EnergyPlus Exercise HVAC 3

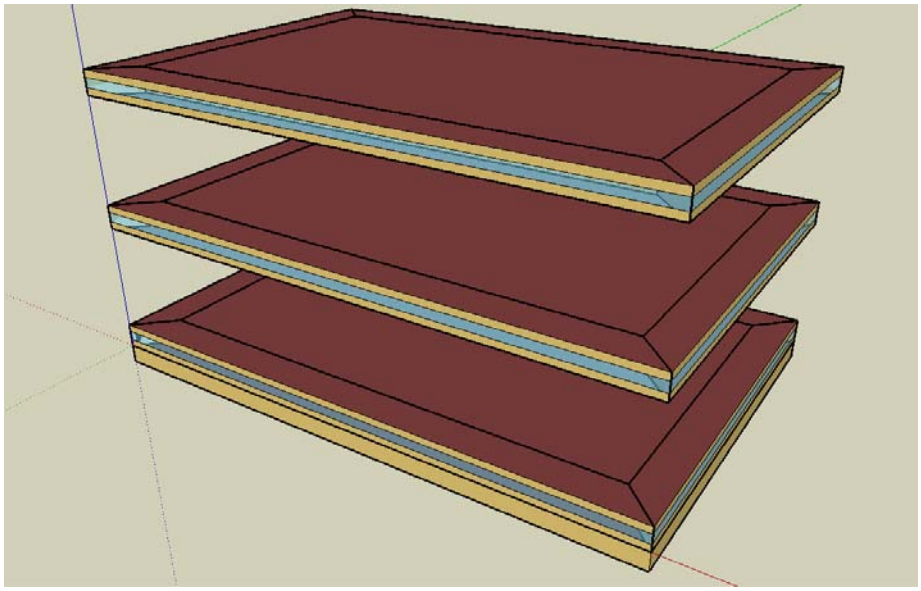
HVAC System Controls and
Plant Equipment Sizing and Performance

Last revised November 2012 for EnergyPlus v7.2.0.006

General Description

Overview

- 12 story building with basement
- Create ASHRAE Std. 90.1, Appendix G baseline building
- Begin with 15 zone VAV/reheat system, centrifugal chiller, gas hot water boiler



Details

Building Description

- 12 floor rectangular building plus basement.
- Floor Area 42,757 m2 (460,235 ft2).
- 15 occupied zones – 5 zones each for top, middle and bottom (4 perimeter, 1 core), with the middle zones duplicated using zone multipliers to represent 10 floors.
- Windows on all 4 facades
- Window to wall ratio is approximately 0.4.
- Lighting is 10.76 W/m2 (1 W/ft2).
- Electric plug loads are 8.76 W/m2 (0.75 W/ft2).
- 195 total occupants, 3.91 per 100 m2 (3.63 per 1000 ft2) of floor area.

- Infiltration in the perimeter zones is 0.3 air changes per hour when fans are off, 0.15 ach when fans are on. In the core, infiltration is 0.15 ach when fans are off, 0.075 ach when fans are on.

Space Conditioning

Heating setpoints: 21C (69.8F) occupied, 13C (55.4F) unoccupied
Cooling setpoints: 24C (75.2F) occupied, 33C (91.4F) unoccupied

Environment

Location:	Chicago, Illinois, USA (O'Hare Airport)
Design Days:	Summer 1% dry bulb
	Winter 99.6% (design days used for sizing only)
Ground Temperature:	19.9-20.4 C from Slab preprocessor

Instructions

Exercise HVAC 3A – Modify HVACTemplate Defaults/Minimum Specification to 90.1 Baseline

Objective: See what types of changes are needed to meet ASHRAE Standard 90.1-2004 Appendix G Baseline specification.

