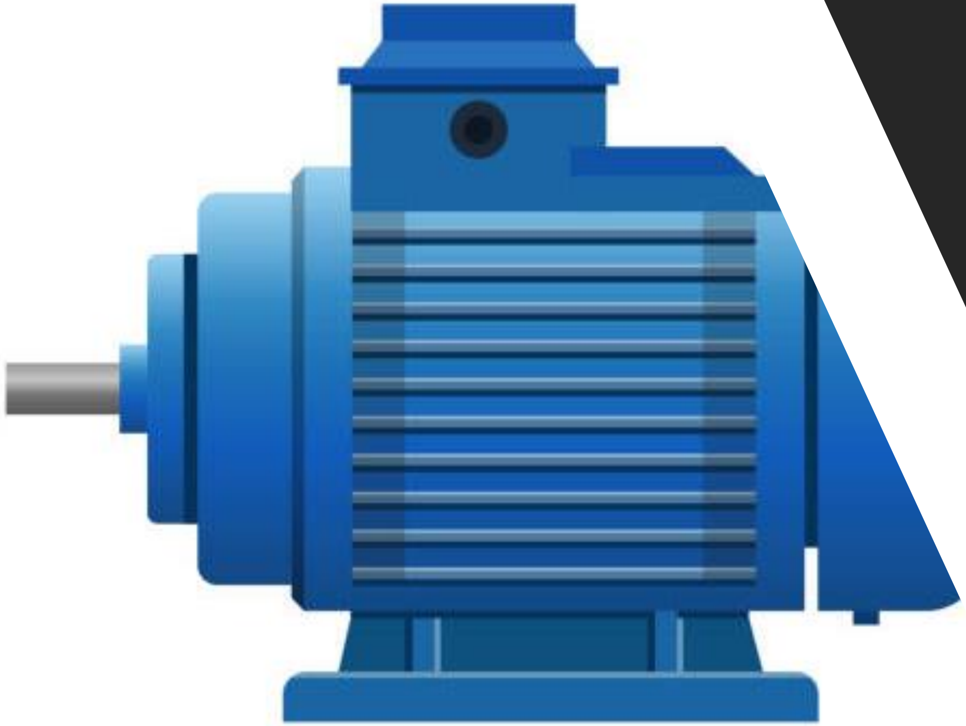


Motors and VFDs
MSU-IAC
1/31/22

MISSISSIPPI STATE UNIVERSITY
INDUSTRIAL ASSESSMENT CENTER

Outline

- Motor losses and efficiencies
- Maintenance and Trending
- Rewind versus Replacement
- Drives – VSDs and others
- Special Applications
- Fans and pumps

Why Talk About Motors?

- **It is estimated that motors use 65 percent of the electricity consumed by industry**
  - Generating 37 million tons of CO2 annually
  - About $90 billion per year
- **The cost of electricity for operating a motor is many times greater than the cost of the motor**
- **Losses in the “motor system” can dwarf motor losses**
  - Slippage in belts
  - Poor system design

