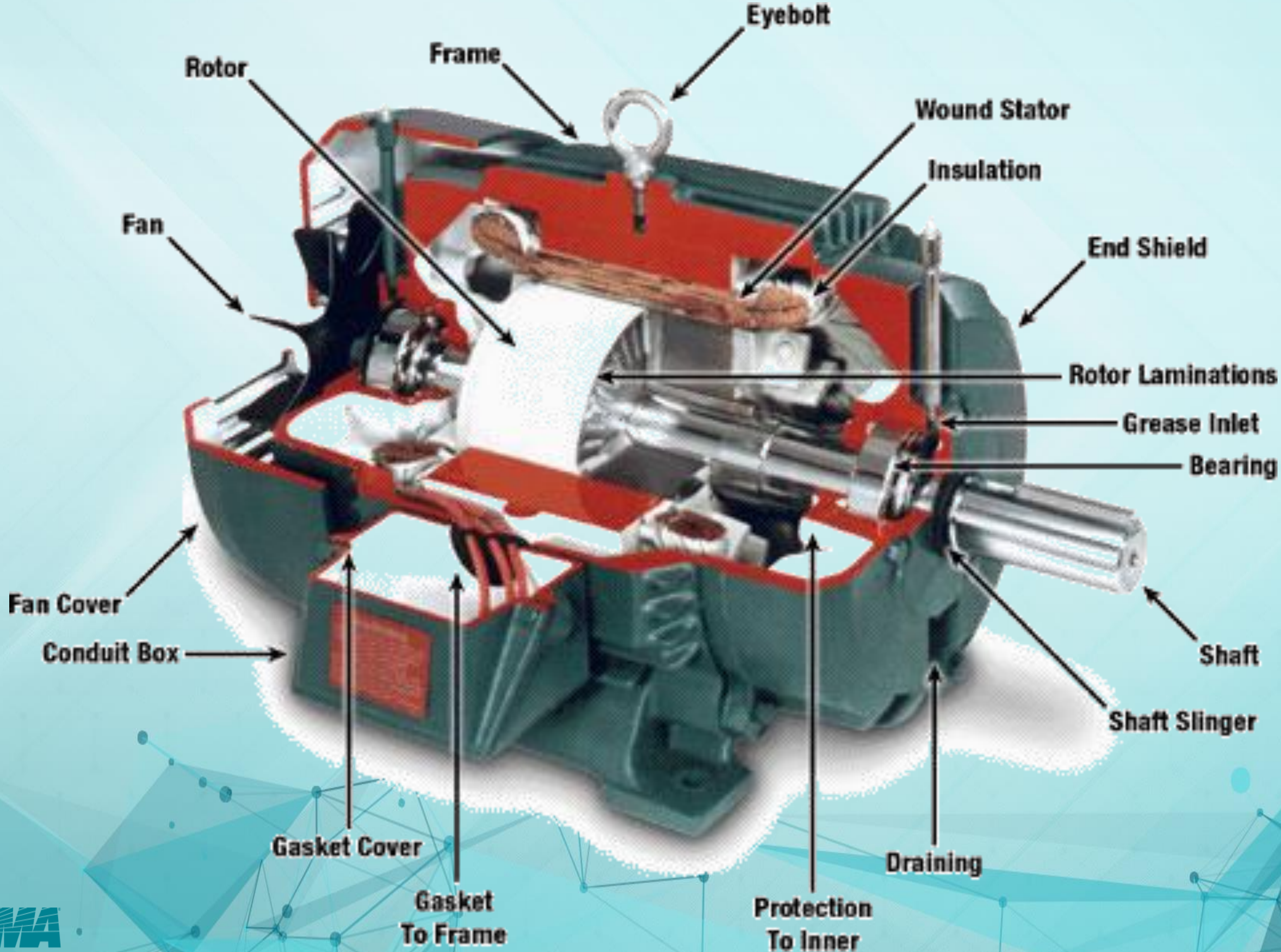
Alternating Current Motors in Detail

- Overview/Objectives:
  - Advanced motor component descriptions/details
  - Design, materials and construction
  - Starting and operation
  - Temperature effects on performance

AC Motor Components



Capacitors


BALDOR
EC1216A02
B M I
216-259 UF 125 VAC
BALDOR
EC1064A01
B M I
64-77 UF 125 VAC
USA
9605H


ECCOL II NO PCB'S
A COMBUSTIBLE FLUID
CSC S10000 AFC PROTECTED
12UF+/-6% 370VAC/B 50/60HZ
40/070/21 P2 SH 0223 70 C
325P126H37N23N4XT OC3012F12
ASM. IN MEXICO
ECCOL II NO PCB'S
A COMBUSTIBLE FLUID
CSC S10000 AFC PROTECTED
20UF+/-6% 370VAC/B 50/60HZ
40/070/21 P2 SH 0229 70 C
325P206H37N23N4XT OC3020F12
ASM. IN MEXICO

