Expansion Tank Application

Characteristics of Water That Make Expansion Tanks Necessary

- Water expands when it is heated (1000 gallons becomes about 1040 gallons when heated from 40° F to 200° F).
- Water is non-compressible for all practical purposes.

Therefore, if provisions are not made for the expansion of water as it approaches operating temperature, it will break out of the system at the weakest point, which is the relief valve (hopefully there is one!).[1] Failure to specify an adequately sized expansion tank results in:

- Weeping from the relief valve as the system cycles from cold to hot
- A resulting infusion of make-up water when system cycles from hot to cool
- Introduction of air into the system (dissolved in the make up water), which accelerates corrosion, and
- Introduction of dissolved minerals into system. Minerals eventually "bake out" on hot surfaces, such as the heat transfer areas of a boiler, a process which often results in boiler failure. The process to failure follows:
    - In a boiler, the hot gasses on one side of a boiler section (or copper tube in the event of a copper tube boiler) reach temperatures in the range of 2800-3000° F. On the other side, water flows at perhaps 200° F.
    - Under normal circumstances, the water flowing on the cold side of the heat transfer surface removes the heat from the metal as fast as it can be added, keeping the metal at a reasonable temperature. As minerals enter with the make-up water, a coating of baked-on minerals forms on the heat transfer surface; this coating increases in thickness with time. This mineral layer is a good insulator, and prevents the transfer of heat from the metal to the water.

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[1] An FHI customer recently had a system in which an automatic valve would close, isolating the relief valve. It took six split pump bodies (2 failures of 3 pumps) before the real problem was discovered.

- Therefore, the metal temperature rises and the metal eventually cracks or splits, resulting in boiler failure.

How an Expansion Tank Works

An **expansion tank** is only partially full of water on start up. The rest of the tank contains air. As the system water expands, the added system volume moves into the expansion tank, compressing the air, thereby increasing the air pressure, which “pushes back” to increase the system pressure.

A properly sized expansion tank:

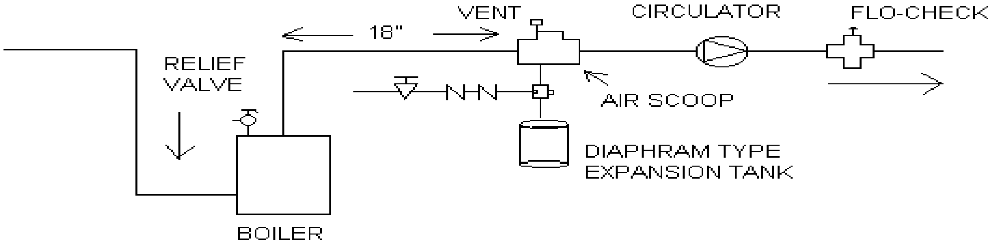
- Limits[2] the system operating pressure increase under the hot condition,
- Provides a safe system pressure without relying on the relief valve to discharge,
- Insures that pump NPSH requirements are met, and
- Establishes a point of "zero pressure change" for the system, ensuring that there will be no negative pressure points anywhere in the system

Air Elimination vs. Air Control

The system designer first decides whether to use an air elimination system or an air control system.

Air Elimination System and its Components

The system below illustrates **air elimination** using an air scoop and air vent. The “**captive air” expansion tank** (described on page 3) allows for expansion. The air scoop separates air from the water, and the vent discharges that air to the equipment room.



