MANUAL 2100-054

OPERATION
AND
TROUBLESHOOTING
WATER-TO-AIR HEAT PUMPS

REFRIGERATION, HEATING AND AIR CONDITIONING

BARD MANUFACTURING CO. • BRYAN, OHIO 43506

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TROUBLESHOOTING TYPICAL HEAT PUMP SYSTEMS

THE WATER-TO-AIR HEAT PUMP

NOTE: THIS MANUAL TO BE USED WITH INSTALLATION MANUAL FOR THE PARTICULAR UNIT BEING SERVICED.

THE BASIC PRINCIPLE

In its approach to basic familiarity with heat pump design, application, and installation, the beginning text of this course noted its limitation generally to "Air-To-Air Systems" since they were in the majority and therefore the type the learner would be called upon to design, apply, install or service most frequently.

There is, however, another type of system which, while not generally as popular as the air-to-air heat pump, has more recently become more widely used in the more temperate sections of North America. This is the "Water-To-Air System".

The basic principle of operation of this system is that heat is rejected to the water from the air to be conditioned (COOLED) on the cooling cycle and heat is gained from the water by the air to be conditioned (HEATED) on the heating cycle. De-humidification is achieved in the usual manner on the cooling cycle by removal of moisture from the air in the form of condensate. The medium of heat transference is the refrigerant. Basic components used in the system are the compressor and a co-axial heat exchanger. As with the air-to-air system, the transfer from cooling to heating mode and visa-versa is accomplished by means of a reversing valve.

The application area for this type system is for heating and cooling residential structures where there is an adequate supply of water above 45°F and a method of disposal of used water is available.

A typical "Water-To-Air" heat pump, and the one to be used as an example in this lesson, is the Bard High Efficiency Water Source Heat Pumps. This typical unit, the cooling and heating cycles of which are pictured in Figure 13, incorporates the conventional high and low pressure controls.

If the system cuts off on one of the pressure controls due to a known reason or power failure, the controls can be reset by turning the thermostat control switch to "OFF", waiting a few minutes for system pressures to equalize, and then turning the thermostat control switch to either "COOL" or "HEAT" as the occasion warrants. This system can also be reactivated after a stoppage as noted, by turning the main power supply to the system off and then on again after the recommended waiting period for pressure equalization.

GROUND WATER HEAT PUMP ELECTRICAL CONTROLS[1]

Understanding water source heat pump controls is an essential element in the overall understanding of heat pump installations, start-up and troubleshooting. Just as the contractor must become familiar with pump and water system controls to do an effective job, knowledge of how ground water heat pump controls operate helps make the installation a success.

Heat pump controls may be classified in two major groups: electrical and refrigeration. Electrical controls are of initial interest to the installer since they more frequently interface with the balance of the water system and other contractor-installed items. In general, ground water heat pump controls operate in a simple, straightforward manner. This section explains individual control components and how they are put together to form control systems. The contractor, however, must familiarize himself with the specifics relating to his line of ground water heat pumps.

Heat pump electrical systems are grouped into two major categories: line voltage systems and low voltage systems. "Low voltage" is also sometimes referred to as "control voltage." Low voltage is generally used for most of the control functions, especially those that are coupled to devices outside the machine (see Figure 1).

[1]Fred Jaeger, "Ground Water Heat Pump Electrical Controls," Ground Water Heat Pump Journal, Summer 1981.

Some of the specific control functions, however, may slide from the line voltage side to the low voltage side or vice versa, depending on the manufacturer.

When low voltage (generally 24 VAC) is used to control heating and air conditioning equipment, the control components can be of a lighter duty and the interconnecting wiring between devices can be made using less expensive materials and wiring methods. There is, however, a strict set of rules that a manufacturer must adhere to when providing a low voltage control system. In order to classify as an NEC (National Electrical Code) Class II control system, the voltage must be 30 volts or less and the power must be limited to 75 VA (volt-amperes). The manufacturer must provide some means to ensure that upon an overload or short-circuit,this power level will not be exceeded. This can be accomplished by providing a fuse or a circuit breaker or by use of an "energy-limiting" transformer. If these rules are met by the manufacturer, the contractor then has a Class II electrical system that he may connect in a very fast and economical manner. Note, however, there is a built-in limitation as to the total power allowed in this control system. Only small control loads such as magnetic contactor coils, relay coils solenoid valve coils, etc., are allowed. As we will see later, these smaller loads are then used to control larger line voltage loads inside the heat pump. Seventy-five VA translates into a maximum current of 3.2 amps at 24 VAC. Thus, the total current that can be used at any time by the control components cannot exceed 3.2 amps. It should be noted that 75 VA is the maximum that can be provided. If a fewer number of control components are normally associated with a manufacturer's piece of equipment, typically, a lesser amount of control power will be made available. Forty VA is another popular power level. In this case, a maximum of 1.6 amps of control power can be used, limited by the size of the control voltage transformer used.

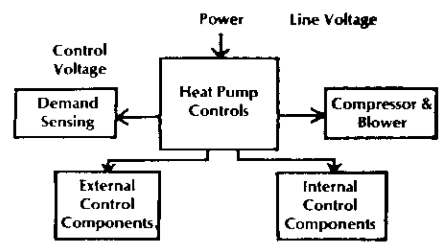


Figure 1. The roll of control voltage and line voltage.

The "demand control" which is, in most cases, the room thermostat, is normally a low voltage device. Modern thermostats are actually rather complex devices. These complexities are required in order to get the thermostat to respond correctly to changes in room conditions. However, the end result of all this is to complete a current path (like closing the switch), telling the heat pump to come on (see Figure 2). In simple terms, it can be thought of as a switch that opens and closes in response to temperature.

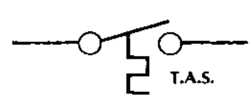


Figure 2. One symbol for a thermostat. T.A.S. stands for "Temperature Actuated Switch."

The low voltage thermostat signal can be used to control large electrical loads such as compressors and blowers by way of a magnetic contactor. The contactor keeps the low voltage and high voltage circuits completely separate and isolated from each other. They are coupled to one another by way of magnetic or mechanical action. In a simple contactor, the control current travels through a magnetic coil which attracts a movable armature carrying contact points connected to a line voltage circuit. When the armature is "pulled in," this independent set of contacts completes a separate line voltage circuit running to the load. It is in this manner that low power signals are used to control high power loads. Figure 3 is a symbolic representation of a magnetic contactor. Note that the terminals to the coil are separate from the terminals to the contact points.

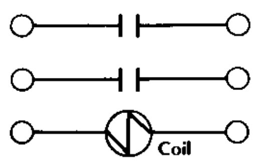


Figure 3. Symbol for a magnetic contactor.

A control relay operates much the same as a contactor, but is used to control other low power loads that are either low voltage or high voltage. Additionally, the switched side of a control relay can have several "poles" or separate circuits that can control different devices. These poles are actuated simultaneously from the same signal to the relay's coil.

Figure 4 depicts a control relay with a coil and two poles, or separate controlled circuits. The contact pairs that are illustrated with diagonal lines through them are "normally closed" contacts and open or break the circuit when the coil is energized.

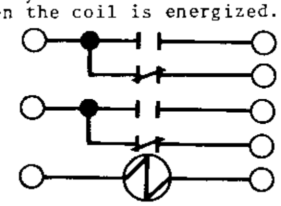


Figure 4. Symbol for a control relay.

Pressure switches are control components that provide a simple switching action, i.e., make or break a control signal in response to refrigerant pressure. A pressure switch is shown symbolically in Figure 5. A ground water heat pump will normally have a high pressure and a low pressure cut-out switch.

Figure 5. Symbol for a pressure switch.

When valves must be opened or closed as part of the heat pump control scheme, low power solenoid coils are used. Just as a low power signal is used to control a large electrical load in a contactor, valves generally encountered in ground water heat pumps use a lower power signal to control the relatively large mechanical force required to actuate the valve. This is done through a "pilot operator." The solenoid coil actuates a small internal valve which then allows the pressure of the fluid ahead of the valve to actually force the valve open. A solenoid capable of providing sufficient force to move the valve stem directly (as in a "direct-acting" valve) would require many times the power. Figures 6 and 7 show two pilot operated valves: a water valve and a refrigerant reversing valve. The reversing valve actually directs two separate flow streams to different locations. Hence the pilot valve and main valve are configured differently than in a water valve. The same principle applies, however: a small control signal causes a larger force to open or change the position of a valve by taking advantage of the fluid pressure difference in the system.

The low voltage control power required to operate these devices is provided by a small transformer which takes the available line voltage and converts it to low voltage (generally 24 VAC) for use in the control system.

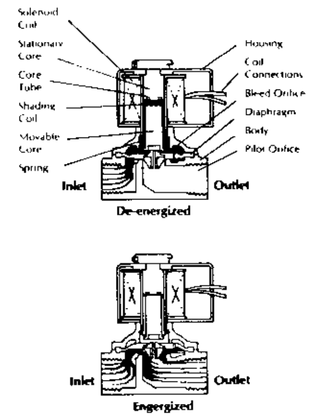


Figure 6. Cut-away view of a pilot-operated solenoid valve.

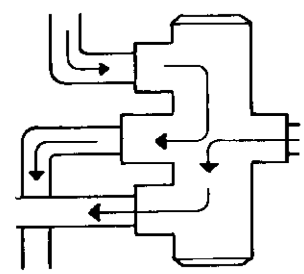


Figure 7. A reversing valve.

Figure 8 is the symbolic representation of a control transformer. Since the control power must be available at all times and the standby power consumed by the transformer is small, it remains energized anytime there is power to the heat pump.

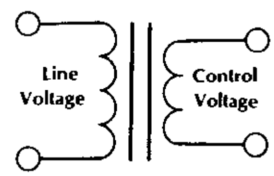


Figure 8. Symbol for a transformer.

What remains is to put all these control components together in such a way that the desired events take place at the right time. This is most easily explained by using a "ladder diagram" which is a control logic representation of a wiring diagram. We have seen how a thermostat, when it closes, creates a "demand" signal that can be used to operate a compressor contactor or control relay. There may be reasons to ignore this signal, interrupt it after the load has started or route it somewhere else. Figure 9 shows a "rung" on a ladder diagram.

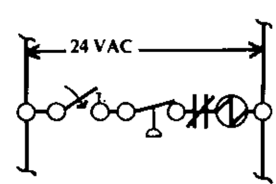


Figure 9. "Rung" on a ladder diagram.

The voltage to be controlled comprises the side members of the ladder. In this example, a temperature-actuated switch, a pressure switch and a normally closed set of contacts of a control relay are placed in series with a contactor coil. All three of the devices ahead of the coil must be closed before the coil will energize. Additionally, if any one of them opens after the coil has been energized, the circuit will be broken and the coil will de-energize. It is in this manner that control signals are properly manipulated inside the heat pump. Note that the intent of the ladder diagram is to show the logical sequence of operation and not to depict the physical relationship between components. The short wire between the temperature switch and pressure switch on the diagram may in fact be many feet long with the components located far from one another.

It is easy to see how several "rungs" may be stacked and interconnected to perform a multitude of functions. No matter how complex the system (and ground water heat pump controls are not very complex), a simple logical procedure can be used to interpret the control sequence. Figure 10 is an example of a complete ladder diagram.

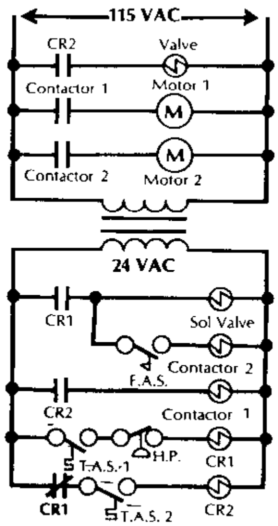


Figure 10. *Example of a ladder diagram.*

Note that the components below the transformer operate at 24 VAC while the components above operate at line voltage, in this case 115 VAC. A single device, control relay two, (labeled "CR2" in the diagram) has its coil in one rung of the ladder. One set of its contacts operates on another rung in the low voltage side, while another set of its contacts operates on the line voltage side. When this coil becomes energized, both contactor one and the 115 VAC valve will actuate (refer to Figure 10). By continuing this analysis of the unit's ladder diagram, the sequence of operation can be fully understood.

