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Discussion 6-03
Air Conditioning Loads

The load analysis is one of the most important steps in the design of an air conditioning system.

Historically, the air conditioning load calculation was a technique that started as a modification of heating load estimates prior to the emergence of buildings "designed" for air conditioning in the late 1940s and early 1950s. As the initial cooling load estimate techniques were developed, they simply addressed heat gain in place of heat loss. The winter outdoor design temperature was replaced with a summer outdoor design temperature. It was quickly recognized that the air conditioning system needed not only to have a capacity to remove heat but also to remove moisture, so the load estimates were expanded to perform this calculation.

Since the time of these early calculation methods modeled after the heating load estimates much change has transpired, not only in calculation technology but also in building technology. The increased knowledge gained from improved techniques in calculating air conditioning loads is in the process of leading the industry and designers of systems to a new paradigm in system design, if not building design. One of these changing paradigms will represent a return to regionalism in building designs based upon climatological characteristics. This move will result in significantly improved architectural design and enhanced building economics.

ASHRAE has provided extensive new weather data information through their Research program and now publishes this information in their Handbook of Fundamentals.

A few of the interesting dynamics of air conditioning load calculations follow.

LOAD COMPONENTS

There are two distinctly different components of the air conditioning load; (1) the sensible load (heat gain) and (2) the latent load (water vapor gain).

1. **SENSIBLE LOADS**
   There are 3 source categories of sensible heat gain:
   - Heat flow from warmer surroundings (sometimes called the transmission load and sensible infiltration load).
   - Heat flow from solar radiation (sometimes called radiation load).
   - Heat flow into the space from energy consuming objects within the space (sometimes called internal loads); these objects usually

include:
- lighting
- office appliances
- cooking or kitchen appliances
- entertainment appliances
- occupants within the space
- any other energy consuming devices

2. **LATENT LOADS**
There are 2 source categories of latent heat gain:
- Moisture entering the space from surroundings that are at a higher vapor pressure (higher humidity ratio) than the space.
- Moisture generated within the space from moisture generating objects. These objects usually include:
  - occupants within the space
  - moisture generated by cooking or warming appliances
  - industrial or production machinery which evaporates water

THE TIME ASPECTS OF LOADS

Considering the above, it becomes immediately evident that throughout the 24 hours of the day each of the load contributors varies with time. The occupants come and go, the sun rises, moves across the sky (and the building surfaces) and sets, the outdoor temperature has a diurnal cycle, lights and appliances cycle on and off, etc. Then, because of the thermal storage characteristics of the building the time at which the space may realize the heat gain as a cooling load will be considerably offset from the time the heat started to flow. The time offset will vary, for each source.

The macro time offset, of course, is the calendar time variations. In most climates the outdoor temperature varies throughout the year. Also in most climates, the solar elevation, azimuth, and radiation intensity vary with the time of year. In some buildings the occupancy characteristics vary with the time of year, such as in school buildings which may have partial or no occupancy in summer months.

DESIGN LOAD

The design load is normally considered the statistical norm of the maximum load. The designer can decide under what conditions this norm will be acceptable. Economically speaking short duration peaks above the system capacity might be tolerated at significant reductions in first cost; this is a simple risk - benefit decision for each building design.

Other dynamics that impact design loads are the time of occurrence of different types of loads. Many load calculation techniques use a so-called "summer design conditions" as expressed by a summer design dry bulb temperature and a statistically coincident wet bulb temperature. Then all air conditioning loads are calculated for a single design day (usually July 20th in the northern hemisphere) with a diurnal temperature distribution represented by a sinusoidal curve, the amplitude of which is the "daily range." The "summer design conditions" so expressed are included in many design contracts as a mandated condition of the contract.

THE AIR CONDITIONING SYSTEM

Air conditioning systems have two related but distinctly different functions to perform.

1. To maintain conditions within the space as defined for the needs of the space - usually environmental comfort. These are usually called the thermal comfort conditions - temperature, humidity, air motion and air purity.
2. To provide ventilation air in the flow quantity necessary to remove contaminants from the space. The ventilation air supplied must itself be free of contaminants so that it does not contaminate the space air.

Many buildings constructed prior to the first half of the twentieth century had envelopes that "breathed", in that they were loose fitting; and normal infiltration of outdoor air provided adequate ventilation. This was not true for buildings that had a high rate of generation of contaminants such as schools and theaters, chemical laboratories, etc. However, with the advent of air conditioning it was found that excessive space relative humidity resulted when warm humid outdoor air entered directly into colder spaces. For this reason, building envelope design changed dramatically providing for very low infiltration and the thermal conditioning of outdoor air through mechanical ventilation systems was added.

Thus, when conducting the load analysis the space load must be determined separately since this will determine the size and cooling capacity of the supply air system, room conditioning devices, etc. The ventilation load is calculated separately.

CALCULATING THE SPACE LOAD

The foregoing discussion of *Design Loads* addressed the concept of "summer design conditions" and this is one of the areas in which there is a shifting paradigm in load calculation technology. St. Louis, Missouri (USA) is in a temperate climate with very hot humid summer days (summer design temperatures, 95° Fdb, 76° Fwb) and some cold winter days (winter design temperatures 2° F). The latitude is 38.75° North. However, the sun at this latitude is very high in the sky in July but shines on a South wall nearly horizontally in the winter. If the cooling load for a 15' x 15' office on the South face of the building with 50% glass is calculated for the summer design conditions on July 20th, it will be only 55% of what is needed on a mild (design) day in November!

However, since the summer solar angle is low on the East and West walls, similar rooms on those exposures will usually experience their maximum design loads on the summer design day.

If, on the other hand, the building is a school building which is not occupied in the summer, the maximum load in the spaces would not occur in July, but only in one of those months of occupancy.

Thus, *the space load for each space must be determined for the time at which that space is realizing its design load.*

The "outdoor conditions" when calculating the space load are usually a design dry bulb and coincident wet bulb.

CALCULATING THE VENTILATION LOAD

The load imposed by the ventilation system is the heat required to be removed from the ventilation air stream as it is conditioned from the outdoor air temperature and humidity to the temperature and humidity level of the indoor air. It should be noted that the process of removing the heat will usually not be a direct process, but this will be covered in a future *discussion*. Furthermore, the outdoor weather conditions used to calculate the design space loads will often not apply to the calculation of the design ventilation load. In many cases, the outdoor design conditions of "design wet bulb with coincident dry bulb" may dictate the ventilation load. Following is an example of four locations in the United States of quite differing climates. Assuming in all locations, indoor conditions at 75° Fdb and 50% RH (h_i = 28.11 BTU/lb), the ? h in Table 1 is the difference between the enthalpy of the outdoor air and the indoor air.

Table 1
Design Conditions Comparison

	Design DB with Mean Coincident WB				Design WB with Mean Coincident DB			
	DB	WB	h	? h	DB	WB	h	? h
Los Angeles	85	64	29.10	0.99	78	70	33.95	5.84
Denver	93	60	26.20	--	81	65	29.88	1.77
St. Louis	95	76	39.29	11.18	90	79	42.40	14.29
Miami	91	77	40.33	12.22	87	80	43.51	15.04

Note that the enthalpy difference (? h) is proportional to the ventilation load and in Los Angeles, St. Louis and Miami using the design wet bulb conditions increases the ventilation cooling loads by 490%, 28% and 23% respectively.

To summarize, the concept of basing an air conditioning load on a simple statement of a design dry bulb temperature with a coincident wet bulb for a single summer day is serious over simplification of the most fundamental data in the most important step in the design of an air conditioning system.