HIGH-GLIDE REFRIGERANTS: WHAT'S THE POINT?

Understanding Bubble Point, Mid Point, Dew Point, & Operational Set Points

Table of Contents

WHAT'S THE POINT?

Well, there are three points actually, which we will review in detail as we explore the pros and cons of high-glide refrigerants. High-glide refrigerants are becoming more popular in commercial and industrial refrigeration because of reduced global warming potential (GWP) compared to older low-glide or non-glide refrigerants.[1] But new refrigerants bring new challenges when designing, building, and operating refrigeration systems. To explore these challenges, we must establish a base knowledge of refrigeration concepts and refrigerants, and then we can dive into the differences between high-glide refrigerants and other refrigerants.

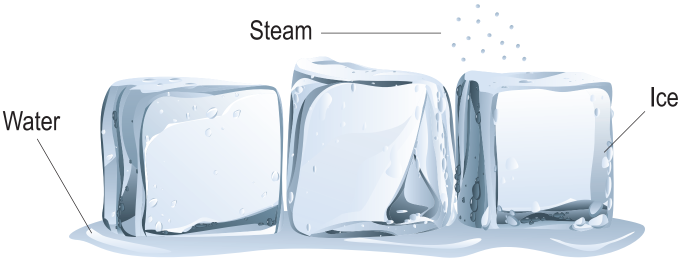
PART I: REFRIGERATION BASICS

Sensible & Latent Heat Transfer

Before we discuss the refrigeration cycle, we must briefly discuss heat transfer. Heat always transfers from warm to cold. You can see evidence of this in your beverage of choice. Your morning coffee may start hot, but as the day wears on, it gets cooler because heat transfers into the surrounding air. At lunch, your soda warms up as heat transfers from the surrounding air. This is called **sensible heat transfer**. You can remember this by thinking about how you can sense (feel) the change. The coffee mug feels hot as heat transfers to you; the soda can feels cold as heat transfers from you.

Heat transfer can also cause a substance to change state between solid, liquid, and gas. This is called **latent heat transfer**. For example, H_2O can exist as a solid (ice), a liquid (water), or a gas (steam) (**See Figure 1**). Between 212°F (100°C) and 32°F (0°C), H_2O will be water.[2] If water is heated beyond 212°F, it will evaporate into steam. If water is cooled below 32°F, it will freeze into ice. As a substance changes state, its original state will be reduced as the other state increases. For example, as ice melts, it disappears and the amount of water increases. If enough heat transfers, the substance will cease to exist in its original state. Latent heat transfer is very useful because it takes more heat to change state than to change temperature.

FIGURE 1: The Three Phases of H_2O: Ice, Water, and Steam



The Refrigeration Cycle

Your unfinished can of soda is now warm. How do you chill it again? You may think the answer is to add cold to it, but remember that heat only moves from warm to cold. It is more accurate to say that you are actually removing the heat from the soda by transferring that heat to another, colder object. This is the concept behind the refrigeration cycle.

The refrigeration cycle comes from the work of William John Macquorn Rankine, who figured out how to transfer heat away from objects that were already cool. Historically, this could be done by placing objects into an ice box. Ice works well as a refrigerant because it maintains a constant 32°F temperature. Warm product (milk, meat, etc.) transfers heat to the ice (latent heat transfer), causing the ice to melt into water. The water (full of heat) drains away, and the refrigerated space and product remain cool.

A modern refrigeration system has four main components that work together to move heat: the **evaporator**, the **compressor**, the **condenser**, and the **expansion device**. Imagine that heat moves in a "bucket" (**See Figure 2 on page 2**) and follow the bullet points which correspond to the figure.

