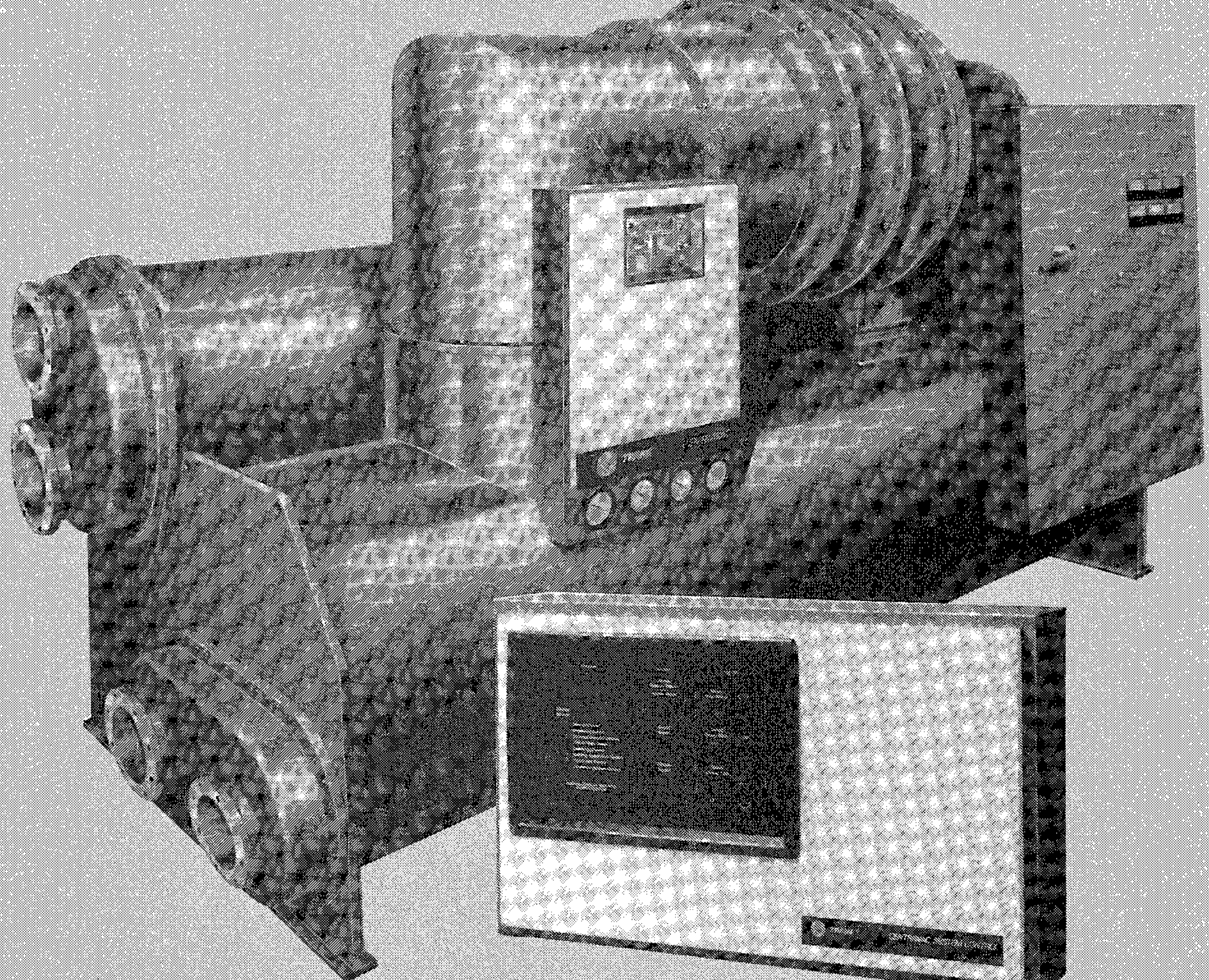
TRANE

Applications Engineering Manual

CenTraVac® Integrated Comfort™ Systems



ICS-AM-2 12/87

CenTraVac® Integrated Comfort™ Systems

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Introduction

This applications Manual discusses an Integrated Comfort System that combines Model CVHE and CVHB CenTraVacs (using a micro-based control panel UCP695) with other parts of an air conditioning system through a Tracer Building Management controller.

The intent of this manual is to aid the designer of chilled water systems that employ CenTraVacs. It is organized to describe the system features, present system design guidelines, and outline application potentials.

This manual is partitioned into ***Part I*** and ***Part II***. Part I describes the systems and the hardware in these systems. Definitions and basic capabilities are covered. Part II focuses on applications and the techniques that can be used to achieve specific results.

PART I

System Description

Simplicity is the key word that describes the Trane Integrated Comfort System concept. In general, individual system components, such as chillers, pumps, cooling towers, fans, coils and valves are designed normally. The basic control strategy is also unchanged. The new ingredients are the control devices, their location and the algorithms that run them.

With the Trane ICS, individual controllers are part of the equipment. For example, the chilled water temperature controller is a part of the CenTraVac. (It is more than a controller, but we'll get back to that later). Alone, this controller is fully capable of executing any of several chiller control strategies. It needs no higher level of control authority in order to function properly.

This controller is built into the CenTraVac at the factory. Every CenTraVac is factory-equipped with an identical micro-based control panel. It's primary functions are to control the supply chilled water temperature and to protect the CenTraVac from conditions which might cause harm or damage to the system, equipment or people. Thus, all controls are categorized as either ***operating*** or ***safety*** controls. In general, safety controls are fixed into the hardware, while operating controls can be altered. In the language of microelectronics, safety controls are "hard-coded" into the micro-chips. Their values cannot be altered without changing the chips. Most operating controls, on the other hand, can be changed by changing software. Their values can be changed at will.

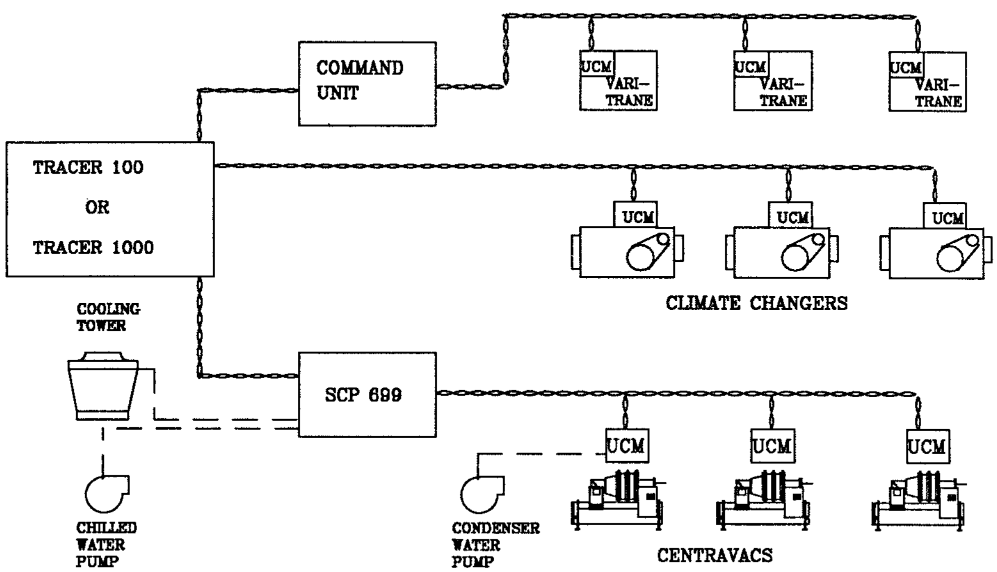


Figure 1

Changes to the various control values can be made manually (on-site) by programming, or remotely through an electronic interface. The latter is the technique used by the Trane Integrated Comfort System (Figure 1). The algorithms used to change operating values may reside in any of several places:

