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General Provisions

1. The contracted mechanical engineer shall consult with a representative of BYU Utilities, Engineering, and Maintenance prior to commencement of project design work to review engineering and contract document expectations and standards.

Excavation

1. The mechanical contractor shall be responsible for excavation, filling and grading of its work in accordance with instructions and procedures listed in Division 31, 32, 33. Prior to covering all new underground utilities, the mechanical contractor shall notify a representative from BYU Utilities, Engineering, and Maintenance to allow them to document the locations of the new utilities. Instructions for high temperature water distribution are contained in Tab A.

Natural Gas Line Contractors

1. Contractors hired to work on the BYU Natural Gas Distribution System shall have a state of Utah approved Operator Qualification Program in place and shall provide written proof of the qualification of every employee working on said system. Documentation must be provided to the BYU Construction Department prior to any work being done. A copy of all documentation is to be maintained in the job file for future reference for a minimum of five (5) years. Types of work included in this requirement are: 1) leak detection and cathodic protection surveys, 2) repair of leaking pipes or regulators, 3) installation of new or replacement of existing natural gas piping, or 4) any other modification of natural gas distribution systems. (Niels Fugal & Sons, Tempest)

Water Supply and Treatment

1. For proposed construction, the owner shall provide a letter of evaluation of the water supply system prepared by a registered architect, engineer or other individual recognized by the State Fire Marshal as competent to make such an evaluation. The evaluation shall include an assessment of adequacy in meeting required fire flows, considering all influencing factors. Appropriate safety factors shall be considered.

   The lowest expected flow available during the year shall be determined and used in the design of automatic sprinkler systems. This requirement applies to both sprinklered and un-sprinkled construction.

2. When any portion of the building protected is in excess of 150 feet from a fire hydrant connected to a water supply on a public street, as measured by an approved route around the exterior of the building, there shall be provided on-site fire hydrants and mains capable of supplying the required fire flow.
3. All exterior water mains four (4) inches and larger shall be Standard Bell and Spigot Cast Iron Pipe, Class 150, as described in Federal Specifications WW-P-421.

4. Joints shall be the "Mechanical Type" as described in "American Waterworks Association" bulletin C111-53 for pressure pipe and fittings; or the "Tyton Joint" using a single gasket to affect the joint seal. Provide polyethylene wrap over entire lengths.

5. The only place where lead caulked joints will be allowed is where a connection is made to an existing lead caulked line and, even in this instance after the connection has been made watertight, it is required that "Style 60 Dresser Adjustable Bell Joint Clamp" be used in addition to the lead caulking.

6. Valves four (4) inches and larger shall be epoxy coated cast iron, elastomer encapsulated ductile iron wedge, bronze non-rising stem with triple o-rings, and conform to AWWA C-509 and C-550 and have a full opening, equal to the inside diameter of the connecting pipe. (American Flow Control, Mueller)

7. All water mains which connect to a municipality main are to be connected with the consent and under the direct supervision of the municipality and, where possible, this work is to be done by the Waterworks Department which serves the community. Metering shall comply with city standards.

8. Fire hydrants shall be of a type which will meet the approval of the local fire department and if the water main serving the fire hydrant proposed is six (6) inches and larger, then the fire hydrant must be a 6-inch flange connection with 6-inch auxiliary valve connected 36” from hydrant. The fire hydrant must have two hose and one steamer nozzle, all of which must meet the local fire department thread standard. The fire hydrant shall meet the latest American Waterworks Association specifications in all respects and shall have a 5-inch valve opening in the hydrant.

9. Fire hydrants shall have a minimum of two 2 1/2” outlets, and one 5” outlet, dry barrel type, with a single valve and drain valve at the base. Threads shall be national standard threads.

Fire hydrants shall be equipped with an independent control valve placed between the hydrant and city supply, located adjacent to the hydrant. (36” spacer)

The fire department connection on automatic fire sprinkler and standpipe systems shall be located a maximum of 100 feet from a fire hydrant.

Fire hydrants shall be placed a maximum of 8 feet from a fire department access-way, with the pumper connection facing the access-way. All connections shall be a minimum of 16" to the centerline above grade and be fully accessible for fire department use.

The spec sheet is to be followed in accordance with Provo City Fire Department specifications (Drawing N. 420).
10. All pipe used in sub mains shall Type K copper pipe and must meet the "American Waterworks Association" latest specifications for pipe and fittings for water lines. Wrap pipe for corrosion protection where applicable.

11. Connections to the cast iron water main by a smaller threaded line shall meet all standard specifications covering the tapping of a water main for connecting smaller service lines and, where necessary, a service clamp or saddle must be used on the cast iron main and a lead gooseneck must be used between the cast iron water main and the sub main. Where the pipe is too large to make a tapped connection into the side of the cast iron water main, then a tapped tee must be placed in the cast iron water line so that the threaded end of the sub main pipe can be threaded into the cast iron tee.

12. Where water softeners are required, a salt storage facility shall be piped to Step Saver truck access.

13. If copper wire or equipment is used, it shall be separated from steel or iron pipe and fittings with dielectric fittings.