On many applications, components external to the heat pump need to be controlled. These may include water pumps, supplemental electric heaters, valves, etc. The way these external devices are controlled is also indicated on the ladder diagram. Figure 11 illustrates a situation where the heat pump, the supplemental electric heaters and the water pump all receive their main power from separate circuits. This power is controlled, however, by low voltage control signals from the heat pump.

Line voltage controls are sometimes used inside the machine for a few of the control functions. Consequently, the contractor must be aware of which control devices are operating at line voltage and which are operating at low voltage. Again, this information will be contained on the unit's ladder diagram. When installing or troubleshooting a heat pump, it is obvious that a ladder diagram is ~~of~~ extreme value. Voltages may be checked at various points to determine what device is closed or open and where the problem may be. In that ground water heat pumps are all controlled a bit differently, it is more important that the contractor be familiar with the manuals and wiring diagrams associated with his particular equipment.

Understanding heat pump controls and wiring diagrams is important from a safety standpoint as well. A particular coil that operated at 24 VAC in one unit may operate at 230 VAC in another. This could come as quite a shock to the service man who thought he could replace that coil without disconnecting the power. Additional training in this area is available through your distributor, the manufacturer or organizations like the Refrigeration Service Engineers' Society (RSES). The serious contractor or service man will also carry the proper tools and equipment necessary to test or troubleshoot heat pump controls. As a minimum, they include such things as a multimeter (capable of measuring voltage, current and resistance), jumpers, terminals, a crimping tool and spare replacement parts. A good quality multimeter is the control system's equivalent of refrigeration service gauges. You can't go very far into the diagnosis of a control system without one.

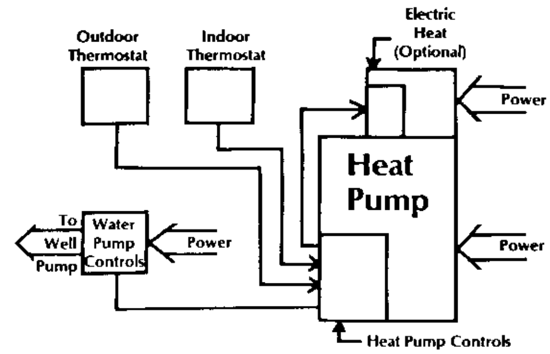


Figure 11. External devices controlled from the heat pump.

As you already know, there is no substitute for experience and training. The principles discussed herein are basic and provide a starting point. A firm understanding of the control system you are working with will reduce the unknowns and risk factors associated with your heat pump installations.

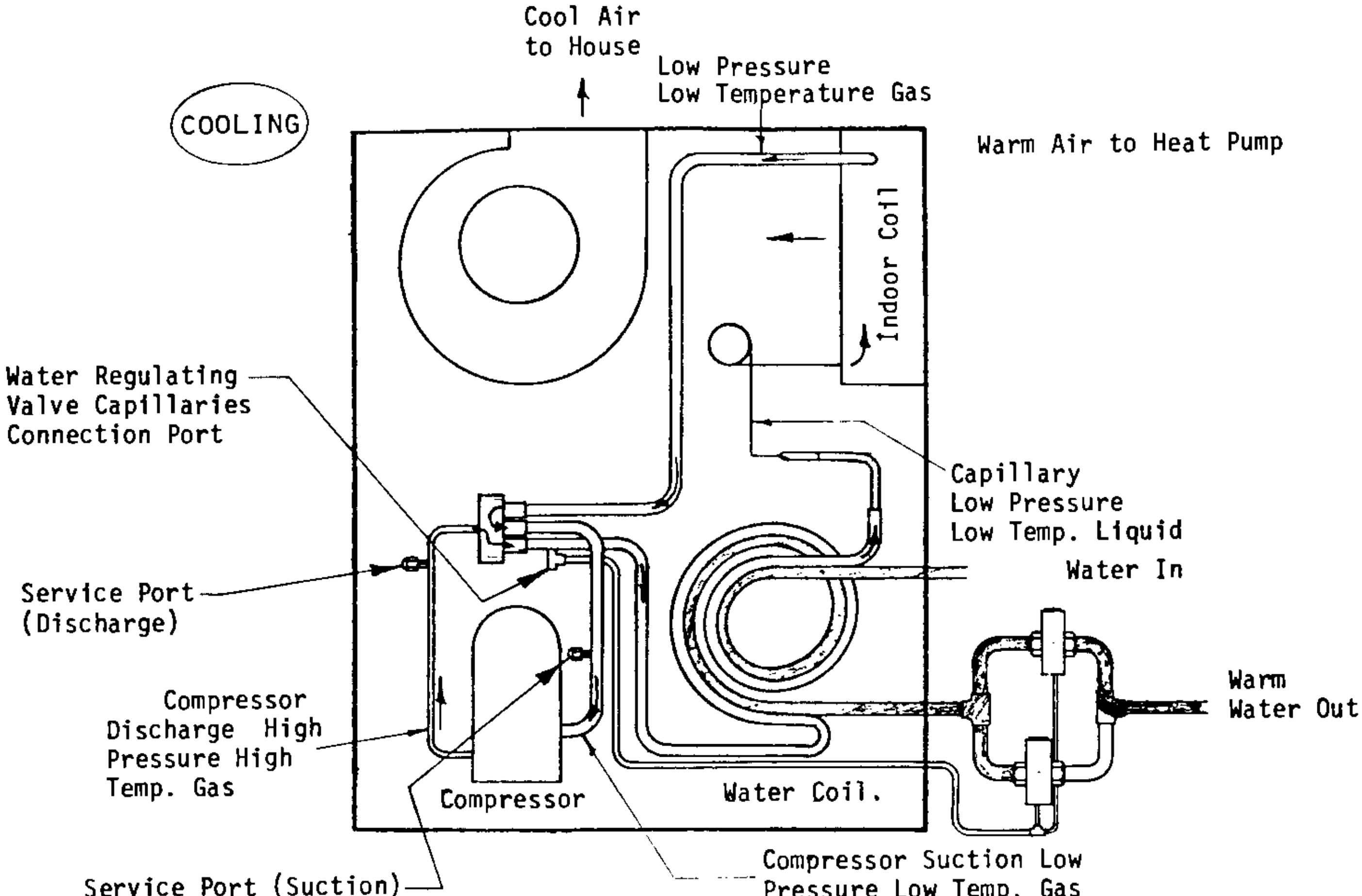
GROUND WATER HEAT PUMP REFRIGERANT CONTROLS[1]

We discussed electrical controls in ground water heat pumps and the importance of the contractor understanding their operation. Installation, proper equipment operation and troubleshooting benefit from this type of understanding. Now we will discuss refrigerant controls in ground water heat pumps. Refrigerant controls are probably of less initial interest to the installing contractor, since they are generally self-contained in the unit, preadjusted and do not require interconnections to other contractor-installed items. However, the contractor should have a sound understanding of the machine he is selling, including the refrigerant controls. Additionally, when it becomes necessary to troubleshoot the unit, or when adjustments are required, an understanding of the refrigerant controls is essential.

By virtue of equipment design, all ground water heat pumps operate a bit differently. Training schools given by the manufacturers or their distributors are generally used to familiarize the contractors with the specific characteristics of their equipment. Also, organizations, such as the "Refrigeration Service Engineers Society" (RSES), with chapters nationwide, offer extensive training in heat pumps and other equipment. This section will overview the common refrigerant controls of ground water heat pumps.

Heat pumps operating in either the heating or cooling mode have basically a high pressure side and a low pressure side of the system (see Figure 13). It is this change in pressure that allows the refrigerant to transfer heat by evaporating and condensing at different temperature levels. The component that increases the refrigerant pressure is the compressor. The component that drops the refrigerant pressure is the expansion device. This continual process of raising then lowering the refrigerant pressure while expelling and absorbing heat, respectively, is the key to the refrigeration cycle that heats and cools the structure.

[1]Fred Jaeger, "Ground Water Heat Pump Refrigerant Controls," Ground Water Heat Pump Journal, Fall 1981.


COOLING
Cool Air to House
Low Pressure Low Temperature Gas
Warm Air to Heat Pump
Indoor Coil
Water Regulating Valve Capillaries Connection Port
Capillary Low Pressure Low Temp. Liquid
Water In
Service Port (Discharge)
Warm Water Out
Compressor Discharge High Pressure High Temp. Gas
Compressor
Water Coil.
Compressor Suction Low Pressure Low Temp. Gas
Service Port (Suction)

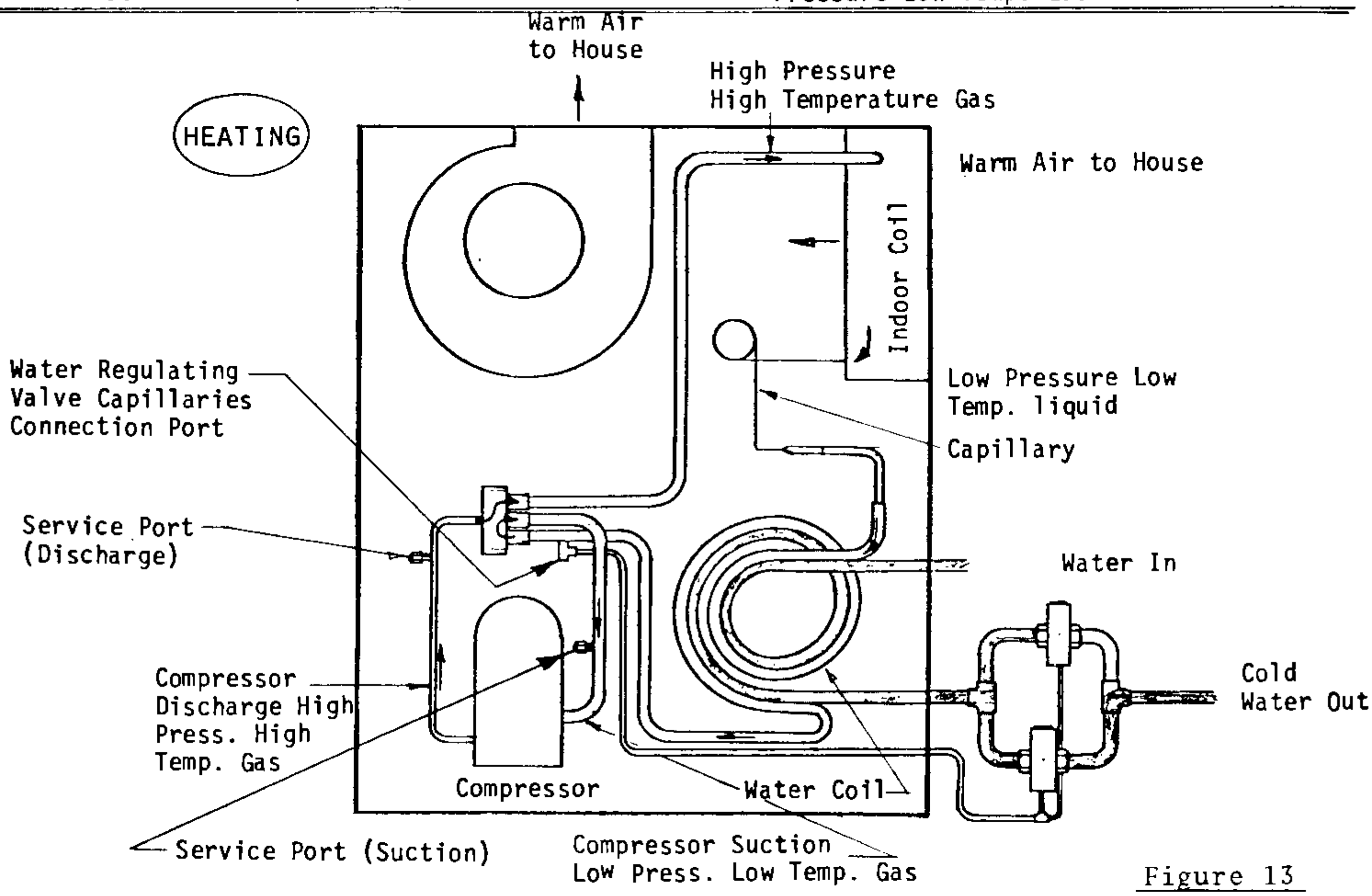

Warm Air to House
HEATING
High Pressure High Temperature Gas
Warm Air to House
Indoor Coil
Water Regulating Valve Capillaries Connection Port
Low Pressure Low Temp. liquid
Capillary
Service Port (Discharge)
Water In
Compressor Discharge High Press. High Temp. Gas
Cold Water Out
Compressor
Water Coil
Service Port (Suction)
Compressor Suction Low Press. Low Temp. Gas

Figure 13

The expansion device is clearly one of the important refrigerant controls. Ahead of the device there is high pressure liquid refrigerant. When passing through the expansion device, the pressure of the liquid is drastically reduced, allowing it to boil (evaporate) at a low temperature, extracting heat from the source. The heat source is water when the machine is heating and room air when the machine is cooling. The heat exchanger into which the refrigerant is evaporating becomes part of the "low pressure" side of the system.

