BRAZED PLATE HEAT EXCHANGERS

Sizing Charts and Technical Handbook

MUELLER®
REFRIGERATION PRODUCTS

Brazed-Plate Heat Exchangers

REFRIGERANT APPLICATIONS

- Condensers
- Subcoolers
- Evaporators
- Oil coolers
- Heat pump, air-conditioning, and chiller applications

APPROVALS

Canada:	Canadian Standard Association (CSA)
Austria:	Technischer Überwachung Verein (TÜV)
Germany:	Technischer Überwachung Verein (TÜV)
U.S.A.:	American Standard Mechanical Engineering (ASME)
U.S.A.:	Underwriters Laboratories Inc. (UL)

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R-22 Subcooling Selection Chart

R-22 SUBCOOLING SELECTION CHART

Model No.	Btuh Required	Evaporator Temperature (°F)	DX Side Pressure Drop (psi)	DX Side Mass Flow (lb/hr)	Liquid-Load Side* Pressure Drop (psi)	Liquid-Load Side* Mass Flow (lb/hr)
WP2-10	7,900	20	0.7	107	0.2	532
WP2-10	8,300	25	0.7	114	0.2	558
WP2-10	8,600	30	0.7	119	0.2	579
WP22-10	15,400	20	2.1	209	0.6	1,036
WP22-10	16,000	25	2.1	220	0.7	1,077
WP22-10	16,700	30	2.1	231	0.7	1,124
WP22-10	17,500	35	2.2	245	0.8	1,177
WP22-16	26,500	20	2.1	360	0.7	1,783
WP22-16	27,750	25	2.1	381	0.8	1,867
WP22-16	29,000	30	2.1	405	0.9	1,951
WP22-16	30,200	35	2.1	423	0.9	2,032
WP22-20	33,750	20	2.1	459	0.8	2,271
WP22-20	35,000	25	2.1	480	0.8	2,355
WP22-20	36,800	30	2.1	510	0.9	2,476
WP22-20	38,500	35	2.1	539	1.0	2,590
WP22-24	44,000	20	2.3	598	0.9	2,960
WP22-24	46,000	25	2.3	631	1.0	3,095
WP22-24	48,000	30	2.3	665	1.0	3,230
WP22-24	49,800	35	2.3	697	1.0	3,351
WP22-26	50,500	20	2.5	686	1.0	3,398
WP22-26	53,000	25	2.6	727	1.1	3,566
WP22-26	55,300	30	2.6	766	1.2	3,721
WP22-26	55,850	35	2.4	781	1.2	3,754
WP22-30	65,900	20	3.1	896	1.3	4,434
WP22-30	68,000	25	3.0	933	1.4	4,575
WP22-30	71,500	30	3.0	991	1.5	4,811
WP24-30	78,000	20	5.5	1,060	2.5	5,248
WP24-30	81,000	25	5.5	1,111	2.6	5,450
WP24-30	84,000	30	5.5	1,164	2.8	5,652
WP24-30	87,000	35	5.5	1,217	3.0	5,854
WP24-40	108,500	20	6.2	1,475	2.8	7,300
WP24-40	114,000	25	6.3	1,564	3.1	7,670
WP24-40	117,500	30	6.2	1,628	3.3	7,906
WP24-40	123,000	35	6.2	1,721	3.6	8,276

NOTE:

▲ This chart is based on:
Entering Liquid Temperature (ELT) = 100°F
Leaving Liquid Temperature (LLT) = 50°F

R-22 Subcooling Selection Chart - Continued

R-22 SUBCOOLING SELECTION CHART

			DX Side		Liquid-Load Side*	
Model No.	Btuh Required	Evaporator Temperature (°F)	Pressure Drop (psi)	Mass Flow (lb/hr)	Pressure Drop (psi)	Mass Flow (lb/hr)
AE5-50	197,000	20	6.6	2,523	3.6	13,255
AE5-50	204,000	25	6.5	2,637	3.9	13,726
AE5-50	214,500	30	6.6	2,800	4.3	14,432
AE5-50	236,000	35	7.1	3,112	5.1	15,879
WP7L-30	310,000	20	4.0	4,213	1.8	20,858
WP7L-30	323,000	25	4.0	4,432	1.9	21,732
WP7L-40	336,000	30	2.6	4,655	1.3	22,607
WP7L-40	340,000	35	2.5	4,757	1.3	22,876
WP7L-30	395,000	20	5.9	5,369	2.9	26,577
WP7L-40	413,000	25	4.0	5,667	1.9	27,788
WP7L-40	423,000	30	3.9	5,860	2.0	28,461
AE7L-50	425,000	35	2.7	5,947	1.5	28,595
AE8-40	520,000	20	5.4	7,068	2.7	34,987
AE8-40	540,000	25	5.3	7,409	2.9	36,333
AE8-50	575,000	30	4.0	7,966	2.2	38,688
AE8-60	575,000	35	2.9	8,046	1.6	38,688
AE8-50	675,000	20	6.1	9,175	3.0	45,416
AE8-50	680,000	25	5.6	9,330	3.0	45,753
AE8-60	690,000	30	4.2	9,559	2.3	46,425
AE8-70	700,000	35	3.2	9,795	1.9	47,098

NOTE:

▲ This chart is based on:
Entering Liquid Temperature (ELT) = 100°F
Leaving Liquid Temperature (LLT) = 50°F

R-22 Condenser Selection Chart - Tower Water

R-22 CONDENSER SELECTION CHART - TOWER WATER

Rating Ton	Model No.	Btuh Required	Refrigerant Side Pressure Drop (psi)	Mass Flow (lb/hr)	Water Side Pressure Drop (psi)	Water Side Flow Rate (gpm)
1	WP22-20	15,000	0.04	173	0.46	3
2	WP22-30	30,000	0.07	345	0.82	6
3	WP22-50	45,000	0.04	518	0.72	9
3	WP24-20	45,000	0.46	518	5.16	9
4	WP24-24	60,000	0.56	691	6.4	12
5	WP24-30	75,000	0.52	863	6.55	15
7.5	WP5-34	112,500	0.57	1,295	7.1	22.5
10	WP5-50	150,000	0.4	1,726	6.2	30
15	WP5-70	225,000	0.42	2,589	7.6	45
20	WP7M-40	300,000	0.41	3,453	6.5	60
25	WP7M-50	375,000	0.46	4,316	6.7	75
30	WP7M-60	450,000	0.42	5,179	7.04	90
35	WP7M-70	525,000	0.39	6,042	7.4	105
40	WP7M-90	600,000	0.22	6,905	6.7	120
40	WP7M-80	600,000	0.38	6,905	7.84	120
45	WP7M-100	675,000	0.19	7,768	7.3	135
45	WP7M-90	675,000	0.35	7,768	8.36	135
50	WP7M-120	750,000	0.09	8,631	7.33	150
50	WP7M-100	750,000	0.31	8,631	8.96	150
60	WP8M-160	900,000	0.01	10,358	3.27	180
60	WP9-90	900,000	1.36	10,358	7.69	120
70	WP9-100	1,050,000	1.5	12,084	8.58	140
80	WP9-120	1,200,000	1.35	13,810	8.12	160
90	WP9-140	1,350,000	1.15	15,536	7.92	180
100	WP9-150	1,500,000	1.24	17,263	8.71	200
100	WP10-90	1,500,000	1.8	17,263	9.07	200
110	WP10-100	1,650,000	1.78	18,989	8.94	220
120	WP10-110	1,800,000	1.73	20,715	8.84	240

NOTES:

This chart is based on the following parameters:

- Refrigerant is R-22, Tgas in at 165°F, liquid out at 100°F.
- Condensing temperature is 105°F, subcooling = 5°F.
- Water side is 85°F in, 95°F out.
- Flow rates above 60 tons reduced for 15°F temperature rise (2 gpm/ton).

R-22 Condenser Selection Chart - City Water

R-22 CONDENSER SELECTION CHART - CITY WATER							
Rating Ton	Model No.	Btuh Required	Refrigerant Side Pressure Drop (psi)	Mass Flow (lb/hr)	Water Side Pressure Drop (psi)	Flow (gpm)	Temperature Out (°F)
1	WP22-10	15,000	0.23	173	0.79	2	90
2	WP22-20	30,000	0.15	345	0.8	4	90
3	WP22-24	45,000	0.25	518	1.24	6	90
4	WP22-30	60,000	0.27	691	1.42	8	90
5	WP22-40	75,000	0.21	863	1.3	10	90
7.5	WP24-30	112,500	1.18	1,295	3.8	11.26	95
10	WP24-34	150,000	1.67	1,726	5.27	15	95
15	WP24-50	225,000	1.46	2,589	6.05	22.5	95
20	WP5-50	300,000	1.86	3,453	6.2	30	95
25	WP5-60	375,000	1.93	4,316	6.9	37.5	95
30	WP5-70	450,000	1.93	5,179	7.6	45	95
30	WP7M-34	450,000	1.75	5,179	5.06	45	95
35	WP7M-40	525,000	1.63	6,042	5.07	52.6	95
40	WP7M-44	600,000	1.74	6,905	5.52	60	95
45	WP7M-50	675,000	1.63	7,768	5.54	67.6	95
50	WP7M-54	750,000	1.7	8,631	5.94	75	95
55	WP7M-60	825,000	1.58	9,494	5.98	82.6	95
60	WP7M-64	900,000	1.62	10,358	6.39	90	95
70	WP7M-80	1,050,000	1.22	12,084	6.08	105	95
80	WP7M-90	1,200,000	1.13	13,810	6.67	120	95
90	WP7M-100	1,350,000	1.02	15,536	7.32	135	95
100	WP7M-110	1,500,000	0.93	17,263	8.04	150	95
110	WP7M-120	1,650,000	0.77	18,989	8.84	165	95
120	WP7M-130	1,800,000	0.59	20,715	9.73	180	95

NOTES:

This chart is based on the following parameters:

- Refrigerant is R-22, Tgas in at 165°F, liquid out at 100°F.
- Condensing temperature is 105°F, subcooling = 5°F.
- City water side is 75°F in, out as listed above.

