

Air Management Sizing And Installation Instructions For Hydronic Heating/Cooling Systems

NOT FOR DOMESTIC (POTABLE) WATER SYSTEMS

INTRODUCTION

Hydronics is the science of heating and cooling with liquids. The liquid which is still the most practical and economical heat transfer medium is water.

Today's hydronic system is best considered a heat transfer machine where the heat transfer medium is used to carry heat to or from an area in accordance with the controls installed. Once the requirements of the structure are determined the versatility of the hydronic system is limited only by the imagination of the designer. Only a few basic fundamentals must be followed to enable the designer to do virtually anything with the heat transfer ability of a hydronic system. It matters not whether the system is the largest multi-building project supplied by a central mechanical plant, or the smallest residence, the basic fundamentals apply.

The purpose of this technical manual is to examine the important points of these basic design fundamentals with regard to air management systems. Every design engineer is concerned with having the completed installation perform as intended. Every owner is concerned with having trouble free, quiet and economical operation with a minimum of maintenance. However, any heating, cooling or dual hydronic system installed without effective air management will provide ample reason for concern. Air bound circuits, questionable hydraulics, noisy operation, poor efficiency and short system life are the result of inadequate air management.

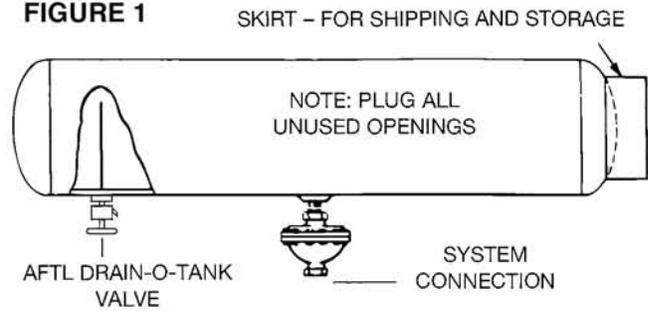
The air in a closed hydronic system is managed by using one of two techniques. In the Air Control method the air cushion and system water actually touch. See Figure 1. During the fill and system pressurization step all excess air is vented and the only air in the system is supposed to be in the tank. Because of the change in solubility of air in water due to the continual changes in the system temperature and pressure, any air leaving the compression tank must be separated from the water and returned to the tank.

In the Air Elimination method the system water and the air cushion are physically separated by a flexible diaphragm or bladder, Figures 2 and 3. The entire hydronic system, piping, radiation and boiler or chiller must be completely purged of air during the initial fill and any free air occurring later must be vented to atmosphere.

The fundamentals presented here are considered by Bell & Gossett Company to be basic for all closed hydronic systems which are to operate in the chilled or LTW heating range. (The LTW range is defined as any heating system designed to operate below 250°F.)

TYPES OF COMPRESSION/EXPANSION TANKS

FIGURE 1



Standard Type Tank, 100 gals and larger, with ATFL Airtrol Tank Fitting
Note the separate vent cut to 2/3 the tank diameter.

Standard Type tank, less than 100 gals, with ATF Airtrol Tank Fitting selected for tank diameter.

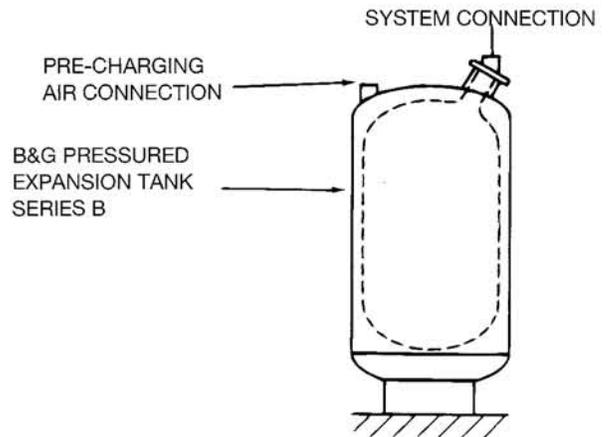
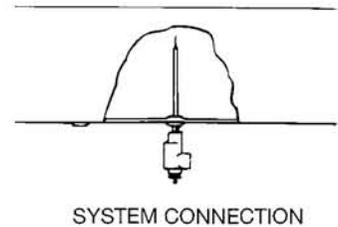
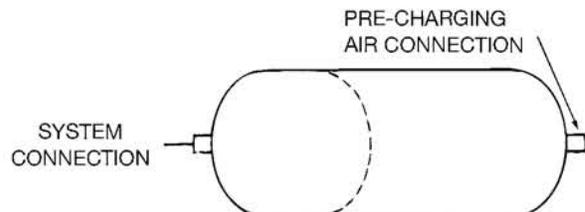


FIGURE 3
Diaphragm Type Pressurized Expansion Tank



CLOSED SYSTEM DESIGN

Piping systems for water transmission can be considered in two general categories - open systems or closed systems. Open systems are piping circuits, pumped or gravity circulated, that are open to the atmosphere at some point. Closed systems are designed and installed as sealed systems and offer several important advantages:

1. When a system is closed, little, if any, make-up water is ever required. With no fresh water added, there will not be an accumulation of oxygen or other corrosive materials. System life is extended indefinitely.
2. Closed systems can be pressurized permitting elevated temperatures and greater temperature drops. Piping and operating costs can be reduced drastically.
3. With positive air management, closed systems offer improved control, faster temperature response and quieter system operation.

Because the system is closed, provision must be made to absorb the changes in water volume due to the changes in system temperature. For this purpose a properly sized compression tank is installed. The tank is also used to set the initial cold fill pressure and to maintain a minimum system pressure. Two basic type tanks are used in modern systems. One is the standard type where the air cushion and the system water actually touch. The other is the pressurized type tank where the air cushion and the system water are separated by a flexible diaphragm or, in some designs, by a flexible bladder.

Obviously closed systems are used whenever possible. However, many systems intended to be closed are not tight and consequently operate as open systems. A system may be designed as a closed system, but it will not be a closed system unless all the piping and components are leak-tight. Special attention must be given to pump seals and air vents.

All closed system circulating pumps should have mechanical seals. Packing gland type pump seals require constant leakage to lubricate the seal. This means fresh water with oxygen and other corrosive agents are constantly added to the system.

Manual air vents should be used at high points in all systems, both air control and air elimination, to vent air as the system is filled and pressurized. Once the system is filled and pressurized the manual vents are closed.

In Air Control systems only manual air vents are recommended to ensure the initial air charge can be held in or returned to the compression tank.

However, in Air Elimination systems automatic air vents are necessary to vent any air accumulated or separated after the initial fill and vent. Since automatic air vents are a potential source of leaks they must be carefully monitored.

DESIGN CONDITIONS FOR PROPER SYSTEM PRESSURIZATION

PRESSURIZATION of CLOSED SYSTEMS

Four modes of pressurization must be considered in closed hydronic systems:

1. Initial cold fill pressure - this is the pressure applied at the filling point to fill a system to its highest point plus a minimum pressure at the top of the system (4 psi minimum) to positively pressurize the system. At elevated system water temperatures a higher cold fill pressure may be necessary to properly pressurize the pump. (See Table A.)
2. Static pressure - this is the pressure caused by the height of water above any given point. Approximately 2.3 feet of water height equals 1 psi.
3. Operating pressure increase - this is the pressure increase caused by the expanded water entering the tank and compressing the air cushion.
4. Pump pressure - the pressure differential created by the operation of the pump.

Closed system design requires the designer to establish values for both the minimum pressurization and the maximum allowable pressure increase. The minimum pressure will exist at the top of the system when it is cold and the circulating pump is not operating. Maximum pressure will be determined by the pressure limits of the system's components and their location in the system. It occurs when the system is hot and at design condition with all pumps in operation. From the standpoint of both the initial cost and the space required, it is desirable to have the compression tank as small as possible. The compression tank size for any closed system is affected by the following:

1. Water expansion - a function of the water content

of the system and the amount of temperature change.

2. Range of system pressure - a function of the initial fill pressure and the maximum allowable pressure increase at the tank of the system.

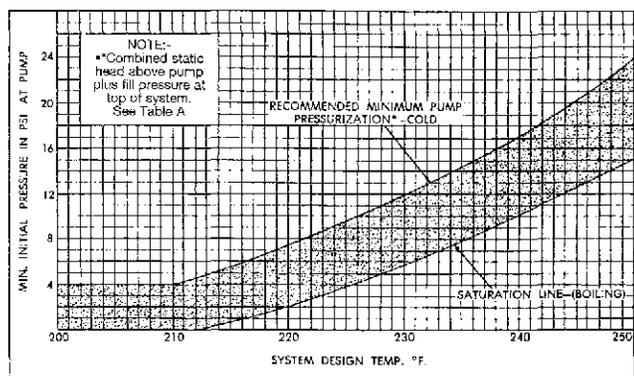
MINIMUM SYSTEM PRESSURIZATION

Generally, the minimum cold pressurization at the top of systems operating in the LTW range can be as low as 4 psig. For systems designed to operate above 220°F, the compression tank will develop the additional pressure needed above 4 psig when the system has reached its maximum design temperature. While it is usually safe to rely on the tank to create the necessary pressure increase for the LTW piping system, additional pressurization at the system pump is recommended. Inadequate pressurization at the pump causes noise, loss of circulation and often serious damage to the pump.

Initial fill then must fulfill three requirements:

1. The entire piping system must be filled with water.
2. The pressure at the top of the system must be high enough to vent air from the system (4 psi adequate).
3. The pressure at all points in the system must be high enough to prevent flashing in the piping or cavitation in the pump.

In the LTW range the use of Table A and Figure 4 will provide the proper pressurization.



In the LTW range, as shown in the graph, adequate fill pressurization for a pump in any pressure that will prevent boiling plus a margin of safety, shown by the gray area. For example, a system with a 230° operating temperature should be filled to a minimum of 12 PSI where a system that operates at 240° must have a cold fill of 17 PSI at the pump.

FIGURE 4

Minimum Cold Pressurization At The Pump

Table A is based on filling a system so that the pressure at the top (the value from the table) and the static height of the water above the pump, produce adequate pump pressurization (to provide a 15°F safety factor above the boiling point) when operating at the maximum design system temperature.

STATIC HEAD ABOVE PUMP ft	MAXIMUM DESIGN TEMPERATURE				
	UP TO 210°F	220°F	230°F	240°F	250°F
PUMP AT TOP	4 psig	4 psig	13 psig	17 psig	25 psig
5	4 psig	4 psig	11 psig	15 psig	23 psig
10	4 psig	4 psig	9 psig	13 psig	21 psig
20	4 psig	4 psig	4 psig	8 psig	16 psig
30	4 psig	4 psig	4 psig	4 psig	12 psig
40	4 psig	4 psig	4 psig	4 psig	8 psig
50	4 psig	4 psig	4 psig	4 psig	4 psig
60 AND ABOVE	4 psig	4 psig	4 psig	4 psig	4 psig

TABLE A

Minimum Cold Pressurization At The Top of Closed LTW Systems (Pumps Off)

Example:

A three story apartment building with hot water heat has the boiler and pump located in the basement. The maximum design temperature is 200°F. (This is the highest temperature the pump would see.) The highest point in the system is 26 feet above the pump. At what should the cold, non operating pressure be set?

Solution:

From Figure 4, the minimum pressure at a pump operating at 200°F is 4 psi. But, 4 psi at the pump would not even fill the system since the static height would only be equal to 4×2.31 or 9.2 feet. If just enough pressure is added to fill the system, the initial pressure due to the height of the water column would be $26 \div 2.31 = 11.3$ psi. The system would be full and there would be adequate pressure at the pump, but there would not be any pressure at the top to vent off air. Refer to Table A. With a static head above the pump of 26 feet of water a pump operating at 200°F requires a cold, non operating pressure at the top of the system of 4 psi. The cold fill pressure then should be equal to the static pressure due to the height of the water column $26 \div 2.31 = 11.3$ plus 4 psi or a total of 15.3 psi. With a 15.3 psi cold fill the minimum cold pressure at the top will be 4 psi and the pressure at the pump will be 11.3 psi exceeding the required 4 psi.

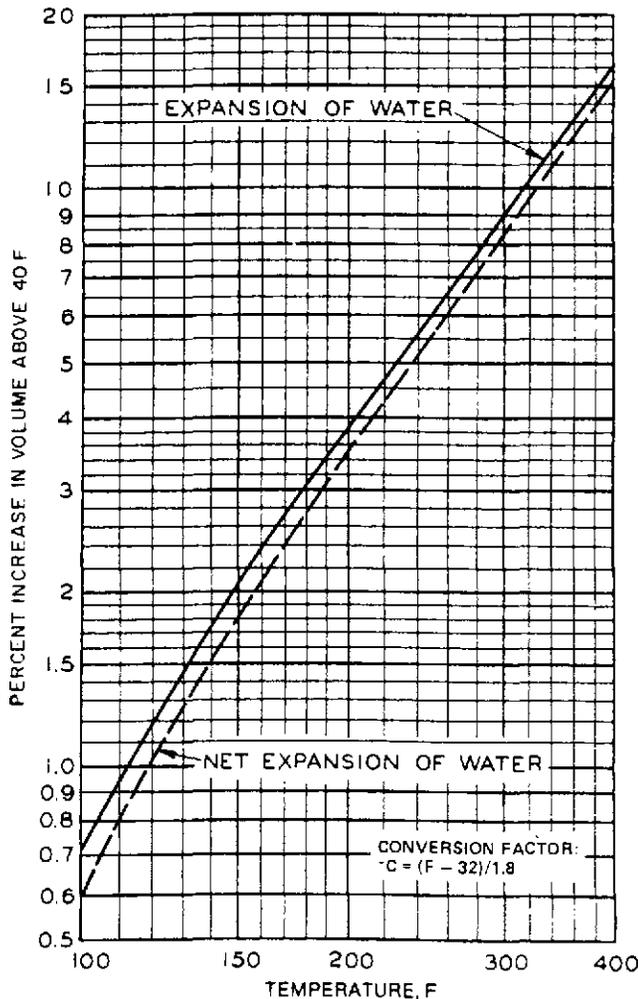
MAXIMUM SYSTEM PRESSURE

The required pressure relief valve setting for the system will establish the allowable increase in pressure. The relief valve should be located so that it

protects the required system components and is not affected by pump operation. Good system design will prevent the pressure reaching the pressure relief valve setting unless the system temperature exceeds the maximum design operating temperature.

WATER EXPANSION

Figure 5 illustrates the rate at which water expands or contracts as its temperature rises or falls. As the water heats up so does the piping in the system. The curve labeled net Expansion of Water takes this into account and is used in sizing a tank. Since water is incompressible a closed system filled with water must have space for any increase in volume as the temperature rises. This is true even in a chilled water system since the chilled water return is higher than the fill temperature. To accommodate this fluctuation in volume a compression tank is commonly used.



SUMMARY:

While hydronic systems designed to operate within the limits of the ASME Section IV Code Rules for Construction of Heating Boilers are limited to 250°F in temperature, they may operate at pressures up to 160 psig providing the installed components are so constructed.

Usually the boiler establishes the maximum working pressure limitation for a hydronic hot water heating system. If the boiler is suitable for only 30 psi working pressure, a 30 psi pressure relief valve should be installed on the top of the boiler. The initial cold pressure at the relief valve will, of course, be equal to the static head of the water above the boiler plus the additional pressure applied at the top of the system. Depending upon the location of the pump in relation to the valve, its operation also may affect the pressure at the relief valve.

The difference between the initial cold fill pressure at the pressure relief valve and the relief valve setting will determine the allowable pressure increase for the system. This increase in system pressure is used to determine the compression tank size. The larger the allowable system pressure increase, the smaller the compression tank.

High rise buildings, for instance, create high static pressures at the lower floors due to the tall water column. Unless system components at these lower floors are constructed to allow a sizable increase in the operating pressure above the cold fill pressure the compression tank will have to be relatively large. Frequently shell and tube converters which have fairly high working pressure ratings are used to isolate low pressure rated boilers from the piping in high static head buildings. Boilers designed to operate within the limits of the ASME Section IV Code Rules for Construction of Heating Boilers may be constructed for working pressures above 30 psi as long as the temperature doesn't exceed 250°F. These then could be used in buildings with high static head pressures. Another alternative is to locate the boiler at some elevated position which reduces the static pressure on it.

As for the tank, some designers elevate it. This reduces the initial pressure on the tank which allows a wider pressure increase resulting in a smaller tank size.

To recap, minimum tank size is the result of minimum initial tank pressures and maximum pressure increase.

TANK SIZING FORMULAS

Whereas both the Air Control and Air Elimination methods of air management use a tank to absorb the volumetric expansion of the system, the design of the tanks differs. The tank used with the Air Control System allows the water and air to touch. This type of tank is commonly called a standard tank. The tank used in an Air Elimination System separates the air from the water by means of a flexible membrane. Tanks used in this type system are frequently referred to as pressurized tanks.

The basic relationship used for sizing either type compression tank derived from the ideal gas law is expressed by:

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2} \quad (1)$$

Although in actual system operation there may be some air temperature change in the tank, the equation above can be simplified considerably by assuming no temperature change ($T_1 = T_2$). The results of the calculation will be within acceptable accuracy for tank sizing purposes. Rewriting equation (1) with $T_1 = T_2$, it becomes Boyle's law:

$$P_1 V_1 = P_2 V_2 \quad (2)$$

By proper substitution in (2), the basic formula for determining minimum tank size is:

$$V_t = \frac{V_1 - V_2}{\frac{P_a}{P_r} - \frac{P_a}{P_o}} = \frac{(E_w - E_p)V_s}{\frac{P_a}{P_r} - \frac{P_a}{P_o}} \quad (3)$$

Where:

- V_t = Compression Tank Size in gals.
- V_s = Volume of System, gal
- $E_w - E_p$ = Net Water Expansion Factor
- P_a = Pressure in Tank Before Water Enters, psia
- P_r = Design Fill Pressure, psia
- P_o = Final Tank Pressure, psia
- $V_1 - V_2$ = Change Of Tank Gas Volume, gals

Equation (3) applies to the selection of both standard and pressurized compression tanks. The pressurized tank application is unique in that the pressure in the tank before filling is not atmospheric (P_a), it is pre-charged to the fill pressure (P_r). Substituting P_r for P_a in equation (3), the minimum tank size for a pressurized tank is:

$$(V_t) = \frac{(E_w - E_p)V_s}{\frac{P_r}{P_r} - \frac{P_r}{P_o}} = \frac{(E_w - E_p)V_s}{1 - \frac{P_r}{P_o}} \quad (4)$$

Due to the physical construction of the flexible membrane (diaphragm, bladder etc.) in a pressurized compression tank, the full tank volume, V_t , may not be available for fluid expansion. The maximum amount of liquid a given tank can accept is known as the acceptance volume, A_c , or sometimes "acceptance allowance". For example, the Series "D" tanks have acceptance volumes less than the tank volume while the Series "B" tanks have acceptance volumes equal to the tank volumes. (See Table O).

Another term used in sizing pressurized tanks that requires explanation is Acceptance Factor, A_e . The acceptance factor is defined as

$$A_e = 1 - \frac{P_r}{P_o} \quad (5)$$

which is the denominator of equation (4). By substitution, (4) becomes

$$V_t = \frac{(E_w - E_p)V_s}{A_e} \quad (6)$$

$(E_w - E_p)V_s$ is the net water expansion volume and (6) can be simplified even more by calling it V_e

$$V_t = \frac{V_e}{A_e} \quad (7)$$

Selecting the correct pressurized compression tank requires satisfying two conditions:

1. The volume of the tank must be large enough to keep the change in pressure due to system heat-up within the system's allowable increase.
2. The tank's acceptance volume must be at least as large as the system's expansion volume.

Whereas the fill pressure in a standard tank is set by fluid going into the tank and compressing the air, the fill pressure in an application using a pressurized tank is preset and then installed in the system. No fluid enters the tank during the system vent/purge/fill procedure. Consequently, if the system pressure falls below the pre-set pressure no make-up water is available to compensate for any further loss from the system and the system pressure can deteriorate rapidly. To eliminate this possibility, pre-charge the tank to a pressure slightly less than the desired fill pressure. This allows some fluid to enter the tank before the desired fill pressure is reached providing a reserve to help keep pressure on the system.

SIZING AND SELECTING THE COMPRESSION TANK

In order to properly size either type compression tank the following information is required:

1. The system volume must be determined as accurately as possible. This volume can be estimated with sufficient accuracy by using Tables C, D & E.
2. Determine the average design temperature.
3. Determine the required fill pressure and the maximum pressure in the tank for the application.

Tolerances in the pressure setting of relief valves may cause nuisance valve discharges. To eliminate this problem many designers discount the rated setting by 10%, 5 psi minimum, when determining the maximum pressure at the tank.

Chilled Water Applications

In a heating system the tank is sized to provide a minimum pressure which is a function of design temperature and pump location, and to absorb the volume of water expanded between the fill and mean design temperatures. A chilled water system also needs a tank to provide a minimum pressure, 4 psi at the system top is sufficient. It must also absorb the increase in volume due to temperature. The concern here is not over the expansion between the fill and operating temperatures. Of course there will be some expansion due even to that small increase. The concern is the expansion due to the ambient air temperature if the system isn't operating. A minimum sizing temperature of 100°F is suggested. If the tank is to be installed in an application where 100°F could be exceeded, use that higher temperature.

Glycol Solutions

Not all systems use water, some use anti-freeze solutions, Ethylene or Propylene glycol solutions are the most common. For a given temperature change a glycol solution expands more than water. To properly size a tank for a glycol solution, size it for water and then multiply the water tank size by the appropriate factor from Table G.

Sizing A Standard Tank

If the minimum size standard tank is to be calculated, obtain the rate of expansion from Table F, then substitute the values for system volume, net water expansion factor, fill pressure, maximum tank pressure and atmospheric pressure in equation (3) and solve. Select the next larger standard tank from Table K, or if a single tank large enough isn't available, multiple tanks to provide the required volume.

The minimum required tank size can also be determined from the prepared selection tables. To use the table method, enter the table at the system volume row, continue to the column for the average design temperature and obtain the minimum tank size required for standard conditions. If the pressures for the application differ from $P_f = 12$ psig and $P_o = 30$ psig, multiply the tank size from Table H by the correction factor from Table I. If the system fluid is a glycol solution, the tank size determined above must be multiplied by the correction factor from Table G. Again, select the next larger standard tank from Table K, or if a single tank large enough isn't available, multiple tanks to provide the required volume.

Examples of standard tank selections:

1. A 2000 gallon system has a mean design water temperature of 180°F. The compression tank will be installed at the top of the system with an initial pressure of 4 psi. The Pressure Relief Valve setting will be 30 psi. The initial pressure at the Relief Valve due to the static head (building height) plus the 4 psi initial pressure at the tank will only allow an increase of 8 psi without the danger of the valve weeping. Consequently the pressure in the tank can only rise 8 more psi.

Solution:

Formula method, using Equation (3) and substituting

$$V_t = \frac{(E_w - E_p)V_s}{\frac{P_a - P_a}{P_f - P_o}} \quad (3)$$

$$P_a = 14.7 \text{ psia}$$

$$P_f = 14.7 + 4 = 18.7 \text{ psia}$$

$$P_o = 14.7 + 4 + 8 = 26.7 \text{ psia}$$

$$\text{from Figure F at } 180^\circ\text{F, } E_w - E_p = .028$$

$$\begin{aligned} \text{therefor } V_t &= \frac{(.028) 2000}{\frac{14.7 - 14.7}{18.7 - 26.7}} \\ &= 237.8 \text{ gals} \end{aligned}$$

Select a standard 240 gal tank with an ATFL tank fitting.

