Variable Frequency Drives: Method of Laboratory Test and a Case Study

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Agenda

- Benefits of Utilizing VFDs
- Standard Method of Test for Electrical Power Drive Systems
- Case Study of Applying VFDs to an HVAC System
- Questions

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Benefits of Utilizing VFDs

Presented by: Tom Lowery, Sales Operations Manager, Schneider Electric

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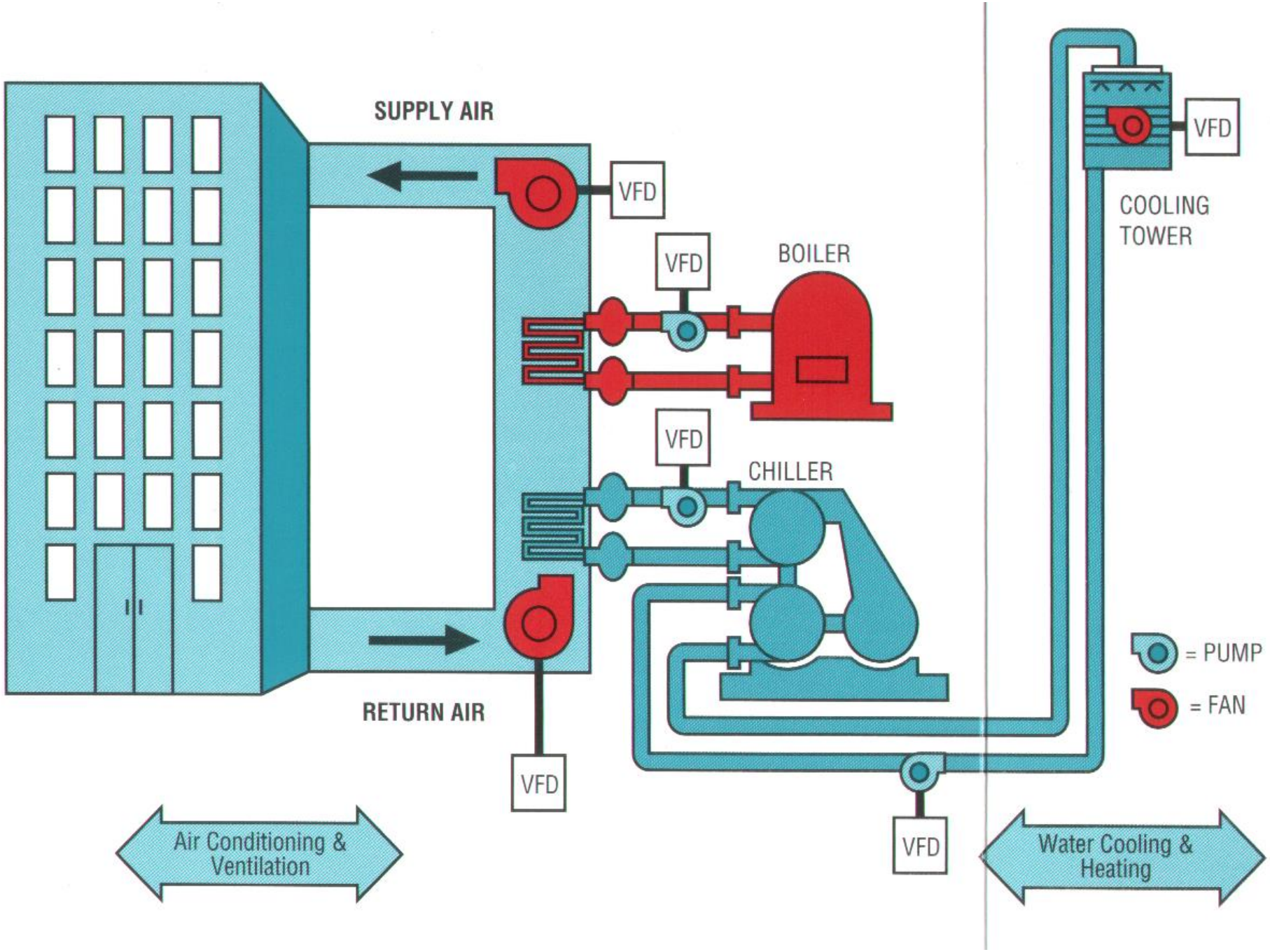

Many Applications in HVAC can benefit from Variable Flow

- Increased efficiency
- Adaptation as loads change and expansion takes place
- Reduced maintenance and extended equipment life

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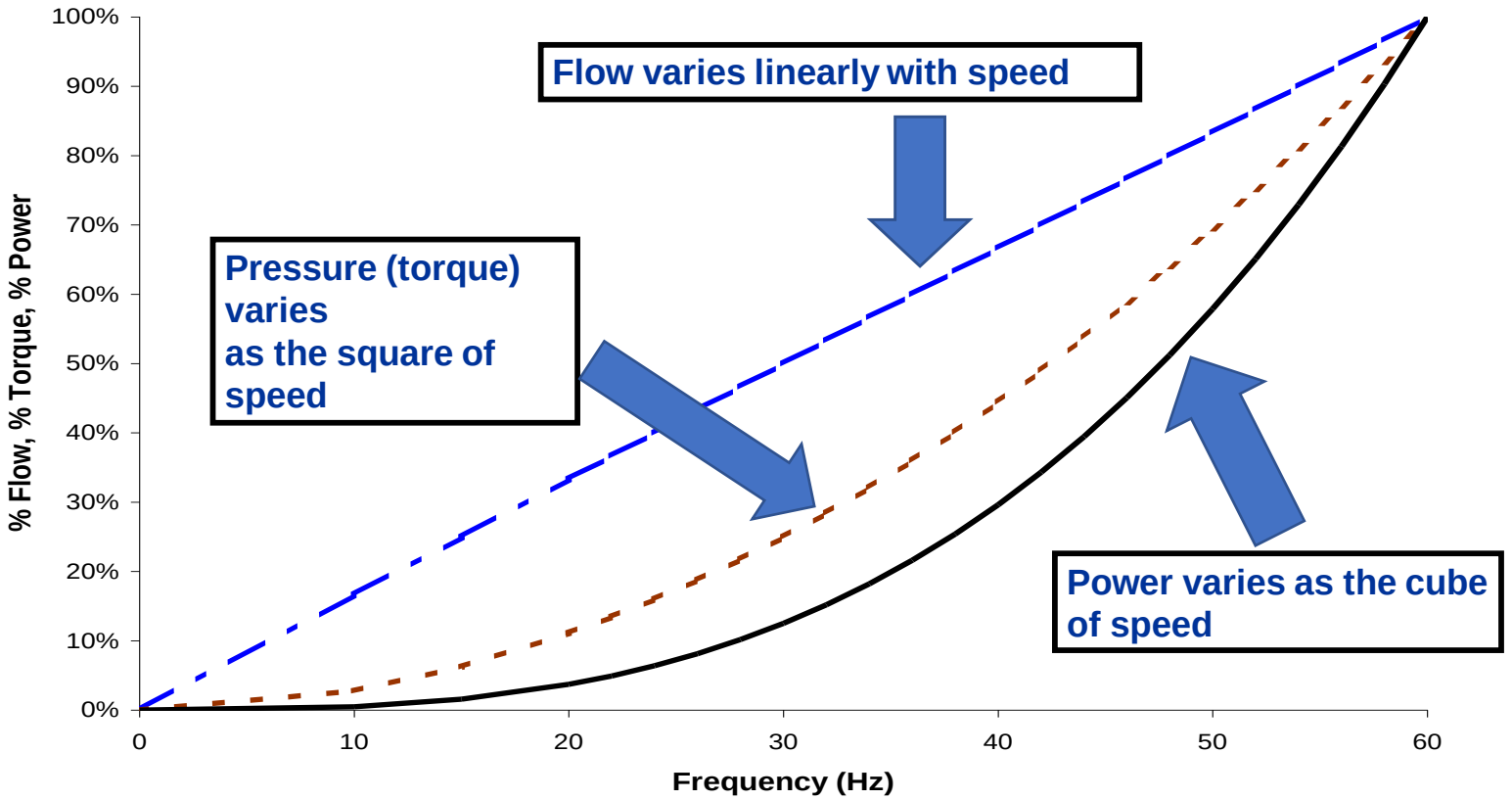