14. Sterilization of Potable Water Piping: The entire domestic water system, including the water main, shall be sterilized with a solution containing 25 parts per million of available chlorine. All piping shall be thoroughly cleaned before sterilization. The chlorinating materials shall be introduced into the system in a manner approved by the owner's representative. The sterilization solution shall be allowed to remain in the system for a period of not less than 24 hours, during which time all valves and faucets shall be opened and closed several times. Not less than 10 parts per million free available chlorine shall be measured at the extreme ends of the lines at the conclusion of the retention period. After sterilization, the solution shall be flushed from the system with clean water until the residual chlorine content is not greater than 0.2 parts per million. Water systems will not be accepted until a negative bacteriological test is made on water taken from the systems by an independent laboratory, such as Bionics Laboratory, Provo, during sterilization. Bypass the water softeners and reverse osmosis unit and lines during sterilization (Ref. AWWA C601-54 Standard of Disinfecting Water Mains).

15. Dedicated Line to Custodial Closets. A dedicated 1” cold water line is required to be installed downstream of the building main water shut off valve and backflow prevention device. This line will have a reduced pressure backflow valve (RPBV) installed in the mechanical room that is no more than 5 feet off the floor and is accessible for testing and service. This line will also include a pressure reducing valve (PRV) with a pressure setting not to exceed 50 PSI, and installed downstream of the RPBV. This line will have no connections made to it except at the custodial rooms where chemical mixing dispensers are to be installed. A one half inch line is to be provided at each of these locations with a ball valve for isolation of the line.

16. Hose bibbs are required in public restrooms (men’s and women’s).
Waste Water Disposal and Treatment

1. Inside waste and vent lines shall be designed in strict compliance with applicable codes.

2. Acceptable inside pipe and fittings materials will include cast iron and copper. ABS plastic may be used above slab only where approved during design. The owner shall approve the selection on each individual project.

3. Outside waste lines on the BYU campus are installed and maintained by the owner. Campus sewer mains are connected into Provo City sewer lines at several points. Permission must be obtained from Provo City for each new connection from BYU on or off campus. Most often, sewer meters are required at city connections. Consult with owner.

4. Outside sewer piping shall be concrete unless approved as PVC during design. Storm drain piping up to 6" may be PVC or concrete; larger sizes shall be concrete.

5. Concrete pipe shall conform to the following standards: The concrete pipe shall comply with all physical and dimensional requirements as set forth in ASTM Specifications C14-57, and the pipe can be standard or extra strength according to depth or traffic. Pipe sizes larger than 6" shall be reinforced concrete. The joints shall be of the bell and spigot type and the joint shall be so designed as to provide for self-centering and where assembled to compress the gasket to form a watertight seal. The gasket shall be confined to a groove on the spigot end of the pipe so that it cannot be displaced by movement of the pipe or by hydrostatic power.

6. All sanitary sewer and storm sewer pipe shall be installed in direct compliance with approved practice and in complete accord with the manufacturer's instructions. The bedding of all sewer pipe shall be in bank run sand having the following graduations: 100% passing a 3/4-inch screen and 90% passing a 1/4-inch screen. The sand shall be placed around pipe so that it completely envelops the pipe except at the joints that are to be left exposed until after the pipe has been tested by water after which the joints are to be covered with sand also.

7. After the outside sewer line has been installed, it must be tested for leakage as follows: The pipe must be plugged at the lower end or manhole and filled with water to at least one foot below the upper end of the pipe; the water must maintain this static level for two (2) hours without losing more than 1% of the water by volume.

8. Water used for cooling purposes such as refrigeration systems, cooling coils, etc., should be plumbed to the storm sewer rather than the sanitary sewer if not contaminated and allowed by code.

9. All clear water should be wasted to storm sewers and not sanitary sewers where possible.
Plumbing
(See Division 10: Specialties, for Special Requirements)

1. Plumbing fixtures, pipe and valves acceptable on the Brigham Young University Campus are as follows:
   **Plumbing Fixtures:** American Standard, Kohler, or Crane
   **Faucets:**
   - **Kitchen Style:** Chicago 1100-HA8 preferred. Kohler or Moen acceptable.
   - **Service Sink:** Kohler K8906 preferred. Chicago acceptable.
   - **Lavatories (manual type):** Chicago 802 preferred. Kohler K7404 acceptable.
   - **Lavatories (sensor type):** Chicago 116.211.AB.1 w/240.627.21.1 cover plate.
   **Flush Valves:**
   - **Water Closet:** Minimum flush rate no less than 1.28 US gallons per flush
     - Sensor type: Sloan Gem II 111-SMO-1.28 preferred. Delany acceptable.
   - **Urinal:** Minimum flush rate no less than 1.00 US gallons per flush
     - Sensor type: Delany 451 preferred. Sloan 186 acceptable.
   **Drinking Fountains (Refrigerated):** Acorn or Elkay (preferred)
   **Water Meters:** Trident, Hersey, Precision or Sensus (preferred).
   - (Meters owned by the City shall meet local requirements.)
   **Lab Fixtures:** Water Saver or Chicago
   **Acid Resistant Pipe:** Enfield, Orion
   **Gate Valves:** 2 1/2” and larger. AFC Series 2500, Nibco Fig. 607-RW
   **Butterfly/Ball Valves:** All butterfly valves shall have EPDM seat, stainless steel disc, lug body, and appropriate operator. This applies especially to seat and seal materials. Any potential vendor shall be approved in advance by the Owner. Ball valves are to have stainless steel balls.