By the table method:

From Table H, a 2000 gallon system at 180°F mean design water temperature and standard pressures requires 252 gallons of compression tank volume. However, the initial pressure at the relief will allow an increase of only 8 psi. Consequently, the pressure at the compression tank can only rise 8 psi. The correction factor from Table I for 4 psi initial pressure and an 8 psi rise is 0.95. The tank required for the

application then is 0.95×252 or 239.4 gallons. A 240 gallon tank is a standard size and should be selected. An ATFL tank fitting is needed with this size tank.

The insignificant difference between the calculated and table sizes is due to rounding off in the tables.

The remaining standard tank examples will be solved using the table method.

2. A primary-secondary pumping system is designed so that the boiler and primary piping contains 500 gallons of water and a 240° to 200°F design temperature range. It supplies secondary piping circuits which are to operate at a design temperature range of 140° to 160°F. The volume of the secondary circuits totals 250 gallons. The tank will be located at the level of the relief valve on the boiler. Initial tank pressure is 12 psi and the relief valve has a 30 psi setting.

Solution:

Knowing the primary system water volume to be 500 gallons at a mean design temperature of 220°F $[(240+200)/2]$, the tank required is 98 gallons. The 250 gallons in the secondary circuits at 150°F $[(140+160)/2]$ requires 20 gallons of compression tank volume. The system tank size required is the sum of the required tank sizes for the primary and that for the secondary or 118 gallons (98+20). A 120 gallon tank is a standard size and should be used. An ATFL Airtrol Tank Fitting is used with this size tank. It's important to note here that, depending upon its location, the pump could see 240°F water. In that case, the tank would have to be larger because the initial pressure at the pump should be a minimum of 17 psi at cold fill.

3. A chilled water system has approximately 900 gallons of water content. Its maximum operating temperature will not exceed room temperature. The pressure relief valve setting will be 30 psi. Initial pressure at the tank will be 12 psi. The tank will be at the same level as the relief valve.

Solution:

Select the tank directly from Table H using the 100°F column, even though the temperature will never reach it. The tank volume required for a 900 gallon system is 23 gallons, a 24 gallon tank is a standard size and should be selected. Here, an ATF 12 Airtrol Tank Fitting is also needed.

4. A system volume is estimated to be 100 gallons of a 50% solution of ethylene glycol and water. Initial pressure at the tank is 12 psig, the maximum pressure at the tank is 30 psig. If the mean design temperature of the system is 160°F, what is the required tank size?

Solution:

Table G shows that a 50% solution of ethylene glycol and water at 160°F expands 1.49 times as much as water alone. Therefore, the tank selected must be 1.49 times as large as the tank size required for water. A 100 gallon system at 160°F requires a 9.5 gallon tank, the 100 gallon glycol system then would require a tank of 14.2 gallons (1.49 x 9.5). A 15 gallon tank is a standard size and would be selected along with an ATF 12.

Sizing A Pressurized Tank

To calculate the minimum size pressurized tank, obtain the rate of expansion from Table F, then substitute the values for system volume, rate of expansion, fill pressure, and maximum tank pressure in equation (5) and solve. Select the pressurized tank from Table O that has an acceptance volume at least equal to the volume of expansion and a tank volume at least equal to that computed. If a single tank isn't available to satisfy those two conditions, select multiple tanks to provide the required acceptance and tank volumes.

The minimum required tank size can also be determined from the prepared selection tables. To use the table method, enter Table M at the system volume row, continue to the column for the average design temperature and obtain the minimum tank and acceptance sizes required for standard pressure conditions. If the pressures for the application differ from $P_f = 12$ psig and $P_o = 30$ psig, multiply the tank size from Table M by the correction factor from Table N. The acceptance volume required doesn't have to be corrected for pressure. If the system fluid is a glycol solution, the tank size determined above must be multiplied by the correction factor from Table G. The acceptance volume obtained from Table M must also be multiplied by the correction factor. Select the pressurized tank from Table O that has as a minimum an acceptance volume equal to the volume of expansion and a tank volume equal to that required from the table or as corrected. If a single tank isn't available to satisfy those two conditions, select multiple tanks to provide the required acceptance and tank volumes.

Examples of pressurized tank selection:

5. Using the information of Example 1 size a pressurized tank by the **formula method**. A 2000 gallon system has a mean design water temperature of 180°F. The compression tank will be installed at the top of the system with an initial pressure of 4 psi. The Pressure Relief Valve setting will be 30 psi. The initial pressure at the Relief Valve due to the static head (building height) plus the 4 psi initial pressure at the tank,

will allow an increase of only 8 psi. Consequently the pressure in the tank can only rise 8 more psi.

Solution:

Using Equation (6),

$$V_t = \frac{(E_w - E_p)V_s}{A_o} \quad (6)$$

and substituting $(E_w - E_p)$ from Figure F and A_o from Equation (5) or Table L

$$A_o = 1 - \frac{P_f}{P_o} \quad (5)$$

$$P_a = 14.7 \text{ psia}$$

$$P_f = 14.7 + 4 = 18.7 \text{ psia}$$

$$P_o = 14.7 + 4 + 8 = 26.7 \text{ psia}$$

$$A_o = 1 - \frac{18.7}{26.7} \\ = 0.2996$$

therefor

$$V_t = \frac{(.028) 2000}{0.2996} \quad (6) \\ = 186.9 \text{ gals}$$

Select a B-800 (211 gals), pressurized tank with full acceptance or one D-200 and one D-180 diaphragm tanks to provide a total V_t of 200 gals and a total acceptance volume of 68 gals to accommodate the expansion volume ($2000 \times 0.028 = 56$ gals).

By the table method:

From Table M, a 2000 gal system at 180°F mean design water temperature and standard pressures requires a pressurized tank with a tank volume of 138.5 gals and an acceptance volume of 55.8 gals. But a 4 psig fill pressure and a 12 psig maximum pressure at the tank are not standard. Multiply the tank volume by 1.34 the pressure correction factor from Table N. The required tank volume then is 185.6 gals, the required acceptance volume remains 55.8 gals. Select a B-800 with full acceptance or two diaphragm tanks a D-180 and a D-200 with partial acceptance to provide a total V_t of 200 gals and a total acceptance volume of 68 gals. Again, the minor differences in the figures are due to rounding off.

The remaining pressurized tank examples will be solved using the table method.

6. Select a pressurized tank for the primary-secondary application described in the example 2.

Solution:

The 500 gals of water in the boiler and primary circuit is at a mean design temperature of 220°F. Table M lists the required tank volume as 53.7 gals and an acceptance volume of 21.65 gals. From the same table, the 250 gallons in the secondary circuit at a mean design temperature of 150°F require a pressurized tank volume of 11.04 gals ($8.83+2.21 = 11.04$) and an acceptance volume of 4.45 gals ($3.56+0.89 = 4.45$). The total tank volume then is $53.7+11.04 = 64.74$ gals and the total required acceptance volume is $21.65+4.45 = 26.1$ gals. Select a B-300 Bladder Tank with 79 gals tank volume and full acceptance volume or a D-120 Diaphragm Tank with a tank volume of 68 gals and acceptance volume of 34 gals.

7. The chilled water system described in example 3 has 900 gals of water and operates with standard pressures.

Solution:

Table M at 100°F prescribes a pressurized tank with a minimum tank volume of 12.73 gals and a minimum acceptance volume of 5.13 gals. As is sometimes the case, the standard sizes available are not a real good fit for the size required and judgment must be used. A B-200 Bladder Tank is the smallest available. It would protect the system to a temperature of about 170°F. A D-40 Diaphragm Tank has only 5.0 gals of acceptance and is a little small but would protect the system to about 98°F. The next larger tank is the D-60 which would protect the system to about 130°F. The most reasonable tank selection would be the D-40.

8. The system described in example 4 is 100 gals of a 50% Ethylene Glycol solution with a mean design temperature of 160°F. The initial pressure at the tank is 12 psig, the maximum pressure at the tank is 30 psig.

Solution:

For these conditions Table M requires a pressurized tank volume of 5.16 gals and an acceptance volume of 2.08 gals. The correction factor for the greater expansion of 50% Ethylene Glycol from Table G is 1.49. The tank required for this application then is one with a minimum tank volume of 7.69 gals (1.49×5.16) and minimum acceptance volume of 3.1 gals (1.49×2.08). Select a D-40, with a tank volume of 21.7 gals and an acceptance volume of 5.0 gals. The next smaller diaphragm tank has only 2.5 gals acceptance and would protect the system to only about 145°F.

COMPRESSION TANK LOCATION

Proper sizing of the compression tank is, of course, very important. But, once sized, where should it be installed in the system? Placement of the compression tank is affected by two separate considerations.

VERTICAL PLACEMENT

First, there is the actual vertical placement of the tank in the building. If the tank is placed low in the building, the static pressure is highest and a larger tank is needed. On the other hand, if the tank is placed high in the building, a smaller tank may be used.

TANK CONNECTION THE POINT OF NO PRESSURE CHANGE

The second design consideration is the location of the tank to system connection. This connection point is the point of no pressure change. The pressure at this point remains the same whether or not the pump is operating.

To explain further, consider a basic closed forced circulation system with boiler, pump, compression tank supply and return piping and radiation (Figure 6). The entire system will be filled with water except for the compression tank which will have some air volume to act as a spring cushion.

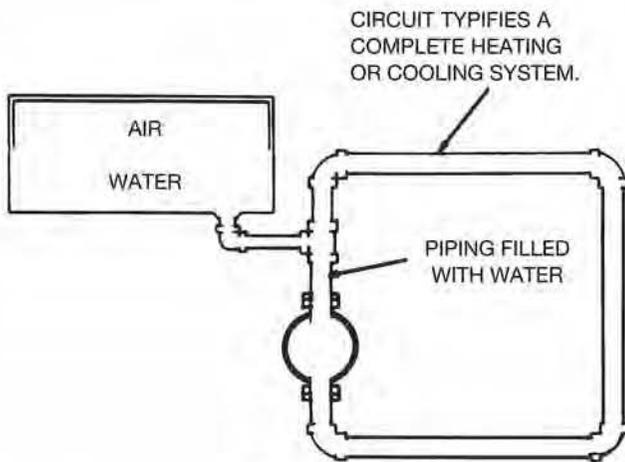


FIGURE 6
Basic Closed Hydronic Heating System

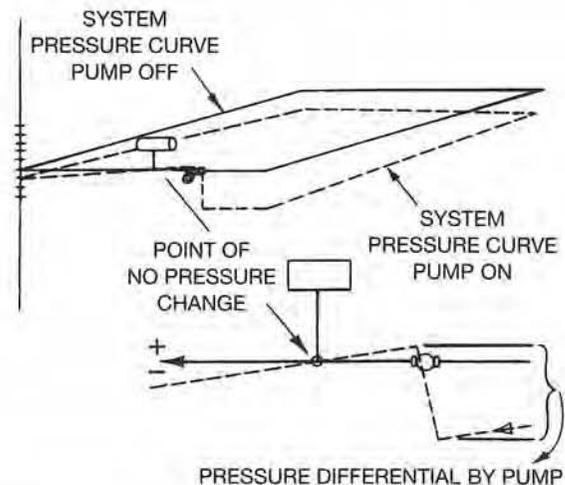
When the water in the system is heated the volume of water expands and the additional water volume enters the tank. The same amount of water is still in the system, the number of pounds of water has not

changed. The only way the pressure in the tank can change further is to add or subtract water from the tank. "What happens when the pump starts up?" The pump can't add or subtract water from the system, consequently it can not change the pressure in the tank or at the point where the tank is connected to the system. The pressure at the connection point of the tank to the system then can not change whether or not the pump is operating.

PUMP LOCATION

However, other changes will occur in the system depending upon where the pump is located in relation to that point of no pressure change. There are two possibilities, the pump can pump towards or away from the point of no pressure change. To simplify the discussion, the pressure loss due to the flow between the pump and the point of no pressure change can be neglected if that connection is very close to either the pump suction or the pump discharge.

First, let's analyze the effect of connecting the compression tank to the pump discharge. When the pump starts up it will develop its head/flow curve. But, since the pressure can't change at the discharge, the pressure at the suction will be reduced by the amount of the friction loss of the system. See Figure 7. The pressure then at every place in the system is less with the pump running than it is with the pump not operating.



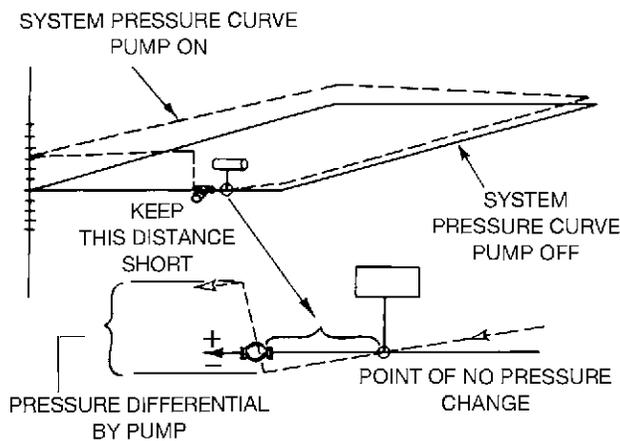
NOTE: Generally a poor location for system pump, illustration shows how pump pressure differential is subtracted from system pressures if pump differential is great enough to offset static head, cavitation, noise and pump damage may occur.

FIGURE 7
Effect of Pump Discharging Into Tank

This is not a good situation. If the existing non-operating pressure acting on the system is not adequate to offset the negative pressure produced by the pump, water flashing to steam, pump cavitation, unheatable circuits and assorted other problems can result. In fact, if automatic air vents are installed at points where negative pressures exist, air can be sucked into the system. None of these possibilities are desirable.

Pumping Away From The Tank

On the other hand, if the point of no pressure change is at the suction, when the pump starts up the pump head is added to the non-operating pressure. See Figure 8. Therefore, when the pump operates, the pressure at every point in the system is always greater than it is with the pump not running.



NOTE: Correct pump location adds pump pressure differential when operating away from point of no pressure change. Always keep distance short and pressure drop low between pump suction and compression tank connection.

FIGURE 8
Recommended Pump Location

LOW vs HIGH HEADED PUMPS

Generally, on small systems where the pumps do not produce more than 15 feet of head, pump location may not be important. However, on larger systems where pumps with higher heads are used location is very important. A good rule to follow is to always install the system pump or pumps to pump away from the point of no pressure change. In this way the pressure differential produced by the pump will at every point in the system always increase the operating pressure above that of the non-operating pressure. Although the operation of the system pump can not change the compression tank pressure, it can affect compression tank sizing. Depending upon the location of the relief valve the non-operating pressure plus the pressure added by the pump can limit the amount

the system pressure can increase without exceeding the valve setting.

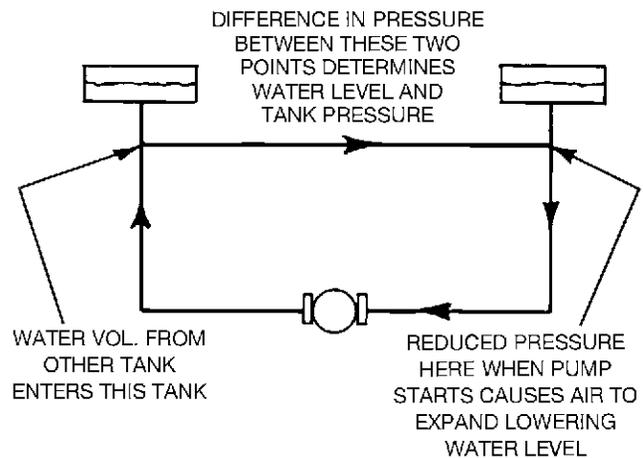
If the pressure reducing valve is positioned in the system so that the pump can reduce the pressure it sees when the pump is in operation it will think the system pressure has dropped and will add water to increase the pressure. When the pump stops, the non-operating pressure will have increased. Subsequent cycles can increase the pressure to that of the relief valve setting causing it to relieve.

The ideal location for the pressure reducing valve and the compression tank is at the pump suction since the operation of the pump will not affect either of them. The pressure relief valve must be sized and located at a position to prevent over-pressurizing any component of the system.

MULTIPLE TANK LOCATIONS

When any piping system is completely filled with water and all of the air is confined to the compression tank, the point where the tank connects to the system will be a point of no pressure change and will be virtually unaffected by pump operation.

However, if another compression tank containing air is installed in the system see Figure 9, the tank pressure will be affected by operation of the pump.



NOTE: When pump starts, point of no pressure change will be established somewhere between the two tanks depending upon change in water level of each.

FIGURE 9
Effect of Pump Operation on Compression Tank Pressures, Multiple Tank Installation

With this scenario the pump will transfer water from one tank to the other in proportion to the pressure differential it can produce between the two tanks. The point of no pressure change then will move to a point somewhere between the two tanks and may even change with changes in the water levels of the tanks. More than one connection to a tank or tanks is not recommended since unreliable pressure conditions result.

A system containing a large amount of free air in the piping and radiation can cause a similar situation. Thorough initial venting and an efficient air separator will usually remedy this type problem and eventually establish a fixed point of no pressure change.

Note how the connection point for a secondary circuit to the primary circuit establishes the non-operating pressure for the secondary circuit. By pumping away from the connection point to the primary circuit the secondary pump will add pressure to the non-operating pressure when operating, providing the same benefits to its circuit as a pump does when pumping away from the compression tank. However, if the secondary pump is pumping into the connection point to the primary circuit and the head of the secondary pump is greater than the non operating pressure of the secondary circuit it will draw a vacuum in the secondary when it operates.

MULTIPLE PUMPS AND POINT OF NO PRESSURE CHANGE

If the operation of a single pump cannot change the pressure within the compression tank, it follows that the operation of many pumps installed throughout the system will not affect a single point of no pressure change. With this single reference point for a starting pressure it is possible to analyze the hydraulics and pressure gradients for the entire system regardless of the number of pumps installed. Primary/Secondary pumping, the subject of a separate Design Manual, is a means of inter-connecting piping circuits so that the operation of one will not affect the other. Figure 10 illustrates the pressure relationship on a typical 1 pipe primary/secondary system.

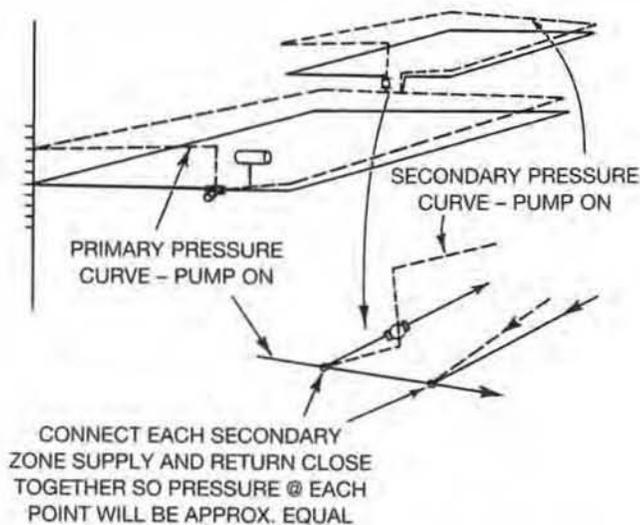


FIGURE 10

Primary/Secondary System Pressure Relationships

AIR SEPARATION

The amount of air water can hold in solution varies depending on the temperature and pressure. Higher pressure or lower temperature water can absorb or hold more air in solution than water that is warmer or at lower pressure. Even the narrow temperature range of chilled water systems demonstrates the effect of temperature on solubility. Figure 11 is familiar proof of how a small change in temperature coupled with the decrease in pressure will cause cold tap water which has been allowed to rise to room temperature to give off free air from solution.



FIGURE 11

Air Bubbles Released From Fresh Tap Water With Pressure and Temperature Change

Deep sea divers experience a similar effect during underwater ascents. Nitrogen which doesn't combine with elements in the human body at atmospheric pressure, is absorbed into the blood stream under the increased pressure of water depth. As the diver rises and the water pressure on the body is reduced, the nitrogen expands. If the ascent is too fast, the expanded nitrogen gas doesn't have a chance to escape from the blood stream causing the so-called "bends".

POINT OF AIR SEPARATION

Free air in a hydronic piping system can cause noise, reduce terminal output or even stop flow. An integral component of an air management system is an air separator to separate and direct any free air. As dis-

cussed previously, the point where the compression tank connects to the system is the point of no pressure change regardless of pump operation.

This point is important in the case of an air management system for another reason. It must also be the point to separate free air from the system water. Installing the boiler, air separator and compression tank at the pump suction optimizes separation because of low pressure and highest temperature.

In order to evaluate air management of a specific application a better understanding of how temperature and pressure affect the solubility of air in water is required. Air is a mixture of gases, approximately 80% nitrogen, 20% oxygen and trace amounts of others. Within a short time after the initial fill, the air in a properly operating closed system begins to lose its oxygen content through oxidation. Unless fresh water with its 2% air is added, the gas remaining becomes nitrogen, an inert gas. The chart in Figure 12 illustrates the effects of pressure and temperature on the solubility of nitrogen in water. This interpretation is based on D.M. Himmelblau's paper published in the Journal of Chemical and Engineering Data, Volume 5, No. 1, January 1960.

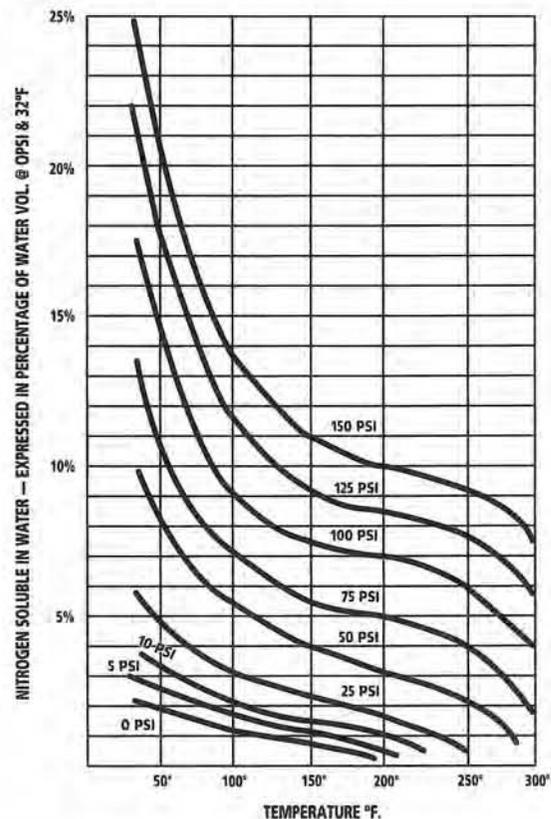


FIGURE 12

Solubility of Nitrogen in Water vs. Temperature and Pressure

The chart shows the maximum amount of nitrogen that can be held in solution expressed in percentage of water volume. It is based on the nitrogen being released from solution and then expanded to atmospheric pressure at 32°F. Obviously, if water is saturated with the maximum amount of air in solution, increased temperature or reduced pressure will allow some of the gas to come out of solution. If the water temperature and pressure are returned to their original level and this free nitrogen is present, it will be re-absorbed. However, if this free nitrogen is separated and vented off or moved somewhere else in the system, the water will remain in a de-aerated condition.

