8.0 Discussion of Original Design

The original rooftop design is almost impossible to beat when it comes to first cost; however, there are also shortcomings to this configuration. All thirteen rooftop units used at the site are single-zone constant volume mixed-air systems. This type of unit is convenient because it can be located directly above the zone that it serves.

In this systems most basic configuration, the thermostat reads the dry bulb temperature of the space that it is serving and modulates the cooling provided. The means of modulating this cooling capacity is achieved by cycling compressors on and off. At full load, this method of cooling is adequate to meet the temperature and relative humidity setpoints. The unit mixes return air from the space with outdoor air and passes this mixed air through the cooling coil. The full load occupied space adds heat and moisture as the dry bulb temperature and relative humidity levels rise towards their setpoints.

The fan provides a constant volume of air regardless of the space's cooling load. At part load, the system is forced to deliver supply air that is warmer than the full load condition air to avoid overcooling the space. When the compressor starts, the coil's surface will become cold quickly. Beads of water form on the coil until there is enough mass for gravity to overcome the surface tension. At this point, the moisture will fall to the drain pan below. The point is that there are a few minutes of lag time between when the compressor turns on and when the condensation reaches the drain pan for removal. Similarly, when the compressor stops running, the droplets that have not gained enough mass to fall are exposed to the outside air. These droplets evaporate back into the supply air, and actually raise the humidity ratio of the air that is coming across the coil. This will occur until all of the droplets are evaporated and the coil dries off completely.

As the percentage of time that compressor runs decreases, the unit's dehumidification effect also decreases. It should be noted that if the compressor cycles too often, there may be no dehumidification effect at all because the cooling coils would never have an opportunity to dry. Proper humidity control is further diminished if the systems are oversized.

Packaged rooftop units have cfm/ton limits that lead to the delivery of more airflow than the cooling load will require, even at design load. This is the case for the LA Fitness units. Increasing the system airflow will create a lower temperature difference which translates to warmer supply air and less dehumidification at all load conditions.

Below is a psychrometric example of RTU-3's coil performance on an average day in March (this example was taken at a part load condition to get a better idea of how a system may normally operate instead of always comparing to design conditions). The outdoor air is at a condition of 80^0F dry bulb and 70.1^0F wet bulb and the room setpoint is 75^0F and 50% relative humidity. The outdoor air will mix with return air to generate the mixed air condition. This mixed air is sent to the coil. The load is going to be some fraction of the total design load, and the resulting indoor conditions will not allow for humidity control. This is how two of the units (RTU-1 and RTU-2) are configured to operate in the original design. It is important to realize that the line from the supply air to the actual room condition is a constant parameter that represents the sensible and latent load generated within the space. With a constant volume system, the compressor must modulate down or cycle off when it receives a temperature signal that is below the setpoint to increase the temperature of the air coming off of the coils. The result from the analysis below shows that although the temperature requirements for the space have been met, the relative humidity is 11% higher than desired. There is no telling what damage this can lead to when considering the effects of mold on a building and its occupants.

