2.3     ADHESIVES

A.     Materials shall be compatible with insulation materials, jackets, and substrates and for bonding insulation to itself and to surfaces to be insulated unless otherwise indicated.

B.     Calcium Silicate Adhesive: Fibrous, sodium-silicate-based adhesive with a service temperature range of 50 to 800 deg F.

    1.     For indoor applications, adhesive shall have a VOC content of 80 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
    2.     Adhesive shall comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."

C.     Cellular-Glass Adhesive: Two-component, thermosetting urethane adhesive containing no flammable solvents, with a service temperature range of minus 100 to plus 200 deg F.

    1.     For indoor applications, adhesive shall have a VOC content of 50 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
    2.     Adhesive shall comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."

D.     Flexible Elastomeric and Polyolefin Adhesive: Comply with MIL-A-24179A, Type II, Class I.

    1.     For indoor applications, adhesive shall have a VOC content of 50 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
    2.     Adhesive shall comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."

E.     Mineral-Fiber Adhesive: Comply with MIL-A-3316C, Class 2, Grade A.

    1.     For indoor applications, adhesive shall have a VOC content of 80 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
    2.     Adhesive shall comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the

Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."

F.    ASJ Adhesive, and FSK and PVDC Jacket Adhesive: Comply with MIL-A-3316C, Class 2, Grade A for bonding insulation jacket lap seams and joints.

1.    For indoor applications, adhesive shall have a VOC content of 50 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).

2.    Adhesive shall comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."

G.    PVC Jacket Adhesive: Compatible with PVC jacket.

1.    For indoor applications, adhesive shall have a VOC content of 50 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).

2.    Adhesive shall comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."

2.4    MASTICS

A.    Materials shall be compatible with insulation materials, jackets, and substrates; comply with MIL-PRF-19565C, Type II.

1.    For indoor applications, use mastics that have a VOC content of 50 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).

B.    Vapor-Barrier Mastic: Water based; suitable for indoor use on below-ambient services.

1.    Water-Vapor Permeance: ASTM E 96/E 96M, Procedure B, 0.013 perm at 43-mil dry film thickness.

2.    Service Temperature Range: Minus 20 to plus 180 deg F.

3.    Solids Content: ASTM D 1644, 58 percent by volume and 70 percent by weight.

4.    Color: White.

C.    Vapor-Barrier Mastic: Solvent based; suitable for indoor use on below-ambient services.

1.    Water-Vapor Permeance: ASTM F 1249, 0.05 perm at 35-mil dry film thickness.

23 07 19 – 6

2.      Service Temperature Range: 0 to 180 deg F.
3.      Solids Content: ASTM D 1644, 44 percent by volume and 62 percent by weight.
4.      Color: White.

D.     Vapor-Barrier Mastic: Solvent based; suitable for outdoor use on below-ambient services.

1.      Water-Vapor Permeance: ASTM F 1249, 0.05 perm at 30-mil dry film thickness.
2.      Service Temperature Range: Minus 50 to plus 220 deg F.
3.      Solids Content: ASTM D 1644, 33 percent by volume and 46 percent by weight.
4.      Color: White.

E.     Breather Mastic: Water based; suitable for indoor and outdoor use on above-ambient services.

1.      Water-Vapor Permeance: ASTM F 1249, 1.8 perms at 0.0625-inch dry film thickness.
2.      Service Temperature Range: Minus 20 to plus 180 deg F.
3.      Solids Content: 60 percent by volume and 66 percent by weight.
4.      Color: White.

2.5     LAGGING ADHESIVES

A.     Description: Comply with MIL-A-3316C, Class I, Grade A and shall be compatible with insulation materials, jackets, and substrates.

1.      For indoor applications, use lagging adhesives that have a VOC content of 50 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
2.      Fire-resistant, water-based lagging adhesive and coating for use indoors to adhere fire-resistant lagging cloths over pipe insulation.
3.      Service Temperature Range: 0 to plus 180 deg F.
4.      Color: White.

2.6     SEALANTS

A.     Joint Sealants:

1.      Materials shall be compatible with insulation materials, jackets, and substrates.
2.      Permanently flexible, elastomeric sealant.
3.      Service Temperature Range: Minus 100 to plus 300 deg F.
4.      Color: White or gray.

5.	For indoor applications, sealants shall have a VOC content of 420 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).

6.	Sealants shall comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."

B.	FSK and Metal Jacket Flashing Sealants:

1.	Materials shall be compatible with insulation materials, jackets, and substrates.

2.	Fire- and water-resistant, flexible, elastomeric sealant.

3.	Service Temperature Range: Minus 40 to plus 250 deg F.

4.	Color: Aluminum.

5.	For indoor applications, sealants shall have a VOC content of 420 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).

6.	Sealants shall comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."

C.	ASJ Flashing Sealants, and Vinyl, PVDC, and PVC Jacket Flashing Sealants:

1.	Materials shall be compatible with insulation materials, jackets, and substrates.

2.	Fire- and water-resistant, flexible, elastomeric sealant.

3.	Service Temperature Range: Minus 40 to plus 250 deg F.

4.	Color: White.

5.	For indoor applications, sealants shall have a VOC content of 420 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).

6.	Sealants shall comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."

2.7	FACTORY-APPLIED JACKETS

A.	Insulation system schedules indicate factory-applied jackets on various applications. When factory-applied jackets are indicated, comply with the following:

1.	ASJ: White, kraft-paper, fiberglass-reinforced scrim with aluminum-foil backing; complying with ASTM C 1136, Type I.

23 07 19 – 8

2. ASJ-SSL: ASJ with self-sealing, pressure-sensitive, acrylic-based adhesive covered by a removable protective strip; complying with ASTM C 1136, Type I.
3. FSK Jacket: Aluminum-foil, fiberglass-reinforced scrim with kraft-paper backing; complying with ASTM C 1136, Type II.
4. FSP Jacket: Aluminum-foil, fiberglass-reinforced scrim with polyethylene backing; complying with ASTM C 1136, Type II.
5. PVDC Jacket for Indoor Applications: 4-mil- thick, white PVDC biaxially oriented barrier film with a permeance at 0.02 perm when tested according to ASTM E 96/E 96M and with a flame-spread index of 5 and a smoke-developed index of 20 when tested according to ASTM E 84.
6. PVDC Jacket for Outdoor Applications: 6-mil- thick, white PVDC biaxially oriented barrier film with a permeance at 0.01 perm when tested according to ASTM E 96/E 96M and with a flame-spread index of 5 and a smoke-developed index of 25 when tested according to ASTM E 84.
7. PVDC-SSL Jacket: PVDC jacket with a self-sealing, pressure-sensitive, acrylic-based adhesive covered by a removable protective strip.
8. Vinyl Jacket: White vinyl with a permeance of 1.3 perms when tested according to ASTM E 96/E 96M, Procedure A, and complying with NFPA 90A and NFPA 90B.

2.8 FIELD-APPLIED FABRIC-REINFORCING MESH

A. Woven Glass-Fiber Fabric: Approximately 2 oz./sq. yd. with a thread count of 10 strands by 10 strands/sq. in. for covering pipe and pipe fittings.

B. Woven Polyester Fabric: Approximately 1 oz./sq. yd. with a thread count of 10 strands by 10 strands/sq. in., in a Leno weave, for pipe.

2.9 FIELD-APPLIED CLOTHS

A. Woven Glass-Fiber Fabric: Comply with MIL-C-20079H, Type I, plain weave, and presized a minimum of 8 oz./sq. yd..

2.10 FIELD-APPLIED JACKETS

A. Field-applied jackets shall comply with ASTM C 921, Type I, unless otherwise indicated.

B. Metal Jacket:

1. Stainless-Steel Jacket: ASTM A 167 or ASTM A 240/A 240M.

a. Factory cut and rolled to size.
b. Material, finish, and thickness are indicated in field-applied jacket schedules.

  c.  Moisture Barrier for Indoor Applications: 3-mil- thick, heat-bonded polyethylene and kraft paper.

  d.  Moisture Barrier for Outdoor Applications: 3-mil- thick, heat-bonded polyethylene and kraft paper.

  e.  Factory-Fabricated Fitting Covers:

    1)  Same material, finish, and thickness as jacket.
    2)  Preformed 2-piece or gore, 45- and 90-degree, short- and long-radius elbows.
    3)  Tee covers.
    4)  Flange and union covers.
    5)  End caps.
    6)  Beveled collars.
    7)  Valve covers.
    8)  Field fabricate fitting covers only if factory-fabricated fitting covers are not available.

## 2.11  TAPES

A.  ASJ Tape: White vapor-retarder tape matching factory-applied jacket with acrylic adhesive, complying with ASTM C 1136.

  1.  Width: 3 inches.
  2.  Thickness: 11.5 mils.
  3.  Adhesion: 90 ounces force/inch in width.
  4.  Elongation: 2 percent.
  5.  Tensile Strength: 40 lbf/inch in width.
  6.  ASJ Tape Disks and Squares: Precut disks or squares of ASJ tape.

B.  FSK Tape: Foil-face, vapor-retarder tape matching factory-applied jacket with acrylic adhesive; complying with ASTM C 1136.

  1.  Width: 3 inches.
  2.  Thickness: 6.5 mils.
  3.  Adhesion: 90 ounces force/inch in width.
  4.  Elongation: 2 percent.
  5.  Tensile Strength: 40 lbf/inch in width.
  6.  FSK Tape Disks and Squares: Precut disks or squares of FSK tape.

C.  PVC Tape: White vapor-retarder tape matching field-applied PVC jacket with acrylic adhesive; suitable for indoor and outdoor applications.

  1.  Width: 2 inches.
  2.  Thickness: 6 mils.
  3.  Adhesion: 64 ounces force/inch in width.
  4.  Elongation: 500 percent.
  5.  Tensile Strength: 18 lbf/inch in width.

D. Aluminum-Foil Tape: Vapor-retarder tape with acrylic adhesive.

1. Width: 2 inches.
2. Thickness: 3.7 mils.
3. Adhesion: 100 ounces force/inch in width.
4. Elongation: 5 percent.
5. Tensile Strength: 34 lbf/inch in width.

2.12 SECUREMENTS

A. Bands:

1. Stainless Steel: ASTM A 167 or ASTM A 240/A 240M, Type 304 or Type 316; 0.015 inch thick, 1/2 inch wide with closed seal.

B. Staples: Outward-clinching insulation staples, nominal 3/4-inch- wide, stainless steel or Monel.

C. Wire: 0.062-inch soft-annealed, stainless steel.

# PART 3 - EXECUTION

3.1 EXAMINATION

A. Examine substrates and conditions for compliance with requirements for installation tolerances and other conditions affecting performance of insulation application.

1. Verify that systems to be insulated have been tested and are free of defects.
2. Verify that surfaces to be insulated are clean and dry.
3. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 PREPARATION

A. Surface Preparation: Clean and dry surfaces to receive insulation. Remove materials that will adversely affect insulation application.

B. Surface Preparation: Clean and prepare surfaces to be insulated. Before insulating, apply a corrosion coating to insulated surfaces as follows:

1. Stainless Steel: Coat 300 series stainless steel with an epoxy primer 5 mils thick and an epoxy finish 5 mils thick if operating in a temperature range between 140 and 300 deg F. Consult coating manufacturer for appropriate coating materials and application methods for operating temperature range.

2. Carbon Steel: Coat carbon steel operating at a service temperature between 32 and 300 deg F with an epoxy coating. Consult coating manufacturer for appropriate coating materials and application methods for operating temperature range.

C. Coordinate insulation installation with the trade installing heat tracing. Comply with requirements for heat tracing that apply to insulation.

D. Mix insulating cements with clean potable water; if insulating cements are to be in contact with stainless-steel surfaces, use demineralized water.

3.3 GENERAL INSTALLATION REQUIREMENTS

A. Install insulation materials, accessories, and finishes with smooth, straight, and even surfaces; free of voids throughout the length of piping including fittings, valves, and specialties.

B. Install insulation materials, forms, vapor barriers or retarders, jackets, and thicknesses required for each item of pipe system as specified in insulation system schedules.

C. Install accessories compatible with insulation materials and suitable for the service. Install accessories that do not corrode, soften, or otherwise attack insulation or jacket in either wet or dry state.

D. Install insulation with longitudinal seams at top and bottom of horizontal runs.

E. Install multiple layers of insulation with longitudinal and end seams staggered.

F. Do not weld brackets, clips, or other attachment devices to piping, fittings, and specialties.

G. Keep insulation materials dry during application and finishing.

H. Install insulation with tight longitudinal seams and end joints. Bond seams and joints with adhesive recommended by insulation material manufacturer.

I. Install insulation with least number of joints practical.

J. Where vapor barrier is indicated, seal joints, seams, and penetrations in insulation at hangers, supports, anchors, and other projections with vapor-barrier mastic.

1. Install insulation continuously through hangers and around anchor attachments.
2. For insulation application where vapor barriers are indicated, extend insulation on anchor legs from point of attachment to supported item to point of attachment to structure. Taper and seal ends at attachment to structure with vapor-barrier mastic.

23 07 19 – 12

3. Install insert materials and install insulation to tightly join the insert. Seal insulation to insulation inserts with adhesive or sealing compound recommended by insulation material manufacturer.

4. Cover inserts with jacket material matching adjacent pipe insulation. Install shields over jacket, arranged to protect jacket from tear or puncture by hanger, support, and shield.

K. Apply adhesives, mastics, and sealants at manufacturer's recommended coverage rate and wet and dry film thicknesses.

L. Install insulation with factory-applied jackets as follows:

1. Draw jacket tight and smooth.

2. Cover circumferential joints with 3-inch- wide strips, of same material as insulation jacket. Secure strips with adhesive and outward clinching staples along both edges of strip, spaced 4 inches o.c.

3. Overlap jacket longitudinal seams at least 1-1/2 inches. Install insulation with longitudinal seams at bottom of pipe. Clean and dry surface to receive self-sealing lap. Staple laps with outward clinching staples along edge at 2 inches o.c.

    a. For below-ambient services, apply vapor-barrier mastic over staples.

4. Cover joints and seams with tape, according to insulation material manufacturer's written instructions, to maintain vapor seal.

5. Where vapor barriers are indicated, apply vapor-barrier mastic on seams and joints and at ends adjacent to pipe flanges and fittings.

M. Cut insulation in a manner to avoid compressing insulation more than 75 percent of its nominal thickness.

N. Finish installation with systems at operating conditions. Repair joint separations and cracking due to thermal movement.

O. Repair damaged insulation facings by applying same facing material over damaged areas. Extend patches at least 4 inches beyond damaged areas. Adhere, staple, and seal patches similar to butt joints.

P. For above-ambient services, do not install insulation to the following:

1. Vibration-control devices.
2. Testing agency labels and stamps.
3. Nameplates and data plates.
4. Manholes.
5. Handholes.
6. Cleanouts.

23 07 19 – 13

## 3.4 PENETRATIONS

A. Insulation Installation at Roof Penetrations: Install insulation continuously through roof penetrations.

    1. Seal penetrations with flashing sealant.
    2. For applications requiring only indoor insulation, terminate insulation above roof surface and seal with joint sealant. For applications requiring indoor and outdoor insulation, install insulation for outdoor applications tightly joined to indoor insulation ends. Seal joint with joint sealant.
    3. Extend jacket of outdoor insulation outside roof flashing at least 2 inches below top of roof flashing.
    4. Seal jacket to roof flashing with flashing sealant.

B. Insulation Installation at Underground Exterior Wall Penetrations: Terminate insulation flush with sleeve seal. Seal terminations with flashing sealant.

C. Insulation Installation at Aboveground Exterior Wall Penetrations: Install insulation continuously through wall penetrations.

    1. Seal penetrations with flashing sealant.
    2. For applications requiring only indoor insulation, terminate insulation inside wall surface and seal with joint sealant. For applications requiring indoor and outdoor insulation, install insulation for outdoor applications tightly joined to indoor insulation ends. Seal joint with joint sealant.
    3. Extend jacket of outdoor insulation outside wall flashing and overlap wall flashing at least 2 inches.
    4. Seal jacket to wall flashing with flashing sealant.

D. Insulation Installation at Interior Wall and Partition Penetrations (That Are Not Fire Rated): Install insulation continuously through walls and partitions.

E. Insulation Installation at Fire-Rated Wall and Partition Penetrations: Install insulation continuously through penetrations of fire-rated walls and partitions. Installation shall maintain a UL fire rated assembly.

F. Insulation Installation at Floor Penetrations:

    1. Pipe: Install insulation continuously through floor penetrations.
    2. Installation shall maintain a UL fire rated assembly.

## 3.5 GENERAL PIPE INSULATION INSTALLATION

A. Requirements in this article generally apply to all insulation materials except where more specific requirements are specified in various pipe insulation material installation articles.

B. Insulation Installation on Fittings, Valves, Strainers, Flanges, and Unions:

1. Install insulation over fittings, valves, strainers, flanges, unions, and other specialties with continuous thermal and vapor-retarder integrity unless otherwise indicated.

2. Insulate pipe elbows using preformed fitting insulation or mitered fittings made from same material and density as adjacent pipe insulation. Each piece shall be butted tightly against adjoining piece and bonded with adhesive. Fill joints, seams, voids, and irregular surfaces with insulating cement finished to a smooth, hard, and uniform contour that is uniform with adjoining pipe insulation.

3. Insulate tee fittings with preformed fitting insulation or sectional pipe insulation of same material and thickness as used for adjacent pipe. Cut sectional pipe insulation to fit. Butt each section closely to the next and hold in place with tie wire. Bond pieces with adhesive.

4. Insulate valves using preformed fitting insulation or sectional pipe insulation of same material, density, and thickness as used for adjacent pipe. Overlap adjoining pipe insulation by not less than two times the thickness of pipe insulation, or one pipe diameter, whichever is thicker. For valves, insulate up to and including the bonnets, valve stuffing-box studs, bolts, and nuts. Fill joints, seams, and irregular surfaces with insulating cement.

5. Insulate strainers using preformed fitting insulation or sectional pipe insulation of same material, density, and thickness as used for adjacent pipe. Overlap adjoining pipe insulation by not less than two times the thickness of pipe insulation, or one pipe diameter, whichever is thicker. Fill joints, seams, and irregular surfaces with insulating cement. Insulate strainers so strainer basket flange or plug can be easily removed and replaced without damaging the insulation and jacket. Provide a removable reusable insulation cover. For below-ambient services, provide a design that maintains vapor barrier.

6. Insulate flanges and unions using a section of oversized preformed pipe insulation. Overlap adjoining pipe insulation by not less than two times the thickness of pipe insulation, or one pipe diameter, whichever is thicker.

7. Cover segmented insulated surfaces with a layer of finishing cement and coat with a mastic. Install vapor-barrier mastic for below-ambient services and a breather mastic for above-ambient services. Reinforce the mastic with fabric-reinforcing mesh. Trowel the mastic to a smooth and well-shaped contour.

8. For services not specified to receive a field-applied jacket except for flexible elastomeric and polyolefin, install fitted PVC cover over elbows, tees, strainers, valves, flanges, and unions. Terminate ends with PVC end caps. Tape PVC covers to adjoining insulation facing using PVC tape.

9. Stencil or label the outside insulation jacket of each union with the word "union." Match size and color of pipe labels.

C. Insulate instrument connections for thermometers, pressure gages, pressure temperature taps, test connections, flow meters, sensors, switches, and

transmitters on insulated pipes. Shape insulation at these connections by tapering it to and around the connection with insulating cement and finish with finishing cement, mastic, and flashing sealant.

D. Install removable insulation covers at locations indicated. Installation shall conform to the following:

1. Make removable flange and union insulation from sectional pipe insulation of same thickness as that on adjoining pipe. Install same insulation jacket as adjoining pipe insulation.
2. When flange and union covers are made from sectional pipe insulation, extend insulation from flanges or union long at least two times the insulation thickness over adjacent pipe insulation on each side of flange or union. Secure flange cover in place with stainless-steel or aluminum bands. Select band material compatible with insulation and jacket.
3. Construct removable valve insulation covers in same manner as for flanges, except divide the two-part section on the vertical center line of valve body.
4. When covers are made from block insulation, make two halves, each consisting of mitered blocks wired to stainless-steel fabric. Secure this wire frame, with its attached insulation, to flanges with tie wire. Extend insulation at least 2 inches over adjacent pipe insulation on each side of valve. Fill space between flange or union cover and pipe insulation with insulating cement. Finish cover assembly with insulating cement applied in two coats. After first coat is dry, apply and trowel second coat to a smooth finish.
5. Unless a PVC jacket is indicated in field-applied jacket schedules, finish exposed surfaces with a metal jacket.