Air Elimination System and its Components

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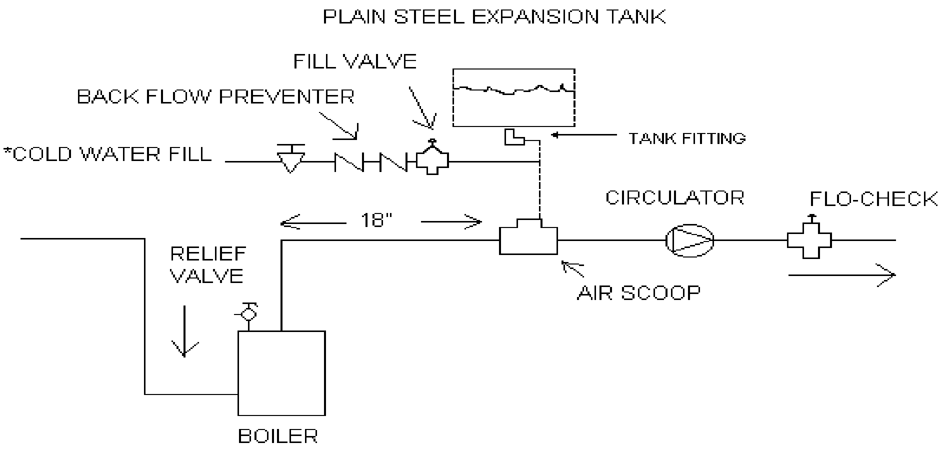
[2] Note that it does not **prevent** an increase in system pressure---just limits it!

The **air control** system operates with an air separator that is **not** equipped with an air vent. Therefore, it does not vent the air, but instead sends it through a special tank fitting into a plain steel expansion tank. Hence it "saves" the separated air to help provide an air cushion. The "tank fitting" works in concert with the air separator and prevents air from re-entering the system on a cool down cycle.



Air Control System

Expansion Tank Styles

Captive air tanks serve air separation systems. With this style, a rubber diaphragm or bladder separates the water from a cushion of air, which is pre-charged into the tank during manufacturing. This is done through a Schrader valve, the same fitting used to fill bicycle tires.

Bladder tanks utilize a rubber bag called a ***bladder.*** If the tank utilizes a bladder capable of expanding to the full size of the tank, as shown in **Figure 1A**, the tank is called a ***full acceptance*** tank. If the tank uses a smaller bag that will not extend to the full dimensions of the tank, it is called a ***partial acceptance*** tank.

Diaphragm tanks, as shown in **Figure 1b**, employ a ***diaphragm*** across the middle portion of the tank. The diaphragm cannot expand to the limits of the steel shell, making diaphragm tanks **partial acceptance** devices.

Generally speaking, partial acceptance tanks cost less, but full acceptance tanks accept more expansion in a smaller package. Diaphragm tanks are available in both ASME code and non-ASME code designs. These are referred to **"Code" and "Non-Code"** tanks. ASME styles feature heavier duty construction and higher factors of safety. Non-code tanks are generally best suited for residences or small commercial buildings (if their use in commercial applications is allowed by local codes).

Some bladder style tanks utilize a **replaceable bladder.** While a replaceable bladder sounds like a great idea, it is a difficult and time-consuming process to replace a bladder. It is often easier to simply replace the whole tank. So where access and clearance exists to get a new tank into the equipment room, designers often choose the less expensive non-replaceable bag designs. For very large tanks, tank replacement may not be feasible, so replaceable bladder tanks provide the best option. Note that diaphragms used in diaphragm style tanks are *not* replaceable.

Plain steel tanks (Figure 1A) are used in air control systems. These simple vessels have no bag or bladder separating the air cushion from the fluid. Plain steel tanks are less expensive than equivalent bladder tanks, but they are larger and often cost more to install than captive air tanks, for reasons discussed later. Plain steel tanks are available in ASME and non-ASME configurations, but non-Code tanks are generally used only in residences.

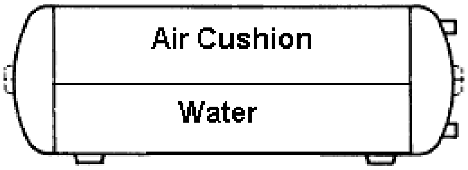


Figure 1A, Plain Steel Tank

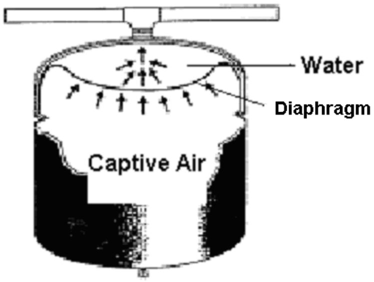


Figure 1B, Diaphragm Tank (Partial Acceptance)

