

Direct-Drive Fans

Bill Dunn

Melia Associates LLC

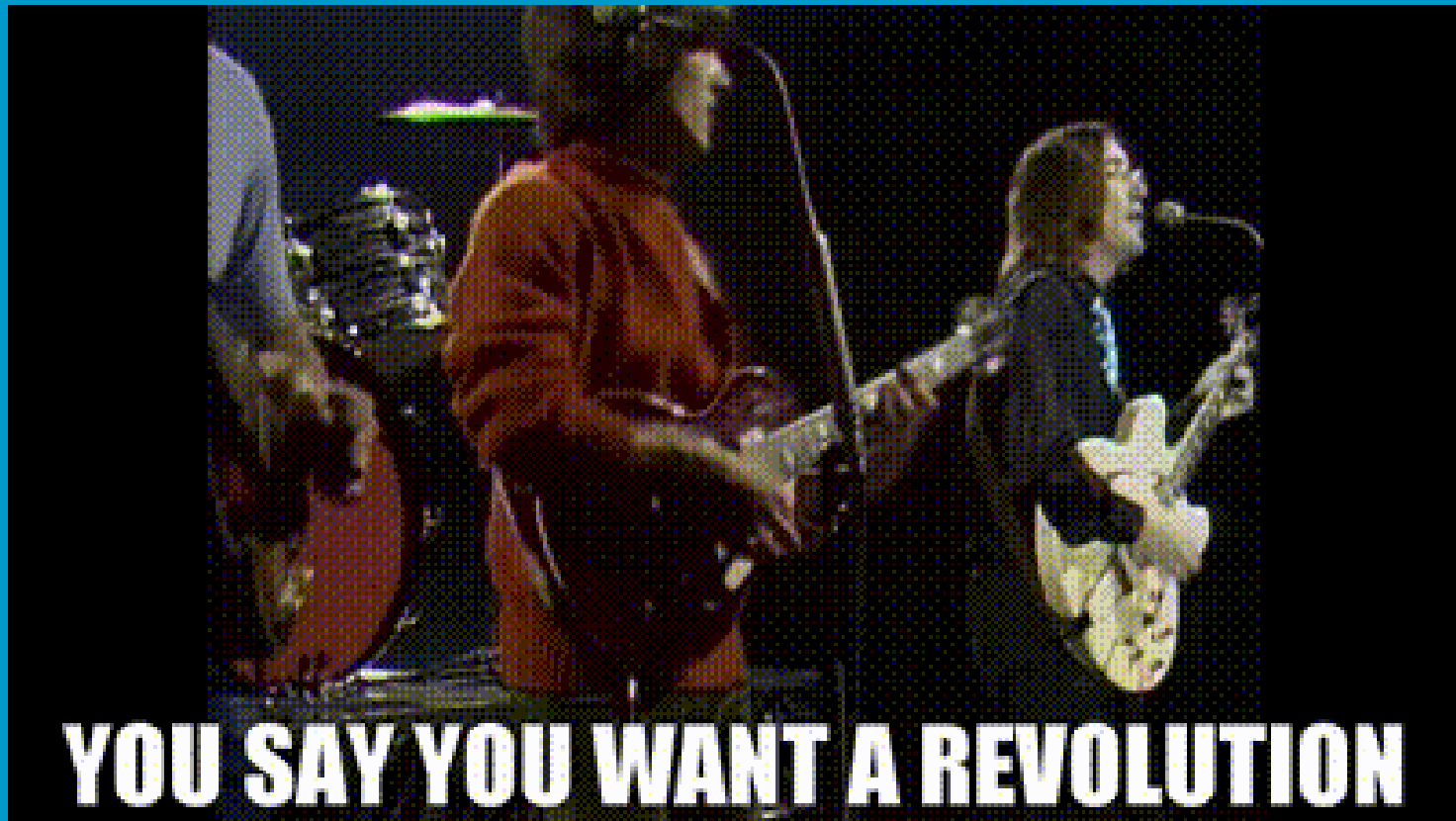


***Direct-Drive Fans are
Awesome...***

***Direct-Drive Fans are
Awesome....***

Except When They're Not!

Direct-Drive Revolution



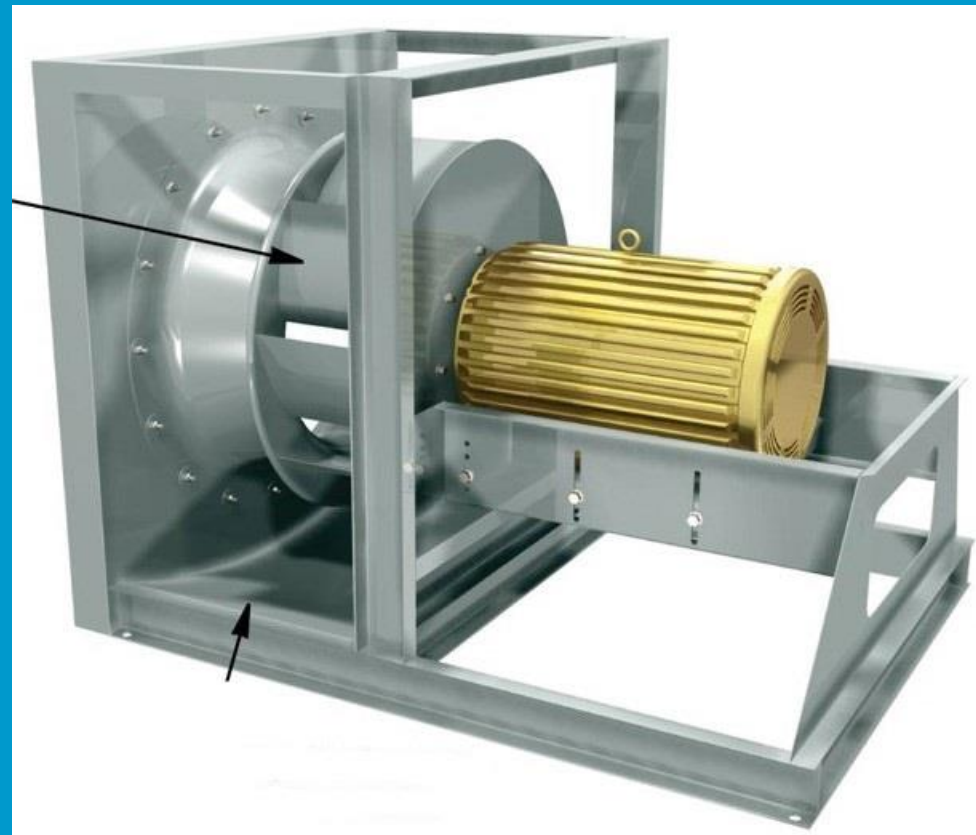
Direct-Drive Revolution

15 years ago, the vast majority of fans & blowers were belt-drive – even tiny roof fans doing 100 CFM.



Direct-Drive Revolution

Now, the vast majority of fans & blowers are direct-drive – even models with 50+ HP motors.



Direct-Drive Revolution

Why the change?

Direct-Drive Revolution

Why the change?

