Refrigeration Fundamentals

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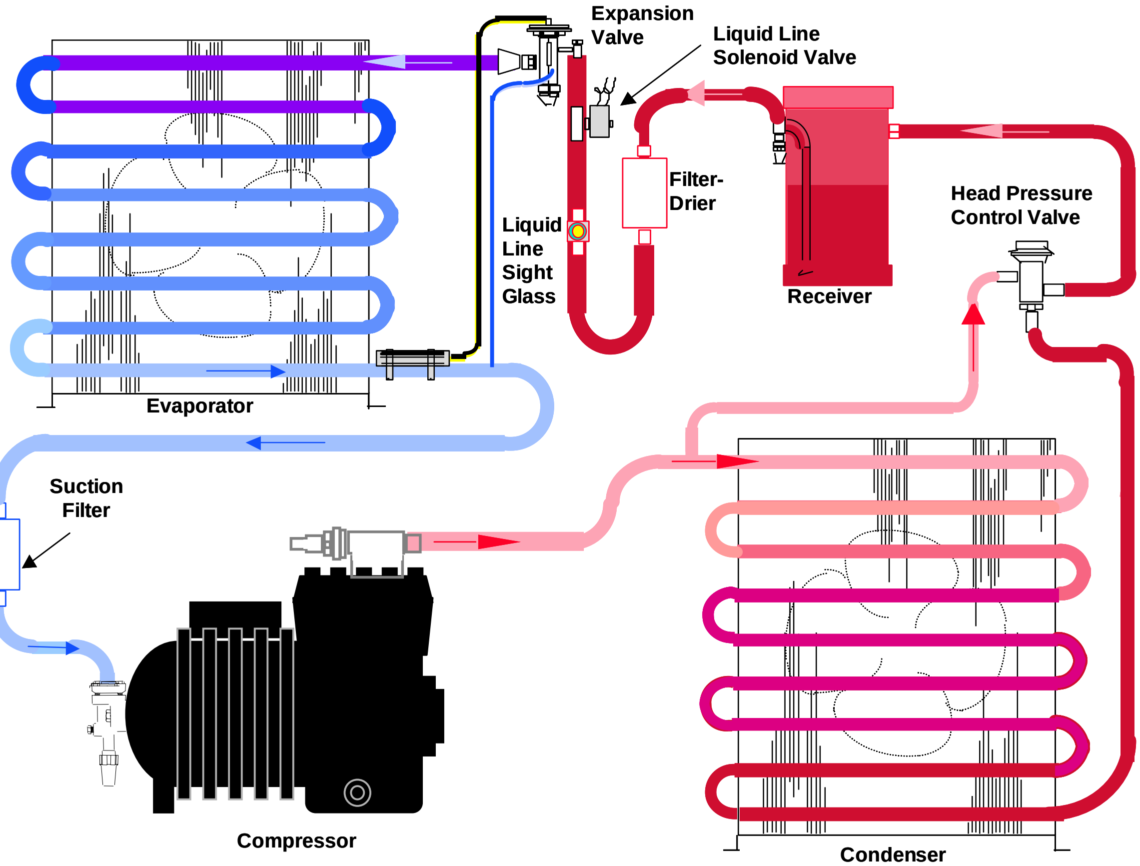
Typical Commercial Refrigeration System



INTRODUCTION

The information in this manual is meant for **entry-level** personnel to the commercial refrigeration industry to improve their understanding of the fundamentals of basic refrigeration principles. There are no specific technical prerequisites required prior to beginning this course material.

The course is structured with the more basic and simple content presented first. It is important that the student have a good understanding of the presented material before continuing to more complex content, which may require a thorough grasp of previously covered material.

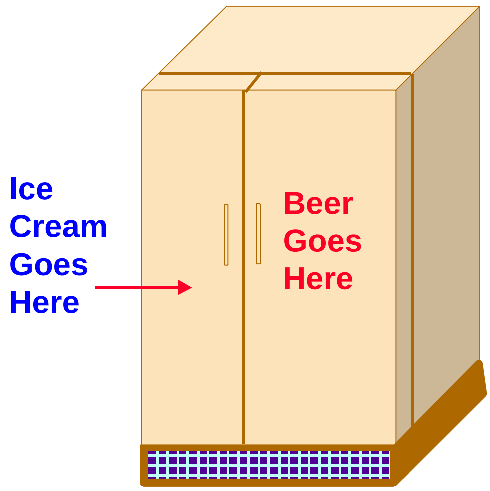
This “building block” technique should allow students to quickly scan the material for understanding, begin more intense use of the material where understanding is known to be lacking, or refer to earlier content to improve understanding of more familiar topics. Further assistance is available by contacting Heatcraft Training Department in Stone Mountain or your local Heatcraft sales representative.

Course objectives are to broaden useful knowledge of commercial refrigeration principles to improve efficiency on the job, allow for more flexibility in job duties, and increase the value of the student to their company and themselves. This manual should provide exposure to new resources and reinforce doctrines or beliefs, which the student may have already adopted.

Simple terms and language will be used throughout the manual to assure that the student clearly comprehends the material. As the student progresses through the manual, more complex definitions and principles will be presented in the simplest terms possible. Our aim is to transfer information to the user in a manner easily understood.

“When promulgating your esoteric cogitations or articulating your superficial sentimentalities and amicable philosophical and psychological observations, beware of platitudinous ponderosity. Let your verbal evaporations and lucidity, intelligibility and veracious vivacity without rodomontade or thespian bombast. Sedulously avoid all polysyllabic profundity, pompous propensity and sophomoric vacuity.” --- ***translation***: Don’t use big words or confusing terms!

BASIC Principles



Most of us have some ideas concerning the purpose of refrigeration and what refrigeration does. The illustration above is a consumer's understanding of refrigeration. Your customers may not need to go beyond this simple understanding of refrigeration. However, they may expect you to have a much greater 'in-depth' understanding of refrigeration to help them solve their cooling needs.

To be able to provide your customers with cooling solutions, you will need to have a firm grasp of the fundamental principles of basic refrigeration. This manual will help guide you through your quest to improve your knowledge of commercial refrigeration.

What is refrigeration?

The basic purpose of refrigeration is to **remove heat from an area where it is not wanted.** Your customers may need refrigeration to cool something that is a source of revenue for them. Normally this something is a perishable product or a process to prepare a product to be sold. They are only concerned with removing the heat from their sellable product and will rely on you to satisfy this cooling need.

In practice, the refrigeration process must **transfer heat from one body to another body**. Usually, the heat is simply dumped into the outdoor air or down the drain where it is not objectionable. Heat reclaim, heat recovery or energy conservation occurs when the heat is sent to an area where it is needed or desired.

Since refrigeration deals completely with the transfer of heat, to better understand how the refrigeration process works, it is necessary to first understand the nature of HEAT. Then we can control the transfer and removal of heat to reduce and maintain the temperature of a space or material below its natural surrounding temperature.

What is heat?

Heat is a form of **energy** like electricity. It comes to us from the sun and is present in every body on the earth. Like all other energy forms, the laws of physics govern it. Thermodynamics is the field of science that studies and deals with the mechanical action of heat. Simply stated, heat is work, and work is heat.

From the **first law** of thermodynamics we learn that **heat cannot be created or destroyed**. Heat can be converted from one energy form to another and is never content to remain stationary or static. It is known as the energy in transfer and never stands still and is always on the move.

All things above absolute zero (-459°F or -273°C) contain heat. Absolute zero is the temperature at which all atoms are at their slowest oscillation and is the coldest any material can be. Scientists have not been able to create this condition in laboratories or identify where it exists in the universe.

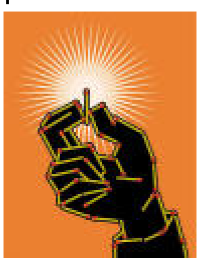
BASIC Principles

How is heat measured?

As a form of energy, heat is intangible and cannot to be measured directly. It can be measured only by measuring the effect it has on a material, such as a change in temperature, state, size, color, etc. This measurement is sometimes referred to as work, heat content or quantity of heat.

The **total heat content** of an object is measured in BTUs or calories based on these definitions:

- **BTU** (British Thermal Unit) is the amount of heat required to change 1 pound of water by 1°F at 1 atmosphere.



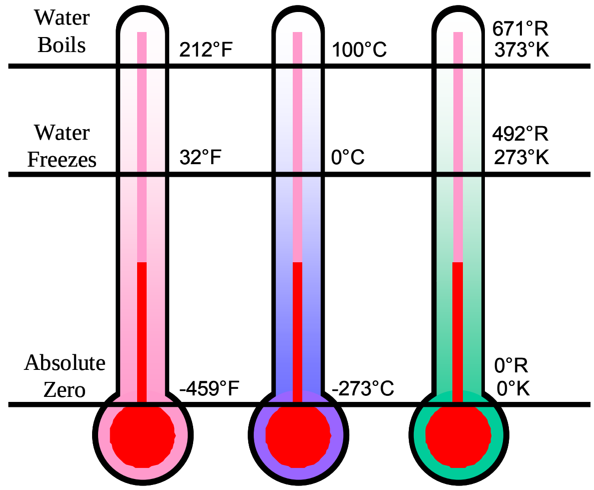
Lighting a kitchen match is equivalent to releasing 1 BTU of energy.

- **Calorie** is the amount of heat required to change 1 gram of water 1°C at 1 atmosphere.

The heat content of an object does not determine its temperature.

Temperature is a property of matter that indicates the **concentration** or **intensity** of heat in a material. Higher intensities of heat have the atoms oscillating quickly, and the material is considered hot or warm. Lower intensities of heat have atoms oscillating slower with the material considered cold or cool.

Cold is simply the absence of heat. Removing heat from a material makes it cooler or colder. An instrument used to measure temperature is a thermometer, which has a scale to indicate intensity.



Temperature scales are based on effects of heat on water with references to boiling and freezing points of water. One of two basic scales is normally used.

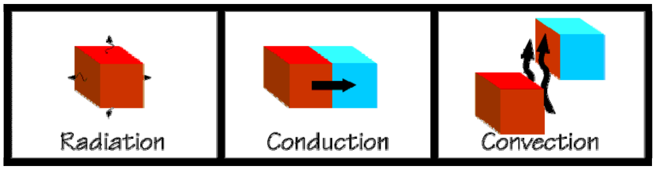
The **Fahrenheit** temperature scale has water boiling at 212° and freezing at 32° with absolute zero at –459°. The **Celsius** temperature scale has water boiling at 100° and freezing at 0° with absolute zero at –273°.

Scientists and engineers use the **Kelvin** and **Rankin** scales with 0° reference point at absolute zero. Kelvin scales uses Celsius increments, and Rankin uses Fahrenheit increments.

How heat flows

The **second law** of thermodynamics states that heat always **moves from the warmer body to the colder** object. Heat cannot move from the colder to the warmer object. There must be a temperature difference for heat to flow from one material to another. Like water, it will always seek its own level.

BASIC Principles



There are three ways heat flows, passes, moves or transfers between bodies:

- **Conduction** – heat passes by direct contact between the bodies, from molecule to molecule.
- **Convection** – heat flows through available medias (such as fluids or gases), by riding piggyback on the moving molecule between the bodies.
- **Radiation** – heat moves on waves of energy carried by photons of light in the infrared and visible portions of the electromagnetic spectrum and does not rely on molecules.

Factors of heat flow

The speed or rate of heat transfer between bodies is influenced by several factors.

Temperature Difference (TD) – One of the most prominent of these factors is TD or temperature difference. If the TD between objects is great, heat will move quickly from the warmer object to the cooler one, and if the TD is small, heat will flow slowly. Without a temperature difference, no heat transfers. Example: Turn system thermostat down to cool off people or products faster.

Surface Area – The amount of surface affects rate of transfer…more surface exposure allows from faster heat flow. Example: A drink cools quicker with crushed or shaved ice than larger ice cubes. Consider a 100-pound ball of meat vs. (400) ¼ pound patties…which one cools down faster in the same room conditions?

