Experience With '60's Era Radiant Cooling: Considered Impractical

This letter is in regard to the November 2001 article "Dedicated Outdoor Air in Parallel with Chilled Ceiling System," by Dr. Stanley Mumma (page 56).

I have always believed that our industry is doomed to repeat past mistakes on a 20 to 30 year cycle. This thought struck me again as I read Dr. Mumma's article on his chilled ceiling system. I believe, that like those that tread before him, he will discover there is a big difference between the theoretical and the practical.

In the 60s quite a few of these systems (called Burgess-Manning Radiant Cooling Systems) were installed in hi-rise buildings in California. The only one I am aware of that is still operational is a 28-story building in downtown Oakland. With the exception of outside air heat recovery, the system described by Dr. Mumma is almost identical to this building. Primary cooling (and heating) is achieved through an aluminum ceiling tile system that is thermally fastened to ½ in. galvanized steel pipes on 1 ft centers.

Floors are zoned into 16 to 18 grids, each with its own four-pipe change over valving arrangement and secondary pump. Ventilation and dehumidification is provided by a dedicated 100% OSA, constant volume fan system with dehumidification and tempering coils in the basement. Because the building was built before energy was an issue, the OSA ventilation rates are fairly high: 0.5-cfm/sq ft. We installed variable-frequency drives on the OSA fans that allows the building operators to reduce the OSA when conditions permit. Dewpoint control technology was not very good in 1965, and the chilled mirror dewpoint controllers that were originally installed never worked properly and were removed shortly after the building was finished.

Until we installed modern dewpoint controls to modulate ceiling water temperature, condensation was a periodic but not a major problem. I have personally seen the ceiling dripping when the controls got out of adjustment – the volume of water is not great but it is enough to discolor the ceiling and damage papers on desks. With modern direct digital controls (ddc) and a large, competent building engineering staff, we got the system to work reasonably well.

Based on 10 years of living with this system I would caution Dr. Mumma on the following points:

- Chilled ceilings are much more expensive to install and remodel than conventional variable-air volume (vav) systems. Many of the IAQ problems associated with vav systems can be alleviated with design "tweaks" which are a lot less expensive than the chilled ceiling alternative. As a contractor and an engineer with 20 years experience, I can state with absolute certainty that the European style radiant cooling systems are much more expensive to install and remodel than a conventional vav system.
- Condensation on the ceiling was initially a problem, albeit not a huge one, however leaks from the circulation system are. I don't care how good the installation is, after a few years piping systems will spring leaks (at valve stems, flanges, pump seals, etc.). The Oakland building has over 120 miles of 1/2 pipe that feed the ceiling, 504 secondary pumps, and over 2,000 control valves; needless to say leaks and drips are a regular occurrence. We live in a litigious

society, and lots of water running around the ceiling above lawyers' offices and their files is asking for trouble (speaking from personal experience).

- Remodeling is a nightmare. Running conduit, wire, piping, etc. above the ceiling after the installation is complete takes 2 to 3 times as much effort as it does over a conventional tile ceiling. For speculative type office space with tenants moving in and out on a regular basis, a radiant cooling system is a disaster.
- Architects absolutely hate the ceiling because it gives them no choice on finishes, ceiling heights, architectural decorations like soffits, etc. About the only thing they can do is choose colors, which results in a lot of paint building up on the ceiling over the years.
- The ceiling provides a fixed amount of cooling capacity per square foot regardless of the actual demand. It works pretty well in open office plans, but it does not work at all well in chopped up spaces. Conference rooms and small offices with high computer loads required us to install supplemental chilled water fan coils for additional cooling capacity. Installing equipment above chilled water ceilings can be very difficult and expensive.

I could go on but in the interest of brevity Ill stop with these problems. Suffice to say, myself, and a lot of other engineers, some with Ph.D.'s, have looked at the radiant concept in this building and shook our heads. It is a solution in search of a problem. It does work (marginally), the tenants are generally comfortable, and the IAQ is good, but the reality of dealing with it on a day-to-day basis makes it totally impractical. North Americans tend to have a inferiority complex when it comes to European engineering, but my personal experience has shown me that European solutions in our industry tend to be expensive, overly complicated, and not significantly better than our systems.

