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Acceptance Testing of the NBS Calibrated Hot Box

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ABSTRACT

This paper describes the acceptance testing requirements for a new calibrated-hot-box facility at the National Bureau of Standards designed to permit simultaneous measurement of heat, moisture, and airflow in wall constructions while subjected to dynamic ambient conditions. The performance requirements specified for the calibrated hot box wall tester and the performance tests required for final acceptance are discussed. Precision and accuracy considerations are set forth. The paper also proposes potential avenues of research and the issues related to carrying out a comprehensive testing program for evaluation of the performance of wall sections.

Key Words: Calibrated hot box; moisture transfer; mass-factor; R-value; thermal testing; wall tester.

INTRODUCTION

The desire to improve the performance of building envelope systems has had several stimuli in the past few years as a result of intense interest in energy conservation, safety, health, and economy. A key element in achieving improved performance was perceived to be the ability to improve the measurement of moisture and airflow through and within walls, as well as the measurement of heat flow; also, there was a need for the ability to measure all three--air, moisture, and thermal transfer—concurrently and in both static and dynamic modes.

Need

The need for improved data on the performance characteristics of materials and structures has been noted by researchers and designers as they employ increasingly sophisticated and demanding mathematical models and utilize the expanding power of computers. Also, there has been a need to evaluate new materials and innovative uses of materials introduced in the name of energy efficient construction. Performance claims of new materials and systems frequently have not been substantiated because adequate test facilities were not available.

The National Program Plan for Building Thermal Envelope Systems and Insulation Materials was first published in January 1979.[1] It has since been reissued, with the latest version, The National Program Plan for the Thermal Performance of Building Envelope Systems and Materials, published in March 1982.[2] The objective of the plan is to provide through government and industry cooperation and cost sharing, the technical data, test procedures, guidelines, and concensus standards needed by manufacturers, designers, and builders to produce buildings of high energy efficiency while concurrently meeting satisfactory safety, habitability, durability, and economic requirements. The plan identifies the need for enhanced test facilities and lists the design, construction, and installation of a calibrated hot box (CHB) at the National Bureau of Standards (NBS).

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Response to Needs

Researchers at NBS had determined the need for replacement and improvement of their test facilities and in 1978 design concepts were developed and a contract was awarded for the preliminary design of a calibrated-hot-box wall tester.[3] The principal components of the apparatus are shown in Fig. 1. Working with the Department of Energy (DOE), NBS developed cost estimates for the proposed calibrated-hot-box wall tester, and joint funding was agreed upon.

Consideration was given to developing the preliminary design documents into a set of construction contract documents suitable for lump-sum bidding. Also, consideration was given to issuance of the preliminary design documents in conjunction with a set of performance requirements. However, it was decided to proceed with a two-step procurement. Under this process the contractor, selected from responses to a request for proposals, was required to prepare a set of construction drawings; then, upon the Government's approval of the construction drawings, the contractor was authorized to proceed with the fabrication, assembly, and start-up of the apparatus. This process permitted the government contracting officer's technical representative (COTR) to review construction drawings and equipment selection before any purchases were made or fabrication started. The COTR shared with the contractor all the design details previously developed by the government and, working together, a set of drawings and a list of equipment was submitted and approved to establish, for the duration of the contract, a basis for compliance with contract requirements. Final acceptance was based on performance.

The calibrated hot box apparatus furnished by the contractor differs little from that conceived and designed by NBS. It accommodates a specimen 4.6 m wide by 3 m high by 600 mm thick and is capable of maintaining a 55°C temperature differential across specimens having thermal resistances from R-0.35 to R-9 $m^2 \cdot K/W$ (R-2 to R-50 $ft^2 \cdot h \cdot {}^\circ F/Btu$). The major change was in the subsystem used to dry infiltration air; the contractor furnished a two-stage dryer using silica gel and a molecular sieve in series, in lieu of a liquid-absorbent type. The contractor improved conditions for moving specimen frames by mounting them on air pads. The metering chamber and climatic chamber were reconfigured to gain floor space. By mounting jacket-water and infiltration-air subsystems on top of the metering chamber, working space for specimen preparation was improved.

Assembly and Start-Up

While the contractor fabricated subassemblies at the plant, NBS prepared one of its high-bay laboratory spaces to receive the calibrated hot box. Utility connections were provided, platforms constructed, crane rails modified, and the floor refinished. The largest components of the CHB, i.e., the climatic chamber, metering chamber, and specimen frames, were shipped by a wideload truck from the plant and rigged into place; the external structural steel supports were removed to provide clearance for the chambers to pass through door openings.