Type of Material – The material separating the bodies through which the heat must pass can either promote or retard the speed of heat movement. Conductors are a type of material, which will let heat pass through them easily and quickly. Insulators, however, will hinder or decrease the flow of heat through them. Example: Aluminum fins are used on cooling coils as conductor instead of plastic fins…insulation in walls to keep heat out of coolers and freezers.

Exercise:
Place one of your hands on a table or desk near you. It should feel cool to your touch. This is because the surface temperature of your hand is warmer than the table or desk. Keep it there for a minute. The heat from your hand should be flowing into the table or desk raising its temperature and lowering your hand's temperature. Now place your hands together. The one that was on the table or desk should feel cool to your other hand. Heat transfer has taken place through conduction.

How heat affects change of state

Most substances can exist in a **solid**, **liquid** or **gaseous** (vapor) physical state. They can also change from one state to another through heating or cooling.

The physical state change of a material from liquid to vapor is called **evaporation** (or boiling.) The material changes from a liquid to a vapor as it absorbs heat beyond its boiling point, but the temperature stays constant. A great amount of heat is needed to release the molecular bonds or attraction of the liquid.

BASIC Principles

Changing state in the opposite direction from vapor to liquid is called **condensation**. As the vapor rejects heat below its boiling point, it changes into a liquid. The heat it loses to change state is just as great.

Fusion occurs when a material rejects heat below its melting/fusion point, as it changes from liquid to solid state. The reciprocal change from solid to liquid form, or **melting**, is a result of absorbing heat beyond its melting point. The same amount of heat is rejected or absorbed to cause the change of physical state for fusion or melting.

Sublimation occurs when a material changes from solid to vapor without turning to a liquid. An example of this is dry ice.

Pressure/Temperature Relationships

The boiling and melting points at which materials change physical state are influenced by the pressures exerted on them. For any one substance, its boiling point temperature is the same and remains constant, under a fixed pressure.

Example: Water boils at 212°F at sea level or 1 atmosphere where the weight of the atmosphere above the earth is exerting 14.7 pounds per square inch. But at higher altitudes, there are fewer atmospheres and less pressure being exerted, and water will boil at a lower temperature because lower surface tension will allow the molecules to escape at a lower velocity.

As pressure increases, the saturation point increases changing the boiling and condensing temperatures, and visa versa, as the pressure decreases so does the saturation point…less vapor/surface tension on molecules to maintain bond/attraction.

Example: ***cooking beans on Pike's Peak***

- Beans cook at 203°F(95°C)
- Water boils at 186°F(85.6°C) on Pike's Peak (14,100 ft above sea level)

Placing the beans in a pot of water over the camp fire or stove will result in the water being boiled off before the beans are cooked, and the beans will be burned. A pressure cooker must be used to raise the pressure exerted on the water to allow water to boil above bean's cooking temperature for the beans to cook.

There is also a relationship between temperature and pressure of a material inside a sealed pressure vessel. If there is vapor and liquid both present, the pressure will always relate to the same temperature for that material. Pressure-temperature tables and charts are available for most gaseous refrigerants used in commercial refrigeration systems.

Latent Heat and Sensible Heat

There are two types of heat categorized by the effect heat has on a material to either change its temperature or change its physical state.

Sensible Heat – indicates heat absorbed or rejected by a material that accompanies or causes a change in temperature. This change can be detected by the sense of touch and measured with a thermometer.

Example: 10 lbs. of water at 45°F will be heated to 95°F when it absorbs 500 BTU at 1 atmosphere (sea level).

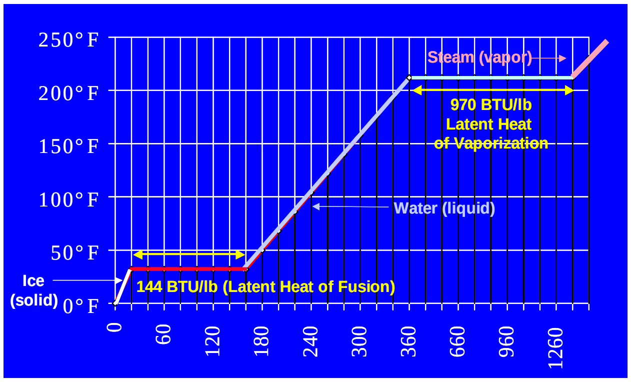
BASIC Principles

Latent Heat – indicates heat absorbed or rejected by a material that accompanies or causes a change of physical state and seems to disappear or hide into the material without having an effect on its temperature. This is also known has 'hidden' heat.

Examples:
LATENT HEAT OF VAPORIZATION is the amount of heat that must be absorbed or rejected at a substance's boiling point to cause a change of state in either direction from liquid to vapor or vapor to liquid.

LATENT HEAT OF FUSION is the amount of heat needed at a substance's melting or fusion point to cause a change of state from either a solid to a liquid or a liquid to a solid.

In both examples, the temperature of the substance would not change during the change of state. If a greater amount of heat than the latent heat is absorbed or rejected, the temperature of the substance would change. The additional amount of heat would be sensible heat.



This graph indicates the saturation/boiling point and freezing point of water at sea level. The appropriate latent heat amounts are also shown here for change of state for the water. Total heat content (enthalpy) is shown along the horizontal axis while temperature is shown on the vertical axis.

Example:

- 10 lbs. of water at 35°F…remove 30 BTU = 32°F water (1BTU / °F / lb.)
- 10 lbs. of water at 32°F…remove 30 BTU = 32°F water (no temperature change)

144 BTU/lb. must be removal from water to fuse it into ice. For 10 lbs. of water to get to 32°F ice 1,440 BTU must be removed (then it will only take ½ BTU / °F / lb. to change ice temperature 1°F).

Leveraging cooling effect by using latent heat properties of substance. It would take 100 pounds of water as a liquid to absorb 3,000 BTU with an increase of 30°F; or about 3 pounds of water changing from liquid to vapor (boiling). Which method would take more energy to pump, store and transport the cooling substance?

Of course, it would be more productive to use the 3 pounds of water method. The horsepower to pump would be less. Tank sizes to store the water would be smaller and so would the line sizes to transport the water.

The trick is to get the water to boil at the right temperature that is compatible with the cooling application. Otherwise, we could only use the latent heat of vaporization at very high temperatures to absorb heat from one substance to boil the water. Using other refrigerants with lower boiling points will also help us use this technique.

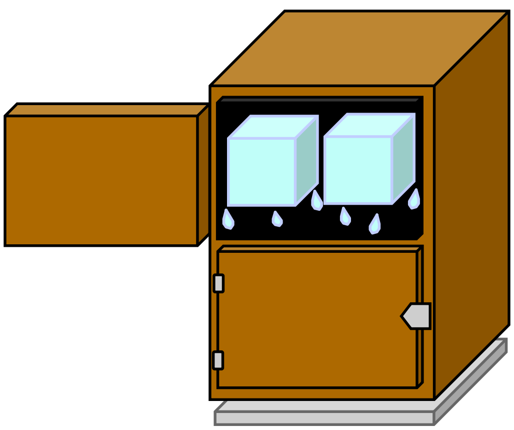
Controlling the temperature at which a specific refrigerant will boil or condense is a matter of controlling its pressure. This is in essence how a refrigeration system works. It controls the pressure exerted on the refrigerant, that determines the boiling and condensing temperature of the refrigerant.

BASIC Principles

How does refrigeration work?

A simple refrigeration process/system must:

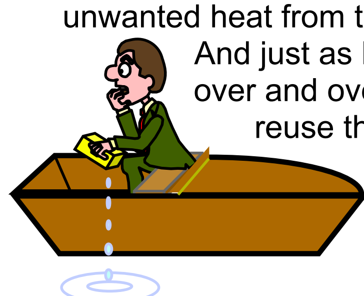
- Attract heat from the warm air surrounding the product
- Absorb heat from the air into cooling media which is cooler than the air
- Use change of state to leverage cooling effect by causing refrigerant to change (from solid to liquid or liquid into vapor)
- Carry heat absorbed into cooling media away from refrigerated area
- Circulate cooled air around product
- Absorb heat from product into cooler air and thereby warming the air
- To reuse cooling media, reverse change of state process (changing it from a liquid to a solid or a vapor to a liquid)
- Cycle continues from start



One of the first examples of refrigeration used ice as the refrigerating media. It was called an **icebox**.

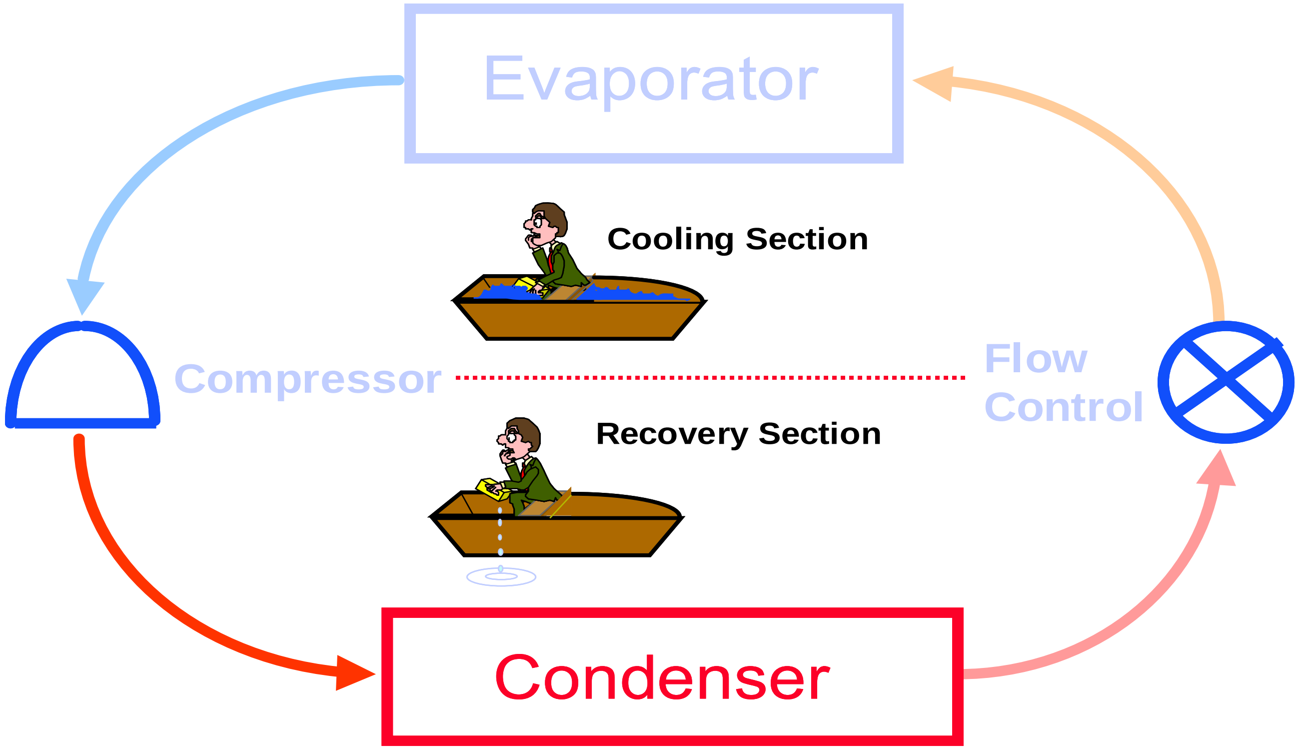
- Ice would be delivered daily and placed in the upper compartment of the icebox to replace melted ice.
- The warm air in the icebox would melt the ice with the ice absorbing its latent heat of fusion (144BTU/lb.).
- Resultant water from the melted ice would drain out of the cabinet.
- Cooled air, which is denser than warmer air, dropped to the bottom of the icebox where perishable products were stored.
- This air then absorbed heat from the warmer product and rose back to ice compartment as it became warmer and its density decreased.
- It was critical to know how much ice would be needed for the entire day as ice was only delivered once per day and cooling depended on it.
- Iceboxes were sized based on how much ice would melt in them within a 24-hour period.
- Larger iceboxes melted many, many pounds of ice and were rated in tons (2000 lbs.) of ice needed.
- One ton of ice melting over 24 hours would absorb 288,000 BTU (2,000 lbs. X 144 BTU/lb lat. Ht. of Fusion).
  Using 32°F water for the cooling instead of ice would have required 144 tons or 288,000 lbs. of water.
- This is equivalent to 12,000 BTU/hr (288,000BTU / 24 hours)
- Today, we still refer to 1 ton of refrigeration as 12,000 BTUH.