R-22 Chiller Selection Chart

R-22 CHILLER SELECTION CHART - 9°F TEMPERATURE APPROACH CONDITIONS

Rating Ton	Model No.	Btuh Required	Refrigerant Side Pressure Drop (psi)	Mass Flow (lb/hr)	Water Side Pressure Drop (psi)	Flow Rate (gpm)
1	WP22-20	12,000	0.5	168	0.3	2.4
2	WP22-40	24,000	0.4	337	0.3	4.8
3	WP24-24	36,000	2.3	505	2.5	7.2
4	WP24-30	48,000	2.5	673	2.9	9.6
5	WP24-40	60,000	2.3	842	2.7	12.0
7.5	AE5-44	90,000	2.5	1,262	3.1	18.0
10	AE5-60	120,000	2.5	1,683	3.1	24.0
15	AE5-80	180,000	3.2	2,524	4.1	36.0
15	AE7M-34	180,000	2.7	2,524	3.4	36.0
20	AE7M-44	240,000	2.8	3,365	3.7	48.0
25	AE7M-54	300,000	3.0	4,207	4.0	60.0
30	AE7M-70	360,000	2.8	5,048	3.7	72.0
40	AE7M-90	480,000	3.0	6,730	4.4	96.0
50	AE7M-120	600,000	4.0	8,413	4.8	120.0
60	AE9-100	720,000	4.5	10,096	6.8	144.0
70	AE9-120	840,000	4.6	11,778	6.8	168.0
80	AE9-140	960,000	4.7	13,461	6.9	192.0
90	AE9-160	1,080,000	4.9	15,143	7.2	216.0
100	AE10-100	1,200,000	6.6	16,826	11.0	240.0
110	AE10-110	1,320,000	6.6	18,506	11.0	264.0
120	AE10-124	1,440,000	6.4	20,191	10.4	288.0

NOTES:

This chart is based on 9°F approach conditions, and the following parameters:

- Refrigerant is R-22, Tevap = 35°F, dT superheat = 9°F.
- 20% R-22 vapor quality assumed at evaporator inlet.
- Water side is 54°F in, 44°F out, 2.4 gpm/ton.
- Contact Paul Mueller Company for selections above 120 tons.

R-22 CHILLER SELECTION CHART - 10°F TEMPERATURE APPROACH CONDITIONS						
Rating Ton	Model No.	Btuh Required	Refrigerant Side Pressure Drop (psi)	Mass Flow (lb/hr)	Water Side Pressure Drop (psi)	Flow Rate (gpm)
1	WP22-20	12,000	0.5	168	0.3	2.4
2	WP22-40	24,000	0.4	337	0.3	4.8
3	WP24-24	36,000	2.6	505	2.9	7.2
4	WP24-30	48,000	2.5	673	2.9	9.6
5	WP24-40	60,000	2.3	841	2.7	12.0
7.5	AE5-40	90,000	2.8	1,262	3.6	18.0
10	AE5-50	120,000	3.1	1,683	4.2	24.0
12	AE5-60	144,000	3.2	2019	4.3	28.8
15	AE5-80	180,000	3.1	2,524	4.1	36.0
15	AE7M-34	180,000	2.6	2,524	3.4	36.0
20	AE7M-44	240,000	2.8	3,365	3.7	48.0
25	AE7M-54	300,000	3.0	4,207	4.0	60.0
30	AE7M-66	360,000	3.0	5,048	4.1	72.0
40	AE7M-90	480,000	3.0	6,730	4.4	96.0
50	AE7M-110	600,000	4.0	8,413	5.3	120.0
60	AE9-80	720,000	4.6	10,096	7.1	144.0
70	AE9-110	840,000	5.1	11,778	7.8	168.0
80	AE9-120	960,000	5.7	13,461	8.8	192.0
90	AE9-140	1,080,000	5.7	15,143	8.7	216.0
100	AE10-90	1,200,000	7.8	16,826	13.4	240.0
110	AE10-100	1,320,000	7.7	18,506	13.2	264.0
120	AE10-110	1,440,000	7.6	20,191	13	288.0

NOTES:

This chart is based on 10°F approach conditions, and the following parameters:

- ▲ Refrigerant is R-22, Tevap = 35°F, dT superheat = 9°F.
- ▲ 20% R-22 vapor quality assumed at evaporator inlet.
- ▲ Water side is 55°F in, 45°F out, 2.4 gpm/ton.
- ▲ Contact Paul Mueller Company for selections above 120 tons.

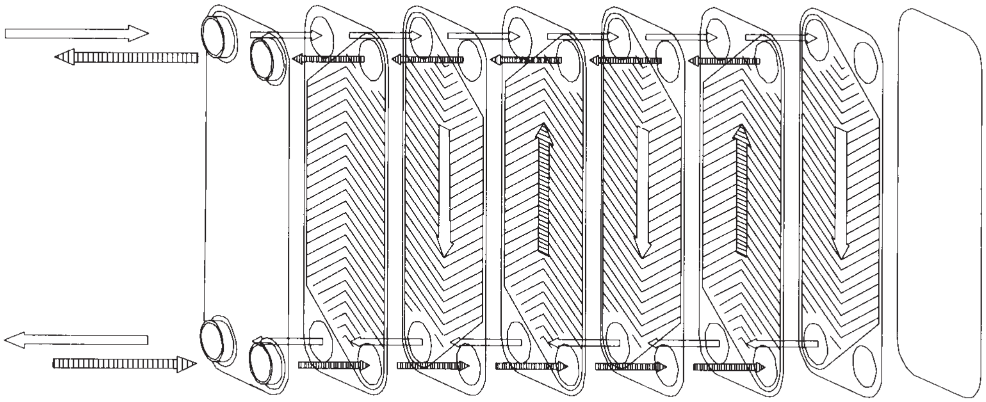
Working Principle

WORKING PRINCIPLE OF BRAZED-PLATE HEAT EXCHANGERS

Brazed-plate heat exchangers consist of up to 200 pattern-embossed plates of acid-resistant stainless steel (see Figure 1). Every other plate is reversed so the ridges of the herringbone pattern intersect one another on adjacent plates forming a lattice of contact points. When these points are vacuum brazed together, a compact and pressure-resistant heat exchanger is formed in which virtually all material is utilized for heat transfer.

After brazing, the impressions in the plates form two separate systems of channels where the two media flow in true countercurrent. This complex channel system causes vigorous turbulence, ensuring maximum heat transfer. The result is a highly efficient heat exchanger with heat transfer coefficients having no counterpart. The largest unit can handle a maximum flow capacity of 600 gpm. The standard unit is designed for UL and CUL to meet 435 psig at 365°F. CSA ratings are 450 psig at 383°F.

Figure 1 - Working Principle



BRAZED-PLATE HEAT EXCHANGER PRODUCT APPLICATIONS

Examples of applications where a brazed-plate heat exchanger can be used:

- Heat pumps
- Industrial chillers: plastic machines, welding machines, hydraulic presses (oil), compressor-oil cooling
- Air conditioning
- Refrigeration
- Water coolers; drinking water or process water for various industries
- Temperature holding for storage tanks (for example, milk tanks)
- Heat recovery from waste water or other processes
- Climatization (computer room and other similar applications)

In refrigerant applications brazed-plate heat exchangers function as:

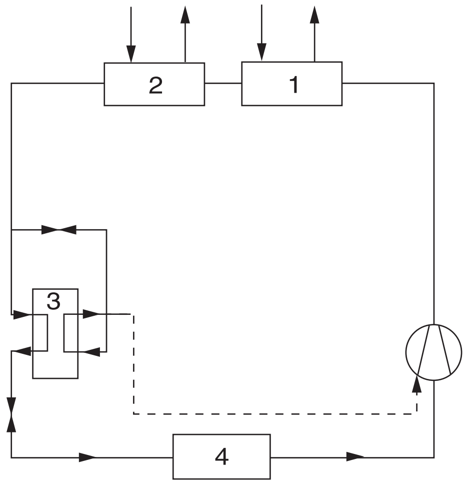
- Condensers
- Evaporators
- Superheaters for gas
- Desuperheaters for gas
- Subcoolers for condensate
- Economizers
- Intercoolers
- Heat recovery with or without partial condensation
- Oil coolers

Brazed-plate heat exchangers can also be used for various media:

- All types of refrigerants except ammonia
- Organic solvents
- Water
- Various brine solutions (glycol mixtures, $CaCl_2$, alcohols, and others)
- Oil and other similar fluids

In heat pumps, air conditioning, and chiller applications, a BPHE can be used for several tasks—primarily as an evaporator and condenser, but also as an economizer, subcooler, oil cooler, or desuperheater. The flow sheet in Figure 2 is a combination of different system variants. Regard it as a source for ideas.

Figure 2 - Brazed-Plate Heat Exchanger Flow Chart



Possible Applications for BPHE in Refrigerant Systems:

1. Condenser
2. Subcooler
3. Economizer
4. Evaporator

Advantages

ADVANTAGES OF BRAZED-PLATE HEAT EXCHANGERS

Brazed-plate heat exchangers have many special features in refrigerant applications such as:

Compact

BPHEs occupy a volume which is extremely small—sometimes down to one-sixth of the space occupied by other types of exchangers. This advantage is especially highly valuable for prefabricated systems.

Small Temperature Differences Between Media

With BPHEs, it is possible to work with a very small difference between the condensing and the cooling-water temperature. This advantage often makes a great impact on the efficiency of the complete system; for example, smaller compressors.

High Working Pressure

The high pressure required on the condensing side of the systems causes no problem to BPHEs. These units are normally tested to a pressure of 40 bar.

Efficient Evaporation

With BPHEs, evaporation to a level of virtually no content of liquid is possible. In most cases, no liquid separator is required. Considerable savings can thus be made.

Low Pressure Drop on Liquid Side

In most cases, the pressure drop in BPHEs is lower than in competing coaxial exchangers.

Less Refrigerant Needed

The small internal volume means that the complete system requires small volumes of refrigerant. BPHEs require only one-seventh of the amount of refrigerant compared to systems with conventional exchangers.

Lightweight

The compact execution and the small hold-up volume means that the weight is only a fraction of the weight of other exchangers.

Low Tendency for Freezing

The high turbulence in the channels minimizes the tendency for freezing on the water side, which means that in evaporation applications the temperature at the water outlet can be lower than in any other heat exchanger type.

High Resistance Against Freezing

If there is a failure in the system and the water in the heat exchanger freezes, a brazed-plate heat exchanger can withstand this much better than traditional types and can often continue to work after defrosting. However, no heat exchanger will stand an unlimited number of freezing cycles; and, therefore, necessary equipment for freeze protection should be built into the system.

