**CHAPTER 4**
**LOAD CALCULATIONS**

## 4.1 CONTEXT

The accurate calculation of heating and cooling loads is essential to provide a sound bridge between fundamental building design decisions and an operating building. If loads are substantially underestimated, occupants and users will likely be hot or cold. If loads are substantially overestimated, equipment will be oversized (usually wasting money, reducing efficiency, increasing energy consumption, and often imperiling comfort). Accurate load calculations are an important part of the design process. This importance is underscored by the constant evolution of load calculation methodologies—which has steadily made load calculations more complex, less intuitive, and more dependent upon computers.

It is imperative that a beginning HVAC&R engineer have a good grasp of the fundamentals of load calculation concepts. Total reliance upon computer software for load analysis is not wise. The adage "junk in, junk out" applies perfectly well to load calculations.

Equipment and systems are sized from "design" loads, which are calculated using statistically significant weather conditions that reflect a building location's climate. A design heating load represents heat loss from a building under a series of generally agreed upon assumptions. A design cooling load represents heat flow into a building via the building envelope and from internal sources, again under a commonly accepted set of assumptions. The term "heat gain" is generally used to describe undifferentiated heat flow into a building or space. The term "cooling load" is used to describe that portion of heat gain that will affect air (as opposed to building material and content) temperature at a given point in time. The vast majority of air conditioning systems respond directly to cooling loads through thermostatic control (and only indirectly to heat gains).

Loads are sensible (affecting air temperature) or latent (affecting relative humidity) or a combination of sensible and latent. Loads may be external (passing through the building envelope) or internal (originating within the building envelope). Space loads affect a particular portion of a building at some point in time; equipment loads are those seen by equipment at some point in time. Equipment loads for central components may not equal the sum of design space loads due to diversity (non-coincidence) of loads, such as between east-facing and west-facing rooms.

Sensible and latent heating and cooling loads arise from heat transfer through the opaque building envelope; solar heat gain through windows and skylights; infiltration through openings in the building envelope; internal heat gains due to lighting, people, and equipment in the conditioned spaces; and outdoor airflow for ventilation and building pressurization. These loads are described in detail in several chapters in the *ASHRAE Handbook—Fundamentals*. Typically, design heating load calculations do not include heat gains to the space, since peak losses typically occur during the night (unoccupied hours for most non-residential buildings). When appropriate, heating credit may be taken for a portion of lighting, occupancy, and equipment gains—but not for solar gains (passive solar heated buildings are an exception to this general rule).

Development of a comprehensive building energy analysis requires the HVAC&R designer to consider the many loads, other than just the design load, that occur throughout a typical year in the life of a building. This type of analysis requires year-long hourly weather data (rather than just design conditions) and substantial computation to calculate loads at off-peak conditions and the resulting response of equipment to such loads. Although there are some manual methods that allow an approximation, accurate energy analyses require fairly sophisticated computer simulation capabilities. There are numerous software programs that can provide such analyses, but these are often specialized programs with steep learning curves.

## 4.2 DEFINITIONS

The following terms are commonly used to describe aspects of heating and cooling loads.

*Block load* is the diversified load that is used to size the HVAC&R systems. It is based upon the consideration that not all perimeter zones in a building peak at the same time. It is the maximum load that equipment (an air handler, chiller, pump, fan) actually sees. It is sometimes called the *refrigeration load*, and is less than the sum of the peak loads.

*Coincident load* is a load that occurs at the same time as another load, such as a latent load that is coincident with a sensible load or a solar load that occurs at the same time as an occupancy load.

*Design load* is a load that represents the highest reasonable heating or cooling load likely to be experienced by a building (or zone) based upon statistically significant climate data. Design load is not the highest load that may or can occur, but rather the highest load it is reasonable to design for considering first cost of equipment and energy efficient operations.

*Diversified load* is the portion of the sum of the peak loads that is coincident. Load diversity accounts for the fact that the peak loads in different building zones often do not occur simultaneously. Therefore, the actual building peak load is generally smaller than the undiversified sum of the zone peak loads.

*Dynamic load* is a load that varies in intensity over time; it is usually incremented in small time steps, such as seconds or minutes.

*Instantaneous load* occurs during a defined time step/period, usually one hour.

*Peak load* is the largest load occurring in a space, a zone, or an entire building. In the building load context, it is the maximum simultaneous or coincident load.