2. All fixture hangers shall be bolted to the floor.

3. Provide auxiliary carrier supports for wall hung water closets when chase wall is less than 4" thick (concrete or block) or when wall is gypsum board.

4. Vent and water piping should be offset away from access doors to pipe chases so as not to block entries.

**Fire Protection (See Tab C)**

**Access Doors for Fire Sprinkler Valves**
An access shall be provided at each OS & Y valve, inspectors test valve and flow switch in ceiling. Also, label ceiling tile as to type of valve.
Heating and Cooling

1. Design and specification recommendations are available in addendum #1 attached for building projects to be heated with high temperature water or cooled with chilled water from the Central Heating and Chilled Water Plant.

2. All vents, shafts and other vertical openings shall be enclosed in accordance with the Uniform Building Code.

3. Air conditioning for each building shall be in accordance with the Program Requirements written for that building.

4. Filters shall be specified to be placed in the circulating hot water or chilled water systems during the construction period to remove foreign matter.

5. When the contractor is permitted to use the heating and ventilating system within a new building during the course of construction, he shall operate the equipment in accordance with the University Standards during this time. This shall consist of properly treating water, maintaining filters, cleaning traps and screens and all other instructions from the respective Physical Plant Department.

6. Mechanical and Utility Rooms
   a. All mechanical or utility rooms shall be painted off-white. Do not paint equipment. All concrete floors shall slope to floor drains. Clean all concrete floors thoroughly and seal.

   b. Room shall be of adequate size to allow a minimum of 36” for maintenance to store equipment. Allow additional space for tube replacement, tube cleaning, coil removal, etc. Provisions shall be provided to allow equipment replacement.

   c. Provide ventilation in all rooms with heat-producing equipment.

7. Water Filtering: An AMF Cuno water filter shall be sized and installed for all secondary heating water systems. Where multiple pumps are provided, the filter shall be piped and valved to operate with each pump and shall be installed where it is accessible for maintenance.

8. Water Treatment: A pot-type chemical feeder with isolation valves shall be provided on all secondary heating hot water and chilled water systems. The chemical treatment will be provided by the owner.
9. Cleaning and Flushing of Heating Piping and Cooling Piping: After the completion of the heating and cooling water systems installation and all pressure tests, the contractor shall clean out pipes under the supervision of a chemical supplier at the time of startup. The systems shall be filled with water and checked for leakage and debris. Add the proper dosage of PECO 5483 liquid cleaner or equivalent and circulate for 24 hours at 120°F - 150°F, or 48 hours at less than 120°F. Drain and flush piping; clean strainers. Flush until system PH is no more than 8.0. The Central Heating Plant and Chiller Plant pumping, heating and cooling equipment cannot used during the washing-out period; therefore, it will be the responsibility of the contractor to furnish auxiliary equipment for this purpose.

10. Valves: Special valving is required for the High Temperature Water system at Brigham Young University. Contact the University for further information.

Valves for secondary Heating Hot Water and Chilled Water systems shall be as follows:

Valves shall be provided in Chilled Water piping at entrance to building.

Valves shall be provided on each leg, two-way or three-way control valves.

Isolating valves shall be provided in the supply and return piping to all equipment to allow for repair, servicing, cleaning strainers or draining coils. Each leg of three-way valves must have isolating valves.

Valves in steam and condensate piping shall be gate valves.

Valves in sizes 2” and smaller may be ball valves unless outlined to be butterfly valves. Ball valves shall be one of the following: Apollo 70-100 or Watts B6000-SS with stainless steel ball.

Gate valves shall be Crane or Walworth with rising steam.

Butterfly valves may be used only where specifically approved by the owner. Butterfly valves shall always be lug-type.

Lubricated plug cocks may be used only as balancing valves. Separate valves shall be provided as isolation valves.

11. Gauges: Pressure and temperature gauges shall be provided at both the inlet and the outlet of all water coils and chillers (evaporator and condenser). Provide liquid filled pressure gauges.

A pressure gauge shall be piped across all strainers. Provide ball valves.

A pressure gauge shall be piped between the suction and discharge of all pumps. Provide ball valves.
12. Backflow Preventers: Reduced pressure backflow preventers shall be provided at all water makeup connections or where backflow contamination may occur. Backflow prevention devices on the city water and fire protection riser must be tested and reports submitted to Provo City and BYU within 10 days of the water being turned on at the project. Failure to do so will result in the water being turned off. Backflow preventers shall be Watts 909 or Wilkins 375 or 975 only.

13. Air Separators for hot water heating and chilled water systems shall have tangential inlet and outlet connections, an internal perforated stainless steel air collector tube designed to direct released air into the compression tank, and a removable system strainer of galvanized steel having 3/16" perforations and a free area of not less than 5 times the cross sectional area of the connecting pipe. A blow-down connection shall be provided for routine cleaning. Installer shall remove and clean strainer element after 24 hours operation and repeat after 30 days of operation. Units shall be constructed in accordance with a. S. M. E. and stamped 125# W.P.

14. Expansion Tanks for hot water heating and chilled water systems shall be hydro-pneumatic diaphragm type as manufactured by Amtrol Inc., Taco or Bell and Gossett.