3.6 INSTALLATION OF CALCIUM SILICATE INSULATION

A. Insulation Installation on Straight Pipes and Tubes:

1. Secure single-layer insulation with stainless-steel bands at 12-inch intervals and tighten bands without deforming insulation materials.
2. Install two-layer insulation with joints tightly butted and staggered at least 3 inches. Secure inner layer with wire spaced at 12-inch intervals. Secure outer layer with stainless-steel bands at 12-inch intervals.
3. Apply a skim coat of mineral-fiber, hydraulic-setting cement to insulation surface. When cement is dry, apply flood coat of lagging adhesive and press on one layer of glass cloth or tape. Overlap edges at least 1 inch. Apply finish coat of lagging adhesive over glass cloth or tape. Thin finish coat to achieve smooth, uniform finish.

B. Insulation Installation on Pipe Flanges:

1. Install preformed pipe insulation to outer diameter of pipe flange.

2. Make width of insulation section same as overall width of flange and bolts, plus twice the thickness of pipe insulation.

3. Fill voids between inner circumference of flange insulation and outer circumference of adjacent straight pipe segments with cut sections of block insulation of same material and thickness as pipe insulation.

4. Finish flange insulation same as pipe insulation.

C. Insulation Installation on Pipe Fittings and Elbows:

1. Install preformed sections of same material as straight segments of pipe insulation when available. Secure according to manufacturer's written instructions.

2. When preformed insulation sections of insulation are not available, install mitered sections of calcium silicate insulation. Secure insulation materials with wire or bands.

3. Finish fittings insulation same as pipe insulation.

D. Insulation Installation on Valves and Pipe Specialties:

1. Install mitered segments of calcium silicate insulation to valve body. Arrange insulation to permit access to packing and to allow valve operation without disturbing insulation.

2. Install insulation to flanges as specified for flange insulation application.

3. Finish valve and specialty insulation same as pipe insulation.

3.7 INSTALLATION OF CELLULAR-GLASS INSULATION

A. Insulation Installation on Straight Pipes and Tubes:

1. Secure each layer of insulation to pipe with wire or bands and tighten bands without deforming insulation materials.

2. Where vapor barriers are indicated, seal longitudinal seams, end joints, and protrusions with vapor-barrier mastic and joint sealant.

3. For insulation with factory-applied jackets on above-ambient services, secure laps with outward-clinched staples at 6 inches o.c.

4. For insulation with factory-applied jackets on below-ambient services, do not staple longitudinal tabs. Instead, secure tabs with additional adhesive as recommended by insulation material manufacturer and seal with vapor-barrier mastic and flashing sealant.

B. Insulation Installation on Pipe Flanges:

1. Install preformed pipe insulation to outer diameter of pipe flange.

2. Make width of insulation section same as overall width of flange and bolts, plus twice the thickness of pipe insulation.

3. Fill voids between inner circumference of flange insulation and outer circumference of adjacent straight pipe segments with cut sections of cellular-glass block insulation of same thickness as pipe insulation.
4. Install jacket material with manufacturer's recommended adhesive, overlap seams at least 1 inch, and seal joints with flashing sealant.

C. Insulation Installation on Pipe Fittings and Elbows:

1. Install preformed sections of same material as straight segments of pipe insulation when available. Secure according to manufacturer's written instructions.
2. When preformed sections of insulation are not available, install mitered sections of cellular-glass insulation. Secure insulation materials with wire or bands.

D. Insulation Installation on Valves and Pipe Specialties:

1. Install preformed sections of cellular-glass insulation to valve body.
2. Arrange insulation to permit access to packing and to allow valve operation without disturbing insulation.
3. Install insulation to flanges as specified for flange insulation application.

3.8 INSTALLATION OF FLEXIBLE ELASTOMERIC INSULATION

A. Seal longitudinal seams and end joints with manufacturer's recommended adhesive to eliminate openings in insulation that allow passage of air to surface being insulated.

B. Insulation Installation on Pipe Flanges:

1. Install pipe insulation to outer diameter of pipe flange.
2. Make width of insulation section same as overall width of flange and bolts, plus twice the thickness of pipe insulation.
3. Fill voids between inner circumference of flange insulation and outer circumference of adjacent straight pipe segments with cut sections of sheet insulation of same thickness as pipe insulation.
4. Secure insulation to flanges and seal seams with manufacturer's recommended adhesive to eliminate openings in insulation that allow passage of air to surface being insulated.

C. Insulation Installation on Pipe Fittings and Elbows:

1. Install mitered sections of pipe insulation.
2. Secure insulation materials and seal seams with manufacturer's recommended adhesive to eliminate openings in insulation that allow passage of air to surface being insulated.

D. Insulation Installation on Valves and Pipe Specialties:

1. Install preformed valve covers manufactured of same material as pipe insulation when available.
2. When preformed valve covers are not available, install cut sections of pipe and sheet insulation to valve body. Arrange insulation to permit access to packing and to allow valve operation without disturbing insulation.
3. Install insulation to flanges as specified for flange insulation application.
4. Secure insulation to valves and specialties and seal seams with manufacturer's recommended adhesive to eliminate openings in insulation that allow passage of air to surface being insulated.

## 3.9 INSTALLATION OF MINERAL-FIBER INSULATION

A. Insulation Installation on Straight Pipes and Tubes:

1. Secure each layer of preformed pipe insulation to pipe with wire or bands and tighten bands without deforming insulation materials.
2. Where vapor barriers are indicated, seal longitudinal seams, end joints, and protrusions with vapor-barrier mastic and joint sealant.
3. For insulation with factory-applied jackets on above-ambient surfaces, secure laps with outward-clinched staples at 6 inches o.c.
4. For insulation with factory-applied jackets on below-ambient surfaces, do not staple longitudinal tabs. Instead, secure tabs with additional adhesive as recommended by insulation material manufacturer and seal with vapor-barrier mastic and flashing sealant.

B. Insulation Installation on Pipe Flanges:

1. Install preformed pipe insulation to outer diameter of pipe flange.
2. Make width of insulation section same as overall width of flange and bolts, plus twice the thickness of pipe insulation.
3. Fill voids between inner circumference of flange insulation and outer circumference of adjacent straight pipe segments with mineral-fiber blanket insulation.
4. Install jacket material with manufacturer's recommended adhesive, overlap seams at least 1 inch, and seal joints with flashing sealant.

C. Insulation Installation on Pipe Fittings and Elbows:

1. Install preformed sections of same material as straight segments of pipe insulation when available.
2. When preformed insulation elbows and fittings are not available, install mitered sections of pipe insulation, to a thickness equal to adjoining pipe insulation. Secure insulation materials with wire or bands.

D. Insulation Installation on Valves and Pipe Specialties:

1. Install preformed sections of same material as straight segments of pipe insulation when available.
2. When preformed sections are not available, install mitered sections of pipe insulation to valve body.
3. Arrange insulation to permit access to packing and to allow valve operation without disturbing insulation.
4. Install insulation to flanges as specified for flange insulation application.

3.10   FIELD-APPLIED JACKET INSTALLATION

A.   Where metal jackets are indicated, install with 2-inch overlap at longitudinal seams and end joints. Overlap longitudinal seams arranged to shed water. Seal end joints with weatherproof sealant recommended by insulation manufacturer. Secure jacket with stainless-steel bands 12 inches o.c. and at end joints.

3.11   FINISHES

A.   Pipe Insulation with ASJ, Glass-Cloth, or Other Paintable Jacket Material: Paint jacket with paint system identified below and as specified in Section 09 90 00 "Painting and Coating."

1. Flat Acrylic Finish:  Two finish coats over a primer that is compatible with jacket material and finish coat paint. Add fungicidal agent to render fabric mildew proof.

a.   Finish Coat Material: Interior, flat, latex-emulsion size.

B.   Flexible Elastomeric Thermal Insulation: After adhesive has fully cured, apply two coats of insulation manufacturer's recommended protective coating.

C.   Color: Final color as selected by Architect. Vary first and second coats to allow visual inspection of the completed Work.

D.   Do not field paint aluminum or stainless-steel jackets.

3.12   FIELD QUALITY CONTROL

A.   Testing Agency:  Engage a qualified testing agency to perform tests and inspections.

B.   Perform tests and inspections.

C.   Tests and Inspections:

1. Inspect pipe, fittings, strainers, and valves, randomly selected by Architect, by removing field-applied jacket and insulation in layers in reverse order of their installation. Extent of inspection shall be limited to three locations of straight pipe, three locations of threaded fittings, three

locations of welded fittings, two locations of threaded strainers, two locations of welded strainers, three locations of threaded valves, and three locations of flanged valves for each pipe service defined in the "Piping Insulation Schedule, General" Article.

D.    All insulation applications will be considered defective Work if sample inspection reveals noncompliance with requirements.

3.13    PIPING INSULATION SCHEDULE, GENERAL

A.    Acceptable preformed pipe and tubular insulation materials and thicknesses are identified for each piping system and pipe size range. If more than one material is listed for a piping system, selection from materials listed is Contractor's option.

B.    Items Not Insulated: Unless otherwise indicated, do not install insulation on the following:

1.    Drainage piping located in crawl spaces.
2.    Underground piping.
3.    Chrome-plated pipes and fittings unless there is a potential for personnel injury.

3.14    INDOOR PIPING INSULATION SCHEDULE

A.    Condensate and Equipment Drain Water below 60 Deg F:

1.    All Pipe Sizes: Insulation shall be one of the following:

a.    Cellular Glass:  1-1/2 inches thick.
b.    Flexible Elastomeric:  1 inch thick.
c.    Mineral-Fiber, Preformed Pipe Insulation, Type I:  1 inch thick.

B.    Generator Cooling Water Supply and Return, above 200 Deg F:

1.    NPS 3/4 and Smaller: Insulation shall be one of the following:

a.    Calcium Silicate:  2 inches thick.
b.    Cellular Glass:  2 inches (75 mm) thick.
c.    Mineral-Fiber, Preformed Pipe, Type I or II:  2 inches (50 mm) thick.

2.    NPS 1 and Larger: Insulation shall be one of the following:

a.    Calcium Silicate:  2 inches thick.
b.    Cellular Glass:  2 inches (100 mm) thick.
c.    Mineral-Fiber, Preformed Pipe, Type I or II:  2 inches (75 mm) thick.

C. Generator Exhaust System Piping, and Equipment, 1200 Deg F:

    1. Insulation shall be one of the following:

        a. Calcium Silicate Type II: 3 inches thick applied in 1 inch overlapping layers.

D. Refrigerant Suction and Hot-Gas Piping:

    1. All Pipe Sizes: Insulation shall be one of the following:

        a. Cellular Glass: 1-1/2 inches thick.
        b. Flexible Elastomeric: 1 inch (25 mm) thick.

E. Refrigerant Suction and Hot-Gas Flexible Tubing:

    1. All Pipe Sizes: Insulation shall be one of the following:

        a. Flexible Elastomeric: 1 inch thick.

3.15 OUTDOOR, ABOVEGROUND PIPING INSULATION SCHEDULE

A. Generator Cooling Water Supply and Return, above 200 Deg F:

    1. All Pipe Sizes: Insulation shall be one of the following:

        a. Calcium Silicate: 3 inches thick.

        b. Cellular Glass: 3 inches thick.

B. Generator Exhaust System Piping, and Equipment, 1200 Deg F:

    1. All Pipe Sizes: Insulation shall be one of the following:
    2. Calcium Silicate: Type II, 3 inches thick applied in 1 inch overlapping layers.

C. Refrigerant Suction and Hot-Gas Piping:

    1. All Pipe Sizes: Insulation shall be one of the following:

        a. Cellular Glass: 2 inches thick.
        b. Flexible Elastomeric: 2 inches thick.

D. Refrigerant Suction and Hot-Gas Flexible Tubing:

    1. All Pipe Sizes: Insulation shall be one of the following:

        a. Flexible Elastomeric: 2 inches thick.

23 07 19 – 22

3.16    INDOOR, FIELD-APPLIED JACKET SCHEDULE

    A.    Install jacket over insulation material. For insulation with factory-applied jacket, install the field-applied jacket over the factory-applied jacket.

    B.    If more than one material is listed, selection from materials listed is Contractor's option.

    C.    Piping, Concealed:

        1.    None.

    D.    Piping, Exposed:

        1.    Stainless Steel, Type 304 or Type 316, Smooth 2B Finish:   0.020 inch 0.024 inch thick.

3.17    OUTDOOR, FIELD-APPLIED JACKET SCHEDULE

    A.    Install jacket over insulation material. For insulation with factory-applied jacket, install the field-applied jacket over the factory-applied jacket.

    B.    If more than one material is listed, selection from materials listed is Contractor's option.

    C.    Piping, Concealed:

        1.    Stainless Steel, Type  304 or 316, Smooth 2B Finish:  0.020 inch thick.

    D.    Piping, Exposed:

        1.    Stainless Steel, Type  304 or 316, Smooth 2B Finish with Z-Shaped Locking Seam:  0.020 inch thick.


**END OF SECTION**

## SECTION 23 09 23
## DIRECT DIGITAL CONTROL (DDC) SYSTEM FOR HVAC

# PART 1 - GENERAL

## 1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

## 1.2 SUMMARY

A. Section Includes:

1. DDC system for monitoring and controlling of HVAC systems.
2. Delivery of selected control devices to equipment and systems manufacturers for factory installation and to HVAC systems installers for field installation.

## 1.3 DEFINITIONS

A. Algorithm: A logical procedure for solving a recurrent mathematical problem. A prescribed set of well-defined rules or processes for solving a problem in a finite number of steps.

B. Analog: A continuously varying signal value, such as current, flow, pressure, or temperature.

C. BACnet Specific Definitions:

1. BACnet: Building Automation Control Network Protocol, ASHRAE 135. A communications protocol allowing devices to communicate data over and services over a network.
2. BACnet Interoperability Building Blocks (BIBBs): BIBB defines a small portion of BACnet functionality that is needed to perform a particular task. BIBBs are combined to build the BACnet functional requirements for a device.
3. BACnet/IP: Defines and allows using a reserved UDP socket to transmit BACnet messages over IP networks. A BACnet/IP network is a collection of one or more IP subnetworks that share the same BACnet network number.
4. BACnet Testing Laboratories (BTL): Organization responsible for testing products for compliance with ASHRAE 135, operated under direction of BACnet International.

5. PICS (Protocol Implementation Conformance Statement): Written document that identifies the particular options specified by BACnet that are implemented in a device.

D. Binary: Two-state signal where a high signal level represents ON" or "OPEN" condition and a low signal level represents "OFF" or "CLOSED" condition. "Digital" is sometimes used interchangeably with "Binary" to indicate a two-state signal.

E. Controller: Generic term for any standalone, microprocessor-based, digital controller residing on a network, used for local or global control. Three types of controllers are indicated: Network Controller, Programmable Application Controller, and Application-Specific Controller.

F. Control System Integrator: An entity that assists in expansion of existing enterprise system and support of additional operator interfaces to I/O being added to existing enterprise system.

G. COV: Changes of value.

H. DDC System Provider: Authorized representative of, and trained by, DDC system manufacturer and responsible for execution of DDC system Work indicated.

I. Distributed Control: Processing of system data is decentralized and control decisions are made at subsystem level. System operational programs and information are provided to remote subsystems and status is reported back. On loss of communication, subsystems shall be capable of operating in a standalone mode using the last best available data.

J. DOCSIS: Data-Over Cable Service Interface Specifications.

K. E/P: Voltage to pneumatic.

L. Gateway: Bidirectional protocol translator that connects control systems that use different communication protocols.

M. HLC: Heavy load conditions.

N. I/O: System through which information is received and transmitted. I/O refers to analog input (AI), binary input (BI), analog output (AO) and binary output (BO). Analog signals are continuous and represent control influences such as flow, level, moisture, pressure, and temperature. Binary signals convert electronic signals to digital pulses (values) and generally represent two-position operating and alarm status. "Digital," (DI and (DO), is sometimes used interchangeably with "Binary," (BI) and (BO), respectively.

O. I/P: Current to pneumatic.

23 09 23 – 2

Direct Digital Control (DDC) System For HVAC                                Bid Set
Tt # 200-11740-10003                                                Tetra Tech, Inc.

P.    LAN: Local area network.

Q.    LNS: LonWorks Network Services.

R.    LON Specific Definitions:

1.    FTT-10: Echelon Transmitter-Free Topology Transceiver.
2.    LonMark: Association comprising suppliers and installers of LonTalk products. Association provides guidelines for implementing LonTalk protocol to ensure interoperability through a standard or consistent implementation.
3.    LonTalk: An open standard protocol developed by the Echelon Corporation that uses a "Neuron Chip" for communication. LonTalk is a register trademark of Echelon.
4.    LonWorks: Network technology developed by Echelon.
5.    Node: Device that communicates using CEA-709.1-C protocol and that is connected to a CEA-709.1-C network.
6.    Node Address: The logical address of a node on the network, consisting of a Domain number, Subnet number, and Node number. "Node number" portion of an address is a number assigned to device during installation, is unique within a subnet, and is not a factory-set unique Node ID.
7.    Node ID: A unique 48-bit identifier assigned at factory to each CEA-709.1-C device. Sometimes called a "Neuron ID."
8.    Program ID: An identifier (number) stored in a device (usually EEPROM) that identifies node manufacturer, functionality of device (application and sequence), transceiver used, and intended device usage.
9.    Standard Configuration Property Type (SCPT): Pronounced "skip-it." A standard format type maintained by LonMark International for configuration properties.
10.   Standard Network Variable Type (SNVT): Pronounced "snivet." A standard format type maintained by LonMark used to define data information transmitted and received by individual nodes. "SNVT" is used in two ways. It is an acronym for "Standard Network Variable Type" and is often used to indicate a network variable itself (i.e., it can mean "a network variable of a standard network variable type").
11.   Subnet: Consists of a logical grouping of up to 127 nodes, where logical grouping is defined by node addressing. Each subnet is assigned a number, which is unique within a Domain. See "Node Address."
12.   TP/FT-10: Free Topology Twisted Pair network defined by CEA-709.3 and is most common media type for a CEA-709.1-C control network.
13.   TP/XF-1250: High-speed, 1.25-Mbps, twisted-pair, doubly terminated bus network defined by "LonMark Interoperability Guidelines" typically used only to connect multiple TP/FT-10 networks.
14.   User-Defined Configuration Property Type (UCPT): Pronounced "U-Keep-It." A Configuration Property format type that is defined by device manufacturer.

15. User-Defined Network Variable Type (UNVT): Network variable format defined by device manufacturer. UNVTs create non-standard communications that other vendors' devices may not correctly interpret and may negatively impact system operation. UNVTs are not allowed.

S. Low Voltage: As defined in NFPA 70 for circuits and equipment operating at less than 50 V or for remote-control, signaling power-limited circuits.

T. Modbus TCP/IP: An open protocol for exchange of process data.

U. MS/TP: Master-slave/token-passing, IEE 8802-3. Datalink protocol LAN option that uses twisted-pair wire for low-speed communication.

V. MTBF: Mean time between failures.

W. Network Controller: Digital controller, which supports a family of programmable application controllers and application-specific controllers, that communicates on peer-to-peer network for transmission of global data.

X. Network Repeater: Device that receives data packet from one network and rebroadcasts it to another network. No routing information is added to protocol.

Y. PDA: Personal digital assistant.

Z. Peer to Peer: Networking architecture that treats all network stations as equal partners.

AA. POT: Portable operator's terminal.

BB. PUE: Performance usage effectiveness.

CC. RAM: Random access memory.

DD. RF: Radio frequency.

EE. Router: Device connecting two or more networks at network layer.

FF. Server: Computer used to maintain system configuration, historical and programming database.

GG. TCP/IP: Transport control protocol/Internet protocol incorporated into Microsoft Windows.

HH. UPS: Uninterruptible power supply.

II. USB: Universal Serial Bus.

JJ.    User Datagram Protocol (UDP): This protocol assumes that the IP is used as the underlying protocol.

KK.    VAV: Variable air volume.

LL.    WLED: White light emitting diode.

1.4    PREINSTALLATION MEETINGS

A.    Preinstallation Conference: Conduct conference at Project site.

1.5    ACTION SUBMITTALS

A.    Multiple Submissions:

1.    If multiple submissions are required to execute work within schedule, first submit a coordinated schedule clearly defining intent of multiple submissions. Include a proposed date of each submission with a detailed description of submittal content to be included in each submission.
2.    Clearly identify each submittal requirement indicated and in which submission the information will be provided.
3.    Include an updated schedule in each subsequent submission with changes highlighted to easily track the changes made to previous submitted schedule.

B.    Product Data: For each type of product include the following:

1.    Construction details, material descriptions, dimensions of individual components and profiles, and finishes.
2.    Operating characteristics, electrical characteristics, and furnished accessories indicating process operating range, accuracy over range, control signal over range, default control signal with loss of power, calibration data specific to each unique application, electrical power requirements, and limitations of ambient operating environment, including temperature and humidity.
3.    Product description with complete technical data, performance curves, and product specification sheets.
4.    Installation, operation and maintenance instructions including factors effecting performance.
5.    Bill of materials of indicating quantity, manufacturer, and extended model number for each unique product.

a.    Operator workstations.
b.    Servers.
c.    Printers.
d.    Gateways.

e. Routers.
f. Protocol analyzers.
g. DDC controllers.
h. Enclosures.
i. Electrical power devices.
j. UPS units.
k. Accessories.
l. Instruments.
m. Control dampers and actuators.
n. Control valves and actuators.

