Estimating Part-Load Performance of Fan Motors and Drives Using AMCA 207

Lisa Cherney

Education Manager, AMCA International

Session Moderator

- Joined AMCA in February 2019
- Responsible for development of AMCA’s education programs; staff liaison for the Education & Training Committee
- Projects include webinars, online education modules, presentations at trade shows, AMCA Speakers Network and many other items.

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- Please place your cell phone on silent or vibrate.
- There will be Q&A at the end of the session.
- To receive PDH credit for attending:
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  - You must be present for the entire session and complete a post-session online evaluation. Partial credit cannot be given for anyone who arrives late, leaves early or does not complete the evaluation.
  - There will be a QR code for the survey on screen at the end of the presentation, and a link will be emailed to everyone within 2 weeks. The survey must be completed to qualify for today's PDH credit. If you do not want PDH credit, completing the survey is optional, and your feedback is greatly appreciated.

Session Bonus!

- All attendees of this session will receive a complimentary electronic copy of AMCA Standard 207: *System Efficiency and Fan System Input Power.* (A $90 value)

- The electronic document will be emailed to you within 30 days of today's session, once we receive the full attendee list from AHR Expo.

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Tim Mathson

Principal Engineer
AMCA International

- Joined AMCA in 2019 as Principal Engineer, and also served as Lab Director for 11 months
- 30 years as Principal Engineer at Greenheck
- Chaired AMCA 210 Committee & 208, which under his leadership created the new FEI fan energy metric currently being used by ASHRAE 90.1
- Current chair of ASHRAE TC 5.1- Fans
- Has worked with ASRAC, the DOE, US Technical Advisory Group to ISO TC117
- Bachelor's Degree in Mechanical Engineering from the University of Wisconsin

Estimating Part-Load Performance of Fan Motors and Drives Using AMCA Standard 207

Purpose and Learning Objectives

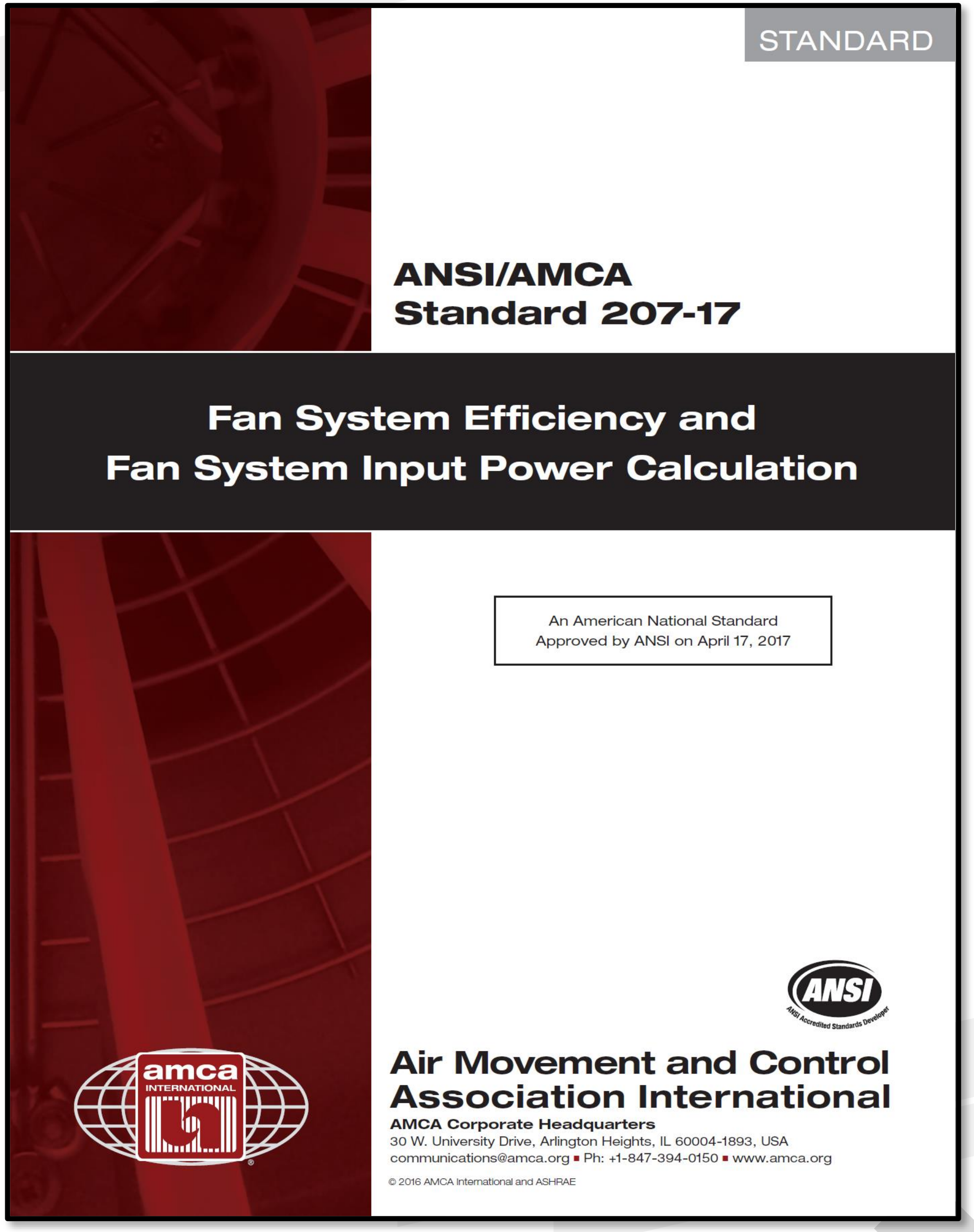
The purpose of this session is to illustrate how use of AMCA Standard 207 provides a means to predict fan drive component efficiencies during part and full-load operation, and how AMCA 207's accuracy has been verified.

At the end of this presentation, you will be able to:

1. Explain what AMCA Standard 207 covers and why it is needed.
2. Specify how AMCA 207 is used to its greatest benefit.
3. Understand, at a high level, the results of part-load & full-load testing involving motors and VFDs.
4. Explain how AMCA 207's accuracy has been proven.

Agenda

- Why is it needed?
- What is covered?
- How is it used?
- What about part load?
- Is it accurate?


STANDARD

ANSI/AMCA Standard 207-17

Fan System Efficiency and Fan System Input Power Calculation

An American National Standard Approved by ANSI on April 17, 2017

Air Movement and Control Association International

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Why is it needed?

Purpose

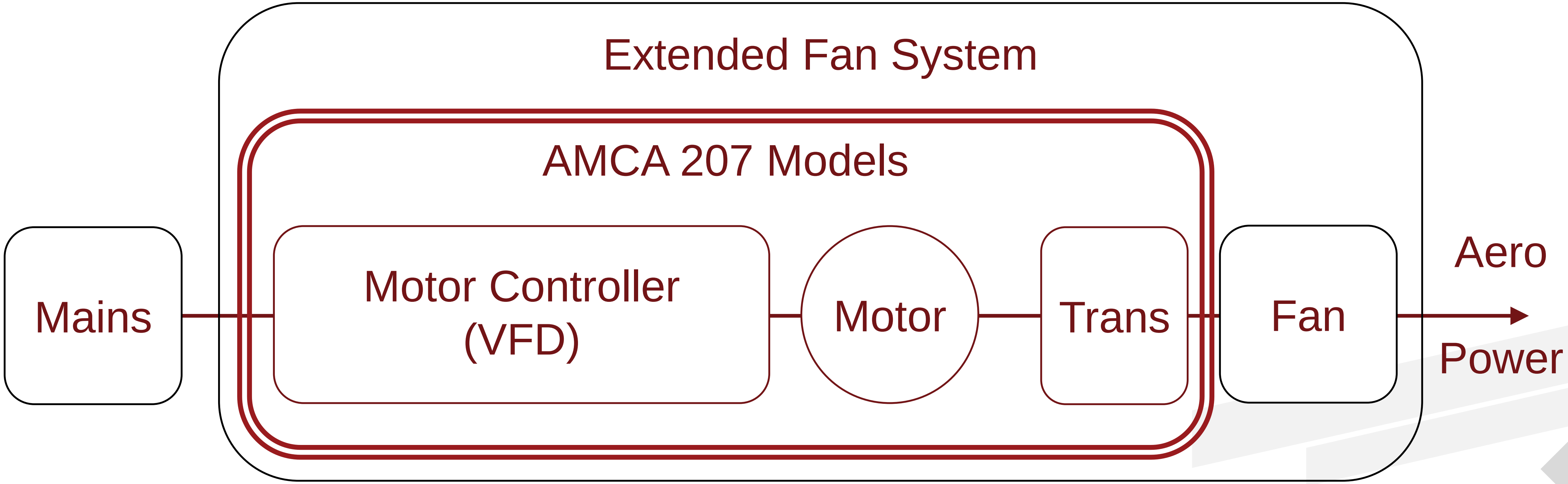
This standard provides a method to **estimate the input power and overall efficiency** of an **extended fan system**.

An extended fan system is composed of a **fan and an electric motor but may also include a transmission and a motor controller**. While direct measurement of fan system performance is preferred, the large number of fan system configurations often makes testing impractical. This standard offers a **standardized method to estimate** fan system performance by modeling commonly used components. Calculations reported in accordance with this standard offers fan users a **tool to compare alternative fan system configurations** in a consistent and uniform manner.

This document does not provide selection guidance. Users must assure that selected components have sufficient capacity and are configured to produce the desired results.

Why is it needed?

- Fans tested for fan shaft power
- Regulations (and users) want electrical power



Extended Fan System

Output Power (Air Power)
"Airflow x Pressure"

Input Power
"Fan Shaft Power"

Fan Electrical
Input Power

What is covered?

- Power Transmission
  - Direct drive (no transmission)
  - V-belt drive
  - Synchronous belt drive (timing belt)
  - Flexible coupling
- Motor
  - Regulated 3 phase induction motor
- Motor Controller
  - Standard VFD (pulse-width modulated)

How is it used?

- To determine electrical input power the fan system when fan shaft power was tested
- To calculate FEI for fan systems using standard power drive components

- Normally used for fan full-load calculations, but can be used for some part-load calculations

Fan Electrical Power

Airflow (cfm)		Fan Static Pressure (in.wg)				
		0.5	1.0	1.5	2.0	2.5
10,000	*N* (rpm)	686	755	831	894	953
	H_i (bhp)	2.12	2.93	3.80	4.66	5.54
12,000	*N* (rpm)	799	855	914	978	1034
	H_i (bhp)	3.28	4.18	5.19	6.23	7.26
14,000	*N* (rpm)	915	962	1011	1061	1117
	H_i (bhp)	4.84	5.85	6.96	8.13	9.35

The ratings shown are based on tests and procedures performed in accordance with AMCA publication 211.
Performance ratings do not include the effects of appurtenances (accessories).
Fan shaft power ratings (H_i) do not include transmission losses.

Fan Electrical Power

Airflow (cfm)		Fan Static Pressure (in.wg)				
		0.5	**1.0**	**1.5**	**2.0**	**2.5**
10,000	N (rpm)	686	755	831	894	953
	H_i (bhp)	2.12	2.93	3.80	4.66	5.54
	W_e (kW)	1.98	2.67	3.35	4.04	4.74
12,000	N (rpm)	799	855	914	978	1034
	H_i (bhp)	3.28	4.18	5.19	6.23	7.26
	W_e (kW)	2.97	3.65	4.46	5.28	6.11
14,000	N (rpm)	915	962	1011	1061	1117
	H_i (bhp)	4.84	5.85	6.96	8.13	9.35
	W_e (kW)	4.18	4.99	5.86	6.8	7.8

The ratings shown are based on tests and procedures performed in accordance with AMCA publication 211.
Performance ratings do not include the effects of appurtenances (accessories).
Fan shaft power ratings (H_i) do not include transmission losses.
Electrical power ratings (W_e) calculated in accordance with AMCA 207 including V-belt drives and 4 pole TEFC motors sized at no more than 80% of nameplate power.

What about part load?

- Building energy modeling
- Fan selections comparing component efficiencies at more common duty points

AMCA 207 also speaks to part-load conditions…

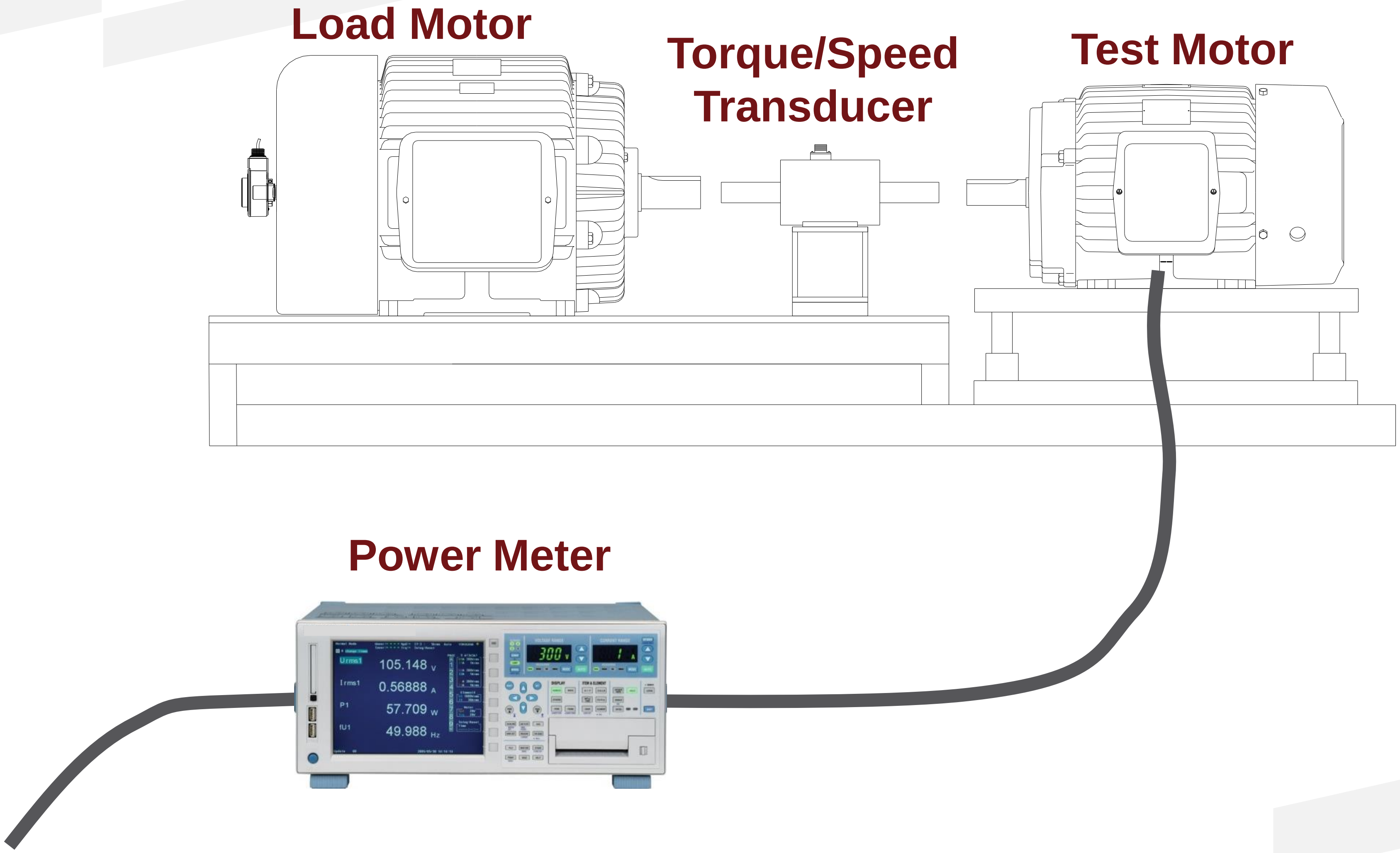
Illustrated through test results at part load

