

Technology Day

Why Large AC Motors Are Different

October 17th, 2013



Topics of Discussion

- **What is Large AC**
- **Enclosures**
- **NEMA Dimensions**
- **Basic Components**
- **Stators**
- **Rotors**
- **Bearings**
- **Accessories**
- **Speed vs Torque**
- **Applications and Starting**

What is Large AC?

Per NEMA, Large Induction Machines include ratings greater than:

Sync. RPM	Motors-HP	Generators-kW
3600	500	400
1800	500	400
1200	350	300
900	250	200
720	200	150
600	150	125
514	125	100
450	ALL	ALL

NEMA MG 1 Part 20

What is Large AC?

For today's discussion, any motor that meets one (or more) of the following criteria:

1. **Stator Winding:** Any form wound motor
2. **Frame size:** NEMA 5000 frame or larger.
3. **Voltage:** 2300 volts or higher.

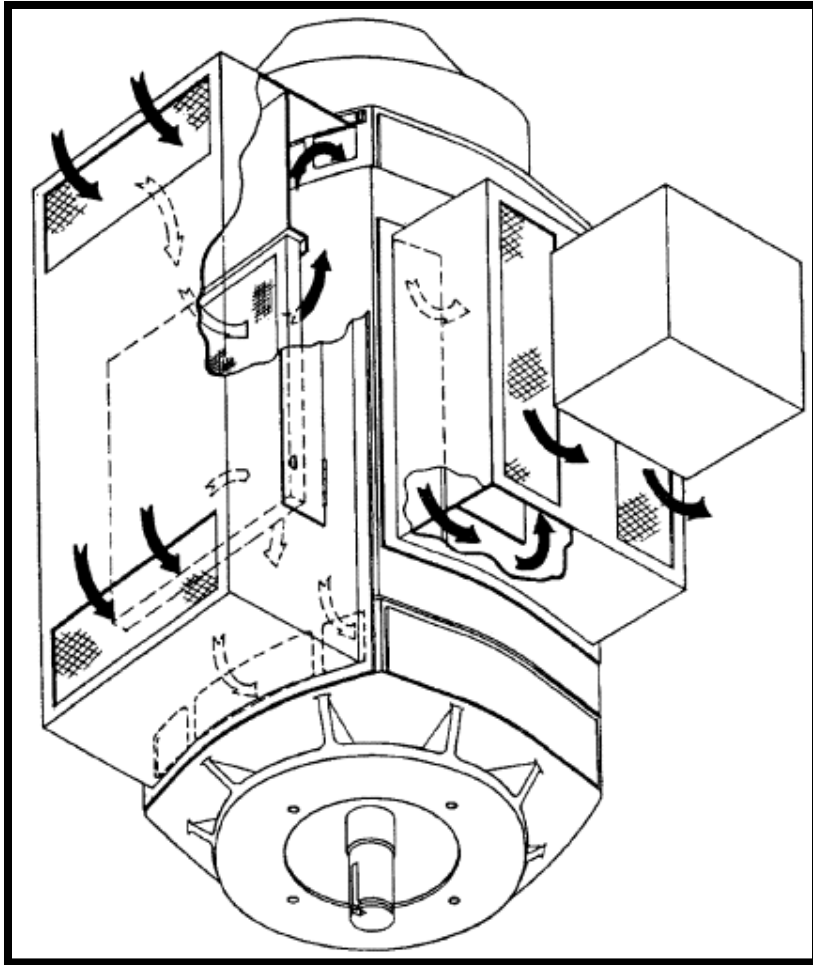


Motor Enclosures

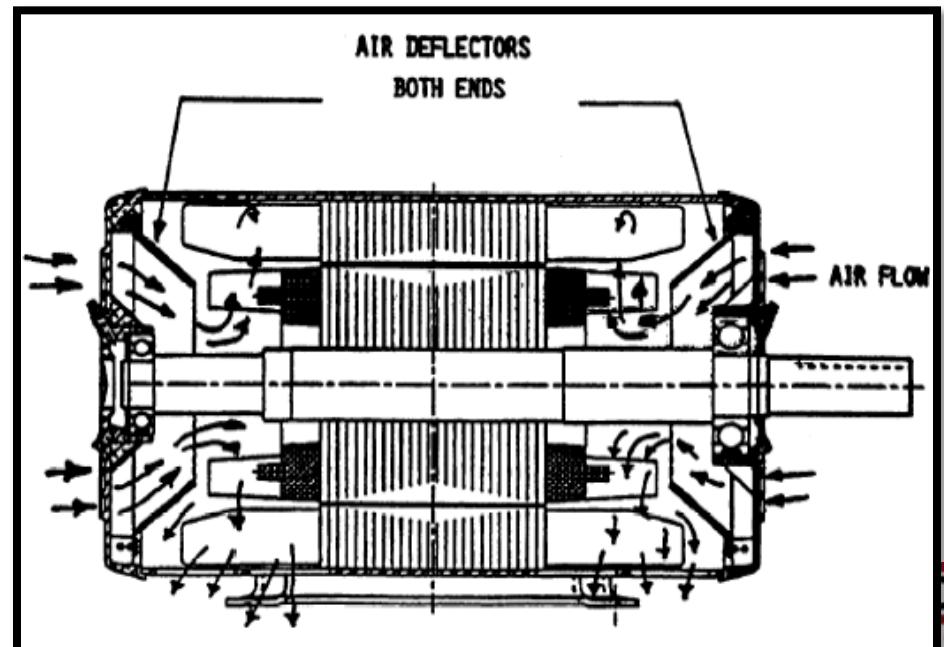
Motor Enclosures



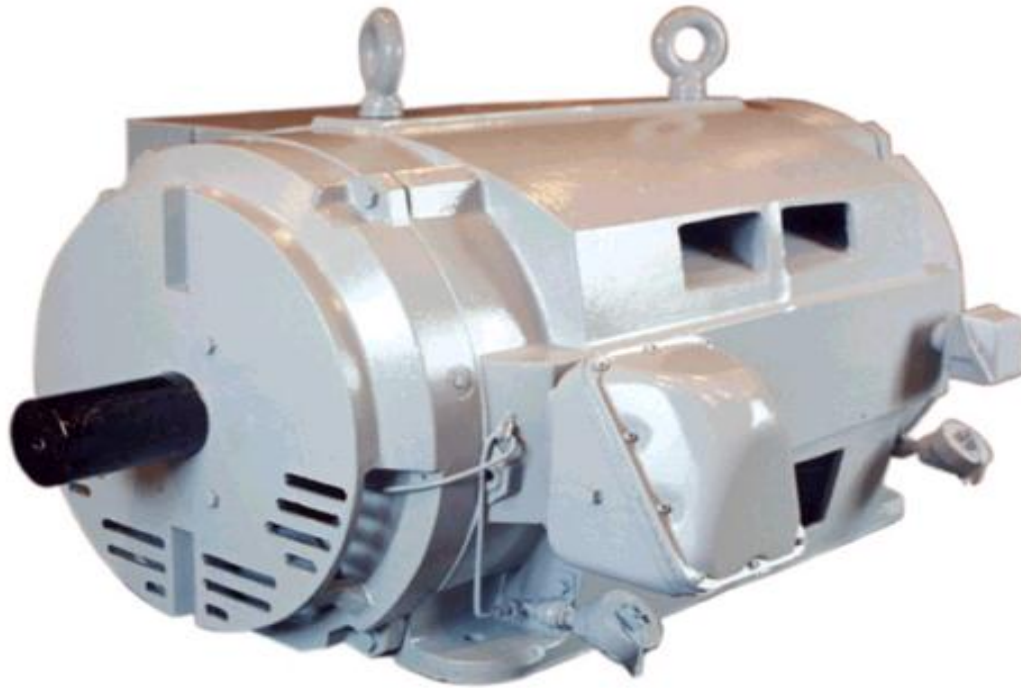
Open Motors



OPEN DRIP PROOF (ODP)
DRIP PROOF GUARDED (DPG)
SPASH PROOF GUARDED (SPG)
WEATHER PROTECTED I (WP-I)
WEATHER PROTECTED II (WP-II)
OPEN DRIP PROOF FORCED VENTILATED (ODP-FV)
SPASH PROOF GUARDED FORCED VENT (SPG-FV)
OPEN DRIP PROOF SEPARATE-VENTILATED (ODP-SV)
SPASH PROOF GUARDED SEPARATE VENTILATD (SPG-SV)

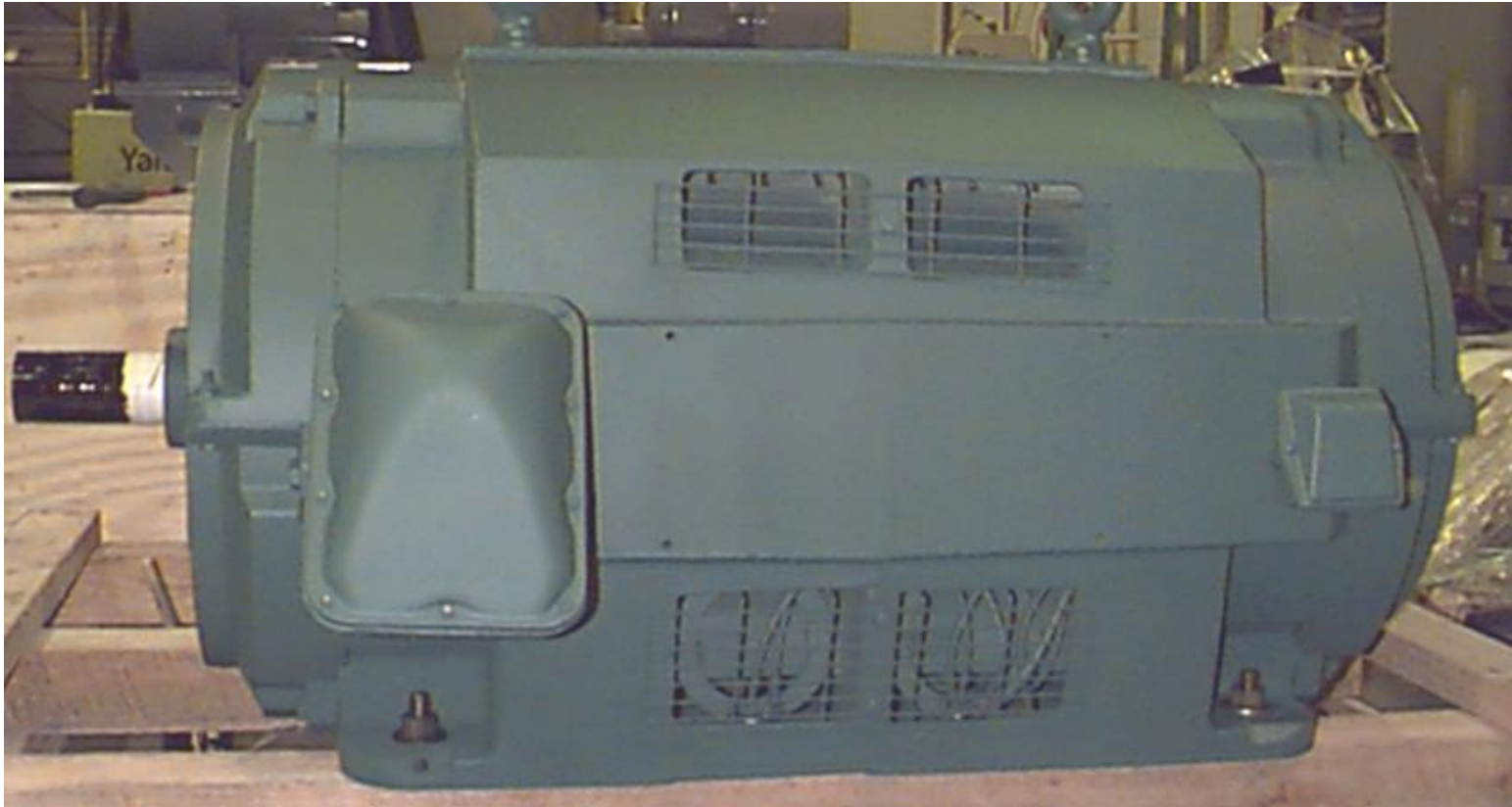


Open Drip Proof – ODP



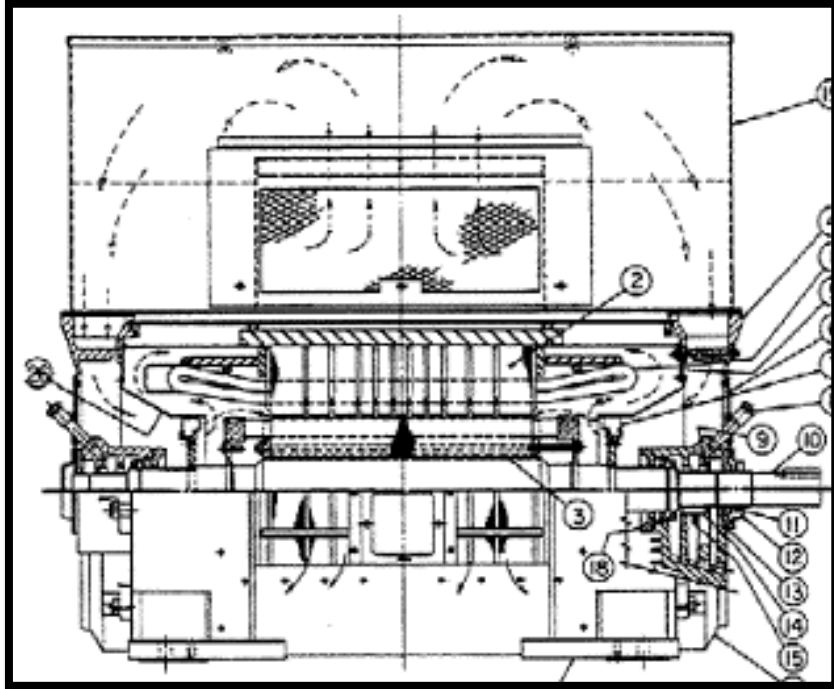
- Suitable for areas with reasonably clean air and non-corrosive environments.
- Protects from water drops falling at up to 15° from the vertical.
- Symmetrical airflow circuit.

Weather Protected (WP – I) Motor Enclosure



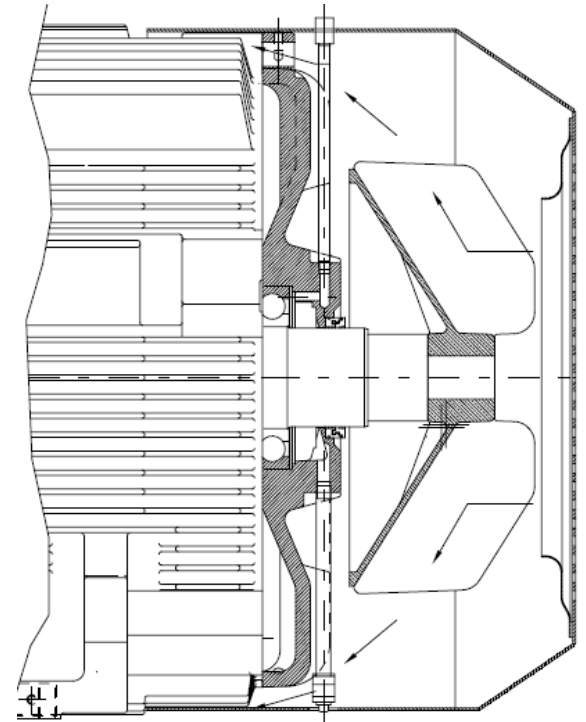
- Ventilation openings constructed to prevent the passage of a $\frac{3}{4}$ " cylindrical rod.
- Mechanical parts and windings painted for protection against atmosphere.

Weather Protected (WP – II) Motor Enclosure



- Airflow path has three 90° directional changes.

Enclosed Examples - TEFC



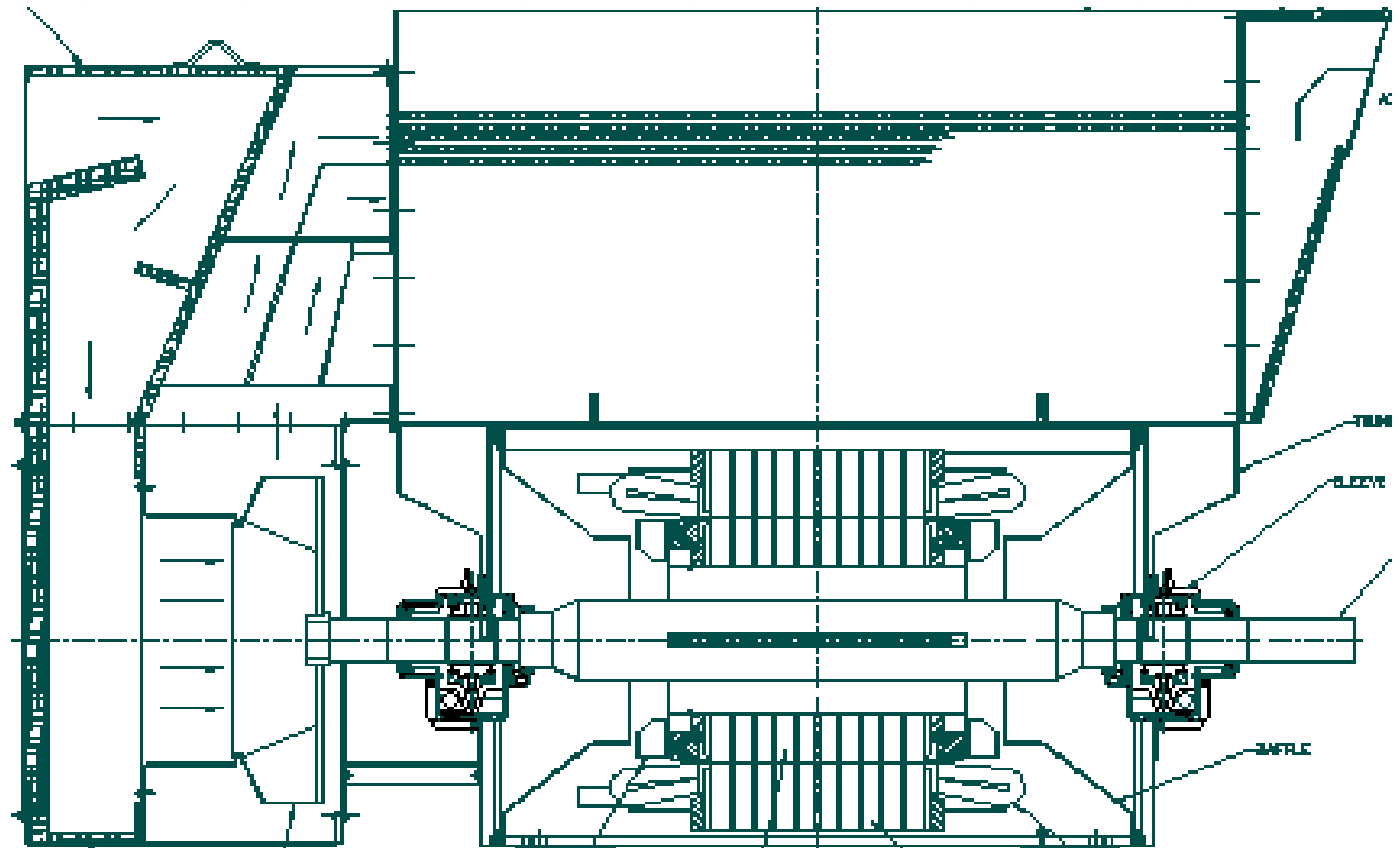
Shaft mounted fan
blows ambient air over
the outside of the
motor frame.

Enclosed Examples - TEAAC



TEAAC = Totally Enclosed Air to Air Cooled

Enclosed Examples - TEAAC



Enclosure Examples - TEWAC



TEWAC = Totally Enclosed Water to Air Cooled

Enclosures: Adjustable Speed



TEAAC – Blower Cooled

Enclosures: Adjustable Speed

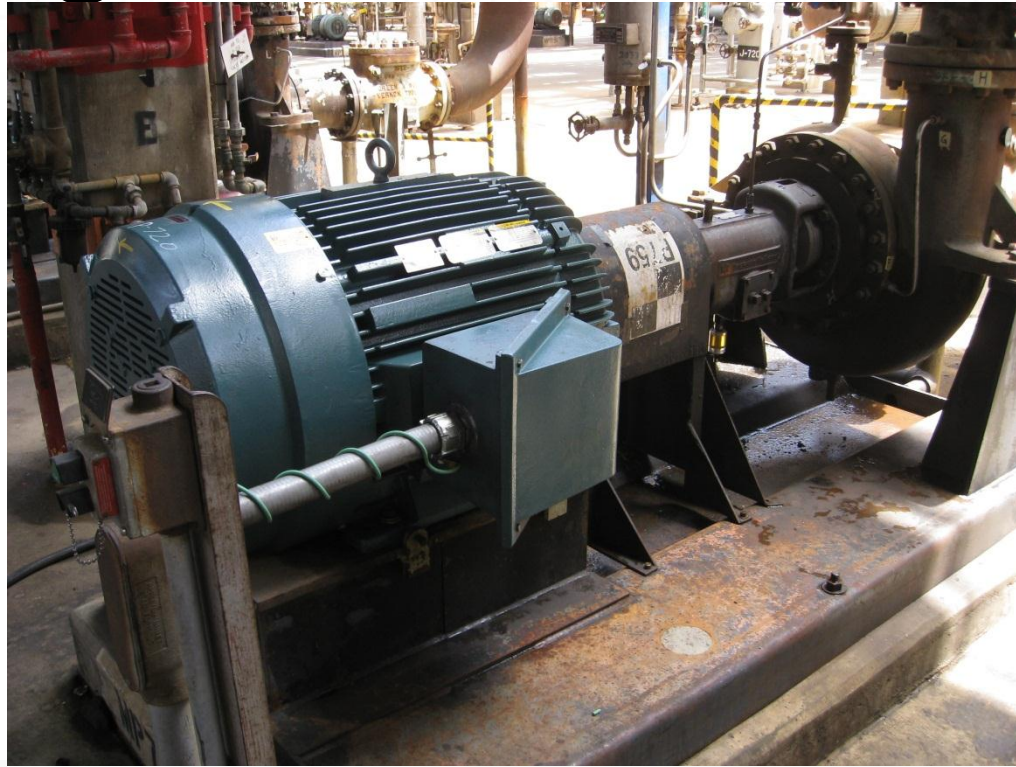


Choosing the Correct Enclosure



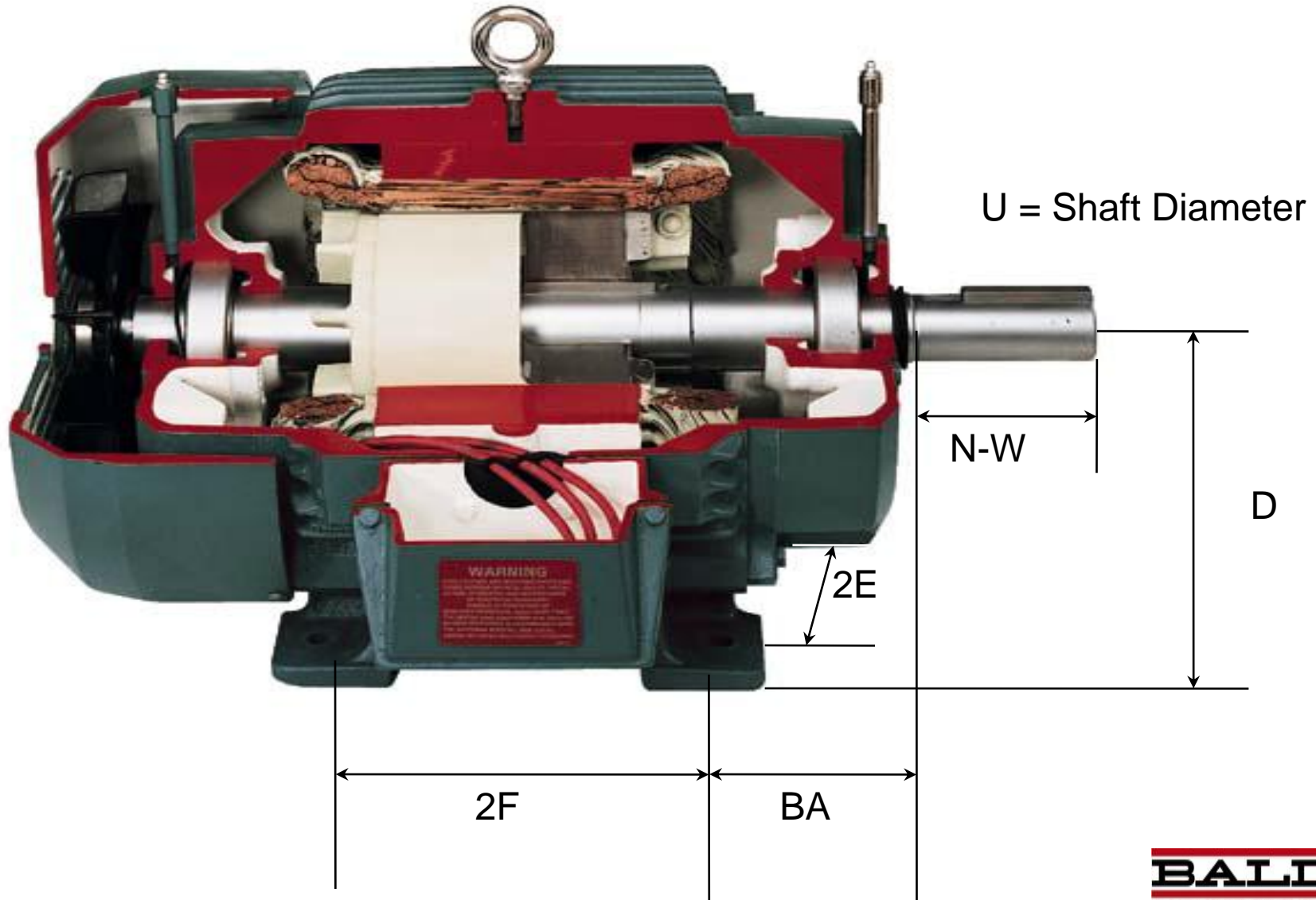
- ODP motors are generally have a lower initial cost.
- Since they force the ambient air through the rotor and stator, they cool more effectively and require less active material.
- The problems with open motors are that moisture and particles present in the motors environment will build up on the rotor and stator, and restrict the air flow through the motor.
- *ODP motors should be installed in clean, dry, indoor environments. They may also require periodic service that includes cleaning the rotor and stator.*

Choosing the Correct Enclosure



- They can be operated indoors or outdoors.
- Since TEFC motors cool by air flow over the surface of the frame, the frame surface should be kept clear of materials that will restrict the air flow or reduce the heat transfer from the frame.
- *TEFC motors are generally well suited for harsh, dirty and wet environments.*

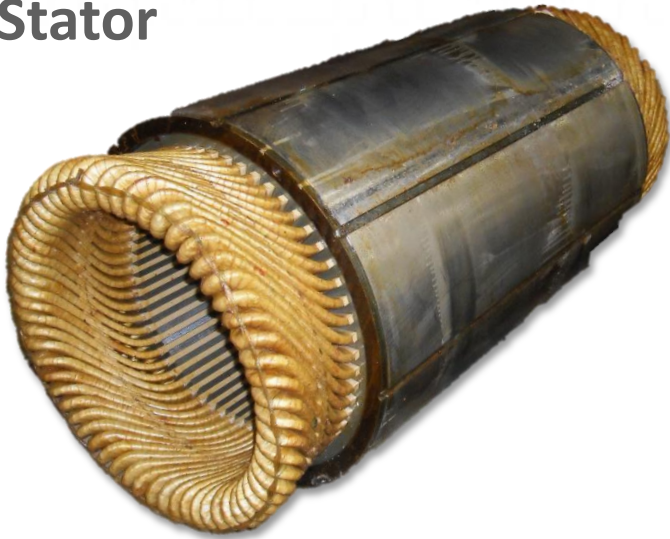
NEMA Dimensions



Basic Components

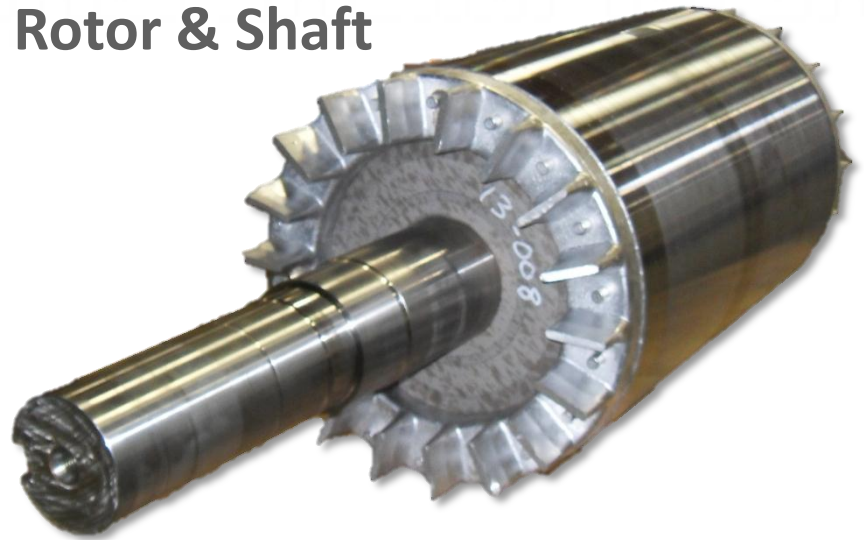
Two Basic Parts of any AC Motor

Stator



- **Stator – Contains the windings within the steel laminations.**
- **The stator is not mechanically connected to the load**

Rotor & Shaft

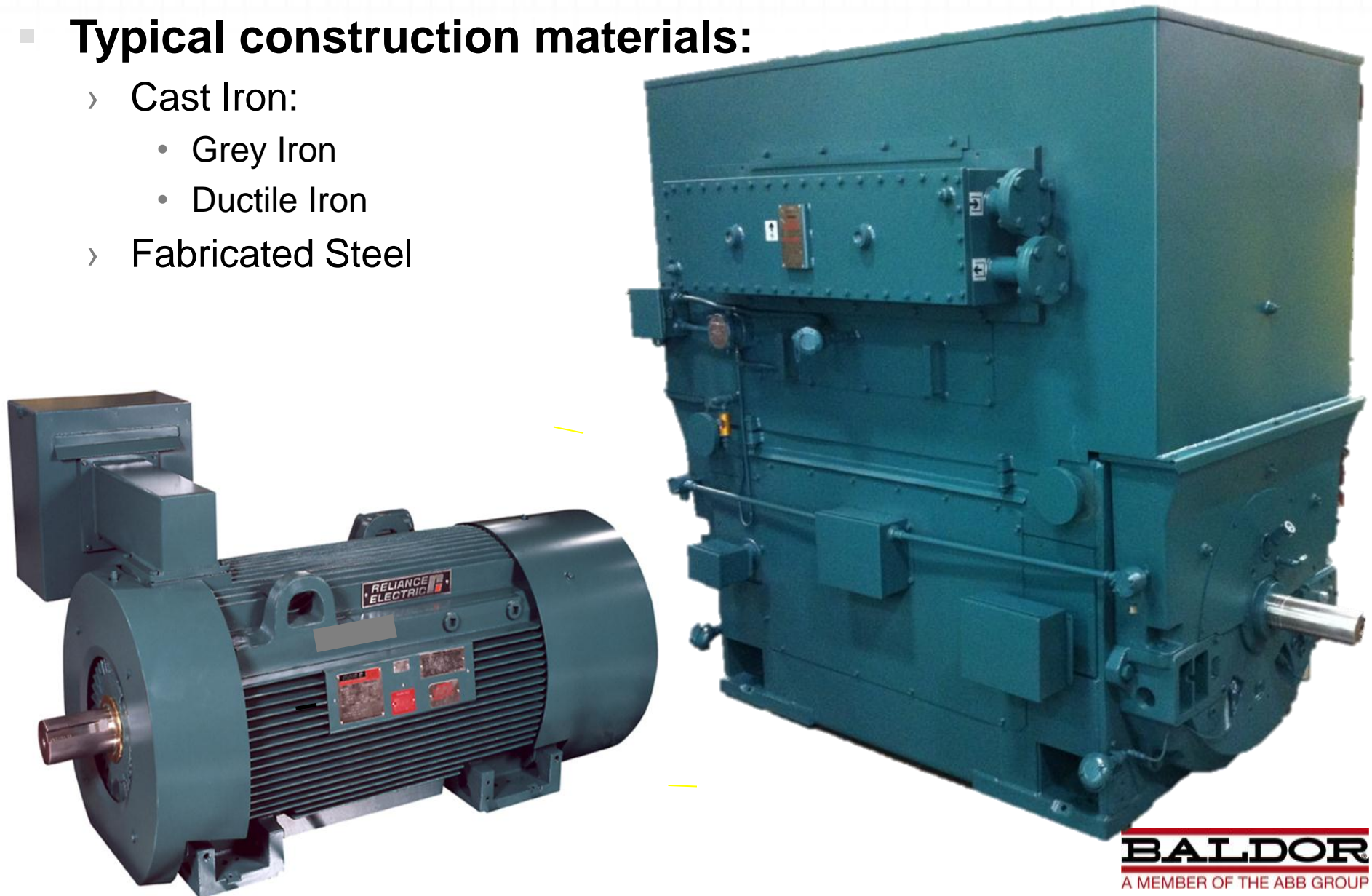


- **Rotor & Shaft – A rotating unit mounted on bearings and provides mechanical power transmission**
- **The rotor and shaft are mechanically connected to the load**

Motor Frame

■ Typical construction materials:

- › Cast Iron:
 - Grey Iron
 - Ductile Iron
- › Fabricated Steel

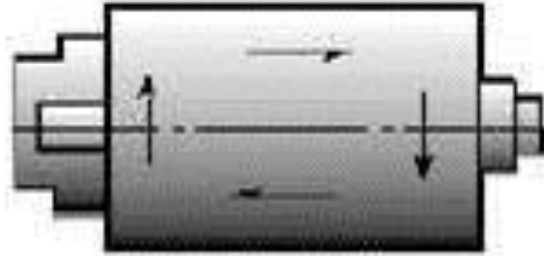


Stators

Why use Laminations?

