White Paper

Precision Motor™ Optimized Motor Selections

Executive Summary

Trane is introducing a new Precision Motor™ option for motor selections. This new offering can maximize part-load efficiency while reducing upstream, connected load costs. For example, if a fan requires 5.85 bhp, you can now select a 6.5 hp motor in lieu of a 7.5 hp motor.

Problem

Traditional motor selections are often oversized and are less efficient during part-part load operation. Multiple-fan systems can exasperate this problem.

Solutions

The Precision Motor™ motor offering from Trane will:

- "Reset" selections to optimize part-load efficiency
- Minimize connected load costs
- Improve serviceability
- Use non-custom motors
- Meet EPACT efficiency requirements
- Maintain unit UL listing

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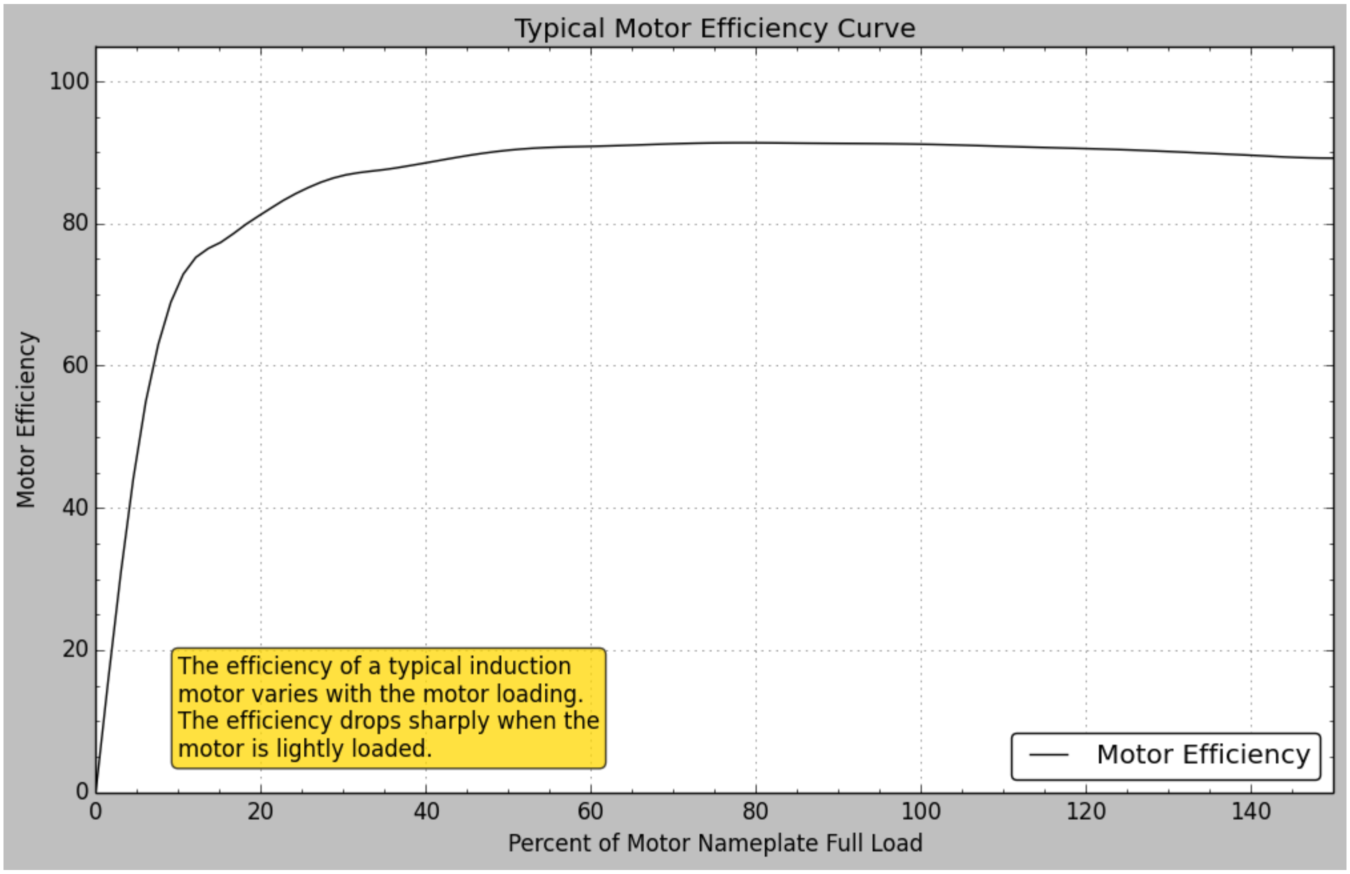
Motor Efficiency

