# Residential New Construction Mechanical Systems Design Submittal Guide

**City of Fort Collins Building Code**

**Updated November 1, 2016**

**City of Fort Collins Building Services**
**Fort Collins Utilities**

## *What This Guide Is . . . and Is Not*

This guide will help you successfully complete the City of Fort Collins "Residential Mechanical Systems Design Submittal."

This guide includes references to publications from Air Conditioning Contractors of America (ACCA) and provides reminder/tips regarding code requirements and steps in the design process. It is intended to reinforce what was covered in City-sponsored contractor trainings 2011, 2012 and 2013. Useful companions to this guide are the training slide sets and the 2011/2012 training handout ("Residential Mechanical Systems Design" class), available by contacting Brad Smith or Kim DeVoe at Fort Collins Utilities (contact information below). When consulting those resources, be aware that a few code details have changed (next paragraph).

This guide has been updated to reflect common problems observed in past submittals, resultant changes made to the submittal requirements in March 2013 and small changes in code requirements with the City's adoption of the 2012 I-Codes in 2014.

Many tips have been included to help you check your own results. See references regarding available tools that help in this regard.

This guide does not include all the details you need to know to correctly design heating, cooling and ventilation systems or how to specify combustion appliance solutions that operate safely. For those details you must consult the referenced procedures, seek specialized training in each of them and become familiar with specific equipment and procedures from manufacturers and software companies with whom you are affiliated.

Some sections of this guide, such as "Heating and Cooling Equipment Selection," have been fully developed only for forced-air heating and cooling using gas-fired furnaces and split-system air conditioning sharing the furnace air handler and ductwork. Other sections apply to all buildings and systems. Specifics regarding applicability are described in some sections.

This guide does not include reminder information regarding every aspect of the code. Be familiar with Fort Collins building code language and, when in doubt, ask Building Services.

This guide is a working document that will be updated as experience continues to be gained with the code's HVAC design requirements. Users are encouraged to direct questions and provide suggestions for improvement to:

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# *Contents*

# 1.0 Code Mechanical Systems Design Requirements

Specific code references are provided in sections that follow. All code references are to 2012 International Codes as amended by City of Fort Collins. The Fort Collins Building Code addresses mechanical systems design in much the same way that the model codes do. The IRC and IECC require local exhaust ventilation, whole-house ventilation and ACCA procedures for heating and cooling system design steps: load calculation (Manual J), equipment selection (Manual S) and duct design (Manual D). A local amendment requires clear documentation of the HVAC design. This documentation conveys the specifics of the design, including the targets referenced when the installed performance of systems is tested, another requirement of the Fort Collins code (IRC M1309). Testing results provide invaluable feedback regarding system design and installation.

## 1.1 Basic Information Needed for Design

You can only do your job with access to accurate building information. The plan set must contain all relevant construction data and specifications. These include, for example, square footages, ceiling heights, component R-values and U-Factors. Accurate data for windows – U-Factor, SHGC, area, orientation and shading – are critical. You must verify that all this information has been provided; certain parts of the design cannot be completed without it. Contact the builder regarding missing data. Do not make assumptions.

## 1.2 Submittal Package

Building Services requires a submittal consisting of:
- "Residential Mechanical Systems Design Submittal," fully completed and signed by the person responsible for the design.
- All applicable attachments referenced in this form.

This submittal package is due with the rest of a residential building permit application. Review of the permit application will not be completed if required mechanical systems design information is missing.

This guide references the related sections on the submittal form.

## 1.3 Project Information  (page 1 of submittal form)

This section of the form helps to ensure that everyone understands specifically which building you are designing for. Orientation, foundation choices, changes in square footage of floor area (bonus rooms, for example) and windows can have a big impact on design loads, equipment size and duct design. Document the building you are modeling here. Your design will be approved for the modeled options; for other combinations you may be required to submit additional designs.

You must also document your source of information for energy specifications.

## 1.4 Designer  (page 1 of submittal form)

This signature section of the form is self-explanatory. Currently, Building Services requires no specific qualifications regarding who may design HVAC systems and submit this documentation. The City will be monitoring the quality of submittals.

## 2.0 *Local Exhaust – Bath Fans*  *(page 1 of submittal form)*

### 2.1 Code Reference
- IRC R303 (amended), M1507.4 (amended)
- IRC M1501.2 (amended), G2447.6 (amended) – Indoor depressurization

### 2.2 Code + Submittal Reminders

- Bath exhaust
  - Bath fans vented to outdoors required in these locations
    ° Bathrooms (a fan is not required in a bathroom with operable window; however it is strongly recommended as moisture problems are most likely in cold weather when occupants are least likely to open the window for ventilation)
    ° Toilet rooms (a master bath with water closet requires one vented fan in either the water closet or the rest of the bathroom)
    ° Powder rooms
    ° (Exhaust fan <u>not</u> required for laundry room)
  - Minimum flow for code-required fans: 50 cfm for intermittent operation or 20 cfm for continuously operating fans. (No minimum flow requirement for other fans.)
  - Backdraft damper required

- Bath fan airflow. The installed fan airflow will be tested and must meet the minimum code requirement. Pay attention to the OEM pressure/flow data and be realistic about the pressure drop the fan will work against. Most bath fan nominal airflow ratings are based on 0.10 IWC static pressure, an unrealistically low number. Pay attention to ducting details to reduce static pressure and increase flow.