For 100 HP (74.6kW) Application:
80% Speed = 51.2% Power
60% Speed = 21.6% Power
40% Speed = 4.8% Power

Less Power Consumed = Lower Operational Costs

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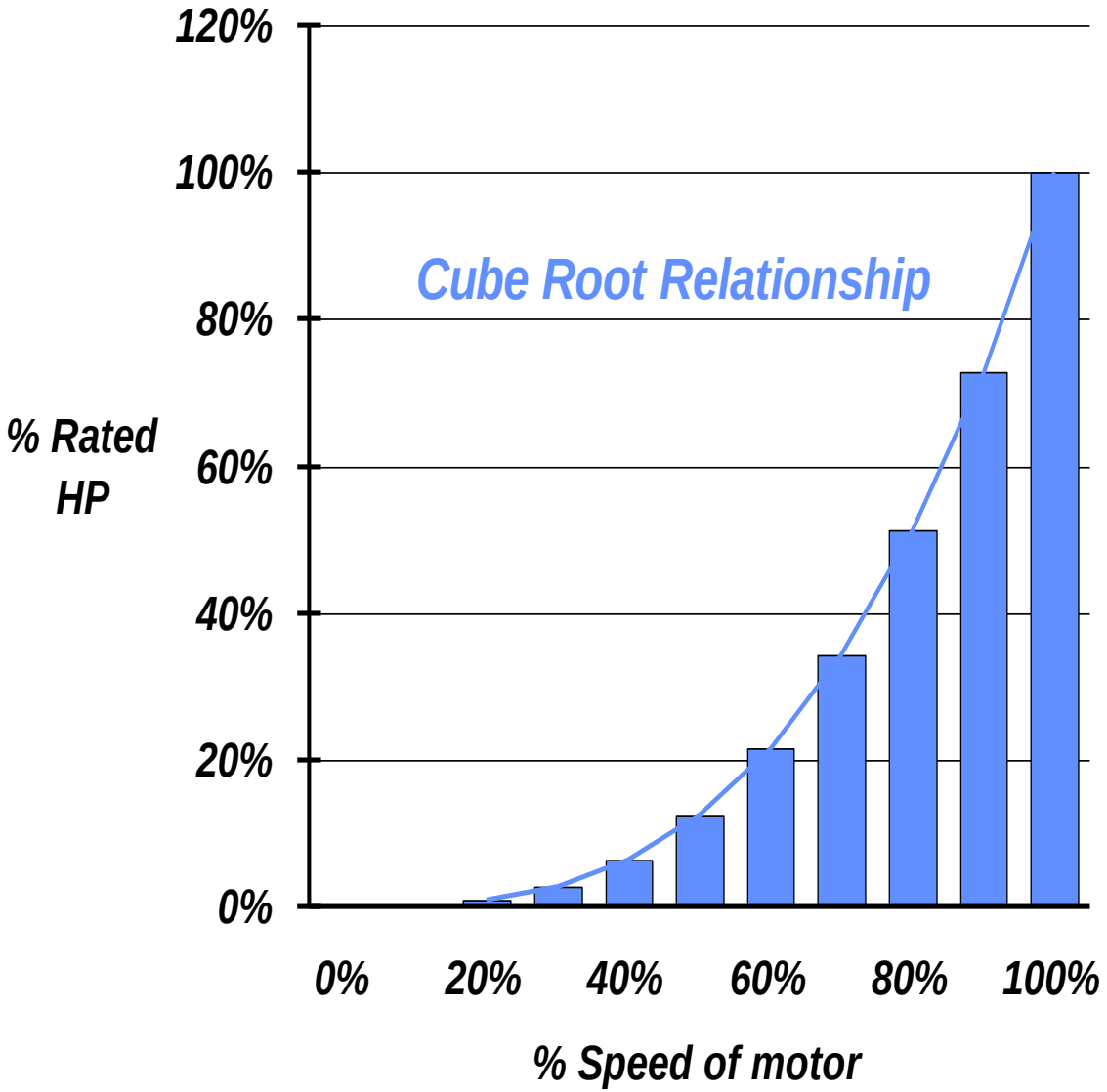
Energy Requirements of Basic Centrifugal Loads



Why are drives a popular choice for saving energy on basic centrifugal loads?

- Loading of VAV systems require dynamic control of the motors
- Oversized system designs
- 20% reduction in speed requires about 50% of the power consumed at full speed

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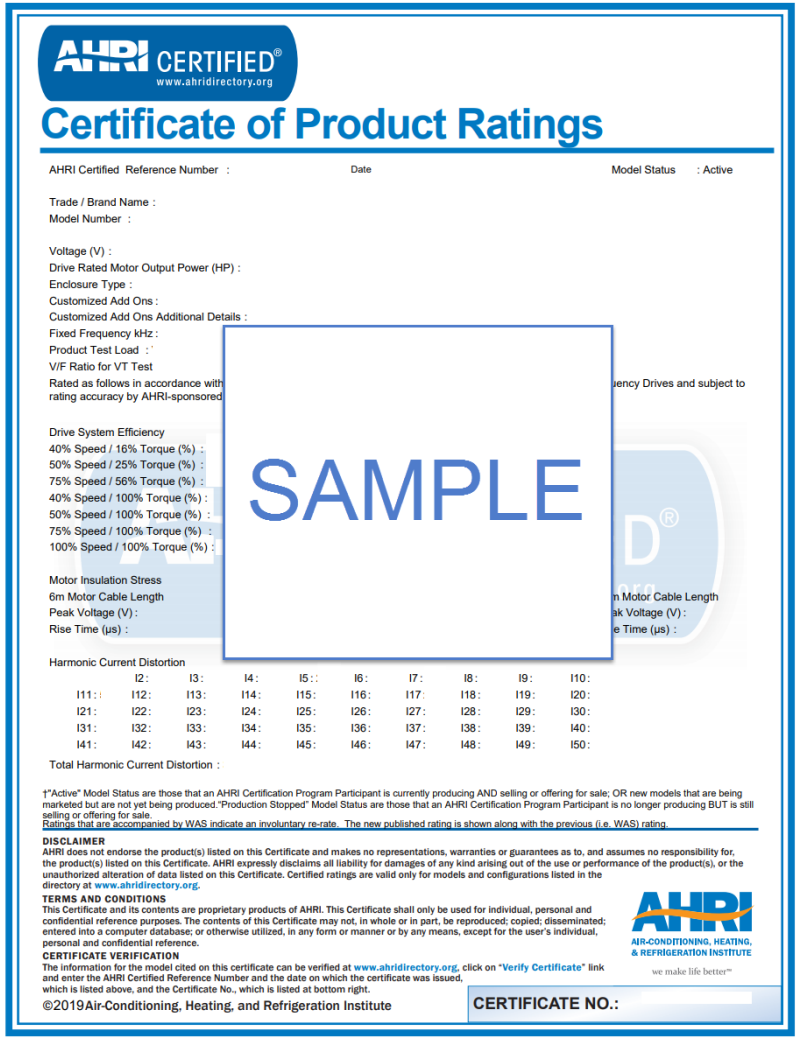
Why use this third party certification for VFDs?