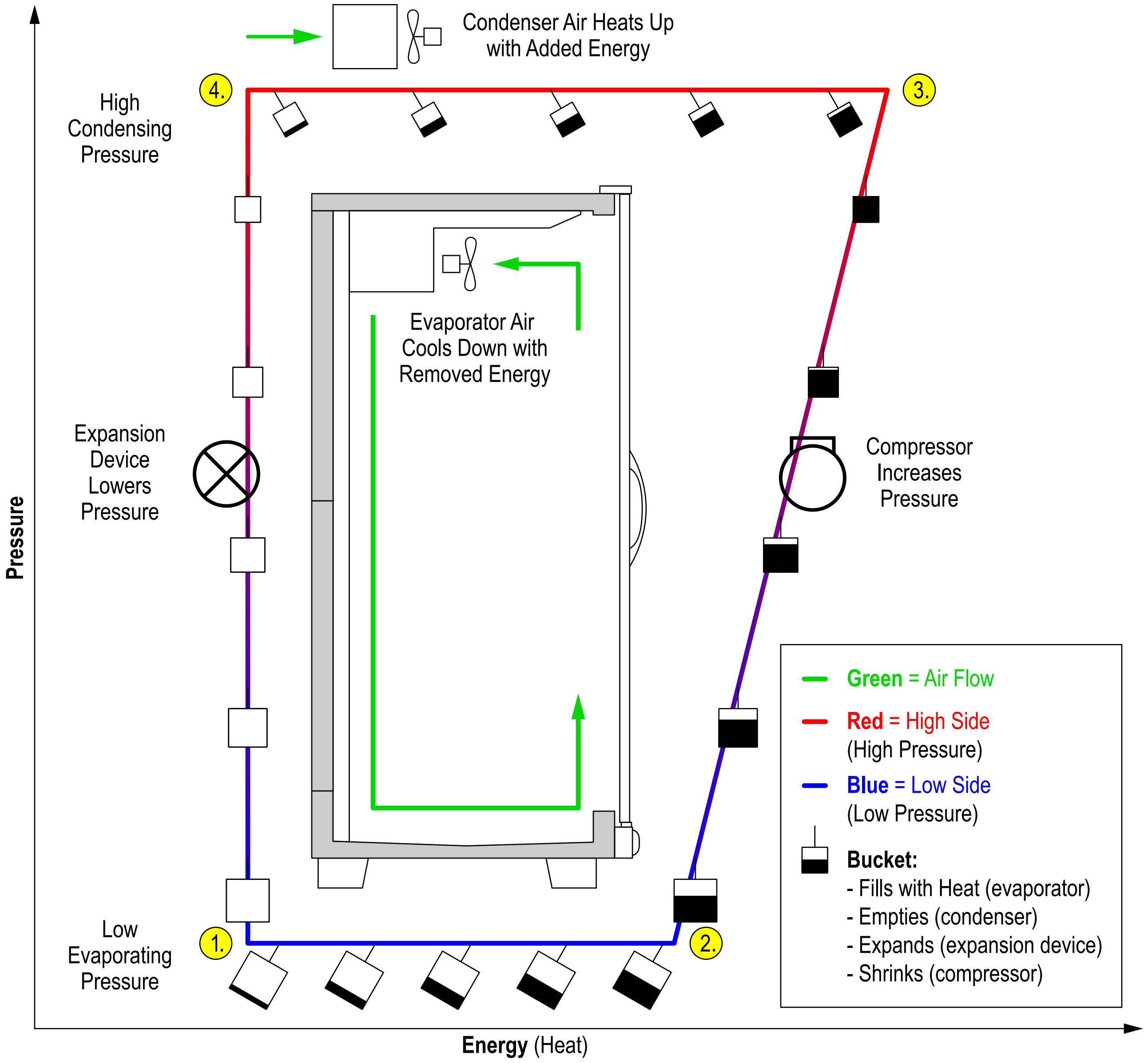
---

1. For simplicity, we refer to both low-glide and non-glide refrigerants collectively as "non-glide refrigerants" for the remainder of this article. Some of these refrigerants have a low amount of glide to them, typically less than 2°F.
2. These temperatures apply at sea level. It will vary at different altitudes and pressures.

