Freon™
Refrigerants

# Temperature Glide in Freon™ MP, Freon™ HP, and Freon™ 407C (R-407C) Series Refrigerant Blends

## Product Information

### Introduction

During the boiling process for a refrigerant, the temperature at which a liquid refrigerant first begins to boil is known as the saturated liquid temperature (also called the bubble point temperature). The temperature at which the last drop of liquid refrigerant has boiled is known as the saturated vapor temperature (also called the dew point temperature). In the condensing process for a refrigerant, the saturated vapor temperature (dew point) is the temperature at which the refrigerant vapor first begins to condense; the saturated liquid temperature (bubble point) is the temperature at which all of the refrigerant has been condensed to liquid. At constant pressure, the difference between the saturated vapor temperature and the saturated liquid temperature is referred to as the "temperature glide" of the refrigerant.

At a given pressure, single component refrigerants, such as CFC-12 and HFC-134a, boil or condense at a constant temperature, i.e., the saturated liquid temperature and saturated vapor temperature are the same. As a result, the "temperature glide" of a single component refrigerant is zero.

Refrigerant mixtures behave somewhat differently than single component refrigerants when they boil or condense. In the two phase regions of the system, such as the evaporator or condenser, liquid and vapor exist in equilibrium. For a refrigerant mixture at a given temperature or pressure, the compositions of the liquid and vapor phases are different, with the vapor composition having a higher concentration of the low boiling point components in the mixture. As a result of this composition difference, refrigerant mixtures have measurable "temperature glide" when they boil or condense. As shown below, these "temperature glides" are small for the Freon™ MP, Freon™ HP, and Freon™ 407C series refrigerant blends:

| | |
|---|---|
| Freon™ MP39 (R-401A), Freon™ MP66 (R-401B) | <11.5 °F |
| Freon™ HP80 (R-402A), Freon™ HP81 (R-402B) | <3.5 °F |
| Freon™ 404A (R-404A) | <1.1 °F |
| Freon™ 407C (R-407C) | <11.5 °F |
| Freon™ 410A (R-410A) | <0.5 °F |

In direct expansion systems using positive displacement compressors, the small "temperature glides" of the Freon™ blends should result in no significant difference in heat transfer performance versus single component refrigerants.

In systems with a centrifugal compressor or with a flooded evaporator, careful design evaluation of the system should be performed before charging a refrigerant mixture, as the composition difference associated with the temperature glide may impact performance. In general, the Freon™ MP blends and Freon™ 407C are not recommended in these applications.

In the single phase regions of a refrigeration system (superheated vapor and subcooled liquid), the composition of a refrigerant mixture is constant and behaves exactly like a single component refrigerant.

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Azeotropic refrigerant mixtures, such as R-500 and R-502, behave like single component refrigerants when they are at or very near their defined azeotropic point. By definition, the compositions of the vapor phase and liquid phase are the same for an azeotropic refrigerant mixture at its azeotropic temperature or pressure. One common misconception about azeotropes, however, is that this behavior holds true everywhere in the refrigeration system. These refrigerant mixtures are, in fact, zeotropic mixtures at temperatures other than their particular azeotropic temperature and, at these conditions, will also have different liquid and vapor phase compositions in the two phase region of a refrigeration system. As a result of this composition difference, azeotropic refrigerant mixtures will also have "temperature glide" at temperatures away from their defined azeotropic point. For R-500 (azeotrope point at 32 °F) and R-502 (azeotrope point at 66 °F), temperature glides away from the azeotrope point are very small, typically less than 0.3 °F.