"Wire-to-Air Fan Power Performance and Energy Consumption", Seminar 25, ASHRAE 2017 Winter Conference

Scope of Testing

- Motors - Premium Efficient Induction
  - 1, 5, 10 hp, 4 Pole, TEFC, 460V 60Hz
- VFD's - General Purpose IGBT for HVAC
  - 1, 5, 10 hp
  - Constant V/Hz, 4 kHz Carrier Frequency
- V-Belt drives
  - Speeds 1200, 1800, 2700 RPM
  - Service Factors 1.0, 1.5, 2.0, 3.0, 4.0
  - Number of belts
- Fan - 27" Mixed Flow
  - Belt or dynamometer driven

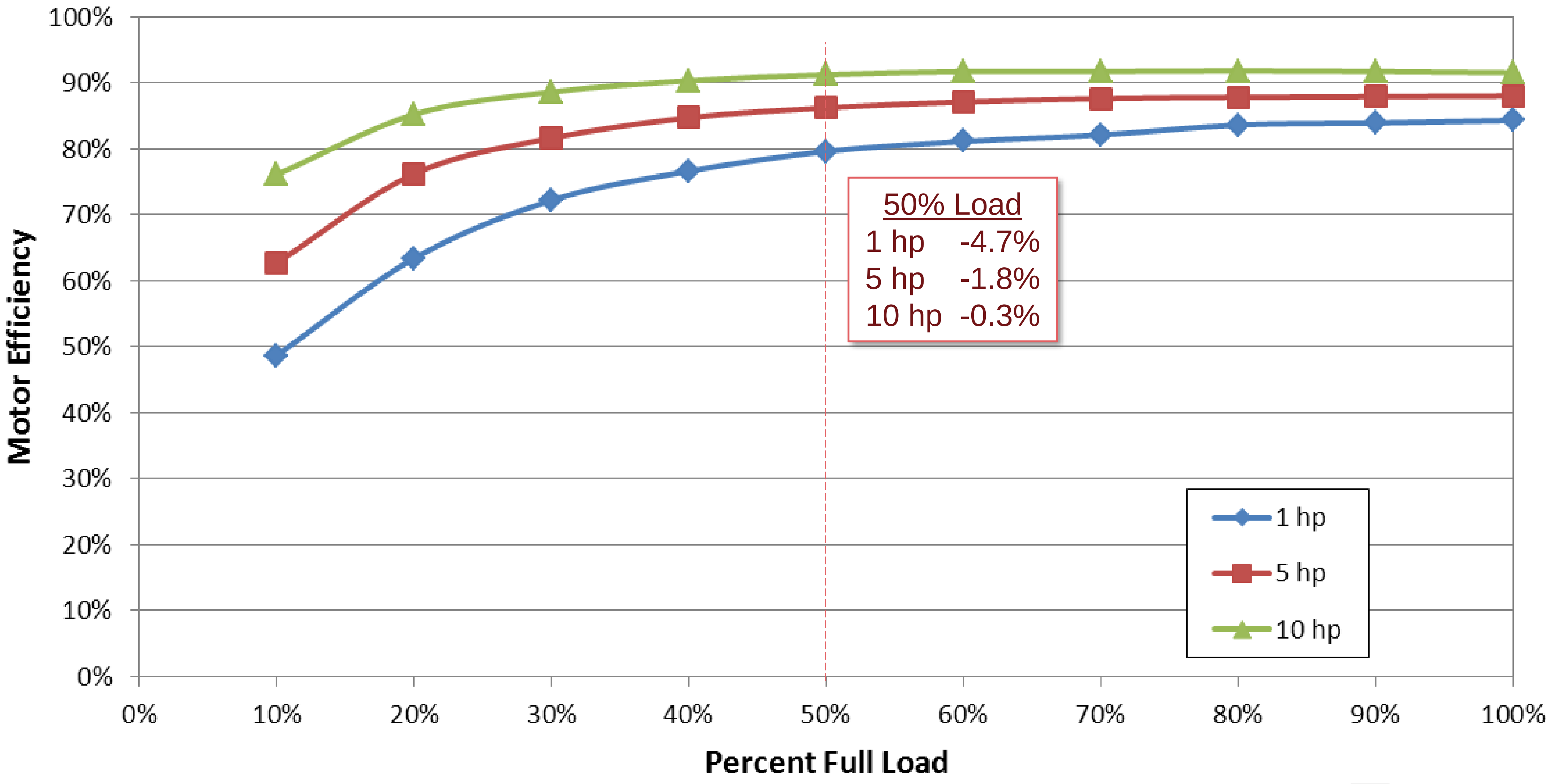
Motor Test Setup – Input/Output Method



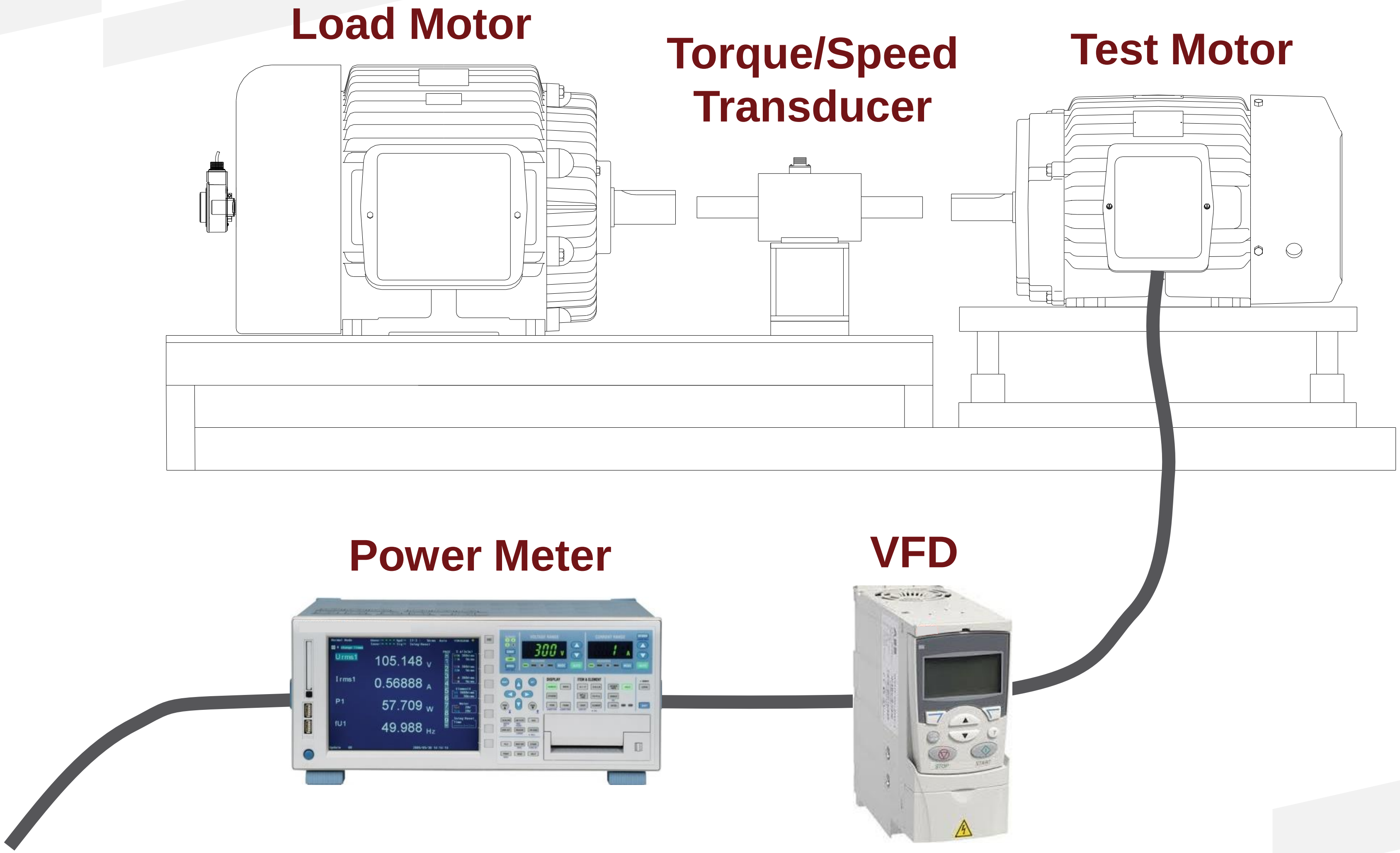
Results – Full Load Motor Efficiency, X-Line

Motor	NEMA Premium Nominal	Measured with 60 Hz Line Power	Difference from Nominal
1 hp	85.5	84.3	-1.2
5 hp	89.5	88.0	-1.5
10 hp	91.7	91.5	-0.2

