FINAL TECHNICAL REPORT

1. DOE Award No. DE-FG36-05GO85022

Awardee: Anwelt Heritage, LLC / Mass Innovation, LLC

Project Title: Geothermal Mill Redevelopment Project in Massachusetts

Project Director: Robert Ansin, Managing Member

Consortium/Team Members: PLAI, LLC (Pete Linn, Architect)
Allied Consulting, Inc. (Mechanical Engineering)
PowerHouse Enterprises, Inc.

2. DISTRIBUTION LIMITATIONS

NONE

3. Project Executive Summary: MassInnovation, LLC is renovating and redeveloping a 120-year old mill complex into a mixed-use development in a lower-income neighborhood in Fitchburg, Massachusetts. The complex includes three buildings totaling 330,000 square feet of developable space. Construction on 84 residential apartments in Building 1 of the complex is now complete and are being rented as affordable housing to persons aged 62 and older. The Department of Energy (“DOE”) earmark was used as an essential component of financing the project to include the design and installation of a 200 ton geothermal system for space heating and cooling.

Geothermal systems are considered to be among the most energy efficient methods for supplying space conditioning. However, there can be significant upfront costs relating to constructing and installing such systems due to the necessity of drilling deep standing water column wells and significant plumbing and equipment interconnections to distribute the thermal energy throughout the building and the individual units (see the Anwelt Heritage Geothermal System Schematic and the HVAC construction drawings and specifications included as part of this Final Technical Report below). Accordingly, this effort to adapt an old, historic building with state of the art energy efficient and renewable energy systems can become an important case study on the technical effectiveness and economic feasibility of the technologies employed.
As part of this project, significant time and expense was invested upfront to assess existing conditions and to analyze various geothermal system alternatives. For instance, in 2005, a major decision was reached to include plate and frame heat exchangers rather than pump the ground water directly around the building as the source loop due to its possible corrosivity. Once all of the major design decisions were reached, final specifications could be developed and accurate cost estimates could be derived. Accordingly, construction of the geothermal system was undertaken without any serious or costly surprises and was completed on time and on budget (a geothermal cost breakdown is included as part of this report, below).

4. Included below is a table which outlines the original project goals as articulated for the DOE as well as their current status/accomplishment:

<table>
<thead>
<tr>
<th>Anwelt Heritage Geothermal Project Goals</th>
<th>Current Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Providing energy efficient/renewable energy via geothermal systems for affordable housing and supporting mixed-use tenants within the building.</td>
<td>Complete. System is currently operating and heading into it’s first winter of operation.</td>
</tr>
<tr>
<td>Revitalizing the immediate, distressed neighborhood and the community by providing 88,000 square feet of mixed-use and 84 high quality apartment homes.</td>
<td>Complete. Approximately 50% of the housing units are rented and occupied.</td>
</tr>
<tr>
<td>Promoting a regional and national model for usage of geothermal and renewable/energy efficient technologies to lower the total cost of housing.</td>
<td>Complete. Recently, the Commonwealth of Massachusetts enacted the Green Communities Act which included, inter alia, provisions supporting and encouraging the use of geothermal heat pumps.</td>
</tr>
<tr>
<td>Reducing the use of fossil fuels directly by households and other tenants and indirectly through energy suppliers.</td>
<td>Partially Complete. No fossil fuel is combusted on-site for space heating and cooling (although there is a back-up gas-fired boiler for use in the event of a failure of the primary geothermal system). MassInnovation continues to explore options to purchase green electricity and/or offsets relating to the electric supply.</td>
</tr>
<tr>
<td>Decreasing total cost of home ownership</td>
<td>Unclear. Initial studies indicated an annual savings of 35-50% against standard code systems. Occupancy has only recently commenced and not enough is known yet about performance to fully assess this metric.</td>
</tr>
<tr>
<td>Reduce or eliminate carbon dioxide emissions from our existing boilers and eventually eliminate a 20,000-gallon oil storage tank</td>
<td>Complete. Old no. 4 fuel oil boilers and tanks were removed last year. Accordingly, local air quality has been improved and there has been an estimated reduction in carbon dioxide emissions in excess of 2,600 tons per year.</td>
</tr>
</tbody>
</table>
5. Summarize project activities for the entire period of funding: See report, above, and project designs and specifications, below.

6. Identify products developed under the award and technology transfer activities, such as:
   a. Publications (list journal name, volume, issue), conference papers, or other public releases of results: NONE
   b. Web site or other Internet sites that reflect the results of this project:
      
      http://www.anweltheritage.com/
      http://www.massinnovation.com/
   c. Networks or collaborations fostered; MassInnovation has developed a number of new associations and collaborations. In fact, the team used for design and construction oversight of the Anwelt Heritage project is being used in a similar large-scale geothermal installation for mixed-use/housing project relating to the rehabilitation of the former Wood Worsted Woolen Mill into the Monarch on the Merrimack project in Lawrence, Massachusetts.
   d. Technologies/Techniques: Geothermal Heat Pumps (i.e. Ground-Coupled Space Heating and Cooling).
   e. Inventions/Patent Applications, licensing agreements: NONE
   f. Other products, such as data or databases, physical collections, audio or video, software or netware, models, educational aid or curricula, instruments or equipment: NONE

7. For projects involving computer modeling, provide . . . NOT APPLICABLE
<table>
<thead>
<tr>
<th><strong>Geothermal Costs breakdown</strong></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Demolition</td>
<td>Coring holes for Geothermal</td>
<td>$4,500</td>
</tr>
<tr>
<td></td>
<td>Open foundation for Geothermal</td>
<td>$3,800</td>
</tr>
<tr>
<td></td>
<td>Remove Granite Obstructions found</td>
<td>$6,400</td>
</tr>
<tr>
<td></td>
<td>Coring holes thru floors for piping</td>
<td>$9,525</td>
</tr>
<tr>
<td>Concrete</td>
<td>Infill / rebuild foundations at geo holes</td>
<td>$4,200</td>
</tr>
<tr>
<td>Excavation</td>
<td>E&amp;B for Geothermal</td>
<td>$7,200</td>
</tr>
<tr>
<td>Drywall</td>
<td>Box around heat pumps</td>
<td>$167,400</td>
</tr>
<tr>
<td>Painting</td>
<td>Painting of boxes @ heat pumps</td>
<td>$40,176</td>
</tr>
<tr>
<td>PH Mechanical</td>
<td>Temperature controls</td>
<td>$48,000</td>
</tr>
<tr>
<td></td>
<td>Piping Insulation</td>
<td>$29,420</td>
</tr>
<tr>
<td></td>
<td>Fire Safing @ heat pumps</td>
<td>$15,890</td>
</tr>
<tr>
<td></td>
<td>test &amp; balance</td>
<td>$21,000</td>
</tr>
<tr>
<td></td>
<td>Water Treatment</td>
<td>$3,000</td>
</tr>
<tr>
<td></td>
<td>Rigging</td>
<td>$10,000</td>
</tr>
<tr>
<td></td>
<td>Heat pumps</td>
<td>$313,000</td>
</tr>
<tr>
<td></td>
<td>pumps</td>
<td>$17,000</td>
</tr>
<tr>
<td></td>
<td>Heat Exchangers</td>
<td>$49,000</td>
</tr>
<tr>
<td></td>
<td>VFD's</td>
<td>$6,000</td>
</tr>
<tr>
<td></td>
<td>Energy Recover Units</td>
<td>$40,000</td>
</tr>
<tr>
<td></td>
<td>Pipe Materials</td>
<td>$49,000</td>
</tr>
<tr>
<td></td>
<td>Coordination</td>
<td>$10,000</td>
</tr>
<tr>
<td></td>
<td>Labor to Install</td>
<td>$289,650</td>
</tr>
<tr>
<td></td>
<td>Additional piping controls added</td>
<td>$3,925</td>
</tr>
<tr>
<td></td>
<td>Sub bonding</td>
<td>$10,000</td>
</tr>
<tr>
<td></td>
<td>Plumbing permit</td>
<td>$1,000</td>
</tr>
<tr>
<td>Geosearch</td>
<td>Well Pumps</td>
<td>$39,900</td>
</tr>
<tr>
<td>Maki Electrical</td>
<td>Electrical for Pumps, Vert Heat Pumps</td>
<td>$15,720</td>
</tr>
<tr>
<td></td>
<td>% of Switchgear and power wiring</td>
<td>$64,930</td>
</tr>
<tr>
<td></td>
<td>Electrical conduit to Wells</td>
<td>$38,000</td>
</tr>
<tr>
<td></td>
<td>Sub bonding</td>
<td>$2,000</td>
</tr>
<tr>
<td></td>
<td>Electrical permit</td>
<td>$1,000</td>
</tr>
<tr>
<td>General Conditions</td>
<td>% of project</td>
<td>$92,848</td>
</tr>
<tr>
<td></td>
<td>1.4m/12.5 *829300</td>
<td></td>
</tr>
<tr>
<td>Project Requirements</td>
<td>$31,088</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1.4m/12.5 *277567</td>
<td></td>
</tr>
<tr>
<td>Insurance</td>
<td>1%</td>
<td>$14,290</td>
</tr>
<tr>
<td>JCA Fee @ 4.5%</td>
<td>$41,141</td>
<td></td>
</tr>
<tr>
<td>Permits &amp; Fees</td>
<td>$5/1000 * 1,400,000 + $50</td>
<td>$7,050</td>
</tr>
<tr>
<td>Total</td>
<td>$ 1,507,053</td>
<td></td>
</tr>
</tbody>
</table>
GROUND LOOP TO BE CONTROLLED BY TEMP, NOT PRESSURE
PART 1 - GENERAL

1. GENERAL CONDITIONS ................................................................................................................................. 3
2. WORK INCLUDED .............................................................................................................................................. 3
3. DEFINITIONS .................................................................................................................................................. 4
4. GENERAL REQUIREMENTS FOR SHEETMETAL DUCTWORK ................................................................. 4
5. RELATED WORK IN OTHER SECTIONS ..................................................................................................... 5
6. CODES AND STANDARDS ............................................................................................................................ 5
7. COORDINATION WITH OTHER BUILDING TRADES .................................................................................. 5
8. SHOP DRAWINGS AND SUBMITTALS ......................................................................................................... 6
9. APPROVAL OF SUBMITTALS ....................................................................................................................... 7
10. RESPONSIBILITY FOR ACCURACY OF SUBMITTALS .............................................................................. 7
11. SUBSTITUTION OF MATERIALS OR EQUIPMENT ..................................................................................... 8
12. FEES AND PERMITS ................................................................................................................................... 8
13. OPERATING INSTRUCTIONS ......................................................................................................................... 8
14. SYSTEM TRAINING ...................................................................................................................................... 8
15. COORDINATION DRAWINGS ..................................................................................................................... 9
16. RECORD DRAWINGS .................................................................................................................................. 9
17. TESTING AND CHECKOUT ......................................................................................................................... 9
18. PROTECTION .................................................................................................................................................. 11
19. DUCT CLEANLINESS .................................................................................................................................. 11
20. IDENTIFICATION OF MECHANICAL SERVICES ......................................................................................... 11
21. DUCT MOUNTED SMOKE DETECTORS .................................................................................................... 12

PART 2 - PRODUCTS ......................................................................................................................................... 12

2.1 MATERIALS .................................................................................................................................................. 12
2.2 ELECTRIC MOTORS AND RELAYS ............................................................................................................. 12
2.3 ACROSS-THE-LINE STARTERS ................................................................................................................... 12
2.4 HANGERS AND SUPPORTS ......................................................................................................................... 13
2.5 ANCHORS ................................................................................................................................................... 14
2.6 VIBRATION ISOLATORS ............................................................................................................................... 14
2.7 PIPING INSULATION MATERIALS .............................................................................................................. 14
2.8 WEATHERPROOFING OF OUTDOOR PIPE INSULATION MATERIALS .................................................. 15
2.9 PIPE LABELS ............................................................................................................................................ 15
2.10 HYDRONIC PIPING .................................................................................................................................... 15
2.11 REFRIGERANT PIPING ............................................................................................................................... 16
2.12 VALVES .................................................................................................................................................... 16
2.13 VALVE TAGS ........................................................................................................................................... 17
2.14 STRainers ................................................................................................................................................. 18
2.15 PIPE EXPANSION COMPENSATION DEVICES ..................................................................................... 18
2.16 SLEEVES ................................................................................................................................................ 18
2.17 PRESSURE GAUGES ................................................................................................................................. 18
2.18 THERMOMETERS .................................................................................................................................. 18
2.19 FLEXIBLE CONNECTORS ......................................................................................................................... 19
2.20 EXPANSION TANKS ............................................................................................................................... 19
2.21 RELIEF VALVES .................................................................................................................................... 19
2.22 AUTOMATIC AIR ELIMINATION ASSEMBLY ......................................................................................... 19
2.23 PURGE/BALANCE VALVES ..................................................................................................................... 19
2.24 PROPYLENE GLYCOL SOLUTION ........................................................................................................... 19
2.25 WATER TREATMENT ............................................................................................................................... 19
2.26 DUCT INSULATION MATERIALS - DUCT WRAP .................................................................................... 20
2.27 ACOUSTICAL DUCT LINING ................................................................................................................... 20
2.28 FILTERS ................................................................................................................................................ 20
2.29 RECTANGULAR DUCTS ........................................................................................................................... 20
2.30 ROUND DUCTS .................................................................................................................................... 20
PART 3 -
EXECUTION.........................................................................................................................................................39
3.1 WORKMANSHIP.................................................................39
3.2 CLEANING OF SYSTEMS AND PREMISES.................................39
3.3 HVAC CONTRACTOR'S WARRANTY........................................40
3.4 SUBMITTALS........................................................................40
3.5 PERFORMANCE.....................................................................41
3.6 START UP ...........................................................................41
3.7 CENTRIFUGAL FANS...........................................................41
3.8 FILTERS ..............................................................................41
3.9 RECTANGULAR DUCTS.........................................................41
3.10 ROUND DUCTS.................................................................42
3.11 FLEXIBLE DUCTS..............................................................43
3.12 SUSPENSION OF DUCTWORK...........................................43
3.13 MISCELLANEOUS DUCT WORK REQUIREMENTS................44
3.14 RECTANGULAR DUCT FITTINGS........................................44
3.15 ROUND DUCT FITTINGS....................................................44
3.16 PIPE HANGERS, SUPPORTS, ANCHORS AND GUIDES........44
3.17 VALVE TAGS ....................................................................44
3.18 VIBRATION ISOLATION.......................................................45
3.19 PIPING SYSTEM INSTALLATION AND ASSEMBLY..............45
3.20 FLUSHING OUT TREATMENT.............................................46
3.21 BALANCING DAMPERS.......................................................46
3.22 CONTROLS........................................................................46
3.23 FINAL ACCEPTANCE..........................................................46
3.24 FIRE DAMPERS.................................................................47
3.25 AIR AND WATER BALANCING..........................................47
3.26 START UP AND TESTING OF COOLING EQUIPMENT............49
3.27 DUCT INSULATION - DUCT WRAP......................................50
3.28 SEQUENCES OF OPERATION.............................................50

Renovations to Building 1 - Fitchburg, MA HVAC - 15600
Page 3 of 50
12/16/05
SECTION 15600 - HVAC
PART 1 - GENERAL
1.1 GENERAL CONDITIONS
A. Division 1, General Conditions are hereby made part of this specification by reference.
B. No materials or supplies for the work shall be purchased by the Contractor or by any Subcontractor subject to any chattel mortgage or under a conditional sale contract or other agreement by which an interest is retained by the seller. The Contractor warrants that he has good title to all materials and
supply used by him in the work, free from all liens, claims or encumbrances.