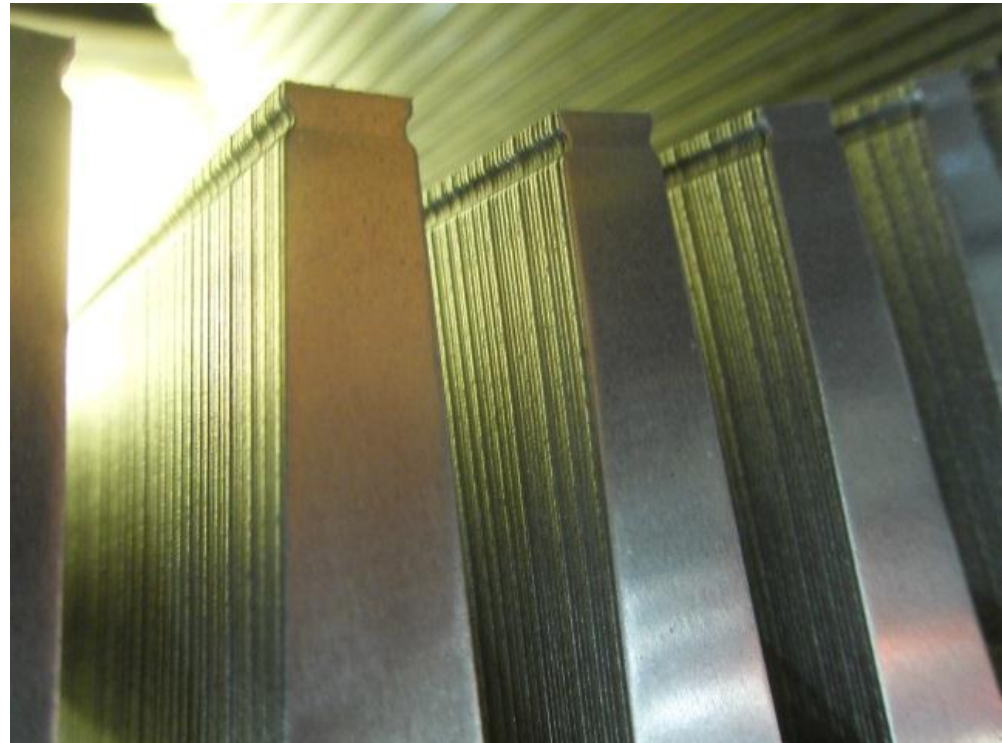
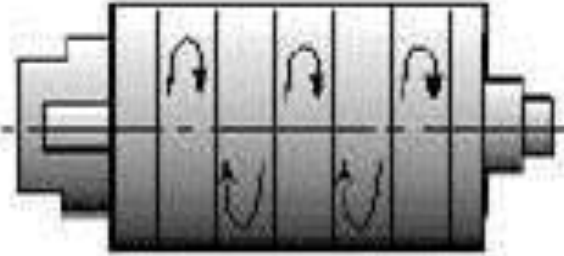
Solid Core

Low resistance
Large eddy currents
Higher core losses



Laminated Core

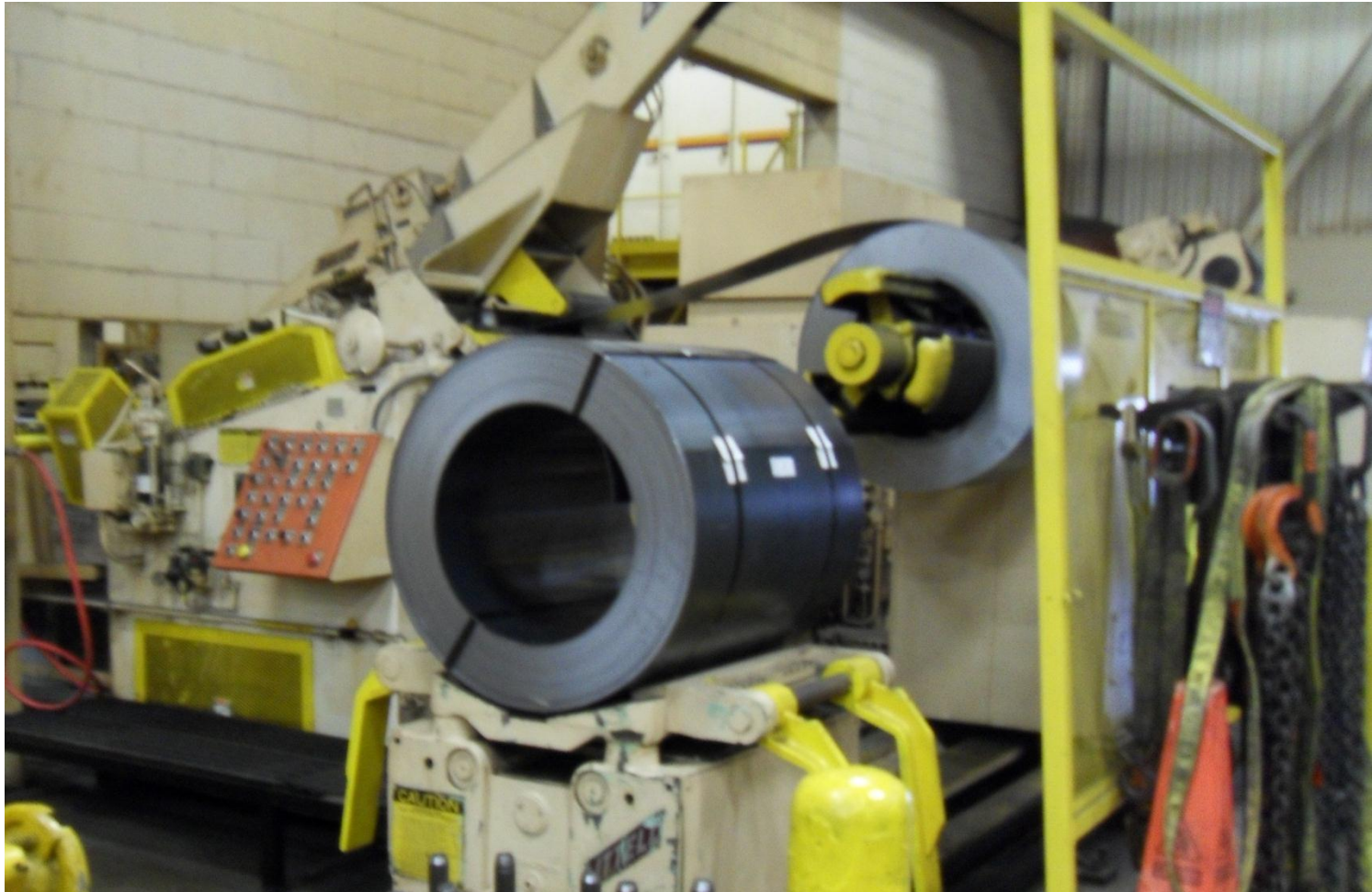
High resistance
Small eddy currents
Lower core losses



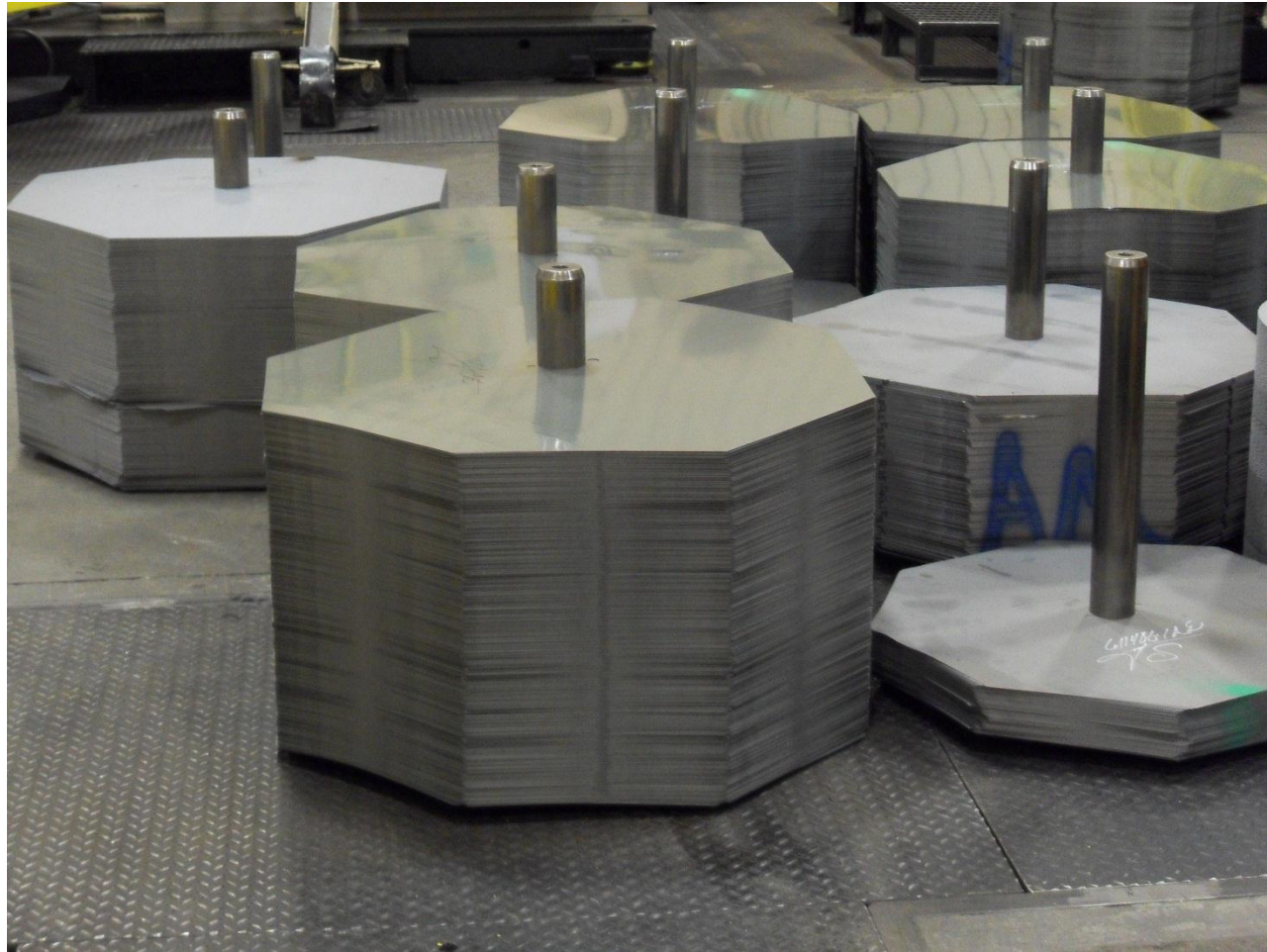
Coil Steel



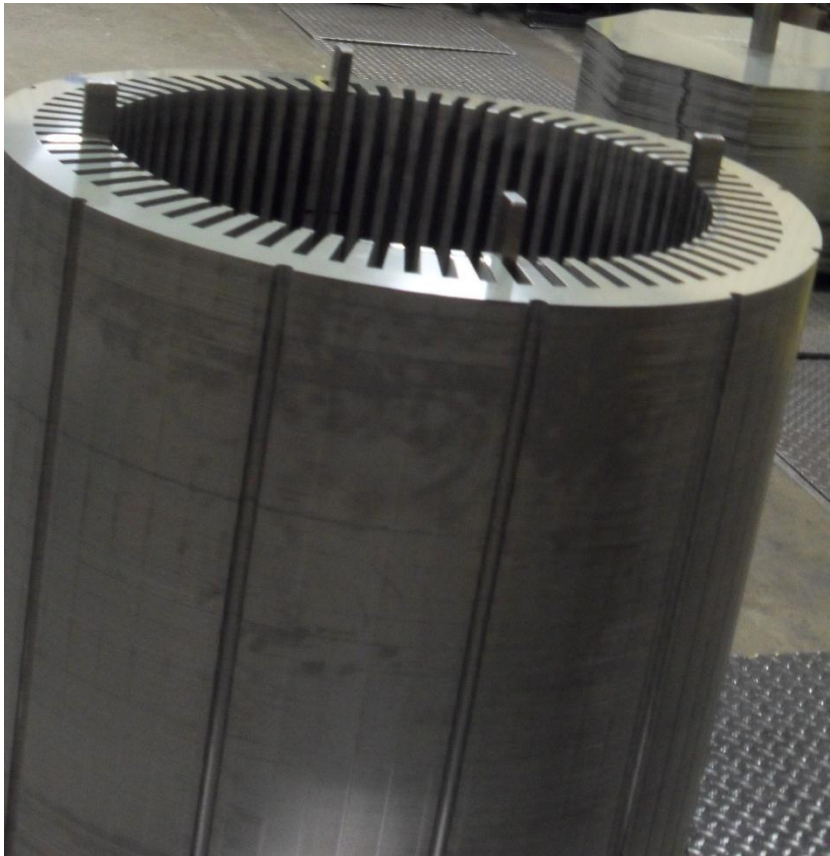
Punch Press



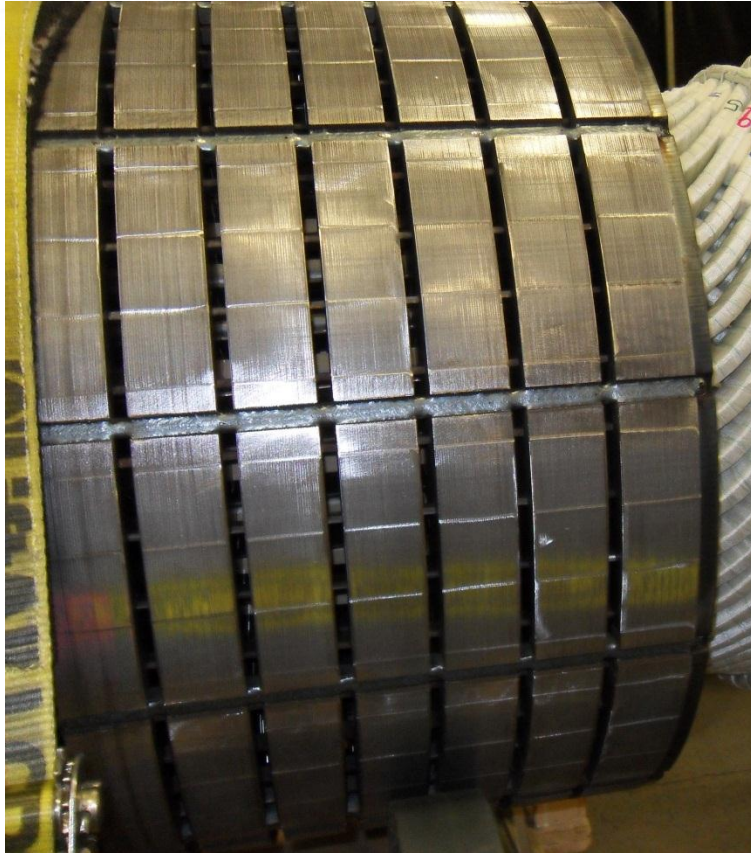
Lamination Blanks



Stator Laminations and Rotor Blanks



Stator Core



Ducted

Solid

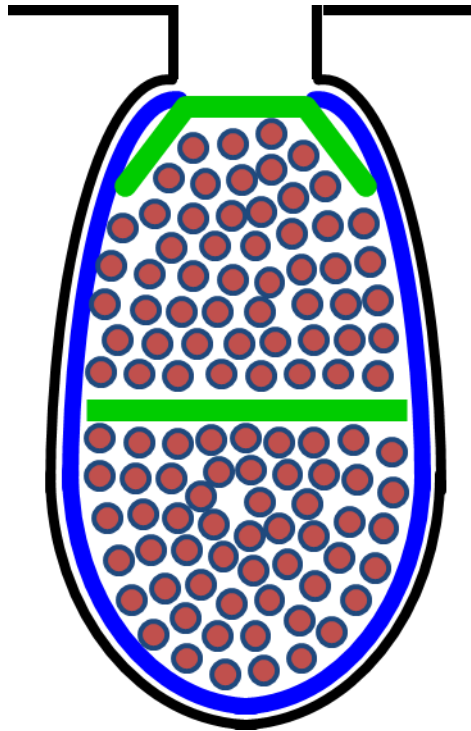


Stator Windings

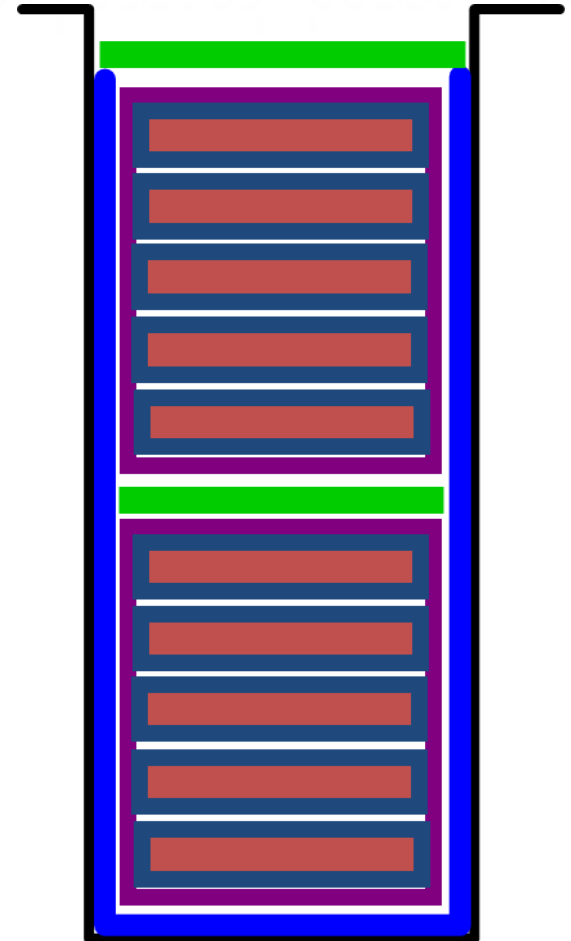
- **All coils are manufactured with insulated copper wire.**
- **Form Wound or Random Wound**
 - › Number of Turns
 - › Size/Shape of Wire
 - › Insulation
 - Class F or Class H
 - Enamel or Glass over Enamel

Stator Windings

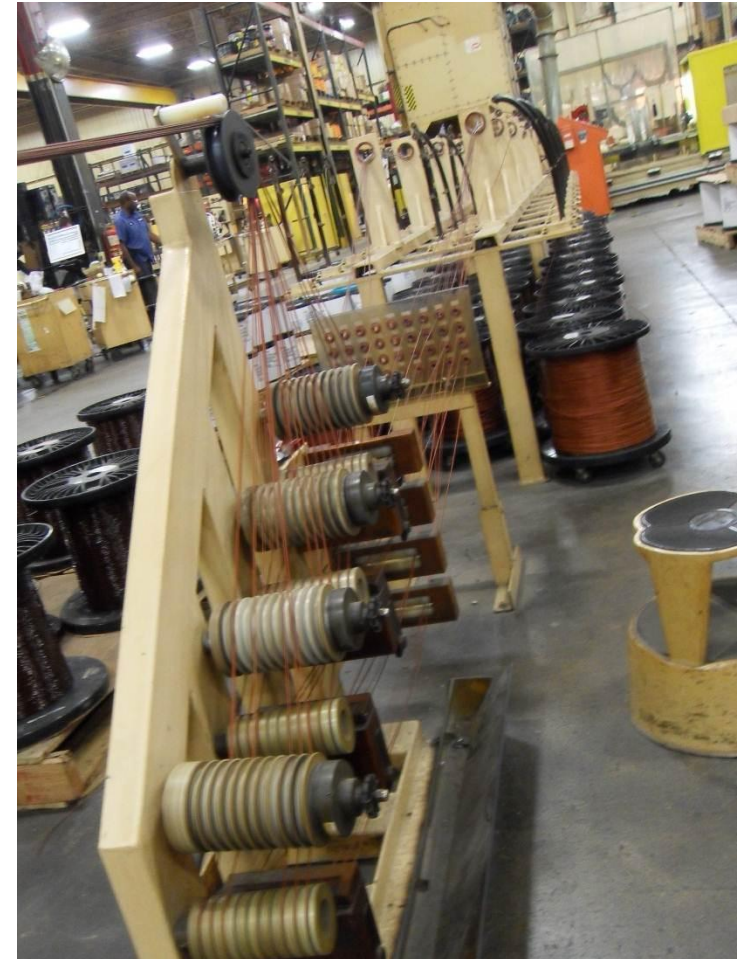
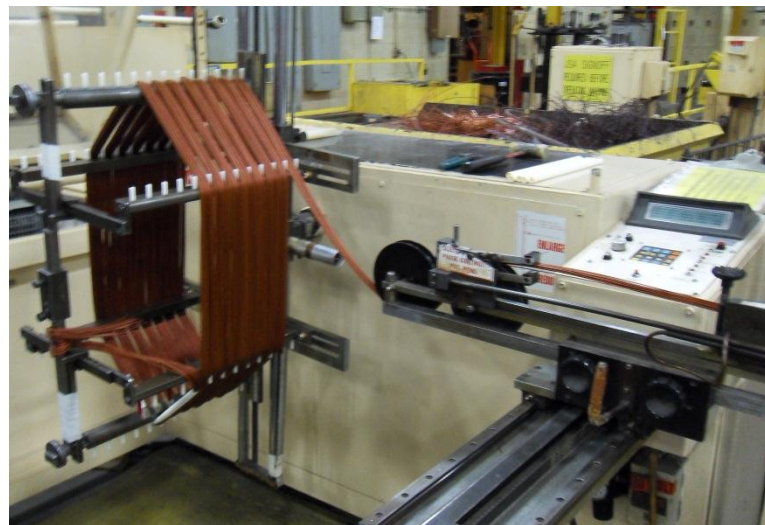
Random



Form



Stator Windings - Random Wound



Stator Windings Random Wound



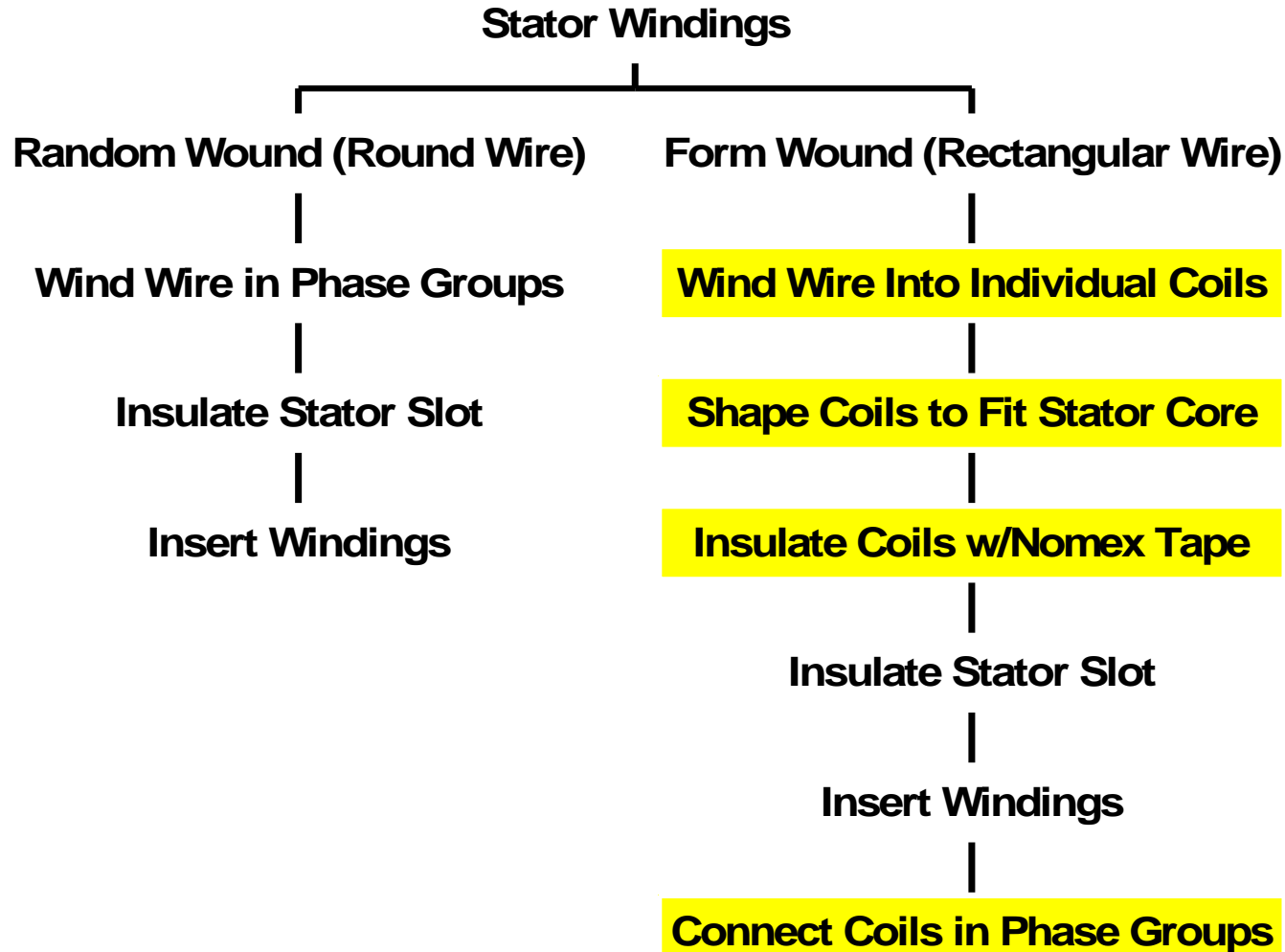
Stator Windings Form Wound



Stator Windings Form Wound



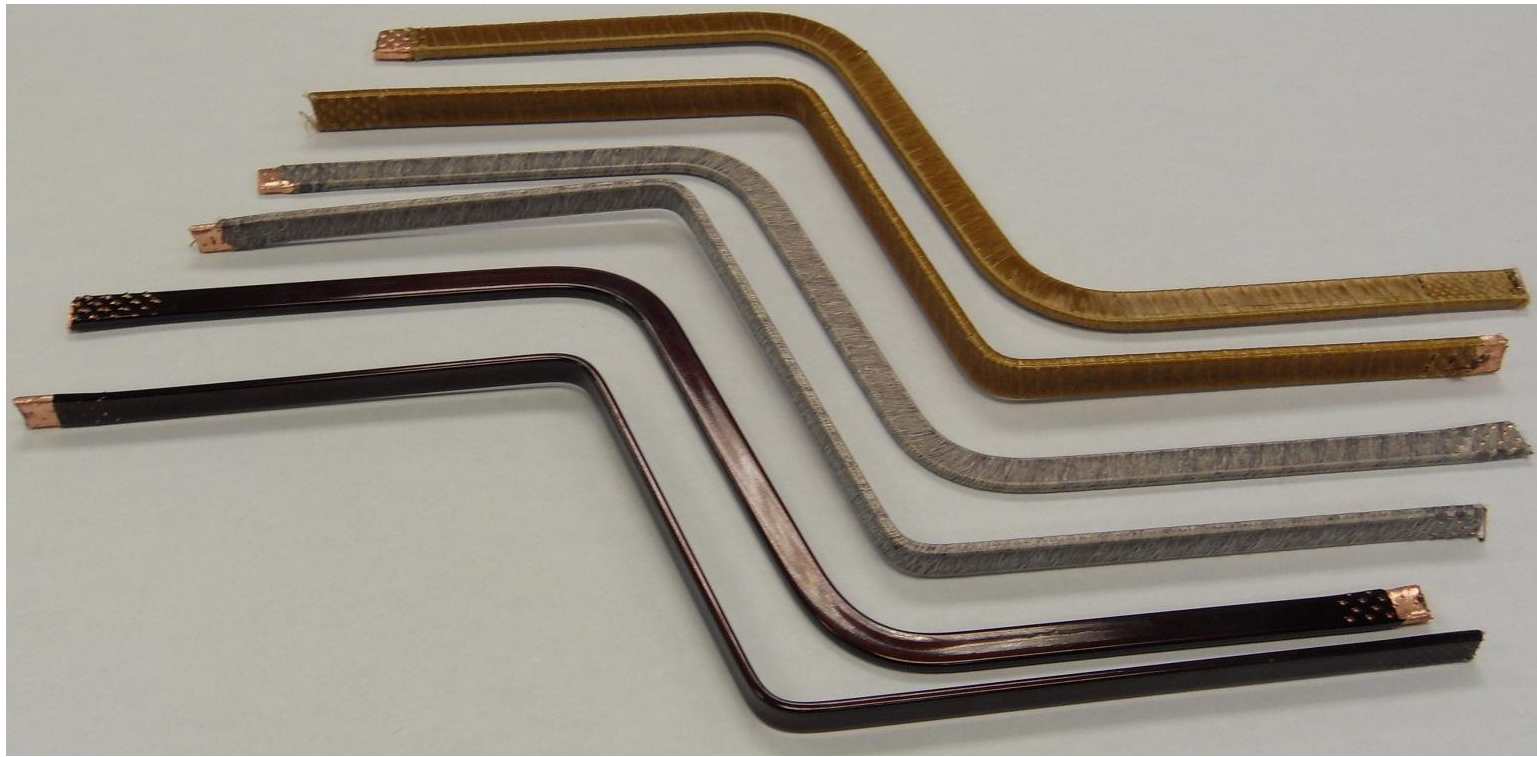
Stator Windings Manufacturing Process



Stator Windings

Magnetic Wire Types

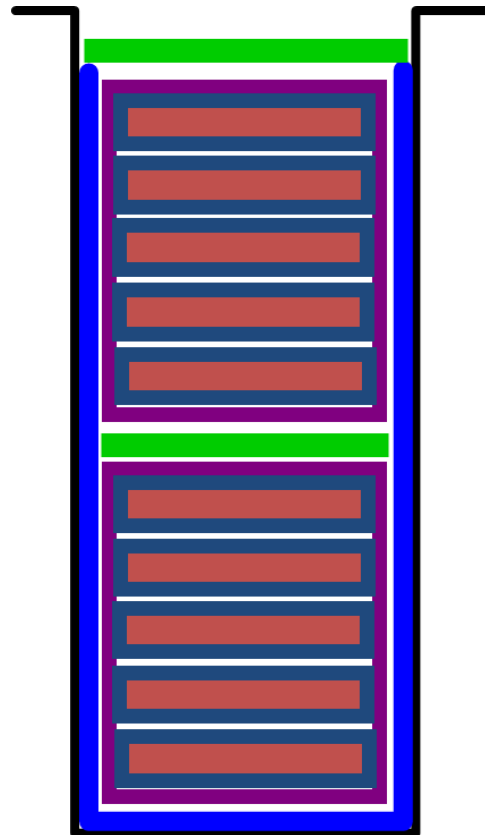
NEMA Class	Description	Insulation Thickness
H	Heavy Film, Single Glass, Epoxy Saturant, Copper Wire	0.013"
F	Heavy Film, Single Glass, Copper Wire	0.013"
F	Dual Film, Copper Wire	0.005"



Form Wound Stator Windings

Ground Wall Insulating Layers by Voltage Class

Voltage	0 to 3kV	3.1 to 5kV	5.1 to 7Kv	7.1 to 13.2kV
Layers ½ Lap Nomex Mica Tape	2	3	5	9



Insulation Systems

Random Wound

- **Dip & Bake**
- **Vacuum Impregnate (VI)**
- **VPI (Vacuum Pressure Impregnation)**

Insulation Systems

Random Wound



Insulation Systems

Form Wound

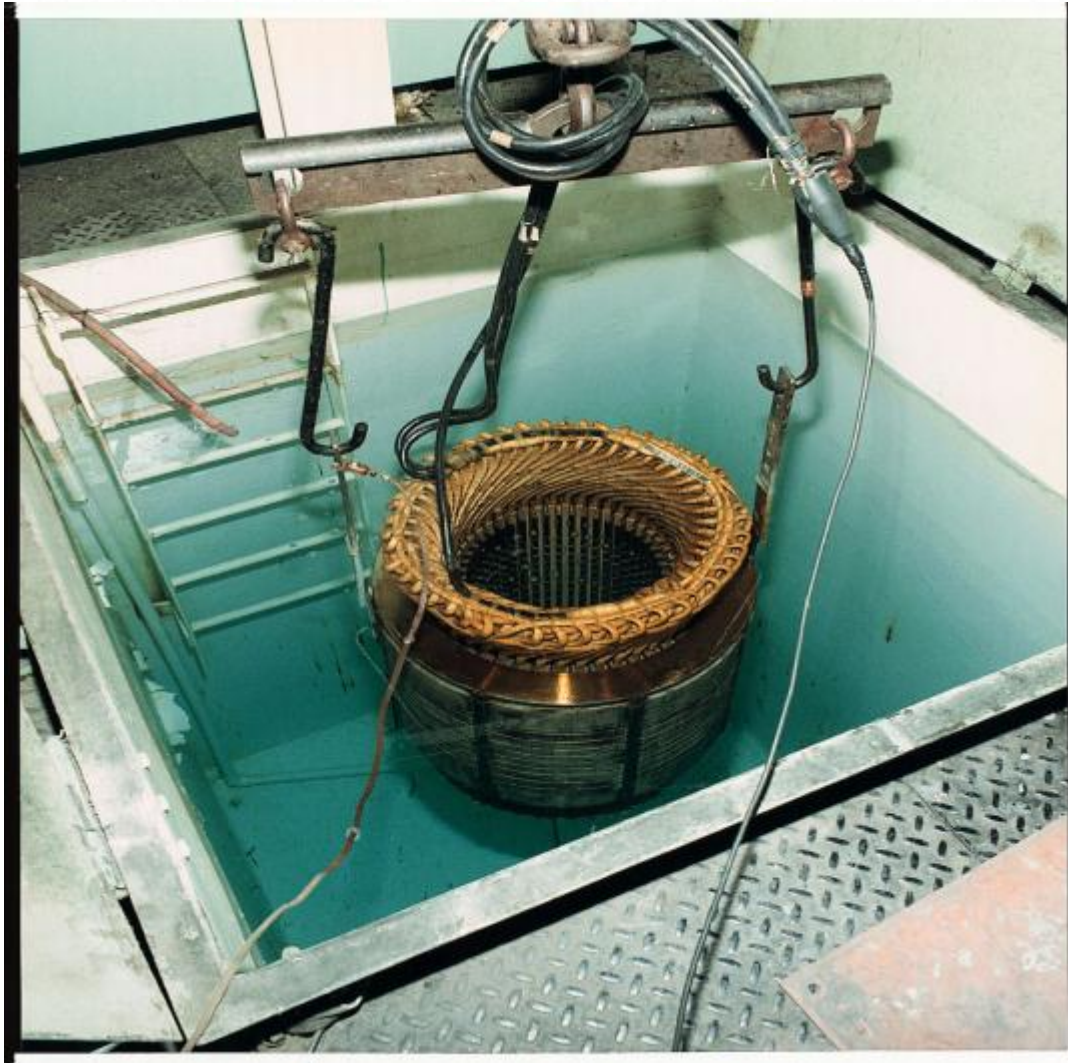
- **VPI (Vacuum Pressure Impregnation)**
- **Sealed VPI**
 - › Additional sealing components
 - › Capable of Passing the Water Immersion Test

Insulation Systems

Form Wound

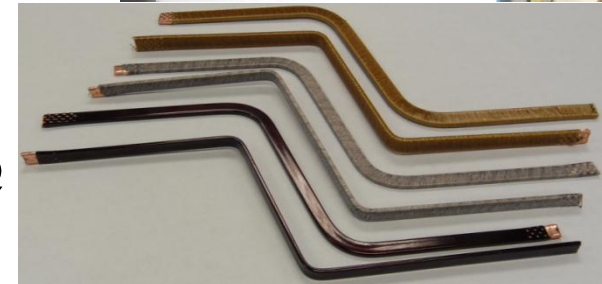


Sealed Insulation Water Test



Stator Windings Testing

- **Magnetic wire test (NEMA MW1000)**
- **Surge (IEEE 522)**
 - › Individual Coils
 - › Wound Stator Before Connect
 - › Wound Stator After Connect
- **High potential test (NEMA MG1-20, IEEE 112)**
- **Added Testing for Sealed System**
 - › One Minute Megger Dry @ 500VDC (IEEE 43)
 - › Polarization Index Wet 10 min to 1 min Ratio @ 500VDC(IEEE 43)
 - › High Potential Test Wet (NEMA MG1-20.18, IEEE 112)
 - › One Minute Megger Wet @ 500VDC (IEEE 43)



Understanding Motor Temperatures

Insulation Class

- **F or H**
 - › Refers to total temperature the Insulation System is designed to withstand and deliver 'full' life
 - › Class B: 130°C
 - The 'previous' NEMA standard
 - › Class F: 155°C
 - Most common insulation class for current AC motors
 - › Class H: 180°C
 - High Ambient
 - Power Density

Temperature Rise per NEMA MG1-2011

20.8.1 Machines with a **1.0** Service Factor at Rated Load

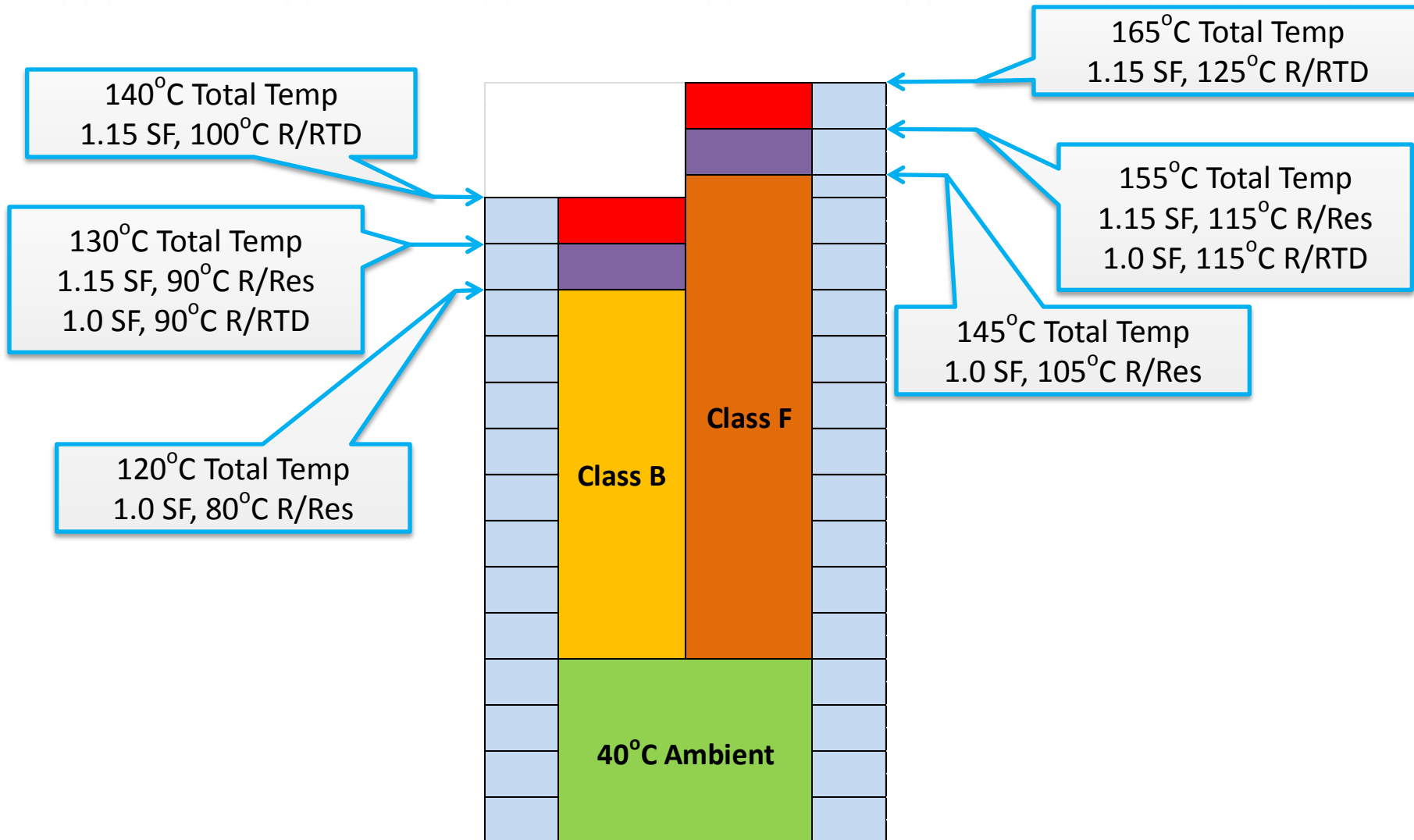
			Temperature Rise, Degrees C			
			Class of Insulation System			
Item	Machine Part	Method of Temperature Determination	A	B	F	H
a	Insulated windings					
	1. All horsepower (kW) ratings	Resistance	60	80	105	125
	2. 1500 horsepower and less	Embedded detector*	70	90	115	140
	3. Over 1500 horsepower (1120 kW)					
	a) 7000 volts and less	Embedded detector*	65	85	110	135
	b) Over 7000 volts	Embedded detector*	60	80	105	125
b	The temperatures attained by cores, squirrel-cage windings, collector rings, and miscellaneous parts (such as brushholders and brushes, etc.) shall not injure the insulation or the machine in any respect.					

