U.S. DEPARTMENT OF ENERGY

Motor Systems
Virtual INPLT Training & Assessment

Session 2

U.S. DEPARTMENT OF ENERGY

Motors Virtual INPLT Facilitator

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Acknowledgments

- Johnny Douglas, P.E.
- Gil McCoy, P.E.
- Dr. Hugh Falkner, England
- Dr. Anibal De Almeida, University of Coimbra, Portugal

- Many industrial clients – both in the US and internationally

U.S. DEPARTMENT OF ENERGY

Safety and Housekeeping

- Safety Moment
  - Motors can be dangerous, and caution should be used around them
  - Ensure that belt guards and equipment covers are fully in place
- You are welcome to ask questions at any time during the webinar
- When you are not asking a question, please MUTE your mic and this will provide the best sound quality for all participants
- We will be recording all these webinars and by staying on-line and attending the meeting you are giving your consent to be recorded
  - A link to the recorded webinars will be provided, afterwards

Learning Objectives

- Discuss impact of poor power factor and its causes
- Review external factors affecting motor efficiency
- List 4 primary categories of causes of motor failure
- List 3 preventive maintenance strategies for improving motor reliability
- List 5 factors that to considered before repairing a burnt-out motor

Power factor and power factor correction

Power factor is a measure of how much work is being done by the delivered amps

$$Power(kW) = \frac{Amps\ x\ Volts\ x\ Power\ Factor\ x\ \sqrt{3}}{1000}$$

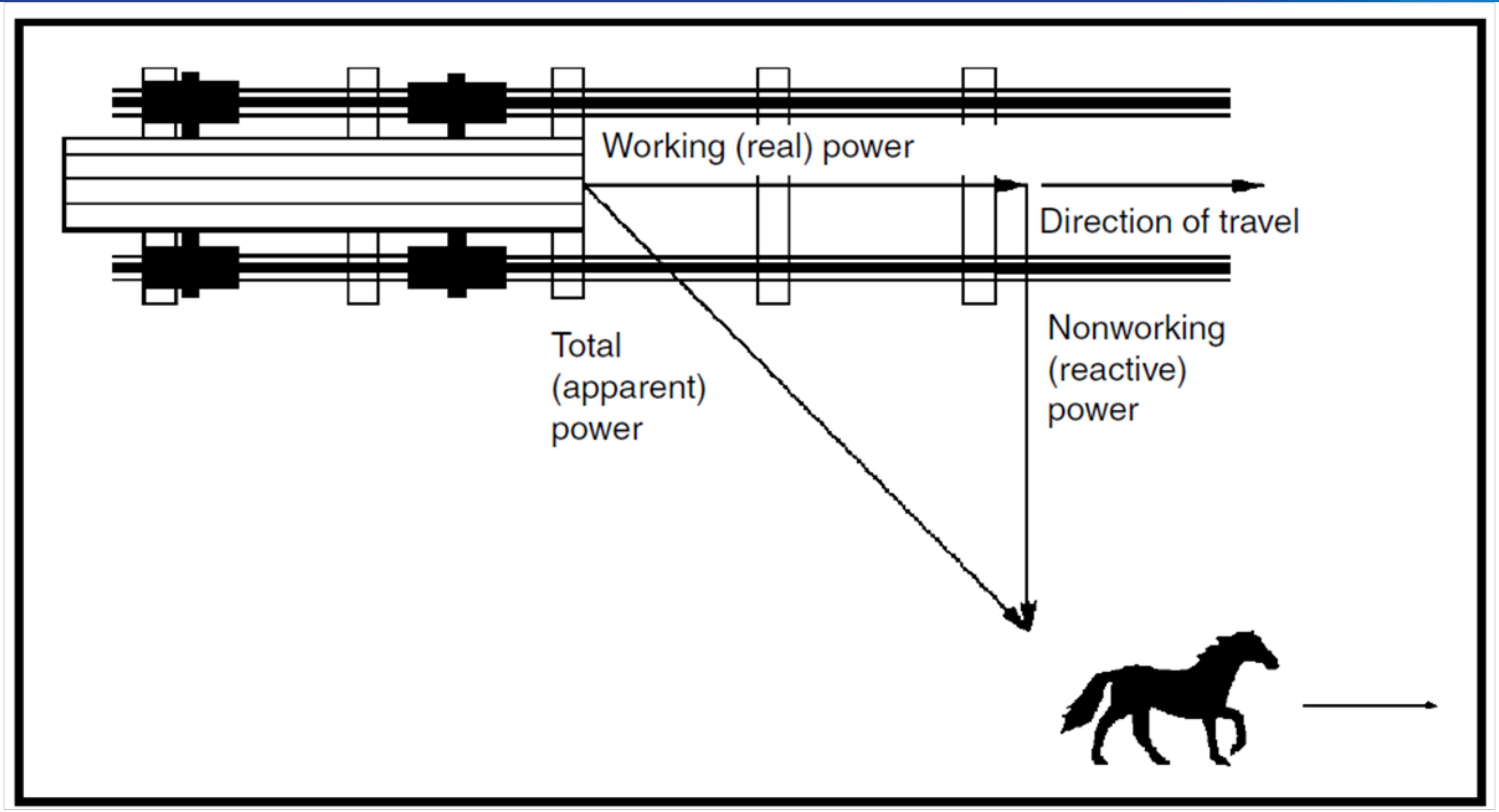
Where Volts is phase-to-phase voltage

- A low power factor “fills” the feeders and transformers with non-productive amps
- Some utility companies charge extra for low power factor

