TECHNICAL BULLETIN

UNDERSTANDING COMPRESSOR CAPACITY

INTRODUCTION

Two of the most perplexing questions facing an air compressor purchaser are "what size should it be and how much air capacity is produced by the compressor"?

This problem is complicated by the wide array of terminology used to express compressor capacity.

Without a clear understanding of this terminology the client runs the risk of purchasing a compressor that doesn't delivery as much air as was required, or one that is far oversized, resulting in wasted energy costs.

Further confusion is caused by the fact that manufacturers and users of compressed air equipment discuss the capacity in terms of "compressed air", when in reality they are discussing free or expanded air, which has been compressed.

To clearly discuss air compressor capacity we must first understand a few important points.

1. Air has weight and mass!

   The density of air is directly proportional to the atmospheric pressure. Therefore the capacity of an air compressor operating in Banff (elevation 4500 feet/12.46 PSIA) will be less than an air compressor operating in Vancouver (sea level/14.7 PSIA).

2. The humidity of the air will, to some extent, affect the capacity of an air compressor!

3. A high temperature reduces the weight (mass) flow of each cubic foot of air. Therefore the same compressor will deliver a lower volume of air on a hot day, than it would on a cold day.

Following are several terms, which are widely used in the industry. Having an understanding of each will clear up some of the confusion that surrounds any discussion into compressor capacity.

CFM (DISPL) OR PISTON DISPLACEMENT

This term applies only to positive displacement type compressors and is the volume displaced per unit of time, generally expressed in cubic feet per minute (CFM). In the piston compressor is the swept volume of the piston as it moves through the cylinder, or the net area of the piston multiplied by the length of the stroke, times the number of strokes per minute.

This piston displacement of a multi-stage compressor is the total displacement of the low pressure or first stage cylinders only.

For double acting compressors it is the swept volume of the low-pressure piston on both the upward and downward strokes.

This figure does not take into account inefficiencies caused by the air cleaner, inlet piping restrictions, as well as leakage past the inlet valves and piston rings. It is in no way representative of the volume of air that will actually be delivered by the compressor.

Some lower priced compressors will have an efficiency of only 50%, which means that although the piston displacement may be 20 CFM, only 10 CFM of usable air will actually be delivered by the compressor.

Another, higher quality, compressor may have the same 20 CFM displacement, but may have an efficiency of 80% and will delivery 16 CFM of usable air.

Piston displacement should therefore never be used when evaluating an air compressor's performance!

FREE AIR

Free air, as defined by CAGI (Compressed Air & Gas Institute) is air at atmospheric conditions at any specific location. Because the barometer and temperature may vary at different localities and at different times, it follows that this term does not mean air under any identical or standard conditions. Before any calculations can be made to convert FREE AIR into flow at other conditions, the barometric pressure, temperature and R.H. at the site must be established. It is suggested that this term be avoided where possible.

The foregoing assumes the gas being handled follows The Perfect Gas Laws, I.E. Compressibility = 1.0

Remember – if the customer specifies SCFM and he does not fully define the standard, we should always use the CAGI/ASME standard in converting to CFM at inlet conditions.

ICFM (INLET CUBIC FEET PER MINUTE)

This is the unit of measure used by most major compressor manufacturers and is defined as the volume of air discharged at a specific pressure, but referred back to inlet conditions (ie: expanded air).

It does not however, use a defined or specific set of ambient conditions. (ie.: specific altitude, atmospheric pressure, relative humidity etc.)

ACFM (ACTUAL CUBIC FEET PER MINUTE)

It is not really clear what ACFM means. According to the "Compressed Air Handbook" ACFM means the volume at discharge referred back to "specified" conditions.

Most brochures, which quote ACFM figures, fail to mention the specified conditions. Most probably they refer back to the very intake of the compressor, ie., inlet flange of the compressor stage. On a warmed up unit the air at the intake flange can be about 20 to 25^{0}C warmer than the ambient temperature so that when referred to "intake" conditions approximately 6 – 9% higher capacity figures can be claimed.

Often ACFM and ICFM are considered to be the same. This is however incorrect.

We consider ACFM to be the actual flow corrected to actual and specific site conditions ie: elevation and temperature.

SCFM (STANDARD CUBIC FEET PER MINUTE)

SCFM clearly defines the volume of air that will be delivered at a consistent set of North American Standards. The American Society of Mechanical Engineers (ASME) defines standard conditions as 68^{0}F., 14.696 PSIA, 36% relative humidity and a density of 0.0750 lbs.ft^3. It should however be noted that the natural gas industry often used 60^{0}F as the standard, rather than 60^0 F.

$$SCFM = ICFM \times \frac{P(15+273)}{14.7\,(T + 273)}$$

Where: P – site atmospheric pressure (PSIA)
T = ambient temperature (degrees C)

NM^3/HR (NORMAL CUBIC METERS PER HOUR

Although similar to the American Standard SCFM, this is the term used throughout Europe as designated by ISO (International Standards Organization).

The standards used are 0^0 C (32^0 F), 1.013528 Bar (14.7 PSIA), 0% relative humidity and a density of 1.118 Kg/M^3 (0.7416 lbs/ft^3)

$$Nm^3/hr = SCFM \times 1.607467 \text{ or } SCFM / .62210$$

WEIGHT FLOW (LBS/HR OR LBS/MIN)

Because most compressed air is used to exert force on some sort of pneumatic device or equipment and fore = "mass X acceleration" the amount of force exerted will depend on the mass flow of the air, the conclusion one would therefore reach is that the only accurate way to evaluate a compressor capacity is to compare the weight flow of air under identical ambient conditions.

Once inlet conditions are known, it is a rather straightforward procedure to convert to ICFM, by the Perfect Gas Law:

$$V = \frac{ZWRT}{144(P)}$$

Where:
- V = Volume at inlet conditions (CFM)
- Z = Compressibility (equals 1.0 in most cases)
- W = Weight flow of gas (lbs./min.)
- R = Gas constant (53.3 for dry air only)
- T = Inlet (Ambient) temperature (^{0} R)
- P = Inlet (Atmospheric) pressure (PSIA)

Even with this quantity there are pitfalls. You must specify if the weight flow includes moisture present, or not (wet or dry).

It is worthwhile noting that SCFM defines a weight flow, since for SCFM the atmospheric pressure, inlet temperature, relative humidity and gas constant for air, are totally defined. Utilizing the above to obtain density from the CAGI standards one can calculate the 0.075 lbs/ft^3 previously mentioned.

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