***Because Airflow is
directly related to
fan Impeller speed***

Direct-Drive Revolution

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fan Impeller speed***

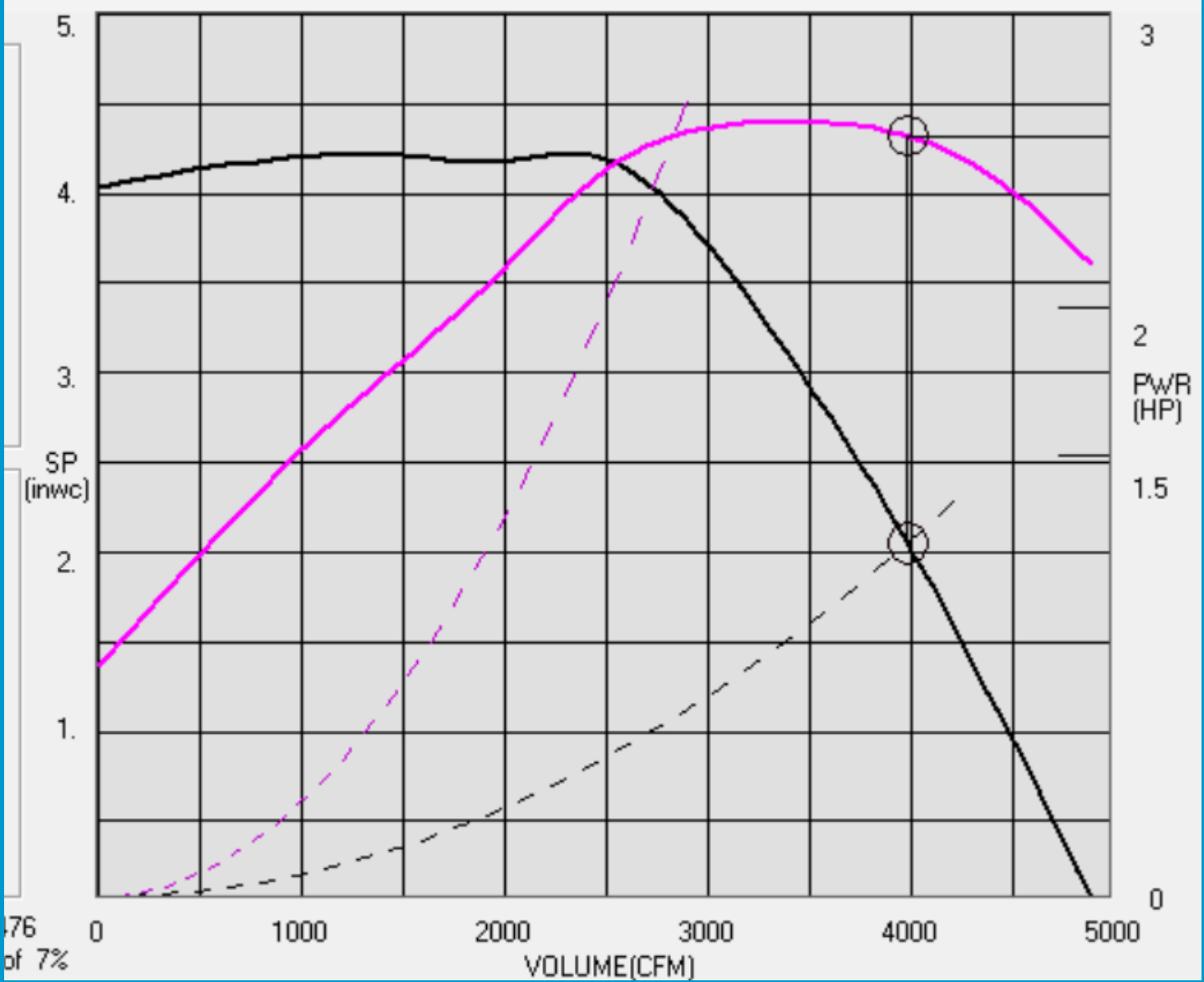
When most motors were constant speed, it was difficult to balance airflow

Direct-Drive Revolution

One option: volume dampers, which add static pressure and reduce airflow

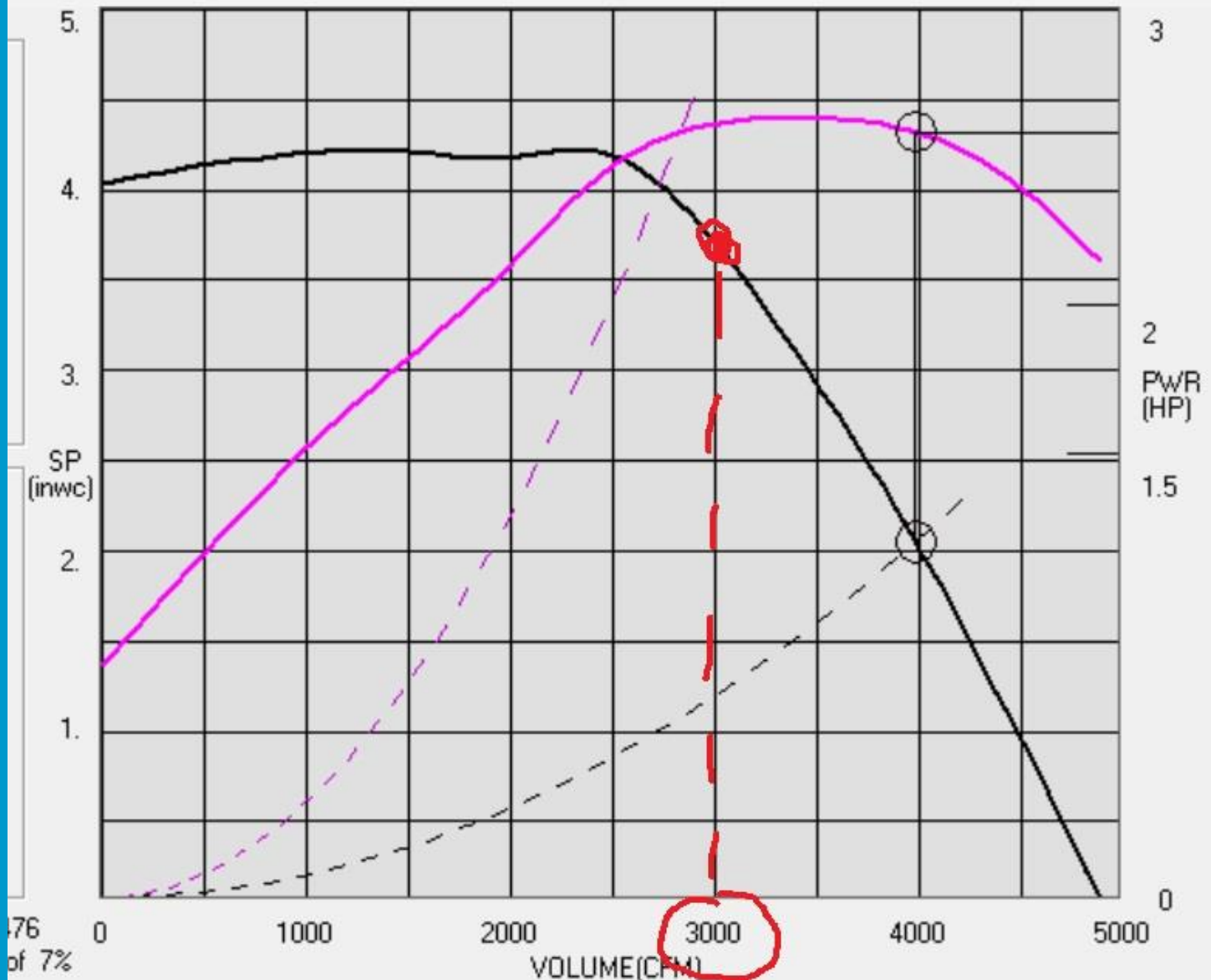


Fan Curve Display - 165 CPS



76
of 7%

Fan Curve Display - 165 CPS



Direct-Drive Revolution

But.... Volume Dampers
do 2 things:

1. Use more energy

2. Generate more noise

Direct-Drive Revolution

For decades, belt-drive fans were King.

Direct-Drive Revolution

For decades, belt-drive fans were King. WHY?

Direct-Drive Revolution

For decades, belt-drive fans were King. WHY?

Because you could adjust the fan speed, even though the motor was constant speed.

Direct-Drive Revolution

HOW?

Direct-Drive Revolution

HOW?

By adjusting the diameters of the pulleys.

