Commissioning to Meet Space Qualification Criteria vs. Energy Consumption Optimization Focused Commissioning

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ABSTRACT

In many cases, the commissioning process is driven by space quality criteria rather than by energy consumption and optimization criteria. This is especially true for the HVAC systems serving clean rooms in the semi-conductor and pharmaceuticals industry. Experience has shown that commissioning targeted at meeting space qualification requirements alone may not necessarily result in an energy efficient delivery system. On the other hand, commissioning that is focused on meeting the space qualification requirements in as efficient a manner as possible will result in success in both areas. This paper will focus on a case study of a make-up air handling system where space-quality-focused commissioning resulted in some very significant energy consumption problems.

INTRODUCTION

At a new wafer fab, the newly hired HVAC and fire protection facilities engineer spent most of the first month on the job learning about the specifics of the production process and playing catch-up with the new construction project. About one third of the facility was operational, doing qualification runs to prove that the fab could manufacture a quality product. The other two thirds was just coming out of the ground

Finally, one July day, the new engineer spent some time exploring the operating portion of the plant, to learn where systems were and get a feel for the general operating status of the HVAC equipment when it was serving an on-line process. To his surprise, when he walked into the service corridor for the 45,000 cfm EPI clean room make up air handling unit, he heard sounds typically associated with high steam flow rates in piping systems. Given that this was a process environment and the system was serving a clean room with specific temperature and humidity operating requirements, he surmised that the steam flow was associated with a reheat burden required to keep the temperature and relative humidity parameters in spec. On closer inspection, however, he noticed that the trap from the preheat coil was quite hot. In the course of the next 30 minutes, he found:

- The preheat coil was active and heating the 81°F outdoor air to 115°F.
- The cooling coil was cooling this air to 40°F.
- The reheat coil was heating this air back up to 46°F.

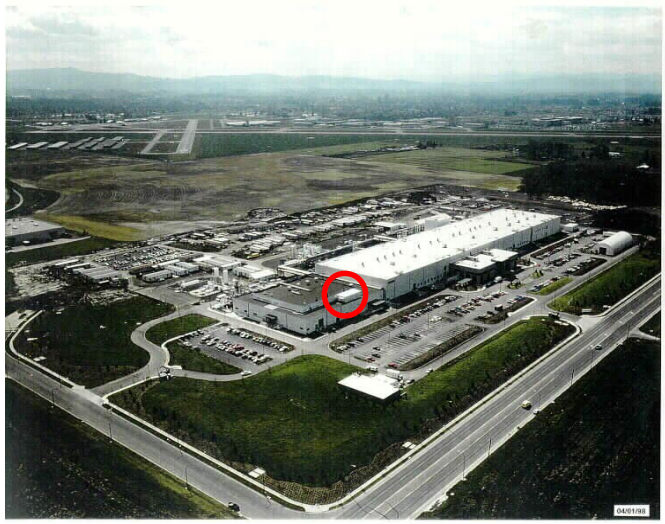

Figure 1 – A Modern Semi-conductor Wafer Plant

To get an idea of scale, the main building is about one quarter mile long. The system that is the subject of the paper serves a clean room at the left end (the area with the dark roof). The air handling unit is circled.

- The humidifier was active and injecting a considerable amount of moisture into the air.
- The fan heat was raising the temperature of the air to 54°F.
- The clean room conditions were right on specification.

This information was gathered using fairly simple techniques including:

- *Visual and sensory observation* – Moisture was visibly being injected by the humidifier and high steam and chilled water flow rates were audible. The traps and piping systems were hot to the touch.
- *Local indicators* – Visual observations were confirmed and refined using local thermometers and a local display on the Direct Digital Control System (DDC System) controller serving the unit.
- *Radio and phone discussions* – Clean room operating status and central plant status were confirmed by phone and radio calls to managers and operators.

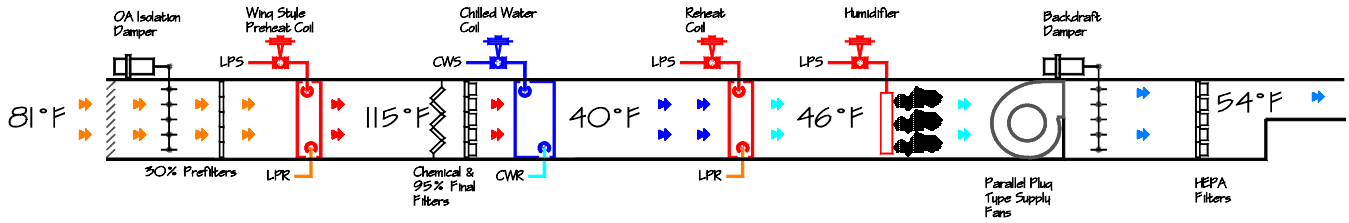

Figure 2 – The System in our Case Study and the Problems it was Having One Day

This schematic depicts the general arrangement of the system.. The temperatures shown are the temperatures that were observed on the day the problems were noticed. At the time this was all going on, the clean room conditions were stable and within specifications: 68°F+1-1/2°F, 45%+5% relative humidity.

- *Hand held, portable temperature probes* – Temperatures were cross-checked against a common denominator using a portable electronic temperature sensor

In other words, none of the symptoms were particularly hidden or difficult to detect.

Figure 2 illustrates these observations on a schematic of the system. Figure 3 compares the observed process with the process needed to satisfy the space temperature and humidity requirements on a psych chart. As evident, the process was consuming much more energy than required to meet the desired space condition. Some key points to notice on the psychrometric chart are:

- Satisfying the space temperature and humidity requirements in a dehumidification mode would require a coil discharge condition of approximately $46°F_{tdb}/45.5°F_{twb}$. In theory, this could be achieved by simply cooling the outdoor air to a 46°F discharge temperature on a sufficiently deep cooling coil.
- There is no psychrometric justification for operating the preheat coil when the outdoor temperature is above the discharge temperature required to meet the space sensible cooling requirements.
- In the "as found" operating mode, the chilled water coil was cooling the air approximately 6°F below the discharge temperature necessary to satisfy the space relative humidity requirement. As a result, the system had to humidify and reheat to hold the necessary space condition. The humidifier was putting water back into the air stream although water had been removed and was probably still in the drain pan approximately 15 feet upstream. The energy impact of this was compounded by the fact that the humidity was generated by using steam to boil Reverse Osmosis DeIonized water (RODI) rather than by direct steam injection. This approach was taken to minimize the potential for contamination via trace chemicals from the water treatment associated with the steam system. All of the water boiled off to humidify was generated by the site's RODI plant, which was an energy intensive process all by itself.

A rough, bin type energy calculation indicated that the system was using between $5,000 and $7,000 more energy per month than it needed in the current operating mode. Most of the extra energy was in the form of steam consumed in the preheat coil, humidifier, and reheat coil. However, there were also some electrical penalties associated with providing unnecessary cooling from the electrically driven chiller plant and providing RODI water for humidification from the RODI plant.

WHY WAS THIS HAPPENING?

As the engineer tried to understand why the system was operating this way, he discovered answers that fell into the following general categories.

- From a process standpoint, the clean room managers and operators were happy if the clean room environment was within specifications (68°F+1-1/2°F, 45%+5% relative humidity) and stable; i.e. any changes that occurred within the tolerance band occurred at a very slow rate.

The plant was essentially a design-build, fast track project, with performance based on a set of "Owner's Requirements" (ORs). The ORs were very specific about the conditions needed in the clean rooms, but didn't specify how to achieve them, although the general configurations of the HVAC systems were specified.