DOE-2.2

Building Energy Use and Cost Analysis Program
Volume 2r: Dictionary – Refrigeration Simulation
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JAMES J. HIRSCH & ASSOCIATES

Volume 2r: Dictionary – Refrigeration Systems

Acknowledgements

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Introduction

This program version marks the beginning of significantly new capabilities in the DOE-2 program. The most obvious change the user will find is the addition of a major new refrigeration module capable of simulating supermarket and industrial refrigeration systems in detail. This module is documented in the section that follows.

What is not as obvious are the ramifications that the new refrigeration module has for the existing HVAC simulations, both air-side and water-side. The differences center around the choice of primary energy variables used in the calculations, and how the variables are calculated. The result of these differences is the beginning of an entirely new HVAC module in DOE-2 that has significantly expanded capabilities to simulate the complex interactions between various components.

OVERVIEW OF APPROACH

Energy Variables

There are five principal energy variables used in energy calculations:

1. <u>Load</u> – is the energy that must be transported, added, or removed from a process.

2. <u>Flow</u> – is the flow of air, water, refrigerant, etc. used to transport the energy associated with satisfying the load.

3. <u>Temperature</u> – is the temperature of the space, air, water, refrigerant, etc.

4. <u>Pressure</u> – is the pressure available to cause a flow.

5. <u>Enthalpy</u> – is the enthalpy of the air, water, refrigerant, etc. For non-refrigerants, enthalpy can be expressed as a function of temperature, and is therefore not a primary variable. However, a refrigerant may exist as a liquid/gas mixture, in which case enthalpy is a primary variable.

In all previous versions of DOE-2,

- The primary energy variables are load and temperature. Flows arise from these two variables.

- The program is not iterative. The program makes detailed calculations at the beginning of each hourly time step to determine what the HVAC conditions will be. In most cases, the program does an excellent job in these estimates. However, the program cannot fully compensate for the initial assumptions if they turn out to be wrong. For example, if a chiller has insufficient capacity to meet the Loads calculated on the air-side, then the unmet load will be carried over to the following hours until the chiller can satisfy it. Supply

temperatures do not rise in the hour of the overload, and fan power does not increase. In subsequent hours, the program makes adjustments to coil capacity and fan power, but the adjustments do not occur in the first hour of the overload.

- Pressure is not considered in the air-side calculations. VAV fan power is modeled using a simple curve without considering where the pressure drops exist in the system, where the static pressure sensor is located, or what the static setpoint is.

- Pressure is considered only for pump power on the water-side. If a pump delivers insufficient pressure for the required flows, the program will warn the user, but cannot choke coil flows

In this new version,

- The primary energy variables are temperature and pressure. Flows arise from the available pressure and action of the controllers, and loads arise from the interaction of temperature, pressure, and flow.

- The program is iterative. Rather than making detailed calculations at the beginning of each time step to determine what the conditions will be, the program starts with the last known conditions and iterates until all variables and all components are in balance.

- Pressure is actively consided in both the air-side and water-side calculations. If a fan cannot deliver sufficient pressure, then the air terminals will be choked. If a pump cannot deliver sufficient pressure, then the coils will be choked.

The new temperature and pressure-based structure allows the program to address many design and operational issues. Examples include:

- If the water-side equipment is overloaded, the loop temperature will float. In turn, this affects coil performance. Coil flows will increase, pressure losses will increase, pumping power will increase, and coil temperatures will float. As the coil temperatures float, VAV airflows will increase, pressure losses will increase, fan power will increase, and zone temperatures will float.

- Similar to the above, if the loop pumps are overloaded, then the coils will be choked, with a similar impact on the air-side performance.

- Effects of oversizing equipment can be fully studied. Popular opinion holds that oversizing HVAC equipment wastes energy. In reality, oversized equipment, intelligently controlled, can actually *save* energy. The new structure can fully address these tradeoffs.

- The trade-offs between control sequences can be fully explored. For example, one popular way of peak shaving is to reset chilled water temperatures. However, this strategy can cause the air-side to float out of control, increasing fan horsepower. A far better approach is to reset zone thermostat setpoints, allowing savings to propagate through the entire HVAC system. The new structure will be able to fully investigate the interactions between all of the HVAC components.

Current capabilities

The new mechanical simulation modules are a work in progress:

- <u>Supermarket Refrigeration</u> - The new refrigeration module is substantially complete for supermarkets. The old refrigeration keywords, specified in the SYSTEM and ZONE commands are no longer used. Instead,

you now build up a refrigeration system out of components, such as display fixtures, compressors, condensers, subcoolers, refrigerants, etc. You should refer to the refrigeration section of this document for information on using the new refrigeration components.

The program models display fixtures in detail. Work will continue on modeling walk-in boxes and heat-reclaim.

- Industrial Refrigeration – The new refrigeration module has already been used to model cold storage warehouses. Work will continue on the coil algorithms.

- Air-side equipment – The new structure has not yet been applied to the air-side systems. All existing DOE-2.2 systems are still fully functional, and operate using the previously existing structure. In the existing structure, the air-side and water -side of a coil are decoupled, so that water-side temperatures and pressures are not accounted for in the air-side performance.

- Water-side equipment - The new water-side skeleton is complete, but most of the plant components have not been ported into the new structure. Currently, this module simulates secondary coolants powered by refrigerant driven chillers. Additional components will be ported over from DOE-2.2 as time and funding permits.

Refrigeration Equipment

OVERVIEW OF SIMULATION

Introduction

The DOE-2 Building Energy Simulation computer program is widely used by architects, engineers, utility personnel, and other building professionals as a tool to aid in the design and retrofit of buildings. While the program does an admirable job of simulating most building envelopes and HVAC systems, it has limited capabilities for modelling retail refrigeration systems, and almost no capability for modeling industrial refrigeration systems. Other commonly used building energy simulation programs do not model refrigeration systems at all. Since retail/industrial refrigeration systems are a major end-user of electric power, the need for an improved analysis tool is apparent.

This document describes the engineering approach used in developing and implementing new refrigeration system simulation capabilities in the DOE-2 program. The refrigeration algorithms are component-based, so that a user can build up a system out of individual components. For example, a supermarket system may consist of numerous display fixtures (diary, produce, frozen food, etc.), attached to various refrigeration circuits. These circuits in turn attach to one or more suction-groups operating at different temperatures, which in turn are built up from one or more compressors. These suction-groups discharge into one or more condensers that condense refrigerant vapor, and return liquid refrigerant back to the fixtures. The system may also have one or more subcoolers and desuperheaters. The refrigeration module allows each of these components to be specified individually, as many as required, and connected together to create one or more systems.

The program includes a large library of refrigeration system components, so that a user can readily build up a system.

This is a working document that will ultimately evolve into the User's Documentation and Engineering Documentation. The intent of this document is to provide information to both the program developers and program sponsors so that topics can be discussed, problems identified, and progress documented.

The inclusion of a topic in this document does not necessarily imply that the topic is within ANY project scope. Some topics may be included simply for the purposes of discussion, and implementation may be deferred to a future phase or project. Ideally, by identifying and discussing these issues during the program design phase, we may be able to structure the simulation code in a fashion that facilitates the inclusion of these capabilities in the future.

IMPORTANT: Most, but not all, keywords documented herein are functional. Please refer to the separate document, KEYTESTS, to determine which keywords have been tested by the program developers. DO NOT SPECIFY ANY KEYWORDS THAT HAVE NOT BEEN IDENTIFIED AS TESTED. SERIOUS/FATAL ERRORS WILL ALMOST CERTAINLY RESULT.

Temperature/Pressure-Mass Flow Model

The simulation algorithms are based on refrigerant temperature, pressure, and mass flow. From these variables arise the refrigerant loads. This calculational approach is different from the approach used in some of the previous simulation programs, and some background information will be useful to better understand the advantages of this approach.

Refrigerant compressors are vapor compressors that pump a certain amount of vapor mass based on the type of refrigerant, the inlet and outlet pressures (primary factor), and the inlet temperature (secondary factor). The compressor doesn't know anything about the rest of the refrigerant cycle, i.e. how and where the refrigerant is used.

Traditionally, though, compressor ratings list a "cooling capacity" in Btu/hr that is based on assumptions about what is happening to the refrigerant. These assumptions include the amount of liquid subcooling downstream of the condensers, and the refrigerant temperature entering the compressor. In that the rated and actual conditions are usually quite different, a compressor's rated cooling capacity can be misleading.

A supermarket is a good example. In addition to productive cooling in the fixture, there is considerable non-productive cooling in the long line runs from the compressors to the fixtures.

Compressor "capacity" ratings are actually comprised of the mass pumping capacity (lb./hr) of the compressor, and the refrigerant heat transport capacity (Btu/lb.):

Compressor Capacity = Mass lb/hr * Btu/lb

When designing refrigeration systems, a more rigorous engineering approach than using compressor "cooling capacities" is to separate the concepts of compressor pumping capacity and refrigerant heat transport capacity. Recently, compressor manufacturers have added mass flow to their ratings for just this reason.

This method decouples the compressor pumping capacity (mass capacity) from the conditions of the refrigerant in the system. This allows more involved and precise modeling of the various components comprising a refrigeration system (compressors, condensers, subcoolers, fixtures, etc.). In addition, this approach is easier to understand and implement.

In this approach, initial assumptions to be made for pressure and temperature each hour in order to calculate the mass flow at each point in the system. Once mass flow is known, pressures and temperatures can be recalculated, and their impact on mass flow evaluated. This approach is iterative, and the program iterates each hour until all components are in balance with each other.

If the compressors in the system do not have sufficient capacity to pump the required refrigerant at the required suction temperature, then the refrigeration loads will float. For example, assume a display fixture is operating at 0°F, and requires 1,000 lb/hour of refrigerant at a suction temperature of –10F to do so. If the compressors can only deliver 800 lb/hour at the required suction temperature, then the suction temperature will float up, the fixture temperature will also float up. The higher fixture temperature results in a decreased load, which reduces the refrigerant flow. The program will iterate until it has found the balance point between the compressor suction temperature and mass flow, and the fixture temperature and mass flow.

Other components are also influenced in the above iteration:

▪ The condensing temperature may drop due to the decreased mass flow, thereby increasing compressor capacity

▪ As the fixture temperature floats up, the zone load will change, affecting the HVAC equipment.

▪ The warmer suction temperature affects the fixture's coil performance, both coil temperature and humidity. If the coil temperature rises sufficiently, any frost present on the coil may spontaneously melt.

Component-based Model

The refrigeration simulation model is component-based. Each major device, such as a refrigerant circuit, display fixture, compressor, condenser, etc. is specified separately, and the model simulates each component separately using a dedicated algorithm.

To simulate a refrigeration system(s), you first define one or more refrigerant systems consisting of at least one each of liquid, suction, and discharge circuits, one or more suction-groups, each suction-group having one or more compressors, and one or more condensers. You then define each of the demanders on the system, such as a dairy case or walk-in box, and attach it to the appropriate circuit(s). You also specify the control parameters, such as the compressor sequencing, suction pressure control, condenser temperature control method, and usage profiles. The program uses this information, together with the information required to simulate the building, HVAC systems, and weather data, to derive the hourly load profiles and energy consumption of the mechanical systems.

Because each device exists as a separate component, it is straightforward to create a library of the various types of equipment that you may want to study. The program incorporates this library concept, and a wide variety of makes and models of various components are available, including display fixtures, compressors, condensers, and refrigerants. For each component, the library stores all the information necessary to simulate the device.

A supermarket commonly contains on the order of 20 or more display fixtures, several refrigeration systems, a variety of compressors built up into suction-groups, and one or more condensers. Using the pre-defined components in the library substantially reduces the time required to create a model of a supermarket, and also reduces the number of errors that could otherwise be generated.

The component-based structure exists within the program as well. Each component, such as a display fixture, contains information on the simulation algorithm it requires in the hourly simulation. The program calls these various algorithms as required. This modularity makes the algorithms more understandable, and also makes it easier to add additional component algorithms for in the future.

Refrigeration System Components

The model incorporates algorithms for all of the common components in a supermarket refrigeration system.

1. <u>Refrigeration systems</u> – A refrigeration system is defined as a group of refrigerant circuits, compressors, condensers, display fixtures, etc. that share a closed refrigerant loop. The program can model multiple refrigeration systems, which may use the same type or different types of refrigerants. While the systems are separate from each each other, they may interact via the heat-exchangers in subcoolers, desuperheaters, or refrigerant-to-refrigerant condensers. These components act to transfer heat from one refrigerant stream to another, while keeping the refrigerants separate.

   Specifications for a refrigeration system include the type of refrigerant,and the condenser control sequence.

2. <u>Liquid circuits</u> – Each refrigeration system must have at least one liquid circuit. This circuit delivers refrigerant liquid from the condensers to the loads. A liquid circuit may experience a pressure drop. It may also interact thermally with its environment (*future*). Any liquid circuit may be subcooled via a subcooler.

   Liquid, suction, and/or discharge circuits may be configured in a network. Any trunk circuit may split

into any number of branches. Each of those branches may split into any number of sub-branches, etc. The number of circuits, branches, sub-branches, etc. is limited only by the total number of circuits permitted in the BDL processor.

3. <u>Suction circuits</u> – Each refrigeration system must have at least one suction circuit that collects cold suction gas from the end-use loads, and delivers the gas to a suction-group. A suction circuit may experience a pressure drop. It may also interact thermally with its environment *(future)*. The pressure in a suction circuit may be limited by an evaporator pressure regulator, so that the circuit is operating at a pressure higher than its suction-group. A suction circuit may be desuperheated via a desuperheater.

   As with liquid circuits, suction circuits may have any number of branches and sub-branches.

4. <u>Suction-groups</u> – Each refrigeration system must have at least one suction-group, and each suction-group must have one or more compressors. Each suction-group is fed by refrigerant from one or more trunk suction circuit(s). The compressors in the suction-group discharge hot gas to one or more discharge circuits.

   The suction-group controls its compressors to maintain the required suction pressure, either fixed or variable setpoint, and may include hot-gas bypass. In addition to staging compressors, a suction-group can generate a control signal to modulate a variable-speed compressor drives, unload cylinders, etc.

5. <u>Compressors</u> – Each suction-group must have one or more compressors. Specifications for the compressors include the make and model (for components in the library), type, and performance data. Capacity control mechanisms include internally-controlledmechanisms such as suction-pressure activated cylinder unloaders, and externally-controlled mechanisms such as variable-speed drives. Compressor types in the library include a variety of reed and Discus semi-hermetic, screw, scroll, and open-drive compressors.

6. <u>Discharge circuits</u> – Each refrigeration system must have at least one discharge circuit that collects the gas from the compressors and delivers it to one or more condensers. A discharge circuit may experience a pressure drop. It may also interact thermally with its environment.

   Discharge circuits may incorporate holdback or diverting valves for heat reclaim. The holdback valves may operate continuously, creating a permanent operating penalty for the upstream compressors, or may modulate their pressure as required by the heat-reclaim loads. Since different compressors may attach to different discharge circuits, not all compressors need be impacted by heat reclaim.

   As with the other types of circuits, there is no limit to the number of branches, sub-branches, etc.

7. <u>Condensers</u> – Each refrigeration system must have at least one condenser. Selections include air-cooled, evaporative, and cascaded condensers. Specifications include the size, design criteria, fan/pump power, and capacity control mechanism, including variable-speed.

   In addition, a condenser may reject its heat to another refrigeration system via a heat exchanger (cascaded system). Finally, a condenser loop may reject its heat to a chilled-water or condenser-water circulation loop via a heat exchanger *(future)*. These loops in turn are served by chillers, cooling towers, fluid coolers, ground-coupled heat-exchangers, rivers, etc.

8. <u>Refrigerated Fixtures</u> - Selections include low temperature single deck, low temperature multi-deck, low and medium temperature glass door, medium temperature single deck, medium temperature multi-deck, service cases, and specialty cases. Specifications include the make and model (for fixtures in

the library), case length, discharge air temperature, saturated-suction temperature, defrost type and control, lighting options, fan options, liquid-suction interchangers, and anti-condensate controls.

9. <u>Walk-ins & Prep Areas</u> *(future)* - Selections include storage walk-ins, walk-in boxes with glass doors (e.g. dairy, beverage and floral boxes), preparation areas that may be fully enclosed or have one side open to the sales area, and other perimeter zones that are air conditioned from the refrigeration system (e.g. bakery prep areas, pharmacy, etc.). Specifications include the make and model (for components in the library), size, temperature, location, reach-in doors, walk-in doors, refrigeration load, lighting, evaporator coils, defrost type and control, fans, and internal loads.

10. <u>Subcooolers</u> – Any liquid circuit, including branch circuits, may have a subcooler. Typically, a subcooler transfers heat from the liquid refrigerant to a suction-group operating at a higher temperature than the liquid's load, thereby improving the overall system efficiency. The subcooler may achieve its cooling effect using refrigerant from either the same system as the subcooled liquid, or from a separate system.

11. <u>Desuperheaters</u> – Any suction circuit, including branch circuits, may have a desuperheater. Depending on type, a desuperheater may achieve its cooling effect using refrigerant from either the same system as the desuperheated suction gas, or from a separate system.

HVAC System Components

The model also includes capabilities for modeling heating, ventilating, and air conditioning (HVAC) equipment commonly found in supermarkets. These capabilities include:

1. <u>Air Handlers</u> - Selections include single-path (with bypass damper) and dual-path (separate fresh air coils) systems with two-speed and variable-speed fan options *(future)*.

2. <u>Heat Recovery</u> - Provides for heat recovery from refrigerant loop discharges for space conditioning and hot-water preheating. Selections include 1st stage hot-gas desuperheat and 2nd stage heat-reclaim holdback valves.

3. <u>Humidity Control</u> - Provides for HVAC equipment operation to meet a humidity setpoint.

Simulation Convergence and Stability

The program iterates until the mass flow, temperature, pressure, enthalpy, etc., of each component is in balance with all other components. Mass flow is the most common variable used in checking convergence, however temperature, pressure, and enthalpy are used where appropriate. For loads and flows, the convergence criteria is 2% of the last calculated value. For temperatures, the criteria is 0.1°F. For pressures, the criteria is 0.1 psia. Experience indicates that convergence will normally be achieved in 3-7 iterations. Tests indicate that smaller error ratios can result in substantially longer run times, with negligible (<<1%) differences in the results. Very small error ratios (<1%) may occasionally result in convergence failures.

Stability is a critical consideration whenever a simulation uses an iterative calculational sequence. As general rule of thumb, the more complex an iterative sequence is, the more likely it is that it may be unstable under certain circumstances. The Refrigeration Module is quite complex, and so has the *possibility* of being unstable. Fortunately, an analysis of the dynamics of refrigeration systems indicates that the this program's calculational sequence should be quite stable, and experience to date bears this out. If the system has failed to converge after 20 iterations, the program will output a message to that effect, and continue on with the simulation.

We are not aware of any simulations to date that do not always converge. However, since the program is still in the development and testing phase, we are very interested in learning about any input configurations that result in stability problems. For this reason, we ask that all users include the following statement in their input:

```
PLANT-REPORT
    VERIFICATION         = ( PV-A )
    SUMMARY              = (PS-B,PS-E,PS-F,PS-H,BEPS,BEPU)
    DUMP-OPTIONS         = (SIMULATION, DEBUG)
     ..
```

The DEBUG switch will cause the program to dump listings of convergence errors. These errors will be listed immediately before the first SV-A report. You should always check to see if there are any convergence failures, and if so, e-mail your input and weather file to:

   steve.gates@doe2.com

Input Order and Example Input

The program enforces an input heirarchy in order to prevent circularities. (For example, to prevent two liquid circuits from attaching to each other, so that they feed refrigerant to each other in a continuous loop.) This order is most obvious when using a graphical user interface such as eQUEST. The general rule is that you must first define a component before referencing (attaching to) that component in another component.

Hierarchy Rules:

1. In general, you must define a component before allowing another component to reference it. The following rules reflect this order.

2. The first component that must be defined is the refrigeration system. If refrigeration systems will cross-connect via subcoolers or desuperheaters, you should first define the warmest system and/or suction-group, together with its liquid and suction lines, prior to defining the system that will utilize the subcooler or desuperheater.

3. Define and attach one or more condensers to the refrigeration system.

4. Define and attach a discharge circuit to the refrigeration system. You may attach any number of discharge circuits to a refrigeration system. You may create networks of discharge circuits by attaching one or more discharge circuits to a previously defined discharge circuit.

5. Define and attach a suction group to a discharge circuit. You may attach any number of suction groups to a discharge circuit.

6. Define and attach one or more compressors to the suction group. A suction group may have any number of compressors. By default the compressors will attach to the discharge circuit defined for the suction group, but you may specify different discharge circuits for different compressors (useful when only a subset of the compressors are to be used for heat-reclaim).

7. If the suction-group uses a desuperheater, define and attach the desuperheater to the suction group. You may attach any number of desuperheaters to the suction group. Also attach the desuperheater to its liquid line, and if needed, its suction line (Refer to Rule #2 above regarding the input heirarchy of refg systems running at different suction temperatures). Refer to the desuperheater component for alternative attachment configurations.

8. Define and attach a suction circuit to the suction group or to one of its desuperheaters. You may attach any number of suction circuits to either the suction group and/or its desuperheaters. You may create networks of suction circuits by attaching one or more suction circuits to a previously defined suction circuit.

9. If the refg system uses a subcooler, define and attach the subcooler to the refg system. You may attach any number of subcoolers to a refg system. Also attach the subcooler to its suction line, and if needed, its liquid line (See Rule #2 regarding the input heirarchy of refg systems operating at different suction temperatures). Refer to the subcooler component for alternative attachment configurations.

10. Define and attach a liquid circuit to the refrigeration system or to one of its subcoolers. You may attach any number of liquid circuits to either the refg system and/or the system's subcoolers. You may create networks of liquid circuits by attaching one or more liquid circuits to a previously defined liquid circuit.

11. Define and attach a refrigerated fixtures to a liquid and suction circuit, and to a zone. You may attach any number of fixtures to the same or different liquid and suction circuits, and zones.

12. If an HVAC system uses either DX cooling provided by a refrigeration system, or heat reclaim from the compressor discharge, you must define the refrigeration system prior to defining the HVAC system.

Example 1: Refrigeration Input

In this example, components are grouped by refrigeration system

COMPRESSOR

This command defines all of the operating characteristics of a compressor. You define each compressor by repeating this command, even for identical compressors.

Most compressors are suitable for use with more than one refrigerant, however their performance characteristics, such as mass pumping capacity and power consumption, will vary from one refrigerant to the next. When selecting a compressor from the library, the program will check to see if the compressor has performance curves for the system refrigerant. If not, then you will be required to input this information.

U-NAME(=)

accepts a mandatory entry for the U-name of this compressor. This U-name will be used in all reports to identify the component. Since a compressor may be used with different refrigerants, and the performance varies with refrigerant; it is recommended that you incorporate the name of the refrigerant into the U-name.

TYPE

accepts a code-word that specifies the type of compressor. This is a mandatory entry:

SEMI-HERMETIC	specifies a semi-hermetic or hermetic compressor. This type of compressor is powered by an electric motor integral to the compressor. Since the motor is integral to the compressor, the performance characteristics must include the motor performance as well as the compressor performance.
	The library contains a large number of entries for semi-hermetic compressors. If you are modeling a compressor similar to one in the library, but of a different size, you can specify the compressor in the library, but also specify the CAPACITY or CAPACITY ratio. The compressor mass flow and power curves will automatically rescale to match the specified capacity.
OPEN	*(not implemented)* specifies an open compressor with an external drive. The drive may be a motor, engine, gas-turbine, etc. For this type of compressor, the performance characteristics must exclude the performance of the motive force; the program models that component separately.
CENTRIFUGAL	specifies a hermetic centrifugal compressor.. The compressor may be modeled as either constant-speed or variable-speed, depending on the PWR-FPLR curve.
	As of this writing (10/2006), the library includes an entry for a relatively small variable-speed centrifugal with frictionless bearings; Turbocor-99kW-HT. This compressor draws 99kW maximum. It can operate using either R-22 refrigerant [~120 tons @ 45/105°F (422 kW @ 7/40°C); COP = 4.29] or R-134a refrigerant [~93 tons @ 45/105°F (330 kW @ 7/40°C); COP = 4.88]. The default curves also are for this compressor. If you are modeling a similar compressor but of a different size, you can use these curves, but also specify the CAPACITY or CAPACITY ratio. The default compressor mass flow and power curves will automatically rescale to match the specified capacity.

*SIM-ALGORITHM

specifies the name of the subroutine the program will use to simulate the compressor. Currently, this feature is not available to the user.

The existing compressor algorithms can simulate hundreds of different compressors. The keyword values for these compressors may already exist in the BDL library, or you can define a new compressor using the keywords in this command, and store the resulting compressor in the library for future use.

SUCTION-GROUP
accepts a mandatory entry specifying the suction-group to which this compressor belongs.

DISCHARGE-CIRCUIT
accepts the U-name of a discharge circuit into which this compressor discharges. The default is the DISCHARGE-CIRCUIT of the suction-group this compressor belongs to. Normally, you will only specify this keyword if you want to take advantage of heat-reclaim, but do not want all of the compressors in a suction group affected.

AUX-MODE
accepts a code-word specifying when theAUX-KW is consumed. The default is that there is no auxiliary power consumption. An example would be a crankcase heater that operates only when the compressor is off.

ALWAYS	indicates that the auxiliary power is consumed all hours.
WHEN-ON	indicates that auxiliary power is consumed only during the hours the compressor is operating.
WHEN-OFF	indicates that auxiliary power is consumed only during the hours the compressor is off.
SCHEDULED	indicates that the power consumption is scheduled.

AUX-KW
accepts a numeric value specifying an auxiliary electrical consumption, such as for a control panel. This is a required keyword when the AUX-MODE is specified.

AUX-SCH
when AUX-MODE = SCHEDULED, accepts a U-name of a schedule that varies the AUX-KW on an hourly basis.

AUX-METER
accepts the U-name of a meter that supplies the auxiliary energy. This keyword defaults to the same meter as the compressor's ELEC-METER.

ELEC-METER
accepts the U-name of a meter that supplies the motor energy. The default is the compressor's SUCTION-GROUP:ELEC-METER.

COST-DATA
accepts the U-name of a MATERIALS-COST command. This command allows you to define first costs, maintenance costs, etc. for this compressor.

EQUIPMENT-REPORTS
accepts the codewords YES or NO. The default is YES. When report RS-H of the REFG-REPORTS is enabled, a report will print for this component unless this keyword is set to NO.

Compressor Capacity

While most DOE-2 components are sized in terms of energy, compressor capacity is defined in terms of mass flow. This is because manufacturers use the same compressor with different refrigerants, and the compressor performance varies according to the refrigerant. Data entered here is for a specific refrigerant; you should modify this data to simulate the compressor with other refrigerants

Performance curves are used differently for compressors than for other components. Compressors do not have a single standard rating point, such as the ARI rating point for chillers, so normalizing the capacity curve to a single rating point does not usually make sense, nor is it necessary if the algorithm is formulated to utilize the *shape* of the curve, rather than the absolute values. In addition, some manufacturers publish performance data in the form of coefficients for a bi-cubic polynomial equation; however the CURVE-FIT command normally only handles bi-quadratic and lower-order polynomials, not bi-cubics.

For these reasons, two new curve types have been created, FLOW-FSST&SDT and PWR-FSST&SDT, that allow you to enter mass flow data and kW data directly. When using these curves, you should NOT normalize the data to 1.0; the program will normalize and/or re-scale the curves as required.

For capacity variation with temperature, you may alternatively use the curve-fit type RATIO-FT&T to define a normalized capacity curve, where the normalization is to some arbitrary value (The program will give the same result, regardless of the normalization point, or even if the curve is not normalized, as it uses the *shape* of the curve vs. temperature, rather than the actual curve output values.)

Capacity is set using the following hierarchy:

- CAPACITY is always used, if specified. You specify the temperatures at which this capacity is rated using the RATED-SST, RATED-SDT, and RATED-SUPERHEAT keywords; these temperatures are then used to locate the capacity on the curve. If actual design temperatures are different from the rated temperatures, then the rated capacity will be adjusted to the design conditions in the design calculations.

- CAPACITY-RATIO is used next, if specified. Capacity will default to the suction-group capacity, multiplied by this ratio. This capacity is assumed to exist at the design temperatures of the suction-group and condenser.

- If neither CAPACITY nor CAPACITY-RATIO is defined, and the curve-fit modifying capacity as a function of temperature is of TYPE = RATIO-FT&T, then the capacity will default according to the suction-group capacity, divided by the number of compressors attached to the loop. The program will re-normalize the capacity curve so that the default capacity is achieved at the design temperatures.

- If the curve-fit modifying capacity as a function of temperature is of TYPE = FLOW-FSST&SDT, then this curve outputs capacity in lbs/hr as a function of temperature, and the design capacity will be determined directly from this curve.

  If CAPACITY is also specified in addition to this curve type, then this curve will be re-scaled so that the rated CAPACITY is achieved at the RATED-SST, RATED-SDT, and RATED-SUPERHEAT. This feature is useful if the compressor you want to use is not in the library, you do not have performance data for the compressor, but a compressor in the library has similar performance characteristics. You may reference the compressor in the library, and specify the CAPACITY you want. The program will then re-scale both the capacity and power performance curves to match the new capacity.

  Similarly to CAPACITY, specifying the CAPACITY-RATIO together with this curve type will cause the

program to re-scale both the capacity and power performance curves so that the default capacity is achieved at the design suction and discharge temperatures.

CAPACITY

accepts a numeric entry specifying the capacity of the compressor in lbs/hr. Note that this keyword represents the mass flow capacity, not the thermal capacity. When you specify the capacity, the program assumes this value is the capacity which occurs at the RATED-SST, RATED-SDT, and RATED-SUPERHEAT. These rated temperatures are used to locate the capacity on the capacity curve, and power on the power curve.

If the compressor has a capacity performance curve of TYPE = FLOW-FSST&SDT, then this curve directly outputs capacity in lbs/hr as a function of temperature. In this case, the curve will be re-scaled so that the rated CAPACITY is achieved at the RATED-SST, RATED-SDT, and RATED-SUPERHEAT. This feature is useful if the compressor you want to use is not in the library, you do not have performance data for the compressor, but a compressor in the library has similar performance characteristics. You may reference the compressor in the library, and specify the CAPACITY you want. The program will then re-scale both the capacity and power performance curves to match the new capacity.

CAPACITY-RATIO

when CAPACITY is not entered, specifies the fraction of the design suction-group capacity that this compressor will be sized to meet. This size is defined at the design temperatures of the suction-group and condenser.

If you are defining two compressors of identical size that should just meet the load, then CAPACITY-RATIO should be set to 0.5 in each compressor definition. If you want to include a 20% safety factor in each compressor, then the CAPACITY-RATIO of each compressor is 0.6.

If the compressor has a capacity performance curve of TYPE = FLOW-FSST&SDT, then this curve directly outputs capacity in lbs/hr as a function of temperature. In this case, the curve will be re-scaled so that the design capacity determined by the CAPACITY-RATIO is achieved at the design temperatures. This feature is useful if the compressor you want to use is not in the library, you do not have performance data for the compressor, but a compressor in the library has similar performance characteristics. You may reference the compressor in the library, and specify the CAPACITY-RATIO you want. The program will then re-scale both the capacity and power performance curves to match the design capacity at the design temperatures.

RATED-SST

when CAPACITY, POWER, POWER-RATIO, or COEF-OF-PERFORM are specified, defines the corresponding saturated-suction temperature at which this quantity is rated. The default is the DESIGN-SST of the compressor's SUCTION-GROUP.

RATED-SDT

when CAPACITY, POWER, POWER-RATIO, or COEF-OF-PERFORM are specified, defines the corresponding saturated-discharge temperature at which this quantity is rated. The default is the DESIGN-SCT of the compressor's REFG-SYSTEM.

RATED-SUPERHEAT

when CAPACITY, POWER, POWER-RATIO, or COEF-OF-PERFORM are specified, defines the corresponding saturated-suction temperature at which this quantity is rated. Note that manufacturers currently do not publish performance data for the effect of superheat on capacity or power consumption.

CAP-FSST&SDT

accepts the U-name of a CURVE-FIT specifying how the compressor capacity varies with saturated-suction temperature and saturated-discharge temperature. This keyword accepts curve-fits of two types:

- CURVE-FIT:TYPE = RATIO-FT&T: This curve should contain data modifying the capacity as a function of suction temperature and discharge temperature. While curves for boilers, chillers, etc., expect this data to be normalized, compressors do not have a standard rating point. Therefore, you may normalize the data to any arbitrary point, or better, simply input the raw capacity data. Regardless of which entry method you use, the program will normalize this curve as required.

- CURVE-FIT:TYPE = FLOW-FSST&SDT: This curve type directly outputs the flow in lbs/hr as a function of suction and discharge temperature. This curve should NOT be normalized; the program will normalize the curve to either a set of rated or design conditions as necessary. If CAPACITY or CAPACITY-RATIO is specified together with a curve of this type, then the curve will be re-scaled to match the new capacity.

CAP-FSUPERHEAT

accepts the U-name of a CURVE-FIT specifying how the compressor capacity varies with the suction superheat. The curve must be of TYPE = RATIO-FDT. As compressors do not have a standard rating point, it is not necessary to normalize this curve to 1.0 at some superheat temperature; instead the program will normalize it based on the design conditions.

At this time, manufacturers do not publish performance data for varying superheat temperatures. As a result, the default curve yields 1.0 for all superheats.

MIN-CAP-FSST&SDT

for centrifugal compressors, accepts the U-name of a CURVE-FIT specifying how the minimum compressor capacity ratio varies with saturated-suction temperature and saturated-discharge temperature. Below this point the compressor is assumed to cycle. The curve must be of TYPE = RATIO-FT&T. This curve should not be normalized, but should output the actual minimum unloading ratio for the given conditions.

As the differential between SST and SDT increases, the part-load range over which a centrifugal compressor can modulate without going into a surge condition decreases.   For this reason, a keyword specifying a single minimum part-load ratio is not sufficient.

MIN-DP

for centrifugal compressors, the minimum allowable pressure differential between the discharge and the suction. This differential is necessary to inject liquid refrigerant into the motor, for motor cooling. If the discharge temperature is lower than the suction pressure plus this differential, then the condensing temperature setpoint of the REFG-SYSTEM will be raised to compensate. This override takes precedence over any other condensing temperature control strategy.

<u>Compressor Power</u>

Like the capacity performance curves, the power performance curves are used differently for compressors than for other components. Compressors do not have a single standard rating point, such as the ARI rating point for chillers, so normalizing the power curve to a single rating point does not usually make sense, nor is it necessary if the algorithm is formulated to utilize the *shape* of the curve, rather than the absolute values. In addition, some manufacturers publish performance data in the form of coefficients for a bi-cubic polynomial equation; however the CURVE-FIT command normally only handles bi-quadratic and lower-order polynomials, not bi-cubics.

For these reasons, two new curve types have been created, FLOW-FSST&SDT and PWR-FSST&SDT, that allow you to enter mass flow data and kW data directly. When using these curves, you should NOT normalize the data to 1.0; the program will normalize and/or re-scale the curves as required.

For generic compressors where you would like to have the power consumption to be independent of refrigerant type, you may alternatively use the curve-fit type COP-FSST&SDT to define a coefficient of performance as a function of temperature.

Power is determined using the following hierarchy:

▪ POWER is always used, if specified. You specify the temperatures at which this rated power consumption occurs via the RATED-SST, RATED-SDT, and RATED-SUPERHEAT keywords. If the actual design temperatures are different from the rated temperatures, then the rated power will be modified for the design conditions.

▪ POWER-RATIO is used next, if specified. Power will default to the rated mass flow, multiplied by this ratio. You specify the temperatures at which this rated power ratio occurs via the RATED-SST, RATED-SDT, and RATED-SUPERHEAT keywords. If the actual design temperatures are different from the rated temperatures, then the rated power will be modified for the design conditions.

▪ COEF-OF-PERFORM, or COP is used next, if specified. Power will default to the rated thermal flow, divided by this ratio and converted to kW. You specify the temperatures at which this rated power ratio occurs via the RATED-SST, RATED-SDT, and RATED-SUPERHEAT keywords. If the actual design temperatures are different from the rated temperatures, then the rated power will be modified for the design conditions.

▪ If neither POWER, POWER-RATIO, or COEF-OF-PERFORM is defined, and the curve-fit modifying power as a function of temperature is of TYPE = COP-FSST&SDT, then the program will derive a COP directly from this curve at the design temperatures. If POWER, POWER-RATIO, or COEF-OF-PERFORM are defined together with this curve, then power will be calculated as described for those keywords, and this curve will be re-scaled to match at the rated temperatures.

▪ If neither POWER, POWER-RATIO, or COEF-OF-PERFORM is defined, and the curve-fit modifying power as a function of temperature is of TYPE = PWR-FSST&SDT, then the program will derive the kW directly from this curve at the design temperatures. If POWER, POWER-RATIO, or COEF-OF-PERFORM are defined together with this curve, then power will be calculated as described for those keywords, and this curve will be re-scaled to match at the rated temperatures.

POWER

when CAPACITY is also specified, accepts a numeric value defining the compressor's rated power consumption in kW. When you specify the power, the program assumes this value is the kW which occurs at the RATED-SST, RATED-SDT, and RATED-SUPERHEAT. Specifying this keyword will cause the power performance curve, either PWR-FSST&SDT or COP-FSST&SDT to be normalized to match.

If the compressor has a capacity performance curve of TYPE = FLOW-FSST&SDT, then this curve directly outputs capacity in lbs/hr as a function of temperature. If you also specify the CAPACITY or CAPACITY-RATIO together with this type of curve, then capacity curve will be rescaled to match. If the power performance curve is of type PWR-FSST&SDT, this curve will also be rescaled to the new capacity, however specifying the POWER, POWER-RATIO, or COEF-OF-PERFORM will override the rescaling based on capacity.

POWER-RATIO

accepts a numeric value defining the ratio of electric power to rated mass flow rate. When you specify the power ratio, the program assumes this value occurs at the RATED-SST, RATED-SDT, and RATED-SUPERHEAT. The program uses this value to default calculate the rated power as:

kW = CAPACITY * POWER-RATIO

Specifying this keyword will cause the power performance curve, either PWR-FSST&SDT or COP-FSST&SDT to be normalized to match at the rated temperatures.

If the compressor has a capacity performance curve of TYPE = FLOW-FSST&SDT, then this curve directly outputs capacity in lbs/hr as a function of temperature. If you also specify the CAPACITY or CAPACITY-RATIO together with this type of curve, then capacity curve will be rescaled to match. If the power performance curve is of type PWR-FSST&SDT, this curve will also be rescaled to the new capacity, however specifying the POWER, POWER-RATIO, or COEF-OF-PERFORM will override the capacity rescaling.

COEF-OF-PERFORM
or COP, accepts a numeric value defining the ratio of thermal energy to electric power, when both are expressed in the same units. When you specify the COP, the program assumes this value occurs at the RATED-SST, RATED-SDT, and RATED-SUPERHEAT. The program uses this value to default calculate the rated power as:

kW = Qthermal/COP, converted to kW

Specifying this keyword will cause the power performance curve, either PWR-FSST&SDT or COP-FSST&SDT to be normalized to match at the rated temperatures.

PWR-FSST&SDT
accepts the U-name of a CURVE-FIT specifying how the compressor power varies with saturated-suction temperature and saturated-discharge temperature. This keyword accepts curve-fits of two types:

- CURVE-FIT:TYPE = COP-FSST&SDT: This curve directly outputs the coefficient-of-performance as a function of suction temperature and discharge temperature. This curve should NOT be normalized. If you also enter either POWER, POWER-RATIO, or COEF-OF-PERFOR, the program will normalize this curve to match.

- CURVE-FIT:TYPE = PWR-FSST&SDT: This curve type directly outputs the power in kW as a function of suction and discharge temperature. This curve should NOT be normalized. If you also enter either POWER, POWER-RATIO, or COEF-OF-PERFOR, the program will normalize this curve to match. If CAPACITY or CAPACITY-RATIO are specified together with a capacity performance curve of type FLOW-FSST&SDT, then the power curve be re-scaled to match the new capacity.

PWR-FSUPERHEAT
accepts the U-name of a CURVE-FIT specifying how the compressor power varies with the suction superheat. The curve must be of TYPE = RATIO-FDT. As compressors do not have a standard rating point, it is not necessary to normalize this curve to 1.0 at some superheat temperature; instead the program will normalize it based on the design conditions.

At this time, manufacturers do not publish performance data for varying superheat temperatures. As a result, the default curve yields 1.0 for all superheats.

PWR-FPLR
accepts the U-name of a CURVE-FIT specifying how the compressor power varies with the load ratio. This keyword applies only to compressors having a capacity control mechanism, such as cylinder unloaders, slide valves, speed, etc. Compressors that cycle do not use this keyword.

- For positive displacement compressors, the curve is of type RATIO-FRATIO or QUADRATIC. For both these curve types, the independent term is the part-load ratio, and the output is the fraction of full-load power.

- A variable-speed centrifugal compressor's ability to unload is sensitive to the difference between the saturated discharge temperature and the saturated suction temperature. For this reason, this compressor has an additional curve-type available, RATIO-FRATIO&DT. The DT (delta T) term is the differential between the saturated discharge temperature and the saturated suction temperature.

MAX-PWR
for a variable-speed centrigugal compressor, specifies the maximum allowable power consumption (kW). For heavy loads and large differentials between the saturated discharge and suction temperatures, a variable-speed centrifugal compressor may require more power than its motor can produce. In this case, the compressor will modulate to prevent power consumption from exceeding the maximum limit.

Capacity Control
The next set of keywords define the capacity control mechanism of the compressor, if any. The capacity control mechanism may be either internally controlled (independent of the suction group), or externally by the suction group. Note that you do not explicity specify the type of capacity control mechanism, such as cylinder unloaders or speed. Instead the effect of these devices is included in the capacity performance curves.

Note that, if the compressor has a capacity control mechanism other than cycling, you should consider reducing the SUCTION-GROUP:TEMP-THROTTLE to a smaller value to take advantage of the higher suction pressure setpoint and smaller throttling range that can now be used without short cycling the compressor. Refer to the SUCTION-GROUP command for more information on suction-group control strategies.

CAPACITY-CTRL
accepts a code-word specifying the type of capacity setpoint control.

NONE	the default, specifies that the compressor has no capacity control mechanism. To modulate capacity, the suction group must cycle this compressor.
INTERNAL-SETPT-T	specifies that the compressor has a capacity control mechanism, such as cylinder unloaders, and that the compressor has its own internal capacity control setpoint. A common example is a compressor with cylinder unloaders controlled directly on suction gas temperature.
	Note that, while INTERNAL-SETPT-T control prevents the parent suction group from directly controlling the output of this compressor, the suction group may still cycle this compressor in order to control the overall capacity of the group.
EXTERNAL-SIGNAL	specifies that the compressor has a capacity control mechanism, such as cylinder unloaders or a variable-speed drive, that is controlled by the parent SUCTION-GROUP.

INTERNAL-SETPT-T
when CAPACITY-CTRL = INTERNAL-SETPT-T, specifies the saturated-suction temperature setpoint of the compressor's internal capacity control mechanism.

INTERNAL-THROTTLE
when CAPACITY-CTRL = INTERNAL-SETPT-T, specifies the throttling range of the internal capacity controller. The throttling range is in °F. The compressor will operate at maximum capacity at the top of the throttling range, and at the MIN-CAPACITY at the bottom of the throttling range.

MAX-EXT-SIGNAL

when CAPACITY-CTRL = EXTERNAL-SIGNAL, specifies the value of the suction group control signal at which the compressor will operate at full output. The default is 1.0

The suction group outputs a control signal of 1.0 at the top of its temperature-control throttling range, and a signal of 0.0 at the bottom. If multiple compressors are running, and you want a particular compressor to be at minimum output at the midpoint of the suction group control signal, and at maximum output at 75% of the control signal, then specify MAX-CTRL-SIGNAL = 0.75, MIN-CTRL-SIGNAL = 0.5

The default values will cause the compressor to modulate over the full suction group control range.

MIN-EXT-SIGNAL

when CAPACITY-CTRL = EXTERNAL-SIGNAL, specifies the value of the suction group control signal at which the compressor will operate at minimum output, defined as MIN-CAPACITY. The default is 0.2

The suction group outputs a control signal of 1.0 at the top of its temperature-control throttling range, and a signal of 0.2 at the bottom. If multiple compressors are running, and you want a particular compressor to be at minimum output at the midpoint of the suction group control signal, and at maximum output at 75% of the control signal, then specify MAX-CTRL-SIGNAL = 0.75, MIN-CTRL-SIGNAL = 0.5

The default values will cause the compressor to modulate over the top 80% of the suction group control range, and cycle below that point.

MIN-CAPACITY

accepts a numeric value defining the fraction of nominal capacity at the bottom of the capacity controller's throttling range. The default is 0.2, meaning the compressor can unload to 20% capacity without having to cycle.

Example: Assume a suction group has two identical screw compressors, with one compressor also having a variable-frequency drive. The compressor having only a slide valve can modulate to 40% capacity, while the VFD compressor can modulate to 20% capacity. When both compressors are running, it is desired to preferentially modulate the VFD compressor, as modulating this compressor is more efficient than modulating the other.

To accomplish this, the VFD compressor should be modulated over the top half of the suction-group's control range, and the slide-valve compressor modulated over the bottom. Also shown here is a SUCTION-GROUP:EQUIP-CTRL sequence that preferentially runs the VFD compressor when only one compressor is needed.

```
    "Medium Temperature SG" = SUCTION-GROUP
       TYPE              = PARALLEL
       . . .
       EQUIP-CTRL        = "Compressor Ctrl"
       ..


    "VFD Compressor" = COMPRESSOR
       TYPE              = SEMI-HERMETIC
       SUCTION-GROUP     = "Medium Temperature SG"
       . . .
       CAPACITY-CTRL     = EXTERNAL-SIGNAL
       MAX-EXT-SIGNAL    = 1.0
       MIN-EXT-SIGNAL    = 0.5
       MIN-CAPACITY      = 0.2
       ..
```

```
"Slide Compressor" = COMPRESSOR
    TYPE               = SEMI-HERMETIC
    SUCTION-GROUP      = "Medium Temperature SG"
    . . .
    CAPACITY-CTRL      = EXTERNAL-SIGNAL
    MAX-EXT-SIGNAL     = 0.5
    MIN-EXT-SIGNAL     = 0.
    MIN-CAPACITY       = 0.4
    ..

"Compressor Ctrl" = EQUIP-CTRL
    TYPE               = SUCTION-GROUP
    COMPRESSORS-1      = ("VFD Compressor", "Slide Compressor")
    ..
```

If the suction-group's control signal is 0.8, the VFD compressor will be modulating while the slide-valve compressor is at full output. The part-load capacity of the VFD compressor will be:

dS   = (Signal – MIN-EXT-SIGNAL) / (MAX-EXT-SIGNAL – MIN-EXT-SIGNAL),
                  limited to a range of (1,0)
PLR   = MIN-CAPACITY + (1.0-MIN-CAPACITY) * dS

dS   = (0.8 – 0.5) / (1.0 – 0.5)   = 0.6
PLR   = 0.2 + (1.0 – 0.2) * 0.6   = 0.68

where Signal is the control signal generated by the suction group, and PLR is the compressor part-load ratio.

CONDENSER

The CONDENSER command defines all of the operating parameters of heat-rejection devices such as air-cooled and evaporative condensers.

You may attach any number of condensers to a REFG-SYSTEM; however more than one is unusual except in industrial applications. If more than one condenser is attached and operating, the pressure in the liquid receiver will be the highest pressure of the attached condensers; the same is true for the discharge circuits.

Many of the keywords may be used for both air-cooled and evaporative condensers, but their meaning changes slightly depending on the condenser type. For this reason, they are repeated for each condenser type.

U-NAME(=)
accepts a mandatory entry for the U-name of this heat-rejection device. This U-name will be used in the reports to identify the device.

TYPE
accepts a mandatory code-word specifying the type of heat-rejection device:

AIR-COOLED	specifies an air-cooled condenser.
EVAPORATIVE	specifies an evaporative condenser.
CASCADED	specifies a refrigerant-to-refrigerant heat-exchanger that allows a low temperature system to cascade into an intermediate-temperature system using a different refrigerant.

SIM-ALGORITHM
specifies the name of the subroutine the program uses to simulate the condenser. Currently, this feature is not available to the user.

REFG-SYSTEM
accepts the U-name of the REFG-SYSTEM this unit serves. Any number of condensers may attach to the same system, although this is unusual in retail applications.

Condenser Capacity
The following set of keywords specify the heat-rejection capacity and the number of independently controlled cells in the heat-rejection device (each cell having its own fan). Manufacturer's data specifies condensers in terms of either tons capacity, or heat of rejection. This program uses the heat of rejection method.

RATED-CAPACITY
specifies the size of the condenser at standard rating conditions, including any condenser subcooling. If you specify the capacity, you must also specify the RATED-SCT (evaporative) or RATED-TD (air-cooled), at which this capacity applies.

If you do not specify this keyword, the capacity will default to the refrigerant circuit heat-rejection load, adjusted by the CAPACITY-RATIO. If no CAPACITY-RATIO is input, then the capacity will default to the heat-rejection load, divided by the number of heat-rejection devices attached to the circuit.

CAPACITY-RATIO

when RATED-CAPACITY is defaulted, accepts a numeric value that indicates the fraction of the refrigeration system's design heat-rejection capacity that this component will be sized to meet. There is no default.

If you are defining two components of identical size that should just meet the design load, then CAPACITY-RATIO should be set to 0.5 in each component definition. If you want to include a 20% safety factor in each component, then the CAPACITY-RATIO of each component is 0.6.

If you do not specify either the RATED-CAPACITY or the CAPACITY-RATIO, then the capacity will default to the system's design heat-rejection capacity, divided by the number of heat-rejection devices serving the system.

Special Note: Until multi-circuit condensers are implemented, this keyword has an additional meaning. To model a multi-circuit condenser of a known size serving more than one refrigeration system, input the condenser at its RATED-CAPACITY and power under each refrigeration system (define the same condenser more than once). For each identical condenser defined, also specify the CAPACITY-RATIO to be the fraction of the circuits dedicated to a given refrigeration system. The program will then modify the effective rated capacity and power as a function of the capacity ratio.

SUBCOOL-EFF

specifies the ambient subcooling effectiveness of the condenser, where subcooling is defined as the differential between the saturated condensing temperature and the actual liquid temperature. The default is the same keyword specified in the attached REFG-SYSTEM. At design conditions subcooling is calculated as:

$$dTsubcool = SUBCOOL\text{-}EFF \ * \ (SCTdes \ - Tdry)$$

where SCTdes and Tdry are the design saturated condensing temperature and the design outdoor drybulb. On an hourly basis, subcooling is calculated in a similar fashion using the actual SCT and outdoor drybulb temperatures. However, the SUBCOOL-EFF will vary as a function of condenser mass flow, air flow, and reduced effectiveness at low wetbulbs.

Note that this ambient subcooling effect is produced within the condenser; mechanical subcoolers may also be defined and are discussed separately.

RATED-REFG-CLASS

when RATED-CAPACITY is input, accepts a code-word defining the refrigerant class to which the rated capacity applies:

HALOCARBON   specifies that the rated capacity is based on condensing a halocarbon refrigerant such as R-22 or R-134a.

AMMONIA   specifies that the rated capacity is based on ammonia. For a given heat rejection load, ammonia has properties that allow the condenser's physical size to be approximately 89% of the size required for a halocarbon refrigerant. This smaller size also applies to the condenser fan and spray-pump power.

The rated refrigerant class does not have to be the same as the actual refrigerant class used in your project. When they are not the same, the program automatically translates the condenser's performance from the rated refrigerant type to the actual. For example, the library contains a variety of makes and models of condensers whose capacities are listed for halocarbon refrigerants. You can safely use one of these condensers in an ammonia-based system.

CLASS-FACTOR
when RATED-CAPACITY is defined, specifies the capacity correction factor when the RATED-REFG-CLASS is not the same as the actual refrigerant. You should not modify this value unless you have reason to disagree with the value set by the default expression:

- 1.0 when the RATED-REFG-CLASS matches the actual refrigerant.

- 1.124 when the RATED-REFG-CLASS is HALOCARBON and the actual refrigerant is ammonia. A condenser's heat-rejection capacity is greater when using ammonia.

- 0.89 when the RATED-REFG-CLASS is AMMONIA and the actual refrigerant is a halocarbon.

KW/FAN
specifies the kW per fan. This entry is required when the RATED-CAPACITY is specified. If not required or specified, this value will be calculated using the FAN-EIR.

NUMBER-OF-FANS
are the total number of independently controlled cells in the component. This entry is mandatory if the KW/FAN is entered, or the REFG-SYSTEM:SCT-CTRL = DRYBULB-STAGED or WETBULB-STAGED; otherwise it is irrelevant.

CONDENSER-DP
specifies the friction head of the condenser heat exchanger. The saturated-condensing temperature (pressure) is assumed to be at the condenser's hot-gas inlet. The pressure at the liquid outlet is somewhat lower due to the pressure drop through the condenser.

Usually, this pressure drop is irrelevant. It is important only if the pressure drop is significant, and the condenser is allowed to operate at very low condensing temperatures. In this case, the pressure differential across the loads may be so low that the loads cannot get adequate refrigerant flow.

RATED-FLOW
specifies the refrigerant flow at which the CONDENSER-DP occurs. If not specified, the default is the design flow.

Capacity Control and Fan Modulation

A REFG-SYSTEM may have multiple condensers attached. While multiple condensers are unusual for supermarket systems, they are not uncommon in industrial systems. Multiple condensers sharing common piping manifolds will all operate at the same condensing temperature. For this reason, condensing temperature control resides at the REFG-SYSTEM level, rather than at individual condensers.

The program supports most common means of condenser temperature control. The following keywords describe the response of this condenser's fans to the control and/or setpoint established by the REFG-SYSTEM served by this condenser.

CAPACITY-CTRL
specifies the control method which regulates the condensing temperature. Options are:

CYCLE-FAN   the default, causes the one speed fan to cycle on and off to maintain the condensing setpoint.

Note that the program assumes the fan can cycle as often as required to maintain the setpoint. In actual practice, fan cycling is usually limited to no more than 4-8 cycles per hour to protect the motor against burnout.

TWO-SPEED-FAN   causes the fan to cycle between off, low and high speeds to maintain the condensing setpoint.

VAR-SPEED-FAN   modulates the airflow so that the rejection capacity exactly matches the load at the desired setpoint. If the required fan speed is below the FAN-MIN-AIRFLOW, then the fan will cycle to maintain the setpoint.