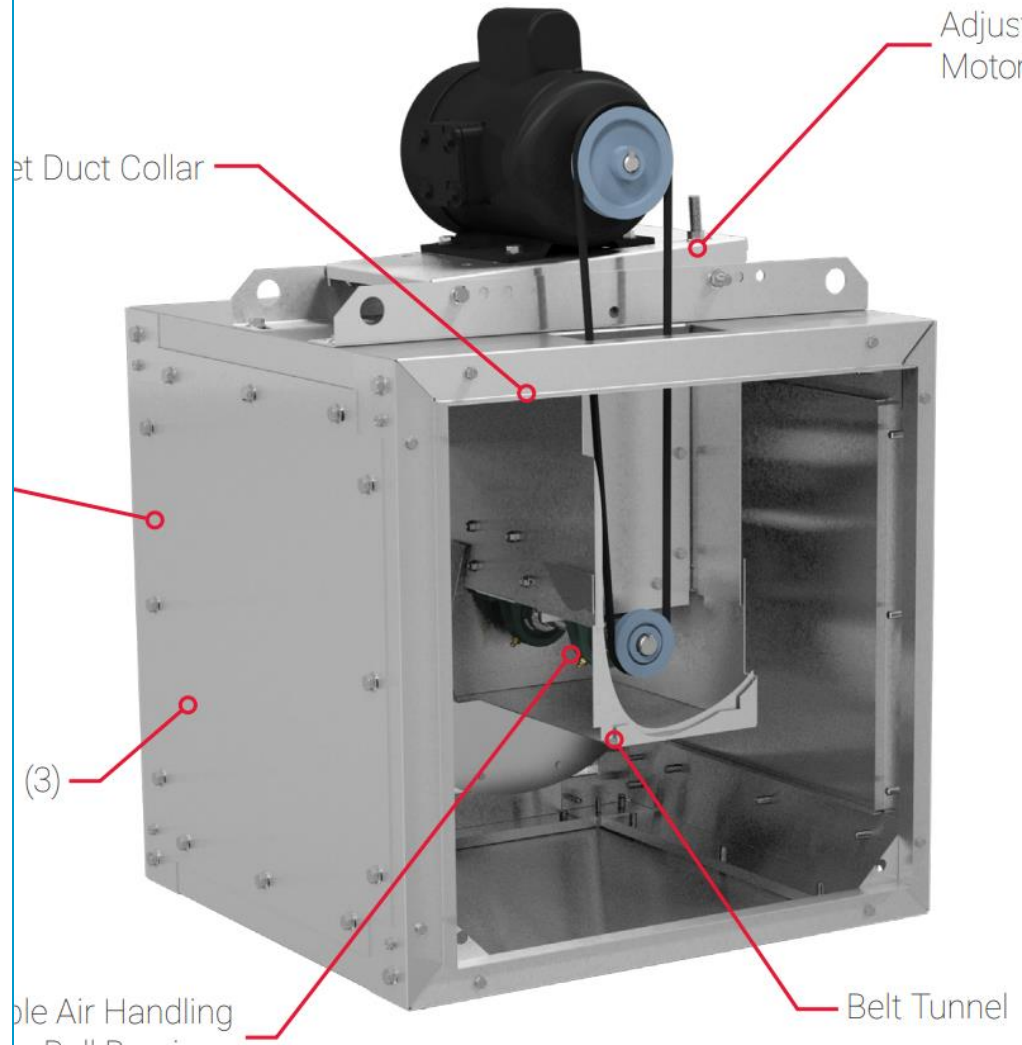
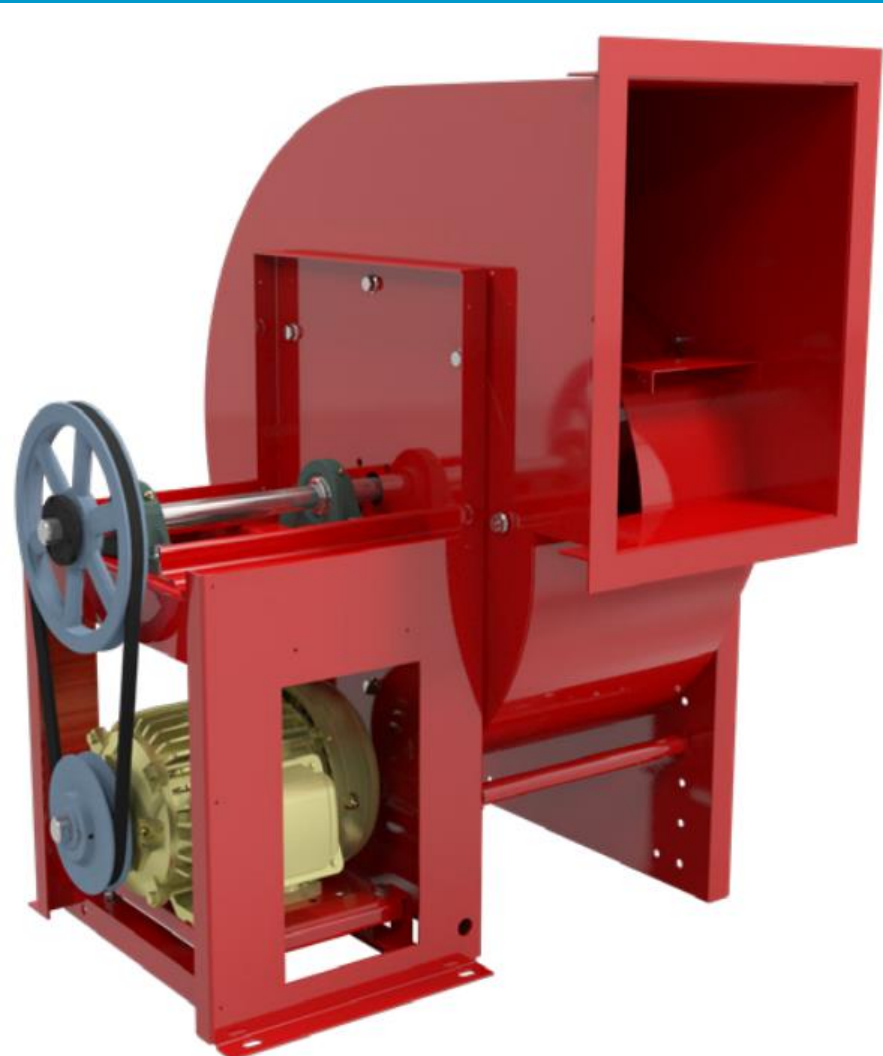
Direct-Drive Revolution

Think 10-speed bicycles...



Direct-Drive Revolution

Same thing with Belt-Drive fans.



Direct-Drive Revolution

So, what caused this revolution?



Direct-Drive Revolution

First, Variable Frequency Drives
(VFDs)



Direct-Drive Revolution

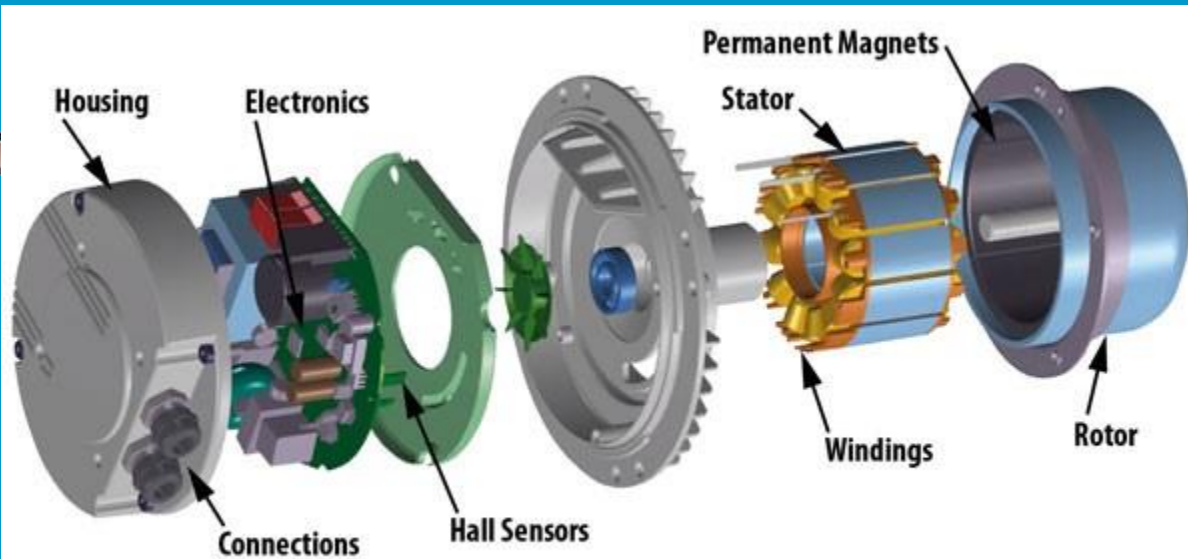
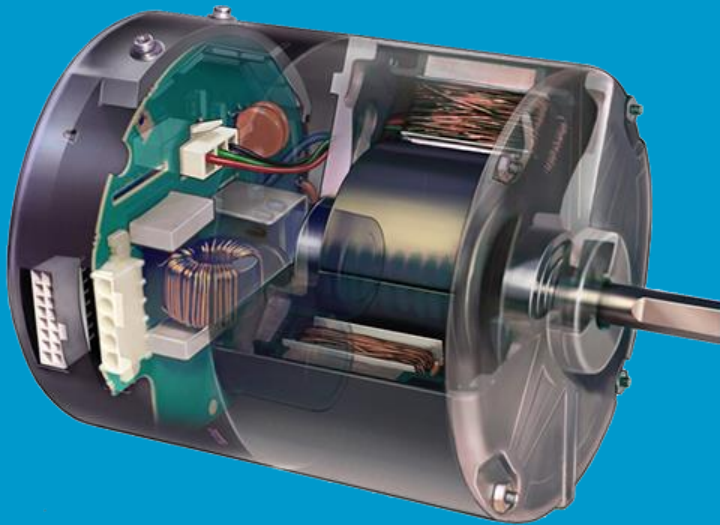
First, Variable Frequency Drives (VFDs)



VFDs vary the speed of the motor by varying the input frequency supplied to the motor. They convert AC input power to DC, then convert it back to AC using IGBT power transistors and Pulse Width Modulation (PWM).

Direct-Drive Revolution

Second, Electronically Commutated Motors (ECM)



EC permanent magnet motor exploded view.

Direct-Drive Revolution



We can now control the speed of the fan motors...
Easily. Economically. Reliably.