Motor efficiency is primarily a function of percent rated output or load. Figure 1 illustrates a typical motor efficiency curve with the horizontal axis representing motor percentage load (bhp/hp). In general, motors will operate near peak efficiency between 50-150 percent load with some drop off above 100 percent load. Below about 50 percent load, motor efficiency drops off dramatically.

Fan demand operates somewhat similarly. As the speed is decreased, the power will decrease by the cube of the speed ratio. When the performance traits of a motor are combined with a fan, motor efficiency can drop off dramatically in a variable air volume system.

$$bhp_2 = bhp_1 * \left(\frac{RPM_2}{RPM_1}\right)^3$$

Figure 1. Typical motor efficiency curve



Motor Efficiency Example

Figure 2 shows how a motor is traditionally selected. If the fan requires 5.85 bhp at full load, one would normally select a 7.5 hp motor. A 7.5 hp motor is generally selected because:

- The nameplate value exceeds the bhp requirement of the fan

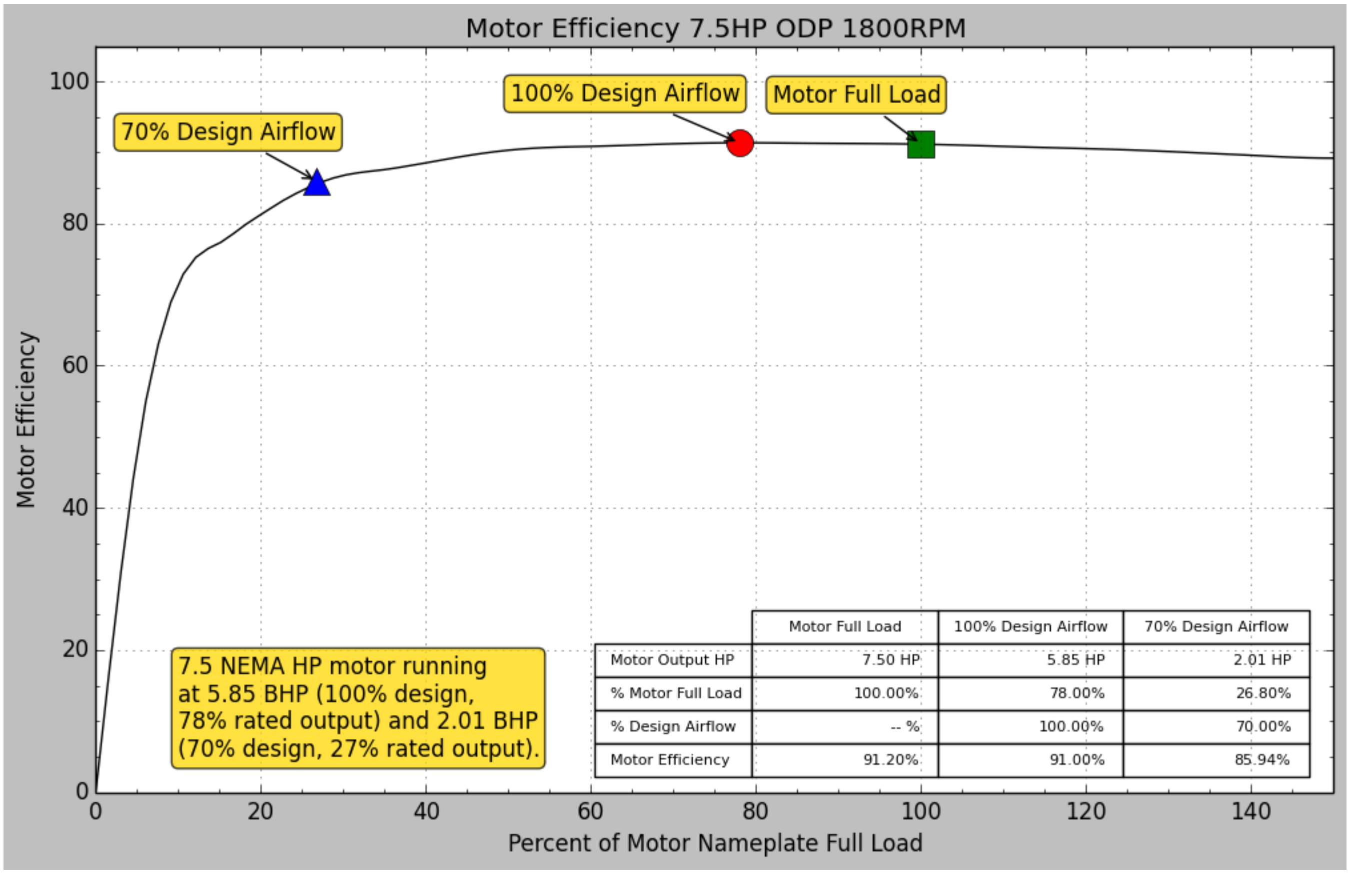
and

- 7.5 hp is the smallest NEMA motor that meets the bhp requirements (required by ASHRAE 90.1).

In this case, motor percentage load = 5.85 bhp/7.5 hp = 78 percent and motor nameplate efficiency assumes 100 percent load. Note how fan full-load efficiency and the motor nameplate efficiency are roughly equal.

In a typical VAV system, substantial fan operation will occur at part-load. Assuming average fan operation at 70 percent of design load, the part-load motor efficiency at 0.78*(0.7)^3 = 27 percent motor load would be roughly 86 percent in this example. Note how this part-load value is lower than the full-load or nameplate values.