Compare refrigeration to a man in a boat with a sponge. He uses the sponge to remove unwanted water from his boat as the refrigeration system uses refrigerant to remove the unwanted heat from the cooled space.



And just as he reuses the sponge over and over again, we can also reuse the refrigerant in a refrigeration system after we remove the heat it has absorbed.

Refrigeration Process



In the **evaporator**, the cool refrigerant absorbs heat from the return-air circulating in the room thus cooling the space. This results in the refrigerant evaporating or boiling from a liquid into a gas or vapor. Normal system design has a minimum of 10°F TD between the refrigerant and the room air temperatures.

Example: 35°F room would have 25°F refrigerant boiling temperature (to take advantage of latent heat of vaporization).

The refrigerant (in vapor form) needs to reject the heat it has absorbed before it can be recycled back into the process.

Next, the evaporated refrigerant is pulled through the suction line and into the **compressor** where its pressure is increased. Because of the pressure-temperature relationship of the refrigerant, its temperature also increases above that of the 95°F outdoor temperature.

Typically, the refrigerant temperature is raised to be 20-25°F greater than the outdoor temperature.

When the high pressure/temperature refrigerant is then circulated inside the **condenser**, it rejects its heat into the outdoor air and is condensed back into a liquid but at a high pressure and a high temperature.

The **flow control device** regulates or meters the flow of refrigerant back into the evaporator to maintain the proper pressure for the refrigerant to boil at 25°F. It also acts as a pressure trap to maintain desired condensing pressure and temperature.

By artificially creating two different pressure conditions, the system controls the boiling and condensing temperatures of the refrigerant. Different refrigerants have different boiling/condensing temperatures and pressure/temperature characteristics.

BASIC Principles

Only a small part of the cooling system is used to actually perform the cooling job or "cooling effect" which is the entire reason for the system. The rest of the system is used to recover the refrigerant from a gas back to a liquid for reuse by the system.

To better understand what happens within the refrigeration process, let's examine what happens to the refrigerant in each phase of the refrigeration process.

Three Conditional States

Refrigerant will exist as a ***liquid*** or a ***vapor*** inside a typical refrigeration system. It will also be in one of three conditional states:

- **Saturation** – liquid and vapor in contact
- **Superheated** – only vapor present
- **Subcooled** – only liquid present

Refrigerant enters the flow control device as a liquid at high pressure and high temperature. As it leaves this device, its pressure and temperature decrease and it immediately begins absorbing heat in the evaporator. This causes the refrigerant to change from a liquid to a vapor. This point is called the saturation or boiling point.

In the **saturation** conditional state, liquid and vapor refrigerant are both present at the same temperature and pressure. Pressure - temperature charts and tables have been developed to indicate the specific saturation temperatures for each particular refrigerant at various pressures.

As the saturated refrigerant absorbs more heat, more of the liquid refrigerant boils and is converted into vapor. This occurs until all of the liquid boils off, and only vapor is left.

If the refrigerant vapor is heated above its saturated temperature and liquid is no longer present, it becomes **superheated** vapor. This is the desired condition of the refrigerant at the outlet of the evaporator.

Although it is superheated in relationship to its saturation point, it is cool to the touch. In our example on the previous page, it will be about 35°F leaving the evaporator with approximately 10°F of superheat.

As the refrigerant is drawn down the suction line toward the compressor, it absorbs more heat and loses some pressure to become even more superheated. At the inlet to the compressor, it may be another 10°F higher.

NO LIQUID REFRIGERANT should be allowed to enter the compressor. We recommend that the refrigerant be a minimum of **20-30°F** superheated at the compressor inlet for proper compressor protection against liquid refrigerant.

Through the compressor, the refrigerant absorbs more heat and increases in pressure. When it leaves the compressor, its superheat has increased and is at a high temperature and pressure. Typically, it can be 225°F leaving the compressor.

Before superheated vapor can be condensed, it must be **de-superheated** at the beginning of the condenser. It must be first cooled to its saturation point where it will begin to condense into a liquid.

As more heat is removed, more of the vapor is condensed until only liquid is left. When the liquid refrigerant is cooled below its saturation temperature, it is **subcooled**. Pressure losses in the liquid line could cause the refrigerant to reach saturation and "flash" unless it has some subcooling.

BASIC Principles

In summary, we expect the refrigerant to be in the following physical states for these specified phases of the refrigeration cycle:

Saturated Refrigerant

– both liquid and vapor are present and in direct contact with each other
– temperature and pressure are linked together corresponding to values of the refrigerant specific P/T table or chart

°F	*R-12*	*R-22*	*R-502*	*R-404A*
-40	***11"***	**0.5**	**4.1**	**4.5**
-20	**0.6**	**10.1**	**15.3**	**16**
0	**9.2**	**24**	**31.1**	**33**
20	**21**	**43**	**52.5**	**56**
40	**37**	**68.5**	**80.5**	**85**
60	**57.7**	**101.6**	**116.4**	**126**
80	**84.2**	**143.6**	**161.2**	**175**
100	**117.2**	**195.9**	**216.2**	**237**
120	**157.7**	**259.9**	**282.7**	**312.5**
140	**206.6**	**337.3**	**262.6**	

where:

– in the ***evaporator*** and ***condenser*** coils where refrigerant is changing state
– in the ***receiver*** where liquid and vapor are both present

Superheated Refrigerant

– only vapor refrigerant is present
– temperature and pressure link is lost and actual temperature will be <u>above</u> P/T chart or table values **where:**
– near the outlet of the ***evaporator*** coil, through the ***suction line***, through the ***compressor*** , through first part of ***condenser*** coil

Subcooled Refrigerant

– only liquid refrigerant is present
– temperature and pressure link is lost and actual temperature will be <u>below</u> P/T chart or table values

where:

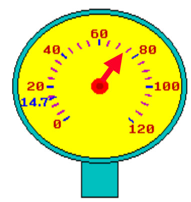
– near the outlet of the ***condenser*** coil; through the ***liquid line***; through the ***flow control device***; to the ***evaporator*** inlet

How can we determine what physical state the refrigerant is in and to what degree?

You must take pressure and temperature measurements and compare to P/T chart or table (a.k.a. saturation chart/table).

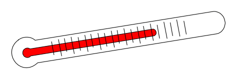
Measuring Physical State of Refrigerant:

1. Take pressure reading with accurate gauge at the system location you need to evaluate



2. From P/T chart or table, determine the *saturation* temperature value for the pressure measured in previous step

3. Take temperature reading with reliable instrument at the same system location



4. Compare actual temperature reading with the *saturation* temperature value from step #2
    a. If the actual temperature is the same as the *saturation* value, the refrigerant is **saturated**
    b. If the actual temperature is <u>higher</u> than the *saturation* value, the refrigerant is **superheated** by the difference in temperatures
    c. If the actual temperature is <u>lower</u> than the *saturation* value, the refrigerant is **subcooled** by the difference in temperatures

Caution: be very careful when working with negative numbers to calculate their differences.

Saturated Temperature Table @ Sea Level

PSIG	12	22	124	134A	502	507	717	404A	409A
5*	-29	-48	3	-22	-57	-59	-34	-57	-22
4*	-28	-47	4	-21	-55	-57	-33	-56	-20
3*	-26	-45	6	-19	-54	-56	-32	-54	-19
2*	-25	-44	7	-18	-52	-55	-30	-53	-17
1*	-23	-43	9	-16	-51	-53	-29	-52	-16
0	-22	-41	10	-15	-50	-52	-28	-51	-15
1	-19	-39	13	-12	-47	-50	-28	-48	-12
2	-16	-37	16	-10	-45	-47	-23	-46	-9
3	-14	-34	18	-8	-42	-45	-21	-43	-7
4	-11	-32	21	-5	-40	-43	-19	-41	-5
5	-9	-30	23	-3	-38	-41	-17	-39	-2
6	-7	-28	26	-1	-36	-39	-15	-37	0
7	-4	-26	28	1	-34	-37	-13	-35	2
8	-2	-24	30	3	-32	-35	-12	-33	4
9	0	-22	32	5	-30	-34	-10	-32	6
10	2	-20	34	7	-29	-32	-8	-30	8
11	4	-19	36	8	-27	-30	-7	-28	9
12	5	-17	38	10	-25	-29	-5	-27	11
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17	14	-9	46	18	-18	-21	2	-19	19
18	15	-8	48	19	-16	-20	3	-18	20
19	17	-7	49	21	-15	-18	4	-16	22
20	18	-5	51	22	-13	-17	6	-15	23
21	20	-4	52	24	-12	-16	7	-14	25
22	21	-3	54	25	-11	-15	8	-12	26
23	23	-1	55	26	-9	-13	9	-11	27
24	24	0	57	27	-8	-12	11	-10	29
25	25	1	58	29	-7	-11	12	-9	30
26	27	2	59	30	-6	-10	13	-8	31
27	28	4	61	31	-5	-9	14	-6	32
28	29	5	62	32	-3	-8	15	-5	34
29	31	6	63	33	-2	-6	16	-4	35
30	32	7	65	35	-1	-5	17	-3	36
32	34	9	67	37	1	-3	19	-1	38
34	37	11	69	39	3	-1	20	1	40
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38	41	15	74	43	7	3	24	5	45 30
40	43	17	76	45	9	5	26	7	47 32
42	45	19	78	47	11	6	28	8	48 34
44	47	21	80	49	13	8	29	10	50 36
46	49	23	82	51	15	10	31	12	38
48	51	24	84	52	16	12	32	14	39
50	53	26	86	54	18	13	34	16	41

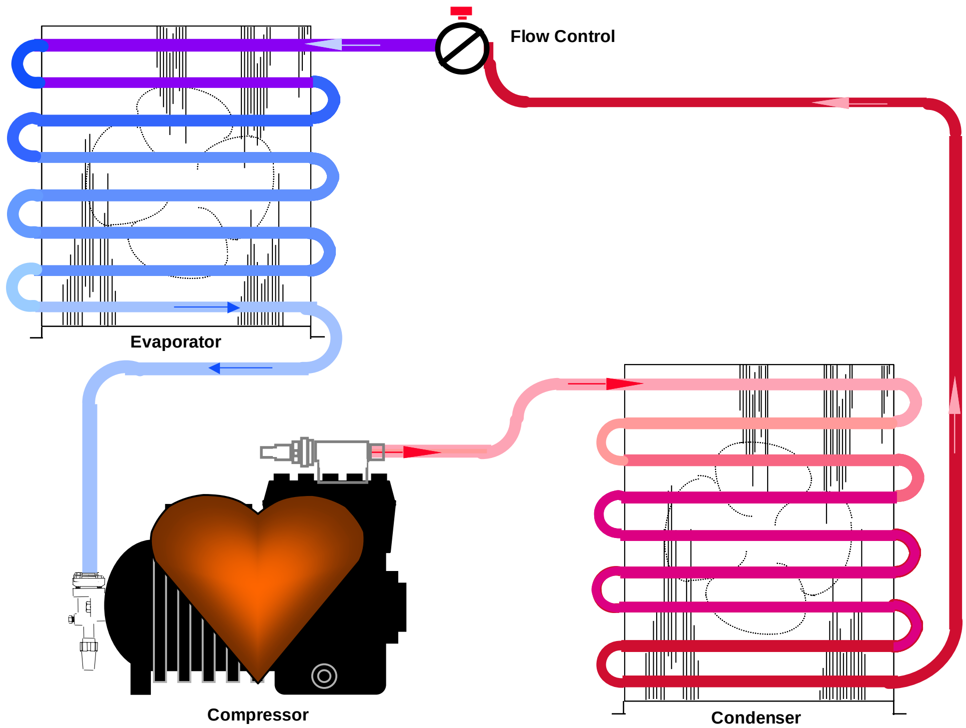
PSIG = pounds per square inch, gauge *(gauge is adjusted to 0 at atmospheric conditions)*