1.2 WORK INCLUDED
A. The work included in the Heating, Ventilating and Air Conditioning specifications consists of furnishing all materials, labor, equipment and appurtenances to perform, and leave in satisfactory operating condition the new systems.
B. It is the intention of these specifications to call for finished work, fully tested and ready for continuous operation. Any apparatus, equipment, material or work not mentioned in the specifications or incidental accessories to make the work completely balanced, perfect in all respects and ready for operation, even if not specifically mentioned, shall be furnished, tested, adjusted or balanced at no additional expense to the Owner. Should there appear to be discrepancies or questions of intent, the Contractor shall refer the matter to the Architect for decision before start of any related work.
C. The drawings, where applicable, show equipment and device locations, required flows at those devices and locations of new thermostats and controls. In addition, the drawings identify routing for new ducting and new piping as well as their respective sizes. The HVAC Contractor shall field verify that the routing is free of obstacles and other trades work.
D. The Contractor shall confer and cooperate with all other building trades so that all work will be installed in the proper relationship to all other work.
E. The Contractor shall provide and maintain all staging, scaffolding, ladders and hoisting equipment required for the execution of the work by his personnel. Remove same from premises when no longer required.
F. The work under this section shall include furnishing all motor starters and components for installation by the electrical contractor.
G. The work under this section shall include all labor, materials, accessories, services, and equipment necessary to furnish and install:
   1. All pipe guides, supports, hangers and anchors.
   2. All vibration isolation equipment, bases and devices.
      a. Unless otherwise noted on the equipment schedule, all mechanical equipment shall be mounted on vibration isolators to prevent the transmission of vibration and mechanically transmitted sound to the building structure. Vibration isolators shall be selected in accordance with the weight distribution so as to produce reasonably uniform deflection. Deflections shall be as noted on the equipment schedule or those required to provide 98% isolation efficiency.
   Renovations to Building 1 - Fitchburg, MA HVAC - 15600
   Page 4 of 50
   12/16/05
   3. All insulation of all parts of all heating and cooling water systems including all pipe, fittings, pipe flanges, valves, expansion joints, vents, drains, etc. which may be subject to thermal losses adverse to the operation of the various systems, or which may sweat.
   4. All insulation of all parts of the supply and outdoor air intake duct systems including all duct, fittings, flanges, dampers, etc. which may be subject to thermal losses adverse to the operation of the various systems, or which may sweat.
   5. All energy recovery units.
   6. All water source heat pumps.
   7. All filters and air cleaning equipment.
   8. All ductwork.
   9. All duct fittings.
   10. All ductwork accessories.
   11. All hot water and condenser water piping.
   12. All condensate piping.
   13. All piping specialties.
   14. All pumps.
   15. All variable frequency drives.
   16. All heat exchangers.
   17. All electric heating devices.
   18. All air inlet and outlet equipment.
   19. All louvers.
   20. All control system components to provide a fully operational automatic temperature control system.
   21. All Testing, Adjusting and Balancing of all components of the HVAC systems.
   22. All propylene glycol.
   23. All water treatment.
1.3 DEFINITIONS
A. Where used in this specification, the following definitions shall apply:
1. Test means to determine quantitative performance of HVAC equipment.
2. Adjust means to produce the specified fluid flows at the terminal equipment.
3. Balance means to establish the specified fluid flows within the distribution systems.
4. Procedure is the standardized approach and execution of sequence of work operations to yield reproducible results.
5. Report forms shall be test data sheets arranged for collection of test data in logical order for submission and review. These data shall form the permanent record which shall be used as the basis for any future testing, adjusting, and balancing required.
6. The testing, adjusting, and balancing Contractor shall hereinafter be referred to as "The Contractor", who may be the HVAC Contractor or a subcontractor to the HVAC contractor.

1.4 GENERAL REQUIREMENTS FOR SHEETMETAL DUCTWORK
A. Where specifications refer to SMACNA standards, the latest SMACNA standards shall be considered as the minimum acceptable. If local codes require other standards, then the local codes shall govern.
B. All ductwork indicated on the drawings is to be considered as shown in schematic. Changes in duct size or duct elevation to clear obstructions or to accommodate field conditions caused by the work of other trades, not shown on the drawings, shall be made by contractor, where necessary to conform to the actual space conditions and shall be provided at no additional cost to the owner. No duct changes shall be fabricated until after written approval of the modified or original shop drawings by the Engineer.

1.5 RELATED WORK IN OTHER SECTIONS
A. The following is a list of related work to be performed or furnished by other trades under other sections of the specifications:
1. Grillage and miscellaneous structural elements to fully support and/or suspend the HVAC equipment.
2. Power wiring to heating and air conditioning equipment.
3. Duct mounted smoke detectors, supplied by the electrical contractor, mounted by the HVAC contractor and wired by the electrical contractor.

1.6 CODES AND STANDARDS
A. All work and materials provided under this specification shall conform to the requirements of the all municipal, state building codes, all referenced standards and guidelines, including but not limited to the National Fire Prevention Association, Underwriters Laboratories, American Society of Mechanical Engineers, American Society of Heating Refrigeration and Air Conditioning Engineers and any other regulatory body having jurisdiction over this work. Where standards or codes are mentioned the latest edition or revision shall be followed. Where provisions of the contract documents conflict with applicable standards, codes, laws, rules or regulations, the latter shall govern. Where provisions of the contract documents are in excess of the applicable standards, codes, laws, rules or regulations, the former shall govern, unless specifically noted otherwise by the contract documents.
B. Equipment shall bear Underwriters' Laboratory labels where applicable.
C. The following publications form a part of this Specification to the extent indicated by the reference thereto. In text, the publications are referred to by the initials of the organization:

1.7 COORDINATION WITH OTHER BUILDING TRADES
A. Structural members and building openings for HVAC equipment, ducts, piping, fans, etc., for use by the HVAC Contractor shown on the architectural or structural plans are the coordination responsibility of the HVAC Contractor.
B. All motors for HVAC equipment shall be furnished and set under this section. All motor starters shall be
provided by the HVAC contractor for installation by the Electrical Contractor. All controls shall be provided and installed. All control wiring shall be provided and installed by this Contractor in accordance with the applicable provisions of the electrical specifications.

Renovations to Building 1 - Fitchburg, MA HVAC - 15600
Page 6 of 50
12/16/05

C. It shall be this Contractor's responsibility to field verify all dimensions and to coordinate his work with the work of other trades. Locations and placement of ducts, pipes, fittings, accessories and equipment shall be coordinated with the work of the other trades before ductwork or piping is fabricated or installed.

1.8 SHOP DRAWINGS AND SUBMITTALS

A. The Contractor shall submit 8 eight copies of all necessary shop drawings for approval to the Architect.

B. Shop drawings for equipment shall include printed catalog specifications and printed capacity data to enable confirmation of capacities and specifications as well as certified dimensional prints, which may have selection data shown thereon.

C. Shop drawings, catalog specification data and capacity ratings of the following equipment, where applicable and such other equipment that is being furnished shall be submitted to the Architect for approval prior to purchase or installation of any work or equipment:

1. Ductwork layouts: minimum scale - ¼”=1', double line elevations and sections of critical areas
2. Pipe, valves, fittings and piping specialties
3. Electric Motors
4. Motor Starters
5. Variable speed drives
6. Duct construction details: minimum scale - ¼”=1'
7. Insulation
8. Registers, Grilles and Diffusers
9. Fans
10. Volume dampers
11. Fire dampers
12. Smoke dampers
13. Automatic Temperature Control schematics with sequence of operations and control devices
14. Filters
15. Flexible connectors
16. Flexible duct
17. Duct lining
18. Energy recovery units
19. Water source heat pumps
20. Heat exchangers
21. Pumps
22. Louvers
23. Water treatment
24. Propylene glycol
25. Expansion tank
26. Testing, Adjusting and Balancing information

D. The Architect's review of shop drawings is for general conformance with the design concept and contract documents. Markings and/or comments shall not be construed as relieving the Contractor from compliance with the plans and specifications or as departures therefrom. The Contractor shall remain responsible for details and accuracy of the drawings.

E. The Contractor is responsible for the dimensions and arrangement of the equipment as it is applied to this project.

F. Submittal of the following information shall be required prior to commencement of the Testing, Adjusting and Balancing work:

Renovations to Building 1 - Fitchburg, MA HVAC - 15600
Page 7 of 50
12/16/05

1. Checklists and procedures to be used for testing, checkout, start-up and verification of system performance.
2. Detailed description of all test equipment to be used by the Contractor to complete the testing, adjusting and balancing work.
3. Calibration tests of test equipment to be used for testing, adjusting and balancing.
4. Detailed narrative procedures, system diagrams and forms for test results. This includes specific standard procedures required and proposed for each system.
G. The following submittals must be presented before final acceptance of the work:
1. Contractor's guarantee and warranty.
2. Manufacturer's literature and supplied information.
3. Maintenance and Operating Instructions Manuals.
4. Record drawings.
5. Logs of all system testing, adjusting, balancing and verification of system performance.
6. After completion, submit complete test reports for approval. Where test results differ from specified design conditions, the Contractor shall report to the Architect the reasons for the difference.

H. Accompany submittals with transmittal letter, in duplicate, containing:
1. Date.
2. Project title and contract number.
3. Contractor's name and address.
4. The number of each shop drawing and product data submitted.
5. System logs with proper identification.
6. Other pertinent data.
A. Submittals shall be clearly identified and include:
7. Date and revision dates.
8. Project title and contract number.
9. The names and addresses of the Contractor, supplier, and manufacturer.
10. Identification of product.
11. Applicable standards, such as ASTM number or ANSI number.
12. Contractor's signature certifying to his review of submittal.

1.9 APPROVAL OF SUBMITTALS
A. The Architect will return signed and approved or disapproved submittals to the Contractor in the timeframe in accordance with the specifications. Any submittals which have been disapproved, shall be resubmitted by the Contractor within one week for final approval.

1.10 RESPONSIBILITY FOR ACCURACY OF SUBMITTALS
A. The Contractor is solely responsible for the accuracy and completeness of all submittals, regardless of corrections made in, or approval given to, such submittals. When the Architect makes comments and returns the submittals, it is incumbent upon the Contractor to thoroughly review the comments and notations made by the Architect. When, in the Contractor's opinion, the notes made by the Architect are in error or in conflict with other elements of the system, it is incumbent upon the Contractor to promptly notify the Architect of his findings or opinion along with substantiating data, in writing to preclude misunderstanding or expensive alterations caused by a review error or oversight. The submittals are intended to provide detailed documentation of the system design and its components. The responsibility for their correctness rests completely, totally and solely with the Contractor.

1.11 SUBSTITUTION OF MATERIALS OR EQUIPMENT
A. Named manufacturers for any equipment specified herein or identified on the drawings are identified for the purpose of identifying quality standards, performance information or type. Any substitution as "or equal" shall be considered. The Architect shall determine whether or not the offered equipment is equal to the specified. Where dimensional constraints exist the contractor shall be responsible for any extra costs associated with extra work required to make the "or equal" equipment fit.
B. After approval of the submittals, substitution of materials or equipment of makes other than those specifically named in the submittals will be approved by the Architect only if the material or equipment proposed for substitution is equal to and/or superior to material or equipment named in construction, efficiency, utility and accuracy; and further that the material or equipment named in the submittals cannot be delivered to the job in proper sequence due to conditions beyond the control of the Contractor.
C. To receive consideration, requests for substitution shall be accompanied by documentary proof of equality or difference of both proposed equipment to be substituted and equipment named in the approved submittals. Substitution by the Contractor of other materials or processes than those named in the approved submittals shall be done only upon written authorization from the Architect.

1.12 FEES AND PERMITS
A. The Contractor shall apply for, obtain and pay for all required permits, inspections, certificates, and incidental charges required for proper performance of the work, and shall furnish the Architect with copies of applications and all correspondence.

1.13 OPERATING INSTRUCTIONS
A. The Contractor shall provide three (3) copies of a OPERATIONS AND MAINTENANCE MANUAL,
bound, indexed and titled in an 8½" x 11" Post binder with hard covers (not a three ring looseleaf type binder). The manuals shall each contain:
1. Full size drawing sheets (with reinforced margins) of the Control Schematics folded into 8½" x 11".
2. Clear and concise instructions for operation of the control system.
3. Clear and concise instructions for operation, maintenance, adjustment and lubrication for all mechanical equipment.
4. A parts list of all parts of the equipment, with catalog numbers and other data necessary for ordering of replacement parts.
5. Copies of all approved equipment shop drawings.
6. Index shall include type of equipment, manufacturer, local representative with address and telephone number.

1.14 SYSTEM TRAINING
A. The Contractor shall provide three (3) days of training on the mechanical systems for the building. Training times and dates shall be coordinated with the Owner.
B. Training shall include but not be limited to:
   1. A general overview of the operation of each system
   2. Heat pump system.
   3. Hot water system.
   4. Energy recovery units.

1.15 COORDINATION DRAWINGS
A. Before materials are purchased or work is begun, prepare coordination drawings showing the size and location of equipment, piping, etc., in the manner described under SUPPLEMENTARY CONDITIONS.
B. Coordination drawings are for the General Contractor's and the Architect's use during construction and shall not be construed as replacing any shop, "as-built" or record drawings required elsewhere in these contract documents.
C. The HVAC Contractor shall be responsible for initiating the preparation of the coordination drawings and passing the drawings to other trades through the General Contractor for addition of the other trade’s work.
D. Before work progresses, and in addition to the shop drawings listed herein, submit coordination drawings at a suitable scale of not less than 3/8 inches equals one foot.
E. Provide one reproducible and one blueprint of the drawings.
F. Provide composite systems coordination drawings showing HVAC duct, piping and equipment, plumbing pipe and equipment, sprinkler piping and equipment and electrical conduit, cable, lights and other equipment.
G. All trades are required to coordinate with the other trades and revise the composite systems coordination drawings to eliminate interferences.

1.16 RECORD DRAWINGS
A. The Architect will furnish the Contractor one set of sepia drawings of the mechanical drawings as issued for this contract. The Contractor shall change these drawings to indicate accurately and neatly the actual duct routing and duct sizes. At the end of the project the Contractor shall deliver to the Architect one set of reproducible "as built" drawings and a compact disc with electronic files of the drawings in Autocad 2000 format for the owner's permanent record.
B. The "as built" drawings shall show the actual location and valve tag number of all valves.

1.17 TESTING AND CHECKOUT
A. After completion of any work installed by the Contractor, field tests shall be performed and checkout of the system accomplished. The tests shall include functional and operational tests where applicable on all equipment under all conditions that exist at the time. All defects of new equipment disclosed by tests shall be rectified without additional cost to the Owner. The Contractor shall be required to make minor adjustments to equipment and accessory material to provide a thoroughly functional installation. All new equipment shall be installed, tested and checked before the Contractor tests, adjusts or balances the system as a whole.
B. The Contractor shall perform the services of testing, adjusting, and balancing of the heating, ventilating, and air conditioning systems. The Contractor shall check and adjust all HVAC systems to produce the performance specified by the construction documents and to achieve total system balance. The Contractor shall be certified by an appropriate air balance council, such as the Associated Air Balance Council.
(AABC), National Environmental Balancing Bureau (NEBB), or other approved agency, or shall employ
technicians certified by an appropriate air balance council, such as the Associated Air Balance Council
(AABC), National Environmental Balancing Bureau (NEBB), or other approved agency to perform the
air balancing procedures. All work done by the Contractor shall be by qualified technicians under the
direct supervision of a certified test and balance engineer. The Contractor shall furnish all certified
engineers, instruments, and provide personnel, trained and experienced, to test, adjust and balance all
airside systems and related automatic temperature control systems, and shall submit system performance
reports.

C. The work to be performed by the Contractor shall include, but not be limited to:
1. Adjustment of the airside performance of the HVAC systems to provide design air quantities and
temperatures.
2. Electrical measurement.
3. The balance of all air distribution systems.
4. Verification of performance of all equipment and automatic controls.

D. The Contractor shall accomplish these objectives by:
1. Checking installations for conformity to design.
2. Measurement and establishment of the air distribution quantities of the systems as required to
meet the design specifications.
3. Adjusting and balancing all HVAC systems to meet the design specifications.
4. Recording and reporting all results in a format approved by the Architect.

E. All work shall be completed in accordance with the standards set by AABC, NEBB, or other approved
testing and balancing organizations. In general, all equipment, materials, and balancing procedures shall
comply with all applicable standards.

F. The qualifications of the Contractor shall include current membership in AABC, or certification by
NEBB, or the Contractor shall submit proof to the satisfaction of the Architect that the Contractor meets
the certification requirements of the AABC or NEBB.

