STANDARD

ANSI/ASHRAE Standard 33-2016
(Supersedes ANSI/ASHRAE Standard 33-2000)

Methods of Testing Forced-Circulation Air-Cooling and Air-Heating Coils

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Methods of Testing Forced-Circulation Air-Cooling and Air-Heating Coils

Online Supporting Files: http://www.ashrae.org/33-2016

NOTE

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FOREWORD

ASHRAE Standard 33 presents a method of test for use in laboratory testing of forced circulation air-heating and air-cooling coils. The 2016 edition of this standard was updated with assistance from the members of the product subsection Forced Circulation Air-Cooling & Air-Heating Coils (ACHC) at Air-Conditioning, Heating and Refrigeration Institute (AHRI). This method of test is used in conjunction with the performance metrics in AHRI Standard 410 as part of AHRI's ACHC certification program. This standard was prepared by ASHRAE Standard Project Committee (SPC) 33. The cognizant technical committee is ASHRAE TC 8.4, Air-to-Refrigerant Heat Transfer Equipment.

Standard 33 includes access to fluid type test data forms, which can be found online at http://www.ashrae.org/33-2016.

1. PURPOSE

1.1 The purposes of this standard are to:

a. Describe and specify testing instruments and apparatus.
b. Describe and specify laboratory test methods and procedures.
c. Describe and specify test data to be recorded.
d. Describe and specify calculations to be made from test data.
e. Define terms used in testing.
f. Specify standard thermodynamic properties.

1.2 It is not the purpose of this standard to specify the types of tests used for production or field testing.

2. SCOPE

2.1 This standard prescribes laboratory methods of testing forced-circulation air-cooling coils, for application under nonfrosting conditions, and forced-circulation air-heating coils to ensure uniform performance information for establishing ratings.

3. DEFINITIONS

3.1 General. A *forced-circulation air-cooling or air-heating coil* is a coil used in an airstream whose circulation is caused by a difference in pressure produced by a fan or blower.

3.1.1 Forced-circulation air-cooling coil. A heat exchanger, with or without extended surfaces, through which either chilled water, chilled aqueous glycol solution, or volatile refrigerant is circulated for the purpose of total cooling (sensible cooling plus latent cooling) of a forced-circulation airstream.

3.1.2 Forced-circulation air-heating coil. A heat exchanger, with or without extended surfaces, through which either hot water, hot aqueous glycol solution, or steam is circulated for the purpose of sensible heating of a forced-circulation airstream.

3.2 Coil Dimensions (See Figure 3.1)

3.2.1 Coil Depth. The depth of a coil is the number of rows of tubes or the dimension in the direction of airflow.

3.2.2 Coil Length. The length of a coil is the dimension of the face of the coil in the direction of the tubes exposed to the flow of air. (See Dimension *L*, Figure 3.1.)

3.2.3 Coil Height. The height of the coil is the dimension of the face of the coil perpendicular to the direction of the tubes and includes only the height over tubes and fins exposed to the flow of air. (See Dimension *H*, Figure 3.1.)

3.2.4 Coil Face Area. The face area of a coil is the product of the length and the height of the coil,

$$L \times H/10^6 \qquad \text{(SI)}$$

$$[L \times H/144] \qquad \text{(I-P)}$$

Note: Here and throughout this document the use of [ ] signifies items evaluated in I-P units. If I-P units are used, the immediately preceding item, which applies to SI units, is not required to also be used.

3.3 Testing Terminology

3.3.1 Equilibrium. *Equilibrium*, for the purpose of this standard, is a steady-state condition during which the fluctuations of variables being measured remain within stated limits as given in Section 9.

3.3.2 Test. A *test* is the recorded group of readings of test variables taken while equilibrium is maintained and used in the computation of results.

3.3.3 Test Run. A *test run* is the complete group of readings of test variables, which includes the following:

a. Those observed or recorded during a sufficient period to indicate that equilibrium was attained prior to the actual test.
b. Those recorded during the period of the test.

4. COIL CLASSIFICATION

Air-cooling and air-heating coils may be classified, with regard to their cooling or heating function, by identifying the heating or cooling fluid as follows:

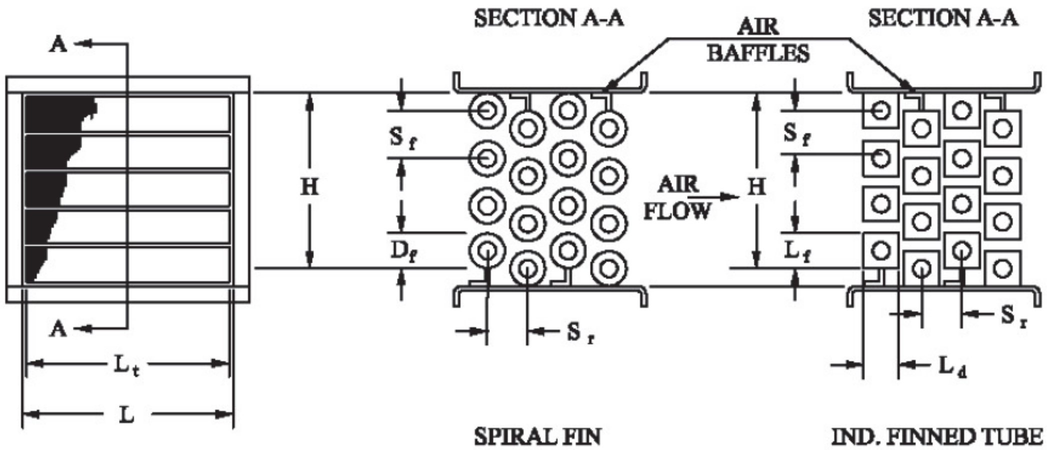
4.1 Volatile Refrigerant Coils. Liquid-vapor mixtures used for air cooling controlled by a thermal expansion valve.

4.2 Steam. Used for air heating.

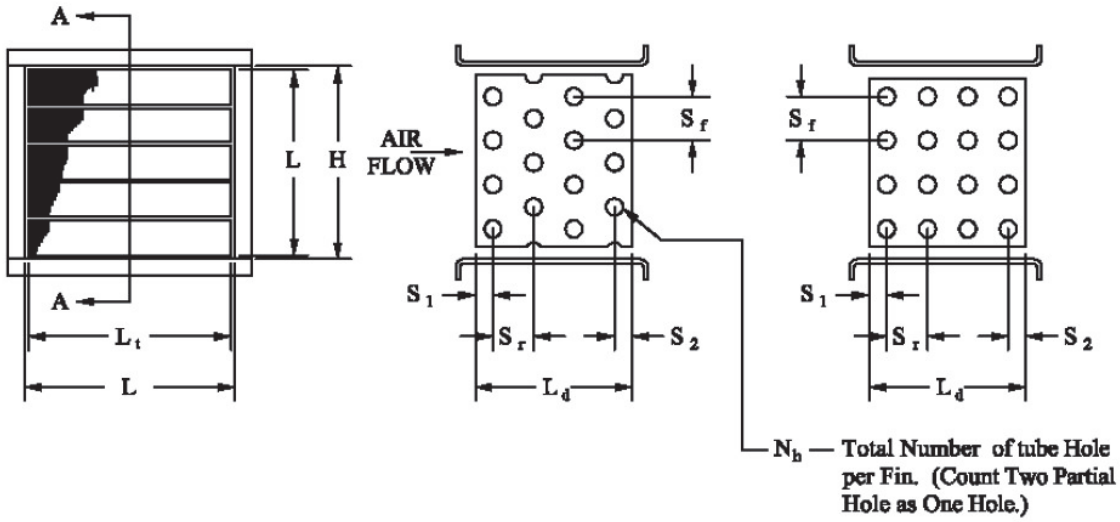
a. Single tube (standard) type
b. Steam distributing tube type

4.3 Water or Aqueous Glycol Solution. Liquids used for air cooling or air heating.

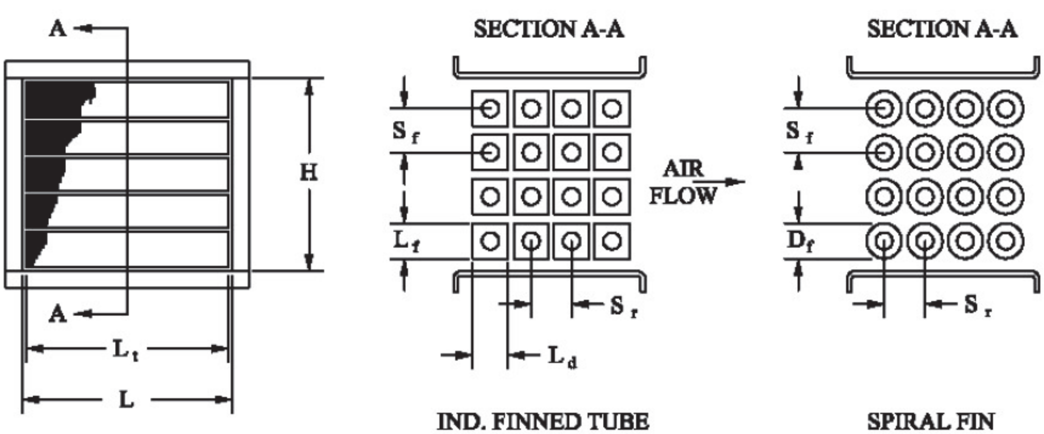
a. Continuous circuit type
b. Self-draining type
c. Cleanable type



Staggered tubes with smooth spiral fins or with flat plate or configurated plate fins on individually-finned tube



Staggered and parallel (in-line) tubes with continuous flat plate or configurated plate fins.



Parallel (in-line) tubes with flat plate or configurated plate fin on individually-finned tube or with smooth or crimped spiral fins

FIGURE 3.1 Coil dimensions.

5. SYMBOLS

5.1 Letter symbols are in SI (metric) units and [I-P (Inch-Pound) units].

A = area, mm^2 [ft^2] (when applied to coil face area, m^2 [ft^2])

CN = discharge coefficient of nozzle = 0.99 (see Section 6.4.2)

c_p = specific heat at constant pressure of air-water vapor mixture, $1.005 + 1.895W$, kJ/(kg dry air·°C) [$0.240 + 0.444W$, Btu/(lb dry air·°F)]. To simplify calculation and rating procedures, a constant value of $c_p = 1.017$ [0.243] may be used for cooling calculations and a constant value of $c_p = 1.009$ [0.241] may be used for heating calculations.

c_pL = specific heat at constant pressure of single-phase fluid, kJ/(kg dry air·°C) [Btu/(lb dry air·°F)]

D = diameter, mm [in.]

E = thermal expansion factor of nozzle material; corresponds to F_a in Figure II-I-3 of *Fluid Meters: Their Theory and Application*[1]

H = coil face height, mm [in.]

h = enthalpy, kJ/kg [Btu/lb]] (when applied to air, kJ/(kg dry air) [Btu/(lb dry air)])

h_L = head loss through coil at average liquid density, m of liquid [ft of liquid]

K = heat leakage constant, kW/°C [Btu/(h·°F)]

L = length, mm [in.]

M = mass of water or aqueous glycol solution collected, kg [lb]

N = number of

P = absolute pressure, kPa abs [psia or in. Hg abs]*

p = gauge pressure, kPa [psi or in. Hg or in. water]*

Δp = difference in pressure, kPa [psi or in. water or in. Hg]*

Δp_{aSTD} = standard air difference in pressure, kPa [psi or in. water or in. Hg] (standard air density = 1.204 kg/m^3 [0.075 lb/ft^3]), which approximates dry air density at 21.1°C [70°F] and 101.325 kPa abs [14.696 psia], m^3/s [scfm]

Q_{lSTD} = standard fluid volumetric flow rate (standard water density = 998.927 kg/m^3 [62.361 lb/ft^3]), which approximates water density at 15.6°C [60°F] and 101.325 kPa abs [14.696 psia], std. m^3/s [sgpm]

q = heat transfer capacity, kW [Btu/h]

s_{hf} = continuous plate fin hole spacing across coil face, mm [in.]

s_{hr} = continuous plate fin hole spacing in direction of airflow, mm [in.]

s_{tf} = tube spacing across coil face, mm [in.]

s_{tr} = tube spacing in direction of airflow, mm [in.]