Effective air management for the design engineer of a closed hydronic system means devising a system so that any nitrogen (system air) released from solution either by heating or by a reduction in pressure will be at only one point. This point should be the connecting point to the compression tank.

The chart in Figure 12 illustrates maximum solubility of nitrogen in water. However, if the total nitrogen in solution can be measured only if removed as a gas and measured at atmospheric pressure and 32°F how does it enable design engineers to understand the management of air in closed hydronic systems? Simply by stressing the importance of locating air separating equipment at the point of lowest air solubility, based on both temperature and pressure.

Conversely, this emphasizes the importance of having adequate system pressurization, since low pressure areas allow nitrogen to be released from solution. This again points out the advisability of locating all pumps so that their operating pressures are always added to the non-operating pressure existing at every point in the system. **Pumps should not create reduced pressure at remote points in the system where air can be released from solution.** Always locate pumps so that their operating heads add pressure at all points in the system.

If it were possible to install the air separator at a point where the absolutely lowest pressure and absolutely highest temperature occurred management of the air in the system would be complete. This is simply not possible. Consequently, the designer must also provide piping circuitry that will be able to move any free air back to the point where it can be separated from the water and properly directed. Normally a water velocity of 2 ft/sec will keep free air entrained and prevent it from forming air pockets. High points in various piping circuits in particular, can be collecting points for free air. Proper pipe sizing is often effective in preventing air traps at high points in systems.

The best location for air separating equipment, of course, depends upon the particular system. No sin-

gle rule can apply to all systems. When possible, select a point which will have both the highest temperature and the lowest pressure. When this isn't possible, the point of highest temperature should receive first consideration as the air separation point. The chart in Figure 12 shows that a large percentage of nitrogen is released from solution when water temperatures rise above 200°F. With the possible exception of high rise buildings, air separation at points of elevated temperatures is generally an effective way to de-aerate system water sufficiently to prevent further release of nitrogen due to the reduced pressure at system high points.

AIR SEPARATORS

Every closed hydronic system requires a device to separate free air from the water and redirect it. In the case of an Air Control System that separated free air is returned to the compression tank. The separated free air in an Air Elimination System is vented to the atmosphere. The principles governing the design of air separators are simple. One is by reducing the water velocity to 1/2 ft/sec or less. Water will not carry along free air bubbles at that velocity. In boilers having large internal water passages, water velocity is low and the free air carried to the boiler by the system water along with additional air released by heating will readily rise to a convenient high point. All of this free

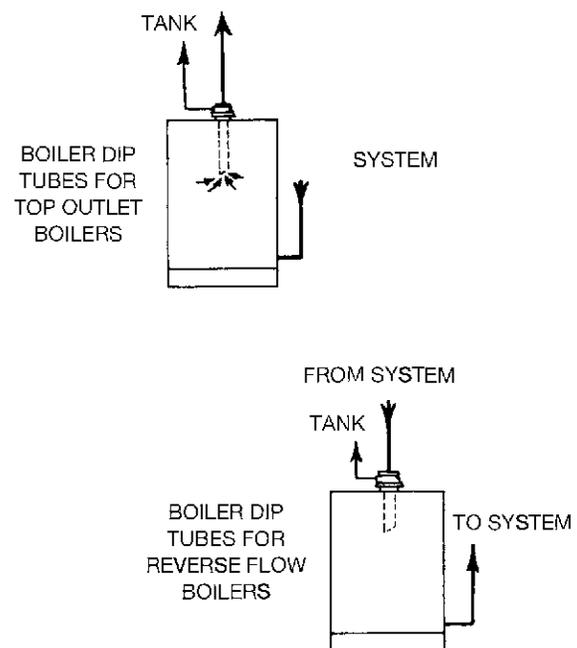


FIGURE 13
Boilers with Diptube Separators

air can then be piped from this collection point to the compression tank. To prevent free air collected at the top of the boiler from being circulated out into the system and into the radiation, boiler dip tubes are used. Some boiler manufacturers offer these dip tubes as standard equipment and B&G offers a wide range of sizes of top outlet boiler fittings for boilers that are not so equipped.

However, a boiler is not always available or useable as the point of air separation and some other means of separating the free air from the system water must be employed.

The IAS-Inline Airtrol Separator operates by collecting air off the top of the water flow and directing it to an opening on top. Because proper operation is a function of the velocity here also, sizing is determined by the flow rate.

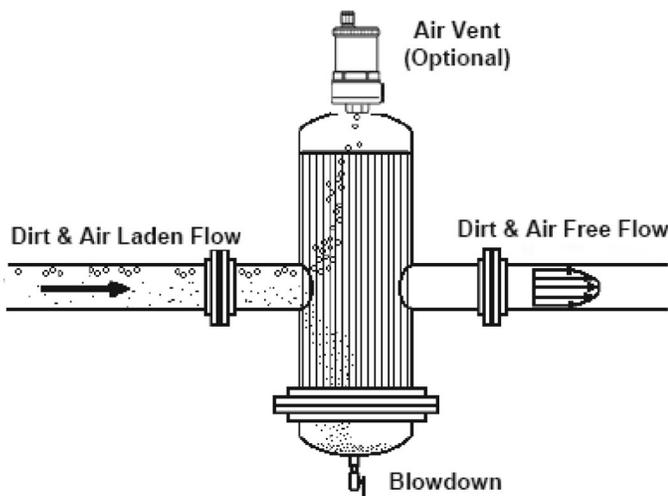


FIGURE 14
CRS Coalescing Removal Separator

Another principle used in the design of air separators is centrifugal force. Tangential nozzles are used to create a vortex at the center of a cylindrical vessel. Air being lighter than water collects in the whirlpool on an air collector screen and is then directed upwards either to return to the compression tank in an air control system or in the case of the air elimination system vented to the atmosphere. A big advantage of this concept is that the tank size required is much smaller than that required for a low velocity type. This

device is called a Rolairtrol by B&G. Since efficiency of separation is a function of velocity here also, sizing depends upon the flow rate.

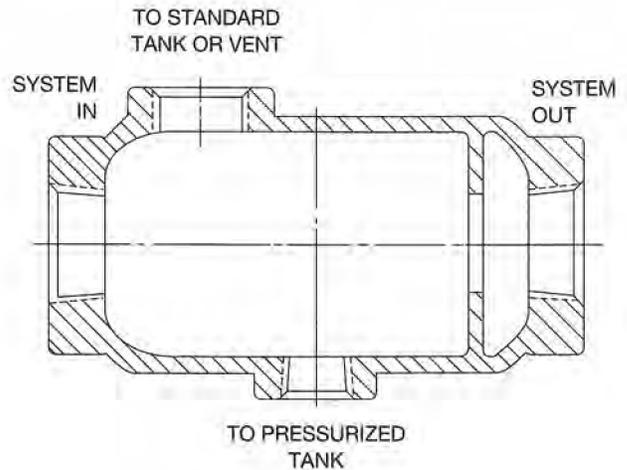


FIGURE 15
IAS In-Line Air Separator



FIGURE 16
Rolairtrol Air Separator

The principle of coalescence is used in another style separator. The coalescing medium allows small bubbles to combine making big bubbles which are much easier than small bubbles to separate from water. This device is called an Enhanced Air Separator. Its sizing is again a function of the flow rate.

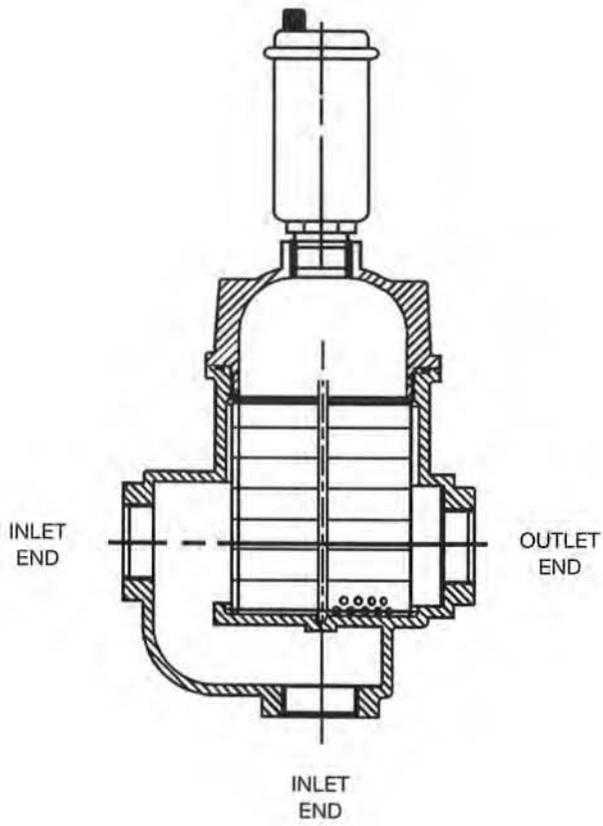


FIGURE 17
EAS Enhanced Air Separator

Each of these designs provide efficient air separators. The type selected depends upon the system designer's specific requirements.

TANK INSTALLATION

STANDARD TANK INSTALLATION

Efficient air separating equipment and correctly sized and positioned compression tanks require simple piping connections for proper performance.

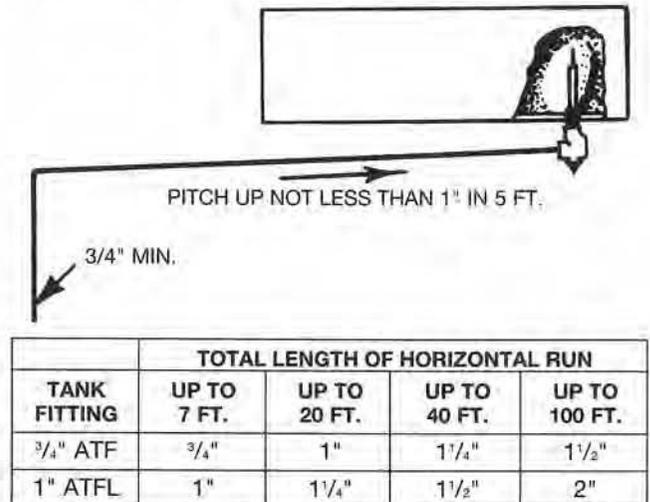
In an air control system connecting piping need only be a riser pitched up to the tank. However, a number of variations exist that can have considerable effect on the overall efficiency of a system as well as on the size of the tank itself. As air bubbles are separated from a system they must be allowed to rise into the compression tank. As that free air rises into the tank, an equal amount of water must return to the system. This means that the piping connection between the air separating device and the tank must always pitch up and be large enough in diameter to allow water and air to pass each other at the same time. Tests have shown that 3/4" pipe is the smallest diameter pipe that should be used to allow simultaneous passage of water and air.

A reduced gravity head is a result of longer horizontal piping which may make it necessary to use piping larger than 3/4". Figure 18 shows recommended pipe sizes to connect tanks to systems depending upon the horizontal length of pipe.

Since the piping to compression tanks should be no smaller than 3/4" and at times even larger in diameter, a relatively large, direct pipe connection exists between the system and the tank. Water that has released air from solution because of a change in pressure or temperature at some point in the system will attempt to absorb free air if the pressure or temperature changes put it in a state of less than saturation. Free air should be confined in the compression tank. Air leaving the tank and the water going into the tank will set up gravity circulation between the system and tank and cause the tank temperature to approach that of the system. The result of increased tank temperature is increased tank size.

Free passage of air rising into the tank while restricting gravity circulation between the tank and the system is needed. A B&G Airtrol Tank Fitting allows air to pass freely, but restricts the circulation of water between the tank and the system reducing tank temperature. As a result the required tank size is smaller. See Figures 19 & 20. The fitting selected depends upon the tank diameter.

While it is impossible to prevent entirely the re-absorption of air from a compression tank, the Airtrol Tank Fittings are helpful in reducing circulation of



*Vertical lines may be one size smaller than horizontal line, but not less than 3/4".

FIGURE 18
Tank to Separator Piping

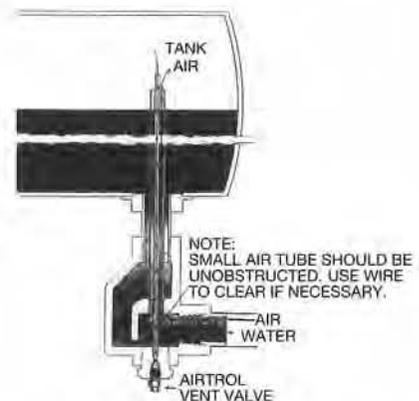


FIGURE 19
ATF Airtrol Tank Fitting

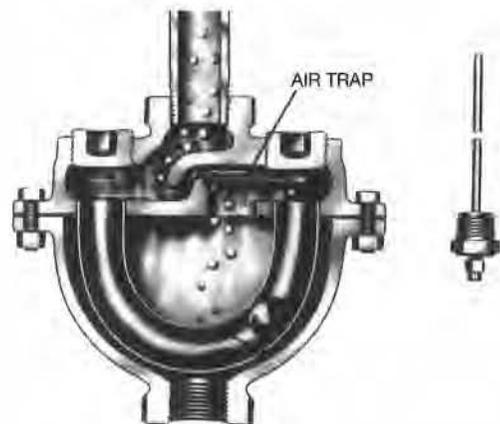
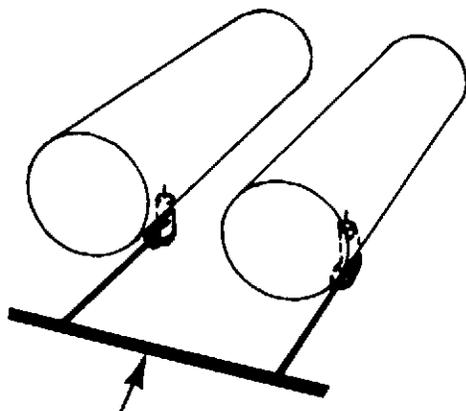


FIGURE 20
ATFL Airtrol Tank Fitting

water between the tank and the system. In addition, these fittings offer the ability to establish the initial water level in the tank on filling the system. Often too much air is trapped when the system is filled for the first time. A manual air vent is furnished, integral in the ATF model separate in the ATFL design, consisting of a small diameter tube which extends up into the tank. The ATF models are selected for the tank diameter and the vent tube length is the proper length for setting the initial ratio of water and air. The vent tube for the ATFL model used on the larger tanks must be cut to a length equal to two thirds the tank diameter. While filling the system, this vent tube is open allowing excess air to escape. When the water level reaches the top of this tube, the vent should be closed.

At times, installation of a single tank is impractical and two or more tanks with a total volume sufficient for the application must be utilized. This may be the result of a low ceiling or a desire to use readily available stocked sizes. Figure 21 lists the proper pipe size for the manifold as a function of the number of tanks to be used.



MANIFOLD HEADER SIZES FOR MULTIPLE TANKS

TANK FITTING	TWO TANKS	UP TO FOUR TANKS	FIVE OR MORE
3/4" ATF	1"	1 1/4"	1 1/2"
1" ATFL	1 1/4"	1 1/2"	2"

FIGURE 21
Manifold Header Sizes

Mechanically pressurized tanks, attic installed tanks and tanks at other than the so-called standard conditions usually require different initial venting procedures. Vent tubes can be easily adjusted to those specific requirements.

Typical piping details for various methods of connecting tanks to systems are outlined in the chapter on Installation Details.

PRESSURIZED TANK INSTALLATION

The tank to system piping in an application using a pressurized compression tank differs from that using a standard tank in several major respects:

1. Air from the system must be vented or purged to the atmosphere and not allowed to enter the tank.
2. Tank-to-system piping must not be pitched-up to the tank.
3. Shut-off and drain valves must be installed in the tank-to-system piping to properly check or recharge tank air pressure after the system has been filled with water.

Typical tank-to-system and air vent/purge piping details are illustrated in the Appendix. General notes regarding this piping follow:

1. The connection point of tank-to-system is the point of no pressure change just as it is when using a standard compression tank.
2. The piping connecting the tank to the system main should be attached to minimize the possibility of air and/or debris from entering the tank. If connected to a horizontal main, avoid bottom (6 o'clock) and top (12 o'clock) positions.

If the connection must be made to the bottom of the main, install a dirt leg with a drain valve to trap and flush debris.

3. The pressurized tank pre-charge pressure is based on a dry (waterless) tank. In order to check or change the pre-charge pressure the tank circuit must be isolated from the main system piping. A high quality, gate type, lock-shield valve is recommended for this purpose. The lock-shield for the valve stem will reduce tampering with the valve which normally must be open during system operation.
4. In addition to the lock-shield valve used to isolate the tank from the system, a drain valve, an automatic air vent and a pressure gauge should be installed in this piping. The drain valve is for flushing and to drain the water from the tank for proper air charging.
5. Since the tank sizing calculations are made on the basis of minimum temperature rise in the tank, an anti-thermosyphon loop must be included in the tank-to-system piping to minimize the effect of gravity circulation into the tank. A drop leg of 12 to 20 inches is usually sufficient. In addition, good practice dictates that the piping and the tank in a heating system not be insulated.

TANK TO SYSTEM PIPE SIZING

Table B lists recommended pipe sizes for the line connecting the tank to the system. The MBH column indicates the output of the heat source. These recommended pipe sizes will cause very low pressure drops and thus prevent a buildup of pressure in the heat generator as the water is heated up, expands and flows towards the tank. If the pipe is too small the resistance to flow can cause the pressure to increase

enough to lift the relief valve. It is customary to size the tank so that the maximum pressure in the tank will prevent the pressure at the relief valve from exceeding 90% of the relief valve setting. All of the pipe sizes listed will prevent the system pressure from increasing more than 10%, thus preventing the relief valve from discharging.

MBH	EQUIVALENT LENGTH UP TO 10'				EQUIVALENT LENGTH 11' TO 30'				EQUIVALENT LENGTH UP 31' TO 100'			
	MAX AVERAGE TEMP. °F				MAX AVERAGE TEMP. °F				MAX AVERAGE TEMP. °F			
	100	150	200	250	100	150	200	250	100	150	200	250
1000	1/2	1/2	1/2	1/2	1/2	1/2	1/2	3/4	1/2	3/4	3/4	3/4
2000	1/2	1/2	1/2	1/2	1/2	3/4	3/4	3/4	3/4	3/4	1	1
3000	1/2	1/2	3/4	3/4	3/4	3/4	1	1	3/4	1	1	1 1/4
4000	1/2	3/4	3/4	3/4	3/4	1	1	1	1	1	1 1/4	1 1/4
5000	1/2	3/4	3/4	1	3/4	1	1	1 1/4	1	1 1/4	1 1/4	1 1/4
6000	1/2	3/4	1	1	3/4	1	1 1/4	1 1/4	1	1 1/4	1 1/4	1 1/2
7000	3/4	1	1	1	1	1 1/4	1 1/4	1 1/4	1 1/4	1 1/4	1 1/4	1 1/2
8000	3/4	1	1	1	1	1 1/4	1 1/4	1 1/4	1 1/4	1 1/4	1 1/2	1 1/2
9000	3/4	1	1	1 1/4	1	1 1/4	1 1/4	1 1/4	1 1/4	1 1/4	1 1/2	2
10000	3/4	1	1	1 1/4	1	1 1/4	1 1/4	1 1/2	1 1/4	1 1/2	2	2
12000	1	1	1 1/4	1 1/4	1 1/4	1 1/4	1 1/2	1 1/2	1 1/4	1 1/2	2	2
14000	1	1	1 1/2	1 1/4	1 1/4	1 1/4	1 1/2	2	1 1/4	2	2	2
16000	1	1 1/4	1 1/2	1 1/4	1 1/4	1 1/2	1 1/2	2	1 1/2	2	2	2 1/2
18000	1	1 1/4	1 1/2	1 1/2	1 1/4	1 1/2	2	2	1 1/2	2	2	2 1/2
20000	1	1 1/4	1 1/2	1 1/2	1 1/4	1 1/2	2	2	1 1/2	2	2 1/2	2 1/2

TABLE B
Minimum Pipe Size from System to Pressurized Tanks

AUTOMATIC AIR VENT SELECTION

Automatic air vents should be selected on the basis of their maximum operating pressure and their venting capacity at the initial system fill pressure.

Nearly all of these vents will be float type and therefore may not operate properly if the system pressure exceeds the maximum design operating pressure of the vent.

The air discharge capacity of the vent at fill pressure is more critical than that at the operating pressure because the greatest amount of air removal takes place during the filling and start-up procedures.

The rate at which air can be removed from the system depends on many factors, some of these are:

1. System Pressure - The air vent discharge capacity increases as the pressure differential across the vent's seat increases.
2. Air Separator Efficiency - An efficient air separator can separate air from water at a very high rate and the vent must release that air at the same rate to prevent the air backing up and being carried back out into the system or creating a blockage.

3. Flow Rate - Generally, the greater the volume flowing through the separator the greater the volume of air the vent must release. Therefore large flow rates require high capacity vents.

4. Temperature - Since warmer water has less soluble gas in solution than cold water, heating the water during the venting process increases the amount of air available for separation.

Since all of the air in a system cannot and need not be removed during the first few passes through the air separator, the sizing of the automatic vent by capacity is not as important as selecting one with the proper maximum working pressure. Figures 39 through 42 offer suggestions for vent selection. The high capacity vent has a discharge capacity of about 12 SCFM at 45 psi differential while the B&G #87 will discharge 2 SCFM and the B&G #7 will pass 3.5 SCFM. Using multiple low capacity vents is an acceptable alternative.

A leaky vent is not only a nuisance, it promotes corrosion with the fresh water and oxygen which eventually is added as make-up. A commercial grade vent will usually outlast the cheap hardware store variety.

DESIGN FOR INITIAL FILL PROCEDURE

Normally a closed system need be filled only once. For some systems this can be a tedious, time consuming task, particularly on large, long circuited systems. However, the designer can simplify the problem considerably by incorporating a few simple design techniques in the initial plan.

Comment has been made previously that automatic air vents should not be used on air control systems unless they can be shut off after the initial fill. Instead, manual air vents at the main high points are recommended. Automatic air vents are required in the air elimination system since any free air must be vented to the atmosphere.

By selecting the system piping to maintain a minimum velocity of 2 ft/sec free air bubbles will be entrained by the water flow and carried back to the separating point where they can be directed to the compression tank or vented depending upon the air management system in use.

Purging may be another way to remove air from a system on initial fill. Purging uses city water pressure to force or chase free air from a piping circuit through an open drain. Figure 44 illustrates a simple purging hookup. Often a system can be designed so that no manual air vents are needed. Instead, purging can be used to free a system of most of the air trapped during the initial fill. A precaution, however, should be observed if purging is to be used. Often when a small pressure reducing valve is used, the rate of fill possible is not adequate to produce the volume of water flow needed for large piping circuits. A manual bypass around the pressure reducing valve as shown in Figure 46 would provide the flow and pressure needed for purging.

WATER FILL REQUIREMENTS AND BACKFLOW PREVENTION

Filling a closed piping system with water and maintaining the correct water volume is normally a simple procedure. An automatic fill valve can be set to limit the system pressure during a fill cycle while the installer or repairman performs any necessary venting. Once the system is filled however it is recommended that the water supply to the valve be shut off. Uncontrolled firing and overheating of boiler components may occur in a hot water heating system that develops leaks or doesn't include a properly installed and operating air management system to compensate for thermal expansion. A low water cutoff and/or alarm

installed in the system piping is recommended to alert the operator to add makeup water when required. Manual fill by direct connection to the city water supply can be made using a positive shut-off type valve. Where adequate city water pressure is not available or to completely isolate a system from the main water supply system, filling may be done by means of an electrically driven pump or even a simple hand-operated hydraulic pump.