1. The evaporator gathers/absorbs heat from the refrigerated space into a "bucket." The "bucket" is low-pressure, and it changes state (latent heat transfer) as it absorbs heat. Then the evaporator moves the low-pressure, heat-filled "bucket" to the compressor.
2. The compressor applies pressure, which compresses the heat-filled "bucket." The heat-filled "bucket" changes from low-pressure to high-pressure as the compressor pushes it from the colder evaporator to the warmer condenser. When pressure is added, the temperature of the "bucket" also increases.
3. The condenser takes the high-pressure, heat-filled "bucket" and releases the heat from the "bucket" to the outside air (or other application). The "bucket" changes state (latent heat transfer) again as it releases heat.
4. The expansion device relieves the pressure on the empty "bucket." When pressure is reduced, the temperature also decreases. The "bucket" cools and expands on its way to the evaporator to absorb more heat again.

The downside of using ice as the "bucket" is that more ice must constantly be added as it melts away. Modern refrigeration systems needed a long-term solution. Refrigerants are the modern "bucket" because refrigerants can continually absorb and release energy without escaping the system. **Refrigerants change state from a liquid to a gas.** Refrigerants must be able to boil at low pressures and low temperatures to be efficient.

FIGURE 2: Refrigeration Cycle



Non-Glide & High-Glide Refrigerants

Water boils at a consistent temperature. Even as it evaporates, the remaining water still boils at that temperature. This is also true of most refrigerants, whether they are natural refrigerants (such as CO_2) or synthetic refrigerants (such as R-404A). In this article, we refer to these as non-glide refrigerants.

High-glide refrigerants do not boil at a consistent temperature. A high-glide refrigerant may start boiling at 18°F, but as it boils into a gas, the boiling point "glides" up to 28°F. Why does this happen? High-glide refrigerants are a mixture of different refrigerants, and each boil at different temperatures. As the concentration of these refrigerants changes, the overall composition changes, and the boiling point "glides."

In this example, a high-glide refrigerant is composed equally of three different refrigerants, and each boil at different temperatures; for example, 18°F, 23°F, and 28°F. At 13°F, the composition is completely liquid and not boiling. But when it reaches 18°F, the first refrigerant boils away. This changes the composition and concentration of the refrigerants, and the remaining refrigerants will boil at a higher temperature. The next refrigerant in the composition will boil at 23°F, and the last refrigerant will boil at 28°F. When the entire composition has evaporated into gas, the boiling point will "glide" up to 28°F, which is 10°F higher than when it started boiling.

High-Glide Refrigerant Mixture	Boiling Temp	13°F	18°F	23°F	28°F
Refrigerant #1	18°F	Liquid	Boiling	Mostly Evaporated	Mostly Evaporated
Refrigerant #2	23°F	Liquid	Liquid	Boiling	Mostly Evaporated
Refrigerant #3	28°F	Liquid	Liquid	Liquid	Boiling

High-glide refrigerants are gaining popularity because of their reduced GWP and ozone depletion from older refrigerants, but the high glide leads to some new challenges when designing and servicing a refrigeration system.

PART II: CHALLENGES WITH HIGH-GLIDE REFRIGERANTS

Bubble, Mid, & Dew Point

With non-glide refrigerants, it is simpler to design a system because the refrigerant boils at the same temperature throughout the operation.[3] But with high-glide refrigerants, the system can be designed for either when the refrigerant starts boiling or when it fully evaporates.

To avoid confusion, refrigeration engineers and contractors need to be familiar with the terms **bubble point**, **mid point**, and **dew point**. These terms define when a refrigerant begins to boil (bubble point), when half of it has boiled away (mid point), and when it finishes boiling (dew point). To remember this, think about how a liquid bubbles as it boils or how dew forms in the morning when water vapor condenses (**See Figure 3**).

