INSTALLATION OPERATION MAINTENANCE AND PARTS MANUAL

SYSTEM - 2000

CHILLED WATER (CAC)

COMPU-AIRE, INC.
8167 BYRON ROAD, WHITTIER, CA 90606
PHONE: (562) 945-8971 FAX: (562) 696-0724
Website: www.compu-aire.com E-mail: compuaire1@aol.com
ISO 9002 REGISTERED COMPANY

Contacting Compu-Aire For Technical Assistance

Compu–Aire, Inc. uses the latest in electronic and software technologies to develop some of the most reliable and cost efficient air conditioning systems in the world. Since many of our customer installations are sensitive to down time, we stock nearly all components for your system ready for same day shipment. In addition, our service departments can usually diagnose and repair the electronic components and return them to you within a few days.

Our customer support staff is available should you require assistance in diagnosing a problem or in setting up your air conditioning system. During usual business hours, you may call at (562) 945–8971 between 7:00 AM and 3:30 PM Pacific time, Monday through Friday except holidays. Or, you may send a facsimile message at (562) 696–0724 anytime. Finally, you may write us at Compu–Aire, Inc., 8167 Byron Road, Whittier, California 90606.

Please, do not return system components without prior authorization from Compu–Aire. Whether repair or replacement is required for in warranty or out of warranty parts, Compu–Aire must know what is being returned and why so that we may keep proper records of your parts. Call Compu–Aire's service center for a returned materials authorization number (RMA) and clearly mark all packages on the outside with the number before sending them to us.

When contacting the factory, please have information ready as to the model and size of the air conditioner system and most important, the job number. Compu–Aire keeps a file on each machine sold detailing system components using this latter number. All such information can be found on the Warranty Plate attached to each machine.

INDEX

GENERAL

The Compu-Aire chilled water series is a complete environmental control system, factory wired, tested, and specifically designed to provide temperature, humidity, and dust control for computer room installations.

The unit as shipped from the factory includes a blower/motor package, chilled water coil, water control valve, humidifier, reheat elements, electrical control package,and other specified special options.

TRANSPORTATION DAMAGE

Visual inspection of the outer casing provides a simple indication of possible internal damage to the equipment. Move the unit to the installation site in the upright position. **FILE A CLAIM WITH THE SHIPPING COMPANY IF THE SHIPMENT IS DAMAGED OR INCOMPLETE. FREIGHT DAMAGE CLAIMS ARE THE RESPONSIBILITY OF THE PURCHASER.**

Optional articles such as jackstand parts, condensate pump, and remote control panel are packaged separately.

PRE-INSPECTION

Upon receipt of the units, inspect the items for either visible or concealed damage.

REPORT ANY DAMAGE TO THE CARRIER. COMPU-AIRE IS NOT RESPONSIBLE FOR FILING OF ANY CLAIMS. ALL NEEDED INSPECTION AND CLAIM FILING IS THE RESPONSIBILITY OF THE RECEIVER.

LOCATING THE AIR CONDITIONER

Proper clearance is important for the unit function and access to various components for adjustment and repair or replacement.

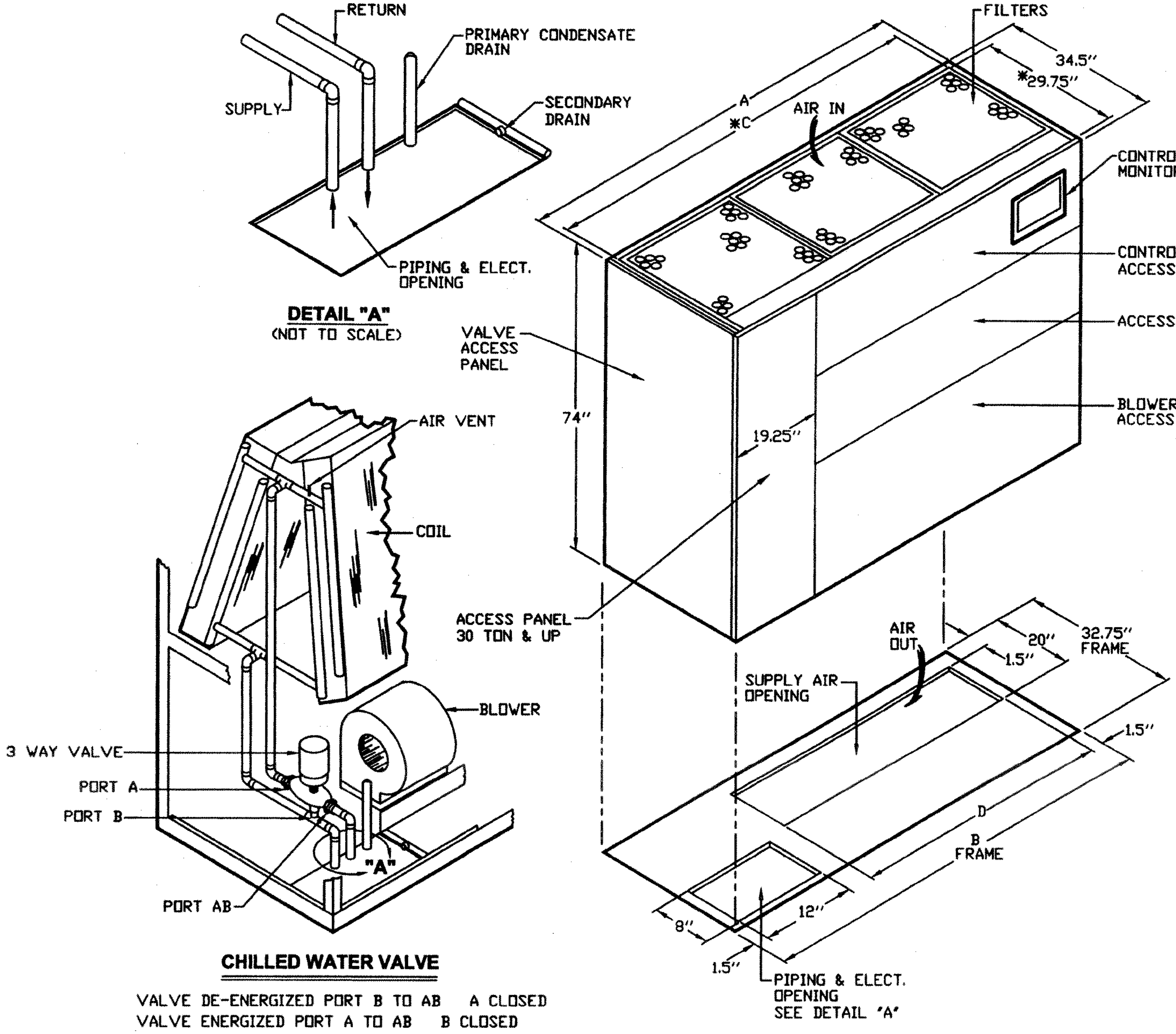
Front*	36"
Left Side	36"
Right Side	36"

REV.	DESCRIPTION	DATE	APPROVED
A	NEW RELEASE	6/5/01	BF

REVISIONS

UNIT SIZES	A	B	C	D
6,8,10 15 TON	50.5"	48"	45"	30"
20 & 25 TON	74.5"	72"	69"	54"
30,35 & 40 TON	99.5"	97"	94"	79"
50 TON	110.5"	108"	105"	90"

*RETURN AIR DUCT FLANGE (IF USED)



CHILLED WATER VALVE

VALVE DE-ENERGIZED PORT B TO AB A CLOSED
VALVE ENERGIZED PORT A TO AB B CLOSED

DOWN FLOW MODEL

COMPU-AIRE,inc.	
CAC SYSTEM 2000 CHILLED WATER FLOOR CUTOUTS	
DRAWN BY B.FUNDERWHITE	DATE 6/5/01
APPROVED BY: [signature]	REVISED
JOB NO.	DWG NO. 682-901-001

IMPORTANT - READ BEFORE INSTALLING

Check the power supply. Voltage, frequency and phase must correspond to that specified on the unit nameplate. The power supply must be able to handle the additional load imposed by this equipment.

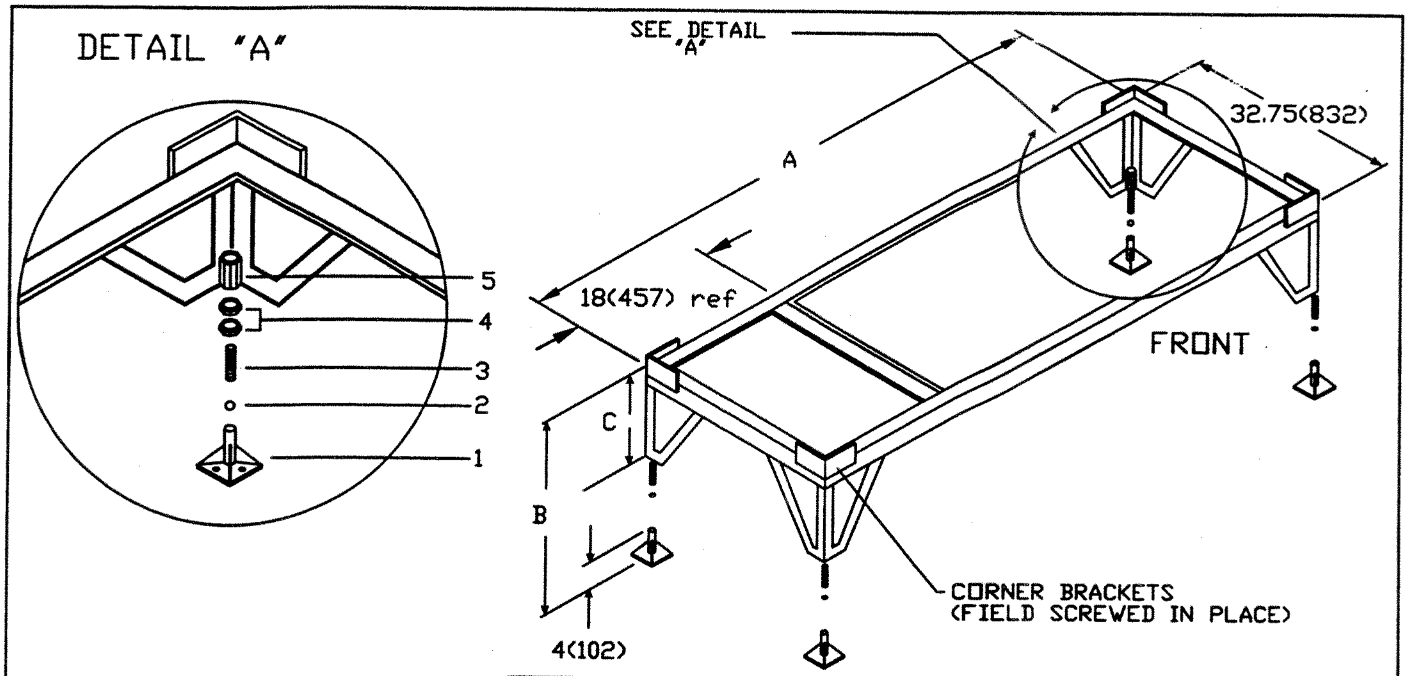
LOCATING THE UNIT

Consult local building codes and National Electrical Code for special installation requirements. When installing the unit, allow sufficient space for air flow clearance, wiring, and servicing the unit. Left side and front should have a minimum clearance of 36 inches of clearance if available. Right side should have 36 inches of clearance if available. Top clearance must be a minimum of 12 inches. No rear clearance is required, but it is suggested that 1 or 2 inches be provided to allow for out-of-square walls. The unit may set directly on top of the raised floor or on adjustable jackstands.

The unit should not be placed near any corner of the room. For best air distribution, the unit should be placed in mid-point against the longest wall, and as close to the load(s) as possible. For multiple units, place them as far apart from each other as possible for optimum air distribution. Before placing a unit directly on the raised floor, it is important that the proper openings have already been cut.

An alternate method of setting the unit is with the use of levelling jackstands. The height of the unit can be raised or lowered through the use of the adjusting rods. The locknuts must be tightened to assure rigidity, as shown below.

UPFLOW UNITS - The unit may be placed directly on the sub floor. The upflow unit has an optional 10" high discharge plenum.



NOTES
1. STAND
2. STEEL PIVOT BALL
3. ADJUSTING ROD
4. LOCK NUT (2 req.)
5.3/4(19) #10X2.5(63) COUPLING NUT

TYPE OF UNIT	UNIT SIZE	A
CAC	6, 8, 10, 15 & 20 TON	48
	25 & 30 TON	72
	35 & 40 TON	97
	50 TON	108

B	C
8"(203) ±1"(25.4)	2.5" (63.5)
12"(305) ±1"(25.4)	6.5" (165)
18"(457) ±1"(25.4)	12.5 (317)
24"(610) ±1"(25.4)	18.5" (470)