There are several types of expansion devices commonly used in ground water heat pumps. The type used depends on the manufacturer of the equipment and the intended application. The capillary tube is one such expansion device. A capillary tube is a length of small-diameter tubing manufactured with its internal diameter held to very close tolerances (see Figure 14). It functions like an orifice (i.e., a small-diameter opening), but is designed like an "elongated orifice" so that its characteristics can be accurately reproduced. Often, several individual capillary tubes will be bunched together (in parallel) to achieve the required refrigerant flow rate. Since it is a fixed device with no moving parts, it gives reliable operation providing the internal passages are kept completely free of foreign matter. A capillary tube expansion system has a fixed effective orifice size, determined by the length, diameter and number of capillary tubes. Therefore, there is generally one optimum operating point (the design condition) for which this selection has been made. For operating conditions significantly removed from the design conditions, performance of the expansion system will be less than optimal. Many ground water heat pump installations operate under relatively fixed conditions of constant water temperature and return air temperature, where a capillary tube expansion device gives suitable performance. The installer should be aware of off-design conditions, however, such as start-up in a cold building. Here the condensing pressure in the unit would be abnormally low. In such a case, the heat pump may cycle off because there is insufficient pressure drop across the capillary tubes to create the required refrigerant flow rate. Also, a capillary tube system is generally very sensitive to the amount of refrigerant charge in the system. Too much, and the condensing pressure can become abnormally high. A shortage of refrigerant allows vapor to enter the capillary tubes (instead of liquid) causing a loss in capacity.

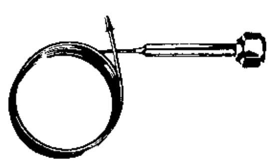


Figure 14. Capillary Tube (coiled up).

Expansion valves are another type of expansion device found in ground water heat pumps. Unlike capillary tubes, the effective opening size changes in response to conditions in the evaporator. The most common type of expansion valve in use today is called a "thermostatic expansion valve," or T.E.V. (see Figure 15). The purpose of this valve is to maintain a constant refrigerant superheat at the evaporator outlet. "Superheat" is the number of degrees of temperature that a gas is heated above its evaporating temperature at a given pressure. The T.E.V. is generally set to give 8 to 12°F of superheat at the evaporator outlet in order to insure that all the refrigerant has evaporated. Changes in the unit's operating conditions can be sensed by a change in superheat at the evaporator. The T.E.V. then opens, or closes slightly, allowing more, or less, refrigerant to pass through maintaining a constant superheat. In general, T.E.V.s can accommodate a wider range of operating conditions (such as varying water temperatures and return air temperatures) than other expansion devices. The effective orifice size automatically changes in response to these changing conditions. For the valve to determine what the superheat actually is, it must measure the temperature and pressure of the refrigerant gas leaving the evaporator. Therefore, you will find a pressure tap and a temperature sensing bulb running from the evaporator outlet to the valve. The temperature sensing bulb is a sealed unit, filled with a fluid that changes its pressure in response to temperature. The valve is purely mechanical in operation. The sensing bulb and evaporator outlet pressures create forces of an internal valve stem that determines the position of the valve pin in relation to its seat. It is in this manner that the optimum refrigerant flow rate is determined in response to the operating conditions imposed on the unit.

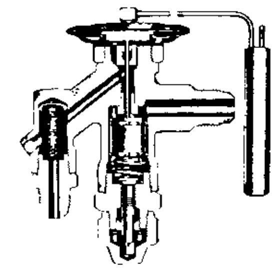


Figure 15. Thermostat Expansion Valve (cut-away view)

Other refrigerant controls typically found in ground water heat pumps include some active and passive components used to direct the flow of refrigerant, contain it, or provide a safety signal to stop the machine if something goes wrong.

Heat pumps that perform both heating and cooling functions contain a reversing valve that directs the flow of high pressure and low pressure gas to and from the proper components (see Figure 16). The high pressure gas exiting the compressor must be routed to the condenser, which is the refrigerant-to-air heat exchanger in the heating mode or the refrigerant-to-water heat exchanger in the cooling mode. Likewise, in order to create a low pressure side in the system, the gas from the heat exchanger which is evaporating the refrigerant must be directed to compressor inlet or "suction." The reversing valve simultaneously directs the flow of the high pressure and low pressure gasses to the proper heat exchangers when it receives a signal from the electrical control system. Reversing valves are "pilot operated" valves, utilizing the difference in refrigerant pressures in the system to move the internal valve shuttle. A small, solenoid-operated pilot valve allows high pressure gas to enter one end of the shuttle while venting the opposite end of the shuttle to the suction side of the system. The resulting unbalanced force on the shuttle moves it to its new position. Since the operation of the valve requires high and low pressures to be present, the main shuttle will not move unless the compressor is operating.

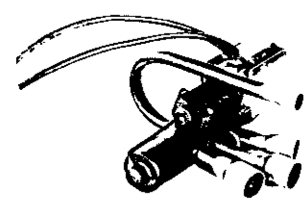


Figure 16. Reversing Valve.

Refrigerant check valves are used in some systems and function in a similar fashion as check valves in a water system; they allow refrigerant to pass in one direction only. A common type consists of a ball and seat, contained in a copper tube (see Figure 17). On reversing-type heat pumps, one would normally find a check valve placed around an expansion valve allowing refrigerant to bypass the valve when the heat exchanger is acting as a condenser rather than an evaporator. When the flow is reversed, requiring the refrigerant to evaporate in the heat exchanger instead of condense, the check valve closes, forcing the refrigerant through the expansion valve.

A "liquid receiver tank" is a passive component found in some systems and is used to store excess refrigerant as the machine operates in different modes, or as the conditions vary in any one mode (such as a change in water temperature). Also, it serves to "drain" the condenser, such that condensed liquid does not take up heat exchanger surface better used for condensing the high pressure gas. The liquid receiver tank is placed on the system between the condenser outlet and the expansion device. In that position it also helps to insure that the expansion device will be supplied with straight liquid, as opposed to a vapor/liquid mixture, which would decrease the heat pump's capacity.

Figure 17. Refrigerant Check Valve

Some heat pumps have a "suction line accumulator" placed just ahead of the compressor inlet. This is also a passive device that intercepts and holds liquid refrigerant that may be in the suction line on its way to the compressor (see Figure 18). Compressors do not think kindly of liquid refrigerant, since they are designed specifically to accept and compress vapor only. The circumstances under which liquid may be in the suction line include start-up, system overcharging, sudden reversal of the unit, or a component failure (like the blower stopping when the unit is cooling). The suction line accumulator is a simple control device that does a very effective job in protecting the compressor against the harmful effects of liquid refrigerant.

It is quite common to find a filter/drier in the refrigerant system. The filter/drier can be either in the liquid line or the suction gas line. Figure 19 shows a liquid line filter/drier. It is very important to keep the refrigerant system free of contaminants for the sake of both proper operation and long unit life. The contaminants that can be introduced into the system, if it is opened for service, are most likely air and moisture. Air can only be removed by proper evacuation techniques after the system is once again sealed up. Ideally, any moisture is also removed during the evacuation process. However, it is rare that evacuation in the field can be as complete or thorough as factory evacuation. The filter/drier contains a desiccant that removes residual moisture that may remain after field evacuation. Since it is a filter as well as a dryer, it will also capture and retain minute particles that may be traveling around with the refrigerant. This does not, however, give license to the serviceman to be sloppy and introduce particulates (copper shavings, dirt, etc.) into the system. They may have to travel some distance in the system before reaching the filter, having plenty of opportunity to get stuck along the way.

Figure 18. Suction Line Accumulator.

Figure 19. Liquid Line Filter-Drier.

There are a few additional devices that bear discussion which are not refrigerant control devices in the strict sense, but utilize refrigerant pressure or temperature to control other things. Pressure actuated switches are commonly used to stop the compressor when some abnormal condition is detected. When the low pressure switch opens, indicating a decrease in refrigerant pressure on the low pressure (suction) side of the system, it could indicate a loss of the heat source to the evaporator, or a blockage of the expansion device. When the high pressure switch opens, it may indicate a loss of the heat sink to the refrigerant condenser, or a blockage in the liquid line or high pressure gas line. Depending on the design of the equipment, other malfunctions may result in the opening of one of the refrigerant actuated pressure switches.

Refrigerant pressure may also be used to actuate water flow control valves. One such valve is shown in Figure 20. The refrigerant pressure is translated into a force acting on the valve stem by way of a sealed bellows. A water flow control valve operating in the cooling mode would be designed to open further as the refrigerant condensing pressure increases. The increase in condensing pressure indicates the condenser could use more water since the condensing temperature must also be increasing. Conversely, a water valve operating in the heating mode would be designed to close as the suction (evaporator) pressure became too high. This indicates more than sufficient heat is available in the source water and its flow rate should be reduced.

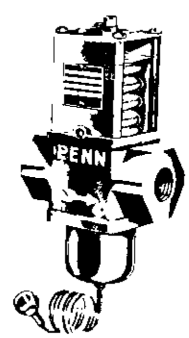
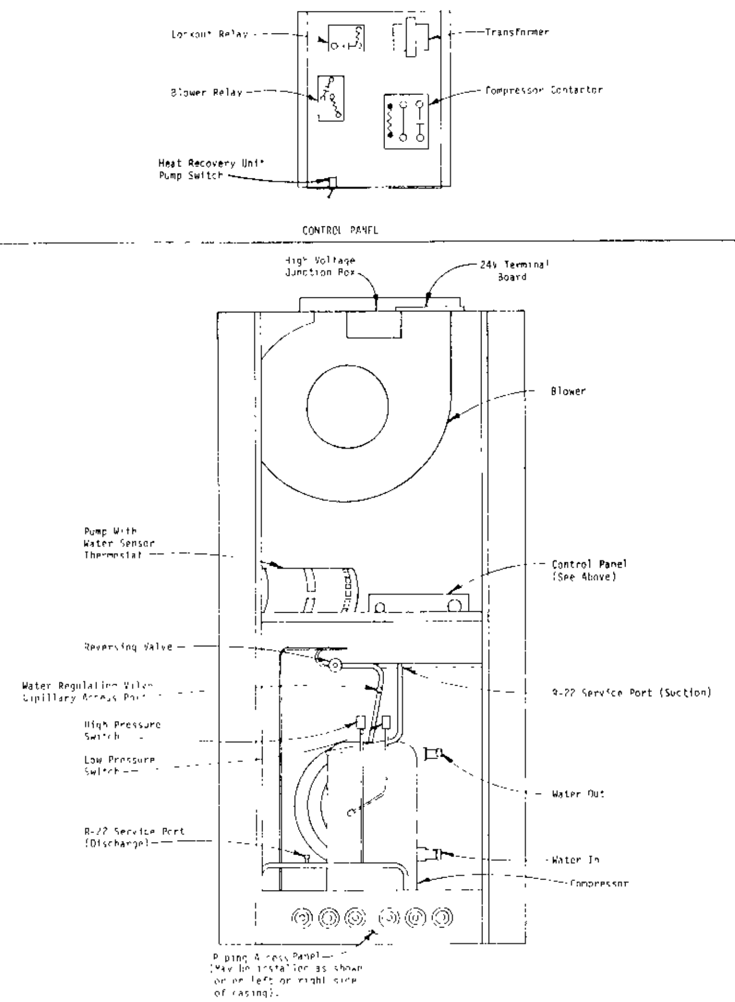


Figure 20. Pressure Actuated Water Flow Valve.