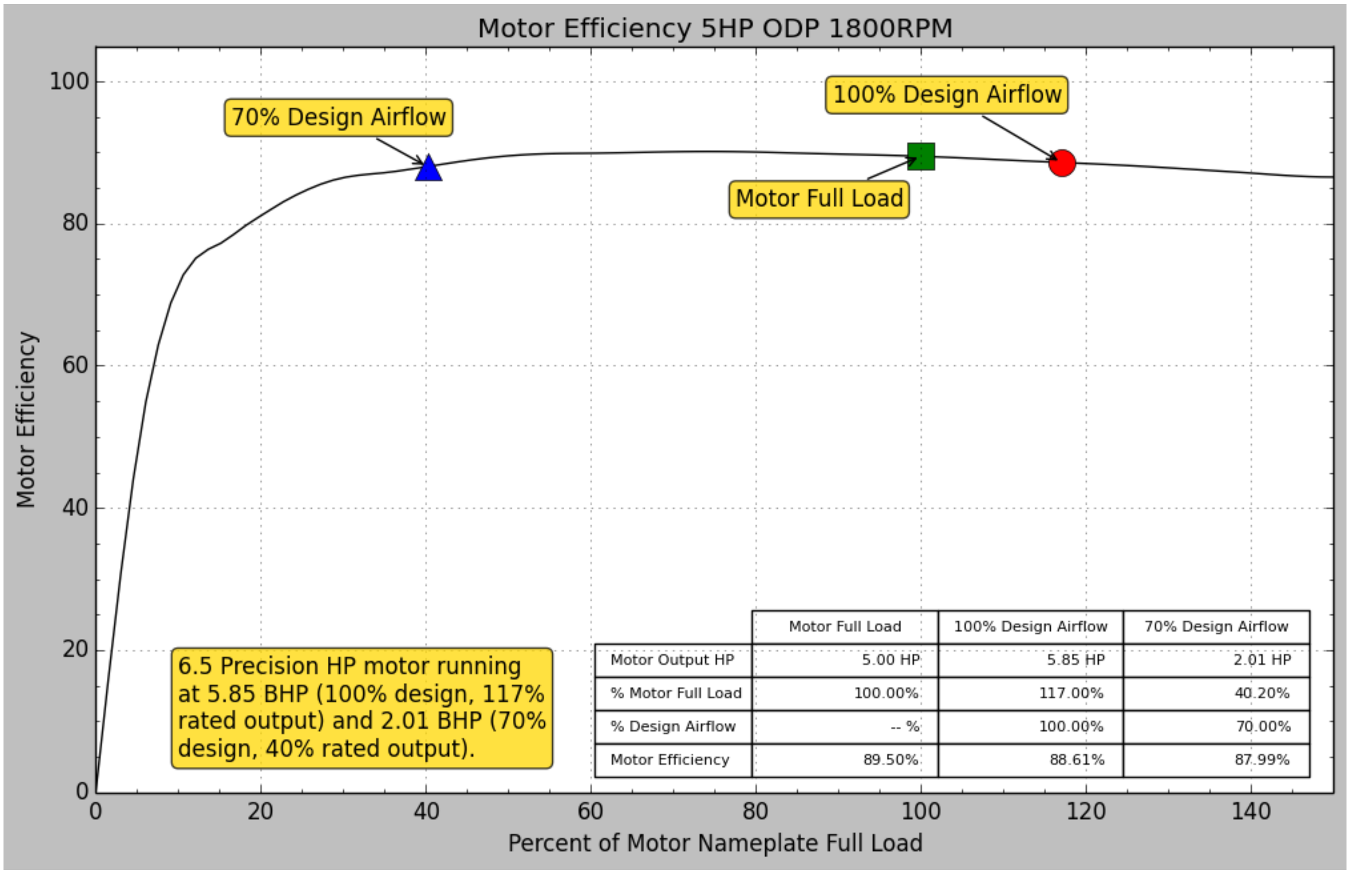
Figure 2. Selecting a traditional motor



	Motor Full Load	100% Design Airflow	70% Design Airflow
Motor Output HP	7.50 HP	5.85 HP	2.01 HP
% Motor Full Load	100.00%	78.00%	26.80%
% Design Airflow	-- %	100.00%	70.00%
Motor Efficiency	91.20%	91.00%	85.94%

Let's instead select a Trane Precision Motor 6.5 hp motor, as show in Figure 3. In this example, the full-load efficiency at 89 percent is slightly less than the nameplate efficiency of 90 percent, but the part-load efficiency of 88 percent is close to the nameplate efficiency. Compared to the 7.5 hp motor selection with a part-load efficiency of 86 percent, the Precision Motor 6.5 hp motor selection efficiency of 88 percent is noticeably higher. Note that this difference will amplify considerably if the average fan operation decreases below 70 percent load.

Figure 3. Selecting a Precision Motor



NEMA Motor HP Increments

The motor hp increments defined by NEMA lose resolution as the motor hp increases:

Table 1. NEMA motor hp increments

1	1.5	2	3	5	7.5	10	15
20	25	30	40	50	60	75	100

Let's consider a fan that requires 10.01 bhp. A 15 hp motor would normally get selected which uses only 10.01 bhp/15 hp = 2/3 the capability of the motor. Now let's assume these motors are to be used in a 6-fan array being driven by a single inverter. That's 10.01*6 = 60.06 bhp versus 15*6 = 90 hp. Since we are using a single inverter, our VFD is sized based on the first increment above 90hp: 100 hp. In this example, 40 hp is unneeded and all upstream components including wiring, fusing, disconnects and of course the inverter, are oversized by this amount.

Not only does this require a motor that's much larger than what's required, the turndown capability of the motor in the high efficiency range is severely compromised. Let's revisit the motor efficiency curves illustrated in the section above. Even a 10 percent reduction in flow or speed will drop the motor below 50 percent load (0.67 * (0.9)^3)*100 < 50%) thus reducing the part-load efficiency of the motor significantly.

