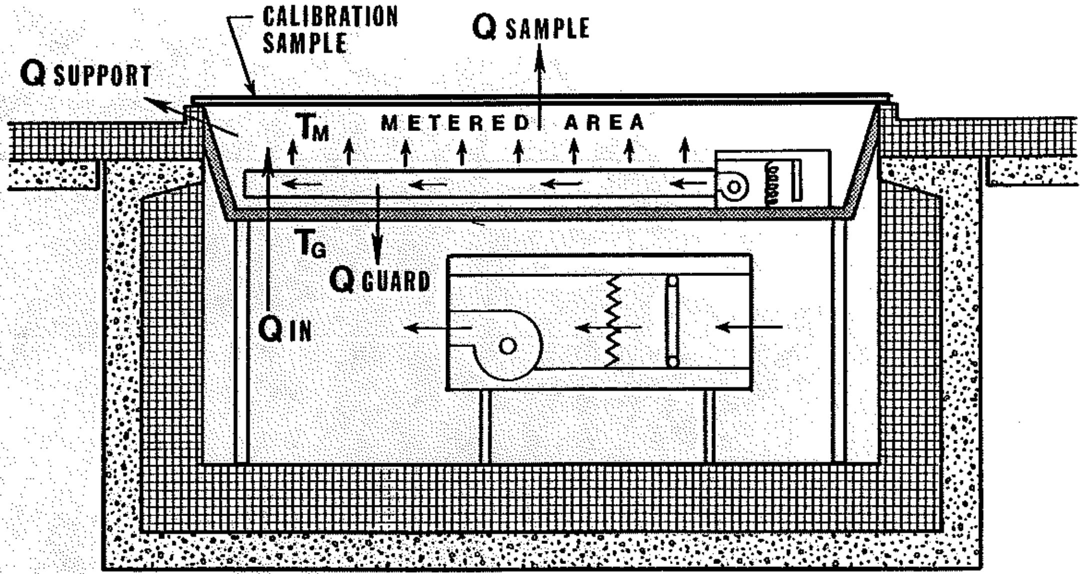

Fig. 5 Modified metering chamber energy balance - schematic

CALIBRATION DATA

HEATING TESTS

Test	ΔT Sample (°F)	ΔT Guard (°F)	T Mean Sample (°F)	Residual/Q_{pred}
1	50	0	25	- .72%
2	75	-1	37	.04%
3	75	0	37	- 2.57%
4	75	+1	37	.37%
5	100	0	50	1.48%
6	25	-1	62	1.37%
7	25	0	62	- 1.62%
8	25	+1	62	1.33%
9	75	0	75	1.79%
10	25	0	100	- 1.63%
11	50	0	125	.97%
12	125	0	62	.51%

HEATING AND COOLING TESTS

$T_{\text{primary chamber}} = T_{\text{metering chamber}} = T_{\text{outside guard}} = 75°F$

Test	Flow (GPM)	ΔT (°F)	$Q_{cooling}$	%(Qp - Qn)/$Q_{cooling}$
1	0.5	11.30	2822	3.45
2	2.0	3.82	3820	4.01
3	1.0	6.60	3298	3.90
4	2.0	2.12	2118	4.29
5	0.5	4.50	1092	3.64
6	1.5	1.67	1254	3.21
7	1.0	2.44	1222	4.47
8	2.5	3.10	3839	4.74
9	2.5	2.80	3681	4.91 T_{prim} = 100°F
10	1.0	7.10	3574	5.04 T_{prim} = 130°F