SG = specific gravity, as in correcting for relative density of air-water vapor mixture =

$$\frac{1 + W}{1 + \frac{W}{0.622}}$$

(dry air SG = 1.00), kg air-water vapor mixture/(kg dry water) [lb air-water vapor mixture/(lb dry water)]

T = absolute temperature, K [°R]

t = temperature, °C [°F]

Δt = difference in temperature, K [°F] (Note: in this use K = °C)

V = volume of refrigerant, water, or aqueous glycol solution collected or difference in volume meter reading, m^3 [ft^3]

V_a = standard air face velocity, m/s [fpm]

v = specific volume (for water or aqueous glycol mixture), m^3/kg [ft^3/lbm]

W = humidity ratio of air-water vapor mixture, kg water vapor mixture/(kg dry water) [lb water vapor mixture/(lb dry water)]

ΔW = difference in air humidity ratio across dehumidifying coil, kg water vapor mixture/(kg dry water) [lb water vapor mixture/(lb dry water)]

w = mass flow rate, kg/s [lbm/h] (for air, kg dry air/s [lbm dry air/min])

x_l = composition by mass of fluid, %

x_r = mass fraction of volatile refrigerant vapor

Y = fin thickness, mm [in.]

Z = time, s [min]

β = ratio of nozzle throat diameter to hydraulic or actual inlet chamber diameter, D_N/D_c. (For noncircular inlet chambers, the hydraulic diameter, D_c, is equal to four times the cross-sectional area divided by the chamber perimeter.)

ρ = density (for water or aqueous glycol mixture), kg/m^3 [lb/ft^3]

ϕ = air adiabatic expansion coefficient, nozzle; corresponds to Y in ASHRAE Standard 41.2[2]

5.2 Subscripts

a. Numerical subscripts are used to define conditions at the following locations:

0 = entering liquid control device

1 = entering coil, condenser, etc.

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* The dimensions for specific symbols are given on the Test Data (TD) forms, which are available online at http://www.ashrae.org/33-2016.

2	=	leaving coil, condenser, etc.
3	=	air entering intake chamber
4	=	air leaving mixing chamber
5	=	average ambient air surrounding intake and mixing chambers
24	=	mixing chamber
31	=	intake chamber

b. Letter subscripts are used to further identify the letter symbols. They are:

a	=	dry air (when used with *h* or *w*)
	=	air-water vapor mixture (when used with *p*)
b	=	barometric
C	=	calibrated compressor
c	=	chamber (when used with *D*)
	=	condenser (when used with *h*, *K*, *P*, *q*, Δt, and *t*)
	=	plate fin external collar (when used with *L*)
	=	tube circuits (when used with *N*)
d	=	plate fin depth in direction of airflow
db	=	dry-bulb
e	=	outside edge of spiral fin
f	=	across coil face (when used with *s*)
	=	coil face (when used with *A*)
	=	outside diameter of spiral fin (when used with *D*)
	=	fins in net finned tube length (when used with *N*)
	=	plate fin length perpendicular to direction of tubes exposed to the airflow (when used with *L*)
	=	plate fins of constant thickness (when used with *Y*)
	=	saturated liquid (when applied to h_r, t_c, t_r, and t_v)
g	=	saturated vapor (when used with h_{g1}, h_r, t_c, t_C, t_r, t_v, v_r, and v_v)
h	=	holes in plate fin
i	=	inside tube
l	=	single-phase fluid, i.e., water and aqueous glycol solution (when used with h_l, *M*, *P*, Δp, *t*, Δt, *w*, *x*, *Z*, and ρ)
m	=	log mean area of condenser insulation (when used with *A*)
	=	mean or average (when used with SG, t_v, *T*, v_v, *W*, and ρ)
ma	=	piezometer ring pressure measurement apparatus
N	=	nozzle
n	=	neutral diameter of crimped spiral fin (when used with *D*)
	=	crimped spiral fin thickness at neutral diameter (when used with *Y*)
o	=	outside tube
p	=	tube passes per circuit
r	=	fin root for spiral fins with constant metal area for heat flow (when used with *Y*)
	=	refrigerant (when used with *h*, *P*, Δp, *v*, *t*, Δt, *w*, and *x*)
	=	rows (in direction of airflow when used with *N* and *s*)
rc	=	volatile refrigerant coil circuit
rf	=	leaving volatile refrigerant flowmeter
rh	=	volatile refrigerant coil suction header
s	=	sensible (when used with *q*)
	=	static (when used with *P*)
sa	=	sensible (air side)
sz	=	sensible (heating or cooling medium side)
t	=	total (when used with *q*)
	=	net finned tube (when used with *L*)
	=	tubes (when used with *N* and *s*)
ta	=	total (air side)
ts	=	test setup (liquid pressure drop of coil and measurement apparatus)
tz	=	total (cooling medium side)
v	=	steam
w	=	water
wb	=	wet-bulb

Where no letter subscript follows c_p, *h*, or *t*, these symbols designate air-water vapor mixture properties.

5.3 Superscripts. Numerical superscripts denote the power to which the number of a symbol is raised.

6. TEST INSTRUMENTS AND CALIBRATION

6.1 Calibration

Measurements from the instruments shall be traceable to primary or secondary standards calibrated by National Institute of Standards and Technology (NIST) or to the Bureau International des Poids et Mesures (BIPM) if a National Metrology Institue (NMI) other than NIST is used. The indicated corrections shall be applied to meet the required error limits given in subsequent sections. Instruments shall be recalibrated on a regular schedule that is appropriate for each instrument, and calibration records shall be maintained. All instruments shall be applied in a manner that ensures compliance with the accuracy specified in the test plan.

6.2 Temperature Measuring Instruments

6.2.1 Temperature and moist air properties measuring instruments shall meet the requirements of ANSI/ASHRAE Standard 41.1[3] and ANSI/ASHRAE Standard 41.6,[4] respectively.

6.2.2 Temperature measurements shall be made with an instrument or instrument system meeting the accuracy and precision requirements in Section 6.2.3.

6.2.3 The accuracy of the temperature measuring instruments shall be:

a. Air dry-bulb and wet-bulb temperatures, ±0.06°C [0.1°F]
b. Water or aqueous glycol solution temperatures, ±0.06°C [0.1°F]
c. Volatile refrigerant temperatures, ±0.06°C [0.1°F]
d. All other temperatures, ±0.3°C [0.5°F]

6.2.4 In no case shall the smallest scale division of the instrument exceed twice the specified precision. For example, if the specified accuracy is ±0.06°C [0.1°F], the smallest scale division shall not exceed 0.1°C [0.2°F].

6.2.5 Where an accuracy closer than ±0.3°C [0.5°F] is specified, the temperature measuring instruments shall be calibrated by comparison with a NIST-certified standard instrument in the range of use or shall itself be certified as to accuracy.

6.2.6 When air humidity is to be established by means of dry-bulb and wet-bulb temperature measurements, it is important that the instruments be matched. That is, they should indicate the same temperature when both are dry and in the same ambient or a correction shall be applied. This ensures accurate determination of the wet-bulb temperature. The two temperature measuring instruments shall be close together in the airstream so as to measure the same sample of air. The air dry-bulb temperature measuring instrument shall be mounted upstream or to one side of the air wet-bulb temperature measuring instrument so that its reading will not be influenced by evaporation of moisture from the wet bulb.

6.2.6.1 Air humidity may also be measured using the dew-point temperature, per ASHRAE Standard 41.6.[4]

6.2.7 Air wet-bulb temperatures shall be read only under conditions that ensure an air velocity of 3.6 to 10.2 m/s [700 to 2000 fpm] preferably near 5.1 m/s [1000 fpm] over the wet bulb, and only after sufficient time has been allowed for evaporative equilibrium to be attained.

6.2.8 A suitable material for the wet-bulb wick is cotton tubing of a fairly soft fine mesh weave. The wet-bulb wick shall fit snuggly on the wet-bulb temperature measuring instrument. Distilled water shall be used on the wick. With continued use, wicks become encrusted with impurities that interfere with proper action; therefore, wicks shall be frequently cleaned and replaced.

6.2.9 Temperature measurements in the airstream are subject to error due to thermal radiation when the temperature measuring instruments are exposed in direct line of sight to surfaces appreciably different in temperature from the airstream. In such cases, the temperature measuring instruments shall be shielded from direct exposure in a suitable manner.

6.2.10 Temperature measurement instruments used to measure the change in temperature of a liquid or gas should be checked for equivalent readings, while in position, at static conditions, just prior to the start of a test run. If equivalent readings within the required tolerance are not attainable by the calibration method, then the reading positions should be so arranged that a single temperature measuring instrument is then readily interchanged between inlet and outlet positions for every test recorded reading. This is to minimize the possibilities of temperature difference reading errors.

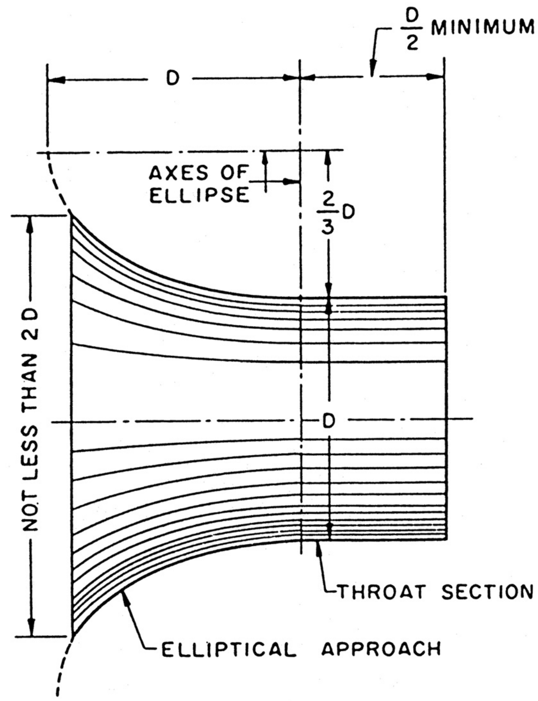


FIGURE 6.1 Airflow measuring nozzle.

6.2.11 The temperatures of fluids within conduits shall be measured by inserting the temperature measuring instrument directly into the fluid or into a liquid-filled well inserted in the conduit.

6.3 Pressure Measuring Instruments

6.3.1 Pressure measuring instruments shall meet the requirements of ANSI/ASHRAE Standard 41.3.[5]

6.3.2 The accuracy of pressure transducers shall be ±2.0% of the absolute pressure for all pressures, unless otherwise specified.

6.3.2.1 The accuracy of the pressure transducers for measuring refrigerants shall permit pressure measurement corresponding to ±0.1°C [±0.2°F] of saturation temperature.

6.3.3 Air static pressure and air differential pressure taps shall be made as shown in Figure 7A of ASHRAE Standard 41.2.[2]

6.4 Airflow Measuring Instruments

6.4.1 Measure airflow either by measuring the static pressure drop across one or more nozzles or by measuring the velocity pressure at each nozzle exit with pitot tubes. Refer to ASHRAE Standard 41.2[2] for a more detailed discussion of airflow measurement.

6.4.2 The nozzles shall be constructed in accordance with Figure 6.1. If the throat diameter is 125 mm [5 in.] or larger, the nozzle discharge coefficient (C_N) may be taken as 0.99 for

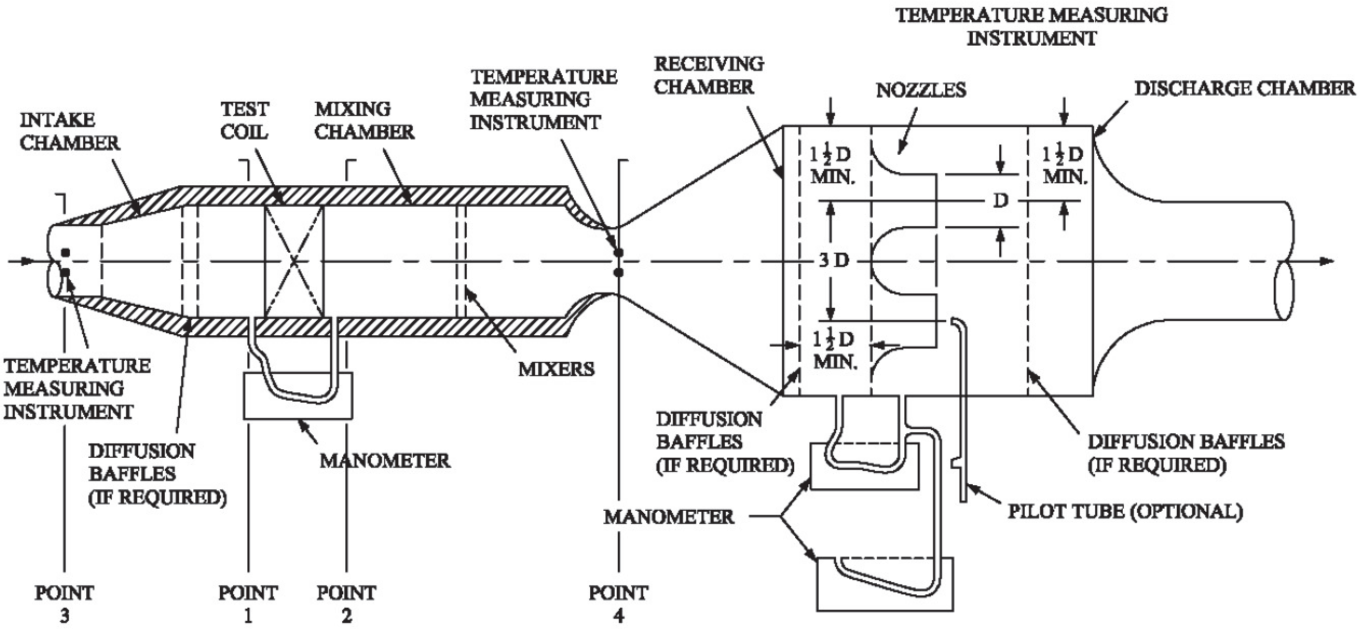


FIGURE 7.1 Recommended airflow, air pressure, and air temperature measuring apparatus.

air within the normal barometric pressure variations and the temperature range covered by the standard. For nozzle diameters less than 125 mm [5 in.], see ASHRAE Standard 41.2[2] for the nozzle discharge coefficients.

