Volume 6, Issue 4

CARRIER® eDESIGN SUITE NEWS

EXchange

Utilizing HAP Diagnostics Reports to Verify Annual System Simulation Results (Part 2)

This is a continuation of an article from the previous Vol 6, Issue 3 EXchange newsletter, [Utilizing HAP Diagnostics Reports to Verify System Simulation Results (Part 1)]. In this article we will focus on how to interpret and diagnose annual Plant and Air System simulation results and demonstrate procedures for identifying any anomalies in the final simulation results.

HAP's simulation capabilities are very robust and allow you to quickly produce Summary reports comparing annual energy use and energy costs of multiple, alternate building designs. In addition, Detailed reports provide annual, monthly, daily and hourly performance data. HAP's extensive use of graphics allows trends and patterns of equipment performance to be quickly understood. Simulation data may be exported to spreadsheet (.CSV) file format for further analysis, if desired.

Simulation reports may be generated at three different levels within HAP:

- **Systems simulation** – extremely useful for identifying monthly, daily or hourly HVAC component cooling and heating loads (KBTU or kWh) as well as energy usage for HVAC components such as compressors, fans, pumps, towers and boilers; and non-HVAC energy use components like lighting and miscellaneous electric loads. In addition, unmet systems loads and zone temperatures may be identified and quantified.

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eDesign Suite

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- **Plants simulation** – quantifies HVAC and non-HVAC component usage such as cooling and heating coil loads and total plant loads and energy usage for chillers, boilers, towers, pumps and service hot water. Unmet plant loads may also be quantified.
- **Building simulation** – quantifies total building energy consumption, operating costs and emissions utilizing graphics and tabular data. Includes energy budget reports, utility billing details, monthly consumption, peak demand and time of peak demand both for electric energy and fuel usage. In addition, a LEED Energy Credit report may be generated for Baseline and Proposed buildings for LEED v3 and newer LEED v4.

The previous article focused on Building simulation reports. This article will focus on the first two levels, the System and Plant Simulation Reports.

We will begin with the Plant Simulation Reports. Note that only hydronic (chilled water, hot water & steam) equipment uses plants. Most direct expansion (DX) equipment does not use or need a plant unless the heating source is hot water or steam, that is because all equipment settings are performed in the air system inputs.

Plant Simulation Reports contain load and equipment performance data produced by the hour-by-hour simulation of plant operation for one year. This information is useful for learning about plant operation and investigating energy consumption patterns. HAP offers four different plant simulation reports, three of which can be generated in tabular, graphical or text file format, as indicated in Figure 1. The latter format (CSV) is used for exporting data to external programs such as spreadsheets. Note that simulation reports are only available in the full edition of HAP and not in the HAP System Design Loads Program, which is the "loads-only" version of HAP.

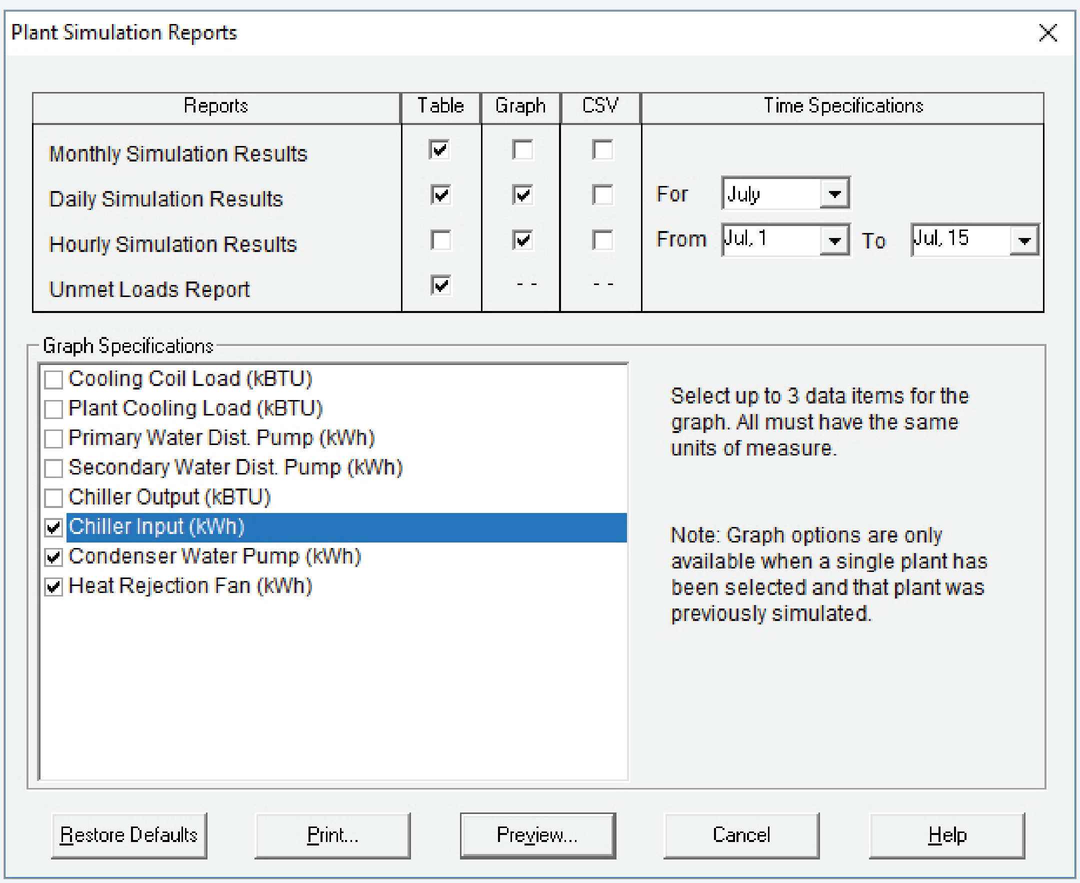

Figure 1. Plant Simulation Reports Selection Screen

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Graphs are a powerful tool to analyze the plant simulation results. Up to three variables may be graphed together provided they all have similar units of measure. As an example, Figure 2 below illustrates the chiller power input, condenser water pump and tower (heat rejection) fan power all graphed for the month of July in units of kWh.

