DOE-2.2

Building Energy Use and Cost Analysis Program
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Volume 6: New Features

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Introduction to New Features

This version of DOE-2 incorporates several new or revised features:

- Residential infiltration using the ASHRAE-Enhanced infiltration algorithm
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- Additional window covering control strategies
- Condensing boiler
- DX evaporative condensers
- Whole-house fan exhaust to an attic
- Photocell override of a schedule
- The ability to mix domestic hot water with cold water
- The ability to specify the convective/radiative split for the various space internal heat gains
- The ability to simulate temperature-dependent space electric loads, such as a refrigerator.
- User-defined daylight-savings intervals
- Direct-expansion fan-powered induction unit systems
- Variable-flow zonal exhaust, such as for a kitchen or laboratory fume hood
- Improvements to skylight modeling and daylight modeling for skylights and daylight obstructions
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- Selecting a window shade deployment variable
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- Time-Dependent Valuation for California 2005 Energy Code
- Cycling indoor fan operation for fan coil and single-zone systems (those supplied by chilled/hot water) plus economizers for fan coil systems
- Revised photovoltaic algorithms
- New sizing options in SYSTEMs that couple the airflow and capacity

- A new staged-volume, packaged single-zone system
- The addition of screw chillers
- The development of new chiller performance data for all electric chillers, including multi-compressor reciprocating chillers and variable-speed centrifugal chillers
- Enhancements to the existing variable-flow condenser algorithms to better assess the effect on chiller performance
- The improvement or addition of new chiller condensers, including air-cooled, remote air-cooled, and remote evaporative-cooled
- The ability to specify a chiller at either the design conditions or the ARI-rated conditions

ENHANCED VAV BOX HEATING CONTROL

Introduction

The simulation of zone VAV boxes was improved to allow the specification of a maximum flow in the heating mode for the case of reverse action thermostatic control. In this case it may be desirable to limit the VAV boxes from fully opening to the maximum cooling flow. This is especially important when the reverse action is combined with supply air temperature reset since lowering the supply air temperature can cause the VAV boxes to open further to compensate.

Building Description Language Changes

SYSTEM command:

HMAX-FLOW-RATIO
In general, specifies the ratio of the maximum (or fixed) heating airflow to the cooling airflow. The specific meaning varies according to the type of zone terminal. This keyword applies only to VAVS and PVAVS systems.

For a variable-volume single duct terminal (VAV, etc.), with ZONE:THERMOSTAT-TYPE = REVERSE-ACTION, this keyword specifies the maximum heating airflow ratio. The heating airflow modulates between the MIN-FLOW-RATIO (or HMIN-FLOW-RATIO) and the HMAX-FLOW-RATIO. The default is the larger of the MIN-FLOW-RATIO (default or specified) and 0.5. If the terminal is constant-volume, or if the THERMOSTAT-TYPE = PROPORTIONAL, then this keyword has no meaning.

Some reverse-acting VAV systems may go out of control if the maximum heating airflow is not restricted . As the zone temperature drops, the box progressively opens to deliver more air. However, since the supply air is usually lower than the zone temperature, more coil energy is required to offset the non-useful reheat (difference between zone temperature and supply air temperature), potentially leaving less coil/boiler capacity available for useful heating. As a result, a terminal at full flow may deliver less useful heating than at lower flow, resulting in an out-of-control situation; the box may go to full flow even though a reduced flow would heat more effectively. The solution is to restrict the maximum flow during reheatng coil and/or boiler is not sized sufficiently large,

ZONE command:

HMAX-FLOW-RATIO
For a reverse-action VAV terminal, specifies the ratio of the maximum heating airflow to the cooling airflow. This keyword also has an equivalent keyword at the SYSTEM level.

ASHRAE-ENHANCED RESIDENTIAL INFILTRATION

Introduction

The infiltration algorithms now include the ASHRAE Enhanced method, as described in the <u>2005 ASHRAE Handbook, Fundamentals</u>, pp.27.21-22

Building Description Language Changes

SPACE command:

INF-METHOD

ASHRAE-ENHANCED   *(new)* The infiltration rate is determined using the "Enhanced" method as described in the <u>2005 ASHRAE Handbook - Fundamentals</u>, pp. 27.21-22. Uses the keywords FLOW-COEF, STACK-COEF, WIND-COEF, PRESSURE-EXP and SHIELDING-COEF.

The enhanced model uses pressurization test results to characterize house air leakage through the leakage coefficients and the pressure exponent. The model is sensitive to these coefficients, which may be quite difficult to determine.

The default values for these keywords are taken from the first example given for this method in ASHRAE (Example 4). The default FLOW-COEF scales according to the space VOLUME.

NONE   *(existing)* No infiltration is calculated.

AIR-CHANGE   *(existing)* The infiltration rate is calculated using the air-change method. AIR-CHANGES/HR or INF-FLOW/AREA should be specified if INF-METHOD = AIR-CHANGE. In this case the value AIR-CHANGES/HR will be corrected for wind speed each hour, but the value of INF-FLOW/AREA will not be corrected. If both AIR-CHANGES/HR and INF-FLOW/AREA are specified, the resulting infiltration rates are added.

RESIDENTIAL   *(existing)* The infiltration rate is determined by the values of RES-INF-COEF and depends on wind speed and outside-inside temperature difference.

S-G   *(existing)* Sherman-Grimsrud Infiltration Method. Applies only to single-zone. Uses keywords HOR-LEAK-FRAC, NEUTRAL LEVEL and FRAC-LEAK AREA.

CRACK   *(existing)* In the case of the Crack Method, a value should be entered for the INF-COEF keyword in the EXTERIOR-WALL instruction, and for the keyword INF-COEF in the WINDOW instruction.

FLOW-COEF

For INF-METHOD = ASHRAE-ENHANCED, specifies the flow coefficient 'c' in the equations:

$$Q_s = c * C_s * dT^n$$

$$Q_w = c * C_w * (sf*Wlocal)^{2n}$$

$$Qnet = [Qs^2 + Qw^2]^{1/2}$$

where

Qs	infiltration due to the indoor/outdoor temperature differenial, cfm
c	flow coefficient, cfm/(in. $H_2O)^n$
Cs	stack coefficient, (in. $H_2O/°F)^n$
dT	absolute value of the indoor/outdoor temperature differential, °F
n	pressure coefficient
Qw	Infiltration due to wind, cfm
Cw	wind coefficient, (in. $H_2O/mph^2)^{2n}$
sf	Shelter factor, modifier of local wind speed based on immediate surroundings
Wlocal	local wind speed as modified by the SITE-PARAMETER terrain parameters, mph
Qnet	Net infiltration due to the combined effect of temperature and wind, cfm

Stack and wind coefficients vary according to the number of stories in the house, whether a flue exists, and whether the house has a crawl space. The default FLOW-COEF is based on the first example given in the 2005 ASHRAE Handbook - Fundamentals, pp. 27.22; scaled by the square root of the ratio of the SPACE:VOLUME divided by the volume in the example, 12,000 ft³.

Because the units are dependent on the pressure exponent 'n', this keyword is dimensionless in the input, and this method currently cannot be used with metric input. If simulated in metric, this keyword must still be defined in English.

STACK-COEF
For INF-METHOD = ASHRAE-ENHANCED, specifies the temperature-dependent stack coefficient 'Cs' in the equations:

$$Qs = c * Cs * dT^n$$

$$Qw = c * Cw * (sf*Wlocal)^{2n}$$

$$Qnet = [Qs^2 + Qw^2]^{1/2}$$

where

Qs	infiltration due to the indoor/outdoor temperature differenial, cfm
c	flow coefficient, cfm/(in. $H_2O)^n$
Cs	stack coefficient, (in. $H_2O/°F)^n$
dT	absolute value of the indoor/outdoor temperature differential, °F
n	pressure coefficient
Qw	Infiltration due to wind, cfm
Cw	wind coefficient, (in. $H_2O/mph^2)^{2n}$
sf	Shelter factor, modifier of local wind speed based on immediate surroundings
Wlocal	local wind speed as modified by the SITE-PARAMETER terrain parameters, mph
Qnet	Net infiltration due to the combined effect of temperature and wind, cfm

Stack and wind coefficients vary according to the number of stories in the house, whether a flue exists, and whether the house has a crawl space. Typical values are listed in Table 3.

Because the units are dependent on the pressure exponent 'n', this keyword is dimensionless in the input, and this method currently cannot be used with metric input. If simulated in metric, this keyword must still be specified in English.

WIND-COEF

For INF-METHOD = ASHRAE-ENHANCED, specifies the wind-dependent stack coefficient 'Cw' in the equations:

$$Qs = c * Cs * dT^n$$

$$Qw = c * Cw * (sf*Wlocal)^{2n}$$

$$Qnet = [\, Qs^2 + Qw^2\,]^{1/2}$$

where

Qs	infiltration due to the indoor/outdoor temperature differenial, cfm
c	flow coefficient, $cfm/(in. H_2O)^n$
Cs	stack coefficient, $(in. H_2O/°F)^n$
dT	absolute value of the indoor/outdoor temperature differential, °F
n	pressure coefficient
Qw	Infiltration due to wind, cfm
Cw	wind coefficient, $(in. H_2O/mph^2)^{2n}$
sf	Shelter factor, modifier of local wind speed based on immediate surroundings
Wlocal	local wind speed as modified by the SITE-PARAMETER terrain parameters, mph
Qnet	Net infiltration due to the combined effect of temperature and wind, cfm

Stack and wind coefficients vary according to the number of stories in the house, whether a flue exists, and whether the house has a crawl space. Typical values are listed in Table 3.

Because the units are dependent on the pressure exponent 'n', this keyword is dimensionless in the input, and this method currently cannot be used with metric input. If simulated in metric, this keyword must still be specified in English.

SHELTER-FACTOR

For INF-METHOD = ASHRAE-ENHANCED, specifies the shelter factor 'sf' in the equations:

$$Qs = c * Cs * dT^n$$

$$Qw = c * Cw * (sf*Wlocal)^{2n}$$

$$Qnet = [\, Qs^2 + Qw^2\,]^{1/2}$$

where

Qs	infiltration due to the indoor/outdoor temperature differenial, cfm
c	flow coefficient, $cfm/(in. H_2O)^n$
Cs	stack coefficient, $(in. H_2O/°F)^n$
dT	absolute value of the indoor/outdoor temperature differential, °F
n	pressure coefficient
Qw	Infiltration due to wind, cfm
Cw	wind coefficient, $(in. H_2O/mph^2)^{2n}$
sf	Shelter factor, modifier of local wind speed based on immediate surroundings
Wlocal	local wind speed as modified by the SITE-PARAMETER terrain parameters, mph
Qnet	Net infiltration due to the combined effect of temperature and wind, cfm

The SITE-PARAMETER keywords TERRAIN-PAR1, TERRAIN-PAR2, etc. modify the wind speed as measured at the weather station for local factors such as ground roughness and height above ground level. The result is Wlocal

in the above equations. The shelter factor further modifies the local wind speed for the height of the house, whether the house has a flue, and the shelter class. Refer to Table 1 through Table 3 for typical values. The shelter factor modifies the wind speed only in the ASHRAE-ENHANCED method. A similar keyword, SITE-PARAMETERS:SHIELDING-COEF modifies the wind speed in the Sherman-Grimsrud infiltration method.

The ASHRAE Handbook also makes reference to a wind speed multiplier 'G'. This factor is not used in eQUEST, as 'G' is an approximate correction factor for local wind speed, already modified in eQUEST by the SITE-PARAMETER:TERRAIN-* keywords.

Table 1
Local Shelter Classes

Shelter Class	Description
1	No obstructions or local shielding
2	Typical shelter for isolated rural house
3	Typical shelter caused by other buildings across the street from the building under study
4	Typical shelter for urban buildings on larger lots where sheltering obstacles are more than one building height away
5	Typical shelter produced by buildings or other structures that are immediately adjacent (closer than one house height): e.g., neighboring houses on the same side of the street, trees, bushes, etc.

Table 2
Enhanced Model Shelter Factors

Shelter Class	No Flue	One Story with Flue	Two Story with Flue	Three Story with Flue
1	1.00	1.10	1.07	1.06
2	0.90	1.02	0.98	0.97
3	0.70	0.86	0.81	0.79
4	0.50	0.70	0.64	0.61
5	0.30	0.54	0.47	0.43

Table 3
Enhanced Model Stack and Wind Coefficients

	One Story		Two Story		Three Story	
	No Flue	With Flue	No Flue	With Flue	No Flue	With Flue
STACK-COEF	0.000893	0.001144	0.001308	0.001478	0.001641	0.001791
WIND-COEF (basement/slab)	0.01313	0.001194	0.001432	0.001313	0.001432	0.001402
WIND-COEF (crawl space)	0.001074	0.001074	0.001194	0.001194	0.001271	0.001295

PRESSURE-EXP

For INF-METHOD = ASHRAE-ENHANCED, specifies the pressure exponent 'n' in the equations:

$$Qs = c * Cs * dT^n$$

$$Qw = c * Cw * (sf*Wlocal)^{2n}$$

$$Qnet = [\, Qs^2 + Qw^2 \,]^{1/2}$$

where

Qs	infiltration due to the indoor/outdoor temperature differenial, cfm
c	flow coefficient, $cfm/(in.\ H_2O)^n$
Cs	stack coefficient, $(in.\ H_2O/°F)^n$
dT	absolute value of the indoor/outdoor temperature differential, °F
n	pressure coefficient
Qw	Infiltration due to wind, cfm
Cw	wind coefficient, $(in.\ H_2O/mph^2)^{2n}$
sf	Shelter factor, modifier of local wind speed based on immediate surroundings
Wlocal	local wind speed as modified by the SITE-PARAMETER terrain parameters, mph
Qnet	Net infiltration due to the combined effect of temperature and wind, cfm

Because the units in several of the coefficients are dependent on the pressure exponent 'n', these keywords are dimensionless in the input, and this method currently cannot be used with metric input. If simulated in metric, all of the keywords acted upon by this exponent must still be specified in English.

ZONAL EXHAUST MAKE-UP VIA INFILTRATION

Introduction

For a zonal exhaust fan, a new keyword has been added to specify the source of make-up air. Previously, exhaust air was always made up by the space conditioning system, and the exhaust fan could operate only when the main fans were on. Now, exhaust can also be make up via zonal air infiltration, and the exhaust can operate independently of the space conditioning system.

Building Description Language Changes

ZONE command:

EXHAUST-SOURCE
Specifies the source of the make up air required by the exhaust fan:

AIR-HANDLER	the default, specifies that the EXHAUST-FLOW is made up via outdoor air supplied by the air handler. In this mode, the exhaust fan can operate only when the supply fan is running. The minimum outside air requirement of the air handler will be forced to be at least the exhaust flow. In addition, the default minimum airflow requirement of VAV terminals will be at least the exhaust requirement.
INFILTRATION	specifies that the EXHAUST-FLOW is made up via outdoor air infiltrating directly into the zone. The exhaust fan operates independently of the space conditioning system, and the exhaust requirement is not included in the calculations of outdoor air flows or VAV minimum terminal flows. The EXHAUST-FAN-SCH must be specified.

A common usage for this mode is to model residential exhaust requirements for bathrooms and kitchens. When the exhaust fan operates, zonal air infiltration is modified by adding the infiltration and exhaust flows in quadrature:

$$\text{Net infiltration} = [\ (\text{Infiltration Flow})^2 + (\text{Exhaust Flow})^2\ ]^{1/2}$$

BALANCED-INFIL	specifies that the EXHAUST-FLOW is made up via outdoor air supplied by an intake fan that exactly balances the exhaust fan. The intake/exhaust fans operate independently of the space conditioning system, and the exhaust requirement is not included in the calculations of outdoor air flows or VAV minimum terminal flows. The exhaust power specified should include the energy of both the intake and exhaust fan. The EXHAUST-FAN-SCH must be specified.

While EXHAUST-SOURCE = INFILTRATION adds exhaust flow to infiltration flow in quadrature, in this mode the addition is linear:

$$\text{Net infiltration} = (\text{Infiltration Flow}) + (\text{Exhaust Flow})$$

A common usage for this mode would be a commercial kitchen exhaust hood that has its own source of makeup air. The exhaust flow specified would be only the portion that impacts the space loads; any exhaust that bypasses directly into the hood would not be included. (To account for the exhaust energy associated with bypass air, the exhaust power/flow would have to be increased

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proportionately.)

Another application would be a residential energy recovery ventilator (ERV) that operates independently of the HVAC system. In this case, the exhaust flow would approximate the inefficiency of the ERV. For example, if the ERV supplied 100 cfm to the space with 80% recovery effectiveness, the EXHAUST-FLOW would be specified to be 20 cfm. The exhaust static or power would be increased by a factor of 5 to account for total ventilation power.

ADDITIONAL WINDOW COVERING CONTROLS

Introduction

Two new keywords have been added to the criteria governing when moveable window insulation/shades are deployed. Previously coverings could be deployed on the basis of the outdoor drybulb temperature dropping below a specified value, or the solar gain exceeding a specified value. Now, high/low limits apply to both outdoor drybulb temperature and solar gain.

Building Description Language Changes

WINDOW command:

The new keywords are CONDUCT-TMAX-SCH and MIN-SOLAR-SCH. For clarity, all four triggers for window coverings are included here.

CONDUCT-TMIN-SCH

Takes the U-name of a SCHEDULE (of TYPE=TEMPERATURE) of values of outside dry-bulb temperature below which movable insulation is deployed on a window. If CONDUCT-TMIN-SCH is specified, a corresponding SHADING-SCHEDULE and CONDUCT-SCHEDULE should also be assigned to the window.

Insulation/shades will be deployed according to CONDUCT-TMIN-SCH, CONDUCT-TMAX-SCH, MAX-SOLAR-SCH or MIN-SOLAR-SCH.. Specified singly, any of these keywords will cause deployment. But, if CONDUCT-TMIN-SCH is specified together with MIN-SOLAR-SCH, then both conditions must be true in order for the insulation/shade to be deployed. The same is true for CONDUCT-TMAX-SCH and MAX-SOLAR-SCH. If all four keywords are specified, then shades will be deployed when:

> CONDUCT-TMIN-SCH and MIN-SOLAR-SCH are both true, or

> CONDUCT-TMAX-SCH and MAX-SOLAR-SCH are both true

CONDUCT-TMAX-SCH

Takes the U-name of a SCHEDULE (of TYPE=TEMPERATURE) of values of outside dry-bulb temperature above which movable insulation is deployed on a window. If CONDUCT-TMIN-SCH is specified, a corresponding SHADING-SCHEDULE and CONDUCT-SCHEDULE should also be assigned to the window.

Insulation/shades will be deployed according to CONDUCT-TMIN-SCH, CONDUCT-TMAX-SCH, MAX-SOLAR-SCH or MIN-SOLAR-SCH.. Specified singly, any of these keywords will cause deployment. But, if CONDUCT-TMIN-SCH is specified together with MIN-SOLAR-SCH, then both conditions must be true in order for the insulation/shade to be deployed. The same is true for CONDUCT-TMAX-SCH and MAX-SOLAR-SCH. If all four keywords are specified, then shades will be deployed when:

> CONDUCT-TMIN-SCH and MIN-SOLAR-SCH are both true, or

> CONDUCT-TMAX-SCH and MAX-SOLAR-SCH are both true

MAX-SOLAR-SCH

Takes the U-name of a schedule (TYPE=RADIATION) of values of solar radiation (in Btu/ft2-hr or W/m2) either incident on the outside of the window or transmitted through the window. The actual hourly value to be used is selected by the value of the MAX-SOLAR-CTRL keyword.. (This is a change from previous DOE-2 program versions, where in 2.1E the transmitted direct solar radiation was used, and in 2.2, prior to version 44d2, the outside incident total solar radiation was used) The schedule must be of TYPE=RADIATION. The solar radiation used by

the calculation logic is either the incident direct (plus optionally the diffuse) radiation after shading by overhangs, fins or detached shading surfaces, or this incident value multiplied by the specified or hourly calculated angular transmittance of the window (and shading coefficient, if appropriate based on the glass specification method.) The program will automatically deploy a shading device whenever the selected solar radiation value, without the shading device, exceeds the schedule value. The shading device will be retracted if the solar radiation value falls below the schedule value. For example, the shades will be deployed if the solar value is 50 Btu/ft2-hr and the schedule value is 20 Btu/ft2-hr (as long as the corresponding SHADING-SCHEDULE value is 1). If MAX-SOLAR-SCH is specified, a corresponding SHADING-SCHEDULE (and CONDUCT-SCHEDULE if desired) should be assigned to the window. The SHADING-SCHEDULE and CONDUCT-SCHEDULE values will only take effect during hours when the shading device is deployed.

Insulation/shades will be deployed according to CONDUCT-TMIN-SCH, CONDUCT-TMAX-SCH, MAX-SOLAR-SCH or MIN-SOLAR-SCH.. Specified singly, any of these keywords will cause deployment. But, if CONDUCT-TMIN-SCH is specified together with MIN-SOLAR-SCH, then both conditions must be true in order for the insulation/shade to be deployed. The same is true for CONDUCT-TMAX-SCH and MAX-SOLAR-SCH. If all four keywords are specified, then shades will be deployed when:

> CONDUCT-TMIN-SCH and MIN-SOLAR-SCH are both true, or

> CONDUCT-TMAX-SCH and MAX-SOLAR-SCH are both true

MIN-SOLAR-SCH

Takes the U-name of a schedule (TYPE=RADIATION) of values of solar radiation (in Btu/ft2-hr or W/m2) either incident on the outside of the window or transmitted through the window. The actual hourly value to be used is selected by the value of the MAX-SOLAR-CTRL keyword.. (This is a change from previous DOE-2 program versions, where in 2.1E the transmitted direct solar radiation was used, and in 2.2, prior to version 44d2, the outside incident total solar radiation was used) The schedule must be of TYPE=RADIATION. The solar radiation used by the calculation logic is either the incident direct (plus optionally the diffuse) radiation after shading by overhangs, fins or detached shading surfaces, or this incident value multiplied by the specified or hourly calculated angular transmittance of the window (and shading coefficient, if appropriate based on the glass specification method.) The program will automatically deploy a shading device whenever the selected solar radiation value, without the shading device, is below the schedule value. The shading device will be retracted if the solar radiation value exceeds the schedule value. For example, the shades will be deployed if the solar value is 50 Btu/ft2-hr and the schedule value is 70 Btu/ft2-hr (as long as the corresponding SHADING-SCHEDULE value is 1). If MIN-SOLAR-SCH is specified, a corresponding SHADING-SCHEDULE (and CONDUCT-SCHEDULE if desired) should be assigned to the window. The SHADING-SCHEDULE and CONDUCT-SCHEDULE values will only take effect during hours when the shading device is deployed.

Insulation/shades will be deployed according to CONDUCT-TMIN-SCH, CONDUCT-TMAX-SCH, MAX-SOLAR-SCH or MIN-SOLAR-SCH.. Specified singly, any of these keywords will cause deployment. But, if CONDUCT-TMIN-SCH is specified together with MIN-SOLAR-SCH, then both conditions must be true in order for the insulation/shade to be deployed. The same is true for CONDUCT-TMAX-SCH and MAX-SOLAR-SCH. If all four keywords are specified, then shades will be deployed when:

> CONDUCT-TMIN-SCH and MIN-SOLAR-SCH are both true, or

> CONDUCT-TMAX-SCH and MAX-SOLAR-SCH are both true

CONDENSING BOILER

Introduction

A new boiler type has been implemented to simulate a condensing boiler. For other fuel-fired boiler types, both the capacity and heat input ratio are assumed to vary as a function of the hot-water supply temperature and the ambient temperature (but no default performance curves exist for either capacity or heat input ratio). However, the performance of a condensing boiler is primarily sensitive to the hot-water return temperature; not the supply temperature. For this reason, condensing boiler is modeled as a separate type.

Building Description Language Changes

BOILER command:

TYPE

Takes a code-word that specifies the type of boiler. Note that the steam boilers are modeled identically to the hot water boilers, except that their efficiencies are lower. The program currently does not model steam loops, so the effects of flash losses, de-aeration, condensate makeup, etc. should be included in the efficiency term. Allowed values of TYPE are:

HW-BOILER	*(existing)* Hot water boiler.	
HW-BOILER-W/DRAFT	*(existing)* Hot water boiler with draft fan.	
ELEC-HW-BOILER	*(existing)* Electric hot water boiler.	
STM-BOILER	*(existing)* Steam boiler.	
STM-BOILER-W/DRAFT	*(existing)* Stream boiler with draft fan.	
ELEC-STM-BOILER	*(existing)* Electric steam boiler.	
HW-CONDENSING	*(new)* Condensing hot-water boiler. As condensing boilers achieve maximum efficiency below return water temperatures of approximately 130°F, the circulation loop and coils supplied by this loop should be designed for temperatures at or below 140°F. Loop temperature reset should also be investigated, to reduce the return temperature as much as possible.	

CAPACITY

The nominal (or rated) heating capacity of the boiler. If the capacity is temperature dependent, (curve CAP-FT is specified), the capacity should correspond to the HW-SUPPLY-T and AMBIENT-T.

For the HW-CONDENSING boiler, the capacity corresponds to the rated return temperature, RATED-HWR-T. The default is 80°F (26.7°C).

If you do not specify CAPACITY,

- If CAPACITY-RATIO is specified, the capacity defaults to the maximum design-day heating loop capacity, multiplied by the CAPACITY-RATIO.

- If no CAPACITY-RATIO is specified, the capacity defaults to the maximum design-day heating loop capacity, divided by the number of boilers attached to the loop, and multiplied by the loop's SIZING-RATIO.

CAPACITY-FT

For all boiler types except HW-CONDENSING, takes the U-name of a curve that modifies the boiler capacity as a function of the supply temperature and the boiler's environmental temperature. If not specified, the capacity is assumed constant for all temperature conditions. The supply temperature is the greater of the loop supply setpoint, or the boiler's internal AQUASTAT-SETPT-T. The environmental temperature may be either the outdoor air temperature, or a zone temperature.

For the HW-CONDENSING boiler, takes the U-name of a curve that modifies the boiler capacity as a function of the return temperature (temperature entering the boiler). The efficiency and capacity of condensing boilers is primarily sensitive to the return temperature, so return temperature is used in lieu of supply temperature and the environmental temperature.

RATED-HWR-T

For the HW-CONDENSING boiler, specifies the return water temperature at which both the CAPACITY and HEAT-INPUT-RATIO are defined. The default is 80°F (26.7°C).

HEAT-INPUT-RATIO

The ratio of fuel heat input to boiler heating capacity at full load (i.e., at the rated conditions). Used only for fuel-consuming boilers. Note that this is a dimensionless ratio, so you must convert fuel consumption and heating capacity to the same units before dividing.

For the HW-CONDENSING boiler, the heat input ratio corresponds to the rated return temperature, RATED-HWR-T. The default is 80°F (26.7°C).

HIR-FT

For all boiler types except HW-CONDENSING, takes the U-name of a curve that modifies the fuel consumption as a function of the supply temperature and the environmental temperature. There is no default; if not specified then the HEAT-INPUT-RATIO is assumed constant for all temperature conditions. The supply temperature is the greater of the loop supply setpoint, or the boiler's internal AQUASTAT-SETPT-T. The LOCATION keyword, below, determines whether the environmental temperature is the outdoor air temperature or a zone temperature.

For the HW-CONDENSING boiler, this curve is not used. Instead, the HIR-FPLR curve is used, and uses both the part-load ratio and the return water temperature.

HIR-FPLR

For all boiler types except HW-CONDENSING, takes the U-name of a curve that modifies the fuel consumption as a function of the boiler part load ratio.

For the HW-CONDENSING boiler, takes the U-name of a curve that modifies the fuel consumption as a function of both the boiler part-load ratio and the return water temperature. This curve must be of the type BI-QUADRATIC-RATIO&T.

DX EVAPORATIVE CONDENSERS

Introduction

Previously, the program had the capability to model water-cooled, air-cooled, and evaporatively precooled condensers for packaged DX equipment. This capability has been expanded to include an evaporative condenser that responds directly to the outdoor wetbulb temperature.

Building Description Language Changes

SYSTEM command:

CONDENSER-TYPE

Takes a code-word that specifies the type of condenser in packaged systems with direct-expansion cooling (and optional heating.) Note that the program changes the default performance data (such as EIR) when you change the condenser type; if the unit being modeled is atypical input data representative of the unit should be used to replace the default performance parameters.

EVAP-COOLED	*(New)* The condenser on a RESYS2, PSZ, PMZS, PVAVS, PTAC, PIU or PVVT system is evaporative. Note that this is different than an EVAP-PRECOOLED condenser, which is an air-cooled condenser with evaporative precooling media.
	Since an evaporative condenser responds to the outdoor wetbulb temperature, not the outdoor drybulb, the nominal capacity and power consumption, together with off-rated performance curves, must be defined relative to the outdoor wetbulb. The ARI rating point is 95°F outdoor drybulb and 75°F outdoor wetbulb. Therefore, the COOLING-CAPACITY and COOLING-EIR must be specified relative to a 75°F outdoor wetbulb (and 67°F indoor wetbulb). The performance curves COOL-CAP-FT, COOL-SENS-FT and COOL-EIR-FT must all be normalized to a 75°F outdoor wetbulb. The program includes generic default curves for these functions. Normally, the COOLING-EIR and COOL-EIR-FT should include the compressor power as well as the condenser fan and spray pump.
AIR-COOLED	*(Existing)* The condenser is air cooled.
WATER-COOLED	*(Existing)* The condenser is water cooled. You must attach the condenser to a CIRCULATION-LOOP of TYPE = CW or WLHP via the CW-LOOP keyword. For PSZ, PVAVS and PVVT, use of this value indicates that a water-to-air heat pump (WLHP) is to be modeled.
EVAP-PRECOOLED	*(Existing)* The air-cooled condenser on a RESYS2, PSZ, PMZS, PVAVS, PTAC, PIU or PVVT system includes an evaporative precooler. The precooler is controlled by a time and/or temperature controller that decides if the unit should operate (see EVAP-PCC-SCH, EVAP-PCC-EFF, and EVAP-PCC-ELEC). When this unit doesn't operate, the condenser returns to CONDENSER-TYPE = AIR-COOLED. The evaporative precooler is only active during cooling mode. If no operation schedule is specified using EVAP-PCC-SCH, a default operation is assumed that provides for cooling mode operation whenever the outside dry-bulb temperature is more than 2F (1.1K) above the value of COOL-FT-MIN.

NATURAL VENTILATION EXHAUST TO ATTIC

Introduction

Natural ventilation has been enhanced to allow the ventilation airflow to be exhausted to an unconditioned zone. The most typical application would be to simulate a residential whole-house fan exhausting to the attic.

Building Description Language Changes

SYSTEM command:

VENT-EXH-ZONE

Accepts the U-name of an unconditioned zone through which natural ventilation from conditioned zones is exhausted. This keyword is typically used in conjunction with NATURAL-VENT-KW to simulate a whole-house fan exhausting into an attic. Ventilation from each conditioned zone served by the SYSTEM will exhaust to this zone. The temperature of the exhaust entering this zone will be the weighted average of each conditioned zone's temperature and flow.

PHOTOCELL OVERRIDE OF A SCHEDULE

Introduction

The SCHEDULE command has been modified to allow a photocell to override the hourly values of the referenced DAY-SCHEDULEs. The hourly values may be overridden either ON or OFF depending on whether the sun is up or down.

Building Description Language Changes

SCHEDULE command:

PHOTOCELL-CTRL

Accepts a code-word specifying whether the hourly value in the referenced DAY-SCHEDULE can be overridden either ON (value = 1.0) or OFF (value = 0.0) according to whether it is day or night.

DAY-OFF	Forces the hourly schedule value to be 0.0 whenever the sun is up.
DAY-ON	Forces the hourly schedule value to be 1.0 whenever the sun is up.
NIGHT-OFF	Forces the hourly schedule value to be 0.0 whenver the sun is down.
NIGHT-ON	Forces the hourly schedule value to be 1.0 whenever the sun is down.

For example, assume lighting in a parking lot is to be on from dusk until 11 p.m. The earliest the lights are allowed to illuminate is 4 p.m., but will not actually start until the sun is down:

```
"Parking Lot DSch" = DAY-SCHEDULE-PD
   TYPE              = ON/OFF
   VALUES            = ( 0., 0., 0., 0., 0., 0.,
                          0., 0., 0., 0., 0., 0.,
                          0., 0., 0., 1., 1., 1.,
                          1., 1., 1., 1., 1., 0. )

"Parking Lot WSch" = WEEK-SCHEDULE-PD
   TYPE              = ON/OFF
   DAY-SCHEDULES     = ("Parking Lot DSch")
   ..

"Parking Lot Sch" = SCHEDULE-PD
   TYPE              = ON/OFF
   PHOTOCELL-CTRL    = DAY-OFF
   MONTH             = (12)
   DAY               = (31)
   WEEK-SCHEDULES    = ("Parking Lot WSch")
   ..
```

MIXING OF DOMESTIC HOT WATER WITH COLD WATER

Introduction

Previously, the CIRCULATION-LOOP:PROCESS-FLOW was assumed to be at the hourly dhw supply setpoint. The user can now specify an end-use temperature so that hot and cold water flows are mixed.

Building Description Language Changes

CIRCULATION-LOOP command:

PROCESS-T

For DHW loops, specifies the temperature of the end-use load. By default, the PROCESS-T is assumed to be the same as the hourly loop setpoint temperature. If the process T is specified, and is less than the heating setpoint temperature, then mixing of hot and cold water is assumed to occur. The hot water is at the heating setpoint temperature, the cold water is at the DHW-INLET-T, and the mixed temperature is at the PROCESS-T. Note that the PROCESS-FLOW is at the mixed temperature, so that the hot-water flow leaving the water heater is actually less than the PROCESS-FLOW.

USER-DEFINED CONVECTIVE/RADIATIVE SPLITS

Introduction

Previously, when custom weighting factors were used, the radiative fractions of various internal heat gains was either restricted or fixed. The radiative fraction of the lighting heat gain could be specified, but was assumed to be the same for all lighting systems in a space. The radiative fractions for task lighting (0.67), people (0.70), and equipment (0.70), and source (0.70) were fixed and could not be modified by the user. For space electric equipment, this assumption could cause cooling loads to be underestimated, as computers and related equipment typically have cooling fans that cause the convective fraction to be the dominant portion of the load.

The user can now specify the radiative portion for all categories of internal heat gains in a space. The default values for these new keywords are the same as the previous hard-coded values, with the exception of the electric equipment loads. Previously, the program assumed a radiant fraction of 0.70; the default for the new keyword is 0.30 to better reflect the large convective gains associated with computers and peripheral equipment.

In addition, various lighting keywords have been expanded to a list of 5 to allow the properties of each lighting systems to be independently specified.

Building Description Language Changes

SPACE command:

PEOPLE-RAD-FRAC
Specifies the fraction of the PEOPLE-HG-SENS that is radiative; the remainder is convective. This keyword is used only with custom weighting factors. Because the radiative portion of a heat gain interacts with the space surfaces and is partially absorbed, there is a time lag between the radiative heat gain and the resultant cooling loads. In contrast, there is no time lag for the convective portion of a heat gain.

LIGHT-RAD-FRAC
Specifies the fraction of the LIGHT-TO-SPACE that is radiative; the remainder is convective. This keyword is used only with custom weighting factors. Because the radiative portion of a heat gain interacts with the space surfaces and is partially absorbed, there is a time lag between the radiative heat gain and the resultant cooling loads. In contrast, there is no time lag for the convective portion of a heat gain. (Accepts a list of 5 corresponding to the lighting systems in the space.)

OTHER-RAD-FRAC
Specifies the fraction of the LIGHT-TO-OTHER that is radiative; the remainder is convective. This keyword is used only with custom weighting factors. Because the radiative portion of a heat gain interacts with the space surfaces and is partially absorbed, there is a time lag between the radiative heat gain and the resultant cooling loads. In contrast, there is no time lag for the convective portion of a heat gain. (Accepts a list of 5 corresponding to the lighting systems in the space.)

TASK-RAD-FRAC
Specifies the fraction of the task lighting energy that is radiative; the remainder is convective. This keyword is used only with custom weighting factors. Because the radiative portion of a heat gain interacts with the space surfaces and is partially absorbed, there is a time lag between the radiative heat gain and the resultant cooling loads. In contrast, there is no time lag for the convective portion of a heat gain.

EQUIP-RAD-FRAC
Specifies the fraction of the EQUIP-SENSIBLE that is radiative; the remainder is convective. This keyword is used only with custom weighting factors. Because the radiative portion of a heat gain interacts with the space surfaces and

is partially absorbed, there is a time lag between the radiative heat gain and the resultant cooling loads. In contrast, there is no time lag for the convective portion of a heat gain. (Accepts a list of 5 corresponding to the equipment loads in the space.)

