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Heating and Cooling Calculation Methods in Revit MEP

The Heating and Cooling Loads feature was designed following the specifications of the ASHRAE Handbook of Fundamentals. There are several ways to determine peak loads, and the one that this feature adheres to is the RTS (Radiant Time Series) method. This method takes into account the time delay effect as heat is transferred from the outside, through envelopes, and into spaces. A more thorough description is given in the Calculation section of this paper. The application used to calculate heating and cooling loads reports is referred to throughout this document as the "engine."

Data Assembly

This section discusses the important data inputs that the Engine expects in order to calculate the peak cooling and heating loads. The data inputs are categorized by building, zone, and space data object types.

Building Data Object Type

The building data object is a wrapper for data sharing by different components of the engine. There is one building object associated with each Revit model, and it holds data that is universal to the project, including weather, building construction type, and window type data.

Weather Data

The building location is specified in the Revit Manage Place and Location dialog. The longitude and latitude coordinates of the selected location are compared to an external database of 4400+ World Meteorological Organization (WMO) weather stations derived from the 2005 ASHRAE Handbook of Fundamentals. The closest WMO weather station is selected along with its weather data.

For the cooling loads calculation, a design day is derived for each of the 12 months of the year, with a maximum dry-bulb temperature corresponding to the 1% monthly percentile temperature for the location. This is the temperature that is exceeded on average, during that month, for 1% of the time. The daily range and profile of the dry-bulb temperature, and the corresponding values of wet-bulb temperature, are derived from data in the ASHRAE database. The clearness number is currently set to 1 for all locations. This will be updated in subsequent versions when this data becomes available for specific locations.

For the heating loads calculation, the design outside dry-bulb temperature is set to the 99% annual percentile temperature for the location - the temperature that is exceeded on average over a period of years for 99% of the time.

The selected city, its coordinates and weather information are stored within the building data object.

Construction Data

A construction is defined as a type of exterior wall, roof, partition (also known as an interior wall), ceiling, or non-glazed door. Each construction is made up of one or more material types. Each of these material types contain thermal properties, when combined to create a construction define the thermal behavior for heating and cooling load calculations.

Each material type contains the following five thermal properties:

Parameter Name	Units
Thickness	m
Conductivity	W/(m-K)
Density	kg/m³
Specific Heat	kJ/(kg-K)
Resistance	(m²-K)/W

Heat capacity (HC) is the ability of a construction assembly to absorb thermal energy. the heat capacity of an assembly is calculated using the following equation:

Equation N2-1

$$HC = \sum_{i=1}^{n} (\rho_i \times c_i \times t_i)$$

where:

n is the total number of layers in the assembly

ρ_i is the density of the i^{th} layer

C_i is the specific heat of the i^{th} layer

t_i is the thickness of the i^{th} layer

all in constant units.

Construction Type Characteristics

When combined, the material thermal properties define the following characteristics for each construction type.

Conduction Time Series (CTS)

A series of conduction time factors for a wall or roof material over a 24-hour period is called a conduction time series (CTS). Chapter 30 of the ASHRAE 2005 HoF contain tables of CTS values for many different wall and roof constructions. The Engine in Revit MEP is able to derive an unlimited number of wall and roof CTS schedules based upon the four thermal properties of each material type that makes up the wall or roof.

Ceilings, partitions, and doors do not require CTS schedules for the cooling load calculations.

U-Values

The R-value of a material or construction represents its thermal resistance or heat loss retardation. The U-value is the reciprocal of R-value. The total U-value of a construction can be derived by adding the reciprocal of the R-values of the individual materials that make up the construction. The R-value (or U-value) of each material is dependent upon the properties of the material, itself, and the thickness of the material. In Revit MEP, construction types for the walls, roofs, doors, and floors are selected for each space either in the space Instance Properties dialog or in the Heating and Cooling Loads dialog.

