**Application Engineering Bulletin**

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# MOTOR HORSEPOWER VS. COMPRESSOR EFFICIENCY

There is a wide-spread belief in the air conditioning and refrigeration industry that the connected motor horsepower in a given compressor or a given installation is in some fashion a measurement of efficiency, and that the less the connected horsepower, the more efficient the application. This is simply not true.

Motor horsepower and motor efficiency are really only remotely related in most hermetic motor applications. The basic design of the motor and the compressor are really the deciding factors in compressor efficiency.

In fact the concept of horsepower as applied to a hermetic motor-compressor is elusive at best, since a hermetic motor works over a wide range of horsepower output. In many cases the nominal horsepower designation is more a matter of convenience and tradition than a reflection of any consistent standard.

## Open Vs. Hermetic Motors

Part of the industry misunderstanding may originate in the difference in application of open and hermetic compressor motors. Open motors are dependent on heat given off to the ambient for motor cooling, while hermetic compressor motors are cooled directly by the refrigerant.

As a result, open type motors are typically classified as having a service factor of 1.1 or 1.25, which means they can only be loaded 10% or 25% above the nameplate horsepower rating. Hermetic compressor motors on the other hand have a very wide operating range, due both to design and refrigerant cooling. A typical nominal 7-1/2 H.P. motor in a Copelametic accessible-hermetic compressor may draw from 5 to 12 horsepower over its published operating range, and can draw as much as 15 horsepower prior to a protector trip.

In general, Copelametic motor-compressors are developing more than their nominal horsepower rating over most of their operating range, while efficiency is at its peak at lightly loaded conditions.

## Efficiency Comparison - Three Phase Motors

Table 1 is a comparison of the efficiency, amperage draw, and speed of nominal 5, 7-1/2, and 10 H.P. motors over a range of torque loading. All of these motors are applied in the Copeland model 9DB1 for different refrigerant applications, but the comparison does illustrate that over the normal operating range there is little difference in either efficiency or motor speed.

Figure 1 is a typical set of curves for a 7-1/2 H.P. three phase motor showing the effect of operation at various torque loading. Note that although the motor can handle a load of over 25 horsepower prior to a motor stall, the efficiency peaks at a load of approximately 20 Lb. Ft. or about 6.5 horsepower.

## Amperage, Power Factor, And Efficiency

Many people associate amperage draw with efficiency, and this may be another source of misunderstanding.

Amperage does vary with power factor. The power factor is maximized under very heavily

loaded conditions, and other things being equal, the higher the power factor the lower the amperage. However, variation in power factor and amperage have nothing to do with power consumption or efficiency.

Therefore, it is quite conceivable that if two different motors are applied on the same application, one heavily loaded and one lightly loaded, the heavily loaded motor may draw less amps due to a high power factor, while the lightly loaded motor may in fact be both more efficient and far more reliable, since a lightly loaded motor would be far better able to cope with adverse voltage conditions.

**Efficiency Comparison - Single Phase Motors**

Small single phase motors may provide an even more dramatic comparison of the lack of correlation between compressor nominal horsepower and efficiency. Table II is a comparison between the Copeland RSL2-0075-IAV motor-compressor, with a capacitor start, induction run 230 volt single phase motor, and the CRA1-0150-PFV, with a permanent split capacitor 230 volt single phase motor. The RSL2-0075 has a displacement of 244 CFH, and was designed for medium temperature R-12 application. The CRAI-0150 has a displacement of 243 CFH and was designed for R-22 air conditioning application. However, the CRA1-0150 can be applied with a high torque capacitor for commercial applications. Table II is a comparison of the two compressors at equivalent torque loading. Despite the fact that the CRA1-0150 has a larger nominal horsepower motor, the high efficiency PSC motor is far more efficient.