20.8.2 Machines with a **1.15** Service Factor at Service Factor Load

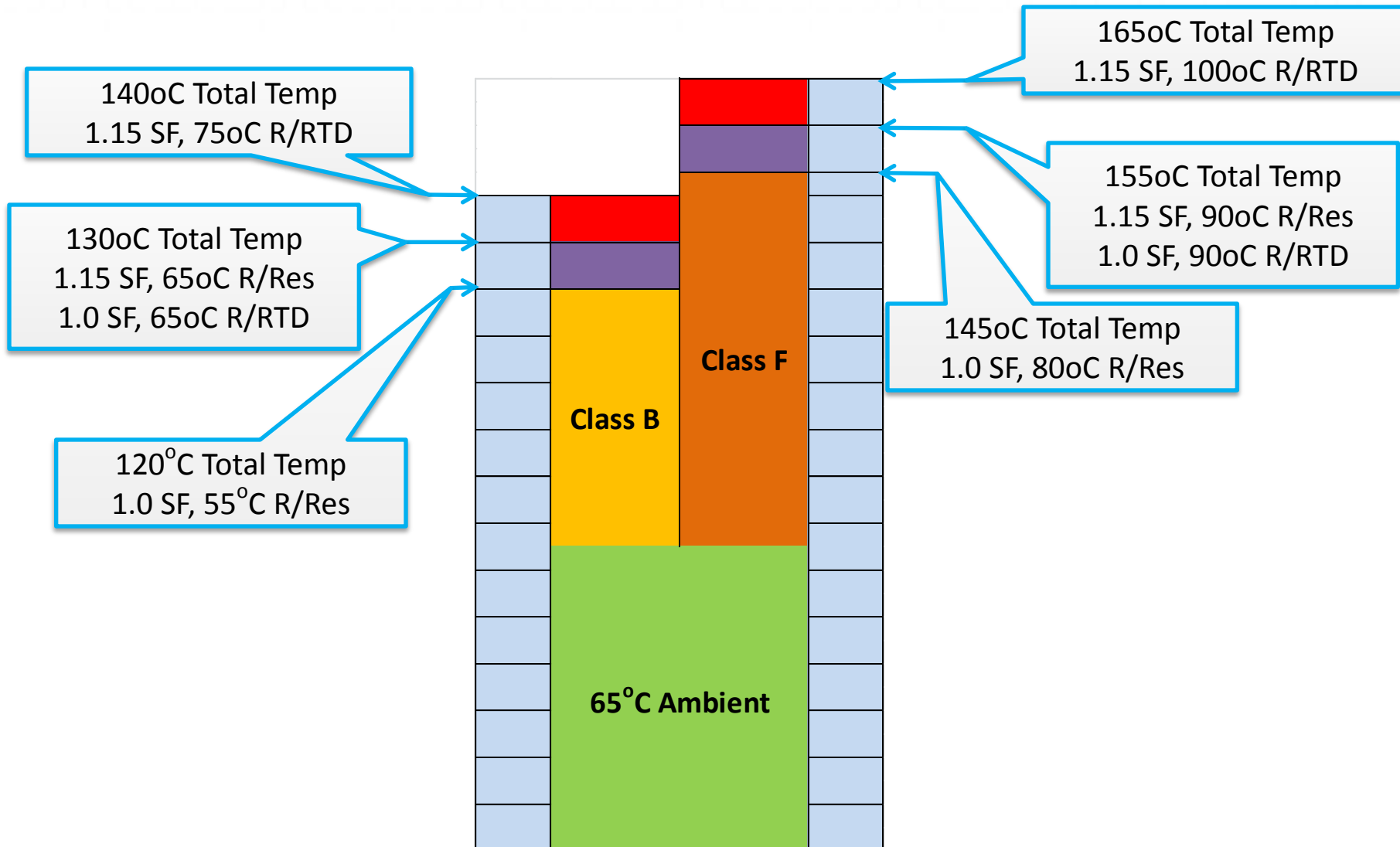
			Temperature Rise, Degrees C			
			Class of Insulation System			
Item	Machine Part	Method of Temperature Determination	A	B	F	H
a	Insulated windings					
	1. All horsepower (kW) ratings	Resistance	70	90	115	135
	2. 1500 horsepower and less	Embedded detector*	80	100	125	150
	3. Over 1500 horsepower (1120 kW)					
	a) 7000 volts and less	Embedded detector*	75	95	120	145
	b) Over 7000 volts	Embedded detector*	70	90	115	135
b	The temperatures attained by cores, squirrel-cage windings, collector rings, and miscellaneous parts (such as brushholders and brushes, etc.) shall not injure the insulation or the machine in any respect.					

*Embedded detectors are located within the slot of the machine and can be either resistance elements or thermocouples. For machines equipped with embedded detectors, this method shall be used to demonstrate conformity with the standard. (See 20.27.)

Temperature Rise & Insulation Class Summary



Temperature Rise & Increased Ambient



Effect of Altitude on Temperature Rise

NEMA MG 1 - 2011

20.8.4 Temperature Rise for Altitudes Greater than 3300 Feet (1000 Meters)

For machines which operate under prevailing barometric pressure and which are designed not to exceed the specified temperature rise at altitudes from 3300 feet (1000 meters) to 13200 feet (4000 meters), the temperature rises, as checked by tests at low altitudes, shall be less than those listed in 20.8.1 and 20.8.2 by 1 percent of the specified temperature rise for each 330 feet (100 meters) of altitude in excess of 3300 feet (1000 meters).

Example: 6600 ft altitude

$$1 - \frac{6,600 - 3,300}{33,000} = 0.9$$

$$80 \times 0.9 = 72$$

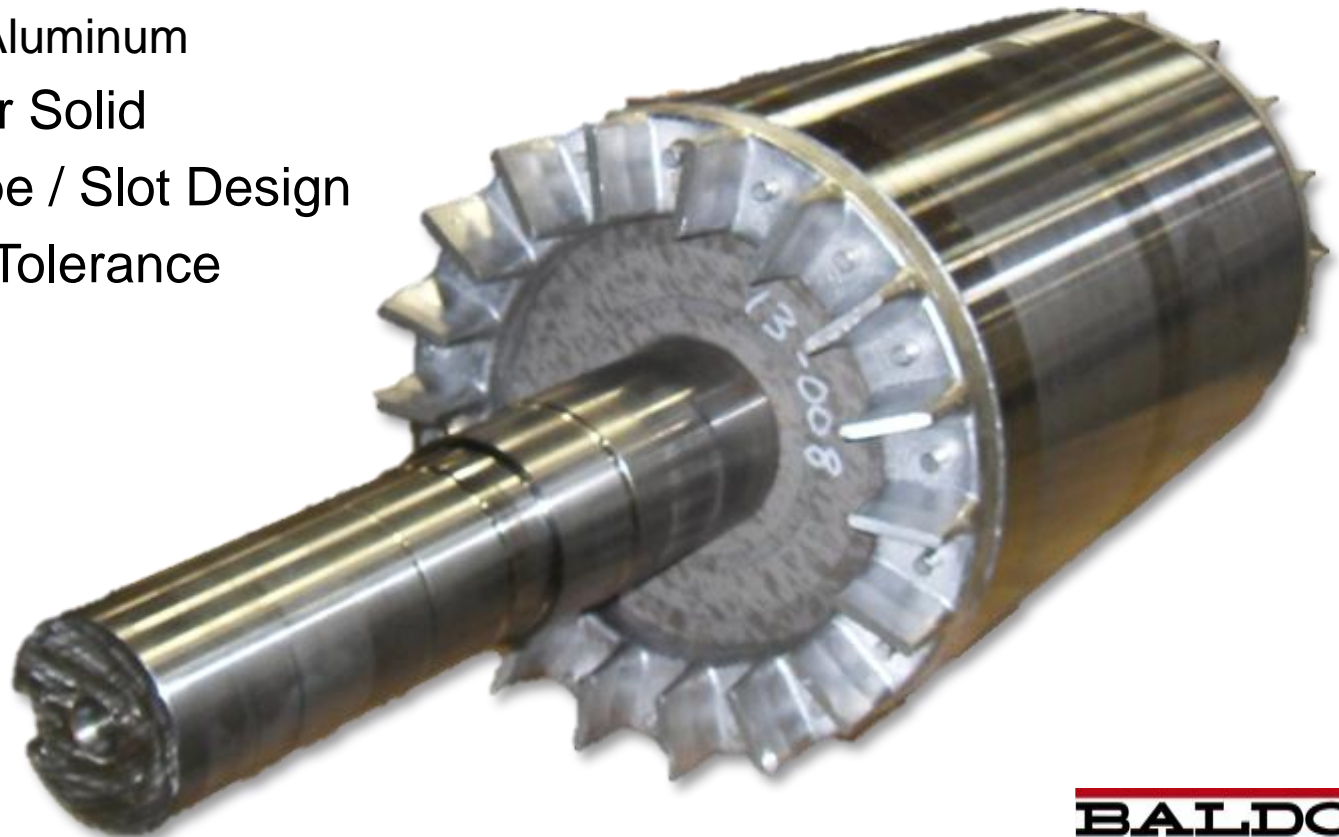
**Therefore, motor must be sized for 72°C Rise by Res
at full load for B Rise**

Rotors

Motor Rotor

■ Rotor Highlights and Considerations

- › Material
 - Copper Bar
 - Cast Aluminum
- › Ducted or Solid
- › Bar Shape / Slot Design
- › Balance Tolerance



Motor Rotor – Material Considerations

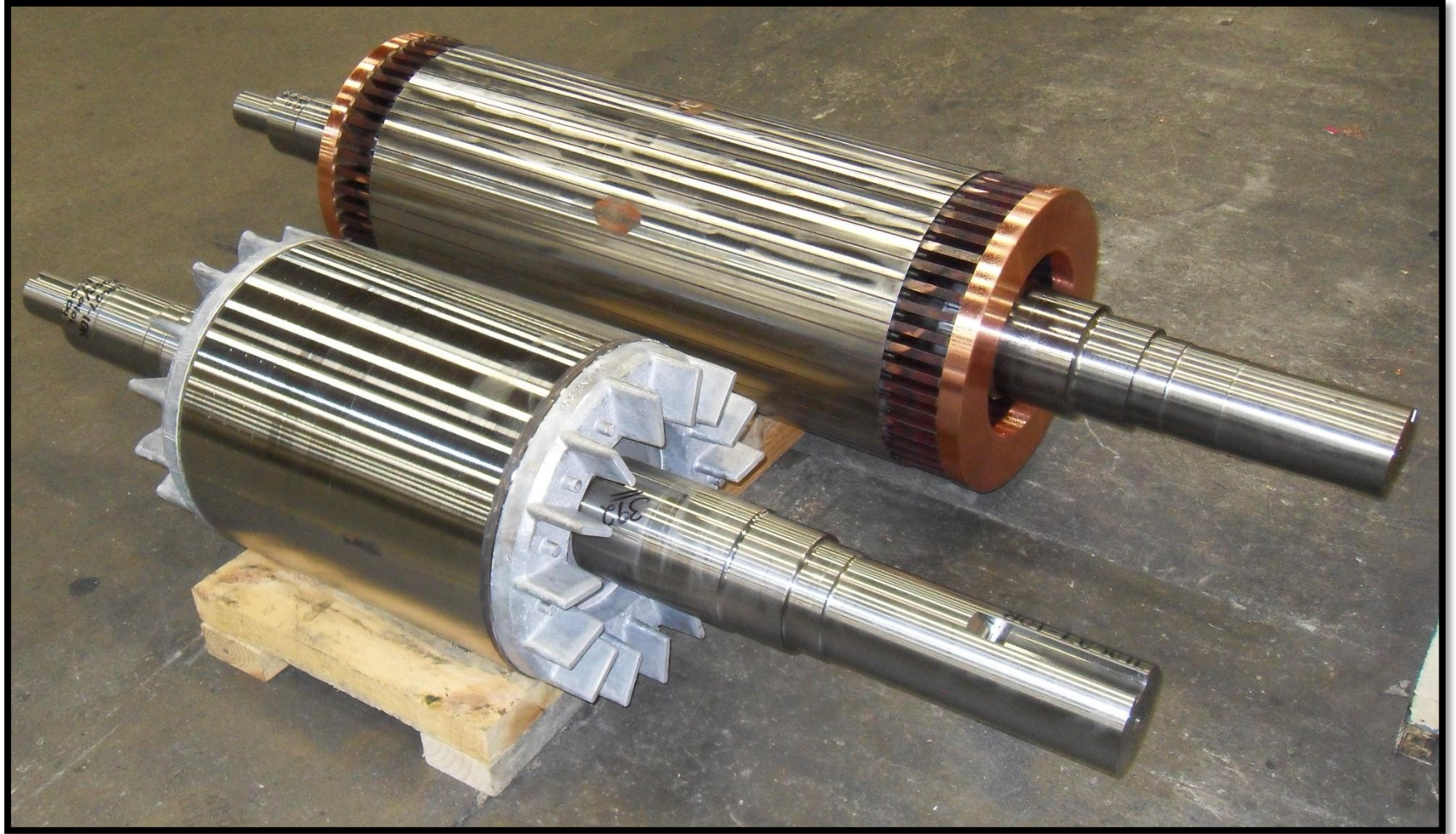
Cast Rotor

- Rotor bars are formed during casting. Therefore, they are in direct contact with laminations
- Less expensive
- Lighter weight
- Internal fans are part of the casting

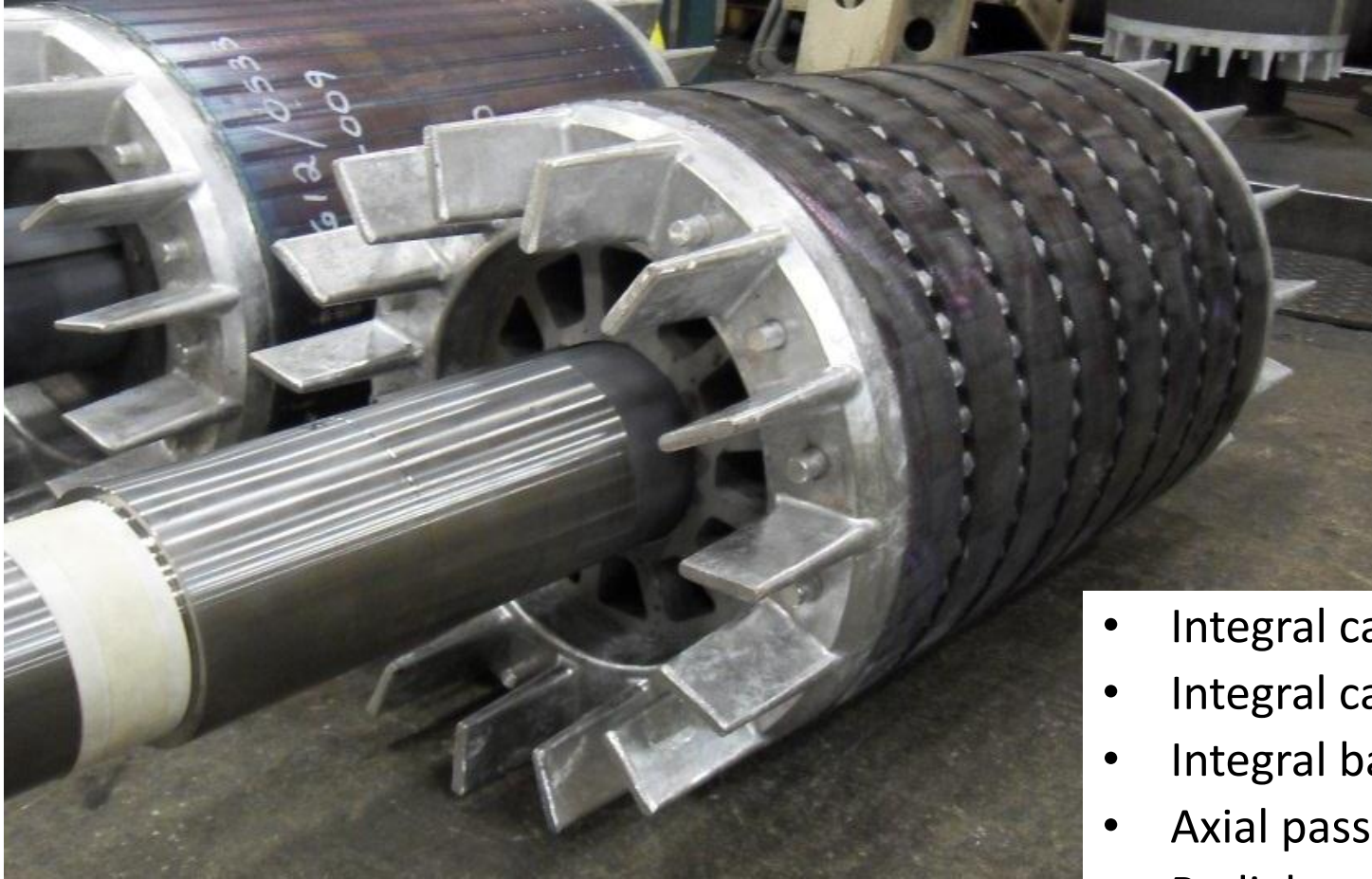
Bar Rotor

- Rugged Construction
- More Expensive
- Repairable
- Multiple Alloys = Different Speed/Torque Characteristics
- Better for high start applications

Motor Rotor – Solid Rotors

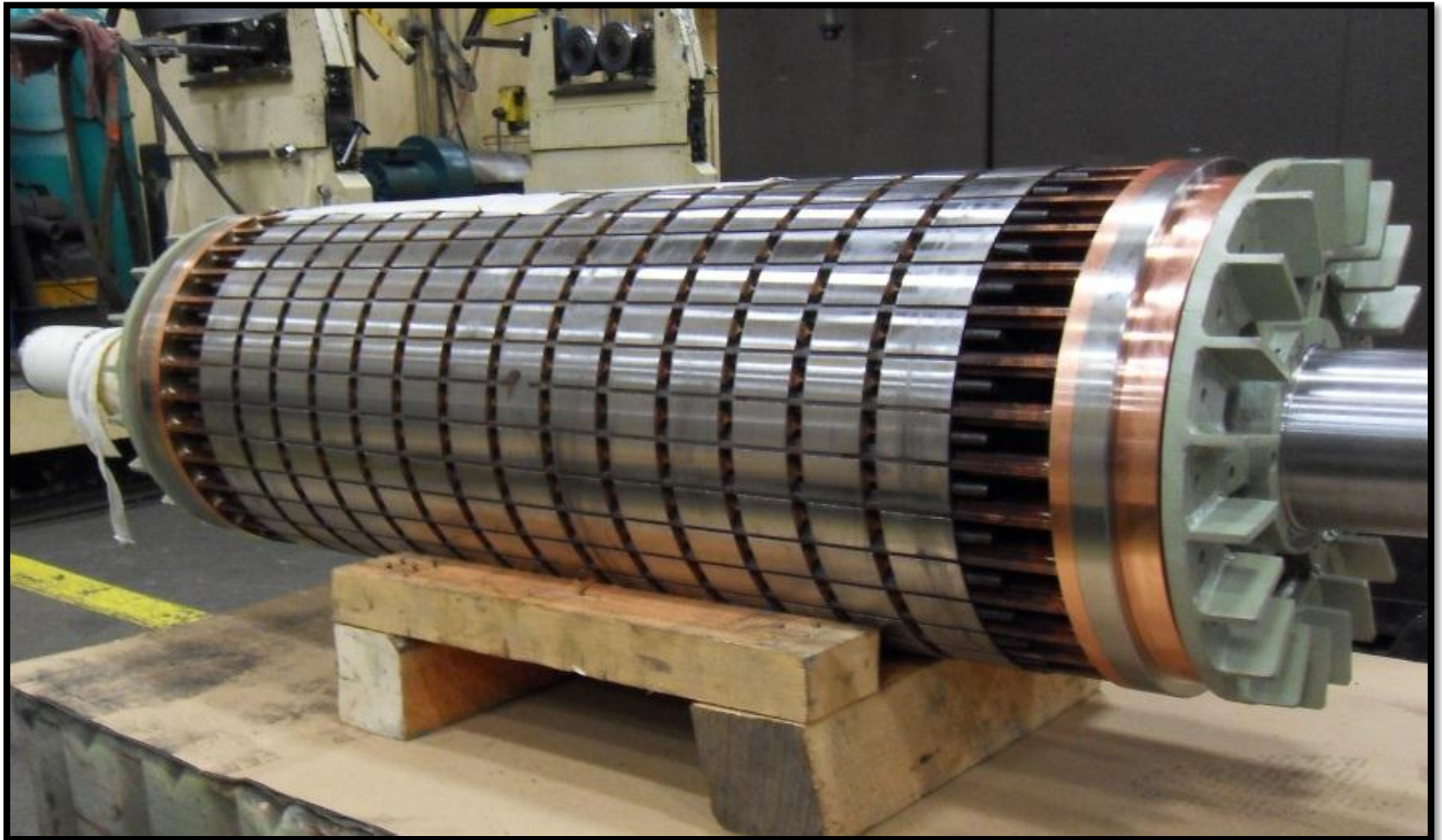


Motor Rotor – Cast Ducted Design



- Integral cast fans
- Integral cast end rings
- Integral balance sprues
- Axial passages thru rotor
- Radial paths thru rotor laminations

Motor Rotor – Bar Ducted Design



Cast Rotor Construction

Cast Rotor Construction

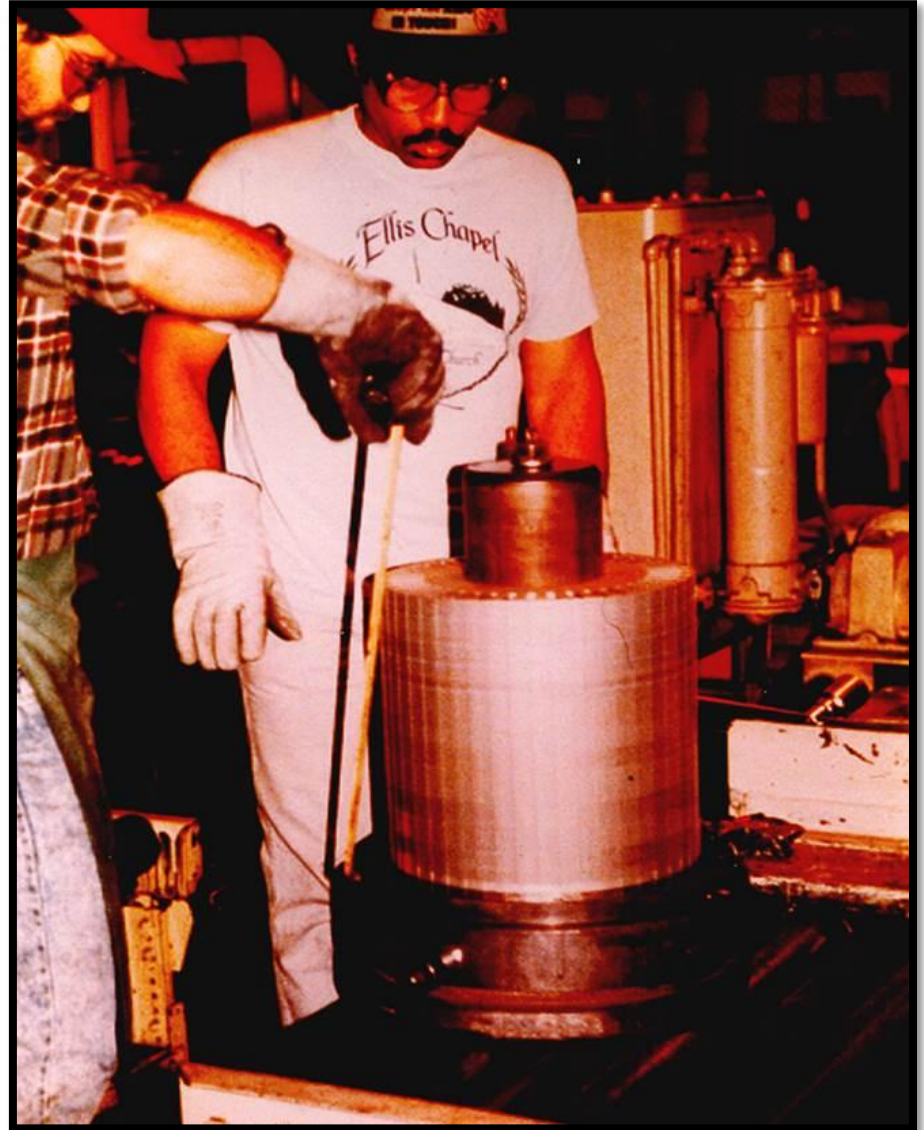


Rotor laminations and molds used to form the end rings and integrally cast fans are placed in a preheated oven.

Preheating helps ensure quality castings by reducing the stresses and voids that would occur due to temperature variations between the molten aluminum and the tooling.

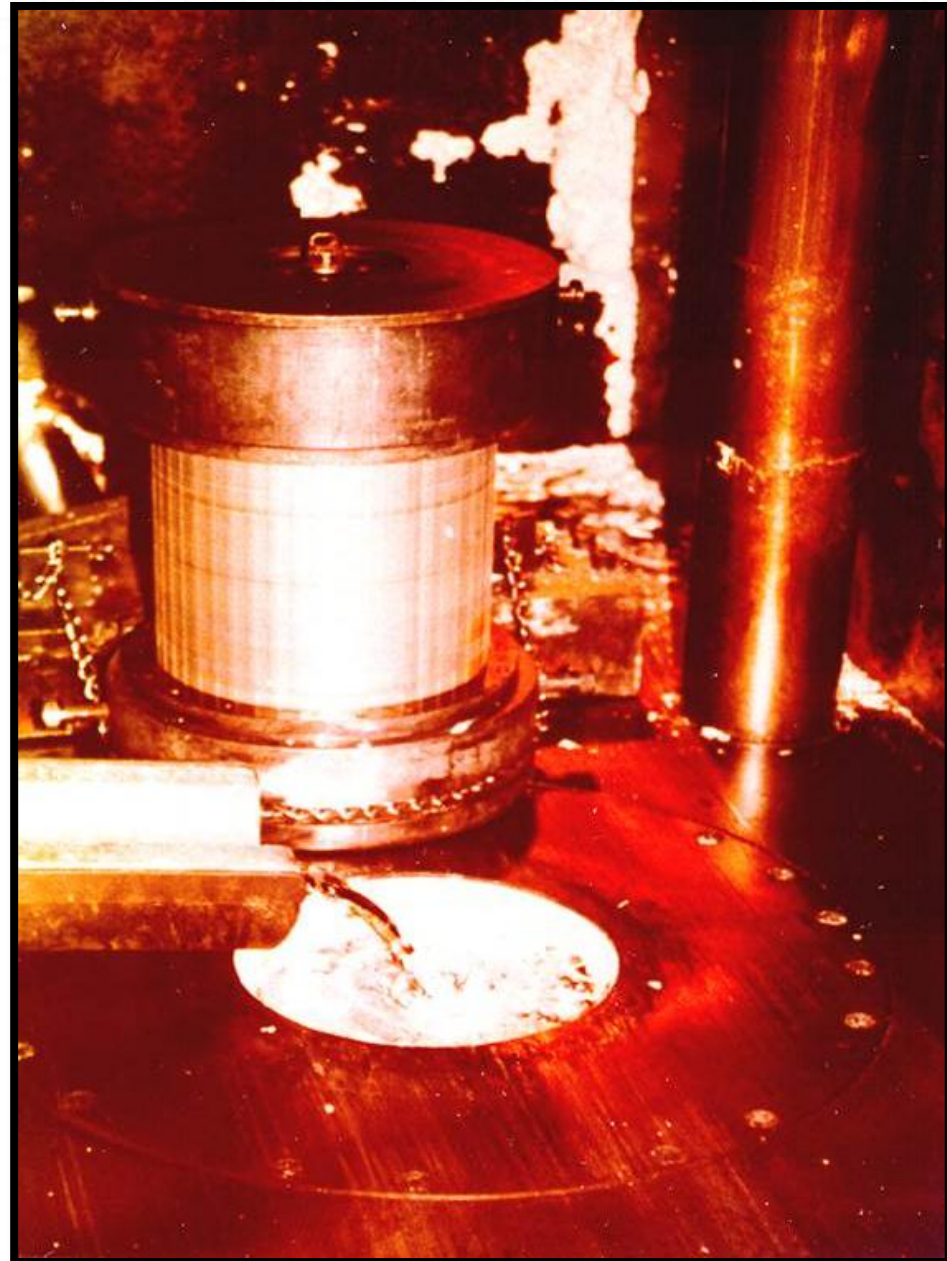
Cast Rotor Construction

- Laminations and molds are stacked on an arbor to form a tooling assembly
- Laminations are rotated during the punching operation to make sure that any thickness variations in the steel are evenly distributed along the length of the rotor.

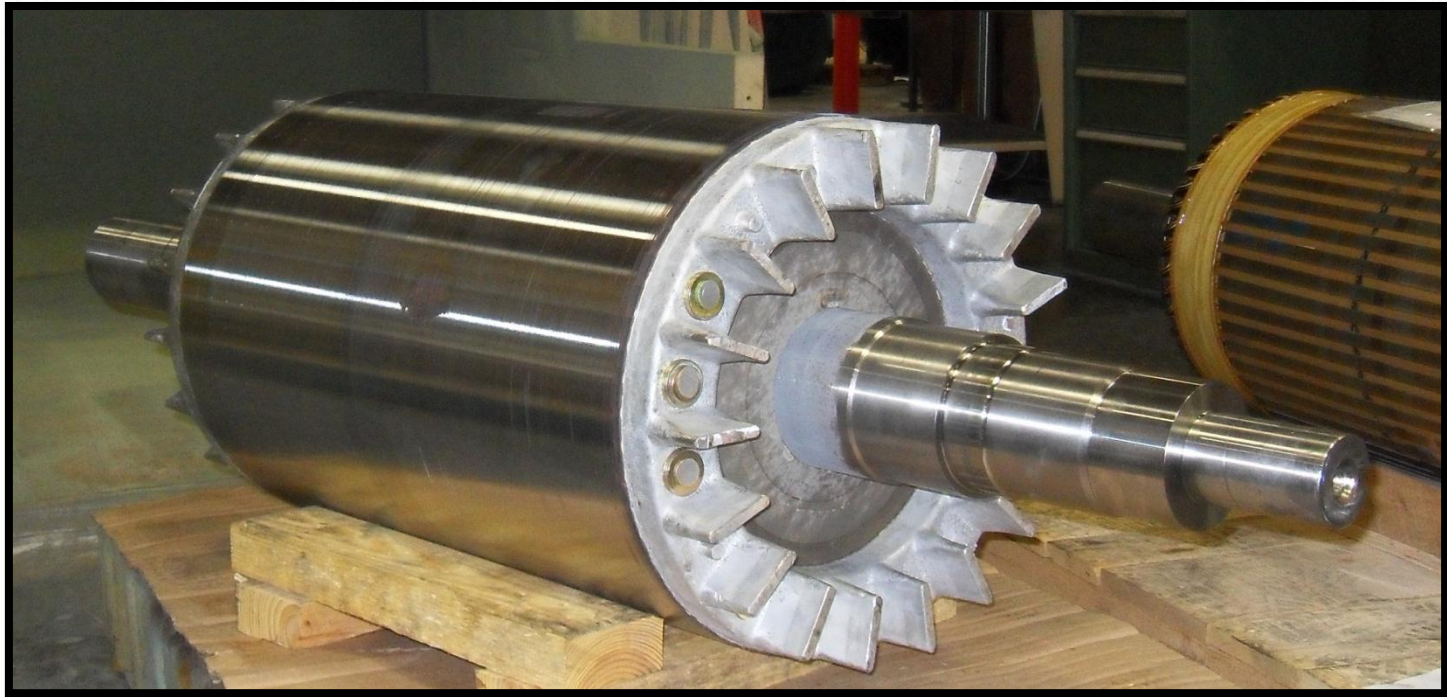


Cast Rotor Construction

- Molten aluminum at over 1200 ° F is poured into the shot well in the bottom of the casting machine.
- The tooling assembly is then placed over the well and pressed together.
- The casting machine door is closed and the aluminum is injected into the tooling assembly.
- Vent holes in the mold (near the top) allow for escape of gases.



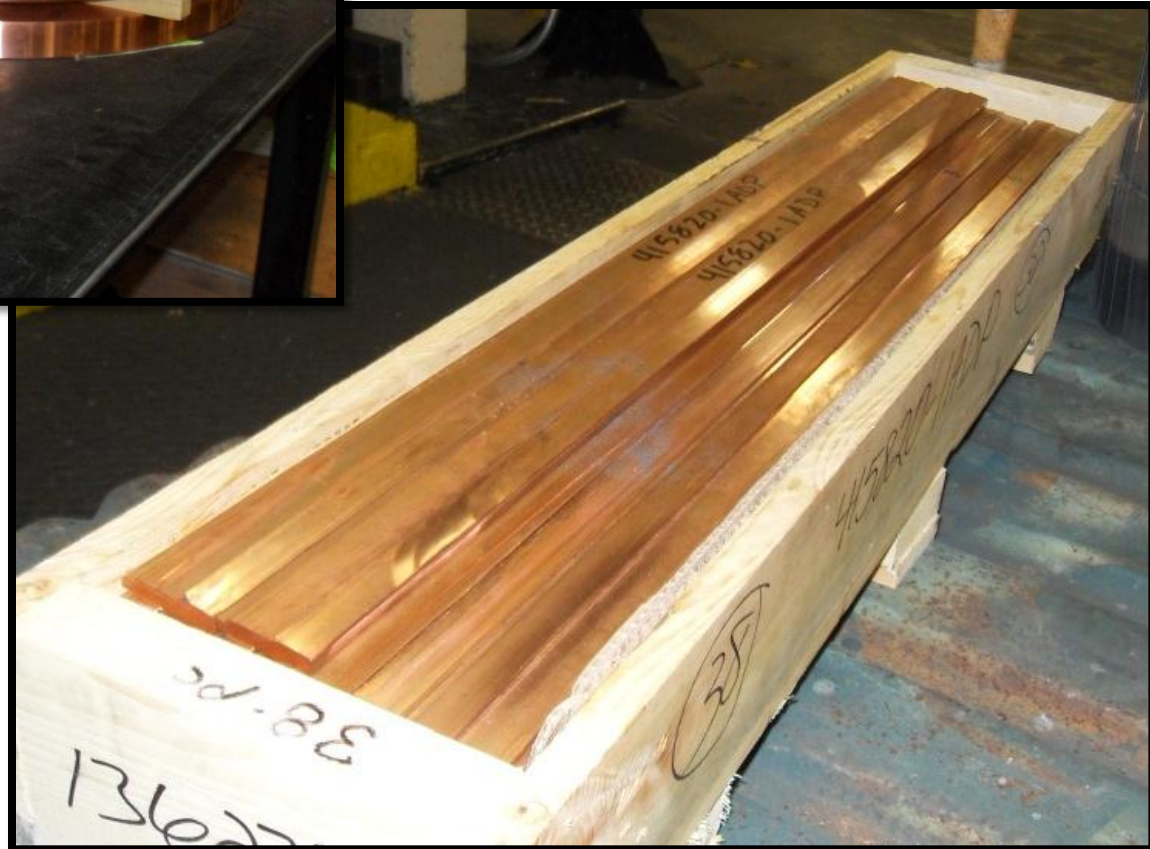
Cast Rotor Construction



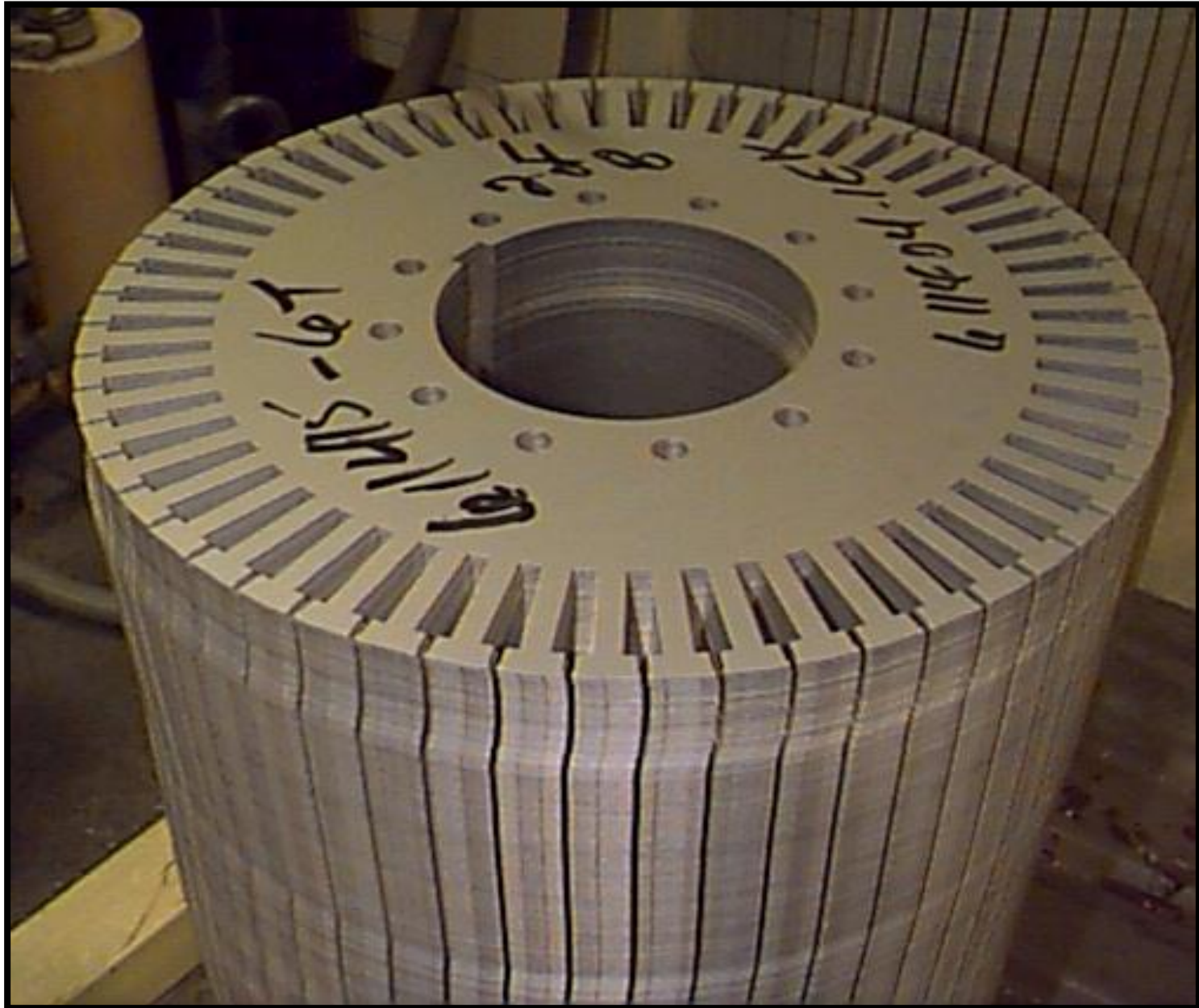
- The tooling assembly is removed from the casting machine and the lower and upper molds are removed.
- At this point the core is now held together by the bars and endrings which are cast into one continuous piece.
- The extra aluminum or flashing is then removed from the rotor by using a file or hand grinder.