## 4.3 OUTDOOR AND INDOOR DESIGN CONDITIONS

Before performing heating and cooling load calculations, the designer must establish appropriate outdoor and indoor design conditions. Outdoor conditions can be obtained from the chapter on Climatic Design Information in the *ASHRAE Handbook—Fundamentals* (and an accompanying CD). Design conditions specified by ASHRAE Standard 90.1 are the 99.6% and 1% values for heating and cooling respectively. For special projects or spaces where precise control of indoor temperature and humidity is required, other design values may be more appropriate.

Indoor design conditions are governed either by thermal comfort conditions or by special requirements for materials or processes housed in a space. In most buildings, such as offices and residences, thermal comfort is the only requirement, and small fluctuations in both temperature and humidity within the comfort zone are not objectionable, as suggested in Figure 3-1. In other occupancies, however, more precise control of temperature and humidity may be required; refer to the appropriate chapter in the *ASHRAE Handbook—HVAC Applications* for recommendations. ASHRAE Standard 55 provides guidance on appropriate winter and summer indoor design conditions. State or local energy codes and particular owner requirements may also affect the establishment of criteria for indoor design conditions.

## 4.4 EXTERNAL LOADS

External loads are highly variable, both by season and by time of day. They cause significant changes in the heating and cooling requirements over time, not only in the perimeter building spaces, but for the total building heating/cooling plant.

### 4.4.1 Conduction through the Building Envelope

Most new buildings are well insulated, and conduction loads through opaque wall and roof elements are generally small compared to those through windows and skylights. Improved glazing products, however, are steadily enhancing the performance of transparent and translucent envelope components. Useful performance data for fenestration products are readily available, much now certified by independent third-party organizations.

### 4.4.2 Solar Heat Gain through Glazing

Solar radiation often represents a major cooling load and is highly variable with time and orientation. Careful analysis of heat gains through windows, skylights, and glazed doors is imperative. Facade self-shadowing, adjacent building shadowing, and reflections from the ground, water, snow, and parking areas must be considered in the loads analysis. Spaces with extensively glazed areas must be analyzed for occupant comfort relative to radiant conditions. Supply air for cooling must enter such spaces in a manner that will offset the potential for warm glass surfaces or otherwise provide adequate cooling to offset mean radiant temperature effects. Exterior or interior shading devices to keep direct solar radiation from falling on occupants should be considered. Close coordination between the architect and HVAC engineer is critical in buildings with extensive glazing.

### 4.4.3 Ventilation Load

The outdoor air ventilation load does not have a direct impact on the conditioned space (except when provided via open windows), but it does impose a load on the HVAC&R equipment. Outdoor air is normally introduced through the HVAC system and adds a load (sensible and latent) to the heating and cooling coils, thus affecting their sizing and selection. The amount of ventilation depends upon the occupancy and function of each space. Refer to ASHRAE Standards 62.1 and 62.2 for recommended ventilation rates; see also the requirements of the local building, mechanical, and energy codes.

### 4.4.4 Infiltration Load

Most commercial and institutional buildings have inoperable windows and are pressurized by the HVAC system to reduce the infiltration (unintended flow) of outdoor air. It is generally assumed that a pressurized building prevents infiltration, although infiltration will often occur in the lower third of a building taller than 80 ft [25 m] with an operating HVAC system and can occur throughout a building when the HVAC system is shut off. The design heating load (including infiltration) often occurs in the early morning hours (2 to 3 AM) when buildings are not occupied or pressurized. General building infiltration for larger buildings can be calculated by the crack method. In entrance lobbies, determine the infiltration rate based upon door-opening rates and pressure differentials due to wind, temperature, and stack effect. See the chapter on Infiltration and Ventilation in the *ASHRAE Handbook—Fundamentals* for details on estimating infiltration. In cold climates infiltration loads can be substantial. In hot, humid climates sensible infiltration loads are lower in magnitude, but latent infiltration loads can be substantial.

## 4.5 INTERNAL LOADS

While external loads can be heat gains or heat losses, internal loads are always heat gains.