G. Submit for approval samples, shop drawings, certificates, literature and data with information sufficient
to evaluate the submission in compliance with the requirements of a completely adjusted and balanced
system. Testing, adjusting and balancing procedures shall equal those of approved submittals and shall
not be completed or incorporated in the work until approved. Approval or acceptance of submittal items
will not preclude rejection of these items upon discovery of defects in them prior to final acceptance of
completed work.

H. All work shall be performed in compliance with the approved submittals. The work schedule shall
include the proposed procedures, proposed forms, diagrams, and reports for documenting the work. The
Contractor shall establish an approved systematic and uniform set of procedures in compliance with the
AABC or NEBB.

I. All test instruments shall be accurately calibrated and maintained in good working order. If requested,
calibration tests of equipment to be used shall be performed in the presence of the Owner.

J. The equipment and systems shall be tested, adjusted and balanced in accordance with the approved
submittals. Wherever the Contractor deviates from the original procedures, he shall be responsible for the
new procedures being a better method. Any changes made necessary by the above shall be brought to the
attention of the Architect and shall be subject to his approval prior to making such change. The
procedural changes shall not be made a basis for additional compensation by the Owner, but shall be
made at the Contractor's own expense.

**Renovations to Building 1 - Fitchburg, MA HVAC - 15600**

1.18 PROTECTION

A. The Contractor shall be responsible for his work and equipment until finally inspected and accepted by
the Owner. The Contractor shall be responsible for proper storage of his materials and equipment.
Equipment and materials storage shall in no way interfere with building operations or personnel. Any
work adversely affected by the work performed by the Contractor shall be repaired or replaced by the
Contractor at the option of the Owner, and at no additional cost to the Owner.

B. Any equipment not intended for installation outside of the building shall not be installed until the roof is
watertight.

1.19 DUCT CLEANLINESS

A. Any equipment connected to ductwork shall not be operated until construction progress has reached a
point where minimal dust is being created as determined by the Architect.

B. If any equipment is to be used prior to the point of minimal dust creation, all return or exhaust intakes
shall be covered with filter material and all filters in the equipment shall be changed on a regular basis.

1.20 IDENTIFICATION OF MECHANICAL SERVICES
A. Identify all piping with plastic adhesive labels identifying the system, supply or return, and flow arrows.
   1. Labels shall be located at all changes of direction, every 20 feet on long pipe runs, at valves and close to points of branch takeoffs.
B. Identify all pumps, controls, starters and similar equipment with white lamacoid engraved nameplates with black letters. Firmly secure with self tapping screws.
C. Fan identification shall be 6”x4” and shall indicate the following information:
   1. Tag number
   2. Design Airflow (CFM)
   3. Design external static pressure
   4. Motor horsepower
   5. Power (volts/phase/Hz)
D. Pump identification shall be 6”x4” and shall include the following information:
   1. Tag number
   2. Design water flow (GPM)
   3. Design pressure (feet)
   4. Motor horsepower
   5. Power (volts/phase/Hz)
E. Heat pump identification shall be 6”x4” and shall include the following information:
   1. Tag number
   2. Nominal cooling capacity (Btu/h)
   3. Room Served (apt. # or number and area for common spaces)
   4. Power (volts/phase/Hz)
F. Heat pump identification shall be 6”x4” and shall include the following information:
   1. Tag number
   2. Nominal cooling capacity (Btu/h)
   3. Room Served (apt. # or number and area for common spaces)

1.21 DUCT MOUNTED SMOKE DETECTORS
A. Duct mounted smoke detectors shall be provided and wired by the electrical contractor and mounted by the HVAC contractor.
B. Smoke detectors shall be provided per the latest edition of the Commonwealth of Massachusetts Building Code, BOCA Mechanical Code 1987 and the latest editions of NFPA 90A and 90B guidelines.
   1. Smoke detectors shall be provided for mounting in the supply duct of all air handling units and systems over 2,000 CFM maximum capacity.
   2. Smoke detectors shall be provided for mounting in all exhaust systems greater than 15,000 CFM maximum capacity.
C. Smoke detectors in the supply air duct shall be mounted downstream of all after filters and fans but before and tees or branch take-offs.

PART 2 - PRODUCTS
2.1 MATERIALS
A. All materials, except as otherwise specified, shall be new, of current production, first quality and the best of each class specified.
B. Required materials not covered by detailed specifications shall be of a suitable class, grade, quality and type and shall be subject to the approval of the Architect. Where two or more units of the same class of equipment are required, these units shall be the products of a single manufacturer.
C. All equipment shall be installed and constructed to operate safely, as designed, without leakage, undue wear, noise, vibration or corrosion.
2.2 ELECTRIC MOTORS AND RELAYS
A. Design, type and ratings of electric motors shall comply with the National Electrical Code, NEMA and Underwriter's Laboratory.
B. Unless otherwise noted or required for special applications, motors shall be open drip-proof with sealed ball bearings.
C. All electric motors shall be of the voltage, type and frame as specified in the electrical portion of the specifications.
D. Motors used for variable speed drives shall be specifically designed for that usage.

2.3 ACROSS-THE-LINE STARTERS

Renovations to Building 1 - Fitchburg, MA HVAC - 15600

Page 13 of 50
12/16/05

A. All motor starters shall be across-the-line start with magnetic contactors and thermal overloads properly sized for the motor nameplate data.
B. All motor starters shall be furnished with a Hand-Off-Auto (HOA) switch mounted on the cover of the enclosure.
C. All motor starters shall be furnished with a fused 120 volt control power transformer rated at a minimum of 2 amps.
D. All motor starters shall be furnished mounted in a NEMA 1 enclosure suitable for the mounting location.
E. All motor starters shall be provided with magnetic contactors having one normally open and one normally closed auxiliary contactor.

2.4 HANGERS AND SUPPORTS

A. Pipe hanger or stanchion support assemblies shall include turnbuckles or other means of vertical adjustment.
B. Trapeze hangers may be used in lieu of separate hangers for closely spaced, parallel lines. Pipe hanger components shall be as per MSS SP-58.
C. Hangers shall have steel rods with two nuts and shall be suspended from suitable beam clamps or concrete inserts. Rod sizes shall be as recommended by the hanger manufacturer and at least the following:
   - Pipe to 2" ..................1/8" diameter
   - 2½" - 3" ..................1/2" diameter
   - 4" - 5" ......................5/8" diameter
   - 6" ..........................3/4" diameter
   - 8" ..........................7/8" diameter
D. Maximum hanger or stanchion support spacing for copper or steel pipe shall be as follows:
   - PIPE MAX PIPE MAX PIPE MAX
   - SIZE SPACING SIZE SPACING SIZE SPACING
   - 3/4” or less 6 feet 2 ½” 11 feet 6” 17 feet
   - 1” 7 feet 3” 12 feet 8” 19 feet
   - 1½” 8 feet 3 ½” 13 feet 10” 22 feet
   - 1½” 9 feet 4” 14 feet 12” 23 feet
   - 2” 10 feet 5” 16 feet 14” 25 feet
E. Hangers or stanchion supports for copper tubing shall be copper plated where they contact the copper tubing.
F. Hangers or stanchion supports for insulated pipe shall have insulation shields.
G. All rigid piping attached to the building and serving equipment subject to vibration shall be hung or supported on vibration isolators for the first 20 feet.
H. Vertical rises shall be supported from stands at the bottom of the rise or hangers at the top of the rise as shown on the drawings per the Contractor’s option.

2.5 ANCHORS

A. Anchor points as shown on the drawings or as required shall be located and constructed to permit the piping system to take up its expansion and contraction freely in opposite directions away from the anchored points.

2.6 VIBRATION ISOLATORS

A. Double deflection neoprene mountings shall have a minimum static deflection of 0.35”. All metal surfaces shall be neoprene covered to avoid corrosion and have friction pads both top and bottom so they need not be bolted to the floor. Bolt holes shall be provided for these areas where bolting is required.
B. Spring type isolators shall be free standing and laterally stable without any housing and complete with ½” neoprene acoustical friction pads between the baseboard and the support. All mountings shall have leveling bolts that must be rigidly bolted to the equipment. Spring diameters shall be no less than 80% of the compressed height of the spring at rated load. Springs shall have a minimum additional travel to solid equal to 50% of the rated deflection. Submittals shall include spring diameters, deflections, compressed spring height and solid spring height.
C. Vibration hangers for piping and mechanical equipment shall contain a steel spring and 0.3” deflection neoprene element in series. The neoprene element shall be molded with a rod isolation bussing that
passes through the hanger box. Spring diameters and hanger box lower hole sizes shall be large enough to permit the hanger rod to swing through an arc of 30° before contacting the hole and short circuiting the spring. Springs shall have a minimum additional travel to solid equal to 50% of the rated deflection. Submittals shall include a scale drawing showing the 30° swing capability. For locations requiring precise elevation during installation the hanger shall be precompressed to the rated deflection and the released after completion of the installation.

D. Vibration hangers for duct systems shall contain a steel spring located in a neoprene cup manufactured with a grommet to prevent short circuiting of the hanger rod. The cup shall contain a steel washer designed to properly distribute the load on the neoprene and prevent its extrusion. Spring diameters and hanger box lower hole sizes shall be large enough to permit the hanger rod to swing through an arc of 30° before contacting the hole and short circuiting the spring. Springs shall have a minimum additional travel to solid equal to 50% of the rated deflection. Submittals shall include a scale drawing showing the 30° swing capability.

E. Horizontal thrust restraints shall be provided on equipment subject to excessive displacement. The horizontal thrust restraint shall consist of a spring element in series with a neoprene pad. The spring element shall be contained within a steel frame and designed so that it can be preset for thrust and adjusted to allow for a maximum of ¼" movement when the equipment starts or stops. The assembly shall be furnished with one rod and angle brackets for attachment to the equipment and the ductwork. Horizontal thrust restraints shall be attached at the centerline of the thrust and symmetrically on each side of the unit.

2.7 PIPING INSULATION MATERIALS

A. Insulation for pipe shall be glass fiber with a K factor of .24 at 100° F mean temperature with a factory applied kraft reinforced foil all service vapor barrier jacket with a factory applied double pressure sensitive adhesive sealing system.

B. Insulation for concealed fittings and valves shall be glass fiber blanket with a K factor of .24 at 75° F mean temperature with a factory applied kraft reinforced foil all service vapor barrier jacket.

C. Exposed fittings, valves and flanges shall be insulated with molded fitting covers or fabricated segments of pipe insulation.

D. Insulation, jacket and sealant shall have a flame spread rating of 25 or less and a smoke developed rating of 50 or less per UL 723.

E. Insulation shall be Owens-Corning Fiberglass ASJ/SSL-II or approved equal.

F. All refrigerant piping (suction and liquid lines) shall be insulated with flexible foamed plastic, minimum 5.0 lb. Per cubic foot density, thermal conductivity not greater the 0.28 Btu-in/sq ft/°F/hour at mean temperature difference of 75°F.

G. All outdoor exposed refrigerant piping shall be painted with two coats of WB Armaflex finish. Prior to applying the finish, the insulation shall be wiped clean with denatured alcohol. The finish shall not be tinted. All seams shall be located on the lower half of the pipe.

H. Insulation thickness shall be as follows:

<table>
<thead>
<tr>
<th>SYSTEM PIPE SIZE THICKNESS</th>
<th>THICKNESS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heating Water ½&quot;-1½&quot;</td>
<td>1&quot;</td>
</tr>
<tr>
<td>Heating Water 2&quot;-4&quot;</td>
<td>1½&quot;</td>
</tr>
<tr>
<td>Heating Water &gt; 4&quot;</td>
<td>2&quot;</td>
</tr>
<tr>
<td>Condenser (Heat Pump) Water</td>
<td>All None Required</td>
</tr>
</tbody>
</table>

2.8 WEATHERPROOFING OF OUTDOOR PIPE INSULATION MATERIALS

A. Finish outdoor insulated piping with .016" thick aluminum jacket with Benjamin Foster 30-45 Foam Seal.

B. Finish fittings and valves with mitered sections of the insulation with factory attached aluminum jackets.

2.9 PIPE LABELS

A. All hydronic piping shall be labeled with plastic adhesive labels at a minimum. Labels shall indicate the piping system (hot water supply, hot water return, chilled water supply, chilled water return, steam, condensate, city water, etc.), and shall indicate the direction of flow. Piping shall be labeled every 20 feet minimum on straight runs and shall be labeled within five feet of changes of direction. Labels shall be applied to the insulation jacket.

2.10 HYDRONIC PIPING

A. Above ground hot & condenser (heat pump) water system piping shall be as follows:
2" AND SMALLER \(2\frac{1}{2}\)" and LARGER

**Construction** Solder joint construction with screwed or flanged connections to valves and equipment as required.

Grooved end connection with flanged connections to equipment as required.

**Pipe** Type "L" hard temper copper tubing.

Carbon steel, Schedule 40 to 8";

ASTM A-120 up to and including 4" ASTM A-53 grade A B for pipe 5" and larger.

**Fittings** Cast bronze or cast or wrought copper fittings with 95-5 solder.

Carbon Steel schedule to match pipe.

**Couplings** Same as fittings

**Unions** Same as fittings

B. Victualic pipe and fittings are acceptable for hot and condenser water piping.

C. Well Piping

1. Above Ground piping within the building shall be high density polyethylene.
2. Below ground piping shall be high density polyethylene.

D. Heat pump unit condensate piping shall be Schedule 80 PVC. All 90° changes in direction shall be made with 45° elbows and tee-wyes with cleanouts, not with straight tees.

2.11 REFRIGERANT PIPING

A. All refrigeration system piping shall be as follows:

**Construction** Hard brazed joints

**Piping** Copper tubing type ACR, hard drawn, cleaned, dehydrated and capped for refrigeration service, ANSI B70.1 ASTM A-280

**Fittings** Wrought copper, Brazed joint type, ANSI B16.22

**Coupling** Same as above

**Brazing Alloy** Easy Flo, Silfos, Phos Co., Minimum 1100 °F melting temperature, ASTM 280

2.12 VALVES

A. All valves shall be first quality of an approved manufacturer, shall be installed with the proper clearances and shall be tight at the specified pressures.

B. Valves shall be of minimum working pressure and materials as fittings specified for the service, however, in no case shall valves be designed for less than 125 PSI working pressure.

C. Where a specific manufacturer, brand and/or figure number is specified, an equivalent figure from an approved manufacturer shall be acceptable.

**Renovations to Building 1 - Fitchburg, MA HVAC - 15600**

Page 17 of 50

12/16/05

D. For shut off service the Contractor shall have the option of using gate valves, butterfly valves or ball valves with full open ID.

E. For throttling or modulating service the Contractor shall use a butterfly valve or another type of valve if a specific valve is specified on the drawings.

F. Butterfly Valves

1. Butterfly valves shall be of the flangeless type and may be lug or wafer style if not specified on the drawings.

2. Butterfly valves shall be rated 200 PSI bi-directional, differential pressure with a 200 PSI dead end service rating.

3. Butterfly valves shall have bodies of shock resistant ductile iron and shall have extended necks for 2" of insulation.

4. Butterfly valves shall have no exposed fasteners in the waterway to pin the disc to the stem.

5. Liners shall be molded in and supported by the valve body at the flange seals.

6. Top and bottom stem bushings of dissimilar material are required with a positive retention mechanism.
8. Butterfly valves larger than 4” shall be provided with gear operators.

G. Check Valves
1. Check valves shall be bronze 2” and smaller; Cast iron or cast steel with bronze trim for 3” and larger.
2. All check valves shall have removable caps and regrindable disc and seat ring.
3. Bronze check valves shall be rated 125 PSI SWP, 200 PSI WOG as NIBCO figure T-413 or S-413.
4. Iron Check valves shall be 125 PSI SWP, 200 PSI WOG as NIBCO figure F-918.

H. Globe Valves
1. Globe valves shall be bronze 2½” and smaller; Iron with iron trim for 3” and larger as NIBCO figure T-211 or S-211.
2. Bronze globe valves shall be rated 125 PSI SWP, 200 PSI WOG
3. Iron globe valves shall be OS&Y 125 PSI SWP, 200 PSI WOG as NIBCO figure F-718-N.
4. All globe valves shall be suitable for repacking under pressure.

