BSR/ASHRAE Standard 64-2011R

Public Review Draft

Methods of Laboratory Testing Remote Mechanical-Draft Evaporative Refrigerant Condensers

First Public Review (August 2019)
(Complete Draft for Full Review)

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ASHRAE, 1791 Tullie Circle, NE, Atlanta GA 30329-2305

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(This foreword is not a part of this standard. It is merely informative and does not contain requirements necessary for conformance to the standard. It has not been processed according to the ANSI requirements for a standard and may contain material that has not been subject to public review or a consensus process.)

FOREWORD

This revision updates the 2011 edition of the standard. Technical revisions have been incorporated as appropriate. Additional revisions have been implemented to bring this standard into compliance with ASHRAE's mandatory language requirements. References have been updated.

1. PURPOSE

This standard prescribes methods of laboratory testing remote mechanical-draft evaporative refrigerant condensers.

2. SCOPE

2.1 This standard provides a method of laboratory testing for obtaining performance data of remote mechanical-draft evaporative refrigerant condensers, including:

a. definition of terms,
b. specification of data to be recorded,
c. calculation formulas,
d. test limits and tolerances, and
e. apparatus and instrumentation with associated accuracies.

2.2 This standard does not cover the following:

a. methods of test for production or field use,
b. heat exchangers that do not fully condense refrigerant vapor, as in heat reclaim applications,
c. methods for rating condensers, nor
d. the performance impact of external air resistance devices not provided by the manufacturer.
e. thermal performance corrections for barometric pressure, fan horsepower, and makeup water.

3. DEFINITIONS

The following key terms are defined in this section. For all other terms, refer to *ASHRAE Terminology of Heating, Ventilation, Air Conditioning and Refrigeration*.[1]

Bubble point: a liquid-vapor equilibrium point for a volatile pure liquid or for a multicomponent mixture of miscible, volatile, pure component liquids, in the absence of noncondensables, where the temperature of the mixture at a defined pressure is the minimum temperature required for a vapor bubble to form in the liquid.

Condenser approach: see Temperature difference.

Condenser subcooling: the difference between the bubble point corresponding to the measured refrigerant outlet pressure and the measured liquid outlet temperature.

Condenser superheat: the difference between the dew point temperature and the measured refrigerant vapor temperature at the inlet.

Condensing temperature: for single component and azeotropic refrigerants, the saturation temperature corresponding to the measured refrigerant pressure at the condenser inlet. For zeotropic refrigerants, the arithmetic average of the dew point and bubble point corresponding to the measured refrigerant pressure at the condenser inlet.

Dew point: a liquid-vapor equilibrium point for a volatile pure vapor or for a multicomponent mixture of miscible, volatile, pure component vapors, in the absence of noncondensables, where the temperature of the mixture at a defined pressure is the maximum temperature required for a liquid droplet to form in the vapor.

Remote mechanical-draft evaporative refrigerant condenser (evaporative condenser): a factory-made encased unit intended for connection in the field to a heat transfer system by means of refrigerant piping. It consists of a heat exchanger section for desuperheating, condensing, and subcooling refrigerant and a means for mechanical-draft circulation where heat is transferred from refrigerant to air. It also contains a recirculating water system to distribute water directly on the heat exchange surface.

Steady-state: required test measurements remain within specified tolerances during a test condition.

Temperature difference: the difference in degrees between the condensing temperature and the entering air wet-bulb temperature. This is commonly known as condenser approach.

Test measurement: the reading of a specific test instrument at a specific point in time.

Test run: a collection of successive test sets at the same specified condition.

Test series: a collection of test runs performed on the same test unit.

Test set: a complete collection of test measurements taken as simultaneously as practicable that includes all data to be recorded.

4. REQUIREMENTS

4.1 Test Setup. Informative Annex A describes known workable systems. This standard does not specify an exclusive list of required components or specific configurations.

4.2 Duration of Test. After establishment of steady-state test conditions, all required readings, a test set, as detailed in Section 7.3, shall be recorded at a maximum of 30-second intervals. The test period, a test run, shall be defined as a minimum of twenty (20) minutes of consecutive readings that are within the specified limits.