1. Open ExerciseHVAC3.idf and save it as ExerciseHVAC3A.idf, using IDF Editor.
2. In the Building object, change the building name to "Exercise HVAC 3A".
   Note: This helps in identifying HTML output files, because the building name is shown at the top and is also part of the window title.
3. In the HVACTemplate:Zone:VAV object, make the following changes:
   a. Change the "Outdoor Air Method" from "flow/person" to "sum".
   b. Change "Outdoor Air Flow Rate per Person" from 0.00944 m3/s to 0.0025 m3/s.
   c. Change "Outdoor Air Flow Rate per Zone Floor Area" from blank to 0.0003 m3/s-m2.
   d. Repeat all three changes for all 15 zones.
      Note: these changes specify the ASHRAE Std. 62.1 zone ventilation rates for office spaces – 2.5 L/s per person plus 0.3 L/s-m2.
4. In the HVACTemplate:System:VAV object, make the following changes:
   a. Change the "Minimum Outdoor Air Control Type" from "ProportionalMinimum" to "FixedMinimum".
      Note: As the VAV system supply air volume is reduced, this change forces the outside air dampers to open wider to maintain the ventilation air volume. If the total supply volume falls below the ventilation volume, however, ventilation volume will be reduced.

b. Change “Economizer Type” from “NoEconomizer” to “DifferentialDryBulb”.

c. Change “Economizer Upper Temperature Limit” to 21.1C (70F)

d. Change the “Cooling Coil Setpoint Reset Type” from “None” to “OutdoorAirTemperatureReset.”

5. In the HVACTemplate:Plant:ChilledWaterLOOP object, make the following changes:

   a. Change the “Chilled Water Pump Configuration” from “ConstantPrimaryNoSecondary” to “ConstantPrimaryVariableSecondary.”

   b. Change the “Chilled Water Setpoint Reset Type” from “None” to “OutdoorAirTemperatureReset.”

   c. Verify that the reset temperature schedule values are correct:
      “Chilled Water Setpoint at Outdoor Dry-Bulb Low” = 12.2C,
      “Chilled Water Reset Outdoor Dry-Bulb Low” = 15.6C,
      “Chilled Water Setpoint at Outdoor Dry-Bulb High” = 6.7C, and
      “Chilled Water Reset Outdoor Dry-Bulb High” = 26.7C

6. In the HVACTemplate:Plant:HotWaterLoop object, make the following changes:

   a. Change the “Hot Water Pump Configuration” from “ConstantFlow” to “VariableFlow.”

   b. Change the “Hot Water Setpoint Reset Type” from “None” to “OutdoorAirTemperatureReset.”

   c. Verify that the reset temperature schedule values are correct:
      “Setpoint at Outdoor Dry Bulb Low” = 82.2C,
      “Reset Outdoor Dry Bulb Low” = -6.7C,
      “Setpoint at Outdoor Dry Bulb High” = 65.6C, and
      “Reset Outdoor Dry Bulb High” = 10.0C

7. In the Sizing:Parameters object, change the “heating sizing factor” to 1.25 and the “cooling sizing factor” to 1.15.
   Note that Std 90.1 App. G specifies 15% oversizing for cooling, and 25% oversizing for heating. For this system type, cooling sets the airflow rates, so the cooling sizing factor will be used to set the airflows and the heating sizing factor essentially has no impact on the boiler sizing. The boiler capacity will need to be adjusted later.

8. Save the idf and run the simulation.

Exercise HVAC 3B – Add second chiller and boiler

Objective: Use HVACTemplate to add a second chiller and boiler as specified by Std 90.1 App. G.

