Required Reading; Cooling Load: Part Two

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This part of the reading material on cooling load presents information on the various components of design cooling load and how they are affected by design decisions.

External Loads

These loads originate at the transition between the interior and the exterior environments established by the building enclosure elements and are determined primarily by design decisions. External loads are critical to the energy performance of smaller-scale buildings and poorly designed larger-scale buildings.

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- Opaque assemblies (walls, roofs, doors) located above ground

Equation and Variables:	**q_s =**	**U**	**A**	**CLTD**
I-P Units:	Btuh	Btuh / ft sq / deg F	ft sq	deg F
Description:	sensible heat flow	overall coefficient of heat transfer	surface area of element	cooling load temperature difference
Discussion:	would like to minimize this variable through design	a measure of the ease with which sensible heat is transferred through an envelope assembly	area of building elements is an outcome of design decisions	a “hypothetical” temperature difference that would result in the same heat flow through a shaded element under static conditions as seen in the “real” case (with solar radiation and heat storage); includes effects of indoor and outdoor air temperatures, daily temperature range, solar radiation, heat storage in assembly, and radiation storage in building mass (minor)
Implications:	affects system size and energy consumption	maximum values often set by energy efficiency codes or standards	function of building form; a sq ft facing north is not the same as a sq ft facing west	affected by orientation, tilt, month, day, hour, latitude, exterior solar absorbtance, and assembly construction (mass)
Notes:	imposes first-costs and life-cycle costs	calculated from information shown in building drawings	calculated from plans and elevations	empirical values; found in reference tables; values are not necessarily intuitive, but they are logical; patterns can be remembered for design

- Convective transfer through transparent/translucent assemblies (glazing in windows, doors, skylights):

Equation and Variables:	**q_s =**	**U**	**A**	**CLTD**
I-P Units:	Btuh	Btuh / ft sq / deg F	ft sq	deg F
Description:	sensible heat flow	overall coefficient of heat transfer	surface area of element	cooling load temperature difference
Discussion:	would like to minimize this variable through design decisions	a measure of the ease with which sensible heat is transferred through a glazing assembly includes effects of both the glass or plastic "view" material and the frame materials and construction	includes area of frame	a "hypothetical" temperature difference that would result in the same heat flow through a shaded element under static conditions as seen in the "real" case; includes effects of indoor and outdoor air temperatures, daily temperature range, and heat storage in assembly (minor)
Implications:	affects system size and energy use	maximum values often set by energy efficiency codes or standards	function of building design	affected by month, day, hour, and assembly construction (mass)
Notes:	imposes first-cost and life-cycle costs	obtained from manufacturers' data as determined by specification of product	calculated from plans and elevations	empirical values; found in reference tables; CLTD for glazing is approximately equal to delta t

- Radiative transfer through transparent/translucent assemblies (glazing in windows, doors, skylights)

Equation and Variables:	**q_s =**	**SC or SHGC**	**A**	**SHGF**	**CLF**
I-P Units:	Btuh	dimensionless	ft sq	Btuh / ft sq	dimensionless
Description:	sensible heat flow	shading coefficient or solar heat gain coefficient	surface area of element	solar heat gain factor	cooling load factor
Discussion:	would like to minimize this variable through design decisions an intent to provide solar heating will require summer / winter coordination	a measure of the shading effectiveness of a glazing product and any interior and/or exterior shading devices (such as overhangs or drapes) SC is the traditional value used for this measure; SHGC is a newer value that is measured in a laboratory	design decisions determine the magnitude of this value	the maximum clear-day solar radiation expected to strike the glazing on the month, day, and hour selected for cooling load calculations; is affected by latitude, tilt, and orientation	an "adjustment" factor that accounts for the percentage of radiant energy that is stored in the building's interior mass and furnishings at the time of analysis
Implications:	affects system size and energy use	maximum values often set by energy efficiency codes or standards	function of building design	affected by orientation, tilt, month, day, hour, and latitude,	CLF is affected by the weight of interior elements; may be less than or greater than 1.0 (indicating storage or discharge)
Notes:	imposes first-cost and life-cycle costs	found by calculation or from testing lab reports	calculated from plans and elevations	statistical data; available in tables	empirical values; found in reference tables; useful as a design tool

- Sensible loads resulting from infiltration or ventilation air flows:

Equation and Variables:	**q_s =**	**Q (cfm)**	**1.1**	**delta t**
I-P Units:	Btuh	cu ft / min	(60) (Btuh) / (cu ft) (deg F)	deg F
Description:	sensible heat flow	rate of air flow	conversion factor (a constant)	temperature difference between indoor and outdoor air
Discussion:	would like to minimize this variable through design decisions and good detailing	infiltration is unintended air flow (leakage) ventilation is intended air flow (usually ducted in active systems)		
Implications:	affects system size and energy consumption	minimum values often set by building codes or air quality standards typically affects indoor air quality	not a design issue	this type of load is instantaneous—there is no capacitive effect from building mass
Notes:	imposes first-cost and life-cycle costs	infiltration may be estimated by the “air change method” or the “crack method” and is established by construction quality ventilation rate is established as a design criterion (part of OPR)	conversion factor applies only to I-P unit calculations	

- Moisture transfer through assemblies located above ground:

Equation and Variables:	**W =**	**M**	**A**	**delta p**
I-P Units:	grains per hour	grains / (hr) (ft sq) (inch of mercury)	ft sq	inch of mercury
Description:	mass of water vapor flow	permeance	surface area of element	difference in vapor pressure between indoor and outdoor air
Discussion:	would like to minimize this variable through design decisions mass can be converted to heat energy equivalent by use of a conversion factor	a measure of the ease with which water vapor is transferred through an assembly effect is conceptually “equivalent” to that of U-value in sensible heat flow value is determined by design decisions	area of element is determined by design decisions	a function of the interior and exterior climate conditions during cooling season, the exterior vapor pressure is usually higher than the interior vapor pressure
Implications:	affects system size and energy consumption	usually only vaguely discussed in energy efficiency codes or standards	function of building design	
Notes:	imposes first- and life-cycle costs can cause comfort and IAQ problems if not properly considered in design	calculated in a manner similar to that used for U-values preferred term for component is “vapor retarder” most glazing materials are impervious (have a very low “M”)	calculated from plans and elevations	found from psychrometric chart (one that shows vapor pressures)

NOTE: the moisture flow units (grains) are the result of the permeance units; this water vapor quantity must be condensed by a vapor compression system (or desiccant system) to be removed from the building; the energy required to do so can be calculated by converting grains to pounds (1 grain = 0.000143 pounds) and multiplying the pounds of water by the latent heat of vaporization (around 970 Btu/pound).

- Latent loads resulting from infiltration or ventilation air flows:

Equation and Variables:	**q_L =**	**Q**	**4840**	**delta W**
I-P Units:	Btuh	cu ft / min [cfm]	(60) (Btuh) / (cu ft) (pound H_2O)	pounds H_2O / pound dry air
Description:	latent heat flow	rate of air flow	conversion factor (a constant)	difference in absolute humidity between indoor and outdoor air
Discussion:	would like to minimize this variable through design decisions and/or details	infiltration is unintended air flow (leakage) ventilation is intended air flow (usually ducted in active systems)		
Implications:	affects system size and energy consumption	minimum values often set by building codes or air quality standards typically affects indoor air quality	not a design issue	this type of load is instantaneous—there is no capacitive effect from building mass
Notes:	imposes first-cost and life-cycle costs and poor design can affect comfort and IAQ	infiltration estimated by the “air change method” or the “crack method” ventilation rate is an established design criterion	conversion factor applies only to I-P unit calculations	found from standard psychrometric chart

Internal Loads

These loads originate within the building and are often determined by a combination of design team (type of electric lamp), owner (types of computers), and occupant (on-off behavior) decisions. Internal loads are critical to the energy performance of larger-scale buildings.

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- Sensible loads from lighting systems:

Equation and Variables:	**q_s =**	**Installed Lamp Watts**	**3.41**	**Usage Factor**	**Ballast Factor**	**CLF**
I-P Units:	Btuh	Watts	Btuh / Watt	dimension-less	dimension-less	dimensionless
Description:	sensible heat flow	connected electrical load for all lamps in building	conver-sion factor	an adjustment factor	an adjustment factor	cooling load factor
Discussion:	would like to minimize this variable through design decisions	usually estimated in schematic design and obtained from electrical plans in later design phases		accounts for any lamps that are installed but would not be operated under conditions assumed for load calculations	accounts for the electrical load imposed by ballasts required for gaseous discharge lamp operation	an “adjustment” factor that accounts for the percentage of radiant energy that is stored in the building=s interior mass
Implications:	usually a large part of the total load in non-residential buildings affected by lighting system selection	lighting budget values are often set by energy efficiency codes or standards use of daylighting will reduce this value (if properly done)			electronic ballasts have reduced this factor from the 1.25 value typically used for magnetic ballasts	CLF is affected by the weight of interior elements and by the arrangement of lighting fixtures with respect to a space and its air flow patterns
Notes:	imposes first- and life-cycle costs			function of design intent	obtained from product data	empirical values; found in ASHRAE reference tables