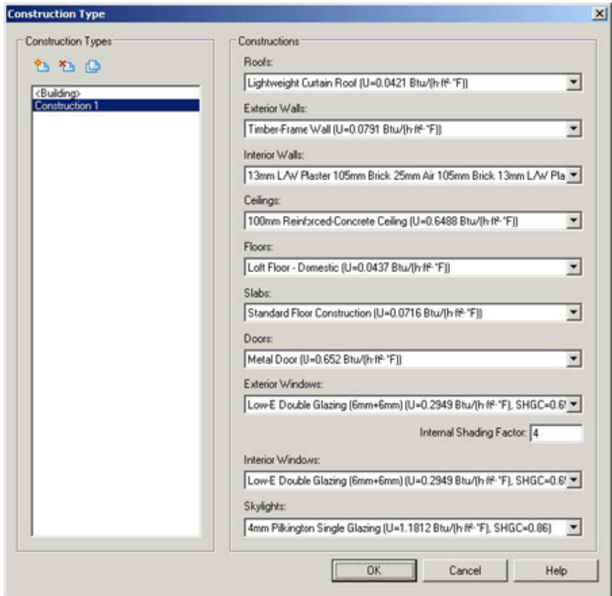
gbXML Construction and Material Tags

Each construction type is comprised of one or more material types that contain the five property types listed above. This list of constructions is derived from a variety of sources including ASHRAE, CIBSE, and others. All of these constructions and their corresponding materials are stored in an XML file. This file loosely follows the gbXML schema and it only contains tags related to constructions.

The following is a sample of a typical gbXML construction and material tags:

```
<Construction id="ASHIF5" surfaceType="Ceiling">
 <Name>8 In. Light Weight Concrete Ceiling</Name>
 <Description>8 In. Light Weight Concrete Ceiling</Description>
 <LayerId layerIdRef="lay-ASHIF5" />
 <U-value unit="WPerSquareMeterK">1.3610</U-value>
 </Construction>
- <Layer id="lay-ASHIF5">
 <MaterialId materialIdRef="mat-AM13" />
 </Layer>
<Material id="mat-AM13">
 <Name>8 in. lightweight concrete</Name>
 <Description>8 in. lightweight concrete</Description>
 <Thickness unit="Meters">0.2032</Thickness>
 <Conductivity unit="WPerMeterK">0.53</Conductivity>
 <Density unit="KgPerCubicM">1280</Density>
 <SpecificHeat unit="JPerKgK">840</SpecificHeat>
 </Material>
```

The construction types in the constructions.xml file is displayed in the Construction Type dialog.



Glazing Data (Windows and Glass Doors)

Revit MEP uses the Solar Heat Gain Coefficient (SHGC) for the thermal properties of window and door glazing.

SHGC measures how well a window blocks heat from sunlight. It is the fraction of the heat from the sun that enters through a window. SHGC is expressed as a number between 0 and 1. The lower the SHGC of a window, the less solar heat it transmits. The solar-optical properties, including the SHGC value, of glazings depend on the incident angle of the radiation passing through the glazing.

The following table is an excerpt from Table 31 in the 2005 ASHRAE Handbook of Fundamentals. The source table contains a tabular listing of 75+ different types of glazings along with their incidence angular-dependent SHGC values.

	Glazing System				Incidence Angles						
ID	Glass, Thick., in.		Center Glazing T_v		Normal 0.00	40.00	50.00	60.00	70.00	80.00	Hemis, Diffuse
Uncoated Single Glazing											
1a	1/8	CLR	0.90	SHGC	0.86	0.84	0.82	0.78	0.67	0.42	0.78
				T	0.83	0.82	0.80	0.75	0.64	0.39	0.75
				R^f	0.08	0.08	0.10	0.14	0.25	0.51	0.14
				R^b	0.08	0.08	0.10	0.14	0.25	0.51	0.14
				A_1^f	0.09	0.10	0.10	0.11	0.11	0.11	0.10

	Glazing System				Incidence Angles						
ID	**Glass, Thick., in.**		**Center Glazing T_v**		**Nor-mal 0.00**	**40.00**	**50.00**	**60.00**	**70.00**	**80.00**	**Hemis, Dif-fuse**
Uncoated Single Glazing											
1b	1/4	CLR	0.88	SHGC	0.81	0.80	0.78	0.73	0.62	0.39	0.73
				T	0.88	0.87	0.85	0.80	0.69	0.43	0.80
				R^f	0.08	0.09	0.11	0.15	0.27	0.53	0.14
				R^b	0.08	0.09	0.11	0.15	0.27	0.53	0.14
				$\mathcal{A}_1^f$	0.16	0.17	0.18	0.19	0.19	0.17	0.17
1c	1/4	BRZ	0.68	SHGC	0.73	0.71	0.68	0.64	0.55	0.34	0.65
				T	0.65	0.62	0.59	0.55	0.46	0.27	0.56
				R^f	0.06	0.07	0.08	0.12	0.22	0.45	0.12
				R^b	0.06	0.07	0.08	0.12	0.22	0.45	0.12
				$\mathcal{A}_1^f$	0.29	0.31	0.32	0.33	0.33	0.29	0.31

U-Values are also associated with glazings for purposes of calculating conduction values for cooling and heating.