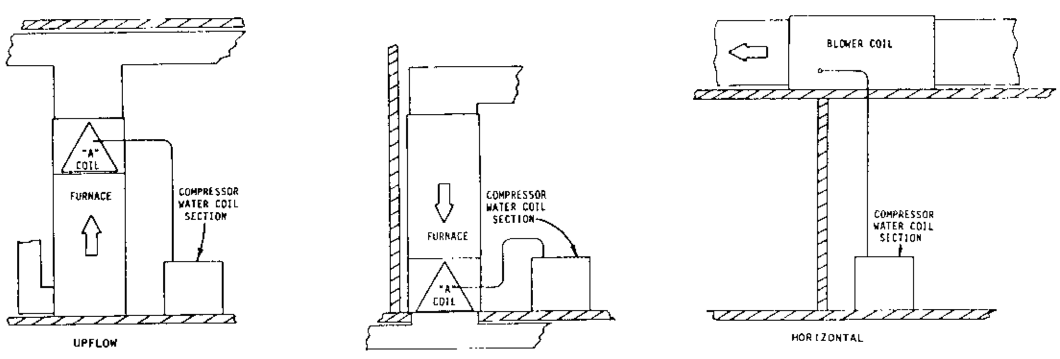
As a final comment, it must be mentioned that refrigeration equipment, including ground water heat pumps, takes some time to respond to adjustments or changes in operating conditions. Often, depending on the degree of adjustment made, it may take 15 to 20 minutes before the result of the adjustment becomes apparent. It is quite possible for a contractor or serviceman to end up "chasing his tail" in making adjustments to heat pump controls too rapidly. Careful, slow adjustments, taken one at a time, is the way to do it.

The above discussion on refrigeration controls is meant to serve only as an introduction. Clearly, participation in training schools offered by the manufacturer or product distributor and the careful study of the service manuals are essential. There is no substitute for training and experience when it comes to insuring success with heat pumps.



BARD PACKAGED UNIT

Figure 22



TYPICAL INSTALLATION
BARD SPLIT WATER SOURCE HEAT PUMP
USING AN "A" COIL OR BLOWER COIL

Figure 23

Bard® SINCE 1914

PERFORMANCE CHECK
WATER SOURCE HEAT PUMPS

INSTALLER PLEASE FILL OUT **AND** RETAIN WITH UNIT

DATE OF INSTALLATION__________ MODEL NO(S).__________ SERIAL NO(S).__________

ITEM	COOLING	HEATING	JOB NUMBER
1. HEAD PRESSURE			NAME OF INSTALLER
2. SUCTION PRESSURE			NAME OF OWNER
3. WATER TEMP.(IN)			ADDRESS
4. WATER TEMP. (OUT)			CITY STATE
5. WATER PRESSURE (IN)			
6. WATER PRESSURE (OUT)			FIELD COMMENTS:
7. WATER FLOW (GPM)			
8. AMPERES (BLOWER)			
9. AMPERES (COMPRESSOR)			
10. LINE VOLTAGE (COMPRESSOR RUNNING)			
11. AIR TEMP.(IN) D.B.			
W.B.			
12. AIR TEMP.(OUT) D.B.			
W.B.			
13. DESUPERHEATER H_2O TEMP. (IN)			
14. DESUPERHEATER H_2O TEMP. (OUT)			

This PERFORMANCE CHECK SHEET should be filled out by installer and retained with unit.

Bard Manufacturing Company
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Bryan, Ohio 43506

TYPICAL INSTALLATION RECOMMENDATIONS

Typical installation examples are illustrated in Figures 22 and 23 for both vertical and horizontal applications. It is particularly important, because of the required water lines, that access panels and water valves be unobstructed. Also note the use of plastic water lines to eliminate transmission of noise and vibration to the building structure. (see Equipment Installation Instructions for specifics).

FINAL CHECK LIST

Before starting unit after installation or servicing, check the following:

1. Proper voltage to unit.
2. Correct fuse sizes.
3. Tight electrical connections.
4. Water system clean and flushed.
5. Air purged from water system.
6. Adequate water flow and pressure to the unit.
7. Water temperature between 45 degrees F and 95 degrees F.
8. Condensate line clear and unclogged.
9. Blower wheel free to rotate.
10. Return air filter is installed.
11. Access panels and enclosures are installed and secured.
12. Thermostat on "Off" position.

To start and check balance the unit, see the "Sequence of Operation" and "System Start Up Procedures" in the installation instructions for the particular unit being serviced.

To check the capacity of a water source heat pump for correct refrigerant charge without installing a gauge manifold, do the following:

<u>Heating Cycle</u>.

Total Btuh Output = Water Coil Btuh + Motor Btuh

Step 1. Water Coil Btuh = GPM x 500 x ΔT °F drop

or (GPM x 60 min. x 8.33 xΔT °F drop)

or (Lbs. of H_2O xΔT °F drop)

BTUH = Capacity of water transfer coil in British Thermal Units per hour.

ΔT = Temperature difference °F, entering to leaving water.

GPM = Flow rate of the water in gallons per minute.

8.33 = Conversion factor to convert gallons of water to pounds of water.

60 = Number of minutes in one hour (omit if flow rate is expressed in gallons per hour)

Step 2. Motor Btuh = Volts x amps x .9 (power factor) x 3.413

Step 3. Water Coil Btuh + Motor Btuh = Total Btuh heating*

Step 4. Air Flow (CFM) = $\frac{\text{Total Btuh heating}}{\Delta T\ °F \text{ rise x } 1.1}$

*The total Btuh for heat pump should be within 10% of the rated capacity for the unit, at the entering water temperature (see unit specification sheet).

INSTALLATION OF RECOMMENDED PIPING TO AND FROM A WATER SOURCE HEAT PUMP TO ENABLE SERVICE MAN TO PROPERLY TROUBLESHOOT THE UNIT'S OPERATION.

Refer to piping Figure 24, Test Points (6) and (7), to measure water temperature and water pressure entering and leaving the unit, must be included in the piping installation. Either the self-sealing threaded test plugs (available from Bard) or more conventional gauge tees and thermometer wells can be used. These test points will aid in the initial start-up of the equipment as well as in the future service work. Water regulating valves 1 and 2, are required on all ground water heat pump installations and on all installations having a hot water desuperheater. These valves insure that the proper water flow is maintained to the heat pump in response to variations in the refrigerant pressure. Two valves are manifolded together as shown in Figure 24. One valve, V46AC, opens in response to an increase in discharge pressure during the cooling cycle. The other valve, V46NC, opens in response to a decrease in suction pressure during the heating cycle. One valve only opens during cooling, the other valve only opens during heating. The valves should be installed on the LEAVING SIDE of the unit as shown. The reason for this location is to maintain pressure on the water system (including the unit water coil) when the unit shuts down. Constant water pressure will help prevent solids, dissolved in the water, from precipitating and causing scaling.

The figure shows the use of shut-off valves (9) and (11), on the IN and OUT water lines to permit isolation of the unit from the plumbing system should future service work require this. Globe valves should not be used as shut off valves because of the excessive pressure drop inherent in the valve design. Instead use gate or ball valves as shut-offs so as to minimize pressure drop.

Drain cocks, (8) and (10), and tees have been included to permit acid cleaning the refrigerant-to-water coil should such cleaning be required. See WATER CORROSION.

TROUBLESHOOTING

THE ANSWER IS Y E S

The question is "do these units require service"? The answer, of course is yes, and as with air-to-air systems or conventional air conditioning systems, troubleshooting is best accomplished by following a planned procedure. The recommended approach to isolating a malfunctioning component in a water-to-air heat pump system is illustrated on the ensuing pages of this text. They should be scrutinized closely, for in the field of heat pump service, troubleshooting without a plan of action, is instead, shooting for trouble...from the owner, especially if repeat calls are involved.

MAINTENANCE PROCEDURES

Proper, regularly scheduled maintenance is important to insure the most efficient operation and longest life for your equipment. The following points are to serve as a general guide. Always consult with your maintenance contractor with regard to the specific requirements of your own installation.

a. Filters — Check the air filters once each month. Wash as required.
b. Bearings — Only sealed bearings are used in the evaporator blower motors. Therefore, bearing oiling is not required.
c. Paint Finish — If paint lifting or peeling occurs, scrape and sand the effected area and touch up with paint obtained from the factory for this purpose.
d. Water system — The pump should be checked whenever filters are cleaned, to assure that it is operating normally. Clogged coils lead to high head pressures and inefficient operation. If coil is limed, acid treatment may be necessary. Condenser coils should be checked yearly for liming or clogging.
e. Refrigerant Pressure — Check at any time unit does not seem to be performing at top efficiency. These should be checked only by a competent service contractor.

MAINTENANCE PROCEDURES (Cont)

f. Contactor Points — Check contactor points twice a year to be sure they are not burned or pitted as a result of low voltage, lightning strikes, or other electrical difficulties.

g. Condensate Drains — Always check to see that condensate is draining properly from the unit, whenever you check the filters.

h. Evaporator Fans — Be alert for any noise that would indicate blower wheel, loose or motors failing.

i. Condensate Drain Pan — Each 6 months, clean and flush evaporator condensate drain pan.

TROUBLESHOOTING PROBLEMS IN WATER-TO-AIR HEAT PUMP SYSTEMS

A. COMPLAINT — Unit Won't Run.

Possible Causes/Corrective Measures

Blown Fuse(s)....Replace fuse(s) or reset circuit breaker.

Supply Voltage Low....If voltage is below minimum voltage specified on dataplate, contact local power company.

Broken or Loose Wires....Replace or tighten wires.

Low Voltage Circuit Malfunction....Check 24 volt transformer for burnout or voltage of less than 18 volts.

B. COMPLAINT — Blower Runs, Compressor Does Not.

Possible Causes/Corrective Measures.

Thermostat Malfunction....Check setting, calibration, and wiring. Replace if defective.

Wiring....Check for loose or broken wires at compressor, capacitor, and/or contactor.

High or Low Pressure Controls....The unit could be off on the high or low pressure cut out control. Reset the thermostat to "OFF". After a few minutes turn to "COOL". If compressor runs, unit was off on high or low pressure (see further complaints for possible causes).

If unit still fails to run, check for faulty pressure switch(es) by jumpering controls individually momentarily. If unit runs, replace pressure control found to be faulty.

Defective Lockout Relay....Check to see if stuck open and does not reset when power is turned on. If bound up and cannot be freed, replace faulty relay as required.

Defective Capacitor....Check capacitor. If defective, remove, replace and reconnect correctly.

Compressor Overload Open....In all cases an "external" or "internal" temperature sensitive compressor overload is used. If the compressor dome is too hot to touch, the overload device will not reset until the compressor cools. If the compressor IS cool, and the overload has not reset itself, the problem could be a defective device. If the overload is defective and is external, replace it, otherwise replace the compressor.

Compressor Motor Grounded....If internal winding is found to be grounded to the compressor shell, replace the compressor. If a burn-out has taken place, replace compressor, following standard burn-out procedure including installation of filter-drier in suction line at compressor.

Compressor Winding Open....Check continuity of compressor windings with an Ohmmeter. If a winding is open, replace compressor.