6. When manufacturer's product datasheets apply to a product series rather than a specific product model, clearly indicate and highlight only applicable information.
7. Each submitted piece of product literature shall clearly cross reference specification and drawings that submittal is to cover.

C. Software Submittal:

1. Cross-referenced listing of software to be loaded on each operator workstation, server, gateway, and DDC controller.
2. Description and technical data of all software provided, and cross-referenced to products in which software will be installed.
3. Operating system software, operator interface and programming software, color graphic software, DDC controller software, maintenance management software, and third-party software.
4. Include a flow diagram and an outline of each subroutine that indicates each program variable name and units of measure.
5. Listing and description of each engineering equation used with reference source.
6. Listing and description of each constant used in engineering equations and a reference source to prove origin of each constant.
7. Description of operator interface to alphanumeric and graphic programming.
8. Description of each network communication protocol.
9. Description of system database, including all data included in database, database capacity and limitations to expand database.
10. Description of each application program and device drivers to be generated, including specific information on data acquisition and control strategies showing their relationship to system timing, speed, processing burden and system throughout.
11. Controlled Systems: Instrumentation list with element name, type of device, manufacturer, model number, and product data. Include written description of sequence of operation including schematic diagram.

D. LEED Submittals:

1. Include supporting data showing energy, flow, gas, moisture, motion, pressure, and temperature instruments, where and if used in Project; and associated application for monitoring and control to satisfy requirements of Project LEED credits.

   a. Indicate applicable locations and area coverage, control set points, description of control operation and other required information to satisfy submission requirements for award of LEED credit.

2. Organize and identify standalone, supporting data for each LEED credit.
3. Project LEED credits include the following:

E. Shop Drawings:

1. General Requirements:

   a. Include cover drawing with Project name, location, Owner, Architect, Contractor and issue date with each Shop Drawings submission.
   b. Include a drawing index sheet listing each drawing number and title that matches information in each title block.
   c. Prepare Drawings using CAD.

2. Include plans, elevations, sections, and mounting details where applicable.
3. Include details of product assemblies. Indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
4. Detail means of vibration isolation and show attachments to rotating equipment.
5. Plan Drawings indicating the following:

   a. Screened backgrounds of walls, structural grid lines, HVAC equipment, ductwork and piping.
   b. Room names and numbers with coordinated placement to avoid interference with control products indicated.
   c. Each desktop operator workstation, server, gateway, router, DDC controller, control panel instrument connecting to DDC controller, and damper and valve connecting to DDC controller, if included in Project.
   d. Exact placement of products in rooms, ducts, and piping to reflect proposed installed condition.
   e. Network communication cable and raceway routing.
   f. Proposed routing of wiring, cabling, conduit, and tubing, coordinated with building services for review before installation.

6. Schematic drawings for each controlled HVAC system indicating the following:

   a. I/O points labeled with point names shown. Indicate instrument range, normal operating set points, and alarm set points. Indicate fail position of each damper and valve, if included in Project.
   b. I/O listed in table format showing point name, type of device, manufacturer, model number, and cross-reference to product data sheet number.
   c. A graphic showing location of control I/O in proper relationship to HVAC system.
   d. Wiring diagram with each I/O point having a unique identification and indicating labels for all wiring terminals.
   e. Unique identification of each I/O that shall be consistently used between different drawings showing same point.
   f. Elementary wiring diagrams of controls for HVAC equipment motor circuits including interlocks, switches, relays and interface to DDC controllers.
   g. Narrative sequence of operation.
   h. Graphic sequence of operation, showing all inputs and output logical blocks.

7. Control panel drawings indicating the following:

   a. Panel dimensions, materials, size, and location of field cable, raceways, and tubing connections.
   b. Interior subpanel layout, drawn to scale and showing all internal components, cabling and wiring raceways, nameplates and allocated spare space.
   c. Front, rear, and side elevations and nameplate legend.
   d. Unique drawing for each panel.

8. DDC system network riser diagram indicating the following:

   a. Each device connected to network with unique identification for each.
   b. Interconnection of each different network in DDC system.
   c. For each network, indicate communication protocol, speed and physical means of interconnecting network devices, such as copper cable type, or fiber-optic cable type. Indicate raceway type and size for each.
   d. Each network port for connection of an operator workstation or other type of operator interface with unique identification for each.

9. DDC system electrical power riser diagram indicating the following:

a.   Each point of connection to field power with requirements (volts/phase//hertz/amperes/connection type) listed for each.

b.   Each control power supply including, as applicable, transformers, power-line conditioners, transient voltage suppression and high filter noise units, DC power supplies, and UPS units with unique identification for each.

c.   Each product requiring power with requirements (volts/phase//hertz/amperes/connection type) listed for each.

d.   Power wiring type and size, race type, and size for each.

10.   Monitoring and control signal diagrams indicating the following:

a.   Control signal cable and wiring between controllers and I/O.

b.   Point-to-point schematic wiring diagrams for each product.

c.   Control signal tubing to sensors, switches and transmitters.

d.   Process signal tubing to sensors, switches and transmitters.

11.   Color graphics indicating the following:

a.   Itemized list of color graphic displays to be provided.

b.   For each display screen to be provided, a true color copy showing layout of pictures, graphics and data displayed.

c.   Intended operator access between related hierarchical display screens.

F.   System Description:

1.   Full description of DDC system architecture, network configuration, operator interfaces and peripherals, servers, controller types and applications, gateways, routers and other network devices, and power supplies.

2.   Complete listing and description of each report, log and trend for format and timing and events which initiate generation.

3.   System and product operation under each potential failure condition including, but not limited to, the following:

a.   Loss of power.

b.   Loss of network communication signal.

c.   Loss of controller signals to inputs and outpoints.

d.   Operator workstation failure.

e.   Server failure.

f.   Gateway failure.

g.   Network failure

h.   Controller failure.

i.   Instrument failure.

j.   Control damper and valve actuator failure.

4. Complete bibliography of documentation and media to be delivered to Owner.
5. Description of testing plans and procedures.
6. Description of Owner training.

G. Delegated-Design Submittal: For DDC system products and installation indicated as being delegated.

1. Supporting documentation showing DDC system design complies with performance requirements indicated, including calculations and other documentation necessary to prove compliance.
2. Schedule and design calculations for control dampers and actuators.

   a. Flow at Project design and minimum flow conditions.
   b. Face velocity at Project design and minimum airflow conditions.
   c. Pressure drop across damper at Project design and minimum airflow conditions.
   d. AMCA 500-D damper installation arrangement used to calculate and schedule pressure drop, as applicable to installation.
   e. Maximum close-off pressure.
   f. Leakage airflow at maximum system pressure differential (fan close-off pressure).
   g. Torque required at worst case condition for sizing actuator.
   h. Actuator selection indicating torque provided.
   i. Actuator signal to control damper (on, close or modulate).
   j. Actuator position on loss of power.
   k. Actuator position on loss of control signal.

3. Schedule and design calculations for control valves and actuators.

   a. Flow at Project design and minimum flow conditions.
   b. Pressure-differential drop across valve at Project design flow condition.
   c. Maximum system pressure-differential drop (pump close-off pressure) across valve at Project minimum flow condition.
   d. Design and minimum control valve coefficient with corresponding valve position.
   e. Maximum close-off pressure.
   f. Leakage flow at maximum system pressure differential.
   g. Torque required at worst case condition for sizing actuator.
   h. Actuator selection indicating torque provided.
   i. Actuator signal to control damper (on, close or modulate).
   j. Actuator position on loss of power.
   k. Actuator position on loss of control signal.

4. Schedule and design calculations for selecting flow instruments.

a. Instrument flow range.
b. Project design and minimum flow conditions with corresponding accuracy, control signal to transmitter and output signal for remote control.
c. Extreme points of extended flow range with corresponding accuracy, control signal to transmitter and output signal for remote control.
d. Pressure-differential loss across instrument at Project design flow conditions.
e. Where flow sensors are mated with pressure transmitters, provide information for each instrument separately and as an operating pair.

1.6     INFORMATIONAL SUBMITTALS

A.     Coordination Drawings:

1.     Plan drawings and corresponding product installation details, drawn to scale, on which the following items are shown and coordinated with each other, using input from installers of the items involved:

a. Product installation location shown in relationship to room, duct, pipe and equipment.
b. Structural members to which products will be attached.
c. Wall-mounted instruments located in finished space showing relationship to light switches, fire-alarm devices and other installed devices.
d. Size and location of wall access panels for products installed behind walls and requiring access.

2.     Reflected ceiling plans and other details, drawn to scale, on which the following items are shown and coordinated with each other, using input from installers of the items involved:

a. Ceiling components.
b. Size and location of access panels for products installed above inaccessible ceiling assemblies and requiring access.
c. Items penetrating finished ceiling including the following:
1) Lighting fixtures.
2) Air outlets and inlets.
3) Speakers.
4) Sprinklers.
5) Access panels.
6) Motion sensors.
7) Pressure sensors.

8)      Temperature sensors and other DDC control system instruments.

B.     Qualification Data:

1.     Systems Provider Qualification Data:

      a.     Resume of project manager assigned to Project.
      b.     Resumes of application engineering staff assigned to Project.
      c.     Resumes of installation and programming technicians assigned to Project.
      d.     Resumes of service technicians assigned to Project.
      e.     Brief description of past project including physical address, floor area, number of floors, building system cooling and heating capacity and building's primary function.
      f.     Description of past project DDC system, noting similarities to Project scope and complexity indicated.
      g.     Names of staff assigned to past project that will also be assigned to execute work of this Project.
      h.     Owner contact information for past project including name, phone number, and e-mail address.
      i.     Contractor contact information for past project including name, phone number, and e-mail address.
      j.     Architect and Engineer contact information for past project including name, phone number, and e-mail address.

2.     Manufacturer's qualification data.
3.     Testing agency's qualifications data.

C.     Welding certificates.

D.     Product Certificates:

1.     Data Communications Protocol Certificates: Certifying that each proposed DDC system component complies with ASHRAE 135.
2.     Data Communications Protocol Certificates: Certifying that each proposed DDC system component complies with LonWorks.

E.     Product Test Reports: For each product that requires testing to be performed by manufacturer.

F.     Preconstruction Test Reports: For each separate test performed.

G.     Source quality-control reports.

H.     Field quality-control reports.

23 09 23 – 12

Direct Digital Control (DDC) System For HVAC            Bid Set
Tt # 200-11740-10003            Tetra Tech, Inc.

I.      Sample Warranty: For manufacturer's warranty.


1.7     CLOSEOUT SUBMITTALS

A.      Operation and Maintenance Data: For DDC system to include in emergency, operation and maintenance manuals.

1.      In addition to items specified in Section 01 78 23 "Operation and Maintenance Data," include the following:

a.      Project Record Drawings of as-built versions of submittal Shop Drawings provided in electronic PDF format.

b.      Testing and commissioning reports and checklists of completed final versions of reports, checklists, and trend logs.

c.      As-built versions of submittal Product Data.

d.      Names, addresses, e-mail addresses and 24-hour telephone numbers of Installer and service representatives for DDC system and products.

e.      Operator's manual with procedures for operating control systems including logging on and off, handling alarms, producing point reports, trending data, overriding computer control and changing set points and variables.

f.      Programming manuals with description of programming language and syntax, of statements for algorithms and calculations used, of point database creation and modification, of program creation and modification, and of editor use.

g.      Engineering, installation, and maintenance manuals that explain how to:
        1)      Design and install new points, panels, and other hardware.
        2)      Perform preventive maintenance and calibration.
        3)      Debug hardware problems.
        4)      Repair or replace hardware.

h.      Documentation of all programs created using custom programming language including set points, tuning parameters, and object database.

i.      Backup copy of graphic files, programs, and database on electronic media such as DVDs.

j.      List of recommended spare parts with part numbers and suppliers.

k.      Complete original-issue documentation, installation, and maintenance information for furnished third-party hardware including computer equipment and sensors.

l.      Complete original-issue copies of furnished software, including operating systems, custom programming language, operator workstation software, and graphics software.

m.      Licenses, guarantees, and warranty documents.

n. Recommended preventive maintenance procedures for system components, including schedule of tasks such as inspection, cleaning, and calibration; time between tasks; and task descriptions.

o. Owner training materials.

## 1.8 MAINTENANCE MATERIAL SUBMITTALS

A. Furnish extra materials and parts that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.

B. Include product manufacturers' recommended parts lists for proper product operation over four-year period following warranty period. Parts list shall be indicated for each year.

C. Furnish parts, as indicated by manufacturer's recommended parts list, for product operation during one-year period following warranty period.

## 1.9 QUALITY ASSURANCE

A. DDC System Manufacturer Qualifications:

1. Nationally recognized manufacturer of DDC systems and products.
2. DDC systems with similar requirements to those indicated for a continuous period of five years within time of bid.
3. DDC systems and products that have been successfully tested and in use on at least five past projects.
4. Having complete published catalog literature, installation, operation and maintenance manuals for all products intended for use.
5. Having full-time in-house employees for the following:

   a. Product research and development.
   b. Product and application engineering.
   c. Product manufacturing, testing and quality control.
   d. Technical support for DDC system installation training, commissioning and troubleshooting of installations.
   e. Owner operator training.

B. DDC System Provider Qualifications:

1. Authorized representative of, and trained by, DDC system manufacturer.
2. In-place facility located within 100 miles of Project.
3. Demonstrated past experience with installation of DDC system products being installed for period within five consecutive years before time of bid.

23 09 23 – 14

Direct Digital Control (DDC) System For HVAC                                      Bid Set
Tt # 200-11740-10003                                                      Tetra Tech, Inc.

4. Demonstrated past experience on five projects of similar complexity, scope and value.
5. Each person assigned to Project shall have demonstrated past experience.
6. Staffing resources of competent and experienced full-time employees that are assigned to execute work according to schedule.
7. Service and maintenance staff assigned to support Project during warranty period.
8. Product parts inventory to support on-going DDC system operation for a period of not less than 5 years after Substantial Completion.
9. DDC system manufacturer's backing to take over execution of Work if necessary to comply with requirements indicated. Include Project-specific written letter, signed by manufacturer's corporate officer, if requested.

C. Testing Agency Qualifications: Member company of NETA or an NRTL.

1. Testing Agency's Field Supervisor: Certified by NETA to supervise on-site testing.

D. Welding Qualifications: Qualify procedures and personnel according to the following:

1. AWS D1.1/D1.1M, "Structural Welding Code - Steel."
2. AWS D1.2/D1.2M, "Structural Welding Code - Aluminum."
3. AWS D1.3/D1.3M, "Structural Welding Code - Sheet Steel."
4. AWS D1.4/D1.4M, "Structural Welding Code - Reinforcing Steel."

E. Pipe and Pressure-Vessel Welding Qualifications: Qualify procedures and operators according to ASME Boiler and Pressure Vessel Code.

1.10 WARRANTY

A. Manufacturer's Warranty: Manufacturer and Installer agree to repair or replace products that fail in materials or workmanship within specified warranty period.

1. Failures shall be adjusted, repaired, or replaced at no additional cost or reduction in service to Owner.
2. Include updates or upgrades to software and firmware if necessary to resolve deficiencies.

   a. Install updates only after receiving Owner's written authorization.

3. Warranty service shall occur during normal business hours and commence within 8 hours of Owner's warranty service request.
4. Warranty Period: Two year(s) from date of Substantial Completion.

   a. For Gateway: Two-year parts and labor warranty for each.

**PART 2 - PRODUCTS**

2.1     DDC SYSTEM DESCRIPTION

    A.    Microprocessor-based monitoring and control including analog/digital conversion and program logic. A control loop or subsystem in which digital and analog information is received and processed by a microprocessor, and digital control signals are generated based on control algorithms and transmitted to field devices to achieve a set of predefined conditions.

        1.    DDC system shall consist of a high-speed, peer-to-peer network of distributed DDC controllers, other network devices, operator interfaces, and software.

    B.    Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

2.2     WEB ACCESS

    A.    DDC system shall be Web based or Web compatible.

        1.    Web-Based Access to DDC System:

            a.    DDC system software shall be based on server thin-client architecture, designed around open standards of Web technology. DDC system server shall be accessed using a Web browser over DDC system network, using Owner's LAN, and remotely over Internet through Owner's LAN.

            b.    Intent of thin-client architecture is to provide operators complete access to DDC system via a Web browser. No special software other than a Web browser shall be required to access graphics, point displays, and trends; to configure trends, points, and controllers; and to edit programming.

            c.    Web access shall be password protected.

        2.    Web-Compatible Access to DDC System:

            a.    Operator workstation and or server shall perform overall system supervision and configuration, graphical user interface, management report generation, and alarm annunciation.

            b.    DDC system shall support Web browser access to building data. Operator using a standard Web browser shall be able to access control graphics and change adjustable set points.

            c.    Web access shall be password protected.

2.3     PERFORMANCE REQUIREMENTS

A.     Delegated Design: Engage a qualified professional to design DDC system to satisfy requirements indicated.

1.     System Performance Objectives:

a.     DDC system shall manage HVAC systems.
b.     DDC system control shall operate HVAC systems to achieve optimum operating costs while using least possible energy and maintaining specified performance.
c.     DDC system shall respond to power failures, HVAC equipment failures, and adverse and emergency conditions encountered through connected I/O points.
d.     DDC system shall operate while unattended by an operator and through operator interaction.
e.     DDC system shall record trends and transaction of events and produce report information such as performance, energy, occupancies, and equipment operation.

B.     Surface-Burning Characteristics: Products installed in ducts, equipment, and return-air paths shall comply with ASTM E 84; testing by a qualified testing agency. Identify products with appropriate markings of applicable testing agency.

1.     Flame-Spread Index:  25 or less.
2.     Smoke-Developed Index:  50 or less.

C.     DDC System Speed:

1.     Response Time of Connected I/O:

a.     AI point values connected to DDC system shall be updated at least every five seconds for use by DDC controllers. Points used globally shall also comply with this requirement.
b.     BI point values connected to DDC system shall be updated at least every five seconds for use by DDC controllers. Points used globally shall also comply with this requirement.
c.     AO points connected to DDC system shall begin to respond to controller output commands within two second(s). Global commands shall also comply with this requirement.
d.     BO point values connected to DDC system shall respond to controller output commands within two second(s). Global commands shall also comply with this requirement.

2.     Display of Connected I/O:

a. Analog point COV connected to DDC system shall be updated and displayed at least every 10 seconds for use by operator.

b. Binary point COV connected to DDC system shall be updated and displayed at least every 10 seconds for use by operator.

c. Alarms of analog and digital points connected to DDC system shall be displayed within 15 seconds of activation or change of state.

d. Graphic display refresh shall update within four seconds.

e. Point change of values and alarms displayed from workstation to workstation when multiple operators are viewing from multiple workstations shall not exceed graphic refresh rate indicated.

D. Network Bandwidth: Design each network of DDC system to include at least 30 percent available spare bandwidth with DDC system operating under normal and heavy load conditions indicated. Calculate bandwidth usage, and apply a safety factor to ensure that requirement is satisfied when subjected to testing under worst case conditions.

E. DDC System Data Storage:

1. Include server(s) with disk drive data storage to archive not less than 24 consecutive months of historical data for all I/O points connected to system, including alarms, event histories, transaction logs, trends and other information indicated.

2. When logged onto a server, operator shall be able to also interact with any DDC controller connected to DDC system as required for functional operation of DDC system.

3. Server(s) shall be used for application configuration; for archiving, reporting and trending of data; for operator transaction archiving and reporting; for network information management; for alarm annunciation; and for operator interface tasks and controls application management.

4. Server(s) shall use IT industry-standard database platforms such as Microsoft SQL Server and Microsoft Data Engine (MSDE).

F. Future Expandability:

1. DDC system size shall be expandable to an ultimate capacity of at least four times total I/O points indicated.

2. Additional DDC controllers, I/O and associated wiring shall be all that is needed to achieve ultimate capacity. Initial network infrastructure shall be designed and installed to support ultimate capacity.

3. Operator interfaces installed initially shall not require hardware and software additions and revisions for ultimate capacity.

G. Input Point Displayed Accuracy: Input point displayed values shall meet following end-to-end overall system accuracy, including errors associated with meter, sensor, transmitter, lead wire or cable, and analog to digital conversion.

1. Energy:

    a. Thermal: Within 3 percent of reading.
    b. Electric Power: Within 1 percent of reading.
    c. Requirements indicated on Drawings for meters not supplied by utility.