Consider:

1. **Independent organization that is industry recognized for equipment certifications**

2. **Standard establishes common Method of Test**

3. **No longer have to rely on internal manufacturer's test data, which may not reflect equal operating conditions**



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Certificate of Product Ratings

AHRI Certified Reference Number : Date Model Status : Active

Trade / Brand Name :
Model Number :

Voltage (V) :
Drive Rated Motor Output Power (HP) :
Enclosure Type :
Customized Add Ons :
Customized Add Ons Additional Details :
Fixed Frequency kHz :
Product Test Load :
V/F Ratio for VT Test
Rated as follows in accordance with ... ency Drives and subject to rating accuracy by AHRI-sponsored

Drive System Efficiency
40% Speed / 16% Torque (%) :
50% Speed / 25% Torque (%) :
75% Speed / 56% Torque (%) :
40% Speed / 100% Torque (%) :
50% Speed / 100% Torque (%) :
75% Speed / 100% Torque (%) :
100% Speed / 100% Torque (%) :

SAMPLE

Motor Insulation Stress
6m Motor Cable Length
Peak Voltage (V) :
Rise Time (µs) :

Harmonic Current Distortion

	I2:	I3:	I4:	I5:	I6:	I7:	I8:	I9:	I10:
I11:	I12:	I13:	I14:	I15:	I16:	I17:	I18:	I19:	I20:
I21:	I22:	I23:	I24:	I25:	I26:	I27:	I28:	I29:	I30:
I31:	I32:	I33:	I34:	I35:	I36:	I37:	I38:	I39:	I40:
I41:	I42:	I43:	I44:	I45:	I46:	I47:	I48:	I49:	I50:

Total Harmonic Current Distortion :

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Verify certification by using on-line listings

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Inside AHRI Standards 1210/1211

Performance Testing

- Drive Efficiency (%) at 40%, 50%, 75% and 100% Speed – Both Drive and Motor
- Drive Input Harmonics (% THD_I) at 100% Speed
- Drive Output Peak Voltage (V) and Rise Time (µsec)

Table 1. Voltage and Power Classifications[1]

VFD Voltage Rating (V)	200 to 240	380 to 480	550 to 600
Supply Voltage V_s (V)	208	460	575
Power (hp)	1.0	1.0	1.0
	2.0	2.0	2.0
	3.0	3.0	3.0
	5.0	5.0	5.0
	7.5	7.5	7.5
	10.0	10.0	10.0
	15.0	15.0	15.0
	20.0	20.0	20.0
	25.0	25.0	25.0
	-	30.0	30.0
	-	40.0	40.0
	-	50.0	50.0
	-	60.0	60.0
	-	-	75.0

Note 1: Nominal horsepower ranges are determined for applied motors that fall within Sections 430.250 NEC Handbook full load current ratings table in amps.

Table 2. Speed/Torque Test Points for Drive System Efficiency and Motor Stress Insulation Tests[1,2]

		Percent Torque			
		16%	25%	56%	100%
Percent Speed	40%	VT			CT
	50%		VT		CT
	75%			VT	CT
	100%				CT/VT

Notes:
1. Output frequency or other readouts from the VFD shall not be used to determine percent speed.
2. Only those cells that contain CT or VT are test points

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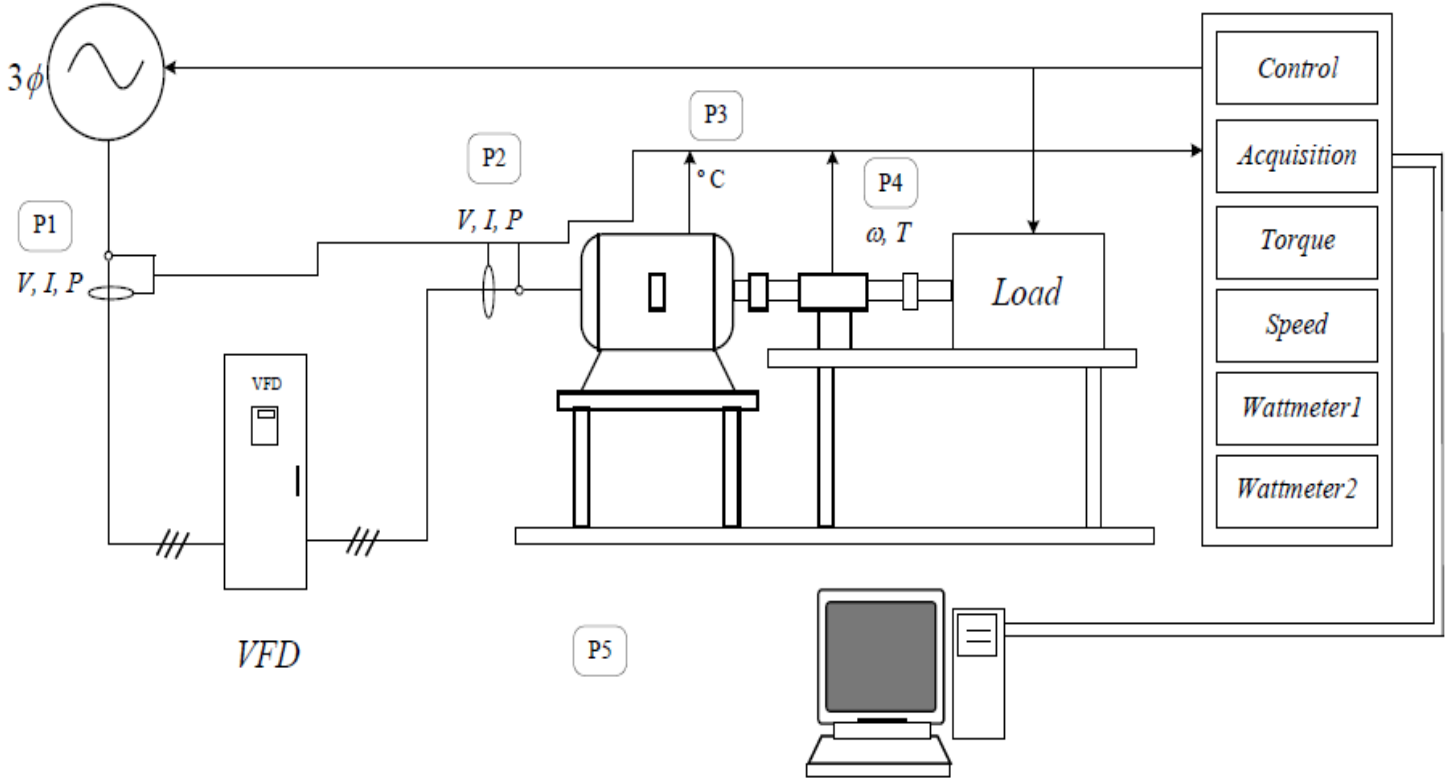
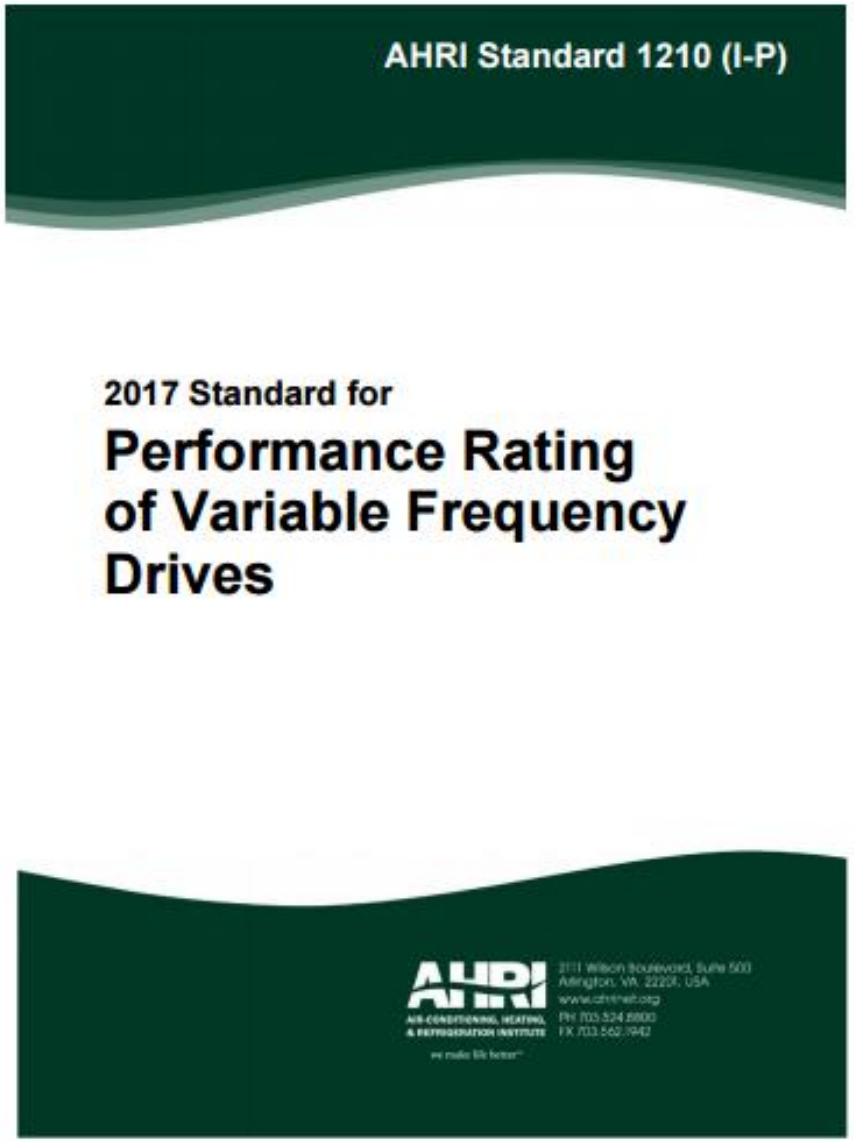
Inside AHRI Standards 1210/1211