Modularity

BPHEs can easily be arranged in parallel for systems built on modules.

Consistent Quality

The plates of a BPHEs are pressed out of homogenous steel and are brazed together. These plates are pressed with the same tool every time, which guarantees that each plate is identical to the others. This means that the exchanger always performs in exactly the same way. This is an outstanding feature when compared to the many tubular exchangers where great variances in the production might exist.

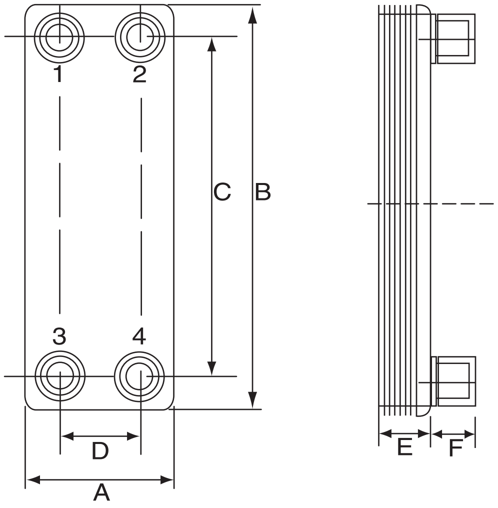
Economical

In most cases, a brazed-plate heat exchanger represents the most economical solution for the customer. This is not only due to the fact that the purchase price of a brazed-plate heat exchanger is, in most cases, lower than for other types of heat exchangers but also to the fact that the mounting of the unit is easier. Therefore, savings can be made on smaller cabinets, tubing, packing, and freight.

BRAZED-PLATE HEAT EXCHANGER DIMENSIONS & SPECIFICATIONS

A BPHE is manufactured in stainless, acid-resistant steel brazed with 99.9% pure copper. Nickle brazed units are available. The range currently consists of nine different models:

Figure 3 - Dimensions



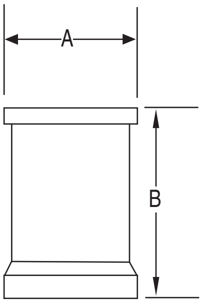
SPECIFICATIONS

	Dimensions (Inches)						Surface	Weight
Type	A	B	C	D	E	F	Plate (ft^2)	Empty (lbs)
WP1/NP1	2.88	8.00	6.56	1.63	0.47 + (0.095 x N)	0.79	0.150	1.65 + (0.11 x N)
WP2/NP2	3.50	9.06	7.19	1.69	0.47 + (0.095 x N)	0.79	0.193	2.42 + (0.13 x N)
WP22/NP22	3.50	12.80	10.98	1.69	0.47 + (0.095 x N)	0.79	0.274	3.14 + (0.13 x N)
WP24	3.50	18.15	16.34	1.69	0.47 + (0.095 x N)	0.79	0.366	4.20 + (0.33 x N)
WG24	3.50	18.15	16.34	1.69	0.47 + (0.112 x N)	0.79	0.366	4.20 + (0.33 x N)
WP3/NP3	4.88	6.73	4.72	2.88	0.47 + (0.095 x N)	0.79	0.189	2.64 + (0.13 x N)
WP4/NP4/AE4	4.88	13.07	11.06	2.88	0.47 + (0.095 x N)	0.79	0.377	3.52 + (0.26 x N)
WP5/NP5/AE5	4.88	20.83	18.81	2.88	0.47 + (0.095 x N)	0.79	0.634	4.40 + (0.53 x N)
DW5	4.88	20.83	18.81	2.88	0.47 + (0.095 x N)	0.79	0.634	4.40 + (0.53 x N)
WP7/AE7	10.59	20.83	18.11	7.88	0.47 + (0.095 x N)	3.74	1.453	12.13 + (1.32 x N)
WP8/AE8	10.59	20.83	16.57	6.34	0.47 + (0.095 x N)	2.44	1.400	16.54 + (1.54 x N)
WP9/AE9	10.59	31.41	27.16	6.34	0.47 + (0.095 x N)	2.44	2.150	21.15 + (1.76 x N)
WP10/AE10	15.08	34.25	28.46	9.33	0.88 + (0.095 x N)	NA	2.690	86.90 + (2.66 x N)

NOTES:

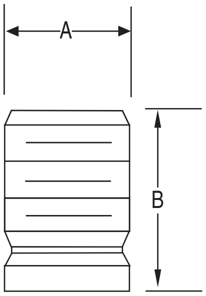
- WP = Copper Brazed
- AE = Evaporator
- NP = Nickel Brazed
- WG = Wide Gap
- DW = Double Wall
- N = Number of Plates

Standard Connections



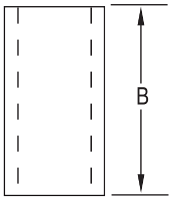
STANDARD CONNECTIONS - SOLDER

ID A(in)	Height B (in)	NP1 WP1	NP2 WP2	NP22 WP22 WP24	NP3 WP3	AE4 NP4 WP4	NP5 WP5 DW5 AE5	WP7 AE7	AE8 WP8	AE9 WP9	AE10 WP10
3/8	.79	X	X	X	X	X	X				
1/2	.79	X	X	X	X	X	X				
5/8	.79	X	X	X	X	X	X				
3/4	.79	X	X	X	X	X	X	X	X		
7/8	.79	X	X	X	X	X	X	X	X		
7/8	1.57							X	X		
1 1/8	.79					X	X	X	X	X	X
1 3/8	.79					X	X	X	X	X	X
1 3/8	1.57							X	X	X	X
1 1/2	.79							X	X		
1 5/8	.79							X	X	X	X
2	.79							X	X	X	X
2 1/8	.79							X	X	X	X
2 5/8	.79								X	X	X
3	.79									X	X
3 1/8	.79									X	X
3 3/8	.79										X



STANDARD CONNECTIONS - MALE NPT, EXTERNAL THREAD

ID A(in)	Height B (in)	NP1 WP1	NP2 WP2	NP22 WP22 WP24	NP3 WP3	AE4 NP4 WP4	NP5 WP5 DW5 AE5	WP7 AE7	AE8 WP8	AE9 WP9	AE10 WP10
1/2	.79	X	X	X	X	X	X				
3/4	.79	X	X	X	X	X	X				
1	.79					X	X				
1 1/4	.79					X	X	X			
1 1/4	1.57							X			
1 1/2	2.56							X	X	X	X
2	2.56							X	X	X	X
2 1/2	2.56								X	X	X
3	2.56									X	X
3 1/2	2.56										X
4	2.56										X



STANDARD CONNECTIONS - FEMALE NPT, INTERNAL THREAD

ID A(in)	Height B (in)	NPO1 WP1	NP2 WP2	NP22 WP22 WP24	NP3 WP3	AE4 NP4 WP4	NP5 WP5 DW5 AE5	WP7 AE7	WP8
1/2	.79	X	X	X	X	X	X	X	
3/4	.79				X	X	X	X	

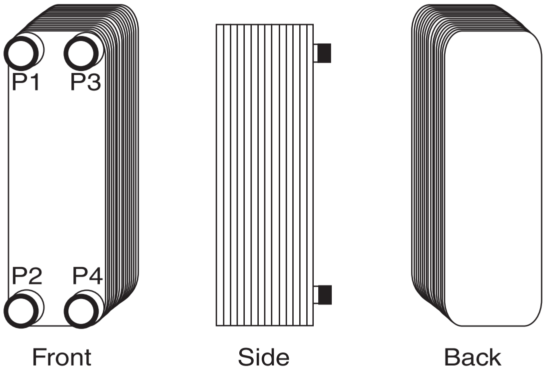
NOTES:

- ▲ For connections other than those listed above, contact Paul Mueller Company.
- ▲ Paul Mueller Company stocks all model types with the most popular solder and threaded connections for immediate delivery.

CONNECTION ARRANGEMENTS

BPHEs offer a wide range of connections and connection arrangements (Figure 4) to simplify installation and reduce applied costs for our customers. Our standard execution consists of two soldering connections for the refrigerant circuit and two male-threaded connections for the water circuit. All four connections are on the front side.

Figure 4 - Connection Arrangements, Standard Execution



P1/P2: Refrigerant circuit, soldering connections

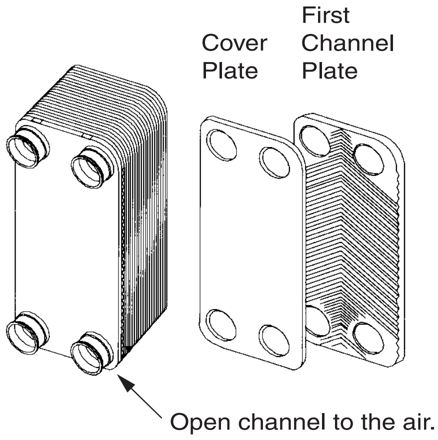
P3/P4: Water circuit, male-threaded connections

SEALING PLATE TO AVOID EXTERNAL FREEZING AND INCREASE MECHANICAL STRENGTH.

Even if your system is controlled to avoid freezing the evaporator from the inside, there is always a risk that it will freeze from the outside when the exchanger is exposed to low temperatures. On the old BPHE versions (Figure 5A), there were openings between the first and last channel plate and the front and back cover plate allowing humid air to enter. When the humid air came into contact with a low-temperature surface, water condensed and froze.

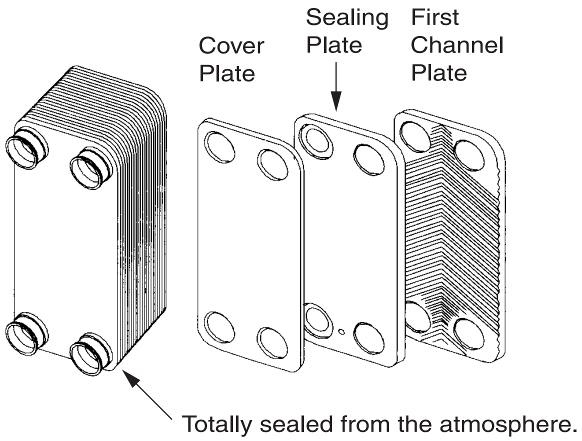
If this freezing was repeated several times, the heat exchanger could break from the outside. We have solved this problem by introducing an additional sealing plate (Figure 5B). This exclusive improvement guarantees a unit that is totally sealed from the atmosphere. The sealing plates also increase the mechanical strength of the BPHE, especially around the ports.