FIGURE 3: Everyday Examples of Bubble Point & Dew Point

---

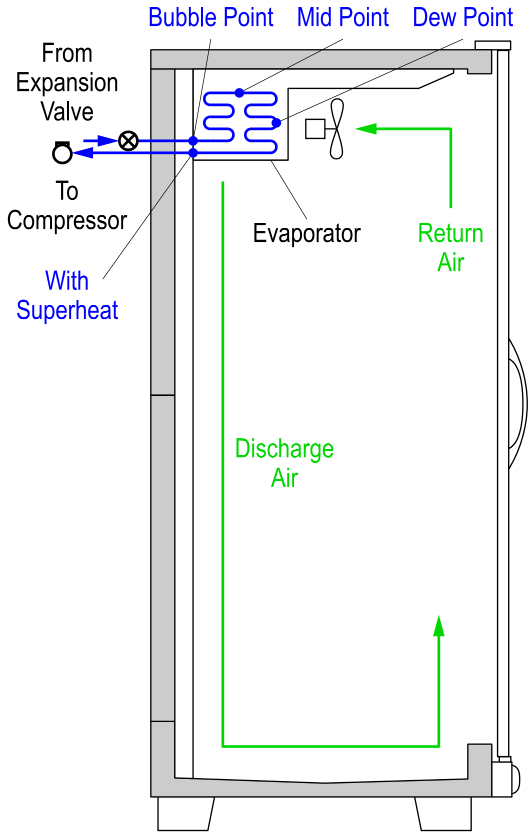
[3] What we call "non-glide refrigerants" is not entirely accurate. Some non-glide refrigerants have a low amount of glide to them, typically less than 2°F. For simplicity in this article, we refer to all refrigerants that are not high-glide as non-glide refrigerants. Other terms include "near-azeotropic" (for refrigerants with low glide) or "single component refrigerants" (which usually have no glide).

Potential Benefit of High-Glide Refrigerants

High-glide refrigerants have a lower bubble point (as it enters the evaporator) compared to its dew point (as it leaves the evaporator) (**See Figure 4**). It is believed that this glide provides an opportunity to design the system with a higher dew point temperature, therefore reducing the energy consumption of the refrigeration system.

Typically, equipment manufacturers rate equipment at the dew point temperature of a standard refrigerant, but refrigerant manufacturers and some equipment manufacturers suggest that the evaporator temperature can be rated at the mid point of a high-glide refrigerant, thereby increasing refrigeration system efficiency. However, we found some limitations in rating the evaporator at the mid point instead of the dew point.

FIGURE 4: Bubble Point, Mid Point, & Dew Point in a Crystal Merchandiser® with Top-Mounted Evaporator Coil



Heat Transfer Coefficient: The Opportunity and the Reality

The evaporator absorbs heat. How much heat needs to be absorbed? The **heat transfer rate** determines how effectively heat will transfer from the air, through the evaporator coil, and into the refrigerant. The heat transfer rate is calculated using three variables: the heat transfer surface area (the size of the evaporator coil), the average temperature difference between the air and the evaporator, and the heat transfer coefficient.

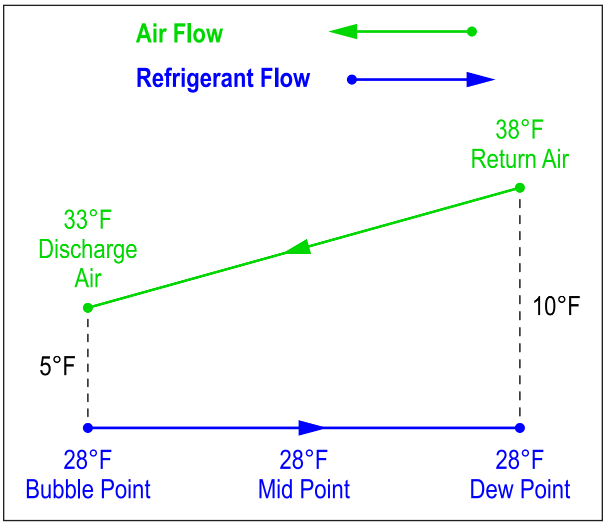
Heat Transfer Rate = Heat Transfer Surface Area x Average Temperature Difference Between Air and Evaporator x Heat Transfer Coefficient

The **heat transfer coefficient** is the resistance against heat transfer. As heat passes through a substance, the heat encounters resistance. Even good conductors of heat, such as copper or refrigerants, have some resistance. A higher heat transfer coefficient indicates less resistance and a more efficient heat transfer rate.

The engineer balances the three variables of the heat transfer rate. If one of these variables increases, the others can drop and still accomplish the same heat transfer. For example, if a larger coil is used (variable 1: surface area), the average temperature difference can drop.