### 4.5.1 Heat Gains from Occupants, Lighting, and Equipment

Heat gains from people are activity related: athletes in a gymnasium release eight times the amount of heat released by a seated audience (see the chapter on Physiological Principles, Comfort, and Health and the chapter on Air-Conditioning Cooling Load in the *ASHRAE Handbook—Fundamentals*). The number of people in a space may be estimated from seat counts, owner estimates, data in ASHRAE publications, and the design engineer's experience. Judgment will always be required; for example, how many people might be crowded around the dice tables in a gambling casino?

Heat gains from lights, people, and equipment (e.g., computers, copy machines, and process equipment) must be determined. Illumination level and lamp/fixture type are usually determined by the electrical engineer. The HVAC&R engineer must determine the amount of heat gain (and its distribution among space and equipment loads) for each space. For example, the radiant and convective heat losses from lighting fixtures must be quantified to determine how much heat can be captured by or near the fixture for return to the air-handling unit and how much is added to the space load to be handled by the room supply air.

Heat gains from equipment in offices can be estimated from allowances expressed on a per square foot [square meter] basis, but in other occupancies, estimating these gains is more complex. For example, in central computer rooms, research laboratories, and processing plants, the heat released from equipment creates most of the cooling load. In a complex laboratory or manufacturing facility, it is important to understand the operation of each piece of equipment, its connected load, sensible and latent heat release to the space, and the length of its operating cycle. For example, an electric oven will use maximum power only during start-up periods; once it reaches its set temperature, it will use only whatever power is required to make up for heat lost to its surroundings. The heat gain to the space, therefore, is the heat loss from the oven, not the connected load or the power required during start-up. If several pieces of equipment are located in one zone, the designer must determine the diversity of use (i.e., how many units will be operating at the same time). With assistance from the client and operating personnel (or from experience), the designer can develop a schedule of use to estimate the maximum heat gain likely to impact the zone. Miscellaneous loads in special occupancies should not be ignored, such as space cooling benefits from open freezers in markets or heat and humidity gains from indoor swimming pools and water features.

4.5.2 Heat Gains from Fans and Pumps

Supply and return air fans add heat to their circulated airstreams, with the magnitude of heat depending upon static pressure and fan/motor efficiencies. If the motor is located in the airstream along with the fan, the heat released due to motor inefficiency must be included in the load calculations. This is the quantity *qsf* in Figure 6-1 (Chapter 6). If the motor is outside the airstream then the inefficiency load heats the space containing the motor. In either case, the motor heat must be included in the cooling load calculations.

In I-P units: fan bhp = (0.000157) (cfm) (TP) / (efficiency) (4-1)

where, bhp is brake horsepower
cfm is airflow rate
TP is total pressure, in. wg

$\Delta$t = (heat input, Btuh) / (1.1) (cfm) (4-2)
= (fan bhp) (2545 Btu/hp) / (1.1) (cfm)
= (0.000157) (cfm) (TP) (2545) / (1.1) (cfm) (efficiency)
= (0.000157) (2545) (TP) / (1.1) (efficiency)
= (0.363) (TP) / (efficiency)

where, efficiency = (motor efficiency) (fan efficiency) (drive efficiency)

In SI units: fan kW = (0.000997) (L/s) (TP) / (efficiency) (4-3)

where, L/s is airflow rate
TP is total pressure, kPa

$$\Delta t = \text{(heat input)} / (1.2)\ (L/s) \quad (4\text{-}4)$$
$$= \text{(fan W)} / (1.2)\ (L/s)$$
$$= (0.000997)\ (L/s)\ (TP) / (1.2)\ (L/s)\ \text{(efficiency)}$$
$$= (0.000997)\ (TP) / (1.2)\ \text{(efficiency)}$$
$$= (0.000831)\ (TP) / \text{(efficiency)}$$

where, efficiency = (motor efficiency) (fan efficiency) (drive efficiency)

This heat gain is approximately equal to 0.7°F per inch of water static pressure [1.6°C per kPa]. When the motor is mounted outside the airstream, only the fan efficiency affects airstream heat gain, which is approximately 10-15% less than fan and motor gain.

The only portion of fan energy that is not converted to a rise in air temperature is the velocity pressure, which is the energy required to increase the air velocity at the fan. The heat of friction related to the gradual pressure drop in a duct system causes no temperature rise along the duct because this heat is equal to and nullified by the expansion cooling effect of the static air pressure reduction.