Costs

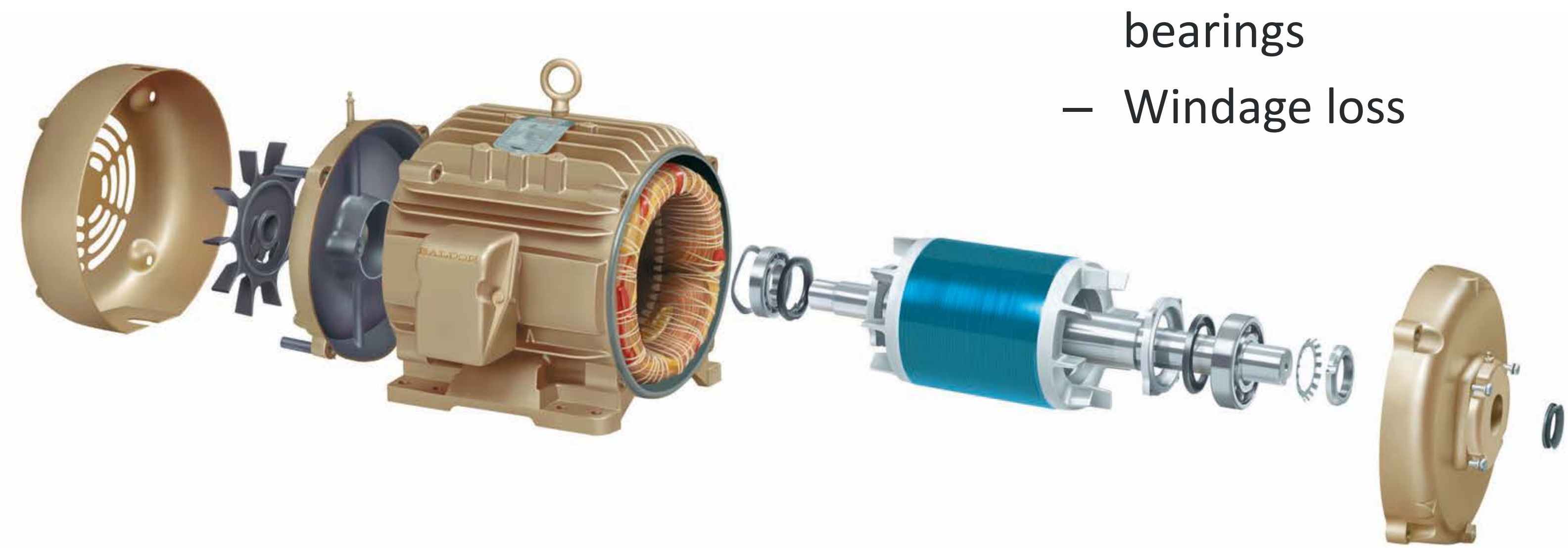
Motor Catalog

	Item #	Output Power [HP]	RPM	Phase	Voltage	Enclosure	NEMA Frame	Multiplier Symbol	MSRP
☐	EJMM3312T	10	3500	3	230 460	ODP	213JM	L1	$1451
☐	EM3312T	10	3500	3	230 460	ODP	213T	L1	$1212

- **Premium 10 hp motor costs $239 more than EPACt**
  - Twenty percent premium in price!!!
- **Example:**
  - 10 hp motor @ 89% efficiency uses 11.24 hp (8.38 kW)
  - Run at 80% load for 8000 hrs per year costs = 53,632 kWh
    - (At $0.10 per kWh this costs $5363 per year)
  - A 1% improvement in efficiency would save $54 per year
    - (4 ½ years to get your money back)

Motor Losses

- **Primary and Secondary Resistance Losses**
  - I^2R (more load, more loss)
  - Rotor = primary;
    Stator = secondary
- **Magnetic Losses**
  - Eddy currents and hysteresis in steel laminations
- **Stray Losses (10% - 15%)**
  - **Flux leakage; non uniform currents; air gap irregularities**
- **Mechanical Losses**
  - Friction in the motor bearings
  - Windage loss



Losses are well known

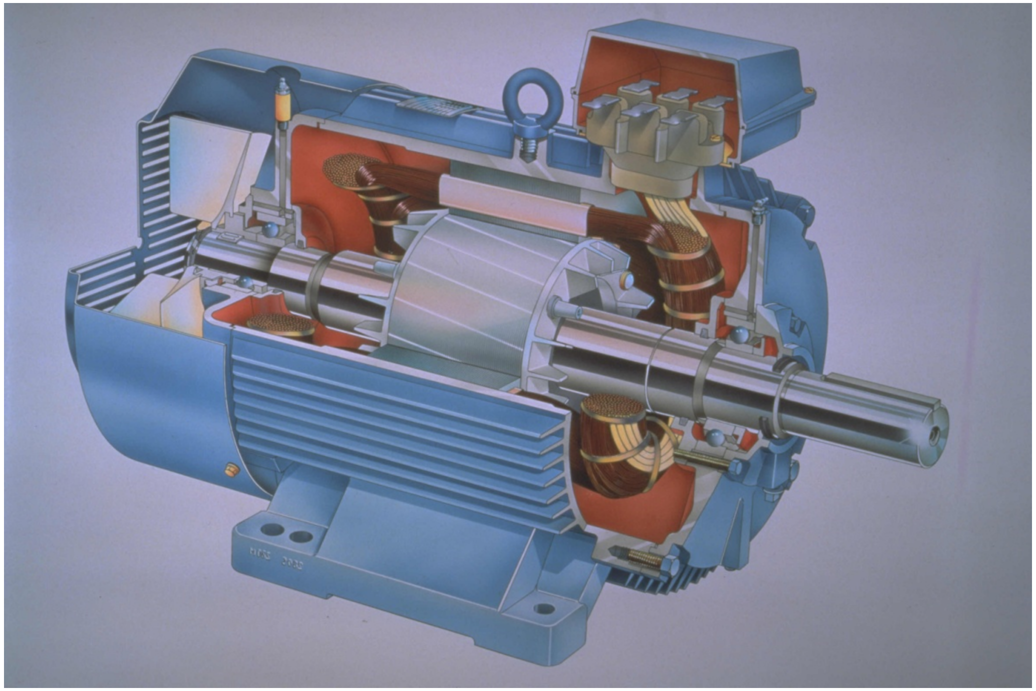
- **Solutions are available**
  - Mostly MORE COPPER!
- **Tradeoff in costs**
  - Feds require improvement through rule making

Factbox 1 Distribution of losses in an ABB M3BP motor

no-load losses	iron losses in core	18%
	windage & friction losses	10%
load losses	stator copper losses	34%
	rotor losses	24%
	stray load losses	14%

So, if motors are so efficient, what to do?