1. Trane Remote Chilled Water Temperature Reset Module (Figure 2).

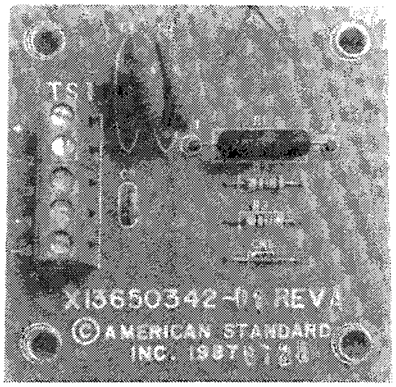


Figure 2

2. Optional "System Control Panel", Model SCP699 (Figure 3), or

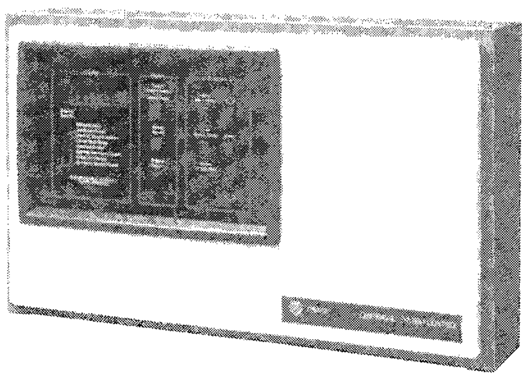


Figure 3

3. Tracer-100 (or Tracer-1000) Building Management Controller (Figure 4), or

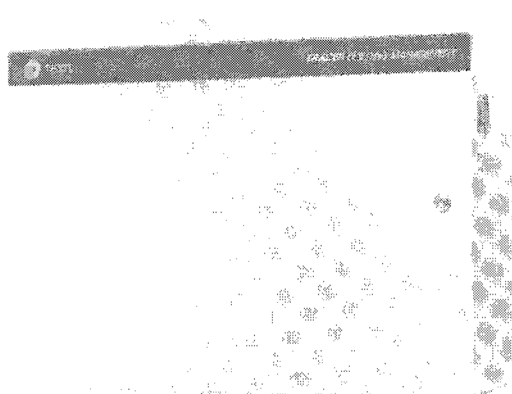


Figure 4

4. Generic BAS Interface through SCP699 (Figure 5).

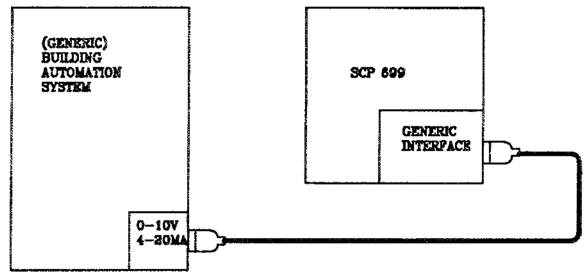


Figure 5

The capabilities and actions of these four "higher level of authority" devices are quite different from each other. Thus, they are described separately.

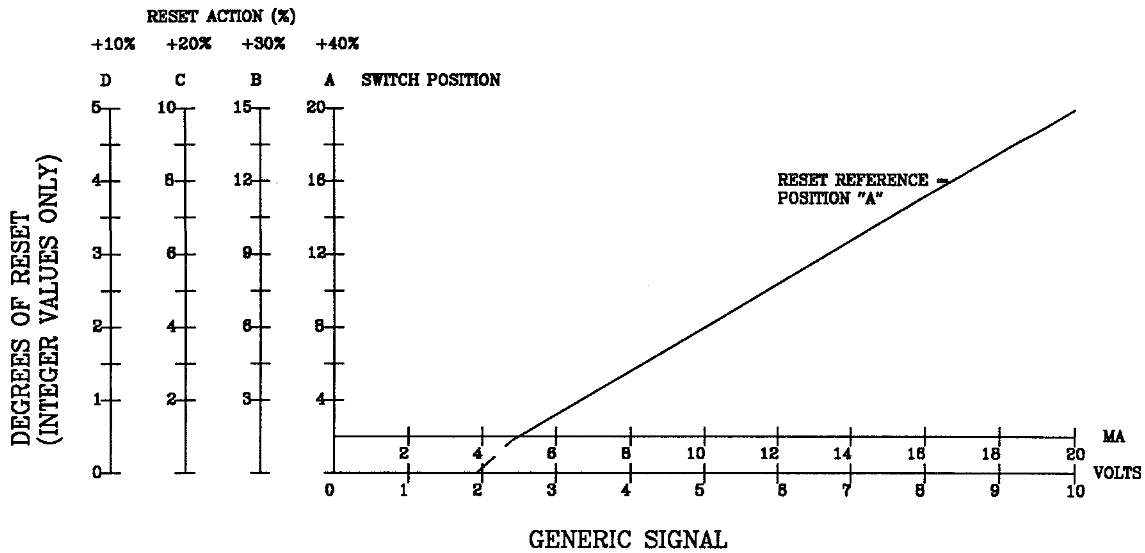
Remote Chilled Water Reset Module

The module identified as Trane part number B4533-2379-01 is a definite-purpose remote chilled water resetting interface. This device permits any remote 4-20 milliamp or 0-10 v.d.c. signal to reset the CenTraVac's supply chilled water temperature setpoint.

Connections are made directly to the CenTraVac panel, module 1U4. Communication is by way of a polarized pair of unshielded low voltage wires.

Chart 1 displays the possible reset relationships. In order to have this module perform its resetting function, four adjustments must be made to the CenTraVac panel 1U3D module:

- Set the "CHILLER" switch to "AUTO-REMOTE"
- Set "RESET TYPE" to "REMOTE TEMP."
- Set "RESET ACTION" to position "A, B, C, or D"
- Set "RESET REFERENCE" to position "A"



NEW CHILLED WATER SETPOINT =
(PANEL SETPOINT) + (DEGREES OF RESET)

Chart 1

As shown in Chart 1, there are two reset ranges. The first range, up to 2.4 v. or 4.8 ma., permits a maximum of only 1.8 F of reset action. The second range is more useful. It permits resetting the temperature up 20 F. Logic within the CenTraVac panel prevents negative resetting.

System Control Panel (SCP699)

Note: For further detailed information on the SCP699 panel, refer to CVMA-IN-1 (Installation), and to CVMA-OG-1 (Operator's Guide).

The Trane SCP699 system is capable of a wide variety of strategies and options. Some of these are mutually exclusive...some are not. Table 1 shows the various features and capabilities of the SCP699, when used alone, as a multiple chiller control panel.

Table 1

1. User interface.
   The "user interface" gives the operator access to data available within the chiller system. This includes all data normally available through the CenTraVac UCP695 panel.
2. Coordinated control.
   1, 2, or 3 CenTraVac chillers with and sequencing UCP695 control panels. Chillers can be piped either 2 or 3 in parallel chillers, or 2 in series.
3. System temperature.
   A common supply water temperature is maintained by regulating individual chiller capacities.
4. Scheduling.
   System operation is scheduled on a 7-day, 24-hour basis, plus holiday scheduling.
5. Cooldown.
   Variable rate "soft-loading;" of chillers minimizes electrical demand peaks.
6. Reset.
   System chilled water temperature reset is executed manually or automatically.
7. Demand limiting.
   System electrical demand limit control is executed based on pulsed signals received from a system electrical demand meter.

8. Centralized manual control. Specific parameters are controlled from a central location (SCP699).

9. Auxiliary components control. Control of major auxiliary chiller system components, such as chilled water pumps.

10. Condenser water temperature. Optional 2-stage *limit control* of cooling tower water temperature permits a variety of special strategies.

11. Free Cooling control. Optional temperature-initiated free-cooling control permits automatic enable/disable commands.

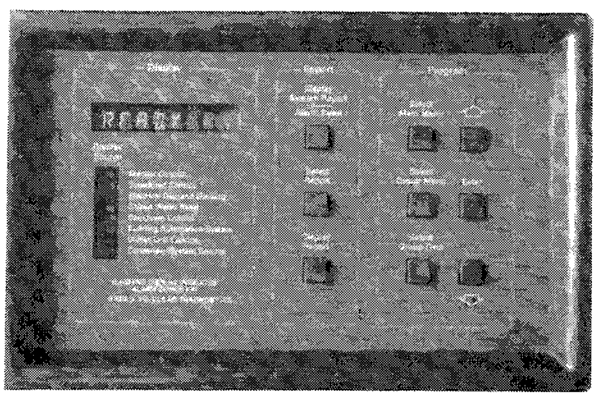


Figure 6

1. User Interface

An 8-character alpha-numeric display, 8 status indicator lights and 9 pushbutton switches comprise the interface section (Figure 6). Three primary groups make up this interface: the *display*, *report*, and *program* groups.

The *display* group indicates to the operator various messages and status information.

The *report* group enables the operator to view as many as 5 preformatted status reports (4 system reports and 1 chiller report).

Programming is performed in two areas; **SYSTEM** and **CHILLER**. Major **system** programming areas are:

- Time scheduling,
- Chilled water setpoint, reset, and control gain strategies,
- Electrical demand limiting setpoint and rate,
- Cooldown (slow-load) strategy, and
- Free-cooling enable/disable temperatures

Major individual **chiller** programming areas are:

- Leaving chilled water temperature setpoint,
- Electrical current limit setpoint,
- Order of rotation for chiller start sequence , and
- Percent chiller capacity to be used as a "trigger" to advance chiller sequence.