Seized Compressor....Try an auxiliary capacitor in parallel with the run capacitor momentarily. If the compressor starts but the problem reoccurs on starting, install an auxiliary start kit. The "Hard Start" kit is comprised of a recommended start relay and a correctly sized capacitor. If the compressor still **does not start,** replace the compressor.

C. COMPLAINT — Unit Off on High Pressure Control.

Possible Causes / Corrective Measures

Discharge Pressure Too High....If system is on COOLING cycle, problem is generally lack of, or inadequate water flow. Entering water too warm. Scaled or plugged condenser. The answer, obviously, is to either correct the water supply problem or clean the condenser, as findings dictate.

If the system is on HEATING cycle, the cause is generally lack of, or inadequate air flow. Entering air too hot. Blower inoperative, filter is clogged, or there is a restriction(s) in coil air passages or in ductwork. Take corrective steps findings dictate.

Refrigerant Overcharge....If unit is found to be overcharged, bleed off refrigerant, evacuate and recharge with specified weight of proper refrigerant.

Defective High Pressure Cutout....If control is found to be stuck open or will not reset, a replacement switch is necessary. When it is necessary to replace either of the pressure switches or the reversing valve, wrap them with a wet cloth and direct heat away from the metal body. Excessive heat can seriously damage these components.

D. COMPLAINT — Unit Off On Low Pressure Control

Possible Cause / Corrective Measures

Suction Pressure Too Low....If on COOLING, problem could be lack of, or inadequate airflow. If belt drive, check belt(s). Entering air could be too cold. Blower could be inoperative. Clogged filter or coil, restriction in ductwork. If on HEATING, lack of, or inadequate water flow could be the cause, or entering water is too cold. Water coil could be scaled or plugged.

When installed in an unconditioned space (never install in a space where temperatures are below 40°F or water pipes will freeze), such as a garage, the unit may not start in cold weather, (approximately 50°F). In this case, it may be necessary to start the unit on cooling in cool weather and let run for three to five minutes. Then shut it off and turn to heat after a one minute shutdown. (It may be necessary to repeat this procedure several times).

Refrigerant Charge....Unit is low on refrigerant. Locate leak(s), repair, evacuate and recharge with specified weight of correct refrigerant.

Defective Low Pressure Switch....Stuck open or does not reset. A replacement is required. The control is to be replaced directly in the suction line, it should be wrapped with a wet cloth and when soldering, heat should be directed away from the control, as excessive heat can damage the pressure switch bellows.

E. COMPLAINT — Unit Short Cycles.

Possible Cause / Corrective Measures

Malfunction Thermostat....The differential is set too close on the thermostat. Readjust heat anticipator.

Wiring and Controls....Loose connections in the wiring or control contactors are defective. Correct as findings dictate.

Compressor Overload....Defective compressor overload, check and replace if necessary. If compressor runs too hot, check for a deficient refrigerant charge.

F. COMPLAINT — Insufficient Cooling or Heating.

Possible Cause / Corrective Measures

Unit Undersized....Recalculate heat gain/losses for space to be conditioned. If excessive, try to rectify by adding insulation, shading, etc.

Loss of Conditioned Air Through Leaks....Check for leaks in ductwork or introduction of ambient air through doors and windows.

Thermostat....Improperly located thermostat (eg., near kitchen, sensing inaccurately the comfort level in living area).

F. COMPLAINT — Insufficient Cooling or Heating (Cont)

Air Flow....Lack of adequate air flow or improper distribution of air. Check belt tensions or duct sizing. Check the air filter. it should be inspected every month, changed if dirty or washed if it is a permanent type.

Refrigerant Charge....Low on refrigerant charge, causing inefficient operation.

Blower Running Backwards....Reverse the two blower motor capacitor leads. This situation is not unusual on three phase systems when repairs to an outside transformer or other Utility Co. equipment results in a switching of phases. If reversal is for this reason, it can be easily corrected by reversing any two (2) of the three supply wires on the motor.

Water....Lack of sufficient pressure, temperature, and/or quantity of water. Possible scaling in the condenser, (refer to cleaning and de-scaling methods), or well and plumbing problems, see your well driller.

Compressor....Check for defective compressor. If discharge pressure is too low and suction pressure too high, compressor is not pumping properly. Replacement recommended.

Reversing Valve....Defective reversing valve creating bypass of refrigerant from discharge to suction side of compressor. When it is necessary to replace the reversing valve, wrap it with a wet cloth and direct heat of soldering or brazing away from the valve body. Excessive heat could seriously damage the valve.

Operating Pressure....Incorrect operating pressure (see Refrigerant Pressure Tables for particular unit in installation instructions).

Refrigerant System....Check strainer and capillary tubes for possible restrictions to flow of refrigerant. The refrigerant system may be contaminated with moisture, non-condensables and particles. Dehydrate, evacuate and recharge the system.

G. COMPLAINT — Noisy Operation.

Possible Cause / Corrective Measures

Rattles and Vibration....Check for loose screws, panels or internal components. Tighten and secure. Copper piping could be hitting the metal surfaces. Carefully readjust by bending slightly.

Airborne Noise and Other Sounds....Undersized ductwork will cause high airflow velocities and noisy operation. Excessive water through the water-cooled heat exchanger will cause a rattling sound. Throttle back on the water flow maintaining adequate flow for good operation but eliminating the noise.

Compressor....Make sure the compressor is not in direct contact with the base or sides of the cabinet. The hold down bolts used for shipping should be loosened so that the compressor is floating free on its isolator mounts. Excessive noise will occur if the compressor has a broken valve or loose discharge tube. Replace the compressor.

Blower and Blower Motor....Blower wheel hitting the casing. Adjust for clearance and alignment. Bent blower; check and replace if damaged. Loose blower wheel on shaft. Check and tighten. Defective bearings; check and replace. It is good practice to inspect for belt (on existing furnace installations) wear and tension at this time. If the belt is excessively tight, there will be excessive heat generated in the bearings and ultimate failure.

Contactors....A "clattering" noise in the contactor could be due to control voltage less than 18 volts. Check for low supply voltage, low transformer output or extra long runs of thermostat wires. If the contactor contacts are pitted or corroded or coil is defective, repair or replace. Humming noise caused by stuck armature.

Water....If water hammer is indicated, reduce water pressure to minimum operating pressure if a water pressure regulating valve is used. It is suggested that such a valve always be incorporated in the system. You may also have undersized piping system.

H. COMPLAINT — Water Leak

Possible Cause / Corrective Measures

Plugged Condensate Drain....Condensate drains pick up dirt or algae can grow causing the drain outlet to clog and condensate to overflow. Inspect and clean as required.

Unit Not Level....Check level of the unit and adjust as required to correct problem.

I. COMPLAINT — Unit Heats Only

Possible Cause / Corrective Measures

Reversing Valve Not Shifting....The solenoid valve may not be energized due to miswiring at the unit or the thermostat. The valve could be stuck. The thermostat may be in the heat position. Check and correct condition(s) indicated by findings.

OPERATING PRESSURES AND TEMPERATURES

The example Heat Pump is a factory charged unit. However, in cases of service or replacement of major components it will be necessary to recharge the unit. Prior to recharging the system the following steps are recommended:

1. Pressure test with dry refrigerant. Locate and repair all leaks.

2. Evacuate the system to less than 1000 microns, using a good vacuum pump and an accurate high vacuum gauge. Operate the pump at 1000 microns, or less, for several hours and then allow the system to stand for several additional hours to be sure the vacuum is maintained.

3. An alternate method of removing moisture and non-condensables from the system is:

   a. Evacuate system to 29 inches for ten minutes per ton of system. Break vacuum with refrigerant to be used for final charging of system and vapor charge to 35-50 lbs. gauge pressure. Leave vapor charge in system for a minimum of five minutes. Reduce pressure to five to zero gauge pressure.

   b. Repeat step (a) two more times.

   c. Evacuate system to 30 inches vacuum for twenty minutes per ton. Charge system with the specified kind and quantity of refrigerant (charge into vacuum)

   NOTE: At no time use the compressor to evacuate the system or any part of it.

4. Disconnect charging line at vacuum pump and connect to refrigerant supply. (Dial-A-Charge Cylinder) crack valve and purge charging line at center on manifold. Then close valve.

5. The system is now ready for the correct operating charge of Refrigerant 22.

6. Charge unit with the quantity of Refrigerant 22 as specified in ounces on the dataplate. Do not attempt to charge the unit by running the machine and measuring the ampere draw to full load conditions.

There are many variables (airflow, air temperatures) in heat pump system that will affect operating refrigerant pressures and temperatures. Table 8.13 shows approximate conditions and is based on airflow at the rated CFM.

For abnormal pressures refer to the Refrigerant Pressure Table for unit being serviced.

A machine that is normally operating well on cooling cycle will have a warm (to touch) compressor dome and cool crankcase at the suction port. If crankcase and dome are very hot (to touch) there is an indication of insufficient charge. On the other hand, if crankcase and dome are very cold or frosting, the unit is likely to be overcharged.

QUICK REFERENCE TROUBLE-SHOOTING CHART FOR WATER TO AIR HEAT PUMP

Bard® SINCE 1914

DENOTES COMMON CAUSE ●

DENOTES OCCASIONAL CAUSE ▲

POSSIBLE CAUSE: POWER SUPPLY

Cycle	Problem Condition	Line Voltage: Power Failure	Line Voltage: Blown Fuse or Tripped Breaker	Line Voltage: Faulty Wiring	Line Voltage: Loose Terminals	Line Voltage: Low Voltage	Line Voltage: Defective Contacts in Contactor	Line Voltage: Compressor Overload	Line Voltage: Potential Relay	Line Voltage: Run Capacitor	Line Voltage: Start Capacitor	Control Circuit: Faulty Wiring	Control Circuit: Loose Terminals	Control Circuit: Control Transformer	Control Circuit: Low Voltage	Control Circuit: Thermostat	Control Circuit: Contactor Coil	Control Circuit: Pressure Controls (High or Low)	Control Circuit: Indoor Blower Relay
HEATING OR COOLING CYCLES	COMPRESSOR WILL NOT RUN NO POWER AT CONTACTOR	●	●	●	●		▲	▲				●	●	●	▲	▲	●	●	
	COMPRESSOR WILL NOT RUN POWER AT CONTACTOR			●	●	●		●	●	●	●								
	COMPRESSOR "HUMS" BUT WILL NOT START			●	●	●	▲		●	●	●								
	COMPRESSOR CYCLES ON OVERLOAD			●	●	●	▲	●	●	●	●								
	THERMOSTAT CHECK LIGHT LITE-LOCKOUT RELAY																	●	
	COMPRESSOR OFF ON HIGH PRESSURE CONTROL																	▲	●
	COMPRESSOR OFF ON LOW PRESSURE CONTROL																		▲
	COMPRESSOR NOISY																		
	HEAD PRESSURE TOO HIGH																		
	HEAD PRESSURE TOO LOW																		
	SUCTION PRESSURE TOO HIGH																		
	SUCTION PRESSURE TOO LOW																		
	I.D. BLOWER WILL NOT START	●	●	●	●							●	●	●	▲	▲			●
	I.D. COIL FROSTING OR ICING																		
	HIGH COMPRESSOR AMPS					●				●									
	EXCESSIVE WATER USAGE																		
COOLING CYCLE	COMPRESSOR RUNS CONTINUOUSLY—NO COOLING																		
	LIQUID REFRIGERANT FLOODING BACK TO COMPRESSOR																		
HEATING CYCLE	COMPRESSOR RUNS CONTINUOUSLY—NO HEATING																		
	REVERSING VALVE DOES NOT SHIFT			●	●														
	LIQUID REFRIGERANT FLOODING BACK TO COMPRESSOR																		
	AUX. HEAT ON I.D. BLOWER OFF			●	●							●	●			▲			●
	EXCESSIVE OPERATING COSTS			▲	▲											▲			
	ICE IN WATER COIL			▲	▲														