- Bath fans also providing whole-house ventilation.
  - Specify that this fan is doing double duty in the "Control and Other Notes" column.
  - Noise limit = 1.5 sone unless it qualifies for an exception.
  - Typically the fan will operate at lower speed for many hours to provide whole-house ventilation, then be intermittently boosted to higher speed for local exhaust. Describe the control strategy in this section of the form or refer to the description in the "Whole-House Ventilation" section.

- Depressurization. Exhaust systems shall not create negative pressure that induces backdrafting of natural-draft combustion appliances or exceeds 3 Pascals in the immediate vicinity of those appliances.
  - This requirement is not relevant if there are no natural-draft combustion appliances.
  - Natural-draft appliances located in an isolated mechanical room meeting the requirements of IRC G2406.2 address this requirement as well.
  - This provision is most likely applicable when a natural draft fireplace is installed

## 3.0 *Whole-House Ventilation*  *(page 2 of submittal form)*

### 3.1 Code Reference
- IRC M1507.3 (amended),

### 3.2 Code + Submittal Reminders

- Airflow rate
  - <u>Minimum</u> airflow requirement (cfm) is based on the "Dwelling Unit Floor Area," number of bedrooms and system operation (continuous versus intermittent), as specified in M1507.3.3.
  - "Dwelling Unit Floor Area" = floor area of conditioned space, including unfinished basement floor area within the thermal envelope.
  - Only finished bedrooms must be counted for the code-minimum airflow requirement.
  - The minimum <u>continuous</u> ventilation rate comes from either of two sources:
    - ° The value from Table M1507.3.3(1)
    - ° An equation:
      Minimum continuous airflow (cfm) = 0.01 x (Conditioned floor area) + 7.5 x (# People +1)
    (The equation will generally yield a lower airflow requirement than the table.)
  - If the ventilation system is designed to operate intermittently, increase the minimum airflow by multiplying by the appropriate factor in Table M1507.3.3(2).
  - <u>Design</u> airflow may exceed the code-minimum requirement. You're encouraged to take into consideration bedrooms that may be added in an unfinished basement.

- System type. The code requirement may be met with exhaust, supply or balanced systems.
  - An exhaust fan can be used to meet both a local exhaust requirement and the whole-house ventilation requirement.
  - Airflow requirement may be met, in part or in full, with continuously operating deep crawl space exhaust ventilation that draws conditioned air from the house.
  - Outdoor air duct connected to the return duct of a forced-air furnace can be used to meet the flow requirement, provided dampering requirements and manufacturer's requirements for minimum return air temperature to the furnace heat exchanger are met. See "Efficient fan motor" below.

- Depressurization. Exhaust systems shall not create negative pressure that induces backdrafting of natural-draft combustion appliances or exceeds 3 Pascals in the immediate vicinity of those appliances. See Section 2.2 for more details.

- Dampers
  - Outdoor air intakes shall have automatic dampers that close when the system is not operating.
  - Exhausts shall have gravity dampers that close when the ventilation system is not operating.

- Efficient fan motor. Ventilation circulation fans of ¼ HP or greater must use brushless DC motors or equivalent (e.g. ECM).

- Sound rating. Whole-dwelling unit ventilation fans shall have a maximum sound rating of 1.5 sone. Read the code language for exceptions.

- Controls
  - System must include readily accessible and labeled controls that enable occupant override.
  - Describe control strategy. Be clear about control for fans doing double-duty for whole-house and local exhaust.

- The system must provide the capacity to provide the code-minimum airflow rate. It is up to the occupant to control the operation per their needs. Educate the homeowner.

- System description. For simple, exhaust-only systems, fill in the blanks on the form with required information and attach a spec sheet for the fan. For other system types, provide narrative and/or plans with sufficient detail for installer, field inspector and mechanical systems testing contractor; also attach a spec sheet for each piece of equipment.

## 4.0 *Heating + Cooling Design Loads*   *(page 2 of submittal form)*

### 4.1 Code Reference
- IRC Table N1101.1
- IRC M1401.3 (amended)
- IECC 403.6 (amended)

### 4.2 Approved Design Procedure and Software Tools
- ACCA Manual J: Residential Load Calculation, Eighth Edition (Manual J8)
- ACCA-Approved Manual J8 software (see current list at https://www.acca.org/industry/system-design/software). Manual load calculations are not accepted.

### 4.3 Procedure Reminders and Constraints
The following information provides guidance on how many load calculation inputs must be handled for the purposes of Fort Collins building code. The handout from the "Residential Mechanical Systems Design" class is another useful reference in this regard. Refer to Manual J8 for the complete procedure.