Saturated Temperature Table @ Sea Level

PSIG	12	22	124	134A	502	507	717	404A	409A
52	55	28	88	56	20	15	35	17	43
54	57	29	90	57	21	16	37	19	45
56	58	31	91	59	23	18	38	20	46
58	60	32	93	60	24	19	40	22	48
60	62	34	95	62	26	21	41	23	50
64	65	37	98	65	29	24	44	26	53
68	68	40	101	68	32	27	46	29	56
72	71	42	104	71	34	29	49	32 31	58
76	74	45	107	73	37	32	51	34 33	61
80	77	48	110	76	40	34	53	37 36	64
85	81	51	114	79	43	37	56	40 39	67
90	84	54	117	82	46	40	58	42 42	70
95	87	56	120	85	49	43	61	45 44	73
100	90	59	123	88	51	46	63	48 47	76
105	93	62	126	90	54	48	66	50	79
110	96	64	129	93	57	51	68	52	82
115	99	67	132	96	59	53	70	55	84
120	102	69	135	98	62	56	73	57	87
125	104	72	138	100	64	58	75	59	89
130	107	74	140	103	67	60	77	62	92
135	109	76	143	105	69	62	79	64	94
140	112	78	145	107	71	64	81	66	96
145	114	81	148	109	73	67	82	68	99
150	117	83	150	112	75	69	84	70	101
155	119	85	152	114	77	71	86	72	103
160	121	87	154	116	80	73	88	74	105
165	123	89	157	118	82	74	90	76	107
170	126	91	159	120	83	76	91	78	109
175	128	92	161	122	85	78	93	80	111
180	130	94	163	123	87	80	95	82	113
185	132	96	165	125	89	82	96	83	115
190	134	98	167	127	91	83	98	85	117
195	136	100	169	129	93	85	99	87	119
200	138	101	171	131	95	87	101	88	121
205	140	103	173	132	96	88	102	90	123
210	142	105	175	134	98	90	104	92	124
220	145	108	178	137	101	93	107	95	128
230	149	111	182	140	105	96	109	98	131
240	152	114	185	143	108	99	112	101	134
250	156	117	188	146	111	102	115	104	137
260	159	120	192	149	114	105	117	107	141
275	163	124	196	153	118	109	121	111	145
290	168	128	201	157	122	112	124	115	149
305	172	132	205	161	126	116	128	118	153
320	177	136	209	165	130	120	131	122	157
335	181	139	213	169	133	123	134	126	161
350	185	143	217	172	137	126	137	129	165

Refrigeration Cycle

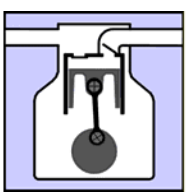
This diagram indicates the four basic components needed for a refrigeration system. There are many different types of these components. Each variation has certain strengths and weaknesses, and which one is to be used depends on the particular design criteria and specific application requirements.



Let's take a closer look at each of the four basic components of a simple refrigeration system. A few of the most popular types are listed below.

Compressor – Heart of the System

Reciprocating – This is the most widely used of all types of compressors. It uses a piston that moves up and down inside a hollow cylinder to compress the refrigerant (much like a typical car engine works).



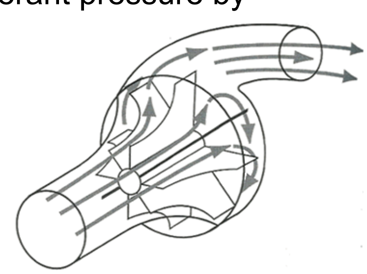
There are two types valve configurations of reciprocating compressors:

- Reed – with intake and exhaust tensioned, straight steel reeds
- Discus – with intake tensioned, circular steel reed and a spring retained solid discharge valve

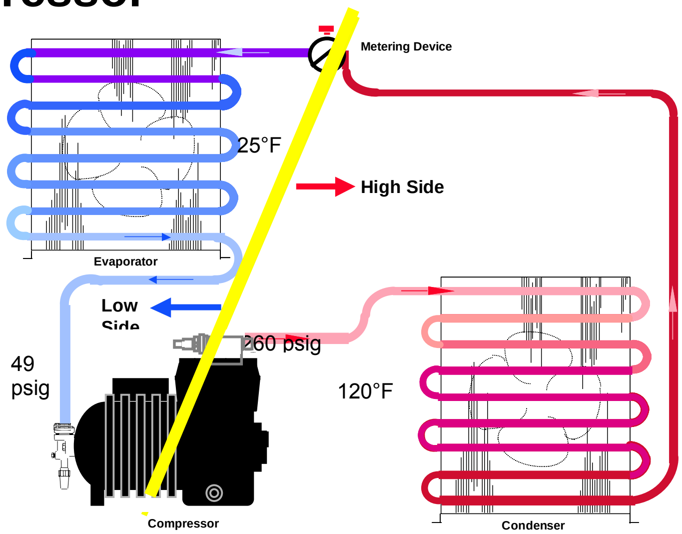
These compressors can also be of hermetic (or welded) design or semi-hermetic (or bolted-construction) design. The latter version can also have either open or direct drive motor configurations and gas or air cooled motor designs.

Scroll – This type compresses the refrigerant using orbiting and fixed scrolls, which squeeze the gas into 6 chambers, which decrease in volume as the scroll rotates. The normal configuration uses a hermetic design.

Centrifugal – The centrifugal compressor increases the refrigerant pressure by throwing it at high velocity (like an ordinary house fan throws air) using a rotating impeller inside a stationary housing.



Compressor



Regardless its type, all compressors must perform the following three jobs:

- Create the required pressure difference
- Pump sufficient volume of refrigerant
- Accommodate the refrigerant used

Create the required pressure difference

The refrigeration system maintains two separate pressurized sections. In one section the pressure is kept low enough for the refrigerant to boil in the evaporator and absorb heat from the air-cooling the room at a temperature desired for this particular application. This low-pressure section of the system is called the “low side” for its low temperature and low-pressure refrigerant.

In the other section, pressure is kept high enough for the refrigerant to condense back into a liquid in the condenser, that is using higher temperature air or water to absorb the heat from the refrigerant. This section is known as the “high side” of the system for it higher temperature and pressure.

Each section’s desired/design pressure is dependent upon the required operating temperatures in the evaporator and in the condenser and also on the refrigerant used in the system. The compressor creates the pressure different between these two sections by its suction action reducing the evaporator pressure and it’s pressurizing the discharge gas entering the condenser.

Using our previous example: +35°F room temperature with desired refrigerant boiling at +25°F would require 49 psig pressure in the evaporator for R-22 refrigerant. Using +95°F outdoor ambient air temperature and 25°F design TD, an air-cooled condenser pressure would need to be 260 psig for 120°F condensing temperature with R-22.

Compression ratio indicates how much pressure change the compressor needs to create in a system. This is found by dividing its absolute discharge pressure by its absolute suction pressure. Converting psig (pounds per square inch, gauge) to psia (pounds per square inch, absolute) is just adding local atmospheric pressure to psig. At sea level you would add 14.7 psi to psig to covert psig to psia.

For our example at sea level: absolute discharge pressure = 260 psig +14.7 psi or 275 psia, and absolute suction pressure = 49 psig +14.7psi or 64 psia. Compression ratio would be ≈ **4.3** (275 psia ÷ 64 psia).

Higher compression ratios are harder on compressors. The lower the temperature, the higher the compression ratios required resulting in tougher and less efficient compressor operation. Some designers set a ratio limit of 10 to 1 or even 7 to 1 for better reliability.

There are compressors specially designed to withstand high-ratio operation. They may have extra piston rings, tighter tolerances and more elaborate cooling systems to compensate for the more demanding conditions associated with higher ratios.

Compressor

Pump sufficient volume of refrigerant

The amount of refrigerant volume needed for a particular system depends on its operating temperature. Lower operating temperatures require more refrigerant gas volume to be in circulation to do the job.

Therefore, larger compressor pumping capacities are needed for the lower temperature applications. A compressor running at a constant, fixed RPM can pump so much refrigerant. This amount may be sufficient for one temperature but not for another, lower temperature.

For a 1 ton (12,000BTUH) application, a specific compressor may be able to cool a given load at +40°F suction temperature. The same compressor may only be able to handle a load of 6,000BTUH or ½ ton at 0°F suction temperature.

It is also important to understand that the load on the motor driving the compressor changes with temperature. Since the compressors running at higher suction temperature have higher capacities, they require larger drive motors.

If a low temperature compressor were applied on a high temperature application, the compressor motor could be greatly "overloaded". **Horsepower and tonnage are not equal or synonymous.**

Accommodate the refrigerant used

Compressors must be compatible with the refrigerant being used in the system. The refrigerant effects the compressor design as it pertains to the size of valve ports, the strength of valve springs, or the design of the cooling system.

Construction materials must also be considered to accommodate the refrigerant. Some refrigerants or their associated lubricant oils could attack certain materials used in some compressor construction. New materials, which are more compatible, need to be used. Actual thickness of materials or different alloys may need to be considered for higher-pressure refrigerants.

Compressors are often classified or sized by their operating range, by refrigerant, and by capacity. Typical suction temperature ranges are classified and indicated as:

- **H** = high
- **M** or **C** = medium or commercial
- **L** = low
- **XL** = extra or ultra low

Compressor Control Devices

There are many safety control devices, which are used to protect the compressors. Many of these are optional or special.

- Low Pressure Control (LPS) – shuts off the compressor, if its inlet pressure falls below a set point value
- High Pressure Control (HPS) – shuts off the compressor, if its outlet pressure goes above a set point value
- Internal Overloads – shuts off the compressor, if internal motor windings get too hot
- Oil Pressure Control – shuts off, if the oil pressure falls below a set point value
- Discharge Line Thermostat – shuts off, if discharge line temperature gets too high
- Compressor Module – shuts off, if amps or temperatures exceed proper limits
- Phase Loss Monitor – shuts off, if power phase is incorrect or voltage is too low
- Demand Cooling Module – shuts off, if discharge gas temperature gets too high

Flow Control

All flow control devices must regulate the flow of refrigerant to do the following jobs:

- Act as pressure trap for the high side
- Regulate desired boiling point pressure
- Maintain proper superheat for protection

Act as pressure trap against high side

In order for the refrigeration system to function, it must create two separate sections with different pressures to allow the refrigerant to boil and to condense at the desired temperatures/pressures. The flow control device acts as a pressure trap to help maintain the high side at the correct pressure. Without this device in place, the compressor alone would not be able to maintain the pressure differences required.

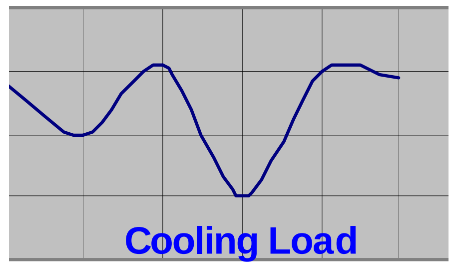
Regulate desired boiling point pressure

When the high-pressure liquid refrigerant passes through the flow control device, it is immediately exposed to lower pressures and tremendous temperature differences. Thus, some of the refrigerant instantly boils, changing to a vapor, and expands. This is why many of these flow control devices are called “expansion” valves.