COMPU-AIRE, inc.
8167 BYRON ROAD WHITTIER, CA 90606
PH(310)945-8971 FAX(310)696-0724

SYSTEM 2100-FLOOR STAND

N KUMAR | 12-27-90
9-12-94
DWG 682-910-003

TECHNICAL DATA

MODEL	CAC-10	CAC-15	CAC-20	CAC-25	CAC-30	CAC-35	CAC-40	CAC-50
CAPACITY DATA • Based on 45°F(7.2°C) Entering Water With 10°F(5.6°C) Temperature Rise								
80°F DB, 67°F WB(26.7°C DB, 19.4°C WB), 50% RH Entering Air								
Total BTU/HR(KW)	164,500(48.1)	216,200(63.4)	266,400(78.0)	326,600(95.6)	409,000(119.7)	461,500(135.1)	557,700(163.3)	654,200(191.5)
Sensible BTU/HR(KW)	114,000(33.4)	147,500(43.2)	170,700(50.0)	221,000(64.7)	261,600(76.6)	307,400(90.0)	364,200(106.6)	420,100(123.0)
Flow Rate GPM(L/S)	30(14.2)	40(18.9)	50(23.6)	60(28.3)	75(35.4)	85(40.1)	106(50.0)	125(59.0)
Pressure Drop PSI(kPA)	5.7(39.3)	4.9(33.7)	7.6(52.3)	5.3(36.5)	7.1(48.9)	4.2(28.9)	6.4(44.1)	8.6(59.2)
75°F DB, 62.5°F WB(23.9°C DB, 16.9°C WB), 50% RH Entering Air								
Total BTU/HR(KW)	112,800(33.0)	145,200(42.5)	185,400(54.3)	226,100(66.2)	286,900(84.0)	314,500(92.1)	394,800(115.6)	474,800(139.0)
Sensible BTU/HR(KW)	96,900(28.4)	123,800(36.2)	145,600(42.6)	188,500(55.2)	221,800(64.9)	260,900(76.4)	309,200(90.5)	359,900(105.4)
Flow Rate GPM(L/S)	24(11.3)	30(14.2)	38(17.9)	48(22.7)	60(25.9)	64(30.2)	80(37.8)	105(49.6)
Pressure Drop PSI(kPA)	3.8(26.2)	2.9(19.9)	4.7(32.3)	3.6(24.8)	4.8(33.1)	4.7(32.3)	5.7(39.2)	4.7(32.3)
72°F DB, 60°F WB(22.2°C DB, 15.5°C WB), 50% RH Entering Air								
Total.BTU/HR(KW)	90,600(26.5)	124,500(36.5)	152,200(44.6)	185,300(54.3)	230,600(67.5)	256,400(75.1)	323,400(94.7)	358,200(104.0)
Sensible.BTU/HR(KW)	86,400(25.3)	113,800(33.3)	134,500(39.4)	185,300(54.3)	201,600(59.0)	256,400(75.1)	278,200(81.5)	312,000(91.4)
Flow Rate GPM(L/S)	18(8.5)	25(11.8)	33(15.6)	37(17.5)	46(21.7)	52(24.5)	66(31.1)	80(37.8)
Pressure Drop PSI(kPA)	6.5(44.7)	5.2(35.8)	5.4(37.2)	3.9(26.8)	9.7(66.8)	4.6(31.6)	8.1(55.8)	7.0(48.3)
72°F DB, 58.6°F WB(22.2°C DB, 14.8°C WB), 50%RH Entering Air								
Total BTU/HR(KW)	85,600(25.1)	114,200(33.4)	139,500(40.9)	173,100(50.7)	209,300(61.2)	237,900(69.7)	292,500(85.6)	321,900(94.0)
Sensible BTU/HR(KW)	85,600(25.1)	114,200(33.4)	139,500(40.9)	173,100(50.7)	204,500(59.9)	237,900(69.7)	284,200(83.2)	321,900(94.0)
Flow Rate GPM(L/S)	17.5(8.3)	23(10.9)	28(13.2)	35(16.5)	42(19.8)	48(22.7)	58.5(3.7)	72(34.0)
Pressure Drop PSI(kPA)	5.9(40.6)	5.4(37.6)	4.3(29.6)	4.7(32.3)	3.6(24.8)	4.1(28.2)	15.7(46.8)	6.1(42.0)
FAN DATA-DWDI FORWARD CURVED CENTRIFUGAL VARIABLE PITCH PULLEY								
CFM (L/S)	5300(2501)	6300(2974)	6000(2832)	9300(4390)	9200(4342)	12700(5994)	12700(5994)	15000(7080)
ESP "WC (Pa)	0.5(125)	0.5(125)	0.5(125)	0.5(125)	0.5(125)	0.5(125)	0.5(125)	0.5(125)
Fan(s)Quantity(Downflow)	1	1	1	2	2	2	2	2
Fan(s)Quantity(Upflow)								
Motor HP	2	3	3	5	5	7.5	7.5	10
CHILLED WATER COIL DATA - "A" Frame 1/2" OD COPPER TUBING, ALUMINUM FINS, 150 PSIG WORKING PRESSURE								
Face Area FT²(M²)	12.1(1.1)	12.1(1.1)	12.1(1.1)	18.75(1.7)	18.75(1.7)	26.1(2.4)	26.1(2.4)	30.2(2.8)
Rows	2	3	3	4	5	4	6	6
Valve Configuration	3 way	3 way	3 way	3 way	3 way	3 way	3 way	3 way
ELECTRIC REHEAT-BTU/HR INCLUDES MOTOR HEAT								
KW	12.0	15.0	22.5	22.5	22.5	30.0	30.0	30.0
BTU/HR	46,100	56,250	87,500	97,270	97,270	121,200	121,200	121,200
Stages	2	2	2	3	3	3	4	4
HUMIDIFIER - ELECTRONIC ELECTRODE WITH DISPOSABLE CYLINDER								
KW	6.8	6.8	10.2	10.2	10.2	10.2	10.2	10.2
Capacity LBS/HR	17.5	17.5	17.5	30	30	30	30	30
FILTER DATA(DOWNFLOW MODEL) DISPOSABLE PLEATED MEDIA 30% EFFICIENCY ASHRAE STANDARD 52-76								
20"X25"X2"	-	2	2	-	-	-	3	-
16"X25"X2"	3	3	2	2	6	6	6	3
Media Area FT²(M²)	46.5(4.3)	46.5(4.3)	69(6.4)	84(7.8)	84(7.8)	84(7.8)	84(7.8)	96(8.9)
FILTER DATA(UPFLOW MODEL) DISPOSABLE PLEATED MEDIA 30% EFFICIENCY ASHRAE STANDARD 52-76								
16"X20"X2"	3	3	2	2	6	6	6	3
20"X20"X2"	-	-	2	2	-	-	-	3
Media Area FT²(M²)	30.3(2.8)	30.3(2.8)	44.6(4.1)	44.6(4.1)	60.6(5.6)	60.6(5.6)	60.6(5.6)	66.9(6.2)
PIPING DATA - All connections Copper O.D.								
Condensate Drains	(2)3/4"	(2)3/4"	(2)3/4"	(2)3/4"	(2)3/4"	(2)3/4"	(2)3/4"	(2)3/4"
Chilled Water Supply	1 1/8"	1 5/8"	1 5/8"	1 5/8"	2 1/8"	2 1/8"	2 1/8"	2 5/8"
Chilled Water Return	1 1/8"	1 5/8"	1 5/8"	2 1/8"	2 1/8"	2 1/8"	2 1/8"	2 5/8"
Humidifier Make-Up	1/4"	1/4"	1/4"	1/4"	1/4"	1/4"	1/4"	1/4"
WEIGHT LBS (KG)	1050(472)	1300(585)	1650(742)	1850(832)	2100(945)	2200(990)	2310(1039)	2410(1084)

ELECTRICAL DATA

TABLE 2 • CHILLED WATER SYSTEMS - CAC

VOLTAGE @ 3Ph, 60Hz	CAC - 10	CAC - 15	CAC - 20	CAC - 25	CAC - 30	CAC - 35	CAC - 40	CAC - 50
208								
FLA	**40.8**	52.2	**52.2**	79.2	**100.1**	107.6	**107.6**	137.6
MCA	**51.0**	65.2	**65.2**	99.0	**125.0**	134.5	**134.5**	167.8
MFS	**55A**	70A	**70A**	100A	**125A**	150A	**150A**	200A
460								
FLA	**18.5**	23.6	**23.6**	35.9	**45.3**	48.7	**48.7**	62.3
MCA	**23.1**	29.5	**29.5**	44.8	**56.6**	60.8	**60.8**	75.9
MFS	**25A**	30A	**30A**	45A	**60A**	60A	**60A**	80A
575								
FLA	**16.5**	17.1	**17.7**	26.4	**36.1**	39.0	**39.0**	49.9
MCA	**20.6**	21.3	**22.1**	33.0	**45.1**	48.7	**48.7**	60.8
MFS	**25A**	25A	**25A**	35A	**50A**	55A	**55A**	70A

FLA - Full Load Amp • **MCA** - Minimum Circuit Ampacity • **MFS** - Maximum Fuse Size

TABLE 3 • FAN MOTOR AND PUMP MOTOR

HORSEPOWER	*VOLTAGE @ 3 Ph, 60 HZ* 208		230		460		575	
	FLA	LRA	FLA	RLA	FLA	RLA	FLA	RLA
1.0	**3.9**	23.1	**3.6**	21.0	**1.8**	10.8	**1.4**	8.4
1.5	**5.7**	33.0	**5.2**	30.0	**2.6**	15.0	**2.1**	12.6
2.0	**7.5**	42.9	**6.8**	39.0	**3.4**	19.8	**2.7**	16.2
3.0	**10.5**	59.4	**9.6**	54.0	**4.8**	27.0	**3.9**	23.4
5.0	**16.7**	99.0	**15.2**	90.0	**7.6**	45.0	**6.1**	36.6
7.5	**24.2**	145.2	**22.0**	132.0	**11.0**	66.0	**9.0**	54.0
10.0	**30.8**	193.0	**28.0**	168.0	**14.0**	84.0	**11.0**	66.0

RLA - Rated Loaded Amps • **LRA** - Locked Rotor Amps

TABLE 4 • REHEAT

VOLTAGE @ 3 Ph, 60 HZ	KILOWATTS 7.5	12.0	15.0	22.5	30.0	37.5
208	**20.8**	33.3	**41.7**	62.5	**83.4**	104.2
230	**18.0**	28.9	**36.1**	54.2	**72.3**	94.2
460	**9.4**	15.1	**18.8**	28.3	**37.7**	47.1
575	**7.0**	12.1	**15.0**	22.5	**30.0**	37.7

TABLE 5 • HUMIDIFIER

VOLTAGE @ 3 Ph, 60 Hz	KILOWATTS INFRA-RED			ELECTRIC IMMERSION	ELECTRIC SELF GENERATING STEAM				
	4.8	6.4	**7.5**	5.4	**3.4***	5.4	**6.8**	8.5	**10.2**
208	**13.3**	17.8	**N/A**	15.0	**16.4**	15.0	**19.0**	23.6	**28.4**
460	**6.0**	8.0	**N/A**	6.8	**7.4**	6.8	**8.5**	10.7	**12.8**
575	**N/A**	N/A	**7.5**	5.4	**6.0**	5.4	**6.9**	8.6	**10.2**

* Nortec 3.4 K.W. HUMIDIFIER is single phase

TABLE 6 • **CORRECTION FACTORS AT VARIOUS ENTERING WATER TEMPERATURE**

ENTERING WATER TEMPERATURE	ENTERING AIR 80° F DB, 67° F WB TOTAL	SENSIBLE	ENTERING AIR 75° F DB, 62.5° F WB TOTAL	SENSIBLE	ENTERING AIR 72° F DB, 60° F WB TOTAL	SENSIBLE
42	1.12	**1.07**	1.13	**1.06**	1.19	**1.10**
45	1.00	**1.00**	1.00	**1.00**	1.00	**1.00**
48	0.87	**0.92**	0.80	**0.93**	0.81	**0.95**

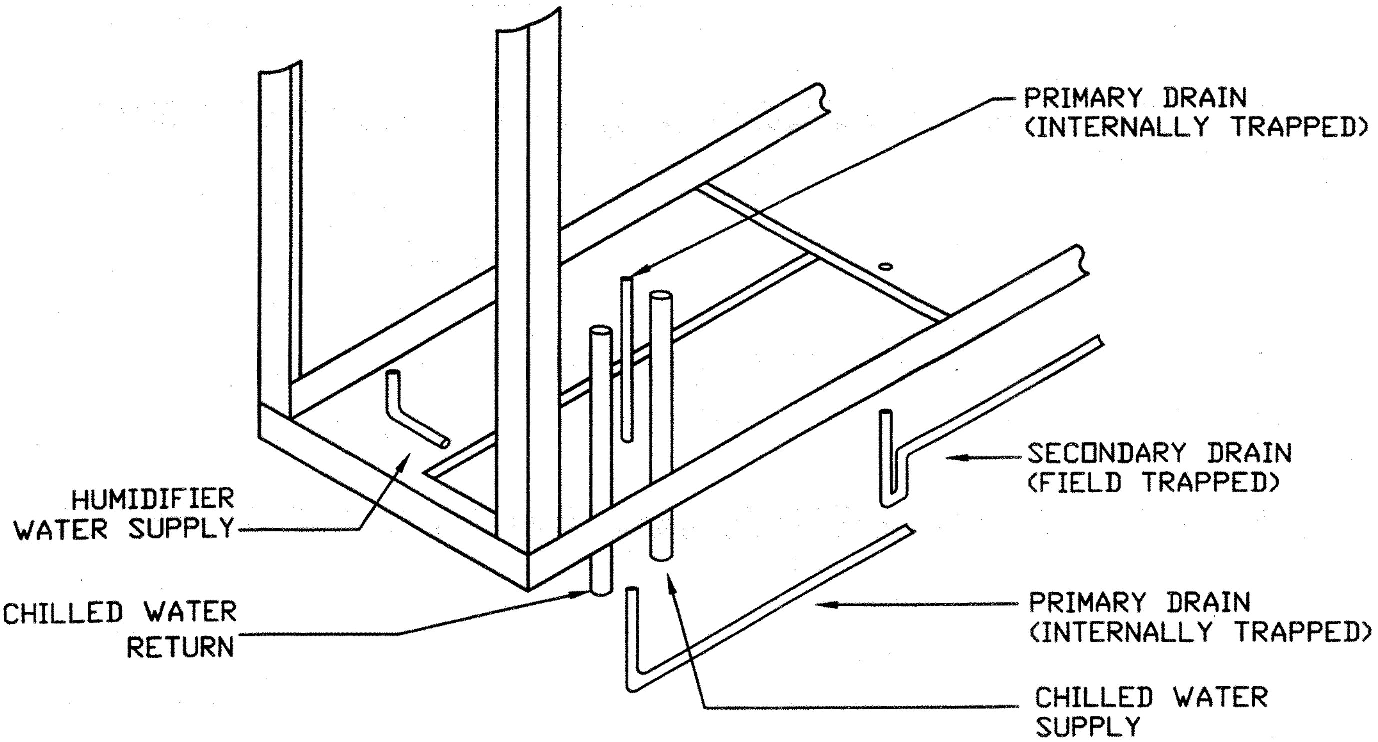
PIPING CONNECTIONS

Note: Water side operating pressure not to exceed 200 psig. Special 250 psig valve is available from the factory.

DOWNFLOW UNIT - All plumbing field piping is brought to the unit through the bottom rear left of the frame as shown below:

UPFLOW UNIT - Field piping is brought through the bottom left hand door.

After all connections are made to the unit, seal off air openings around the pipes using tubing insulation material such as Armaflex.



Shut-off valves should be used on the inlet and outlet for future servicing if desired. A fill valve with hose bib connection should also be used to either the supply or return line at the lowest point of the system. This valve may be used to fill as well as to drain the system, if necessary.

Unions may be used for unit connections. A strainer should be installed in the system and must be cleaned periodically. Automatic air vents should be installed in various locations in the piping system to remove air. More than one vent may be necessary. It is preferable to install these vents at the highest point of the system. For more information on piping, please refer to ASHRAE Standards or any other common practice trade publication.

The water "in" and "out" connections sizes are as follows:

CAC 10	1-1/8" O.D. stub
CAC 12	1-3/8" O.D. stub
CAC 15 & 20	1-5/8" O.D. stub
CAC 25 & 30	2-1/8" O.D. stub

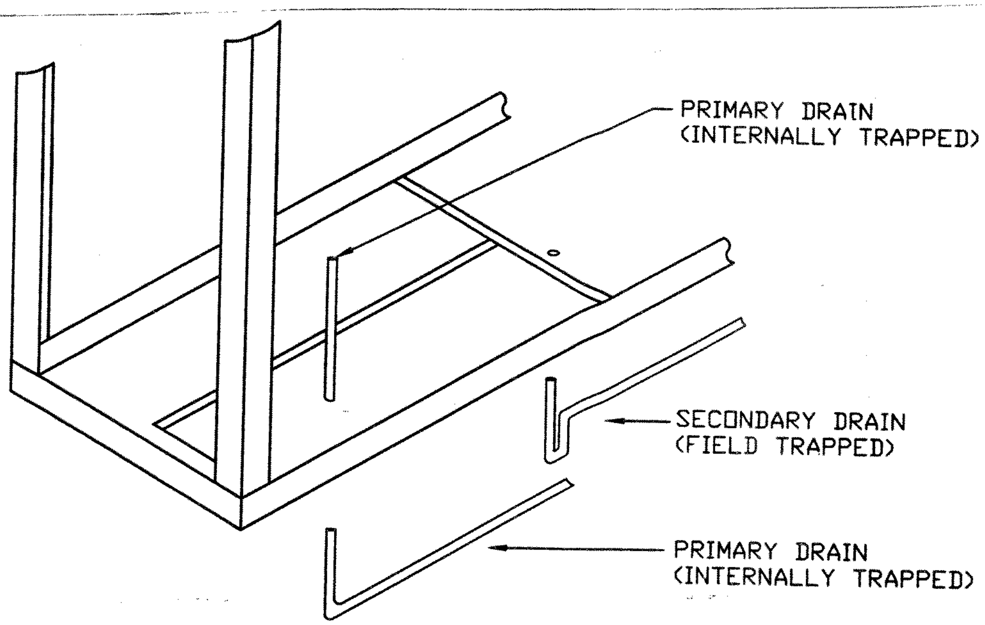
Note: These sizes are at the unit. LARGER SIZE PIPES MAY HAVE TO BE USED ON SOME APPLICATIONS DEPENDING ON PRESSURE DROP, LENGTH OF RUN, NUMBER OF FITTINGS AND VALVES, AND THE SIZE OF THE PUMP USED IN THE SYSTEM. To assist the installer in determining the size of the pipes, please use the following table:

LIFE SIZE NOMINAL	90 STD	45 STD	GLOBE VALVE	GATE VALVE	SWING CHECK	"Y" STRAINER*
1 1/4"	3.3	1.7	38	1.5	14	9
1 1/2"	4.0	2.1	43	1.8	16	10
2"	5.0	2.6	55	2.3	20	14
2 1/2"	6.0	3.2	69	2.8	25	20
3"	7.5	4.0	84	3.2	30	40

*Screwed end

CONDENSATE DRAIN CONNECTION

Two 3/4" copper stub are provided on each unit for condensate removal. A trap is already provided. It is recommended that unions be installed in each line to permit ready disconnection from the unit for easy cleaning. Where local codes permit, PVC pipe may be used for drain lines. It is important that the drain line be installed with sufficient slope to permit easy draining. Drain lines should have a pitch away from the unit not less than 1/4" for each 10 feet of run. DO NOT REDUCE THE SIZE OF THE DRAIN LINE.