15. Strainers: Provide strainers ahead of all control valves and pumps. Provide a blow-off valve at all strainers.

16. Heating and Cooling Coils: All coils shall be specified to have copper tubes and return bends with a minimum thickness of .035". Specify fins per inch. Fourteen fins shall not be used; suggest maximum of 10 fins per inch or less. Provide stainless steel condensate pans.

17. Use Farr header frame Durafil filters, type 8 frame with vertical reinforcement and pre-filter. Flanders or American Air Filter.

Air Distribution

1. Air conditioning for each building shall be in accordance with the Program Requirements written for that building.

2. When the contractor is permitted to use the heating and ventilating system within a new building during the course of construction, he shall operate the equipment in accordance with the University standards during this time. This shall consist of properly treating water, maintaining filters, cleaning traps and screens, lubricating bearings and all other instructions from the respective Physical Plant Department.

3. Operation of heating and air conditioning equipment on new construction shall be tested for completion, adequacy of design, contractors’ adherence to design and equipment performance in accordance with specifications by the engineer as soon as the job is completed. The engineer shall not be considered to have completed its responsibility until the entire system is performing satisfactorily and in accordance with the design.
4. Where flexible ductwork is used, a maximum of 3 feet will be allowed.

5. Provide Dwyer manometer gauge at all filter banks.

6. Access shall be provided for all dampers, controls, valves, fire dampers, etc., which are located above ceilings. Access shall be adequate to repair or replace the equipment.

7. Refrigerant monitors in chiller rooms—provide Bacharach HGM 300/RDM 800 only.

Controls and Instrumentation

1. The Brigham Young University has installed the Siemens/Staefa campus-wide monitor and control system. The control station is located in the Air Conditioning shop of the Physical Plant Department.

2. Existing monitoring and control capabilities:

   Monitoring:
   - Ventilation air temperatures
   - Secondary heating and cooling water temperature
   - Secondary air and steam pressure
   - Humidity
   - Motor status (running or stopped)

   Controls:
   - Programmable start and stop of chiller, fan, and pump motors
   - Programmable adjustments to ventilation air controls
   - Complete software verification of all points and operations

   Status Identification:
   - On-off indication shall be accomplished with a pressure differential switch and an auxiliary contact on the motor starter connected in series.

3. Control Air Compressors:

   All control air compressors shall have duel compressors with alternator. No equipment shall be connected to the control air supply except the temperature control system. The compressor system shall be sized to run no more than 33% of the time. The tank shall have an automatic blow-down. A refrigerated air drier with bypass valves, oil filter on air system and pressure reducing station shall be provided. Compressors shall be two-stage Sulley air compressors and automatic blow-down valves.
4. Control Air Piping:
   
   a. Piping, in general, may be polyethylene tubing, except piping in the high temperature hot water (HTHW) equipment and fan room which shall be Type "L" copper, securely attached to the structure or equipment and run parallel or at right angles to the structure. Piping installed outside the equipment rooms shall be concealed in walls or above the ceiling. This piping shall be placed in these locations as required by the progress of the structure. If plastic tubing is used for the pneumatic control system, it shall be run inside conduit and identified at each end. All take-off circuits shall be made up in junction boxes and identified at each end. If large tube bundle is used, several spares shall be left.
   
   b. The automatic control contractor shall provide sleeves for piping passing through masonry walls and floors to protect the piping.
   
   c. Piping shall not be run concealed under duct insulation, inside of duct or in direct contact with surfaces colder than normal room temperature, such as outside air ducts, conditioned air supply ducts, etc.
   
   d. All piping shall be supported using hangers of the clamp type being securely attached to the structure or equipment.
   
   e. The entire air piping system shall be tested by placing it under 30 psi air pressure for 24 hours. During this period, the pressure drop shall not exceed 1 psi.
   
   f. Provide isolation valves at each floor and equipment room.

5. Control Diagrams:
   Control diagrams shall be provided for all pneumatic and electric control and automation systems. All wiring shall be tagged at 1-inch from each terminal and number-coded to the as-built control diagrams. These should be provided before bid date for checking purposes.

6. Heating and Cooling Monitoring:
   Both the heating and cooling water supply piping shall be provided with GE Sensing temperature sensors and flow taps to send a signal to the Building Automation System (BAS) for monitoring BTU usage in the building.

7. Duct Ionization Smoke Detectors shall be furnished and installed by Electrical Contractor under the Fire Alarm System Specifications. Room flood detectors shall be provided with Fire Alarm System.

8. Specification Section 230513-COMMON MOTOR REQUIREMENTS FOR HVAC EQUIPMENT shall include a LonWorks BAS Interface Card.
Commissioning, Startup, Testing and Operator Familiarization

1. Heating and Air Conditioning
   a. The operation of the heating and air conditioning equipment shall be tested for completion, adequacy of design, contractor's adherence to design and equipment performance in accordance with specifications by the engineer as soon as the job is completed. The engineer shall not be considered to have completed its responsibility until the entire system is performing satisfactorily and in accordance with the design.
   
   b. The above commissioning and performance testing shall be done by a competent engineer specifically assigned to be on the job consistently enough to ascertain the adequacy and integrity of the system and equipment. He will be assisted where necessary by a Brigham Young University journeyman equipment operator. The BYU Air Conditioning Shop has full time trained temperature control technicians and HVAC mechanics.
   
   c. On major projects of 100,000 square feet or more, the engineer will provide at least 8 hours operator familiarization and training period in the classroom and on the job site, as necessary. On smaller jobs, this period will be reduced.