As the refrigerant passes through the evaporator coil it absorbs more and more heat causing more liquid to boil into vapor. So long as there is liquid present, the heat being absorbed will not raise the refrigerant temperature but will instead be used to continue vaporizing the liquid refrigerant.

When the last trace of liquid is boiled off, any additional heat absorbed by the refrigerant will increase its temperature above its saturated temperature. It will then become a superheated refrigerant vapor.

The rate at which the refrigerant boils will depend upon the amount and degree of heat load present in the evaporator and the amount of refrigerant available. To properly maintain the pressure for the desired boil point, the flow control device must regulate the flow for varying load conditions and to constantly readjust its position.



If the flow control device “over-feeds” the amount of refrigerant needed for the load, some of the liquid refrigerant may not boil off. This liquid refrigerant could pass through the evaporator, into the suction line, and be drawn into the compressor where it might cause severe damage.

On the other hand, the “under-feeding” of refrigerant could result in the refrigerant boiling off into a vapor too soon in the evaporator. The heat transfer efficiency of the evaporator and system performance would suffer under this condition.

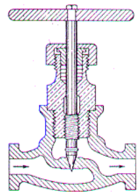
Maintain proper superheat for protection

Proper feeding of refrigerant should allow fully active boiling of refrigerant through almost the entire length of the evaporator for optimum heat transfer performance.

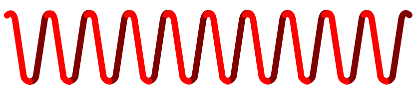
However, no liquid refrigerant should be permitted to leave the evaporator and enter the suction line. Only superheated vapor should be present at the evaporator outlet to help prevent liquid refrigerant from ever reaching the compressor.

Flow Control

Hand Valve – This simple, low cost form of flow control is seldom used because it must be constantly adjusted to compensate for changing load conditions. It may be used in large systems as a bypass valve around automatic controls in case of failure or during repairs.

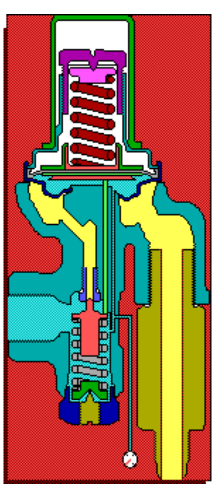


Capillary Tube – This method is very elementary and uses a length of small diameter tubing to control flow by imposing a restriction or pressure drop. It is used on small unitary equipment such as window air conditioners, domestic refrigerators and commercial refrigeration cases (reach-ins).



Major advantage is that it allows system pressures to equalize during the off cycle. This allows for use of low starting torque motors on compressors.

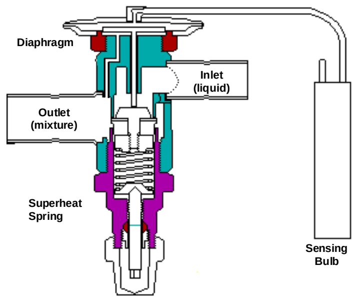
Disadvantage is critical refrigerant system charge to prevent compressor overloading and possible liquid flood-back to the compressor during the off cycle. Also, it is not much better than the hand valve in reacting to varying load conditions.

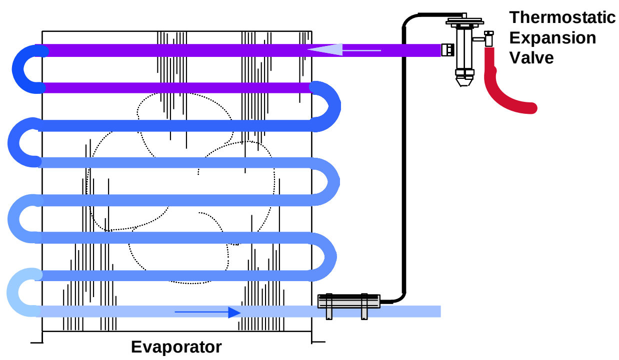


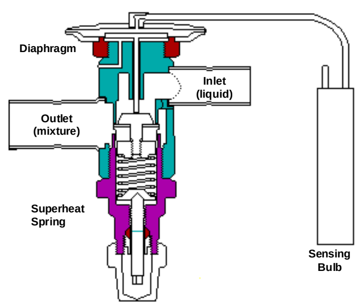
Automatic Expansion Valve – It is a pressure-reducing device actuated to keep evaporator pressure constant and does fluctuate somewhat to match varying load conditions. Used infrequently as it tends to starve the system during heavy loads and floods the system during light loads.

Thermostatic Expansion Valve (TEV) – It senses the conditions of the refrigerant inside the evaporator and automatically adjusts the flow to maintain a preset value for superheat at the evaporator outlet.

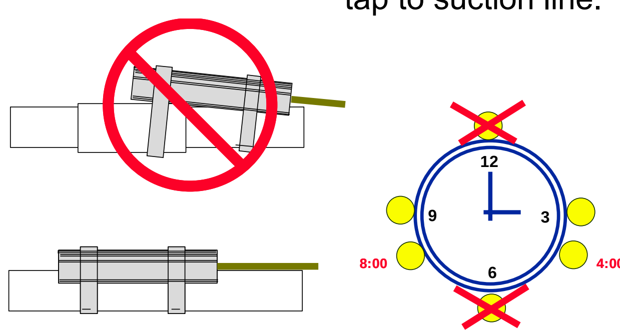
Internal equalized: senses refrigerant pressure at the TEV and the temperature of refrigerant leaving the evaporator by attaching a sensing bulb to suction line.







External equalized: sense refrigerant pressure and its temperature at the evaporator outlet by attaching a sensing bulb and pressure tap to suction line.



Proper sensing bulb mounting is essential to assure accurate temperature readings for correct and reliable operation of the TEV.

Flow Control

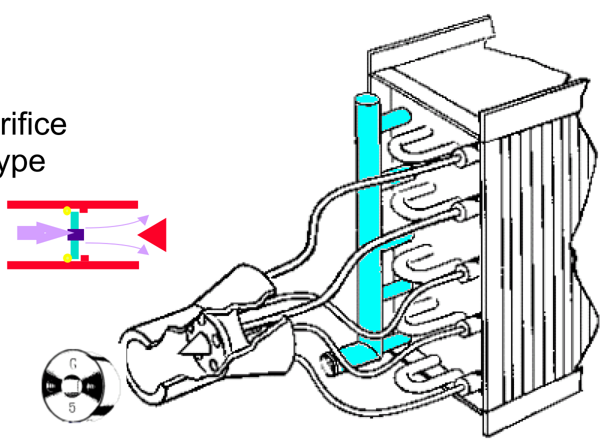
When evaporators are large enough for TEVs, they also have sufficient pressure losses though them to require the use of distributors for proper feeding of their refrigerant circuits. Capillary tubes, automatic expansion valves and internal equalized TEV should not be used on evaporators with multiple refrigeration circuits.

Distributors are designed to evenly feed multiple circuited evaporators. They are not designed to regulate flow of refrigerant as flow control devices perform. There are two basic types of distributors:

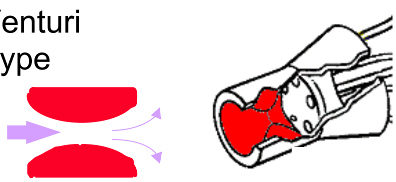
Orifice Type: uses different nozzles sized for the refrigerant, temperatures, and flow of the application. It has the flexibility to be able to change to suite different conditions.

Venturi Type: uses a specially machined housing designed for a specific refrigerant, temperature and flow conditions. It is more efficient than the orifice type, but cannot be easily changed to suit different conditions.

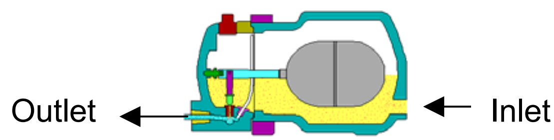
Orifice Type



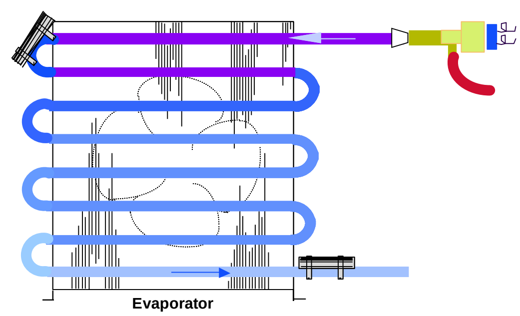
Venturi Type



Float Control – This device is used with some flooded evaporators and has a ball that floats on the refrigerant to indicate the level of refrigerant in the evaporator. If the level gets too high or too low, the float rises or falls and adjusts a valve, which controls the flow of liquid refrigerant. Flooded systems are more efficient than direct expansion. However, they are more complex and susceptible to mechanical failures and leaks with high risk of flooding.



Electric/Electronic – These devices are electrically actuated from a controller with sensors to measure superheat conditions of the refrigerant leaving the evaporator. The electric valve uses a motor to adjust a stem on a seat to regulate flow. The electronic valve regulates flow by opening and closing multiple times and at varying time periods.



There are many advantages to using real logic to control refrigerant flow including better tools to monitor and diagnose system operations. Drawbacks include sensitive components, which may be more delicate than conventional, more system complexity, unfamiliar set up steps for technicians, and different parts to troubleshoot and replace when failures occurs.

Evaporator

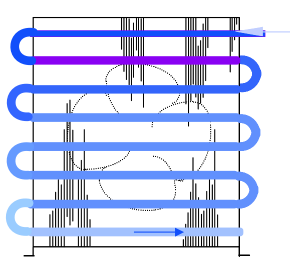
This major component is in the low side of the refrigeration system where the boiling of the refrigerant occurs and produces the cooling effect. There are several types of evaporators or coils in use:

- **Direct Expansion** – Refrigerant is completely boiled off in the evaporator with no liquid refrigerant at the coil outlet. The circuit is said to be "dry" due to lack of refrigerant liquid. This type is efficient, economical and used in all sizes of refrigeration systems.

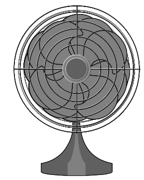
- **Flooded** – Liquid refrigerant fills most of the evaporator coil like a bucket. It is very efficient. Recirc versions of this type overfeed the evaporator with refrigerant and have liquid refrigerant actually leaving the coil. Flooded coils are used in cooling other liquids, such as water or brine and are typically found in larger refrigeration systems.

Evaporator coils utilize tubes to contain the refrigerant with air or fluids being circulated on the outside of the tubes. The tubes have two heat transfer resistant surfaces, internal and external. To overcome these resistances or surface films, various counter measure methods are available.

External "surface film"



Airside surface film is especially difficult to overcome. The nature of air, like most gases, is to be a poor conductor with great resistance to heat flow. Increasing the amount of air surface area by attaching fins or collars to the tubes can compensate for this surface film.

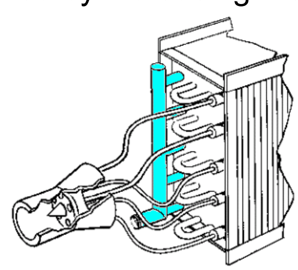


Another technique is to increase the airflow over the coil tubes (and fins) with a fan or blower. This also increases convection currents to improve heat transfer. Caution must be used not to blow too much air over the coil, which could blow condensate off the coil and in the space and onto product.

Increasing the turbulence in the air stream over the coil will also improve its heat flow. This can be accomplished using external fin with different corrugations, edges, lancing, turning vanes, and louvers.

Fluid-side surface film is similar and has its own special challenges according to the type of fluid or solution being used. Basic techniques of increasing turbulence and decreasing pressure drop also apply here.

Internal "surface film"



On the inside of the evaporator, heat transfer can be improved by increasing the wetting of the tube walls with refrigerant. This can be challenging with the constant changing of the refrigerant from liquid to vapor at the tube walls. Multiple refrigerant circuiting is one technique to improve this situation and also impose less work on the compressor through less pressure drop.