Advantages of Direct Drive fans

Advantages of Direct Drive fans

- Less maintenance

Advantages of Direct Drive fans

- Less maintenance
- Lower cost *

Advantages of Direct Drive fans

- Less maintenance
- Lower cost *
- Easy to balance

Advantages of Direct Drive fans

- Less maintenance
- Lower cost *
- Easy to balance
- More efficient – no drive losses

Routine Maintenance

Belt-Drive fans

1. Tighten all sheave & bearing set screws

Setscrews				Hold Down Bolts	
Size	Key Hex Across Flats	Recommended Torque Inch-lbs.		Size	Wrench Torque (inch-lbs)
		Min.	Max.		
No.10	3/32"	28	33	3/8"-16	240
1/4"	1/8"	66	80	1/2"-13	600
5/16"	5/32"	126	156	5/8"-11	1200
3/8"	3/16"	228	275	3/4"-10	2100
7/16"	7/32"	348	384	7/8"- 9	2040
1/2"	1/4"	504	600	1" - 8	3000
5/8"	5/16"	1104	1200	1-1/8" - 7	4200
3/4"	3/8"	1440	1800	1-1/4" - 7	6000

Routine Maintenance Belt-Drive fans

2. Check sheave alignment

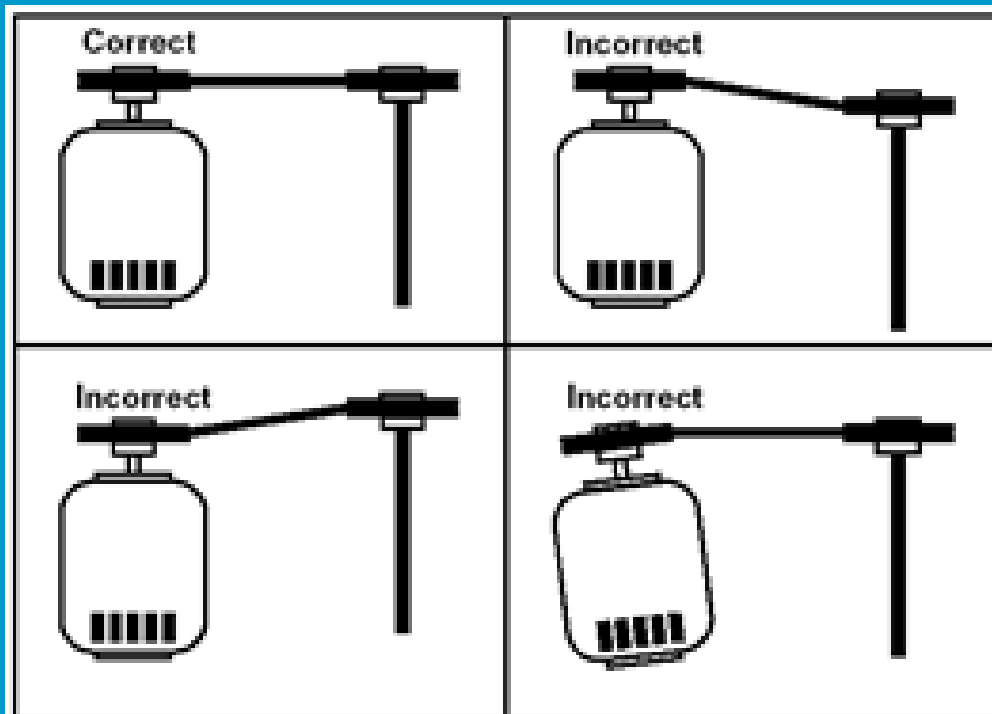
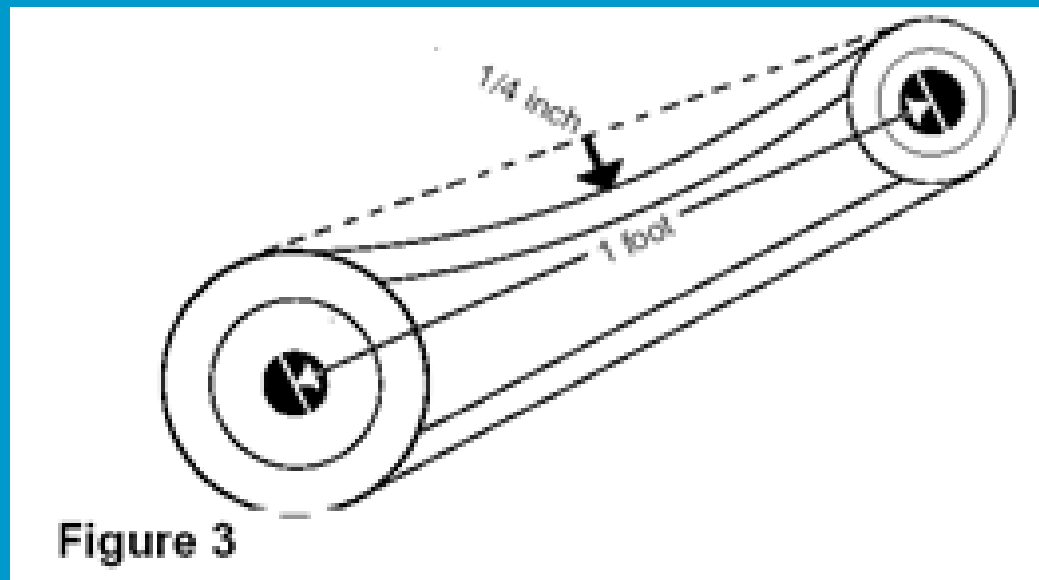


Figure 4

Routine Maintenance Belt-Drive fans

3. Check belt tension

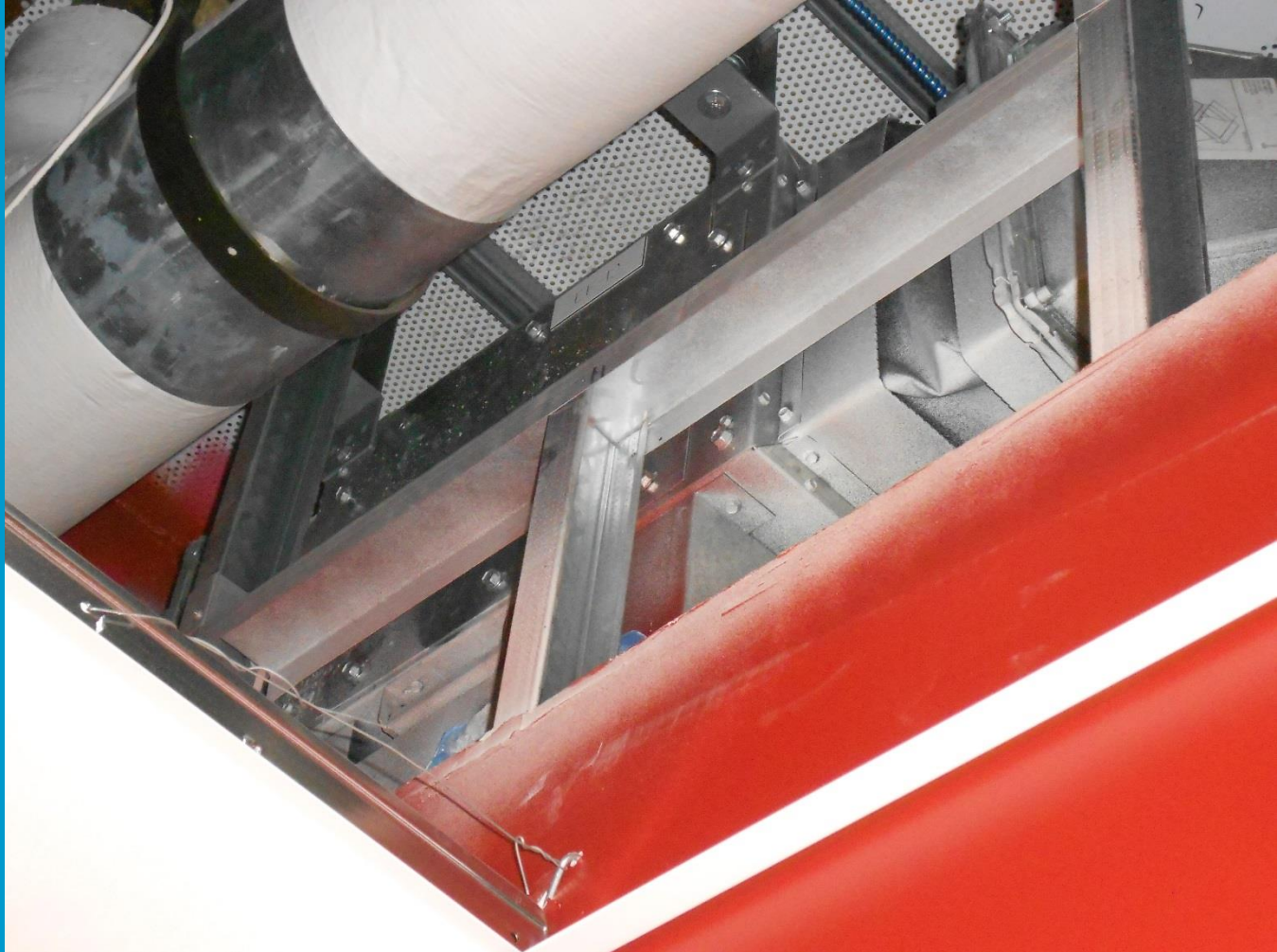


Routine Maintenance Belt-Drive fans

4. Grease bearings

Conditions Chart			
RPM	Temperature	Fan Status	Greasing Interval
100	Up to 120°F	Clean	6 to 12 months
500	Up to 150°F	Clean	2 to 6 months
1000	Up to 210°F	Clean	2 weeks to 2 months
1500	Over 210°F	Clean	Weekly
Any Speed	Up to 150°F	Dirty	1 week to 1 month
Any Speed	Over 150°F	Dirty	Daily to 2 weeks
Any Speed	Any Temperature	Very Dirty	Daily to 2 weeks
Any Speed	Any Temperature	Extreme Conditions	Daily to 2 weeks