2. Instruction Manual
   a. Appropriate personnel will provide two (2) complete operating instruction manuals for the heating and air conditioning equipment. This manual shall be dated and shall cover such issues as:
      1. Troubleshooting
      2. Service
      3. Preventive maintenance
      4. General operating instructions
      5. System operating sequences, procedures, functions, etc.
      6. Single line diagrams of operation of all related equipment
      7. Spare parts
      8. Equipment product bulletins showing dimensions, capacities and operation
      9. Lubrication instructions
      10. The manual shall contain complete description of all mechanical equipment, including operating characteristics and parts lists, with a recommended list of spare parts
      11. Control diagrams

3. Air and Water Balancing
   a. All air and water systems shall be provided with dampers, valves, etc., to allow balancing in accordance with the design drawings. All systems shall be balanced by qualified personnel, approved by Owner, with complete reports provided to the Owner in the O & M manuals (3 copies).
4. **Flow and BTU Meters**
   
a. The project engineer shall specify model number and manufacturer, size, welded flanged or screwed connections, and an installation detail for flow meters and temperature sensors with the specific installation locations. The project engineer shall submit to the BYU Utilities Department flow conditions, sizing calculations, and design criteria for approval before completion of bid document.

b. Complete documentation, including all manufacturer’s literature and part numbers, shall be supplied with all components.

c. Before final acceptance of the meter by BYU, the installer shall demonstrate, to the appropriate BYU personnel, the calibration and maintenance of the meter and its associated components.

d. **High temperature water systems:** All wetted components and systems shall be rated for a working temperature of 400° F, a working pressure of 300 psi, and a pressure rating of 400 psi.

e. **Chilled water systems:** All wetted components and systems shall be rated for a working pressure of 150 psi.

5. **Specifications for BTU Meter Temperature Sensors**
   
a. Complete documentation, including all manufacturer’s literature and part numbers, shall be supplied with all temperature sensors.

b. Each temperature sensor shall be installed to echo telemetry to BYU’s STAEFA or Bailey control networks.

c. **High temperature water systems:** Sensors shall be 100 Ohm Platinum RTD’s in stainless steel thermal wells, matched to 0.5 degrees F. at 300 degrees F. (one for supply and one for return).

d. Each sensor shall be installed with a matching 4-20 ma transmitter for telemetry, calibrated to a span of 100 to 400° F.

e. Transmitter and housing shall be located at least 12 inches from any high temperature lines. If transmitter housing is connected to the thermal well by a conduit or pipe, they shall be separated by a union or other disconnecting device.

f. **Chilled water systems:** Sensors shall be 1000 Ohm Platinum RTD’s in stainless steel thermal wells, matched to 0.1° F. at 50° F. (one for supply and one for return).
g. Each sensor shall be installed with a matching 4-20 ma transmitter for telemetry, calibrated to a span of 40° F to 70° F.

Flow Meters and Applications at BYU

1. Differential Pressure, Annubar Flow Meters
   a. Application: Permanent CHW, HTW, natural gas, or steam meter for locations with large (greater than 3"), stable, and high velocity flow.
   b. Theory of Operation: A pressure sensor is used to measure the difference between the pressure of moving water in the system, (measured at the front of the Annubar) and the pressure of the static water in the system (measured at the back of the Annubar). The differential pressure is proportional to the velocity head of the flow, and using Bernoulli’s Principle, can be used to derive the velocity of the fluid. The cross-sectional area of the pipe and the velocity are then used to determine a volumetric flow-rate.

1. Pros:
   a. Cause minimal interference with the system being measured.
   b. Can be installed with the system in operation, and are relatively small.
   c. Differential pressure can be measured and verified with test gauges.

2. Cons:
   a. Accuracy between 5-10%.
   b. System interference increases with decreasing pipe size.
   c. Installation on other than a horizontal pipe, causes calibration problems.
   d. Require a differential pressure transducer and a square-root calculation.
   e. Differential pressure usually less than 10" H2O, making it difficult to verify or calibrate the DP-Cell.
   f. Do not perform well on unstable, turbulent, low flow, or low velocity systems.
   g. Air or sediment in the transducer lines, leaking transducer lines, machining tolerances, and built up deposits on the orifice can significantly impair accuracy.

2. Differential Pressure, Orifice Plate or Flow Nozzle Flow Meters
   a. Application: Permanent CHW, HTW, natural gas, or steam meter for locations with large (greater than 3"), and stable flow.
   b. Theory of Operation: A pressure sensor is used to measure the difference between the pressure of the faster moving water at the orifice, and the pressure of the slower moving water upstream of the orifice. The differential pressure can be related to the velocity head of the flow, and using Bernoulli’s Principle, can be used to derive the
velocity of the fluid. The cross-sectional area of the pipe and the velocity are then used to determine a volumetric flow-rate.

1. Pros:
   a. Differential pressure can be measured and verified with test gauges.
   b. Can be sized for a wide range of differential pressures usually 50" to 100" H2O.