4.3 Safety Requirements. All components in the test apparatus and the condenser shall meet the design requirements for safety as outlined in ANSI/ASHRAE Standard 15, *Safety Standard for Refrigeration Systems*.[2]

5. INSTRUMENTS

5.1. Instruments (or instrument systems) shall be selected to meet the minimum accuracies given in Table 1.

Table 1. Instrumentation Accuracy

Measurement	Medium	Minimum Accuracy		Instrument Examples
		SI	I-P	
Temperature	Air dry-bulb	± 0.06 °C	± 0.1 °F	Resistance Temperature Detector (RTD) or Thermistor
	Air wet-bulb			
	Refrigerant liquid			
	Refrigerant vapor	± 0.06 °C	± 0.1 °F	
	Makeup Water	± 0.06 °C	± 0.1 °F	
	Recirculating Water	± 0.06 °C	± 0.1 °F	
	Others	± 0.6 °C	± 1.0 °F	Liquid-in-glass
Pressure	Refrigerant	Pressure corresponding to ± 0.1 °C of saturation temperature	Pressure corresponding to ± 0.2 °F of saturation temperature	Transducer
	Air	± 169Pa	± 0.05in. Hg	Barometer
	Recirculating Water	± 2%		Manometer
Flow	Refrigerant	±1 %		Mass flowmeter, volumetric flowmeter
	Makeup Water	±1%		Mass flowmeter, volumetric flowmeter
Electrical	Motor kilowatts / amperes / voltage	±1 %		Power meter
				Amp probe
				Multimeter
Speed	Motor / fan	±1 %		Tachometer
Weight	Oil / refrigerant solution	±0.5 %		Gravimeter (scale or analytical balance)
Time	Hours / minutes / seconds	±0.5 %		Electronic clock
Wind Speed	Air	±0.5 m/s	±1.0 mph	Vane anemometer

5.2 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 Institute (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.

5.3 Instruments shall be applied and used in accordance with the following documents:

a. Temperature sensors — ANSI/ASHRAE Standard 41.1[3]
b. Pressure — ANSI/ASHRAE Standard 41.3[4]
c. Electrical — ANSI/ASHRAE Standard 41.11[5]
d. Flowmeters — ANSI/ASHRAE Standard 41.10[6]

5.4 The current version of *NIST Thermodynamic Properties of Refrigerants and Refrigerant Mixtures Software*[7] or a reference that provides compliant properties per ISO 17584:2005[8] shall be the source for thermodynamic properties. Refrigerant manufacturer's refrigerant property data shall be used if properties are not in the NIST reference.

6. METHOD OF TESTING

6.1 Heat Rejection Measurements. Refrigerant flow through the condenser shall be measured. Entering and leaving refrigerant enthalpies shall be determined from the corresponding pressure and temperature measurements.

6.1.1 Refrigerant Flow Rate Determination. Both a refrigerant vapor flow rate entering the condenser and a liquid flow rate leaving the condenser shall be measured using refrigerant flowmeters with the accuracy listed in Table 1.

6.1.1.1 Temperature and pressure-measuring instruments shall be installed upstream of the vapor line flowmeter and at the entrance to the heat exchanger. The degree of superheat shall be calculated and recorded for each test set.

6.1.1.2 For vapor refrigerant flow measurements, the refrigerant at the heat exchanger inlet must be superheated a minimum of 10°C (18°F).

6.1.1.3 A sight glass shall be located immediately after the liquid flowmeter. Observation of the condition of the liquid flow shall be made during each test run and the condition recorded.

6.1.1.4 Temperature and pressure-measuring instruments shall be installed at the liquid line flowmeter upstream locations. The degrees of subcooling shall be calculated and recorded for each test set.

6.1.1.5 For liquid refrigerant flow measurements, the refrigerant after the heat exchanger outlet must be subcooled a minimum of 3°C (5.4°F).

6.1.1.6 Average Refrigerant Mass Flow Rate. Volumetric flow rates shall be converted to mass flow rates. The average of the liquid and vapor flows shall be the average refrigerant mass flow rate.