Figure 5A - Old Version of BPHE



Open channel to the air.

Figure 5B - New Version of BPHE



Totally sealed from the atmosphere.

Fouling Characteristics

FOULING CHARACTERISTICS OF BRAZED-PLATE HEAT EXCHANGERS

BPHEs differ greatly in design, construction, and performance from other types of heat exchangers and have completely different fouling characteristics.

There are no similarities between the compact brazed exchanger and conventional heat exchangers such as the coaxial or the shell-and-tube heat exchanger. Therefore, standard fouling factors written for conventional heat exchanger types do not apply to compact brazed heat exchangers. Because of their unique construction, BPHEs are much less prone to fouling than heat exchangers using tubular construction.

Factors Effecting Fouling

Temperature, turbulence, velocity, flow distribution, surface finish, and water quality all affect fouling within a heat exchanger.

Types of Fouling

Scaling is caused by substances dissolved in the heat transfer medium which deposit on the heat transfer surface. Generally, scaling will increase with increases in temperature, concentration, and pH. The temperatures normally encountered within refrigerant condensers are usually not high enough to lead to scaling.

Particulate fouling is caused by suspended solids in the heat transfer medium such as mud, silt, sand, or other particles. Particulate fouling is affected by velocity, distribution of the medium, roughness of the heat transfer surface, and the size of the particles.

PRIMARY CAUSES OF FOULING IN BRAZED-PLATE HEAT EXCHANGERS

Laminar versus turbulent flow. When a fluid passes through a tube, the greatest velocity is at the center of the tube. The tube wall has no turbulence to keep particles in the fluid in suspension. These particles are allowed to precipitate out and collect on the tube wall which causes fouling of the heat transfer surface.

Conventional types of heat exchangers are very sensitive to low velocities and easily get into the laminar region. The opposite of laminar flow is turbulent flow (Figures 6A and 6B). Operating with turbulent flow is the best way to avoid fouling in the heat exchangers. BPHEs impart a high degree of turbulence to the fluid which keeps particles in the fluid in suspension and actually performs a scouring action to keep the heat transfer surface clean. This is accomplished by the unique design of the BPHE. As the fluid passes through the channels, it is constantly changing direction and velocity, disturbing the boundary layer and ensuring turbulent flow even at extremely low velocities. When using water, the BPHE will always operate with fully developed turbulence.

Figure 6A - Laminar Flow

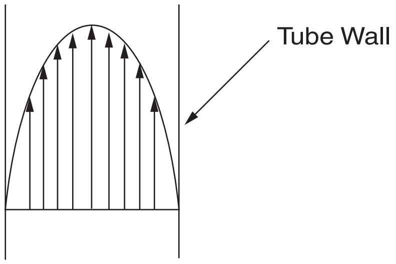
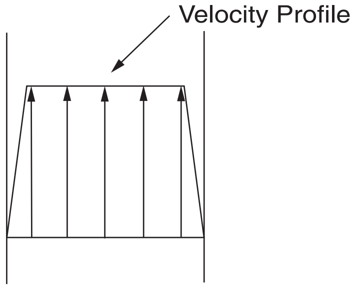


Figure 6B - Turbulent Flow



Uneven flow distribution. Within conventional heat exchangers, there can be areas of low velocity resulting in laminar flow due to uneven distribution of the fluid through the exchanger. These sections are prone to foul. The fouling starts at these low-velocity areas and spreads over the heat transfer surface. Since all plates used in a BPHE are identical, the channels will be identical. This guarantees the same velocity in each parallel channel, ensuring that the incoming fluid is distributed equally among the channels. No low-velocity areas are created where fouling can start to build up.

Poor distribution over the heat transfer surface. It is of great importance to have well-distributed flow over the heat transfer surface to maintain uniform velocity. The unique flow pattern of the BPHE distributes the flow evenly as it enters each flow channel providing uniform velocity gradients over the entire heat transfer surface.

Heat transfer surface quality. Rough surfaces are known to encourage fouling by collecting particulate matter. The material used in every BPHE is AISI 316 stainless steel, and the smooth surface of this material has a positive effect in minimizing fouling.

In applications where a cooling tower or other open systems are used, the cooling water will be rich in oxygen. This can cause corrosion of material such as carbon steel used in conventional heat exchangers. Usually, this corrosion is in the form of iron oxide scale on the carbon steel surface, but loose iron oxide can be deposited elsewhere as well. The stainless steel used in a BPHE is not subject to uniform corrosion which causes fouling problems (even though it isn't completely immune to corrosion under certain conditions).

Scaling. Scaling is the deposit on the heat transfer surface of hard or soft substances which are dissolved in the water. The most common types are calcium carbonate and calcium sulphate scaling which forms due to inverse solubility effects when the water is heated above approximately 160°F. The tendency for this type of fouling increases with increased temperature, concentration, and pH. Studies have shown that a high degree of turbulence and a small hydraulic diameter, such as with BPHEs, have beneficial effects on this type of fouling. Proper maintenance and treatment of the cooling water, especially in cooling towers, greatly reduce the risk of scaling. If water-quality information is provided at the design stage, this effect can be avoided by taking it into consideration.

CORROSION RESISTANCE

Corrosion is a complex process influenced by many different factors. The resistance guide table below is an attempt to give a picture of the resistance of AISI 316 stainless steel and copper to the most important chemical factors.

NOTE:

This table is a considerable simplification and should not be overvalued.

RESISTANCE GUIDE
AISI 316 STAINLESS STEEL AND COPPER

Water Containing:	Concentration (mg/l)	AISI 316 Stainless Steel	Copper
Organic elements		+	0
Electrical conductivity	<500 S/cm	+	+
	>500 S/cm	+	-
NH_3	<2	+	+
	2 - 20	+	0
	>20	+	-
Chloride*	<300	+	-
	>300	0	+
Sulphite, free chloride	<5	0	+
	>5	0/-	0
Iron (soluted)	<10	+	+
	>10	+	0
Free (aggressive)	<20	+	0
carbon acids	20 - 50	+	-
	50	+	-
Mangan (soluted)	<1	+	+
	>1	+	0
pH-value	<6	0	+
	6 - 9	0/+	+
	>9	+	0
Oxygen	<2	+	+
	>2	+	+
Sulphate	<70	+	+
	70 - 300	+	0
	>300	-	-

NOTES:

- Maximum 140°F.
- + = Good resistance under normal conditions.
- 0 = Corrosion problems may occur especially when more factors are valued 0.
- - = Not usable.

SELECTING THE RIGHT TYPE AND SIZE OF BRAZED-PLATE HEAT EXCHANGERS

Software Package

The software package represents the "state of the art" in two-phase heat transfer calculations. These duties offer particularly difficult calculation situations while the conditions in the process are continuously changing. By handling the duties as a large number of surface elements in series, the varying conditions can be simulated; and the final result becomes very accurate.

The condensation program calculates liquid-cooled, brazed-plate heat exchanger condensers and recognizes and handles the following heat transfer processes as well as combinations of them:

- Dry wall desuperheating of gas
- Wet wall desuperheating of gas
- Condensation of saturated gas
- Subcooling of liquid

The program will warn the user when an unusual or performance-deteriorating situation is expected to occur; for example:

- Unreasonable pressure loss
- High connection pressure drop
- High velocities in connections and/or channels
- Flow maldistribution in the plate pack

The evaporator program calculates liquid-heated brazed-plate heat exchanger evaporators and handles the following heat transfer processes as well as combinations of them:

- Subcooled heat transfer liquid/liquid
- Subcooled nucleate boiling
- Mist flow
- Gas/liquid heat transfer
- Film boiling

The program will warn the user when an unusual or performance-deteriorating situation is expected to occur; for example:

- High connection pressure drop
- High velocities in connection and/or channels
- Flow maldistribution in the plate pack
- Too low velocity to carry oil in Freon channels

For some common duties you have the possibility to do a selection using the Selection Guides at the beginning of this handbook. This will give you a rough idea of the sizes you need; but to get an optimal design for your special application, please contact Paul Mueller Company.

Selection Specifications

Mueller distributors and agents offer you full service in selecting BPHEs. With the assistance of our design software package, they are always capable of offering you the optimal solution for your applications. The form on the next page will assist us in designing the optimum brazed-plate heat exchanger for your application. Please include as much information as you can. Mail or fax the completed form to us, or call with the information. The software program will quickly and accurately design the right heat exchanger for your requirements.

Selection Form

Company: ______________________ Date: __________

Address: ______________________

Phone: ______________________ Fax: ______________________

Name: ______________________ Title: ______________________

Products Manufactured: ______________________

CONDENSER	**Side One**	**Side Two**
Fluid Type:		
Ref. Discharge Temperature:		
Inlet Temperature:		
Outlet Temperature:		
Condensing Temperature:		
Subcooling Temperature (minimum 3.6°F):		
Mass Flow Rate (lbs/hr):		
Maximum Pressure Drop:		
Oversurface (% required):		

EVAPORATOR OR SUBCOOLER	**Side One**	**Side Two**
Fluid Type:		
Evaporator Temperature:		
Superheat*:		
Inlet Temperature:		
Outlet Temperature:		
Mass Flow Rate (lbs/hr):		
Maximum Pressure Drop:		
Oversurface (% required):		

**Computer selection program has a default value of 9°F.*

For applications other than those listed above, please contact Paul Mueller Company for design assistance.
Telephone: 1-800-683-5536 • Fax: 1-888-446-8265 • E-mail: refrigeration@muel.com

GENERAL INFORMATION

The BPHE should be mounted in the vertical position with the arrow on the front plate pointing upwards (Figure 7). Take care that neither vibrations nor pulsations can be transferred to the heat exchanger by installing, for example, mufflers or vibration absorbers. In the case of larger connection diameters, we advise using an expanding device in the pipeline. Usually a rubber mounting strip can be used as buffer between the BPHE and the mounting clamp. Figure 8 shows several mounting suggestions.