BACK FLOW PREVENTION

When city water supply is used to fill a hydronic system, the city supply provides the pressure needed to add water to the system and to set the initial cold fill pressure. However, if that supply source loses pressure system water will flow back into the fresh water supply unless some type of back-flow prevention is used. B&G pressure reducing valves have a built-in anti-siphon check valve to prevent the possibility of this back-flow happening. Standard swing check valves or B&G Flow control valves are also effective back-flow preventers. However, many government jurisdictions require more elaborate types of back-flow prevention devices and local codes must be consulted.

FILL CONNECTION LOCATION

The pressure created by the circulating pump affects system pressure at all points except one - the point of no pressure change - which is the compression tank and where it connects to the system. In order to provide the necessary minimum initial pressure at the top of the system, the only point in a system where pump operation will not give an erroneous pressure indication on filling is at the point of no pressure change. Therefore, the best location to make the fill connection is to the line connecting the tank to the system. The fill connection at this point also serves to direct any free air entering with fresh water make-up into the compression tank without first entering the system. In the case of an air elimination system any free air entering with the make-up water has ready access to an automatic air vent. Cold water fill at any other point in the system, particularly when high head pumps are being used, will be affected by the pump head at the point of entry. With the exception of low head pump systems, this can be an important consideration, often making fill impossible or undesirable while the pump is in operation.

MECHANICALLY PRESSURIZED SYSTEMS

Mechanical pressurization is often considered for large systems or those having high static heads where large compression tanks would be required. By adding gas volume to a conventionally installed standard compression tank, most of the tank volume becomes available as space for system expansion. The result is a much smaller tank for a given application. An air compressor or a tank of nitrogen is used to increase the gas volume, usually to approximately 80% of the compression tank capacity. See Table J for the procedure to size standard compression tanks using this method. Several important design considerations should be observed when using mechanical pressurization for the compression tank:

Closed system design and installation procedures as outlined previously should be followed closely. A mechanically pressurized system must be constructed with pressure tight components and thoroughly tested for installation leaks. Gauge glasses on compression tanks are particularly susceptible to leaks when packing glands dry out. If gauge glasses are used, shut-off valves should always be used at each connecting point.

When possible, always check the possibility of elevating the standard compression tank. A conventionally installed tank at the top of the system will always be smaller than a mechanically pressurized tank located at the bottom of the system.

Automatic operation of the gas source, either an air compressor or bottled nitrogen, is generally not recommended. Manual charging of compression tanks when necessary is preferred. Regular or excessive need for pressurizing the system will indicate a system leak requiring repair.

Should a system leak occur on a mechanically pressurized system having adequate air control, any loss in water volume normally will register first as a lower water level at the tank. However, since the water level in a tank charged with 80% gas is already near the bottom, even a small system loss could lower the water level into the piping system. A low water cutoff and/or alarm is recommended on a mechanically charged system to notify an operator to correct the condition.

SYSTEM CLEANING AND STARTUP

If a piping system could be installed in perfectly clean surroundings using component parts that were also completely clean and free of all foreign material, it probably could be filled with water from the average city supply, started and operated satisfactorily ever after. However, this type of cleanliness in the assembly of a piping system is virtually impossible. The coatings normally used as rust preventive on pipe, the cutting oils used in threading pipe, the chips that result, the flux used in sweating copper fittings, sand, dirt of all types, etc. are all typical of the foreign matter commonly found in a newly completed piping system.

Consequently, every piping system should be thoroughly cleaned and flushed before startup. Various commercial cleaning compounds are available for this purpose. It is recommended that the system pumps be used to circulate the fluid for several hours. After draining and flushing the system with fresh water, remove and clean any strainers, then refill the system with fresh water. To aid in speeding up the flushing operation, purge valves might be used. See the Water Fill Requirements And Backflow Prevention sections.

System water should be maintained slightly on the alkaline side (pH above 7 but below 9). Once started in this manner, a properly designed system installed correctly with a properly sized compression tank will remain in operating condition indefinitely.

It is easy to see how a clean hydronic system is a necessity for efficient operation, circulation and long life. In areas where water supplies are apt to be somewhat corrosive initially, even a thoroughly cleaned and flushed system may need chemical treatment to raise the pH level into the 7 to 9 range. Obviously, any additive to a system that is intended to give many years of trouble-free operation must be selected with great care. Chemicals that aid in protection of some components may adversely affect others. These chemicals must be avoided. Silicates, borax and various leak sealers are typical chemicals that are detrimental to certain parts of a circulating water system. Chemicals such as these destroy the sealing ability of the pump mechanical seals, valve glands, etc. due to erosion. When a chemical additive is required, it should be selected on the basis of its effect on the entire system.

One of the reasons tightly closed hydronic systems rarely require an additive to establish the desired pH level is that when a cleaning compound is used initially, some small amount adheres to the piping

after the system is drained. This is usually enough alkaline material to raise the pH level to within the 7 to 9 range when the system is refilled. Open systems, however, continually exposed to the atmosphere, with fresh water being frequently added, usually require some form of chemical additive.

START-UP

A properly designed and installed system that is pressure tight and thoroughly cleaned and flushed is easily put into service.

The system should be filled and the air managed properly. If the Air Control method is to be used, all excess air must be vented or purged and the proper ratio of water to air established in the compression tank. When using the Air Elimination method, all air must be vented or purged from the system.

The type of piping system determines the method of initial air removal. Two pipe and Monoflo systems require an air vent on each piece of radiation. A series loop or radiant panel piping system must be purged to eliminate the excess air at the initial fill.

Adequate pressurization at the top of the system is required (see the Design Conditions for Proper System Pressurization Chapter). For best results the system should be circulated without the boiler firing for several hours. This will scavenge air bubbles that adhere to the surface of piping and system components. A final venting or purging at high points should then be repeated.

The initial air level in the compression tank should be established in accordance with the installation instructions. The Bell & Gossett Airtrol Tank Fitting is furnished with a manual vent tube to help set the proper initial water level in the tank. The ATF models are selected for the tank diameter and the vent tube is the proper length for setting the initial ratio of water and air. The ATFL model used on larger size tanks has a separate vent which must be cut to the proper length for the tank diameter.

Often, particularly on low static head buildings, too much air will be trapped in the compression tank when filling the system. The vent tube permits this excess air to escape and the proper water level to be established. The proper cold fill water level for a conventional 12 psi system is approximately two-thirds of the tank diameter. Then, as the system is heated, additional air is released from solution, sepa-

rated by the air separator and directed to the tank. After the system's water has been de-aerated by heating, the Airtrol vent should not be opened unless, for some reason, the system must be drained.

To de-aerate the system water initially, apply heat before circulation is started, raising the temperature to at least 220°F. By starting the system pump when the temperature reaches 220°F, the water entering the system will be more easily de-aerated. Upon cooling, this water will then absorb any free air that has collected at remote points in the system. Operation at 220°F will quickly de-aerate most systems. Radiant panel systems, certain fan coil systems, or any system that should not be heated to 220°F should be heated to the maximum system design temperature.

For chilled water systems not equipped with a heat source, thorough initial venting at the high points and circulation at room temperature for several hours is recommended.

Venting of the tank will not be necessary on mechanically pressurized systems since gas must be added either by a compressor or from a nitrogen tank to set the initial tank proportions of 80% air and 20% water. Venting at the high points while filling, circulating the system water for several hours without heat, venting high points again and then de-aerating the system water by bringing it up to 220°F or the maximum design temperature would complete the start-up procedure for mechanically pressurized systems.

SPECIAL PRESSURIZED TANK REQUIREMENTS

TANK AIR/GAS CHARGING PROCEDURE

Before the system is filled with water check the pre-charge pressure. Unless otherwise noted the tank is factory charged to 12 psig. This is not always the correct pre-charge pressure.

To determine the correct pre-charge pressure, first check the print. If it isn't indicated, either select it from Figure 4 or call your local B&G representative for help. To pre-charge the tank:

1. Check the tank air pressure at the pre-charge connection with an accurate tire gauge.
2. If additional pressure is required, charge the tank with oil-free compressed air or nitrogen gas. Occasionally check the pressure as when filling a tire.

3. Check the air valve for leakage. If it leaks, relieve the pressure and replace the core with a Schraeder type tire core. Do not depend on the valve cap to seal the leak.

RE-CHARGING AFTER THE SYSTEM IS FILLED WITH WATER

If it becomes necessary to check the pre-charge pressure after the system has been in operation, the following steps are recommended:

1. Turn off the heat source and allow the system water to cool to ambient temperature.

IMPORTANT: The tank can not be properly air charged other than at the "fill" temperature.

2. Close the tank purge valve in the tank-to-system piping.
3. Open the drain valve to empty the water from the tank. Check the tank air pressure at the pre-charge connection with an accurate tire gauge.
4. Charge the tank with nitrogen gas or oil-free compressed air. Again, occasionally check the tank air pressure.
5. Check the air valve for leakage. If it leaks, replace the core with a Schraeder type valve core. Do not depend on the valve cap to seal the leak.
6. Close the drain valve, open the lock-shield valve and turn on the heat source.

SYSTEM COMPONENT INSTALLATION DETAILS

Installations of the components for hydronic systems in general are not affected by the type of Air Management being employed. In either case natural laws are at work. Air goes up; hot water rises but dirt falls. For air to be returned to the standard compression tank in an Air Control system the piping must pitch up from the air separator. In an air elimination system the vents must sit above the air separator and the piping again must pitch up between the two. Because the standard tank normally will be above the connection to the system piping in order for the air to return, dirt will not be able to travel to the tank. As for natural convection between the cooler tank and the warmer system water in a heating system or vice-versa in a cooling system, the Airtrol Tank Fitting

eliminates the problem. In the case of the pressurized tank in an Air Elimination system, it is frequently installed below or to the side of its connection to the system. Consequently, steps are necessary to prevent dirt flowing into the tank and an anti-thermosyphon loop may be required to prevent hot water getting to the flexible diaphragm.

So, while the requirements of the Air Management systems are similar, there are differences. Details of hook-ups for each type system follow.

STANDARD COMPRESSION TANK INSTALLATIONS FOR AIR CONTROL TYPE AIR MANAGEMENT SYSTEMS

This section of the Air Management manual includes schematics illustrating typical system installation of the various components.

- Standard Compression Tank with ABF Airtrol Boiler Fitting Air Separator
- Standard Compression Tank with IAS Inline Separator
- Standard Compression Tank with Low Ceiling or Floor Mounted Air Separator
- Multiple Standard Compression Tanks with Low Ceiling Installation
- Standard Compression Tank with Low Ceiling and Secondary Air Separator
- Standard Compression Tank with Multiple Boilers, Preferred Method A
- Standard Compression Tank with Multiple Boilers, Preferred Method B
- Standard Compression Tank with Multiple Boilers, Alternate Method
- Standard Compression Tank with Multiple Boilers, Incorrect Method
- Converter Installation
- Converter Installation with 3 Way Valve
- Boiler Installation with 3 Way Valve
- Air Control with Primary/Secondary Pumping System using Rolairtrol Air Separator
- Air Control with Primary/Secondary Pumping System using ABF Airtrol Boiler Fitting Air Separator
- Air Control in Combination Heating/Cooling Hydronic Systems
- Typical CRS Hookup
- Typical Rolairtrol Hookup

STANDARD TANK INSTALLATIONS FOR AIR CONTROL SYSTEMS

A standard compression tank will normally be located above the connection point to the piping system. This connection point is at the air separator. The type of air separator makes no difference. Figures 22 & 23 illustrate typical hook ups for a normal residential installation.

All installations are not normal. The additional figures illustrate the hook up required to ensure proper system operation for a particular set of circumstances.

FIGURE 22
Standard Tank with ABF Airtrol
Boiler Fitting Air Separator
(reference only- ABF no longer available)

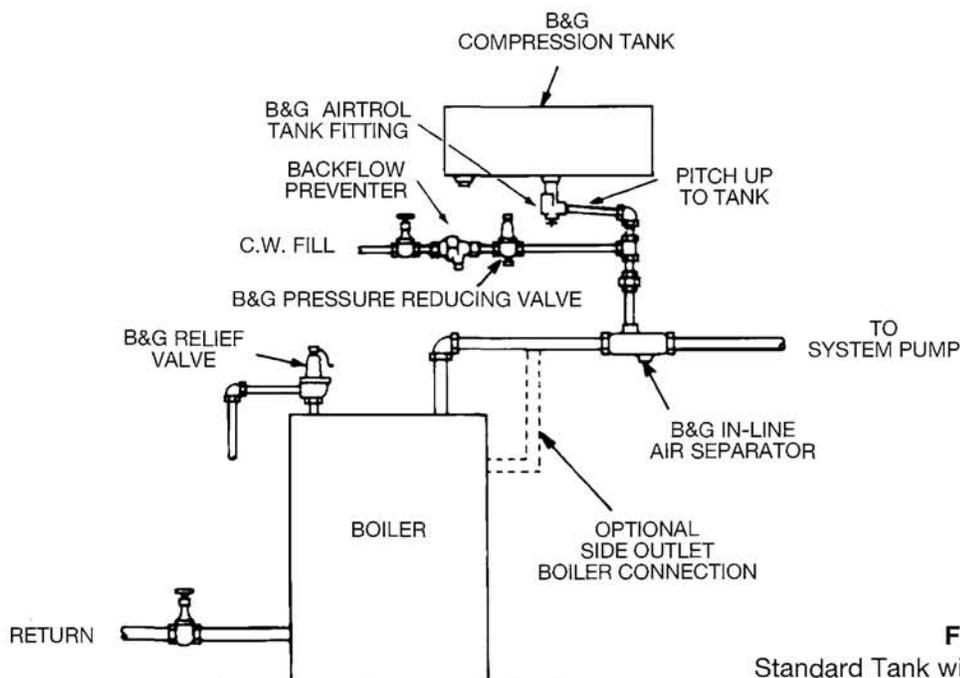
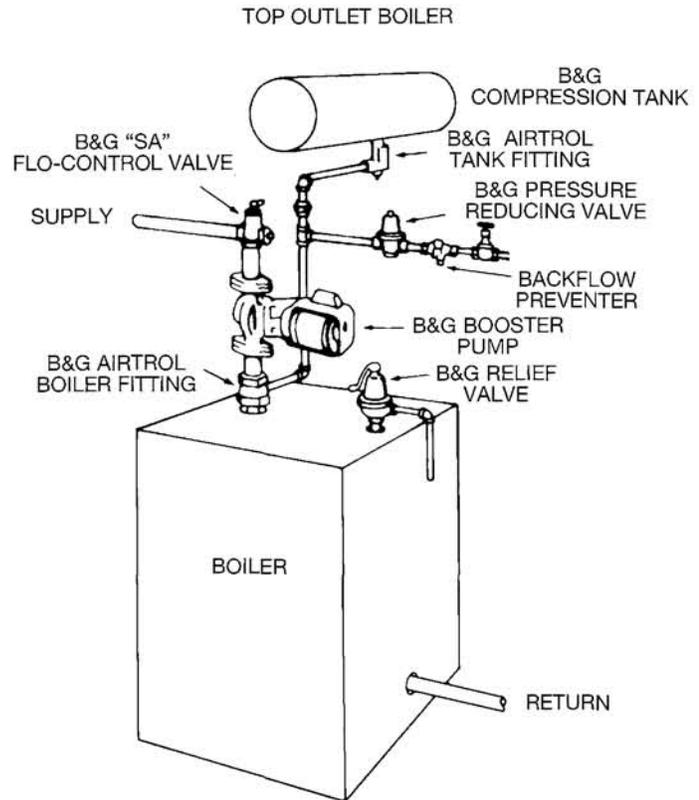


FIGURE 23
Standard Tank with IAS Inline Air Separator

LOW CEILING INSTALLATION

The following sketches illustrate installation methods for obtaining satisfactory management of air in Air Control systems when it is impossible to pitch the air return line from the air separating device up to the compression tank. This may be the result of a low ceiling or a tall boiler. Figure 24 illustrates the use of an external air separator to lower the point of air separation below the compression tank. Figure 25 illustrates the use of multiple small diameter compression tanks to permit proper pitching up of the connecting piping.

A third method of solving this problem is to make use of an auxiliary separator. Figure 26 illustrates this method. Air laden water from the main separator is directed through the "air line" by the small circulator to the secondary separator where the air is separated and directed to the compression tank. The small booster must be selected so that its shutoff head is 2 to 3 ft greater than the static height "H" shown.

FIGURE 24
Low Ceiling or Floor Mounted
External Separator

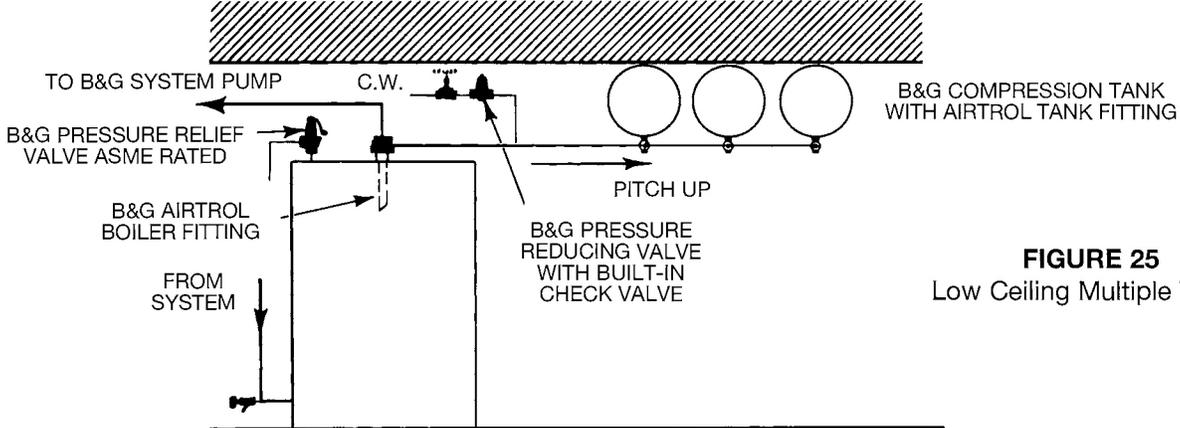
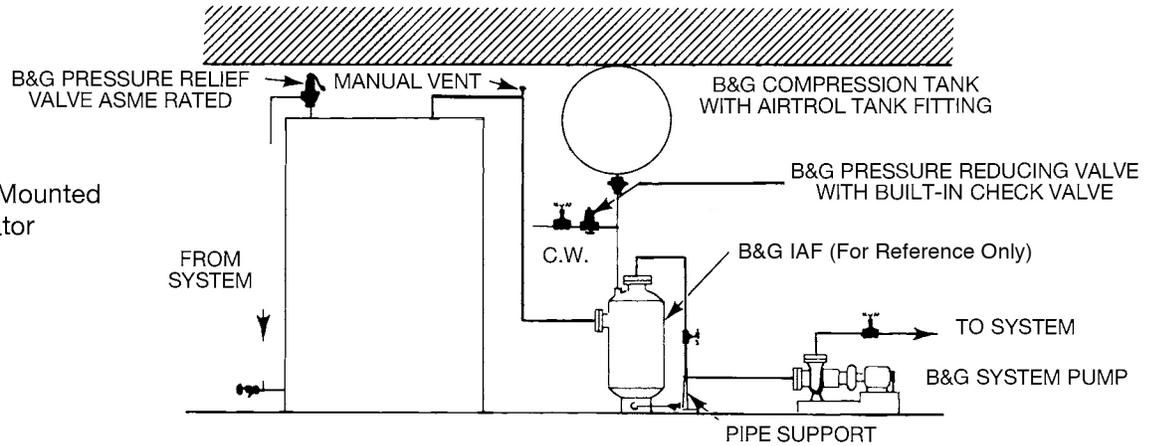
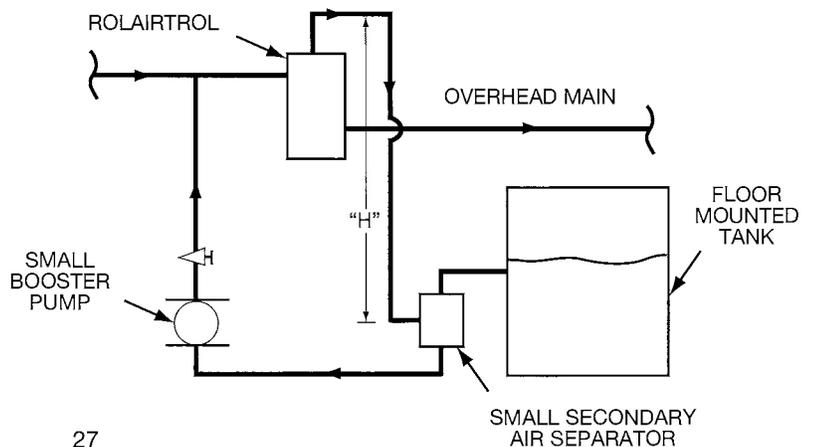


FIGURE 25
Low Ceiling Multiple Tanks

FIGURE 26
Low Ceiling Secondary Separator



MULTIPLE BOILER INSTALLATION

The preferred methods for connecting multiple boilers are shown in Figures 27 and 28. Both of these sketches illustrate how a single tank can accommodate two or more boilers. An acceptable alternative using multiple tanks and air separators is shown in Figure 29.

In the alternate method, size each tank for the proportion of the total system capacity its boiler will produce. If each boiler will produce 100% of the system capacity each compression tank must be selected to handle 100% of the system expansion. Note, under this circumstance, if both boilers operate together at part load, the compression tank space available will be considerably greater than that required to handle the reduced amount of system expansion and may

prevent proper pressurizing of the system. In addition, when boiler operation is switched from one to the other, the shut-off valves for water fill must be adjusted either automatically or manually.

The consequences of connecting multiple boilers, hot water generators, converters and other water heaters with a common air line to a compression tank or tanks is shown in Figure 30. In this case, free air, upon being separated from the system piping, must rise by gravity into the compression tank. Pumped circulation can exist through a common air line thus preventing free air from rising into the tank from one of the boilers. This method of connecting multiple boilers to a single tank is not recommended.