Assembly of the operating components, equipment, and controls proceeded slowly because of the complexity and unique requirements. For example, the environmental conditioning unit, a custom-designed preassembled two-stage dryer and regeneration unit, had to be moved through the CHB laboratory, into an adjacent operating laboratory, and mounted on a mezzanine over ongoing experiments; all this was accomplished with clearances measured in millimeters. Another example was the use of the specimen-frame air pads to move the climatic and metering chambers into position; again, clearances were measured in millimeters.

Concurrent with the contractor's installation of operating systems and controls, NBS staff was installing an automated data acquisition system and interconnecting it with sensors and contractor-installed metering and operating devices. The contractor-furnished operating controls and the government-furnished data acquisition system, data logger, computer, disc-drive, and tape deck, were mounted in three adjacent racks; raceways for power and signal wiring were shared. This control center, CRT-keyboard terminal, and printer were installed in a room adjacent to the CHB. As assembly of the CHB neared completion, subsystems were started up to demonstrate proper operation, to permit checkout of operating controls and monitoring signals, and to initiate preliminary testing and calibration.

PERFORMANCE REQUIREMENTS AND TESTS

A key element in the entire procurement process was a dependence upon performance requirements in the technical specification section of the contract. These requirements were defined by a series of acceptance tests (See Appx A1 and A2) that required the contractor to operate the

CHB under simulated normal operating conditions. During acceptance tests provision was made for NBS to monitor the overall operation of the CHB as well as to observe performance of components. The conduct of these tests and the results are described in the following parts of this paper.

The Contract Schedule, Article III -- Inspection and Acceptance states:

> The Contractor shall in accordance with Section 11 of the Technical Specifications, after installation of the government furnished equipment, operate the apparatus to demonstrate that it can meet the full range of operating conditions and obtain the precision of control required by the specifications in a safe manner and without overload or malfunction.

The operating conditions referred to in the above paragraph included, among others, the dry-bulb temperature, dew-point temperature, air curtain velocity, and absolute pressure for both the metering chamber (MC) and the climatic chamber (CC).[4] The range of temperatures to be covered by the tests is shown graphically on a psychometric chart (see Appx A8). Typical test report pages indicate how the tests were to be conducted and the information recorded (see Appx A6 and A7).

In addition to confirming the capability of the CHB to achieve specified climatic conditions, tests were conducted on the air tightness of each chamber using tracer gas (sulphur hexafluoride) to assure that the leakage from either chamber would not exceed 6 L/s when pressurized to 125 Pa. Also, operating controls were set to demonstrate that the air curtain temperature could track a programmed (diurnal) temperature cycle within $\pm$ 0.3°C in both chambers simultaneously; actual tracking was recorded on the NBS monitoring system, ADAS. Other required tests were designed to demonstrate the operation of the heat flow meters (transducers) in the wall of the metering chamber, the performance of the water jacket, the movement and positioning of the chambers, test frames, baffles, thermocouple grids, etc.

As an overall performance check, the CHB was to be operated with a 30°C temperature differential across a 100 mm cellular polystyrene test specimen and a complete set of data logged to permit comparison of the measured thermal transmittance with the values determined independently using other test methods. Finally, the CHB was to be set to run unattended overnight and then, under emergency conditions, required to shut down automatically, without damage, and with appropriate alarm display, i.e., to fail safe.

The acceptance tests for such comprehensive requirements were time-consuming. Tests of components and subsystems were run before running larger systems, and considerable adjustment, balancing, and debugging was required for each operating system and control loop. The day-to-day coordination between the contractor's personnel and NBS staff was the key element in resolving extremely complex problems on a routine basis.

DISCUSSION OF REQUIREMENTS

The discussion of the acceptance tests requirements is made in the context of the intent of the designers, as represented by the Range of Operating Parameters for the Chambers in the Technical Specification, (see Appx A3). Also, the discussion reflects the consideration given to the precision and accuracy statement which needs to be developed for the calibrated-hot-box and refined as operating experience becomes available.

Range of Operating Parameters

For both the metering chamber and the climatic chamber, a maximum and/or minimum value and a tolerance is listed for each measured parameter. The tolerance is listed as an incremental or percentage deviation of the measured value from the set value. In the design phase, the range of values for the parameters was established to provide an apparatus that could

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[4] In the design and construction phases, the chamber opposite the metering chamber was referred to as the environmental chamber (EC). For acceptance tests and subsequent operation, it was referred to as the climatic chamber (CC) in conformance with ASTM Test Method for Thermal Performance of Building Assemblies by Means of a Calibrated Hot Box, C-976, 1982.

measure the transfer of heat, moisture, and air through specimens having thermal resistance from R-0.35 to R-9 $m^2 \cdot K/W$ (R-2 to R-50, $ft^2 \cdot h \cdot °F/Btu$).