Hide 'N Seek Where is the fan? How to service it?



Routine Maintenance Direct-Drive fans

1. Inspect fan. Make sure it's running.

Routine Maintenance Direct-Drive fans

1. Inspect fan. Make sure it's running.
2. Go get a coffee, cuz you're done, son!

Direct-Drive Revolution

Bottom line:

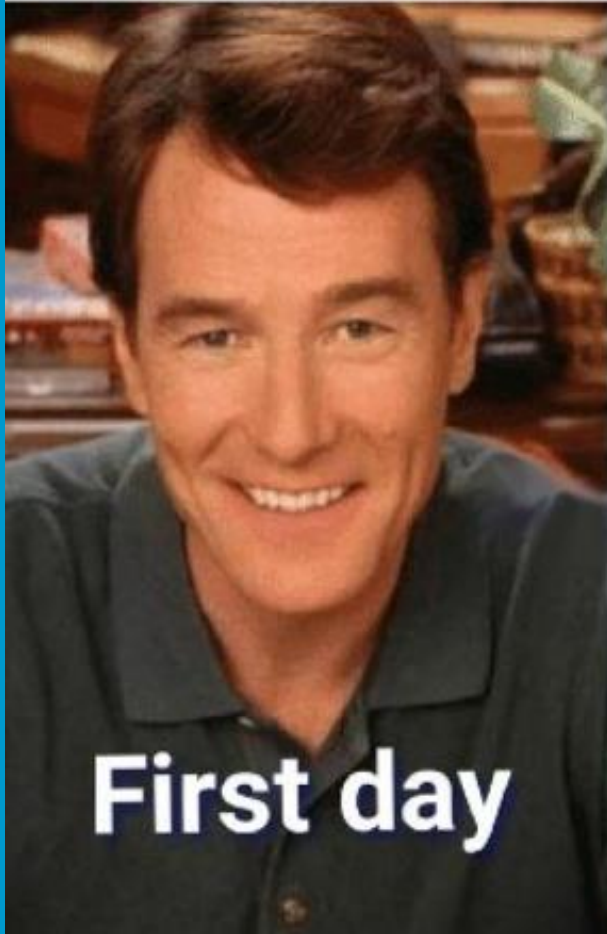
Direct-Drive Fans are

Awesome!

Who loves Direct-Drive fans
more than anybody?

Who loves Direct-Drive fans more than anybody?

Your first job as a Facilities Manager



First day



**One month
later**

Who loves Direct-Drive fans
more than anybody?



Direct-Drive Revolution

Bottom line:

Direct-Drive Fans are

Awesome!

Direct-Drive Revolution

Bottom line:

Direct-Drive Fans are

Awesome!

Except When They're Not

Dis-advantages of Direct Drive fans

Dis-advantages of Direct Drive fans

1. More difficult to replace
motor

Motor inside fan. Hard to reach.

When motor is detached from fan wheel, the wheel drops.



Good luck
replacing
these large
direct-drive
motors.



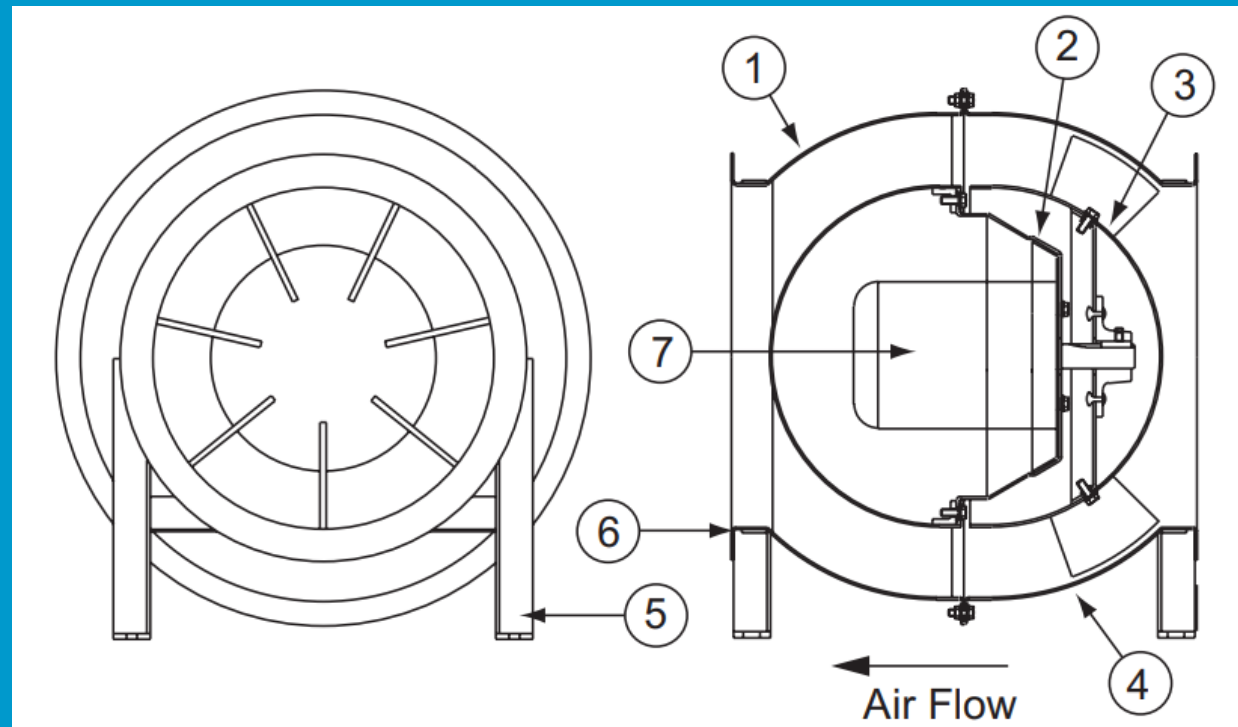
Belt drive:
Motor is outside of
fan, easy to
access.
Fan wheel never
moves while motor
is replaced.



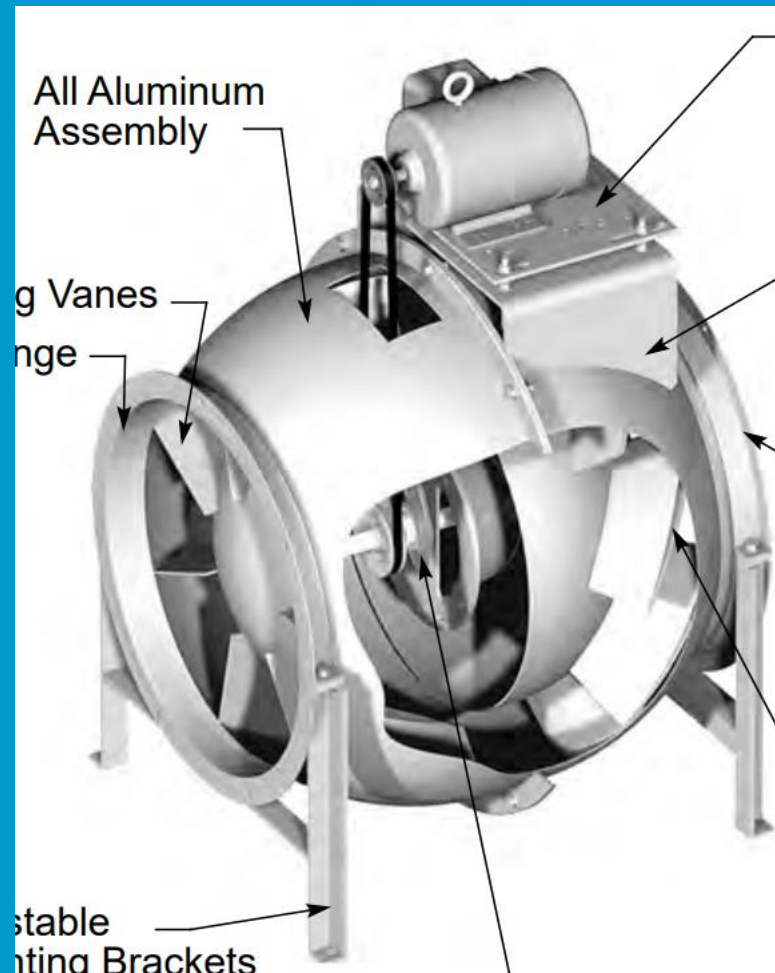
Dis-advantages of Direct Drive fans

1. More difficult to replace motor
2. Motor often in the airstream

All-aluminum fan,
often used for
dishwasher exhaust.
But motor in airstream
gets soaked.



