How Inlet Conditions Impact Centrifugal Air Compressors

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Centrifugal technology is based on dynamic compression. In a dynamic compressor, air is drawn between the blades of a rapidly rotating impeller and accelerates to high velocity. The air is then discharged through a diffuser, where the kinetic energy is transformed into static pressure. Most dynamic compressors are turbo compressors with an axial or radial flow pattern and are designed for larger volume flow rates.

The performance of a dynamic compressor is very much dependent on environmental conditions. We will explain the impact of the different environmental parameters and their effect on performance below. When considering an investment in a centrifugal type compressor it is critical to consider the yearly extremes, as well as the average conditions when sizing the equipment for the application to achieve maximum performance.

The environmental parameters that influence the performance are:

1) Inlet temperature
2) Inlet pressure
3) Relative humidity (RH)
4) Cooling water temperature

To understand the impact of these parameters, we need to look at the performance curves of a dynamic compressor and see how performance is impacted with changing environmental parameters.

Inlet Temperature

The inlet temperature of the air has an impact on the density of the air at the intake of the compressor and will influence the kinetic energy transferred by the blades to the air. Increased density *at lower intake temperatures* will result in a *higher free air delivery (acfm)* and also *higher power consumption of the compressor.*

Another effect of the change in air or gas density is the available turndown of the compressor. That is the flow range where efficient regulation through use of a throttle valve or inlet guide vanes is possible. From the illustrations below it is clear that with *lower temperatures* a *higher turndown* range is available.

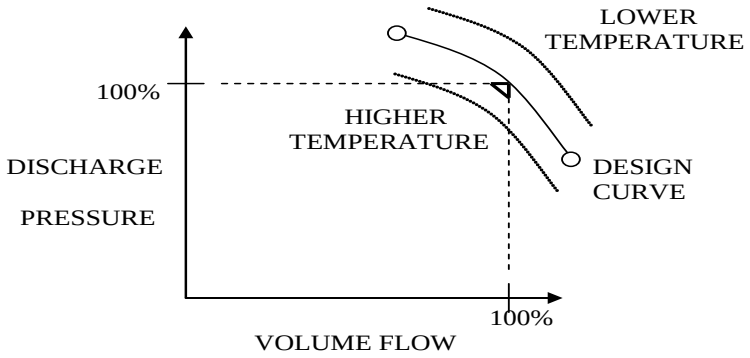
Figures 1 and 2 show the effect of inlet temperature on the performance of turbo compressor.

INLET TEMPERATURE

Inlet temperature changes produce large changes in performance. In cold weather, a centrifugal can deliver much more weight flow of air than in warm weather if the drive is sized to provide the additional power required.

Lower Temperature:

- Increases the surge pressure.
- Increases the maximum capacity (weight flow) at a given discharge pressure.
- Increases power consumption (horsepower).



Higher Temperature:

- Decreases the surge pressure.
- Decreases the maximum capacity (weight flow) at a given discharge pressure.
- Decreases power consumption (horsepower).

Figure 1: Density of air increases with reduction of air temperature.

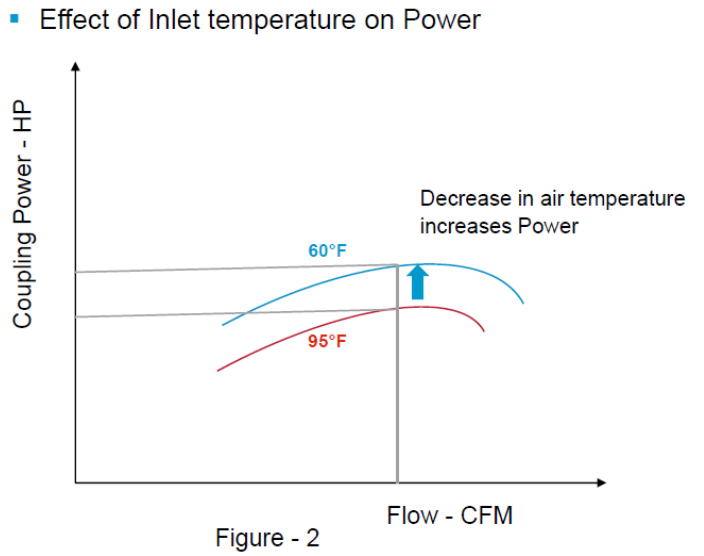


Figure 2: How inlet temperature affects power

The mentioned parameters have similar effects on compressor performance. The impact of these parameters can also be understood from the aforementioned performance graphs.

Inlet pressure

A decrease in inlet pressure will reduce the density of the air at the compressor intake. As with higher temperatures, it will result in lower free air delivery and power. Changes in inlet pressure can be caused by fouled inlet filters or changing barametric pressure. The same goes for the available turndown -lower intake pressure will result in smaller available turndown. (See Figure 3)

Lower inlet pressure:

- Decreases the discharge pressure along the entire curve.
- Decreases the maximum capacity (weight flow).
- Decreases power consumption or horsepower (due to reduced weight flow).