The following diagrams show the average temperature difference (variable 2) for a non-glide refrigerant (**See Figure 5**), a high-glide refrigerant (**See Figure 6**), and a high-glide refrigerant with a temperature shift (**See Figure 7 on page 6**).[4]

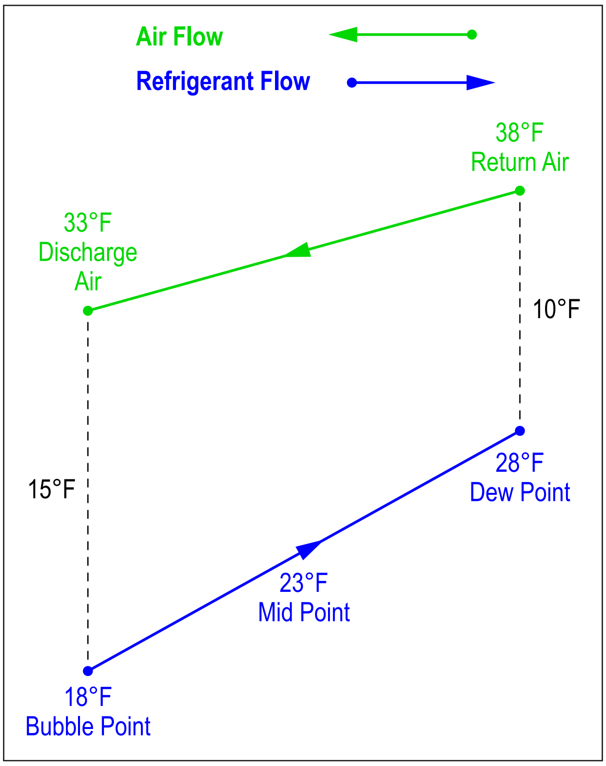
FIGURE 5: Average Temperature Difference for a Non-Glide Refrigerant



Average Temperature Difference: (5°F + 10°F) ÷ 2 = 7.5°F

For a non-glide refrigerant, the bubble and dew point are the same. The temperature difference of the discharge air and bubble point is averaged with the temperature difference of the return air and dew point.

FIGURE 6: Average Temperature Difference for a High-Glide Refrigerant (No Temperature Shift)[5]



Average Temperature Difference: (15°F + 10°F) ÷ 2 = 12.5°F

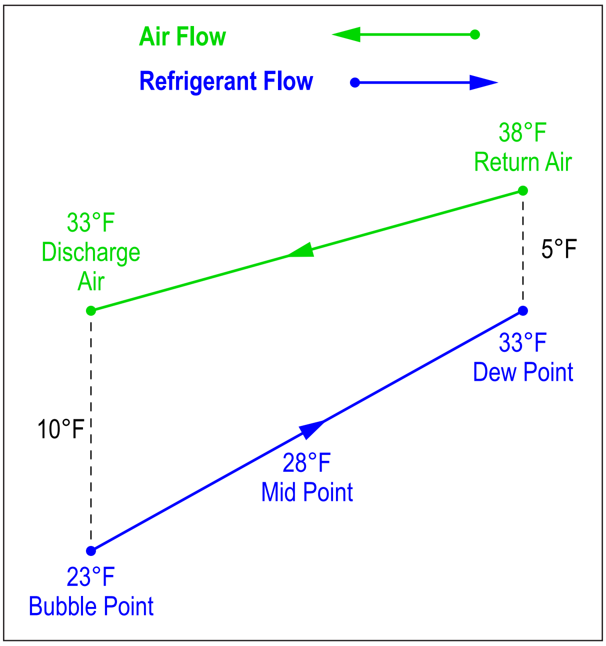
For a high-glide refrigerant with the same dew point, the average temperature difference is greater. This should mean that the dew point could be shifted to a warmer temperature and maintain the same heat transfer rate (**See Figure 7 on page 6**). However, this assumes that the heat transfer coefficient remains the same, and it does not account for superheat setting.

---

[4] Since refrigeration equipment is typically rated at the dew point temperature of a standard refrigerant, we define "temperature shift" as the change in dew point temperature between high-glide and non-glide refrigerants.