Zone Data Object

In Revit MEP, a zone is considered an HVAC system. A number of “like" spaces (i.e. - same orientation, all internal, all offices, etc.) are assigned to a zone, and the zone is served by one piece of HVAC equipment whether it is a VAV box or rooftop unit. The zone data object in Revit MEP is assigned all of the spaces it contains, and it also contains its own properties that are unique to HVAC systems. These properties include:

1. Service Type
2. Cooling coil properties
3. Heating coil properties
4. Ventilation
5. Coil bypass.

Service Type

The user selects a service type from a drop down list of 20+ options located in the zone instance properties dialog. The service types are grouped into 4 different categories, and depending upon which category the selection falls under, will determine the type of calculation or output.

1. **Constant volume:** A constant volume service type refers to a constant volume HVAC system, where the fan air volume output is constant no matter what the actual space cooling loads are at that point in time. The cooling calculation engine performs peak of the sum room load calculations, meaning that the engine determines at which month and hour of the year the sum of all of the individual room cooling loads for the zone is the greatest. This type of service type is utilized for simpler HVAC systems with little cooling diversity and no plans for variable air volume systems.
2. **Variable air volume (VAV):** A variable air volume service type refers to a variable air volume HVAC system, where the fan air volume output may vary depending upon the diversity of the cooling loads in the individual spaces. The cooling calculation engine performs sum of the peak room load calculations, meaning that the engine determines at which month and hour of the year the peak cooling load occurs for each individual space. This allows the HVAC designer to properly size variable air volume boxes for each room(s) that it serves. Please note that the zone cooling load components will continue to display the constant volume (peak of the sum) values for the sake of properly sizing the fan or rooftop unit, while the individual space cooling load components will represent the peak values for the individual space.
3. **Hydronic:** A hydronic service type refers to a hydronic HVAC system such as a chiller or boiler. By selecting a hydronic service type, some of the output results will display hydronic units such as gallons per minute (GPM) or liters/second (L/s) versus BTU/hour for conventional air system types. Any service type with the word "water", "radiator", or "hydronic" is a hydronic service type.
4. **Other:** The reason the other choices remain is to support an export to gbXML (specifically to continue to maintain an IES link, but also potentially for other consuming applications).

The service type also specifies whether there is reheat applied (reheat is no applied by default, and only Service Types that include the word "Reheat" turn it on). Reheat is the process of cooling air to a lower set point that you want and the heating it back up before it's spread to the spaces. This can be useful when a particular relative humidity is required (for example in an emergency room or museum).

Set Points and Humidification

Heating and cooling set points are set for a given zone and not for spaces in a building. The heating and cooling set points, as well as the supply air temperature and humidification, clearly affect the load calculations, but also play important roles in determining the psychrometric results (covered in greater depth below).

There are two ways a user can specify the humidification values. Either he can set the humidification directly, or he can allow the engine to determine the best case humidity value given the other parameters (set point and supply air temperatures). In the former case, in order to satisfy psychrometric conditions, a significant reheat value may be required. In the latter case, the engine will attempt to find a reheat value of 5% or less in certain ranges of humidity values (first searching 40-60%, then 60-80%, 20-40%, and so on). There are certain cases where a given psychrometric condition cannot be satisfied, and the user is notified of this psychrometric error via the loads report. In this situation, the loads that are affected by the error will not be displayed. The user should use the report as a guide to determine which of the three variables (set point, supply temperature, humidity) to adjust in order to get valid results.

Plenums

A plenum is an unconditioned area above a conditioned space that holds ductwork returning air from the space to the coil. Plenums are special because they contribute both to the space load and to the equipment load. A plenum receives heat from several sources: conduction through its walls and roofs, the lighting from the space below, and heat from the return air. This causes the plenum to raise itself to a temperature higher than its adjacent spaces, and so conduction is transferred to those spaces. Similarly, this heat contributes to a load that the equipment must take in to account as the return air is circulated back.