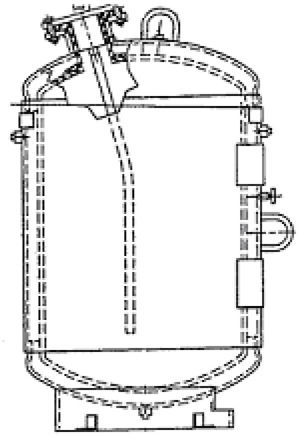


Figure 1 C, Bladder Tank--Full Acceptance

Choosing the System and Tank Type

The decision of whether to use air control or air elimination is inherently intertwined with the tank selection type and vice versa. The following factors contribute to the final choice:

- **First cost:** Generally plain steel tanks cost the least for a given volume of expansion. However, the following off-setting factors apply:
    - **Size/space:** Plain steel tanks are larger than bladder/diaphragm tanks for a given application.
    - **Arrangement:** Plain steel tanks must be suspended from the ceiling. Bladder/diaphragm tanks may be suspended, mounted vertically on the floor, or horizontally on the floor, but they are generally mounted on the floor for convenience.
    - **Structural Support:** Plain steel tanks usually require more robust structural support because they are larger and hold more water.

  Therefore, the labor and material cost savings for mounting captive air tanks generally override the first cost advantage of plain steel tanks, at least for cases where the plain steel tank would be around 200 gallons or more.
- **Simplicity of Operation:** Operators today generally understand air elimination systems better than air control systems. Air elimination systems do away with

concerns of waterlogged tanks. They simplify start up, as “saving” the proper amount of air for the cushion in a plain steel tank becomes a non-issue.

Taco Styles Are:

Model	**Acceptance**	**Replaceable Bladder?**	**Notes**
CA	**Full**	**Yes**	**Potable OK, FDA**
CBX	**Partial**	**No**	**Non Potable**
CX	**Partial**	**No (Diaphragm)**	**Non Potable**
PAX	**Partial**	**Yes**	**Potable, FDA**

Data Required for Sizing the Expansion Tank

To properly size an expansion tank, we must know the following values:

- System volume
- Fill temperature,
- Fill pressure,
- Maximum design pressure,
- Maximum design temperature.

Let’s consider each of these factors:

Determine System Volume by adding the water-holding capacities of all the components of the piping system, including boilers/ chillers, coils, piping, air separators, etc. Use the tables at the end of this chapter to estimate the volume of piping and many common types of HVAC equipment. For items not shown in the tables, use catalogs from specific manufacturers. Note that in determining system volume, it is best to be safe. ***An undersized expansion tank results in the problems outlined on Page 1. An oversized tank results in no operational problems.***

Fill temperature: The temperature of the water available to fill the system. In our climate, use about 40° F.

Fill pressure: The pressure to which the system will be initially filled at start up. The fill pressure setting on the *fill valve* establishes this pressure. (This valve admits water to the system whenever the system pressure falls below the fill valve setting). Two factors impact the chosen fill pressure for a system.

1. The fill pressure must lift the water to the highest point in the system.

Recall that 2.31 feet of water column equals a pressure of 1 PSI, so a system with a high point in the piping of 23' above the fill valve requires a pressure of 10 PSIG at the valve (23'/2.31). To this minimum pressure, add an additional 5 PSIG safety margin. The reason: as the system fills, the water displaces the air, which rises to high points in the system. At start up this air must be manually vented using manual air vents. The pressure in the piping needs to be *greater than atmospheric pressure* to insure that the air will readily move from the pipe, through the air vent, and into the atmosphere. ***In no case, should the fill pressure be less than 10-12 PSIG, even for one-story buildings.*** Systems operating at lower pressures simply take longer to vent.

Example 1: What is the fill pressure recommended for a 23' high system?

Solution: (23'/2.31) + (5 PSIG) = 15 PSIG

Example 2: What is the fill pressure recommended for a 12' high system?
Solution: (12'/2.31) + (5 PSIG) = 10.2'; Therefore revert to the minimum of 12 PSIG.

2. The fill pressure must prevent cavitation. *As a rule of thumb, perform the NPSH calculations when designing a system for 210 degrees or greater, and the pump NPSHr is greater than 20-25 feet.* If the fill pressure determined by the building height is insufficient to prevent cavitation, find a lower NPSHr pump or resort to a higher fill pressure .

