SIZING THE EXTROL®
DIAPHRAGM-TYPE
HYDRO-PNEUMATIC TANK

AMTROL®
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Sizing the EXTROL® Diaphragm-Type Hydro-Pneumatic Tank

For pressurization and expansion control of low temperature water systems

Accurate Critical Sizing A Must

When selecting and sizing hydro-pneumatic tanks for maintaining pressurization and expansion control in engineered space heating systems involving hot water as the heat transfer medium, the designer must consider the important space, time and energy factors which affect the choice of all mechanical system components.

As a result of these priorities, the most important consideration in selecting and applying hydro-pneumatic (compression/expansion) tanks in large systems is one of critical sizing.

Designers of mechanical systems cannot afford the luxury of over-sizing system components to achieve a safety margin. Nor can they take the chance of under-sizing through the use of inaccurate averaging approaches, traditionally used for sizing expansion tanks in the past.

To meet the critical sizing requirements, the designer must be able to provide an adequate tank volume to guarantee full system pressurization at all times, plus the accommodation of the accurately calculated amount of expanded water which the system will generate. But, the designer must provide this with a tank size of minimum volume and weight so that a minimal amount of space and time will be consumed in its installation, and no waste of energy will be encountered.

Manufacturers' Selection Tables and Short Cut Methods Do Not Allow Critical Sizing

The sizing methods, such as manufacturers' selection tables and "short cuts" nomographs, which system designers may have used in the past, are at their best, "rule of thumb" approximations only. In many cases, the designer has used these methods to arrive at a general size range and then added his own safety margin to select a tank of larger size than originally calculated.

While this practice has resulted in tanks sufficiently over-sized to include an adequate safety margin, it does not meet the critical sizing requirements that must be met in modern system design.

ASHRAE Formula Method

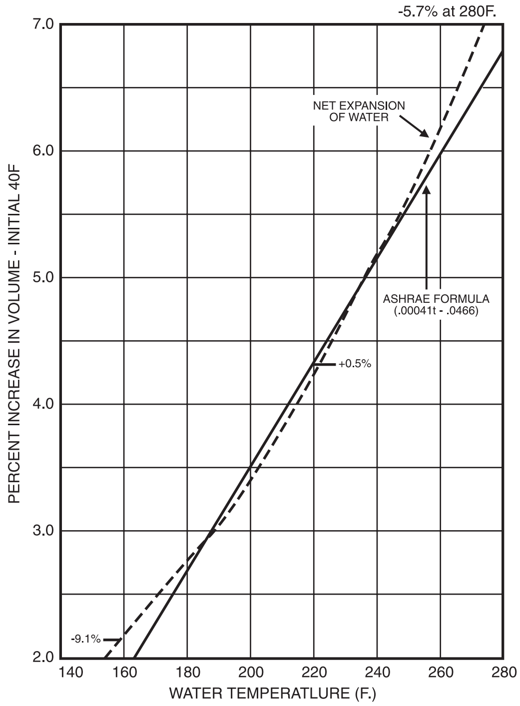
The ASHRAE Formula for sizing diaphragm-type hydro-pneumatic tanks is published in Chapter 15 of the ASHRAE Handbook, 1976 Systems Edition:

$$V_t = \frac{(.00041t - .0466)\ V_8}{1 - \dfrac{P_f}{P_o}}$$

It is a formula for accurately estimating tank sized for systems with operating temperatures of 160°F to 280°F. However, it does reflect some inaccuracies in the calculation of the amount of expanded water generated by the operating heating system.

NOTE: This data has been excerpted from AMTROL's "Engineering Handbook" - Chapter Two, Section B, "Hydro-pneumatics in Hot Water Heating Systems".

The complete handbook covers the application of hydro-pneumatics in heating, plumbing, cooling, water supply and commercial water heating systems. If a copy is desired, request it in a letter, stating your title and job function. Address your request to AMTROL Inc., 1400 Division Road, West Warwick, RI 02893.