- Design conditions. Most of what you need is included in IRC Table N1101.1. These are repeated in the following table with supplemental data. If you choose values other than those in this table, call them out on the submittal form and be prepared to justify your choices.

| Fort Collins Design Conditions – Outdoor and Indoor | | |
| --- | --- | --- |
| Parameter | Winter | Summer |
| Outdoor dry bulb temp | 6 F | 90 F<br>Daily range = High |
| Daily range | N/A | High |
| Outdoor moisture<br>  Relative humidity<br>  Wet-bulb temp<br>  Humidity ratio | <br>70%<br>3 F<br>6 grains moisture / lb dry air | <br>23%<br>62 F<br>57 grains moisture / lb dry air |
| Indoor dry bulb temp | 72 | 75F |
| Indoor moisture<br>  Relative humidity<br>  Wet-bulb temp<br>  Humidity ratio | <br>30%<br>53 F<br>42 grains moisture / lb dry air | <br>50%<br>62 F<br>78 grains moisture / lb dry air |
| Moisture difference | 36 grains moisture / lb dry air | -21 grains moisture / lb dry air |
| Wind speed | 15 mph | 7.5 mph |

- – Outdoor conditions are not intended to represent the most extreme conditions encountered each year. They are based on analysis of Fort Collins long-term weather records and represent statistically valid design conditions per ACCA Manual J8 procedures.
  - – Select Fort Collins as the location; override default weather conditions in the software as needed to match the design data in the table above.

- Building geometry
  - – Check to be sure the information about options provided in the "Project Information" section is accurate for the building for which you're modeling heat loss and gain. These calculations may not be appropriate for other configurations of this plan. Cooling load differences of 6,000 Btuh or greater, for different options, trigger a requirement for more than one design.
  - – The commonly used software packages provide the option to either draw the building with a built in CAD program or to enter takeoff data manually using a worksheet approach. It is

strongly recommended that you use the CAD drawing approach to reduce the chances of careless mistakes in the building size and shape.
  − Check area takeoffs against the plans to be sure that they are reasonable (Section 4.4).

- Attached garage. Manual J8 and the software packages allow you to account for the buffering effect of an attached garage. Several parameters must be handled correctly to use this feature. However, because the surfaces adjoining the garage are typically well-insulated (R-15 and higher for walls, R-30 and higher for frame floors above), the impact of the garage on design loads is generally very small. To keep it simple and reduce errors, you are advised to ignore the garage and treat surfaces adjacent to the garage as if they are exterior components.

- Crawl space. Virtually all modern crawl spaces are built as "conditioned:" exterior walls are insulated, the floor above is not, no ventilation to outside, crawl space temperature is close to the house temperature (even if minimal conditioning is provided). Software packages allow you to model crawl spaces in different ways. The recommendation is to model crawl spaces as conditioned, specifying areas and construction types for the crawl space walls and floor.

- Knee walls to attic space. These walls can have significant loads due to the wide attic temperature variation. Whether you need to account for knee walls depends on their dimensions. Small knee walls (e.g. rooms with a ceiling 1' taller than adjoining rooms, rooms with slightly vaulted ceilings) can be ignored. However it is very important to accurately account for knee walls that add significant area. Learn how to model knee walls in the software package you use.

- Windows. Because windows are often responsible for half of the cooling load and a significant portion of the heating load, it is critical to accurately model them. Doublecheck and accurately enter window area, orientation, U-Factor and SHGC. Document window information on the submittal form. Note any unusual windows there.

  Regarding window shading:
  − Exterior architectural overhangs must be accounted for in the model.
  − Windows set in below-grade window wells must be treated as shaded. For a reasonable approximation, set an overhang projection at 2' and vertical gap between top of window and projection at 0'.
  − Insect screens. Model bug screens on operable windows: exterior, 50% coverage on sliders and single-hung windows; interior, 100% coverage on casement, awning and double-hung windows.
  − Interior window shading. You are not required to model interior shading. However people are sensible and will shade windows that overheat a room. The recommendation is to choose interior blinds, medium color, set at 45-degree angle, 100% coverage for all accessible windows.

- Other envelope components
  − All components must be modeled to match construction type, thermal parameters (R-value, U-value) and areas specified on construction plans. (Though the HVAC designer is not responsible for the energy code submittal, it is a good idea to review those reports for consistency with the HVAC model.)
  − Software packages allow custom construction assemblies to be defined. Though this provides flexibility, it can also create confusion due to multiple ways in which U-values are calculated and used within the software. For consistency, it is typically best to choose the closest pre-defined Manual J8 assembly rather than define a new one. For example, if the frame wall is specified with R-23 cavity insulation, you'll find there is no pre-defined R-23 assembly; choose either R-21 or R-25. Similarly, R-11 basement drape is best modeled as the predefined R-10 continuous insulation. These approximations will have very little impact on the design loads.
  − See the Section 4.4 reference to the "Common MJ8 U-Values" reference table.

- Ductwork. Ducts in unconditioned space can have very significant load impacts. Model them accurately.
  - Location: You must provide general information about duct locations on the submittal form. If ductwork in garages or adjacent to an exterior wall is handled in accordance with details approved by Building Services, model it as <u>inside</u> conditioned space.
  - Insulation: Code requires R-8 minimum for supply ducts, R-6 minimum for return ducts. Higher levels of insulation are strongly recommended, particularly for attic ductwork.
  - Leakage: Specify sealed ductwork.

- Infiltration
  - Code requires tight building shells; every building is tested to ensure compliance. The maximum allowed leakage rate in the code adopted in 2014 is even lower than that allowed in the prior code. Use <u>Manual J8</u>'s simplified infiltration approach. Specify "Tight" or "Semi-Tight" construction and let the software calculate the corresponding leakage rate.
  - Specify "0" fireplaces if direct-vent units are being used (typical). Count fireplaces only if natural-draft (e.g. B-vent) units are specified.

