MAKING BUILDINGS WORK

A case study of an innovative cold-air retrofit

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The first-cost focus of new construction can often result in buildings that don't work, particularly the HVAC systems. This article presents an innovative cold-air retrofit that corrected HVAC inadequacies in an office building that stemmed from poor design. By utilizing cold air, the retrofit overcame insufficient airflow and insufficient cooling capacity at the air handling units, thereby avoiding a massive and very disruptive retrofit of a fully occupied office building. The resulting retrofit cost less than half of the conventional alternatives and was easily implemented during weekend hours. It resulted in a building that actually worked for the first time since its original construction some 15 years prior. The author's more than two decades of experience in restoration and remediation of existing buildings provides some valuable insight into how to creatively and cost-effectively fix nagging comfort problems in existing buildings.

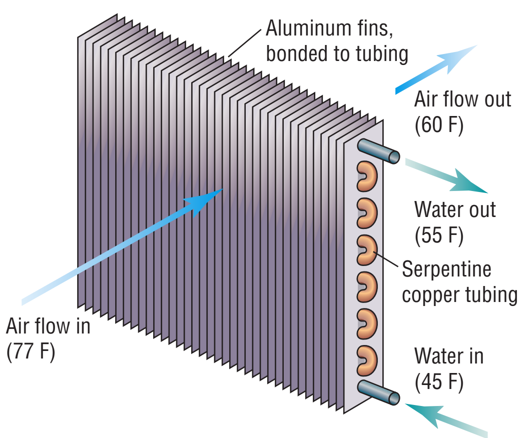

FIGURE 1. Typical water-to-air heat exchanger. Coils can be up to 10 rows deep with as many as 16 fins per inch.

RETROFIT BASICS

In reading this article, it is important to realize that the world of retrofit is poorly understood and a completely unique niche of the building construction industry. We find that most building owners and most design professionals don't understand this. By and large, traditional design professionals, who grew up in the world of new construction, are ill equipped to face the constraints of fixing problems in existing buildings—short of wholesale replacement of systems (which gets us right back to "clean sheet" or new construction design). In the world of retrofits, all those little problems that were resolved in the field by the original builders, and all those remodels and modifications all need to be identified and dealt with by the retrofit engineer. Frequently, whole-building testing is necessary to identify the cause of the complaints. In addition, retrofit frequently requires that the building be modified while the building is fully occupied, meaning that working conditions are difficult, and major disruption to the occupants cannot be allowed. We frequently liken it to performing a heart transplant on a marathon runner—during a marathon. The project described herein is just such a project.

THE SITUATION

We were called into the project by the service contractor for the building, who was trying to figure out how to help the owner keep their tenants happy. They weren't very happy because the building was uncomfortably warm nearly all year long in its northern California climate. Only during the coldest months of the year was the building comfortable. We set about to ferret out the source of the problem. What we learned was that the original designer made some fundamental conceptual errors in determining the operating parameters of the air-handling equipment, which effectively resulted in under-sizing of both the airflow and the cooling coils. This was in spite of the fact that he had done a good job of estimating the cooling needs of the building. The problem wasn't in the capacity of the chiller or in the apparent capacity of the air-han-

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dling units. There was a problem, though, in the performance of the air-handling units.

There are a couple of aspects of load calculations that, as the cartoon character Dilbert is wont to say about nuclear energy, "can be used for good or evil." Those aspects have to do with space loads versus system loads. Astute HVAC system designers are very careful when considering these loads, realizing that any cooling load that can be kept out of the occupied space allows the designer to reduce the supply air quantity needed to cool the space and, in turn, allows the use of a smaller air-handling unit. Seems pretty obvious, right?

Well, in this case, the designer assumed that 100 percent of the heat from the lights would go into the return air instead of the space. After all, he was assuming that return-air-troffer lighting fixtures would be used, and, therefore, all the heat from the lights would go into the return air passing through the fixtures. On the surface, this seems plausible. However, certain fixture manufacturers actually document the percentage of the total heat from a fluorescent fixture that is transferred into the air stream. The highest value we've seen so far is about 30 percent, and we think even that is a bit optimistic. When you consider that the lighting system heat gain can contribute as much as 40 to 60 percent of the total heat gain in an occupied space, this had a dramatic effect on the calculated supply air cfm. Add to this the fact that the HVAC system was designed for a "shell" building and the eventual tenant build-out did not employ return air troffer lighting fixtures, you can start to get an idea of how much trouble this building was in. But there's more.