Figure 7 - Advised Mounting Position

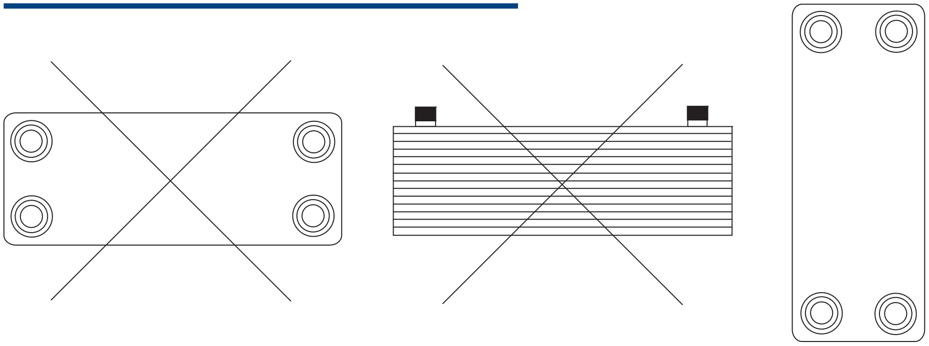
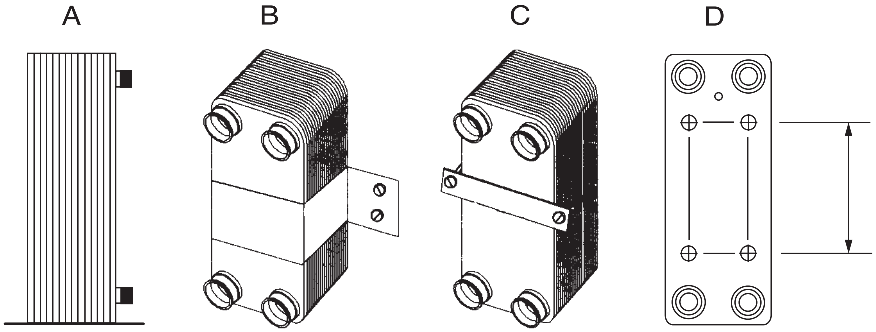


Figure 8 - Mounting Suggestions



A. BPHE supported from the bottom
B. Sheet-metal bracket (Armaflex between the bracket and the BPHE)
C. Crossbar and bolts (Armaflex between the BPHE and the wall)
D. Stud bolts

BRAZED-PLATE HEAT EXCHANGER INSTALLATION

It is very important, especially for evaporators, that every Freon channel is surrounded by a water channel on both sides. This implies that the first and the last channel in every BPHE must be a water channel. By wrongly connecting the Freon instead of water to the first and last channel, the evaporation temperature will drop over 9°F with the risk of freezing and very bad performance (less than 50%). Normally, the Freon circuit must be connected on the left side and the water circuit on the right side of the BPHE. The starting point to define left and right is an upright standing position of the heat exchanger with the arrow on the front plate pointing upwards.

Condensers

The refrigerant gas enters at the top (Figure 9), and condensate (liquid) leaves at the left, bottom side. The water inlet is at the bottom, and the water outlet at the right, top side. The refrigerant and water flows should always be connected countercurrent. When used as condensers, BPHEs should be fitted with soldering connections on the refrigerant side.

Evaporators

The refrigerant gas/liquid mixture enters at the left, bottom side; and the gas leaves at the left, top side (Figure 10). The water inlet is at the top and the water outlet at the right, bottom side. The refrigerant and water flows should be connected countercurrent. The expansion valve should be placed close to the inlet connection, whereas the bulb should be mounted about 20" from the Freon outlet connection (Figure 11). The pipe diameter between the expansion valve and the BPHE should be the same as the diameter of the liquid line. BPHEs used as evaporators should always be fitted with soldering connections on the refrigerant side. For V-model heat exchangers, the pressure drop taken by the internal distributor system must be added to the pressure drop taken by the expansion valve to arrive at the total pressure drop. Normally, selecting the next largest valve will result in satisfactory performance.

Threaded Connections

Be sure that the female part is not threaded on with such force that the connection will be damaged. It is advisable to use a connection type where the female part seals against the top of the heat exchanger connection.

Soldering Connections

Piping should be soldered using silver as the soldering material with a minimum 45% silver.

Figure 9 - Condenser Flow Arrangement

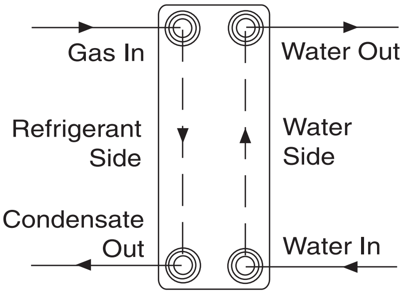


Figure 10 - Evaporator Flow Arrangement

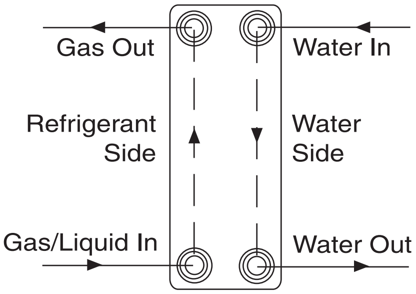
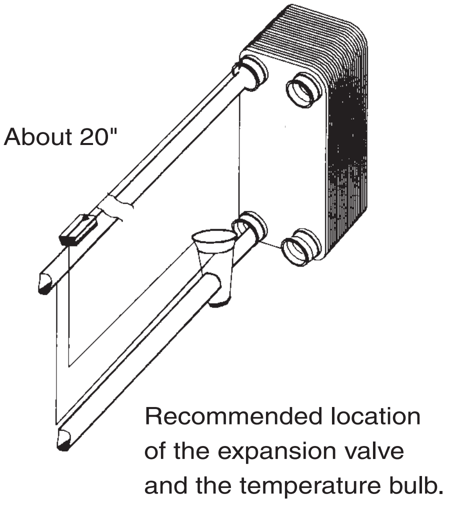


Figure 11 - Expansion Valve Location



BRAZED-PLATE HEAT EXCHANGER SOLDERING INSTRUCTIONS

All BPHEs are vacuum brazed with copper. This means that a BPHE, in no circumstance, can ever exceed 1,470°F during normal soldering conditions (no vacuum). Temperatures over 800°C could cause the copper solder to change its structure, resulting in internal or external leakage at the connection.

Properties of Hard-Silver Solder

- **Relatively low soldering temperature**
  - the mechanical properties of the metals to be connected are maintained
  - restriction of thermal tensions
  - short soldering time saving energy and labor
- **High moistening and fluidity properties (affix properties)**
  - the capillary suction is improved and thus the soldering quickly fills the area
  - minimal amount of silver solder and hardly any finishing needed
  - tight and strong connections
- **High mechanical strength**
  - the strength of the connection is generally higher than the strength of the soldered materials
- **Good conductivity of heat, which is highly important to the refrigeration and heating industries**
- **Good resistance against corrosion**
  (The corrosion resistancy is generally better than those of the used materials depending on the nature of the materials to be connected and heating method.)

Types of Hard-Silver Soldering Connections:

In the refrigeration field, we only have to deal with an overlap pipe in pipe joint, with a minimum length of 0.31".

The Soldering Process:

The hard-silver soldering procedure for all BPHE connections can be carried out without any use of cooling water neither by dimpling under water nor, for example, water flow through the waterside of the exchanger.

1. Oxidation within connection pipes not allowed in the refrigeration installations. Therefore, it is recommended to avoid this by sending a flow of nitrogen through the pipe during the soldering procedure. (The nitrogen flow could be between 1.5-5.5 US gpm depending on the size of the pipe.)
2. Start by cleaning the joints to be soldered. Clean the inside of the connection on the BPHE and the outside of the pipe. Degrease the connections properly with some kind of solvent; for example, Tri.
3. Center the pipe into the connection. (If possible, carry out the soldering procedure by laying the BPHE on its back.)
4. The first part of the cooling is done by keeping nitrogen flowing through the heat exchanger. The final cooling could be done with water.
5. Because of the fast cooling in the water, the last hardened flux should be removed on the inside and outside of the joint.

	Nominal Compounds				Melting Range (°F)	Norms	
	Ag	Cu	Cd	Zn		DIN	BS1845ANSI/A WS A5.8
Hard Silver Sold: 454	45	15	24	Rest	1,150-1,175	DIN 8513 L-Ag45CD	BAG-1
Flux: 800°F					1,110-1,470	DIN 8511 F-SH1	Paste

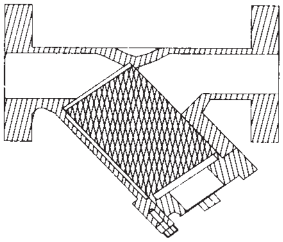
Recommendations:

The minimal compound of silver must be at least 45%.

STRAINERS

When there are particles in the fluid that could block the heat exchanger, strainers should be used (Figure 12). Particles up to 1mm diameter will not cause any problems. This corresponds to a mesh size of 16-20 mesh (depending on the wire diameter).

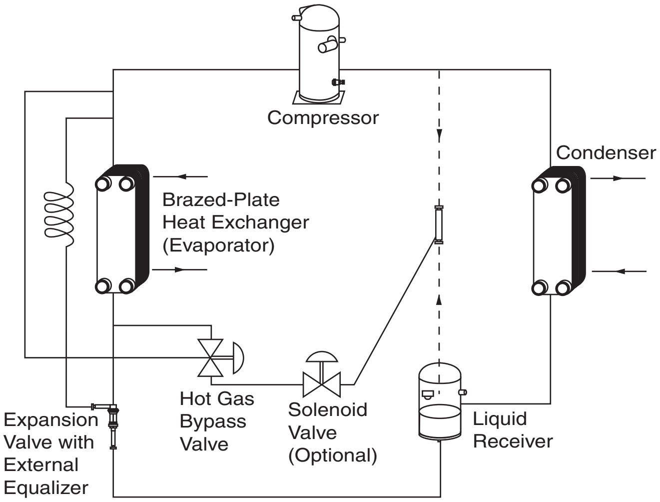
Figure 12 - Strainer



FREEZE PROTECTION IN EVAPORATOR APPLICATIONS

Normally, freezing occurs at the water outlet (at the bottom of the evaporator) where the water temperature reaches its lowest point (Figure 13). In a dx system, the outgoing gas temperature is controlled at the refrigerant outlet (at the top of the evaporator). To create a potential risk for freezing, evaporation has to take place at 32°F or below. The pressure drop on the refrigerant side will correspond to approximately 36°F under normal conditions. This implies that saturated conditions at the control bulb have to be 28°F or less to be able to reach 32°F at the evaporator inlet. The most critical situation occurs at startup, when the suction pressure tends to be low, corresponding to 5-15°F evaporation.