- Whole-house unit ventilation
  - Set central ventilation equal to the whole-house ventilation system design airflow rate (Section 3.2). Override the software default value. IMPORTANT: for systems designed to operate intermittently, enter the design flow rate averaged over four hours; i.e. divide the design flow rate by the factor in IRC Table 1507.3.3(2).
  - Regardless of whether the ventilation system is exhaust-only, supply-only or balanced, enter the ventilation airflow rate as if it were balanced; i.e. exhaust airflow = supply airflow.
  - Do not model local exhaust fan airflow; not likely to operate at time of peak heating or cooling.

- Humidification. Humidification loads can be automatically calculated by the software, if that option is selected. This accounts for the latent heat associated with the addition of moisture to reach the winter indoor design humidity level. Selecting this option increases the design heating load.

- Internal gains / people. Heat gain from people will increase the design cooling load.
  - # People is defined as # Bedrooms + 1. Be consistent with the number of bedrooms specified for whole-house ventilation (Section 3.2).
  - Occupants may be placed in any room as long as the total number is correct.
  - The typical per-person heat gain is 230 Btuh sensible, 200 Btuh latent. If you use different values, document your reasoning.

- Internal gains / lighting and appliances. These will increase the design cooling load.
  - Account only for gains likely to be generating heat during summer peak cooling conditions.
  - 1,200 Btuh is typical for kitchens. It is not unusual for there to be 1,000 Btuh in gains from other appliances (e.g. computers, entertainment and lighting). See <u>Manual J8</u> Tables 6A, 6B.
  - If you specify more than 3,000 Btuh in this category, document them on the submittal form.
  - 1 Btuh ~0.3 Watts, meaning 3,000 Btuh ~900 W.

- Adjustment factors. Both of the most commonly used software packages include default "adjustment factors" which attempt to help you size equipment. Unfortunately, these factors tend to add confusion between actual design loads and recommended equipment sizes. You are strongly encouraged to eliminate the confusion by setting these factors to 1.00:
  - Wrightsoft Right Suite Universal

- "Rate/swing multiplier." This factor, listed on the "Project Summary" report, defaults to 0.94. Set it to 1.00 through the Options menu by <u>un</u>checking "Adjust load for AHRI standard rating."
    - "SHR." This factor, listed on the "Project Summary" report, defaults to 0.70. Set it to 1.00 on the Zone Information screen.
  - Elite Software RHVAC
    - There are three elevation-related de-rating factors, listed on the "Project Report," that default to the following numbers for 5,000' elevation: "Elevation Sensible Adjustment Factor" = 0.860; "Elevation Total Adjustment Factor" = 0.973; "Elevation Heating Adjustment Factor" = 0.880. Set these to 1.000 in the "Elev. Derating" line in the Design Conditions tab under the General Project Data screen.
    - Note that the "Altitude Factor" = 0.832, also listed in the "Project Report," is correct and should be left as such. It is the ratio of air density at 5,000' to air density at sea level.

- Building orientation
  - Before running reports, be sure you've oriented the building as follows (report the orientation and corresponding cooling loads on the submittal form):
    - Site-specific permit applications: the <u>actual</u> building orientation
    - Stock plan permit applications: the <u>worst-case</u> orientation (highest cooling load)
  - <u>For all submittals</u>, you are required to calculate cooling loads for the full range of building orientation (this information is used for checking results; see Section 4.4). The commonly used software packages make this very easy to do. Make sure you understand the procedure and properly label the worst-case orientation.
  - For stock plans, if the range in total cooling load is equal to or greater than 6,000 Btuh, at least two designs will be needed; one AC size for orientations in the low end of the range, a larger size for elevations in the upper end of the range.

## 4.4 Checking Your Results

With the amount of data required to calculate design loads, coupled with defaults and other complexities of the software, there are many ways to make mistakes! <u>Don't accept results at face value without checking to be sure they are reasonably accurate.</u> Mistakes in load calculations can ripple through to cause even larger errors in the rest of the heating and cooling design. The following information will help you review and locate problems.

- Design load screening. For most new single-family detached homes built under the current Fort Collins code, you can use a simple spreadsheet tool to quickly check whether the design loads you calculated are reasonable. The tool is based on carefully calculated design loads for a sample of new homes representing a diverse range of sizes, foundations and number of stories. The spreadsheet ("Residential Design Load Screening") is available at no cost from Doug Swartz at Fort Collins Utilities (contact information p. 2).
  - Check house/plan against "Screening Tool Validity Checklist" in tool (tool will be valid for most new, SFD houses).
  - Data requirements are minimal:
    - Total "shell" area of the home (tools in the spreadsheet help calculate this; it is best to make this calculation based on the plans rather than from your load calculation reports)
    - Total window area
    - Duct losses and gains
    - Design loads: heating, sensible cooling (minimum and maximum over 360 degree rotation), latent cooling

- Follow other instructions in tool.
- The resulting plots will indicate whether the loads you calculated fall inside or outside expected ranges. Significant deviations suggest modeling problems.
- Note the magnitudes of the design loads – they remarkably low compared to what we've been used to in the past! This reflects much improved thermal shells in recent years.

