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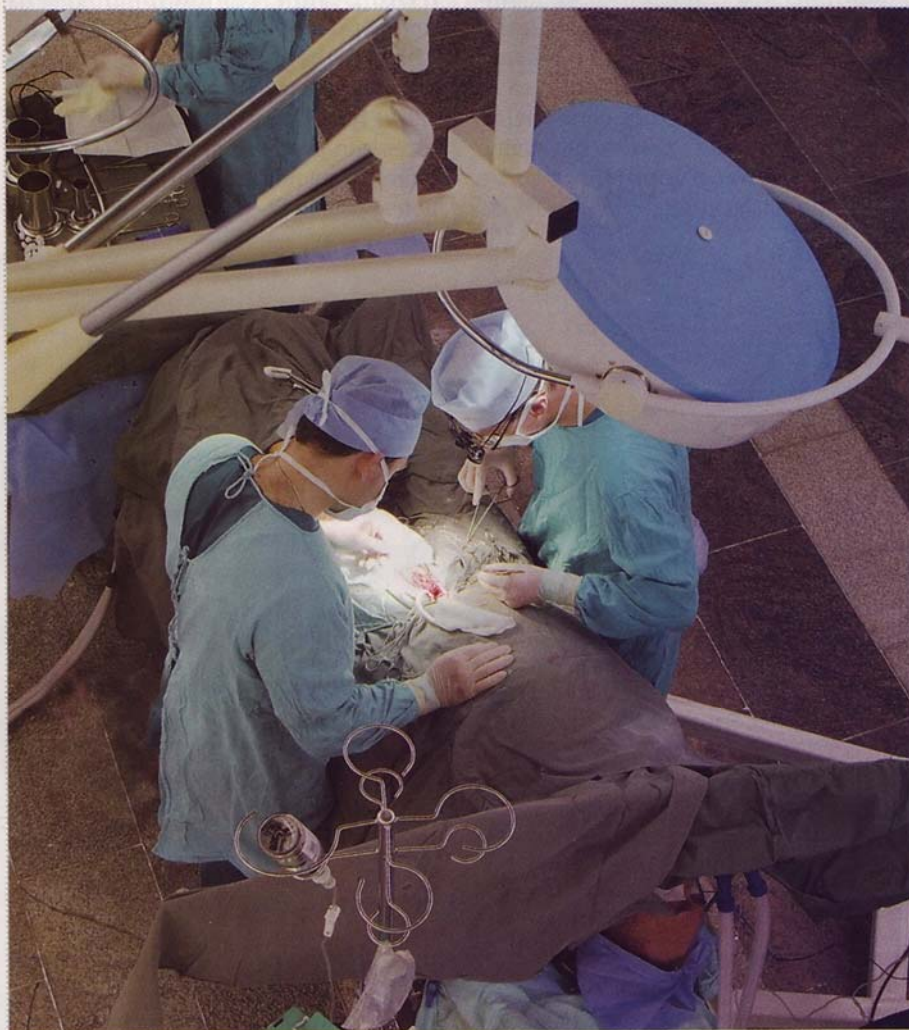
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RAIN OUT



Getting operating room humidity under control

by R. Mark Nunnally, P.E.



There are a number of reasons why controlling operating room humidity has been such a struggle for hospital facilities professionals.

Three fundamental reasons are a lack of understanding of basic psychrometrics; the HVAC systems being designed without consideration of the American Society of Heating, Refrigerating and Air-Conditioning Engineers' (ASHRAE's) more recently published weather design data and real-world space condition design guidelines; and inappropriate HVAC systems being designed and installed for the task.

However, with proper design considerations, HVAC systems can be built without the threat of higher than acceptable humidity levels or condensate dripping from the ceiling and suspended fixtures.

Who'll stop the rain?

Many health facilities professionals are used to early morning calls from the surgical staff. Chances are likely that they are calling with complaints about it being too hot or that it is "raining" in the rooms. While the temperature complaint seems easy enough to remedy, the root of that problem is often the same as with the "raining" complaint in the operating rooms. Both can be problems associated with excessive humidity in the space. We know

Requests for OR temperatures cooler than the HVAC system was designed to handle may lead to humidity problems.

that an environment with excessive humidity will make it feel warmer than it really is. This results in the "hot" calls. But what is this "raining" phenomenon, how common is it and what causes it?

The expression of it "raining" in the operating room merely means that there is condensate dripping from the ceiling and/or any of the fixtures hanging from the ceiling. This problem isn't new, but it appears that it is occurring far more frequently now than just a few years ago. Why? Many of the operating rooms today are being maintained at a temperature much cooler than the room's HVAC system was originally designed to sustain.