The four dips in the power curves represent weekend time periods when the building is in setback.

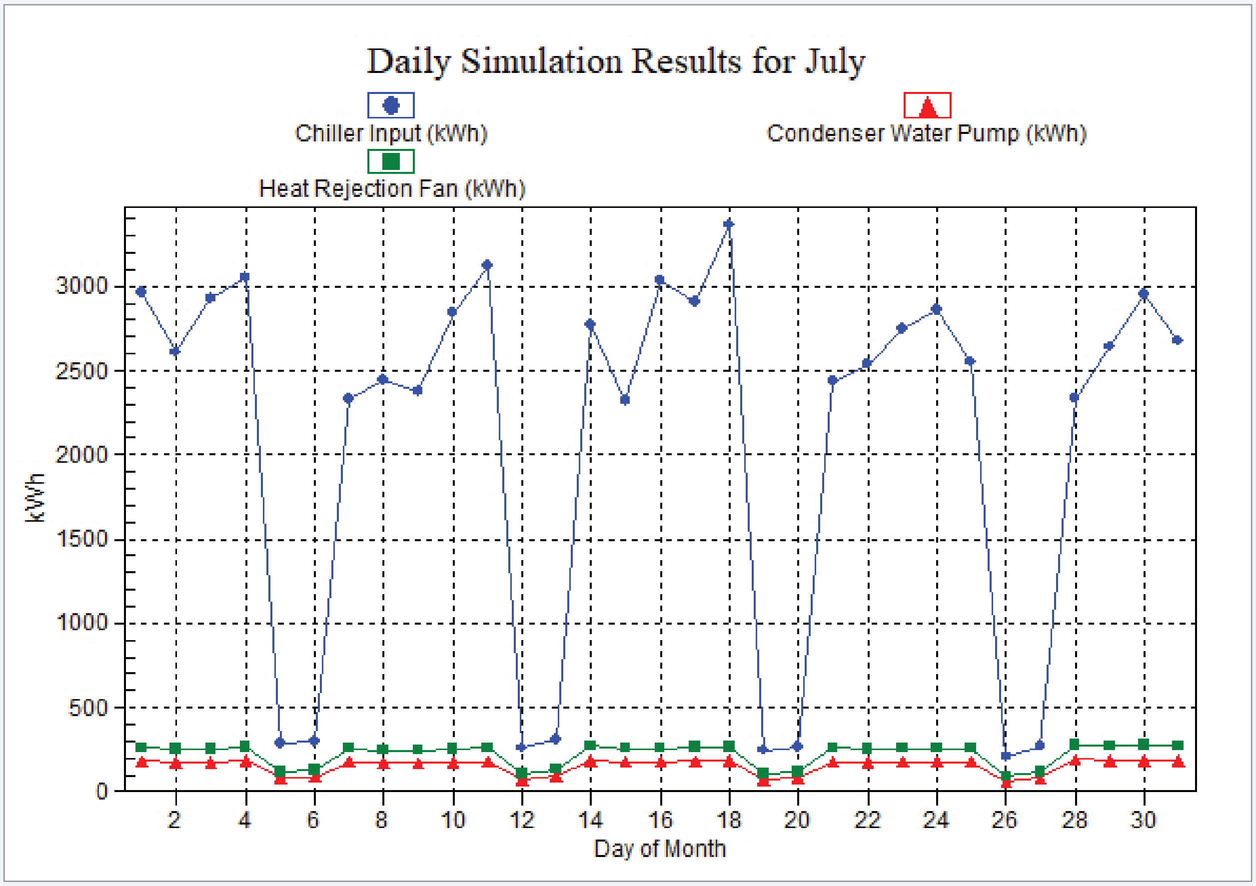

Figure 2. Plant Simulation Report – Chiller, Cond Pump & Tower Fan Input for July

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The Unmet Plant Loads report, Figure 3, is a good report to review as it can identify any times when the plant load exceeds plant capacity. If using auto-sizing, it is unlikely there will be unmet plant loads. But if you are analyzing an existing chiller plant with a known capacity this report will identify any plant capacity deficiencies.

1. Unmet Cooling Load Statistics

Month	Equipment Capacity is Sufficient (hrs)	Capacity Insufficient by 0%-5% (hrs)	Capacity Insufficient by 5%-10% (hrs)	Capacity Insufficient by >10% (hrs)	Total Hours with Unmet Loads	Total Hours with Equipment Loads
January	625	0	0	0	0	625
February	557	0	0	0	0	557
March	643	0	0	0	0	643
April	676	0	0	0	0	676
May	730	0	0	0	0	730
June	720	0	0	0	0	720
July	738	4	1	1	6	744
August	744	0	0	0	0	744
September	712	6	1	0	7	719
October	719	0	0	0	0	719
November	633	0	0	0	0	633
December	621	0	0	0	0	621
Total	**8118**	**10**	**2**	**1**	**13**	**8131**

Figure 3. Plant Simulation Report – Unmet Loads

In the example in Figure 3, there are a few hours per year when the plant capacity is insufficient by as much as 5% of the total hours with equipment loads. This generally is nothing to be concerned about because in this case there are 8131 hours per year of equipment loads. If there were significant plant capacity deficiencies you would need to research further and verify your plant sizing inputs.

It is beyond the scope of this article to explore all of the possible plant simulation reports. You should generate all of the various reports to become familiar with them. Then press the Help button for a detailed explanation of each one.

Let's move now to the air systems simulation reports. System Simulation Reports contain hour-by-hour load and equipment simulation performance data for a full year. This information is useful for analyzing equipment operation and for investigating energy consumption patterns. HAP offers five different system simulation reports, three of which can be generated in tabular, graphical or text file format, as indicated in Figure 4. The latter format (CSV) is used for exporting data to external programs such as spreadsheets. Note that simulation reports are only available in the full edition of HAP and not in the HAP System Design Loads Program.