LIGHT-TO-SPACE

This keyword has been expanded to a accept list of 5 values corresponding to each of the lighting systems defined for the space. The specified value is the fraction of the heat from overhead lighting that goes into the space. The rest goes into the return air or into an adjacent space, as determined by the keywords LIGHT-TO-OTHER, LIGHT-TO-RETURN, LIGHT-HEAT-TO, and LIGHT-RAD-FRAC. (Accepts a list of 5 corresponding to the lighting systems in the space)

LIGHT-TO-OTHER

This keyword has been expanded to a accept list of 5 values corresponding to each of the lighting systems defined for the space. The specified value is the fraction of light heat that is deposited in an adjacent space. Unless the light fixture is in contact with an adjacent space or unless the interior wall between this space and the adjacent space is translucent or transparent, LIGHT-TO-OTHER should be zero. (Accepts a list of 5 corresponding to the lighting systems in the space)

LIGHT-HEAT-TO

This keyword has been expanded to a accept list of 5 values corresponding to each of the lighting systems defined for the space. The specified value is the U-name of an unconditioned or plenum space. This space receives the fraction of light heat specified as LIGHT-TO-OTHER. This is a required keyword if LIGHT-TO-OTHER > 0. Only unconditioned or plenum spaces may be the recipients of such heat from lights. (Accepts a list of 5 corresponding to the lighting systems in the space)

LIGHT-TO-RETURN

This keyword has been expanded to a accept list of 5 values corresponding to each of the lighting systems defined for the space. The specified value is the fraction of light heat that goes directly into the return air stream. Unless the return air passes through the light fixtures, LIGHT-TO-RETURN should be zero. The default is 1.0 – (LIGHT-TO-SPACE + LIGHT-TO-OTHER). (Accepts a list of 5 corresponding to the lighting systems in the space)

TEMPERATURE-DEPENDENT SPACE EQUIPMENT

Introduction

The program can now modify the SPACE:EQUIPMENT-KW or SPACE:EQUIPMENT-W/AREA as a function of space temperature. This feature applies to equipment, such as a refrigerator, whose heat gain varies with the space temperature.

Building Description Language Changes

SPACE command:

EQUIP-PWR-FT

Accepts the U-name of a CURVE-FIT that modifies the electrical equipment power and heat gain as a function of space temperature. For example, if a refrigerator is modeled, the refrigerator will typically consume more power at higher space temperatures. This curve is typically normalized to 1.0 at the EQUIP-RATED-T, but this is not necessary; the program will normalize the curve internally. (Accepts a list of 5 corresponding to the electric equipment loads in the space.)

In the LOADS module, the curve will use the value of the SPACE:TEMPERATURE all hours. In the HVAC module, the power will be corrected by the actual hourly zone temperature.

EQUIP-RATED-T

When EQUIP-PWR-FT is used, specifies the temperature at which the EQUIPMENT-W/AREA or EQUIPMENT-KW is defined. The EQUIP-PWR-FT curve will modify power consumption for other space temperatures. (Accepts a list of 5 corresponding to the electric equipment loads in the space.)

USER-DEFINED DAYLIGHT-SAVINGS INTERVALS

<u>Introduction</u>

New modeling capabilities have been added to allow the user to specify the daylight-savings interval. Previously, only United-States daylight savings periods were supported. Now, any interval is supported, including intervals for the Southern hemisphere.

As part of this work, U.S. defaults have been added for year 2007 and later. These algorithm enhancements are utilized via new keywords in the SITE-PARAMETERS command.

For example, to define a daylight savings period starting the second Sunday in March, and ending the first Sunday in November:

```
SITE-PARAMETERS
    DAYLIGHT-SAVINGS   = YES
    DS-START-WEEK      = SECOND
    DS-START-DAY       = SUN
    DS-START-MONTH     = MAR
    DS-END-WEEK        = FIRST
    DS-END-DAY         = SUN
    DS-END-MONTH       = NOV
```

To specify a daylight savings interval in Australia starting the last Sunday in October thru the last Sunday in March:

```
SITE-PARAMETERS
    DAYLIGHT-SAVINGS   = YES
    DS-START-WEEK      = LAST
    DS-START-DAY       = SUN
    DS-START-MONTH     = OCT
    DS-END-WEEK        = LAST
    DS-END-DAY         = SUN
    DS-END-MONTH       = MAR
```

If DAYLIGHT-SAVINGS = YES, but no interval is defined, the interval will default to the U.S. daylight-savings interval corresponding to the year of the RUN-PERIOD. The default distinguishes between run periods pre-1986; 1986 thru 2006; and 2007 and beyond.

<u>Building Description Language Changes</u>

<u>*SITE-PARAMETERS command:*</u>

DS-START-WEEK
Takes a code-word that specifies the week in the month when daylight savings starts. Allowed values of DS-START-WEEK are:

FIRST	Daylight savings starts in the first 7-day interval of the month. The specific day is specified by DS-START-DAY.
SECOND	Daylight savings starts in the second 7-day interval of the month. The specific day is specified by DS-START-DAY.

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THIRD	Daylight savings starts in the third 7-day interval of the month. The specific day is specified by DS-START-DAY.
FOURTH	Daylight savings starts in the fourth 7-day interval of the month. The specific day is specified by DS-START-DAY.
LAST	Daylight savings starts in the last 7-days of the month. The specific day is specified by DS-START-DAY.

DS-START-DAY

Takes a code-word that specifies the day of the week when daylight savings starts. Allowed values of DS-START-DAY are:

SUN	Daylight savings starts on Sunday. DS-START-WEEK specifies whether the Sunday is the FIRST, SECOND, ... or LAST Sunday in the month.
MON	Daylight savings starts on Monday. DS-START-WEEK specifies whether the Monday is the FIRST, SECOND, ... or LAST Monday in the month.
TUE	Daylight savings starts on Tuesday. DS-START-WEEK specifies whether the Tuesday is the FIRST, SECOND, ... or LAST Tuesday in the month.
WED	Daylight savings starts on Wednesday. DS-START-WEEK specifies whether the Wednesday is the FIRST, SECOND, ... or LAST Wednesday in the month.
THU	Daylight savings starts on Thursday. DS-START-WEEK specifies whether the Thursday is the FIRST, SECOND, ... or LAST Thursday in the month.
FRI	Daylight savings starts on Friday. DS-START-WEEK specifies whether the Friday is the FIRST, SECOND, ... or LAST Friday in the month.
SAT	Daylight savings starts on Saturday. DS-START-WEEK specifies whether the Saturday is the FIRST, SECOND, ... or LAST Saturday in the month.

DS-START-MONTH

Takes a code-word that specifies the month when daylight savings starts. Allowed values of DS-START-MONTH are JAN, FEB, MAR, APR, MAY, JUN, JUL, AUG, SEP, OCT, NOV, DEC.

DS-END-WEEK

Takes a code-word that specifies the week in the month when daylight savings ends. Allowed values of DS-END-WEEK are the same as for DS-START-WEEK.

DS-END-DAY

Takes a code-word that specifies the day of the week when daylight savings ends. Allowed values of DS-END-DAY are the same as for DS-START-DAY.

DS-END-MONTH

Takes a code-word that specifies the month when daylight savings ends. Allowed values of DS-END-MONTH are the same as for DS-START-MONTH.

DIRECT-EXPANSION PIU SYSTEMS

Introduction

New modeling capabilities have been added to allow fan-powered induction unit systems (PIU) to use direct-expansion cooling compressors in additional to chilled-water. Electric heat-pumps and gas heat-pumps are also supported, as are air-cooled and water-cooled condensers. These algorithm enhancements are utilized via added keywords in the SYSTEM command.

Building Description Language Changes

SYSTEM command:

COOL-SOURCE

For the PIU system only, takes a code-word that specifies the cooling source for the SYSTEM's main cooling coil. Allowed values of COOL-SOURCE are:

CHILLED-WATER   The system uses a chilled-water coil. This option requires that you also specify the CHW-LOOP that supplies this system.

ELEC-DX   The system uses an electric direct-expansion compressor. Both air-cooled and water-cooled CONDENSER-TYPEs are supported. When using this option, you specify the DX performance in a manner identical to packaged-VAV or packaged single-zone systems; using the COOLING-EIR, etc.

If the HEAT-SOURCE = HEAT-PUMP, then the COOL-SOURCE keyword will not be available for user input as it will automatically be set to HEAT-PUMP. Both air-cooled and water-cooled CONDENSER-TYPEs are supported.

If the HEAT-SOURCE = GAS-HEAT-PUMP, then the COOL-SOURCE keyword will not be available for user input as it will automatically be set to GAS-HEAT-PUMP.

HEAT-SOURCE

All of these code-words are the same as before, but HEAT-PUMP and GAS-HEAT-PUMP take on new meanings:

NONE   No heating is allowed.

ELECTRIC   The heat source is an electric resistance element.

HOT-WATER   The heat source is hot water provided by a CIRCULATION-LOOP.

FURNACE   The heat source is a furnace.

HEAT-PUMP   The source of heat is an electric air-to-air heat pump. Used only for the RESYS, PSZ, PTAC, PVVT, PVAVS, PIU, RESYS-VVT, and RESYS2 systems. For PSZ, PVVT. PVAVS and PIU, when used in conjunction with CONDENSER-TYPE of WATER-COOLED, a water-to-air heat pump is modeled.

           If the system is a PIU system, and you specify HEAT-SOURCE = HEAT-PUMP, then the COOL-SOURCE will not be available as it will automatically be set to HEAT-PUMP.

GAS-HEAT-PUMP   The heat source is a natural-gas engine-driven heat pump. Used only with the
                        PSZ, PVVT, PTAC, RESYS, PVAVS, and PIU system types.

                        If the system is a PIU system, and you specify HEAT-SOURCE = GAS-HEAT-
                        PUMP, then the COOL-SOURCE will not be available as it will automatically be
                        asset to GAS-HEAT-PUMP.

GAS-HYDRONIC   For the PTGSD system type, specifies that the heat source is a gas-fired hot water
                        generator..

DHW-LOOP   The heat source is hot water provided by a CIRCULATION-LOOP of TYPE =
                        DHW (domestic hot water). Residential buildings in mild climates sometimes use
                        the domestic water heater to also provide space heat.

VARIABLE-FLOW ZONAL EXHAUST

Introduction

New modeling capabilities have been added to allow variable-flow zonal exhaust, such as for a kitchen or laboratory fume hood. Included is the ability for a variable-volume terminal to track the hourly exhaust flow, and adjust its minimum flow ratio on the basis of either the hourly exhaust or other criteria. These algorithm enhancements are utilized via added keywords in the ZONE command.

Building Description Language Changes

ZONE command:

EXHAUST-FAN-CTRL
Takes a code-word that specifies the type of exhaust airflow reduction control. The program calculates the part-load power consumption of the exhaust fan using the fan power vs. part load characteristics corresponding to the control mode selected (Figure 1). Allowed code words are:

CONSTANT-VOLUME	No airflow control; the exhaust fan runs at constant flow all hours it is enabled.
	If the exhaust flow from the zone is variable (as defined by the EXHAUST-FAN-SCH), but the EXHAUST-FAN-CTRL = CONSTANT-VOLUME, then an outdoor-air makeup is assumed at the inlet to the fan, so that the fan discharge is constant volume. This configuration can be used to simulate a variable-flow fume hood in the zone, and a constant-velocity discharge on the roof; typical of many laboratories.
SPEED	Control is by varying motor speed (Curve 1 in Figure 1). If specified, then the EXHAUST-FAN-SCH must also be specified.
INLET	Control is by varying the position of inlet vanes. If specified, then the EXHAUST-FAN-SCH must also be specified.
DISCHARGE	Control is by varying the position of discharge dampers or allowing the duct pressure to build behind the VAV box (Curve 3 in Figure 1). If specified, then the EXHAUST-FAN-SCH must also be specified.
CYCLING	Control is by cycling the fans on and off (Curve 4 in Figure 1). If specified, then the EXHAUST-FAN-SCH must also be specified.
FAN-EIR-FPLR	Fan control method is user specified using the U-name of a curve as input to FAN-EIR-FPLR. See description of FAN-EIR-FPLR. If specified, then the EXHAUST-FAN-SCH must also be specified.

If the zone's airhandler cycles during the hour, then the exhaust fan will also cycle. Fan power is calculated based on the scheduled airflow, and then reduced by the fraction of the hour the fan is cycled off.
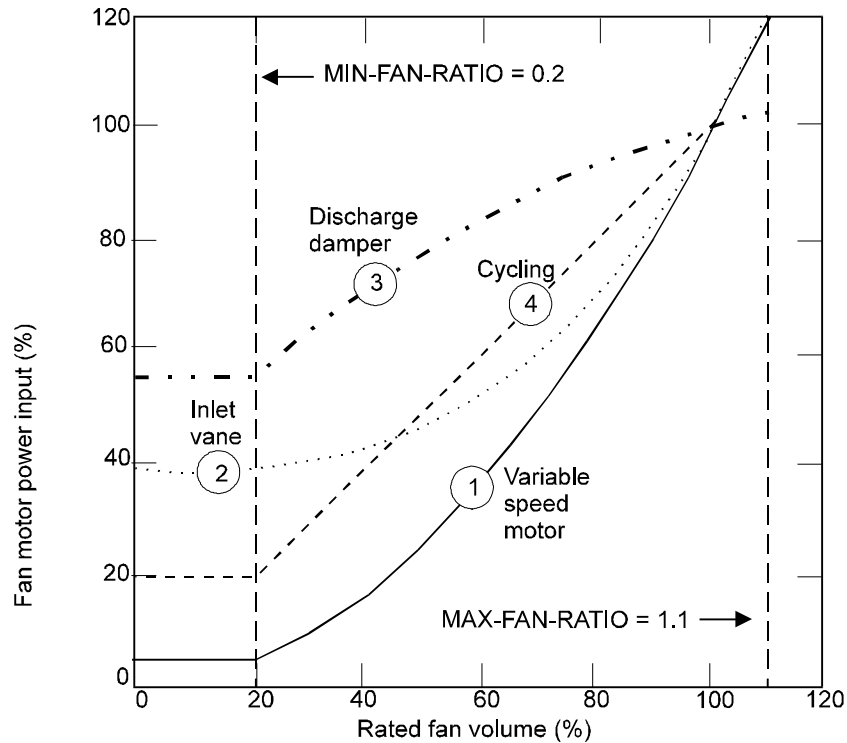
Figure 1 Typical power requirements at part-load operation for four different methods of air flow control. Note that for FAN-CONTROL = CYCLING, MIN-FAN-RATIO is meaningless when the fan is off.

EXHAUST-EIR-FPLR

When EXHAUST-FAN-CTRL = FAN-EIR-FPLR, takes the U-name of a linear, quadratic, or cubic curve that gives the ratio of exhaust fan electric energy to full-load fan electric energy, as a function of airflow.

EXHAUST-FAN-SCH

Accepts U-name of a schedule (TYPE = ON/OFF or FRACTION) that specifies the hours of operation of the zonal exhaust fan. A zero value indicates that the exhaust fan is off. A non-zero value indicates the exhaust is on. A fractional value between zero and one indicates that the exhaust is variable, such as for a kitchen hood or a laboratory fume hood.

The exhaust fans can only operate when the main fans are on (FAN-SCHEDULE is positive). If the zonal EXHAUST-FAN-SCH is not specified, it defaults to its parent SYSTEM:EXHAUST-FAN-SCH; otherwise operation is the same as the SYSTEM:FAN-SCHEDULE.

If the zone's airhandler cycles during the hour, then the exhaust fan will also cycle. The hourly fan airflow will be reduced by the amount of time the air handler is cycled off. This is in addition to any modulation specified by the EXHAUST-FAN-SCH.

AIRFLOW-TRACKING

Specifies whether and how the exhaust flow is tracked and coordinated with the supply flow. Acceptable code-words are:

NONE
: The exhaust flow is not coordinated with the supply airflow; other than design parameters. The design supply airflow will be at least the exhaust flow. For a VAV terminal, the default ZONE:MIN-FLOW-RATIO will be based on the greater of the ventilation air requirement or the maximum EXHAUST-FLOW.

TRACK-EXHAUST
: Indicates that a VAV terminal will track the hourly exhaust flow. Each hour, the VAV terminal flow will be the greater of the exhaust flow, the requirement for space conditioning, or the flow corresponding to the MIN-FLOW-RATIO. Normally, the EXHAUST-FAN-SCH will be specified to simulate variable-flow exhaust.

  The default ZONE:MIN-FLOW-RATIO will be based on the ventilation air requirement only; the peak exhaust flow will be ignored. However, the peak exhaust flow will be taken into account in sizing the terminal reheat coil.

  This mode may be used to simulate a laboratory fume hood where the supply airflow to the space is modulated as the hood's sash is raised and lowered. If the space temperature requires a supply airflow greater than the exhaust, then the non-exhausted supply will be returned to the air handler. To exhaust all of the supply, specify TRACK-BOTH.

TRACK-SUPPLY
: The exhaust flow will modulate to exactly match the supply air flow. In this mode, the EXHAUST-FLOW is not specified or controlled independently of the supply. Instead, the peak exhaust flow is set the same as the peak supply, and the hourly exhaust flow is the same as the supply hourly.

  The default ZONE:MIN-FLOW-RATIO will be based on the ventilation air requirement only; the peak exhaust flow will be ignored.

  This mode may be used to simulate a variable-volume space that does not have fume hoods or other specific exhaust needs, but where none of the supply is allowed to return to the air handler.

TRACK-BOTH
: Both the hourly exhaust flow and the supply flow are tracked, and both are set to the greater of the two. The peak exhaust flow is not specified, but instead is the same as the peak supply. The hourly exhaust flow is set by the EXHAUST-FAN-SCH, and the supply according to the space conditioning requirements. If the exhaust is less than the supply, then the exhaust is increased to match the supply. If the supply is less than the exhaust, then the supply is increased to match the exhaust.

  The default ZONE:MIN-FLOW-RATIO will be based on the ventilation air requirement only; the peak exhaust flow will be ignored.

  This mode is useful in simulating a laboratory with variable-flow fume hoods, where no supply should return to the air handler. If the exhaust hood airflow drops below the supply flow, then an auxiliary exhaust damper modulates to

remove the excess supply. If instead the fume hoods are exhausting more than the supply needed for space conditioning, then the supply will open to match the exhaust. Reheat may then be required to maintain space temperature.

SKYLIGHT AND DAYLIGHTING MODELING ENHANCEMENTS

Introduction

New modeling capabilities have been added to more accurately simulate the performance of skylights, lighting system controls and account for obstructions to daylight that can interact with lighting system response to daylight. These algorithm enhancements are utilized via added keywords in the WINDOW and SPACE commands.

Building Description Language Changes

WINDOW command: Defining a Window Type

WINDOW-TYPE
Takes a code-word that indicates the method of inputting the solar-thermal characteristics of the window glazing. The choice of window type will determine default value for the window as well as how the window utilizes other daylighting properties.

STANDARD	Default. Indicates that the window is composed of standard vertical flat glass glazing with an optional frame. This window will use VERT-OBS1-FACTOR & VERT-OBS2-FACTOR for daylighting calculations and will not be affected by obstructions associated with skylights.
SKYLIGHT-FLAT	Indicates that the window is a skylight using flat glass glazing. This type of window includes a default curb and frame and utilizes inputs for skylight obstructions (see below). This window type can have an associated light well used for daylighting calculations.
SKYLIGHT-DOMED	Indicates that the window is a skylight using domed glazing. Default solar transmittance properties are included along with a default dome depth. This type of window also includes a default curb and frame and utilizes inputs for a light well and for skylight obstructions (see below).
SKYLIGHT-TUBULAR	Indicates that the window is a skylight using a tubular daylighting device with an exterior domed glazing, a light tube with high interior reflectivity and an optional diffuser at the bottom of the tube. Default solar transmittance properties appropriate for a domed glazing surfa ce are included along with a default dome depth. This type of window also includes a default curb and frame and utilizes inputs for skylight obstructions (see below) but does not have an associated light well.

DIFFUSING-GLASS
Takes a code-word that indicates the diffusing characteristics of the window glazing.

YES	Indicates that the glazing is diffusing, and that all transmitted energy (thermal or visible) arrives inside the window as diffuse.

> NO   Indicates that the glazing is not diffusing, and that energy (thermal or visible) is
> transmitted through the window based on the direct and diffuse incident solar
> radiation.

DIRT-DEPREC-SCH

Takes the U-name of a previously-entered or library SCHEDULE command of TYPE FRACTION or
MULTIPLIER. This schedule defines an hourly multiplier on, or fractional value of, the visible light transmitted
through the window. This value represents the effect of dirt accumulation on the window and acts in a very similar
manner as the SHADING-SCHEDULE in that that the visible light and transmitted solar gain is reduced to this
fractional value. The reduction in transmittance is assumed to result in an equal increase in absorptance; the hourly
absorptance of the outermost pane of glass is increased by the sum of the reduction of direct and diffuse solar, as
defined hourly by one minus the value of DIRT-DEPREC-SCH times the unaltered direct and diffuse transmission
amounts.

WINDOW command: Domed Skylight Properties

The following keywords are used for the modeling of skylights when WINDOW-TYPE is SKYLIGHT-DOMED
or SKYLIGHT-TUBULAR.

DOME-DEPTH

When WINDOW-TYPE is SKYLIGHT-DOMED or SKYLIGHT-TUBULAR, accepts a numeric value that is
the dome projection above the plane of the skylight frame. For tubular daylighting devices this value is defaulted
based on the TUBE-DIAMETER. For rectangular domed skylights this value is defaulted based upon the
minimum dimension of the skylight height and width.

SKY-TRANS-ANG

When WINDOW-TYPE is SKYLIGHT-DOMED or SKYLIGHT-TUBULAR, accepts a list of up to ten values
of direct solar incident angle upon the outside surface of the window glazing, that together with the paired value of
SKY-TRANS-ANG provides the transmitted solar energy relative to the value for normal incident solar.. For
skylights that do not utilize flat glass the transmitted visible and solar heat is calculated using the direct normal value
times a multiplier derived from the solar incident angle and the SKY-TRANS-ANG and SKY-TRANS-MULT
keywords; the two keywords are used to provide a piece-wise linear relation that the calculation uses with hourly
linear interpolation. The first value should be 0.0 (normal incidence) and the last value should be 90.0. Default
values for SKY-TRANS-ANG and SKY-TRANS-MULT are provided for standard domed skylights and tubular
daylighting devices; new values can be entered for specific skylight dome shapes if the required information is
available.

SKY-TRANS-MULT

When WINDOW-TYPE is SKYLIGHT-DOMED or SKYLIGHT-TUBULAR, accepts a list of up to ten values
of solar transmission through the window glazing, that together with the paired value from SKY-TRANS-ANG
(which is the direct solar incident angle upon the outside surface) provides the transmitted solar energy relative to
the value for normal incident solar.. For skylights that do not utilize flat glass the transmitted visible and solar heat is
calculated using the direct normal value times a multiplier derived from the solar incident angle and the SKY-
TRANS-ANG and SKY-TRANS-MULT keywords; the two keywords are used to provide a piece-wise linear
relation that the calculation uses with hourly linear interpolation. The values should be the ratio, at the
corresponding angle value of SKY-TRANS-ANG, of skylight transmission divided by the value of transmission at
normal incident angle for the window GLASS-TYPE. Default values for SKY-TRANS-ANG and SKY-TRANS-
MULT are provided for standard domed skylights and tubular daylighting devices; new values can be entered for
specific skylight dome shapes if the required information is available. Default values are found in the Table 4

Table 4 Skylight Transmission Multipliers

Value position	SKYLIGHT-DOMED		SKYLIGHT-TUBULAR	
	SKY-TRANS-ANG	SKY-TRANS-MULT	SKY-TRANS-ANG	SKY-TRANS-MULT
1	0.0	1.0	0.0	1.0
2	90.0	1.0	50.0	1.0
3			70.0	0.95
4			78.0	0.88
5			81.0	0.85
6			83.0	0.85
7			87.0	1.0
8			90.0	1.1

WINDOW command: Skylight Light Well Daylighting Properties

The following keywords are used for the modeling of skylights when WINDOW-TYPE is SKYLIGHT-FLAT or SKYLIGHT-DOMED. The specification of a light well replaces the need for the user to modify the visible transmittance of the glass type used for the window based on a manually calculated light well efficiency.

LIGHT-WELL
When WINDOW-TYPE is SKYLIGHT-FLAT or SKYLIGHT- DOMED, accepts a codeword that allows a light well to be defined for the skylight. The light well, if specified, will be placed directly under the window (and only the window with this keyword set as YES) and will have a direct impact upon the daylight contribution from this window to the parent space.

NO   Indicates that no window light well is to be modeled for this window.

YES   Indicates that a light well is to be modeled for the daylighting contribution for this window to its parent space.

WELL-EFF-METHOD
When WINDOW-TYPE is SKYLIGHT-FLAT or SKYLIGHT- DOMED, accepts a codeword method by which the overall light well daylighting visible light transmittance will be obtained. Unless the user has specific information about an unusual light well, it is recommended that the program be allowed to calculate the well efficiency.

SPECIFY   Indicates that the overall light well visible transmittance efficiency will be supplied via the keyword WELL-EFFICIENCY.

CALCULATE   Indicates that the overall light well visible transmittance efficiency will be calculated by DOE-2 using a coefficient of utilization methodology.

WELL-EFFICIENCY
When WINDOW-TYPE is SKYLIGHT-FLAT or SKYLIGHT- DOMED and WELL-EFF-METHOD is SPECIFY, accepts a numeric value that is the overall light well visible transmittance efficiency.

WELL-DEPTH

When WINDOW-TYPE is SKYLIGHT-FLAT or SKYLIGHT- DOMED and WELL-EFF-METHOD is CALCULATE, this is a required numeric value that is the depth of the a light well under the skylight frame. This value is the distance from the inside edge of the frame of the skylight to the bottom of the well (usually at the space ceiling level.)

WELL-WIDTH-BOT

When WINDOW-TYPE is SKYLIGHT-FLAT or SKYLIGHT- DOMED and WELL-EFF-METHOD is CALCULATE, accepts a numeric value that is the width of the well at the ceiling level. This value defaults to the window WIDTH.

WELL-LENGTH-BOT

When WINDOW-TYPE is SKYLIGHT-FLAT or SKYLIGHT- DOMED and WELL-EFF-METHOD is CALCULATE, accepts a numeric value that is the length (equivalent to window height) of the well at its bottom. This value defaults to the window HEIGHT.

WELL-VIS-REFLECT

When WINDOW-TYPE is SKYLIGHT-FLAT or SKYLIGHT- DOMED and WELL-EFF-METHOD is CALCULATE, accepts a numeric value that is the visible reflectance (hemispherical average) of the inside surface of the well walls.

WINDOW command: Tubular Skylight Daylighting Device Properties

The following keywords are used for the modeling of skylights when WINDOW-TYPE is SKYLIGHT-TUBULAR. A primary parameter is the Tube diameter. Additionally, a set of keywords allows for the calculation of a visible-transmittance correction factor for tubular skylight devices. This assumes that the visible transmittance entered for the GLASS-TYPE assigned to the window command does not already account for the tube. The only required keyword is TUBE-EFFICIENCY; that value can be either specified or calculated.

TUBE-DIAMETER

When WINDOW-TYPE is SKYLIGHT-TUBULAR, is a required numeric value that is the diameter of the tube (and dome at its base) at the point of the intersection of the dome and tube with the device mounting frame. When TUBE-EFF-METHOD is CALCULATE this value is used in the calculation of the overall tubular device visible transmittance efficiency. This value will also be used in calculation of tubular window "area" and in defaulting the window height and width **only** if the height and width are not specified (allowed to default – or set to default) when the WINDOW-TYPE is changed from an alternate value to SKYLIGHT-TUBULAR.

TUBE-EFF-METHOD

When WINDOW-TYPE is SKYLIGHT-TUBULAR, accepts a codeword method by which the overall tubular device daylighting visible light transmittance will be obtained.

SPECIFY   Indicates that the overall tubular device visible transmittance efficiency will be supplied via the keyword TUBE-EFFICIENCY (which then becomes required).

CALCULATE   Indicates that the over tubular device visible transmittance efficiency will be calculated by DOE-2 using an hourly methodology based on TUBE-DIAMETER, TUBE-LENGTH and TUBE-VIS-REFLECT..

TUBE-EFFICIENCY

When WINDOW-TYPE is SKYLIGHT-TUBULAR and TUBE-EFF-METHOD is SPECIFY, accepts a numeric value that is the overall tubular device visible transmittance efficiency.

TUBE-LENGTH
When WINDOW-TYPE is SKYLIGHT-TUBULAR and TUBE-EFF-METHOD is CALCULATE, accepts a numeric value that is the length of the tube from the frame mounting to the diffuser at the opposite end of the tube from the exterior dome.

TUBE-VIS-REFLECT
When WINDOW-TYPE is SKYLIGHT-TUBULAR and TUBE-EFF-METHOD is CALCULATE, accepts a numeric value that is the visible reflectance of the inside surface of the tube.

TUBE-DIFF-TRANS
When WINDOW-TYPE is SKYLIGHT-TUBULAR and TUBE-EFF-METHOD is CALCULATE, accepts a numeric value that is the visible transmittance of the diffuser at the bottom of the tube.

Skylight Curbs
For glazing in an EXTERIOR-WALL, the following keywords are used to describe the curb under the frame of a skylight. Curbs (as well as frames) cannot be specified for windows in sunspace INTERIOR-WALLs.

CURB-HEIGHT
The height of the skylight curb perpendicular to the plane of the glazing, displacing a skylight frame and glazing above the roof surface. The program assumes that the curb height is the same on all sides of the skylight. If this is not the case, use the average curb height.

CURB -ABS
The solar absorptance of the outside surface of a skylight curb.

CURB -CONDUCT
Conductance of the skylight curb, excluding the outside air film but including the inside air film.

Notes:

1. You can define curbs only for exterior windows and skylights, not for interior windows.

2. If the CURB-HEIGHT is zero no curb calculations will be performed.

3. The curb area is **not** subtracted from the associated exterior wall area.

4. Each hour, the program adds the effect of a wind speed-dependent outside air film to the user specified CURB-CONDUCT.

5. The various elements of a curb (top, bottom, side, dividers, etc.) may have different conductances. In this case, CURB-CONDUCT should be an area-weighted average of the different elements.

6. The program finds the overall window conduction by adding curb, frame, edge-of-glass, and center-of-glass contributions. Thus, all three of these contributions are included in each of the following report quantities:
    "Window Conduction" in summary reports LS-B, LS-C, LS-E, and LS-F;
    "Window U-Value" and "Window Area" in verification report LV-D and LV-H;
    WINDOW hourly report variable #1, "Window U-Value".

7. A WINDOW multiplier also multiplies the curb area.

8. Window fins and overhangs shade the curb as well as the glazing.

9. Shading devices, like blinds and drapes, that you specify using the WINDOW keywords SHADING-SCHEDULE and CONDUCT-SCHEDULE, affect only the glazed part of the window. They do not affect the heat conduction through the curb.

10. If the window has a setback, the curb is also set back by the same amount.

SPACE command: New Lighting Control Systems for Daylighting

WORKPLANE-HEIGHT
For spaces with DAYLIGHTING as YES and/or LIGHTING-SPEC-METHOD either LUMINAIRE-COUNT or ILLUMINANCE, the distance from the floor to the workplane at which illuminance is determined. Although defaulted, this value is required if LIGHTING-SYSTEM is specified. This keyword takes a single value that applies to all of the lighting subsystems. For the case when DAYLIGHTING is YES, this value is used for the calculation of daylighting coefficients of utilization for both the open space and for obstructions.

LTG-CTRL-METHOD1, LTG-CTRL-METHOD2
Takes one of a list of 25 code-words that specifies the type of electric lighting control system at LIGHT-REF-POINT1 and LIGHT-REF-POINT2, respectively. For compatibility with earlier versions, the default value DefaultOrSpecified causes the defaults based on the valuers of other keywords to be used; additionally there are 7 CONTINUOUS (Table 5) and 17 DISCRETE (Table 6) alternate control strategies.

DefaultOrSpecified Specifies that default values are to be used for the LIGHT-CTRL-TYPE1, MIN-POWER-FRAC and MIN-LIGHT-FRAC.

Table 5 lists the predefined continuous dimming lighting controls for fluorescent lighting systems and for Metal Halide and High Pressure Sodium lighting systems in both high bay and low bay applications. Table 6 lists the predefined stepped lighting controls for a variety of lighting systems and applications. All of these controls utilize the new commands for specifying DISCRETE lighting control. The new method of specifying lighting power as a function of light output is similar to the existing STEPPED lighting control method, but is far more flexible in it's ability to specify as many as 10 lighting power levels and their associated lighting output. Values from both these tables are from the SkyCalc 2.0 default lighting controls.

Table 5 Predefined Continuous Lighting Control Specifications

LTG-CTRL-METHOD1 or 2	MIN-POWER-FRAC	MIN-LIGHT-FRAC
Fluor:Dimming:5%Light	0.21	0.05
Fluor: Dimming: 10% Light	0.19	0.1
Fluor:Dimming:20%Light	0.36	0.22
MH:HighBay:Dimming:25%	0.56	0.25
MH:LowBay:Dimming:20%	0.51	0.19
HPS:HighBay:Dimming:5%	0.21	0.05
HPS:LowBay:Dimming:10%	0.29	0.1

Table 6 Predefined Discrete Lighting Control Specifications

LTG-CTRL-METHOD1 LTG-CTRL-METHOD2	DISCRETE-POWER1 DISCRETE-POWER2				DISCRETE-LIGHT1 DISCRETE-LIGHT2			
	1	2	3	4	1	2	3	4
On/Off	1	0			1	0		
Switch:2Level+Off	1	0.5	0		1	0.5	0	
Switch:3Level+Off	1	0.667	0.333	0	1	0.667	0.333	0
Switch:1/2On/Off	1	0.5			1	0.5		
Switch:1/3On/Off	1	0.667			1	0.667		
Switch:2/3On/Off	1	0.667	0.333		1	0.667	0.333	
Fluor:Hi/LoBallast	1	0.6			1	0.55		
MH:HighBay:Hi/LoBallast	1	0.48			1	0.22		
MH:HighBay:3PhaseHi/LoBallast	1	0.83	0.65	0.48	1	0.74	0.48	0.22
MH:LowBay:Hi/LoBallast	1	0.57			1	0.32		
MH:LowBay:3PhaseHi/LoBallast	1	0.86	0.71	0.57	1	0.77	0.55	0.32
HPS:HighBay:Hi/LoBallast	1	0.4			1	0.26		
HPS:HighBay:3PhaseHi/LoBallast	1	0.80	0.60	0.4	1	0.75	0.51	0.26
HPS:HighBay:3-LevelBallast	1	0.65	0.4		1	0.62	0.26	
HPS:LowBay:Hi/LoBallast	1	0.26			1	0.1		
HPS:LowBay:3PhaseHi/LoBallast	1	0.75	0.51	0.26	1	0.70	0.40	0.1
HPS:LowBay:3-LevelBallast	1	0.55	0.26		1	0.5	0.1	

DISCRETE-POWER1, DISCRETE-POWER2
Takes a list of up to ten values of fraction power input to the lighting system that, together with DISCRETE-LIGHT1, defines the lighting power use as a function of lighting output when LIGHT-CTRL-TYPE1 or LIGHT-CTRL-TYPE2 is DISCRETE.

DISCRETE-LIGHT1, DISCRETE-LIGHT2
Takes a list of up to ten values of fraction light output from the lighting system that, together with DISCRETE-POWER1, defines the lighting power use as a function of lighting output when LIGHT-CTRL-TYPE1 or LIGHT-CTRL-TYPE2 is DISCRETE.

SPACE command: Enhanced existingLighting Control Systems for Daylighting
The following space daylighting-related keywords have been augmented to allow the specification of control parameters independently for both lighting system 1 and lighting system 2. In previous version of the program a single keyword was used for both systems; the first keyword listed is the previously existing keyword.

LIGHT-CTRL-STEPS, LIGHT-CTRL-STEP2
Gives the number of steps, excluding zero, in a stepped lighting control system. The steps are assumed to be equally spaced. An on-off control system has LIGHT-CTRL-STEPS=1. LIGHT-CTRL-STEPS applies to the lighting system 1, LIGHT-CTRL-STEP applies to the lighting system 2.

MIN-POWER-FRAC, MIN-POWER-FRAC2
Specifies the minimum input power fraction for a CONTINUOUS or CONTINUOUS/OFF lighting control system. See manufacturer's data for appropriate value. MIN-POWER-FRAC applies to the lighting system 1, MIN-POWER-FRAC2 applies to the lighting system 2.

MIN-LIGHT-FRAC, MIN-LIGHT-FRAC2
Specifies the fractional light output that a CONTINUOUS or CONTINUOUS/OFF lighting control system produces at the minimum fractional input power given by MIN-POWER-FRAC. See manufacturer's data for appropriate value. MIN-LIGHT-FRAC applies to the lighting system 1, MIN-LIGHT-FRAC2 applies to the lighting system 2.

LIGHT-CTRL-PROB, LIGHT-CTRL-PROB2
May be specified if a stepped lighting control system is manually operated, such as in a simple one-step, on-off system. LIGHT-CTRL-PROB gives the probability the occupants of a daylit space will set the electric lights to the correct level to obtain the required illuminance. The rest of the time the lights are assumed to be set one step too high. For example, consider an on-off system with LIGHT-SET-POINT1 = 60, LIGHT-CTRL-TYPE1 = STEPPED, LIGHT-CTRL-STEPS = 1, and LIGHT-CTRL-PROB = 0.7. Then, when daylighting exceeds 60 fc, the electric lights will be off 70 percent of the time and on 30 percent of the time. LIGHT-CTRL-PROB applies to the lighting system 1, LIGHT-CTRL-PROB2 applies to the lighting system 2.

MAX-GLARE, MAX-GLARE2
The program will automatically deploy window shading devices to reduce daylight glare (if WIN-SHADE-TYPE = MOVABLE-INTERIOR or MOVABLE-EXTERIOR) whenever the glare (at either lighting reference point) with bare windows exceeds the MAX-GLARE value. Table 7 below gives recommended MAX-GLARE values for different situations. For example, MAX-GLARE = 22 would be specified for general office work. If a space has two or more windows, the shading devices will be deployed one by one in the order in which the windows are input, until the glare level at each lighting reference point falls below MAX-GLARE. If MAX-GLARE is not specified, no glare control will occur. This is a daylighting keyword; see TOPIC - DAYLIGHTING. MAX-GLARE applies to the lighting system 1, MAX-GLARE2 applies to the lighting system 2.