2. Flow:

    a. Air: Within 2 percent of design flow rate.
    b. Air (Terminal Units): Within 5 percent of design flow rate.
    c. Water: Within 2 percent of design flow rate.

3. Pressure:

    a. Air, Ducts and Equipment: 1 percent of instrument span.
    b. Space: Within 1 percent of instrument span.
    c. Water: Within 1 percent of instrument span.

4. Temperature, Dew Point:

    a. Air: Within 1 deg F (0.5 deg C).
    b. Space: Within 1 deg F (0.5 deg C).
    c. Outdoor: Within 3 deg F (1.5 deg C).

5. Temperature, Dry Bulb:

    a. Air: Within 0.5 deg F (0.2 deg C).

H. Precision of I/O Reported Values: Values reported in database and displayed shall have following precision:

1. Current:

    a. Milliamperes: Nearest 1/100th of a milliampere.
    b. Amperes: Nearest 1/10th of an ampere up to 100 A; nearest ampere for 100 A and more.

2. Energy:

    a. Electric Power:
        1) Rate (Watts): Nearest 1/10th of a watt through 1000 W.
        2) Rate (Kilowatts): Nearest 1/10th of a kilowatt through 1000 kW; nearest kilowatt above 1000 kW.
        3) Usage (Kilowatt-Hours): Nearest kilowatt through 10,000 kW; nearest 10 kW between 10,000 and 100,000 kW; nearest 100 kW for above 100,000 kW.

3. Flow:

   a. Air: Nearest 1/10th of a cfm through 100 cfm; nearest cfm between 100 and 1000 cfm; nearest 10 cfm between 1000 and 10,000 cfm; nearest 100 cfm above 10,000 cfm (Nearest 1/10th of a L/s through 100 L/s; nearest L/s between 100 and 1000 L/s; nearest 10 L/s between 1000 and 10,000 L/s; nearest 100 L/s above 10,000 L/s).

   b. Water: Nearest 1/10th gpm through 100 gpm; nearest gpm between 100 and 1000 gpm; nearest 10 gpm between 1000 and 10,000 gpm; nearest 100 gpm above 10,000 gpm (Nearest 1/10th of a L/s through 100 L/s; nearest L/s between 100 and 1000 L/s; nearest 10 L/s between 1000 and 10,000 L/s; nearest 100 L/s above 10,000 L/s).

   c. Steam: Nearest 1/10th lb/hr through 100 lbs/hr; nearest lbs/hr between 100 and 1000 lbs/hr; nearest 10 lbs/hr above 1000 lbs/hr (Nearest 1/10th of a L/s through 100 L/s; nearest L/s between 100 and 1000 L/s; nearest 10 L/s between 1000 and 10,000 L/s; nearest 100 L/s above 10,000 L/s).

4. Gas:

   a. Carbon Dioxide (ppm): Nearest ppm.
   b. Carbon Monoxide (ppm): Nearest ppm.
   c. Oxygen (Percentage): Nearest 1/10th of 1 percent.
   d. Refrigerant (ppm): Nearest ppm.

5. Moisture (Relative Humidity):

   a. Relative Humidity (Percentage): Nearest 1 percent.

6. Level: Nearest 1/100th of an inch through 10 inches; nearest 1/10 of an inch between 10 and 100 inches; nearest inch above 100 inches (Nearest 1/100th of a mm through 10 mm; nearest 1/10th of a mm between 10 and 100 mm; nearest mm above 100 mm).

7. Speed:

   a. Rotation (rpm): Nearest 1 rpm.
   b. Velocity: Nearest 1/10th fpm through 100 fpm; nearest fpm between 100 and 1000 fpm; nearest 10 fpm above 1000 fpm (Nearest 1/100th of a M/s through 10 M/s; nearest 1/10th of a M/s above 10 M/s).

8. Position, Dampers and Valves (Percentage Open): Nearest 1 percent.

9. Pressure:

        a.      Air, Ducts and Equipment: Nearest 1/10th in. w.c. (Nearest Pa up to 1000 Pa; nearest 10 Pa above 1000 Pa).

        b.      Space: Nearest 1/100th in. w.c. (Nearest 1/10th Pa).

        c.      Steam: Nearest 1/10th psig through 100 psig; nearest psig above 100 psig (Nearest kPa through 1000 kPa; nearest 10 kPa above 1000 kPa).

        d.      Water: Nearest 1/10 psig through 100 psig; nearest psig above 100 psig (Nearest kPa through 1000 kPa; nearest 10 kPa above 1000 kPa).

10.     Temperature:

        a.      Air, Ducts and Equipment: Nearest 1/10th of a degree.

        b.      Outdoor: Nearest degree.

        c.      Space: Nearest 1/10th of a degree.

        d.      Chilled Water: Nearest 1/10th of a degree.

        e.      Condenser Water: Nearest 1/10th of a degree.

        f.      Heating Hot Water: Nearest degree.

        g.      Heat Recovery Runaround: Nearest 1/10th of a degree.

        h.      Steam: Nearest degree.

11.     Vibration: Nearest 1/10th in/s (Nearest 1/10th mm/s).

12.     Voltage: Nearest 1/10 volt up to 100 V; nearest volt above 100 V.

I.     Control Stability: Control variables indicated within the following limits:

1.      Flow:

        a.      Air, Ducts and Equipment, except Terminal Units: Within 2 percent of design flow rate.

2.      Gas:

        a.      Carbon Dioxide: Within 50 ppm.

        b.      Carbon Monoxide: Within 5 percent of reading.

        c.      Oxygen: Within 5 percent of reading.

3.      Moisture (Relative Humidity):

        a.      Air: Within 2 percent RH.

        b.      Space: Within 2 percent RH.

        c.      Outdoor: Within 2 percent RH.

J.     Environmental Conditions for Controllers, Gateways, and Routers:

1. Products shall operate without performance degradation under ambient environmental temperature, pressure and humidity conditions encountered for installed location.

   a. If product alone cannot comply with requirement, install product in a protective enclosure that is isolated and protected from conditions impacting performance. Enclosure shall be internally insulated, electrically heated, cooled and ventilated as required by product and application.

2. Products shall be protected with enclosures satisfying the following minimum requirements unless more stringent requirements are indicated. Products not available with integral enclosures complying with requirements indicated shall be housed in protective secondary enclosures. Installed location shall dictate the following NEMA 250 enclosure requirements:

   a. Outdoors, Protected:  Type 3.
   b. Outdoors, Unprotected:  Type 4X.
   c. Localized Areas Exposed to Washdown:  Type 4X.

K. Environmental Conditions for Instruments and Actuators:

1. Instruments and actuators shall operate without performance degradation under the ambient environmental temperature, pressure, humidity, and vibration conditions specified and encountered for installed location.

   a. If instruments and actuators alone cannot comply with requirement, install instruments and actuators in protective enclosures that are isolated and protected from conditions impacting performance. Enclosure shall be internally insulated, electrically heated, cooled and ventilated as required by instrument and application.

L. Electric Power Quality:

1. Power-Line Surges:

   a. Protect DDC system products connected to ac power circuits from power-line surges to comply with requirements of IEEE C62.41.
   b. Do not use fuses for surge protection.
   c. Test protection in the normal mode and in the common mode, using the following two waveforms:
      1) 10-by-1000-mic.sec. waveform with a peak voltage of 1500 V and a peak current of 60 A.

2) 8-by-20-mic.sec. waveform with a peak voltage of 1000 V and a peak current of 500 A.

2. Power Conditioning:

a. ProtectDDC system products connected to ac power circuits from irregularities and noise rejection. Characteristics of power-line conditioner shall be as follows:
1) At 85 percent load, output voltage shall not deviate by more than plus or minus 1 percent of nominal when input voltage fluctuates between minus 20 percent to plus 10 percent of nominal.
2) During load changes from zero to full load, output voltage shall not deviate by more than plus or minus 3 percent of nominal.
3) Accomplish full correction of load switching disturbances within five cycles, and 95 percent correction within two cycles of onset of disturbance.
4) Total harmonic distortion shall not exceed 3-1/2 percent at full load.

3. Ground Fault: Protect products from ground fault by providing suitable grounding. Products shall not fail due to ground fault condition.

M. Backup Power Source:

1. HVAC systems and equipment served by a backup power source shall have associated DDC system products that control such systems and equipment also served from a backup power source.

N. UPS:

1. DDC system products powered by UPS units shall include the following:

a. Desktop operator workstations.
b. Printers.
c. Servers.
d. Gateways.
e. DDC controllers, except application-specific controllers.

O. Continuity of Operation after Electric Power Interruption:

1. Equipment and associated factory-installed controls, field-installed controls, electrical equipment, and power supply connected to building normal and backup power systems shall automatically return equipment and associated controls to operating state occurring immediately before

loss of normal power, without need for manual intervention by operator when power is restored either through backup power source or through normal power if restored before backup power is brought online.

2.4     PANEL-MOUNTED, MANUAL OVERRIDE SWITCHES

   A.   Manual Override of Control Dampers:

      1.   Include panel-mounted, two-position, selector switch for each automatic control damper being controlled by DDC controller.

      2.   Label each switch with damper designation served by switch.

      3.   Label switch positions to indicate either "Manual" or "Auto" control signal to damper.

      4.   With switch in "Auto" position signal to control damper actuator shall be control loop output signal from DDC controller.

      5.   With switch in "Manual" position, signal to damper actuator shall be controlled at panel with either an integral or separate switch to include local control.

         a.   For Binary Control Dampers: Manual two-position switch shall have "Close" and "Open" switch positions indicated. With switch in "Close" position, damper shall close. With switch in "Open" position, damper shall open.
         b.   For Analog Control Dampers: A gradual switch shall have "Close" and "Open" switch limits indicated. Operator shall be able to rotate switch knob to adjust damper to any position from close to open.

      6.   DDC controller shall monitor and report position of each manual override selector switch. With switch placed in "manual" position, DDC controller shall signal an override condition to alert operator that damper is under manual, not automatic, control.

      7.   Configure manual override switches to allow operator to manually operate damper while at panel without DDC controller installed and operational.

      8.   Terminal equipment including VAV units, fan-coil units, and unit heaters do not require manual override unless otherwise indicated by sequence of operation.

   B.   Manual Override of Control Valves:

      1.   Include panel-mounted, two-position, selector switch for each automatic control valve being controlled by a DDC controller.

      2.   Label each switch with valve designation served by switch.

23 09 23 – 24

Direct Digital Control (DDC) System For HVAC                                    Bid Set
Tt # 200-11740-10003                                                  Tetra Tech, Inc.

3.     Label switch positions to indicate either "Manual" or "Auto" control signal to valve.
4.     With switch in "Auto" position, signal to control-valve actuator shall be a control loop output signal from DDC controller.
5.     With switch in "Manual" position, signal to valve actuator shall be controlled at panel with either an integral or a separate switch to include local control.

    a.     For Binary Control Dampers: Manual two-position switch shall have "Close" and "Open" switch positions indicated. With switch in "Close" position, damper shall close. With switch in "Open" position, damper shall open.
    b.     For Analog Control Dampers: A gradual switch shall have "Open" and "Close" switch limits indicated. Operator shall be able to rotate switch knob to adjust damper to any position from close to open.

6.     DDC controller shall monitor and report position of each manual override selector switch. With switch placed in "manual" position, DDC controller shall signal an override condition to alert operator that valve is under manual, not automatic, control.
7.     Configure manual override switches to allow operator to manually operate valve while at panel without DDC controller installed and operational.

8.     Terminal equipment including VAV units, fan-coil units, and unit heaters do not require manual override unless otherwise indicated by sequence of operation.

## 2.5     SYSTEM ARCHITECTURE

A.     System architecture shall consist of no more than two levels of LANs.

1.     Level one LAN shall connect network controllers and operator workstations.
2.     Level one LAN shall connect programmable application controllers to other programmable application controllers, and to network controllers.

B.     DDC system shall consist of dedicated LANs that are not shared with other building systems and tenant data and communication networks.

C.     System architecture shall be modular and have inherent ability to expand to not less than three times system size indicated with no impact to performance indicated.

D.     System architecture shall perform modifications without having to remove and replace existing network equipment.

E. Number of LANs and associated communication shall be transparent to operator. All I/O points residing on any LAN shall be capable of global sharing between all system LANs.

F. System design shall eliminate dependence on any single device for system alarm reporting and control execution. Each controller shall operate independently by performing its' own control, alarm management and historical data collection.

G. Special Network Architecture Requirements:

1. Air-Handling Systems: For control applications of an air-handling system that consists of air-handling unit(s) and VAV terminal units, include a dedicated LAN of application-specific controllers serving VAV terminal units connected directly to controller that is controlling air-handling system air-handling unit(s). Basically, create a DDC system LAN that aligns with air-handling system being controlled.

2.6 DDC SYSTEM OPERATOR INTERFACES

A. Operator Means of System Access: Operator shall be able to access entire DDC system through any of multiple means, including, but not limited to, the following:

1. Desktop and portable operator workstation with hardwired connection through LAN port.
2. Portable operator terminal with hardwired connection through LAN port.
3. Portable operator workstation with wireless connection through LAN router.
4. PDA with wireless connection through LAN router.
5. Remote connection using outside of system personal computer or PDA through Web access.
6. Remote connection using portable operator workstation and telephone dial-up modem.

B. Access to system, regardless of operator means used, shall be transparent to operator.

C. Network Ports: For hardwired connection of desktop or portable operator workstation. Network port shall be easily accessible, properly protected, clearly labeled, and installed at the following locations:

1. Each mechanical equipment room.
2. Each boiler room.
3. Each chiller room or outdoor chiller yard.
4. Each cooling tower location.

5.      Each different roof level with roof-mounted air-handling units or rooftop units.
6.      Security system command center.
7.      Fire-alarm system command center.

D.      Desktop Workstations:

1.      Connect to DDC system Level one LAN through a communications port directly on LAN or through a communications port on a DDC controller.
2.      Able to communicate with any device located on any DDC system LAN.
3.      Able to communicate, with modems, remotely with any device connected to any DDC system LAN.
4.      Communication via a modem shall not interfere with LAN activity and LAN activity shall not prevent workstation from handling incoming calls.

E.      Portable Workstations:

1.      Connect to DDC system Level one LAN through a communications port directly on LAN or through a communications port on a DDC controller.
2.      Able to communicate with any device located on any DDC system LAN.
3.      Connect to DDC system LAN through a communications port on an application-specific controller, or a room temperature sensor connected to an application-specific controller.
4.      Connect to system through a wireless router connected to Level one LAN.
5.      Portable workstation shall be able to communicate with any device connected to any system LAN regardless of point of physical connection to system.
6.      Monitor, program, schedule, adjust set points, and report capabilities of I/O connected anywhere in system.
7.      Have dynamic graphic displays that are identical to desktop workstations.

F.      POT:

1.      Connect DDC controller through a communications port local to controller.
2.      Able to communicate with any DDC system controller that is directly connected or with LAN or connected to DDC system.

G.      Personal Digital Assistant:

1.      Connect to system through a wireless router connected to LAN.
2.      Able to communicate with any DDC controller connected to DDC system.

H.      Telephone Communications:

1. Through use of a standard modem, operator shall be able to communicate with any device connected to any system LAN.
2. Have auto-dial and auto-answer communications to allow desktop and portable workstations and DDC controllers to communicate with remote workstations and remote DDC controllers via telephone lines.

    a. Desktop and Portable Operator Workstation Computers with Modems:
        1) Operators shall be able to perform all control functions, report functions, and database generation and modification functions as if directly connected to system LAN.
        2) Have routines to automatically answer calls, and either file or display information sent remotely.
        3) Communications taking place over telephone lines shall be completely transparent to operator.
        4) Dial-up program shall maintain a user-definable cross-reference and associated telephone numbers so it is not required to remember or manually dial telephone numbers.
    b. DDC Controllers:
        1) Not have modems unless specifically indicated for a unique controller.
        2) Controllers with modems shall automatically place calls to report critical alarms, or to upload trend and historical information for archiving.
        3) Analyze and prioritize alarms to minimize initiation of calls.
        4) Buffer noncritical alarms in memory and report them as a group of alarms, or until an operator manually requests an upload.
        5) Make provisions for handling busy signals, no-answers, and incomplete data transfers.
        6) Call default devices when communications cannot be established with primary devices.

I. Critical Alarm Reporting:

1. Operator-selected critical alarms shall be sent by DDC system to notify operator of critical alarms that require immediate attention.
2. DDC system shall send alarm notification to multiple recipients that are assigned for each alarm.
3. DDC system shall notify recipients by any or all means, including e-mail, text message and prerecorded phone message to mobile and landline phone numbers.

J.     Simultaneous Operator Use: Capable of accommodating up to five simultaneous operators that are accessing DDC system through any one of operator interfaces indicated.

2.7     NETWORKS

A.     Acceptable networks for connecting operator workstations and network controllers include the following:

1.     ATA 878.1, ARCNET.
2.     CEA-709.1-C.
3.     IP.
4.     IEEE 8802-3, Ethernet.

B.     Acceptable networks for connecting programmable application controllers include the following:

1.     ATA 878.1, ARCNET.
2.     CEA-709.1-C.
3.     IP.
4.     IEEE 8802-3, Ethernet.

C.     Acceptable networks for connecting application-specific controllers include the following:

1.     ATA 878.1, ARCNET.
2.     CEA-709.1-C.
3.     EIA-485A.
4.     IP.
5.     IEEE 8802-3, Ethernet.

2.8     NETWORK COMMUNICATION PROTCOL

A.     Network communication protocol(s) used throughout entire DDC system shall be open to public and available to other companies for use in making future modifications to DDC system.

B.     ASHRAE 135 Protocol:

1.     ASHRAE 135 communication protocol shall be sole and native protocol used throughout entire DDC system.
2.     DDC system shall not require use of gateways except to integrate HVAC equipment and other building systems and equipment, not required to use ASHRAE 135 communication protocol.
3.     If used, gateways shall connect to DDC system using ASHRAE 135 communication protocol and Project object properties and read/write services indicated by interoperability schedule.

4. Operator workstations, controllers and other network devices shall be tested and listed by BACnet Testing Laboratories.

C. CEA-709.1-C Protocol:

1. DDC system shall be an open implementation of LonWorks technology using CEA 709.1-C communication protocol and using LonMark SNVTs as defined in LonMark SNVT list exclusively for communication throughout DDC system.
2. LNS shall be used for all network management including addressing and binding of network variables.

   a. Final LNS database shall be submitted with Project closeout submittals.
   b. All devices shall be online and commissioned into LNS database.

3. All devices connected to DDC system network(s) shall use CEA-709.1-C protocol and be installed so SCPT output from any node on network can be bound to any other node in the domain.

D. Industry Standard Protocols:

1. DDC system shall use any one or a combination of the following industry standard protocols for network communication while complying with other DDC system requirements indicated:

   a. ASHRAE 135.
   b. CEA-709.1-C.
   c. Modbus Application Protocol Specification V1.1b.

2. Operator workstations and network controllers shall communicate through ASHRAE 135 or CEA-709.1-C protocol.
3. Portions of DDC system networks using ASHRAE 135 communication protocol shall be an open implementation of network devices complying with ASHRAE 135. Network devices shall be tested and listed by BACnet Testing Laboratories.
4. Portions of DDC system networks using CEA-709.1-C communication protocol shall be an open implementation of LonWorks technology using CEA-709.1-C communication protocol and using LonMark SNVTs as defined in LonMark SNVT list exclusively for DDC system.
5. Portions of DDC system networks using Modbus Application Protocol Specification V1.1b communication protocol shall be an open implementation of network devices and technology complying with Modbus Application Protocol Specification V1.1b.
6. Gateways shall be used to connect networks and network devices using different protocols.

## 2.9 DDC SYSTEM WIRELESS NETWORKS

A. Use an open industry standard and technology used by multiple DDC system manufacturers' technology to create a wireless mesh network to provide wireless connectivity for network devices at multiple system levels including communications from programmable application controllers and application-specific controllers to temperature sensors and from network controllers to programmable application controllers and application-specific controllers.

B. Installer shall design wireless networks to comply with DDC system performance requirements indicated. Wireless network devices shall co-exist on same network with hardwired devices.

C. Hardwired controllers shall be capable of retrofit to wireless devices with no special software.

D. A wireless coordinator shall provide a wireless interface between programmable application controllers, application-specific controllers, and network controllers.

E. Wireless Coordinators:

1. Each wireless mesh network shall use wireless coordinator(s) for initiation and formation of network.
2. Use direct sequence spread spectrum RF technology.
3. Operate on the 2.4-GHz ISM Band.
4. Comply with IEEE 802.15.4 for low-power, low duty-cycle RF transmitting systems.
5. FCC compliant to 47 CFR 15, Subpart B, Class A.
6. Operate as a bidirectional transceiver with sensors and routers to confirm and synchronize data transmission.
7. Capable of communication with sensors and routers up to a maximum distance of 250 feet (76 m) in line of sight.
8. Include visual indicators to provide diagnostic information required for operator verification of operation.