1. Open ExerciseHVAC3A. idf in IDF editor and save it as ExerciseHVAC3B.idf. ;
2. In the Building object, change the building name to "Exercise HVAC 3B".
3. In the HVACTemplate:Plant:Chiller object, select Chiller 1 and click the Dup Obj button. Select the new object and change the "Chiller Name" from "Chiller 1" to "Chiller 2."
4. With two chillers, you must specify how to apportion the capacity. Set the "Sizing Factor" field at the end of each HVACTemplate:Plant:Chiller object to 0.5 to specify two equal size chillers.
   Note: The air system has already been oversized by 15%, so the combined chiller capacity will also be oversized by 15%.
5. In the HVACTemplate:Plant:Boiler object, select Boiler 1 and click the Dup Obj button. Select the new object and change the "Boiler Name" from "Boiler 1" to "Boiler 2."
6. The goal for the boilers is to have the total boiler capacity oversized by 25%. Since the air system is already oversized by 15%, the sum of the "Sizing Factor" inputs for the two boilers should equal 1.25/1.15=1.09. For two boilers of equal size, set the "Sizing Factor" to 0.545 on each boiler.
7. Add two new Output:Variable objects to report "Plant Loop Cooling Demand" and "Plant Loop Heating Demand" hourly.
   Note: These objects may be copied directly from the ExerciseHVAC3A.rdd output and pasted into IDF Editor.
8. Save the idf and run the simulation.
9. Open the eio output file, search for "CHILLER:" and find the autosized chiller capacities. (*Note: Use the table below for steps 9-12)*
10. Open the Variables (csv) output file and find the peak total load for the chillers. Is the total chiller capacity approximately 15% greater than the peak load?
11. In the eio output file, search for "BOILER:" and find the autosized boiler capacities.
12. In the Variables (csv) output file find the peak total load for the boilers. Is the total boiler capacity approximately 25% greater than the peak load?

	Chiller 1	Chiller2	Chlr Tot	Boiler 1	Boiler 2	Blr Tot
Rated Capacity [W]						
Peak Load [W]	n/a	n/a		n/a	n/a	
Capacity/Peak Load	n/a	n/a		n/a	n/a	

Note: It is important to perform this check against design day results, because the current EnergyPlus sizing algorithm may significantly oversize certain types of plant equipment depending on the application type and climate. It may be necessary to either hard-size the equipment or recalculate the equipment sizing factors to achieve the desired result.

Exercise HVAC 3C – Modify Chiller Performance Curves

Objective: Learn how to use the EXPIDF output file to edit the HVACTemplate system defaults.

1. Open ExerciseHVAC3B.expidf in a ***text editor*** and save it as ExerciseHVAC3C.idf.
2. In the Building object, change the building name to "Exercise HVAC 3C". *(Search for "Building,", searching for Building takes you to many comment lines.)*
3. Locate the Chiller:Electric:EIR objects.
4. Open \EnergyPlusVx-0\Datasets\Chillers.idf in a ***text editor***. This dataset file contains sets of chiller objects and corresponding curve objects for dozens of specific chillers. For the purpose of this exercise, locate the group of objects for the chiller labeled: ! ElectricEIRChiller Carrier 19XR 1407kW/6.04COP/VSD.
5. The rows marked with bold underline below are the performance data for this chiller. Copy these rows from Chillers.idf and replace the corresponding rows in the two Chiller:Electric:EIR objects in ExerciseHVAC3C.idf

```
Chiller:Electric:EIR,
    ElectricEIRChiller Carrier 19XR 1407kW/6.04COP/VSD,  !- Name
    1406600,                 !- Reference Capacity {W}
    6.04,                    !- Reference COP {W/W}
    6.67,                    !- Reference Leaving Chilled Water Temperature {C}
    29.44,                   !- Reference Entering Condenser Fluid Temperature {C}
    0.06057,                 !- Reference Chilled Water Flow Rate {m3/s}
    0.07571,                 !- Reference Condenser Water Flow Rate {m3/s}
    ElectricEIRChiller Carrier 19XR 1407kW/6.04COP/VSD CAPFT,  !- Cooling Capacity
Function of Temperature Curve Name
    ElectricEIRChiller Carrier 19XR 1407kW/6.04COP/VSD EIRFT,  !- Electric Input to
Cooling Output Ratio Function of Temperature Curve Name
    ElectricEIRChiller Carrier 19XR 1407kW/6.04COP/VSD EIRFPLR,  !- Electric Input to
Cooling Output Ratio Function of Part Load Ratio Curve Name
    0.20,                    !- Minimum Part Load Ratio
. . .
```

6. Back in Chillers.idf, copy the 3 curve objects for ElectricEIRChiller Carrier 19XR 1407kW/6.04COP/VSD and paste them into ExerciseHVAC3C.idf
   Note: These only need to be pasted once, since both chillers refer to the same curve object names.
7. Save the idf and run the simulation for ExerciseHVAC3C.
   (Remember to select ExerciseHVAC3C as the input in EP-Launch before pressing Simulate.)