Fig. 6 Final calibration data

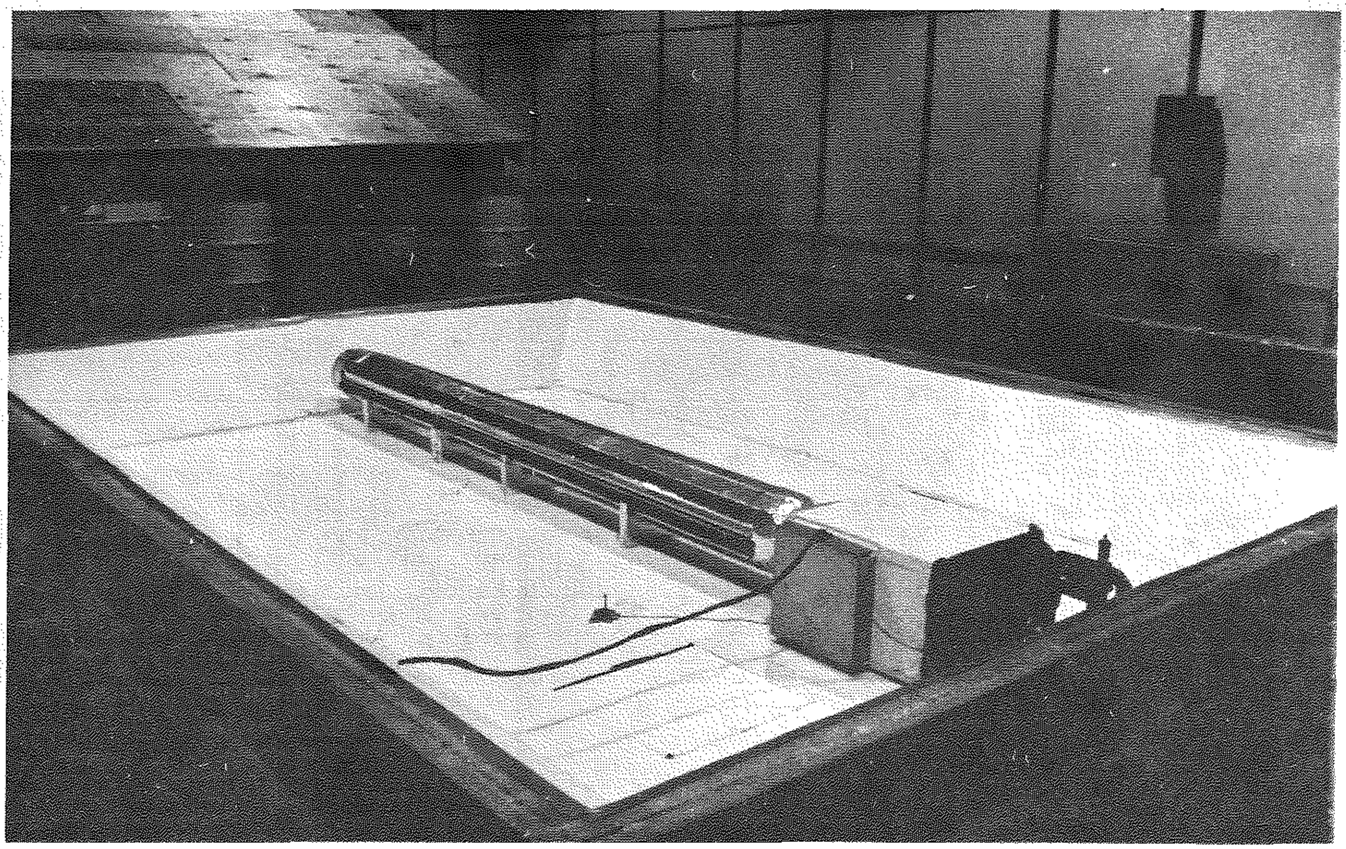

Fig. 3 Modified metering chamber - assumes a metering chamber temperature of 24°C (75 F)