The tolerance values for the parameters were based on the level of performance that could be expected from quality components, selected and matched for optimum operating characteristics. The intent was to seek the best possible performance from commercially available components, since a justification could not be made for the possible incremental benefit from the use of custom-made or untried components.

Precision and Accuracy

The need for a precision and accuracy (P&A) statement was an overlay on both the criteria for the range of parameters and criteria for the tolerance in maintaining and measuring parameter settings. A rigorous P&A analysis will be started as soon as acceptance tests are completed and the apparatus begins a planned calibration test series. However, in anticipation of the P&A analysis, there was a need to examine parameters both during design and during acceptance tests to assure that a weak link was not being forged into the apparatus.

Since measurement of temperature is one of the more critical and more common measurements, examination of the specified parameter values and their tolerance demonstrates the design approach. Specified metering chamber and climatic chamber air temperatures reflect the design objective of a 55°C (100°F) temperature differential across the test specimen at an appropriate mean temperature. Therefore, climatic and metering chamber temperatures of 65°C to 10°C (150°F to 50°F) were selected, producing a mean summer temperature of 37.5°C (100°F). Likewise, -40°C to 15°C (-40°F to 60°F) at -12.5°C (10°F) mean was selected for winter.

The cold-side temperatures (10°C summer in MC and -40°C winter in CC) are equipment dependent; that is, the cost would be prohibitive to go beyond the capability of chilled water coils in the MC or of commercial refrigeration systems for the CC.

The considerations that enter into tolerance values are best demonstrated by looking at the parameters in the equation:

$$R = A \cdot \Delta t/Q \qquad (1)$$

where

R is the thermal resistance in $m^2 \cdot K/W$

A is the specimen area in m^2

Δt is the temperature differential across the specimen in K

Q is the heat transmission per unit time in W

For R-values within the capability of the apparatus, representative parameter values could be as follows:

Example A Measured Values	Incremental Error	% Error	Remarks
R = 0.20	--	2.0	Measured value from another apparatus, i.e., guarded hot plate
A = 15	$\pm$ .024	0.16	Specimens can be measured to about 3 mm in each dimension
Δt = 10	$\pm$ 0.2	2.0	Thermocouples and readout system are accurate to about 0.2°C
Q = 750	$\pm$ 1	0.13	Meter measures one count per watt-hour

Example B Measured Values	Incremental Error	% Error	Remarks
R = 9.0	--	2.0	Same as in Example A
A = 15	± .024	0.16	Same as in Example A
Δt = 100	± 0.2	0.20	Same as in Example A
Q = 167	± 1	0.60	Same as in Example A

In example A, the dominant error for the apparatus is in temperature measurement, which is dependent upon the accuracy of the thermocouples and their readout system. The temperature on each side of a specimen is measured by 40 thermocouples that can be readily connected and quickly reconnected through any one of 80 channels on the thermocouple modules in the data logger. Each of the thermocouple modules (and each thermocouple, if desired) can be calibrated over the CHB operating temperature range to within about 0.1°C using a reference readout accurate to 0.01°C. With periodic calibration, the error can be held within 0.2°C, as in the example, and is deemed acceptable.

In example B, the dominant error for the apparatus is in the power measurement of the watt/watt-hour transducer. The example indicates the error introduced by the loss of one count, one watt-hour, for a steady-state condition of one hour duration.

Parametric analysis will certainly contribute to development of the P&A statement for the apparatus. However, during the design stage there was a need to base equipment selection on a rational determination of the level of accuracy required. For example, the quantity of air circulated through the climatic chamber relates directly to the calculated addition or removal of heat and moisture from the chamber. However, in the metering chamber, neither heat nor moisture addition or removal is related directly to the quantity of air recirculated within the chamber. Therefore, in the CC, multiple ASME nozzles were selected to provide acceptable accuracy for a wide range of air quantity (500-2500 L/s), even at the expense of considerable pressure drop and attendant fan power heat input to the airstream outside the chamber. In the MC, extraneous heat input to the airstream is undesirable; so to reduce fan heat, the choice was a hot-wire anemometer in lieu of a laminar flow element, thus reducing considerably the static pressure loss and required fan power inside the chamber.

During subsystem tests, emphasis was placed on completing functional tests to demonstrate proper operation of the entire apparatus. Measured values were checked to assure correct order of magnitude and, where possible, components were calibrated. Some calibrations, after evaluation of specific conditions, were deferred so as not to delay acceptance tests. Detailed investigation of measured values and calibration of components will be done in the future as deemed necessary to reduce the uncertainty in measurements.