Maximum Design Pressure: Use a maximum operating pressure is normally input at about 5-10 PSIG below the relief valve setting. (Relief valves often "weep" at settings below their relief setting. The 5-10 PSIG margin minimizes the chance of weeping). The relief valve setting is determined by a combination of factors including:

1. The maximum pressure rating of equipment in the system, such as boilers, chillers, pumps and accessories. Though relief valves may be ordered for any

setting, distributors stock relief valves set at 30#, 50#, 75# and 125#, so one of these pressures is normally chosen. **All other factors being equal, the higher the maximum design pressure, the smaller the expansion tank.**

2. The relative price of available backflow preventers. Using a 30# relief valve results in an inexpensive backflow preventer. In small buildings, this often favors a setting of 30# in spite of the fact that other items in the system would withstand a higher pressure.

Remember the pressure will be higher than at other points in the system than it is at the expansion tank if the tank is properly located at the pump suction. ***For example, the pressures at the discharge of the pump will be higher by the amount the of pump head. Therefore, when selecting the relief valve setting, take into account the location of the valve and the pressures at other points in the system to avoid exceeding equipment pressure ratings.***

Example: The hydronic components of a system carry a rating of 125 PSIG. The designer selects a relief valve setting of 125 PSIG and sizes his expansion tank accordingly. The contractor installs the relief valve on the suction side of the pump. The pump is provides a head of 70'. When the system heats up, the pressure on the suction side of the pump (point of connection to the expansion tank) reaches 120 PSIG. Think about the pressure on the discharge side of the pump with the pump in operation. Is the system adequately protected against over pressurization?

Maximum Design Temperature

For heating systems use either the maximum expected normal operating temperature of the boiler (or the high limit setting on the boiler for a bit more safety). For chilled water systems, use the maximum expected temperature of the water system on a summer day with the cooling system is turned off (perhaps 95-105 degrees).

Selecting the Expansion Tank

This was formerly a manual calculation, but today we plug the system volume, fill temperature, fill pressure, maximum design temperature, and maximum design pressure into the TacoNet software to select multiple sizes and types of tanks for our consideration.

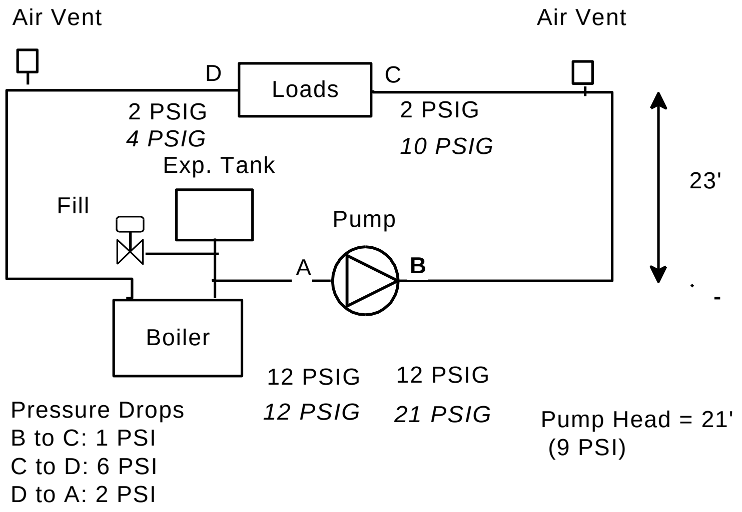
For buildings of two stories and less and relief valve settings of 30 PSIG, you may use the “Quick Sizing Chart” on page 14 of this chapter to pick Flexcon (and similar) non-ASME and Taco ASME captive air tanks.