Table 7 Recommended MAX-GLARE values

Activity	MAX-GLARE	Activity	MAX-GLARE
Art Galleries	16	Laboratories	22
Factories		Museums	20
Rough Work	28	Offices	
Engine Assembly	26	General	22
Fine Assembly	24	Drafting	20
Instrument Assembly	22	School Classrooms	20
Hospital Wards	18		

VIEW-AZIMUTH, VIEW-AZIMUTH2

Direction of occupant view (in the horizontal plane), measured as a clockwise angle from the space y-axis (see Figure 2). It is used by the program to calculate daylight glare. If not specified, VIEW-AZIMUTH will be calculated by the program for a view direction parallel to the first window in the space (obtained by rotating clockwise by 90 (the horizontal projection of the window outward normal). In general, the daylight glare contribution from a particular window is highest when the occupant faces the window. VIEW-AZIMUTH applies to the lighting system 1, VIEW-AZIMUTH2 applies to the lighting system 2.
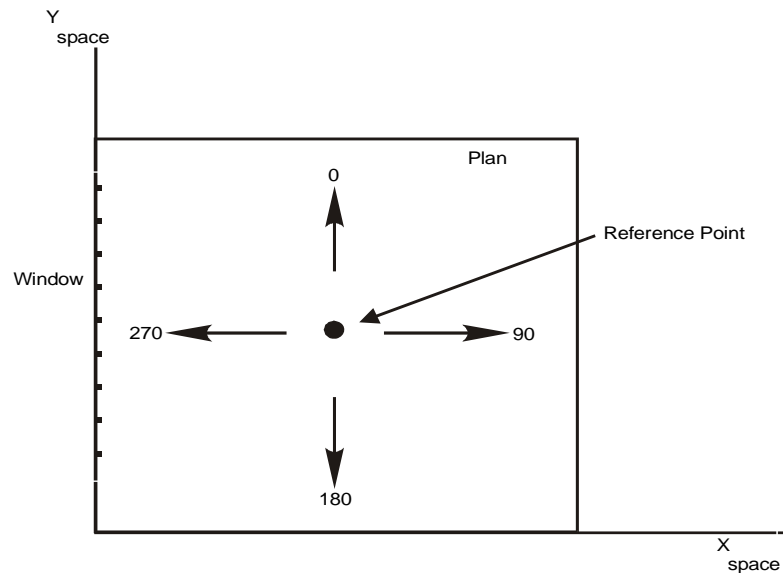
Figure 2 VIEW-AZIMUTH for four occupant view directions.
(Daylight glare from the window is greatest when facing window)

SPACE command: The Interaction of Space Contents with Daylighting

The following space daylighting-related keywords are used to define how the contents of the space act to obstruct the daylight from reaching the work plane and thus decrease the ability of daylight to allow the reduction of overhead electric lighting power use.

VERT-OBS1-FACTOR, VERT-OBS2-FACTOR

These factors, which are numeric values from 0.0 to 1.0, represent the fraction of daylight from windows with WINDOW-TYPE allowed to default or set to STANDARD that will reach the work plane specified bv LIGHT-REF-POINT1 and LIGHT-REF-POINT2, respectively. This value is less than 1.0 if space obstructions are to be taken into account when calculating the daylight contribution to work plane illuminance.

SKY-OBS1-METHOD, SKY-OBS2-METHOD

Accepts a codeword that specifies how the SKY-OBS1-FACTOR and SKY-OBS2-FACTOR values are obtained. These factors represent the fraction of daylight from skylights that will reach the work plane; this value is less than 1.0 if space obstructions are to be taken into account when calculating the daylight contribution to work plane illuminance.

SPECIFY	Use a specified value for SKY-OBS1-FACTOR or SKY-OBS2-FACTOR
CALCULATE	Specifies the values for SKY-OBS1-FACTOR or SKY-OBS2-FACTOR is to be calculated based upon entered or defaulted values of the type and size of the obstructions..

SKY-OBS1-FACTOR, SKY-OBS2-FACTOR

When SKY-OBS1-METHOD or SKY-OBS2-METHOD is SPECIFY, accepts a numeric value that represents the fraction of daylight from skylights that reaches the work plane. Applies to daylighting contribution from windows with WINDOW-TYPE set to SKYLIGHT-FLAT or SKYLIGHT-DOMED.

SKY-OBS-TYPE1, SKY-OBS-TYPE2

When SKY-OBS1-METHOD or SKY-OBS2-METHOD is CALCULATE, accepts a codeword that specifies the type of space obstructions are to be taken into account when calculating the daylight contribution to work plane illuminance. If obstructions are selected to be modeled, their dimensions can either be specified or allowed to default; default obstruction dimensions are based upon the obstruction type and the space dimensions including height, with and depth (or area if the shape is a polygon.)

NONE	Specifies that no interior obstructions are to be modeled as reducing daylight from skylights to the work plane.
SHELVES/RACKS	Specifies that rows of shelves are to be modeled as reducing daylight from skylights to the work plane; the obstructions will take on sizes either from default values typical of shelves and racks or may be specified.
PARTITIONS	Specifies that partitions, or cubicles, are to be modeled as reducing daylight from skylights to the work plane; the obstructions will take on sizes either from default values typical of partitions for the defined space geometry (space height and area) or may be specified.

SKY-OBS1-HT, SKY-OBS2-HT

When SKY-OBS1-METHOD or SKY-OBS2-METHOD is CALCULATE, accepts a numeric value that specifies typical height of the obstructions to skylight daylight. For shelves or partitions this is the typical height of the top of the shelves/partitions above the floor.

SKY-OBS1-WID, SKY-OBS2-WID

When SKY-OBS1-METHOD or SKY-OBS2-METHOD is CALCULATE, accepts a numeric value that specifies typical width of the obstructions to skylight daylight. For shelves this is the typical depth of the shelves from front to back. For partitions this is the typical width of the partitions.

SKY-OBS1-LEN, SKY-OBS2-LEN

When SKY-OBS1-METHOD or SKY-OBS2-METHOD is CALCULATE, accepts a numeric value that specifies typical width of the obstructions to skylight daylight. For shelves this is the typical width of the aisles between the shelves. For partitions this is the typical length of the partitions perpendicular to the direction of their specified width (using SKY-OBS1-WID or SKY-OBS2-WID.)

SKY-OBS1-REFL, SKY-OBS2-REFL

When SKY-OBS1-METHOD or SKY-OBS2-METHOD is CALCULATE, accepts a numeric value that specifies typical reflectance of the obstructions to skylight daylight.

SKY-CU-SPC-HT, SKY-CU-SPC-WID, SKY-CU-SPC-LEN

When SKY-OBS1-METHOD or SKY-OBS2-METHOD is CALCULATE, these are numeric values that specify the space height, width and length to be used when calculating the open (unobstructed) space coefficient of utilization for daylight from skylights. These will default to the defined space geometry using the space area if the shape is a polygon.

GLASS-TYPE command: Selecting the glass properties modeling method
GLASS-PROP-CALC

When TYPE=GLASS-TYPE-CODE, accepts a code-word that specifies the method that is to be used to calculate the angular dependence of glass properties. The data for solar transmission, visible transmission, and layer-by-layer solar absorption are calculated by the Window program and input using the GLASS-TYPE-CODE command. The Window program provides ten values for each transmission (solar and visible) and absorption (up to five glass layers); a value for angles of 0 to 90 degrees at increments of 10 degrees. This keyword allows the choice of two alternative methods of using this data in the hourly calculation of glass performance. The choices are as follows:

QUICK-FIT   Use a two coefficient fit to the Window program values. The default as was used in DOE-2.1E.

INTERPOLATION   Use the ten values calculated by the Window program with linear interpolation between the values. A more accurate and also faster calculation method not available in DOE-2.1E.

SMALL FRICTIONLESS CHILLERS

Introduction

Centrifugal chillers most commonly have been available in sizes 300 tons (1000 kW) and larger. Recent developments in compressor technology now allow hermetic centrifugal chillers to be available in sizes as small as 70 tons (250 kW). These compressors utilize frictionless bearings and do not circulate oil with the refrigerant. Capacity modulation is via a variable-speed drive and inlet vanes. Multiple compressors can share a common evaporator and condenser (not circuited separately), further improving part load performance.

The current implementation is for chillers with water-cooled condensers. As with any variable-speed centrifugal, part-load performance is maximized by allowing the cooling tower temperature to float, or by utilizing a wetbulb-reset strategy.

Building Description Language Changes

CHILLER
VARIABLE-SPEED
for the centrifugal chiller types, accepts the value YES or NO indicating whether the chiller utilizes a variable-speed drive. If YES, then the program will select a different default EIR-FPLR performance curve from the library to model part-load performance, and increase the full load ELEC-INPUT-RATIO by 4% to account for drive losses; this keyword has no other effect.

For the hermetic centrifugal chiller only (ELEC-HERM-CENT), two additional codewords are available to model small frictionless compressors. Selecting either of these will modify the full load ELEC-INPUT-RATIO and the capacity and EIR performance curves:

Sml-Frictionless-Water-3F   Specifies a frictionless compressor with a water-cooled condenser. Both the evaporator and condenser are sized for a 3°F (1.67°C) approach. This selection is appropriate for a new chiller. Either a single-compressor or dual-compressor chiller may be modeled by specifying COMPRESSORS/CKT = ONE or TWO; a different default EIR-FPLR curve will be selected accordingly.

Sml-Frictionless-Water-10F   Specifies a frictionless compressor with a water-cooled condenser. Both the evaporator and condenser are sized for a 10°F (5.5°C) approach. This selection is appropriate for a retrofit to an existing reciprocating chiller. Either a single-compressor or dual-compressor chiller may be modeled by specifying COMPRESSORS/CKT = ONE or TWO; a different default EIR-FPLR curve will be selected accordingly.

COMPRESSORS/CKT
For a hermetic centrifugal chiller with a small frictionless compressor (CHILLER:VARIABLE-SPEED = Sml-Frictionless-Water-3F, or Sml-Frictionless-Water-10F), accepts the values ONE or TWO indicating whether the chiller has a single compressor, or two compressors sharing a common evaporator and condenser. A two-compressor machine has better part-load performance, and can also unload further than a single-compressor chiller.

For electric chillers other than centrifugal, accepts the values ONE, TWO, THREE, and FOUR indicating the number of compressors on each circuit. Based on the number of compressors per circuit, the program will select a

typical default EIR-FPLR performance curve from the library to model part-load performance; this keyword has no other effect.

The default curves are based on chillers having two independent refrigerant circuits, and up to four compressors per circuit. Not all chiller types have curves for three or four compressors; if you specify more compressors than exist in the performance curves for that chiller type, then the program will select the curve representing the maximum number of compressors for which a curve exists.

More compressors does not always represent better part-load performance; actual performance depends on the chiller configuration, the staging order of compressors, the use of cylinder unloaders or slide valves, the type of expansion valves, etc.

SELECTING WINDOW SHADE DEPLOYMENT VARIABLE

Introduction

.A keyword has been added to the window command to allow the selection of the solar radiation variable used by the calculation logic to decide if a window covering is to be deployed. In previous versions of DOE-2 this value was not user selectable. In DOE-2.1E the transmitted direct solar radiation was used. In DOE-2.2, prior to version 44d2, the outside incident total solar radiation was used.

Building Description Language Changes

WINDOW
MAX-SOLAR-SCH
Takes the U-name of a schedule (TYPE=RADIATION) of values of solar radiation (in Btu/ft2-hr or W/m2) either incident on the outside of the window or transmitted through the window. The actual hourly value to be used is selected by the value of the MAX-SOLAR-CTRL keyword.. (This is a change from previous DOE-2 program versions, where in 2.1E the transmitted direct solar radiation was used, and in 2.2, prior to version 44d2, the outside incident total solar radiation was used) The schedule must be of TYPE=RADIATION. The solar radiation used by the calculation logic is either the incident direct (plus optionally the diffuse) radiation after shading by overhangs, fins or detached shading surfaces, or this incident value multiplied by the specified or hourly calculated angular transmittance of the window (and shading coefficient, if appropriate based on the glass specification method.) The program will automatically deploy a shading device whenever the selected solar radiation value, without the shading device, exceeds the schedule value. The shading device will be retracted if the solar rasdiation value falls below the schedule value. For example, the shades will be deployed if the solar value is 50 Btu/ft2-hr and the schedule value is 20 Btu/ft2-hr (as long as the corresponding SHADING-SCHEDULE value is 1). If MAX-SOLAR-SCH is specified, a corresponding SHADING-SCHEDULE (and CONDUCT-SCHEDULE if desired) should be assigned to the window. The SHADING-SCHEDULE and CONDUCT-SCHEDULE values will only take effect during hours when the shading device is deployed.

MAX-SOLAR-CTRL
Takes a code-word that specifies the variable to be used as the quantity to decide if the shade is closed. The hourly value of the variable specified is used in the comparison with the hourly value of the MAX-SOLAR-SCH in the logic to decide if the shade is open or closed. The value used is the average value for the entire window as selected from the list below; this value is calculated by multiplying the solar radiation intensity by the fraction of the window that is shaded. The transmitted solar radiation value is calculated as the product of the incident value, the hourly calculated angular transmittance of the window, and, if appropriate based on the window specification method, the shading coefficient of the window.

INCIDENT-DIRECT	The direct solar radiation incident on the outside surface of the window is used as the control variable. This was the default value in DOE-2.2 prior to version 44d2.
INCIDENT-TOTAL	The total (direct plus diffuse) solar radiation incident on the outside surface of the window is used as the control variable.
TRANSMITTED-DIRECT	The direct solar radiation transmitted through the window is used as the control variable. This was the default value in DOE-2.1E
TRANSMITTED- TOTAL	The total (direct plus diffuse) solar radiation transmitted through the window is used as the control variable. This is the default value as of DOE-2.2 version 44d2.

WATER-LOOP AND GROUND SOURCE HEAT PUMP ENHANCEMENTS

Introduction

The ability to model water loop heat pumps , in both ground coupled and conventional configurations, has been greatly enhanced in two major ways:

1. <u>Water-source heat pump</u> – the PVVT, PVAVS and PSZ systems can now be specified to be water-loop heat pump systems thus allowing all the options of these SYSTEM TYPEs to be available for use in modeling water –loop heat pump configurations (including variable flow, staged heating and cooling, heat recovery, ERV's, as well as sub-zone conditioning and return air plenum pathways.

2. <u>Vertical well ground source heat exchangers</u> – a new modeling approach has been added to more accurately model vertical wells. This new model allows the specification of grout properties, the fluid type plus a library of 42 well configurations is included..

These enhancements to the water-source and ground-source heat pump modeling capability of DOE-2.2 were supported, in part, by ClimateMaster, Inc. The new vertical well ground heat exchanger model was implemented by Xiaobing Liu of ClimateMaster. That model is based upon work by Claesson, Eskilson, Hellstrom, .et.al, at the University of Lund, Sweden and Spitler, .et.al, at Oklahoma State University.

Water-Loop Heat Pump Enhancements

The ability to model water-loop heat pump equipment has been improved by allowing the PVAVS, PVVT and PSZ systems to accept a combined specification of water cooled condenser with a heat pump heat source. No new keywords have been added to enable this feature; two existing keywords, CONDENSER-TYPE and HEAT-SOURCE, have a new combination of values that were not previously allowed.

Building Description Language Changes

SYSTEM
CONDENSER-TYPE

Takes a code-word that specifies how the condenser in packaged systems with direct-expansion cooling is cooled. Note that the program does not change any of the default performance data (such as EIR) when you change the condenser type, so you should input data representative of the unit you are modelling.

WATER-COOLED   The condenser is water cooled. You must attach the condenser to a CIRCULATION-LOOP of TYPE = CW or WLHP via the CW-LOOP keyword.. This option is not allowed when HEAT-SOURCE is HEAT-PUMP except for PSZ, PVVT and PVAVS systems; when HEAT-SOURCE is HEAT-PUMP it is then required that a CIRCULATION-LOOP of TYPE = WLHP be specified via the CW-LOOP keyword..

HEAT-SOURCE

Takes a code-word that specifies the heat source for the SYSTEM's main heating coils.

HEAT-PUMP   The source of heat is an electric air-to-air heat pump when CONDENSER-TYPE is AIR-COOLED; only for the RESYS, PSZ, PTAC, PVVT, PVAVS,

RESYS-VVT, and RESYS2 systems. The source of heat is an electric water-to-air heat pump when CONDENSER-TYPE is WATER-COOLED; only for the PSZ, PVVT and PVAVS systems. .

Ground-Source Heat Pump Enhancements

A new modeling approach, based on the G-function method, developed by researchers in Sweden and utilized in the Earth Energy Designer (EED) borehole heat exchanger design software package, has been added to more accurately model vertical wells. This new model allows the specification of grout properties, the GLHX fluid type, plus a library of 42 well configurations (EED calculated g-functions) is included..

Building Description Language Changes

GROUND-LOOP-HX
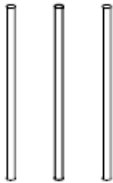
TYPE

Accepts a code-word that specifies the type of ground-coupled heat-exchanger. This keyword is required and should be the first entered. Acceptable values are:

VERT-WELL-NEW   One or more vertical wells in a field of wells using the EED g-function formulation to model the wells.

CONFIGURATION

For TYPE = VERT-WELL-NEW, accepts a code-word specifying the configuration of the well-field. Acceptable entries are:

Geometry & Illustration	Configuration	# Bores
Single	Single	1
Straight Line	Line-Of-2	2
	Line-Of-3	3
	Line-Of-4	4
	Line-Of-5	5
	Line-Of-6	6
	Line-Of-7	7
	Line-Of-8	8
	Line-Of-9	9
	Line-Of-10	10

One L-shaped Line
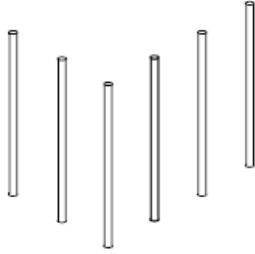
L-Config-2x2	3
L-Config-2x3	4
L-Config-2x4	5
L-Config-2x5	6

Two Parallel L-shaped Lines
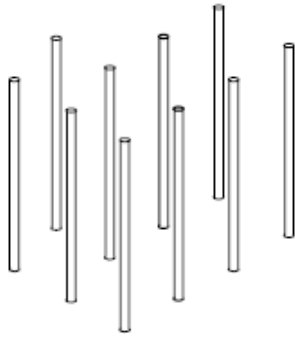
L2-Config-3x3	8
L2-Config-3x4	10
L2-Config-3x5	12

U-shaped Lines
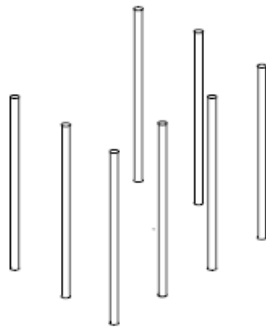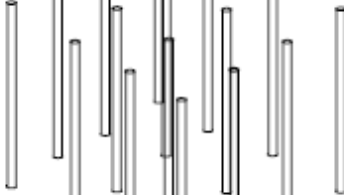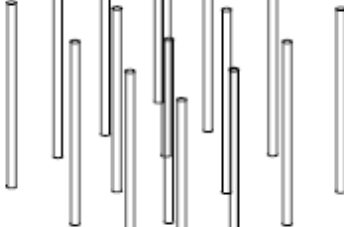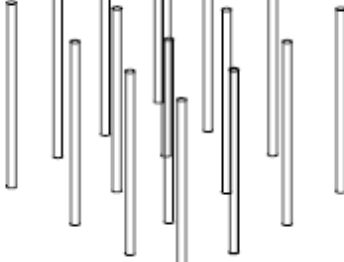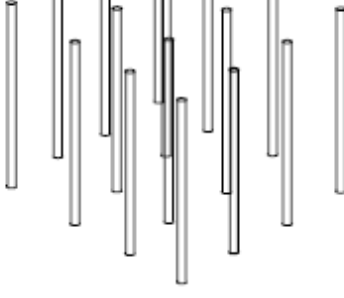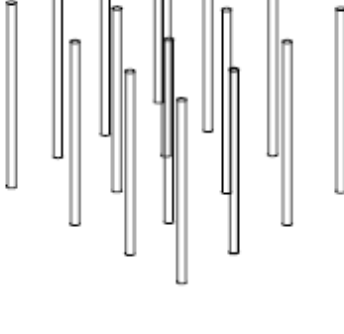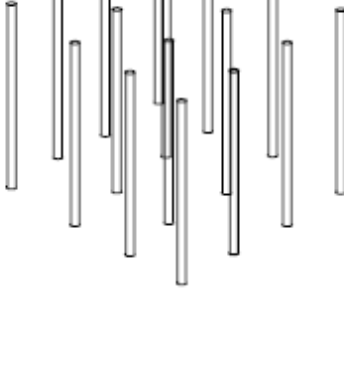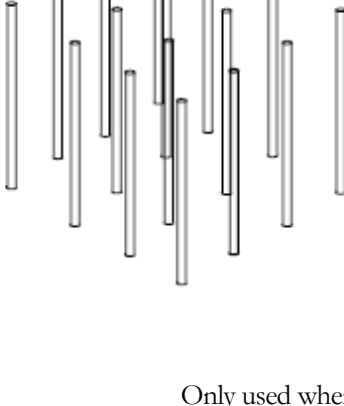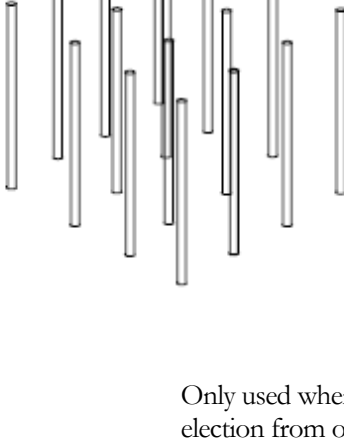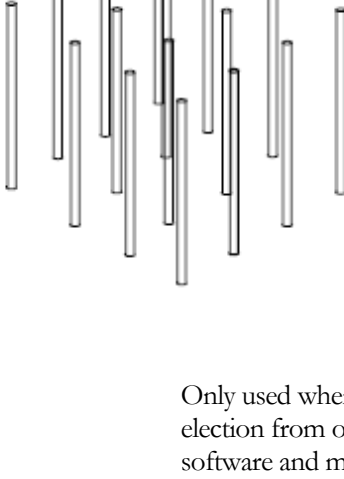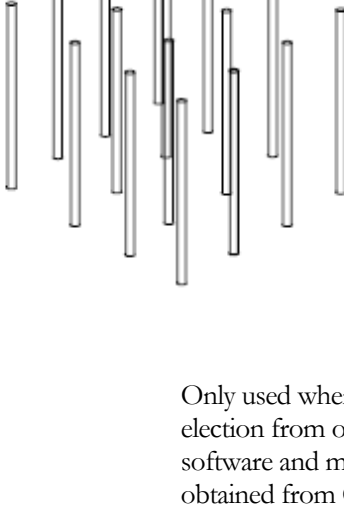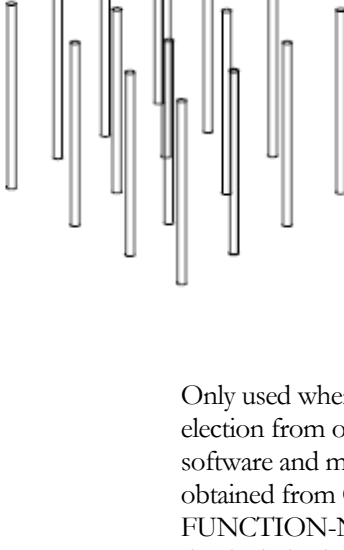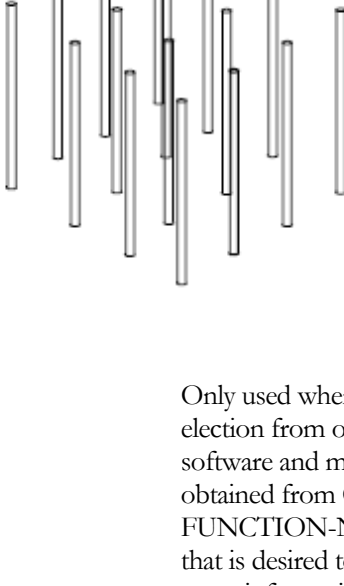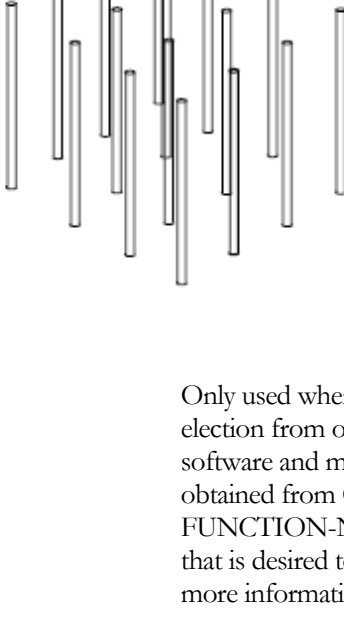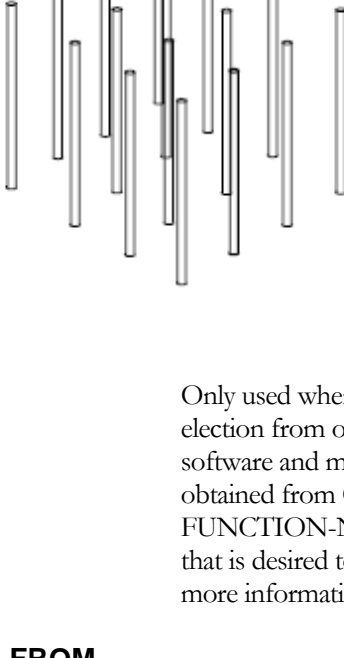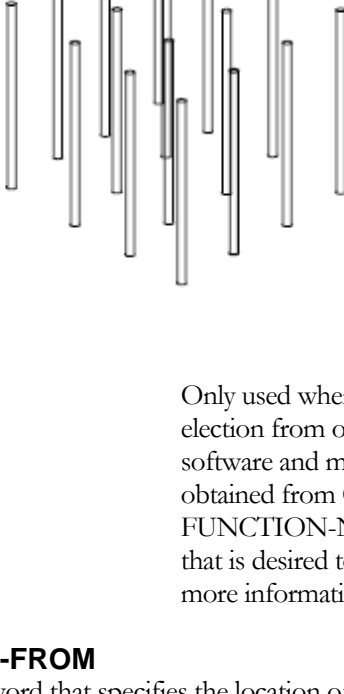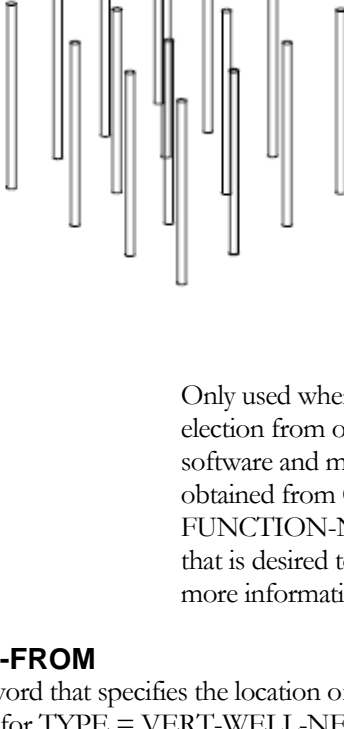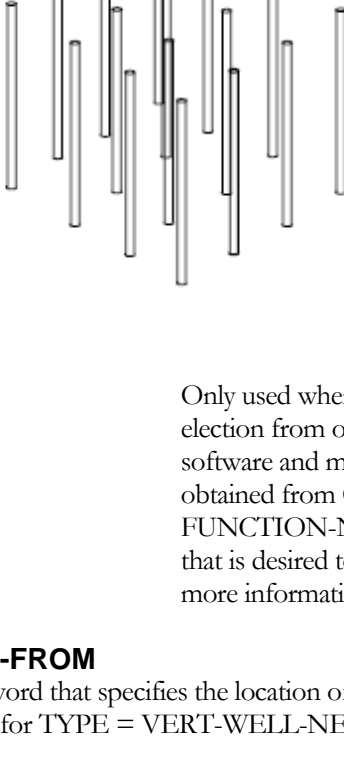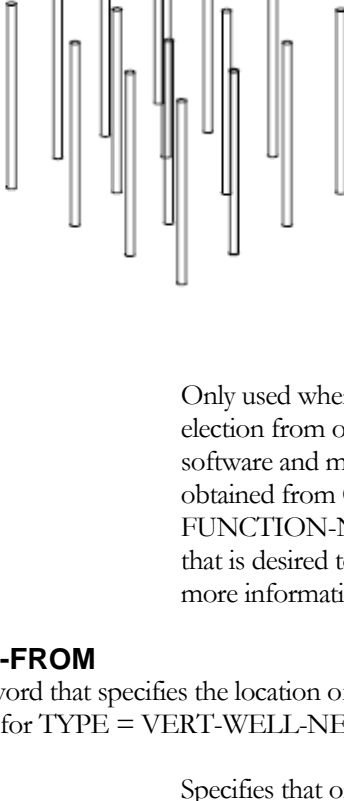
U-Config-3x2	5
U-Config-3x3	7
U-Config-3x4	9
U-Config-3x5	11

Open Rectangle
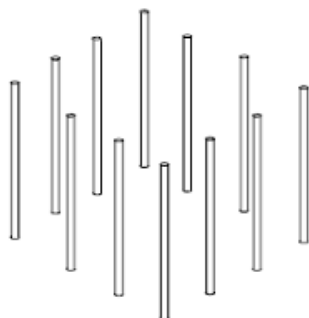
Open-Rectangle-3x3	8
Open-Rectangle-3x4	10
Open-Rectangle-3x5	12

	Rectangle-2x2	4
Rectangle	Rectangle-2x3	6
	Rectangle-2x4	8
	Rectangle-2x5	10
	Rectangle-2x6	12
	Rectangle-2x7	14
	Rectangle-2x8	16
	Rectangle-2x9	18
	Rectangle-2x10	20
	Rectangle-3x3	9
	Rectangle-3x4	12
	Rectangle-3x5	15
	Rectangle-3x6	18
	Rectangle-4x4	16
	Rectangle-4x5	20
	Rectangle-4x6	24
	Rectangle-4x7	28
	Rectangle-4x8	32

Custom-CM   Only used when the G-FUNCTION-FROM keyword is CUSTOM. Allows election from over 300 "custom" configurations created using EED G-Funtion software and made available via the LTS_gfnc.bin library. This library can only be obtained from ClimateMaster. This codeword value requires that the G-FUNCTION-NUM keyword be set equal the integer number of the G-Function that is desired to be retrieved from the library. See G-FUNCTION-NUM for more information on this library.

G-FUNCTION-FROM
Accepts a code-word that specifies the location of the G-Functions to be used for modeling this ground-loop heat exchanger. Used for TYPE = VERT-WELL-NEW only. Acceptable entries are:

LIBRARY   Specifies that one of the 43 G-functions found in the DOE-2.2 default library, as listed under the CONFIGURATION keyword, are to be used to model the well field..

CUSTOM   Specifies that G-functions are to be retrieved from the custom library (LTS_gfnc.bin) with the specific G-functions to be used specified via the G-FUNCTION-NUM keyword.

G-FUNCTION-NUM
Accepts a integer value that specifies the G-Functions number, from the LTS_gfnc.bin library, to be used for modeling this ground-source heat exchanger.. Used for TYPE = VERT-WELL-NEW only. Only used when the G-FUNCTION-FROM keyword is CUSTOM. This library is not part of the standard DOE-2.2 release; it is produced using the Earth Energy Designer (EED) borehole heat exchanger design software package . A DOE-2.2/eQUEST compatible version of this library, containing over 300 configurations, is available; information about this library can be obtained by contacting Xiaobing Liu at ClimateMaster (405) 745-6000 x335.

DEPTH
The distance (in feet) between the ground surface and the bottom of the well. This is a required keyword.

SPACING
The distance (in feet) between the centerlines of the wells. This is a required keyword.

BOREHOLE-DIAM
The diameter (in inches) of the borehole. Used for TYPE = VERT-WELL-NEW only.

FIELD-MULTIPLIER
The number of identical fields. The program assumes that these fields do not interact with each other.

Pipe Properties
The following keywords define the properties of the pipe.

PIPE-OUTSIDE-DIA
The outside diameter in (inches) of the U-tube or pipe. Typical values for common pipe classifications are listed in the tables below. This is a required keyword.

PIPE-INSIDE-DIA
The inside diameter (in inches) of the U-tube or pipe. Typical values for common pipe classifications are listed in the tables below. This is a required keyword.

Pipe Dimensions					
Pipe Size		Pressure Ratings			
		SDR 11		SDR 17	
Size (in)	Nom. OD (in)	ID (in)	Wall Thick. (in)	ID (in)	Wall Thick. (in)
3/4	1.05	0.859	0.095	0.926	0.062
1	1.315	1.076	0.120	1.160	0.077
1-1/4	1.66	1.358	0.151	1.465	0.098
1-1/2	1.9	1.555	0.173	1.676	0.112
2	2.375	1.943	0.216	2.096	0.140

Pipe Dimensions					
Pipe Size		Pressure Ratings			
		Schedule 40		Schedule 80	
Size (in)	Nom. OD (in)	ID (in)	Wall Thick. (in)	ID (in)	Wall Thick. (in)
3/4	1.05	0.824	0.113	0.742	0.154
1	1.315	1.049	0.133	0.957	0.179
1-1/4	1.66	1.38	0.14	1.278	0.191
1-1/2	1.9	1.61	0.145	1.5	0.2
2	2.375	2.067	0.154	1.939	0.218

U-TUBE-LEG-SEP
The separation (in inches) between the outer surfaces of the tubes. For TYPE = VERT-WELL-FIELD and VERT-WELL-NEW, only. This is a required keyword.

PIPE-COND
The thermal conductivity (BTU/HR-FT-F) of the pipe. Typical values are found in the table below. This is a required keyword.

Material	Thermal Conductivity Btu/hr-ft-F
Polyethylene	0.23
Polybutylene	0.13

Fluid Properties

The following keywords define the properties of the fluid used in the GLHX pipe circuit..

FLUID

Accepts a code-word that specifies the fluid used in the circulation loop of this ground-loop heat exchanger. Used for TYPE = VERT-WELL-NEW only. Acceptable entries are:

WATER	The default..
PROPYLENE-GLYCOL	aqueous solutions of Propylene Glycol
ETHANOL	aqueous solutions of Ethylene Glycol
ETHYLENE-GLYCOL	aqueous solutions of Methanol.
METHANOL	aqueous solutions of Ethanol

ANTI-FREEZE-CONC

The concentration (in percent) of the anti-freeze fluid, as specified using the FLUID keyword, and water. Used for TYPE = VERT-WELL-NEW only.

Ground Properties

The following keywords define the properties of the ground..

REF-GRND-TEMP

The undisturbed far-field ground temperature (in degrees F) for vertical wells. For TYPE = VERT-WELL-NEW only, if this values is not specified it is calculated as the average annual outdoor dry bulb temperature using the weather file that is selected for the simulation.

REF-GRND-ADJ

The adjustment (in delta degrees F), for local conditions, to the undisturbed far-field ground temperature. Used for TYPE = VERT-WELL-NEW only.

GRND-DIFFUSIVITY

The ground diffusivity (FT2/HR). Typical values are found in the table below.

GRND-COND

The ground conductivity (BTU/HR-FT-F). Typical values are found in the table below.

> The data in the table below are compiled from following sources: Database of EED version 2.0 (Demo) (Hellstrom, et al 2000); Kavanaugh, Stephen and K. Rafferty, Ground-Source Heat Pumps, ASHRAE 1997; Soil and Rock Classification for the Design of Ground-Coupled Heat Pump Systems, IGSHPA 1989.

| Description | Recommended | | Description |
| | Conductivity | Difussivity | |
	Btu/hr-ft-F	Ft^2/hr	
Amphibolite	1.7	0.0432	Igneous or metamorphic rock composed largely or dominantly of amphibole minerals.
Andesite	1.3	0.0355	Extrusive usually dark grayish rock consisting essentially of oligoclase or feldspar.
Anhydrite	2.4	0.0794	Mineral consisting of an anhydrous calcium sulfate that is usually massive and white or slightly colored.
Aplite	1.8	0.0501	Fine-grained light-colored granite consisting almost entirely of quartz and feldspar.
Arkose	1.7	0.0562	Sandstone characterized by feldspar fragments that is derived from granite or gneiss which has disintegrated rapidly
Basalt	1.0	0.0274	Dark gray to black dense to fine-grained igneous rock that consists of basic plagioclase, augite, and usually magnetite.
Breccia	1.6	0.0517	Rock consisting of sharp fragments embedded in a fine-grained matrix (as sand or clay).
Clay, dry	0.2	0.0097	Earthy material that is plastic when moist but hard when fired, that is composed mainly of fine particles of hydrous aluminum silicates and other minerals.
Clay, moist - wet	0.9	0.0258	
Claystone	1.3	0.0371	Rock composed chiefly of Clay.
Coal	0.2	0.0065	Black or brownish black solid combustible substance formed by the partial decomposition of vegetable matter without free access of air and under the influence of moisture and often increased pressure and temperature that is widely used as a natural fuel.
Concrete	0.9	0.0344	Hard strong building material made by mixing a cementing material (as portland cement) and a mineral aggregate (as sand and gravel) with sufficient water to cause the cement to set and bind the entire mass
Conglomerate	1.6	0.0517	Rock composed of rounded fragments varying from small pebbles to large boulders in a cement (as of hardened clay).
Diorite	1.5	0.0347	Granular crystalline igneous rock commonly of acid plagioclase and hornblende, pyroxene, or biotite.
Dolomite	1.9	0.0496	Limestone or marble rich in magnesium carbonate.
Dunite	2.4	0.0561	A granitoid igneous rock consisting chiefly of olivine.
Eclogite	1.7	0.0363	Any member of metamorphic rocks whose original composition is similar to that of basalt.
Gabbro	1.1	0.0283	Granular igneous rock composed essentially of calcic plagioclase, a ferromagnesian mineral, and accessory minerals.
Gneiss	1.7	0.0535	Foliated metamorphic rock corresponding in composition to a feldspathic plutonic rock (as granite).
Granite	2.0	0.0549	Very hard natural igneous rock formation of visibly crystalline texture formed essentially of quartz and orthoclase or microcline.
Granodiorite	1.9	0.0492	Granular intrusive quartzose igneous rock intermediate between granite and quartz-containing diorite with plagioclase predominant over orthoclase.
Gravel, dry	0.2	0.0103	Loose rounded fragments of rock.
Gravel, saturated	1.0	0.0291	
Gypsum	0.9	0.0310	Widely distributed mineral consisting of hydrous calcium sulfate that is used especially as a soil amendment and in making plaster of paris.
Ignimbrite	1.7	0.0554	Hard rock formed by solidification of chiefly fine deposits of volcanic ash.
Limestone, marly	1.3	0.0371	Rock that is formed chiefly by accumulation of organic remains (as shells or coral), consists mainly of calcium carbonate, is extensively used in building, and yields lime when burned.
Limestone, massive	1.6	0.0472	
Limestone, oolitic	1.4	0.0404	
Marble	1.5	0.0504	Limestone that is more or less crystallized by metamorphism, that ranges from granular to compact in texture, that is capable of taking a high polish, and that is used especially in architecture and sculpture.

