Better Buildings Alliance - Laboratories Project Team

Minimizing Simultaneous Heating and Cooling in Existing Laboratory Buildings with Reheat Systems

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1 Introduction

Reheat systems can be very energy intensive because they use simultaneous heating and cooling to achieve temperature (and sometimes humidity) control. If your building Heating, Ventilating and Air-Conditioning (HVAC) system is equipped with reheat, you can apply the techniques discussed here to identify and quantify the excessive heating and cooling energy associated with the system. You can also use the diagnostic and modification methods to minimize reheat and thus save money, energy, and greenhouse gas emissions.

This "getting started" guide is primarily intended for energy and sustainability managers interested in addressing this efficiency opportunity. It is also informative for facilities staff responsible for laboratory HVAC systems, although it is not a detailed engineering manual.

2 What is Simultaneous Heating and Cooling, and What is Reheat?

What is simultaneous heating and cooling, and what is reheat? Simultaneous heating and cooling of the air supplied to laboratories is intentionally done for temperature and humidity control. In the case of humidity control, the air is cooled below its dewpoint temperature, causing moisture to condense out of it. This cooled, drier air is typically colder than desired for cooling the occupied spaces, so heat is added to the air to raise its temperature to the desired level. This "reheat" process is often performed at the central air-handling unit (AHU). Temperature control in the zones is then performed by some combination of airflow control and additional heating or cooling.

In the case of temperature control, a very common HVAC scheme is Variable Air Volume with Reheat (VAV-RH). The reheating is primarily or exclusively done at the zone level and is sometimes called VAV with Terminal Reheat. In general (e.g. for offices), this system works by having the central air-handling unit (AHU) cool all the air just to the point needed by the hottest zone with its VAV box wide open (maximum air flow to the zone). The zones with lesser cooling demand will throttle their VAV boxes down as far as their minimum flows, and if the air is still too cold, will then reheat the air using a hot water or electric resistance coil at each zone. This situation is exacerbated in laboratories due to the wide range in internal loads (Figure 1). Furthermore, labs are a little more complicated than offices, because they typically have room pressurization controls that supply a bit less air than is exhausted in order to keep the room at a negative pressure, so the flow isn't only controlled to maintain temperature; often this means relatively high minimum flows, which results in more reheat.

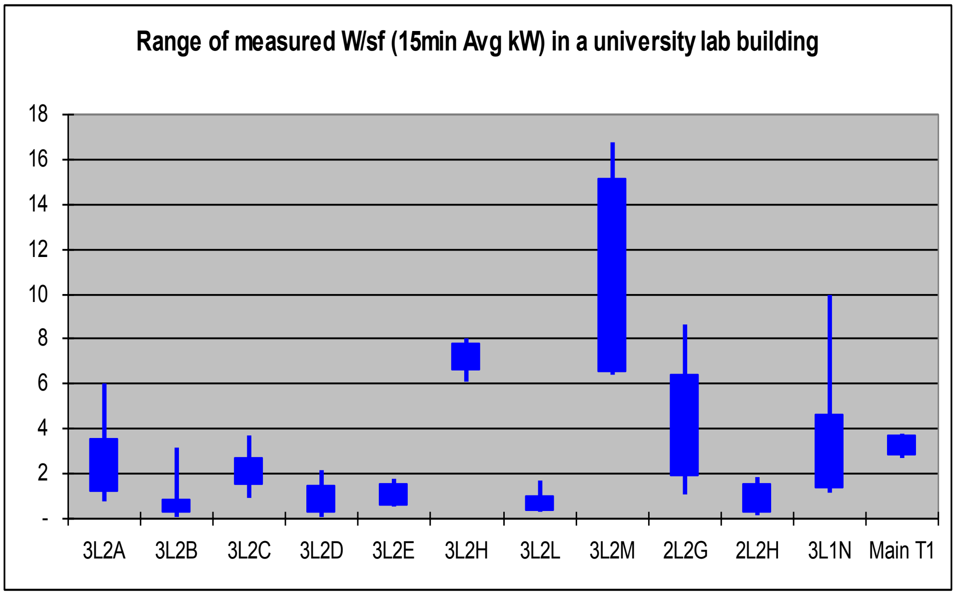

Figure 1. Measured internal loads (electrical Watts per net square foot of floor area) in a laboratory building. Note that the highly loaded space (3L2M) will force down the supply air temperature, causing excessive reheat in the other spaces. (Labs21 2005)

3 Determining Whether the Building has a Reheat System

Check with your facilities personnel as to the basic HVAC system in your laboratory. While VAV-RH is a very common system in labs, there are several other schemes. Some of them (e.g. constant volume-RH, dual duct) also do simultaneous heating and cooling and the detection, quantification, and solution schemes are very similar to those discussed here. Other schemes (chilled beams or other radiant cooling) and terminal cooling (cooling coil in the VAV box or fan-coil unit in the space) do not do simultaneous heating and cooling.

You can also look at graphics screens on your Energy Monitoring and Control System (EMCS, also known as a Building Management System (BMS) or a Direct Digital Control (DDC) system). If there is cooling at the central air-handling unit (AHU) and heating at the zones with hot water or electric coils, the building has reheat.

If the control system "sequence of operation" (an English-language text version of the control system programming) is available (on drawings, specifications, or online), look for tell-tale wording like "reheat coil" or "terminal heating coil" in the descriptions of zone temperature control; either of these indicate a reheat system.