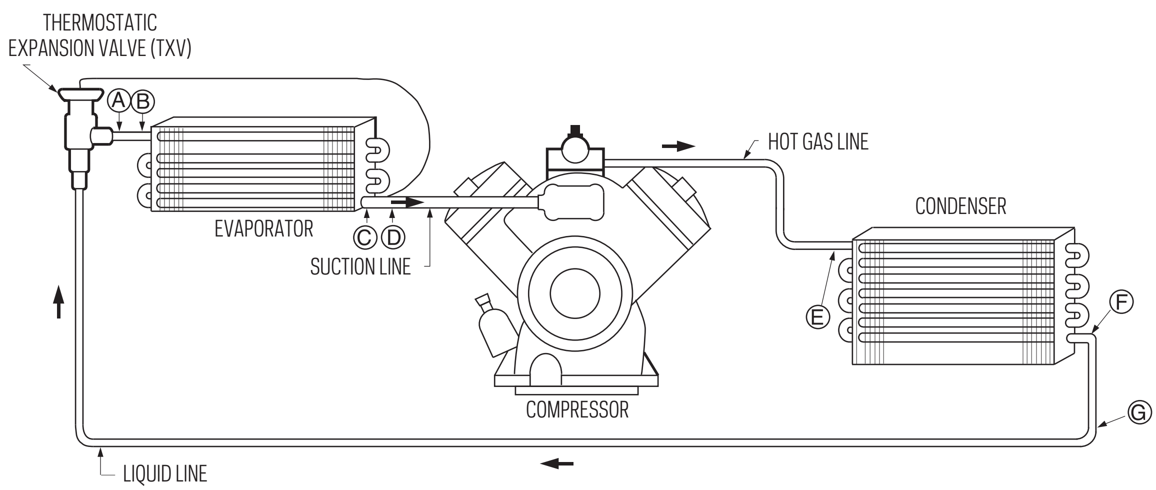
## Temperature Glide in an Evaporator

In the boiling process for a given composition refrigerant mixture, the liquid phase starts to boil at its saturated liquid temperature. While the liquid continues to boil, the liquid phase becomes richer in the high boiling point components as the low boiling point components boil off into the vapor phase. Because the liquid composition is continually changing during the boiling process, the saturated liquid temperature also changes. As the liquid phase becomes richer in the high boiling point components, the saturated liquid temperature increases until eventually all of the liquid is boiled off and the saturated vapor temperature is reached. The saturated vapor composition at the exit of the evaporator is the same as the saturated liquid composition when boiling started at the expansion device.

It should be noted that both liquid and vapor phases are already present in equilibrium at the inlet of the evaporator, due to the liquid flashing that takes place when the pressure is reduced in the expansion device. As a result, the effective evaporator "temperature glide," which is the difference between the evaporator inlet and exit temperatures, is less than the total "temperature glide" difference between the saturated liquid and saturated vapor temperature for a given composition refrigerant mixture. For Freon™ refrigerant blends, the effective evaporator "temperature glide" is typically about 65–75% of the total "temperature glide."

To illustrate this point, **Figure 1** shows a comparison of Freon™ MP39 and CFC-12 at an average evaporator temperature of 5 °F. Subcooled liquid from the condenser (point G) enters the thermostatic expansion valve (TXV) at 104 °F. As the pressure is let down in the TXV, Freon™ MP39 first begins boiling when the pressure is reduced to the saturated liquid pressure at 104 °F and enters the evaporator (point B) as a mixture of vapor and liquid at 1 °F. For reference, the saturated liquid temperature for Freon™ MP39 at the evaporator pressure (point A) is –2.5 °F. Freon™ MP39 continues boiling in the evaporator and exits the evaporator (point C) as a saturated vapor at 9 °F. Although the total "temperature glide" (point C minus point A) is 11.5 °F, the effective evaporator "temperature glide" (point C minus point B) is only 8 °F or about 70% of the total "temperature glide." By comparison, CFC-12 enters the evaporator at 5 °F and remains at that temperature until boiling is complete. For both Freon™ MP39 and CFC-12, the amount of vapor superheat at a point in the suction line to the compressor (point D) is calculated from the saturated vapor temperature.

**Figure 1.** Typical Thermal Expansion Valve Refrigeration System (Comparison Between CFC-12 and Freon™ MP39)




**Evaporator at 12 psig for Freon™ MP39 and CFC-12**

| | Temperature, °F Freon™ MP39 | Temperature, °F CFC-12 |
|---|---|---|
| Ⓐ Saturated liquid at evaporator pressure | –2.5 | 5 |
| Ⓑ Evaporator inlet (liquid/vapor mixture) | 1.0 | 5 |
| Ⓒ Evaporator exit (saturated vapor) | 9.0 | 5 |
| Ⓓ Compressor suction (superheated vapor) | 14.0 | 14 |
| Average Evaporator Temperature: | 5.0 | 5 |
| Evaporator Temperature Glide: | 8.0 | 0 |
| Amount of Vapor Superheat at Ⓓ : | 5.0 | 9 |

**Condenser at 163 psig for Freon™ MP39; at 142 psig for CFC-12**

| | Temperature, °F Freon™ MP39 | Temperature, °F CFC-12 |
|---|---|---|
| Ⓔ Condenser inlet (saturated vapor) | 117 | 113 |
| Ⓕ Condenser exit (saturated liquid) | 109 | 113 |
| Ⓖ Liquid line to TXV (subcooled liquid) | 104 | 104 |
| Average Condenser Temperature: | 113 | 113 |
| Condenser Temperature Glide: | 8 | 0 |
| Amount of Liquid Subcool at Ⓖ : | 5 | 9 |

## Temperature Glide in a Condenser

In the condensation process for a given composition refrigerant mixture, the vapor phase starts to condense at its saturated vapor temperature. While the vapor continues to condense, the vapor phase becomes richer in the low boiling point components as the high boiling point components condense into the liquid phase. Because the vapor composition is continually changing during the condensation process, the saturated vapor temperature also changes. As the vapor phase becomes richer in the low boiling point components, the saturated vapor temperature decreases until eventually all of the vapor is condensed and the saturated liquid temperature is reached. The saturated liquid composition at the exit of the condenser is the same as the saturated vapor composition when condensation started at the inlet of the condenser. Therefore, in the condenser, the difference between the starting saturated vapor temperature and the ending saturated liquid temperature for a given composition refrigerant mixture is the total "temperature glide" for that refrigerant mixture.