The "more" is the other effect of the designer's assumption about the space loads—its effect on the load the system experiences. You see, if you assume that 100 percent of the heat from the lights goes into the return air, instead of a return air temperature of, say, 76 F, you will calculate a return air temperature of more like 86 F. This means that, when combined with a fairly high ambient design temperature, the mixed-air temperature will calculate out to about 88 F—instead of a more correct value like 78 F. This only becomes a problem when selecting a cooling coil for your (already undersized) air handling unit. Since there will be more heat transferred from 88-F air to 45-F chilled water than from 78-F air (total temperature difference is now thought to be 88 F minus 45 F, or 43 F, rather than 78 F minus 45 F, or 33 F), it will appear that you can get all the cooling done that you need with a pretty small coil—fewer rows and/or fewer fins per inch (fpi). Indeed, such an undersized coil was selected by the system designer.

Description	ROWS/FPI	EDB/EWB	LDB/LWB	EWT/LWT	GPM	APD	MBH
Existing	4/12	74/60	53.5/51.8	45/58.5	30	.69	203
Retrofit	8/9	74/57	45.8/44.6	40/54.4	39	.70	281

TABLE 1. Forty-percent increase in AHU cooling capacity by replacing the coil.

The net-net of all the above is that by making one seriously wrong assumption, the system designer put into the building an air-side system that could never cool the building—and, indeed, it didn't.

SOLVING THE PUZZLE

Once we understood the root source of the problem, we had to face the question of what to do about it.

The immediately obvious solution was to yank out the air-handling units (AHUs) and replace them—the "traditional" approach to such a problem. After all, this would correct the fundamental error that was made in the first place. The problems with this approach are many. To name a few:

• The AHUs were located in interior mechanical rooms in the "core" area of each floor and replacing them would require knocking out walls and seriously disrupting the occupants and operations of the building

• Increasing the horsepower of the AHUs would require significant cost for electrical work as all the units were fed electrical power from the basement and the entire conduit and conductor riser would need to be replaced as it had no excess capacity

• The mechanical rooms were very cramped and there really was no room at all in them for larger AHUs. Doing so would require re-configuring the floor plan layout of the "core", another very expensive proposition, and not really feasible)

Recognizing that a more traditional approach really didn't constitute a suitable solution for this problem (and was likely the reason the problem had gone unresolved for 15 years), we chose to "re-engineer" the HVAC system from the inside out, assuming that the AHUs themselves could not be replaced, nor could their fan horsepower be increased (due to the limitations of the building's power-distribution system). Grinding away with a computerized coil-selection program and rethinking other parts of the HVAC system, we determined that the AHUs could be made to perform by:

• Replacing the existing 4-row chilled water coils with 8-row coils of equal air pressure drop (examination of factory certified dimension drawings confirmed that they would fit in the AHUs).

• Increasing the chilled water flow through the coils, which is feasible with a much higher horsepower pump, and within the allowable flow rate for the chiller. This required more than twice the original horsepower to achieve a 30 percent increase in flow.

• Reducing the chilled water supply temperature from 45 F to 40 F, also with the allowable operating parameters for the chiller.

• Installing new AHU temperature controls to reset the planned low supply-air temperature upward during cool weather. If this was not done, "cold" complaints would replace "hot" complaints.

Without negatively impacting the air-handling systems' air-supply rate, the new system would be capable of supplying 46-F air and, thereby, produce the actual cooling needed to satisfy the occupied space.

MAKING THE FIX

Upon completion of the study, we prepared the final installation documents. This work was performed in collaboration with the owner's selected contractor so as to achieve maximum integration of design concepts and the contractor's working knowledge of the building. The chosen contractor had the service contract for the building.

Final selection of equipment was made, simplified installation drawings were prepared and the project was installed and put into operation over a 90-day period, including start-up. No tenant disruption was caused during the installation (which would have been the case had the conventional approach of replacing the air handling units been followed).

Upon completion of the project, the building's HVAC systems provided comfort for the first time in the 15-year life of the building. The utterly prosaic business of HVAC engineering doesn't get any more exciting than this.