Description	Recommended Conductivity	Recommended Difussivity	Description
	Btu/hr-ft-F	**Ft²/hr**	
Marl	1.2	0.0354	Loose or crumbling earthy deposit (as of sand, silt, or clay) that contains a substantial amount of calcium carbonate.
Marl, clayey/argillaceous	1.2	0.0352	
Marl, dolomitic	1.3	0.0371	
Peat	0.2	0.0070	Partially carbonized vegetable tissue formed by partial decomposition in water of various plants.
Pegmatite	1.7	0.0554	Coarse variety of granite occurring in dikes or veins.
Peridotite	2.3	0.0574	Any of a group of granitoid igneous rocks composed of ferromagnesian minerals and especially olivine.
Quartzite	3.5	0.1107	Compact granular rock composed of quartz and derived from sandstone by metamorphism.
Rhyolite	1.9	0.0609	Very acid volcanic rock that is the lava form of granite.
Rock Salt	3.1	0.1744	Crystalline compound NaCl that consists of sodium chloride.
Sand, dry	0.2	0.0111	Loose granular material that results from the disintegration of rocks, consists of particles smaller than gravel but coarser than silt.
Sand, dry compacted	0.7	0.0274	
Sand, frozen	1.2	0.0517	
Sand, moist	0.6	0.0215	
Sand, saturated	1.4	0.0372	
Sandstone	1.3	0.0446	Sedimentary rock consisting of usually quartz sand united by some cement (as silica or calcium carbonate).
Shale	1.2	0.0354	Fissile rock that is formed by the consolidation of clay, mud, or silt, has a finely stratified or laminated structure, and is composed of minerals essentially unaltered since deposition.
Schist	1.8		Metamorphic crystalline rock that has a closely foliated structure and can be split along approximately parallel planes.
Silt, dry	0.2	0.0097	Loose sedimentary material with rock particles usually 1/20 millimeter or less in diameter.
Silt, moist - wet	1.0	0.0317	
Siltstone	1.4	0.0404	Rock composed chiefly of indurated silt
Slate	1.2		Dense fine-grained metamorphic rock produced by the compression of various sediments (as clay or shale) so as to develop a characteristic cleavage.
Syenite	1.5	0.0420	Igneous rock composed chiefly of feldspar.
Till (boulder clay, moraine)	1.2	0.0369	Unstratified glacial drift consisting of clay, sand, gravel, and boulders intermingled.
Tonalite	1.6	0.0436	
Trachyte	1.6	0.0517	Usually light-colored volcanic rock consisting chiefly of potash feldspar.
Tuff	0.6	0.0388	Rock composed of the finer kinds of volcanic detritus usually fused together by heat.

Grout Properties

The following keywords define the properties of the grout (backfill) material.

GROUT-COND

The thermal conductivity (Btu/Hr-Ft-F) of the grout. Used for TYPE = VERT-WELL-NEW only. Typical values are listed in the table below.

Description	Thermal Conductivity
	Btu/hr-ft-F
Grouts without Additives	
Bentonite 10%, frozen	0.8
Bentonite 10%, in water	0.4
Bentonite 20%, in water	0.3
Bentonite 40%, frozen	0.5
Bentonite 40%, in water	0.3
Bentonite, dry	0.1
Clay, dry	0.2
Clay, moist - wet	0.9
Concrete	0.9
Gravel, dry	0.2
Gravel, saturated	1.0
Sand, dry	0.2
Sand, dry, compacted	0.7
Sand, frozen	1.2
Sand, moist	0.6
Sand, saturated	1.4
Silt, dry	0.2
Silt, moist - wet	1.0
Till	1.2
Thermally Enhanced Grouts	
20% Bentonite -40% Quartzite	0.9
30% Bentonite -30% Quartzite	0.8
30% Bentonite -30% Iron Ore	0.5
60% Quartzite -Flowable Fill (Cement + Fly Ash + Sand)	1.1

The above data are compiled from following sources:

Database of EED version 2.0 (Demo) (Hellstrom, et al 2000).

Kavanaugh, Stephen and K. Rafferty, Ground-Source Heat Pumps, ASHRAE 1997.

GLASS MANUFACTURER WINDOW LIBRARY

<u>Introduction</u>

A new set of window entries have been added to the window library. These entries reflect actual products sold on the market today. Depending on whether the glazing system is single glazed, double glazed or triple glazed, the user can select a window with a glazing system from a specific glass manufacturer. The user needs to be familiar with the glass types offered by a manufacturer in order to select the corresponding window system from the library. A listing of the new window library follows this discussion. The listing is set up the same way as the existing DOE-2 Window Library with the addition of the name for each pane of glass. If the user cannot find the window in the library, we recommend creating the window in WINDOW 5 and importing it to eQUEST.

The new windows were created in WINDOW 5.2 using glass from release 14.4 of the International Glazing Database (IGDB 14.4). The International Glazing Database includes spectral data for glass manufactured by all glass manufacturers who have chosen to submit their data for peer review to Lawrence Berkeley National Laboratory.   Use of these windows improves the accuracy of the calculations because the windows represent actual products and the simulations employ the angular properties of the glazing systems from WINDOW 5.2.

The new Glass Manufacturer Window Library is organized by type of window (single, double, triple), the manufacturer, and the glass type. The user selects single, double or triple-glazed units by manufacturer. The list of products offered by a manufacturer has a window name and a description. The window name gives an abbreviated name for each glazing layer separated by the gas fill type, e.g. Brz /Air/Clr 6. . The description of the glazing system indicates the window library identification number, U-Factor, SHGC and visible light transmittance for the glazing system.

In the window name, the first glazing listed represents the outboard lite. In units with multiple glazings, the gas fill is either air or argon (Arg). For air, two different widths were modeled. Air1 designates a 6.3 mm (0.25 in) gap in the double and triple glazed units. In the double glazed units, Air or Arg corresponds to a 12.7 mm (0.5 in) gap. In the triple glazed units with suspended films, Air corresponds to a 9.5 mm (0.375 in.) gap width.

The thickness of the glass in the glazing system is given at the end of the window name.   There is 3mm (3) and 6mm (6) glass. Typically, 3mm glass is used on residential-scale projects and 6mm glass is used for commercial applications. All double-glazed units with 6mm glass have a gap that is air-filled and 12.7 mm (o.5 in) wide. It is rare to see the narrower gap widths on commercial projects; however, a user can use WINDOW 5.2 to create such a product.

The window ID number can be used to reference the window library documentation and see the details of the glazing system. In the window ID number, the first three digits have significance:

<u>6</u>   <u>2</u>   <u>4</u>   0

| The thousandths digit is the window type (single, double or triple) | The hundredths digit identifies the manufacturer. | The tenths digit identifies the glass type. |
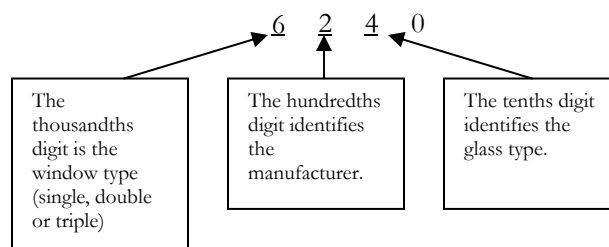
In this set of library entries all window ID's in the 5000 range are single glazed; those in the 6000 range are double glazed and those in the 7000 range are triple glazed. Within each of these window types, glass manufacturer have been assigned a range of ID's. Window ID numbers between 5000 and 5100, and 6000 and 6100 represent generic glazing. Clr/Tint glazings are those glass types that are produced by multiple manufacturers and have nearly the

same performance, such as clear, bronze, grey and green. The range of ID's for AFG are in the 100's, so 5100 to 5199 and 6100 to 6199 are AFG products.

Because there are so many different types of glass, the library attempts to segregate the most common glass types. Windows with clear glass are assigned ID's between 0 and 10 within the window type and manufacturer categories. For example, a window ID of 6120 is a double-glazed window from AFG and has grey tinted glass. Coding by glass types falls apart with all the different kinds of coatings, so verify that you have selected the appropriate window. The table below shows the corresponding ID's for each manufacturer.

Guide to Glass Manufacturer Window Library ID's					
Window		**Manufacturer**		**Glass Type**	
ID	**Type**	**ID**	**Name**	**ID**	**Type**
5000	Single	<100	Clr/Tint	<10	Clear
6000	Double	100	AFG	10	Bronze
7000	Triple	200	Visteon	20	Grey
		300	Cardinal	30	Green
		400	Guardian	40	Blue
		500	PPG	45	Bluegreen
		600	Viracon	>50	Low-E on Clear
		700	Interpane (not included)		
		800	Pilkington		

G-T-C	Name	U-SI	U-IP	SC	SHGC	Tsol	Rfsol	Tvis	Rfvis	Pane #1 Id	Wid	Pane #1 IGDB Glass Name
Single Clr/Tint												
5000	Clr 3	5.88	1.04	0.99	0.86	0.83	0.08	0.90	0.08	102	3.0	Generic Clear Glass
5001	Clr 6	5.78	1.02	0.94	0.82	0.77	0.07	0.88	0.08	103	5.7	Generic Clear Glass
5002	Optiwhite 3	5.88	1.04	1.04	0.91	0.90	0.08	0.91	0.09	9811	2.9	Optiwhite
5003	Optiwhite 6	5.78	1.02	1.03	0.90	0.89	0.08	0.91	0.08	9814	5.8	Optiwhite
5004	Lexan XL 3	5.63	0.99	0.96	0.83	0.80	0.09	0.86	0.09	3501	3.0	Lexan XL
5005	Lexan XL 6	5.17	0.91	0.93	0.81	0.77	0.08	0.81	0.08	3503	6.0	Lexan XL
5006	Plexiglas MC 3	5.63	0.99	1.00	0.87	0.85	0.07	0.92	0.07	2601	3.0	Plexiglas MC
5007	Plexiglas MC 6	5.16	0.91	0.99	0.86	0.83	0.07	0.92	0.07	2604	6.0	Plexiglas MC
5010	Brz 3	5.87	1.03	0.84	0.73	0.65	0.06	0.68	0.07	100	3.1	Generic Bronze Glass
5011	Brz 6	5.78	1.02	0.71	0.62	0.49	0.05	0.53	0.06	101	5.7	Generic Bronze Glass
5020	Gry 3	5.87	1.03	0.81	0.70	0.61	0.06	0.62	0.06	104	3.1	Generic Grey Glass
5021	Gry 6	5.79	1.02	0.69	0.60	0.45	0.05	0.47	0.05	1334	5.7	Versalux Grey
5030	Grn Float 3	5.88	1.04	0.80	0.70	0.60	0.06	0.83	0.08	3023	3.0	Green Float Glass
5031	Grn Float 6	5.79	1.02	0.68	0.59	0.44	0.06	0.76	0.07	3026	5.6	Green Float Glass

G-T-C	Name	U-SI	U-IP	SC	SHGC	Tsol	Rfsol	Tvis	Rfvis	Pane #1 Id	Pane #1 Wid	Pane #1 IGDB Glass Name
Single Visteon												
5212	Versalux Brz RC 6	5.79	1.02	0.47	0.41	0.28	0.28	0.21	0.35	1315	5.7	Versalux Bronze RC
5220	Versalux Gry 2000 6	5.79	1.02	0.38	0.33	0.07	0.04	0.08	0.04	1336	5.7	Versalux Grey 2000
5222	Versalux Gry RC 6	5.79	1.02	0.45	0.39	0.26	0.28	0.18	0.35	1338	5.7	Versalux Grey RC
5230	Versalux Grn 2000 3	5.87	1.03	0.70	0.61	0.48	0.05	0.76	0.07	1323	3.2	Versalux Green 2000
5231	Versalux Grn 2000 6	5.79	1.02	0.59	0.51	0.33	0.05	0.66	0.06	1326	5.7	Versalux Green 2000
5232	Versalux Grn RC 6	5.79	1.02	0.43	0.38	0.23	0.27	0.30	0.35	1330	5.7	Versalux Green RC
5233	Versalux Grn 2000 R 6	5.78	1.02	0.37	0.32	0.15	0.27	0.25	0.35	1328	5.9	Versalux Green 2000 R
5240	Versalux Blu 6	5.78	1.02	0.70	0.61	0.47	0.05	0.57	0.06	1305	5.9	Versalux Blue
5241	Versalux Blu 2000 6	5.78	1.02	0.57	0.50	0.31	0.05	0.43	0.05	1302	5.9	Versalux Blue 2000
5242	Versalux Blu RC 6	5.78	1.02	0.46	0.40	0.27	0.28	0.22	0.35	1307	5.9	Versalux Blue RC
5243	Versalux Blu2 RC 6	5.78	1.02	0.37	0.32	0.16	0.27	0.16	0.35	1309	5.9	Versalux Blue RC
Single PPG												
5501	Starphire 6	5.79	1.02	1.03	0.90	0.89	0.08	0.91	0.08	5004	5.7	Starphire
5511	Solarcool SolarBrz 6	5.79	1.02	0.45	0.40	0.27	0.30	0.21	0.36	5108	5.7	Solarcool Solarbronze
5521	Solargray 6	5.79	1.02	0.66	0.57	0.42	0.05	0.44	0.06	5052	5.7	Solargray
5522	Graylite 6	5.79	1.02	0.53	0.46	0.26	0.05	0.14	0.05	5057	5.7	Graylite
5523	Solarcool Solargray 6	5.79	1.02	0.42	0.36	0.23	0.30	0.17	0.36	5120	5.7	Solarcool Solargray
5524	Optigray 23 6	5.79	1.02	0.48	0.42	0.19	0.05	0.23	0.05	5294	5.7	Optigray 23
5531	SolarGrn 6	5.79	1.02	0.60	0.52	0.34	0.05	0.67	0.07	5028	5.7	Solargreen
5541	Azurlite 6	5.79	1.02	0.58	0.51	0.32	0.05	0.68	0.07	5036	5.7	Azurlite
5542	Caribia 6	5.79	1.02	0.58	0.51	0.32	0.05	0.68	0.07	5326	5.7	Caribia
5543	Solarcool Azurlite 6	5.79	1.02	0.35	0.30	0.14	0.30	0.26	0.36	5095	5.7	Solarcool Azurlite
5544	Solarcool Caribia 6	5.79	1.02	0.35	0.30	0.14	0.30	0.26	0.36	5336	5.7	Solarcool Caribia

G-T-C	Name	U-SI	U-IP	SC	SHGC	Tsol	Rfsol	Tvis	Rfvis	Pane #1 Id	Pane #1 Wid	Pane #1 IGDB Glass Name
Single Pilkington												
5820	SuperGry 3	5.87	1.03	0.51	0.44	0.23	0.04	0.25	0.05	9891	3.2	SuperGrey
5821	SuperGry 6	5.79	1.02	0.39	0.34	0.08	0.04	0.09	0.04	9894	5.7	SuperGrey
5830	EverGrn 3	5.87	1.03	0.71	0.62	0.49	0.06	0.77	0.07	9881	3.2	EverGreen
5831	EverGrn 6	5.78	1.02	0.59	0.51	0.33	0.05	0.66	0.06	9889	5.9	EverGreen
5840	Arctic Blu 6	5.78	1.02	0.59	0.51	0.33	0.05	0.53	0.06	9989	5.9	Arctic Blue
5845	Optifloat Blu-Grn 6	5.78	1.02	0.71	0.62	0.48	0.06	0.75	0.07	9879	5.9	Optifloat Blue-Green
5850	Eclipse AdvClr 6	3.66	0.65	0.71	0.62	0.58	0.19	0.67	0.25	9909	5.9	Eclipse AdvantageClear
5851	Eclipse AdvBrz 6	3.66	0.65	0.51	0.45	0.35	0.10	0.38	0.11	9908	5.9	Eclipse AdvantageBronze
5852	Eclipse AdvGry 6	3.66	0.65	0.46	0.40	0.29	0.09	0.32	0.10	9911	5.9	Eclipse AdvantageGrey
5853	Eclipse Adv EverGrn 6	3.66	0.65	0.41	0.36	0.23	0.08	0.48	0.16	9910	5.9	Eclipse AdvantageEverGreen
5854	Eclipse Adv Arctic Blu 6	3.66	0.65	0.41	0.36	0.23	0.08	0.39	0.12	9906	5.9	Eclipse Advantagerctic Blue
5855	Eclipse Adv Blu-Grn 6	3.66	0.65	0.51	0.45	0.35	0.11	0.56	0.19	9907	5.9	Eclipse AdvantageBlue-Green
5860	Energy Adv LowE 3	3.51	0.62	0.83	0.72	0.69	0.11	0.82	0.11	9921	3.0	Energy AdvantageLow-E
5861	Energy Adv LowE 6	3.48	0.61	0.80	0.70	0.66	0.10	0.82	0.10	9924	5.6	Energy AdvantageLow-E
5870	Solar E 3	3.49	0.62	0.63	0.55	0.48	0.08	0.60	0.08	9931	3.0	Solar E
5871	Solar E 6	3.49	0.62	0.61	0.53	0.46	0.07	0.61	0.07	9935	5.7	Solar E
5880	Activ Clr 3	5.88	1.04	0.95	0.82	0.80	0.12	0.84	0.15	9937	3.0	Activon Clear
5881	Activ Clr 6	5.79	1.02	0.90	0.78	0.75	0.12	0.83	0.15	9941	5.6	Activon Clear

G-T-C	Name	U-SI	U-IP	SC	SHGC	Tsol	Rfsol	Tvis	Rfvis	Pane #1 Id	Pane #1 Wid	Pane #1 IGDB Glass Name	Gap #1 Gas	Gap #1 Wid	Pane #2 Id	Pane #2 Wid	Pane #2 IGDB Glass Name
Double Clr/Tint New																	
6000	Clr/Air1/Clr 3	3.12	0.55	0.87	0.76	0.70	0.13	0.81	0.15	102	3.0	Generic Clear Glass	Air	6.3	102	3.0	Generic Clear Glass
6001	Clr/Air1/Clr 6	3.07	0.54	0.80	0.70	0.61	0.11	0.79	0.14	103	5.7	Generic Clear Glass	Air	6.3	103	5.7	Generic Clear Glass
6002	Clr/Air/Clr 3	2.73	0.48	0.88	0.76	0.70	0.13	0.81	0.15	102	3.0	Generic Clear Glass	Air	12.7	102	3.0	Generic Clear Glass
6003	Clr/Air/Clr 6	2.68	0.47	0.81	0.70	0.61	0.11	0.79	0.14	103	5.7	Generic Clear Glass	Air	12.7	103	5.7	Generic Clear Glass
6010	Brz /Air1/Clr 3	3.12	0.55	0.72	0.63	0.55	0.09	0.61	0.10	100	3.1	Generic Bronze Glass	Air	6.3	102	3.0	Generic Clear Glass
6011	Brz /Air1/Clr 6	3.09	0.54	0.59	0.52	0.41	0.07	0.48	0.08	101	5.7	Generic Bronze Glass	Air	6.3	102	3.0	Generic Clear Glass
6012	Brz /Air/Clr 3	2.72	0.48	0.72	0.62	0.55	0.09	0.61	0.10	100	3.1	Generic Bronze Glass	Air	12.7	102	3.0	Generic Clear Glass
6013	Brz /Air/Clr 6	2.71	0.48	0.59	0.51	0.41	0.07	0.48	0.08	101	5.7	Generic Bronze Glass	Air	12.7	102	3.0	Generic Clear Glass
6020	Gry /Air1/Clr 3	3.12	0.55	0.69	0.60	0.51	0.09	0.56	0.09	104	3.1	Generic Grey Glass	Air	6.3	102	3.0	Generic Clear Glass
6021	Versalux Gry/Air1/Clr 6	3.07	0.54	0.55	0.48	0.36	0.07	0.41	0.07	1334	5.7	Versalux Grey	Air	6.3	103	5.7	Generic Clear Glass
6022	Gry /Air/Clr 3	2.72	0.48	0.69	0.60	0.51	0.09	0.56	0.09	104	3.1	Generic Grey Glass	Air	12.7	102	3.0	Generic Clear Glass
6023	Versalux Gry/Air/Clr 6	2.69	0.47	0.55	0.48	0.36	0.07	0.41	0.07	1334	5.7	Versalux Grey	Air	12.7	103	5.7	Generic Clear Glass
6030	Grn Float /Air1/Clr 3	3.12	0.55	0.69	0.60	0.51	0.09	0.75	0.13	3023	3.0	Green Float Glass	Air	6.3	102	3.0	Generic Clear Glass
6031	Grn Float /Air1/Clr 6	3.07	0.54	0.55	0.48	0.37	0.07	0.67	0.12	3026	5.6	Green Float Glass	Air	6.3	103	5.7	Generic Clear Glass
6032	Grn Float /Air/Clr 3	2.73	0.48	0.68	0.59	0.51	0.09	0.75	0.13	3023	3.0	Green Float Glass	Air	12.7	102	3.0	Generic Clear Glass
6033	Grn Float /Air/Clr 6	2.69	0.47	0.55	0.47	0.37	0.07	0.67	0.12	3026	5.6	Green Float Glass	Air	12.7	103	5.7	Generic Clear Glass

G-T-C	Name	U-SI	U-IP	SC	SHGC	Tsol	Rfsol	Tvis	Rfvis	Pane #1 Id	Pane #1 Wid	Pane #1 IGDB Glass Name	Gap #1 Gas	Gap #1 Wid	Pane #2 Id	Pane #2 Wid	Pane #2 IGDB Glass Name
Double AFG																	
6170	Comfort E Clr/Air1/Clr 3	2.54	0.45	0.75	0.65	0.59	0.14	0.75	0.15	907	3.1	Comfort E on Clear	Air	6.3	102	3.0	Generic Clear Glass
6171	Comfort E Clr/Air1/Clr 6	2.5	0.44	0.71	0.62	0.52	0.13	0.73	0.14	910	5.6	Comfort E on Clear	Air	6.3	103	5.7	Generic Clear Glass
6172	Comfort E Clr/Air/Clr 3	1.98	0.35	0.75	0.65	0.59	0.14	0.75	0.15	907	3.1	Comfort E on Clear	Air	12.7	102	3.0	Generic Clear Glass
6173	Comfort E Clr/Air/Clr 6	1.95	0.34	0.71	0.62	0.52	0.13	0.73	0.14	910	5.6	Comfort E on Clear	Air	12.7	103	5.7	Generic Clear Glass
6174	Comfort E Clr/Arg/Clr 3	1.76	0.31	0.75	0.65	0.59	0.14	0.75	0.15	907	3.1	Comfort E on Clear	Arg	12.7	102	3.0	Generic Clear Glass
6175	Comfort E Clr/Arg/Clr 6	1.73	0.30	0.71	0.62	0.52	0.13	0.73	0.14	910	5.6	Comfort E on Clear	Arg	12.7	103	5.7	Generic Clear Glass
6176	Comfort Ti-AC LowE/Air1/Clr 3	2.31	0.41	0.46	0.40	0.36	0.41	0.61	0.29	917	3.1	Comfort Ti-AC LowE on Clear	Air	6.3	102	3.0	Generic Clear Glass
6177	Comfort Ti-AC LowE/Air1/Clr 6	2.28	0.40	0.44	0.38	0.32	0.36	0.59	0.29	919	5.6	Comfort Ti-AC LowE on Clear	Air	6.3	103	5.7	Generic Clear Glass
6178	Comfort Ti-AC LowE/Air/Clr 3	1.67	0.29	0.46	0.40	0.36	0.41	0.61	0.29	917	3.1	Comfort Ti-AC LowE on Clear	Air	12.7	102	3.0	Generic Clear Glass
6179	Comfort Ti-AC LowE/Air/Clr 6	1.65	0.29	0.43	0.38	0.32	0.36	0.59	0.29	919	5.6	Comfort Ti-AC LowE on Clear	Air	12.7	103	5.7	Generic Clear Glass
6180	Comfort Ti-AC LowE/Arg/Clr 3	1.41	0.25	0.46	0.40	0.36	0.41	0.61	0.29	917	3.1	Comfort Ti-AC LowE on Clear	Arg	12.7	102	3.0	Generic Clear Glass
6181	Comfort Ti-AC LowE/Arg/Clr 6	1.39	0.25	0.43	0.37	0.32	0.36	0.59	0.29	919	5.6	Comfort Ti-AC LowE on Clear	Arg	12.7	103	5.7	Generic Clear Glass

G-T-C	Name	U-SI	U-IP	SC	SHGC	Tsol	Rfsol	Tvis	Rfvis	Pane #1 Id	Pane #1 Wid	Pane #1 IGDB Glass Name	Gap #1 Gas	Gap #1 Wid	Pane #2 Id	Pane #2 Wid	Pane #2 IGDB Glass Name
Double AFG (cont.)																	
6182	Comfort Ti-PS LowE/Air1/Clr 3	2.34	0.41	0.64	0.56	0.50	0.25	0.77	0.12	921	3.1	Comfort Ti - PS LowE on Clear	Air	6.3	102	3.0	Generic Clear Glass
6183	Comfort Ti-PS LowE/Air1/Clr 6	2.32	0.41	0.61	0.53	0.45	0.21	0.75	0.12	923	5.7	Comfort Ti - PS LowE on Clear	Air	6.3	103	5.7	Generic Clear Glass
6184	Comfort Ti-PS LowE/Air/Clr 3	1.72	0.30	0.63	0.55	0.50	0.25	0.77	0.12	921	3.1	Comfort Ti - PS LowE on Clear	Air	12.7	102	3.0	Generic Clear Glass
6185	Comfort Ti-PS LowE/Air/Clr 6	1.71	0.30	0.61	0.53	0.45	0.21	0.75	0.12	923	5.7	Comfort Ti - PS LowE on Clear	Air	12.7	103	5.7	Generic Clear Glass
6186	Comfort Ti-PS LowE/Arg/Clr 3	1.46	0.26	0.63	0.55	0.50	0.25	0.77	0.12	921	3.1	Comfort Ti - PS LowE on Clear	Arg	12.7	102	3.0	Generic Clear Glass
6187	Comfort Ti -PS LowE/Arg/Clr 6	1.45	0.26	0.60	0.53	0.45	0.21	0.75	0.12	923	5.7	Comfort Ti - PS LowE on Clear	Arg	12.7	103	5.7	Generic Clear Glass
6188	Comfort Ti-R LowE/Air1/Clr 3	2.3	0.41	0.55	0.48	0.43	0.36	0.71	0.21	925	3.2	Comfort Ti-R LowE on Clear	Air	6.3	102	3.0	Generic Clear Glass
6189	Comfort Ti-R LowE/Air1/Clr 6	2.28	0.40	0.50	0.44	0.37	0.30	0.66	0.21	927	5.6	Comfort Ti-R LowE on Clear	Air	6.3	103	5.7	Generic Clear Glass
6190	Comfort Ti-R LowE/Air/Clr 3	1.67	0.29	0.54	0.47	0.43	0.36	0.71	0.21	925	3.2	Comfort Ti-R LowE on Clear	Air	12.7	102	3.0	Generic Clear Glass
6191	Comfort Ti-R LowE/Air/Clr 6	1.65	0.29	0.50	0.43	0.37	0.30	0.66	0.21	927	5.6	Comfort Ti-R LowE on Clear	Air	12.7	103	5.7	Generic Clear Glass
6192	Comfort Ti-R LowE/Arg/Clr 3	1.4	0.25	0.54	0.47	0.43	0.36	0.71	0.21	925	3.2	Comfort Ti-R LowE on Clear	Arg	12.7	102	3.0	Generic Clear Glass
6193	Comfort Ti-R LowE/Arg/Clr 6	1.39	0.25	0.49	0.43	0.37	0.30	0.66	0.21	927	5.6	Comfort Ti-R LowE on Clear	Arg	12.7	103	5.7	Generic Clear Glass
6194	Radiance3.AFG/Air1/Clr 3	2.89	0.51	0.78	0.68	0.62	0.18	0.69	0.26	970	3.1	Radiance3.AFG	Air	6.3	102	3.0	Generic Clear Glass
6195	Radiance3.AFG/Air/Clr 3	2.43	0.43	0.78	0.68	0.62	0.18	0.69	0.26	970	3.1	Radiance3.AFG	Air	12.7	102	3.0	Generic Clear Glass
6196	Radiance3.AFG/Arg/Clr 3	2.26	0.40	0.78	0.68	0.62	0.18	0.69	0.26	970	3.1	Radiance3.AFG	Arg	12.7	102	3.0	Generic Clear Glass
Double Visteon																	
6212	Versalux Brz RC/Air/Clr 6	2.69	0.47	0.36	0.31	0.21	0.28	0.19	0.35	1315	5.7	Versalux Bronze RC	Air	12.7	103	5.7	Generic Clear Glass
6220	Versalux Gry 2000/Air/Clr 6	2.69	0.47	0.23	0.20	0.05	0.04	0.07	0.04	1336	5.7	Versalux Grey 2000	Air	12.7	103	5.7	Generic Clear Glass
6221	Versalux Gry RC/Air/Clr 6	2.69	0.47	0.34	0.30	0.20	0.28	0.16	0.35	1338	5.7	Versalux Grey RC	Air	12.7	103	5.7	Generic Clear Glass
6230	Versalux Grn 2000/Air1/Clr 3	2.72	0.48	0.58	0.51	0.41	0.08	0.69	0.12	1323	3.2	Versalux Green 2000	Air	12.7	102	3.0	Generic Clear Glass
6231	Versalux Grn 2000/Air1/Clr 6	2.69	0.47	0.45	0.40	0.28	0.06	0.59	0.10	1326	5.7	Versalux Green 2000	Air	12.7	103	5.7	Generic Clear Glass
6232	Versalux Grn RC/Air/Clr 6	2.69	0.47	0.33	0.28	0.19	0.28	0.27	0.36	1330	5.7	Versalux Green RC	Air	12.7	103	5.7	Generic Clear Glass
6233	Versalux Grn 2000 R/Air/Clr 6	2.68	0.47	0.26	0.23	0.12	0.28	0.23	0.35	1328	5.9	Versalux Green 2000 R	Air	12.7	103	5.7	Generic Clear Glass
6240	Versalux Blu/Air/Clr 6	2.68	0.47	0.56	0.49	0.37	0.07	0.51	0.08	1305	5.9	Versalux Blue	Air	12.7	103	5.7	Generic Clear Glass
6241	Versalux Blu 2000/Air/Clr 6	2.68	0.47	0.43	0.37	0.25	0.06	0.38	0.07	1302	5.9	Versalux Blue 2000	Air	12.7	103	5.7	Generic Clear Glass
6242	Versalux Blu RC/Air/Clr 6	2.68	0.47	0.35	0.31	0.21	0.28	0.19	0.35	1307	5.9	Versalux Blue RC	Air	12.7	103	5.7	Generic Clear Glass
6243	Versalux Blu2 RC/Air/Clr 6	2.68	0.47	0.26	0.23	0.12	0.28	0.15	0.35	1309	5.9	Versalux Blue RC	Air	12.7	103	5.7	Generic Clear Glass

G-T-C	Name	U-SI	U-IP	SC	SHGC	Tsol	Rfsol	Tvis	Rfvis	Pane #1 Id	Pane #1 Wid	Pane #1 IGDB Glass Name	Gap #1 Gas	Gap #1 Wid	Pane #2 Id	Pane #2 Wid	Pane #2 IGDB Glass Name
Double Cardinal																	
6308	Brz /Air1/LoE 270 Clr 3	2.31	0.41	0.43	0.37	0.26	0.26	0.53	0.09	100	3.1	Generic Bronze Glass	Air	6.3	2026	3.0	LoE 270 on Clear
6309	Brz /Air1/LoE 270 Clr 6	2.28	0.40	0.36	0.32	0.19	0.16	0.41	0.07	101	5.7	Generic Bronze Glass	Air	6.3	2029	6.0	LoE 270 on Clear
6310	Brz /Air/LoE 270 Clr 3	1.67	0.29	0.42	0.37	0.26	0.26	0.53	0.09	100	3.1	Generic Bronze Glass	Air	12.7	2026	3.0	LoE 270 on Clear
6311	Brz /Air/LoE 270 Clr 6	1.65	0.29	0.35	0.30	0.19	0.16	0.41	0.07	101	5.7	Generic Bronze Glass	Air	12.7	2029	6.0	LoE 270 on Clear
6312	Gry /Air1/LoE 270 Clr 3	2.31	0.41	0.41	0.36	0.24	0.24	0.48	0.08	104	3.1	Generic Grey Glass	Air	6.3	2026	3.0	LoE 270 on Clear
6313	Versalux Gry/Air1/LoE 270 Clr 6	2.28	0.40	0.34	0.30	0.17	0.15	0.35	0.06	1334	5.7	Versalux Grey	Air	6.3	2029	6.0	LoE 270 on Clear
6314	Gry /Air/LoE 270 Clr 3	1.67	0.29	0.40	0.35	0.24	0.24	0.48	0.08	104	3.1	Generic Grey Glass	Air	12.7	2026	3.0	LoE 270 on Clear
6315	Versalux Gry/Air/LoE 270 Clr 6	1.65	0.29	0.33	0.28	0.17	0.15	0.35	0.06	1334	5.7	Versalux Grey	Air	12.7	2029	6.0	LoE 270 on Clear
6316	Grn Float /Air1/LoE 270 Clr 3	2.31	0.41	0.46	0.40	0.28	0.18	0.64	0.11	3023	3.0	Green Float Glass	Air	6.3	2026	3.0	LoE 270 on Clear
6317	Grn Float /Air1/LoE 270 Clr 6	2.28	0.40	0.41	0.36	0.23	0.10	0.58	0.10	3026	5.6	Green Float Glass	Air	6.3	2029	6.0	LoE 270 on Clear
6318	Grn Float /Air/LoE 270 Clr 3	1.67	0.29	0.45	0.39	0.28	0.18	0.64	0.11	3023	3.0	Green Float Glass	Air	12.7	2026	3.0	LoE 270 on Clear
6319	Grn Float /Air/LoE 270 Clr 6	1.65	0.29	0.39	0.34	0.23	0.10	0.58	0.10	3026	5.6	Green Float Glass	Air	12.7	2029	6.0	LoE 270 on Clear
6360	LoE 178 Clr/Air1/Clr 3	2.38	0.42	0.67	0.59	0.53	0.24	0.78	0.12	2006	3.0	LoE 178 on Clear	Air	6.3	102	3.0	Generic Clear Glass
6361	LoE 178 Clr/Air1/Clr 6	2.35	0.41	0.63	0.55	0.47	0.20	0.76	0.11	2009	5.7	LoE 178 on Clear	Air	6.3	103	5.7	Generic Clear Glass
6362	LoE 178 Clr/Air/Clr 3	1.77	0.31	0.67	0.58	0.53	0.24	0.78	0.12	2006	3.0	LoE 178 on Clear	Air	12.7	102	3.0	Generic Clear Glass
6363	LoE 178 Clr/Air/Clr 6	1.75	0.31	0.63	0.55	0.47	0.20	0.76	0.11	2009	5.7	LoE 178 on Clear	Air	12.7	103	5.7	Generic Clear Glass
6364	LoE 178 Clr/Arg/Clr 3	1.51	0.27	0.67	0.58	0.53	0.24	0.78	0.12	2006	3.0	LoE 178 on Clear	Arg	12.7	102	3.0	Generic Clear Glass
6365	LoE 178 Clr/Arg/Clr 6	1.5	0.26	0.63	0.55	0.47	0.20	0.76	0.11	2009	5.7	LoE 178 on Clear	Arg	12.7	103	5.7	Generic Clear Glass
6366	LoE-272 Clr/Air1/Clr 3	2.32	0.41	0.49	0.42	0.38	0.35	0.72	0.11	2011	3.0	LoE-272 on 3 mm Clear	Air	6.3	102	3.0	Generic Clear Glass
6367	LoE-272 Clr/Air1/Clr 6	2.29	0.40	0.47	0.41	0.34	0.29	0.69	0.11	2014	5.7	LoE-272 on 6 mm Clear	Air	6.3	103	5.7	Generic Clear Glass
6368	LoE-272 Clr/Air/Clr 3	1.68	0.30	0.48	0.42	0.38	0.35	0.72	0.11	2011	3.0	LoE-272 on 3 mm Clear	Air	12.7	102	3.0	Generic Clear Glass
6369	LoE-272 Clr/Air/Clr 6	1.67	0.29	0.46	0.40	0.34	0.29	0.69	0.11	2014	5.7	LoE-272 on 6 mm Clear	Air	12.7	103	5.7	Generic Clear Glass