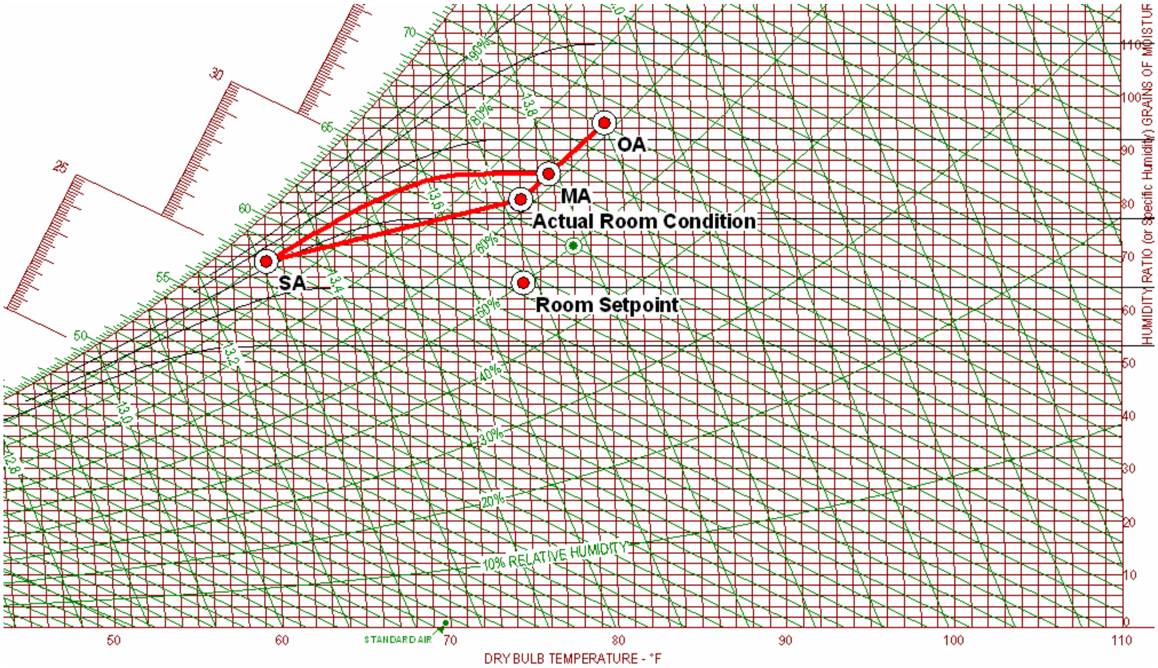

Figure 8.1 – RTU- 3 Loses Humidity Control without Reheat on a Part Load Day in March

The addition of a humidity sensor and reheat is an approach that will work to control some of the humidity problems associated with the systems discussed above. The designers of the original systems realized this and added hot gas reheat to eleven of the thirteen systems in question. It is unclear why the other two units did not receive this option as they receive the same outdoor air at the same conditions. Below is the same scenario as illustrated in Figure 8.1 with a reheat option.