- Spend extra for more efficiency
- Maintenance
- Correct Sizing
- Efficient System Design

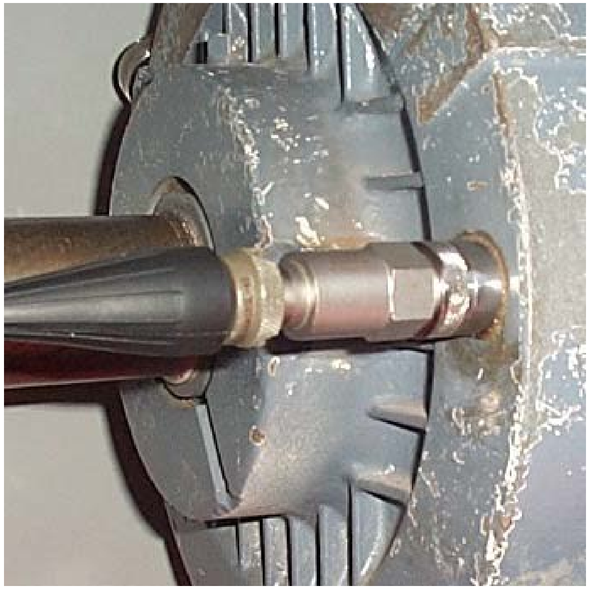


Motor Maintenance

- **Very often ignored by many plants.**
- **A good maintenance program can extend lifetime, reduce downtime, failures, reduce repair costs.**
- **Cleaning – Dirt is an insulator, motors run hotter**
  - Degrade lubricants, damages bearings and insulation.
  - Sound insulation is usually unnecessary and can raise operating temperatures significantly
- **Lubrication – Most factory sealed bearings do not require lubrication.**

Vibration meter use

- Vibration sensors can mount magnetically – note flat or round mounting!



- Always make temperature and vibration measurements from the same spot on the motor.
- Always make measurements after the motor is warmed up and under the same motor loading conditions.

When motors fail

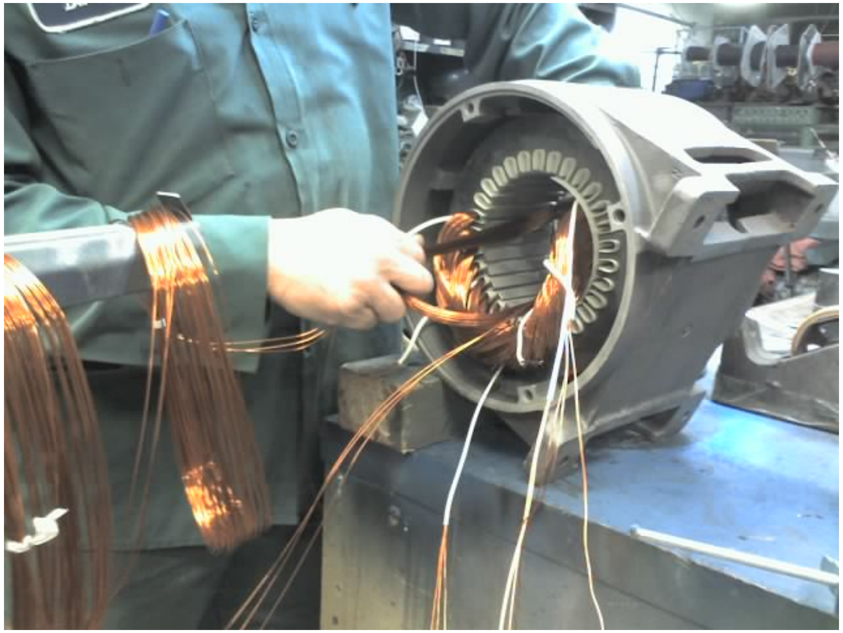
- **Unplanned down time – often biggest cost**
  - Results in urgency to have motor back up and running
- **Decision needs to be made on whether to replace or rewind the motor**
  - **Policy needed**
    - Cannot be done after motor has failed
- **Inventory control helps**
  - Easier to have backup motors

Rewinding

- **Can be done well – if time is taken**
  - Careful, hand rewound motors can have better efficiencies than the original motor
  - Oven temps for curing and stripping are key
- **Studies have shown increased <u>core loss</u> caused by excessive lamination heating during oven stripping of a failed winding.**
  - Rule of thumb: "Stay below 750 °F"
  - Many "burn-off" ovens operate at 1400 °F!
- **Same issues pertain to curing/drying**