Glycol Corrections

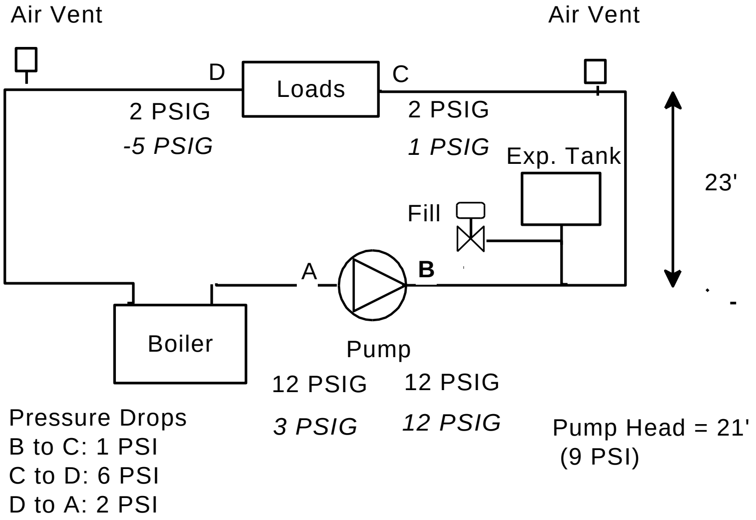
Note that both ethylene and propylene glycol expand more than water. If you are using glycol, ***inflate the system volume before entering manual selection tables such as the Quick Sizing Chart!*** Please see the glycol correction factors on page 16 of this chapter.

Point of Connection to the System

The point where the expansion tank connects to the system is called *the point of zero pressure change*. The reason is that the pressure in the tank and at the point of connection is the same whether the pump is off or on. The diagram below shows system pressures throughout a system with the pump off (upper figure) and on (lower figure) when the tank is ***properly connected*** to the suction side of the pump.



The diagram below shows what will happen to the system pressures at various points when the expansion tank is improperly connected to the discharge side. Note that with the pump connected to the discharge side of the pump, the pressure can become a vacuum at some points in the system. This could create NPSH problems (Why?). It could also result in air being drawn into the system. The example shows the importance of having the point of zero pressure change (the point of connection to the expansion tank) at the inlet to the pump.



To most people, the idea that improper tank connection location could cause the pump to "pull" rather than to "push" is counter-intuitive. To prove our point, we will demonstrate this in our lab, showing that this is really true!

Remember that "the point of zero pressure change" only refers to the fact that the pressure will not change whether the pump is "on" or "off." [3] The pressure WILL change as the system temperature changes.

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[3] This is a difficult concept. Think of it this way. With the pump off and the system at a stable temperature, a fixed volume of air is in the air cushion. There is also a fixed volume of water in the system. Simply starting or stopping the pump does not affect the volume of water in the system. Without a change in water volume, the air cushion cannot compress or expand. Without a compression or expansion, the air pressure will not change and therefore the pressure exerted on the water by the air cushion will not change; therefore the system pressure at the point of connection cannot change. Make sense—sort of?

CAST IRON BOILER WATER CONTENT (GALLONS) FOR BOILERS MANUFACTURED 1965 TO PRESENT

NO.	RESIDENTIAL		COMMERCIAL INDUSTRIAL		COMMERCIAL INDUSTRIAL	
OF	CAST IRON		WATER BOILER CONVERTIBLE TO STEAM		WATER ONLY	
SECTIONS	BURNHAM 2 SERIES MBH	**WATER CONTENT**	BURNHAM PF5 MBH	**WATER CONTENT**	BURNHAM 8 SERIES MBH	**WATER CONTENT**
2	41	**2.5**				
3	52	**3.2**				
4	80	**4.0**				
5	108	**4.7**			212	**11.9**
6	136	**5.5**	321	**37.6**	264	**13.9**
7	163	**6.2**	374	**43.4**	317	**15.9**
8	181	**7.0**	437	**49.1**	378	**17.9**
9	218	**7.7**	499	**54.9**	422	**19.9**
10	244	**8.2**	562	**60.6**	475	**21.9**
11			624	**66.4**		
12			686	**72.1**		
13			749	**77.9**		
14			811	**83.7**		
15			874	**89.4**		
16			936	**95.2**		
17			998	**100.9**		
18			1061	**106.7**		
19			1123	**112.5**		
20			1186	**118.2**		
21			1248	**124.0**		
22			1310	**129.7**		
			1485	**141.2**		
			1560	**152.8**		

NOTE:
1. Chart is based on Burnham cast iron boiler gas fired.
2. If boiler is oil fired select MBH load and use next larger size for water content.
3. For boilers made before 1965 consult manufacturers literature.