2. Coordinated Control and Sequencing of Multiple Chillers

Coordinated control and sequencing is accomplished through programming the "**CHILLER**" portion of the **main menu** (Figure 7). Three unit inputs and the unit sequence inputs are revealed in the **group menu**.

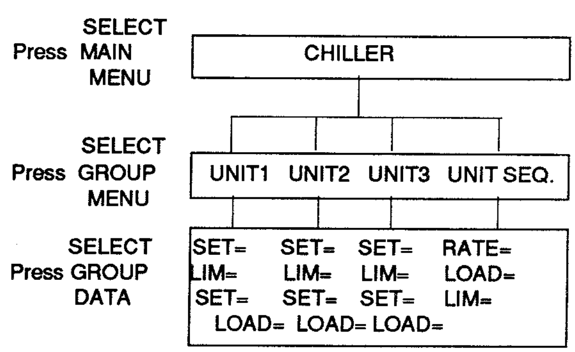


Figure 7

In general, temperature and current limit **group data** settings made in the "**CHILLER**" portion, take precedence over those made in the "**SYSTEM**" portion. The default value for "SET" and "LIM." values is "AUTO". This setting allows the settings entered in "**SYSTEM**" to assume control.[Reminder: For further detailed information on SCP699 panel programming, refer to CVMA-IN-1 (Installation), and to CVMA-OG-1 (Operator's Guide).]

Group data entries for "UNIT SEQ. SET =" determine the order of chiller sequence rotation. The entry in "RATE =" will then determine the rotation period (time). At the end of each period, the sequence order is advanced.

3. System Temperature Control

Chillers are sequenced on or off on the basis of the current drawn by operating chillers relative to a "trigger" current entered in "LOAD =" (UNIT SEQUENCE). A normal value between 90% and 95% will cause the next chiller in the sequence rotation to be started. Similarly, the "LIM. =" entry will cause the last chiller started to be turned off. A value less than 50% is recommended for this entry.

Whenever the system's common chilled water temperature strays from the setpoint, SCP699 resets the individual operating chiller setpoints. In this way, all operating chillers are persuaded to meet the system load.

4. Scheduling

SCP699 incorporates sophisticated 24-hour, 7-day time-clock and calendar functions. Different operating schedules can be set for each day of the week and holidays. Specific chilled water setpoints can also be established (ice storage systems). The panel contains a back-up battery to keep time during power failures.

5. Cooldown

"Cooldown" describes a slow-load strategy that limits the amount of system load the chillers will accept. This amount is gradually increased over time. This time period can be adjusted from 0 through 2-hours, in 15-minute increments.

For the specified period, chiller capacity is limited by SCP699. At the start of the period, the difference between the actual temperature and the setpoint is noted. Compressor currents are allowed to increase until the temperature begins to fall. At intervals, a calculation is made to extrapolate the cooldown time. After each calculation, the setpoint is adjusted to make the extrapolated time equal the cooldown time. At the end of the period, the "cooldown" limits are removed. Chiller control is no longer influenced by a slow-load strategy.

6. Reset

Three reset strategies are available. One resets the system control setpoint whenever the returning chilled water temperature is less than the system design return temperature. If the **SYSTEM group menu** "CHILLED WATER RESET" **group data** entry "SET =" is <25, the new setpoint is determined by an equation that permits a variety of reset rates. The new setpoint is raised as the system load decreases.

The second strategy uses outside air temperature as the reset indicator. If the above **SYSTEM** entry is >25, the new setpoint is proportional to the difference between a base design outdoor air temperature and the actual temperature.

A special DIP switch setting permits "normal" or "reverse" authority for this resetting strategy.

Examples of several ***load-based*** reset strategies are shown in Figures 8 through 11. A definition of abbreviations is needed:

- STMP — Actual system leaving chilled water temperature.
- AUXTMP — Actual system return chilled water temperature.
- SCWS — Scheduled or BAS-generated system chilled water setpoint.
- CWR (RATE) — Decimal value of the entered reset rate that determines reset aggressiveness.
- CWR (SET) — Entered reset temperature that acts as a base amount of reset.
- RSCWS — The newly calculated chilled water reset temperature.

The mathematical expression for the resetting equation is:

RSCWS = SCWS + CWR(RATE) x [CWR(SET) + STMP - AUXTMP]

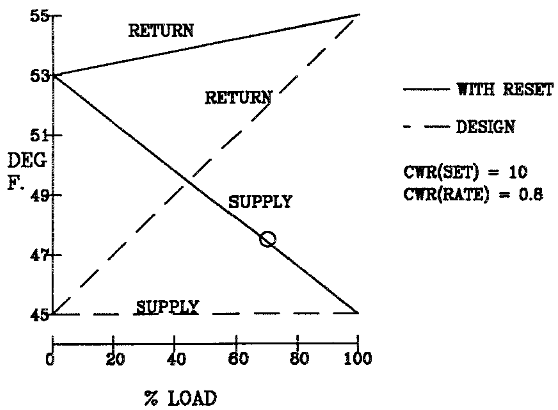


Figure 8

Figure 8 shows what happens if:

The system temperature rise at design is 10 F and, STMP = 45 F, AUXTMP = 52 F, SCWS = 45 F, CWR(RATE) = 0.8 (80%), and CWR(SET) = 10 F.

This particular load condition causes the temperature setpoint to be reset to 47.4 F. The slope of the pictured reset line is expressed mathematically above. Increases in either CWR entries will make resetting more aggresive.

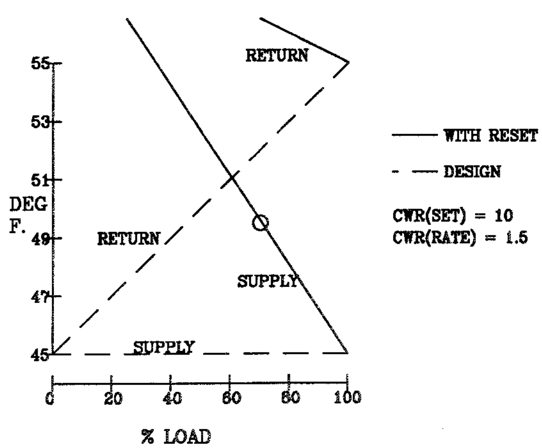


Figure 9

For example, Figure 9 shows the effect of increasing CWR(RATE) to 1.5. RSCWS now is 49.5 F, all other conditions remaining constant. When CWR(RATE) is established at a value higher than 1.0, resetting is so aggressive that the return water temperature rises with decreasing load. If CWR(RATE) is entered at 1.0 (100%), and CWR(SET) is fixed at the system temperature rise at design, the reset schedule will attempt to keep the return water temperature constant. This is shown in Figure 10.

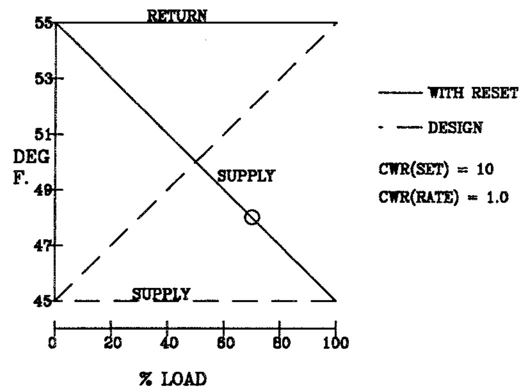


Figure 10

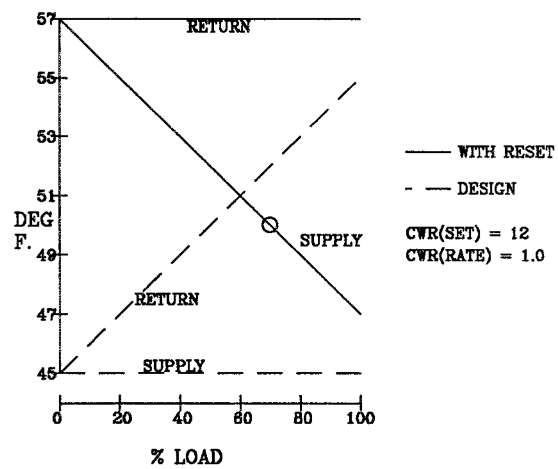


Figure 11

Figure 11 shows what happens when CWR(SET) is established at 12 F. This value, being higher than the system ΔT, causes a 2.0 F "bias" reset at all loads for both supply and return water temperatures. CWR(RATE) of 1.0 establishes a constant return temperature of 57 F.

The second reset strategy is ***ambient-based***. The exact meaning of two variables changes:

- AUXTMP The actual ambient temperature.
- CWR(SET) The base reset increment must now be greater than 25 F. This input is usually the design ambient temperature.

