

SECTION 23 08 00

COMMISSIONING FOR HVAC

PART 1 GENERAL

1.01 CONTRACTOR REQUIREMENTS

- A. The commissioning responsibilities applicable to the mechanical Contractor, commissioning authority (CA), control system contractor, and others are outlined in Section 230800 - Commissioning. This section covers the specific commissioning tasks required. Commissioning shall be provided in this section and as required by the AHJ in accordance with the 2015 IECC.

1.02 SECTION INCLUDES

- A. Preparation of mechanical equipment for operation including cleaning, lubrication, and final alignment.
- B. Testing to verify compliance with requirements of contract documents.
- C. Perform testing of mechanical equipment, control station equipment, balancing of distribution system, and adjustment of systems of project.
- D. Sound measurement of equipment at operating conditions.
- E. Vibration measurement of equipment at operating conditions.

1.03 SUBMITTALS

- A. Provide submittal documentation relative to commissioning to the CA as requested by the CA.
- B. Schedule of equipment and system start-up to Engineer, DPS, and CA.
- C. Results of vendor's shop and field tests.
- D. Required documentation as required by Code, the AHJ, and listed within the contract documents and herein.
- E. Equipment and instrumentation calibration certification or documentation for all test instruments.
- F. Documentation that the vendor's storage and handling requirements were met for all equipment and materials.
- G. Results of air pressure test for boiler setting and ductwork.
- H. Results of hydrostatic test for boiler, pressure vessels and piping systems.
- I. Boil out procedure for steam boiler and results.
- J. Equipment vendor's recommendations for:
 - 1. Alignment tolerances.
 - 2. Allowable vibration levels.
 - 3. Lubrication requirements.
 - 4. Cleaning procedures.
- K. Observed installation data:
 - 1. Alignment readings.
 - 2. Operating vibration levels.
 - 3. Test and inspection reports.
- L. Results of potable water tests including chemical test showing residual chlorine in plumbing system of less than 10 ppm.
- M. Results of water testing results and final chemical concentrations for boiler feedwater, condenser water, chilled water, and hydronic systems.
- N. Certification of backflow preventer assemblies from testing agency.

- O. Certifications for storm and sanitary sewer as required by Denver Water.
- P. Instrument calibration reports in duplicate for each instrument and control loop:
 - 1. Include instrument calibration data and status of equipment.
 - 2. Note any deficiencies yet to be corrected on instruments that are suitable for operation (e.g. broken lenses, faulty local indicators on transmitters that can still perform correct output transmission, etc.). Contractor shall correct these deficiencies at earliest possible date.
 - 3. Each calibration report shall be signed by contractor's representative witnessing test.
- Q. At completion of Work, contractor shall submit to DPS certification that equipment has been tested and commissioned, and is in operating condition in accordance with contract documents.
- R. Final Reports: Refer to Section 01915 for final report requirements.

1.04 QUALITY ASSURANCE

- A. Contractor shall perform specified services with qualified personnel, or employ and pay for qualified organization to perform specified services.
- B. Contractor shall provide calibrated instruments required for commissioning and testing operations.
 - 1. Make instruments available to engineer to facilitate spot checks during testing
 - 2. Retain possession of instruments; remove from site at completion of services
- C. Test equipment shall have calibration checks by equipment vendor or authorized facility to assure accuracy of commissioning process every six months.
- D. Furnish material, tools, and labor required to perform start-up of each respective item of equipment, instrument and system.
- E. Coordinate the startup of equipment and systems with existing operations or facility equipment so that it does not affect owner's operations.
- F. Nondestructive examination of pressure part welds shall be in accordance with ASME Boiler and Pressure Vessel Code – Section V.
- G. Provide equipment vendor's authorized service representative to inspect and approve installation where required in individual specification sections.
- H. Comply strictly with specified vendor's, engineer's, and CA's procedures in starting up and commissioning specified systems.

1.05 COORDINATION

- A. Coordinate startup, testing and commissioning services of the various trades to ensure rapid completion of services.
- B. Promptly report to engineer and CA any deficiencies noted during performance of commissioning and testing services.

1.06 JOB CONDITIONS

- A. Prior to start of testing and commissioning, verify that required "job conditions" are met:
 - 1. Systems installation is complete and in full operation
 - 2. Ambient conditions are within reasonable range relative to design conditions
 - 3. Special equipment such as computers, laboratory equipment, and electronic equipment are in full operation
- B. Verify that requirements for preparation for testing and balancing have been met for elements of each of systems that require testing.

PART 2 PRODUCTS – No Requirements

PART 3 EXECUTION

3.01 INSTRUMENTS

- A. Register, grille, and diffuser readings: "Anemotherm" by Anemostat Products Div., Dynamics Corp. of America, or "Velometer" by Alnor Instrument Co., Div. of Illinois Testing Laboratories, Inc., within the past 6 months.
- B. Duct velocity readings: Pitot tube and inclined manometer with scale appropriate for value of readings to be taken.
- C. Duct dry and wet bulb temperatures: Dial type thermometers with scale graduations of 1 degree or less. Minimum 2" (50 mm) diameter scale. Minimum bulb length of 5" (125 mm). Type of wick for wet bulb thermometer to be approved in advance.
- D. Area dry and wet bulb thermometer: Glass, with maximum scale graduations of 1 degree. Type of wick for wet bulb thermometer shall be approved in advance.
- E. Flow gauges in piping may be used to obtain water flow data in branch piping where such gauges are furnished.
- F. Calibrate thermometers before and after testing.
- G. Maintain instruments and equipment in good working order during testing.

3.02 EQUIPMENT CLEANING

- A. When no longer required, thoroughly clean equipment of temporary protective coatings and foreign materials.
- B. Remove excess shipping accessories including packing, shipping bolts, temporary blocking, crating, and banding.
- C. Remove construction debris including temporary supports, shims, scaffolding, etc.
- D. Perform cleaning procedures recommended by equipment vendor.