For both the MC and CC, the specified tolerance for the air curtain velocity is the greater of 0.025 m/s or 3 percent. Preliminary tests indicate that this tolerance may have to be relaxed until there is improved ability to adjust airflow over the large air curtain area. Initial effort has been to seek a uniform flow within the air curtain by adjusting louvers, dampers, and baffles while using a velometer to check results. Ultimately, the air curtain velocity will be based upon the baffle position and the quantity of air circulated within the respective chamber. Therefore, the estimated error in the air curtain velocity will be somewhat larger than the estimated error for the measured air quantity.

In summary, there has been a continuing awareness of the requirement, ultimately, for a comprehensive P&A statement. The measurement uncertainty for each component was carefully considered in the design of subsystems and the selection of equipment. During acceptance tests, the apparatus demonstrated capability to meet functional and operational requirements.

RESEARCH TASKS

In order to obtain the best utilization of the CHB, it will be necessary to reconcile the needs and opportunities of tasks that tend toward problem solving with those that tend to advance the state of the art. Some suggested task opportunities are:

- Refining transmission coefficients for building materials and envelope constructions, as for example, the values given in the ASHRAE Handbook-- Fundamentals Volume.

- Investigating validity and application of compressed weather cycles.

- Measuring thermal storage and time constants for building walls; developing data to assess effect of massiveness.

- Measuring effect of moisture migration in permeable walls subject to dynamic climatic conditions.

- Generating data to validate mathematical models of conventional and innovative constructions.

- Providing calibration and referee service.

Other opportunities which appear to have a high priority may arise during the time required to investigate those listed above. Therefore, it is desirable to establish a sound basis for selecting projects and for continuing development of the testing program. The criteria for selecting projects might include the following:

- What are the near-term objectives and the long-range impacts?

- Who can benefit from this work; who may participate or cooperate?

- How will it be financed (by whom)?

- Is the approach well defined? Does it have peer review?

The necessity for careful development of a testing program becomes apparent when actual test schedules are laid out. The time interval required for each test and the number of tests necessary to measure seemingly endless permutations of environmental conditions result in long test periods for a single specimen. For example, consider a wall to be tested under summer and winter conditions, with north and south exposure, and with or without day-night setbacks. Under this rather basic set of conditions, one could conduct eight tests, possibly running up to one month each and still have voids in the data required to carry out credible validation of that wall. Questions likely would be unanswered as to whether additional testing of this wall would be more profitable than would be testing of related walls. In any event, many considerations must be included when developing testing programs.

Testing Plan

Prior to starting any testing program with the CHB on wall components or systems, it will be necessary to conduct a series of tests using well characterized specimens in order to develop the initial calibration values for box losses, time constants, and other operating characteristics. The initial specimen will be a 100-mm expanded polystyrene material. The polystyrene is faced with a latex-base paint over an adhesive. Before conducting the calibration test series, this specimen will be used in the acceptance tests for the CHB. Additional similar specimens are in hand for NBS participation in an ASTM C16.30 round-robin tests for hot boxes.[5]

Upon completion of the calibration effort, a series of tests will be initiated on representative envelope constructions (wall specimens) having a range of R-values and range of densities. These specimens will be constructed of ordinary materials using conventional building practices. In a parallel activity, an effort is underway to develop mathematical models for test specimens, test frames, specimen position in the frame, mounting techniques, etc.[6] Investigations are being made into a finite-element approach and a response-factor approach, seeking models that can achieve credibility and acceptance upon rigorous validation using CHB test data.

Due to the time interval dedicated to acceptance tests, calibration tests, and roundrobin tests, the test series on representative envelope constructions will not start before mid-1983. In the continuing development of a comprehensive plan for testing and analysis, this will permit consideration of suggestions resulting from this paper.

REFERENCES

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2. U.S., Department of Energy, The National Program Plan for the Thermal Performance of Building Envelope Systems and Materials, ORNL/Sub-7973/1, March 1982.

3. P. R. Achenbach, "Design of a Calibrated Hot Box for Measuring the Heat, Air and Moisture Transfer of Composite Building Walls," Proceedings of the ASHRAE/DoE-ORNL Conference, Thermal Performance of the Exterior Envelopes of Buildings (New York: ASHRAE, 1980).

4. ASTM Test Method for Thermal Performance of Building Assemblies by Means of a Calibrated Hot Box, C-976, 1982.

5. Ervin L. Bales, Plan for a Round Robin of Hot Boxes, U.S., National Bureau of Standards, NBSIR 81-2443, February 1982.