Results – Part Load Motor Efficiency, X-Line



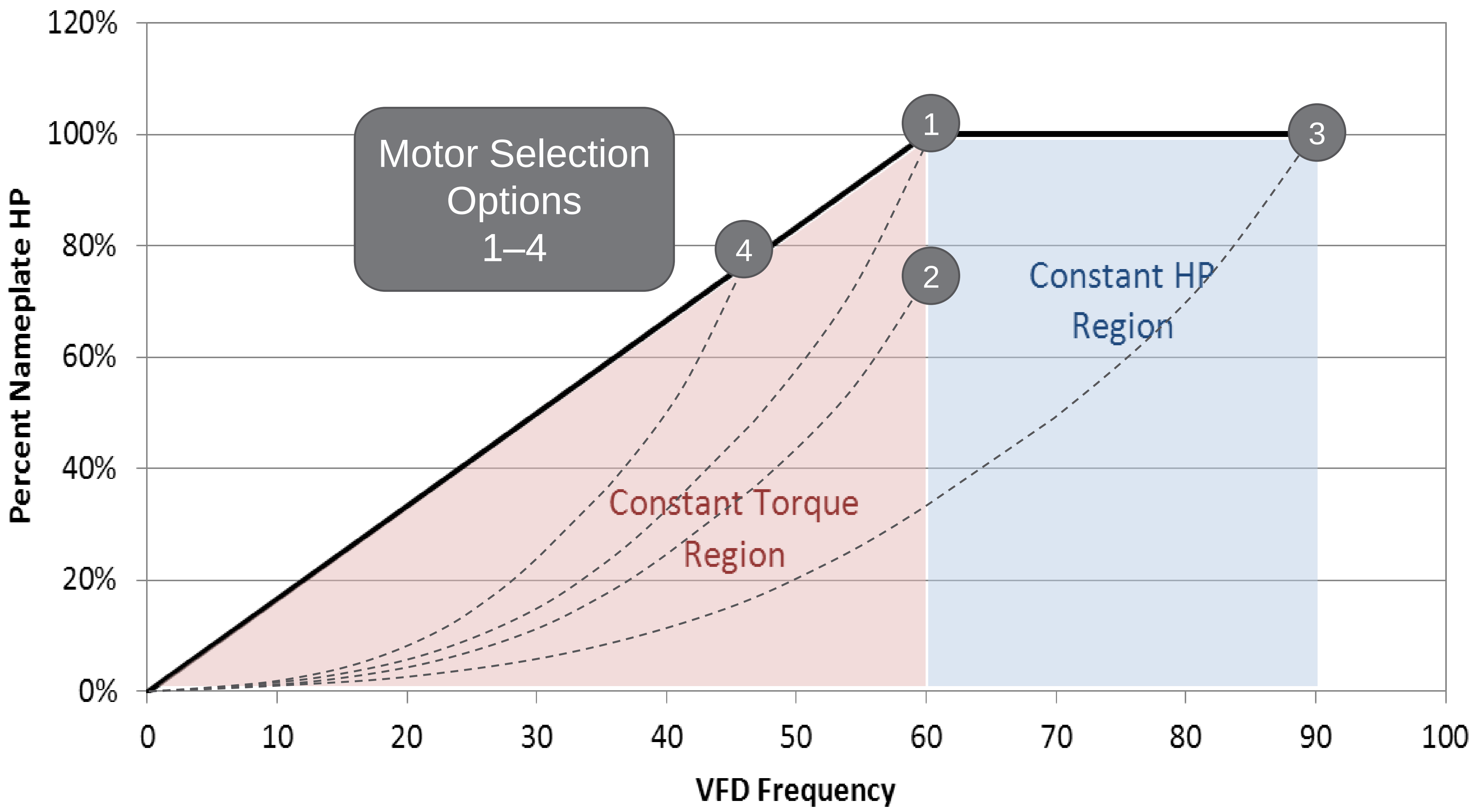
Motor & VFD Test Setup – AHRI 1210



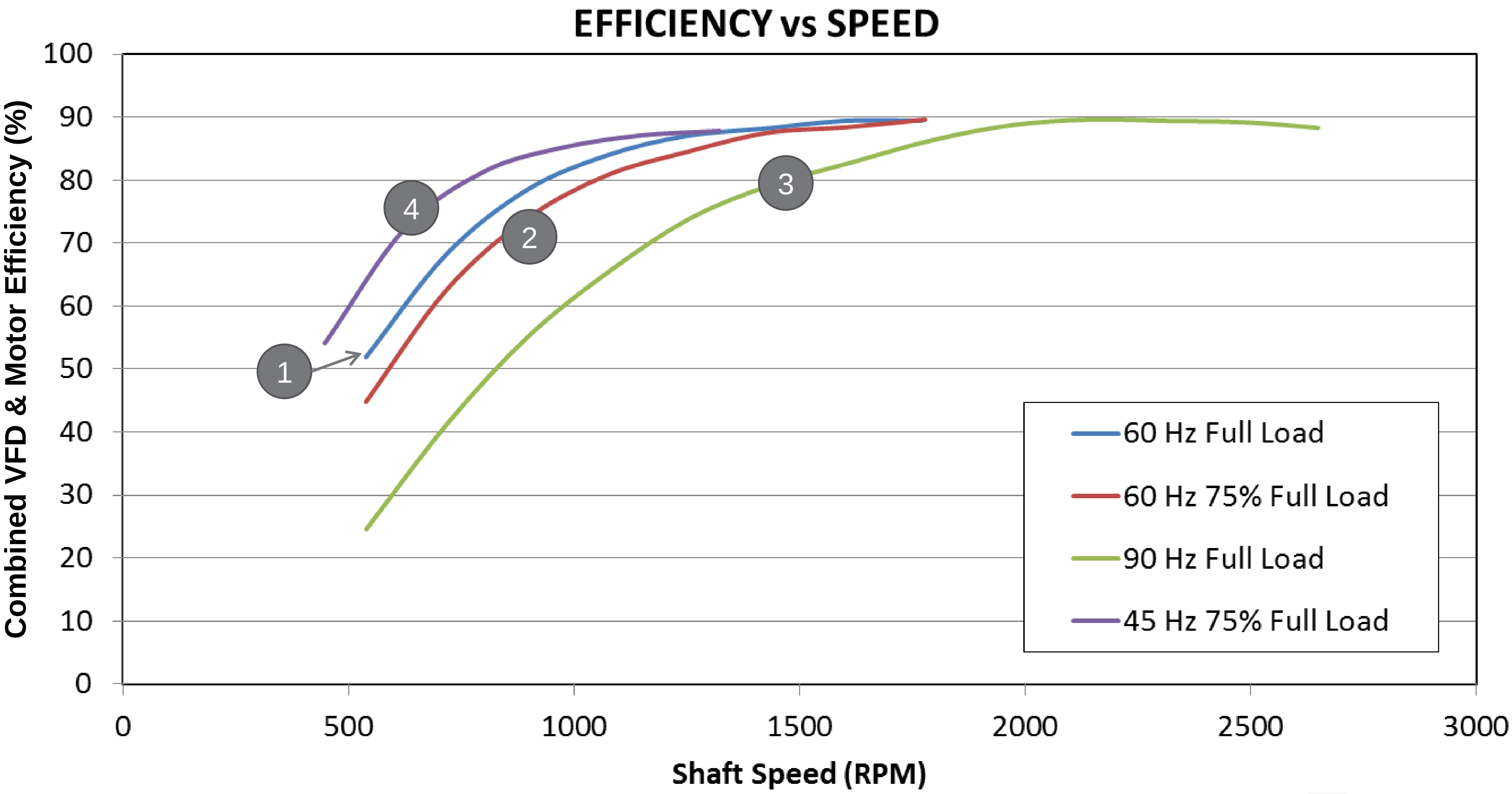
Results – Motor & VFD at Full Load

Motor	Motor Alone With 60 Hz Line Power	Combined Motor & VFD @ 60 Hz
1 hp	84.3	82.4
5 hp	88.0	87.0
10 hp	91.5	89.7

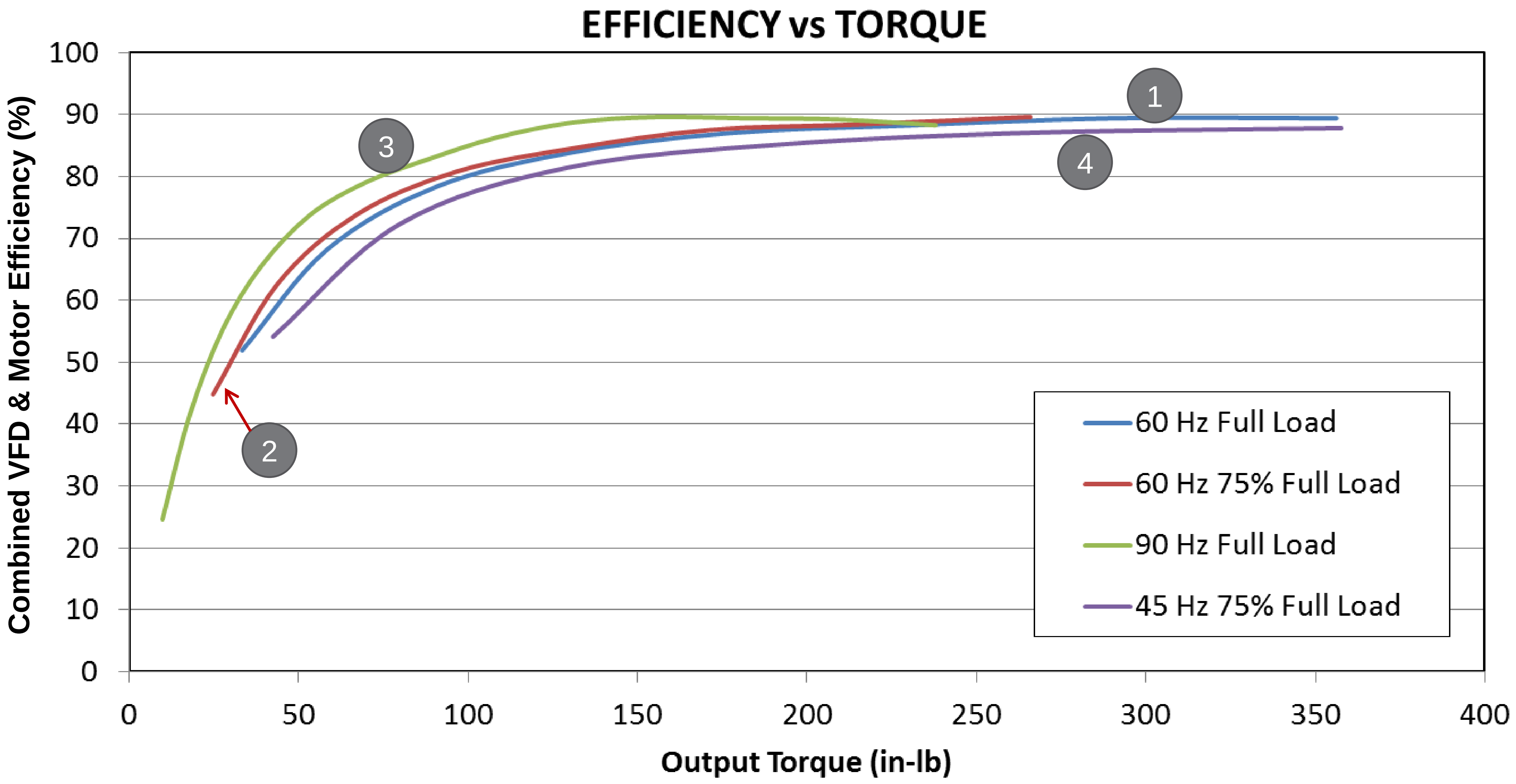
Motor & VFD - Part Load Operation



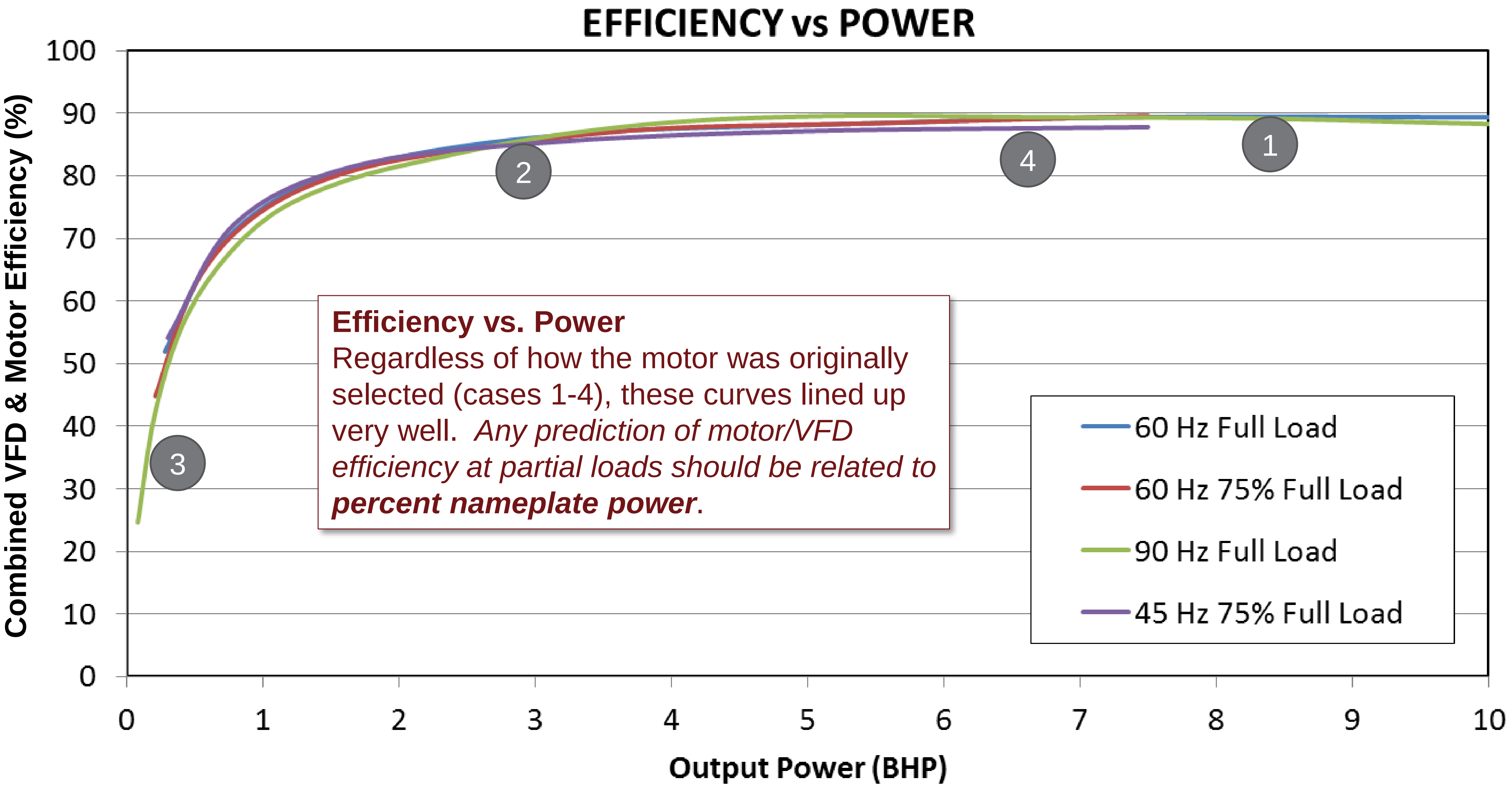
Results – 10 hp Motor & VFD at Part Load