As with the other simulation reports the Help button is readily available and provides a very detailed and thorough explanation of all possible reports. There is not adequate space here to go through all of the air system simulation reports in detail; however, we will highlight a couple of the more important ones.

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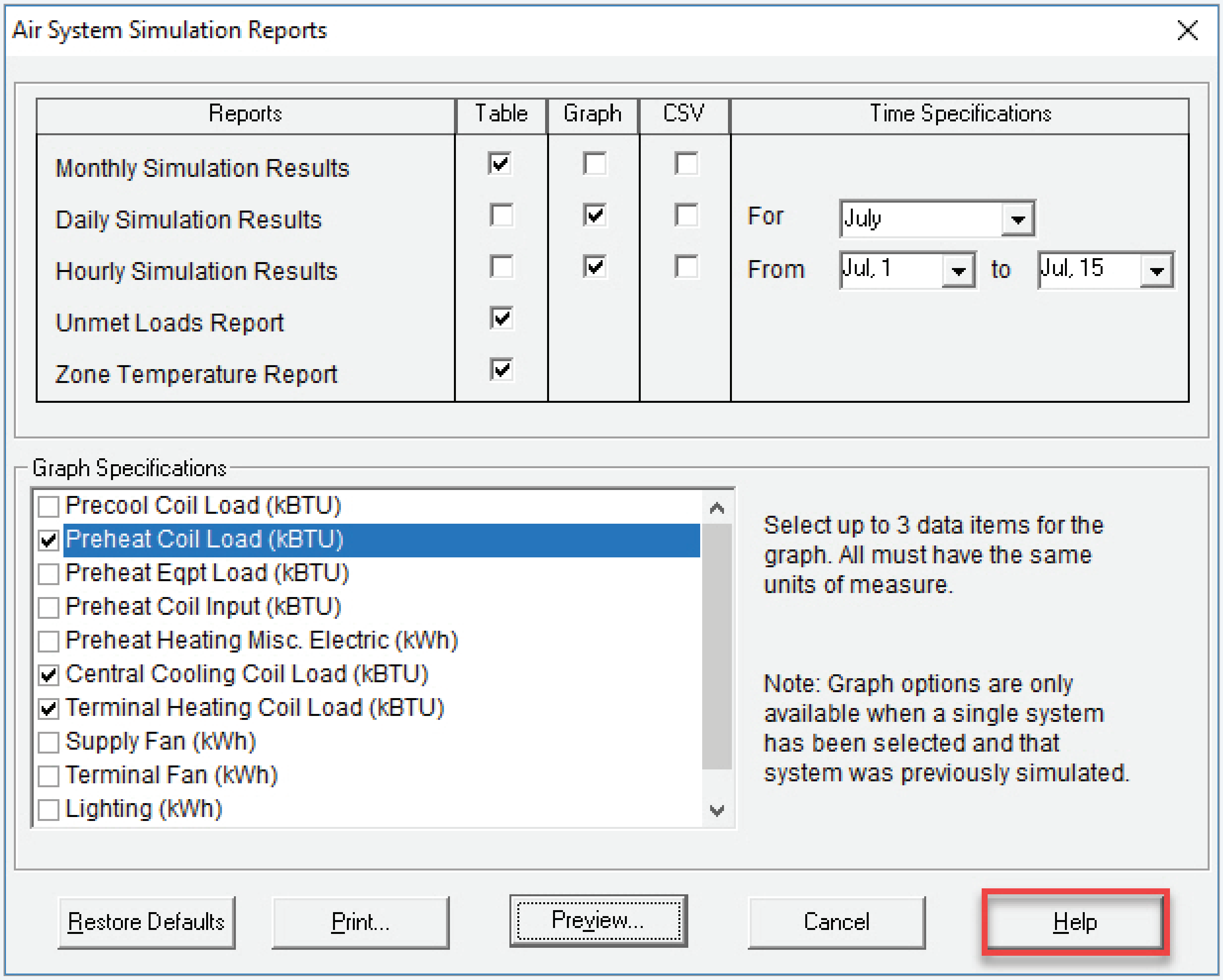

Figure 4. Air System Simulation Reports

Generally, the Monthly Simulation Report provides an adequate and sufficiently detailed level of information to make high-level decisions. If you see any sort of discrepancies or other results that do not look reasonable you should generate the daily and hourly simulation reports. An example Monthly Simulation report for a VAV system is shown in Figure 5.

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Monthly Simulation Results for VAV AREA A (CHW)

Project Name: EXchange 6-4 Project 07/05
Prepared by: Carrier 06:

Air System Simulation Results (Table 1):

Month	Precool Coil Load (kBTU)	Preheat Coil Load (kBTU)	Preheat Eqpt Load (kBTU)	Preheat Coil Input (kBTU)	Preheat Heating Misc. Electric (kWh)	Central Cooling Coil Load (kBTU)	Terminal Heating Coil Load (kBTU)
January	29589	19963	19836	20662	0	11130	2209
February	21040	18836	18835	19619	0	8509	2069
March	27211	11288	11288	11759	0	11120	105
April	42042	5289	5289	5509	0	15959	286
May	60101	2055	2055	2141	0	21586	1361
June	76998	430	430	448	0	25487	2672
July	96676	235	235	245	0	29095	2570
August	82824	413	413	430	0	25831	2268
September	69205	908	908	946	0	22506	1496
October	50509	4706	4706	4902	0	17929	279
November	30351	8072	8072	8409	0	11777	74
December	27508	21776	21697	22601	0	10476	1638
Total	**614054**	**93971**	**93762**	**97669**	**0**	**211406**	**17029**

Air System Simulation Results (Table 2):

Month	Supply Fan (kWh)	Terminal Fan (kWh)	Lighting (kWh)	Electric Equipment (kWh)
January	313	0	3400	456
February	271	0	2962	397
March	312	0	3119	418
April	398	0	3254	437
May	522	0	3259	437
June	581	0	3113	418
July	649	0	3400	456
August	586	0	3119	418
September	557	0	3254	437
October	434	0	3400	456
November	306	0	2973	399
December	310	0	3400	456
Total	**5240**	**0**	**38653**	**5186**

Figure 5. Monthly Air System Simulation Report – VAV System

Just like with the plant reports, graphs are a powerful tool to analyze the system simulation results. Up to three variables may be graphed together provided they all have the same units of measure. As an example, Figure 6 shows the preheat coil, central cooling coil and terminal reheat coil loads all graphed for the month of July.