Thermal Expansion of Water
(Actual vs. ASHRAE Formula)

The top line of the ASHRAE Formula, (".00041t - .0466) V8", is an averaging equation based on the ASHRAE curve for net expansion of water. It may be used for temperatures that fall between 160°F and 280°F. If we plot the equation as a straight line curve and compare it with the actual curve as shown in the ASHRAE Handbook, (Figure 22), on a linear chart, we can see that at the extreme upper and lower portions of the temperature range, the percentage of error increases as much as 9%.

Fill Temperatures Other Than 40°F.

The ASHRAE equation for calculating expanded water also assumes that the system is initially filled with water at 40°F. This means that systems filled with water higher in temperature that 40°F will actually generate less expanded water than calculated by the ASHRAE equation. In the case of critically sizing systems with large system volumes, this could easily mean total tank volumes larger than actually required.

Critical Sizing Method

This is an accurate sizing method and is strongly recommended when critical sizing of system components is required and when initial fill temperatures higher that 40˚F are encountered.

It involves three steps:

1. Determination of the amount of expanded water by use of net expansion factors. These factors are based on the gross expansion of water as expressed in the Smithsonian Tables and as acceptable coefficient of expansion for metallic system components. (See Tables 5 - Metric or English)

2. The second step in determining the acceptance factor for the pressure values of the system. These factors are a straight mathematical expression of Boyle's Law of Perfect Gases. (See Tables 6 - Metric or English)

3. The third step is a mathematical computation , accomplished by dividing the amount of expanded water by the amount of acceptance factor:

$$V_t = \frac{\text{Expanded water, in liters or gallons}}{\text{Acceptance Factor}}$$

Summation of Sizing Methods

In summation, it is recommended that the designer use either the ASHRAE Formula method for accurately estimating tank sizes, or the critical sizing method for computing the exact minimum tank volume required.

Since the ultimate goal in selection and sizing of hydro-pneumatic tanks is one of minimum size and weight, the sizing methods (ASHRAE and Critical) that follow will be for diaphragm-type tanks only. They cannot be used for sizing plain steel expansion tanks.

Preliminary Sizing Data Required

Before actual sizing computations are begun, certain basic data must be determined:

A. Total System Volume

This value must be determined before sizing by the ASHRAE Formula method or the Critical Sizing Method can be used. While in some smaller systems, average content tables, based on the BTUH carrying capacity, or load, of the system can be used for a quick approximation of total system volume, in the case of larger systems, this value is critical in accurately computing the amount of expanded water the system will generate. The only accurate method of determining this is a complete compilation of all system component water contents.

Water Content of Boilers - Refer to manufacturers' literature or to supplement booklet, "Boiler Contents and Ratings of Major Manufacturers", in AMTROL's Engineering Handbook.

Water Content of Unit Heaters, Fan Coil Units and Convectors - Since these contain small amounts of water, and are uniform in volumetric ratios, a BTU output conversion factor will be sufficiently accurate. Refer to Table 6 for these factors.

Water Content of Commercial Finned Tube, Baseboard Radiation, and Piping - Refer to Table 7, "Water Volume of Pipe or Tube". Consider commercial finned tube as steel pipe and baseboard radiation as copper tubing.

Water Content of Heat Exchangers - Refer to Table 8.

B. Determine Tank Location

Refer to Chapter 15, ASHRAE Handbook, or to Chapter One, Section B of AMTROL Engineering Handbook.

C. Determine System Pressure Values at Tank Location

Refer to Chapter 15, ASHRAE Handbook, or to Chapter One, Sections A and B of AMTROL Engineering Handbook.

D. Determine Average Design Temperature (*t*)

E. Importance of Listed Acceptance Volumes in Smaller EXTROL® Diaphragm Hydro-pneumatic Tanks

Sizing AX Model EXTROLS® - When the total tank volume calculated is 498 liters (132 gallons) or less, the amount of expanded water calculated must be equal to or less than the acceptance volumes listed in Table 7A. If both the calculated total tank volume and the amount of expanded water are not met by the listed total volume and acceptance volume, select the next larger AX model.

Sizing "L" Series EXTROLS® - If the calculated total tank volume is larger than 498 liters (132 gallons) refer to Table 7B and select for total tank volume only.