Also, the equation is changed to:

RSCWS = SCWS + CWR(RATE) x [CWR(SET)- AUXTMP]

If: SCWS =45 F
CWR (RATE) = 0.3 (30%)
CWR (SET) = 95 F
AUXTMP = 80 F
then,
RSCWS = 49.5 F

The third reset strategy permits an outside analog signal (4 - 20 milliamps, or 0 - 10 volts) to reset system chilled water temperature setpoint directly at the SCP699. This external analog reset can also be used with the "generic BAS" interface, as described on page 10.

7. Demand Limiting

System electrical demand can be limited by sensing the building's (or system's) electrical demand meter pulses. A maximum (percent) of the total building or system demand is input to SCP699. The actual demand is compared to this product. The current draw of all operating chillers is reduced at a minimum rate of 2% per minute whenever the input peak is exceeded.

In order to be most effective, the total chiller electrical power should be a significant portion of the building power, as sensed by the demand meter. Otherwise, the chillers could be unloaded completely without greatly impacting the building electrical demand.

A current limit and temperature control heirarchy protects the chillers. CenTraVac inlet vanes are positioned on the basis of an ordered structure of regulators. Individual chillers are controlled to respond to the minimum capacity determined by these limiters:

- Evaporator refrigerant temperature
- Condenser refrigerant pressure
- Compressor motor load limit current
- CenTraVac electrical demand limit setting
- Chiller system current limits issued by "Cooldown" or Trane BAS interface
- System electrical demand limit
- Leaving chilled water temperature

In other words, control over the leaving chilled water temperature is sacrificed if any of the electrical demand or current limits restrict capacity. And, the supply chilled water temperature will drift upwards if the supplied capacity does not meet the imposed cooling loads.

8. Centralized Manual Control

This capability is simply the coordination of all the preceeding capabilities at one central location....the SCP699 panel. In addition, unit chilled water pump control, condenser water temperature limit control, and free cooling control are also included.

There are significant operating advantages to be gained from this capability. The ability to execute manual control over the operation of a chilled water system from a central location is important to many designers and operators.

The SCP699 panel can be remotely located. The maximum distance for the communications links and sensors (using 14 ga. wire) is 5000 feet. A single twisted pair of wires handles all bi-directional communications between the SCP699 and the chillers, which can be "daisy-chained" (Figure 12). Dedicated wiring for other sensors, inputs, alarms, and system components (pumps) is also required. Specific wiring connections are detailed in the "Installation Manual" CVMA-IN-1A.

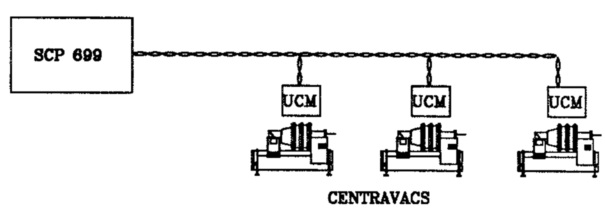


Figure 12

SCP699 is equipped to accept 2 binary pairs of input:

- Scheduled System Enable/Disable. This permits a remote device to enable or disable the entire chiller system. This can be any on/off switch.

- Free Cooling Enable/Disable. This allows a remote on/off device to enable or disable system-wide free cooling.

Either, or both, of these functions can be initiated remotely without effecting other SCP699 capabilities.

9. Auxiliary Components Control

Various water pumps can be controlled by SCP699.

- one (1) system chilled water pump

- three (3) unit chilled water pumps

- no (0) condenser water pumps. No condenser water pumps are controlled by SCP699. Instead, signals to start specific condenser water pumps originate in each CenTraVac UCP695 controller. Interlocking, to verify condenser water flow, also is accomplished at the chiller UCP's.

- no (0) cooling tower fans. No tower fans are controlled by SCP699. The interlocking and temperature control of cooling towers is a separate function and is not integrated with this system. See the next section, "Condenser Water Temperature", for additional information on this subject.

10. Condenser Water Temperature

The condenser limit option is not a condenser water temperature *controller*. Rather, it is an enhancement that permits dual-stage *limitation* of temperature by way of the normal condenser water temperature control system. Its purpose is to maintain a minimum refrigerant pressure differential between each chiller's evaporator and condenser.

An optional "sideboard" is factory-installed inside the SCP699 enclosure. (This sideboard is the same device that serves as a *"generic BAS analog interface"*).

One condenser refrigerant temperature sensor must be installed for each chiller that is to be interfaced with this option. This sensor is connected to terminals in UCP695. The "side board" has one set of terminals dedicated to condenser limiting. These accept a (read only) sensor which can be in water or air. The condenser relays are located on the main board of SCP699.

Evaporator refrigerant temperatures for each chiller are available at SCP699 through the bidirectional communications link (BCL). The difference between the condenser and evaporator refrigerant temperatures is calculated. When this difference increases to a pre-established limit, the output relay is closed, thus enabling the normal tower water control system. Adjustments are in 4 F increments between 36 F and 64 F. Likewise, a drop in this difference opens the output relay, disabling the normal control system. Adjustments to open vary from 24 F to 52 F, and the minimum "open" time is 2 minutes.

SCP699 monitors the refrigerant temperature differential of each operating chiller. It uses the unit with the lowest differential to determine if the cooling tower water temperature control should be disabled.

For example, closure of an output relay at a differential of 50 F (85 - 35) enables the normal tower water control system to function. When the differential temperature falls to 38 F (73 - 35), relay opening can be made to disable the normal control. Or, relay opening could be arranged to open a tower bypass valve. Thus, a minimum limit of 38 F differential temperature is established between the evaporator and condenser refrigerant.

11. Free Cooling Control

The free cooling option on SCP699 permits the system operator to select either manual or automatic switching to (or from) free cooling. Once switched to free cooling, the entire chiller system is in the free cooling mode. It is not possible for individual chiller's free cooling mode to be controlled through SCP699. This can only be accomplished at the chiller UCP.

Manual execution of the system-wide free cooling mode is simply a matter of pressing the

SCP699 front panel push buttons.

A third type of free cooling uses the "free cooling binary input". Closed, free cooling is initiated; open , it is terminated. The open/close decision is external to SCP699.

Automatic, thermostatically-controlled free cooling requires the addition of a sensor in either the common entering condenser water line or outdoor ambient. This sensor is used as a trigger to *start* free cooling, but only if the chillers are not running. The decision to *stop* free cooling is based on the supply chilled water temperature sensor. When a high-limit temperature is reached, free cooling is cancelled and chillers return to the powered cooling mode. To prevent possible cycling, any action to cancel free cooling is suspended during the "cooldown" period.

Chillers not equipped with the free cooling option cannot be operated at the same time with chillers on free cooling without independent condenser water control. Running powered chillers while being supplied with uncontrolled very cold condenser water can cause chiller malfunction or damage. Trane Applications Manual CON-AM-21 provides alternative ways to design and execute condenser water temperature control.

Generic Building Automation System (BAS)

A generic building automation system (BAS) interface to SCP699 is provided at the same "sideboard" terminal strip used for "Condenser Water Temperature Control" (See item 10, page 9). When this connection is made, most SCP699 capabilities are disabled and must be performed separately by the generic BAS. Those SCP699 functions that remain operative are:

- Condenser water temperature limit control
- Remote system enable/disable
- Remote or automatic free cooling enable/ disable
- System alarms (system-level only)
- Unit-level chilled water temperature setpoints, via 4 - 20 ma., or 0 - 10 vdc. direct resetting inputs.
- Unit-level current limits, via 4 - 20 ma., or 0 - 10 vdc. direct resetting inputs.

All other SCP functions are mute.

Tracer-100 Building Management Controller

(Figure 13) Tracer-100 is a powerful Trane building management controller. The Trane Integrated Comfort System uses the Tracer-100 to orchestrate a system-wide control strategy. It

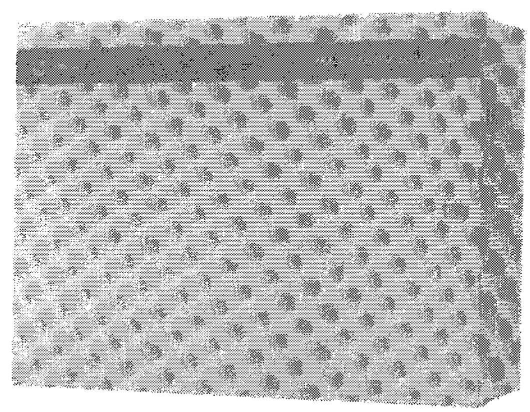


Figure 13

communicates with SCP699 through a twisted pair of wires using a proprietary bi-directional communications link (BCL). All information that is available at the SCP699 user-interface is also available at the Tracer-100. And, the Tracer can be used to communicate all programmable control settings to SCP699.