G-T-C	Name	U-SI	U-IP	SC	SHGC	Tsol	Rfsol	Tvis	Rfvis	Pane #1 Id	Pane #1 Wid	Pane #1 IGDB Glass Name	Gap #1 Gas	Gap #1 Wid	Pane #2 Id	Pane #2 Wid	Pane #2 IGDB Glass Name
Double Cardinal (cont.)																	
6370	LoE-272 Clr/Arg/Clr 3	1.42	0.25	0.47	0.41	0.38	0.35	0.72	0.11	2011	3.0	LoE-272 on 3 mm Clear	Arg	12.7	102	3.0	Generic Clear Glass
6371	LoE-272 Clr/Arg/Clr 6	1.41	0.25	0.46	0.40	0.34	0.29	0.69	0.11	2014	5.7	LoE-272 on 6 mm Clear	Arg	12.7	103	5.7	Generic Clear Glass
6375	LoE 270 Clr/Air1/Clr 3	2.31	0.41	0.43	0.38	0.34	0.39	0.70	0.12	2026	3.0	LoE 270 on Clear	Air	6.3	102	3.0	Generic Clear Glass
6376	LoE 270 Clr/Air1/Clr 6	2.28	0.40	0.43	0.37	0.31	0.32	0.67	0.12	2029	6.0	LoE 270 on Clear	Air	6.3	103	5.7	Generic Clear Glass
6377	LoE 270 Clr/Air/Clr 3	1.68	0.30	0.48	0.42	0.38	0.35	0.72	0.11	2011	3.0	LoE-272 on 3 mm Clear	Air	12.7	102	3.0	Generic Clear Glass
6378	LoE 270 Clr/Air/Clr 6	1.65	0.29	0.41	0.36	0.31	0.32	0.67	0.12	2029	6.0	LoE 270 on Clear	Air	12.7	103	5.7	Generic Clear Glass
6379	LoE 270 Clr/Arg/Clr 3	1.41	0.25	0.42	0.37	0.34	0.39	0.70	0.12	2026	3.0	LoE 270 on Clear	Arg	12.7	102	3.0	Generic Clear Glass
6380	LoE 270 Clr/Arg/Clr 6	1.39	0.25	0.41	0.36	0.31	0.32	0.67	0.12	2029	6.0	LoE 270 on Clear	Arg	12.7	103	5.7	Generic Clear Glass
6381	LoE 240 Clr/Air1/Clr 3	2.34	0.41	0.32	0.27	0.21	0.31	0.40	0.14	2044	3.0	LoE 240 on Clear	Air	6.3	102	3.0	Generic Clear Glass
6382	LoE 240 Clr/Air1/Clr 6	2.31	0.41	0.30	0.27	0.19	0.27	0.37	0.13	2047	5.7	LoE 240 on Clear	Air	6.3	103	5.7	Generic Clear Glass
6383	LoE 240 Clr/Air/Clr 3	1.71	0.30	0.30	0.26	0.21	0.31	0.40	0.14	2044	3.0	LoE 240 on Clear	Air	12.7	102	3.0	Generic Clear Glass
6384	LoE 240 Clr/Air/Clr 6	1.69	0.30	0.28	0.25	0.19	0.27	0.37	0.13	2047	5.7	LoE 240 on Clear	Air	12.7	103	5.7	Generic Clear Glass
6385	LoE 240 Clr/Arg/Clr 3	1.45	0.26	0.29	0.25	0.21	0.31	0.40	0.14	2044	3.0	LoE 240 on Clear	Arg	12.7	102	3.0	Generic Clear Glass
6386	LoE 240 Clr/Arg/Clr 6	1.44	0.25	0.28	0.24	0.19	0.27	0.37	0.13	2047	5.7	LoE 240 on Clear	Arg	12.7	103	5.7	Generic Clear Glass
6390	LoE2-138 Clr/Air1/Clr 3	2.33	0.41	0.30	0.26	0.20	0.31	0.38	0.13	2092	3.0	LoE2-138 on 3 mm clear	Air	6.3	102	3.0	Generic Clear Glass
6391	LoE2-138 Clr/Air1/Clr 6	2.3	0.41	0.30	0.26	0.18	0.26	0.37	0.12	2095	5.7	LoE2-138 on 6 mm clear	Air	6.3	103	5.7	Generic Clear Glass
6392	LoE2-138 Clr/Air/Clr 3	1.7	0.30	0.28	0.24	0.20	0.31	0.38	0.13	2092	3.0	LoE2-138 on 3 mm clear	Air	12.7	102	3.0	Generic Clear Glass
6393	LoE2-138 Clr/Air/Clr 6	1.68	0.30	0.28	0.24	0.18	0.26	0.37	0.12	2095	5.7	LoE2-138 on 6 mm clear	Air	12.7	103	5.7	Generic Clear Glass
6394	LoE2-138 Clr/Arg/Clr 3	1.44	0.25	0.27	0.24	0.20	0.31	0.38	0.13	2092	3.0	LoE2-138 on 3 mm clear	Arg	12.7	102	3.0	Generic Clear Glass
6395	LoE2-138 Clr/Arg/Clr 6	1.42	0.25	0.27	0.23	0.18	0.26	0.37	0.12	2095	5.7	LoE2-138 on 6 mm clear	Arg	12.7	103	5.7	Generic Clear Glass

G-T-C	Name	U-SI	U-IP	SC	SHGC	Tsol	Rfsol	Tvis	Rfvis	Pane #1 Id	Pane #1 Wid	Pane #1 IGDB Glass Name	Gap #1 Gas	Gap #1 Wid	Pane #2 Id	Pane #2 Wid	Pane #2 IGDB Glass Name
Double Guardian																	
6450	Sun-Guard SN-68 Clr/Air/Clr 6	1.66	0.29	0.43	0.37	0.32	0.30	0.67	0.10	3110	5.6	Sun-Guard SN-68 on Clear	Air	12.7	103	5.7	Generic Clear Glass
6451	Sun-Guard LE63 Clr/Air/Clr 6	1.97	0.35	0.58	0.51	0.42	0.14	0.62	0.13	3122	5.6	Sun-Guard LE63 on Clear	Air	12.7	103	5.7	Generic Clear Glass
6452	Sun-Guard LE63/Air/Clr 6	1.97	0.35	0.39	0.34	0.25	0.08	0.52	0.11	3123	5.6	Sun-Guard LE63 on Green	Air	12.7	103	5.7	Generic Clear Glass
6453	Sun-Guard NP-61 Clr/Air/Clr 6	1.74	0.31	0.46	0.40	0.34	0.29	0.60	0.21	3124	5.6	Sun-Guard NP-61 on Clear	Air	12.7	103	5.7	Generic Clear Glass
6454	Sun-Guard LE-50 Clr/Air/Clr 6	1.9	0.33	0.45	0.39	0.31	0.19	0.50	0.15	3128	5.6	Sun-Guard LE-50 on Clear	Air	12.7	103	5.7	Generic Clear Glass
6455	Sun-Guard LE-50/Air/Clr 6	1.9	0.33	0.33	0.29	0.20	0.09	0.42	0.12	3129	5.6	Sun-Guard LE-50 on Green	Air	12.7	103	5.7	Generic Clear Glass
6456	Sun-Guard AG-43 Clr/Air/Clr 6	1.72	0.30	0.34	0.30	0.24	0.35	0.43	0.31	3130	5.6	Sun-Guard AG-43 on Clear	Air	12.7	103	5.7	Generic Clear Glass
6457	Sun-Guard AG-43/Air/Clr 6	1.72	0.30	0.27	0.23	0.16	0.15	0.37	0.24	3131	5.6	Sun-Guard AG-43 on Green	Air	12.7	103	5.7	Generic Clear Glass
6458	Sun-Guard LE-40 Clr/Air/Clr 6	1.88	0.33	0.36	0.32	0.24	0.22	0.40	0.18	3132	5.6	Sun-Guard LE-40 on Clear	Air	12.7	103	5.7	Generic Clear Glass
6459	Sun-Guard LE-40/Air/Clr 6	1.88	0.33	0.28	0.24	0.16	0.10	0.34	0.15	3133	5.6	Sun-Guard LE-40 on Green	Air	12.7	103	5.7	Generic Clear Glass
6460	Sun-Guard Silver-32/Air/Clr 6	2.4	0.42	0.34	0.30	0.19	0.18	0.28	0.22	3136	5.6	Sun-Guard Silver-32 on Clear	Air	12.7	103	5.7	Generic Clear Glass
6461	Sun-Guard Silver-20/Air/Clr 6	2.26	0.40	0.24	0.21	0.12	0.28	0.18	0.32	3138	5.6	Sun-Guard Silver-20 on Clear	Air	12.7	103	5.7	Generic Clear Glass
6470	Perf Plus II Clr/Air1/Clr 3	2.32	0.41	0.48	0.42	0.37	0.39	0.69	0.19	3213	3.0	Performance Plus II on Clear	Air	6.3	102	3.0	Generic Clear Glass
6471	Perf Plus II Clr/Air1/Clr 6	2.29	0.40	0.46	0.40	0.34	0.33	0.67	0.18	3216	5.6	Performance Plus II on Clear	Air	6.3	103	5.7	Generic Clear Glass
6472	Perf Plus II Clr/Air/Clr 3	1.69	0.30	0.47	0.41	0.37	0.39	0.69	0.19	3213	3.0	Performance Plus II on Clear	Air	12.7	102	3.0	Generic Clear Glass
6473	Perf Plus II Clr/Air/Clr 6	1.67	0.29	0.45	0.40	0.34	0.33	0.67	0.18	3216	5.6	Performance Plus II on Clear	Air	12.7	103	5.7	Generic Clear Glass
6474	Perf Plus II Clr/Arg/Clr 3	1.42	0.25	0.47	0.41	0.37	0.39	0.69	0.19	3213	3.0	Performance Plus II on Clear	Arg	12.7	102	3.0	Generic Clear Glass
6475	Perf Plus II Clr/Arg/Clr 6	1.41	0.25	0.45	0.39	0.34	0.33	0.67	0.18	3216	5.6	Performance Plus II on Clear	Arg	12.7	103	5.7	Generic Clear Glass
6480	Perf Plus II Grn/Air1/Clr 3	2.32	0.41	0.42	0.36	0.29	0.19	0.63	0.16	3223	3.0	Performance Plus II Green	Air	6.3	102	3.0	Generic Clear Glass
6481	Perf Plus II Grn/Air1/Clr 6	2.29	0.40	0.37	0.32	0.23	0.12	0.56	0.14	3226	5.6	Performance Plus II Green	Air	6.3	103	5.7	Generic Clear Glass
6482	Perf Plus II Grn/Air/Clr 3	1.69	0.30	0.40	0.35	0.29	0.19	0.63	0.16	3223	3.0	Performance Plus II Green	Air	12.7	102	3.0	Generic Clear Glass
6483	Perf Plus II Grn/Air/Clr 6	1.67	0.29	0.34	0.30	0.23	0.12	0.56	0.14	3226	5.6	Performance Plus II Green	Air	12.7	103	5.7	Generic Clear Glass
6484	Perf Plus II Grn/Arg/Clr 3	1.42	0.25	0.39	0.34	0.29	0.19	0.63	0.16	3223	3.0	Performance Plus II Green	Arg	12.7	102	3.0	Generic Clear Glass
6485	Perf Plus II Grn/Arg/Clr 6	1.41	0.25	0.33	0.29	0.23	0.12	0.56	0.14	3226	5.6	Performance Plus II Green	Arg	12.7	103	5.7	Generic Clear Glass

G-T-C	Name	U-SI	U-IP	SC	SHGC	Tsol	Rfsol	Tvis	Rfvis	Pane #1 Id	Pane #1 Wid	Pane #1 IGDB Glass Name	Gap #1 Gas	Gap #1 Wid	Pane #2 Id	Pane #2 Wid	Pane #2 IGDB Glass Name
Double PPG																	
6501	Starphire/Air/Clr 6	2.69	0.47	0.90	0.78	0.69	0.14	0.81	0.15	5004	5.7	Starphire	Air	12.7	103	5.7	Generic Clear Glass
6502	SB 60 on Starphire/Air/Clr 6	1.65	0.29	0.45	0.40	0.35	0.43	0.72	0.11	5349	5.7	Solarban 60 on Starphire	Air	12.7	103	5.7	Generic Clear Glass
6503	SB 70XL on Starphire/Air/Clr 6	1.64	0.29	0.32	0.28	0.24	0.51	0.64	0.11	5000	5.7	Solarban 70XL on Starphire	Air	12.7	103	5.7	Generic Clear Glass
6511	Solarcool SolarBrz/Air/Clr 6	2.69	0.47	0.35	0.30	0.21	0.31	0.18	0.37	5108	5.7	Solarcool Solarbronze	Air	12.7	103	5.7	Generic Clear Glass
6521	Solargray/Air/Clr 6	2.69	0.47	0.52	0.45	0.33	0.07	0.40	0.07	5052	5.7	Solargray	Air	12.7	103	5.7	Generic Clear Glass
6522	Graylite/Air/Clr 6	2.69	0.47	0.39	0.34	0.19	0.05	0.12	0.05	5057	5.7	Graylite	Air	12.7	103	5.7	Generic Clear Glass
6523	Solarcool Solargray/Air/Clr 6	2.69	0.47	0.31	0.27	0.17	0.30	0.15	0.37	5120	5.7	Solarcool Solargray	Air	12.7	103	5.7	Generic Clear Glass
6524	Optigray/Air/Clr 6	2.69	0.47	0.34	0.29	0.15	0.05	0.21	0.05	5294	5.7	Optigray 23	Air	12.7	103	5.7	Generic Clear Glass
6525	SB 60 on Solargray/Air/Clr 3	1.66	0.29	0.34	0.30	0.23	0.20	0.48	0.08	5286	3.3	Solarban 60 on Solargray	Air	12.7	103	5.7	Generic Clear Glass
6531	SolarGrn/Air/Clr 6	2.69	0.47	0.46	0.40	0.29	0.06	0.60	0.11	5028	5.7	Solargreen	Air	12.7	103	5.7	Generic Clear Glass
6541	Azurlite/Air/Clr 6	2.69	0.47	0.41	0.36	0.19	0.06	0.48	0.10	5036	5.7	Azurlite	Air	12.7	5036	5.7	Azurlite
6542	Caribia/Air/Clr 6	2.69	0.47	0.41	0.36	0.18	0.06	0.47	0.10	5326	5.7	Caribia	Air	12.7	5036	5.7	Azurlite
6544	Solarcool Caribia/Air/Clr 6	2.69	0.47	0.25	0.21	0.12	0.30	0.23	0.37	5336	5.7	Solarcool Caribia	Air	12.7	103	5.7	Generic Clear Glass
6560	Sungate 100 Clr/Air1/Clr 3	3.09	0.54	0.64	0.55	0.49	0.29	0.75	0.10	5142	3.3	Sungate 100 on Clear	Air	6.3	102	3.0	Generic Clear Glass
6561	Sungate 100 Clr/Air1/Clr 6	3.04	0.54	0.60	0.52	0.44	0.29	0.73	0.10	5148	5.7	Sungate 100 on Clear	Air	6.3	103	5.7	Generic Clear Glass
6562	Sungate 100 Clr/Air/Clr 3	2.7	0.48	0.63	0.55	0.49	0.29	0.75	0.10	5142	3.3	Sungate 100 on Clear	Air	12.7	102	3.0	Generic Clear Glass
6563	Sungate 100 Clr/Air/Clr 6	2.67	0.47	0.60	0.52	0.44	0.29	0.73	0.10	5148	5.7	Sungate 100 on Clear	Air	12.7	103	5.7	Generic Clear Glass
6564	Sungate 100 Clr/Arg/Clr 3	2.56	0.45	0.63	0.55	0.49	0.29	0.75	0.10	5142	3.3	Sungate 100 on Clear	Arg	12.7	102	3.0	Generic Clear Glass
6565	Sungate 100 Clr/Arg/Clr 6	2.53	0.45	0.60	0.52	0.44	0.29	0.73	0.10	5148	5.7	Sungate 100 on Clear	Arg	12.7	103	5.7	Generic Clear Glass

G-T-C	Name	U-SI	U-IP	SC	SHGC	Tsol	Rfsol	Tvis	Rfvis	Pane #1 Id	Pane #1 Wid	Pane #1 IGDB Glass Name	Gap #1 Gas	Gap #1 Wid	Pane #2 Id	Pane #2 Wid	Pane #2 IGDB Glass Name
Double PPG (cont.)																	
6570	Sungate 500 Clr/Air1/Clr 3	2.55	0.45	0.76	0.66	0.60	0.15	0.76	0.17	5242	3.3	Sungate 500 on Clear	Air	6.3	102	3.0	Generic Clear Glass
6571	Sungate 500 Clr/Air1/Clr 6	2.52	0.44	0.71	0.62	0.52	0.13	0.73	0.16	5248	5.7	Sungate 500 on Clear	Air	6.3	103	5.7	Generic Clear Glass
6572	Sungate 500 Clr/Air/Clr 3	1.99	0.35	0.76	0.66	0.60	0.15	0.76	0.17	5242	3.3	Sungate 500 on Clear	Air	12.7	102	3.0	Generic Clear Glass
6573	Sungate 500 Clr/Air/Clr 6	1.97	0.35	0.71	0.62	0.52	0.13	0.73	0.16	5248	5.7	Sungate 500 on Clear	Air	12.7	103	5.7	Generic Clear Glass
6574	Sungate 500 Clr/Arg/Clr 3	1.77	0.31	0.76	0.66	0.60	0.15	0.76	0.17	5242	3.3	Sungate 500 on Clear	Arg	12.7	102	3.0	Generic Clear Glass
6575	Sungate 500 Clr/Arg/Clr 6	1.76	0.31	0.71	0.62	0.52	0.13	0.73	0.16	5248	5.7	Sungate 500 on Clear	Arg	12.7	103	5.7	Generic Clear Glass
6576	Clr/Air/Sungate 500 Clr 3	1.99	0.35	0.81	0.71	0.60	0.17	0.76	0.18	102	3.0	Generic Clear Glass	Air	12.7	5242	3.3	Sungate 500 on Clear
6577	Clr/Air/Sungate 500 Clr 6	1.97	0.35	0.75	0.66	0.52	0.15	0.73	0.17	103	5.7	Generic Clear Glass	Air	12.7	5248	5.7	Sungate 500 on Clear
6578	Clr/Arg/Sungate 500 Clr 3	1.77	0.31	0.82	0.71	0.60	0.17	0.76	0.18	102	3.0	Generic Clear Glass	Arg	12.7	5242	3.3	Sungate 500 on Clear
6579	Clr/Arg/Sungate 500 Clr 6	1.76	0.31	0.76	0.66	0.52	0.15	0.73	0.17	103	5.7	Generic Clear Glass	Arg	12.7	5248	5.7	Sungate 500 on Clear
6580	Solarban 60 Clr/Air1/Clr 3	2.3	0.41	0.46	0.40	0.35	0.35	0.72	0.11	5281	3.3	Solarban 60 on Clear	Air	6.3	102	3.0	Generic Clear Glass
6581	Solarban 60 Clr/Air1/Clr 6	2.28	0.40	0.45	0.39	0.33	0.29	0.70	0.11	5284	5.7	Solarban 60 on Clear	Air	6.3	103	5.7	Generic Clear Glass
6582	Solarban 60 Clr/Air/Clr 3	1.67	0.29	0.45	0.39	0.35	0.35	0.72	0.11	5281	3.3	Solarban 60 on Clear	Air	12.7	102	3.0	Generic Clear Glass
6583	Solarban 60 Clr/Air/Clr 6	1.65	0.29	0.44	0.38	0.33	0.29	0.70	0.11	5284	5.7	Solarban 60 on Clear	Air	12.7	103	5.7	Generic Clear Glass
6584	Solarban 60 Clr/Arg/Clr 3	1.4	0.25	0.44	0.39	0.35	0.35	0.72	0.11	5281	3.3	Solarban 60 on Clear	Arg	12.7	102	3.0	Generic Clear Glass
6585	Solarban 60 Clr/Arg/Clr 6	1.39	0.25	0.43	0.38	0.33	0.29	0.70	0.11	5284	5.7	Solarban 60 on Clear	Arg	12.7	103	5.7	Generic Clear Glass
6590	Solarban 80 Clr/Air1/Clr 3	2.29	0.40	0.29	0.25	0.21	0.44	0.49	0.33	5313	3.3	SOLARBAN 80 on clear	Air	6.3	102	3.0	Generic Clear Glass
6591	Solarban 80 Clr/Air1/Clr 6	2.26	0.40	0.29	0.25	0.19	0.38	0.47	0.33	5316	5.7	SOLARBAN 80 on clear	Air	6.3	103	5.7	Generic Clear Glass
6592	Solarban 80 Clr/Air/Clr 3	1.65	0.29	0.28	0.24	0.21	0.44	0.49	0.33	5313	3.3	SOLARBAN 80 on clear	Air	12.7	102	3.0	Generic Clear Glass
6593	Solarban 80 Clr/Air/Clr 6	1.63	0.29	0.27	0.24	0.19	0.38	0.47	0.33	5316	5.7	SOLARBAN 80 on clear	Air	12.7	103	5.7	Generic Clear Glass
6594	Solarban 80 Clr/Arg/Clr 3	1.38	0.24	0.27	0.23	0.21	0.44	0.49	0.33	5313	3.3	SOLARBAN 80 on clear	Arg	12.7	102	3.0	Generic Clear Glass
6595	Solarban 80 Clr/Arg/Clr 6	1.37	0.24	0.27	0.23	0.19	0.38	0.47	0.33	5316	5.7	SOLARBAN 80 on clear	Arg	12.7	103	5.7	Generic Clear Glass

G-T-C	Name	U-SI	U-IP	SC	SHGC	Tsol	Rfsol	Tvis	Rfvis	Pane #1 Id	Pane #1 Wid	Pane #1 IGDB Glass Name	Gap #1 Gas	Gap #1 Wid	Pane #2 Id	Pane #2 Wid	Pane #2 IGDB Glass Name
Double Viracon																	
6600	VE12M Clr/Air/Clr 6	1.66	0.29	0.43	0.38	0.33	0.31	0.70	0.11	6046	5.7	LowE on Clear	Air	12.7	103	5.7	Generic Clear Glass
6601	VE140 Clr/Air/Clr 6	1.76	0.31	0.32	0.28	0.21	0.25	0.36	0.15	6047	5.7	LowE on Clear	Air	12.7	103	5.7	Generic Clear Glass
6602	VE152/Air/Clr 6	1.78	0.31	0.46	0.40	0.32	0.20	0.50	0.16	6048	5.7	LowE on Clear	Air	12.7	103	5.7	Generic Clear Glass
6603	VE155 Clr/Air/Clr 6	1.76	0.31	0.40	0.35	0.28	0.22	0.47	0.11	6049	5.7	LowE on Clear	Air	12.7	103	5.7	Generic Clear Glass
6604	VE185 Clr/Air/Clr 6	1.75	0.31	0.62	0.54	0.47	0.21	0.76	0.12	6050	5.7	LowE on Clear	Air	12.7	103	5.7	Generic Clear Glass
6610	VE42M Brz/Air/Clr 6	1.66	0.29	0.30	0.27	0.20	0.15	0.41	0.07	6061	5.7	LowE on Bronze	Air	12.7	103	5.7	Generic Clear Glass
6611	VE440 Brz/Air/Clr 6	1.76	0.31	0.24	0.21	0.13	0.13	0.22	0.08	6062	5.7	LowE on Bronze	Air	12.7	103	5.7	Generic Clear Glass
6612	VE452 Brz/Air/Clr 6	1.78	0.31	0.32	0.28	0.20	0.11	0.30	0.08	6063	5.7	LowE on Bronze	Air	12.7	103	5.7	Generic Clear Glass
6613	VE455 Brz/Air/Clr 6	1.76	0.31	0.29	0.25	0.17	0.12	0.27	0.07	6064	5.7	LowE on Bronze	Air	12.7	103	5.7	Generic Clear Glass
6614	VE485 Brz/Air/Clr 6	1.75	0.31	0.43	0.37	0.28	0.11	0.45	0.07	6065	5.7	LowE on Bronze	Air	12.7	103	5.7	Generic Clear Glass
6620	VE32M Gry/Air/Clr 6	1.66	0.29	0.28	0.24	0.17	0.12	0.35	0.06	6056	5.7	LowE on Gray	Air	12.7	103	5.7	Generic Clear Glass
6621	VE340 Gry/Air/Clr 6	1.76	0.31	0.22	0.19	0.11	0.11	0.18	0.07	6057	5.7	LowE on Gray	Air	12.7	103	5.7	Generic Clear Glass
6622	VE352 Gry/Air/Clr 6	1.78	0.31	0.29	0.26	0.17	0.09	0.25	0.07	6058	5.7	LowE on Gray	Air	12.7	103	5.7	Generic Clear Glass
6623	VE355 Gry/Air/Clr 6	1.76	0.31	0.26	0.23	0.14	0.10	0.23	0.06	6059	5.7	LowE on Gray	Air	12.7	103	5.7	Generic Clear Glass
6624	VE385 Gry/Air/Clr 6	1.75	0.31	0.38	0.33	0.25	0.10	0.38	0.07	6060	5.7	LowE on Gray	Air	12.7	103	5.7	Generic Clear Glass
6630	VE22M Grn/Air/Clr 6	1.66	0.29	0.36	0.31	0.24	0.10	0.60	0.09	6051	5.7	LowE on Green	Air	12.7	103	5.7	Generic Clear Glass
6631	VE240 Grn/Air/Clr 6	1.76	0.31	0.26	0.22	0.14	0.10	0.32	0.12	6052	5.7	LowE on Green	Air	12.7	103	5.7	Generic Clear Glass
6632	VE252 Grn/Air/Clr 6	1.78	0.31	0.34	0.29	0.21	0.09	0.43	0.12	6053	5.7	LowE on Green	Air	12.7	103	5.7	Generic Clear Glass
6633	VE255 Grn/Air/Clr 6	1.76	0.31	0.30	0.26	0.18	0.09	0.40	0.10	6054	5.7	LowE on Green	Air	12.7	103	5.7	Generic Clear Glass
6634	VE285 Grn/Air/Clr 6	1.75	0.31	0.45	0.39	0.31	0.09	0.65	0.10	6055	5.7	LowE on Green	Air	12.7	103	5.7	Generic Clear Glass

G-T-C	Name	U-SI	U-IP	SC	SHGC	Tsol	Rfsol	Tvis	Rfvis	Pane #1 Id	Pane #1 Wid	Pane #1 IGDB Glass Name	Gap #1 Gas	Gap #1 Wid	Pane #2 Id	Pane #2 Wid	Pane #2 IGDB Glass Name
Double Pilkington																	
6820	SuperGry/Air1/Clr 3	3.12	0.55	0.38	0.33	0.19	0.05	0.23	0.05	9891	3.2	SuperGrey	Air	6.3	102	3.0	Generic Clear Glass
6821	SuperGry/Air1/Clr 6	3.07	0.54	0.26	0.22	0.06	0.04	0.08	0.04	9894	5.7	SuperGrey	Air	6.3	103	5.7	Generic Clear Glass
6822	SuperGry/Air/Clr 3	2.72	0.48	0.37	0.32	0.19	0.05	0.23	0.05	9891	3.2	SuperGrey	Air	12.7	102	3.0	Generic Clear Glass
6823	SuperGry/Air/Clr 6	2.69	0.47	0.24	0.21	0.06	0.04	0.08	0.04	9894	5.7	SuperGrey	Air	12.7	103	5.7	Generic Clear Glass
6824	SuperGry/Air1/Energy Adv LowE 3	2.48	0.44	0.33	0.28	0.16	0.05	0.21	0.05	9891	3.2	SuperGrey	Air	6.3	9921	3.0	Energy AdvantageLow-E
6825	SuperGry/Air1/Energy Adv LowE 6	2.45	0.43	0.21	0.18	0.05	0.04	0.07	0.04	9894	5.7	SuperGrey	Air	6.3	9924	5.6	Energy AdvantageLow-E
6826	SuperGry/Air/Energy Adv LowE 3	1.9	0.33	0.30	0.26	0.16	0.05	0.21	0.05	9891	3.2	SuperGrey	Air	12.7	9921	3.0	Energy AdvantageLow-E
6827	SuperGry/Air/Energy Adv LowE 6	1.88	0.33	0.18	0.15	0.05	0.04	0.07	0.04	9894	5.7	SuperGrey	Air	12.7	9924	5.6	Energy AdvantageLow-E
6828	SuperGry/Arg/Energy Adv LowE 3	1.66	0.29	0.29	0.25	0.16	0.05	0.21	0.05	9891	3.2	SuperGrey	Arg	12.7	9921	3.0	Energy AdvantageLow-E
6829	SuperGry/Arg/Energy Adv LowE 6	1.65	0.29	0.16	0.14	0.05	0.04	0.07	0.04	9894	5.7	SuperGrey	Arg	12.7	9924	5.6	Energy AdvantageLow-E
6830	EverGrn/Air1/Clr 3	3.12	0.55	0.59	0.52	0.42	0.08	0.69	0.12	9881	3.2	EverGreen	Air	6.3	102	3.0	Generic Clear Glass
6831	EverGrn/Air1/Clr 6	3.06	0.54	0.47	0.41	0.28	0.06	0.58	0.10	9889	5.9	EverGreen	Air	6.3	103	5.7	Generic Clear Glass
6832	EverGrn/Air/Clr 3	2.72	0.48	0.59	0.51	0.42	0.08	0.69	0.12	9881	3.2	EverGreen	Air	12.7	102	3.0	Generic Clear Glass
6833	EverGrn/Air/Clr 6	2.68	0.47	0.46	0.40	0.28	0.06	0.58	0.10	9889	5.9	EverGreen	Air	12.7	103	5.7	Generic Clear Glass
6834	EverGrn/Air1/Energy Adv LowE 3	2.48	0.44	0.53	0.47	0.35	0.09	0.64	0.14	9881	3.2	EverGreen	Air	6.3	9921	3.0	Energy AdvantageLow-E
6835	EverGrn/Air1/Energy Adv LowE 6	2.45	0.43	0.42	0.36	0.24	0.07	0.54	0.11	9889	5.9	EverGreen	Air	6.3	9924	5.6	Energy AdvantageLow-E
6836	EverGrn/Air/Energy Adv LowE 3	1.9	0.33	0.52	0.46	0.35	0.09	0.64	0.14	9881	3.2	EverGreen	Air	12.7	9921	3.0	Energy AdvantageLow-E
6837	EverGrn/Air/Energy Adv LowE 6	1.88	0.33	0.40	0.35	0.24	0.07	0.54	0.11	9889	5.9	EverGreen	Air	12.7	9924	5.6	Energy AdvantageLow-E
6838	EverGrn/Arg/Energy Adv LowE 3	1.66	0.29	0.52	0.45	0.35	0.09	0.64	0.14	9881	3.2	EverGreen	Arg	12.7	9921	3.0	Energy AdvantageLow-E
6839	EverGrn/Arg/Energy Adv LowE 6	1.65	0.29	0.39	0.34	0.24	0.07	0.54	0.11	9889	5.9	EverGreen	Arg	12.7	9924	5.6	Energy AdvantageLow-E

G-T-C	Name	U-SI	U-IP	SC	SHGC	Tsol	Rfsol	Tvis	Rfvis	Pane #1 Id	Pane #1 Wid	Pane #1 IGDB Glass Name	Gap #1 Gas	Gap #1 Wid	Pane #2 Id	Pane #2 Wid	Pane #2 IGDB Glass Name
Double Pilkington (cont.)																	
6840	Arctic Blu/Air1/Clr 6	3.06	0.54	0.46	0.40	0.27	0.06	0.47	0.08	9989	5.9	Arctic Blue	Air	6.3	103	5.7	Generic Clear Glass
6841	Arctic Blu/Air/Clr 6	2.68	0.47	0.45	0.39	0.27	0.06	0.47	0.08	9989	5.9	Arctic Blue	Air	12.7	103	5.7	Generic Clear Glass
6842	Arctic Blu/Air1/Energy Adv LoE 6	2.45	0.43	0.41	0.36	0.23	0.07	0.43	0.09	9989	5.9	Arctic Blue	Air	6.3	9924	5.6	Energy AdvantageLow-E
6843	Arctic Blu/Air/Energy Adv LowE 6	1.88	0.33	0.39	0.34	0.23	0.07	0.43	0.09	9989	5.9	Arctic Blue	Air	12.7	9924	5.6	Energy AdvantageLow-E
6844	Arctic Blu/Arg/Energy Adv LowE 6	1.65	0.29	0.38	0.33	0.23	0.07	0.43	0.09	9989	5.9	Arctic Blue	Arg	12.7	9924	5.6	Energy AdvantageLow-E
6845	Optifloat Blu-Grn/Air1/Clr 6	3.06	0.54	0.58	0.51	0.39	0.08	0.67	0.12	9879	5.9	Optifloat Blue-Green	Air	6.3	103	5.7	Generic Clear Glass
6846	Optifloat Blu-Grn/Air/Clr 6	2.68	0.47	0.58	0.50	0.39	0.08	0.67	0.12	9879	5.9	Optifloat Blue-Green	Air	12.7	103	5.7	Generic Clear Glass
6847	Opti BluGrn/Air1/EnergyAdv LoE 6	2.45	0.43	0.53	0.46	0.34	0.09	0.62	0.13	9879	5.9	Optifloat Blue-Green	Air	6.3	9924	5.6	Energy AdvantageLow-E
6848	Opti BluGrn/Air/EnergyAdv LowE 6	1.88	0.33	0.52	0.45	0.34	0.09	0.62	0.13	9879	5.9	Optifloat Blue-Green	Air	12.7	9924	5.6	Energy AdvantageLow-E
6849	Opti BluGrn/Arg/EnergyAdv LowE 6	1.65	0.29	0.52	0.45	0.34	0.09	0.62	0.13	9879	5.9	Optifloat Blue-Green	Arg	12.7	9924	5.6	Energy AdvantageLow-E
6850	Eclipse AdvClr/Air/Clr 6	1.96	0.35	0.63	0.55	0.46	0.21	0.60	0.29	9909	5.9	Eclipse AdvantageClear	Air	12.7	103	5.7	Generic Clear Glass
6851	Eclipse AdvBrz/Air/Clr 6	1.96	0.35	0.43	0.38	0.28	0.11	0.34	0.13	9908	5.9	Eclipse AdvantageBronze	Air	12.7	103	5.7	Generic Clear Glass
6852	Eclipse AdvGry/Air/Clr 6	1.96	0.35	0.38	0.33	0.23	0.09	0.29	0.11	9911	5.9	Eclipse AdvantageGrey	Air	12.7	103	5.7	Generic Clear Glass
6853	Eclipse AdvEverGrn/Air/Clr 6	1.96	0.35	0.33	0.29	0.20	0.09	0.43	0.17	9910	5.9	Eclipse AdvantageEverGreen	Air	12.7	103	5.7	Generic Clear Glass
6854	Eclipse AdvArctic Blu/Air/Clr 6	1.96	0.35	0.33	0.29	0.19	0.09	0.35	0.13	9906	5.9	Eclipse Advantagerctic Blue	Air	12.7	103	5.7	Generic Clear Glass
6855	Eclipse AdvBlu-Grn/Air/Clr 6	1.96	0.35	0.44	0.38	0.29	0.12	0.51	0.21	9907	5.9	Eclipse AdvantageBlue-Green	Air	12.7	103	5.7	Generic Clear Glass