CONCLUSION

One of the lessons that can be learned from this project is that the age-old tradition of linking engineering fees to construction cost—our traditional way of paying design professionals—would not have allowed this project to take place. After all, it took a lot of engineering to avoid spending money. So engineering fees went up, and construction costs went down, making the engineer's fees look "large" as a percentage of construction costs. Many building owners would insist that less money be spent on engi-

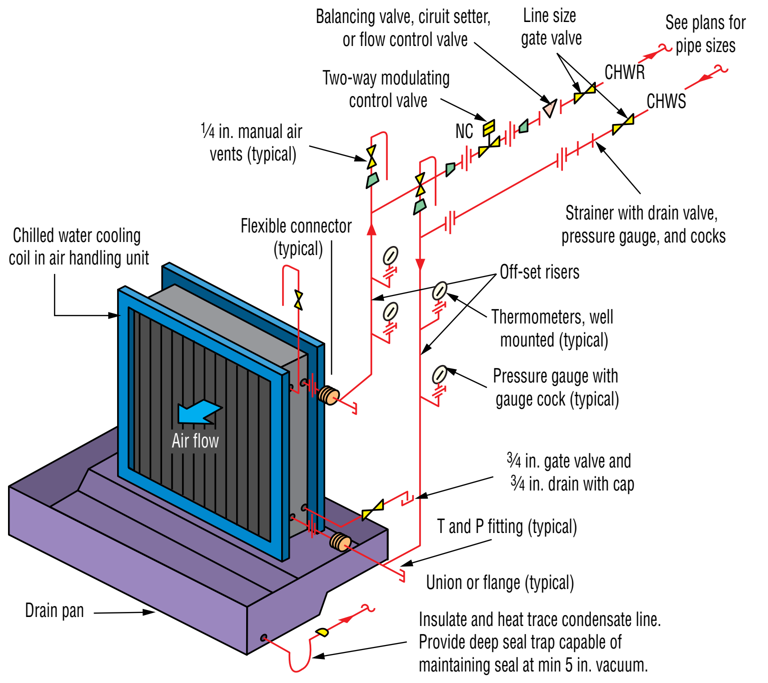

FIGURE 2. Typical coil piping for variable flow.

neering. The result of this is an engineer forced to get his eraser out to create a "clean sheet of paper" and do a very simple design, one that doubles or triples costs. Suddenly, the engineer's fees, look "small" as a percentage of construction. Building owners, take heed.

Another, perhaps more technical, lesson to be learned is that by understanding the essential nature of the engineering problem being faced, it is often possible to re-engineer a system from the inside out and make it work, even when it seems impossible. Design engineers, take heed.

Even in today's energy-sensitive environment, making buildings work (i.e., having them provide the function they were intended to provide: a comfortable and productive work environment) is equally, if not more, important than saving a few dollars on the utility bill.

Finally—and this is a tip for new building HVAC designers—if you want to build a little "safety" into your HVAC system, selecting a cooling coil with more rows (and perhaps a few less fpi) is really cheap "insurance."

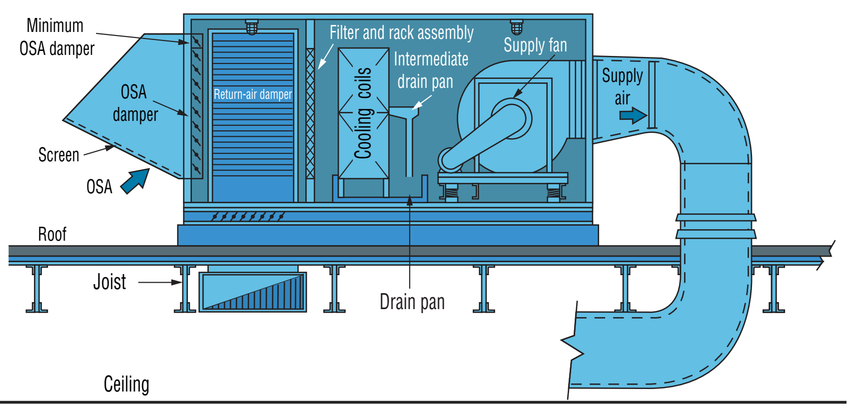

FIGURE 3. Cooling coil in a typical rooftop air handling unit installation.