6.1.2 Condenser Refrigerant Enthalpy Difference. Dual refrigerant temperature and pressure instruments shall be installed at both the entering and leaving connections to the condenser. The measurements shall be made no more than 91.4 cm (36 in.) from the test unit connection interface(s). The average of the dual temperature and dual pressure measurements at each location shall be used to determine the entering and leaving enthalpies.

6.2 Air Temperature Measurement. The air temperatures entering the condenser coil(s) and any secondary heat exchange section such as fill shall be the arithmetic average of the individual recorded station readings at a specific time during a test run.

6.2.1 Entering-Air Wet-Bulb Temperature. The number of entering-air temperature measurement stations shall be based on the total net free inlet area at the point of measurement. The inlet area of concern applies to each individual air inlet area rather than the total air inlet area of the test unit. Evaporative cooled condensers shall use the number of wet-bulb measuring stations defined by ~~Part III~~ Appendix F in *CTI ATC-106*[9]. This standard is referenced for minimum quantity of measuring stations per air inlet area as shown in the equation below.

$$N = (K)\,(A)^{0.4}$$

Where n = minimum number of stations
K= a constant to adjust for units of measure equal to 0.9 (SI) and 0.35 (IP)
A= the inlet area of concern, m^2, (ft^2)

For details on the location of the stations, see Appendix F of *CTI ATC-106*[9].

6.2.2 Entering-Air Dry-Bulb Temperature The dry-bulb temperature of the air entering the condenser shall be taken as the average reading of two measuring stations.

6.3 Test runs conducted with the condenser positioned outdoors shall be invalid when average wind velocity exceeds 4.5 mps (10 mph) or when wind velocity exceeds 7 mps (15 mph) over a 1-minute duration. An informative reference for this aspect of testing is *CTI ATC-106.*

6.4 See Table 2 for stability criteria for test conditions.

Table 2 Test Condition Stability Requirement

Variable Description	Test Condition Stability Over Test Run Duration	
	°C	°F
Dry bulb Temperature	NA	NA
Temperature Difference*	+/-0.3	+/-0.5
Average Refrigerant Flow Rate	+/- 3.0%	
Inlet Refrigerant Temperature	+/-1.0	+/-1.8
Inlet Refrigerant Dew Point Temperature	+/-1.0	+/-1.8
Outlet Refrigerant Temperature	+/-0.5	+/-0.9
Outlet Refrigerant Dew Point Temperature	+/-0.5	+/-0.9
Makeup Water Temperature	+/-1.0	+/-1.8
Recirculating Water Pressure (at inlet centerline)**	+/-10%	+/-10%

*The Wet-bulb temperature tolerance is set by the Temperature Difference.
The minimum Temperature Difference shall be 5.6°C (10°F).
**Only required for recirculating water pump by others.

6.5 Piping and charging with refrigerant shall be in accordance with the manufacturer's specification. All components in the test apparatus and test condenser shall conform to the design requirements for safety as outlined in ANSI/ASHRAE Standard 15, *Safety Code for Mechanical Refrigeration*[2].

6.6 Condenser Operation

6.6.1 The power supply voltage shall be ±10% of the nameplate ratings on the condenser fan motor(s) and spray pump motor(s) or the condenser nameplate, whichever states lower values. 50/60 hertz motors shall be operated at 60 hertz unless otherwise specified. Dual-voltage motors shall be operated at the nameplate value for the voltage selected.

6.6.2 Where the condenser fans are driven by a nonelectric power source, the fans shall rotate at a speed within 1% of that specified on the condenser nameplate.

7. DATA TO BE RECORDED

The data listed in Sections 7.1 through 7.3 shall be recorded. Capacity calculations, including corrections for barometric pressure, fan horsepower, and makeup water are not covered in this standard.

7.1 Test System Description

The system type used with applicable schematic. See Informative Annex A for examples of system type and applicable schematics.

7.2 Manufacturer's Condenser Data

a. Manufacturer's name and address
b. Unit model number, serial number, and all nameplate data. Digital photograph of unit nameplate.

See manufacturing submittal document/technical data sheet for unit details. Functional condition of the condenser shall be verified and recorded.

