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Capacity & Performance Testing of Packaged Air Conditioners

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Packaged air conditioners are self-contained air conditioning units compressing a refrigeration system and an air-handling system, usually (but not necessarily) connected to ducting for distributing the conditioned air at different desired locations. These units are usually made in capacities upwards of 10,000 W (about 3 TR) and may consist of one or more assemblies, which are designed to be used together. Indian Standard IS. 8148-1976 covers packaged air conditioners in the range of 3 to 15 TR, which also happens to be the range commonly manufactured in India.

ASHRAE Standard 37-1988 specifies the Indoor side air-enthalpy method for determining the cooling capacity less than 39,560 W. (11.25 TR), ASHRAE prescribes an additional confirming test such as Outdoor side air-enthalpy method.

IS: 8148-1976 specifies both Indoor side and Outdoor side air-enthalpy methods for air-cooled condensers. These tests shall be described in some detail in this article.

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Air Enthalpy or Psychrometric Test Method

In this method, capacity is determined from the difference in enthalpies of air entering and leaving the Unit Under Test (UUT) and the associated air flow rate under specified test conditions. The enthalpies are read off from the standard psychrometric chart / table for the measured dry-bulb and wet bulb temperatures of the entering and leaving air. The air flow measurement is carried out in accordance with AMCA standard 210-85 / ASHRAE standard 41.2 - 1987 by the measurement of the pressure drop across standard ASHRAE nozzles. These measurements may be carried out only on the indoor side or both the indoor and outdoor sides. Since this method is based on the properties of air, it is often referred to as the Psychrometric method of test.

Description of Test Facility

Test Rooms: The Psychrometric test facility (**Fig.1**) consists of an indoor side and an outdoor side room, in which the dry-bulb and wet-bulb temperature conditions are closely controlled and maintained as specified. The rooms shall be of sufficient volume and shall circulate air in a manner such that it does not affect the normal air circulation pattern of the UUT Air velocities in the vicinity of the UUT shall not exceed 2.5 m/s The room dimensions shall be such that the distance from any room surface to UUT surface shall be not less than 1 m (and 2 m from any UUT surface discharging air)

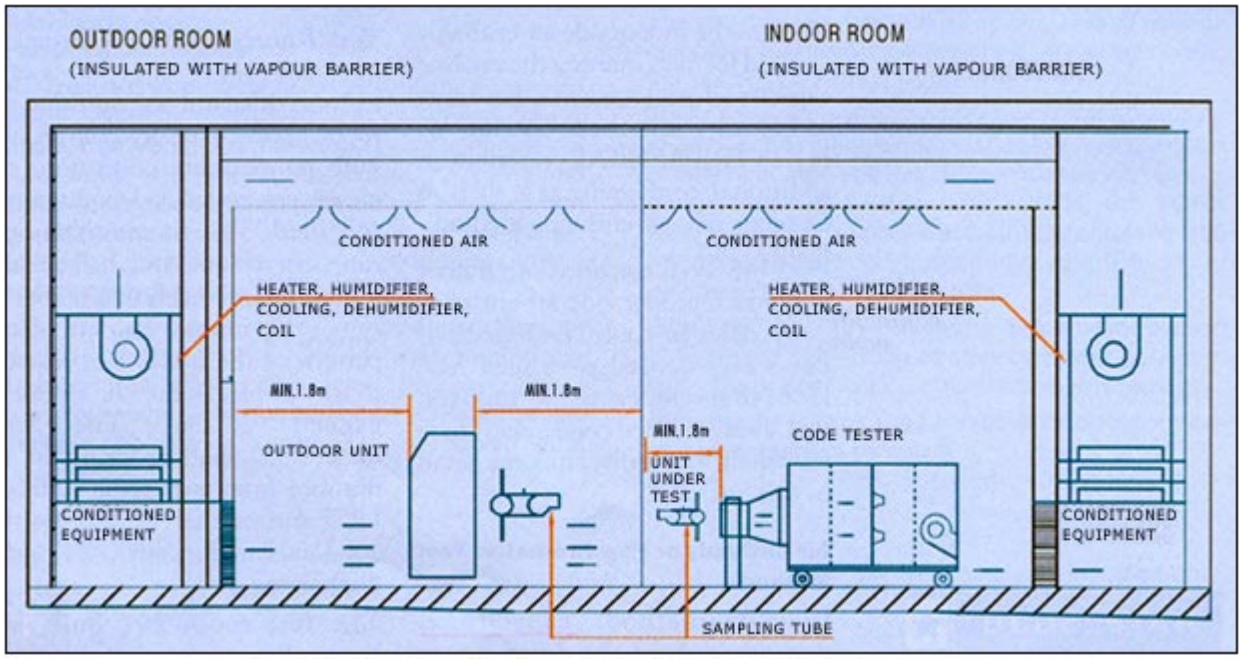

Fig. 1: Psychrometric Test Facility (Air Cooled Packeged Air Conditioners)

The test rooms are built with thermally insulated walls with a vapour barrier in order to minimize the effect of outside ambient conditions.