A secondary drain connection must be made to the bottom of the blower pan. The connection is 3/4" stub trap thin drain.

On some applications were a floor sink or other means of condensate disposal is not available, a condensate pump of adequate size should be used. There are several small pumps available, complete with built-in floats for automatic condensate removal. The correct choice of pump depends greatly on the pressure head(vertical riser) that must be overcome. In some instances, where the head is higher than pump head capacity, two pumps piped in series may be necessary. A check valve must be installed at the discharge side of all condensate pumps to reduce short cycling.

NOTE: For units having an automatic flush cycle on the humidifier, a condensate pump with metal sump tank should be used, due to the high temperature of the water being flushed. **POWER SUPPLY FOR CONDENSATE PUMP SHOULD BE FROM A SEPARATE SOURCE, USUALLY 115 VOLT OUTLET, AND MUST NOT IN ANY WAY BE CONNECTED WITH THE AIR CONDITIONING UNIT.**

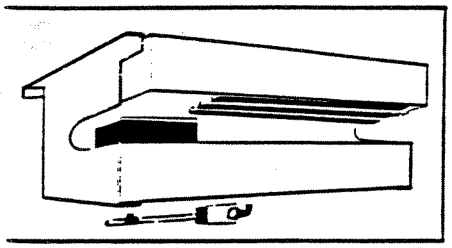
HUMIDIFIER PIPING CONNECTION

The standard humidifier supplied with Compu-Aire units is a disposable generator type humidifier. A 1/4" compression fitting is provided for the water supply, a 1/4" O.D. copper tubing should be used for make-up water.

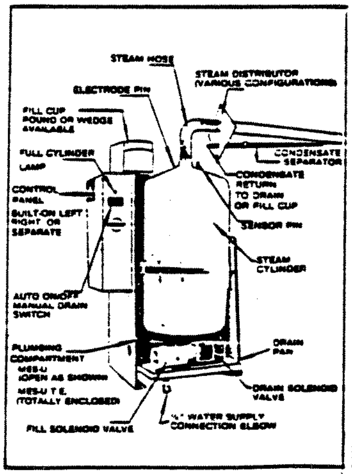
For the optional infra-red humidifier or the electric immersion, piping connections are identical to the standard humidifier. All require a 1/4" O.D. tubing.

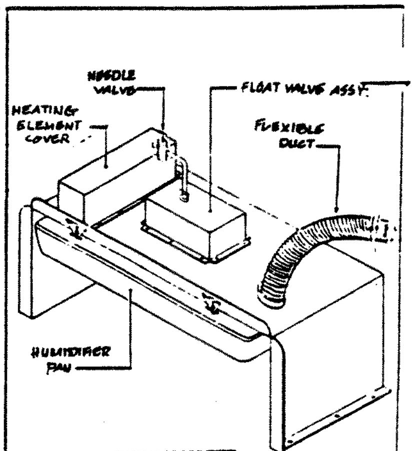
A water line shut off valve MUST be provided outside the air conditioner for future disconnection and service. In addition, an in-line water pressure regulator and a strainer should be installed in the make-up water line. Water pressure should be set between 30 and 50 psig.

For infra-red and electric immersion the float is factory adjusted to maintain minimum water in the humidifier where the elements are just submersed in water. For field adjustment, loosen the float arm, or slightly bend the arm as shown below.



Infra-Red Humidifier





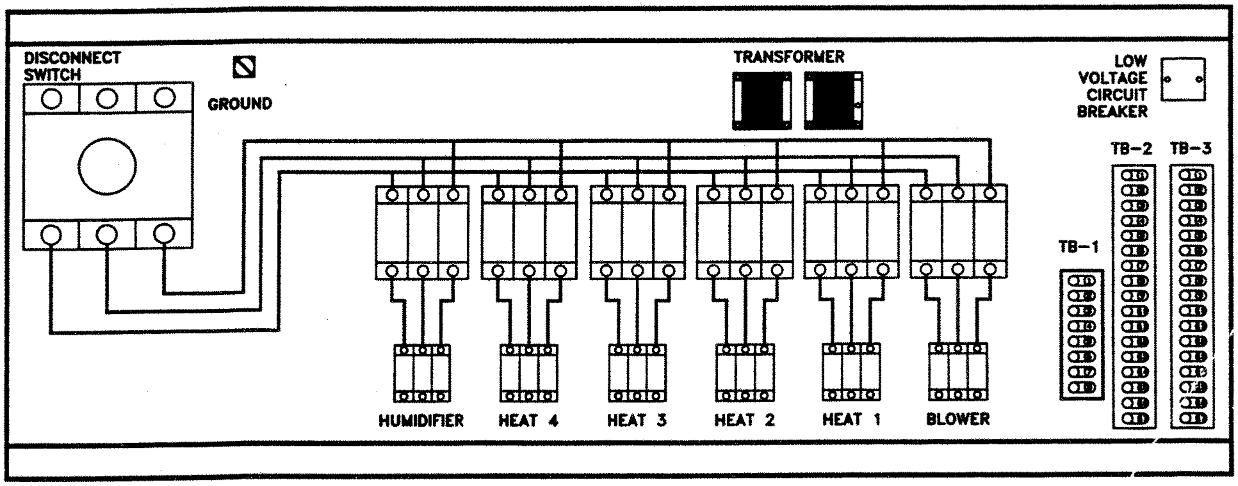
ELECTRIC IMMERSION HUMIDIFIER

LEAK TESTING

No installation is complete until the entire system has been thoroughly checked for leaks. This includes water tubing, humidifier make-up and condensate lines.

ELECTRICAL CONNECTION

IMPORTANT - Before proceeding with the electrical connections, make certain that the volts, hertz and phase correspond to that specified on the unit rating plate. Also, check to be sure that the service provided by the utility is sufficient to handle the additional load imposed by this equipment. Refer to the unit rating plate for equipment electrical requirements. The attached wiring diagram shows the proper high and low voltage field wiring. The table below indicates electrical requirements of standard units, however, the nameplate must be referred to for exact requirements.

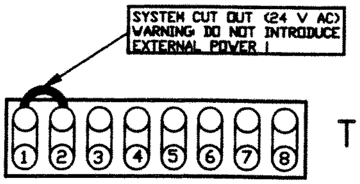


Make all electrical connections in accordance with National Electrical Code and any local code ordinances that may apply. USE COPPER CONDUCTORS ONLY.

Warning: The unit cabinet must have an uninterrupted or unbroken electrical ground to minimize personal injury if an electrical fault should occur. It is important that an electrical ground wire of adequate size can be connected to the ground lug provided inside the control box.

Supply voltage at the unit must be within ± 10% of the voltage indicated on the nameplate. For a dual voltage rating, supply voltage must be within 5% from the lower nameplate rating and within 10% from the higher rating. Phase to phase imbalance must not exceed 3%. Contact your local utility company for correction of improper line voltage. Improper electrical power supply may cause premature failures and void unit warranties.

The unit is completely factory wired with self-contained controls.



TB-1

The system cutout terminals on the terminal strip are for connection to a "panic button" or remote shut-off if required. This should only be connected to a switch and **NO EXTERNAL SOURCE OF POWER SHOULD BE INTRODUCED AT THIS POINT**. The conductors should be sized depending on the length of run and the number of control transformers used in the unit. Maximum voltage drop must not exceed 1 volt. Each control transformers draws approximately 3 amps @ 24v. for long runs where the conductor size becomes too large, and interlocking relay(field provided) should be used.

A dry contact(24 volts rating) is provided for terminals for a remote alarm connection. Whenever the unit alarm is energized, terminals 6,7,8 on T.B. #2.

If the control panel includes a condensate probe, make sure it is mounted below the unit against the floor area where water may collect. To check the operation of the probe, submerse it in a cup of water. The condensate alarm should energize.

START UP AND TEST PROCEDURE

A. With All Power to Unit OFF - Check that all Wiring is Correct

Check that properly sized fuses are installed in the disconnect switch. Correct fuse size and minimum circuit ampacity are listed on the unit nameplate. Now, check the wiring connections in the Main Control Panel to see if they are tight. It is best that this be checked prior to operating the machine. After checking, close the Main Control Panel cover and proceed as follows:

Solid-State Control Panel - With the system switch in the "OFF" position, apply power to the unit. The "Power On" light should illuminate.

B. Check for Correct Phasing

The equipment should now be checked for correct phasing required to make the blower motor turn in the correct directions. For this test it is necessary to open the front access panel or the right side doors of the unit to observe the blower and blower motor. Now, momentarily switch the system switch to the "ON" position and then back to "OFF". The blower will have started and it is therefore possible to determine rotation. On Compu-Aire units, the blower should be rotating in a CLOCKWISE direction in the downflow units and COUNTER CLOCKWISE in the upflow units, looking in the right side of the unit. Heaters and humidifiers are not affected by phasing.

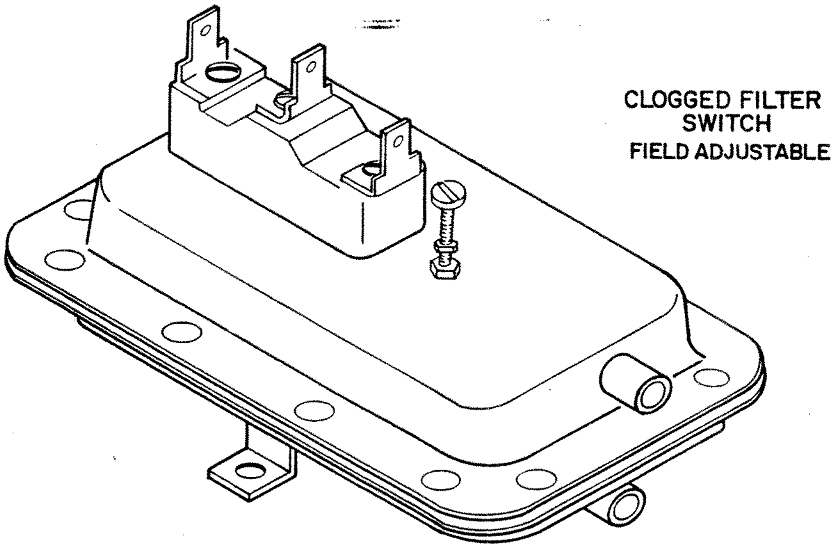
C. Blower Speed Adjustment

Adjustment of the air flow may be desired. The air flow can be readily adjusted with the variable pitch pulley provided on the blower motor. After the unit has been started and the air flow properly adjusted, check the blower motor current to ensure that the motor is not overloaded. Any time the blower speed is increased, the blower motor current should be checked. If a field adjustment is made, the motor should run for at least one hour at maximum design room temperature to see if motor trips on internal overload.

D. No Air Flow & Clogged Filter Adjustment

The "No Air Flow" light and alarm should be checked prior to the completion of the installation. Although the control is adjusted at the factory, varying local conditions make it impossible to provide accurate pressure adjustments.

To check the filter pressure switch, let the unit operate on cooling for about 30 minutes. This will allow the evaporator coil surface to become wet. With the unit cooling and with the filters in place, block off approximately 75% of the air intake. If the sensing device is correctly adjusted, the "Clogged Filter" alarm should energize; the sensing device should have just turned on the alarm at the 75% blocked inlet condition. An Air Flow Sail switch is also provided at the discharge side of the blower and will activate the No Air Flow malfunction light and alarm.



E. Humidifier Operations

Check to see that the unit is securely mounted on a level surface with the proper drain and water supply. Check for correct voltage with appropriately sized service. Check that the steam distributor, steam supply hose and condensate line are correctly installed and routed back to the unit. Ensure that the external control humidistat is located in an area to properly sense the relative humidity to be maintained by the humidifier, and that the inter-connecting low voltage wires between the humidistat and unit's control terminal strip are in accordance with the wiring diagram.

Check all electrical connections for wires which may have been become loose in shipping. Components burnt due to loose connection are NOT under warranty.

Check electrode plugs to ensure they are pressed firmly onto the electrode pins. Important: Loose connections will cause overheating of the cylinder plugs and probably melting of the plugs and/or cylinder.

Open the isolating gate valve in the feed water line to the unit.

Make sure the humidistat is et high enough to call for humidification.

Turn on the main disconnect in the primary service feeding the unit and check that unit has power at the primary terminal block.

Water will start to enter the cylinder through its bottom port and rise in the cylinder to a point determined by the solid state control circuitry.

It is not unusual upon initial start-up for the water to fill the cylinder an cycle on the red high water level indicator light.

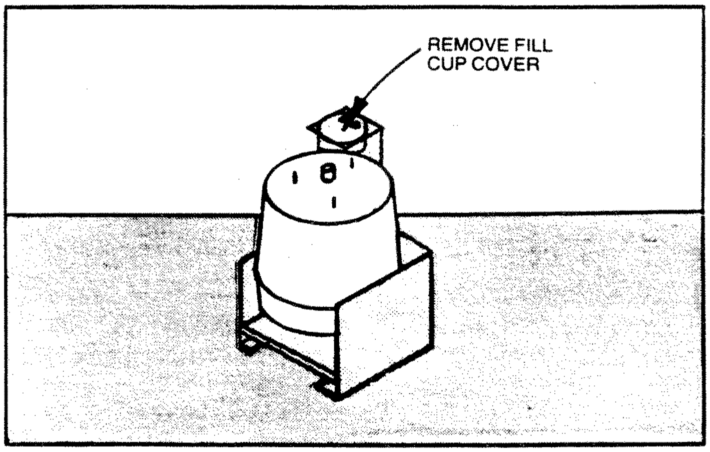
The red light simply acts as a safety to shut off the fill valve and prevent over fitting. With the red light on, the water in the cylinder will continue to heat an after a few minutes start to boil. After the boiling action of the water has lowered the water level go out and fill solenoid will again open until the cylinder is again full.

This cycling of the red light and fill valve will continue until the unit's full output capacity is reached after which the water level will automatically lower itself in the cylinder. (The increased concentration allows for lower electrode coverage while maintaining the same output). When a stabilized condition is reached the waster will be boiling close to the cylinder seam level. The solid state circuitry will maintain the proper concentration in the cylinder by introducing short drains only when necessary.

If the cylinder is manually drained, the above process will repeat itself.

LOW WATER CONDUCTIVITY

Should normalization of the unit be required immediately after start-up, the installer may speed up the process by artificially increasing water conductivity. The installer should dissolve half a teaspoon of table salt(no more) in a cup of water and add it to the cylinder by means of the fill cup attached to the plumbing section, during a fill cycle.

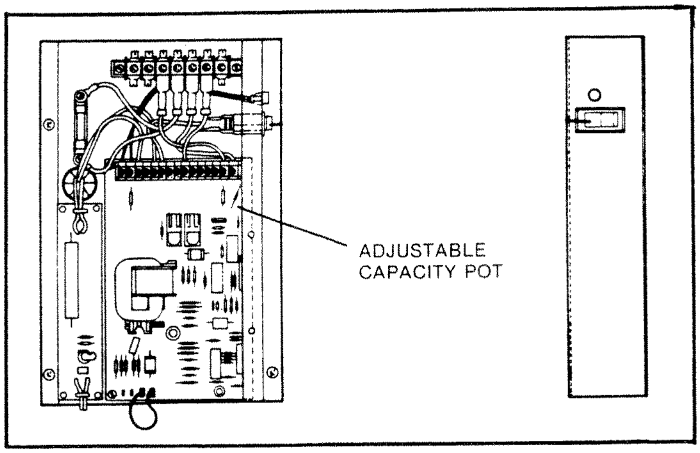


FILL CUP

To obtain access to this fill cup simply pry open the fill cup cover plate. (Do not displace the splash diverter underneath). Excessive amounts of salt will result in erratic operation of the unit; however, normalization of the unit will be corrected automatically through the solid state control sequence.