Figure 1 shows a comparison of Freon™ MP39 and CFC-12 at an average condenser temperature of 113 °F. Freon™ MP39 enters the condenser (point E) as a saturated vapor at 117 °F and exits the condenser (point F) as a saturated liquid at 109 °F for a "temperature glide" of 8 °F. By comparison, CFC-12 begins condensing at 113 °F and remains at that temperature until condensation is complete. For both Freon™ MP39 and CFC-12, the amount of liquid subcool at a point in the liquid line to the TXV (point G) is calculated from the saturated liquid temperature (point E).

## Average Evaporator and Condenser Temperature Calculation

When comparing the performance of zeotropic or azeotropic refrigerant mixtures with that of single component refrigerants, it is important that the comparison be made at the average evaporator temperature and the average condenser temperature. The average evaporator temperature is the average of the evaporator inlet and the evaporator saturated vapor temperature (usually the evaporator exit temperature). The average condenser temperature is the average of the condenser inlet temperature (saturated vapor) and the condenser saturated liquid temperature (usually the condenser exit temperature). In a refrigeration system, the evaporator saturated vapor temperature is determined at the suction pressure of the compressor; the condenser saturated vapor temperature and the condenser saturated liquid temperature are determined at the discharge pressure of the compressor.

## Freon™ MP39, Freon™ MP66, and Freon™ 407C

For the typical application ranges for Freon™ MP39, Freon™ MP66, and Freon™ 407C, both the evaporator and condenser temperature glides are approximately 8 °F. The average evaporator temperature can be calculated by subtracting 4 °F from the saturated vapor temperature. The average condenser temperature can be calculated by averaging the saturated vapor temperature and saturated liquid temperature. In field service, where a Pressure–Temperature chart may contain only the saturated vapor or the saturated liquid temperature, the average condenser temperature can be more easily calculated by either subtracting 4 °F from the saturated vapor temperature or adding 4 °F to the saturated liquid temperature.

Note: The amount of vapor superheat is always calculated from the actual saturated vapor temperature; the amount of liquid subcool is always calculated from the actual saturated liquid temperature.

**Example:** Freon™ MP39 operating at an evaporator pressure of 12 psig and a condenser pressure of 163 psig (same conditions as shown in **Figure 1**).

Saturated Vapor Temperature at 12 psig = 9 °F

Saturated Vapor Temperature at 163 psig = 117 °F

Saturated Liquid Temperature at 163 psig = 109 °F

Average Evaporator Temperature: 9 °F – 4 °F = 5 °F

Average Condenser Temperature: 117 °F – 4 °F = 113 °F
OR 109 °F + 4 °F = 113 °F
OR (117 °F + 109 °F)/2 = 113 °F

## Freon™ HP80, Freon™ HP81

For the typical application ranges for Freon™ HP80 and Freon™ HP81, the evaporator temperature glide and the condenser temperature glide are approximately 2 °F. The average evaporator temperature can be calculated by subtracting 1 °F from the saturated vapor temperature. The average condenser temperature can be calculated by averaging the saturated vapor temperature and saturated liquid temperature. In field service, where a Pressure–Temperature chart may contain only the saturated vapor or the saturated liquid temperature, the average condenser temperature can be more easily calculated by either subtracting 1 °F from the saturated vapor temperature or adding 1 °F to the saturated liquid temperature.

Note: The amount of vapor superheat is always calculated from the actual saturated vapor temperature; the amount of liquid subcool is always calculated from the actual saturated liquid temperature.

**Example:** Freon™ HP80 operating at an evaporator pressure of 15 psig and a condenser pressure of 301 psig.

Saturated Vapor Temperature at 15 psig = –24.3 °F

Saturated Vapor Temperature at 301 psig = 114 °F

Saturated Liquid Temperature at 301 psig = 112 °F

Average Evaporator Temperature: –24.3 °F – 1 °F = –25.3 °F

Average Condenser Temperature: 114 °F – 1 °F = 113 °F
OR 112 °F + 1 °F = 113 °F
OR (114 °F + 112 °F)/2 = 113 °F

## Freon™ 404A, Freon™ 410A

For the typical application ranges for Freon™ 404A and Freon™ 410A, the evaporator temperature glide and the condenser temperature glide are very small, less than 1.1 °F for Freon™ 404A and less than 0.5°F for Freon™ 410A. For field service purposes, this glide can be neglected in calculating the average evaporator or average condenser temperatures. The evaporator temperature can be considered equal to the saturated vapor temperature at the compressor suction pressure; the condenser temperature can be considered equal to the saturated vapor temperature or the saturated liquid temperature at the compressor discharge pressure.

Note: The amount of vapor superheat is always calculated from the actual saturated vapor temperature; the amount of liquid subcool is always calculated from the actual saturated liquid temperature.

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