Figure 13 - Freeze Protection - Hot Gas Bypass



If possible, take hot gas from liquid receiver (lower gas temperature).

STANDARD APPLICATIONS IN SYSTEM DESIGN:

- Low pressure control on the suction line will switch off the compressor when pressure decreases under normal working conditions, thereby avoiding dips in the evaporation temperature. In reversible systems, the low-pressure switch should be mounted before the reversing valve to be able to set at as high pressure as possible. Since the pressure is low at startup, a timer could be used to bypass this function during this step. The safest way is to use hot gas bypass under these conditions.

- The temperature sensor in the water circuit has two functions: to work as a security thermostat to switch off the machine when the outgoing temperature decreases to a point near freezing; and to start the circulation pump when the temperature falls due to the system being off in combination with low ambient temperature. We recommend using an electronic-type (HTC) with the sensor directly in the water flow. To shorten the reaction time, the temperature sensors could be applied inside the heat exchanger. For outdoor installations, the evaporator should be insulated and applied with a wrap around the electrical heating device.

- The flow switch in the fluid line will shut off the machine, thereby avoiding freeze-ups due to pump failures or disrupted water flow rates.

- A time relay will continue to run the fluid pump for a few minutes after the machine has been switched off. This will allow the remaining coolant in the heat exchanger to evaporate.

AVOIDING WATER HAMMER

"Water hammer" is a phenomenon which occurs when the installation pipelines carry incompressible fluids such as water, ethylene glycol, etc., and the fluid flow suddenly changes velocity. A common cause of water hammer is the quick closing of a solenoid valve in liquid lines. Abruptly stopping the fluid flow will produce a substantial pressure rise above normal.

High-intensity pressure waves (Figures 14A and B) will travel back and forth in the pipelines between the point of closure and a point of relief (such as a larger-diameter header with an extreme high speed). During its travels, the shock wave alternately expands and contracts the pipelines.

Water hammer (Figure 15) is the cause of many problems, such as ruptured pipes. It also damages valves, BPHEs, and other equipment. In a BPHE, water hammer will cause a bulb in the front or back plate, resulting in internal/external leakages. To avoid or eliminate these problems, the designer can install an air chamber or a water-hammer arrester. Another method for controlling water hammer is to use valves with controlled closing times or controlled closing characteristics. The graphs in Figure 14 dramatically illustrate the difference between using standard, quick-closing water valves and slow-closing, time-controlled water valves.

Figure 14A - Standard, Quick-Closing Valve

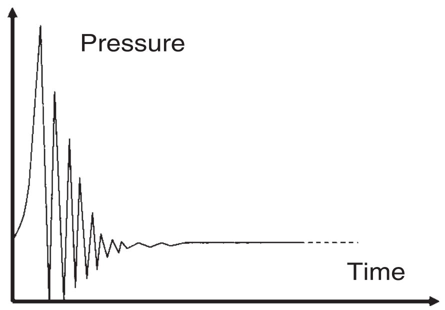


Figure 14B - Slow-Closing, Time-Controlled Valve

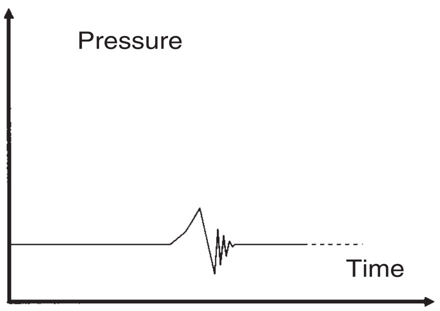
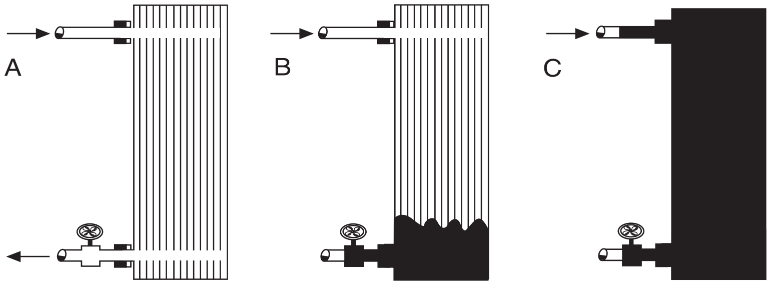


Figure 15 - Water Hammer



A: Normal working conditions, open valve.

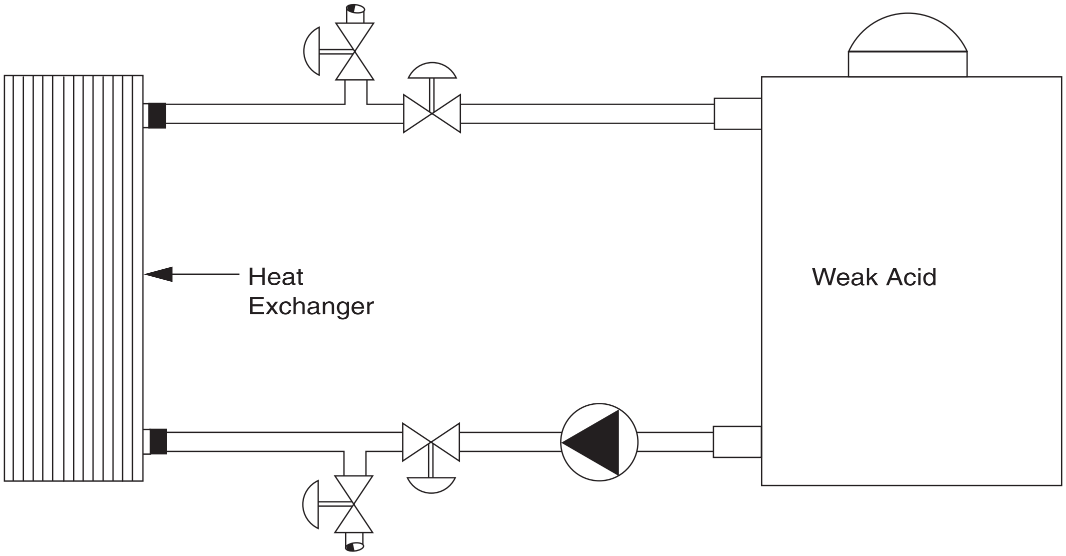
B: Quick closing of a solenoid valve, producing a substantial pressure rise.

C: High-intensity pressure waves traveling back and forth in the pipelines.

CLEANING

In some applications the fouling tendency could be very high; for example, when using extremely hard water. It is always possible to clean the heat exchanger by circulating a cleaning liquid (CIP) (Figure 16). Use a tank with a weak acid, 5% phosphoric acid; or, if the heat exchanger is frequently cleaned, 5% oxalic acid. Pump the cleaning liquid through the heat exchanger. For optimum cleaning, the cleaning-solution flow rate should be a minimum of 1.5 times normal flow rate, preferably in a back-flush mode. Afterwards, rinse with large amounts of fresh water in order to get rid of all the acid before starting the system again. Clean at regular intervals.

Figure 16 - Cleaning in Place (CIP)



THE COMPRESSION REFRIGERATION CYCLE

The purpose of a refrigerant system is to transfer heat from a cold chamber which is at a temperature lower than that of its surroundings. Heat is absorbed at the low temperature and rejected at a higher temperature as work is supplied. The simplest refrigeration system consists of an evaporator, a compressor, a condenser, and an expansion valve. See Figure 17.

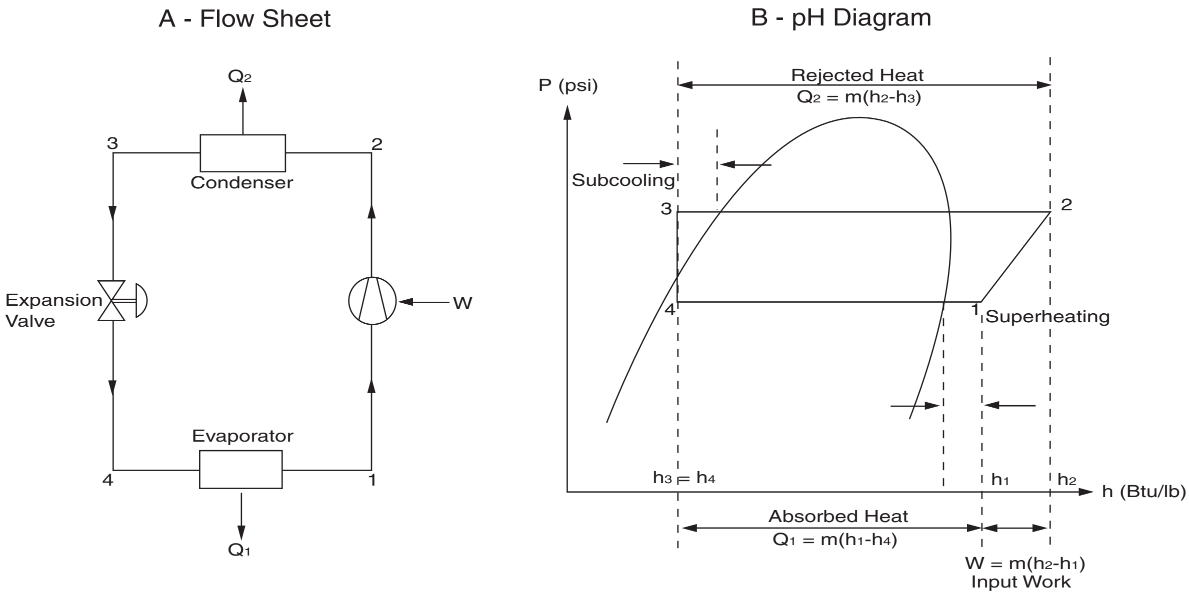
In the evaporator, the refrigerant is boiling at a constant low pressure and temperature. The heat of absorption is taken from the heat source. It is a practical necessity to allow the refrigerant vapor to become superheated in order to prevent the carry-over of liquid refrigerant into the compressor where it can cause severe damage due to its incompressibility and where it also interferes with the lubrication. The amount of superheat should be kept to a minimum to reduce the work to be done by the compressor as well as the necessary heat transfer surface in the evaporator. The heat absorbed by the refrigerant is Q1. The compressor sucks away the refrigerant vapor and thereby creates such low pressure in the evaporator that the evaporation temperature is kept below the surrounding temperature. The dry vapor entering the compressor, State 1, is compressed to such a high pressure that condensation is made possible at the temperature level prevailing in the condenser (Process 1-2). The work input for this process is represented by W in Figure 17.

