Reducing LEED Unmet Load Hours in HAP v4.5

1. Introduction

This e-Help describes a systematic approach for efficiently reducing LEED unmet load hours that appear in the "Section 1.3 - Advisory Messages" portion of the LEED EA Credit 1 Summary Report.

A companion e-Help titled *Understanding LEED Unmet Load Hours in HAP v4.5* describes the principles used to compile LEED unmet load hours. Readers are encouraged to review this companion e-Help. Understanding those principles is essential to effective use of the diagnostic procedures in this e-Help.

2. Overview

In HAP's LEED EA Credit 1 Summary Report, the "Section 1.3 - Advisory Messages" lists the unmet heating and cooling load hours for the Proposed and Baseline buildings (Figure 1). This data is used to demonstrate compliance with the Performance Rating Method rules that neither the Proposed nor Baseline building can have more than 300 total unmet load hours, and the Proposed unmet load hours cannot exceed the Baseline by more than 50 hours. When either of these limits is exceeded, the energy model must be adjusted to reduce unmet load hours to bring them within the required limits. Often excessive unmet load hours indicate a problem with the energy model, and correcting the problem will improve quality of the results.

Advisory Messages

	Proposed Building	Baseline Building (0 deg. rotation)	Difference
Number of hours heating loads not met	870	31	+839
Number of hours cooling loads not met	647	38	+609

Figure 1. Advisory Messages Section from LEED EA Credit 1 Summary Report

A systematic approach for identifying the causes of excessive unmet load hours and then correcting the problems is described in the following sections:

- **Section 3 - Quick Start** provides a concise summary of the steps in the procedure. This section is useful for readers highly proficient with HAP operating concepts and for those already familiar with the procedure who are seeking a refresher.

- **Section 4 - Procedure Discussion** explains each step in the procedure. The basic concept behind each step, the specific tasks to complete the step and an example applying these principles are all provided in this section. This section is useful for those learning about the procedure for the first time.
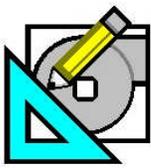
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3. Quick Start

The key steps in the diagnostic procedure are shown below. More extensive discussions of each step in the procedure plus an example problem are provided in section 4.

#	Task
1	Identify Problem Scope: *a. Generate LEED EA Credit 1 Summary Report and inspect "Section 1.3 - Advisory Messages".* *b. Determine whether Proposed building requires attention for cooling and/or heating.* *c. Determine whether Baseline building requires attention for cooling and/or heating.*
Perform steps 2-5 once for Proposed building and once for Baseline 0-degree building as required.	
2	Identify Individual Air Systems and Plants Responsible for the Unmet Loads *a. Identify the plants and air systems included in the building.* *b. Identify which plants are contributing to the problem. Inspect Unmet Load Report for each plant.* *c. Identify which air systems are contributing to the problem. Inspect Unmet Load Report for each system. Inspect Zone Temperature Report for each air system.*
3	Evaluate and Resolve Air System Air-Side Problems Identified in Step #2 *Using the Zone Temperature Report for each air system showing problems:* *a. Identify which zones require attention* *b. Identify the magnitude of problem.* *c. Identify relevant zone and system characteristics.* *d. Combine findings from (a) thru (c) to formulate and implement corrective action.*
4	Evaluate and Resolve Air System Equipment-Side Problems Identified in Step #2 *Using the Unmet Load Report for each air system showing problems:* *a. Identify which equipment component or components require attention.* *b. Identify the maximum equipment load occurring during the simulation.* *c. Determine the equipment design capacity.* *d. Determine when unmet loads occur. Identify patterns or causes.* *e. Combine findings from (a) thru (d) to formulate and implement corrective action.*
5	Evaluate and Resolve Plant Equipment-Side Problems Identified in Step #2 *Using the Unmet Load Report for each plant showing problems:* *a. Identify the maximum plant load occurring during the simulation* *b. Determine the plant design capacity.* *c. Determine when unmet loads occur. Identify patterns or causes.* *d. Combine findings from (a) thru (c) to formulate and implement corrective action.*
Perform step 6 if any changes were made to the Baseline 0-deg building in preceding steps	
6	Synchronize Baseline Building 90-deg, 180-deg, 270-deg Data with any Changes Made to Baseline 0-deg Building *a. Erase all existing input data for 90-deg, 180-deg and 270-deg versions of Baseline building.* *b. Use "Perform LEED (90.1 PRM) Rotations" option to regenerate 90-deg, 180-deg and 270-deg Baseline buildings.*

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4. Procedure Discussion

Steps in the diagnostic procedure are discussed below. For each step the basic concept, the individual tasks required and an example problem are provided.

Step 1 - Identify Problem Scope

Concept: Efficiently resolving unmet load hour problems depends on isolating the specific zones, air systems or plants causing the problems. First evaluate the Proposed and Baseline buildings for cooling and heating issues. For example, if the Baseline building has minimal or no unmet load hours, there is no reason to spend any time looking at Baseline building zones, systems or plants.

Tasks:

a. Generate the LEED EA Credit 1 Summary Report and inspect "Section 1.3 - Advisory Messages".

b. Determine whether the Proposed building requires attention:

Proposed building requires attention if:	Cooling + heating unmet load hours for Proposed > 300
	OR Proposed cooling unmet hrs - Baseline cooling unmet hrs > 50
	OR Proposed heating unmet hrs - Baseline heating unmet hrs > 50
Cooling performance can be ignored if:	Quantity of cooling unmet load hours is small or zero.
Heating performance can be ignored if:	Quantity of heating unmet load hours is small or zero.

c. Determine whether the Baseline building requires attention:

Baseline building requires attention if:	Cooling + heating unmet load hours for Baseline > 300
Cooling performance can be ignored if:	Quantity of cooling unmet load hours is small or zero.
Heating performance can be ignored if:	Quantity of heating unmet load hours is small or zero.

Note: If the Baseline building requires revision, remember we are dealing specifically with the 0-degree version of the Baseline building, typically denoted with the prefix [B000] for building, system, plant and space names.

Example:

a. Generate LEED EA Credit 1 Summary Report and inspect "Section 1.3 - Advisory Messages". See Figure 2 below.

Advisory Messages

	Proposed Building	Baseline Building (0 deg. rotation)	Difference
Number of hours heating loads not met	870	31	+839
Number of hours cooling loads not met	647	38	+609

Figure 2. Advisory Messages Section from LEED EA Credit 1 Summary Report

b. Evaluate Proposed building unmet loads.

Conclusion: The Proposed building requires further study. The sum of cooling and heating unmet load hours exceeds 300 and both cooling and heating hours exceed the Baseline building hours by more than 50. Significant unmet hours exist for both cooling and heating so both aspects of HVAC operation will need to be investigated.

c. Evaluate Baseline building unmet loads.

Conclusion: The Baseline building will not require further study. Its unmet load hours for both cooling and heating are well below the 300 hour limit permitted by the Performance Rating Method.

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Perform Steps 2-5 once for Proposed building and once for Baseline 0-deg building as required.