Low PF

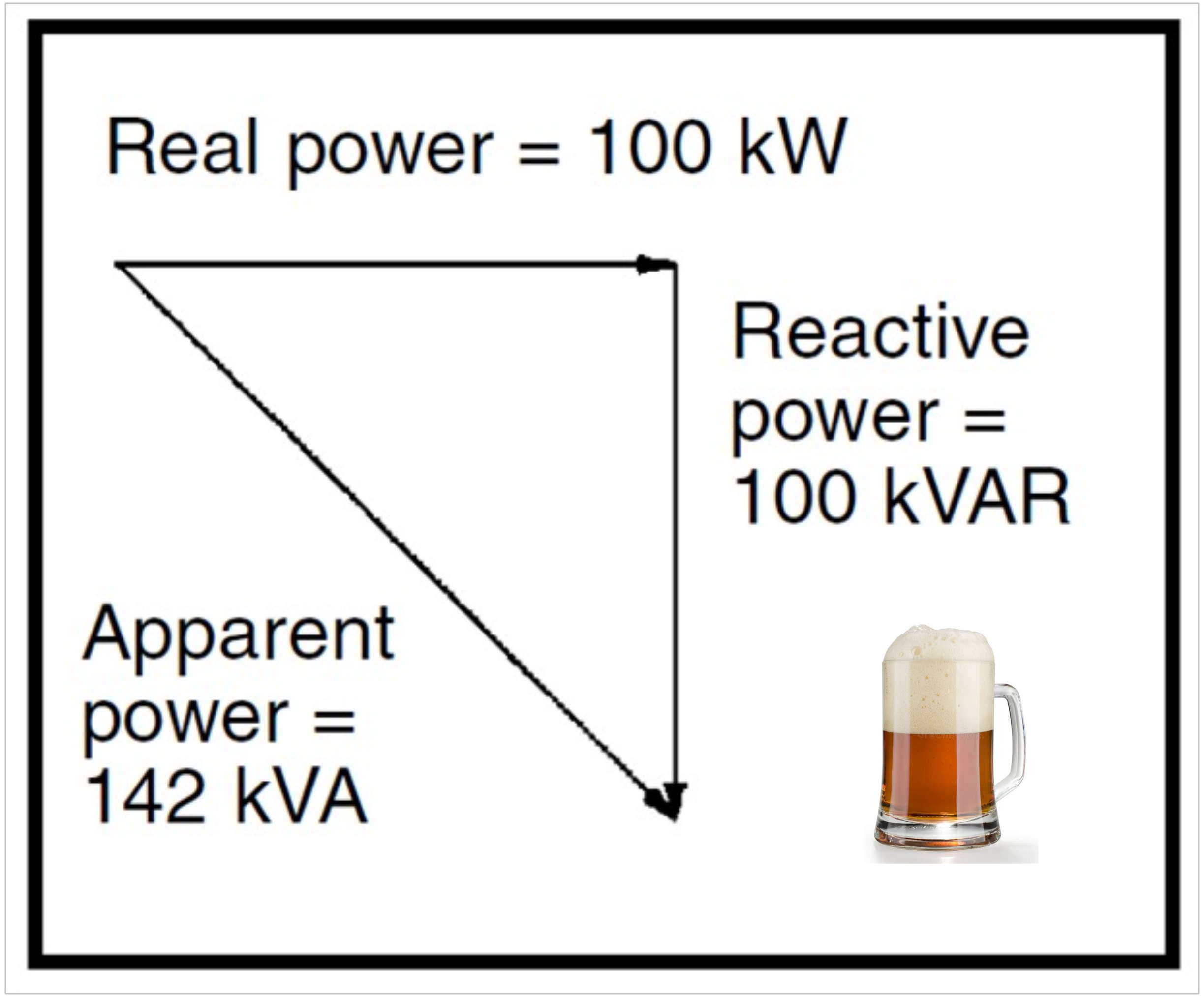
High PF

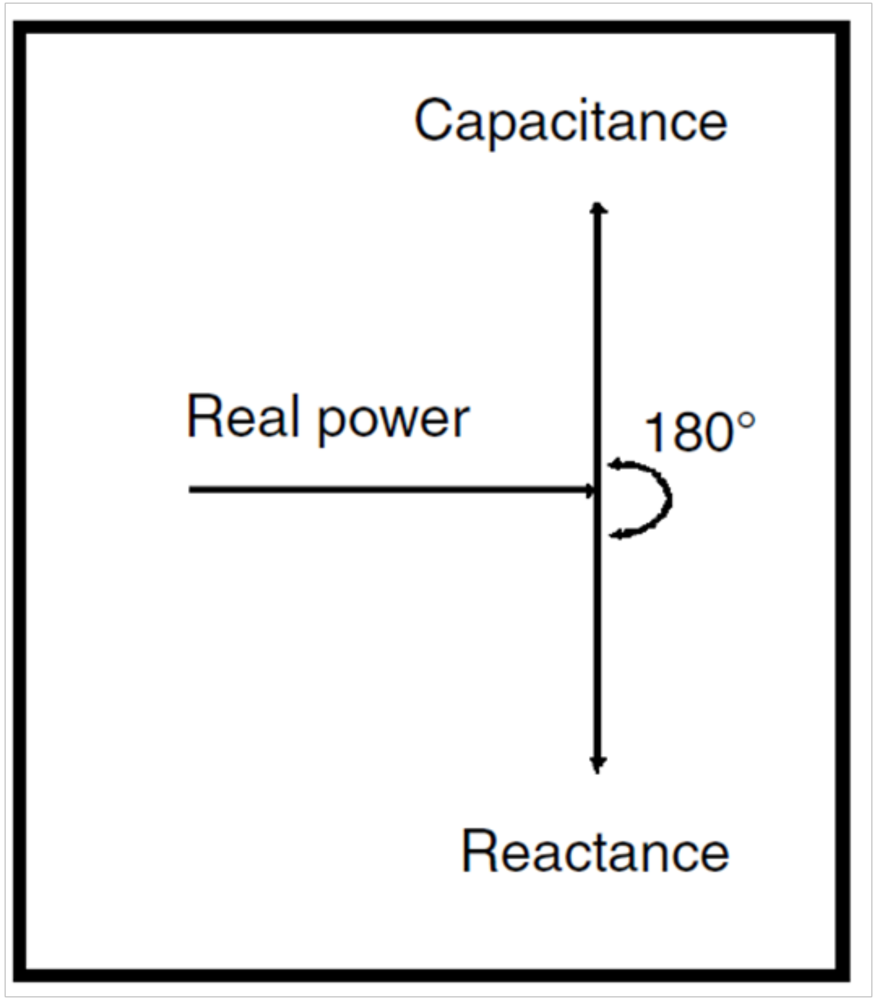
Power Factor



Courtesy of DOE ITP

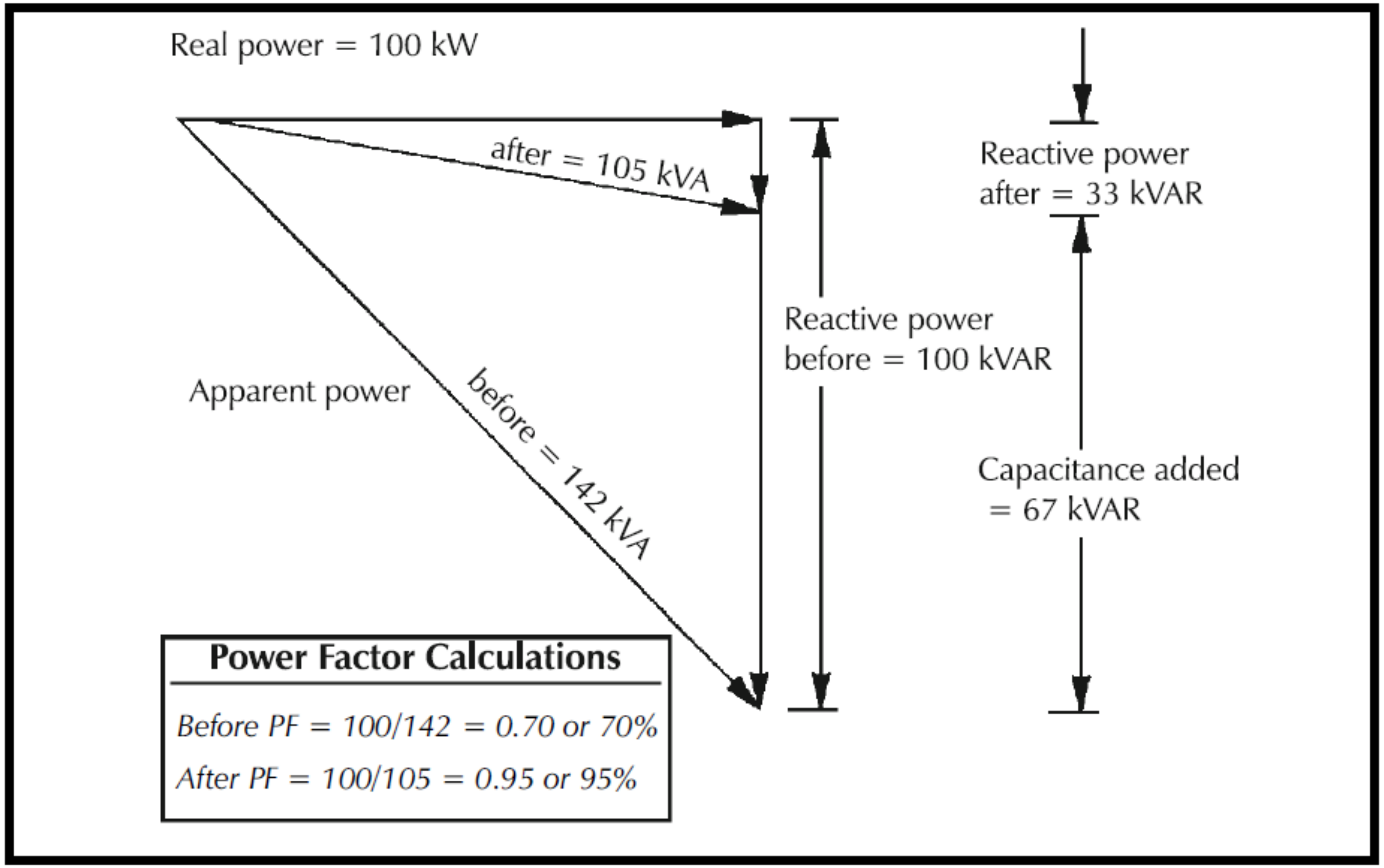
Power Factor





Courtesy of DOE ITP

Power Factor Calculations



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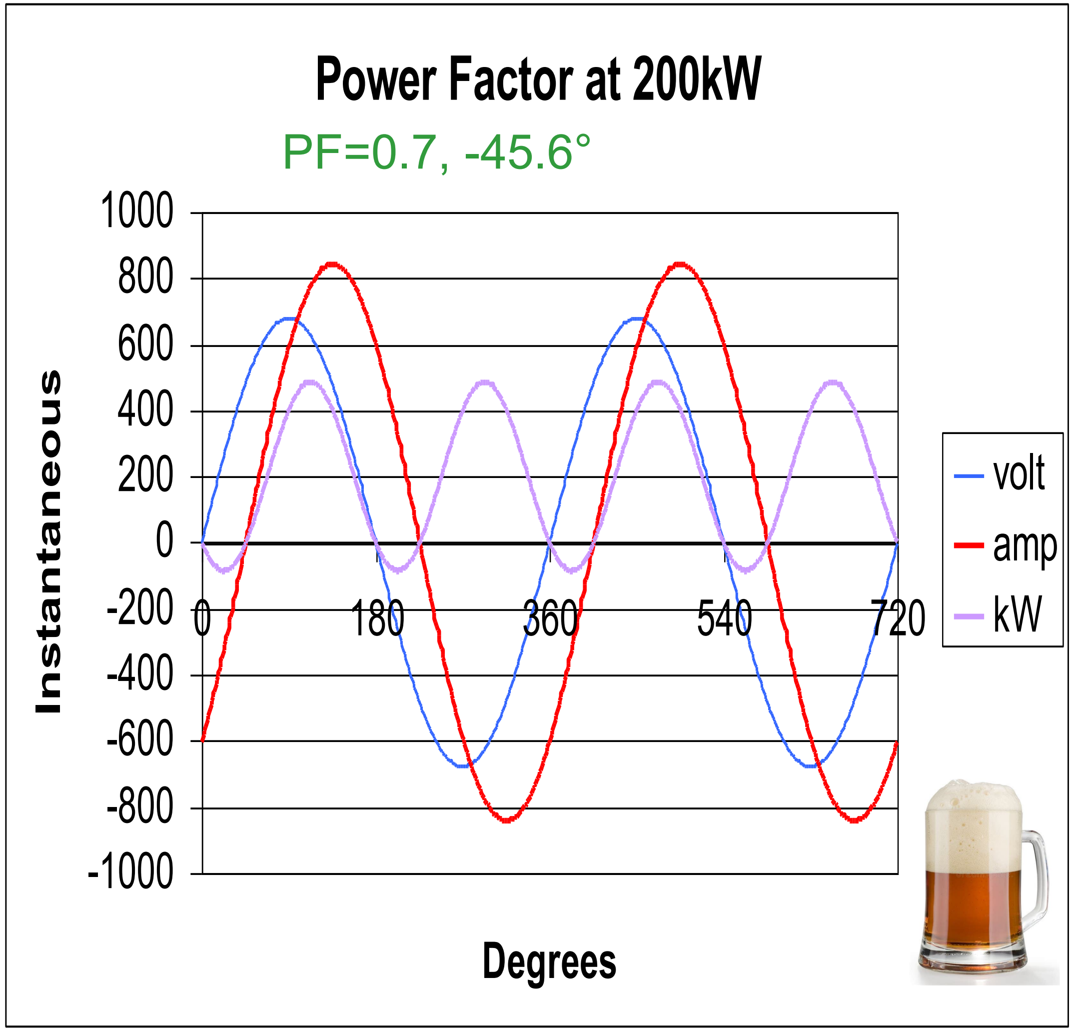
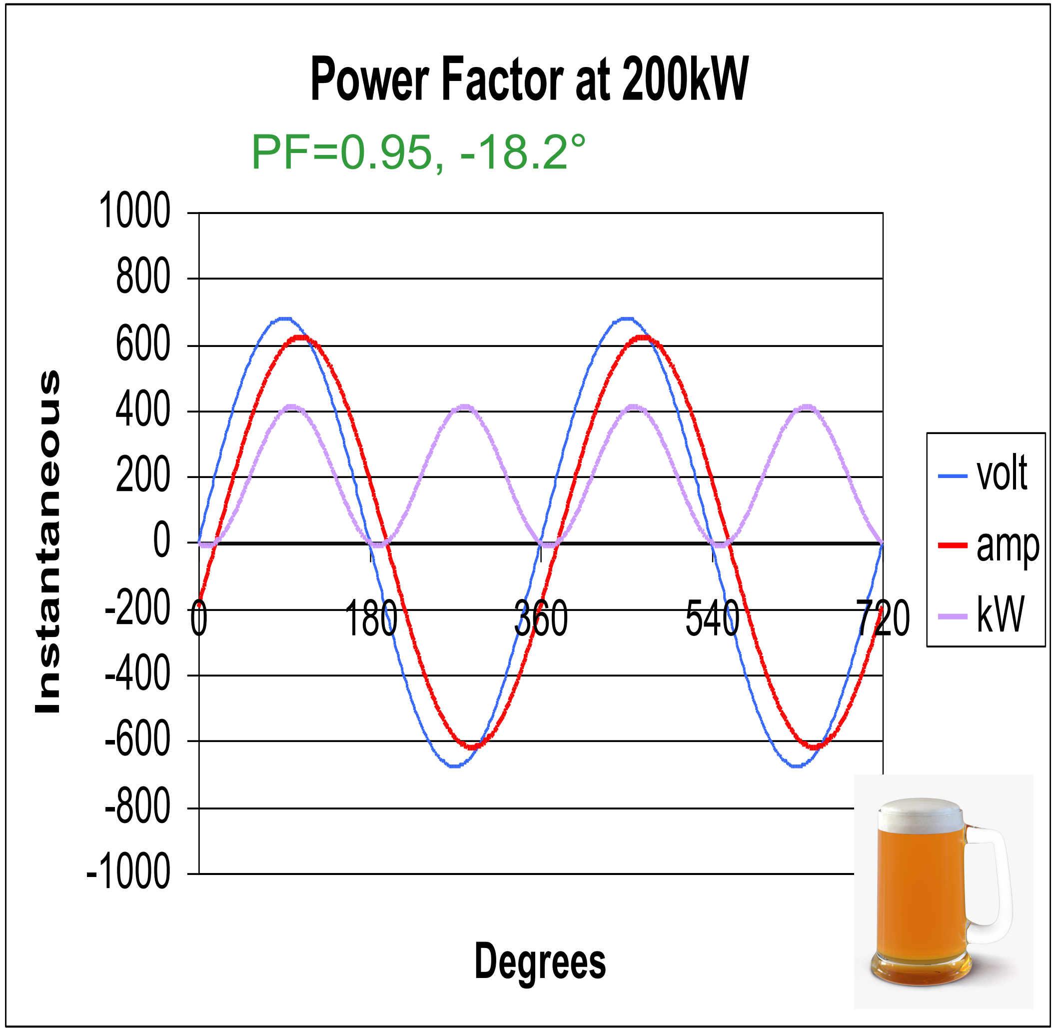
Poor Power Factor





External Factors Affecting Motor Efficiency

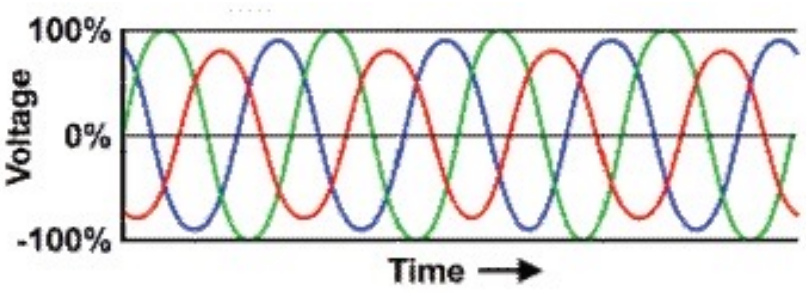
- Efficiency is never constant. External factors can reduce efficiency and require derating. Beginning with the worst, these include:
  - Voltage unbalance
  - Voltage deviation
  - Voltage harmonics

Voltage Unbalance

Definition

Voltage unbalance is given by:

$$\%VU = \frac{\text{max. voltage deviation from the avg. voltage}}{avg.voltage} \times 100$$



Courtesy Anibal T. De Almeida and Hugh Falkner and UNIDO

Voltage unbalance example

L1 = 600 V

L2 = 585 V

L3 = 609 V

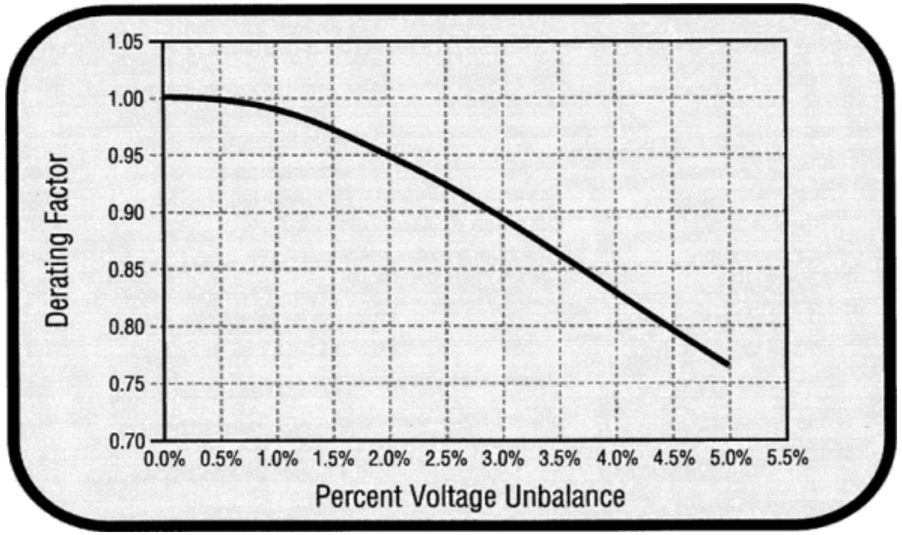
$$Average\ Voltage = \frac{600 + 585 + 609}{3} = 598\ \mathrm{V}$$

$$Max.\ deviation\ from\ avg. = 598 - 585 = 13\ V$$

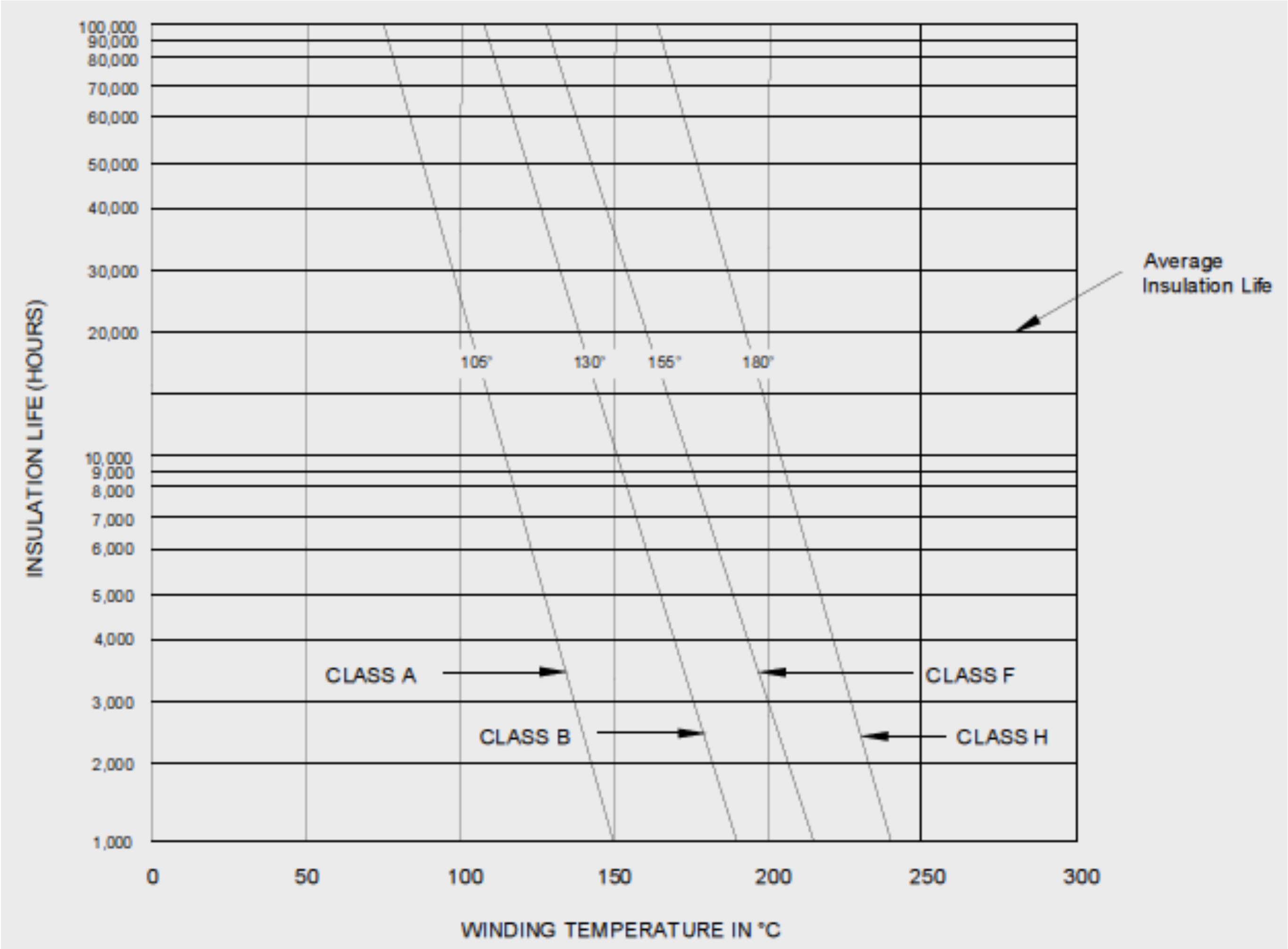
Courtesy Anibal T. De Almeida and Hugh Falkner and UNIDO

Voltage Unbalance

- Unbalances greater than 5% should be immediately corrected.
- Significant increase in motor losses.
- Possible causes:
  - Improper transformer setup
  - Single phase loads
  - Faulty regulating equipment
  - Utility unbalance
  - Open connections
  - Unequal conductor or component impedance.