FIGURE 27
Multiple Boilers Preferred Method "A"

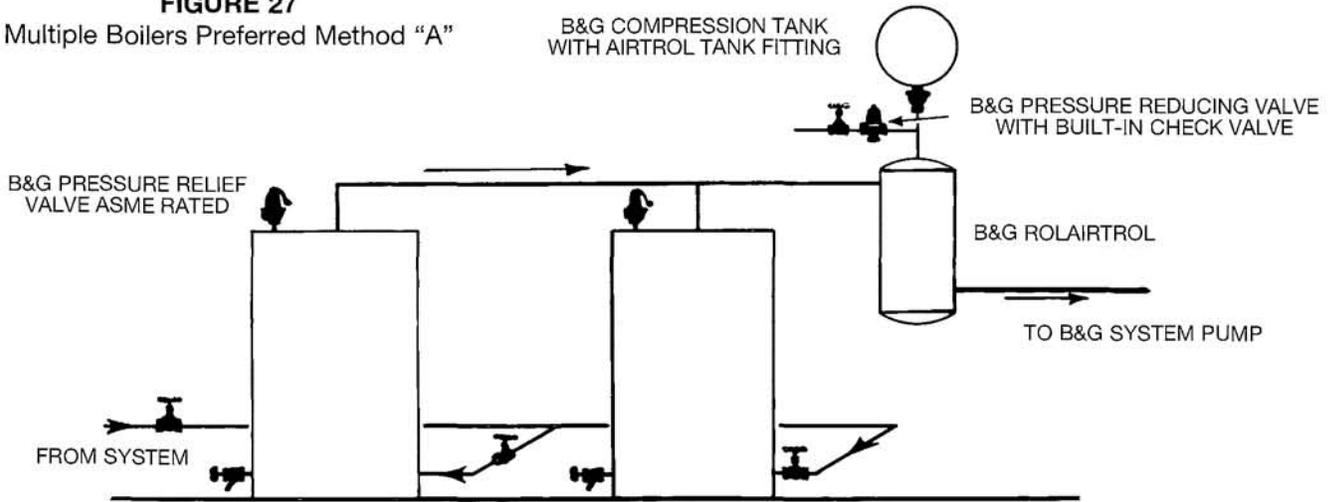


FIGURE 28
Multiple Boilers Preferred Method "B"

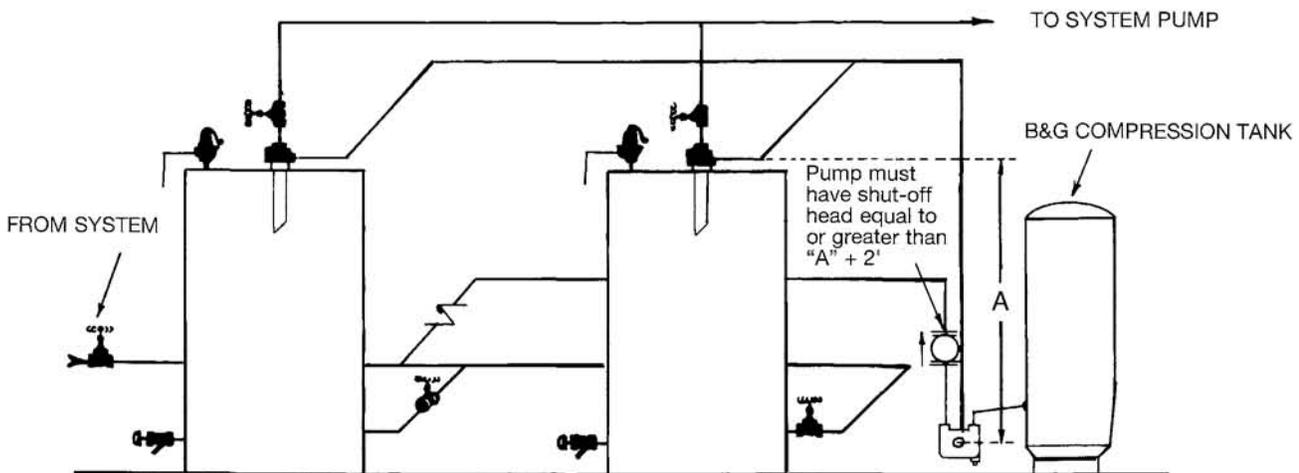


FIGURE 29
Multiple Boilers Alternate Method

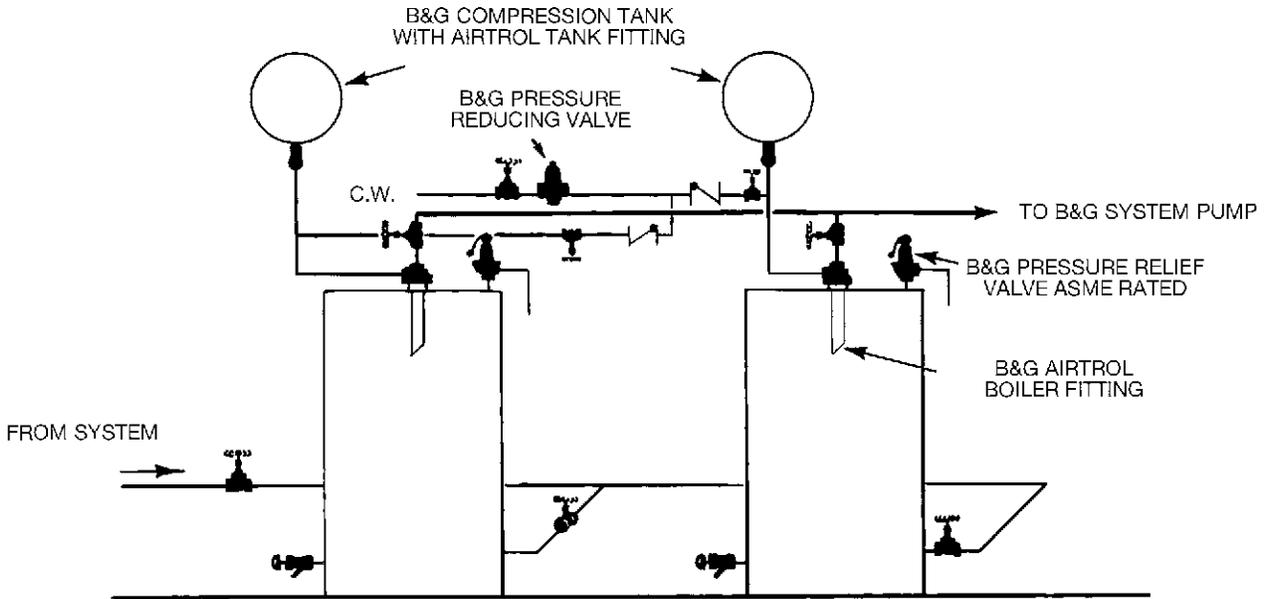
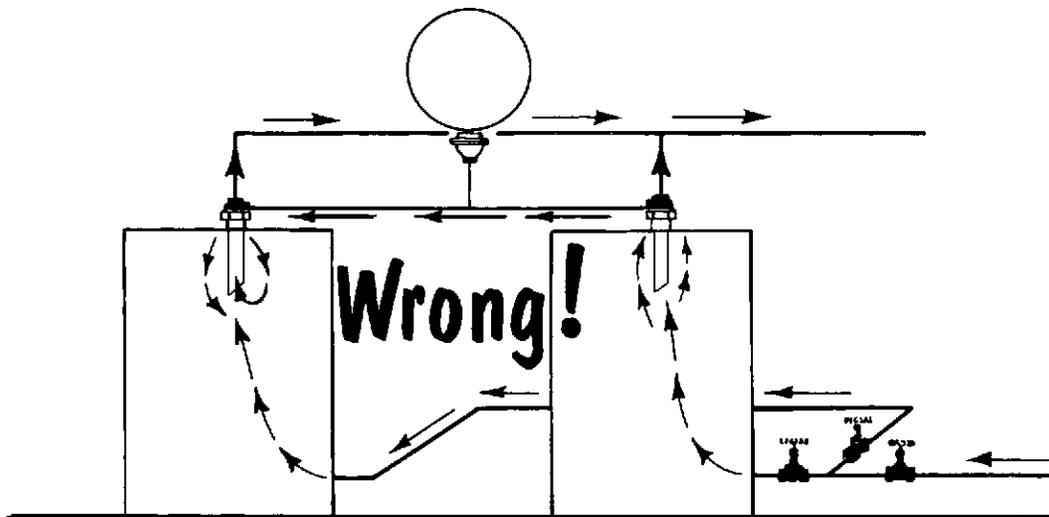


FIGURE 30
Multiple Boilers Incorrect Method



CONVERTER INSTALLATION

Since the shell and tube converters of the type shown in Figures 31 and 32 are used to isolate one closed piping system from another, in general an air separator must be installed to maintain management of the

air in the isolated system. Although the tube side is shown here as the isolated system it could just as well be the shell side that is the closed isolated system requiring air management.

FIGURE 31
Converter Installation

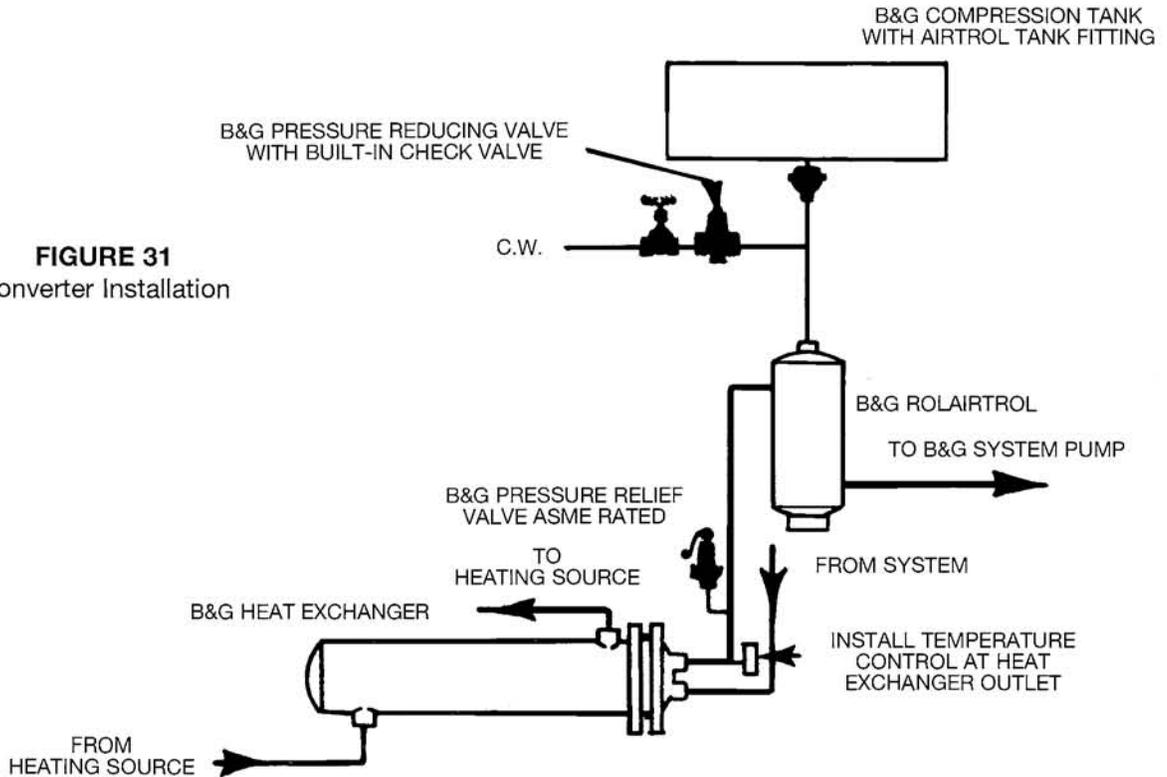
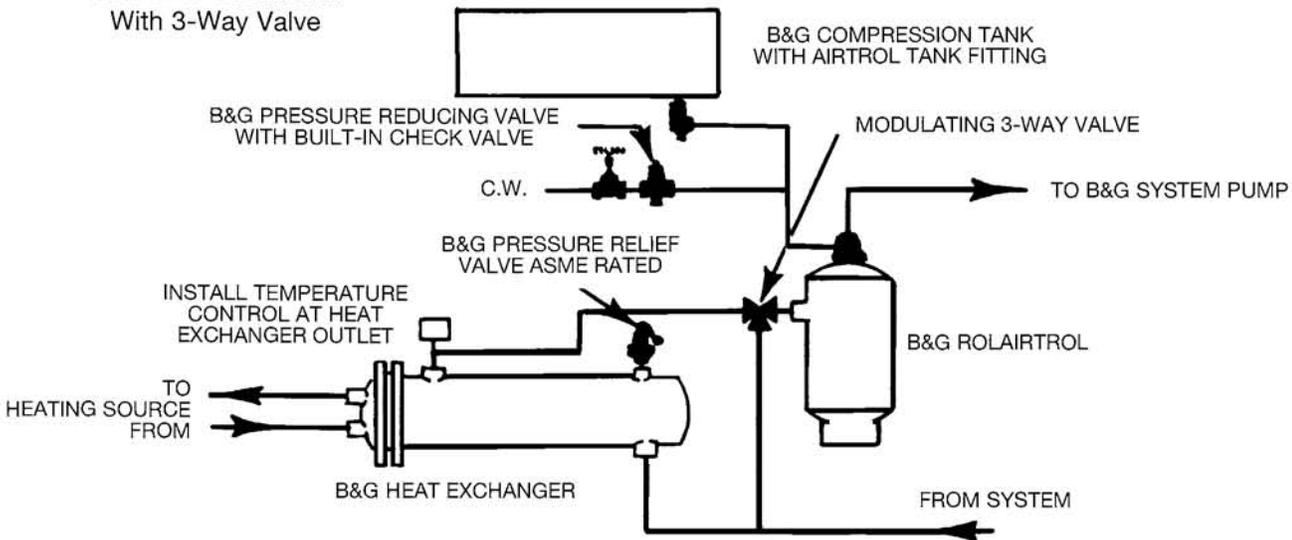


FIGURE 32
Converter Installation
With 3-Way Valve

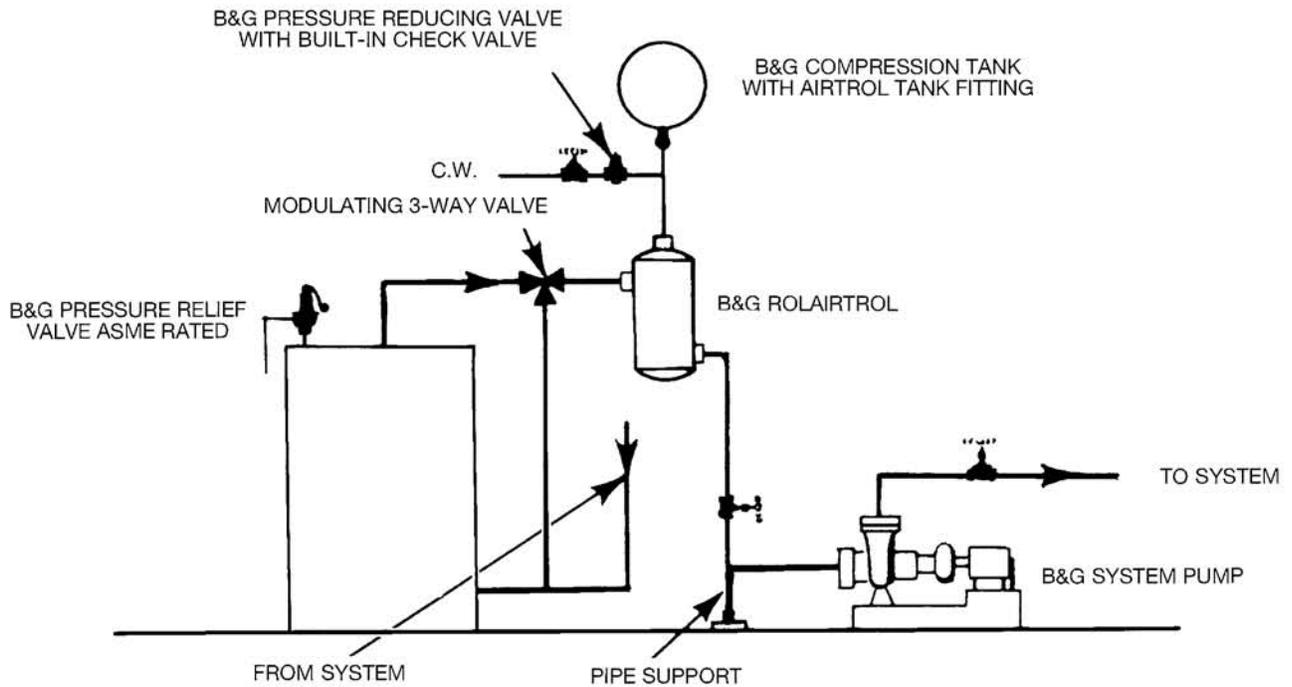


THREE WAY VALVE INSTALLATIONS

When a three way valve is used to modulate water temperatures and provide continuous circulation an air separator sized for the main system flow should be installed. Such an installation is shown in Figures 32 & 33 and permits the use of a three way mixing type

valve to provide water temperature modulation with continuous fluid circulation through the system. Note the location of the point of no pressure change at the air separator is also at the suction side of the pump.

FIGURE 33
Boiler Installation With 3-Way Valve



TEMPERATURE MODULATION WITH SECONDARY PUMPING

An effective yet inexpensive method of system temperature modulation is accomplished by employing secondary pumping. The required temperature of the water being continuously circulated through the primary system can be maintained to satisfy the needs of the secondary heating system by a small heat injection pump that cycles, putting hot boiler water into the loop to offset the heat removed in the active heating zones. Figures 34 and 35 illustrate the piping arrangements and components required. The injection pump required is usually much smaller than the primary circulating pump and can

often be an in-line Booster Pump. The cost of a small heating pump and the smaller size piping to the heat source is usually less than the cost of a modulating three way valve which must be sized for the full system water flow.

Keep in mind the possibility of thermal shock due to cold water entering a hot boiler. Several methods can be used to guard against this, see B&G Bulletins TEH-775 and TEH-1275. As illustrated, year-around boiler usage is possible since system pressurization is maintained.

FIGURE 34

Air Control With Primary/Secondary Pumping

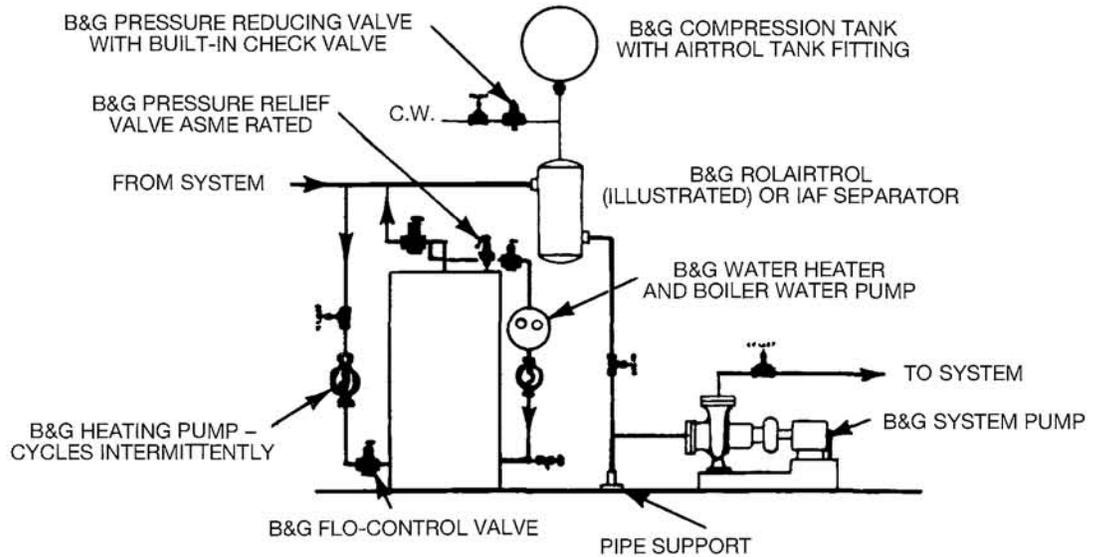
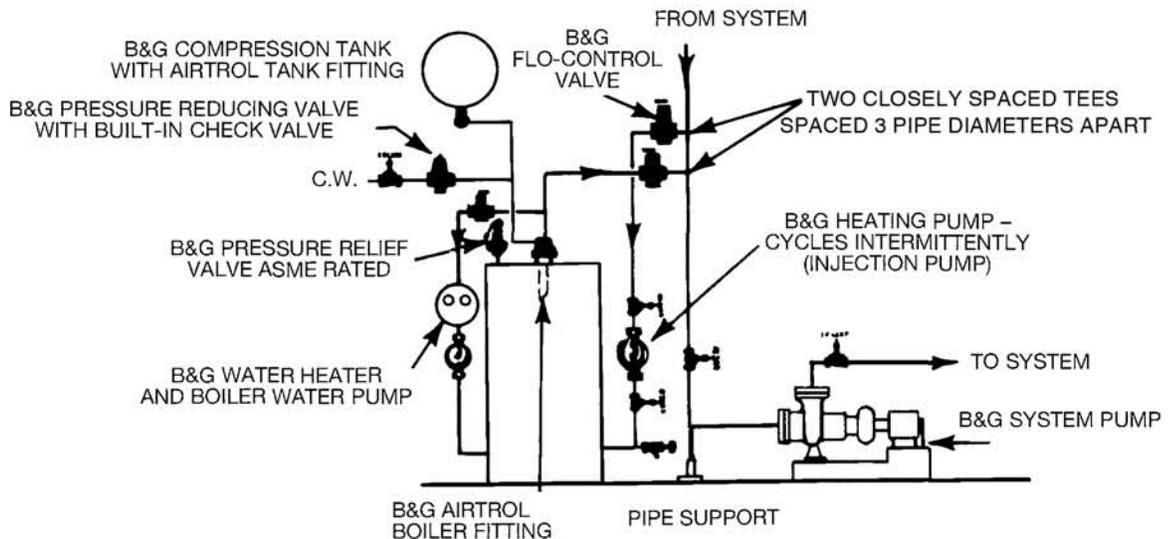


FIGURE 35

Air Control With Primary/Secondary Pumping

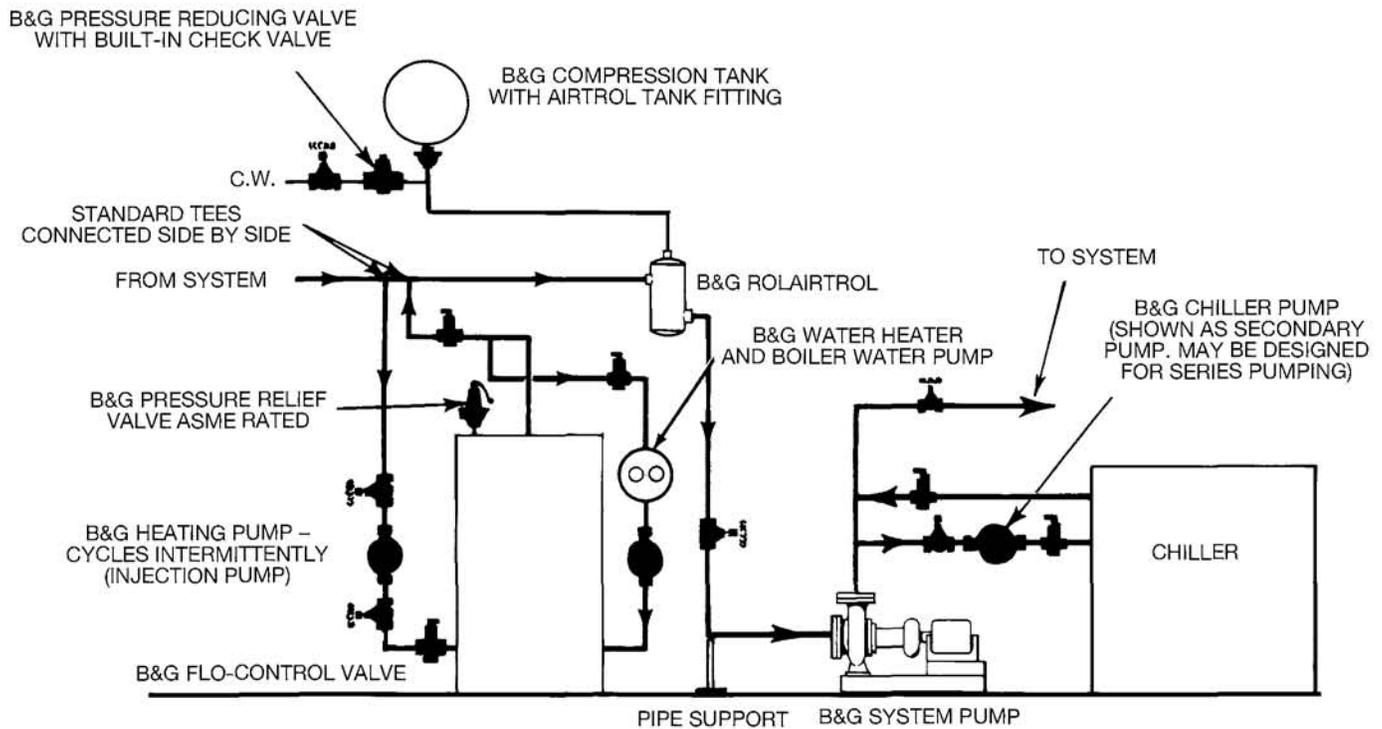


AIR CONTROL IN COMBINATION HEATING AND COOLING SYSTEMS

All closed hydronic systems, heating and/or cooling, require air management with adequate system pressurization. In addition, a single compression tank connection remains a requirement to achieve a fixed point of no pressure change. Multiple tank connections in a closed system permit the water level to change in each tank and the point of no pressure change to move. The preferred method for installing air control

equipment and connecting a single compression tank for a combination heating/cooling system is shown in Figure 36. The pressure on the system is equalized at all times during heating or cooling cycles by the Flo-control valve arrangement between the chilled water circuit and boiler circuit. Switchover can be either automatic or manual, the system will never be isolated from the tank.