CAPACITY ADJUSTMENT

The M.E.S. series of humidifiers are factory set to cover most normal conditions. If an extreme situation is encountered notify the factory for instructions.



ADJUSTABLE POT

SERVICE AND MAINTENANCE INSTRUCTIONS

A. **Filters**

1) The filters should be checked and changed periodically. When they become dirty, an alarm is activated by the filter pressure switch. If the filters are dirty, they must be changed for efficient operation of your system. To check the alarm indicator, cover approximately 75% of the return air opening; the alarm should energize.

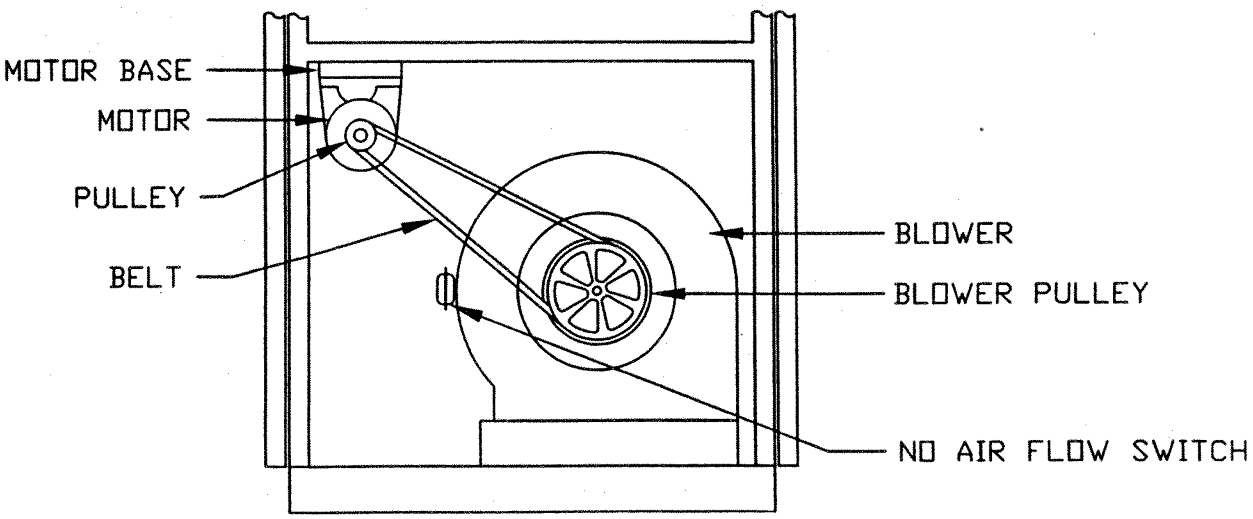
   If the alarm energizes prematurely or does not energize when it should, adjust the filter switch. All doors to machine should remain closed before determining whether an adjustment is necessary.

2) Spare filters should be kept in stock. Filters should be checked monthly and replaced if necessary.

B. **BLOWER DRIVE**

Easy access can be made to the drive set by opening the front right door. This gives a full view of the motor and the drive set.

Belt tension should be checked every month to assure proper, efficient operation. If tightening is needed, slightly loosen the four motor mounting bolts. Then turn the adjusting screw (located in the front of the motor mounting channel), until the belt is properly adjusted. RE-TIGHTEN THE FOUR MOUNTING BOLTS.

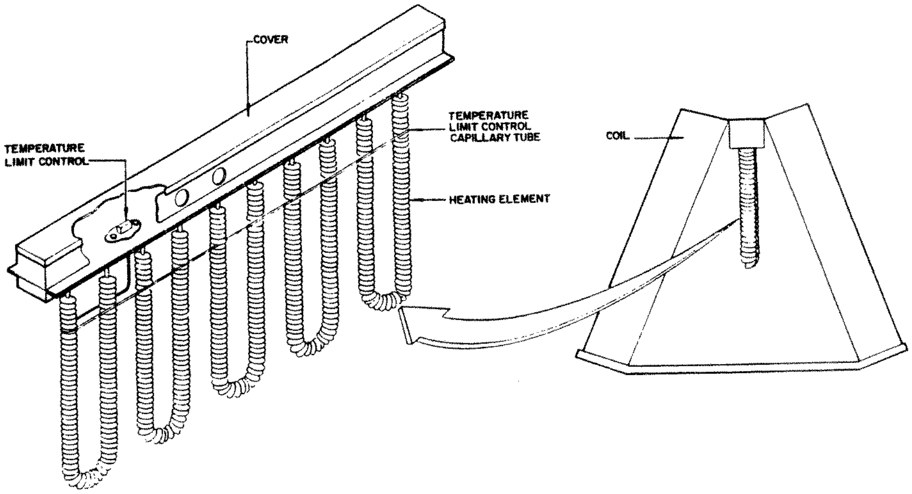


C. **BLOWER BEARINGS**

Blower bearings are permanently lubricated and do not require any maintenance. However, in special cases, some units have bearings that require lubrication at least every six months.

D. **HEATING ELEMENTS**

The heating elements are finned type, and there is no maintenance required. Access to the heater box can be obtained from the right hand side of the unit.



E. **HUMIDIFIER**

Four kinds of humidifiers are used in Compu-Aire Units: Electric Immersion, Infra-Red, Dry Steam, and Replaceable Generator.

1. **ELECTRIC IMMERSION**

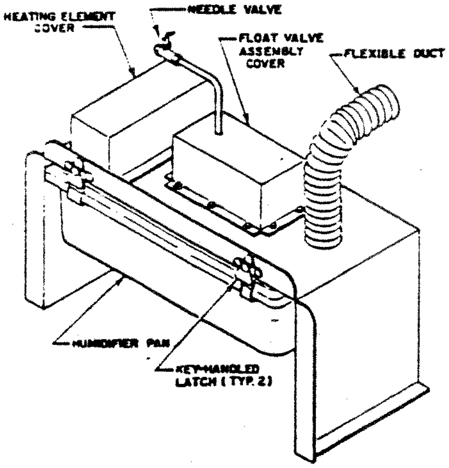
This type humidifier will probably require the most maintenance. If is necessary to thoroughly clean out the humidifier pan at regular intervals. The frequency for this depends entirely on the nature of the water used, and the frequency at which the humidifier is called into operation. To begin with, it is recommended that the humidifier be checked every two weeks. When excessive scale has formed in the lower pan and on the heating elements, it will be necessary to thoroughly clean this pan.

To inspect the humidifier, de-energizes the power to the unit at the disconnect switch. Open the left front access door. The humidifier is now fully exposed. Visually inspect the pan and the heating elements.

If cleaning of the humidifier is required, shut off the water supply at the valve located on the side of humidifier assembly. Disconnect the humidifier electrical plug, release the front pan latch, disconnect the auto flush hose(if used) and overflow drain connections. Remove the whole humidifier assembly to a nearby sink for thorough cleaning.

To remove the scale, sulfamic acid scale remover is recommended (check with your local supply house). Flush out all free scale, then add scale remover as noted by the manufacturer of the scale remover to the humidifier pan filled with water. Empty the pan and rinse. If necessary, repeat the de-scaling procedure until the pan is clean. NOTE: DO NOT EMPTY THE RESIDUE FROM EITHER OF THESE OPERATIONS INTO THE UNIT DRAIN SYSTEM. After cleaning, re-install the humidifier. Check to ensure that the drain valve is shut, push the humidifier assembly back into place firmly, engage the latch, re-connect the electrical plug and piping hoses, then open the water supply valve.

If the humidifier is equipped with automatic flush cycle, draining the humidifier can be accomplished by moving the lever on the flush valve to the manual position. Make sure that the lever is returned to the auto position when the cleaning operation is completed.

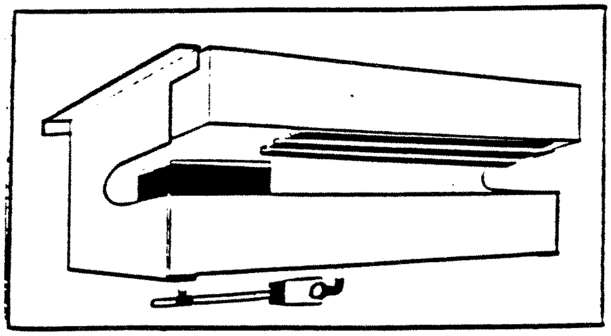


ELECTRIC IMMERSION HUMIDIFIER

2. INFRA-RED HUMIDIFIER

The inspection procedure for the infra-red humidifier is the same as for the Electric Immersion type described below. If cleaning is required, remove the humidifier assembly to a nearby sink for cleaning.

Clean the pan using the method described in 1 below, again, using care not to allow scale to clog the drain in the pan or the unit. Carefully clean the reflector and lamps of any scale or deposits. BEFORE REPLACING THE LAMPS, WIPE OFF ALL GREASE, OIL, ETC. WITH A CLEAN DRY CLOTH. ANY GREASE OR OIL MAY CAUSE A HOT SPOT AND LAMP FAILURE. REMEMBER LAMPS ARE NOT COVERED IN THE UNIT WARRANTY.



Infra-Red Humidifier

3. **DRY STEAM**

When units are equipped with dry steam type humidifiers, the necessary steam connections are made through additional connections.

a) The operation of a steam humidifier is explained below:

1) The steam supply is taken from the top of the steam main.

2) Steam passes through a strainer to prevent dirt or scale from reaching the humidifier.

3) Incoming steam strikes a baffle to divert any condensate to the drain.

4) Steam fills the body and cap castings. Casting temperature will approximate the steam temperature (approximately 240°F at 10 psig), preventing condensation and dripping at the outlet when the steam passes through at atmospheric pressure.

5) The humidistat actuates the operator to open the valve for humidity.

6) Steam enters the re-evaporating chamber through a tube. Any condensate droplets will fall and evaporate on contact with hot metal.

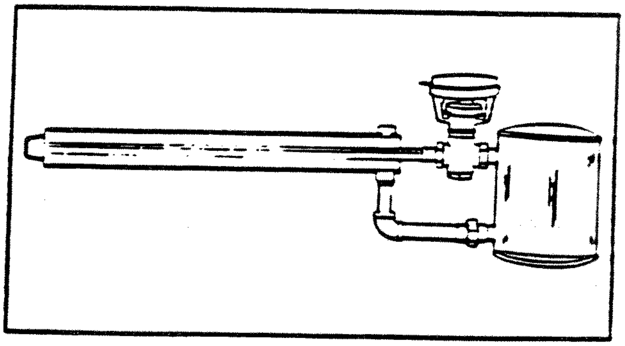
7) Dry steam passes up and out through muffling asbestos wicking on stainless steel.

8) The steam is discharged directly in the unit.

b. Maintenance of a dry steam humidifier is as follows:

1) Clean the strainer in the supply a few days after operation, and thereafter at least twice a year or as required.

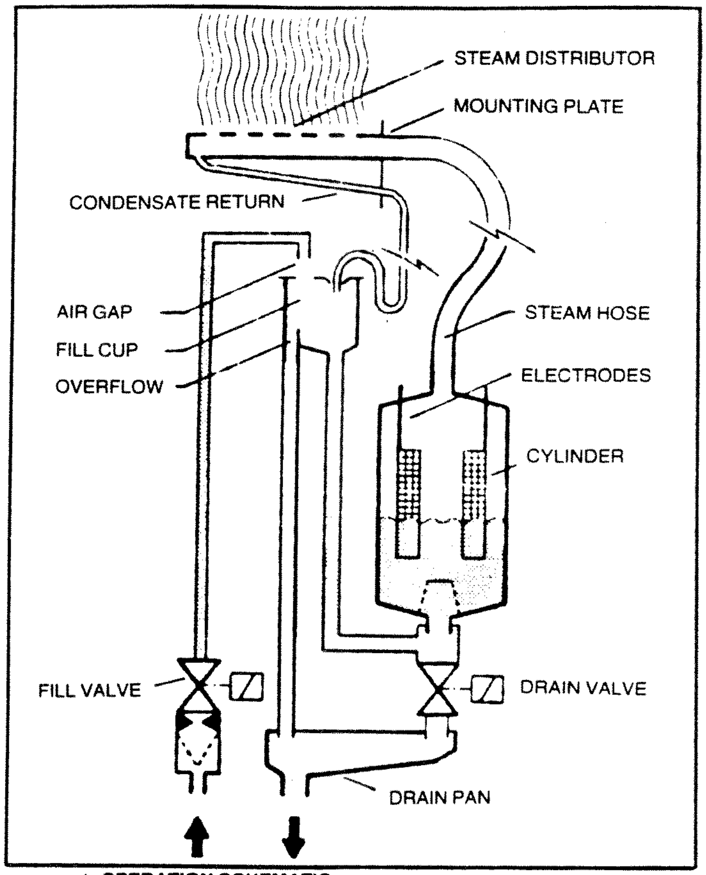
2) If the solenoid valve should stick, touch up the plunge with fine emery cloth and wipe out the plunger tube.



Steam Humidifier

4. Steam Generator Type Humidifier

PRINCIPLE OF OPERATION



OPERATION SCHEMATIC

When the humidistat calls, the cylinder fills to 110% of the Full Load Amperage (F.L.A.) or to the top of the cylinder, whichever comes first.

If it reaches 110% F.L.A. the water heats and boils away to a level giving only 90% F.L.A.

An electronic timer uses the rate of fall to determine the water level. The objective is to concentrate current-carrying minerals in the cylinder so that a smaller volume of water is required to produce the rated steam output.

This achieve the longest life for the disposable cylinder because of minimum electrode coverage and uses less energy because the high concentration allows minimal drain rate.

When it reaches 90% F.L.A. the fill valve comes on. The drain valve should only come on in addition if the water level is too low and a dilution is required. Otherwise this fill boil cycle continues until the water reaches an optimum low water level, always maintaining an average of 100% F.L.A.

If the water reaches top of cylinder before 110% F.L.A. the fill valve shuts off via the sensor and fill-boil-fill-boil cycle continues, cycling off the red full cylinder light until the concentration becomes high enough to reach 100% F.L.A. Then the following described control process takes over.

WATER SUPPLY AND PLUMBING

1) The orifice in the fill valve(s) is sized for an extended water pressure range of 30 to 85 psi.

2) For water pressure between 15 and 30 psi, notify the factory and the next larger size of fill valve will be supplied.

3) For cases below 15 psi, notify the factory and fill valve with largely oversized orifice will be supplied.

4) For cases above 85 psi, install a pressure reducing valve in the water feed line to the unit. Otherwise insufficient cylinder water will drain when fill and drain mix during the automatic dilution cycle.

5) With extremely dirty or muddy water sources, e.g. some well sources, ensure proper filtration by adding and external filter to the water line entering the unit. (Consult factory for accessories such as filters).

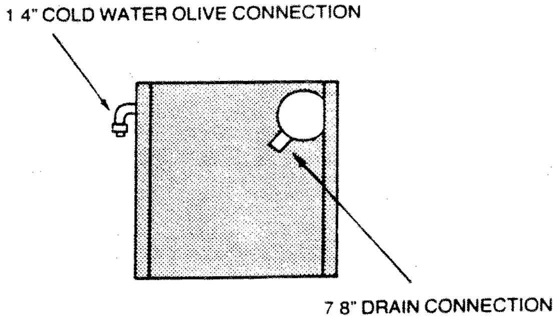
6) DO NOT soften water with Condair unit because it is much too conductive.

7) DO NOT use completely demineralized water with the Condair unit as it is the minerals that allow the electrode principle to work.

8) DO NOT use a hot water source as it will cause deposits to eventually block the fill valve orifice.

Water Connection

1) A copper compression olive type coupling for 1/4" soft copper tubing is provided with unit and requires no soldering for the water connection to the unit.