- Inputs + outputs. Even if the whole-building load checked in the previous step falls within the expected range, it is smart to continue checking at the next level of detail to increase the chances that your input data and the software output data are reasonable.
  - Do the numbers make sense? The "Typical Input and Load Ranges" tab in the design load screening tool spreadsheet is a "crib sheet" that can be very helpful. It provides references against which you can check many inputs and outputs, along with guidance where to find the data in the software reports.
  - Are the building size and geometry reasonable? Double-check takeoff areas against the plans to be sure they're correct. If you have access to the energy code compliance reports (HERS or Rescheck reports), you can also cross-check to those.
    ° Caveat: energy reports may have errors, too!
    ° Caveat: <u>Manual J8</u> software reports NET wall areas = GROSS wall areas less window and door areas. In contrast, HERS software reports GROSS wall areas.
  - Have the building assembly thermal properties been correctly specified? Review the Wrightsoft Right Suite Universal "Component Constructions" report or the Elite Software RHVAC "Total Building Summary Loads" report. Do the descriptions make sense compared to what you know about the building plans and specs? Compare U-values and Construction Numbers against those listed in the "Common MJ8 U-Values" tab in the design load screening tool spreadsheet.
  - Is the latent cooling load zero? If not, it should be very small.
  - Do the component loads make sense? These are shown in the pie charts in the Wrightsoft Right Suite Universal "Building Analysis" report or the Elite Software RHVAC "Building Pie Chart" report. Compare them with the examples in the "Typical Input and Load Ranges" tab in the design load screening tool spreadsheet. Specifics will vary with the design.
  - Do heating and cooling loads, by level of the house, make sense? For example, in a two-story house, typically the upper level has the largest cooling load, the main level has a smaller load and the basement cooling load is minimal.
  - Does the AED analysis make sense?
    ° Which rooms have high AED excursions? Does this make sense with glazing amount and orientation?
    ° If the AED excursion is outside the recommended range, advise the architect, builder and/or future homeowner of the comfort consequences of the current design. Encourage them to consider design changes to reduce the problem.
  - Does the variation in cooling load by orientation make sense based on the amount of window area on each elevation?
  - Where is the error? When you see an input or output number that looks suspicious, you may need to do more detective work to determine where the problem occurred. The detailed room-by-room reports (Wrightsoft "Right-J Worksheet," Elite Software "Detailed Room Loads") provide many clues.

- Elite Software RHVAC total cooling load error. When calculating the total cooling load, this software package does not correctly account for negative latent loads in the "Total Building Load Totals" line or the "Building Loads" section of the "Total Building Summary Loads" report. If the latent load is negative (typical for the Fort Collins climate), total cooling load = sensible load.

## 5.0 _Heating + Cooling Equipment Selection_  _(page 3 of submittal form)_

### 5.1 Code Reference
- IRC M1401.3 (amended), IECC 403.6 (amended)
- IRC N1103.2.2.1, IECC R403.2.2.1

### 5.2 System and Building Types
Until further notice, these requirements will be enforced in full for gas-fired, forced-air furnaces and central air conditioning for new construction, where each dwelling unit has a dedicated heating and cooling system, for new buildings and new systems installed in additions to existing buildings.

### 5.3 Approved Design Procedure
ACCA Manual S: Residential Equipment Selection

**\*\*\* There is no ACCA-Approved software for Manual S procedures. \*\*\***

### 5.4 Procedure Reminders and Constraints
The following information provides guidance on equipment selection procedures for the purposes of Fort Collins building code. The handout from the "Residential Mechanical Systems Design" class is a very useful reference. Refer to ACCA Manual S for the complete procedure. At 5,000 feet, it is critical to correct for altitude.

- Design heating and cooling loads
  - Use design loads calculated using Manual J8, with no additional "safety" factors, as your starting point for equipment selection. Do not select equipment unless you have confidence in the design load!
  - For custom homes and other one-time builds, orientation for the load calculation report must match actual.
  - For stock plans, check the variation in cooling design load over multiple orientations.
    - ° If the range is less than or equal to 6,000 Btuh, select equipment based on the worst-case cooling load.
    - ° If the range is more than 6,000 Btuh, more than one system design will be required.
    - ° Select equipment and design ductwork that will work well for a designated range of orientations.

- **VERY IMPORTANT!** Do NOT rely on software packages approved for Manual J8 and/or Manual D to select equipment. Their built-in databases typically don't properly account for 5000' altitude or very low latent cooling loads. Instead, equipment selection must be done "off-line" following Manual S procedures, starting with OEM expanded performance data, as covered in training. This is not difficult.

- Matched components
  - For all cooling systems, the AC indoor coil and outdoor unit must be matched.
    - ° Most combinations will have an AHRI number. If so, enter this on the form.
    - ° In some cases, no AHRI number is available. To be considered a matched combination, you must submit OEM expanded performance data for the combination you plan to use.
  - For multi-stage or variable-speed furnaces, the air handler must also be matched to the cooling components.