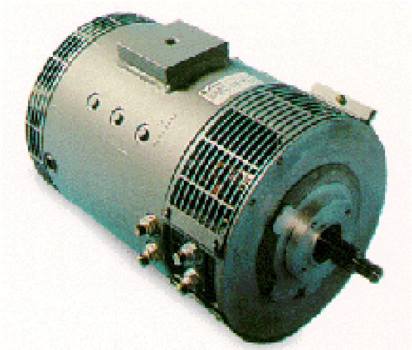
Rewinding (cont.)

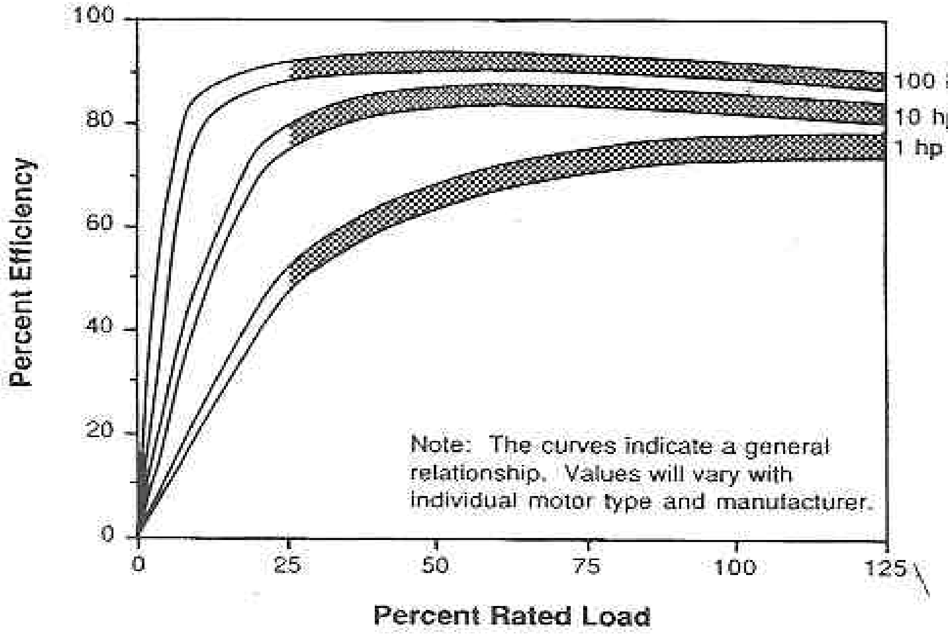
- **Our conclusion – most times rewinding is done too quickly – impacts efficiency (1 – 2%)**
- **Our recommendation – never rewind twice!!!**
  - Replacement motor must be available to reduce down time



