# ACFM vs. SCFM vs. ICFM

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## TERMINOLOGY

ACFM – Actual Cubic Feet per Minute
CFM – Cubic Feet per Minute
ICFM – Inlet Cubic Feet per Minute
MDCFD – Thousand Standard Cubic Feet per Day
psia – Pounds Per Square Inch in Absolute pressure
SCFM – Standard Cubic Feet per Minute

## NOMENCLATURE

| | |
|---|---|
| $P_1$ | Barometric pressure at the non-standard site in psia |
| $T_1$ | Ambient air temperature in °R |
| $P_F$ | Pressure after the inlet filter in psia |
| $T_F$ | Air temperature after the inlet filter in °R |
| $P_{sat}$ | Saturation Pressure |
| $\phi$ | Relative Humidity at the non-standard site |
| $T_{std}$ | Standard temperature in degrees in °R (60°F = 60 + 460 = 520 °R) |
| $P_{std}$ | Standard air pressure in psia (14.696 psia) |

## INTRODUCTION

The term CFM is often confusing and difficult to define for one condition, and one definition does not satisfy all conditions we encounter in our customer's applications throughout the world. Simply put, CFM is an acronym for Cubic Feet per Minute, and defines the volumetric flow rate of a fluid displaced by a pump (like a compressor, a blower, or a booster). The term CFM is generally used to describe a pump's capacity, and is used to determine the size of the source system for medical, industrial and other applications. The common terms used to specify a volumetric flow rate in different industries are SCFM, ACFM, ICFM, MCFM, MSCFD, etc. Often times these terms are very vague, and in turn, misunderstood.

The primary reason for all the difficulties described above is because air is a compressible fluid, due to the atmospheric variation in air pressure, temperature and density - the fluid properties are constantly changing. The conditions are dependent on location, time of the year, altitude, etc. Thus, it is important to understand that the conditions in Los Angeles vary significantly from the conditions in Denver. The terms SCFM, ACFM and ICFM are often used to define the different instances and conditions of a compressor's capacity and operation. If the CFM terms are used appropriately, they can be useful in the direct and relative comparison to their operating conditions, and to other source systems. The intent of this paper is to provide a better understanding of SCFM, ACFM and ICFM and their meaning, so we can properly select and size compressors for their specified and intended applications.

## DESCRIPTION

The term *cubic feet per minute* (***CFM)*** describes the fluid flow rate, (measured in volume - $ft^3$) not the weight per minute on the inlet side of a compressor. The compressor's performance capability is measured in how many one $ft^3$ cubes of fluid are able to move per minute through the inlet.

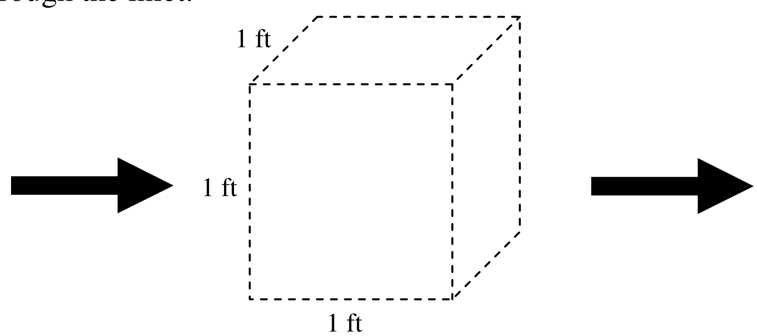


Figure 1 – One Cubic Feet of Volume

Now consider the conditions in Los Angeles, where one cubic feet of air weighs 0.075 lbs., and in Denver, where one cubic feet of air weighs 0.062 lbs. Even though the volume is the same, the weight (mass) of the air is different.