2. Cons:
   a. Accuracy between 5-10%.
   b. Can interfere with the system being measured. Constant head loss in the system can become significant and expensive for any sizable system. Can also interfere with system drainage.
   c. Cannot be installed with the system in operation, and require flanges in the pipe.
   d. Installation on other than a horizontal pipe causes calibration problems.
   e. Require a differential pressure transducer and a square-root calculation.
   f. Do not perform well on unstable, turbulent, low flow, or low velocity systems.
   g. Air or sediment in the transducer lines, leaking transducer lines, machining tolerances, and built up deposits on the orifice can significantly impair accuracy.

3. Differential Pressure, Venturi Flow Meters

   a. Application: Permanent CHW, HTW, natural gas, or steam meter for locations with small pipe (less than or equal to 3"), and stable flow.

   b. Theory of Operation: A pressure sensor is used to measure the difference between the pressure of the faster moving water at the orifice, and the pressure of the slower moving water upstream of the orifice. The differential pressure can be related to the velocity head of the flow, and using Bernoulli’s Principle, can be used to derive the velocity of the fluid. The cross-sectional area of the pipe and the velocity are then used to determine a volumetric flow-rate.

   1. Pros:
      a. Differential pressure can be measured and verified with test gauges.
      b. Cause some interference with the system being measured, but less than an orifice plate, because 75% to 97% of the velocity head is reclaimed after the differential pressure is measured.
      c. Size can be matched to a limited range of differential pressures usually 50% to 100" H2O.

   2. Cons:
      a. Accuracy between 5-10%.
b. Cannot be installed with the system in operation, and usually are larger than orifice plates.
c. Cost increases significantly with increasing pipe size. Usually more expensive than orifice plates.
d. Installation on other than a horizontal pipe, causes calibration problems.
e. Require a differential pressure transducer and a square-root calculation.
f. Do not perform well on unstable, turbulent, low flow, or low velocity systems.
g. Air or sediment in the transducer lines, leaking transducer lines, machining tolerances, and built up deposits on the orifice can significantly impair accuracy.

4. Ultrasonic, Transit-time Flow Meters (Most often used)
   a. Application: Portable CHW or HTW. Permanent CHW, HTW, or natural gas meter.
   b. Theory of Operation: A sound wave is conducted at an angle, through a pipe with a flowing fluid. The time is measured for the sound to travel upstream, and compared with the time to travel downstream, to calculate the velocity of the fluid. The cross-sectional area of the pipe and the velocity are then used to determine a volumetric flow-rate.

   1. Pros:
      a. Accuracy between 1-2%, do not require a square-root calculation.
      b. Can be portable/non-invasive, or installed with the transducers in permanent contact with the fluid.
      c. Can be calibrated by switching the transducers.
      d. Cause no interference with the system being measured.
      e. Will work with both clean and dirty fluids.
      f. Same cost for large pipes as for small pipe sizes.

   2. Cons:
      a. Have been more expensive than other types of meters, although pricing has dropped in recent years.
      b. Transducers must be replaced periodically, more so with HTW applications.
      c. Same cost for small pipes as for large pipe sizes.

5. Ultrasonic, Doppler Flow Meters
   a. Application: Possible portable CHW meter for locations that are tight for space, with very turbulent flow.
   b. Theory of Operation: A sound wave is conducted through a pipe with a flowing fluid. The frequency of the echo, off of any particulate or alternate phase, is compared against the original sound frequency using the Doppler Theorem to calculate the
velocity of the fluid. The cross-sectional area of the pipe and the velocity are then used to determine a volumetric flow-rate.

1. Pros:
   a. Accuracy between 1-3%, do not require square-root calculation.
   b. Can be portable/non-invasive, or installed with the transducers in permanent contact with the fluid.
   c. Cause no interference with the system being measured.
   d. Less expensive than transit-time flow meters.
   e. Work well with unstable or turbulent systems.

2. Cons:
   a. Transducers must be replaced periodically.
   b. Will not work with clean fluids, unless the fluid is extremely turbulent at the location being metered.

6. Ultrasonic, Level Measurement and Flume Flow Meters
   a. Application: Permanent sewer or irrigation water meter.
   b. Theory of Operation: A sound wave is bounced off the surface of a fluid flowing in a known geometric shaped flume. The time is measured for the echo to return to the sensor, and compared to stored reference values to determine the water level. With the water level and the flow data for the specific geometric shape of the flume, a volumetric flow-rate can be determined.

1. Pros:
   a. Accuracy between 1-3%, do not require square-root calculation.
   b. After flume installation non-invasive.
   c. Cause minimal interference with the system being measured.
   d. Can be calibrated without any additional equipment

2. Cons:
   a. Very sensitive to calibration error.
   b. Expensive with the installation of the meter, the flume, and the manhole.
   c. Some types are sensitive to ambient temperature changes significantly impairing accuracy. The type that BYU specifies is not affected by temperature changes.

7. Strain Gauge, Target Flow Meters
   a. Application: Permanent CHW meter for locations with large (greater than 3"), and stable low.
   b. Theory of Operation: A strain gauge is used to measure the force exerted by the flowing fluid on a target of known size and position in the flow. The force exerted on
the target is proportional to the momentum of the moving fluid, and can be used to derive the velocity of the fluid. The cross-sectional area of the pipe and the velocity are then used to determine a volumetric flow-rate.