Copper Bar Rotor Construction

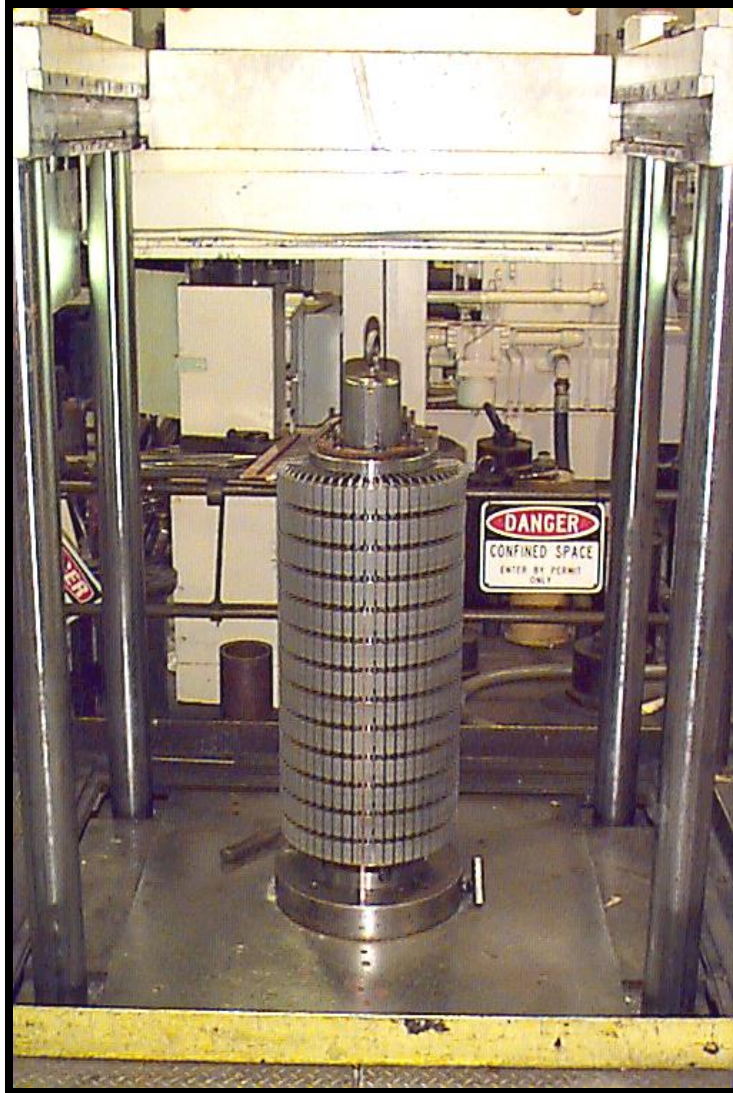
Copper Bar Rotor Construction



Copper Bar Rotor Construction



Copper Bar Rotor Construction



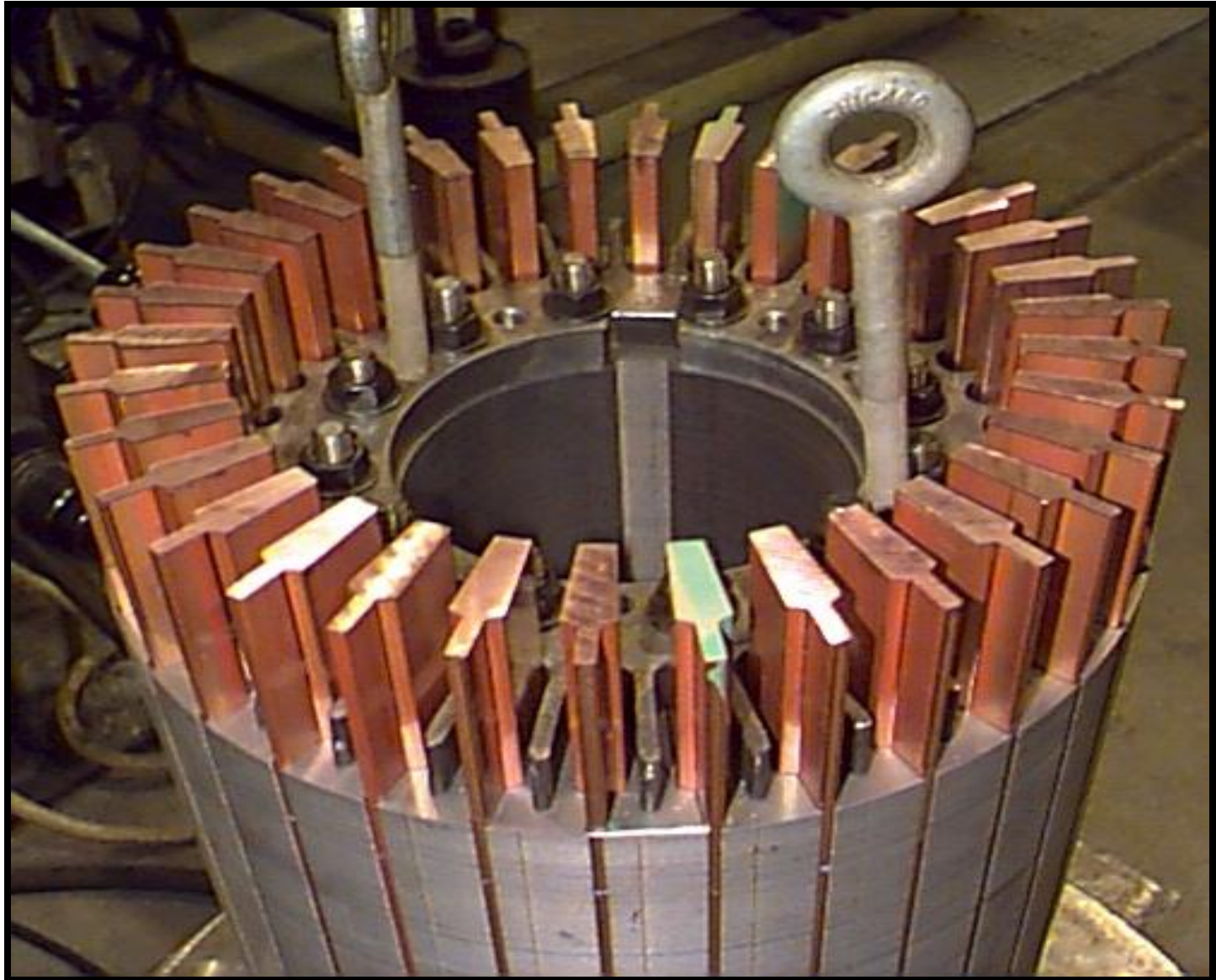
LDOR

A MEMBER OF THE ABB GROUP

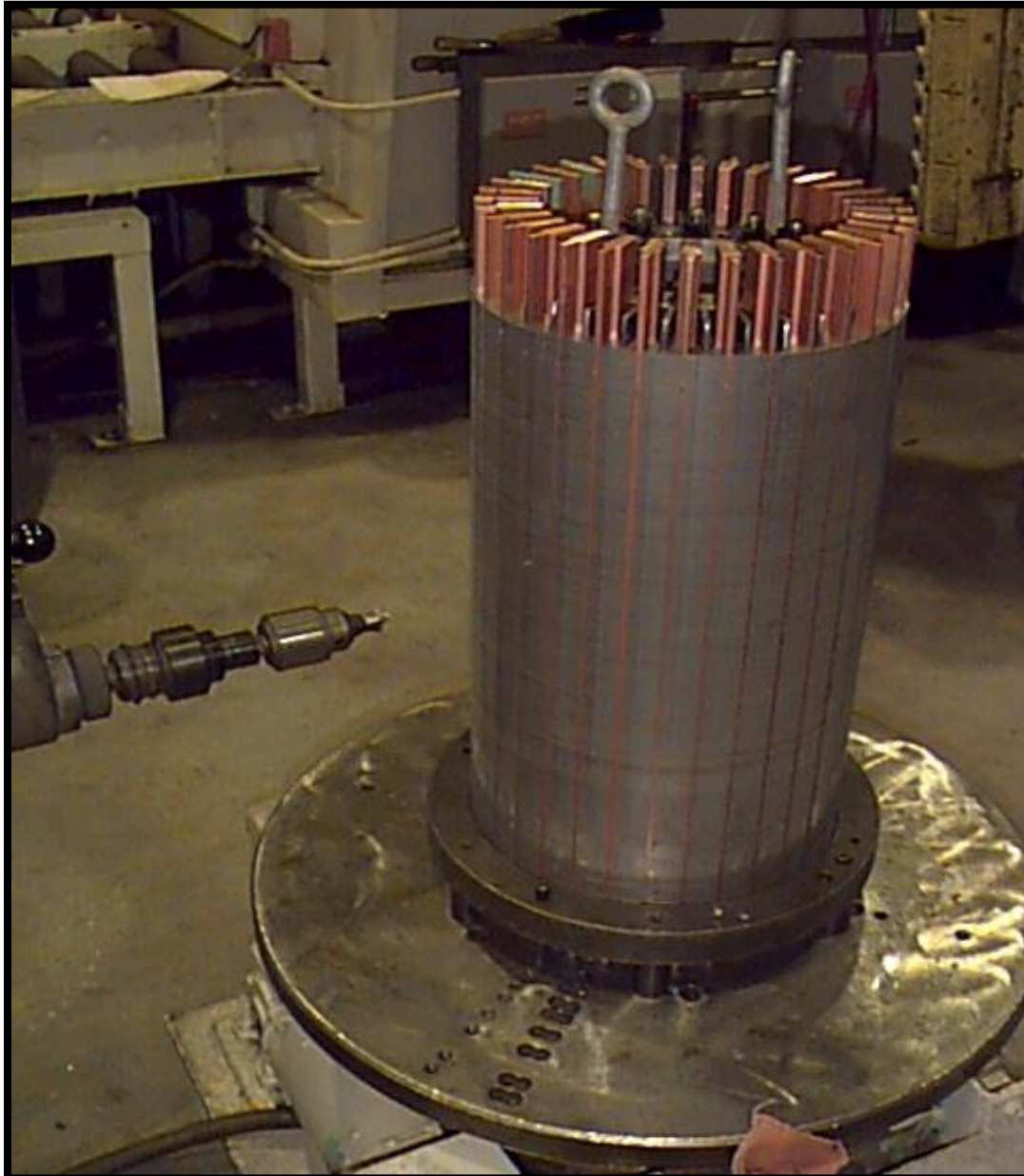
Copper Bar Rotor Construction



Copper Bar Rotor Construction



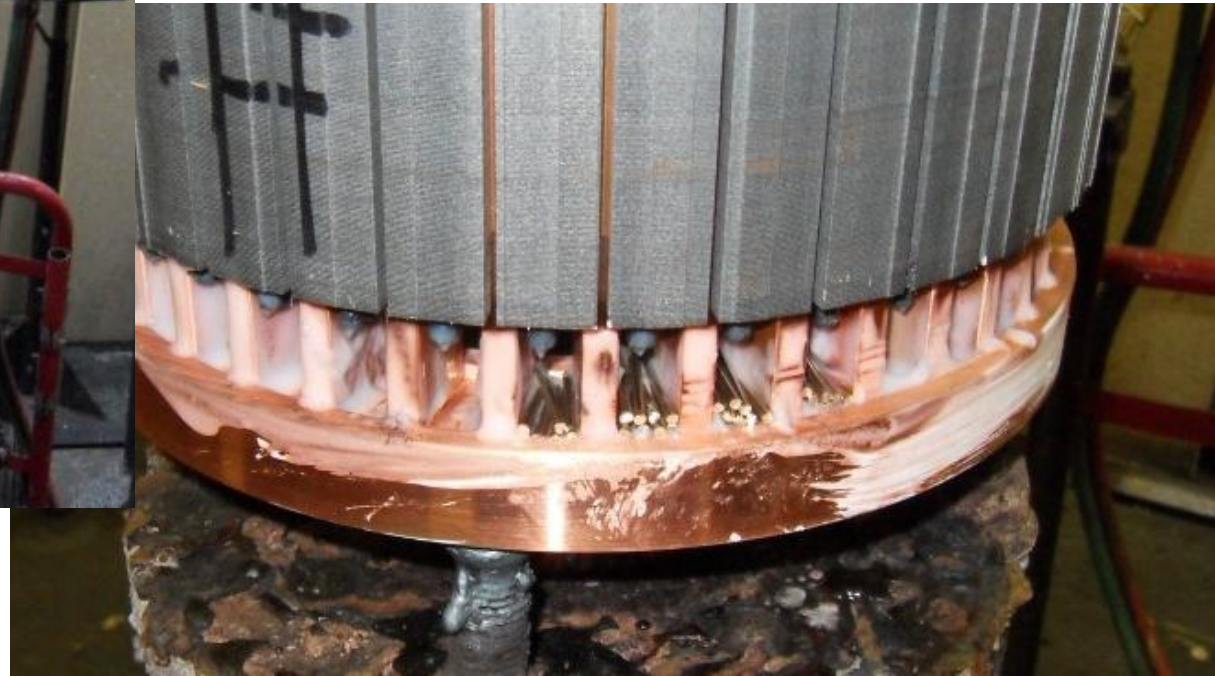
Copper Bar Rotor Construction



Copper Bar Rotor Construction



- Silver Solder and Flux installed between bars.
- A machine cuts each piece of solder to the same length from a spool of material.
- The same number of solder pieces are placed between each bar.

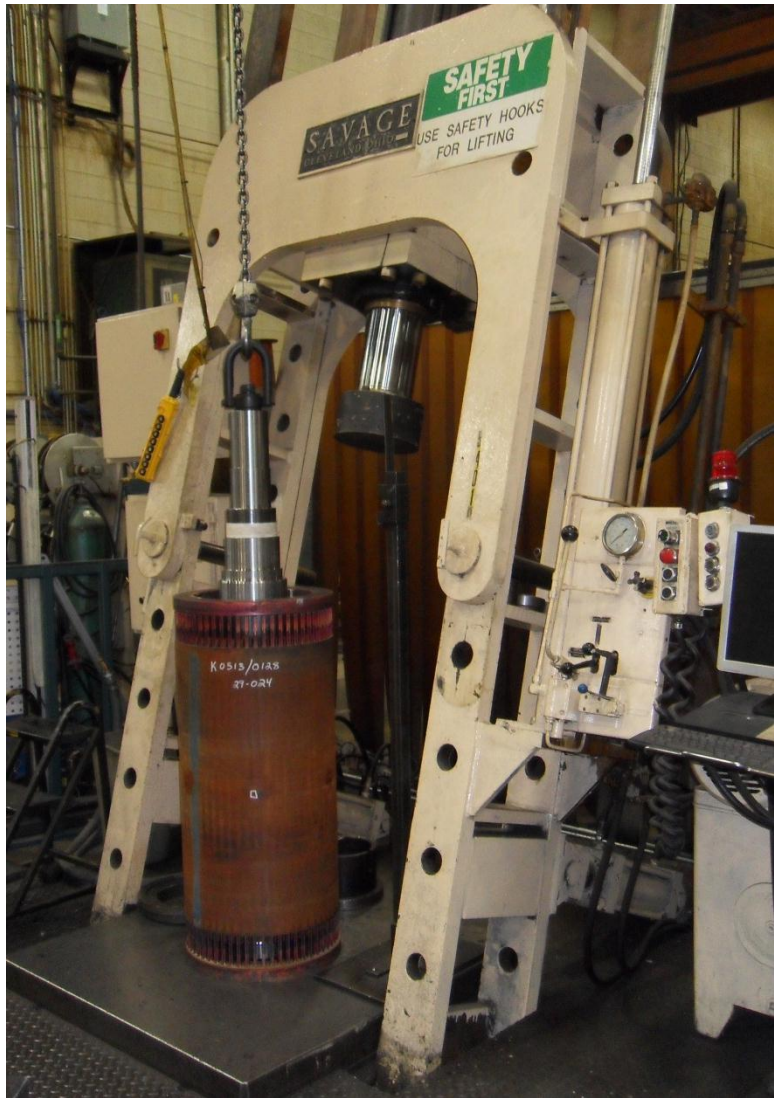


Copper Bar Rotor Construction

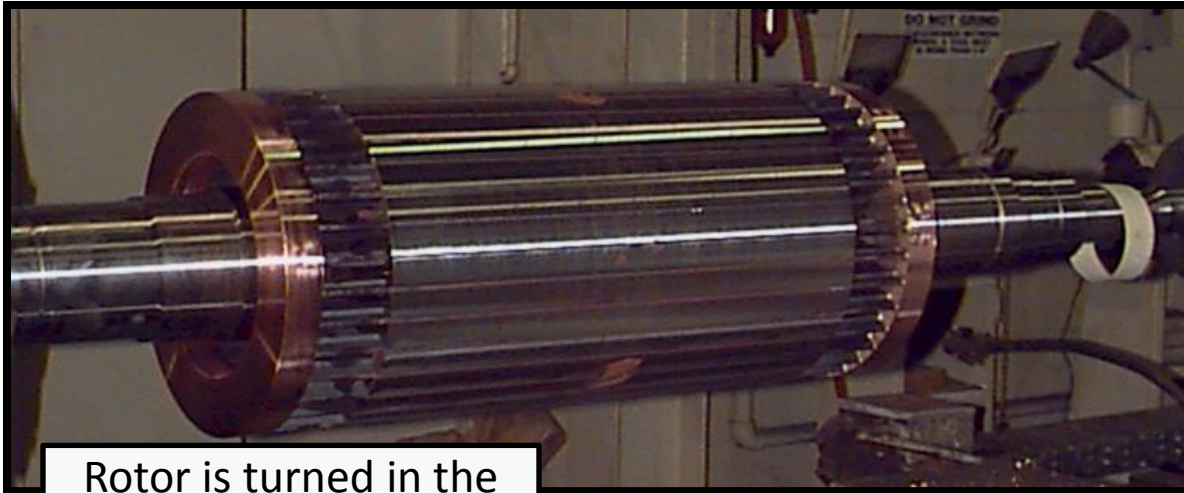


Rotor/Shaft Construction

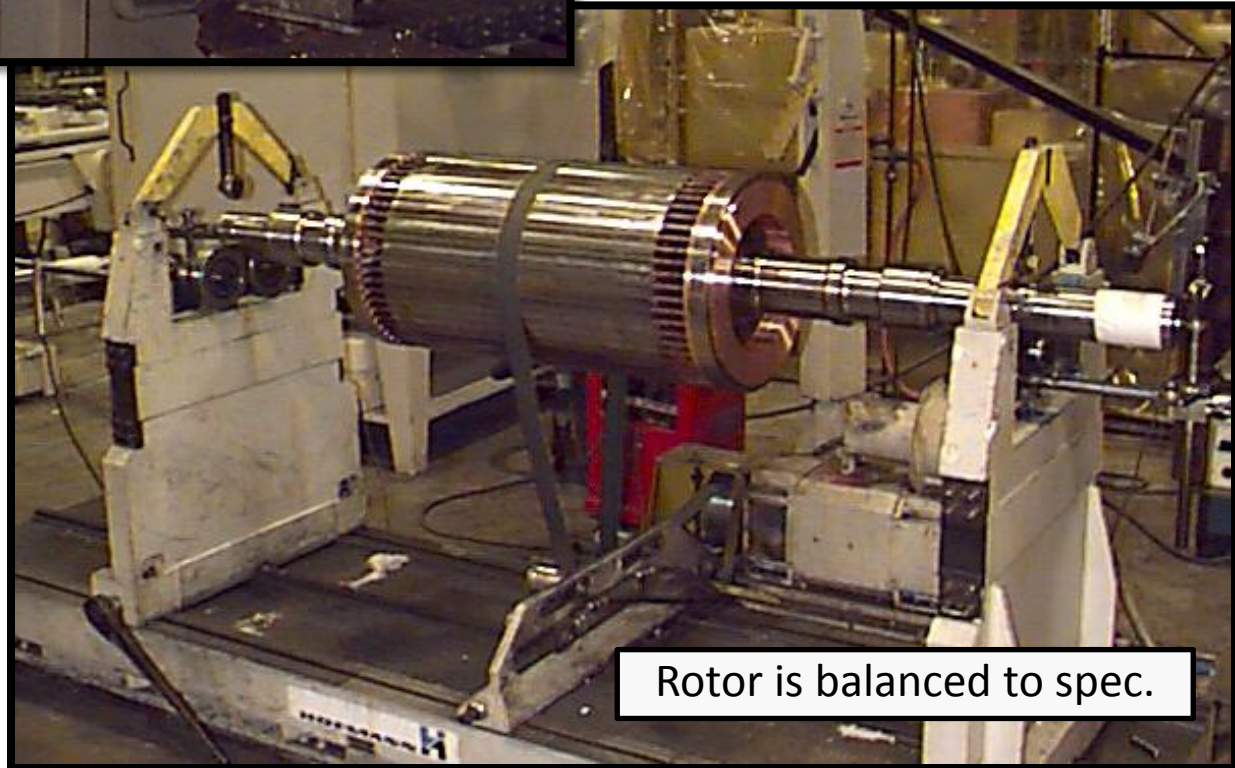
Rotor/Shaft Construction



Rotor/Shaft Construction

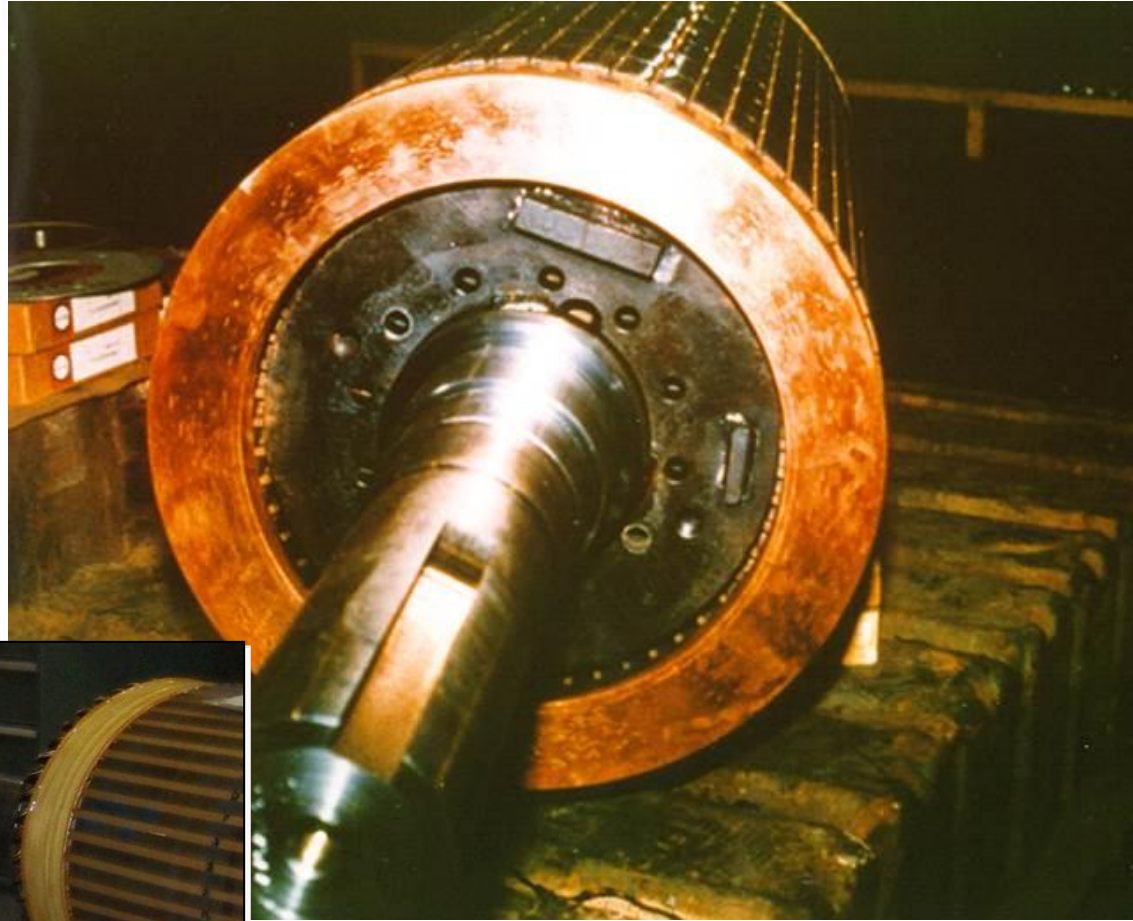


Rotor is turned in the lathe to size.

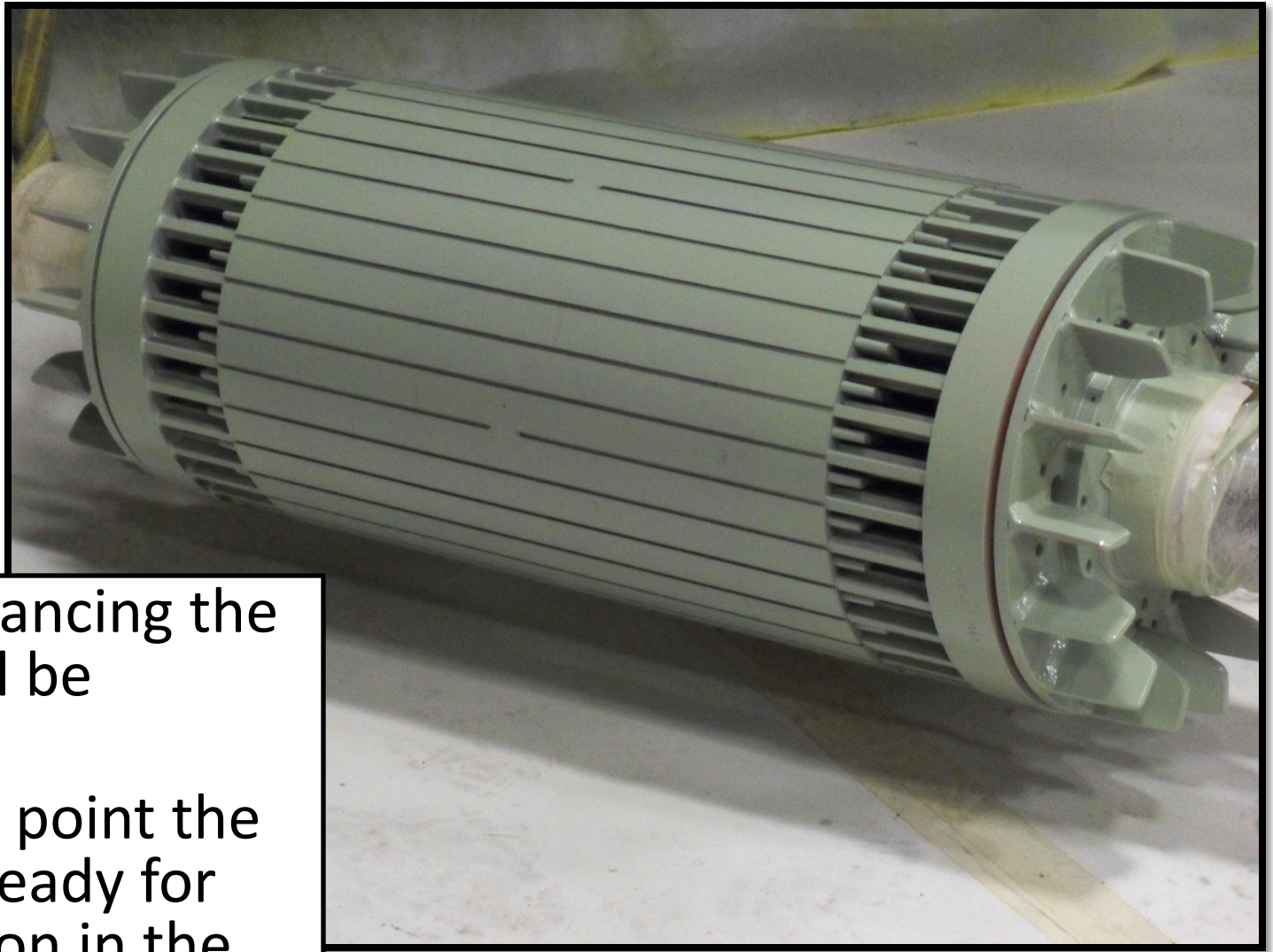


Rotor is balanced to spec.

Rotor/Shaft Balance Weight



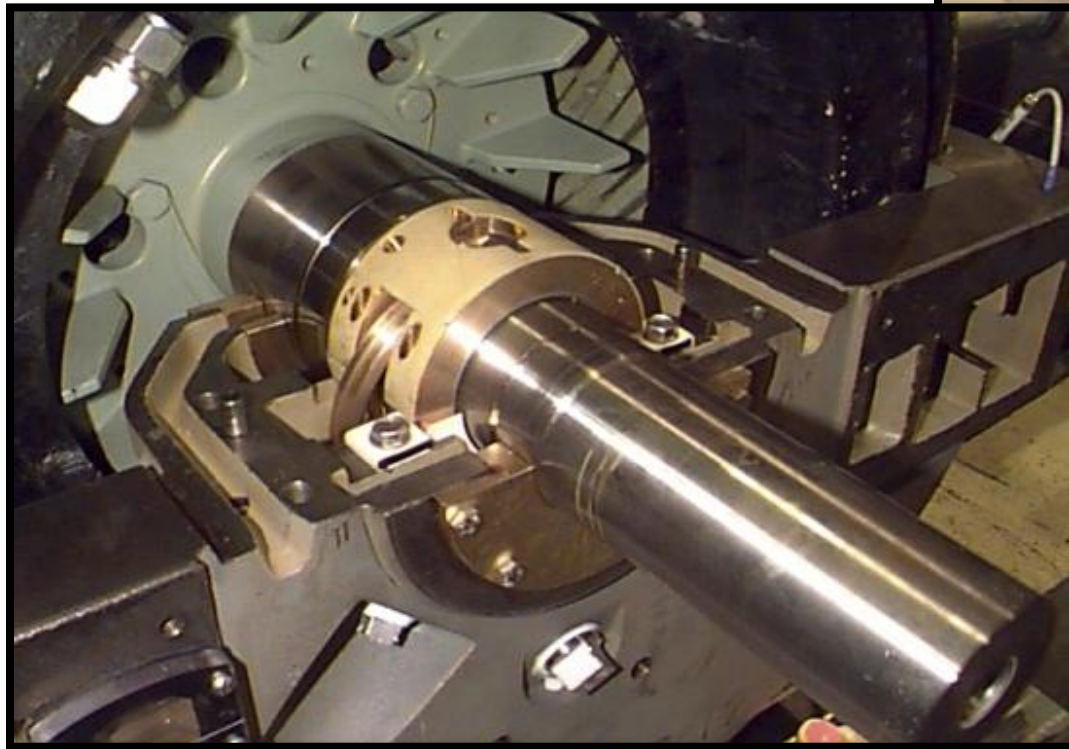
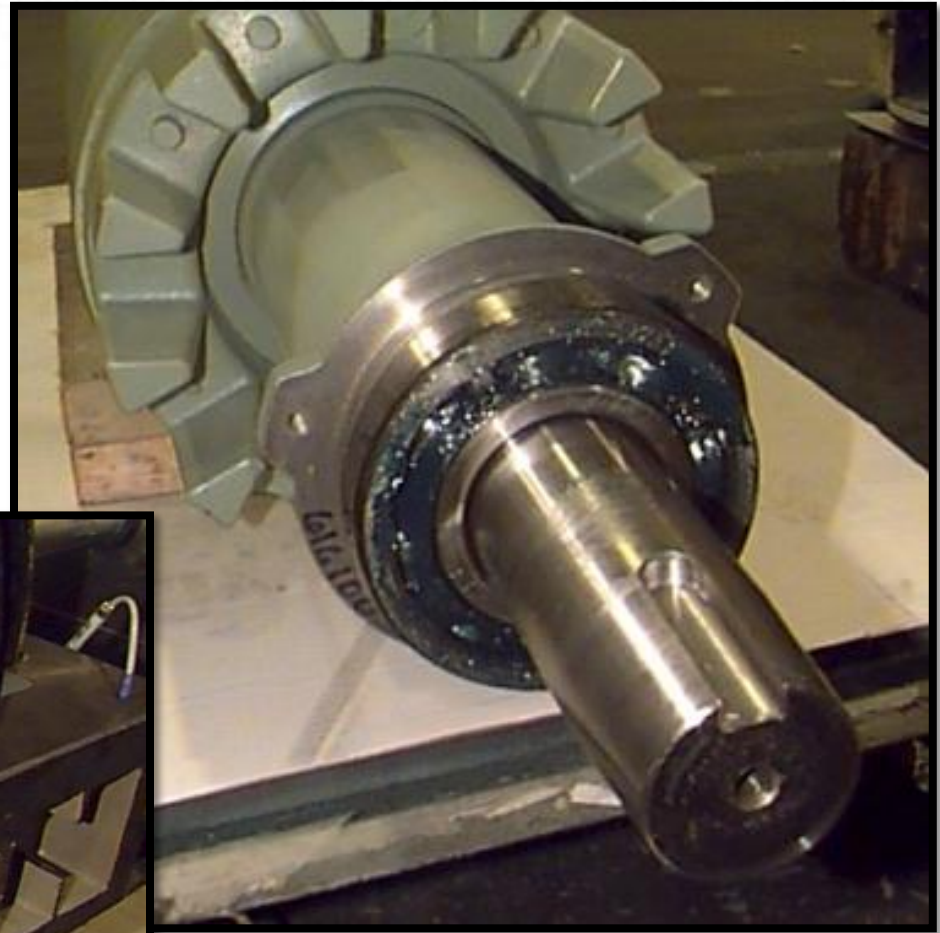
Rotor/Shaft Construction



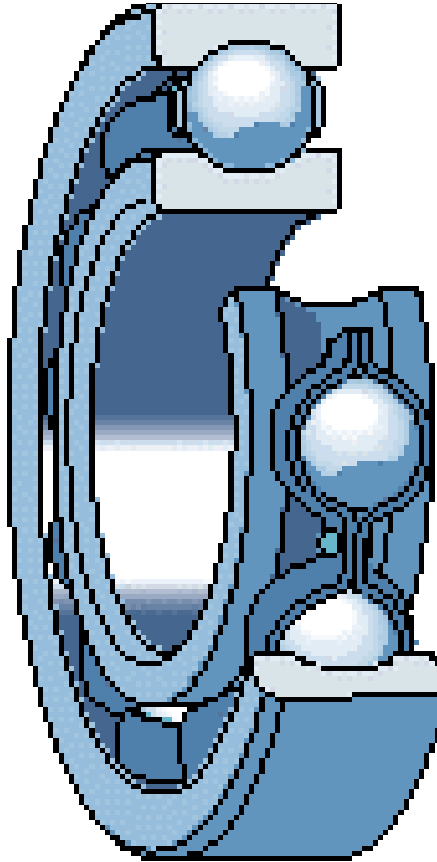
- After balancing the rotor will be painted.
- At which point the rotor is ready for installation in the motor.