Table 7A - Total Tank Volumes and Acceptance Volumes of "AX" Model EXTROL® Diaphragm Hydro-pneumatic Tanks. Use for Calculated Total Tank Volumes of 498 Liters (132 Gallons) or Less

Total Volume		Acceptance Volume		
Liter	Gal.	Liter	Gal.	Model No.
30	7.8	10	2.5	AX-15
41	10.9	10	2.5	AX-20
82	21.7	19	5.0	AX-40
127	33.6	43	11.5	AX-60, AX-60V
168	44.4	87	23.0	AX-80, AX-80V
211	55.7	87	23.0	AX-100, AX-100V
254	67.0	87	23.0	AX-120, AX-120V
291	7.0	87	23.0	AX-144, AX-144V
343	90.7	131	34.5	AX-180, AX-180V
419	110.7	131	34.5	AX-200, AX-200V
498	131.7	174	46.0	AX-240, AX-240V

Table 7B ...Total Tank Volumes of "L" Series EXTROL® Diaphragm Hydro-pneumatic Tanks. Use for Calculated Total Tank Volumes of More than 498 Liters (132 Gallons)

Total Volume		
Liter	Gal.	Model No.
600	158	600-L EXTROL
800	211	800-L EXTROL
1000	264	1000-L EXTROL
1200	317	1200-L EXTROL
1400	370	1400-L EXTROL
1600	423	1600-L EXTROL
2000	528	2000-L EXTROL

I. Sizing EXTROL® Diaphragm-Type Hydro-Pneumatic Tanks By Formula Method (ASHRAE)

This formula is published by ASHRAE for use in sizing diaphragm-type expansion tanks (see Chapter 15, ASHRAE handbook). It may be used to calculate the approximate size of expansion tanks for systems with design temperatures that lie in the range of 71°C. to 137°C. (160°F - 280°F), and with the system fill water temperature assumed to be 4° C. (40°F). It is accurate from + 0.5% to -9%. The formula is stated:

Metric (SI)

$$V_t = \frac{(0.000\,738t - 0.033\,48)\,V_8}{1 - \frac{P_f}{P_o}}$$

English

$$V_t = \frac{(.00041t - .0466)\,V_8}{1 - \frac{P_f}{P_o}}$$

where:

V_t = the minimum tank volume

t= maximum average design temperature

V_8 = total system water content

P_f = the initial or minimum operating pressure at the tank expressed in kilopascal, absolute (kPA, absolute), or in pounds per square inch, absolute (Psia)

P_o = the final or maximum operating pressure at the tank expressed in kPa, absolute, or in Psia

Converting Pressure Volumes to kPa, and Psia

Metric: kPa, gauge + 101.3 = kPa, absolute

English: Psig + 14.7 = Psia

NOTE: The International System of Units (SI) designates the pascal (N/m2) as the basic unit of pressure. However, for convenience, kilopascal (1000 pascal) shall be used in sizing of EXTROL® hydro-pneumatic tanks. See Chapter 46, ASHRAE handbook, 1976 Systems Edition.

In the Metric (SI) and English sizing examples that follow, no direct conversion of values should be attempted because of different base values between the systems. The designer should always work in one or the other and not convert from one to the other.

Sizing Example Using the Formula Method:

	Metric (SI)	English
System Water Volume (V_8):	22000 liters	1135 gal.
Maximum Average Operating Temperature(t):	110° C	210° F
Minimum Operating Pressure at the tank (P_f):	300 kPa, gauge	35 psig
Maximum Operating Pressure at the tank (P_o):	750 kPa, gauge	65 psig
System Fill Water Temperature (T_f):	4° C	40° F

NOTE: The above sizing example in Metric (SI) and in English are distinct separate problems and do not have equal values.