How common is this phenomenon? It is difficult to say with certainty. However, when hospital engineering groups are asked for a show of hands during humidity control seminars, 50 percent to 75 percent of the attendees typically respond that they have experienced "raining" in their operating rooms. While they are not scientific, these informal surveys conducted at national and Southeastern United States regional conferences indicate that this is a major concern for the health care industry.

What is the harm? Unquestionably, there is the loss of productivity (with surgical staff as well as facility operations personnel) associated with the uncomfortable operating room conditions. But, more importantly, there are serious health concerns associated with moisture condensing on a cool, probably unsterile, ceiling or suspended fixture. While it may often be considered just a nuisance to have the water droplets falling from the ceiling, it can become much more than simply a nuisance if these droplets were to fall into an open body cavity during a surgical procedure.

Equipment sizing

Two important factors must be considered when determining the capacity requirements of OR HVAC systems.

First, it must be determined what conditions are expected to be maintained in the surgical suites. It is recommended that the design team (architect and engineer) and representatives of the hospital staff (facilities personnel as well as surgical staff) meet to determine the actual space conditions to be achieved and maintained by the HVAC

system. Simply sizing equipment to achieve "normal" or "typical" conditions isn't sufficient. Secondly, the quantity of ventilation air or outdoor air, is significant for a surgical suite. Therefore, care must be taken that accurate ambient conditions are considered when calculating the cooling and dehumidification requirements (as well as humidification requirements for winter months).

While the recommended design guidelines may vary by region of the country, it is generally accepted that the guidelines adhered to are usually those of the American Institute of Architects (AIA), the most current ASHRAE standards or possibly the respective state's health department requirements (which typically reference the AIA or ASHRAE standards).

For example, a portion of the table of the design guidelines from ASHRAE's *HVAC Design Manual for Hospitals and Clinics* appears below on this page. Although the range of acceptable conditions according to any of these guidelines allows for a fairly wide range of temperatures and absolute moisture levels, the more commonly targeted design condition appears to be 68 degrees Fahrenheit

COMPARISON OF ENGINEERING BEST PRACTICE WITH AIA GUIDELINES AND ASHRAE HANDBOOK

FUNCTION SPACE	OPERATING ROOM 100% outside air system	OPERATING ROOM Recirculating air system	OPERATING ROOM Surgical cystoscopic rooms
Minimum air changes of outdoor air per hour			
Manual	*	5	5
ASHRAE Handbook	15	5	*
AIA Guidelines	*	*	3
Minimum total air changes per hour			
Manual	*	25	25
ASHRAE Handbook	15	25	*
AIA Guidelines	*	*	15
Relative humidity, percentage			
Manual	*	30-60	30-60
ASHRAE Handbook	45-55	*	*
AIA Guidelines	*	*	30-60
Design temperature, degrees Fahrenheit			
Manual	*	68-75	68-75
ASHRAE Handbook	62-80	*	*
AIA Guidelines	*	*	68-73

*No value given

INFORMATION COURTESY OF THE AMERICAN SOCIETY OF HEATING, REFRIGERATING AND AIR-CONDITIONING ENGINEERS.

(F) drybulb and 50 percent relative humidity (RH), as it is in the center of the range. Looking on the psychrometric chart (see the top graphic on this page), it can be found that the absolute humidity at this condition is 48.7 F dewpoint (51 grains per pound (gr/#)).

OR Conditions

However, it has become very common for surgeons to request cooler temperatures than the HVAC system was designed to maintain under the AIA Guidelines. Due to the heavy, multiple-layered gowning and the long procedures, many surgeons require their surgical suites to be maintained at 60 F to 65 F drybulb or lower during their surgical procedures. In addition to the concern for the surgeon's comfort, it is often necessary to maintain these lower drybulb temperatures in the operating rooms due to therapeutic reasons or to keep the adhesive cements used in orthopedics from setting too quickly. Even at these lower drybulb temperatures, the relative humidity in the space is still expected to be maintained near 50 percent by the surgical staff.

Looking again at the psychrometric chart, it can be observed that the corresponding absolute humidity at a relative humidity of 50 percent for both 60 F and 65 F is 41.3 F dewpoint (38.5 gr/#) and 45.9 F dewpoint (45.9 gr/#), respectively. As can be observed, if the installed HVAC system were only designed to achieve an absolute moisture level in the operating suite of 48.7 F dewpoint (51 gr/#) (this is the absolute moisture level at 68 F and 50 percent RH), that moisture level would be too high to maintain 50 percent RH when the drybulb temperature of the space is lowered.