F. Wireless Routers:

1. Each wireless mesh network shall use wireless routers with any controller to provide a wireless interface to a network controller, through a wireless coordinator.
2. Use direct sequence spread spectrum RF technology.
3. Operate on the 2.4-GHz ISM Band.
4. Comply with IEEE 802.15.4 for low-power, low duty-cycle RF transmitting systems.
5. FCC compliant to 47 CFR 15, Subpart B, Class A.

6.     Operate as a bidirectional transceiver with other mesh network devices to ensure network integrity.

7.     Capable of communication with other mesh network devices at a maximum distance of 250 feet (76 m) in line of sight.

8.     Include indication for use in commissioning and troubleshooting.

G.    Wireless Temperature Sensors:

1.     Wireless temperature sensors shall sense and transmit room temperatures, temperature set point, room occupancy notification and low battery condition to an associated router.

2.     Use direct sequence spread spectrum RF technology.

3.     Operate on the 2.4-GHz ISM Band.

4.     Comply with IEEE 802.15.4 for low-power, low duty-cycle RF transmitting systems.

5.     FCC compliant to CFR 15, Subpart B, Class A.

6.     Include set point adjustment between 55 to 85 deg F (13 to 30 deg C).

7.     Multiple sensors shall be able to report to a router connected to a DDC controller for averaging or high and low selection.

H.    One-to-One Wireless Network Receivers:

1.     One-to-one wireless receivers shall receive wireless RF signals containing temperature data from multiple wireless room temperature sensors and communicate information to programmable application controllers or application-specific controllers.

     a.     Use direct sequence spread spectrum RF technology.

     b.     Operate on the 2.4-GHz ISM Band.

     c.     Comply with IEEE 802.15.4 for low-power, low duty-cycle RF transmitting systems.

     d.     FCC compliant to 47 CFR 15, Subpart B, Class A.

     e.     Operate as a bidirectional transceiver with the sensors to confirm and synchronize data transmission.

     f.     Capable of communication up to a distance of 200 feet (61 m).

     g.     Include visual indication of the following:

          1)     Power.

          2)     Receiver activity.

          3)     Wireless RF transmission from wireless sensors.

          4)     No transmission, weak signal, adequate signal or excellent signal.

I.    One-to-One Wireless Network Sensors:

1.     One-to-one wireless sensors shall sense and report room temperatures to one-to-one receiver.

a.　　Use direct sequence spread spectrum RF technology.
　　　　　　b.　　Operate on the 2.4-GHz ISM Band.
　　　　　　c.　　Comply with IEEE 802.15.4 for low-power, low duty-cycle RF transmitting systems.
　　　　　　d.　　FCC compliant to CFR 15, Subpart B, Class A.
　　　　　　e.　　Include set point adjustment between 55 to 85 deg F (13 to 30 deg C).

2.10　　DESKTOP OPERATOR WORKSTATIONS

　　A.　Performance Requirements:

　　　　1.　Performance requirements may dictate equipment exceeding minimum requirements indicated.
　　　　2.　Energy Star compliant.

2.11　　SYSTEM SOFTWARE

　　A.　System Software Minimum Requirements:

　　　　1.　Real-time multitasking and multiuser 64-bit operating system that allows concurrent multiple operator workstations operating and concurrent execution of multiple real-time programs and custom program development.
　　　　2.　Operating system shall be capable of operating DOS and Microsoft Windows applications.
　　　　3.　Database management software shall manage all data on an integrated and non-redundant basis. Additions and deletions to database shall be without detriment to existing data. Include cross linkages so no data required by a program can be deleted by an operator until that data have been deleted from respective programs.
　　　　4.　Network communications software shall manage and control multiple network communications to provide exchange of global information and execution of global programs.
　　　　5.　Operator interface software shall include day-to-day operator transaction processing, alarm and report handling, operator privilege level and data segregation control, custom programming, and online data modification capability.
　　　　6.　Scheduling software shall schedule centrally based time and event, temporary, and exception day programs.

　　B.　Operator Interface Software:

　　　　1.　Minimize operator training through use of English language prorating and English language point identification.
　　　　2.　Minimize use of a typewriter-style keyboard through use of a pointing device similar to a mouse.

3. Operator sign-off shall be a manual operation or, if no keyboard or mouse activity takes place, an automatic sign-off.
4. Automatic sign-off period shall be programmable from one to 60 minutes in one-minute increments on a per operator basis.
5. Operator sign-on and sign-off activity shall be recorded and sent to printer.
6. Security Access:

   a. Operator access to DDC system shall be under password control.
   b. An alphanumeric password shall be field assignable to each operator.
   c. Operators shall be able to access DDC system by entry of proper password.
   d. Operator password shall be same regardless of which computer or other interface means is used.
   e. Additions or changes made to passwords shall be updated automatically.
   f. Each operator shall be assigned an access level to restrict access to data and functions the operator is cable of performing.
   g. Software shall have at least five access levels.
   h. Each menu item shall be assigned an access level so that a one-for-one correspondence between operator assigned access level(s) and menu item access level(s) is required to gain access to menu item.
   i. Display menu items to operator with those capable of access highlighted. Menu and operator access level assignments shall be online programmable and under password control.

7. Data Segregation:

   a. Include data segregation for control of specific data routed to a workstation, to an operator or to a specific output device, such as a printer.
   b. Include at least 32 segregation groups.
   c. Segregation groups shall be selectable such as "fire points," "fire points on second floor," "space temperature points," "HVAC points," and so on.
   d. Points shall be assignable to multiple segregation groups. Display and output of data to printer or monitor shall occur where there is a match of operator or peripheral segregation group assignment and point segregations.
   e. Alarms shall be displayed and printed at each peripheral to which segregation allows, but only those operators assigned to peripheral and having proper authorization level will be allowed to acknowledge alarms.
   f. Operators and peripherals shall be assignable to multiple segregation groups and all assignments are to be online programmable and under password control.

8. Operators shall be able to perform commands including, but not limited to, the following:

 a. Start or stop selected equipment.
 b. Adjust set points.
 c. Add, modify, and delete time programming.
 d. Enable and disable process execution.
 e. Lock and unlock alarm reporting for each point.
 f. Enable and disable totalization for each point.
 g. Enable and disable trending for each point.
 h. Override control loop set points.
 i. Enter temporary override schedules.
 j. Define holiday schedules.
 k. Change time and date.
 l. Enter and modify analog alarm limits.
 m. Enter and modify analog warning limits.
 n. View limits.
 o. Enable and disable demand limiting.
 p. Enable and disable duty cycle.
 q. Display logic programming for each control sequence.

9. Reporting:

 a. Generated automatically and manually.
 b. Sent to displays, printers and disk files.
 c. Types of Reporting:
  1) General listing of points.
  2) List points currently in alarm.
  3) List of off-line points.
  4) List points currently in override status.
  5) List of disabled points.
  6) List points currently locked out.
  7) List of items defined in a "Follow-Up" file.
  8) List weekly schedules.
  9) List holiday programming.
  10) List of limits and deadbands.

10. Summaries: For specific points, for a logical point group, for an operator selected group(s), or for entire system without restriction due to hardware configuration.

C. Graphic Interface Software:

1. Include a full interactive graphical selection means of accessing and displaying system data to operator. Include at least five levels with the penetration path operator assignable (for example, site, building, floor, air-

23 09 23 – 35

Direct Digital Control (DDC) System For HVAC      Bid Set
Tt # 200-11740-10003             Tetra Tech, Inc.

handling unit, and supply temperature loop). Native language descriptors assigned to menu items are to be operator defined and modifiable under password control.

2.    Include a hierarchical-linked dynamic graphic operator interface for accessing and displaying system data and commanding and modifying equipment operation. Interface shall use a pointing device with pull-down or penetrating menus, color and animation to facilitate operator understanding of system.

3.    Include at least 10 levels of graphic penetration with the hierarchy operator assignable.

4.    Descriptors for graphics, points, alarms and such shall be modified through operator's workstation under password control.

5.    Graphic displays shall be online user definable and modifiable using the hardware and software provided.

6.    Data to be displayed within a graphic shall be assignable regardless of physical hardware address, communication or point type.

7.    Graphics are to be online programmable and under password control.

8.    Points may be assignable to multiple graphics where necessary to facilitate operator understanding of system operation.

9.    Graphics shall also contain software points.

10.   Penetration within a graphic hierarchy shall display each graphic name as graphics are selected to facilitate operator understanding.

11.   Back-trace feature shall permit operator to move upward in the hierarchy using a pointing device. Back trace shall show all previous penetration levels. Include operator with option of showing each graphic full screen size with back trace as horizontal header or by showing a "stack" of graphics, each with a back trace.

12.   Display operator accessed data on the monitor.

13.   Operator shall select further penetration using pointing device to click on a site, building, floor, area, equipment, and so on. Defined and linked graphic below that selection shall then be displayed.

14.   Include operator with means to directly access graphics without going through penetration path.

15.   Dynamic data shall be assignable to graphics.

16.   Display points (physical and software) with dynamic data provided by DDC system with appropriate text descriptors, status or value, and engineering unit.

17.   Use color, rotation, or other highly visible means, to denote status and alarm states. Color shall be variable for each class of points, as chosen by operator.

18.   Points shall be dynamic with operator adjustable update rates on a per point basis from one second to over a minute.

19.   For operators with appropriate privilege, points shall be commanded directly from display using pointing device.

        a.      For an analog command point such as set point, current conditions and limits shall be displayed and operator can position new set point using pointing device.

        b.      For a digital command point such as valve position, valve shall show its current state such as open or closed and operator could select alternative position using pointing device.

        c.      Keyboard equivalent shall be available for those operators with that preference.

20.     Operator shall be able to split or resize viewing screen into quadrants to show one graphic on one quadrant of screen and other graphics or spreadsheet, bar chart, word processing, curve plot and other information on other quadrants on screen. This feature shall allow real-time monitoring of one part of system while displaying other parts of system or data to better facilitate overall system operation.

21.     Help Features:

        a.      On-line context-sensitive help utility to facilitate operator training and understanding.

        b.      Bridge to further explanation of selected keywords. Document shall contain text and graphics to clarify system operation.

            1)     If help feature does not have ability to bridge on keywords for more information, a complete set of user manuals shall be provided in an indexed word-processing program, which shall run concurrently with operating system software.

        c.      Available for Every Menu Item:

            1)     Index items for each system menu item.

22.     Graphic generation software shall allow operator to add, modify, or delete system graphic displays.

        a.      Include libraries of symbols depicting HVAC symbols such as fans, coils, filters, dampers, valves pumps, and electrical symbols.

        b.      Graphic development package shall use a pointing device in conjunction with a drawing program to allow operator to perform the following:

            1)     Define background screens.
            2)     Define connecting lines and curves.
            3)     Locate, orient and size descriptive text.
            4)     Define and display colors for all elements.
            5)     Establish correlation between symbols or text and associated system points or other displays.

D.    Project-Specific Graphics: Graphics documentation including, but not limited to, the following:

23 09 23 – 37

Direct Digital Control (DDC) System For HVAC                     Bid Set
Tt # 200-11740-10003                                           Tetra Tech, Inc.

1. Site plan showing each building, and additional site elements, which are being controlled or monitored by DDC system.
2. Plan for each building floor, including interstitial floors, and each roof level of each building, showing the following:

   a. Room layouts with room identification and name.
   b. Locations and identification of all monitored and controlled HVAC equipment and other equipment being monitored and controlled by DDC system.
   c. Location and identification of each hardware point being controlled or monitored by DDC system.

3. Control schematic for each of following, including a graphic system schematic representation with point identification, set point and dynamic value indication, sequence of operation and control logic diagram.
4. Graphic display for each piece of equipment connected to DDC system through a data communications link. Include dynamic indication of all points associated with equipment.
5. DDC system network riser diagram that shows schematic layout for entire system including all networks and all controllers, gateways operator workstations and other network devices.

E. Customizing Software:

1. Software to modify and tailor DDC system to specific and unique requirements of equipment installed, to programs implemented and to staffing and operational practices planned.
2. Online modification of DDC system configuration, program parameters, and database using menu selection and keyboard entry of data into preformatted display templates.
3. As a minimum, include the following modification capability:

   a. Operator assignment shall include designation of operator passwords, access levels, point segregation and auto sign-off.
   b. Peripheral assignment capability shall include assignment of segregation groups and operators to consoles and printers, designation of backup workstations and printers, designation of workstation header points and enabling and disabling of print-out of operator changes.
   c. System configuration and diagnostic capability shall include communications and peripheral port assignments, DDC controller assignments to network, DDC controller enable and disable, assignment of command trace to points and application programs and initiation of diagnostics.
   d. System text addition and change capability shall include English or native language descriptors for points, segregation groups and

access levels and action messages for alarms, run time and trouble condition.

e. Time and schedule change capability shall include time and date set, time and occupancy schedules, exception and holiday schedules and daylight savings time schedules.

f. Point related change capability shall include the following:
1) System and point enable and disable.
2) Run-time enable and disable.
3) Assignment of points to segregation groups, calibration tables, lockout, and run time and to a fixed I/O value.
4) Assignment of alarm and warning limits.

g. Application program change capability shall include the following:
1) Enable and disable of software programs.
2) Programming changes.
3) Assignment of comfort limits, global points, time and event initiators, time and event schedules and enable and disable time and event programs.

4. Software shall allow operator to add points, or groups of points, to DDC system and to link them to energy optimization and management programs. Additions and modifications shall be online programmable using operator workstation, downloaded to other network devices and entered into their databases. After verification of point additions and associated program operation, database shall be uploaded and recorded on hard drive and disk for archived record.

5. Include high-level language programming software capability for implementation of custom DDC programs. Software shall include a compiler, linker, and up- and down-load capability.

6. Include a library of DDC algorithms, intrinsic control operators, arithmetic, logic and relational operators for implementation of control sequences. Also include, as a minimum, the following:

a. Proportional control (P).
b. Proportional plus integral (PI).
c. Proportional plus integral plus derivative (PID).
d. Adaptive and intelligent self-learning control.
1) Algorithm shall monitor loop response to output corrections and adjust loop response characteristics according to time constant changes imposed.
2) Algorithm shall operate in a continuous self-learning manner and shall retain in memory a stored record of system dynamics so that on system shut down and restart, learning process starts from where it left off.

7. Fully implemented intrinsic control operators including sequence, reversing, ratio, time delay, time of day, highest select AO, lowest select

23 09 23 – 39

Direct Digital Control (DDC) System For HVAC                          Bid Set
Tt # 200-11740-10003                                           Tetra Tech, Inc.

AO, analog controlled digital output, analog control AO, and digitally controlled AO.

8. Logic operators such as "And," "Or," "Not," and others that are part of a standard set available with a high-level language.

9. Arithmetic operators such as "Add," "Subtract," "Multiply," "Divide," and others that are part of a standard set available with a high-level language.

10. Relational operators such as "Equal To," "Not Equal To," "Less Than," "Greater Than," and others that are part of a standard set available with a high-level language.

F. Alarm Handling Software:

1. Include alarm handling software to report all alarm conditions monitored and transmitted through DDC controllers, gateways and other network devices.

2. Include first in, first out handling of alarms according to alarm priority ranking, with most critical alarms first, and with buffer storage in case of simultaneous and multiple alarms.

3. Alarm handling shall be active at all times to ensure that alarms are processed even if an operator is not currently signed on to DDC system.

4. Alarms display shall include the following:

   a. Indication of alarm condition such as "Abnormal Off," "Hi Alarm," and "Low Alarm."

   b. "Analog Value" or "Status" group and point identification with native language point descriptor such as "Space Temperature, Building 110, 2nd Floor, Room 212."

   c. Discrete per point alarm action message, such as "Call Maintenance Dept. Ext-5561."

   d. Include extended message capability to allow assignment and printing of extended action messages. Capability shall be operator programmable and assignable on a per point basis.

5. Alarms shall be directed to appropriate operator workstations, printers, and individual operators by privilege level and segregation assignments.

6. Send e-mail alarm messages to designated operators.

7. Send e-mail, page, text and voice messages to designated operators for critical alarms.

8. Alarms shall be categorized and processed by class.

   a. Class 1:
      1) Associated with fire, security and other extremely critical equipment monitoring functions; have alarm, trouble, return to normal, and acknowledge conditions printed and displayed.

2) Unacknowledged alarms to be placed in unacknowledged alarm buffer.
3) All conditions shall cause an audible sound and shall require individual acknowledgment to silence audible sound.

b. Class 2:
1) Critical, but not life-safety related, and processed same as Class 1 alarms, except do not require individual acknowledgment.
2) Acknowledgement may be through a multiple alarm acknowledgment.

c. Class 3:
1) General alarms; printed, displayed and placed in unacknowledged alarm buffer queues.
2) Each new alarm received shall cause an audible sound. Audible sound shall be silenced by "acknowledging" alarm or by pressing a "silence" key.
3) Acknowledgement of queued alarms shall be either on an individual basis or through a multiple alarm acknowledgement.
4) Alarms returning to normal condition shall be printed and not cause an audible sound or require acknowledgment.

d. Class 4:
1) Routine maintenance or other types of warning alarms.
2) Alarms to be printed only, with no display, no audible sound and no acknowledgment required.

9. Include an unacknowledged alarm indicator on display to alert operator that there are unacknowledged alarms in system. Operator shall be able to acknowledge alarms on an individual basis or through a multiple alarm acknowledge key, depending on alarm class.

10. To ensure that no alarm records are lost, it shall be possible to assign a backup printer to accept alarms in case of failure of primary printer.

G. Reports and Logs:

1. Include reporting software package that allows operator to select, modify, or create reports using DDC system I/O point data available.

2. Each report shall be definable as to data content, format, interval and date.

3. Report data shall be sampled and stored on DDC controller, within storage limits of DDC controller, and then uploaded to archive on workstation server for historical reporting.

4. Operator shall be able to obtain real-time logs of all I/O points by type or status, such as alarm, point lockout, or normal.

5.     Reports and logs shall be stored on workstation and server hard drives in a format that is readily accessible by other standard software applications, including spreadsheets and word processing.

6.     Reports and logs shall be readily printed and set to be printed either on operator command or at a specific time each day.

H.     Standard Reports: Standard DDC system reports shall be provided and operator shall be able to customize reports later.

1.     All I/O: With current status and values.

2.     Alarm: All current alarms, except those in alarm lockout.

3.     Disabled I/O: All I/O points that are disabled.

4.     Alarm Lockout I/O: All I/O points in alarm lockout, whether manual or automatic.

5.     Alarm Lockout I/O in Alarm: All I/O in alarm lockout that are currently in alarm.

6.     Logs:

     a.     Alarm history.

     b.     System messages.

     c.     System events.

     d.     Trends.

I.     Custom Reports: Operator shall be able to easily define any system data into a daily, weekly, monthly, or annual report. Reports shall be time and date stamped and shall contain a report title.

J.     Tenant Override Reports: Prepare Project-specific reports.

1.     Weekly report showing daily total time in hours that each tenant has requested after-hours HVAC.

2.     Monthly report showing daily total time in hours that each tenant has requested after-hours HVAC.

3.     Annual summary report that shows after-hours HVAC usage on a monthly basis.

K.     HVAC Equipment Reports: Prepare Project-specific reports.

1.     Chiller Report: Daily report showing operating conditions of each chiller according to ASHRAE 147, including, but not limited to, the following:

     a.     Chilled-water entering temperature.

     b.     Chilled-water leaving temperature.

     c.     Chilled-water flow rate.

     d.     Chilled-water inlet and outlet pressures.

     e.     Evaporator refrigerant pressure and temperature.

| | f. | Condenser refrigerant pressure and liquid temperature. |
|---|---|---|
| | g. | Condenser-water entering temperature. |
| | h. | Condenser-water leaving temperature. |
| | i. | Condenser-water flow rate. |
| | j. | Refrigerant levels. |
| | k. | Oil pressure and temperature. |
| | l. | Oil level. |
| | m. | Compressor refrigerant discharge temperature. |
| | n. | Compressor refrigerant suction temperature. |
| | o. | Addition of refrigerant. |
| | p. | Addition of oil. |
| | q. | Vibration levels or observation that vibration is not excessive. |
| | r. | Motor amperes per phase. |
| | s. | Motor volts per phase. |
| | t. | Refrigerant monitor level (PPM). |
| | u. | Purge exhaust time or discharge count. |
| | v. | Ambient temperature (dry bulb and wet bulb). |
| | w. | Date and time logged. |

L.  Utility Reports: Prepare Project-specific reports.

1.  Electric Report:

    a.    Include weekly report showing daily electrical consumption and peak electrical demand with time and date stamp for each meter.

    b.    Include monthly report showing the daily electrical consumption and peak electrical demand with time and date stamp for each meter.

    c.    Include annual report showing the monthly electrical consumption and peak electrical demand with time and date stamp for each meter.

    d.    For each weekly, monthly and annual report, include sum total of submeters combined by load type, such as lighting, receptacles and HVAC equipment showing daily electrical consumption and peak electrical demand.

    e.    For each weekly, monthly and annual report, include sum total of all submeters in building showing electrical consumption and peak electrical demand.