Computations:

Metric (SI)

1. $$V_t = \frac{(0.000\,738 \times 110 - 0.033\,48)\,22\,000}{1 - \frac{300 + 101.3}{750 + 101.3}}$$

2. $$V_t = \frac{1\,049.4 \text{ liters expanded water}}{0.529 \text{ acceptance factor}}$$

3. V_t = 1 983.7 liters, minimum EXTROL® total volume

4. Table 1B shows that 2000-L EXTROL® has a total volume of 2000 liters. This would be the correct size.

English

1. $$V_t = \frac{(.00041 \times 210 - .0466)\,1135}{1 - \frac{35 + 14.7}{65 + 14.7}}$$

2. $$V_t = \frac{44.8 \text{ gallons expanded water}}{.376 \text{ acceptance factor}}$$

3. V_t = 119.1 gallons, minimum EXTROL® total volume

4. Table 1A shows that AX-240, AX-240V have a total volume of 132 gallons and will accept up to 46 gallons of expanded water. Either an AX-240, or an AX-240V (vertical style) would be the correct size.

II. Sizing EXTROL® Diaphragm-Type Hydro-Pneumatic Tanks By The Critical Sizing Method

This sizing method is recommended when critical sizing is required and/or when system fill temperatures are higher than 4°C. (40°F). It involves three steps:

A. Determining Expanded Water

Refer to Tables 5 - Metric or English, "Net Expansion Factors for Water..." (Note: These tables are excerpts from the complete table of factors for net expansion of water at temperatures from 4°C. to 148°C. and from 40°F. to 300°F. as published in the AMTROL Engineering Handbook.)

On the horizontal base line find the initial or fill temperature (T_f). On the vertical base line find the final, or maximum average design temperature (*t*). At the intersection of the two columns, read the net expansion factor. Multiply the total system water content (V_8) by the expansion factor to determine the exact amount of expanded water.

B. Determining Acceptance Factor

Refer to Tables 6 - Metric or English, "Acceptance Factors for Initial and Final Pressures". (Note: These tables are excerpts from a complete table of acceptance factors for pressures from 50 kPa, gauge to 1700 kPa, gauge and from 5 psig to 250 psig as published in the AMTROL Engineering Handbook.)

On the horizontal base line, "Initial, or Fill Pressures (P_f)," find the correct pressure value. On the vertical base line, "Final, or Maximum Operating Pressure (P_0)", find the correct pressure value. At the intersection of the two columns, read the acceptance factor.

C. Computing EXTROL Size

Divide the amount of expanded water by the acceptance factor to determine the minimum total tank volume required (V_t).

$$\text{Or } V_t = \frac{\text{Amount of expanded water in liter or gallons}}{\text{Acceptance Factor}}$$

Sizing Example Using the Critical Sizing Method:

	Metric (SI)	English
System Water Volume (V_8):	3470 liters	4400 gal.
Maximum Average Design Temperature(*t*):	90° C	230° F
Minimum Operating Pressure at the tank (P_f):	150 kPa, gauge	50 psig
Maximum Operating Pressure at the tank (P_o):	300 kPa, gauge	110 psig
System Fill Water Temperature (T_f):	15° C	70° F

NOTE: The above sizing example in Metric (SI) and in English are distinct separate problems and do not have equal values.

Computations:

Metric (SI)

1. From Table 5, find the intersecting point of vertical column, "15°C.", and horizontal column "90°C.", and read "0.0323".
2. 0.0323 x 3470 = 112.0 liters expanded water.
3. From Table 6, find the intersecting point of vertical column, "150 kPA, gauge" and horizontal column, "300 kPa, gauge" and read "0.374".
4. $V_t = \frac{112.0}{0.374}$ = 299.5 liters, minimum EXTROL® total volume
5. Table 7A shows the AX-180, AX-180V have a total volume of 343 liters and will accept up to 131 liters of expanded water Either an AX-180, or an AX-180V (vertical style) will be the correct size.

English

1. From Table 5, find the intersecting point of vertical column, "70° F.", and horizontal column, "230° F.", and read "0.0461".
2. 0.0461 x 4400 = 202.8 gallons of expanded water.
3. From Table 6, find the intersecting point of vertical column, "50 psig", and horizontal column, "110 psig", and read "0.481".
4. $V_t = \frac{202.8}{0.481}$ = 421.6 gallons, minimum EXTROL® total volume
5. Table 7B shows that 1600-L EXTROL® has a total volume of 423 gallons. This would be the correct size.