Trane Precision Motor Offering

The Precision Motor offering affords an opportunity to both maximize part-load motor efficiency and precisely size the motor for the application. Testing of the motors in the actual application ensure UL requirements are met and motor reliability isn't compromised.

The ability to precisely size the motor yields a number of substantial benefits with few drawbacks:

Benefits

- Higher part-load motor efficiencies

- Lower cost
  - Both of the motor and upstream components
- Lighter weight (increased serviceability)
- Smaller (physically) upstream electrical components
- Reduced torque penalty for flexible motor speed selections above 90Hz
  - Instead of having to jump up a full NEMA frame size, these new motor horsepower sizes will minimize the impact of >90 Hz selections.

Drawbacks

- Lower full-load motor efficiencies

The Precision Motor offering takes a general purpose motor and re-rates that motor for higher rated loads. The motors become definite purpose, evaluated and approved for use with the fan and ambient conditions realized by Trane air-handling equipment.

Offering Scope

The Precision Motor offering is available with the following:

- Direct-drive fans only
- 1200 and 1800 RPM motors only
- ODP or TEFC
- Available in all voltages
- UL-listed unit
- Shaft grounding ring as standard

Terminology

In general, we will refer to two motor options:

- Precision Motor option – incremental motors up to and including the next nameplate hp
- NEMA Motor option – traditional motor increments as defined by NEMA

Examples:

- 6.5 hp will be a Precision Motor option
- 7.5 hp can be either a Precision Motor option (a 5.0 hp motor applied at 7.5 hp) or a NEMA motor option (a 7.5 hp motor)

Precision Motor HP Increments

The increments for the Precision Motor offering are listed in the table below. Smaller motors (up to 30 hp) will have 0.5 hp increments and larger motors will have 1.0 hp increments. With one exception, all motors are applied up to and including the next NEMA nameplate hp. The only exception – a 3.0 hp motor rated up to 5.0 hp – is excluded as the motor manufacturer is not required to test beyond 150 percent load.

Table 2. Precision Motor hp increments

Nominal hp	2	3	5	7.5	10	15	20	25	30
	2.5	3.5	5.5	8	10.5	15.5	20.5	25.5	31
	3	4	6	8.5	11	16	21	26	32
		4.5	6.5	9	11.5	16.5	21.5	26.5	33
			7	9.5	12	17	22	27	34
Precision Motor hp			7.5	10	12.5	17.5	22.5	27.5	35
					13	18	23	28	36
					13.5	18.5	23.5	28.5	37
					14	19	24	29	38
					14.5	19.5	24.5	29.5	39
					15	20	25	30	40

As mentioned previously, the Precision Motor offering is designed to:

- Continue to meet EPACT efficiency requirements at full-load for the Precision Motor™ hp increment
- Maintain design temperature limits.

A list of motors that don't meet these goals is included below.

Table 3. Precision Motor hp exclusions

HP	Voltage	Speed	Enclosure	Load, hp
5	230/460	1800	ODP	7
5	230/460	1800	ODP	7.5
5	200	1800	ODP	7
5	200	1800	ODP	7.5
10	200	1800	ODP	14
10	200	1800	ODP	14.5
10	200	1800	ODP	15
5	230/460	1200	TEFC	7
5	230/460	1200	TEFC	7.5
2	230/460	1800	TEFC	2.5
2	230/460	1800	TEFC	3

Note: TOPSS™ selection software will disallow the selection of these motors.

Competitive Information

Unlike some implementations that utilize "air-over" motors, the Trane offering uses non-custom motors for replacement. An air-over motor must be replaced with another air-over motor with identical attributes. A Precision Motor on the other hand, can be replaced in one of two ways:

- Through the Trane Parts Center
- Using the exact motor manufacturer and motor spec number (not the catalog number) listed on the motor nameplate

Static pressure optimization virtually eliminates the need for fan staging to boost a fan's mechanical efficiency. However, fan staging can sometimes be used to boost a motor's electrical efficiency if the system is designed to operate at very low turndowns. The Precision Motor option can significantly increase the amount of time a motor will operate in an efficient region thus reducing or eliminating any benefits of fan staging.