Within the engine itself, the plenum values are highly dependent on the airflow (the CFM) coursing through the system. Therefore, most of the other loads and psychrometrics must be calculated first, then the plenum values, and then the psychrometrics a second time to take into account this additional load.

Space Data

Spaces are the main contribution to the loads of the system. Heat gain comes from a variety of sources including solar radiation through windows and skylights, conduction through exterior and interior envelopes, heat generated by internal factors (people, lights, appliances), and infiltration.

Space Type

The space type is a Revit construct made up of gbXML defined space types about which the engine knows nothing about. The space type is used to populate certain defaults for engine parameters of commonly used spaces, such as occupancy, carpeting, plenum lighting, and many others. Most of these parameters are overrideable by the user.

Lighting, Electrical Equipment, and People

Schedules for power (like computers and coffee machines), lighting, and occupancy allow the user to specify which hours of the day to use these loads and at what percentage. These schedules are sent to the engine either directly through parameters on the space's type (see above).

Equipment and lighting both contribute a sensible heat gain directly given by the amount of power they emit. Lighting also may contribute to any plenums that serve a given space and so a percentage of this contribution is taken in to account within the engine. This value can be specified in the Electrical Loads section of a space or by the space's type.

In addition to sensible heat gain, people also give off a latent heat gain. This latent gain is instantaneous, while the sensible gain (like those for appliances) is affected by the thermal storage characteristics of the space.

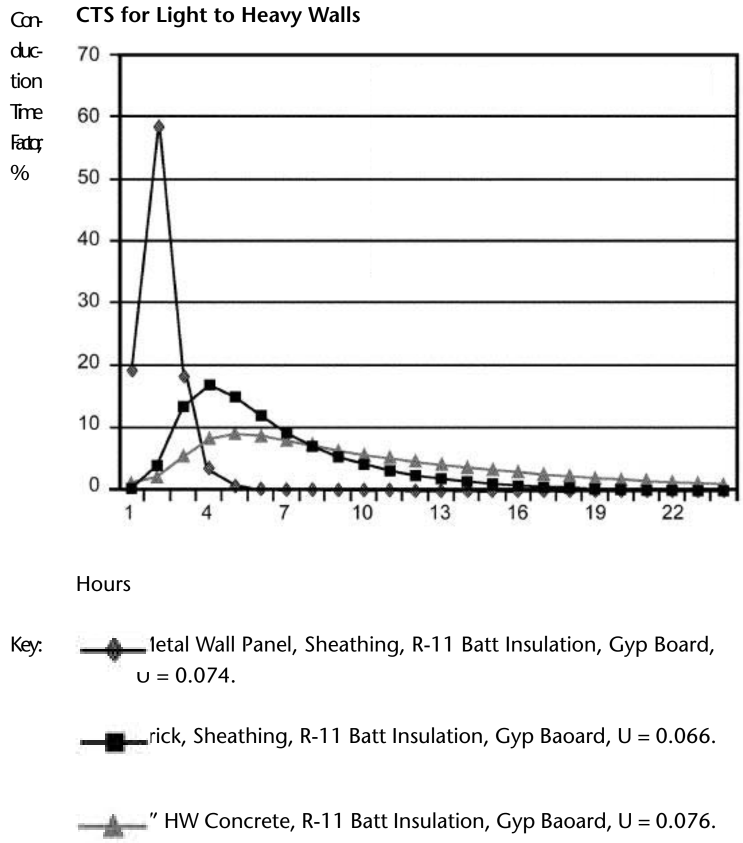
Condition Type

There are several different options for conditioning in Revit. Heated maps to heating loads only, Cooled maps to cooling loads only, Unconditioned maps to no conditioning at all. All other values map to both heating and cooling loads.

External Walls and roofs

Heat gain from exterior surfaces is affected by the rate of conductive heat transfer through them. In order to determine this rate, the engine uses conduction time series (CTS) values. Each exterior wall and roof has

24 different CTS percentage values, summing to 100%, that indicate how much of the heat stored in the envelope has come through after a given amount of time.