The bi-directional communications link (BCL) connection is made at terminal board TB2 inside the SCP699 panel. This is a direct serial connection, just as are the SCP699 connections to individual chillers. If more than 15 minutes elapses between Trane BAS communication updates, SCP699 will default to its own internal control values. During a period of "lost Tracer contact", SCP699 sequencing and control logic remain intact.

A Tracer-100 that is connected to SCP699 is probably also being used to perform other system-level chores. A particularly useful application involves the Tracer's ability to monitor data and format reports. The Tracer-100 can interface conventional personal microcomputers via the "Tracer Building Management Network".

This network permits report generation, trend logging, alarm call-out through a telephone modem, and remote data inquiry through the same telephone modem. Service companies find this capability an extremely valuable productivity improvement tool.

Tracer-100 provides other building-level and system-level capabilities. Among these are: control of cooling towers , fans and pumps; extensive building electrical demand limiting; coordinated scheduling; timed override; optimal start/stop; and plant lock-out. All individual chiller monitored points, even those not interfaced by SCP699, are available at the Tracer-100.

Extensive application and user information for Tracer-100 is available in two publications:

- EMTB-OG-1 Tracer-100 Operator's Guide
- EMTN-OG-2 Tracer Building Management Network Operator's Guide

Tracer-1000 Building Management System

The Tracer-1000 system is an extremely powerful building automation and control system, that is part of the Trane Integrated Comfort System architecture. The Tracer 1000 interface to the SCP699 takes full advantage of the bi-directional communications link by way of a Unit Control Interface (UCI) panel. The bi-directional communication link is connected to the UCI which, in turn, is connected via a twisted shielded pair of wires to the Tracer 1000. The UCI serves as a communication translator for the Tracer 1000 system.

When connected to the SCP699, the Tracer 1000 monitoring and control capabilities can be applied to the chilled water mechanical system. Like the Tracer 100, the Tracer 1000 has access to all chiller diagnostic information and can control system chilled water and current limit setpoints.

The Tracer 1000 allows ***all*** SCP699 information points to be assigned as actual Tracer 1000 points. This is unlike the Tracer 100, which allows only a subset of SCP699 information points to be assigned as actual Tracer 100 points. This means that chiller data is available for monitoring via color graphic displays, trend logs, reports, etc., and for control by the Tracer 1000 standard application programs. This adds up to 115 monitoring and control points for each SCP699 panel.

The Tracer 1000 has the added capability to control individual chiller chilled water and current limit setpoints via the SCP699. This permits increased chiller plant control flexibility on an individual chiller basis.

The Tracer 1000 system can interface with multiple SCP699 panels. The maximum configuration will depend upon system hardware and software structure and the applications being performed.

Detailed explanations of Tracer-1000 interfaces to CenTraVacs, programming, and application information are available in the following publications:

- BAS-OG-1
- EMTC-PG-1
- EMTC-AG-1

PART II

This section of the manual is broken into *"How To Design The System"* and *"How To Put The Parts Together"*. They are arranged in "cookbook" fashion in hopes that application to everyday systems will be made more simple.

How To Design The System

1. Qualify the Application

Any CenTraVac installation can be an acceptable "Integrated Comfort System" candidate. In order to qualify, the CenTraVac *must* be equipped with the model UCP695 control panel. Older machines can be retrofitted to have this capability.

Any of the following qualifiers point to a good reason for selecting the ICS option:

- Remote monitoring of chiller(s) or system operating parameters
- Remote adjustment of chiller(s) or system operating parameters
- Coordinated control of multiple chillers
- Automated enable/disable instructions for various chiller(s) or system operating parameters
- Limiting of system-wide electrical demand

2. Establish a clear expression of your goal(s)

In order to translate any concept into reality, a clear expression of the goal is necessary. A fuzzy idea of what you want to accomplish will not do. The clear expression may not be completely doable, but at least it is a starting point. It is best to separate the goals and not combine them into one unmanageable statement. Keep the expressions simple.

Examples of several goal expressions might be:

- Start and stop the chilled water system according to hourly/daily/weekly schedules.
- Remotely reset the system chilled water supply temperature from the building supervisor's office.
- Operate three chillers in a sequence which is changed periodically to equalize chiller operating times.

3. Determine which goals can be accomplished

Part I of this manual describes the various features and functions associated with the four different electronic interface possibilities. If a particular objective is not covered, it may still be possible. Chances are, however, that such objectives, while theoretically possible to achieve, are excessively troublesome to accomplish. Their economic justification should then be researched to avoid the "radar on a canoe" syndrome.

4. Establish the method you will use to accomplish each goal

This step will confirm that the goals are achievable, because a specific method of execution is defined. There may be more than one way to achieve a goal. In that case, the alternative ways must be measured and compared. Not all methods give exactly the same results. And, all do not cost the same.

Further, certain features are grouped. This permits the cost of one option to serve multiple functions. You will want to perform as much grouping as possible, for economical reasons.

How to Put the Parts Together

This section of the manual is a "cookbook".

- Reset chilled water supply temperature
- Remote system start/stop (timeclock)
- Remote alarm(s)
- Reset chiller electrical demand
- Remote monitoring
- Coordinated control of multiple chillers
- Control ice storage system
- Convert existing chiller(s) to permit coordination with new chiller
- Control or monitor Trane chillers from non-Trane BAS

Common objectives are listed. An explanation follows the objective.

Since there are only four pieces of hardware that are used (as indicated on page 3), these are our only "ingredients". The rest is "method".

Reset Chilled Water Supply Temperature

1. Automatic temperature resetting only. This is an optional feature of every CenTraVac equipped with the UCP695 control panel. This feature can be enabled or disabled at the chiller. Logic for resetting can be *load-based* or *ambient temperature-based.* Examples of the results of various reset schedules are shown by Figures 8 through 12.

   a. *To automatically reset the supply chilled water temperature of an individual chiller, use the load or ambient-based optional resetting capability of the CenTraVac control panel.*

2. Remote reset.

   a. *To remotely reset the chilled water temperature setpoint of a **single CenTraVac**, the Trane Remote Chilled Water Temperature Reset Module, described on page 3, is used.* This is a specific purpose device. It can perform no other function. One module is needed for each chiller, since a pair of communicating wires are tied directly into the 1U4 module in each chiller's control panel. No particular reset strategy is built into this module. Instead, it simply acts as a transducer that interprets an input analog signal and sends out the appropriate reset message directly to a CenTraVac UCP695 panel.

   If this is the only function desired, this is the least expensive way to achieve it. This solution can be applied to any number of multiple chillers. But, one module is needed for each chiller. All modules can be fed from a common analog resetting voltage (0-10 vdc.), or current (4-20 ma). The maximum amount of reset is +20 F.

   b. *Use the capabilities of SCP699 to reset the **system** chilled water temperature setpoint.* Temperature resetting is but one of the many SCP699 capabilities, as outlined on page 3. A more detailed explanation appears on page 6. Some examples are also shown.

   c. *Use a Tracer 100 or Tracer 1000, through SCP699,to reset the **system** chilled water temperature setpoint.* Since a Tracer-100 of Tracer 1000 interface through a SCP699 can perform everything that the SCP699 and UCP695 can, remote resetting by way of several strategies is possible. This is done via the bi-directional communications link, and thus does not interfere with other SCP699 functions.

   d. *Use a "generic BAS "through SCP699 to reset the **system** chilled water temperature setpoint.* Resetting through a "generic BAS" (to SCP699 equipped with the "sideboard" terminal strip) is explained on page 10. When this method is used to reset the chilled water temperature, most other SCP699 capabilities are lost. The maximum amount of reset is +20 F.

Remote System Start/Stop Timeclock

1. Unit-level control. Any CenTraVac requires chilled water flow in order to operate. Consequently, chilled water flow is a required electrical interlock. A CenTraVac will not start, or continue to run, without this interlock being closed.

   a. *An electrical contact in series with the flow interlock can be used to enable/ disable an individual CenTraVac.*

   While this is a simple way to execute remote start/stop commands, it contains an unwelcome flaw: Whenever this contact is opened, the CenTraVac microprocessor interprets the event as a flow stoppage and displays the appropriate diagnostic message. This presents no operational problem other than the misleading message.