3.03 INSPECTION

- A. Inspect equipment installations and verify in writing status of work meets requirements for starting equipment including, but not limited to, the following:
 - 1. Lubrication type, quantity, and date.
 - 2. Proper drive rotation before connecting coupling, belts, or chains.
 - 3. Proper belt tension.
 - 4. Check out of wiring and control systems.
 - 5. Proper instrument control range.
 - 6. Proper motor and electric device voltage ratings.
 - 7. Proper alignment and running clearances.
 - 8. Coupling guards, belt guards, etc., in place.
 - 9. Control systems operational
 - 10. Equipment, including coils, tubes, drums, hoppers, ducts, and breeching: Internals clear of shipping materials, packing, blocks, construction debris, welding rod, etc.
 - 11. Auxiliary services connected, i.e., cooling water, alarm and trip circuits, and safety devices.
 - 12. Proper damper operation and clearance for damper drive linkage travel.
 - 13. Proper clearance for thermal expansion.
 - 14. Instrumentation calibration.
- B. Engineer, owner, and CA reserves right to witness contractor's inspections.

3.04 ADJUSTING

- A. Check equipment for alignment after piping and duct connections have been made and before equipment is placed in operation. Equipment shall be rechecked for alignment after reaching operating temperature.
- B. Align equipment so that at operating temperatures, shaft angular (coupling face) misalignment and shaft parallel misalignment does not exceed vendor's recommendations.
- C. Alignment settings shall be recorded and copies provided to engineer.
- D. After initial operation, accessory equipment supports shall be drilled, reamed, and fastened in place on baseplate using tapered dowel pins to maintain permanent alignment.
- E. Variable and constant spring hangers shall be adjusted to appropriate cold settings prior to operation. Monitor movement during initial operation to verify calculated load and travel are adequate. Perform necessary adjustments.
- F. Monitor movement of expansion joints during initial operation to verify calculated travel. Perform necessary adjustments.
- G. Make other adjustments necessary on equipment furnished in order to properly place equipment into operation.

3.05 EQUIPMENT VIBRATION BALANCING

- A. Rotating equipment shall be dynamically balanced at vendor's shop. Field assembled rotating equipment shall be dynamically balanced. Balancing procedure in accordance with vendor's instructions.
- B. Balance rotating equipment if operating vibration exceeds "good" region as shown on "General Machinery Vibration Severity Chart" by IRD Mechanalysis or vendor's recommendations, whichever is more stringent.
- C. Vibration readings at startup will be conducted by contractor.

3.06 LUBRICATION

- A. Lubricate bearings and fill oil reservoirs prior to operation. Perform lubrication in accordance with vendor's recommendations.
- B. Lubricants for initial operation, storage, and flushing shall be furnished by contractor.
- C. After contractor lubricates equipment, contractor shall affix tag to equipment stating lubricant used, quantity, date lubricated, and name of person lubricating equipment.

3.07 GENERAL MECHANICAL SYSTEMS

- A. Pre-Functional Testing and Inspection:
 - 1. Perform water testing in accordance with AHJ for potable water systems.
 - 2. Review test certificates of reduced pressure backflow preventer assemblies. Testing shall be performed by a certified backflow technician.
 - 3. Verify steam, hot water, condensate, chilled water or DX piping is connected to cooling coils, pressure tested, cleaned, and chemical treatment performed (as applicable).
- B. Plumbing:
 - 1. Confirm roof drains are open and unobstructed.
 - 2. Confirm operation at each plumbing fixture and availability of hot/cold water.
 - 3. Confirm operation of each plumbing specialty item through its full range of operation.
 - 4. Confirm automatic operation of water heaters, air separators and expansion tanks.
 - 5. A smoke test shall be performed on sanitary vent lines prior to applying wall finishes. The test shall be witnessed by the DPS representative.
 - 6. System Flushing:
 - a) Before operational tests or disinfection, potable piping systems shall be flushed with potable water

- b) Sufficient water shall be used to produce a minimum velocity of 2.5 feet/sec through the piping. Flushing shall continue until all the dirt and other material are removed and the water is not discolored. Drain the system at low points
7. Operational tests shall be performed after flushing and before disinfecting. Operational tests shall last not less than 8 hours for each system and shall included the following:
- a) Time, date, and duration of the test.
 - b) Water pressure at most remote and highest fixture.
 - c) Operation of each fixture and trim.
 - d) Operation of each valve, hydrant, and faucet.
 - e) Pump suction and discharge pressure (if applicable).
 - f) Temperature of domestic water supply.
 - g) Operation of each floor and roof drain (if applicable) by flooding with water
 - h) Operation of each vacuum breaker and backflow preventer.
 - i) Operation of the water booster system including pump start and stop pressure (if applicable).
 - j) Compressed air reading at each compressor inlet and outlet.
 - k) Laboratory piping shall be tested in accordance with the vendor's recommendations.
8. Disinfection:
- a) After flushing and operational testing is complete, the domestic hot and cold water system shall be disinfected with chlorinated water. The chlorination procedure shall be in accordance with AWWA M20.
 - b) The water shall remain in the system for a minimum of 24 hours.
 - c) Each valve shall be opened a minimum of 2 times during the testing period to ensure proper disinfection.
 - d) After disinfection the piping system shall be flushed so that not more that 25 ppm of chlorine is present. Testing of chlorine content shall occur within 1 hour of taking sample.
- C. Verify control valves and damper actuators are installed; control power is energized; and valves and dampers are operable.
- D. Bearings:
- 1. Inspect for cleanliness; clean and remove foreign materials.
 - 2. Verify alignment.
 - 3. Replace defective bearings, and those that run roughly or noisily.
 - 4. Grease as necessary, and in accordance with vendor's recommendations.
- E. Drives:
- 1. Adjust tension in V-belt drives, and adjust variable pitch sheaves and drives for proper equipment speed.
 - 2. Adjust drives for alignment of sheaves and V-belts.
 - 3. Clean; remove foreign materials before starting operation.
 - 4. Perform operational testing of variable frequency drives (VFDs) for all equipment, including air handling units, pumps, fans, etc.
- F. Motors:
- 1. Check each motor for amperage comparison to nameplate value.
 - 2. Check motor bearing temperatures and vibration during run in.