CTS values are derived through a complicated process that examines the material properties that make up each construction. For the purposes of cooling, the U-value of a construction is also used (for heating, only the U-value is used and not CTS values). The weight of a construction (also derived from material properties) also plays a role in determining the thermal storage characteristics of a space.

External Windows and Skylights

Windows, similar to constructions, are also dependent on a set of values known as solar heat gain coefficient (SHGC) values. These values determine the heat gain at a given time of day (and therefore the incident angle of the sun). At this time, the engine is unable to derive SHGC values given properties of a window and is therefore dependent on having them sent in directly. Like a construction's CTS values, the SHGC values are used in conjunction with the U-value for cooling loads. Only the U-value is used during winter for heating calculation.

Ceilings and Partitions

Interior separations of zones, such as ceilings and partitions (interior walls), are handled in a much simpler way than exterior constructions. A U-value is all that is required (along with the temperature differences found in the set points of the zones that hold the adjacent spaces) to determine the heat transfer across these surfaces. Ceilings are also used for plenum heat transfer, and partitions are normally only used when different zones contain spaces which are adjacent to each other. Interior windows (but not interior doors) are also used in determining the heat transfer across a partition. The only construction never used in the load calculation engine is the slab.

Calculation

Once all the data has been assembled, the engine can calculate the loads. For standard calculations, the engine will examine each space from the months of April to November and from 6am to 6pm (Oct-May in the southern hemisphere). After the loads of all the spaces have been determined, the maximum month/hour (depending on the calculation type) is used to determine the psychrometrics, airflow, and coil loads. The following (borrowed liberally from the ASHRAE 2005 Handbook of Fundamentals) is a discussion of the calculation process and principles employed.

Overview

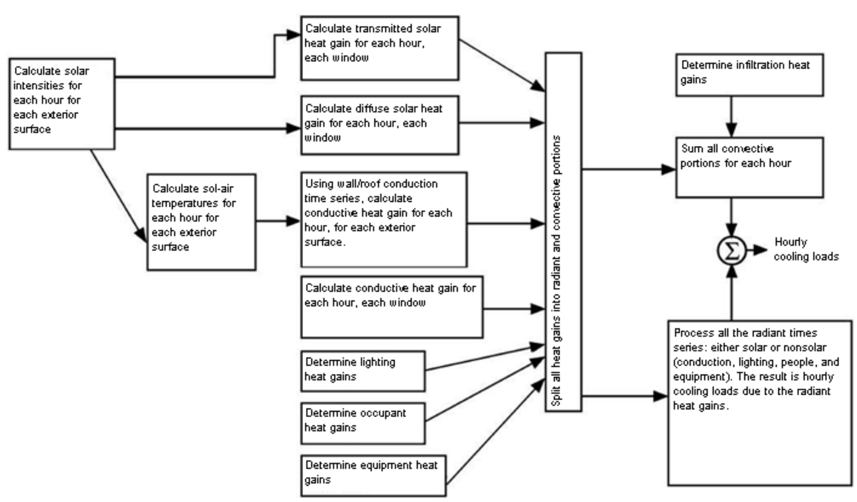
Design cooling loads are based on the assumption of steady periodic conditions (i.e., the design day's weather, occupancy, and heat gain conditions are identical to those for preceding days such that the loads repeat on an identical 24 h cyclical basis). Thus, the heat gain for a particular component at a particular hour is the same as 24 h prior, which is the same as 48 h prior, etc. Cooling load calculations must address two time-delay effects inherent in building heat transfer processes:

1. Delay of conductive heat gain through opaque massive exterior surfaces (walls, roofs, or floors)
2. Delay of radiative heat gain conversion to cooling loads.

Exterior walls and roofs conduct heat because of temperature differences between outdoor and indoor air. In addition, solar energy on exterior surfaces is absorbed, then transferred by conduction to the building interior. Because of the mass and thermal capacity of the wall or roof construction materials, there is a substantial time delay in heat input at the exterior surface becoming heat gain at the interior surface.

Most heat sources transfer energy to a room by a combination of convection and radiation. The convective part of heat gain immediately becomes cooling load. The radiative part must first be absorbed by the finishes and mass of the interior room surfaces, and becomes cooling load only when it is later transferred by convection from those surfaces to the room air. Thus, radiant heat gains become cooling loads over a delayed period of time.