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Table 1: Capacity Rating and other Type test conditions

IS: 8148 -1976 specifies the following test conditions for Capacity Rating and other Type tests

Description of test	Capacity Rating	Maximum operating Condition	Freeze up test	Enclosure sweat test	Condensate disposal
Indoor (evaporator) Side inlet air temp					
-Dry Bulb°C27+0.25	35	21	27	27	
-Wet Bulb°C19+0.25	24	16	24	24	
Outdoor (condenser) Side inlet air temp Dry Bulb°C	35±0.25	46	21	27	27
Condenser water Inlet temp. °C	30±0.25	34	19	27	27
Condenser water Outlet temp.°C	35±0.25 Min.	-	-	-	-
Water & air flow rate	-	Same as for capacity rating test.			

Conditioning equipment: It is installed in plenums attached to both the test rooms. The purpose of this equipment is to provide heating and humidification / cooling in the indoor and outdoor side rooms respectively to nullify the cooling and dehumidification / heating effects produced by the UUT and thereby maintain specified equilibrium conditions of temperature and humidity in the two rooms. The conditioning equipment for each room comprises electric heaters, humidifier, cooling and dehumidification coils and air circulation fans discharging into the test space. The fans in each room shall be capable of handling twice the air flow quantity of he UUT The cooling and dehumidification coils may be either direct expansion (with variable refrigerant volume - control) or chilled water coils (with modulated chilled water control) fed from a chilled water plant.

Water-cooled packaged air conditioners require only the indoor side room complete with its conditioning equipment and air flow measurement, with the addition of a cooling tower(**Fig.2**) and an arrangement to control and maintain the condenser water inlet temperature as specified. A water flow meter of the specified accuracy shall be provided in the condenser water circuit.

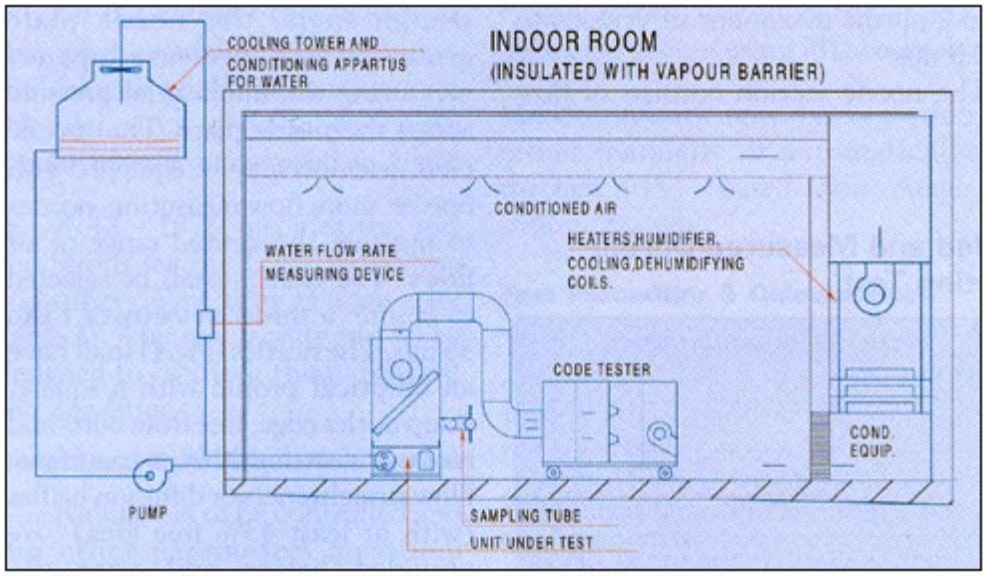
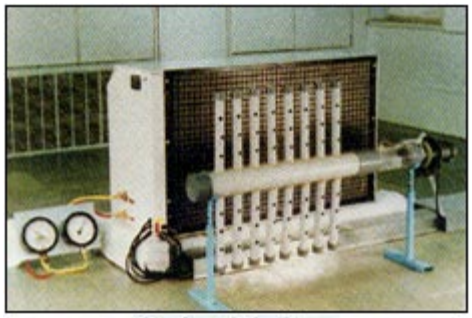


Fig. 2: Psychrometric Test Facility (Water Cooled Packeged Air Conditioners)