Table 5 - Net Expansion of Water - Metric (SI)

Factors for Calculating Net Expansion of Water

(Gross Expansion Minus System Expansion. Based on Expansion of Metallic System Components)

Final Temp. (*t*) °C	Initial Temperature (T_f) °C						
	4°	10°	15°	20°	25°	30°	35°
50°	0.010 4	0.010 3	0.009 9	0.009 2	0.008 2	0.007 0	0005 5
55°	0.012 6	0.012 6	0.012 1	0.011 4	0.010 4	0.009 1	0.007 8
60°	0.015 0	0.014 9	0.014 5	0.013 8	0.012 8	0.011 6	0.010 2
65°	0.017 6	0.017 5	0.017 1	0.016 4	0.015 4	0.014 2	0.012 7
70°	0.020 3	0.020 2	0.019 8	0.019 1	0.018 1	0.016 9	0.015 4
75°	0.023 2	0.023 0	0.022 6	0.021 9	0.020 9	0.019 7	0.018 3
80°	0.026 2	0.026 2	0.025 7	0.025 0	0.024 0	0.022 8	0.021 4
85°	0.029 4	0.029 3	0.028 9	0.028 2	0.027 2	0.026 0	0.024 6
90°	0.032 7	0.032 7	0.032 3	0.031 6	0.030 6	0.029 3	0.027 9
95°	0.036 3	0.036 2	0.035 8	0.035 1	0.034 1	0.032 9	0.031 4
100°	0.039 9	0.039 9	0.039 4	0.038 7	0.037 7	0.036 5	0.035 1
105°	0.043 7	0.043 7	0.043 3	0.042 6	0.041 6	0.040 3	0.038 9
110°	0.047 6	0.047 6	0.047 1	0.046 4	0.045 4	0.044 2	0.042 8
115°	0.051 7	0.051 7	0.051 3	0.050 5	0.049 6	0.048 3	0.046 9

Table 5 - Net Expansion of Water - English

Factors for Calculating Net Expansion of Water

(Gross Expansion Minus System Expansion. Based on Expansion of Metallic System Components)

Final Temp. (*t*) °F	Initial Temperature (T_f) °F								
	40°	**50°**	**60°**	**70°**	**80°**	**90°**	**100v**	**110°**	**120°**
120°	0.0100	0.0099	0.0095	0.0086	0.0074	0.0060	0.0043	0.0023	-
130°	0.0124	0.0123	0.0118	0.0109	0.0098	0.0083	0.0066	0.0047	0.0023
140°	0.0150	0.0149	0.0145	0.0135	0.0124	0.0110	0.0093	0.0073	0.0052
150°	0.0179	0.0178	0.0173	0.0164	0.0153	0.0133	0.0121	0.0101	0.0078
160°	0.0209	0.0208	0.0204	0.0194	0.0181	0.0165	0.0148	0.0129	0.0109
170°	0.0242	0.0241	0.0236	0.0227	0.0216	0.0201	0.0184	0.0165	0.0141
180°	0.0276	0.0275	0.0271	0.0261	0.0250	0.0236	0.0219	0.0199	0.0176
190°	0.0313	0.0312	0.0307	0.0298	0.0287	0.0272	0.0255	0.0236	0.0212
200°	0.0351	0.0350	0.0346	0.0336	0.0325	0.0311	0.0294	0.0274	0.0251
210°	0.0391	0.0390	0.0386	0.0376	0.0365	0.0351	0.0334	0.0314	0.0291
220°	0.0434	0.0433	0.0428	0.0419	0.0408	0.0393	0.0376	0.0356	0.0333
230°	0.0476	0.0475	0.0471	0.0461	0.0450	0.0436	0.0419	0.0399	0.0376
240°	0.0522	0.0521	0.0517	0.0507	0.0496	0.0482	0.0465	0.0445	0.0422

Table 6 - Acceptance Factors

$$\left(1 - \frac{P_f}{P_o}\right) \text{ - Metric (SI)}$$

(Use Gauge Pressure)