Selection Process

If the system is variable-air-volume (VAV), operating well below design a substantial amount of the time, choose a motor with maximum part-load efficiency. If the system is constant volume, or if substantial operation is expected to occur within 90-100 percent of load, choose a motor with maximum full-load efficiency. Note that it's possible a NEMA motor hp choice might be a better option in these scenarios so be sure to compare the full-load efficiency of a Precision Motor option with the full-load efficiency of a NEMA motor option. When redundancy is required in a multiple-fan system, continue to size the motor based on the redundancy hp, not the design hp.

To aid in the selection of a motor, the TOPSS™ selection software includes two new outputs:

- Full-load motor efficiency
- Part-load motor efficiency

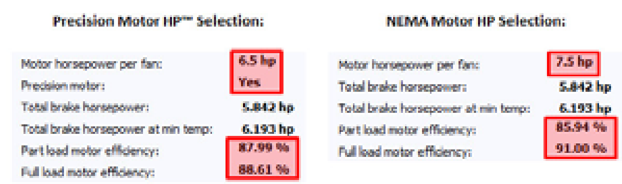
Full-load motor efficiency is based on the design load, not the motor rated load (e.g., 5.85 not 6.5). Part-load efficiency assumes 70 percent of design load (0.7*5.85). Simply compare the part-load or full-load motor efficiencies in TOPSS and choose the motor with the highest, relevant efficiency.

Note: The legacy "NEMA nominal motor efficiency" output field in TOPSS, which represented the EPACT requirements for nameplate efficiency, will no longer be output.

Note that the efficiency at the Precision Motor rated hp will meet or exceed EPACT requirements but the full-load motor efficiency could be less.

Consider the example TOPSS output in Figure 5. The Precision Motor selection has lower full-load efficiency (89%) than the NEMA selection (91%). However, the part-load efficiency for the Precision Motor selection (88%) is superior to the NEMA selection (86%).

Figure 4. TOPSS output - Precision Motor selections vs. NEMA motor selections

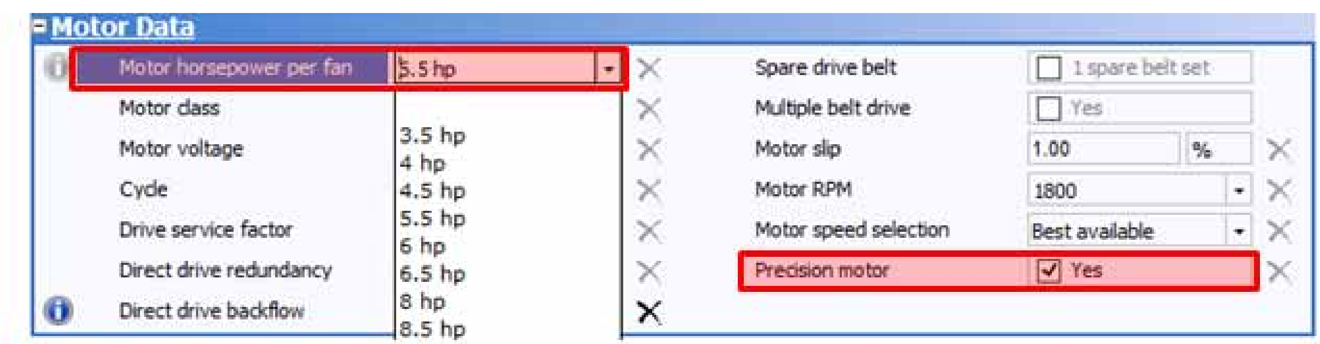


A new motor selection input called "Precision motor" is included in the "Motor Data" section of TOPSS. "Yes" will enable Precision Motor selections and will be the default. When enabled, the "Motor horsepower per fan" drop-down will include any incremental hp selections that are available. If some hp options are missing (e.g., 5.0, 7.0, and 7.5 in the image below), the motor is likely excluded. If the increment equals a conventional NEMA motor hp (e.g., 5.0, 7.5, etc...), the motor is a Precision Motor selection, not a NEMA selection. If the NEMA selection is desired, clear the "Precision motor" checkbox.