Water Volume Contained in Common HVAC Equipment

Fan Coils, Unit Ventilators, Cabinet Heaters, Booster Coils

Gallons Per Coil Row

Finned Width (inches)	Finned Length (inches)								
	18	24	30	36	42	48	60	72	84
6	0.11	0.15	0.19	0.22	0.26	0.30	0.37	0.45	0.52
9	0.17	0.22	0.28	0.34	0.39	0.45	0.56	0.67	0.79
12	0.22	0.30	0.37	0.45	0.52	0.60	0.75	0.90	1.05

Air Handling Units and Built Up Coils

Gallons Per Coil Row

Finned Width (inches)	Finned Length (inches)												
	18	24	30	36	48	60	72	84	96	108	120	132	144
12	0.22	0.30	0.37	0.45	0.60	0.75	0.90	1.05	1.20	1.35	1.50	1.65	1.80
18	0.34	0.45	0.56	0.67	0.90	1.12	1.35	1.57	1.80	2.02	2.25	2.47	2.70
24	0.45	0.60	0.75	0.90	1.20	1.50	1.80	2.10	2.40	2.70	3.00	3.29	3.59
30	0.56	0.75	0.94	1.12	1.50	1.87	2.25	2.62	3.00	3.37	3.74	4.12	4.49
36	0.67	0.90	1.12	1.35	1.80	2.25	2.70	3.14	3.59	4.04	4.49	4.94	5.39
42	0.79	1.05	1.31	1.57	2.10	2.62	3.14	3.67	4.19	4.72	5.24	5.77	6.29
48	0.90	1.20	1.50	1.80	2.40	3.00	3.59	4.19	4.79	5.39	5.99	6.59	7.19

Estimated Volume In Water Chillers (Gallons in Evaporator)

Reciprocating and Screw Compressor Units												
Tons	15	20	25	30	40	50	60	75	100	120	150	200
Gallons	6	8	10	15	17	21	25	40	50	60	75	90

Centrifugal Units						
Tons	200	500	750	1000	1250	1500
Gallons	40	100	125	180	250	325

Water Volume Contained in Common HVAC Equipment (Continued)

Shell and Tube Heat Exchangers

Shell Dia.	Gallon/Foot – Shell Length	
	In Shell	In Tubes
4	0.43	0.23
6	1.0	0.5
8	1.8	0.9
10	2.4	1.2
12	4.0	2.2
14	5.0	2.6
16	6.5	3.5
18	8.0	4.5
20	10.0	5.5
24	15.0	7.5

VOLUME OF WATER IN PIPING (GALLONS PER LINEAL FOOT)

TYPE	½”	¾”	1”	1-1/4”	1-1/2”	2”	2-1/2”	3”	4”	5”	6”
STEEL PIPE	.016	.028	.045	.078	.105	.172	.250	.385	.667	1.00	1.40
COPPER TUBE	.012	.025	.043	065	.092	.161	.250	.357	.625	1.00	1.40

TYPE	8”	10”	12”	14”	16”	18”	20”	24”
STEEL PIPE	2.60	4.09	5.88	7.16	9.48	12.13	15.11	21.94

Pex ½” I.D.	1.0 Gallon/100 Feet
Pex 5/8” I.D.	1.6 Gallon/100 Feet

NOTES:

- Pipe coils (bench coils) – size as piping
- Commercial fin tube & residential baseboard – size as piping

Water Volume Contained in Common HVAC Equipment (Continued)

Volume of Commercial Air Separators

Model	Diam., "	Length, "	Gallons
AC-2	8.6	18	5
AC-2.5	10.75	20	8
AC-3	12.75	24.25	13
AC-4	16	29.13	25
AC-5	16	31.25	27
AC-6	20	36.75	50
AC-8	20	41.38	56
AC-10	24	49.5	97
AC-12	30	56.94	174
AC-14	36	65	286
AC-16	36	71.5	315
AC-18	42	74.81	449
AC-20	48	82.81	649