So what does this mean for the surgical suite's environment? If the absolute humidity in the space was designed to be 48.7 F dewpoint (51 gr/#) and the drybulb temperature were dropped to 60 F by the surgical staff prior to surgery, the resulting relative humidity in the room would be 66.1 percent, at best (see the bottom graphic on this page).

Applying psychrometrics

With this little bit of review on psychrometrics and design standards, it can be demonstrated why the condensation occurs. Consider, for example, that the HVAC system installed is an air handler with chilled water coils. Assuming the entering water temperature is 44 F, the supply air condition (i.e., leaving air temperature) would be approximately 52 F saturated (i.e., 52 F drybulb, 52 F wetbulb, and also 52 F dewpoint (57.8 gr/#)).

be only 3 F), the supply air register's surface temperature, as well as any other surface nearby, would also be approximately 55 F drybulb. If the air surrounding these cooler surfaces had an absolute moisture content of 56 F to 58 F dewpoint (67.1 gr/# to 72.2 gr/#), moisture would begin to condense and begin to drip into the operating theater.

Understanding the absolute humidity needs of the space will reveal that the supply air dewpoint temperatures will likely need to be lowered, considering the lower temperatures the surgical staff is now demanding in the space.

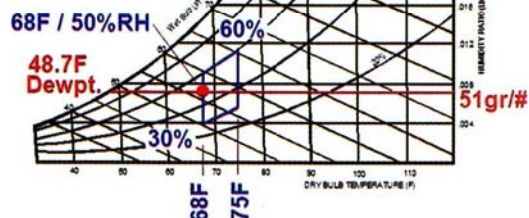
Consider, for example, that the intended space design condition was only 68 F drybulb and 50 percent RH. Again, this is an absolute moisture level of 48.7 F dewpoint (51 gr/#). If the scheduled supply air condition from an air handler is delivering 52 F (saturated), this means that the air is being supplied at a moisture level already greater than the intended design condition (i.e., 52 F dewpoint air being supplied into the space versus 48.7 F dewpoint desired) ... and this doesn't take into account the added moisture that can be expected from the staff.

In addition to establishing the proper space design conditions, a second point of concern regards the design conditions used for the ventilation air. In calculating the cooling and dehumidification loads of the space, too often only the ambient peak design condition

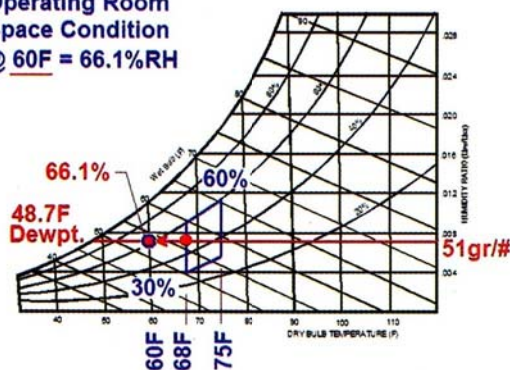
for cooling is considered, ignoring the valuable weather data that is available in the *ASHRAE Fundamentals Handbook*, 2005.

The 1997 edition of the handbook for the first time included a set of tables to be used when sizing ventilation equipment and/or when humidity control is important to the end user. This table indicates the occurrences of the peak latent ambient condition: dewpoint/humidity ratio and mean coincident drybulb. The engineer must be sure that not only the peak drybulb temperatures

AIA Design Range



Operating Room Space Condition @ 60F = 66.1%RH



Assuming the surgical team contributes a latent load (i.e., moisture gain) sufficient to raise the absolute moisture level of the operating room—which was designed to be maintained at 68 F drybulb/50 percent RH (48.7 F dewpoint (51 gr/#))—by 4 F to 6 F in dewpoint, the resulting space absolute humidity would be about 56 F to 58 F dewpoint (67.1 gr/# to 72.2 gr/#).

If the air being delivered through the supply air registers into the room were to be 55 F (assuming heat gain in the duct from the air handler to the room to

ASHRAE AMBIENT DESIGN CONDITIONS

0.4 percent occurrence for Birmingham, Ala.

Cooling DB/MWB	Evaporation WB/MDB	Dehumidification DP/HR/MDB
94 Fdb / 75 Fwb 100.1 gr/# 67.3 F dewpoint	78 Fwb / 89 Fdb 127.3 gr/# 74.1 F dewpoint	75 Fdp / 135 gr / 83 Fdb 135 gr/# 75 F dewpoint

ABBREVIATIONS: DB = drybulb; MWB = mean coincidental wetbulb; WB = wetbulb; MDB = mean coincidental drybulb; DP = dewpoint; HR = humidity ratio; Fdb = Fahrenheit drybulb; Fwb = Fahrenheit wetbulb; gr/# = grains per pound; and F = Fahrenheit.