7.3 Test Data (Taken at Each Reading Interval)

7.3.1 Condenser Data

a. Barometric pressure, kPa (in. Hg)
b. Dry-bulb temperatures of air entering the condenser, °C (°F)
c. Wet-bulb temperatures of air entering the condenser, °C (°F)
d. Pressure of refrigerant vapor entering the condenser, kPa (psia)
e. Temperature of the refrigerant vapor entering the condenser, °C (°F)
f. Pressure of refrigerant liquid leaving the condenser, kPa (psia)
g. Temperature of the refrigerant liquid leaving the condenser, °C (°F)
h. Electric power input to fan motors(s), kW_{rms}
i. Voltage at fan motor terminals, V_{rms}
j. Amperage at fan motor terminals, A_{rms}
k. Fan speed, rpm
l. Electric power input to integral spray pump motor(s), kW_{rms}
m. Voltage at integral spray pump motor terminals, V_{rms}
n. Amperage at integral spray pump motor terminals, A_{rms}
o. Vapor refrigerant mass flow rate, kg/s (lb/h) or volumetric flow rate, l/s (ft^3/min)
p. Liquid refrigerant mass flow rate, kg/s (lb/h) or volumetric flow rate, l/s (ft^3/min)
q. Liquid head in receiver, mm (in.)
r. Pressure of refrigerant entering vapor flow meter, kPa (psia)
s. Temperature of refrigerant entering vapor flow meter, ºC (ºF)

t. Pressure of refrigerant entering liquid flow meter, kPa (psia)
u. Temperature of refrigerant entering liquid flow meter, ºC (ºF)
v. Temperature of makeup water entering basin, ºC (ºF)
w. Flow rate of makeup water entering basin, l/s (gal/min)
x. Temperature of recirculating water at the discharge of the recirculating pump, ºC (ºF)
y. Static pressure at centerline of recirculating water inlet connection (spray pump by others), kPa (psia)

8. NOMENCLATURE AND COMPUTATIONS

8.1 Nomenclature

E_{fm} = fan motor voltage, V_{rms}
h_1 = refrigerant enthalpy entering the condenser, kJ/kg (Btu/lb)
h_2 = refrigerant enthalpy leaving the condenser, kJ/kg (Btu/lb)
i = station number for air temperature measurement
M_{r1} = mass flow rate of refrigerant liquid, kg/s (lb/h)
M_{r2} = mass flow rate of refrigerant vapor, kg/s (lb/h)
M_r = average mass flow rate of refrigerant through condenser, kg/s (lb/h)
n = total number of stations for air temperature measurement
P_{fm} = electrical power input to fan motor, kW_{rms}
P_B = barometric pressure, kPa (in. Hg)
P_0 = pressure of refrigerant vapor entering flowmeter, kPa (psia)
P_1, P_{1a}, P_{1b} = pressure of refrigerant vapor entering the condenser, kPa (psia)
P_2, P_{2a}, P_{2b} = pressure of refrigerant liquid leaving the condenser, kPa (psia)
P_3 = gauge pressure of refrigerant liquid entering flowmeter, kPa (psia)
t_{sat3} = saturation temperature corresponding to refrigerant pressure entering flowmeter, °C (°F)
t_{sub} = degrees of subcooling of refrigerant liquid entering flowmeter, °C (°F)
t_{sup} = degrees of superheat of refrigerant vapor entering condenser, °C (°F)
t_{sat1} = saturation temperature corresponding to refrigerant pressure entering condenser, °C (°F)
t_{db1} = average dry-bulb temperature of air entering condenser, °C (°F)
t_{db1a}, t_{db1b} = dry-bulb temperature of air entering condenser, °C (°F)
t_{wb1} = average wet-bulb temperature of air entering condenser, °C (°F)
t_{wbi}, t_{wbn} = wet-bulb temperature of air entering condenser, °C (°F)
t_{r0} = temperature of refrigerant vapor entering flow meter, °C (°F)
t_{r1}, t_{r1a}, t_{r1b} = temperature of refrigerant vapor entering the condenser, °C (°F)
t_{r2}, t_{r2a}, t_{r2b} = temperature of refrigerant liquid leaving the condenser, °C (°F)
t_{r3} = temperature of liquid refrigerant entering flowmeter, °C (°F)
t_{s1} = temperature corresponding to refrigerant pressure at condenser inlet. For zeotropic refrigerants, the arithmetic average of the dew point and bubble point corresponding to the measured refrigerant pressure at the condenser inlet, °C (°F)
τ = time, s
TD = condenser temperature difference, °C (°F)
v_{r1} = specific volume of refrigerant liquid at flow meter inlet, m^3/kg (ft^3/lb)
v_{r2} = specific volume of refrigerant vapor at flow meter inlet, m^3/kg (ft^3/lb)
V_{r1} = volumetric flow rate of refrigerant liquid l/s (ft^3/hr)
V_{r2} = volumetric flow rate of refrigerant vapor l/s (ft^3/hr)