Copper Fin Boilers

Based on Thermal Solutions

Model	MBH	Gallons
EVH-250	250	5.4
EVH-500	500	6.1
EVH-750	750	15.9
EVH-1000	1000	16.4
EVH-1500	1500	17.4
EVH-2000	2000	18.5

Expansion Tank Quick Sizing Chart

BASED ON: 4O°F TO 200°F, 12 PSIG FILL, 30 PSIG RELIEF

SYSTEM VOLUME IN GALLONS	SYSTEM EXP. MIN. ACCEPT	MINIMUM TANK VOL.	FLEXCON MODEL NO.	TACO MODEL NO.
25	0.9	2.18	VR15F	CX15
50	1.8	4.35	VR30F	CX15
75	2.6	6.53	VR60F	CX30
100	3.5	8.71	VR90F	CX30
125	4.4	10.89	VR90F	CX42
150	5.3	13.06	VR90F	CX84
175	6.1	15.24	SXVR30F	CX84
200	7.0	17.42	SXVR30F	CX84
225	7.9	19.60	SXVR30F	CX84
250	8.8	21.77	SXVR30F	CX84
275	9.7	23.95	SXVR60F	CX84
300	10.5	26.13	SXVR60F	CX130
325	11.4	28.31	SXVR60F	CX130
350	12.3	30.48	SXVR90F	CX130
375	13.2	32.66	SXVR90F	CX130
400	14.0	34.84	SXVR90F	CX130
425	14.9	37.02	SXVR90F	CX130
450	15.8	39.19	SXVR110F	CBX170
475	16.7	41.37	SXVR110F	CBX170
500	17.6	43.55	SXVR110F	CBX170
525	18.4	45.73	SXVR110F	CAX170
550	19.3	47.90	SXVR110F	CBX254
575	20.2	50.08	SXVR110F	CBX254
600	21.1	52.26	SXVR110F	CBX254
625	21.9	54.44	SXVR160F	CBX254
650	22.8	56.60	SXVR160F	CBX254
675	23.7	58.79	SXVR160F	CBX254
700	24.6	60.97	SXVR160F	CBX254
725	25.4	63.15	SXVR160F	CBX254
750	26.3	65.32	SXVR160F	CBX254
775	27.2	67.50	SXVR160F	CBX254
800	28.1	69.68	SXVR160F	CBX300
825	29.0	71.85	SXVR160F	CBX300
850	29.8	74.03	SXVR160F	CBX300
875	30.7	76.21		CBX300
900	31.6	78.39		CBX300
925	32.5	80.56		CBX300
950	33.3	82.74		CBX350
975	34.2	84.92		CBX350
1000	35.1	87.10		CBX350
1025	36.0	89.27		CBX350
1050	36.9	91.45		CBX350

NOTES: FLEXCON TANKS – NON CODE, MAX. WP 100 PSIG, MAX. TEMP 240°F
TACO TANKS – ASME CODE, MAX. WP 125 PSIG, MAX. TEMP 240°F

CORRECTION FACTORS FOR EXPANSION OF ETHYLENE GLYCOL

(Based on 50° Fill Temperature)

MAX. TEMP ° F	% ETHYLENE GLYCOL BY VOLUME		
	20%	40%	50%
100°	1.60	1.83	1.90
140°	1.28	1.42	1.50
160°	1.20	1.33	1.40
180°	1.15	1.25	1.31
200°	1.13	1.22	1.28
220°	1.10	1.19	1.24
240°	1.08	1.17	1.22

Multiply Expansion for Water Times Above Figures or Inflate System Volume Before Selecting Tank (Not Required if Using Taconet)

CORRECTION FACTORS FOR EXPANSION OF PROPYLENE GLYCOL

(Based on 50° Fill Temperature)

MAX. TEMP ° F	% PROPYLENE GLYCOL BY VOLUME		
	20%	40%	50%
100°	1.18	2.46	2.74
120°	1.15	2.26	2.34
140°	1.14	2.06	2.17
160°	1.13	1.86	2.02
180°	1.12	1.66	1.89
200°	1.11	1.54	1.64
220°	1.10	1.37	1.45
240	1.09	1.40	1.51

Multiply Expansion for Water Times Above Figures or Inflate System Volume Before Selecting Tank (Not Required if Using Taconet)