Step 2 - Identify the Air Systems and/or Plants Responsible for the Unmet Loads.

Concept: To narrow the focus further, next identify individual air systems and plants that are responsible for the unmet loads. If you are lucky, problems are isolated in a single system or plant, making your work easy. As noted in the companion e-Help *Understanding LEED Unmet Load Hours in HAP v4.5*, unmet load hours can be caused by air-side modeling problems indicated on the Zone Temperature Report, or can be caused by equipment-side problems indicated on the Unmet Load Reports for air systems or plants.

Tasks:

a. Identify the plants and air systems included in the building.
   - A fast way to do this is to print the input report for the building. It lists all plants and air systems linked to the building.

b. Identify which plants are contributing to the problem.
   - Generate the Unmet Load Report for each plant included in the building.
   - If the report shows unmet load hours, then print the report. The plant needs to be studied further and the report will provide important data in step #5 guiding this evaluation.
   - If the report shows no unmet load hours, then the plant can be eliminated from consideration.

c. Identify which air systems are contributing to the problem
   - Generate the Zone Temperature and Unmet Load Reports for each air system included in the building.
   - If the Unmet Load Report shows unmet load hours, print the report. The air system needs to be evaluated further and the report will provide important data in step #4 for this evaluation.
   - If the Zone Temperature Report shows zone temperatures out of range, then print the report. The air system needs to be evaluated further and the report will provide important data in step #3 to guide this evaluation.
   - If there are no zone temperatures out of range and no unmet load hours, the air system can be eliminated from consideration.

Example:

a. Identify plants and air systems included in the building.

Discussion: The Building Input report was generated for the Proposed building. An excerpt from this report (see Figure 3) shows the building includes one hot water plant and three RTU air systems..

2. Plants Included in this Building:

| Plant Name |
| --- |
| Boiler Plant |

3. Air Systems Included in this Building:

System Name	Mult.
RTU-3	1
RTU-2	1
RTU-1	1

Figure 3. Excerpt from Building Input Report

b. Identify which plants are contributing to the problem.

Discussion: Generate the Unmet Load Report for the "Boiler Plant". This report (see Figure 4) shows no unmet load hours. Therefore, there are no hot water boiler plant equipment-side problems contributing to LEED unmet load hours.

Conclusion: The "Boiler Plant" is not the cause of the problems and does not require further study.
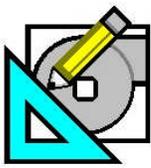
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1. Unmet Load Statistics

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	578	0	0	0	0	578
February	453	0	0	0	0	453
March	420	0	0	0	0	420
April	144	0	0	0	0	144
May	9	0	0	0	0	9
June	0	0	0	0	0	0
July	0	0	0	0	0	0
August	0	0	0	0	0	0
September	0	0	0	0	0	0
October	129	0	0	0	0	129
November	416	0	0	0	0	416
December	577	0	0	0	0	577
Total	2726	0	0	0	0	2726

Figure 3. Unmet Load Hours for Hot Water Boiler Plant

c. Identify which air systems are contributing to the problem.

Discussion: First generate the Unmet Load Reports the RTU-1, RTU-2 and RTU-3 air systems. These reports are shown in Figures 4a thru 4c. There are no unmet loads for the combustion preheater in any of the three RTU systems. While RTU-1 and RTU-2 show a small number of unmet loads for the air-cooled DX cooling equipment, the quantity of unmet loads is small enough it does not require attention. Therefore, it is not necessary to further evaluate equipment-side issues for the air systems.

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	164	0	0	0	0	164
February	115	0	0	0	0	115
March	87	0	0	0	0	87
April	42	0	0	0	0	42
May	14	0	0	0	0	14
June	0	0	0	0	0	0
July	0	0	0	0	0	0
August	0	0	0	0	0	0
September	0	0	0	0	0	0
October	58	0	0	0	0	58
November	112	0	0	0	0	112
December	154	0	0	0	0	154
Total	746	0	0	0	0	746

2. Unmet Load Statistics - Central Cooling Unit - Air-Cooled DX

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	8	0	0	0	0	8
February	11	0	0	0	0	11
March	29	0	0	0	0	29
April	122	0	0	0	0	122
May	314	0	0	0	0	314
June	460	0	0	0	0	460
July	628	0	0	0	0	628
August	503	0	1	1	2	505
September	322	0	0	0	0	322
October	124	0	0	0	0	124
November	14	0	0	0	0	14
December	4	0	0	0	0	4
Total	2539	0	1	1	2	2541

Figure 4a. RTU-1 Unmet Load Report

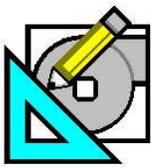1. Unmet Load Statistics - Preheat Unit - Combustion

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	173	0	0	0	0	173
February	117	0	0	0	0	117
March	92	0	0	0	0	92
April	46	0	0	0	0	46
May	14	0	0	0	0	14
June	0	0	0	0	0	0
July	0	0	0	0	0	0
August	0	0	0	0	0	0
September	0	0	0	0	0	0
October	60	0	0	0	0	60
November	118	0	0	0	0	118
December	159	0	0	0	0	159
Total	779	0	0	0	0	779

2. Unmet Load Statistics - Central Cooling Unit - Air-Cooled DX

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	8	0	0	0	0	8
February	18	0	0	0	0	18
March	51	0	0	0	0	51
April	160	0	0	0	0	160
May	386	0	0	0	0	386
June	518	0	0	0	0	518
July	667	6	0	0	6	673
August	599	5	1	2	8	607
September	436	0	0	0	0	436
October	195	0	0	0	0	195
November	18	0	0	0	0	18
December	4	0	0	0	0	4
Total	3060	11	1	2	14	3074

Figure 4b. RTU-2 Unmet Load Report

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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	130	0	0	0	0	130
February	75	0	0	0	0	75
March	36	0	0	0	0	36
April	4	0	0	0	0	4
May	0	0	0	0	0	0
June	0	0	0	0	0	0
July	0	0	0	0	0	0
August	0	0	0	0	0	0
September	0	0	0	0	0	0
October	7	0	0	0	0	7
November	58	0	0	0	0	58
December	129	0	0	0	0	129
Total	**439**	**0**	**0**	**0**	**0**	**439**

Figure 4c. RTU-3 Unmet Load Report

2. Unmet Load Statistics - Central Cooling Unit - Air-Cooled DX

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	25	0	0	0	0	25
February	48	0	0	0	0	48
March	107	0	0	0	0	107
April	256	0	0	0	0	256
May	537	0	0	0	0	537
June	632	0	0	0	0	632
July	732	0	0	0	0	732
August	684	0	0	0	0	684
September	578	0	0	0	0	578
October	286	0	0	0	0	286
November	40	0	0	0	0	40
December	16	0	0	0	0	16
Total	**3941**	**0**	**0**	**0**	**0**	**3941**

Figure 4c. RTU-3 Unmet Load Report (continued)

Next, generate the Zone Temperature Reports for the three air systems. These reports are shown in Figure 5a thru 5c.

