# <u>Feeling the Heat</u>

(HVAC Issues and Triple Digit Temperatures) By Ron Prager

As I sit down to write this article, we are in the third day of a triple digit heat wave in New York City. We have broken the all time record high for the second day in a row. Welcome to global warming, I guess. As a national provider of HVAC service, we knew this was coming. We watched the soaring temperatures march across the country from the west coast to the Midwest, and finally to our doorstep in the northeast. We could have tracked the advance of the heat wave by the increase in service call volume in each city as the temperatures exceeded the mid nineties. So I'm sitting here asking myself why we see such a drastic increase in call volume as we hit these record high temperatures and what can be done to reduce the number of breakdowns. Like most questions, this has a simple answer and a whole lot of not so simple answers. The simple answer (for simple people) is that as the outdoor ambient temperature rises, the equipment has to work harder. I'll attempt to address the not so simple below.

Many of the service requests we receive are actually nuisance calls where nothing can be done to lower the occupied space temperatures because the systems were never designed to deal with the cooling loads they are experiencing, or the occupants are expecting performance that the systems were never designed to provide.

When a Mechanical Engineer is called upon to design an HVAC system, he begins by performing a cooling load estimate. The load consists of external loads that are influenced by outdoor temperature and sunlight as well as internal loads that are not affected by outdoor temperatures. There are also ventilation loads, which for our purposes will fall into the external category. Internal loads are due to heat and moisture within the conditioned space produced by people (approx 500 BTUH per person) and heat produced by lighting and other appliances. The lighting and appliance load is relatively easy to estimate and usually remains constant. ( 3412 BTUH per Kilowatt). The load due to people varies depending on occupancy , which is usually a function of how much business your store is doing. The Engineer usually uses the highest occupancy he anticipates the store will experience during peak business periods when calculating this load.

Skin loads such as roof, floor, wall, and glass loads are calculated based upon the thermal resistance of the structure, the <u>outdoor temperature</u>, and the amount of sunlight and angle of the sunlight. Today, most Engineers utilize a sophisticated computer program that calculates these loads for different times of day and different days of the year. The Engineer uses the period of greatest external load during occupied hours for his design. Ventilation load is calculated based on the amount of code required outdoor air that must be introduced into the store for ventilation and the <u>temperature and humidity content</u> of this air. Required ventilation air may be a function of the square footage of the space or the number of people anticipated.

The Engineer now must decide what temperature and humidity level he wants to maintain within the space and what the maximum outdoor temperature and humidity level will be. Today, many energy codes set this indoor temperature well above the 70° to 72° indoor temperatures customers expect when shopping. Most Engineers find a way to cheat the code and get the indoor design down to at least 72°F. The outdoor design temperature and humidity levels are where the issue is. Engineers determine outdoor design conditions from a set of tables of Climactic Design Information produced by The American Society of Heating, Refrigerating and Air Conditioning Engineers. These tables list temperature and humidity levels for over 4000 cities at percentile values of .4%, 1%, and 2%. Common practice is to use the 2% table. This practice assumes that 98% of the time, outdoor design conditions did not exceed these levels in past history. This leaves the facility manager with three issues. 1. Two percent of the time, the air conditioning system will not be able to satisfy the load in the space. 2. In recent years, the overall outdoor temperature appears to be rising on an average basis within the United States. 3. Due to increases in code required quantities of outdoor air for ventilation, changes in outdoor conditions have a greater effect on equipment load that they did in the past.

In New York City, the outdoor design temperature used by most Engineers is 91°F. If we assume an indoor design temperature of 72°F, we can expect the equipment to deliver an indoor temperature 19°F lower than outdoor temperature on a design day. However, today, I am reading an outdoor temperature on my thermometer of 103°F and the weather forecast tells us that the "real feel," temperature is 110° due to high humidity conditions. Even though only the external component of the equipment load is influenced by outdoor conditions, there is no way the equipment in local stores can maintain space temperatures of 72°F at an outdoor temperature of 103°F. This would be a 32° difference and the systems were designed for a a 19° difference. The actual indoor conditions will probably be around 78°F during the hottest time of the day and this will prompt service calls from store managers. In some cases, there will actually be a failure of a component. In other cases, a tech will arrive at a site much later than the facility manager would like him to arrive, go up to the roof where the surface temperature is 135°F and find that the unit is doing all it can. Perhaps he will recommend coil cleaning in hopes of getting a little more efficiency out of the 10 year old condenser. (More about this later.)