POSSIBLE CAUSE: WATER COIL SECTION

Problem Condition	Compressor: Disch. Line Hitting Inside of Shell	Compressor: Bearings Defective	Compressor: Seized	Compressor: Valve Defective	Compressor: Motor Windings Defective	Refrigerant System: Refrigerant Charge Low	Refrigerant System: Refrigerant Overcharge	Refrigerant System: High Head Pressure	Refrigerant System: Low Head Pressure	Refrigerant System: High Suction Pressure	Refrigerant System: Low Suction Pressure	Refrigerant System: Non-Condensables	Refrigerant System: Unequalized Pressures
COMPRESSOR WILL NOT RUN NO POWER AT CONTACTOR													
COMPRESSOR WILL NOT RUN POWER AT CONTACTOR		▲	●		●								●
COMPRESSOR "HUMS" BUT WILL NOT START		●	●		●								●
COMPRESSOR CYCLES ON OVERLOAD		▲		▲	▲	●	●	▲		▲		●	
THERMOSTAT CHECK LIGHT LITE-LOCKOUT RELAY													
COMPRESSOR OFF ON HIGH PRESSURE CONTROL							●					●	
COMPRESSOR OFF ON LOW PRESSURE CONTROL						●			●		●		
COMPRESSOR NOISY	▲	▲		●									
HEAD PRESSURE TOO HIGH							●					●	
HEAD PRESSURE TOO LOW				●		●					●		
SUCTION PRESSURE TOO HIGH				●			●	●					
SUCTION PRESSURE TOO LOW						●			▲				
I.D. BLOWER WILL NOT START													
I.D. COIL FROSTING OR ICING						●					●		
HIGH COMPRESSOR AMPS		●	●		▲		●	●		●		●	
EXCESSIVE WATER USAGE													
COMPRESSOR RUNS CONTINUOUSLY—NO COOLING				●		●					●		
LIQUID REFRIGERANT FLOODING BACK TO COMPRESSOR (COOLING)							●	●					
COMPRESSOR RUNS CONTINUOUSLY—NO HEATING				●		●					●		
REVERSING VALVE DOES NOT SHIFT						▲			▲				
LIQUID REFRIGERANT FLOODING BACK TO COMPRESSOR (HEATING)							●	●					
AUX. HEAT ON I.D. BLOWER OFF													
EXCESSIVE OPERATING COSTS						●	●						
ICE IN WATER COIL						●							

Problem Condition	Water Reg. Valve: Water Reg. Valve Stuck Closed (HTG)	Water Reg. Valve: Water Reg. Valve Stuck Closed (CLG)	Water Reg. Valve: Water Reg. Valve Stuck Open (HTG or CLG)	Rev. Valve: Leaking	Rev. Valve: Defective Valve or Coil	Check Valve: Sticking Closed	Check Valve: Leaking or Defective	Water Coil: Plugged or Restricted Cap Tube (HTG)	Water Coil: Scalled or Plugged Coil (HTG)	Water Coil: Scalled or Plugged Coil (CLG)	Water Coil: Water Volume Low (HTG)	Water Coil: Water Volume Low (CLG)	Water Coil: Low Water Temperature (HTG)
COMPRESSOR WILL NOT RUN NO POWER AT CONTACTOR													
COMPRESSOR WILL NOT RUN POWER AT CONTACTOR													
COMPRESSOR "HUMS" BUT WILL NOT START													
COMPRESSOR CYCLES ON OVERLOAD				▲					▲	▲	▲	▲	
THERMOSTAT CHECK LIGHT LITE-LOCKOUT RELAY													
COMPRESSOR OFF ON HIGH PRESSURE CONTROL		●				●		▲		▲		●	
COMPRESSOR OFF ON LOW PRESSURE CONTROL	●		▲						▲		●		▲
COMPRESSOR NOISY													
HEAD PRESSURE TOO HIGH		●			▲	▲		▲		●		●	
HEAD PRESSURE TOO LOW	▲		▲	▲			▲		●		●		●
SUCTION PRESSURE TOO HIGH				▲			▲						
SUCTION PRESSURE TOO LOW	●					▲		▲	●		●		▲
I.D. BLOWER WILL NOT START													
I.D. COIL FROSTING OR ICING						▲							
HIGH COMPRESSOR AMPS						▲		▲		●		●	
EXCESSIVE WATER USAGE			●						▲	▲			
COMPRESSOR RUNS CONTINUOUSLY—NO COOLING										▲		▲	
LIQUID REFRIGERANT FLOODING BACK TO COMPRESSOR (COOLING)													
COMPRESSOR RUNS CONTINUOUSLY—NO HEATING	●			▲				▲	●		●		▲
REVERSING VALVE DOES NOT SHIFT					●								
LIQUID REFRIGERANT FLOODING BACK TO COMPRESSOR (HEATING)	●			▲	▲				●		●		●
AUX. HEAT ON I.D. BLOWER OFF													
EXCESSIVE OPERATING COSTS	▲	▲	▲	●	●				▲	▲	▲		
ICE IN WATER COIL	●				●				▲		●		

POSSIBLE CAUSE: INDOOR SECTION / AUX. / GEN.

Problem Condition	Indoor Blower Motor & Coil: Plugged or Restricted Cap Tube (CLG)	Indoor Blower Motor & Coil: Fins Dirty or Plugged	Indoor Blower Motor & Coil: Motor Winding Defective	Indoor Blower Motor & Coil: Air Volume Low	Indoor Blower Motor & Coil: Air Filters Dirty	Indoor Blower Motor & Coil: Undersized or Restricted Ductwork	Check Valve: Sticking Closed	Check Valve: Leaking or Defective	Aux. Heat: Aux. Heat Upstream of Coil	Aux. Heat: Outdoor Thermostat (Split System)	Gen.
COMPRESSOR WILL NOT RUN NO POWER AT CONTACTOR											
COMPRESSOR WILL NOT RUN POWER AT CONTACTOR											
COMPRESSOR "HUMS" BUT WILL NOT START											
COMPRESSOR CYCLES ON OVERLOAD		▲	▲	▲	●	▲					
THERMOSTAT CHECK LIGHT LITE-LOCKOUT RELAY											
COMPRESSOR OFF ON HIGH PRESSURE CONTROL	▲	●	●	●	●	●	●		●		
COMPRESSOR OFF ON LOW PRESSURE CONTROL	●										
COMPRESSOR NOISY											
HEAD PRESSURE TOO HIGH	▲	▲	▲	●	●	▲	▲		●		
HEAD PRESSURE TOO LOW								▲			
SUCTION PRESSURE TOO HIGH								▲			
SUCTION PRESSURE TOO LOW	▲	●	▲	●	●	▲	▲				
I.D. BLOWER WILL NOT START											
I.D. COIL FROSTING OR ICING	▲	●	●	●	●	▲					
HIGH COMPRESSOR AMPS	▲	●	●	●	●	▲	▲		▲		
EXCESSIVE WATER USAGE											
COMPRESSOR RUNS CONTINUOUSLY—NO COOLING	▲	●	●	●	●	▲					
LIQUID REFRIGERANT FLOODING BACK TO COMPRESSOR (COOLING)		●	●	●	●	▲		▲			
COMPRESSOR RUNS CONTINUOUSLY—NO HEATING											
REVERSING VALVE DOES NOT SHIFT											
LIQUID REFRIGERANT FLOODING BACK TO COMPRESSOR (HEATING)											
AUX. HEAT ON I.D. BLOWER OFF			●								
EXCESSIVE OPERATING COSTS		▲	▲	▲						●	
ICE IN WATER COIL											

WATER SUPPLY

It is important to have water with enough pressure to insure the proper flow for the unit, and purity to prevent scaling which impedes heat transfer and reduces efficiency. Insufficient water, in the heating mode for example, particularly at low water temperatures, will cause the low pressure control to trip, shutting down the heat pump. In assessing the capacity of the water system, it is advisable that the complete water system be evaluated to prevent possible lack of water or water pressure at various household fixtures whenever the heat pump turns on. All plumbing to and from the unit is to be installed in accordance with local plumbing codes. The use of plastic pipe, where permissible, is recommended to prevent electrolytic corrosion of the water pipe. Because of the relatively cold temperatures encountered with well water, it is strongly recommended that the water lines connecting the unit be insulated to prevent water droplets from condensing on the pipe surface.

Bard high efficiency water source heat pumps are designed to be used with ground water in the temperature ranges of 45°F - 75°F. We do not recommend the use of ponds for supply water and have very heavily discouraged people from this type of application due to the severe and large amount of problems encountered. This unit is not designed to be used on lakes, ponds or rivers because in areas where they freeze over, these water temperatures drop to 38°F, which is too cold for the proper operation.

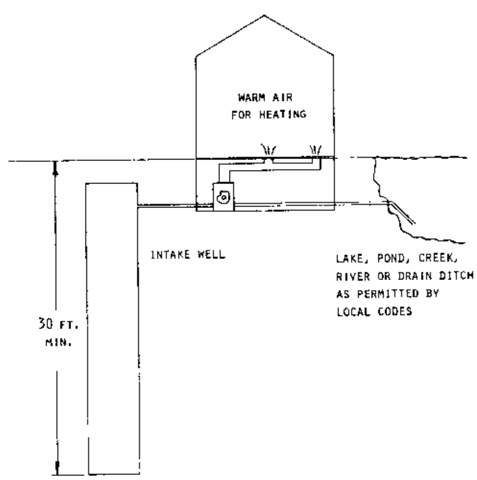
Besides becoming too cold for proper operation of units, the few people who have tried ponds have had considerable problems with dirt, silt, fish, etc., and found it very, very hard to filter.

We recommend the use of lakes, ponds and rivers for disposal of water only.

People have also tried closed loop systems whereby they inserted a long plastic piping system under water to use as a heat sink source. They ran into problems after a period of time with algae and growth on the outside of the plastic piping and losing thermal conductivity. They also encountered problems with anchors from fishing boats pulling up and breaking the plastic pipes.

WATER DISPOSAL METHODS

DISCHARGE TO LAKE OR POND



ADVANTAGES OF LAKE OR POND DISPOSAL

1. Simplicity
2. Low first cost
3. Easy maintenance

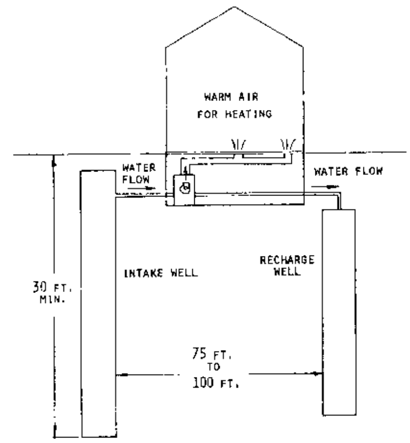
DISADVANTAGES

1. Pond may flood
2. Aquifer may deplete
3. May require large surface area

RECOMMENDATIONS

1. Check soil permeability

TWO WELL INSTALLATION



ADVANTAGES OF RETURN WELL

1. Tidiest method
2. Includes most installations

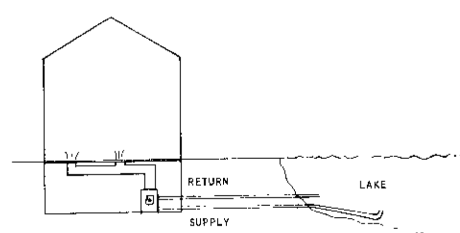
DISADVANTAGES

1. High first cost
2. Subject to clogging
3. Environmentally potential problem
4. Thermal interference between wells

RECOMMENDATIONS

1. Oversize return well
2. Keep pipe pressure loss to a minimum - both wells
3. Space wells adequately - minimum 50 feet
4. Consult a qualified well driller

LAKE AS SUPPLY AND HEAT SINK



NOT RECOMMENDED BY BARD

ADVANTAGES

1. Low cost

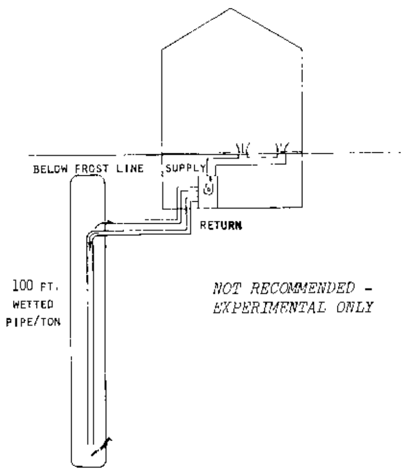
DISADVANTAGES

1. Water must be minimum 45° supplying the unit for heating.
2. Water must be 85° maximum supplying the unit for cooling.
3. Site selective
4. Thermal interference
5. Subject to plugging

RECOMMENDATIONS

1. Screen over intake and discharge
2. Spacing between intake and discharge
3. At least 5 acres for a 3-ton unit
4. Average depth 18 feet or more
5. Intake below 15 foot level

SINGLE WELL CLOSED LOOP INSTALLATION



WELL PUMP SIZING

Strictly speaking, sizing the well pump is the responsibility of the well drilling contractor. It is important, however, that the HVAC contractor be familiar with the factors that determine what size pump will be required. Rule of thumb estimates will invariably lead to under or oversized well pumps. Undersizing the pump will result in inadequate water to the whole plumbing system but with especially bad results to the heat pump—NO HEAT/NO COOL calls will result. Oversized pumps will short cycle and could cause premature pump motor or switch failure.