									Pane #1		Pane #1 IGDB	Gap #1		Pane #2		Pane #2 IGDB
G-T-C	Name	U-SI	U-IP	SC	SHGC	Tsol	Rfsol	Tvis	Rfvis	Id	Wid		Gas	Wid	Id	Wid	
												Glass Name					Glass Name
Double Pilkington (cont.)																	
6860	Energy Adv Low-E/Air1/Clr 3	2.48	0.44	0.75	0.65	0.59	0.15	0.75	0.17	9921	3.0	Energy AdvantageLow-E	Air	6.3	102	3.0	Generic Clear Glass
6861	Energy Adv Low-E/Air1/Clr 6	2.45	0.43	0.71	0.62	0.52	0.13	0.73	0.16	9924	5.6	Energy AdvantageLow-E	Air	6.3	103	5.7	Generic Clear Glass
6862	Energy Adv Low-E/Air/Clr 3	1.9	0.33	0.75	0.65	0.59	0.15	0.75	0.17	9921	3.0	Energy AdvantageLow-E	Air	12.7	102	3.0	Generic Clear Glass
6863	Energy Adv Low-E/Air/Clr 6	1.88	0.33	0.71	0.62	0.52	0.13	0.73	0.16	9924	5.6	Energy AdvantageLow-E	Air	12.7	103	5.7	Generic Clear Glass
6864	Energy Adv Low-E/Arg/Clr 3	1.66	0.29	0.75	0.65	0.59	0.15	0.75	0.17	9921	3.0	Energy AdvantageLow-E	Arg	12.7	102	3.0	Generic Clear Glass
6865	Energy Adv Low-E/Arg/Clr 6	1.65	0.29	0.71	0.62	0.52	0.13	0.73	0.16	9924	5.6	Energy AdvantageLow-E	Arg	12.7	103	5.7	Generic Clear Glass
6866	Clr/Air1/Energy Adv LowE 3	2.48	0.44	0.80	0.70	0.59	0.16	0.75	0.18	102	3.0	Generic Clear Glass	Air	6.3	9921	3.0	Energy AdvantageLow-E
6867	Clr/Air1/Energy Adv LowE 6	2.45	0.43	0.75	0.65	0.52	0.14	0.73	0.17	103	5.7	Generic Clear Glass	Air	6.3	9924	5.6	Energy AdvantageLow-E
6868	Clr/Air/Energy Adv LowE 3	1.9	0.33	0.81	0.71	0.59	0.16	0.75	0.18	102	3.0	Generic Clear Glass	Air	12.7	9921	3.0	Energy AdvantageLow-E
6869	Clr/Air/Energy Adv LowE 6	1.88	0.33	0.76	0.66	0.52	0.14	0.73	0.17	103	5.7	Generic Clear Glass	Air	12.7	9924	5.6	Energy AdvantageLow-E
6870	Clr/Arg/Energy Adv LowE 3	1.66	0.29	0.82	0.71	0.59	0.16	0.75	0.18	102	3.0	Generic Clear Glass	Arg	12.7	9921	3.0	Energy AdvantageLow-E
6871	Clr/Arg/Energy Adv LowE 6	1.65	0.29	0.77	0.67	0.52	0.14	0.73	0.17	103	5.7	Generic Clear Glass	Arg	12.7	9924	5.6	Energy AdvantageLow-E
6875	Solar E/Air1/Clr 3	2.47	0.44	0.57	0.49	0.41	0.10	0.54	0.11	9931	3.0	Solar E	Air	6.3	102	3.0	Generic Clear Glass
6876	Solar E/Air1/Clr 6	2.45	0.43	0.54	0.47	0.36	0.09	0.54	0.10	9935	5.7	Solar E	Air	6.3	103	5.7	Generic Clear Glass
6877	Solar E/Air/Clr 3	1.89	0.33	0.55	0.48	0.41	0.10	0.54	0.11	9931	3.0	Solar E	Air	12.7	102	3.0	Generic Clear Glass
6878	Solar E/Air/Clr 6	1.88	0.33	0.53	0.46	0.36	0.09	0.54	0.10	9935	5.7	Solar E	Air	12.7	103	5.7	Generic Clear Glass
6879	Solar E/Arg/Clr 3	1.66	0.29	0.55	0.48	0.41	0.10	0.54	0.11	9931	3.0	Solar E	Arg	12.7	102	3.0	Generic Clear Glass
6880	Solar E/Arg/Clr 6	1.66	0.29	0.52	0.45	0.36	0.09	0.54	0.10	9935	5.7	Solar E	Arg	12.7	103	5.7	Generic Clear Glass
6890	Activ Clr/Air/Clr 3	2.73	0.48	0.84	0.73	0.68	0.17	0.76	0.21	9937	3.0	Activon Clear	Air	12.7	102	3.0	Generic Clear Glass
6891	Activ Clr/Air/Clr 6	2.69	0.47	0.78	0.68	0.59	0.16	0.74	0.21	9941	5.6	Activon Clear	Air	12.7	103	5.7	Generic Clear Glass

G-T-C	Name	U-SI	U-IP	SC	SHGC	Tsol	Rfsol	Tvis	Rfvis	Pane #1 Id	Pane #1 Wid	Pane #1 IGDB Glass Name	Gap #1 Gas	Gap #1 Wid	Pane #2 Id	Pane #2 Wid	Pane #2 IGDB Glass Name	Gap #2 Gas	Gap #2 Wid	Pane #3 Id	Pane #3 Wid	Pane #3 IGDB Glass Name
Triple Clr/Tint New																						
7000	Clr/Air1/Clr /Air1/Clr 3	2.14	0.38	0.78	0.68	0.60	0.17	0.74	0.21	102	3.0	Generic Clear Glass	Air	6.3	102	3.0	Generic Clear Glass	Air	6.3	102	3.0	Generic Clear Glass
7001	Clr/Air/Clr /Air/Clr 3	1.77	0.31	0.78	0.68	0.60	0.17	0.74	0.21	102	3.0	Generic Clear Glass	Air	12.7	102	3.0	Generic Clear Glass	Air	12.7	102	3.0	Generic Clear Glass
7002	Clr/Arg/Clr /Arg/Clr 3	1.64	0.29	0.79	0.68	0.60	0.17	0.74	0.21	102	3.0	Generic Clear Glass	Arg	-0.1	102	3.0	Generic Clear Glass	Arg	-0.1	102	3.0	Generic Clear Glass

G-T-C	Name	U-SI	U-IP	SC	SHGC	Tsol	Rfsol	Tvis	Rfvis	Pane #1 Id	Pane #1 Wid	Pane #1 IGDB Glass Name	Gap #1 Gas	Gap #1 Wid	Pane #2 Id	Pane #2 Wid	Pane #2 IGDB Glass Name	Gap #2 Gas	Gap #2 Wid	Pane #3 Id	Pane #3 Wid	Pane #3 IGDB Glass Name
Triple Southwall																						
7054	Clr/Air1/HM44 Susp/Air1/Clr 6	1.71	0.30	0.28	0.24	0.17	0.50	0.37	0.48	103	5.7	Generic Clear Glass	Air	6.3	1502	0.1	Heat Mirror44 Susp Film	Air	6.3	103	5.7	Generic Clear Glass
7055	Clr/Air/HM44 Susp/Air/Clr 6	1.36	0.24	0.28	0.24	0.17	0.50	0.37	0.48	103	5.7	Generic Clear Glass	Air	9.5	1502	0.1	Heat Mirror44 Susp Film	Air	9.5	103	5.7	Generic Clear Glass
7056	Clr/Air1/HM55 Susp/Air1/Clr 6	1.71	0.30	0.34	0.29	0.21	0.45	0.45	0.39	103	5.7	Generic Clear Glass	Air	6.3	1503	0.1	Heat Mirror55 Susp Film	Air	6.3	103	5.7	Generic Clear Glass
7057	Clr/Air/HM55 Susp/Air/Clr 6	1.37	0.24	0.34	0.29	0.21	0.45	0.45	0.39	103	5.7	Generic Clear Glass	Air	9.5	1503	0.1	Heat Mirror55 Susp Film	Air	9.5	103	5.7	Generic Clear Glass
7058	Clr/Air1/HM66 Susp/Air1/Clr 6	1.72	0.30	0.39	0.34	0.26	0.40	0.53	0.32	103	5.7	Generic Clear Glass	Air	6.3	1504	0.1	Heat Mirror66 Susp Film	Air	6.3	103	5.7	Generic Clear Glass
7059	Clr/Air/HM66 Susp/Air/Clr 6	1.38	0.24	0.39	0.34	0.26	0.40	0.53	0.32	103	5.7	Generic Clear Glass	Air	9.5	1504	0.1	Heat Mirror66 Susp Film	Air	9.5	103	5.7	Generic Clear Glass
7060	Clr/Air1/HM77 Susp/Air1/Clr 6	1.74	0.31	0.49	0.43	0.33	0.32	0.63	0.22	103	5.7	Generic Clear Glass	Air	6.3	1505	0.1	Heat Mirror77 Susp Film	Air	6.3	103	5.7	Generic Clear Glass
7061	Clr/Air/HM77 Susp/Air/Clr 6	1.41	0.25	0.50	0.43	0.33	0.32	0.63	0.22	103	5.7	Generic Clear Glass	Air	9.5	1505	0.1	Heat Mirror77 Susp Film	Air	9.5	103	5.7	Generic Clear Glass
7062	Clr/Air1/HM88 Susp/Air1/Clr 6	1.78	0.31	0.62	0.54	0.43	0.22	0.70	0.18	103	5.7	Generic Clear Glass	Air	6.3	1506	0.1	Heat Mirror88 Susp Film	Air	6.3	103	5.7	Generic Clear Glass
7063	Clr/Air/HM88 Susp/Air/Clr 6	1.46	0.26	0.62	0.54	0.43	0.22	0.70	0.18	103	5.7	Generic Clear Glass	Air	9.5	1506	0.1	Heat Mirror88 Susp Film	Air	9.5	103	5.7	Generic Clear Glass
7064	Clr/Air1/SC75 Susp/Air1/Clr 6	1.7	0.30	0.41	0.36	0.28	0.34	0.60	0.22	103	5.7	Generic Clear Glass	Air	6.3	1510	0.1	Heat MirrorSingle Coat 75 Susp	Air	6.3	103	5.7	Generic Clear Glass
7065	Clr/Air/SC75 Susp/Air/Clr 6	1.36	0.24	0.40	0.35	0.28	0.34	0.60	0.22	103	5.7	Generic Clear Glass	Air	9.5	1510	0.1	Heat MirrorSingle Coat 75 Susp	Air	9.5	103	5.7	Generic Clear Glass
7066	Clr/Air1/TC88 Susp/Air1/Clr 6	1.53	0.27	0.55	0.48	0.35	0.22	0.63	0.13	103	5.7	Generic Clear Glass	Air	6.3	1511	0.1	Heat MirrorTwin Coat 88 Susp	Air	6.3	103	5.7	Generic Clear Glass
7067	Clr/Air/TC88 Susp/Air/Clr 6	1.19	0.21	0.55	0.48	0.35	0.22	0.63	0.13	103	5.7	Generic Clear Glass	Air	9.5	1511	0.1	Heat MirrorTwin Coat 88 Susp	Air	9.5	103	5.7	Generic Clear Glass

CHILLER WATER-ECONOMIZER

<u>Introduction</u>

A water-side economizer provides "free cooling" by allowing cooling tower water to bypass the chiller(s) and directly cool a chilled-water loop. The cooling is not actually "free", as energy must still be expended in the cooling tower fans and pumps. Water-side economizers may be divided into three principal configurations:

- <u>Direct injection</u> – The condenser water is filtered and directly injected into the chilled-water loop. While this method maximizes the effectiveness of the economizer, it introduces oxygen and other contaminants into the piping. These contaminants may ultimately corrode and/or foul the piping and coils; thereby degrading the performance of the system and shortening its life.

- <u>Indirect heat-exchanger</u> - A plate-and-frame heat-exchanger to indirectly cools the chilled-water loop. The heat-exchanger prevents the relatively dirty condenser water from fouling the chilled-water components. Since the effectiveness of a heat-exchanger is always less than 1.0, this method cannot achieve the same performance as direct injection.

- <u>Thermocycle</u> – A chiller can be configured so that its heat-exchangers and refrigerant act as a passive heat transfer mechanism. Like the indirect method, this method prevents cross-contamination of the chilled and condenser loops. However, it does not usually achieve the same cooling capacity for a given temperature differential.

The capability to simulate a water-side economizer was omitted from earlier versions of DOE-2 because of the lack of funding necessary to implement this component properly. Nevertheless, many high-rise buildings utilize water-side economizers, and many users have expressed the need to simulate these components.

The program now partially remedies this problem by introducing a new type of chiller that is a simple plate-and-frame heat-exchanger. This is not a complete implementation, and the following rules must be understood:

1. The program assumes a water-side economizer is used in an "all or nothing" mode. If the water-side economizer can handle the entire cooling load, then it will be used. Otherwise, the loop will use its other chillers. A water-side economizer cannot precool the return flow prior to entering the chillers.

    The "all or nothing" mode precludes the use of an EQUIP-CTRL sequence to coordinate the operation of an economizer chiller with other chillers. If you list a water-side economizer chiller in an EQUIP-CTRL sequence, it will be ignored.

2. There must be a one-to-one correspondence between a CHW loop, a water-side economizer, and a CW loop. A CHW loop may be supplied by only one water-side economizer, and a CW loop may supply only one water-side economizer. In other words, a plant may have any number of chilled water loops having water-side economizers, but those economizers cannot draw from the same CW loop. The program will generate an error if this condition is not met.

3. If a CW loop supplies a water-side economizer, it may also supply chillers serving the same CHW loop as the economizer. However, it cannot supply chillers serving other CHW loops. The program will generate an error if this condition is not met.

4. A CW loop supplying a water-side economizer should have only one cooling tower. More than one cooling tower is allowed, however only the first tower defined will be checked to see if sufficient free cooling capacity is available. Once free cooling is allocated to a CW loop, the program may use any combination of

towers to satisfy it. *The program may underpredict the water-side economizer savings if more than one cooling tower serves a given CW loop. To minimize the underprediction, define the largest tower first.*

5. If there is any water-cooled packaged equipment in the SYSTEM command, this equipment will be ignored when determining whether the tower has sufficient free cooling capacity. *This may cause the program to overpredict water-side economizer savings.*

6. For maximum effectiveness, the CHW loop should have COOL-SETPT-CTRL = LOAD-RESET. This allows the CHW temperature setpoint to rise during periods of low loads, maximizing the effectiveness of the water-cooled economizer.

Building Description Language Changes

The water-side economizer is implemented as a new chiller TYPE

TYPE
Takes a code-word that defines the type of the chiller.

WATER-ECONOMIZER   Not actually a chiller; this specifies a water-side economizer utilizing a heat-exchanger to cool a CHW loop using a CW loop.

Like other chillers, this chiller may have a pump on either the CHW or CW side. The CW flow may be either constant or variable; the higher dT associated with variable improves the tower performance somewhat and gives slightly better results.

WATER-ECONO-EFF
for a WATER-ECONOMIZER, specifies the effectiveness of the heat-exchanger. The simple heat-exchanger model in this component assumes a constant effectiveness for all chilled-water and condenser-water flows. It is used in the following equation for load:

$$Q_{econo} = M_{chw} * Cp_{chw} * Eff * (T_{return} - T_{cw})$$

where

Q_{econo}	maximum load the economizer can handle
M_{chw}	chilled-water mass flow rate
Cp_{chw}	chilled-water specific heat
Eff	heat-exchanger effectiveness
T_{return}	chilled-water return temperature
T_{cw}	condenser-water supply temperature

The default effectiveness is 0.8. To model direct-injection (strainer cycles), specify an effectiveness of 1.0.

RETURN DUCT THERMAL LOSSES

Introduction

The program has simulated supply duct thermal heat gains/losses for several years. This capability has been extended to return ducts.

Building Description Language Changes

The following is a brief summary of new/changed items.

SYSTEM

RETURN-UA

The UA value of the return duct. This value should include losses through the duct insulation as well as any bypass effects due to the duct hangars, crushed insulation, etc. This keyword applies only for air handlers having return ducts; if the return is via plenums, then this keyword is ignored.

BOILER AND CHILLER CYCLING LOSSES

Introduction

When a boiler or chiller is online, but there is no load on the equipment, the equipment may still use energy simply to remain at the required supply temperature. Previously, this effect was approximated using a portion of the START-UP-TIME. Now, a keyword is used to explicitly account for this standby energy.

Building Description Language Changes

The following is a brief summary of new/changed items.

CHILLER

STANDBY-TIME

The number of hours of equivalent full-load time required to maintain a chiller at temperature, when the cooling load is zero. When operating below the MIN-RATIO, the chiller is assumed to be cycling. When cycled on, the chiller will operate at the MIN-RATIO. When off, losses and energy are determined using this keyword. The program interpolates between energy consumed at the MIN-RATIO, and energy in full standby mode; based on the fraction of the time the chiller is cycled on.

BOILER

STANDBY-TIME

The number of hours of equivalent full-load time required to maintain a boiler at temperature, when the heating load is zero. When operating below the MIN-RATIO, the boiler is assumed to be cycling. When cycled on, the boiler will operate at the MIN-RATIO. When off, losses and energy are determined using this keyword. The program interpolates between energy consumed at the MIN-RATIO, and energy in full standby mode; based on the fraction of the time the chiller is cycled on.

DEMAND CONTROLLED VENTILATION

Introduction

Demand controlled ventilation (DCV) modeling has been added as an optional way of setting the hourly minimum outside air damper position in all types of systems except UHT, FC, RESYS, RESVVT, EVAP-COOL. In variable flow systems an option has been added to allow the VAV box minimum flow fraction to be reset based upon the hourly outside air ventilation requirement.. Additionally, an ASHRAE Standard 62 compliant method for calculating the design and hourly minimum OA fraction, with and without the use of DCV, has been added for all mtui-zone system types.

Building Description Language Changes

The following is a brief summary of new/changed items.

SYSTEM

MIN-OA-METHOD

Allows the choice of method used to set the hourly minimum OA damper position. This keyword only has an effect on the minimum damper position with any specified outside air economizer operation working as specified (or defaulted) via the economizer related keywords. For system without an economizer, or with the economizer feature not specified, this keyword is operational but specifies how the outside air damper position is controlled each hour. Using this keyword, previous releases of DOE-2 allowed the minimum OA damper position to be set hourly based on the design OA fraction either as a fraction of the design system flow (FRAC-OF-DESIGN) or the hourly system flow (FRAC-OF-HOURLY); this keyword was not available for zonal systems (UVT, HP, PTAC.) This has been modified to allow the modeling of two types of demand controlled ventilation (DCV) sensor placements: sensing the average zone requirement (such as placement of a sensor in the return air) and sensing the highest zone requirement (such as placing sensors in each zone or the critical zone.) If the MIN-AIR-SCH is specified, its hourly specified value will always be used (even if MIN-OA-METHOD is specified) unless the hourly scheduled value is -999. MIN-OA-METHOD is now used by zonal systems to add DCV to each zone unit. When INDOOR-FAN-MODE = INTERMITTANT in FC systems, during the hours when DCV is active (MIN-OA-METHOD = DCV codeword and MIN-AIR-SCH, if specified, has an hourly value of -999.) the INDOOR-FAN-MODE is switched to CONTINUOUS for that hour.

DCV-RETURN-SENSOR   This codeword instructs the program to model a DCV device that uses a CO_2 differential between the SYSTEM return air stream and OA intake air stream to determine the hourly minimum OA fraction. The program calculates the OA minimum requirement and sets the minimum damper position hourly based upon the sum of the ZONE requirements. Each zone OA requirement is calculated based upon the hourly maximum of either OA-CFM/PER (times the NUMBER-OF-PEOPLE adjusted by the hourly PEOPLE-SCHEDULE) or a minimum OA ventilation rate. The zone minimum OA ventilation rate is either MIN-OUTSIDE-AIR if specified or the maximum of OA-CHANGES (times the zone VOLUME/60), OA-FLOW/AREA (times the zone AREA.)

DCV-ZONE-SENSORS   This codeword instructs the program to model a DCV device that uses the highest CO_2 differential between the each ZONE air and OA intake air stream to determine the hourly minimum OA fraction. The program calculates the OA minimum requirement and sets the minimum damper position hourly using the "critical" zone requirement; the critical zone requirement is defined as the zone having the highest fraction of OA relative to its hourly supply air flow rate. Each zone OA requirement is calculated based upon the hourly maximum of either

OA-CFM/PER (times the NUMBER-OF-PEOPLE adjusted by the hourly PEOPLE-SCHEDULE) or a minimum OA ventilation rate. The zone minimum OA ventilation rate is either MIN-OUTSIDE-AIR if specified or the maximum of OA-CHANGES (times the zone VOLUME/60), OA-FLOW/AREA (times the zone AREA.). The value of the zone minimum OA ventilation flow rate is divided by the specified/calculated zone supply flow to calculate hourly zone OA fraction; the zone with the highest hourly flow fraction value is the "critical" zone. Setting the sum of the ZONE OA flow requirements divided by the system total supply fan flow to X, and letting the critical zone OA fraction be denoted as Z, the system hourly minimum OA flow fraction is then $X/(1+X-Z)$

FRACTION-OF-DESIGN (Default) unchanged except design minimum OA fraction used can be set by OA-SIZING-METHOD.

FRACTION-OF-HOURLY unchanged except design minimum OA fraction used can be set by OA-SIZING-METHOD.

OA-SIZING-METHOD

Allow the choice of method used to calculate the **design and hourly minimum** outside air flow rate fraction for multi-zone air system types; this keyword does not apply to SUM/FPH, zonal systems UVT/FC/HP/PTAC, or not OA systems UHT/RESYS/RESVVT.) Previously the only method allowed was the summation of ZONE OA flow requirements into a SYSTEM OA flow requirement; this was then divided by the calculated/specified SUPPLY-FLOW to set the MIN-OUTSIDE-AIR keyword which was also used in the design/sizing calculation. Now the option is available to calculate the SYSTEM OA requirement based upon the ZONE requiring the highest fraction of OA flow relative to its design supply flow; this is the method required by ASHRAE Standard 62. If the MIN-AIR-SCH is specified, its hourly specified value will always be used (even if OA-SIZING-MTHOD is specified) unless the hourly scheduled value is -999. The allowed codewords are:

SUM-OF-ZONE-OA (default) The program calculates the SYSTEM design OA flow fraction based upon a sum of the zone requirements divided by the SUPPLY-CFM. This is the default and the method used in previous releases of DOE-2. In each zone OA calculation, a specified MIN-OUTSIDE-AIR overrides any specified values for OA-CHANGES (times zone VOLUME/60), OA-FLOW/AREA (times the zone AREA.) and OA-CFM/PER (times the NUMBER-OF-PEOPLE).

SET-BY-CRITICAL-ZONE The program calculates the SYSTEM design OA flow fraction based upon the ZONE with the highest OA requirement. In each ZONE OA calculation, a specified MIN-OUTSIDE-AIR overrides any specified values for OA-CHANGES (times SPACE VOLUME/60), OA-FLOW/AREA (times the zone AREA.) and OA-CFM/PER (times the NUMBER-OF-PEOPLE) The value for zone OA ventilation flow rate is then divided by the specified/calculated zone supply flow rate and the zone with the highest such value (the "critical" zone) is found. Setting the sum of the zone OA requirements divided by the system total supply fan flow rate to X, and the critical zone OA fraction to Z, then the system design and hourly minimum OA flow fraction is set to $X/(1+X-Z)$ This is the method specified for multi-zone systems in ASHRAE Standard 62.

OA-FROM-SYSTEM

Several Error and Warning messages were added to prevent incorrect simulations and new sizing calculations were addeed for OA-FROM-SYSTEM referenced SYSTEMs. Previously, if a SYSTEM had an OA-FROM-SYSTEM specified, the referencing SYSTEM value for MIN-OUTSIDE-AIR was reset to the MIN-OUTSIDE-AIR of the referenced OA-FROM-SYSTEM; this has been removed and replaced with the opposite action. In the current version, the sum of the OA requirements for all SYSTEMs that reference an OA-FROM-SYSTEM is used to set

the referenced OA-FROM-SYSTEM value for MIN-OUTSIDE-AIR, SUPPLY-FLOW as well as adjust the referenced OA-FROM-SYSTEM directly served ZONE maximum and minimum flows for both heating and cooling. Additionally the referenced OA-FROM-SYSTEM has its calculated/specified cooling (total and sensible), heating, and preheat capacities adjusted if its SUPPLY-FLOW was increased. If the referenced OA-FROM-SYSTEM and its ZONEs have sufficient minimum OA specified (greater than that required by the referencing SYSTEMs) no adjustments are made. If any adjustments are made a warning is issued that informs the user of the adjustments and recommends the project be re-run with the values in the input corrected. Also, errors are issued (and the simulation terminated) if the referenced OA-FROM-SYSTEM is either an incorrect type (a zonal system or a system that cannot have outside air) or the referenced OA-FROM-SYSTEM is not placed into the input file before all referencing SYSTEMs.

ZONE
MIN-FLOW-CTRL
Allows the choice of method used to set the hourly minimum VAV box flow fraction.. If the MIN-FLOW-SCH, CMIN-FLOW-SCH or HMIN-FLOW-SCH are specified, their hourly specified values will always be used, for the appropriate VAV box minimum flow setting, unless the hourly scheduled value is -999 even if MIN-FLOW-CTRL is specified.

FIXED/SCHEDULED   (Default) This codeword instructs the program to model VAV boxes as having a fixed or scheduled minimum. A fixed minimum is used unless a minimum flow fraction schedule is specified through the use of MIN-FLOW-SCH, CMIN-FLOW-SCH or HMIN-FLOW-SCH.

DCV-RESET-UP/DOWN   This codeword instructs the program to model VAV boxes that have their minimum flow fraction reset either upwards (raised) or downwards (lowered) due to demand controlled ventilation determined zone minimum OA flow rate requirements. The program calculates the zone minimum OA requirement and sets the zone VAV box minimum damper position hourly. Each zone OA requirement is calculated based upon the hourly maximum of either OA-CFM/PER (times the NUMBER-OF-PEOPLE adjusted by the hourly PEOPLE-SCHEDULE) or a minimum OA ventilation rate. The zone minimum OA ventilation rate is either MIN-OUTSIDE-AIR if specified or the maximum of OA-CHANGES (times the zone VOLUME/60), OA-FLOW/AREA (times the zone AREA.)

DCV-RESET-UP   This codeword instructs the program to model VAV boxes that have their minimum flow fraction reset upwards (raised) due to demand controlled ventilation determined zone minimum OA flow rate requirements. The program calculates the zone minimum OA requirement and sets the zone VAV box minimum damper position upwards hourly if that is necessary; other wise the minimum is set at the design value. Each zone OA requirement is calculated based upon the hourly maximum of either OA-CFM/PER (times the NUMBER-OF-PEOPLE adjusted by the hourly PEOPLE-SCHEDULE) or a minimum OA ventilation rate. The zone minimum OA ventilation rate is either MIN-OUTSIDE-AIR if specified or the maximum of OA-CHANGES (times the zone VOLUME/60), OA-FLOW/AREA (times the zone AREA.)

DCV-RESET-DOWN   This codeword instructs the program to model VAV boxes that have their minimum flow fraction reset downwards (lowered) due to demand controlled ventilation determined zone minimum OA flow rate requirements. The program calculates the zone minimum OA requirement and sets the zone VAV box

minimum damper position downwards hourly if that is necessary; other wise the minimum is set at the design value. Each zone OA requirement is calculated based upon the hourly maximum of either OA-CFM/PER (times the NUMBER-OF-PEOPLE adjusted by the hourly PEOPLE-SCHEDULE) or a minimum OA ventilation rate. The zone minimum OA ventilation rate is either MIN-OUTSIDE-AIR if specified or the maximum of OA-CHANGES (times the zone VOLUME/60), OA-FLOW/AREA (times the zone AREA.)

OA-FLOW/AREA
This keyword allows the specification of a minimum zone outside air (OA) flow rate per unit of zone floor area. The use of OUTSIDE-AIR-FLOW will over ride the value of this keyword. The maximum of values resulting from OA-FLOW/AREA, OA-FLOW/PER, and OA-CHANGES will be used unless an over-ride value for OUTSIDE-AIR-FLOW is specified.

REPORT-BLOCK

The hourly calculated required OA flow and fraction are available in the ZONE/SYSTEM report blocks.

ZONE

Variable-List Number	Variable in FORTRAN Code	Description
100	<DCVOAcfmZ>	Hourly zone OA CFM requirement for DCV calculation (cuft/min)
101	<DCVOAcfmFrac>	Hourly zone OA/total flow for DCV calculation (cfm/cfm)

SYSTEM

Variable-List Number	Variable in FORTRAN Code	Description
319	<DCVOAcfmS>	Hourly summed ZONE OA CFM for DCV calculation (cuft/min)
320	<DCVOAcfmFracCrit>	Hourly max ZONE OA/total flow for DCV calculation (cfm/cfm)

TIME-DEPENDENT VALUATION

Introduction

Many building energy codes distinguish between energy consumed on site versus the actual source energy required to produce and deliver the site energy. For example, it is commonly assumed that for every unit of electricity consumed on site, three units are consumed in the generating plant and in transmission losses. (Actually, the original 3:1 ratio was based on the assumption the electricity *costs* 3x as much to generate and deliver than the source fuel; so it never actually represented source energy.) The conversion factors for site vs. source energy are specified in the SOURCE-SITE-EFF keywords in the various types of meters, and the BEPS and BEPU reports account for differences in site vs. source energy consumption using these factors.

The State of California takes this logic one step further, and weights the "source" energy factors hourly to take into account differences in the delivered cost of energy for different seasons, outdoor temperatures, and time of use. For electricity consumption these costs include the costs of providing sufficient generation, transmission and distribution capacity which are allocated to those hours of highest electricity consumption. These costs also include the variable costs of producing power and fixed cost allocated evenly by consumption for administration, profit etc. The costing for gas and propane is less variable than electricity but includes the seasonal fluctuations in cost; gas is cheaper in the summer than in the winter.

The hourly ratios used to weight the site energy are termed "time-dependent valuation factors", or "TDV factors", and the equivalent energy produced is termed "TDV energy". TDV energy is in units of nominal kBtu of natural gas based upon long term forecasts of the relative cost of electricity, natural gas and propane. Fuels other than natural gas or propane are recognized as being equivalent to propane.

The TDV factors are specific to each of the 16 official California Climate Zones used to show compliance with the State's energy code. Whenever one of these climate zones is used in a simulation (CZ01 thru CZ16), the program automatically loads the appropriate hourly values of the TDV factors, and weights the hourly site energy consumption by these factors to determine the hourly TDV energy.   This linkage is completely automatic; since the TDV data is dependent on outdoor temperature (the hottest days have the highest generating and transmission costs), it would not make sense to use this data with a weather file other than the one for which it was created.

The TDV energy is tabulated in reports TDV1, TDV2 and TDV2. TDV1 is similar to the BEPS report, and is generated automatically whenever the BEPS report is specified, and one of the 16 California climate zones is used. Similarly, TDV2 is similar to the PS-E summary of meters report, and is generated automatically for electric and fuel meters whenever the PS-E reports are enabled together with TDV calculations. Lastly, TDV3 is similar to the PS-F meter report, and is generated automatically for each meter whenever the PS-F reports are enabled together with TDV calculations. Refer to the *Libraries & Reports* for more information on these reports.

California also requires that outdoor lighting not be included in a compliance analysis simulation. For this reason, if outdoor lighting is specified (ELEC-METER:EXTERIOR-POWER, with EXTERIOR-EU = EXT-USAGE), the EXT-USAGE end-use category is by default not included in TDV1, TDV2 or TDV3. Exterior power is included in all other reports, as well as the costs computed in the UTILITY-RATE(s).

Building Description Language Changes

The following is a brief summary. Please see the documentation for details.

MASTER-METERS

If a user wishes to override the default exclusion of the EXT-USAGE end-use from these two reports, the following keyword is provided within the MASTER-METERS command:

EXCLUDE-FROM-TDV
accepts a list of code words specifying which end-uses are to be excluded from the TDV1/2/3 time-dependent valuation reports. Acceptable entries are NONE (all end-uses are included), LIGHTS, TASK-LIGHTS, MISC-EQUIP, SPACE-HEATING, SPACE-COOLING, HEAT-REJECT, PUMPS&AUX, VENT-FANS, REFRIG-DISPLAY, HT-PUMP-SUPPLEM, DOMEST-HOT-WTR, and EXT-USAGE. The default is EXT-USAGE.

ELEC-METER
EXTERIOR-EU
Accepts a list of up to 10 code-words specifying the end-use category of the EXTERIOR-POWER. The code-words correspond to the end-use categories in the end-use reports (PS-E, PS-F, BEPS, BEPU, TDV1 TDV2, TDV3). Acceptable entries are LIGHTS, TASK-LIGHTS, MISC-EQUIP, SPACE-HEATING, SPACE-COOLING, HEAT-REJECT, PUMPS&AUX, VENT-FANS, REFRIG-DISPLAY, HT-PUMP-SUPPLEM, DOMEST-HOT-WTR, and EXT-USAGE.

Note that, while exterior energy can be entered via the EXTERIOR-POWER keyword, it may also be entered via the INTERIOR-POWER and INTERIOR-EU = EXT-USAGE keywords. The same is true for REFG-POWER.

FUEL-METER
EXTERIOR-EU
Accepts a list of up to 10 code-words specifying the end-use category of the EXTERIOR-POWER. The code-words correspond to the end-use categories in the end-use reports (PS-E, PS-F, BEPS, BEPU, TDV1 TDV2, TDV3). Acceptable entries are LIGHTS, TASK-LIGHTS, MISC-EQUIP, SPACE-HEATING, SPACE-COOLING, HEAT-REJECT, PUMPS&AUX, VENT-FANS, REFRIG-DISPLAY, HT-PUMP-SUPPLEM, DOMEST-HOT-WTR, and EXT-USAGE.

Note that, while exterior energy can be entered via the EXTERIOR-POWER keyword, it may also be entered via the INTERIOR-POWER and INTERIOR-EU = EXT-USAGE keywords.

STEAM-METER
EXTERIOR-EU
Accepts a list of up to 10 code-words specifying the end-use category of the EXTERIOR-POWER. The code-words correspond to the end-use categories in the end-use reports (PS-E, PS-F, BEPS, BEPU, TDV1 TDV2, TDV3). Acceptable entries are LIGHTS, TASK-LIGHTS, MISC-EQUIP, SPACE-HEATING, SPACE-COOLING, HEAT-REJECT, PUMPS&AUX, VENT-FANS, REFRIG-DISPLAY, HT-PUMP-SUPPLEM, DOMEST-HOT-WTR, and EXT-USAGE.

Note that, while exterior energy can be entered via the EXTERIOR-POWER keyword, it may also be entered via the INTERIOR-POWER and INTERIOR-EU = EXT-USAGE keywords.

CHW-METER
EXTERIOR-EU
Accepts a list of up to 10 code-words specifying the end-use category of the EXTERIOR-POWER. The code-words correspond to the end-use categories in the end-use reports (PS-E, PS-F, BEPS, BEPU, TDV1 TDV2). Acceptable entries are LIGHTS, TASK-LIGHTS, MISC-EQUIP, SPACE-HEATING, SPACE-COOLING,

HEAT-REJECT, PUMPS&AUX, VENT-FANS, REFRIG-DISPLAY, HT-PUMP-SUPPLEM, DOMEST-HOT-WTR, and EXT-USAGE.

Note that, while exterior energy can be entered via the EXTERIOR-POWER keyword, it may also be entered via the INTERIOR-POWER and INTERIOR-EU = EXT-USAGE keywords.

REPORT-BLOCK
The hourly TDV Energy multiplier is available as Item 22 in both the ELEC-METER and FUEL-METER report blocks.

Output Reports
Three new output reports are included to summarize TDV Energy consumption. In addition to the summaries below, please refer to the *Libraries and Reports* volume for more information.

REPORT TDV1 TDV Energy Performance Summary
This report prints automatically whenever the BEPS report is specified, and time-dependent valuation is enabled. Time-dependent valuation (TDV) is automatically enabled whenever the weather file is one of California's official compliance weather files; CZ01 thru CZ16 (See *Time-Dependent Valuation* in the Dictionary for more information).

This report makes it possible to quickly review annual TDV-energy use according to energy type (ELECTRICITY, NATURAL-GAS, or PROPANE) and category of use (LIGHTS, SPACE HEATING, etc.). The energy types shown are those that you have specified with the ELEC-METER and FUEL-METER commands. As California does not recognize steam, chilled-water or fuels other than natural gas or propane in compliance analysis, no entries are provided for those meter types. The categories of use (also called energy end uses) are defined under the description of Report PS-E.

The energy values in this report are all in the same units (TDV-MBtu in English units or TDV-MWh in metric units). This allows a direct comparison of end-use intensities. Report BEPS provides the same information as TDV1, but in site units, and BEPU reports energy usage in "utility units," such as kWh, therms, etc.

Energy is reported only for meters that draw or supply power across the building boundary. The consumption of submeters is excluded, so that energy is not double-counted.

REPORT TDV2 TDV Energy End-Use Summary for All <Electric/Fuel> Meters
This report is created automatically for electric and fuel meters whenever the PS-E reports are specified, and time-dependent valuation is enabled. Time-dependent valuation (TDV) is automatically enabled whenever the weather file is one of California's official compliance weather files; CZ01 thru CZ16 (See *Time-Dependent Valuation* in the Dictionary for more information). As California does not recognize steam or chilled-water utilities in compliance analysis, no reports are provided for those meter types.

REPORT TDV3 TDV End-Use Summary for   <meter name>
This report is created automatically for each electric and fuel meter whenever the PS-F reports are specified, and time-dependent valuation is enabled. Time-dependent valuation (TDV) is automatically enabled whenever the weather file is one of California's official compliance weather files; CZ01 thru CZ16 (See *Time-Dependent Valuation* in the Dictionary for more information). As California does not recognize steam or chilled-water utilities in compliance analysis, no reports are provided for those meter types.

For each month, these reports list, for different TDV-weighted source end uses, the total usage, the peak usage, and the day/hour during which the peak occurred. Also listed, for each end-use, is the average load-weighted TDV multiplier for each end-use, and the unweighted maximum, minimum, and average TDV multiplier for the month.

Fuel consumed by electric generators and consumed on-site is allocated to the building end-uses. However, the portion of fuel used to generate power that is sold to a utility, if any, is not allocated to any of these categories, but is included in the total. In this case, the total will not match the sum of the reported end-uses.

CYCLING FANCOIL AND SINGLE ZONE SYSTEMS

Introduction

It is very common for fan coil and single zone systems, those defined by the SYSTEM command with TYPE = FC or SZRH, respectively to be designed to cycle with the zone load. In previous versions of DOE-2 it was not possible to model these types of system with indoor fan cycling control. Version 44 of DOE-2.2 has been enhanced to include this feature. For these systems this feature works exactly the same as this feature for other systems type, such as PSZ and PVVT, for which the feature has been available for some time. The keyword that activates this feature is described below.

Additionally, economizers have been added to fan coil system to allow cooling via outside air economizer cycle; however, none of the add-on economizer features, such as evaporative cooling or desiccant cooling, are available for the FC (or any zonal) system.

Building Description Language Changes

The following is a brief summary. Please see the Dictionary for details.

SYSTEM

If a user wishes to model a SZRH or FC system with indoor fan which cycle with internal load, based upon thermostat setpoints and a dead band, the INDOOR-FAN-MODE keyword within the SYSTEM command must be specified.

INDOOR-FAN-MODE

accepts a code word specifying which mode to use for indoor fan operation: CONTINUOUS (the default) will model the fans to operate with continuous flow whenever the fan are scheduled to be on with the supply temperature to the space modulated to meeting the heating and/or cooling requirements; INTERMITTENT will model fans which cycle with internal load to modulate heating and/or cooling to the space with the supply temperature being that which is delivered at full coil capacity during the fan on period of operation.