6. P.J. Burns, R.J. Onega, Flank Users Manual, U.S., National Bureau of Standards, Draft NBSIR 82-xxxx, September 1982.

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APPENDIX

As a record of the procedures to be followed in testing the performance of the calibrated hot box, there was prepared for in-house use a Report on Acceptance Tests for Calibrated Hot Box Wall Tester. Parts of an early draft of that report have been copied for this Appendix as follows:

Appx A1 Requirement from Technical Specification, Acceptance Tests (page 2)

Appx A2 Requirements from Technical Specification, Acceptance Tests (page 3)

Appx A3 Requirements from Technical Specification, Range of Operating Parameters (page 6)

Appx A4 Conduct of Acceptance Tests General Requirements (sample instruction, page 12)

Appx A5 Conduct of Acceptance Tests General Requirements (sample instruction, page 14)

Appx A6 Performance Data on Tests, Test 11.1 (sample page 19)

Appx A7 Performance Data on Tests, Test 11.1 (sample, page 21)

Appx A8 Psychometric Chart, Test 11.1

APPENDIX A1

Requirements from Technical Specification

11. ACCEPTANCE TESTS

Upon completion of the work, the contractor shall put the calibrated hot box wall test apparatus into service with a test specimen in place. Contractor shall operate the apparatus and the COTR will observe and evaluate the performance. Contractor shall, during the conduct of specified tests, instruct designated NBS personnel in the operation of the apparatus.

11.1 Range of Operating Parameters

The apparatus shall be operated in a steady-state heat-transfer mode with an R-10 monolithic polystyrene test wall installed in the 12 inch Test Specimen Frame, clamped between the Metering and Environmental Chambers. The Metering Chamber shall initially be set to operate at 75°F and the Environmental Chamber at 20°F. Each of the operating parameters specified in Table 2 shall be made to vary separately over the full specified range. The controls for each of the operating parameters will be observed for instability such as hunting, overshooting, undershooting and underdamping.

11.2 Air Tightness of Apparatus

The apparatus shall be operated in a steady-state heat-transfer mode with an R-10 monolithic polystyrene test wall specimen in place. The interior and exterior surfaces of this test wall shall be covered with 4 mil polyethylene sealed at lapped joints and edges (where the test wall meets the supporting frame) with duct tape. The Metering Chamber shall be set to operate at 75°F and the Environmental Chamber at 20°F. Air circulation in both the Metering and Environmental Chambers shall be 1200 cfm.

With fans running, a tracer gas (SF_6) shall be introduced into both the Metering and Environmental Chambers. The decay of the tracer gas shall be measured as a function of time. The air leakage rate, as determined from this decay process, shall be less than 6 cfm from each chamber.

The foregoing test shall be repeated with both the Metering and Environmental Chambers pressurized to 0.5 inches of water column. For this test, the air-leakage rate as determined from the tracer-gas techniques, shall be less than 12 cfm from each chamber.

11.3 Dynamic Programming

With the same test specimen in place, the Metering Chamber control shall be programmed for night setback and the Environmental Chamber for a diurnal temperature cycle. After a steady-periodic condition is reached, the air curtain temperature shall track the programmed temperature within $\pm$ 0.5°F.

11.4 Heat-Flow Meters and Water Jacket

With the same test specimen in place, run Metering Chamber at 150°F and Environmental Chamber at 20°F. Humidifier system, off; Infiltration Air system, off; Water Jacket system, off. Measure rate of heat transfer through Metering Chamber walls using the array of heat-flow meters until steady-state conditions is reached.

Start Water Jacket system and set it to operate at 150°F. Measure heat transfer same as before. Measured heat transfer rate shall be reduced by not less than 90 percent by operation of the Water Jacket system.

11.5 Steady-State Thermal Transmittance

With the same test specimen in place, Metering Chamber at 75°F, Environmental Chamber at 20°F, a complete set of data shall be logged to permit the measured thermal transmittance to be compared with the calculated. Humidifier system, off; Infiltration Air system, off; Water Jacket system, off. Neglecting flanking loss, measured thermal transmittance shall be within 10 percent of calculated.

11.6 Movement of Chamber and Frames

The 12 inch Test Specimen Frame shall be removed from the test position between the Metering Chamber and Environmental Chamber and the 24 inch Test Specimen Frame moved into place, ready for test. The 24 inch Frame may contain a specimen wall prepared by NBS or may be weighted to simulate the weight of a thick masonry wall.