The well pump must be capable of supplying enough water and at an adequate pressure to meet competing demands of water fixtures. The well pump must be sized in such a way that three requirements are met:

1. Adequate flow rate in gpm.
2. Adequate pressure at the fixtures.
3. Able to meet the above from the depth of the well-feet of lift.

The pressure requirements put on the pump are directly affected by the diameter of pipe being used as well as by the water flow rate through the pipe. The worksheet included in these instructions should guarantee that the well pump has enough capacity. It should also ensure that the piping is not undersized which would create too much pressure due to friction loss. High pressure losses due to undersized pipe will reduce efficiency and require larger pumps and could also create water noise problems.

The worksheet assumes a residence having a submersible pump and three branches in the water system, (1) well pump to the pressure tank branch,(2) the household plumbing branch, and (3) the water source heat pump branch. If your installation requires more branches (and therefore more peak demand for water flow), these additional branches must be included in the calculations for sizing the well pump.

Most household water systems will require 30 psig pressure to work dishwashers, clotheswashers, etc. It is reasonable to assume a 30 psig pressure requirement for the household and avoid pipe sizing calculations for an entire household plumbing system.

Most well systems include a pressure storage tank connected to the well pump. The purpose of this tank is to maintain adequate pressure for the plumbing while avoiding turning on the well pump every time a small amount of water is required.

Hydropneumatic water storage tanks should not be used. These tanks are partially filled with air which is compressed as the water is pumped into the tank. Thus, the compressed air maintains a constant pressure on the water. However, air under pressure will dissolve into the water requiring more and more water to maintain pressure. Additionally, the air and water mixture can be somewhat more corrosive.

Instead, diaphragm or bladder type pressure tanks must be installed. This type of tank separates the water from the air with a heavy rubber diaphragm inside the metal tank and prevents the water and compressed air from mixing.

The pressure tank setting of the water storage tank should be selected to provide adequate pressure for that branch of the water system having the highest pressure requirement. This could be the household plumbing branch or the heat pump branch.

TABLE 8.4

Water Uses	Peak Demand Allowance for Pump gpm Column 1	Individual Fixture Flow Rate gpm Column 2
Household Uses		
Bathtub or tub-and-shower combination	2.00	8.0
Shower only	1.00	4.0
Lavatory	.50	2.0
Toilet—flush tank	.75	3.0
Sink, kitchen—including garbage disposal	1.00	4.0
Diswasher	.50	2.0
Laundry Sink	1.50	6.0
Clothes Washer	2.00	8.0
Irrigation, Cleaning and Miscellaneous		
Lawn irrigation (per sprinkler)	2.50	5.0
Garden irrigation (per sprinkler)	2.50	5.0
Automobile washing	2.50	5.0
Tractor and equipment washing	2.50	5.0
Flushing driveways and walkways	5.00	10.0
Cleaning milking equipment & milk storage tank	4.00	8.0
Hose cleaning barn floors, ramps, etc.	5.00	10.0
Swimming pool (initial filling)	2.50	5.0

TABLE 8.8

FRICTION LOSSES THROUGH FITTINGS
IN TERMS OF EQUIVALENT LENGTHS OF PIPE

Type Fitting & Application	Pipe & Ftg. Material (Note 1)	Equivalent Length of Pipe Nominal Size Fitting & Pipe 1/2	3/4	1	1¼	1½	2	2½
Insert Coupling	Plastic	3	3	3	3	3	3	3
Threaded Adapter Plastic or Copper to Thread	Copper Plastic	1 3	1 3	1 3	1 3	1 3	1 3	1 3
90° Standard Elbow	Steel Copper Plastic	2 2 4	3 3 5	3 3 6	4 4 7	4 4 8	5 5 9	6 6 10
Standard Tee Flow Thru Run	Steel Copper Plastic	1 1 4	2 2 4	2 2 4	3 3 5	3 3 6	4 4 7	5 5 8
Standard Tee Flow Thru Side	Steel Copper Plastic	4 4 7	5 5 8	6 6 9	8 8 12	9 9 13	11 11 17	14 14 20
Gate Valve	Note (2)	2	3	4	5	6	7	8
Swing Check Valve	Note (2)	4	5	7	9	11	13	16

Friction loss tables for fittings (Table 8.8). Figures given are friction losses in terms of equivalent length (in feet) of straight pipe. Note: (1) Loss figures are based on equivalent lengths of indicated pipe material and (2) Loss figures are for screwed valves and are based on equivalent lengths of steel pipe.

GPM	1/2" ID = .622"				3/4" ID = .824"				1" ID = 1.049"			
	Steel		Plastic		Steel		Plastic		Steel		Plastic	
	Ft	Lbs	Ft	Lbs	Ft	Lbs	Ft	Lbs	Ft	Lbs	Ft	Lbs
2	4.8	2.1	4.1	1.8								
3	10.0	4.3	8.7	3.8	2.5	1.1	2.2	1.0				
4	17.1	7.4	14.8	6.4	4.2	1.8	3.7	1.6				
5	25.8	11.2	22.2	9.6	6.3	2.7	5.7	2.5	1.9	.8	1.8	.8
6	36.5	15.8	31.2	13.5	8.9	3.9	8.0	3.5	2.7	1.2	2.5	1.1
7	48.7	21.1	41.5	18.0	11.8	5.1	10.6	4.6	3.6	1.6	3.3	1.4
8	62.7	27.2	53.0	23.0	15.0	6.5	13.5	5.9	4.5	2.0	4.2	1.8
9	78.3	34.0	66.0	28.6	18.8	8.2	16.8	7.3	5.7	2.5	5.2	2.3
10	95.9	41.6	80.5	34.9	23.0	10.0	20.4	8.9	6.9	3.0	6.3	2.7
12					32.6	14.1	28.6	12.4	9.6	4.2	8.9	3.9
14					43.5	18.9	38.0	16.5	12.8	5.6	11.8	5.1
16					56.3	24.4	48.6	21.1	16.5	7.2	15.1	6.6
18					70.3	30.5	60.5	26.3	20.6	8.9	18.7	8.1
20					86.1	37.4	73.5	31.9	25.1	10.9	22.8	9.9
22					104.0	45.1			30.2	13.1	27.1	11.8
24									35.6	15.5	31.1	13.5
25									38.7	16.8	34.6	15.0
30									54.6	23.7	48.1	20.9
35									73.3	31.8	64.3	27.9
40									95.0	41.2	82.0	35.6

Areas above the heavy lines are recommended for normal operation.

TABLE 8.6

Friction loss Tables 8.6 and 8.7 for common pipe diameters and materials. Figures given are friction loss in feet of head per one hundred feet of pipe. Doubling the diameter of a pipe increases its capacity four times, not two times.

GPM	1¼" ID - 1.380"				1½" ID = 1.610"				2" ID - 2.067"			
	Steel		Plastic		Steel		Plastic		Steel		Plastic	
	Ft	Lbs	Ft	Lbs	Ft	Lbs	Ft	Lbs	Ft	Lbs	Ft	Lbs
10	1.8	.8	1.7	.7								
12	2.5	1.1	2.3	1.0	1.2	.5	1.1	.5				
14	3.3	1.4	3.1	1.3	1.5	.7	1.4	.6				
16	4.2	1.8	4.0	1.7	2.0	.9	1.9	.8				
18	5.2	2.3	4.9	2.1	2.4	1.1	2.3	1.0				
20	6.3	2.7	6.0	2.6	2.9	1.3	2.8	1.2				
25	9.6	4.2	9.1	3.9	4.5	2.0	4.3	1.9	1.3	.6	1.3	.6
30	13.6	5.9	12.7	5.5	6.3	2.7	6.0	2.6	1.8	.8	1.8	.8
35	18.2	7.9	16.9	7.3	8.4	3.6	8.0	3.5	2.4	1.0	2.4	1.0
40	23.5	10.2	21.6	9.4	10.8	4.7	10.2	4.4	3.1	1.3	3.0	1.3
45	29.4	12.8	28.0	12.2	13.5	5.9	12.5	5.4	3.9	1.7	3.8	1.6
50	36.0	15.6	32.6	14.1	16.4	7.1	15.4	6.7	4.7	2.0	4.6	2.0
60	51.0	22.1	45.6	19.8	23.2	10.1	21.6	9.4	6.6	2.9	6.4	2.8
70	68.8	29.9	61.5	26.7	31.3	13.6	28.7	12.5	8.9	3.9	8.5	3.7
80	89.2	38.7	77.9	33.8	40.5	17.6	36.8	16.0	11.4	5.0	10.9	4.7
90	112.0	48.6	96.6	41.9	51.0	22.1	45.7	19.8	14.2	6.2	13.6	5.9
100	138.0	59.9			62.2	27.0	56.6	24.6	17.4	7.6	16.5	7.2
120					88.3	38.3			24.7	10.7	23.1	10.0
140					119.0	51.6			33.2	14.4	30.6	13.2
160					156.0	67.7			43.0	18.7	39.3	17.1
180									54.1	23.5	48.9	21.2
200									66.3	28.8	59.4	25.8
220									80.0	34.7		
240									95.0	41.2		
260									111.0	48.2		

Areas above the heavy lines are recommended for normal operation.

TABLE 8.7

3.12 - WATER SYSTEM WORKSHEET

(METHOD APPLICABLE TO SUBMERSIBLE PUMPS. CONSULT WELL DRILLER FOR SIZING OF OTHER TYPES OF PUMPS)

A. WELL PUMP SIZING

Branch "A" - Well Pump	-	Piping from pump in well to pressure tank.
Branch "B" - Domestic Water Supply	-	Piping from tank to the fixtures throughout house.
Branch "C" - Heat Pump Water Supply	-	Piping from tank through heat pump coil to drain.

1. Determine household water needs from Table 8.4, Column 1. Enter here. ________ gpm Branch B

2. Enter gpm flow rate for unit to be installed from specifications (water coil rated flow). ________ gpm Branch C

3. Add lines 1 and 2 for total water flow rate required. ________ gpm Branch A

NOTE: IF PIPING LAYOUT HAS MORE BRANCHES, DETERMINE THE FLOW RATE FOR THESE FROM TABLE 8.4, COLUMN 1, AND INCLUDE IN TOTAL.

B. DETERMINING WATER PRESSURE REQUIREMENTS PIPE SIZING FOR EACH PIPE BRANCH—Household plumbing, Branch B, may be assumed to have a total pressure requirement of 30 psig.