Note: If the Precision Motor option is not desired, this checkbox should be cleared.

Note that the fan curve hp lines won't change – only the NEMA motor hp lines will be displayed.

Figure 5. TOPSS Precision Motor inputs



Installation and Replacement

Care must be taken when:

- Selecting field-provided equipment

or

- Replacing the motor

The unit nameplate, not the motor nameplate, should be consulted. The Performance Climate Changer™ Air Handler Installation, Operation and Maintenance (IOM) manual contains additional information.

Field-Provided Components

To size a field-provided VFD, choose a VFD with an output current greater than the unit FLA.

Fan arrays require an independent motor connection for each fan. However, note that the unit nameplate may list a total FLA instead of an FLA per motor.

Note that if a larger motor is needed after installation, the factory must be consulted to ensure an adequate motor will be provided.

Warning Sticker

The motor nameplate will always match the motor's NEMA rating; only the unit nameplate will accurately reflect motor data. The following label, located near the motor nameplate, will therefore be included on ALL direct-drive fans - regardless if a NEMA or Precision Motor option is selected. The label appropriately alerts any downstream users that the unit nameplate, not the motor nameplate, must be consulted for installation of field-provided components or motor replacement information.

Figure 6. Label alerting user to see unit nameplate

REFER TO THE UNIT NAMEPLATE FOR ELECTRICAL SIZING OR REPLACEMENT

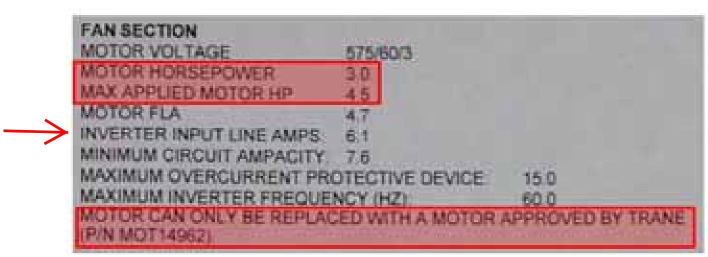
Do not use the MOTOR nameplate for electrical sizing or replacement. Refer to the UNIT nameplate for electricial information and refer to the unit Installation, Operation and Maintenance (IOM) Manual for information on motor replacement.

Unit Nameplate

The unit nameplate should be used to size upstream components or to replace a motor. There are now two motor hp lines on the unit nameplate:

- MOTOR HORSEPOWER – The NEMA motor horsepower value
- MAX APPLIED MOTOR HP – The Precision Motor™ horsepower value

Figure 7. Unit nameplate

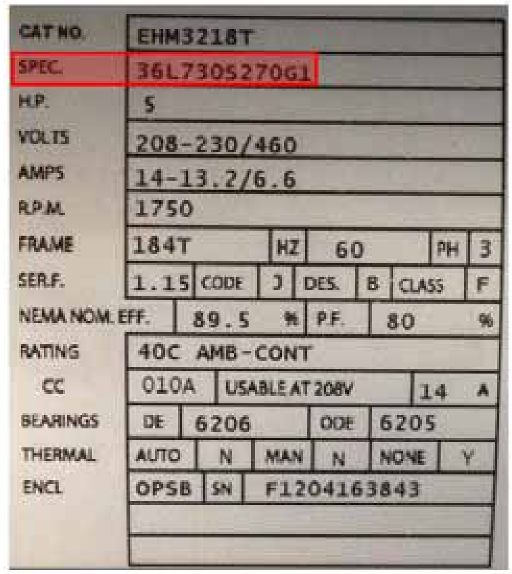


Note that MOTOR FLA and the other related outputs are a function of the MAX APPLIED MOTOR HP, not the MOTOR HORSEPOWER.