3. Correct conditions which produce excessive current flow, and which exist due to equipment malfunction.

G. Fans:

1. Inspect and verify proper mounting of fan.
2. Check motor interlocks, control system contactors and motor protection devices.
3. Confirm adequate fan and motor bearing lubrication.
4. Verify unobstructed rotation of fan.
5. “Bump test” to verify correct rotation of fan.
6. Check sheaves for alignment and adjust belt tension (if required).
7. Replace defective bearings and those that run roughly.
8. Operate fan motor uncoupled for 1 hour to perform “run-in” on motor. Check for excessive vibration on fan motor.
9. Couple fan to motor and operate for 1 hour, minimum. Check for vibration on fan assembly. Rebalance fan or replace components as necessary to allow fan to run smoothly and within vendors recommended vibration limits.

H. Pumps:

1. Check mechanical seals for cleanliness and adjustment before running pump.
2. Confirm adequate pump and motor bearing lubrication.
3. Inspect shaft sleeves for scoring.
4. Inspect mechanical faces, chambers, and seal rings; replace if defective.
5. Verify that piping system is free of dirt and scale before circulating liquid through pump.
6. Check expansion joints for proper installation before running.
7. Check sealing fluid supply for flushed mechanical seals.
8. Check impeller for correct installation and direction of rotation.

I. Piping systems:

1. Tighten flanges after system has been placed in operation. Replace flange gaskets that show any sign of leakage after tightening.
2. Inspect screwed joints for leakage.
 - a) Promptly remake each joint that appears to be faulty; do not wait for rust to form.
 - b) Clean threads on both parts, apply compound, and remake joints.
3. After system has been placed in operation, clean strainers, dirt pockets, orifices, valves seats, and headers in fluid systems, to assure they are free of foreign materials.
4. Open air vents; remove operating elements. Clean thoroughly, replace internal parts and put back into operation.
5. Remove any rust, scale, and foreign materials from equipment and renew defaced surfaces.
6. Repair damaged insulation.
7. Vent gasses trapped in any part of systems.
8. Check piping for leaks at every joint, and at every screwed, flanged, or welded connection.

J. Control valves:

1. Inspect both hand and automatic control valves; clean bonnets and stems.
2. Tighten packing glands to assure no leakage, but permit valve stems to operate without galling.

3. Replace packing in valves to retain maximum adjustment after system is judged complete.
4. Replace packing on any valve that continues to leak.
5. Remove and repair bonnets that leak.
6. Coat packing gland threads and valve stems with surface preparation of anti-rust compound after cleaning.

K. Heat Exchangers:

1. Observe testing of pressure relief valves and review test results.
2. Field hydrostatic test pressure parts and connecting piping in accordance with ASME Boiler and Pressure Vessel Code or Tubular Exchanger Manufacturer's Association (TEMA) (as applicable). Submit proper certificates after testing is complete. Testing shall be performed prior to insulating of heat exchanger.
3. Measure and record flow and temperature of entering and leaving water. Adjust to obtain required output.
4. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.

3.08 ENVIRONMENTAL SYSTEMS

A. Reference Specification Section 15990, "Testing, Adjusting and Balancing" and "HVAC Controls", paragraph below for additional requirements.

B. Computer Room Air Conditioning:

1. Vendor's Field Service: Engage a factory-authorized service representative to inspect, test, and adjust field-assembled components and equipment installation, including connections, and to assist in field testing. Report results in writing.
2. Perform the following field tests and inspections and prepare test reports:
 - a) Inspect for and remove shipping bolts, blocks, and tie-down straps.
 - b) After installing computer-room air-conditioning units and after electrical circuitry has been energized, test for compliance with specification requirements.
 - c) Operational Test: After electrical circuitry has been energized, start units to confirm proper motor rotation and unit operation.
 - d) Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.

C. Air Handling Units with Coils:

1. Vendor's Field Service: Engage a factory-authorized service representative to inspect field-assembled components and equipment installation, including piping and electrical connections. Report results in writing.
 - a) Leak Test: After installation, fill water and steam coils with water and test coils and connections for leaks. Repair leaks and retest until no leaks exist.
 - b) Charge refrigerant coils with refrigerant and test for leaks. Repair leaks and retest until no leaks exist.
 - c) Fan Operational Test: After electrical circuitry has been energized, start units to confirm proper motor rotation and unit operation. Remove malfunctioning units, replace with new units, and retest.
 - d) Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.

D. Packaged Heating and Cooling Rooftop Equipment:

1. Vendor's Field Service: Engage a factory-authorized service representative to inspect test, and adjust field-assembled components and equipment installation, including connections, and to assist in field testing. Report results in writing and deliver to DPS Project Manger.
2. Perform the following field quality-control tests and inspections and prepare test reports:
 - a) After installing rooftop air conditioners and after electrical circuitry has been energized, test units for compliance with requirements.
 - b) Inspect for and remove shipping bolts, blocks, and tie-down straps.

- c) Operational Test: after electrical circuitry has been energized, start units to confirm proper motor rotation and unit operation.
 - d) Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.
 - 3. Remove malfunctioning units, replace with new units, and retest as specified above.
- E. Air Terminal Units:
 - 1. Perform the following field tests and inspections and prepare test reports:
 - a) After installing air terminal units and after electrical circuitry has been energized, test for compliance with requirements.
 - b) Leak Test: after installation, fill water coils and test for leaks. Repair leaks and retest until no leaks exist.
 - c) Operational Test: after electrical circuitry has been energized, start units to confirm proper motor rotation and unit operation.
 - d) Test and adjust controls and safeties. replace damaged and malfunctioning controls and equipment.
 - 2. Remove and replace malfunctioning units and retest as specified above.
- F. Geothermal Systems:
 - 1. Field hydrostatic test pressure parts and connecting piping in accordance with piping code. Submit certificates after testing is complete. Testing shall be performed prior to insulating field joints.
 - 2. Vendor's Field Service: engage a factory-authorized service representative to inspect test, and adjust field-assembled components and equipment installation, including connections, and to assist in field testing. Report results in writing and deliver to DPS Project Manger.
 - 3. After installing computer-room air-conditioning units and after electrical circuitry has been energized, test for compliance with specification requirements.
 - 4. Operational Test: after electrical circuitry has been energized, start units to confirm proper motor rotation and unit operation.
 - 5. Test and adjust controls and safeties: replace damaged and malfunctioning controls and equipment.
- G. Air Cooled Condensing Units:
 - 1. Verify chilled water piping or DX piping is connected to cooling coils, pressure tested, cleaned, and chemical treatment performed (as applicable).
 - 2. Condenser Fans:
 - a) Check motor interlocks, control system contactors and motor protection devices.
 - b) Confirm adequate fan and motor bearing lubrication.
 - c) Verify unobstructed rotation of fans.
 - d) "Bump test" to verify correct rotation of fan.
 - e) Check sheaves for alignment and adjust belt tension (if required).
 - f) Replace defective bearings and those that run roughly.
 - 3. Compressors:
 - a) Verify compressor outlet pressure.
 - b) Check adequate lubrication for compressor and motor bearings.
 - c) Check vibration levels on compressor.
 - 4. Operational Test: After electrical circuitry has been energized, start units to confirm proper unit operation.
 - 5. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.