This code word simulates both variable speed drives as well as variable pitch fans. The program calculates power consumption at reduced airflows using the FAN-KW-FAIRFLOW curve.

DISCHARGE-DAMPER   uses a discharge damper to modulate the fan airflow and rejection capacity. Power consumption is approximatly linear down to 50% airflow, but then flattens out and remains relatively constant at lower airflows. If the required fan volume is below the FAN-MIN-AIRFLOW, then the fan will cycle to maintain the setpoint.

The program calculates power consumption at reduced airflows using the FAN-KW-FAIRFLOW curve, using an appropriate damper curve from the library.

FAN-KW-FAIRFLOW
accepts the U-name of a CURVE-FIT instruction that expresses the component fan horsepower as a function of fan output, either speed or damper volume. The output of this curve is the fraction of the full airflow horsepower used at the current fan output. The default varies according to whether the fan is speed-controlled or damper-controlled.

FAN-OFF-AIRFLOW
specifies the ratio of airflow through the unit when the fans are off, to the airflow at high speed. That is, this is the flow rate caused by natural convection, divided by the airflow rate at high speed (design). The program uses this value in calculating the condenser performance during the times when the fan has cycled off, but refrigerant is still flowing.

FAN-LOW-AIRFLOW
specifies the ratio of airflow through the unit when the fans are on low speed, to the airflow at high speed. This keyword is used only when the CAPACITY-CTRL is TWO-SPEED. The program uses this value in calculating the condenser performance during the times when the fan is operating on low speed.

FAN-LOW-PWR
specifies the ratio of the power consumed by the fan at low speed to the power consumed at high speed. This keyword is used only when the CAPACITY-CTRL is TWO-SPEED.

If not specified, the program will calculate this value by feeding the FAN-LOW-AIRFLOW value into the FAN-KW-FAIRFLOW curve.

FAN-MIN-AIRFLOW
when a speed-controlled or damper-controlled fan is used, specifies the minimum fraction of nominal fan speed at which the fan can operate. The default is 0.15 for variable-speed, and 0.25 for dampers. If the load is such that the condenser will overcool the refrigerant at this minimum speed, then the fan will cycle between off and minimum speed.

It is possible that the fan may reach a "critical speed" as the airflow is reduced. The value of this keyword should be above this value, as otherwise excessive vibration may damage the unit. For specific applications, you should consult with the unit's manufacturer.

FAN-STAGE-T

When the REFG-SYSTEM:SCT-CTRL = DRYBULB-STAGED or WETBULB-STAGED, accepts a list of successively increasing temperatures defining the points at which the condenser fans are staged on. When using this control, there is no temperature setpoint. Instead the condensing temperature floats with the load and number of fans running. Refer to the REFG-SYSTEM component for more information on this control strategy.

For example, assume a condenser has three independently-controlled fans (cells). One fan is to run continuously, the second is to stage on whenever the drybulb is at or above 40°F, and the third fan is to stage on at 60°F. Within the condenser component:

```
NUMBER-OF-FANS     = 3
FAN-STAGE-T        = (-100., 40., 60.)
```

If instead the condenser has four fans, two of which always run:

```
NUMBER-OF-FANS     = 4
FAN-STAGE-T        = (-100., -100., 40., 60.)
```

The number of staging temperatures must equal the number of fans. If the condenser has 6 fans, that stage in pairs, then an example would be:

```
NUMBER-OF-FANS     = 6
FAN-STAGE-T        = (-100., -100., 40., 40., 60., 60.)
```

Air-Cooled Condensers

The air-cooled condenser algorithm can model performance for any combination of ambient and condensing temperatures. Since the unit is not evaporatively cooled, the condensing temperature will always be above the ambient drybulb temperature. In hot climates, this can have a significant impact on system efficiency.

RATED-TD

when the RATED-CAPACITY is defined, specifies the differential between saturated condensing temperature and outdoor drybulb temperature corresponding to the RATED-CAPACITY.

Condenser Airflow and Fan Power

The next set of keywords describe the design airflow through an air-cooled condenser.

AIRFLOW

defines the design airflow at the RATED-CAPACITY. You may enter this value if you also specify the RATED-CAPACITY; otherwise this keyword is unused.

AIRFLOW-TD/CAP

when AIRFLOW is not specified, is the ratio of airlow in cubic feet/minute, divided by the condenser capacity at 1°F temperature differential. The design airflow is then

AIRFLOW = AIRFLOW-TD/CAP * RATED-CAPACITY / RATED-TD

This airflow is used in the heat-exchanger design calculations, and also to modify the hourly heat-exchanger effectiveness as a function of airflow.

FAN-EIR-TD

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

    ratio = (fan electric power in Btuh) / (Btuh/TD)

where Btuh/TD is the condenser heat rejection capacity per degree of temperature difference between the SCT and the outdoor drybulb.

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

If you specify the KW/FAN, then the program ignores the FAN-EIR-TD.

<u>Evaporative Condensers</u>

An evaporative condenser consists of a heat-exchanger through which refrigerant circulates, enclosed within an evaporatively-cooled water spray. Because an evaporative condenser responds to the ambient wetbulb temperature rather than the drybulb temperaure, it can achieve a lower condensing temperature than can an air-cooled condenser. The compressor efficiency will usually be higher using evaporative condensers, however this energy savings may be at least partially offset by the power consumption of the condenser fan(s) and spray pump(s), water usage costs, and water treatment.

The evaporative condenser algorithm can model performance for wetbulbs in the range of 30 to 90°F and condensing temperatures of 120 to 55°F. The algorithm models both single-circuit attached to a single refrigeration system, and multi-circuit condensers *(future)* attached to more than one system.

The heat-rejection capacity of a condenser varies dramatically with saturated condensing temperature (SCT) and wetbulb temperature. The most important criterion is the temperature difference (TD) between the SCT and wetbulb. However, for a given TD, the absolute value of the wetbulb is also important (capacity drops off at lower wetbulbs). For these reasons, it is important to specify the actual temperatures for which the condenser capacity is rated.

Manufacturers also distinguish condenser performance on the basis of whether the refrigerant is a halocarbon (R-22, R-134a, etc.) or ammonia. For a given set of conditions (load, condensing temperature and wetbulb), ammonia has properties that allow the physical size of the condenser to be approximately 89% of the size required for halocarbons. The smaller size also applies to condenser fan and spray-pump power.

For halocarbon condensers, standard rating conditions are 105°F SCT and 78°F wetbulb. For the larger ammonia condensers commonly found industrial applications, standard rating conditions are 96.3°F SCT and 78°F wetbulb. However, it is also common for manufacturers to list the "base heat-rejection capacity" at the standard conditions for halocarbons (105/78), and to include tables of capacity correction factors for both halocarbon and ammonia refrigerants.

The program accepts entries for either halocarbon or ammonia condensers, and can translate the condenser's performance from one set of temperature conditions and refrigerant to another set of temperatures and/or refrigerant. For example, you can specify a condenser rated at 1.0 MMBtuh for a halocarbon at 95°F SCT and 74°F wetbulb, but use the condenser in an ammonia-based system running at 85°F SCT and 71°F wetbulb. Similarly, the condensers included in the library whose capacities are listed for halocarbons may be safely used in ammonia-based systems.

RATED-WETBULB

specifies the wetbulb temperature at which the rated capacity and pressure drop apply. The standard rating wetbulb temperature is 78°F, however condensers are commonly specified for the actual anticipated conditions.

RATED-SCT

specifies the saturated condensing temperature at which the rated capacity and pressure drop apply. The standard condensing temperatures are 105°F for a halocarbon condenser, and 96.3°F for a ammonia condenser. However, condensers are commonly specified for the actual anticipated conditions. The RATED-SCT is not necessarily the same as the REFG-SYSTEM:DESIGN-SCT.

DESIGN-WETBULB

specifies the wet-bulb temperature used in the condenser design calculations. The default is the design wetbulb specified for the REFG-SYSTEM.

The DESIGN-WETBULB is not necessarily the same as the RATED-WETBULB. For example, a condenser pulled from the library may have a RATED-CAPACITY = 1.0 MMBtu at a RATED-WETBULB of 78°F. If the DESIGN-WETBULB is 72°F, the program will modify the actual condenser capacity in the design calculations to be the capacity at 72°F.

CAP-FSCT&WB

accepts the U-name of a CURVE-FIT instruction that defines a bi-quadratic equation. That equation will be used to express a factor that adjusts the capacity as a function of the saturated condensing temperature and wetbulb temperatures.

The program calculates the hourly capacity (Btu/hr) of the condenser as

$$Cap = CapCTI * f(SCT,WB) * f(Airflow)$$

where CapCTI is the nominal capacity at the Cooling Tower Institute conditions, f(SCT,WB) is the curve CAP-FSCT&WB, and f(airflow) is the curve CAP-FAIRFLOW.

CAP-FAIRFLOW

accepts the U-name of a CURVE-FIT intstruction that defines a linear or quadratic equation. That equation will be used to express a factor that adjusts the condenser capacity as a function of the airflow through the condenser.

Cooling towers have an almost linear relationship between airflow and capacity. Evaporative condensers, however, do not. At 50% airflow, an evaporative condenser may still retain 70% of its capacity. This is because, as the airflow drops and the capacity falls off, the temperature differential across the heat exchanger also drops, which partially compensates for the reduced airflow. For this reason, 2-speed or variable-speed fans may be very cost effective options. The program can simulate all of the common fan control options available.

FAN-EIR

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

$$ratio = (fan\ electric\ power\ in\ Btu/hr) / (RATED\text{-}CAPACITY\ in\ Btu/hr)$$

where RATED-CAPACITY is the heat rejection capacity at the standard rating conditions. Because the size may be specified at a given RATED-WETBULB and RATED-SCT, while the FAN-EIR may be allowed to default, the FAN-EIR is specified at the capacity produced at the EIR-RATED-WB and EIR-RATED-SCT.

If you specify the KW/FAN, then the program ignores the FAN-EIR.

SPRAY-KW

specifies the kW of the spray pump. If the condenser has more than one spray pump, this is the total. The default is the SPRAY-EIR, multiplied by the rated capacity.

Evaporative condensers come with a factory-mounted spray pump that sprays water over the evaporatively-cooled coil. Unlike most other pumps, the spray pump is not defined as a PUMP component. This is because the spray pump always delivers a constant flow and consumes a constant kW whenever operating.

SPRAY-EIR

specifies the electric input ratio of the spray pump, expressed as kW/RATED-CAPACITY. Because the size may be specified at a given RATED-WETBULB and RATED-SCT, while the SPRAY-EIR may be allowed to default, the SPRAY-EIR is specified for the capacity produced at the EIR-RATED-WB and EIR-RATED-SCT.

EIR-RATED-WB

is the wetbulb temperature at which the FAN-EIR and SPRAY-EIR are specified; the default is 78F.

EIR-RATED-SCT

is the saturated condensing temperature at which the FAN-EIR and SPRAY-EIR are specified; the default is 105°F for a halocarbon condenser, and 96.3°F for a ammonia condenser.

Cascaded Condensers

A refrigeration plant may have multiple refrigerations systems, each operating at a different temperature and/or using a different refrigerant. A cascaded system consists of one or more low-temperature systems that reject their heat to an intermediate-temperature system. The two systems usually have different refrigerants, and are coupled via a refrigerant-to-refrigerant condenser.

To model this, first define the intermediate-temperature system. Then define the low temperature system, together with a CASCADED condenser. Attach this condenser to the appropriate liquid and suction circuits of the intermediate-temperature system.

The program supports any number of levels of cascading. For example, a very low-temperature system may cascade into a low-temperature system, which in turn cascades into an intermediate-temperature system.

LIQUID-CIRCUIT

accepts the U-name of REFG-CIRCUIT of the intermediate-temperature system that supplies liquid refrigerant to the heat-exchanger. This circuit must belong to the same refrigeration system as the suction circuit.

SUCTION-CIRCUIT

accepts the U-name of a REFG-CIRCUIT of the intermediate-temperature system that removes vaporized refrigerant from the heat-exchanger. This circuit must belong to the same refrigeration system as the liquid circuit.

RATED-TD

specifies the differential between saturated-condensing temperature and the saturated-suction temperature at the RATED-CAPACITY.

SUPERHEAT-DT

specifies the design superheat of the refrigerant leaving the heat-exchanger. The superheat is assumed constant all hours of operation.

TEMP-CTRL

accepts a code word specifying the temperature control mechanism:

FLOAT   specifies that the condensing temperature floats according to the load, the suction pressure of the intermediate system, and the heat-exchanger characteristics.

LOCAL-EPR   specifies that the condenser has its own evaporator pressure regulator that maintains a constant saturated-suction temperature in the evaporator. The condensing temperature then varies according to the setpoint (as determined by the low-temperature refg-system), the heat-exchanger load, and heat-exchanger characteristics.

THERMOSTAT   the default, specifies that the condensing temperature setpoint is directly controlled by the low-temperature refg-system to which the condenser belongs.

SUCTION-FLOW
specifies the design suction refrigerant flow. This value defaults according to the design load and refrigerant characteristics.

SUCTION-DP
specifies the design pressure drop of the suction refrigerant flowing through the heat-exchanger. The pressure drop is in units of pressure. This pressure drop is for the heat-exchanger and thermal expansion valve controlling the superheat; any drop associated with an evaporator pressure regulator or thermostat is specified via the CTRL-VALVE-DT keyword.

This pressure drop is important when the intermediate suction-group is resetting the suction pressure on the basis of worst-case demand, or the high-temperature condensers are using a floating head-pressure control. Also, if there is insufficient pressure drop available for the required flow, then the load will not be met and the temperature of the condenser will float above setpoint.

CTRL-VALVE-DT
For all TEMP-CTRL strategies other than FLOAT, specifies the saturated temperature drop through the evaporator pressure regulator or temperature control valve; the drop associated with the heat-exchanger and thermal expansion valve is ispecified via the SUCTION-DP keyword. The valve is assumed to be on the suction side of the evaporator, so that the available suction pressure of the suction group is reduced by the pressure (temperature) drop through this valve. The pressure drop through the valve varies hourly as a function of the actual refrigerant flow.

COND-FILM-RES
specifies the fraction of the overall heat-exchanger resistance that is on the condensed side of the heat-exchanger. Note that the sum of this value and the SUPPLY-FILM-RES must be less than 1.0. The program modifies this value on an hourly basis as a function of the flow.

SUPPLY-FILM-RES
specifies the fraction of the overall heat-exchanger resistance that is due to the evaporator side of the heat-exchanger. Note that the sum of this value and the COND-FILM-RES must be less than 1.0. The program modifies this value on an hourly basis as a function of the flow.

Miscellaneous Inputs
ELEC-METER
accepts the U-name of the electric meter powering the fan and spray pump. The default is the ELEC-METER of the associated REFG-SYSTEM.

AUX-MODE

accepts a code-word specifying when theAUX-KW is consumed. The default is that there is no auxiliary power consumption

ALWAYS	indicates that the auxiliary power is consumed all hours.
WHEN-ON	indicates that auxiliary power is consumed only during the hours the suction group is operating.
WHEN-OFF	indicates that auxiliary power is consumed only during the hours the suction group is off.
SCHEDULED	indicates that the power consumption is scheduled.

AUX-KW

accepts a numeric value specifying an auxiliary electrical consumption, such as for a control panel. This is a required keyword when the AUX-MODE is specified.

AUX-SCH

when AUX-MODE = SCHEDULED, accepts a U-name of a schedule that varies the AUX-KW on an hourly basis.

AUX-METER

accepts the U-name of a meter that supplies the auxiliary energy.

COST-DATA

EQUIPMENT-REPORTS

accepts the codewords YES or NO. The default is YES. When report RS-H of the REFG-REPORTS is enabled, a report will print for this component unless this keyword is set to NO.

DESUPERHEATER

Note: Since the program library currently does not have any compressor performance curves for superheat, it does not make sense to model a desuperheater unless you also input compressor performance curves for superheat.

This command defines the characteristics of a desuperheater. A desuperheater cools a refrigerant vapor to remove most of its superheat. Used on a suction circuit, this allows the refrigerant to enter a compressor at a lower temperature. Desuperheaters are commonly used with compounded compressors to cool the gas discharging from one stage of compression prior to entering the next. Otherwise, the resulting high degree of superheat will reduce compression efficiency and possibly damage the following compressor.

The outlet of a desuperheater may be attached to either:

- Directly to a suction-group – all suction gas entering the desuperheater is desuperheated immediately before entering the compressors.

- The inlet of a suction circuit – all suction gas entering the desuperheater is desuperheated, and then flows into a downstream suction circuit. The gas in the downstream circuit may then pick up superheat from thermal gains.

Any number of desuperheaters may attach to a suction-group or to the inlet of a downstream suction circuit. Any number of upstream suction circuits may attach to a desuperheater's inlet.

U-NAME(=)
accepts a mandatory entry for the U-name of this desuperheater. This U-name will be used all reports to identify the component.

TYPE
accepts a code-word specifying the type of desuperheater:

REFG-INJECTION	specifies that liquid refrigerant will be injected into the suction gas. The liquid will desuperheat the refrigerant as it evaporates, and will add to the mass flow.
*REFG-HX	is similar to REFG-INJECTION, but the desuperheater uses a heat-exchanger to avoid adding additional refrigerant to the mass flow entering the suction group. Normally, you would use this type of desuperheater only if you want to desuperheat using refrigerant from a completely separate refrigeration system.
*EVAP-COOLED	specifies that an evaporatively-cooled heat-exchanger will be used to desuperheat the suction gas. The heat-exchanger may be either a separate component, or a circuit in a multi-circuit evaporative condenser.
*AIR-COOLED	specifies that an air-cooled heat-exchanger will be used to desuperheat the suction gas. The air entering the heat-exchanger is assumed to be at ambient (outdoor) temperature.
*WATER-COOLED	specifies that a water-cooled heat-exhanger will be used to desuperheat the suction gas. The water may come from either a chilled-water, condenser-water, or heat-pump circulation-loop.

ATTACH-TO
specifies the attachment of the desuperheater's outlet. This is a mandatory entry.

> SUCTION-GROUP the leaving desuperheated gas flows directly into a suction group. Any number of desuperheaters may attach to the same suction group.

> DESUPER-CIRCUIT the leaving desuperheated gas flows into a downstream suction circuit. Any number of desuperheaters may attach to the same downstream suction circuit.

Note that the upstream suction circuits attach to the desuperheater from within their components. Any number of upstream circuits may attach to the same desuperheater.

SUCTION-GROUP
when ATTACH-TO = SUCTION-GROUP, accepts the U-name of the SUCTION-GROUP into which the gas leaving the desuperheater will flow.

DESUPER-CIRCUIT
when ATTACH-TO = DESUPER-CIRCUIT, accepts the U-name of the downstream REFG-CIRCUIT of TYPE = SUCTION into which the gas leaving the desuperheater will flow.

REFG-SYSTEM
is set by an expression and should never be changed by the user. This is the U-name of the REFG-SYSTEM to which the desuperheated gas ultimately flows. This keyword has no user function; it is set so that upstream components can determine the system to which they belong.

CAPACITY
specifies the capacity of the desuperheater in Btu/hr. If not specified, the program will default this value based on the suction circuit's design mass flow and temperature drop through the subcooler.

SUPERHEAT-SETPT
specifies the setpoint in degrees superheat for the desuperheater. The temperature leaving the desuperheater will be the sum of this value and the saturated suction temperature.

DESUPER-FLOW
specifies the design flow of refrigerant to be desuperheated. This value will default to the design flow of the suction circuit to be desuperheated. this value is used in calculating the hourly pressure drop through the desuperheater.

DESUPER-DP
specifies the pressure drop of the refrigerant to be desuperheated as it flows through the desuperheater. The program modifies this value hourly as a function of mass flowrate.

SUCTION-CIRCUIT
for a REFG-HX desuperheater, accepts the U-name of the SUCTION circuit returning the evaporated liquid to its system. The SUCTION-CIRCUIT must be part of the same system as the LIQUID-CIRCUIT, but does not necessarily have to belong to the same system as the desuperheated gas. Note that the desuperheater attaches to the suction circuit to be desuperheated via a keyword in that suction circuit.

LIQUID-CIRCUIT
for a REFG-INJECTION or REFG-HX desuperheater, accepts the U-name of the LIQUID circuit supplying refrigerant to the desuperheater. Note that the desuperheater attaches to the suction circuit to be desuperheated via a keyword in that suction circuit.

LIQUID-FLOW
for a REFG-INJECTION or REFG-HX desuperheater, specifies the design flow of refrigerant providing the desuperheating effect.

LIQUID-DP
for a REFG-INJECTION or REFG-HX desuperheater, specifies the pressure differential between the liquid and suction circuits of the refrigerant providing the desuperheating effect, at the LIQUID-FLOW. This differential includes the pressure drop through the thermal expansion valve, heat exchanger (if any), and any other components. The program modifies this value hourly as a function of mass flowrate.

This pressure drop is important only if the suction-group is resetting the suction pressure on the basis of fixture demand, or the condensers are using a floating head-pressure control. If there is insufficient pressure drop available for the required flow, then the load will not be met and the temperature of the desuperheated gas will float above setpoint.

SST-DESUPER-TD
for all types except REFG-INJECTION, specifies the design temperature differential between the leaving temperature of the refrigerant to be desuperheated, and the entering temperature of the medium doing the desuperheating (for a REFG-HX, this is the saturated-suction temperature). This keyword is used in sizing the heat-exchanger.

The default is the difference between the design entering temperature of the refrigerant to be desuperheated, and the design temperature of the medium doing the desuperheating.

SUPERHEAT-DT
for a REFG-HX desuperheater, specifies the design superheat of the suction gas leaving the subcooler. The program assumes this superheat is constant all hours.

HX-UA
for all types except REFG-INJECTION, specifies the effective conductivity of the heat-exchanger. If not specified, the program will calculate this value based on the load, flow, and temperature characteristics of the desuperheater.

HX-CONFIGURATION
for all types except REFG-INJECTION and REFG-HX, specifies the heat-exchanger configuration. Acceptable entries are *(future)*.

DESUPER-FILM-RES
for all types except REFG-INJECTION, specifies the fraction of the overall heat exchanger resistance (where resistance = 1.0 / HX-UA) due to the film resistance on the desuperheated side of the heat exchanger.

The program uses this value to determine the design desuperheated-side film resistance. The program modifies this design value on an hourly basis to account for the change in HX-UA due to variations in flow:

$$Rsup = Rsup\text{-}design * (Hourly\ Flow/FLOW)**DESUPER\text{-}FILM\text{-}EXP$$

The default values are only approximate. You should verify the relative fractions of the desuperheated-side and supply-side film resistances if off-design performance is of critical importance in your analysis.

The design resistance fractions of the desuperheated-side, supply-side, and the heat exchanger resistances must add up to 1.0. Therefore, the sum of the desuperheated-side and supply-side film resistance fractions must be less than or equal to 1.0. The program checks for this condition, and will generate an error if your input does not meet this criteria.

DESUPER-FILM-EXP
for all types except REFG-INJECTION, specifies the exponent used to modify the DESUPER-FILM-RES as a function of the hourly refrigerant flow. The default is 0.52, which corresponds to gas flow over a finned surface.

The program assumes that this exponent is valid over the entire flow range. If the flow (and Reynolds number) drops low enough, the flow will transition from turbulent to laminar, and this assumption will not be valid.   For most applications, this transition will normally not occur until the flow is in the 25% range or lower. The errors generated will be small and should have a negligible impact on energy consumption

SUPPLY-FILM-RES
for all types except REFG-INJECTION, is identical to DESUPER-FILM-RES, but describes the fraction of overall heat-exchanger resistance that is on the supply side of the heat-exchanger.

SUPPLY-FILM-EXP
for all types except REFG-INJECTION, specifies the exponent used to modify the DESUPER-FILM-RES as a function of the hourly refrigerant flow. The default is 0.52, which corresponds to gas flow over a finned surface.

The following keywords are miscellaneous:

AUX-MODE
accepts a code-word specifying when theAUX-KW is consumed. The default is that there is no auxiliary power consumption.

ALWAYS	indicates that the auxiliary power is consumed all hours.
WHEN-ON	indicates that auxiliary power is consumed only during the hours the suction group is operating.
WHEN-OFF	indicates that auxiliary power is consumed only during the hours the suction group is off.
SCHEDULED	indicates that the power consumption is scheduled.

AUX-KW
accepts a numeric value specifying an auxiliary electrical consumption, such as for a control panel. This is a required keyword when the AUX-MODE is specified.

AUX-SCH
when AUX-MODE = SCHEDULED, accepts a U-name of a schedule that varies the AUX-KW on an hourly basis.

AUX-METER
accepts the U-name of a meter that supplies the auxiliary energy.

COST-DATA
accepts the U-name of a MATERIALS-COST command. This command allows you to define first costs, maintenance costs, etc. for this component.

EQUIPMENT-REPORTS

accepts the codewords YES or NO. The default is NO. When report RS-H of the REFG-REPORTS is enabled, a report will print for this component when this keyword is YES.

PROCESS-LOAD

This component defines the characteristics of a process load. You use this component to define an energy-consuming process that takes energy from either a circulation loop (hot-water, chilled-water, etc.), a refrigeration system, or a meter (electric or fuel). The energy consumed may simply disappear into the process, or a portion of the energy may show up as a load on a space. While (some) process loads may be defined within the space component, this command allows for greater flexibility in how multiple processes are defined.

For example, consider a dairy that produces pasturized milk, yogurt, ice cream, etc. The milk may be first pasturized using heat from a hot-water plant, then cooled and/or frozen using processes served by a refrigeration system. This command allows you to define each of these processes individually, and attach them to the appropriate systems.

U-NAME(=)
accepts a mandatory entry for the U-name of this process load. This U-name will be used in all reports to identify the component.

TYPE
accepts a code-word that specifies the type of process. This is a mandatory entry:

HOT-WATER	specifies a process connected to a hot-water plant.
DOM-HOT-WATER	specifies a process connected to a domestic hot-water plant.
CHILLED-WATER	specifies a process connected to a chilled-water or condenser-water plant.
REFRIGERATION	specifies a process connected across the liquid and suction lines of a refrigeration system.
ELECTRIC	specifies a process connected to an electric meter.)
FUEL	specifies a process connected to a fuel meter.

MULTIPLIER
defines the number of identical processes. The remainder of the keywords apply to a single process, the program will adjust the net load as a function of the multiplier.

PROCESS-LOAD
for all types except DOM-HOT-WATER, defines the magnitude of the process load in Btu/hr.

PROCESS-SCH
accepts the U-name of a schedule that modifies the process load on an hourly basis. If not defined, the program assumes a constant load all hours.

END-USE
accepts a code-word specifying the energy end-use category of the process. These categories correspond to the categories reported on the METER reports (PS-E and PS-F), as well as the BEPS and BEPU reports.

The program is capable of accurately tracking loads through all distribution networks and energy using devices. For example, a process heating load attached to a hot-water loop will show up in the meters that supply energy to the boilers serving that loop. Similarly, a process refrigeration load on a system whose condenser cascades into a chilled-water loop will show up in the meters that supply energy to the chillers serving that loop.

LIGHTS	general interior lighting
TASK-LIGHTS	interior task lighting
EQUIPMENT	miscellaneous equipment. This is the default for HOT-WATER, CHILLED-WATER, ELECTRIC, and FUEL process loads.
SPACE-HEATING	energy used to heat a space
SPACE-COOLING	energy used to cool a space, including heat consuming chillers (absorption, gas-fired, engine-driven).
HEAT-REJECTION	energy in heat-rejection devices such as cooling towers and condensers
HVAC-AUXILIARY	auxiliary equipment, primarily pumps.
VENTILATION-FANS	HVAC ventilation fans
REFRIGERATION	supermarket display fixtures and industrial processes other than space cooling. This is the default for REFRIGERATION processes.
SUPP-HEAT-PUMP	supplemental energy consumed by a heat pump
DOM-HOT-WATER	domestic hot water. This is the default for DOM-HOT-WATER processes
EXTERIOR	energy consumed outside of a building, such as for signage, parking lot lighting, and fountains.

Hot/Chilled-Water Loop Interactions

For HOT-WATER and CHILLED-WATER processes, the following keywords define the interaction of the process with its circulation loop:

CIRCULATION-LOOP
accepts the U-name of the CIRCULATION-LOOP that supplies this process.

PROCESS-T
specifies the final temperature of the product in the process. The product is either heated or cooled to this temperature.

PROCESS-DT
specifies the temperature change of the product in the process. The program uses this value in the heat-exchanger calculations to determine the required supply flow and temperature. If not specified, then the process is assumed to be at a uniform temperature.

SUPPLY-T
is the required entering temperature of the supply fluid.

SUPPLY-DT
is the temperature change of the supply fluid.

SUPPLY-HEAD

is the pressure drop of the supply fluid through the process heat-exchanger, excluding the pressure drops of the control valve and/or balance valve.

CTRL-VALVE-TYPE

accepts a code-word specifying the type of control valve:

TWO-WAY	is a 2-way valve. This valve is used for variable-flow circulation-loops.
THREE-WAY	is a 3-way valve. Flow is constant all hours; with the flow not needed by the process bypassed to the return.

CTRL-VALVE-HEAD

is the pressure drop through the control valve when wide open.

BALANCE-VALVE

accepts a code-word specifying the type of balance valve:

NONE	specifies that no balancing valve exists. The maximum hourly flow through the process is strictly a function of the available pressure differential across the supply/return legs, and the pressure drop of the heat-exchanger and control valve.
MANUAL	is a valve set manually during the building commissioning process. The program sets the pressure drop of this valve to consume the excess pressure available across the supply/return legs at the design conditions. The maximum hourly flow through the process is then a function of the available pressure differential across the supply/return legs, and the pressure drop of the heat-exchanger, control valve, and balance valve.
FLOW-LIMITING	is a valve that modulates to limit the maximum flow. The maximum hourly flow through the process is then a function of the available pressure differential across the supply/return legs, and the pressure drop of the heat-exchanger, control valve, and flow-limiting valve; subject to a maximum limit of 110% of the design flow.

BALANCE-HEAD

is the pressure drop of the balance valve when fully open at the design flow.

For a manual valve, the program will adjust the valve setting during the building commissioning process to trim the excess pressure at design conditions. In this case, the BALANCE-HEAD is the minimum possible pressure drop of the valve (fully open).

For a flow-limiting valve, this is the pressure drop at the design flow, assuming the valve is fully open. On an hourly basis the valve will modulate as required to prevent the flow from exceeding 110% of the design flow.

HX-CONFIGURATION

when PROCESS-DT is non-zero, specifies the heat-exchanger configuration. All standard DOE-2 heat-exchanger configurations are acceptable, as defined elsewhere.

When PROCESS-DT is zero (uniform), the program uses the NTU/effectiveness equation for a phase-change material.

Domestic Hot Water Loop Interactions

For DOM-HOT-WATER processes, the following keywords define the interaction of the process with its circulation loop:

PROCESS-FLOW

specifies the design process flow. This flow is assumed to be consumed within the process (goes down the drain). As such, it draws from the supply-side of a loop, but does not discharge to the return-side of a loop. This flow is modified hourly by the PROCESS-SCH

The actual load on the plant is calculated as a function of the process flow, the supply temperature, and the temperature of the make-up water entering the loop.

CIRCULATION-LOOP

accepts the U-name of the CIRCULATION-LOOP that supplies this process.

PROCESS-T

specifies the temperature at which the water is used. If the loop supply temperature is hotter than this temperature, then cold water will be mixed with the loop water to achieve the required temperature. The PROCESS-FLOW is then reduced by the amount of cold water used.

The cold make-up water temperature is as defined for the CIRCULATION-LOOP:DHW-INLET-T.

RECIRC-FLOW

specifies the flow that is constantly recirculated from the supply leg to the return leg. This flow is in addition to the PROCESS-FLOW.

Many commercial domestic water loops recirculate a small amount of water to keep the loop hot at all times. To model this:

- Specify a non-zero flow here,

- In the CIRCULATION-LOOP, specify the LOOP-OPERATION to be STANDBY. (If the loop-operation is DEMAND, then fluid will recirculate only when there is an active demand.) You must also attach a PUMP to the loop. This pump will normally be on the return leg of the loop, prior to the cold-water make-up, so that its size reflects only the recirculation flow.

BALANCE-VALVE

when the RECIRC-FLOW is non-zero, accepts a code-word specifying the type of balance valve controlling the recirculation flow:

NONE	specifies that no balancing valve exists. The maximum hourly flow through the process is strictly a function of the available pressure differential across the supply/return legs. For this calculation, the program assumes the recirculation leg has a 2' pressure drop (set by BALANCE-HEAD).
MANUAL	is a valve set manually during the building commissioning process. The program sets the pressure drop of this valve to consume the excess pressure available across the supply/return legs at the design conditions. The maximum hourly flow through the process is then a function of the available pressure differential across the supply/return legs, and the pressure drop of the balance valve.

FLOW-LIMITING   is a valve that modulates to limit the maximum flow. The maximum hourly flow through the process is then a function of the available pressure differential across the supply/return legs, and the pressure drop of the flow-limiting valve; subject to a maximum limit of 110% of the design flow.

BALANCE-HEAD
is the pressure drop of the balance valve when fully open at the design flow.

For a manual valve, the program will adjust the valve setting during the building commissioning process to trim the excess pressure at design conditions. In this case, the BALANCE-HEAD is the minimum possible pressure drop of the valve (fully open).

For a flow-limiting valve, this is the pressure drop at the design flow, assuming the valve is fully open. On an hourly basis the valve will modulate as required to prevent the flow from exceeding 110% of the design flow.

Refrigeration Interactions
For REFRIGERATION processes, the following keywords define the interaction of the process with its liquid and suction circuits:

PROCESS-T
specifies the final temperature of the product in the process. The product is cooled to this temperature.

PROCESS-DT
specifies the temperature change of the product in the process. The program uses this value in the heat-exchanger calculations to determine the required suction flow and temperature. If not specified, then the process is assumed to be at a uniform temperature.

LIQUID-CIRCUIT
accepts the U-name of the liquid REFG-CIRCUIT that supplies this process.

SUCTION-CIRCUIT
accepts the U-name of the suction REFG-CIRCUIT that supplies this process.

SUCTION-T
is the required suction temperature of the refrigerant.

SUPERHEAT-DT
is the degrees of superheat in the leaving suction gas..

SUCTION-DP
is the pressure drop of the refrigerant through the process heat-exchanger and TXV, excluding the pressure drop of the control valve.

CTRL-VALVE-DT
is the full-open pressure drop of the temperature control valve, expressed in degrees temperature.

Zone Interactions
The following set of keywords describe the impact the process has on a space.

PROCESS-ZONE

accepts the U-name of a zone impacted by the process. If not defined, then all of the process load is assumed to be consumed by the process itself, and none of the heating/cooling energy is absorbed by a zone.

CONVECTIVE

when a PROCESS-ZONE is defined, specifies the fraction of the process energy that is lost via convection to the zone.

RADIANT (future)

when a PROCESS-ZONE is defined, specifies the fraction of the process energy that is lost via radiation to the zone. (not implemented)

LATENT

when a PROCESS-ZONE is defined, specifies the fraction of the process energy that is lost via latent moisture to the zone. For example, a DOM-HOT-WATER load may be comprised of showers that add humidity to a space. This latent load will act to decrease the sensible-heat ratio of the HVAC equipment cooling the space.

If the process load is cooling, thereby creating a heating load on the space, then this fraction represents moisture taken from the space.

Miscellaneous

The following are miscellaneous inputs.

AUX-MODE

accepts a code-word specifying when theAUX-KW is consumed. The default is that there is no auxiliary power consumption

ALWAYS	indicates that the auxiliary power is consumed all hours.
WHEN-ON	indicates that auxiliary power is consumed only during the hours the process load is active is operating.
WHEN-OFF	indicates that auxiliary power is consumed only during the hours the process load is off.
SCHEDULED	indicates that the power consumption is scheduled.

AUX-KW

accepts a numeric value specifying an auxiliary electrical consumption, such as for a control panel. This is a required keyword when the AUX-MODE is specified.

AUX-SCH

when AUX-MODE = SCHEDULED, accepts a U-name of a schedule that varies the AUX-KW on an hourly basis.

AUX-METER

accepts the U-name of a meter that supplies the auxiliary energy.

AUX-CONVECTIVE

when a PROCESS-ZONE and AUX-MODE are defined, specifies the fraction of the auxiliary energy that is lost via convection to the zone.

AUX-RADIATIVE (future)
when a PROCESS-ZONE and AUX-MODE are defined, specifies the fraction of the auxiliary energy that is lost via radiation to the zone. (not implemented)

AUX-LATENT
when a PROCESS-ZONE and AUX-MODE are defined, specifies the fraction of the auxiliary energy that is lost via latent moisture to the zone.

COST-DATA (future)
accepts the U-name of a MATERIALS-COST command. This command allows you to define first costs, maintenance costs, etc. for this component.

EQUIPMENT-REPORT accepts the codewords YES or NO. The default is NO. When report PS-H of the PLANT-REPORTS is enabled, a report will print for this component when this keyword is YES.

REFG-CIRCUIT

This command defines the characteristics of a refrigerant circuit. Here, the program defines a circuit as the refrigerant piping that connects two components together. For example, the suction piping that connects a refrigerated display case to its suction-group is a circuit. So also is the discharge piping that connects a compressor to a condenser, as is the liquid piping that connects a condenser to a refrigerated display case (Figure ??).

Circuits may attach to other circuits, thereby forming a tree. For example, two display cases may each have their own branch suction circuit. Those branch circuits may in turn attach to a trunk suction curcuit, which in turn attaches to a suction-group. Additional trunk suction curcuits may attach to the same suction group. There is no limit to the number of branches that attach to a trunk, or the number of sub-branches that attach to a branch, etc. (Figure ??).

U-NAME(=)
accepts a mandatory entry for the U-name of this circuit. This U-name will be used all reports to identify the component.

TYPE
accepts a code-word that specifies the type of circuit. This is a mandatory entry:

LIQUID — specifies that the refrigerant in this circuit is liquid. This type of circuit passes liquid refrigerant from the liquid receiver tank in the REFG-SYSTEM to a load such as a display case or direct-expansion cooling coil.

SUCTION — specifies that the refrigerant in this circuit is a low pressure gas. This type of circuit passes the suction gas discharged by a load such as a display case or direct-expansion cooling coil to a suction-group.

DISCHARGE — specifies that the refrigerant in this circuit is a high pressure gas. This type of circuit passes high-pressure gas discharged from compressors to the condenser(s) in the REFG-SYSTEM that will reject the heat.

*SIM-ALGORITHM
specifies the subroutine the program will use to simulate this circuit. Currently, this entry cannot be changed by the user.

*COST-DATA
accepts the U-name of a MATERIALS-COST command. This command allows you to define first costs, maintenance costs, etc. for this component. For example, this entry could account for the cost of pipe insulation.

EQUIPMENT-REPORTS
accepts the codewords YES or NO. The default is NO. When report RS-H of the REFG-REPORTS is enabled, a report will print for this component when this keyword is YES.

TYPE-Specific Entries

Liquid Circuits

For liquid circuits, the circuit's *inlet* receives liquid from an upstream refg-system, subcooler, or trunk liquid circuit. The *outlet* delivers liquid to loads or downstream branch circuits. The *inlet* attaches here; loads or downstream branch circuits attach to this circuit's *outlet* from within their components.

ATTACH-TO
specifies the attachment of the liquid circuit's inlet. This is a mandatory entry.

REFG-SYSTEM	the inlet receives refrigerant directly from the condensers in a REFG-SYSTEM. Any number of circuits may attach to a refg-system.
SUBCOOLER	the inlet receives subcooled refrigerant from a subcooler. Any number of circuits may attach to a subcooler.
TRUNK-CIRCUIT	the inlet receives refrigerant from an upstream liquid circuit. Any number of circuits may attach to an upstream circuit.

REFG-SYSTEM
when ATTACH-TO = REFG-SYSTEM, requires the U-name of the REFG-SYSTEM feeding this circuit.

when ATTACH-TO is value other than REFG-SYSTEM, this keyword is set by an expression to be the REFG-SYSTEM of the liquid's origin. In this case, *you should not override the expression's value.* Downstream components need to know which system they belong to, so that they can check for cross-connections between systems, and set various parameters based on the refrigerant.

SUBCOOLER
when ATTACH-TO = SUBCOOLER, requires the U-name of the SUBCOOLER feeding this circuit.

TRUNK-CIRCUIT
when ATTACH-TO = TRUNK-CIRCUIT, requires the U-name of the upstream circuit feeding this circuit.

Suction Circuits

For suction circuits, the circuit's *inlet* receives gas from upstream loads or suction circuits. The *outlet* delivers the gas to a suction group, desuperheater, or downstream trunk suction circuit. The *outlet* attaches here; loads or upstream branch circuits attach to this circuit's *inlet* from within their respective components.

ATTACH-TO
specifies the attachment of the suction circuit's outlet. This is a mandatory entry.

SUCTION-GROUP	the outlet discharges suction gas directly into a suction group. Any number of circuits may attach to the same suction group.
DESUPERHEATER	the outlet discharges suction gas into a desuperheater. Any number of circuits may attach to a desuperheater
TRUNK-CIRCUIT	the outlet discharges suction gas into a downstream trunk suction circuit. Any number of suction circuits may attach to a downstream circuit.

SUCTION-GROUP

when ATTACH-TO = SUCTTION-GROUP, requires the U-name of the suction group into which this circuit feeds.

DESUPERHEATER

when ATTACH-TO = DESUPERHEATER, requires the U-name of the desuperheater into which this circuit feeds.

TRUNK-CIRCUIT

when ATTACH-TO = TRUNK-CIRCUIT, requires the U-name of the downstream circuit into which this circuit feeds.

REFG-SYSTEM

this keyword is set by an expression to be the REFG-SYSTEM of the origin of the suction gas. *You should not override the expression's value.* Upstream components need to know which system they belong to, so that they can check for cross-connections between systems, and set various parameters based on the refrigerant.

The following keywords describe how the upstream suction pressure may be limited by a pressure regulating valve.

EPR-VALVE

accepts a code-word specifying the existence of an evaporator pressure regulator valve, if any. This valve maintains a constant suction pressure on its upstream side, independent of the downstream pressure. (Of course, if the downstream pressure rises above the EPR's setpoint, the valve will be ineffective. In this case, the outlet pressure tracks the inlet pressure, modified by the pressure drop of the valve.)

NO   the default, specifies that the circuit does not have an EPR valve.

YES   specifies that an EPR is at the outlet (downstream) end of the piping.

EPR-SETPT

specifies the saturated suction temperature setpoint of the EPR. The default is the design pressure at the outlet of the circuit, modified by the pressure loss through the valve.

VALVE-DP

specifies the pressure drop through the EPR valve at the circuit's design FLOW. This pressure drop has units of pressure, not temperature.

Discharge Circuits

For discharge circuits, the circuit's *inlet* receives gas from upstream compressors or discharge circuits. The *outlet* delivers the gas to a refg-system, heat-reclaim, or downstream trunk discharge circuit. The *outlet* attaches here; compressors or upstream branch circuits attach to this circuit's *inlet* from within their respective components.

ATTACH-TO

specifies the attachment of the discharge circuit's outlet. This is a mandatory entry.

REFG-SYSTEM   the outlet discharges into the condensers controlled by a REFG-SYSTEM. Any number of circuits may attach to a refg-system.

TRUNK-CIRCUIT   the outlet discharges gas into a downstream trunk discharge circuit. Any number of discharge circuits may attach to a downstream circuit.

REFG-SYSTEM

when ATTACH-TO = REFG-SYSTEM, requires the U-name of the REFG-SYSTEM into which this circuit feeds.

when ATTACH-TO is a value other than REFG-SYSTEM, this keyword is set by an expression to be the REFG-SYSTEM of the refrigerant's origin. In this case, *you should not override the expression's value.* Downstream components need to know which system they belong to, so that they can check for cross-connections between systems, and set various parameters based on the refrigerant.

TRUNK-CIRCUIT

when ATTACH-TO = TRUNK-CIRCUIT, requires the U-name of the downstream circuit into which this circuit feeds.

The following keywords describe how heat may be recovered from the hot discharge gas for use in an HVAC system or other load. For a complete discussion of heat reclaim, refer to "Heat Recovery to HVAC Systems".

HOLDBACK-CTRL

specifies the control mechanism for the holdback valve. Note that no heat recovery is simulated if no heat-recovery demands are attached:

NONE   the default, specifies that there is no active holdback control. The heat-recovery coil(s) will operate primarily in the desuperheat mode, although refrigerant may also condense according to the coil and refrigerant conditions.

Note that, while this strategy assumes no holdback valve, it is possible to raise the setpoint of the condenser to the point where latent heat can be reclaimed. The condenser setpoint may be either fixed at a high value all hours, or may be reset according to the heat-reclaim load. Refer to the REFG-SYSTEM component for a discussion of condenser-level heat-reclaim control strategies.

ALWAYS   specifies that the holdback valve is active all hours of operation, independent of whether heat-recovery is actually required. HOLDBACK-SETPT specifies the control setpoint. This mechanism, while common, may force the compressors to operate at a higher discharge pressure than they might otherwise, at an additional energy cost.

ON/OFF   specifies that the holdback valve is active only when there is a heat-recovery demand on the circuit. HOLDBACK-SETPT specifies the control setpoint.

SCHEDULED   specifies that the holdback valve is operates according to a schedule of type ON/OFF/TEMP. An hourly value of 0 indicates that the valve is not active, and 1 indicates that it is active. Any other value will cause the valve to activate only when the outdoor air temperature is below the setpoint. HOLDBACK-SETPT specifies the control setpoint.

OA-RESET   specifies that the holdback valve is always active, and maintains a setpoint according to a reset schedule.

LOAD-RESET   specifies that the holdback valve activates only when there is a demand, and modulates so that the pressure upstream of the valve is just high enough to meet the worst-case heat recovery demand. This mechanism, while uncommon, is the most energy-efficient. The maximum allowable pressure is specified by the HOLDBACK-SETPT.

HOLDBACK-SETPT
for all strategies utilizing a fixed holdback setpoint, specifies the saturated condensing temperature setpoint of the holdback valve. For LOAD-RESET, this is the maximum allowable holdback temperature.

HOLDBACK-SCH
when HOLDBACK-CTRL = SCHEDULED, accepts the U-name of a SCHEDULE of type ON/OFF/TEMP to indicate when heat-recovery is active. An hourly value of 0 indicates that the valve is not active, and 1 indicates that it is active. Any other value will cause the valve to activate only when the outdoor air temperature is below the setpoint.

HOLDBACK-RESET-SCH
when HOLDBACK-CTRL = OA-RESET, accepts the U-name of a RESET-SCH that controls the setpoint of the holdback valve.

VALVE-DP
specifies the pressure drop through the holdback valve at the circuit's DESIGN-FLOW, when no heat-recovery is required (valve fully open). No valve loss is simulated if there are no attached heat-recovery demands.

The default pressure drop varies according to the HOLDBACK-CTRL. NONE assumes the system uses a 3-way diverting valve with a 5 psig pressure drop. All other modes (holdback modes) assume a 30 psig loss.

BYPASS-DP
for all holdback modes that can be inactivated (NONE, CYCLE-ON-DEMAND, SCHEDULED, LOAD-RESET), specifies the pressure drop through a valve that allows refrigerant to bypass the holdback valve when heat-recovery is inactive. Since a holdback valve typically has a high pressure drop even when fully open (necessary for controllability), this bypass valve allows the system to avoid the pressure penalty that would otherwise occur when heat reclaim is inactive (otherwise, the holdback valve is assumed to be fully open during inactive periods). An entry of 0.0 means that no bypass is simulated; any non-zero entry means a bypass is simulated.

The default varies according to the type of control:

- ALWAYS and OA-RESET default to 0 psig, which means that a bypass is not simulated.

- All other modes (ON/OFF, SCHEDULED, LOAD-RESET) default to 5 psig.

Friction and Thermal Losses
A refrigerant circuit may have a pressure loss, and may interact thermally with its environment. The following keywords define the piping characteristics of the circuit. Note that inlet refers to the end of the pipe where the refrigerant enters (upstream end), and outlet refers to the end of the pipe where the refrigerant exits (downstream end).

FRICTION-DT

specifies the design pressure drop from the inlet to the outlet of the piping. The units are °F saturated temperature, and is always a positive number. The hourly pressure drop will be modified as a function of the mass flow rate and density.

CONDUCTION-DT

specifies the design temperature change from the inlet to the outlet of the piping (i.e., in the direction of the refrigerant flow) due to thermal gains/losses. This value may be either positive or negative.

Currently, this value is assumed constant all hours; the program does not explicitly account for the heat exchange between the pipe and its environment.

FLOW

specifies the design mass flow at which the FRICTION-DT and THERMAL-DT occur. This value defaults to the design flow the program calculates based on the end-use loads.

Rules:

1. Each REFG-SYSTEM must have at least one LIQUID circuit, one SUCTION circuit, and one DISCHARGE circuit circuit. There may be any number of trunk circuits of the various types attached to a REFG-SYSTEM or SUCTION-GROUP, and any number of branch circuits.

2. A SUCTION-GROUP typically discharges into a DISCHARGE circuit, however it may discharge into a SUCTION circuit that feeds into a different SUCTION-GROUP. This allows the program to simulate multi-stage systems. For example, a low-temperature suction-group serving ice-cream freezers may discharge into a medium-temperature suction-group also serving dairy and produce cases (Figure ??).

3. Circuits cannot intertie separate refrigeration plants. For example, a display case cannot draw refrigerant from a LIQUID circuit attached to a given REFG-SYSTEM, and discharge that refrigerant to a SUCTION circuit attached to a different REFG-SYSTEM.

4. Subcoolers and desuperheaters may intertie separate refrigeration systems, as long as they utilize heat exchangers to keep the gas streams separate.

REFG-FIXTURE

This command defines the characteristics of a refrigerated fixture. This fixture may be a supermarket display case, a walk-in cooler or freezer, the air handler in a meat preparation room or warehouse, etc. A fixture has a given configuration and operating temperature that determine the interaction between the fixture and its adjoining space(s). The library includes a wide variety of fixtures ranging from ice cream tubs to horizontal meat and produce displays to vertical dairy cases, both with and without doors.

A fixture experiences heat gains from sources both exterior to the fixture as well as interior to the fixture. Exterior sources include:

- Sensible conduction through the fixture surfaces. This conduction may be entirely from one space, or may be from more than one space if the fixture forms part of the boundary between two spaces. The magnitude of the conduction is dependent upon the temperature differential between the fixture and the space.

- Sensible convection through the fixture openings. This is normally from one space only, and is dependent upon the temperature differential between the fixture and the space.

- Latent convection through the fixture openings. This is normally from one space only, and is dependent upon the humidity ratio differential (lb. moisture / lb air) between the fixture evaporator and the space.

- Radiant gain from lights and surfaces in the enclosing space *(future)*. For surfaces, the radiant gain is a function of the difference between the surface and the fixture, each temperature raised to the fourth power. For lights, the radiant gain may be assumed constant whenever the lights are on.

Fixtures also experience sensible and latent heat gains from within the case. These gains include:

- Sensible gains from interior lighting, evaporator fans, evaporator defrost, anti-condensate heaters, and the temperature differential between product newly introduced to the fixture and the fixture. Product respiration can also be a factor (vegetables are alive and generate heat), but is minor compared to the other loads.

- Latent gains from evaporator defrost and interior evaporation. For example, the water sprays used in produce cases can produce a significant latent load.

The first set of keywords define the general characteristics of the fixture:

U-NAME(=)
accepts a mandatory entry for the U-name of this fixture. This U-name will be used all reports to identify the component.

TYPE
accepts a code-word that specifies the type of fixture. This is a mandatory entry:

SINGLE-DECK   specifies a horizontal (tub) fixture whose access is from the top.

SINGLE-DECK-DOORS   specifies a horizontal (tub) fixture whose access is from the top, and that has doors.

MULTI-DECK   specifies a vertical, multiple-shelf fixture whose access is from the front.

MULTI-DECK-DOORS   specifies a vertical, multiple-shelf fixture whose access is from the front, and that has doors.

The principal difference between these fixture types is whether the fixture has doors or not. Many of the following keywords allow a fixture parameter (lights, conduction, infiltration, etc.) to be defined in terms of a unit length. The unit length has a different definition when the fixture has doors:

- No doors – The unit length is the actual length of the fixture, expressed in feet or meters. Lighting or other parameters are expressed in units of kW/ft or kW/meter.

- Doors – Since the fixture is available in incremental lengths corresponding to the width of one door, the unit length is a door. Lighting or other parameters are expressed in units of kW/door.

*SIM-ALGORITHM
accepts the name of the subroutine the program will use to simulate this component. This feature is not available to the user at the present time.

The existing algorithm can simulate hundreds of different fixtures. The keyword values for these fixture may already exist in the BDL library, or you can define a new fixture using the keywords in this command, and store the resulting fixture in the library for future use.

LINE-UP-LENGTH
NUMBER-OF-DOORS
defines the length of the line-up, or the number of doors in the line-up, used in calculating the per unit-length loads.

Many of the fixture variables can be input as either a total value, or a value per unit length. For example, heat conduction from a zone into a fixture is specified using the CONDUCTION and/or CONDUCTION/LEN keywords. The two keywords are used identically, except that CONDUCTION/LEN is multiplied by the LINE-UP-LENGTH to get the net effect.

If both keywords are specified, the effects are additive. This allows for variable-length fixtures to be input, with separate accounting for end effects. In this example, CONDUCTION/LEN would represent the load that varies per unit length, and CONDUCTION would represent heat conduction through the two ends.

For fixtures with doors, the same is true, except that CONDUCTION/LEN, etc., becomes COND/DOOR, etc.

MULTIPLIER
specifies the number of identical fixtures.

Fixture Temperature
The following set of keywords specify the fixture temperature and humidity, and how the temperature varies over time.

RATED-SUPPLY-T
specifies supply air temperature entering the fixture from the evaporator at which the fixture loads (CONDUCTION, etc.) are rated. This temperature may be different than the DESIGN-SUPPLY-T, which should represent the temperature at which the fixture will typically be operating.

A fixture in the library will have values for CONDUCTION, etc. listed for a single temperature, which should be the RATED-SUPPLY-T. The fixture may operate over a range of temperatures. The program will calculate the design loads on the basis of the loads at the RATED-SUPPLY-T, adjusted to the DESIGN-SUPPLY-T.

DESIGN-SUPPLY-T

specifies the air temperature entering the fixture from the evaporator at actual design conditions. This temperature may be different from the RATED-SUPPLY-T, which is the temperature at which the fixture loads (CONDUCTION, etc.) are specified.