Motor Bearings

Motor Bearings



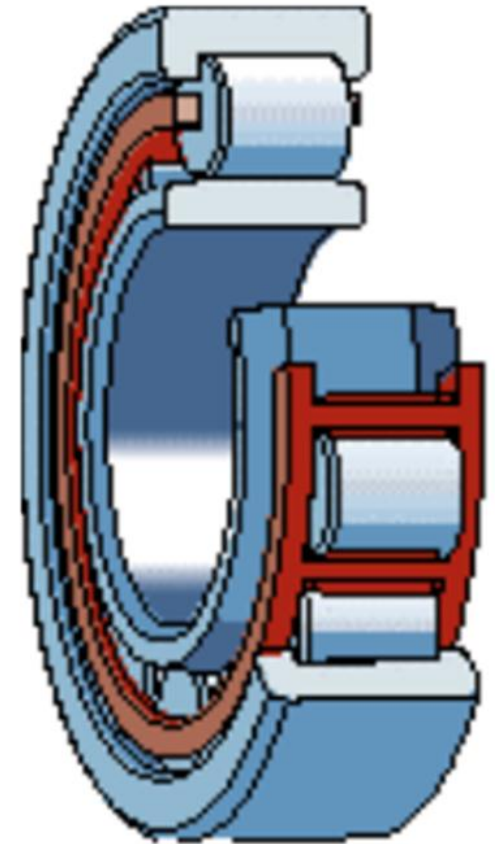
Anti-friction Bearings



Deep Groove
Ball



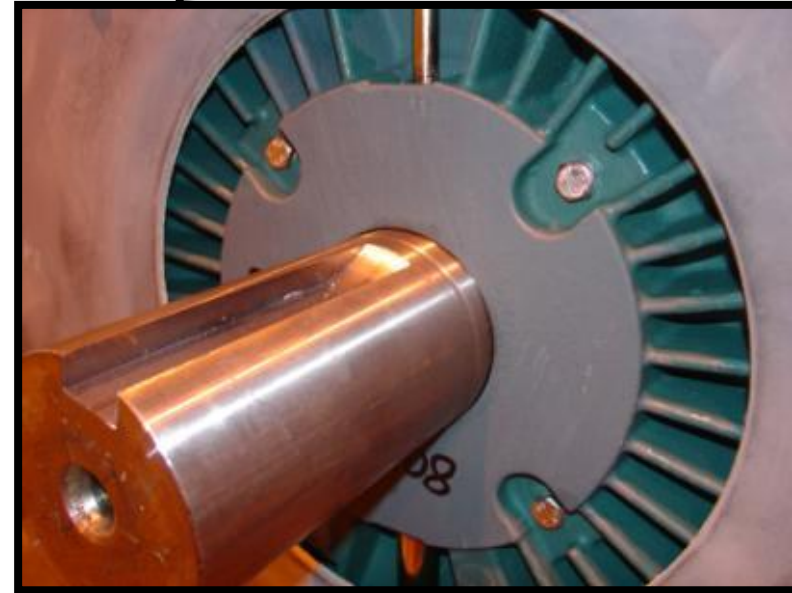
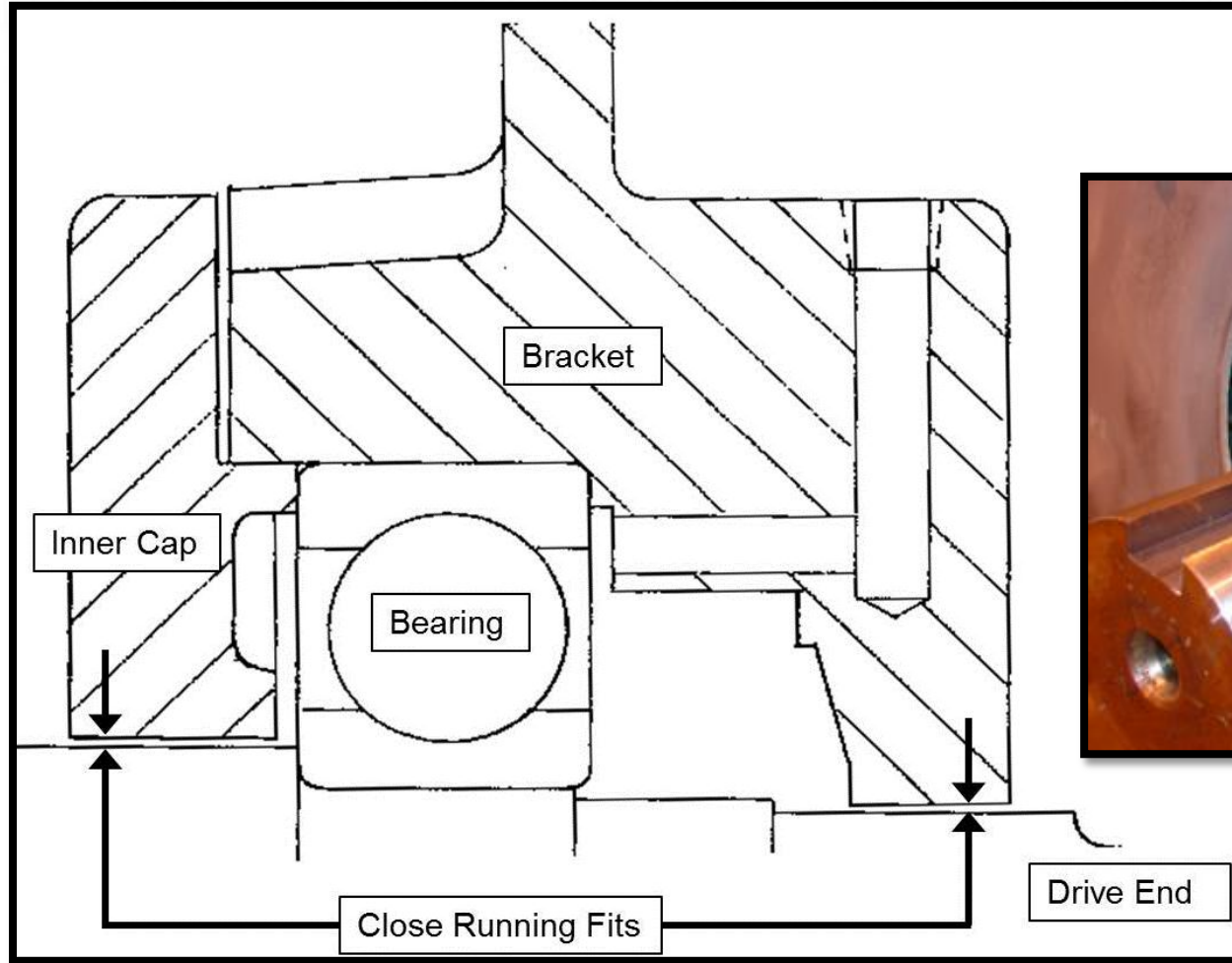
Angular Contact



Cylindrical
Roller

A/F Bearing Seals & Protection

A/F Bearing Seals & Protection



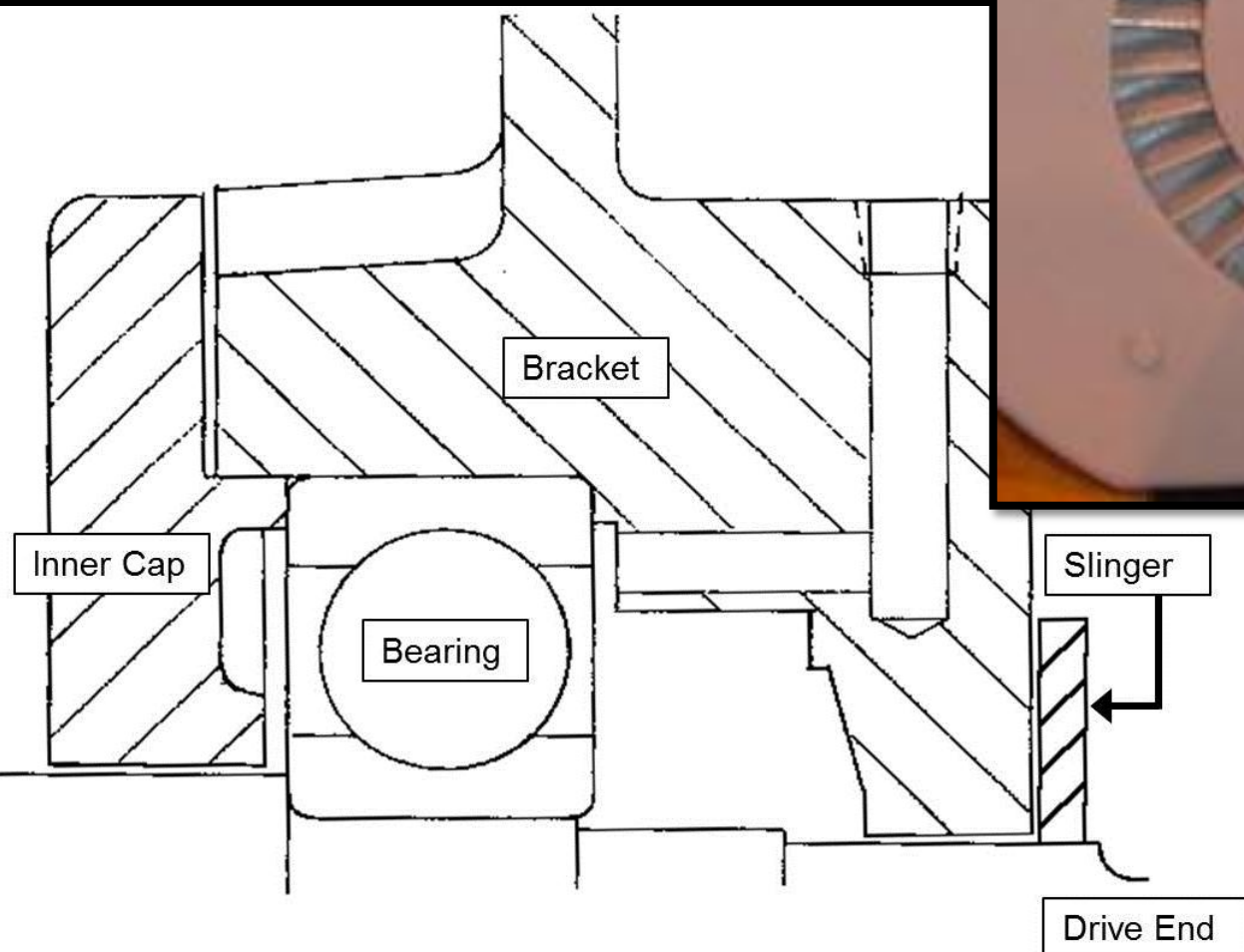
Close Running Fit

- Most basic of seal types.
- Controlled gap between shaft and end bell/inner cap.

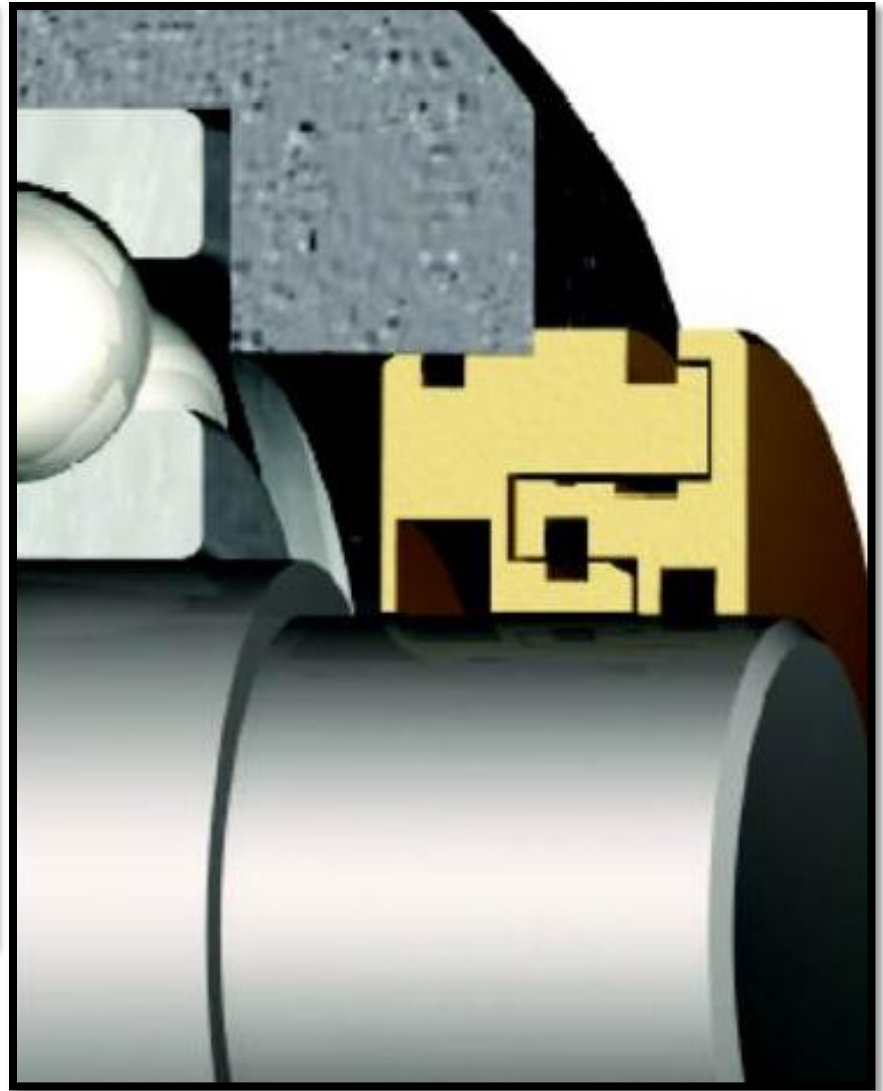
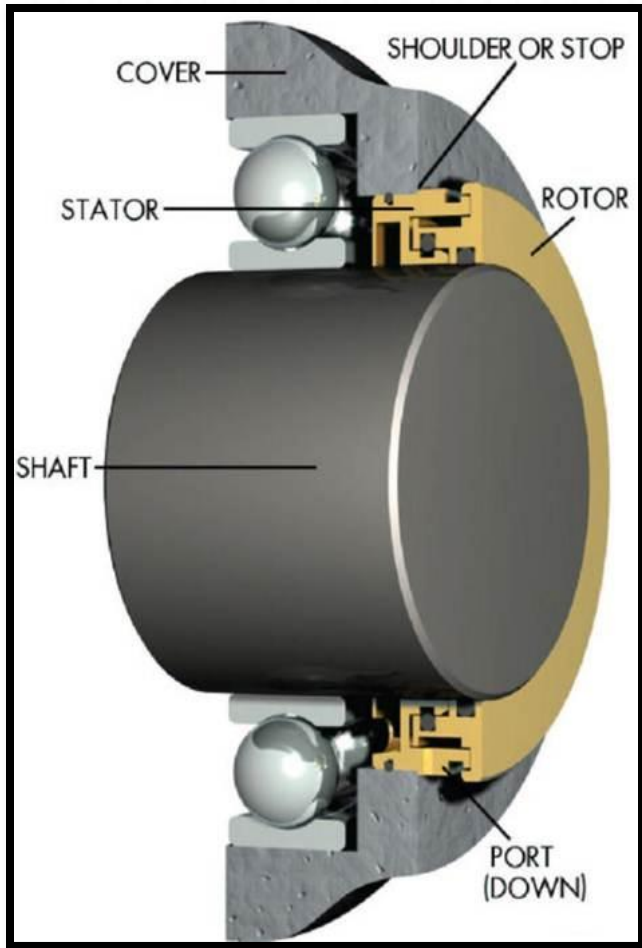
A/F Bearing Seals & Protection

Close Running Fit and Slinger

- External slingers provide an extra level of protection.
- Common material may be brass.



A/F Bearing Seals & Protection

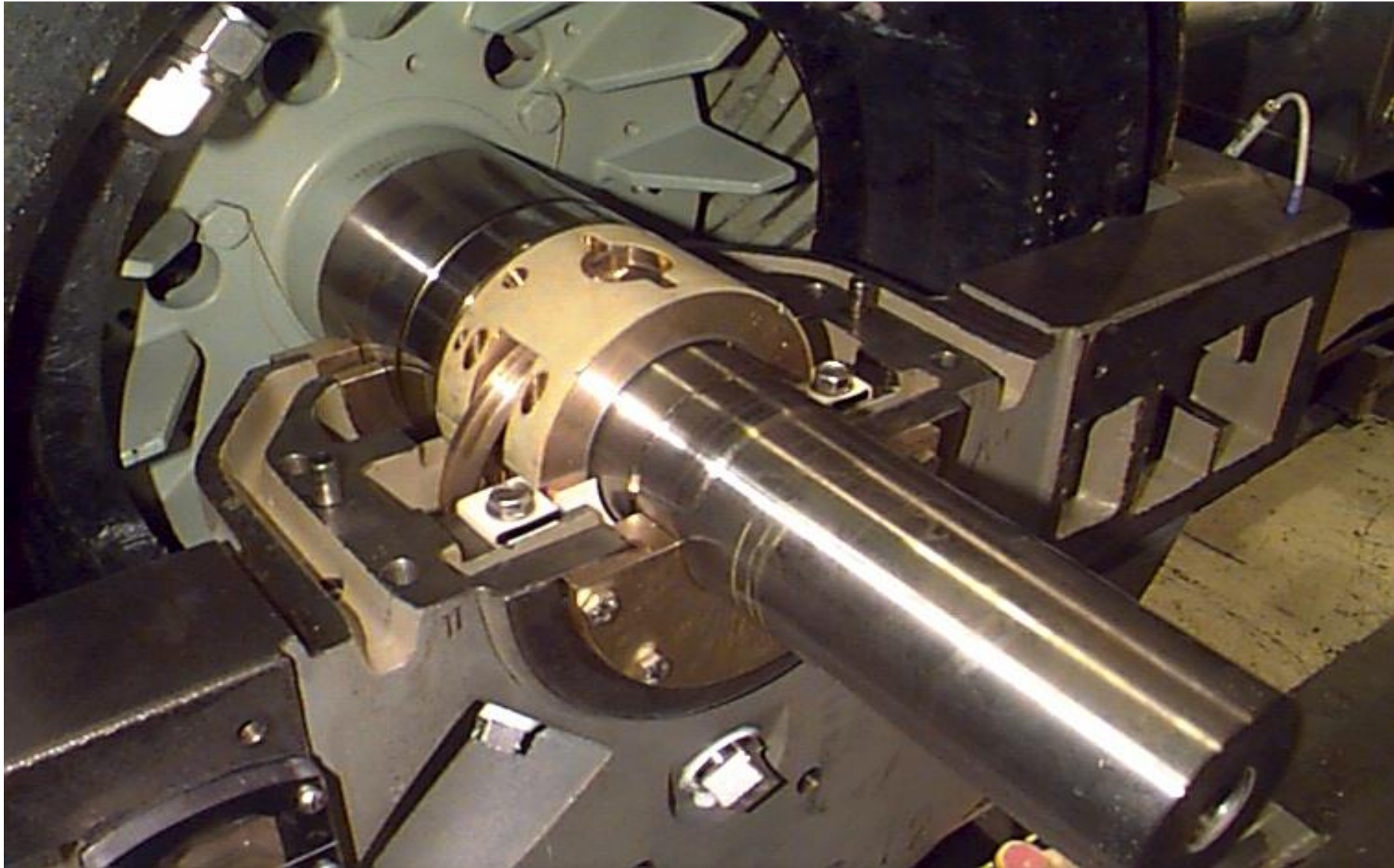


Bearing Isolator (Labyrinth Seal)

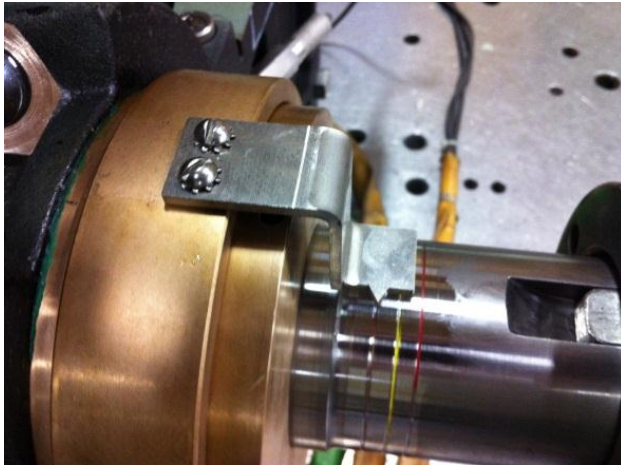
- Two piece design.
- Multiple labyrinths and O-ring protection.
- Bracket must be machined to accommodate isolator.

Sleeve Bearings

Sleeve Bearings



Sleeve Bearings

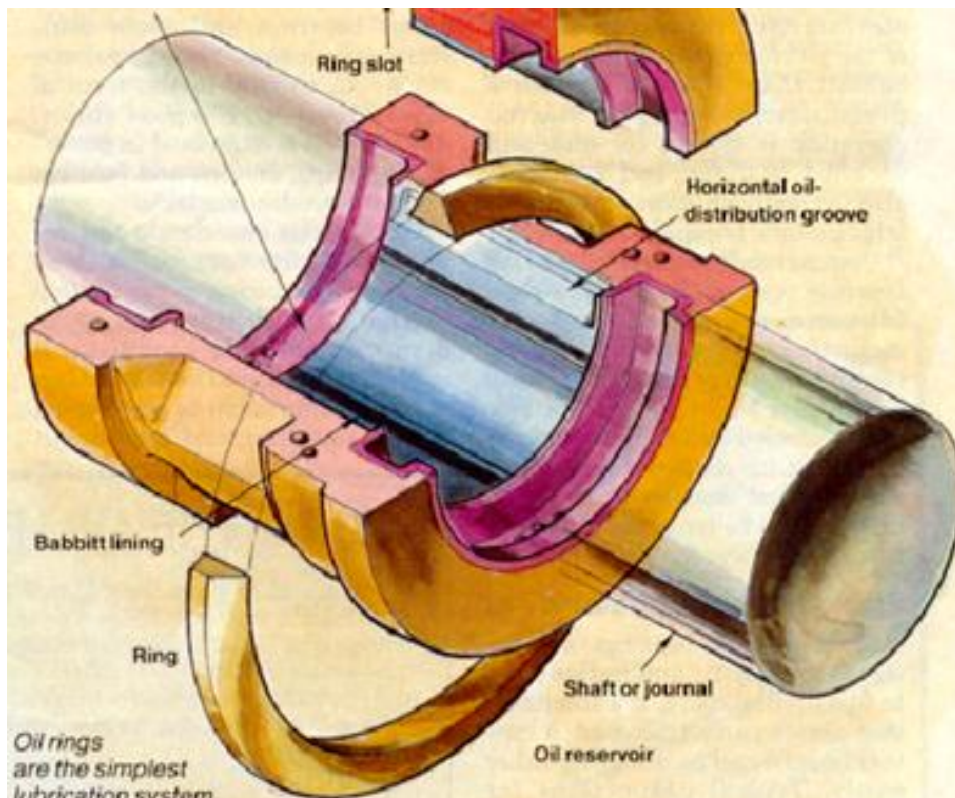


Journal Bearings

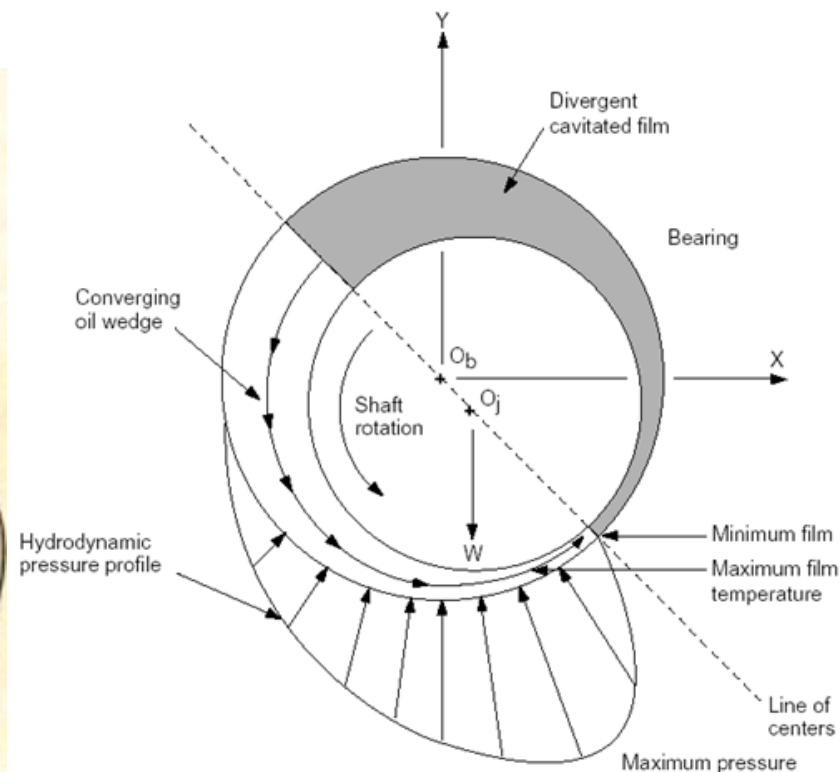
- **Cylinder Seat**
- **Horizontally Split**
- **Bronze Alloy Shell**
- **Tin Based Babbitt**
- **Theoretical Infinite Life**
- **Coupled duty only**
- **No axial load**

Sleeve Bearing Lubrication

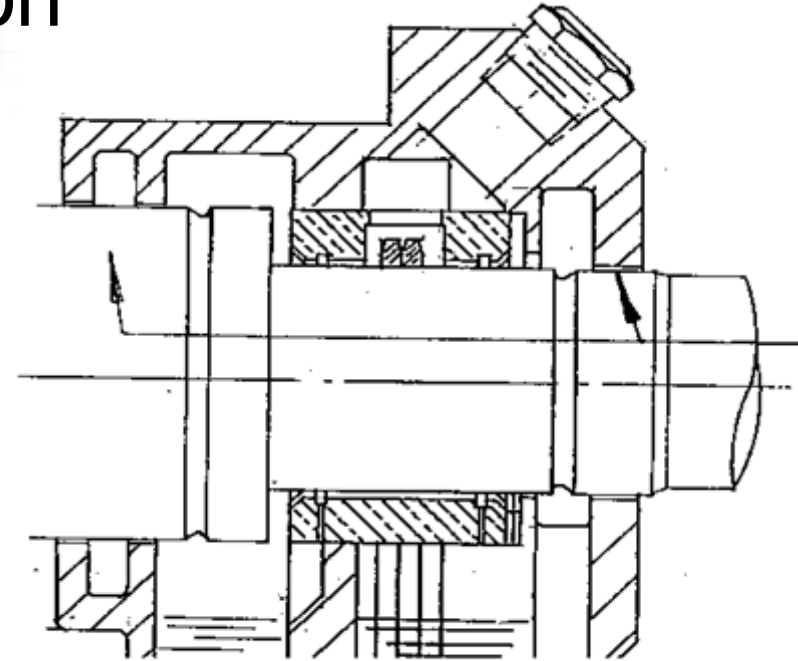
- Oil Lubricated: Light Turbine Oil, 150 SSU
- Self Lubricating: Oil Ring Feed Oil Film
- Hydrodynamic Fluid Film Lubrication: Shaft rotation builds an oil wedge to float the shaft, riding on an oil film- No metal to metal contact



Oil rings are the simplest lubrication system. The ring rides on a shaft with one portion immersed in the oil sump. When the shaft turns, the ring turns, bringing oil to the bearing. The rings can be used as a primary lubrication device or as a backup.



Sleeve Bearing Lubrication



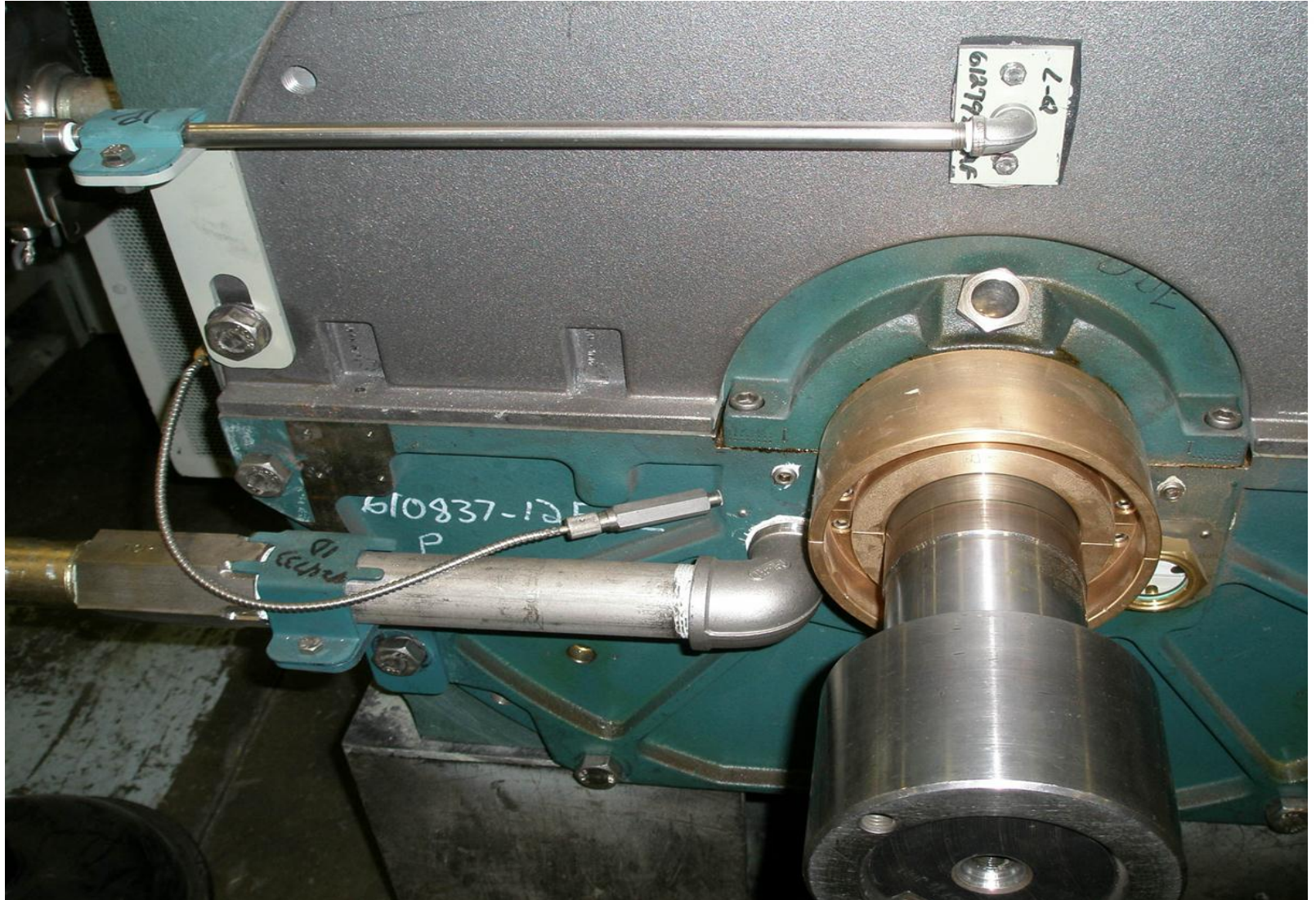
- **Standard Self Contained**
- **Constant Level Oilers**
 - › Additional Safeguard to Replace Oil Consumed over Time.
- **Flood Lube, Wet Sump**
 - › Constant Flow of Oil into the Bearing in Addition to Sump and Oil Ring Lubrication.
 - › Continuously Clean, Cool Oil to Improve Life.

Sleeve Bearing Lubrication

Constant Level Oilers



Sleeve Bearing Flood Lube

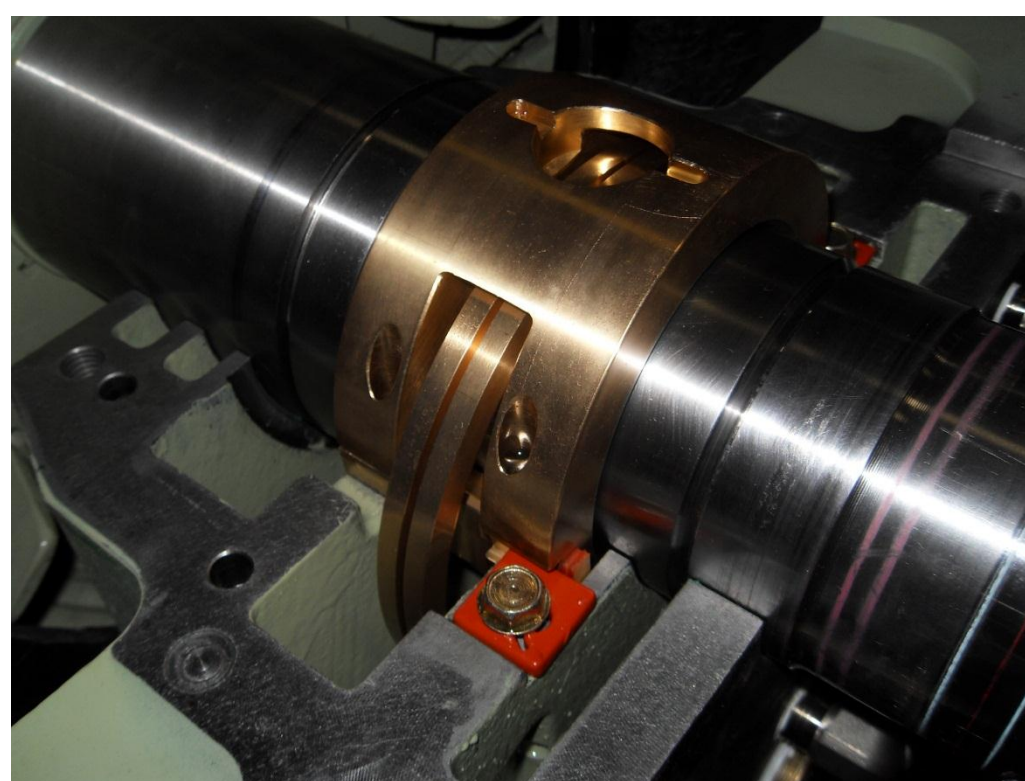
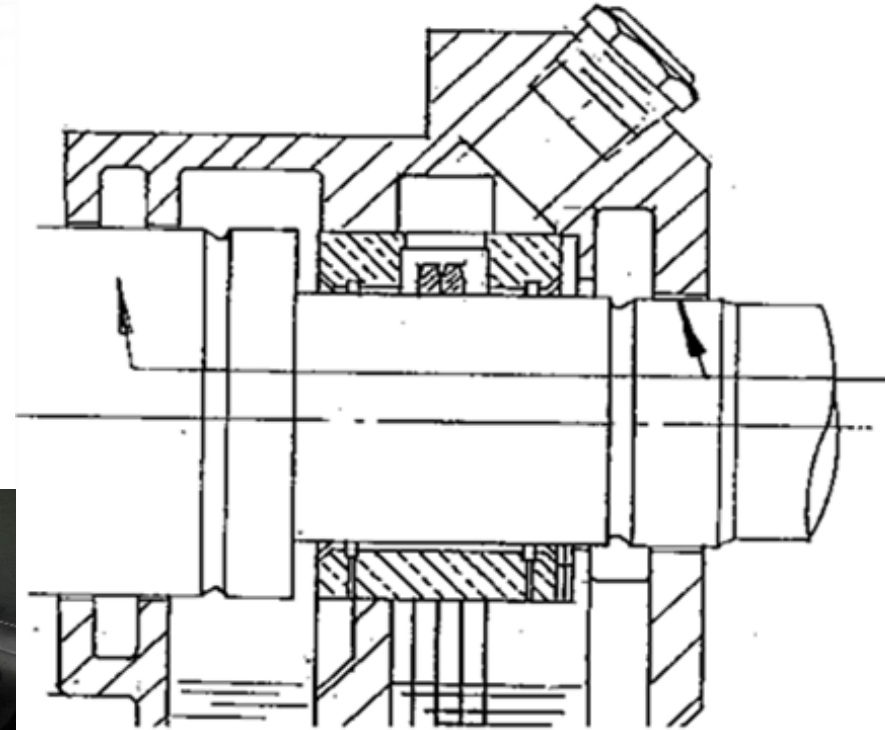


Sleeve Bearing Seals & Protection

Sleeve Bearing Seals

Standard Seal

- **Close Running Cast Iron Seals**
- **Minimize Oil Migration into Motor**
- **Minimize Contaminants Entering into Bearing**



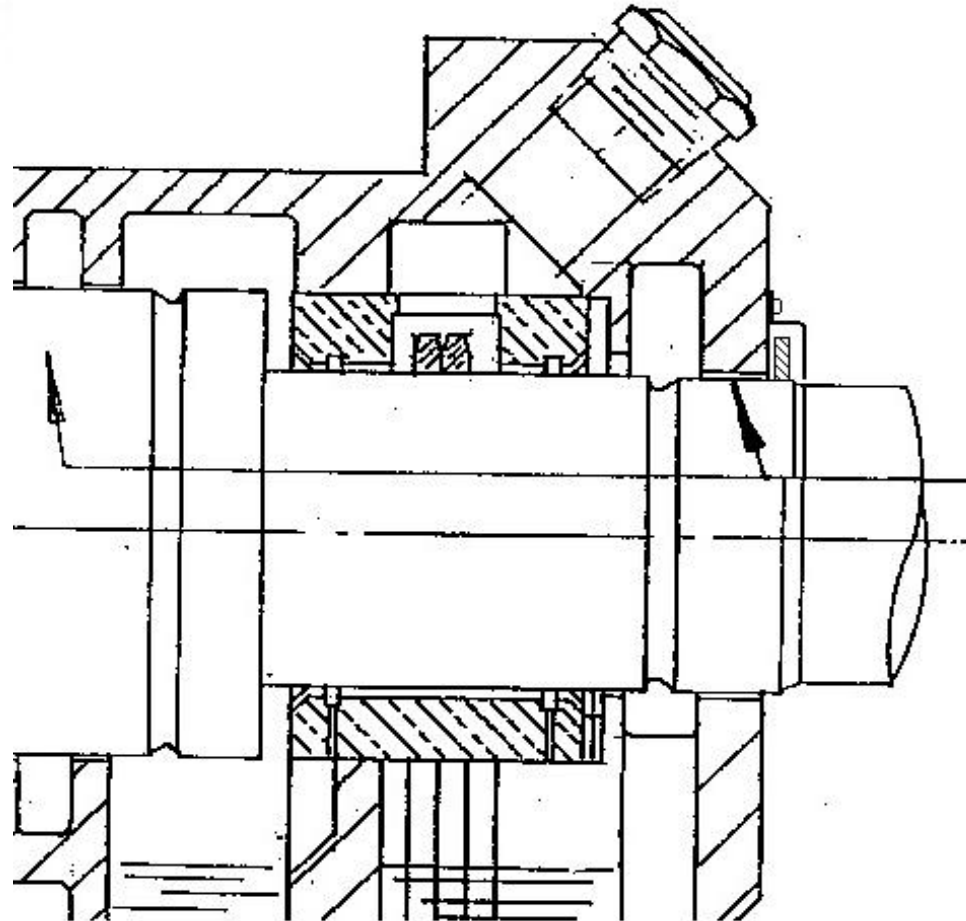
Sleeve Bearing Seals

Slinger and Cap In Addition to Standard

- **Minimize Oil Migration into Motor**

- **Additional Protection Against Contaminants Entering into Bearing from Outside the Motor**