H. Exhaust Fans:

1. Operational Test: after electrical circuitry has been energized, start units to confirm proper unit operation. Test fan for rotational speed, total cfm and static pressure.
2. Test and adjust controls and safeties: replace damaged and malfunctioning controls and equipment.

I. Makeup Air Units:

1. Operational Test: after electrical circuitry has been energized, start units to confirm proper unit operation. Test fans for rotational speed, total cfm and static pressure.
2. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.
3. Confirm interlocks with kitchen hoods, exhaust fans and other air handling equipment.

3.09 STEAM BOILERS

A. Pre-Functional Testing and Inspection:

1. Review burner commissioning test report from burner vendor.
2. Observe testing of pressure relief valves and review test results.

B. Air pressure test boiler setting and ductwork; submit procedure to ENGINEER prior to test. Provide necessary equipment and materials required for testing including fans, compressed air, blank-off plates, gaskets, and bracing. System shall be pressurized to 10" water gauge (w.g.) (2.5 kPa). Test pressure shall not decrease more than 10% in 10 minutes after sources of incoming air are shut off.

C. Field hydrostatic test pressure parts and connecting piping in accordance with Section I of ASME Boiler and Pressure Vessel Code and ASME B31.1 Power Piping Code. Submit proper ASME certificates after testing is complete. Testing shall be performed prior to insulating field joints.

D. Boilout:

1. Flush tubes and headers to remove weld slag, dirt and construction debris.
2. Boiler shall be cleaned by boiling out in manner that will remove of grease, oil, and other organic compounds.
3. Provide temporary gaskets on manholes and handholes for boilout; after boilout replace with new gaskets for operation. Spare gaskets specified shall not be used for this purpose.
4. Furnish and install chemicals required for boilout.
5. Provide service engineers (if required by vendor) and construction labor as required for boilout.
6. Furnish and install temporary equipment required for boilout, including but not limited to, temporary piping required to fill and drain boiler, temporary gauge glass, and other temporary instruments.
7. Contractor will provide labor to dispose of cleaning solution.

E. Commissioning:

1. Forced Draft (FD) and Induced Draft (ID) Fans:

- a) Inspect and verify proper mounting of fan.
- b) Check motor interlocks, control system contactors and motor protection devices.
- c) Confirm adequate fan and motor bearing lubrication.
- d) Verify unobstructed rotation of fan.
- e) "Bump test" to verify correct rotation of fan.
- f) Check sheaves for alignment and adjust belt tension (if required).
- g) Replace defective bearings and those that run roughly.
- h) Operate fan motor uncoupled for 1 hour to perform "run-in" on motor. Check for excessive vibration on fan motor.

- i) Couple fan to motor and operate for one (1) hour, minimum. Check for vibration on fan assembly. Rebalance fan or replace components as necessary to allow fan to run smoothly and within vendors recommended vibration limits.
2. Flue Gas Recirculation (FGR) Damper:
 - a) Verify manual and automatic actuation of damper.
 - b) Verify unobstructed, full range of motion.
 - c) Verify orientation of damper blades.
 - d) Verify tight closure of damper.
 3. Controls:
 - a) Check controls to maintain individual boiler operation.
 - b) Check automatic shutdowns, safety shutdowns, low water cutouts and alarms.
 - c) Verify burner operation for a turn down of 10:1 on natural gas and 8:1 on fuel oil.
 - d) Check field instrumentation versus control system display.
 - e) Inspect boiler control panel for operation of controls and indicating lights.
 - f) Provide boiler stack analysis to verify full load and part load thermal efficiency.
 - g) Verify operation of plant master for the control of multiple boilers.
- F. Measure and record steam output at full load, half load, and quarter load conditions. Adjust to maintain required output.

3.10 HOT WATER BOILERS

- A. Pre-Functional Testing and Inspection:
 1. Review burner commissioning test report from burner vendor.
 2. Observe testing of pressure (water) relief valves and review test results.
- B. Field hydrostatic test pressure parts and connecting piping in accordance with Section I or Section IV of ASME Boiler and Pressure Vessel Code (as applicable), and ASME B31.1 Power Piping Code. Submit proper ASME certificates after testing is complete. Testing shall be performed prior to insulating field joints.
- C. Commissioning:
 1. Forced Draft (FD) or Induced Draft (ID) Fan:
 - a) Inspect and verify proper mounting of fan.
 - b) Check motor interlocks, control system contactors and motor protection devices.
 - c) Confirm adequate fan and motor bearing lubrication.
 - d) Verify unobstructed rotation of fan.
 - e) “Bump test” to verify correct rotation of fan.
 - f) Check sheaves for alignment and adjust belt tension (if required).
 - g) Replace defective bearings and those that run roughly.
 - h) Operate fan motor uncoupled for one (1) hour to perform “run-in” on motor. Check for excessive vibration on fan motor.
 - i) Couple fan to motor and operate for one (1) hour, minimum. Check for vibration on fan assembly. Rebalance fan or replace components as necessary to allow fan to run smoothly and within vendors recommended vibration limits.
 2. Controls:
 - a) Activate control system for automatic/manual boiler start sequence.

- b) Start boiler water pump, establish flow, and activate boiler proof of flow switch.
 - c) Start boiler internal circulation pump.
 - d) Verify low water cutoff safety and water makeup supply.
 - e) Verify operation of temperature and pressure gauges. Operate high-pressure limit control.
 - f) Verify burner operation for a turn down of 4:1 on natural gas.
 - g) Check controls to maintain individual boiler operation.
 - h) Check automatic shutdowns, safety shutdowns, low water cutouts and alarms.
 - i) Inspect boiler control panel for operation of controls and indicating lights.
 - j) Check field instrumentation versus control system display.
 - k) Provide boiler stack analysis to verify full load and part load thermal efficiency.
 - l) Verify operation of plant master for the control of multiple boilers.
- D. Measure and record flow and temperature of hot water. Adjust to obtain required output.