2.  Natural Gas Report:

    a.    Include weekly report showing daily natural gas consumption and peak natural gas demand with time and date stamp for each meter.

    b.    Include monthly report showing the daily natural gas consumption and peak natural gas demand with time and date stamp for each meter.

    c.       Include annual report showing the monthly natural gas consumption and peak natural gas demand with time and date stamp for each meter.

    d.       For each weekly, monthly and annual report, include sum total of submeters combined by load type, such as boilers and service water heaters showing daily natural gas consumption and peak natural gas demand.

    e.       For each weekly, monthly and annual report, include sum total of all submeters in building showing natural gas consumption and peak natural gas demand.

3.      Service Water Report:

    a.       Include weekly report showing daily service water consumption and peak service water demand with time and date stamp for each meter.

    b.       Include monthly report showing the daily service water consumption and peak service water demand with time and date stamp for each meter.

    c.       Include annual report showing the monthly service water consumption and peak service water demand with time and date stamp for each meter.

    d.       For each weekly, monthly and annual report, include sum total of submeters combined by load type, such as cooling tower makeup and irrigation showing daily service water consumption and peak service water demand.

    e.       For each weekly, monthly and annual report, include sum total of all submeters in building showing service water consumption and peak service water demand.

4.      Prepare report for each purchased energy utility, indicating the following:

    a.       Time period being reported with beginning and end date, and time indicated.

    b.       Consumption in units of measure commonly used to report specific utility consumption over time.

    c.       Gross area served by utility.

    d.       Consumption per unit area served using utility-specific unit of measure.

    e.       Cost per utility unit.

    f.       Utility cost per unit area.

    g.       Convert all utilities to a common energy consumption unit of measure and report for each utility.

    h.       Consumption per unit area using common unit of measure.

5.      Prepare report for each renewable energy source, indicating the following:

Direct Digital Control (DDC) System For HVAC         Bid Set

Tt # 200-11740-10003         Tetra Tech, Inc.

a. Time period being reported with beginning and end date, and time indicated.
b. Harvested energy in units of measure commonly used to report specific harvested energy consumption over time.
c. Gross area served by renewable energy source.
d. Harvested energy per unit area served using specific unit of measure.
e. Cost per purchased utility unit displaced by renewable energy.
f. Cost savings attributed to harvested energy source.
g. Cost savings per unit area attributed to harvested energy.
h. Convert all renewable energy sources to a common energy consumption unit of measure and report for each.
i. Harvested energy per unit area using common unit of measure.

6. Prepare purchased energy utility report for each submetered area that indicates the following:

a. Time period being reported with beginning and end date, and time indicated.
b. Gross area served.
c. Energy consumption by energy utility type.
d. Energy consumption per unit area by energy utility type.
e. Total energy consumption of all utilities in common units of measure.
f. Total energy consumption of all utilities in common units of measure per unit area.
g. Unit energy cost by energy utility type.
h. Energy cost by energy utility type.
i. Energy cost per unit area by energy utility type.
j. Total cost of all energy utilities.
k. Total cost of all energy utilities per unit area.

7. Prepare Project total purchased energy utility report that combines all purchased energy utilities and all areas served. Project total energy report shall indicate the following:

a. Time period being reported with beginning and end date, and time indicated.
b. Gross area served.
c. Energy consumption by energy utility type.
d. Energy consumption per unit area by energy utility type.
e. Total energy consumption of all utilities in common units of measure.
f. Total energy consumption of all utilities in common units of measure per unit area.
g. Unit energy cost by energy utility type.

h.      Energy cost by energy utility type.

i.      Energy cost per unit area by energy utility type.

j.      Total cost of all energy utilities.

k.      Total cost of all energy utilities per unit area.

M.    Standard Trends:

1.      Trend all I/O point present values, set points, and other parameters indicated for trending.

2.      Trends shall be associated into groups, and a trend report shall be set up for each group.

3.      Trends shall be stored within DDC controller and uploaded to hard drives automatically on reaching 75 of DDC controller buffer limit, or by operator request, or by archiving time schedule.

4.      Preset trend intervals for each I/O point after review with Owner.

5.      Trend intervals shall be operator selectable from 10 seconds up to 60 minutes. Minimum number of consecutive trend values stored at one time shall be 100 per variable.

6.      When drive storage memory is full, most recent data shall overwrite oldest data.

7.      Archived and real-time trend data shall be available for viewing numerically and graphically by operators.

N.    Custom Trends: Operator shall be able to define a custom trend log for any I/O point in DDC system.

1.      Each trend shall include interval, start time, and stop time.

2.      Data shall be sampled and stored on DDC controller, within storage limits of DDC controller, and then uploaded to archive on workstation hard drives.

3.      Data shall be retrievable for use in spreadsheets and standard database programs.

O.    Programming Software:

1.      Include programming software to execute sequences of operation indicated.

2.      Include programming routines in simple and easy to follow logic with detailed text comments describing what the logic does and how it corresponds to sequence of operation.

3.      Programing software shall be as follows:

a.      Graphic Based: Programming shall use a library of function blocks made from preprogrammed code designed for DDC control systems.

            1)     Function blocks shall be assembled with interconnection lines that represent to control sequence in a flowchart.

            2)     Programming tools shall be viewable in real time to show present values and logical results of each function block.

    b.     Menu Based: Programming shall be done by entering parameters, definitions, conditions, requirements and constraints.

    c.     Line by Line and Text Based: Programming shall declare variable types such as local, global, real, integer, and so on, at the beginning of the program. Use descriptive comments frequently to describe programming code.

4.     Include means for detecting programming errors and testing software control strategies with a simulation tool before implementing in actual control. Simulation tool may be inherent with programming software or as a separate product.

P.     Database Management Software:

1.     Where a separate SQL database is used for information storage, DDC system shall include database management software that separates database monitoring and managing functions by supporting multiple separate windows.

2.     Database secure access shall be accomplished using standard SQL authentication including ability to access data for use outside of DDC system applications.

3.     Database management function shall include summarized information on trend, alarm, event, and audit for the following database management actions:

    a.     Backup.

    b.     Purge.

    c.     Restore.

4.     Database management software shall support the following:

    a.     Statistics: Display database server information and trend, alarm, event, and audit information on database.

    b.     Maintenance: Include method of purging records from trend, alarm, event and audit databases by supporting separate screens for creating a backup before purging, selecting database, and allowing for retention of a selected number of day's data.

    c.     Backup: Include means to create a database backup file and select a storage location.

    d.     Restore: Include a restricted means of restoring a database by requiring operator to have proper security level.

5. Database management software shall include information of current database activity, including the following:

    a.    Ready.
    b.    Purging record from a database.
    c.    Action failed.
    d.    Refreshing statistics.
    e.    Restoring database.
    f.    Shrinking a database.
    g.    Backing up a database.
    h.    Resetting Internet information services.
    i.    Starting network device manager.
    j.    Shutting down the network device manager.
    k.    Action successful.

6. Database management software monitoring functions shall continuously read database information once operator has logged on.

7. Include operator notification through on-screen pop-up display and e-mail message when database value has exceeded a warning or alarm limit.

8. Monitoring settings window shall have the following sections:

    a.    Allow operator to set and review scan intervals and start times.
    b.    E-mail: Allow operator to create and review e-mail and phone text messages to be delivered when a warning or an alarm is generated.
    c.    Warning: Allow operator to define warning limit parameters, set reminder frequency and link e-mail message.
    d.    Alarm: Allow operator to define alarm limit parameters, set reminder frequency and link e-mail message.
    e.    Database Login: Protect system from unauthorized database manipulation by creating a read access and a write access for each of trend, alarm, event and audit databases as well as operator proper security access to restore a database.

9. Monitoring settings taskbar shall include the following informational icons:

    a.    Normal: Indicates by color and size, or other easily identifiable means that all databases are within their limits.
    b.    Warning: Indicates by color and size, or other easily identifiable means that one or more databases have exceeded their warning limit.
    c.    Alarm: Indicates by color and size, or other easily identifiable means that one or more databases have exceeded their alarm limit.

2.12    OFFICE APPLICATION SOFTWARE

    A.    Include current version of office application software at time of Substantial Completion.

    B.    Office application software package shall include multiple separate applications and use a common platform for all applications, similar to Microsoft's "Office Professional."

        1.    Database.
        2.    E-mail.
        3.    Presentation.
        4.    Publisher.
        5.    Spreadsheet.
        6.    Word processing.

2.13    MAINTENANCE MANAGEMENT SOFTWARE

    A.    Scope:

        1.    Include complete and functional software-driven maintenance management system. Software shall perform scheduling of preventive maintenance and generation of work orders, for mechanical and electrical equipment and systems.
        2.    Work orders shall be automatically generated from alarm conditions, run time, and calendar time. Each work order generated shall list parts, tools, craftspeople, and define task to be performed.
        3.    Work order generated shall be used to schedule a repair or preventive maintenance routine.
        4.    Work order shall be used to track completion of work, parts used and total cost of repair.
        5.    A database shall include an inventory tracking system. Work orders generated shall automatically update inventory database to show quantity of tools, repair parts and expendables used for a work order.
        6.    Work orders and preventive maintenance schedules shall be printed on a dedicated printer assigned solely to maintenance management function.

    B.    Additional Hardware Requirements:

        1.    Maintenance management software shall not require additional hardware, except for an additional printer that is dedicated to maintenance management.
        2.    Maintenance management software shall be integrated into DDC system.

    C.    Software Requirements:

1. From main menu of maintenance management system, it shall be possible through selection of icons to penetrate to individual functions described below.
2. Work Orders:

   a. Automatically generate work orders initiated from alarm conditions, accumulated run time or calendar time. Work orders generated shall specify a particular task to be accomplished including the labor, material and tools needed to accomplish work.

   b. Include at least two of the following types of work orders:
      1) Corrective and emergency maintenance work orders shall be generated for a specific job or repair for emergency, breakdown, or scheduled work.
      2) Preventive maintenance that are used on a periodic basis to generate preventive maintenance work orders.

   c. Include the following functions:
      1) Work Order Tracking: Perform every function related to processing work orders including creating, approving and initiating work orders, checking their status history and closing or reworking them when appropriate.
      2) Work Requests: Report any problems that require corrective maintenance activity generated by dispatchers and those people designated to request work orders.
      3) Quick Reporting: Report work done on an open work order or a small job.
      4) Work Manager: Specify the type of labor to be applied to a specific work order at specific times. It shall include the capability to dispatch one or more laborers to top-priority jobs on as-needed basis and to interrupt work in progress to reassign labor to higher priority tasks.

   d. Reports:
      1) Daily Maintenance Schedule by Supervisor: List a schedule of open work orders for a specified date by supervisor.
      2) Equipment Cost Roll-up Report: Include a roll-up of equipment costs incurred since the date the report was last run.
      3) Delinquent Work Order Report: List open work orders whose target completion date is earlier than the date the report is run.
      4) Employee Job Assignments: List labor codes that have job assignments for the specified date.
      5) Daily Work Order Assignment: List work orders that have labor assignments for the specified date.
      6) Estimated versus Actual Work Order Costs: List a cost summary of outstanding work orders.

7) Open Work Orders Report: List open work orders for locations and equipment.

3. Inventory:

    a. Include an inventory tracking system to keep track of stocked, non-stocked and special-order items.

    b. Link inventory tracking to database and when items are consumed, as noted on a work order issued by system, inventory of stocked items shall be automatically updated.

    c. Include the following functions:

        1) Inventory Control: Enter, display, and update information on each inventory item. It shall allow viewing of master inventory records that are independent of storeroom locations or item/location records. Include a screen that lists inventory transactions that move items in or out of inventory or from one storeroom location to another. Minimum information tracked shall include the following:

            a) Vendors supply items.

            b) Item balances, including the bin and lot level for each storeroom location.

            c) Alternative items.

        2) Issues and Transfers: Issue stock directly from inventory, with or without a work order. When transfer of stock from one location to another location occurs, provide appropriate adjustments in stock balance record. Include a trace record of stock transfers from one storeroom to another.

        3) Item Assembly Structures: Include modeling of equipment with inventory items and building of equipment and location hierarchies.

        4) Metered Material Usage:

            a) Track usage by a piece of equipment.

            b) Record against a standing work order for a selected piece of equipment.

            c) Material usage transaction shall be written for each item of material used and be provided as an input to calculation for per unit material consumption report for a piece of equipment.

    d. Reports:

        1) Inventory Analysis Report: List for a given storeroom location, inventory items analysis information that allows quick identification of which inventory items represent greatest monetary investment for dollar value and rate of turnover.

2) Inventory Cycle Count Report: List for a specified storeroom, inventory items that are due to be cycle-counted, based on cycle-count frequency and last count date.

3) Economic Order Quantity Report: For a given storeroom location, display optimum economic ordering quantity for items in selected results set.

4) Inventory Pick Report: A pick list, by work order for items needed to be pulled from a designated storeroom's inventory for work orders having a target start date of specified date.

5) Suggested Order Report: List inventory items in selected results set that are due to be recorded, for a specified storeroom location, based on the following calculation: Suggest a reorder if current balance minus reserve quantity plus on-order quantity is less than reorder point.

6) Reorder Point Report: List selected set of items and optimum minimum level to have in stock based on demand, lead delivery time and a reserve safety stock.

7) Inventory Valuation Report: Gives an accounting of cost of current inventory, for inventory records in a designated storeroom location.

8) Item Order Status: Lists items on order.

9) List of Expired Items: Lists expired lot items in a storeroom. Report shall include item number, description, expiration date, bin number, lot number, manufacturer lot number, and quantity of expired items in that lot and bin.

10) Item Availability at All Locations: Lists alternative storeroom locations for selected items.

11) Where Used Report: List equipment on which item is recorded as being used.

4. Equipment:

a. Include equipment and location records; establish relationships between equipment, between locations, and between equipment and locations; track maintenance costs; and enter and review meter readings.

b. Include the following functions:

1) Equipment: Store equipment numbers and corresponding information including equipment class, location, vendor, up/down status and maintenance costs for each piece of equipment. Include building of equipment assemblies. Equipment assemblies hierarchical ordering shall be

23 09 23 – 52

Direct Digital Control (DDC) System For HVAC                                    Bid Set
Tt # 200-11740-10003                                                    Tetra Tech, Inc.

provided for arrangement of buildings, departments, equipment and sub-assemblies.

2) Operating Locations: Facilitate creation of records for operating locations of equipment, and track equipment that is used in multiple locations. In addition, allow hierarchical organization of equipment operating in facility by means of grouping equipment locations into areas of responsibility.

3) Failure Codes: Develop and display failure hierarchies to acquire an accurate history of types of failures that affect equipment and operating locations.

4) Condition Monitoring: Display time related or limit measurements recorded for a piece of equipment. It shall be possible to generate work orders from this screen and to take immediate action on problem conditions.

c. Reports:

1) Availability Statistic by Location: List equipment availability by location over a user-specified time period.

2) Equipment Failure Summary: List total number of failures by problem code for a piece of equipment for a specified time period.

3) Detailed Equipment Failure Report by Equipment: List of failure reports for the current piece of equipment for a specified time period.

4) Equipment Hierarchy Report: List of equipment.

5) Equipment History Graphs: Include a graphical report in histogram format that displays equipment breakdown history over a specified period.

6) Equipment Measurement Report: Tabular listing and description of each measurement point for a piece of equipment and the history of measurements taken for that point.

7) Maintenance Cost by Equipment: List of transactions costs for elected equipment in the specified date range.

8) Failure Count by Equipment: Graphically report the number of failures for each piece of equipment showing number of failures for each piece of equipment over a specified time period, occurrence of each problem code within set of failures and failures by problem code.

9) Failure Analysis Graphs: Graphically report number of failures for each piece of equipment over a specified time period, number of occurrences of each problem code within set of failures and failures by problem code.

10) Failure Code Hierarchy Report: List of failure codes in each level of the failure hierarchy.

11) Location Failure Summary: A summary for each selected location of failures reported and any hierarchy level locations for specified time period.

12) Failure Summary by Location: A summary of failures for the selected location and their subordinate locations that are part of the hierarchical system.

13) Detailed Failure Report by Location: List all failures for selected location and its subordinate locations that are part of a hierarchical system.

14) Maintenance Cost by System: List of total costs reported in a given date range for locations in selected hierarchical system.

15) Location Hierarchy Report: Lists member locations of a hierarchical system displayed in hierarchical fashion.

5. Purchasing:

   a. Include preparation and generation of purchase requisitions and purchase orders; to report receipt of both items and services, match invoices with purchase orders and receipts and define and convert foreign currencies.

   b. Include the following functions:

      1) Purchase Requisition: Create and process purchase requisitions for items and services.

      2) Purchase Orders: Create and process purchase orders for items and services from scratch or from purchase requisitions. Record receipts of items and services.

      3) Invoices: Include functionality to match purchase orders with invoices and receipts. It shall also be possible to match a service receipt to an invoice. Project for entering of an invoice for bills that do not require purchase orders or receipts.

      4) Currency Management: Define currencies and specify exchange rates. Include preparation of purchase requisitions and purchase orders in currency of vendor, while tracking costs in systems base currency.

   c. Reports:

      1) Invoice Approval Report: Include an approval form for entered invoices.

      2) Inventory Receipts Register: List purchase orders and inventory received for the user-specified time frame.

      3) Direct Purchase Back-Order Report: List of items ordered as a direct purchase not received by the required delivery date.

> 4) Standard Purchase Order: A printing of primary purchase order with vendors shipping information, and items purchased.
> 5) Purchase Order Status Report: List of purchase orders whose status has changed during a certain time period.
> 6) Standard Purchase Requisition: A printing of primary purchase requisition, including vendor name and shipping information.

6. Job Plans:

   a. Include creation of a detailed description of work to be performed by a work order. The job plan shall contain operations, procedures and list of estimated material, labor and tools required for work.

7. Labor:

   a. Store information on employees, contractors, and crafts and include the following functions:
      1) Labor: Create, modify and view employee records. Employee records shall contain pay rate, overtime worked, overtime refused, specials skills and certifications.
      2) Crafts: Create, modify and view craftspeople records.
      3) Labor Reporting: Report labor usage by employee or craft externally from the work orders module.

   b. Reports:
      1) Employee Attendance Analysis: List of planned attendance, actual attendance, vacation and sick time in hours as a percentage of planned attendance for selected employees for specified time period.
      2) Labor Productivity Analysis: List of actual labor hours by labor report category showing each by percentage.
      3) Labor Availability versus Commitments by Crafts: A graphical report that details available labor hours versus committed work order hours by craft and day.

8. Calendars:

   a. Establish calendar records indicating working time for equipment, location, craft, and labor records.

9. Resources:

   a. Include entry and retrieval of data associated with resources required to maintain facility and to include the following functions:

       1)      Companies: Establish and update data on vendors and other companies.

       2)      Tools: Create and maintain information on the tools used on jobs. The information contained within this module shall be available to job plans and work orders.

       3)      Service Contracts: Specify information on service contracts with vendors or manufacturers.

10.     Custom Applications:

    a.     Include creation of customized database tables and application screens that supplement functions specified.

11.     Setup:

    a.     Include configuration of database, security and setup applications.

    b.     Perform the following functions:

       1)      Reports and Other Applications: Register reports and other applications for use within system.

       2)      Documents: Enter, track and link information from Drawings to equipment and inventory items.

       3)      Chart of Accounts: Add or modify accounts; set up financial periods; enter inventory accounts, company accounts, and resource recovery accounts; and define tax codes and rates.

       4)      Signature Security: Establish each user's access rights to modules, applications, screens and options.

       5)      Database Configuration: Customize database, including adjusting field lengths and modifying data types.

       6)      Application Setup: Change position of icons and menu items on the main menu screen.

       7)      Application Launching: Allow for connecting of third-party applications to data fields and push buttons.

12.     Utilities:

    a.     Include utilities module that allows system administrator to customize system and to maintain database.

    b.     Include the following functions:

       1)      Interactive SQL: Include access to database for database management functions of import/export and backup.

       2)      Edit Windows: Display a dialog box to customize an application.

       3)      Archive Data: Remove records from database and store them for future reference.

23 09 23 – 56

Direct Digital Control (DDC) System For HVAC           Bid Set
Tt # 200-11740-10003           Tetra Tech, Inc.

D.  Documentation:

1.  Include complete documentation for the system consisting of a User Manual and Systems Administrator Guide.
2.  User Manual shall describe how to use each application module and screen with step-by-step instructions detailing entry and retrieval of data for functions specified.
3.  Include a step-by-step description of how each report is defined and retrieved.
4.  Bind documentation and clearly title it indicating volume number and use.