Insulation Life vs. Temperature



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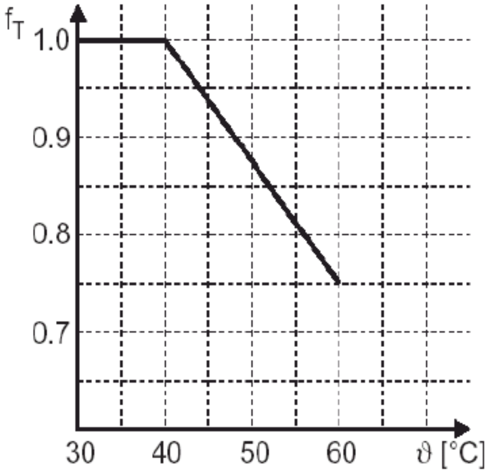
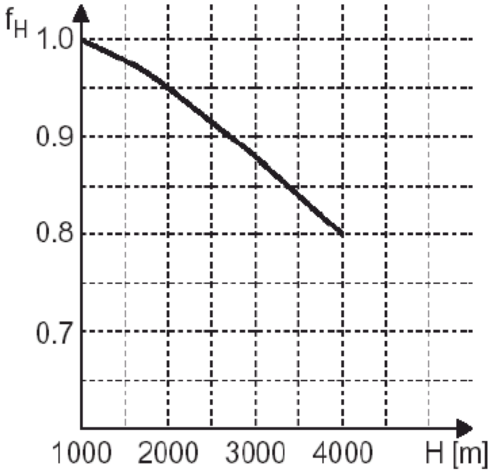
Motor Derating

For temperatures above 40ºC and below 60 º C



For altitudes above 1000m



$$P_{Nred} = P_N \bullet f_T \bullet f_H$$

Courtesy Anibal T. De Almeida and Hugh Falkner and UNIDO

Motor Starts / Stops

Allowable starts per hour and minimum off-time between starts

- 10 hp / 1800 RPM 12.5 (46 sec)
- 50 hp / 1800 RPM 6.8 (72 sec)
- 200 hp / 1800 RPM 4.0 (300 sec)
  - Source: NEMA Standard MG 10

The Starter

Four elements: (generally in a box on the wall)

- Means of isolation (positive shutoff)
- Circuit protection (protect upstream wiring from shorts)
- Motor controller (stops, starts, ramps up; may even regulate voltage)
- Motor protection (protects motor from overload current and certain other fault conditions).

The Load

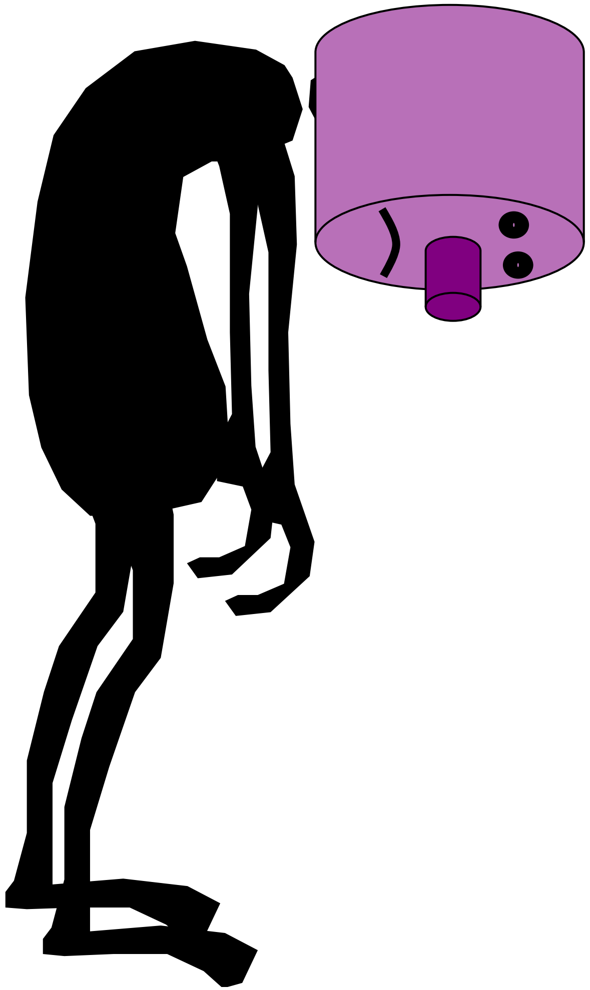
- Constant Torque
  - This means the load's torque demand does not vary with motor speed.

- Variable Torque
  - The load varies with torque. Most common is the cube law variation. Torque varies as the square of speed (plus a constant) and horsepower varies as the cube. Pumps and fans (i.e. centrifugal loads) are the most common examples.

Load Characteristics - Inertia

- High inertia loads present a challenge for motors to accelerate.
- Motors capability to start high inertia loads is covered in NEMA MG1 Part 20.
- If load inertia is too high, it may be necessary to upsize to a larger motor
- Variable Frequency Drives can be programmed for a slow ramp up without overheating. Other reduced voltage drives may overheat.

Why/how do motors fail?



- Neglect / abuse
- Misapplication
- Severe Environment
- Normal Wear and Tear

Failures of Neglect and Abuse

- Dirt
- Bad Lubrication
- Poor Power Quality
- Harmonics
- Unbalance in voltage
- Over/under voltage
- Poor belt drive maintenance

Failures of Misapplication

- Under-sizing
- Over-sizing
- Wrong enclosure
- Coupling, Belts & Shimming

Failures of Severe Environment

- Hot Ambient
  - Requires derating
- High Altitude
  - Causes overheating – requires derating
- Humidity
  - Motors in storage (zaps insulation or bearings)
  - Motors with significant off time (zaps insulation)
  - Requires internal or ambient heating
- Airborne Contaminants
  - Damages insulation or bearings
  - Kills by abrasion or chemical deterioration

Failures of Normal Wear and Tear

Without unusual stresses, motors sometimes last for many tens of thousands of operating hours but will eventually succumb to…

- Bearing wear
- Insulation failure due to time and temperature.

How much maintenance?

Size *Importance level*	*Maintenance Level*
Small **non-critical**	**Break down o.k. Preventive recommended**
Medium **non-critical**	**Preventive**
Medium, & Large **Critical**	**Preventive & Predictive**

Image courtesy DOE

Computerized Maintenance Management System - CMMS

- Many software providers offer CMMS products to track maintenance, prioritize work, maintain spares, inventory, trend condition changes, and generate reports to organize and optimize whole plant maintenance.