So why don't we just oversize the equipment you ask. There are three answers. The first involves how much you want to pay per square foot to build a store. The second is that if equipment is substantially oversized, the result is poor humidity control and a cool damp space. The third, is that many energy codes limit the capacity of the equipment that may be installed or dictate the design conditions that must be met.

**<u>Equipment Performance:</u>**
The capacity of an air cooled air conditioning unit such as a packaged rooftop unit is typically rated at an outdoor temperature of 95°F and a mixed air (return and outdoor air mixed) of 80°F. The good news is that as the mixed air temperature rises, the capacity of the unit actually increases. A fifteen ton rooftop unit will deliver 189,000 BTUH with a mixed air temperature of 80°F and an outdoor air temperature of 95°F. If the mixed air temperature rises to 90°F and the outdoor temperature remains 95°F, the same unit will deliver 194,000 BTUH. Unfortunately, this is the only good news. As the <u>outdoor temperature rises</u>, the unit looses capacity. This same unit will only deliver 177,000 BTUH at an outdoor temperature of 105°F and 162,000 BTUH at an outdoor temperature above 115°F. We loose 14% capacity on a new unit when the outdoor temperature rises from 95°F to 115°F. Keep in mind that this is the condenser inlet temperature we are talking about. On a sunny day, roof surface temperatures can easily reach 135°F when outdoor ambient temperatures are 100°F. Under these conditions it is not uncommon to see condenser inlet temperatures of 115°F and higher. The unit in question is only rated up to 115° condenser inlet air.

The information above is for a brand new unit. You can imagine what happens if the condensers have lost efficiency due to age, hail damage, multiple cleanings, and corrosion. HVAC equipment is designed to operate within a specific range of temperatures and pressures. As outdoor air temperatures increase, or condensers become less efficient, the temperatures and pressures within the system rise above the design limits of the equipment. One effect of the increased pressures and temperatures is that the compressor must work harder. As it works harder it draws more current and gets hotter. This may cause the compressor to trip off on its overload protector and ultimately to fail. Sometimes the pressure within the condenser rises high enough to cause the system to trip off on high pressure safety control before it trips on internal overload. Either way, the unit is down until it is reset, and resetting it only allows it to operate until once again it exceeds design limits. Even if the compressor stays on line because the safety control limits have not been reached, insufficient condensing due to the factors above, cause the unit to deliver a mixture of hot gas and liquid to the metering device within the unit rather than delivering a continuous stream of liquid. This reduces the capacity of the equipment significantly. It also raises the temperature of the gas that is entering the compressor and due to the fact that compressors are designed to be cooled by this gas, compressor life is shortened significantly.

**<u>Utility Issues:</u>**
We are all familiar with the term "Brownout." Basically, this is a reduction in the voltage being supplied to your site. Air conditioning equipment is rated at a particular voltage and can operate with a tolerance of + - 10%. As the voltage to your unit is reduced, the current draw of the unit increases. The increased current

draw causes the conductors feeding the unit to get hot and this causes the voltage to drop further because conductors offer greater resistance at higher temperatures. At reduced voltage and increased current, motors run hotter. This can cause bearing failure due to high temperature or winding failure due to high temperature. This applies to the motor within the compressor as well as to the condenser fan motors and blower motors.

Low line voltage can have another negative impact. Most air conditioning equipment uses a 24 volt control system to power relays, contactors, thermostats, etc. When the line voltage to the transformer within the unit drops, the voltage on the secondary side of this control transformer drops. This causes the relays and contactors powered by this transformer to draw more current and this causes more of a voltage drop on the secondary side of the transformer. Instead of 24 volts, the control circuit voltage can drop below 20 volts. This can cause chattering of relays and contactors which destroys these components and can cause compressor and or motor failure.

Some chains have opted to enroll in utility sponsored programs where lower utility rates are offered in return for the utility having the ability to shut down HVAC units or raise their set point during peak usage emergencies. Unfortunately, most of these emergencies occur during periods of triple digit outdoor temperatures, when the stores need every bit of cooling capacity. Think long and hard about how high occupied space temperatures will affect sales and product prior into entering into such an agreement.

**Other Issues:**

There are many other issues that affect HVAC performance marginally at normal temperatures and cause breakdown during triple digit temperatures. If your equipment is water cooled and the cooling tower that serves it is not operating efficiently, or the strainers on your units are partially restricted, your system will suffer from the same issues listed above that affect equipment with inefficient air cooled condensers.