A fixture in the library will have values for CONDUCTION, etc. listed for a single temperature, which should be the RATED-SUPPLY-T. The fixture may operate over a range of temperatures. The program will calculate the design loads on the basis of the loads defined at the RATED-SUPPLY-T, adjusted to the DESIGN-SUPPLY-T.

SUPPLY-RETURN-DT

specifies the air temperature rise through the fixture. The average fixture temperature for design purposes is the DESIGN-SUPPLY-T plus one-half of this value..

SUPPLY-DIST

not fully debugged; do not change!

accepts a code-word specifying the airflow from the supply to the return:

MIXED	the default for the horizontal fixtures, specifies that the supply air fully mixes with the air in the fixture, so that the return air tempature and humidity is the same as the average fixture conditions.
UNMIXED	the default for the vertical fixtures, specifies that the supply air flows from the supply to the return without fully mixing in the interim; the fixture temperature is coldest at the supply and warmest at the return, and the average fixture conditions are midway between these two temperatures.

TEMP-CTRL

accepts a code-word specifying the temperature control mechanism for the display fixture:

FLOAT	specifies that the fixture temperature floats as a function of the load, evaporator characteristics, and saturated-suction temperature. Note that the saturated-suction temperature may be controlled by an evaporator pressure regulator (EPR) somewhere in the suction circuiting, and that the pressure may vary according to the EPR control characteristics. If no EPR exists, then the saturated-suction temperature will vary according to the operation of the suction-group into which this fixture feeds.
THERMOSTAT	specifies that the fixture has a temperature sensor that operates a valve in the suction line to control the fixture temperature.
THERMOSTAT-SCH	is similar to THERMOSTAT, but allows the temperature setpoint to vary according to a schedule.
LOCAL-EPR	specifies that the fixture has its own evaporator pressure regulator that maintains a constant saturated-suction temperature in the evaporator. The fixture temperature then varies according to the TEMP-SETPT, the evaporator load, and evaporator characteristics.

LOCAL-EPR-SCH   is similar to LOCAL-EPR, but allows the local EPR's setpoint to vary according to a schedule.

TEMP-SETPT
when TEMP-CTRL = LOCAL-EPR or THERMOSTAT, specifies the target supply temperature setpoint of the local evaporator pressure regulator or temperature sensor.

For an evaporator pressure regulator (EPR), this value represents the supply-air temperature setpoint when the evaporator is at design load. Note that an EPR valve does not directly measure supply temperature; instead it controls the refrigerant temperature. Therefore, the program will set the actual EPR setpoint to the temperature necessary to hold the supply air temperature at the TEMP-SETPT, assuming the design load. At design conditions, TEMP-CTRL = LOCAL-EPR will give the same results as TEMP-CTRL = THERMOSTAT. However, when using TEMP-CTRL = LOCAL-EPR, as the hourly load drops, the differential temperature across the heat-exchanger will decrease, and the actual supply-air temperature will droop and approach the evaporator temperature as maintained by the EPR. For this reason, a LOCAL-EPR will cause a fixture to run colder at low loads than will a THERMOSTAT (and warmer at high loads).

TEMP-SETPT-SCH
when TEMP-CTRL = LOCAL-EPR-SCH or THERMOSTAT-SCH, accepts the U-name of a schedule specifying the target supply temperature setpoint of the local evaporator pressure regulator or temperature sensor.

For an evaporator pressure regulator (EPR), this value represents the supply-air temperature setpoint when the evaporator is at design load. Note that an EPR valve does not directly measure supply temperature; instead it controls the refrigerant temperature. Therefore, the program will set the actual EPR setpoint to the temperature necessary to hold the supply air temperature at the TEMP-SETPT-SCH, assuming the design load. At design conditions, TEMP-CTRL = LOCAL-EPR will give the same results as TEMP-CTRL = THERMOSTAT. However, when using TEMP-CTRL = LOCAL-EPR, as the hourly load drops, the differential temperature across the heat-exchanger will decrease, and the actual supply-air temperature will droop and approach the evaporator temperature as maintained by the EPR. For this reason, a LOCAL-EPR will cause a fixture to run colder at low loads than will a THERMOSTAT (and warmer at high loads).

TEMP-THROTTLE
specifies the throttling range of either a thermostat or local evaporator pressure regulator.

Zone Interactions
The next set of keywords define the sensible and latent coupling of the fixture to its adjoining space. The program can couple the fixture to either one or two spaces. The following are the keywords for the first, or primary, space; the next section presents similar keywords for a second space.

ZONE
accepts the U-name of the zone to which this fixture is coupled. This is a mandatory entry.

ZONE-T
specifies the zone temperature at which the design fixture loads occur. The default is 75°F.

ZONE-RH
specifies the zone relative humidity at which the design fixture loads occur. The default is 55%.

*ZONE-LIGHTS (future)
specifies the zone lighting power at which the design fixture loads occur.

CONDUCTION

specifies the design heat gain due to conduction through the fixture surfaces. The value of this entry must correspond to the ZONE-T, the RATED-SUPPLY-T, and SUPPLY-RETURN-DT.

CONDUCTION/LEN
COND/DOOR

is like CONDUCTION, but is per unit-length, and is multiplied by LINE-UP-LENGTH or the NUMBER-OF-DOORS. If both CONDUCTION and CONDUCTION/LEN are specified, the net load is the sum of the two.

CONDUCTION-SCH

accepts the U-name of a schedule that modifies the conduction rate on an hourly basis.

If covers are placed over the fixture to reduce infiltration losses during unoccupied times, infiltration will decrease, but conductivity will usually increase. To model this effect, the conduction schedule should have a value greater than 1.0. The conduction and infiltration schedules must be carefully coordinated to achieve the desired effect.

INF-LOAD

specifies the design heat gain due to the air exchange between the fixture and the zone. The value of this entry must correspond to the ZONE-T, ZONE-RH, RATED-SUPPLY-T, SUPPLY-RETURN-DT, and SUPPLY-RH. Based on the total heat gain and these values, the program will calculate the infiltration airflow, and the split between the sensible and latent portions.

This keyword is ignored if INF-FLOW is specified.

INF-LOAD/LEN
INF-LOAD/DOOR

is like INF-LOAD, but is per unit-length, and is multiplied by LINE-UP-LENGTH or the NUMBER-OF-DOORS. If both INF-LOAD and INF-LOAD/LEN are specified, the net load is the sum of the two.

INF-FLOW

specifies the air infiltration rate from the zone into the fixture. When specified, this keyword overrides INF-LOAD, as INF-LOAD would otherwise be used to calculate the air infiltration rate.

INF-FLOW/LEN
INF-FLOW/DOOR

is like INF-FLOW, but is per unit-length, and is multiplied by LINE-UP-LENGTH or the NUMBER-OF-DOORS. If both INF-FLOW and INF-FLOW/LEN are specified, the net load is the sum of the two.

INF-SCH

accepts the U-name of a schedule that modifies the infiltration rate on an hourly basis.

If covers are placed over the fixture to reduce infiltration losses during unoccupied times, infiltration will decrease, but conductivity will usually increase. To model this effect, the conduction schedule should have a value greater than 1.0. The conduction and infiltration schedules must be carefully coordinated to achieve the desired effect.

FRAC-TO-RETURN

specifies the fraction of the conductive and infiltration zone heat losses that are allocated directly to the HVAC system's return air, rather than impacting the zone. This entry can approximate the effect of under-floor return air systems that "drain" the cold air that could otherwise pool around a display fixture. The default is 0.0, which means that none of the conductive/infiltration zone heat losses go directly to the return; all of the losses impact the zone.

SURF-RAD (future)

specifies the design heat gain due to radiant exchange between the fixture and the zone surfaces. The value of this entry must correspond to the ZONE-T, RATED-SUPPLY-T, and SUPPLY-RETURN-DT.

SURF-RAD/LEN (future)
SURF-RAD/DOOR

is like SURF-RAD, but is per unit-length, and is multiplied by LINE-UP-LENGTH or the NUMBER-OF-DOORS. If both SURF-RAD and SURF-RAD/LEN are specified, they are added.

LIGHTS-RAD (future)

specifies the design heat gain due to radiant exchange between the fixture and the zone lighting system. The value of this entry must correspond to the ZONE-LIGHTS conditions.

LIGHTS-RAD/LEN (future)
LIGHTS-RAD/DOOR

is like LIGHTS-RAD, but is per unit-length, and is multiplied by LINE-UP-LENGTH or the NUMBER-OF-DOORS. If both LIGHTS-RAD and LIGHTS-RAD/LEN are specified, the net load is the sum of the two.

Fixture Lighting

The next set of keywords describe the lighting load internal to the fixture:

CANOPY-KW

specifies the lighting power in the fixture canopy.

CANOPY-KW/LEN
CANOPY-KW/DOOR

is like CANOPY-KW, but is per unit-length, and is multiplied by LINE-UP-LENGTH or the NUMBER-OF-DOORS. If both CANOPY-KW and CANOPY-KW/LEN are specified, the net load is the sum of the two.

CANOPY-TO-ZONE

specifies the fraction of canopy lighting energy that appears as a load on the adjacent space. Not all of the fixture's lighting energy may be an evaporator load; some radiates to the adjacent zone. In addition, the lighting ballasts may be external to the fixture.

If the fixture is coupled to two spaces, the CANOPY-TO-ZONE-2 keyword allows for coupling to the second space.

SHELF-KW

specifies the lighting power of one shelf in the fixture.

SHELF-KW/LEN
SHELF-KW/DOOR

is like SHELF-KW, but is per unit-length, and is multiplied by LINE-UP-LENGTH or the NUMBER-OF-DOORS. If both SHELF-KW and SHELF-KW/LEN are specified, the net load is the sum of the two.

NUM-SHELVES

acts as a multiplier on the SHELF-KW or SHELF-KW/LEN to adjust for the number of shelves in the fixture.

SHELF-TO-ZONE
specifies the fraction of shelf lighting energy that appears as a load on the adjacent space. Not all of the fixture's lighting energy may be an evaporator load; some radiates to the adjacent zone. In addition, the lighting ballasts may be external to the fixture.

If the fixture is coupled to two spaces, the SHELF-TO-ZONE-2 keyword allows for coupling to the second space.

LIGHTING-SCH
accepts the U-name of a schedule that modifies the design lighting load. The schedule acts on both the canopy and shelf lighting.

Evaporator Fan
The next set of keywords describe the evaporator fan:

FAN-KW
specifies the evaporator fan power.

FAN-KW/LEN
FAN-KW/DOOR
is like FAN-KW, but is per unit-length, and is multiplied by LINE-UP-LENGTH or the NUMBER-OF-DOORS. If both FAN-KW and FAN-KW/LEN are specified, the net load is the sum of the two.

FAN-TO-ZONE
specifies the fraction of fan energy that appears as a load on the adjacent space. Not all of the fixture's fan energy may be an evaporator load; the fan motor may be located outside of the air stream and/or outside of the cold section of the fixture.

If the fixture is coupled to two spaces, the FAN-TO-ZONE-2 keyword allows for coupling to the second space.

Anti-Sweat Heater and Control
The next set of keywords describe the anti-condensate heater:

HEATER-CTRL
accepts a code-word specifying the type of anti-condensate control:

FIXED	indicates that the anti-condensate heater operates at a fixed output all hours.
SCHEDULED	indicates that the anti-condensate heater operates at a scheduled output. This allows the heater output to be reduced or shut off during off-hours.
RELATIVE-HUMIDITY	specifies that the anti-condensate heater controls to the relative humidity of the adjacent space. When the fixture is coupled to 2 zones, the heater controls to the humidity in the first zone.
HUMIDITY-RATIO	specifies that the anti-condensate heater controls to the humidity ratio of the adjacent space. When the fixture is coupled to 2 zones, the heater controls to the humidity in the first zone.

MAX-HUMIDITY
when HEATER-CTRL = RELATIVE-HUMIDITY, specifies the zone relative humidity at which the heater is at full output.

MIN-HUMIDITY
when HEATER-CTRL = RELATIVE-HUMIDITY, specifies the zone relative humidity at which the heater is off.

MAX-HUMIDITY-RAT
when HEATER-CTRL = HUMIDITY-RATIO, specifies the zone humidity ratio at which the heater is at full output.

MIN-HUMIDITY-RAT
when HEATER-CTRL = HUMIDITY-RATIO, specifies the zone humidity ratio at which the heater is off.

MAX-HEATER-CTRL
when HEATER-CTRL = RELATIVE-HUMIDITY or HUMIDITY-RATIO, specifies the maximum heater output corresponding to MAX-HUMIDITY or MAX-HUMIDITY-RAT. Normally, this value should be 1.0

MIN-HEATER-CTRL
when HEATER-CTRL = RELATIVE-HUMIDITY or HUMIDITY-RATIO, specifies the minimum heater output corresponding to MIN-HUMIDITY or MIN-HUMIDITY-RAT. For fixtures with doors, the minimum output is usually greater than 0., as the heaters in the door mullion and door frame may either be on a separate circuit than the door glass heater, of may not be modulated fully off in order to keep the door gasket from freezing.

HEATER-KW
specifies the anti-condensate heater power.

HEATER-KW/LEN
HEATER-KW/DOOR
is like HEATER-KW, but is per unit-length, and is multiplied by LINE-UP-LENGTH or the NUMBER-OF-DOORS. If both HEATER-KW and HEATER-KW/LEN are specified, the net load is the sum of the two.

HEATER-TO-ZONE
specifies the fraction of anti-condensate heater energy that appears as a load on the adjacent space. Not all of the fixture's heater energy may be an evaporator load; a portion may conduct and radiate to the adjacent space.

If the fixture is coupled to two spaces, the HEATER-TO-ZONE-2 keyword allows for coupling to the second space.

Interaction with Second Zone

The program can couple a fixture to either one or two spaces. The above keywords describe the coupling to the first, or primary, zone. The next set of keywords define a coupling to a secondary zone. These keywords are identical to keywords previously described, with the exception of the '-2' suffix, and have identical meanings.

ZONE-2
accepts the U-name of the secondary zone to which this fixture is coupled. This is an optional input. If you do not specify a secondary zone, but one or more secondary zone loads are defined (CONDUCTION-2, etc.), then the secondary zone load will be assigned to the primary zone.

ZONE-T-2
specifies the zone temperature at which the design fixture loads occur. The default is 75°F.

ZONE-RH-2
specifies the zone relative humidity at which the design fixture loads occur. The default is 55%.

ZONE-LIGHTS-2 (future)
specifies the zone lighting power at which the design fixture loads occur.

CONDUCTION-2
specifies the design heat gain due to conduction through the fixture surfaces. The value of this entry must correspond to the ZONE-T-2, RATED-SUPPLY-T, and SUPPLY-RH.

CONDUCTION/LEN-2
COND/DOOR-2
is like CONDUCTION-2, but is per unit-length.

CONDUCTION-SCH-2
accepts the U-name of a schedule that modifies the conduction rate on an hourly basis.

If covers are placed over the fixture to reduce infiltration losses during unoccupied times, infiltration will decrease, but conductivity will usually increase. To model this effect, the conduction schedule should have a value greater than 1.0. The conduction and infiltration schedules must be carefully coordinated to achieve the desired effect.

INF-LOAD-2
specifies the design heat gain due to the air exchange between the fixture and the zone. The value of this entry must correspond to the ZONE-T-2, ZONE-RH-2, RATED-SUPPLY-T, SUPPLY-RETURN-DT, and SUPPLY-RH. Based on the total heat gain and these values, the program will calculate the infiltration airflow, and the split between the sensible and latent portions.

This keyword is ignored if INF-FLOW-2 is specified.

INF-LOAD/LEN-2
INF-LOAD/DOOR-2
is like INF-LOAD-2, but is per unit-length.

INF-FLOW-2
specifies the air infiltration rate from the zone into the fixture. When specified, this keyword overrides INF-LOAD-2, as INF-LOAD-2 would otherwise be used to calculate the air infiltration rate.

INF-FLOW/LEN-2
INF-FLOW/DOOR-2
is like INF-FLOW-2, but is per unit-length.

INF-SCH-2
accepts the U-name of a schedule that modifies the infiltration rate on an hourly basis.

If covers are placed over the fixture to reduce infiltration losses during unoccupied times, infiltration will decrease, but conductivity will usually increase. To model this effect, the conduction schedule should have a value greater than 1.0. The conduction and infiltration schedules must be carefully coordinated to achieve the desired effect.

SURF-RAD-2 (future)
specifies the design heat gain due to radiant exchange between the fixture and the zone surfaces. The value of this entry must correspond to the ZONE-T-2, RATED-SUPPLY-T, and SUPPLY-RETURN-DT.

SURF-RAD/LEN-2 (future)
SURF-RAD/DOOR-2
is like SURF-RAD-2, but is per unit-length.

LIGHTS-RAD-2 (future)
specifies the design heat gain due to radiant exchange between the fixture and the zone lighting system. The value of this entry must correspond to the ZONE-LIGHTS-2 conditions.

LIGHTS-RAD/LEN-2 (future)
LIGHTS-RAD/DOOR-2
is like LIGHTS-RAD-2, but is per unit-length.

CANOPY-TO-ZONE-2 (future)
specifies the fraction of canopy lighting energy that appears as a load on the adjacent space. Not all of the fixture's lighting energy may be an evaporator load; some radiates to the adjacent zone. In addition, the lighting ballasts may be external to the fixture.

SHELF-TO-ZONE-2
specifies the fraction of shelf lighting energy that appears as a load on the adjacent space. Not all of the fixture's lighting energy may be an evaporator load; some radiates to the adjacent zone. In addition, the lighting ballasts may be external to the fixture.

FAN-TO-ZONE-2
specifies the fraction of fan energy that appears as a load on the adjacent space. Not all of the fixture's fan energy may be an evaporator load; the fan motor may be located outside of the air stream and/or outside of the cold section of the fixture.

HEATER-TO-ZONE-2
specifies the fraction of anti-condensate heater energy that appears as a load on the adjacent space. Not all of the fixture's heater energy may be an evaporator load; a portion may conduct and radiate to the adjacent space.

Note that, when controlling to humidity or humidity ratio, the anti-sweat heater is controlled by the conditions in the primary zone. Any heat gain to the secondary zone is passive.

Fixture Contents

The next set of keywords specify the heat gains and thermal storage effects of the fixture contents, both sensible and latent. These loads/storage arise from both the product stored within the fixture, as will as the fixture itself:

CONTENT-SENSIBLE
specifies the average hourly sensible load due to the fixture's contents. Normally, this load arises primarily from the temperature change, if any, associated with introducing the product into the fixture. If the product is delivered and/or stored at the same temperature as the fixture, then the product load should default to 0.

This load can also include the sensible heat gain due to product respiration.

If a portion of the product load is latent, the latent gain should be included in this term, and the corresponding weight of moisture should be entered in CONTENT-LATENT. Note that the program assumes that one pound of evaporated moisture will convert 1061 Btu/lb of sensible gain to latent.

CONTENT-SENS/LEN
CONTENT-SENS/DOOR
is like CONTENT-SENSIBLE, but is per unit-length, and is multiplied by LINE-UP-LENGTH or the NUMBER-OF-DOORS. If both CONTENT-SENSIBLE and CONTENT-SENS/LEN are specified, the net effect is the sum of the two.

SENSIBLE-SCH
accepts the U-name of a schedule defining the variation in product load over time. The default is a constant CONTENT-SENSIBLE all hours.

SENSIBLE-STORAGE
specifies the thermal capacity of the fixture contents. This term accounts for the thermal storage effect of fixture contents (and the fixture itself) as the fixture temperature changes. The storage effect is most important for fixtures having a defrost cycle, but is important for any fixture that may undergo significant temperature swings.

The default is calculated in one of two ways:

- If the fixture has a defrost cycle, this value is calculated as a function of the DEFROST-DT, the DEFROST-DURATION, the loads during defrost, and the SENSIBLE-DECAY factor.

- Otherwise, this keyword defaults to 40% of the fixture's coil capacity.

SENS-STORE/LEN
SENS-STORE/DOOR
same as SENSIBLE-STORAGE, but per unit length, and is multiplied by LINE-UP-LENGTH or the NUMBER-OF-DOORS. If both SENSIBLE-STORAGE and SENS-STORE/LEN are specified, the net effect is the sum of the two.

SENSIBLE-DECAY
specifies the rate per hour at which the temperature of the fixture contents will approach the fixture temperature. The algorithm assumes that Newton's Law of Cooling applies, and that the internal temperature of the contents is uniform, so that the content's temperature will decay exponentially over time to the fixture temperature.

The default is 0.4, which means that the contents temperature will change by 40% of the temperature difference between the contents and the fixture each hour.

For example, if the contents are at 40°F and the fixture is at 30°F, then one hour later the contents will be at 36°F (40°F + 0.4*(30°F-40°F)). The storage load on the evaporator will be 4°F * STORAGE-CAPACITY. Assuming the fixture temperature remains constant, the next hour the contents will cool to 33.6°F (36°F + 0.4*(30°F-36°F).

Note that the assumption of the contents having a uniform internal temperature is quite reasonable for liquid products, such as milk, but may not be as valid for solids, such as oranges or frozen foods.

The values for SENSIBLE-STORAGE and SENSIBLE-DECAY are most important when modelling the short term temperature swings that occur during defrost cycles. The program will use these values, together with zone effects and internal loads, in calculating the temperature the fixture will achieve during the defrost cycle, as well as the resulting pull-down load once the defrost cycle is terminated. Therefore, the values of these keywords should be chosen to best represent the short term impact on fixture temperature.

CONTENT-LATENT
specifies the hourly weight of moisture that evaporates from the fixture contents. This evaporation decreases the sensible load on the evaporator, and increases the latent load.

Evaporation can arise from moisture in the product, or from other sources such as the water sprays commonly used in vegetable display fixtures. If the evaporator operates below freezng, the water vapor associated with this latent load will turn to frost, and will increase the defrost load.

The program takes internal evaporation into account in the hourly moisture balance. The actual rate is determined by the fixture humidity, product surface humidity, and the effectiveness of the evaporative process as specified by the LATENT-EFF-COND and LATENT-EFF-FROST keywords. If more moisture is specified here than can evaporate in a given hour, the excess moisture is assumed to build up within the fixture, subject to the maximum LATENT-STORAGE, and may evaporate at a later time when conditions are more favorable.

CONTENT-LAT/LEN
CONTENT-LAT/DOOR
is like CONTENT-LATENT, but is per unit-length, and is multiplied by LINE-UP-LENGTH or the NUMBER-OF-DOORS. If both CONTENT-LATENT and CONTENT-LAT/LEN are specified, the net effect is the sum of the two.

LATENT-SCH
accepts the U-name of a schedule defining the variation in evaporation over time. The default is a constant CONTENT-LATENT rate all hours.

LATENT-STORAGE
specifies the total weight of moisture that can be stored within the fixture from all sources, including CONTENT-LATENT and any moisture carryover from the defrost cycle. The program will attempt to evaporate all moisture within the fixture, subject to a limit of 100% relative humidity within the fixture. If more moisture is present than can be evaporated, the excess will be stored within the fixture, subject to the upper limit this keyword represents. Moisture above this amount is assumed to be removed via drains or other devices.

LATENT-STORE/LEN
LATENT-STORE/DOOR
same as LATENT-STORAGE, but per unit length, and is multiplied by LINE-UP-LENGTH or the NUMBER-OF-DOORS. If both LATENT-STORAGE and LATENT-STORE/LEN are specified, the net effect is the sum of the two.

LATENT-EFF-COND
describes the effectiveness of the evaporative process between the fixture humidity ratio and the saturated humidity at the product surface temperature:

$$Wfixture = Wmix + (Wsurface-Wmix)*Eff$$

where Wfixture is the average humidity ratio in the fixture, Wmix is the average humidity ratio assuming that there is no transfer of moisture between the mixed air and the fixture/product surfaces, and Wsurface is the saturated humidity ratio at the product surface temperature.

The fixture surfaces/product will store moisture (dry the air) whenever the fixture humidity ratio is above the fixture surface temperature, and will release stored moisture during the opposite conditions. Moisture storage will commonly occur during electric/off-cycle defrost cycles where the air returning to the case has been humidified by moisture evaporating off the coil. It may also occur if the supply temperature suddenly increases (possibly due to a setpoint schedule or change at the suction group), so that the surface temperature is sufficiently below the supply temperature. Storage will also occur if moisture is being added at a rate greater than the rate at which it is evaporating (produce sprays). Moisture release will occur once a defrost cycle is terminated and the air in the fixture once again is dried by the coil. Moisture release will also occur whenever moisture is directly added to the fixture via

the CONTENT-LATENT keyword. Note, however, that moisture will evaporate at a slower rate if the moisture has taken the form of frost (see LATENT-EFF-FROST).

LATENT-EFF-FROST

is identical to LATENT-EFF-COND, but specifically describes the effectiveness of the evaporative process when the product surface temperature is below 32°F. This keyword allows moisture to evaporate at a different rate than it condenses when frost is formed. For example, an electric defrost cycle may circulate warm, moist air through a fixture which normally operates below freezing. In this case, moist air may condense rapidly upon the product surfaces (specified by LATENT-EFF-COND), but the resulting frost may evaporate at a slower rate specified by LATENT-EFF-FROST.

Cooling Coil

The next set of keywords specify the fixture's evaporator or secondary coolant coil characteristics.

COIL-CAPACITY

specifies the design evaporator capacity. The manufacturer will normally size the evaporator for an assumed set of conditions, including a safety factor. If not specified, the program will calculate this value based on the component loads described above, modified by the SIZING-RATIO. In addition, the capacity will be further increased to take into account the degradation due to frost buildup, as specified by MAX-FROST-DT.

COIL-CAPACITY/LEN
COIL-CAPACITY/DOOR

is like COIL-CAPACITY, but is per unit-length, and is multiplied by LINE-UP-LENGTH or the NUMBER-OF-DOORS. If both COIL-CAPACITY and COIL-CAPACITY/LEN are specified, the net capacity is the sum of the two.

SIZING-RATIO

specifies the safety factor used when sizing the evaporator on the basis of the component loads. The program ignores this keyword if the COIL-CAPACITY is directly specified.

SUPPLY-FLOW

specifies the design evaporator air flow rate. The default will be based on the required evaporator capacity and fixture conditions.

SUPPLY-FLOW/LEN
SUPPLY-FLOW/DOOR

is like SUPPLY-FLOW, but is per unit-length, and is multiplied by LINE-UP-LENGTH or the NUMBER-OF-DOORS. If both SUPPLY-FLOW and SUPPLY-FLOW/LEN are specified, the net flow is the sum of the two.

LIQUID-CIRCUIT

accepts the U-name of the REFG-CIRCUIT that supplies liquid refrigerant to the fixture.

SUCTION-CIRCUIT

accepts the U-name of the REFG-CIRCUIT that removes vaporized refrigerant from the fixture.

REFG-FLOW

specifies the design flow of refrigerant powering the evaporator. .

SUPPLY-DP
specifies the required pressure drop between the liquid and suction circuits at design conditions. This entry includes the pressure losses of the thermal expansion valve, evaporator, and other trim, but excludes the pressure drop of items specified separately, such as a local EPR valve.

The hourly pressure drop through the evaporator is calculated as a function of this value and the refrigerant flow. If the differential between the liquid and suction lines is less than this value, then the refrigerant flow (and evaporator capacity) is adjusted to match the available pressure drop.

This value is also used in calculating the required suction pressure when the suction-group is resetting the suction pressure on the basis of fixture demand. In this case, the required pressure of the fixture is a function of the available liquid pressure, adjusted by this hourly value, and further adjusted by any local EPR valve.

Finally this value is used when the condensers are using a floating head-pressure control. The required liquid pressure is calculated as a function of the available suction pressure at the evaporator, modified by any local EPR valve, and further modified by this hourly value.

CTRL-VALVE-DT
for all TEMP-CTRL modes except FLOAT, specifies the temperature drop through the control valve at design conditions. This valve may be either an evaporator pressure regulator, or a thermostatic control valve. The valve is assumed to be on the suction side of the evaporator, so that the available suction pressure of the suction group is reduced by the pressure (temperature) drop through this valve. The pressure drop through the valve varies hourly as a function of the actual refrigerant flow.

MIN-CTRL-DP
for all TEMP-CTRL modes except FLOAT, specifies the minimum pressure drop through the control valve required to operate the valve. This pressure drop is independent of flow. The suction pressure available to the evaporator will be reduced by this amount. The default is 0.

Many of the older internally-actuated valves require a minimum pressure, below which they cannot function; this pressure is typically on the order of 2 psi. Newer externally-actuated valves do not incur this penalty.

Coil Characteristics

The next set of keywords specify the heat transfer characteristics of the fixture's evaporator. The program utilizes an enthalpy-based NTU/effectiveness coil model, with extensions to explicitly account for condensate/frost enthalpy and frost buildup.

COIL-UA
specifies the design UA for the evaporator. The program will default this value based on the flows, inlet and outlet temperatures, etc.

SST-SUPPLY-TD
specifies the design temperature differential between the wetbulb temperature leaving the evaporator (supply to the fixture) and the saturated-suction temperature.

MAX-FROST-DT
for evaporators that accumulate frost, specifies the design temperature differential across the frost at the design conditions of MAX-FROST and the design load. The resistance of the coil varies hourly according to the actual amount of frost buildup.

AIR-RES

specifies the fraction of the design coil resistance due to the air film. The program modifies the resulting air film resistance on an hourly basis to take into account air flow variations. The coil algorithm utilizes the air film in calculating the coil properties; modifying this value will cause the split between sensible and latent loads to vary.

The total coil resistance is the sum of the AIR-RES, REFG-RES, and the resistance of the heat-exchanger media. Therefore, the sum of the AIR-RES and REFG-RES should be less than 1.0 to allow for the heat-exchanger resistance.

REFG-RES

specifies the fraction of the design coil resistance due to the refrigerant or coolant film. The program modifies the resulting refrigerant film resistance on an hourly basis to take into account refrigerant flow variations.

The total coil resistance is the sum of the AIR-RES, REFG-RES, and the resistance of the heat-exchanger media. Therefore, the sum of the AIR-RES and REFG-RES should be less than 1.0 to allow for the heat-exchanger resistance.

DRY/WET-RESIS

for a wet coil, specifies the ratio of the air resistance of a dry coil to the air resistance of a wet coil. For cooling coils that may also dehumidify, the design calculations assume the coil is fully wet. When a fully dry operating condition is encountered, the program multiplies the AIR-RESIS by this value to take into account the change in resistance due to the dry surface. For partially wet coils, the program prorates this factor.

SUPERHEAT-DT

specifies the design superheat of the suction gas leaving the evaporator. The program assumes this superheat is constant all hours.

Coil Defrost

The next set of keywords describe the evaporator defrost cycle, if any. During the simlation, if the program encounters a frost condition (coil operating wet with a surface temperature below freeazing), and no defrost mechanism exists, then the program will warn you to that effect, and will ignore the effect of any frost buildup on coil performance.

DEFROST-TYPE

accepts a code-word specifying the type of evaporator defroster:

ELECTRIC	the default whenever the SUPPLY-T is below 34°F, specifies that the defroster consists of an electric heating element.
	Normally, the fan continues to operate with an electric defroster. In this case, the heater is upstream of the coil, and warms the air before it passes over the coil. However, you may specify the fan to be off during defrost (FAN-W/DEFROST = CYCLE-OFF), in which case the program assumes the defrost element is integral to the coil. See FAN-W/DEFROST for more information on how the airflow impacts the fixture temperature and humidity.
HOT-GAS	specifies that hot discharge gas from the discharge of the system defrosts the coil. This gas condenses, returns to the receiver of the discharge, and is available for use by other fixtures. Note that, for this scheme to be effective, there must be more than one fixture on the discharge, and the fixtures must have relatively non-coincident defrost cycles. The fan is normally off during defrost periods,

however, you may force the fan to continue operating (FAN-W/DEFROST = STAY-OFF).

OFF-CYCLE   specifies that air returning from the fixture defrosts the coil. This type of defrost is commonly used in dairy and deli fixtures that operate close to, but above freezing. The refrigerant flow to the coil is shut off, but the fan continues to run, gradually melting the frost by circulating fixture air over the evaporator.

DEFROST-CAP
for ELECTRIC and HOT-GAS defrosters, specifies the capacity of the defroster. This keyword is not used for off-cycle defrost. The program will default this value as a function of the maximum allowable frost build-up, MAX-FROST, and the duration of the defrost cycle, DEFROST-DURATION.

If the fan is on during defrost, the program will also take into account the load the air will impose on the defroster. However, the program may considerably overestimate the thermal load of the airflow (the design calculations assume the air returns to the coil at the design condition; it will usually be warmer during defrost). On an hourly basis, an oversized defroster may produce unrealistic heating of the fixture, expecially when the DEFROST-TERMINATE = TIME. For this reason, it is recommended that you specify the capacity.

DEFROST-CAP/LEN
DEFROST-CAP/DOOR
is like DEFROST-CAP, but is per unit-length, and is multiplied by LINE-UP-LENGTH or the NUMBER-OF-DOORS. If both DEFROST-CAP and DEFROST-CAP/LEN are specified, the net capacity is the sum of the two.

DEFROST-RATIO
for ELECTRIC and HOT-GAS defrosters, specifies the sizing ratio used when defaulting the size of the defroster.

DEFROST-EFF
for ELECTRIC and HOT-GAS defrosters, specifies the fraction of defroster energy that is available to heat either the airflow (electric, with fan on), or the coil (hot-gas, or electric with fan off). The remainder represents undesireable conduction, radiation, or residual energy in the coil that will act to warm the fixture and will become a refrigeration load once the defrost cycle is terminated.

DEFROST-DT
specifies the time-weighted temperature rise in the fixture during the defrost cycle. If the sensible heat capacity of the fixture's contents is not specified (SENSIBLE-STORAGE), then the program will calculate the effective storage capacity as a function of this value, the heat gains into the fixture at this value, and the SENSIBLE-DECAY rate. The actual temperature during defrost can then be calculated as a function of the hourly conditions.

Note that this value is not the temperature at the end of the cycle, but instead is the time-weighted temperature during the cycle.

DEFROST-INF
specifies the fraction of design infiltration that occurs during defrost. When FANS-W/DEFROST = CYCLE-OFF, the default is 0.5. Otherwise the default is 1.0.

DEFROST-INITIATE
accepts a code-word specifying how the defrost cycle is initiated:

TIME   specifies that the defrost cycle initiates on a scheduled basis.

DEMAND   specifies that the defrost cycle initiates when the amount of ice on the evaporator
                                  has exceeded the value of MAX-FROST.

DEFROST-SCH
when DEFROST-INITIATE = TIME, accepts the U-name of the schedule defining the defrost times. This schedule may use the same time(s) every day of the year, or may vary the times according to the time of year in anticipation of zone humidity levels.

NUM-DEFROSTS/DAY
specifies the number of defrost cycles per day for design calculations. The program uses this value, together with the design entering and leaving evaporator conditions, to calculate the design amount of frost that will build up between defrost cycles. This amount is then the default value for MAX-FROST.

FAN-W/DEFROST
accepts a code word specifying whether the evaporator fan is cycled off during the defrost cycle.

STAY-ON   the default, indicates that the fan continues to operate during the defrost cycle.

CYCLE-OFF   indicates that the fan shuts off during the defrost cycle.

The default is STAY-ON for ELECTRIC defrost, and CYCLE-OFF for hot-gas. This keyword has no meaning for OFF-CYCLE defrost, as the fan always runs in that mode.

STAY-ON has important ramifications on the defrost cycle. For an ELECTRIC defroster, the heating element is located in the air upstream of the coil. The air is warmed to above freezing by the element, and is then partially cooled as it melts the frost on the coil. The air returns to the fixture, where it is further cooled by the fixture contents (warming the contents) before returning to the evaporator.

A similar process happens to the air moisture. If the air entering the evaporator has a humidity ratio lower than the surface humidity of the coil (the surface is assumed to be saturated at 32°F), then the air will pick up moisture from the coil. The moist air returns to the fixture, where it may be partially dried by contact with the fixture contents (moistening the contents), provided the surface dewpoint of the contents is less than the dewpoint of the air. The moisture stored on the surface of the contents may then re-evaporate once the defrost cycle is terminated and the coil once again is de-humidifying the airflow.

How does the program calculate the heat/moisture transfer between the air and the coil? The program uses an enthalpy-based NTU/effectiveness model for the cooling coil. As part of this model, the program separately accounts for the resistance between the air and the coil surface. This resistance directly correlates to the coil bypass factor. During defrost, the coil surface temperature (apparatus dew point) is explicitly known (melting ice is at 32°F and saturated). Therefore the program can uses the bypass factor, together with the surface and entering air temperatures and humidities, to calculate the leaving air conditions. Note that defrost is the only time a bypass-factor model is utilized in the refrigeration systems.

LIGHTS-W/DEFROST
accepts a code word specifying whether the lights are cycled off during the defrost cycle.

STAY-ON   the default, indicates that the lights continue to operate during the defrost cycle.

CYCLE-OFF   indicates that the lights turn off during the defrost cycle.

HEATER-W/DEFROSTaccepts a code word specifying whether the anti-condensate heater is cycled off during the defrost cycle.

STAY-ON   the default, indicates that the heater continues to operate during the defrost cycle.

CYCLE-OFF   indicates that the heater shuts off during the defrost cycle.

MAX-FROST
Specifies the weight of ice that will accumulate on the evaporator at design conditions between defrost cycles. The default will be based on the NUM-DEFROSTS/DAY and the evaporator design entering and leaving conditions.

MAX-FROST/LEN
MAX-FROST/DOOR
is like MAX-FROST, but is per unit-length, and is multiplied by LINE-UP-LENGTH or the NUMBER-OF-DOORS. If both MAX-FROST and MAX-FROST/LEN are specified, the net frost is the sum of the two.

MELT-T
specifies the temperature of the melted frost as it goes down the drain.

DEFROST-TERMINATE
accepts a code-word specifying how the defrost cycle is terminated:

TIME   specifies that the defrost cycle terminates after a fixed number of minutes. If all the ice is melted before the defrost cycle terminates, the remainder of the defrost energy goes into the fixture, and becomes an evaporator load after the cycle has terminated.

TEMPERATURE   specifies that the defrost cycle terminates once all the ice has melted.

The default is TIME for OFF-CYCLE defrost cycles, and TEMPERATURE for ELECTRIC and HOT-GAS. Note that the defrost cycle never exceeds an hour in length, regardless of the termination control method.

DEFROST-DURATION
when DEFROST-TERMINATE = TIME, specifies the duration in minutes of the defrost cycle. This keyword is also used to calculate the default defroster capacity, DEFROST-CAP, for both ELECTRIC and HOT-GAS defrost cycles.

HOT-GAS-CIRCUIT
when DEFROST-TYPE = HOT-GAS, specifies the discharge ciruit from which the hot gas used for defrost will be drawn. The program assumes that the condensed liquid will be returned to the LIQUID trunk circuit of the same system from which the hot gas is drawn.

The HOT-GAS-CIRCUIT does not have to belong to the same circuit as the SUCTION-CIRCUIT and LIQUID-CIRCUIT. In other words, the coil may use hot gas from any of the refrigeration systems for defrost. Of course, it would not make sense to use a circuit having a different type of refrigerant.

Note that it does not normally make sense for a coil to utilize hot-gas defrost if it is the only coil on the system. In this case, the available hot gas mass flow is zero whenever the coil is in the defrost mode. The program does not check for this condition, but rather uses the average mass flow availability during the hour. The exception to this rule would be if the coil is on a dedicated system, but uses hot gas from a separate system for defrost.

Liquid/Suction Interchanger *(future)*
The next set of keywords define the liquid-suction interchanger, if any.

LIQUID-SUCTION-HX (future)

accepts the U-name of the HEAT-EXCHANGER the program will use to model the performance of the liquid-suction interchanger. The default is no interchanger. When defined, the program will force the heat exchanger to be of TYPE = REFG-GAS-TO-LIQUID. If you do not specify the heat-exchanger's configuration, it will default to COUNTERFLOW.

LIQUID-SUCTION-DT (future)

specifies the temperature difference between the liquid and gas streams leaving the heat-exchanger. If the HEAT-EXCHANGER:UA-PRODUCT is not specified, the program will calculate the effective UA product based on this value, together with the design mass flow rates, heat-exchanger configuration, and inlet temperatures.

The program uses the liquid and gas specific heats to correlate a subcooled or superheated temperature to an enthalpy. Superheated densities are calculated assuming ideal gas laws.

Thermal Island Effect

The exterior sensible and latent gains may be modified by an "island effect". As the fixture dumps cool air into its enclosing space, this cool air may form a pool of cool air around the fixture that partially isolates the fixture from the surrounding space. This is particularly applicable to supermarket display cases. Almost everyone has experienced the discomfort (and sometimes summertime relief) associated with walking down a supermarket isle where both sides of the isle are formed by open multi-deck fixtures.

This thermal island may be more or less pronounced depending on the location of the fixture, the proximity of other fixtures, the configuration of shelving and other barriers near the fixtures, and the design of the HVAC system. For example, an HVAC system with return air inlets below the fixtures can effectively "drain" the pool of air whenever the system is operating. The net effect will then be an increase in refrigeration load whenever the HVAC fans operate.

Thermal islands may be approximated in DOE-2 by specifying the affected aisle as a separate zone. This zone is then coupled to the main retail zone via airwalls with a relatively high conductivity. As this technique is more "art" than "science", it is suggested that you create hourly reports of zone temperatures so that you can adjust the conductivity of the airwalls so that the zone temperatures approximate the expected effect. If a portion of the HVAC return air is taken from below the fixtures, specify the FRAC-TO-RETURN.

REFG-SYSTEM

This command is the foundation upon which you build a refrigeration system. DOE-2 defines a refrigeration system to be a closed set of components (circuits, loads, compressors, condensers, etc.) that share a common refrigerant. The system is closed because the refrigerant in the system can flow to any of the components in the system, but cannot flow to any components outside the system (Figure ??). The common point in each system is the liquid receiver tank immediately downstream of the condensers. From here, one or more liquid circuits deliver refrigerant to various loads. The loads evaporate the refrigerant, and suction circuits pass the refrigerant on to one or more suction groups (compressor racks). Each suction group has one or more compressors. The compressors discharge into one or more discharge circuits, which pass the refrigerant on to one or more condensers. The condensers discharge liquid refrigerant into the liquid receiver.

The REFG-SYSTEM command is similar to the CIRCULATION-LOOP command in that condensers attach to this component, and are controlled by this component. However, compressors do not attach directly to the REFG-SYSTEM. This is because a given REFG-SYSTEM may have multiple suction groups, each operating at a different suction temperature, serving a different set of loads, but discharging into the same condenser. In addition, different compressors may discharge into different discharge circuits, some of which may be controlled for heat reclaim, and others not. For this reason, suction-group/compressor assemblies are defined separately from the REFG-SYSTEM.

You may define more than one REFG-SYSTEM. The only caveat is that multiple systems cannot be cross-connected so that refrigerant leaves one system and enters the other. In other words, refrigerant leaving the liquid receiver of one system must return to the same receiver. Systems can be cross-connected in the sense that refrigerant from one system can act on the refrigerant of another system via a heat-exchanger. For example, a subcooler for a low-temperature system can be fed with refrigerant from a medium-temperature system, as long as the subcooler utilizes a heat-exchanger to keep the refrigerant streams completely separate (Figure ??). The same is true of desuperheaters, and refrigerant-to-refrigerant condensers.

The program checks to see if a load, such as a REFG-FIXTURE, is cross-connected between two REFG-SYSTEMs. Such cross-connections will cause the program to abort.

A REFG-SYSTEM can be quite complex, and REFG-SYSTEMS can be intertied in manners which allow even greater complexity. For example, because a REFG-SYSTEM may have multiple suction groups operating at different temperatures, a single system can serve both low and medium-temperature loads. In addition, suction groups can be staged so that the compressors of a lower-temperature load discharge into a higher-temperature suction group. When multiple REFG-SYSTEMS use refrigerants of different types, it is possible to cascade the load of a lower-temperature system into a higher-temperature system via a refrigerant-to-refrigerant condenser. Examples are given that illustrate these concepts as well as others.

A condenser attaches to a REFG-SYSTEM from the CONDENSER command. The program allows a refrigeration system to have more than one condenser.

While a REFG-SYSTEM normally expects there to be a condenser to reject heat, you do not have to specify a condenser. In this case, the liquid and discharge circuits will always be at the hourly condensing temperature setpoint, the high-temperature energy in the discharge refrigerant will simply disappear without the expenditure of any condenser energy. This feature can be useful if you are in the process of constructing a refrigeration system, and would prefer to specify a condenser after you know more about the design refrigeration loads and system operating characteristics.

U-NAME(=)

accepts a mandatory entry for the U-name of this system. This U-name will be used all reports to identify the system.

REFRIGERANT

is the refrigerant used in the system. Different REFG-SYSTEMs may have the same or different types of refrigerant, however refrigerant may not flow from one system to another. Note that you define the properties of a refrigerant via the REFRIGERANT command. The library contains entries for many of the common refrigerants.

All components attached to the system, such as display cases, compressors, and condensers, use this refrigerant. Each of these components must have performance characteristics compatible with the refrigerant. For example, if the refrigerant defined here is R-22, then all compressors in this system must have a set of performance curves for R-22.

DESIGN-WETBULB

specifies the wet-bulb temperature used in the condenser sizing calculations.

DESIGN-SCT

specifies the design saturated condensing temperature of the refrigerant leaving the condenser(s). This temperature is the value used in the design calculations to determine the design size of the condensers, the design saturated liquid temperature entering the liquid circuits and/or subcoolers, and the design saturated condensing temperature on the discharge of the compressors. For this reason, this keyword should always be given an accurate value.

SUBCOOL-EFF

specifies the effectiveness of the ambient subcooling process of the attached condensers at the design conditions. If the DESIGN-SCT is 105, the DESIGN-WETBULB is 74, and the subcooling effectiveness is 0.1 then the ambient subcooling at design conditions will be:

Tsubcool = SUBCOOL-EFF * (DESIGN-SCT - DESIGN-WETBULB)

Tsubcool = 3.1°F

Ambient subcooling will vary on an hourly basis depending on the actual operating conditions. A value of zero will force the condensers to deliver liquid at the SCT with no subcooling.

The condensers have the same keyword, and will inherit this value unless otherwise specified.

Note that this ambient subcooling effect is within the condensers; mechanical subcoolers may also be defined and are discussed separately.

EQUIP-CTRL

accepts the U-name of an EQUIP-CTRL sequence defining how the condensers are to be staged with the load. By default, the program will allocate the condensing load to the mix of condensers that best meets the load.

This keyword is applicable only when multiple condensers are attached to the REFG-SYSTEM. Refer to the EQUIP-CTRL command for more information.

ELEC-METER

Accepts the U-name of an electric meter. The default is the MASTER-METERS:REFG-ELEC-METER. This meter will be the default meter for all components in this system involved in the production of liquid refrigerant, such as compressors, condensers, subcoolers, and desuperheaters. It is *not* the default meter for end-users of refrigerant attached to this system, such as refg-fixtures, process-loads, airhandlers, etc.

AUX-MODE
accepts a code-word specifying whether auxiliary power is consumed for controls or other devices. The default is that there is no auxiliary power consumption.

ALWAYS   indicates that the auxiliary power is consumed all hours.

WHEN-ON   indicates that auxiliary power is consumed only during the hours the suction group is operating.

WHEN-OFF   indicates that auxiliary power is consumed only during the hours the suction group is off.

SCHEDULED   indicates that the power consumption is scheduled.

AUX-KW
accepts a numeric value specifying an auxiliary electrical consumption, such as for a control panel. This is a required keyword when the AUX-MODE is specified.

For an evaporative condenser having a filtration system, the AUX-KW can represent the power consumption of the filter pump. If the filter runs only when the condenser is running, then the AUX-MODE should be set to WHEN-ON.

AUX-SCH
when AUX-MODE = SCHEDULED, accepts a U-name of a schedule that varies the AUX-KW on an hourly basis.

AUX-METER
accepts the U-name of a meter that supplies the auxiliary energy.

Condensers and Condensing Temperature Control

A REFG-SYSTEM may have multiple condensers attached. While multiple condensers are unusual for supermarket systems, they are not uncommon in industrial systems. Multiple condensers sharing common piping manifolds will all operate at the same condensing temperature. For this reason, condensing temperature control resides at the REFG-SYSTEM level, rather than at individual condensers.

SCT-CTRL
accepts a code-word defining the control sequence for the saturated-condensing temperature.

FLOAT   There is no temperature control, the SCT floats with the load and ambient conditions. All condenser fans operate at full output whenever a load exists.

FIXED   The condensing setpoint is a constant value all hours, specified by SCT-SETPT.

SCHEDULED   The condensing setpoint varies according to a schedule, specified by SCT-SCH. As with all schedules, the setpoint may vary both by time of day and time of year.

RESET-TEMP-SCH   The condensing setpoint varies according to a schedule of TYPE = RESET-TEMP. This stragegy resets the condensing setpoint according to the outside air temperature, as defined in the reset schedule. Based on the values input in the reset schedule, the differential between the setpoint and the ambient temperature

may be either constant, or vary. While intended for air-cooled condensers, this strategy may also be used for evaporative condensers.

DRYBULB-RESET   The condensing setpoint varies directly with the outdoor drybulb temperature, adjusted by a fixed differential:

SCTset = Tdry + SCT-AMBIENT-DT

where Tdry is the outdoor drybulb temperature. To prevent excessively hot or cold condensing temperatures, you may also specify an OVERRIDE-MAX-SCT and/or an OVERRIDE-MIN-SCT.

While intended for air-cooled condensers, this strategy may be used with any type of condenser, including evaporative.

WETBULB-RESET   The condensing setpoint varies with the wetbulb temperature, modified by a variable differential. At design conditions, the setpoint will be:

SCTset = Twet + SCT-AMBIENT-DT

where Twet is the outdoor wetbulb temperature.

For a given load, a condenser cannot achieve the same wetbulb differential as the wetbulb drops (the approach will increase). Accordingly, the program modifies the differential as the wetbulb drops:

dTwet   = (DESIGN-WETBULB - Twet) * WETBULB-RATIO

SCTset   = Twet + SCT-AMBIENT-DT + dTwet

The WETBULB-RATIO defaults to 0.28. For example, if the design wetbulb is 74°F and the SCT-AMBIENT-DT is 20°F, then the SCT setpoint at design will be 94°F. At a wetbulb of 50°F, the setpoint will be:

dTwet   = (74°F-50°F) * 0.28 = 6.7°F

SCTset   = 50°F + 20°F + 6.7 = 76.7°F

To force the setpoint to be a fixed differential without any correction at low wetbulbs, set the WETBULB-RATIO = 0. To prevent excessively hot or cold condensing temperatures, you may also specify an OVERRIDE-MAX-SCT and/or an OVERRIDE-MIN-SCT.

While intended for evaporative condensers, this strategy may be used with any type of condenser, including air-cooled.

DRYBULB-STAGED   The fans of a multi-cell condenser will stage directly as a function of the outdoor drybulb temperature. There is no condensing setpoint; instead the condensing temperature floats with the load, the number of fans operating, and the ambient temperature. Staging fans on drybulb temperature is common in multi-circuit condensers. In this case, each condenser circuit will usually have a back-flooding control (HeadMaster) to prevent an excessively low SCT. While intended for air-

cooled condensers, this strategy may be used for any type of condenser having fans, including evaporative.

When using this strategy, each condenser attached to this system will require the CONDENSER:NUMBER-OF-FANS to be defined, as well as a list of CONDENSER:FAN-STAGE-T's. For example, assume a condenser has three independently-controlled fans (cells). One fan is to run continuously, the second is to stage on whenever the drybulb is at or above 40°F, and the third fan is to stage on at 60°F. Within the condenser component:

    NUMBER-OF-FANS   = 3
    FAN-STAGE-T   = (-100., 40., 60.)

If instead the condenser has four fans, two of which always run:

    NUMBER-OF-FANS   = 4
    FAN-STAGE-T   = (-100., -100., 40., 60.)

It is possible for more than one condenser to be controlled in this manner, with each condenser having a different number of cells and fan-staging temperatures.

To prevent excessively hot or cold condensing temperatures, you may also specify an OVERRIDE-MAX-SCT and/or an OVERRIDE-MIN-SCT. In this case, the condensers will revert to normal temperature control whenever the floating SCT approaches one of these limits, and will modulate as necessary to prevent the SCT from exceeding these limits.

WETBULB-STAGED   The fans of a multi-cell condenser will stage directly as a function of the outdoor wetbulb temperature. There is no condensing setpoint; instead the condensing temperature floats with the load, the number of fans operating, and the ambient temperature. While intended for evaporative condensers, this strategy may be used with any type of condenser, including air-cooled.

When using this strategy, each condenser attached to this system will require the CONDENSER:NUMBER-OF-FANS to be defined, as well as a list of CONDENSER:FAN-STAGE-T's. For example, assume a condenser has three independently-controlled fans (cells). One fan is to run continuously, the second is to stage on whenever the wetbulb is at or above 40°F, and the third fan is to stage on at 60°F. Within the condenser component:

    NUMBER-OF-FANS   = 3

    FAN-STAGE-T   = (-100., 40., 60.)

It is possible for more than one condenser to be controlled in this manner, with each condenser having a different number of cells and fan-staging temperatures.

To prevent excessively hot or cold condensing temperatures, you may also specify an OVERRIDE-MAX-SCT and/or an OVERRIDE-MIN-SCT. In this case, the condensers will revert to normal temperature control whenever the floating SCT approaches one of these limits, and will modulate as necessary to prevent the SCT from exceeding these limits.

LOAD-RESET   The fan(s) of a condenser will modulate directly as a function of the condenser load. There is no condensing setpoint; instead the condensing temperature floats with the load, the fan output, and the ambient temperature.

This strategy attempts to achieve an optimal compromise between condenser fan energy and compressor energy. To accomplish this, the condenser must have either variable-speed fans, or discharge dampers. Refer to the following section "Load-Reset Temperature Control" for a detailed discussion of this control strategy.

The defaults for the reset coefficients result in 80% airflow at 100% load, and 40% airflow at 30% load.

To prevent excessively hot or cold condensing temperatures, you may also specify an OVERRIDE-MAX-SCT and/or an OVERRIDE-MIN-SCT. In this case, the condensers will revert to normal temperature control whenever the floating SCT approaches one of these limits, and will modulate as necessary to prevent the SCT from exceeding these limits.

PAN-T   The fans of an evaporative condenser are controlled to maintain the temperature of the water pan. This strategy is applicable primarily to multi-circuit condensers.

SCT-SETPT
when SCT-CTRL = FIXED, specifies the condensing temperature setpoint.