6.4.3 Diameters of nozzles shall be determined by measuring their diameters to an accuracy of ±0.2% in four places approximately 45° apart around the nozzles in each of two planes through the nozzle throat, one at the inlet and the other at the outlet of the throat section.

6.4.4 Pitot tubes should be of the accepted commercial type. A detailed description of the pitot tube is given in ASHRAE Standard 41.2.[2]

6.5 Volatile Refrigerant Flow Measuring Instruments

6.5.1 Instruments for measuring volatile refrigerant flow shall have an accuracy of ±1.0% of the quantity measured.

If measuring liquid refrigerant flow, ensure that sufficient subcooling is present in the refrigerant entering and exiting the flowmeter such that flashing of refrigerant does not occur in the meter. To this end, Coriolis mass flowmeters or similar meters that have very little refrigerant pressure drop are suggested.

6.5.2 Volatile refrigerant liquid volumetric/mass flow measuring instruments shall be in accordance with ANSI/ASHRAE Standard 41.10.[6]

6.6 Water or Aqueous Glycol Solution Flow Measuring Instruments

6.6.1 Measure water or aqueous glycol solution flow with one or more of the following instruments, calibrated for the intended liquid, ensuring an accuracy of ±1.0% of the mass flow rate measured:

a. Liquid volume flowmeter
b. Liquid mass flowmeter

If using a liquid volume flowmeter, ensure that the temperature of the liquid is measured to within 0.17°C [0.3°F]. The net error in mass flow rate shall be less than ±1.0%.

6.6.2 Single-phase liquid volumetric/mass flow measuring instruments shall be in accordance with ASHRAE Standard 41.8[7] for liquid orifice flowmeters, ISA-RP31.1[8] for turbine flowmeters, and/or ASME MFC-11[9] for Coriolis flowmeters. The single-phase liquid volumetric/mass flow measuring instruments shall be used and installed in accordance with the manufacturer's instructions.

6.6.3 The method used for determining the composition by mass of aqueous glycol solution (x_g) shall have an accuracy of ±2%.

6.7 Steam Condensate Flow Measuring Instruments

6.7.1 Measure steam condensate flow with a liquid quantity meter having an accuracy of ±1.0% of the net quantity measured.

7. TEST APPARATUS

7.1 Airflow, Air Pressure, and Air Temperature Measuring Apparatus

7.1.1 Airflow rates, air static pressures, air static pressure drops, air velocity pressures, and air dry-bulb and wet-bulb temperatures may be measured with various types of apparatus as illustrated in Figure 7.1. The airflow through this apparatus is as follows:

a. The air enters the intake chamber through a restricted opening or openings, passes through the diffusion baffles, when required, and enters the coil under test. When sampling tubes are used, it is not necessary to restrict the intake chamber cross-sectional area.

b. The air then leaves the coil under test and enters an insulated mixing chamber where it passes through a mixing device.
c. The air then leaves the mixing chamber through a restricted opening or openings and enters the receiving chamber. When sampling tubes are used, it is not necessary to restrict the mixing chamber cross-sectional area.
d. After proceeding through another set of diffusion baffles, when required, the air enters the airflow measuring nozzles and discharges into the discharge chamber.
e. The air finally leaves the discharge chamber.

7.1.2 The inlet of the coil under test shall be connected to an intake chamber, at the inlet of which the entering air dry-bulb (t_{3db}) and wet-bulb (t_{3wb}) temperatures shall be measured in a restricted opening or openings, so that the velocity of the air passing over the temperature measuring instruments will be approximately 5.1 m/s [1000 fpm] but not less than 3.6 m/s [700 fpm]. The use of sampling tubes shall cause no detectable change in air temperature or velocity. If necessary, the intake chamber shall contain diffusion baffles to ensure uniform air velocity over the face of the coil and uniform temperature as required in Section 9.1.2. The uniformity of the velocity of the air entering the coil shall be initially determined by a pitot tube traverse made on the first test run only to prove out the setup, as described in Normative Annex C. The maximum velocity shall not exceed the minimum by more than 20%. The intake chamber need not be insulated when the surrounding air is at the same temperature as the air entering the chamber.

7.1.2.1 The entering air dry-bulb temperatures (t_{3db}) may also be measured using a grid of evenly spaced resistance temperature devices (RTDs) or by using sampling tubes in an unrestricted opening.

7.1.3 The outlet of the coil under test shall be connected to a mixing chamber, at the outlet of which the leaving air dry-bulb (t_{4db}) and wet-bulb (t_{4wb}) temperatures shall be measured in a restricted opening or openings, so that the air velocity passing over the temperature measuring instruments will be approximately 5.1 m/s [1000 fpm] but not less than 3.6 m/s [700 fpm]. (Leaving air wet-bulb temperatures are not required for heating coils.) The use of sampling tubes shall cause no detectable change in air temperature or velocity. If necessary, the mixing chamber shall contain deflectors or vanes to mix the airstream to an extent that air temperatures in the plane of measurement do not vary more than 1.0°F [0.6°C]. Three suggested designs for air mixing devices are given in ASHRAE Standard 41.2.[2] The mixing chamber and the intake chamber shall be insulated so that the heat leakage through the chamber walls does not exceed 2.0% of the air-side coil capacity.

7.1.3.1 The exiting air dry-bulb temperatures (t_{4db}) may also be measured using a grid of evenly spaced RTDs or by using sampling tubes in an unrestricted opening.

7.1.4 The receiving chamber shall be of sufficient size and arrangement to provide uniform approach velocity to the nozzle or nozzles or shall have suitable diffusion baffles to accomplish this purpose. The area of the receiving chamber perpendicular to the axis of flow to the nozzles shall be not less than 11.4 times the area of the nozzles installed. Under these conditions, the approach velocity correction can be neglected.

7.1.5 The intake, mixing, and receiving chambers shall be sealed against air leakage at any static pressure within the test range. An air leakage test shall be performed prior to initial use and at least annually thereafter, with corrective action taken if necessary. See Annex B of ASHRAE Standard 51[10] for two recommended leakage test methods.

7.1.6 One or more nozzles constructed in accordance with Figure 6.1 shall be fitted into one wall of the receiving chamber, discharging into the discharge chamber. These nozzles shall be of such a size that the throat velocity will be not less than 15.2 m/s [3000 fpm]. Center-to-center distances between nozzles in use shall not be less than three throat diameters, and the distance from the center of any nozzle to any of the four adjacent side walls shall not be less than 1.5 throat diameters. If the nozzles are of different diameters, the minimum distance between axes shall be based upon the average diameter.

7.1.7 The walls of the discharge chamber shall be smooth and continuous with those of the receiving chamber, and the distances from any nozzle outlet to the nearest obstruction shall be not less than 5 throat diameters of the largest nozzle unless suitable diffusion baffles are installed.

7.1.8 If diffusion baffles are used, they shall cover the entire cross section of the duct and shall be not less than 2.5 throat diameters from the largest nozzle. (See Figure 7.1.) Perforated metal sheets are recommended with either one sheet having 40% free area or two separate sheets each having 65% free area. Where more than one perforated sheet is used, they should be separated by at least four times the center-to-center distance between holes.

7.1.9 A set of four static pressure taps located flush with the inner walls of the receiving chamber upstream from the nozzle plate shall be required, with one tap located at the center of each of the four duct sides. Similarly, a set of four static pressure taps shall be located at the throat of the nozzle or shall be located flush with the inner walls of the discharge chamber and downstream from the nozzle plate. If the static pressure taps are in the discharge chamber, they shall be located at the center of each of the four duct sides. If the four static pressure taps are located in the throat of the nozzle they shall be 90° apart. The pressure drop across the nozzle (Δp_N) can be measured with a pressure measuring instrument having one side connected to a manifold of the four upstream static pressure taps and the other side similarly connected to a manifold of the four downstream or nozzle throat static pressure taps. Individual static pressure readings shall be taken at each tap and must not vary more than 5% from the other individual tap readings. To determine the air-water vapor mixture density entering the nozzle, the air static pressure entering the nozzle (p_{N1}) shall be taken using a pressure measuring instrument open to the atmosphere with the pressure taps located either in the throat of the nozzle or downstream from the nozzle plate, together with the air dry-bulb temperature entering the nozzle (t_{N1db}).

7.1.10 The velocity pressure of the airstream leaving the nozzle (Δp_N) may be measured by a pitot tube. When more than one nozzle is in use, the velocity pressure shall be determined for each nozzle.

7.1.11 A minimum of four static pressure taps, with one tap at the center of each of the four air duct sides, shall be located at least 300 mm [12 in.] from the coil both upstream and downstream to determine the coil air pressure drop (Δp_a). To determine the air-water vapor mixture density entering the coil, the air static pressure entering the coil (p_{a1}) shall be taken using a pressure measuring instrument open to the atmosphere with the manifold connection from the set of four upstream taps. Individual pressure drop readings must not vary more than 10% or 5 Pa [0.02 in. water gauge], whichever is the greater. In dehumidifying coil tests, the manifold connections to the floor taps shall be disconnected and capped to prevent condensate from entering these lines. Suitable trapped drains should be provided for condensate drainage from the duct floor.

7.1.12 The air dry-bulb temperature shall be measured at no less than two locations surrounding the intake and mixing chambers. The temperatures shall be averaged to determine the average air dry-bulb temperature surrounding intake and mixing chambers (t_{5db}).

7.2 Liquid Flowmeter for Volatile Refrigerant Flow Measurement

7.2.1 The mass flow rate of volatile refrigerant liquid (w_r) may be measured by a liquid flowmeter measuring either the instantaneous mass flow rate or the volumetric flow rate as illustrated in Figure 7.2. The meter shall be connected in the liquid line between the liquid receiver outlet and the refrigerant control device. In order that the meter may function properly under all conditions, the following additional apparatus shall be provided:

a. A subcooler ahead of the meter to prevent vaporization of the refrigerant in the meter when required. The liquid line subcooling entering the meter shall be not less than 2.8°C [5°F].
b. Sight glasses located immediately before and after the meter to observe that vapor bubbles are not mixed with the liquid refrigerant.
c. A temperature measuring instrument for measuring the temperature at which subcooled refrigerant liquid leaves the meter.
d. An oil separator located in the compressor discharge line with provision for returning oil to the crankcase, either manually or automatically.

7.3 Condenser Water Method for Volatile Refrigerant Flow Measurement

7.3.1 The mass flow rate of volatile refrigerant (w_r) may be determined by the condenser water method as illustrated in Figure 7.2. The method determines the refrigerant mass flow rate by measuring its change in enthalpy and the heat removed from it on passing through the condenser. Refer to ANSI/ASHRAE Standard 41.9[11] for a more detailed discussion of the condenser water method for volatile refrigerant flow measurement.

7.3.2 The temperature (t_{c1}) and pressure (P_{c1}) of the superheated refrigerant vapor shall be measured as it enters the condenser, and the temperature (t_{c2}) and pressure (P_{c2}) of the subcooled refrigerant liquid shall be measured as it leaves the condenser. The superheat of the refrigerant vapor entering the condenser (Δt_{c1}) shall not be less than 5.6°C [10°F]. The subcooling of the refrigerant liquid leaving the condenser (Δt_{c2}) shall not be less than 2.8°C [5°F] unless means are provided to indicate that no vapor is present.

7.3.3 Water temperatures shall be measured as the water enters (t_{w1}) and leaves (t_{w2}) the condenser, and the water flow rate (w_w) shall be determined by one of the instruments listed in Section 6.5.

7.3.4 The condenser shall be insulated to limit the heat loss to not more than 2.0% of the total heat removal.[11] The calculated heat loss shall be included in the total heat calculations.