Other measures to increase the turbulence of the refrigerant will also increase the wetting effect on the tube walls. These include turbulators (elongated springs inside the tubes), smaller tubing diameters (to increase velocities), and enhanced tube (rifling or grooving of inside surfaces).

Evaporator

All evaporators must meet the following three requirements:

- Sufficient internal volume
- Minimum pressure drop
- Proper surface design

Sufficient internal volume

There must be enough internal volume to accommodate the amount of refrigerant required to meet the cooling demands placed on the system. Based on the refrigerant being used, the temperatures required for the application and the amount of heat load, there is a particular internal volume required for the refrigerant to boil and expand at the required temperature.

If there is not enough internal volume, the heat transfer requirements will not be met and the refrigeration system will fail to do its job. Too much internal volume will require greater refrigerant flow to maintain the proper boiling temperature/pressure and the refrigeration system may “short cycle” due to oversized capacity.

Minimum pressure drop

The refrigerant must be allowed to flow through the evaporator with a minimum amount of pressure drop. For every pound of pressure drop the refrigerant experiences passing through the evaporator, the system compressor has to raise the pressure of the refrigerant to offset for the condenser cycle.

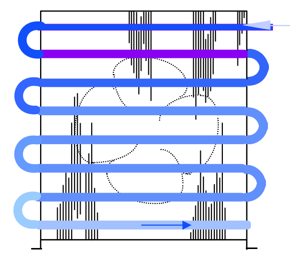
Each refrigerant at a particular temperature and pressure has an optimal allowable pressure drop range. Evaporators must be designed to stay within that allowable range through use of multiple circuiting methods.

Proper surface design

Sufficient surface must be available in the evaporator for heat to pass easily and quickly into the refrigerant inside the tubes. The materials used must be compatible with the application requirements.

If the application is low temperature and frost will build up on the evaporator surface, the fins-per-inch should not high enough to cause “plugging” of the coil with heavy frost. Applications with the evaporator located inside a caustic or acidic environment will require the use of material resistive to the caustic conditions.

Cooling coils



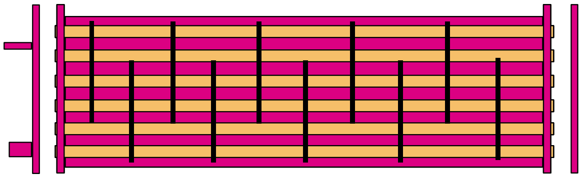
This simple but very popular design is for absorbing heat from the air. It is consists of a bundle of tubes brazed together to form a serpentine circuit or circuits through which refrigerant flows. Air flows over the outside of this coil, which may also have external surface fins to enhance the heat transfer from the air into the tubes.

Some of this style of coil may also have a blower or a fan to force air over the coil. These are sometimes called induce air or induced circulation coils. Convection coils do not use fans but instead rely on natural convection currents for air circulation.

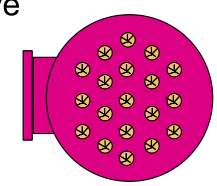
Demands of the application will determine which evaporator style is the most appropriate or proper to get the job done.

Evaporator

Shell and Tube



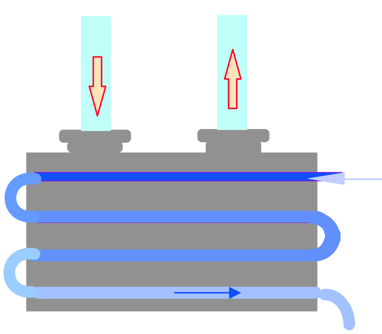
In this design, the bundle of tubes is inside a large pipe and is used to absorb heat from a fluid or solution circulated inside the pipe over the tubes containing the refrigerant. It may also have multiple circuits and use surface baffles and/or tube inserts to improve heat transfer performance.



This coil style is sometimes called a “chiller” or “chiller barrel” because of its particular design characteristics or application. When the solution being cooled is used to cool something else in another heat exchanger, it may also be called the “secondary refrigerant”.

Cooling Plate

There are many other types of evaporator designs or styles such as cooling plates, flat plate heat exchangers, etc. Most of these are used in cooling water, brine or other solutions. Each of these designs also has special methods or techniques to improve or enhance the heat transfer characteristics for their special applications.



Condenser

Condenser Requirements

Condenser designs must overcome the same type of “surface films” as the evaporators. Many of the same methods and techniques apply to the different types or styles of condensers. All condensers must meet the following requirements:

- Sufficient internal volume
- Proper surface design

Sufficient internal volume

It must have enough internal volume to accommodate the amount of refrigerant required to meet the demands placed on the system. Based on the refrigerant being used, the temperatures under which it is subjected and the amount of heat load, there is an appropriate internal volume required for the refrigerant to condense at the desired temperature/pressure for the entire annual system operation.

If there is not enough internal volume, the heat transfer requirements will not be met and the refrigeration system will fail to do its job. Too much internal volume will require greater refrigerant volume to maintain the proper condensing temperature/pressure, which may be more costly and/or exceed other system capacities or criterion.

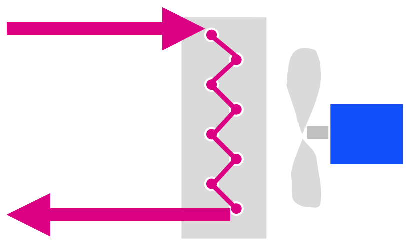
Proper surface design

Sufficient surface must be available for the condenser to reject all of the heat added to the refrigerant in the evaporator and in the compression process. This must also be done at its operating temperatures and pressures. Some applications require wide fin spacing due to natural contaminants.

Condenser

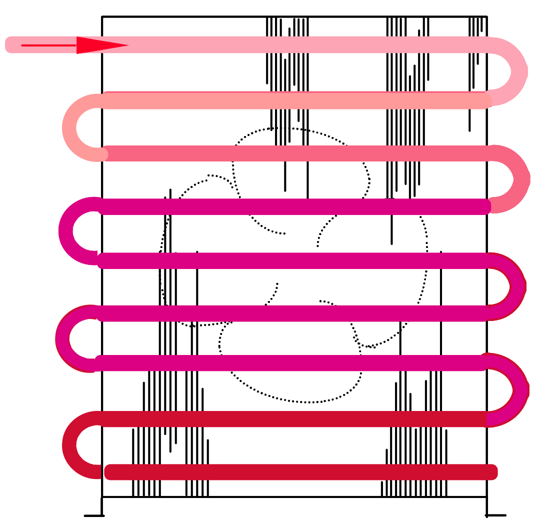
Air-cooled condenser

This design is similar to the cooling coil with many of the same features and is used to reject heat from the refrigerant into air, which is normally outside, outdoor air. It may also have surface fins and a fan or blower to force air over the condenser coil.



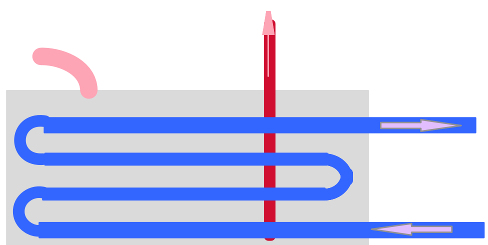
Most have multiple refrigerant circuits to minimize the pressure drop through the condenser coil. It may also have multiple system circuits with more than one system using its surface to reject heat to condense refrigerant.

These condensers must have a condenser surface well maintained to keep it clean to run efficiently. Collection of dirt or grease will block air and heat flow as the "surface films" described in the evaporator section.

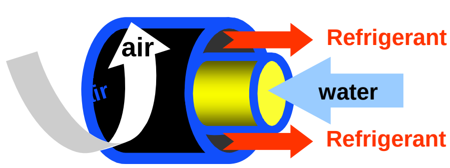


A major disadvantage of the air-cooled condenser is its dependency on air temperature, which tends to fluctuate over time and seasons. This may cause the compressor to work harder during times when the air temperature is higher to raise the condensing pressure to compensate for the reduced cooling capacity of the air.

Water-cooled condenser
Water is used to absorb the heat from the refrigerant for condensation in this design and avoids the problems of air temperature fluctuations. This also permits a lower and more consistent condensing pressure. These condensers can also handle larger loads and are more compact because water can absorb more BTUs than air.

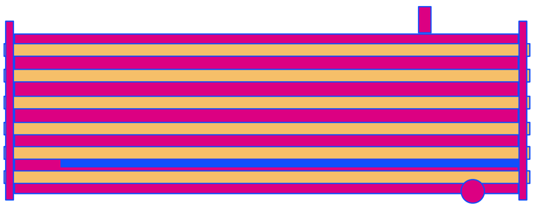


Tube-in-tube or **double pipe condenser** passes the refrigerant through a large outer tube while water passes through a smaller inner tube in the opposite direction. Air passing over the outer tube and the water in the inner tube both will absorb heat from the refrigerant. This design offers a lot of capacity in a very small package.



Condenser

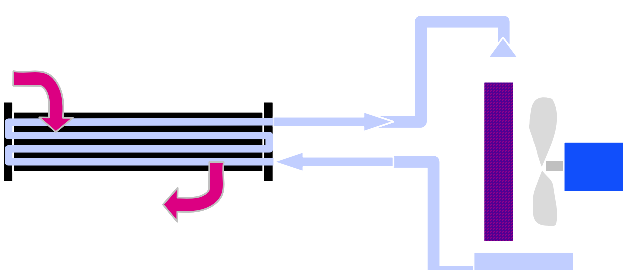
Shell and tube condenser has the hot refrigerant dropping into the top of the shell surrounding the water being circulated in the tubes. The shell acts as the condenser reservoir or receiver for the condensed refrigerant, which is pulled from the bottom as liquid.



Tubes of water-cooled condenser must be periodically cleaned to remove deposits, which settle out of the water and reduce heat transfer thereby reducing capacity.

Water towers allow water from water-cooled condensers to be cooled by the outdoor air and reused. Without the water towers sometimes called "cooling towers", city water would have to be used in the condensers, which is becoming more and more expensive to use.

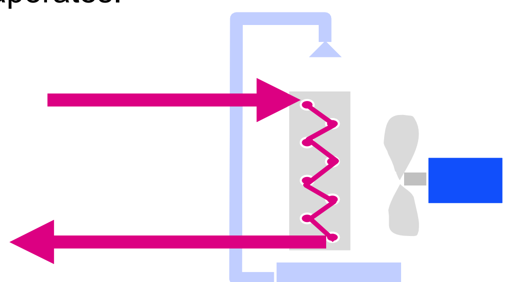
The cooling towers use sensible and latent cooling techniques to cool the water. As the water flows from the top of the tower over a series of baffles, outdoor air is blown across the baffles sensibly cooling the water while a small portion of the water evaporates and provides additional latent cooling as it absorbs it latent heat of vaporization from the water to evaporate.



Evaporative condenser

This style of condenser uses sensible and latent cooling techniques to condense the refrigerant. It is like a water tower and condenser combined.

Refrigerant passes through tubes in a coil with water and air circulating over the outside of the coil. Some of the water evaporates and cools the remaining water, which cools the refrigerant along with the outdoor air. Like a water or cooling tower, water in the sump is pumped to flow over the tubes. Make-up water is also needed to replace the small amount of water that evaporates.



Water treatment and regular maintenance are necessary for all the water-cooled and evaporative condensers styles. Some chemical additives may include inhibitors to lessen the corrosive properties of the fluid solutions.

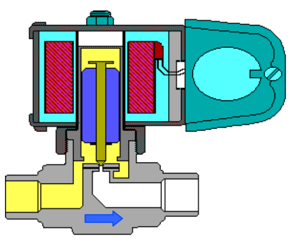
Also, glycol may be needed to prevent freezing during very low ambient conditions. Special precautions may require seasonal operation changes to protect sumps from freezing, such as adding glycol or running them "dry" during freezing conditions.