8.2 Computations

8.2.1 Average Refrigerant Mass Flow Rate

$$M_r = \frac{M_{r1}+M_{r2}}{2}$$

8.2.2 Condenser Temperature Difference *(TD)*

$$TD = t_{s1} - t_{wb1}$$

8.2.3 Calculation of Refrigerant Mass Flow Rate from Volumetric Flow Rate

$$M_{r1} = \frac{V_{r1}}{v_{r1}}$$

$$M_{r2} = \frac{V_{r2}}{v_{r2}}$$

8.2.4 Calculation of Average Entering Refrigerant Conditions to the Condenser

$$P_1 = \frac{P_{1a}+P_{1b}}{2}$$

$$t_1 = \frac{t_{r1a}+t_{r1b}}{2}$$

8.2.5 Calculation of Average Leaving Refrigerant Conditions to the Condenser

$$P_2 = \frac{P_{2a}+P_{2b}}{2}$$

$$t_2 = \frac{t_{r2a}+t_{r2b}}{2}$$

8.2.6 Calculation of Average Entering Dry Bulb to the Condenser

$$t_{db1} = \frac{t_{db1a}+t_{db1b}}{2}$$

8.2.7 Calculation of Average Entering Wet Bulb to the Condenser

$$t_{wb1} = \frac{\sum_1^n t_{wbi}}{n}$$

8.2.8 Calculation of Degrees of Refrigerant Subcooling

$$t_{sub} = t_{sat3} - t_{s3}$$

8.2.9 Calculation of Degrees of Refrigerant Superheat

$$t_{sup} = t_1 - t_{sat1}$$

9. NORMATIVE REFERENCES

1. *ASHRAE Terminology of Heating, Ventilation, Air Conditioning and Refrigeration,* 2nd Edition, 1991, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., 1791 Tullie Circle NE, Atlanta, GA 30329.

2. ANSI/ASHRAE Standard 15-2016, *Safety Standard for Refrigeration Systems*, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., 1791 Tullie Circle NE, Atlanta, GA 30329.

3. ANSI/ASHRAE Standard 41.1-2013, *Standard Method for Temperature Measurement*, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., 1791 Tullie Circle NE, Atlanta, GA 30329.

4. ANSI/ASHRAE Standard 41.3-2014, *Standard Method for Pressure Measurement*, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., 1791 Tullie Circle NE, Atlanta, GA 30329.

5. ANSI/ASHRAE Standard 41.11-2014, *Standard Methods for Power Measurement*, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., 1791 Tullie Circle NE, Atlanta, GA 30329.

6. ANSI/ASHRAE Standard 41.10-2013, *Standard Methods for Volatile Refrigerant Mass Flow Measurement Using Flowmeters*, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., 1791 Tullie Circle NE, Atlanta, GA 30329.

7. Lemmon, E.W., Bell, I.H., Huber, M.L., McLinden, M.O. NIST Standard Reference Database 23: Reference Fluid Thermodynamic and Transport Properties-REFPROP, Version 10.0, National Institute of Standards and Technology, Standard Reference Data Program, Gaithersburg, 2018.

8. ISO/IEC. (2005). ISO International Standard ISO/IEC 17584:2005(en), *Refrigerant properties*, Geneva, Switzerland: International Organization for Standardization (ISO).