Standardized Test Procedure

(including test motor)





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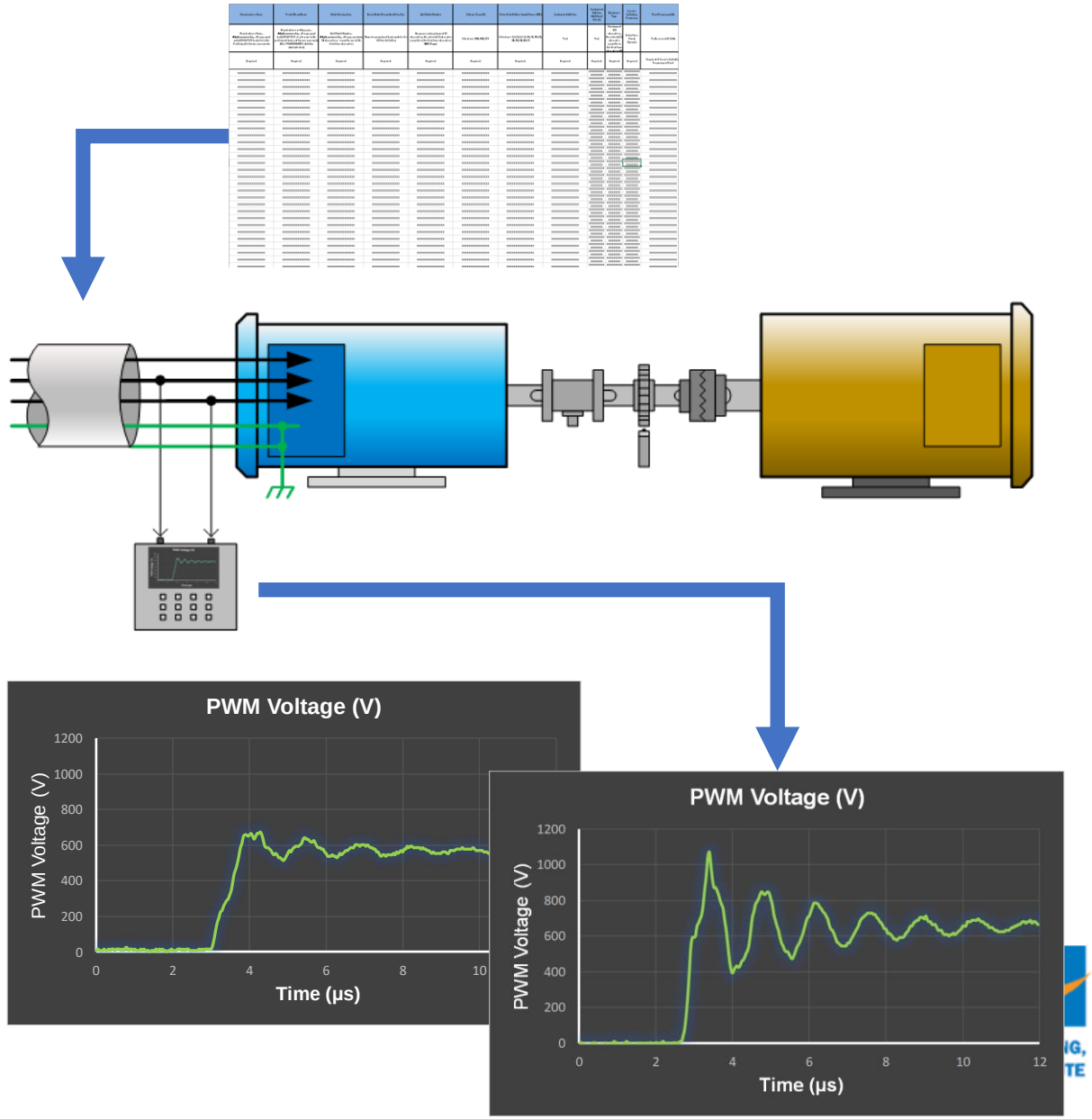
AHRI 1210/1211 Certification Process

Steps	Tasks
Manufacturer provides performance ratings for each model	1. Test Internally to AHRI Standards 1210/1211 at a lab
Submit ALL required data for each model number per AHRI 1210/1211	1. Complete required form for each model number 2. Submit data so AHRI can verify
AHRI will randomly select model number samples for certification testing	1. Lab will make selection of certification testing 2. Sample is shipped to lab for testing
Performance testing is conducted annually	1. Certification testing conducted annually 2. Test failures can be re-tested or VFDs are re-rated



Conclusions

AHRI Standard 1210/1211 gives engineers and others that require certified VFD performance a new tool to:

1. Compare performance criteria between certified VFD manufacturers under a standardized method of test

2. Guarantee clients that the specified VFDs will meet minimum efficiency, harmonic and dV/dt performance levels

3. Compliment other equipment that is specified using AHRI Standards and certification programs

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Standard Method of Test for Electrical Power Drive Systems

ANSI/ASHRAE Standard 222-2018

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ANSI/ASHRAE Standard 222-2018

Standard Method of Test for Electrical Power Drive Systems

Approved by ASHRAE on July 31, 2018, and by the American National Standards Institute on August 1, 2018.

ASHRAE® Standards are scheduled to be updated on a five-year cycle; the date following the Standard number is the year of ASHRAE approval. The latest edition of an ASHRAE Standard may be purchased on the ASHRAE website (www.ashrae.org) or from ASHRAE Customer Service, 1791 Tullie Circle, NE, Atlanta, GA 30329-2305. E-mail: orders@ashrae.org. Fax: 678-539-2129. Telephone: 404-636-8400 (worldwide) or toll free 1-800-527-4723 (for orders in US and Canada). For reprint permission, go to www.ashrae.org/permissions.