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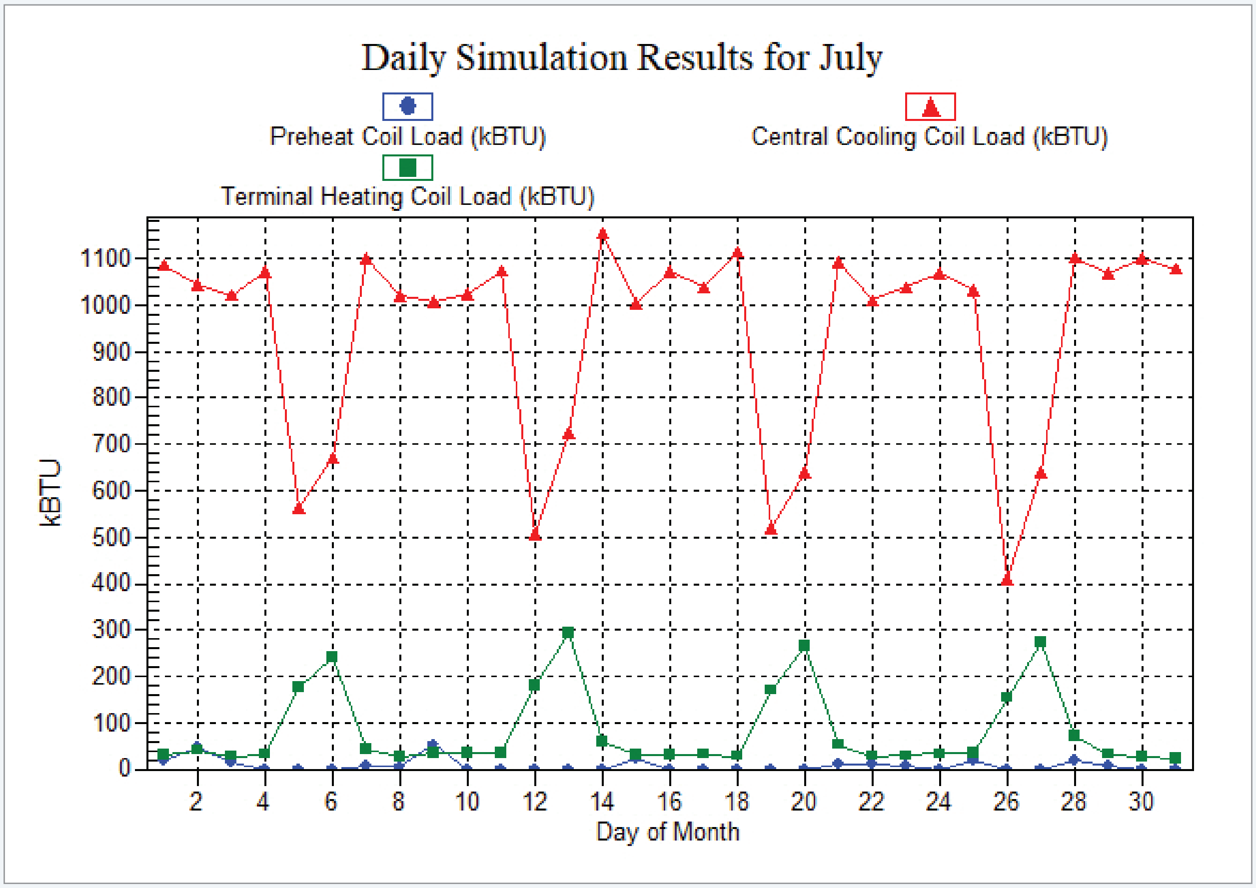

Figure 6. System Simulation Report – Preheat Coil, Central Cooling Coil & Terminal Reheat Coil Loads for July

The graph indicates that terminal reheat coil loads occur as the cooling coil loads decrease, the VAV boxes go to minimum position and the reheat coils are energized. The four pronounced dips in the central cooling load are again due to a weekend setback schedule. You should get in the habit of reviewing these sorts of reports to look for any anomalies in the system operation over the year.

Typical examples of possible anomalies: *why is cooling happening in winter* or *why is the preheat coil operating in summer? How might we reduce the amount of terminal reheat required in July?* As mentioned previously, a cooling supply air reset control strategy may be considered, provided the resulting room relative humidity does not increase beyond the desired upper range (~60%), a real possibility in Houston, TX.

There are two additional system simulation reports we shall look at: the Unmet Loads Report and the Zone Temperature Report. As with the Plant Report the unmet loads for the system indicate all hours where the system capacity is insufficient to meet the loads. In this particular case there are a few of hours in winter where the preheat coil is slightly undersized, as shown in Figure 7. Seventeen hours out of 1642 total heating load hours (~ 1%) is nothing to be concerned about. Had these unmet load hours been more severe we would need to investigate further.

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Unmet Load Report for VAV AREA A (CHW)

Project Name: EXchange 6-4 Project 07/05/2018
Prepared by: Carrier 07:34PM

Note: Data shown in this report is for diagnostic purposes only. Values represent total unmet hours for each cooling and/or heating unit. No deductions are made when unmet hours for one unit coincide with those in another unit.