Outdoor-Side Room

Indoor-Side Room

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Air flow measurement: The Airflow tester(Fig.3) also referred to as Code tester measured the quantity and dry-bulb and wet-bulb temperatures of the air discharged from the UUT It is an insulated tunnel consisting of a receiving chamber containing an air mixer and psychrometric sampler, nozzle section and exhaust fan section. The receiving chamber / air mixing section is designed to provide a true uniform temperature distribution to a single sample point by:

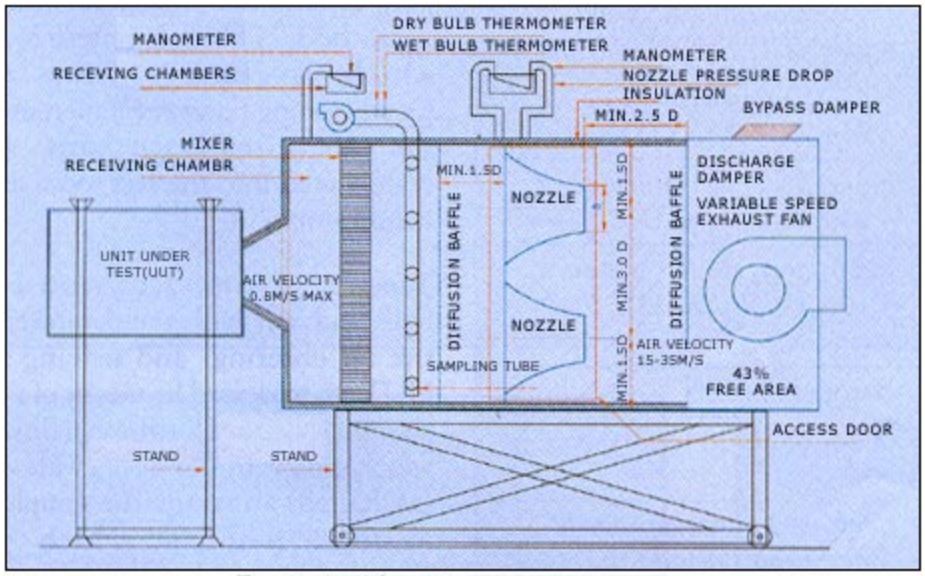

Fig. 3: Air Flow Measuring Apparatus

- Mixing the UUT discharge air thoroughly through shear-type centrifugal or static baffle type air mixers. Air mixers are particularly necessary if the UUT is of "blow through" design.
- Extracting the air sample at nearly uniform condition through a tree shaped sampling device.(**Fig.5**)

The receiving chamber is designed to limit the maximum air velocity to 0.8 m/s.

The nozzle section consists of flow straighteners, the nozzle plate assembly and pressure raps for measuring the differential pressure across the nozzle plate. The nozzle plate assembly may be equipped with to measure the desired range of air flows. The nozzles (**Fig.4**) shall have an elliptical profile with a square, sharp outlet edge, free from burns and nicks and a smooth inner surface. Flow straighteners or diffusion baffles (with at least 43% free area) are provided before and after the nozzle plate.

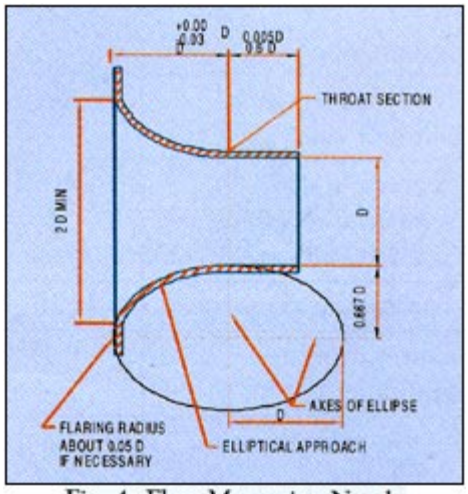

Fig. 4: Flow Measuring Nozzle

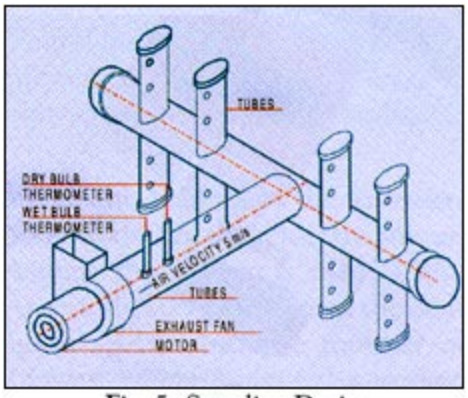

Fig. 5: Sampling Device

The last section of the Code tester consists of a variable speed exhaust blower and an adjustable bypass damper in order to control the air flow through the Code tester. The sped of the blower is adjusted to maintain the desired external static pressure of the UUT, which to measure by a draft gauge manometer at the receiving chamber. The bypass damper is adjusted to select the operating point of the exhaust blower.