9. CTI ATC-106, Cooling Technology Institute, *Acceptance Test Code*, 2011, 3845 Cypress Creek Parkway, Suite #420, Houston, TX 77068, Appendix F.

10. INFORMATIVE REFERENCES

1. ANSI/ASHRAE Standard 41.4-2015, *Standard Method for Measuring the Proportion of Lubricant in Liquid Refrigerant*, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., 1791 Tullie Circle NE, Atlanta, GA 30329.

2. ASME Power Test Code (PTC) 19.5-2004 (R2013), *Application, Part II of Fluid Meters: Interim Supplement on Instruments and Apparatus*, American Society of Mechanical Engineers, 345 E. 47th St., New York NY 10017.

3. ANSI/ASHRAE Standard 34-2016, *Designation and Safety Classifications of Refrigerants*, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., 1791 Tullie Circle NE, Atlanta, GA 30329.

INFORMATIVE ANNEX A

For the test apparati indicated, guidelines are provided herein. Other components and designs meeting the intent of this standard may be used.

A.1 Receiver Location and Sizing

A.1.1 The liquid head in the receiver, as indicated in Figures A-1, A-2, and A-3, shall be maintained such that there is a visible level in the receiver as confirmed with sight glasses.

A.1.2 The condenser exit pipe line shall be sized for a maximum liquid refrigerant velocity of 0.5 m/s (100 ft/min). The line shall be sloped at least 10 mm/m (0.125 in./ft) of pipe length.

A.2 Systems

A.2.1 High-Side Gravity Recirculation Systems. The system in Figure A-1 is a gravity recirculating system where the entire system is at the high side or condensing pressure level. The liquid head from the liquid level of the receiver to the flow-regulating valve of the evaporator is required to provide the necessary pressure to deliver the liquid through the liquid flowmeter and up to the regulating valve into the evaporator without flashing. The pressure in the boiler/evaporator shall be higher than that in the receiver to deliver the required refrigerant flow rate through the piping, flowmeter, and condenser.

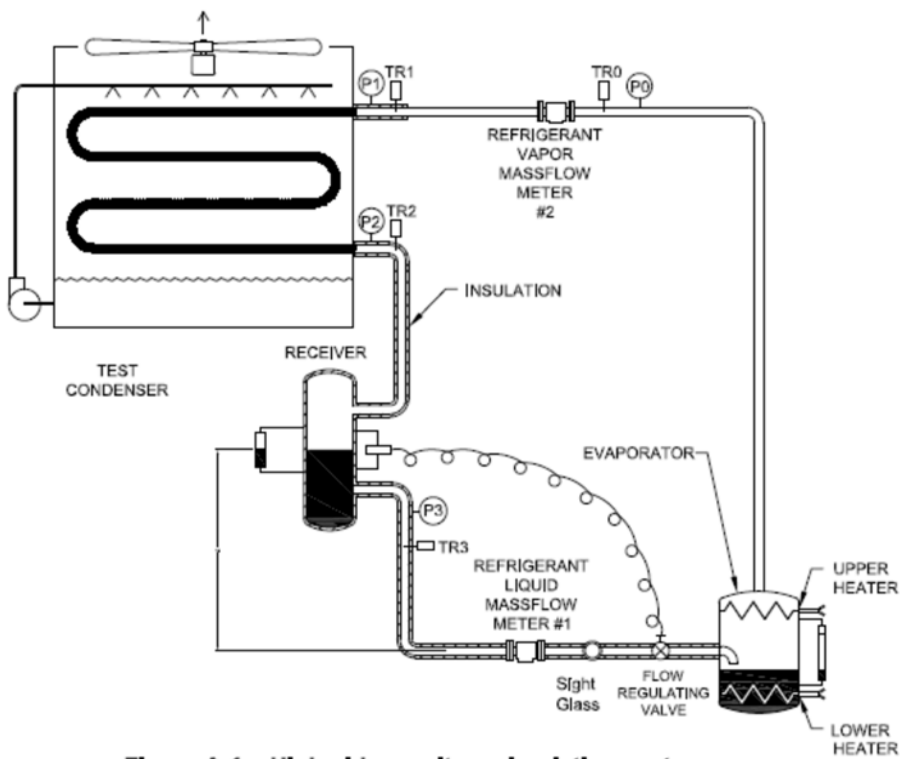

Figure A-1 High-side gravity recirculation system.