Accessories & Options

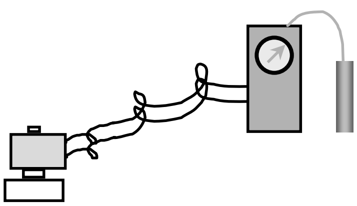
Solenoid Valve

This is an electrically actuated valve in the liquid line, which controls the flow of refrigerant to the flow control device. It is an open or closed valve and does not modulate.

This device has an iron core plunger which seats into the valve orifice and an electrical solenoid coil. It is normally closed when the coil is de-energized, and the forces of gravity and an optional spring seat the plunger.



One of the most important features is the distinctive arrow, which indicates the proper direction of refrigerant flow through the valve. If the flow is reversed, the refrigerant pressure will push up against the plunger preventing the valve from closing.



Normally it is wired in series with the room thermostat. When the room temperature is satisfied, the thermostat contacts open and the solenoid valve loses power and closes, shutting off the flow of refrigerant to the expansion valve. With the flow of refrigerant shut off, the compressor will continue to operate until the pressure falls below the cut-out set point of the low pressure switch/control (LPS).

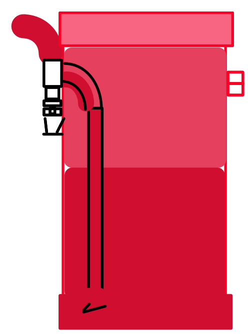
Solenoid valves are available with flare or sweat connections and with optional manual lift stem feature. The manual lift stem allows the valve to be manually opened in an emergency.

The electric or electronic expansion valve closes as secure as a solenoid valve and normally does not need a solenoid valve included with its installation.

Receiver

This is a liquid refrigerant storage tank in the liquid line to contain refrigerant not in use or needed in circulation. The amount of refrigerant needed in circulation may vary as the load conditions fluctuate.

It can also be used to hold the entire system's refrigerant charge during maintenance procedures. A valve at the receiver outlet is needed to pump the entire charge into the receiver and hold it there,



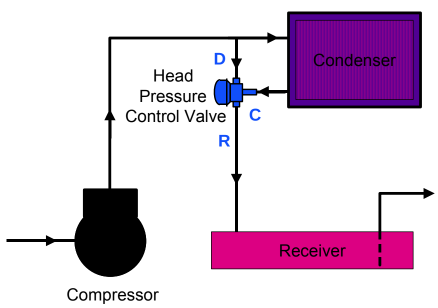
The typical design of the receiver includes a dip tube, which extends to within ½" of the bottom of the receiver to maintain a liquid seal for pulling only liquid into the liquid line when needed. Since both liquid and vapor refrigerant are present, the refrigerant is at saturation in the receiver. Horizontal and vertical versions of the receiver are available.

Accessories & Options

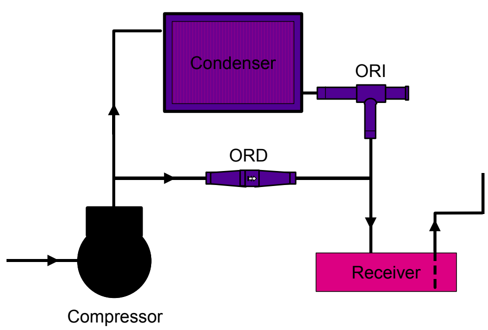
Head Pressure Control Valve

This device is used to create an artificial head pressure when temperatures get too low for the system to operate effectively. Typically, this valve will restrict the flow of refrigerant leaving the condenser when the pressure of that refrigerant falls too low for the flow control device to operate properly. This will cause liquid refrigerant to back up in the condenser reducing its effective surface area for heat transfer resulting in higher condensing temperatures. Liquid refrigerant continues to 'flood' the condenser until adequate condensing pressures are achieved.

The extra refrigerant needed to 'flood' the condenser with liquid refrigerant is stored in the receiver when it is not needed in the condenser. During the flooding of the condenser, a certain amount of compressor discharge gas is bypassed into the liquid line to build up enough pressure for the system to operate under proper pressures.



Some designs use a single device to flood the condenser and bypass discharge gas as shown above. Other designs use two separate valves as shown below.

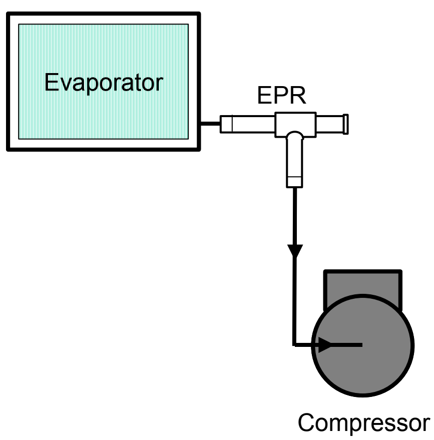


Head pressures can also be controlled for water-cooled condensers using a water flow control valve to regulate flow based on condensing temperature/pressure. For the water-cooled condensers, a receiver to hold extra refrigerant for flooding the condenser will not be needed.

Evaporator Pressure Regulator Valve (EPR)

This is used to prevent the refrigerant pressure inside the evaporator from falling below a desired set point value. It is located in the suction line and modulates from fully closed to fully open in response to inlet pressure, closing on fall in inlet pressure to restrict refrigerant flow, which raise the evaporator pressure.

It can be used to allow multiple evaporators to operate at different temperatures on a single central system such as is used in supermarket applications. Another use for this value is to prevent evaporators being used in medium temperature applications from operating below freezing and frosting.

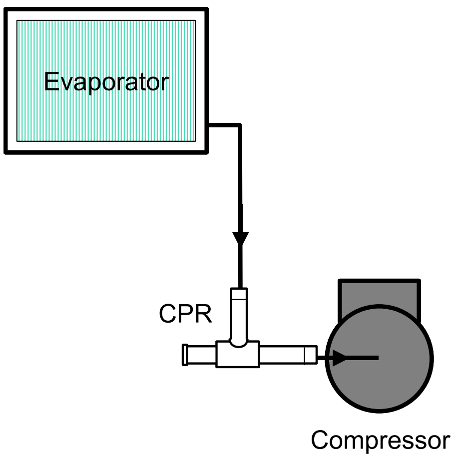


EPR valves are typically located at or near the evaporator outlet.

Accessories & Options

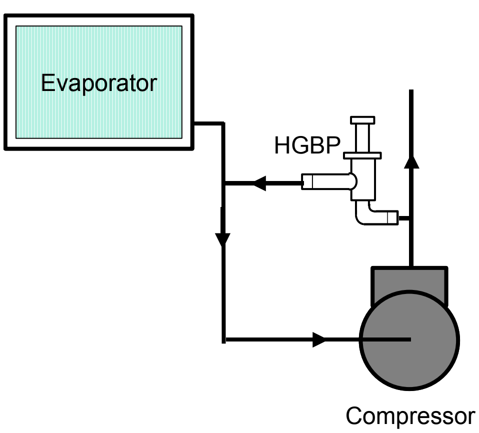
Crankcase Pressure Regulator Valve (CPR) – Holdback Valve

This valve operates similar to an EPR and is used to limit its compressor's refrigerant pressure from rising above a desired set point value. Located in the suction line, it modulates from fully open to fully closed in response to its outlet pressure, closing on rise in outlet pressure to prevent the compressor from overloading.



Hot Gas Bypass Valve

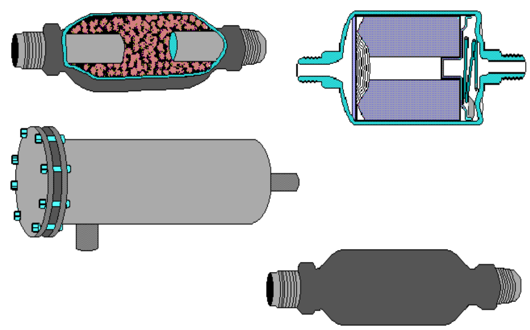
Hot gas bypass valves are located in a bypass line between the suction and the compressor discharge lines and can fully modulate in response to outlet (suction) pressure, opening on fall of downstream pressure. This valve is used to maintain a desired minimum suction pressure during times when the compressor is running at very low load conditions.



Filter-Drier

This device is located in the liquid line and is used to filter out large contaminants and moisture left in the system at the time of installation. If these are not removed or filtered, they can plug small opening in the system (such as TEV or oil "pick-up" in the compressor crankcase or sump) and cause other system inefficiencies.

Filter-driers have a shell filled with filtering material and desiccant or drying agent and may have flare or sweat type connections. The fill material can be a porous block form or loose fill type and be hermetically sealed or "replaceable core" configuration.



Suction Filter

This filter is used to protect the compressor from contaminants and is located in the suction line just ahead of the compressor. It may be a sealed or replaceable core type similar to those of the filter-drier with either flare or sweat type connections.

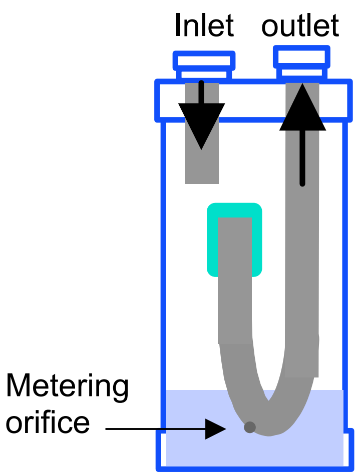
It is considered good practice to replace all filters and filter-driers in a system with new filters or filter-drier each time the system is opened. This may require use of special filters and multiple replacements to clean up after a compressor "burn-out".

Accessories & Options

Suction Accumulator

To prevent liquid refrigerant from entering the compressor, a suction accumulator can be added to the suction line ahead of the compressor. It must be large enough to hold the maximum amount of liquid refrigerant that flood through the suction line to the compressor and have provisions to return of oil to the compressor so that the oil is not trapped in the accumulator.

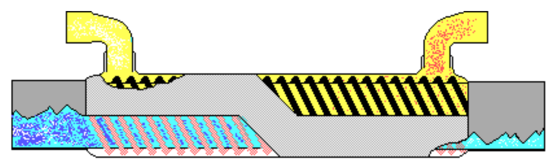
Typical design has the connection of the suction line on the top of a vertical shell. A "U" tube with an oil-metering orifice at the bottom and the refrigerant pick-up near the top of the shell. This is meant to ensure only refrigerant vapor is pulled into the suction line inlet to the compressor.



This device is not needed on most properly piped systems, but is used on many heat pump and truck refrigeration system. Other systems employ the suction accumulator to correct an actual or potential liquid refrigerant flood-back risk caused by anticipated operating conditions or existing system shortcomings.

Suction to Liquid Heat Exchanger

This component is used to transfer heat from the refrigerant liquid in the liquid line to the refrigerant vapor in the suction line. Since the refrigerant vapor is at a lower temperature than the liquid in the liquid line, the vapor absorbs heat becoming more superheated to protect the compressor and the liquid is subcooled for prevent flash gas. A typical heat exchanger design will have the suction gas flowing through a large center tube for minimal pressure drop, while the liquid is circulated through smaller tube wrapped around the outside of the larger tube.



Oil Separator

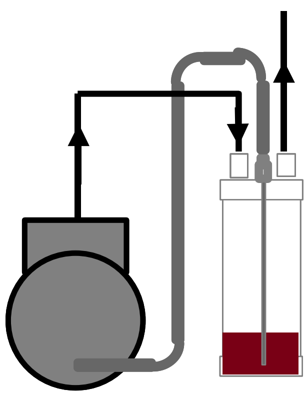
Basically, this component separates the oil from the refrigerant discharge gas after it leaves the compressor. It is installed in the discharge line between the compressor and the condenser.

Some oil is always circulating with the refrigerant in a refrigeration system. In very low temperature systems, the oil becomes very thick and is reluctant to return with the refrigerant to the compressor. It is highly recommended that oil separators be used to collect and return the majority of the oil to the compressor before it has a chance to be scattered throughout the system for applications with –20°F room temperatures and lower. It is not recommended to use them on medium temperature application or higher.