FIGURE 36
Air Control In Combination Heating/Cooling



TYPICAL AIR SEPARATOR INSTALLATION DETAILS

Illustrated are typical installation details for air separators in both Air Control and Air Elimination air management systems. Note that in all cases the connection between the tank and the piping system (the

point of no pressure change) is at the pump suction. This is always the preferred location but is the required location for high headed pumps.

FIGURE 37
CRS Coalescing Removal Separator

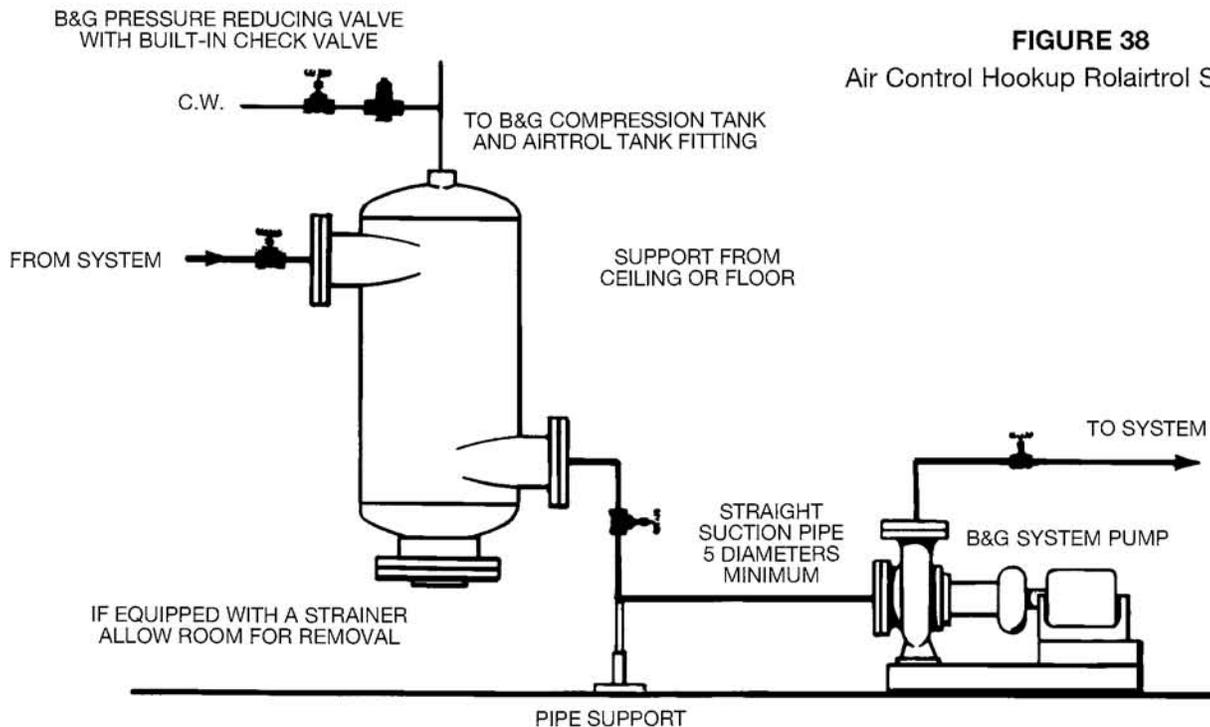
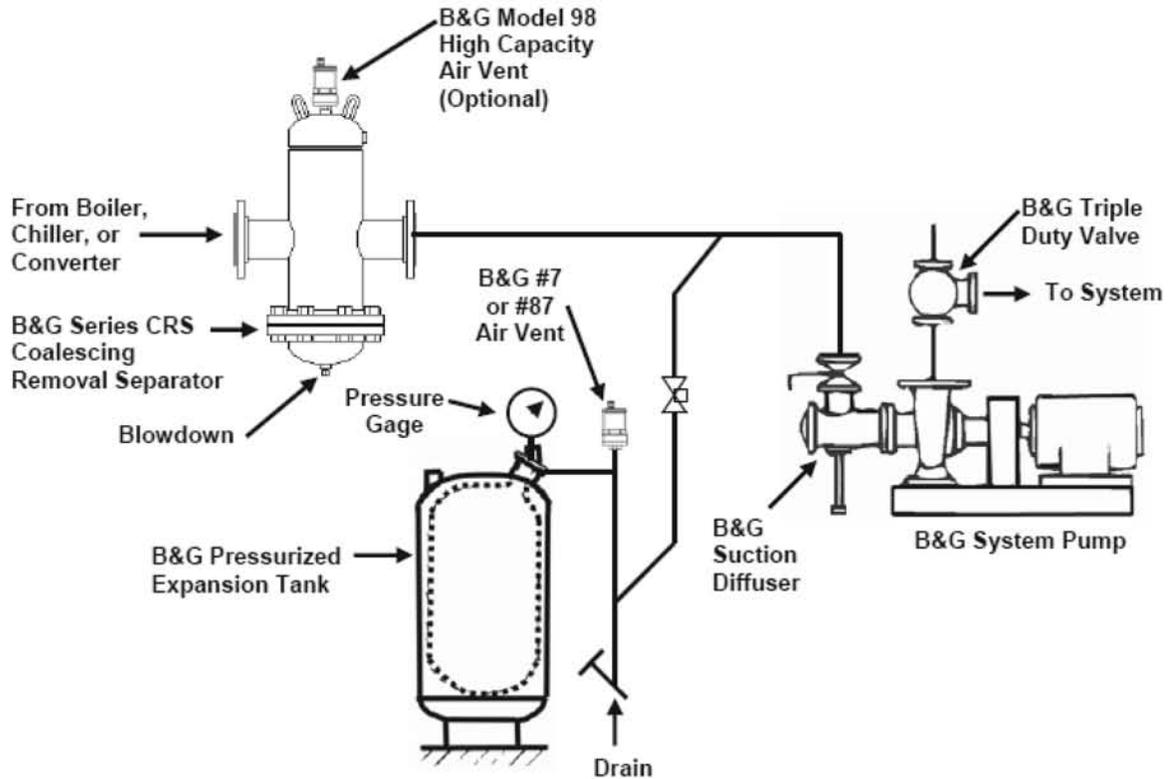


FIGURE 38
Air Control Hookup Rolairtrol Separator

PRESSURIZED EXPANSION TANK INSTALLATION DETAILS FOR AIR ELIMINATION TYPE AIR MANAGEMENT SYSTEMS

The following figures illustrate the proper hookup of a pressurized tank in an Air Elimination System.

- Vertical Pressurized Expansion Tank with Rolairtrol Air Separator
- Horizontal Pressurized Expansion Tank with Rolairtrol Air Separator
- Typical piping using IAF or ABF Air Separators (for reference only)
- Pressurized Expansion Tank with IAS Air Separator

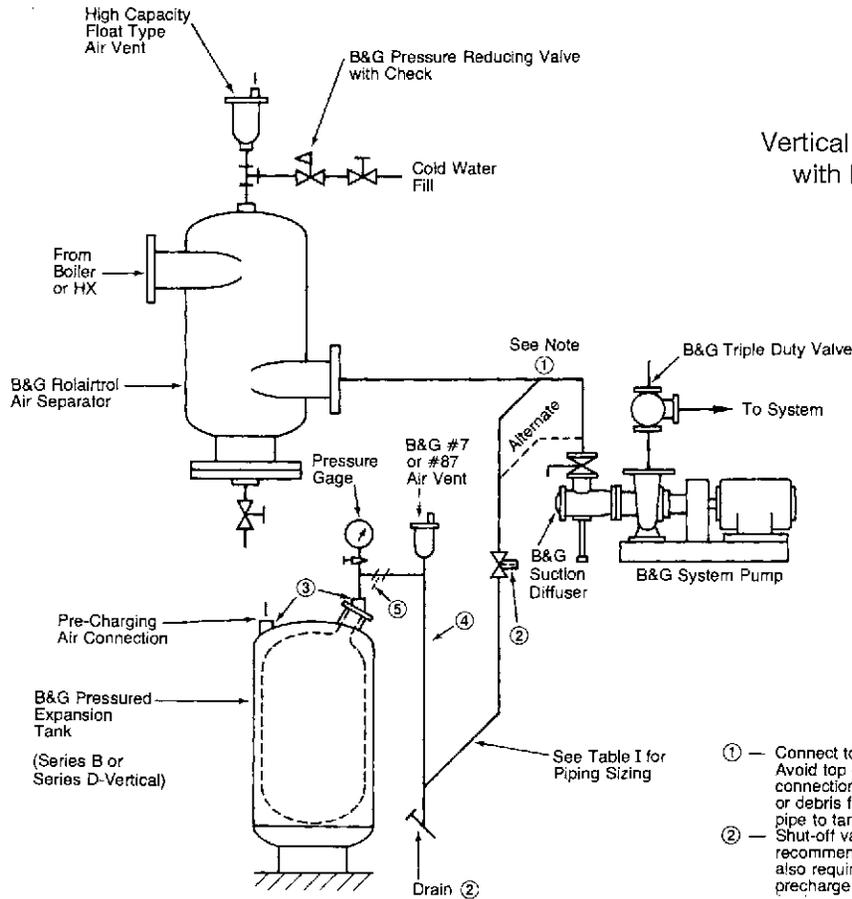
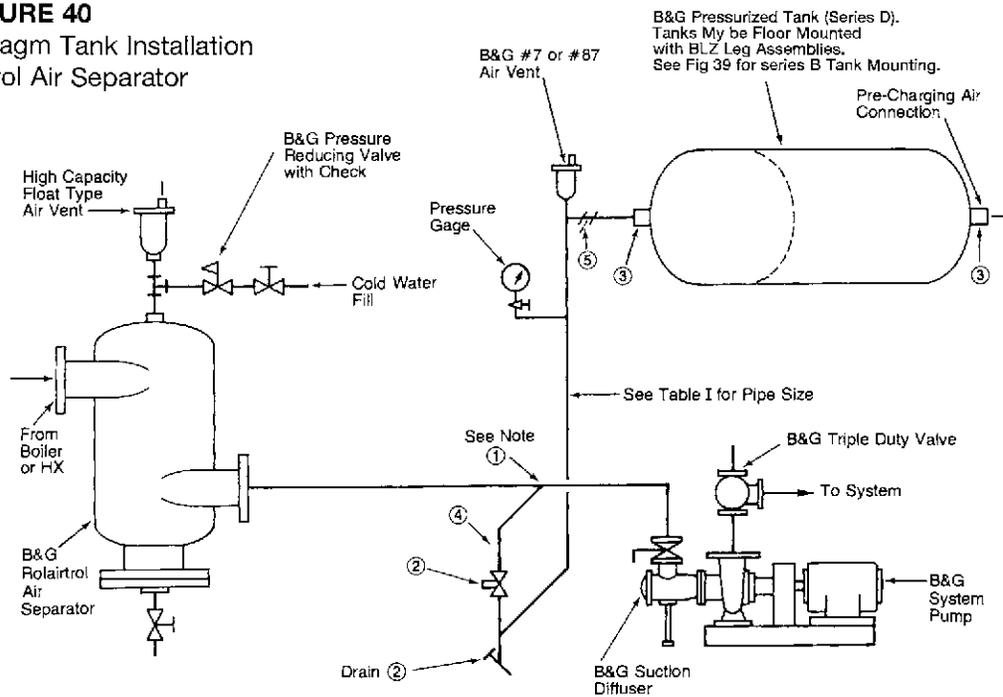


FIGURE 39
Vertical Bladder Tank Installation
with Rolairtrol Air Separator

- ① — Connect to side of main. Avoid top or bottom connection to prevent air or debris from entering pipe to tank.
- ② — Shut-off valve recommended. Drain valve also required to properly precharge tank.
- ③ — Tank connection locations may vary depending on tank size and model.
- ④ — Provide anti-thermo-syphon loop to prevent gravity heating of tank. 12" min. drop.
- ⑤ — Insert tee here for system water connection of parallel tanks (if used).

FIGURE 40
Horizontal Diaphragm Tank Installation
with Rolairtrol Air Separator



- NOTES:**
- ① — Connect to side of main. Avoid top or bottom connection to prevent air or debris from entering pipe to tank.
 - ② — Shut-off valve recommended. Drain valve also required to properly precharge tank.
 - ③ — Tank connection locations may vary depending on tank size and model.
 - ④ — Provide anti-thermo-syphon loop to prevent gravity heating of tank. 12" min. drop.
 - ⑤ — Insert tee here for system water connection of parallel tanks (if used).

FIGURE 41

Typical piping with IAF In-Line Air Separator or Airtrol Boiler Fitting

(for reference only.
NOTE: IAF and ABF are obsolete products)

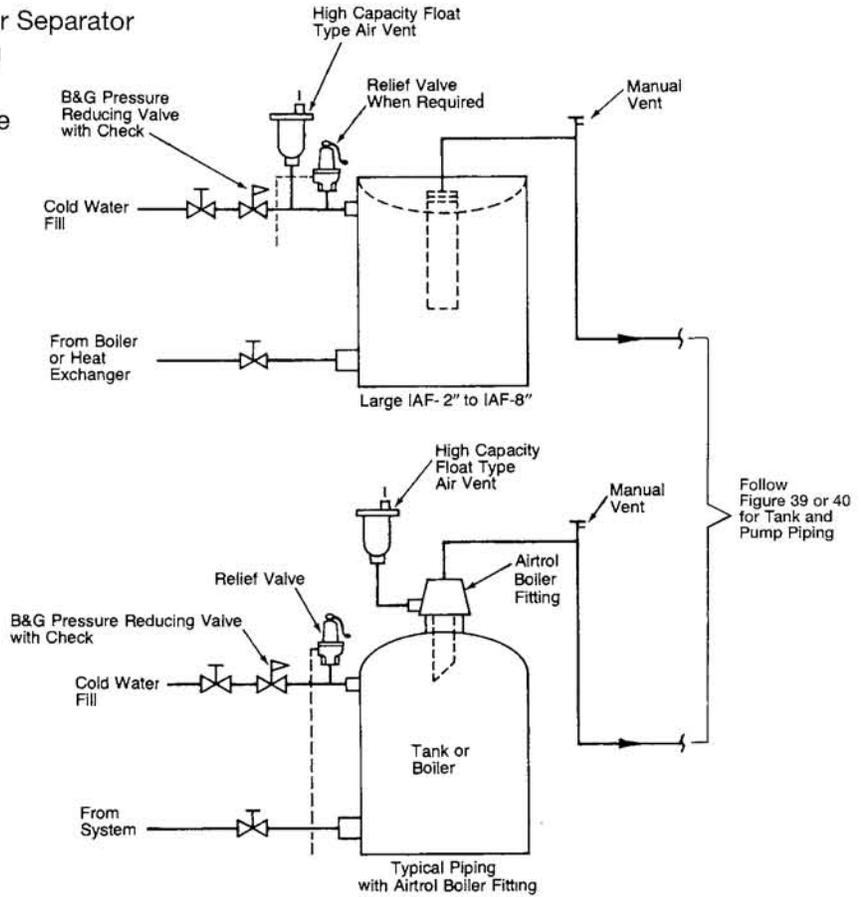
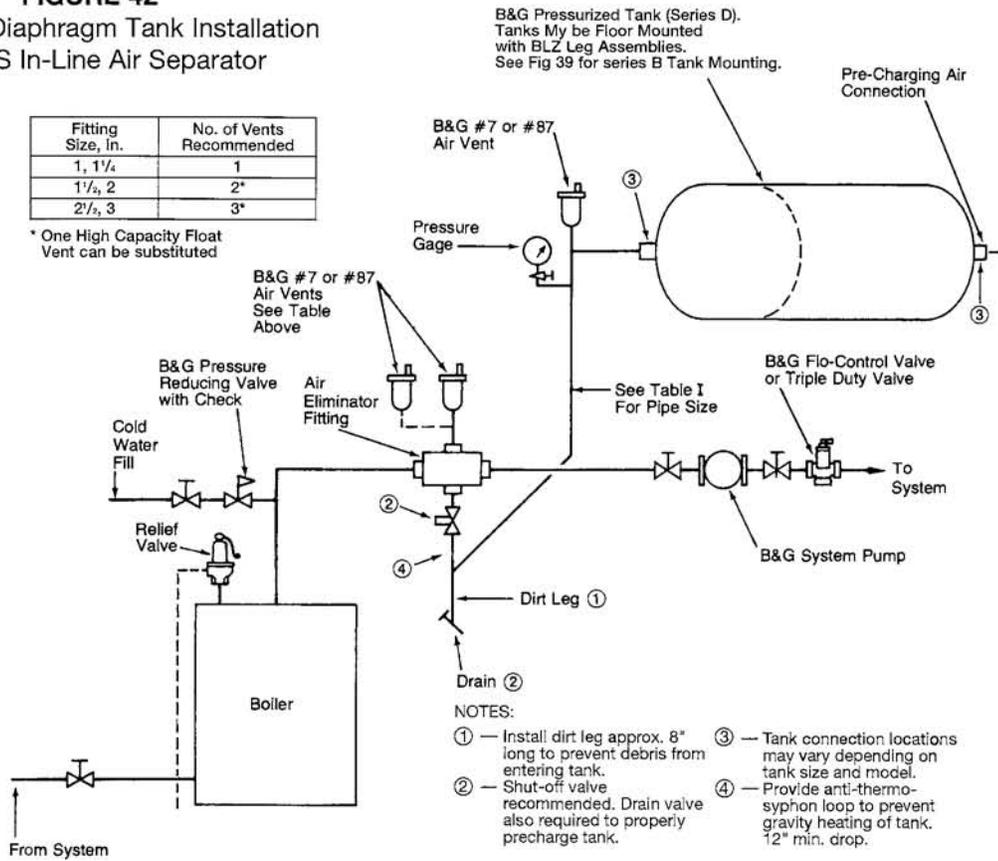


FIGURE 42

Horizontal Diaphragm Tank Installation with IAS In-Line Air Separator

Fitting Size, in.	No. of Vents Recommended
1, 1 1/4	1
1 1/2, 2	2*
2 1/2, 3	3*

* One High Capacity Float Vent can be substituted



NOTES:

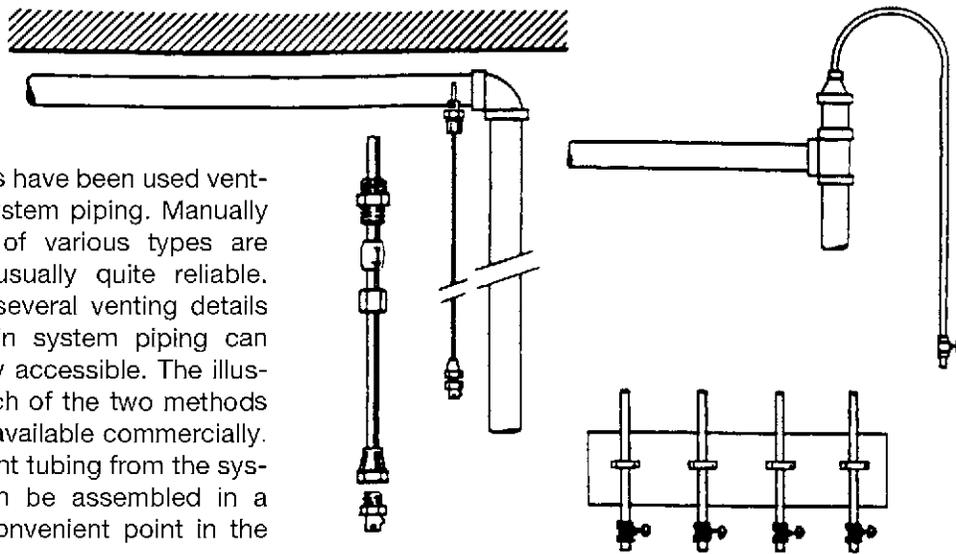
- ① — Install dirt leg approx. 8" long to prevent debris from entering tank.
- ② — Shut-off valve recommended. Drain valve also required to properly precharge tank.
- ③ — Tank connection locations may vary depending on tank size and model.
- ④ — Provide anti-thermosiphon loop to prevent gravity heating of tank. 12" min. drop.

TYPICAL VENTING AND PURGING DETAILS

A number of methods have been used to vent high points of system piping. Manually operated air vents of various types are available, are usually reliable and definitely should be used instead of automatic versions for this service, and for all uses in an Air Control air management installation. Automatic air vents are necessary to vent the air separated in an Air Elimination

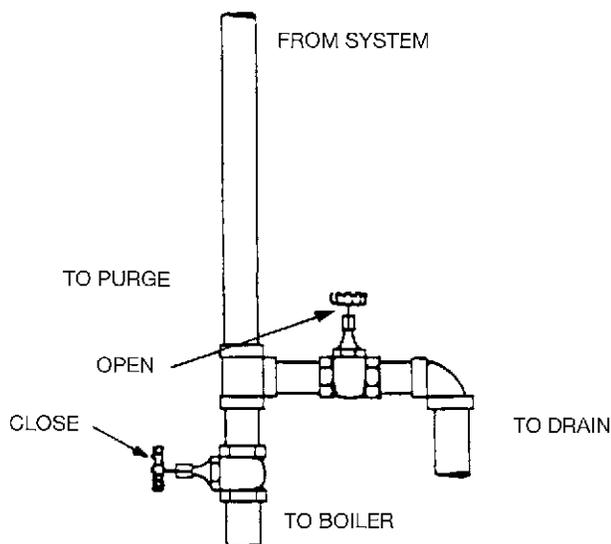
air management installation. However, care must be exercised in the location of these automatic air vents to ensure accessibility should they require maintenance. Illustrated here are several details which make venting high points in a system more easily accessible. The fittings shown are commercially available.