List of New or Modified Objects

This is a listing of new objects added or modified in this Exercise.

Exercise HVAC 3A

Modified objects (repeated for 15 occurrences):

```
HVACTemplate:Zone:VAV,
 . . .
Sum,                     !- Outdoor Air Method
0.0025,                  !- Outdoor Air Flow Rate per Person {m3/s}
0.0003,                  !- Outdoor Air Flow Rate per Area {m3/s-m2}

HVACTemplate:System:VAV,
 . . .
FixedMinimum,            !- Minimum Outdoor Air Control Type
,                        !- Minimum Outdoor Air Schedule Name
DifferentialDryBulb,     !- Economizer Type
NoLockout,               !- Economizer Lockout
21.1,                    !- Economizer Upper Temperature Limit {C}
. . .
OutdoorAirTemperatureReset,  !- Cooling Coil Setpoint Reset Type

HVACTemplate:Plant:ChilledWaterLoop,
 . . .
    ConstantPrimaryVariableSecondary,  !- Chilled Water Pump Configuration
. . .
    OutdoorAirTemperatureReset,  !- Chilled Water Setpoint Reset Type
    12.2,                    !- Chilled Water Setpoint at Outdoor Dry-Bulb Low {C}
    15.6,                    !- Chilled Water Reset Outdoor Dry-Bulb Low {C}
    6.7,                     !- Chilled Water Setpoint at Outdoor Dry-Bulb High {C}
    26.7;                    !- Chilled Water Reset Outdoor Dry-Bulb High {C}

HVACTemplate:Plant:HotWaterLoop,
 . . .
    CONTINUOUS,              !- Pump Control Type
. . .
    VariableFlow,            !- Hot Water Pump Configuration
. . .
    OutdoorAirTemperatureReset,  !- Hot Water Setpoint Reset Type
    82.2,                    !- Hot Water Setpoint at Outdoor Dry-Bulb Low {C}
    -6.7,                    !- Hot Water Reset Outdoor Dry-Bulb Low {C}
    65.6,                    !- Hot Water Setpoint at Outdoor Dry-Bulb High {C}
    10;                      !- Hot Water Reset Outdoor Dry-Bulb High {C}

Sizing:Parameters
    1.25,                    !- Heating Sizing Factor
    1.15;                    !- Cooling Sizing Factor
```

Exercise HVAC 3B

Modified objects:

```
HVACTemplate:Plant:Chiller,
    Chiller 1,                !- Name
    ElectricCentrifugalChiller,  !- Chiller Type
    autosize,                 !- Capacity {W}
    6.5,                      !- Nominal COP {W/W}
    WaterCooled,              !- Condenser Type
    ,                         !- Priority
    0.5;                      !- Sizing Factor

HVACTemplate:Plant:Boiler,
    Boiler 1,                 !- Name
    HotWaterBoiler,           !- Boiler Type
    autosize,                 !- Capacity {W}
    0.8,                      !- Efficiency
    NaturalGas,               !- Fuel Type
    ,                         !- Priority
    0.545;                    !- Sizing Factor
```