2) An isolating gate valve should ALWAYS be placed in feed water line allowing service of the fill valve.

3) Each unit is fitted with a fill solenoid valve located on the base drain pan. Flow orifices ar designed for water pressures from 30-85 psi and are protected by the built-in strainer.

4) For inlet water pressure outside this range, the factory should be contacted. (See also water supply section)

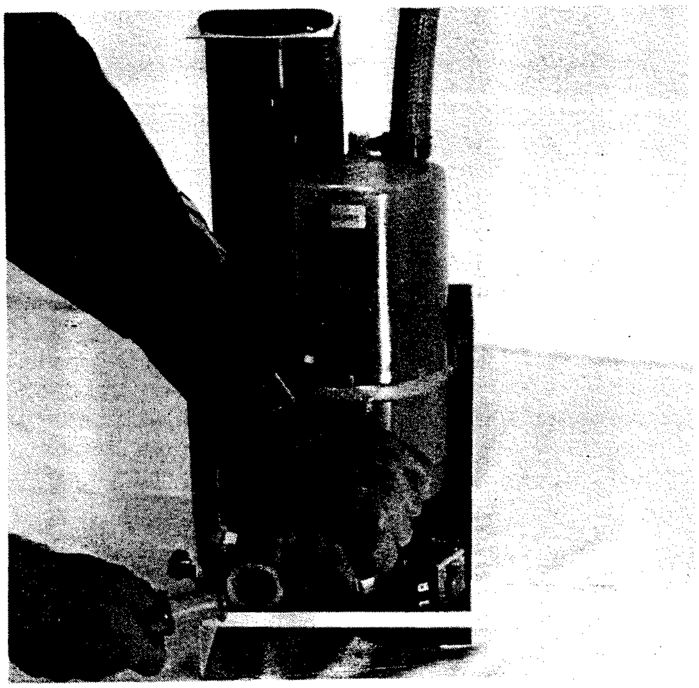
The Inlet Water Strainer

The fill solenoid is equipped with a built-in serviceable strainer to prevent foreign particles, such as sand or solder from blocking the fill orifice.

1) To clean the strainer, first turn off the unit, close the gate valve on the water supply line, remove the locking bar located in the fill solenoid and slide out the strainer.

2) Rinse the strainer and back flush it thoroughly with tap water to ensure the removal of all debris.

3) To re-install strainer, reverse procedure.



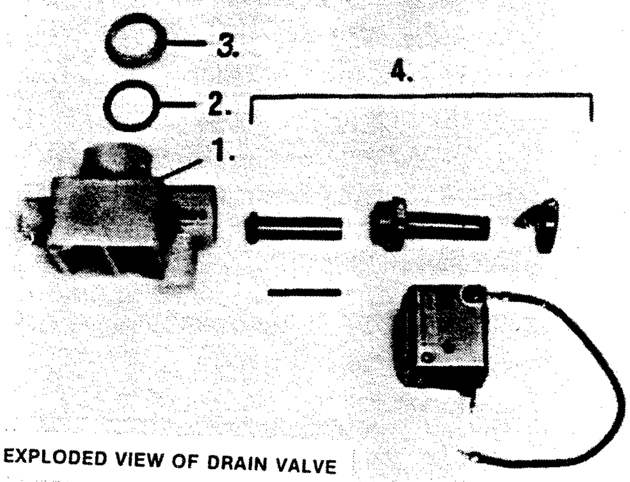
STRAINER

Drain Connection

1) Unit is equipped with a 7/8" O.D. unthreaded drain outlet on the underside of the base drain pan. Cut a few inches of steam supply hose, available from the factory, and connect from drain outlet to 3/4" nominal diameter copper pipe and route to closest (floor) drain.

2) Where municipalities, counties or cities require an air gap to isolate unit from sanitary drainage system, a funnel drain under the unit should be incorporated.

3) Drain canal on bottom of unit must be removed and cleaned at least once a year. Ensure that rubber gasket is re-installed properly.



EXPLODED VIEW OF DRAIN VALVE

ITEM NO.	DESCRIPTION	NORTEC P/N
1	VALVE BODY (Small)	132-4042
1	VALVE BODY (Large)	132-4041
2	O-RING	132-5014
3	STUFFING BLOCK	132-1042
4	COIL ASSEMBLY COMPLETE	132-6002

4) Drain valve must be disassembled and cleaned each time a cylinder is replaced. (These three components, i.e. drain canal, drain valve and cylinder are continually exposed to concentrated mineral water.

REPLACEMENT OF THE STEAM CYLINDER

Consult factory or agent for replacement. Quote the cylinder model form the white 3-digit label on the cylinder or quote model, voltage and serial number from unit specification label.

After an extended period of operation in accordance with life expectancy information, see Figure 24, the cylinder is completely used as indicated by a red light illuminated on the face of the cabinet. When this condition is reached, a new replacement cylinder is to be installed.

NOTE: Red light may come on during initial start-up but does not mean cylinder replacement.

Any time that the unit is going to be shut down for an extended period of time, including summer shutdown, ALWAYS drain down the cylinder before disconnecting power. Otherwise, the electrodes are subject to harmful corrosion.

REMOVING THE CYLINDER

1) Turn off the water supply to the unit.

2) The old cylinder must be drained completely before removing. This is done by pushing the auto on/off drain switch to the "drain" position.

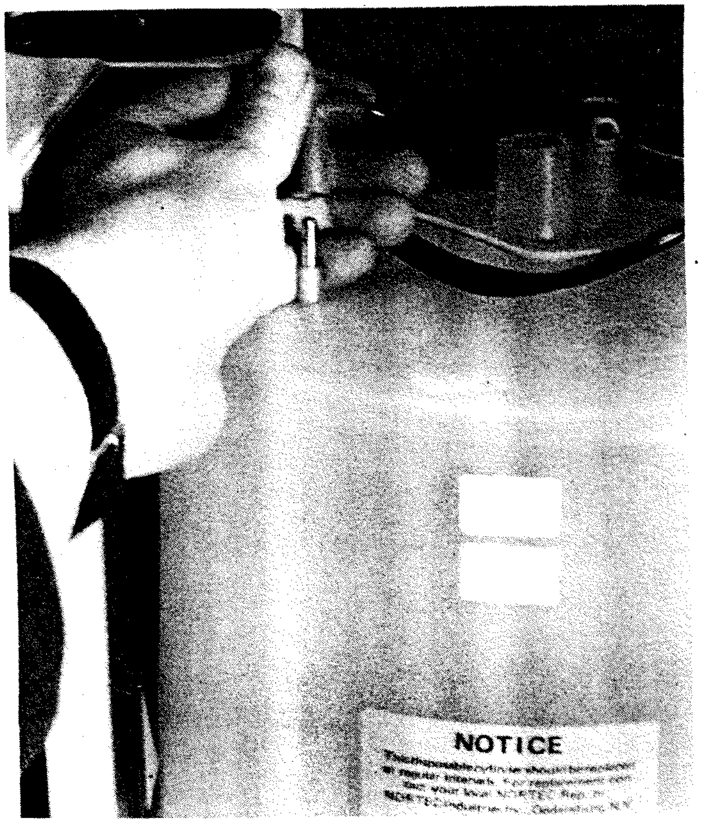
3) When completely drained, push the auto/on/off drain switch to the "off" position.

4) Open the main disconnect during the entire cylinder change operation.

5) The power wires to the cylinder are attached by cylinder plugs to the electrode pins on top of the cylinder. Pull these plugs vertically off the pins.

6) Using slot screw driver, loosen the steam hose clamp(s) and pull steam hose off vertically.

7) The cylinder is now ready to be lifted out of the unit.



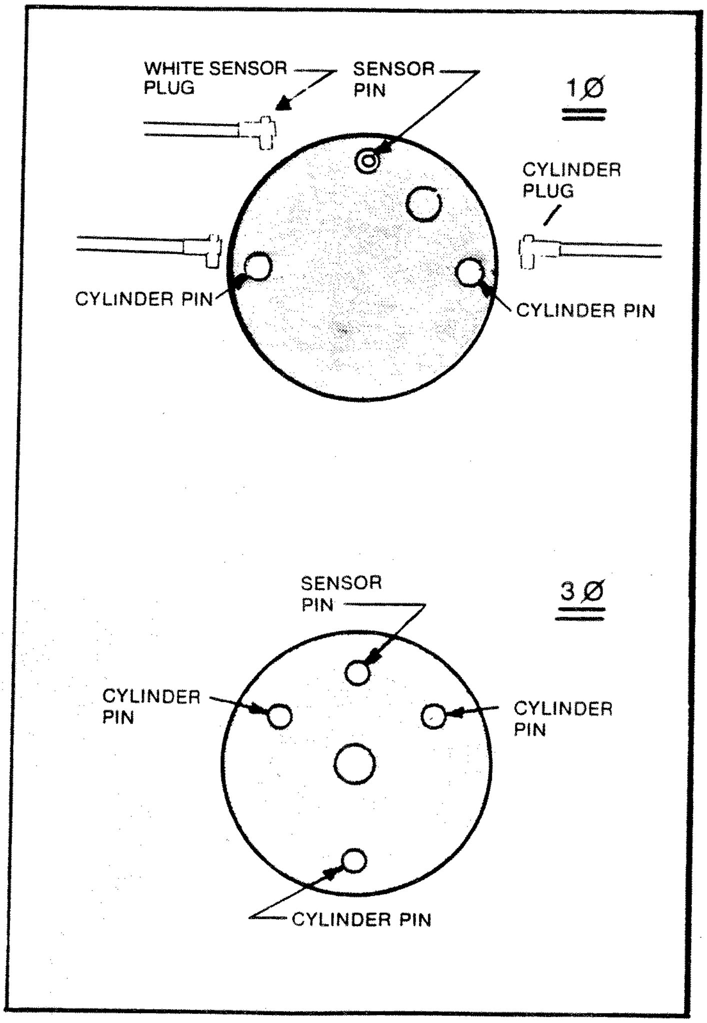
CYLINDER REMOVAL

INSTALLING THE NEW CYLINDER

1) The reverse procedure should be followed to install a new cylinder. The main disconnect is to be left open until the cylinder is completely installed an reconnected.

2) Ensure that the cylinder mounting stubs are seated properly in the allotted side mounting slots within the unit.

3) The white cylinder plug on all units is for the sensor electrode which always goes on the single pin offset from the others.



PLUGS

4) Ensure that cylinder plugs are very snug on the pins.

5) For loose fitting plugs, squeeze with a pliers before installing, since loose plugs may generate enough heat to melt and destroy the plug and cylinder.

TROUBLE-SHOOTING

Auto on/off/drain switch in "on" position-unit will not fill:

When the on/off control circuit is made and the "auto on/off/drain" switch is pushed to "on", the 24 volt holding coil of the primary contactor should energize. The resulting magnetic pull closes the high voltage contacts with a distinct and audible "clunk". If the contactor will not make, then inspect the following while referring to the wiring diagram.

1) Check for 24VAC across pins 33 and 39.
2) Jumper contacts 1 & 2 on external control terminal strip. If contactor operates then control system is at fault.
3) The low voltage 3 amp fuse located on front of the unit.
4) The "on/off" jumper plug connection on the basic unit.
5) The wire ribbon connecting the basic unit to the current transformer board.
6) The contactor holding coil could be open of shorted.

Recheck that the "auto/on/off drain" switch is still at "on". if it is, then shut off the main disconnect and check fuses or breaker of the main disconnect. If they are serviceable, turn power back on.

To test for a defective "auto/on/off drain" switch, disconnect the red wire from pin 38 on the main p.c. board(basic unit) and touch it to pin 39. If the contactor activates, the "on" side of the switch is defective. If the contactor does not activate, then the basic unit p.c. board could be defective.

If the 3 amp control fuse blows when the red wire form pin 38 is touched to pin 39, contactor holding coil could be shorted. After contactor has been replaced and contactor still will not activate then the basic unit "on/off" jumper circuit could be burnt. This can be temporarily bypassed by placing a jumper between terminals 35 and 39 until replacement of the basic unit. Return the red wire to pin 38.

After the necessary components have been replaced and the contactors pull in, there is high voltage to the cylinder(s) and the control sequence can begin.

Approximately 30 seconds after the contactor pulls in, the fill valve coil should energize. There is also a visible fill relay on the basic printed circuit board. It is physically located in line with pin 36. The points on this relay must be touching in order for the fill valve could be energized.

If the points will not touch after the built-in time delay, then the sensor input may be interfering. To confirm, remove the red and black wire sensor input from the male connector on the basic p.c. board. (It is located 1/2" from the right hand side of the board.) wait 30 seconds and if the fill relay point now touch, then sensor should be replaced. If they do not touch, then the basic p.c. board could be faulty. To confirm, disconnect the red wire from pin 38 and touch it to pin 36. If the fill valve coil activates then the basic p.c. board should be replaced. If it still does not activate then the fill valve coil should be replaced.

Having changed the necessary components, water starts filling the cylinder and begins to submerge the electrodes. Because of the high voltage across the electrodes, the water can now conduct electricity.

red Light on- Water at top of cylinder:

- Common occurrence on start-up - See previous pages
- Water level should be at the top of the cylinder - if cylinder is new this is normal
- if cylinder is old, it indicates replacement time (can be ordered from factory

red light on - water NOT at top of cylinder:

- water foaming to top of cylinder to activate red light, also may be accompanied by arcing(flashing)inside cylinder
- indicates abnormal water condition(softened) or over concentration of contained water in the cylinder caused by:

1) Blocked water filter(clean)
2) Inoperative fill valve(check)
3) Inoperative drain valve(check)
4) Blocked drain valve(disassemble and clean)
5) Blocked screen at bottom of cylinder(remove and back flush)
6) Faulty sensor really (remove sensor concentration from p.c. board and wait 60 seconds)
7) White sensor plug interchanged with power plug at top of cylinder(white plug should be on terminal offset from the others).

Water remains at high level and won't concentrate:

- normal on cold start-up, can be accelerated by adding maximum 1 tsp. of salt to the cylinder(thorough the plastic fill cup on fill cycle.
- if the unit has been operating extensively, observe for normal fill, boil, fill, boil, cycle; no drain should be occurring.

Water beyond top of cylinder up into spout:

- red light not on and fill still activated; jump across connection of sensor on basic unit p.c. board, if fill shuts off, then sensor was faulty.
- if fill remains on when connection is jumped, then basic unit is faulty.
- consult factory for new part and replacement instructions.

Unit drains continually:

- if cylinder almost empty check for magnetic pull on drain solenoid indicating miswiring. If no pull drain actuator is blocked open, remove, disassemble and clean.
- if drain is occurring thorough activated drain valve, valve id miswired or electronics is faulty-consult factory.
- if drain is occurring through the overflow on the fill cup, this is due to an abnormal restriction on the steam line and back pressure forces water out of the cylinder; therefore water cannot concentrate and level must stay high; review installation of steam line to ensure no blockages or excessive static pressure in air system.

To make service simpler and to check on its normal electronic functions, an optional solid state plug-in check adapter is available from the factory at cost by ordering BMF-9513.

