

Operation of high temperature water cooling system in hospitality environment: Field Experiment

Mika Ruponen¹, Rajnish Cani², Pasi Oksanen¹

¹Halton Oy

²Cani Merchandizing Pvt. Ltd.

Corresponding e-mail: mika.ruponen@halton.com

Summary

This field experiment was initiated by the uncertainty of high temperature water cooling systems viability for hospitality environment. The concern among the industry professionals has been risk of condensation especially due to humidity escaping from a bathroom during showering. Other concern has been response times of the high temperature systems in both cooling and heating.

This experiment was conducted in a hotel located in Paris, France with two identical rooms. One room equipped with a traditional fan coil system and the other room equipped with an active chilled beam. The two rooms located next to each other on the same façade to ensure similar loading conditions.

The results of this study show that humidity escaping from the bathroom pose a risk of condensation only when shower is being used for extensively long periods. Response times for cooling down a room from non occupied mode is more dependant on the thermal loading of the structures for the both systems rather the difference they have in cooling capacity. Conducted velocity measurements show excellent comfort conditions for the active chilled beam.

Introduction

Active chilled are becoming more popular choice to provide ventilation and air conditioning into hospitality environments, especially in hotel rooms. Their quiet operation and low maintenance makes them especially interesting alternative to fancoils that are traditionally used for those spaces. Active chilled beams utilize primary air to induce room air that is channelled to flow through a heat exchanger where the circulated room air can be heated or cooled by means of water. Typically for every unit of primary air some 5 [1] units of room air can be re-circulated. Amount of supply air can be reduced similarly amount compared to all air cooling.

Chilled beam operate on dry principle i.e. condensation is not allowed in the heat exchanger. Due to dry operation maintenance of the device is reduced as there is no need for condensate removal system and no need for filtering the re-circulated air due to absence of wet surfaces to collect dust from the room air. Maintenance of the condensate removal system and especially filter changing are major cost items related maintenance of fan coils. Reduced maintenance cost was found to be one of the key factors contributing to lower life cycle cost studied by Kosonen et al. [2].

Correctly designed primary air nozzles ensure quiet operation of these units. This is particularly interesting feature for the hospitality environment. Sound level lower than 30 dB(A) can easily be achieved using active chilled beams at full capacity. This sometimes works also as disadvantage because occupants lack the perception of sound and air movement as response to change of temperature settings.

In the absence of recirculation fan and due to higher water supply temperature active chilled beam typically have lower maximum cooling capacity compared to traditional wet fancoils. However many installations show that in continuous operation active chilled beam provides sufficient capacity to maintain comfortable room temperatures. The energy consumption of continuous operation compared to intermittent operation has been studied [3] and results show some 6 % higher cooling energy consumption to continuous operation. The higher energy consumption is quite acceptable to ensure that customer's thermal comfort and air quality perception, when entering the room, is always perfect.

It has been proved by the existing research that active chilled beam are viable option for hospitality environment. This paper focuses on testing active chilled beam under field conditions. Real hotel environment was used to study whether the provided cooling capacity was enough to maintain comfortable room conditions. Try cooling systems are believed to be sensitive to occurring internal humidity gains and that clearly needed to be studied. Finally, room temperature levels were studied during start up following period when air conditions had been turned off.

Experimental set-up

The experiments were carried out in two almost identical hotel room located in Paris, France. Initially the two rooms were equipped with fan coils. The purpose build active chilled was installed in one of the rooms and this room later referred as the test room. The other room still equipped with a fancoil unit was used for comparative purposes and is referred here after as the reference room. The two rooms located next to each other with identical furniture. The rooms were mirror images to each other. Figure 1 presents layout of the rooms and specify location where velocity measurements were made on different heights.

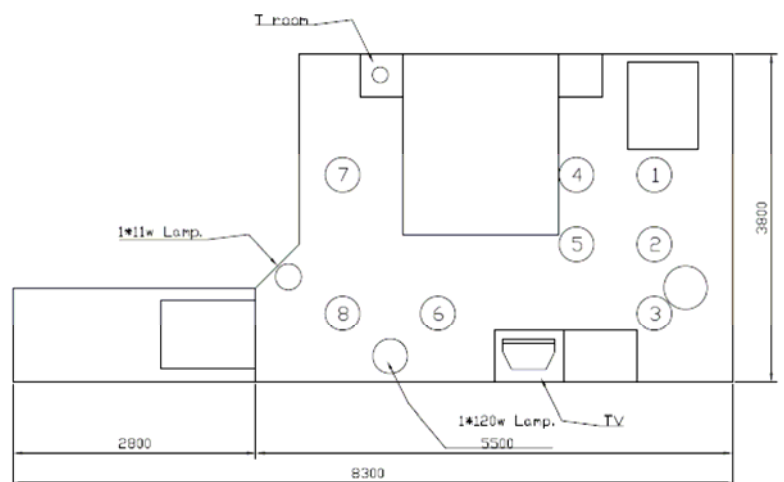


Figure 1. Room layout and location of measurement points.