The report for RTU-1 shows a no cooling hours out of range and a relatively small number of heating hours out of range. Only heating performance may need attention for this system.

The report for RTU-2 shows a large number of cooling hours out of range for one zone, and a relatively small number of heating hours out of range for several zones. Cooling performance will definitely need attention. Heating performance may need attention.

Finally, the report for RTU-3 shows a large number of heating hours out of range for two zones. A small to moderate number of cooling hours out or range exist for several zones. Heating performance will definitely need attention in this system. Cooing performance may need attention.

Overall Conclusion: This review of the plant and air system reports indicates that LEED unmet load hours are almost entirely due to air-side issues. The majority of the hours appear to come from just three zones.

1. Zone Temperature Statistics

Zone Name	Occ Max Zone Temp (°F)	Occ Hours > 5.0 °F Above Throt. Range	Occ Hours 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 0 to 5.0 °F Below Throt. Range	Occ Hours > 5.0 °F Below Throt. Range	Occ Min Zone Temp (°F)
Zone 1	75.8	0	0	76.5	3079	68.5	0	0	68.6
Zone 2	75.6	0	0	76.5	3079	68.5	0	0	68.6
Zone 3	75.8	0	0	76.5	3079	68.5	0	0	68.8
Zone 4	75.8	0	0	76.5	3078	68.5	1	0	68.2
Zone 5	76.4	0	0	76.5	3054	68.5	25	0	66.8
Zone 6	75.7	0	0	76.5	3056	68.5	23	0	66.3
Zone 7	75.5	0	0	76.5	3036	68.5	43	0	66.2

Figure 5a. RTU-1 Zone Temperature Report

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1. Zone Temperature Statistics

Zone Name	Occ Max Zone Temp (°F)	Occ Hours > 5.0 °F Above Throt. Range	Occ Hours 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 0 to 5.0 °F Below Throt. Range	Occ Hours > 5.0 °F Below Throt. Range	Occ Min Zone Temp (°F)
Zone 8	76.3	0	0	76.5	3055	68.5	24	0	66.9
Zone 9	79.3	0	612	76.5	2447	68.5	20	0	67.3
Zone 10	80.9	0	3	76.5	3076	68.5	0	0	69.7
Zone 12	75.6	0	0	76.5	3027	68.5	52	0	65.5
Zone 13	78.8	0	3	76.5	3073	68.5	3	0	67.9
Zone 14	75.3	0	0	76.5	3021	68.5	58	0	66.2
Zone 15	75.5	0	0	76.5	3011	68.5	68	0	66.1
Zone 16	75.5	0	0	76.5	3030	68.5	49	0	66.3
Zone 17	75.7	0	0	76.5	3030	68.5	49	0	66.3
Zone 18	75.6	0	0	76.5	3039	68.5	40	0	66.3
Zone 19	75.5	0	0	76.5	3015	68.5	64	0	66.2
Zone 20	75.6	0	0	76.5	3079	68.5	0	0	68.5
Zone 21	82.7	1	2	76.5	3072	68.5	4	0	67.8
Zone 22	76.2	0	0	76.5	3079	68.5	0	0	68.6
Zone 23	76.1	0	0	76.5	3079	68.5	0	0	68.6
Zone 24	76.1	0	0	76.5	3077	68.5	2	0	68.0
Zone 25	75.9	0	0	76.5	3065	68.5	14	0	67.3
Zone 26	77.0	0	2	76.5	3077	68.5	0	0	68.6
Zone 27	75.5	0	0	76.5	3034	68.5	45	0	66.2
Zone 28	75.2	0	0	76.5	3032	68.5	47	0	66.4

Figure 5b. RTU-2 Zone Temperature Report

1. Zone Temperature Statistics

Zone Name	Occ Max Zone Temp (°F)	Occ Hours > 5.0 °F Above Throt. Range	Occ Hours 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 0 to 5.0 °F Below Throt. Range	Occ Hours > 5.0 °F Below Throt. Range	Occ Min Zone Temp (°F)
Zone 29	79.4	0	27	76.5	3052	68.5	0	0	69.2
Zone 30	84.7	18	14	76.5	3047	68.5	0	0	75.1
Zone 31	84.7	18	14	76.5	3047	68.5	0	0	75.1
Zone 32	80.1	0	32	76.5	3047	68.5	0	0	72.8
Zone 33	80.8	0	24	76.5	3055	68.5	0	0	69.0
Zone 34	80.8	0	23	76.5	3056	68.5	0	0	68.9
Zone 35	80.9	0	32	76.5	3047	68.5	0	0	69.4
Zone 36	84.7	4	14	76.5	2192	68.5	335	534	49.3
Zone 37	83.4	15	17	76.5	3047	68.5	0	0	70.2
Zone 38	77.8	0	15	76.5	2664	68.5	380	20	61.2
Zone 39	84.1	17	15	76.5	3047	68.5	0	0	75.0
Zone 40	84.3	18	14	76.5	3047	68.5	0	0	75.0

Figure 5c. RTU-3 Zone Temperature Report

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Step 3 - Evaluate and Resolve Air-Side Problems in Air Systems Identified in Step #2.

Concept: During Step #2, if an air system's Zone Temperature Report shows hours when zone temperatures are out of range for cooling or heating, the system has air-side operating problems. Air system data needs to be investigated to isolate and then correct the problem. The "Analytical Approach" subsection below describes a systematic approach for understanding the problem, identifying root causes and formulating solutions.

Analytical Approach:

(Repeat these tasks for each air system exhibiting air-side problems.)

a. Identify which zones require attention.

   Review the Zone Temperature Report to identify which particular zones are responsible for the majority of hours out of range or whether all zones have significant hours out of range.

   Often only one or a handful of zones in a multiple-zone system require attention to resolve unmet load problems. Further, only cooling or only heating performance may require attention. By identifying which zones and which modes of operation require attention, you can focus your analysis to resolve problems faster.

   Remember the Zone Temperature Report shows bulk hours out of range -- that is, the total number of hours out of range for each zone. This bulk number is usually far larger than the resulting unmet hours on the LEED EAc1 Summary Report due to the "coinciding hours" rule. That is, if 50 zones in a building are all out of range for the same hour, this counts as 1 LEED unmet load hour, not 50 unmet load hours. Therefore, if 49 of 50 zones in a system show 10 hours out of cooling range on the Zone Temperature Report, and one shows 100 hours out of cooling range, the zone with 100 hours is the one to focus on. If the hours in the other 49 zones coincide, its likely those zones won't add much more than 10 hours to the LEED total. Further, if the hours in the 49 zones coincide with those in the single bad zone, its possible the 49 zones add little or nothing to the LEED total. The companion eHelp titled *Understanding LEED Unmet Load Hours in HAP v4.5* explains these principles in greater detail.

b. Identify the magnitude of the problem

   For the zones identified in (a), use the Zone Temperature Report to determine the maximum occupied zone temperature for cooling problems or the minimum occupied zone temperature for heating to assess the extent of the problem. This determines whether small or large adjustments to system behavior are likely needed to eliminate hours out of range.