**Table I**

**COMPARISON OF NOMINAL 5, 7-1/2, AND 10 H.P. MOTORS OVER A RANGE OF TORQUE VALUES**

| Motor Torque Lb. Ft. | Approx. H.P. Input | 5 H.P. | | | 7-1/2 H.P. | | | 10 H.P. | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Efficiency | Amps | RPM | Efficiency | Amps | RPM | Efficiency | Amps | RPM |
| 10 | 3.4 | 86% | 12 | 1760 | 84% | 16 | 1760 | | | |
| 12 | 4 | 88% | 12.6 | 1760 | 87% | 17 | 1760 | | | |
| 15 | 5 | 89.5% | 15 | 1750 | 90% | 18 | 1750 | 85% | 21 | 1760 |
| 22.5 | 7.5 | 89.5% | 20 | 1730 | 92% | 26 | 1750 | 87% | 25 | 1760 |
| 30 | 10 | 88% | 26 | 1720 | 90% | 28 | 1720 | 88% | 29 | 1750 |
| 37.5 | 12.5 | | | | 89.5% | 34 | 1710 | 88% | 35 | 1740 |
| 45 | 14.5 | | | | 88% | 39 | 1700 | 87% | 39 | 1720 |
| Break Down Torque | | 50 Lb. Ft. | | | 105.2 Lb. Ft. | | | 134.8 Lb. Ft. | | |

**Table II**

**COMPARISON OF NOMINAL 3/4 AND 1-1/2 H.P. SINGLE PHASE MOTORS OVER A RANGE OF TORQUE VALUES**

| Motor Torque Oz. Ft. | Approx. H.P. Input | RSL2-0075-IAV | | | CRA1-0150-PFV | | |
|---|---|---|---|---|---|---|---|
| | | Efficiency | Amps | RPM | Efficiency | Amps | RPM |
| 12 | 1/2 | 69% | 4.8 | 3550 | 68% | 3.2 | 3575 |
| 18 | 3/4 | 74% | 5.6 | 3520 | 75% | 3.9 | 3560 |
| 24 | 1 | 76.5% | 6.4 | 3490 | 80% | 4.8 | 3550 |
| 30 | 1-1/4 | 77% | 7.2 | 3465 | 81.5% | 5.2 | 3540 |
| 36 | 1-1/2 | 77% | 8.4 | 3430 | 83% | 6.0 | 3530 |
| 48 | 2 | 73% | 10.8 | 3360 | 84% | 8.0 | 3500 |
| Break Down Torque | | 77 Oz. Ft. | | | 121.6 Oz. Ft. | | |

**Horsepower Vs. Capacity**

Another common misconception is that the horsepower of a compressor indicates its capacity. To a considerable extent this is true since motors are designed to the compressor's power requirement.

But the primary factor in a compressor's capacity is its displacement. For a given compressor displacement operating with a given refrigerant, the only effects of a motor change would be in motor efficiency or motor speed, and as Table I illustrates, these may be practically nonexistent.

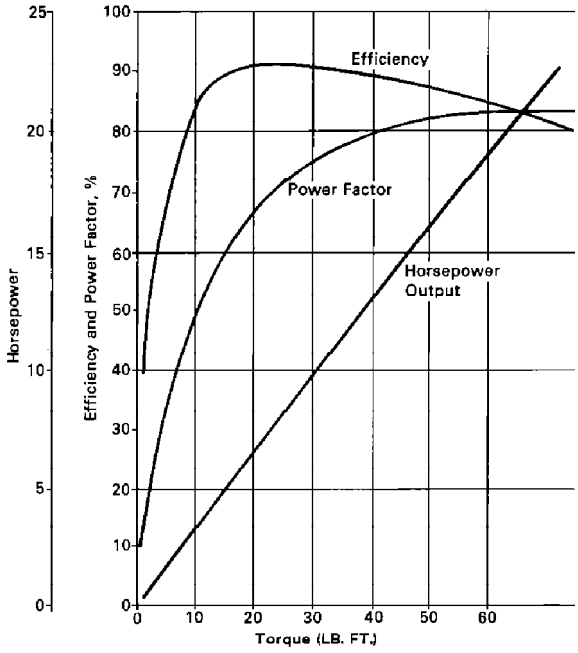
**Summary**

Users mistakenly tend to evaluate a compressor's efficiency and capacity in terms of the nominal horsepower motor applied. Efficiency is not primarily related to horsepower, and capacity is related to displacement.

For economic reasons, motors should be sized properly for their application. Wiring size and contactor selection are dictated by rated load and locked rotor amperage values.

But a motor-compressor should be evaluated on the basis of its performance and application, not on mistaken myths.

Such factors as starting and pull down capacity under heavy load must be considered. The notion that a smaller motor is a better motor is not necessarily so.




TYPICAL THREE PHASE MOTOR CURVES

**Figure 1**

**TYPICAL THREE PHASE MOTOR CURVES**

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