2. System-level control. SPC699 embraces a sophisticated scheduling regimen, as explained on page 4.

   a. *Use the 7-day, 24-hour, scheduling capabilities of SCP699 to start and stop the complete chilled water system.*

   b. *Use Tracer 100 or Tracer 1000, through the SCP699 bi-directional communications link, to override established SCP699 schedules.*

   c. *Use binary enable/disable inputs to SCP699 (TB3) to turn the chilled water system on or off.* When this connection is made to SCP699, most other features are retained, as this binary connection does not interfere in the same way as the "generic BAS" interface does.

Alarms

1. Announce chiller diagnostic codes.

   a. *Use the standard CenTraVac control panel to display all chiller diagnostic codes.*

2. Remote annunciation of chiller alarm(s). Remote chiller alarm annunciation schemes cannot reset "latching" diagnostics. Any chiller trip that mandates manual resetting requires that the resetting occur at the effected chiller.

   a. *Use the optional "alarm relay package" on the CenTraVac control panel.* This set of dry contacts can be used to establish continuity in a remote alarm circuit. The signal does not define the nature of the alarm....only that the chiller is inoperative because one or more safety-related devices has tripped.

   b. *Use SCP699 to display all chiller diagnostics.* The full set of standard individual CenTraVac diagnostic codes is automatically displayed at the SCP699 when they occur.

   c. *Use Tracer 100 or Tracer 1000, through SCP699, to display all chiller diagnostics.* This arrangement duplicates the SCP699 monitoring capabilities described in the preceding paragraph.

   d. *Use Tracer Building Management Network, through a Tracer and SCP699, to permit a personal computer (IBM-PC or equivalent) to act as a remote monitor.* Tracers and the Network can be programmed to respond with an audible signal whenever any monitored variable strays outside a permitted range of values.

   e. *Use SCP699 "alarm relay" interface (to generic alarm) to indicate an SCP latching (requiring manual reset) diagnostics.* This connection will not alarm diagnostic conditions that occur at the chiller(s).

Reset Chiller(s) Electrical Demand

1. Individual chiller electrical current demand.

   a. *Reset the maximum current demand of an individual chiller at the* ***unit control panel.*** This is a manual adjustment made at the CenTraVac control panel.

   b. *Use SCP699 to reset individual chiller current limit values remotely.* This setting will supercede the unit control panel setting.

   c. *Use Tracer 100 or Tracer 1000, through SCP699, to set individual chiller current limit values.*

   d. *Use "generic BAS" interface (to SCP699) to set individual chiller current limit values.* Analog signals (4 - 20 ma. or 0 - 10 vdc.) sent to SCP699 are used to reset the current limits.

2. System-level electrical current demand.

   a. *To establish and maintain* ***chiller(s)*** *ampere demand limit based on the total full load currents of all chillers in the systems, use SCP699.* Whenever the established limit is met, SCP699 controls chiller inlet vane positions on all operating chillers so the limit is not exceeded.

b. *Use SCP699 to establish and maintain a* ***system power (kw) demand limit*** *based on the total power absorbed by the system.*

This method uses a system watt-hour/ pulse initiator to measure the system's instantaneous power level.

Whenever the established limit is met, SCP699 controls chiller inlet vane position on all operating chillers so the limit is not exceeded. Since chillers do not account for all power absorbed, their control over total power is not absolute. To make this strategy more responsive, the chillers must represent a majority of system power requirements.

c. *Use Tracer 100 or Tracer 1000 to perform system-level demand limiting via a connection to the system's power meter.* This concept is similar to the SCP699 method described above. In this case, however, Tracer performs electrical demand limiting on components both within and outside the chilled water system; eg. lights, heaters, etc.

Remote Monitoring

Several strategies of remote monitoring are possible. Major determinants are 1) the number of "points" to be monitored, 2) the nature of monitored items, and 3) the distance between the monitored item and the display. Any remote monitoring, using existing sensors, requires a system control panel SCP699 for communications.

1. <u>All monitored items are accessed by the CenTraVac or SCP699 panels.</u>

a. *Use SCP699 to display all chiller and/ or system dignostics.* The full set of standard individual chiller diagnostic codes is automatically displayed at the SCP699 when they occur. In addition, the full set of system reports is accessible anytime at the SCP. Four system and as many as 3 chiller "status reports" are available at the SCP699.

b. *Use Tracer 100 or Tracer 1000 to communicate SCP699 data to a separate telephone modem.* When the full sets of data referenced above need to be transmitted great distances (more than 5000 feet), or need to be sent to a location other than that of the SCP699, a telephone modem and phone line are required. A Tracer Building Management Network, using PC's as monitors, can also be connected to the modem.

2. <u>Monitored points are not restricted to the chiller(s) or the chilled water system.</u>

a. *Use SCP699 and Tracer 100 or Tracer 1000 to gather data and display it or develop reports at the Tracer.*

b. *Add Tracer Building Management Network, using PC's as monitiors, to the above equipment if monitoring location is remote from Tracer, or this location is one of several to be monitored.*

c. *Add modem and telephone line to the above equipment if distances are great, or this location is one of several to be monitored.*

Coordinated Control Of Multiple Chillers

A wide variety of strategies can be used to fit a specific multiple chiller control concept. It is

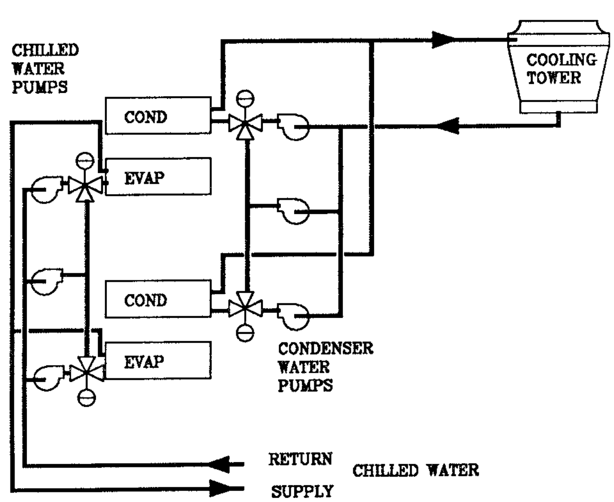


Figure 14

fundamentally crucial to have clear understanding of the physical system....the piping scheme, pumps, sequences of operation, etc. The first step is to make a schematic drawing of the piping and pumping sytem, including the loads and their control elements. This drawing should reduce the system to its most simple elements. A "ladder" diagram is often useful for this purpose. Figure 14 shows an example of a useful schematic drawing.

Next, a brief description of how the system operates should be written. It is often helpful to have someone other than the designer read this description for logic and clarity. Table 2 contains a brief description (not a specification) of the system shown in Figure 14.

Table 2

Two equally sized chillers are piped with evaporators in parallel. Each chiller is served by a dedicated chilled water pump. A third standby chilled water pump is piped and valved so that it can be used in place of either of the two dedicated pumps.
Condenser water pumps are likewise dedicated to a specific chiller and piped in parallel, with a third standby pump availble. Condenser water pumps take tower sump water, push it through its condenser, and send it to the top of the cooling tower, where it is cooled via evaporation and falls back into the sump. Control of condenser water supply temperature is accomplished by fan control separately.
The system is to be controlled by a system panel that sequences pumps and chillers on and off on the basis of load. This panel also changes chiller sequence automatically to equalize running time. The panel will maintain a common chilled water supply temperature.
The system is enabled and disabled by the system panel through a programmed schedule (timeclock function). Chilled water pumps are energized by the system panel. Condenser water pumps are sequenced by the chiller panel interlocking.

Once these steps are completed, the following list of possible combinations can be reviewed for a "fit". If no fit can be found, the two possibilities are: 1) the proposed system may not work, or 2) the proposed system may work but it will require custom engineering and design. And, it may require control devices that are not commonly available, or are improperly applied.

- 2 or 3 chillers, common parallel pumps (Fig. 15).
- 2 chillers, common series flow (Fig. 16).
- 2 or 3 chillers, dedicated parallel pumps (Fig. 14).
- 2 or 3 chillers, decoupled chiller and distribution pumps (Fig. 17).
- 4 or more chillers, decoupled chiller and distribution pumps (Fig. 18).
- any of the above applied to ***constant*** or ***variable*** system chilled water flow.
- any of the above applied to ***common*** or ***dedicated*** condenser water supplies.

Coordinated control of a multiple chiller system requires some kind of system controller. Individual chiller temperature controls are not capable of communicating directly with other chiller controls to establish a system control strategy.