 ISSN 1041-2336

- Determine wire-to-shaft performance
- HVAC&R-related electric motor systems
- Adjustable-speed types
- Alternating-current (AC) input

https://www.techstreet.com/ashrae/ashrae_standards.html

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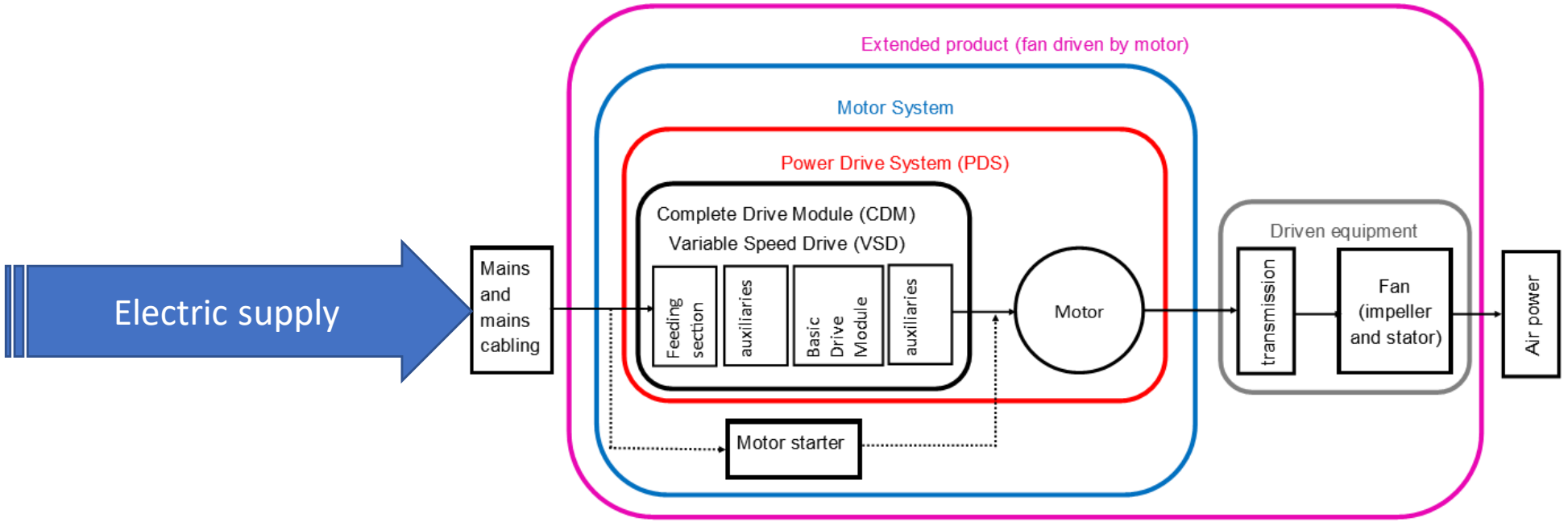

Terminology	Examples
Complete Drive Module	Variable frequency drive or electronic commutation unit
+ motor	Mechanical assembly of rotor, stator, housing
Power Drive System	Separate CDM or integrated
+ motor starter	
motor system	
+ driven equipment	Bare fan, pump, air compressor including mechanical transmission
extended product	

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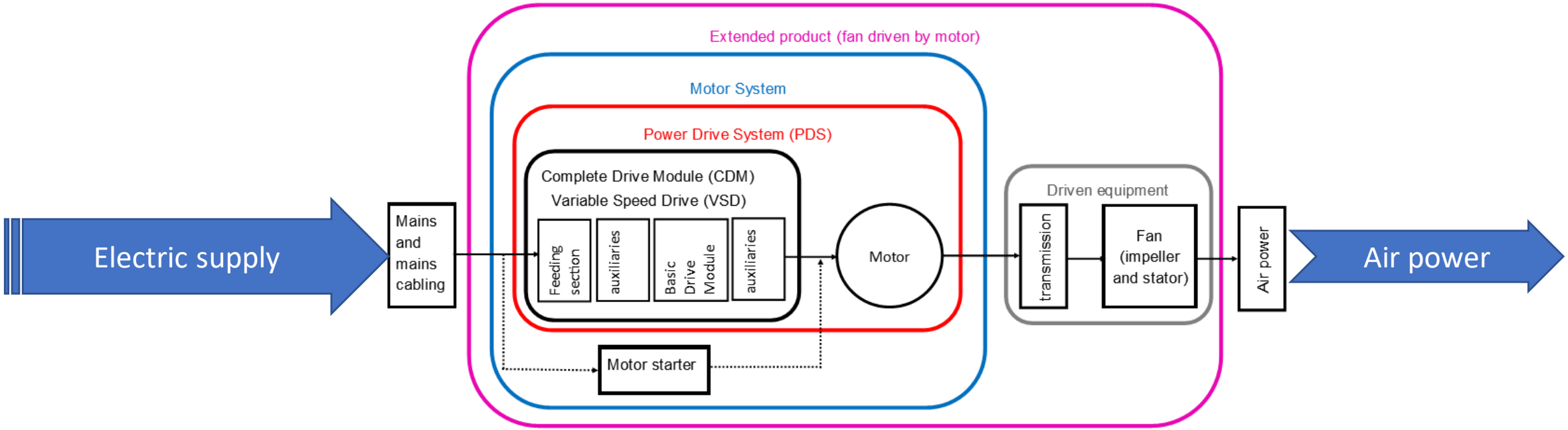

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+ driven equipment	Bare fan, pump, air compressor including mechanical transmission
extended product	Driven fan unit

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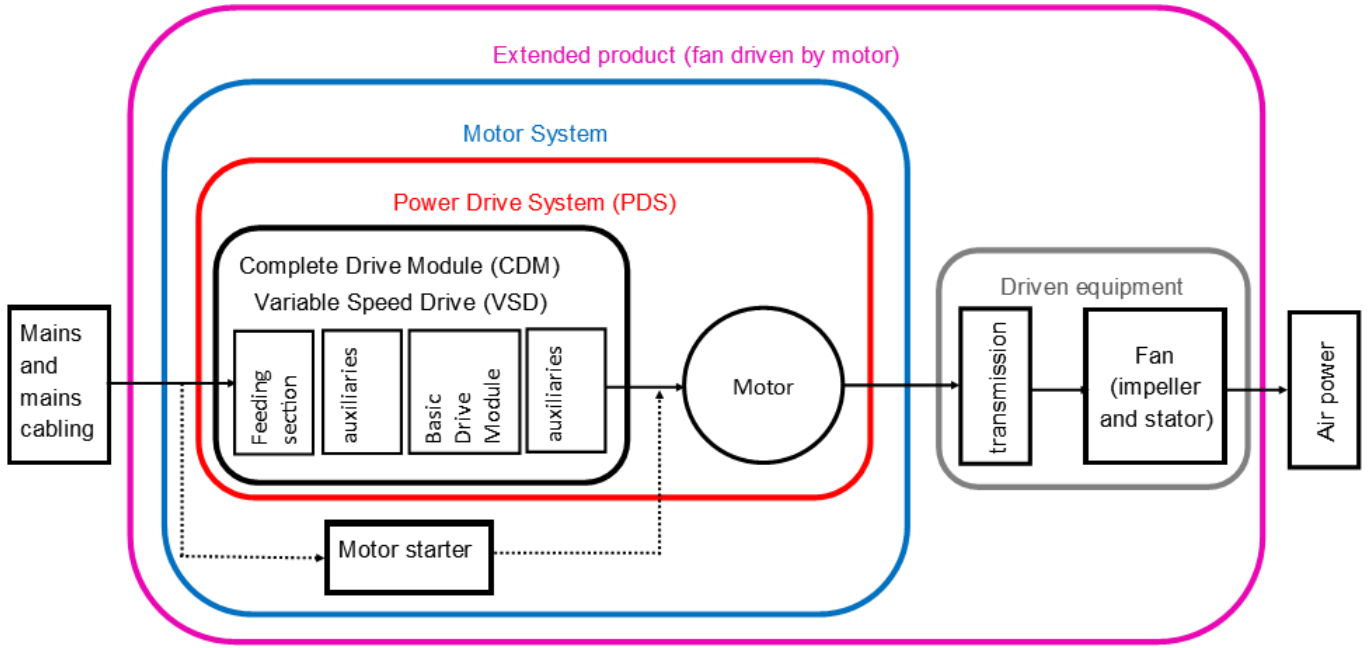