Informative Note: A method of calculating heat leakage from a cylinderical surface condenser is given in *ASHRAE Handbook—Fundamentals*.[12]

7.3.5 The ambient air dry-bulb temperature at the condenser (t_{adb}) shall be measured at the condenser.

7.4 Calibrated Compressor Method for Volatile Refrigerant Flow Measurement

7.4.1 The mass flow rate of volatile refrigerant (w_r) may be determined by the calibrated compressor method, as positioned in the refrigeration circuit illustrated in Figure 7.2. This method determines the refrigerant mass flow rate by calibration of the compressor under conditions identical to test conditions.

7.4.2 The calibrated compressor shall be the compressor used for the tests. It shall be calibrated in accordance with ANSI/ASHRAE Standards 23.1[13] and 23.2[14] before and after each complete coil test. The two calibrations shall not differ by more than 2.0%. Calibration tests shall be conducted under conditions applicable to the discharge and suction pressures and temperatures experienced under operation of the coil on test. It is good practice to conduct calibration tests at pressures slightly above and below the operating range and note the variations over this range.

7.4.3 The temperature (t_{C1}) and pressure (P_{C1}) of the superheated refrigerant vapor shall be measured as it enters the compressor. The temperature (t_{C2}) and pressure (P_{C2}) of the superheated refrigerant vapor shall be measured as it leaves the compressor. The superheat of the refrigerant vapor entering the compressor (Δt_{C1}) shall be not less than 5.6°C [10°F]. The superheat of the refrigerant vapor leaving the compressor (Δt_{C2}) during calibration and test operation shall not differ more than 5.6°C [10°F] under the same operating conditions.

7.5 Volatile Refrigerant Properties Measuring Apparatus

7.5.1 The temperatures and pressures of refrigerant entering and leaving the coil may be measured by the apparatus as illustrated in Figure 7.2. The connecting tubing attached to the refrigerant liquid line connection does not have a size requirement. The connecting tubing attached to the suction header connection shall be the same size as the coil suction header connection.

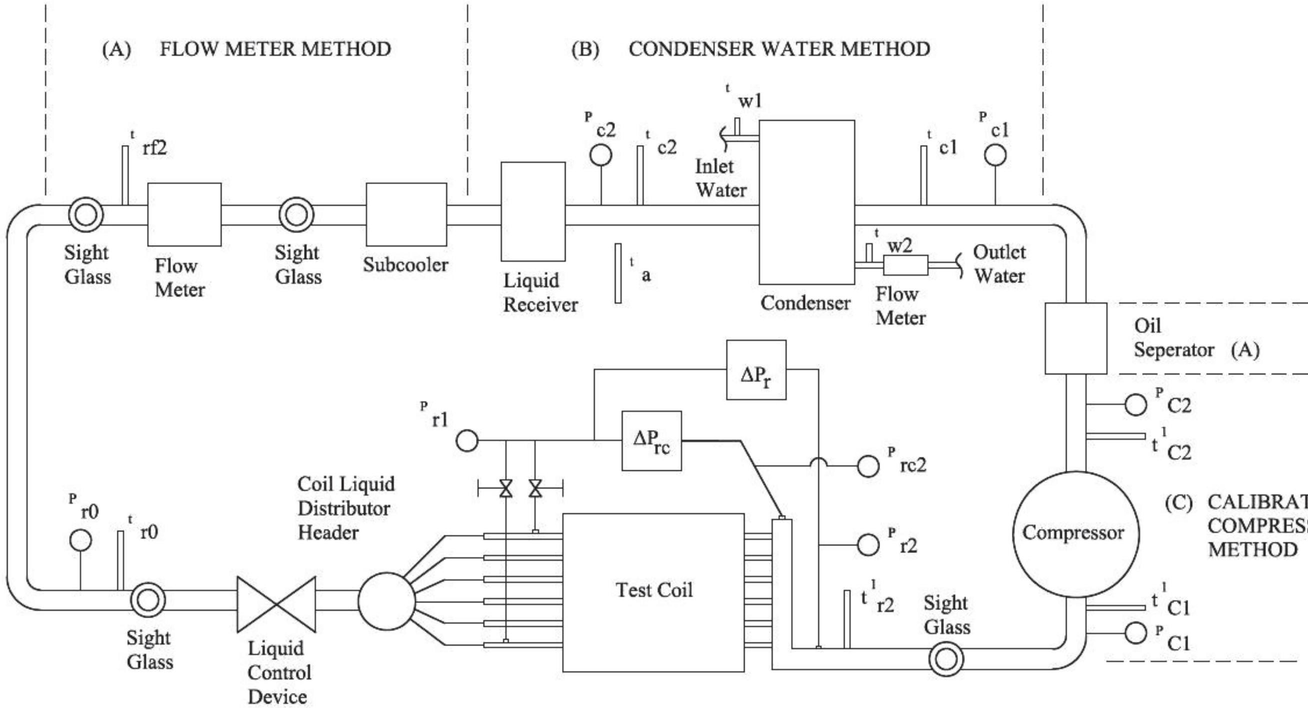


FIGURE 7.2 Measuring apparatus for determining volatile refrigerant properties and flow.

7.5.2 Temperature measuring instruments shall be placed in the refrigerant circuit at the following places:

a. Adjacent to the pressure tap ahead of the liquid control device (P_{r0}) to determine the subcooled refrigerant liquid temperature entering the liquid control device (t_{r0}).
b. Adjacent to the pressure tap downstream of the suction header (P_{r2}) to determine the superheated refrigerant vapor temperature leaving the coil suction header (t_{r2}).

The refrigerant lines shall be insulated at and adjacent to the temperature measuring instruments.

7.5.3 Pressure taps, for connection to pressure and pressure drop measuring instruments, shall be placed in the refrigerant circuit at the following places:

a. Six to 15 tube inside diameters ahead of the liquid control device and a minimum of 10 diameters downstream from any tube fitting to determine the subcooled refrigerant liquid absolute pressure entering the liquid control device (P_{r0}).
b. Five to 10 tube inside diameters downstream from the distributor tube connection to the coil to determine the refrigerant absolute pressure entering the coil (P_{r1}). To accomplish this, it may be necessary to extend the coil tubes. In multi-feed coils the number of upstream taps shall be 1 tap per 5 feeds, with a minimum of 2 taps.
c. At the dead end of the coil suction header to determine the superheated refrigerant vapor absolute pressure leaving the coil circuits (P_{rc2}).
d. A minimum of 10 pipe inside diameters downstream of an elbow, mitered bend, or tee in the suction header to determine the superheated refrigerant vapor absolute pressure leaving the coil suction header (P_{r2}).

7.5.4 The liquid control device used during testing shall be located as near the liquid distributor header as possible and shall be one of the following:

a. A conventional thermostatic expansion valve that is manually controlled by imposing a pressure on the valve diaphragm. This may be done by removing the remote thermal bulb and applying air or other noncondensible gas pressure through the capillary tube.
b. A manually operated expansion valve.
c. A manually controlled electronic expansion valve.

7.5.5 The suction pressure at the coil shall be controlled by regulating the capacity of the refrigerant compressor. This may be accomplished by any desired means that will maintain steady-state conditions, such as a hand-operated throttling valve in the suction line or a hand-operated bypass valve between the high and low sides of the compressor.

7.5.6 A sight glass shall be placed in the suction line near the coil outlet to detect whether liquid floods through the coil. A sight glass shall also be placed in the liquid line ahead of the temperature measuring instrument to ensure that flash gas is not present.

7.5.7 It is recommended that the last passes of each circuit be provided with thermocouples in accordance with ANSI/ASHRAE Standard 41.1_3 to monitor superheat and circuit balance.

7.5.8 Suitable means shall be provided for determining the refrigerant pressure drop through coil and suction header

(Δp_r) and the refrigerant pressure drop through the coil circuits (Δp_{rc}).

7.6 Liquid Quantity Meter for Water or Aqueous Glycol Solution Flow Measurement

7.6.1 The mass flow rate of the single-phase fluid (w_l) may be determined by a liquid quantity meter measuring either the mass change (M_l) or volume change (V_l) over a period of time as illustrated in Figure 7.3. The device shall consist of a tank having sufficient capacity to accumulate the flow for at least two minutes and shall be located so that the liquid leaving the coil under test can be diverted into it.

7.7 Liquid Flowmeter for Water or Aqueous Glycol Solution Flow Measurement

7.7.1 The mass flow rate of the single-phase liquid (w_l) may be determined by a liquid flowmeter measuring the instantaneous mass flow rate or the volumetric flow rate as illustrated in Figure 7.3.

7.8 Water or Aqueous Glycol Solution Properties Measuring Apparatus

7.8.1 The temperatures and pressures of water or aqueous glycol solution entering and leaving the coil may be measured by the apparatus as illustrated in Figure 7.3. The connecting piping shall be the same size as the coil supply and return connections.

7.8.2 Temperature measuring instruments shall be placed so as to measure the temperature of the liquid entering (t_{l1}) and leaving (t_{l2}) the coil. The liquid lines shall be insulated at and adjacent to the temperature measuring instruments. Suitable insulation having an RSI of 0.79 $m^2 \cdot °C/W$ [R-value of 4.5 $ft^2 \cdot °F \cdot h/Btu$] or greater shall be applied from the unit under test to at least 150 mm [6 in.] upstream of the inlet temperature sensor and 150 mm [6 in.] downstream of the outlet temperature sensor. Temperature sensor stems shall be insulated. To minimize possible temperature stratification, appropriate mixers, such as "static mixers," shall be inserted in the inlet and outlet liquid lines upstream from the temperature measuring instruments. Alternatively, two close-coupled 90° elbows just upstream of the temperature measuring instruments can serve as mixers provided that the water velocity at the mixing section is not below 0.3 m/s [1 ft/s].

7.8.3 Suitable means shall be provided for determining the liquid absolute pressure entering the coil (P_{l1}) and the liquid pressure drop through the coil and measurement apparatus (Δp_{lts}) as shown in Figure 7.3. The piezometer rings shall be located and constructed in accordance with the dimensions shown in Figure 7.3. Pressure taps may be used in lieu of piezometer rings. The test setup measurement of pressure drop between piezometer rings or pressure taps shall be reduced by the pressure drop of the total length of pipe between the piezometer rings or pressure taps and the coil (Δp_{lma}). The piping loss shall be determined by calibration of the measurement apparatus.

The pressure drop in the test measurement apparatus, including any pipe between the coil and the measuring devices, at the test flow shall be calculated and subtracted from the measurement. This piping loss shall be determined by calibration of the test apparatus or by calculation of pressure drop based on type of material used for the pipe using Normative Annex B.

7.9 Steam Properties and Condensate Flow Measuring Apparatus

7.9.1 The properties of steam entering the coil and the properties and flow rate of condensate leaving the coil may be measured by the apparatus illustrated in Figure 7.4. The connecting pipes shall be the same size as the coil supply and return connections.

7.9.2 Temperature measuring instruments shall be placed so as to measure the temperature of the superheated steam entering the coil (t_{v1}) and of the condensate leaving the coil (t_{v2}). Steam lines shall be insulated between the temperature measuring instruments and the heat exchange apparatus.

7.9.3 Steam entering the coil shall be superheated (Δt_{v1}) at least 5.6°C [10°F] but not more than 16.7°C [30°F]. If necessary, superheating shall be accomplished by any suitable heating means or by throttling. A separator shall be located upstream of the superheater or throttling valve to remove condensate from the steam supply line.