Back in the early 90s a group of engineers from Lawrence Livermore Labs came to tell us about a wonderful new European radiant cooling system. I showed them the example in Oakland, and the problems associated with it, and they offered to install a test system in the building to compare the old and new technology. They tore out one room of the Burgess-Manning system and we installed their system. Lots of sensors were installed to compare performance (black-body radiation sensors, humidity, flow, etc.) and a test was run. The ending of the story is somewhat of an anti-climax: We were expecting to get a detailed report of the test and what really happened is that the people involved just sort of evaporated and we never heard from them again. All we could assume was that the latest and greatest European ceiling panels were not much better than the 30-year-old Burgess Manning system.

Radiant cooling systems are nothing new in this country. They apparently have a place in Europe, and they may even have a place in the U.S. in specific applications, however for the vast majority of new construction they are totally impractical, overly expensive, and overly complicated.

One last note, the engineer that specified and designed this particular system killed himself not long after the building was built (late 60's I believe). The legend is that his suicide was attributable the bankruptcy of his firm, caused in part by trying to solve all the problems associated with this system.

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Dr. Mumma responds:

Thank you Mr. Linford for the forceful reminder that systems which have been poorly designed and utilize inadequate equipment will almost certainly experience the kind of problems that you identify in your letter to the *ES* editor. Your reminder is important today, since I learn nearly weekly about additional contractors who are attempting to enter the radiant cooling business, with little or no concept of what the issues are.

I am sorry that you have had this bad experience. As a person with over 35 years of practical and applied research experience in our industry, I have seen problems with every type of hvac system where poor design, equipment and or maintenance were involved. Chief among them are variable-air volume (vav) systems, and it has been shown that design tweaks cannot overcome their IAQ problems[1,2].

The panel design you describe is inferior by today's standards, and would operate with low heat removal flux. Consequently, I can understand that the operators were always struggling to meet capacity by lowering the panel temperature, thus constantly flirting with condensation. With current panel designs working in parallel with a properly engineered dedicated outdoor air system[3] (DOAS/radiant), this need not be the case, as we are demonstrating with the proof-of-concept project.

Further, the poor thermal performance of your cooling panels dictates a large ceiling fill factor. No wonder this would frustrate architects who may wish to use soffits etc. In most cases, with proper design, no more than 50% of the ceiling is required for panels, leaving the other 50% for architectural decorations, illumination, and air diffusion equipment. In addition, today's panels come in a variety of textures, patterns, colors, and acoustical perforation. They can be made to appear like most other ceiling systems.

One thing I have learned over my 35 years of experience is the value of the "keep it simple stupid" (KISS) principle. The system you describe is a KISS disaster in my opinion. Using a four-pipe change over system is unthinkable in this application. And based upon the numbers in your letter, it would appear that there are 16 to18 zones per floor in the 28-story building. That means there are up to 504 zones in the building.

By the way, a comparably controlled vav system would have 504 vav boxes, required reheat coils, large ductwork, and the associated control complexity and first cost. The unnecessarily complicated hydronic system you describe uses over 2,000 control valves, or over four per zone.

With my DOAS/radiant design, there is only one control valve for cooling per zone. Zones that need terminal reheat in the DOAS (these are the same zones that would require terminal reheat in vav systems) have one control valve for heating. A perimeter heating system to overcome skin loss could operate on an open loop control adding one more heating control valve to the building. As a result, the DOAS/radiant control points per zone are identical in number to that of a vav system.

The piping in the plenum for a four-pipe system would clearly be a problem as you discuss. However with my cooling only panel system (heating is done by terminal reheat in the DOAS and the skin with perimeter heating) and the use of push-on-connector flexible hoses linking the panels to each other and to the main distribution piping, performing maintenance in the plenum is much easier. Panels can be moved aside without disconnecting the hoses, for easy access above. They can also be easily removed and reconnected for either extensive maintenance or evolving space use requirements without breaking normal threaded or sweat solder plumbing connections.

Finally, using 504 small circulating pumps, or one per zone, is not a bad idea. But if this were to be done, the pumps should be located in distributed mechanical closets for ease of maintenance, noise control, and leak isolation. The pumping for the panels could also be done centrally with variable-frequency drive (VFD) pumps[4] just as effectively, thereby eliminating the potential for noise, leaks, and maintenance in the conditioned spaces. Likewise the control valves could be centralized in mechanical closets, with the pumps, for ease of service and leak isolation.