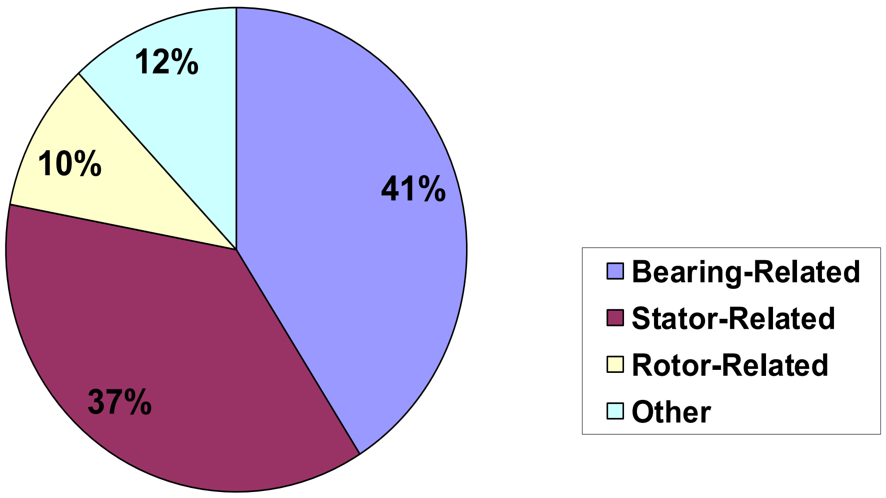
Polling Question 1 & 2

Polling Question

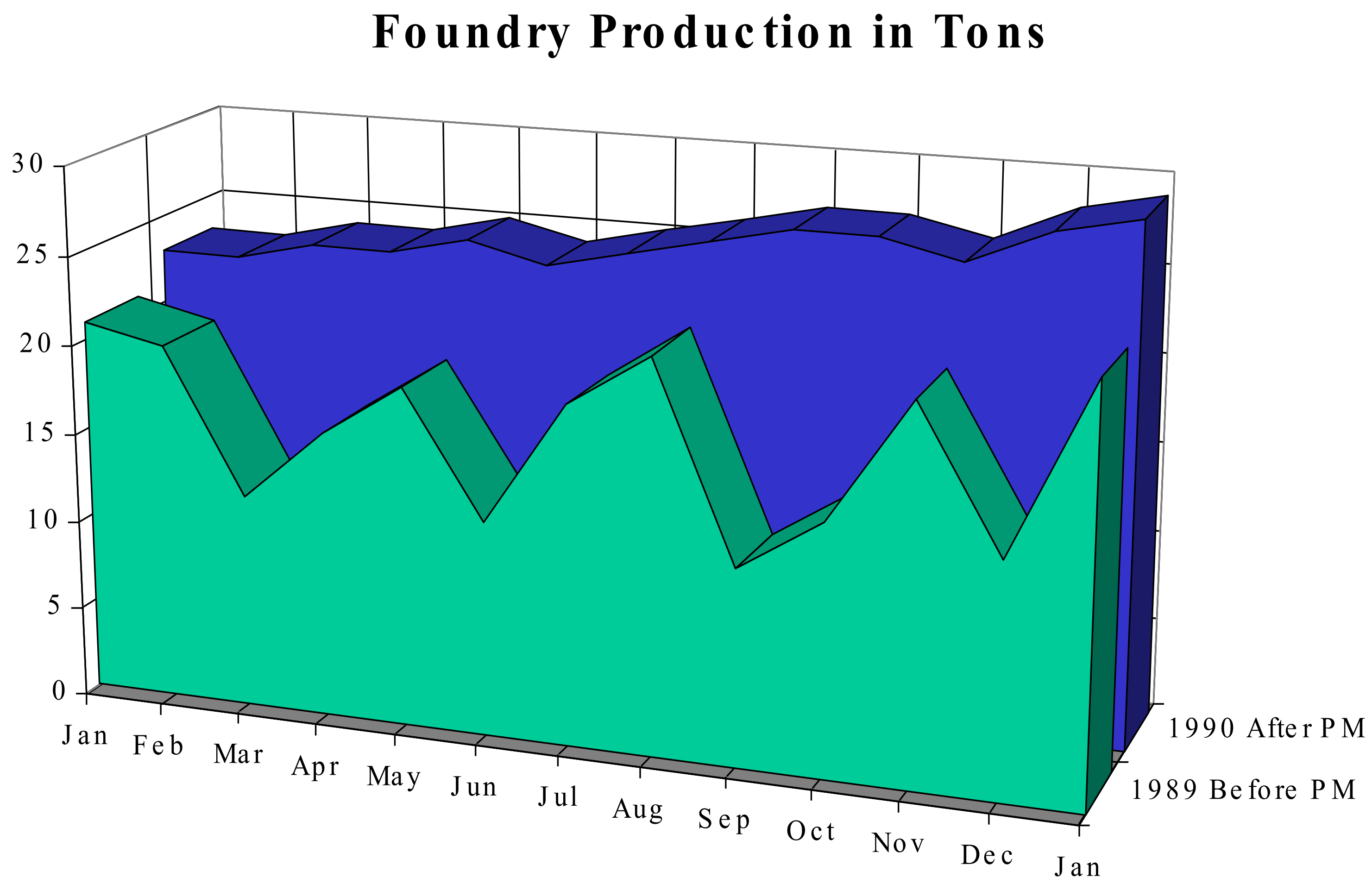
1) Does your organization use a CMMS?
   a) Yes
   b) No
2) If so, which one do you use, or if you have experience with more than one, which do you prefer?

Importance of Motor Maintenance

- According to the 2021 Motor Systems Market Assessment Report:
- Collectively, all US industry suffers from 6 million hours of downtime annually due to motor-related failures
- On average, an industrial facility will experience 47 hours per year of downtime due to motor-related failures



Foundry Case Study – Implemented PM program



Mechanical Transmissions Gears

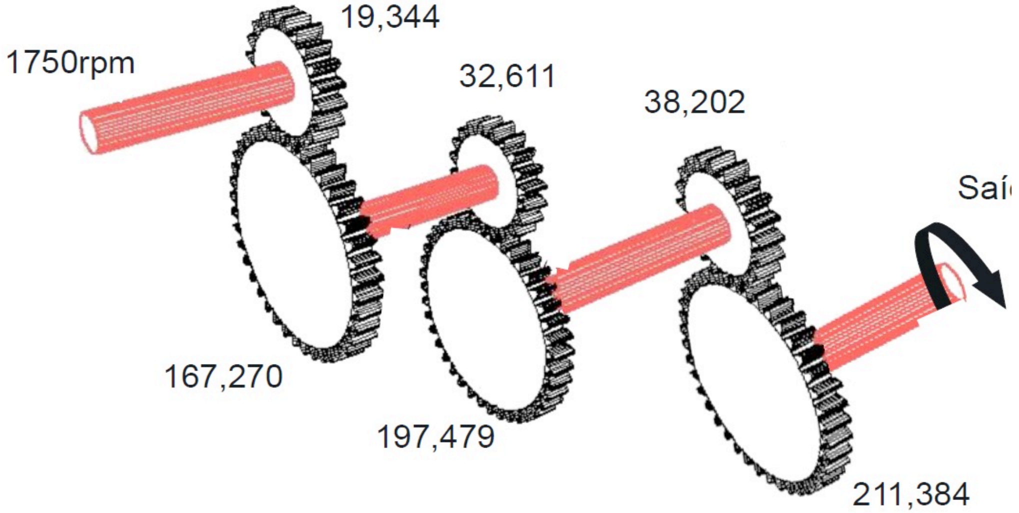
- Used for low speed, high torque loads
- Several types: helicoidal, spur, conic, and screw
- Losses are related to the friction of gears and bearings, windage and lubricating viscosity.

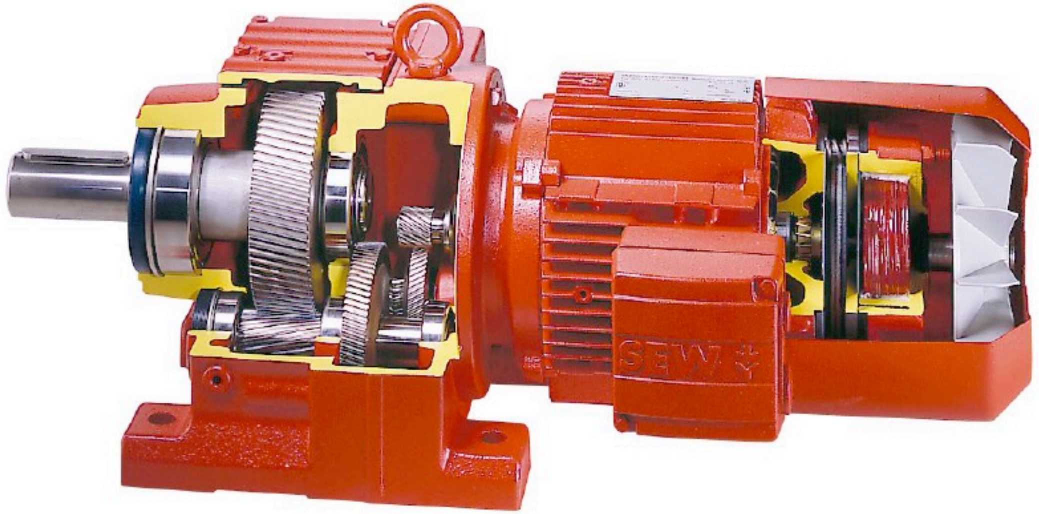
Mechanical Transmissions Gears

- Worm gear efficiency between 50 & 85%, depending on:
  - The transmission ratio
  - Speed
  - Lubricant
  - Temperature

Courtesy Anibal T. De Almeida and Hugh Falkner and UNIDO

Mechanical Transmissions Helical Gears

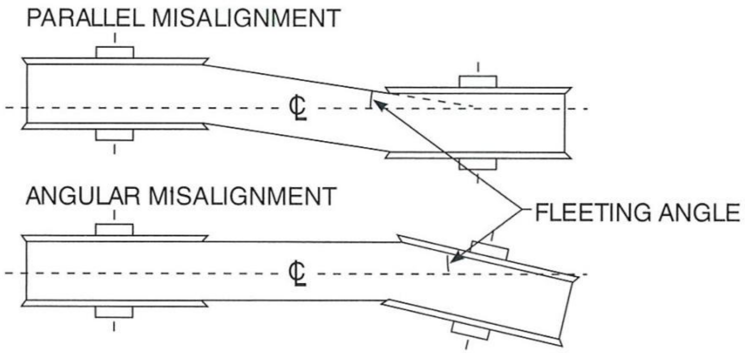




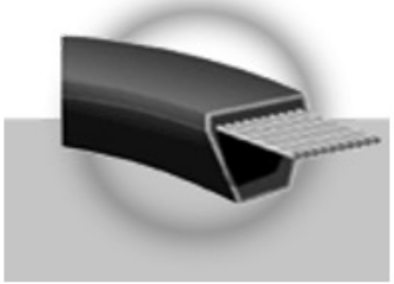
Helical and conic gears have an efficiency of 98-98.5% per stage (1.5-2% loss per stage)

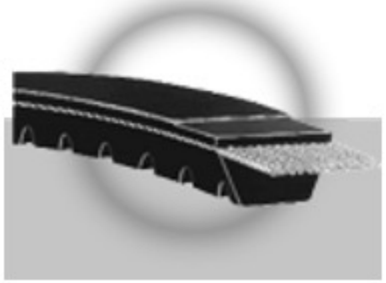
Courtesy Anibal T. De Almeida and Hugh Falkner and UNIDO

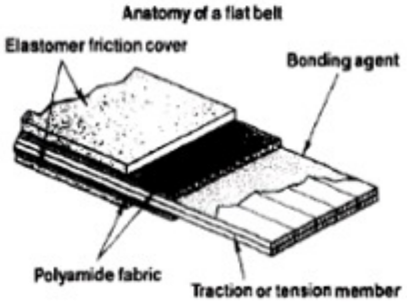
Mechanical Transmissions - Belts



- 1/3 of motors use belts.
- High flexibility of speed adjustment.
- Several types:
  - Vee belts
  - Vee belts without cogs
  - Flat belts
  - Synchronous belts
- The Vee type is the widely used, with an efficiency of 90-96% for larger motor sizes (depending on the motor size, elasticity, tension slip, and alignment).
- If the tension is excessive: accelerated wear of the belts and bearings.
- If the tension is too low: the slip and losses increase.
- The most efficient belt types are the flat and the synchronous. The synchronous has an efficiency of about 98-99%.