I. Ball Valves.
1. Ball valves shall be bronze 2½” and smaller as Pittsburgh Brass Manufacturing (PBM) Code B and shall be rated for 200 PSI @ 250°F.
2. Ball valves shall be provided with self draining balls to drain to downstream side.

J. Valve Handles and Operators.
1. Butterfly valves shall be provided with locking lever type hand operators notched to allow incremental positioning and with a positional lock to function as a memory stop. The lock shall be lockable via a padlock.
2. Gate valves shall be provided with handwheels.

2.13 VALVE TAGS
A. Valve Tags shall be a minimum of 2” in diameter, constructed of No. 18 gauge aluminum with stamped numbers and letters filled in with black paint, fastened to valve by heavy aluminum or brass hooks or chain and shall be a different pattern than those used by plumbing and fire protection.

Renovations to Building 1 - Fitchburg, MA HVAC - 15600
Page 18 of 50
12/16/05
2.14 STRAINERS
A. Strainers shall be installed at the inlet connections to each pump, make-up water connection, water regulating valve and vent, to protect the functionality of all automatic apparatus.
B. Strainers shall be Mueller or approved equal.
C. Strainers shall be line size, Y-pattern and set in the horizontal or vertical downward orientation.
D. Strainers shall be bronze rated 225 PSI at 150°F, 2½” and smaller; Cast iron rated ANSI 125# for 3” and larger.
E. Bronze strainers shall be Mueller model 351.
F. Cast iron strainers shall be Mueller model 751.
G. Provide valved dirt blow off connections for each strainer with a valve located 6” to 1'-0” below strainer. Nipples and valves for dirt blow off connections to be full size of strainer blow off tapping. Valves shall have hose bibb connections angled down and shall be provided with a chained cap.

2.15 PIPE EXPANSION COMPENSATION DEVICES
A. Piping shall be installed with expansion loops, expansion couplings, offsets or elbows to accommodate expansion and/or contraction. Where such accommodations are not possible or at the Contractor's option an expansion compensation device may be used.

2.16 SLEEVES
A. Provide Schedule 40 galvanized steel pipe sleeves for each pipe passing through a wall, floor, partition or roof.

2.17 PRESSURE GAUGES
A. Pressure gauges shall be 4½” diameter dial, stainless steel case and ring phosphor bronze bourdon type, 1 percent full scale accuracy with bottom connection. Each gauge shall be provided with an isolation cock and pulsation snubber.
B. Gauges at pump inlets and outlets shall have a red setpoint indicator.
C. Gauge ranges shall be 0-100 PSIG or 10-50 PSIG as appropriate for the system and location.

2.18 THERMOMETERS
A. Thermometers shall be industrial type with 9 inch scale, red perma-colored liquid, black scale divisions on white background, union hub, separable brass well and adjustable swivel base. Extension wells shall be provided on insulated lines.
B. Thermometer ranges shall be 50-250°F for the heating water system and 0-100°F for the cooling water
2.19 FLEXIBLE CONNECTORS
A. Flexible connectors shall be as manufactured by Mason Industries Model MFTNC twin sphere neoprene connectors.

2.20 EXPANSION TANKS
A. The expansion tank shall be a diaphragm type tank with a permanently sealed in air cushion contained in the tank. The tank shall be welded steel construction, tested and stamped in accordance with Section VIII of the ASME Code for a working pressure of 125 psi and pre-charged to the minimum operating pressure.

2.21 RELIEF VALVES
A. Relief valves shall be constructed with iron bodies and all bronze working parts. They shall be set for the pressures indicated on the drawings or as required by the system and built to comply with the requirements of ASME.

2.22 AUTOMATIC AIR ELIMINATION ASSEMBLY
A. The air separator shall be a tangential inlet and outlet type separator. The air shall be vented to atmosphere via an automatic float activated vent valve located in the top of the air separator. The air elimination system shall be constructed of cast iron or welded steel; constructed and tested in accordance with Section VIII of the ASME code for a working pressure of 150 psi.

B. Vent valves shall be piped with a 3/8” copper tubing to the nearest floor drain.

2.23 PURGE/BALANCE VALVES
A. Purge valves shall be all bronze construction with a ½” drain tapping. Purge valves shall be installed as shown on the drawings and as required to completely purge all branches of the piping systems.

2.24 PROPYLENE GLYCOL SOLUTION
A. The propylene glycol solution shall meet the following requirements.
1. The fluid shall be an industrially inhibited propylene glycol (phosphate-based).
2. The fluid shall be dyed [bright yellow] to facilitate leak detection.
3. The fluid shall be easily analyzed for glycol concentration and inhibitor level.
4. For systems containing more than 250 gallons of fluid, annual analysis must be provided free of charge by the fluid manufacturer.
5. The fluid must pass ASTM D1384 (less than 0.5 mils penetration per year for all system metals).
6. The reserve alkalinity of the fluid shall be at least 19 to provide long-term resistance to acidic pH.

B. Propylene glycol shall be added to the system to provide a 30% concentration.

2.25 WATER TREATMENT
A. Furnish equipment, chemicals and service to provide a complete water treatment program.

B. All water treatment applied must be non-pollutant and meet all State, Federal, Municipal and County regulation covering effluent disposal.

C. Closed loop water systems
1. A liquid chemical bypass type shot feeder of five gallons capacity, complete with valves and fittings shall be connected across each closed water system.
2. Water system shall be treated with sufficient quantities of the proper chemicals to prevent corrosion damage.

2.26 DUCT INSULATION MATERIALS - DUCT WRAP
A. Insulation for ducts and fittings shall be glass fiber with a K factor of .25 at 75° F mean temperature with a factory applied kraft reinforced foil all service vapor barrier jacket with a 2” stapling flange.

B. Insulation, jacket and sealant shall have a flame spread rating of 25 or less and a smoke developed rating of 50 or less per UL 723.

C. Insulation shall be Owens-Corning Fiberglass Type 150 or approved equal.

D. The following ducts shall be insulated:
1. All unlined heat pump supply ducts located shall be have 1-½” of insulation.

2.27 ACOUSTICAL DUCT LINING
A. Acoustical duct lining shall be constructed of a semi-rigid board of glass fiber with a black-pigmented, fire resistant coating on the side toward the airstream. The duct lining shall comply with the requirements of NFPA 90 and ASTM C 1071.

B. Duct lining shall have a thermal conductivity of 0.25 Btu*in/hr*ft*ºF.

C. The following ducts shall be lined:
1. All horizontal heat pump supply and return ducts shall have 1” lining for the first 5 feet or past the first elbow, whichever is further.
2. All energy recovery supply and exhaust duct for the first 10 feet away from the unit or past the first elbow, whichever is further.

2.28 FILTERS
A. Unless otherwise noted panel filters shall be FARR 30/30.

2.29 RECTANGULAR DUCTS
A. All ductwork shall be fabricated of G-60 coated galvanized steel of lockforming grade and conforming to ASTM standards A-525 and A-527, unless otherwise noted, and shall be constructed in accordance with the latest SMACNA standards.

2.30 ROUND DUCTS

2.31 FLEXIBLE DUCTS
A. All flexible ducts shall be made from aluminum sheet, spiral wound into a corrugated tube. No adhesives shall be used in its construction. Spiral wound flexible ducts will not be acceptable.
B. All flexible ducts must conform to NFPA 90A requirements and be tested in accordance with UL-181 and bear a UL label and be installed in accordance with their listing by UL.

2.32 RECTANGULAR DUCT FITTINGS
A. All ductwork shall be fabricated of G-60 coated galvanized steel of lockforming grade and conforming to ASTM standards A-525 and A-527, unless otherwise noted, and shall be constructed in accordance with the latest SMACNA standards.

2.33 FLEXIBLE CONNECTORS
A. All connections between vibrating or rotating equipment and ductwork shall be made with a flexible connection consisting of a heavy fiber glass fabric, double coated with neoprene and shall be fireproof conforming to NFPA 90A, waterproof and airtight. The flexible connection shall be a minimum of 6” long and held in place with heavy metal bands.
1. Provide airtight, gasketed access panels for cleaning at all changed in direction and at the base of all risers and every 20 feet in long, horizontal runs. Bottom of access panels should be at least 1½ inches above the bottom of the duct.

2.34 DRIP PANS
A. Examine the drawings and in cooperation with the Electrical Contractor confirm the final location of all electrical equipment to be installed in the vicinity of piping. Plan and arrange all overhead piping no closer than two feet from a vertical line to electric motors and controllers, switchboards, or similar equipment. Piping is not permitted in electric equipment, transformer, switch gear and telephone gear rooms.
B. Where the installation of piping does not comply with the requirements of foregoing paragraph, where feasible the piping shall be relocated.
C. Where relocation of piping is not feasible, furnish gutters as follows:
1. Provide and erect a gutter of 16 ounce cold rolled copper or 18 gauge galvanized steel, under every pipe which is within 2 feet from a vertical line to any motor, electrical controllers, switchboards, panelboards or the like.
2. Each gutter shall be reinforced, rimmed, soldered and made watertight, properly suspended and pitched to a point outside of the electrical room.

2.35 DRYER EXHAUST DUCT
A. Dryer exhaust duct shall be constructed of aluminum alloy 3003. All longitudinal seams shall be made on the top of the duct, thus creating a “U” shaped seamless bottom piece. All transverse joints shall be sealed watertight with a suitable duct sealer.
B. Flexible dryer duct may be used to connect from the dryer outlet to the wall. All duct beyond that point shall not be flex.
C. Dryer vent caps shall be square louvered type, with the louver blades as a backdraft damper.

2.36 ACCESS PANELS
A. Hinged access panels shall be provided at locations of firestats, smoke detectors, fire dampers and elsewhere as required to service the duct systems. Access doors shall be fully gasketed for air tight seal at
the rated working pressures of the systems in which they are installed. Access doors shall be adequately sized for their intended purpose and equipped with a minimum of two sash locks. Access doors in insulated ducts shall be double wall and insulated.

2.37 FIRE DAMPERS
A. Furnish and install fire dampers at locations shown on the plans by the symbol FD and where required by code. Fire dampers shall be the folding type with fusible links. Type “A” mountings shall be used for velocities up to 2500 FPM, type “B” mountings for velocities up to 4000 FPM and type “C” mountings for velocities over 4000 FPM, where the velocity is defined as the net velocity through the free area of the damper. Fire dampers shall meet the requirements of the latest NFPA 90A and shall be tested in accordance with UL555 and bear a UL label.
B. An approved access door or other suitable means of access shall be provided at each fire damper to service and inspect the fusible link.
C. Local codes shall take precedence where they supercede NFPA, however, the Contractor shall notify the Engineer, in writing, citing such differences by reference to such codes should the contract documents not reflect these differences.

2.38 SMOKE DAMPERS
A. The Contractor shall clearly indicate the locations of fire dampers on the shop drawings and shall provide an itemized list of fire dampers for inspection and for posting in the building Engineer's office.
B. Furnish and install smoke dampers at locations shown on the plans by the symbol SD and where required by code. Smoke dampers shall meet the requirements of the latest NFPA 90A and shall be tested in accordance with UL555S and bear a UL label.
C. The smoke damper shall be wired to the fire alarm system and shall operate in accordance with the latest version NFPA 90A or The BOCA National Building Code.
D. Smoke dampers shall be provided and installed by the HVAC Contractor and wired to the fire alarm system by the Electrical Contractor.

2.39 REGISTERS, GRILLES AND DIFFUSERS
A. The types, sizes and airflow patterns of the registers, grilles and diffusers as specified and as shown on the plans have been selected to accomplish the intent and purpose of the system. Any substitutions proposed for items scheduled, shown or specified must provide the same airflow patterns, at the same air volumes and must have the same acoustical characteristics as the specified elements.
B. All interiors of all ducts in back of all registers, grilles and diffusers shall be painted with one coat of flat black nonflammable paint.
C. Duct connections to supply devices shall be made inside the collars, if any, and, duct connections to return or exhaust devices shall be made outside the collars, if any.
D. All registers, grilles and diffusers shall have a baked enamel, off-white, semi-gloss finish.
E. Square and rectangular diffusers shall have removable cores with opposed blade dampers, gasketed borders and concealed fastenings.
F. Frame types of diffusers shall be as appropriate for the type of ceiling in which they are to be installed.
G. Supply, return and exhaust air registers shall have opposed blade dampers and gasketed borders.

2.40 IN-LINE CENTRIFUGAL PUMPS
A. Furnish and install centrifugal in-line single stage pump with capacities and characteristics as shown on the Plans.
B. Pump volute or casing shall be constructed of class 35 cast iron. The pump shall be fitted with replaceable bronze wear rings, drilled and tapped for gauge ports at both the suction and discharge flanges and for drain port at the bottom of the casing. The pump shall be capable of being serviced without disturbing system piping.
C. The impeller shall be bronze and hydraulically balanced by either back vanes or back wear ring and balancing holes. The impeller shall be dynamically balanced and shall be fitted to the shaft with a key.
D. The pump shall be close coupled to a NEMA standard JM regreaseable motor. The pump shall incorporate a dry shaft design to prevent the circulating fluid from contacting the shaft. The shaft shall be covered with a replaceable bronze shaft sleeve.
E. The pump shall have a factory installed seal flushing line running from the seal area to the pump suction to insure removal of trapped air from the seal area, removal of sediment and cooling of the seal to extend seal life.
F. The pump seal shall be EPT Ceramic rated to 250°F.

2.41 CLOSED COUPLED PUMPS
A. Furnish and install pumps with capacities as shown on plans.
B. Pumps shall be base mounted, single-stage, end suction design with true back pull-out, capable of being
serviced without disturbing piping connections.

**Renovations to Building 1 - Fitchburg, MA HVAC - 15600**

**Page 24 of 50**

12/16/05

C. Pump volute shall be Class 30 cast iron with integrally-cast pedestal support. The impeller shall be cast bronze, enclosed-type, dynamically balanced to ANSI Grade G6.3, keyed to the shaft and secured by a locking capscrew.

D. The liquid cavity shall be sealed off at the pump shaft by an internally-flushed mechanical seal with ceramic seal seat of at least 99.5% alumina oxide content providing a hardness of 68 Rockwell C, and carbon seal ring, suitable for continuous operation at 225 °F. A replaceable aluminum bronze shaft sleeve shall completely cover the wetted area under the seal.

E. Pumps shall be rated for minimum of 175 psi working pressure. Casing shall have gauge ports at nozzles and vent and drain ports at top and bottom of casing.

F. Pump bearing housing assembly shall have heavy-duty regreaseable ball bearings, replaceable without disturbing piping connections and have foot support at coupling end.

G. Baseplate shall be of structural steel or fabricated steel channel configuration fully enclosed at sides and ends, with securely welded cross members and fully open grouting area. A flexible-type coupler, capable of absorbing torsional vibration, shall be employed between the pump and the motor and it shall be equipped with a suitable coupling guard as required. Contractor shall level and grout each unit according to manufacturer’s instructions.

H. The motor shall meet NEMA specifications and shall be the size, voltage and enclosure called for on the plans. Pump and motor shall be factory aligned, and shall be realigned by the contractor after installation.

I. Each pump shall be factory tested. It shall then be thoroughly cleaned and painted with at least one coat of high-grade machinery enamel prior to shipment.

J. Each unit shall be checked by the contractor and regulated for proper differential pressure, voltage and amperage draw. This data shall be noted on a permanent tag or label and fastened to the pump for owner’s reference.

---

2.42 WELL PUMPS

2.43 VARIABLE FREQUENCY DRIVES

A. General

1. The VFD's carry UL or cUL independent testing company label. The VFD shall be rated and labeled according to Paragraph 53.4 of UL508C for mounting in plenum compartments. Additional standards include IEEE 519 - 1992, NEC 508, and NEMA.

B. Warranty

1. The warranty shall take affect after factory startup of the VFD's and shall be in force for 2 years following date of shipment from the factory.

2. The warranty shall include on site, factory authorized, repair or replacement of parts, travel time, and travel expenses for warranty repairs.