1. **Pros:**
   a. Accuracy between 1-2%.
   b. Cause minimal interference with the system being measured.
   c. After installation and calibration, they perform consistently and reliably.
   d. Some types can be installed with the system in operation.
   e. Does not require a pressure transducer, or connecting lines.

2) **Cons:**
   a. Cannot be calibrated or verified without a completely separate metering device.
   b. Require a square-root calculation, although accuracy is still high.
   c. Do not perform well on unstable or low velocity systems.
   d. Machining tolerances, orientation, built up deposits on the target, or temperature fluctuations can impair accuracy.

8. **Inductance or Magnetic Flow Meters**

   a. **Application:** Permanent sewer meter. Permanent CHW or HTW flow meter.

   b. **Theory of Operation:** A pair of electrical coils is located perpendicular to the flowing fluid, and a pulsed DC current in the coils produce an alternating magnetic field in the moving fluid. Electrodes in contact with the fluid measure the voltage induced by the flowing conductive fluid, which is proportional to the velocity of the fluid. The signal from the electrodes can be used to derive the velocity of the fluid. The cross-sectional area of the pipe and the velocity are then used to determine a volumetric flow-rate.

   1. **Pros:**
      a. Cause no interference with the system being measured.
      b. Accuracy less than 1% of flow rate, does not require a square-root calculation.
      c. Works well with clean or dirty fluids.
      d. Does not require a pressure transducer, or connecting lines.

   2. **Cons:**
      a. Cost increases rapidly with increasing size.
      b. Cannot be calibrated or verified without a completely separate metering device.
      c. Cannot be installed with the system in operation.
9. **Vortex Flow Meters**
   
a. **Application:** Permanent CHW, HTW, natural gas, or steam flow meter.
   
b. **Theory of Operation:** An obstruction, called a vortex shedder, is located in the flowing fluid. The resulting vortex created downstream oscillates from side to side at a rate proportional to the velocity of the fluid. Pressure sensors detect the oscillating pressure, and a computer is used to derive the velocity of the fluid from the timing of the vortex oscillations. The cross-sectional area of the pipe and the velocity are then used to determine a volumetric flow-rate.
   
   1. **Pros:**
      a. Cause minimal interference with the system being measured.
      b. Accuracy about 1% of flow rate, do not require a square-root calculation.
      c. Pressure transducer integrally mounted.
      d. Cost less than magnetic flow meters.
   
   2. **Cons:**
      a. Must be sized specifically for application.
      b. Do not perform well on unstable or low velocity systems.
      c. Cannot be calibrated or verified without a completely separate metering device.
      d. Cannot be installed with the system in operation.

10. **Coriolis Force Mass Flow Meters**
   
a. **Application:** Permanent steam or natural gas mass flow meter.
   
b. **Theory of Operation:** The inertial forces of the earth’s rotation and of the flowing gas or fluid create oscillation patterns proportional to the mass flowing in the pipe. Optical sensors measure the oscillations of a pipe with a fluid or gas flowing in it and compare the phase of the oscillations downstream with the phase upstream. A computer correlates the oscillations with a mass flow rate.
   
   1. **Pros:**
      a. Accuracy between 0.2 and 1%, do not require square-root calculation.
      b. Measure mass flow directly.
      c. Cause no interference with the system being measured.
      d. Work well with slurries and polyphase fluids.
   
   2. **Cons:**
      a. More expensive than other metering systems.
      b. Cannot be calibrated or verified without a completely separate metering device.
      c. Cannot be installed with the system in operation.
      d. Available for small pipes only, 3” or less.
11. **Turbine, Mechanical Flow Meters**

   a. **Application:** Permanent culinary water or natural gas meter for large pipe and flows.

   b. **Theory of Operation:** The flow is routed through a turbine, causing it to turn at a rate proportional to the volume of fluid passing through it. Mechanical means such as gears, are used to correlate the rotation of the turbine to the volume of flow.

   1. **Pros:**
      a. Accuracy between 1-2%.
      b. Do not require electricity to operate.

   2. **Cons:**
      a. Interfere with the system being measured.
      b. Cannot be installed with the system in operation.
      c. Mechanical parts deteriorate with time, use, and deposit build up impairing accuracy.
      d. Cannot be calibrated or verified without a completely separate metering device.
      e. Very limited flow range offerings, usually larger flow rates and pipe sizes.
      f. Do not perform well on low velocity systems.

12. **Propeller, Magnetic Flow Meters**

   a. **Application:** Permanent culinary water meter for small pipe and flows.

   b. **Theory of Operation:** A propeller with a magnet is placed in the flow, causing it to turn at a rate proportional to the velocity of fluid passing by it. The rotation of the magnet is detected electrically, without contact with the fluid, and the velocity of the fluid is derived from the rotation. The cross-sectional area of the pipe and the velocity are then used to determine a volumetric flow-rate.

   1. **Pros:**
      a. Accuracy between 1-2%.
      b. Have only one moving part, the impeller.
      c. Usually small and inexpensive.
      d. The only part in contact with the fluid is the impeller. No seals required.

   2. **Cons:**
      a. Cause some interference with the system being measured.
      b. Usually cannot be installed with the system in operation.
      c. Deposit build up on propeller impairs accuracy.
      d. Magnet collects ferrous particles in the fluid.
      e. Cannot be calibrated or verified without a completely separate metering device.
f. Very limited flow range offerings, usually smaller flow rates and pipe sizes.