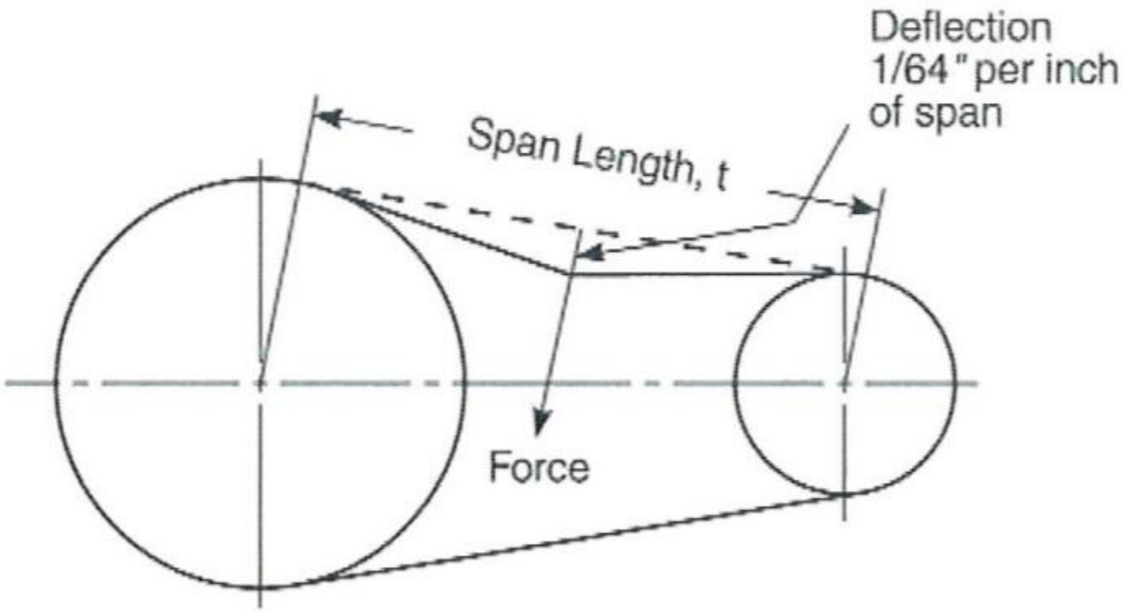


Critical V-Belt Installation Parameters

- Replace all belts at the same time.
- Never use a crowbar to put on the new belts.
- Align the shafts and pulleys.
- Tension the belt properly using a:
  - Sonic tensioning meter or
  - Straight-edge & belt tensioning testing tool
- Run the machine for 24 hours.
- Re-tension the belts.

Belt Tensioning Tools & Techniques

- Use Manufacturer's recommended deflection force.



Images courtesy Gates Rubber

Critical Elements for Proper Motor Greasing

RTFM

- Schedule
- Type of Grease
- Amount of Grease
- Purge old Grease

Image courtesy Peterson Predictive Maintenance

Lubrication Interval Guide

Recommendations by
Electrical Apparatus Service
Association

Lubrication Guide: Frequency in Months

RPM	Frame Range	Type of Service: 8 Hours/Day	Type of Service: 24 Hours/Day
3600	143T-256T	*	*
	284TS-286TX	6	2
	324TS-587US	4	2
1800	143T-256T	*	*
	284T-326T	48	18
	364T-365T	12	4
	404T-449T	9	3
	505U-587U	6	2
1200 and below	143T-256T	*	*
	284T-326T	48	18
	354T-449T	12	4
	505U-587U	9	3

* These motors often do not have bearings that can be relubricated.
Replace after 14,000 to 17,000 service hours.

Corporate culture & lubrication

- Leverage QC processes to document correct procedure
  - Six Sigma
  - ISO
- Delegate to a responsible team
- Consider outsourcing?
- Consider using more motors with sealed bearings?

Infra-Red Photography

Hot Bearing Headed for Failure

- The motor is supposed to be warmer than the bearing

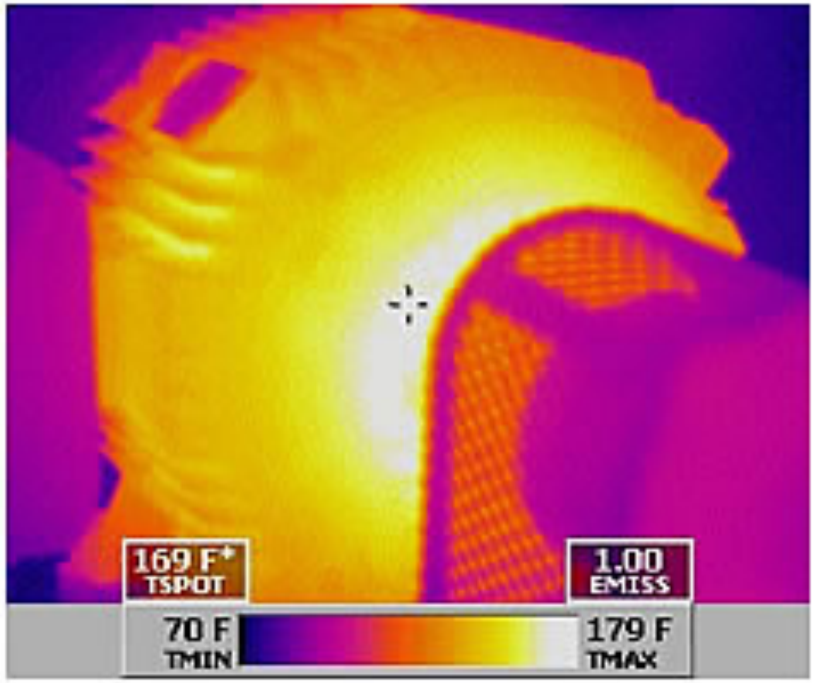


Image courtesy Peterson Predictive Maintenance

Ultrasonic Bearing Maintenance

Bearing Check

Acoustic Grease gun adapter

Image courtesy SDT North America

Equipment Set-Up: Mechanical

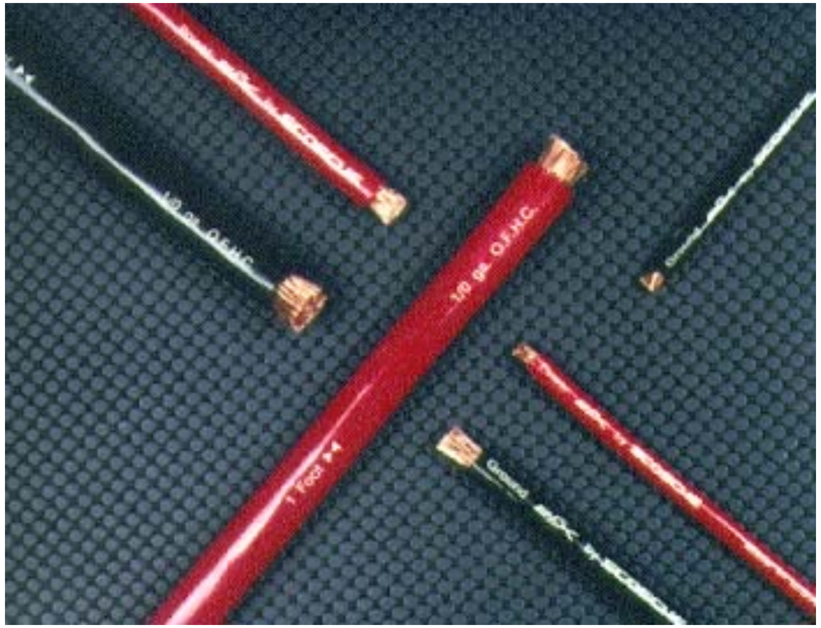
- Provide a flat, rigid mounting for motors and driven equipment.
- Ensure that motor and load are properly aligned.
- Proper Alignment:
  - Reduces motor frame distortions
  - Reduced motor frame stress
  - Reduced vibration
  - Increases motor life
  - Increases efficiency