C. Variable Frequency Drive

1. The VFD shall convert three-phase, 60 Hertz utility power to adjustable voltage and frequency, three-phase, AC power for motor speed control on variable torque loads with NEMA Design B motors. All general options and modifications shall be included with the standard variable frequency controller in a single UL listed assembly and supplied by a single manufacturer.

---

Renovations to Building 1 - Fitchburg, MA HVAC - 15600

**Page 25 of 50**

12/16/05

2. The variable frequency control shall include transient voltage suppression to allow reliable operation on a typical industrial or commercial power distribution system. The VFD shall operate satisfactorily when other VFD's are operated from the same bus. It shall be nameplated for 85,000 AIC. Optional power line fusing shall be rated 200,000 AIC.

3. Individual or simultaneous operation of all the VFD's shall not add more than 5% total harmonic voltage distortion to the facility point of common coupling (PCC), per IEEE 519-1992.

D. Schedule

1. Drives shall be of the size, capacity and quantity as shown on the fan and / or pump schedules.

E. Basic Description

1. The VFD shall produce an adjustable AC voltage / frequency output. It shall be of the Pulse-Width Modulated (PWM) technology and shall consist of a full-wave diode bridge converter to convert incoming AC utility power to DC power, a capacitor filter/storage network and an inverter power transistor switching output section. The inverter output shall be generated by an Intelligent Power Module (IPM), with internal base driver, protection and sensing circuits, for enhanced reliability through the use of circuit integration and simplified board level circuits. The IPM shall
be IGBT based and capable of extended carrier frequency operation. The VFD shall switch its output waveform with an adjustable carrier frequency from a minimum of 1.5 kHz for maximum efficiency, through at least 8 kHz for quiet motor operation without requiring derating of the VFD.

2. The VFD shall have a continuous output current rating of 100% motor nameplate current, with an overload rating of 120% VFD nameplate rating for 1 minute. The VFD PWM output shall not induce excessive power losses in the motor. The VFD Full load output currents shall be based on National Electric Code ratings.

3. DC buss capacitors shall be high performance and printed circuit board mounted. To minimize radiated RFI and EMI cable or buss bar connected capacitors are not allowed.

F. Control Features

1. The keypad of each VFD shall include an alphanumeric readout for all drive functions on a 32-character, backlit, LCD display. The backlit LCD alphanumeric digital readout shall present all diagnostic messages and parameter values in English with standard engineering units. Codes are not an acceptable alternative. The display shall have settings for high, medium, and low viewing angles.

2. The keypad shall be capable of controlling the VFD and setting drive parameters. The keypad shall include a "HAND/OFF/AUTO", "SPEED SOURCE" selector, "PROGRAM/RUN" pushbutton, "ENTER" push-button, "SCROLL UP" and "SCROLL DOWN" arrow push-buttons. The Hand/Off/Auto function shall be coordinated with any remote Hand/Off/Auto switch, such that stopping and restarting at the VFD remains possible, but only according to the remote setting. Available speed source selection shall include manual adjustment, automatic (4-20 mA, 0-10 VDC, floating point, or Serial Communication), and preset speeds.

3. The VFD shall be software programmable to provide automatic restart after a fault trip condition resulting from overcurrent, overvoltage, undervoltage, or overtemperature. The VFD shall shut down and require manual reset and restart if the automatic reset/restart function is not successful within the programmed number of restart attempts. During the automatic restart attempts the LCD display shall show the warning, "START PENDING".

4. An overcurrent speed reduction shall be activated to avoid tripping the drive during transient overloads. The drive shall return to set speed after the overload is removed. If the acceleration or deceleration rate is too rapid for the connected load, the drive shall automatically compensate to prevent a fault trip.

5. A critical speed avoidance will allow for the selection of two skip speeds and a rejection band of 0 to 10 hertz around each speed for a total range of 20 Hz. The drive speed will stay above or below that band when the speed reference signal calls for a speed within the rejection band.

6. The VFD shall resume control of a rotating motor from an auto-restart command by matching frequency and accelerating or decelerating to set speed without tripping into a fault condition. The VFD shall have three selectable levels of auto-restart capabilities.

7. Sleep mode shall allow the VFD to go into a sleep mode when the commanded speed falls below an adjustable limit for an adjustable set time. When the speed command rises above this limit the drive shall resume normal operation.

8. There shall be an included RS485 serial communication port, Windows based, control software, Modbus, Metasys N2, Siemens P1 or Lon Works compatible protocol.

9. Loss of the 4-20 mA signal shall stop the VFD or, if selected, revert to a preset speed.

10. The control configuration settings shall be field adjustable through the keypad / display unit. Repeated access to programming parameters from the run mode shall not require password entry or a search for the parameter, but shall jump directly to that parameter for ease of reprogramming. All settings shall be retained in a non-volatile RAM memory.

G. Protective Features and Circuits

1. Phase-to-ground or 3-phase short circuit
2. Overcurrent undervoltage, and overvoltage
3. High and low line voltage
4. Power unit overtemperature
5. Inverse time, electronic thermal overload
6. Open terminals for external fault conditions
7. Shall be insensitive to incoming power phase sequence
8. DC bus discharge circuit
9. Input line noise suppression
10. 0.5 second (30 cycles) power loss control circuit ride through
11. AC Motor heating circuit to prevent condensation buildup
12. Isolated Operator controls

H. Diagnostic Fault Handling
1. The VFD shall include a comprehensive microprocessor based digital diagnostic system, which monitors its own control functions and displays faults and operating conditions.
2. A fault log shall record, store, and display upon demand, the 8 most recent events and drive activity when the fault occurred. All fault records shall be retained in a non-volatile RAM memory.

I. Inputs and Outputs
1. Analog Outputs
   a. 0 to 10 vdc and 2 to 10 vdc proportional to speed and load
   b. 24 vdc @ 50 madc for powering remote devices.
2. Digital Outputs
   a. Three programmable Form C relay rated 2 Amps at 28 VDC or 120 VAC for; Run, Fault, Fault Lockout, At Speed, Above Set Speed, Current Limit, Follower Present, Auto Mode or Min/Max transducer level in PID mode
3. Analog Inputs
   a. 4-20 ma speed
   b. 0-10 VDC speed
   c. Potentiometer speed
4. Digital Inputs
   a. Two wire remote Start / Stop
   b. Three wire remote Start / Stop
   c. Local / Remote start and stop commands
   d. Auto / Manual speed commands
   e. Four Preset Speeds

J. Analog Outputs
   a. 0 to 10 vdc
   b. 2 to 10 vdc
   c. 24 vdc @ 50 madc

K. Service Conditions
1. The controller shall be designed and constructed to operate within the following environmental conditions:
   a. Elevation: To 3300 Feet (1000 meters)
   b. Ambient Operating Temperature Range: 0º C to 40º C
   c. Atmosphere: Non-Condensing relative humidity to 95%
2. The controller shall be designed and constructed to operate within the following electrical conditions:
   a. AC Line Voltage Variation from the applied voltage:
      1) 200 / 240 VAC supply: -15% to +10%
      2) 400 / 480 VAC supply: -15% to +10%
      3) 480 / 590 VAC supply: -15% to +10%
   b. AC Line Frequency Variation: 48 to 62 Hertz

L. Enclosure
1. All VFD drive and accessories components shall be factory mounted, assembled and wired by the VFD manufacturer in a NEMA-1 steel enclosure. Assemblies or modifications by a third-party are not allowed. Units furnished with plastic enclosures must be placed in a steel enclosure for mechanical protection and to minimize RFI and EMI radiation.

M. Drive Bypass
1. Integral NEMA 1 steel enclosure, with VFD module and 3 contactor bypass module shall be independently enclosed and completely isolated from each other when the bypass door is opened. All power and control terminations shall be brought from the VFD module to terminals within the
bypass module.
2. A door interlocked disconnect switch with through-the-door handle and padlock facility in the OFF position, to provide positive disconnect of incoming AC power.
3. PT type fuses for the VFD input, equivalent to Bussman type KTK-R and rated 200,000 AIC.
4. Door mounted Phenolic Nameplates with Pump, Fan or Machine Tag number.
5. 3 phase input AC line reactor (minimum 2.5% impedance), this line reactor is to be factory mounted and wired within the VFD assembly. DC bus inductors / reactors will not be considered as a substitute for AC line reactors on power input.
6. A three contactor bypass is required to be provided to allow the motor to run across the line in the event of VFD shutdown. The transfer from the VFD to the line shall be accomplished manually by means of a BYPASS / OFF / DRIVE switch. The bypass shall include a mechanically inter-locked VFD output contactor, full-voltage motor starting contactor and a VFD input contactor for drive isolation and test. Exceptions to an input contactor will not be allowed. A thermal overload relay to provide motor protection, fused motor bypass and a fused control power transformer. A HAND/OFF/AUTO switch, TEST/OFF/DRIVE switch, BYPASS/OFF/DRIVE switch, POWER ON pilot light, BYPASS ON pilot light, DRIVE ON pilot light and SAFETY CIRCUIT TRIPPED pilot light (with reset) shall be mounted on the front of the bypass enclosure.
7. A dedicated terminal strip in the bypass control shall be included for 120 V customer connections. These shall include terminals for external fault conditions, Start/Stop, Smoke Purge (that forces either the VFD or bypass to Run), and bypass contactor interlock (to prevent bypass operation).

Renovations to Building 1 - Fitchburg, MA HVAC - 15600
Page 28 of 50
12/16/05
This terminal strip shall contain all VFD control terminals. Transfer to line bypass will require manual switching unless automatic transfer is specified. Provisions for an automatic transfer, after automatic restart attempts have failed to start the VFD, shall include a bypass lockout that can be activated to prevent unsafe bypass operation.
8. PID set-point control to maintain the level set by a keypad, a 4-20 mA signal, a 0 -10 VDC signal, or a manual potentiometer. This output must be capable of starting the VFD, stopping the VFD, or sending an alarm signal, as required. This control shall accept feedback from a remote sensor, as specified, with a 4-20 mA, 0-10VDC.

N. System Operation
1. When in HAND, the drive speed shall normally be controlled either by Increase and Decrease pushbuttons on the drive keypad. When AUTO is selected, speed shall be controlled by a 0-10 VDC signal, 4-20 mA signal, or faster / slower floating point contacts or preset speed. PID set point may be changed with the keypad or from a remote 0-10 VDC or 4-20 mA signal.
2. Start and Stop shall be controlled by a Hand/Off/Auto switch. A remote contact closure shall start the drive in Auto mode.

O. Quality Assurance And Factory Tests
1. Power Modules shall be tested to ensure correct function and highest reliability.
2. Every controller will be functionally tested with a motor to ensure that when the drive is started up according to the instruction manual provided, the unit will run properly. Load tests and burn in of the VFD must be performed in the United States factory where the VFD is manufactured.

P. Startup and Training
1. VFD’s shall not be powered up without authorization from the VFD manufacturer. The contractor shall notify the VFD manufacturer when the units have been installed and shall schedule a minimum of one day of startup, by a factory trained and authorized technician, for every group of 5 VFD units. This technician shall complete a startup report that records all VFD data, settings, and a check list of tests and observations. The VFD manufacturer shall retain this report.
2. Provide one 4 hour training session on site by a VFD factory trained and authorized technician. This session shall review all operation and maintenance requirements plus the fundamentals of VFD’s and their application to AC motors.

2.44 PLATE AND FRAME HEAT EXCHANGERS
A. The plate and frame heat exchanger shall consist of pressed type 304 stainless steel plates as to provide the required heat transfer area to meet the operating conditions specified on the drawings. Each heat transfer plate shall have one piece molded nitrile gaskets. Gasketing shall have relieving grooves to prevent intermixing of fluids and cause leaks to flow to the outside of the unit.
B. All materials in contact with the fluids shall be 304 stainless steel.
C. The entire frame shall be bolted together. Welded frame assemblies shall not be acceptable.
D. The complete assembly shall be tested in accordance with the ASME code, Section VIII, Division I and furnished with an ASME Code certification for a design pressure of 150 psig @ 240°F for both circuits.
2.45 WATER SOURCE HEAT PUMPS (HORIZONTAL AND VERTICAL)
A. Heat pumps shall have the capacities and electrical characteristics as indicated on the plans.

Renovations to Building 1 - Fitchburg, MA HVAC - 15600
Page 29 of 50
12/16/05

B. Cabinet: Provide unit factory assembled and pre-wired consisting of: galvanized steel cabinet with 1/2" fiberglass on interior, discharge duct collar and return collar with filter rack to accommodate 1" or 2" thick throwaway filters.

C. Sound
1. Sound attenuation shall be applied as a standard feature in the product design. The sound reduction package shall include vibration isolation to the compressor and water-to-refrigerant coil, discharge line muffler, compressor blanket, 16-gauge access panels, neoprene gasketing on all access panels, and 1" insulation on the interior of the unit.
2. Acoustical data obtained in accordance with ARI 260.

D. Refrigeration System
1. Compressor: The unit shall include a compressor. External vibration isolation shall be provided by mounting devices located underneath the mounting base of the compressor. Thermal overload protection shall be provided.
2. Water-to-Refrigerant Heat Exchanger: The water-to-refrigerant heat exchanger shall a copper coaxial coil. The copper coil shall be deeply fluted to enhance heat transfer and minimize fouling and scaling. The coil shall have a working pressure of 450 psig on the refrigerant side and 400 psig on the water side.
3. Reversing Valve: The reversing valve shall be a pilot operating sliding piston type with replaceable encapsulated magnetic coil. This valve shall be energized in cooling.
4. Tubing: The refrigerant tubing shall be of 99% pure copper. This system shall be free from contaminants and conditions such as drilling fragments, dirt, and oil. All refrigerant and water lines shall be insulated with an elastomeric insulation that has a 3/8” thick wall wherever air is introduced to the assembly.
5. Refrigerant Metering: The equipment shall be provided with a thermal expansion valve (TXV) to allow operation of the unit with entering fluid temperatures from 25F to 120F. Capillary tubes will not be acceptable.
6. Schraeder Connections: The refrigerant access ports shall be factory supplied on the high and low pressure sides for easy refrigerant pressure or temperature testing.
7. Air-to-Refrigerant Coil: The air-to-refrigerant coil shall contain copper tubes mechanically expanded into evenly spaced aluminum fins. All coils are to be leak tested. The proof must be performed at 450 psi operating pressure and the leak test at 125 psi operating pressure with helium. In addition, the tubes are to be completely evacuated of air prior to shipment. The refrigerant coil distributor assembly shall be of orifice style with round copper distributor tubes. The tubes shall be sized consistently with the capacity of the coil. Suction headers shall be fabricated from rounded copper pipe.

E. Electrical: The factory tested and installed control panel shall contain all necessary devices to allow heating and cooling operation of the equipment to occur from a remote wall thermostat or zone sensor. These devices shall be as follows:
1. 24 VAC contactor for compressor control.
2. 18 pole terminal strip located inside the control panel behind the service access panel. This terminal strip shall be used for low voltage (thermostat/zone sensor) connections.
3. An electrically operated safety lockout relay shall help prevent cycling of the compressor during adverse conditions of operation. This device shall be reset either at the remote thermostat/zone sensor, or by cycling power to the unit.
4. A high pressure switch shall help protect the compressor against operation at refrigerant system pressure in excess of 395 psig.
5. A low pressure switch shall help prevent compressor operation under low charge or catastrophic loss of charge situations.

F. Controls
1. Control package shall include a 75 VA transformer with the features listed below:
   a. Lockout relay
   b. Anti-short cycle compressor protection
   c. Random start delay
d. Brown out protection

e. Low pressure time delay

f. Compressor delay on start

2. The unit shall be controlled by a T-87 type thermostat with subbase, 1-stage cool, 1-stage heat and
Fan On – Auto switch, with large numbers.

3. Thermostats in common spaces shall be 7-day programmable type.

G. 1/2 - 5 Ton Motor and Fan Assembly:

1. All fan motors shall be three speed high efficiency PSC, wired on the high speed tap. The motor
shall have permanently lubricated and sealed bearings. All motors shall have internal thermal
overload protection.

2. Standard static pressure motors to be provided.

3. The fan assembly shall be arranged for back, left, or right discharge. The discharge must also be
capable of being changed in the field.