Partial Loading

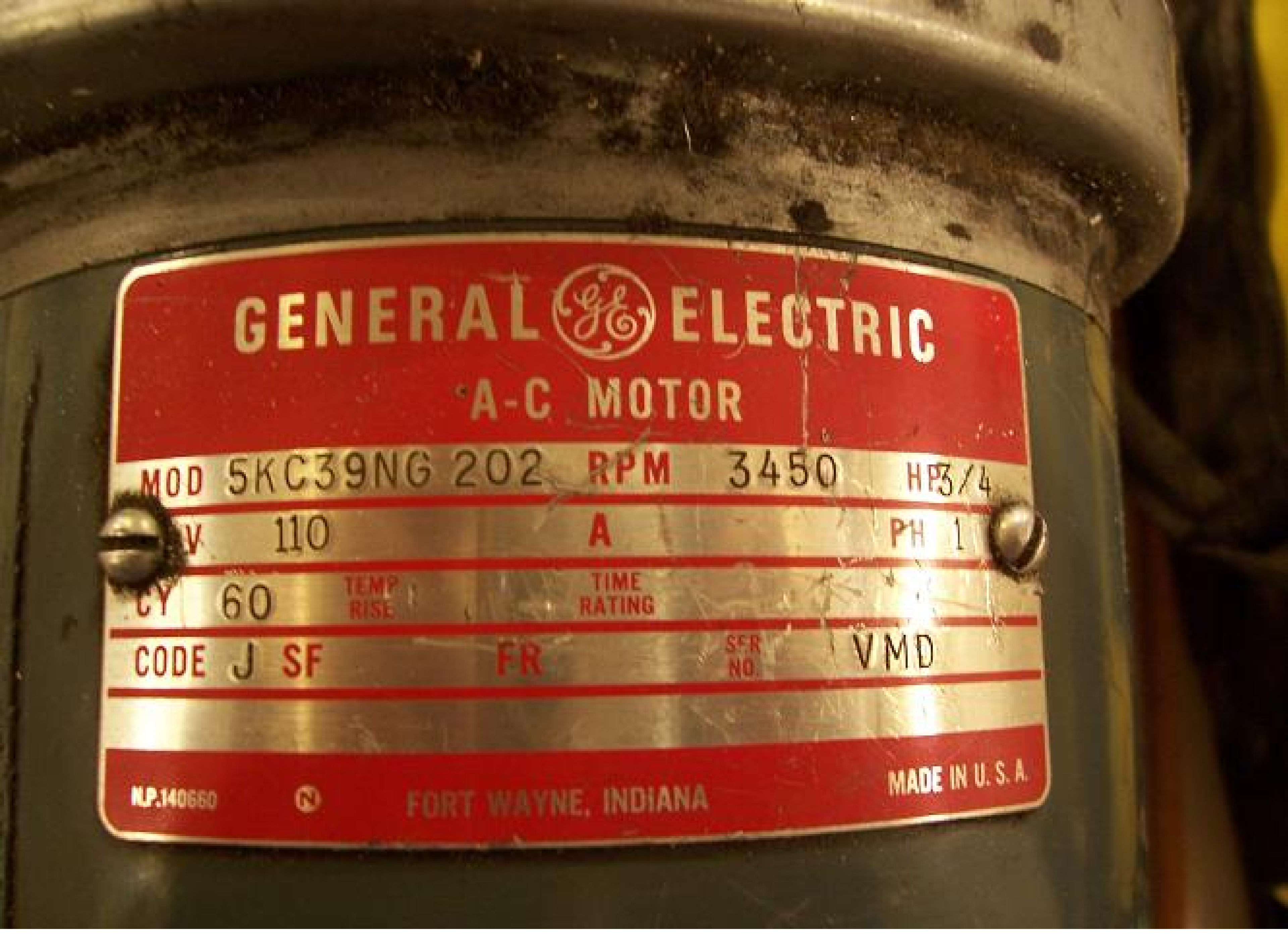
- **Most motors are intentionally oversized.**
- **At 75% to 80% of full load power, motor efficiency and power factor are high.**
- **Motor efficiency and power factor decrease rapidly at less than 25% loading.**





Remember, AC motors slip

- **Unloaded RPM should be:**
  - 3600 for 2 pole
  - 1800 for 4 pole
  - 1200 for 6 pole
  - 900 for 8 pole
- **Nameplate gives full load RPM**
- **Tachometers give some sense of motor load**
- **Premium efficiency motors will have less slip**
  - Some applications makes this a problem!!


GENERAL ELECTRIC
A-C MOTOR
MOD 5KC39NG 202
RPM 3450
HP 3/4
V 110
A
PH 1
CY 60
TEMP RISE
TIME RATING
CODE J
SF
FR
SER NO.
VMD
N.P.140660
FORT WAYNE, INDIANA
MADE IN U.S.A.

Motor Labels – confusing info

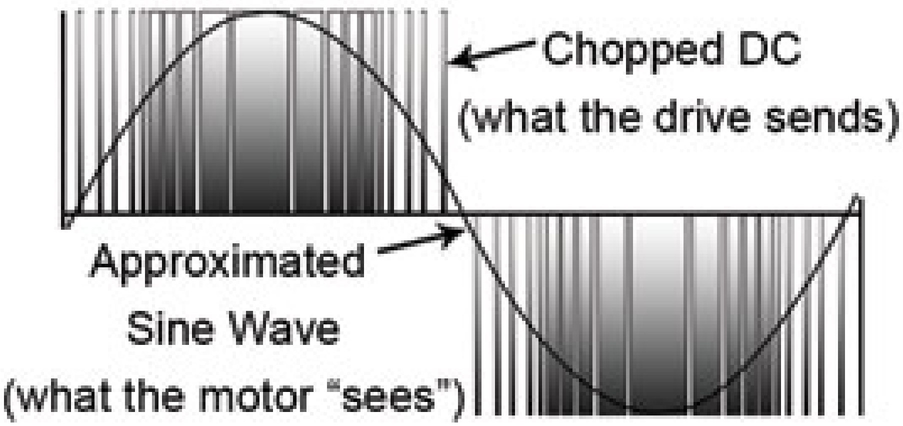
- **Not well standardized**
- **Common abbreviations:**
  - FLA Full load amps
  - RLA Running load amps
  - LRA Locked Rotor Amps
    - Is the in-rush current at startup
  - SFA Service factor amps
  - SF Service factor
    - Amount rated loads can be exceeded either as a percent or in amps
  - PF Power factor

Partial Loading

- **Solutions include:**
  - Downsizing
  - Multiple motors serving same system
  - Two speed motors
  - Motors controlled with variable speed drives.