SCT-THROTTLE
All control strategies involving a setpoint (FIXED, SCHEDULED, RESET-TEMP-SCH, DRYBULB-RESET and WETBULB-RESET) also utilize a control throttling range. Fan output will be at maximum when the condensing temperature climbs to the top of the throttling range, and will be at minimum at the bottom of the throttling range. For condensers having single-speed or two-speed fans, the throttling range defines the points at which the fans cycle off/on or off/low/high. Refer to the condenser component for more information regarding the hysteresis of cycling fans.

SCT-SETPT-SCH
when SCT-CTRL = SCHEDULED, accepts the U-name of a schedule defining the hourly condensing temperature setpoint.

SCT-RESET-SCH
when SCT-CTRL = RESET-TEMP-SCH, accepts the U-name of a reset schedule defining the relationship between the outdoor air temperature and the condensing temperature setpoint.

SCT-AMBIENT-DT
when SCT-CTRL = DRYBULB-RESET or WETBULB-RESET, specifies the differential between the condensing setpoint and the outdoor drybulb or wetbulb temperature.

WETBULB-RATIO
when SCT-CTRL = WETBULB-RESET, specifies the ratio applied to the difference between the design wetbulb and actual wetbulb when resetting the condensing setpoint. The default is 0.28

LOAD-MAX-AIRFLOW
LOAD-MAX-PLR

LOAD-MIN-AIRFLOW
LOAD-MIN-PLR
when SCT-CTRL = LOAD-RESET, these four keywords define the reset relationship between fan output and condenser load. Refer to the "Load-Reset Temperature Control" section for more information.

OVERRIDE-MAX-SCT
This keyword applies to all SCT-CTRL strategies except FLOAT, DRYBULB-STAGED, and WETBULB-STAGED. It specifies an optional upper limit on the condensing temperature. The condensers will revert to normal temperature control whenever the SCT approaches this limit, and will modulate as necessary to prevent the SCT from exceeding this limit. Note that the SCT may still exceed this limit if the condenser load is sufficiently large, and the ambient conditions sufficiently hot.

OVERRIDE-MIN-SCT
This keyword applies to all SCT-CTRL strategies except FLOAT, DRYBULB-STAGED, and WETBULB-STAGED. It specifies an optional lower limit on the condensing temperature. The condensers will revert to normal temperature control whenever the SCT approaches this limit, and will modulate as necessary to prevent the SCT from dropping below this limit. Note that the SCT may still exceed this limit if the condenser load is sufficiently small, and the ambient conditions sufficiently cool. (When the fans are off, a condenser still has approximately 10% of its capacity due to convection.)

To ensure the condensing temperature never exceeds a given lower limit, regardless of fan control strategy, you may back flood the condenser with liquid. Refer to BACKFLOOD-CTRL for more information.

ALARM-MAX-T
Specifies the maximum saturated condensing temperature above which a safety is assumed to shut down the system. The program will issue an error message and abort in this situation. The default is 20°F above the DESIGN-SCT.

If the program trips in this situation, check to make sure that your condenser capacity is adequate. Also, if using CASCADED or WATER-COOLED condensers, make sure that the systems supplying these condensers have adequate capacity, and are operating at the necessary temperature.

Many of the compressor curves are limited over the range of condensing temperatures they can handle. Therefore, it is not normally resonable to override this default, unless the DESIGN-SCT is unusually low.

This keyword applies to all SCT-CTRL strategies except FLOAT, DRYBULB-STAGED, and WETBULB-STAGED. It specifies an optional lower limit on the condensing temperature. The condensers will revert to normal temperature control whenever the SCT approaches this limit, and will modulate as necessary to prevent the SCT from dropping below this limit. Note that the SCT may still exceed this limit if the condenser load is sufficiently small, and the ambient conditions sufficiently cool. (When the fans are off, a condenser still has approximately 10% of its capacity due to convection.)

ALARM-MIN-T
Specifies the minimum saturated condensing temperature below which a safety is assumed to shut down the system. The program will issue an error message and abort in this situation. The default is 50°F, or the DESIGN-SCT – SCT-THROTTLE, whichever is less.

In real situations, the condensing temperature can drop below the alarm temperature during periods of low loads, coupled with extremely cold outdoor temperatures. To prevent this, specify a BACKFLOOD-CTRL, or reduce the CONDENSER:FAN-OFF-AIRFLOW to very close to zero (such as 0.0001).

Note that the program currently does not simulate the sub-hour effect of one compressor in a system cycling on/off. Instead, the condenser averages the compressor flow over the entire hour, which may result in a colder

condensing temperature than what really exists. In this case, the best solution is to reduce the CONDENSER:FAN-OFF-AIRFLOW as described above.

If you want to achieve condensing temperatures below the alarm temperature, you may lower the alarm temperature. However, excessively low condensing temperatures can result in an insufficient pressure differential across the coils and their thermal expansion valves, resulting in choked refrigerant flow. In addition, many of the compressor curves are limited over the range of condensing temperatures they can handle. Therefore, it is not normally resonable to override this default, unless the DESIGN-SCT is unusually low, and you know that the compressor curves are fit down to the target temperature.

Load-Reset Temperature Control

The SCT-CTRL = LOAD-RESET specifies that the fan speed (variable-speed or damper) will vary as a function of the load. The condensing temperature will float according to the fan speed and drybulb or wetbulb temperature. This strategy attempts to achieve an optimal compromise between condenser fan energy and compressor energy. The sequence is as follows:

- The condenser load is determined on an hourly basis. In the field, this would be accomplished either by monitoring the refrigerant flow rate, or by correlating the number of compressors running with their capacity.

- The condenser airflow (and fan output) required to reject a given load varies according to the load. Rather than controlling a variable-speed condenser fan on the basis of condensing temperature as is conventionally done, this algorithm will vary the condenser fan speed directly on the basis of the heat-rejection load. For example, the condenser fan can run at 60% speed when the heat-rejection load is 50% of design. The condensing temperature then floats with both the ambient temperature (drybulb or wetbulb) and the heat-rejection load. This concept gives priority to minimizing condenser energy consumption, but still achieves compressor energy savings as the ambient temperature drops.

- To further increase compressor efficiency, it can be recognized that the condenser fan power varies approximately as the cube of the airflow (and load), and that the majority of the energy savings are achieved when the fan is close to full speed. Once the fan speed has been reduced to 70% or so, additional condenser fan energy savings may be negligible compared to the potential compressor savings that might be achieved by reducing the condensing temperature.

- Maximum and minimum condenser temperature limits are included. For example, the user might not want the condensing temperature to ever exceed 105°F or to drop below 70°F. The fan output algorithm will be overridden if these limits are exceeded.

Keywords are provided to allow the user to experiment with these concepts. For example, at 30% load the default fan speed will be 40%. You might want to investigate what happens if the condenser fan is not allowed to drop below 65% speed at 40% load. ?? expand this explanation with an example and diagram.

Fan output varies with load according to the following relationships:

PLR   = Mrefg / Mdesign
PLR   = MIN(PLR, LOAD-MAX-PLR)
PLR   = MAX(PLR, LOAD-MIN-PLR)

PLRfan   = (LOAD-MIN-AIRFLOW)
              +[(LOAD-MAX-AIRFLOW - LOAD-MIN-AIRFLOW)
                 * (PLR − LOAD-MIN-PLR) / (LOAD-MAX-PLR − LOAD-MIN-PLR)]

where Mrefg is the current refrigerant flow, Mdesign is the refrigerant flow at design conditions, and PLRfan is the fan part load ratio (or output ratio), expressed as a fraction of full airflow.

Condenser Back-flooding Temperature Control

Cycling, staging, or modulating condenser fans is one method of controlling the condensing temperature. Another method is to use an arrangement of valves to bypass hot compressor gas around the condenser. The increased pressure on the condensed liquid causes the liquid to flood back into the condenser; thereby reducing the condenser's effective heat-transfer area and raising the saturated condensing temperature. One commercially available system is the "HeadMaster" control.

Three back-flooding methods are commonly used:

1. <u>Discharge/liquid mixing</u> – The hot compressor discharge gas is mixed with the liquid leaving the condenser, causing the mixture's saturated temperature and pressure to rise. The liquid flows on to the loads in an essentially saturated state, with little or no subcooling.

2. <u>Discharge/liquid stratification</u> – The compressor discharge gas is bypassed to the top of the liquid receiver, acting as a "spring" to exert pressure on the liquid. While the discharge gas heats the very top of the receiver, the temperature in the receiver stratifies, resulting in very little heating of the liquid flowing to the loads (the receiver is above the main liquid flow). Since the liquid backed up in the condenser can experience a considerable amount of subcooling, a highly subcooled liquid is available for the loads, resulting in smaller refrigerant mass flow rates and reduced compressor energy. However, the reduction is compressor energy is at least partially offset by increased condenser fan energy (fan output could have been modulated rather than back-flooding).

3. <u>Stratification/mixing</u> – In very cold climates, excessive subcooling can cause liquid to flood evaporator coils, resulting in control problems and insufficient working refrigerant charge. A combination of the previous two scenarios can prevent this. A portion of the discharge gas is bypassed to the top of the liquid receiver to maintain the SCT, while additional gas is directly mixed with the liquid to modulate the amount of subcooling.

Subcooling achieved via backflooding is a form of ambient subcooling, in that the subcooling is achieved by the condenser rather than via a mechanical subcooler. It is not necessary for the condenser to have a subcooling circuit for backflooding to produce this effect.

Back-flooding can be used with any of the SCT-CTRL sequences, but is most commonly used with multi-circuit condensers employing the DRYBULB-STAGED or PAN-T methods. In this case, each condenser circuit has its own back-flooding controller.

BACKFLOOD-CTRL
accepts a code-word specifying the type of back-flooding temperature control.

NONE	the default, specifies that no backflooding occurs.
FIXED	specifies that backflooding will prevent the SCT from dropping below the BACKFLOOD-SETPT.
MAX-REQD	specifies that the backflooding setpoint will be reset according to the maximum liquid refrigerant pressure required by any of the attached loads. This strategy allows the SCT to be as low as possible, while still ensuring that each load has sufficient liquid pressure to achieve its mass flow requirements.

The liquid pressure required by each load is calculated hourly as a function of the load's current mass flow requirement, the load's pressure drop associated with the current mass flow, and the suction pressure downstream of the load. It is further adjusted by the hourly pressure drops of the liquid lines attaching the load to the REFG-SYSTEM.

The BACKFLOOD-SETPT can optionally be specified for this strategy. If so, the actual setpoint will be the greater of the maximum required pressure or the BACKFLOOD-SETPT.

BACKFLOOD-SETPT
specifies the saturated condensing temperature setpoint of the backflooding controls. The default is 70F for BACKFLOOD-CTRL = FIXED. This keyword is optional for BACKFLOOD-CTRL = MAX-REQD.

BACKFLOOD-SUBCOOL
specifies the degrees of ambient subcooling allowed when the backflooding control is active.

The default is 0, meaning that backflooding is accomplished by mixing hot gas directly with the liquid, producing a liquid saturated at the BACKFLOOD-SETPT (scenario #1 described above).

A relatively small entry will cause the amount of ambient subcooling to be modulated to this setpoint in accordance with scenario #3 (described above).

A large value (for example, 100.) will allow all ambient subcooling produced by the condenser to flow onto the loads.

Note that this entry acts as a limit on the amount of ambient subcooling produced by the condensers; it does not force the subcooling to be greater than what the condensers can actually achieve.

Rules
1. When SCT-CTRL = DRYBULB-RESET, WETBULB-RESET, or LOAD-RESET, the program will default the OVERRIDE-MIN-SCT to be equal to the (BACKFLOOD-SETPT - BACKFLOOD-SUBCOOL). If BACKFLOOD-SUBCOOL is zero, then the condensers will modulate their fans prior to initiating the backflooding control. This minimizes condenser fan energy, but reduces the amount of ambient subcooling that could otherwise be produced by the backflooding effect.

2. If BACKFLOOD-SUBCOOL is non-zero, then the OVERRIDE-MIN-SCT will default to the backflooding setpoint, minus the amount of ambient subcooling allowed. This increases condenser fan energy but produces more subcooling.

3. Note that the OVERRIDE-MIN-SCT acts as a lower limit on the normal condenser fan control strategy; setting this keyword to a very low temperature will not cause the fans to increase their output more than they would otherwise. To prevent the OVERRIDE-MIN-SCT from having any effect on back-flooding, specify a value of zero.

4. The backflooding calculations are done within the REFG-SYSTEM component, *after the condensers have been simulated*. It is assumed that backflooding has no effect on condenser energy consumption. But, since backflooding reduces the mass flow through the condensers, the condenser reports will overstate the amount of heat rejected.

Condenser Heat Reclaim Temperature Control

Heat reclaim from the compressor discharge gas is common in supermarket refrigeration systems. Heat is typically recovered for use in the space conditioning systems and/or domestic water heating. Heat recovery can be either sensible or latent:

- The compressor discharge gas can be desuperheated without condensing. This method allows heat to be recovered without impacting the discharge pressure and compressor energy. However, the total amount of energy available is limited by the amount of sensible superheat, and does not take advantage of the considerably larger amount of heat available as latent heat.

- The compressor discharge gas can be condensed. This method can recover the entire amount of energy available in the refrigerant. However, the recovered heat is often needed at a temperature higher than the ideal condensing temperature. The condensing temperature must be raised to the required recovery temperature, which increases the compressor energy.

When recovering refrigerant latent heat, the compressor energy penalty associated with the increased condensing temperature may or may not be greater than the value of the heat recovered. To a large extent, the trade-off depends on the amount of heat to be recovered, the number of compressors impacted, and the duration of the impaction. This program can simulate a wide variety of heat reclaim methods, but can be summarized as follows:

- Holdback valves – A holdback valve places a pressure restriction between one or more compressors and the condenser. The holdback valve operates as required to deliver a pressure higher than the condenser temperature to the heat-reclaim devices, allowing the condenser to operate at its normal temperature. A holdback valve can be placed on the discharge line serving a single compressor, a group of compressors, or all the compressors in a REFG-SYSTEM. The holdback valve may operate continuously, may be scheduled, or may be controlled in a load-reset fashion. Since the holdback valve is in the compressor discharge circuit, its control is discussed in the REFG-CIRCUIT, TYPE = DISCHARGE component.

- Condenser control – The simplest and lowest first-cost method to recover latent heat from the refrigerant is to operate the condenser at a higher condensing temperature. For example, instead of controlling to an 85-95°F range, the condenser could be controlled to 115°F. The advantage of this approach is that the condenser size is smaller than it would be otherwise, and will consume less energy. However, such operation impacts all compressors in the system, and may result in a very large compressor energy penalty. To avoid this, a large refrigeration system may be broken into several smaller ones, and/or the condensing temperature may be reset according to the heat-reclaim load.

The following presents condenser control sequences for heat reclaim. These sequences act as lower-limit overrides to the condenser control that would otherwise occur. In other words, heat-reclaim can force the condensing setpoint up, but not down. In addition, they may be active only when heat reclaim is needed, and may produce a control setpoint that may vary in response to the heat-reclaim load. Heat-reclaim holdback valves may co-exist; each control method will operate independently of the other.

These strategies act as a lower-limit override to all condenser control sequences, except for SCT-CTRL = DRYBULB-STAGED, WETBULB-STAGED, or PAN-T. The program assumes these sequences are normally for multi-circuit condensers, with each circuit operating at its own SCT. Therefore, it would not reasonable to apply a single override to multiple circuits.

Backflooding valves may co-exist with these heat-reclaim sequences. However, the heat-reclaim sequences described here will act to force up the condensing temperature by reducing the output of the condenser fans; thereby reducing the amount of subcooling that could otherwise be achieved. If high ambient subcooling is desired together with latent heat reclaim, use holdback valves in the compressor discharge circuits instead of these sequences.

NOTE: THESE STRATEGIES ARE IMPLEMENTED, BUT HAVE NOT BEEN TESTED. THE KEYWORDS ARE CURRENTLY DISABLED.

*HTREC-CTRL

accepts a code-word specifying whether the condensers in this REFG-SYSTEM are to be controlled in response to a heat-reclaim demand.

NONE	the default, specifies that there is no heat-reclaim override in the temperature setpoint calculations.
ON/OFF	ecifies that the HTREC-SETPT shall override the normal temperature control whenever a heat-reclaim load exists. When no heat reclaim is needed, then the condenser controls normally.
SCHEDULED	ecifies that the HTREC-SETPT shall override the normal temperature control in accordance with a SCHEDULE of TYPE = ON/OFF/TEMP. A schedule value of 0 means that no heat reclaim is in effect, and the condenser controls normally. A value of 1 means that heat reclaim is in effect, and the HTREC-SETPT is enabled. A value other than 0 or 1 represents an outdoor air temperature: Heat reclaim will be in effect whenever the actual outdoor temperature is below the schedule value.
LOAD-RESET	sets the heat-reclaim setpoint based on the heat-reclaim load requiring the highest temperature. When determining the reset temperature, the program ignores any discharge circuits having holdback valves. In other words, the reset temperature will be based only on the requirements of the discharge circuits having a heat-reclaim load, but not having a holdback valve. The MAX-HTREC-T can optionally be entered, in which case it acts as an upper limit on the reset temperature.

*HTREC-SETPT

for HTREC-CTRL = ON/OFF or SCHEDULED, defines the heat reclaim setpoint. This value acts as a lower limit on the condensing temperature control. In other words, it can force the condensing temperature to be higher, but will not force it to be lower.

*HTREC-SCH

when HTREC-CTRL = SCHEDULED, accepts the U-name of a SCHEDULE of TYPE = ON/OFF or ON/OFF/TEMP. A schedule value of 0 means that no heat reclaim is in effect, and the condenser controls normally. A value of 1 means that heat reclaim is in effect, and the HTREC-SETPT is enabled. A value other than 0 or 1 represents an outdoor air temperature: Heat reclaim will be in effect whenever the actual outdoor temperature is below the schedule value.

*MAX-HTREC-SETPT

when HTREC-CTRL = LOAD-RESET, specifies an optional upper limit on the heat-reclaim setpoint.

Multi-Stage Refrigeration Systems

Refrigeration systems operating at very low temperatures may require two or more stages of compression. There are several ways to accomplish this:

1. <u>Multi-stage or compound compressor</u> – a compressor may have two or stages of compression, with an intercooler between each stage to prevent compressor damage and/or refrigerant degradation. *The program does not currently simulate these compressors.*

2. <u>Multi-stage systems (common refrigerant)</u> – These systems consists of one or more compressors that operate at low suction pressure and discharge at intermediate pressure, and have one or more compressors that operate at intermediate pressure and discharge to the condenser. To model this configuration, each set of compressors is configured as a separate suction group. The low-temperature suction group draws from one or more low-temperature suction circuits, and discharges into an intermediate-temperature suction circuit feeding into the intermediate-temperature suction group. The intermediate-temperature group discharges into a discharge circuit that feeds into the condenser(s).

    Since the gas discharged from the low-temperature group will be highly superheated, it must be cooled prior to entering the intermediate compressors. To model this, attach a desuperheater to the intermediate suction group, and attach the intermediate-temperature suction circuit to this desuperheater.

3. <u>Cascaded systems (separate refrigerants)</u> – These consist of two or more completely separate refrigeration systems using different refrigerants. The low-temperature system discharges into a refrigerant-cooled condenser. This condenser is in turn a load on the intermediate-temperature system. The program can simulate any number of cascaded levels. For example, a very low-temperature system may cascade into a low-temperature system, which in turn cascades into an intermediate temperature system.

    To model cascaded system, define the warmest-temperature system first. Then define the next warmest-temperature system, together with a CASCADED condenser. Attach this condenser to the appropriate liquid and suction circuits of the warmest-temperature system. You may repeat this logic as required.

    In addition to the cascaded condenser, the low temperature system may have other condensers, such as an air-cooled condenser, that rejects heat directly. In very cold climates, the air-cooled condenser may be used in the winter, and the cascaded condenser in the summer. The switching is via a LOAD-MANAGEMENT sequence that selects the appropriate EQUIP-CTRL sequence as a function of the outdoor air temperature or a schedule.

REFRIGERANT

This command inputs the properties of a given refrigerant into a table. The relevant properties for a refrigerant are the saturated temperature and pressure, the saturated enthalpies (liquid and gas), and the specific heats (for superheat and subcooling). In addition, exponents to adjust heat-transfer film coefficients and piping pressure drops are included.

While the performance of most DOE-2 components is characterized using performance curves, the program uses a look-up table for all refrigerant properties. This approach ensures better accuracy than curves over the entire range of values; otherwise, errors could be generated when comparing the difference between two different curves.

U-NAME(=)
accepts a mandatory entry for the U-name of this refrigerant. This U-name will be used all reports to identify the refrigerant, and may also be referenced by compressors or other components if their performance curves vary by refrigerant type.

The following set of keywords all accept lists of up to 40 values. Values for saturated temperature may be entered in either ascending or descending order. All other values must have a one-to-one correspondence with the values listed for temperature.

SATURATED-T
accepts a list in parenthesis of the saturated temperatures corresponding on a one-to-one basis to the values in the following keyword lists. You may wish to enter values using a given differential such as 10°F (e.g. -40, -30, -20, etc.), but this is not necessary. You may enter up to 40 values in the list.

SATURATED-P
accepts a list in parenthesis of the saturated pressures corresponding to the values in the SATURATED-T list.

LIQUID-H
accepts a list in parenthesis of the saturated liquid enthalpies corresponding to the values in the SATURATED-T list.

LIQUID-CP
accepts a list in parenthesis of the saturated liquid specific heat corresponding to the values in the SATURATED-T list.

LIQUID-DENSITY
accepts a list in parenthesis of the liquid densities corresponding to the values in the SATURATED-T list.

LIQUID-VISCOSITY
accepts a list in parenthesis of the liquid viscosities corresponding to the values in the SATURATED-T list.

LIQUID-CONDUCT
accepts a list in parenthesis of the liquid conductivities corresponding to the values in the SATURATED-T list.

VAPOR-H
accepts a list in parenthesis of the gas enthalpies corresponding to the values in the SATURATED-T list.

VAPOR-CP

accepts a list in parenthesis of the gas specific heats corresponding to the values in the SATURATED-T list.

VAPOR-VOLUME

accepts a list in parenthesis of the accepts a list in parenthesis of the gas densities corresponding to the values in the SATURATED-T list.

VAPOR-VISCOSITY

accepts a list in parenthesis of the vapor viscosities corresponding to the values in the SATURATED-T list.

VAPOR-CONDUCT

accepts a list in parenthesis of the vapor conductivities corresponding to the values in the SATURATED-T list.

SUBCOOLER

This command defines the characteristics of a mechanical subcooler. A mechanical subcooler cools a refrigerant liquid to below its saturated condensing temperature by evaporating liquid refrigerant on the opposite side of a heat-exchanger. The liquid to be evaporated may be taken from either same circuit as the liquid to be subcooled, or a different circuit; which may be in either the same system or a different system than the subcooled liquid.

"Subcooling" can also be achieved via a pump that raises the pressure of the liquid line downstream of the condensers. Refer to the REFG-CIRCUIT:LIQUID-PUMP section for more information *(future)*.

The inlet of a subcooler may be attached to either:

- Directly to a REFG-SYSTEM – hot condensed liquid enters the subcooler directly from a refg-system's condensers. The subcooler cools the liquid and passes it on to downstream liquid circuits.

- The outlet of a liquid circuit – hot condensed liquid flows through one or more liquid circuits prior to entering the subcooler. The subcooler cools the liquid and passes it on to downstream liquid circuits.

Any number of subcoolers may attach to a refg-system or to the outlet of an upstream liquid circuit. Any number of downstream liquid circuits may attach to a subcooler's outlet.

U-NAME(=)
accepts a mandatory entry for the U-name of this subcooler. This U-name will be used all reports to identify the component.

TYPE
accepts a code-word specifying the type of subcooler:

MECHANICAL	specifies a subcooler using a heat-exchanger and refrigerant feed. Because of the heat-exchanger, this subcooler may utilize refrigerant from one refrigerant system to subcool a liquid circuit belonging to another refrigerant system.
FLASH	specifies a subcooler that flashes a portion of the refrigerant to subcool the remainder. The pressure of the liquid leaving the subcooler will be reduced to the flash temperature. Since no heat-exchanger is used, the liquid and suction circuits utilized must both belong to the same refrigeration system. However, the suction circuit may feed into any suction-group belonging to the refrigeration system.
ECONOMIZER	specifies a subcooler identical to FLASH, but that is meant to temporarily approximate a subcooler that feeds into the economizer port(s) of a compressors(s). The suction gas is dumped into the discharge circuit of the compressor's suction-group. The compressor performance curves must include the assumed effect of the economizer gas.

ATTACH-TO
specifies the attachment of the subcooler's inlet. This is a mandatory entry.

REFG-SYSTEM	the hot liquid to be subcooled flows directly from the condensers in a refg-system. Any number of subcoolers may attach to the same refg-system.

SUBCOOL-CIRCUIT	the hot liquid to be subcooled flows from an upstream liquid circuit. Any number of subcoolers may attach to the same upstream liquid circuit.

Note that the downstream liquid circuits attach to the subcooler from within their components. Any number of downstream circuits may attach to the same subcooler.

REFG-SYSTEM
when ATTACH-TO = REFG-SYSTEM, accepts the U-name of the REFG-SYSTEM that feeds hot liquid into this subcooler.

When ATTACH-TO = SUBCOOL-CIRCUIT, *is set by an expression and should never be changed by the user.* This is the U-name of the REFG-SYSTEM from which the liquid to be subcooled originated. In this case, this keyword has no user function; it is set so that downstream components can determine the system to which they belong.

CAPACITY
specifies the capacity of the subcooler in Btu/hr. If not specified, the program will default this value based on the subcooler's rated flow and liquid/suction refrigerant conditions.

FLOW
specifies the design flow of subcooled liquid through the subcooler at the SUBCOOL-DT and OUTLETS-TD. The default is the design flow of the subcooled liquid circuit, adjusted by the FLOW-RATIO.

FLOW-RATIO
when the FLOW is undefined, specifies the sizing ratio that will be applied to the flow.

DESIGN-SUBCOOL-T
defines the design leaving liquid temperature of the subcooler. The actual leaving temperature is subject to the temperature control strategy and the subcooler performance characteristics. This is a mandatory entry.

SST-SUBCOOL-TD
defines the differential between the leaving subcooled liquid and the saturated-suction temperature at the rated flow.

SUPERHEAT-DT
specifies the superheat setpoint of the suction gas leaving the subcooler.

TEMP-CTRL
accepts a code-word specifying the temperature control mechanism for the subcooler:

FLOAT,	the default, specifies that the subcooled liquid temperature floats as a function of the load, subcooler characteristics, and, for a refrigerant-cooled subcooler, the saturated-suction temperature. Note that the saturated-suction temperature may be controlled by an evaporator pressure regulator (EPR) somewhere in the suction circuiting, and that the pressure may vary according to the EPR control characteristics. If no EPR exists, then the saturated-suction temperature will vary according to the operation of the suction-group into which this subcooler feeds.
LOCAL-EPR	specifies that the fixture has its own evaporator pressure regulator that maintains a constant saturated-suction temperature in the evaporator. The leaving liquid temperature then varies according to the TEMP-SETPT, the load, and subcooler characteristics.

LOCAL-EPR-SCH   is similar to LOCAL-EPR, but allows the local EPR's setpoint to vary according
                        to a schedule.

THERMOSTAT   specifies that the subcooler has a temperature sensor that controls the leaving
                        subcooled liquid temperature.

THERMOSTAT-SCH   is similar to THERMOSTAT, but allows the temperature setpoint to vary
                        according to a schedule.

SATURATION-DT   specifies that the subcooler maintains a fixed differential between the subcooled
                        temperature and the saturated temperature. While uncommon, this strategy can
                        help to ensure sufficient subcooling when using a floating head pressure control
                        strategy.

LOAD-RESET   specifies that the subcooler cools the refrigerant sufficiently so that there is no
                        flash gas present at the end of the worst-case branch circuit. This strategy
                        assumes there is a temperature and pressure sensor at the end(s) of all branch
                        circuits to detect flash gas, and controls to the worst case pair of sensors.

TEMP-SETPT

when TEMP-CTRL = LOCAL-EPR or THERMOSTAT, specifies the target subcooled liquid temperature
setpoint of the local evaporator pressure regulator or temperature sensor.

For an evaporator pressure regulator (EPR), this value represents the subcooled liquid temperature setpoint when
the subcooler is at design load. Note that an EPR valve does not directly measure the liquid temperature; instead it
controls the suction temperature. Therefore, the program will set the actual EPR setpoint to the temperature
necessary to hold the temperature at the TEMP-SETPT, assuming the design load. At design conditions, TEMP-
CTRL = LOCAL-EPR will give the same results as TEMP-CTRL = THERMOSTAT. However, when using
TEMP-CTRL = LOCAL-EPR, as the hourly load drops, the differential temperature across the heat-exchanger will
decrease, and the actual liquid temperature will droop and approach the evaporator temperature as maintained by
the EPR. For this reason, a LOCAL-EPR will cause a subcooler to run colder at low loads than will a
THERMOSTAT (and warmer at high loads).

TEMP-SETPT-SCH

when TEMP-CTRL = LOCAL-EPR-SCH or THERMOSTAT-SCH, accepts the U-name of a schedule specifying
the target subcooled liquid setpoint of the local evaporator pressure regulator or temperature sensor.

For an evaporator pressure regulator (EPR), this value represents the subcooled liquid temperature setpoint when
the subcooler is at design load. Note that an EPR valve does not directly measure the liquid temperature; instead it
controls the suction temperature. Therefore, the program will set the actual suction setpoint to the temperature
necessary to hold the temperature at the TEMP-SETPT, assuming the design load. At design conditions, TEMP-
CTRL = LOCAL-EPR will give the same results as TEMP-CTRL = THERMOSTAT. However, when using
TEMP-CTRL = LOCAL-EPR, as the hourly load drops, the differential temperature across the heat-exchanger will
decrease, and the actual liquid temperature will droop and approach the evaporator temperature as maintained by
the EPR. For this reason, a LOCAL-EPR will cause a subcooler to run colder at low loads than will a
THERMOSTAT (and warmer at high loads).

SATURATION-DT

when TEMP-CTRL = SATURATION-DT, specifies the degrees of subcooling below the saturation temperature.

LIQUID-CIRCUIT

for mechanical subcoolers, accepts the U-name of the LIQUID circuit supplying the refrigerant used to provide the subcooling. This circuit may be the same as the circuit to be subcooled, or different. This circuit does not have to be part of the same refrigeration system as the subcooled liquid. However, both the liquid circuit and the suction circuit have to belong to the same system.

By default, the program assumes that the refrigerant used to subcool the liquid line will be drawn from the subcooled liquid line.

SUCTION-CIRCUIT

accepts the U-name of the SUCTION circuit returning the evaporated liquid to a suction group. The SUCTION-CIRCUIT must be part of the same system as the LIQUID-CIRCUIT, but does not necessarily have to belong to the same system as the subcooled liquid.

This is a mandatory entry; there is no default.

SUCTION-FLOW

specifies the design flow of refrigerant providing the subcooling effect. This is the flow on the suction side of the heat exchanger, not the flow of subcooled liquid.

SUBCOOL-DP

specifies the design pressure drop of the subcooled liquid flowing through the subcooler. The pressure drop is in units of pressure.

SUCTION-DP

specifies the design pressure drop of the suction liquid flowing through the subcooler. The pressure drop is in units of pressure. This pressure drop is for the heat-exchanger and thermal expansion valve controlling the superheat; any drop associated with an evaporator pressure regulator or a temperature control valve is specified via the CTRL-VALVE-DT keyword.

This pressure drop is important when the suction-group is resetting the suction pressure on the basis of worst-case demand, or the condensers are using a floating head-pressure control. Also, if there is insufficient pressure drop available for the required flow, then the load will not be met and the temperature of the subcoooled liquid will float above setpoint.

CTRL-VALVE-DT

For all TEMP-CTRL strategies other than FLOAT, specifies the saturated temperature drop through the evaporator pressure regulator or temperature control valve; the drop associated with the heat-exchanger and thermal expansion valve is ispecified via the SUCTION-DP keyword. The valve is assumed to be on the suction side of the evaporator, so that the available suction pressure of the suction group is reduced by the pressure (temperature) drop through this valve. The pressure drop through the valve varies hourly as a function of the actual refrigerant flow.

HX-UA

specifies the effective conductivity of the heat-exchanger. If not specified, the program will calculate this value based on the load, flow, and temperature characteristics of the subcooler.

SUBCOOL-FILM-RES

specifies the fraction of the overall heat exchanger resistance (where resistance = 1.0 / HX-UA) due to the film resistance on the subcooled side of the heat exchanger.

The program uses this value to determine the design subcooled-side film resistance. The program modifies this design value on an hourly basis to account for the change in HX-UA due to variations in flow:

Rsup = Rsup-design * (Hourly Flow/FLOW)**SUBCOOL-FILM-EXP

The default values are only approximate. You should verify the relative fractions of the supply-side and demand-side film resistances if off-design performance is of critical importance in your analysis.

The design resistance fractions of the subcooled-side, suction-side, and the heat exchanger resistances must add up to 1.0. Therefore, the sum of the subcooled-side and suction-side film resistance fractions must be less than or equal to 1.0. The program checks for this condition, and will generate an error if your input does not meet this criteria.

SUBCOOL-FILM-EXP
specifies the exponent used to modify the SUBCOOL-FILM-RES as a function of the hourly refrigerant flow. The default is 0.8, which corresponds to turbulent flow in a tube.

The program assumes that this exponent is valid over the entire flow range. If the flow (and Reynolds number) drops low enough, the flow will transition from turbulent to laminar, and this assumption will not be valid.   For most applications, this transition will normally not occur until the flow is in the 25% range or lower. The errors generated will be small and should have a negligible impact on energy consumption.

SUCTION-FILM-RES
is identical to SUBCOOL-FILM-RES, but describes the fraction of overall heat-exchanger resistance that is on the suction side of the heat-exchanger.

The following keywords are miscellaneous:

COST-DATA
accepts the U-name of a MATERIALS-COST command. This command allows you to define first costs, maintenance costs, etc. for this component.

EQUIPMENT-REPORTS
accepts the codewords YES or NO. The default is NO. When report RS-H of the REFG-REPORTS is enabled, a report will print for this component when this keyword is YES.

SUCTION-GROUP

A suction group is a group of compressors (one or more) that draw from a common set of branch circuits (one or more), and are controlled to a common suction temperature. Typically, the compressors will discharge to a common discharge circuit, but this is not mandatory. Additional suction groups may discharge to the same discharge circuit, but never draw from the same branch circuits. (Figure ??)

A suction group has a suction pressure setpoint that is the basis for staging and/or modulating compressors. This setpoint may be fixed, scheduled, or may be reset on the basis of the branch circuit requiring the lowest pressure. (Note, however, that individual compressors within a suction-group may have their own internal capacity control setpoints.) Below this setpoint, the suction group may either cycle a compressor or use hot-gas bypass to maintain the suction temperature within the control range.

The setpoint controller also has a throttling range that can have a significant impact on compressor energy consumption and cycling. A very small throttling range achieves closer pressure control, but may result in excessive compressor cycling unless one or more of the compressors has a capacity control mechanism (unloaders, variable-speed, slide valve, etc.), or hot-gas bypass is used. A very large throttling range may result in poor pressure control and/or operation of compressors at unreasonably low suction pressures.

One or more of the compressors in a suction group may have a capacity control mechanism such as suction-valve unloading, discharge-valve unloading, a slide valve (screw compressor), inlet vanes (centrifugal compressor), and/or variable-speed control. The control setpoint may be as determined by the suction group (such as electric unloaders or variable-speed drives), or may be set internally to the compressor (e.g. valve unloaders activated on suction pressure).

While a suction-group normally expects there to be one or more attached compressors, you do not have to specify any compressors. In this case, the suction temperature will always be at at the hourly setpoint, and the pressure of the refrigerant in the suction lines will be raised to the pressure in the discharge lines without the expenditure of any compressor energy. This feature can be useful if you are in the process of constructing a refrigeration system, and would prefer to specify the compressor(s) after you know more about the design refrigeration loads and system operating characteristics.

U-NAME(=)
accepts a mandatory entry for the U-name of this suction group. This U-name will be used all reports to identify the component.

TYPE
accepts a code-word that specifies the type of suction-group. This is a mandatory entry:

> PARALLEL　　　　　　　　　specifies that all of the compressors within this suction group operate in parallel.

> *SERIES-PARALLEL*　　　　*(not implemented)* specifies that one or more compressors in parallel discharge into the inlet of one or more compressors, also in parallel. "Compound" compressors is another term for this type of arrangement.

**SIM-ALGORITHM*
accepts a code word specifying the name of the subroutine the program will use to simulate the suction-group. Currently, this feature is not available to the user.

DESIGN-SST
specifies the design saturated suction temperature. This value is used in the default sizing calculations for the attached compressors. If not specified, the default is the TEMP-SETPT plus one half of the throttling range (in other words, the compressors will be sized to meet the load when operating at the top of the throttling range). If the TEMP-SETPT is not specified, then this value will default to the minimum pressure requirement of any of the attached suction loads.

DISCHARGE-CIRCUIT
accepts the U-name of the DISCHARGE refrigeration circuit to which the compressors in this group discharge. Note that, by default, all compressors in this suction-group will discharge to this circuit. However, individual compressors may discharge into separate discharge circuits for better control of heat reclaim.

ELEC-METER
accepts the U-name of the METER that the attached compressors will use by default. The default is the ELEC-METER of the associated REFG-SYSTEM.

Temperature Control

The next set of keywords define the temperature control of the suction group, if any.

TEMP-CTRL
accepts a code-word specifying the control strategy for suction temperature:

FLOAT	specifies that the suction group does not have any temperature control mechanism. All compressors will run continuously, and the suction pressure will float with refrigerant mass flow and compressor capacity characteristics.
	Note that, while the suction-group may not have a temperature-control mechanism, individual compressors may. In this case, set the COMPRESSOR:CAPACITY-CTRL = INTERNAL-SETPT-T to allow one or more compressors to control based on their internal setpoints.
	Note also that this control sequence, as the others, can utilize hot-gas bypass to maintain a minimum suction temperature.
	If, in a given hour, the suction group has a very low mass flow, then the compressor(s) may attempt to pull the suction temperature down to an extremely low value. If the balance point temperature is below the minimim temperature defined in the refrigerant table, or the compressor capacity curve is not valid in the region of the balance point temperature, then the program will not be able to find the balance point and achieve convergence, and will issue a large list of errors to this effect.
FIXED	specifies that the suction group controls to a fixed setpoint, defined as TEMP-SETPT.
SCHEDULED	specifies that the suction group controls to a scheduled setpoint.
LOAD-RESET	specifies that the setpoint varies as a function of the worst case demand on the group.

TEMP-SETPT

when TEMP-CONTROL = FIXED, specifies the saturated-suction temperature setpoint of the suction group. The default is the DESIGN-SST, decreased by one-half of the throttling range.

The TEMP-SETPT is the midpoint of the maximum and minimum desired temperatures, and the TEMP-THROTTLE is the difference between the maximum and minimum temperatures. For example, if the maximum and minimum desired temperatures are 0°F and –30°F respectively, then

    TEMP-SETPT   = -15°F
    TEMP-THROTTLE = 30°F

TEMP-SETPT-SCH

when TEMP-CTRL = SCHEDULED, accepts the U-name of a schedule defining the saturated-suction temperature setpoint of the suction group.

The TEMP-SETPT-SCH value is the midpoint of the maximum and minimum desired temperatures, and the TEMP-THROTTLE is the difference between the maximum and minimum temperatures. See TEMP-SETPT for more information.

TEMP-THROTTLE

specifies the throttling range of the suction group capacity controller, in °F. The default is 20°F.

The TEMP-SETPT is the midpoint of the maximum and minimum desired temperatures, and the TEMP-THROTTLE is the difference between the maximum and minimum temperatures. For example, if the maximum and minimum desired temperatures are 0°F and –30°F respectively, then

    TEMP-SETPT   = -15°F
    TEMP-THROTTLE = 30°F

The suction group will select a mix of compressors that can meet the load at the top of the throttling range. One of these compressors will cycle off if, while using the mix of compressors selected at the top of the throttling range, the suction pressure falls to the bottom of the range. This compressor will cycle back on once the suction pressure again rises to the top of the range. When cycling, the program will calculate the proportion of time the compressors operate at each point in the throttling range, and will weight the electrical consumption and average saturated-suction temperature accordingly. Calculating this effect is particularly important when one or more of the compressors has its own internal capacity control mechanism. (You can prevent compressor cycling by specifying CYCLE-COMPRESSORS = NO). To minimize the amount of cycling, while preventing the suction temperature from falling unrealistically low, specify a large throttling range, such as 40°F.

The TEMP-THROTTLE is also used to generate a control signal for compressors having an internal capacity control mechanism that is controlled externally by the suction group controller.

When the suction-group control signal is to be used by individual compressors to modulate their capacity (cylinder unloaders, speed, etc.), set the COMPRESSOR:CAPACITY-CTRL = EXTERNAL-SIGNAL for the compressors to which this applies. Those compressors will then operate at their maximum capacity at the top of the throttling range, and at their MIN-RATIO at the bottom of the throttling range. You can also split the suction-group control signal, so that different compressors modulate over different parts of the range. See the COMPRESSOR component for more details.

To approximate proportional plus integral or proportional plus integral plus derivative control (PI or PID), decrease the throttling range to a small, but non-zero, value. Normally, this type of control is feasible only for compressors having some type of capacity control mechanism.

MAX-TEMP-SETPT
when TEMP-CTRL = LOAD-RESET, specifies the maximum allowed suction temperature setpoint.

MIN-TEMP-SETPT
when TEMP-CTRL = LOAD-RESET, specifies the minimum allowed suction temperature setpoint.

Staging and Capacity Control

The next set of keywords define the capacity control mechanism of the suction group. When the suction group has more than one compressor, the program always assumes that the primary method of capacity control will be staging compressors. For all TEMP-CTRL options except FLOAT, the suction group selects the hourly mix of compressors required to meet the load, either via default or an EQUIP-CTRL sequence. However, to maintain the suction temperature within the control range, it may be necessary to either cycle a compressor or use hot-gas bypass.

When using hot-gas bypass, it may be necessary to provide a mechanism to partially desuperheat the bypassed gas. Otherwise the compressors may be damaged due to an excessive inlet temperature. Desuperheating may not be necessary if a desuperheater is already attached to the suction line feeding into the suction group, and the discharge of the hot-gas bypass is attached to that circuit or an upstream branch.

EQUIP-CTRL
accepts the U-name of an EQUIP-CTRL command that defines how the compressors in the suction group stage with the load. If you do not specify an EQUIP-CTRL sequence, the program will select the mix of compressors that best matches the required mass flow.

An EQUIP-CTRL sequence is useful when there is a fixed order in which the equipment stages. For example, assume a suction group has three compressors of equal size, but one compressor is more efficient than the other two. In this case, you might want to base load the most efficient compressor, and stage the other two as required. The EQUIP-CTRL command allows you to do this. Refer to the EQUIP-CTRL command for more information.

CYCLE-COMPRESSORS
accepts a code-word specifying whether compressors will cycle to maintain the suction pressure within the throttling range:

YES	the default, specifies that compressors will cycle to maintain the suction temperature within the throttling range. Compressors are cycled with hysteresis; of the mix selected, one of the compressors will cycle off when the suction pressure reaches the bottom of the throttling range, and will cycle on when the pressure reaches the top of the range. The program calculates the time-weighted suction pressure and compressor energy during cycling.
NO	specifies that a compressor mix will be selected that meets the load at the top of the throttling range, but compressors will not cycle to prevent the suction temperature from dropping below the bottom of the range. Instead the program will calculate the suction temperature at which the compressor's mass flow matches the required flow.

If HOT-GAS-BYPASS = YES, then the suction group will use hot-gas bypass to maintain a minimum suction pressure, and CYCLE-COMPRESSORS will always be NO.

Note that, when CYCLE-COMPRESSORS = NO and HOT-GAS-BYPASS = NO, it may not be possible for the suction-group to find a balance point. The balance point calculation is most likely to fail if only one compressor exists and the compressor does not have any internal capacity control (unloaders, slide-valve, speed, etc.). In this

situation, the balance point temperature may be below the minimum point on the compressor capacity curve, or may be below the minimum temperature in the refrigerant table. A warning message will be issued if this situation arises.

HOT-GAS-BYPASS

accepts a code-word specifying whether hot-gas bypass will be used to maintain a minimum suction pressure. Acceptable entries are NO, the default, and YES.

HGB-SETPT

when HOT-GAS-BYPASS= YES, specifies the suction temperature below which the hot-gas bypass valve will open. The default is the bottom of the control setpoint throttling range.

HGB-SUCTION

when HOT-GAS-BYPASS=YES, specifies the suction circuit that accepts the bypassed hot gas. This circuit must feed into this suction group, and may be either a trunk or an upstream branch circuit (the program does not check this condition, and serious errors will result otherwise). If not specified, the hot-gas is assumed to bypass directly into the inlet of the suction group.

Specifying this suction circuit, together with a HGB-LIQUID circuit, allows the program to closely approximate hot-gas bypass control schemes that feed the hot gas into the inlet of an evaporator so that the gas can mix with and be desuperheated by the liquid refrigerant also feeding into the evaporator. The mass flow rate and refrigerant enthalpy of all circuits between this circuit and the suction group is increased accordingly, so that pressure drops and thermal losses can be accurately simulated.

HGB-LIQUID

when HOT-GAS-BYPASS=YES, specifies the liquid circuit that will be used to desuperheat the hot gas. Desuperheating the hot gas may be necessary to prevent compressor damage, and the program insists that bypassed gas be desuperheated.

HGB-SUPERHEAT-DT

when an HGB-LIQUID-CIRCUIT exists, specified the degrees of superheat above the suction temperature to which the hot gas will be desuperheated.

The following are miscellaneous inputs.

AUX-MODE

accepts a code-word specifying when theAUX-KW is consumed. The default is that there is no auxiliary power consumption

ALWAYS	indicates that the auxiliary power is consumed all hours.
WHEN-ON	indicates that auxiliary power is consumed only during the hours the suction group is operating.
WHEN-OFF	indicates that auxiliary power is consumed only during the hours the suction group is off.
SCHEDULED	indicates that the power consumption is scheduled.

AUX-KW

accepts a numeric value specifying an auxiliary electrical consumption, such as for a control panel. This is a required keyword when the AUX-MODE is specified.

AUX-SCH

when AUX-MODE = SCHEDULED, accepts a U-name of a schedule that varies the AUX-KW on an hourly basis.

AUX-METER

accepts the U-name of a meter that supplies the auxiliary energy.

COST-DATA

accepts the U-name of a MATERIALS-COST command. This command allows you to define first costs, maintenance costs, etc. for this suction group.

EQUIPMENT-REPORTS

accepts the codewords YES or NO. The default is YES. When report RS-H of the REFG-REPORTS is enabled, a report will print for this component unless this keyword is set to NO.

EQUIP-CTRL AND LOAD-MANAGEMENT

These are existing commands that has been extended for the refrigeration module to allow user control of compressors in suction-groups, and condensers on discharge circuits. Only the new features are discussed here.

As with boilers, chillers, etc. on circulation-loops and generators on electric meters, the program supports a heirarchy of control levels consisting of default controls, user-specified EQUIP-CTRL sequences, and LOAD-MANAGEMENT control sequences:

1. Default is the most basic level. For a suction group, the program surveys all attached compressors, and determines the mix of compressors that best matches the refrigerant flow (equipment fully loaded, but not overloaded). The default sequences assume the equipment may be mixed and matched in any fashion.

2. EQUIP-CTRL sequences are the next level of control. For a suction group, you can use an EQUIP-CTRL sequence to explicitly define the mix of compressors that the program will use to meet a given load. An EQUIP-CTRL sequence is dedicated to a specific suction group; if you have more than one suction group, you must specify separate EQUIP-CTRL sequences for each group. (Note, however, that you may specify an EQUIP-CTRL sequence for one suction group, and allow a different suction group to default.)

3. LOAD-MANAGEMENT sequences are the highest level of control. LOAD-MANAGEMENT sequences look at factors such as a schedule, outdoor temperature, or other factors and select the EQUIP-CTRL sequences to be used for each load. The LOAD-MANAGEMENT sequences act globally; they can simultaneously select EQUIP-CTRL sequences for suction groups, chillers on circulation loops, generators on electric meters, etc.

The same defaulting heirarchy applies to condensers on discharge circuits. While a discharge circuit will normally have only one condenser, the program supports multiple condensers.

SUCTION-GROUP keywords
EQUIP-CTRL
accepts the U-name of the EQUIP-CTRL sequence used to control the compressors attached to this suction group. There is no default.

If you do not specify this entry, then by default the program will select the compressor mix that best matches the hourly refrigerant flow. If a LOAD-MANAGEMENT command activates a different EQUIP-CTRL sequence for this suction group, then that sequence will override this locally defined EQUIP-CTRL sequence for that hour, and control will revert to the locally defined EQUIP-CTRL (or to default operation) for all other hours.

REFG-SYSTEM keywords
EQUIP-CTRL
accepts the U-name of the EQUIP-CTRL sequence used to control the condensers attached to this system. There is no default.

If you do not specify this entry, then by default the program will select the condenser mix that best matches the hourly refrigerant flow. If a LOAD-MANAGEMENT command activates a different EQUIP-CTRL sequence for

this system, then that sequence will override this locally defined EQUIP-CTRL sequence for that hour, and control will revert to the locally defined EQUIP-CTRL (or to default operation) for all other hours.

EQUIP-CTRL keywords

For completeness, all keywords relevant to refrigeration are presented here. Additional types of EQUIP-CTRL sequences for other components (circulation loops and electric meters) are described in other documentation. Please refer to that documentation for a complete discussion of EQUIP-CTRL and LOAD-MANAGEMENT sequences.

U-name accepts the U-name that all other commands will use to reference this control sequence. A unique entry is mandatory.

TYPE
accepts the U-name of the EQUIP-CTRL sequence used to control the compressors attached to this suction group. Acceptable entries include:

SUCTION-GROUP	specifies that this sequence will control COMPRESSORs to satisfy the refrigerant flow requirement of their SUCTION-GROUP.
CONDENSERS	specifies that this sequence will control CONDENSERs to satisfy the refrigerant flow requirement of a discharge trunk REFG-CIRCUIT.

Type = Suction-Group
The following group of keywords apply to compressors attached to a SUCTION-GROUP:

SUCTION-GROUP
accepts the U-name of the SUCTION-GROUP to which this control sequence will apply.

FLOWS-THRU-1
specifies the flow in lbs/hr for which the compressors specified in COMPRESSORS-1 will be used. If you do not specify this value, the program will default it to the hourly mass flow capacity of the compressors listed in COMPRESSORS-1. Since the capacity of compressors varies significantly with the entering and leaving refrigerant conditions, it is strongly recommended that you allow this entry to default.

COMPRESSORS-1
accepts a list of U-names of the compressors that will be used to match the flow listed under FLOWS-THRU-1. There is no default. The equipment listed must be attached to the same suction group as this EQUIP-CTRL sequence.

COMPRESSOR-SEQ-1
accepts a list of whole numbers (integer 1-10) corresponding to and enterend in the same order as the equipment listed in COMPRESSORS-1. These numbers specify the order in which the equipment will start to satisfy the load. The default is that the equipment will start in the order in which it is listed.

More than one equipment unit can have the same sequence number. for example, if two units are to always start and operate togheter, then they should both be given the same sequence number.

Equipment assigned sequence number 1 will start first, fowwed by 2, etc. The entry of equipment in COMPRESSORS-1 is not order dependent per se; equipment can be listed in any order, and COMPRESSOR-SEQ-1 numbers assigned in any order.

The EQUIP-CTRL algorithm will start as many equipment units required to meet the load. The flow per unit will be prorated based on that unit's capacity relative to the total capacity enabled (but see MAX-FLOW-1).

MAX-FLOW-1
accepts a list of values corresponding to and entered in the same order as the equipment listed in COMPRESSORS-1. These numbers specify the maximum flow that each equipment unit will be given. If not specified, the maximum flow will default to each unit's maximum hourly flow capacity. If specified, this value will act as an upper limit on each unit's flow.

Type = Refg-System
The following group of keywords applies to condensers attached to a REFG-SYSTEM:

REFG-SYSTEM
accepts the U-name of the refrigeration system to which this control sequence will apply.

FLOWS-THRU-1
specifies the flow in lbs/hr for which the condensers specified in CONDENSERS-1 will be used. If you do not specify this value, the program will default it to the hourly mass flow capacity of the condensers listed in CONDENSERS-1. Since the capacity of condensers varies significantly with ambient and condensing conditions, it is strongly recommended that you allow this entry to default.

CONDENSERS-1
accepts a list of U-names of the condensers that will be used to match the flow listed under FLOWS-THRU-1. There is no default. The equipment listed must be attached to the same refrigeration circuit as this EQUIP-CTRL sequence.

CONDENSER-SEQ-1
accepts a list of whole numbers (integer 1-10) corresponding to and entered in the same order as the equipment listed in CONDENSERS-1. These numbers specify the order in which the equipment will start to satisfy the load. The default is that the equipment will start in the order in which it is listed.

More than one equipment unit can have the same sequence number. for example, if two units are to always start and operate together, then they should both be given the same sequence number.

Equipment assigned sequence number 1 will start first, followed by 2, etc. The entry of equipment in CONDENSERS-1 is not order dependent per se; equipment can be listed in any order, and CONDENSER-SEQ-1 numbers assigned in any order.

The EQUIP-CTRL algorithm will start as many equipment units required to meet the load. The flow per unit will be prorated based on that unit's capacity relative to the total capacity enabled (but see MAX-FLOW-1).

MAX-FLOW-1
accepts a list of values corresponding to and entered in the same order as the equipment listed in CONDENSERS-1. These numbers specify the maximum flow that each equipment unit will be given. If not specified, the maximum flow will default to each unit's maximum hourly flow capacity. If specified, this value will act as an upper limit on each unit's flow.

LOAD-MANAGEMENT
The LOAD-MANAGEMENT command is used to specify the hourly mix of EQUIP-CTRL sequences that will be applied to the various CIRCULATION-LOOPs, ELEC-METERs, SUCTION-GROUPs, and REFG-

CIRCUITS. EQUIP-CTRL sequences set by the LOAD-MANAGEMENT command(s) will override any control sequences defined locally within each component.

This command can now specify EQUIP-CTRL sequences for refrigeration equipment via the existing keywords; there are no new inputs required.

Please refer to the existing documentation for information regarding this command and its uses.

HEAT RECLAIM FROM REFG-CIRCUIT TO HVAC SYSTEM

Many supermarkets and other facilities incorporating refrigeration systems may experience heating loads for all or a substantial portion of the year. In many instances, the heat available in the hot gas discharged from the refrigeration system compressor(s) can be readily recovered for space heating.