4. Removal of the motor and fan wheel shall be made with the assistance of a factory provided
orifice ring assembly. This assembly shall attach the wheel and motor to the fan housing
providing single side service access.

H. Drain Pan: The drain pan shall be constructed of corrosion resistant material and insulated to prevent
sweating. The bottom of the drain pan shall be sloped on two planes which pitches the condensate to the
drain connection.

I. Provide four (4) rigid hanging brackets for horizontal, ceiling-mounted units. Hanging bracket shall be
capable of receiving vibration isolation and come factory mounted to the unit.

J. Filters shall be 1” throwaway.

K. Warranty

1. The unit shall be warranted by the manufacturer against defects in material and factory
workmanship for one year from the date of startup.

2. 46 VERTICAL STACKING WATER SOURCE HEAT PUMPS

A. General

1. Equipment shall be completely assembled, piped, internally wired and test operated at the factory.

2. The equipment shall contains an ETL listing and label prior to leaving the factory.

3. Service and caution area labels shall be placed on the unit in their appropriate locations.

B. Casing

1. The cabinet assembly shall be constructed of heavy-gauge galvanized steel.

2. It shall house the blower, fan and control hook-up to the unit thermostat.

3. A basepan with condensate hose shall be included with the cabinet design.

4. Base rails shall allow ease of chassis installation/removal for service or maintenance.

5. The chassis shall be constructed of heavy-gauge galvanized steel.

6. The chassis shall house the compressor, reversing valve, water-to-refrigerant heat exchanger, airto-
refrigerant heat exchanger, thermal expansion valve, corrosive resistant condensate pan, and
water inlet/outlet connections.

7. The chassis shall be installed into the cabinet by sliding it in place on the locating rails within the

cabinet design.

Renovations to Building 1 - Fitchburg, MA HVAC - 15600

Page 31 of 50

12/16/05

8. The insulation shall have a flame spread rating of less than 25 and smoke density rating of less
than 50 (as tested in accordance with ASTM-85).

C. Sound Attenuation

1. An sound attenuation package shall be provided and shall a heavy gage base plate, gasket and
insulation around the compressor enclosure, and vibration isolation between the chassis and

cabinet. An additional dampening treatment shall be applied around the compressor enclosure to
achieve greater acoustical reductions.

D. Filters

1. Unit shall be provided with one inch, throwaway filters. The filters shall have an average
resistance of 76-percent and dust holding capacity of 26-grams per square foot.

E. Compressors

1. All units shall have direct-drive, hermetic, rotary (unit sizes 009-018) and reciprocating (unit sizes
024 and 036) type compressors.

2. The compressor shall have rubber isolation to aid in noise reduction during compressor start/stop.

3. Internal thermal overload protection and compressor anti-short cycle timers shall be provided.

4. Protection against excessive discharge pressure shall be provided by means of a high pressure
switch.
5. Loss of charge protection shall be provided by a low temperature sensor.

F. Refrigerant Circuits
1. The refrigerant circuit shall contain a thermal expansion device, service pressure ports, and system safety devices factory-installed as standard.

G. Air-to-Refrigerant Coil
1. Coil shall be constructed of internally finned, 3/8-inch copper tubes mechanically bonded to a configured aluminum plate fin.
2. Coils shall be leak tested at the factory to ensure the pressure integrity. The coil shall be leak tested to 200 psig and pressure tested to 450 psig.

H. Drain Pan
1. The condensate pan shall be constructed of corrosive resistant material.
2. The bottom of the drain pan shall be sloped in two planes to pitch the condensate towards the drain connection.
3. Condensate shall be piped to a lower base pan through condensate hose for ease of chassis removal.
4. A clear drain hose shall be factory clamped onto the drain connection for field hook-up.

I. Water-to-Refrigerant Heat Exchanger
1. The water-to-refrigerant heat exchanger shall be of a high quality co-axial coil for maximum heat transfer.
2. The copper coil shall be deeply fluted to enhance heat transfer and minimize fouling and scaling.
3. The coil shall have a working pressure of 400 psig on both the refrigerant and water sides.

J. Indoor Fan
1. The blower shall be a double width, double inlet (DWDI) forward curved wheel supported by a PSC fractional horsepower motor.
2. The motor shall be multiple speed, and wired for a HIGH or LOW setting.
3. Service or maintenance to the blower/motor shall be achieved by removal of a single bracket.

K. Risers
1. Factory supply, return, and drain risers shall be Type L copper.

L. Controls
1. The unit control box contains all necessary devices to allow heating and cooling operation to occur from a unit mounted, plug-in thermostat or sensor.
2. The devices are as follows:
   a. 24 VAC energy limiting class II 75 VA breaker type transformer.
   b. 24 VAC blower motor relay
   c. 24 VAC compressor contactor for compressor control
   d. Lockout relay which controls cycling of the compressor shall be provided to protect the compressor during adverse operating conditions. The device may be reset by interrupting the 24 VAC control circuit. Reset may be done either at the thermostat or by momentary
   e. main power interruption.
   f. A high pressure switch protects the compressor against operation at refrigerant system pressures exceeding 395 psig.
   g. A low pressure temperature sensor prevents the compressor operation at leaving water temperatures below 20º F.
   h. Factory installed wire harness is available for the Deluxe and ZN510 control packages. Basic controls are provided for retrofit applications.
   i. Power connections are made through a factory installed conduit located at the top of the unit’s cabinet. An optional disconnect is provided. The conduit grants access directly to the control box.
3. Nameplate information shall be given for the application of either time-delay fuses or HACR circuit breakers for branch circuit protection from the primary source of power.
4. Single phase, single voltage rated equipment shall be designed to operate between plus or minus 10 percent of nameplate utilization voltage.

M. Additional Controls
1. The additional control package shall provide a 75 VA transformer with circuit breaker.
2. The controller shall be a micro-processor based controller designed to include a lockout relay, anti-short cycle compressor protection, random start delay, brown-out protection, low pressure time delay, compressor delay on start and an open relay for night setback or pump request.
3. LEDs (light emitting diodes) shall be included for diagnostics of the equipment.
4. The controller accepts either a standard 24V digital or mercury thermostat.

N. Return-Air Hinged Acoustical Door
1. A frame mounted acoustical door shall be provided to attenuate noise.
2. The door shall be hinged to the wall frame, and contain magnetic latches to keep the door aesthetically in place.
3. The door shall be flush mounted to the wall as to not protrude into the owner space.
4. The door shall allow access to the unit for ease of filter replacement.
5. The door shall be constructed from heavy gauge formed galvanized steel and painted Polar white.

2.47 Console Water Source Heat Pumps
2.48 Gas Fired Boiler

A. General
1. The boiler(s) shall be design certified and tested with a minimum thermal efficiency of 82%, and shall bear the ASME stamp and be inspected and approved by the National Board for 160 PSIG working pressure complete with Manufacturer's Data Report.
2. The boiler(s) shall be equipped with a PSIG ASME Pressure relief valve, piped by the installer to an approved drain, and a temperature and pressure gauge.

Renovations to Building 1 - Fitchburg, MA HVAC - 15600
Page 33 of 50
12/16/05

3. The water tube heat exchanger of the boiler(s) shall be of the single bank, horizontal grid design with integral copper fin tubes, each end of which is rolled into an ASME boiler quality steel tube sheet and sealed to 160 PSIG rated headers with Silicone "O" rings, having a temperature rating over 500°F. The low water volume heat exchanger shall be explosion proof on the water side and shall bear a 20 year Warranty against "Thermal Shock" caused by boiler operation with large changes, not exceeding 150°F between the water temperature at the boiler inlet and the boiler outlet temperature up to 230°F maximum. The headers shall be secured to the tube sheet by stud bolts with flange nuts to permit inspection and maintenance without removing external piping connections. The heat exchanger shall incorporate "V" Baffles, between the tubes, to insure complete contact of the external tube surfaces with the products of combustion.
4. The boiler(s) shall be capable of operating down to 105°F without condensation.
5. The lightweight, high temperature, interlocking castable combustion chamber liner shall reduce standby radiation losses. The corrosion resistant galvanized steel jackets shall be finished with a baked on powder finish, suitable for outdoor installation, and shall incorporate louvers, in the outer panels, to divert air used for combustion, past heated surfaces reducing jacket losses and increasing unit efficiency.
6. The stainless steel alloy burners shall be of the raised port design with fixed primary air ports, capable of quiet ignition and extinction without flashback at the orifice at firing rates between 20% and 100%, and mounted in a slide out burner drawer for ease of inspection.
7. The boiler(s) shall have a floor loading of 70 lbs/square foot or less.
8. The boiler(s) shall be completely assembled and fire tested prior to shipment from the factory.

B. Pilot Control System
1. The boiler(s) shall be equipped with a 100% safety shutdown on loss of pilot flame.
2. The pilot ignition shall be an electronic intermittent ignition system with electronic flame supervision having a nominal 0.8 second flame response time.

C. Firing Mode
1. The boiler(s) shall be equipped to provide two stage control of the gas input to the boiler.
2. In addition, all gas control trains must have a redundant safety shut off feature, main gas regulation, shut off cock and plugged pressure tapping to meet the requirements of ANSI Z21.13.

D. Boiler Control
1. The boiler(s) shall be equipped with an operating temperature control and high limit control.
2. A flow switch, mounted and wired shall be provided as standard except Model 133.
3. An energy saving pump control relay, mounted and wired shall be provided for system efficiency.

2.49 Electric Wall Heater

A. The electric fan powered wall heater shall be designed for recessed mounting.
B. The heater shall be designed for surface or recessed wall mounting in any position. For surface mounting, a Berko SRSM surface mounting box shall be used. For semi-recessed installation a Berko SRS-1 or SRS-2 semi-recessed sleeve shall be used.
C. The back box shall be designed for duty as a recessed rough-in box in either masonry or frame. The back box shall be 20-gauge cold rolled steel and shall contain knock outs through which field wiring leads are brought and connected to pigtails of the preinstalled female disconnect receptacle. Connecting of the male plug of the inner frame completes the wiring of the heater.
D. The inner frame assembly shall consist of a 20-gauge steel chassis on which are mounted the heating element, fan motor and blade, thermostat, fan control and thermal cut out. The inner frame assembly shall be completely prewired with the leads terminating in a male plug, thus facilitating positive disconnect and easy removal for service without disturbing the back box or field wiring.

E. The heating element be of nonglowing design consisting of a special resistance wire enclosed in a steel sheath to which steel plate fins are brazed. The element shall cover the entire air discharge area to ensure uniform heating of all discharge air.

F. The fan motor shall be impedance protected, permanently lubricated and with totally enclosed rotor.

G. Fan control shall be bimetallic, snap-action type and shall activate fan after heating element reaches operating temperature, and continue to operate the fan after the thermostat is satisfied and until all heated air has been discharged. The thermostat shall be of bimetallic, snap-action, two-pole type with enclosed contacts and with positive "off" on all models. Thermal cutout shall be bimetallic, snap-action type designed to automatically shut off heater in the event of over heating and reactivate the heater when temperatures return to normal.

H. The louvered front cover shall be of 20-gauge cold rolled steel finished in desert tan baked enamel or chrome finish, with four mounting holes, mounting screws, and plug button to match finish.

I. Unit shall be supplied with front covers without the hole for the thermostat knob to provide full tamperproof installation.

J. All sheet metal parts, except chrome finished front covers, shall be phosphatized, then completely painted as determined by the architect by an electrostatic, baked enamel, painting process.

2.50 ENERGY RECOVERY UNITS WITH GAS HEAT

A. General
1. Units shall be Listed per ANSI/UL 1995, Heating and Cooling Equipment.
2. Ventilators shall bear the AMCA Certified Ratings Seal for air performance.
3. Energy transfer ratings of the energy recovery wheel shall be ARI Certified. Performance shall be as scheduled on plans.

B. Unit Casing and Frames
1. Unit shall be of internal frame type construction of galvanized steel.
2. Frame and panels shall be G90 galvanized steel.
3. All panels exposed to the weather shall be a minimum of 18 gauge galvanized steel.
4. Unit shall be internally lined with galvanized sheet metal creating a double wall.
5. Where top panels are joined there shall be an overlapping, standing seam to insure positive weather protection.
6. All metal-to-metal seams shall be factory sealed, requiring no caulking at job site.
7. Permatector exterior finish shall be provided for outdoor units.
8. Unit base to be designed for curb mounting. Unit base shall overhang the curb for a positive seal against water run-off.

C. Weatherhoods
1. Weatherhoods shall be the same finish as the unit.
2. Outdoor air weatherhood shall incorporate a louvered design and moisture eliminator.
3. Weatherhoods shall be tested in accordance with AMCA Standard 500-L to prevent water penetration up to 3 in/hr at 29 mph.

D. Insulation
1. Unit casing to be insulated with 1 inch fiberglass. Insulation shall meet requirements of NFPA 90A and tested to meet UL 181 erosion requirements.
2. Insulation to be enclosed in double wall construction.

E. Energy Recovery Wheel
1. Wheel shall be of the enthalpy type for both sensible and latent heat recovery and be designed to insure laminar flow.
2. Energy transfer ratings must be ARI Certified to Standard 1060 and bear the ARI Certification symbol for ARI Air-to-Air Energy Recovery Ventilation Equipment Certification Program based on ARI 1060. Ratings “in accordance with 1060” without certification are not acceptable.
3. Desiccant shall be silica gel for maximum latent energy transfer.
4. Wheel shall be constructed of lightweight polymer media to minimize shaft and bearing loads. Polymer media shall be mounted in a stainless steel rotor for corrosion resistance.
5. Wheel design shall consist of removable segments for ease of service and/or cleaning.
6. Silica gel desiccant shall be permanently bonded to wheel media to retain latent heat capability after cleaning. Wheels with sprayed on desiccant coatings are not acceptable. Wheels with desiccant applied after wheel formation are not acceptable.
7. Energy recovery device shall transfer moisture entirely in the vapor phase.
8. Energy recovery drive belt material shall be high strength urethane and shall be factory installed in a pre-stretched state, eliminating the need for field belt tension adjustment.

F. Access Doors
1. All components shall be easily accessible through removable doors for exhaust, supply, filter, and damper compartments.
2. Energy recovery wheels (smaller than 58 inches) shall be mounted in a slide-out track for ease of inspection, removal, and cleaning.
3. Access doors shall be operable without the use of tools.

G. Roof Curbs
1. Roof curb to be supplied by unit manufacturer for field assembly.
2. Curb shall consist of die formed galvanized steel sections.
3. Curb shall be full perimeter type with gasketing provided for field installation between curb and unit base.

H. Fan Sections
1. Centrifugal fans to be double width, double inlet, forward curved type.
2. All blower wheels shall be statically and dynamically balanced.
3. Ground and polished steel fan shafts shall be mounted in permanently lubricated, sealed ball bearing pillow blocks.
4. Bearings shall be selected for a minimum (L10) life in excess of 100,000 hours at maximum cataloged operating speeds.
5. Separate motors for exhaust and supply blowers shall be provided.
6. Adjustable sheaves on belt-driven fans with motors less than 10 hp shall allow independent balancing of exhaust and supply airflow.
7. Fan and motor assemblies are mounted to unit base with neoprene isolators as standard.
8. Fans shall be located in draw-through position in reference to the energy recovery wheel.

I. Motors and Drives
1. Motors shall be energy efficient, complying with EPACT standards, for single speed ODP and TE enclosures.
2. Motors shall be permanently lubricated, heavy-duty type, matched to the fan load and furnished at the specified voltage, phase, and enclosure.
3. Drives shall be sized for a minimum of 150% of driven horsepower.

Renovations to Building 1 - Fitchburg, MA HVAC - 15600
Page 36 of 50
12/16/05
4. Pulleys shall be of the fully machined cast type, keyed and securely attached to the fan wheel and motor shafts; 10 horsepower and less shall be supplied with an adjustable drive pulley.
5. Energy wheel motors shall have integral overload protection.

J. Filters
1. Supply and exhaust air filters shall be 2-inch thick pleated fiberglass, 30% efficient and tested to meet UL Class 2.
2. Filter racks shall be die-formed galvanized steel.