Results – 10 hp Motor & VFD at Part Load

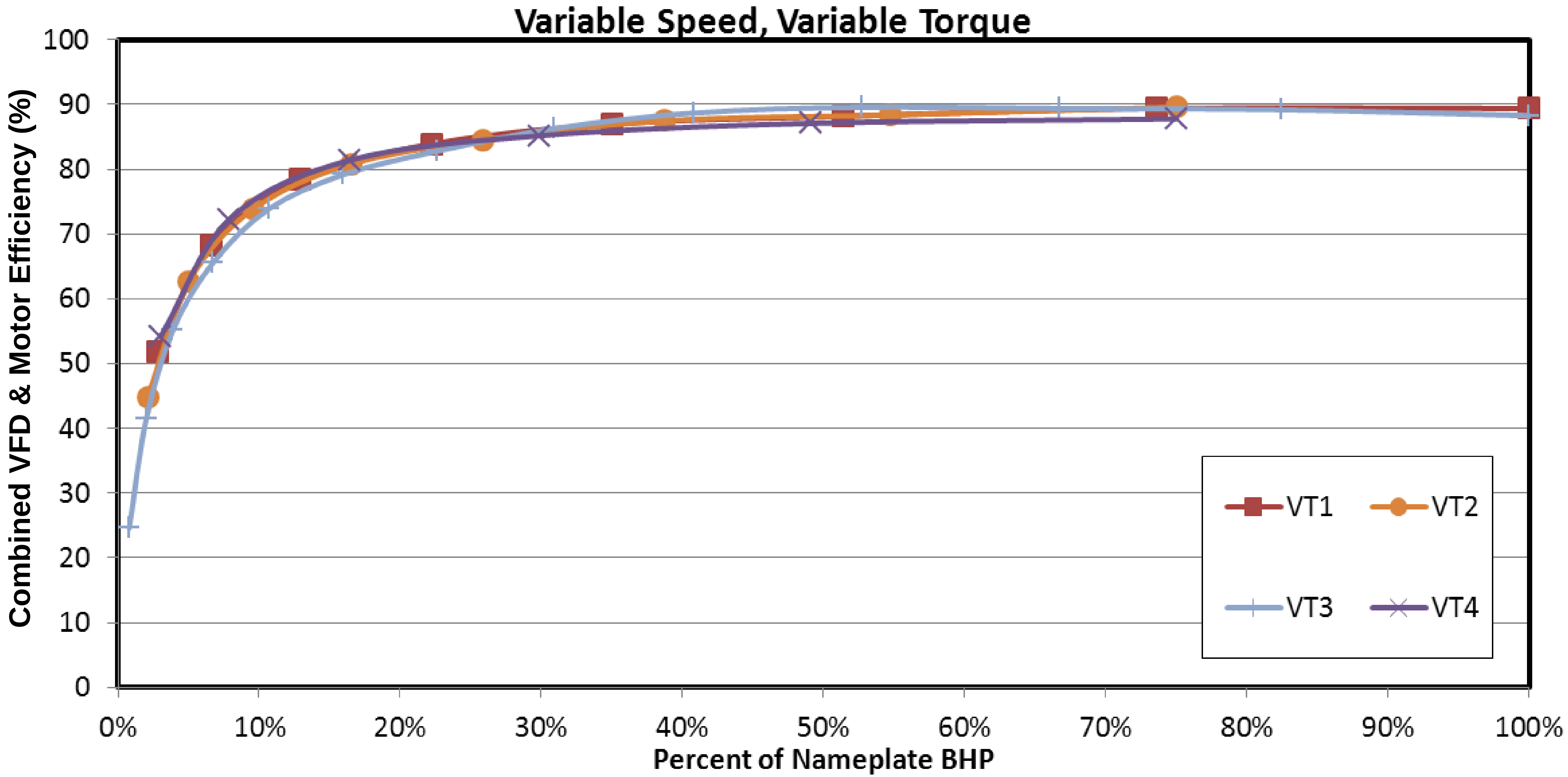


Results – 10 hp Motor & VFD at Part Load

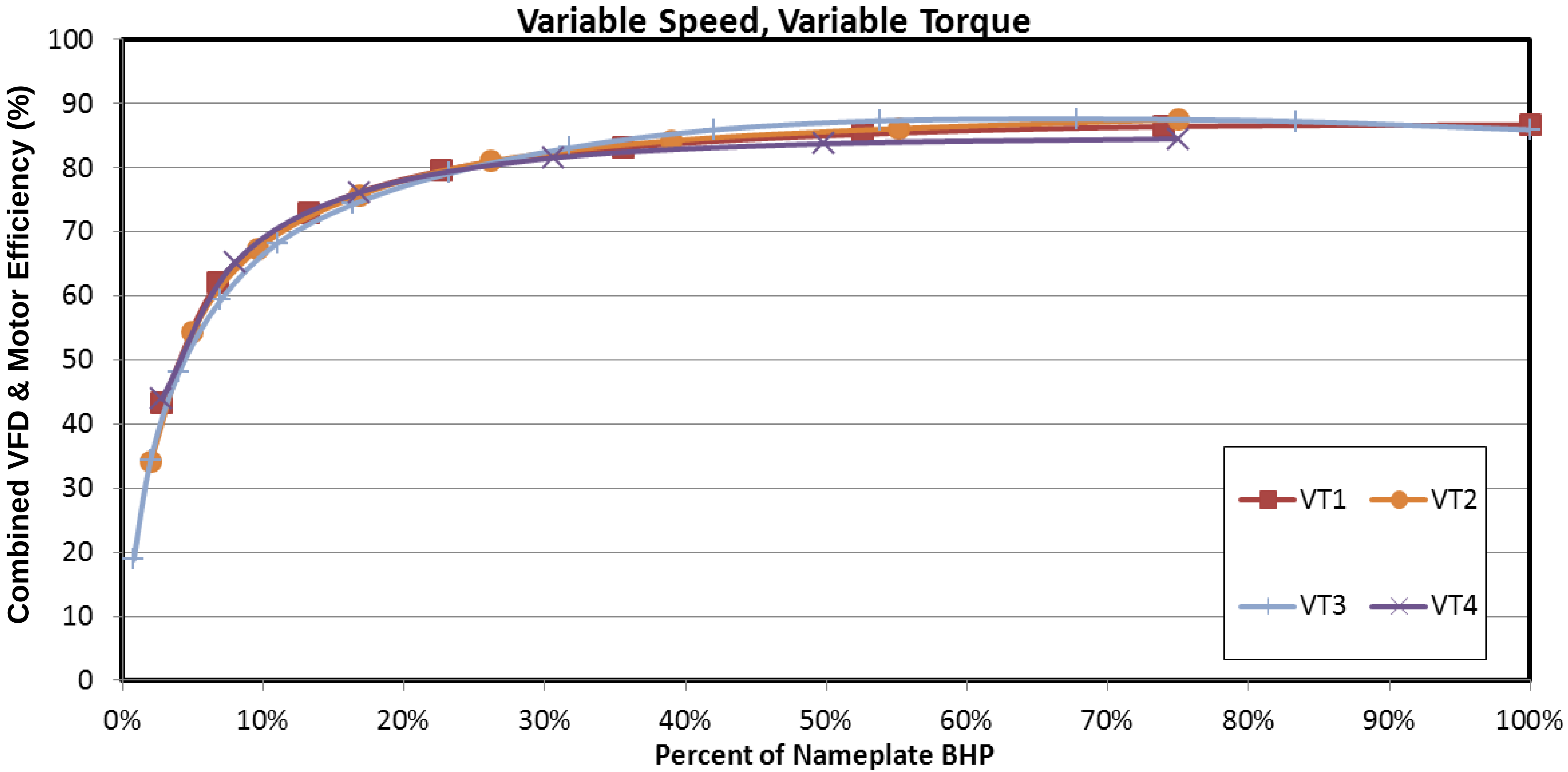


Efficiency vs. Power
Regardless of how the motor was originally selected (cases 1-4), these curves lined up very well. *Any prediction of motor/VFD efficiency at partial loads should be related to* ***percent nameplate power***.

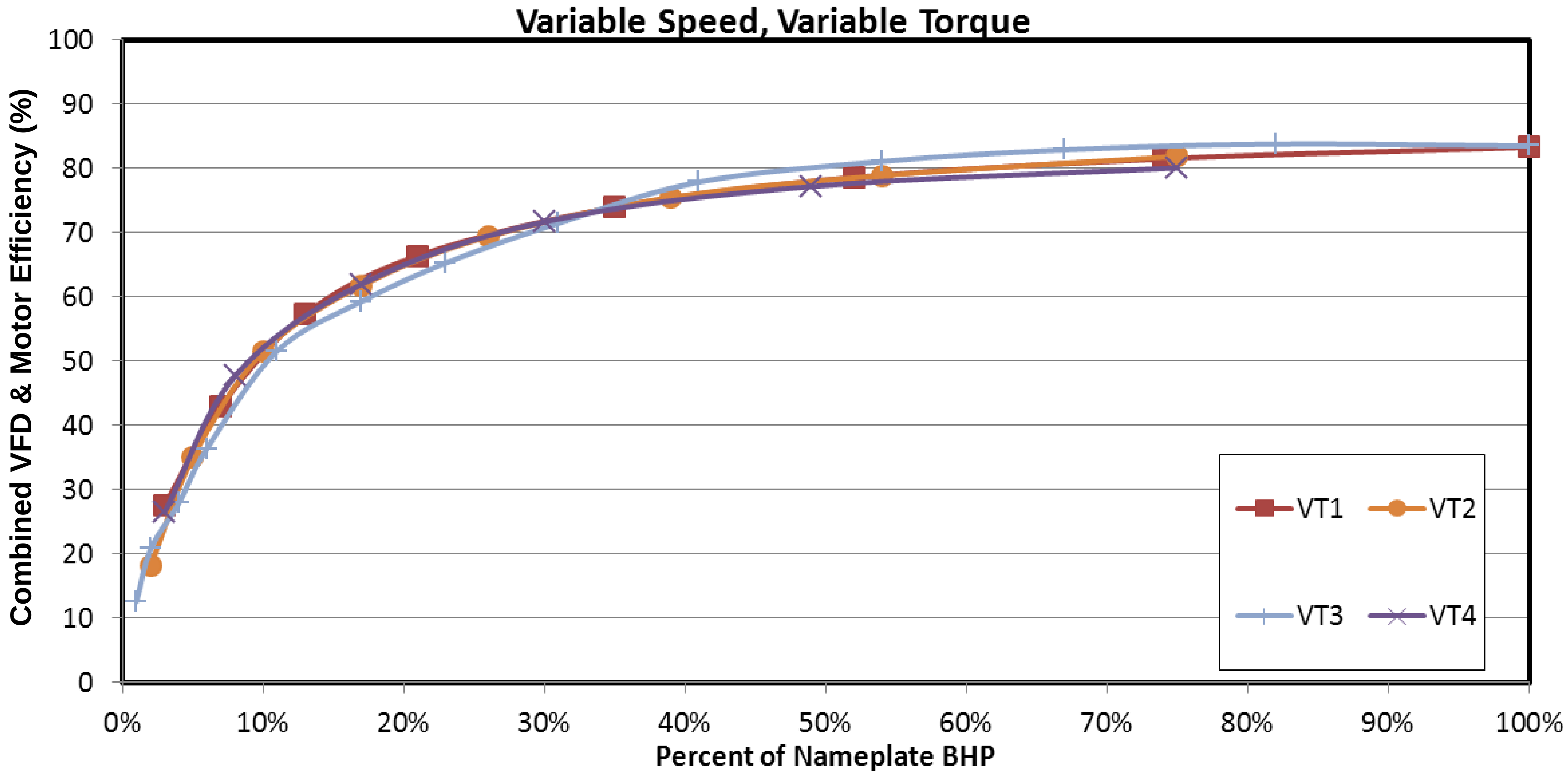
Results – 10 hp Motor & VFD at Part Load



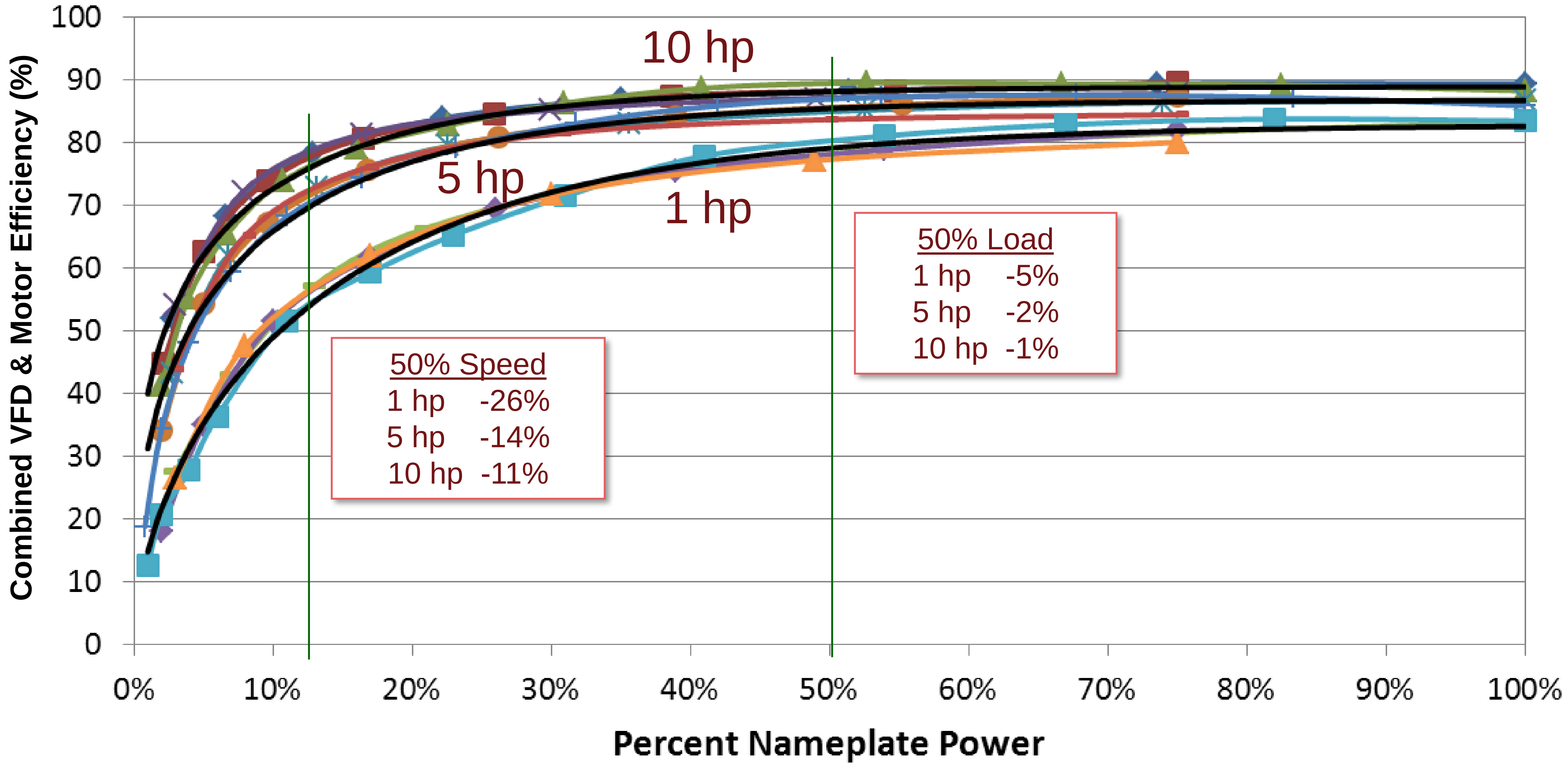
Results – 5 hp Motor & VFD at Part Load



Results – 1 hp Motor & VFD at Part Load



Results – Motor & VFD at Part Load



AMCA 207 Model

$$\eta_m = \eta_R\left(\frac{aL_m}{b + L_m} + cL_m^2\right) \qquad \eta_{mc} = \eta_m\left(\frac{dL_c}{e + L_c} + fL_c\right)$$