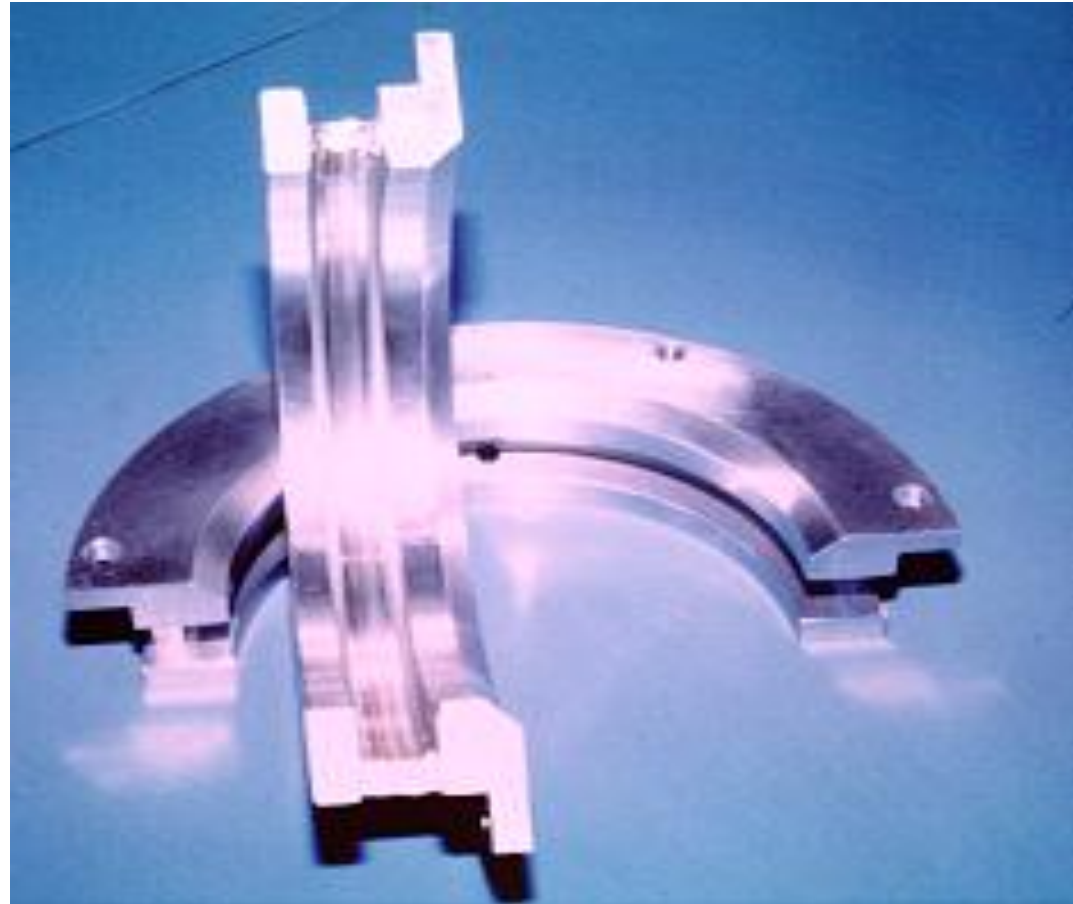
- **Standard on WPI and WP11 Enclosures**



Sleeve Bearing Seals

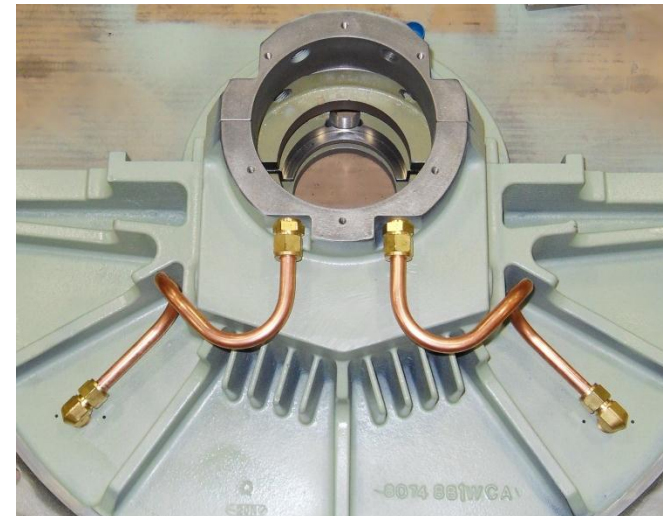
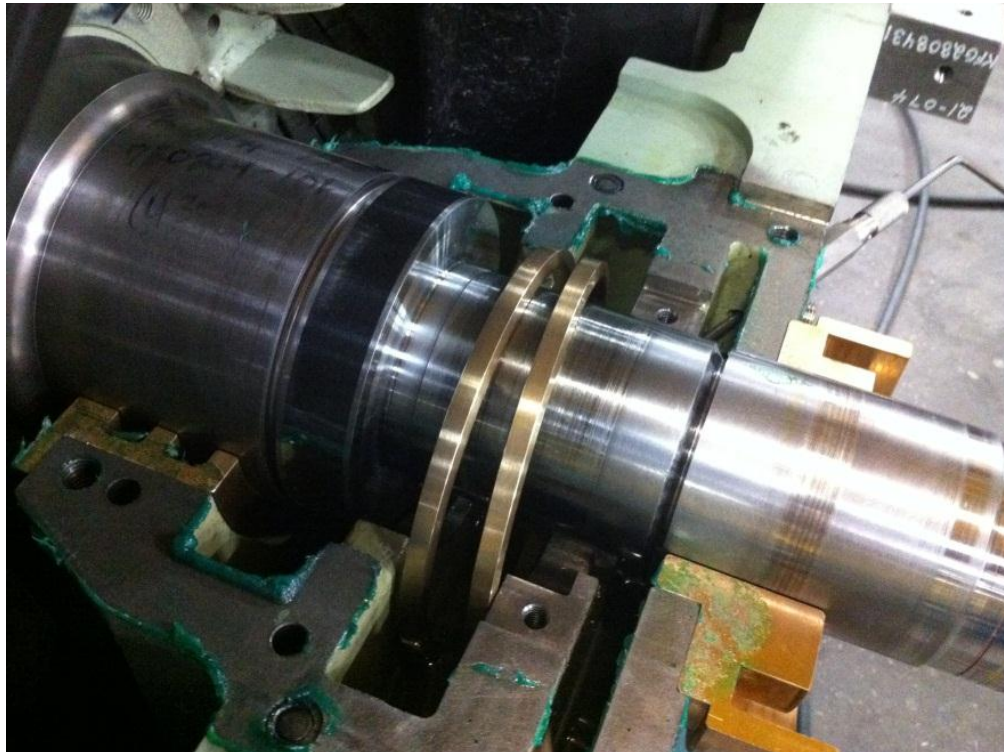
Coast-To Rest Wear Seals

- **Non Contact, Non Sparking Aluminum Labyrinth**
- **Minimizes Shaft Damage if a Failure does occur**
- **Minimize Oil Migration into Motor**
- **Additional Protection Against Contaminants Entering into Bearing from Outside the Motor**

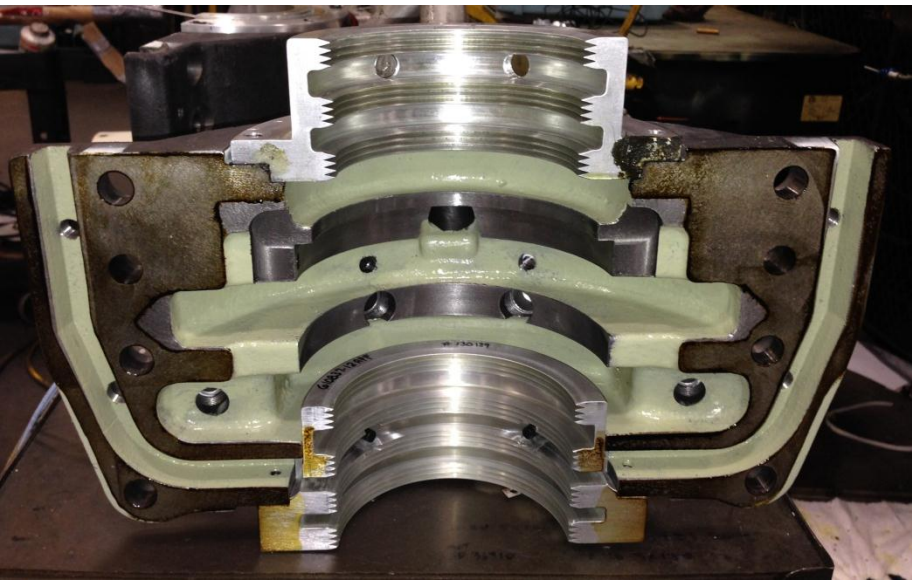
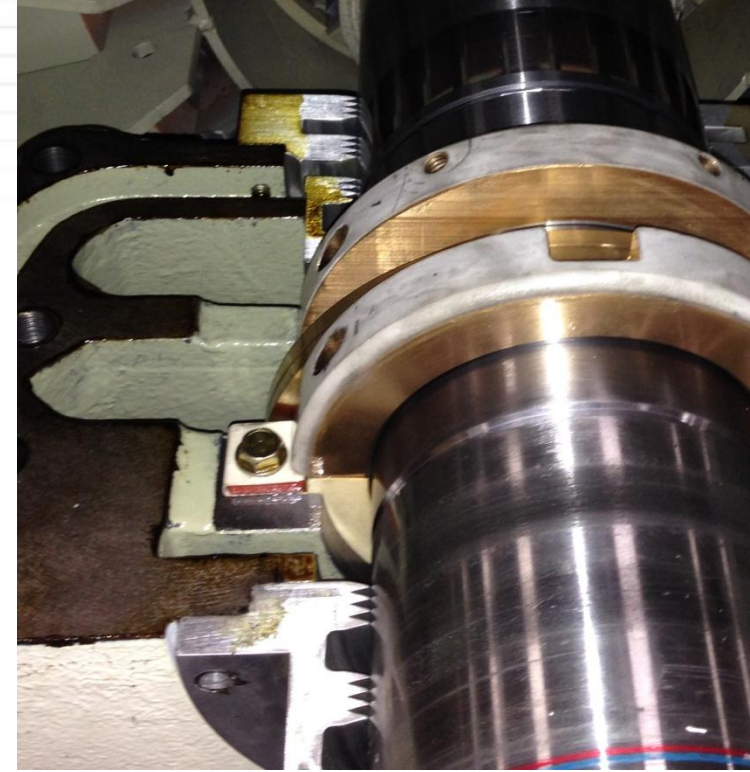


Sleeve Bearing Seals

- **IP55 Seals**
- **Non Contact, Non Sparking Brass Labyrinth Seal**
- **Minimizes Shaft Damage if a Failure does occur**
- **Minimize Oil Migration into Motor**
- **Premium Protection Against Contaminants Entering into Bearing**



Sleeve Bearing Seals



- Air Purged Knife Edge Seals
- Non Contact, Non Sparking Aluminum Knife Edge Seal
- Minimizes Shaft Damage if a Failure does occur
- Minimize Oil Migration into Motor
- Premium Protection Against Contaminants Entering into Bearing

Bearing Insulation



Motor Accessories

Motor Accessories – Space Heaters

- **Open Motors - Strip or Ring Type Heaters**
 - › Mounted inside the motor frame. Heaters may be installed without significant disassembly
- **Fan Cooled Motors - Ring or Tube Type Heaters**
 - › Anti-friction motors utilize “ring” type heaters mounted on the inner cap. Motor must be disassembled to install / replace.
 - › Sleeve bearing motors utilize “tube” type heaters mounted inside the motor frame. Motor must be disassembled to install / replace.



Motor Accessories – Space Heaters



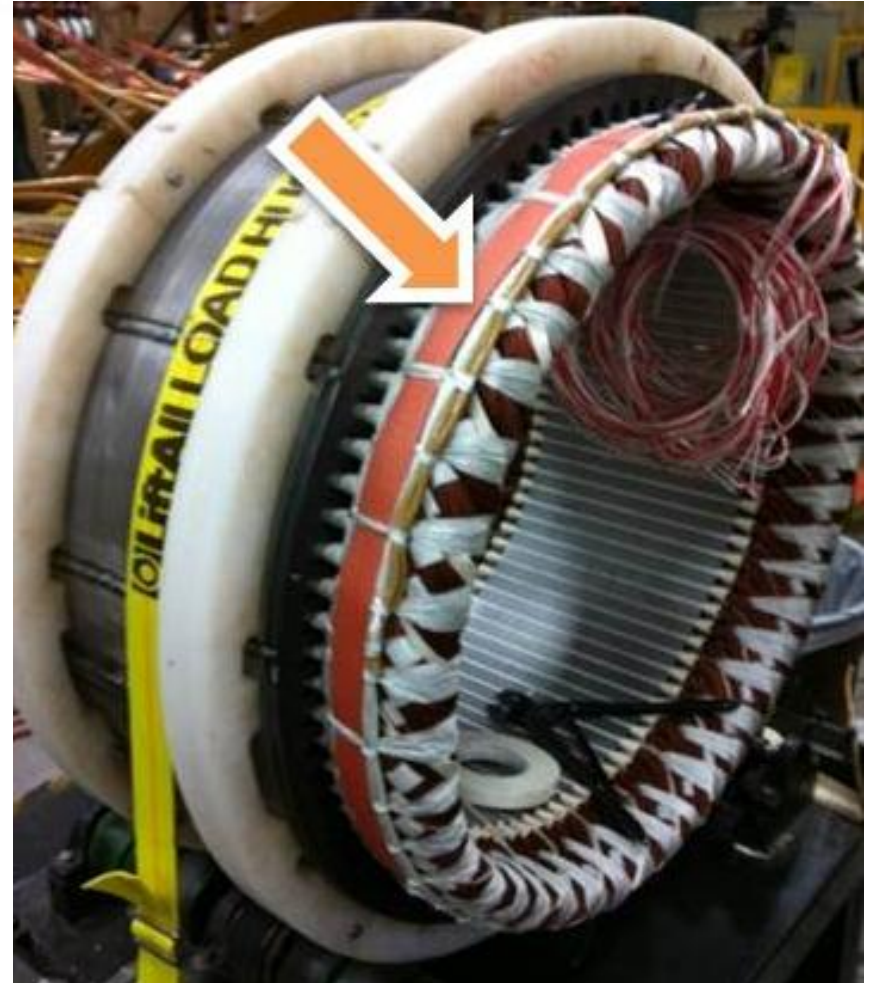
Tube Type Replaceable Space Heater

Motor Accessories – Space Heaters



Ring Type Replaceable Heater installed in frame

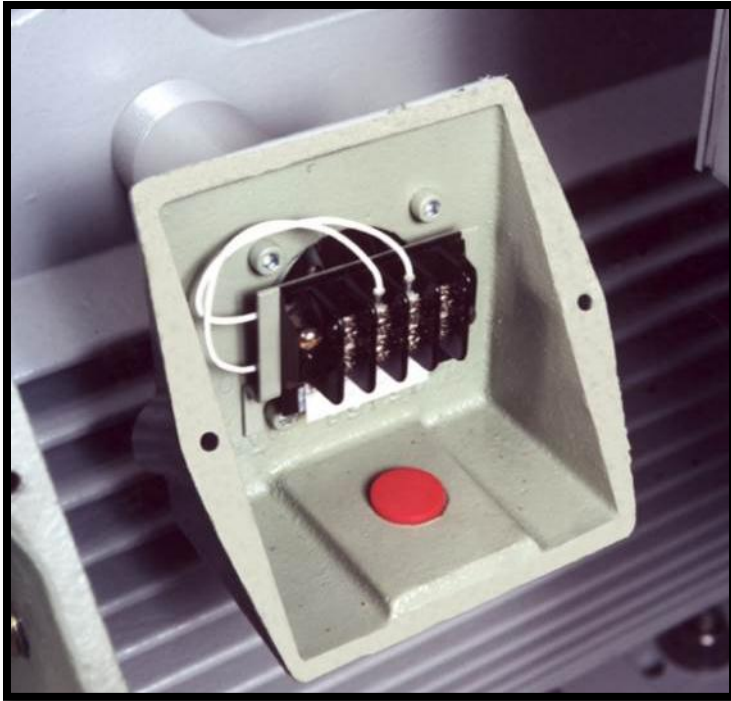
Motor Accessories – Space Heaters



Coilhead Space Heaters

- Used on both Open and Fan Cooled Motors
 - › Install during winding process.
 - › **Non-replaceable** after curing.

Motor Accessories – Auxiliary Boxes

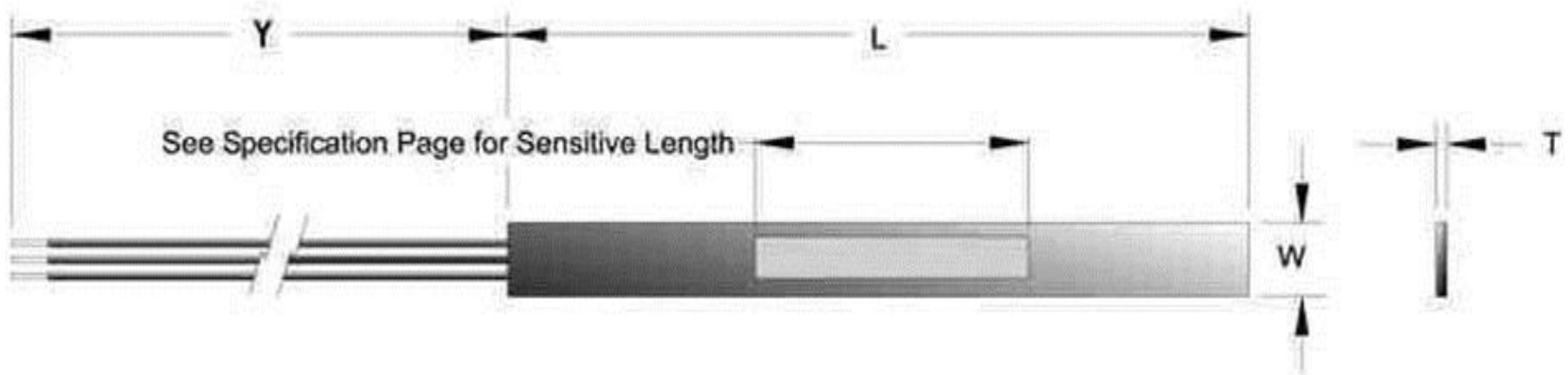


- Mounted to motor frame via pipe nipple
- Boxes available
 - › Cast Iron - Standard
 - NEMA 4
 - IP54, 55
 - › Fabricated Stainless Steel
 - NEMA 4X
 - IP 54, 55
 - › Cast Aluminum
 - IP 54, 55
 - Suitable for Div I

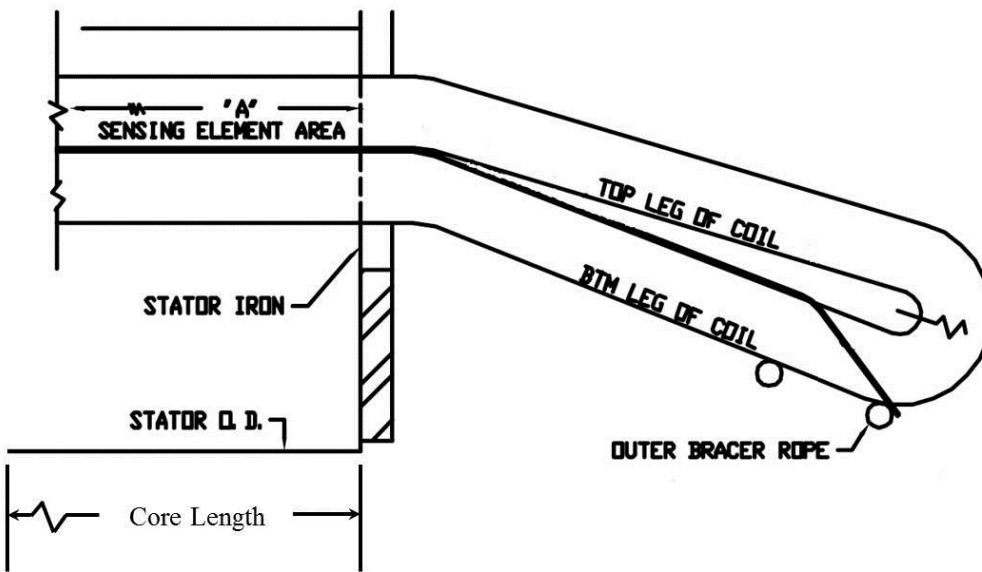
Temperature Devices - Winding

Motor Accessories – RTD's

- Resistance Temperature Detector (RTD) (Temperature Detector)
 - › RTD's are thermal sensing devices containing a sensing element that is a non-inductively wound coil molded into a rectangular or round laminate with leads coming from the resistance coil. By knowing the rated change of resistance with temperature, the RTD can be used to continuously measure the internal winding temperature.
 - › Types of RTD's
 - 10 ohms at 25° C (Copper wire)
 - 100 ohms at 0° C (Platinum wire) Most Common
 - 120 ohms at 0° C (Nickel wire)



Motor Accessories – RTD's

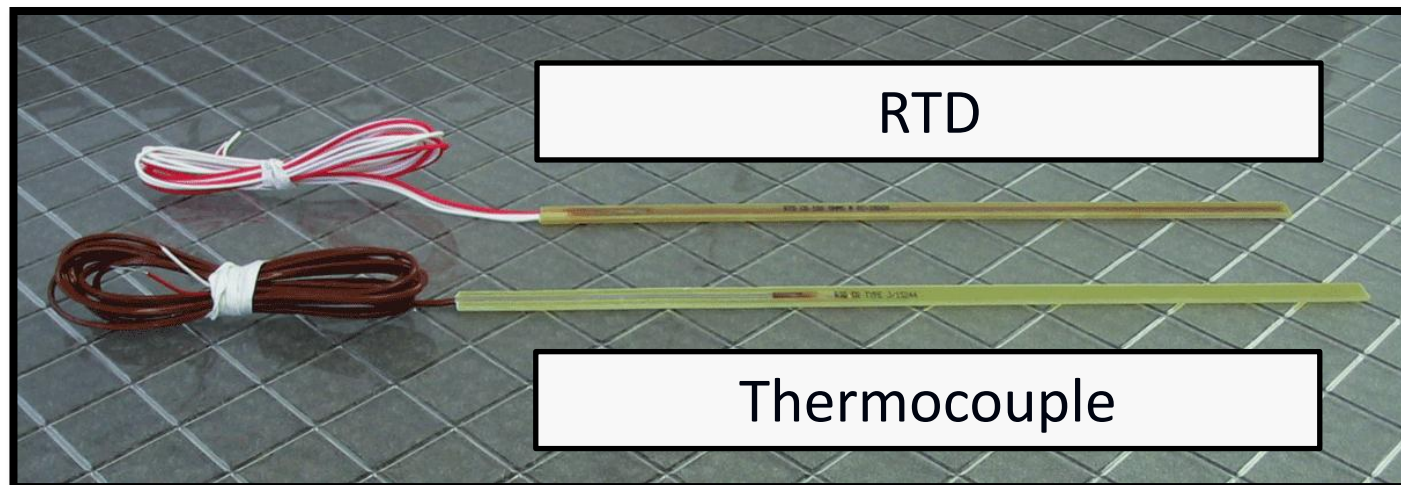


- RTD's inserted between top and bottom coil per NEMA
- All RTD's routed to common point on stator
- 1,2,3 per phase options available

Motor Accessories - Thermocouples

■ Thermocouple (TC) (Temperature Detector)

- › Thermocouples are used to measure temperature in order to monitor and/or display the temperature reading. The sensing point of the TC is a junction of two (2) dissimilar metals that produces a small voltage (current) proportional to the temperature of the measured area. By knowing the rate of change of voltage with temperature, the TC can be used to continuously measure temperature
- › Types of TC's used at RSN
 - Iron-constantan (Type J) Most Common
 - Copper-constantan (Type T)
 - Chromel-constantan (Type E)
 - Chromel-alumel (Type K)



Motor Accessories - Thermistors

- **Thermistor (PTC) (Temperature Switch on/off)**
 - › Thermistors are positive temperature coefficient devices that operate with a solid state relay. At normal temperatures, the resistance is relatively low. The resistance remains relatively constant up to a pre-determined temperature, depending on thermistor design. A rise in temperature above this pre-set limit causes the resistance to greatly increase very abruptly, thus tripping the relay.



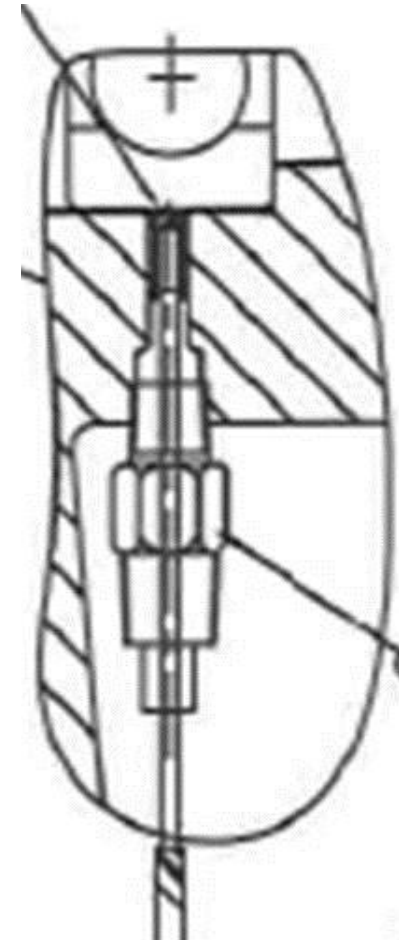
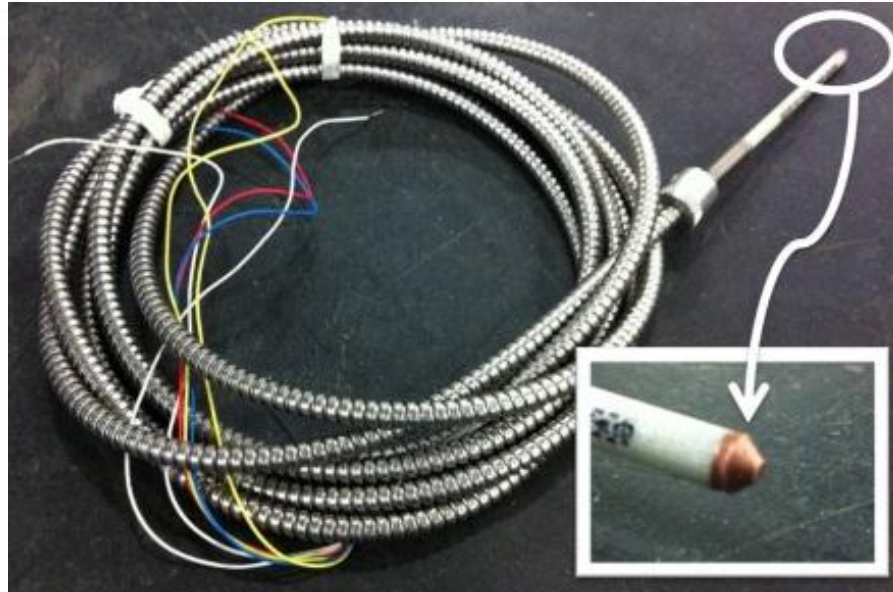
Motor Accessories - Thermostats

- **Thermostat (Temperature Switch on/off)**
 - › Thermostats are bi-metallic snap switches. They use bi-metallic discs to operate a set of contacts. When heated the internal stresses of the bi-metal causes the disc to reverse its curvature with a snap action at a fixed non-adjustable temperature and open the electrical contacts. A decrease in the temperature below reset temperature of the disc relieves the internal stresses in the disc which returns the disc to its normal curvature and closes the contacts.



Temperature Devices - Bearings

Motor Accessories – Bearing Probes



Motor Accessories – Bearing Probes



- Bayonet style probe installed into bracket using bayonet adapter.
- RTD leads routed to conduit.



Motor Accessories – Condulet Heads



- One condulet per bearing is standard
- Bearing RTD's may be routed to winding RTD box via flex conduit

Terminal Box Accessories

ACCESSORIES

Bus Bar / Standoff



- **Bus Bar**
 - › Used as connection point for motor power leads and customer supply leads
 - › Silver plated copper is standard
 - › Tin plated as option
- **Standoff**
 - › Used to insulate Bus Bar from terminal box.
 - › Two sizes available
 - $\leq 5\text{kv} = 3.50''$ tall
 - $> 5\text{kv} < 15\text{kv} = 6.00''$ tall

ACCESSORIES

Current Transformers

- Load CTs allow continuous monitoring of line current
- Self-Balancing differential CT's protection scheme



ACCESSORIES

Surge Protection

- **Surge Capacitors**

- › Increase surge voltage rise time allowing voltage to distribute more evenly throughout the motor winding.

- **Lightning Arrestors**

- › Limit magnitude of voltage spike by “Chopping” the voltage wave at a specific Level

- **Best protection when both are used**

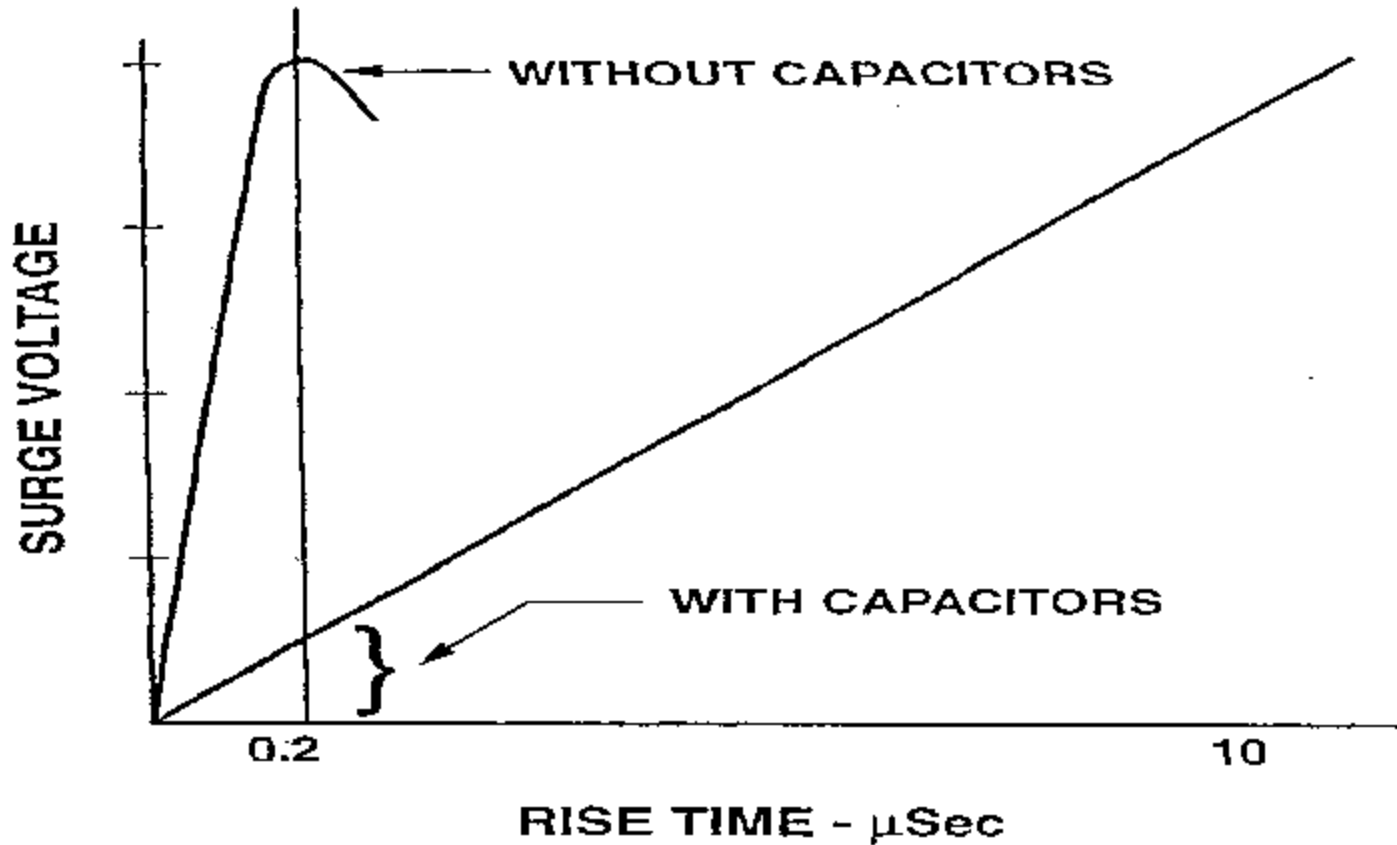
ACCESSORIES

Surge Capacitor



ACCESSORIES

Surge Capacitor



EFFECT OF CAPACITORS ON RISE TIME

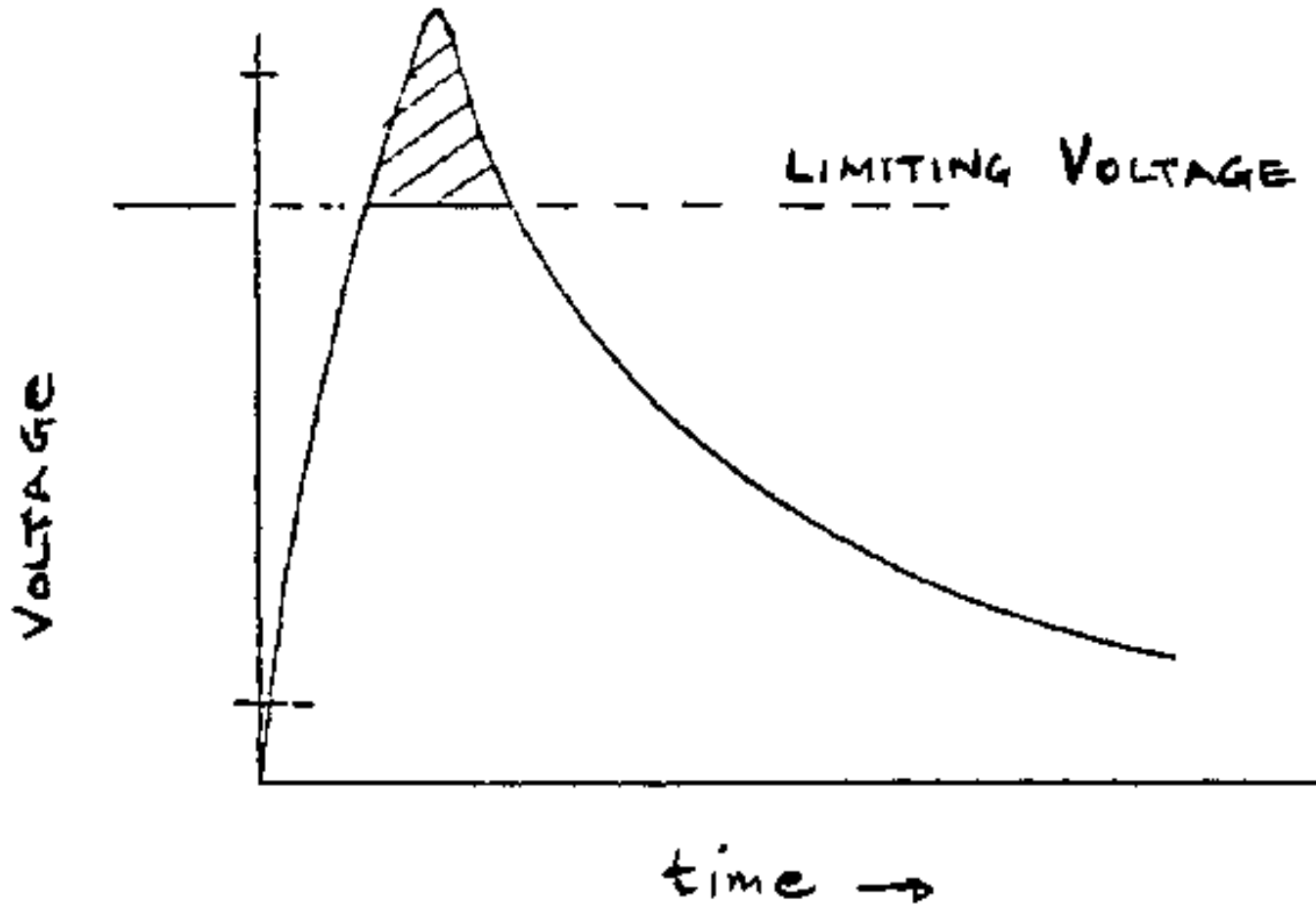
ACCESSORIES

Lightning Arrestors



ACCESSORIES

Lightning Arrestors



ACCESSORIES

Mounted in Main Terminal Box



Standoff

Lightning Arrestor

Bus Bar

Neutral Bus

Current Transformer

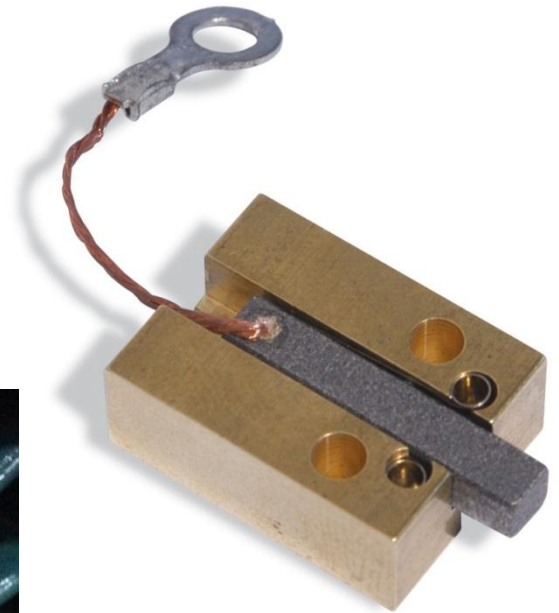
CT Secondary Leads

Surge Capacitor

Ground Pad

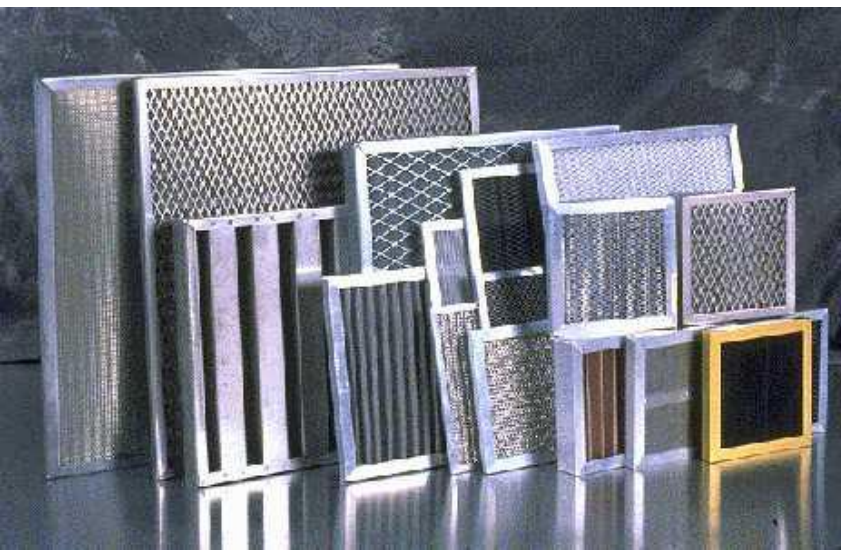
Shaft Grounding

- Brush type



Motor Accessories - Filters

- **Types of filters**
 - › Galvanized Steel
 - › Stainless Steel
 - › Aluminum
- **Where Used**
 - › WP-II
 - › Force Vent