New objects:

```
HVACTemplate:Plant:Chiller,
    Chiller 2,                !- Name
    ElectricCentrifugalChiller,  !- Chiller Type
    autosize,                 !- Capacity {W}
    6.5,                      !- Nominal COP {W/W}
    WaterCooled,              !- Condenser Type
    ,                         !- Priority
    0.5;                      !- Sizing Factor

HVACTemplate:Plant:Boiler,
    Boiler 2,                 !- Name
    HotWaterBoiler,           !- Boiler Type
    autosize,                 !- Capacity {W}
    0.8,                      !- Efficiency
    NaturalGas,               !- Fuel Type
    ,                         !- Priority
    0.545;                    !- Sizing Factor

Output:Variable,*,Plant Loop Cooling Demand,hourly;
Output:Variable,*,Plant Loop Heating Demand,hourly;
```

Exercise HVAC 3C

Modified objects:

```
Chiller:Electric:EIR,
    Chiller 1,                !- Name
    autosize,                 !- Reference Capacity {W}
    6.04,                     !- Reference COP {W/W}
    6.67,                     !- Reference Leaving Chilled Water Temperature {C}
    29.44,                    !- Reference Entering Condenser Fluid Temperature {C}
    autosize,                 !- Reference Chilled Water Flow Rate {m3/s}
    autosize,                 !- Reference Condenser Fluid Flow Rate {m3/s}
    ElectricEIRChiller Carrier 19XR 1407kW/6.04COP/VSD CAPFT,  !- Cooling Capacity
Function of Temperature Curve Name
    ElectricEIRChiller Carrier 19XR 1407kW/6.04COP/VSD EIRFT,  !- Electric Input to
Cooling Output Ratio Function of Temperature Curve Name
```

```
    ElectricEIRChiller Carrier 19XR 1407kW/6.04COP/VSD EIRFPLR,  !- Electric Input
to Cooling Output Ratio Function of Part Load Ratio Curve Name
. . .
```

(Similar changes for Chiller 2)

New objects:

```
!
! Curve set (3 Curves):
!
! Cooling Capacity Function of Temperature Curve
! x = Leaving Chilled Water Temperature and y = Entering Condenser Water
Temperature
Curve:Biquadratic,
    ElectricEIRChiller Carrier 19XR 1407kW/6.04COP/VSD CAPFT,  !- Name
    1.042261E+00,            !- Coefficient1 Constant
    2.644821E-03,            !- Coefficient2 x
    -1.468026E-03,           !- Coefficient3 x**2
    1.366256E-02,            !- Coefficient4 y
    -8.302334E-04,           !- Coefficient5 y**2
    1.573579E-03,            !- Coefficient6 x*y
    4.44,                    !- Minimum Value of x
    10.00,                   !- Maximum Value of x
    12.78,                   !- Minimum Value of y
    32.22;                   !- Maximum Value of y

!
! Energy Input to Cooling Output Ratio Function of Temperature Curve
! x = Leaving Chilled Water Temperature and y = Entering Condenser Water
Temperature
Curve:Biquadratic,
    ElectricEIRChiller Carrier 19XR 1407kW/6.04COP/VSD EIRFT,  !- Name
    1.026340E+00,            !- Coefficient1 Constant
    -1.612819E-02,           !- Coefficient2 x
    -1.092591E-03,           !- Coefficient3 x**2
    -1.784393E-02,           !- Coefficient4 y
    7.961842E-04,            !- Coefficient5 y**2
    -9.586049E-05,           !- Coefficient6 x*y
    4.44,                    !- Minimum Value of x
    10.00,                   !- Maximum Value of x
    12.78,                   !- Minimum Value of y
    32.22;                   !- Maximum Value of y

!
! Energy Input to Cooling Output Ratio Function of Part Load Ratio Curve
! x = Part Load Ratio (load/capacity)
Curve:Quadratic,
    ElectricEIRChiller Carrier 19XR 1407kW/6.04COP/VSD EIRFPLR,  !- Name
    1.188880E-01,            !- Coefficient1 Constant
    6.723542E-01,            !- Coefficient2 x
    2.068754E-01,            !- Coefficient3 x**2
    0.20,                    !- Minimum Value of x
    1.04;                    !- Maximum Value of x
```