Demonstrate that the above can be accomplished by two persons and the NBS forklift track without damage to the facility or laboratory space, and without risk to personnel. Other available shop and laboratory tools and the equipment and short-term (1-2 hours) assistance from other laboratory technicians may be used.

11.7 Operation of Controls

Apparatus shall be set to run unattended overnight (5:00 p.m. - 8:00 a.m.). Under normal conditions, operation and testing will continue uninterrupted the second day. To simulate an emergency shutdown, building chilled water supply (CHW) shall be shut off to the Metering Chamber; in this situation appropriate equipment and systems shall shut down automatically and their status displayed at the Control Console with an alarm. Test shall be repeated with shut off to CHW to refrigeration compressor/condensor unit.

APPENDIX A3

Requirements from Technical Specifications

Range of Operating Parameters for the Chambers (SI Units)

Parameter	Metering Chamber	Environmental Chamber	Tolerance
Steady-State Temperature Range, °C	10 to 65	-40 to 65	± 0.1°C
Dew-point Range, °C (no control above 24 DB)	8 DP[a] to 10 DB[b] 20 DP at 24 DB	-43 DP to -40 DB 20 DP at 24 DB	± 0.5°C
Static Pressure Difference, Pa	0 to 125	0 to 125	± 5.0 Pa
Air Leakage Rate, l/s (either direction)	0 to 70	0 to 70	± 0.15 l/s or 1%[c]
Max. Heating Load, kW	7.6	--	--
Max. Heating Load, kW	6.7	--	--
Velocity of Air Curtain, m/s (inlet and outlet)	0.25 to 0.75	0.4 to 4.0	± 0.025 m/s or 3%[c]
Heating Rate at 26°C, °C/hr	10	10	± 0.5°C/hr
Cooling Rate at -6°C, °C/hr	8	8	± 0.5°C/hr
Max. Moisture Vapor Make-up, g/s	.025 to 0.38	.025 to 0.38	± .013 g/s
Max. Diurnal Temperature Amplitude, °C	16	56	± 0°C

[a] DP = dew-point temperature.

[b] DB = dry-bulb temperature.

[c] Whichever is greater.

(6)

to velocity, expressed in m/s. When multiplied by the duct area at the plane of measurement, the result is the metering chamber circulated air quantity.

$$q_{2MC} = (m/s)\ (520\ mm \cdot 520\ mm)\ 10^{-3}\ l/s$$

$$= (\text{channel } \underline{126} \text{ value})\ (270)\ l/s$$

To check the operation of the sensor and its readout, a test series was run to generate the information shown in Table 3.

7. Measured Air Quanity - Infiltration Air System

The measuring devices for infiltration air are laminar flow elements used in conjunction with differential pressure transducers as follows:

Supply to MC:	Meriam Model*	________________	Serial	________________
	Viatran Model*	________________	Serial	________________
Exhaust from MC:	Meriam Model	________________	Serial	________________
	Viatran Model	________________	Serial	________________

The pressure transducers transmit signals, 4 to 20 mADC, to channels 139 and 130, respectively, for supply and exhaust. The mA signals are converted to l/s.

To check the operation of the flow element and its readout, a test series was run to generate the information shown in Table 4.

8. Damper Operation:

Dampers that change the direction of curtain air flow (i.e., up and down) and dampers that direct infiltration air to MC or CC or to atmosphere were observed to operate in response to reset controls on panel. Other dampers will be manually ajdusted and set by the Contractor. Damper sequences will be described in the Operation Manual.

9. Differential Pressure:

Readout to the data acquisition system is provided by differential pressure transducers to indicate apparatus pressures as follows:

Channel	Signal	Readout	Service
132	10-14 mADC	-125 to +125 Pa	ΔP, MC to atmos.
137	10-14 mADC	-125 to +125 Pa	ΔP, MC to CC
138	4-10.7 mADC	0 to 2500 Pa	ΔP, MC condensate

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* Identification of equipment used in testing or as part of the calibrated-hot-box apparatus is not an endorsements of that equipment.