Electronic Variable Speed Drives

- **Also called**
  - VFD’s (variable frequency drives)
  - ASD’s (adjustable speed drives)
  - Inverters
- **Rectifies incoming AC to DC**
- **Inverts the DC to AC using square waves**



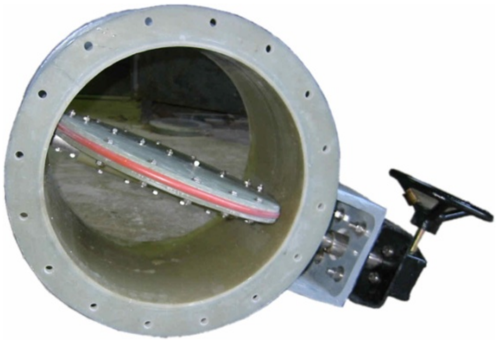
Electronic Variable Speed Drives

- **VSD’s should only be coupled to motors that are suitable for VSD’s**
- **Must use “inverter duty” versus “general purpose” motors**
  - A VFD-driven general purpose motor can overheat if it is run too slowly.
  - The voltage “chopping” that occurs in the drive actually sends high-voltage spikes (at the DC bus level) down the wire to the motor
  - This can lead to premature failure of the motor insulation
- **The terms "inverter duty", "inverter ready", and "inverter rated" are undefined and, as such, are fair game for any marketer to use**
  - Need to talk with motor manufacturer

VFD applications

- **VSD's are used in constant and variable torque applications**
- **Slowing the motor speed reduces the torque on the motor, can result in significant energy savings**
- **Most common applications include pump and fan systems, conveyor belts and rollers**
- **Improves process control and reduces maintenance costs**

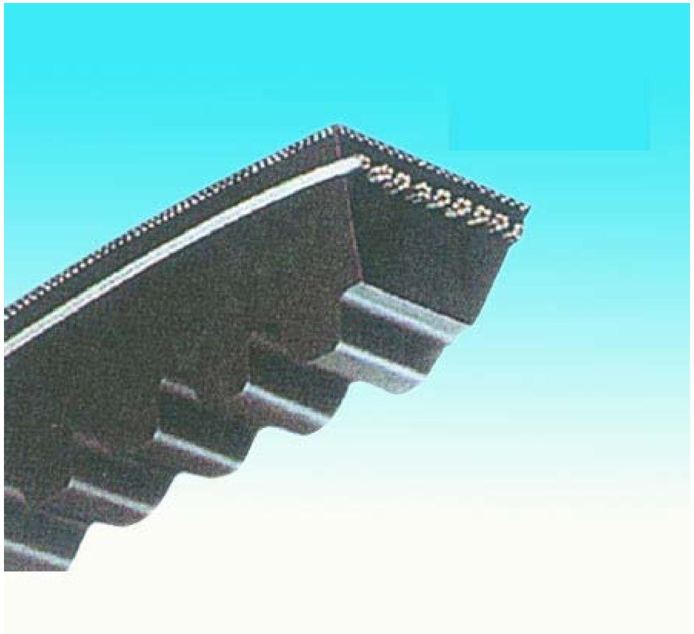
VFD Impacts on Pumps and Fans



- **Two main types**
  - Reduce fan or pump energy
    - Flow rates commonly controlled by dampers
      - Like driving your car using only the brake with the accelerator fully engaged
    - Theoretically, the energy required to move any fluid CUBES every time the flow rate is doubled.
      - If a fan is run at double it's normal speed, it uses 8 times the energy. 1/2 speed = 1/8 the normal energy draw.
      - VFD's allow this saving to be achieved (partially)
  - Lower load on secondary equipment
    - Example – Draft fan on a furnace
      - Normal mode is to operate the fan at constant speed
        - » Draws air through the furnace whether it is needed or not
      - VFDs allow feedback to limit air flow through the furnace with enormous savings