1. Unmet Load Statistics - Preheat Unit - Combustion

Month	Equipment Capacity is Sufficient (hrs)	Capacity Insufficient by 0%-5% (hrs)	Capacity Insufficient by 5%-10% (hrs)	Capacity Insufficient by >10% (hrs)	Total Hours with Unmet Loads	Total Hours with Equipment Loads
January	255	3	3	3	9	264
February	236	0	0	0	0	236
March	210	0	0	0	0	210
April	154	0	0	0	0	154
May	77	0	0	0	0	77
June	27	0	0	0	0	27
July	21	0	0	0	0	21
August	23	0	0	0	0	23
September	45	0	0	0	0	45
October	132	0	0	0	0	132
November	179	0	0	0	0	179
December	266	5	1	2	8	274
Total	**1625**	**8**	**4**	**5**	**17**	**1642**

Figure 7. System Simulation Report – Unmet Loads

Unmet loads can occur for several reasons:

1. The gross capacity of the heating or cooling equipment is less than the maximum loads imposed on the equipment. Examine graphs of hourly coil loads to identify the maximum coil load. Then compare this against the gross capacity specified for the equipment.

2. The gross capacity for auxiliary heating equipment used with air source heat pumps and water source heat pump systems may be insufficient to meet the design heating load. Double-check the inputs for auxiliary heaters.

3. For air-cooled DX cooling equipment, maximum load may occur at a temperature warmer than the equipment design temperature. Because cooling capacity decreases as condensing temperature rises, large loads occurring at temperatures above the design temperature may result in insufficient capacity. Use the Simulation Weather Summary report (available in HAP) to identify maximum summer temperatures and then examine cooling loads at these times. Additional capacity (or an over-sizing factor) may be needed to accommodate these operating conditions. Because the unmet loads report is an energy simulation report it utilizes 8760 hr simulation weather, not the design load weather. In some instances, simulation weather can be more extreme (hotter or colder) than the design weather, therefore without the use of an oversizing factor it is possible to have unmet loads even when using "auto-sizing". This is normal, especially in hot climates.

4. A minimum cutoff temperature prevents air-cooled DX cooling equipment from operating during hours when cooling coil loads occur. These conditions will typically appear as hours in the "Insufficient by >10%" column in the colder months of the year. One solution is to specify low temperature (head pressure control) operation for the DX unit. Another solution is to add an outdoor air economizer to eliminate cooling loads at outdoor temperatures below the DX equipment cutoff temperature.

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In addition to these tips, Carrier provides three HAP e-Help articles to further assist you with identifying and reducing unmet load hours. These e-Helps are located on the eDesign support web page. Look for e-Helps 019, 020 & 021.

Zone temperature reports are the final simulation report we will look at. The Zone Temperature Report provides statistics about air temperatures in zones served by the air system. This data is useful for identifying control problems during the simulation such as when the system is unable to maintain comfort conditions. It is also useful for identifying maximum and minimum temperature levels in conditioned areas. An example report is shown in Figure 8 below.

Zone Temperature Report for VAV AREA A (CHW)

Project Name: EXchange 6-4 Project
Prepared by: Carrier

07/05/2018
07:57PM

1. Zone Temperature Statistics

Zone Name	Occ Max Zone Temp (°F)	Occ Hours More Than 5.0 °F Above Throt. Range	Occ Hours 1.0 to 5.0 °F Above Throt. Range	Occ Cooling Setpoint plus Throt. Range (°F)	Occ Hours Within Throt. Range or Dead-band	Occ Heating Setpoint minus Throt. Range (°F)	Occ Hours 1.0 to 5.0 °F Below Throt. Range	Occ Hours More Than 5.0 °F Below Throt. Range	Occ Min Zone Temp (°F)	Unocc Max Zone Temp (°F)	Unocc Cooling Setpoint plus Throt. Range (°F)	Unocc Heating Setpoint minus Throt. Range (°F)	Unocc Min Zone Temp (°F)
FCU-A-01	77.6	0	22	76.5	3371	68.5	0	0	69.7	80.2	81.5	63.5	68.9
FCU-A-02	77.0	0	0	76.5	3393	68.5	0	0	69.7	80.2	81.5	63.5	68.5
FCU-A-03	77.1	0	0	76.5	3393	68.5	0	0	69.0	80.3	81.5	63.5	64.7
FCU-A-04	77.1	0	0	76.5	3393	68.5	0	0	69.0	80.3	81.5	63.5	64.7
FCU-A-05	77.0	0	0	76.5	3393	68.5	0	0	69.7	80.2	81.5	63.5	68.5
FCU-A-06	77.4	0	0	76.5	3393	68.5	0	0	69.7	80.2	81.5	63.5	68.9
FCU-A-07	77.1	0	0	76.5	3393	68.5	0	0	69.0	80.2	81.5	63.5	64.8
FCU-A-08	77.3	0	0	76.5	3393	68.5	0	0	69.7	80.2	81.5	63.5	69.0
FCU-A-09	77.2	0	0	76.5	3393	68.5	0	0	69.5	80.2	81.5	63.5	67.3
FCU-A-10	77.2	0	0	76.5	3393	68.5	0	0	69.5	80.2	81.5	63.5	67.3
FCU-A-13	77.5	0	1	76.5	3392	68.5	0	0	69.6	80.1	81.5	63.5	66.0
FCU-A-11	77.2	0	0	76.5	3393	68.5	0	0	69.5	80.2	81.5	63.5	67.3
FCU-A-12	76.8	0	0	76.5	3393	68.5	0	0	75.0	80.5	81.5	63.5	76.1
FCU-A-14	77.9	0	44	76.5	3349	68.5	0	0	68.8	80.5	81.5	63.5	65.1

Note: For any occupied hours in which cooling is unavailable or scheduled off, zone temperature out of range statistics are not reported.
Note: For any occupied hours in which heating is unavailable or scheduled off, zone temperature out of range statistics are not reported.