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~~extended product~~	

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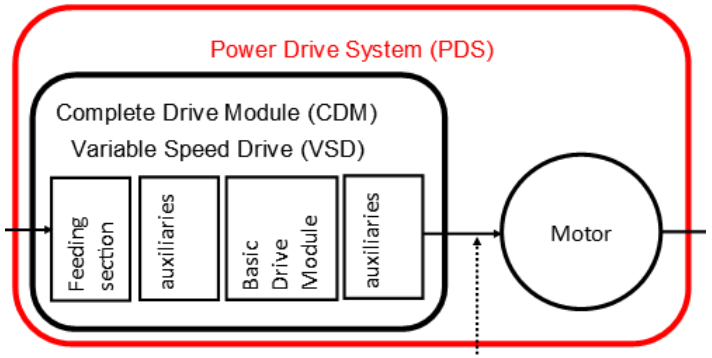
Scope of ASHRAE standard 222



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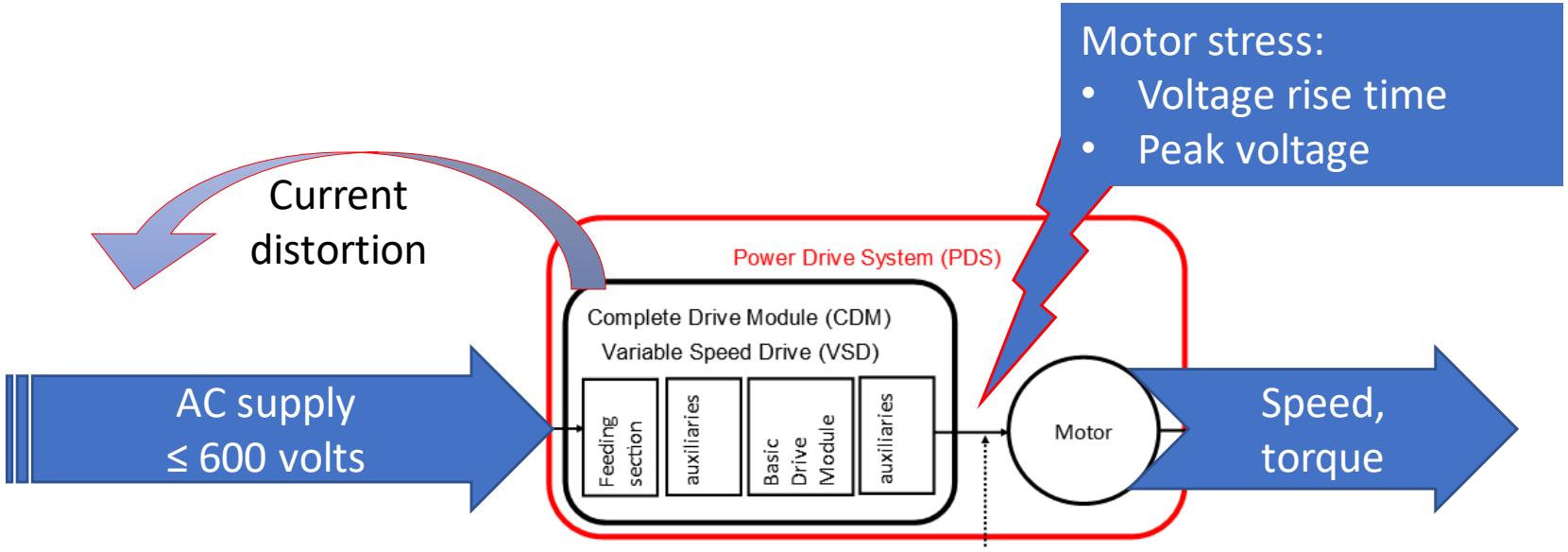

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Purpose

- Determine energy efficiency alongside motor stress and harmonics emissions.
  (Corrective measures for one can influence another.)
- $\eta_{sys} = \frac{P_o}{P_i} = \frac{motor\ shaft\ power}{line\ input\ power}$
  - Not using loss segregation methods
  - Not measuring power between the electronic drive and the motor
- This test method is entirely harmonized with AHRI's existing certification program for variable frequency drives that are rated inclusive of a specific set of NEMA Premium efficient motors.
- The new scope is not limited to certain motor or drive technologies.

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Power drive system classifications and tests

	Efficiency	Harmonic current emission spectrum	Motor stress
Electronic drives designed for use with interchangeable motors connected with cables	Y	Y	Y
Motors with drive electronics integrated by the manufacturer	Y	Y	Not possible and not necessary

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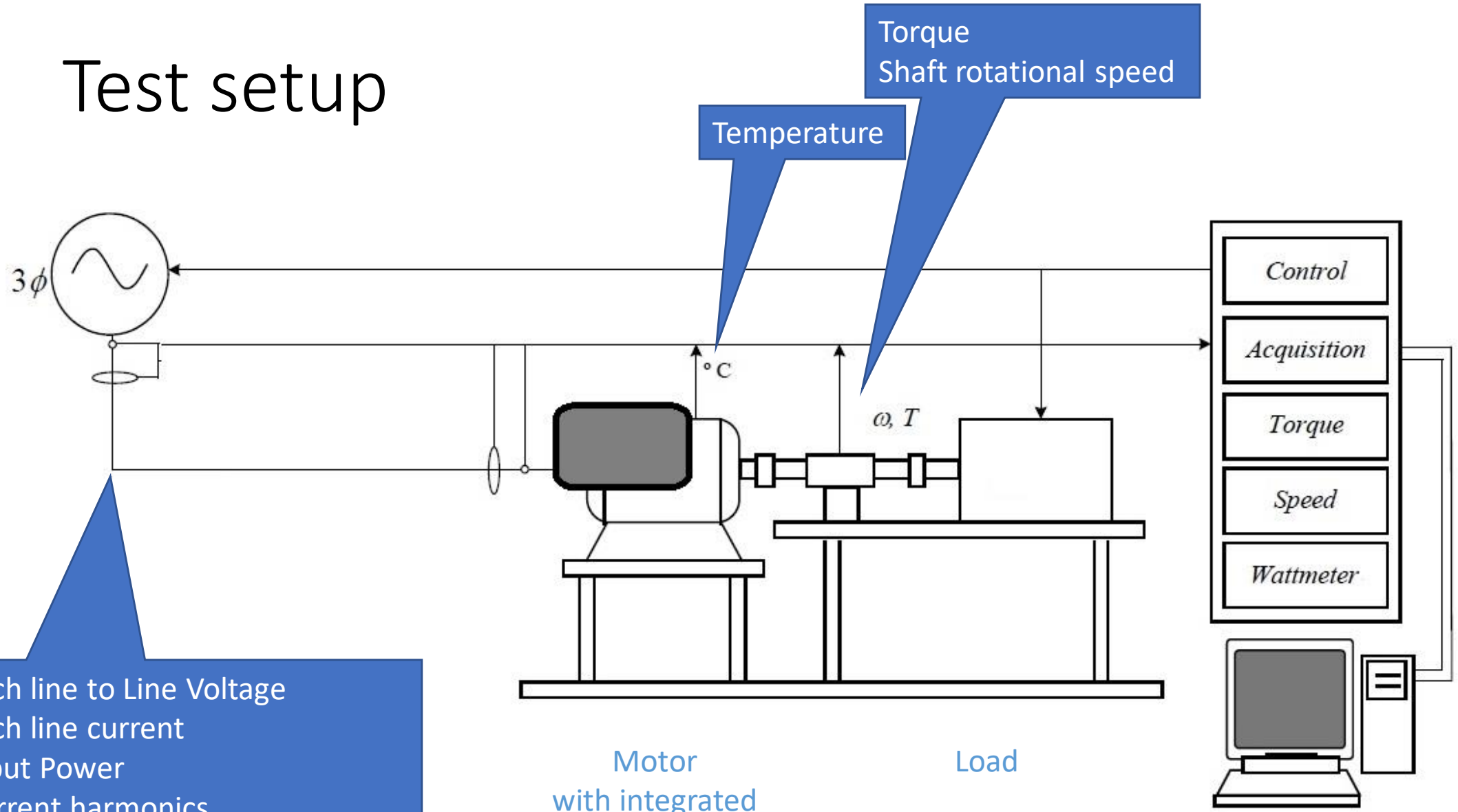
Test setup