Thermal comfort conditions test and start up test were carried out and performance of the test room and the reference room were compared. During the comfort conditions test, it was also recorded whether the installed active chilled beam was able to maintain required design temperature levels. Additionally condensation test with bathroom shower on was carried out in the test room equipped with the active chilled beam.

Installation and Commissioning

The beam was delivered and installed and tested during latter part July. The existing fancoil was removed from the room and replaced by the purpose build designed active chilled beam. The chilled water supply of the hotel was designed for condensing fancoils and therefore a water mixing system shown in Figure 2 was installed to elevate water temperature from 53.4°F (12°C) to 57.2°F (14°C). This is an additional system that is not required for the beam system. Figure 3 shows finalised installation of the active chilled beam in the test room.



Figure 2. Photograph of the mixing system

During the commissioning it was discovered that the expected system duct pressure of 100 Pa was only in fact 0.30 in WC (74 Pa), however once the dedicated outdoor air system's filters were changed a pressure of 0.34 in WC (85 Pa) was recorded. This lower pressure level would reduce the supply air volume into the beam from the design condition of 68 cfm (33 l/s) to 64 cfm (30 l/s).

The tests on the chilled beam were carried under the following recorded conditions:-

Ambient temperature	= 91.4°F (33°C)
Air onto beam	= 73.4°F (23°C)
Air off beam	= 65.7°F (18.7°C)
Water flow to chilled beam	= 58.5°F (14.7°C)
Water return temperature	= 61.7°F (16.5°C)
Beam return air room temperature	= 73.2°F (22.9°C)
Water temperature to mixing valves	= 53.6°F (12°C)
Air duct pressure drop	= 0.34 in WC (85Pa)

The outdoor ambient conditions were very close to design conditions for the northern France during the test period with the highest temperature occurring between 3pm and 4pm of 91.4°F (33°C). During this test period DOAS was not capable of maintaining supply air temperature into the beam at its design condition of between 60.8°F (16°C) or even at the set point of 68°F (20°C). Therefore to supply air condition onto the beam was 73.4°F (23°C) instead. Clear reason for that was not found.



Figure 3. Photograph of installation of the active chilled beam in the test room

Key factors effecting active chilled beam operation are supply air flow rate and static chamber pressure. Field conditions differed from the design conditions as explained above and therefore design capacity of 3756 BTU/h (1100 W) was not achieved under current operating conditions. Under new condition the installed chilled beam provided 2732 BTU/h (800 W) of sensible cooling. This raised some concern whether available capacity would keep temperatures in acceptable limits.

Methods

The installed and commissioned chilled beam was allowed to run over night at the temperature set point of 75.2°F (24°C). Over night the room was left unoccupied. At 9 am in the morning, three persons occupied the room to carry out the measurements. During the measurement room thermostat was put on full demand to ensure full cooling load on all measurement points. Velocity was measured on six different heights from finished floor level: 0.33 ft (0.1 m), 0.66 ft (0.2 m), 1.6 ft (0.5 m), 3.6 (1.1 m), 5.9 ft (1.8 m) and 7.2 ft (2.2 m) in both rooms. Minimum and maximum fan speed setting were used in reference room to get full range of velocities. The first 2 hours were used for reparation to make the actual measurements and the following load were turned on as the test room was occupied:-

- 3 number occupants
- Curtains and nets net curtains open
- All lights were on with the task light set @ 50% capacity
- TV on
- Computer on
- Fridge On
- Small power loads from associated testing equipment

- Window surface temperature varied from 86-104°F (30-40°C) during the day – clear skies

The testing of the reference room was carried out the following day under virtually identical weather conditions.

The both rooms were heated up using the heating function in the beam and in the fancoil. Turning cooling on to full power in both rooms started the tests. The room temperature was measured in 30 minutes intervals.

Results

During velocity measurement temperatures were measured simultaneously. During the day with load as shown outlined above very stable temperatures were measured. The results show that average of all points was 75.2°F (22.7°C) with minimum value of 71.2°F (21.8°C) and maximum 74.8°F (23.8°C).

Measured velocities are presented in Figure 4. Within the occupied zone measured velocities for the fan coil on speed 1 and those of chilled beam are rather similar. In the thermal comfort point of view most critical are the ones found closer to façade and there some values for the fan coil on speed 3 exceed those accepted for office environment [4]. Active chilled beam shows superior performance compared to fan coil.