Figure 8. System Simulation Report – Zone Temperatures

The zone temperatures look pretty good with the exception of the first and last zone. The cooling thermostat occupied period setpoint is 75F with a 1.5F degree throttling range so the system tries to maintain the zones at 76.5F or less. In our case most zones are trending a bit outside this range by less than a degree or so; however the first zone is 1.1F and the last zone is 1.4F degrees above the desired cooling control range. Because this is only 66 hours out of 3393 (<2%) of the occupied cooling hours, it might be insignificant. Should you desire to bring these zone temperatures a bit lower you would need to figure out if these 66 hours occur during a pulldown cycle (the first hours of occupancy after a night setup schedule) or if these hours occur at a different time. One quick way to tell if it is due to pulldown loads is to start the occupied thermostat schedule one or two hours earlier and see what effect that has, if any, on reducing these zone temperatures. If no effect it is unlikely due to pulldown loads. The e-Help articles mentioned previously provide additional steps to troubleshoot unmet load hours and out-of-range zone temperatures.

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As with unmet loads, the zone temperature report is an energy simulation report, not a design load report, and utilizes 8760 hr simulation weather, which may be more extreme (hotter or colder) than design load weather used for equipment sizing purposes. Design airflow quantities are determined using design weather data, not simulation weather data, so it is possible to have a few zone temperature hours off-target. This is normal and the maximum or minimum zone temperature is usually very close to target.

So, to summarize, you should become intimately familiar with the HAP diagnostics reports to verify simulation performance for systems, plants and buildings. We hope this discussion has given you some tips and pointers to verify that your system performance results are reasonable and functioning as intended.

Frequently Asked Questions

FAQ #1: Why is there no cooling system psychrometric report available for a CAV - Make-up Air / DOAS unit? And are there any other systems that we cannot display a psychrometric report for?

Answer: A CAV - MAU/DOAS is very different from all other systems in the program and as a result it has a few quirks; this is one. When you check the peak box that is telling HAP to find the month/hour when the largest "central cooling coil" load occurs (or in the case of terminal units, the maximum coincident load on terminal fan coil units). A CAV - MAU/DOAS system does not have what is classified as a "central cooling coil" or a "terminal cooling coil" so when you check the "peak" box it says there is no peak load because you don't have these coils. Hence, certain printouts affected by the peak box lack data. While a CAV - MAU/DOAS system can have a cooling coil, that is classified internally as a "precool" coil — a cooling coil controlled by a duct thermostat instead of a room thermostat. The algorithm behind the peak box doesn't look at loads for this coil. When you are on the Air System Sizing Summary it is showing you peaks for individual components — peak for the fan, peak for the cooling coil (precool), peak for the heating coil (preheat coil), etc. That report can show you July 1600 is the peak for the cooling coil. What is needed is extra reporting logic that says "if this is a CAV - MAU/DOAS system look at the month/hour of the peak of the precool coil" to determine how to handle the peak box selection. That feature is planned for a future update to HAP.

The other system type that won't display a psychrometric graph is the ***Terminal Units*** class of systems. In those systems you essentially have up to 100 Terminal Units (the zone FCUs or WSHPs) in the system, sometimes interconnected with a DOAS unit. If we tried to plot this quantity of data it would be overwhelming and unreadable.

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FAQ #2: I am trying to control the humidity level in the zones on a WSHP terminal unit system to maintain between 35-55% RH. The WSHP terminals are served by a DOAS delivering air at 60F without any latent (passive dehumidification) control. How do I model this?

Answer: Set up a WSHP system with DOAS unit with DOAS cooling coil set to 60F. If active humidity control is not used on the DOAS system then do not check the Dehumidification checkbox, just set the cooling coil on the DOAS to 60F. As far as having "active" humidity control on the WSHP terminal units, this is not possible. These systems are typically controlled from a room thermostat that measures DB only.

To achieve passive humidity control you must use a trial-and-error approach. As a first pass assume a reasonable cooling coil LAT off the WSHP units, in the range of 55-57F, then run the psychrometrics report. This will show you the resulting specific humidity in the zones (Figure 1).

System Psychrometrics for WSHP DOAS

Project Name: WSHP Hotel 04/13/2018
Prepared by: Carrier 08:23AM

July DESIGN COOLING DAY, 1800

TABLE 1: SYSTEM DATA

Component	Location	Dry-Bulb Temp (°F)	Specific Humidity (lb/lb)	Airflow (CFM)	CO2 Level (ppm)	Sensible Heat (BTU/hr)	Latent Heat (BTU/hr)
Ventilation Air	Inlet	89.0	0.01458	2063	400	26188	32749
Vent - Return Mixing	Outlet	89.0	0.01458	2063	0	-	-
Vent. Cooling Coil	Outlet	58.9	0.01013	2063	400	65422	42556
Vent. Heating Coil	Outlet	58.9	0.01013	2063	400	0	-
Ventilation Fan	Outlet	60.0	0.01013	2063	400	2293	-
Cold Supply Duct	Outlet	60.0	0.01013	2063	400	0	-
Zone Air	-	76.3	0.01109	2063	1079	212096	18000
Return Plenum	Outlet	76.3	0.01109	2063	1079	0	-
Exhaust Fan	Outlet	77.0	0.00000	2063	1079	1529	-

Figure 1. System Psychrometrics Report – Zone Conditions for 57F Coil LAT

A quick glance at a psych chart will show you the resulting room RH%, which is at the intersection point of the DB and the specific humidity axes. Here is an example for a WSHP system assuming 60F off the DOAS unit and 57F coil LAT on the WSHP unit (Figure 2):