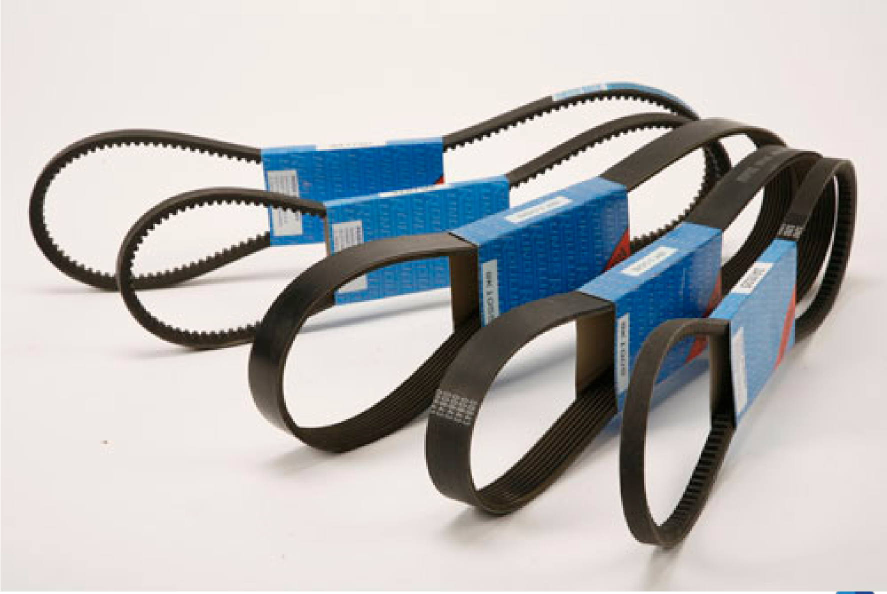
Cogged V-belts

- Cogged belts have slots that run perpendicular to the belt's length.
- The slots reduce the <u>bending resistance</u> of the belt.
- Cogged belts can be used with the same pulleys as equivalently rated V-belts.
- Efficiency that is about 1.5% higher than that of standard V-belts.



Cogged V-belts

- **Cogged V-belts last at least 50% longer than standard V-belts**
- **Cogged V-belts are slightly noisier than standard V-belts.**
- **Compensates for the 20% to 50% higher cost**
- **Recommend cogged V-belts in all V-belt applications except**
  - Clutching uses
  - Dirty environments