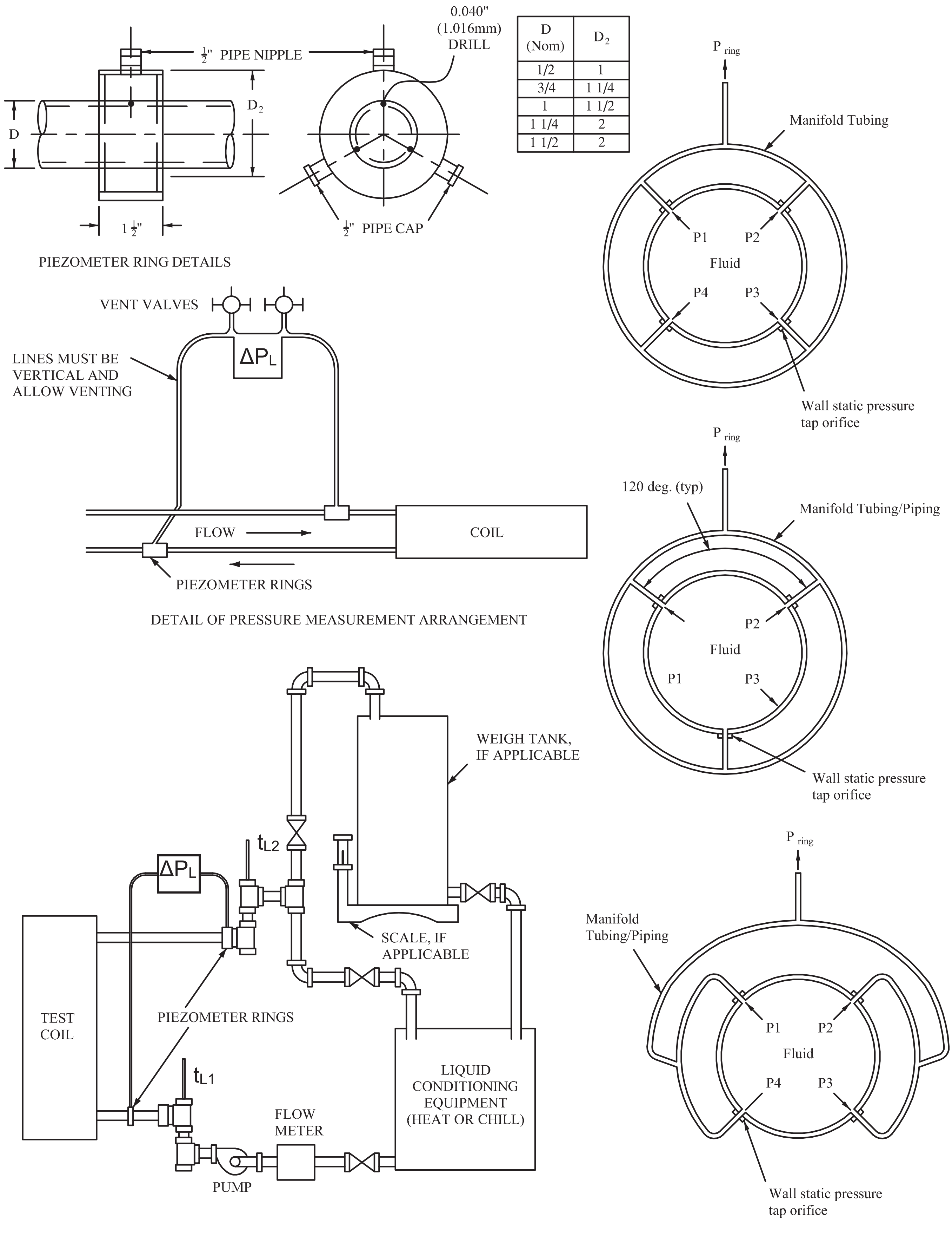
7.9.4 The pressure of the steam entering the coil (P_{v1}) shall be determined by a pressure measuring instrument located between the control valve and the coil.

7.9.5 Suitable means shall be provided for determining the steam pressure drop through a coil, from inlet to outlet (Δp_v). Both legs of the differential pressure measurement device, including the lines leading to the inlet and outlet headers, shall be maintained with a liquid column of condensate. The effect of the water legs and the differences in static head shall be considered in determining steam pressure drop through the coil. The differential pressure measurement device shall be located below the outlet.

7.9.6 The condensate flow rate (w_v) shall be determined by a liquid quantity meter as described in Section 7.6. Flashing of the condensate shall be prevented by means of a suitable heat exchanger. A condensate control valve shall be provided to regulate the condensate level. The condensate level shall be the same each time a reading is taken. The top of the insulated condensate leg shall be vented continuously during test. The vent rate shall be controlled through a specially drilled petcock as shown in Figure 7.5. Two different petcock air vent hole diameters (D_v) shall be used based on the average heating capacities. For average heating capacities less than 44 kW [150,000 Btu/h], use D_v = 0.762 mm [0.030 in.]. For average heating capacities greater than or equal to 44 kW [150,000 Btu/h], use D_v = 1.143 mm [0.045 in.]. The petcock shall be connected to the top of the condensate receiver or float trap and positioned so that only the specially drilled vent hole opening is operative during the test.

7.10 General Testing Requirements

7.10.1 Air-side humidity and conditioning apparatus (typically a steam grid humidifier) shall not cause fin surface fouling or change fin surface wettability of coils.



D (Nom)	D_2
1/2	1
3/4	1 1/4
1	1 1/2
1 1/4	2
1 1/2	2

FIGURE 7.3 Measuring apparatus for water or aqueous glycol.

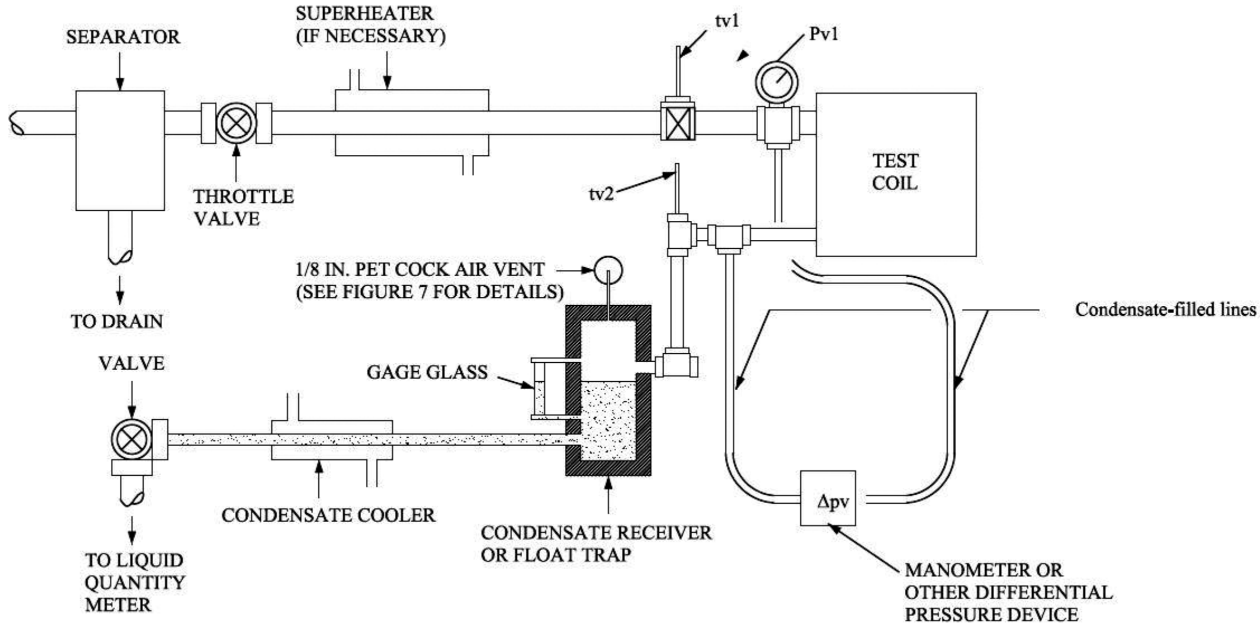


FIGURE 7.4 Measuring apparatus for determining steam properties and condensate flow.

0.030" [0.76 mm] Drill - Units ≤ 150000 Btu/h [44 kW]

0.045" [1.14 mm] Drill - Units ≥ 150000 Btu/h [44 kW]

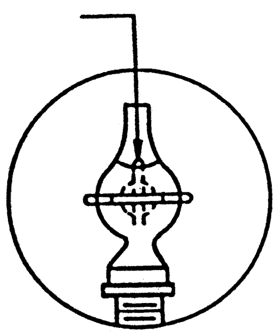


FIGURE 7.5 Detail of petcock air vent.

7.10.2 Suitable air blenders shall be provided upstream of the coil to ensure complete mixing of the air. The blenders shall not cause the air entering the coil to be turbulent.

8. METHODS OF TESTING

8.1 General

8.1.1 To fulfill the requirements of this standard, two simultaneous methods of determining coil capacity shall be used. One method shall measure the cooling or heating capacity on the air side; the other method shall measure the cooling or heating capacity on the cooling or heating medium side.

8.1.2 The capacities measured on the air side and the cooling or heating medium side shall agree within 5%.

8.2 Air-Side Determinations

8.2.1 The air-side cooling and heating effect shall be determined by means of the apparatus described in Section 7.1.

8.3 Cooling and Heating Medium-Side Determinations

8.3.1 The cooling capacity on the cooling medium side shall be determined by means of applicable apparatus described in Sections 7.2 through 7.8, inclusive.

8.3.2 The heating capacity on the heating medium side shall be determined by means of applicable apparatus described in Sections 7.6 through 7.9, inclusive.

9. TEST PROCEDURE

9.1 Air-Side Test Procedure

9.1.1 The average entering dry-bulb air temperature shall not vary by more than 0.3°C [0.5°F] from the desired value. The average entering wet-bulb air temperature for a dehumidifying coil test shall not vary by more than 0.17°C [0.3°F] from the desired value. The average airflow rate shall not vary by more than 1% of the desired value.

9.1.2 No individual entering air dry-bulb temperature reading shall vary by more than 0.6°C [1.0°F] from the average entering air dry-bulb temperature. No individual entering air wet-bulb temperature reading for a test shall vary by more than 0.3°C [0.5°F] from the average entering air wet-bulb temperature. No individual entering airflow shall vary by 2% from the average airflow rate.

9.2 Cooling Medium-Side Test Procedure, Volatile Refrigerant Evaporating Coils

9.2.1 The suction line throttling means shall be adjusted to obtain the suction pressure corresponding to the desired refrigerant temperature. A liquid control device capable of meeting the requirements of Section 9.2.2 shall be used to maintain the desired refrigerant vapor superheat. A record of the type and size of the expansion device shall be recorded.

9.2.2 The average temperature corresponding to the pressure during any test shall not deviate more than 0.3°C [0.5°F] and the maximum deviation shall not exceed 1.1°C [2.0°F] from the desired refrigerant temperature. The suction temperature shall be taken as the average of the recorded readings. In no case shall a test be acceptable if liquid refrigerant floods through at any time.

9.2.3 The subcooled refrigerant liquid temperature entering liquid control device shall be adjusted to the desired values. The average subcooled refrigerant liquid temperature entering liquid control device during any test shall not deviate more than 0.3°C [0.5°F] and the maximum deviation shall not exceed 1.1°C [2.0°F] from the desired refrigerant temperature.

9.2.4 For independent test lab consistency, lubricant circulation rate on the sample basis, as measured per ANSI/ASHRAE Standard 41.4[15] and defined as the mass flow rate of lubricant divided by the mass flow rate of the refrigerant-lubricant mixture, shall be 0.5% or less. The lubricant circulation rate on the sample basis shall be verified for the laboratory test stand for each type of refrigerant prior to the commissioning of the test stand. After commissioning of the test stand and after refrigerant changes, as applicable, the lubricant circulation rate on the sample basis shall be measured and verified.

9.3 Cooling and Heating Medium-Side Test Procedure, Water or Aqueous Glycol Solution Coils

9.3.1 The entering liquid temperature and liquid mass flow rate shall be adjusted to the desired values. The liquid temperature shall not be permitted to vary more than 0.1°C [0.2°F] from the desired temperature for cooling coils and 0.6°C [1.0°F] for heating coils, and the liquid mass flow rate shall not vary more than 1.0%.

9.4 Heating Medium-Side Test Procedure, Steam Coils

9.4.1 The pressure of the steam entering the coil shall be adjusted to the desired value. The steam pressure shall not vary more than 1.7 kPa [0.5 in. Hg] from the desired pressure. The entering steam shall be superheated at least 5.6°C [10°F], but not more than 27.7°C [50°F].

9.5 General

9.5.1 The barometric pressure (P_b) shall be recorded each time that data are sampled.

9.6 Duration of Test

9.6.1 The duration of each test shall be not less than one-half hour after thermal-hydraulic and air pressure drop equilibrium has been attained. A continual set of readings with a maximum sampling interval of 30 seconds shall be recorded during this period. The mean of these readings shall be used for the test calculations. (The number of consecutive sets of readings shall be recorded).

10. DATA TO BE RECORDED

10.1 General Data

10.1.1 The general data shall be recorded as shown on the TD form applicable to the tested fluid type (available online at http://www.ashrae.org/33-2016). An equivalent test form may be used provided it contains the information shown on the forms available online.

10.2 Coil Physical Data

10.2.1 The physical coil data, based on actual measurements of the test coil, shall be recorded as shown on the TD form applicable to the tested fluid type (available online at http://www.ashrae.org/33-2016). An equivalent test form may be used provided it contains the information shown on the forms available online.

10.3 Air-Side Test Data and Airflow Measuring Nozzle Data

10.3.1 The air-side test data and airflow measuring nozzle test data shall be recorded as shown on the TD form applicable to the tested fluid type (available online at http://www.ashrae.org/33-2016). An equivalent test form may be used provided it contains the information shown on the forms available online.

10.4 Volatile Refrigerant Evaporating Air-Cooling Coils: Refrigerant-Side Test Data, Heat Transfer Calculations, and Pressure Drop Calculations

10.4.1 The general data, physical coil data, refrigerant-side test data, heat transfer calculations, and pressure drop calculations shall be recorded as shown on Form 33TD-DX (available online at http://www.ashrae.org/33-2016). An equivalent test form may be used provided it contains the information shown on Form 33TD-DX.