OA-CONTROL

accepts a code word specifying which mode to use for economizer control. The default for fan coil systems is FIXED; options are FIXED, OA-TEMP, OA-ENTHALPY, DUAL-TEMP, DUAL-ENTHALPY. When OA-CONTROL is not FIXED the standard economizer keywords are available for use.

REVISED PHOTOVOLTAIC ALGORITHMS

Introduction

The PV-MODULE algorithms have been updated to incorporate the current Sandia/King algorithm consistent with the on-line Sandia database of PV modules. The previous Sandia/King algorithm was based on a formulation several years old, and was no longer consistent with Sandia's database of coefficients. Serious errors would result if the current coefficients were used with the old DOE-2 formulation.

Building Description Language Changes

The following is a brief summary. Please see the documentation for details.

ELEC-GENERATOR

The WIND-COEF keyword has been replace by WIND-COEF-A and WIND-COEF-B. These are always specified using METRIC units.

OFFSET-T and CELL-T-COEF are no longer used.

PV-MODULE

Except for the physical dimensions (HEIGHT and WIDTH), all performance data is entered in METRIC units, even when simulating in English. The physical dimensions are entered in English or metric, consistent with the rest of the input.

For clarity and convenience, keywords corresponding to the Sandia/King coefficients are given abbreviations identical to the headings in the Sandia database. Note that DOE-2 abbreviations are in upper case only; no lower case.

VOLTS/E-MAX-PWR
(Sandia database: 'MBVMP')
specifies the correction to VOLTS/T-MAX-PWR for irradiance levels other than 1000W/m². This entry is always in metric, Volts/°C.

A0-A4
accepts a list in parenthesis of the five coefficients having the same name in the Sandia PV database. If specified, this 4th-order polynomial will be used in lieu of IRRADIANCE-FAM.

As before, the correction for airmass may be specified by referencing a CURVE-FIT via the IRRADIANCE-FAM keyword. However, as curve-fits are limits to cubics, and the Sandia database utilizes a 4th order polynomials for airmass, you may directly enter these five coefficients as a list under this keyword.

B0-B5
accepts a list in parenthesis of the six coefficients having the same name in the Sandia PV database. If specified, this 5th-order polynomial will be used in lieu of IRRADIANCE-FAOI.

As before, the correction for angle of incidence may be specified by referencing a CURVE-FIT via the IRRADIANCE-FAOI keyword. However, as curve-fits are limits to cubics, and the Sandia database utilizes a 5th order polynomial for angle-of-incidence, you may directly enter these six coefficients as a list under this keyword.

NOM-OPER-CELL-DT (Sandia database: 'DTC')
specifies the temperature difference between the cell and the back surface at the reference irradiation of 1000 w/m². This entry is always in metric, °C.

NOCT-AMBIENT, NOCT-IRRADIANCE, NOCT-WINDSPEED, and REF-IRRADIANCE are no longer used.

SYSTEM AIRFLOW/CAPACITY COUPLING

Introduction

Previous versions of DOE-2 did not allow the relationship between a SYSTEM's main cooling coil capacity and airflow to be specified. While both derive from the loads in the building, the two may not match what is commonly available from a manufacturer. For example, while DOE-2 may select a 1-ton unit at 500 cfm, the equipment might only be available at 400 cfm/ton.

The SIZING-METHOD keyword allows the user to specify the relationship between airflow and cooling capacity:

- The program first sizes the supply airflow and resulting cooling coil capacity based on the zone and outside air requirements.

- If the SIZING-METHOD = DEFAULT, the above are the capacities used in the program.

- If the SIZING-METHOD is FLOW/CAPACITY, then the program uses the above default cooling coil capacity to recalculate the airflow, overriding the default airflow.

- If the SIZING-METHOD is CAPACITY/FLOW, then the program uses the default zonal airflows to calculate the capacity, overriding the default capacity.

- The flow/capacity may be explicitly specified, or the maximum/minimum limits may be specified.

Building Description Language Changes

SIZING-METHOD

DEFAULT	The program calculates the cooling capacity and supply airflow, but does not explicitly link one to the other. Note that the user may specify either the COOLING-CAPACITY or the SUPPLY-FLOW to override the default calculation
FLOW/CAPACITY	The program calculates the default cooling capacity, and uses it to set the supply airflow. If the user specifies the COOLING-CAPACITY, this value will be used to set the airflow.
CAPACITY/FLOW	The program calculates the default supply airflow, and uses it to set the cooling capacity. If the user specifies the SUPPLY-FLOW, this value will be used to set the cooling capacity.

FLOW/CAPACITY
when SIZING-METHOD = FLOW/CAPACITY or CAPACITY/FLOW, is the ratio of the SUPPLY-FLOW to the COOLING-CAPACITY. If you do not specify this value, the program will assume a range of values are acceptable, as specified by the MAX-FLOW/CAPACITY and MIN-FLOW/CAPACITY limits.

MIN-FLOW/CAPACITY
when SIZING-METHOD = FLOW/CAPACITY or CAPACITY/FLOW, and the FLOW/CAPACITY ratio is not specified, defines the lower limit of the range of flow per capacity values. The program will independently calculate the COOLING-CAPACITY and the SUPPLY-FLOW, but then apply this limit.

For example, assume the SIZING-METHOD is FLOW/CAPACITY, and the MIN-FLOW/CAPACITY and MAX-FLOW/CAPACITY are 350 and 500 cfm/ton respectively. The program determines the COOLING-CAPACITY is 120,000 Btuh, or 10 tons. If the default airflow is 4000 cfm, then the cfm/ton ratio = 4000/10 = 400 cfm/ton, which is within the allowed range. In this case the default airflow will not be overridden. If instead the default airflow is 3000 cfm, this corresponds to 300 cfm/ton which is below the minimum allowed limit of 350 cfm/ton. The program will override the default airflow to be 10 tons * 350 cfm/ton = 3500 cfm.

MAX-FLOW/CAPACITY

when SIZING-METHOD = FLOW/CAPACITY or CAPACITY/FLOW, and the FLOW/CAPACITY ratio is not specified, defines the upper limit of the range of flow per capacity values. The program will independently calculate the COOLING-CAPACITY and the SUPPLY-FLOW, but then apply this limit.

For example, assume the SIZING-METHOD is FLOW/CAPACITY, and the MIN-FLOW/CAPACITY and MAX-FLOW/CAPACITY are 350 and 500 cfm/ton respectively. The program determines the COOLING-CAPACITY is 120,000 Btuh, or 10 tons. If the default airflow is 4000 cfm, then the cfm/ton ratio = 4000/10 = 400 cfm/ton, which is within the allowed range. In this case the default airflow will not be overridden. If instead the default airflow is 6000 cfm, this corresponds to 600 cfm/ton which is above the maximum allowed limit of 500 cfm/ton. The program will override the default airflow to be 10 tons * 500 cfm/ton = 5000 cfm.

STAGED-VOLUME, PACKAGED SINGLE-ZONE SYSTEM

Introduction

A staged-volume HVAC system is a variation of the packaged single-zone systems available in the 7-1/2 ton to 20 ton range. These systems commonly have two compressors, yielding two stages of mechanical cooling. These systems also commonly have two stages of heating, provided by either a gas furnace or a heat pump. The staged-volume concept recognizes that, during the times the unit is not at maximum heating or cooling, it may not be necessary to operate the fan at full output. Compared to constant-volume fan operation, this control strategy can achieve fan energy savings of more than 50% on an annual basis, while simultaneously achieving excellent humidity control in humid climates.

Physically, the system is almost identical to a conventional packaged single-zone system, with the following modifications:

- While a packaged single-zone unit typically utilizes two separate refrigerant circuits and a split-faced evaporator coil, a staged-volume unit incorporates either an interlaced coil, or better yet, allows the compressors to share a common circuit. In addition, the unit may utilize a single multi-stage compressor, unequally-sized compressors, or a combination of compressors and multi-stage compressors (up to four stages total). The key idea is that low-stage cooling must utilize the entire evaporator area so that airflow can be reduced without unduly affecting compressor performance.

- A variable-speed drive that modulates the fan output as a function of heating/cooling staging, and discharge air temperature.

Control Sequence

The program simulates up to four stages of heating and/or cooling. It is not necessary that heating and cooling have the same number of stages.

- Zone thermostat – Like a packaged single-zone unit, the system uses a two-stage heating/cooling thermostat, located in the control zone. Based on zone temperature and heating/cooling setpoints, the thermostat calls for successive stages of heating or cooling.

- Discharge air temperature sensor – The unit incorporates a discharge air temperature sensor. As the zone thermostat stages the heating/cooling capacity in a step-wise fashion, the discharge air temperature sensor modulates the fan output to maintain a discharge air temperature setpoint.

  Note that the thermostat does NOT modulate the airflow as it would in a VAV system; it stages heating/cooling capacity. The discharge air sensor modulates the airflow. As the thermostat stages heating/cooling capacity, airflow will tend to stage with capacity, hence the term "staged-volume".

  The discharge setpoint may be either constant for all stages of heating or cooling, or may vary with the staging. For example, while the high-stage heating setpoint may be 105°F, it might be desirable to operate low-stage heating at 95°F. This strategy can reduce temperature stratification in the zone due to the more moderate supply temperature and increased flow rate.

- High-stage heating – The unit operates at maximum heat output. Depending on the differential between the discharge-air setpoint and the mixed-air temperature, the fan may be operating at either the maximum output, or at a reduced output to maintain the discharge setpoint. The zone thermostat will cycle the unit between high-stage and low-stage heating as required.

The user may specify the minimum allowable flow ratio. If the airflow must be less than this ratio to maintain the discharge air setpoint, then the flow will be maintained at this setting and the discharge air temperature will float below the sepoint. Also, the discharge air temperature will float above setpoint if the fan cannot maintain the setpoint at 100% output.

- <u>Low-stage heating</u> – Similar to high stage heating, except that the fan will typically be operating at a lower output to maintain the low-stage discharge setpoint. The zone thermostat will cycle the unit between high/low/floating stages as required. As with high-stage heating, the fan will not modulate below the minimum allowed flow ratio.

- <u>Floating</u> - When the zone temperature is between the heating and cooling setpoints, the user may specify whether the fan is to continue running, or is to cycle off. Note that most codes require that the fan run continuously unless ventilation air is provided by another means. If running, the fan will operate at the minimum allowed flow ratio.

- <u>Economizer cooling</u> – When cooling is required and outdoor conditions permit economizer operation, the fan will modulate between the minimum flow ratio and 100% output as required to maintain the zone cooling setpoint. If the economizer delivers more cooling at the minimum flow than the zone requires, then the unit will cycle between the economizer and floating modes. If the economizer cannot meet the entire cooling load, then the unit will cycle between the economizer and low-stage modes.

- <u>Low-stage cooling</u> – If economizer operation at 100% output is insufficient to maintain the zone temperature, then low stage cooling will start, and the fan will modulate as required to maintain the low-stage discharge setpoint. The fan may operate as high as 100% output, depending on how much cooling the economizer is providing. (For example, if the mixed air temperature is 60°F, and the low-stage discharge setpoint is 55°F, then low-stage cooling will usually be able to achieve setpoint at maximum fan output.) The fan will not modulate below the minimum flow ratio.

  In dry climates where humidity control is not an issue, it might be desirable to specify a low-stage discharge air setpoint higher than the high-stage setpoint to minimize the possibility of diffuser dumping.

- <u>High-stage cooling</u> – Similar to low-stage cooling, except that the fan will typically be operating at a higher output to maintain the discharge setpoint. Economizer operation is fully integrated into both low-stage and high-stage cooling.

- <u>Subzones</u> – Like the packaged single-zone system, this system may serve more than one zone. The control zone will determine the operation of the system (heating vs. cooling), the supply temperature, and the airflow ratio. Each subzone will receive air at the temperature and airflow ratio as determined by the control zone, and may or may not be comfortable depending on how intelligently the building zones are divided among the systems.

  Also like the packaged single-zone system, each subzone may have a reheat coil controlled by its own thermostat. This can prevent a subzone from being underheated, but cannot prevent a subzone from being undercooled. For reheat, specify the REHEAT-DELTA-T and the zonal HEATING-SCH. The cooling thermostat schedule has no effect on a subzone.

Building Description Language Changes

TYPE

PVVT   Functionally, the staged-volume system is quite similar to the packaged variable-volume, variable-temperature system, and shares its code word.

AIR/TEMP-CONTROL
accepts a code-word specifying the type of airflow and temperature control employed:

VARIABLE-VOL/TEMP   the default, specifies the common PVVT temperature control strategy.

STAGED-VOLUME   specifies the staged-volume strategy described herein.

NUM-COOL-STAGES
specifies the number of stages of cooling capacity; specified by the code words ONE, TWO, THREE, or FOUR. The default is two stages, corresponding to a unit with two equally-sized compressors.

COOL-STAGES
accepts a list in parenthesis of numbers specifying the fraction of the full-load capacity associated with each cooling stage. The list must be entered in ascending numerical order, starting with the lowest stage.

For example, the default for a two-stage unit is (0.5, 1.0), corresponding to 50% low-stage capacity, and 100% high stage. High stage is always 100%, regardless of what you enter here. The default for a three-stage unit is (0.33, 0.67, 1.0), etc. While the default staging steps are equal in size, this is not a requirement.

COOL-STAGES-DT
accepts a list in parenthesis of temperature differentials specifying the change in cooling setpoint for each low stage relative to the high stage. These entries correspond to the COOL-STAGES capacities defined above. The default for the lower stages is 0°F; the high stage is always the COOL-SET-T, regardless of what you enter here.

For example, if you have a three-stage unit, the COOL-SET-T is 55°F, and you want to operate the two lower stages at 60°F, enter: (5.0, 5.0, 0.0)

NUM-HEAT-STAGES
specifies the number of stages of heating capacity; specified by the code words ONE, TWO, THREE, or FOUR. The default is two stages, corresponding to a heat-pump with two equally-sized compressors, or a gas furnace with two stages of heating.

HEAT-STAGES
accepts a list in parenthesis of numbers specifying the fraction of the full-load capacity associated with each heating stage. The list must be entered in ascending numerical order, starting with the lowest stage. The number of heating stages does not have to be the same as the number of cooling stages.

For example, the default for a two-stage unit is (0.5, 1.0), corresponding to 50% low-stage capacity, and 100% high stage. High stage is always 100%, regardless of what you enter here. The default for a three-stage unit is (0.33, 0.67, 1.0), etc. While the default staging steps are equal in size, this is not a requirement.

HEAT-STAGES-DT
accepts a list in parenthesis of temperature differentials specifying the change in heating setpoint for each low stage relative to the high stage. These entries correspond to the HEAT-STAGES capacities defined above. The default for the lower stages is -10°F; the high stage is always the HEAT-SET-T, regardless of what you enter here.

For example, if you have a three-stage unit, the HEAT-SET-T is 105°F, and you want to operate the two lower stages at 85°F and 95°F respectively, enter: (-20.0, -10.0, 0.0)

Keywords with Modified Meaning
The following are existing keywords whose meaning is either clarified or modified.

MIN-FLOW-RATIO

when *floating* between the heating and cooling setpoints and FAN-CONTROL = CONTINUOUS, specifies the fraction of design flow that the unit delivers.

When *cooling*, specifies the minimum allowable flow ratio. For a given cooling stage, the discharge air sensor modulates the fan output to maintain the discharge temperature setpoint. If the flow ratio falls below this fraction, then the flow will be maintained at this value, and the discharge temperature will float.

HMIN-FLOW-RATIO

when *heating*, specifies the minimum allowable flow ratio. For a given heating stage, the discharge air sensor modulates the fan output to maintain the discharge temperature setpoint. If the flow ratio falls below this fraction, then flow will be maintained at this value, and the discharge temperature will float.

While the default is the same as the MIN-FLOW-RATIO, you might want to specify a higher heating minimum; either to prevent damage to a gas furnace, or to minimize temperature stratification in the zone.

THERMOSTAT-TYPE

This keyword is unused for PVVT systems, however the unit functions as though the thermostat is reverse acting.

Engineering Description

In this description, variables in all capitals are typically keywords.

Definitions of major variables

StgVCoolPLR(n) – the fraction of high-stage cooling capacity for each by stage. By definition, high stage will have a value of 1.0

StgVCoolTset(n) – the cooling supply air temperature setpoint for each stage

StgVCoolT(n) – the actual hourly cooling supply temperature for each stage

StgVCoolCFMr(n) – the actual hourly airflow ratio for each stage

Staging

The user specifies the number of mechanical stages of heating and cooling for the unit. The program adds several additional stages. For cooling,

Stage	Cooling Mode
1	Floating
2	Economizer, if any
3	Low-stage cooling
…	Intermediate stages
Max	High-stage cooling

Note that, if there is no cooling economizer, the economizer stage becomes identical to the floating stage. Heating staging is similar to cooling staging, except there is no economizer stage. In addition, for a heat pum, there is an additional stage for supplemental heat.

Stage	Heating Mode
1	Floating
2	Low-stage heating
…	Intermediate stages
Max-1	High-stage heating
Max	Heat-pump supplemental heat, if any

Beginning of run setup

For each stage, n, transfer the user-specified part-load stages into the working arrays, and calculate the supply temperature setpoint for each stage.

    StgVCoolPLR(n)   = COOL-STAGES(n)
    StgVCoolTset(n)   = COOL-SET-T + COOL-STAGES-DT(n)

    StgVHeatPLR(n)   = HEAT-STAGES(n)
    StgVHeatTset(n)   = HEAT-SET-T + HEAT-STAGES-DT(n)

Beginning of hour initialization (DKTEMP)

At the beginning of each hour DKTEMP is called to estimate the hourly equipment capacity, and the maximum and minimum possible supply temperatures. Then the routine sets the airflow ratios and supply temperatures for each stage of cooling and heating.

a) Floating between setpoints – if the temperature of the control zone is floating between the heating and cooling setpoints, then neither heating nor cooling is active. The supply temperature is at the mixed-air temperature, and the flow (if the fan is on) is at the minimum airflow:

    StgVCoolT(n)   = TMMAX + DuctDT
    StgVCoolCFMr(n)   = MIN-CFM-RATIO

where

    TMMAX   the mixed air temperature at minimum outside air, °F
    DuctDT   the temperature rise through the ducting, °F
    MIN-CFM-RATIO   the minimum allowed airflow ratio

b) Economizer cooling – if outdoor conditions are suitable, the economizer will be operating. The supply temperature is initialized to be the minimum possible economizer temperature, and the airflow to maximum. These values may be reset in VARVOL if the economizer can handle the entire cooling load:

StgVCoolT(n)   = TMMIN + DuctDT
StgVCoolCFMr(n)   = 1.

where

TMMIN   is the economizer temperature, adjusted for fan heat, °F

c) Mechanical cooling – the program assumes the economizer is fully integrated with mechanical cooling, for all stage of mechanical cooling. For any given stage, first calculate the capacity and resulting supply temperature at full airflow:

Qstg   = QCS * StgVCoolPLR(n)
TCstg   = TMMIN – Qstg/(CONS(1) * SUPPLY-CFM)

where

Qstg   the capacity for a given stage, Btuh
QCS   the hourly temperature-adjusted high-stage cooling capacity, Btuh
TCstg   the supply temperature assuming full airflow, °F
CONS(1)   the air heat transport capacity factor, Btuh/(cfm-dT)
SUPPLY-CFM   the design airflow, cfm

Next, adjust this stage's temperature setpoint for any dehumidification requirement:

Tset   = Min(StgVCoolTset(n), TCHUM)

where

Tset   the desired cooling supply temperature for this stage, °F
TCHUM   the supply temperature required to maintain MAX-HUMIDITY, °F

Compare Tset to TCstg. If TCstg is less than Tset, then the unit can meet the setpoint at full airflow; set the airflow ratio to 1.0 Otherwise, calculate, the maximum airflow the unit can deliver at setpoint, but do not let it drop below the minimum allowable airflow:

CFMr   = Qstg / (CONS(1)*SUPPLY-CFM*(TMMIN-Tset))
CFMr   = Max(MIN-CFM-RATIO, CFMr)

where

CFMr   the fraction of design supply airflow

Finally, calculate the actual supply temperature for this stage:

StgVCoolT(n)   = TMMIN - Qstg/(CONS(1)*SUPPLY-CFM*CFMr) + DuctDT

d) Heating – the calculations for each heating stage are identical to those for cooling, except there is no economizer stage. If heating is provided by a heat pump, then one extra stage of heating calculations are performed to take into account the supplemental heating that is available in addition to maximum compressor heating.

Hourly calculations (VARVOL and FANPWR)

The staged-volume system is similar to the more conventional PVVT system, and uses many of the same calculations. The staged-volume algorithm recognizes that the unit will typically be cycling between two stages (floating/economizer, economizer/low, low/intermediate, intermediate/high). Each stage is explicity accounted for so that the fan energy associated with each stage can be calculated accurately.

Like the conventional PVVT system, the control zone is simulated first so that the average supply temperature and airflow can be determined. These values are then passed to the non-control zones, which float according to these values (non-control zones do not have their own temperature control schedules, which is why these types of systems are termed 'single zone').

a) Cooling – After the TEMDEV (temperature control) calculations are complete for the control zone, the algorithm cycles through the stages, starting with the lowest, to find stage required to meet the zone's heat-extraction requirement:

$$Qmax = CONS(1) * CFMAX * StgVCoolCFMr * (TAVE - StgVCoolT(n))$$

where

Qmax	the heat-extraction capacity of this stage, Btuh
CFMAX	the design zonal airflow rate, cfm
TAVE	the average hourly zone temperature calculated in TEMDEV, °F

Next, compare Qmax to the required zonal extraction rate, QNOW. If Qmax is greater, then the maximum required stage has been found; otherwise set Qmin to Qmax and repeat the above for the next higher cooling stage. Once the correct stage has been found, calculate the fraction of the hour the system will be operating at the higher stage:

$$StgVFracHi = (QNOW-Qmin) / (Qmax-Qmin)$$

where

StgVFracHi	the fraction of the hour the system is at the higher stage
QNOW	the zonal extraction rate required to hold the zone at setpoint, Btuh
Qmax	the capacity of the higher stage, Btuh
Qmin	the capacity of the lower stage, Btuh

The average airflow during the hour is:

$$ZCFM = CFMAX * StgVCoolCFMr(n) * StgVFracHi \\ + CFMAX * StgVCoolCFMr(n-1) * (1-StgVFracHi)$$

and the average supply temperature is

$$TC = TAVE - QNOW/(CONS(1)*CFMZ)$$

where

(n)	references the higher stage of cooling
(n-1)	references the lower stage of cooling
ZCFM	the average airflow during the hour, cfm
TC	the weighted average supply temperature, °F

TAVE   the average zone temperature during the hour, °F
Qmin   the capacity of the lower stage, Btuh

An exception to the above exists if the economizer can handle the entire load. In this case, the airflow ratio will be set to that required to exactly meet the load, and the economizer will be active the entire hour (no cycling between stages).

ZCFM   = QNOW / (CONS(1) * (TAVE-StgVCoolT(n)))
StgVCoolCFMr(n)   = ZCFM / CFMAX

Note that, if the flow ratio is less than the MIN-FLOW-RATIO, then the flow will be held at the minimum, and the supply temperature will be reset.

Finally, calculate the fraction of the hour the fan is running, and the airflow ratio that is passed to the non-control zones. If the fan is specified to run continuously, or the low stage is higher than floating:

CFMCYC   = 1.0
CFMVVT   = ZCFM / CFMAX

If the fan cycles on/off, it will cycle off only if the low stage is the floating stage. During these times:

CFMCYC   = StgVFracHi
CFMVVT   = StgVCoolCFMr(n),   n = index of higher stage

where

CFMCYC   the fraction of the hour the fan is running
CFMVVT   the average airflow ratio passed to the non-control zones.

b) Heating – Heating calculations are identical to the cooling calculations, except there is no economizer. If heating is provided by a heat pump, the highest stage is the combination of compressor and supplemental heating capacity.

c) Fan power – In the above calculations, an average airflow ratio is calculated for the control zone, and this value is used by any other zones in their temperature calculations. However, since the staged-volume system uses a variable-speed drive, and variable-speed power is not linear with airflow, and average airflow ratio cannot be used in calculating fan power. Instead, fan power must be calculated for the airflow ratio associated with each stage, and then weighted by the time each stage was active.

PLhi   = Max(MIN-FAN-RATIO,
                      Min(MAX-FAN-RATIO, CFMr(n)))
PLhi   = Curve(SUPPLY-EIR-FPLR,PLhi)

PLlo   = Max(MIN-FAN-RATIO,
                      Min(MAX-FAN-RATIO, CFMr(n-1)))
PLlo   = Curve(SUPPLY-EIR-FPLR>,PLlo)

PLR   = PLhi*StgVFracHi + PLlo*(1.-StgVFracHi)

where

PLhi   fraction of full-load fan power of the higher stage
PLlo   fraction of full-load fan power of the lower stage

PLR   weighted average fraction of full load fan power
MIN-FAN-RATIO   minimum allowed fan ratio; fan bypasses below this point
MAX-FAN-RATIO   maximum allowed fan ratio; usually 1.0

These calculations are repeated for the return fan, if it exists.

All other calculations are done identically to the conventional PVVT system

SCREW CHILLERS

Introduction

This new chiller type is an electrically-driven screw machine. You define this chiller using the same keywords as are already used for electric centrifugal and reciprocating machines.

Building Description Language Changes

TYPE

Takes an new code-word that specifies a screw chiller:

ELEC-SCREW   Hermetic screw chiller powered by an internal electric motor. The default part load performance curves assume two independent refrigerant circuits; you may specify the number of compressors in each circuit.

           The program includes generic performance data for water-cooled, air-cooled, remote air-cooled, and remote evaporatively-cooled condensers.

NEW CURVE-FIT TYPE

<u>Introduction</u>

A new type of curve has been introduced to allow chiller part-load energy consumption to be modeled as a function of both part-load ratio (PLR) and temperature differential between the condenser and evaporator.

<u>Building Description Language Changes</u>

TYPE

Takes a new code-word:

BI-QUADRATIC-RATIO&dT   The curve is bi-quadratic in 2 independent variables. It has the form

$$f(r1,dT) = c1 + c2*r1 + c3*r1^2 + c4*dT + c5*dT^2 + c6*r1*dT,$$

where c1, c2, c3, c4, c5, and c6 are coefficients. R1 is a dimensionless variable. dT is a variable with units of delta temperature.

CHILLER PERFORMANCE

Introduction

Prior to this release, the chiller performance data for centrifugal and reciprocating machines were based on chillers manufactured around 1975. Newer chillers can be significantly more efficient, for several reasons:

- <u>Heat-exchanger performance</u> – enhanced heat-exchanger surfaces and larger surface areas result in reduced temperature differentials between the refrigerant and the chilled water and/or condenser fluid

- <u>Reciprocating compressor unloading</u> – Suction cutoff unloading, coupled with 2-circuit chillers and/or multiple compressors per circuit, allows for minimal degradation in performance at part load.

- <u>Electronic expansion valves</u> – allow for better part-load performance

- <u>Variable-speed centrifugals</u> – Centrifugal chillers with variable-speed drives are becoming common. To properly simulate these, it is necessary to include a condenser/evaporator temperature differential term in the part load performance curve.

The ability to store components in the library, coupled with the ability of expressions to pull components out of the library, now allows the program to simulate a wider variety of chillers than before.

Users of this version of the program may observe differences of 10% or more in annual chiller energy; in particular, the performance of reciprocating machines is markedly improved (annual reductions of 30-50% compared to previously).

Chiller Capacity and Energy Consumption

The need to incorporate the temperature differential across the chiller in the part-load performance of centrifugal chillers results in a small modification to the hourly calculations. In the following presentation, the changes are highlighted in *italicized red*.

The program uses the following relationship to calculate the electricity input to the chiller each hour:

Cap_{hour} = Capacity * CAPf(t1,t2)
PLR   = Load / Cap_{hour}
dT   = t2 – t1
$Elec_{hour}$ = Cap_{hour} * EIR * EIRf(t1,t2) * EIRf(PLR,*dT*) / 3413 Btu/kW

where

Cap_{hour}	hourly capacity, Btuh
Capacity	rated capacity, Btuh
CAPf(t1,t2)	correction to capacity for temperatures, curve CAP-FT
t1	leaving chilled-water temperature, °F
t2	condenser temperature, °F
PLR	Part load ratio
Load	Hourly load, Btuh
dT	*Temperature differential across chiller, °F*
$Elec_{hour}$	electric input to the chiller, kW
EIR	rated electric input ratio

EIRf(t1,t2)	correction to EIR for temperatures, curve EIR-FT
EIRf(PLR,dT)	correction to EIR for part-load ratio and dT, curve EIR-FPLR

The meaning of the condenser temperature (t2) varies according to the type of condenser:

- <u>Water-cooled</u> – the entering condenser water temperature (leaving cooling-tower temperature). *Note that, for condenser flows other than the rated flow, the entering condenser temperature is biased based on leaving temperature to correct the error in the curves that would result otherwise.*

- <u>Air-cooled</u> – the outdoor air drybulb temperature

- *Remote condenser – the saturated condensing temperature*

If you change any one of the above curves you should either change the others or verify that they are reasonable over the expected range of operating conditions.

Thermal energy consumption of absorption and engine chillers is calculated in a similar manner.

Building Description Language Changes

Centrifugal Chillers
VARIABLE-SPEED
for the centrifugal chiller types, accepts the value YES or NO indicating whether the chiller utilizes a variable-speed drive. If YES, then the program will select a different default EIR-FPLR performance curve from the library to model part-load performance; this keyword has no other effect.

Part-load capacity reduction in a variable-speed centrifugal chiller utilizes a combination of impeller speed and inlet vanes. To maximize the part-load efficiency of a variable-speed centrifugal chiller, some form on condenser temperature relief must be employed at part load to reduce the temperature (and pressure) differential across the chiller. Otherwise, the performance of a variable-speed chiller may not be significantly different from that of a constant-speed chiller. This is because the pressure rise across the impeller is proportional to the square of the impeller's speed. If the condenser temperature never drops below the design value, then the pressure differential between the evaporator and condenser will remain almost constant, no significant impeller speed reduction will be possible, and most of the capacity reduction will be accomplished via the inlet vanes.

To account for the effect of temperature differential on part-load performance, the EIR-FPLR curve has been modified to include a dT term.

EIR-FPLR
Takes the U-name of a curve that adjusts the electric input ratio as a function of

- <u>The part load ratio (PLR)</u> – The PLR is defined as the ratio of the hourly load to the hourly capacity; Load / Cap_{hour}

- <u>The evaporator/condenser dT</u> - The temperature differential between the condenser and leaving chilled-water. The meaning of the condenser temperature varies according to condenser type.

For most chillers, the dT has a relatively small effect on part-load performance. However, for variable-speed centrifugal chillers, the effect of dT is as important as the PLR. This is because the pressure rise across the impeller is proportional to the square of the impeller's speed. Unless some form on condenser temperature relief is

employed to reduce the temperature (and pressure) differential across the chiller at part load, the performance of a variable-speed chiller may not be significantly different than that of a constant-speed chiller.

To model power consumption as a function of the PLR only, use a CURVE-FIT of TYPE = QUADRATIC or CUBIC. To model as a function of both PLR and dT, use a BI-QUADRATIC-RATIO&DT curve. The curve must be normalized to 1.0 at full load and the rated temperature differential.

Note that, for centrifugal chillers, 'full load' is defined as the 'maximum capacity', not the 'design capacity'. Refer to the DESIGN-PLR keyword for more information.

HIR-FPLR

Takes the U-name of a curve that gives the chiller HIR as a function of:

- The part load ratio (PLR) – The PLR is defined as the ratio of the hourly load to the hourly capacity; Load / Cap_{hour}

- The temperature differential between the condenser and leaving chilled-water (dT) – The meaning of the condenser temperature varies according to condenser type.

For most chillers, the dT has a relatively small effect on part-load performance. However, for variable-speed centrifugal chillers, the effect of dT is as important as the PLR. This is because the pressure rise across the impeller is proportional to the square of the impeller's speed. To maximize the efficiency at part load, some form on condenser temperature relief must be employed to reduce the temperature (and pressure) differential across the chiller at part load.

To model power consumption as a function of the PLR only, use a CURVE-FIT of TYPE = QUADRATIC or CUBIC. To model as a function of both PLR and dT, use a BI-QUADRATIC-RATIO&DT curve. The curve must be normalized to 1.0 at full load and the rated temperature differential.

CHILLER RATED VS. DESIGN CONDITIONS

Introduction

In prior versions of DOE-2, both the program and the documentation were ambiguous as to whether chillers should be specified at the standard rating conditions (ARI in the United States), or at the actual design conditions. This ambiguity is now eliminated.

The program now allows chillers to be specified at either the:

1. <u>Rated conditions</u> – as specified by ARI or other rating organizations. For all chiller types, ARI rates the evaporator conditions as 54°F entering and 44°F leaving chilled water (which corresponds to 2.4 gpm/ton). For water-cooled chillers, the condenser conditions are 85°F entering condenser water at a flow of 3 gpm/ton. Air-cooled chillers are rated at 95°F entering outdoor drybulb temperature. Chillers with remote condensers, are rated at 125°F saturated-condensing temperature.

2. <u>Design conditions</u> – the actual conditions at which the chiller is sized and designed to operate.

When specifying a chiller, it is important to distinguish whether the stated chiller performance (capacity and energy consumption) are defined at the rated or actual conditions. Most chiller types can be specified at either the ARI rated conditions, or the actual design conditions. However, for centrifugal chillers, it may not make sense to specify performance at the ARI rated conditions, as the chiller *may not be able to actually operate at those conditions*.

For example, consider a water-cooled centrifugal chiller serving a building in a relatively cool, dry climate. The engineer specifies the chiller capacity and efficiency at 46°F leaving chilled water and 76°F entering condenser water. To achieve the specified efficiency at minimum cost, assume the chiller manufacturer configures the impeller and heat-exchangers to exactly meet the design conditions. If this chiller is then operated at the more extreme ARI conditions of 44°F/85°F, the compressor may not be able to overcome the pressure differential between the evaporator and condenser, and the chiller will surge if it tries to deliver water at 44°F. To operate successfully at 85°F entering condenser water, it will have to deliver water warmer than 44°F.

For this reason, the program defaults assume that centrifugal chillers are specified at the design conditions. All other chiller types are assumed to be specified at the rated conditions, unless you specify otherwise.

Building Description Language Changes

Design Conditions

DESIGN-CHW-T
The leaving chilled-water temperature at the design conditions. The default is the same as the DESIGN-COOL-T of the chilled-water loop to which this chiller is attached.

DESIGN-COND-T
The condenser temperature at the design conditions. The meaning of this keyword varies according to the condenser type:

- <u>Water-cooled</u> – The entering condenser water temperature. The default is the same as the DESIGN-COOL-T of the condenser water loop to which this chiller is attached.

- <u>Air-cooled</u> – The entering air temperature. The default is the maximum entering air temperature encountered during cooling.

- <u>Remote condenser</u> – The saturated condensing temperature. The default is 125°F for air-cooled, and 105°F for evaporatively cooled.

DESIGN-PLR

For centrifugal chillers only, specifies the ratio of the design capacity to the maximum capacity. The maximum capacity of a centrifugal chiller is often greater than the design capacity; either because of the components used to build up the chiller, or in order to meet the efficiency requirements at the specified conditions.

For example, consider a chiller specified to deliver 500 tons at 44°F chilled water, 80°F entering condenser water at 3 gpm/ton, and 0.6 kW/ton power consumption. The chiller manufacturer's selection program might determine that the least expensive chiller that meets the specifications is actually one having a maximum capacity of 550 tons and a power consumption of 0.64 kW/ton at full load. However, when unload to 500 tons, the efficiency of the chiller improves, and the part load power consumption is 0.6 kW/ton; thereby meeting the engineer's specifications. (Centrifugal chillers are most efficient when running at part load.)

To specify the above chiller in DOE-2, set

```
SPECIFIED-AT      = DESIGN-CONDITIONS
CAPACITY          = 6.       $ 500 tons *12000 Btu/ton / 1000000
ELEC-INPUT-RATIO  = 0.171    $ 0.6 kW/ton * 3413 Btu/kW / 12000 Btu/ton
DESIGN-PLR        = 0.91     $ 500 design tons / 550 maximum tons
```

The capacity and power performance curves are always relative to the maximum capacity, not the design capacity. The DESIGN-PLR keyword identifies the design point relative to the maximum operating point on the performance curves.

<u>Rated Conditions</u>

The next set of keywords describe the rating conditions of a chiller, either ARI or other:

RATED-CHW-T

The chilled-water temperature at the rated conditions, either ARI or other. This is the value at which the chiller performance curves are normalized. Normally, you should not change the default value of this keyword unless you are also specifying the chiller performance curves, and the curves are normalized to a different value.

RATED-COND-T

The condenser temperature at the rated conditions, either ARI or other. The default varies by condenser type. This is the value at which the chiller performance curves are normalized. Normally, you should not change the default value of this keyword unless you are also specifying the chiller performance curves, and the curves are normalized to a different rating condition.

RATED-CW-FLOW

For a water-cooled condenser, specifies the condenser flow at the rated conditions, either ARI or other. This is the value at which the chiller performance curves are normalized. The default for ARI-rated chillers is 3.0 gpm/ton. Normally, you should not change the default value of this keyword unless you are also specifying the chiller performance curves, and the curves are normalized to a different rating condition.