Belt-drive motor out of
airstream.
(Belt tunnel can be
provided to protect belt.)



Dis-advantages of Direct Drive fans

1. More difficult to replace motor
2. Motor often in the airstream
3. Tricky making selections

Belt-Drive:

Model	Drive	Volume	SP	Power	Motor	RPM	Max (Fan)	OVEL	TSPD
		CFM	inwc	HP	HP		RPM	fpm	fpm
150 ACEB	Belt	2500	.75	.744	.750	1454	1519	1697	5709
165 ACEB	Belt	2500	.75	.626	.750	1166	1296	1402	5036
180 ACEB	Belt	2500	.75	.613	.750	968	1513	1178	4561
195 ACEB	Belt	2500	.75	.589	.750	837	1348	1004	4272

Belt-Drive:

Model	Drive	Volume	SP	Power	Motor	RPM	Max (Fan)	OVEL	TSPD
		CFM	inwc	HP	HP		RPM	fpm	fpm
150 ACEB	Belt	2500	.75	.744	.750	1454	1519	1697	5709
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195 ACEB	Belt	2500	.75	.589	.750	837	1348	1004	4272

Direct-Drive:

Model	Drive	Volume	SP	Power	Motor	Speed	Hz	RPM	Motor	Max (Fan)	OVEL	TSPD
		CFM	inwc	HP	HP	Control			RPM	RPM	fpm	fpm
150C15D	Direct	2738	.75	.793	.750	NONE	-	1550	1550	1550	1858	6086
165C11D	Direct	2408	.75	.518	.750	NONE	-	1140	1140	1140	1351	4924
150C15D	Direct	2500	.75	.669	.750	FSC	-	1454	1550	1550	1697	5709
180C10D	Direct	2500	.75	.545	.750	FSC	-	968	1050	1075	1178	4561
150C17D (VF)	Direct	2500	.75	.669	.750	EC	-	1454	1725	1486	1697	5709
150C17D (VF)	Direct	2500	.75	.669	1.25	EC	-	1454	1725	1762	1697	5709
150C17D (VF2)	Direct	2500	.75	.669	1	EC	-	1454	1725	1633	1697	5709
165C17D (VF)	Direct	2500	.75	.557	.625	EC	-	1166	1725	1192	1402	5036
165C17D (VF)	Direct	2500	.75	.557	1.25	EC	-	1166	1725	1502	1402	5036
165C17D (VF2)	Direct	2500	.75	.557	1	EC	-	1166	1725	1285	1402	5036
180C17D (VF)	Direct	2500	.75	.545	.625	EC	-	968	1725	997	1178	4561
180C17D (VF)	Direct	2500	.75	.545	1.25	EC	-	968	1725	1256	1178	4561
180C17D (VF2)	Direct	2500	.75	.545	1	EC	-	968	1725	982	1178	4561
195C17D (VF)	Direct	2500	.75	.523	1.25	EC	-	837	1725	1089	1004	4272
195C17D (VF2)	Direct	2500	.75	.523	1.50	EC	-	837	1725	987	1004	4272
150C16DEC	Direct	2500	.75	620w	1	EC	-	1444	1650	1650	1697	5670
150C16DEC	Direct	2500	.75	620w	1	EC	-	1444	1650	1650	1697	5670
150C17D (VF)	Direct	2500	.75	.669	.750	EC	-	1454	1725	1486	1697	5709
150C17D (VF)	Direct	2500	.75	.669	1.25	EC	-	1454	1725	1762	1697	5709
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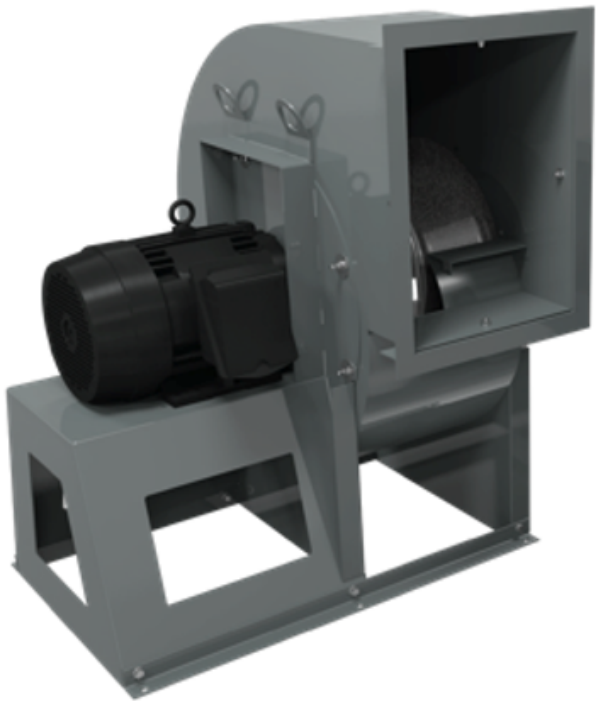
Dis-advantages of Direct Drive fans

1. More difficult to replace motor
2. Motor often in the airstream
3. Tricky making selections
4. Induction motors w/ VFDs

Induction Motors

Number of Poles (p)	Synchronous Speed at 50 Hz, in rpm	Synchronous Speed at 60 Hz, in rpm
2	3000	3600
4	1500	1800
6	1000	1200
8	750	900
10	600	720
12	500	600

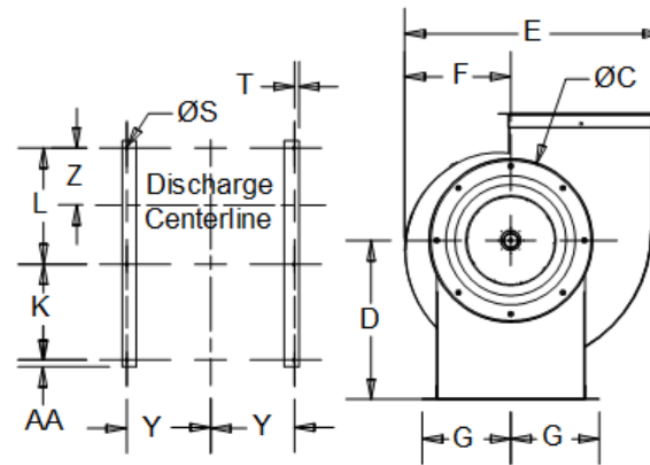
Induction Motors



	<u>Rated</u>	<u>Nominal</u>
•	3600	(3450)
•	1800	(1725)
•	1200	(1140)
•	900	(860)

- ***Nominal RPM: Fan and Motor Size***

Sometimes the best selection operates above 60 Hz



Performance

Qty	Catalog Number	Flow (CFM)	SP (inwc)	Fan RPM	Power (HP)	FEG	FEI	Speed Ctrl/Hz
1	195 CPS	5000	3.00	1749	3.65	85	1.27	VFD/61

Altitude (ft): 180 Temperature (F): 70

Motor Information

HP	RPM	Volts/Ph/Hz	Enclosure	FLA	VFD Rated
5	1725	460/3/60	ODP -PE	7.6	Yes

NEMA Premium® efficiency motor per MG-1 (2014) Table 12-12
 FLA based on NEC (2017) Table 430.250