   Example 1: A zone has 350 hours out of cooling range. The thermostat setpoint is 76 F with a throttling range of 2 F. The maximum occupied zone temperature is 78.8 F. Out of range hours are counted when the room temperature exceeds setpoint + throttling range + 0.1 F. That means, all 350 hours out of range are between 78.1 F and 78.8 F. Therefore, it is likely a small adjustment to system characteristics for this zone will erase most or all of the out of range hours.

   Example 2: A zone has 350 hours out of cooling range. The thermostat setpoint is again 76 F with a throttling range of 2 F. The maximum occupied zone temperature is 92.1 F. This means the 350 hours out of range occur between 78.1 F and 92.1 F, a spread of 14 F. This suggests a more significant adjustment to system characteristics will be needed to erase these out of range hours.

c. Identify zone and system characteristics.

   Before formulating solutions, it is useful to think about characteristics of the air system that can affect control of zone air temperature. The following are some of the key questions to ask about the air system.

   - *What type of air system is involved?* This initiates thinking about the configuration of components and controls used to provide cooling and heating.
   - *How is cooling provided?* Identify the primary source of space cooling for the zones. This will always be forced air cooling, but could be supplied by a central air-conditioning unit or a fan coil or WSHP located in the zone. Zone load, supply airflow and supply temperature will be key elements involved in controlling zone air temperature.

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- *How is heating provided?* Identify the primary source of space heating for the zones. If the heat source is an AHU or FCU heating coil, the key factors involved will be zone load, supply airflow and supply temperature. If the heat source is a terminal reheat coil, zone load and the reheat coil capacity will be key factors. If the heat source is a parallel fan powered mixing box, the mixing box airflow, supply temperature, reheat coil capacity and zone load will be key factors. If the heat source is a zone heating unit (e.g. a baseboard unit), the zone load and heating unit capacity will be key factors.
- *How were system sizes determined?* If the "user-defined" sizing option was used, it may be important to check whether computer-generated sizing yields larger supply airflows or terminal reheat coil capacities. User-defined sizes can sometimes be insufficient to meet peak loads modeled in the building.
- *What are key setpoints?* Thermostat setpoints for occupied or unoccupied are important as they influence pulldown and warmup cycles and can affect hours out of range. Thermostat throttling range can also be important.
- What are the fan/thermostat schedules like? The length of unoccupied periods, especially extended periods occurring across weekends or holiday periods can affect the size of pulldown or warmup loads at the start of the next occupied cycle and can therefore affect hours out of range.

d. Formulate and implement solution.

Combine findings from (a) thru (c) to draw conclusions about the cause of the hours out of range. Then formulate and implement corrective action. Because hours out of range can be caused by many things, it is not possible to provide an exhaustive list to cover every specific possibility. Instead, some key issues to consider when formulating action are provided below.

Cooling Hours Out of Range

- **User-Defined Sizing** - If "user-defined" sizing was used for the system, it is possible the specified supply airflow rates are insufficient to meet peak zone loads. To test this, make a copy of the air system, change sizing back to "computer-generated" and then generate the Zone Sizing Summary report. Compare supply airflow rates on this report versus those on the Zone Sizing Summary for the original system with user-defined sizing. If "computer-generated" shows a larger supply airflow for a problem zone, it is likely cooling hours out of range are due to insufficient airflow. To solve the problem, edit the original system to increase supply airflow for that zone.

- **Pulldown Loads** - Cooling hours out of range could result from problems quickly bringing air temperatures into the zone cooling range at the start of an occupied period. This is especially likely if extended unoccupied periods such as a weekend or holiday period coincide with unusually hot and sunny weather. At the start of the next occupied cycle, the system may face an unusually large accumulation of heat in the building mass and may have trouble quickly pulling the air temperature down into the occupied operating range. Possible solutions include increasing zone supply airflow, reducing supply air temperature (while using the same supply airflows), reducing the delta-T between occupied and unoccupied setpoints, or starting the occupied period one or more hours earlier.

  A severe instance of this problem can occur if you specified cooling is not permitted during the unoccupied period. If internal loads are scheduled ON during unoccupied periods, or if unoccupied periods (such as during weekends or holidays) involve exposure to hot, sunny conditions, indoor temperatures can rise to very high levels and create extremely large pulldown loads at the start of the next occupied period. The solution is to permit cooling during unoccupied periods to reduce hours out of range. The other solutions noted in the previous paragraph may also be needed to further reduce these hours out of range.

- **Simulation Day Zone Cooling Loads Larger than Cooling Design Day Loads** - There are a number of reasons that more severe load conditions can be created on simulation days. If so, the system, which has been sized on loads for a design cooling day, may not have the airflow capacity to meet the loads and keep temperatures under control. The following can cause this:

  - Weather conditions more severe on simulation days. Compare simulation and design weather profiles to see if simulation temperature profiles are significantly warmer than design profiles. In some cases simulation weather and design weather might be mismatched. It may be necessary to increase summer design values. Or the
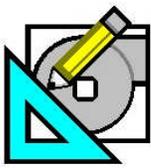
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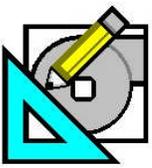
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deviation may be natural. After all a 0.4% summer design value means that 35 hours in an average year will exceed this temperature. For natural cases, the solution may be to increase supply airflow rate.

- Schedule profiles for internal loads more severe for simulation days than design days. Inspect the schedule profiles for lights, occupants, plugs and other internal gains. If the profile used on simulation days has larger values or a longer duration, that may cause loads on simulation days to exceed those on design days which were used for sizing. For example, the profile values on simulation days are at 100%, while those for design days are at 50%. Usually the solution is to correct the schedules so design day profiles will create the worst case conditions.

- Infiltration for simulation days specified as more severe than on design days. Infiltration is specified separately for cooling design, heating design and simulation days. If the infiltration value for simulation days is larger than for cooling design, more severe infiltration loads will exist for simulation days. The solution is to make the cooling design infiltration value equal to or larger than the simulation day value.

- Fan / Thermostat schedules more severe for simulation days than design days. Inspect the schedule profiles for fan/thermostat control in the air system. Generally the problem here is that the design day schedule uses a 24-hour-a-day occupied period while the occupied period on simulation days is less than 24 hours. This creates pulldown load conditions that did not exist in the design analysis. Usually the solution is to increase supply airflow rates to provide more airflow capacity to deal with the pulldown load.

- **Thermostat Throttling Range** - If you specified a very small throttling range, such as something in the range from 0.1 F or 0.5 F, the system will be more prone to hours out of range. Any excursion above design load levels may be quickly trigger hours out of range. The solution is to use a larger throttling range.