Pay particular attention to the note at the bottom of the nameplate. The motor must be replaced through Trane Aftermarket using this part number. Alternatively, the EXACT motor that shipped with the unit can be purchased locally. To ensure an exact replacement, use the motor's SPEC number - not the catalog number, model number, or individual motor attributes (e.g., RPM, voltage, etc…).

An example motor nameplate with the SPEC number highlighted is shown in Figure 8.

Figure 8. Motor nameplate



Frequently Asked Questions

The following questions are frequently asked regarding the new Precision Motor motor option.

- Why aren't the motor manufacturers already doing this? Why are the motors so oversized?
  – General purpose motors need to be sized for constant torque applications in a wide variety of environments. A motor contained within an air handler is subject to a variable torque application and operating in a conditioned environment.
- Are the motors not running in the safety factor (e.g., 15 percent)? Aren't motors supposed to only operate in the service factor for a short range of time?
  – A Precision Motor isn't necessarily operating in the safety factor. The safety factor is meant to provide a means to operate a general purpose motor beyond nameplate conditions for a short period of time. A Precision Motor is technically operating in a definite purpose application and has been tested within that application.
- Should a higher safety factor be used? Is the service factor affected?
  – No, the standard 10-15 percent safety factor (e.g., hp >= 1.1*bhp or hp >= 1.15*bhp) is still adequate.
  – There's no change to the service factor when switching from a NEMA motor to a Precision Motor.

- Are there any concerns with reliability and/or warranty?
  - As mentioned above, the motors are designed by the motor manufacturer to be general purpose. The Precision Motor offering was tested and limited to maintain existing temperature limits and ensure reliability/warranty would not be compromised.
- Are the motors considered “air-over”?
  - The motors are not considered air-over. Specific (motor manufacturer and SPEC number), general purpose motors that have been evaluated and approved for use in these applications are used instead.
- How do the FLA’s differ?
  - As the Precision Motor offering increments increase, the FLAs increase as well.
  - Note that it’s possible that a Precision Motor hp selection could have a higher FLA than a NEMA hp selection because of motor inefficiency. For example, it’s possible a 14.5 hp Precision Motor could have a higher FLA than a 15 hp NEMA motor.
- What value do I use for the fan power limitation (e.g., ASHRAE 90.1)?
  - If using the hp method in lieu of the bhp method, the Precision Motor option should aid in the selection of a motor that will meet the limitation.
  - Be sure to select a motor no larger than the first available NEMA motor size greater than the brake horsepower (bhp). For example, if the bhp = 5.85, a 7.5 hp motor is the largest that can be selected. Any Precision Motor increment between and including 6.0 to 7.5 can be selected, just don’t go above 7.5 hp.
- Can the motors still be selected at or above synchronous speed?
  - Yes, the testing also considered flexible motor speed selections to ensure they can continue to operate as they do today.
- Is minimum turndown affected?
  - No, motors can still be turned down to the same minimum speeds.
- Are VFDs also available with incremental hp ratings?
  - As standard, the VFD label will not change. In other words, a 25 hp VFD would be used for a unit containing a 22.5 Precision Motor motor. This is no different from how the speed affects VFDs today.
- Do the motor temperature classes (e.g., F and H) change?
  - No, there will be no change to the motor temperature classes. For example, a class ‘H’ NEMA motor will remain class ‘H’ with the Precision Motor option.
- Do the motors meet NEMA MG 31?
  - A Precision Motor motor is no different than a NEMA motor for purposes of NEMA MG 31.
- Are acoustics affected?
  - No, acoustics are not affected.
- What if my application runs substantially less than 70 percent of design?
  - Continue to evaluate and select based on part-load motor efficiency.

Summary

Trane’s Precision Motor™ offering can maximize part-load efficiency while reducing upstream, connected load costs.

Testing of the motors in the actual application ensure UL requirements are met and motor reliability isn’t compromised. These non-custom motors become definite purpose, evaluated and approved for use with the fan and ambient conditions realized by Trane air handling equipment.

Care must be taken when replacing a motor or when sizing field-provided equipment to use the unit nameplate, not the motor nameplate.

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