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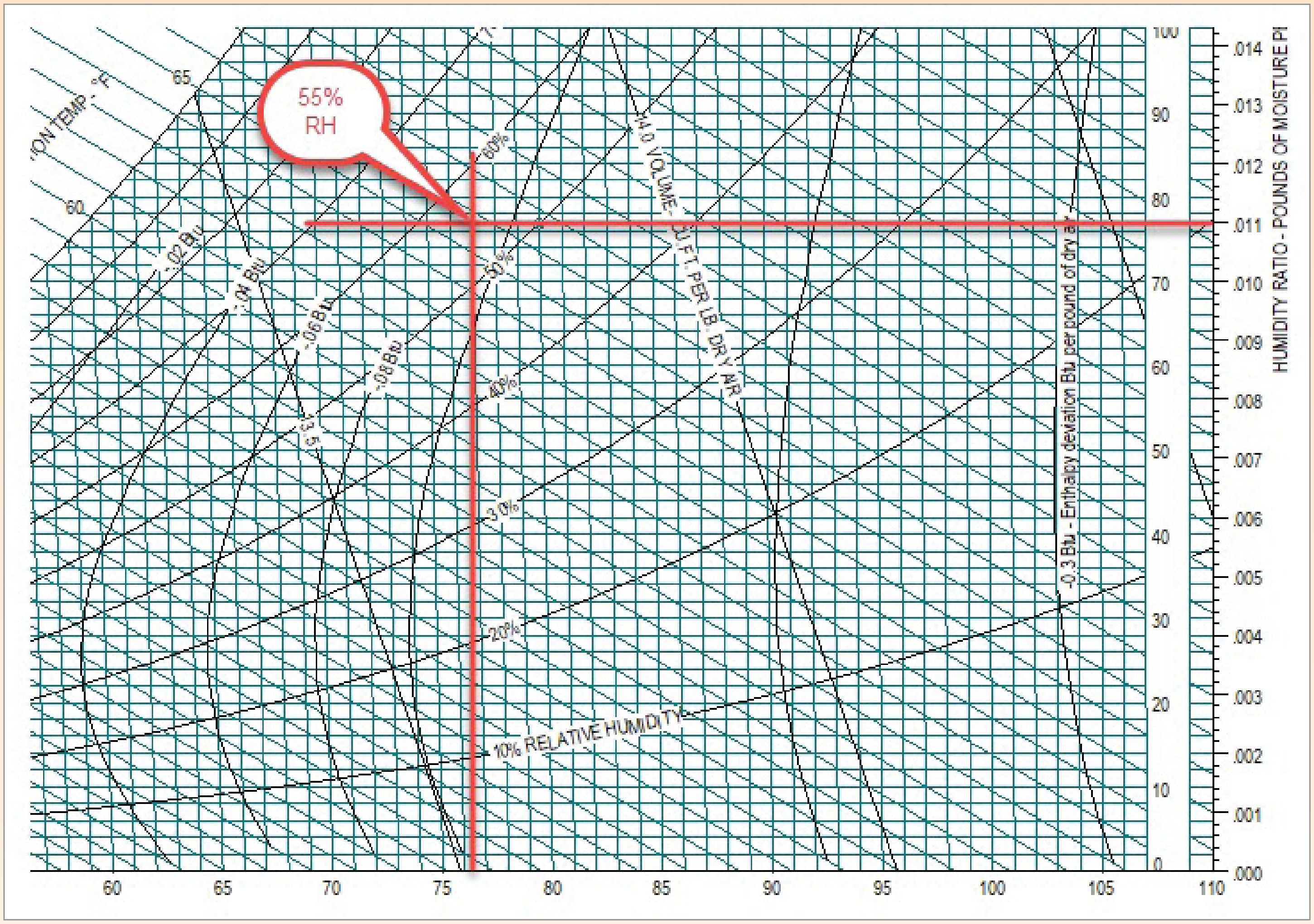

Figure 2. System Psychrometrics Plot – Zone Conditions for 57F Coil LAT

This assumed cooling coil LAT of 57F results in a zone RH of 55%, which is at the upper limit of your desired range of 35-55%. To reduce the RH further go back and reduce the WSHP cooling coil LAT down to 56 or 55F.

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Changing the WSHP cooling coil LAT to 55F and recalculating:

System Psychrometrics for WSHP DOAS

Project Name: WSHP Hotel 04/13/2018
Prepared by: Carrier 08:32AM

July DESIGN COOLING DAY, 1700

TABLE 1: SYSTEM DATA

Component	Location	Dry-Bulb Temp (°F)	Specific Humidity (lb/lb)	Airflow (CFM)	CO2 Level (ppm)	Sensible Heat (BTU/hr)	Latent Heat (BTU/hr)
Ventilation Air	Inlet	90.4	0.01458	2063	400	29384	40190
Vent - Return Mixing	Outlet	90.4	0.01458	2063	0	-	-
Vent. Cooling Coil	Outlet	58.9	0.01008	2063	400	68405	43019
Vent. Heating Coil	Outlet	58.9	0.01008	2063	400	0	-
Ventilation Fan	Outlet	60.0	0.01008	2063	400	2293	-
Cold Supply Duct	Outlet	60.0	0.01008	2063	400	0	-
Zone Air	-	76.2	0.01037	2063	1079	212762	18000
Return Plenum	Outlet	76.2	0.01037	2063	1079	0	-
Exhaust Fan	Outlet	76.9	0.00000	2063	1079	1529	-

Figure 3. System Psychrometrics Report – Zone Conditions for 55F Coil LAT

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Re-plotting the psych state points:

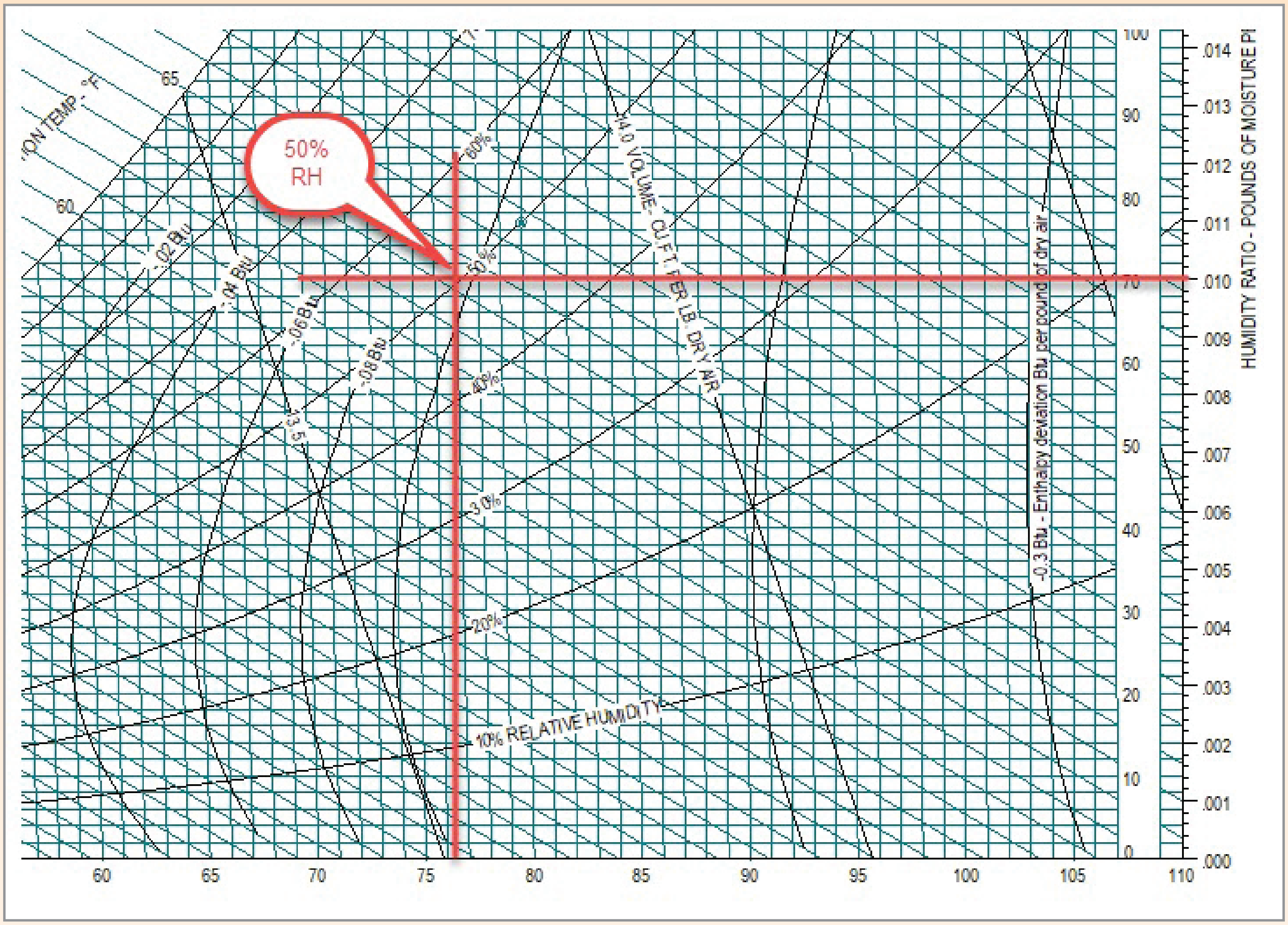

Figure 4. System Psychrometrics Plot – Zone Conditions for 55F Coil LAT

Lowering the WSHP cooling coil LAT from 57 to 55F resulted in a 5% reduction in zone RH, down to 50%.

Keep in mind that the WSHP equipment you actually select and install must be capable of cooling the supply air down to 55F. Many small DX units have a difficult time producing supply air this cold, so be sure your selected and installed terminal unit equipment can meet your assumed design conditions. If you find that your terminal unit equipment cannot deliver air this cold (and dry), your only option is to apply an active humidity control to the OA such that the OA is further dehumidified to a point such that it is delivered at room-neutral conditions (75F/50% RH). This ensures that the OA does not impose an additional latent load on the zones.

In some cases, it may even be desirable to deliver the OA drier than the room RH such that the OA offsets some of the zone latent loads resulting in acceptable zone relative humidity levels.

Upcoming eDesign Suite Training Classes

Location	**Load Calculation for Commercial Buildings** *System Design Load HAP*	**Energy Simulation for Commercial Buildings** *HAP*	**Energy Modeling for LEED® Energy & Atmosphere Credit 1** *HAP*	**Advanced Modeling Techniques for HVAC Systems** *HAP*	**Engineering Economic Analysis** *EEA*	**Block Load Basic** *Block Load*
Toronto, ON	Dec 4	Dec 5	—	Dec 6	—	—
New York City, NY	Dec 11	Dec 12	—	Dec 13	—	—
Chicago, IL	Jan 28	Jan 29	—	Jan 30	—	—
Denver, CO*	Jan 29	Jan 30	—	Jan 31	—	—
Charlotte, NC	Mar 12	Mar 13	—	Mar 14	—	—
Dallas, TX	Apr 30	May 1	—	May 2	—	—

This schedule is current as of November 26, 2018. Additional classes are continually being added and scheduled, including the 2019 locations. Please click here to check for updated schedules. Item marked with * has been updated since 11/19/18.

Click here to **REGISTER FOR UPCOMING CLASSES.**

eDesign Suite Software Current Versions (North America)		
Program Name	**Current Version**	**Functionality**
HAP — Hourly Analysis Program (HAP)	v5.11	Peak load calculation, system design, whole building energy modeling, LEED® analysis
BSO — Building System Optimizer	v1.60	Rapid building energy modeling for schematic design
BLK — Block Load	v4.16	Peak load calculation, system design
EEA — Engineering Economic Analysis	v3.06	Lifecycle cost analysis
RPD — Refrigerant Piping Design	v5.00	Refrigerant line sizing
SDL — System Design Load	v5.11	Peak load calculation, system design

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Carrier University
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