NEMA table 30-1

Section IV
APPLICATION CONSIDERATIONS

MG: 1-2011
Part 30, Page 9

**Table 30-1
MAXIMUM SAFE OPERATING SPEEDS FOR DIRECT-COUPLED MOTORS USED ON ADJUSTABLE
FREQUENCY CONTROLS**

Horsepower	Totally Enclosed Fan-Cooled			Open Dripproof		
	Synchronous Speed at 60 Hz					
	3600	1800	1200	3600	1800	1200
	Maximum Safe Operating Speed					
1/4	7200	3600	2400	7200	3600	2400
1/3	7200	3600	2400	7200	3600	2400
1/2	7200	3600	2400	7200	3600	2400
3/4	7200	3600	2400	7200	3600	2400
1	7200	3600	2400	7200	3600	2400
1.5	7200	3600	2400	7200	3600	2400
2	7200	3600	2400	7200	3600	2400
3	7200	3600	2400	7200	3600	2400
5	7200	3600	2400	7200	3600	2400
7.5	5400	3600	2400	7200	3600	2400
10	5400	3600	2400	5400	3600	2400
15	5400	3600	2400	5400	3600	2400
20	5400	3600	2400	5400	3600	2400
25	5400	2700	2400	5400	2700	2400
30	5400	2700	2400	5400	2700	2400
40	4500	2700	2400	5400	2700	2400
50	4500	2700	2400	4500	2700	2400
60	3600	2700	2400	4500	2700	2400
75	3600	2700	2400	3600	2700	2400
100	3600	2700	1800	3600	2700	1800
125	3600	2700	1800	3600	2700	1800

NEMA MG 1 table 30-1

Allowable Over Speed Limits

POLES / RPM	200% / 120Hz	150% / 90Hz	125% / 75Hz
2 / 3600	Up to 5 HP	Up to 30 HP	Up to 50 HP
4 / 1800	Up to 20 HP	Up to 150 HP	Up to 300 HP
6 / 1200	Up to 75 HP	Up to 350 HP	N/A

BASED ON NEMA MG 1 TABLE 30-1

Conclusion:

It is perfectly OK to run an induction motor above 60 Hz with a VFD...

As long as you don't exceed the nameplate amps.

Another issue...

Fan manufacturers must provide motor large enough to run if VFD goes into bypass, that is, at 60 Hz

Example:

Kitchen fan, 3000 cfm @ 2.0" ESP,
Best selection is at 1351 rpm,
VFD at 47 Hz, BHP = 1.78

Performance

Qty	Catalog Number	Flow (CFM)	SP (inwc)	Fan RPM	Power (HP)	FEG	FEI	Speed Ctrl/Hz
1	245VX17D	3000	2.00	1351	1.78	63	1.15	VFD/47

Altitude (ft): 180 Temperature (F): 70

Motor Information

HP	RPM	Volts/Ph/Hz	Enclosure	FLA	VFD Rated
5	1725	208/3/60	ODP -PE	16.7	Yes

FLA based on NEC (2017) Table 430.250

However, even though the BHP = 1.78, the fan manufacturer must provide 5 HP motor.

Motor Specifications:	
Motor Hp:	5
Enclosure:	ODP -3 PHASE
Voltage:	208
Motor Rpm:	1725

Motor/Drive Options:	
Thermal OverLoad:	No
Shaft Grounding Ring: ?	Yes
Efficiency * :	Premium - 89.5 %
Motor VFD Rated: ?	Yes

**UL listing available only when motors are supplied by

* Motors meet EPACK/EISA requirements where applicable

SE motor not available. PE motor is selected

Fan Bhp: 1.781 Fan RPM: 1351

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Why? Because if the VFD goes into bypass (60 Hz), The BHP jumps to 3.71. The next largest motor is 5 HP.

ookware v8.0 - Fan Law Calculator ✕

ons Help

Initial Conditions:

CFM:

SP:

RPM:

HP:

Estimate HP based on Motor Amps

New Conditions:

CFM

SP

RPM

HP

The Fan Laws have a *huge* impact on motor HP.

CFM varies Directly with RPM

$$CFM1/CFM2 = RPM1/RPM2$$

SP varies with the Square of the RPM

$$SP1/SP2 = (RPM1/RPM2)^2$$

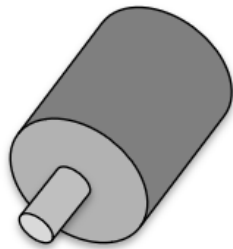
HP varies with the Cube of the RPM

$$HP1/HP2 = (RPM1/RPM2)^3$$

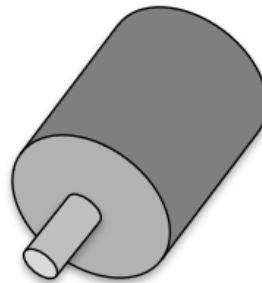
A Couple More Direct-Drive DIS-advantages:

A Couple More Direct-Drive DIS-advantages:

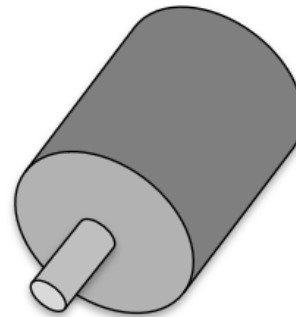
- Lower RPM motors have more poles, which means they're larger, heavier, and more expensive.



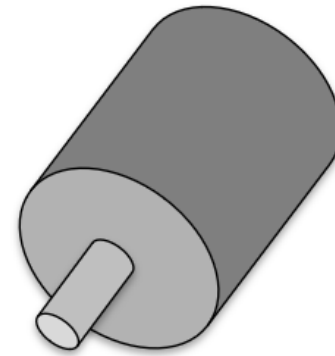
3600



1800



1200



900

Motor Sizes Increase at Lower RPM

A Couple More Direct-Drive DIS-advantages:

- Lower RPM motors have more poles, which means they're larger, heavier, and more expensive.

5 HP				
RPM	860	1140	1725	3450
Poles	8	6	4	2
Relative Cost	4.3	2.6	1	1.3
Frame Size	254T	215T	184T	182T
Weight	180	135	80	70

A Couple More Direct-Drive DIS-advantages:

- *Sometimes—like during a worldwide pandemic—microchips needed for EC Motors sit on a container ship in Long Beach Harbor for many months, making the lead time for direct-drive fans jump to 20+ weeks, while belt-drive fans can ship in 2 days.*

EC Motors are amazing, but...



Control module

Motor module

Be careful of the...

Motor Specifications:

Motor Hp: 1/6

Enclosure: OPEN -1 PHASE

Voltage: 115 (110/120)

Motor Rpm: 1725

EC speed control options selected on next screen.

(HT) designation by HP indicates higher torque version of motor.
Three phase motor selections are offered in (VF2) products on previous screen.

Motor price below is for motor mounted speed control version.

Motor/Drive Options:

Thermal OverLoad: No

Shaft Grounding Ring: ? No

Efficiency * : Standard -

Motor VFD Rated: ? No

**UL listing available only when motors are supplied by Cook.

*Motors meet EPACT/EISA requirements where applicable.

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Cancel

EISA Information

Fan Bhp: .156 Fan RPM: 1193

This motor NOT available on 24 hr express

Programmable Max RPM is: 1201

InvNum	Description	XP*	Std Lead Time*	List	Total List
801680	120 ACED	1d	4w	\$684.00	\$1536.00
700116	OPEN -1/6Hp - 115V/1 PH/ 60 1725/0000 -EC	3d	4w	\$852.00	

'Programmable Max RPM'

Motor Specifications:

Motor Hp:

Enclosure:

Voltage:

Motor Rpm:

EC speed control options selected on next screen.

(HT) designation by HP indicates higher torque version of motor.
Three phase motor selections are offered in (VF2) products on previous screen.

Motor price below is for motor mounted speed control version.

Motor/Drive Options:

Thermal OverLoad:

Shaft Grounding Ring: ?

Efficiency * :

Motor VFD Rated: ?

**UL listing available only when motors are supplied by Cook.

*Motors meet EPACT/EISA requirements where applicable.

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Cancel

EISA Information

Fan Bhp: .156 Fan RPM: 1193

This motor NOT available on 24 hr express

Programmable Max RPM is: 1201

Invtum	Description	XP*	Std Lead Time*	List	Total List
801680	120 ACED	1d	4w	\$684.00	\$1536.00
700116	OPEN -1/6Hp - 115V/1 PH/ 60 1725/0000 -EC	3d	4w	\$852.00	

Select 1/4 HP, then...

Motor Specifications:

Motor Hp:

Enclosure:

Voltage:

Motor Rpm:

EC speed control options selected on next screen.

Motor/Drive Options:

Thermal OverLoad:

Shaft Grounding Ring: ?

Efficiency *:

Motor VFD Rated: ?

**UL listing available only when motors are supplied by Cook.

*Motors meet EPACK/EISA requirements where applicable.

(HT) designation by HP indicates higher torque version of motor.
Three phase motor selections are offered in (VF2) products on previous screen.

Motor price below is for motor mounted speed control version.