Heating Hours Out of Range

- **User-Defined Sizing** - If "user-defined" sizing was used for the system, it is possible the specified supply airflow rate, reheat coil capacity or zone heating unit capacity is insufficient to meet peak zone heating loads. To test this, make a copy of the air system, change sizing back to "computer-generated" and then generate the Zone Sizing Summary report. Compare supply airflow rates, reheat coil capacities and zone heating unit capacities (as applicable) versus those on the Zone Sizing Summary for the original system with user-defined sizing. If "computer-generated" shows a larger values for a problem zone, it is likely heating hours out of range will result.. To solve the problem, edit the original system to increase the supply airflow, reheat coil capacity or zone heating unit capacity. Note: When dealing with parallel fan powered mixing box (PFPMBX) units as the primary source of heat for the zone, "supply airflow" is the PFPMBX fan airflow

- **Warmup Loads** - Heating hours out of range could result from problems quickly bringing air temperatures into the zone heating range at the start of an occupied period. The industry-standard heating design calculation procedure is a single-hour steady-state calculation and therefore does consider warmup dynamics. Therefore, systems sized for this condition without any safety factor built into the supply airflow or heating coil capacity often have problems quickly bringing the zone air temperature into the operating range during the simulation. This is especially true if extended unoccupied periods such as a weekend or holiday period coincide with unusually cold weather. Solutions include increasing zone supply airflow, reheat coil capacity or zone heating unit capacity (as applicable), increasing supply air temperature (while using the same supply airflows), reducing the delta-T between occupied and unoccupied setpoints, or starting the occupied period one or more hours earlier.

- **Simulation Day Zone Heating Loads Larger than Design Heating Loads** - There are two reasons why more severe heating load conditions can be created on simulation days. If simulation days have larger heating loads, the system, which has been sized on loads for the design heating hour, may not have the capacity to meet these loads and keep temperatures under control. The following can cause this:

    - Weather conditions more severe on simulation days. Compare the minimum outdoor air temperature in the simulation weather profile with the winter design temperature and evaluate whether simulation temperatures are

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significantly colder than the winter design value. In some cases simulation weather and design weather may be mismatched. It may be necessary to adjust the winter design temperature. Or the deviation may be natural. After all a 99.6% winter design value means that 35 hours in an average year will be at colder temperatures. For natural cases, the solution may be to increase supply airflow rate, reheat coil capacity or zone heating coil capacity, as applicable.

- Infiltration for simulation days specified as more severe than on design days. Infiltration is specified separately for cooling design, heating design and simulation days. If the infiltration value for simulation days is larger than for heating design, more severe infiltration loads will exist for simulation days. The solution is to make the heating design infiltration value equal to or larger than the simulation day value.

- **Excessively Cold Primary Air** - In systems whose primary source of heat is a terminal reheat coil or is in the zone, unusually cold primary air may create hours out of range.

    Example: A VAV/RH system does not contain a preheat coil. When all zones are in heating, supply air is close to 100% outdoor air. Winter weather often reaches 0 F. Therefore, at these conditions the supply air coming to the VAV/RH box will be close to 0 F. Such a cold primary air temperature may result in situations where the reheat coil does not have enough capacity to hold zone temperature. One solution is to provide a preheat coil to temper the primary air. Another solution is to increase reheat coil capacity to have capacity to handle these extreme conditions.

    This problem can affect central systems whose primary source of heat is a terminal reheat coil, a fan powered mixing box, a zone heating unit (baseboard or fan coil). For fan coil, PTAC and WSHP systems, the problem is less common but can occur if a common ventilation unit is supplying very cold untreated air to the zones.

- **Thermostat Throttling Range** - If you specified a very small throttling range, such as something in the range from 0.1 F or 0.5 F, the system will be more prone to hours out of range. Any excursion above design load levels may be quickly trigger hours out of range. The solution is to use a larger throttling range.

Example Problem:

Air System = RTU-2

a. Identify which zones require attention.
b. Identify magnitude of problem

Inspecting the Zone Temperature Report in Figure 5b we can see "Zone 9" is responsible for the vast majority of cooling hours out or range. The maximum deviation in temperature is 2.8 F

c. Identify zone and system characteristics

This is a VAV/RH air system which uses user-defined sizing.

d. Formulate and implement solution.

Whenever user-defined sizing exists, it is useful to make a copy of the system, switch to "computer-generated" sizing, run design calculations and compare computer generated with user-defined. This comparison shows a user defined supply airflow for "Zone 9" of 635 CFM and a computer-generated airflow of 1135 CFM. Therefore the cooling hours out of range are likely due to a shortage of supply air. User-defined CFMs may have been used to represent an existing system. But if unmet load hours are to be eliminated, the supply airflow must be increased to this zone so peak room sensible loads can be met. If the supply air is increased to 1135 CFM, cooling hours out of range for "Zone 9" drop from 612 to 6 hrs.

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Air System = RTU-3

a. Identify which zones require attention.
b. Identify magnitude of problem

Inspecting the Zone Temperature Report in Figure 5c we can see "Zone 36" and "Zone 38" are responsible for the vast majority of heating hours out of range. The minimum zone temperature for Zone 36 is roughly 19 F below the heating operating limit. For Zone 38 it is 7 F below the limit. So this represents a significant deficit in heating capability.

c. Identify zone and system characteristics

This is a VAV/RH air system which uses user-defined sizing. In this kind of system the primary source of space heat is the reheat coils in the VAV/RH air terminals. Therefore, we need to look at sizing and operating issues for these reheat coils.

d. Formulate and implement solution.

Whenever user-defined sizing exists, it is useful to make a copy of the system, switch to "computer-generated" sizing, run design calculations and compare computer generated with user-defined. This comparison shows a user defined reheat coil capacity of 0 MBH for both Zone 36 and Zone 38. The computer-generated reheat coil capacities are 6.1 and 2.7 MBH respectively. User-defined values of 0 MBH may have been entered to represent an actual system. But if unmet load hours are to be eliminated, the reheat coil capacities for these two zones must be increased. It appears this is a case of zones having heating loads and no ability to supply heat. If the reheat coil capacities for Zones 36 is changed to 7 MBH and the capacity for Zone 38 is changed to 3 MBH, heating hours out of range for Zone 36 drop from 869 to 0 and for Zone 38 they drop from 400 to 0.

Interim Assessment

After the substantial reduction in cooling unmet load hours in RTU-2 and heating unmet load hours in RTU-3, check the LEED EAc1 Summary Report to evaluate the overall effect on LEED unmet load hours. This report (Figure 6) shows the total Proposed building unmet load hours are now acceptable (140 total is below the limit of 300), but the heating unmet load hours for Proposed still exceed Baseline by slightly more than 50. Therefore further work on heating unmet load hours is needed.

Advisory Messages

|	Proposed Building	Baseline Building (0 deg. rotation)	Difference
Number of hours heating loads not met	82	31	+51
Number of hours cooling loads not met	58	38	+20

Figure 6. LEED Unmet Load Hours After Initial Air System Changes

Second Iteration

Looking at the remaining heating hours out of range in the Zone Temperature Reports we see:

*   RTU-3 has no heating hours out of range and therefore requires no further attention.

*   RTU-1 and RTU-2 have small to moderate numbers of heating hours out of range - varying from about 10 to 70. And the magnitude of the temperature deviation is relatively small up to 3 or 4 F.