10.5 Chilled-Water Air-Cooling Coils and Hot-Water Air-Heating Coils: Water-Side Test Data, Heat Transfer Calculations, and Pressure Drop Calculations

10.5.1 The general data, physical coil data, water-side test data, heat transfer calculations, and pressure drop calculations shall be recorded as shown on Form 33TD-SINGLEPHASE (available online at http://www.ashrae.org/33-2016). An equivalent test form may be used provided it contains the information shown on Form 33TD- SINGLEPHASE.

10.6 Steam Condensing Air-Heating Coils: Steam-Side Test Data, Heat Transfer Calculations, and Pressure Drop Calculations

10.6.1 The general data, physical coil data, steam-side test data, heat transfer calculations, and pressure drop calculations shall be recorded as shown on Form 33TD-STEAM (available online at http://www.ashrae.org/33-2016). An equivalent test form may be used provided it contains the information shown on Form 33TD-STEAM.

10.7 Chilled Aqueous Glycol Solution Air-Cooling Coils and Hot Aqueous Glycol Solution Air-Heating Coils: Aqueous-Glycol-Solution-Side Test Data, Heat Transfer Calculations, and Pressure Drop Calculations

10.7.1 The aqueous-glycol-solution-side test data, heat transfer calculations, and pressure drop calculations shall be recorded as shown on Form 33TD-SINGLEPHASE (available online at http://www.ashrae.org/33-2016). An equivalent test form may be used provided it contains the information shown on Form 33TD-SINGLEPHASE.

11. CALCULATIONS

11.1 Airflow Calculations

11.1.1 Calculate the dry air mass flow rate through a single nozzle by the following equation when effects due to air compressibility, thermal expansion and contraction of nozzles, and approach velocity are negligible ($\phi = 1$, $E = 1$, $\beta = 0$):

$$w_a = \frac{6.556}{10^5} C_N D_N^2 \left(\frac{\Delta p_N P_{N1}}{T_{N1db}(1 + W_{N1})(1 + W_{N1}/0.622)} \right)^{0.5}, \text{ kg dry air/s} \quad \text{(SI)}$$

$$\left[w_a = 6.888 C_N D_N^2 \left(\frac{\Delta p_N P_{N1}}{T_{N1db}(1 + W_{N1})(1 + W_{N1}/0.622)} \right)^{0.5} \right] \text{ [lb dry air/min]} \quad \text{(I-P)}$$

where Δp_N is kPa [in. of water] and P_{N1} is kPa abs [in. Hg abs].

11.1.2 Calculate the dry air mass flow rate (when dry air velocity through the nozzle throat exceeds 7000 fpm [35.6 m/s]) through a single nozzle by the following equation when effects due to air compressibility, thermal expansion and contraction of nozzles, and approach velocity are not negligible (reference *Fluid Meters: Their Theory and Application*[1]):

$$w_a = \frac{6.556}{10^5} C_N (D_N)^2 E \cdot \phi \times \left(\frac{\Delta p_N P_{N1}}{T_{N1db}(1 + W_{N1})(1 + (W_{N1}/0.622))} \right)^{0.5} \text{ kg dry air/s} \quad \text{(SI)}$$

$$\left[w_a = 6.888 C_N (D_N)^2 E \cdot \phi \times \left(\frac{\Delta p_N P_{N1}}{T_{N1db}(1 + W_{N1})(1 + (W_{N1}/0.622))} \right)^{0.5} \right] \text{ [lb dry air/min]} \quad \text{(I-P)}$$

where Δp_N is kPa [in. of water] and P_{N1} is kPa abs [in. Hg abs].

11.1.3 Where multiple nozzles are used, the total dry air mass flow rate is the sum of the individual dry air mass flow rates for each nozzle used.

11.1.4 Calculate the standard air volumetric flow rate as follows:

$$Q_{aSTD} = \frac{w_a}{1.204}, \text{ std. m}^3\text{/s} \quad \text{(SI)}$$

$$\left[Q_{aSTD} = \frac{w_a}{0.075} \right], \text{ [scfm]} \quad \text{(I-P)}$$

11.1.5 Calculate the standard air face velocity as follows:

$$V_a = \frac{w_a}{1.204 A_f}, \text{ std. m/s} \quad \text{(SI)}$$

$$\left[V_a = \frac{w_a}{0.075 A_f} \right], \text{ [std. ft/min]} \quad \text{(I-P)}$$

11.2 Heat Leakage Calculations

11.2.1 The heat leakage constants for the intake (K_{31}) and mixing (K_{24}) chambers are calculated from the product of the exposed area of the chamber and the heat transmission coefficient corresponding to the insulation used. Heat leakage shall be measured or calculated and correction of the coil capacity shall be made accordingly.

11.2.2 To correct for the effects of air duct heat leakage, entering and leaving air conditions at the coil, upon which thermal performance shall be based, are calculated as follows:

11.2.2.1 For cooling and dehumidifying coils only:

a. Entering air enthalpy at coil:

$$h_1 = h_3 + \frac{K_{31}(t_{5db} - t_{3db})}{w_a}, \text{ kJ/kg} \quad \text{(SI)}$$

$$\left[h_1 = h_3 + \frac{K_{31}(t_{5db} - t_{3db})}{60 w_a} \right], \text{ [Btu/lb]} \quad \text{(I-P)}$$

b. Leaving air enthalpy at coil:

$$h_2 = h_4 - \frac{K_{24}(t_{5db} - t_{4db})}{w_a}, \text{ kJ/kg} \quad \text{(SI)}$$

$$\left[h_2 = h_4 - \frac{K_{24}(t_{5db} - t_{4db})}{60 w_a} \right], \text{ [Btu/lb]} \quad \text{(I-P)}$$

11.2.2.2 For all cooling and heating coils:

a. Entering air dry-bulb temperature at coil:

$$t_{1db} = t_{3db} + \frac{K_{31}(t_{5db} - t_{3db})}{w_a c_p}, \text{ °C} \quad \text{(SI)}$$

$$\left[t_{1db} = t_{3db} + \frac{K_{31}(t_{5db} - t_{3db})}{60 w_a c_p} \right], \text{ [°F]} \quad \text{(I-P)}$$

b. Leaving air dry-bulb temperature at coil:

$$t_{2db} = t_{4db} - \frac{K_{24}(t_{5db} - t_{4db})}{w_a c_p}, \text{ °C} \quad \text{(SI)}$$

$$\left[t_{2db} = t_{4db} - \frac{K_{24}(t_{5db} - t_{4db})}{60 w_a c_p} \right], \text{ [°F]} \quad \text{(I-P)}$$

11.2.3 If the total heat leakage is less than 1% of the coil test capacity, no correction is necessary.

11.3 Air-Side Cooling Capacity Calculations

11.3.1 Calculate the air-side total cooling capacity as follows:

$$q_{ta} = w_a ((h_1 - h_2) - \Delta W c_{pw} \cdot t_{4wb}), \text{ kW} \quad \text{(SI)}$$

$$[q_{ta} = 60 w_a ((h_1 - h_2) - \Delta W c_{pw}(t_{4wb} - 32))], \text{ [Btu/h]} \quad \text{(I-P)}$$

Correct the enthalpy of the air-water vapor mixture for the barometric pressure and wet-bulb depression. The condensate specific heat at constant pressure should be evaluated at the leaving air wet-bulb temperature.

11.3.2 Calculate the air-side sensible cooling capacity as follows:

$$q_{sa} = w_a c_p (t_{1db} - t_{2db}), \text{ kW} \quad \text{(SI)}$$

$$[q_{sa} = 60 w_a c_p (t_{1db} - t_{2db})], \text{ [Btu/h]} \quad \text{(I-P)}$$

where

$$c_p = 1.005 + 1.859 W_2, \text{ kJ/(kg dry air·°C)} \quad \text{(SI)}$$

$$[c_p = 0.240 + 0.444 W_2], \text{ [Btu/(lb dry air·°F)]} \quad \text{(I-P)}$$

For simplification, a value of c_p = 1.017 [0.243] may be used and

$$q_{sa} = 1.017 w_a (t_{1db} - t_{2db}), \text{ kW} \quad \text{(SI)}$$

$$[q_{sa} = 60 \cdot 0.243 \cdot w_a (t_{1db} - t_{2db})], \text{ [Btu/h]} \quad \text{(I-P)}$$

11.4 Air-Side Heating Capacity Calculations

11.4.1 Calculate the air-side heating capacity as follows:

$$q_{sa} = w_a c_p (t_{2db} - t_{1db}), \text{ kW} \quad \text{(SI)}$$

$$[q_{sa} = 60 w_a c_p (t_{2db} - t_{1db})], \text{ [Btu/h]} \quad \text{(I-P)}$$

For simplification, a value of c_p = 1.009 [0.241] may be used and

$$q_{sa} = 1.009 w_a (t_{2db} - t_{1db}), \text{ kW} \quad \text{(SI)}$$

$$[q_{sa} = 60 \cdot 0.241 \cdot w_a (t_{2db} - t_{1db})], \text{ [Btu/h]} \quad \text{(I-P)}$$

11.5 Volatile Refrigerant Flow Calculations

11.5.1 Calculate volatile refrigerant mass flow rates, kg/s [lbm/h], as follows:

a. Liquid flowmeter: Determine w_r from the flowmeter calibration chart supplied by the flowmeter manufacturer.
b. Condenser water method:

$$w_r = \frac{w_w c_{pw}(t_{w2} - t_{w1}) + q_c}{h_{c1} - h_{c2}}$$

Evaluate the condenser water specific heat at constant pressure and temperature at $0.5(t_{w1} + t_{w2})$. For simplification, a constant value of c_{pw} = 4.187 [1.000] may be used.

c. Calibrated compressor method:

$$w_r = \frac{q_c}{h_{C2} - h_{C1}}$$

11.5.2 Calculate the heat loss from the condenser to surrounding air, kW [Btu/h], as follows:

$$q_c = K_c(t_{c1g} - t_{adb})$$

11.5.3 Calculate the heat leakage constant (K_c) for the condenser from the transmission coefficient of the insulation used and the log mean of the areas inside and outside the insulation.

11.6 Water, Aqueous Glycol Solution, and Steam Condensate Flow Calculations

11.6.1 Calculate water, aqueous glycol solution, and steam condensate mass flow rates as follows:

Liquid quantity meter:

a. Water and aqueous glycol solution:

$$w_w = M_w / Z_w = \rho_w V_w / Z_w, \text{ kg/s} \quad \text{(SI)}$$

$$[w_w = 60 M_w / Z_w = 60 \rho_w V_w / Z_w], \text{ [lb/h]} \quad \text{(I-P)}$$

b. Steam condensate:

$$w_v = M_v / Z_v = \rho_v V_v / Z_v, \text{ kg/s} \quad \text{(SI)}$$

$$[w_v = 60 M_v / Z_v = 60 \rho_v V_v / Z_v], \text{ [lb/h]} \quad \text{(I-P)}$$

depending on whether mass or volume is measured.

An alternative to this fluid flow rate calculation method is that fluid flow rates may be read directly from the applicable flowmeter calibration chart supplied by the flowmeter manufacturer.

11.6.2 Calculate standard water and standard aqueous glycol solution volumetric flow rates as follows:

$$Q_{lSTD} = \frac{w_l}{998.927}, \text{ std. m}^3\text{/s} \quad \text{(SI)}$$

$$\left[Q_{lSTD} = \frac{w_l}{500.187}\right], \text{ [sgpm]} \quad \text{(I-P)}$$

11.7 Tube-Side Cooling Capacity Calculations

11.7.1 Calculate tube-side cooling capacity, kW [Btu/h], as follows:

a. Volatile refrigerant evaporating coils:

$$q_{tz} = w_r (h_{r2} - h_{r1})$$

For all practical purposes, $h_{r1} = h_{r0}$, where h_{r0} is the refrigerant liquid enthalpy that corresponds to the refrigerant liquid temperature (t_{r0}) entering the refrigerant liquid control device.

b. Water coils and aqueous glycol solution coils:

$$q_{tz} = w_l (h_{l2} - h_{l1})$$

For simplification, the following formula may be used:

$$q_{tz} = w_l c_{pl} (t_{l2} - t_{l1})$$

Evaluate the specific heat of the chilled water at constant pressure and temperature at $0.5(t_{l1} + t_{l2})$. For simplification, a constant value of c_{pl} = 4.187 [1.000] may be used.

Use the following formula when enthalpy is not available for aqueous glycol solution coils:

$$q_{tz} = w_l[c_{pl}(t_{l2} - t_{l1}) + \upsilon(P_{l2} - P_{l1})]$$

Evaluate the specific heat of the chilled glycol solution at constant pressure and temperature at $0.5(t_{l1} + t_{l2})$.

Evaluate the specific volume of the chilled glycol solution at $T_{lm} = 0.5(t_{l1} + t_{l2})$ and $P_{lm} = 0.5(P_{l1} + P_{l2})$.