P0 - Max. Oper. Pressure At Tank (kPa, Gauge)	P_f - Minimum Operating Pressure at Tank (psig)									
	50	**100**	**150**	**200**	**250**	**300**	**350**	**400**	**450**	**500**
200	0.498	0.332	0.166	-	-	-	-	-	-	-
250	0.569	0.427	0.285	0.142	-	-	-	-	-	-
300	0.623	0.498	0.374	0.249	0.125	-	-	-	-	-
350	0.665	0.554	0.443	0.332	0.222	0.111	-	-	-	-
400	0.698	0.598	0.499	0.399	0.299	0.199	0.100	-	-	-
450	0.726	0.635	0.544	0.453	0.363	0.272	0.181	0.091	-	-
500	0.748	0.665	0.582	0.499	0.416	0.333	0.249	0.167	0.083	-
550	0.768	0.691	0.614	0.537	0.461	0.384	0.307	0.230	0.154	0.077
600	0.784	0.713	0.642	0.570	0.499	0.428	0.356	0.285	0.214	0.143
650	0.799	0.732	0.666	0.599	0.532	0.466	0.399	0.333	0.267	0.200
700	0.811	0.749	0.686	0.624	0.562	0.499	0.437	0.374	0.312	0.250
750	0.822	0.764	0.705	0.646	0.584	0.529	0.470	0.411	0.352	0.294

Table 6 - Acceptance Factors

$$\left(1 - \frac{P_f}{P_o}\right) \text{ - English}$$

(Use Gauge Pressure)

P0 - Max. Oper. Pressure At Tank (Psig)	P_f - Minimum Operating Pressure at Tank (psig)										
	5	**10**	**12**	**15**	**20**	**30**	**40**	**50**	**60**	**70**	**80**
27	0.527	0.408	0.360	0.288	0.168	-	-	-	-	-	-
30	0.560	0.447	0.403	0.336	0.224	-	-	-	-	-	-
35	0.604	0.503	0.463	0.403	0.302	0.101	-	-	-	-	-
40	0.640	0.548	0.512	0.457	0.366	0.183	-	-	-	-	-
45	0.670	0.586	0.553	0.503	0.419	0.251	0.084	-	-	-	-
50	0.696	0.618	0.587	0.541	0.464	0.309	0.155	-	-	-	-
55	0.717	0.646	0.617	0.574	0.502	0.359	0.215	0.072	-	-	-
60	0.736	0.669	0.643	0.602	0.536	0.402	0.268	0.134	-	-	-
65	0.753	0.690	0.665	0.627	0.565	0.439	0.314	0.188	0.062	-	-
70	0.767	0.708	0.685	0.649	0.590	0.472	0.354	0.236	0.118	-	-
75	0.780	0.725	0.702	0.669	0.613	0.502	0.390	0.279	0.167	0.056	-
80	0.792	0.739	0.718	0.686	0.634	0.528	0.422	0.317	0.211	0.106	-
90	0.812	0.764	0.745	0.716	0.669	0.573	0.478	0.382	0.287	0.191	0.096
100	0.828	0.785	0.767	0.741	0.698	0.610	0.523	0.436	0.347	0.261	0.174
110	0.842	0.802	0.786	0.762	0.723	0.642	0.561	0.481	0.401	0.321	0.241

Table 1 - Water Content - Unit Heaters, Fan Coil Units and Convectors

(Kilojoule/hour to Liters Conversion Factors) (BTUH to Gallons Conversion Factors)

	Liter/10 550 KjH		Gals./10,000 BTUH	
	At 93.3 C	At 82.2 C	At 200 F	At 180 F
Convectors	2.42	-	0.64	-
Unit Heaters	-	0.757	-	0.2
Fan Coil Units	-	0.757	-	0.2

Table 2 - Volume of Water in Pipe and Tubing

(Liters Per Lineal Meter - Gallons Per Lineal Foot)