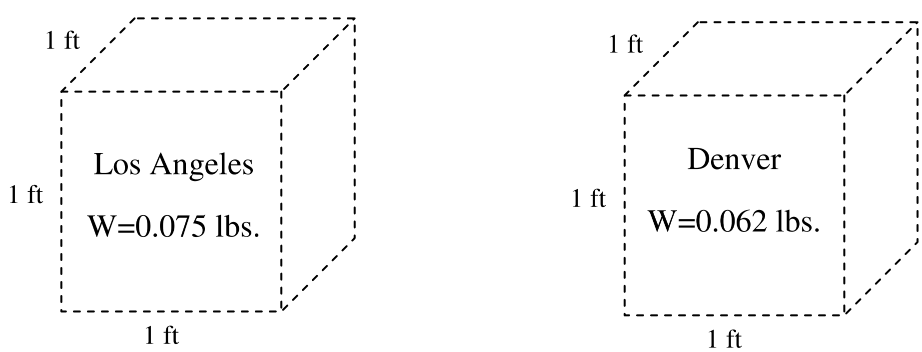


Figure 2 – Constant Volume

Now consider a constant weight (mass) condition. A balloon filled with 31 actual cubic feet of air in Los Angeles is then taken up to Denver. The balloon now contains 38 standard cubic feet of air.

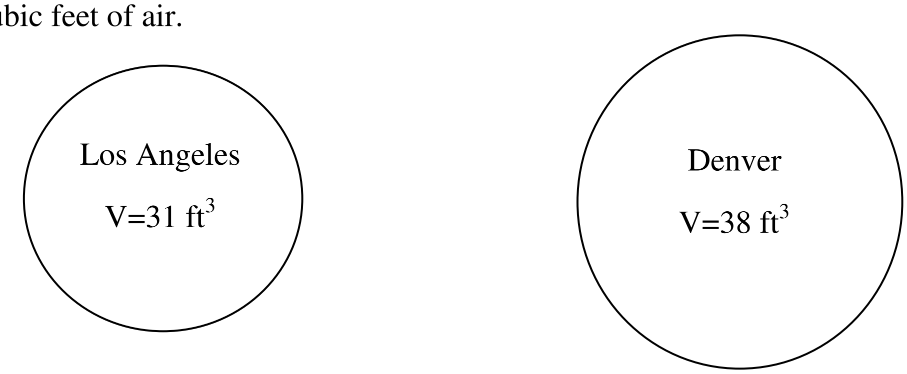


Figure 3 – Constant Mass

The two examples illustrate the confusion of measuring volume due to the fact air is compressible. In this instance, the number of gas molecules occupying a particular volume, depends on the pressure and temperature conditions of that location. At a microscopic level, the air molecules are closer together (greater air density) in Los Angeles compared to the air molecules in Denver.

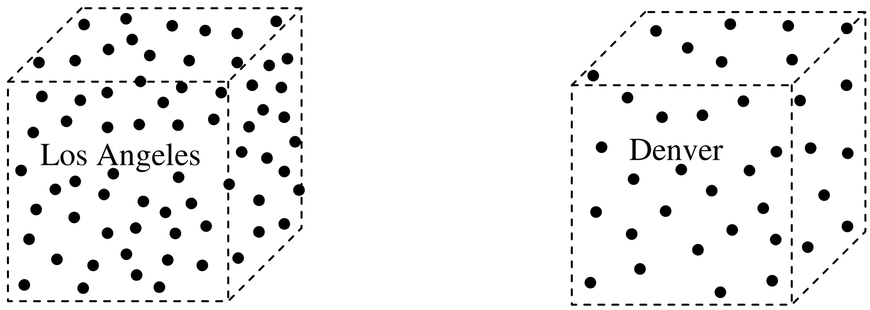


Figure 4 – Variation in Air Molecule Density

A variation in air pressure results in a variation in air density, as show in Figure 4, and is consistent with constant volume concept in Figure 2. Another way to look at this is to analyze the number of air molecules in a 120-gallon receiver tank at 80 psia and 100 psia, where the higher pressure tank occupies a greater number of molecules. The weight and density vary primarily because the atmospheric pressure is significantly different between the two cities, as show in Table 1. Note the terms for "actual" and "standard" for the volumes described above leads us to "SCFM" and "ACFM".