- Detailed manufacturer performance data must be used as your starting point.
  - <u>Performance data you submit must list the specific components you select</u>.
  - <u>Ignore AHRI rating data</u>; it does not reflect Fort Collins design conditions or altitude.
  - Carefully read footnotes on the performance data tables.
  - The detailed OEM data table for a given outdoor AC unit typically does not list all the possible indoor coils with which it is approved. For other OEM-approved combinations, the manufacturer will provide a multiplier that converts the detailed data to apply to other coils; attach OEM documentation to this effect.
  - If you use an on-line OEM database rather than a table to determine equipment performance, you must specify Fort Collins design conditions and understand whether the database reflects sea-level or 5,000' performance. The report you provide must be clearly labeled in this regard.

- Furnace performance data must reflect performance at 5,000'
  - Start with OEM sea-level data and correct for much lower air density at this elevation.
  - De-rate heating capacity, using manufacturer specification for de-rating % per 1000:'

    Heating capacity at 5000' = (Sea-level capacity) x (1 − [5 x de-rating % per 1000'])
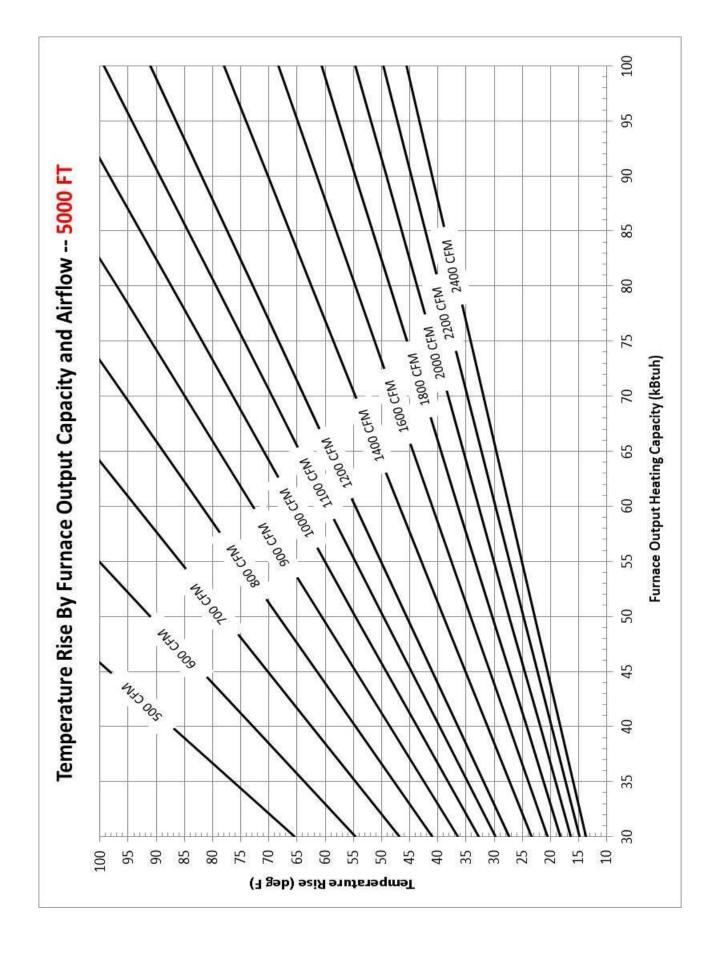
    Altitude de-rating factors range from 2% to 4% per 1000' above sea level, equivalent to a capacity de-rating of 10% to 20% at 5000.'

  - Calculate design temperature rise and report it on the submittal form:

    Temp rise at 5000' = (5,000' output capacity) / (0.832 x 1.1 x design cfm)

    The chart on the following page is another way to determine the temperature rise.

  - Temp rise must be within the OEM certified range. It is strongly advised that you design for a temp rise in the middle of the range or below because temp rise typically increases over time as the system gets dirty or registers or closed by occupants.

- AC performance data must reflect performance in dry climate at 5000'
  - Start with OEM sea-level data. Highlight design conditions, chosen airflow and corresponding rated capacity in data table:
    - For 90 F summer outdoor design dry bulb temperature, use "condenser entering dry bulb air temperature" = 95 F or interpolate between 85 F and 95 F capacity.
    - For air entering indoor coil
      - ⇒ Dry-bulb temperature = 75 F (beware: many tables are based on 80 F)
      - ⇒ Typical wet-bulb temperature ~ 62 F unless there is a significant latent load (unusual; source of this load must be documented).
      - ⇒ The 75 F dry-bulb / 62 F combination is sometimes referred to as "TVA rating conditions" in the performance data table footnotes.
  - Approximate AC equipment capacities for the dry climate by transferring half of OEM latent capacity to sensible capacity.
  - Correct AC airflow and/or equipment capacity for much lower air density at altitude, using one of these techniques (<u>Manual S</u> Appendix 6)
    - Increase volumetric airflow, no change in capacity: CFM 5000' = Sea-level CFM / 0.832
    - De-rate cooling capacity, no change in airflow: 5000' capacity = Sea-level capacity x 0.96
    Specify the altitude correction method you used on the submittal form.