- Sensible loads from occupants:

Equation and Variables:	**q_s =**	**Number of People**	**Sensible Load per Person**	**CLF**
I-P Units:	Btuh	integer number	Btuh	dimensionless
Description:	sensible heat flow	occupant loading	sensible heat discharge	cooling load factor
Discussion:		a function of building program and design	a result of the body's search for thermal equilibrium	an "adjustment" factor that accounts for the percentage of radiant energy that is stored in the building's interior mass and furnishings
Implications:	a function of design, but not controllable via design		a function of occupant activity level and age/gender mix of occupants	affected by time selected for load calculation relative to daily occupancy patterns
Notes:	often a substantial load in assembly occupancies	calculated from information shown in building drawings	empirical values; found in reference tables	empirical values; found in reference tables; values are not necessarily intuitive, but are logical

- Latent loads from occupants:

Equation and Variables:	**q_L =**	**Number of People**	**Latent Load per Person**
I-P Units:	Btuh	integer number	Btuh
Description:	latent heat flow	occupant loading	latent heat discharge
Discussion:		a function of building program and design	a result of the body's search for thermal equilibrium
Implications:	a function of design, but not controllable via design		a function of occupant activity level and age/gender mix of occupants
Notes:	often a substantial load in assembly occupancies	calculated from information shown in building drawings	empirical values; found in reference tables

NOTE: there is no CLF (cooling load factor) applied to this load; the latent (moisture) load from occupants is assumed to not be affected by storage of water vapor in the building mass or furnishings; in other words, the load is assumed to be instantaneous.

- Sensible loads from equipment and appliances:

Equation and Variables:	**q_s =**	**Installed Wattage**	**3.41**	**Usage Factor**	**CLF**
I-P Units:	Btuh	Watts	Btuh / Watt	dimensionless	dimensionless
Description:	sensible heat flow	connected electrical load (or its thermal equivalent) for all equipment and appliances in building	conversion factor	cooling load factor	
Discussion:	would like to minimize this variable through design decisions	usually estimated in schematic design and obtained from plans and equipment data in later design phases		accounts for any equipment that is installed but would not be operated under the conditions assumed for load calculations	an "adjustment" factor that accounts for the percentage of radiant energy that is stored in the building=s interior mass
Implications:	although a function of the building program, some control of these loads is possible through design	even with efficiency improvements, the magnitude of equipment loads seems to increase as more and more electronic equipment is used in all types of buildings		usage factor may also be used to account for the portion (if any) of equipment heat dissipation that is removed from a building by exhaust devices (vents, hoods)	CLF is affected by the weight of interior elements and the percentage of equipment load that is radiant
Notes:	imposes first-cost and life-cycle costs			function of design intent	empirical values; found in ASHRAE reference tables

- Latent loads from equipment and appliances:

Equation and Variables:	**q_L =**	**Latent Output**	**Usage Factor**
I-P Units:	Btuh	Btuh	dimensionless
Description:	latent heat flow	heat equivalent of moisture output from equipment	an adjustment factor
Discussion:	would like to minimize this variable through design decisions	usually estimated in schematic design and obtained from plans and equipment data in later design phases	accounts for any equipment that is installed but would not be operated under the conditions assumed for load calculations
Implications:	although a function of the building program, some control of these loads is possible through design		usage factor may also be used to account for the portion (if any) of equipment moisture dissipation that is removed from a building by exhaust devices (vents, hoods)
Notes:	imposes first- and life-cycle costs	some information available in generic tables; usually obtained from product data	estimated from design intent and equipment data

NOTE: there is no CLF (cooling load factor) applied to this load; the latent (moisture) load from equipment and appliances is assumed to not be affected by storage of water vapor in the building mass or furnishings; the load is assumed to be instantaneous.