Fan Bhp: .156 Fan RPM: 1193

This motor NOT available on 24 hr express

Programmable Max RPM is: 1374

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Next >

Cancel

EISA Information

InvNum	Description	XP*	Std Lead Time*	List	Total List
801680	120 ACED	1d	4w	\$684.00	\$1536.00
700108	OPEN -1/4Hp - 115V/1 PH/ 60 1725/0000 -EC	3d	4w	\$852.00	

Programmable Max RPM jumps to 1374 !

Motor Specifications:

Motor Hp: 1/4
Enclosure: OPEN -1 PHASE
Voltage: 115 (110/120)
Motor Rpm: 1725

EC speed control options selected on next screen.

Motor/Drive Options:

Thermal OverLoad: No
Shaft Grounding Ring: ? No
Efficiency *: Standard -
Motor VFD Rated: ? No

**UL listing available only when motors are supplied by Cook.

*Motors meet EPACK/EISA requirements where applicable.

(HT) designation by HP indicates higher torque version of motor.
Three phase motor selections are offered in (VF2) products on previous screen.

Motor price below is for motor mounted speed control version.

Fan Bhp: .156 Fan RPM: 1193

This motor NOT available on 24 hr express

Programmable Max RPM is: 1374

< Back

Next >

Cancel

EISA Information

InvNum	Description	XP*	Std Lead Time*	List	Total List
801680	120 ACED	1d	4w	\$684.00	\$1536.00
700108	OPEN -1/4Hp - 115V/1 PH/ 60 1725/0000 -EC	3d	4w	\$852.00	

Same List Price means...

Motor Specifications:

Motor Hp: 1/6
Enclosure: OPEN -1 PHASE
Voltage: 115 (110/120)
Motor Rpm: 1725

EC speed control options selected on next screen.

(HT) designation by HP indicates higher torque version of motor.
Three phase motor selections are offered in (VF2) products on previous screen.

Motor price below is for motor mounted speed control version.

Motor/Drive Options:

Thermal OverLoad: No
Shaft Grounding Ring: ? No
Efficiency * : Standard -
Motor VFD Rated: ? No

**UL listing available only when motors are supplied by Cook.

*Motors meet EPACT/EISA requirements where applicable.

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Cancel

EISA Information

Fan Bhp: .156 Fan RPM: 1193
This motor NOT available on 24 hr express
Programmable Max RPM is: 1201

InvNum	Description	XP*	Std Lead Time*	List	Total List
801680	120 ACED	1d	4w	\$684.00	\$1536.00
700116	OPEN -1/6Hp - 115V/1 PH/ 60 1725/0000 -EC	3d	4w	\$852.00	

It's the EXACT SAME motor !!

Motor Specifications:

Motor Hp: 1/4
Enclosure: OPEN -1 PHASE
Voltage: 115 (110/120)
Motor Rpm: 1725

EC speed control options selected on next screen.

Motor/Drive Options:

Thermal OverLoad: No
Shaft Grounding Ring: ? No
Efficiency *: Standard -
Motor VFD Rated: ? No

**UL listing available only when motors are supplied by Cook.

*Motors meet EPACK/EISA requirements where applicable.

(HT) designation by HP indicates higher torque version of motor.
Three phase motor selections are offered in (VF2) products on previous screen.

Motor price below is for motor mounted speed control version.

Fan Bhp: .156 Fan RPM: 1193

This motor NOT available on 24 hr express

Programmable Max RPM is: 1374

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Cancel

EISA Information

InvNum	Description	XP*	Std Lead Time*	List	Total List
801680	120 ACED	1d	4w	\$852.00	\$1536.00
700108	OPEN -1/4Hp - 115V/1 PH/ 60 1725/0000 -EC	3d	4w	\$852.00	

Submittal page snip:

Performance

Qty	Catalog Number	Flow (CFM)	SP (inwc)	Fan RPM	Power (HP)	FEG	Speed Control
1	120C17DOR92VF	900	.500	1193	.156	n/a(<1HP)	EC

Altitude (ft): 180 Temperature (F): 70

Motor Information

HP	RPM*	Volts/Ph/Hz	Enclosure	RLA
1/6	1725	115/1/60	OPEN -EC	2.4



*Motor programmed to max speed of 1201 RPM.

RLA based on motor manufacturer's data at programmed HP and max RPM.

Motor is electronically/thermally protected.

Submittal page snip:

Which number...

Performance

Qty	Catalog Number	Flow (CFM)	SP (inwc)	Fan RPM	Power (HP)	FEG	Speed Control
1	120C17DOR92VF	900	.500	1193	.156	n/a(<1HP)	EC

Altitude (ft): 180 Temperature (F): 70

Motor Information

HP	RPM*	Volts/Ph/Hz	Enclosure	RLA
1/6	1725	115/1/60	OPEN -EC	2.4



*Motor programmed to max speed of 1201 RPM.

RLA based on motor manufacturer's data at programmed HP and max RPM.

Motor is electronically/thermally protected.

Submittal page snip: ...is more noticeable?

Performance

Qty	Catalog Number	Flow (CFM)	SP (inwc)	Fan RPM	Power (HP)	FEG	Speed Control
1	120C17DOR92VF	900	.500	1193	.156	n/a(<1HP)	EC

Altitude (ft): 180 Temperature (F): 70

Motor Information

HP	RPM*	Volts/Ph/Hz	Enclosure	RLA
1/6	1725	115/1/60	OPEN -EC	2.4



*Motor programmed to max speed of 1201 RPM.

RLA based on motor manufacturer's data at programmed HP and max RPM.

Motor is electronically/thermally protected.

BEWARE

BEWARE

Direct-Drive Fans are Great!

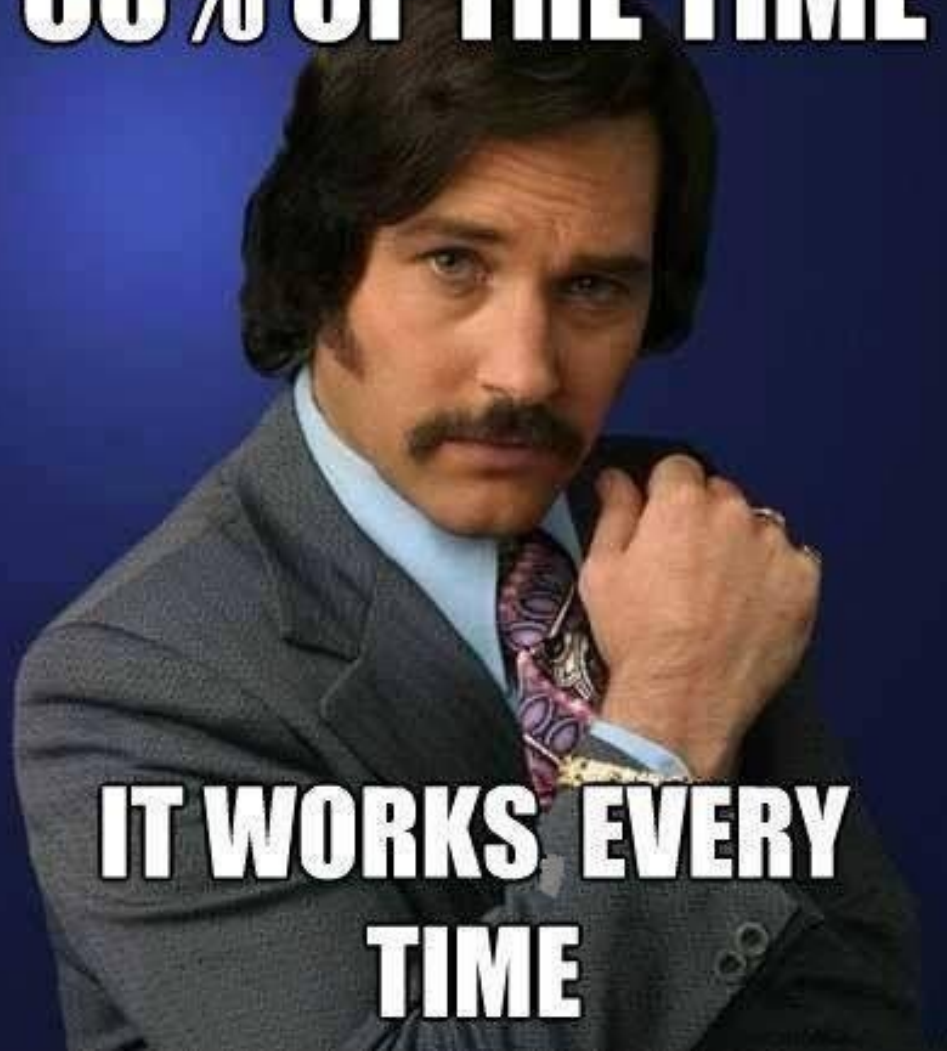
BEWARE

Direct-Drive Fans are Great!

But Not Always.

With a Direct-Drive Fan....

60% OF THE TIME



**IT WORKS EVERY
TIME**