Heat recovery from refrigeration systems to HVAC space heating commonly employs several steps:

1. <u>De-superheat</u> - The hot gas may have a considerable amount (10-50%) of its heat available as superheat. A portion of the energy in the superheat can be recovered, even when the refrigerant's condensing temperature is less than the heating supply temperature. Recovery of superheat energy is commonly used as the first stage of heat recovery.

2. <u>De-superheat/condensing</u> - If the refrigerant's condensing temperature is greater than the heating supply temperature, then a portion of the refrigerant gas may condense, releasing its heat of vaporization. Recovery of some or all of the heat of fusion may also be part of the first stage of heat recovery.

3. <u>Forced condensation, holdback valve</u> - If the above processes do no yield enough heat, then a holdback valve can be used to force the refrigerant's saturated condensing temperature (and pressure) to be greater than the heating supply temperature. Depending on the size of the heat-recovery coil and the airflow, up to 100% of the refrigerant's latent heat of vaporization may be recovered in this fashion (Stage 2 heat recovery). Note that, because the compressors are now discharging to a higher pressure, compressor energy consumption increases.

4. <u>Forced condensation, condenser control</u> – The simplest and lowest first-cost method to recover latent heat from the refrigerant is to operate the condenser at a higher condensing temperature. For example, instead of controlling to an 85-95°F range, the condenser could be controlled to 115°F. The advantage of this approach is that the condenser size is smaller than it would be otherwise, and will consume less energy. However, such operation impacts all compressors in the system, and may result in a very large compressor energy penalty. To reduce the compressor energy penalty, the condensing setpoint may be reset according to the heat-reclaim load. A discussion of condenser heat-reclaim control strategies is found in the REFG-SYSTEM component.

The program will either desuperheat or condense refrigerant depending on the entering air temperature, the refrigerant entering temperature (superheat temperature), and the saturated condensing temperature. If the differential between entering air temperature and condensing temperature is sufficient to meet the load, then refrigerant will condense. Otherwise, if desuperheating provides a greater capacity, then desuperheating will occur instead.

More than one airhandler can reclaim heat from the same discharge circuit. In this case, heat reclaim is not prorated to each air handler, but instead is allocated in the order in which the airhandlers are defined. For example if two airhandlers are simultaneously recovering heat, the first air handler defined will have first priority on the hot gas, and the second air handler will use the remaining gas.

In addition, the facility may recover heat to a domestic water heater, or to a hot-water circulation loop *(future)*.

Discharge Circuit Keywords

The following keywords are part of the REFG-CIRCUIT component, for DISCHARGE circuits:

HOLDBACK-CTRL

specifies the control mechanism for the holdback valve. Note that no heat recovery is simulated if no heat-recovery demands are attached:

NONE
the default, specifies that there is no active holdback control. The heat-recovery coil(s) will operate primarily in the desuperheat mode, although refrigerant may also condense according to the coil and refrigerant conditions.

Note that, while this strategy assumes no holdback valve, it is possible to raise the setpoint of the condenser to the point where latent heat can be reclaimed. The condenser setpoint may be either fixed at a high value all hours, or may be reset according to the heat-reclaim load. Refer to the REFG-SYSTEM component for a discussion of condenser-level heat-reclaim control strategies.

ALWAYS
specifies that the holdback valve is active all hours of operation, independent of whether heat-recovery is actually required. HOLDBACK-SETPT specifies the control setpoint. This mechanism, while common, may force the compressors to operate at a higher discharge pressure than they might otherwise, at an additional energy cost.

ON/OFF
specifies that the holdback valve is active only when there is a heat-recovery demand on the circuit. HOLDBACK-SETPT specifies the control setpoint.

SCHEDULED
specifies that the holdback valve is operates according to a schedule of type ON/OFF/TEMP. An hourly value of 0 indicates that the valve is not active, and 1 indicates that it is active. Any other value will cause the valve to activate only when the outdoor air temperature is below the setpoint. HOLDBACK-SETPT specifies the control setpoint.

OA-RESET
specifies that the holdback valve is always active, and maintains a setpoint according to a reset schedule.

LOAD-RESET
specifies that the holdback valve activates only when there is a demand, and modulates so that the pressure upstream of the valve is just high enough to meet the worst-case heat recovery demand. This mechanism, while uncommon, is the most energy-efficient. The maximum allowable pressure is specified by the HOLDBACK-SETPT.

HOLDBACK-SETPT

when HOLDBACK-CTRL = ALWAYS, ON/OFF, or SCHEDULED, specifies the saturated condensing temperature setpoint of the holdback valve.

HOLDBACK-SCH

when HOLDBACK-CTRL = SCHEDULED, accepts the U-name of a SCHEDULE of type ON/OFF/TEMP to indicate when heat-recovery is active. An hourly value of 0 indicates that the valve is not active, and 1 indicates that it is active. Any other value will cause the valve to activate only when the outdoor air temperature is below the setpoint.

HOLDBACK-RESET-SCH

when HOLDBACK-CTRL = OA-RESET, accepts the U-name of a RESET-SCH that controls the setpoint of the holdback valve.

VALVE-DP

specifies the pressure drop through the holdback valve at the circuit's DESIGN-FLOW, when no heat-recovery is required (valve fully open). No valve loss is simulated if there are no attached heat-recovery demands.

The default pressure drop varies according to the HOLDBACK-CTRL. NONE assumes the system uses a 3-way diverting valve with a 5 psig pressure drop. All other modes (holdback modes) assume a 30 psig loss.

BYPASS-DP

for all holdback modes that can be inactivated (NONE, CYCLE-ON-DEMAND, SCHEDULED, LOAD-RESET), specifies the pressure drop through a valve that allows refrigerant to bypass the holdback valve when heat-recovery is inactive. Since a holdback valve typically has a high pressure drop even when fully open (necessary for controllability), this bypass valve allows the system to avoid the pressure penalty that would otherwise occur when heat reclaim is inactive (otherwise, the holdback valve is assumed to be fully open during inactive periods). An entry of 0.0 means that no bypass is simulated; any non-zero entry means bypass is simulated.

The default varies according to the type of control:

- ALWAYS and OA-RESET default to 0 psig, which means that a bypass is not simulated.

- All other modes (ON/OFF, SCHEDULED, LOAD-RESET) default to 5 psig.

SYSTEM Keywords

The next set of keywords are part of the SYSTEM command, and specify how DISCHARGE heat-recovery is used for space heating::

REFG-HTREC

accepts a code-word specifying whether heat recovery is available from a refrigeration system.

NO   the default, indicates that no heat recovery is available.

YES   indicates that heat recovery is available.

REFG-HTREC-CKT

when REFG-HTREC = YES, accepts the U-name of a DISCHARGE REFG-CIRCUIT that will provide recoverable heat for this system. A given system can recover heat from at most one refrigerant circuit; different systems may recover heat from the same or different systems.

REFG-HTREC-CAP

specifies the design capacity of the refrigerant heat-recovery coil. If not specified, the program will default this value to be the same as the HEATING-CAPACITY. This capacity is defined at a given temperature differential, REFG-HTREC-TD.

REFG-HTREC-TD

specifies the differential between the entering air temperature and the refrigerant saturated condensing temperature necessary to achieve the REFG-HTREC-CAP.

HTREC-SETPT (future)

if entered, specifies the setpoint of the air temperature leaving the heat recovery coil to which a 1-stage diverting valve or a 2-stage holdback valve will control. The leaving air temperature will be the lesser of this value or the required heating temperature.

The program also uses this variable to calculate the effective size of the heat-exchanger used to model the coil whend the HEAT-EXCHANGER:UA-PRODUCT is not specified.

HTREC-HX (future)
accepts the U-name of the HEAT-EXCHANGER the program will use to model the performance of the heat-recovery coil. When defined, the program will force the heat-exchanger to be of TYPE = REFG-GAS-TO-AIR for 1-stage heat recovery, and REFG-PHASE-TO-AIR for 2-stage heat recovery.

HTREC-AIR-DT (future)
specifies the design temperature rise of the air flowing through the heat-recovery coil. The program uses this value, together with the design air flow, to calculate the default REFG-HTREC-CAP.

Rules
The following rules apply to DISCHARGE heat-recovery:

1. Each component demanding heat-recovery, such as an airside SYSTEM or DW-HEATER, can attach to only one DISCHARGE circuit. Different components may attach to the same or different DISCHARGE circuits. Each DISCHARGE circuit may have any number of attached heat-recovery components.

2. The recoverable heat from a DISCHARGE circuit is allocated to the various components in the order in which the various components are simulated.

3. You may attach a heat-recovery demand to any DISCHARGE circuit, whether a trunk or branch. You may attach to any trunk circuit without restriction., or to any one DISCHARGE branch in a refrigeration system. You may also attach loads to more than one branch in a refrigerant system, as long as neither branch is downstream of the other. In other words, do not attach one heat-recovery load to a branch, and another load to a branch or trunk downstream of the first branch. Doing so may give erroneous results (the program may overestimate the recoverable heat). *The program does not check for this condition.*

CURVE-FIT

This is an existing command that provides for the input of performance data in the form of curves for varous components. The command now has several significant enhancements:

1. The command has been restructured to allow better handling of metric units for both independent and dependent variables.

2. The program additional input capabilities that allow bi-cubic equations to be specified for refrigeration compressors. Performance data in the form of bi-cubics are commonly published by compressor manufacturers. Note however, that only compressors can accept bi-cubic curves.

3. The program can now invert cubic and bi-cubic curves.

4. Maximum/minimum limits can be specified for both independent and dependent variables.

5. If the program needs to use the curve in a region outside of the operational map over which it was fit (defined by the maximum/minimum limits of the independent terms), the program will check to see if extrapolation is allowed. If so, the program will extrapolate in the region of the curve that is still well-behaved.

Because of these new features restructuring, virtually all of the keywords have been renamed or are new.

Because so many of the keywords are new or have been renamed, all keywords are presented here. The following describes the keywords in general terms; a table follows which presents all keywords by type. Also, many of the keywords have been assigned abbreviations that vary by TYPE; the user may use either the standard keyword name, or the specialized abbreviation.

TYPE
accepts a mandatory entry specifying the type of curve. The original unitless DOE-2.1E types are still supported. The newer DOE-2.2 types having independent variables with units are also supported, but in a different format. In additional there are new types having units on both the independent and/or dependent variables. The original curve types are:

LINEAR
specifies a linear curve in one independent variable. It has the form $f(r1) = c1 + c2*r1$, where c1 and c2 are the coefficients and r1 is a dimensionless variable.

BI-LINEAR
specifies a linear curve in two independent variables. It has the form $f(r1,r2) = c1 + c2*r1 + c4*r2$, where c1, c2, and c4 are coefficients and r1 and r2 are dimensionless variables. Note that a bi-linear curve is treated by the program as if it were bi-quadratic with zero coefficients on the non-linear terms. Thus 4 coeffients should be input for a bi-linear curve; with the 3rd coefficient c3 = 0.

QUADRATIC
specifies a 2nd order curve in one independent variable. It has the form $f(r1) = c1 + c2*r1 + c3*r1Y$, where c1, c2, and c3 are coefficients and r1 is a dimensionless variable.

BI-QUADRATIC
specifies a 2nd order curve in two independent variables. It has the form $f(r1,r2) = c1 + c2*r1 + c3*r1^2 + c4*r2 + c5*r2Y + c6*r1*r2$, where c1, c2, c3, c4, c5, and c6 are coefficients and r1 and r2 are dimensionless variables.

CUBIC

specifies a 3rd order curve in one independent variable. It has the form $f(r1) = c1 + c2*r1 + c3*r1Y + c4*r1Y$, where $c1$, $c2$, $c3$, and $c4$ are coefficients, and $r1$ is a dimensionless variable.

Most other curve types are identical to the 5 types described above, but instead of being dimensionless, have either independent and/or dependent variables with dimensions. They are defined as separate types for easy conversion between English and metric units, and to ensure that the dimensions are consistent with requirements of the program. These types are listed in the table below.

Two curve types are special for refrigeration compressors. Compressor manufacturers commonly report compressor mass flow and power quantities in a bi-cubic function of the saturated-suction temperature (SST) and saturated-discharge temperature (SDT). For types FLOW-FSST&SDT and PWR-FSST&SDT, the curves have the form:

$$f(SST,SDT) \quad = \quad c1 + c2*SST + c4*SST^2 + c7*SST^3 + (c3 + c5*SST + c8*SST^2) * SDT + (c6 + c9*SST) *SDT^2 + c10*SDT^3$$

Note that the program does not calculate fits for bi-cubic expressions. For these two types, only coefficients can be input.

Two additional TYPEs may have dimensions specified by the user. Currently, no keywords will accept a curve of either of these two types:

CUSTOM-F1

specifies a curve having custom units in one independent variable.

NUM-INDEPENDENTS
accepts a code-word specifying the number of independent variables the curve will have. This keyword is predefined for all TYPEs, and is not changeable by the user.

ONE-INDEPENDENT

specifies that the output variable is defined in terms of one independent variable (linear, quadratic, and cubic types).

TWO-INDEPENDENTS

specifies that the output variable is defined in terms of two independent variables (bi-linear, bi-quadratic, and the special compressor curves).

ORDER-OF-FIT
accepts a code-word specifying the order of the polynomial fit. This is a mandatory entry for most TYPEs, except for the 5 basic types defined above (LINEAR, BI-LINEAR, QUADRATIC, BI-QUADRATIC, CUBIC) for which this keyword is predefined.

LINEAR

specifies a linear fit. Depending on whether the TYPE utilizes one independent variable or two, the resulting curve is either linear or bi-linear.

QUADRATIC

specifies a quadratic, or second order, fit. Depending on whether the TYPE utilizes one independent variable or two, the resulting curve is either quadratic or bi-quadratic.

CUBIC

specifies a cubic, or third order, fit. The program does cubic fits only for curves having one independent variable; this option is not allowed for curves having two independent variables (bi-cubics).

INPUT-TYPE
accepts a code-word that specifies the type of data entry:

COEFFICIENTS	specifies that the curve's coefficients (c1 up to c10) are to be directly specified.
DATA	specifies that the program is to calculate the curve's coefficients based upon the data to be provided.

INPUT-UNIT-1
for the first or only independent variable in a curve having dimensions, specifies the number corresponding to the dimension in DOE-2's units table. This keyword is predefined and unchangeable for all TYPES except CUSTOM-F1 and CUSTOM-F2.

MIN-INPUT-1
for the first or only independent variable, specifies the minimum allowable value of the variable. This input is required for all curves having a 2nd or 3rd order fit (not required for linear). This requirement exists because the program may need to invert a curve (back out one of the independents variables as a function of the other independent, if any, and the dependent). When inverting, the program will normally find two possible answers for a 2nd order curve, and three for a 3rd order curve. The program chooses the correct answer on the basis of these limits or, if extrapolating beyond the limits, on the slope that exists between the limits.

Normally, this value should be the minimum value used in the original curve fit. If not specified, then the program will not limit the value of the input in the hourly simulation. If specified and EXTRAPOLATE = NO, then the program will not allow the input to drop below this value (i.e., the program will prevent extrapolation into a potentially inaccurate region of the curve). If specified and EXTRAPOLATE = YES, the program will allow extrapolation below this value, but will check to make sure that the curve does not extrapolate into a region where the slope of the curve has changed signs.

You should refer to EXTRAPOLATE for information on what happens if this value is exactly 0.0

MAX-INPUT-1
similar to MIN-INPUT-1, but specifies the maximum allowable value of the variable.

INPUT-UNIT-2
is like INPUT-UNIT-1, but is for the second independent variable, if any.

MIN-INPUT-2
is like MIN-INPUT-1, but is for the second independent variable, if any.

MAX-INPUT-2
is like MAX-INPUT-1, but is for the second independent variable, if any.

EXTRAPOLATE
accepts a code-word specifying whether the program should allow the curve to extrapolate beyond the input limits defined by MIN-INPUT-1, MAX-INPUT-1, MIN-INPUT-2, and MAX-INPUT-2.

NO	specifies that no extrapolation is allowed beyond the input limits. The program will limit the input variables to the specified maximum and minimum values.
YES,	the default, specifies that extrapolation is allowed beyond the specified maximum and minimum values. However, the program will check to ensure that the extrapolation is not so extreme that the slope of the curve changes sign (a change

in sign of the slope is a sure indication that the extrapolation is in an invalid region of the curve).

Most curves give excellent fits in the region over which they were created, but may or may not give reasonable results when extrapolated to new regions. Extrapolation of linear curves is generally safe, although not necessarily accurate. Extrapolation of quadratic curves may or may not be safe, and extrapolating on a cubic curve may be quite dangerous. The program will allow extrapolation beyond the input limits, but will refuse to extrapolate beyond the point at which the curve reverses direction.

There is one exception to the extrapolation rule. If MIN-INPUT-* is set to be exactly zero, then the program will not extrapolate that input variable to a value below zero. The program will still allow extrapolation above MAX-INPUT-*. and, for a curve with two independent variables, will allow extrapolation below the minimum value of the other independent. This restriction applies to MIN-INPUT-* only, no similar restriction applies to MAX-INPUT-*.

For example, consider a curve that calculates power consumption as a function of part-load ratio. If the MIN-INPUT-1 is 0.0, the MAX-INPUT-1 is 1.0, and EXTRAPOLATE = YES, then the program will allow the part-load ratio curve to extrapolate beyond 1.0, but will not allow extrapolation below 0.0. Changing the MIN-INPUT-1 to 0.01, -0.01, or some other non-zero value would the allow extrapolation to occur below this value, even into negative values of part-load ratio. Of course, if a negative part-load ratio is allowed, the curve might yield a negative power consumption!

OUTPUT-UNIT
is like INPUT-UNIT-1, but is for the dependent variable.

MIN-OUTPUT
for the dependent variable, specifies the minimum allowable value of the variable. This keyword is not required.

If not specified, then the program will not limit the value of the output in the hourly simulation. However, the output may still be limited by the limits placed on the independent variables, and whether those variables are allowed to EXTRAPOLATE.

If specified, then the program will limit the value of the output to this value, regardless of the value of EXTRAPOLATE.

In other words, the program may EXTRAPOLATE the independent variables and the resulting dependent value, but will never allow the dependent to exceed this keyword.

MAX-OUTPUT
is like MIN-OUTPUT, but is the maximum limit.

COEFFICIENT-UNITS
for curves having dimensional inputs and/or outputs, accepts a code-word that specifies whether the curves are defined in English or metric units:

ENGLISH   the default, specifies that the curve coefficients are based on English input and output units, and do not have to be translated by the program. English users of the program should never change this keyword!   If you are creating your input in metric, the program will first convert the metric input and output variables to English units, and create a curve having English coefficients.

METRIC   specifies that the curve coefficients are based on metric input and output units, and produce an output also in metric units. When using a curve of this type, the

program will convert the hourly input values from English to metric, feed them into the curve to produce a metric output value, and then convert the metric output back into English for use in the program.

Metric users may specify that curve coefficients be either English or metric. English coefficients execute slightly faster than metric, as the program does not have to do any hourly conversion of input and output variables. However, you may prefer using curves with metric coefficients because they are more intuitive, or because you are using coefficients provided directly by an equipment supplier, and those coefficients are in metric units.

If you store a metric curve in the library, be sure to specify this keyword; otherwise the program will assum the curve has English units, even if in a metric library! This is because the program authors assume that a metric library will include the existing default performance curves for equipment, all of which have English coefficients, and that these English curves will comprise the majority of curves in the library.

COEFFICIENTS
when INPUT-TYPE = COEFFICIENTS, accepts a list of up to 10 coefficients – these correspond to c1 - c10 in the description of the keyword TYPE above. If too few coefficients are entered for a given curve TYPE, an error message will be issued. If too many are entered, the extra values will be ignored.

INPUT-1
when INPUT-TYPE = DATA, accepts a list of up to 20 data points for the first or only independent variable. (DOE-2 will fit a curve of the specified TYPE through the points, arriving at a set of coefficients).

INPUT-2
when INPUT-TYPE = DATA, and the TYPE utilizes two independent variables, accepts a list of up to 20 data points for the second independent variable. This list must have a one-to-one correspondence to the variables listed in INPUT-1.

OUTPUT
when INPUT-TYPE = DATA, accepts a list of up to 20 data points for the dependent variable. This list must have a one-to-one correspondence to the variables listed in INPUT-1 and INPUT-2.

The following tables summarize the different curve types, their units, and special abbreviations.

Table 1 Curve-Fit Keywords by TYPE

TYPE	LINEAR	BI-LINEAR	QUADRATIC	BI-QUADRATIC
INPUT-UNIT-1	*	*	*	*
MIN-INPUT-1	MIN-1	MIN-1	MIN-1	MIN-1
MAX-INPUT-1	MAX-1	MAX-1	MAX-1	MAX-1
INPUT-UNIT-2	*	*	*	*
MIN-INPUT-2	*	MIN-2	*	MIN-2
MAX-INPUT-2	*	MAX-2	*	MAX-2
OUTPUT-UNIT	*	*	*	*
MIN-OUTPUT	MIN-OUT	MIN-OUT	MIN-OUT	MIN-OUT
MAX-OUTPUT	MAX-OUT	MAX-OUT	MAX-OUT	MAX-OUT
INPUT-1	INPUT	INPUT-1	INPUT	INPUT-1
INPUT-2	*	INPUT-2	*	INPUT-2
OUTPUT	OUTPUT	OUTPUT	OUTPUT	OUTPUT

TYPE	CUBIC	RATIO-FT	RATIO-FT&T	RATIO-FDT
INPUT-UNIT-1	*	F or C	F or C	F(delta) or C(delta)
MIN-INPUT-1	MIN-1	MIN-T	MIN-T1	MIN-DT
MAX-INPUT-1	MAX-1	MAX-T	MAX-T1	MAX-DT
INPUT-UNIT-2	*	*	F or C	*
MIN-INPUT-2	*	*	MIN-T2	*
MAX-INPUT-2	*	*	MAX-T2	*
OUTPUT-UNIT	*	Frac or Mult	Frac or Mult	Frac or Mult
MIN-OUTPUT	MIN-OUT	MIN-RAT	MIN-RAT	MIN-RAT
MAX-OUTPUT	MAX-OUT	MAX-RAT	MAX-RAT	MAX-RAT
INPUT-1	INPUT	T	T-1	DT
INPUT-2	*	*	T-2	*
OUTPUT	OUTPUT	RATIO	RATIO	RATIO

TYPE	RATIO-FDT&T	RATIO-FT&RATIO	RATIO-FRATIO&T	RATIO-FRATIO
INPUT-UNIT-1	F(delta) or C(delta)	F or C	Frac or Mult	Frac or Mult
MIN-INPUT-1	MIN-DT	MIN-T1	MIN-RAT1	MIN-RAT1
MAX-INPUT-1	MAX-DT	MAX-T1	MAX-RAT1	MAX-RAT1
INPUT-UNIT-2	F or C	Frac or Mult	F or C	*
MIN-INPUT-2	MIN-T	MIN-RAT2	MIN-T2	*
MAX-INPUT-2	MAX-T	MAX-RAT2	MAX-T2	*
OUTPUT-UNIT	Frac or Mult	Frac or Mult	Frac or Mult	Frac or Mult
MIN-OUTPUT	MIN-RAT	MIN-RAT	MIN-RAT	MIN-RAT
MAX-OUTPUT	MAX-RAT	MAX-RAT	MAX-RAT	MAX-RAT
INPUT-1	DT	T	RATIO-IN	RATIO-IN
INPUT-2	T	RATIO-IN	T	*
OUTPUT	RATIO	RATIO	RATIO	RATIO

TYPE	RATIO-FRATIO&RATIO	FLOW-FSST&SDT	PWR-FSST&SDT	DENS-FT*PCT
INPUT-UNIT-1	Frac or Mult	F or C	F or C	F or C
MIN-INPUT-1	MIN-RAT1	MIN-SST	MIN-SST	MIN-T
MAX-INPUT-1	MAX-RAT1	MAX-SST	MAX-SST	MAX-T
INPUT-UNIT-2	Frac or Mult	F or C	F or C	PERCENT
MIN-INPUT-2	MIN-RAT2	MIN-SDT	MIN-SDT	MIN-PCT
MAX-INPUT-2	MAX-RAT2	MAX-SDT	MAX-SDT	MAX-PCT
OUTPUT-UNIT	Frac or Mult	LB/HR or KG/HR	KW	LB/CUFT or KG/M3
MIN-OUTPUT	MIN-RAT	MIN-FLOW	MIN-PWR	MIN-DENS
MAX-OUTPUT	MAX-RAT	MAX-FLOW	MAX-PWR	MAX-DENS
INPUT-1	RATIO-1	SST	SST	T
INPUT-2	RATIO-2	SDT	SDT	PCT
OUTPUT	RATIO	FLOW	POWER	DENS

TYPE	VISC-FT&PCT	COND-FT&PCT	CP-FT&PCT	CUSTOM-F1
INPUT-UNIT-1	F or C	F or C	F or C	UNIT-IN
MIN-INPUT-1	MIN-T	MIN-T	MIN-T	MIN-IN
MAX-INPUT-1	MAX-T	MAX-T	MAX-T	MAX-IN
INPUT-UNIT-2	PERCENT	PERCENT	PERCENT	*
MIN-INPUT-2	MIN-PCT	MIN-PCT	MIN-PCT	*
MAX-INPUT-2	MAX-PCT	MAX-PCT	MAX-PCT	*
OUTPUT-UNIT	CENTIPOISE or mPa-Sec	LB/CUFT or KG/M3	BTU/LB-F or J/KG-K	UNIT-OUT
MIN-OUTPUT	MIN-VISC	MIN-DENS	MIN-CP	MIN-OUT
MAX-OUTPUT	MAX-VISC	MAX-DENS	MAX-CP	MAX-OUT
INPUT-1	T	T	T	INPUT
INPUT-2	PCT	PCT	PCT	*
OUTPUT	LOG-VISC	DENS	CP	OUTPUT

TYPE	COP-FSST&SDT	T-FHOURS	RATIO-FHOURS	T-FPCT
INPUT-UNIT-1	F or C	HOURS	HOURS	PERCENT
MIN-INPUT-1	MIN-SST	MIN-HRS	MIN-HRS	MIN-PCT
MAX-INPUT-1	MAX-SST	MAX-HRS	MAX-HRS	MAX-PCT
INPUT-UNIT-2	F or C	*	*	*
MIN-INPUT-2	MIN-SDT	*	*	*
MAX-INPUT-2	MAX-SDT	*	*	*
OUTPUT-UNIT	Ratio (COP)	F or C	Frac or Mult	F or C
MIN-OUTPUT	MIN-COP	MIN-T	MIN-RAT	MIN-T
MAX-OUTPUT	MAX-COP	MAX-T	MAX-RAT	MAX-T
INPUT-1	SST	HOURS	HOURS	PCT
INPUT-2	SDT	*	*	*
OUTPUT	COP	T	RATIO	T

TYPE	DENS-FT	VISC-FT	COND-FT	CP-FT
INPUT-UNIT-1	F or C	F or C	F or C	F or C
MIN-INPUT-1	MIN-T	MIN-T	MIN-T	MIN-T
MAX-INPUT-1	MAX-T	MAX-T	MAX-T	MAX-T
INPUT-UNIT-2	*	*	*	*
MIN-INPUT-2	*	*	*	*
MAX-INPUT-2	*	*	*	*
OUTPUT-UNIT	LB/CUFT or KG/M3	CENTIPOISE or mPa-Sec	LB/CUFT or KG/M3	BTU/LB-F or J/KG-K
MIN-OUTPUT	MIN-DENS	MIN-VISC	MIN-DENS	MIN-CP
MAX-OUTPUT	MAX-DENS	MAX-VISC	MAX-DENS	MAX-CP
INPUT-1	T	T	T	T
INPUT-2	*	*	*	*
OUTPUT	DENS	LOG-VISC	DENS	CP

TYPE	RATIO-FVISC	RATIO-FRATIO&DT		
INPUT-UNIT-1	Centistoke	Frac or Mult		
MIN-INPUT-1	MIN-VISC	MIN-RAT1		
MAX-INPUT-1	MAX-VISC	MAX-RAT1		
INPUT-UNIT-2	*	F or C (delta)		
MIN-INPUT-2	*	MIN-DT2		
MAX-INPUT-2	*	MAX-DT2		
OUTPUT-UNIT	Frac or Mult	Frac or Mult		
MIN-OUTPUT	MIN-RAT	MIN-RAT		
MAX-OUTPUT	MAX-RAT	MAX-RAT		
INPUT-1	VISC	RATIO-IN		
INPUT-2	*	DT		
OUTPUT	RATIO	RATIO		

HVAC Equipment

OVERVIEW OF SIMULATION

Introduction

As part of the refrigeration additions, it was necessary to restructure the HVAC portions of the program, including the water-side components. Some of the keywords are new, others were revised to have new meanings, and others were eliminated or replaced.

The most significant change is not readily apparent to the user. The previous DOE-2.2 HVAC modules are not iterative. However, the new refrigeration module must interact intimately with the plant equipment in order to simulate secondary coolants, refrigeration heat reclaim, water-cooled condensers, etc. Because the refrigeration calculations are iterative, it is necessary that the water-side also be iterative. This iterative interaction required the water-side program to be entirely rewritten.

At the time of this release, the new water-side structure is in place, but the majority of DOE-2.2 plant components have not been ported into the new structure. Components will be converted to the new structure as time and funding permit. *However, the majority of the water-side is not yet operational.*

Operational Components

At the time of this release, the following HVAC components are operational:

- Air-side Components – All SYSTEM and ZONE features contained in the initial DOE-2.2 release are unmodified and fully functional. Features added after the intial release, such as enthalpy heat-recovery wheels, ice rinks, and photovoltaics, will be ported in the future as time and funding permit.

- Circulation-loops – Only the new secondary coolant loops are operational. The new structure permits the simulation of brine coolants, including the impact of brines on pumping power and heat-transfer.

- Pumps – fully operational

- Chillers – only the new REFG-HX chiller is operational.

- Equip-Ctrl – fully implemented, but restructured to allocate flows instead of loads. New types for compressors and condensers.

- Load-Management – fully implemented, no change from before.

- <u>Meters</u> – A new METER component replaces the previous ELEC-METER, FUEL-METER, STEAM-METER, and CHW-METER components. For electric meters only, the previous program provided for 3 levels of metering (UTILITY, BUILDING, SUB-METER). The new structure allows for an unlimited number of levels, for any type of energy.

CIRCULATION-LOOP

What's New

- <u>Iterative structure</u> - This component has been completely rewritten to support the new temperature and pressure-based iterative structure.

- <u>Brines</u> – Glycol and brine solutions running below 32°F can now be simulated. The program models both their effect on pumping energy as well as their effect on heat transfer surfaces in coils and chillers.

- <u>Refrigerant-to-water heat-exchanger</u> – In industrial applications, brines are commonly cooled via a heat-exchanger coupled to a refrigeration system. The program incorporates a new chiller type to accommodate this process.

Pump Operation

DOE-2.2 represented a major improvement over previous program versions in terms of pump simulation capabilities. However, the non-iterative approach taken by DOE-2.2 restricted the ability of the program to calculate pump pressures at all points in the system. DOE-2.3 has lifted this restriction, and pump pressures are now calculated iteratively at all points throughout the distribution system. While the impact on user-required input in minimal, the ramifications during simulation can be significant:

- The capacity of a coil can now be restricted by the available pressure differential across the coil. For example, if the fluid flow necessary to meet the coil load requires a differential pressure of 15' of head, but only 11' are available, then the coil flow will be less than required.

- The capacity of a chiller or other plant component can now be restricted by the available pressure differential across the chiller. For example, if the design flow of a chiller requires 20' of head, and only 15' of head is available, then the flow will be reduced accordingly. For a given setpoint at the chiller outlet, the chiller's thermal capacity will also be reduced.

- DOE-2.2 assumed that the pump would always be able to meet the flow/head requirements created by the loads, and would simply warn you when the requirements could not be met. DOE-2.3 will iterate until it finds the balance point between coil flows, pressure differentials, pressure drops in the distribution piping, pressure drops and temperatures at the plant components, and pump performance. Coil capacities will vary accordingly, and additional chillers or other plant components may be turned on in parallel in order to reduce the pressure drop across these components in order to free up more head for the loads.

All of the above comments apply to new coils only. The existing SYSTEM and ZONE coils that use the DOE-2.2 structure are decoupled on the air-side and water-side, and are unchanged from DOE-2.2.

PUMP-LOCN
when the plant has pumps, accepts a code word specifying the location of the pump:

SUPPLY-SIDE	specifies that the pump is located at the supply-side of the plant, downstream of the plant components, at the outlet to the supply circuits.
RETURN-SIDE	specifies that the pump is located on the return-side of the plant, upstream of the plant components.

The default varies according to the type of plant. For CHW, PIPE2, WLHP and CW plants, the pump is on the supply side. Since the plant temperature setpoint is assumed to be the fluid temperature at the outlet of the plant, the equipment setpoint will be reduced by the amount of pump heat added (usually a very small effect). For HW plants, the pump is often located in the return, upstream of the boilers, to reduce the possibility of cavitation in the pump inlet (since hot fluids cavitate at a lower pressure then cold fluids), and to allow the motor to run at a lower temperature. For DHW plants, the pump is normally located in the return, and acts only on the recirculated fluid. If located in the DHW supply, then the program will size the pump for the full flow, not the recirculated flow.

Piping Thermal Losses (untested)

DOE-2.3 simplifies the specification of thermal losses in piping, when the design criteria is temperature losses rather than UA products.

SUPPLY-LOSS-DT

accepts a value that defines the supply fluid temperature change due to thermal losses from the piping to its environment. For a circuit that is warmer than its environment at the design conditions (heating type loops), the circuit will loose heat, and this value should be negative. Conversely, a circuit that is colder than its environment will gain heat, and this value should be positive.

This temperature change is assumed to occur when the loop is at its design flow, and should also be consistent with SUPPLY/ENVIR-DT.

This keyword is an alternative to specifying the LOOP-SUPPLY-UA. If both are input, this keyword is ignored.

The value represents the average temperature change due to losses of all fluid delivered. In actual systems, coils further from the central plant (on longer pipe runs) will normally experience larger losses than coils closer to the central plant.   This effect is not explicitly modeled.

PowerDOE uses this value to calculate a supply piping UA product at the design conditions. This UA is used to calculate the hourly losses as previously described.

For loops that can provide both heating and cooling (two-pipe or water-loop heat-pump), this keyword may represent either the heating or cooling condition, as long as it is consistent with the SUPPLY/ENVIR-DT.   In other words the two keywords should represent either the cooling condition, or the heating condition.

Through experimentation, you may find that the overall HVAC energy consumption is relatively sensitive to the loop losses. This may be especially true for a system with a large number of distributed coils, such as reheat systems. In these cases, it is essential that you input an accurate value for the pipe loss.

SUPPLY/ENVIR-DT

this is a new keyword used in the design calculations for supply piping thermal losses. It is the design temperature difference between the temperature of the fluid entering the supply piping and the environment. Its sign should be consistent with the SUPPLY-LOSS-DT. For example a loop that is warmer than its environment should have a positive value for this keyword and, because it is loosing heat, should have a negative value for LOOP-SUPPLY-DT.

RETURN/ENVIR-DT

this keyword is identical to the SUPPLY/ENVIR-DT, but is for the return piping.

HEATING-ENVIR-T   has been superseded by SUPPLY-ENVIR-DT and RETURN-ENVIR-DT

COOLING-ENVIR-T   has been superseded by SUPPLY-ENVIR-DT and RETURN-ENVIR-DT

~~LOSSES-BASED-ON~~   has been superseded by SUPPLY-ENVIR-DT and RETURN-ENVIR-DT

Design Fluid Temperatures

In previous versions of the program, the HEAT-SETPT-T and COOL-SETPT-T also doubled as the design temperatures. This could cause a problem if you wanted the design temperatures to be different than the operating setpoints; you would have to define schedules for the setpoints, even if the setpoints were constant all year.

DESIGN-HEAT-T

specifies the design heating supply temperature of the fluid leaving the plant, entering the distribution circuits. Prior to entering the coils or other loads, this temperature will be modified by any thermal losses that may accrue.

In previous program versions, the HEAT-SETPT-T also doubled as the design temperature. This is no longer the case.

DESIGN-COOL-T

specifies the design cooling supply temperature of the fluid leaving the plant, entering the distribution circuits. Prior to entering the coils or other loads, this temperature will be modified by any thermal losses that may accrue.

In previous program versions, the COOL-SETPT-T also doubled as the design temperature. This is no longer the case.

While a circulation loop normally expects there to be one or more attached primary equipment components (boilers, chillers, etc.), you do not have to specify any primary equipment. In this case, the loop will always operate at the supply temperature and pressure setpoints, and the heating or cooling load will simply disappear without the expenditure of any primary equipment energy. This feature can be useful if you are in the process of constructing a system, and would prefer to specify the primary equipment after you know more about the design loads and system operating characteristics.

The same is true for a pump: If no primary equipment is specified, then no pump need be specified.

MAX-RESET-T when using a LOAD-RESET control sequence, specifies the maximum allowable temperature, for both heating and cooling loops.

MIN-RESET-T when using a LOAD-RESET control sequence, specifies the minimum allowable temperature, for both heating and cooling loops.

Series and Parallel Operation (future)

Previously, circulation loops could only simulate multiple equipment components operated in parallel. Now the program can simulate 2 components in series, as well as two or more components in parallel, in series with two or more components in parallel. This latter arrangement can approximate the operation of two components in series, in parallel with another two components in series.

For example, the program can now simulate a WLHP plant containing a cooling tower in series with a ground-loop heat-exchanger. For WLHP systems, this configuration may be necessary for buildings that are cooling dominated. Otherwise, the ground may saturate with heat after a few years of operation, and the resulting high ground temperature could seriously degrade the cooling capacity and energy efficiency of the WLHP units.

Modeling two chillers in series is now straightforward. In addition the program can approximate the operation of two chillers in series, in parallel with an additional two chillers in series, possibly in parallel with an additional two chillers in series, etc. Please refer to the examples for more information on how components may be configured.

A keyword now exists in the various plant components (chillers, etc.) that specifies the location of the component relative to the other components in a plant. By default, the configuration is PARALLEL, which simulates the only configuration that was available previously.

SERIES-SETPT-RAT

when equipment is configured in series, specifies the ratio of the difference between the upstream equipment setpoint and the return water temperature, to the difference between the downstream equipment setpoint and the return water temperature, or

$$Ratio = (Tsetpt\_Upstream - Treturn) / (Tsetpt\_downstream - Treturn)$$

By default, the program will calculate the setpoint to be the setpoint required to evenly load both the upstream and downstream equipment, when both are required to operate to meet the load. For example, if two chillers of equal size are in series, then the ratio will default to be 0.5 when both chillers are operating. If the return water temperature is 55, and the desired supply temperature is 45°F, then the setpoint for the upstream chillers will be 50°F, and the setpoint for the downstream chillers will be 45°F. Please refer to the examples for more details.

Brines

The program can now simulate glycol and brine solutions. While primary intended for use below 32°F, the algorithm can account for the effect of brine at any temperature.

The fluid properties of a brine can differ markedly from pure water: The viscosity of a brine is typically higher than water, while the specific heat, conductivity, and density are usually lower. In addition, the properties, particularly viscosity, change with both concentration and temperature. For example, propylene glycol acts similarly to Jello at very low temperatures.

The performance of heat transfer surfaces can be significantly degraded in a brine system. This applies to chillers as well as coils. The program takes these effects into account *(but not in the previously existing air-side coils)*.

Typically, pumping costs are greater in a brine system. The increased fluid viscosity, coupled with a lower density and specific heat, results in significantly higher friction losses. A portion of these losses can be offset by increasing the size of the piping. However, this is not practical in chillers or coils because of the tendency of the fluid to transition into laminar flow at relatively high part-load flows. Instead, velocities may actually need to be increased to avoid laminar flow, which increases head losses.

All pressure drops and performance characteristics for chillers, coils, and piping are normally specified relative to *pure water at the average operating temperature*. If desired, you may specify another rating condition, however all components should then be specified relative to that condition. The program will adjust the performance for the specific brine, concentration, and operating temperature.

Actual Fluid

The following keywords define the fluid actually used in the plant:

FLUID

Specifies the U-name of the FLUID component defining the properties of the fluid in this loop. DOE-2 has several predefined FLUIDs in the library:

| WATER | the default, is pure water. |

| ETHYLENE-GLYCOL | specifies ethylene glycol. |

| PROPYLENE-GLYCOL | specifies propylene glycol. |

You may define other FLUIDs and use them in lieu of these.

FREEZING-T

for fluids other than WATER, is the design freezing temperature of the brine. If specified, the program will calculate the required brine concentration. The program will issue a warning if the plant operating temperature is below this value.

FLUID-CONC

for fluids other than WATER, and as an alternative to specifying the FREEZING-T, you may specify the brine concentration as in terms of either the percentage by volume, or the percentage by weight. This entry is a percentage, and as such has a range of 0-100%.

The predefined glycols in the library assume the concentration is in terms of the *percent by volume*. In the future, if brines are added to the library, they will be specified in terms of the *percent by weight*. If you define a new fluid, you may use either definition as long as your input is consistent.

Rated Fluid

The following keywords define the fluid for which the performance of the piping, coils, chillers, etc. are rated. The program will correct the rated values to match the actual fluid conditions. For example, if the rated head of a coil is 20', the rated fluid is pure water, and the actual fluid is propylene glycol, then the program may determine that the actual head of the coil is 28'.

RATED-FLUID

accepts the U-name of the fluid for which the performance of the piping, coils, chillers, etc. are rated. The default is WATER, however any fluid is acceptable.

RATED-FLUID-CONC

for fluids other than WATER, is the brine concentration expressed as either the percentage by volume, or the percentage by weight. As this entry is a percentage, it has a range of 0-100%.

The predefined glycols in the library assume the concentration is in terms of the *percent by volume*. In the future, if brines are added to the library, they will be specified in terms of the *percent by weight*. If you define a new fluid, you may use either definition as long as your input is consistent.

RATED-FLUID-T

is the temperature of the rated fluid at which the performance of the piping, coils, chillers, etc. is rated

FLUID-RELATIONS

accepts a code-word specifying the level of detail of the hourly calculations:

| FAST | specifies that the program calculates all fluid properties during the design calculations, and does not modify them hourly. |
| DETAILED | specifies that the program re-calculates all fluid properties hourly. This mode is the most accurate method, but takes more calculation time. You should only specify |

this mode if the fluid properties vary significantly over the operating temperature range of the fluid.

For WATER, you should let the program use the FAST mode, except possibly for 2-pipe loops. Here, the loop temperature may vary 100°F or more in the heating vs. cooling mode. Most brines or glycols can also use the FAST mode. PROPYLENE-GLYCOL operating below 0°F should use the DETAILED mode, as the viscosity varies significantly over just a few degrees.

Piping Head Losses

the next set of keywords describe the design head losses, and parameters that allow the program to calculate the hourly head losses as a function of flow and fluid properties.

PIPE-HEAD
is the design head loss of the piping, assuming the RATED-FLUID at the RATED-FLUID-CONC and RATED-T. The program will correct the hourly head as a function of the actual fluid conditions and flow.

PIPE-MATERIAL
accepts the U-name of the piping material. The program assumes a piping roughness based on this entry. Acceptable entries are

COPPER/PLASTIC

WROUGHT-STEEL/IRON

GALVANIZED-STEEL/IRON

CAST-IRON

PIPE-ROUGHNESS
in lieu of specifying the PIPE-MATERIAL, you may directly specify the relative roughness of the piping.

PIPE-DIAMETER
is the typical diameter of the piping in the system. The program uses this value in calculating a Reynold's number and the piping friction factor.

FLUID-VELOCITY
is the typical design velocity of the piping in the system. The program uses this value in calculating a Reynolds's number and the piping friction factor.

Secondary Coolant Loops

The program incorporates a new type of circulation loop intended to model secondary coolant loops (loops using a brine and operating at very low temperatures). This type of loop is almost identical to the existing chilled water loop. The only difference is that the program assumes that the chiller that provides the cooling to the loop rejects its energy to a refrigeration system. In other words, the chiller is a water-to-refrigerant heat exchanger (a CHILLER of TYPE = REFG-HX). For iterative efficiency, this loop is simulated at a different point than conventional chilled water loops.

REFG-CHW   is similar to a chilled-water loop (CHW), but is assumed to operate at below freezing temperatures. While you can attach any type of cooling load or chiller to this loop, the program assumes that the loop is normally cooled by a refrigeration

system, and its order in the iterative sequence is optimized for this application.

See the writeup on the CHILLER:TYPE = REFG-HX for more information on secondary coolant systems.

EQUIP-CTRL

DOE-2.2 had two keywords for the default user-specified equipment control sequences, HEAT-EQUIP-CTRL and COOL-EQUIP-CTRL. Because the equipment allocations are now based on flow instead of thermal load, it is not necessary to distinguish between heating and cooling modes. For dual-mode loops (2-pipe and water-loop heat-pump), heating and cooling equipment may be specified in the same EQUIP-CTRL sequence; cooling equipment will be automatically disabled (zero flow capacity) when in the heating mode, and vice versa.

EQUIP-CTRL

accepts the U-name of an EQUIP-CTRL command that specifies the control of the primary equipment attached to this loop. If not defined, the program will select the combination of equipment whose capacity best matches the flow on an hourly basis. An EQUIP-CTRL sequence specified here may be overridden by a different EQUIP-CTRL sequence selected by a LOAD-MANAGEMENT instruction on either a time, temperature, or load basis. Refer to theLOAD-MANAGEMENT documentation for more information.

CHILLER

Series vs. Parallel (future)

Previously, a plant having multiple chillers could only have the chillers operated in parallel. Now the chillers can be operated in series.

CONFIGURATION

accepts a code-word specifying the configuration of the equipment within the plant:

PARALLEL   the default, specifies that this component is to be configured in parallel with any other equipment in the plant.

SERIES-UPSTREAM   specifies that this component is to be configured in series with other component(s), and is to be located upstream of the other component(s). More than one component may be located at the SERIES-UPSTREAM point. If so, all equipment at this point is in parallel with each other, and in series with the downstream equipment.

SERIES-DOWNSTREAM   specifies that this component is to be configured in series with other component(s), and is to be located downstream of the other component(s). More than one component may be located at the SERIES-DOWNSTREAM point. If so, all equipment at this point is in parallel with each other, and in series with the upstream equipment.

Refrigerant-powered Chiller

The program now allows chilled water to be generated via a refrigerant-to-water heat-exchanger. This heat-exchanger draws its refrigerant from a refrigeration system. From the perspective of the central plant, this heat-exchanger has all of the properties of a chiller, and in fact is defined via the CHILLER command. Its temperature is controlled via the temperature setpoint of its plant, its operation may be coordinated with other chillers and/or chilled-water meters via one or more EQUIP-CONTROL sequences, and it may (or may not) have its own evaporator pump.

This chiller type is most commonly used to provide chilled glycol to a secondary coolant loop, but may in fact be used the same as any other chiller.

This component shares many of the same keywords as other chiller types. All applicable keywords are described below.

U-name (=)

accepts an mandatory entry for the U-name of this chiller. This U-name will be used in the heading of the chiller report to identify the chiller

TYPE

accepts a code-word that specifies the type of chiller.

REFG-HX   specifies a refrigerant-to-water heat-exchanger.

CAPACITY
the size of the chiller.

If you do not specify this keyword, the capacity will default to the plant capacity, adjusted by the CAPACITY-RATIO. If no CAPACITY-RATIO is input, then the capacity will default to the plant capacity, divided by the number of chillers attached to the plant.

CAPACITY-RATIO
when CAPACITY is defaulted, accepts a numeric value that indicates the fraction of the design plant capacity that this chiller will be sized to meet. There is no default.

If you are defining two chillers of identical size that should just meet the design plant load, then CAPACITY-RATIO should be set to 0.5 in each chiller definition. If you want to include a 20% safety factor in each chiller, then the CAPACITY-RATIO of each chiller is 0.6.

If you do not specify either the CAPACITY or the CAPACITY-RATIO, then the capacity will default to the plant capacity, divided by the number of chillers attached to the plant.

Central Plant Relationships
The next set of keywords describe how this chiller is attached to a chilled-water plant. This chiller may attach to either a conventional CHW plant, or a REFG-CHW secondary coolant plant. If the chiller has a dedicated pump in a recirculation loop, the pump is attached to the chiller from within the chiller command.

CHW-PLANT
accepts the U-name of the primary CHW plant to which this chiller is attached.

CHW-PUMP
accepts the U-name of a PUMP directly attached to the chiller's evaporator. Normally, this pump will be a recirculation pump that acts to decouple the flow of the chiller from the plant. In this case, the pump may be either CONSTANT-FLOW or VARIABLE-FLOW, and eliminates the chiller evaporator head requirement from the primary loop.

If the plant does not have its own pumps, then this pump will also power the loop(s) leaving the plant. In this case, the head of this pump will be the sum of the design plant head (including static head), and the chiller's evaporator head. The hourly flow of the pump (and chiller) will be determined based on the loop flow and the number of other chillers running (CHW-FLOW-CTRL does not apply in this case). This subject is relatively complex, and you should refer to ??? for a more complete discussion.

CHW-DT
accepts a numeric value specifying the design temperature change of the chilled water through the chiller. The default is the LOOP-DESIGN-DT of the chilled-water plant.

The program uses this keyword to size the recirculation pump, if any, on the evaporator. If no recirculation pump exists, then the flow through the chiller is based on the LOOP-DESIGN-DT.

CHW-HEAD
accepts a numeric value specifying the head loss through the chiller at design flow. .

CHW-STATIC-HEAD
accepts a numeric value specifying the static head of the chiller.

CHW-FLOW-CTRL

accepts a code-word specifying the type of flow through the chiller evaporator. This keyword applies only if the chiller has a CHW-PUMP, and the pump is acting as a recirculation pump. If the pump is also powering the plant, this keyword is ignored.

CONSTANT-FLOW   the default, specifies that the evaporator flow is constant, and independent of the flow the chiller actually delivers to the plant.

VARIABLE-FLOW   indicates that the evaporator flow varies with the flow the chiller actually delivers to the plant. While many manufacturers recommend that the flow through the evaporator be constant, others have incorporated controls that allow the chiller to operate safely with variable flow.

Note that, if the plant flow is constant, then the chiller flow will also be constant.

For a chiller serving a low-temperature, secondary-coolant loop, the brine may be quite viscous. This can cause the evaporator flow to transition to laminar at a relatively high partl-load flow (70% or greater). Chiller performance will be seriously impaired when the evaporator flow is laminar. CONSTANT-FLOW is the safest way to run a low-temperature chiller.

CHW-MIN-FLOW

when CHW-FLOW-CTRL = VARIABLE-FLOW, specifies the minimum allowable fraction of the design flow through the evaporator. Typically, the minimum flow should be above the point where the flow transitions from turbulent to laminar.

CHW-MAX-FLOW

specifies the ratio of the maximum allowable flow ratio to the design flow ratio. The default is 1.4 for all chillers. The program will not allow the flow the exceed this value, even if there is sufficent pump pressure available to do so.

TEMP-CTRL

accepts a code word specifying the temperature control mechanism:

FLOAT   specifies that the chilled-water temperature floats according to the entering chilled-water temperature and flow, the saturated-suction temperature of the refrigeration system, and the heat-exchanger characteristics.

LOCAL-EPR   specifies that the chiller has its own evaporator pressure regulator that maintains a constant saturated-suction temperature in the evaporator. The chilled-water temperature then varies according to the setpoint (as determined by the plant), the heat-exchanger load, and heat-exchanger characteristics. If the central plant's chilled-water setpoint is varied (via a schedule or reset), then the EPR setpoint will also vary.

THERMOSTAT   the default, specifies that the chilled-water temperature setpoint is directly controlled by the plant to which the chiller belongs.

DESIGN-CHW-T

specifies the design chilled-water temperature leaving the heat-exchanger. If not specified, this entry will default to the design temperature of the attached central plant.

LIQUID-CIRCUIT
accepts the U-name of a REFG-CIRCUIT that supplies liquid refrigerant to the heat-exchanger. This circuit must belong to the same refrigeration system as the suction circuit.

SUCTION-CIRCUIT
accepts the U-name of a REFG-CIRCUIT that removes vaporized refrigerant from the heat-exchanger. This circuit must belong to the same refrigeration system as the liquid circuit.

HX-UA
specifies the UA product of the heat-exchanger. The program calculates the default based on the design load, chilled-water parameters, and refrigerant parameters.

REFG-CHW-TD
specifies the design temperature differential between the chilled-water leaving the heat-exchanger and the saturated suction temperature.

REFG-FLOW
specifies the design refrigerant flow. This value defaults according to the design load and refrigerant characteristics.

REFG-DP
specifies the design pressure drop of the refrigerant flowing through the chiller. The pressure drop is in units of pressure. This pressure drop is for the heat-exchanger and thermal expansion valve controlling the superheat; any drop associated with an evaporator pressure regulator or thermostat is specified via the CTRL-VALVE-DT keyword.

This pressure drop is important when the suction-group is resetting the suction pressure on the basis of worst-case demand, or the condensers are using a floating head-pressure control. Also, if there is insufficient pressure drop available for the required flow, then the load will not be met and the temperature of the chilled water will float above setpoint.

CTRL-VALVE-DT
For all TEMP-CTRL strategies other than FLOAT, specifies the saturated temperature drop through the evaporator pressure regulator or temperature control valve; the drop associated with the heat-exchanger and thermal expansion valve is ispecified via the REFG-DP keyword. The valve is assumed to be on the suction side of the evaporator, so that the available suction pressure of the suction group is reduced by the pressure (temperature) drop through this valve. The pressure drop through the valve varies hourly as a function of the actual refrigerant flow.

CHW-FILM-RES
specifies the fraction of the overall heat-exchanger resistance that is due to the water film resistance. Note that the sum of this value and the REFG-FILM-RES must be less than 1.0. The program modifies this value on an hourly basis as a function of the flow.

REFG-FILM-RES
specifies the fraction of the overall heat-exchanger resistance that is due to the refrigerant film resistance. Note that the sum of this value and the CHW-FILM-RES must be less than 1.0. The program modifies this value on an hourly basis as a function of the flow.

Miscellaneous
AUX-KW
accepts a numeric value specifying an auxiliary electrical consumption, such as for a control panel. The default is 0.0

AUX-MODE
accepts a code-word specifying when the AUX-KW is consumed.

    ALWAYS   the default, indicates that the auxiliary power is consumed all hours.

    WHEN-ON   indicates that auxiliary power is consumed only during the hours the chiller is operating.