If the supply fan blows air through the cooling coil, all fan energy heat (except that from velocity pressure) is absorbed in the coil and does not affect the supply air load to the zones. With a draw-through coil arrangement, however, the supply air capacity must be increased (or the supply air temperature lowered) to make up for the fan heat gain that occurs downstream of the cooling coil. In either arrangement, the fan heat increases the equipment cooling load.

In all-water and air-and-water systems, the heat added by the water circulating pumps must be included in the chilled water load; this can be assumed to be approximately 1.5% of the building load, or can be calculated as follows:

heat added in Btuh = (pump bhp) (2545 Btu/hp) … per hour (4-5)
[heat added in W = pump W]

$\Delta t\ ^oF$ = (Btuh) / (500) (gpm) (4-6)
[$\Delta t\ ^oC$ = (W) / (4177) (L/s)]

where, gpm = gallons per minute flow rate [L/s = liters per second flow rate]

### 4.5.3 Duct Losses

The chapter on Duct Design in the *ASHRAE Handbook—Fundamentals* describes methods for calculating ductwork losses, which are generally equal to 3% of total system air volume. Greater leakage may occur, however, and could affect the design calculations (see the quantity $q_{sd}$ in Figure 6-1, Chapter 6). It is customary to specify leakage testing for high-pressure duct systems, but not for low-pressure systems. Leakage in un-taped low-pressure duct systems can run from 10 to 20% of total air volume. Low-pressure connections to some diffusers can leak as much as 35% of terminal air volume unless taped and sealed. Duct leakage does not affect overall system loads unless it occurs within unconditioned spaces, but it always affects supply air quantities and can affect system controllability if excessive. Leakage through zone control dampers affects supply air quantities for multi-zone and dual-duct systems, as explained in Chapter 6. Suitable rules for duct design are given in Section 5.8.

## 4.6 CALCULATION METHODS

Numerous heating and cooling load calculation procedures are available to the designer. Most of the procedures are based upon ASHRAE research and publications, with simplifications and adjustments sometimes incorporated for specific applications. Loads for small envelope-load-dominated buildings are often manually calculated using a single design-day peak hour with the addition of a safety factor when selecting equipment. Loads for large, multizoned buildings are almost universally calculated using computer programs.

HVAC&R designers should not accept the results of computer calculations without review and analysis. Until the 1960s, all HVAC load calculations were performed manually. A good understanding of building behavior was gained through repeated iterations of manual calculations. Computers have greatly shortened calculation time, permit the use of more complex analytical techniques, and help to structure load analyses. Nevertheless, it is important to review and understand load calculation methods before relying upon computer analyses. This involves understanding the variables that go into load calculations, the effects of such variables on loads, and the interactions between variables. Designers should carefully review computer program documentation to determine what calculation procedures are used. It is valuable to compare computer results with approximate manual calculations, and to conduct sample load validations to confirm that the program being used delivers what it claims. Software vendors do not accept responsibility for the correctness of calculations or the use of a particular program—such responsibility lies in the hands of the HVAC&R designer.

It is hard to generalize about computer load and energy analysis software as there are so many variations available. Simpler programs tend to use automated implementations of manual methodologies and a limited set of weather data. More complex programs use calculation methodologies that are not amenable to manual solution and a full 8760 annual hours of weather data. Energy simulations typically address envelope, equipment, and system performance parameters and their interactions. Be sure to understand exactly what load/energy software being proposed for use does—and how it does it. For a sense of the range of software that is currently available see the *Building Energy Software Tools Directory* (DOE 2005).

The largest cooling loads in most commercial/institutional buildings are due to solar radiation through glazing and internal loads. In many special-purpose buildings (factories, shopping malls), internal loads predominate. Inputs affecting these key loads must therefore be developed with care. They include window and skylight sizes, properties of glazing assemblies, interior and exterior shading devices, lighting loads and controls, sensible and latent loads due to people and equipment, and various operating schedules. Some loads programs completely ignore exterior facade shadowing, most simulate overhangs and side fins, but only a few account for shadowing from adjacent buildings. Bear in mind that connected electrical loads are not hourly demand loads, most individual equipment does not operate at full load during a building's operating hours, and multiple equipment items often exhibit diversity.

## 4.7 COMPUTER INPUTS AND OUTPUTS

The accuracy of computer program output depends upon the user's inputs and the program’s calculation procedures. The inputs include not only the typical architectural parameters of surface areas and building material and assembly properties and indoor design conditions, but also ventilation airflow requirements, internal loads, and their schedules of use.