Overview of Radiant Time Series Method



RTS Calculation Method

The general procedure for calculating cooling load for each load component (lights, people, walls, roofs, windows, appliances, etc.) with RTS is as follows:

1. Calculate 24 h profile of component heat gains for design day (for conduction, first account for conduction time delay by applying conduction time series).
2. Split heat gains into radiant and convective parts.
3. Apply appropriate radiant time series to radiant part of heat gains to account for time delay in conversion to cooling load.
4. Sum convective part of heat gain and delayed radiant part of heat gain to determine cooling load for each hour for each cooling load component.

After calculating cooling loads for each component for each hour, the engine sums those to determine the total cooling load for each hour and selects the hour with the peak load for design of the air-conditioning system. The engine repeats this process for multiple design months to determine the month when the peak load occurs.

Heat gain through exterior opaque surfaces is derived from the same elements of solar radiation and thermal gradient as that for fenestration areas. It differs primarily as a function of the mass and nature of the wall or roof construction, because those elements affect the rate of conductive heat.

Sol-Air Values

Sol-air temperature is the outdoor air temperature that, in the absence of all radiation changes, gives the same rate of heat entry into the surface as would the combination of incident solar radiation, radiant energy exchange with the sky and other outdoor surroundings, and convective heat exchange with outdoor air.

The heat balance at a sunlit surface gives the heat flux into the surface q/A as

$$\frac{q}{A} = \alpha E_t + h_o(t_o - t_s) - \varepsilon \Delta R \quad (28)$$

where:

α = absorptance of surface for solar radiation

E_t = total solar radiation incident on surface, Btu/h·ft²

h_o = coefficient of heat transfer by long-wave radiation and convection at outer surface, Btu/h·ft²·°F

t_o = outdoor air temperature, °F

t_s = surface temperature, °F

ε = hemispherical emittance of surface

$$\frac{q}{A} = \alpha E_t + h_o(t_o - t_s) - \varepsilon\Delta R \quad \textbf{(28)}$$

where:

ΔR = difference between long-wave radiation incident on surface from sky and surroundings and radiation emitted by blackbody at outdoor air temperature, Btu/h·ft²

Assuming the rate of heat transfer can be expressed in terms of the sol-air temperature te,

$$\frac{q}{A} = h_o(t_e - t_s) \quad (29)$$

and from Equations (28) and (29),

$$t_e = t_o + \frac{\alpha E_t}{h_o} - \frac{\varepsilon \Delta R}{h_o} \quad (30)$$

Calculating Conductive Heat Gain

Conduction through exterior walls and roofs is calculated using conduction time series (CTS). Wall and roof conductive heat input at the exterior is defined by the familiar conduction equation as

$$q_{i,\text{q-}n} = UA(t_{e,\text{q-}n} - t_{rc}) \quad \textbf{(31)}$$

where:

$q_{i,\text{q-}n}$ = conductive heatinput for the surface n hours ago, Btu/h

U = overall heat transfer coefficient for the surface, Btu/h·ft²·°F

A = surface area, ft²

$t_{e,\text{q-}n}$ =sol-air temperature n hours ago, °F

t_{rc} = presumed constant room temperature, °F

Conductive heat gain through walls or roofs can be calculated using conductive heat inputs for the current hours and past 23 h and conduction time series:

$$q_q = c_0 q_{i,q} + c_1 q_{i,q-1} + c_2 q_{i,q-2} + c_3 q_{i,q-3} + \ldots + c_{23} q_{i,q-23}$$
(32)

where:

q_q = hourly conductive heat gain for the surface, Btu/h

$q_{i,q}$ = heat input for the current hour

$q_{i,q-n}$ = heat input n hours ago

c_0, c_1 etc. = conduction time factors

The conduction time factors can be used in Equation (32) and provide a means for comparison of time delay characteristics between different wall and roof constructions. Construction heat gains calculated for walls or roofs using periodic response factors (and thus CTS) are identical to those calculated using conduction transfer functions for the steady periodic conditions assumed in design cooling load calculations.