A.2.2 High-Side Pump Recirculation System. The entire system in Figure A-2, is at the high side or condensing pressure level. This system eliminates the need for a high static head between the receiver and the boiler/evaporator, as in Figure A-1, by using a pump to provide the pressure necessary to deliver the refrigerant through the flowmeter and to the regulating valve of the boiler/evaporator without flashing. In this system, the liquid head is the head required to deliver the liquid (without flashing) into the pump by gravity.

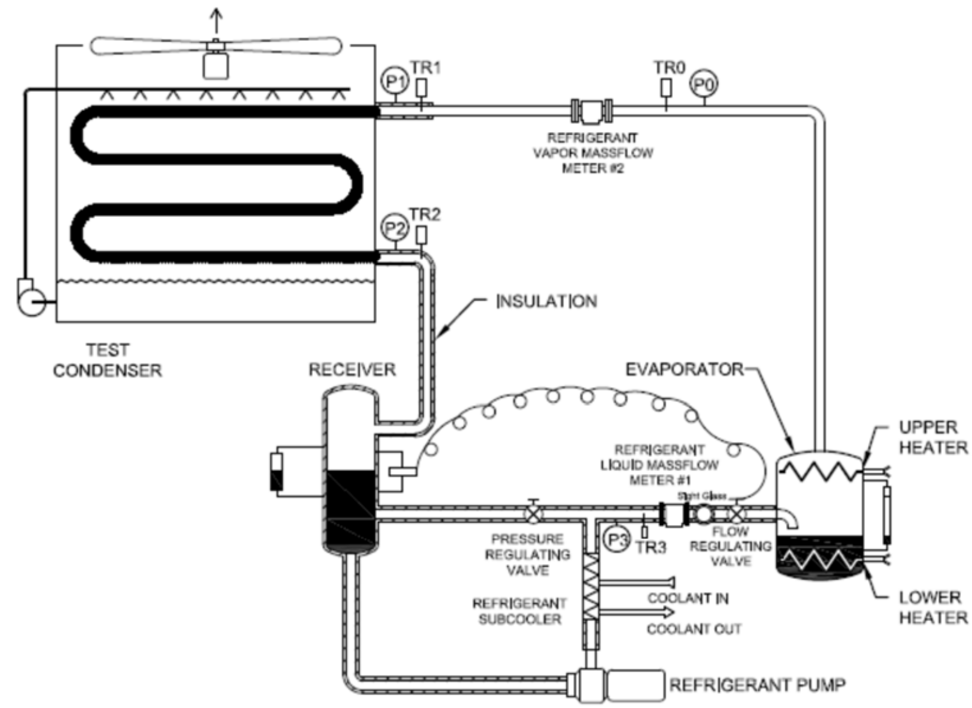

Figure A-2 High-side pump recirculation system.

A.2.3 Compressor-Driven Recirculation Systems. In the system in Figure A-3, the oil separator shall meet the specifications of the compressor manufacturer and shall reduce the oil content of the refrigerant to a maximum of 0.5% by weight. Testing lubricant concentration shall be performed a minimum of once per Test Series per article under test following ANSI/ASHRAE Standard 41.4 *Standard Method for Measuring the Proportion of Lubricant in Liquid Refrigerant* unless the system does not contain lubricant.