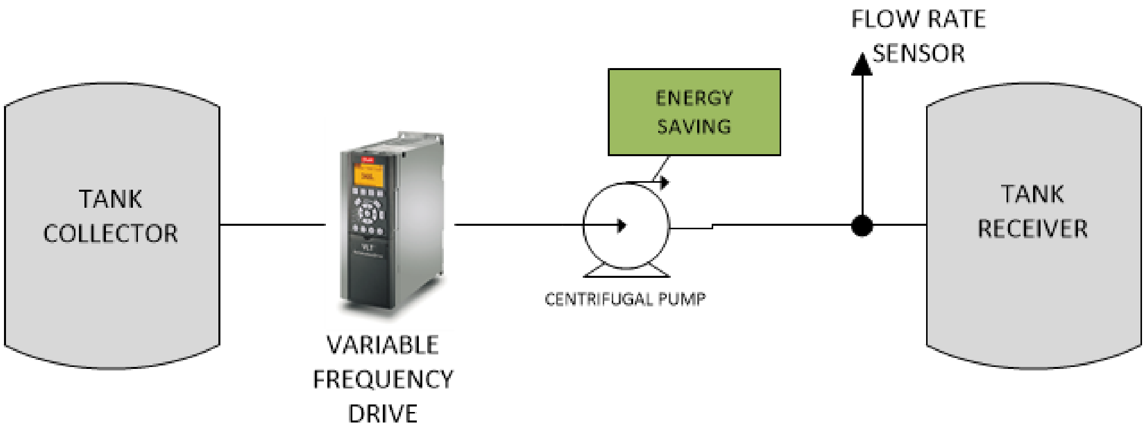


Conclusions: Common Motor System Recs

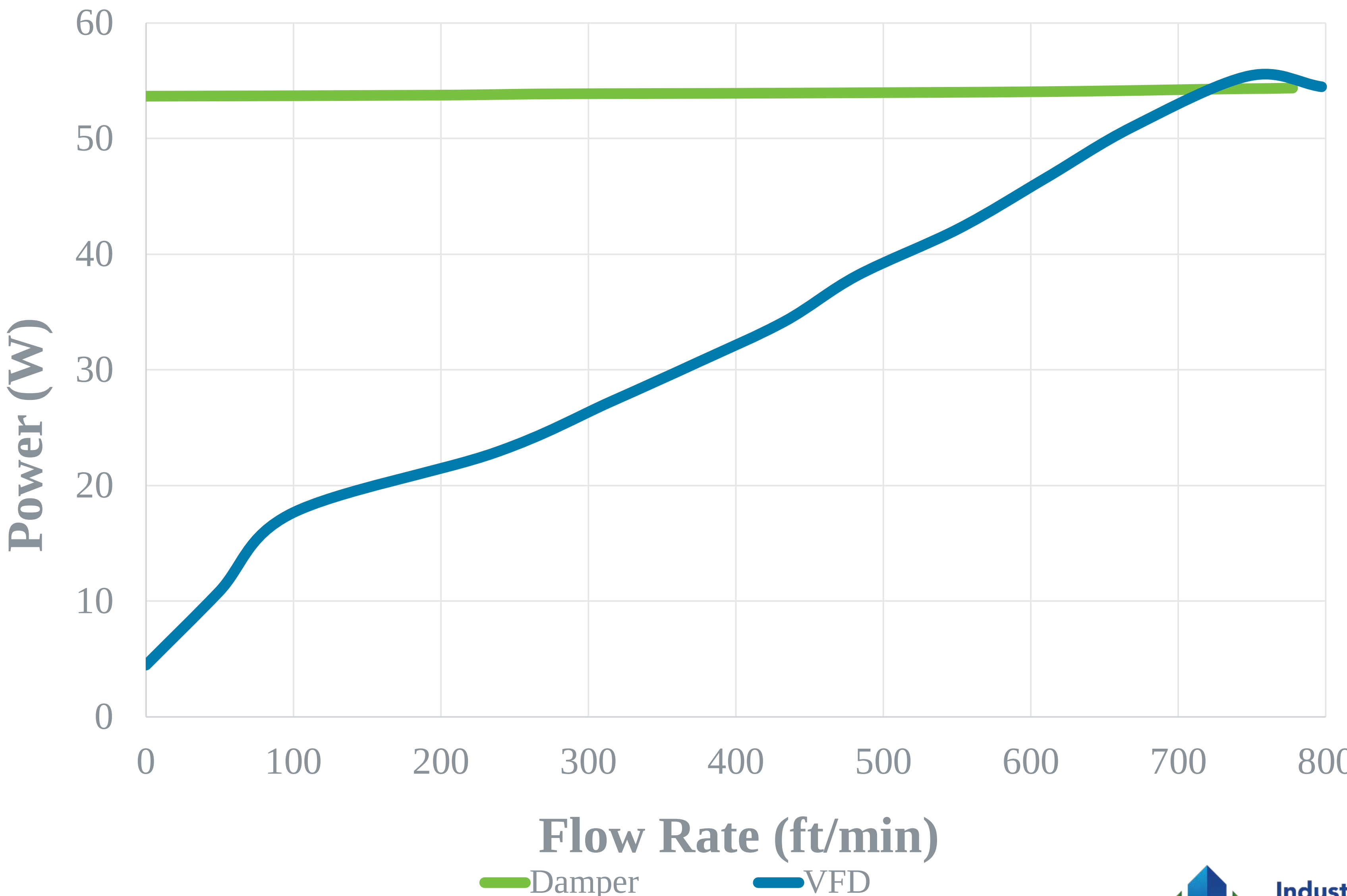
- **Reducing Run-Time**
    - Turn off motors whenever possible.
    - Use programmable time clocks or controllers whenever possible.
- **Reducing Peak Electrical Demand**
    - Run equipment during off-peak periods to reduce peak electrical demand.
- **Improving Efficiency of Motor Drive trains**
    - Use direct drive or synchronized drives whenever possible
    - In belt drives, use cogged v-belts instead of standard v-belts.
- **Match Motor with use**
    - – Replace Oversize Motors
    - – Use special duty motors
- **Establish a Replace/Rewind Motor Policy**
- **Use VFD's whenever the application allows**

Procedure

- What is a VFD?
  - Variable Frequency Drives (VFDs) control the speed of the AC induction motors by changing the frequency
- Data was taken from a
  - Damper measurements were taken as the damper was opened and closed
  - VFD measurements were taken as the frequency was turned up and down



Power vs. Flow Rate



Recommendation

Instead of using dampers or loaded/unloaded operations, motors should include VFDs to reduce energy usage

- Assumptions and knowns
  - 1/25 HP motor
  - (Power*LF/Efficiency) is found from data
  - Operating hours (OH) = 8760 hrs
  - Electricity unit cost (EUC) = \$0.08/kWh
  - Demand unit cost (DUC) = \$10/kW
  - Required Load Factor (LF) = 75%
  - Utility Factor (UF) = 100%
  - C = # of months in a year, 12

Recommendation

- Data for example calculation
  - Damper power at 75% open = 54.305 W
  - VFD power at 75% load = 46.595 W
- Equations
  - Energy Usage (EU) = (Power*LF/Efficiency)*UF*OH
  - Demand Usage (DU) = (Power*LF/Efficiency)*UF*C
  - Energy Cost (EC) = (Power*LF/Efficiency)*UF*OH*EUC
  - Demand Cost (DC) = (Power*LF/Efficiency)*UF*C*DUC