Temperature Rise By Furnace Output Capacity and Airflow -- 5000 FT

Furnace Output Heating Capacity (kBtuh)

Temperature Rise (deg F)

500 CFM
600 CFM
700 CFM
800 CFM
900 CFM
1000 CFM
1100 CFM
1200 CFM
1400 CFM
1600 CFM
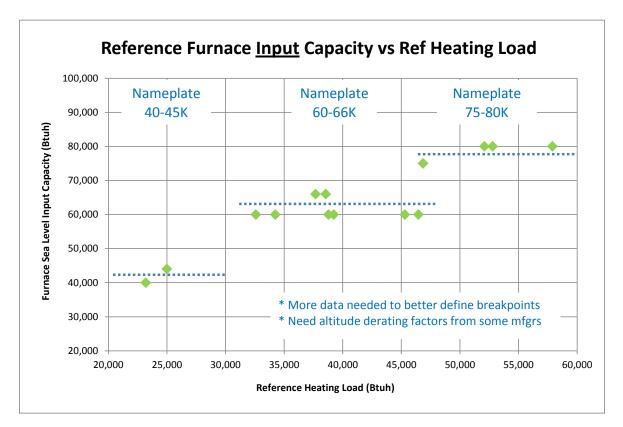1800 CFM
2000 CFM
2200 CFM
2400 CFM

- Right-sizing. Equipment capacities, calculated as described above, must fall within these limits:
  – Furnace: Output heating capacity must be in range of 100% to 140% of design heating load (unless larger size blower is needed to meet cooling load).
  – AC:
    ° <u>Sensible</u> cooling capacity must meet design sensible load.
    ° <u>Total</u> cooling capacity must be in the range of 95% to 115% of design total cooling load or not exceed design total cooling load by more than 6,000 Btuh. Given the small cooling loads for most new construction in Fort Collins, the 6,000 Btuh limit is typically more applicable than the 115% limit.
  – Where no available equipment is within these sizing limits, the next largest nominal piece of available equipment may be used.
  – If the selected equipment does not fall within code sizing ranges, explain why on the submittal.

- Airflow. You must document design airflow and static pressure targets for both heating and cooling. This means picking operating points within the OEM blower data table.
  – Use realistic static pressures. External Static Pressure of 0.50 to 0.70 IWC is typical for systems with an AC coil. Static pressures typically increase over time as components get dirty and occupants close some registers.
  – Remember that the design airflow is volumetric cfm at 5000' air density. Doublecheck that you have correctly adjusted OEM sea-level performance data as described above.

- Other furnace / air handler considerations:
  – IRC N1103.2.2.1/IECC R403.2.2.1 requires a sealed air handler be specified.
  – If a sealed combustion furnace is specified, you must also specify two-pipe installation. Check the box on the submittal form.
  – Natural-draft gas furnaces (including induced-draft furnaces) must be located and tested in accordance with IRC G2406.2.
  – You must report the blower motor type on the submittal form. If the furnace blower is being used to circulate air for whole-house ventilation and is ¼ HP or larger, a brushless-DC blower motor must be specified.

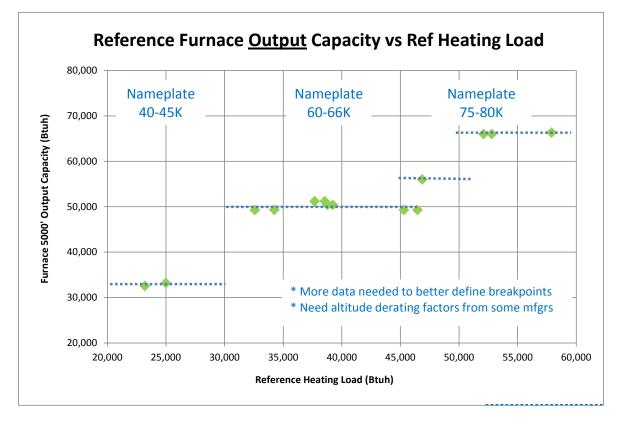- For multiple systems, submit a "Heating + Cooling Equipment Selection" page for each system.
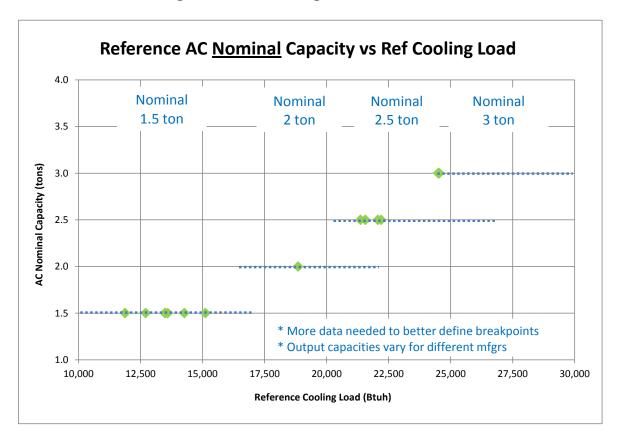
## 5.5 Checking Your Results

Is the equipment you selected a reasonable match for the design loads? The plots on the next two pages show typical relationships between design loads and right-sized equipment for new Fort Collins homes. It is based on the same sample of homes used to develop the design load screening tool (Section 4.4 above). The "reference" equipment size was established using <u>Manual S</u> procedures. Plots are shown for both nameplate / nominal capacities and output capacities (corrected for dry climate and altitude). Equipment ratings from six different manufacturers is represented. In a small number of cases, cooling airflow needs drove a step up in furnace size.

As noted on the plots, a larger sample will be needed to better define the breakpoints between different sizes of equipment. There is variation among manufacturers due to output capacity differences for equipment with the same nominal rating. Nonetheless, this provides an easy way to do a coarse screening check on your equipment sizing.