K. Electrical
1. All internal electrical components shall be factory wired for single point power connection.
2. Units with electric reheat will be wired with independent power supply.
3. All electrical components shall be UL Listed, Approved, or Classified where applicable and wired in compliance with the National Electrical Code.
4. Weatherproof, integral door interlocking disconnect switch, motor starters, control circuit fusing, control transformer for 24 VAC circuit, and terminal strip shall be supplied as standard components in the control center.

L. Indirect Gas
1. Indirect fired gas furnace shall be 80% efficient, UL Certified and Listed per ANSI Z83.8 - 2002, C.G.A. approved per 2.6 - 2002 and have a blow through fan design.
2. Furnace shall be capable of operation with natural or LP gas and have a power venting system.
3. The burner and heat exchanger shall be constructed of aluminized steel.
4. Standard furnace features shall include main gas pressure regulator, main gas valve, electronic staged or electronic modulating controls, direct spark ignition system, high limit and a 24 volt control transformer.

M. Frost Control
1. The unit shall be provided with electric preheat that is activated by the wheel pressure drop.

N. Variable Speed Drives
1. Units noted on the schedule to have variable speed drives shall be provided with variable speed drives for both the supply and exhaust fans.
2. The variable speed drives shall be controlled based on the room carbon monoxide levels.

O. Dampers
1. The units shall be provided with gravity exhaust dampers and motorized supply dampers.
2. Dampers controls shall be by the unit manufacturer.

P. Remote Panel
1. Units shall be provided with a remote panel indicating fan status and wheel status.

2.51 AUTOMATIC TEMPERATURE CONTROL SYSTEM

A. Provide complete temperature control system by Johnson Controls, Inc., Barber Coleman, Tour & Anderson, Seimens, or Honeywell Controls Co.

1. Control system shall be installed by competent control mechanics and electricians regularly employed by control equipment manufacturer. Control equipment shall be by one manufacturer and controllers, dampers and devices shall be commercial grade type.

B. Scope

Renovations to Building 1 - Fitchburg, MA HVAC - 15600
Page 37 of 50
12/16/05

1. Control system shall consist of thermostats, temperature transmitters, controllers, automatic valves and dampers, damper operators, control panels, electrical wiring and other components required to fulfill the intent of specifications and provide for complete and operable system. Control equipment shall be fully proportioning, except as noted otherwise. Sequence of operation shall be as indicated in these specifications.

a. In general this specification is intended to cover following:
   b. Heat pumps.
   c. Energy recovery units.
   d. Condenser water system.
   e. Hot water system.
   f. Electric heating devices.

C. Provide services of control manufacture to supervise related work done under other paragraphs of this Section.

1. Installation of automatic valves and separable wells furnished under this Paragraph.
2. Provision of valved pressure taps water drain and over flow connections and piping.
3. Provision of auxiliary contacts with buttons, switches and indicator lights in required configurations, on magnetic starters.
4. Installation of automatic dampers.
5. Provisions of blank-off plates (safing) for dampers that are smaller than duct size.
6. Assembly of multiple section dampers with required interconnecting linkages and shafts through duct for external mounting of damper motors.
7. Provision of baffles to eliminate stratification and provide specified air volumes, affixed permanently after stratification is eliminated.
8. Provision of access doors for service to control equipment.

D. Electric Wiring

1. Electric wiring and wiring connections required for installation of temperature control system, as herein specified, shall be provided by hvac contractor, unless otherwise indicated on Drawings.
2. Wiring shall comply with requirements of the electrical work specifications.

E. Submittal Brochure: Submit following for approval:

1. Control drawings with detailed wiring diagrams and/or pneumatic piping, including bill of material and description for systems.
2. Panel layouts and name plate lists for local and central panels.
3. Valve and damper schedules showing size, configuration, capacity and location of equipment.
4. Data sheets for control system components.

F. Instruction and Adjustment: Upon completion of project, temperature control manufacturer shall:
1. Completely adjust and ready for use: thermostats, controllers, valves, damper operators, relays, and other components and equipment provided under this paragraph.
2. Furnish three instruction manuals covering function and operation of control systems on project for use by Owner's operating personnel. Competent technician shall be provided for instruction purposes.

G. Programmed maintenance:
1. Upon completion of installation, temperature control manufacturer shall submit to owner an agreement to provide necessary programmed maintenance and to keep various control systems in proper working condition.
2. Programmed maintenance agreement shall fully describe maintenance work to be performed and shall advise cost of work for subsequent years after guarantee period. This programmed maintenance agreement shall be provided free of charge during guarantee period.

H. Room Type Instruments:

Renovations to Building 1 - Fitchburg, MA HVAC - 15600
Page 38 of 50
12/16/05
1. Modulating common area thermostats shall be tamper proof. Thermostats shall have concealed adjustable setpoints. Operating range of 55 to 85ºF. Accuracy shall be ±1ºF.
2. Room thermostats shall have room temperature display and setpoint indication. Operating range shall be 55-85ºF. Accuracy shall be ±1ºF.

I. Automatic Control Valves:
1. Automatic control valves shall be fully proportioning with modulating plug or V-port inner guides, unless otherwise specified. Valves shall be quiet in operation and fail-safe in either normally open or normally closed position in event of control failure. Valves shall be capable of operating in sequence when required by operation.
2. Control valves shall be sized by temperature control manufacture and shall be guaranteed to meet heating and cooling loads as specified. Control valves shall be suitable for pressure conditions and shall close against differential pressure involved.
3. Valve actuators shall be modulating sealed electro-hydraulic or pneumatic type with spring return. Ambient temperature range shall be 40ºF to 150ºF. Body pressure rating and connection type (screwed or flanged) shall conform to pipe schedule specified elsewhere.

J. Low Temperature Safety Thermostat: low temperature warning thermostats shall have 20 ft. Low point sensitive elements (not averaging type) installed to cover entire duct area. Thermostats shall be two-position manual reset type. Where coils are two banks provide two freezestats wired in series to shut down supply fan, sound alarm, etc., as shown on Drawings.

K. High Temperature Safety Thermostat: high temperature thermostats shall have bi-metal type sensing element with at least 10” insertion length. Thermostats shall be two-position manual reset.

L. Dampers:
1. Furnish single or multiple blade automatic dampers for installation under Ductwork Paragraph as required.
2. Damper frames shall be constructed of 13 gauge galvanized sheet metal and shall have flanges for duct mounting.
3. Damper blades shall not exceed 6” in width. Blades shall be two sheets corrugated of 22 gauge galvanized sheet steel, spot welded together. Blades shall be suitable for high velocity performance.
4. Damper bearings shall be nylon. Bushings that turn in bearings shall be oil impregnated sintered metal.
5. Provide replaceable butyl rubber seals with damper on top, bottom and sides of frame and along each blade edge. Seals shall provide tight closing, low leakage damper. Submit leakage and flow characteristic charts for approval. 48” x 48” damper section shall have leakage less than 7 cfm/sf at 4” WG differential pressure. Dampers shall be Honeywell D643, Johnson D1300, Arrow AFD-20, Vent Products 5900, or Ruskin CD50.

M. Damper Operators:
1. Operators shall operate in sequence when required. Operators shall have external adjustable stops to limit stroke in both directions. Linkage arrangement shall permit normally open or normally closed damper positions.
2. Damper operators on modulating dampers shall have pilot positioners with inter-connecting linkage to provide accurate positioning and control. Valve and damper actuators shall be modulating sealed electro-hydraulic or pneumatic with spring return. Ambient temperature range shall be -40ºF to 150ºF.

N. Local Control Panels:
1. Controllers, relays, switches, etc. shall be mounted on enclosed control panels with hinged locking type doors mounted adjacent to system controlled. Temperature settings, adjustments and
calibrations shall be made at system control panel. Panel shall have canopy light and on-off switch.

2. Provide remote transmission thermometers on local panels. Temperature indications shall be provided for each point of temperature measurement for control and, additionally, for those points outlined in this Section or shown on Drawings.

3. Details of each panel shall be submitted for approval prior to fabrication. Locations of each panel shall be convenient for adjustment and service. Provide engraved nameplates beneath each panel mounted control device. Manual switches, dial thermometers and indicating gauges shall be flush mounted on hinged door.

4. Electrical devices within panels shall be factory pre-wired to numbered terminal strip. Wiring within panel shall be in accordance with NEMA and UL standards.

O. Miscellaneous Devices: Provide relays, positioners, electric switches, clocks, transformers, etc. necessary to make complete and operable system. Locate these devices on local panel unless specified otherwise.

Time clocks shall be seven day program type with ten hour spring reserve and manual override.

P. Thermometers
1. Thermometers shall be industrial type with 9 inch scale, red perma-colored liquid, black scale divisions on white background, union hub, separable brass well and adjustable swivel base. Extension wells shall be provided on insulated lines.

2. Thermometer ranges shall be 0-100°F for the heat pump loop system 0-250°F for the heating water system.

Q. Smoke Detection and Dampers in Air Handling Units.
1. Install duct smoke detectors furnished under electrical section where shown on Drawings. Wire to fan shutdown. Wiring to fire alarm system shall be part of work of electrical section.

2. Provide normally closed smoke dampers in return and supply air ducts to close automatically upon fan shutdown due to fire or smoke detection or upon manual shutdown.

3. Smoke dampers shall be controlled so that fans shall not start until dampers are open and fans shall stop before smoke dampers are fully closed. End switches, damper switches, and other components required shall be by temperature control manufacturer.

PART 3 - EXECUTION

3.1 WORKMANSHIP
A. All work shall be coordinated with the work to be installed by other sections of these specifications.
B. All work shall be executed in a workmanlike manner by workmen skilled in this type of work and shall present a neat appearance when completed.
C. All duct supports, structural members, hangers and other apparatus necessary to support firmly and substantially the various components of the systems shall be provided under this section.
D. Nameplates, catalog numbers, and rating identifications shall be securely attached to equipment.
E. The work shall be performed in a timely manner so as to cause no delay in the overall job progress. The Contractor shall cooperate with the other trades so that the work is installed in the most beneficial sequence for expeditious project completion.

3.2 CLEANING OF SYSTEMS AND PREMISES

A. Before the systems are tested and balanced, all ducts serving the area under construction shall be cleaned so that no dirt, dust or other foreign matter will be carried through or deposited in the systems or the space served by the duct systems.
B. At all times keep the premises clear of rubbish.
C. Upon completion of the work in an area, remove all debris and rubbish resulting from the execution of this contract, and dispose of same. At anytime should the General Contractor be dissatisfied with the performance of the HVAC Contractor's clean up responsibilities, he may elect after notifying the HVAC Contractor to undertake this operation and to backcharge the HVAC Contractor accordingly.

3.3 HVAC CONTRACTOR'S WARRANTY
A. The HVAC Contractor shall provide a one year warranty against failure of the installed materials for any reason. The warranty shall cover the full costs of parts and labor required to remedy the defect, including, if necessary, replacement at the site, and shall run from the date of the Architect's acceptance of the system. The warranty shall also include provision for field inspection at no charge to the Owner, to verify failure, establish probable cause, and determine corrective action required. The HVAC Contractor shall furnish all service during the first year of operation. Any material that in the opinion of the architect, requires
excessive service during the first year of operation shall be considered defective and will be replaced by the HVAC Contractor at no charge to the Owner.
B. The HVAC Contractor shall provide a listing of all manufacturers’ commercial warranties provided by those manufacturers on their materials. The list of these warranties must include the time period of each warranty. One copy each of those warranties shall be submitted with the listing.
C. The HVAC Contractor shall be responsible for warranting the testing, adjusting and balancing work for a period of one year after final date of completion. The HVAC Contractor shall also be responsible for all damage to existing systems as a result of the work performed. All damaged systems shall be repaired or replaced at the option of the Owner at no additional cost to the Owner. All such repair or replacement work shall be done immediately upon finding.
D. Warranty response to any malfunction shall be on a next day, normal working hour basis.
E. Work under warranty shall be performed by fully qualified workmen and/or technicians.
F. All guarantees and warranties required to be provided for the work in this Section shall begin their term on the date of final written acceptance of the entire system by the Owner.
3.4 SUBMITTALS
A. The capacity of each HVAC unit shall be substantiated by computer generated selection data or other detailed selection data provided by the manufacturer, for the specific conditions defined on the drawings.
1. The selection data shall clearly show the entering and leaving fluid conditions, the fluid flow volume and the fluid pressure drop through the unit, the ambient conditions, the heat rejection media entering and leaving conditions, the available external static pressure, the unit total static pressure, the airside pressure drops, the refrigerant and the saturated suction temperature, the required RPM of the unit, the motor horsepower, the motor voltage, the motor efficiency, the motor RPM, the motor type, the fuel efficiency, the fuel consumption rate, the maximum capacity, the part load performance data of the anticipated operation of the system, and the radiated sound ratings at design conditions as may be appropriate for any specific piece of equipment.

Renovations to Building 1 - Fitchburg, MA HVAC - 15600
Page 41 of 50
12/16/05
B. Contractor shall submit shop drawings indicating the method of supporting all units.
3.5 PERFORMANCE
A. The drawings are diagrammatic and the final arrangement of the work shall suit the existing and field conditions, the characteristics of the materials used and the instructions of the Engineer and/or the Architect.
B. The Contractor shall be responsible for repair of damaged or disturbed existing work or the work of other trades caused by his work, testing of his work or repair to his work.
C. All devices shall be installed in accordance with the manufacturer's recommendations, the Engineer's instructions and so as to provide all required access for cleaning, operation, repair and maintenance.
3.6 START UP
A. All equipment, systems, controls and units shall be started as part of a heating, ventilating and air conditioning system, in accordance with all manufacturers recommendations.
3.7 CENTRIFUGAL FANS
A. Duct connections to centrifugal fans shall be via flexible connectors.
3.8 FILTERS
A. Replace filters in all make up air units with FARR 30/30 filters prior to start-up, testing, adjusting and balancing.
B. Provide one additional set of replacement 30/30 filters to the owner upon final acceptance of the installation.
3.9 RECTANGULAR DUCTS
A. General
1. All ductwork shall be installed in accordance with the best trade practices and SMACNA standards shall be the minimum requirements.
2. The Contractor shall follow the application recommendations of the manufacturer of all hardware and accessory items and make selections of such consistent with the duct classification and services.
B. Sealing
1. All ductwork shall be sealed in accordance with the following table:
SEALING REQUIRED
SMACNA
STATIC PRESSURE
CONSTRUCTION CLASS
A All transverse joints
All longitudinal seams
All duct wall penetrations
4" W.G. and up
B All transverse joints
All longitudinal seams
3" W.G.
C All transverse joints 2" W.G. and down
2. For the purposes of these specifications sealing shall mean the following:
   a. The use of adhesives, gaskets, liquids, mastics, hot melt sealant, pressure sensitive tape or
      combinations thereof to close openings in the surface of the ductwork and field erected
      plenums and casings through which air leakage would occur.
   b. The requirements to seal apply to both positive and negative pressure modes.
3. Pressure sensitive tape shall only be acceptable for sealing ductwork which operates at a static
   pressure of ½" or less.
4. Liquid sealant shall only be acceptable for slip joints where metal clearances do not exceed 1/16".
5. Gaskets shall be used for all flanged connections and shall have an adhesive backing to adhere to
   the flange during assembly of the joint.
C. Reinforcement
1. Unless specified otherwise on the drawings rectangular ductwork shall be constructed and
   reinforced per the following "Rectangular Duct Reinforcement" tables, where the duct wall
   thickness, the reinforcement spacing and the rigidity class are specified by duct size and pressure
   classification. Rigidity class designations are based on the SMACNA standards for "Intermediate
   Reinforcement" and "Transverse Joint Reinforcement" as published in the SMACNA "HVAC
   DUCT CONSTRUCTION STANDARDS - Metal and Flexible".
2. Duct sides that are 19” and over and are 20 gauge or less with more than 10 square feet of
   unbraced panel shall be cross broken or beaded unless they are lined or externally insulated.
3. Fittings shall be reinforced similarly to sections of straight duct. On size change fittings the
   greater fitting dimension determines the duct gauge. Where fitting curvature or internal members
   provide equivalent rigidity, such features may be credited as reinforcement.
4. The duct side with the largest dimension shall determine the duct gauge.
5. Holes made in the duct walls for the passage of tie rods shall be of minimum size and shall be
   sealed in accordance with the required duct seal classification.
6. Where used tie rods shall be evenly spaced in the width of the duct dimension.
D. Transverse Joints
1. Transverse joints shall be selected and used consistent with the static pressure class, sealing
   requirements and duct support intervals for proper assembly.
2. Where bar or angle stock is incorporated in a joint it shall be secured.
3. Fasteners shall be steel and may be zinc or cadmium coated. They shall not project into duct more
   than ½”.
4. Where bolts or welds are specified other types of fasteners shall not be used.
E. Seams
1. Seams shall be suitably selected for the material and pressure classification of the duct.
2. Seams shall be formed and assembled with proper dimension and proportion for tight and secure
   fit.
3.10 ROUND DUCTS
Renovations to Building 1 - Fitchburg, MA HVAC - 15600
Page 43 of 50
12/16/05
A. General
1. All ductwork shall be installed in accordance with the best trade practices and SMACNA
   standards shall be the minimum requirements.
2. The Contractor shall follow the application recommendations of the manufacturer of all hardware
   and accessory items and make selections of such consistent with the duct classification and
   services.
B. Duct Gauge
1. Round ducts shall be constructed of the galvanized steel with duct walls in accordance with
3.11 FLEXIBLE DUCTS
A. Use
1. All flexible duct used on the supply air system shall be insulated with 1 1/2" thick vinyl jacketed fiberglass insulation.
B. Length
1. The minimum length of flexible duct shall be used.
2. The maximum length of flexible duct in any single duct run shall be four feet.
C. Bends
1. Bends shall be made with not less than one and one half duct diameter centerline radius.
2. Maximum bend shall be 90°.
D. Fastening
1. Secure flexible duct to collar or sleeve by peeling back jacket and insulation at end of flexible duct. Fit duct over collar or sleeve and clamp with ½" wide galvanized steel or stainless steel bands or clamps and matching seals. Pull jacket and insulation back in place and secure with two wraps of pressure sensitive sealing tape. Clamping device shall be two inches back from end of flexible duct. Seal with two wraps of duct tape.
E. Installation
1. Flexible duct is to be installed as straight as possible and as tight as possible.
2. Submittals shall include product data sheets as well as the manufacturer’s recommended installation practices.