SCP699 is specifically designed to function as a

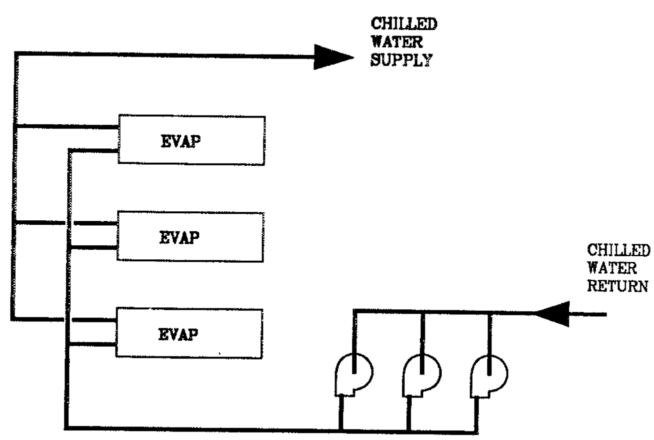


Figure15

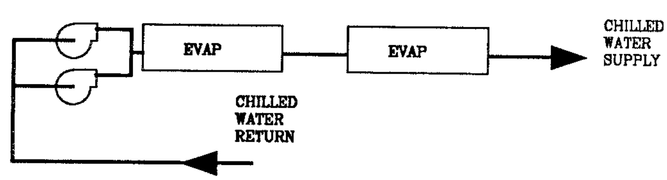


Figure 16

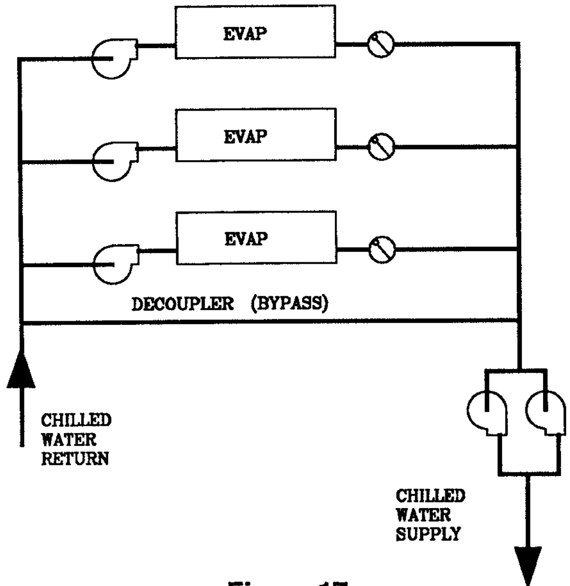


Figure 17

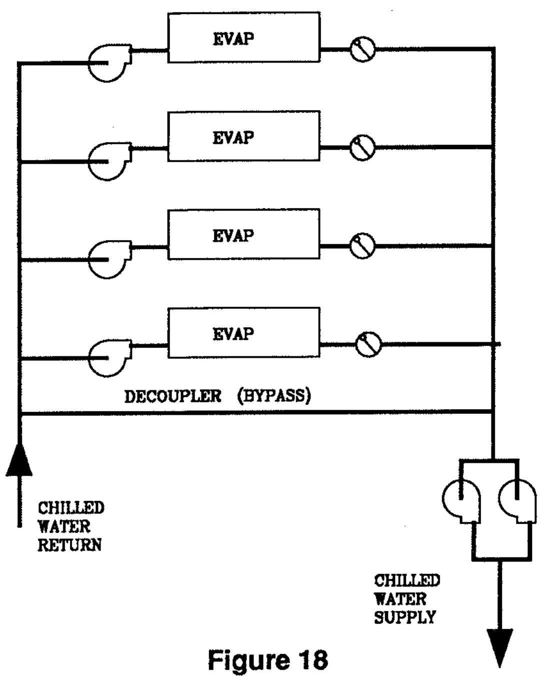


Figure 18

system controller. As is indicated in Table 1 on page 4, this is one of the 11 primary functions of SCP699. In order to set up SCP699 for any of the above named systems, follow the instructions included in the SCP699 Operator's Guide, CVMA-OG-1.

A single SCP699 can control up to 3 chillers. For coordinated control of 4 or more chillers, additional SCP699 panels are needed, a maximum of 3 chillers per panel.

<u>Figure 15. 2 or 3 chillers, common parallel pumps.</u> This arrangement is commonplace. Often, it is seen as using a single pump instead of multiple pumps. Chilled water pump(s) provide circulation in the chillers and the loads. Water flows through the evaporators of all chillers constantly. Loads are either "wild" coils or coils controlled by 3-way valves. This provides a constant flow of water throughout the system.

Since the common supply temperature is a mixture of water from each chiller, it is an average of all chillers, whether they are operating or not. This executes supply water temperature control if each chiller is controlled at a constant temperature. As system load decreases, individual chillers are unequally unloaded or turned off. Some designers feel that this provides "automatic reset" of the common supply temperature.

a. Using this philosophy, system control can be as simple as *using a return chilled water controller (actually, a thermostat) to establish the number of operating chillers.* Once established, the sequence of chiller operation can only be changed electrically with the equivalent of a dpdt switch (2 dpdt switches for 3 chillers) on the output of the controller.

b. *If more sophisticated control coordination or response is required, use SCP699 as a system controller.* See SCP699 Operator's Guide CVMA-OG-1 for details.

<u>Figure 16. 2 chillers, common series flow.</u> A single pump circulates water throughout the system. Flow is constant. Each operating chiller produces chilled water at a different temperature. The inoperative chiller simply allows water to pass through without a temperature change. A pressure loss is sustained in this process.

In its simplest form, coordinated control means setting each chiller for its design temperature. When the load raises the returning chilled water to a temperature high enough to start the downstream chiller, it starts and carries all the load it can. When the return temperature rises so far that the downstream chiller cannot carry the load, the upstream chiller will start. The reverse process occurs when the cooling loads decrease.

a. Alternate chiller sequencing may or may not be possible, depending on the specific selection of chillers. If all chillers are designed for the system common supply temperature, *sequencing (first chiller to start) can be changed by setting the temperature controllers for the upstream chiller lower than the downstream chiller.* While this is inelegant and cumbersome, it will work.

b. As in the case of parallel chillers, *a SCP699 panel will coordinate sequencing and alternating of series connected chillers.* This panel sequences chillers by a combination of resetting supply water temperature setpoints and chiller motor loading. Basically, the panel will lower individual chiller setpoints in an effort to maintain the common system supply temperature. A signal to start an additional chiller is given when exiting chillers indicate loading via their motor current consumption.

Figure 14. 2 or 3 chillers, dedicated parallel pumps. Pumps and chillers operate in dedicated pairs. Any given chiller will not operate without its pump, and vice-versa. As in the case of common chilled water pumps, system loads (coils) are either "wild" or controlled by 3-way valves. With this arrangement, system flow varies depending on the number of pumps and chillers running.

Simplistic coordinated multiple chiller control is difficult to achieve, because system loads (demand) are not easily found.

a. *Use SCP699 System Control Panel to coordinate the control of this system.* This controller uses chiller motor current to determine individual chiller loading, and the need for additional chiller capacity. It also sequences pumps appropriately with the chillers.

Figure 17. 2 or 3 chillers, decoupled chiller and distribution pumps. This arrangement dedicates chiller pumps to individual chillers. In addition, it dedicates a system distribution pump to the task of circulating all the water the system loads need. Usually, this flow varies with load changes. Individual chiller flows, however, are constant....either on or off.

a. Two fundamentally different control methods exist. The first scheme *uses a SCP699 to coordinate control of the chillers and all pumps.* As before, chiller sequencing signals are a consequence of motor loading. Since chiller/pump sequencing can dramatically change the perceived return water temperature at each operating chiller, load shifts occur relatively quickly. Thus, the chiller water temperature controller should be set for a faster than normal response time.

b. The second scheme uses the direction and amount of flow in the decoupling bypass water line to determine chiller/pump sequencing activity. A full explanation of the dynamics of this concept appears in Trane Application Manual CON-AM-21 (587). See Figure 14. A single "Annubar" flow measuring probe is used to detect both overflow and reverse flow in the bypass decoupler line. A "zero flow" signal is interpretted as reverse flow and causes the "Eagle-Eye" pressure switch to close and operate the cam switch motor in the direction of "more pumps". The "Eagle Eye" switch is set to close in the "overflow" mode when it detects flow of approximately 115% of the rating of the next pump to stop. *More elegant system control strategies are possible by using a Tracer 100 through SCP699.* When bypass flow is used as the sequencing determinant, the electric outputs of the flow meter (either binary or analog) are fed into the Tracer for processing. SCP699 can still be used for system duties other than coordinated control, which is assumed by the Tracer 100 with this scheme.

c. An alternate approach is to use *Tracer 100 analog temperature inputs*, per Figure 19. These values are then processed by the Tracer to calculate flows without ever actually measuring them. Classic temperature and flow mixing equations are used. Appropriate timing functions are also included in the Tracer programming.