13. Positive Displacement Flow Meters


   b. Theory of Operation: A cavity of known volume is filled with the flowing fluid, and then emptied, counting the number of times that the cavity is filled to determine the volume of fluid that has passed.

Specifications for Differential Pressure Type Water Flow Meters

1. Complete documentation including flow vs. differential pressure curves shall be supplied with all differential pressure flow meters.

2. Orifice plates, flow nozzles, and Venturi(s) shall be sized to produce between 50 and 100 inches of differential head at the full load condition of the circuit being measured.

3. For locations where the full flow condition is less than 100 gpm, the preferred differential pressure device for flow metering is a Venturi.

4. Approval to use an Annubar as a differential pressure device, including the size, must be obtained from the BYU Utilities Department prior to bid.

5. All orifice plates, flow nozzles, and Annubars shall be stainless steel. Venturi(s) shall be stainless steel, brass, or bronze.

6. All differential pressure transducers shall be installed with a 3-way isolation valve manifold.

7. Each differential pressure transducer shall be installed to echo telemetry to BYU’s STAEFA or Bailey control networks.

8. Differential pressure transducers shall be Bailey PTS Smart, Foxboro 823 Intelligent, or SMAR LD301 with internal square root function, non-interacting zero and span calibration, local LCD numeric flow indicator configurable to gpm, and 4-20 ma linear output proportional to flow. Exceptions by prior approval only.

9. High temperature water systems shall include a secondary differential pressure transducer with a span 20% that of the primary transducer.

10. Orifice plates shall be installed with factory manufactured flange taps. Field taps are not acceptable.
11. For metering of liquids, the impulse piping or tubing to the differential pressure transducers shall slope down to the transducers at an angle not less than 10 degrees, to allow any air in the lines to vent back into the main flow. The pressure taps shall also be installed not less than 10 degrees down from the horizon. Annubars shall be installed on the bottom of the pipe.

12. For metering of gases or steam, the impulse piping or tubing to the differential pressure transducers shall slope up to the transducers at an angle not less than 10 degrees, to allow any condensate in the lines to drain back into the main flow. The pressure taps shall also be installed not less than 10 degrees up from the horizon. Annubars shall be installed on the top of the pipe.

13. An exception is made for steam, if it is advantageous to use the condensate to insulate the differential pressure sensor from the higher temperature of the steam, then the impulse piping shall slope down to the transducers at an angle not less than 10 degrees, to allow any air in the lines to vent back into the main flow. The pressure taps shall also be installed not less than 10 degrees down from the horizon. Annubars shall be installed on the bottom of the pipe.

Specifications for Ultrasonic, Transit-time Flow Meters

1. Each meter shall be installed with a local LCD numeric flow indicator configurable to GPM.

2. Each meter shall output a 4-20 ma linear signal proportional to flow, and be installed to echo telemetry to BYU’s STAEFA or Bailey control networks.

Specifications for Ultrasonic, Level Measurement and Flume Flow Meters

1. Each meter shall be installed with a local LCD numeric flow indicator configurable to GPM and CFM.

2. Each meter shall output a 4-20 ma linear signal proportional to flow, and be installed to echo telemetry to BYU’s STAEFA or Bailey control networks.

Specifications for Strain Gauge, Target Flow Meter

1. Each meter shall be installed with a local LCD numeric flow indicator configurable to GPM.

2. Each meter shall output a 4-20 ma linear signal proportional to flow, and be installed to echo telemetry to BYU’s STAEFA or Bailey control networks.
Specifications for Inductance or Magnetic Flow Meter
1. Each meter shall be installed with a local LCD numeric flow indicator configurable to GPM.
2. Each meter shall output a 4-20 ma linear signal proportional to flow, and be installed to echo telemetry to BYU’s STAEFA or Bailey control networks.

Specifications for Vortex Flow Meter
1. Each meter shall be installed with a local LCD numeric flow indicator configurable to GPM.
2. Each meter shall output a 4-20 ma linear signal proportional to flow, and be installed to echo telemetry to BYU’s STAEFA or Bailey control networks.

Specifications for Coriolis Force Flow Meter
1. Each meter shall be installed with a local LCD numeric flow indicator configurable to PPM or KPH.
2. Each meter shall output a 4-20 ma linear signal proportional to flow, and be installed to echo telemetry to BYU’s STAEFA or Bailey control networks.

Specifications for Turbine, Mechanical Flow Meters
1. Each meter shall be installed with a local flow indicator and totalizer configurable to GPM.
2. Each meter shall output a 4-20 ma linear signal proportional to flow, and be installed to echo telemetry to BYU’s STAEFA or Bailey control networks.

Specifications for Propeller, Magnetic Flow Meters
1. Each meter shall be installed with a local flow indicator and totalizer configurable to GPM.
2. Each meter shall output a 4-20 ma linear signal proportional to flow, and be installed to echo telemetry to BYU’s STAEFA or Bailey control networks.

Specifications for Positive Displacement Flow Meters
1. Natural gas meters shall be Dresser Measurement TQM ROOTS Meter with temperature compensation and counter with pulser.
2. Each meter shall be installed with a local flow indicator and totalizer configurable to CFM.
3. Each meter shall output a pulsed signal proportional to flow, and be installed to echo telemetry to BYU’s STAEFA or Bailey control networks.