### 4.7.1 Computer Inputs

All computer programs require input to perform the necessary calculations; some inputs are mandatory, others may be optional. If a user does not provide data for optional inputs, built-in program default values are generally used. The designer must understand and accept the appropriateness of the default values or override them by the input of more appropriate values. Most load programs require user inputs of the basic properties of construction types. When a proposed construction is not defined in the chapter on Air-Conditioning Cooling Load in the *ASHRAE Handbook—Fundamentals* (or another publication), you may need to use data from a similar type of construction or develop the required input data by hand or by computer. For this purpose, you may use component properties listed in the chapter on Thermal and Vapor Transmission Data (*ASHRAE Handbook—Fundamentals*) or in other publications. Typically, the thermal properties of most assemblies (except prefab components) must be calculated from fundamental material properties.

Most load programs allow input of internal loads on a unit floor area basis. If the load is specified on a unit area basis, the program will use the zone area to calculate the load. Be sure to enter building-specific use schedules for people, lights, and equipment so that appropriate load diversity is included in the HVAC system and central plant calculations. Remember that design use schedules are not the same as average use schedules. Design schedules are used to determine peak cooling loads in each space, while average schedules are used for energy calculations. If actual use schedules are not available, they must be estimated. One approach is to assume a constant load profile and add an experience-derived diversity factor to the system and the central plant load calculations. Energy calculations, unlike load calculations, are significantly affected by equipment control schedules.

Many programs use the air change method to calculate infiltration loads. Given the number of air changes per hour as input, the program multiplies this value by the input zone area and height. In specifying zone height, distinguish between the floor-to-ceiling height and the building's floor-to-floor height. The zone height must correspond to the air change rate for the same height. Most programs allow the user to specify the ventilation load in cubic feet per minute (cfm) [liters per second (L/s)], cfm per square foot [L/s per square meter], or cfm per person [L/s per person]. You may also usually input the zone exhaust in cfm. Load programs typically compare the ventilation rate with the exhaust rate and select the larger of the two as the outdoor air requirement.

Select the HVAC system and zones that will be served by that system. For each system, input the maximum and minimum supply air temperatures or the cfm [L/s] to be supplied to each zone. If supply air temperatures are input, most programs will determine the zone cfm [L/s] based upon the calculated zone sensible heat. After the supply and outdoor air quantities have been determined, most programs will also calculate the fan heat and perform the necessary psychrometric analyses.

4.7.2 Computer Outputs

All comprehensive computer load programs provide a summary of peak sensible and latent cooling loads and sensible heating loads for each thermal zone. The cooling load should be itemized by roof conduction, wall conduction, floor conduction, glass conduction, glass solar transmission, people, lights, equipment, and infiltration. The time and date when the peak cooling loads occur are usually given, and some programs also indicate the outdoor conditions at the time of the peak load. Most programs also provide psychrometric data for each HVAC system, including state points for room air dry-bulb temperature and humidity, outdoor and supply airflow rates, outdoor and mixed-air dry- and wet-bulb temperatures, and cooling coil entering and leaving conditions. These data are necessary for the final selection of heating and cooling coils.

Do not assume that computer output is correct simply because it is given to decimal-place accuracy. There is usually substantial room for input errors, and there can also be glitches in the computer program itself. Output should be studied in detail to determine its correctness, and any inconsistencies must be resolved. It is important to check some of the outputs with hand calculations and review summary results (such as Btuh/ft$^2$ [W/m$^2$] and cfm/ft$^2$ [L/s m$^2$]) for reasonableness. Apply a common sense test to results. Investigate all anomalies to determine if they represent errors or simply quirks in building response. Also, realize that additional psychrometric analysis is required to establish a final HVAC system design in most situations.

4.7.3 Computer Programs

Design-day heating and cooling loads are required to (1) determine peak hour sensible and latent heat loads in each thermal zone, (2) establish supply air quantities, (3) select cooling and heating coils, and (4) obtain building diversified loads (also called block loads) for sizing of equipment. To determine the zone peak loads, perform calculations for each hour of the year to be sure that each thermal zone is exposed to the greatest impact due to the weather (temperature, humidity, solar) and internal loads (people, lights, equipment). Coincident zone loads add up to the diversified load imposed upon the central heating and cooling equipment.