Laser Alignment

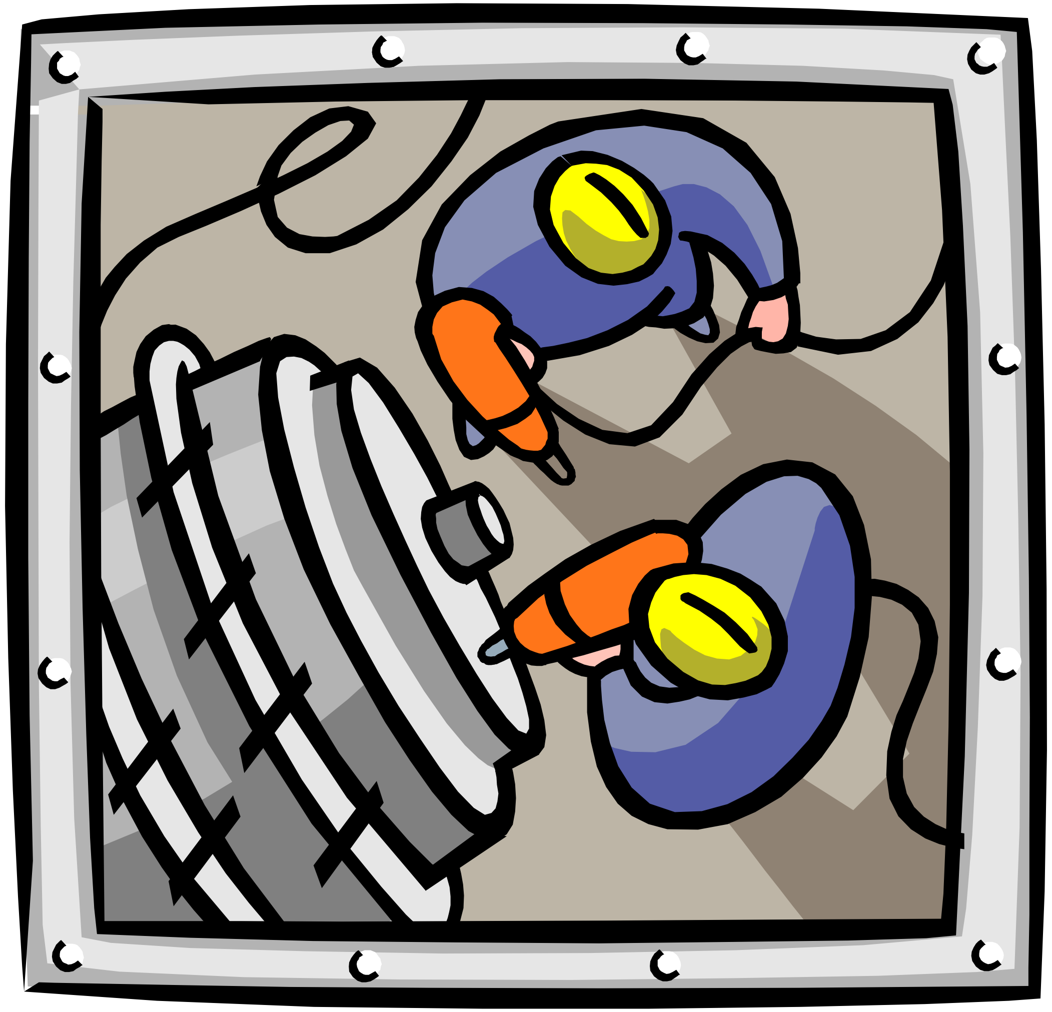
If not properly aligned, the coupling will quickly fail

Equipment Set-up: Electrical

- Electrical codes generally based on 2% loss
- Suggested practice –
  upsize wire gauge one size larger than required by code
- Specify adequate conductor size:
  - Reduces line losses
  - Mitigates harmonics
  - Reduces sags
  - Reduces undervoltage
  - Accommodates load growth
  - Accommodates low power factor
  - Accommodates Design A motors



Repairing, Rewinding, and Rebuilding



Polling Questions

Polling Question

1) We rewind very few motors if any. T/F
2) We rewind definite or special purpose motors. T/F
3) We rewind general purpose TEFC motors 50 hp and smaller.
4) We rewind general purpose TEFC motors over 50 hp. T/F
5) We rewind general purpose ODP motors 50 hp and smaller. T/F
6) We rewind general purpose ODP motors over 50 hp T/F

Repair vs. Replace policy:

According to the 2021 Motor Systems Market Assessment Report…

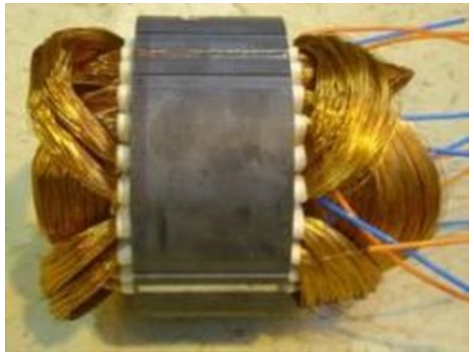
- Only 54% of industrial facilities have a repair replace policy, and sometimes these are very informal.
- In 36% of industrial facilities, the guiding policy is lowest first cost among the repair vs replace options.
- 4% of industrial motors were rewound in the last 2 years
- Less than 1% of commercial motors were rewound over the past 2 years

Repair vs. Replace:

Things to Consider…

- Rewinding a motor *can* reduce efficiency 0.5 to 1% (if not done according to EASA best practices)
- First cost of repair and new purchase.
- Efficiency of existing and proposed new motor.
- Urgency and availability of each alternative.
- Possible modifications to the mounting.
- Annual hours of operation.
- Cost of down time and repairs from a possible early failure in either scenario.

How does a poor rewind degrade efficiency?



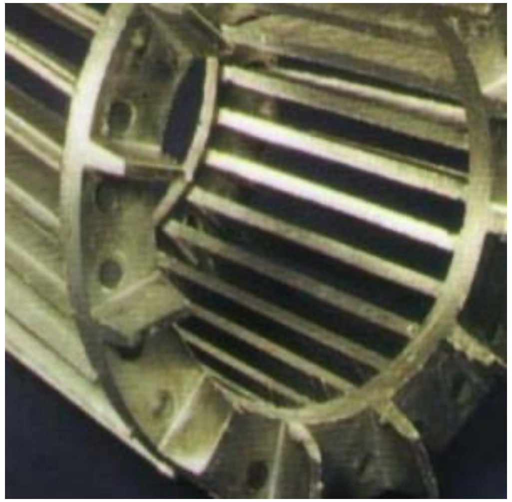
Stator Winding

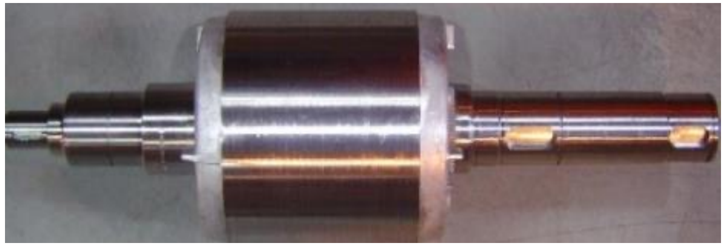
- Undersize wire may be used.
- Errors can occur in the turn count.
- Winding pattern may be revised

How does a poor rewind degrade efficiency?

Rotor

- Damaged rotor bars may be missed and not repaired.
- Machine work on the rotor may increase the air gap or smear the laminations together on the rotor surface.
- Failure to repair bent shaft can interfere with magnetic flux uniformity in the air gap.

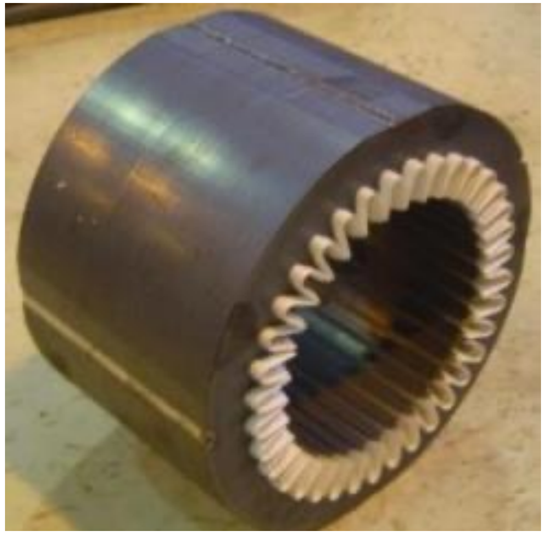




How does a poor rewind degrade efficiency?

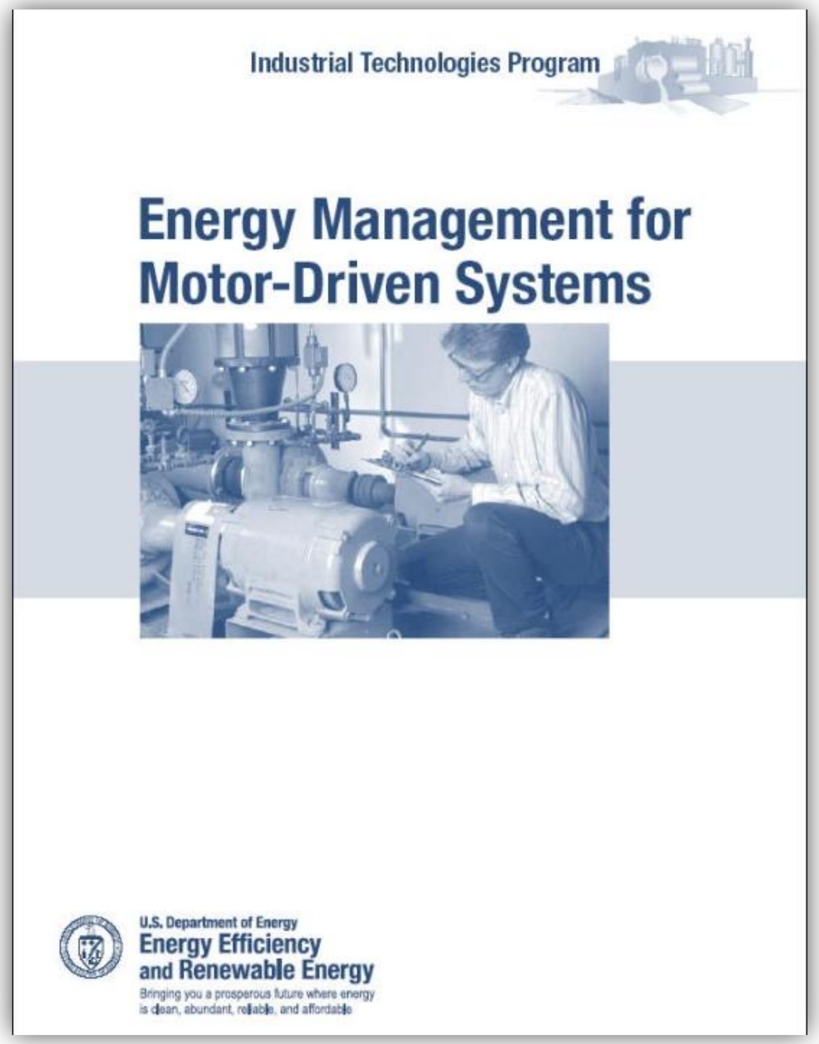
Stator Core Iron

- Overheating to roast out the old windings can damage interlaminar insulation.
- Machining can increase the air gap or smear the laminations together on the stator surface.
- Failure to repair damage from the actual fault condition can leave a hole in the stator or welded laminations.