| City | Altitude (ft) | Atmospheric Pressure (psia) |
|---|---|---|
| Los Angeles | 0 | 14.69 |
| Denver | 5280 | 12.12 |

Table 1 – Variation in Atmospheric Pressure between the Two Cities

## SCFM and ACFM

The term *standard cubic feet per minute* ***(SCFM)*** is usually used as a standard reference condition for flow rate performance for atmospheric pressure at sea level, as opposed to *actual cubic feet per minute* ***(ACFM)*** is typically used to rate flow rate performance of compressor systems for actual pressure and temperature. SCFM is defined as air at 14.696 psia and 520°R (60 °F). Sometimes other conditions are used, such as 530°R (70°F), 528°R (68°F), 0% and 36% Relative Humidity for describing the standard conditions. It is important to remember SCFM is defined by a fixed set of conditions or common reference point for comparing different compressors systems. Otherwise the consequences are the improper sizing of the compressor system for its true application. This point will be apparent in the two examples to follow.

The conditions at sea level are generally not experienced by our customers and for practicality purposes ACFM is typically used for sizing compressors for these applications (+100°F and lower pressures). The conversion for ACFM from SCFM is shown by the formula below.

$$ACFM = SCFM \times \frac{P_{std}}{P_1 - \left(P_{sat_1} \times \phi_1\right)} \times \frac{T_1}{T_{std}} \qquad \text{Equation 1}$$

Note, absolute units must be used in the equation.

**SCFM – ACFM EXAMPLE 1 – Normal Day**

For this example we will reference a 30-hp compressor operating at 1020 rpm, and use it in Los Angeles and Denver to demonstrate how SCFM and ACFM should be used. Assume the requirement for compressed air is 125 psig discharge pressure, and 100 SCFM of demand, and the site ambient conditions are $T_1$ = 80 °F (540 °R), $P_1$ = 14.7 psia and $\phi$ = 75%, and this results in the following:

$$ACFM = 106.6$$

If we assume that all ambient conditions remain the same with the exception of moving the compressor to Denver, where the atmospheric pressure will drop to $P_1$ = 12.12 psia, the resulting volumetric flow requirement becomes:

$$ACFM = 130.0$$

In order to deliver the same amount of work (100 SCFM at 125 psig), the compressor in Denver must ingest larger quantities of the lower-density air, due to the change in the atmospheric pressure.

| Location | SCFM | ACFM | % Diff. |
|---|---|---|---|
| Los Angeles, CA | 100 | 106.6 | 6.6 % |
| Denver, CO | 100 | 130.0 | 30.0 % |

Table 1 – Normal Day between the Two Cities

To provide the required 100 SCFM of work in Denver, the compressor must be able to process 130 ACFM.

**SCFM – ACFM EXAMPLE 2 – Hot Humid Day**

For this example we will reference the first example for Los Angeles and Denver and change the conditions to a hot humid day. Assume the same requirements and conditions except for the ambient temperature of $T_1$ = 100 °F (560 °R) and relative humidity of $\phi$ = 100%, which results in the following:

| Location | SCFM | ACFM | % Diff. |
|---|---|---|---|
| Los Angeles, CA | 100 | 115.1 | 15.1 % |
| Denver, CO | 100 | 141.6 | 41.6 % |

Table 3 – Hot Humid Day between the Two Cities

The results at the higher temperature and higher humidity condition show an even greater amount of air is needed (approximately 10% more air is needed compared to Example 1) to meet capacity requirements. Thus, we recommend using hot humid days to calculate the worst case conditions for sizing a system. Tables can be constructed to size systems from Equation 1, but it is up to the specifier to determine the proper conditions. Table 4 in Appendix A shows the expansion ratio conversions for SCFM and ACFM for the conditions described in this example.

