White Paper

Ducted Systems Fan Power Requirements of ASHRAE 90.1-2016

August 2020

Introduction

Standard 90.1-2016 of the American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE) outlines the requirements for fan power in HVAC systems. The International Energy Conservation Code (IECC-2018) also adopts the same requirement. In particular, the standard can easily be misinterpreted when applied to **direct drive fan motor** combinations.

Fan Power Limitations

Section 6.5.3.1.1 of the ASHRAE standard applies to all fans in a HVAC system when the nameplate of the motor exceeds 5 hp. Table 1, which is duplicated from the table in the ASHRAE standard, shows the fan limits. Option 1 provides name plate horsepower limit. Option 2 provides brake horsepower limit. The system must meet the requirements of either option.

This requirement applies to the supply, return and exhaust fans that are integral to an RTU. It also applies to fans that work independent of the RTU but are part of the complete system such as remote exhaust fans. For example, remote exhaust fans and fan-powered terminal units.

Fan Efficiency

Section 6.5.3.1.3 of Standard 90.1-2016 identifies a required fan efficiency grade. This grade does not apply to unitary equipment less than 760 mbh (63 tons) because of exceptions 3 and 4 of section 6.5.3.1.3 where the equipment is designed and rated to meet AHRI and Standard 90.1 minimum efficiency. Equipment larger than 63 tons or not covered by a unit minimum efficiency standard must meet the fan efficiency grade (FEG).

Exception 3 refers to a list of equipment found in section 6.4.1.1, which includes electrically operated unitary air conditions and condensing units.[3]

The associated table 6.8.1-1 found in section 6.8 contains the necessary information for identifying the minimum efficiency requirements for air and water cooled unitary air conditioners.[4] Exception 4 in section 6.5.3.1.3 explains that fans that are part of equipment that has a third-party-certified seal for air or energy performance are exempt from the fan efficiency grade.[4] Johnson Controls units are tested and certified by an independent agency, the Air-conditioning, Heating and Refrigeration Institute (AHRI). Table 6.8.1-1[4] in section 6.8 also includes the test procedure carried out by the AHRI for each equipment type and their size:

- Air conditioners, air cooled
- Through the wall, air cooled
- Small duct velocity, air cooled
- Air conditioners, water cooled
- Air conditioners, evaporatively cooled
- Condensing units, air cooled
- Condensing units, water cooled
- Condensing units, evaporatively cooled [4]

Motor Horsepower

Section 6.5.3.1.2 specifies the maximum motor size of a fan. The specification also states that the bhp must be available on the design documents. This ensures that a code official can verify the compliance of the equipment.[5]

Table 1: Fan system, nameplate (hp) and brake horsepower limit

Constant Volume:	Option 1: hp < cfm × 0.0011
	Option 2: bhp < cfm × 0.00094 + A
Variable Volume:	Option 1: hp < cfm × 0.0015
	Option 2: bhp < cfm × 0.0013 + A

Section 6.5.3.1.2 also has four exceptions based on:

- Fans with less than 6 bhp when the next motor larger than the bhp has a nameplate rating within 50% of the bhp
- Fans that are 6 bhp and greater when the next motor larger than the bhp has a nameplate rating within 30% of the bhp
- Systems that are compliant with option 1 in section 6.5.3.1.1
- Fans with a motor nameplate hp of less than 1 hp

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Variable Speed Drives on Direct Drive Fan Motors