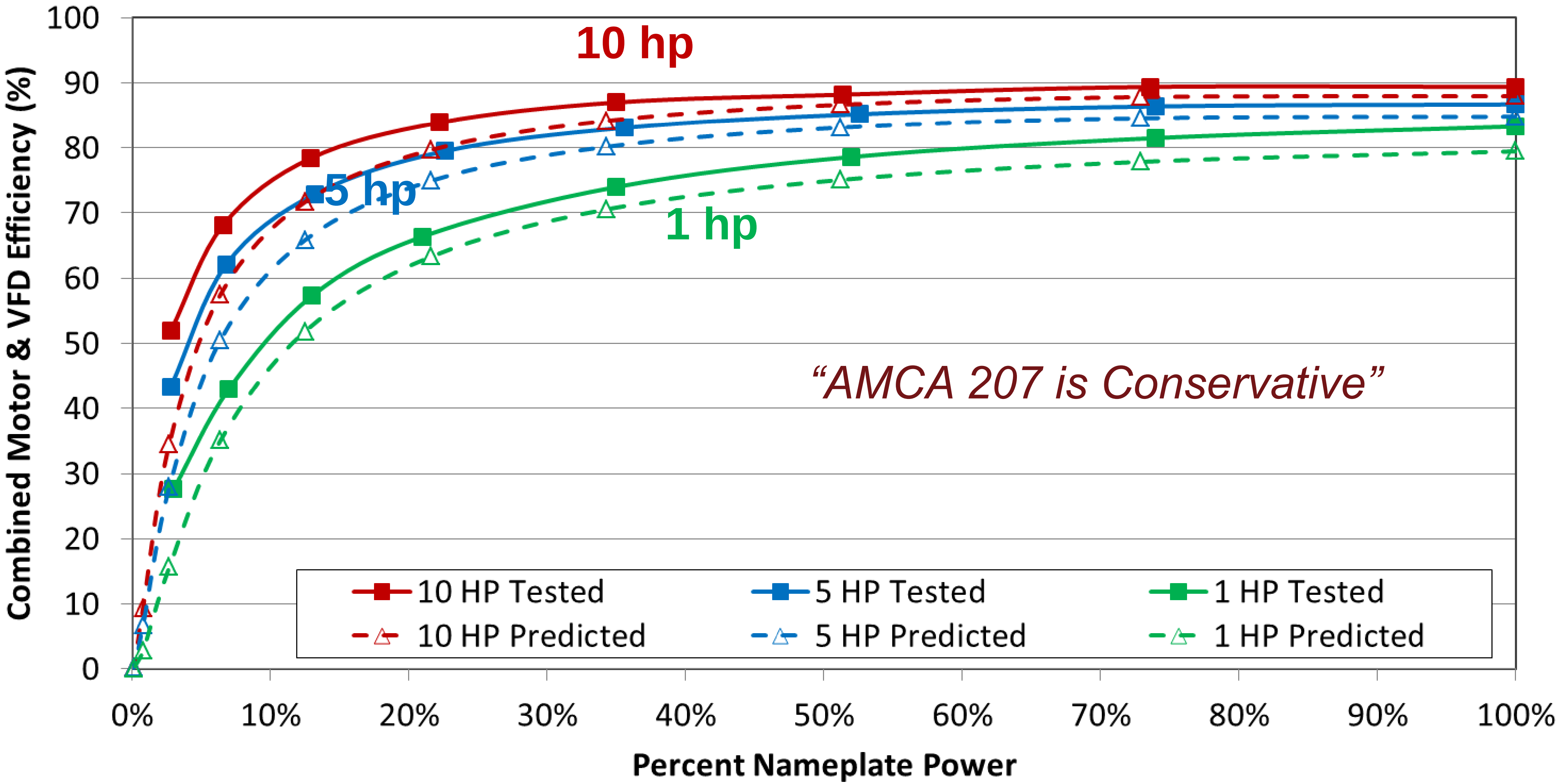
where,

η_R = nominal rated motor efficiency

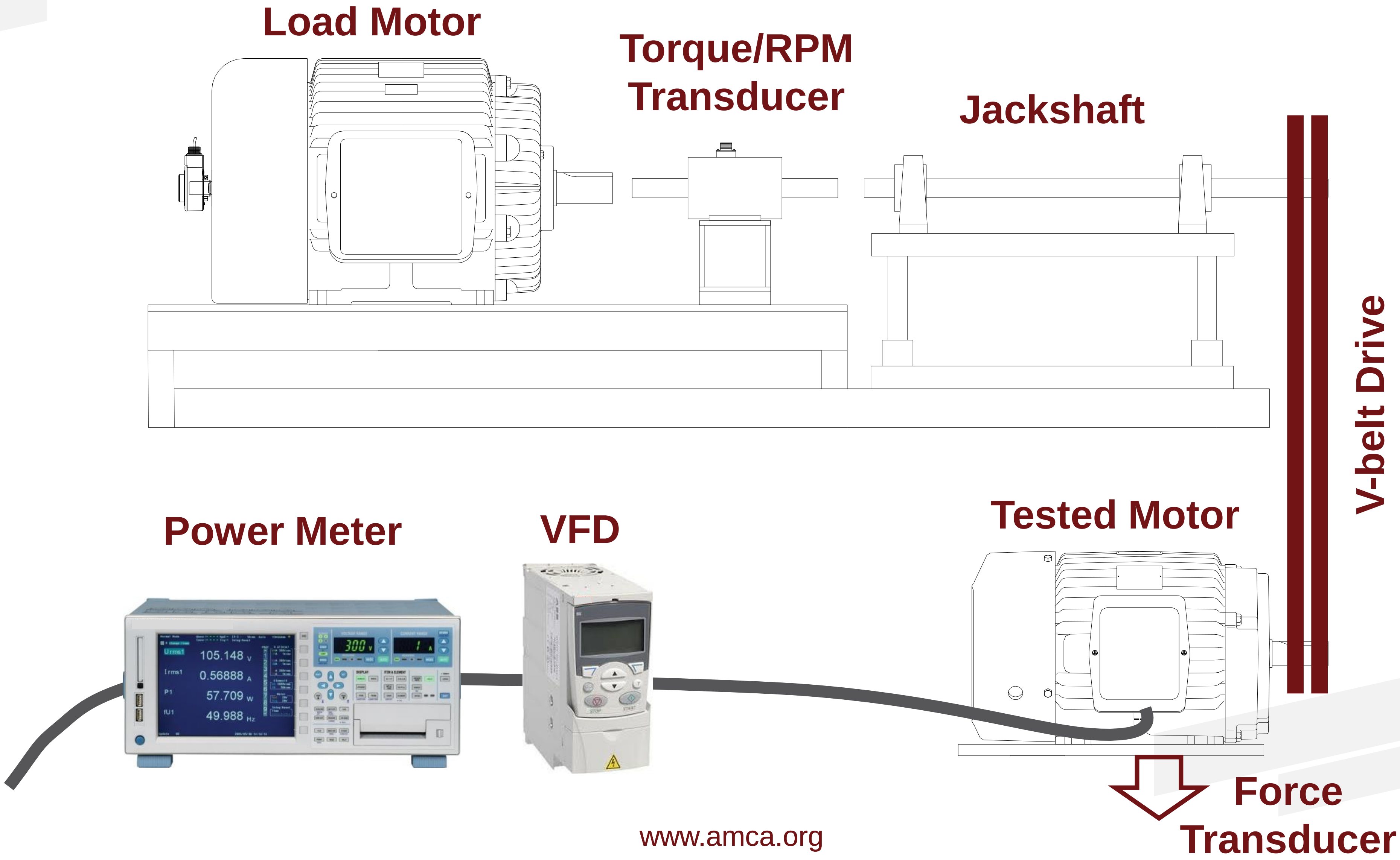
L_m & L_c = Load ratios of motor and motor controller