    WHEN-OFF   indicates that auxiliary power is consumed only during the hours the chiller is off.

    SCHEDULED   indicates that the power consumption is scheduled.

AUX-SCH
when AUX-MODE = SCHEDULED, accepts a U-name of a schedule that varies the AUX-KW on an hourly basis.

AUX-METER
accepts the U-name of a meter that supplies the auxiliary energy.

DW-HEATER

This command defines the operating parameters of a domestic water heater. Normally, the heater comes with a storage tank but you can also simulate instantaneous water heaters by setting the tank volume to a very small number. These heaters attach to a CIRCULATION-LOOP of TYPE=DHW and provide heated water for domestic purposes such as dish washing, showers, etc.

A U-name is mandatory for this command. .

Example Input:

```
DHW-1 = DW-HEATER
   TYPE             = GAS
   CAPACITY         = 300000             $Btu/hr
   DHW-PLANT        = DHW-LOOP-1
   TANK-VOLUME      = 100                $Gallons
   ..
```

What's New

▪ <u>Iterative structure</u> - This component has been completely rewritten to support the new temperature and pressure-based iterative structure.

▪ <u>Capacity</u> is specified in Btu, rather than millions of Btu.

TYPE
Takes a code-word that specifies the type of water heater. Available types are:

GAS   A gas-fired water heater.

ELEC   An electric resistance water heater.

HEAT-PUMP   *A heat pump water heater with electric resistance backup. (future)*

TANK-VOLUME
The volume of the heater's storage tank. If not specified, the storage volume will default to the hourly capacity of the burner, immersion heater, or heat pump providing heat to the tank, at the design loop supply and inlet (makeup) temperature. This value will be rounded up to the nearest commonly available size (30, 40, 50, 75, 100, 150 gal, etc.)

RATED-FLOW
As an alternative, specifies the flow corresponding to the plant's design supply and makeup temperature.

CAPACITY
The heating capacity of the burner, immersion heater, or heat pump used to meet the DHW load and charge the tank. If you do not specify this keyword, the capacity will default to the design loop load, adjusted by the CAPACITY-RATIO. If no CAPACITY-RATIO is input, then the capacity will default to the loop capacity, divided by the number of DW-HEATERs attached to the loop.

CAPACITY-RATIO

When CAPACITY is not specified, this is the fraction of the design loop capacity that this heater will be sized to meet. There is no default. If you are defining two heaters of identical size that should just meet the design loop load, then CAPACITY-RATIO should be set to 0.5 for each heater. If you want to include a 20%, then the CAPACITY-RATIO of each heater is 0.6. If you do not specify either the CAPACITY or the CAPACITY-RATIO, then the capacity will default to the loop capacity divided by the number of heaters attached to the loop.

CAPACITY-FT

Takes the U-name of a curve that modifies the heater's capacity as a function of the supply temperature and the heater's environmental temperature. There is no default curve for GAS and ELEC heaters, so if CAPACITY-FT is not specified for these types, their capacity will be constant for all temperature conditions. For HEAT-PUMP water heaters, the default is curve DW-HeatPump-Cap-fSupplyT&EDB.

Energy Consumption

The next set of keywords defines the energy consumption of the water heater. Not all keywords are used for every heater type. For example, an electric water heater does not consume any fuel and so does not have an HIR. However, a fuel-fired heater may have electrical usage, such as for a draft fan, and the electrical consumption of this fan may vary with load. Consequently, the fuel-fired heaters may use both the EIR and HIR set of keywords

AQUASTAT-SETPT-T

The setpoint of the domestic hot water heater's internal aquastat. The effective supply temperature is the larger of this value and the setpoint of the attached DHW loop. Range is 55.0 to 350.0 F (12.8 to 176.6 C) and the default is the attached DHW loop's HEAT-SETPOINT-T.

ELEC-INPUT-RATIO

The ratio of electric input power to nominal heater capacity. The EIR is dimensionless, so the same units for input and capacity should be used when calculating it. Note that "capacity" for a water heater refers to the burner, element, or heat-pump capacity and excludes the storage capacity of the tank.

EIR-FT

Takes the U-name of a curve that modifies the electric consumption as a function of the supply temperature and the environmental temperature. There is no default curve for GAS and ELEC heaters, so if EIR-FT is not specified for these types, their EIR will be constant for all temperature conditions.

EIR-FPLR

Takes the U-name of a curve that gives the EIR as a function of the heater part load ratio. If not specified, a default curve from the library will be used for electric and heat-pump water heaters. This curve must be normalized to 1.0 at full load.

HEAT-INPUT-RATIO

For GAS heaters only, this is the ratio of fuel heat input to heater capacity at full load (i.e., at the rated conditions). This is a dimensionless ratio, so you must convert heat input and heating capacity to the same units before dividing. Note that "capacity" for a water heater refers to the burner, element, or heat-pump capacity and excludes the storage capacity of the tank.

HIR-FT

Takes the U-name of a curve that modifies the HIR as a function of the supply temperature and the environmental temperature. There is no default. If HIR-FT is not specified, the HIR will be constant for all temperature conditions. The LOCATION keyword, below, determines whether the environmental temperature is the outdoor air temperature or a zone temperature.

HIR-FPLR
For GAS heaters only, takes the U-name of a curve that modifies the HIR as a function of the heater part load ratio. This curve must be normalized to 1.0 at full load.

TANK-UA
The overall heat loss coefficient (UA) of the heater. The heat loss is calculated as this value multiplied by the temperature difference between the water in the heater and the environmental temperature. TANK-UA should include conductive losses through the tank skin, as well as steady-state losses during times the burner is not firing. The default is calculated as follows:

For GAS heaters, the default is TANK-VOLUME (in gallons) times 0.3 Btu/hr-gal-F or TANK-VOLUME (in liters) times 0.042 W/l-K.

For ELEC and HEAT-PUMP heaters, the default is TANK-VOLUME (in gallons) times by 0.1 Btu/hr-gal-F or TANK-VOLUME (in liters) times 0.042 W/l-K This is 1/3 the default loss of a gas heater.

LOCATION
Takes a code-word that specifies the location of the heater:

OUTDOOR	The heater is located outdoors or possibly in an unconditioned space, such as a garage, that has an average temperature close to the outdoor temperature.
ZONE	The heater is located in the zone specified by ZONE-NAME, below. The heater and the zone interact, with the temperature of one influencing the temperature of the other.

ZONE-NAME
Takes the U-name of the zone containing the heater when LOCATION = ZONE. The zone temperature will be influenced by the thermal gains/losses of the water heater.

AQUASTAT-SETPT-T
accepts the setpoint of an internal temperature controller; if not specified, the water heater will control to the setpoint of the plant it serves. On an hourly basis, the actual setpoint will be the greater of this value or the plant setpoint.

For example, assume a plant supplies water at a temperature of 130°F. However, to maximize storage, the water heater operates at an internal aquastat setpoint of 180°F. In this case, a portion of the water flowing into the tank will be bypassed so that the leaving temperature is 130°F.

AUX-KW
The auxiliary electrical consumption, such as for an internal pump that you do not wish to model explicitly, a draft fan, and/or controls.

AUX-MODE
Takes a code-word that specifies when the AUX-KW is consumed:

ALWAYS	Auxiliary power is consumed all hours.
WHEN-ON	Auxiliary power is consumed only during the hours the heater is operating.
WHEN-OFF	Auxiliary power is consumed only during the hours the heater is off.

SCHEDULED   Auxiliary power consumption is scheduled according to AUX-SCH.

AUX-SCHEDULE
When AUX-MODE = SCHEDULED, takes the U-name of a schedule of TYPE = MULTIPLIER that varies the AUX-KW on an hourly basis.

AUX-METER
Takes the U-name of a meter that supplies the auxiliary energy. This keyword defaults to the same meter as the heater's ELEC-METER.

ELEC-METER
Takes the U-name of the ELEC-METER to which the electricity consumption of the heater is assigned. Default is the MASTER-METER: DHW-ELEC-METER.

FUEL-METER
Takes the U-name of the FUEL-METER to which the fuel consumption of the heater is assigned. Default is the MASTER-METER: DHW-FUEL-METER.

Attachment to DHW Loop

DHW-PLANT
Takes the U-name of the primary DHW loop to which this heater is attached.

~~DHW-PUMP~~
~~Takes the U-name of a PUMP directly attached to the heater. Usually, if a domestic water loop has a pump, it will be a very small pump sized to circulate a small amount of water sufficient to offset the loop losses. This pump is located on the return leg of the loop (it does not pump the main supply flow, only the smaller recirculation flow). This type of pump should normally be specified within the CIRCULATION-LOOP command. If the heater has a pump that provides internal circulation, then this pump should be specified here. This pump would be in addition to the loop pump and would act to circulate water within the heater and not the loop. Also, if the loop has multiple heaters attached and each heater has its own loop recirculation pump (very unusual), then this pump should be specified here and no pump should be attached within the CIRCULATION-LOOP command. This pump will then act to circulate water within the heater and through the loop.~~

DHW-HEAD
The head loss through the heater at design flow. The default assumes that the relevant flow is for pumping the recirculated flow, not the supply flow (the program assumes that the pressure in the water main moves the supply flow).

DHW-STATIC-HEAD
The static head of the heater (non-varying with flow).

~~DW-MIN-FLOW~~
~~The minimum allowable fraction of the design recirculation flow for the pump.~~

DW-MAX-FLOW
The ratio of the maximum allowable supply flow to the design supply flow. The program will try to use more heaters if the flow is greater than this value.

HEAT-PUMP Water Heater *(future)*

HP-SUPP-CAPACITY
For the HEAT-PUMP water heater only, this is the capacity of the backup immersion heater. The default is CAPACITY.

MAX-HP-TANK-T
For the HEAT-PUMP water heater only, this is the maximum water temperature that the heat pump can provide. Any additional boost to the supply temperature will be provided by the backup immersion heaters. For example, assume that a heater must provide 140F (60C) water to the DHW loop, the makeup water (inlet) temperature is 50F (10C) and the MAX-HP-TANK-T is 100F (37.8C). The heat pump will raise the temperature of the water entering the heater from 50F to 100F (10C to 37.8C) and the immersion heater will provide the final boost from 100F to 140F (37.8C to 60C).

Heat Recovery from Superheat

The next keyword defines the size of the tank-mounted heat-exchanger that recovers heat from the superheat of a direct-expansion air conditioning unit.

MAX-HTREC-RATE
The maximum hourly rate at which heat can be recovered. The default is no maximum limit. Heat will be recovered at this rate or the amount of superheat available, whichever is smaller, until the tank is heated to its CIRCULATION-LOOP setpoint temperature. This heater is referenced via the SYSTEM component from which desuperheat will be accomplished.

(future) Energy for domestic water heating can also be recovered from the condensers of CHILLERs or the cooling jacket or exhaust of ELEC-GENERATORs. Unlike DX superheat recovery, this heat does not go directly into a water heater's storage tank; instead it is recovered on the makeup/return side of a domestic hot water CIRCULATION-LOOP and preheats the water entering the attached water heaters. Because the heat is recovered to the loop, no heat can be recovered during hours there is no loop flow. As a result, during times there is no loop flow, the burner in a DW-HEATER will have to operate to recharge the tank and/or offset thermal losses even though there may be waste heat available from the heat recovery devices.

(future) For chiller heat recovery, refer to the HTREC keywords in the CHILLER component. For generators, refer to the HTREC keywords in the ELEC-GENERATOR component.

Space Heating from a Domestic Water Heater

Usually, hot water coils used for space heating are attached to a CIRCULATION-LOOP of TYPE = HW or PIPE2. There are some systems, however, that use the heat from a domestic water heater to provide space heating. These systems are typically in homes or apartments in climates requiring relatively little heating. To simulate this type of system, specify HEAT-SOURCE, ZONE-HEAT-SOURCE, PREHEAT-SOURCE, and/or BASEBOARD-SOURCE in the SYSTEM command to be of type DHW-LOOP. Then attach the coil to a domestic water loop using the SYSTEM's DHW-LOOP keyword or the ZONE's DHW-LOOP keyword (for a zonal coil). The program will take into account the required coil capacity when sizing the loop and auto-size the domestic water heaters attached to the loop. You should review the sizing parameters to make sure they are reasonable. Also, you should make sure that the heating coils entering water temperature is at least 10F (5.6K) warmer than the leaving air temperature, otherwise the program will not be able to size the coil correctly. Domestic water loops without any heating coils or recirculation do not need to be pumped; the program assumes the water main pressure is sufficient. The addition of heating coils to the loop requires the loop to be pumped. For DHW loops, this pump is located on the return side of the loop; it does not pump water that is used for dish washing or other domestic water uses, only

water that returns to the water heaters. The pump is attached within the CIRCULATION-LOOP component, or alternatively, to each of the water heaters attached to the loop.

Miscellaneous

COST-DATA

Takes the U-name of a MATERIALS-COST command, which allows you to define first costs, maintenance costs, etc. for this heater.

EQUIPMENT-REPORTS

Accepts the code-words YES or NO; the default is YES. When report PS-H of the PLANT-REPORTS is enabled, a report will print for this component unless the code-word is set to NO.

PUMP

Defines the operating parameters of a pump. U-name is required. The pump attaches to a CIRCULATION-LOOP or a piece of primary equipment (such as a chiller) by referencing the pump's U-name in the CIRCULATION-LOOP or primary equipment command. A unique pump must be defined for each application. In other words, a pump U-name can be referenced by only one CIRCULATION-LOOP or by one piece of primary equipment. Multiple references to the same pump will result in an error.

Example input:

```
"CHW pump" = PUMP ..
```

FLOW
The design flow of thepump, per pump. If not specified, the flow will default to the design loop flow, divided by the number of pumps.

NUMBER
The number of identical pumps attached to a loop. Multiple pumps will stage as required by the current loop flow and head.

HEAD
The design pressure rise across the pump when the pump is running. The default is the sum of the maximum head of any demander on the circulation loop (coils, etc.), the maximum head of any supplier to the circulation loop (boilers, chillers, etc.) and the loop head loss, with the sum adjusted by HEAD-RATIO. The program calculates the pump's design power consumption using this value together with the fluid flow rate, fluid properties, impeller efficiency and motor efficiency.

HEAD-RATIO
The over sizing ratio for the pump head when default sizing occurs.

~~HEAD-SETPT~~
~~The same as HEAD-SETPT for the CIRCULATION-LOOP and defaults to that value. When individual pumps are attached to the supply side of the equipment attached to a loop, and no loop pump is specified (i.e., the equipment-recirculation pumps are powering the loop), this keyword allows you to specifiy a separate setpoint for each of the active pumps. This is useful only when the pumps have different heads because the heads of their associated equipment units are different. Normally, you should let this keyword default.~~

~~HEAD-SETPT-RATIO~~
~~The same as HEAD-SETPT-RATIO for the CIRCULATION-LOOP and defaults to that value. As with HEAD-SETPT for the PUMP, this keyword allows pumps to have varying setpoints when pumps are attached to individual equipment units that are powering the loop. Normally, you should let this keyword default.~~

MECH-EFF
The impeller efficiency of the pump when acting on pure water at 60F.

EFF-FVISCOSITY
accepts the U-name of a curve that modifies the mechanical (impeller) efficiency as a function of the fluid viscosity, in centistokes (mm2/sec). This relationship is used only when CIRCULATION-LOOP:FLUID-RELATIONS = DETAILED.

MOTOR-EFF

The efficiency of the pump's motor. If not specified, the default is based on the nameplate power and the efficiency classification (MOTOR-CLASS) of the motor. The program assumes that the nameplate power is the brake power increased by 30% to ensure that the motor is not overloaded over the range of the pump curve. See Table 2 below.

Table 2 Default motor efficiencies

Brake Power		MOTOR-CLASS		
HP	kW	STANDARD	HI-EFF	PREMIUM
0.083	0.064	.490	.490	.490
0.125	0.096	.550	.550	.550
0.167	0.129	.600	.600	.600
0.250	0.193	.640	.640	.640
0.333	0.256	.660	.660	.660
0.500	0.385	.700	.760	.800
0.750	0.578	.720	.770	.840
1.0	0.770	.790	.825	.855
1.5	1.16	.800	.840	.855
2.5	1.93	.800	.840	.855
3.9	3.00	.810	.865	.875
6.9	5.31	.820	.875	.902
12.9	9.93	.850	.885	.917
17.9	13.8	.860	.910	.910
20.9	16.1	.870	.910	.924
29.9	23.0	.880	.917	.930
69.9	53.8	.890	.930	.941
139.9	107.7	.900	.941	.950
1,000,000	770,000	.910	.950	.962

MOTOR-CLASS

Takes a code-word that specifies the efficiency classification the motor. The program uses this keyword to determine the efficiency of the motor when MOTOR-EFF is not entered. See Tabe 2 under MOTOR-EFF

STANDARD   A standard efficiency motor.

HI-EFF   A NEMA high-efficiency motor.

PREMIUM   A NEMA premium-efficiency motor.

PUMP-KW

The design power consumption of the pump. If entered, its value should be consistent with the values for the pump's head, flow, impeller efficiency and motor efficiency. If not consistent, the program will recalculate the impeller efficiency to force consistency.

CAP-CTRL

Accepts a code-word that defines how the pump modulates as the flow varies. When you specify NUMBER to be more than one, then the pumps will first stage according to the load and then modulate capacity according to the CAP-CTRL mode:

ONE-SPEED-PUMP   The pump rides its curve as the flow varies (2-way valves in at least one system are necessary for this to happen).

TWO-SPEED-PUMP   The pump can operate at two speeds. The low-speed is determined by MIN-SPEED. You should choose MIN-SPEED to match the actual low speed ratio of the pump, typically 0.67 or 0.5.

VAR-SPEED-PUMP   The pump has a variable frequency drive. The minimum pump speed is specified by MIN-SPEED. Note that a pump's speed is not usually proportional to flow; speed is a function of both the pump flow as well as the pump head requirement. If the pump head requirement does not fall off as the square of flow (for example, when the pump has a fixed head setpoint), then the pump will operate at a speed higher than it would otherwise.

Note that if the loop flow is zero for the entire hour, the pump will be off for the hour no matter what CAP-CTRL is. To force a pump to run during a no-load condition, either one or more coils must have a 3-way valve or the CIRCULATION-LOOP's LOOP-MIN-FLOW or LOOP-RECIRC-FLOW must be nonzero.

MIN-SPEED

The low speed of a 2-speed pump or the minimum speed of a variable-speed pump. For a 2-speed pump this value should match the low pump speed, typically either 0.67 or 0.5. When CAP-CTRL = VAR-SPEED-PUMP, it is possible that the pump may never run at the MIN-SPEED. This is because the program calculates the head requirement on an hourly basis and includes the hourly head in the calculation for pump speed. When a static head exists somewhere on the loop the pump may be forced to run at a relatively high speed to overcome the static head even in a no-flow situation.

HEAD-FFLOW   ~~PUMP-HEAD-FFLOW~~

Takes the U-name of a curve defining how the head of the pump varies with flow. Head and flow are both normalized to 1.0. This curve can be linear or quadratic, but not cubic. The default is Pump-Head-fFlow, which is representative of a pump with a typical curve. When using a variable-speed or 2-speed pump, the pump performance curves are "re-normalized" hourly to match the actual pump speed.

HP-FFLOW   ~~PUMP-HP-FFLOW~~

Takes the U-name of a curve that defines how the pump power varies with flow. The default is representative of a pump with a flat curve. When using a variable-speed or 2-speed pump, the pump performance curves are "re-normalized" hourly to match the actual pump speed.

MAX-FLOW-RATIO   ~~PUMP-MAX-RATIO~~

The maximum pump flow divided by the design flow. A pump can often move significantly more fluid than the design volume provided the head is lower than design. This situation commonly occurs when two (or more) pumps are used in parallel. When both pumps are operating each pump moves its design flow at the design head. When only one pump is running the loop flow and loop head are reduced. The reduced head allows the remaining pump to move more than its design flow. The maximum flow of the pump is limited by this keyword. Note that if PUMP-MAX-RATIO is too large, the maximum flow may correspond to a negative head.

POWER-EXP   ~~PUMP-POWER-EXP~~
Specifies how the pump power varies with speed when all other parameters obey the ideal pump laws. If the pump were ideal, the exponent would be 3.0. The default accounts for non-ideal performance within the pump itself. This exponent should not be adjusted to account for the effects of non-ideal factors external to the pump, such as head pressure control; the program accounts for those factors separately. (Many designers assume that the actual horsepower exponent is in the range of 2.0 to 2.5, which approximates the effect of a fixed head pressure setpoint.) It is strongly recommended that you not change this parameter, as it will suffice for most pumps.

VFD-LOSS
When CAP-CTRL = VAR-SPEED-PUMP, accepts a value that represents the fraction of VFD drive looses expressed as a fraction of full load pump kW. The net load on the electric meter, at pump full load, will be the sum of the two values.

For example, if the pump kW is 40 and VFD-LOSS is 0.05, then the full-load drive loss is 2 kW, and the net load on the meter is 42 kW.

VFD-LOSS-FPLR
When CAP-CTRL = VAR-SPEED-PUMP, accepts the Uname of a CURVE-FIT command that is used hourly to modify (as a multiplier on) VFD-LOSS. The independent input to the curve is the current hour power output fraction calculated as (current hour motor kW)/(Design motor kW).

Extending the above example, if the pump motor is currently drawing 24 kW, then the part-load ratio on the drive is 24/40 = 0.60. If feeding this value into the VFD-LOSS-FPLR curve yields a value of 0.73, then the drive loss is 2 kW * 0.73 = 1.46 kW, and the net load on the meter is 25.46 kW.

ELEC-METER
Takes the U-name of an ELEC-METER command. The pump electricity is provided by this meter. If not specified, the default is the meter specified by AUX-ELEC-METER in the MASTER-METER command.

EQUIPMENT-REPORTS
When report PS-H of the PLANT-REPORTS is enabled, a report will print for this pump unless this keyword is set to NO.

COST-DATA
Takes the U-name of a MATERIALS-COST command, which allows you to define first costs, maintenance costs, etc. for this pump.

FLUID

This component defines the properties of a fluid in a circulation loop. The fluid may be either water, a glycol, or a brine. For the purpose of the discussions that follow, both glycols and brines will be referred to as "brines".

The fluid properties of a brine solution can differ markedly from pure water: The viscosity of a brine is typically higher than that of water, while the specific heat, conductivity, and density are usually lower. In addition, the properties, particularly viscosity, change with both concentration and temperature. For example, propylene glycol acts similarly to Jello at very low temperatures.

The performance of heat transfer surfaces can be significantly degraded in a brine system. This applies to chillers as well as coils. The program takes these effects into account *(but not in the previously existing air-side coils)*.

Typically, pumping costs are greater in a brine system. The increased fluid viscosity, coupled with a lower density and specific heat, results in a greater pumped volume and significantly higher friction losses. A portion of these losses can be offset by increasing the size of the piping. However, this is not practical in chillers or coils because of the tendency of the fluid to transition into laminar flow at relatively high part-load flows. Instead, velocities may actually need to be increased to avoid laminar flow, which increases head losses.

All pressure drops and performance characteristics for chillers, coils, and piping are normally specified relative to *pur water at the average operating temperature*. If desired, you may specify another rating condition, however all components must then be specified relative to that condition. The program will adjust the performance for the specific brine concentration, and operating temperature.

U-name
accepts the user-defined name for this fluid. The library contains the following pre-defined fluids that may be referenced by circulation-loops, chillers, etc.:

WATER   the default for all components, is pure water.

ETHYLENE-GLYCOL   defines the properties of ethylene glycol

PROPYLENE-GLYCOL

TYPE
Specifies the type of fluid:

PURE-WATER   is pure water.

GLYCOL   specifies a glycol, such as ethylene or propylene glycol.

BRINE   specifies a salt solution, such as calcium chloride.

<u>Fluid Characteristics</u>
The following keywords define the fluid's performance characteristics. Characteristics include:

- <u>Freezing point</u> as a function of temperature,

- <u>Density</u> as a function of temperature and concentration

- <u>Viscosity</u> as a function of temperature and concentration.

- <u>Specific heat</u> as a function of temperature and concentration

- <u>Conductivity</u> as a function of temperature and concentration

A brine may operate over a range varying from less than –20°F to greater than 250°F. This very large range may be very difficult to fit with one performance curve. For example, the viscosity of propylene glycol changes very little at high temperatures, but changes drastically at temperatures below 0°F. For this reason, two curves *may* be specified for each characteristic, one for colder temperatures, and one for hotter temperatures:

1. <u>Single curve</u> – if the performance over the intended operating range can be specified using a single curve, then only one curve is required.

2. <u>Two curves</u> – if a low-temperature and high-temperature curve are required, the combination of the two curves must be valid over the entire temperature range, and the range of each curve should overlap the other by a few degrees. In other words, for the colder curve, the CURVE-FIT:MAX-T should be several degrees greater than the hotter curve's CURVE-FIT:MIN-T.

    When operating in the range where the two curves overlap, the program splines the two curves together to produce a smooth transition from one curve to the other.

    See the curve fit command for more information, and inspect the fluid curves defined in the library for an example of overlapping ranges.

The fluid performance curves have units associated with the output variable as well as the input variables. For so that metric curves can be defined, the program has a specific CURVE-FIT:TYPE associated with each fluid characteristic.

PCT-FT-FREEZE
for types other than PURE-WATER, accepts the U-name of a curve the relates the percent concentration to the freezing temperature. This is a mandatory entry. The CURVE-FIT must be of TYPE = RATIO-FT.

DENS-FT&PCT
accepts the U-name of a curve the relates the density to the temperature and concentration. The CURVE-FIT must be of TYPE = DENS-FT&PCT. If there is no concentration dependence, the curve may be of type DENS-FT.

VISC-FT&PCT
accepts the U-name of a curve the relates the viscosity to the temperature and concentration. The CURVE-FIT must be of TYPE = VISC-FT&PCT. If there is no concentration dependence, the curve may be of type VISC-FT.

CP-FT&PCT
accepts the U-name of a curve the relates the specific heat to the temperature and concentration. The CURVE-FIT must be of TYPE = CP-FT&PCT. If there is no concentration dependence, the curve may be of type CP-FT.

COND-FT&PCT
accepts the U-name of a curve the relates the conductivity to the temperature and concentration. The CURVE-FIT must be of TYPE = COND-FT&PCT. If there is no concentration dependence, the curve may be of type COND-FT.

DENS-FT&PCT-HOT
VISC-FT&PCT-HOT
CP-FT&PCT-HOT
COND-FT&PCT-HOT
If the above keywords cannot describe the fluid's performance over the entire temperature range of interest, you may input a second set of curves. In this case, the CURVE-FIT:MIN-T of these curves should match the CURVE-FIT:MAX-T of the first set of curves.

METER

DOE-2.2 introduced the concept of meters for electricity, fuel, steam, and chilled-water energy sources. In addition, DOE-2.2 incorporated the concept of submetering for electric meters, but did not allow submetering for any other type of energy. This program version restructures the meters to make them more flexible, and allows submetering for all meter types.

Previously there were four meter commands: ELEC-METER, FUEL-METER, STEAM-METER, and CHW-METER. These separate commands have now been combined into a single command, METER, having various TYPEs for electricity, fuel, etc. You may define as many of each meter type as required. In addition, any METER can have any number of submeters that draw from it. In turn, each of those submeters can feed any number of sub-submeters, etc. In other words, there is no limit to the number of meters, no limit to the number of submeters below a meter, and no limit to the number of levels of submetering. This concept can allow multiple buildings on a campus to be individually metered, and the metering aggregated at the campus level. In addition, it allows metering by floor(s), air handler(s), tenent(s), etc.

For clarity, the keywords that were previously in the four different meter commands are all described here. Any keyword previously in a command that is not here is no longer used.

U-name
accepts a mandatory user-defined name for this meter. While the name may be up to 32 characters in length, we strongly recommend that you only use 4 characters (EM1 for the first electric meter, etc.). Because of the large number of meters that may need to be displayed in reports and/or PowerDOE spreadsheets, some of these reports have been structured to display only the first 4 characters.

TYPE
accepts a mandatory code-word that defines the type of this meter. Available codewords are:

ELECTRIC	meters an electrical load. Any of the ELEC-METER or AUX-METER keywords in any of the other components may reference the name of this meter.
FUEL	meters a fuel load. Any of the FUEL-METER keywords in any of the other components may reference the name of this meter. Because a fuel meter may represent one of number of different fuel types, you can also define the SUBTYPE of a fuel meter; the default SUBTYPE is NATURAL-GAS.
STEAM	meters a steam load. A steam meter may be referenced by one or more of the various circulation loops, in which case all loop loads not met by plant equipment (boilers, etc.) will be passed on to this meter.
CHILLED-WATER	meters a chilled-water load. A chilled-water meter may be referenced by one or more of the various circulation loops, in which case all loop loads not met by plant equipment (chillers, etc.) will be passed on to this meter.
ELECTRIC-SALE	meters power produced by ELEC-GENERATORS that is sold to a utility rather than being consumed on-site. Please refer to the cogeneration documentation for more information.

SUBTYPE

for fuel meters only, accepts a code-word specifying the type of fuel to be monitored. NATURAL-GAS is the default. Other types are LPG (liquified petroleum gas, such as propane), FUEL-OIL, DIESEL-OIL, COAL, METHANOL, and OTHER-FUEL. OTHER-FUEL allows you to define the characteristics of a less common fuel, such as wood chips or other biomass. The number of Btu's per billing unit varies according to the type of fuel.

TRUNK-METER

for a submeter, accepts the U-name of the meter that feeds energy to the sub-meter being defined. That meter may be either a utility-level meter, or a previously defined submeter. In this fashion, a heirarchy of meters may be defined, with sub-meters feeding into higher level sub-meters, etc., and ultimately to a utility meter at the highest level.

BTU/UNIT

specifies the number of Btu's in a billing unit. For example, assuming NATURAL-GAS is billed in therms, the default value of this keyword is 100000. The value of this keyword must be coordinated with the energy and demand consumption units specified in UNIT-INDEX and DEM-UNIT-INDEX. For example, NATURAL-GAS by default is billed in therms, has BTU/UNIT = 100000, UNIT-INDEX = 88 (THERM) and a DEM-UNIT-INDEX = 89 (THERM/HR). Normally, you should have no need to specify this value.

UNIT-INDEX

accepts an integer value defining the billing unit as listed in the units table. This value is used in the reports, and allows English units to be converted to the correct metric units. The default varies by TYPE and, for fuel meters, by SUBTYPE. Normally, you should have no need to specify this value.

DEM-UNIT-INDEX

accepts an integer value defining the billing unit of maximum demand as listed in the units table. This value is used in the reports, and allows English units to be converted to the correct metric units. The default varies by TYPE and, for fuel meters, by SUBTYPE. Normally, you should have no need to specify this value.

SOURCE-SITE-EFF

accepts a numeric input defining the fraction of energy between the original energy source at the utility used to generate the energy, and the energy delivered to the site boundary. The default varies by TYPE and, for fuel meters, by SUBTYPE.

INTERIOR-POWER

accepts a list of up to 5 numeric inputs defining the hourly energy consumed by miscellaneous uses inside the building that do not show up anywhere else. This energy shows up as a load on the meter, but does not appear as a space load.

INTERIOR-SCH

accepts a list of up to 5 U-Names of schedules that modify the INTERIOR-POWER values on an hourly basis. Interior power will be constant all hours if you do not define a schedule.

EXTERIOR-POWER   accepts a list of up to 5 numeric inputs defining the hourly energy consumed by miscellaneous uses outside the building that do not show up anywhere else. This energy shows up as a load on the meter, but does not appear as a space load.

EXTERIOR-SCH

accepts a list of up to 5 U-Names of schedules that modify the EXTERIOR-POWER values on an hourly basis. Exterior power will be constant all hours if you do not define a schedule.

METER-REPORT
accepts a code-word that defines if reports are to be output for this meter; available codewords YES and NO, with YES the default. If PLANT-REPORTS:PS-F is specified, then a report will print for each meter where a report is allowed.

Transformer Losses
The following keywords apply to ELECTRIC and/or ELECTRIC-SALE meters.

TRANSFORMER-SIZE
accepts a numeric value which defines the capacity, in KW, of the transformer for this meter. There is no default; if no value is specified then no transformer is simulated for this meter (and thus the following two keywords are unused).

TRANSFORMER-SIZE
accepts a numeric value defining the fraction of output power that is lost at full load conditions (full load being the TRANSFORMER-SIZE).

TRANS-LOSS-FPLR
accepts the U-name of a CURVE-FIT command that defines the multiplier on TRANSFORMER-LOSS, as a function of the part load fraction (current hours load on this meter divided by TRANSFORMER-SIZE for this meter). The transformer loss is calculated hourly as equal to the TRANSORMER-SIZE times TRANSFORMER-LOSS times the value of TRANS-LOSS-FPLR evaluated at PLR=load/ TRANSFORMER-SIZE; where load is the sum of all directly connected equipment and, for TYPE = UTILITY and BUILDING, other ELEC-METERs. The default for this curve is TRANSFORMER-LOSS-FPLR in the DOE-2.2 library; this curve is linear from 0.10, at no load, to 1.0, at full load.

*Electric Generation (future)
The following keywords apply to ELECTRIC and/or ELECTRIC-SALE meters that are attached to ELEC-GENERATORS. Please refer to the cogeneration documentation for more information on the use of these keywords.

COGEN-TRACK-MODE
accepts a code-word that describes how the cogeneration equipment attached to this meter is to be controlled. This keyword can be overridden by the COGEN-TRACK-SCH keyword. In the following, each code-word is followed by a number in parenthesis. The code-word applies to this keyword, and the number in parenthesis the flag value that is equivalent to the code-word when the COGEN-TRACK-SCH is used:

DONT-RUN (0)	specifies that the generators are shut off. This mode of operation allows a COGEN-TRACK-SCH to shut off the generators during certain times of the day or year.
TRACK-ELEC (1)	specifies that the generators are to track the meter's electrical load. This mode works only for UTILITY electric meters, as ELECTRIC-SALE meters do not have any demands that can be tracked.
TRACK-THERMAL (2)	specifies that the generators are to track the thermal load of an attached CIRCULATION-LOOP. For this mode to work, each attached generator must also be attached to a CIRCULATION-LOOP. Note that, while multiple generators may be on the same ELEC-METER, each of these generators may be

attached to the same or different CIRCULATION-LOOPs, and may therefore be tracking the same or different thermal loads when operating in this mode.

When using this mode with a UTILITY meter, it is possible that the generators might produce more electricity than this meter demands. In this case, you should also attach each generator to a meter of type ELECTRIC-SALE (via the generator's SURPLUS-SALE keyword); otherwise the surplus power will be lost.

When using this mode with an ELECTRIC-SALE meter, all power will be sold. The amount generated and sold will then be a function of the thermal demands.

TRACK-LESSER (3)   specifies that each generator is to track the smaller of this meter's electric demand, and the thermal demand of the generator's attached CIRCULATION-LOOP. This mode works only for UTILITY electric meters, and only when the generators are also attached to CIRCULATION-LOOP(s).

TRACK-GREATER (4)   specifies that each generator is to track the greater of this meter's electric demand, and the thermal demand of the generator's attached CIRCULATION-LOOP. This mode works only for UTILITY electric meters, and only when the generators are also attached to CIRCULATION-LOOP(s).

When using this mode, it is possible that the generators might produce more electricity than this meter demands. In this case, you should also attach each generator to a meter of type ELECTRIC-SALE (via the generator's SURPLUS-SALE keyword); otherwise the surplus power will be lost.

MAX-OUTPUT (5)   specifies that the generators are to run at maximum output.

When using this mode with a UTILITY meter, it is possible that the generators might produce more electricity than this meter demands. In this case, you should also attach each generator to a meter of type ELECTRIC-SALE (via the generator's SURPLUS-SALE keyword); otherwise the surplus power will be lost.

COGEN-TRACK-SCH
accepts the U-name of a SCHEDULE of TYPE = FLAG. Acceptable flag values are 0, 1, 2, 3, 4, and 5, and have the meaning as described for COGEN-TRACK-MODE. When specified, this schedule will override any value given for COGEN-TRACK-MODE. This keyword allows the operational mode of generators to shift according to the time of day or year.

EQUIP-CTRL
accepts the U-name of an EQUIP-CTRL of TYPE = ELECTRICAL that coordinates the operation of multiple generators attached to this meter. In addition, this sequence can operate the generator(s) in a peak shaving mode so that the generators only pick up the load above some upper limit.

A LOAD-MANAGEMENT command can select an EQUIP-CTRL sequence that overrides this sequence on the basis of a schedule, outdoor air temperature, etc.

This keyword can be used with any of the electric tracking modes (TRACK-ELEC, TRACK-LESSER, TRACK-GREATER); it is ignored for all of the other modes (DONT-RUN, TRACK-THERMAL, MAX-OUTPUT). If not specified, then the program will automatically select the mix of generators that best matches the hourly load.

Note that, when tracking thermal loads (TRACK-THERMAL, TRACK-LESSER, TRACK-GREATER), the operation of generators can be coordinated with boilers via the EQUIP-CTRL keyword in the CIRCULATION-LOOP command.

Example input: electric metering heirarchy. Note that, for clarity, we are ignoring our recommendation to limit U-names to four characters:

```
SUBSTATION = METER
   TYPE               = ELECTRIC $ no transformer - utility owned
   ..

OFFICE-BUILDING-1 = METER
   TYPE               = ELECTRIC  $ submeter of SUBSTATION
   TRANSFORMER-SIZE   = 30.
   TRUNK-METER        = SUBSTATION
   ..

OFFICE-BUILDING-2 = METER
   TYPE               = ELECTRIC  $ submeter of SUBSTATION
   TRANSFORMER-SIZE   = 25.
   SUB-METER-OF       = SUBSTATION
   ..

BANKinB1 = METER
   TYPE               = ELECTRIC  $ sub-submeter of
                                  $ OFFICE-BUILDING-1
   TRANSFORMER-SIZE   = 15.
   TRUNK-METER        = OFFICE-BUILDING-1
   ..

FLOOR2inB1 = METER
   TYPE               = ELECTRIC  $ sub-submeter of
                                  $OFFICE-BUILDING-1
   TRANSFORMER-SIZE   = 10.
   TRUNK-METER        = OFFICE-BUILDING-1
   ..

FLOOR3inB1 = METER
   TYPE               = ELECTRIC  $ sub-submeter of
                                  $ OFFICE-BUILDING-1
   TRANSFORMER-SIZE   = 10.
   TRUNK-METER        = OFFICE-BUILDING-1
   ..

STOREinB2  = METER
   TYPE               = ELECTRIC  $ sub-submeter of
                                  $ OFFICE-BUILDING-2
   TRANSFORMER-SIZE   = 20.
   TRUNK-METER        = OFFICE-BUILDING-2
   ..

FLOOR2inB2 = METER
   TYPE               = ELECTRIC  $ sub-submeter of
                                  $ OFFICE-BUILDING-2
   TRANSFORMER-SIZE   = 10.
```

```
        TRUNK-METER        = OFFICE-BUILDING-2
        ..


    "Blimpo's" = METER
        TYPE               = ELECTRIC  $ totally separate meter in
        TRANSFORMER-SIZE   = 50.       $ attached fast-food
        ..                             $ restaurant
```

UTILITY-RATE Revisions

To complement the new METER structure, a few of the UTILITY-RATE keywords have been changed:

TYPE
specifies the type of energy:

ELECTRIC	specifies that one or more electric meters will be aggregated into this utilty rate.
FUEL	specifies that one or more fuel meters will be aggregated into this utility rate. Currently, the program does not check to see that different fuel types are not mixed.
STEAM	specifies that one or more steam meters will be aggregated into this utlity rate.
CHILLED-WATER	specifies that one or more chilled-water meters will be aggregated into this utlity rate.
ELECTRIC-SALE	specifies that one or more electric-sale (surplus generation) meters will be aggregated into this utlity rate.

The NATURAL-GAS, LPG, DIESEL-OIL, FUEL-OIL, COAL, METHANOL and OTHER-FUEL code-words are no longer used here.

METERS
accepts of list of METERs whose energy will be aggregated into this utility rate.

This keyword replaces the ELEC-METERS, FUEL-METERS, STEAM-METERS, and CHW-METERS keywords in previous versions.

EQUIP-CTRL

The EQUIP-CTRL command is used to specify the mix of equipment to be used to meet a load. Each EQUIP-CTRL command is dedicated to a specific load (circulation loop or electric meter), and can control only the equipment attached to that load.

You can define more than one EQUIP-CTRL sequences for a given load, but only one sequence will be active any given hour. The LOAD-MANAGEMENT sequences determine which EQUIP-CTRL sequence is active at any given time.

Background

In DOE-2.2, the operating capacities of most plant equipment types (boiler, chiller, etc.) were expressed in terms of energy, and fluid-flow capacities were a secondary consideration. Only the heat-rejection equipment (cooling towers) calculated operating capacities in terms of flow. Because DOE-2.3 is fully based on flow, pressure and temperature, with load being a secondary variable, all of the equipment that acts upon a fluid or refrigerant now has an hourly operating capacity based on flow. Only generators have an energy capacity (kW).

The ramifications of this difference are significant. For example, assume a chiller at design conditions can deliver 100 tons of cooling at a 44°F supply temperature, 85°F condenser temperature, 2.4 gpm/ton (10°F chilled-water temperature drop), and 20' evaporator head loss. If the chiller is operating at design conditions, but the return temperature is 49°F instead of 54°F (5°F chilled-water temperature drop) , then the chiller cannot deliver its rated capacity (at 44°F) unless the flow through the chiller doubles. However, to double the flow, the available head must be 348% of design, or 70'. (The program assumes that friction in a pipe varies as the 1.8 power of the flow.) If this head is not available, or a doubled flow is not allowed, then the chiller will not be able to deliver its rated thermal capacity. (Note that the available head varies hourly as a function of the flow, the number of pumps running, and the head losses throughout the system.)

In DOE-2.2, the EQUIP-CTRL command allocated an energy load to the boilers, chillers, etc. The program then checked to see if the flow requirements were met, and if not, re-distributed the load/flow using the default allocation routines. In other words, it was not uncommon for DOE-2.2 to override your control sequences, especially if the system had 3-way valves on the coils.. DOE-2.3 improves upon this by calculating all operating capacities in terms of flow, and the EQUIP-CTRL command selects equipment on the basis of flows rather than energy loads.

U-name

accepts the U-name that all other commands will use to reference this control sequence. A unique entry is mandatory.

TYPE

accepts a code-word specifying the type of load this sequence will control. Acceptable entries are:

> CENTRAL-PLANT   specifies that this sequence will control central-plant equipment that conditions a fluid (boilers, chillers, heat-rejection, etc.) Included here are steam and chilled-water meters and thermal storage. Electric generators are also included here, provided the generator outputs recoverable heat, and the generator is to be controlled on the basis of the heating demand

SUCTION-GROUP   specifies that this sequence will control compressors in a refrigeration suction
                        group.

REFG-SYSTEM   specifies that this sequence will control condensers attached to a discharge
                        refrigeration circuit..

ELEC-GENERATION   specifies that this sequence will control the electric output of generators

TYPE = CENTRAL-PLANT

In large plants, equipment may be started and stopped according to flow and load. For example, a small chiller(s)
may be used for small loads as long as the small load correlates to a small flow. As the load increases, the small
chillers may be shut down, and larger chillers brought on line. The EQUIP-CTRL sequence can accommodate up
to 5 flow ranges, each range having a different mix of equipment, with the equipment brought on-line in a different
order. The following defines the keywords for the first flow range; the second through fifth ranges are identical
except for the suffix number. (Shown as 1,5 for each keyword.)

CIRCULATION-LOOP
accepts the U-name of the CIRCULATION-LOOP to which this control sequence will apply. This is a mandatory
entry.

FLOWS-THRU-1 FLOWS-THRU-2 FLOWS-THRU-3 FLOWS-THRU-4 FLOWS-THRU-5
specifies the flow for which the equipment specified in BOILERS-1, etc. will be used. The input is in gallons/min
for central plants, and lbs/hour for refrigeration components.

If you do not specify this flow range, but specify equipment in BOILERS-1, etc., then this entry will default to the
hourly flow capacity of the equipment listed in BOILERS-1, etc. Using the default allows the load range to exactly
match the capacity of the equipment. Since the flow capacity of equipment may vary substantially from hour to
hour, it is strongly recommended that you let this value default.

You must enter the FLOWS-THRU-n ranges in ascending numerical order, without skipping any lower ranges. In
other words, FLOWS-THRU-2 must be greater than FLOWS-THRU-1. FLOWS-THRU-3 cannot be used unless
FLOWS-THRU-1 and FLOWS-THRU-2 are also defined.

BOILERS-1 BOILERS-2 BOILERS-3 BOILERS-4 BOILERS-5
accepts a list of up to 10 U-names of the boilers that will be used to satisfy the flow listed under FLOWS-THRU-1.
The boilers must be attached to the same circulation loop as this EQUIP-CTRL, or the program will generate an
error.

BOILERS-SEQ-1 BOILERS-SEQ-2 BOILERS-SEQ-3 BOILERS-SEQ-4 BOILERS-SEQ-5
accepts a list of whole numbers (integer 1-10) corresponding to and entered in the same order as the equipment
listed in BOILERS-1, etc. These numbers specify the order in which the equipment will start to satisfy the flow
requirement. The default is that the equipment will start in the order listed.

More than one equipment unit can have the same sequence number. For example, if two units are to always start
and operate together, then they should both be given the same sequence number.

Equipment assigned sequence number 1 will start first, followed by 2, etc. The entry of equipment in BOILERS-1,
etc. is not order dependent per se; equipment can be listed in any order, and BOILERS-SEQ-1 numbers assigned in
any order.

The EQUIP-CTRL algorithm will start as many equipment units required to satisfy the flow. The flow per unit will be prorated based on that unit's capacity relative to the total capacity enabled (but see MAX-FLOW-1).

BOILERS-MAX-1 BOILERS-MAX-2 BOILERS-MAX-3 BOILERS-MAX-4 BOILERS-MAX-5

accepts a list of values corresponding to and entered in the same order as the equipment listed in BOILERS-1, etc. These numbers specify the maximum flow that each equipment unit will be given. If not specified, the maximum will default to each unit's maximum hourly flow capacity. If specified, this value will act as an upper limit on each unit's flow.

This value is entered in gallons/min for central plants.

CHILLERS-1 CHILLERS-2 CHILLERS-3 CHILLERS-4 CHILLERS-5

identical to BOILERS-1,5 but for chillers. Note that a chiller heater will normally be attached to both a hot-water and chilled-water loop, and may have separate equip-ctrl sequences for each mode. In this case, the hot-water loop equip-ctrl sequence may include both BOILERS-1,5 and CHILLERS-1,5 entries.

CHILLERS-SEQ-1 CHILLERS-SEQ-2 CHILLERS-SEQ-3 CHILLERS-SEQ-4 CHILLERS-SEQ-5
CHILLERS-MAX-1 CHILLERS-MAX-2 CHILLERS-MAX-3 CHILLERS-MAX-4 CHILLERS-MAX-5

For boilers and chiller/heaters on the same loop, the respective BOILER-SEQ-* and CHILLER-SEQ-* numbers may be used to coordinate the start order of the various components.

DW-HEATERS-1 DW-HEATERS-2 DW-HEATERS-3 DW-HEATERS-4 DW-HEATERS-1
DW-HEATERS-SEQ-1 DW-HEATERS-SEQ-2 DW-HEATERS-SEQ-3 DW-HEATERS-SEQ-4 DW-HEATERS-SEQ-5
DW-HEATERS-MAX-1 DW-HEATERS-MAX-2 DW-HEATERS-MAX-3 DW-HEATERS-MAX-4 DW-HEATERS-MAX-5

control domestic hot water heaters in a manner similar to BOILERS-* described above.

HEAT-REJ-1 HEAT-REJ-2 HEAT-REJ-3 HEAT-REJ-4 HEAT-REJ-5
HEAT-REJ-SEQ-1 HEAT-REJ-SEQ-2 HEAT-REJ-SEQ-3 HEAT-REJ-SEQ-4 HEAT-REJ-SEQ-5
HEAT-REJ-MAX-1 HEAT-REJ-MAX-2 HEAT-REJ-MAX-3 HEAT-REJ-MAX-3 HEAT-REJ-MAX-5

control heat-rejection devices in a manner similar to BOILERS-* described above.

GLHX-1 GLHX-2 GLHX-1 GLHX-3 GLHX-4 GLHX-5
GLHX-SEQ-1 GLHX-SEQ-2 GLHX-SEQ-3 GLHX-SEQ-4 GLHX-SEQ-5
GLHX-MAX-1 GLHX-MAX-2 GLHX-MAX-3 GLHX-MAX-4 GLHX-MAX-5

control ground-loop heat-exchangers in a manner similar to BOILERS-* described above.

Dual-Mode Central Plants

DOE-2.2 had two keywords in the CIRCULATION-LOOP component for the default user-specified equipment control sequences, HEAT-EQUIP-CTRL and COOL-EQUIP-CTRL. For dual mode loops (2-pipe and water-loop heat pump), the HEAT-EQUIP-CTRL was used to control boilers, etc., and the COOL-EQUIP-CTRL was used to control chillers, etc.

Because the equipment allocations are now based on flow instead of thermal load, it is not necessary to distinguish between heating and cooling modes. For dual-mode loops (2-pipe and water-loop heat-pump), heating and cooling equipment may be specified in the same EQUIP-CTRL sequence; cooling equipment will be automatically disabled (zero flow capacity) when in the heating mode, and vice versa.

Thermal Storage

The following keywords allow you to coordinate the use of a THERMAL-STORAGE device with the other equipment listed in the CHILLERS-n, etc. list. Note that a plant can have at most one THERMAL-STORAGE device attached (discharging to the plant). This discussion assumes the storage is for a cooling plant; storage for heating plant is handled identically.

STORE-SEQ-1

specifies the sequence number of the THERMAL-STORAGE device, if any attached to this loop. The default is that no storage will be used in this FLOWS-THRU-n range.

When a THERMAL-STORAGE device is to be coordinated with other equipment, it is not listed in the CHILLERS-n keyword. Instead, its operation is coordinated via this entry.

To use storage after the chillers listed in CHILLERS-1 are fully loaded, give the storage a higher sequence number than the chillers (using this keyword for the storage, and the CHILLERS-SEQ-1 keyword for the chillers). To use storage before the chillers, give the storage a sequence number of 1, and give the chillers higher sequence number(s). To use storage together with the chillers (loads prorated according to capacity), give the storage device the same sequence number as the chillers.

Normally, the load is prorated to all equipment started in a given FLOWS-THRU-n range. Storage (and meters) is the exception to this rule. Once you enable a storage device, it will be given as much of the remaining load as it can handle.

If the storage is started prior to other equipment (lower sequence number), then it will be given as much of the load as possible, subject to the THERMAL-STORAGE:MAX-DCHRG-RATE and the STORE-MAX-LOAD-n. If the storge cannot satisfy the entire load, then the remaining load will be given to the other equipment according to their sequence numbers. This strategy base loads the storage.

If the storage is started after the other equipment (higher sequence number), then it will be given as much of the remaining load as possible; the equipment having lower sequence numbers will remain fully loaded. This strategy allows the storage to peak shave.

If the storage is started together with other equipment (same sequence number), then the load will be prorated to all equipment including storage according to each unit's hourly capacity.

If the storage has already been depleted from previous usage, then no load will be assigned to storage.

STORE-MAX-LOAD-1

specifies the maximum load to be assigned to a storage device. The actual load assigned will be the lesser of this value, the THERMAL-STORAGE:MAX-DCHRG-RATE, the load, or the remaining storage capacity.

The following keywords allow you to coordinate the use of a STEAM-METER or CHW-METER with on-site equipment. Normally, a building using one of these meters would not also have on-site boilers or chillers. In that case, there is no need to specify a meter within an EQUIP-CTRL sequence; the program will simply use the meter all hours.

For exceptional circumstances where on-site equipment is attached to a loop in addition to a meter, the default configuration will be to use the equipment first (either by default or through an EQUIP-CTRL sequence), and let the meter pick up any unmet load. The only time a meter must be listed within an EQUIP-CTRL sequence is when the meter is used prior to or coordinated with the on-site equipment. The keywords and rules of usage for a meter in this case are identical to those for thermal storage:

Steam or CHW Meter

Meters may also be coordinated with on-site boilers and chillers.

METER-SEQ-1

specifies the sequence number of the steam or chilled-water METER, if any, attached to this meter. The default is that no meter will be used in this FLOWS-THRU-n range. Note that you must define a meter and attach it to the same loop as the EQUIP-CTRL sequence for this keyword to be functional.

When a meter is to be coordinated with other equipment, it is not listed in the EQUIP-n keyword. Instead, its operation is coordinated via this entry.

To use the meter after the equipment listed in EQUIP-1 is fully loaded, give the meter a higher sequence number than the other equipment (using this keyword for the meter, and the EQUIP-SEQ-1 keyword for the other equipment). To use the meter before other equipment, give the meter a sequence number of 1, and give the other equipment higher sequence number(s). To use the meter together with other equipment (loads prorated according to capacity), give the meter the same sequence number as the other equipment.

Normally, the load is prorated to all equipment started in a given FLOWS-THRU-n range. Meters (and storage) are the exception to this rule. Once you enable a meter, it will be given as much of the remaining load as it can handle.

If the meter is enabled prior to other equipment (lower sequence number), then it will be given as much of the load as possible, subject to the METER:CAPACITY and the METER-MAX-LOAD-n. If the meter cannot satisfy the entire load, then the remaining load will be given to the other equipment according to their sequence numbers. This strategy base loads the meter.

If the meter is enabled after the other equipment (higher sequence number), then it will be given as much of the remaining load as possible; the equipment having lower sequence numbers will remain fully loaded. This strategy allows the meter to peak shave.

If the meter is started together with other equipment (same sequence number), then the load will be prorated to all equipment including meter according to each unit's hourly capacity.

METER-MAX-LOAD-1

specifies the maximum load to be assigned to a storage device. The actual load assigned will be the lesser of this value, the METER:CAPACITY, or the load.

TYPE = SUCTION-GROUP

The next set of keywords coordinate the staging of compressors in a suction-group.

SUCTION-GROUP

accepts the U-name of the SUCTION-GROUP to which this control sequence will apply. This is a mandatory entry.

FLOWS-THRU-1
FLOWS-THRU-2
FLOWS-THRU-3
FLOWS-THRU-4
FLOWS-THRU-5

specifies the flow for which the equipment specified in COMPRESSORS-1, etc. will be used. The input is in lbs/hour for refrigeration components.