The fan motor size is selected based on the required CFM, total system static pressure, and fan performacne curves. The maximum motor speed is set to the design rpm of the fan at the rated airflow of the equipment. In most cases, this design rpm is below the motor's synchronous speed of 1800 rpm. The hp of the motor is calculated using this formula (where torque is measured in pounds):

$$\text{Horse power} = \frac{(\text{Torque} \times \text{rpm})}{5252}$$

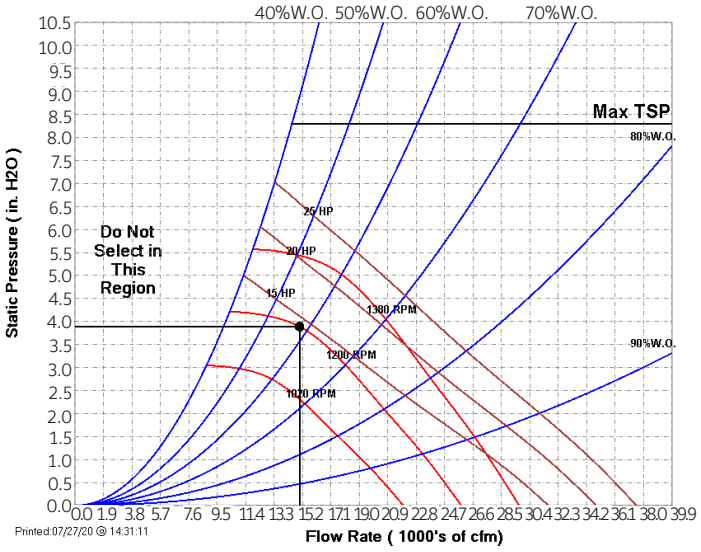
The hp indicated on the motor nameplate is at rated operating speed of the motor, which is normally 1770 rpm, 1200 rpm, or other. Decreasing the speed of the motor using a VFD decreases the hp of the motor while the torque remains constant.

Example

Table 2: Typical 40 ton package unit

Total capacity (4 comp)	497.2 MBH w/15 Stgs
IEER (At AHRI)	14.5
Supply airflow	15,000 cfm
Brake horsepower	14.1 bhp
Fan Speed (rpm)	1200 rpm
Supply fan motor	25 hp @ 1800 rpm
Supply total ESP	2.0 in. W.G.
Total static pressure	3.89 in. W.G.
MCA/MOP	1108 A/125 A at 460 V
Supply fan current draw	23.5 A

Figure 1: Fan curve



A rooftop unit's supply air fan is rated for the design airflow at 1150 rpm with a bhp = 14.1. According to the requirements of ASHRAE section 6.5.3.1.2, the maximum motor size is 15 hp. Under exception 2, the bhp could be raised 30% to 18.3 bhp, which is a 20 hp motor.

The speed of the motor must be reduced from the 1770 to 1200 using a VFD because the fan rpm is 1200.

We calculate the hp output of the 20 hp motor at the lower rpm of 1200 using the formula:

$$\text{Horse power} = \frac{(\text{Torque} \times \text{rpm})}{5252}$$

Torque remains constant:

$$\frac{hp_1}{rpm_1} = \frac{\text{Torque}}{5252} = \frac{hp_2}{rpm_2}$$

By adding the values, we see that:

$$\frac{15\ hp_1}{1800\ rpm_1} = \frac{\text{Delivered } hp_2}{1200\ rpm_2}$$

The resulting hp = 10.

The system requires 14.1 hp. As a result, a 15 hp motor does not work. We must look at 20 hp and 25 hp motors.

- 20 hp motor at 1770 rpm reduced to 1200 rpm = 13.3 hp
- 25 hp motor at 1770 rpm reduced to 1200 rpm = 16.7 hp

A 25 hp motor is the final selection. However, does this meet the requirements of ASHRAE 90.1-2016 section 6.5.3.1.2? The simple answer is yes; the 25 hp does meet 90.1-2016, and there is a negligible affect on MCA/MOP or other performance issues.

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Calculations of Fan System Power Limitations

Table 6.5.3.1-1 contains two options to calculate the maximum allowable hp for the application[1] (See Table 1, Figure 1 and 2).