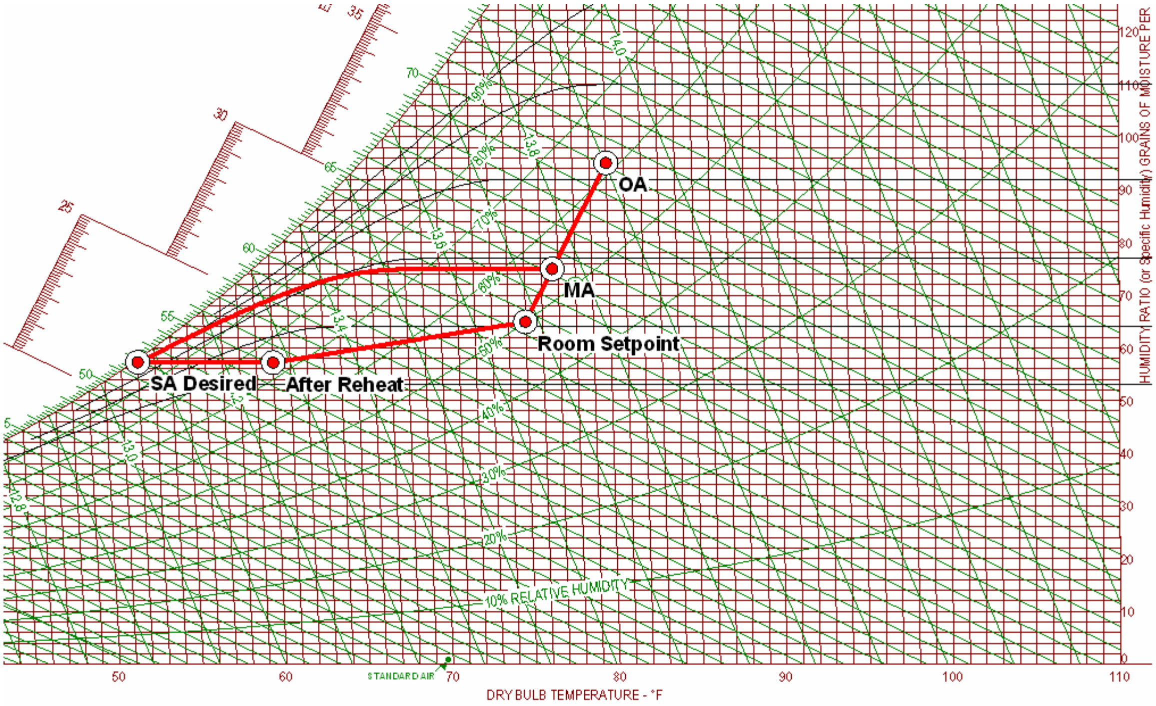

Figure 8.2 – RTU-3 with Hot Gas Reheat: Performance for a Part Load Day in March

A hot gas reheat option works by adding a refrigerant-to-air heat exchanger between the compressor and the condenser. After the coil has removed the required amount of moisture from the air, the heat exchanger adds sensible heat from the hot refrigerant vapor to the supply air downstream of the cooling coil.

It should be noted that the above hot gas configuration will adequately serve the required design and part load conditions. Knowing that this configuration will work, the question then becomes "Is this the best way to meet the loads?" The answer to that question depends on who you ask it to. If you ask a building owner, the answer is probably a simple and cheap "Yes." However, from a mechanical system design standpoint the answer is a hopeful "No." In order to meet the required loads for building, compressor energy is being used to cool the air down to 55^0F only to have it reheated back up to 60^0F. The reasoning behind this method of meeting space temperatures has been clearly illustrated by the example, but perhaps there is a better approach.

8.1 Desiccant Dehumidification

Desiccant technology relies on changing vapor pressures to perform dehumidification. Desiccants are characterized by having very low surface vapor pressures. When a relatively moist stream of air passes over a desiccant, the lower vapor pressure attracts the moisture out of the air. This removes latent energy from the air stream in a reaction that also generates sensible heat. If this process is accomplished with a solid desiccant, the desiccant is considered an adsorbent. Adsorbents are like sponges that collect and release moisture. There is another type of desiccant called an absorbent; these desiccants undergo some form of chemical or physical change while they dehumidify.

After a desiccant has collected moisture from the air, it becomes useless unless there is a means to release that moisture. This process is referred to as reactivation of the desiccant. A typical way of reactivating solid desiccants is to send a hot, dry stream of air to collect and exhaust the moisture from the surface. Often a hot enough stream is not available from the exhaust alone. In this scenario, a heater or heat exchanger is used to get the exhaust stream to a high enough temperature to collect the necessary moisture and reactivate the wheel. Once heat is added for regeneration, the system is deemed an “active desiccant” system. An example of a passive desiccant system would be an enthalpy wheel.

A rotary honeycomb style desiccant wheel can be sectioned off into two airflow regions as shown below in Figure 8.3. The airflow that is to be dehumidified flows through the larger section of the wheel (75% of the wheel in Figure 8.3) where it deposits moisture and gains sensible heat. The wheel rotates, and the smaller section of the wheel receives a hot and relatively dry air stream that flows in the opposite direction to reactivate the desiccant material for future dehumidification of the process air stream.

Figure 8.3 – Rotor Source’s Desiccant Wheel

The processed air leaving the desiccant is now hot and dry. If the process is to be used for a cooling application, it would be wise to run the processed air through a sensible heat recovery wheel that uses the same exhaust stream. This process will lower the dry bulb temperature of the air while leaving the humidity ratio reached by the desiccant process alone. These two processes will bring the processed air to a temperature that is relatively close to the original dry bulb temperature only with a much lower humidity ratio. Figure 8.4 has been created to illustrate how these two wheels work in tandem.