Figure 18. 4 or more chillers, decoupled chiller and distribution pumps. Once a system reaches this size, it is usually large and complex enough for the power of a Tracer 1000. SCP699 capbilities are limited to monitoring functions only. A

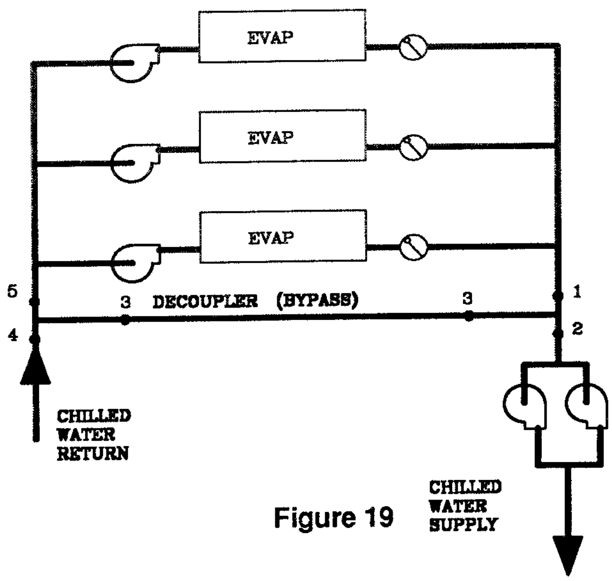


Figure 19

Tracer 100 can accept a "twisted pair" connection to only one SCP699. Therefore, a system of 4 or more chillers would require multiple Tracer 100/SCP699 pairs to accomplish all 11 functions listed in Table 1,page 4, plus remote monitoring.

a. *Use Tracer 1000 to connect multiple SCP699 panels via the "twisted pair".* This scheme permits the Tracer 1000 to function as a single point BAS for all chiller system functions.

b. *Use the mechanical system described on page 18 to sequence multiple chillers and chilled water pumps.* This concept is more thoroughly explained on pages 7 and 8, CON-AM-21 (587). Temperature control remains confined to the individual chillers. System scheduling can be accomplished by a simple "time-clock" to enable the step controller shown in Figure 16, page 8, CON-AM-21 (587).

Ice Storage System Control

The control of only one of several possible ice storage systems is explained here. Figure 20 shows a CenTraVac applied to Calmac® tanks. This system is described more fully in Application Manual SYS-AM-10.

Control strategy focuses on several characteristics of this system:

1. It is not possible for a CenTraVac to "overcool" the chilled anti-freeze solution so

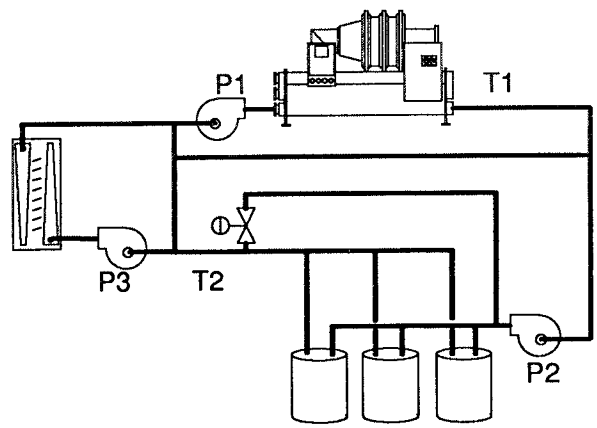


Figure 20

long as the water in the tanks is a liquid.

2. Completion of the tank "freeze cycle" is accompanied by a dramatic and sudden reduction in return chilled solution temperature.

3. The system can have 5 modes of operation:

   a. **Build ice.** In this mode the chiller has this one objective. Since this mode occurs when electric energy and demand are at minimum cost, the chiller is allowed to operate without power or temperature restrictions. The chiller temperature controller is reset to a value which it may not be able to reach. In this way, the chiller will run at its maximum capacity for these conditions.

   b. **Burn ice.** In this mode, ice is melted by the system chilled water load. The chiller is not operating because this mode of operation occurs at a time when the energy cost of chiller operation is being avoided.

c. **Build and cool.** Some systems require cooling while the ice is being stored. In this case, the chiller must be capable of accepting the added system load and reaching the output temperature required for ice production, **simultaneously**. This requires the added chiller capacity and the ability to modulate capacity as the cooling load changes.

d. **Burn and chill.** Many ice storage systems employ "partial storage" or "load leveling" as a way to lower energy costs. This scheme involves loading the chiller 24 hours a day to meet design load conditions. During the day, then, system loads are satisfied by melting ice **and** operating the chiller. Further, this strategy permits anticipation of future loads so as to optimally select the lowest cost way (ice or instantaneous chilling) to produce cooling capacity.

e. **Direct cool; save ice.** "Partial storage" systems require some way to save stored ice for a particular high demand period of the day. For example, the chiller can be piped to provide instantaneous cooling directly to the load during morning hours. In the afternoon, when other electrical loads peak, the chiller is either modulated or turned off to allow stored ice to meet the loads.

Table 3

Mode	P1(gpm)	P2(gpm)	P3(gpm)	T1(F)	T2(F)
1	1000	1000	OFF	24	-
2	OFF	1000	800	OFF	40
3	1000	1000	800	24	-
4	1000	1000	800	40	40
5	1000	OFF	800	40	-

Table 3 shows the various pump, valve and control settings to accomplish each of these modes of operation. (See Figure 20).

To automate system control, use SCP699 and Tracer 100. SCP699 is used, with or without multiple CenTraVacs, to permit full bidirectional communications with the Tracer 100 BAS. Tracer is equipped with custom software to execute the above 5 modes of operation at the appropriate times. Tracer software is available in "pattern" form for individual project customization.

"Fail-Safe" Communications

When SCP699 is used as the system controller, it is serially connected to each CenTraVac control panel. If, for any reason, SCP699 communications are lost or interrupted, all CenTraVac controls revert to their own individual settings. Chillers and pumps that were running continue to operate. Idle pumps, and their interlocked chillers, will not start unless they are manually started.

Convert existing chiller(s) to permit coordination with new chiller.

Increasing numbers of chiller installations are additions to or renovations of existing chilled water systems. Consequently, the retrofit of existing chillers to be compatible with the new technologies is an important capability.

Any electrically driven centrifugal chiller can be converted to "look like" a new CenTraVac to the control system. Usually, this conversion involves replacing or reworking the following subassemblies:

1. The chilled water temperature controller
2. The chiller control panel
3. The compressor inlet vane modulation mechanism
4. The compressor motor starter

It is not a trivial project to make the necessary conversion. But, it is often a very worthwhile goal to integrate the complete chilled water system. Accomplishing any or all of the objectives listed on page 12 is difficult, if not impossible, without this integration.

Control,Or Monitor,Trane Chillers From Non-Trane BAS

The "language and protocol" of both the CenTraVac UCP695 and SCP699 are unique. The reason for this has nothing to do with a desire to hold them "secret". Instead, it is a matter of cost. Communications from one microprocessor to another can be done in a variety of ways. Numerous standards exist. One such generic communication standard, for example, is commonly known as "RS232". Everyone familiar with personal computers has heard of "RS232". It could be used to handle all control communications as well.

However, RS232 requires considerable "translation" at both ends of the communications line. Translators are quite expensive, compared to the rest of the microelectronics apparatus in HVAC controls. Therefore, manufacturers normally do not incorporate them in their products. It represents an unnecessary cost burden, whereas the communications protocol Trane uses does not require a translator between microprocessors. The disadvantage, of course, is that the "conversation" is proprietary.

SCP699 is equipped with limited translator capabilities. It is able to communicate with generic control systems through the "generic interface" described on page 10. As indicated, this interface employs specific binary and analog signals, and does not use any particular microelectronics industry communication standard designation, such as RS232 or RS485. The SCP generic interface is a **control** interface, and is **not** intended as a **monitor** interface.

Control, through a generic interface, can be accomplished by:

a. *Use the SCP699 "generic interface" to permit non-Trane BAS to control:*

   (1) System enable/disable

   (2) Free-cooling enable/disable

   (3) Chilled water temperature (unit-level setpoints)

   (4) Current limit (unit-level setpoints)

Several methods permit "generic" **monitoring** of Trane chillers. To gain access to any of the existing CenTraVac control points (sensors), SCP699 must be used. Other monitoring is separate and does not involve either UCP695 or SCP699.

a. *Use Tracer 100 (or Tracer 1000) through SCP699 to output all monitored CenTraVac points through the Tracer RS232 port.*

b. *Use separate hardwired sensors to monitor parameters that are not monitored CenTraVac points.*

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