If your store is served by a VAV system connected to a landlord operated unit, performance will be reduced during periods of extreme temperature because these systems are designed assuming a certain degree of diversity. The assumption is that there will never be a time when all zones connected to the system are calling for full cooling simultaneously. This is an incorrect assumption when outdoor temperatures exceed the outdoor design temperature. Similarly, if your store is served by landlord chilled water, chilled water temperatures may rise during periods of extreme heat because the landlord’s chillers or cooling towers cannot meet the required demand.

Many municipalities have adopted laws concerning the shielding of roof mounted HVAC units due to noise or line-of-sight considerations. These shields or screens often cause equipment to short cycle condenser air to the extent that the condenser inlet air is 20ºF warmer than the air on the roof outside the screens. While your equipment may be capable of operating under these conditions, as outdoor temperatures hit the 100ºF mark, the condenser inlet air hits 130ºF and the unit shuts down. We had a situation like this the other day in Oklahoma. The tech was reading an air temperature on the roof of 106°F. Inside the screened area surrounding the rooftop units he was reading 135°F and the units were cutting out on high pressure safety controls.

No HVAC service company can staff appropriately for the volume of work generated by triple digit temperatures. This applies to office staff as well as to field technicians. Response time slows due to the increased quantity of service requests and due to the fact that the productivity levels of technicians drops sharply as temperatures hit the100ºF mark. Your stores complain bitterly because they can’t operate with space temperatures in the nineties. Imagine what it is like to spend eight hours installing a new compressor on a 120ºF degree roof with the sun beating down. If this weren’t taxing enough, realize that installation of a compressor involves brazing copper with a torch operates at 1600ºF.

There is no way the office staff of a typical service company can turn quotes around as quickly as required and no way that proposed work can be accomplished quickly. It is not uncommon for a clerical person to spend an hour on the phone attempting to get pricing and availability for an OEM replacement part, only to find out that the part has a lead time of two weeks. Manufacturers and distributors cannot afford to stock the quantity of parts required to meet peak demand during a heat wave; nor can they staff their parts departments appropriately to meet these demands.

Finally, we have the human factor. When people are uncomfortable, they become less tolerant. Upper level management walks in the door with a short fuse after commuting in 100ºF temperatures and is frustrated that even though a tech visited a flagship location yesterday, the store is still hot today. Managers and district managers blame lower same day sales on high store temperatures. Sometimes I think people expect the technician to arrive, wave his magic wand, and make the store 70ºF. Technicians and clerical help also are running with high frustration levels and short fuses. This leads to poor customer service and the perception that the vendor does not appreciate the urgency of the situation or the fact that the store is losing business.

**Tempering the Issues:**

I know that I've presented a pretty bleak picture in the previous paragraphs, but after living the HVAC business for over thirty years, I believe these to be the actual circumstances we are faced with. However, there are things that the retail facility manager can do to limit the number of catastrophic failures of HVAC equipment during periods of extremely high temperatures and strategies that can be employed to allow vendors to deal quickly and efficiently with the failures that do occur.

**What can be accomplished during the design stage?**

- First and foremost, your construction department and your Mechanical Engineer need to be on the same page. If your business is dependent on the store being maintained at 72ºF at all times, he needs to be aware of this fact. If he needs to be using the .4% tables rather than the 2% tables in order to assure adequate performance, then he has to be made aware of this fact.
- Designs should call for multiple units in every store so that you are never in a position where you are going to lose 100% of your cooling capacity.
- We strongly recommend the use of Carbon Dioxide sensors and minimal outdoor air damper settings as this will minimize the impact that high outdoor ambient temperatures have on the cooling load.
- Store lighting circuiting can be designed so that in times of HVAC system failure, lighting levels can be reduced by 30%, which will reduce the store temperature. If you can reduce the lighting level by 2 watts per square foot, you reduce the heat load by 6.28 BTUH per square foot.
- If your equipment is to be surrounded by screening, make certain that the construction of the screen does not allow short cycling of condenser air.
- Specify hail guards on equipment to minimize condenser damage due to wind driven hail.
- Specify coated condenser coils in all areas subject to salt air and corrosive atmospheres to maximize condenser coil life.
- Specify high efficiency equipment as high efficiency units normally operate at lower condensing pressures than standard efficiency equipment.
- Specify the highest quality equipment and make sure each unit is equipped with multiple refrigerant circuits, high pressure cutouts, and low pressure cutouts, to provide increased reliability and compressor protection.