The vapor enters the condenser at State 2 and is condensed at constant pressure and temperature to State 3, where it is completely liquified. The heat rejected is Q2. The condensed liquid is usually subcooled to a temperature below that of the saturation temperature corresponding to the condenser pressure for two reasons. The cooling capacity in Process 4-1 is increased and the risk that there will be gas bubbles in the flow fed to the expansion valve is avoided. (Gas bubbles in the inlet flow to the expansion valve will disrupt the regulation mechanism.) The expansion valve has two functions: to maintain the pressure difference between the condenser and the evaporator together with the compressor and to regulate the refrigerant volume to the evaporator.

There is no difference in operation between a refrigeration plant and a heat pump. With the refrigeration system, the important quantity is the energy removed from the cold chamber, Q_1, called the cooling capacity; and with the heat pump, it is the energy to be rejected by the refrigerant for heating purposes, Q_2. The power input is W and is important because it is the quantity which has to be paid and constitutes the main item of running cost. Refrigeration and heat-pump performances are defined by means of the Coefficient Of Performance (COP) which is given by:

COP refrigeration = Q_1/W
COP heat pump = Q_2/W

Figure 17 - The Compression Refrigeration Cycle



A - Flow Sheet

B - pH Diagram

SUBCOOLERS

In the condenser, the saturated refrigerant liquid is subcooled to a temperature below the dew point (a-b in Figures 18 and 19) to secure pure liquid without gas into the expansion valve. The subcooling can be done either in the last part of the condenser or in a separate heat exchanger (i.e., subcooler).

Figure 18 - Subcooling in a pH Diagram

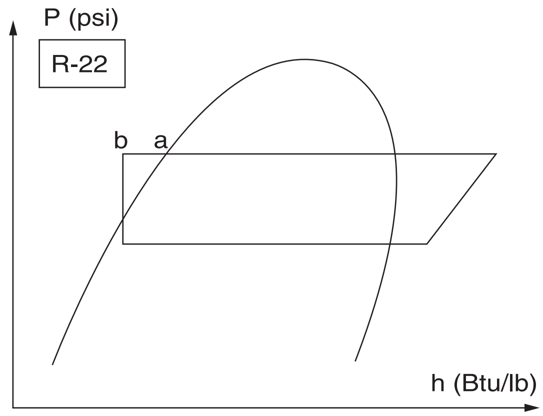
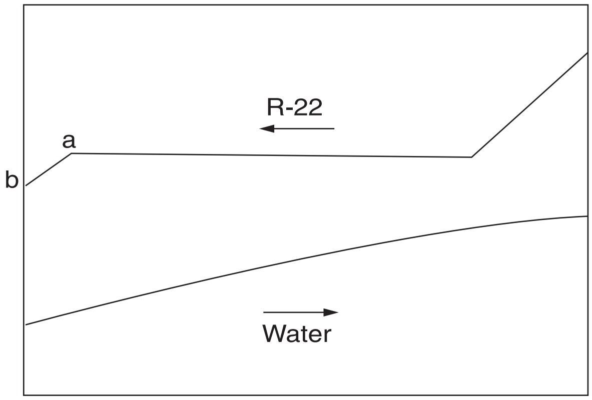


Figure 19 - Condenser Temperature Program



A system without a receiver can be charged with refrigerant to give the desired subcooling even without a separate subcooler (see Figure 20). When the system includes a receiver, the liquid going to the expansion valve may be slightly subcooled if there is a temperature stratification in the receiver liquid. To obtain a substantial subcooling in this case, a separate subcooler is required (see Figure 21).

Figure 20 - Condenser

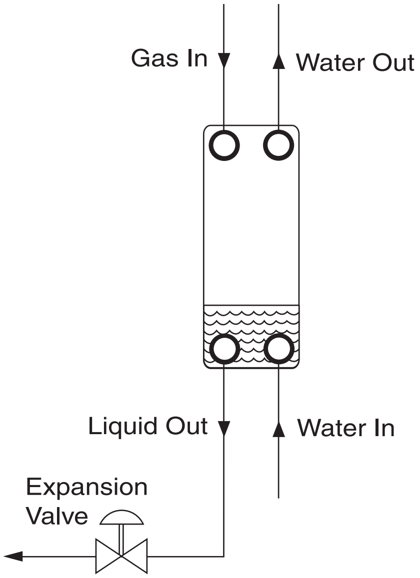
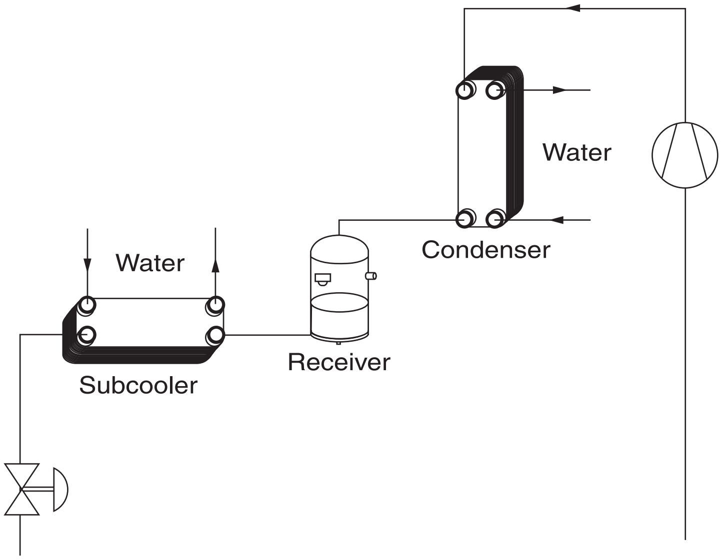


Figure 21 - Subcooler



ECONOMIZERS

In the economizer system (shown in Figure 22), the refrigerant liquid exiting the condenser is split into two streams. The major part, m_1, is fed through one side of the BPHE economizer/subcooler where it becomes subcooled liquid (a-b) before entering the expansion valve and the evaporator. The heat rejected during the subcooling is absorbed by the remaining liquid, m_2, which evaporates (c-d) at some intermediate pressure, p_2, on the other side of the BPHE economizer/subcooler after being fed through an expansion valve (a-c). The superheated gas leaving the BPHE (d) is led into the compressor's economizer connection (e) where the pressure is at the intermediate level, p_2, into the expansion valve. The subcooling can be done either in the last part of the condenser or in a separate heat exchanger; that is, a subcooler.

The subcooling decreases the inlet vapor quality to the evaporator which increases the cooling capacity. The increase in cooling capacity is utilized in the evaporator at the pressure, p_1, but is generated at the intermediate pressure level, p_2. The high efficiency of the BPHE economizer/subcooler minimizes the temperature difference between the subcooling and the evaporating stream which in turn increases the overall efficiency of the system. The economizer system requires a compressor with an additional suction connection at some intermediate pressure level. As an alternative, two compressors can be used.

Figure 22 - Economizer System

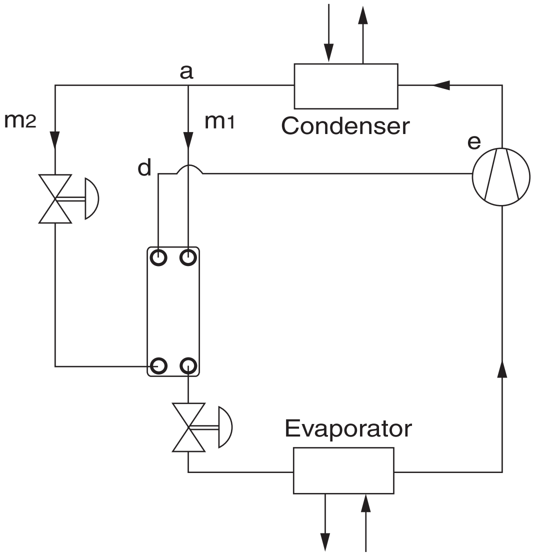


Figure 23 - Economizer Process in a pH Diagram

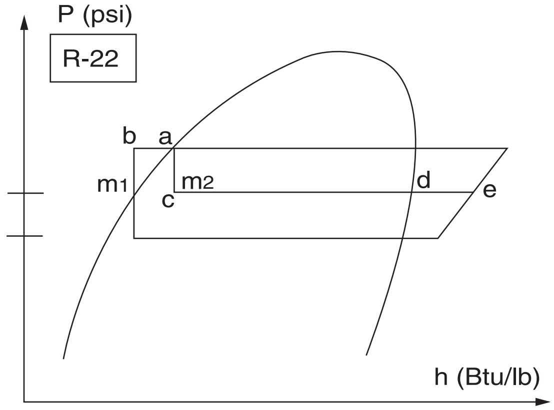
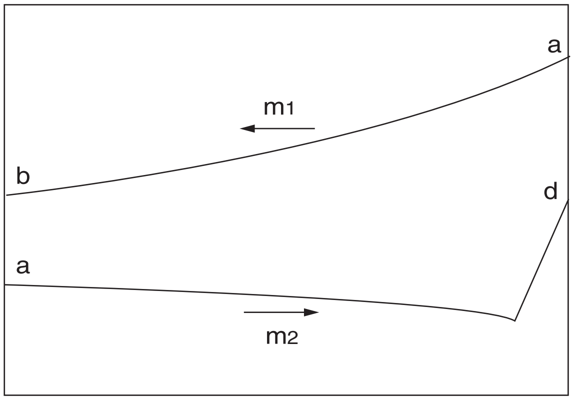


Figure 24 - BPHE Economizer/Subcooler Temperature Program

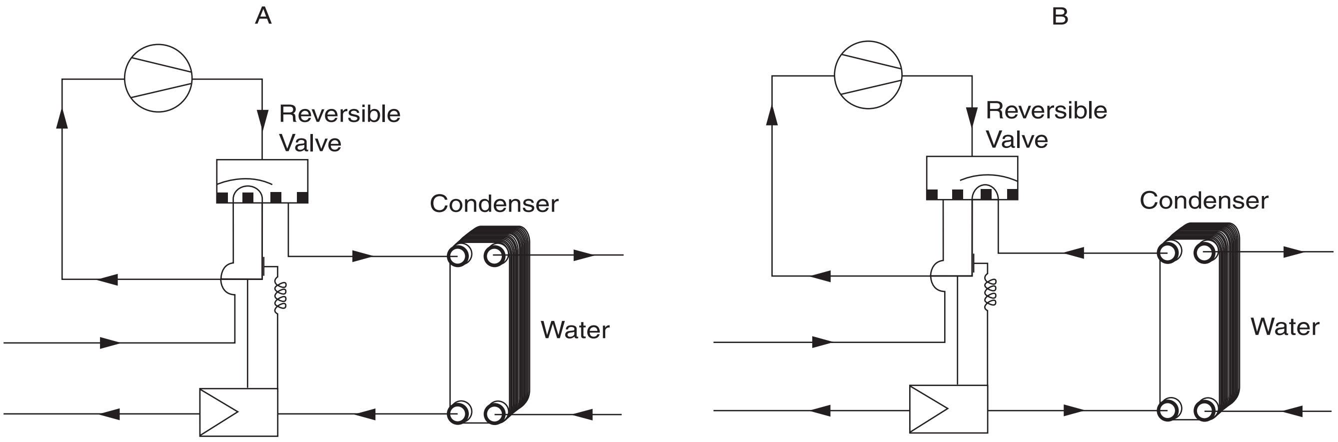


REVERSIBLE SYSTEMS

Reversible systems use the same BPHE both as evaporator and condenser. The condenser/evaporator duty is switched over by a reversible valve. Usually the climate in which the system is going to be used and whether the system is air or water based are the factors for deciding on the condenser or the evaporator for cocurrent (parallel) flow.