FIGURE 43
Typical Venting Details



A number of methods have been used venting high points of system piping. Manually operated air vents of various types are available and are usually quite reliable. Illustrated here are several venting details where high points in system piping can be made more easily accessible. The illustrated fittings for each of the two methods shown are normally available commercially. In larger systems, vent tubing from the system high points can be assembled in a manifold at some convenient point in the mechanical room.

FIGURE 44



The purging hookup shown here is typical. Purging uses city water pressure to sweep the air in the system to a point where it is vented off. City water continues to flow until the discharge entering the drain is clear. Use care when city water pressures are high to ensure that the working pressures of all system components are not exceeded.

TYPICAL SYSTEM FILL DETAILS

A typical closed system with manual fill is illustrated in Figure 45. Manual fill can be by direct or hose connection to the city water supply. When the system uses anti-freeze, the fill tank shown would be used. In either case good practice would include installation of a low water cutoff to protect the system.

A typical automatic water fill using a small Bell & Gossett pressure Reducing Valve is illustrated in Figure 46. The optional by-pass line (valve is normally

closed) permits a faster fill rate than with the pressure reducing valve. If the system requires purging to get rid of the air at initial fill, a by-pass is necessary. Good practice now dictates installing a low water cutoff and shutting off the city water supply to the heating system after the initial fill and setting of the cold fill pressure.

Check local codes, many require installation of a backflow preventer.

FIGURE 45
Manual Fill Closed System

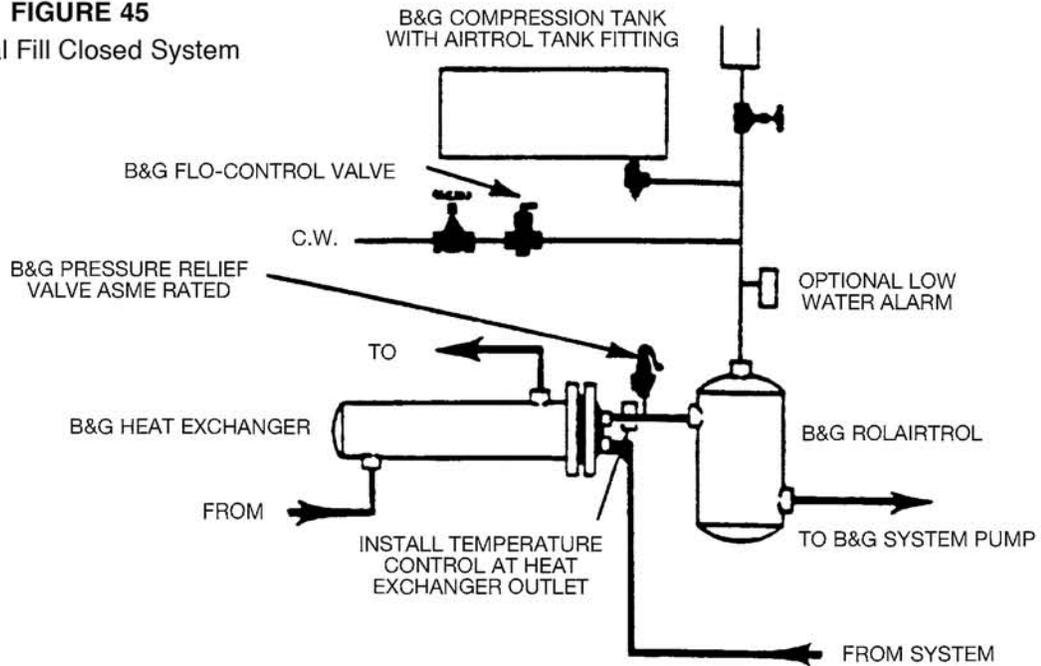
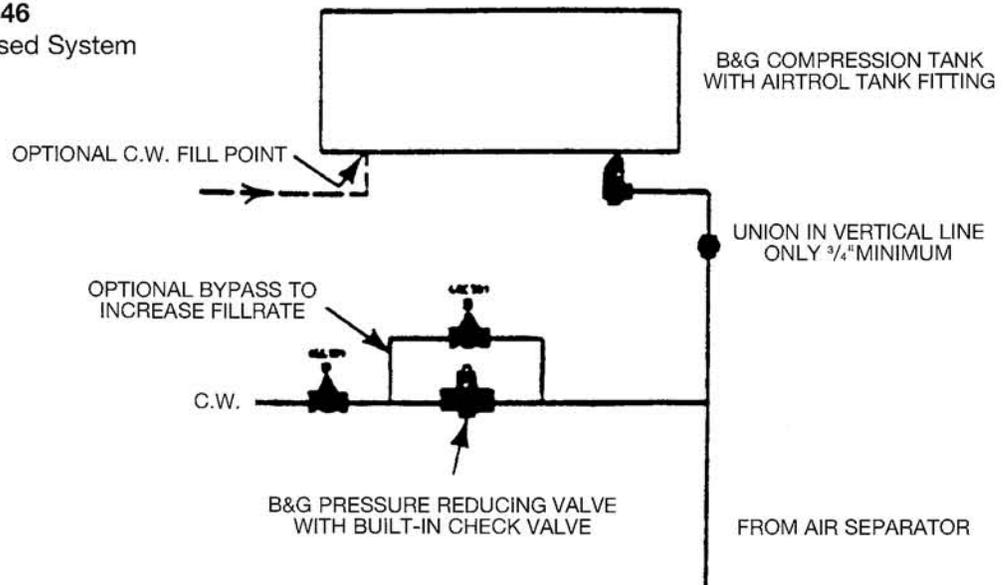


FIGURE 46
Automatic Fill Closed System



APPENDIX

FIGURE NO.	TITLE
47	Standard Compression Tank Sizing Worksheet
48	Pressurized Expansion Tank Sizing Worksheet
TABLE NO.	TITLE
C	Average Water Content of System Components
D	Water Volume Per Foot of Pipe
E	Shell & Tube Heat Exchanger Average Water Volume
F	Net Water Expansion Factors
G	Aqueous Glycol Solution Correction Factor
H	Standard Compression Tank Sizing Chart
I	Pressure Correction Factors for Standard Compression Tank Table Selections
J	Correction Factors for Mechanically Charged Standard Compression Tanks
K	Stock Standard Compression Tanks
L	Acceptance Factors
M	Pressurized Expansion Tank Sizing Chart
N	Pressure Correction Factors for Pressurized Expansion Tank Table Selections
O	Stock Pressurized Expansion Tanks

TABLE C - Average Water Content of System Components, Gals

MBH 1000's BTU/HR	BOILERS		RADIATION										AVERAGE PIPING SYSTEM BASED ON AVERAGE PIPE SIZES FOR 20°F TEMP DROP		
	CONVENTIONAL (NOT WATER TUBE)	SMALL FLASH TYPE	CAST IRON			NON-FERROUS			FAN COIL UNIT HEATER	ONE PIPE	TWO PIPE	RADIANT PANEL			
			LARGE TUBE	THIN TUBE	CONNECTOR	BASEBOARD	CONNECTOR	BASEBOARD							
5	1.2	.6	2.9	1.4	0.6	2.4	0.3	0.2	0.1	0.8	1.1	1.1			
10	2.4	1.0	5.7	2.8	1.3	4.7	0.7	0.4	0.2	1.4	2.1	2.4			
15	3.6	1.5	8.6	4.4	2.0	7.1	1.0	0.6	0.3	2.2	3.2	3.5			
20	4.8	2.0	11.4	5.6	2.5	9.5	1.3	0.8	0.4	2.9	4.3	4.6			
25	6.0	2.7	14.3	7.9	3.5	11.8	1.6	1.0	0.5	3.9	5.3	5.5			
30	7.2	3.2	17.1	8.4	3.8	14.2	2.0	1.1	0.6	4.5	6.3	6.8			
35	8.4	3.6	20.0	9.8	4.4	16.5	2.3	1.3	0.7	5.0	7.3	8.0			
40	9.6	4.0	23.0	11.4	5.0	18.9	2.6	1.5	0.8	5.8	8.5	9.3			
45	10.8	4.3	26.0	12.6	5.6	21.0	2.9	1.7	0.9	6.5	9.0	10.5			
50	12.0	5.4	29.0	15.7	7.0	24.0	3.2	1.9	1.0	7.8	10.5	11.0			
60	14.5	6.4	34.0	16.8	7.5	28.0	4.0	2.2	1.2	9.0	12.5	13.5			
70	17.0	7.2	40.0	20.0	8.7	33.0	4.5	2.6	1.4	10.0	14.5	16.0			
80	19.5	5.0	46.0	22.0	10.0	38.0	5.2	3.0	1.6	11.5	17.0	18.5			
90	22.0	8.6	51.0	25.0	11.3	43.0	5.8	3.3	1.8	13.0	18.0	21.0			
100	25.0	9.4	57.0	28.0	12.5	47.0	6.5	3.7	2.0	14.0	21.0	24.0			
125	30.0	11.0	71.0	39.0	17.7	59.0	8.1	4.6	2.5	18.0	27.0	30.0			
150	36.0	13.0	86.0	48.0	21.0	71.0	9.7	5.5	3.0	22.0	34.0	37.0			
175	42.0	14.5	99.0	55.0	25.0	83.0	11.3	6.5	3.5	26.0	40.0	44.0			
200	48.0	16.0	114.0	64.0	29.0	94.0	13.0	7.4	4.0	30.0	47.0	50.0			
250	60.0		142.0	80.0	36.0	118.0	16.2	9.0	5.0	39.0	62.0	65.0			
300	70.0		171.0	96.0	43.0	142.0	19.5	11.0	6.0	49.0	78.0	70.0			
350	84.0		199.0	111.0	50.0	165.0	23.0	13.0	7.0	58.0	94.0				
400	95.0		228.0	127.0	57.0	189.0	26.0	15.0	8.0	70.0	110.0				
450	107.0		256.0	143.0	64.0	212.0	29.0	17.0	9.0	80.0	130.0				
500	120.0		285.0	157.0	71.0	236.0	33.0	18.0	10.0	90.0	150.0				
600	140.0		342.0	191.0	86.0	283.0	39.0	22.0	12.0	115.0	190.0				
700	160.0		399.0	223.0	99.0	330.0	46.0	26.0	14.0	140.0	225.0				
800	190.0		456.0	251.0	114.0	377.0	52.0	30.0	16.0	165.0	260.0				
900	210.0		513.0	287.0	128.0	424.0	59.0	33.0	18.0	195.0	310.0				
1000	235.0		570.0	319.0	142.0	477.0	65.0	37.0	20.0	225.0	360.0				
2000	480.0		1140.0	638.0	285.0	942.0	130.0	74.0	10.0	540.0	900.0				
3000	720.0		1710.0	957.0	427.0	1414.0	195.0	110.0	60.0	960.0	1500.0				
4000	960.0		2280.0	1276.0	560.0	1885.0	260.0	150.0	80.0	1350.0	2100.0				
8000	1200.0		4560.0	2553.0	1140.0	3770.0	520.0	300.0	160.0	3400.0	5000.0				
12000	3000.0		6840.0	3830.0	1710.0	5655.0	780.0	445.0	240.0	5000.0	9000.0				
16000	3700.0		9120.0	5107.0	2280.0	7542.0	1040.0	580.0	320.0	8300.0	13000.0				

TABLE D
Water Volume per Foot of Pipe

PIPE SIZE NOMINAL	GAL PER LINEAL FT.	PIPE SIZE NOMINAL	GAL PER LINEAL FT.
1/8	0.016	3	0.38
3/8	0.028	4	0.66
1	0.045	5	1.04
1 1/4	0.078	6	1.50
1 1/2	0.106	8	2.66
2	0.170	10	4.20
2 1/2	0.250	12	5.96

TABLE E
Shell and Tube Heat Exchangers, Average Water Volume

NOMINAL SHELL DIAMETER, INCHES	GALLONS PER FOOT OF SHELL LENGTH	
	IN SHELL	IN TUBES
4	0.43	0.23
6	1.00	0.50
8	1.80	0.90
10	2.40	1.20
12	4.00	2.20
14	5.00	2.60
16	6.50	3.50
18	8.00	4.50
20	10.00	5.50
24	15.00	7.50

TABLE F
Net Water Expansion Factors

TEMPERATURE °F	FACTOR						
100	0.0057	140	0.0149	180	0.0279	220	0.0433
105	0.0068	145	0.0167	185	0.0296	225	0.0457
110	0.0080	150	0.0178	190	0.0314	230	0.0475
115	0.0092	155	0.0196	195	0.0332	235	0.0505
120	0.0097	160	0.0208	200	0.0350	240	0.0523
125	0.0115	165	0.0225	205	0.0374	245	0.0547
130	0.0126	170	0.0243	210	0.0391	250	0.0571
135	0.0138	175	0.0261	215	0.0415	255	0.0595

TABLE G
Aqueous Glycol Solution Correction Factors

TYPE	% BY VOLUME	APPROX. FREEZE TEMP °F	TEMPERATURE °F											
			100	110	120	130	140	150	160	180	200	220	240	250
ETHYLENE GLYCOL	10	25	1.70	1.47	1.46	1.31	1.28	1.24	1.20	1.13	1.11	1.08	1.06	1.05
	20	16	1.75	1.54	1.51	1.38	1.35	1.29	1.25	1.18	1.15	1.12	1.10	1.09
	30	4	1.96	1.68	1.66	1.49	1.45	1.38	1.35	1.25	1.22	1.18	1.15	1.14
	40	-13	2.06	1.77	1.75	1.56	1.52	1.45	1.41	1.31	1.27	1.23	1.20	1.19
	50	-35	2.24	1.91	1.88	1.67	1.63	1.55	1.49	1.38	1.34	1.29	1.25	1.24
PROPYLENE GLYCOL	10	26	1.76	1.53	1.52	1.37	1.34	1.29	1.26	1.18	1.16	1.12	1.11	1.10
	20	18	2.07	1.79	1.76	1.58	1.55	1.47	1.43	1.34	1.30	1.26	1.24	1.23
	30	8	2.42	2.08	2.05	1.83	1.77	1.68	1.63	1.50	1.46	1.40	1.37	1.35
	40	-7	2.61	2.25	2.19	1.96	1.90	1.81	1.75	1.62	1.56	1.50	1.46	1.45
	50	-28	2.87	2.47	2.42	2.15	2.07	1.97	1.90	1.75	1.68	1.61	1.57	1.55

Correct the standard compression tank selected from Table H or the pressurized tank selected from Table M with the above factor.
Both tank volume and acceptance volume must be corrected for pressurized tanks.

STANDARD COMPRESSION TANK SIZING WORKSHEET

SYSTEM VOLUME

Use actual if available. If not, Table C has average volumes for boilers, radiation and piping systems.

<u>ITEM</u>	<u>BTU RATING</u>	<u>WATER CONTENT</u>
Boiler or Chiller	_____	_____
Radiation or Terminal Unit	_____	_____
Piping	_____	_____
	SYSTEM VOLUME	_____

TANK SIZING

1. Average design water temperature, °F _____
2. Initial tank pressure, psi _____
3. Maximum pressure at the tank, psi _____
4. Tank required, standard conditions, (Table H) _____ gals
5. Correction factor for non standard pressures (Table I), use 1 if standard _____
6. Correction factor for Glycol (Table G), use 1 if water _____
7. Adjusted tank volume required (Multiply line 4 by lines 5 & 6) _____ gals

TANK AND AIRTROL TANK FITTING SELECTED

TANK MODEL _____, gal _____ TANK FITTING NO. _____

NOTE: Tank volume of Model selected must be greater than that required in step 7.

FIGURE 47
Standard Compression Tank Sizing Worksheet

TABLE H
Standard Tank Sizing Chart

Sizing based on pressures at the tank, $P_{initial} = 12\text{psi}$ and $P_{max\ operating} = 30\text{psi}$

MEAN DESIGN WATER TEMPERATURE, °F

SYSTEM VOLUME gal	100	110	120	130	140	150	160	180	200	220	240	250
	V_i gal											
1	0.03	0.04	0.04	0.06	0.07	0.08	0.09	0.13	0.16	0.20	0.24	0.26
2	0.05	0.07	0.09	0.11	0.13	0.16	0.19	0.25	0.32	0.39	0.47	0.52
3	0.08	0.11	0.13	0.17	0.20	0.24	0.28	0.38	0.47	0.59	0.71	0.77
4	0.10	0.14	0.17	0.23	0.27	0.32	0.38	0.50	0.63	0.78	0.94	1.03
5	0.13	0.18	0.22	0.28	0.34	0.40	0.47	0.63	0.79	0.98	1.18	1.29
6	0.15	0.22	0.26	0.34	0.40	0.48	0.57	0.76	0.95	1.17	1.42	1.55
7	0.18	0.25	0.31	0.40	0.47	0.56	0.66	0.88	1.11	1.37	1.65	1.80
8	0.21	0.29	0.35	0.45	0.54	0.64	0.76	1.01	1.26	1.56	1.89	2.06
9	0.23	0.32	0.39	0.51	0.60	0.72	0.85	1.13	1.42	1.43	2.12	2.32
10	0.26	0.36	0.44	0.57	0.67	0.80	0.95	1.26	1.58	1.95	2.36	2.58
20	0.50	0.70	0.90	1.10	1.30	1.60	1.90	2.50	3.20	3.90	4.70	5.20
30	0.80	1.10	1.30	1.70	2.00	2.40	2.80	3.80	4.70	5.90	7.10	7.70
40	1.00	1.40	1.70	2.30	2.70	3.20	3.80	5.00	6.30	7.80	9.40	10.30
50	1.30	1.80	2.20	2.80	3.40	4.00	4.70	6.30	7.90	9.80	11.80	12.90
60	1.50	2.20	2.60	3.40	4.00	4.80	5.70	7.60	9.50	11.70	14.20	15.50
70	1.80	2.50	3.10	4.00	4.70	5.60	6.60	8.80	11.10	13.70	16.50	18.00
80	2.10	2.90	3.50	4.50	5.40	6.40	7.60	10.10	12.60	15.60	18.90	20.60
90	2.30	3.20	3.90	5.10	6.00	7.20	8.50	11.30	14.20	17.60	21.20	23.20
100	2.60	3.60	4.40	5.70	6.70	8.00	9.50	12.60	15.80	19.50	23.60	25.80
200	5.00	7.00	9.00	11.00	13.00	16.00	19.00	25.00	32.00	39.00	47.00	52.00
300	8.00	11.00	13.00	17.00	20.00	24.00	28.00	38.00	47.00	59.00	71.00	77.00
400	10.00	14.00	17.00	23.00	27.00	32.00	38.00	50.00	63.00	78.00	94.00	103.00
500	13.00	18.00	22.00	28.00	34.00	40.00	47.00	63.00	79.00	98.00	118.00	129.00
600	15.00	22.00	26.00	34.00	40.00	48.00	57.00	76.00	95.00	117.00	142.00	155.00
700	18.00	25.00	31.00	40.00	47.00	56.00	66.00	88.00	111.00	137.00	165.00	180.00
800	21.00	29.00	35.00	45.00	54.00	64.00	76.00	101.00	126.00	156.00	189.00	206.00
900	23.00	32.00	39.00	51.00	60.00	72.00	85.00	113.00	142.00	176.00	212.00	232.00
1000	26.00	36.00	44.00	57.00	67.00	80.00	95.00	126.00	158.00	195.00	236.00	258.00
2000	51.00	72.00	87.00	114.00	134.00	161.00	189.00	252.00	316.00	391.00	472.00	515.00
3000	77.00	108.00	131.00	170.00	202.00	241.00	284.00	378.00	474.00	586.00	708.00	773.00
4000	103.00	144.00	175.00	227.00	269.00	321.00	379.00	503.00	631.00	781.00	944.00	1030.00
5000	129.00	180.00	218.00	284.00	336.00	401.00	474.00	629.00	789.00	977.00	1180.00	1288.00
6000	154.00	216.00	262.00	341.00	403.00	482.00	568.00	755.00	947.00	1172.00	1415.00	1545.00
7000	180.00	253.00	306.00	398.00	470.00	562.00	663.00	881.00	1105.00	1367.00	1651.00	1803.00
8000	206.00	289.00	349.00	455.00	538.00	642.00	758.00	1007.00	1263.00	1562.00	1887.00	2060.00
9000	231.00	325.00	393.00	511.00	605.00	723.00	852.00	1133.00	1421.00	1758.00	2123.00	2318.00
10000	257.00	361.00	437.00	568.00	672.00	803.00	947.00	1258.00	1579.00	1953.00	2359.00	2576.00

TABLE I
Pressure Correction Factors
 Use to size standard tanks at other than standard pressure conditions

INITIAL PRESSURE ON THE TANK PSI	ALLOWABLE SYSTEM PRESSURE INCREASE, PSI											
	6	8	10	12	14	16	20	25	30	40	50	75
4	1.16	0.95	0.81	0.72	0.66	0.61	0.55	0.49	0.46	0.42	0.39	0.35
8	1.64	1.31	1.12	0.99	0.90	0.83	0.73	0.65	0.60	0.54	0.50	0.45
12	2.20	1.75	1.48	1.30	1.17	1.08	0.94	0.83	0.76	0.67	0.62	0.55
18	3.20	2.51	2.11	1.84	1.65	1.50	1.30	1.14	1.03	0.90	0.82	0.71
24	4.36	3.41	2.84	2.47	2.20	2.00	1.71	1.49	1.34	1.15	1.04	0.88
30		4.43	3.68	3.20	2.82	2.56	2.18	1.88	1.68	1.43	1.28	1.08
38			4.98	4.29	3.79	3.42	2.89	2.47	2.19	1.84	1.63	1.35
50							4.10	3.50	3.10	2.60	2.24	1.82
60								4.49	3.93	3.23	2.81	2.25
70									4.88	3.98	3.34	2.71

Multiply the tank size selected from Table H by the correction factor to determine the standard tank size required for the non standard pressure conditions.

TABLE J
Correction Factors for Standard Tanks Selected from Table H
 When tank is mechanically charged with gas to 80% of the tank's volume

INITIAL PRESSURE AT TANK	ALLOWABLE SYSTEM PRESSURE INCREASE, - RELIEF VALVE OPERATING RANGE											
	6	8	10	12	14	16	20	25	30	40	50	75
8	1.15	1.00	0.90	0.84	0.77	0.72	0.65	0.58	0.53	0.48	0.45	0.45
12	1.40	1.20	1.05	0.97	0.89	0.85	0.72	0.63	0.58	0.51	0.49	0.47
18	1.70	1.50	1.25	1.10	1.03	0.95	0.82	0.70	0.63	0.55	0.53	0.52
24	2.15	1.75	1.50	1.30	1.20	1.10	0.96	0.73	0.70	0.60	0.55	0.53
30	2.30	1.90	1.65	1.43	1.30	1.18	1.00	0.83	0.73	0.63	0.60	0.55
38		2.15	1.85	1.60	1.45	1.30	1.10	0.92	0.83	0.70	0.62	0.59
50			2.25	1.90	1.73	1.58	1.30	1.10	0.95	0.80	0.72	0.62
60				2.15	1.90	1.73	1.45	1.23	1.07	0.88	0.77	0.68

TABLE K
Stock Standard Tanks

STANDARD COMPRESSION TANK CAPACITIES & TANK FITTING	
TANK MODEL NUMBER AND VOLUME, gals	TANK FITTING MODEL NUMBER
15	ATF-12
24	ATF-12
30	ATF-12
40	ATF-12
60	ATF-16
80	ATF-20
100	ATFL
120	ATFL
135	ATFL
175	ATFL
220	ATFL
240	ATFL
305	ATFL
400	ATFL

PRESSURIZED EXPANSION TANK SIZING WORKSHEET

SYSTEM VOLUME

Use actual if available. If not, Table C has average volumes for boilers, radiation and piping systems.