3.11 STEAM PIPING

- A. Pre-Functional Testing and Inspection:
 - 1. Review installation of piping, valves and accessories for conformance to drawings.
- B. Field hydrostatic test piping in accordance with ASME B31.1 Power Piping Code. Testing shall be performed prior to insulating field joints.
- C. Commissioning:
 - 1. Perform flushing of piping and clean filters at final acceptance.
 - 2. Clean strainers, dirt pockets, orifices, valve seats and blow down steam traps.
 - 3. Valves
 - 4. Check valve bonnets for leakage; tighten as necessary.
 - 5. Verify manual and automatic actuation of process control valves.
 - 6. Pipe Supports.
 - 7. Check support location and installation prior to filling of system.
 - 8. Check and adjust support after filling of system.
 - 9. Check piping during operation for leaking flanges, joints or connections, vibration or unusual movement.
 - 10. Check expansion joints after piping system reaches operating temperature for binding, squirm or unusual movement.
 - 11. Replace flange gaskets that show any sign of leakage after tightening.
 - 12. Verify all flange gaskets are metal impregnated flexatallc type gaskets. Garlock or Neoprene gaskets shall be rejected and replaced prior to placing system into service.
 - 13. Repair any damaged insulation.

3.12 HOT WATER SUPPLY & RETURN PIPING

- A. Pre-Functional Testing and Inspection:
 - 1. Review installation of piping, valves and accessories for conformance to drawings.
- B. Field hydrostatic test piping in accordance with ASME B31.1 Power Piping Code. Testing shall be performed prior to insulating field joints.
- C. Commissioning:
 - 1. Perform flushing of piping and clean filters at final acceptance.

2. Clean strainers, dirt pockets, and valve seats.
3. Valves
4. Check valve bonnets for leakage; tighten as necessary.
5. Verify manual and automatic actuation of process control valves.
6. Pipe Supports
7. Check support location and installation prior to filling of system.
8. Check and adjust support after filling of system.
9. Check piping during operation for leaking flanges, joints or connections, vibration or unusual movement.
10. Replace flange gaskets that show any sign of leakage after tightening. Repair any threaded joints that show any sign of leakage.
11. Verify all flange gaskets are metal impregnated flexatallitic type gaskets. Garlock or Neoprene gaskets shall be rejected and replaced prior to placing system into service.
12. Repair any damaged insulation.

3.13 CONDENSATE PIPING

- A. Pre-Functional Testing and Inspection:
 1. Review installation of piping, valves, tank and accessories for conformance to drawings.
 2. Review condensate pump installation alignment results.
- B. Field hydrostatic test piping in accordance with ASME B31.1 Power Piping Code. Testing shall be performed prior to insulating field joints.
- C. Commissioning:
 1. Perform flushing of piping and clean filters at final acceptance.
 2. Check piping during operation for leaking flanges, joints or connections, vibration or unusual movement.
 3. Replace flange gaskets that show any sign of leakage after tightening. Repair any threaded joints that show any sign of leakage.
 4. Verify all flange gaskets are metal impregnated flexatallitic type gaskets. Garlock or Neoprene gaskets shall be rejected and replaced prior to placing system into service.
 5. Repair any damaged insulation.
 6. Valves
 - a) Check valve bonnets for leakage; tighten as necessary.
 - b) Verify manual and automatic actuation of process control valves.
 7. Pipe Supports
 - a) Check support location and installation prior to filling of system.
 - b) Check and adjust support after filling of system.
 8. Tank
 - a) Verify cleanliness of tank.
 - b) Observe level indicator and confirm proper operation.

3.14 MAKEUP WATER SYSTEM

- A. Pre-Functional Testing and Inspection:
 1. Observe testing of pressure relief valves and review test results.
 2. Perform integrity check of bed support or retainers for dealkalizers and water softeners.

- B. Field hydrostatic piping in accordance with ASME B31.1 Power Piping Code. Testing shall be performed prior to insulating field joints.
- C. Commissioning:
 - 1. Check all level instrumentation for proper operation.
 - 2. Check automatic operation of control system.
 - 3. Check automatic backflush.
 - 4. Verify brine concentration for flow to dealkalizers and softeners (~12% salt solution).
 - 5. Check mixers and metering pump operation for chemical feed system.
 - 6. Check operation of chemical feed systems to:
 - a) Boilers.
 - b) Steam distribution system.
 - c) Cooling towers/condenser water system.
 - d) Chilled water system.
 - 7. Perform quality tests on samples of:
 - a) Steam.
 - b) Condensate.
 - c) Chilled water.
 - d) Brine solution.
 - 8. Check piping during operation for leaking flanges, joints or connections, vibration or unusual movement.
 - 9. Replace flange gaskets that show any sign of leakage after tightening.

3.15 BOILER FEEDWATER SYSTEM

- A. Pre-Functional Testing and Inspection:
 - 1. Review installation of piping, valves, deaerator and accessories for conformance to P&IDs.
 - 2. Review feed water pump installation alignment results.
- B. Field hydrostatic test piping in accordance with ASME B31.1 Power Piping Code. Testing shall be performed prior to insulating field joints.
- C. Commissioning:
 - 1. Perform flushing of piping and clean filters at final acceptance.
 - 2. Valves
 - a) Check valve bonnets for leakage; tighten as necessary.
 - b) Verify manual and automatic actuation of process control valves.
 - 3. Pipe Supports:
 - a) Check support location and installation prior to filling of system.
 - b) Check and adjust support after filling of system.
 - 4. Deaerator:
 - a) Verify cleanliness of tank.
 - b) Observe level indicator and confirm proper operation.
 - 5. Check piping during operation for leaking flanges, joints or connections, vibration or unusual movement.

6. Replace flange gaskets that show any sign of leakage after tightening. Repair any threaded joints that show any sign of leakage.
7. Repair any damaged insulation.