2.14   ASHRAE 135 GATEWAYS

A.  Include BACnet communication ports, whenever available as an equipment OEM standard option, for integration via a single communication cable. BACnet-controlled plant equipment includes, but is not limited to, boilers, chillers, and variable-speed drives.

B.  Include gateways to connect BACnet to legacy systems, existing non-BACnet devices, and existing non-BACnet DDC-controlled equipment, only when specifically requested and approved by Owner.

C.  Include with each gateway an interoperability schedule showing each point or event on legacy side that BACnet "client" will read, and each parameter that BACnet network will write to. Describe this interoperability of BACnet services, or BIBBs, defined in ASHRAE 135, Annex K.

D.  Gateway Minimum Requirements:

1.  Read and view all readable object properties on non-BACnet network to BACnet network and vice versa where applicable.
2.  Write to all writeable object properties on non-BACnet network from BACnet network and vice versa where applicable.
3.  Include single-pass (only one protocol to BACnet without intermediary protocols) translation from non-BACnet protocol to BACnet and vice versa.
4.  Comply with requirements of Data Sharing Read Property, Data Sharing Write Property, Device Management Dynamic Device Binding-B, and Device Management Communication Control BIBBs according to ASHRAE 135.
5.  Hardware, software, software licenses, and configuration tools for operator-to-gateway communications.
6.  Backup programming and parameters on CD media and the ability to modify, download, backup, and restore gateway configuration.

2.15    ASHRAE 135 PROTOCOL ANALYZER

A.    Analyzer and required cables and fittings for connection to ASHRAE 135 network.

B.    Analyzer shall include the following minimum capabilities:

1.    Capture and store to a file data traffic on all network levels.
2.    Measure bandwidth usage.
3.    Filtering options with ability to ignore select traffic.

2.16    CEA-709.1-C NETWORK HARDWARE

A.    Routers:
1.    Network routers, including routers configured as repeaters, shall comply with requirements of CEA-709.1-C and include connection between two or more CEA-709.3 TP/FT-10 channels or between two or more CEA-709.3 TP/FT-10 channels and a TP/XF-1250 channel.
2.    IP Routers:

a.    Perform layer three routing of CEA-709.1-C packets over an IP network according to CEA-852-B.
b.    Include appropriate connection to the IP network and connections to CEA-709.3 TP/FT-10 or TP/XF-1250 network.
c.    Support the Dynamic Host Configuration Protocol for IP configuration and use of an CEA-852-B Configuration Server (for CEA-852-B configuration), but shall not rely on these services for configuration.
d.    Capable of manual configuration via a console RS-232 port.

B.    Gateways:

1.    Perform bidirectional protocol translation from one non-CEA-709.1-C protocol to CEA-709.1-C.
2.    Incorporate a network connection to a TP/FT-10 network according to CEA-709.3 and a connection for a non-CEA-709.1-C network.

2.17    DDC CONTROLLERS

A.    DDC system shall consist of a combination of network controllers, programmable application controllers and application-specific controllers to satisfy performance requirements indicated.

B.    DDC controllers shall perform monitoring, control, energy optimization and other requirements indicated.

C.	DDC controllers shall use a multitasking, multiuser, real-time digital control microprocessor with a distributed network database and intelligence.

D.	Each DDC controller shall be capable of full and complete operation as a completely independent unit and as a part of a DDC system wide distributed network.

E.	Environment Requirements:

	1.	Controller hardware shall be suitable for the anticipated ambient conditions.
	2.	Controllers located in conditioned space shall be rated for operation at 32 to 120 deg F (Zero to 50 deg C).
	3.	Controllers located outdoors shall be rated for operation at 40 to 150 deg F (40 to 65 deg C).

F.	Power and Noise Immunity:

	1.	Controller shall operate at 90 to 110 percent of nominal voltage rating and shall perform an orderly shutdown below 80 percent of nominal voltage.
	2.	Operation shall be protected against electrical noise of 5 to 120 Hz and from keyed radios with up to 5 W of power located within36 inches (900 mm) of enclosure.

G.	DDC Controller Spare Processing Capacity:

	1.	Include spare processing memory for each controller. RAM, PROM, or EEPROM will implement requirements indicated with the following spare memory:

		a.	Network Controllers:  70 percent.
		b.	Programmable Application Controllers: Not less than 60 percent.
		c.	Application-Specific Controllers: Not less than 70 percent.

	2.	Memory shall support DDC controller's operating system and database and shall include the following:

		a.	Monitoring and control.
		b.	Energy management, operation and optimization applications.
		c.	Alarm management.
		d.	Historical trend data of all connected I/O points.
		e.	Maintenance applications.
		f.	Operator interfaces.
		g.	Monitoring of manual overrides.

H.	DDC Controller Spare I/O Point Capacity: Include spare I/O point capacity for each controller as follows:

1. Network Controllers:

    a. 20 percent of each AI, AO, BI, and BO point connected to controller.
    b. Minimum Spare I/O Points per Controller:
        1) AIs: Three.
        2) AOs: Three.
        3) BIs: Three.
        4) BOs: Three.

2. Programmable Application Controllers:

    a. 20 percent of each AI, AO, BI, and BO point connected to controller.
    b. Minimum Spare I/O Points per Controller:
        1) AIs: Three.
        2) AOs:Three.
        3) BIs: Three.
        4) BOs: Three.

3. Application-Specific Controllers:

    a. 10 percent of each AI, AO, BI, and BO point connected to controller.
    b. Minimum Spare I/O Points per Controller:
        1) AIs: Two.
        2) AOs: Two.
        3) BIs: Two.
        4) BOs: Two.

I. Maintenance and Support: Include the following features to facilitate maintenance and support:

1. Mount microprocessor components on circuit cards for ease of removal and replacement.
2. Means to quickly and easily disconnect controller from network.
3. Means to quickly and easily access connect to field test equipment.
4. Visual indication that controller electric power is on, of communication fault or trouble, and that controller is receiving and sending signals to network.

J. General Requirements for CEA-709.1-C DDC Controllers:

1. Controllers shall be LonMark certified.
2. Distinguishable and accessible switch, button, or pin, when pressed shall broadcast its 48-bit Node ID and Program ID over network.

3. TP/FT-10 transceiver according to CEA-709.3 and connections for TP/FT-10 control network wiring.

4. TP/XF-1250 transceiver according to CEA-709.3 and connections for TP/XF-1250 control network wiring.

5. Communicate using CEA-709.1-C protocol.

6. Controllers configured into subnets, as required, to comply with performance requirements indicated.

7. Network communication through LNS network management and database standard for CEA-709.1-C network devices.

8. Locally powered, not powered through network connection.

9. Functionality required to support applications indicated, including, but not limited to, the following:

   a. Input and outputs indicated and as required to support sequence of operation and application in which it is used. SNVTs shall have meaningful names identifying the value represented by an SNVT. Unless an SNVT of an appropriate engineering type is unavailable, all network variables shall be of an SNVT with engineering units appropriate to value the variable represents.

   b. Configurable through SCPTs defined in LonMark SCPT List, operator-defined UCPTs, network configuration inputs (NCIs) of an SNVT type defined in LonMark SNVT List, NCIs of an operator-defined network variable type, or hardware settings on controller itself for all settings and parameters used by application in which it is used.

10. Programmable controllers shall conform to LonMark Interoperability Guidelines and have LonMark certification.

K. Input and Output Point Interface:

1. Hardwired input and output points shall connect to network, programmable application and application-specific controllers.

2. Input and output points shall be protected so shorting of point to itself, to another point, or to ground will not damage controller.

3. Input and output points shall be protected from voltage up to 24 V of any duration so that contact will not damage controller.

4. AIs:

   a. AIs shall include monitoring of low-voltage (zero- to 10-V dc), current (4 to 20 mA) and resistance signals from thermistor and RTD sensors.

   b. AIs shall be compatible with, and field configurable to, sensor and transmitters installed.

c. Controller AIs shall perform analog-to-digital (A-to-D) conversion with a minimum resolution of 8 bits or better to comply with accuracy requirements indicated.

d. Signal conditioning including transient rejection shall be provided for each AI.

e. Capable of being individually calibrated for zero and span.

f. Incorporate common-mode noise rejection of at least 50 dB from zero to 100 Hz for differential inputs, and normal-mode noise rejection of at least 20 dB at 60 Hz from a source impedance of 10000 ohms.

5. AOs:

a. Controller AOs shall perform analog-to-digital (A-to-D) conversion with a minimum resolution of 8 bits or better to comply with accuracy requirements indicated.

b. Output signals shall have a range of 4 to 20 mA dc as required to include proper control of output device.

c. Capable of being individually calibrated for zero and span.

d. AOs shall not exhibit a drift of greater than 0.4 percent of range per year.

6. BIs:

a. Controller BIs shall accept contact closures and shall ignore transients of less than 5-ms duration.

b. Isolation and protection against an applied steady-state voltage of up to 180-V ac peak.

c. BIs shall include a wetting current of at least 12 mA to be compatible with commonly available control devices and shall be protected against effects of contact bounce and noise.

d. BIs shall sense "dry contact" closure without external power (other than that provided by the controller) being applied.

e. Pulse accumulation input points shall comply with all requirements of BIs and accept up to 10 pulses per second for pulse accumulation. Buffer shall be provided to totalize pulses. Pulse accumulator shall accept rates of at least 20 pulses per second. The totalized value shall be reset to zero on operator's command.

7. BOs:

a. Controller BOs shall include relay contact closures or triac outputs for momentary and maintained operation of output devices.

1) Relay contact closures shall have a minimum duration of 0.1 second. Relays shall include at least 180 V of isolation. Electromagnetic interference suppression shall be provided

on all output lines to limit transients to non-damaging levels. Minimum contact rating shall be 1 A at 24-V ac.

        2)      Triac outputs shall include at least 180 V of isolation. Minimum contact rating shall be 1 A at 24-V ac.

    b.      BOs shall include for two-state operation or a pulsed low-voltage signal for pulse-width modulation control.

    c.      BOs shall be selectable for either normally open or normally closed operation.

    d.      Include tristate outputs (two coordinated BOs) for control of three-point floating-type electronic actuators without feedback.

    e.      Limit use of three-point floating devices to VAV terminal unit control applications, and other applications indicated on Drawings,. Control algorithms shall operate actuator to one end of its stroke once every 24 hours for verification of operator tracking.

## 2.18 NETWORK CONTROLLERS

A. General Network Controller Requirements:

1. Include adequate number of controllers to achieve performance indicated.
2. System shall consist of one or more independent, standalone, microprocessor-based network controllers to manage global strategies indicated.
3. Controller shall have enough memory to support its operating system, database, and programming requirements.
4. Data shall be shared between networked controllers and other network devices.
5. Operating system of controller shall manage input and output communication signals to allow distributed controllers to share real and virtual object information and allow for central monitoring and alarms.
6. Controllers that perform scheduling shall have a real-time clock.
7. Controller shall continually check status of its processor and memory circuits. If an abnormal operation is detected, controller shall assume a predetermined failure mode and generate an alarm notification.
8. Controllers shall be fully programmable.

B. Communication:

1. Network controllers shall communicate with other devices on DDC system Level one network.
2. Network controller also shall perform routing if connected to a network of programmable application and application-specific controllers.

C. Operator Interface:

        1.      Controller shall be equipped with a service communications port for connection to a portable operator's workstation or PDA.

        2.      Local Keypad and Display:

            a.      Equip controller with local keypad and digital display for interrogating and editing data.

            b.      Use of keypad and display shall require security password.

D.    Serviceability:

        1.      Controller shall be equipped with diagnostic LEDs or other form of local visual indication of power, communication, and processor.

        2.      Wiring and cable connections shall be made to field-removable, modular terminal strips or to a termination card connected by a ribbon cable.

        3.      Controller shall maintain BIOS and programming information in event of a power loss for at least 72 hours.

## 2.19    PROGRAMMABLE APPLICATION CONTROLLERS

A.    General Programmable Application Controller Requirements:

        1.      Include adequate number of controllers to achieve performance indicated.

        2.      Controller shall have enough memory to support its operating system, database, and programming requirements.

        3.      Data shall be shared between networked controllers and other network devices.

        4.      Operating system of controller shall manage input and output communication signals to allow distributed controllers to share real and virtual object information and allow for central monitoring and alarms.

        5.      Controllersshall have a real-time clock.

        6.      Controller shall continually check status of its processor and memory circuits. If an abnormal operation is detected, controller shall assume a predetermined failure mode and generate an alarm notification.

        7.      Controllers shall be fully programmable.

B.    Communication:

        1.      Programmable application controllers shall communicate with other devices on network.

C.    Operator Interface:

        1.      Controller shall be equipped with a service communications port for connection to a portable operator's workstation or PDA.

        2.      Local Keypad and Display:

23 09 23 – 64

Direct Digital Control (DDC) System For HVAC                   Bid Set
Tt # 200-11740-10003                                  Tetra Tech, Inc.

        a.        Equip controller with local keypad and digital display for interrogating and editing data.

        b.        Use of keypad and display shall require security password.

D.    Serviceability:

    1.      Controller shall be equipped with diagnostic LEDs or other form of local visual indication of power, communication, and processor.

    2.      Wiring and cable connections shall be made to field-removable, modular terminal strips or to a termination card connected by a ribbon cable.

    3.      Controller shall maintain BIOS and programming information in event of a power loss for at least 72 hours.

## 2.20    APPLICATION-SPECIFIC CONTROLLERS

A.    Description: Microprocessor-based controllers, which through hardware or firmware design are dedicated to control a specific piece of equipment. Controllers are not fully user-programmable but are configurable and customizable for operation of equipment they are designed to control.

    1.      Capable of standalone operation and shall continue to include control functions without being connected to network.

    2.      Data shall be shared between networked controllers and other network devices.

B.    Communication: Application-specific controllers shall communicate with other application-specific controller and devices on network, and to programmable application and network controllers.

C.    Operator Interface: Controller shall be equipped with a service communications port for connection to a portable operator's workstation. Connection shall extend to port on space temperature sensor that is connected to controller.

D.    Serviceability:

    1.      Controller shall be equipped with diagnostic LEDs or other form of local visual indication of power, communication, and processor.

    2.      Wiring and cable connections shall be made to field-removable, modular terminal strips or to a termination card connected by a ribbon cable.

    3.      Controller shall use nonvolatile memory and maintain all BIOS and programming information in event of power loss.

## 2.21    CONTROLLER SOFTWARE

A.    General Controller Software Requirements:

1. Software applications shall reside and operate in controllers. Editing of applications shall occur at operator workstations.
2. I/O points shall be identified by up to 30-character point name and up to 16-character point descriptor. Same names shall be used at operator workstations.
3. Control functions shall be executed within controllers using DDC algorithms.
4. Controllers shall be configured to use stored default values to ensure fail-safe operation. Default values shall be used when there is a failure of a connected input instrument or loss of communication of a global point value.

B. Security:

1. Operator access shall be secured using individual security passwords and user names.
2. Passwords shall restrict operator to points, applications, and system functions as assigned by system manager.
3. Operator log-on and log-off attempts shall be recorded.
4. System shall protect itself from unauthorized use by automatically logging off after last keystroke. The delay time shall be operator-definable.

C. Scheduling: Include capability to schedule each point or group of points in system. Each schedule shall consist of the following:

1. Weekly Schedule:

   a. Include separate schedules for each day of week.
   b. Each schedule should include the capability for start, stop, optimal start, optimal stop, and night economizer.
   c. Each schedule may consist of up to 10 events.
   d. When a group of objects are scheduled together, include capability to adjust start and stop times for each member.

2. Exception Schedules:

   a. Include ability for operator to designate any day of the year as an exception schedule.
   b. Exception schedules may be defined up to a year in advance. Once an exception schedule is executed, it will be discarded and replaced by regular schedule for that day of week.

3. Holiday Schedules:

   a. Include capability for operator to define up to 99 special or holiday schedules.

    b.  Schedules may be placed on scheduling calendar and will be repeated each year.

    c.  Operator shall be able to define length of each holiday period.

D. System Coordination:

  1.  Include standard application for proper coordination of equipment.

  2.  Application shall include operator with a method of grouping together equipment based on function and location.

  3.  Group may then be used for scheduling and other applications.

E. Binary Alarms:

  1.  Each binary point shall be set to alarm based on operator-specified state.

  2.  Include capability to automatically and manually disable alarming.

F. Analog Alarms:

  1.  Each analog object shall have both high and low alarm limits.

  2.  Alarming shall be able to be automatically and manually disabled.

G. Alarm Reporting:

  1.  Operator shall be able to determine action to be taken in event of an alarm.

  2.  Alarms shall be routed to appropriate operator workstations based on time and other conditions.

  3.  Alarm shall be able to start programs, print, be logged in event log, generate custom messages, and display graphics.

H. Remote Communication:

  1.  System shall have ability to dial out in the event of an alarm.

I. Electric Power Demand Limiting:

  1.  Demand-limiting program shall monitor building or other operator-defined electric power consumption from signals connected to electric power meter or from a watt transducer or current transformer.

  2.  Demand-limiting program shall predict probable power demand such that action can be taken to prevent exceeding demand limit. When demand prediction exceeds demand limit, action will be taken to reduce loads in a predetermined manner. When demand prediction indicates demand limit will not be exceeded, action will be taken to restore loads in a predetermined manner.

  3.  Demand reduction shall be accomplished by the following means:

    a.  Reset air-handling unit supply temperature set points.

| | b. | Reset space temperature set points. |
| | c. | De-energize equipment based on priority. |

4. Demand-limiting parameters, frequency of calculations, time intervals, and other relevant variables shall be based on the means by which electric power service provider computes demand charges.

5. Include demand-limiting prediction and control for any individual meter monitored by system or for total of any combination of meters.

6. Include means operator to make the following changes online:

    a. Addition and deletion of loads controlled.
    b. Changes in demand intervals.
    c. Changes in demand limit for meter(s).
    d. Maximum shutoff time for equipment.
    e. Minimum shutoff time for equipment.
    f. Select rotational or sequential shedding and restoring.
    g. Shed and restore priority.

7. Include the following information and reports, to be available on an hourly, daily, weekly, monthly and annual basis:

    a. Total electric consumption.
    b. Peak demand.
    c. Date and time of peak demand.
    d. Daily peak demand.

J. Maintenance Management: System shall monitor equipment status and generate maintenance messages based on operator-designated run-time, starts, and calendar date limits.

K. Sequencing: Include application software based on sequences of operation indicated to properly sequence chillers, boilers, and other applicable HVAC equipment.

L. Control Loops:

1. Support any of the following control loops, as applicable to control required:

    a. Two-position (on/off, open/close, slow/fast) control.
    b. Proportional control.
    c. Proportional plus integral (PI) control.
    d. Proportional plus integral plus derivative (PID) control.
        1) Include PID algorithms with direct or reverse action and anti-windup.

<div style="text-align: right;">

2)     Algorithm shall calculate a time-varying analog value used to position an output or stage a series of outputs.

3)     Controlled variable, set point, and PID gains shall be operator-selectable.

e.     Adaptive (automatic tuning).

</div>

M.     Staggered Start: Application shall prevent all controlled equipment from simultaneously restarting after a power outage. Order which equipment (or groups of equipment) is started, along with the time delay between starts, shall be operator-selectable.

N.     Energy Calculations:

1.     Include software to allow instantaneous power or flow rates to be accumulated and converted to energy usage data.

2.     Include an algorithm that calculates a sliding-window average (rolling average). Algorithm shall be flexible to allow window intervals to be operator specified (such as 15, 30, or 60 minutes).

3.     Include an algorithm that calculates a fixed-window average. A digital input signal shall define start of window period (such as signal from utility meter) to synchronize fixed-window average with that used by utility.

O.     Anti-Short Cycling:

1.     BO points shall be protected from short cycling.

2.     Feature shall allow minimum on-time and off-time to be selected.

P.     On and Off Control with Differential:

1.     Include an algorithm that allows a BO to be cycled based on a controlled variable and set point.

2.     Algorithm shall be direct- or reverse-acting and incorporate an adjustable differential.

Q.     Run-Time Totalization:

1.     Include software to totalize run-times for all BI and BO points.

2.     A high run-time alarm shall be assigned, if required, by operator.

2.22     ENCLOSURES

A.     General Enclosure Requirements:

1.     House each controller and associated control accessories in aenclosure. Enclosure shall serve as central tie-in point for control devices such as switches, transmitters, transducers, power supplies and transformers.

2.     Do not house more than one controller in a single enclosure.

<div style="text-align: center;">23 09 23 – 69</div>

Direct Digital Control (DDC) System For HVAC            Bid Set
Tt # 200-11740-10003            Tetra Tech, Inc.