Why is this keyword relevant? Chiller manufacturers normally report performance as a function of the *entering* condenser water temperature, and the DOE-2 performance curves conform to this convention. However, the *leaving*

condenser water temperature is actually a more important determinant of chiller performance, and must be taken into account when simulating a chiller with a condenser flow other than the rated flow. The program uses this keyword to bias the entering condenser temperature for off-rated and/or variable condenser flows.

For example, assume a chiller operating at a 3 gpm/ton condenser flow has a 9°F rise through the condenser at rated conditions. In this case, an 85°F entering condenser temperature corresponds to 94°F leaving temperature. If the condenser flow is reduced to 2 gpm/ton, then the rise will be approximately 15°F and the leaving temperature will be 100°F. To account for this increase in leaving temperature, the program will bias the entering temperature by 6°F, so that the value used in the curves for entering condenser temperature is 91°F instead of 85°F. (This example oversimplifies the problem; the program iterates to find the balance point between the biased entering condenser temperature, and the impact of that temperature on capacity, power consumption, rejected heat, and leaving temperature.)

SPECIFIED-AT
accepts a code-word specifying the conditions at which the user is specifying a chiller.

RATED-CONDITIONS	the default for all non-centrifugal chillers, indicates the user-specified capacity is defined at the ARI or other rated conditions; RATED-CHW-T, RATED-COND-T, etc.
DESIGN-CONDITIONS	the default for centrifugal chillers, indicates that the user-specified capacity is defined at the actual design conditions; DESIGN-CHW-T, DESIGN-COND-T, etc. The program converts the specified design capacity to the corresponding rated capacity. The rated capacity is displayed in all reports. On an hourly basis, the rated capacity is converted to the actual capacity using the CAPACITY-FT performance curve.

On an hourly basis, the rated capacity is converted to the actual capacity using the CAPACITY-FT performance curve. Similarly, the rated power is converted to the actual power using the EIR-FT and EIR-FPLR, and/or the HIR-FT and HIR-FPLR performance curves.

Note that, for an auto-sized chiller, the program always selects the size based on the design conditions, and then translates that size to the rated conditions. However, other parameters, such as the ELEC-INPUT-RATIO, may be at either the rated or design conditions.

Air-to-Water HEAT-PUMP Chiller
The HEAT-PUMP chiller with CONDENSER-TYPE = AIR-COOLED has been modified to allow the rated and design conditions to be specified in the heating mode. Since this type of chiller is common in Europe, but not in the United States, the performance curves are normalized at the Eurovent rating conditions, rather than ARI.

In the keywords below, the term "condenser" refers to the air-side heat-exchanger, whether in the heating or cooling mode:

DESIGN-HW-T
The leaving hot-water temperature at the heating design conditions. The default is the same as the DESIGN-HEAT-T of the 2-pipe loop to which this chiller is attached.

DESIGN-COND-T-HT
The air-side heat-exchanger entering air temperature at the design heating conditions. The default is the minimum outdoor temperature encountered during heating when the building is occupied.

RATED-HW-T

specifies the leaving hot-water temperature at the rated conditions, either ARI or Eurovent (The default is for Eurovent). This is the value at which the heating mode performance curves are normalized. Normally, you should not change the default value of this keyword unless you are also specifying the heat-pump performance curves, and the curves are normalized to a different value.

RATED-COND-T-HT

The air-side heat-exchanger entering air temperature when in the heating mode, at the rated conditions. This is the value at which the heating mode performance curves are normalized. Normally, you should not change the default value of this keyword unless you are also specifying the heat-pump performance curves, and the curves are normalized to a different value.

HEAT/COOL-CAP

Is the ratio of the heating capacity to the cooling capacity at the standard rating conditions.

The chiller's CAPACITY is the cooling capacity at the standard cooling rating conditions (SPECIFIED-AT = RATED-CONDITIONS). At the standard heating rating conditions, the heating capacity is usually very close to the cooling CAPACITY. If, however, the heating capacity was only 80% of the cooling capacity, then this keyword would have a value of 0.8

When the CAPACITY is allowed to default:

- Cooling capacity - The program looks at the peak cooling requirement at the actual peak conditions, calculates the capacity at these conditions, and translates the capacity to the rated conditions.

- Heating capacity – The program looks at the peak heating requirements at the actual peak heating conditions, calculates the heating capacity at these conditions, and translates the capacity to the rated conditions.

Greater of the two – The program takes the rated heating capacity and calculates an equivalent cooling capacity by dividing by the HEAT/COOL-CAP. The CAPACITY is the greater of the rated cooling capacity, or the equivalent cooling capacity required for heating.

Water-to-Water HEAT-PUMP Chiller

The HEAT-PUMP chiller with CONDENSER-TYPE = AIR-COOLED has been modified to allow the rated and design conditions to be specified in the heating mode. Since this type of chiller is common in Europe, but not in the United States, the performance curves are normalized at the Eurovent rating conditions, rather than ARI.

In the keywords below, the term "condenser" refers to the well-side heat-exchanger, whether in the heating or cooling mode:

DESIGN-HW-T

The leaving hot-water temperature at the design heating conditions. The default is the same as the DESIGN-HEAT-T of the 2-pipe loop to which this chiller is attached.

DESIGN-COND-T-HT

The entering lake/well temperature at the design heating conditions. The default is the DESIGN-HEAT-T of the lake/well loop.

CW-DT

The design temperature change of the lake/well water when in the cooling mode. The default is 90°F (32°C) minus the CW-LOOP:DESIGN-COOL-T. For example, if the design cooling temperature of the lake/well loop is 60°F, then the design temperature change will be 30°F.

The expansion valve of the heat pump is sized for the high pressure differential that normally exists in the heating mode. In the cooling mode, if 60°F water were to enter the heat pump with only a 10°F rise, then the condensing pressure would be too low to maintain refrigerant flow through the expansion valve. For this reason, flow is normally reduced through the condenser when in the cooling mode. This is accomplished via a solenoid valve in parallel with a restricting valve. During cooling, the solenoid valve is closed, and condenser flow is restricted through the balance valve (thereby achieving the CW-DT). During heating, the solenoid valve is open, allowing full flow.

CW-DT-HT

The design temperature change of the lake/well water when in the heating mode. The default is 9°F (5°C).

The expansion valve of the heat pump is sized for the high pressure differential that normally exists in the heating mode. In the cooling mode, if 60°F water were to enter the heat pump with only a 10°F rise, then the condensing pressure would be too low to maintain refrigerant flow through the expansion valve. For this reason, flow is normally reduced through the condenser when in the cooling mode. This is accomplished via a solenoid valve in parallel with a restricting valve. During cooling, the solenoid valve is closed, and condenser flow is restricted through the balance valve (thereby achieving the CW-DT). During heating, the solenoid valve is open, allowing full flow.

RATED-HW-T

specifies the leaving hot-water temperature at the rated conditions, either ARI or Eurovent (The default is for Eurovent). This is the value at which the heating mode performance curves are normalized. Normally, you should not change the default value of this keyword unless you are also specifying the heat-pump performance curves, and the curves are normalized to a different value.

RATED-COND-T-HT

The entering lake/well temperature when in the heating mode, at the rated heating conditions. This is the value at which the heating mode performance curves are normalized. Normally, you should not change the default value of this keyword unless you are also specifying the heat-pump performance curves, and the curves are normalized to a different value.

RATED-HT/CL-FLOW

specifies the ratio of the flow during heating to the flow during cooling at the rated conditions. Heating and cooling performance is usually rated at a constant CW-LOOP temperature change of 9°F (5°C). However, because the heat taken or rejected to the CW-LOOP is not the same in both modes, the rated flow used to develop the performance curves is different in each case; usually with the heating flow smaller than the cooling flow.

Normally, you should not change the default value of this keyword unless you are also specifying the heat-pump performance curves, and the curves are normalized to a different value.

HEAT/COOL-CAP

Is the ratio of the heating capacity to the cooling capacity at the standard rating conditions.

The chiller's CAPACITY is the cooling capacity at the standard cooling rating conditions (SPECIFIED-AT = RATED-CONDITIONS). At the standard heating rating conditions, the heating capacity is usually very close to the cooling CAPACITY. If, however, the heating capacity was only 80% of the cooling capacity, then this keyword would have a value of 0.8

When the CAPACITY is allowed to default:

- Cooling capacity - The program looks at the peak cooling requirement at the actual peak conditions, calculates the capacity at these conditions, and translates the capacity to the rated conditions.

- Heating capacity – The program looks at the peak heating requirements at the actual peak heating conditions, calculates the heating capacity at these conditions, and translates the capacity to the rated conditions.

- Greater of the two – The program takes the rated heating capacity and calculates an equivalent cooling capacity by dividing by the HEAT/COOL-CAP. The CAPACITY is the greater of the rated cooling capacity, or the equivalent cooling capacity required for heating.

HEAT-CAP-FT

Takes the U-name of a curve the gives the heating capacity of the chiller as a function of the leaving hot water temperature and the entering lake/well temperature. This curve should be normalized to 1.0 at the ARI or Eurovent rating point.

Loop-to-Loop Heat-Pump Chiller (3-loop)

The LOOP-TO-LOOP-HP chiller has been modified to allow the rated and design conditions to be specified in the heating mode. Since this type of chiller is common in Europe, but not in the United States, the performance curves are normalized at the Eurovent rating conditions, rather than ARI.

In the keywords below, the term "condenser" refers to the air-side heat-exchanger, whether in the heating or cooling mode:

DESIGN-HW-T

The leaving hot-water temperature at the heating design conditions. The default is the same as the DESIGN-HEAT-T of the hot-water loop to which this chiller is attached.

DESIGN-COND-T

The entering condenser temperature at the design *cooling* conditions. This is the temperature leaving the condenser-side heat-exchanger and entering the chiller condenser. The default is the DESIGN-COOL-T of the lake/well water loop, plus 5°F.

When autosizing a chiller, the default assumes that heating does not occur simultaneously with peak cooling. If heating does occur simultaneously with peak cooling, change this value to approximate the hot-water return temperature at the peak cooling conditions.

EVAP-HX-DESIGN-T

The design temperature of the water leaving the evaporator-side heat-exchanger (heating mode). The default is the DESIGN-HEAT-T of the lake/well loop, minus 5°F. This value is used in the design heating calculations.

EVAP-HX-SETPT-T

When the chiller is in the heating-only mode and heat-exchanger IC-EV is adding heat to the evaporator loop, specifies the temperature setpoint of the chilled-water *leaving* the heat-exchanger and entering the evaporator. The default is the same as the EVAP-HX-DESIGN-T.

The program uses this setpoint, together with the hourly load, UA product and chilled-water flow, to calculate the chilled-water temperature and required well-water flow. Note that this setpoint may not be maintained if the well-water is too cold. For example, if the setpoint is 60°F but the well-water is only 50°F, then it will be impossible to meet the setpoint, and the evaporator temperature will float somewhere below 50°F.

This keyword applies to the *heating-only* mode. In all other modes involving cooling, the heat-exchanger is controlled so that the temperature requirement of the chilled-water loop (chilled-water supply temperature) is met.

EVAP-HX-TD

is the design temperature differential between the chilled-water and well-water streams *entering* the evaporator-side heat-exchanger (IC-EV in the diagrams). The differential is the differential when the chiller is operating in the heating-only mode, which represents maximum heat-exchanger loading. The program uses this value, together with the design evaporator load in the heating mode, and the design chilled-water and well-water flows, to calculate the UA product of the heat-exchanger.

The default is calculated as

$$TD = Twell - (Tsetpt+dTchw)$$

where

TD	the design entering temperature differential
Twell	the DESIGN-HEAT-T of the well water loop
Tsetpt	the EVAP-HX-SETPT-T
dTchw	the design chilled water temperature rise, CHW-DT

COND-HX-SETPT-T

When the chiller is in the cooling-only mode and heat-exchanger IC-CD is removing heat from the hot-water loop, specifies the temperature setpoint of the hot-water *leaving* the heat-exchanger and entering the condenser. The default is the same as the DESIGN-COND-T.

The program uses this setpoint, together with the hourly load, UA product and chilled-water flow, to calculate the condenser-water temperature and required well-water flow. Note that this temperature may not be maintained if the lake/well-water is too warm. For example, if the setpoint is 75°F but the chiller is attached to a lake that peaks at 80°F, then it will be impossible to meet the setpoint.

This keyword applies to the *cooling-only* mode. In all other modes involving heating, the heat-exchanger is controlled so that the temperature requirement of the hot-water loop (hot-water supply temperature) is met.

COND-HX-TD

is the design temperature differential between the hot-water and well-water streams *entering* the condenser-side heat-exchanger (IC-CD in the diagrams). The differential is the differential when the chiller is operating in the cooling-only mode, which represents maximum heat-exchanger loading. The program uses this value, together with the design condenser load in the cooling mode, and the design hot-water and well-water flows, to calculate the UA product of the heat-exchanger.

The default is calculated as

$$TD = Tsetpt+dTcw - Twell$$

where

TD	the design entering temperature differential
Tsetpt	the CO ND-HX-SETPT-T
dTcw	the design condenser-water temperature rise, CW-DT
Twell	the DESIGN-COOL-T of the well water loop

Keywords with Modified Meaning

The following are existing keywords whose meaning is either clarified or modified.

CAPACITY

The cooling capacity of the chiller. The SPECIFIED-AT keyword indicates whether the specified capacity is at the RATED-CONDITIONS or the DESIGN-CONDITIONS.

If you do not specify CAPACITY, it defaults to the chilled water loop capacity times CAPACITY-RATIO. If no CAPACITY-RATIO is input, the capacity will default to the loop capacity divided by the number of chillers attached to the loop.

Deleted Keywords

MAX-RATIO

For centrifugal chillers, this keyword has replaced with DESIGN-PLR, which has a different meaning than MAX-RATIO had. For all other chiller types, the program assumes that the maximum capacity is identical to the rated capacity.

OFF-RATED AND VARIABLE-FLOW CONDENSERS

Introduction

The earlier versions of DOE-2.2 contained keywords to allow water-cooled, variable-flow condensers to be simulated. The variable-flow algorithms have been improved to better model the chiller's response to a variable-flow condenser.

Building Description Language Changes

CW-DT

The design temperature change of the water flowing through the condenser. The program uses this keyword to determine the component's design flow, which in turn is used to size the equipment-recirculation pump, if any, on the component, and to calculate the hourly pressure drop. Default is the LOOP-DESIGN-DT of the condenser loop.

Note that the CW-DT will usually result in a calculated design flow somewhat different than the rated flow, RATED-CW-FLOW. Chiller manufacturers normally report performance as a function of the *entering* condenser water temperature, and the DOE-2 performance curves conform to this convention. However, the *leaving* condenser water temperature is actually a more important determinant of chiller performance, and must be taken into account when simulating a chiller with a condenser flow other than the rated flow. The program corrects for off-rated condenser flows, either fixed or variable, by biasing the entering condenser water temperature. Please refer to the section *Chiller Rated vs. Design Conditions* for more information on this topic.

CW-FLOW-CTRL

Takes a code-word that specifies the type of flow through the chiller.

CONSTANT-FLOW   Indicates that the condenser flow is independent of the chiller load.

VARIABLE-FLOW   The condenser flow varies linearly with the load, in accordance with CW-MIN-FLOW and CW-MIN-PLR. If the leaving condenser temperature exceeds the MAX-COND-T, then flow will be increased, up to the design flow, to maintain setpoint.

PLRratio = (PLR – CW-MIN-PLR) / (1.0 – CW-MIN-PLR)
FlowRatio = CW-MIN-FLOW + (1. – CW-MIN-FLOW) * PLRratio

To prevent the water flow from falling off as rapidly as the load, make the CW-MIN-PLR smaller than the CW-MIN-FLOW.

CW-MIN-FLOW

When CW-FLOW-CTRL = VARIABLE-FLOW, specifies the minimum allowable fraction of the design flow through the evaporator. This flow is assumed to occur at the part-load ratio corresponding to the CW-MIN-PLR, and is linear between full load and this part load. Typically, the minimum flow should be above the point where the flow transitions from turbulent to laminar.

Note that the flow will be increased, up to design, if the leaving condenser temperature exceeds the MAX-COND-T.

CW-MIN-PLR
When CW-FLOW-CTRL = VARIABLE-FLOW, specifies the minimum part load ratio at which the minimum flow occurs. The default is the same as the CW-MIN-FLOW, so that condenser flow is exactly proportional to load.

Note that the flow will be increased, up to design, if the leaving condenser temperature exceeds the MAX-COND-T.

MAX-COND-T
When CW-FLOW-CTRL = VARIABLE-FLOW, specifies the temperature that acts as an upper limit on the leaving condenser temperature. Normally, the flow will be reset linearly according to the chiller's part-load ratio (PLR), the CW-MIN-FLOW and the CW-MIN-PLR. However, if the leaving condenser temperature exceeds the MAX-COND-T, then the flow will be controlled, up to design, to maintain the MAX-COND-T.

MIN-COND-T
Specifies the minimum allowable condensing temperature setpoint. This value will override any of the control schemes to maintain the setpoint at or above this value. Some chillers may require a certain pressure differential between the evaporator and the condenser in order to maintain full refrigerant flow through an expansion valve. If the condenser pressure drops too low, then chiller capacity will be adversely affected.

- For water-cooled condensers, this value represents the minimum entering condenser water temperature.

- For air-cooled chillers, this value represents the minimum entering air temperature

For remote condensers, this value is the minimum allowable saturated condensing temperature.

REMOTE CONDENSERS

Introduction

Remoter condensers were added to a previous version of DOE-2.2, however, they are now better integrated and are expected to give better results than previously.

A remote condenser is a sub-component of a CHILLER. Its keywords are contained within the CHILLER component, but it has its own temperature control sequences, and the power consumption of its fans are calculated separately from the chiller's ELEC-INPUT-RATIO and associated performance curves.

Since a remote condenser is essentially separate from its chiller, the chiller's performance curves must be defined in terms of the saturated condensing temperature of the condenser. The outdoor drybulb has no direct impact on the chiller, as the condenser has its own temperature control strategy. Note however, that the condenser temperature will float up if overloaded, and this will affect the chiller performance.

As part of this project, new performance curves for air-cooled condensers were also added to the DOE-2 library.

Building Description Language Changes

CONDENSER-TYPE
Takes a code-word that defines the type of the chiller's condenser.

WATER-COOLED | Water-cooled condenser. The chiller's performance curves are defined relative to the entering condenser water temperature (leaving cooling tower temperature). Any type of chiller may be water-cooled.

AIR-COOLED | Air-cooled condenser. The chiller's performance curves are defined relative to the outdoor drybulb temperature. All energy consumption associated with the condenser fans is included in the chiller's ELEC-INPUT-RATIO and associated performance curves; there are no separate keywords describing the condenser fans. Only electric chillers and the heat-pump chiller may be air cooled; all others must be water-cooled.

REMOTE-AIR-COOLED | A remotely located, air-cooled condenser. The chiller's performance curves are defined relative to the saturated condensing temperature. Temperature control of the remote condenser, and the energy consumption of its fans, are defined using a separate set of keywords within the CHILLER component. In other words, the chiller's ELEC-INPUT-RATIO and associated performance curves apply to the chiller compressor only.

Only conventional electric chillers may have a remote condenser.

REMOTE-EVAP-COOLED | A remotely located, evaporatively-cooled condenser. The chiller's performance curves are defined relative to the saturated condensing temperature. Temperature control of the remote condenser, and the energy consumption of its fans, are defined using a separate set of keywords within the CHILLER component. In other words, the chiller's ELEC-INPUT-RATIO and associated performance curves apply to the chiller compressor only.

Only conventional electric chillers may have a remote condenser.

Air-cooled and evaporatively-cooled remote condensers have many keywords in common, but have enough differences that they are presented in separate sections.

Air-Cooled Remote Condenser
COND-CAPACITY
Specifies the capacity of the condenser at a given temperature differential between saturated condensing temperature and ambient drybulb temperature, SCT-AMB-DT. If you do not specify the capacity, it will default to the design heat rejection load of the chiller. The program will not allow you to specify the condenser's capacity unless you also specify the chiller's capacity.

SCT-AMB-DT
Specifies the differential between the saturated condensing temperature and the outdoor drybulb temperature at which the COND-CAPACITY is specified.

- When COND-CAPACITY is specified, this keyword is required

- When COND-CAPACITY is not specified, you may define this keyword. If you do not, the program will default it to be the difference between the DESIGN-COND-T and the maximum outdoor drybulb temperature encountered during cooling.

COND-SETPT-CTRL
Accepts a code-word specifying the saturated condensing temperature setpoint control:

FIXED	the default, specifies that the temperature setpoint is constant all hours.
VARIABLE	specifies that the condensing temperature setpoint varies according to the hourly drybulb temperature, plus a fixed differential; the differential being specified by COND-SETPT-DT.
AMBIENT	specifies that the condenser fans are staged according to the hourly drybulb temperature. The fraction of the condenser that is active is defined by the curve AMB-FRAC-FT. The actual condensing temperature then floats according to the load, the outdoor temperature, and the fraction of the condenser that is active.

COND-SETPT-T
When COND-SETPT-CTRL is FIXED, specifies the saturated condensing temperature (SCT) setpoint. The condenser will hold this setpoint all hours, unless the load or outdoor temperature is such that the SCT must float upward. In this case, the program will iterate to find the balance point between the SCT and the chiller performance.

COND-SETPT-DT
When COND-SETPT-CTRL is VARIABLE, specifies the saturated condensing temperature setpoint differential.

For example, if a chiller has an air-cooled condenser, this keyword is 20°F, and the drybulb temperature is 84°F, then the current condensing temperature setpoint is 104°F.

MIN-COND-T
Specifies the minimum allowable condensing temperature setpoint. This value will override any of the control schemes to maintain the setpoint at or above this value. Some chillers may require a certain pressure differential between the evaporator and the condenser in order to maintain full refrigerant flow through an expansion valve. If the condenser pressure drops too low, then chiller capacity will be adversely affected.

- For water-cooled condensers, this value represents the minimum entering condenser water temperature.

- For air-cooled chillers, this value represents the minimum entering air temperature

- For remote condensers, this value is the minimum allowable saturated condensing temperature.

COND-FAN-CTRL

When COND-SETPT-CTRL is FIXED or VARIABLE, accepts a code word specifying the mechanism by which the fans are controlled to hold the setpoint. The value of this code word is used to select a curve from the library that modifies the fan power consumption as a function of the condenser load (COND-PWR-FPLR).

PRESSURE-SWITCHES	the default, specifies that the fans are staged/cycled according to the condensing pressure (temperature) . Power consumption is assumed to be linear with load. The default curve is Rcond-Fan-Pwr-fPLR-ACpress.
DAMPER-MODULATION	specifies that fans run continuously, with air flow modulated by discharge dampers. The default curve is Rcond-Fan-Pwr-fPLR-Damper.
TWO-SPEED-FANS	specifies a condenser having two-speed fans. The default curve is Rcond-Fan-Pwr-fPLR-2speed.
VFD-ON-FANS	specifies a condenser with a variable-speed drive. The default curve is Rcond-Fan-Pwr-fPLR-VFDair or Rcond-Fan-Pwr-fPLR-VFDevap.

AMB-FRAC-FT

when COND-SETPT-CTRL is AMBIENT, accepts the U-name of a curve that defines the fraction of the condenser that is active as a function of the outdoor drybulb or wetbulb temperature. This curve approximates the effect of staging or modulating fans directly as a function of ambient temperature, without regard to the actual condensing temperature.

COND-FAN-EIR-TD

is the electric input to nominal capacity ratio for the component fan expressed as

$$FanEIR = (Fan\ electric\ power\ in\ Btuh) / (Condenser\ capacity\ in\ Btuh/TD)$$

where TD is the SCT-AMBIENT-TD.

The default for air-cooled condensers is 0.55 Btu-TD/Btu, which corresponds to proximally 0.28 HP per 15,000 Btuh at 10°F TD.

COND-PWR-FPLR

accepts the U-name of a curve that modifies the condenser fan energy consumption as a function of the condenser part load ratio.

Water-Cooled Remote Condenser

DESIGN-WETBULB

Specifies the design wetbulb temperature of the condenser.

COND-CAPACITY

Specifies the capacity of the condenser at either the rated conditions or the design conditions. If you do not specify the capacity, it will default to the design heat rejection load of the chiller. The program will not allow you to specify the condenser's capacity unless you also specify the chiller's capacity.

The SPECIFIED-AT keyword determines whether the user-specified capacity is at the rated conditions or the design conditions:

- The rated conditions (to which the COND-CAP-FT curve is normalized) are 105°F saturated condensing temperature and 78°F outdoor wetbulb temperature (40.5°C/25.5°C).

- The design conditions are the DESIGN-COND-T and the DESIGN-WETBULB. If you specify the capacity at the design conditions, the program will translate the capacity to the rated conditions. The rated capacity will be modified hourly according to the actual conditions.

COND-CAP-FT

Accepts the U-name of a curve that modifies the design condenser capacity as a function of the saturated condensing temperature and the wetbulb temperature. This curve should be normalized to the rating conditions. The default curve assumes rating conditions of 105°F saturated condensing temperature and 78°F outdoor wetbulb temperature (40.5°C/25.5°C).

COND-FAN-EIR

specifies the electric input ratio (EIR) of the condenser fan(s), where the EIR is a dimensionless ratio of the fan energy consumption to the condenser capacity:

$$EIRfan = Fan\ power,\ Btu\ /\ Condenser\ capacity,\ Btu$$

You may specify the fan EIR at either the rated or design condenser capacity, according to the SPECIFIED-AT keyword. If you specify the EIR at the design capacity, the program will translate it to the rated capacity.

The hourly fan energy is calculated as:

$$kWfan = RatedCap * EIRfan * f(PLR) * Frac$$

where RatedCap is the rated capacity of the chiller, f(PLR) is a curve that modifies fan energy as a function of the condenser part load ratio (COND-PWR-FPLR), and Frac is the fraction of the hour the chiller is operating.

COND-PUMP-EIR

specifies the electric input ratio (EIR) of the condenser spray pump(s), where the EIR is a dimensionless ratio of the pump energy consumption to the condenser capacity:

$$EIRpump = Pump\ power,\ Btu\ /\ Condenser\ capacity,\ Btu$$

You may specify the pump EIR at either the rated or design condenser capacity, according to the SPECIFIED-AT keyword. If you specify the EIR at the design capacity, the program will translate it to the rated capacity.

The condenser pump energy is independent of condenser load, but will cycle on/off if the chiller is also cycling.

COND-PWR-FPLR

accepts the U-name of a curve that modifies the condenser fan energy consumption as a function of the condenser part load ratio.

COND-SETPT-CTRL

Accepts a code-word specifying the saturated condensing temperature setpoint control:

FIXED   the default, specifies that the temperature setpoint is constant all hours.

VARIABLE   specifies that the condensing temperature setpoint varies according to the hourly
                         wetbulb temperature, plus a fixed differential; the differential being specified by
                         COND-SETPT-DT.

AMBIENT   specifies that the condenser fans are staged according to the hourly wetbulb
                         temperature. The fraction of the condenser that is active is defined by the curve
                         AMB-FRAC-FT. The actual condensing temperature then floats according to the
                         load, the outdoor temperature, and the fraction of the condenser that is active.

COND-SETPT-T

When COND-SETPT-CTRL is FIXED, specifies the saturated condensing temperature (SCT) setpoint. The condenser will hold this setpoint all hours, unless the load or outdoor temperature is such that the SCT must float upward. In this case, the program will iterate to find the balance point between the SCT and the chiller performance.

COND-SETPT-DT

When COND-SETPT-CTRL is VARIABLE, specifies the saturated condensing temperature setpoint differential.

For example, if a chiller has an evaporatively-cooled condenser, this keyword is 10°F, and the wetbulb temperature is 74°F, then the current condensing temperature setpoint is 84°F.

MIN-COND-T

Specifies the minimum allowable condensing temperature setpoint. This value will override any of the control schemes to maintain the setpoint at or above this value. Some chillers may require a certain pressure differential between the evaporator and the condenser in order to maintain full refrigerant flow through an expansion valve. If the condenser pressure drops too low, then chiller capacity will be adversely affected.

- For water-cooled condensers, this value represents the minimum entering condenser water temperature.

- For air-cooled chillers, this value represents the minimum entering air temperature

- For remote condensers, this value is the minimum allowable saturated condensing temperature.

COND-FAN-CTRL

When COND-SETPT-CTRL is FIXED or VARIABLE, accepts a code word specifying the mechanism by which the fans are controlled to hold the setpoint. The value of this code word is used to select a curve from the library that modifies the fan power consumption as a function of the condenser load (COND-PWR-FPLR).

PRESSURE-SWITCHES   the default, specifies that the fans are staged/cycled according to the condensing
                         pressure (temperature) . Power consumption is assumed to be linear with load.
                         The default curve is Rcond-Fan-Pwr-fPLR-ACpress.

DAMPER-MODULATION specifies that fans run continuously, with air flow modulated by discharge
                         dampers. The default curve is Rcond-Fan-Pwr-fPLR-Damper.

TWO-SPEED-FANS   specifies a condenser having two-speed fans. The default curve is Rcond-Fan-
                         Pwr-fPLR-2speed.

VFD-ON-FANS	specifies a condenser with a variable-speed drive. The default curve is Rcond-Fan-Pwr-fPLR-VFDair or Rcond-Fan-Pwr-fPLR-VFDevap.

AMB-FRAC-FT
when COND-SETPT-CTRL is AMBIENT, accepts the U-name of a curve that defines the fraction of the condenser that is active as a function of the outdoor drybulb or wetbulb temperature. This curve approximates the effect of staging or modulating fans directly as a function of ambient temperature, without regard to the actual condensing temperature.

Keywords with Modified Meaning
The following are existing keywords whose meaning is either clarified or modified.

CAPACITY-FT
Takes the U-name of a curve that adjusts the capacity of the chiller as a function of the leaving evaporator water temperature and the condenser temperature. This curve should be normalized to 1.0 at the rated conditions (RATED-CHW-T, RATED-COND-T, etc.).

The meaning of condenser temperature varies according to the type of condenser:

- Water-cooled – the entering condenser water temperature (leaving cooling-tower temperature). For condenser flows other than the RATED-CW-FLOW, the program will bias the entering condenser temperature to account for the off-rated flow.

- Air-cooled – the outdoor air drybulb temperature

- Remote condenser – the saturated condensing temperature

EIR-FT
Takes the U-name of a curve that adjusts the electric input ratio as a function of the leaving chilled water temperature and the condenser temperature. This curve should be normalized to 1.0 at the ARI point (RATED-CHW-T, RATED-COND-T, etc.).

The meaning of condenser temperature varies according to the type of condenser:

- Water-cooled – the entering condenser water temperature (leaving cooling-tower temperature). For condenser flows other than the RATED-CW-FLOW, the program will bias the entering condenser temperature to account for the off-rated flow.

- Air-cooled – the outdoor air drybulb temperature

- Remote condenser – the saturated condensing temperature

LOOP DESIGN TEMPERATURES

Introduction

Prior to this release, the circulation-loop HEAT-SETPT-T and/or COOL-SETPT-T acted as both the setpoints for the loop temperature controller, as well as the values for use in the design calculations. As the setpoint temperature may not necessarily be the same as the design temperature, new keywords explicitly specify the design conditions.

Building Description Language Changes

DESIGN-HEAT-T

For loops that can heat, specifies the design hot-water supply temperature. This value may be used in the design calculations for various components, such as boilers and chillers.

For a LAKE/WELL loop this is the design temperature used for components that draw heat from the loop, such as a CHILLER of TYPE = HEAT-PUMP. As such, this value should represent the winter condition.

DESIGN-COOL-T

For loop that can cool, specifies the design chilled-water temperature. This value is used in the design calculations for various components, such as chillers.

For a CW and WLHP loops, this is the design temperature that the cooling towers or fluid coolers can deliver. For LAKE/WELL loops, this is the design temperature used for components that reject heat to the loop; as such this value should represent the summer condition.

Keywords with Modified Meaning

The following are existing keywords whose meaning is either clarified or modified.

HEAT-SETPT-T

The heating setpoint when HEAT-SETPT-CTRL = FIXED. The default is the DESIGN-HEAT-T.

This keyword is no longer used as the design temperature.

COOL-SETPT-T

Accepts a numeric value which defines the cooling setpoint when COOL-SETPT-CTRL = FIXED. The default is the DESIGN-COOL-T.

For a CW loop having COOL-SETPT-CTRL = LOAD-RESET, this value acts as an upper limit on the floating temperature control. If the floating loop temperature exceeds this value, the fans will modulate as required to prevent the loop temperature from exceeding this value. Refer to the cooling tower sections for more information.

This keyword is no longer used as the design temperature.

DHW LOOP ENHANCEMENTS

Introduction

Previously, domestic hot-water loops could be simulated with a constant recirculation flow. The loop algorithm has been enhanced to allow for variable recirculation flow.

During times when the PROCESS-FLOW in the supply leg is large enough that recirculation is not necessary (the supply leg temperature drop is not excessive), then the flow in the return leg will be zero and the pump will be off. At lower process flows, the return leg flow can modulate to maintain a minimum supply flow.

Building Description Language Changes

Two existing keywords have been enhanced to allow variable recirculation:

LOOP-MIN-FLOW

The minimum flow fraction in the loop. The meaning of this keyword varies depending on the type of loop:

- <u>For all loops except DHW</u>, the default is 0.05. For loops serving coils with 3-way valves or constant-flow condensers, the loop flow will be constant, and this keyword has no meaning. For loops serving coils with 2-way valves or water-cooled condensers having condenser valves, the loop flow will be variable and may drop to a very small fraction of the design load, or even zero. When this happens, the circulation pump may cause a very large temperature rise in the fluid, or may overheat and fail. The LOOP-MIN-FLOW prevents this from happening by opening a bypass valve as required to maintain the minimum loop flow. An alternate way of preventing this problem would be to assign 3-way valves to one or more of the coils attached to this loop.

- <u>For DHW loops having a recirculation pump</u>, the default is zero. This keyword specifies the minimum fraction of design flow in the *supply* leg of the loop. As the process flow varies, (the flow assumed to go down the drain), the return flow will be modulated so that the resulting supply flow does not drop below this value. For example, if the design process flow is 15 gpm and this keyword is 0.33, then the minimum flow in the supply leg will be 5 gpm. If the process flow is currently 2 gpm, then 3 gpm will bypass into the return leg so that the supply flow is 5 gpm. If the process flow is 10 gpm, then no flow will pass into the return leg, and the circulation pump will be off.

  This control strategy is useful in minimizing circulation pump energy consumption, and thermal losses in the return leg. To model a constant recirculation flow, specify the LOOP-RECIRC-FLOW.

LOOP-RECIRC-FLOW

The flow that recirculates in the loop at all times that the pump is running. The meaning of this keyword varies depending on the type of loop:

- <u>For all loops other than DHW</u>, this value represents the flow through a constant-flow device (such as a Griswold) that bypasses fluid from the supply directly back to the return. In these types of loops, this is another method that can be used to ensure that a variable-volume loop never has a zero-flow condition. Note that the amount of fluid bypassed is constant every hour.

- <u>For a DHW loop</u>, this value represents the flow that returns to the water heater, and is usually the only flow in the return leg (unless an HVAC coil is also attached). This is commonly done to keep the loop supply leg hot. This keyword is mandatory when a DHW loop has a pump, however you may specify a value of 0.0, in which case there is no recirculation flow. However, you must provide for some return flow, as the pump is assumed to act only on the return flow, not the supply. Return flow may also be

provided via the LOOP-MIN-FLOW (variable-flow recirculation), or by attaching one or more of the airside HW-LOOPs to this loop.

METER END-USE POWER

Introduction

Previous versions of the program allowed miscellaneous interior power, such as for elevators, to be defined via the INTERIOR-POWER keyword. The same was true for exterior power, such as for parking-lot lighting, via the EXTERIOR-POWER keyword. Both of these keywords are lists of 10.

Interior power was always assigned to the "Miscellaneous Equipment" category in the BEPS, BEPU, PS-E, and PS-F reports. Exterior power was assigned to the "Exterior Usage" category in the same reports. A new keyword has been added to allow the INTERIOR-POWER to be assigned to any of the end-use categories.

Building Description Language Changes

Within the ELEC-METER, FUEL-METER, STEAM-METER, and CHW-METER commands:

INTERIOR-EU

Accepts a list of up to 10 code-words specifying the end-use category of the INTERIOR-POWER. The code-words correspond to the end-use categories in the end-use reports (PS-E, PS-F, BEPS, BEPU). Acceptable entries are LIGHTS, TASK-LIGHTS, MISC-EQUIP, SPACE-HEATING, SPACE-COOLING, HEAT-REJECT, PUMPS&AUX, VENT-FANS, REFRIG-DISPLAY, HT-PUMP-SUPPLEM, DOMEST-HOT-WTR, and EXT-USAGE.

Note that, while exterior energy can be entered via the EXTERIOR-POWER keyword, it may also be entered via the INTERIOR-POWER and INTERIOR-EU = EXT-USAGE keywords.

Section

2
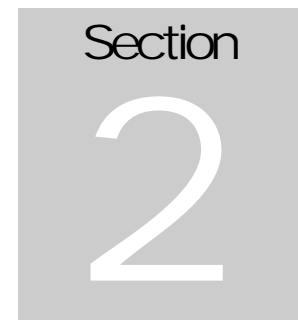
Version 40

Version 40 features are described in a separate document entitled "DOE-2.2-040 ENHANCEMENTS" (and incorporated into the other volumes of this set of manuals.) Version 40 enhancements include Ice-Skating Rinks, CHILLER Air-Cooled and Evaporatively-Cooled Condensers, Economizer Controls, Air-to-Air Energy-Recovery Ventilators, Photovoltaic Electric Generation Systems, Air-Source Chiller/Heat-Pumps, Water-Source Chiller/Heat Pumps, Loop-to-Loop Chiller/Heat Pumps, and Return Duct Infiltration.