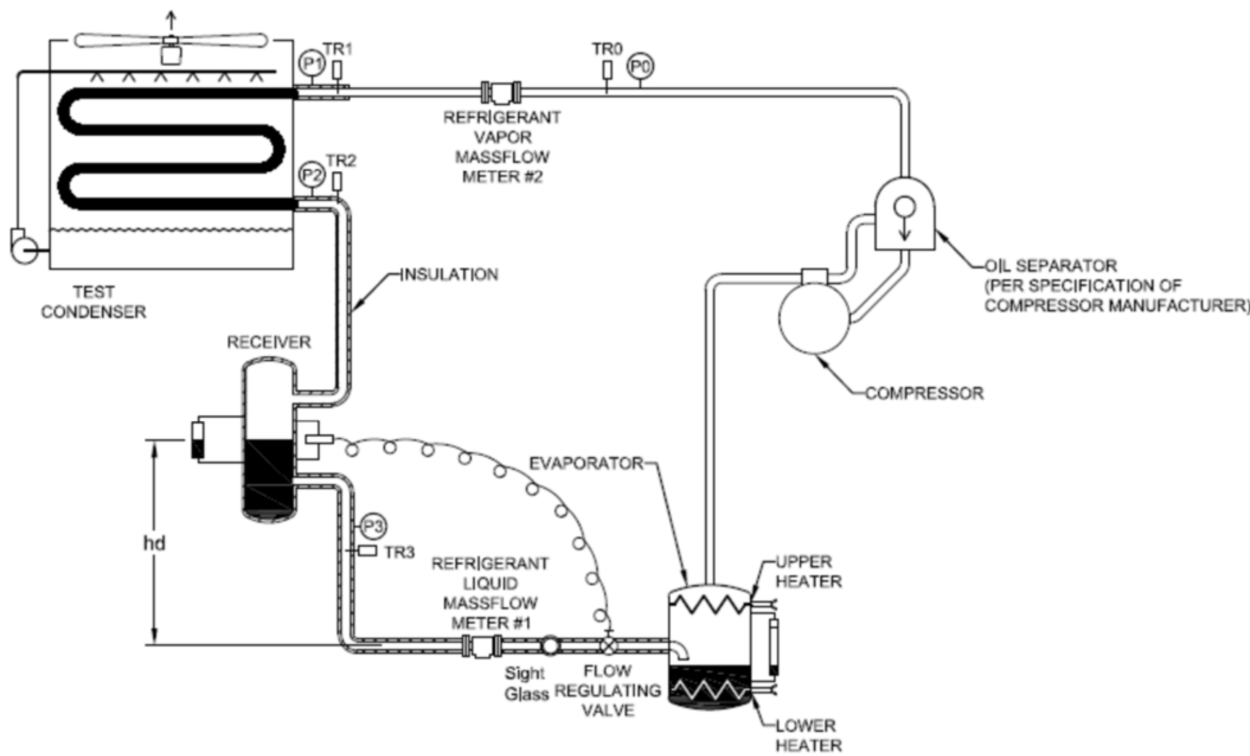

Figure A-3 Compressor-driven recirculation system.

A.3 Heat Input: Electrical, Steam, or Hot Water. The lower heaters in the boiler/evaporators of Figures A-1, A-2, and A-3 will evaporate the liquid as it is delivered from the test condenser. The total heat input (electrical, steam, or hot water) regulates the refrigerant flow rate. The upper heater is used to provide precise control of the superheat. The upper heaters in the boiler/evaporators of Figures A-1 and A-2 are used to control the superheat of the vapor entering the condenser. The upper heater in the boiler/evaporator of Figure A-3 controls the superheat at the inlet to the compressor to that specified by the manufacturer.

A.4 Noncondensables. Prior to the beginning of the test, the system shall have been purged or evacuated to reduce noncondensable gases to industry standards.

See Informative Annex B for a method to remove noncondensable gases in the condenser.

INFORMATIVE ANNEX B

METHOD FOR REMOVING NONCONDENSABLES IN REMOTE MECHANICAL-DRAFT REFRIGERANT CONDENSERS

After leak testing the refrigeration system and prior to charging with refrigerant, connect a vacuum pump capable of attaining 100 microns or less when blanked off to the system. Operate the vacuum pump until the system reaches a pressure of 500 microns. Isolate the vacuum pump from the system and observe the vacuum gauge. If the pressure rises, check for leaks in the system or at the vacuum line connections. Repeat the evacuation until the system will hold a pressure of 500 microns for 1 hour after the vacuum pump has been disconnected. Break the vacuum with refrigerant and charge the system.