4 Determining Whether Reheat is Minimized

A necessary (but not sufficient) condition for minimizing reheat is whether the supply air temperature is barely cool enough to cool the most-demanding zone with its VAV box set to maximum flow (i.e. the damper is wide open). Check your control system to see if there is at least one box that is close to flowing at its design air flow. In lab spaces, there are often two VAV boxes: one on the supply, and one on the room exhaust (often called general exhaust or GX); typically one is controlled to maintain room pressure, the other to maintain room temperature, with the pressure-controlled box adjusting its flow to compensate for changes due to the temperature-controlled box, variations in fume hood sash position, etc. If there is no wide-open box in the system, the supply air temperature is too low and excessive reheat is happening. See measures in the solutions section to further reduce reheat even when there is a wide-open box.

5 How to Quantify the Reheat

If your system has a DDC control system to the zone level, and the VAV boxes have flow stations (with air flows usually indicated in cubic feet per minute or cfm) and temperature sensors at the discharge air (i.e. in the air flowing out of the supply air diffuser into the room), the amount of heat at each box is proportional to the product of the airflow and the temperature rise across the reheat coil. Specifically:

Reheat in Btu/hr = 1.08 x zone airflow in cfm x (zone discharge air temperature in °F – AHU supply air temperature in °F)

This equation will indicate the reheat at any given moment. In a typical direct digital control (DDC) system, the flows and temperatures can be trended and the trend data can be used to determine the amount of reheat energy over time (summed over time and over all the zones with reheat). How much is wasted can be determined by taking the difference between measurements taken before and after operational changes.

To translate zone energy into boiler plant energy, the gas use (or savings) is equal to the total reheat energy used (or saved) at the zones (see previous calculation method) divided by the boiler plant efficiency, which is typically about 80% for a non-condensing plant and about 90% for a condensing one.

In order to estimate how much excessive cooling is being supplied, first determine if the system is in simultaneous heating and cooling or just excessive heating. When the cooling is being provided “free” during cool weather (typically when the outside air temperature is below the AHU supply air temperature), there is no excess chiller usage attributed to the reheat, but there is still excessive heating being done because the air is colder than needed.

When chilled water is being used to supply the cooling, the amount of excessive cooling energy is equal to the amount of excessive reheat energy. To convert the excessive cooling energy to electricity, use the following formula:

Excessive chiller plant electricity use in kWh =
(excessive cooling Btu / 12,000 Btu/ton-hour) x chiller plant performance in kW/ton

Typical water-cooled chiller plants range from 0.6 to 1 kW/ton; typical air-cooled plants from 1 to 1.5 kW/ton.

6 Solutions: Strategies to Minimize Reheat

1. As noted earlier, <u>at least one zone should be operating without reheat</u>, i.e. either the supply box or exhaust box is wide open and the heating coil is not in operation. If there is no such zone, check to see if there’s a supply air temperature reset (often called “worst zone reset”) programmed into the controls. This programming should automatically change the setpoint temperature of the AHU supply air to keep the VAV damper for most-demanding zone at or near wide open. If there is no such programming, add it. Also check that the reset control is allowed to operate automatically (i.e. it is not over-ridden by the control system operator). If it is over-ridden, remove the over-ride(s).

2. Once at least one zone is without reheat, <u>track which zone(s) are driving the supply air temperature, and determine why</u>. Often a single zone will cause the SAT to operate well below optimum for the rest of the zones (see Figure 1, e.g.). Focus on the problem zone(s); first check to make sure their controls are calibrated and working properly (temperature, pressurization, and flow sensors, damper and valve actuators, hot-water valves for internal leakage, etc.). If the maximum air flow rate can be increased in a problem space, set the box for higher flow—this will allow more air to be used instead of colder air. Also make sure the cooling setpoint temperature for these spaces is as high as acceptable to the occupants and processes. See if the cooling

loads can be reduced in these spaces (with setback or timer controls on equipment, relocating equipment, using water rather than air-cooled equipment, directly exhausting hot air from heat sources, reducing solar gain by shading windows, etc.). See if the minimum airflow setpoint can be decreased in the over-cooled spaces (allowing less air rather than warmer air to be used for conditioning).

3. More expensive but possibly cost-effective is to provide auxiliary cooling to the hot spaces. Options include upsizing or adding VAV boxes, adding a chilled water or process cooling water fan coil, or ductless split air-conditioner.

4. Even if reheat is otherwise minimized, reducing the air-change rate (air changes per hour or ACH) in the spaces that are in reheat mode will reduce the amount of reheated air flowing through, and as the air flow gets closer to just meeting the load, the zone controls will lower the discharge air temperature to the space, further reducing or even eliminating reheat. Minimizing ACH generally saves fan, heating and cooling energy. For more on this topic, see the Labs21 guide "Optimizing Laboratory Ventilation Rates" (Labs21 2008).

5. Check the control scheme for the general exhaust registers in the spaces, to make sure they are controlled by temperature (if the VAV supply box is controlled by pressure) or that they are controlled by pressure (if the VAV supply box is controlled by temperature). Either of these schemes will allow the lab space to behave as much like a temperature-controlled VAV space as possible, i.e. allowing more rather than cooler air to be used in high-load zones.

Beyond the above strategies, you may consider converting reheat systems to systems that do not use simultaneous heating and cooling. This is usually a major retrofit. More information can be found in the Labs21 best practice guide "Minimizing Reheat Energy Use in Laboratories" (Labs21 2005).

7 References

Labs21 2008. Optimizing Laboratory Ventilation Rates. Laboratories for the 21st Century. Available at: http://www.i2sl.org/documents/toolkit/bp_opt_vent_508.pdf (accessed March 2013).

Labs21 2005. Minimizing Reheat Energy Use in Laboratories. Laboratories for the 21st Century. Available at: http://www.i2sl.org/documents/toolkit/bp_reheat_508.pdf (accessed March 2013).

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