3.12 SUSPENSION OF DUCTWORK
A. Rigid round and rectangular ducts shall be installed with support systems as required to maintain alignment. Horizontal ducts shall have a support within two feet of each elbow and within four feet of each branch intersection.
B. Strap hangers on rectangular ducts may be used on ducts less than 60" wide if they are secured to the bottom of the duct with an approved fastener and with a minimum 1" tab below the duct, or with no fasteners if the strap is a single continuous loop.
C. Multiple trapeze hangers may be suspended from rod hangers to support ducts directly above and below each other if the rods are sized to support the combined load.
D. Round ducts less than 10" in diameter may be suspended by wire.
E. All hangers and trapezes shall be sized, spaced and selected in accordance with Section IV of SMACNA "HVAC DUCT CONSTRUCTION STANDARDS".

3.13 MISCELLANEOUS DUCT WORK REQUIREMENTS
A. Ductwork connected to intake or discharge louvers shall be painted inside for the first ten feet with bitumastic and pitched to a low point. The low point is to be provided with a 1 1/2" copper drain piped by this trade to a building drain.
B. A gasket type joint shall be used where dissimilar metals are joined.

3.14 RECTANGULAR DUCT FITTINGS
A. General
1. All ductwork shall be installed in accordance with the best trade practices and SMACNA standards shall be the minimum requirements.
2. The Contractor shall follow the application recommendations of the manufacturer of all hardware and accessory items and make selections of such consistent with the duct classification and services.

3.15 ROUND DUCT FITTINGS
A. Elbows larger than 8" shall be five piece welded construction.
B. Branch and take-off fittings shall be conical tee or conical reducing tee fittings.
C. Final connections to the individual terminal supply units shall be by means of flexible duct.

3.16 PIPE HANGERS, SUPPORTS, ANCHORS AND GUIDES
A. Contractor shall submit shop drawings indicating the method of supporting all piping furnished by this trade.
B. The Structural Engineer or Architect must approve the method of hanging before work is commenced.
C. Shop drawings of anchors shall be submitted before work is commenced.
D. Shop drawings of guides shall be submitted before work is commenced.
E. Sleeves of the specified type shall be installed wherever pipe lines penetrate walls, roofs, floors or partitions.
F. Sleeves shall be installed in accordance with the requirements of NFPA and BOCA Building Code.

3.17 VALVE TAGS
A. Valve tag scheme shall be approved by the Engineer prior to installation in the field and insertion on the record drawings.

B. Contractor shall provide a valve tag chart and clearly label the valve tags on the record drawings. The valve chart shall include but not be limited to: tag #, location, valve type, size, how valve operates (solenoid, modulating, manual).

C. Valve tags shall be securely fastened to the valve handle by heavy aluminum or brass hooks or chain.

3.18 VIBRATION ISOLATION

A. All equipment, piping, etc. shall be mounted on or suspended from approved foundations and supports, as specified herein or as shown on the drawings.

B. Mounting sizes shall be determined by the mounting manufacturer and the mountings shall be installed in accordance with the manufacturer’s recommendations. The Contractor shall be responsible for the adequacy of the mountings to provide the minimum isolation efficiency required by these specifications or as specifically noted on the drawings.

C. Suspended centrifugal fans shall be installed on vibration isolation hangers.

3.19 PIPING SYSTEM INSTALLATION AND ASSEMBLY

A. All piping shall be installed at right angles to building surfaces, supports and structures.

B. Pipe welding shall be performed by a certified welder with oxy-acetylene or electric arc in accordance with the latest revision of the applicable code, ASME Boiler Construction Code, ASA Code for Pressure Piping, or state and/or local codes which may supersede codes mentioned.

C. Threaded joints shall be made with Teflon tape only applied to male threads and care being taken to insure that the tape does not reach the interior of the pipe. All burrs and/or cuttings shall be removed and the pipe shall be reamed or filed out to not less than the original diameter. Piping shall be kept free from scale and dirt.

D. All pipe shall be straight, true and round without obstructions and with sharp, full cut threads or with ends beveled for welding.

E. Provide drain valves with hose connections at all low points and at the bottoms of all risers to allow for complete drainage of the system.

F. All openings shall be capped or plugged during construction to prevent dirt and/or rubbish from entering the piping.

G. Unions or flanged connections shall be placed wherever necessary to permit easy dismantling of the piping and equipment.

H. Where possible, piping shall be grouped together and supported in a neat and orderly manner.

I. Insulating bushings or dielectric nipples shall be provided between steel piping and copper piping on equipment.

J. Air vents shall be provided where indicated on the drawings and at all high points in the water systems.

K. Pipe must be supported before and after expansion compensation devices.

L. Mount all pressure gauges to be read from the floor.

M. Install pressure gauges on the suction and discharge of pumps.

N. Provide two spare pressure gauges of each pressure range and type.

O. Mount all thermometers to be read from the floor.

P. Install thermometers on the supply and return of the chilled water system.

Q. Provide two spare thermometers of each range and type.

3.20 FLUSHING OUT TREATMENT

A. After completion of the installation of the piping system and prior to the start up of the systems, the system shall be flushed out with chemicals.

B. The flush out compound shall be trisodium phosphate, three percent by weight.

C. Flush out recirculation shall be for a period of not less than 48 hours.

D. Tests shall be performed following the chemical flushing out and a report shall be issued in writing to the Architect, stating that the cleaning and flushing has been completed satisfactorily.

E. Allowable chemical concentrations after flushing out shall be phosphate - zero, alkalinity - 100 parts per million maximum, suspended solids - zero.

3.21 BALANCING DAMPERS

A. Balancing dampers shall be located as shown on the drawings and in the following locations as a minimum:

1. All supply and return air branches from the trunks and all sub-branches from the mains shall have
balancing dampers.

2. Branch duct connections from low pressure ducts to diffusers shall be made with dampered spin collars.

B. Locate dampers as far as possible from air outlets.

3.22 CONTROLS

A. The control systems shall be installed by trained workmen or technicians, specially trained to install control equipment.

B. The controls shall be installed in accordance with the concepts illustrated on the contract drawings and in accordance with the sequences of control in the specifications.

C. The Contractor shall provide 8 hours of operating instruction to the owner's personnel in the operation and maintenance of the control systems.

3.23 FINAL ACCEPTANCE

Renovations to Building 1 - Fitchburg, MA HVAC - 15600

A. The Contractor shall leave all system components in proper working order, such as belt guards in place, access doors closed, doors to electrical switch boxes closed, thermostats restored to specified setting. All recorded data shall represent a true, actually measured, or observed condition. Any abnormal conditions in the mechanical systems or conditions which prevent total system balance, shall be reported to the Architect immediately upon finding. The Contractor shall permanently mark all dampers and other adjustment devices in a manner that will allow the settings to be restored.

B. The Contractor shall verify control system operation as specified, and shall report all system problems and malfunctions. The verification and checkout of the control system shall be accomplished during the heating and cooling cycles of operation for an appropriate period of time to assure control response and overall stability.

C. The Contractor shall verify that all air systems are in compliance with all standards, such as ASHRAE minimum outside air, and all other applicable codes and requirements.

D. All filters shall be replaced by the Contractor before commencing.

E. The Contractor shall make any necessary changes in fan speed, and shall realign all belts when necessary.

3.24 FIRE DAMPERS

A. Fire dampers shall be installed in accordance with UL rating requirements where required. The HVAC contractor shall provide a gypsum board sheath and/or metal sleeve for the fire damper opening.

3.25 AIR AND WATER BALANCING

A. The HVAC Subcontractor shall employ an independent Balancing subcontractor, acceptable to and approved by the Architect/Engineer, to balance and adjust the air and water systems.

B. Balancing and adjusting shall not begin until all HVAC systems have been installed and are in full working order. Prior to the start of balancing, the following shall be checked:

1. Rotation of all fans and pumps.
2. Dampers are free to open and close
3. Fire and smoke dampers are open.
4. Clean filters are in place.

C. Upon completion of balancing and adjusting of the systems hereinafter specified, submit six (6) copies of the data for review and approval by the Architect/Engineer.

D. The balancing Subcontractor shall be procured early enough in the project to allow for him/her to review the project documents and determine if sufficient components are in place to balance and adjust the systems. The balancing subcontract shall provide a list of any deficient are he/she identifies.

E. Balancing Subcontractor shall provide all testing instruments, manpower, temporarily connections and materials needed for balancing and adjusting of the air and water systems. All test instruments should have been calibrated within the last six (6) months. Balancing Subcontractor shall provide verification of calibration upon request.

F. Architect/Engineer and Owner shall be notified a minimum of five (5) days prior to balancing commencing so that a representative can be available to witness the balancing work. In addition, the Balancing Subcontractor shall (upon completion of the balancing work and report submittal), at the request of the Architect/Engineer or Owner's representative, verify the balancing readings at four (4) locations. The locations shall be chosen by the Architect/Engineer or Owner's representative.

G. All balancing and adjusting of air and water systems shall be done in accordance without the latest edition of the NEBB procedural Standards for Testing, Adjusting and Balancing of Environmental systems or the latest edition of SMACNA's HVAC Systems Testing, Adjusting and Balancing.
H. Balancing of the cooling systems shall be performed in the air conditioning season, heating systems in the heating season.

I. Prior to balancing of the air and water systems, and as part of the balancing report, the Balancing subcontractor shall prepare ductwork and piping schematics of the systems to be balanced. Schematics shall be similar to those indicated in the NEBB and SMACNA publications previously identified. Piping schematics shall be of similar content to ductwork schematics.

J. Air and Water Balancing Report forms shall be similar to the standard NEBB and SMACNA forms found in the previously identified manuals. The following information shall be provided at minimum (reports for equipment and systems not indicated shall be obtained from the NEBB/SMACNA manuals or prepared by the Balancing Subcontractor. Reports prepared by the Balancing Subcontractor shall be submitted for review and approval prior to final Balancing Report submittal):

1. Air Apparatus Test Report
   a. Location.
   b. System Number.
   c. Manufacturer.
   d. Airflow, design and actual.
   e. Total CFM.
   f. Total Static pressure.
   g. Discharge Static Pressure.
   h. Suction Static Pressure.
   i. Coil pressure drops (static pressure).
   j. Filter pressure drops.
   k. Motor volts and amps.
   l. Outside Air and Return Air CFM.
   m. Drive data.

2. Coil Test Report
   a. System Number.
   b. Location.
   c. Manufacturer.
   d. Airflow, design and actual.
   e. Entering air temperature (DW/WB), design and actual.
   f. Leaving air temperature (DW/WB), design and actual.
   g. Water flow GPM, design and actual.
   h. Entering water temperature, design and actual.
   i. Leaving water temperature, design and actual.
   j. Waterside pressure drop.
   k. Airside pressure drop.

3. Fan Test Report
   a. System Number.
   b. Location.
   c. Manufacturer.
   d. Airflow, design and actual.
   e. Total static pressure, design and actual.
   f. Inlet static pressure.
   g. Discharge static pressure.
   h. Motor and Drive data.
   i. Fan RPM.
   j. Voltage and Amperage.

4. Duct Traverse
   a. System zone/branch.
   b. Duct Size.
   c. Area.
   d. Design Velocity.
   e. Design Airflow.
   f. Test Velocity.
   g. Test Airflow.
   h. Duct Static Pressure.
   i. Air temperature.
5. Air Outlet Report
   a. Area Served.
   b. Outlet Number.
   c. Type.
   d. Size.
   e. AK factor.
   f. Velocity, design and actual.
   g. Airflow, design and actual.
6. Pump Test Report
   a. Unit Number.
   b. Manufacturer.
   c. Motor data.
   d. Voltage and amperage data.
   e. Waterflow, design and actual.
   f. Suction Pressure.
   g. Discharge Pressure.
   h. Total Head Pressure
K. The Balancing Subcontractor shall balance and adjust air and water systems to meet design requirements. ± 5%. Balancing shall be accomplished by adjusting dampers, drives, valves, etc. to obtain design requirements.
L. The HVAC subcontractor shall cooperate and make provisions for the Balancing Subcontractor as needed to accommodate the air and water balancing. As part of this Contract, the HVAC Subcontractor shall provide and/or change pulleys, belts, sheaves, valves and dampers, at no additional cost, in order to properly balance the systems to design requirements.
3.26 START UP AND TESTING OF COOLING EQUIPMENT
A. All cooling equipment shall be tested to verify that the equipment operates mechanically and electrically as specified.
B. The Contractor shall verify that all operating and safety controls are correctly adjusted.
C. The Contractor shall verify that the cooling equipment controls are operating properly.
D. Tests shall be made to verify that the capacity control is fully modulating according to the required load, and that all control valves are operating according to the specifications. Tests shall be made at minimum load, 50% load, 100% load and various other loads throughout the modulating cycle.
E. The Contractor shall record the following non-test data:
   1. Equipment designation number.
   2. Equipment manufacturer.
   3. Model number.
   4. Serial number.
   5. Rated input.
   6. Rated output.
   7. All other pertinent data.
F. The Contractor shall perform and record the following to meet minimum requirements:
   1. Verify proper system operation.
   2. Verify that the cooling system controls are operating according to design specifications.
   3. All other measurements required for complete system testing.
G. The Contractor shall calculate the system coefficient of performance as measured. All calculations made using the measured data shall be included in the report. In general, the Contractor shall complete all tests necessary for complete cooling system analysis.
3.27 DUCT INSULATION - DUCT WRAP
A. All work shall be in strict accordance with applicable codes and ordinances and the manufacturer’s recommendations.
B. All completed work shall be smooth in appearance.
C. Seams shall be stapled 6” on center with outward clinching staples and sealed with pressure sensitive aluminum foil tape.
D. All seams, joints punctures and tears shall be sealed with pressure sensitive aluminum, foil tape.
E. All ductwork for outdoor air intakes into the ERV units and air conditioning supply ductwork shall be insulated.
3.28 SEQUENCES OF OPERATION
END OF SECTION