11.8 Tube-Side Heating Capacity Calculations

11.8.1 Calculate the tube-side heating capacity, kW [Btu/h], as follows:

a. Water coils and aqueous glycol solution coils:

$$q_{sz} = w_l (h_{l1} - h_{l2})$$

For simplification, the following formula may be used:

$$q_{sz} = w_l c_{pl} (t_{l1} - t_{l2})$$

Evaluate the specific heat of the hot water at constant pressure and temperature at $0.5(t_{l1} + t_{l2})$. For simplification, a constant value of $c_{lw} = 4.187$ [1.000] may be used.

Evaluate the specific heat of the hot glycol solution at constant pressure and temperature at $0.5(t_{l1} + t_{l2})$.

Use the following formula when enthalpy is not available for aqueous glycol solution coils:

$$q_{sz} = w_l [c_{pl} (t_{l1} - t_{l2}) + \nu(P_{l1} - P_{l2})]$$

Evaluate the specific heat of the hot glycol solution at constant pressure and temperature at $0.5(t_{l1} + t_{l2})$.

Evaluate the specific volume (ν) of the hot glycol solution at $T_{lm} = 0.5(t_{l1} + t_{l2})$ and $P_{lm} = 0.5(P_{l1} + P_{l2})$.

b. Steam coils:

$$q_{sz} = w_v (h_{v1} - h_{v2})$$

11.9 Average Capacities and Heat Balance Calculations

11.9.1 For cooling and dehumidifying coils, find the average capacity, kW [Btu/h], as follows:

$$q_t = 0.5(q_{ta} + q_{tz})$$

where the heat balance between fluids for any test shall fall within the following limits, as specified in Section 8.1.2:

$$+5\% \geq \frac{100(q_{ta} - q_{tz})}{q_t} \geq -5\%$$

$$q_s = q_t \left(\frac{q_{sa}}{q_{ta}}\right).$$

11.9.2 For sensible cooling or heating coils, find the average capacity, kW [Btu/h], as follows:

$$q_s = 0.5(q_{sa} + q_{sz})$$

where the heat balance fluids for any test shall fall within the following limits, as specified in Section 8.1.2:

$$+5\% \geq \frac{100(q_{sa} - q_{sz})}{q_s} \geq -5\%$$

11.10 Pressure Drop Calculations

11.10.1 Calculate the air pressure drop, at standard conditions, for volatile refrigerant evaporating air cooling coils, chilled-water air cooling coils, hot-water air heating coils, chilled aqueous glycol solution air cooling coils, and hot aqueous glycol solution air heating coils as follows:

$$\Delta p_{st} = \frac{\rho_m \Delta p_a}{1.204}\text{, kPa gage} \qquad \text{(SI)}$$

$$\left[\Delta p_{st} = \frac{\rho_m \Delta p_a}{0.075}\right]\text{, [in. water gage]} \qquad \text{(I-P)}$$

where the average air-water vapor mixture density (ρ_m) is evaluated at the average air absolute static pressure at coil (P_s), average air humidity ratio (W_m), and average air dry-bulb temperature (t_{mdb}).

11.10.2 Calculate the air pressure drop at standard conditions for steam condensing air heating coils as follows:

$$\Delta p_{st} = \frac{\rho_4 \Delta p_a}{1.204}\text{, kPa gage} \qquad \text{(SI)}$$

$$\left[\Delta p_{st} = \frac{\rho_4 \Delta p_a}{0.075}\right]\text{, [in. water gage]} \qquad \text{(I-P)}$$

where the air-water vapor mixture density leaving the mixing chamber (ρ_4) is evaluated at the average air absolute static pressure at coil (P_s), air humidity ratio entering coil (W_1), and air dry-bulb temperature leaving the mixing chamber (t_{4db}).

11.10.3 Calculate the head loss through the coil at average water density for water and aqueous glycol solution coils as follows:

$$\frac{101.935 \Delta p_l}{(\rho_{lm})}\text{, m of fluid} \qquad \text{(SI)}$$

$$\left[\frac{144 \Delta p_l}{(\rho_{lm})}\right]\text{, [ft of fluid]} \qquad \text{(I-P)}$$

Evaluate the density of the aqueous glycol solution at $t_{lm} = 0.5(t_{l1} + t_{l2})$ and $P_{lm} = 0.5(P_{l1} + P_{l2})$.

12. REFERENCE PROPERTIES AND DATA

12.1 Thermodynamic Properties of Air

12.1.1 The thermodynamic properties of air-water vapor mixtures shall be obtained from the latest edition of *ASHRAE Handbook—Fundamentals*.[12]

12.2 Thermodynamic and Thermophysical Properties of Water, Steam, and Aqueous Glycol Solutions

12.2.1 The thermodynamic properties of water and steam shall be obtained from the latest edition of *Steam Tables: Thermodynamic Properties of Water Including Vapor, Liquid, and Steam*.[16,17] The thermophysical properties of water shall be obtained from the latest edition of *ASHRAE Handbook—Fundamentals*.[12]

12.2.2 The thermodynamic and thermophysical properties of aqueous glycol solution shall be obtained from NIST Reference Fluid Thermodynamic and Transport Properties Database (REFPROP)[18] or the glycol's manufacturer.

12.3 Thermodynamic Properties of Volatile Refrigerants

12.3.1 The thermodynamic properties of volatile refrigerants shall be obtained from the latest edition of *ASHRAE Handbook—Fundamentals*,[12] NIST REFPROP,[18] or the refrigerant manufacturer.

12.4 Heat Transmission Coefficients

12.4.1 The heat transmission coefficients for various insulating materials shall be obtained from the latest edition of *ASHRAE Handbook—Fundamentals*[12] or the material manufacturer.

13. NORMATIVE REFERENCES

1. *Fluid Meters: Their Theory and Application*, 6th ed., American Society of Mechanical Engineers, 1971.
2. ASHRAE Standard 41.2-1987 (RA 92), *Standard Methods for Laboratory Airflow Measurement.*
3. ANSI/ASHRAE Standard 41.1-2013, *Standard Method for Temperature Measurement.*
4. ANSI/ASHRAE Standard 41.6-2014, *Standard Methods for Humidity Measurement.*
5. ANSI/ASHRAE Standard 41.3-2014, *Standard Method for Pressure Measurement.*
6. ANSI/ASHRAE Standard 41.10-2013, *Standard Methods for Refrigerant Mass Flow Measurement Using Flowmeters.*
7. ASHRAE Standard 41.8-1989, *Standard Methods of Measurements of Flow of Liquids in Pipes Using Orifice Flowmeters.*
8. ISA-RP31.1-1977 *Specification, Installation, and Calibration of Turbine Flowmeters*, International Society of Automation.
9. ASME MFC-11-2006, *Measurement of Fluid Flow by Means of Coriolis Mass Flowmeters*, American Society of Mechanical Engineers.
10. ANSI/ASHRAE Standard 51-2007 (AMCA 210-07), *Laboratory Methods of Testing Fans for Certified Aerodynamic Performance Rating.*
11. ANSI/ASHRAE Standard 41.9-2011, *Standard Methods For Volatile-Refrigerant Mass Flow Measurements Using Calorimeters.*
12. 2013 *ASHRAE Handbook—Fundamentals.*
13. ANSI/ASHRAE Standard 23.1-2010, *Methods of Testing for Performance Rating Positive Displacement Refrigerant Compressors and Condensing Units That Operate at Subcritical Temperatures of the Refrigerant*.
14. ANSI/ASHRAE Standard 23.2-2014, *Methods of Testing for Performance Rating Positive Displacement Refrigerant Compressors and Condensing Units That Operate at Supercritical Temperatures of the Refrigerant*.
15. ANSI/ASHRAE Standard 41.4-2015, *Standard Methods for Proportion of Lubricant in Liquid Refrigerant Measurement.*
16. *Steam Tables: Thermodynamic Properties of Water Including Vapor, Liquid, and Solid Phases*, J.H. Keenan, F.G. Keyes, P.G. Hill, and J.G. Moore, John Wiley & Sons, Inc., 1978 SI version (Reprint Edition 1992).
17. *Steam Tables: Thermodynamic Properties of Water Including Vapor, Liquid, and Solid Phases*, J.H. Keenan, F.G. Keyes, P.G. Hill, and J.G. Moore, John Wiley & Sons, Inc., 1969 I-P version.
18. NIST Reference Fluid Thermodynamic and Transport Properties Database (REFPROP), http://www.nist.gov/srd/nist23.cfm.
19. ANSI/AHRI Standard 550/590-2015, *Performance Rating of Water-chilling and Heat Pump Water-heating Packages Using the Vapor Compression Cycle*.

14. INFORMATIVE REFERENCES

Blake, K.A., “The design of piezometer rings,” *Journal of Fluid Mechanics* 78(2):415–28, 1976.

ANSI/AHRI Standard 410-2001 with Addenda 1, 2 and 3: *Method of rating forced air cooling and heating coils.*

2012 *ASHRAE Handbook—HVAC Systems and Equipment*, Chapter 27, Heating Coils.

2012 *ASHRAE Handbook—HVAC Systems and Equipment*, Chapter 23, Cooling Coils.

Crane Technical Paper No. 410.

(This is a normative annex and is part of the standard.)

NORMATIVE ANNEX A
TEST DATA (TD) FORMS

General and test data shall be recorded as shown on the Test Data (TD) form applicable to the tested fluid type. An equivalent test form may be used provided it contains the information shown on the forms in Normative Annex A.

The TD forms available online at http://www.ashrae.org/33-2016 as part of this standard include the following:

- TD-33 DX (I-P).xlsx = TD form for direct expansion (DX) coils in I-P units
- TD-33 DX (SI).xlsx = TD form for direct expansion (DX) coils in SI units
- TD-33 Single Phase (I-P).xlsx = TD form for single-phase fluids coils in I-P units
- TD-33 Single Phase (SI).xlsx = TD form for single-phase fluids coils in SI units
- TD-33 Steam (I-P).xlsx = TD form for steam coils in I-P units
- TD-33 Steam (SI).xlsx = TD form for steam coils in SI units

(This is a normative annex and is part of the standard.)

NORMATIVE ANNEX B
WATER-SIDE PRESSURE DROP
MEASUREMENT PROCEDURE

B1. PURPOSE

The purpose of this annex is to prescribe a measurement method for water pressure drop and a correction method to compensate for friction losses associated with external piping measurement sections. The measurement method only applies to pipe of circular cross section.

B2. BACKGROUND

As a certified test point for air-to-refrigerant heat exchangers, the water-side pressure drop needs to be determined by test with acceptable measurement uncertainty. The measured pressure drop per this standard will be determined by using static pressure taps external to the unit in upstream and downstream piping. When using external piping, adjustment factors are allowed to compensate the reported pressure drop measurement. Numerous studies conclude that the determination of a calculated correction term for these external components may contain significant sources of error; therefore, the use of external correction factors is restricted to limit the magnitude of these potential errors. For units with small connection sizes, it is feasible that straight pipe sections be directly connected to the units with adequate length to obtain static pressure measurements with acceptable systematic errors due to instrument installation location.

B3. MEASUREMENT LOCATIONS

Static pressure taps shall simultaneously meet all of the following requirements:

B3.1 Static pressure taps may be in either the unit connections (i.e., nozzles) or in additional external piping provided for the purpose of test measurements.

B3.2 If using additional external piping, the piping arrangement shall use rigid pipe and may include fittings such as elbows, reducers, or enlargers between the pressure tap locations and the unit connections. Flexible hose is prohibited between the unit connections and the pressure taps.

B3.3 Single-phase liquid pressure measurements shall be constructed in accordance with the following requirements:

a. The single-phase liquid pressure measurement apparatus shall be constructed in accordance with the length requirements outlined in Table B1.
b. Construct the single-phase liquid pressure measurement apparatus using a material suitable for the rated pressure of the coil being tested. Ends shall be threaded or have flanges. An example table for Schedule 40 Stainless Steel Piping can be found in Table B2.

B4. STATIC PRESSURE TAPS

Static pressure taps shall be in a piezometer ring or piezometer manifold arrangement with a minimum of 3 taps located circumferentially around the pipe, all taps at equal angle spacing. To avoid introducing measurement errors from recirculating flow within the piezometer ring, each of the pipe tap holes shall have a flow resistance that is greater than or equal to 5 times the flow resistance of the piezometer ring piping connections between any pair of pressure taps. A “triple-tee” manifold arrangement using 4 pipe tap holes is the preferred arrangement but is not required if the manifold being used meets the flow resistance requirement described above.

B4.1 For design or evaluation purposes, flow resistance may be estimated by resistance coefficient K-factor calculation methods as found in Crane Technical Paper No. 410. Generally, manifold tubing or piping can be evaluated using the K-factor, and pressure tap holes can be evaluated using orifice flow equations.