The Code tester discharges the air from the UUT into the test room, which is sucked into the Conditioning Equipment plenum by the air circulation fans and re-circulated into the test room after conditioning it.

Temperature measurement: Dry bulb and we bulb temperature of the air entering and leaving the UUT are measured by means of tree shaped sampling tubes which sample the air over a wide area (as desired) and route the sample to a single point at which the thermometers / temperature sensors are provided. A small motorized

exhaust fan extracts the air sample through the sampling tube such that the velocity of the air sample over the we wick of the wet bulb thermometer is maintained at 5 m/s

IS: 8148 - 1976 specifies the test conditions for the Capacity Rating and other Type tests.(Please refer **Table 1**) The test facility has to be designed to achieve these different test conditions.

Control and Date Acquisition System

The parameters to be controlled and the other parameters measured during he test are listed in **Table 2.**

Table 2: Parameters Controlled and Measured During Capacity Rating Test

Parameter	Accuracy of Measurement	Means of measurement
Controlled parameters		
DBT,UUT inlet indoor side	0.1°C	Hg in glass thermometer or 4 wire Pt. (Platinum)100 RTD
DBT,UUT inlet indoor side	0.1°C	Hg in glass thermometer or 4 wire Pt. 100 RTD.
WBT,UUT inlet indoor side	0.05°C	Hg in glass thermometer or 4 wire Pt. 100 RTD.
Water inlet temperature (water cooled condenser)	0.1°C	Hg in glass thermometer or 4 wire Pt. 100 RTD.
Water flow	1%	Magnetic flow meter
External resistance to Evaporator air flow	2.5 Pa	Draft gauge manometer or Pressure transmitter
Voltage to UUT	0.5%	Voltmeter/Voltage transmitter
Frequency	0.5%	Frequency meter/Frequency Transmitter
Measured Parameters		
DBT,UUT outlet Indoor side	0.1°C	Hg in glass thermometer or 4 wire Pt. (Platinum) RTD sensor
WBT,UUT outlet Indoor side	0.1°C	Hg in glass thermometer or 4 wire Pt. 100 RTD sensor
DBT,UUT outlet Outdoor side	0.1°C	Hg in glass thermometer or 4 wire Pt. 100 RTD.
Water outlet temperature (water-cooled condenser)	0.1°C	Hg in glass thermometer or 4 wire Pt. 100 RTD.
Barometric pressure	1milli bar	Barometer
Power input to Equipment	0.5%	Wattmeter
Static pressure difference Difference across nozzle(s)	0.25mm WG	Draft gauge manometer or differential pressure transmitter

The controlled parameters may be controlled either manually or automatically by means of a Programmable Logic Controller or a dedicated system using PID controls.

Measurements may be recorded either manually or automatically through a PC based Data Acquisition System.

Test Procedure & Calculations

The procedure for capacity rating and other tests is described in IS: 8148-1976 and it is not intended to repeat them in detail here.

Briefly, for the capacity rating test, the test conditions shall be maintained until equilibrium has been reached and maintained for one hour, after which data shall be recorded every 15 minutes for 2 hours.

The cooling capacities & evaporator air flow capacities are computed by the equations given below.

$$\text{Total cooling capacity} \quad (W) = Qm \times \Delta h \div Vm$$
$$\text{Sensible cooling capacity} \quad (W) = 1020 \times Qm \times \Delta t \div Vm$$
$$\text{Latent cooling capacity} \quad (W) = 2{,}460{,}000 \times Qm \times \Delta q \div Vm$$
$$\text{Evaporator Air Flow} \quad (m^3/s) = 1.41 \times N \times An \times \sqrt{\Delta p \times Vi}$$

Where Qm	=	Evaporator air flow (m^3/s)
Vm	=	Specific Volume at measurement point (m^3/kg)
Vi	=	Specific volume at nozzle inlet (m^3/kg)
Δh	=	Enthalpy difference between entering and leaving air (J/kg)
Δt	=	Dry bulb temperature difference between entering and leaving air (°C)
Δq	=	Difference in specific humidity between entering and leaving air (kg of moisture/kg of dry air)
An	=	Area of nozzle
N	=	Nozzle coefficient
Δp	=	Pressure drop across nozzle (Pa)

Nozzle discharge coefficient usually varies from 0.97 to 0.99 and is a function of nozzle diameter, velocity pressure at the nozzle and dry bulb temperature.
More details can be found in IS: 1391-1992 for room air conditioners.