RTU-1 and RTU-2 are VAV/RH systems. The primary source of space heating is the terminal reheat coil. Inspection of air system input data shows the user-defined reheat coil capacities are roughly equal to computer-generated values and use no safety margin. It is likely the heating hours out of range problem is due to warm-up loads (see discussion under Step 3 Tasks, item (d)). Therefore as a solution we will increase the reheat coil capacities for affected zones by 20% to provide a margin of safety that can be used to better handle warmup loads.
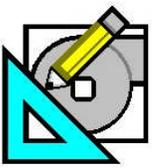
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After making this change, simulations are rerun for RTU-1 and RTU-2. Results show a reduction in heating hours out of range. When the LEED EAc1 Summary Report is re-generated, the overall LEED unmet load hours shown in Figure 7 are obtained. At this point the total Proposed unmet load hours are not more than 300 and Proposed cooling hours do not exceed Baseline by more than 50, and Proposed heating hours do not exceed Baseline by more than 50. Therefore, the unmet load problems have been resolved.

Advisory Messages

	Proposed Building	Baseline Building (0 deg. rotation)	Difference
Number of hours heating loads not met	71	31	+40
Number of hours cooling loads not met	62	38	+24

Figure 7. LEED Unmet Load Hours After 2nd Iteration of Air System Changes

Step 4 - Evaluate and Resolve Equipment-Side Problems in Air Systems Identified in Step #2

Concept: During Step #2, if an Air System Unmet Load Report indicated unmet load hours, then the system has equipment-side operating problems related to DX cooling, heat pump heating or combustion heating equipment operation. The air system needs to be investigated to isolate and then correct the problem.

Air system unmet loads are always due to times when the equipment capacity is less than the load imposed on the equipment. While that is a simple concept, the root causes of a capacity deficit vary widely depending on the equipment, air-side system, building load profile and environmental conditions. The "Analytical Approach" subsection below describes a systematic approach for understanding the problem, identifying root causes and formulating solutions.
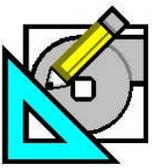
Analytical Approach:

(Repeat these tasks for each air system exhibiting equipment-side problems.)

a. Identify which equipment component or components require attention.

- Inspect the Air System Unmet Load Report and identify which table or tables show significant unmet load hours. The equipment components represented by these tables are the only ones which will require further investigation. Note: If a table shows only a small number of unmet load hours, it may not be worthy of attention. But a table that shows dozens or hundreds of unmet load hours is worthy of attention.

  The Air System Unmet Load Report contains one or multiple tables providing unmet load data for different equipment components. At the start of this investigation it is important to identify which equipment component has capacity problems. If only one component has operating problems it greatly simplifies the investigation. The following table shows the eight possible tables that can appear on an unmet load report and the components described by each.

#	Table Name	Equipment Component
1	Preheat Unit	Combustion heater serving a preheat coil.
2	Precool Unit	A/C DX equipment serving a precool coil.
3	Ventilation Heating Unit	A/C DX or WSHP equipment serving the cooling coil in a common vent unit.
4	Ventilation Cooling Unit	Combustion or WSHP equipment serving the heating coil in a common vent unit
5	Central Heating Unit	ASHP or combustion heater equipment serving the heating coil in a central system.
6	Central Cooling Unit	A/C DX or W/C DX cooling equipment serving the cooling coil in a central system.
7	Terminal Heating Unit	Combustion, ASHP or WSHP equipment in a terminal PTAC, PTHP or WSHP unit.
8	Terminal Cooling Unit	A/C DX or WSHP cooling equipment in a terminal PTAC, PTHP or WSHP unit.

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(Repeat (b) thru (e) for each component requiring attention).

b.   Identify the maximum equipment load occurring during the simulation

•   Use the Air System Hourly Simulation graph report. Generate a graph of "Coil Load" data from January 1 thru December 31 for the component of interest. For example if the "Central Cooling Unit" table showed significant unmet load hours, you would graph the "Central Cooling Coil Load". Visually inspect the graph to identify the maximum value in the 8,760-hour load profile. If you want to be more precise, you can generate the graph reports for successively shorter ranges of days to identify the day having the maximum load, and then generate the tabular hourly report for that single day to identify the specific maximum equipment load value.

c.   Determine the equipment capacity

If the equipment has "user-defined" equipment capacity:

•   Use information on the air system input report to determine the user-specified equipment gross cooling or gross heating capacity.

If the equipment has "auto-sized" equipment capacity:

•   Use the air system input report to determine the program-calculated equipment gross cooling or gross heating capacity.

d.   Determine when unmet loads occur. Identify patterns or causes.

•   From the Air System Unmet Load Report identify one month with the largest number of unmet loads. Generate an Air System Hourly Simulation graph report for all days in this month. Graph the "Coil Load" and "Equipment Load" components together. For example, if evaluating a central cooling unit, you would graph "Central Cooling Coil Load" and "Central Cooling Equipment Load". Times when the coil load exceeds equipment load are times of unmet loads.

•   Review the times when unmet loads occur and consider what may be happening with weather conditions, load conditions or system operation at these times. For example:

➢   If unmet loads occur for extended periods on specific days, are these days with unusually high outdoor dry-bulb or wet-bulb temperatures. Are these unusually hot and sunny days? Are these unusually cold days? Inspecting weather profile graphs for the same group of days helps in this assessment.

➢   If unmet loads occur during the same time of day for many or all days, this might indicate a problem with pulldown loads or economizer operation, but could be due to other factors. For example, use of a dry-bulb economizer in a humid climate can cause cooling loads to spike when 100% OA for cool, humid conditions is introduced into the system. Or use of an enthalpy economize without in a dry climate and no upper cutoff can cause cooling loads to spike when 100% OA for dry but very hot air is introduced into a system.

e.   Formulate and implement corrective action.

Combine findings from (b) thru (d) to draw conclusions about the cause of the unmet loads. Then formulate and implement corrective action. Some key guidelines to help formulating action are provided below.

•   If you feel the maximum coil load is legitimate, then the solution to the problem is to simply increase equipment capacity to equal or exceed the maximum load identified from (b).. If the equipment specifies "user-defined" equipment capacity, then the gross capacity for the equipment must be increased to resolve the problem.. If the equipment specifies "auto-sized" capacity, then the "Capacity Oversizing Factor" needs to be increased to resolve the problem.

•   In some cases, rather than indicating a capacity problem, the unmet loads indicate a problem with equipment or air system modeling. While increasing equipment capacity in the previous bullet is the simple solution and will eliminate unmet loads, if you are oversizing versus design load by unusually large margins like 50% or 75% you more likely

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have a problem with equipment control, air system control or air system modeling. There are many possible causes of these kinds of equipment and air-side problems. Common causes are listed below:

Cooling Equipment

➢ **OAT Cutoff Settings for Air-Cooled DX Equipment** - For air-cooled DX cooling equipment, when unmet load hours occur in off-design or winter months and are in the "Capacity Insufficient By > 10%" column, the problem is likely the outdoor air temperature cutoff setting. For example, if you specified an OAT Cutoff of 45 F for equipment, and the air-side simulation calculated cooling coil loads when it is colder than 45 F, the DX equipment will not be able to serve these loads and your equipment capacity will essentially be deficient by 100%. One solution is to reduce the OAT cutoff. Another is to modify air side modeling to eliminate the cooling coil loads at cold outdoor temperatures. This sometimes involves a problem with economizer controls.