Your letter implies that vav systems would not have piping systems, and associated leak potential overhead. However many vav systems use hydronic terminal reheat, with the piping and control valves overhead without any great leakage problem. Also, a great number of buildings have a wet sprinkler system overhead without the irritation of leaks. In other words, buildings served by vav systems do have water running around above the ceiling, and no doubt in many cases above lawyer's offices and files.

I have learned that the experimental results from the revisions you made for the National Lab were presented at the Orlando ASHRAE meeting in the summer of 1994. It was reported that the building, located on the west bank of Lake Merritt in the center of Oakland, CA, experienced very high solar loads during the fall as a result of reflection from the lake. Apparently the design engineer had overlooked this component of the cooling load. Measurements showed that the southeast facing single glazed windows were experiencing internal surface temperatures of 122F (50C). The air delivery system was modified in the test space to prevent short-circuiting between the supply and return by moving the return to the top of the windows, thus removing much of the solar load before it entered the space. Updated design cooling panels were also installed delivering up to 53% greater sensible cooling capacity than their predecessors.

The condensation problems that you experienced are the result of the poorly designed outdoor air system (OAS), no doubt because of the large reflected solar load oversight, in that it was not capable of completely decoupling the space sensible and latent loads while handling a portion of the space sensible load. The load decoupling is an absolute must when using radiant cooling! Further, since condensation can occur when equipment malfunctions, there must be a fail-safe way to prevent it. Obviously the system you described did not have that. It must be passive and fail safe, analogous to coil freeze stats. It must not work through the direct digital control (ddc), and could work like the one described in the paper and used in our proof-of-concept project.

You also note that where the panel capacity was insufficient, you had to retrofit some spaces with fancoil units. This is another sign of the poor OAS design. It is easy in conference rooms, small offices, and perimeter spaces that need additional cooling capacity to increase the design flow of dedicated outdoor air, generally supplied at 45°F[5], to overcome the added load that the panels and minimum ventilation air could not meet. This of course is one important reason not to supply the ventilation air at a neutral temperature! The other reason is a nearly 35% reduction in the first cost of the panel cooling system.

Finally, you express a major concern over first cost. I have addressed this issue in some detail[6] and show that with proper design, the first cost of a DOAS/radiant system is actually less than an all-air vav system in a 186,000 sq ft building located in Philadelphia. To achieve this outcome, it does require competent design.

In conclusion, it appears that you are locked into a negative radiant cooling paradigm because of one bad experience. It is because of skeptics like you that we have built our proof-of-concept project. I don't know if a successful DOAS/radiant project would change you point of view, but you are welcome to visit our little project. Further, in addition to European success stories with radiant cooling, panel-cooling technology has been used successfully here in the U.S. in hospitals and airport terminals for years.

I encourage you and all skeptical consulting engineers to revisit this issue, because I am convinced that DOASs are the future for both environmental safety (including terrorist attacks) and quality. And perhaps the optimum sensible cooling technology to use in parallel with the DOAS is panel cooling. Thanks again for your reminder and the opportunity to dialog about the DOAS/radiant systems.

References: note, all accessible from the following web address: *http://doas.psu.edu/papers.html.*

1. "Extension Of The Multiple Spaces Concept Of ASHRAE Standard 62 To Include Infiltration, Exhaust/Exfiltration, Interzonal Transfer, And Additional Short Circuit Paths" ASHRAE *Transactions*, 1998, V 104(2), pp. 1232-1241

2. "Fresh Thinking: Dedicated Outdoor Air Systems" *Engineered Systems* 18(5) 54-60, 2001

3. "Designing Dedicated Outdoor Air Systems" ASHRAE *Journal* 43(5): 28-31, 2001

4. "Ceiling Radiant Cooling Panels As A Viable Distributed Parallel Sensible Cooling Technology Integrated With Dedicated Outdoor-Air Systems" ASHRAE *Transactions*, V107(1), 2001

5. "Selecting The Supply Air Conditions For A Dedicated Outdoor Air System Working In Parallel With Distributed Sensible Cooling Terminal Equipment" ASHRAE *Transactions*, V107(1), 2001

6. "Ceiling Panel Cooling Systems" ASHRAE *Journal* 43(11): 28-32, 2001