$a - f$ = Constants

Results vs. AMCA 207 Prediction

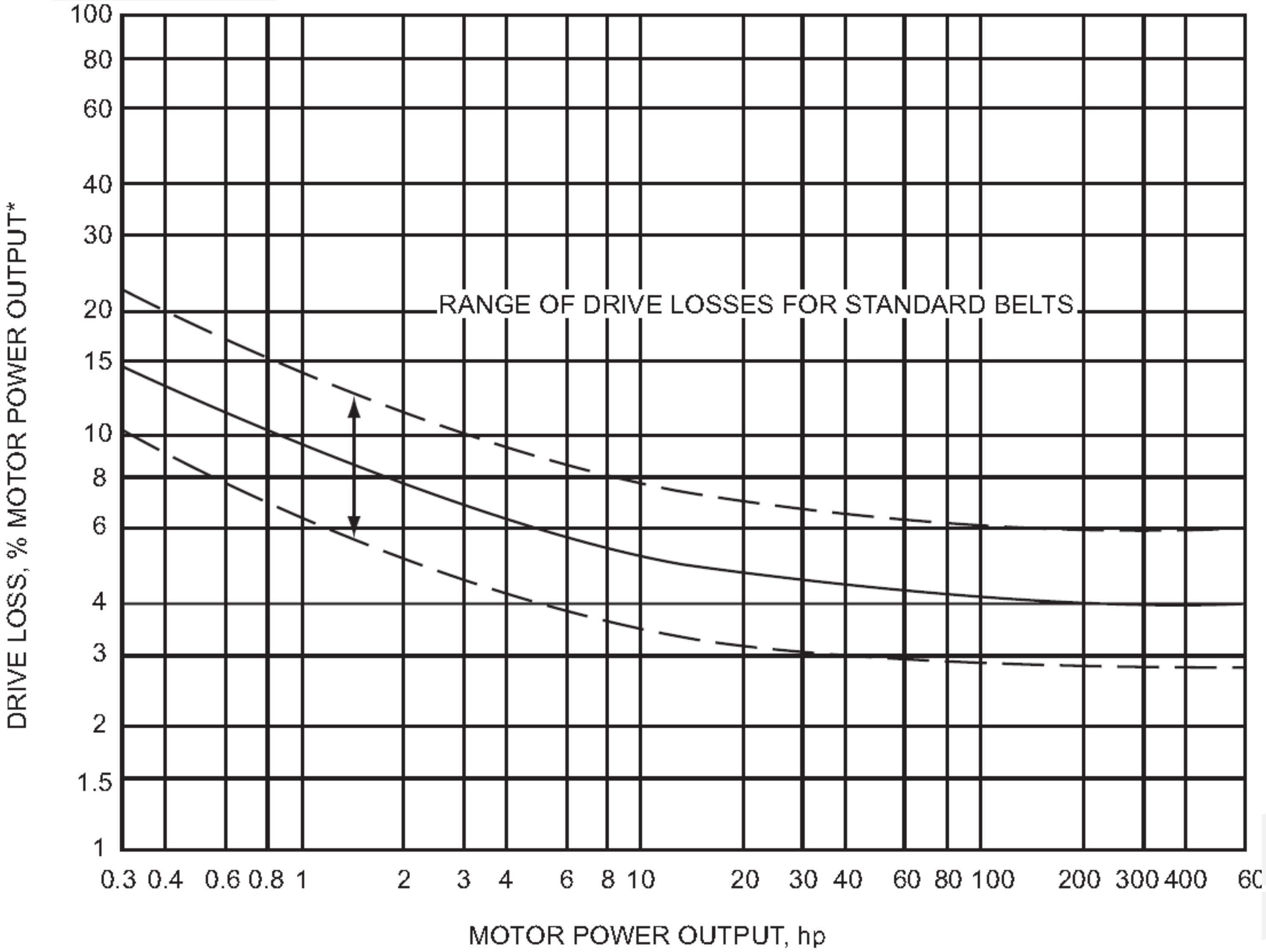


Belt Drive Test Setup

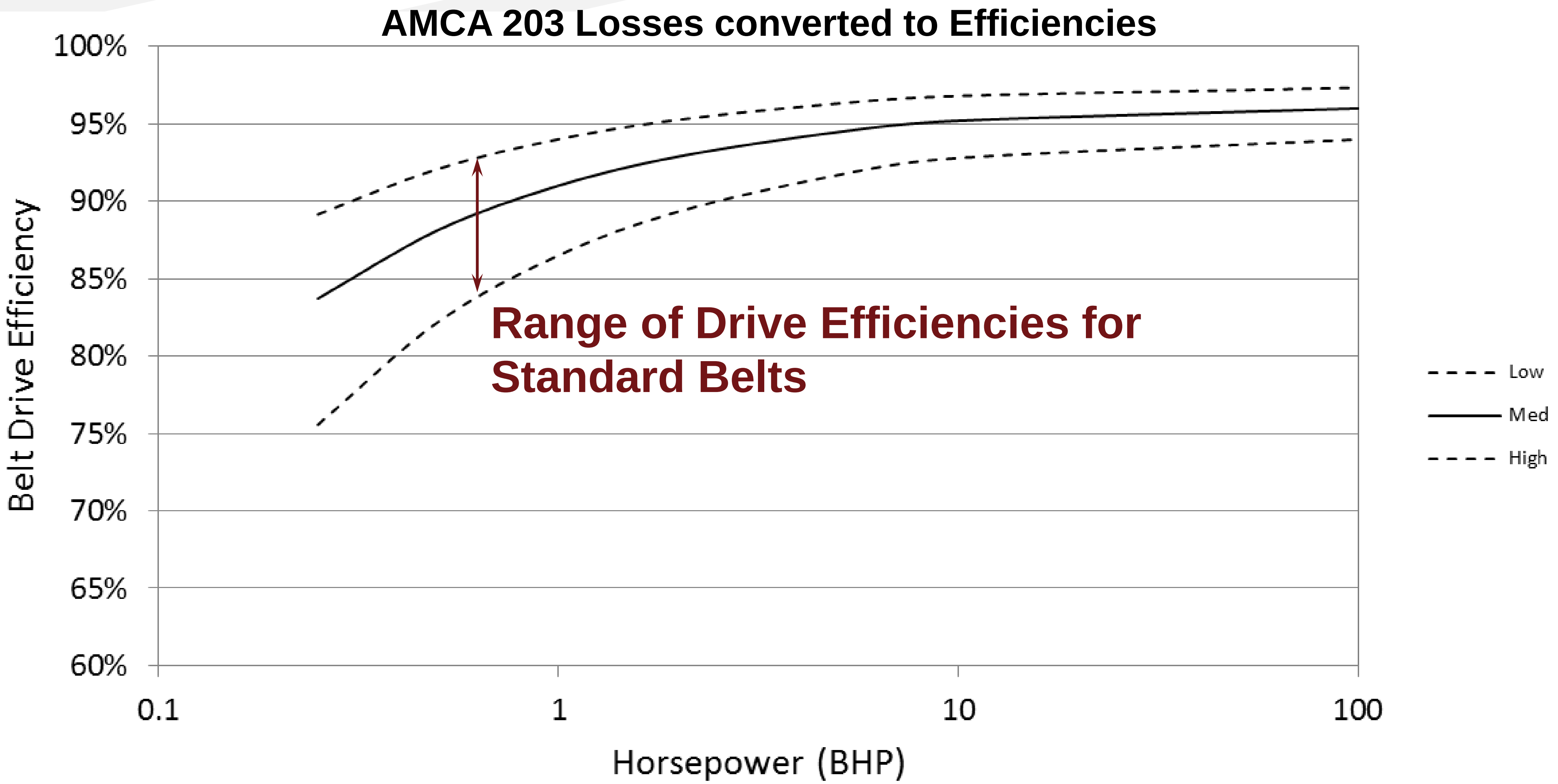


Belt Drive Efficiency – AMCA 203

AMCA 203
Appendix L



Belt Drive Efficiency – AMCA 203



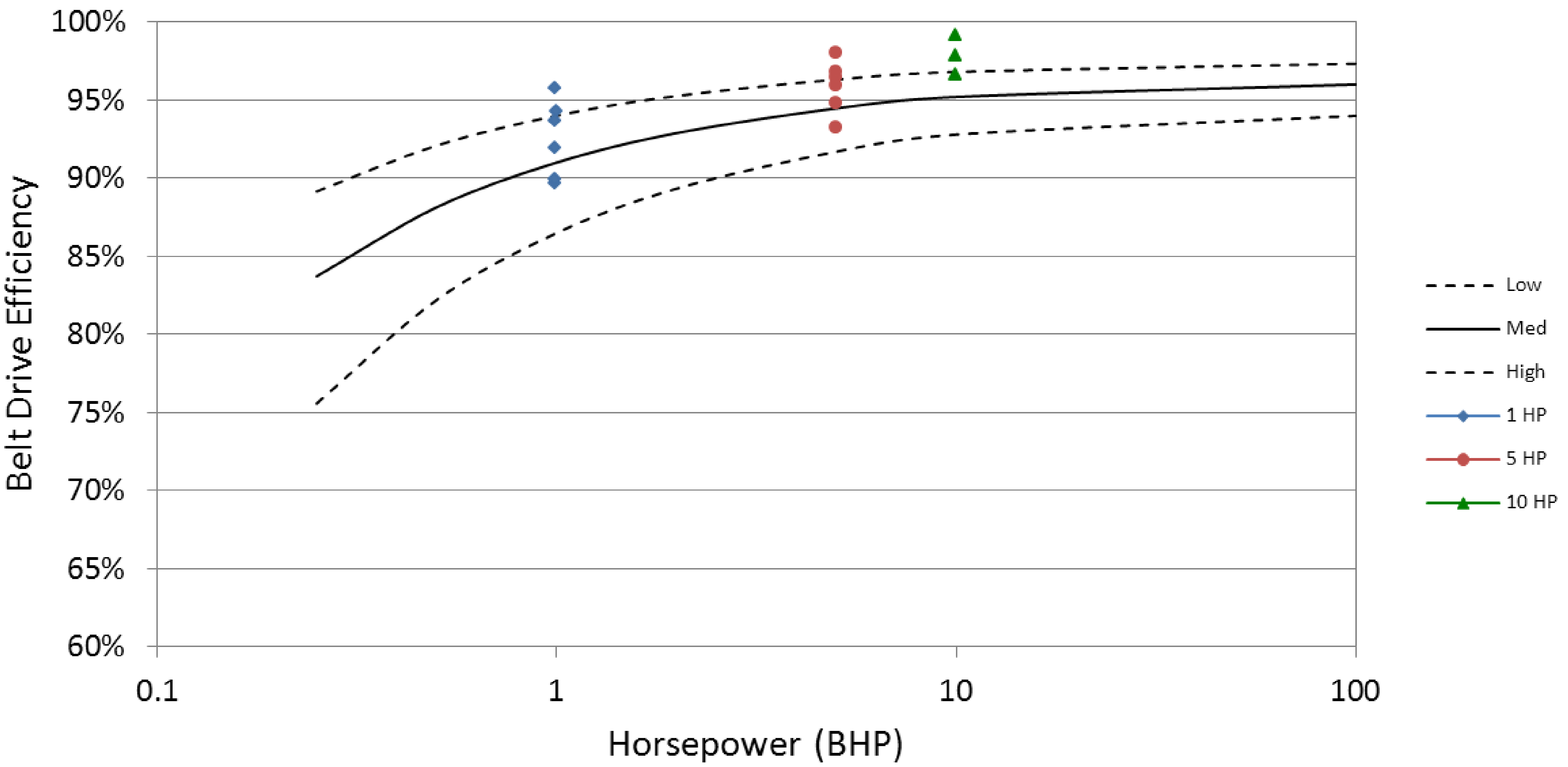
Belt Drive Efficiency

Experimental Variables:

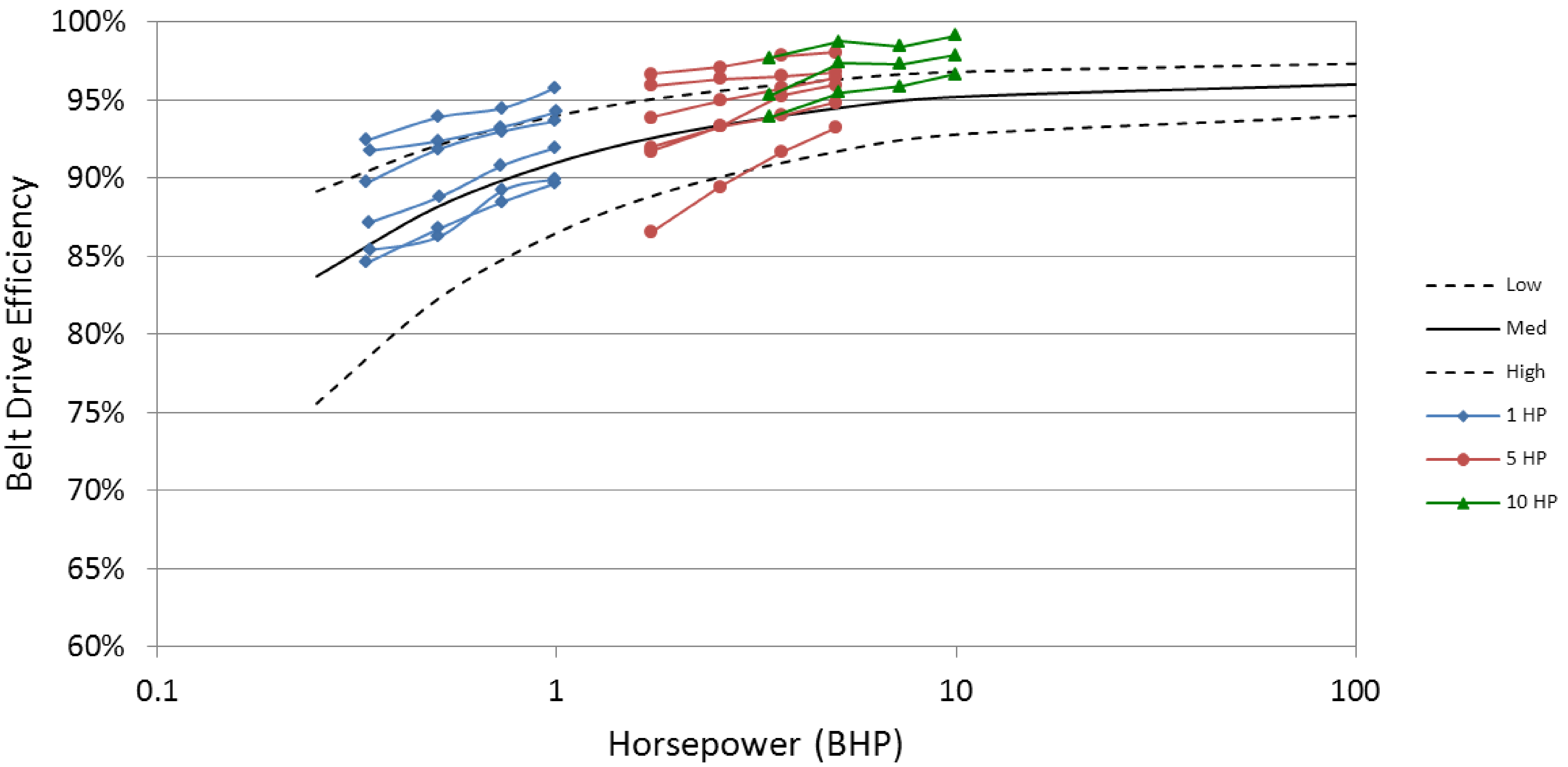
1. Power (hp)
2. Shaft Speed (rpm)
3. Service Factor

Motor HP	DriveN RPM	# Belts	SF	Full Load Efficiency
1 HP	2700	1	1.5	94
		2	3	90
	1800	1	1.5	96
		2	3	90
	1200	1	1.5	96
		2	3	92
5 HP	2700	1	1.5	96
		2	3	93
	1800	1	2	98
		2	4	96
	1200	1	1	97
		2	2	95
10 HP	2700	2	1.5	97
	1800	2	1.5	98
	1200	2	1.5	99

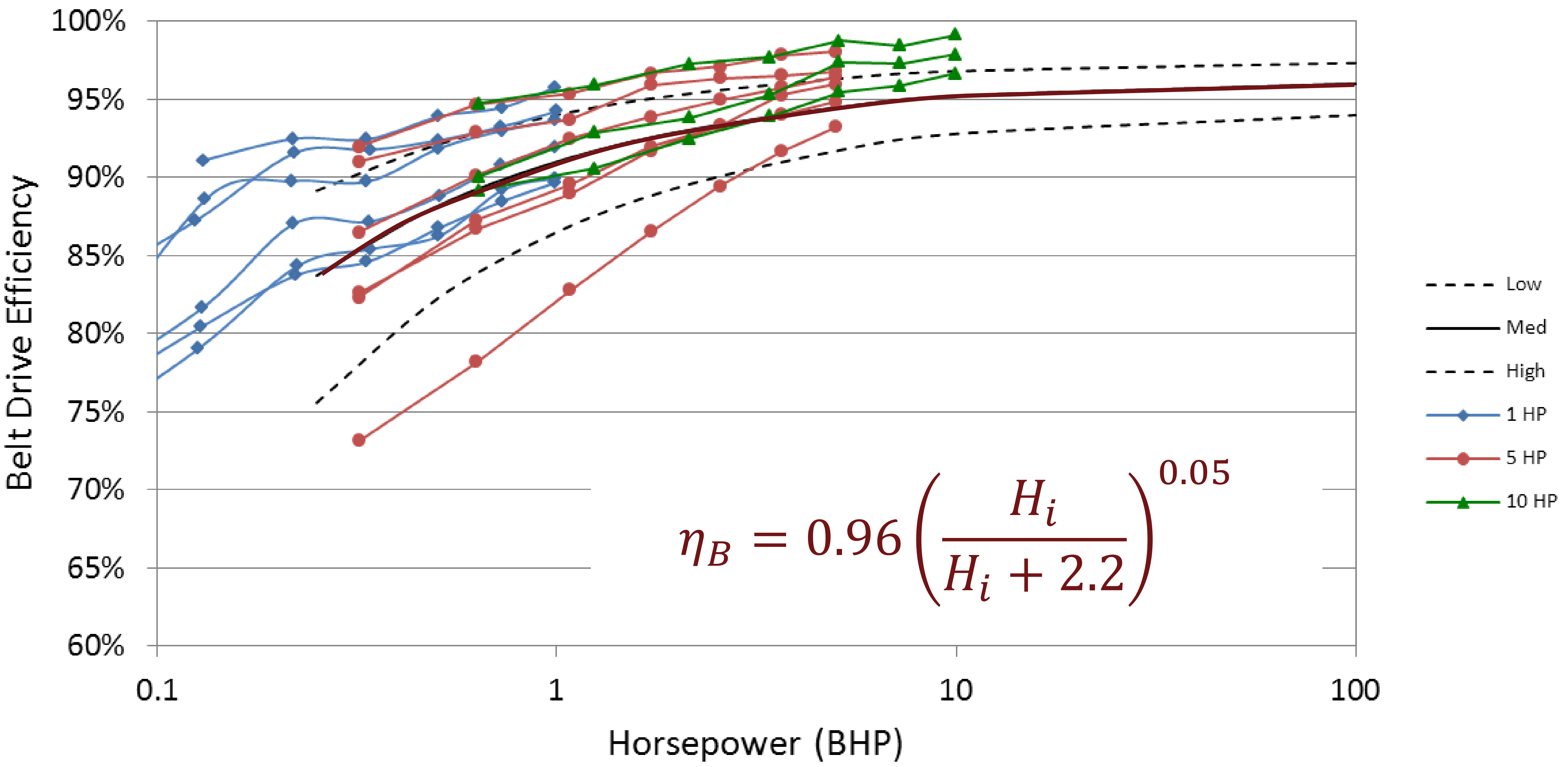
Results – Belt Drive at Full Load



Results – Belt Drive at Part Load



Results – Belt Drive at Part Load



$$\eta_B = 0.96\left(\frac{H_i}{H_i + 2.2}\right)^{0.05}$$

ASHRAE Research Project 1769

- Approximately 100 drive combinations
- Specific model
  - Belt type, number of belts, speed ratio, power, service factor
- General model
  - Transmitted power

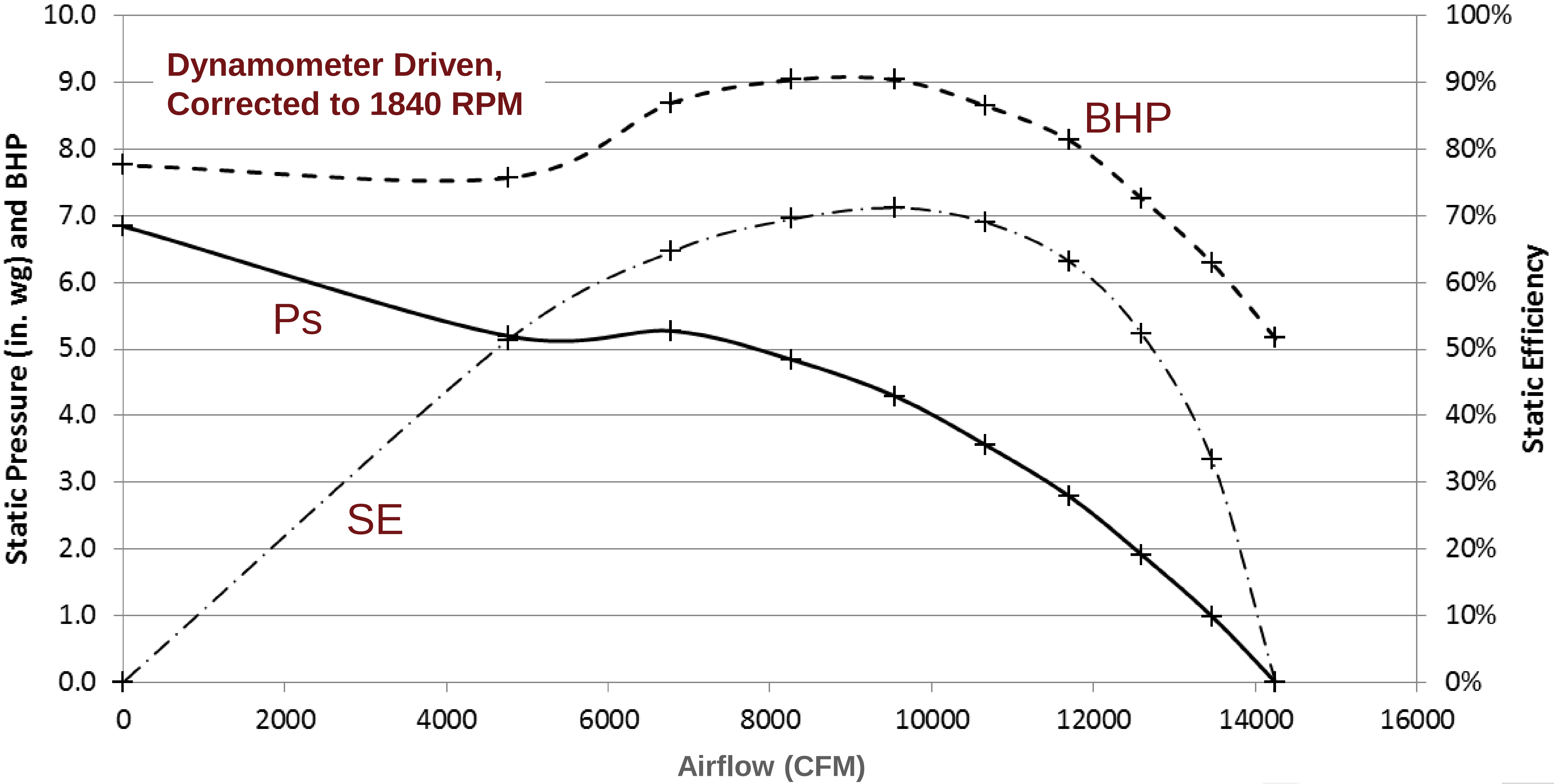
- Part load - Losses are essentially constant