3.16 NATURAL GAS SYSTEM

- A. Review installation of piping, valves and accessories for conformance to P&IDs.
- B. Blow out piping to remove debris.
- C. Review piping pressure test results.
- D. Witness gas solenoid safety valve operational test.
- E. Clean dirt pockets.
- F. Check piping during operation for leaking flanges, joints or connections, vibration or unusual movement.
- G. Replace flange gaskets that show any sign of leakage after tightening.
- H. Record pressure on both sides of regulator.

3.17 PUMPS

- A. Pre-Functional Testing and Inspection:
 1. Verify pumps are fully installed with baseplate grouted securely in foundation and isolation devices (if required) are functional.
 2. Check for adequate lubrication for pump and motor bearings.
 3. Review pump installation alignment results.
 4. Check mechanical seals for cleanliness and adjustment.
 5. Verify seal flush flow and quantity.
 6. Check motor interlocks, control system contactors and motor protection devices.
 7. “Bump test” to verify correct rotation of pump.
 8. Replace defective bearings and those that run roughly.
 9. Clean inlet strainer.
 10. Check for pump “soft foot.”
- B. Commissioning:
 1. Confirm individual pump flow and head after startup. Adjust as required.
 2. Confirm pump flow and head in combination with other equipment.
 3. Check motor FLA at design operation conditions.
 4. Correct conditions that cause excessive current draw by the motor or inadequate flow or head from the pump.
 5. Check vibration levels for radial vibration (2 planes) and axial vibration.
 6. Measure sound level at a distance of 3’ (1 m) from operating equipment.

3.18 CHILLED WATER/CONDENSER WATER

- A. Pre-Functional Testing and Inspection:
 1. Review pressure test results (evaporator and condenser).
 2. Observe testing of pressure relief valves and review test results.
 3. Measure and record refrigerant that is loaded into chiller (pounds).
 4. Verify that equalizer and overflow piping is open and not restricted (cooling tower).

5. Review installation of piping, cooling towers, pumps, chillers, valves and accessories for conformance to P&IDs.
- B. Field hydrostatic test chiller, chilled water and condenser water piping in accordance with ASME B31.1 Power Piping Code. Testing shall be performed prior to insulating field joints.
- C. Commissioning:
 1. Piping:
 - a) Perform flushing of piping and clean filters at final acceptance.
 - b) Vent air from system and confirm filling of piping system.
 2. Check piping during operation for leaking flanges, joints or connections, vibration or unusual movement.
 3. Replace flange gaskets that show any sign of leakage after tightening.
 - a) Repair any damaged insulation.
 4. Valves:
 - a) Check valve bonnets for leakage. Tighten as necessary.
 - b) Verify manual and automatic actuation of process control valves.
 5. Pipe Supports
 - a) Check support location and installation prior to filling of system.
 - b) Check and adjust support after filling of system.
 6. Measure sound level at a distance of 3' (1 m) from operating equipment.
- D. Water Chillers:
 1. Refrigerant:
 - a) Check refrigerant leak detection and automatic shut down system.
 - b) Check refrigerant recovery piping and storage tank.
 - c) Record volume (mass) of refrigerant that is installed in chiller.
 2. Check motor interlocks, control system contactors and motor protection devices.
 3. Compressor:
 - a) Verify compressor outlet pressure.
 - b) Check adequate lubrication for compressor and motor bearings.
 - c) Check vibration levels on compressor.
 4. Oil Pump:
 - a) Check for adequate lubrication for pump and motor bearings.
 - b) "Bump test" to verify correct rotation of pump.
 - c) Replace defective bearings and those that run roughly.
 - d) Check motor FLA at design operation conditions.
 5. Controls:
 - a) Activate control system for automatic/manual chiller start sequence.
 - b) Start chilled water pump, establish flow, and activate evaporator proof of flow (differential pressure) switch.
 - c) Start condenser water pump, establish flow, and activate condenser proof of flow (differential pressure) switch.
 - d) Verify control system energizes chiller start sequence.

- e) Verify operation of temperature and pressure gauges and control system monitoring of temperature and pressure.
 - f) Verify operation of flow instrumentation.
 - g) Verify chiller thermal load within system, confirm chilled water set point.
 - h) Inspect chiller control panel for operation of controls and indicating lights.
 - i) Check field instrumentation versus control system display.
 - j) Check automatic shutdowns and alarms.
 - k) Check field instrumentation versus control system display.
 - l) Verify chiller shutdown sequence after thermal load is removed.
6. Operate chiller through full range of loads from local control panel and control system.
 7. Confirm and record chiller efficiency (kW/ton) at 100%, 75%, and 50% operation.
- E. Cooling Tower:
1. Check piping during operation for leaking flanges, joints or connections, vibration or unusual movement.
 2. Replace flange gaskets that show any sign of leakage after tightening.
 3. Repair any damaged insulation.
 4. Check motor interlocks, control system contactors and motor protection devices.
 5. Fan:
 - a) Inspect and verify proper mounting of fan.
 - b) Confirm adequate fan and motor bearing lubrication.
 - c) Check sheaves for alignment and adjust belt tension (if required).
 - d) Replace defective bearings and those that run roughly.
 - e) Verify unobstructed rotation of fan.
 - f) “Bump test” to verify correct rotation of fan.
 - g) Perform “Run-in test” to check for excessive vibration.
 6. Review fill for damage; replace fill as required to allow unrestricted airflow into the tower.
 7. Check basin level instrumentation and makeup water float operation.
 8. Controls:
 - a) Activate control system for automatic/manual cooling tower start sequence.
 - b) Verify operation of temperature and pressure gauges and control system monitoring of temperature and pressure.
 - c) Verify operation of flow instrumentation.
 - d) Verify condenser water thermal load within system; confirm condenser water set point.
 - e) Check field instrumentation versus control system display.
 - f) Check fan vibration switch and low oil level alarms.
 - g) Check cooling automatic shutdowns and alarms.
 - h) Check field instrumentation versus control system display.
 9. Operate cooling tower through full range of loads from control system.