B4.2 For more information about the design of piezometer rings, see the article by Blake listed in the Informative References.

B4.3 Provisions shall be made to bleed air out of the lines connected to pressure measurement devices. These provisions shall take into consideration the orientation of pressure taps and manifold connections.

B5. CORRECTION METHOD

Measured water pressure drop values shall be adjusted to subtract additional static pressure drop due to external piping. The additional static pressure drop shall be the sum of all losses between the unit connections and the location of static pressure taps. Record the original measured value, the calculated adjustment value, and the final calculated result for water pressure drop.

B5.1 The adjustment shall not exceed 10% of the measured water pressure drop.

B5.2 The general form of the adjustment equations uses the methods in Crane Technical Paper No. 410. A Darcy friction factor is determined using the Swamee-Jain Equation:

$$f = 0.25/[\log_{10}[\in/3.7\cdot D + 5.74/\mathrm{Re}^{0.9}]]^2$$

where

$\in$ = absolute roughness, 0.04575 mm [0.00015 ft] (for purposes of this standard)

D = internal pipe diameter, mm [ft]

Re = Reynolds number for the flow in the pipe

The pressure drop (h_L) associated with a flow component or fitting may be calculated using the friction factor as detailed above or the equation may use a K-factor. These are shown in the following equation:

$$h_L = f\cdot(L/D)\cdot V^2/2g$$

when the Darcy friction factor is used for straight pipe sections, where

L = pipe length, m [ft]

D = internal diameter, mm [ft]

V = average velocity calculated at the entrance to the component, m/s [ft/s]

g = standard gravitational term, 9.81m/s^2 [32.174 ft/s^2]

TABLE B1 Straight Length in Flow Path

Unit Connection, Nominal Pipe Size	Straight Length in Flow Path	
	Upstream of Pressure Tap	Downstream of Pressure Tap
≤75 mm [≤3 in.]	Minimum 10 · D_i	Minimum 3 · D_i
100, 125, or 150 mm [4, 5, or 6 in.]	Minimum 6 · D_i	Minimum 2 · D_i
≥200 mm [≥8 in.]	Minimum 3 · D_i	Minimum 1 · D_i

Notes:
1. Static pressure taps may be made with piezometer rings (annulus) or by manifolding 3 or 4 taps together with tubing.
2. Static pressure tap construction (annulus, braze joints, tubing, etc.), shall be strong enough to withstand 1.5 times maximum tube-side single-phase liquid pressure without leaking.
3. The upstream and downstream distances from the pressure tap shall be no less than 150 mm [6 in.].

TABLE B2 Example Single-Phase Liquid Pressure Measurement Apparatus Sizing for Schedule 40 Stainless Steel Piping

Nominal Pipe Size (NPS), in.	Schedule Number	Pipe Outside Diameter, D_o, in.	Wall Thickness, t_w, in.	Pipe Inside Diameter, D_i, in.	Minimum Length Upstream of Pressure Tap, in.	Minimum Length Downstream of Pressure Tap, in.	Minimum Total Length Single-Phase Liquid Pressure Measurement Apparatus, in.
0.25	40S	0.54	0.09	0.36	6.00	6.00	12.00
0.375	40S	0.68	0.09	0.49	6.00	6.00	12.00
0.50	40S	0.84	0.11	0.62	6.22	6.00	12.22
0.75	40S	1.05	0.11	0.82	8.24	6.00	14.24
1.00	40S	1.32	0.13	1.05	10.49	6.00	16.49
1.25	40S	1.66	0.14	1.38	13.80	6.00	19.80
1.50	40S	1.90	0.15	1.61	16.10	6.00	22.10
2.00	40S	2.38	0.15	2.07	20.67	6.20	26.87
2.50	40S	2.88	0.20	2.47	24.69	7.41	32.10
3.00	40S	3.50	0.22	3.07	30.68	9.20	39.88
3.50	40S	4.00	0.23	3.54	35.40	10.62	46.02

B5.3 A Microsoft Excel® spreadsheet is available as part of ANSI/AHRI Standard 550/590[19] for computation of the pressure drop adjustment factors.

B6. PRESSURE MEASUREMENT PIPE CALIBRATION

The pressure measurement pipes shall be calibrated by conducting the following test and comparing the measurements to calculated adjustment values.

B6.1 Connect the entering coil pressure measurement pipe exit (minimum straight length downstream of taps = 3·D_i or 150 mm [6 in.], whichever is greater) to the leaving coil pressure measurement pipe entrance (minimum straight length upstream of taps = 10·D_i or 150 mm [6 in.], whichever is greater). The coupling shall have the same nominal pipe size as the pressure measurement pipes. Connect the pipes to a single-phase liquid flow source.

B6.2 The instrumentation for the test shall consist of the following:

a. Single-phase liquid temperature entering the coil pressure measurement pipe, °C [°F]
b. Single-phase liquid absolute pressure entering the coil pressure measurement pipe, kPa [psi]
c. Single-phase liquid temperature leaving the coil pressure measurement pipe, °C [°F]
d. Single-phase liquid pressure drop through entering coil and leaving coil pressure measurement pipes, kPa [psi]
e. Single-phase liquid mass flow rate, kg/s [lbm/h]

B6.3 Data to be recorded for each test run are as follows:

a. Pressure measurement pipe inside diameter, mm [in.]
b. Entering coil pressure measurement pipe straight length downstream of pressure taps, mm [in.]
c. Leaving coil pressure measurement pipe straight length upstream of pressure taps, mm [in.]
d. Pressure measurement pipe material
e. Single-phase liquid type (water, aqueous solution, etc.)

f. Aqueous solution composition by mass, % (if not water)
g. Single-phase liquid temperature entering the coil pressure measurement pipe, °C [°F]
h. Single-phase liquid absolute pressure entering the coil pressure measurement pipe, kPa [psi]
i. Single-phase liquid temperature leaving the coil pressure measurement pipe, °C [°F]
j. Single-phase liquid pressure drop through entering coil and leaving coil pressure measurement pipes, kPa [psi]
k. Single-phase liquid mass flow rate, kg/s [lbm/h]

B6.4 Conduct the single-phase liquid pressure drop test with at least four different single-phase liquid velocities inside the pressure measurement pipe covering the range of 0.3 to 4.3 m/s [1 to 14 ft/s] in approximately equally spaced velocity increments on a logarithmic scale.

B6.5 Record the test data continuously for at least 10 rounds after steady-state condition has been achieved. Average the rounds to determine each run's test values.

B6.6 Use the following input data and the ANSI/AHRI Standard 550/590[19] Excel spreadsheet to calculate the single-phase liquid pressure drop through entering coil and leaving coil pressure measurement pipes at the test input conditions.

a. Pressure measurement pipe inside diameter, mm [in.]
b. Entering coil pressure measurement pipe straight length downstream of pressure taps, mm [in.]
c. Leaving coil pressure measurement pipe straight length upstream of pressure taps, mm [in.]
d. Pressure measurement pipe material
e. $\in$ = pressure measurement pipe absolute roughness; start with 0.04575 mm [0.00015 ft]
f. Single-phase liquid type (water, aqueous solution, etc.)
g. Aqueous solution composition by mass, % (if not water)
h. Single-phase liquid temperature entering the coil pressure measurement pipe, °C [°F]
i. Single-phase liquid absolute pressure entering the coil pressure measurement pipe, kPa [psi]
j. Single-phase liquid temperature leaving the coil pressure measurement pipe, °C [°F]
k. Single-phase liquid mass flow rate, kg/s [lbm/h]

B6.7 The measurement shall not exceed the calculated adjustment by more than 10%, otherwise additional corrections shall be applied and noted.

B6.8 If the pressure measurement pipes are made from a noncorroding material and the single-phase liquid under test has "soft" water, the pipe's absolute roughness should not change as a function of time.

B6.9 The laboratory shall conduct an annual calibration of the pressure measurement pipes.

(This is a normative annex and is part of the standard.)

NORMATIVE ANNEX C
METHOD OF VERIFICATION FOR TEST STAND VELOCITY AND TEMPERATURE UNIFORMITY

C1. PURPOSE

The purpose of this annex is to provide a method for verifying a test stand's velocity and temperature uniformity. The velocity and temperature uniformity verifications shall be performed prior to initial use and at least annually thereafter, with corrective action taken if necessary. If any modifications are made to the test stand which may affect velocity or temperature uniformity, the verifications shall be re-performed.

C2. UNIFORM FACE VELOCITY

C2.1 The highest face velocity shall not exceed the lowest face velocity by more than 20%.

C2.1.1 Laboratories shall run their periodic verifications using two coils. One coil shall have the smallest coil face height (*H*) and/or coil face length (*L*) that may be tested and one coil shall have the largest coil face height (*H*) and/or coil face length (*L*) that may be tested.

Exception: If the variation between the smallest coil face height (*H*) and/or coil face length (*L*) that may be tested and the largest coil face height (*H*) and/or coil face length (*L*) that may be tested is less than 15%, the laboratory may choose to test only one coil for the verification.

C2.2 Procedure for Measuring Face Velocity. Any of the following instruments may be used:

a. Pitot tube
b. Vane anemometer with a diameter of no more than 25 mm [1 in.]
c. Hot wire anemometer
d. A permanent grid of hot wire anemometers that meet the requirements of Section C1.2.3.

C2.2.1 The coil fins shall be dry when the air velocity is measured.

C2.2.2 The velocities shall be measured in a grid with the distance between measurements to be no less than *L*/6, *H*/6, or at least every 150 mm [6 in.], whichever is the greater distance.

C2.2.2.1 The velocities shall be measured in a plane at least 225 mm [9 in.] upstream of the coil and no more than 450 mm [18 in.] upstream of the coil.

C2.2.2.2 The velocities shall be measured at least 50 mm [2 in.] away from duct walls.

C2.2.3 Laboratories shall run their periodic verifications using the minimum and maximum velocities that may be tested. (For example, if a laboratory only tests from 2 to 4 m/s [400 to 800 fpm], the verifications would be performed at 2 and 4 m/s [400 and 800 fpm].)

C2.2.4 The air pressure drop of the coil(s) used for the verification shall not exceed 50 Pa [0.2 in. w.c.] at 2.5 m/s [500 fpm].

C3. UNIFORM TEMPERATURE

The entering dry-bulb temperature shall not vary by more than 0.6°C [1°F] across the face of the coil.

C3.1 Measurement during the verification. The dry-bulb entering air temperatures shall be measured in a grid with horizontal and vertical spacing no less than *L*/6, *H*/6, or at least every 150 mm [6 in.], whichever is the greater distance.

C3.1.1 The temperatures shall be measured at least 225 mm [9 in.] upstream of the coil and no more than 450 mm [18 in.] upstream of the coil.

C3.1.2 The temperatures shall be measured at least 50 mm [2 in.] from the duct walls.

C3.1.3 Each point shall be individually measured and recorded.

POLICY STATEMENT DEFINING ASHRAE'S CONCERN FOR THE ENVIRONMENTAL IMPACT OF ITS ACTIVITIES

ASHRAE is concerned with the impact of its members' activities on both the indoor and outdoor environment. ASHRAE's members will strive to minimize any possible deleterious effect on the indoor and outdoor environment of the systems and components in their responsibility while maximizing the beneficial effects these systems provide, consistent with accepted Standards and the practical state of the art.

ASHRAE's short-range goal is to ensure that the systems and components within its scope do not impact the indoor and outdoor environment to a greater extent than specified by the Standards and Guidelines as established by itself and other responsible bodies.

As an ongoing goal, ASHRAE will, through its Standards Committee and extensive Technical Committee structure, continue to generate up-to-date Standards and Guidelines where appropriate and adopt, recommend, and promote those new and revised Standards developed by other responsible organizations.

Through its *Handbook*, appropriate chapters will contain up-to-date Standards and design considerations as the material is systematically revised.

ASHRAE will take the lead with respect to dissemination of environmental information of its primary interest and will seek out and disseminate information from other responsible organizations that is pertinent, as guides to updating Standards and Guidelines.

The effects of the design and selection of equipment and systems will be considered within the scope of the system's intended use and expected misuse. The disposal of hazardous materials, if any, will also be considered.

ASHRAE's primary concern for environmental impact will be at the site where equipment within ASHRAE's scope operates. However, energy source selection and the possible environmental impact due to the energy source and energy transportation will be considered where possible. Recommendations concerning energy source selection should be made by its members.

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About ASHRAE

ASHRAE, founded in 1894, is a global society advancing human well-being through sustainable technology for the built environment. The Society and its members focus on building systems, energy efficiency, indoor air quality, refrigeration, and sustainability. Through research, Standards writing, publishing, certification and continuing education, ASHRAE shapes tomorrow's built environment today.

For more information or to become a member of ASHRAE, visit www.ashrae.org.

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