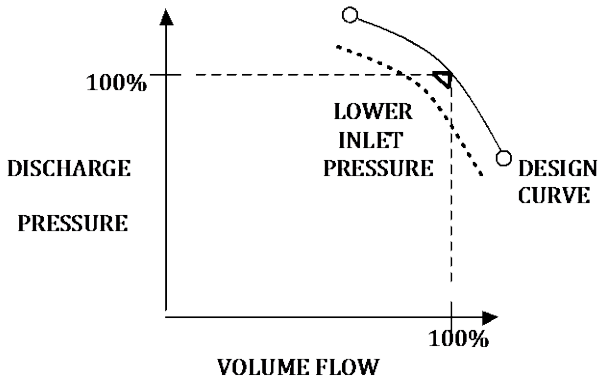


Figure 3: How lower inlet pressure impacts centrifugal compressor performance

Relative humidity (RH)

An increase in relative humidity (RH) reduces flow and power, and a decrease in RH will increase flow and power. The addition of water vapor to the air makes air humid and reduces the density of the air. This is due to the molar mass of water being less than that of air. (See Figure 4).

RELATIVE HUMIDITY

Humidity has a slight affect on discharge pressure and a greater affect on weight flow.

Higher relative humidity:

- Decreases the discharge pressure at surge.
- Decreases the maximum capacity (weight flow).
- Decreases the flow at which surge occurs.
- Decreases power consumption (horsepower).

The higher condensate losses on high humidity days results in reduce flow delivered to the plant air system.

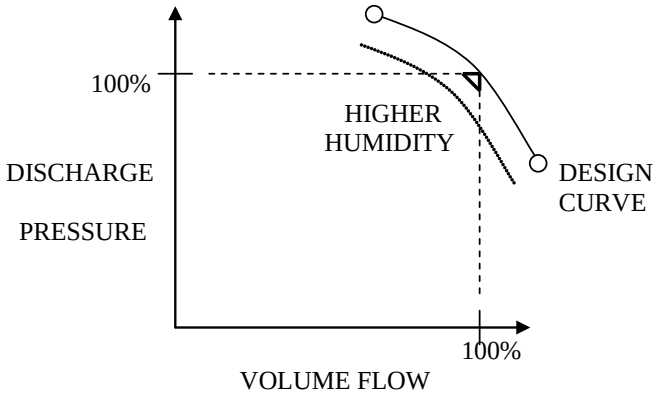


Figure 4: How relative humidity impacts centrifugal compressor performance

Cooling water temperature

The cooling water temperatures will affect the intake temperatures to the second stage and any further stages, if present. Colder water increases flow and power, and warmer water reduces flow and power.

To size a centrifugal compressor, you should consider the demand flow pattern of customer operation and site inlet conditions (minimum / average / high) for optimum performance.

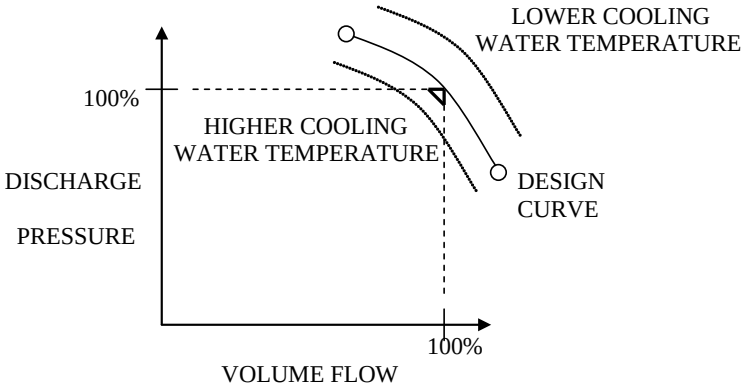
Another important point for consideration is motor sizing. If the motor / driver is selected based on performance at lower inlet temperatures, it will ensure that even during low inlet temperatures the motor has sufficient power available to take care of flow increases. The customer can then take advantage of the increased flow available from their compressor. (See Figure 5)

COOLING WATER TEMPERATURE / INTERSTAGE TEMPERATURE

Cooling water temperature will affect the performance of the compressor stage after the first stage. The affect in performance is similar to that of inlet air temperature. This of course is true because cooling water temperature variations will directly affect the temperature of the air entering the second, third and subsequent stages where there are intercoolers located between stages.

Lower cooling water temperature:

- Increases discharge pressure.
- Increases maximum capacity (weight flow).
- Increases power consumption (horsepower).



Higher cooling water temperature:

- Decreases discharge pressure.
- Decreases maximum capacity (weight flow).
- Decreases power consumption (horsepower).

Figure 5: The effect of cooling water temperature on centrifugal performance

CAGI and its Centrifugal Compressor Section Members – Atlas Copco, FS Elliott, Hanwha Power Systems, and Ingersoll Rand have trained engineers to assist and guide users through selecting the right size compressor for their operation. A compressor system assessment is recommended when upgrading and/or replacing existing systems to ensure that system performance is maximized.

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