3.19 HVAC CONTROLS (see also “Instrumentation Systems”, this section)

- A. Verify control devices are in place, operable, calibrated and communicating with local control panels and operator workstations.
- B. System Power:
 - 1. Test and verify power supplies, wiring, low voltage transformers, and related interlocks are available and meet the requirements of the Contract Documents.
 - 2. Check wiring continuity and voltage drops to most remote points in system.
 - 3. Verify power to the UPS and shutdown power to the EMS/DDC and confirm automatic transfer to the UPS and 1-hour of operation.
 - 4. Remove power from control units and verify that the configuration properly reloads automatically upon restoration of power.
- C. Verify that control software program has been loaded, edited and is operational.
- D. Review configuration of the logic in each controller against the Sequence of Operations.
- E. Verify installation and configuration of I/O against Contract Documents.
- F. Operator Work Stations:
 - 1. Verify that any operator workstation can be taken out of service without loss of facility control.
 - 2. Verify graphics screens against both soft and hard I/O.
 - 3. Verify operation of operator workstation and control of HVAC systems.
 - 4. Verify report and alarm generation meets requirements of Owner.
 - 5. Verify self-diagnostics operate and report properly.
- G. Test each control loop for:
 - 1. Full range and span of input/output.
 - 2. Proper display on process, trend and alarm graphic screens.
 - 3. Response on loss of signal.
 - 4. Testing of control/feedback mismatch.
- H. Confirm controls operation for HVAC systems for:
 - 1. Start up of each HVAC system.
 - 2. Space occupied.
 - 3. Night and weekend set-back.
 - 4. Warm-up cycle.
 - 5. Modulation of control valves and dampers.
 - 6. Space temperature control.
 - 7. Emergency condition operation including power failure.
- I. Verify automatic shutdown of systems (particularly operation of the firestat duct sensor at each AHU.)
- J. Verify operation of fire-smoke dampers and automatic reset (if applicable).

3.20 INSTRUMENT PIPING

- A. Branch instrument air headers shall be blown down and leak tested prior to introducing air to the instrument.
- B. Blow down header to remove moisture, foreign particles, etc. Larger outlets shall be blown down first; then proceed to smaller outlets, until all supply lines have been cleaned.
- C. Pressurize headers to 120 psig (830 kPa) and hold to confirm system is tight. Perform repairs to headers and retest until leaks are eliminated.

- D. Blow down and test pneumatic tubing circuits to confirm continuity, tightness and elimination of leaks. Disconnect tubing from instruments when blowing down each circuit.
- E. Reconnect instrument (if instrument has suitable pressure rating) and pressurize tubing to 35 psig (240 kPa) to confirm system is tight. Perform repairs to tubing circuits to eliminate leaks.
- F. If instrument air is not available at time of commissioning, supply instrument quality air from portable compressor, bottled dry air, or nitrogen for testing.

3.21 INSTRUMENTATION SYSTEMS

- A. Commission controls and instruments prior to start-up to assure in-situ performance in accordance with specifications under simulated operating conditions. Contractor to determine initial start-up conditions.
- B. Remove shipping stops from instruments before starting with procedures listed herein. Contractor shall have instruction manuals available, and shall install miscellaneous components such as charts, illumination, etc., which have been supplied separately but are integral parts of equipment.
- C. If any doubt exists as to correct method for calibrating or checking calibration of instrument, vendor's printed recommendations shall be used.
- D. Many instruments contain small supply pressure gauges or output pressure gauges. Calibration of these gauges will not be required. However, if gauge is found to be defective, instrument involved shall be immediately called to attention of owner and reporting of its condition confirmed in writing.
- E. If any instrument cannot be properly adjusted, it shall be immediately called to attention of owner and report of its condition confirmed in writing.
- F. Instrument check: Verify data on nameplate with respect to conditions of range, operating temperature, specific gravity, and components as stated on unit specifications. Any discrepancies shall be immediately called to attention of owner and report of condition confirmed in writing.
- G. Verify that control valve seats are free from foreign material, and are properly positioned for intended service.
- H. Loop checks:
 - 1. Verify wiring from instrument back to control system. Check wiring tagging matches wiring diagrams.
 - 2. Check continuity of conductors and polarity.
 - 3. Verify calibration range of each instrument and compare to required range for process.
 - 4. Contractor shall maintain written record of all loop checks.
- I. Test procedures:
 - 1. Check handswitches, pushbuttons, and pilot lights.
 - 2. Check interlocking circuits installed for conformance to schematic diagrams and "Sequence of Operation".
 - 3. Perform work of placing in initial operation equipment installed or wired under this contract, following instructions and recommendations of equipment vendors.
 - a) After energizing and prior to start-up, check control circuits for proper sequence of operation and interlocking functions.
 - b) Wiring changes required as result of such checks shall be properly identified by changing terminal strip and/or wiring markers.
 - 4. Contractor shall provide necessary construction labor to make equipment final adjustments that are required to place systems in good operating condition, and furnish labor to assist in solving instrument or control problems.
 - 5. Contractor shall calibrate instruments and components in accordance with vendor's calibration data over full operational range, prove instruments to be within published specification, accuracy, and affix calibration sticker. Instruments shall be calibrated individually and where applicable, as system (i.e., control loop transmitter, controller, and valve). Components that have adjustable features shall be carefully set for

specific conditions and applications of this project. Each calibration sticker shall be signed by contractor's representative witnessing test.

6. Calibration sticker shall contain the following information:
 - a) Equipment identification tag number.
 - b) Range of calibration.
 - c) Date and name of person doing calibration.
7. Pressure gauges: Shall be checked at 10%, 50%, and 90% of their ranges for linearity within vendor's stated specifications.
8. Gauges not meeting vendor's specifications shall be repaired or replaced.
9. Dial thermometers shall be checked at mid-range and ambient temperature. Thermometers not meeting vendor's specifications shall be repaired or replaced.
10. Temperature switches: calibrate in accordance with vendor's specifications.
11. Valves and Operations:
 - a) Control Valves:
 - i) Inspect both hand and automatic control valves; clean bonnets and stems.
 - ii) Tighten packing glands to assure no leakage, but permit valve stems to operate without galling.
 - iii) Replace packing in valves to retain maximum adjustment after system is judged complete.
 - iv) Replace packing on any valve that continues to leak.
 - v) Remove and repair bonnets that leak.
 - vi) Coat packing gland threads and valve stems with surface preparation of anti-rust compound after cleaning.
 - vii) Operation of control valve shall be verified within limits of practicality. Particular attention must be given to vendor's instructions and applicable nameplate data in reference to valve spring scale and actuation conditions. Pay close attention to bench set.
 - b) Valve action: check valve action for conformance to specifications (open or closed on air or power failure).
 - c) Valve positioner: check for conformance to specifications relative to spring action and input range (particularly for split range applications), valve action, and length of stroke. If valve positioner is fitted with standard characterized cam, check to see if proper cam is mounted. Do not cut or modify standard cam.
 - d) Check valve position with a signal input of 0%, 25%, 50%, 75%, and 100%. Check valve opening corresponds to the input signal. If position feedback is available, check that feedback indication corresponds to the input signal.
12. Panel-mounted instruments:
 - a) Receiver instruments: check zero and span at 0%, 25%, 50%, 75%, and 100% of range by impressing measured signal into input or signal connections or instrument.
 - b) Controllers:
 - i) Controllers shall be checked for proper operation and adjusted in accordance with vendor's instructions. Vary process input signal and check output signal for direction.
 - ii) Set initial proportional band, reset rate, and rate time as recommended by vendor. It may be necessary to determine process dynamics in actual operation before settings can be made.
 - iii) Control loops shall be observed for operability and conformance to specifications by impressing simulated input signal at primary element and checking response of final control element.