Motor Accessories – Pressure Switch



- Used to monitor filter condition for WP11 motors
- Used to monitor air inlet condition for TEBC motors
 - › Rain-tight for outdoor use, and are UL listed for use in hazardous locations
 - › Supply Voltage
 - 24 VDC
 - 120 VAC
 - 240VAC

Motor Accessories – Pressure Gage



- Used to provide a visual monitor of filter condition for WPII motors
- Used to provide a visual monitor of air inlet condition for TEBC motors

Motor Accessories – Pressure Switch and Gage

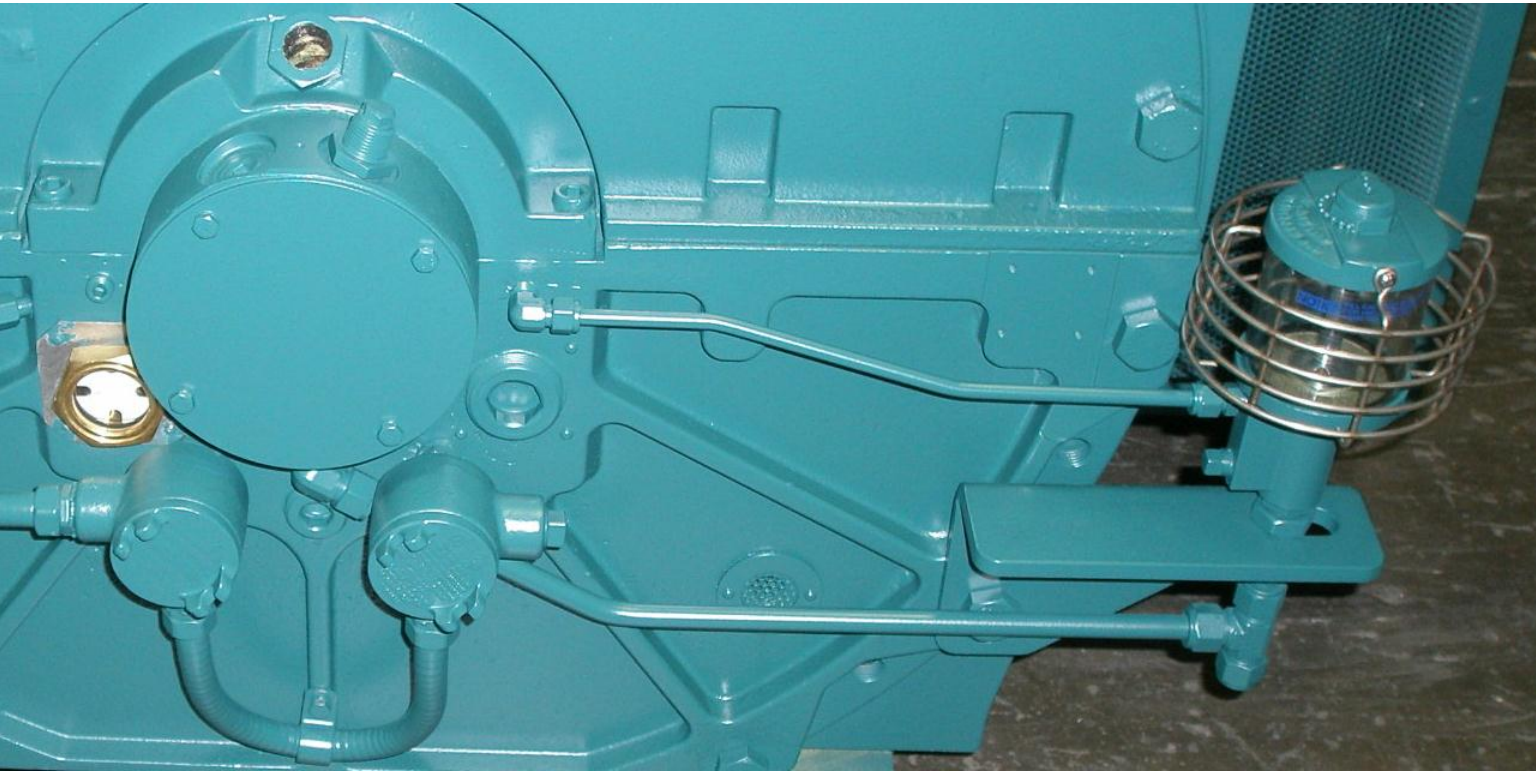


Motor Accessories – Leak Detector

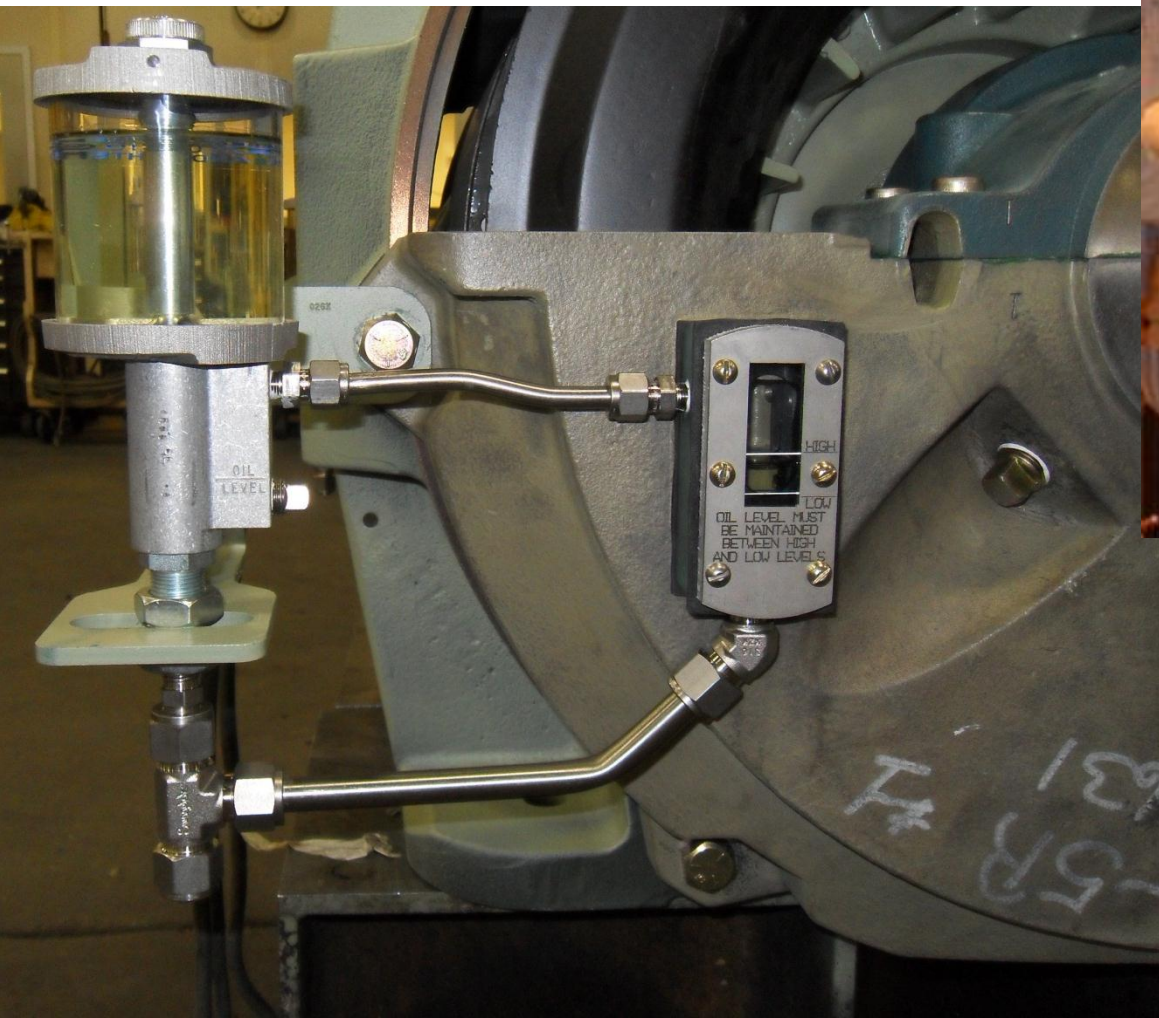


Motor Accessories - Oilers

- **Constant level oilers are used to maintain a fixed level in a oil lubricated sump.**
- **When the liquid in the bearing recedes due to bearing consumption, the liquid seal on the inside of the oiler is temporarily broken. This allows air from the air intake to enter the oiler reservoir, releasing the oil until a seal and proper level are again established.**



Motor Accessories - Oilers



Motor Accessories - Oilers

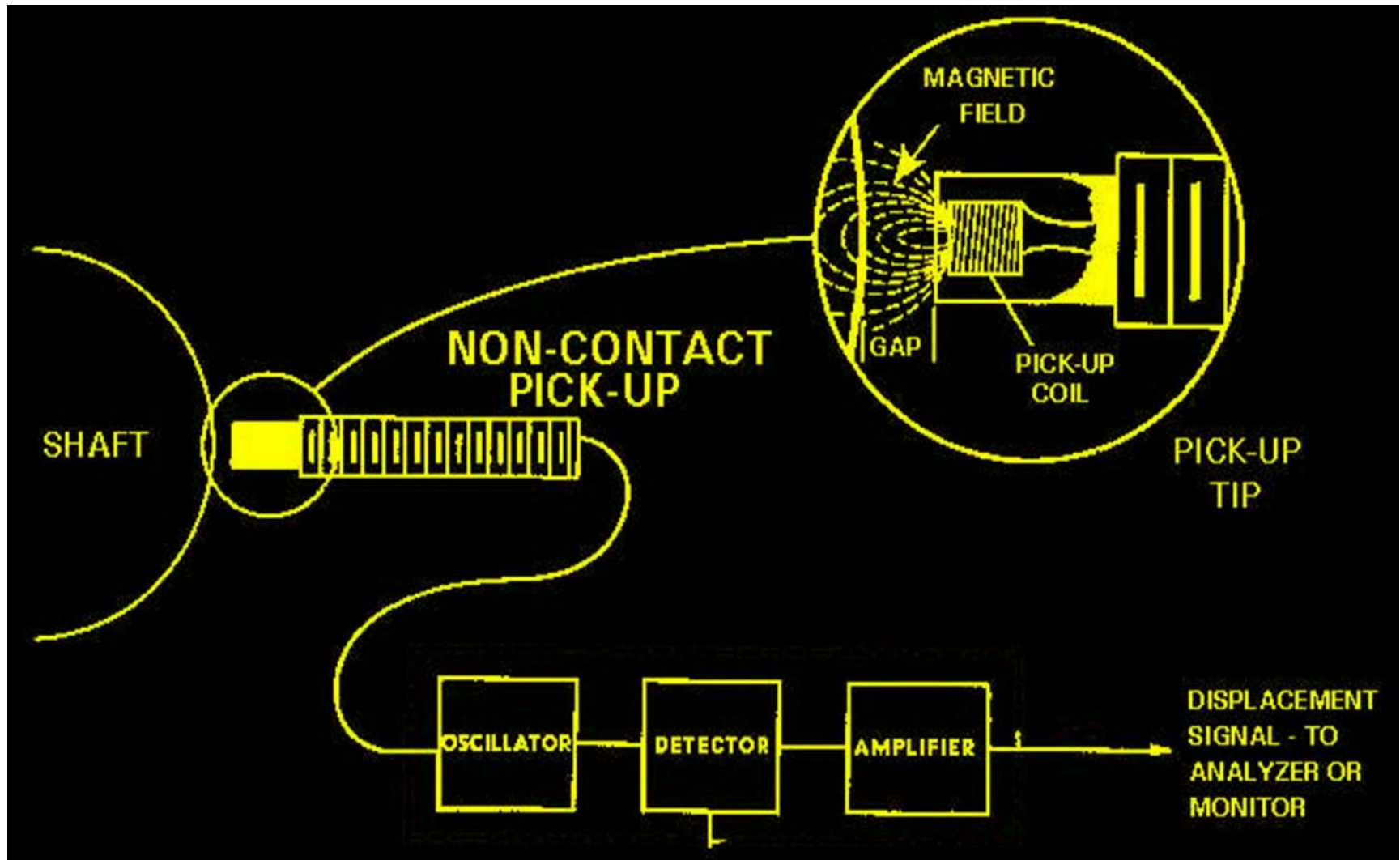


Motor Accessories – Proximity Probes

- Typical Proximity Transducer System



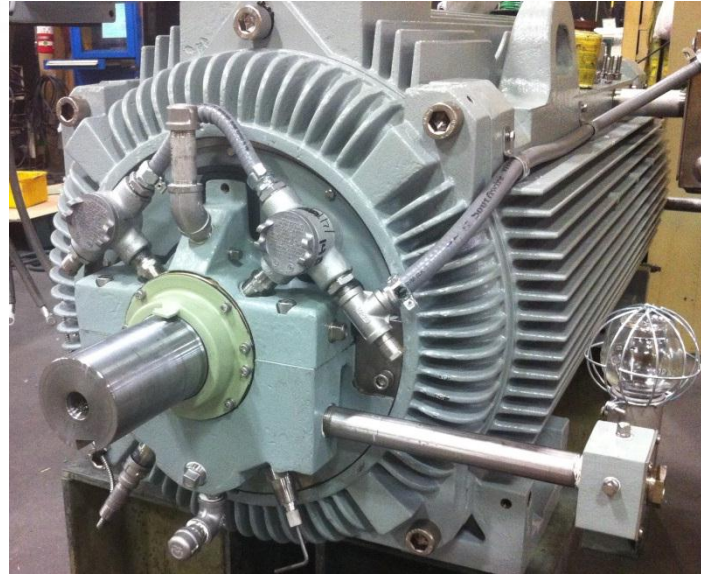
Motor Accessories— Proximity Probes



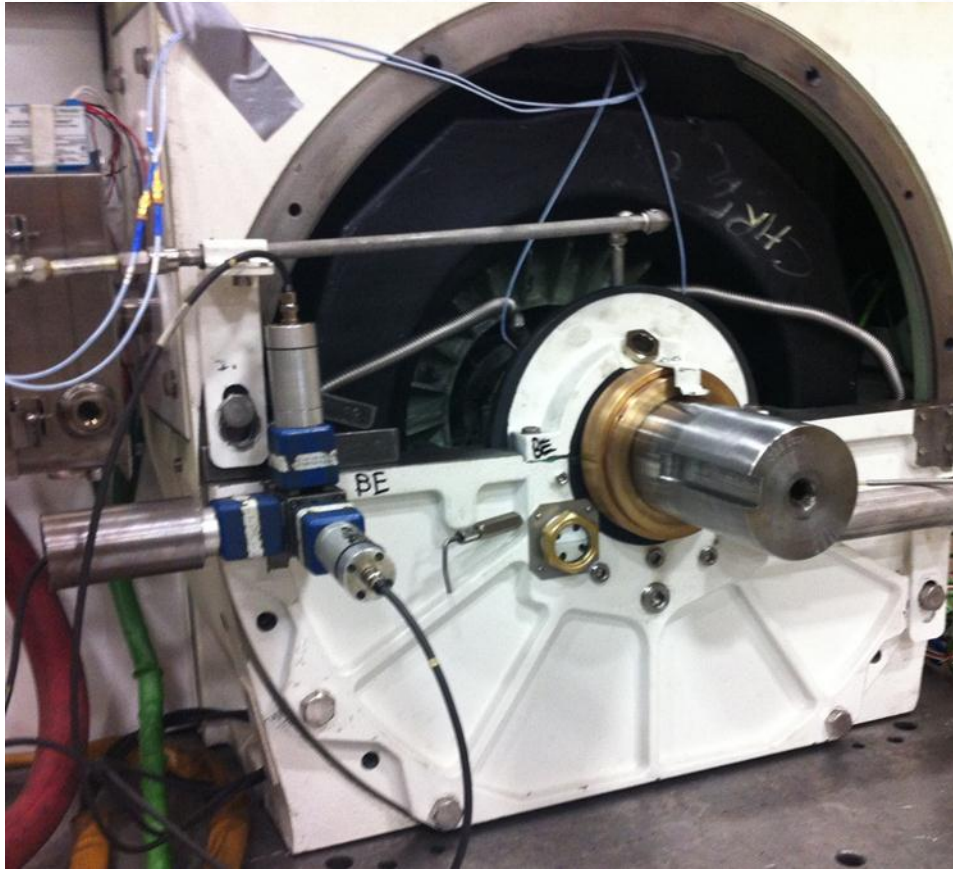
Motor Accessories– Proximity Probes

- **Proximity probe detects three things**
 - › Movement of surface of shaft due to vibration (purpose)
 - › Mechanical runout of probe target surface
 - › Electrical runout of probe target surface
- **Slow roll test to measure accuracy of reading**
 - › Run motor at approximately 200 to 300 RPM to eliminate the vibration component
 - › Readings at this condition are attributed to runout

Motor Accessories – Proximity Probes



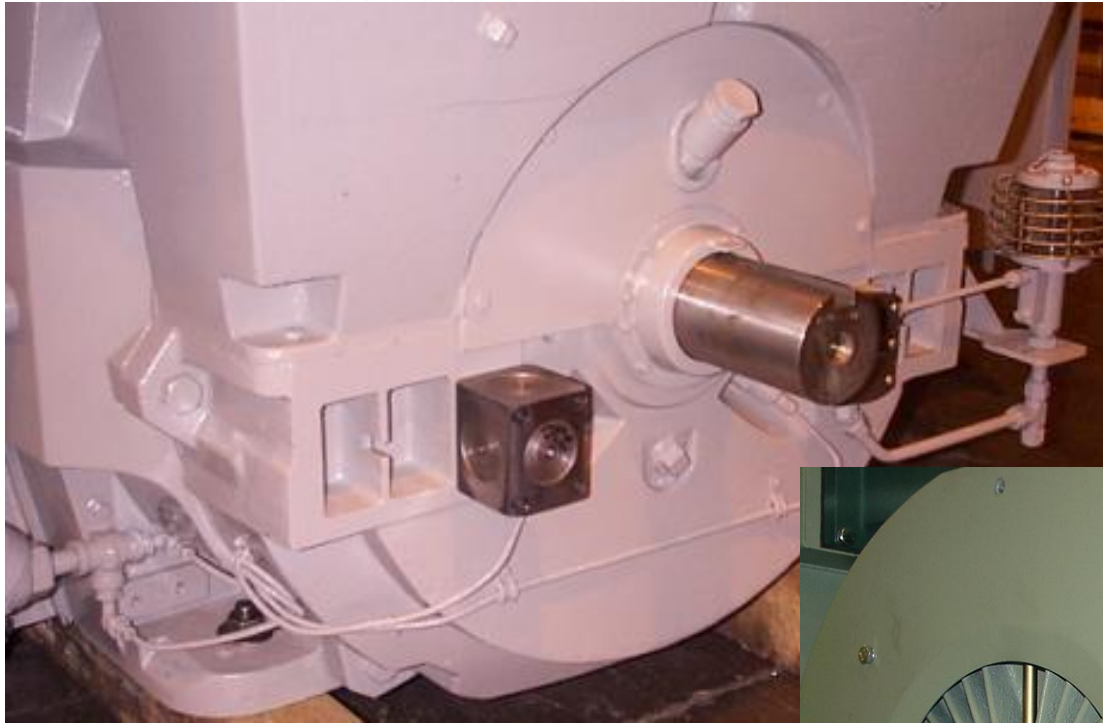
Motor Accessories – Velocity Transducers



■ Velocity Transducer

- Measures bearing housing velocity
- Usually able to monitor & trend motor condition
- Ball and sleeve bearing motors

Motor Accessories – Velocity Transducers



Provisions only



Motor Accessories – Vibration Switch



Motor Accessories - Encoders

- Encoders
 - Commonly used are incremental encoders
 - Can be hollow shaft or shafted.



- Will indicate speed of shaft
- Used for feedback into drives for VFD operation

Speed vs Torque

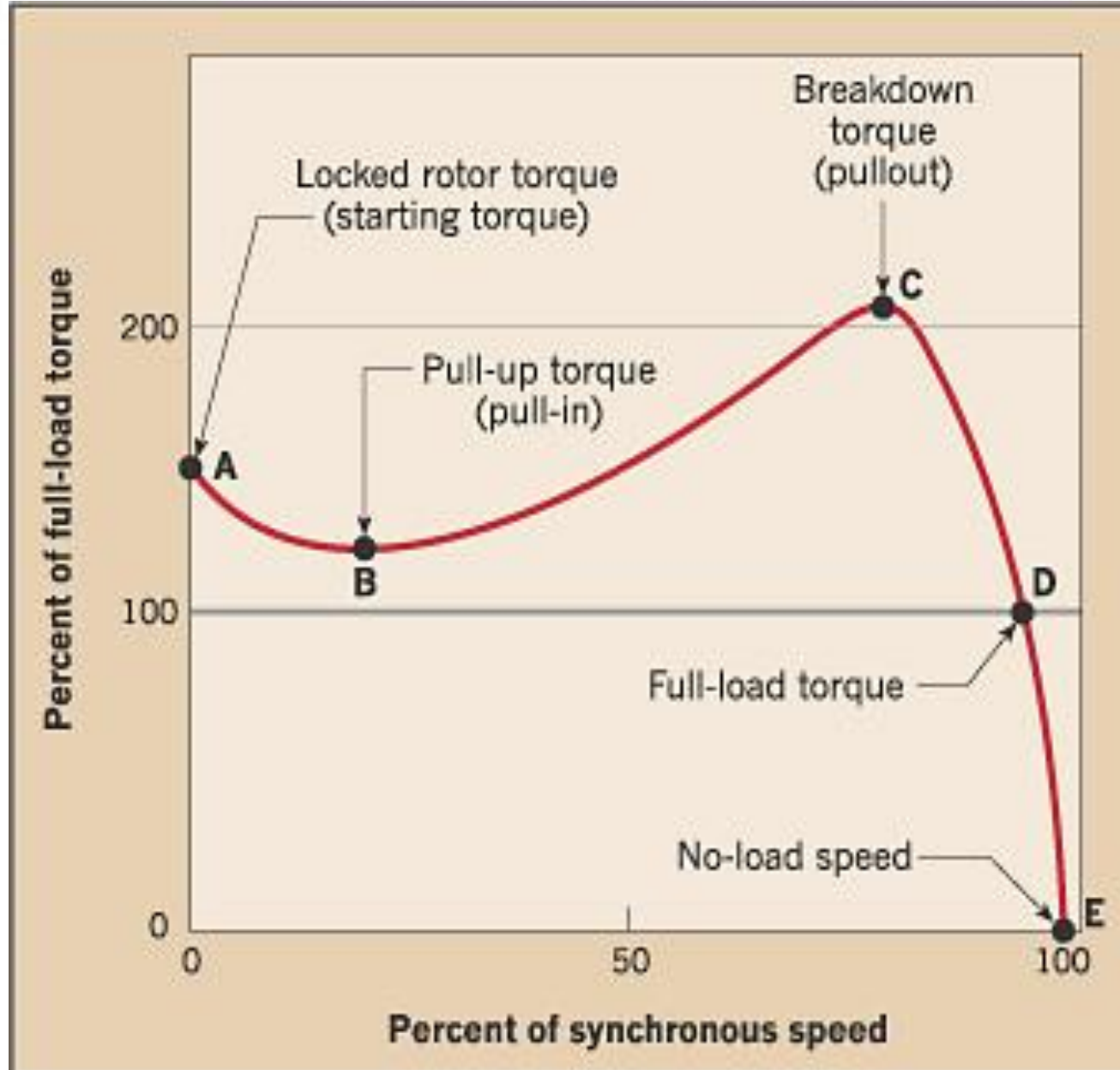
Speed vs Torque

Poles	Torque/Hp	Speed @ 60Hz
	(lb/ft)	Synchronous
2	1.5	3600
4	3	1800
6	4.5	1200
8	6	900
10	7.5	720
12	9	600

$$HP = \frac{Speed \times Torque}{5252}$$

$$Torque = \frac{HP \times 5252}{Speed}$$

Motor Speed Torque Curve

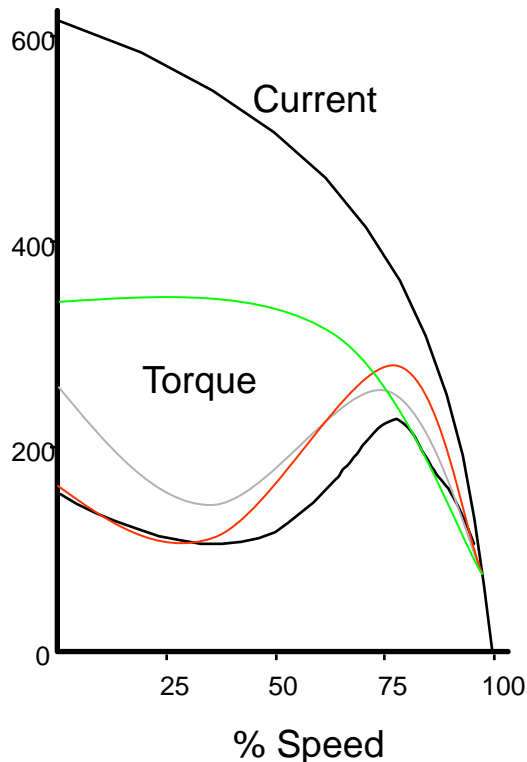


Motor Designs

- **The Material and Shape of the Rotor Bars Are the Main Factors in Obtaining Various Speed/Torque Curves**
- **NEMA Defines 4 Basic Types of Speed/Torque Characteristics for Induction Motors:**
 - › DESIGN A
 - › DESIGN B
 - › DESIGN C
 - › DESIGN D
- **The Stator Has Little to Do With the Shape of the Motors Speed/Torque Curve**
- **Different Rotors Could Be Used With the Same Stator to Change the Characteristic Shape**

Typical Current & Torque Relationship for Squirrel Cage Induction Motor

% Current
% Torque



Nema Des.	Starting Torque	LR amps	BD torq	FL slip	Applications
A	Normal	High	High	Low	Mach. Tools, fans
B	Normal	Normal	Normal	Normal	General Industrial
C	High	Normal	Normal	Normal	Conveyor
D	Very High	Low	n/a	High	Hoists

What is Large AC?

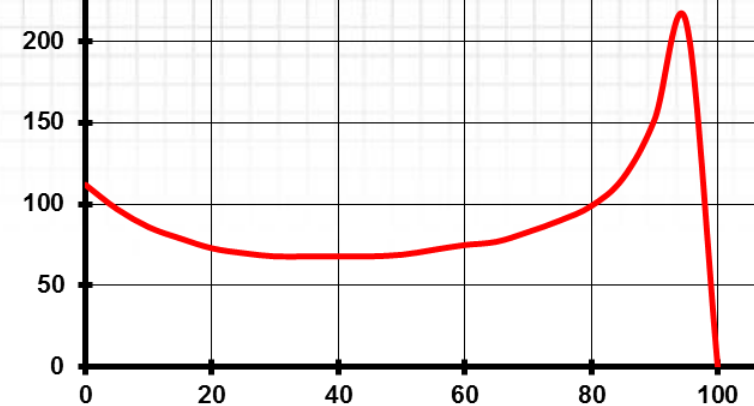
Per NEMA, Large Induction Machines include ratings greater than:

Sync. RPM	Motors-HP	Generators-kW
3600	500	400
1800	500	400
1200	350	300
900	250	200
720	200	150
600	150	125
514	125	100
450	ALL	ALL

NEMA MG 1 Part 20

Speed vs Torque

NEMA MG 1- 20.10



20.10.1 Standard Torque

The torques, with rated voltage and frequency applied, shall be not less than the following:

Torques	Percent of Rated Full-Load Torque
Locked-rotor*	60
Pull-up*	60
Breakdown*	175

20.10.2 High Torque

When specified, the torques with rated voltage and frequency applied, shall not be less than the following:

Torques	Percent of Rated Full-load Torque
Locked-rotor	200
Pull-up	150
Breakdown	190

20.10.3 Motor Torques When Customer Specifies A Custom Load Curve

When the customer specifies a load curve, the torques may be lower than those specified in 20.10.1 provided the motor developed torque exceeds the load torque by a minimum of 10% of the rated full-load torque at any speed up to that at which breakdown occurs, with starting conditions as specified by the customer (refer to 20.14.2.3).

Speed vs Torque - Application

Constant Torque

- Reciprocating Compressor
- Reciprocating Pump
- Extruder
- Conveyor

Variable Torque

- Centrifugal Pump
- Centrifugal Compressor
- Fan



Application Characteristics

- Required HP, Speed, and Voltage
- Application (Type of Load)
- Starting / Running Method



Motor Starts

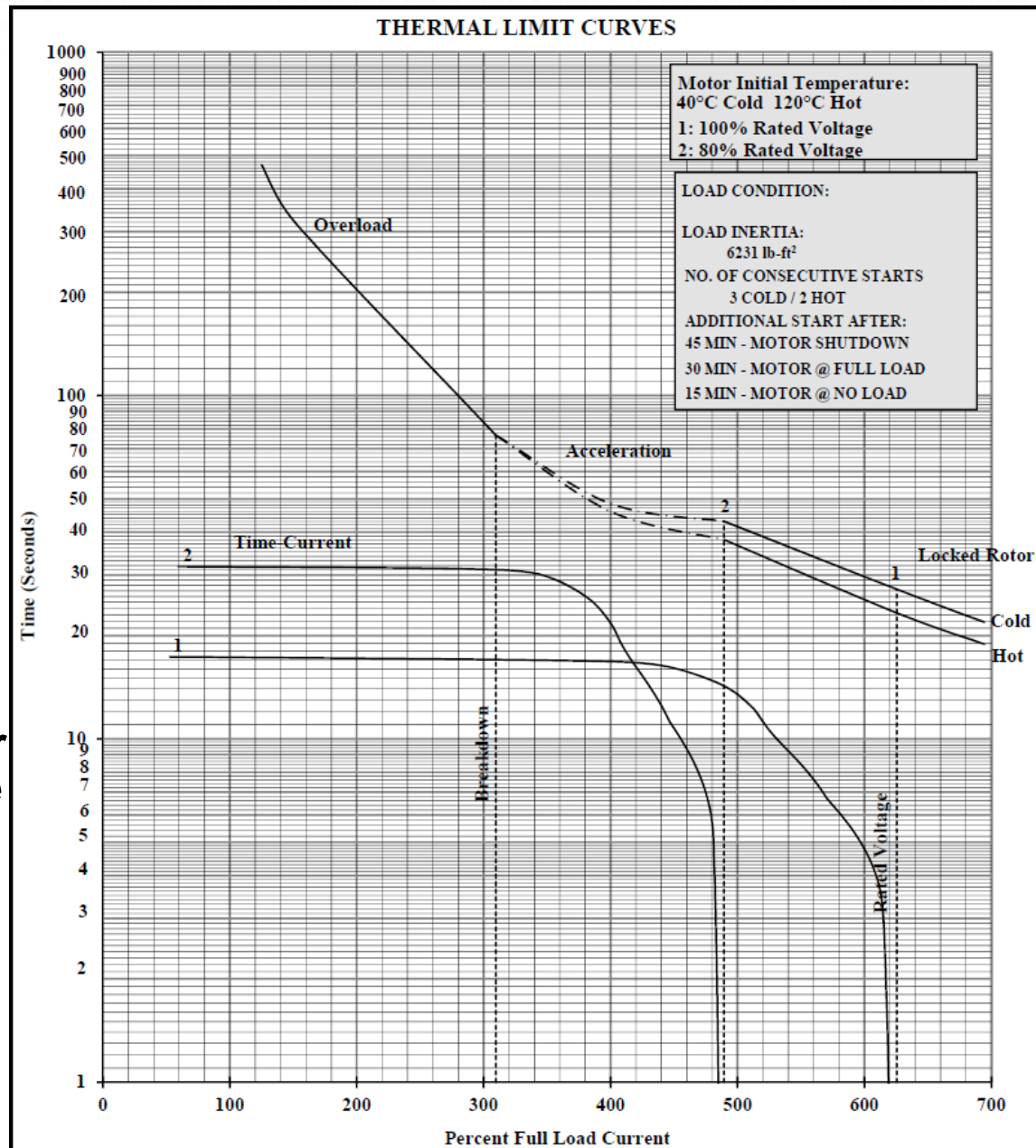
■ Every time a motor starts its components are subjected to mechanical and thermal stress.

- › Rotors
- › Winding insulation

■ Number of allowable starts should not be exceeded.

- › 2 starts loaded with motor at ambient temperature
- › 1 start loaded with motor at operating temperature
- › Followed by required cooling time

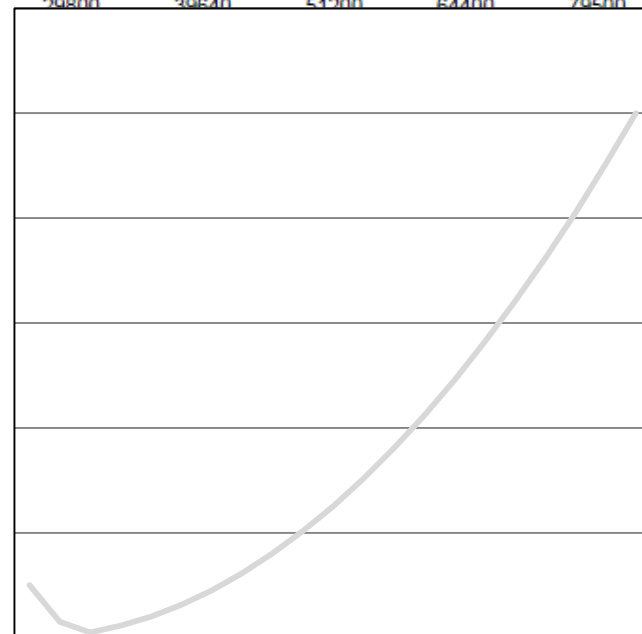
Note: NEMA MG 1 requires 2 cold / 1 hot



Consider the applied load inertia at the motor shaft.....