Each line to Line Voltage
Each line current
Input Power
Current harmonics
Total harmonic current distortion
Real power factor

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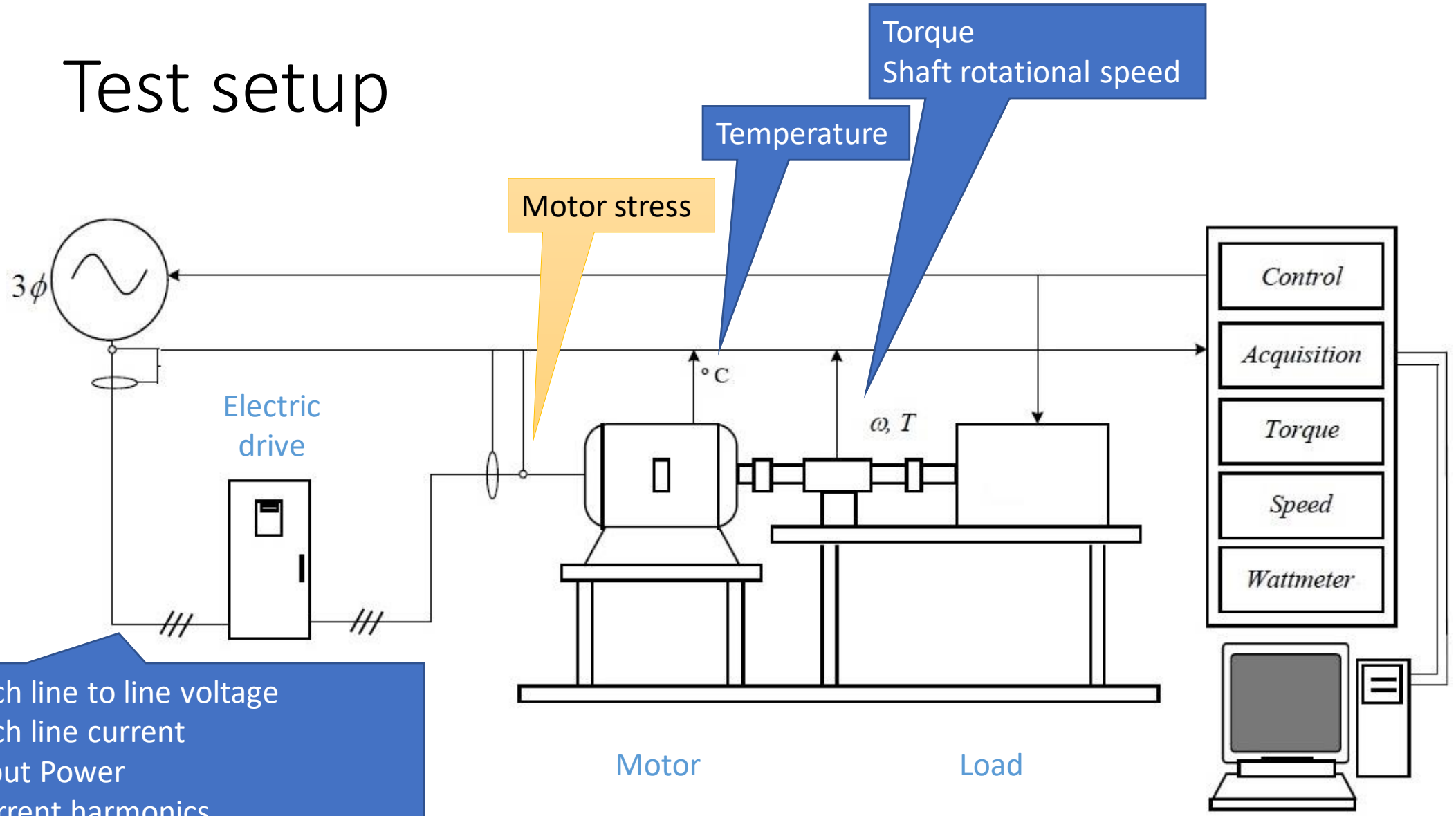
Test setup



Each line to line voltage
Each line current
Input Power
Current harmonics
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Test standard without test conditions

Customized projects
Energy codes
Certification program

* Load points
* Source voltage & frequency
*Motor conductor lengths

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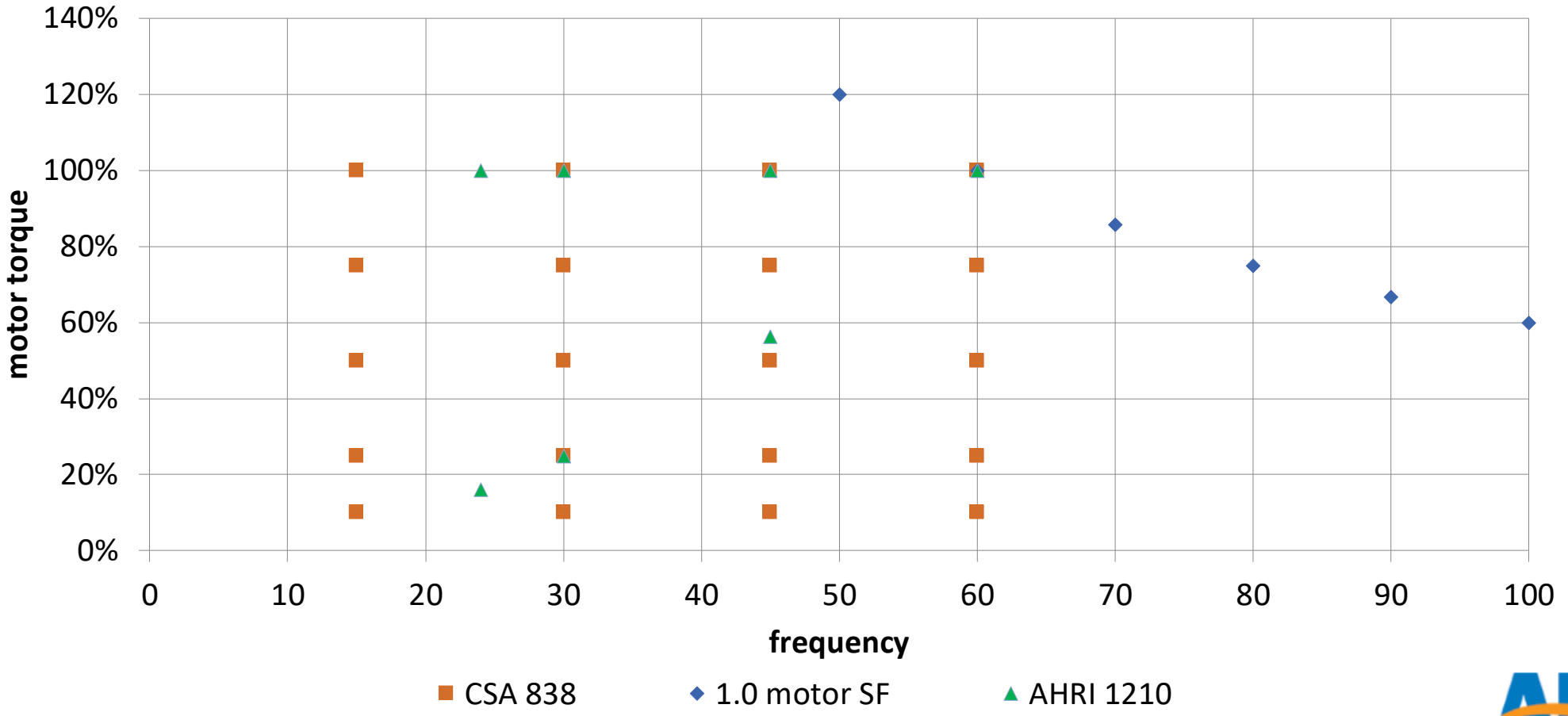
Test standard without test conditions