SOURCE: THE AMERICAN SOCIETY OF HEATING, REFRIGERATING AND AIR-CONDITIONING ENGINEERS

a supply dewpoint temperature somewhere in the 50 F to 52 F range. The apparatus dewpoint or the dewpoint of the air being supplied from the cooling coils is typically 6 to 8 degrees higher than the entering water temperature. This may be too high to achieve the desired humidity conditions in the surgical suite while maintaining the lower drybulb temperatures. For the general patient rooms and other less-demanding spaces within the hospital, these supply air dewpoint temperatures will likely suffice; however, for the surgical suites, other technologies must now be considered.

If a low temperature chiller (i.e., a glycol-based solution) were to be used to supply cooler chilled water to the coils, the lowest water temperature likely to be considered would be 38 F. With the entering water temperature of 38 F, the resulting supply air temperature from the coils is likely to be 44 F to 46 F dewpoint. If the absolute humidity of the operating rooms were to be designed to be anything greater than 50 F to 52 F (after considering the latent gain from the surgical staff), this might be a viable solution.

• **Desiccant technology.** However, a more effective technology to consider for these lower dewpoint supply conditions would be a desiccant-based air handler.

A desiccant is any material that has a great affinity toward moisture. In the majority of the commercially available desiccant-based dehumidification systems, the desiccant material is silica gel and is bonded onto the substrate material of a rotor or wheel.

The desiccant material on the rotor removes moisture in the vapor stage from the "process" airstream by adsorption.

This is the airstream that is to be dehumidified, whether it is all outside air or a mixture of outside air and return air. The moisture-laden rotor then rotates through a section of the air handler known as the "reactivation" or "regeneration" section. In this section, the desiccant material on the rotor is dried with heat using either a gas-fired burner, a

steam coil or even an electric resistance heater. This process operates continuously as long as there is a need for dehumidification.

By incorporating a desiccant-based dehumidification system into the mechanical design for the hospital's operating suite, the overall system can be designed for optimal and active humidity control. No longer would the surgical staff have to tolerate less than desirable space conditions.

And no longer would there be a threat of it "raining" in the operating room during surgeries. The common problem of the fogging of microscope lenses would also be eliminated with the lowering of the dewpoint temperature of the air in the operating rooms.

With a desiccant system, the absolute humidity levels can be dropped much

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Achieving Impressive Customer Service

ACHIEVING IMPRESSIVE CUSTOMER SERVICE

7 Strategies for the Health Care Manager

Wendy Leebov, Gail Scott, Lolma Olson

7 Strategies for the Health Care Manager

Wendy Leebov, Gail Scott, Lolma Olson

A comprehensive array of detailed, useful strategies to improve customer service are presented in this easy-to-use manual. Health care administrators, managers, and supervisors in any provider organization, regardless of size, will benefit from core service strategies like:

- Establishing high standards of customer service
- Helping staff hear the voice of the customer
- Hiring customer service pros
- Helping staff cope better in a stressful atmosphere
- Reducing anxiety to increase satisfaction
- and more!

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lower than the chilled-water or DX coils are capable of achieving. Regardless of the drybulb temperature desired in the space, the humidity can be controlled to the lower levels without requiring low chilled-water temperatures. A desiccant-based system can be added to strictly condition the ventilation air requirements of the surgery suite or it can be sized to treat the entire supply air requirements of the suite.

As the compressor and the cooling coils make up the heart of the conventional HVAC system, the desiccant rotor and the reactivation heater make up the heart of the desiccant-based system. All the other components within the air handlers are the same for mechanical or desiccant systems (e.g., filters, blowers and motors, heating and cooling coils and controls).

While there are a number of factors to consider when choosing between these two technologies, the driving factor is usually the desired absolute humidity level of the supply air or its dewpoint.

Mechanical systems are limited to the lowest coil temperatures possible with the entering water temperatures, whereas the desiccant technologies are capable of achieving much lower supply air dewpoints. In general, when supply air dewpoints of 45 F or less are required, desiccant-based systems are the technologies to install.

No longer a threat

With local weather data now available to the design community, a better understanding of designing for absolute moisture supply conditions and a basic understanding of the technologies available today, condensation problems and "raining" operating rooms no longer have to be a threat. ■

R. Mark Nunnally is principal at the engineering firm of Nunnally & Associates Inc., Birmingham, Ala. This article is based on his presentation to the 2004 International Conference on Health Facility Planning, Design and Construction, co-sponsored by the



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