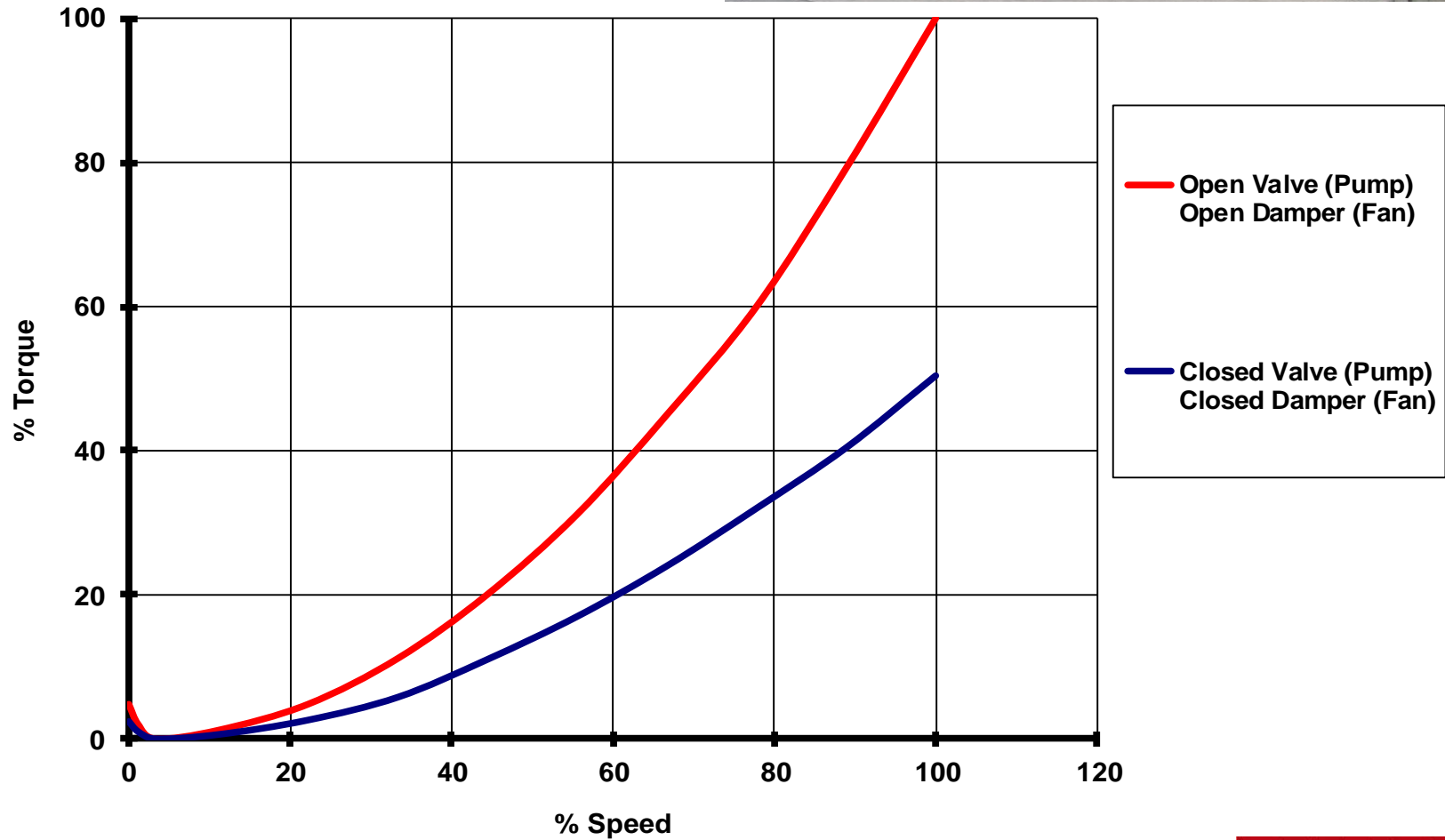
Table 20-1
LOAD Wk^2 FOR POLYPHASE SQUIRREL-CAGE INDUCTION MOTORS*

Hp	Synchronous Speed, Rpm											
	3600	1800	1200	900	720	600	514	450	400	360	327	300
	Load Wk^2 (Exclusive of Motor Wk^2), Lb-ft ²											
100	---	---	---	---	---	---	---	12670	16830	21700	27310	33690
125	---	---	---	---	---	---	---	15610	20750	26760	33680	41550
150	---	---	---	---	---	---	13410	18520	24610	31750	39960	49300
200	---	---	---	---	---	12060	17530	24220	32200	41540	52300	64500
250	---	---	---	---	9530	14830	21560	29800	39640	51200	64400	79500
300	---	---	---	6540	11270	17550	25530	---	---	---	---	---
350	---	---	---	7530	12980	20230	29430	---	---	---	---	---
400	---	---	4199	8500	14670	22870	33280	---	---	---	---	---
450	---	---	4666	9460	16320	25470	37090	---	---	---	---	---
500	---	---	5130	10400	17970	28050	40850	---	---	---	---	---
600	443	2202	6030	12250	21190	33110	48260	---	---	---	---	---
700	503	2514	6900	14060	24340	38080	55500	---	---	---	---	---
800	560	2815	7760	15830	27440	42950	62700	---	---	---	---	---
900	615	3108	8590	17560	30480	47740	69700	---	---	---	---	---
1000	668	3393	9410	19260	33470	52500	76600	---	---	---	---	---
1250	790	4073	11380	23390	40740	64000	93600	---	---	---	---	---
1500	902	4712	13260	27350	47750	75100	110000	---	---	---	---	---
1750	1004	5310	15060	31170	54500	85900	126000	---	---	---	---	---
2000	1096	5880	16780	34860	61100	96500	141600	---	---	---	---	---
2250	1180	6420	18440	38430	67600	106800	156900	---	---	---	---	---
2500	1256	6930	20030	41900	73800	116800	171800	---	---	---	---	---
3000	1387	7860	23040	48520	85800	136200	200700	---	---	---	---	---
3500	1491	8700	25850	54800	97300	154800	228600	---	---	---	---	---
4000	1570	9460	28460	60700	108200	172600	255400	---	---	---	---	---
4500	1627	10120	30890	66300	118700	189800	281400	---	---	---	---	---
5000	1662	10720	33160	71700	128700	206400	306500	---	---	---	---	---
5500	1677	11240	35280	76700	138300	222300	330800	---	---	---	---	---
6000	---	11690	37250	81500	147500	237800	354400	---	---	---	---	---
7000	---	12400	40770	90500	164900	267100	399500	---	---	---	---	---
8000	---	12870	43790	98500	181000	294500	442100	---	---	---	---	---
9000	---	13120	46330	105700	195800	320200	482300	685000	931000	1223000	1563000	1953000
10000	---	13170	48430	112200	209400	344200	520000	741000	1009000	1327000	1699000	2125000
11000	---	---	50100	117900	220000	366700	556200	794000	1084000	1428000	1830000	2291000
12000	---	---	51400	123000	233500	387700	590200	844800	1155000	1524000	1956000	2452000
13000	---	---	52300	127500	244000	407400	622400	893100	1224000	1617000	2078000	2608000
14000	---	---	52900	131300	253600	425800	652800	934200	1289000	1707000	2195000	2758000
15000	---	---	53100	134500	262400	442900	681500	983100	1352000	1793000	2309000	2904000



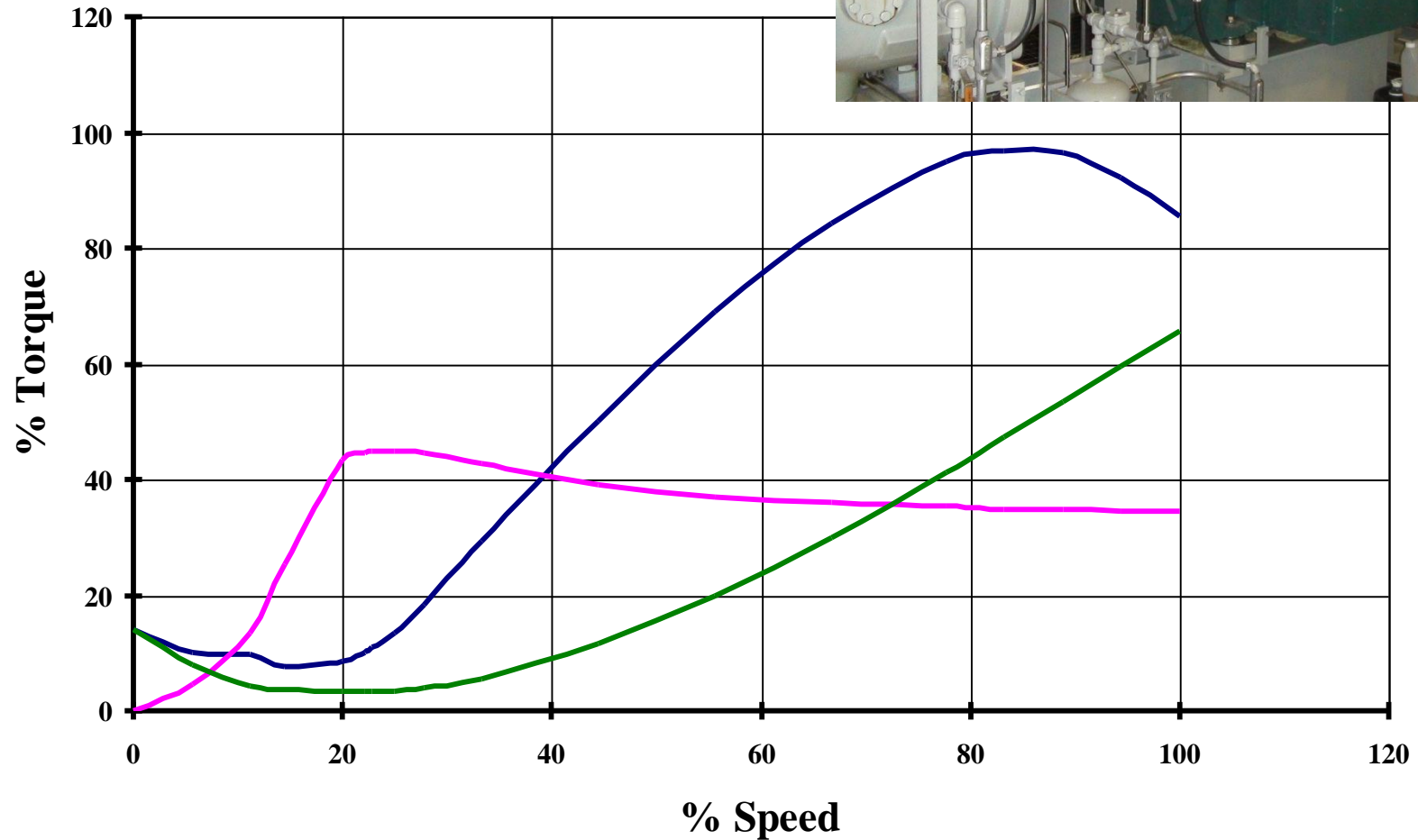
LOAD CURVES

Pump/Fan

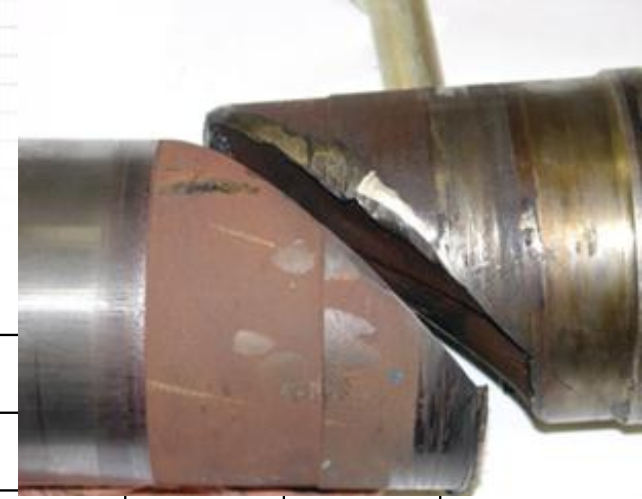
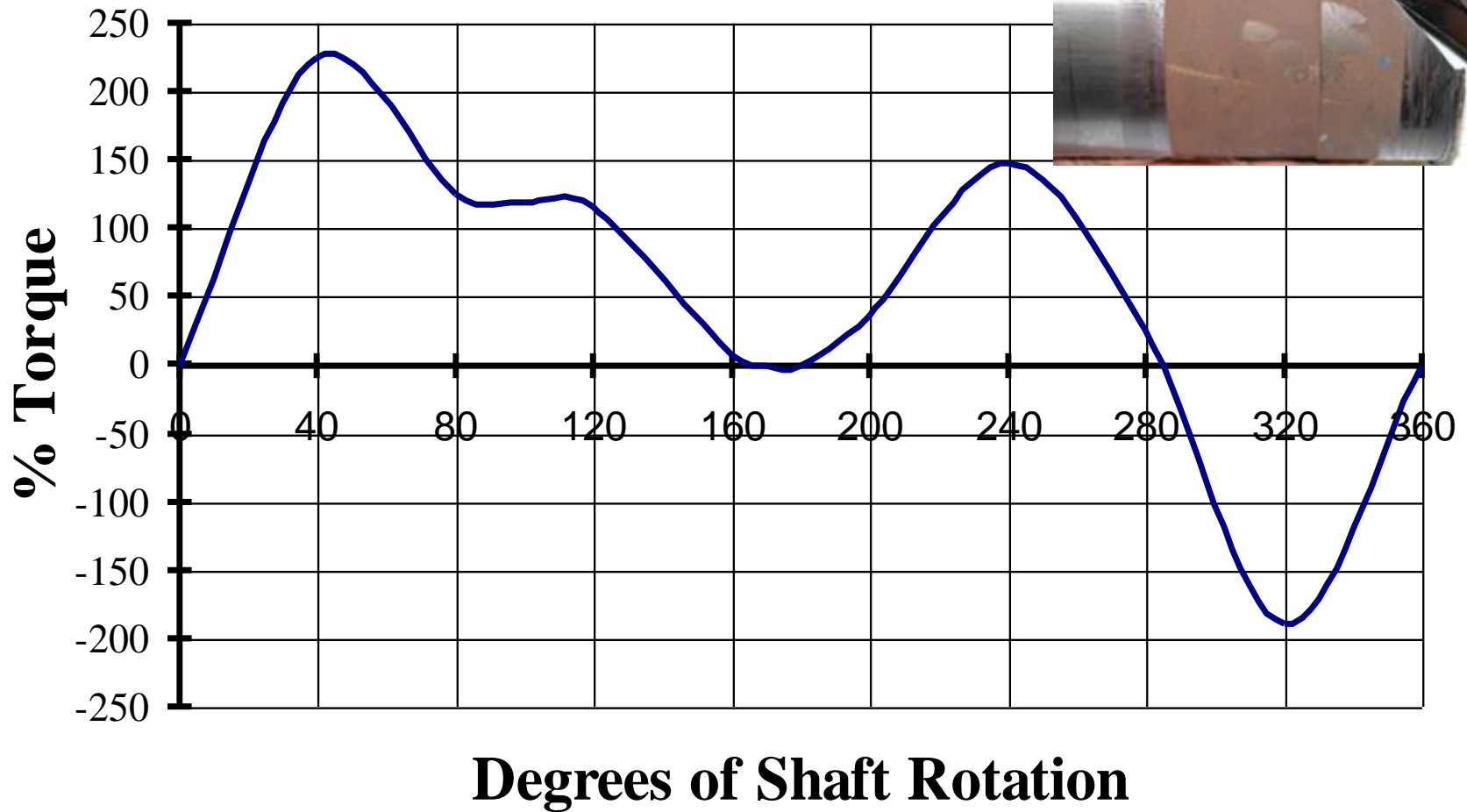


LOAD CURVES

Compressor

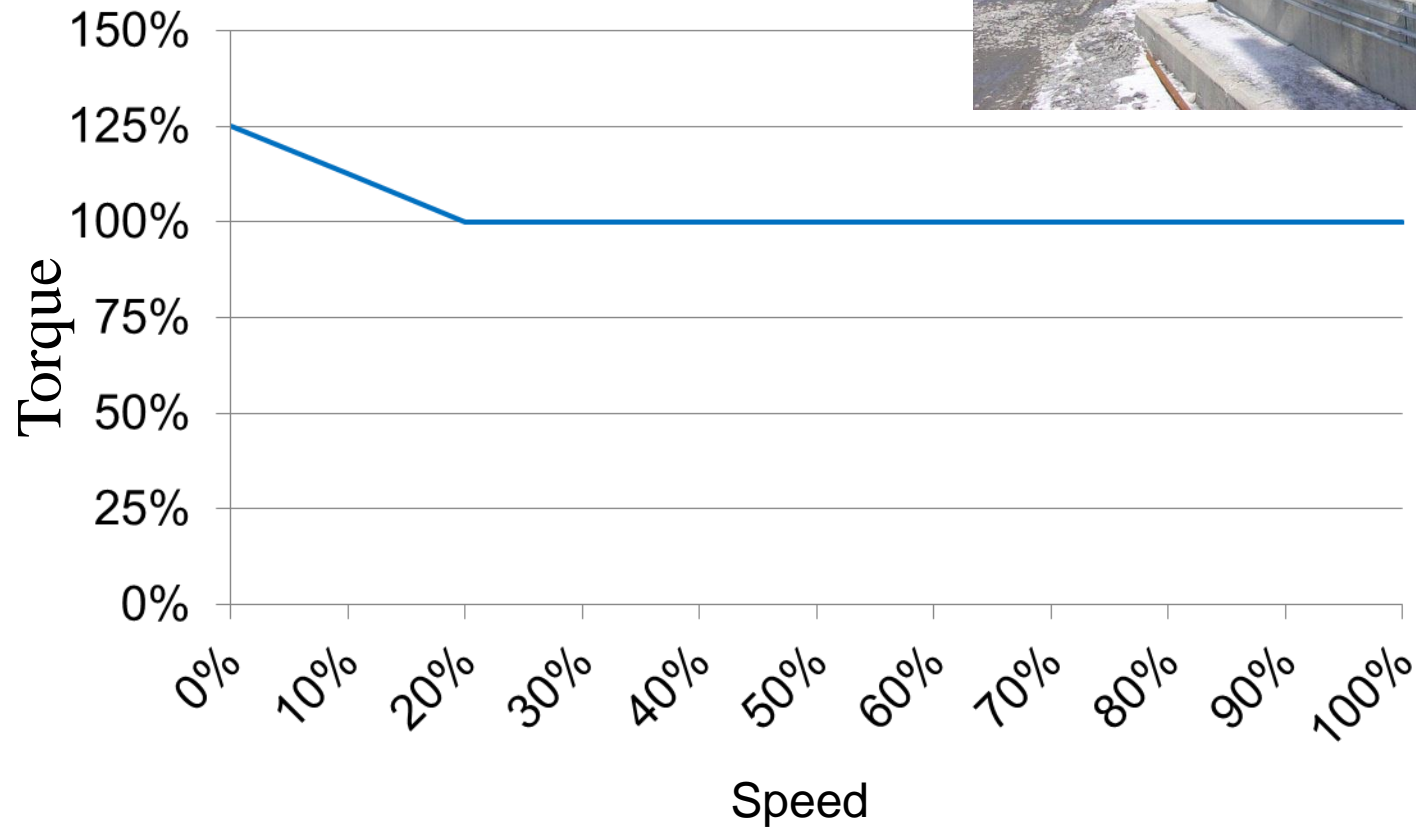


Reciprocating Compressor Torque Effort Curve



LOAD CURVES

Conveyor



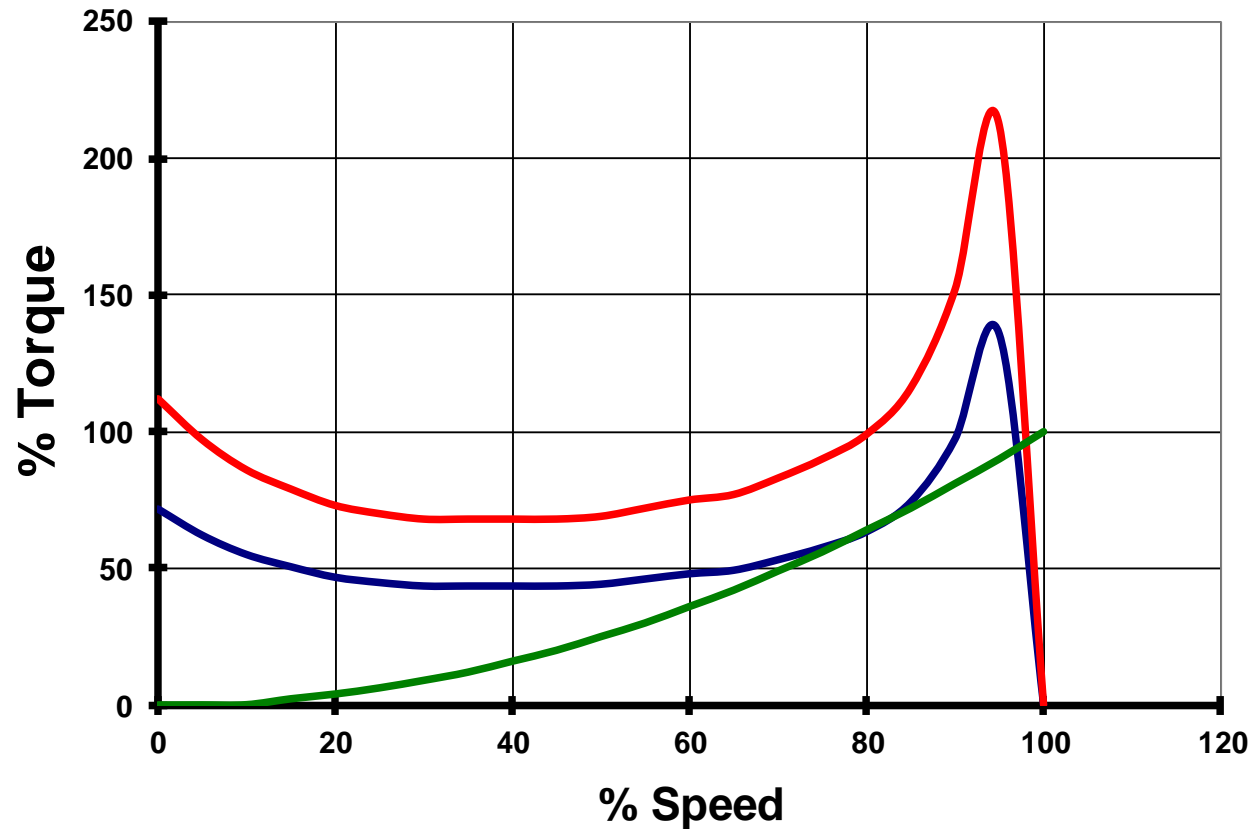
Starting Method

- Full Voltage
- Auto Transformer / Voltage Dip
- Current Limiting Soft Start
- Adjustable Speed Drive



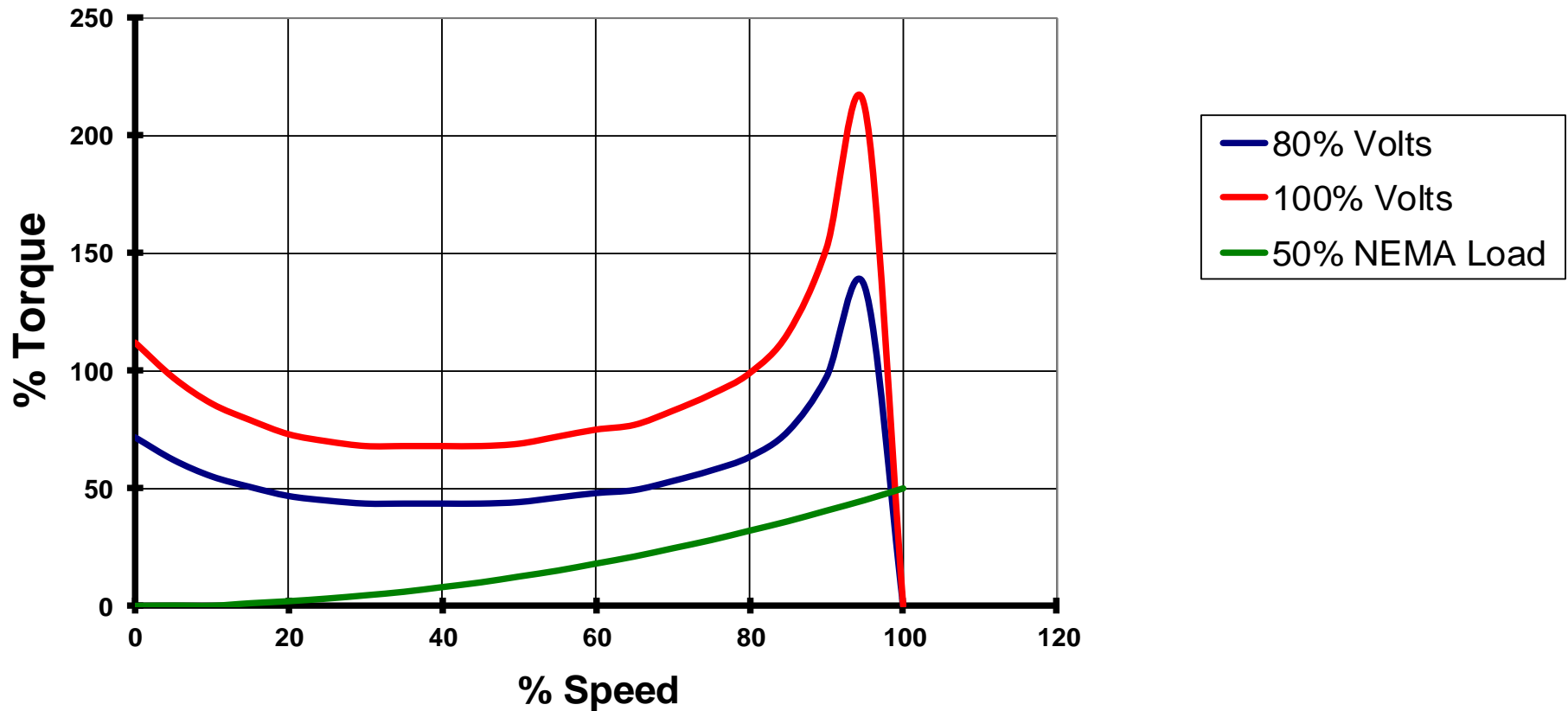
STARTING METHODS

Reduced Voltage - NEMA Load Curve



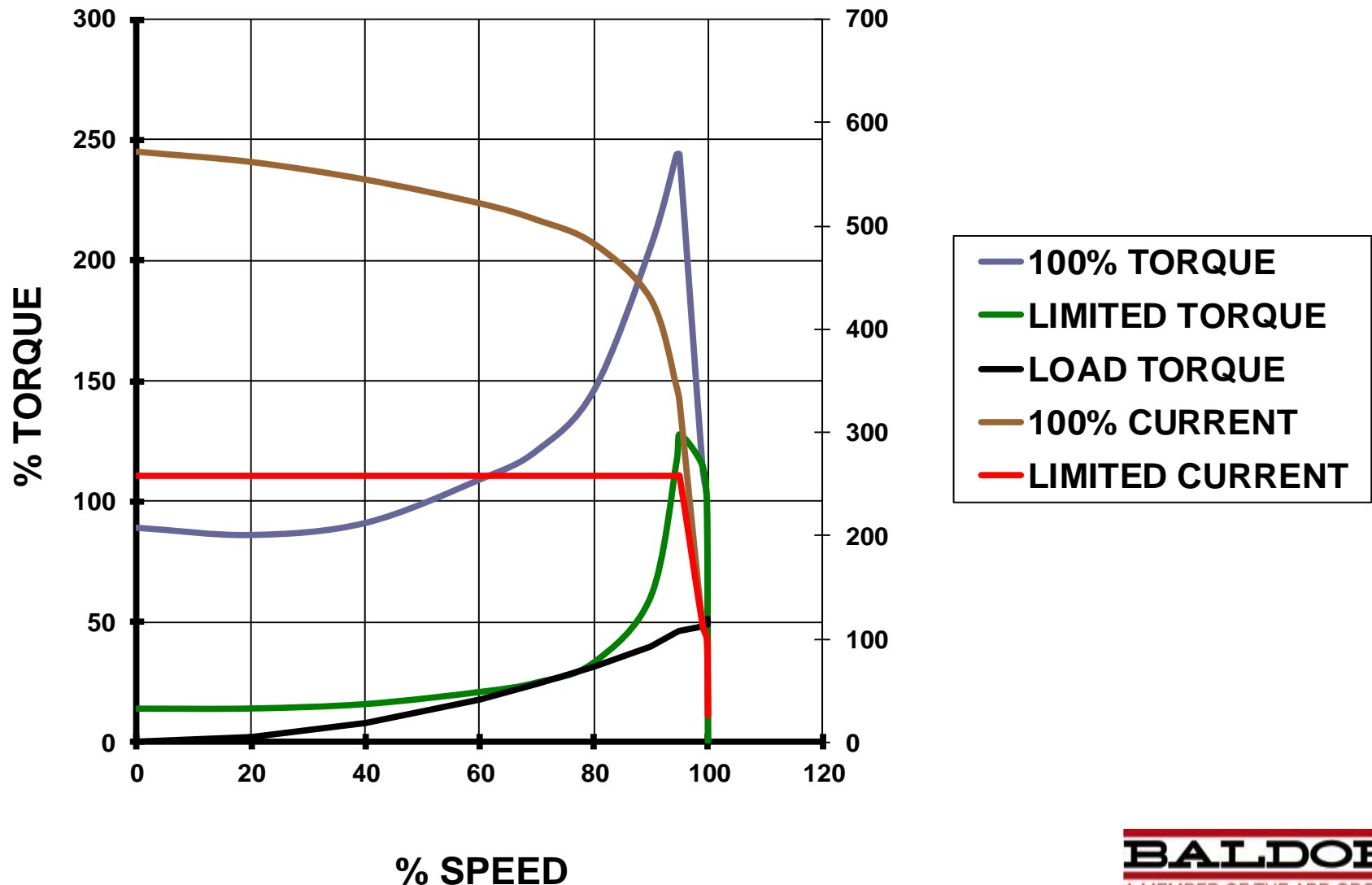
STARTING METHODS

Reduced Voltage - 50% NEMA Load Curve

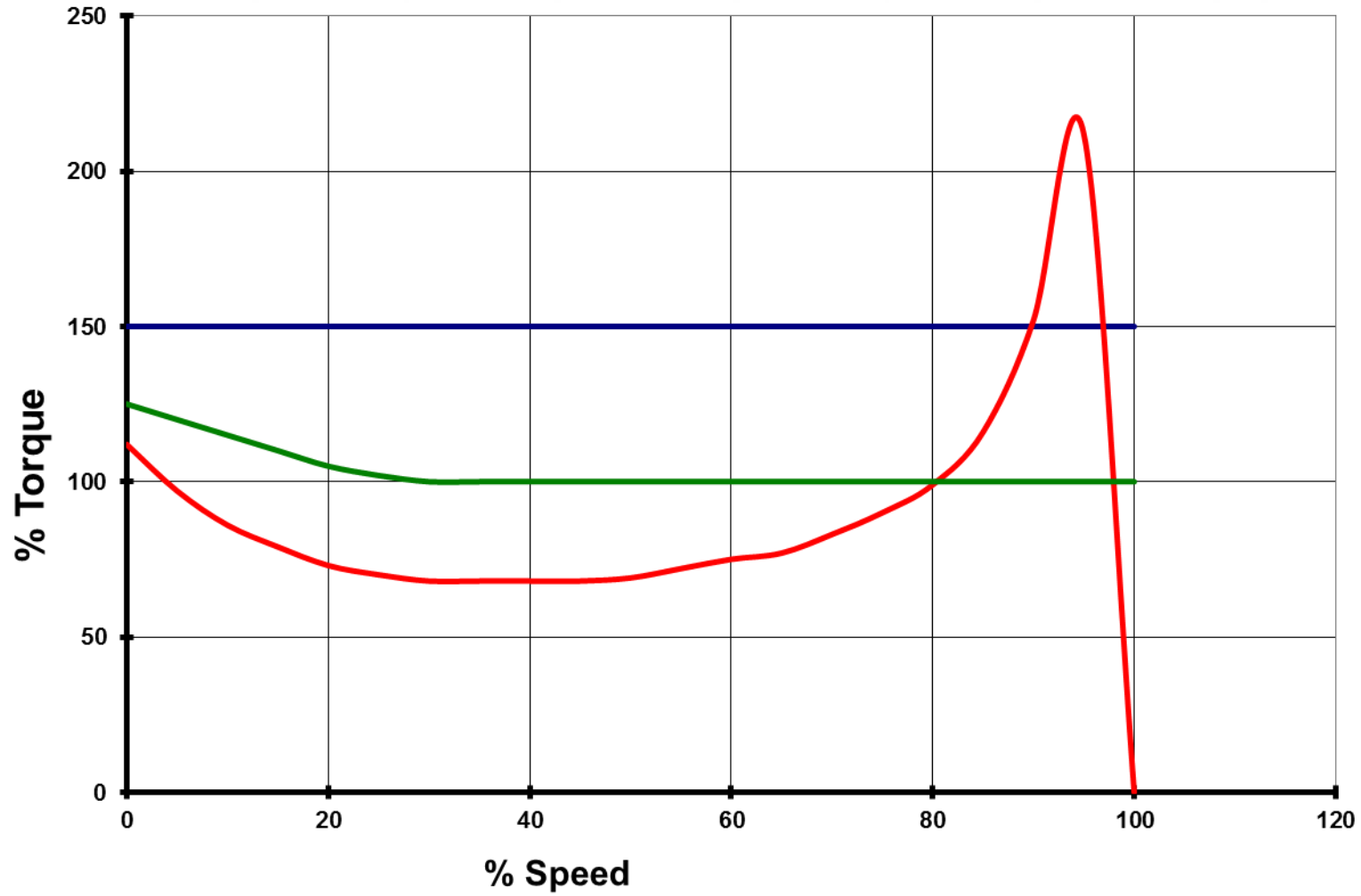


STARTING METHODS

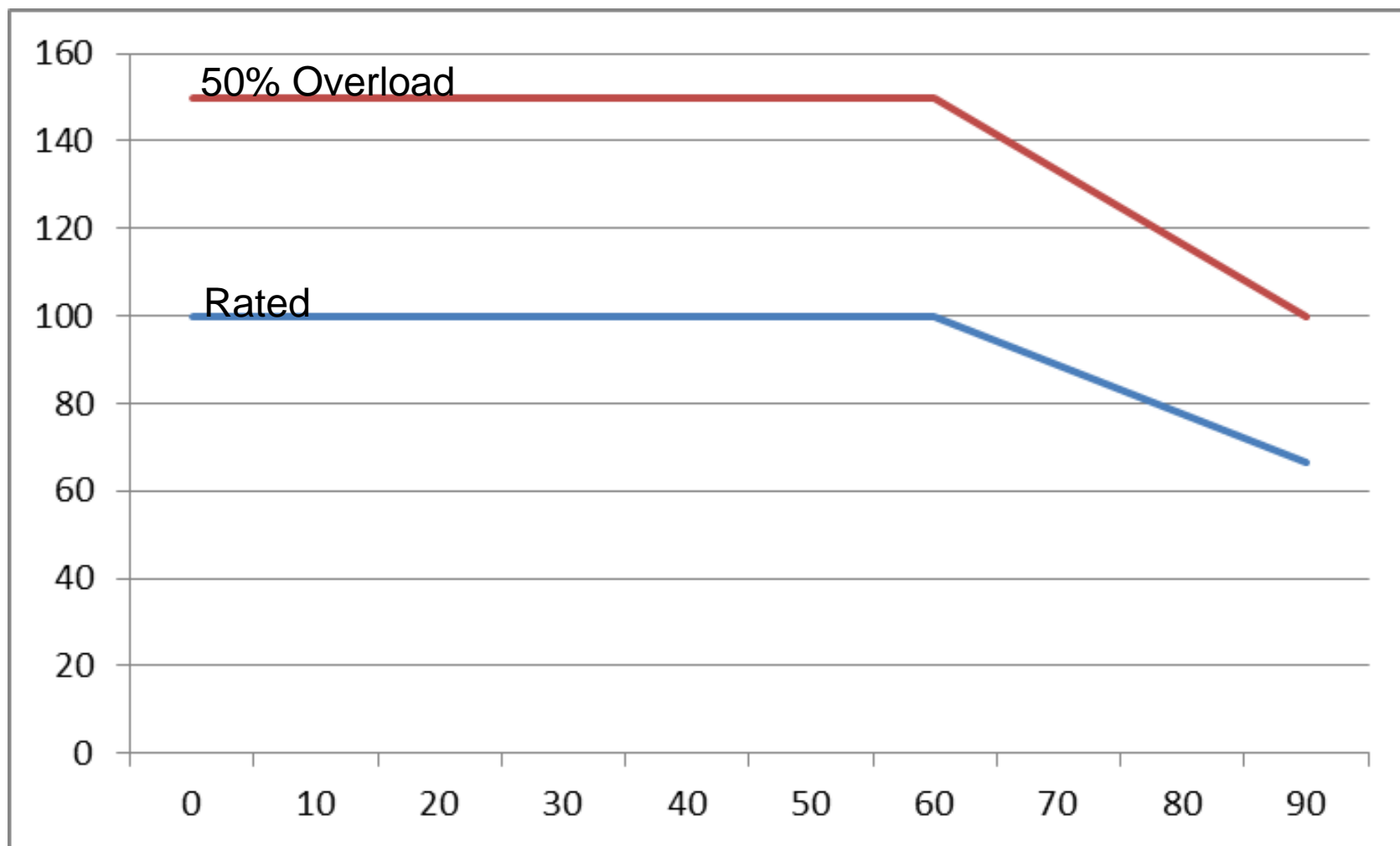
Current Limiting Soft-Start (250% FLA)



VFD Starting



AC Motor Torque on Variable Frequency



Thank you

Questions

Contact information

If you have further questions, please contact us

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