Figure 2: Fan horsepower limit - constant volume

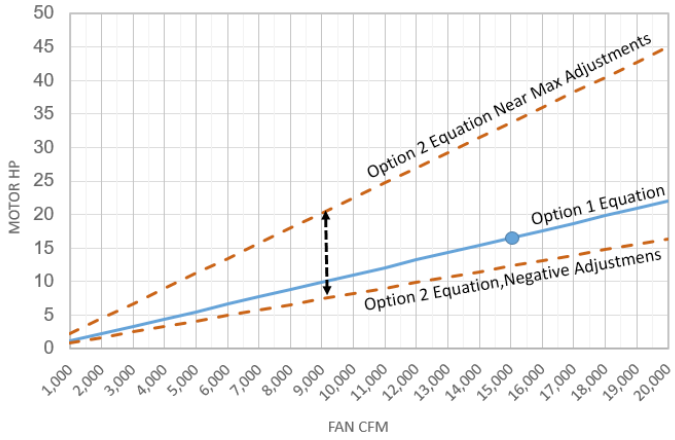
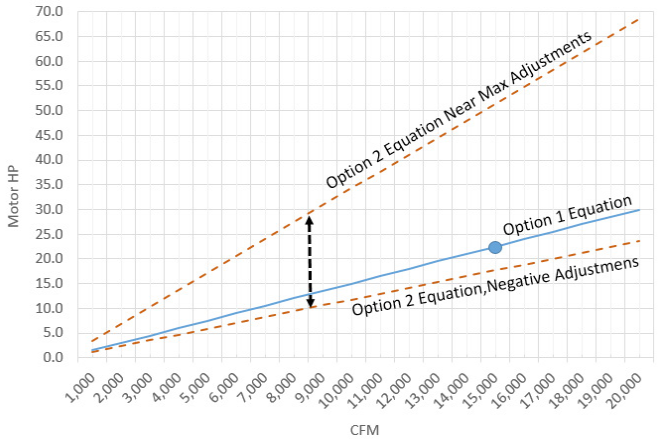


Figure 3: Fan horsepower limit - variable volume systems



Option 1 defines the nameplate motor horsepower limit of the system based as a linear function of CFM.

Option 2 is based on the brake hp of all fan motors in the system when operating at design conditions.

Each option has a different method of calculation depending on whether the system is **constant volume or variable air volume (VAV)**. Section 6.5.3.1.1 states that a single zone VAV must meet the requirements of constant volume[1]. Option 2 allows adjustment of the equation to account for specific static pressure which could result in a significant increase in horsepower. Typical adjustment factors include:

- Fully ducted return
- Air filters MERV 9 and greater
- Energy recovery device (for example, an energy recovery wheel (ERW)
- Sound attenuation

The consulting engineer is typically interested in whether the RTU meets the specification by itself. We will therefore concentrate on the fans and the equipment included within the RTU. For our 25 hp example, the unit clearly does NOT meet the option 1 requirement. However, when reviewing the system using option 2, the system does meet the limit requirement.

We have developed a spreadsheet to make these calculations easier. This spreadsheet clearly explains if the application and the selected equipment meet the nameplate or brake horsepower limitations.

Fan Power Calculation Spreadsheet

The required information is indicated by blue highlighted fields in the spreadsheet. The required information is found on your quotation data sheet from Selection Navigator. Inputs include:

- cfm at design conditions
- Nameplate and brake hp for each fan motor
- Inputs for air filters that are MERV 9 or greater
- ERW information and designation of cool or electric heat versions

The spreadsheet contains all of the required calculations. A green highlighted cell indicates that your application passes the required hp limitations while a red highlighted cell indicates a failure of the application to pass the required hp limitations.

See page 5 for an example of the calculation spreadsheet.
Refer to document 5773250-UTS-A-719 for the complete spreadsheet and ASHRAE table references.

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Calculation Example

A 40 Ton Premier unit is used in a VAV application with open return (no duct) and electric heat. The following information is added to the Fan Power Calculation Spreadsheet:

- **Supply Fan: 15,000 cfm**
  Fan bhp = 14.1
  Motor Nameplate = 25 hp

- **Merv 8 and 15 filters**

Using the spreadsheet calculations (Table 3), this unit does not meet the spec based on the Motor Nameplate, but it does meet the requirements based on bhp.