- Resist the temptation to use existing HVAC equipment when you build out a new space. If a cool space is required to do business, the lower first costs will not justify the revenue lost due to equipment down time. Replacing equipment on existing operating stores is becoming extremely difficult in some cases. This is due to the reluctance of some landlords to accept the use of curb adapters and the fact that when replacing a split system with a new system containing R410A, the indoor section of the unit must be replaced as well as the outdoor section.
- If your system is going to use landlord condenser water, chilled water, or conditioned air, I recommend that you design for water or air temperatures 10% higher than the mall criteria dictate. It is almost impossible to get the landlord to deliver the temperatures listed in the design criteria after the space is built out.
- It is imperative that frost-proof domestic water hose connections be provided within 100' of each air conditioning unit. This not only facilitates coil cleaning, but it provides a source of water for emergency measures to cool inefficient condensers.

**<u>How to limit maintenance and service issues:</u>**

- If you don't have a good preventive maintenance program in place you can anticipate many catastrophic breakdowns in hot weather. Your service contractors should be proposing repairs that will prevent breakdowns when the outdoor temperatures rise. A condenser fan motor can run with bad bearings, but raise the bearing temperature another 40ºF and watch it fail. A compressor can run with the unit slightly under charged at 80ºF, but watch it heat up and drop out at 100ºF. Proactive maintenance is a must. Don't assume that because your space is currently cool, no equipment repairs are required.
- Clean condenser coils when a technician determines they require cleaning. Dirty coils are the largest cause of extreme weather failure. This does not mean that you clean all coils every year, nor does it mean that you hire a coil cleaning company to proactively clean coils when they hit a particular geographic area of the country. Sub cooling measurements and air temperature rise across the condenser are good indicators of the cleanliness of a condenser coil. These are the determining factors a trained technician uses to determine when it's time to clean a coil. Remember that some coils must actually be physically split in order to be cleaned thoroughly. We have seen too many cases where coils were "proactively cleaned," in February and are the cause of high head pressure in August.
- Partner with an HVAC service provider you trust and who truly values your business above the business of others. The fact is, when the mercury climbs, some people are not going to receive timely service. A true partner values the relationship, the loyalty, and the year round commitment to maintenance. This relationship should translate into your work getting priority over the client who performs no maintenance or who sits on quotes for six months and expects the work to be performed overnight when he finally approves something.

- Give your HVAC partner the highest approval levels possible. You can chip away at system down time if the contractor can complete repairs while onsite or if he does not have to waste the time to send you a formal quotation prior to ordering parts or starting repairs.
- Put a proactive equipment replacement program in place. Most catastrophic failures occur in extreme temperatures on equipment that is more than 10 years old. If a rooftop unit is more than 15 years old it does not belong on your roof. It is a liability and it belongs in the junk yard. Would you expect reliability from a 10 year old car in 100ºF weather?
- Have your vendor rate the condition of each HVAC unit annually so that you can intelligently choose what equipment should be replaced.
- If your stores have multiple units, don't be tempted to leave one unit down because the quoted repairs are expensive and you are afraid to blow your budget. It all comes down to how important it is to have a comfortable store when it's 100ºF outside within your particular corporate culture. Keep in mind, the store that has one unit down because you chose not to repair it can easily lose two additional units when it heats up outside. How do you justify having to close a store because three units are down and one of them has been down for three months?
- If parts procurement is an issue, consider overnight shipping or allowing the use of universal replacement parts rather than OEM parts on a one time basis. In the case of semi-hermetic compressors, sometimes a locally rebuilt compressor will be available immediately when a factory rebuilt compressor is a week out. Some parts wholesalers will actually open a closed facility after hours for a fee of a couple of hundred dollars. Ask your vendor if this service is available.
- Many retailers call for temporary portable coolers to be installed if a system must be left down for more than a day. My personal experience is that while these units may serve the store psychologically and provide a place of cool refuge, they actually raise the store temperature unless you can find a way to vent the units to the outdoors. This is due to the fact that this equipment actually rejects approximately 25% more heat than it removes.

Actually, if you look at what is written above, most of it comes down to good communication. Communication with the design team prior to a project being built, communication with managers and executives as to what expectations are realistic, and communication with your service vendor as to the condition of your equipment, your expectations, and his ability to meet those expectations. It also comes down to a willingness to spend money. You will never get to the point where you have zero catastrophic breakdowns, but I guarantee you can reduce the number of breakdowns substantially if you are willing and able to commit the funds required to do so. It all comes down to what downtime costs your company. At one end of the spectrum we have the retailer who performs breakdown maintenance and if hasn't failed yet, he doesn't fix it. On the other end of the spectrum we have data processing facilities and government installations where functional full capacity backup systems exist and components are replaced based upon number of hours of use rather than being replaced when they fail. You and your vendors need to determine where your stores fit in this range, develop strategies that you can afford, and that provide the reliability you require. That's really what managing your HVAC systems is about.