3. Include enclosure door with key locking mechanism. Key locks alike for all enclosures and include one pair of keys per enclosure.
4. Equip doors of enclosures housing controllers and components with analog or digital displays with windows to allow visual observation of displays without opening enclosure door.
5. Individual wall-mounted single-door enclosures shall not exceed 36 inches (900 mm) wide and 48 inches (1200 mm) high.

B. Internal Arrangement:

1. Internal layout of enclosure shall group and protect pneumatic, electric, and electronic components associated with a controller, but not an integral part of controller.
2. Arrange layout to group similar products together.
3. Include a barrier between line-voltage and low-voltage electrical and electronic products.
4. Factory or shop install products, tubing, cabling and wiring complying with requirements and standards indicated.
5. Terminate field cable and wire using heavy-duty terminal blocks.
6. Include spare terminals, equal to not less than 20 percent of used terminals.
7. Include spade lugs for stranded cable and wire.
8. Install a maximum of two wires on each side of a terminal.
9. Include enclosure field power supply with a toggle-type switch located at entrance inside enclosure to disconnect power.
10. Include enclosure with a line-voltage nominal 20-A GFCI duplex receptacle for service and testing tools. Wire receptacle on hot side of enclosure disconnect switch and include with a 5-A circuit breaker.
11. Mount products within enclosure on removable internal panel(s).
12. Include products mounted in enclosures with engraved, laminated phenolic nameplates (black letters on a white background). The nameplates shall have at least 1/4-inch- (6-mm-) high lettering.
13. Route tubing cable and wire located inside enclosure within a raceway with a continuous removable cover.
14. Label each end of cable, wire and tubing in enclosure following an approved identification system that extends from field I/O connection and all intermediate connections throughout length to controller connection.
15. Size enclosure internal panel to include at least 25 percent spare area on face of panel.

C. Environmental Requirements:

1. Evaluate temperature and humidity requirements of each product to be installed within each enclosure.

2. Calculate enclosure internal operating temperature considering heat dissipation of all products installed within enclosure and ambient effects (solar, conduction and wind) on enclosure.

3. Where required by application, include temperature-controlled electrical heat to maintain inside of enclosure above minimum operating temperature of product with most stringent requirement.

4. Where required by application, include temperature-controlled ventilation fans with filtered louver(s) to maintain inside of enclosure below maximum operating temperature of product with most stringent requirement.

5. Include temperature-controlled cooling within the enclosure for applications where ventilation fans cannot maintain inside temperature of enclosure below maximum operating temperature of product with most stringent requirement.

6. Where required by application, include humidity-controlled electric dehumidifier or cooling to maintain inside of enclosure below maximum relative humidity of product with most stringent requirement and to prevent surface condensation within enclosure.

D. Wall-Mounted, NEMA 250, Type 1:

1. Enclosure shall be NRTL listed according to UL 50 or UL 50E.
2. Construct enclosure of steel, not less than:

   a. Enclosure size less than 24 in. (600 mm): 0.053 in. (1.35 mm) or 0.067 in. (1.7 mm) thick.
   b. Enclosure size 24 in. (600 mm) and larger: 0.067 in. (1.7 mm) or 0.093 in. (2.36 mm) thick.

3. Finish enclosure inside and out with polyester powder coating that is electrostatically applied and then baked to bond to substrate.

   a. Exterior color shall be white.
   b. Interior color shall be manufacturer's standard.

4. Hinged door full size of front face of enclosure and supported using:

   a. Enclosures sizes less than 36 in. (900 mm) tall: Multiple butt hinges.
   b. Enclosures sizes 36 in. (900 mm) tall and larger: Continuous piano hinges.

5. Removable internal panel with a white polyester powder coating that is electrostatically applied and then baked to bond to substrate.

   a. Size less than 24 in. (600 mm): Solid or Perforated steel, 0.053 in. (1.35 mm) thick.

       b.      Size 24 in. (600 mm) and larger: Solid aluminum, 0.10 in. (3 mm) or steel, 0.093 in. (2.36 mm) thick.

6.     Internal panel mounting hardware, grounding hardware and sealing washers.
7.     Grounding stud on enclosure body.
8.     Thermoplastic pocket on inside of door for record Drawings and Product Data.

E.    Wall Mounted NEMA 250, Types 4 and 12:

1.     Enclosure shall be NRTL listed according to UL 508A.
2.     Seam and joints are continuously welded and ground smooth.
3.     Where recessed enclosures are indicated, include enclosures with face flange for flush mounting.
4.     Externally formed body flange around perimeter of enclosure face for continuous perimeter seamless gasket door seal.
5.     Single-door enclosure sizes up to 60 inches tall by 36 inches wide (1500 mm tall by 900 mm wide).
6.     Double-door enclosure sizes up to 36 inches tall by 60 inches wide (900 mm tall by 1500 mm wide).
7.     Construct enclosure of steel, not less than the following:

       a.      Size Less Than 24 Inches (600 mm): 0.053 inch (1.35 mm) or 0.067 inch (1.7 mm) thick.
       b.      Size 24 Inches (600 mm) and Larger: 0.067 inch (1.7 mm) thick.

8.     Finish enclosure with polyester powder coating that is electrostatically applied and then baked to bond to substrate.

       a.      Exterior color shall be white.
       b.      Interior color shall be manufacturer's standard.

9.     Corner-formed door, full size of enclosure face, supported using multiple concealed hinges with easily removable hinge pins.

       a.      Sizes through 24 Inches (600 mm) Tall: Two hinges.
       b.      Sizes between 24 Inches (600 mm) through 48 Inches (1200 mm) Tall: Three hinges.
       c.      Sizes Larger 48 Inches (1200 mm) Tall: Four hinges.

10.    Double-door enclosures with overlapping door design to include unobstructed full-width access.

23 09 23 – 72

Direct Digital Control (DDC) System For HVAC               Bid Set
Tt # 200-11740-10003                                        Tetra Tech, Inc.

a. Single-door enclosures 48 inches (1200 mm) and taller, and all double-door enclosures, with three-point (top, middle and bottom) latch system.

11. Removable internal panel with a white polyester powder coating that is electrostatically applied and then baked to bond to substrate.

a. Size Less Than 24 Inches (600 mm): Solid or perforated steel, 0.053 inch (1.35 mm) thick.
b. Size 24 Inches (600 mm) and Larger: Solid aluminum, 0.10 inch (3 mm) or steel, 0.093 inch (2.36 mm) thick.

12. Internal panel mounting studs with hardware, grounding hardware, and sealing washers.
13. Grounding stud on enclosure body.
14. Thermoplastic pocket on inside of door for record Drawings and Product Data.

F. Wall-Mounted, NEMA 250, Type 4X SS:

1. Enclosure shall be NRTL listed according to UL 508A.
2. Seam and joints are continuously welded and ground smooth.
3. Externally formed body flange around perimeter of enclosure face for continuous perimeter seamless gasket door seal.
4. Construct enclosure of stainless steel, not less than the following:

a. Size Less Than 24 Inches (600 mm): 0.053 inch (1.35 mm) thick.
b. Size 24 Inches (600 mm) and Larger: 0.067 inch (1.7 mm) thick.

5. Outside body and door of enclosure with brushed No. 4 finish.
6. Corner-formed door, full size of enclosure face, supported using multiple concealed hinges with easily removable hinge pins.

a. Sizes through 24 Inches (600 mm)Tall: Two hinges.
b. Sizes between 24 Inches (600 mm)through 48 Inches (1200 mm)Tall: Three hinges.
c. Sizes Larger 48 Inches (1200 mm)Tall: Four hinges.

7. Corner-formed door, full size of enclosure face, supported using continuous piano hinge full length of door.
8. Doors fitted with three-point (top, middle, and bottom) latch system with single, heavy-duty, liquid-tight Type 316 stainless-steel handle with integral locking mechanism.
9. Removable internal panel shall be 0.093-inch (2.36-mm) solid steel with a white polyester powder coating that is electrostatically applied and then baked to bond to substrate.

10. Internal panel mounting studs and hardware, grounding hardware, and sealing washers.
11. Install corrosion-resistant polyester vent drain in a stainless-steel sleeve at the bottom of enclosure.
12. Include enclosure with stainless-steel mounting brackets.

G. Freestanding, NEMA 250, Type 1:

1. Enclosure shall be NRTL listed according to UL 508A.
2. Seam and joints are continuously welded and ground smooth.
3. Externally formed body flange around perimeter of enclosure face.
4. Single-door enclosure sizes up to 84 inches tall by 36 inches wide (2100 mm tall by 900 mm wide).
5. Double-door enclosure sizes up to 84 inches tall by 72 inches wide (2100 mm tall by 900 mm wide).
6. Construct enclosure of steel, not less than 0.067 inch (1.7 mm) thick.
7. Finish enclosure with polyester powder coating that is electrostatically applied and then baked to bond to substrate.

   a. Exterior color shall be white.
   b. Interior color shall be manufacturer's standard.

8. Corner-formed flush door, full size of enclosure face, supported using four concealed hinges with easily removable hinge pins.
9. Double-door enclosures with overlapping door design to include unobstructed full-width access.
10. Doors with three-point (top, middle, and bottom) latch system with single heavy-duty handle and integral locking mechanism.
11. Removable back covers.
12. Removable solid steel internal panel, 0.093 inch (2.36 mm) thick, with a white polyester powder coating that is electrostatically applied and then baked to bond to substrate.
13. Internal panel mounting studs with hardware, grounding hardware, and sealing washers.
14. Grounding stud on enclosure body.
15. Thermoplastic pocket on inside of door for record Drawings and Product Data.
16. Nominal 4-inch- (100-mm-) tall integral lifting base, not less than 0.123 inch (3.12 mm) thick, with predrilled holes for attachment to mounting surface.
17. Each top end of enclosure fitted with lifting tabs, not less than 0.172 inch (4.37 mm) thick.
18. Internal rack-mount shelves and angles as required by application.

H. Freestanding, NEMA 250, Types 4 and 12:

1. Enclosure shall be NRTL listed according to UL 508A.

2. Seam and joints are continuously welded and ground smooth.
3. Externally formed body flange around perimeter of enclosure face.
4. Type 12 Enclosure Sizes:

   a. Single-door enclosure sizes up to 90 inches tall by 36 inches wide (2250 mm tall by 900 mm wide).
   b. Double-door enclosure sizes up to 90 inches tall by 72 inches wide (2250 mm tall by 900 mm wide).

5. Type 4 Enclosure Sizes:

   a. Single-door enclosure sizes up to 72 inches tall by 36 inches wide (1800 mm tall by 900 mm wide).

6. Construct enclosure of steel, not less than 0.093 inch (2.36 mm) thick.
7. Finish enclosure with polyester powder coating that is electrostatically applied and then baked to bond to substrate.

   a. Exterior color shall be white.
   b. Interior color shall be manufacturer's standard.

8. Corner-formed door with continuous perimeter oil-resistant gasket supported using continuous piano hinge full length of door.
9. Doors fitted with three-point (top, middle, and bottom) latch system with latching rod rollers and single, heavy-duty oil-tight handle with integral locking mechanism.
10. Removable solid steel internal panel, 0.093 inch (2.36 mm) thick, with a white polyester powder coating that is electrostatically applied and then baked to bond to substrate.
11. Internal panel mounting studs with hardware, grounding hardware, and sealing washers.
12. Grounding stud on enclosure body.
13. Thermoplastic pocket on inside of door for record Drawings and Product Data.
14. Top of enclosure fitted with no fewer than two lifting eyes.
15. Internal rack-mount shelves and angles as required by application.

I. Accessories:

1. Electric Heater:

   a. Aluminum housing with brushed finish.
   b. Thermostatic control with adjustable set point from zero to 100 deg F (Minus 18 to 38 deg C).
   c. Capacity: 100, 200, 400, and 800 W as required by application.

d.   Fan draws cool air from bottom of enclosure and passes air across thermostat and heating elements before being released into enclosure cavity. Heated air is discharged through the top of heater.

2.   Ventilation Fans, Filtered Intake and Exhaust Grilles:

a.   Number and size of fans, filters and grilles as required by application.
b.   Compact cooling fans engineered for 50,000 hours of continuous operation without lubrication or service.
c.   Fans capable of being installed on any surface and in any position within enclosure for spot cooling or air circulation.
d.   Thermostatic control with adjustable set point from 32 to 140 deg F (Zero to 60 deg C).
e.   Airflow Capacity at Zero Pressure:
1)   4-Inch (100-mm) Fan: 100 cfm (47 L/s).
2)   6-Inch (150-mm) Fan: 240 cfm (113 L/s).
3)   10-Inch (250-mm) Fan: 560 cfm (264 L/s).
f.   Maximum operating temperature of 158 deg F (70 deg C).
g.   4-inch (100-mm) fan thermally protected and provided with permanently lubricated ball-bearings.
h.   6- and 10-inch (150- and 250-mm) fans with ball-bearing construction and split capacitor motors thermally protected to avoid premature failure.
i.   Dynamically balanced impellers molded from polycarbonate material.
j.   Fan furnished with power cord and polarized plug for power connection.
k.   Fan brackets, finger guards and mounting hardware provided with fans to complete installation.
l.   Removable Intake and Exhaust Grilles:  stainless steel of size to match fan size and suitable for NEMA 250, Types 1 and 12 enclosures.
m.   Filters for NEMA 250, Type 1 Enclosures: Washable foam or aluminum, of a size to match intake grille.
n.   Filters for NEMA 250, Type 12 Enclosures: Disposable, of a size to match intake grille.

3.   Air Conditioner:

a.   Electric-powered, self-contained air-conditioning unit specially designed for electrical enclosures to maintain temperature inside enclosure below ambient temperature outside enclosure.
b.   Thermostatic control with adjustable set point from 60 to 120 deg F (16 to 49 deg C).

  c.  Enclosure side or top mounting with unit capacity as required by application.

  d.  Designed for closed-loop cooling with continuous operation in ambient environments up to 125 deg F (52 deg C).

  e.  HFC refrigerant.

  f.  Reusable and washable air filter.

  g.  High-performance, industrial-grade, and high-efficiency fans.

  h.  Furnished with power cord and polarized plug for power connection.

  i.  Condensate management system with base pan side drain.

  j.  Mounting hardware, gaskets, mounting template and instruction manual furnished with unit.

  k.  Outdoor units equipped with head pressure control for low ambient operation, compressor heater, coated condenser coil and thermostat.

4.  Thermoelectric Humidifier:

  a.  ABS plastic enclosure.

  b.  Capacity of 8 oz. (0.24 L) of water per 24 hours.

  c.  Built-in drain captures moisture and plastic hose directs moisture to outside enclosure through a drain.

  d.  Controlled to maintain enclosure relative humidity at an adjustable set point.

  e.  Unit power supply shall be internally wired to enclosure electrical power source.

5.  Framed Fixed Window Kit for NEMA 250, Types 4, 4X, and 12 Enclosures:

  a.  0.25-inch- (6-mm-) thick, scratch-resistant acrylic or polycarbonate window mounted in a metal frame matching adjacent door material.

  b.  Enclosure types, except NEMA 250 Type 1, shall have a continuous gasket material around perimeter of window and frame to provide watertight seal.

  c.  Window kit shall be factory or shop installed before shipment to Project.

6.  Frameless Fixed Window Kit for NEMA 250, Type 1 Enclosures:

  a.  0.125-inch- (3-mm-) thick, polycarbonate window mounted in enclosure door material.

  b.  Window attached to door with screw fasteners and continuous strip of high-strength double-sided tape around window perimeter.

c.	Window kit shall be factory or shop installed before shipment to Project.

7.	Frame Fixed or Hinged Window Kit for NEMA 250, Types 1 and 12 Enclosures:

a.	0.25-inch- (6-mm-) thick, scratch-resistant acrylic or polycarbonate window mounted in a metal frame matching adjacent door material.
b.	Enclosure types, except NEMA 250 Type 1, shall have a continuous gasket material around perimeter of window and frame to provide watertight seal.
c.	Window kit shall be factory or shop installed before shipment to Project.

8.	Bar handle with keyed cylinder lock set.

## 2.23	RELAYS

A.	General-Purpose Relays:

1.	Relays shall be heavy duty and rated for at least 10 A at 250-V ac and 60 Hz.
2.	Relays shall be either double pole double throw (DPDT) or three-pole double throw, depending on the control application.
3.	Use a plug-in-style relay with an eight-pin octal plug for DPDT relays and an 11-pin octal plug for three-pole double-throw relays.
4.	Construct the contacts of either silver cadmium oxide or gold.
5.	Enclose the relay in a clear transparent polycarbonate dust-tight cover.
6.	Relays shall have LED indication and a manual reset and push-to-test button.
7.	Performance:

a.	Mechanical Life: At least 10 million cycles.
b.	Electrical Life: At least 100,000 cycles at rated load.
c.	Pickup Time: 15 ms or less.
d.	Dropout Time: 10 ms or less.
e.	Pull-in Voltage: 85 percent of rated voltage.
f.	Dropout Voltage: 50 percent of nominal rated voltage.
g.	Power Consumption: 2 VA.
h.	Ambient Operating Temperatures: Minus 40 to 115 deg F (Minus 40 to 46 deg C).

8.	Equip relays with coil transient suppression to limit transients to non-damaging levels.

9. Plug each relay into an industry-standard, 35-mm DIN rail socket. Plug all relays located in control panels into sockets that are mounted on a DIN rail.

10. Relay socket shall have screw terminals. Mold into the socket the coincident screw terminal numbers and associated octal pin numbers.

B. Multifunction Time-Delay Relays:

1. Relays shall be continuous duty and rated for at least 10 A at 240-V ac and 60 Hz.

2. Relays shall be DPDT relay with up to eight programmable functions to provide on/off delay, interval and recycle timing functions.

3. Use a plug-in-style relay with either an 8- or 11-pin octal plug.

4. Construct the contacts of either silver cadmium oxide or gold.

5. Enclose the relay in a dust-tight cover.

6. Include knob and dial scale for setting delay time.

7. Performance:

   a. Mechanical Life: At least 10 million cycles.
   b. Electrical Life: At least 100,000 cycles at rated load.
   c. Timing Ranges: Multiple ranges from 0.1 seconds to 100 minutes.
   d. Repeatability: Within 2 percent.
   e. Recycle Time: 45 ms.
   f. Minimum Pulse Width Control: 50 ms.
   g. Power Consumption: 5 VA or less at 120-V ac.
   h. Ambient Operating Temperatures: Minus 40 to 115 deg F (Minus 40 to 46 deg C).

8. Equip relays with coil transient suppression to limit transients to non-damaging levels.

9. Plug each relay into an industry-standard, 35-mm DIN rail socket. Plug all relays located in control panels into sockets that are mounted on a DIN rail.

10. Relay socket shall have screw terminals. Mold into the socket the coincident screw terminal numbers and associated octal pin numbers.

C. Latching Relays:

1. Relays shall be continuous duty and rated for at least 10 A at 250-V ac and 60 Hz.

2. Relays shall be either DPDT or three-pole double throw, depending on the control application.

3. Use a plug-in-style relay with a multibladed plug.

4. Construct the contacts of either silver cadmium oxide or gold.

5. Enclose the relay in a clear transparent polycarbonate dust-tight cover.

6. Performance:

> a. Mechanical Life: At least 10 million cycles.
> b. Electrical Life: At least 100,000 cycles at rated load.
> c. Pickup Time: 15 ms or less.
> d. Dropout Time: 10 ms or less.
> e. Pull-in Voltage: 85 percent of rated voltage.
> f. Dropout Voltage: 50 percent of nominal rated voltage.
> g. Power Consumption: 2 VA.
> h. Ambient Operating Temperatures: Minus 40 to 115 deg F (Minus 40 to 46 deg C).

7. Equip relays with coil transient suppression to limit transients to non-damaging levels.

8. Plug each relay into an industry-standard, 35-mm DIN rail socket. Plug all relays located in control panels into sockets that are mounted on a DIN rail.

9. Relay socket shall have screw terminals. Mold into the socket the coincident screw terminal numbers and associated octal pin numbers.

D. Current Sensing Relay:

1. Monitors ac current.
2. Independent adjustable controls for pickup and dropout current.
3. Energized when supply voltage is present and current is above pickup setting.
4. De-energizes when monitored current is below dropout current.
5. Dropout current is adjustable from 50 to 95 percent of pickup current.
6. Include a current transformer, if required for application.
7. House current sensing relay and current transformer in its own enclosure. Use NEMA 250, Type 12 enclosure for indoors and NEMA 250, Type 4 for outdoors.

E. Combination On-Off Status Sensor and On-Off Relay:

1. Description:

> a. On-off control and status indication in a single device.
> b. LED status indication of activated relay and current trigger.
> c. Closed-Open-Auto override switch located on the load side of the relay.

2. Performance:

> a. Ambient Temperature: Minus 30 to 140 deg F (Minus 34 to 60 deg C).
> b. Voltage Rating: Single-phase loads rated for 300-V ac. Three-phase loads rated for 600-V ac.