APPENDIX A5

TABLE 2

Air Flow Thru ASME Nozzles[a]

23.9°C (75°F)[b], 101.14 kPa (29.95 in Hg)[b], 0.990 Discharge Coefficient

Velocity, m/s	15.24	20.16	24.70	28.50	31.89	34.92	35.56
Diff. Press., Pa	142	249	374	498	623	747	774
Nozzle Combination	Air Flow in l/s						
1 x 5-1/2	--	--	--	--	489	536	545
1 x 6	--	--	--	520	582	637	649
1 x 5-1/2 + 1 x 6	--	677	829	957	1071	1173	1194
2 x 6	556	736	902	1040	1164	1274	1298
3 x 6	834	1104	1352	1560	1746	1912	1947
4 x 6	1112	1473	1803	2080	2328	2549	2595
5 x 6	1390	1841	2254	2600	2910	--	--

For acceptance tests, the mass flow of air for the several tests will be established as follows:

- Establish desired air curtain velocity.
- Establish thermocouple location.
- Establish baffle location.
- Calculate required air curtain quantity.
- Calculate measured air quantity thru nozzles, corrected for baffle leakage.
- Select pressure drop and nozzle combination to produce desired l/s.
- Start fan and bring up to the speed that produces selected pressure drop across nozzles.

For acceptance test, corrections need not be made for temperature or pressure.

[a] This information will be stored in the computer system in equation format.

[b] Standard air, ASHRAE, SI, is defined as dry air at 101.325 kPa and 20°C.

B. Steady-State:

Changed conditions may not be initiated until both chambers are judged to be in a steady-state (SS) as indicated by constant sequential readings (i.e., within specified tolerance) for the following parameters:

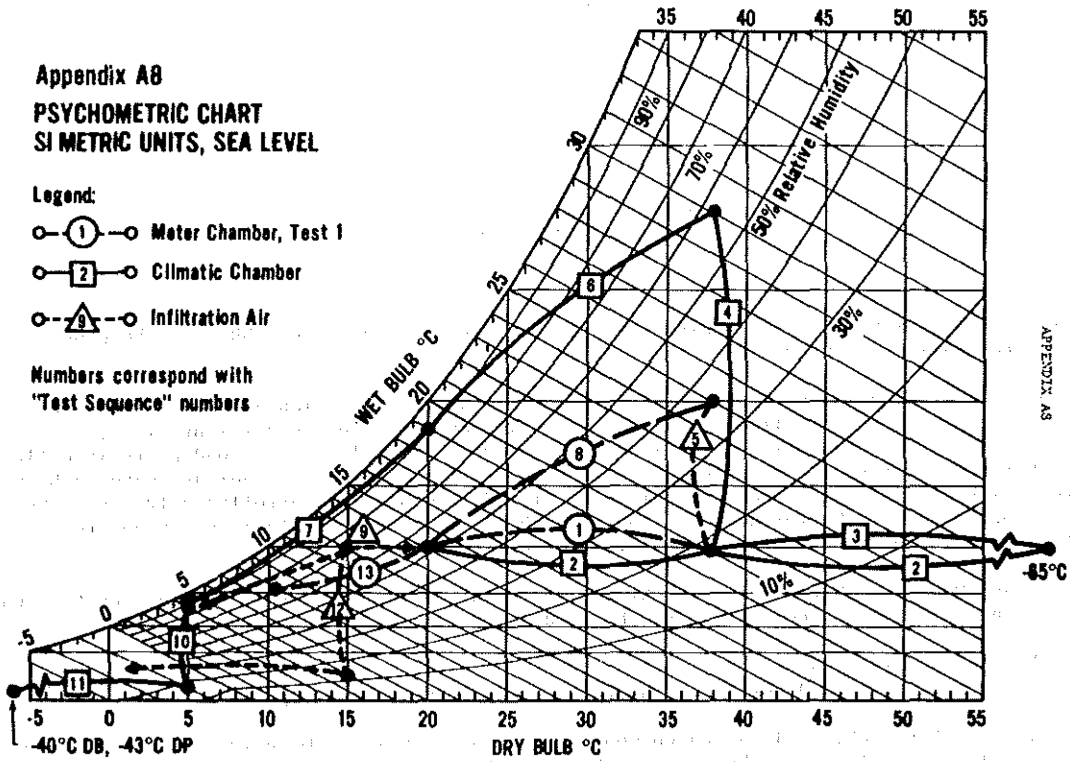
Parameter	Tolerance	Channel Number	Analog Signal
MC Air grid	± 0.1°C	030-069 Average	______
MC Dew point	± 0.5°C	120	______
MC Dew point	± 0.5°C	120	______
MC Air velocity	± 2.0 l/s	126	______
MC Air pressure	± 5.0 Pa	132	______
CC Air grid	± 0.1°C	070-109 Average	______
CC Dew point	± 0.5°C	123	______
CC Air velocity	± 10 l/s	131	______
CC Air pressure	± 5.0 Pa	137	______