**ICFM**

The term *Inlet Cubic Feet per Minute* ***(ICFM)*** is used by compressor vendors to establish the conditions at the inlet of compressor – in front of the inlet filter, blower, or booster. If the pressure and temperature condition at the inlet is the same as after the filter, blower, or booster, then the ICFM and ACFM values will be the same. However, as the air passes through these components, there will be always be a pressure drop or rise, and Equation 2 is used to approximate ACFM.

$$ACFM = ICFM \times \frac{P_1}{P_F} \times \frac{T_F}{T_1} \qquad \text{Equation 2}$$

Then ICFM is used to measure inlet capacity, which will approximate ACFM for this type of a system. Note, when a blower or booster is added, the inlet may experience significantly higher pressure and temperature conditions than the actual ambient conditions. Greater the difference in pressure and temperature, greater the difference in ACFM and ICFM. Finally, there are losses (air seal, heat, etc.) associated with the use of these components and coupled with the pressure and temperature differences, the use of ICFM will result in a misleading outcome in determining a compressor's capability.

Note at higher altitudes, the specifier must account for the decrease in air pressure when estimating a compressor's performance and sometimes blowers or boosters are used for economic reasons, but this is not always the best solution. Thus, in certain markets, like the Medical, where tighter controls are employed, ICFM should not be used to determine a compressor's capacity, instead ACFM should be used.

**CONCLUSION**

This paper defined, summarized and applied the terms SCFM, ACFM and ICFM, and the differences between them. The term CFM, at a fundamental level, is defined such that a compressor will pump a specific volume of air in a given amount of time when the compressor speed and flow resistance matches the test conditions.

A specifier's most difficult task is sizing a compressor properly, by specifying the compressor's required capacity. It is important to note that the proper understanding of these terms will help a specifier in selecting a compressor. The specifier should use SCFM to compare differences in compressor capacities, and ACFM for actual non-standard site conditions and proper load applications. ICFM should be used only when a filter, a booster or a blower is added to the system, and should not be used in determining compressor selection, due to misleading results.

Finally, the reference pressure, temperature, and discharge pressure must be specified, in addition to the required capacity. When specifying the compressed air requirement, the worst case conditions should be used (i.e. - generally hot humid days, as shown in Example 2). Otherwise, there will be confusion in the sizing process. Other important factors to consider in compressor capacity and system sizing are:

- Air requirement or demand in a given day
- Normal operating conditions
- Other operating conditions (hot humid days are the worst)
- Single-stage or two-stage compressor (compression ratio)
- CFM reduction due to flow resistance
- Electrical characteristics and power requirement
- Area classification (Elevation)
- Compressors with a higher CFM rating will pump more air than compressors with lower CFM

## APPENDIX A

| | Volume Expansion Ratio | |
|---|---|---|
| Pressure (psia) | SCFM to ACFM | ACFM to SCFM |
| 14.70 | 1.151 | 0.869 |
| 14.50 | 1.168 | 0.856 |
| 14.25 | 1.190 | 0.840 |
| 14.00 | 1.213 | 0.824 |
| 13.75 | 1.237 | 0.809 |
| 13.50 | 1.261 | 0.793 |
| 13.25 | 1.287 | 0.777 |
| 13.00 | 1.314 | 0.761 |
| 12.75 | 1.341 | 0.745 |
| 12.50 | 1.371 | 0.730 |
| 12.25 | 1.401 | 0.714 |
| 12.00 | 1.433 | 0.698 |
| 11.75 | 1.466 | 0.682 |
| 11.50 | 1.500 | 0.666 |
| 11.25 | 1.537 | 0.651 |
| 11.00 | 1.575 | 0.635 |
| 10.75 | 1.615 | 0.619 |
| 10.50 | 1.658 | 0.603 |
| 10.25 | 1.702 | 0.588 |
| 10.00 | 1.749 | 0.572 |
| 9.75 | 1.799 | 0.556 |
| 9.50 | 1.851 | 0.540 |
| 9.25 | 1.907 | 0.524 |
| 9.00 | 1.966 | 0.509 |
| 8.75 | 2.029 | 0.493 |
| 8.50 | 2.097 | 0.477 |
| 8.25 | 2.168 | 0.461 |

Table 4 – Volume Expansion Ratio Conversion Chart