<u>ITEM</u>	<u>BTU RATING</u>	<u>WATER CONTENT</u>
Boiler or Chiller	_____	_____
Radiation or Terminal Unit	_____	_____
Piping	_____	_____
	SYSTEM VOLUME	_____

TANK SIZING

- | | |
|--|------------|
| 1. Average design water temperature, °F | _____ |
| 2. Initial tank pressure, psi | _____ |
| 3. Maximum pressure at the tank, psi | _____ |
| 4. Tank required, standard conditions, (Table M) | _____ gals |
| 5. Acceptance volume required, (Table M) | _____ gals |
| 6. Correction factor for non standard pressures (Table N), use 1 if standard | _____ |
| 7. Correction factor for Glycol (Table G), use 1 if water | _____ |
| 8. Adjusted tank volume required (Multiply line 4 by lines 6 & 7) | _____ gals |
| 9. Adjusted acceptance required (Multiply line 5 by line 7) | _____ gals |

TANK SELECTED

MODEL _____ TANK, gal _____ ACCEPTANCE, gal _____

NOTE: Model selected must have tank volume and acceptance volume greater than those required in steps 8 and 9.

FIGURE 48
Pressurized Expansion Tank Sizing Worksheet

TABLE L

Acceptance Factors ($A_e = 1 - P/P_{maxop}$) Based on atmospheric pressure of 14.7 psi

* P_{maxop} MAXIMUM OPERATING PRESSURE psig	* P_1 - MINIMUM OPERATING PRESSURE AT TANK, psig																								
	5	10	12	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	105	110	115	
10	0.202																								
12	0.262	0.075																							
15	0.337	0.168	0.101																						
20	0.432	0.288	0.231	0.144																					
25	0.504	0.378	0.327	0.252	0.126																				
27	0.528	0.408	0.360	0.288	0.168																				
30	0.559	0.447	0.403	0.336	0.224	0.112																			
35	0.604	0.503	0.463	0.402	0.302	0.201	0.101																		
40	0.640	0.548	0.512	0.457	0.366	0.274	0.183	0.091																	
45	0.670	0.586	0.553	0.503	0.419	0.335	0.251	0.168	0.084																
50	0.696	0.618	0.587	0.541	0.464	0.386	0.309	0.232	0.155																
55	0.717	0.646	0.617	0.574	0.502	0.430	0.359	0.287	0.215	0.143	0.072														
60	0.736	0.669	0.643	0.602	0.535	0.469	0.402	0.335	0.268	0.201	0.134	0.067													
65	0.753	0.690	0.665	0.627	0.565	0.502	0.438	0.376	0.314	0.251	0.188	0.125	0.063												
70	0.767	0.708	0.685	0.649	0.590	0.531	0.472	0.413	0.354	0.295	0.236	0.177	0.118	0.059											
75	0.780	0.725	0.702	0.669	0.613	0.557	0.502	0.446	0.390	0.334	0.279	0.223	0.167	0.111	0.056										
80	0.792	0.739	0.718	0.686	0.634	0.581	0.528	0.475	0.422	0.370	0.317	0.264	0.211	0.158	0.106	0.053									
85	0.802	0.752	0.732	0.702	0.652	0.602	0.552	0.502	0.451	0.401	0.351	0.301	0.251	0.201	0.150	0.100	0.050								
90	0.812	0.764	0.745	0.716	0.669	0.621	0.573	0.525	0.478	0.430	0.382	0.334	0.287	0.239	0.191	0.143	0.096	0.048							
95	0.820	0.775	0.757	0.729	0.684	0.638	0.593	0.547	0.501	0.456	0.410	0.365	0.319	0.273	0.228	0.182	0.137	0.091	0.046						
100	0.828	0.785	0.767	0.741	0.697	0.654	0.608	0.562	0.516	0.472	0.426	0.381	0.335	0.290	0.244	0.199	0.154	0.109	0.064						
105	0.835	0.794	0.777	0.752	0.710	0.668	0.627	0.585	0.543	0.501	0.459	0.418	0.376	0.334	0.292	0.251	0.209	0.167	0.125	0.084	0.042				
110	0.842	0.802	0.786	0.762	0.722	0.682	0.642	0.601	0.561	0.521	0.481	0.441	0.401	0.361	0.321	0.281	0.241	0.200	0.160	0.120	0.080	0.040			
115	0.848	0.810	0.794	0.771	0.732	0.694	0.655	0.617	0.578	0.540	0.501	0.463	0.424	0.386	0.347	0.308	0.270	0.231	0.193	0.154	0.116	0.077	0.039		
120	0.854	0.817	0.802	0.780	0.742	0.705	0.668	0.631	0.594	0.557	0.520	0.483	0.445	0.408	0.371	0.334	0.297	0.260	0.223	0.186	0.148	0.111	0.074	0.037	
125	0.859	0.823	0.809	0.787	0.752	0.716	0.680	0.644	0.608	0.573	0.537	0.501	0.465	0.429	0.394	0.358	0.322	0.286	0.251	0.215	0.179	0.143	0.107	0.072	
130	0.864	0.829	0.815	0.795	0.760	0.726	0.691	0.657	0.622	0.587	0.553	0.518	0.484	0.449	0.415	0.380	0.346	0.311	0.276	0.242	0.207	0.173	0.138	0.104	
135	0.868	0.835	0.822	0.802	0.768	0.735	0.701	0.668	0.635	0.601	0.568	0.534	0.501	0.468	0.434	0.401	0.367	0.334	0.301	0.267	0.234	0.200	0.167	0.134	
140	0.873	0.840	0.827	0.808	0.776	0.743	0.711	0.679	0.646	0.614	0.582	0.549	0.517	0.485	0.452	0.420	0.388	0.356	0.323	0.291	0.259	0.226	0.194	0.162	
145	0.877	0.845	0.833	0.814	0.783	0.751	0.720	0.689	0.657	0.626	0.595	0.564	0.532	0.501	0.470	0.438	0.407	0.376	0.344	0.313	0.282	0.250	0.219	0.188	
150	0.880	0.850	0.838	0.820	0.789	0.759	0.729	0.698	0.668	0.638	0.607	0.577	0.546	0.516	0.486	0.455	0.425	0.395	0.364	0.334	0.304	0.273	0.243	0.213	
155	0.884	0.854	0.843	0.825	0.796	0.766	0.737	0.707	0.678	0.648	0.619	0.589	0.560	0.530	0.501	0.471	0.442	0.412	0.383	0.354	0.324	0.295	0.265	0.236	
160	0.887	0.859	0.847	0.830	0.801	0.773	0.744	0.716	0.687	0.658	0.630	0.601	0.572	0.544	0.515	0.487	0.458	0.429	0.401	0.372	0.343	0.315	0.286	0.258	
165	0.890	0.863	0.851	0.835	0.807	0.779	0.751	0.723	0.696	0.668	0.640	0.612	0.584	0.556	0.529	0.501	0.473	0.445	0.417	0.390	0.362	0.334	0.306	0.278	
170	0.893	0.866	0.855	0.839	0.812	0.785	0.758	0.731	0.704	0.677	0.650	0.623	0.596	0.568	0.541	0.514	0.487	0.460	0.433	0.406	0.379	0.352	0.325	0.298	
175	0.896	0.870	0.859	0.843	0.817	0.791	0.764	0.738	0.712	0.685	0.659	0.633	0.606	0.580	0.554	0.527	0.501	0.474	0.448	0.422	0.395	0.369	0.343	0.316	
180	0.899	0.873	0.863	0.847	0.822	0.796	0.770	0.745	0.719	0.693	0.668	0.642	0.616	0.591	0.565	0.539	0.514	0.488	0.462	0.437	0.411	0.385	0.360	0.334	
185	0.901	0.876	0.866	0.851	0.823	0.801	0.776	0.751	0.726	0.701	0.676	0.651	0.626	0.601	0.576	0.551	0.526	0.501	0.476	0.451	0.426	0.401	0.376	0.351	
190	0.904	0.879	0.870	0.855	0.830	0.806	0.782	0.757	0.733	0.708	0.684	0.660	0.635	0.611	0.586	0.562	0.537	0.513	0.489	0.464	0.440	0.415	0.391	0.366	
195	0.906	0.882	0.873	0.858	0.835	0.811	0.787	0.763	0.739	0.715	0.691	0.668	0.644	0.620	0.596	0.572	0.548	0.525	0.501	0.477	0.453	0.429	0.405	0.381	
200	0.908	0.885	0.876	0.862	0.838	0.815	0.792	0.769	0.745	0.722	0.699	0.675	0.652	0.629	0.605	0.582	0.559	0.536	0.512	0.489	0.466	0.442	0.419	0.396	
205	0.910	0.888	0.878	0.865	0.842	0.819	0.797	0.774	0.751	0.728	0.706	0.683	0.660	0.637	0.614	0.592	0.569	0.546	0.523	0.501	0.478	0.455	0.432	0.410	
210	0.912	0.890	0.881	0.868	0.846	0.823	0.801	0.779	0.757	0.734	0.712	0.690	0.668	0.645	0.623	0.601	0.579	0.556	0.534	0.512	0.490	0.467	0.445	0.423	
215	0.914	0.892	0.884	0.871	0.849	0.827	0.805	0.784	0.762	0.740	0.718	0.697	0.675	0.653	0.631	0.609	0.588	0.566	0.544	0.522	0.501	0.479	0.457	0.435	
220	0.916	0.895	0.886	0.873	0.852	0.831	0.810	0.788	0.767	0.746	0.724	0.703	0.682	0.660	0.639	0.618	0.597	0.575	0.554	0.533	0.511	0.490	0.469	0.447	
225	0.918	0.897	0.889	0.876	0.855	0.834	0.814	0.793	0.772	0.751	0.730	0.709	0.688	0.668	0.647	0.626	0.605	0.584	0.563	0.542	0.521	0.500	0.480	0.459	
230	0.919	0.899	0.891	0.879	0.858	0.838	0.817	0.797	0.776	0.756	0.736	0.715	0.695	0.674	0.654	0.633	0.613	0.593	0.572	0.552	0.531	0.511	0.490	0.470	
235	0.921	0.901	0.893	0.881	0.861	0.841	0.821	0.801	0.781	0.761	0.741	0.721	0.701	0.681	0.661	0.641	0.621	0.601	0.581	0.561	0.541	0.521	0.501	0.481	
240	0.923	0.903	0.895	0.883	0.864	0.844	0.824	0.805	0.785	0.766	0.746	0.726	0.707	0.687	0.667	0.648	0.628	0.609	0.589	0.569	0.550	0.530	0.510	0.491	
245	0.924	0.905	0.897	0.886	0.867	0.847	0.828	0.809	0.789	0.770	0.751	0.732	0.712	0.693	0.674	0.655	0.635	0.616	0.597	0.578	0.559	0.539	0.520	0.501	
250	0.926	0.907	0.899	0.888	0.869	0.850	0.831	0.812	0.793	0.774	0.756	0.737	0.718	0.699	0.680	0.661	0.642	0.623	0.604	0.586	0.567	0.548	0.529	0.510	

*When using tables, use gauge pressure for P and P_{maxop} . When using the formula, P and P_{maxop} must be absolute pressures.

TABLE M
Pressurized Expansion Tank Sizing Chart

MEAN DESIGN WATER TEMPERATURE, °F

SYSTEM VOLUME gal	100		110		120		130		140		150		160		180		200		220		240		250		
	V _i gal	A _s gal																							
1	0.01	0.006	0.02	0.01	0.02	0.01	0.03	0.01	0.04	0.01	0.02	0.04	0.02	0.05	0.02	0.1	0.03	0.1	0.04	.1	0.04	.1	0.05	.1	0.06
2	0.03	0.011	0.04	0.02	0.05	0.02	0.06	0.03	0.09	0.03	0.04	0.09	0.04	0.10	0.04	0.1	0.06	0.2	0.07	.2	0.09	.3	0.10	.3	0.11
3	0.04	0.017	0.06	0.02	0.07	0.03	0.09	0.04	0.13	0.04	0.13	0.05	0.15	0.06	0.2	0.08	0.2	0.10	.3	0.13	.4	0.16	.4	0.17	
4	0.06	0.023	0.08	0.03	0.10	0.04	0.13	0.05	0.16	0.06	0.18	0.07	0.21	0.08	0.3	0.11	0.3	0.14	.4	0.17	.5	0.21	.6	0.23	
5	0.07	0.029	0.10	0.04	0.12	0.05	0.16	0.06	0.22	0.09	0.22	0.09	0.26	0.10	0.3	0.14	0.4	0.17	.5	0.22	.6	0.26	.7	0.29	
6	0.08	0.034	0.12	0.05	0.14	0.06	0.19	0.08	0.22	0.09	0.27	0.11	0.31	0.12	0.4	0.17	0.5	0.21	.6	0.26	.8	0.31	.9	0.34	
7	0.10	0.040	0.14	0.06	0.17	0.07	0.22	0.09	0.26	0.10	0.31	0.12	0.36	0.15	0.5	0.20	0.6	0.24	.8	0.30	.9	0.37	1.0	0.40	
8	0.11	0.046	0.16	0.06	0.19	0.08	0.25	0.10	0.30	0.12	0.35	0.14	0.41	0.17	0.6	0.22	0.7	0.28	.9	0.35	1.0	0.42	1.1	0.46	
9	0.13	0.051	0.18	0.07	0.22	0.09	0.28	0.11	0.33	0.13	0.40	0.16	0.46	0.19	0.6	0.25	0.8	0.31	1.0	0.39	1.2	0.47	1.3	0.51	
10	0.14	0.057	0.20	0.08	0.24	0.10	0.31	0.13	0.37	0.15	0.44	0.18	0.52	0.21	0.7	0.28	0.9	0.35	1.1	0.43	1.3	0.52	1.4	0.57	
20	0.28	0.114	0.40	0.16	0.48	0.19	0.63	0.25	0.74	0.30	0.88	0.36	1.03	0.42	1.4	0.56	1.7	0.70	2.1	0.87	2.6	1.05	2.8	1.14	
30	0.42	0.171	0.60	0.24	0.72	0.29	0.94	0.38	1.11	0.45	1.33	0.53	1.55	0.62	2.1	0.84	2.6	1.05	3.2	1.30	3.9	1.57	4.3	1.71	
40	0.57	0.228	0.79	0.32	0.96	0.39	1.25	0.50	1.48	0.60	1.77	0.71	2.06	0.83	2.8	1.12	3.5	1.40	4.3	1.73	5.2	2.09	5.7	2.28	
50	0.71	0.285	0.99	0.40	1.20	0.48	1.56	0.63	1.85	0.75	2.21	0.89	2.58	1.04	3.5	1.40	4.3	1.75	5.4	2.17	6.5	2.62	7.1	2.86	
60	0.85	0.342	1.19	0.48	1.44	0.58	1.88	0.76	2.22	0.89	2.65	1.07	3.10	1.25	4.2	1.67	5.2	2.10	6.4	2.60	7.8	3.14	8.5	3.43	
70	0.99	0.399	1.39	0.56	1.68	0.68	2.19	0.88	2.59	1.04	3.09	1.25	3.61	1.46	4.8	1.95	6.1	2.45	7.5	3.03	9.1	3.66	9.9	4.00	
80	1.13	0.456	1.59	0.64	1.92	0.77	2.50	1.01	2.96	1.19	3.53	1.42	4.13	1.66	5.5	2.23	6.9	2.80	8.6	3.46	10.4	4.18	11.3	4.57	
90	1.27	0.513	1.79	0.72	2.16	0.87	2.81	1.13	3.33	1.34	3.98	1.60	4.65	1.87	6.2	2.51	7.8	3.15	9.7	3.90	11.7	4.71	12.8	5.14	
100	1.41	0.570	1.99	0.80	2.40	0.97	3.13	1.26	3.70	1.49	4.42	1.78	5.16	2.08	6.9	2.79	8.7	3.50	10.7	4.33	13.0	5.23	14.2	5.71	
200	2.83	1.140	3.97	1.60	4.80	1.94	6.25	2.52	7.39	2.96	8.83	3.56	10.32	4.16	13.8	5.58	17.3	6.99	21.5	8.66	26.0	10.46	28.3	11.42	
300	4.24	1.710	5.96	2.40	7.21	2.90	9.38	3.78	11.09	4.47	13.25	5.34	15.48	6.24	20.8	8.37	26.0	10.49	32.2	12.99	38.9	15.89	42.5	17.13	
400	5.68	2.280	7.94	3.20	9.61	3.87	12.51	5.04	14.79	5.96	17.67	7.12	20.65	8.32	27.7	11.16	34.7	13.98	43.0	17.32	51.9	20.92	56.7	22.84	
500	7.07	2.850	9.93	4.00	12.01	4.84	15.63	6.30	18.49	7.45	22.08	8.90	25.81	10.40	34.6	13.95	43.4	17.48	53.7	21.65	64.9	26.15	70.8	28.55	
600	8.49	3.420	11.91	4.80	14.41	5.81	18.76	7.56	22.18	8.94	26.50	10.68	30.97	12.48	41.5	16.74	52.0	20.97	64.5	25.98	77.9	31.38	85.0	34.26	
700	9.90	3.990	13.90	5.60	16.81	6.78	21.89	8.82	25.88	10.43	30.92	12.46	36.13	14.56	48.5	19.53	60.7	24.47	75.2	30.31	90.8	36.61	99.2	39.97	
800	11.32	4.560	15.88	6.40	19.22	7.74	25.01	10.08	29.58	11.92	35.33	14.24	41.29	16.64	55.4	22.32	69.4	27.97	86.0	34.64	103.8	41.84	113.3	45.68	
900	12.73	5.130	17.87	7.20	21.62	8.71	28.14	11.34	33.28	13.41	39.75	16.02	46.45	18.72	62.3	25.11	78.1	31.46	96.7	38.97	116.8	47.07	127.5	51.39	
1000	14.14	5.700	19.85	8.00	24.02	9.68	31.27	12.60	36.97	14.90	44.17	17.80	51.61	20.80	69.2	27.90	86.7	34.96	107.4	43.30	129.8	52.30	141.7	57.10	
2000	28.29	11.400	39.70	16.00	48.04	19.36	62.53	25.20	73.95	29.80	88.34	35.60	103.23	41.60	138.5	55.80	173.5	69.91	214.9	86.60	259.6	104.60	283.4	114.20	
3000	42.43	17.100	59.55	24.00	72.06	29.04	93.80	37.80	110.92	44.70	132.51	53.40	154.84	62.40	207.7	83.70	260.2	104.87	322.3	129.90	389.3	156.90	425.1	171.30	
4000	56.58	22.800	79.40	32.00	96.08	38.72	125.06	50.40	147.89	59.60	176.67	71.20	206.45	83.20	276.9	111.60	347.0	139.83	429.8	173.20	519.1	209.20	566.7	228.40	
5000	70.72	28.500	99.26	40.00	120.10	48.40	156.33	63.00	184.86	74.50	220.84	89.00	258.06	104.00	346.2	139.50	433.7	174.79	537.2	216.50	648.9	261.50	708.4	285.50	
6000	84.86	34.200	119.11	48.00	144.12	58.08	187.59	75.60	221.84	89.40	265.01	106.80	309.68	124.80	415.4	167.40	520.5	209.74	644.7	259.80	778.7	313.80	850.1	342.60	
7000	99.01	39.900	138.96	56.00	168.14	67.76	218.86	88.20	258.81	104.30	309.18	124.60	361.29	145.60	484.6	195.30	607.2	244.70	752.1	303.10	908.4	366.10	991.8	399.70	
8000	113.15	45.600	158.81	64.00	192.16	77.44	250.12	100.80	295.78	119.20	353.35	142.40	412.90	166.40	553.8	223.20	693.9	279.66	859.6	346.40	1038.2	418.40	1133.5	456.80	
9000	127.30	51.300	178.66	72.00	216.18	87.12	281.39	113.40	332.75	134.10	397.52	160.20	464.52	187.20	623.1	251.10	780.7	314.62	967.0	389.70	1168.0	470.70	1275.2	513.90	
10000	141.44	57.000	198.51	80.00	240.20	96.80	312.66	126.00	369.73	149.00	441.69	178.00	516.13	208.00	692.3	279.00	867.4	349.57	1074.0	433.00	1297.8	523.00	1416.9	571.00	

REVISED 12/96

Sizing based on pressures at the tank, P_{max} = 12 psi and P_{min} (allowing) = 30 psi.

V_i = Tank Volume Required.

A_s = Acceptance Volume Required.

TABLE N
Pressure Correction Factors

Use to size pressurized tanks at other than standard pressure conditions

P _{initial}	ALLOWABLE SYSTEM PRESSURE INCREASE (P _{max operating} - P _{initial}), PSI												
	6	8	10	12	14	16	18	20	25	30	40	50	75
4	1.66	1.34	1.16	1.03	0.94	0.87	0.82	0.78	0.70	0.65	0.59	0.55	0.50
8	1.93	1.55	1.32	1.16	1.06	0.97	0.91	0.86	0.77	0.71	0.63	0.59	0.52
12	2.19	1.75	1.48	1.30	1.17	1.07	1.00	0.94	0.83	0.76	0.67	0.62	0.55
18	2.60	2.05	1.72	1.50	1.34	1.23	1.13	1.06	0.93	0.84	0.73	0.67	0.58
24	3.00	2.35	1.96	1.70	1.52	1.38	1.27	1.18	1.03	0.92	0.79	0.71	0.61
30	3.40	2.65	2.20	1.90	1.69	1.53	1.40	1.30	1.12	1.00	0.85	0.76	0.64
38	3.90	3.06	2.52	2.17	1.92	1.73	1.58	1.46	1.25	1.11	0.93	0.83	0.69
50	4.70	3.66	3.01	2.57	2.26	2.03	1.85	1.71	1.44	1.27	1.05	0.92	0.75
60	5.40	4.16	3.41	2.91	2.55	2.28	2.07	1.91	1.61	1.41	1.15	1.00	0.80
70	6.09	4.67	3.81	3.25	2.84	2.53	2.30	2.11	1.77	1.54	1.26	1.08	0.86

Use to correct the pressurized compression tank selected from Table M.
Correct only the tank volume, the acceptance volume is not affected.

TABLE O
Stock Pressurized Tanks

PRESSURIZED EXPANSION TANK CAPACITIES				
SERIES D MODEL NUMBER	TANK VOLUME gal	ACCEPTANCE VOLUME gal	SERIES B MODEL NUMBER	TANK AND ACCEPTANCE VOLUME, gal
15	7.8	2.5	200	53
20	10.9	2.5	300	79
40	21.7	5	400	105
60	33.6	11.5	500	132
80	44.4	22.6	600	158
100	55.7	22.6	800	211
120	68	34	1000	264
144	77	34	1200	317
180	90	34	1400	370
200	110	34	1600	422
240	132	46	2000	528

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