Fan Efficiency - 27” Mixed Flow

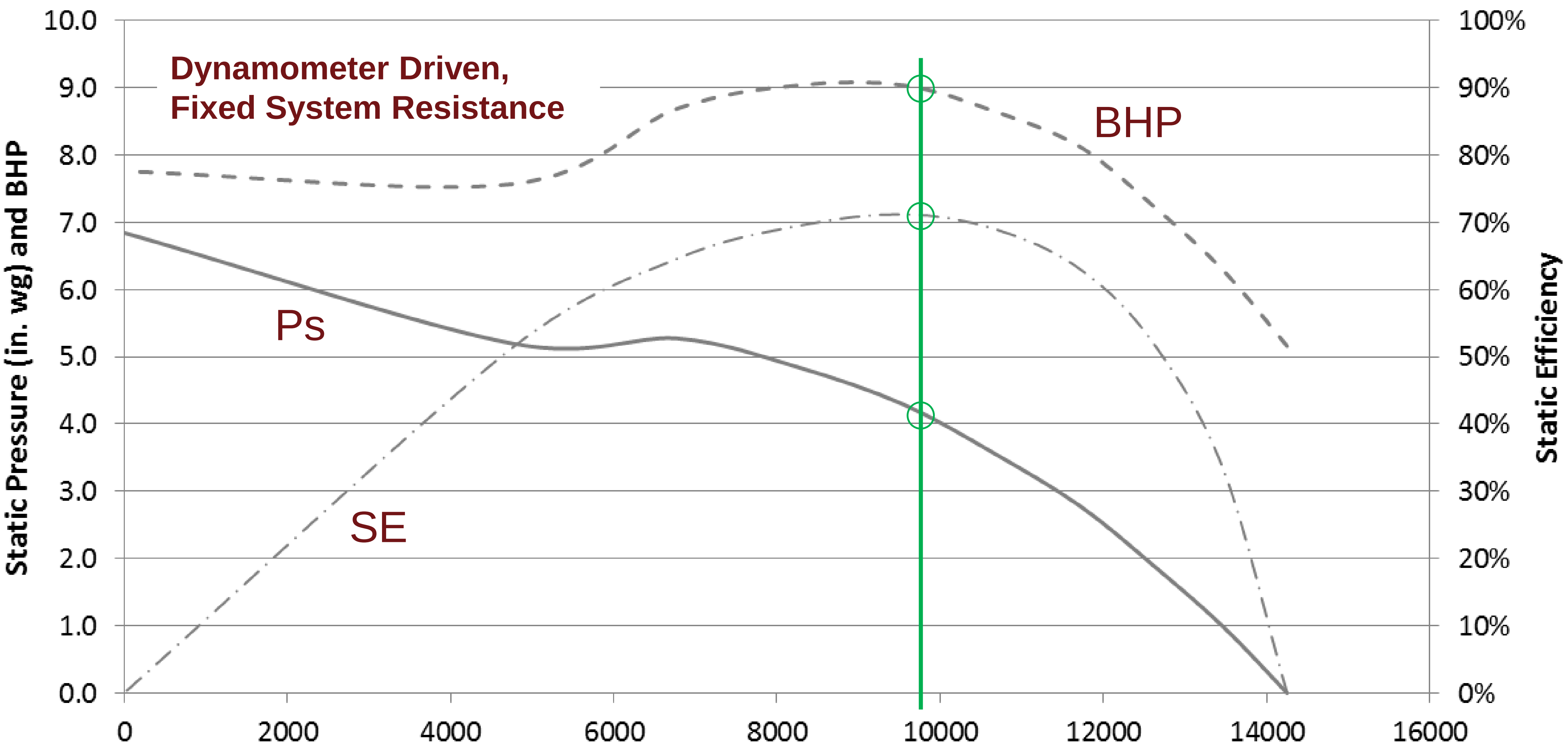
AMCA 210/ASHRAE 51 Test, Figure 12, Installation Type B