Condensation test and results

The condensation test was carried out during the 3rd day of testing. Prior to these humidity tests it was generally considered that a hot bathroom shower caused the greatest risk of condensation. This was expected to be the case especially when the bathroom door was left open to the guest room. The tests were performed with the bathroom door deliberately left open in order to ascertain out under what conditions and how fast condensation would occur. The results and findings of the test are presented in Table 1.

The tests were conducted under the following conditions: -

Room temperature	= 74.5°F (23.6°C)
Window surface temperature	= 97°F (36.3°C)
Water supply temperature	= 57°F (14°C)
Shower water temperature	= 100°F (38°C) (safety limiter)

Exhaust grille within bathroom is positioned just above the shower.

- Bathroom door fully open to guest room.
- Shower cabin door closed.

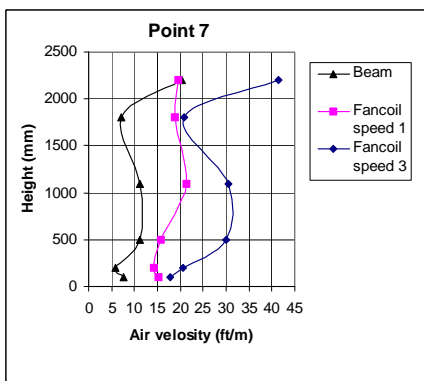
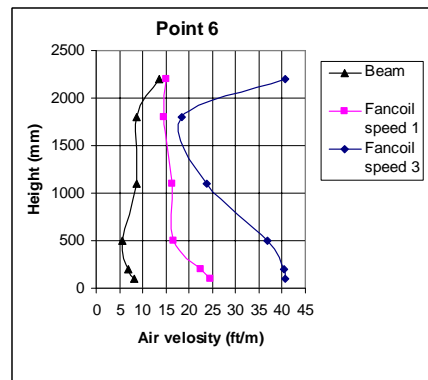
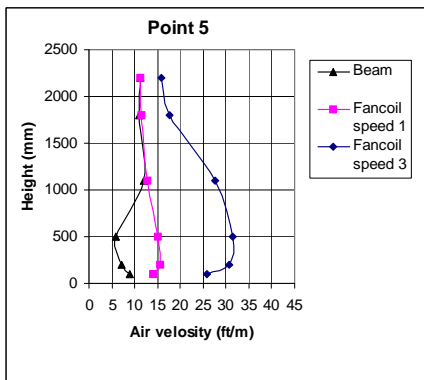
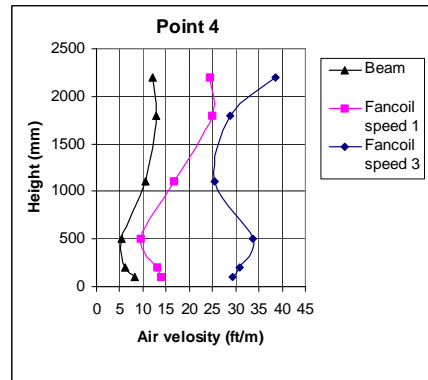
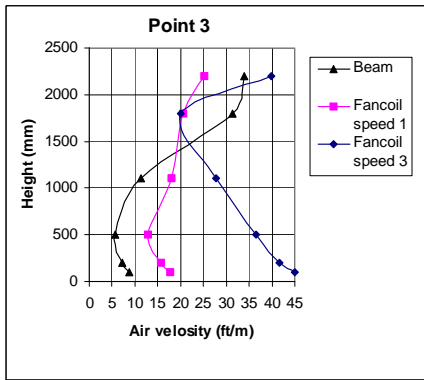
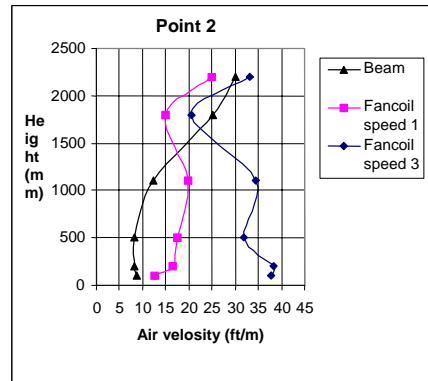
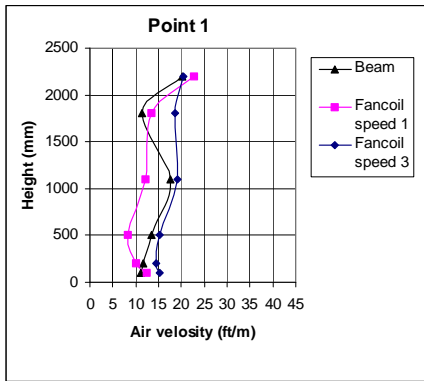