SPARE PARTS LIST
SYSTEM 2000
CHILLED WATER MODELS

PART NUMBER	DESCRIPTION	103*		123*		153*		203*		253*		303*	
		2	4	2	4	2	4	2	4	2	4	2	4
202-020-052	3HP MOTOR 182T	1	1	1	1	1	1	-	-	-	-	-	-
202-050-062	5HP MOTOR 184T	-	-	-	-	-	-	1	1	-	-	-	-
202-075-062	7.5 HP MOTOR 184T	-	-	-	-	-	-	-	-	1	1	1	1
279-060-094	BLOWER PULLEY 2AK-94	-	-	1	1	-	-	-	-	-	-	-	-
279-060-084	BLOWER PULLEY 2AK-84	1	1	-	-	1	1	-	-	-	-	1	1
279-060-074	BLOWER PULLEY 2AK-74	-	-	1	1	-	-	1	1	1	1	-	-
279-040-003	MOTOR PULLEY 2VP-50	1	1	1	1	1	1	1	1	1	1	-	-
279-068-001	MOTOR PULLEY 2VP-68	-	-	-	-	-	-	-	-	-	-	1	1
278-010-048	BELT A-48	2	2	2	2	2	2	-	-	-	-	2	2
278-010-045	BELT A-45	-	-	-	-	-	-	2	2	2	2	-	-
294-010-100	BEARING 1"	2	2	2	2	2	2	3	3	3	3	3	3
273-001-024	SHAFT 1" X 24"	1	1	1	1	1	1	-	-	-	-	-	-
273-001-055	SHAFT 1" X 55"	-	-	-	-	-	-	1	1	1	1	1	1
222-041-008	WATER VLV 1"	1	1	1	1	-	-	-	-	-	-	-	-
222-041-009	WATER VLV 1 1/4	-	-	-	-	1	1	-	-	-	-	-	-
222-042-010	WATER VLV VB-9313-000-11 OPERATOR MS-830-13	-	-	-	-	-	-	1	1	1	1	1	1
253-025-001	NO AIR FLOW & CLOGGED FILTER SWITCH	2	2	2	2	2	2	2	2	2	2	2	2
251-001-102	HUMIDIFIER CYLINDER #202	1	-	1	-	-	-	-	-	-	-	-	-
251-001-104	HUMIDIFIER CYLINDER #204	-	1	-	1	-	1	-	-	-	-	-	-
251-001-202	HUMIDIFIER CYLINDER #303	-	-	-	-	-	-	1	-	-	-	-	-

SPARE PARTS LIST
SYSTEM 2000
CHILLED WATER MODELS

PART NUMBER	DESCRIPTION	103* 2	103* 4	123* 2	123* 4	153* 2	153* 4	203* 2	203* 4	253* 2	253* 4	303* 2	303* 4
251-001-204	HUMIDIFIER CYLINDER #311	-	-	-	-	-	-	-	1	-	-	-	-
251-001-402	HUMIDIFIER CYLINDER #403	-	-	-	-	-	-	-	-	1	-	1	-
251-001-404	HUMIDIFIER CYLINDER #411	-	-	-	-	-	-	-	-	-	1	-	1
251-010-009	HTG. ELEMENT 2KW 220V	6	-	-	-	-	-	-	-	-	-	-	-
251-010-002	HTG. ELEMENT 2KW 277V	-	6	-	-	-	-	-	-	-	-	-	-
251-010-010	HTG. ELEMENT 2.5KW 220V	-	-	6	-	6	-	9	-	12	-	12	-
251-010-005	HTG. ELEMENT 2.5KW 277V	-	-	-	6	-	6	-	9	-	12	-	12
256-010-003	THERMODISC	2	2	2	2	2	2	3	3	4	4	4	4
259-010-001	FUSIBLE LINK	4	4	4	4	4	4	6	6	8	8	8	8
249-010-030	CONTACTOR 25A	4	4	4	4	4	4	5	5	6	6	6	6
240-030-020	FUSE 20A 208V	12	-	2	-	-	2	-	-				
240-031-010	FUSE 10A 460V	-	12	-	2	-	2	-	-	-	-	-	-
240-030-025	FUSE 25A 208V	-	-	9	-	9	-	12	-	12	-	12	-
240-031-015	FUSE 15A 460V	-	-	-	9	-	9	-	12	-	12	-	12
240-030-030	FUSE 30A 208V	-	-	-	-	-	-	3	-	6	-	6	-
240-031-020	FUSE 20A 460V	-	-	-	-	-	-	-	3	-	6	-	6
268-020-002	TRANSFORMER 208V/24V	2	-	2	-	2	-	3	-	3	-	3	-
268-050-002	TRANSFORMER 460V/24V	-	2	-	2	-	2	-	3	-	3	-	3
270-018-012	18 X 13 BLOWER WHEEL	1	1	1	1	1	1	-	-	-	-	-	-
271-015-015	15 X 15 BLOWER WHEEL	-	-	-	-	-	-	2	2	2	2	-	-
298-100-011	MICROPROCESSOR 2000	1	1	1	1	1	1	1	1	1	1	1	1
298-100-013	SENSOR BOARD	1	1	1	1	1	1	1	1	1	1	1	1

F. WARRANTY

Now that all start up tests have been completed, the warranty card attached to the unit MUST be completed and returned to Compu-Aire so that the unit warranty can be made effective.

STANDARD ONE YEAR WARRANTY

We warrant this Compu-Aire, Inc. computer room unit to be free from defects in material and workmanship; our obligation being limited to repairing or replacing at our factory any part (except as noted below) within one year from the date of start-up and not exceeding ________ months from the date of shipment to the original purchaser. Parts to be returned to us PREPAID.

This warranty is effective only if the unit has been installed in accordance with our instructions and connected to proper and adequate electric, water and drain services, correctly dehydrated and placed into operation by a competent service representative.

Fan motor warranty is covered by original manufacturer's warranty and any repair or replacement should be made by the local authorized service facility as listed in the telephone book.

Maintenance and service such as replacing filters, belts, cleaning, lubrication, calibration and adjusting are NOT INCLUDED in this warranty.

Replacement or repair parts shall be shipped from the factory prepaid and invoiced for the full amount. Upon receipt of warranted parts and which our inspection discloses the parts are defective, and show no signs of misuse, alterations, or abuse, full credit will be issued.

Compu-Aire, Inc. does not assume any responsibility for labor expense for changing defective parts or replacement of any refrigerant or other cooling medium such as glycol etc.

All parts and goods are thoroughly inspected and packed to meet the requirements of railroad freight classifications bureaus, and under standard shippers risk, when they leave our factory. SHOULD GOODS ARRIVE DAMAGED, call the agents attention to damage and have same noted on freight bill. For concealed damage, demand immediate inspection from agent of the shipping company and insist on a notation being made on freight bill.

EXTENDED 4-YEAR WARRANTY

EXTENDED 4-YEAR WARRANTY ON COMPRESSORS ONLY- During the second through fifth years after the start of the ONE-YEAR WARRANTY, COMPU-AIRE further warrants the compressors against defects in material or workmanship under normal use and maintenace. A new or remanufactured compressor at COMPU-AIRE sole option, will be provided under the same conditions as stated in the ONE-YEAR WARRANTY.

VOID

THIS WARRANTY DOES NOT INCLUDE LABOR OR OTHER COSTS incurred for diagnosing, repairing, removing, installing, shipping, servicing or handling of either defective parts or replacement parts or complete unit. Such costs may be covered by a separate warranty provided by the installer.

VOID

Purchaser-User ____________________

Model Number ____________________ Serial Number ____________________

Expiration Date ____________________

COMPU-AIRE INC.

8167 BYRON ROAD
WHITTIER, CA 90606
(562) 945-8971

THREE-WAY VALVES

For many years, three-way mixing* valves and three-way diverting* valves have been commonly used for controlling temperature and flow, or both, in the water circuits of heating and air conditioning systems. Despite this, there is still wide-spread confusion and conflicting opinion regarding their proper application. This is principally due to a lack of information on how and why three-way mixing and diverting valves differ from each other and how each type may be used to its best advantage.

WHY THREE-WAY VALVES ARE USED: (The order of presentation below is random and in no way implies priority of importance or frequency of use.)

A. To maintain constant flow (and therefore constant pumping head) in a supply system with a heat exchanger (such as a water chiller or boiler), while controlling the output of zone heat exchangers. As water flow is throttled to the zone heat exchanger by a three-way valve, more supply water is by-passed to the return, thereby maintaining a nearly constant flow (and pumping head) in the supply system. See Fig. 1.

B. To maintain constant water flow in a zone heat exchanger while controlling its heat output. In this case, a secondary pump is required for each zone heat exchanger. The three-way valve varies the amount of return water recirculated from the zone heat exchanger in relation to the amount of supply water delivered to the exchanger from the primary circuit. Thus, heat output is individually controlled by varying the temperature of the exchanger supply water, rather than the water flow rate. See Fig. 2.

C. To maintain constant supply water flow and temperature to a refrigeration condensing-unit heat exchanger. Cool water, from a cooling tower or other source, is mixed with return water from the condenser, as needed, to maintain desired inlet water temperature. Flow remains relatively constant. See Fig. 3.

* Defined shortly

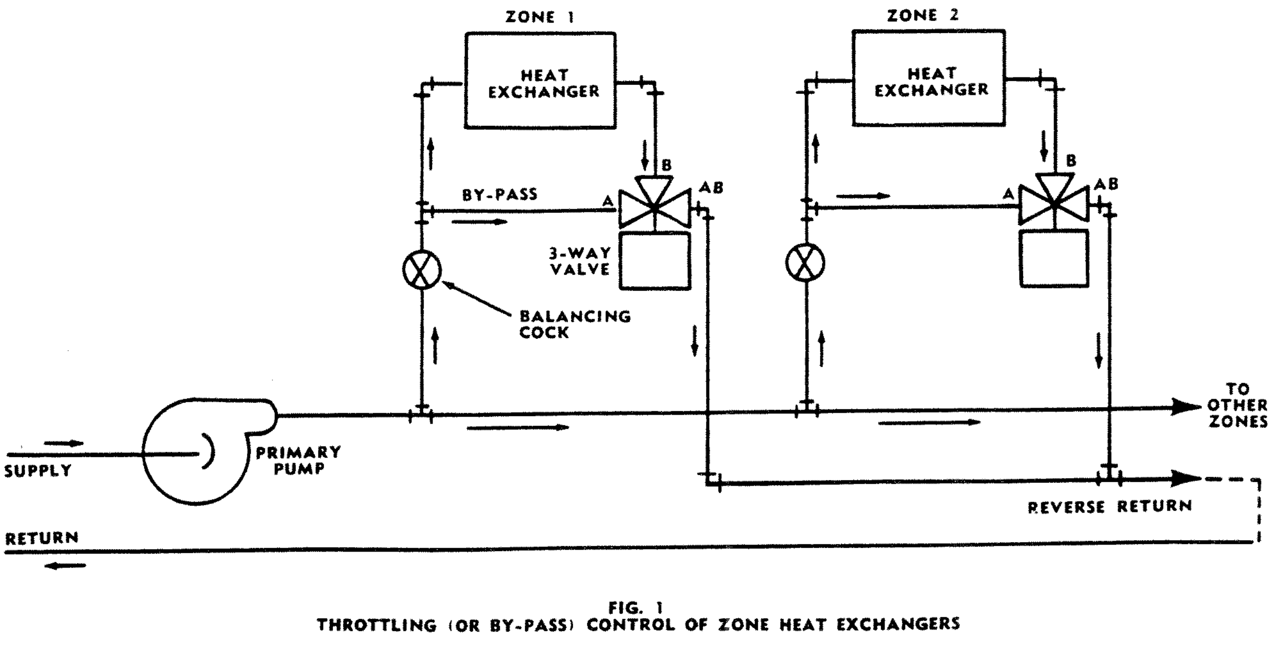


FIG. 1
THROTTLING (OR BY-PASS) CONTROL OF ZONE HEAT EXCHANGERS

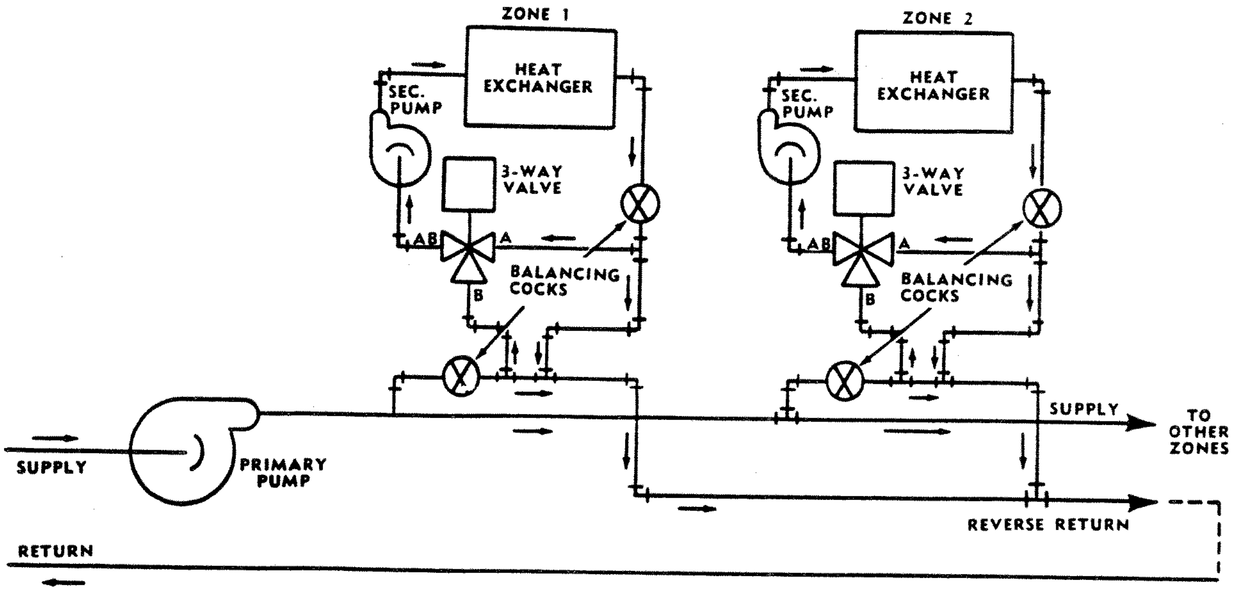


FIG. 2
CONSTANT FLOW — VARIABLE TEMPERATURE CONTROL OF ZONE HEAT EXCHANGERS WITH SECONDARY PUMPS

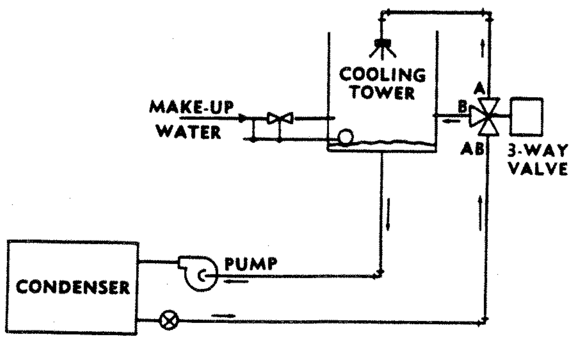


FIG. 3
CONSTANT FLOW — CONSTANT TEMPERATURE CONTROL OF CONDENSER COOLING WATER

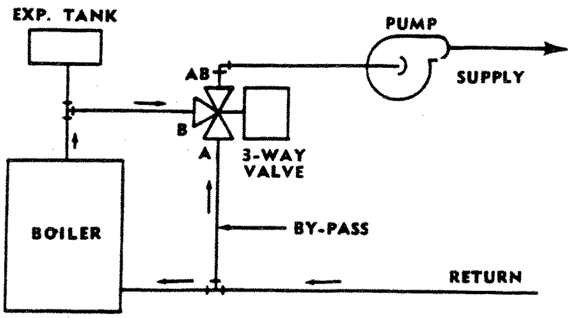


FIG. 4
CONSTANT FLOW — VARIABLE TEMPERATURE CONTROL OF HOT WATER SUPPLY

D. To vary the temperature of primary or zone supply water where the main heat exchanger, such as a boiler, delivers water at a constant temperature. Return water from the system or zone is mixed with water from the main exchanger to obtain the desired supply water temperature. This supply water temperature is often reset from outdoor temperature. See Fig. 4.

E. To provide for changeover of year-around air conditioning systems from hot water supply to chilled water supply.

1. When two-pipe distribution systems are used, the entire system or pumping zone is changed over from heating to cooling (or from cooling to heating) at the same time. A two-position three-way changeover valve with a very slow-acting actuator (15 to 30 minutes) is often used to allow automatic changeover without overloading the chiller, or "shocking" the boiler with too cold return water. Use of a changeover valve with a long timing allows gradual cool-down or warm-up of the distribution system. See Fig. 5A.
2. On four-pipe distribution systems, two three-way valves may be used to obtain year-around control of a zone heat exchanger with two-position control on both heating and cooling cycles (refer to Fig. 5B), or one two-position three-way changeover valve may be used to connect the zone exchanger with the proper return while the supply control valves furnish hot or chilled water as required (refer to Fig. 5C).