**Furnace Sizing Coarse Screening Check**

## Reference Furnace <u>Input</u> Capacity vs Ref Heating Load



Y-axis: Furnace Sea Level Input Capacity (Btuh)
X-axis: Reference Heating Load (Btuh)

Nameplate 40-45K    Nameplate 60-66K    Nameplate 75-80K

* More data needed to better define breakpoints
* Need altitude derating factors from some mfgrs

## Reference Furnace <u>Output</u> Capacity vs Ref Heating Load



Y-axis: Furnace 5000' Output Capacity (Btuh)
X-axis: Reference Heating Load (Btuh)

Nameplate 40-45K    Nameplate 60-66K    Nameplate 75-80K

* More data needed to better define breakpoints
* Need altitude derating factors from some mfgrs

# Air Conditioner Sizing Coarse Screening Check

## Reference AC <u>Nominal</u> Capacity vs Ref Cooling Load

Nominal 1.5 ton    Nominal 2 ton    Nominal 2.5 ton    Nominal 3 ton

AC Nominal Capacity (tons)

Reference Cooling Load (Btuh)

* More data needed to better define breakpoints
* Output capacities vary for different mfgrs

## Reference AC <u>Output</u> Capacity vs Ref Cooling Load

Nominal 1.5 ton    Nominal 2 ton    Nominal 2.5 ton    Nominal 3 ton

AC Total Output Capacity - FC (Btuh)

Reference Cooling Load (Btuh)

* More data needed to better define breakpoints
* Output capacities vary for different mfgrs

## 6.0 <u>Heating + Cooling Ductwork</u>  *(page 4 of submittal form)*

### 6.1 Code Reference
- IRC M1601.1 (amended)
- IECC 403.6 (amended)

### 6.2 System and Building Types
Until further notice, these requirements will be enforced in full for gas-fired, forced-air furnaces and central air conditioning for new construction, where each dwelling unit has a dedicated heating and cooling system, for new buildings and new systems installed in additions to existing buildings. I.e. not for other system types.

### 6.3 Approved Design Procedure and Software Tools
- ACCA <u>Manual D: Residential Duct Systems</u>
- ACCA-Approved <u>Manual D</u> software (see <u>https://www.acca.org/industry/system-design/software</u> for current list).
- Manual duct designs are acceptable.

### 6.4 Procedure Reminders and Constraints
The following information provides guidance and reminders regarding ductwork design procedures for the purposes of Fort Collins building code. The handout from the Residential Mechanical Systems Design class is a useful reference. Refer to ACCA <u>Manual D</u> for the complete procedure and data tables.

- Equipment performance data
  - The <u>Manual S</u> equipment selection procedure (Section 5.0) above includes specification of design air handler blower performance: heating and cooling airflow at specified external static pressures and blower speeds. This is your starting point for duct design.
  - If you use one of the approved software packages to design ductwork, be sure that the equipment performance information matches all aspects of your equipment selection. Typically the built-in database information will not correctly adjust OEM data for the dry climate and 5000' altitude. <u>You must override the defaults to match your design equipment performance</u>.

- Available Static Pressure (ASP)
  - ASP = (Total external static pressure) – (Device pressure losses)
  - When calculating the device pressure losses, 0.03 IWC is often used to account for balancing dampers, supply and return grilles. For other devices in the flow path, determine pressure drop with OEM or <u>Manual D</u> data.

- Total Effective Length (TEL)
  - Calculate TEL based on the longest supply path plus the longest return path, including the effective lengths of all fittings, reducers, etc.
  - If your TEL is extremely long, try using supply and return air fittings with lower pressure drop at the air handler. Using turning vanes or radius fittings in just these two locations can reduce your TEL by 100' or more.
  - Design Friction Rate
    - Friction rate = (ASP x 100) / TEL

- Per <u>Manual D</u>, design friction rate should be between 0.06 and 0.18. Outside this range, blower performance data will not be reliable.

- Air distribution system design
  - Building cavities may not be used as supply or return "ductwork."
  - All rooms with supply delivery must have a return path large enough so that pressure imbalances do not exceed 3 Pascals. Return paths may include distributed return runs, transfer grilles, jumper ducts. Door undercuts are rarely sufficient.
  - Designers are strongly advised to avoid or minimize duct runs through attics and cantilevers. Attic ductwork, in particular, may significantly increase design heating and cooling loads. If running ductwork through floors over garages or adjacent to exterior walls, you are strongly advised to work with the builder to implement Building Services-approved details that will allow the ductwork to be considered inside conditioned space . . . and perform better!
  - Check air velocity to avoid objectionable noise levels. Refer to <u>Manual D</u> Section 1-12 and Table A1-1. Excessive noise (and inadequate flow) can also be caused by grilles and registers that are not properly sized. Refer to ACCA <u>Manual T</u> for a detailed review of sizing procedures.

- Duct design submittal
  - The duct plan must be sufficiently detailed so that installers can build the intended duct system and field inspectors can determine whether the installed duct system matches the plan. See the checklist in the submittal form for required information.
  - The plan can be produced as a software report or drawn by hand, provided sufficient information is included. All labels must be large enough to read without a magnifying glass!