Figure 4. Recorded velocities in different locations

Table 1. Results of the condensation test

Time	Elapsed time	Comments and actions
11:44	0:00	Start Time
11:57	0:13	Non-insulated parts in the primary circuit are becoming moist. Water temperature of the primary circuit is 53.6°F (12°C)
12:07	0:23	Upper pipework in the mixing circuit starts to become moist.
12:18	0:34	Water is dripping from bathroom exhaust grille
12:22	0:38	Droplets are forming on the primary circuit
12:29	0:45	No significant changes in condensation. Bathroom extract closed.
12:38	0:54	First drops of water drip from the non-insulated casing 53.6°F (12°C) surface of the water strainer.
12:44	1:00	Primary circuit pipe work continues to condense.
12:47	1:03	Pipework within the heat exchanger becomes moist.
13:00	1:16	Mixing circuit is moist, thermometer glass is partly steamed up, and control valve and primary circuit is moist, however only the metal casing of the strainer produces water droplets.
13:10	1:26	Very thin film of moist visible at aluminium fins of the coil. Situation is stable. No dripping. Bathroom extract reopened. Shower cabin door opened.
13:18	1:34	Supply air duct is moist and some droplets on pump surface.
13:23	1:39	First droplet of water drips from the heat exchanger.
13:24	1:40	Test terminated

Temperature decrease in both room are presented in Figure 5 and show more rapid decrease for the room equipped with the fan coil. This was quite an unexpected result as it was known that the fancoil would have more cooling capacity. However, later on it was discovered that the structures on the reference room had more time charge compared to test room an the test room was kept longer in the higher temperature.

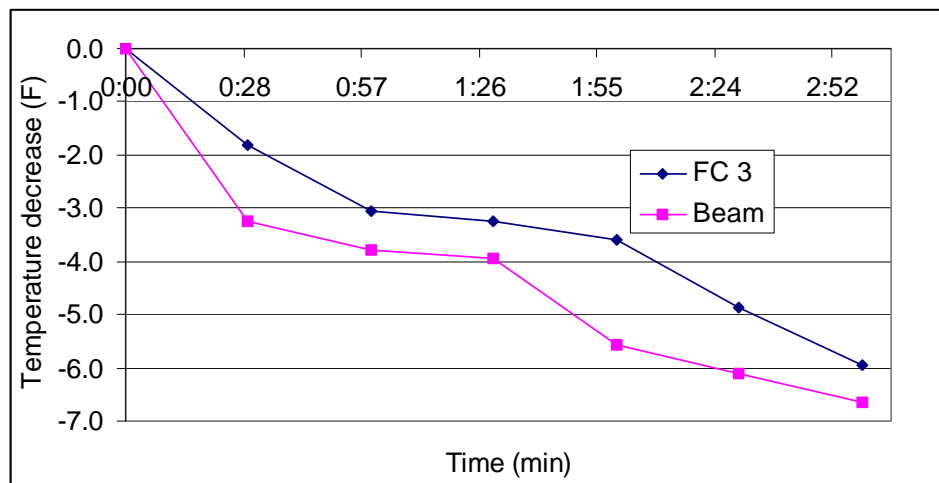


Figure 5. Results of temperature decrease test

Discussion and conclusions

Comfort

The temperature and velocity results measured with the bulkhead chilled beam clearly indicate that good indoor air conditions can be achieved. Velocities measured with the bulkhead chilled were on average lower than that of the fan-coil system. The temperature gradient within the room was also more stable when controlled with the chilled beam. We can therefore summarise that bulkhead chilled beam provided improved ventilation and cooling conditions within the room.

Condensation

Extremely encouraging results were also collated during the condensation tests with the shower in operation. From the information gathered during the test it was observed that condensation was extremely slow to form on the heat exchanger. In fact the shower had to be running for over an hour before any condensation was detected on the heat exchanger, and for nearly one and a half hours before droplets were formed. It should also be noted that the both bathroom door and shower cabin door needed to be open before any dripping of water from the heat exchanger took place. This makes occurrence of condensation due to humidity coming from customer activity very unlikely.

Temperature decrease (response time)

After the test it was found that the rooms did not start the test under same conditions. However, general observations show that the chilled beam and fan-coil at speed 3 perform similarly. One of the most important factors when measuring cooling response time is the thermal mass of the building. If the measurements are made with different heat energy levels stored in building and the tests are not comparable. It can be concluded from the results that about 1 hour is needed to decrease room temperature by 2°F (1°C) after the first hour when even the effect is twice as much.

References

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