Energy Management for Motor Driven Systems

This book is a very comprehensive guide to managing your electric motor systems for an improved bottom line.



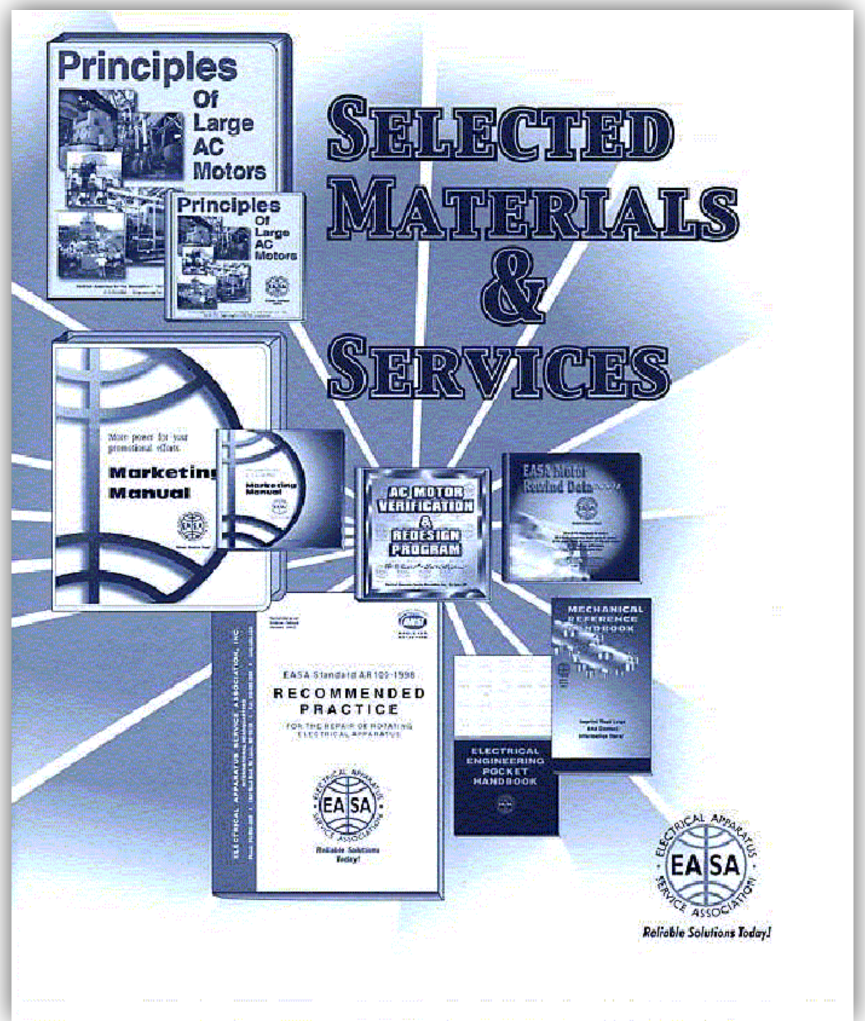
Resources Pertaining to Motor Repair and Rewinding

Electrical Apparatus Service Association

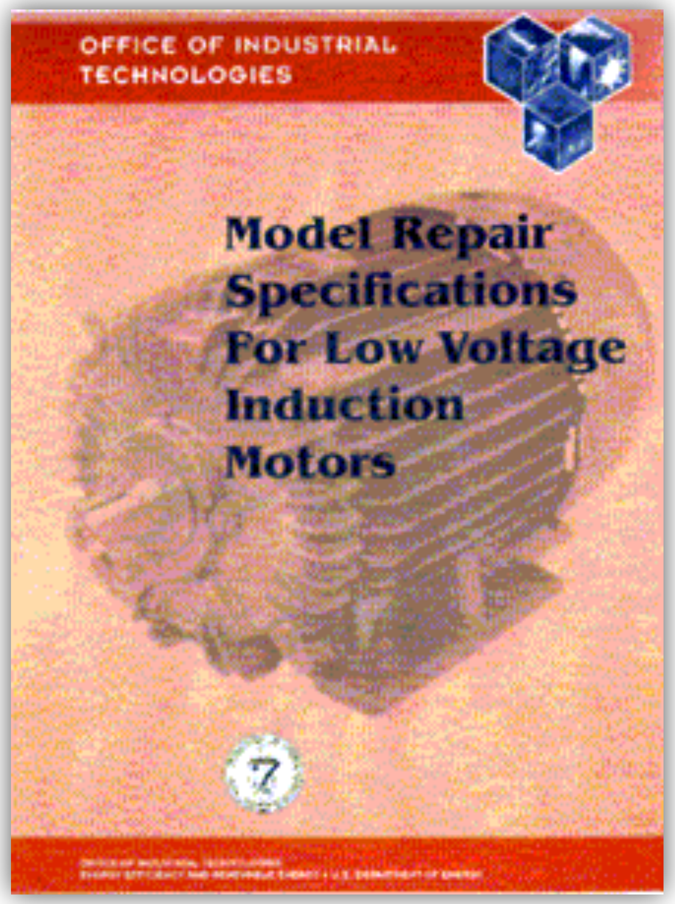
EASA

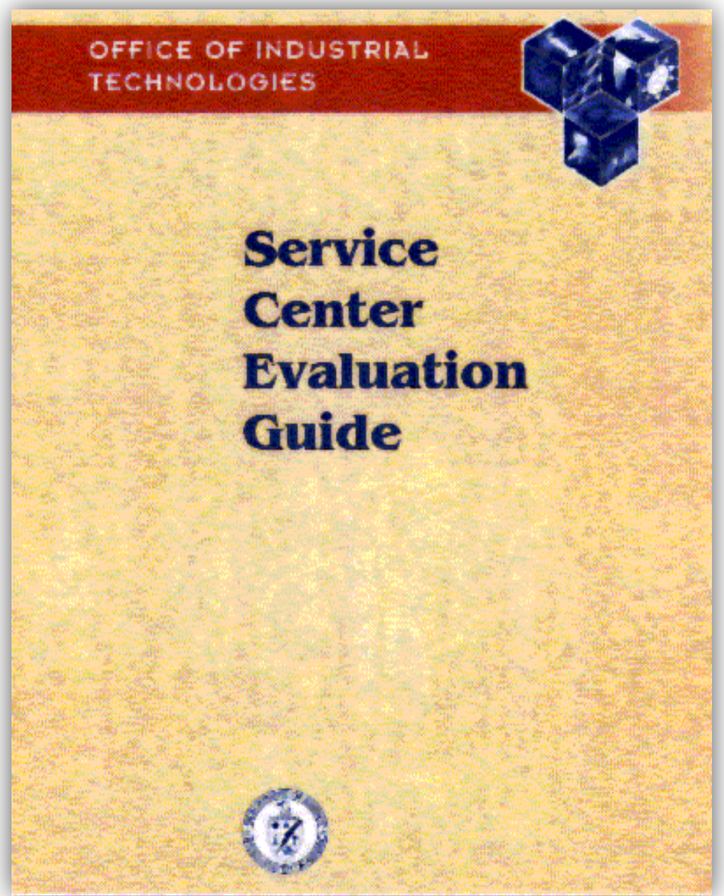
Catalog of Resources

www.easa.com

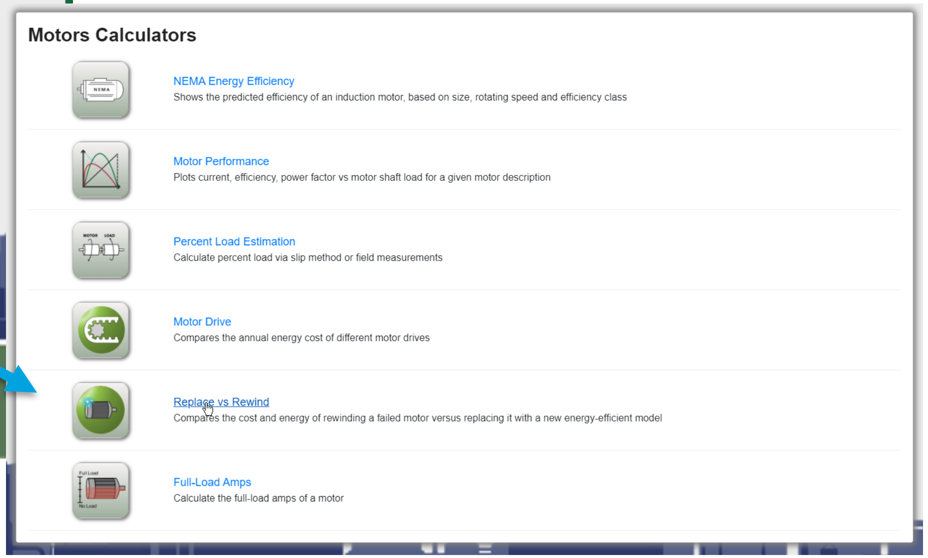


Resources Pertaining to Motor Repair and Rewinding





Switch to live demonstration of MEASUR motor calculators



Thank you!

For Questions or Comments please reach out to the following:

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