C. Test Sequence:

1. Reset MC DBC from 20°C to 38°C		
Observe time to reach, SS, T6	003	______
Observe dew point during change, M1	120	______
2. Reset CC DBC from 20°C to 65°C		
Observe time to reach, SS, T22	009	______
Observe dew point during change, M4	123	______
3. Reset CC DBC from 65°C to 38°C		
Observe time to reach SS, T22	009	______
4. Reset CC DPC from 14°C to 30°C		
Observe time to reach SS, M4	123	______

(19)

		Channel Number	Analog Signal
9b.	Set controls for air flow IA to MC Observe and record damper settings		
	Read DP7: ____________ Pa	132	______
	Read DP1: ____________ Pa	137	______
	Read A3: ____________ 1/s	139	______
	Read A4: ____________ 1/s	130	______
9c.	Reset control for air flow IA to CC Observe and record damper settings		
	Read DP7: ____________ Pa	132	______
	Read DP1: ____________ Pa	137	______
	Read A3: ____________ 1/s	139	______
	Read A4: ____________ 1/s	130	______
10.	Start up dryer system		
	Set CC DPC from 4°C to -2°C		
	Observe time to reach SS, M4	123	______
11.	Set CC DBC from 5°C to -40°C		
	Set CC DPC from -2°C to -43°C		
	Observe time to reach SS, T22	009	______
	Observe time to reach SS, M4	123	______
	Observe change in T6	003	______
	Observe change in M1	120	______
12a.	Set IA DPC to 5°C		
	Observe time to reach SS, M3	122	______



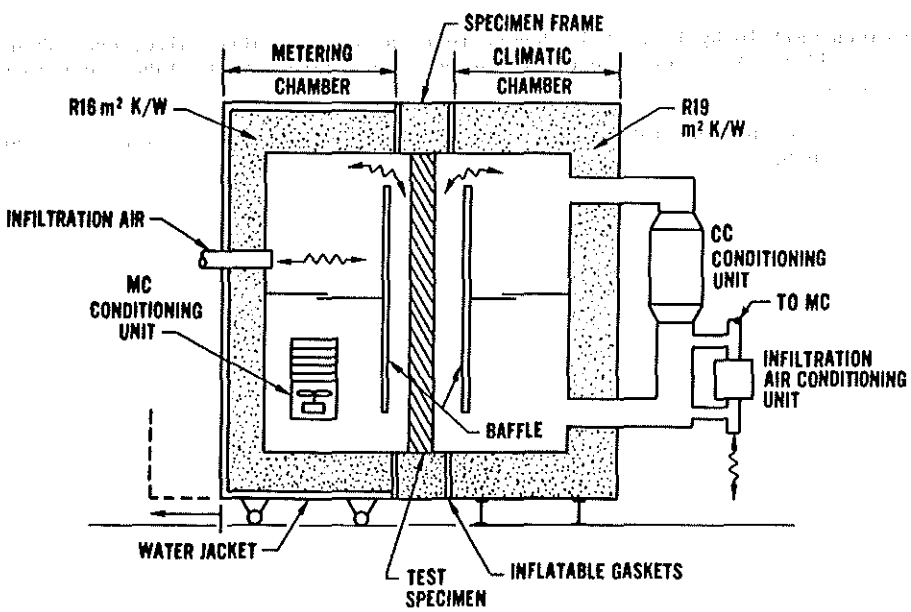


Figure 1. Cross section of calibrated hot box apparatus (schematic not to scale)

Discussion

R.H. Kim, College of Engineering, Univ. of North Carolina at Charlotte: What is the probe for the condensation measurement?

R.R. Jones: The dew point of the air in the chambers (and infiltration air) is measured by six hygrometers of the optical/condensation type. The condensation measurement, i.e., condensate from the dehumidifier coil, is determined volumetrically. The condensate is collected in a beaker (external to the metering chamber) that has its water column height measured by a differential pressure cell. When the column is filled, a manually controlled valve is opened to drain the contents. Differences in liquid depth are recorded on data-logger scans to permit calculation of condensation rate for different time intervals.

J. Christian, Oak Ridge Natl. Lab., Oak Ridge, TN: Can you run accelerated weathering test on the walls and determine R decay? Can the box model roofs?

Jones: Neither accelerated weather tests nor tests of roofs were included in the design criteria for this calibrated hot box. The test frames hold vertical specimens.

R. Bowen, Bldg. Research, Natl. Research Council of Canada, Ottawa, Ontario: Why was the box built 10 by 15 feet? What was the cost of the facility?

Jones: A specimen wall 10 by 15 feet is deemed to be a representative size, even when windows and/or doors are added. A larger size could not be accommodated by the laboratory in which the apparatus is confined.

The calibrated hot box was fabricated, assembled, and put into operation at a contract cost of under $600,000.