Nominal Pipe Size Inches	Steel Pipe		Copper Tube	
	Liters/Meter	Gals/Foot	Liters/Meter	Gals/Foot
1/2	0.199	0.016	0.149	0.012
3/4	0.348	0.028	0.310	0.025
1	0.559	0.045	0.534	0.043
1 1/4	0.969	0.078	0.807	0.065
1 1/2	1.30	0.105	1.14	0.092
2	2.14	0.172	2.00	0.161
2 1/2	3.11	0.250	3.11	0.250
3	4.78	0.385	4.43	0.357
4	8.28	0.667	7.76	0.625
5	12.42	1.00	12.42	1.00
6	18.63	1.50	17.39	1.40
8	32.66	2.63	30.18	2.43
10	52.16	4.20	46.94	3.78
12	73.27	5.90	67.06	5.40

Table 3 - Water Content - Heat Exchangers

Shell Dia. Nominal Pipe Size In Inches	Liters/Meter of Shell Length		Gals/Foot of Shell Length	
	In Shell	In Tubes	In Shell	In Tubes
4	5.3	2.9	0.4	0.2
6	12.4	6.2	1.0	0.5
8	22.4	11.2	1.8	0.9
10	29.8	14.9	2.4	1.2
12	49.7	27.3	4.0	2.2
14	62.1	32.3	5.0	2.6
16	80.7	43.5	6.5	3.5
18	99.3	55.9	8.0	4.5
20	124.2	68.3	10.0	5.5
24	186.3	93.1	15.0	7.5

Derivation of "Net Expansion Factors"

(Table 5 - Metric or English)

The net expansion factors listed in Table 5 Degrees Celsius, and Table 5, Degrees Fahrenheit, were derived from the Smithsonian Tables for "Relative Density and Volume of Water" and an acceptable coefficient of expansion for metallic system components.

Metric (SI) - 3(12.24E-06)t (°C)

English - 3(6.8 x 10-0)t (°F)

Where "*t*" = Temperature differential, in degrees, between initial and final temperature.

Method Of Derivation

1. Gross Water Expansion Factor

From the "Volume column of the Smithsonian Tables, the figure given for the initial temperature was subtracted from the figure given for the design temperature.

Example:

Metric (SI)	Smithsonian Tables Volume Column
Final Temperature 90°C	1.035 90
Initial Temperature 15°C	-1.000 87
Gross Water Expansion	0.035 03

English	
Final Temperature 230°F	1.0515
Initial Temperature 70°F	-1.0021
Gross Water Expansion	.0494

Relative Density and Volume of Water

The mass of one cubic centimeter of water at 4°C is taken as unity.

The values given are numerically equal to the absolute density in grams per millimeter.

(Smithsonian Tables, compiled from Various Authors)

Temp °F	Temp °C	Density	Volume	Temp °F	Temp °C	Density	Volume
	-10	0.99815	1.00186	95.0	+35	0.99406	1.00598
	-9	843	157	96.8	36	371	633
	-8	869	131	98.6	37	336	669
	-7	892	108	100.4	38	299	706
	-6	912	088	102.2	39	262	743
	-5	0.99930	1.00070	104.0	40	0.99224	1.00782
	-4	945	055	105.8	41	186	821
	-3	958	042	107.6	42	147	861
	-2	970	031	109.4	43	107	901
	-1	979	021	11.2	44	066	943
	+0	0.99987	1.00013	113.0	45	0.99025	1.00985
	1	993	007	114.8	46	0.98982	1.01028
	2	997	003	116.6	47	940	072
	3	999	001	118.4	48	896	116
39.2	4	1.00000	1.00000	120.2	49	852	162
41.0	5	0.99999	1.00001	122.0	50	0.98807	1.01207
42.8	6	997	003	123.8	51	762	254
.6	7	993	007	125.6	52	715	301
46.4	8	988	012	127.4	53	669	349
48.2	9	981	019	129.2	54	621	398
50.0	10	0.99973	1.00027	131.0	55	0.98573	1.01448
51.8	11	963	037	140.0	60	324	705
53.6	12	952	048	149	65	059	979
55.4	13	940	060	158.0	70	0.97781	1.02270
57.2	14	927	073	167.0	75	489	576
59.0	15	0.99913	1.00087	176.0	80	0.97183	1.02899
60.8	16	897	103	185.0	85	0.96865	1.03237
62.6	17	880	120	194.0	90	534	590
4.4	18	862	138	203.0	95	192	959
66.2	19	843	157	212.0	100	0.95838	1.04342
68.0	20	0.99823	1.00177	230.0	110	0.9510	1.0515
69.8	21	802	198	248.0	120	0.9434	1.0601
71.6	22	780	221	266.0	130	0.9352	1.0693
73.4	23	756	244	284.0	140	0.9264	1.0794
75.2	24	732	268	302.0	150	0.9173	1.0902
77.0	25	0.99707	1.00294	320.0	160	0.9075	1.1019
78.8	26	681	320	338.0	170	0.8973	1.1145
80.6	27	654	347	356.0	180	0.8866	1.1279
82.4	28	626	375	374.0	190	0.8750	1.1429
84.2	29	597	405	392.0	200	0.8628	1.1590
86.0	30	0.99567	1.00435	410.0	210	0.850	1.177
87.8	31	537	466	428.0	220	0.837	1.195
89.6	32	505	497	446.0	230	0.823	1.215
91.4	33	473	530	464.0	240	0.809	1.236
93.2	34	440	563	482.0	250	0.794	1.259