If you do not specify this flow range, but specify equipment in COMPRESSORS-1, etc., then this entry will default to the hourly flow capacity of the equipment listed in COMPRESSORS-1, etc. Using the default allows the load range to exactly match the capacity of the equipment. Since the flow capacity of equipment may vary substantially from hour to hour, it is strongly recommended that you let this value default.

You must enter the FLOWS-THRU-n ranges in ascending numerical order, without skipping any lower ranges. In other words, FLOWS-THRU-2 must be greater than FLOWS-THRU-1. FLOWS-THRU-3 cannot be used unless FLOWS-THRU-1 and FLOWS-THRU-2 are also defined.

COMPRESSORS-1
COMPRESSORS-2
COMPRESSORS-3
COMPRESSORS-4
COMPRESSORS-5

accepts a list of up to 10 U-names of the boilers that will be used to satisfy the flow listed under FLOWS-THRU-1. The compressors must be attached to the same suction-group as this EQUIP-CTRL, or the program will generate an error.

COMPRESSORS-SEQ-1
COMPRESSORS-SEQ-2
COMPRESSORS-SEQ-3
COMPRESSORS-SEQ-4
COMPRESSORS-SEQ-5

accepts a list of whole numbers (integer 1-10) corresponding to and entered in the same order as the equipment listed in COMPRESSORS-1, etc. These numbers specify the order in which the equipment will start to satisfy the flow requirement. The default is that the equipment will start in the order listed.

More than one equipment unit can have the same sequence number. For example, if two units are to always start and operate together, then they should both be given the same sequence number.

Equipment assigned sequence number 1 will start first, followed by 2, etc. The entry of equipment in COMPRESSORS-1, etc. is not order dependent per se; equipment can be listed in any order, and COMPRESSORS-SEQ-1 numbers assigned in any order.

The EQUIP-CTRL algorithm will start as many equipment units required to satisfy the flow. The flow per unit will be prorated based on that unit's capacity relative to the total capacity enabled (but see MAX-FLOW-1).

~~COMPRESSORS-MAX-1,5~~

this keyword is shown as struck out because, while one might think it has symmetry with boilers and other components controlled by equip-ctrl sequences, it doesn't. Once a compressor is enabled, a suction group will find the balance point between suction pressure and all enabled compressors.

While the flow through one compressor will never be limited by the suction-group, it is possible to preferentially load or unload one compressor over the others. You can do this by specifying COMPRESSOR:CAPACITY-

CTRL = INTERNAL-SETPT-T, and then specifying the COMPRESSOR:INTERNAL-SETPT-T. If the compressor's internal temperature setpoint is higher than the suction group's, then it will not load until the suction pressure floats up sufficiently. The opposite is true if the compressor has a lower internal suction pressure than the suction-group.

TYPE = CONDENSER

The next set of keywords coordinate the staging of condensers in a refrigeration system.

REFG-SYSTEM

accepts the U-name of the REFG-SYSTEM to which this control sequence will apply. This is a mandatory entry.

FLOWS-THRU-1
FLOWS-THRU-2
FLOWS-THRU-3
FLOWS-THRU-4
FLOWS-THRU-5

specifies the flow for which the equipment specified in CONDENSERS-1, etc. will be used. The input is in lbs/hour for refrigeration components.

If you do not specify this flow range, but specify equipment in CONDENSERS-1, etc., then this entry will default to the hourly flow capacity of the equipment listed in CONDENSERS-1, etc. Using the default allows the load range to exactly match the capacity of the equipment. Since the flow capacity of equipment may vary substantially from hour to hour, it is strongly recommended that you let this value default.

You must enter the FLOWS-THRU-n ranges in ascending numerical order, without skipping any lower ranges. In other words, FLOWS-THRU-2 must be greater than FLOWS-THRU-1. FLOWS-THRU-3 cannot be used unless FLOWS-THRU-1 and FLOWS-THRU-2 are also defined.

CONDENSERS-1
CONDENSERS-2
CONDENSERS-3
CONDENSERS-4
CONDENSERS-5

accepts a list of up to 10 U-names of the boilers that will be used to satisfy the flow listed under FLOWS-THRU-1. The compressors must be attached to the same suction-group as this EQUIP-CTRL, or the program will generate an error.

CONDENSER-SEQ-1
CONDENSER-SEQ-2
CONDENSER-SEQ-3
CONDENSER-SEQ-4
CONDENSER-SEQ-5

accepts a list of whole numbers (integer 1-10) corresponding to and entered in the same order as the equipment listed in COMPRESSORS-1, etc. These numbers specify the order in which the equipment will start to satisfy the flow requirement. The default is that the equipment will start in the order listed.

More than one equipment unit can have the same sequence number. For example, if two units are to always start and operate together, then they should both be given the same sequence number.

Equipment assigned sequence number 1 will start first, followed by 2, etc. The entry of equipment in COMPRESSORS-1, etc. is not order dependent per se; equipment can be listed in any order, and COMPRESSORS-SEQ-1 numbers assigned in any order.

The EQUIP-CTRL algorithm will start as many equipment units required to satisfy the flow. The flow per unit will be prorated based on that unit's capacity relative to the total capacity enabled (but see MAX-FLOW-1).

CONDENSER-MAX-1
CONDENSER-MAX-2
CONDENSER-MAX-3
CONDENSER-MAX-4
CONDENSER-MAX-5
accepts a list of values corresponding to and entered in the same order as the equipment listed in CONDENSERS-1, etc. These numbers specify the maximum flow that each equipment unit will be given. If not specified, the maximum will default to each unit's maximum hourly flow capacity. If specified, this value will act as an upper limit on each unit's flow.

This value is entered in lb/hr for condensers.

Generator Control (future)

When generator output is modulated, a generator may track either an electric or thermal load. Please refer to the "Cogeneration" section in the METER component for full information. However, for the purposes of this section, it is important to note the following.

- Electric tracking - The generator modulates its output to match an electric load. The waste heat may be recoverable, but is not actively controlled.

- Thermal tracking – The generator modulates its output to match a heating load. The 'waste' electricity is either consumed on-site or sold to a utility, but is not actively controlled. When tracking a thermal load, *the generator is acting like a boiler, and is controlled identically to a boiler.*

TYPE = ELEC-GENERATION

The following keywords coordinate generator operation when tracking an electric load. In this mode, generator output varies strictly as a function of the electric load. If any waste heat is recovered, it is strictly in a passive mode.

ELEC-METER
accepts the U-name of the METER to which this control sequence will apply. This is a mandatory entry.

LOADS-THRU-1
LOADS-THRU-2
LOADS-THRU-3
LOADS-THRU-4
LOADS-THRU-5
specifies the load for which the equipment specified in GENERATORS-1, etc. will be used. The input is in kW.

If you do not specify this load range, but specify equipment in GENERATORS-1, etc., then this entry will default to the hourly electric capacity of the equipment listed in GENERATORS-1, etc. Using the default allows the load range to exactly match the capacity of the equipment.

You must enter the LOADS-THRU-n ranges in ascending numerical order, without skipping any lower ranges. In other words, LOADS-THRU-2 must be greater than LOADS-THRU-1. LOADS-THRU-3 cannot be used unless LOADS-THRU-1 and LOADS-THRU-2 are also defined.

GENERATORS-1

accepts a list of U-names of the electric generators whose electric output will be used to match the load listed under LOADS-THRU-1. There is no default. The equipment listed must be attached to the same meter as this EQUIP-CTRL sequence.

GENERATORS-SEQ-1

accepts a list of whole numbers (integer 1-10) corresponding to and entered in the same order as the equipment listed in GENERATORS-1. These numbers specify the order in which the equipment will start to satisfy the load. The default is that the equipment will start in the order listed.

GENERATORS-MAX-1

accepts a list of values corresponding to and entered in the same order as the equipment listed in GENERATORS-1. These numbers specify the maximum load that each equipment unit will be given. If not specified, the maximum load will default to each unit's maximum hourly operating capacity. If specified, this value will act as an upper limit on each unit's load. In no case, however, will a unit be assigned a load greater than its hourly capacity.

TYPE = CENTRAL-PLANT

The following keywords coordinate generator operation when tracking a heating load. In this mode, generator output varies strictly as a function of the heating load. In other words, the generator is acting like a boiler, and so can be coordinated with boilers. The 'waste' electricity generated may be consumed on-site or sold to a utility.

CENTRAL-PLANT
FLOWS-THRU-1
FLOWS-THRU-2
FLOWS-THRU-3
FLOWS-THRU-4
FLOWS-THRU-5

Assuming that generators are being coordinated with boilers, these keywords are as described for boilers.

GENERATORS-1

accepts a list of U-names of the electric generators whose *thermal flow capacity* will be used to match the flow listed under FLOWS-THRU-1. There is no default. The equipment listed must be attached to the same central plant as this EQUIP-CTRL sequence.

GENERATORS-SEQ-1

accepts a list of whole numbers (integer 1-10) corresponding to and entered in the same order as the equipment listed in GENERATORS-1. These numbers specify the order in which the equipment will start to satisfy the load. The default is that the equipment will start in the order listed.

GENERATORS-MAX-1

accepts a list of values corresponding to and entered in the same order as the equipment listed in GENERATORS-1. These numbers specify the maximum flow that each equipment unit will be given. If not specified, the maximum load will default to each unit's maximum hourly flow capacity. If specified, this value will act as an upper limit on each unit's flow. In no case, however, will a unit be assigned a flow greater than its hourly capacity.

This value is entered in gallons/min for heating loads in central plants.

SYSTEM

The SYSTEM command has a number of new features for heat-recovery from a refrigeration system, DX cooling provided by a refrigeration system, dual path units, etc.

Heat Recovery from Refrigeration

Refer to the section in this document, "Heat Reclaim"

DX Cooling from Refrigeration

Several of the system types now allow a central cooling coil to be a direct-expansion coil powered by a refrigeration system (PSZ,PVVT,SZRH, VAVS, RHFS, CBVAV). This is common in many supermarkets, where the main air handler has a DX coil attached to one of the medium-temperature refrigeration systems.

COOL-SOURCE

specifies the type of cooling coil in a central air handler:

DEFAULT   specifies that the air handler has the cooling source typical for that type of equipment. Packaged equipment utilizes a self-contained cooling system (PSZ, PVAVS, HP, etc.). Equipment which does not have a self-contained cooling system is assumed to have a chilled-water coil, and must attach to a chilled-water CIRCULATION-LOOP (VAVS, DDS, SZRH, etc.).

REFG-SYSTEM   specifies that the air handler has a direct-expansion coil coupled to a refrigeration system.

COOL-END-USE

For the output reports that break down energy consumption by end-use (BEPS, BEPU, PS-E and PS-F), specifies the end-use category for the cooling energy consumed by the air handler. Currently, this keyword is applicable only when COOL-SOURCE = REFG-SYSTEM, and determines the end-use category of the energy consumed by the suction-group that supplies this air handler. If the suction-group supplies loads falling in more than one end-use category, the energy is prorated to the categories on an hourly basis.

Any of the end-use categories can be selected; however the most appropriate choices are:

SPACE-COOLING   the default, specifies that the air handler is supplying a conventional space with a conventional cooling load.

REFRIGERATION   can be used to specify that the air handler is supplying a special space, such as a walk-in box or warehouse, that is refrigerated to a low temperature.

EQUIPMENT   can be used to specify that the air handler is supplying a space with equipment that generates a large cooling load, such as a computer room.

CIRCULATION-LOOP

when COOL-SOURCE = DEFAULT, and the system does not have a self-contained cooling system, accepts the U-name of the chilled-water CIRCULATION-LOOP that supplies this unit.

REFG-LIQUID-CKT
when COOL-SOURCE = REFG-SYSTEM, accepts the U-name of the liquid REFG-CIRCUIT attached to this coil.

REFG-SUCTION-CKT
when COOL-SOURCE = REFG-SYSTEM, accepts the U-name of the suction REFG-CIRCUIT attached to this coil.

SST-SUPPLY-TD
when COOL-SOURCE = REFG-SYSTEM, specifies the design temperature differential between the air leaving the coil (supply air temperature), and the refrigerant suction temperature. This entry is used in calculating the required suction pressure when the associated SUCTION-GROUP is resetting the suction pressure based on load.

Duty-cycling a Freezer Fan

The thermostat in many coolers and freezers is in the intake to the evaporator. Therefore, if the fan is cycling instead of running continuously (INDOOR-FAN-MODE = INTERMITTENT), the thermostat may not be reading the cooler temperature correctly. Two new keywords have been added to allow the fan to start periodically for a brief period so that the thermostat can better check the cooler temperature:

MIN-DUTY-CYCLE
if fan is off for the hour (no cooling load), specifies the fraction of the hour the fan will operate so that the thermostat can check the space temperature. The default is 0. This keyword applies only when INDOOR-FAN-MODE = INTERMITTENT, and only for PSZ and PVVT systems.

This keyword is used together with MAX-DUTY-CYCLE to add additional run time to the fan, using the relationship

AdditionalFanTime = MIN-DUTY-CYCLE * (1.-FanTime/MAX-DUTY-CYCLE)

where

FanTime   The hourly fraction the fan must run to satisfy the load
AdditionalFanTime   The additional hourly fraction used in the duty cycle

The program assumes the duty cycling time will be spread out over the hour. Both the fan power and cooling load will be increased by the duty cycle time.

For example, if the fan is to be duty-cycled 3 minutes out of every hour when the fan is off, with no duty-cycling once the fan is running more than 50% of every hour:

```
        TYPE               = PVVT
        INDOOR-FAN-MODE    = INTERMITTENT
        MIN-DUTY-CYCLE     = 0.05              $ 3 / 60
        MAX-DUTY-CYCLE     = 0.5               $ 1/2 hour
```

MAX-DUTY-CYCLE
when duty cycling, specifies the fraction of the hour the fan operates above which no duty cycling will occur. The default is 0. This keyword applies only when INDOOR-FAN-MODE = INTERMITTENT for PSZ and PVVT systems, and only when MIN-DUTY-CYCLE is also specified.

This keyword is used together with MIN-DUTY-CYCLE to add additional run time to the fan, using the relationship

AdditionalFanTime = MIN-DUTY-CYCLE * (1.-FanTime/MAX-DUTY-CYCLE)

where

FanTime   The hourly fraction the fan must run to satisfy the load
AdditionalFanTime The additional hourly fraction used in the duty cycle

The program assumes the duty cycling time will be spread out over the hour. Both the fan power and cooling load will be increased by the duty cycle time.

For example, if the fan is to be duty-cycled 3 minutes out of every hour when the fan is off, with no duty-cycling once the fan is running more than 50% of every hour:

```
TYPE               = PVVT
INDOOR-FAN-MODE    = INTERMITTENT
MIN-DUTY-CYCLE     = 0.05                    $ 3 / 60
MAX-DUTY-CYCLE     = 0.5                     $ 1/2 hour
```

ZONE

Interzonal Convective Transfer through Doors

Keywords are provided in the ZONE command to describe convection between two zones, or between a zone and the outdoors. Uses for this feature include the modeling of airwalls between two zones, or infiltration through the door of a walk-in freezer.

The convection is assumed to occur through doors or other openings. Convection includes both sensible and latent exchange, and may be either natural (density-dependent and/or wind-driven), or forced (user-specified airflow):

For density-dependent natural convection, the user specifies the door dimensions, the number of times the door is opened per hour, the length of time the door is open for each passage, a modifying schedule, etc. The program uses these parameters, together with the temperature of the air on either side of the door (actually the density) to determine the flow through the door when the door is open. Leakage during the time the door is closed is also modeled. The natural convection model is based upon the equations presented in the 2006 ASHRAE Handbook - Refrigeration", pp 13.4-13.6.

For wind-driven convection, the user specifies the flow through the door when the wind speed is 10 miles per hour. Hourly, a linear correction to flow is made based on the actual wind speed, with zero flow at zero wind speed. The same usage pattern is applied as for density-dependent convection (door openings per hour, etc.).

For forced convection, the user specifies an airflow, which may be modified hourly by a schedule.

If both density-driven and wind-driven flow is specified, the maximum of the two is used hourly. Forced convection, if any, is added to this maximum.

All of the following keywords are lists of two, allowing this zone to be convectively coupled to two different zones.

NUM-ZONE-DOORS
Specifies the number of openings through which interzonal convection occurs. All of the related interzonal convection keywords are multiplied by this value when determining the total flow. This keyword is a list of two, allowing for convection to two different zones.

DOOR-TYPE
When NUM-ZONE-DOORS is defined, specifies whether the door couples the zone to an interior space, or the outdoors.

    INTERIOR   specifies that the door couples the zone to an adjacent zone, which is defined by the keyword ADJACENT-ZONE.

    EXTERIOR   specifies that the door couples the zone to the outdoors.

ADJACENT-ZONE
When NUM-ZONE-DOORS is defined, and DOOR-TYPE = INTERIOR, specifies the name of the zone(s) adjacent to this zone that will be convectively coupled to this zone. The zone may be either conditioned or unconditioned, but not a plenum. Accepts a list of two zones, allowing for convection to two different zones.

DOOR-HEIGHT

When NUM-ZONE-DOORS is defined, and density-driven natural convection is to be modeled, specifies the height of the door. Accepts a list of two, allowing for convection to two different zones.

If no density-driven airflow exists, do not specify the door height.

DOOR-WIDTH

When NUM-ZONE-DOORS is defined, and density-driven natural convection is to be modeled, specifies the width of the door. Accepts a list of two, allowing for convection to two different zones.

If no density-driven airflow exists, do not specify the door width.

DOOR-FLOW-FACTOR

When NUM-ZONE-DOORS is defined, and density-dependent natural convection is to be modeled, is the ratio of actual air exchange to the theoretical fully established flow. Refer to the ASHRAE Handbook for a detailed description of this keyword and recommended values (typically 0.8 to 1.1 depending on temperature differentials). Accepts a list of two, allowing for convection to two different zones.

Normally, this factor excludes the reduction in convection due to a doorway protective device, such as a strip curtain or automatic door closer; those are typically modeled separately using the DOOR-CTRL-EFF keyword. However, since these two factors are both modifiers on the theoretical fully established flow, they can be combined into a single value if desired.

If no density-driven airflow exists, (door height not specified), this keyword is not used.

PASSAGES/HR

When NUM-ZONE-DOORS is defined, and natural convection is to be modeled (density-dependent or wind-driven), specifies the number of times per hour that the door is opened and closed. This value is modified hourly by the DOOR-SCH. Accepts a list of two, allowing for convection to two different zones.

PASSAGE-TIME

When PASSAGES/HR is defined, specifies the time in seconds that the door is open during each passage. Accepts a list of two, allowing for convection to two different zones.

STAND-OPEN-TIME

When NUM-ZONE-DOORS is defined, and natural convection is to be modeled (density-dependent or wind-driven), specifies the time in minutes/hour that the door is left standing open. The total fraction of the hour the door is open is then

```
FracOpen = (PASSAGES/HR * PASSAGE-TIME / 3600) + (STAND-OPEN-TIME / 60)
```

The program will limit FracOpen to be not more than 1.0 (fully open the entire hour). FracOpen is modified hourly by the DOOR-SCH. Accepts a list of two, allowing for convection to two different zones.

To model an opening with a strip curtain but without a door, the STAND-OPEN-TIME may be set to 60 minutes, so that the door will never close. The door control effectiveness, DOOR-CTRL-EFF, is then the effectiveness of the strip curtain. Alternatively, the door can be left closed the entire hour, and the DOOR-LEAKAGE defined to be the effectiveness of the strip curtain.

For other than strip curtains, the user is cautioned against entering an unreasonably long stand open time. For a relatively small freezer, leaving the door open for a prolonged period of time may cause the freezer temperature to

warm considerably, so that the average convection is considerably less than the initial convection. The program does not explicitly model this sub-hour transient effect; but instead uses the average temperature over the hour.

DOOR-SCH
When NUM-ZONE-DOORS is defined, specifies an schedule that modifies the hourly convective flow. This schedule acts on both forced convection, as well as density-dependent and wind-driven convection. Accepts a list of two, allowing for convection to two different zones.

DOOR-CTRL-EFF
When NUM-ZONE-DOORS is defined, and natural convection is to be modeled (density-dependent or wind-driven), specifies the effectiveness of any doorway protective device, such as a strip curtain or automatic door closer. A value of 0.0 means there is no protective device; a value of 1.0 means that the device is 100% effective at suppressing convection. The default is 0. Accepts a list of two, allowing for convection to two different zones.

The DOOR-CTRL-EFF is applied to both density-dependent and wind-driven convection. It does not apply to the DOOR-FORCED-FLOW.

DOOR-LEAKAGE
When NUM-ZONE-DOORS is defined, and natural convection is to be modeled, specifies the fraction of maximum flow that occurs when the door is closed. This value represents leakage. Accepts a list of two, allowing for convection to two different zones.

Door leakage is applied to both density-dependent and wind-driven convection. It does not apply to the DOOR-FORCED-FLOW.

DOOR-WIND-FLOW
When NUM-ZONE-DOORS is defined, specifies the wind-driven airflow, at 10 miles per hour. Accepts a list of two, allowing for convection to two different zones. Normally, wind-driven flow will only apply to DOOR-TYPE = EXTERIOR.

Hourly, this value will be adjusted linearly for the actual wind speed (zero flow at zero wind speed). The door usage parameters are also applied (PASSAGES/HR, PASSAGE-TIME, STAND-OPEN-TIME, and DOOR-SCH), as is the DOOR-CTRL-EFF and DOOR-LEAKAGE.

The actual hourly flow will be the maximum of this wind-driven flow or the density-dependent airflow defined by related keywords. The DOOR-FORCED-FLOW will be added to this maximum.

DOOR-FORCED-FLOW
When NUM-ZONE-DOORS is defined, specifies a forced airflow that is independent of density or wind. This value is modified hourly by the schedule defined by DOOR-SCH, but is not modified by any other usage parameters. Accepts a list of two, allowing for convection to two different zones.

This airflow will be in addition to any natural convection; where natural convection is the hourly maximum of the density-dependent flow or the wind-driven flow.

SIM-PARAMETERS

Convergence Errors

An iterative program determines when convergence is achieved by comparing the current value of a variable to the value in the last iteration. An exact agreement is almost never achieved. Instead, the convergence criteria is satisfied when the error compared to the previous iteration is sufficiently small.

The following are the convergence errors the program uses for the various energy variables. Experience indicates that convergence using these variables will normally be achieved in 3-7 iterations.

- Smaller convergence errors - Tests indicate that error criteria one-half of these values may increase run times by 5-fold or more, with neglibible ($\ll 1\%$) differences in the results. Very small error ratios ($<1\%$) may occasionally result in convergence failures.

- Larger convergence errors – Tests indicate that larger error ratios will result in slightly faster run times, and errors in the yearly results of 1% or so.

- Mixed convergence errors – Decreasing some error criteria while increasing others has not been tested. The program developers believe that doing so may "unbalance" the calculations and result in convergence failures.

You should not change these variables unless you have good reason to do so. As is, if the program encounters a convergence failure, it will quit iterating after 30 tries and go on to the next hour.

The program has been extensively tested using a wide variety of inputs, and there are no known circumstances in which the program fail to converge. However, if you encounter a run that reports convergence failures, we would like to see it! Please e-mail the input and weather file to steve.gates@doe2.com.

ERROR-LOAD
specifies the maximum error in the load of a component or one of its subcomponents. The error in load is calculated as

$$\text{Error} = \text{Absolute value of } (1. - Q_{last}/Q_{now})$$

ERROR-FLOW
specifies the maximum error in the flow of a component or one of its subcomponents. Flow may represent air, water, or refrigerant. The error in flow is calculated as

$$\text{Error} = \text{Absolute value of } (1. - Q_{last}/Q_{now})$$

ERROR-T
specifies the maximum error in the temperature of a component or one of its subcomponents. The error in temperature is calculated as

$$\text{Error} = \text{Absolute value of } (T_{last} - T_{now})$$

ERROR-HEAD
specifies the maximum error in the pressure of a component or one of its subcomponents. The error in pressure is calculated as

Error = Absolute value of $(P_{last} - P_{now})$

ERROR-H

specifies the maximum error in the enthalpy of a component or one of its subcomponents. The error in enthalpy is calculated as

Error = Absolute value of $(H_{last} - H_{now})$

ERROR-W

specifies the maximum error in the humidity ratio of an airstream. The error in humidity ratio is calculated as

Error = Absolute value of $(W_{last} - W_{now})$

Section

9
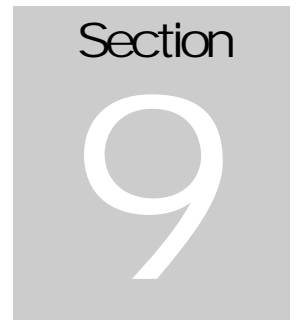
Summary Reports

PLANT-REPORT (PS-) REFRIGERATION REPORTS

PS-H LOADS AND ENERGY USAGE FOR <Compressor Name>

For each compressor, this report summarizes relevant design information as well as monthly and yearly performance. For this report to print, PS-H must be specified in PLANT-REPORTS, and the compressor's EQUIPMENT-REPORTS = YES.

The design information are the first entries in the report:

FEEDS INTO
lists the discharge circuit of this compressor.

DRAWS FROM / OTHER
lists the suction group and the electric meter to which this compressor is attached.

REFG FLOW
lists the design refrigerant flow of this compressor.

POWER
lists the compressor power consumption at design conditions, excluding any auxiliary power, such as for a crankcase heater.

SUCTION
specifies the design suction temperature

SUPERHEAT
specifies the superheat in the suction gas.

DISCHARGE
specifies the design discharge temperature.

Following the design data is the monthly and yearly performance summary:

REFG LOAD
is the refrigerant load equivalent to the refrigerant flow through this compressor. This load is calculated as a function of the refrigerant flow, the suction enthalpy, and the liquid enthalpy leaving the condenser(s), but before any subcooling.

REFG FLOW
is the refrigerant flow handled by this compressor.

COMPRESSOR
is the compressor power, excluding any auxiliary energy such as a crankcase heater.

TOTAL PWR
is the sum of the compressor power plus any auxiliary energy, such as for a crankcase heater.

For each month and for the year, information is presented on the category total, peak monthly or yearly value, and the time when the peak occurred. Bin information is presented in terms of the number of hours the flow and power fell into the appropriate part load bin. The part load bin is calculated in terms of the hourly value divided by the design value.

D I C T I O N A R Y

FEEDS INTO	DRAWS FROM / OTHER	REFG FLOW (LB/HR)	POWER (KW)	SUCTION (F)	SUPERHEAT (F (DELTA))	DISCHARGE (F)
HS Trunk 1	Rack SST:B1 EM1	843.8	12.6	-25.0	3.3	104.1

MON	SUM PEAK	REFG LOAD (MBTU) (KBTU/HR)	REFG FLOW (LB) (LB/HR)	COMPRESSOR (KWH) (KW)	TOTAL PWR (KWH) (KW)		00 10	10 20	20 30	30 40	40 50	50 60	60 70	70 80	80 90	90 100	100 +	TOTAL RUN HOURS
JAN	SUM	29.7	448734.	6461.	6461. FLOW		0	0	0	0	0	0	0	1	161	356	56	574
	PEAK	60.5	915.	12.149	12.149 ELEC		0	0	0	0	0	0	0	0	301	273	0	574
	DAY/HR	18/22	18/22	19/14	19/14													
FEB	SUM	25.6	387025.	5627.	5627. FLOW		0	0	0	0	0	0	0	1	171	328	4	504
	PEAK	58.4	879.	11.830	11.830 ELEC		0	0	0	0	0	0	0	0	326	178	0	504
	DAY/HR	23/17	23/17	23/17	23/17													
MAR	SUM	28.4	428140.	6228.	6228. FLOW		0	0	0	0	0	0	0	1	187	362	8	558
	PEAK	59.8	903.	12.012	12.012 ELEC		0	0	0	0	0	0	0	0	379	179	0	558
	DAY/HR	20/ 1	20/ 1	20/ 1	20/ 1													
APR	SUM	27.5	416066.	6046.	6046. FLOW		0	0	0	0	0	0	0	3	181	328	28	540
	PEAK	61.5	929.	12.093	12.093 ELEC		0	0	0	0	0	0	0	0	354	186	0	540
	DAY/HR	23/21	23/21	22/21	22/21													
MAY	SUM	28.2	425953.	6226.	6226. FLOW		0	0	0	0	0	0	0	4	215	323	16	558
	PEAK	57.6	876.	11.885	11.885 ELEC		0	0	0	0	0	0	0	0	403	155	0	558
	DAY/HR	25/21	12/17	12/17	12/17													
JUN	SUM	27.2	411192.	6022.	6022. FLOW		0	0	0	0	0	0	0	7	207	293	33	540
	PEAK	59.5	902.	12.034	12.034 ELEC		0	0	0	0	0	0	0	0	377	163	0	540
	DAY/HR	9/13	9/13	9/13	9/13													
JUL	SUM	28.2	428242.	6257.	6257. FLOW		0	0	0	0	0	0	0	5	224	277	52	558
	PEAK	59.1	895.	11.978	11.978 ELEC		0	0	0	0	0	0	0	0	332	226	0	558
	DAY/HR	13/21	13/21	13/21	13/21													
AUG	SUM	28.2	427103.	6245.	6245. FLOW		0	0	0	0	0	0	0	9	224	268	57	558
	PEAK	58.8	891.	11.956	11.956 ELEC		0	0	0	0	0	0	0	0	361	197	0	558
	DAY/HR	16/21	18/21	14/21	14/21													
SEP	SUM	27.2	411424.	6027.	6027. FLOW		0	0	0	0	0	0	0	6	225	281	28	540
	PEAK	58.7	890.	11.959	11.959 ELEC		0	0	0	0	0	0	0	0	366	174	0	540
	DAY/HR	24/21	24/21	23/21	23/21													
OCT	SUM	28.2	425508.	6220.	6220. FLOW		0	0	0	0	0	0	0	6	204	345	3	558
	PEAK	56.7	858.	11.743	11.743 ELEC		0	0	0	0	0	0	0	0	408	150	0	558
	DAY/HR	4/21	4/21	4/21	4/21													
NOV	SUM	27.6	417134.	6055.	6055. FLOW		0	0	0	0	0	0	0	3	172	345	21	541
	PEAK	61.7	932.	12.134	12.134 ELEC		0	0	0	0	0	0	0	0	349	192	0	541
	DAY/HR	21/17	21/17	21/17	21/17													
DEC	SUM	28.4	428027.	6222.	6222. FLOW		0	0	0	0	0	0	0	5	185	368	0	558
	PEAK	54.2	819.	11.510	11.510 ELEC		0	0	0	0	0	0	0	0	353	205	0	558
	DAY/HR	15/11	13/ 7	13/ 7	13/ 7													
YR	SUM	334.3	5054548.	73635.	73635. FLOW		0	0	0	0	0	0	0	51	2356	3874	306	6587
	PEAK	61.7	932.	12.149	12.149 ELEC		0	0	0	0	0	0	0	0	4309	2278	0	6587
	MON/DAY	11/21	11/21	1/19	1/19													

PS-H LOADS AND ENERGY USAGE FOR <Condenser Name>

For each condenser, this report summarizes relevant design information as well as monthly and yearly performance. For this report to print, PS-H must be specified in PLANT-REPORTS, and the condenser's EQUIPMENT-REPORTS = YES.

The design information are the first entries in the report:

FEEDS INTO
lists the refrigeration system to which this condenser is attached. If this is a refrigerant-cooled or water-cooled condenser, also lists the discharge attachment of the fluid providing the condensing effect.

DRAWS FROM / OTHER
repeats the refrigeration system attachment, as well as the electric meter. If this is a refrigerant-cooled or water-cooled condenser, also lists the inlet attachment of the fluid providing the condensing effect.

CAPACITY
is the design heat rejection capacity of the condenser.

REFG FLOW
lists the design refrigerant flow.

FAN PWR
is the power consumed by the fan, if any.

TOTAL PWR
is the total power consumed in the condenser, including the fan and spray pump, if any.

SAT COND
is the design saturated condensing temperature.

Following the design data is the monthly and yearly performance summary:

REFG LOAD
is the heat rejected by the condenser.

REFG FLOW
is the refrigerant flow through the condenser.

FAN PWR
is the power consumed by the condenser fan, if any.

TOTAL PWR
is the total power consumed by the condenser; which may include the fan, spray pump, and auxiliary energy.

For each month and for the year, information is presented on the category total, peak monthly or yearly value, and the time when the peak occurred. Bin information is presented in terms of the number of hours the flow and power fell into the appropriate part load bin. The part load bin is calculated in terms of the hourly value divided by the design value.

D I C T I O N A R Y

FEEDS INTO	DRAWS FROM / OTHER	CAPACITY (MBTU)	REFG FLOW (LB/HR)	FAN PWR (KW)	TOTAL PWR (KW)	SAT COND (F)
Refg System 1	Refg System 1 EM1	0.513	4485.4	2.6	2.8	105.0

MON	SUM PEAK	REFG LOAD (MBTU) (KBTU/HR)	REFG FLOW (LB) (LB/HR)	FAN PWR (KWH) (KW)	TOTAL PWR (KWH) (KW)	00 10	10 20	20 30	30 40	40 50	50 60	60 70	70 80	80 90	90 100	100 +	TOTAL RUN HOURS
JAN	SUM	117.4	1004125.	33.	234. FLOW	0	148	159	352	82	3	0	0	0	0	0	744
	PEAK	271.0	2259.	0.137	0.407 ELEC	0	744	0	0	0	0	0	0	0	0	0	744
	DAY/HR	24/21	24/21	18/21	18/21												
FEB	SUM	100.8	858621.	26.	208. FLOW	0	164	125	374	9	0	0	0	0	0	0	672
	PEAK	218.4	1916.	0.077	0.347 ELEC	0	672	0	0	0	0	0	0	0	0	0	672
	DAY/HR	23/17	23/17	7/ 9	7/ 9												
MAR	SUM	112.9	961885.	29.	231. FLOW	0	182	119	432	11	0	0	0	0	0	0	744
	PEAK	236.7	2070.	0.069	0.338 ELEC	0	744	0	0	0	0	0	0	0	0	0	744
	DAY/HR	20/ 5	20/ 5	20/ 5	20/ 5												
APR	SUM	114.0	972221.	33.	229. FLOW	0	160	86	427	47	0	0	0	0	0	0	720
	PEAK	228.5	2037.	0.102	0.372 ELEC	0	720	0	0	0	0	0	0	0	0	0	720
	DAY/HR	23/21	23/21	25/17	25/17												
MAY	SUM	119.0	1012825.	38.	240. FLOW	0	179	53	465	47	0	0	0	0	0	0	744
	PEAK	219.5	1929.	0.119	0.390 ELEC	0	744	0	0	0	0	0	0	0	0	0	744
	DAY/HR	12/17	12/17	11/17	11/17												
JUN	SUM	118.0	1004670.	44.	239. FLOW	0	176	27	445	72	0	0	0	0	0	0	720
	PEAK	223.1	1977.	0.130	0.401 ELEC	0	720	0	0	0	0	0	0	0	0	0	720
	DAY/HR	9/13	9/13	6/17	6/17												
JUL	SUM	124.5	1061832.	57.	258. FLOW	0	184	3	455	102	0	0	0	0	0	0	744
	PEAK	224.5	1987.	0.217	0.489 ELEC	0	744	0	0	0	0	0	0	0	0	0	744
	DAY/HR	13/21	13/21	13/17	13/17												
AUG	SUM	125.1	1066122.	53.	255. FLOW	0	184	2	454	104	0	0	0	0	0	0	744
	PEAK	224.2	1976.	0.204	0.475 ELEC	0	744	0	0	0	0	0	0	0	0	0	744
	DAY/HR	16/21	16/21	7/17	7/17												
SEP	SUM	118.5	1008618.	44.	239. FLOW	0	180	15	451	74	0	0	0	0	0	0	720
	PEAK	223.2	1975.	0.181	0.452 ELEC	0	720	0	0	0	0	0	0	0	0	0	720
	DAY/HR	24/21	23/21	23/17	23/17												
OCT	SUM	117.1	996545.	34.	236. FLOW	0	186	56	475	27	0	0	0	0	0	0	744
	PEAK	215.8	1887.	0.091	0.361 ELEC	0	744	0	0	0	0	0	0	0	0	0	744
	DAY/HR	4/21	4/21	18/17	18/17												
NOV	SUM	112.1	955651.	30.	226. FLOW	0	166	94	427	33	0	0	0	0	0	0	720
	PEAK	239.2	2083.	0.092	0.358 ELEC	0	720	0	0	0	0	0	0	0	0	0	720
	DAY/HR	21/21	21/21	6/13	6/13												
DEC	SUM	108.5	924112.	26.	228. FLOW	0	186	167	391	0	0	0	0	0	0	0	744
	PEAK	203.8	1747.	0.055	0.325 ELEC	0	744	0	0	0	0	0	0	0	0	0	744
	DAY/HR	28/21	28/21	29/13	29/13												
YR	SUM	1387.8	11827226.	448.	2822. FLOW	0	2095	906	5148	608	3	0	0	0	0	0	8760
	PEAK	271.0	2259.	0.217	0.489 ELEC	0	8760	0	0	0	0	0	0	0	0	0	8760
	MON/DAY	1/24	1/24	7/13	7/13												

PS-H LOADS AND ENERGY USAGE FOR <Display-Fixture Name>

For each display fixture, this report summarizes relevant design information as well as monthly and yearly performance. This is a summary report; more detailed information can be found in report PS-I.

For this report to print, PS-H must be specified in PLANT-REPORTS, and the fixture's EQUIPMENT-REPORTS = YES.

The design information are the first entries in the report:

FEEDS INTO
lists itself.

DRAWS FROM / OTHER
lists itself, and the electric meter to which this fixture is attached.

REFG LOAD
is the refrigeration load at the design conditions

REFG FLOW
is the refrigeration flow corresponding to the design load.

TOTAL PWR
is the connected power consumed by the fixture lights, fan, defroster, anti-sweat heater, etc. This value is not necessarily the peak power, as different components may draw at different times. This entry does not include the power of the compressors or other refrigeration components to which this fixture is attached, unless this fixture is self-contained.

CONDUCT
is the conduction load at design conditions.

INFIL
is the infiltration flow at design conditions.

Following the design data is the monthly and yearly performance summary:

REFG LOAD
is the refrigeration load

REFG FLOW
is the refrigerant flow

ELECTRICAL
is the total power consumed by components within this fixture, such as lights, fan, defroster, anti-sweat heaters, etc. This entry does not include the power of the compressors or other refrigeration components to which this fixture is attached, unless this fixture is self-contained.

For each month and for the year, information is presented on the category total, peak monthly or yearly value, and the time when the peak occurred. Bin information is presented in terms of the number of hours the load fell into the appropriate part load bin. The part load bin is calculated in terms of the hourly value divided by the design value.

D I C T I O N A R Y

```
-----------------------------------------------------------------------------------------------------------------------
                                                      REFG LOAD   REFG FLOW   TOTAL PWR    CONDUCT      INFIL
FEEDS INTO                         DRAWS FROM / OTHER   (MBTU)      (LB/HR)      (KW)     (BTU/HR-F)    (CFM)
--------------------------------   ----------------   ----------  ----------  ----------  ----------  ----------
1B11                               1B11                  0.068       887.3        2.3        58.3       283.2
                                   EM1
```

```
                REFG LOAD   REFG FLOW  ELECTRICAL      -------- Number of hours within each PART LOAD range  --------- TOTAL
           SUM   (MBTU)       (LB)       (KWH)       00   10   20   30   40   50   60   70   80   90  100    RUN
MON  PEAK  (KBTU/HR)   (LB/HR)     (KW)         10   20   30   40   50   60   70   80   90  100    +   HOURS
---  ----  ----------  ----------  ----------  ---- ---- ---- ---- ---- ---- ---- ---- ---- ---- ---- ----

JAN  SUM     36.1     447004.       704.    LOAD 186    0    0    0    0    0   28  113  145   87  185  744
     PEAK    84.9       1052.      2.180
     DAY/HR  30/17      18/21      18/17

FEB  SUM     32.2     399117.       552.    LOAD 168    0    0    0    0    0   24  126  124   66  164  672
     PEAK    83.6       1029.      1.991
     DAY/HR   7/21       7/21      23/18

MAR  SUM     36.0     445295.       617.    LOAD 186    0    0    0    0    0   15  140  134   85  184  744
     PEAK    82.4       1022.      1.603
     DAY/HR  24/21      24/21      18/13

APR  SUM     35.7     441644.       627.    LOAD 180    0    0    0    0    0    3  106  150   96  185  720
     PEAK    85.0       1056.      1.845
     DAY/HR  27/21      27/21      22/18

MAY  SUM     37.6     465814.       609.    LOAD 186    0    0    0    0    0    0   99  146  111  202  744
     PEAK    85.9       1062.      1.553
     DAY/HR  10/21       7/21      13/11

JUN  SUM     37.3     461676.       579.    LOAD 180    0    0    0    0    0    0   84  122  105  229  720
     PEAK    87.9       1092.      1.789
     DAY/HR  26/21      26/21       9/11

JUL  SUM     39.4     488624.       581.    LOAD 186    0    0    0    0    0    0   66   91  141  260  744
     PEAK    90.4       1126.      1.268
     DAY/HR  28/21      12/21       1/17

AUG  SUM     39.5     489539.       584.    LOAD 186    0    0    0    0    0    0   45  116  140  257  744
     PEAK    90.4       1125.      1.552
     DAY/HR  16/21      16/21       7/13

SEP  SUM     37.5     464979.       563.    LOAD 180    0    0    0    0    0    0   64  128  113  235  720
     PEAK    90.1       1113.      1.327
     DAY/HR  23/21      24/17      26/15

OCT  SUM     37.4     462599.       585.    LOAD 186    0    0    0    0    0    2  108  140  110  198  744
     PEAK    86.8       1069.      1.427
     DAY/HR  18/21      18/21      21/18

NOV  SUM     35.3     437705.       608.    LOAD 180    0    0    0    0    0    7  122  137   93  181  720
     PEAK    83.9       1045.      2.044
     DAY/HR  11/21      11/21      21/19

DEC  SUM     35.2     435954.       583.    LOAD 186    0    0    0    0    0   35  147  135   61  180  744
     PEAK    81.6       1009.      1.436
     DAY/HR  28/21      29/21       9/13
             ==========  ==========  ==========         ==== ==== ==== ==== ==== ==== ==== ==== ==== ==== ==== ====

YR   SUM    439.1    5439949.      7193.    LOAD2190    0    0    0    0    0  114 1220 1568 1208 2460 8760
     PEAK    90.4       1126.      2.180
     MON/DAY  8/16       7/12       1/18
```

PS-H LOADS AND ENERGY USAGE FOR <Refg-Circuit Name>

For each refrigerant circuit, this report summarizes relevant design information as well as monthly and yearly performance. For this report to print, PS-H must be specified in PLANT-REPORTS, and the circuit's EQUIPMENT-REPORTS = YES.

The design information are the first entries in the report:

FEEDS INTO
lists the display fixtures, process loads, HVAC systems, suction groups, branch circuits, etc. that are fed from this circuit.

DRAWS FROM / OTHER
lists the display fixtures, process loads, HVAC systems, suction groups, branch circuits, etc. that are feed into this circuit.

REFG FLOW
is the design refrigerant flow.

DT
is the design temperature rise of the circuit due to thermal gains.

DP
is the design change in saturated temperature due to friction losses.

Following the design data is the monthly and yearly performance summary:

REFG FLOW
is the refrigerant flow through the circuit.

HEAT GAIN
is the increase in enthalpy due to heat gains to the circuit

HEAT LOSS
is the decrease in enthalpy due to heat losses from the circuit

HEAT RCVR
for a discharge circuit, is the amount of heat that was recovered for other uses

For each month and for the year, information is presented on the category total, peak monthly or yearly value, and the time when the peak occurred. Bin information is presented in terms of the number of hours the flow fell into the appropriate part load bin. The part load bin is calculated in terms of the hourly value divided by the design value.

D I C T I O N A R Y

```
DOE2.2 Supermarket Sample "Market 1"                                     DOE-B2.2-R20   5/14/2002   10:32:59  BDL RUN  1
Using JJH DOE2.2 Beta Release 30NT
REPORT- PS-H Loads and Energy Usage for     Liquid Trunk 5               WEATHER FILE- CZ10RV2 WYEC2
-------------------------------------------------------------------------------------------------------------------------
                                                         REFG FLOW      DT          DP
FEEDS INTO                    DRAWS FROM / OTHER           (LB/HR)   (F (DELTA)) (F (DELTA))
---------------------------   ---------------------------  ---------- ----------  ----------
5F49                          Refg System 5                 2620.2        0.0         0.0
5F50
5F51
5F52
5F61
```

```
           REFG FLOW  HEAT GAIN  HEAT LOSS  HEAT RCVR   -------- Number of hours within each PART LOAD range  --------- TOTAL
      SUM    (LB)      (MBTU)     (MBTU)     (MBTU)      00   10   20   30   40   50   60   70   80   90  100   RUN
MON  PEAK  (LB/HR)   (KBTU/HR)  (KBTU/HR)  (KBTU/HR)    10   20   30   40   50   60   70   80   90  100    +   HOURS
---  ----  ---------- ---------- ---------- ----------  ---- ---- ---- ---- ---- ---- ---- ---- ---- ---- ---- ----

JAN  SUM    787467.      0.0       0.0        0.0 FLOW   0   34   82  263  208  130   27    0    0    0    0  744
     PEAK     1661.      0.0       0.0        0.0
     DAY/HR   30/17     0/ 0      0/ 0       0/ 0

FEB  SUM    687167.      0.0       0.0        0.0 FLOW   0   34   77  240  224   97    0    0    0    0    0  672
     PEAK     1515.      0.0       0.0        0.0
     DAY/HR    7/15     0/ 0      0/ 0       0/ 0

MAR  SUM    782423.      0.0       0.0        0.0 FLOW   0   34   67  268  209  166    0    0    0    0    0  744
     PEAK     1485.      0.0       0.0        0.0
     DAY/HR   23/23     0/ 0      0/ 0       0/ 0

APR  SUM    816284.      0.0       0.0        0.0 FLOW   0   29   61  208  188  207   27    0    0    0    0  720
     PEAK     1638.      0.0       0.0        0.0
     DAY/HR   14/17     0/ 0      0/ 0       0/ 0

MAY  SUM    901381.      0.0       0.0        0.0 FLOW   0   24   69   91  262  212   86    0    0    0    0  744
     PEAK     1711.      0.0       0.0        0.0
     DAY/HR   11/17     0/ 0      0/ 0       0/ 0

JUN  SUM    937053.      0.0       0.0        0.0 FLOW   0   11   79   12  273  133  212    0    0    0    0  720
     PEAK     1790.      0.0       0.0        0.0
     DAY/HR   26/19     0/ 0      0/ 0       0/ 0

JUL  SUM   1033082.      0.0       0.0        0.0 FLOW   0    0   70   23  243  137  204   67    0    0    0  744
     PEAK     1985.      0.0       0.0        0.0
     DAY/HR   13/17     0/ 0      0/ 0       0/ 0

AUG  SUM   1042415.      0.0       0.0        0.0 FLOW   0    0   74   19  200  177  232   42    0    0    0  744
     PEAK     1965.      0.0       0.0        0.0
     DAY/HR   16/19     0/ 0      0/ 0       0/ 0

SEP  SUM    955738.      0.0       0.0        0.0 FLOW   0    5   75   21  250  156  190   23    0    0    0  720
     PEAK     1940.      0.0       0.0        0.0
     DAY/HR   23/15     0/ 0      0/ 0       0/ 0

OCT  SUM    882666.      0.0       0.0        0.0 FLOW   0   19   74  101  286  209   55    0    0    0    0  744
     PEAK     1691.      0.0       0.0        0.0
     DAY/HR   18/21     0/ 0      0/ 0       0/ 0

NOV  SUM    793957.      0.0       0.0        0.0 FLOW   0   30   60  227  177  225    1    0    0    0    0  720
     PEAK     1573.      0.0       0.0        0.0
     DAY/HR   11/15     0/ 0      0/ 0       0/ 0

DEC  SUM    728598.      0.0       0.0        0.0 FLOW   0   46   75  319  280   24    0    0    0    0    0  744
     PEAK     1391.      0.0       0.0        0.0
     DAY/HR   29/15     0/ 0      0/ 0       0/ 0
           ========== ========== ========== ==========  ==== ==== ==== ==== ==== ==== ==== ==== ==== ==== ==== ====

YR   SUM  10348231.      0.0       0.0        0.0 FLOW   0  266  863 1792 2800 1873 1034  132    0    0    0 8760
     PEAK     1985.      0.0       0.0        0.0
     MON/DAY   7/13     0/ 0      0/ 0       0/ 0
```

PS-H LOADS AND ENERGY USAGE FOR <Refg-System Name>

For each refrigeration system, this report summarizes relevant design information as well as monthly and yearly performance. For this report to print, PS-H must be specified in PLANT-REPORTS, and the refrigeration system's EQUIPMENT-REPORTS = YES.

The design information are the first entries in the report:

FEEDS INTO
lists the liquid refrigeration circuits and/or subcoolers that draw from this system.

DRAWS FROM / OTHER
lists the discharge refrigeration circuits that feed into this system, and the attached condensers.

Following the design data is the monthly and yearly performance summary:

REFG FLOW
is the refrigerant flow through all circuits in this system.

HEAT REJ
is the heat rejected through the condensers. Note that, if there are subcoolers rejecting heat to other systems, this value excludes the subcooling heat rejection.

POWER
is the total power consumed by components within this refrigeration system, specifically compressors and condensers, and possibly other components that consume electricity such as an air-cooled desuperheater (future). It does not include the power consumption of *loads* on the system, such as the lights, fans, and defroster in a display fixture.

For each month and for the year, information is presented on the category total, peak monthly or yearly value, and the time when the peak occurred. Bin information is presented in terms of the number of hours the flow, heat rejection, and power fell into the appropriate part load bin. The part load bin is calculated in terms of the hourly value divided by the design value.

D I C T I O N A R Y

```
DOE2.2 Supermarket Sample "Market 1"                                   DOE-B2.2-R20   5/14/2002   10:32:59  BDL RUN  1
Using JJH DOE2.2 Beta Release 30NT
REPORT- PS-H Loads and Energy Usage for     Refg System 1                            WEATHER FILE- CZ10RV2 WYEC2
-----------------------------------------------------------------------------------------------------------------------

                                                    REFG FLOW
FEEDS INTO                   DRAWS FROM / OTHER       (LB/HR)
---------------------------  ---------------------------  ----------
2D23                         HS Trunk 1                   3737.8
                             Condenser 1
                             Condenser 1


            REFG FLOW    HEAT REJ    POWER        -------- Number of hours within each PART LOAD range  --------- TOTAL
      SUM     (LB)       (MBTU)      (KWH)        00   10   20   30   40   50   60   70   80   90  100    RUN
MON  PEAK   (LB/HR)    (KBTU/HR)    (KW)          10   20   30   40   50   60   70   80   90  100    +   HOURS
---  ----   ----------  ----------  ----------   ---- ---- ---- ---- ---- ---- ---- ---- ---- ---- ----  ----

JAN  SUM   1068099.    117.459     15199.   FLOW  0    0  125   19  104  402   64   30    0    0    0   744
     PEAK     2242.    270.825     36.135   HTREJ 0    0  141   37  217  222  108   16    3    0    0   744
    DAY/HR   18/21      24/21       24/21   ELEC  0  125   75  260  268   13    3    0    0    0    0   744

FEB  SUM    926070.    101.085     13120.   FLOW  0    0  144   17   71  419   21    0    0    0    0   672
     PEAK     1924.    217.830     26.993   HTREJ 0    0  162    7  217  242   44    0    0    0    0   672
    DAY/HR   23/17      23/17        5/21   ELEC  0  143   38  281  210    0    0    0    0    0    0   672

MAR  SUM   1050291.    113.112     14695.   FLOW  0    0  170    3   27  467   77    0    0    0    0   744
     PEAK     1853.    238.639     29.545   HTREJ 0    0  173   13  225  275   57    1    0    0    0   744
    DAY/HR   19/21      20/ 5       20/ 5   ELEC  0  154   40  301  249    0    0    0    0    0    0   744

APR  SUM   1001957.    114.074     14831.   FLOW  0    0  167   13   50  437   53    0    0    0    0   720
     PEAK     1907.    230.988     27.869   HTREJ 0    0  148   32  167  262  111    0    0    0    0   720
    DAY/HR   22/17      23/21       23/21   ELEC  0  106   74  227  313    0    0    0    0    0    0   720

MAY  SUM   1046110.    119.048     15526.   FLOW  0    0  188    0   14  512   30    0    0    0    0   744
     PEAK     1834.    219.550     27.437   HTREJ 0    0  169   17  127  323  108    0    0    0    0   744
    DAY/HR   10/17      25/21       12/17   ELEC  0  102   84  214  344    0    0    0    0    0    0   744

JUN  SUM   1031050.    118.163     15418.   FLOW  0    0  139    1  132  398   50    0    0    0    0   720
     PEAK     1997.    222.142     27.661   HTREJ 0    0  162   18   70  320  150    0    0    0    0   720
    DAY/HR    9/13       9/13        9/13   ELEC  0   85   95  156  384    0    0    0    0    0    0   720

JUL  SUM   1104076.    124.599     16286.   FLOW  0    0  189   14  107  102  332    0    0    0    0   744
     PEAK     2012.    223.984     28.101   HTREJ 0    0  145   41   55  297  206    0    0    0    0   744
    DAY/HR   31/21      28/21       12/21   ELEC  0   86  100  114  444    0    0    0    0    0    0   744

AUG  SUM   1122172.    125.262     16353.   FLOW  0    0  136   28  107  186  287    0    0    0    0   744
     PEAK     2012.    224.223     28.014   HTREJ 0    0  145   41   49  291  218    0    0    0    0   744
    DAY/HR   16/21      14/21       16/21   ELEC  0   83  103   98  460    0    0    0    0    0    0   744

SEP  SUM    983963.    118.661     15487.   FLOW  0    0  160   93   36  316  115    0    0    0    0   720
     PEAK     1987.    221.949     28.025   HTREJ 0    0  161   19   66  311  163    0    0    0    0   720
    DAY/HR   23/21      23/21       23/21   ELEC  0   82   98  145  395    0    0    0    0    0    0   720

OCT  SUM   1034504.    117.430     15271.   FLOW  0    0  206    0    7  483   48    0    0    0    0   744
     PEAK     1832.    217.982     27.135   HTREJ 0    0  184    2  140  335   83    0    0    0    0   744
    DAY/HR   13/21      18/21        4/21   ELEC  0  123   63  249  309    0    0    0    0    0    0   744

NOV  SUM   1018784.    112.121     14561.   FLOW  0    0  155   17   29  449   70    0    0    0    0   720
     PEAK     1993.    239.832     29.985   HTREJ 0    0  158   22  196  254   87    3    0    0    0   720
    DAY/HR   17/21      21/21       21/21   ELEC  0  128   52  261  278    1    0    0    0    0    0   720

DEC  SUM   1018262.    108.926     14123.   FLOW  0    0  137    2  160  445    0    0    0    0    0   744
     PEAK     1751.    206.731     26.049   HTREJ 0    0  186    0  293  246   19    0    0    0    0   744
    DAY/HR   28/21      29/21       28/21   ELEC  0  183   24  345  192    0    0    0    0    0    0   744
           ==========  ==========  ==========  ==== ==== ==== ==== ==== ==== ==== ==== ==== ==== ====  ====

YR   SUM  12405337.   1389.939    180872.   FLOW  0    0 1916  207  844 4616 1147   30    0    0    0  8760
     PEAK     2242.    270.825     36.135   HTREJ 0    0 1934  249 1822 3378 1354   20    3    0    0  8760
   MON/DAY    1/18       1/24        1/24   ELEC  0 1400  846 2651 3846   14    3    0    0    0    0  8760
```

PS-H LOADS AND ENERGY USAGE FOR <Subcooler Name>

For each subcooler, this report summarizes relevant design information as well as monthly and yearly performance. For this report to print, PS-H must be specified in PLANT-REPORTS, and the subcooler's EQUIPMENT-REPORTS = YES.