	Branch A	Branch C	
4. Tentatively select a pipe size and enter here. Table 8.6 or 8.7.	______	______	inch pipe
5. Consult Table 8.8 and enter equivalent feet of pipe for one elbow of the size selected in step 4 above using gpm of the branch. Enter here.	______	______	equiv. feet
6. From the piping layout, determine the number of elbows needed for the branch. Enter here.	______	______	elbows
7. Multiply line 5 by line 6. Enter total here.	______	______	equiv. feet
8. From piping layout, determine total lineal feet of pipe in the branch. Enter here.	______	______	lineal feet
9. Add lines 7 and 8. Enter here.	______	______	total feet
10. Consult Table 8.6 and 8.7 for total feet (line 9) and total gpm needed (for each branch determined from Section A above) and enter friction loss here.	______	______	ft.hd/100 ft.
11. Multiply line 10 by line 9, divide by 100 and enter here as total piping friction loss.	______	______	ft. hd.
12. Multiply line 11 by 0.433 to convert to psig. Enter here.	______	______	psig
13. Consult manual for the unit to be installed and enter unit pressure drop here. Branch C only. (Water coil pressure drop)		______	psig unit
14. Consult Table 8.10 for the pressure drop of the water regulating valve using the appropriate size and flow rate (line 2). Branch C.		______	psig regulating valves
15. Calculate total pressure drop, Branch C, by adding lines 12, 13 and 14. Enter here. Branch A pressure drop is the same as line 12 Branch A and should be entered here.	______	______	psig

16. From the piping layout, determine parallel flow among the branches. Beginning at the well pump, add the friction loss in psig for the well pump branch (Branch A) to the branch having the higher pressure drop (Branch B or Branch C). Note: If more than three branches are required by the piping layout, select that branch which has the highest pressure drop and add this pressure drop to Branch A. Enter in line 16 the number obtained as total piping pressure loss due to pipe friction. ________ psig

17. To the branch having the higher pressure drop (Branch B or C used in line 16), add 20 psig to obtain the pressure switch cut out point. Enter this value here. ________ psig Tank cut-out setting

18. Pump requirements will be: ________ gpm (line 3) at ________ psig (line 17)
at ________ feet lift (Vertical distance to water in the well)

REFER TO PUMP MANUFACTURER'S TABLE TO ACTUALLY SELECT THE PUMP MODEL BASED ON REQUIREMENTS ENTERED IN LINE 18.

FORM 1001-1081

-OVER-

C. WATER TANK SIZING (Applicable to bladder or diaphragm type tanks only - recommended type).

19. Enter desired minimum off time of the well pump in minutes and fractions of minutes. Never less than two minutes. ____________ minutes

20. Enter pressure switch cut-in point psig. At least as great a pressure as required for Branch B or C. ____________ psig

21. Enter pressure cut-out point psig. Usually 20 psig higher than value in line 20. ____________ psig

CALCULATE TANK SIZE

22. Multiply line 3 by line 19 to determine minimum acceptance volume. ____________ gals.

23. Refer to Table 8.11. Find the tank pressure factor for lines 20 and 21. ____________ P.F.

24. Divide line 22 by line 23 and enter the minimum total tank volume corrected for pressure. ____________ gals.

25. Refer to Table 8.12 and select a tank model that is greater than line 24 for "Total Volume" and equal to or greater than line 25 for "Acceptance Volume." (Refer to water tank manufacturer's specifications).

TABLE 8.10

MINIMUM WATER REGULATING VALVE PRESSURE DROP						
	1/2"		3/4"		1"	
GPM	Psi	Ft.Hd.	Psi	Ft.Hd.	Psi	Ft.Hd.
4	4	9.2	1	2.3	-	-
5	6	13.9	1.3	3.0	-	-
10.6	9.5	22.0	3	6.9	1.5	3.5
12.7	15	34.6	4.2	9.7	2	4.6

TABLE 8.12

TOTAL VOLUME AND ACCEPTANCE VOLUME	
Nominal Tank Size (Total Vol.Gals)	Maximum (Acceptance Volume)
2.0	0.9
4.4	2.4
8.6	3.2
14.0	11.3
20.0	11.3
32.0	11.3
44.0	34.0
62.0	34.0
86.0	34.0

WATER CORROSION

Two concerns will immediately come to light when considering a water source heat pump, whether for ground water or for a closed loop application: Will there be enough water? And, how will the water quality affect the system?

Water quantity is an important consideration and one which is easily determined. The well driller must perform a pump down test on the well according to *methods described by the National Well Water Association*. This test, if performed correctly, will provide information on the rate of flow and on the capacity of the well. It is important to consider the overall capacity of the well when thinking about a water source heat pump because the heat pump may be required to run for extended periods of time.

The second concern, about water quality, is equally important. Generally speaking, if the water is not offensive for drinking purposes, it should pose no problem for the heat pump. The well driller or local water softening company can perform tests which will determine the chemical properties of the well water.

Water quality problems will show up in the heat pump in one or more of the following ways:

1. Increased water flow to the unit.
2. Decreased heat transfer of the water coil (entering to leaving water temperature difference is less).

There are four main water quality problems associated with ground water. These are:

(1) Biological growth. This is the growth of microscopic organisms in the water and will show up as a slimy deposit throughout the water system. Shock treatment of the well is usually required and this is best left up to the well driller. The treatment consists of injecting chlorine into the well casing and flushing the system until all growth is removed.

(2) Suspended particles in the water. Filtering will usually remove most suspended particles (fine sand, small gravel) from the water. The problem with suspended particles in the water is that it will erode metal parts, pumps, heat transfer coils, etc. So long as the filter is cleaned and periodically maintained, suspended particles should pose no serious problem. Consult with your well driller.

(3) Corrosion of metal. Corrosion of metal parts results from either highly corrosive water (acid water, generally not the case with ground water) or galvanic reaction between dissimilar metals in the presence of water. By using plastic plumbing or di-electric unions galvanic reaction is eliminated. The use of corrosion resistant materials (such as the Cupro nickel coil) throughout the water system will reduce corrosion problems significantly.

TABLE 8.11 - PRESSURE FACTORS

PUMP CUT-OUT PRESSURE – PSIG	PUMP CUT-IN PRESSURE – PSIG														
	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90
30	.22														
35	.30	.20													
40	.37	.27	.18												
45	.42	.34	.25	.17											
50	.46	.39	.31	.23	.15										
55	.50	.43	.36	.29	.22	.14									
60	.54	.47	.40	.33	.27	.20	.13								
65		.50	.44	.38	.31	.25	.19	.13							
70		.53	.47	.41	.35	.30	.24	.18	.12						
75			.50	.45	.39	.33	.28	.22	.17	.11					
80			.53	.48	.42	.37	.32	.26	.21	.16	.11				
85				.50	.45	.40	.35	.30	.25	.20	.15	.10			
90				.53	.48	.43	.38	.33	.29	.24	.19	.14	.10		
95					.50	.46	.41	.36	.32	.27	.23	.18	.14	.09	
100					.52	.48	.44	.39	.35	.31	.26	.22	.17	.13	.09

(4) Scale formation. Of all the water problems, the formation of scale by ground water is by far the most common. Usually this scale is due to the formation of calcium carbonate but magnesium carbonate or calcium sulfate may also be present. Carbon dioxide gas (CO_2), the carbonate of calcium and magnesium carbonate, is very soluble in water. It will remain dissolved in the water until some outside factor upsets the balance. This outside influence may be a large change in water temperature or pressure. When this happens, enough carbon dioxide gas combines with dissolved calcium or magnesium in the water and falls out of solution until a new balance is reached. The change in temperature that this heat pump produces is usually not high enough to cause the dissolved gas to fall out of solution. Likewise if pressure drops are kept to a reasonable level, no precipitation of carbon dioxide should occur.

REMEDIES OF WATER PROBLEMS

WATER TREATMENT. Water treatment can usually be economically justified for closed loop systems. However, because of the large amounts of water involved with a ground water heat pump, water treatment is generally too expensive.

ACID CLEANING THE WATER COIL OR HEAT RECOVERY UNIT.

If scaling of the coil is strongly suspected, the coil can be cleaned up with a solution of Sulfamic Acid (toxic) or Phosphoric Acid (food grade acid). Follow the manufacturer's directions for mixing, use, etc. Refer to the, Cleaning Water Coil, Figure 24). The acid solution can be introduced into the heat pump coil through the hose bib (Part 8 of Figure 24). Be sure the isolation valves (Parts 9 and 11 of Figure 24) are closed to prevent contamination of the rest of the system by the coil. The acid should be pumped from a bucket into the hose bib (Part 8, Figure 24) and returned to the bucket through the other hose bib (Part 10, Figure 24). Follow the manufacturer's directions for the product used as to how long the solution is to be circulated, but it is usually circulated for a period of several hours.

UNDER NO CIRCUMSTANCES SHOULD THE HEAT PUMP BE OPERATED IN SUCH A WAY AS TO FREEZE THE COIL IN AN ATTEMPT TO BREAK SCALE FREE.

While no damage is expected to be done to the coil from freezing, undue strain is put on the refrigeration system and this practice should not be attempted.

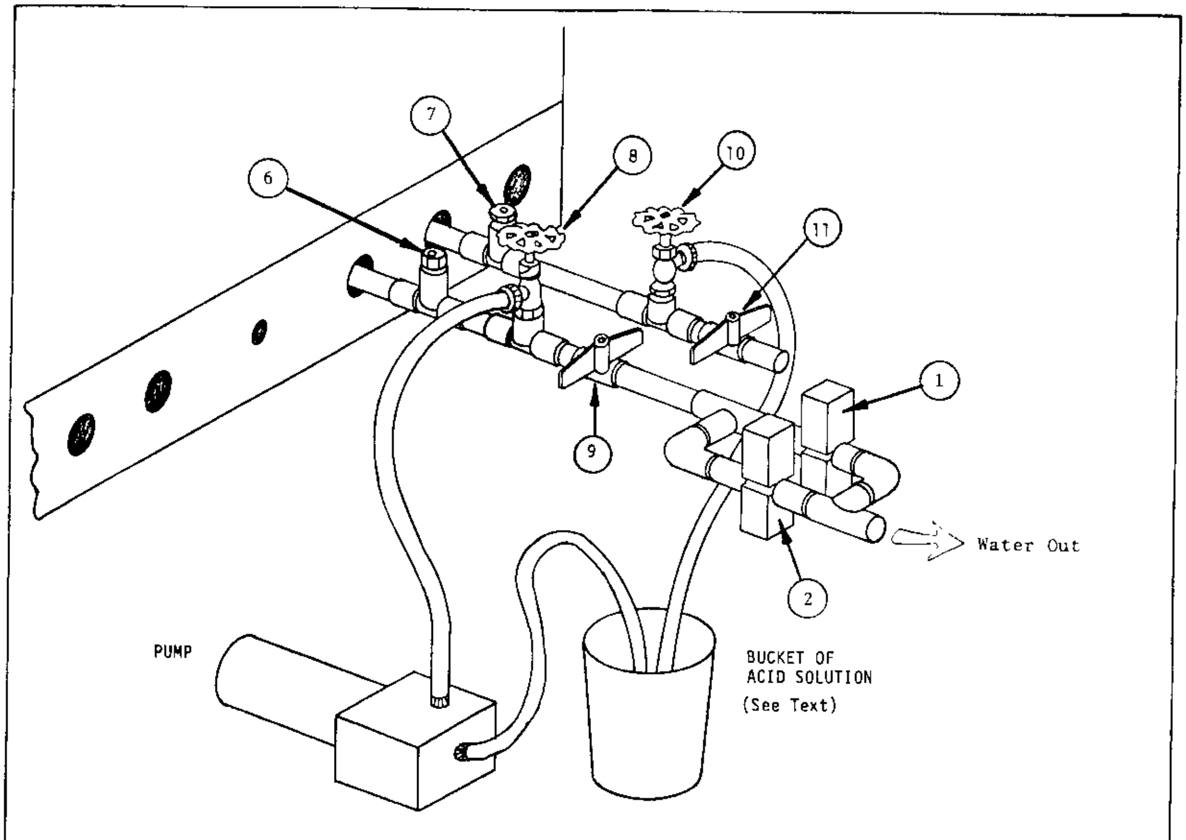


Figure 24