Heat Gain through Interior Surfaces

Whenever a conditioned space is adjacent to a space with a different temperature (i.e. in a different zone), heat transfer through the separating physical section must be considered. The heat transfer rate is given by

$$q = UA(t_b - t_i)$$ **(33)**

where:

q = heat transfer rate, Btu/h

U = coefficient of overall heat transfer between adjacent and conditional space, Btu/h·ft²·°F

A = area of separating section concerned, ft²

t_b = average air temperature in adjacent space, °F

t_i =air temperature in conditioned space, °F

Fenestration Heat Gain

For windows and skylights, the engine uses the following equations to calculate heat gain:

Direct beam solar heat gain qb:

$$q_b = AE_D \, \text{SHGC}(\theta) \quad (13)$$

Diffuse solar heat gain qd:

$$q_d = A(E_d + E_r)\langle \text{SHGC} \rangle_D$$

(14)

Conductive heat gain qc:

$$q_c = UA(T_{out} - T_{in})$$

(15)

Total fenestration heat gain Q:

$$Q = q_b + q_d + q_c$$

(16)

where:

A = window area, ft²

E_D, E_d, and E_r = direct, diffuse, and ground-reflected irradiance

$\text{SHGC}(\theta)$ = direct solar heat gaincoefficient as a function of incident angle q; may be interpolated between values

$\langle \text{SHGC} \rangle_D$ = diffuse solar heat gain coefficient (also referred to as hemispherical SHGC)

T_{in} = inside temperature, °F

T_{out} = outside temperature, °F

U = overall U-factor, including frame and mounting

Once this breakdown of all the space loads and coil loads is finished, the engine determines the month and hour for the maximum zone load (for the purposes of display, a zone load is always a constant volume load, or peak of the sums, regardless if the individual spaces are variable volume). The engine then moves on to deal with plenums and psychrometrics.

Plenum Loads

The space above a ceiling, when used as a return air path, is a ceiling return air plenum. Unlike a traditional ducted return, the plenum may have multiple heat sources in the path. These heat sources may be radiant and convective loads from lighting and transformers; conduction loads from adjacent walls, roofs, or glazing; or duct and piping systems within the plenum. The following equations show how temperatures and heat transfer for plenums are calculated in the engine:

$$q_1 = U_c A_c (t_p - t_r) \quad (35)$$

$$q_2 = U_f A_f (t_p - t_{fa}) \quad (36)$$

$$q_3 = 1.1Q(t_p - t_r) \quad (37)$$

$$q_{lp} - q_2 - q_1 - q_3 = 0$$
(38)

$$Q = \frac{q_r + q_1}{1.1(t_r - t_s)} \quad (39)$$

where:

q_1 = heat gain to space from plenum through ceiling, Btu/h

q_2 = heat loss from plenum through floor above, Btu/h

q_3 = heat gain "pickup" by return air, Btu/h

Q = return airflore, Btu/h

q_{lp} = light heat gain to plenum via return air, Btu/h

q_{lr} = light heat gain to space, Btu/h

q_f = heat gain from plenum below, through floor, Btu/h

q_w = heat gain from exterior wall, Btu/h

q_r = space cooling load, including appropriate treatment of and/or , Btu/h

t_p = plenum temperature, °F

t_r = space temperature, °F

$$q_1 = U_c A_c (t_p - t_r) \quad (35)$$

$$q_2 = U_f A_f (t_p - t_{fa}) \quad (36)$$

$$q_3 = 1.1 Q (t_p - t_r) \quad (37)$$

$$q_{lp} - q_2 - q_1 - q_3 = 0$$
(38)

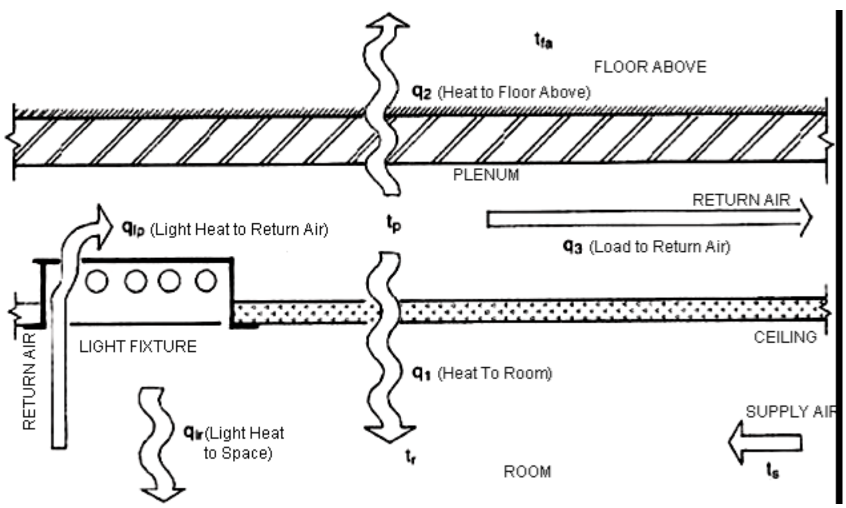
$$Q = \frac{q_r + q_1}{1.1(t_r - t_s)} \quad (39)$$