The spreadsheet does not calculate the Fan Power for the entire HVAC system. It does, however, provide a simple way to quickly prove compliance to your customer for the quoted equipment.

FAN POWER LIMITATIONS PER ASHRAE 90.1-2016 PARAGRAPH 6.5.3.1-1
RTU ONLY. EXCLUDES OTHER SYSTEM FANS (TERMINAL BOXES, SEPARATE EXHAUST FANS)

Note: Input fields are highlighted in blue						
Project name	**Example**					
Supply Airflow, CFM at Design Conditions	15000					
Option 1 Nameplate HP						
			Constant Volume or Single Zone VAV		**VAV System**	
SA Fan Motor Nameplate HP	25		ASHRAE 90.1 HP Limit: nameplate HP ≤ cfm x 0.0011		ASHRAE 90.1 HP Limit: hp ≤ cfm x 0.0015	
Exhaust Fan Motor Namplate HP	0					
Return Fan Motor Nameplate HP						
Total Rooftop HP	**25**		Max Nameplate HP (CV/SZVAV)	16.5	Max Nameplate HP (VAV)	22.5
			Meets 90.1 HP Limitation?	**NO**		**NO**
Option 2 Brake HP						
SA fan Brake HP at design conditions	14.1		**Constant Volume or SZ VAV**		**Variable Volume**	
Exhaust Fan Brake HP	0		ASHRAE 90.1 HP Limit: bhp ≤ cfm x 0.00094 + A		ASHRAE 90.1 HP limit: bhp ≤ cfm x 0.0013 + A	
Return Fan Brake HP						
Total Brake HP of RTU	**14.1**		Maximum allowable bhp ≤	**21.00**	Maximum allowable bhp ≤	**26.40**
		Pressure Drop Adjustments				
Ducted Return Y/N	Y	0.5				
Is ducted return for a laboratory or vivarium Y/N	N					
Return and/or exhaust airflow control devices? Y/N	N	0				
			Meets 90.1 bHP Limitation?	**NO**	**Meets 90.1 bHP Limitation?**	**YES**
MERV 9 to MERV 12 Air filter? Y/N	Y	0.5				
MERV 13 to MERV 15 Air filter? Y/N	Y	0.9				
MERV 16 or Greater Air Filter? Enter clean filter pressure drop at fan design conditions	0	0				
Energy Recovery Wheel? Enter Enthalpy Recovery Ratio	0	0				
Sound attenuation section (fans serving spaces with design background noise goals below NC35)? Y/N	N	0				
Cooling Only RTU? Y / N	N	0				
Electric Heat? Y / N	N	0				
Total Pressure Drop Adjustment		**1.9**				
A = PD x cfm/4131 =		**6.9**				

Table 3: Fan power limitations per ASHRAE 90.1-2019 Paragraph 6.5.3.1-1 RTU only

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References

Notes:

1. Chapter 6: Heating, Ventilating and Air Conditioning, (*Energy Standard for Buildings Except Low-Rise Residential Buildings I-P Edition*. Atlanta: GA: ASHRAE, 2016), 94.
2. Chapter 6: Heating, Ventilating and Air Conditioning, 94.
3. Chapter 6: Heating, Ventilating and Air Conditioning, 74-75.
4. Chapter 6: Heating, Ventilating and Air Conditioning, 110-111.
5. Chapter 6: Heating, Ventilating and Air Conditioning, 94.
6. Chapter 6: Heating, Ventilating and Air Conditioning, 95.

Bibliography

1. American Society of Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE). ANSI/ASHRAE/IES Standard 90.1-2016. *Energy Standard for Buildings Except Low-Rise Residential Buildings (I-P Edition)*. Sections 6.5.3.1.1, 6.5.3.1.2, 6.8.1-1. Atlanta: GA: ASHRAE.