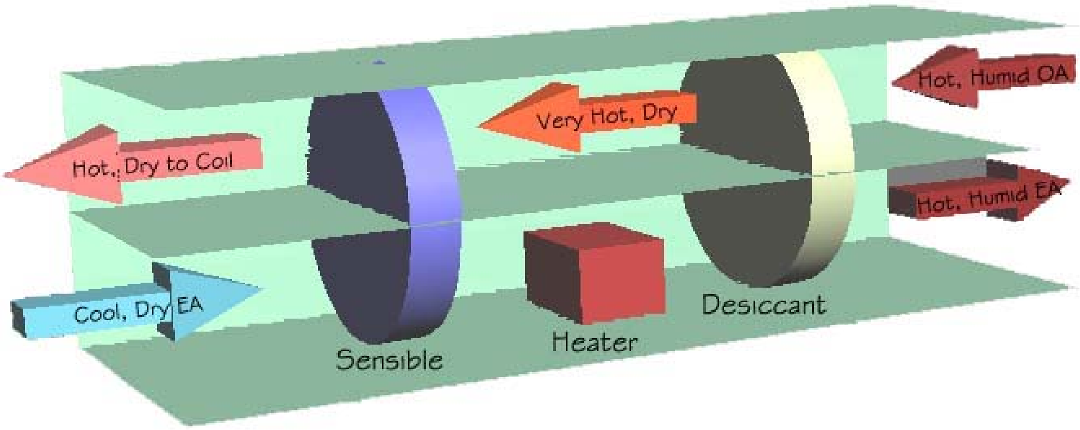

Figure 8.4 – Desiccant Dehumidification with the Addition of a Sensible Wheel Configuration

The outdoor air psychrometric state points will look like some variation of Figure 8.5 for the configuration above on a typical cooling day for Houston.

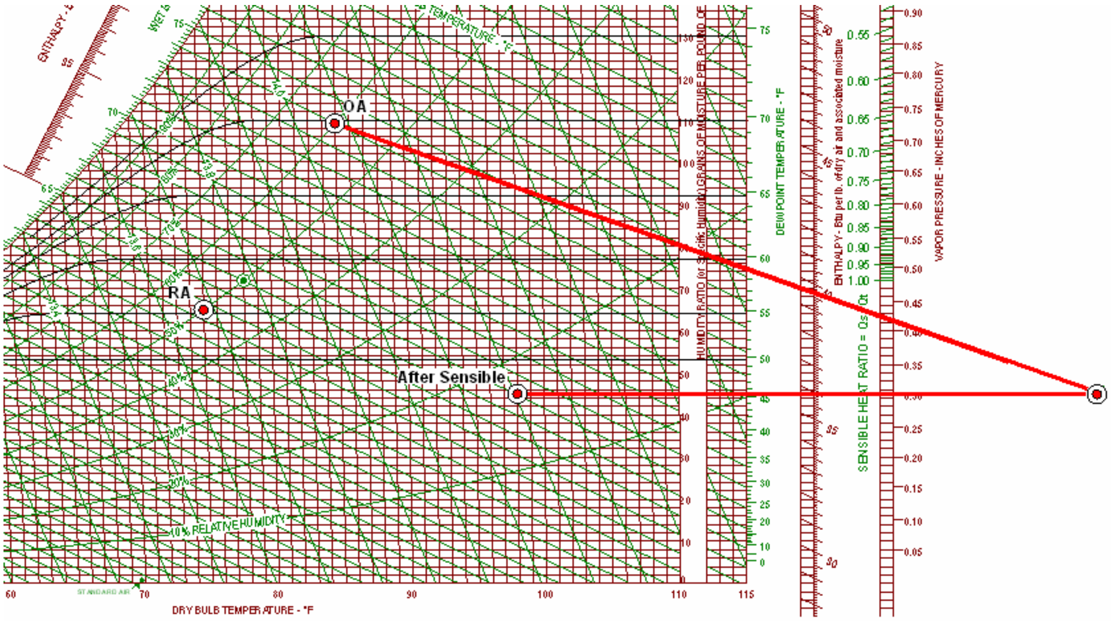

Figure 8.5 – Desiccant Dehumidification of Outdoor Air Followed By Sensible Heat Recovery

If the air is dry enough, the coils on the rooftop units will only need to remove sensible heat from the loads. This system eliminates much of the time that droplets from the coil would be evaporating back into the air stream as discussed before. This system will also undoubtedly save cooling coil energy. The design then lends itself to the question, “Can this design save enough cooling coil energy to have a reasonable payback period?” The recommendation provided in Section 9.0 will provide an analysis and an answer to that question.