where:

t_{fa} = space temperature of the floor above, °F

t_s = supply temperature, °F

Schematic Diagram of Typical Return Air Plenum



Heating Loads

After we have collected all of the cooling load components for each space, the heating load is calculated. Techniques for estimating design heating loads for commercial buildings are essentially the same as those for estimating design cooling loads with the following exceptions:

- Temperatures outside conditioned spaces are generally lower than maintained space temperatures.
- Credit for solar or internal heat gains is not included
- Thermal storage effect of building structure or content is ignored.

Heat losses (negative heat gains) are thus considered to be instantaneous, heat transfer essentially conductive, and latent heat treated only as a function of replacing space humidity lost to the exterior environment. This simplified approach is justified because it evaluates worst-case conditions that can reasonably occur during a heating season. Therefore, the worst-case load is based on the following:

- Design interior and exterior conditions
- Including infiltration and/or ventilation
- No solar effect (at night or on cloudy winter days)
- Before the periodic presence of people, lights, and appliances has an offsetting effect

Psychrometrics

Psychrometric calculations use thermodynamic properties to analyze conditions and processes involving moist air. By calculating these various saturations we can determine the necessary airflows, entering and leaving air temperatures, and equipment loads of the zone. The various equations themselves are beyond the scope this paper but a brief overview of the process follows.

Psychrometric conditions are controlled by three variables: supply air temperature, set point, and humidity (which Revit allows to float). In Revit, the user must set the first two variables to a specified value, and the third he has the option to either set or allow to float (i.e. let the engine determine an optimal humidity). If the humidity is allowed to float, then the engine will attempt to find a humidity that minimizes additional load gains. If the humidity is specified, there may be cases where the psychrometric conditions cannot be attained (the engine allows a 5% tolerance). In this case, an error is displayed for the user in the loads report.

Assuming that the conditions can be attained, the airflow for the zone is the first component calculated, followed by the required ventilation. Once these are known, the engine determines the psychrometric characteristics for the outside air conditions. This allows for the calculation of the entering air and the mixing air temperatures. After these temperatures and airflows are known, the engine can determine the remaining values including ventilation loads, equipment loads, and reheat values.

Zone, Level, and Building Loads

Once the individual space loads, psychrometrics, and equipment loads are all calculated, the engine determines the final block loads of the zones, levels, and building. These values are simple block loads that sum the component breakdowns at the hour and month of the maximum load value. The zone and building summary also includes the equipment from their respective sources. The values of the various peak loads are dependent on whether the equipment used is constant or variable air volume. They break down as such:

	Constant Air Volume	Variable Air Volume
Building	Peak of space sums in building + sum of zone equipment	Peak of space sums in building + sum of zone equipment
Level	Peak of space sums on level (no equipment)	Peak of space sums on level (no equipment)
Zone	Peak of space sums in zone + equipment	Peak of space sums in zone + equipment
Space	Load at zone's max month/hour	Load at space's max month/hour

At the end of the process, the engine has populated component breakdown arrays ranging over each hour and month combination for each space, as well as a maximum value of each of these components for every level, every zone and the building. It is a large amount of data, but it gives the consuming application (Revit) the ability to show many different patterns, trends, and data to the user.

References and Images

ASHRAE. 2005. Chapter 30: Nonresidential Cooling and Heating Load Calculations. 2005 ASHRAE Handbook - Fundamentals

Roth, Stephen. 2006. Documentation written for Autodesk's HVAC Load Calculation Extension (formerly Loadsoft 6.0). Autodesk HVAC Load Calculation Extension

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