FIG. 5A
CHANGEOVER APPLICATION — 2-PIPE DISTRIBUTION SYSTEMS

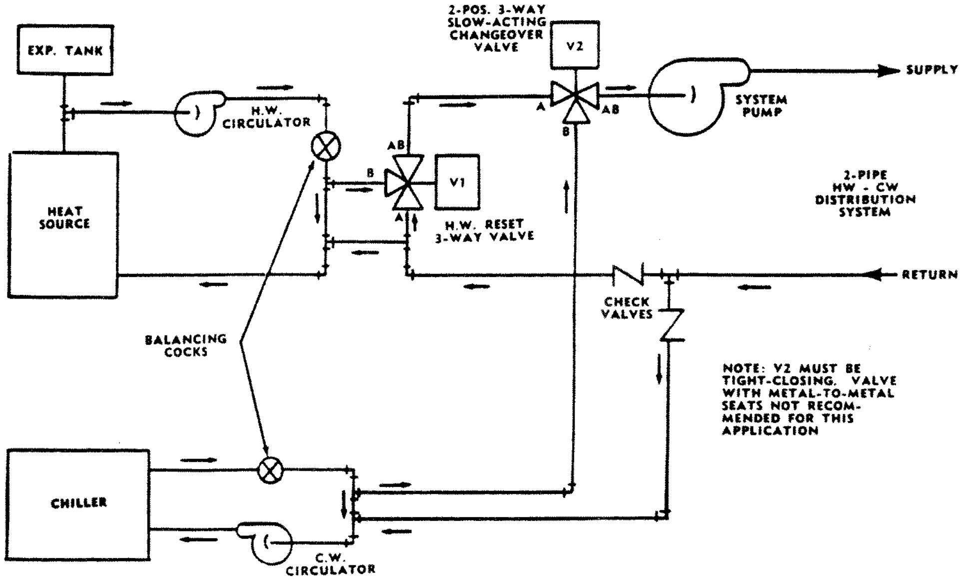


FIG. 5B
TWO-POSITION ZONE CONTROL WITH CHANGEOVER — 4-PIPE DISTRIBUTION SYSTEMS

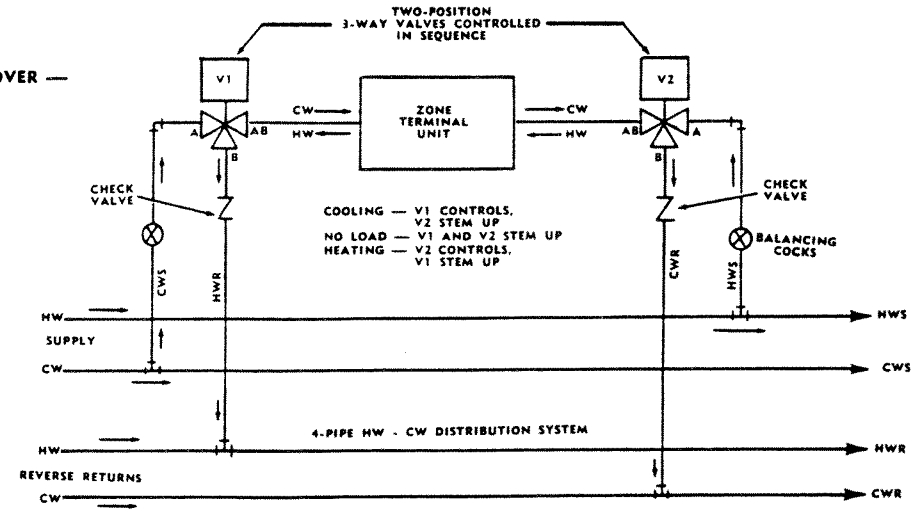
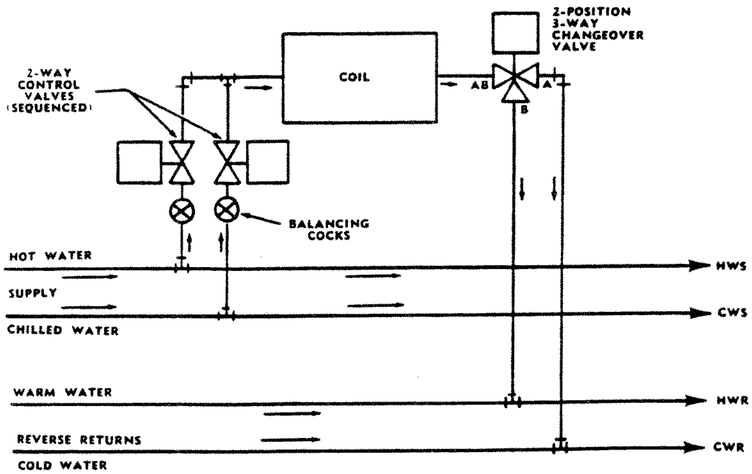


FIG. 5C
PROPORTIONAL ZONE CONTROL WITH CHANGEOVER— 4-PIPE DISTRIBUTION SYSTEMS



TERMINOLOGY

Although a three-way valve is generally thought of as any valve having three pipe or tubing connections, there are actually two distinctly different types as stated previously. The ASHRAE GUIDE AND DATA BOOK, FUNDAMENTALS AND EQUIPMENT, defines these as MIXING VALVES and DIVERTING VALVES. The difference is in the internal construction of the valve bodies themselves, and it is this internal construction which determines how the valve must be piped, regardless of the application.

MIXING VALVE DEFINED

Of the two types, three-way **mixing** valves are more commonly used in the heating and air conditioning field. This valve can be considered as an adaptation of a two-way, single-seated valve body. See Fig. 6. A second seat is added in the body and the throttling plug is modified to provide the upper seating surface. Some three-way valves are actually made from two-way body castings by this method.

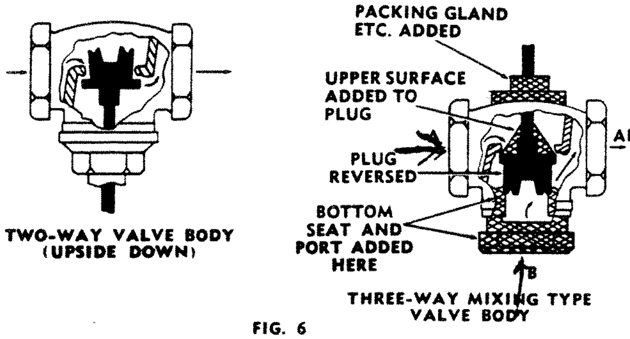


FIG. 6

This type of three-way valve must be used only for mixing service. That is, the two individual ports A and B are inlets and flow must enter either or both ports, leaving through the common port AB. Direction of flow must be such that the valve plug closes **against** the force created by fluid flow through the valve. It is also good practice to pipe two-way valves such that the actuator works against the force developed by fluid flowing through the valve. This assists in obtaining good flow control, even at low flow rates when the valve plug is positioned near the seat.

If a three-way mixing type valve were piped for diverting service, that is, with flow entering the common port AB and leaving individual ports A and B, valve plug chatter or instability would usually result. When the plug is positioned toward either seat, force created by the velocity pressure of the fluid flowing through the port will tend to slam the plug down against the seat. See Fig. 7. When the plug closes the port completely, the velocity pressure will drop to zero (since there is no flow) and the plug will tend to back off the seat. This results in instability and chatter. This situation is further aggravated by the clearances and tolerances necessarily found in all linkages connecting the valve plug to the control actuator that positions it.

DIVERTING VALVE DEFINED

The three-way **diverting** valve is often described as a modification of a double-seated two-way valve. See Fig. 8. A port is added to the bottom of the valve and a section is added to isolate this port from the side outlet. The plug on this bottom port is then reversed so that it approaches the seat from the outlet side. Now, when the diverting valve is correctly piped, the direction of movement of the throttling plugs approaching either seat will be opposite the velocity force developed by the fluid flow through that port. Smooth control of fluid flow results even at low flow rates, without instability or plug chatter.

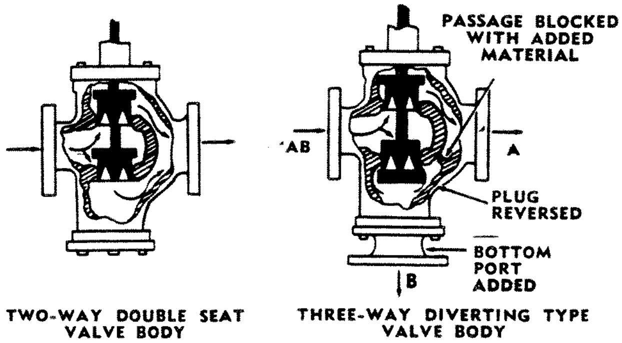


FIG. 8

Here again, if this type of valve body were incorrectly piped for mixing service, the velocity force would be in the same direction as plug movement; plug chatter and instability would likely result. See Fig. 9. This action can be compared to that of attempting to hold a rubber stopper just above a bathtub drain as water is flowing out. It takes little effort to hold the stopper some distance away from the drain hole. However, as the stopper is moved closer to the drain, approaching the seal-off point, the velocity pressure of the water going down the drain will tend to slam the stopper into the seat. As soon as the drain is completely closed, the velocity force is gone, and the stopper can be removed with less force than would have been required to prevent it from slamming against the seat. A cycle which repeats itself can easily develop in this situation, and could be directly compared to plug chatter in modulating three-way valves piped incorrectly.

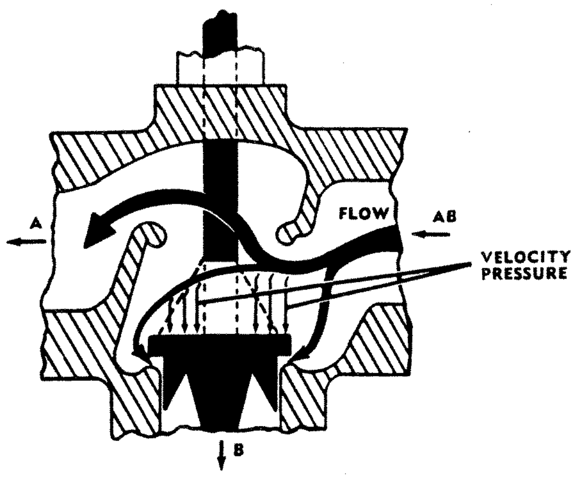


FIG. 7
MIXING TYPE THREE-WAY VALVE
(PIPED INCORRECTLY FOR DIVERTING SERVICE)

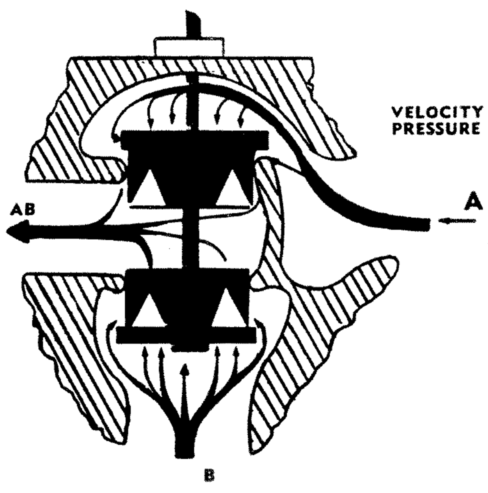


FIG. 9
THREE-WAY DIVERTING TYPE VALVE
(PIPED INCORRECTLY FOR MIXING SERVICE)

TERMINOLOGY

The terms "mixing service" and "diverting service" as used here refer only to the direction of fluid flow through the valve body, and do not refer to the application of the valve in the system. For instance, the application described in Fig. 1 is often referred to as a "diverting" application of a three-way valve because, as the valve modulates, a portion of the supply water is diverted around the coil. Actually, the use of the word diverting in this instance is misleading, because the valve itself can be piped either for mixing service (Fig. 10A) or diverting service (Fig. 10B). A better word to describe this situation would be a "by-pass" application of a three-way valve. Naturally, the piping method chosen will depend on what type of valve body is specified. Normally, a mixing type body piped as shown in Fig. 10A would be preferred for this application.

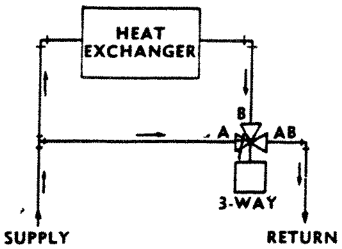


FIG. 10A
THREE-WAY MIXING VALVE ON "BY-PASS" APPLICATION

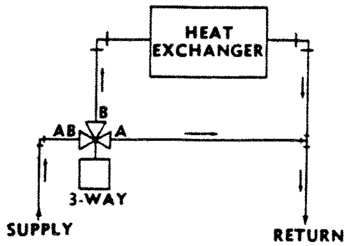


FIG. 10B
THREE-WAY DIVERTING VALVE ON "BY-PASS" APPLICATION

TWO-POSITION VALVES

The previous discussion on the internal construction of three-way valves for mixing and diverting service applies primarily to modulating valves. Where three-way valves are used with two-position actuators, the internal construction is not quite so important. For instance, if a mixing type valve were used piped for one inlet and two outlets (diverting), the plug would still tend to slam against the seat at each end of the actuator stroke. But as the actuator does not stop at any intermediate position, plug chatter normally will not be a problem in smaller valves. In general, no trouble would be expected if a mixing type three-way valve body were used on a **two-position** diverting application in sizes 2" or smaller. However, mixing type three-way bodies should not be used on two-position diverting applications in sizes over 2", particularly if the valve is to be used at or near its maximum close-off pressure rating.

PRESSURE RATINGS DESCRIBED

Another area of some confusion has been the static and close-off or differential pressure ratings required when using three-way valves.

First, the type of piping system—closed or open loop—will influence the requirements.

Closed loop systems for this discussion are defined as those in which the piping system is not open to atmosphere at any point (except for venting), and a static fill pressure above atmospheric pressure is maintained in the piping circuit.

Open loop systems are defined as those where the piping system is open to atmosphere at some point, such as normally found in cooling tower applications.

Other considerations, such as the location of the valves with respect to the pump, will also influence the ratings required. Typical applications can be broken down into four general categories with their basic requirements as follows:

I. CONSTANT FLOW IN PRIMARY CIRCUIT — CLOSED LOOP

Typical applications where the three-way valves are piped for constant flow in the primary pumping circuit include A and D (Figs. 1 and 4) described previously. Operating requirements are as follows:

Static Pressure Rating: Must be equivalent to, or greater than, the static or "fill" pressure in the system. If the valve is located downstream from the primary pump (as in Applications A and B) the static pressure rating must be greater than the sum of static pressure plus pumping head pressure at that point in the system. Pump head pressure at the valve location is considered equal to total pump head minus piping friction loss in piping between the valve and the pump. From the above, a formula may be developed for determining the necessary valve body static pressure rating as follows:

$$\text{Static Pressure Rating (in PSI)} = \frac{(h_{fp} - h_t) + (h_p - h_f)}{2.31}$$

h_{fp} = Fill Pressure at low point of system in ft. of water
h_t = Distance of valve above low point of system in ft.
h_p = Total pump head in ft. of water
h_f = Friction loss in piping between valve and pump in ft. of water

See Fig. 11 for an example.

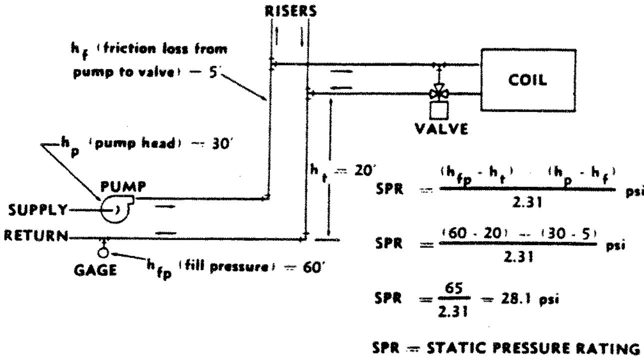


FIG. 11
VALVE STATIC PRESSURE RATING — EXAMPLE

Close-off Pressure Rating: Must be equivalent to the total pressure difference which can occur across either port when that port is closed. Normally, in closed loop system applications such as described previously in A, B or E, the water flow rate in the system remains nearly constant. (In A and B, that is why the three-way valve was used in the first place.) Therefore, the pressure which the valve must close off against is only the pressure drop in the leg where water is flowing, that is, between the common port of the valve and the point where the by-pass joins the main system. See Figs. 12A and 12B.