[5] To simplify this concept, we talk as if the refrigerant is completely a liquid at the bubble point. Some of the refrigerant will actually enter the evaporator as a vapor, which would increase the actual bubble point and mid point.

FIGURE 7: Average Temperature Difference for a High-Glide Refrigerant (With Temperature Shift)



Average Temperature Difference: (10°F + 5°F) ÷ 2 = 7.5°F

In this example, the mid point of the high-glide refrigerant is shifted to match the mid point of a non-glide refrigerant, as recommended by refrigerant manufacturers. This makes the average temperature difference the same (**See Figure 5 on page 5**). If this works, it would improve the efficiency of the refrigeration system because the evaporator temperature does not need to be set as low. As shown in **Figure 6 on page 5**, this assumes that the heat transfer coefficient is the same, and it does not account for superheat.

In summary, the glide of a high-glide refrigerant increases the temperature difference between the air and the evaporator, providing an opportunity to shift the evaporator temperature while maintaining the same heat transfer rate. This would increase efficiency.

Unfortunately, our tests indicate that the heat transfer coefficient (variable 3) for high-glide refrigerants is poorer than reported. The reality of a lower heat transfer coefficient means a larger average temperature difference is required to maintain the same heat transfer rate. This means the system cannot be shifted from the evaporating dew point to the mid point. Our experience indicates that operating at the mid point of a high-glide refrigerant results in only a 1-3°F shift from the dew point temperature.

Superheat Limitations

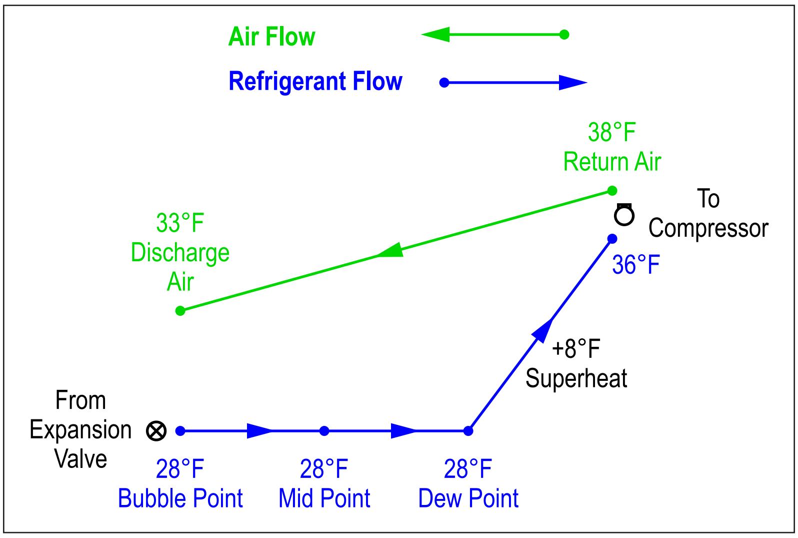
Heat-laden, vapor refrigerant moves from the evaporator to the compressor. A compressor can only compress vapor refrigerant, and any liquid refrigerant will damage the compressor. As a safety factor, the refrigerant is **superheated** to prevent liquid refrigerant from passing into the compressor. The preferred superheat setting is around 8°F.

The return air must be a certain amount warmer than the evaporator temperature for superheat (of the refrigerant) to be possible. Typically, superheat can be set to 2°F less than the return air; this is the minimum temperature difference possible. Therefore, if the return air is 38°F, the refrigerant cannot be heated above 36°F. If the preferred superheat setting is 8°F, then the evaporator temperature should be set at 28°F (**See Figure 8 on page 7**).

For a non-glide refrigerant, it does not matter whether the evaporator is set at bubble point, mid point, or dew point because they are all the same temperature. But for a high-glide refrigerant, the evaporator temperature must be set at a specific point. A higher dew point means less superheat, which increases the risk of liquid refrigerant entering the compressor.