➢ **Capacity Oversizing** - If no margin of safety is provided in the equipment capacity, then it is likely unmet loads will occur when above-design cooling conditions occur. Design load estimating procedures are based on the premise that you design for statistical design value -- such as a 0.4% design dry-bulb for cooling for example -- and for other assumptions about typical above normal load conditions. Typical practice is then to select equipment that exceeds the peak coil load by some margin of safety. If no margin of safety is provided, then unmet loads may occur when conditions above the design occur -- such as extreme weather conditions, extreme pulldown loads, etc.. If "user-defined" equipment capacity was used, this situation occurs when a gross capacity exactly equal to peak coil load is specified. For "auto-sized" capacity it involves using an oversizing factor of zero. The solution is to specify equipment capacity that exceeds peak coil load by a margin of safety - either via direct specification of gross capacity, or by specifying a capacity oversizing factor greater than zero.

➢ **Design OAT or EWT Specifications Mismatched with Operating Conditions** - In air-cooled DX and WSHP cooling equipment, equipment capacity varies with the entering condenser temperature. Equipment capacity decreases as entering temperature increases. If equipment capacity is specified for an entering condenser temperature well below the maximum encountered in the simulation, the equipment may be short of capacity at high entering temperatures and as a result generate unmet load hours.

Example #1 - A rooftop unit in Phoenix was specified with a gross cooling capacity of 120 MBH at an OAT design condition of 95 F. Phoenix weather conditions are frequently well above 95 F. As the outdoor air dry-bulb increases the gross cooling capacity will decrease, making it likely unmet loads will occur. The solution is to specify the true OAT design temperature that corresponds with the peak cooling load. For a climate like Phoenix may be as high as 110 F.

Example #2 - In a WSHP system, all WSHP units were specified with design EWT as 86 F. The maximum loop setpoint was specified as 95 F. Therefore, for many hours in the cooling season, the WSHP units will face an entering water temperature of 95 F. At 95 F the units will have less cooling capacity than the capacity sized at 86 F EWT. Unmet load hours can occur as a result. The solution is to make sure the Design EWT is specified as equal to the maximum loop setpoint for the WSHP system.

➢ **Simulation Loads More Severe than Design Day Loads** - There are a number of ways to mistakenly create more severe load conditions for simulation days than on design days. Since equipment capacity is determined based on peak coil loads from a design day analysis, more severe loads on simulation days will result in unmet load hours. Common ways to create more severe loads on simulation days involve using more intense schedules for internal loads, using higher infiltration airflow, or more demanding fan / thermostat schedules.

➢ **Misapplication of OA Economizers** - Certain outdoor air economizer controls when matched with the wrong climate can increase rather than decrease loads. For example, an integrated dry-bulb economizer control used in a humid climate can create situations in which the economizer activates during cool but humid conditions. Bringing in 100% OA during these times can cause sharp increases in the latent cooling coil load. An integrated enthalpy economizer used in a hot, dry climate without an upper cutoff temperature can result in situations where

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the economizer activates during marginal conditions where it outdoor air is dry but hot, causing sharp increases in the sensible cooling coil load.
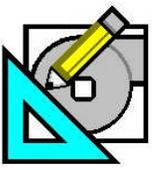
➢ **Excessive Pulldown Loads** - Certain simulation conditions can occur which cause more severe pulldown loads to occur than seen in the design analysis. For example if a long holiday weekend or summer shutdown period coincides with a series of hot, sunny days, the pulldown load occurring at the start of the next occupied cycle may be unusually large. Depending on circumstances, solutions can include earlier equipment startup for occupied cycles or use of a smaller delta-T between occupied and unoccupied period setpoints.

Heating Equipment

➢ **Capacity Oversizing** - This is the same concept discussed under "Cooling Equipment" above, applied to heating.

➢ **Simulation Loads More Severe than Design Day Loads** - Similar to the discussion under cooling, there are ways to mistakenly create more severe load conditions for simulation days than for the design heating condition. Since equipment capacity is determined based on peak coil loads from a design heating hour analysis, more severe loads on simulation days will result in unmet load hours. The most common way to create more severe simulation day heating loads involves using higher infiltration flow rates for simulation days than for the design heating hour.

➢ **Warm-Up Loads** - The industry standard design heating calculation utilized by HAP is a single-hour steady state calculation. It does not consider warm-up loads. If no oversizing of heating capacity versus the peak heating coil load is applied, it is likely unmet loads could occur due to warm-up cycles. Even if capacity oversizing is applied, it is possible that extreme warm-up loads could exceed the margin of safety. This most frequently happens when extended set-back periods, such as a weekend, a holiday weekend coincide with times of unusually cold weather. In these cases a larger amount of capacity oversizing that is usually applied may be required to eliminate the unmet load hours.

➢ **Design EWT Specifications Mismatched with Operating Conditions** - In WSHP heating equipment, equipment capacity varies with the entering water temperature. If equipment capacity is specified for an entering water temperature well above the minimum encountered in the simulation, the equipment may be short of capacity and will generate unmet load hours.

Example - In a WSHP system, all WSHP units were specified with design EWT as 68 F. The minimum loop setpoint is specified as 55 F. Therefore, for many hours in the heating season, the WSHP units will face an entering water temperature of 55 F. At 55 F the units will have less heating capacity than the capacity sized at 68 F EWT. Unmet load hours can occur as a result. The solution is to make sure the Design EWT is specified as equal to the minimum loop temperature for the system.

➢ **Common Ventilation Systems for WSHP** - For WSHP systems the Unmet Loads Report displays combined unmet load statistics are provided for all WSHPs in the system - both those providing space heating duty in the zones and for the WSHP in the common ventilation unit which is tempering ventilation air. Because different issues can cause equipment-side problems in the zones and in the ventilation unit, it is sometimes useful to apply a trick to separate the zone units from the common ventilation unit to see if one or the other is the source of unmet load hours. This trick involves making a copy of the system and then temporarily changing the common ventilation unit to use air-cooled DX cooling and combustion heating. When you rerun the simulation unmet load statistics for the common ventilation unit will be separate from the zone WSHPs. There are three possible outcomes of this test. (1) If the results show the same unmet load hours for WSHPs, then you know all of the problem is at the zone level. (2) If zero unmet load hours are reported for the WSHPs, then you know all of the original unmet load hours are in the common ventilation unit. (3) If reduced but still significant unmet load hours appear for the zone WSHPs, then you know both zone WSHPs and the ventilation WSHP are the source of problems. Where the problem lies will guide your corrective action, using principles described in the previous bullets.