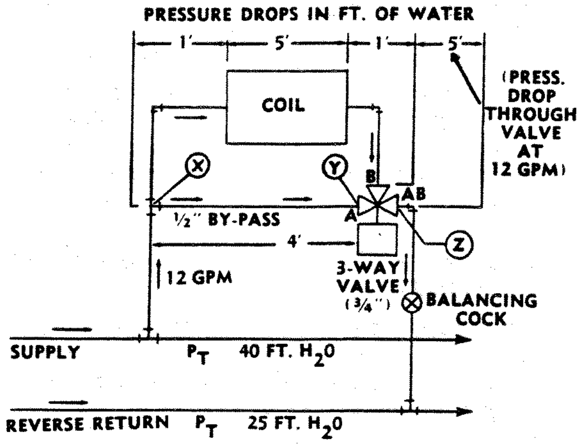


FIG. 12A
CLOSE-OFF PRESSURE RATING — ZONE CONTROL

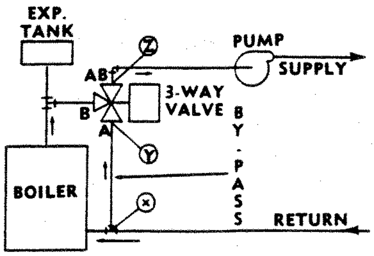


FIG. 12B
CLOSE-OFF PRESSURE RATING — H W SUPPLY CONTROL

In Fig. 12A, the **maximum** pressure the valve would have to close against would be equal to the sum of pressure drops in the coil, the coil piping, and the valve with full flow through the coil leg. This is due to the fact that when there is no flow through the by-pass, the pressures at points X and Y are the same. The pressure drop from point X to point Z is 12 ft. The pressure difference between Y (A port) and Z (common port) is therefore 12 ft. (or about 5.2 psi), and this is the highest pressure difference the valve must be able to close against. The pressure difference between supply and return mains, and the drops in the piping between point X and the supply main, and between point Z and the return main are not involved. **The maximum pressure difference the valve must close against is equal only to the pressure drop from X to the valve through whichever port circuit (A or B) has the highest resistance at maximum flow (in this case the coil circuit), plus the pressure drop through the valve itself.**

In Fig. 12B the situation is much the same. The valve must be able to close off against the highest pressure drop from point X to Z (through the boiler circuit and valve, or through the by-pass circuit and valve—whichever path has the greater resistance at full flow).

II. CONSTANT FLOW IN SECONDARY CIRCUIT — CLOSED LOOP

A typical application where the three-way valve is piped for constant flow in the secondary pumping circuit is application B described previously. Operating requirements are:

Static Pressure Rating: The static pressure requirements are the same here as in Case I, and may be determined in the same manner.

Close-off Pressure Rating: Again, the valve close-off pressure rating must be at least equivalent to the greatest pressure difference which can occur from either the A or B port (when closed) to the common (AB) port.

In a primary and secondary pumping system of this type, it becomes necessary to analyze some basic concepts before the requirements for the control valve can be determined. Normal practice is to pipe **the take-offs for the** secondary system as close together as possible on a bypass leg across the primary system supply and return. See Fig. 13A. This serves two purposes: First, the bypass leg on the primary system allows for practically constant circulation in the primary pumping circuit, whether the secondary systems are using primary water or not. Secondly, by keeping the pressure drop (ΔP) to an absolute minimum in the common pipe between the supply and return take-offs for the secondary circuit, the pumping head developed by the primary pump will be practically the same on both the supply and return of the secondary circuit. Therefore, the primary pump does **not** tend to cause flow in the secondary circuit; its only function becomes circulation of water in the primary circuit. The water flow rate in the secondary circuit is then determined only by the secondary pump, and the sizing and close-off pressure requirements of the three-way control valve are functions of the secondary circuit pump only.

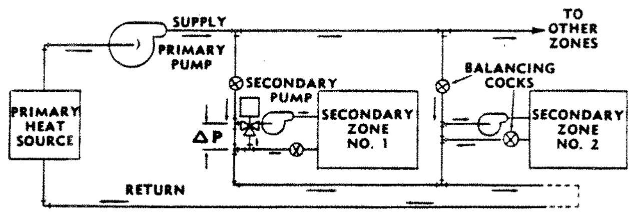


FIG. 13A
PRIMARY-SECONDARY PUMPING CIRCUITS

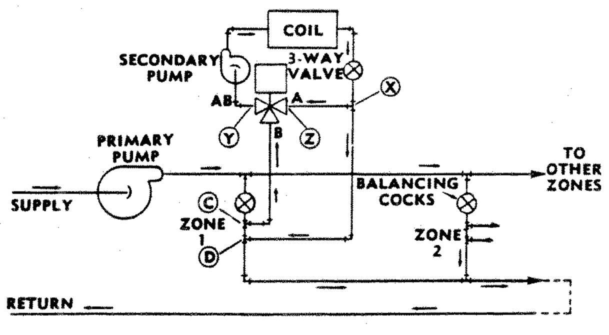


FIG. 13B
VALVE CLOSE-OFF REQUIREMENT FOR PRIMARY-SECONDARY PUMPING CIRCUITS

Assuming the pressure drop from C to D at the supply take-off to the zone (refer to Fig. 13B) is negligible as outlined above, the close-off pressure requirement for the three-way valve again is independent of the pressures existing in the primary supply and return circuit. The close-off requirement will be equal to the greatest friction drop at full flow in either of the two legs from point X to the A or B ports, plus the pressure drop through the valve itself. Normally the friction drop will be greater in the circuit from X to the supply-return connection and back to port B (because it is longer than the X to A leg). Therefore, the close-off rating must normally be at least equal to the sum of the pressure drops from point X to port B plus the valve pressure drop. (When the A port is closed there is no flow from X to A, and the system pressures are equal at point X and port A. The pressure at point Y is less by the amount of friction drop from X to B plus the valve drop —hence the valve must close against this pressure difference when closing to port A.)

III. THREE-WAY VALVE CHANGEOVER APPLICATIONS — CLOSED LOOP

These applications include those where the valve is used for seasonal or zone changeover as described previously in E (Figs. 5A and 5B), or other applications where the valve must close against a pump in the system. Operating requirements are:

Static Pressure Rating: The static pressure rating requirement will normally be the sum of the static fill pressure plus the pump head pressure (developed by the highest head pump in the system) minus the height of the valve (in ft.) above the fill pressure measuring point. Obviously, all pressures must be in ft. of water before summation; the final sum may then be divided by 2.31 to obtain static pressure rating in psi.

Close-off Pressure Rating: The close-off pressure requirement will usually be equal to the pump pressure developed by the highest head pump in the system. This is true because when the valve is positioned to supply hot water, the chilled water pump may be off, and vice versa. The static fill pressure will be present on both the hot and chilled side of the valve ports (cancelling out), and the valve will have to close off against the pump which is running to prevent leakage into the part of the system which is shut down.

As 100% tight shut-off against pump head is a normal requirement in this application, two-position two-way valves with soft seats are often used in place of a globe type three-way valve with metal-to-metal seats. The two-way valves may be either globe type or rubber lined butterfly valves and are arranged so that one opens as the other closes. When the valve size is 4″ or larger, the butterfly type often has a cost advantage, as two valves applied to a tee can be linked together for operation from one actuator. Also, higher close-off pressure ratings and lower pressure drops are often characteristic of butterfly valves as compared to the same size globe type valve.

IV. OPEN LOOP TEMPERATURE CONTROL — COOLING TOWERS

Open loop applications, where the control valve maintains a desired condition by varying the flow rate through that portion of the system open to atmosphere, present special problems. A typical example is the cooling tower application described previously under C, where a three-way valve can be used to maintain a constant inlet water temperature to the condenser. The valve selects the proportion of return water delivered to the sprays, and bypasses the rest to the sump, to maintain the desired inlet water temperature (at a constant flow rate) to the condenser. (See Fig.

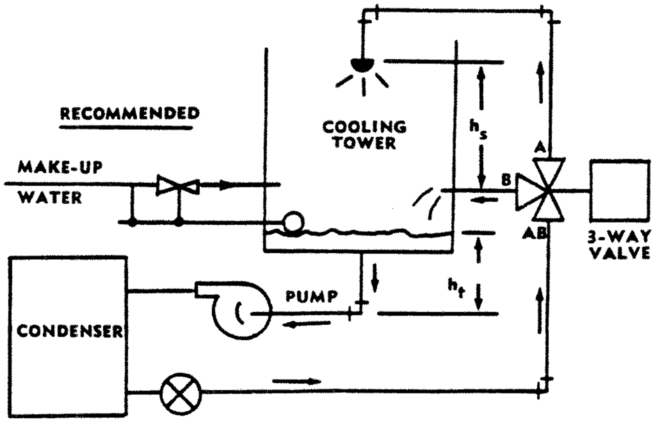


FIG. 14A
COOLING TOWER CONTROL — OPEN LOOP

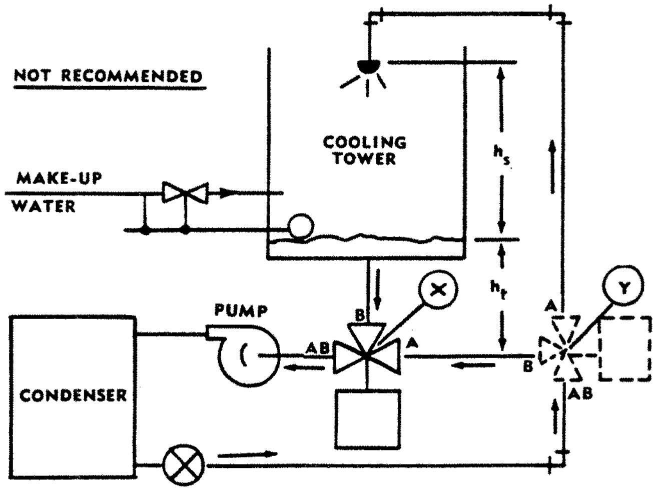


FIG. 14B
COOLING TOWER CONTROL — OPEN LOOP

This application is perhaps one of the most difficult as far as valve requirements and location are concerned. Large water flow rates are encountered on larger tonnage machines, particularly where absorption refrigeration units are used. High head pumps are also common due to condenser and piping friction losses at large flow rates, and also because the cooling tower is often located some distance away from the condenser.

VALVE TYPE AND LOCATION

A. Not Recommended (Fig. 14B, Location X): It has been general practice to specify a three-way valve for tower control located at point X in a piping arrangement as shown in Fig. 14B, allowing the use of a less expensive mixing type three-way valve body. This location often turns out to be unsatisfactory, however, as pressure drop through the valve plus piping friction losses may easily result in a negative operating pressure (below atmospheric pressure) at the pump inlet, causing pump cavitation. This is particularly true when the cooling tower is located some distance away, but at or near the same level as the pump, as the positive static head (h_t) will be very small in relation to piping and valve pressure losses. This location also has another problem as noted below, and is, therefore, not recommended.

B. Not Recommended (Fig. 14B, Location Y): The problem of the control valve pressure drop appearing as a negative drop on the suction side of the pump can be eliminated by relocating the three-way valve to point Y in the same piping arrangement. However, this arrangement requires a diverting type three-way valve, and still has the disadvantage that the system pressure drop through the by-pass will be somewhat less than the pressure drop through the tower leg (which has much more pipe, spray heads, etc.). This is particularly true if the valve is located near the pump rather than at the tower, and results in an increased water flow rate through the pump and condenser as the valve modulates to by-pass more water around the tower under reduced loads. On water chillers, this will often lead to chilled water control instability (particularly on absorption machines) as well as to increased condenser pump horsepower.

This problem will be aggravated by locating the control valve near the pump rather than near the tower when the two are some distance apart. A manual balancing cock in the by-pass line will enable one to balance the flow with the control valve in the full by-pass position, but as the flow in the by-pass is reduced, the pressure drop across the balancing cock reduces as to the square of the flow. This creates a high pressure unbalance on the "B" port when the valve is open to the "A" port (tower leg), resulting in non-linear flow control by the three-way valve, with control instability likely whenever low flow rates through the by-pass are required to meet desired conditions.

The only real solution to obtaining good flow control, with a control valve located at point X or Y, is to use reduced trim on the by-pass port, or to use two different size two-way valves (such as butterfly valves) linked together so that as one closes the other opens. In either case, the size of the by-pass port or valve is reduced to compensate for the reduced piping friction in the by-pass leg. In this manner, balanced flow through both the tower leg and the by-pass leg is possible, but valve sizing is somewhat critical — accurate calculations of piping friction losses for the piping as installed will be required to properly size the by-pass port or valve.

C. Recommended (Fig. 14A): The above problems can be overcome by locating a diverting type three-way valve at the cooling tower piped to by-pass to the tower sump. This location has several advantages:

1. System operating pressure at the pump inlet is determined only by the height of the tower above the pump minus the pipe friction losses from tower to pump (h_t–h_f); the control valve pressure drop is not involved.
2. The total length of pipe (and, therefore, pressure drop) in the pumping circuit remains nearly the same as the valve modulates from the tower leg to the by-pass position. This results in a nearly constant water flow rate through the pump and condenser regardless of valve position and without the use of balancing cocks, reduced port trim, or a smaller valve on the by-pass leg. (Assuming that the pressure drop through the spray heads is a minor portion of total pump head requirements.)
3. Tower winterizing requirements are greatly reduced or eliminated. Whenever the refrigeration machine is operated at outdoor temperatures below 32F, the rejected condenser heat in the water by-passed to the tower sump, plus the fact that full water flow always circulates through the sump, will normally prevent any freezing of the sump and drain lines. Additional heat to prevent freezing will normally be needed only when the refrigeration machine is shut down. This would not be true if only spray water reached the sump during below freezing conditions, as would be the case with arrangements shown in Fig. 14B.

VALVE SIZE AND PRESSURE RATINGS

A. Recommended Valve Size and Style: The control valve should be sized so that the valve pressure drop is at least equal to the pressure drop through the spray heads, plus the height (in ft.) of the spray heads above the valve.

For the diverting application shown in Fig. 14A, when the valve size is 5" or above, it will often pay to consider the use of two butterfly valves mounted on a common tee and linked together for positioning from one control actuator, rather than specifying a more expensive globe type three-way diverting valve. The characterized flow characteristics of the butterfly valves will normally provide stable control when sized for sufficient pressure drop as outlined above. Although usually not a requirement for this application, tight-closing butterfly valves may be obtained by calling for the rubber-lined type, but these require more powerful actuators for the same size valve.

B. Static Pressure Requirement: In the case of 14A, static pressure rating required for the valve body is practically nil, as the maximum total system pressure at this point will be equal to the friction pressure drop from port AB through the valve piping and spray head, plus the height of the spray head above the valve when the valve is full open to port A. The following formula may be used:

$$\text{Static Pressure Rating (in PSI)} = \frac{h_s + h_{sf}}{2.31} + P_v$$

h_s = height of spray head above valve in ft.

h_{sf} = friction pressure drop of spray head and piping to port A in ft. of water

P_v = valve pressure drop in psi

C. Close-off Pressure Requirement: Again, the three-way valve must close off only against the greatest pressure drop in the two loops connected to ports A and B. In this case, both loops exhaust to atmosphere, with the spray head loop obviously having the higher pressure drop. Actually, the maximum close-off pressure requirement in psi (for port B) happens to be exactly the same as the static pressure requirement given above, and can be calculated using the same formula.

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