The evaporator works in cocurrent and the condenser in countercurrent, as shown in Figure 25. Normal performance can be expected for the condenser. Usually the evaporator working cocurrent would give less performance than when working countercurrent, due to a lower LMTD. In this special case, however, the evaporator performs as it would in a normal counter-current application for the following reason: A part of the superheat is created by the relatively hot reversible valve which acts as a small heat exchanger in the suction line. Due to the fact that the expansion valve bulb always has to be connected behind the reversible valve (for protection against high hot-gas temperatures in condenser duty), the evaporator works with a very small superheat. This gives nearly the same performance as a countercurrent case with “normal” superheat. A disadvantage of controlling the Freon flow this way is that the expansion valve reacts very slowly to changes.

Figure 25 - Reversible Systems



A - The BPHE working as a condenser in countercurrent.
B - The BPHE working as an evaporator in cocurrent.

THERMOSTATIC EXPANSION VALVES

A thermostatic expansion valve (TEV) is a device designed to maintain a constant value of the superheat, independent of the evaporating temperature. The superheat is defined as the difference between the gas temperature and the saturation temperature of the refrigerant at the evaporator outlet. The TEV is not designed to control the evaporating temperature.

A certain superheat is required to prevent liquid refrigerant from entering the compressor. Liquid drops could cause severe damage to the compressor due to their incompressibility. On the other hand, as low superheat as possible, or rather no superheat at all, is desired with the purpose of operating the evaporator at a high heat transfer capacity. Because of these two contrary desires, the TEV operates to maintain an optimal superheat that is sufficient to protect the compressor from liquid drops without being unnecessarily high.

A TEV is schematically shown in Figure 26. It consists of a bulb connected to the actual valve by capillary tube. The bulb contains refrigerant with a slightly different

THERMOSTATIC EXPANSION VALVES - continued

composition than the rest of the system, and it is attached to the outside of the suction line leaving the evaporator where it senses the outlet gas temperature. As the bulb contains both liquid and vapor, the pressure inside the bulb system is equivalent to the saturation pressure corresponding to the gas temperature in the suction line. The closing forces operating on the valve needle are the spring force (P_3) and the force caused by the evaporator inlet pressure acting on the lower side of the membrane (P_2) while the bulb-system pressure acting on the upper side of the membrane (P_1) causes the valve needle to open.

For a given evaporating temperature, the pressure in the bulb system has to exceed the evaporator inlet pressure with an amount corresponding to the spring force to bring the valve open. With this arrangement, the gas leaving the evaporator has to become superheated before the valve opens and lets more refrigerant into the evaporator. The amount of superheat is determined by presetting the spring. There are two types of thermostatic expansion valves:

- TEV with internal pressure equalization
- TEV with external pressure equalization

Figure 26 - Thermostatic Expansion Valve

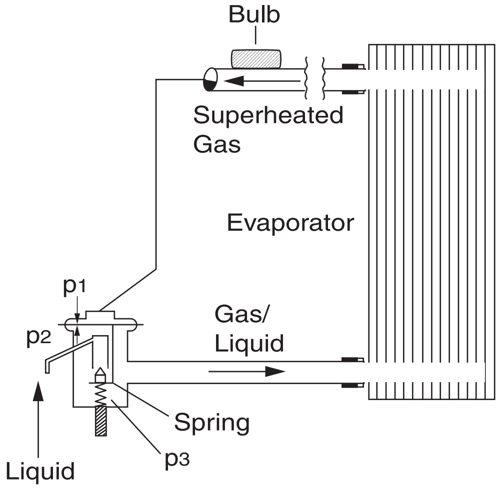
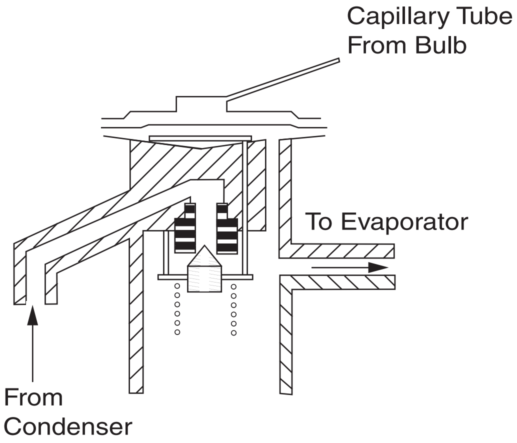


Figure 27 - Internal Pressure Equalization



INTERNAL PRESSURE EQUALIZATION

In order to estimate the amount of superheat correctly, the temperature of the gas leaving the evaporator should be compared with the saturation temperature (pressure) at the evaporator outlet. The valve shown in Figures 27 and 28 is a TEV with internal pressure equalization. This type compares the leaving gas temperature with the saturation temperature (pressure) at the evaporator inlet and should consequently only be used in connection with evaporators which have a relatively low pressure drop on the refrigerant side. If a TEV with internal pressure equalization is used together with an evaporator with a high pressure drop, it will result in a superheat greater than what was intended (see example). This in turn will decrease the heat transfer capacity in the evaporator; that is, the evaporating temperature will drop.

Example:

An evaporator Type V is used together with a TEV with internal pressure equalization. Assume 15psi pressure drop over the fluid distributor rings, Tvap = 36°F, and that the TEV is preset on 9°F superheat. The pressure at the evaporator inlet, State “a” in Figure 29, corresponds to approximately 46°F; and consequently the temperature of the gas leaving the evaporator will be 55°F (State “c”). This causes the superheat to be 19°F instead of the intended 9°F (State “d”).

EXTERNAL PRESSURE EQUALIZATION

To accomplish a correct estimation of the superheat when an evaporator with a high pressure drop on the refrigerant side is used, it is necessary to use a TEV with external pressure equalization. See Figure 29. A pressure tube is connected to the suction line at the evaporator outlet, and it transmits the pressure prevailing there to the lower side of the membrane. As can be seen in Figure 27, it is extremely important to use this type of expansion valve in conjunction with an evaporator Type V since it has built-in fluid distributor rings which cause an additional pressure drop ("a" to "b" in Figure 28) at the inlet of the refrigerant side. It is to be noted that this pressure drop does not decrease the evaporating pressure (temperature). Since it occurs prior to the actual heat transfer surface, it only uses some of the available pressure difference between the high- and low-pressure side from the expansion valve.

Figure 28 - Fluid Distribution Pressure Drop

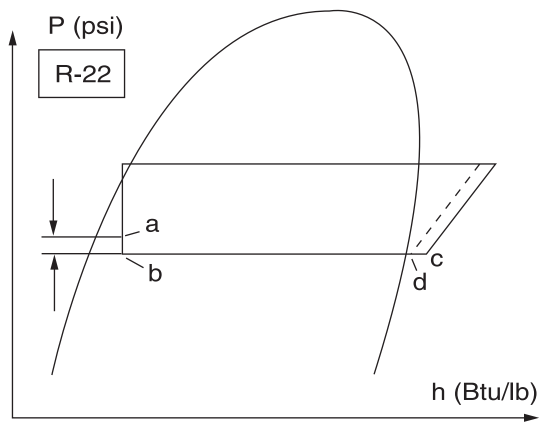
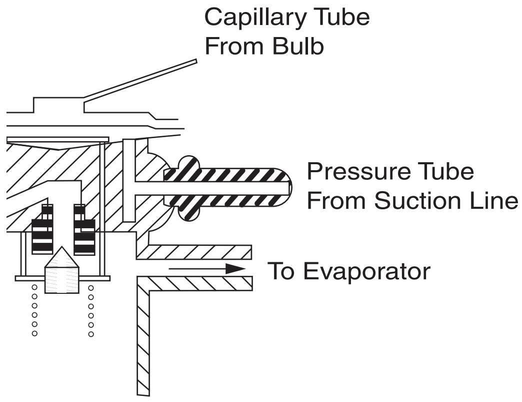


Figure 29 - External Pressure Equalization



Appendix: System Unit Guide

APPENDIX: SYSTEM UNIT GUIDE

Nomenclature

OA	area available for the flow of heat	ft^2
BPHE	brazed-plate heat exchanger	
C_p	specific heat capacity	Btu/(lb°F)
ELT	entering liquid temperature	°F
h	enthalpy	Btu/lb
LLT	leaving liquid temperature	°F
m	flow rate	lb/h
np	number of plates	
p	pressure	psi
Q	heat transferred per unit time	Btu/h
QTHR	total heat of rejection	Btu/h
QTHA	total heat of absorption	Btu/h
T	temperature	°F
T_c	condensation temperature	°F
T_{gas}	temperature of gas in	°F
T_{vap}	evaporation temperature	°F
dT_{sc}	subcooling	°F
dT_{sh}	superheating	°F
LMTD	logarithmic mean-temperature difference	°F
U	heat transfer coefficient	Btu/(ft^{-2}°F)

Notes

Notes

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