13. Controllers; field mounted: Simulate "Set Point" and "Measured Variable" signals at controller, with separate regulated signals.
14. Acceptable calibration standards:
- a) Vacuum or draft:
 - i) 0" to 5" w.c. (0 kPa to 1.25 kPa): inclined water filled manometer graduated in tenths and inches of water (kPa).
 - ii) 5" to 25" Hg (17 kPa to 85 kPa): precision test pressure gauge, 0-30" Hg (0-102 kPa), ¼ of 1% accuracy, 6" (150 mm) dial.
 - iii) 5" to 60" H₂O (1.25 kPa to 15 kPa): water manometer graduated in inches of water (kPa).
 - b) Pressure:
 - i) 0" to 5" w.c. (0 kPa to 1.25 kPa): inclined water filled manometer graduated in tenths and inches of water (kPa).
 - ii) 5" to 60" w.c. (1.25 kPa to 15 kPa): water manometer graduated in inches of water (kPa).
 - iii) 3 to 25 psig (20.7 kPa to 175 kPa): precision test pressure gauge, 0-30 psig (0-210 kPa), ¼ of 1% accuracy, 6" (150 mm) dial.
 - iv) 25 to 150 psig (175 kPa to 1050 kPa): precision test pressure gauge, 0-200 psi (0-1500 kPa), 1/4 of 1% accuracy, 4-1/2" (115 mm) dial minimum.
 - v) 150 to 750 psig (1050 kPa to 5200 kPa): precision test pressure gauge, 0-800 psi (0-5500 kPa), 1/2 of 1% accuracy, 4-1/2" (115 mm) dial minimum.
 - c) Differential:
 - i) 0" to 5" w.c. (0 kPa to 1.25 kPa): inclined water filled manometer graduated in tenths and inches of water (kPa).
 - ii) 5" to 300" w.c. (1.25 kPa to 75 kPa): water manometer graduated in inches of water (kPa).
 - iii) 5 to 25 psig (34 kPa to 175 kPa): precision test pressure gauge, 0-30 psig (0-210 kPa), ¼ of 1% accuracy, 6" (150 mm) dial.
 - iv) Above 25 psig (175 kPa): use pressure gauges listed above.
 - d) Temperature:
 - i) -40 to 250°F (-40°C to 220°C): laboratory thermometers of suitable range.
 - ii) Other ranges: use thermocouple and precision potentiometer.
15. Digital instruments:
- a) Instruments designed to transmit signals via a digital protocol (BACNet) shall be calibrated using a handheld communications device, laptop computer, or through a DDC console.
 - b) Verify calibration data, tag information, and other programmable parameters.
 - c) Verify wiring from the instrument to the correct control system I/O, when calibration is performed in the field.

3.22 SAFETY AND ALARM SYSTEMS

- A. Verify operation of emergency notification and alarm systems. Verify notification at fire alarm control panel (FACP).
- B. Perform pneumatic, hydrostatic, and final tests of fire suppression system.
- C. Perform hydrant flow test to confirm sufficient water supply for all hydrants.
- D. Verify anti-freeze to water solution ratio in fire suppression system as applicable.
- E. Verify operation of emergency signals, sensors and detectors.

- F. Verify operation of fire suppression system for wet pipe and dry pipe systems. Verify foam concentration for fire suppression systems in fuel oil storage area.
- G. Verify operation of refrigerant leak detection equipment shutdown and start of ventilation fans.
- H. Verify operation of fire-smoke dampers and automatic reset (if applicable).
- I. Witness third party testing of backflow prevention devices for plumbing, irrigation and fire protection systems.
- J. Witness functional testing of kitchen hood controls, including fan operation and fire alarm and suppression system.

3.23 LIGHTING CONTROLS

- A. Lighting controls shall be commissioned as required in division 26 and as required by the AHJ in the 2015 IECC.

3.24 SERVICE WATER HEATING

- A. Service water heating equipment and domestic water circulating pumps and controls shall be commissioned as required in this section and as required by the AHJ in the 2015 IECC.

3.25 ACCEPTANCE FOR OPERATION

- A. Each piece of equipment installed by this contract shall carry "Acceptance for Operation Checklist." Each checklist shall be signed by the contractor's representative and DPS, or owner's representative. Each list shall have applicable blanks filled in and attached to items indicating that it is prepared for operation.
- B. Owner will accept equipment and systems for operation when construction has been substantially completed by contractor. "Acceptance for Operation" shall mean owner will assume operational and routine maintenance duties. "Acceptance for Operation" does not relieve contractor from responsibilities related to defective materials and workmanship; neither does it constitute final acceptance of materials and equipment.
- C. After owner has accepted a system for operation, contractor shall continue to perform following as requested and scheduled by owner at no additional cost to owner until final acceptance:
 - 1. Troubleshooting, adjustments, and repairs until system operation and performance is accepted by owner.
 - 2. Assist instrument and control personnel with instrument calibration.
 - 3. Craft labor as required.
- D. After owner has accepted a system for operation, contractor shall continue to supply technical services when needed until final acceptance by owner.

END OF SECTION 23 08 00