Most design offices routinely use personal-computer-based programs that calculate design-day heating and cooling loads. Such programs are an important production tool and, to be viable, must have the capacity to handle a large number of thermal zones. Other multiparameter calculations, such as the sizing of duct and piping networks and the analysis of sprinkler loops, can also be handled by available computer programs. On the other hand, comprehensive energy calculation programs are used primarily for energy code compliance and, in most offices, are only infrequently used for comparative energy studies.

Remember that internal load schedules for peak-load calculations are not the same as those used in annual energy simulations. Energy calculations require average use schedules, while peak-load calculations require design load schedules to be certain that the HVAC&R system will meet all the design-day space loads. A typical office building load schedule is shown in Table 4-1.

TABLE 4-1 Typical Office Building Load Profile

| | Percent of Peak | | |
|---|---|---|---|
| Hour | Lights | Receptacles | Occupancy |
| 1 | 5 | 0 | 0 |
| 2 | 5 | 0 | 0 |
| 3 | 5 | 0 | 0 |
| 4 | 5 | 0 | 0 |
| 5 | 5 | 0 | 0 |
| 6 | 5 | 0 | 0 |
| 7 | 10 | 0 | 0 |
| 8 | 90 | 55 | 100 |
| 9 | 90 | 55 | 100 |
| 10 | 95 | 50 | 100 |
| 11 | 95 | 55 | 80 |
| 12 | 95 | 90 | 40 |
| 13 | 80 | 60 | 80 |
| 14 | 80 | 80 | 100 |
| 15 | 90 | 70 | 100 |
| 16 | 90 | 75 | 100 |

| | | | |
|---|---|---|---|
| 17 | 95 | 30 | 30 |
| 18 | 80 | 30 | 10 |
| 19 | 70 | 50 | 10 |
| 20 | 60 | 5 | 10 |
| 21 | 40 | 0 | 0 |
| 22 | 30 | 0 | 0 |
| 23 | 20 | 0 | 0 |
| 24 | 20 | 0 | 0 |

## 4.8 EFFECTS OF ALTITUDE

Standard psychrometric charts and performance data published by manufacturers generally assume equipment operation at sea level. When a project is located at a significantly higher altitude, allowances must be made. Factors by which the usual (sea level) data must be multiplied when operating at higher altitudes are summarized in Table 4-2. For items not listed, consult appropriate sources, such as the *Engineering Guide for Altitude Effects* (Carrier) or contact equipment manufacturers.

TABLE 4-2 Altitude Correction Factors[a]

| | Altitude, ft [m] | | | |
|---|---|---|---|---|
| Item | 2500 [762] | 5000 [1525] | 7500 [2285] | 10,000 [3050] |
| Compressors | 1.0 | 1.0 | 1.0 | 1.0 |
| Condensers, air-cooled | 0.95 | 0.90 | 0.85 | 0.80 |
| Condensers, evaporative | 1.00 | 1.01 | 1.02 | 1.03 |
| Condensing units (air-cooled) | 0.98 | 0.97 | 0.95 | 0.93 |
| Chillers | 1.0 | 1.0 | 1.0 | 1.0 |
| Induction room terminals (chilled water) | 0.93 | 0.86 | 0.80 | 0.74 |
| | | | | |
| Fan-coil units | | | | |
| Total capacity (SHR[b] = .40 - .95) | 0.97 | 0.95 | 0.93 | 0.91 |
| Sensible capacity (SHR = .40 - .95) | 0.92 | 0.85 | 0.78 | 0.71 |
| Total capacity (SHR = .95 - 1.00) | 0.93 | 0.86 | 0.79 | 0.73 |
| | | | | |
| Packaged air-conditioning units, air-cooled condenser | | | | |
| Total capacity (SHR[b] = 40 - .95) | 0.98 | 0.96 | 0.94 | 0.92 |
| Sensible capacity (SHR = .40 - .95) | 0.92 | 0.85 | 0.78 | 0.71 |
| Total capacity (SHR = .95 - 1.00) | 0.96 | 0.82 | 0.88 | 0.84 |

[a] Table excerpted by permission from *Engineering Guide for Altitude Effects* (Carrier)
[b] SHR = sensible heat ratio = (sensible heat) / (sensible + latent heat)

## 4.9 REFERENCES

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