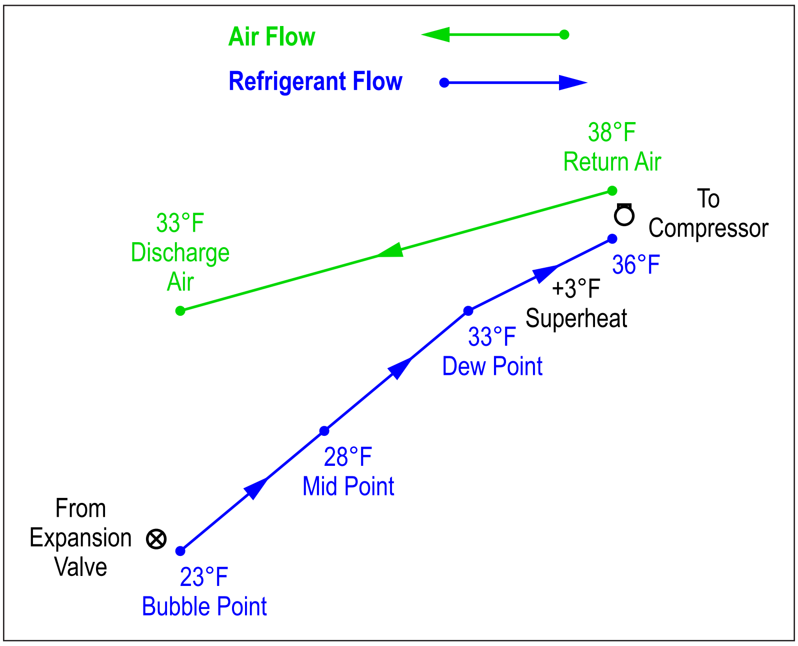
The following diagrams show how superheat is affected depending on whether the evaporator temperature is set at mid point (**See Figure 9**), at a small evaporator temperature shift (**See Figure 10 on page 8**), or no evaporator temperature shift (**See Figure 11 on page 8**).

FIGURE 8: Superheat Setting for a Non-Glide Refrigerant



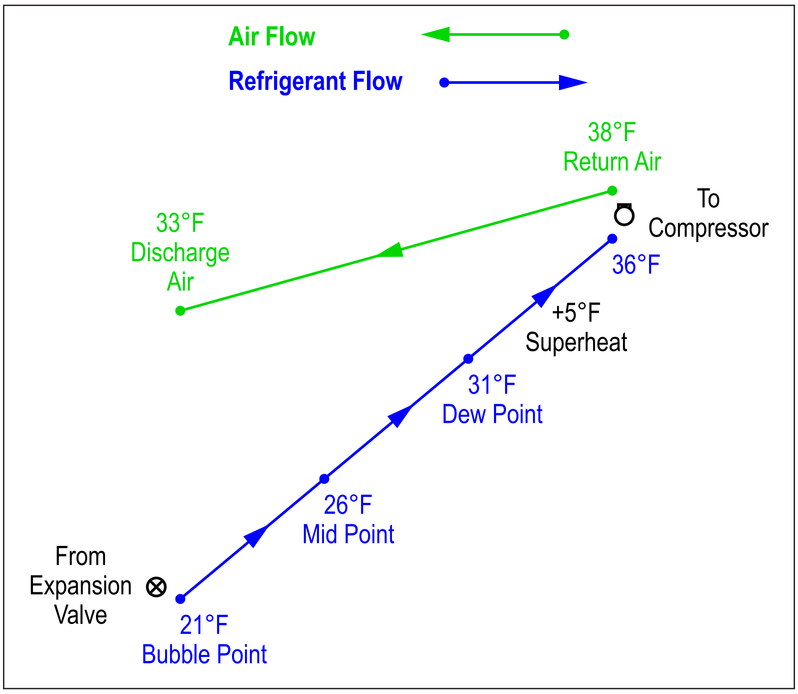
With a return air temperature of 36°F and an evaporator temperature of 28°F, superheat can be set at 8°F.