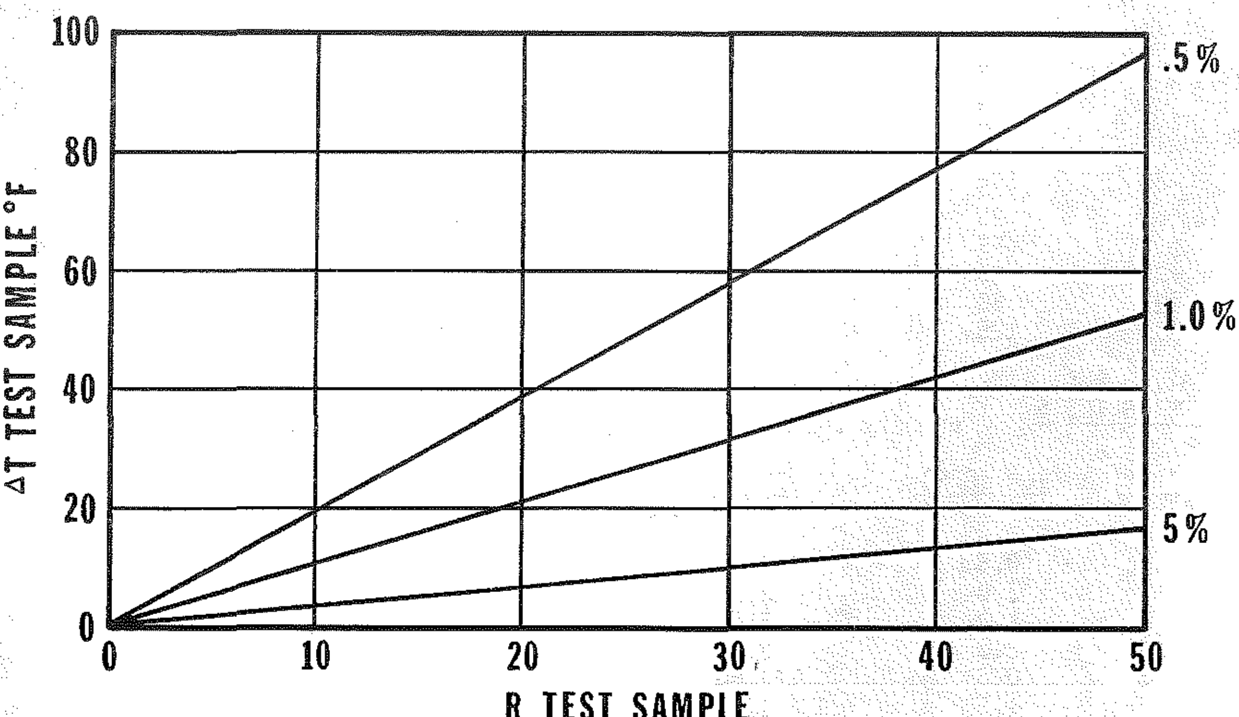

Fig. 4 Percent guard losses vs sample losses for modified metering chamber: assumes conductivity of guard of 0.20 Btu-in./hr-ft^2-°F, guard area of 29 m^2 (315 ft^2), guard temperature differential of 0.2°C (o.4 F)

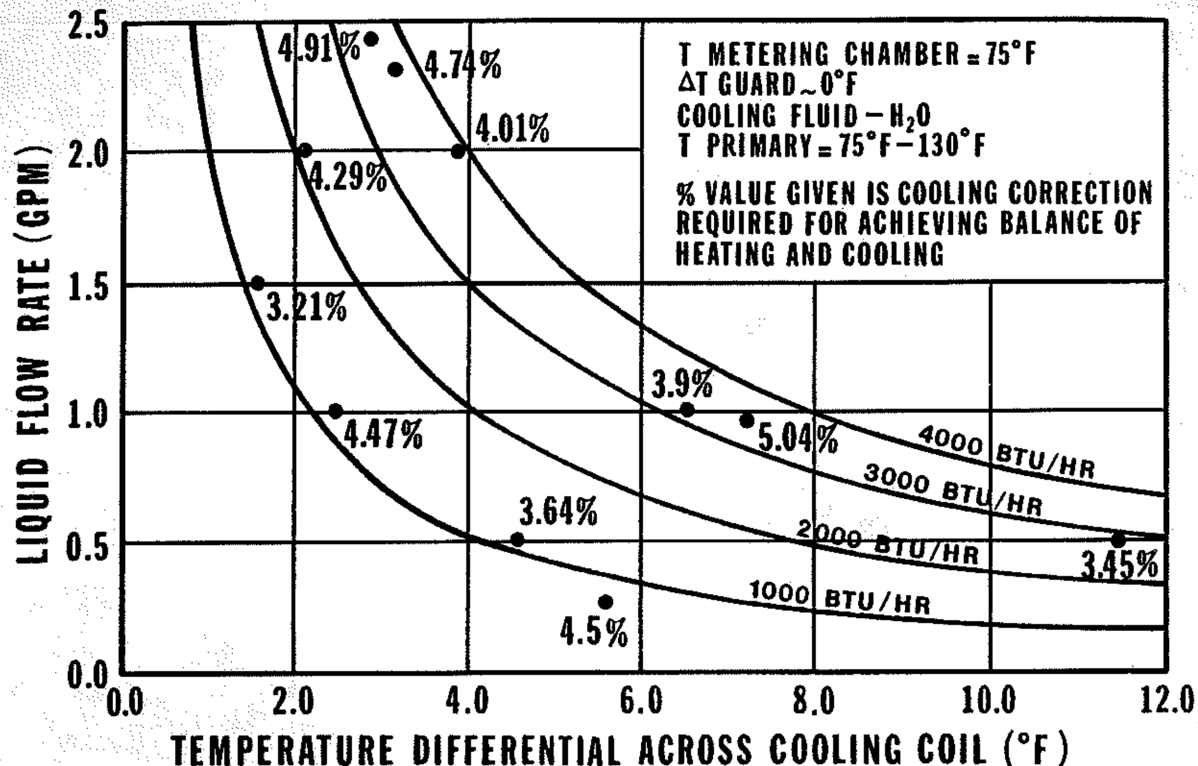

Fig. 7 Cooling system calibration data