Extended fan shaft allows Dynamometer or Motor driven

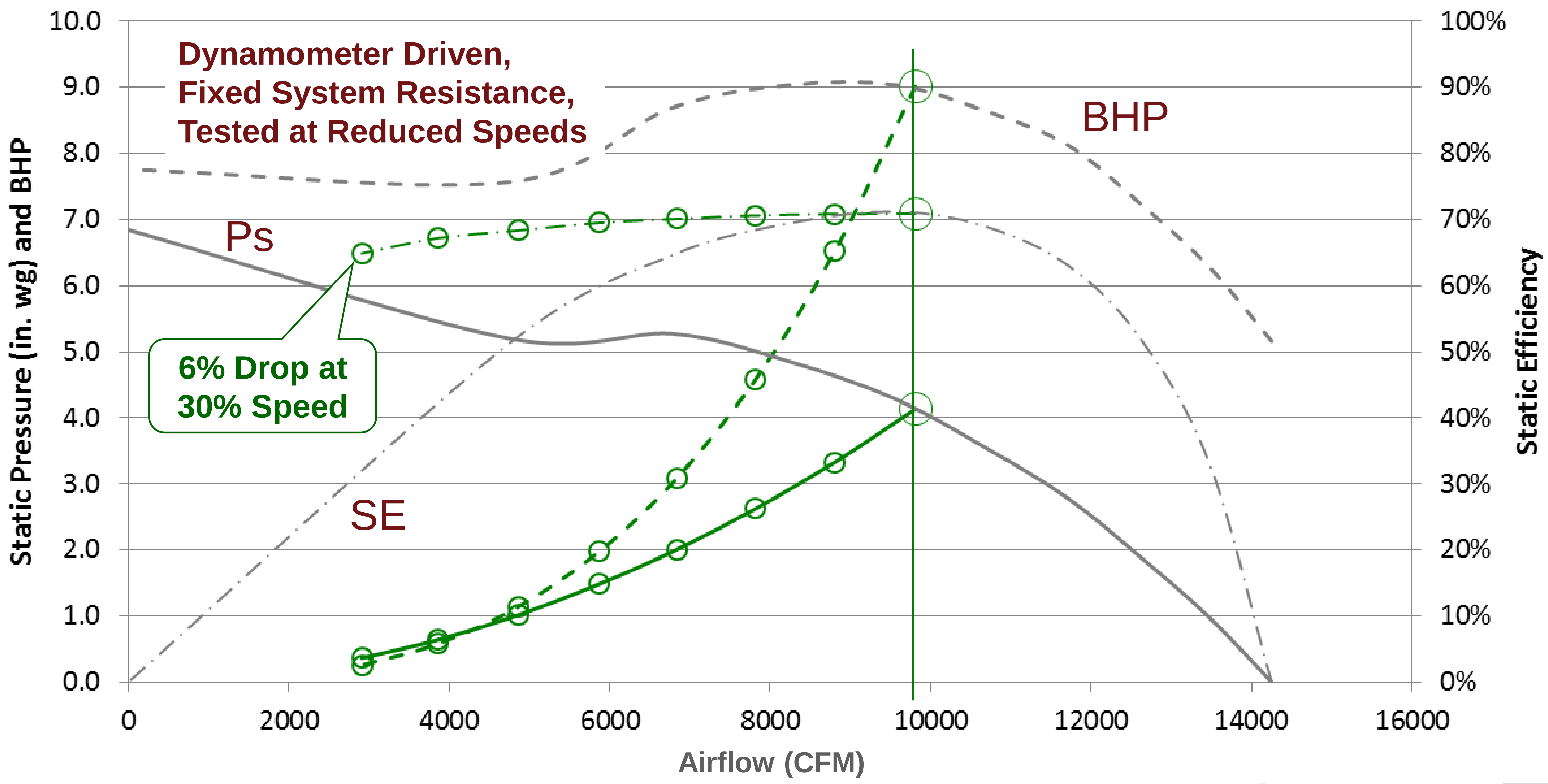
Fan Curve at Constant Speed



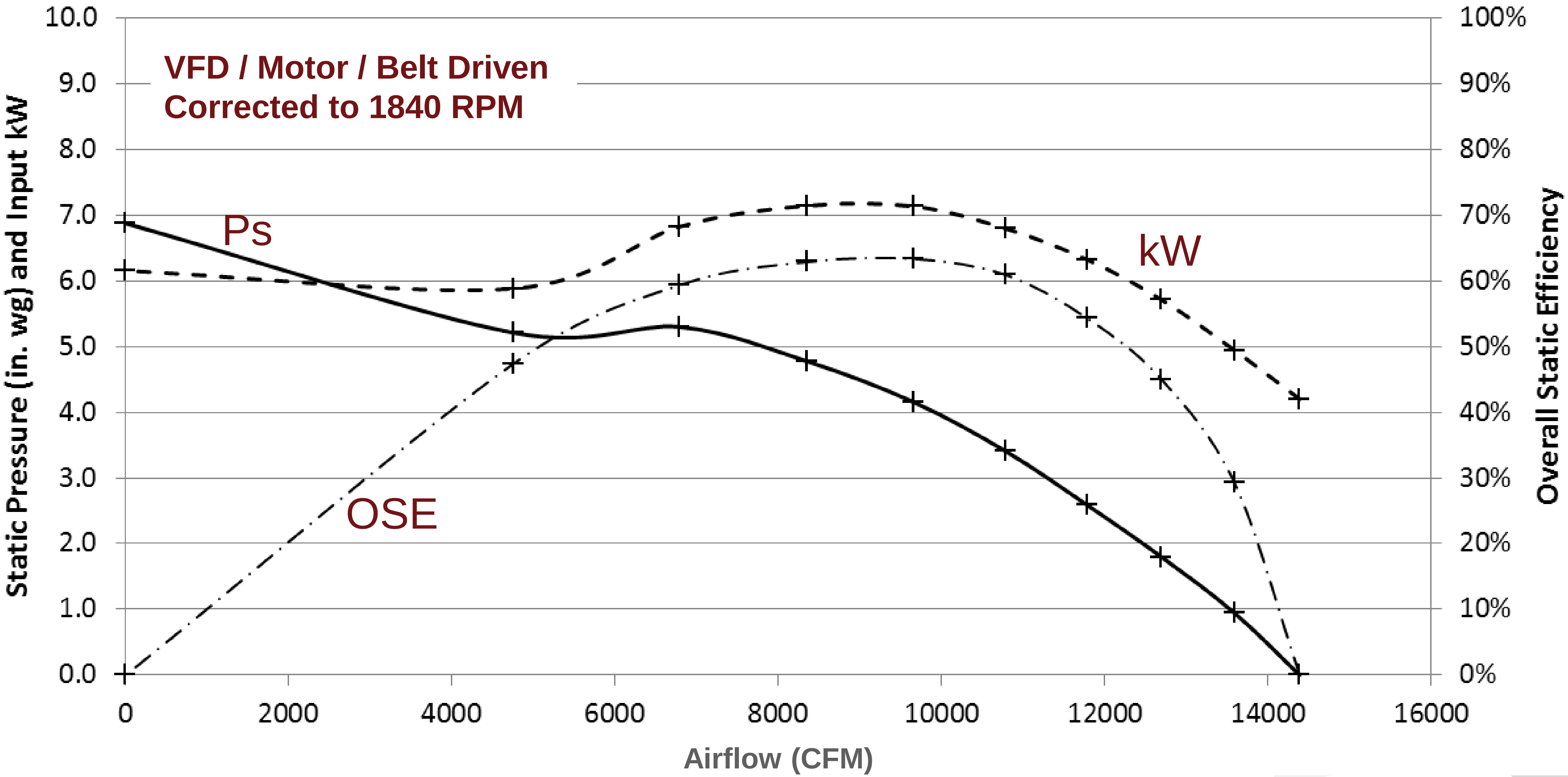
Fixed System Resistance



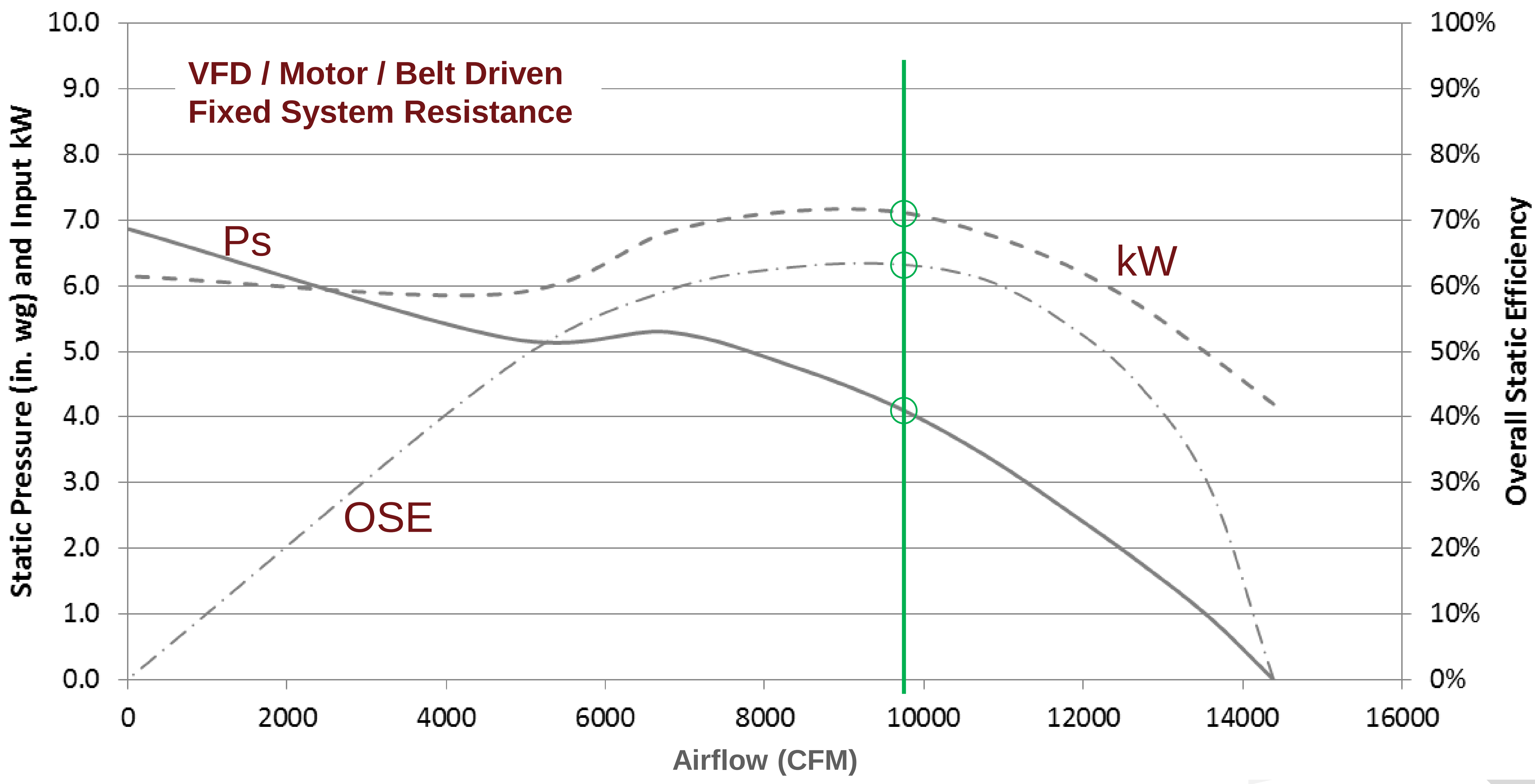
Variable Speed Test



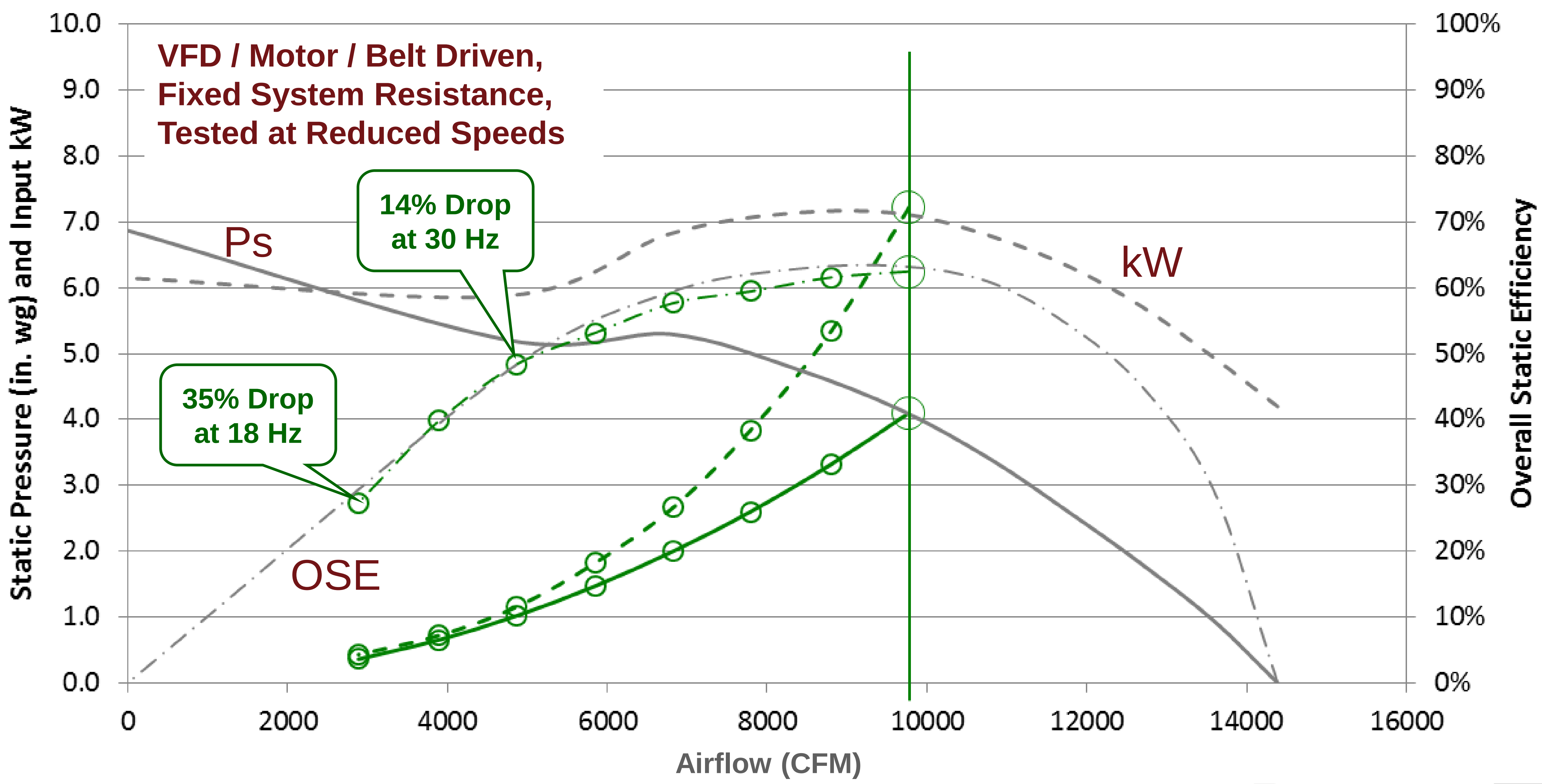
Fan Curve at Constant Speed



Fixed System Resistance

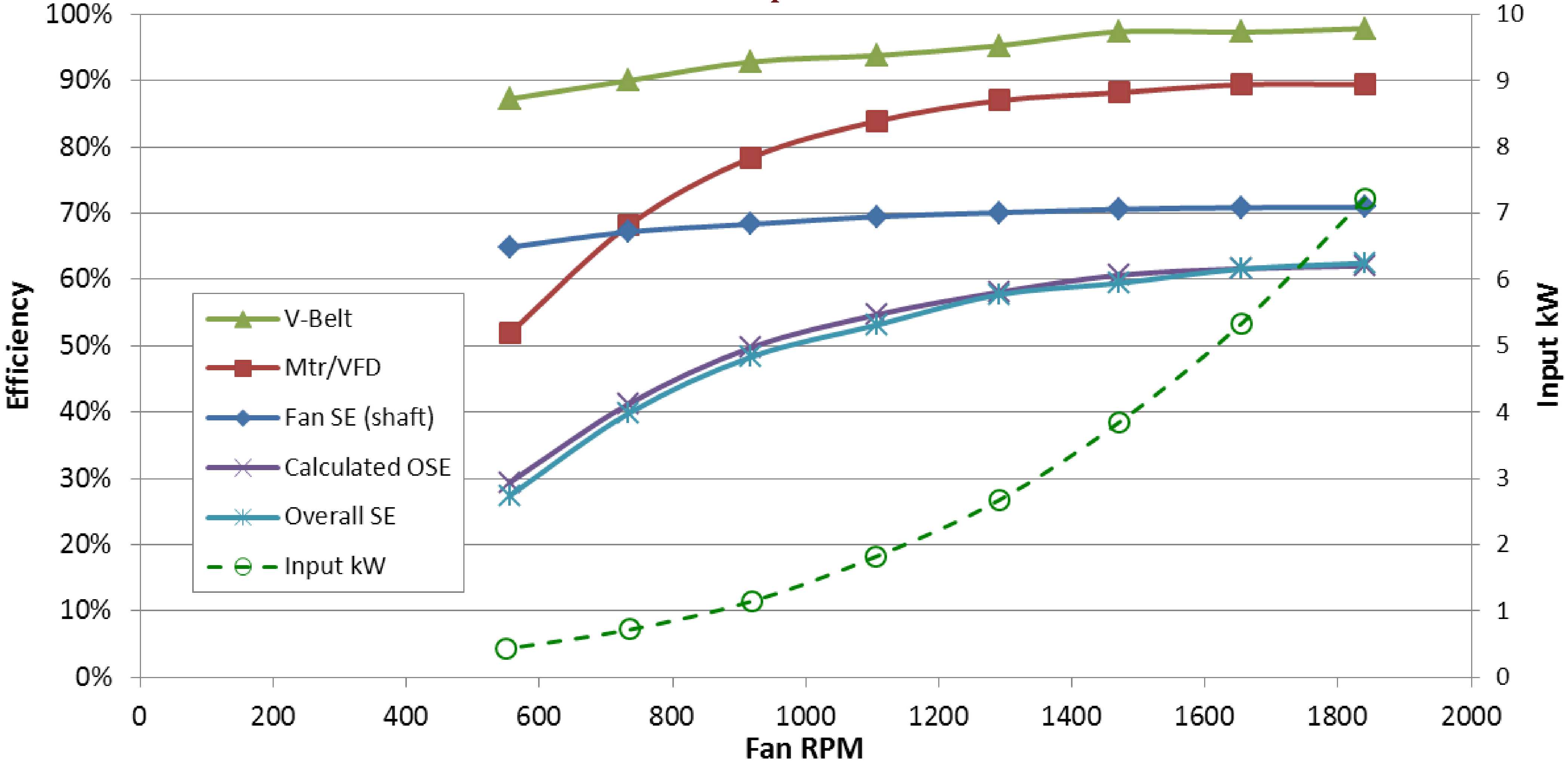


Variable Speed Test



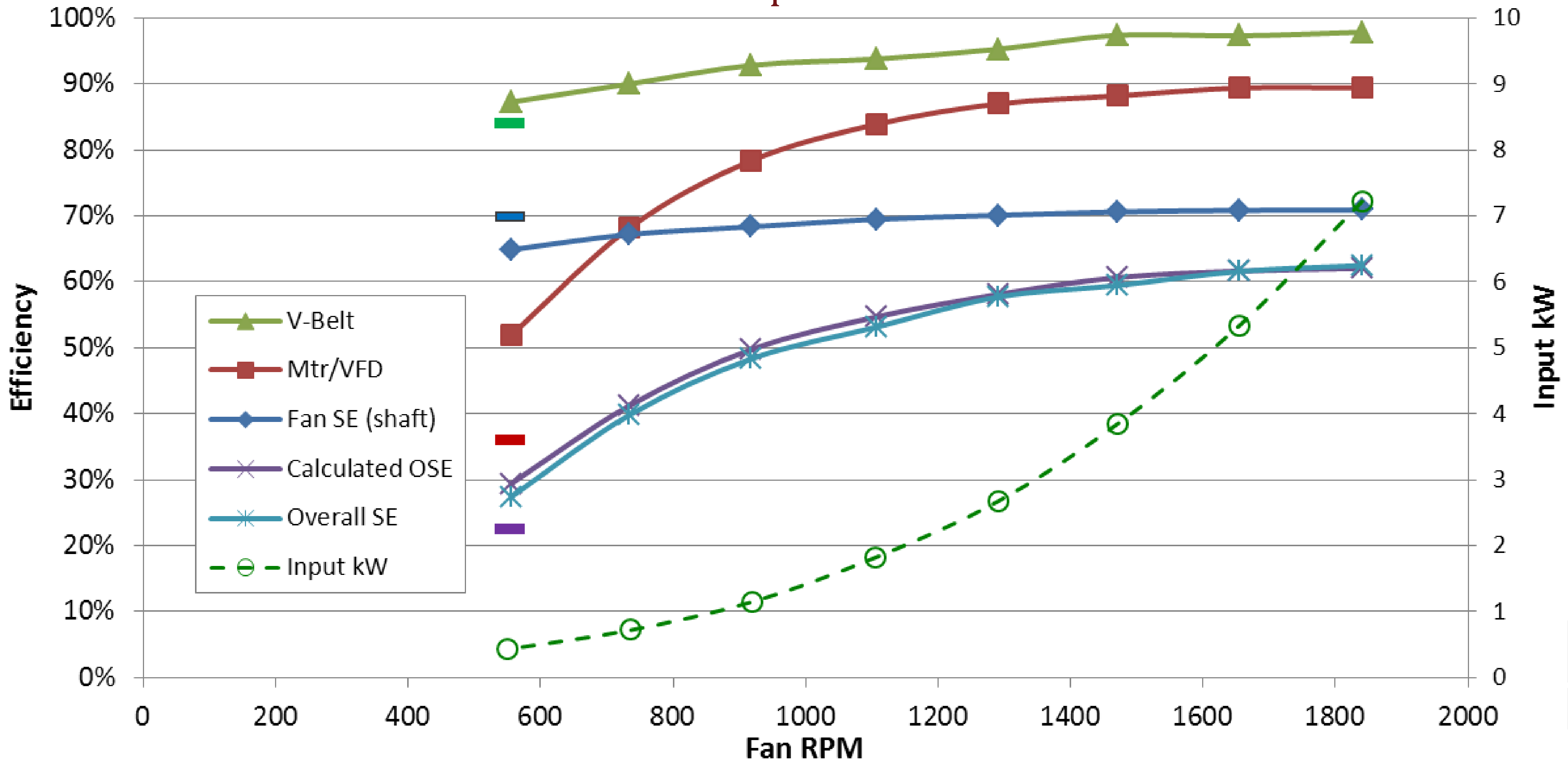
Overall Fan Static Efficiency

$$\eta_{overall} = \frac{\text{Output Power}}{\text{Electrical Input Power}} = \eta_{fan} \times \eta_{trans} \times \eta_{mtr} \times \eta_{vfd}$$



AMCA 207 Estimates

$$\eta_{overall} = \frac{\text{Output Power}}{\text{Electrical Input Power}} = \eta_{fan} \times \eta_{trans} \times \eta_{mtr} \times \eta_{vfd}$$



Conclusions

Component Efficiencies:

- Motor efficiency is a function of load and is typically available from motor manufacturers
- For fan loading, motor/VFD efficiency is a function of load (power), regardless of torque or speed
- Fan efficiency drops slightly with speed
- AMCA 207 is a conservative model of power drive component efficiencies and can also be used for part-load modeling
- Largest losses at part load are from Motor/VFD

Overall efficiency is the product of component efficiencies:

- $\eta_{\mathrm{overall}} = \eta_{\mathrm{fan}} \times \eta_{\mathrm{trans}} \times \eta_{\mathrm{mtr}} \times \eta_{\mathrm{vfd}}$

Q & A

Survey QR Code:

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Attendees will receive an email at the address provided on your 2023 AHR Expo registration, listing the total credit hours awarded and a link to a printable certificate of completion.

If you have any questions, please contact Lisa Cherney, Education Manager, at AMCA International (lcherney@amca.org).

NEXT SESSION @ 4:00PM:

Harmonization of Standards in the Industry