2. Piping Expansion Factor

The formula for determining the factor for expansion of the piping was computed:

Example:

Metric (SI)

3 (12.24E-06)(90-15) = 0.000 036 7 x 75 = 0.002 752 5

English

3(6.8 x 10 -6)(230-70) = .0000204 x 160 = .0032640

3. Net Water Expansion Factor

	Metric (SI)	English
Gross Water Expansion	0.035 03	.0494
Less Piping Expansion	-0.002 752 5	-.003264
Net Water Expansion	0.032 277 5	.046136

CRITICAL SIZING PROCEDURE

THINGS YOU MUST KNOW:

		METRIC (SI)	ENGLISH
1.	Total System Water Content (V_8)	(1) ________ liters	(1) ________ gallons
2.	Temperature of water when system is filled (T_f)........	(2) ________ °C.	(2) ________ °F.
3.	Average Design Temperature (*t*)	(3) ________ °C.	(3) ________ °F.
4.	Minimum Operating Pressure (P_f) .... at EXTROL® Tank.	(4) ________ kPa, gauge	(4) ________ PSIG
5.	Maximum Operating Pressure (P*o*) .... at EXTROL® Tank.	(5) ________ kPa, gauge	(5) ________ PSIG

SELECTION OF EXTROL® MODEL:

		METRIC (SI)	ENGLISH
6.	Enter Total System Water Content (V_8) from Line 1	(6) ________ liters	(6) ________ gallons
7.	Find and enter "Net Expansion Factor" .... If Lines (2) and (3) are in °C., use Table 5-Metric If Lines (2) and (3) are in °F., use Table 5-English	(7) ________	(7) ________
8.	Multiply Line (6) by Line (0 to arrive at amount of Expanded Water	(8) ________ liters	(8) ________ gallons
9.	Find and enter "Acceptance Factor"........	(9) ________	(9) ________
10.	Divide Line (8) by Line (9) and enter answer here........ This is Minimum Total EXTROL® Volume.	(10) ________ liters	(10) ________ gallons

11. If Line 10 is 498 liters (132 gallons) OR LESS:
use Table 7A and find "AX" Model EXTROL® that meets
both "Total Tank Volume" (Line 10) and
"Acceptance Volume" (Line 8) .... (11) ____________________
AX-Model EXTROL

12. If Line 10 is MORE THAN 498 liters (132 gallons):
Use Table 7B and find "L" Series EXTROL® that meets
"Total Tank Volume" (Line 10)........ (12) ____________________
"L" Series EXTROL

FUNCTION OF SIZING PROCEDURE AS A FORMULA

$$\text{Minimum Total EXTROL® Volume} = \frac{\text{Expanded Water in liters or gallons (Line 8)}}{\text{Acceptance Factor (Line 9)}}$$

JOB NAME ______________________________ ______________________________

LOCATION ______________________________ SALES REPRESENTATIVE ____________________

ENGINEER ______________________________ ______________________________

CONTRACTOR ______________________________ DATE SUBMITTED ____________________

AMTROL

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Part #: 9003-036 (04/11)