** Load points may be chosen as needed or elsewhere specified **

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ANSI/ASHRAE 222-2018 summary

- Efficiency, current distortion, and motor stress are reportable together.
- Foundation for fair motor system comparisons so that inverter-only motors are indeed evaluated including the necessary electronic drive.
  - Wire-to-shaft efficiency
- Universal
  - Remote or integrated drives
  - Variable frequency drives, induction motors, permanent magnet, synchronous reluctance, et al

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Case Study of Applying VFDs to an Existing HVAC System

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1970: A New Building

- 100 year design life.
- 64 stories tall.
- The tower doesn't taper at the top. Each story has an acre of floor space (43,560 ft^2 / 4047 m^2).
- Leasable space: over 2.3 million ft^2 / 213,000 m^2.
- A university medical center is now the largest tenant (500,000 ft^2 / 46,000 m^2).

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1970 - 2000: Operating costs increase

The potable water pumping system was the first retrofit target.

- Water is pumped up to a 300 gallon (1100 ℓ) tank on the 64th floor.
- The redundant pumping system consists of 2 pairs of 100 HP pumps.
  - Each pair was alternated weekly.
  - If necessary, one pump could handle the entire load.
- Each pump was started directly across the power line and could only run at two specific speeds.
  - The jump in speeds produced a large stress on the system.
  - The limited set of speeds kept the pumps from running at the optimum speed for the system.
- This caused premature wear on the pumps.
- The system was also unable to run at high efficiency.

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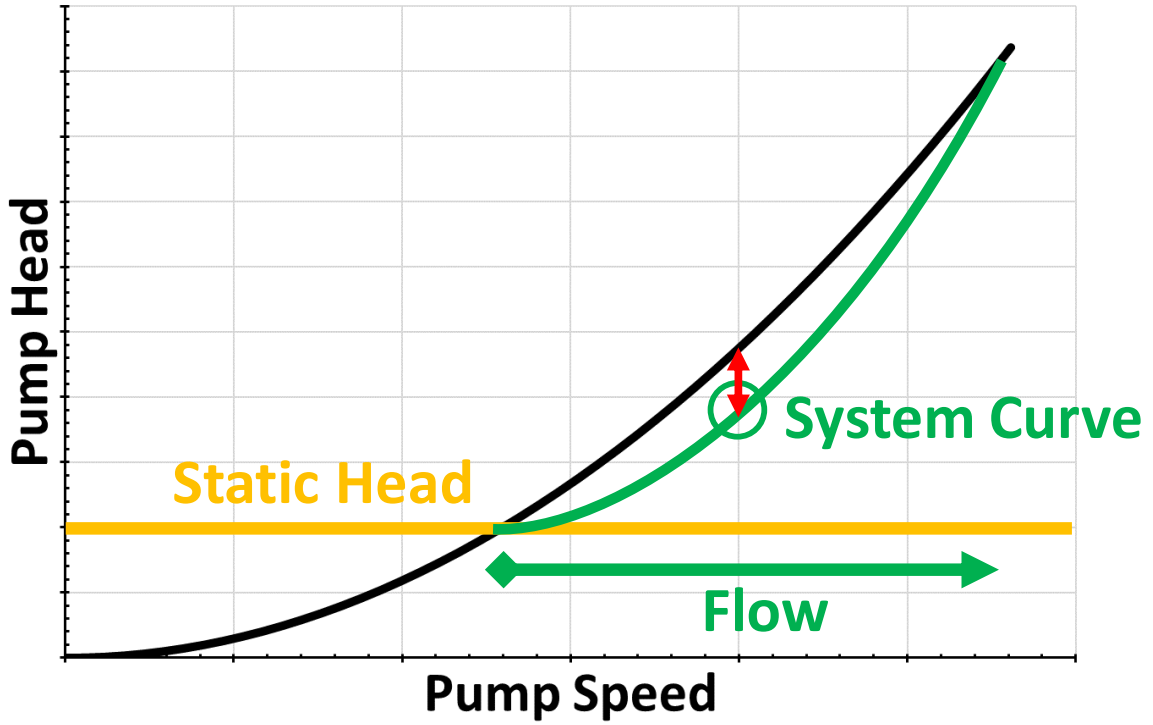
2000: Reducing operating costs

- When the system was updated with variable frequency drives (VFDs), it was possible to smoothly control the pump speed to reduce stress and increase efficiency.
- While the VFDs saved energy, the Engineering Manager for the property was most impressed because "*pump-motor rebuilds have been zero*."



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2008 - 2010: The state mandates energy cuts

- The mandates required reducing:
  - electric energy consumption and
  - peak electrical demand.
- In response to this, the local power utility instituted a rebate program.

- VFDs were applied to the 200 to 250 HP circulation fans.
- After this, fans down to 30 HP received VFDs.
- This program resulted in annual electrical energy savings of **$535,000.**
- This, plus the utility rebate, resulted in a **one-year payback**.

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2011 - 2013: Phase 2 through 4 retrofits

- **2011** saw a project for retrofitting VFDs on chilled water and water pre-heat loops.
  - While the pumps were smaller than the previous pumps and fans, there were more of them.
  - 40 pump motors from 50 to 200 HP received new VFDs.
  - Annual electric energy savings were **$138,000**.

- 16 drives for 250 HP motors were added in **2012**.
  - Annual electrical energy savings were **$317,000**.

- In **2013** 40 VFDs driving 7.5 through 60 HP were added.
  - This resulted in an annual electrical energy savings of **$152,000**.

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Summary of energy cost savings

- In **2009** the annual electrical energy consumption was **65 million kWh**.
- As of **2015**, the building's annual electrical energy consumption was **43 million kWh**, more than a 32% reduction.
- During the same time, the peak demand went from **16 to 17 MW** to **10 MW**, more than a 33% reduction.

- The 150 VFDs which have been installed have produced more than **$1.1 million** in annual savings in energy reduction and reduced demand charges.
  - The energy and maintenance savings resulted in an occupancy level of nearly 98%.
  - 17 floors of the building earned silver LEED status and 6 reached a gold LEED status.
  - The BOMA 360 Performance Program also recognized the building.

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An important bonus: communication

- Each VFD comes with a variety of HVAC serial communication protocols.
- This allows the Building Automation System (BAS) to:
  - directly control individual VFDs.
  - log the VFD's performance and energy consumption.
  - support proactive maintenance by monitoring the status of the VFD and the equipment which it drives.

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The relevance of AHRI 1210 and 1211

- The first item that attracted the management team for the building was the reliability of the system when the VFD was used.
  - It is important to ensure that the VFD and the motor will work together reliably.
  - The certified values of the rise time and peak value of the PWM pulses sent to the motor by the VFD are used to ensure motor/VFD compatibility.
- The efficiency of the VFD and the driven motor is essential.
  - This data is freely available on the AHRI web site.
- When many VFDs are applied in a facility, it is important to consider the impact which they will have on the facility's power grid.
  - The harmonic current drawn by the VFD is the other certified value.

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