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Example Problem:

In Step 2 the Air System Unmet Load Reports showed minimal unmet load hours. Therefore no action is needed for this step. Proceed to step 5.

Step 5 - Evaluate and Resolve Equipment-Side Problems in Plants identified in #2

Concept: During Step #2, if a Plant Unmet Load Report indicated unmet load hours, then the plant has equipment-side operating problems. The plant needs to be investigated to isolate and then correct the problem.

Plant unmet loads are always due to times when the plant capacity is less than the load imposed on the plant. While that is a simple concept, the root causes of a capacity deficit vary widely depending on the plant characteristics, air-side system performance, building load profile and environmental conditions. The "Analytical Approach" subsection below describes a systematic approach for understanding the problem, identifying root causes and formulating solutions.

Analytical Approach:

(Repeat these tasks for each plant exhibiting equipment-side problems.)

a.   Identify the maximum plant load occurring during the simulation

- Use the Plant Hourly Simulation graph report. Generate a graph of "Plant Load" data from January 1 thru December 31. Visually inspect the graph to identify the maximum value in the 8,760-hour load profile. If you want to be more precise, you can generate the graph reports for successively shorter ranges of days to identify the day having the maximum load, and then generate the tabular hourly report for that single day to identify the specific maximum plant load value.

b.   Determine the plant capacity

If the plant has "user-defined" equipment capacities:

- Use information on the plant input report to determine the plant capacity.

If the plant has "auto-sized" equipment capacities:

- Use the plant input report to determine the plant oversizing factor.
- Use the plant design load report to determine the plant design load For a chilled water plant use the "Cooling Plant Sizing Summary". For a hot water or steam plant use the "Heating Plant Sizing Summary"
- Calculate the plant capacity as (design load) x (1 + Oversizing Factor). Example: A chiller water plant has an oversizing factor of 15% and the Cooling Plant Sizing Summary shows the design load is 462 tons. The program-calculated plant capacity would be (462 tons) x 1.15 = 531.3 tons.

c.   Determine when unmet loads occur. Identify patterns or causes.

- From the Plant Unmet Load Report identify one month with the largest number of unmet loads. Generate a Plant Hourly Simulation graph report for all days in this month. For a chiller plant, graph the Plant Load and Chiller Output together. For a boiler plant, graph the Plant Load and Boiler Output together. Times when plant load exceeds chiller output or plant load exceeds boiler output are times of unmet loads.

  Note: For a chiller plant which uses hydronic free cooling, a special approach is required. In this type of plant differences between the Plant Load and Chiller Output could indicate either the free cooling effect or an unmet load. To isolate just the unmet load hours, first make a copy of the plant. In the copy remove the hydronic free cooling. Then run the simulation and generate the Plant Hourly Simulation graph to compare Plant Load and Chiller Output. With the free cooling excluded, all differences between Plant Load and Chiller Output indicate times of unmet load.

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Reducing LEED Unmet Load Hours
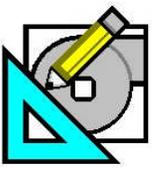## in HAP v4.5

- Review the times when unmet loads occur and consider what may be happening with weather conditions, load conditions or system operation at these times. For example:

  ➢ If unmet loads cluster together on just a few days, are these days with unusually high outdoor dry-bulb or wet-bulb temperatures? Are these unusually hot an sunny days? Are these unusually cold days? Inspecting weather profile graphs for the same group of days helps in this assessment.

  ➢ If unmet loads occur repeatedly during the same time of day for many or all days, this might indicate a problem with pulldown loads or economizer operation. For example, use of a dry-bulb economizer in a humid climate can cause cooling loads to sharply increase when 100% OA for cool, humid air is introduced into the system. Or use of an enthalpy economizer in a dry climate can cause cooling loads to sharply increase when 100% OA for dry but very hot air is introduced into a system.

d.   Formulate and implement corrective action.

Combine findings from (a) thru (c) to draw conclusions about the cause of the unmet loads. Then formulate and implement corrective action. Some key guidelines to help formulating action are provided below.

- If the maximum plant load is legitimate, then the solution to the problem is to increase plant capacity to equal or exceed the maximum load identified from (a).. If the plant specifies "user-defined" equipment capacity, then the capacities of the chillers or boilers in the plant must be increased to resolve the problem. If the plant specifies "auto-sized" capacity, then the "Capacity Oversizing Factor" needs to be increased to resolve the problem.

- In some cases, rather than indicating a plant problem, the unmet loads indicate a problem with air system modeling or performance. While increasing plant capacity in the previous bullet is the simple solution and will almost always eliminate unmet loads, if you are oversizing versus design load by large amounts like 50% or 75% you more likely have a problem on the air-side that requires solving. There are many possible causes of these kinds of air-side problems. A few of the more common errors include space inputs involving schedules, infiltration or setpoints that create much more severe load conditions during the energy simulation than are present during the design load calculation, miss-application of outdoor air economizers (mentioned in an example under item (c)), and excessive pulldown loads.

Example Problem:

In Step 2 the Plant Unmet Load Report for the HW boiler plant showed no unmet load hours. Therefore no action is needed for this step. Proceed to step 6.

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Perform step 6 if any changes were made to the Baseline 0-deg building in preceding steps.

Step 6 - Synchronize Baseline 90-deg, 180-deg, 270-deg Data with Changes Made to Baseline 0-deg Building

Concept: If modifications were made to the Baseline 0-degree building to resolve unmet load hour problems, then those modifications need to be made in the other three rotations of the Baseline building so all four Baseline rotations use consistent modeling.

Note: When performing a LEED EA Credit 1 analysis it is often most efficient to create the Proposed and Baseline 0-degree buildings first, run initial calculations, and then work to eliminate any unmet load hour problems that are found. Once unmet load hour problems are eliminated, the 90-degree, 180-degree and 270-degree Baseline rotations can be created, guaranteeing the four Baseline buildings have synchronized data. This eliminates the need to re-synchronize data if the four Baselines were created before eliminating unmet load issues.

Tasks:

a. Erase all input data for the 90-degree, 180-degree and 270-degree Baseline building rotations.

Make sure to locate and erase data in all of the following data categories. Data items can be quickly identified by looking for the [B090], [B180] and [B270] prefixes in item names.

- Chillers
- Cooling Towers
- Boilers
- Spaces
- Air Systems
- Plants
- Buildings

b. Regenerate the 90-degree, 180-degree and 270-degree Baseline building rotations

- From the main HAP window click the Buildings item in the left-hand panel.
- In the right-hand panel right-click the Baseline 0-degree building item.
- On the pop-up menu which appears select "Perform LEED (90.1 PRM) Rotations"
- Click the OK button in the confirmation window that appears.
- Save the project.
- Select the Proposed and all four Baseline buildings and generate the LEED EA Credit 1 Summary Report.

Example Problem:

In our example problem only the Proposed building required modifications to eliminate the LEED unmet load hour problem. Therefore Step 6 does not need to be performed for the example problem.