FIGURE 9: Superheat Setting for a High-Glide Refrigerant (With 5°F Temperature Shift)



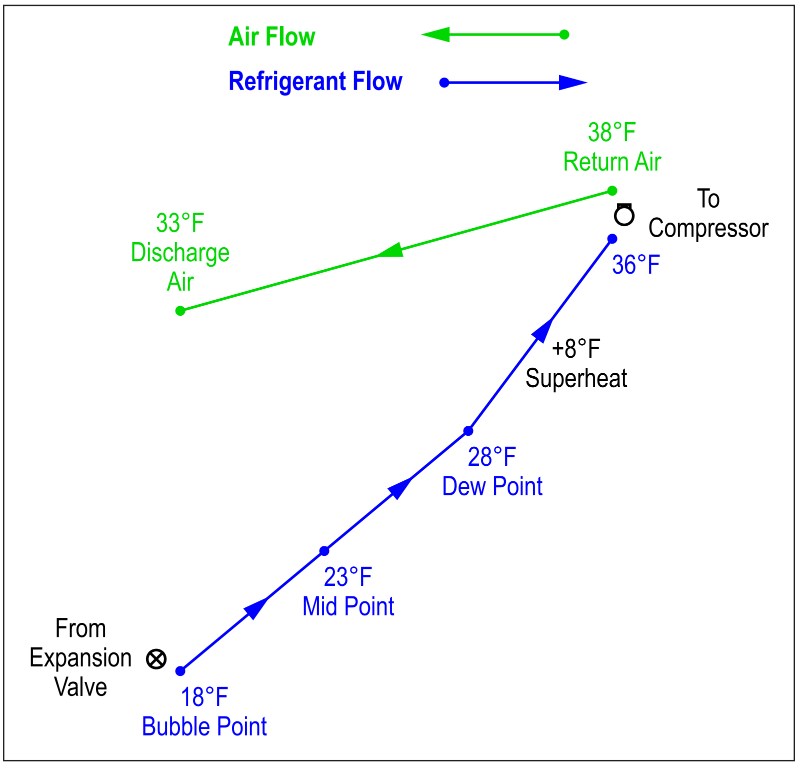
If the evaporator temperature is set at the same mid point as a non-glide refrigerant (a 5°F shift from 28°F dew point), the maximum superheat is just 3°F. Such a low superheat will make many service contractors uneasy because it risks damaging the compressor.

FIGURE 10: Superheat Setting for a High-Glide Refrigerant (With 3°F Temperature Shift)



Setting the evaporator temperature to 3°F more than the dew point of a non-glide refrigerant would increase the superheat to 5°F. This is less than the preferred superheat setting, but it reduces the risk of damaging the compressor.

FIGURE 11: Superheat Setting for a High-Glide Refrigerant (With No Temperature Shift)



Setting the evaporator temperature to the same dew point as a non-glide refrigerant means it is possible to have the preferred superheat of 8°F. This eliminates the risk of damaging the compressor.

Engineers designing systems using high-glide refrigerants must accept one of three compromises when setting evaporator temperature:

1. Increased system efficiency with decreased superheat and greater risk to the compressor (**See Figure 9 on page 7**).
2. Slightly increased system efficiency with slightly decreased superheat and less risk to the compressor (**See Figure 10 on page 8**).
3. The same system efficiency with the desired superheat and minimal risk to the compressor (**See Figure 11 on page 8**).

Zero Zone recommends option 3 because it protects the compressor, although option 2 is acceptable. These options make it simpler to identify the temperature difference between the air and evaporator and maintain enough superheat.

SUMMARY

High-glide refrigerants are an exciting option for the refrigeration industry with their lower GWP and potential energy savings. However, everyone must be careful when setting evaporator temperatures because of reduced heat transfer coefficients. To get desired superheat, evaporators may not be able to operate at mid point, as reported by some equipment manufacturers. We believe the best option is to set evaporators to dew point or a slight dew point shift. ***Warning: If there is ambiguity about whether equipment was designed for dew point, mid point, or bubble point, ask the equipment manufacturer. Do not make assumptions and risk damaging the equipment by running it incorrectly.***

For more information about this White Paper, contact:

Director of Regulatory Compliance & Refrigeration Technology
Zero Zone, Inc.

800-247-4496

ZERO ZONE, INC. • ZERO-ZONE.COM
CASE & SYSTEMS • 800-247-4496