Accessories & Options

Oil separators can use a series of baffles and other velocity reduction techniques to separate the oil into a collection chamber. From there, the oil is returned to the compressor by means of a float system to sense the oil level in the chamber. The very best of separators is not 100% effective in separating the oil. If a system is logging oil, an oil separator will not cure the situation, but may only delay the inevitable.

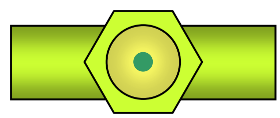
A small solenoid valve may be needed to prevent oil from migrating into the compressor crankcase during off cycles. Many separators are also heated and insulated when located inside outdoor condensing unit.



Sight Glass/Moisture Indicator

This component allows visual observation of refrigerant flow in the liquid line and may be used to determine if the system has been adequately charged. Foaming and bubbles normally indicate shortage of refrigerant, or a restriction in the liquid line.

A moisture indicator incorporated in this device provides a means of determining if too much moisture has entered the system. It will warn the observer when the filter/drier needs to be serviced to keep the system “dry” and functioning.



Review

♦ How much heat is required to raise 100 pounds of water from 70°F to 120°F at sea level?

__________________________ BTU

♦ The heat that changes the physical state of a substance is called …

______________ heat.

♦ What is a ton of refrigeration? ____

♦ What is the purpose of a thermostatic Expansion valve? (select answer from the list)

a. control liquid line temperature
b. meter refrigerant to evaporator
c. create temperature drop
d. all of the above

♦ T.D. in refrigeration means? (select answer from the list)

a. thermal device
b. temperature difference
c. touch down
d. thermo-dynamics

♦ What is the purpose of superheat in an evaporator? ___________________________

____

♦ What are two (2) types of condensers? ___________________ _________________

♦ R-12 gauge reads 15 psig, and measured temperature is 0°F (at sea level).

The refrigerant is in what physical state? ____________________________________

♦ Where is refrigerating done in the system? __________________________________

♦ Refrigerant is superheated entering and leaving what key component?

____

♦ If the gauge pressure equals the equivalent temperature on a temperature pressure table/chart, the refrigerant is _________________________________.

Glossary of basic terms related to Commercial Refrigeration

Absolute Humidity: The weight of water vapor in a unit of volume, usually expressed as grains per cubic feet.

Accumulator: A shell placed in the suction line just ahead of the compressor for separating liquid refrigerant entrained in the suction gas before it can reach the compressor and cause harm.

Air Bound: Air trapped in piping equipment such as steam radiator, which prevents maximum heat transfer or air trapped in the suction side of a pump which causes loss of suction.

Air Changes: The number of times per hour (or per day) the complete volume of air in a space or room is replaced with other air (i.e. conditioned air, supply air, infiltrating air).

Air Throw: The distance air will carry measured along the axis of an air stream from the supply opening to the position in the stream at which air motion reduces to 50 fpm (feet per minute).

Ambient temperature: The temperature of air in a space (i.e. room temperature, outside temperature, surrounding air).

Anhydrous: Free of water, especially water of crystallization.

Back Pressure: Pressure in the compressor suction or at the outlet of the evaporator. It is also known as "low-side " pressure. (see also, suction pressure

Balanced Port Valve: Type of thermostatic expansion valve with special design to negate or offset the effects of the fluctuating liquid line pressure on the operation of the valve. Conventional TEV will require a means of creating an artificial, steady liquid line pressure while the balanced port valves will not require this feature.

Brine: In refrigeration systems, any liquid that is cooled by the refrigerant and pumped through the cooling coils to pick up heat. It does not undergo any change in state, but only in temperature. Brine is used in indirect systems; refrigerant is used in direct systems.

British Thermal Unit (BTU): The quantity of heat required to raise the temperature of one pound of water one degree Fahrenheit (°F).

Calorie: The quantity of heat required to raise the temperature of one gram of water one degree Celsius (°C).

Chill: Moderate application of refrigeration to cool a product without freezing it.

Chill (or Chilling) Room: A refrigerated room where animal carcasses are cooled after dressing prior to cold storage.

Chilled water: A cooling medium that removes heat from the area to be cooled and gives up the heat in the chiller.

Chiller: A heat exchanger in which low-pressure refrigerant boils or vaporizes, thus absorbing the heat that was removed from the refrigerated area by the cooling medium (water).

Chiller Load: An indication of the number of tons of refrigerant being produced.

Coefficient Of Performance (COP): The ratio of refrigerating effect to work of compression. A high coefficient of performance means high efficiency. The theoretical coefficients range from about 2.5 to more than 5.

Comfort Cooling: Refrigeration for comfort as opposed to cooling for storage or manufacturing.

Condenser: Major component of a refrigeration system in which heat absorbing media (water or air) is used to cool and condense refrigerant gas for reuse within the system.

Condensing Unit: Refrigeration equipment containing condenser and compressor components with associated controls … a.k.a. "high side".

Condensing Pressure: See Head Pressure

Cooling medium: A fluid used for picking up heat which is circulated to the heat exchanger, where heat is removed. Ex: Chilled water and brine.

Defrost Cycle: A refrigeration cycle for the removal of frost from the evaporator coil surfaces during an off cycle using room air or through use of other active heating sources and / or methods.

Degree-Day: For any given day, the number of heating degree-days is the difference, in degrees, between the average temperature for that day and 65°F.

Dehumidification: The condensing of water vapor from air by cooling below the dew point or removal of water vapor from air by chemical or physical methods.

Dehumidify: To reduce the quantity of water vapor within a space.

Dehydration: (1) The removal of water vapor from air by the use of absorbing or absorbent materials. (2) The removal of water from product stored in a refrigerated space or room.

Dew point: The temperature at which the water vapor in the air begins to condense or the temperature at which the relative humidity of air becomes 100 percent.

Differential (of a control): The difference between the cut-in and cut-out settings of pressure or temperature or the open and closed position of the control's switch.

Discharge Line: The tube or pipe, which carries the high-temperature, high-pressure refrigerant from the compressor to the condenser.

Dry Bulb Temperature: Temperature measured by an ordinary thermometer.

Enthalpy: The total heat or heat content of a substance, expressed in Btu/lb.

Evaporator: Major component of a refrigeration system in which refrigerant liquid is vaporized to absorb heat for a cooling media (water, air, brine, etc.) to produce the refrigeration effect.

Evaporating Pressure: See Suction Pressure

External Equalizer: A tube connection from the outlet (suction line or header) of a refrigeration evaporator to its thermostatic expansion valve. This pressurizes the chamber under the valve's power element diaphragm to compensate for excessive pressure drop through the evaporator.

Flash Gas: Caused by pressure reduction or losses, it is the gas resulting from the instantaneous evaporation of refrigerant to cool the refrigerant to maintain its saturated state at lower pressure.

Flood-back: An undesired condition when refrigerant in liquid form returns to the compressor through the suction line. This could cause the lubricant oil in the crankcase to "wash out" of the compressor and cause damage to bearings and other lubrication dependent components; or the liquid could "slug" into the compression chambers and result in parts breakage and rendering the compressor inoperative.

Flooded Refrigeration system: A type of system where only part of the circulated refrigerant is evaporated, with the remainder being separated from the vapor and then recirculated.

Freeze-up: Ice formation on a refrigeration system at the expansion device, making the device inoperative.

Frost Back: Condition where frost accumulates on the suction line caused by the refrigerant temperature being below the freeze point and the dew point of the ambient air surrounding the suction line. This is not necessarily indicative of "flood-back" (see previous term) conditions.

Head Pressure: The pressure at which a refrigerant is changing state from vapor to liquid; also known as "high-side" pressure, condensing pressure, discharge pressure.

Heat Exchanger: Apparatus in which heat is exchanged from one fluid or media to another through a partition between them.

High side: The portion of a refrigeration system that is under discharge or condenser pressure. It extends from the compressor discharge to the expansion valves inlet.

Horse Power per Ton: Mechanical input in horse power, divided by tons of refrigerating effect produced. If the coefficient of performance is known, the horsepower per ton can be figured directly; divide 12,000 Btu/hp-hr and the coefficient of performance.

Infiltration: Air flowing inward as through a wall, cracks, openings, etc. potentially introducing additional heat loads into the space.

Latent Heat: The heat added or extracted when a substance changes state but does not change temperature. For example, when ice melts in a refrigerator, 144Btu/lb must be added to produce the melting or when ice freezes in an ice tank, 144 Btu/lb must be extracted; 144 Btu/lb is the latent heat of fusion.

Liquid Line: Refrigerant piping or tubing carrying liquid refrigerant from the outlet of the condenser or receiver to the flow control device(s).

Low side: The portion of a refrigeration system in which the refrigerant is at low pressure and temperature. It extends from the expansion valves outlet to the suction inlet of the compressor.

Mechanical Equivalent of Heat: One Btu equals 778.2 ft-lb of mechanical energy

Pressure Drop: Loss in pressure, as from one end of a refrigerant line to the other, due to friction, restrictions, etc.

Pump-Down: The operation by which the refrigerant in a charged system is pumped in liquid form into the condenser/receiver, and the compressor is shut off when the suction pressure falls below the cut-out set point value of the low pressure switch.

Refrigeration Effect: The amount of heat absorbed by in the evaporator, which is the same as the amount of heat removed from the space to be cooled. It is measured by subtracting the heat content of 1 lb of refrigerant as it enters the expansion valve from the heat content of the same pound of refrigerant as it enters the compressor.

Respiration: Production of CO_2 and heat by ripening of perishables in storage.

Return Air: Air, which has absorbed heat from the refrigerated or conditioned space, being recycled or returned to the evaporator for heat removal.

Saturation or Saturated Temperature: The temperature at which a substances changes state from liquid to vapor or vapor to liquid.

Sensible Heat: Heat associated with a temperature change of a substance (specific heat x change of temperature) in contrast to a heat interchange in which a change of state (latent heat) occurs.

Specific Heat (cp): Amount of energy (heat) per unit of mass required to produce one degree of change in temperature, usually BTU per lb. per °F, numerically equal to Calorie Per gram per °C, specific to particular substance and its physical state. (i.e. cp of water = 1 BTU/lb/°F; ice = ½)

Standard Air: Air weighting .0075 lb. per ft^3, which is 70°F dry air (0%RH) at sea level. (or about 68°F DB at 50%RH at a barometric pressure of 29.92 inches of mercury)

Standard-Ton conditions: An evaporating temperature of °F, a condensing temperature of 86°F, liquid before the expansion valve at 77°F, and a suction gas temperature of 14°F produce standard-ton conditions. Refrigerating machines are often rated under standard-ton conditions.

Subcooling: When the temperature of a liquid substance is below its saturated temperature for a given pressure condition.

Suction Line: Tubing or piping which carries the refrigerant vapor from the evaporator to the compressor inlet.

Suction Pressure: The pressure at which the refrigerant is change state from a liquid to a vapor. It is also known as "low-side " pressure, back pressure, or evaporating pressure.

Superheated Vapor: When a gaseous substance has a temperature above its saturated temperature for a given pressure.

Ton of Refrigeration: A rate of heat exchange of 12,000 BTU per hour; 200 BTU per minute.

Unit Cooler: Adapted from unit heater to cover any cooling equipment of condensed physical proportions and large surface, generally equipped with a fan.

Volatile: Easily evaporated. This is a necessary property of all compression refrigerants.

Vapor Pressure: Pressure exerted on a saturated liquid.

Wet-Bulb Temperature: Equilibrium temperature of water evaporating into the air, when the sensible heat of the air supplies the latent heat of vaporization. This is usually measured using a sling psychrometer have a 'wetted-sock' over the thermometer bulb being spun around in the air.

Wind-chill factor: Temperature effect on exposed flesh at certain wind speeds and temperatures. If the weather temperature is +10°F, for example, and the wind is blowing at 20mph, the wind chill factor is -25°F.

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