The design information are the first entries in the report:

FEEDS INTO
lists the liquid refrigeration circuits that draw from this subcooler, as well as the suction line that removes the flashed refrigerant.

DRAWS FROM / OTHER
lists the refrigeration system or liquid circuit containing the refrigerant to be subcooled, as well as the liquid line supply the refrigerant to be flashed.

REFG LOAD
is the design subcooling load.

SUBCL FLOW
is the design flow of the liquid refrigerant to be subcooled.

SUCTN FLOW
is the design flow of the refrigerant that provides the subcooling effect.

SUBCOOL T
is the design temperature of the subcooled liquid.

HT-EXCH UA
is the UA product of the subcooler's heat-exchanger

Following the design data is the monthly and yearly performance summary:

REFG LOAD
is the heat removed from the subcooled liquid refrigerant.

SUBCL FLOW
is the flow of the subcooled liquid refrigerant

SUCTN FLOW
is the flow of the (suction) refrigerant providing the subcooling effect.

For each month and for the year, information is presented on the category total, peak monthly or yearly value, and the time when the peak occurred. Bin information is presented in terms of the number of hours the load, subcooled liquid flow, and suction flow fell into the appropriate part load bin. The part load bin is calculated in terms of the hourly value divided by the design value.

D I C T I O N A R Y

```
DOE2.2 Supermarket Sample "Market 1"                                       DOE-B2.2-R20   5/14/2002   10:32:59  BDL RUN  1
Using JJH DOE2.2 Beta Release 30NT
REPORT- PS-H Loads and Energy Usage for     Subcooler 2D23                  WEATHER FILE- CZ10RV2 WYEC2
-------------------------------------------------------------------------------------------------------------------------

                                                       REFG LOAD  SUBCL FLOW  SUCTN FLOW  SUBCOOL T  HT-EXCH UA
FEEDS INTO                      DRAWS FROM / OTHER      (MBTU/HR)   (LB/HR)     (LB/HR)       (F)     (BTU/HR-F)
------------------------------  --------------------    ---------  ----------  ----------  ---------  ----------
Liquid Trunk 1                  Refg System 1             0.049      2926.4      710.6        50.0      1710.8
Suction Trunk 3                 Liquid Trunk 2


              REFG LOAD  SUBCL FLOW  SUCTN FLOW           -------- Number of hours within each PART LOAD range --------- TOTAL
        SUM    (MBTU)      (LB)        (LB)           00   10   20   30   40   50   60   70   80   90  100    RUN
MON   PEAK   (KBTU/HR)   (LB/HR)     (LB/HR)          10   20   30   40   50   60   70   80   90  100    +   HOURS
---   ----  ----------  ----------  ----------       ---- ---- ---- ---- ---- ---- ---- ---- ---- ---- ---- ----

JAN   SUM        14.4    1004756.    199229.   LOAD     0   41  120  176  290  105   12    0    0    0    0   744
      PEAK       31.1       2258.    428.133   SBCL     0    0  146   38  238  215   87   20    0    0    0   744
      DAY/HR     24/21      24/21      24/21   SUCT     0   68   98  236  261   79    2    0    0    0    0   744

FEB   SUM        12.4     860874.    171064.   LOAD     0   37  130  153  326   26    0    0    0    0    0   672
      PEAK       26.7       1911.    368.492   SBCL     0    0  163   10  244  233   22    0    0    0    0   672
      DAY/HR      5/17      23/17       5/21   SUCT     0   64  104  226  270    8    0    0    0    0    0   672

MAR   SUM        13.9     963359.    191529.   LOAD     0   29  156  145  377   37    0    0    0    0    0   744
      PEAK       28.8       2089.    395.203   SBCL     0    0  180    7  261  264   31    1    0    0    0   744
      DAY/HR     20/ 5      20/ 5      20/ 5   SUCT     0   69  117  232  318    8    0    0    0    0    0   744

APR   SUM        14.0     973004.    194024.   LOAD     0    5  171   84  361   99    0    0    0    0    0   720
      PEAK       28.8       2062.    393.787   SBCL     0    0  155   25  201  263   75    1    0    0    0   720
      DAY/HR     23/21      23/21      23/21   SUCT     0   45  134  171  330   40    0    0    0    0    0   720

MAY   SUM        14.6    1013685.    202518.   LOAD     0    0  186   54  397  107    0    0    0    0    0   744
      PEAK       27.6       1927.    385.145   SBCL     0    0  177    9  175  310   73    0    0    0    0   744
      DAY/HR     12/17      25/21      12/17   SUCT     0   12  174  129  385   44    0    0    0    0    0   744

JUN   SUM        14.6    1006315.    201317.   LOAD     0    0  180   24  371  145    0    0    0    0    0   720
      PEAK       27.7       1969.    387.564   SBCL     0    0  175    5  110  328  102    0    0    0    0   720
      DAY/HR      9/13       9/13       9/13   SUCT     0    1  179   64  408   68    0    0    0    0    0   720

JUL   SUM        15.4    1062842.    214229.   LOAD     0    0  186    4  339  215    0    0    0    0    0   744
      PEAK       28.1       1971.    396.065   SBCL     0    0  174   12   66  342  150    0    0    0    0   744
      DAY/HR     28/21      28/21      28/21   SUCT     0    0  186   40  405  113    0    0    0    0    0   744

AUG   SUM        15.5    1067880.    214412.   LOAD     0    0  186    0  348  210    0    0    0    0    0   744
      PEAK       28.1       1976.    397.544   SBCL     0    0  175   11   60  347  151    0    0    0    0   744
      DAY/HR     14/21      14/21      14/21   SUCT     0    0  186   32  417  109    0    0    0    0    0   744

SEP   SUM        14.7    1010742.    202663.   LOAD     0    0  180   16  367  157    0    0    0    0    0   720
      PEAK       28.0       1964.    392.742   SBCL     0    0  176    4   94  334  112    0    0    0    0   720
      DAY/HR     23/21      23/21      23/21   SUCT     0    0  180   58  411   71    0    0    0    0    0   720

OCT   SUM        14.4     999521.    199200.   LOAD     0    5  181   74  400   84    0    0    0    0    0   744
      PEAK       27.4       1904.    377.465   SBCL     0    0  186    0  188  311   59    0    0    0    0   744
      DAY/HR     18/21       4/21      18/21   SUCT     0   15  171  141  393   24    0    0    0    0    0   744

NOV   SUM        13.8     956190.    190141.   LOAD     0   14  160  114  353   79    0    0    0    0    0   720
      PEAK       29.3       2092.    402.399   SBCL     0    0  164   16  229  246   62    3    0    0    0   720
      DAY/HR     29/21      21/21      29/21   SUCT     0   59  118  199  317   27    0    0    0    0    0   720

DEC   SUM        13.3     927211.    184108.   LOAD     0   60  126  223  333    2    0    0    0    0    0   744
      PEAK       24.8       1769.    339.301   SBCL     0    0  186    1  318  237    2    0    0    0    0   744
      DAY/HR     28/21      28/21      28/21   SUCT     0   93   93  300  258    0    0    0    0    0    0   744
             ==========  ==========  ==========       ==== ==== ==== ==== ==== ==== ==== ==== ==== ==== ==== ====

YR    SUM       171.0   11846378.   2364435.   LOAD     0  191 1962 1067 4262 1266   12    0    0    0    0  8760
      PEAK       31.1       2258.    428.133   SUBC     0    0 2057  138 2184 3430  926   25    0    0    0  8760
      MON/DAY     1/24       1/24       1/24   SUCT     0  426 1740 1828 4173  591    2    0    0    0    0  8760
```

PS-H LOADS AND ENERGY USAGE FOR <Suction-Group Name>

For each suction group, this report summarizes relevant design information as well as monthly and yearly performance. For this report to print, PS-H must be specified in PLANT-REPORTS, and the suction group's EQUIPMENT-REPORTS = YES.

The design information are the first entries in the report:

FEEDS INTO
lists the compressor in this suction group.

DRAWS FROM / OTHER
lists the suction circuits and desuperheaters that feed into this group. Also list an auxiliary electric meter, if attached.

REFG LOAD
is the design refrigerant load on this group.

REFG FLOW
is the design refrigerant flow on this group.

SAT SUCT
is the design saturated suction temperature of this group.

Following the design data is the monthly and yearly performance summary:

REFG LOAD
is the refrigerant load equivalent to the refrigerant flow through all compressors in this group. This load is calculated as a function of the refrigerant flow, the suction enthalpy, and the liquid enthalpy leaving the condenser(s), but before any subcooling.

REFG FLOW
is the refrigerant flow handled by all compressors in this group.

COMPRESSOR
is the power of all compressors in this group, excluding any auxiliary energy such as a crankcase heater.

TOTAL PWR
is the sum of the compressor power plus any auxiliary energy, such as for a crankcase heater.

For each month and for the year, information is presented on the category total, peak monthly or yearly value, and the time when the peak occurred. Bin information is presented in terms of the number of hours the flow and power fell into the appropriate part load bin. The part load bin is calculated in terms of the hourly value divided by the design value.

D I C T I O N A R Y

```
DOE2.2 Supermarket Sample "Market 1"                              DOE-B2.2-R20   5/14/2002   10:32:59  BDL RUN  1
Using JJH DOE2.2 Beta Release 30NT
REPORT- PS-H Loads and Energy Usage for     Rack SST:F1                          WEATHER FILE- CZ10RV2 WYEC2
-----------------------------------------------------------------------------------------------------------------
                                                  REFG LOAD   REFG FLOW   SAT SUCT
FEEDS INTO                   DRAWS FROM / OTHER     (MBTU)     (LB/HR)      (F)
---------------------------  ------------------    ---------  ---------   --------
Comp SST:F1:1                Suction Trunk 6          0.176     2620.2       8.0
Comp SST:F1:2
Comp SST:F1:3
```

MON	SUM PEAK DAY/HR	REFG LOAD (MBTU) (KBTU/HR)	REFG FLOW (LB) (LB/HR)	COMPRESSOR (KWH) (KW)	TOTAL PWR (KWH) (KW)		00 10	10 20	20 30	30 40	40 50	50 60	60 70	70 80	80 90	90 100	100 +	TOTAL RUN HOURS
JAN	SUM	55.3	792532.	6547.	6547.	FLOW	0	33	80	252	213	133	33	0	0	0	0	744
	PEAK	115.9	1665.	13.717	13.717	ELEC	6	126	446	165	1	0	0	0	0	0	0	744
	DAY/HR	30/18	30/17	30/17	30/17													
FEB	SUM	48.3	691705.	5733.	5733.	FLOW	0	32	75	238	221	106	0	0	0	0	0	672
	PEAK	108.5	1559.	12.630	12.630	ELEC	4	116	443	109	0	0	0	0	0	0	0	672
	DAY/HR	7/15	7/15	7/15	7/15													
MAR	SUM	54.9	787016.	6472.	6472.	FLOW	0	33	66	265	208	172	0	0	0	0	0	744
	PEAK	104.6	1500.	12.028	12.028	ELEC	3	105	460	176	0	0	0	0	0	0	0	744
	DAY/HR	23/23	23/23	23/23	23/23													
APR	SUM	57.3	821379.	6769.	6769.	FLOW	0	29	61	195	183	228	24	0	0	0	0	720
	PEAK	113.8	1635.	13.350	13.350	ELEC	0	91	373	256	0	0	0	0	0	0	0	720
	DAY/HR	14/17	14/17	14/17	14/17													
MAY	SUM	63.1	905109.	7459.	7459.	FLOW	0	22	71	86	257	223	85	0	0	0	0	744
	PEAK	118.4	1713.	14.135	14.135	ELEC	0	93	349	291	11	0	0	0	0	0	0	744
	DAY/HR	11/15	11/15	11/15	11/15													
JUN	SUM	65.4	940225.	7731.	7731.	FLOW	0	6	78	20	262	146	208	0	0	0	0	720
	PEAK	123.9	1793.	14.865	14.865	ELEC	0	89	277	255	99	0	0	0	0	0	0	720
	DAY/HR	26/18	26/18	26/18	26/18													
JUL	SUM	71.7	1033233.	8480.	8480.	FLOW	0	0	69	24	237	145	198	71	0	0	0	744
	PEAK	135.6	1965.	16.503	16.503	ELEC	0	79	250	171	244	0	0	0	0	0	0	744
	DAY/HR	13/17	13/17	13/17	13/17													
AUG	SUM	72.5	1043985.	8491.	8491.	FLOW	0	0	62	31	189	186	238	38	0	0	0	744
	PEAK	134.3	1943.	16.280	16.280	ELEC	0	75	204	239	226	0	0	0	0	0	0	744
	DAY/HR	16/17	16/17	16/17	16/17													
SEP	SUM	66.7	958445.	7848.	7848.	FLOW	0	5	71	24	245	160	196	19	0	0	0	720
	PEAK	133.3	1930.	16.171	16.171	ELEC	0	83	263	281	93	0	0	0	0	0	0	720
	DAY/HR	23/17	23/17	23/17	23/17													
OCT	SUM	61.8	886433.	7312.	7312.	FLOW	0	15	77	98	282	216	56	0	0	0	0	744
	PEAK	117.9	1694.	13.863	13.863	ELEC	0	93	375	274	2	0	0	0	0	0	0	744
	DAY/HR	1/23	1/23	1/23	1/23													
NOV	SUM	55.8	799004.	6557.	6557.	FLOW	0	29	61	214	176	240	0	0	0	0	0	720
	PEAK	108.9	1566.	12.743	12.743	ELEC	0	90	389	241	0	0	0	0	0	0	0	720
	DAY/HR	11/17	11/17	11/17	11/17													
DEC	SUM	51.2	733199.	6134.	6134.	FLOW	0	45	75	309	288	27	0	0	0	0	0	744
	PEAK	100.2	1435.	11.084	11.084	ELEC	5	139	566	34	0	0	0	0	0	0	0	744
	DAY/HR	28/23	28/23	28/23	28/23													
YR	SUM	724.0	10392263.	85534.	85534.	FLOW	0	249	846	1756	2761	1982	1038	128	0	0	0	8760
	PEAK	135.6	1965.	16.503	16.503	ELEC	18	1179	4395	2492	676	0	0	0	0	0	0	8760
	MON/DAY	7/13	7/13	7/13	7/13													

PS-I LOADS AND ENERGY USAGE FOR <Refg-Fixture Name>

For each display fixture, this report provides detailed performance data for the individual components comprising the fixture. This is a multi-part report in 3 sections: electric loads, refrigeration loads, and defrost performance.

For this report to print, PS-I must be specified in PLANT-REPORTS, and the fixture's EQUIPMENT-REPORTS = YES.

Part I: Electric Loads

This section e design information are the first entries in the report:

Part I: Electric Loads
This section breaks down the electric consumption of the fixture into the following categories: lights, fans, anti-sweat heaters, electric defrost, auxiliary energy, and the total. For each category, and by month and year, the report gives the total electric consumed, the peak consumption, and the time when the peak consumption occurred.

Part II: Fixture Loads
This section summarizes the refrigeration loads on the fixture. Loads are grouped into several categories:

- Zone Loads – including conduction, sensible infiltration, and latent infiltration

- Electrical Loads – these are the heat gains to the fixture from the lights, fans and anti-sweat heaters. Depending on the fraction of energy specified to flow to the fixture vs. the zone, not all of the electric energy summarized in Part I will become a load on the coil.

- Product Loads – arise from product placed in the fixture at a different temperature, from internal respiration, or from produce sprays that convert sensible energy to latent.

- Defrost Loads – arise from the defroster. In addition to adding sensible heat to a fixture, a defroster may also add latent heat. During an ambient defrost, a portion of the frost may evaporate into the airstream and may then condense on the cold surfaces of the fixture and the product within the fixture. Once defrost is terminated, the condensed moisture in the fixture may slowly re-evaporate and be re-deposited upon the coil. The same is true during an electric defrost where the fan continues to operate.

- Coil Load – this is the total load on the coil.

Note: This section of the report requires additional refinement. Ideally, the sum of the zone, electrical, product, and defrost loads should closely match the coil load. However, because of the way the various categories are calculated, the categories will often not sum to the coil load. The categories will sum closely to the coil load for a fixture operating at a constant temperature; but deviations can be significant in a fixture encountering significant temperature swings due to defrost.

Part III: Defrost Efficiency
This section provides information on the performance of the fixture's defrost mechanism. The default defrost sizing calculations are based on design conditions that may not actually be achieved in the store. For example, the relative humidity in the store may be higher than expected, resulting in a higher frost accumulation rate. As a result, the default defroster may be undersized, the defrost period may not be long enough, and/or the number of defrost intervals during the day may not be sufficient.

Alternatively, an oversized defroster operated in a time-initiated and time-terminated mode may run the defroster for periods considerably longer than necessary. This will result in excessive fixture heating during defrost, and higher refrigeration loads once the defrost is terminated.

WEIGHT OF FROST

is the weight of frost accumulated on the coil.

HEAT IN FROST

is the difference between the enthalpy of water at the freezing point, and the enthalpy of the frost at the actual temperature of the frost. This is the heat that must be provided to melt the frost, assuming a 100% efficient process.

REQUIRED DEF HEAT

is the heat output *of the defroster* required to melt the frost. While one would expect that this quantity would be the same as the heat in the frost, this is not usually true.

For example, consider a fixture operating at –10°F; utilizing an electric defrost where the fan remains on during defrost, and the defrost element heats the air prior to the coil. After leaving the coil, the air discharges into the fixture, and the returns to the fan. Depending on the amount and temperature of infiltration into the case, the infiltration may contribute to the defrost process, so so that energy required of the defrost element is less than the heat required to melt the frost.

In the above example, the opposite may also be true. If air infiltration is relatively small compared to the "coolth" stored in the fixture and its contents, then a substantial amount of the defroster's energy may be lost as the air circulates through the fixture. In this case, the required defrost heat will be larger than the heat in the frost.

▪ required to melt the frost, including both the heat of fusion and the sensible heat associated with the frost existing at a temperature below the freezing.

is the design change in saturated temperature due to friction losses.

ACTUAL DEF HEAT

is the actual heat output of the defroster. Ideally, this quantity should be the same as the required defrost heat.

Time-terminated defrost cycles will usually provide more energy than required, resulting in an inefficiency that wastes defroster energy and also increases the refrigeration load. If this quantity is less than the required defrost heat, then not all of the frost was melted.

Note that if frost builds up to more than twice the design weight, the fixture will automatically initiate a defrost cycle, even if the initiation is supposed to be scheduled. Check the "MESSAGE LIST FROM SYSTEMS" in the output to see if this condition ever occurs.

REQUIRED DEF TIME

is the time required to melt the frost, given the capacity of the defroster.

ACTUAL DEF TIME

is the actual amount of time the fixture was in the defrost mode. Ideally, this quantity should match the required defrost time, but, for a time-terminated defrost may be greater or less than the required. Also note that a temperature-terminated defrost will never be longer than 59 minutes, even if a longer period is necessary to fully melt the frost.

```
DOE2.2 Supermarket Sample "Market 1"                                    DOE-B2.2-R20   5/14/2002   10:32:59  BDL RUN  1
Using JJH DOE2.2 Beta Release 30NT
REPORT- PS-I Loads and Energy Usage for     1B11                        WEATHER FILE- CZ10RV2 WYEC2
-----------------------------------------------------------------------------------------------------------------------

*** ELECTRIC LOADS ***

            LIGHTS      FANS     ANTI-SWT   DEFROST      AUX       TOTAL
        SUM (KWH)      (KWH)      (KWH)      (KWH)      (KWH)      (KWH)
MON PEAK (KW)       (KW)       (KW)       (KW)       (KW)       (KW)
--- ----  ---------  ---------  ---------  ---------  ---------  ---------


JAN  SUM    375.       206.       123.      8574.        0.       9278.
     PEAK   0.991      0.277      0.912     46.099      0.000     48.232
     DAY/HR 1/15       1/ 1      12/19      1/ 4        0/ 0      19/16

FEB  SUM    339.       186.        27.      7745.        0.       8297.
     PEAK   0.991      0.277      0.795     46.099      0.000     47.962
     DAY/HR 1/17       1/ 1      23/19      1/ 4        0/ 0      23/20

MAR  SUM    376.       206.        34.      8574.        0.       9191.
     PEAK   0.991      0.277      0.881     46.099      0.000     47.696
     DAY/HR 1/17       1/ 1      20/ 5      1/ 4        0/ 0      18/12

APR  SUM    364.       199.        64.      8298.        0.       8925.
     PEAK   0.991      0.277      0.752     46.099      0.000     47.934
     DAY/HR 1/17       1/ 1      23/20      1/ 4        0/ 0      23/20

MAY  SUM    375.       206.        28.      8574.        0.       9183.
     PEAK   0.991      0.277      0.418     46.099      0.000     47.645
     DAY/HR 1/17       1/ 1       1/ 6      1/ 4        0/ 0      13/12

JUN  SUM    364.       199.        16.      8298.        0.       8877.
     PEAK   0.991      0.277      0.613     46.099      0.000     47.876
     DAY/HR 1/17       1/ 1       9/11      1/ 4        0/ 0       9/12

JUL  SUM    375.       206.         0.      8574.        0.       9156.
     PEAK   0.991      0.277      0.000     46.099      0.000     47.366
     DAY/HR 1/17       1/ 1       0/ 0      1/ 4        0/ 0       4/16

AUG  SUM    376.       206.         2.      8574.        0.       9159.
     PEAK   0.991      0.277      0.377     46.099      0.000     47.605
     DAY/HR 1/17       1/ 1       7/13      1/ 4        0/ 0       7/12

SEP  SUM    363.       199.         1.      8298.        0.       8861.
     PEAK   0.991      0.277      0.129     46.099      0.000     47.366
     DAY/HR 1/15       1/ 1      26/15      1/ 4        0/ 0       1/16

OCT  SUM    375.       206.         3.      8574.        0.       9159.
     PEAK   0.991      0.277      0.273     46.099      0.000     47.456
     DAY/HR 1/17       1/ 1       8/ 4      1/ 4        0/ 0       7/16

NOV  SUM    362.       199.        47.      8298.        0.       8906.
     PEAK   0.991      0.277      0.868     46.099      0.000     48.053
     DAY/HR 1/17       1/ 1      21/19      1/ 4        0/ 0      21/16

DEC  SUM    375.       206.         2.      8574.        0.       9158.
     PEAK   0.991      0.277      0.261     46.099      0.000     47.438
     DAY/HR 1/17       1/ 1       9/13      1/ 4        0/ 0       9/16
            =========  =========  =========  =========  =========  =========

YR   SUM   4421.      2425.       347.    100956.        0.     108149.
     PEAK   0.991      0.277      0.912     46.099      0.000     48.232
   MON/DAY  1/ 1       1/ 1       1/12      1/ 1        0/ 0       1/19
```

```
DOE2.2 Supermarket Sample "Market 1"                              DOE-B2.2-R20   5/14/2002   10:32:59  BDL RUN  1
Using JJH DOE2.2 Beta Release 30NT
REPORT- PS-I Loads and Energy Usage for     1B11                              WEATHER FILE- CZ10RV2 WYEC2
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```

*** FIXTURE LOADS ***

MON	SUM PEAK DAY/HR	CONDUCT (MBTU) (KBTU/HR)	INF SENS (MBTU) (KBTU/HR)	INF LAT (MBTU) (KBTU/HR)	LIGHTS (MBTU) (KBTU/HR)	FANS (MBTU) (KBTU/HR)	ANTI-SWT (MBTU) (KBTU/HR)	SENSIBLE (MBTU) (KBTU/HR)	LATENT (MBTU) (KBTU/HR)	SENSIBLE (MBTU) (KBTU/HR)	LATENT (MBTU) (KBTU/HR)	TOTAL (MBTU) (KBTU/HR)
		---------- ZONE LOADS ---------			---------- ELECTRICAL ---------			------ PRODUCT -----		------ DEFROST -----		-- COIL --
JAN	SUM	0.369	2.219	3.330	0.000	0.703	0.251	-0.004	0.000	29.390	0.000	36.087
	PEAK	-6.154	-36.988	10.923	0.000	0.945	1.868	-116.037	0.000	158.524	0.000	84.866
	DAY/HR	1/ 8	1/ 8	24/18	0/ 0	1/ 1	12/19	6/16	0/ 0	24/20	0/ 0	30/17
FEB	SUM	0.360	2.163	2.617	0.000	0.635	0.056	0.003	0.000	26.534	0.000	32.234
	PEAK	-6.194	-37.229	8.852	0.000	0.945	1.628	-116.164	0.000	158.293	0.000	83.636
	DAY/HR	24/ 8	24/ 8	5/19	0/ 0	1/ 1	23/19	7/16	0/ 0	3/20	0/ 0	7/21
MAR	SUM	0.408	2.453	3.114	0.000	0.703	0.070	-0.002	0.000	29.384	0.000	35.971
	PEAK	-6.164	-37.050	8.766	0.000	0.945	1.804	-116.465	0.000	158.294	0.000	82.410
	DAY/HR	3/ 8	3/ 8	18/19	0/ 0	1/ 1	20/ 5	23/20	0/ 0	18/20	0/ 0	24/21
APR	SUM	0.457	2.748	3.380	0.000	0.680	0.131	-0.001	0.000	28.450	0.000	35.652
	PEAK	-6.066	-36.458	10.186	0.000	0.945	1.539	-117.172	0.000	158.480	0.000	84.981
	DAY/HR	21/ 8	21/ 8	14/18	0/ 0	1/ 1	23/20	28/16	0/ 0	14/20	0/ 0	27/21
MAY	SUM	0.552	3.316	3.794	0.000	0.703	0.056	-0.001	0.000	29.410	0.000	37.596
	PEAK	-5.933	-35.659	10.215	0.000	0.945	0.857	-117.443	0.000	158.508	0.000	85.884
	DAY/HR	4/ 8	4/ 8	12/18	0/ 0	1/ 1	1/ 6	7/16	0/ 0	11/20	0/ 0	10/21
JUN	SUM	0.641	3.852	3.835	0.000	0.680	0.032	-0.004	0.000	28.470	0.000	37.261
	PEAK	-5.857	-35.206	10.926	0.000	0.945	1.256	-118.291	0.000	158.562	0.000	87.866
	DAY/HR	10/ 8	10/ 8	22/19	0/ 0	1/ 1	9/11	30/20	0/ 0	6/20	0/ 0	26/21
JUL	SUM	0.791	4.754	3.950	0.000	0.703	0.000	-0.001	0.000	29.424	0.000	39.377
	PEAK	-5.729	-34.435	12.644	0.000	0.945	0.000	-118.984	0.000	158.773	0.000	90.354
	DAY/HR	23/ 8	23/ 8	13/18	0/ 0	1/ 1	0/ 0	10/20	0/ 0	13/20	0/ 0	28/21
AUG	SUM	0.800	4.811	4.011	0.000	0.703	0.004	0.002	0.000	29.427	0.000	39.490
	PEAK	-5.721	-34.387	11.981	0.000	0.945	0.772	-118.578	0.000	158.703	0.000	90.420
	DAY/HR	24/ 8	24/ 8	16/19	0/ 0	1/ 1	7/13	13/20	0/ 0	16/20	0/ 0	16/21
SEP	SUM	0.717	4.310	3.566	0.000	0.680	0.002	0.001	0.000	28.465	0.000	37.523
	PEAK	-5.854	-35.185	10.975	0.000	0.945	0.264	-118.662	0.000	158.663	0.000	90.133
	DAY/HR	29/ 8	29/ 8	23/18	0/ 0	1/ 1	26/15	3/16	0/ 0	24/20	0/ 0	23/21
OCT	SUM	0.622	3.737	3.062	0.000	0.703	0.007	0.006	0.000	29.389	0.000	37.368
	PEAK	-5.973	-35.904	9.934	0.000	0.945	0.559	-118.553	0.000	158.460	0.000	86.832
	DAY/HR	30/ 8	30/ 8	19/19	0/ 0	1/ 1	8/ 4	3/20	0/ 0	19/20	0/ 0	18/21
NOV	SUM	0.453	2.722	3.106	0.000	0.680	0.096	0.000	0.000	28.441	0.000	35.339
	PEAK	-6.057	-36.409	10.162	0.000	0.945	1.778	-116.867	0.000	158.460	0.000	83.945
	DAY/HR	18/ 8	18/ 8	11/18	0/ 0	1/ 1	21/19	10/16	0/ 0	11/20	0/ 0	11/21
DEC	SUM	0.390	2.343	2.536	0.000	0.703	0.005	-0.002	0.000	29.364	0.000	35.234
	PEAK	-6.128	-36.834	7.533	0.000	0.945	0.534	-116.461	0.000	158.176	0.000	81.637
	DAY/HR	25/ 8	25/ 8	1/19	0/ 0	1/ 1	9/13	29/16	0/ 0	1/20	0/ 0	28/21
YR	SUM	6.560	39.428	40.303	0.000	8.277	0.710	-0.003	0.000	346.149	0.000	439.131
	PEAK	-6.194	-37.229	12.644	0.000	0.945	1.868	-118.984	0.000	158.773	0.000	90.420
	MON/DAY	2/24	2/24	7/13	0/ 0	1/ 1	1/12	7/10	0/ 0	7/13	0/ 0	8/16

D I C T I O N A R Y

*** DEFROST EFFICIENCY SUMMARY ***

MON	SUM PEAK	WEIGHT OF FROST (LB) (LB)	HEAT IN FROST (KBTU) (KBTU)	REQUIRED DEF HEAT (KBTU) (KBTU)	ACTUAL DEF HEAT (KBTU) (KBTU)	REQUIRED DEF TIME (MINUTES) (MINUTES)	ACTUAL DEF TIME (MINUTES) (MINUTES)
JAN	SUM	3091.7	520.	205.	29264.	77.	10974.
	PEAK	29.7	4.976	1.794	157.333	1.	59.
	DAY/HR	24/20	24/20	24/20	1/ 4	24/20	1/ 4
FEB	SUM	2444.1	411.	165.	26432.	62.	9912.
	PEAK	23.3	3.914	1.461	157.333	1.	59.
	DAY/HR	5/20	5/20	5/20	1/ 4	5/20	1/ 4
MAR	SUM	2903.7	488.	195.	29264.	73.	10974.
	PEAK	23.3	3.921	1.467	157.333	1.	59.
	DAY/HR	18/20	18/20	28/20	1/ 4	28/20	1/ 4
APR	SUM	3127.0	526.	205.	28320.	77.	10620.
	PEAK	27.8	4.658	1.683	157.333	1.	59.
	DAY/HR	14/20	14/20	14/20	1/ 4	14/20	1/ 4
MAY	SUM	3490.2	587.	226.	29264.	85.	10974.
	PEAK	27.8	4.665	1.683	157.333	1.	59.
	DAY/HR	11/20	11/20	17/20	1/ 4	17/20	1/ 4
JUN	SUM	3518.4	591.	224.	28320.	84.	10620.
	PEAK	28.9	4.853	1.722	157.333	1.	59.
	DAY/HR	6/20	6/20	13/20	1/ 4	13/20	1/ 4
JUL	SUM	3629.4	609.	228.	29264.	85.	10974.
	PEAK	34.0	5.697	1.953	157.333	1.	59.
	DAY/HR	13/20	13/20	13/20	1/ 4	13/20	1/ 4
AUG	SUM	3674.2	617.	232.	29264.	87.	10974.
	PEAK	31.7	5.307	1.818	157.333	1.	59.
	DAY/HR	16/20	16/20	16/20	1/ 4	16/20	1/ 4
SEP	SUM	3290.8	553.	211.	28320.	79.	10620.
	PEAK	29.8	4.993	1.765	157.333	1.	59.
	DAY/HR	24/20	24/20	24/20	1/ 4	24/20	1/ 4
OCT	SUM	2859.1	481.	188.	29264.	70.	10974.
	PEAK	26.9	4.511	1.630	157.333	1.	59.
	DAY/HR	19/20	19/20	19/20	1/ 4	19/20	1/ 4
NOV	SUM	2891.4	486.	191.	28320.	72.	10620.
	PEAK	27.4	4.603	1.672	157.333	1.	59.
	DAY/HR	11/20	11/20	11/20	1/ 4	11/20	1/ 4
DEC	SUM	2395.3	403.	163.	29264.	61.	10974.
	PEAK	20.2	3.403	1.319	157.333	0.	59.
	DAY/HR	9/20	9/20	9/20	1/ 4	9/20	1/ 4
		=========	=========	=========	=========	=========	=========
YR	SUM	37315.2	6272.	2433.	344560.	912.	129210.
	PEAK	34.0	5.697	1.953	157.333	1.	59.
	MON/DAY	7/13	7/13	7/13	1/ 1	7/13	1/ 1

Section

10
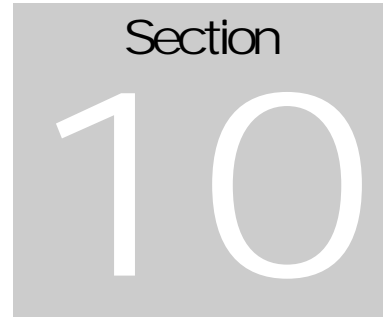
Hourly-Reports

REPORT-BLOCK REFRIGERATION VARIABLE-TYPES

<u>REFG-FIXTURE</u>

Variable-List Number	Variable in FORTRAN Code	Description
1	<Xao;Qoutlet>	Air-side load
2	<ac;Qnet>	Refrigerant-side load
3	<rf;RunFrac>	Fraction of hour not in defrost
4	<rf;QfixCoil>	Fixed load (lights, fans, anti-sweat heaters, etc.)
5	<rf;QfixCoil'	Fixed load during defrost
6	<rf;QdefSen>	Defroster load on fixture, sensible
7	<rf;QdefLat>	Defroster load on fixture, latent
8	<rf;QprodSenNet>	Net sensible load from product heat, including storage
9	<rf;QprodSen>	Sensible load from product heat
10	<rf;QprodLat	Latent load from product heat
11	<Xai;Tinlet>	Fixture supply temperature
12	<Xai;Winlet>	Fixture supply humidity ratio
13	<ao;Toutlet>	Fixture return temperature
14	<ao;Woutlet>	Fixture return humidity ratio
15	<rf;Tfixture>	Fixture temperature, average
16	<rf;Wfixture>	Fixture humidity ratio, average
17	<rf;dQIntLat">	Contents latent heat in evaporated moisture, non-defrost
18	<rf;dMIntLat">	Contents moisture that evaporated, non-defrost
19	<rf;Tdefrost>	Fixture temperature at end of defrost cycle
20	<rf;Wdefrost>	Fixture humidity at end of defrost cycle
21	<rf;dQIntLat'>	Contents latent heat in evaporated moisture, defrost
22	<rf;dMIntLat'>	Contents moisture that evaporated, defrost
23	<rf;Qua>	Conduction load through fixture surfaces
24	<rf;UA>	UA to Zone 1
25	<rf;UA2>	UA to Zone 2
26	<rf;QinfSen>	Sensible infiltration load
27	<rf;QinfLat>	Latent infiltration load
28	<rf;CFMinfil>	Infiltration from Zone 1, volume
29	<rf;CFMinfil2>	Infiltration from Zone 2, volume
30	<rf;Qlights>	Lights heat gain to fixture
31	<rf;kWlights>	Lights power
32	<rf;Qfans>	Fans heat gain to fixture
33	<rf;kWfans>	Fan power

Variable-List Number	Variable in FORTRAN Code	Description
34	<rf;Qsweat>	Anti-sweat heater heat gain to fixture
35	<rf;kWsweat>	Anti-sweat power
36	<rf;Tsurface>	Contents temperature, beginning of hour
37	<rf;Tsurface'>	Contents temperature, after defrost
38	<rf;Tsurface">	Contents temperature, end of hour
39	<rf;MIntLat>	Contents moisture, maximum that can evaporate
40	<rf;MIntLat'>	Contents moisture, maximum that can evaporate after defrost
41	<rf;MIntLat">	Contents moisture, end of hour
42	<ac;OverloadHours>	Hours coil cannot meet setpoint conditions
43	<ac;Mfrost>	Frost on coil, beginning of hour
44	<ac;Mfrost'>	Frost on coil, after defrost
45	<ac;Mfrost">	Frost on coil, end of hour
46	<ac;Qfrost>	Energy in frost, beginning of hour
47	<ac;Qfrost'>	Energy in frost, after defrost
48	<ac;Qfrost">	Energy in frost, end of hour
49	<ac;SST>	Saturated-suction temperature, adjusted by EPR valve (if any)
50	<ac;SSTreqdCoil>	SST required to hold setpoint, at coil
51	<ac;SSTreqd>	SST required to hold setpoint, entering suction line
52	<ac;Mlatent>	Condensate/frost produced
53	<ac;Hlatent>	Condensate/frost enthalpy
54	<ac;SurfTi>	Surface temperature at air inlet
55	<ac;Tb>	Surface temperature at dry/wet boundary
56	<ac;SurfTo>	Surface temperature at air outlet
57	<ac;FracWet>	Fraction of coil that is wet
58	<ac;SurfHb>	Surface enthalpy at dry/wet boundary
59	<ac;FracFrosted>	Fraction of wet coil that is frosted

REFG-CIRCUIT

Variable-List Number	Variable in FORTRAN Code	Description
1	<ri;Mrefg> *(<ro;Houtlet>- <ri;Hinlet>)	Heat gain, inlet to outlet
2	dH	Change in enthalpy, inlet to outlet
3	dP	Change in pressure, inlet to outlet
4	<ri;Qinlet>	Inlet load[1]
5	<ri;Minlet>	Inlet flow
6	<ri;Mreqd>	Required inlet flow
7	<ri;Tinlet>	Inlet temperature
8	<ri;Treqd>	Inlet temperature, required or requested
9	<ri;Pinlet>	Inlet pressure
10	<ri;Preqd>	Inlet pressure, required or requested
11	<ri;Hinlet>	Inlet enthalpy
12	<ro;Qoutlet>	Outlet load[1]
13	<ro;Moutlet>	Outlet flow
14	<ro;Mreqd>	Required outlet flow
15	<ro;Toutlet>	Outlet temperature
16	<ro;Treqd>	Outlet temperature, required or requested
17	<ro;Poutlet>	Outlet pressure
18	<ro;Preqd>	Outlet pressure, required or requested
19	<ro;Houtlet>	Outlet enthalpy
20	<rx;Qrefg>	Heat reclaim load
21	<rx;Mrefg>	Heat reclaim flow
22	<rx;Mreqd>	Required Heat reclaim flow
23	<rx;Trefg>	Heat reclaim temperature
24	<rx;Treqd>	Heat reclaim temperature, required or requested
25	<rx;Prefg>	Heat reclaim pressure
26	<rx;Preqd>	Heat reclaim pressure, required or requested
27	<rx;Hrefg>	Heat reclaim enthalpy
28	f(<rx;Prefg>)	Heat reclaim temperature, saturated

[1]Relative to liquid trunk inlet enthalpy

REFG-SYSTEM

Variable-List Number	Variable in FORTRAN Code	Description
1	<rs;Qrej>	Heat rejected thru condensers
2	Sum(<mx;Load>)	Power of all components in system (compressors, condensers, etc.)
3	<ri;Minlet>	Inlet flow
4	<ri;Tinlet>	Inlet temperature
5	<ri;Pinlet>	Inlet pressure
6	<ri;Hinlet>	Inlet enthalpy
7	<ro;Moutlet>	Outlet flow
8	f(P,H)	Outlet temperature
9	f(<ro;Poutlet>)	Outlet temperature, saturated
10	<ro;Poutlet>	Outlet pressure
11	<ro;Houtlet>	Outlet enthalpy
12	<r1;Tsetpt>	SCT setpoint

SUCTION-GROUP

Variable-List Number	Variable in FORTRAN Code	Description
1	<ri;Qinlet>	Suction load[1]
2	<ri;Mrefg>	Refrigerant flow
3	<rx;Mrefg>	Hot gas bypass flow
4	<rx;Mrefg>	Desuperheater flow
5	Sum(<sg;ListCompElec>)	Compressor power
6	AuxKWh	Auxiliary power
7	RefgT_fP(<ri;Preqd>)	Suction temperature required to meet worst load
8	<sg;SSTsetpt>	Suction temperature setpoint
9	RefgT_fP(<ri;Pinlet>)	Saturated suction temperature
10	RefgSuper_fPH(<ri;Pinlet>,<ri;Hinlet>)	Suction superheat
11	<ri;Pinlet>	Suction pressure
12	<ri;Hinlet>	Suction enthalpy
13	<cl;CtrlSignal>	Compressor control signal, valid only if not cycling a compressor

[1]Relative to liquid trunk inlet enthalpy

<u>COMPRESSOR</u>

Variable-List Number	Variable in FORTRAN Code	Description
1	<ri;Qinlet>	Suction load[1]
2	<ri;Mrefg>	Refrigerant flow
3	Sum(CompkW)	Compressor motor power
4	AuxKWh	Auxiliary power
5	<cp;BinRunTime>	Fraction of hour running (if cycling)
6	RefgT_fP(<rx;Prefg>)	Saturated suction temperature (average)
7	RefgSuper_fPH(<rx;Prefg>, <rx;Hrefg>)	Suction superheat (average)
8	<rx;Prefg>	Suction pressure
9	<rx;Hrefg>	Suction enthalpy
10	<ro;Qoutlet>	Discharge load[1]
11	RefgT_fPH(<Xro;Poutlet>,<ro;Houtlet>)	Discharge temperature
12	RefgT_fP(<Xro;Poutlet>)	Discharge saturated condensing temperature
13	<ro;Houtlet>	Discharge enthalpy
14	<cp.PLR>	Average part load ratio while running
		[1]Relative to liquid trunk inlet enthalpy

<u>CONDENSER</u>

Variable-List Number	Variable in FORTRAN Code	Description
1	\<cd.Qrej>	Condenser load
2	\<ro.MaxMrefg>	Available capacity
3	\<ro.Mrefg>	Refrigerant flow
4	\<cd.Tsetpt>	Saturated condensing setpoint
5	\<cd.SCT>	Saturated condensing temperature
6	\<cd.Subcool>	Degrees of subcooling
7	\<cd.SCT> - Twetbulb	Approach to wetbulb
8	Twetbulb	Wetbulb temperature
9	\<cd.FanKWr>	Fraction of fan power
10	\<cd.FankW>	Fan power
11	\<cd.SpraykW>	Spray pump power
12	\<Xri.Hinlet>	Entering refrigerant enthalpy
13	\<ro.Houtlet>	Leaving refrigerant enthalpy
14	\<ro.Moutlet>	Suction flow (cascaded)
15	\<Xri.Hinlet>	Suction entering enthalpy (cascaded)
16	\<ro.Houtlet>	Suction leaving enthalpy (cascaded)

<u>SUBCOOLER</u>

Variable-List Number	Variable in FORTRAN Code	Description
1	sc;Qsubcool	Subcooler load
2	sc;Tsetpt	Setpoint temperature
3	sc;UA	Heat-exchanger UA product (varies hourly)
4	ri;Qinlet	Subcooled side – Inlet load[1]
5	ri;Mrefg	Subcooled side – Flow
6	RefgT_fPH(Xri;Pinlet, Xri;Hinlet)	Subcooled side – Inlet temperature
7	Xri;Pinlet	Subcooled side – Inlet pressure
8	ri;Preqd	Subcooled side – Inlet required pressure
9	Xri;Hinlet	Subcooled side – Inlet enthalpy
10	ro;Qoutlet	Subcooled side – Outlet load[1]
11	ro;Mrefg	Subcooled side – Flow
12		unused
13	ro;Toutlet	Subcooled side – Outlet temperature
14	ro;Treqd	Subcooled side – Outlet required temperature
15	ro;Poutlet	Subcooled side – Outlet pressure
16	ro;Preqd	Subcooled side – Outlet required pressure
17	ro:Houtlet	Subcooled side – Outlet enthalpy
18	ri;Qinlet	Suction side – Inlet load[1]
19	ri;Mrefg	Suction side – Flow
20	Xri;Pinlet	Suction side – Inlet pressure
21	ri;Preqd	Suction side – Inlet required pressure
22	Xri;Hinlet	Suction side – Inlet enthalpy
23	ro;Qoutlet	Suction side – Outlet load[1]
24	ro;Mrefg	Suction side – Flow
25	Xro;Poutlet	Suction side – Outlet pressure
26	ro;Preqd	Suction side – Outlet required pressure
27	ro;Houtlet	Suction side – Outlet enthalpy

[1]Relative to liquid trunk inlet enthalpy

<u>DESUPERHEATER</u>

Variable-List Number	Variable in FORTRAN Code	Description
1	ds;Qdesuper	Desuperheat load
2	ri;Qinlet	Desuperheated side – Inlet load[1]
3	ri;Mrefg	Desuperheated side – Flow
4	RefgT_fPH(Xri;Pinlet, Xri;Hinlet)	Desuperheated side – Inlet temperature
5	Xri;Pinlet	Desuperheated side – Inlet pressure
6	ri;Preqd	Desuperheated side – Inlet required pressure
7	Xri;Hinlet	Desuperheated side – Inlet enthalpy
8	ro;Qoutlet	Desuperheated side – Outlet load[1]
9	ro;Mrefg	Desuperheated side – Flow
10	unused	unused
11	ro;Toutlet	Desuperheated side – Outlet temperature
12	ro;Treqd	Desuperheated side – Outlet required temperature
13	ro;Poutlet	Desuperheated side – Outlet pressure
14	ro;Preqd	Desuperheated side – Outlet required pressure
15	ro:Houtlet	Desuperheated side – Outlet enthalpy
16	ri;Qinlet	Liquid side – Inlet load[1]
17	ri;Mrefg	Liquid side – Flow
18	Xri;Pinlet	Liquid side – Inlet pressure
19	ri;Preqd	Liquid side – Inlet required pressure
20	Xri;Hinlet	Liquid side – Inlet enthalpy
21	ro;Qoutlet	Liquid side – Outlet load[1]
22	ro;Mrefg	Liquid side – Flow
23	Xro;Poutlet	Liquid side – Outlet pressure
24	ro;Preqd	Liquid side – Outlet required pressure
25	ro;Houtlet	Liquid side – Outlet enthalpy
26	ds;Tsetpt	Setpoint temperature
27	ds;UA	Heat-exchanger UA product (varies hourly)

[1]Relative to liquid trunk inlet enthalpy

BOILER

Variable-List Number	Variable in FORTRAN Code	Description
1	<fo.Mfluid>	Boiler flow, external to boiler
2	<bl;Qheat	Boiler flow, internal to boiler
3	<bl;Elec>	Electric consumption, excluding auxiliary
4	<bl;Fuel>	Fuel consumption
5	<bl;Qstart>	Start-up load
6	<bl;PLR>	Part load ratio
7	<bl;RunFrac>	Fraction of hour in operation
8	<bl;EIR>	Adjusted electric input ratio (EIR)
9	<bl;EIRfPLR>	EIR part load correction factor
10	<bl;EIRfT	EIR temperature correction factor
11	<bl;HIR>	Adjusted heat input ratio (HIR)
12	<bl;HIRfPLR>	HIR part load correction factor
13	<bl;HIRfT>	HIR temperature correction factor
14	<bl;dP>	Fluid pressure drop
15	<bl;Theat>	Internal temperature
16	<bl;Tenvir>	Environmental temperature
17	<bl;OpCap>	Available capacity
18	<md.Elec>	Auxiliary electric consumption
19	<Xfi.Tinlet>	Fluid inlet temperature
20	<Xfi.Pinlet>	Fluid inlet pressure
21	<fo.Toutlet>	Fluid outlet temperature
22	<fo.Poutlet>	Fluid outlet pressure
23	<Xfo.Tsetpt>	Required temperature at outlet
24	<Xfo.Treqd>	Required pressure at outlet
25		

CHILLER

Variable-List Number	Variable in FORTRAN Code	Description
1	<fo.Mfluid>	Fluid flow
2	<ch;Qcool>	Cooling load
3	<ch;kW>	Electric power
4	<ch;Fuel>	Fuel use
5	<ch;Qstart>	Start-up load
6	<ch;PLR>	Part load ratio
7	<ch;RunFrac>	Fraction of hour running
8	<ch;EIR>	Electric input ratio (EIR), actual
9	<ch;EIRfPLR>	EIR adjustment for part load
10	<ch;EIRfT>	EIR adjustment for temperature
11	<ch;HIR>	Heat input ratio (HIR), actual
12	<ch;HIRfPLR>	HIR adjustment for part load
13	<ch;HIRfT>	HIR adjustment for temperature
14	<ch;CHWdP>	Chilled water pressure drop
15	<ch;GrossCapacity>	Gross operating capacity, not adjusted for start-up load
16	<ch;OpCap>	Operating capacity, adjusted for start-up load
17	<ch;Pctrl>	Suction pressure upstream of any EPR valve (REFG-HX)
18	<ch;SSTreqd>	Required suction pressure (REFG-HX)
19	<ch;QcoolMax>	Maximum theoretical cooling capacity (REFG-HX)
20	<ch;Tsetpt>	Local CHW setpoint temperature (REFG-HX)
21	<md;Elec>	Auxiliary electric use
22	<Xfi.Tinlet>	CHW inlet temperature
23	<Xfi.Pinlet>	CHW inlet pressure
24	<fo.Toutlet>	CHW outlet temperature
25	<fo.Poutlet>	CHW outlet pressure
26	<Xfo.Tsetpt>	CHW setpoint temperature (set by plant)
27	<Xfo.Preqd>	CHW required pressure (set by plant)

DW-HEATER

Variable-List Number	Variable in FORTRAN Code	Description
1	<fo.Mout.et>	Flow thru heater
2	<fo.Qoutlet>	Plant load
3	<md.Elec>	Burner power
4	<md.Fuel>	Burner fuel
5	<dw.Qstart>	Start-up load
6	<dw.Qgross>	Gross load, including losses
7	<dw.Qnet>	Net load, after DX heat recovery
8	<dw.PLR>	Part load ratio
9	<dw.EIR>	Net electric input ratio
10	<dw.EIRfPLR>	Value of EIR-fPLR curve
11	<dw.EIRfT>	Value of EIR-fT curve
12	<dw.HIR>	Net heat input ratio
13	<dw.HIRPLR>	Value of HIR-fPLR curve
14	<dw.HIRfT>	Value of HIR-fT curve
15	<dw.Ttank'>	Tank temperature, end of hour
16	<dw.Tenvir>	Environment temperature
17	<dw.Qua>	Tank thermal losses
18	<dw.OpCap>	Net operating capacity
19	<dw.dP>	Fluid pressure drop
20	<Xfi.Tinlet>	Fluid inlet temperature
21	<Xfi.Pinlet>	Fluid inlet pressure
22	<fo.Toutlet>	Fluid outlet temperature
23	<fo.Poutlet>	Fluid outlet pressure
24	<md.Elec>	Auxiliary electric

PUMP

Variable-List Number	Variable in FORTRAN Code	Description
1	<pm.Number>	Number running
2	<pm.Mfluid>	Fluid flow
3	<pm.dP>	Pump head
4	<pm.kW>	Electric power, all pumps running
5	<pm.Qfluid>	Fluid heat gain
6	<pm.dT>	Head ratio, head / design head
7	<pm.RunFrac>	Run fraction
8	<pm.GPMmax>	Maximum flow at required head
9	<pm.GPMr>	Speed ratio, speed / design speed
10	<pm.RPMr>	Flow ratio, flow / design flow
11	<pm.HEADr>	Head ratio, head / design head
12	<pm.HPrpm>	Ideal horsepower as function of speed
13	<pm.xGPMr>	Modified flow ratio, flow ratio / speed ratio
14	<pm.HPfGPM>	Power as a function of modified flow ratio
15	<pm.Psetpt>	Required head
16	<pm.MechEff>	Efficiency modified by viscosity
17	<pm.VFDkWloss>	VFD loss

<u>ZONE</u>

Variable-List Number	Variable in FORTRAN Code	Description
72	zn;W'	End of hour zone humidity ratio
73	RHFUNC(<TNEW>, <zn;W'>,PATM)	End of hour zone relative humidity
74	zn;MWequip	Moisture gain from attached equipment (excludes space latent)

METER

Variable-List Number	Variable in FORTRAN Code	Description
1	me;Load	Meter load, units of consumption
2	me;Loss	Transformer loss
3	eu;Lights	Lighting energy
4	eu;TaskLights	Task lighting energy
5	eu;Equipment	Equipment (plug loads) energy
6	eu;Heating	Space heating energy
7	eu;Cooling	Space cooling energy
8	eu;HeatRejection	Heat rejection energy
9	eu;Auxiliary	HVAC auxiliary energy (pumps, controls, etc.)
0	eu;VentFans	Ventilation fan energy
11	eu;Refrigeration	Process refrigeration energy
12	eu;Supplemental	Supplemental heat pump energy
13	eu;DomHotWater	Domestic water heating energy
14	eu;Exterior	Exterior energy
15		
16		
17		
18		
19		
20		
21		
22	me.TDVsrc	Multiplier to convert site energy to source 'TDV energy'

PROCESS-LOAD

Variable-List Number	Variable in FORTRAN Code	Description
1	<pq;Qprocess	Process load
2	<ro;Moutlet>	Refrigerant flow, lbs/hr
3	<fi.Minlet>	Fluid flow, gal/min
4	<md;Elec>	Auxiliary electric
5	<pq;Qoverload>	Process overload
6	<pq;SSTreqd>	Required suction temperature