Centrifugal Switching

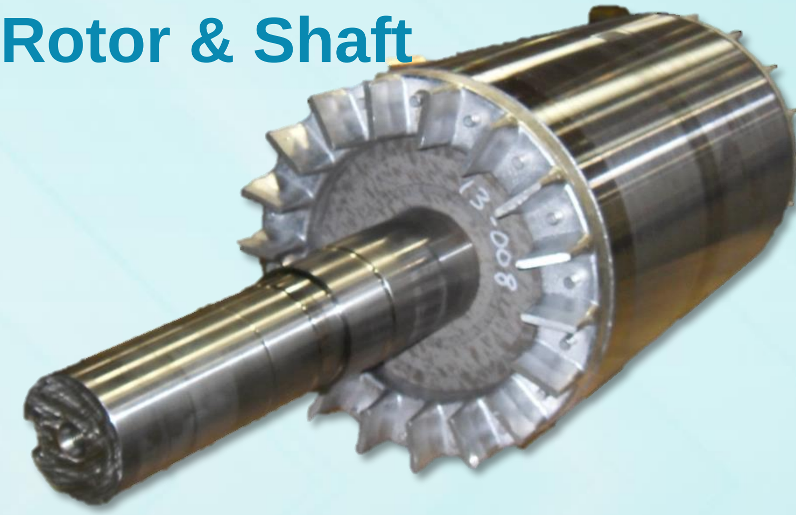
- Centrifugal Switching

Essential Components

Two Basic Parts of any AC Motor

Stator

Rotor & Shaft

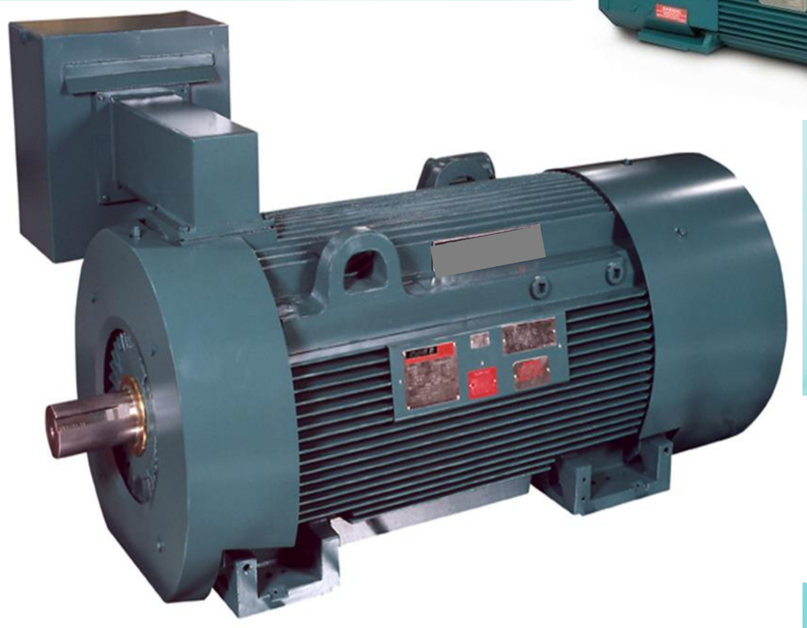


- Stator – Contains the windings within the steel laminations.
- The stator is not mechanically connected to the load

- 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

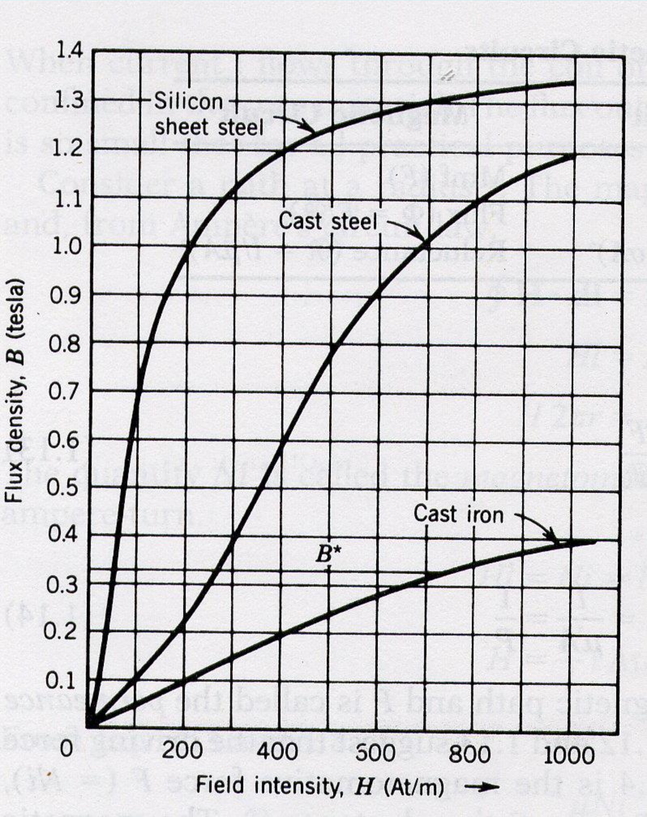
- Typical construction materials:
  - Steel Band: Carbon and Stainless Steel
  - Laminated
  - Cast Iron: Grey and Ductile Iron
  - Fabricated Steel



Stators

What is Electrical Steel?

- A special cold rolled steel with special coating on both sides (also called lamination steel)
- It has relatively low energy loss (in a motor this is called core loss)
- Mixture of ~ 3- 6% silicon
- Very efficient at generating/concentrating magnetic fields per given current flow



Microscopic view

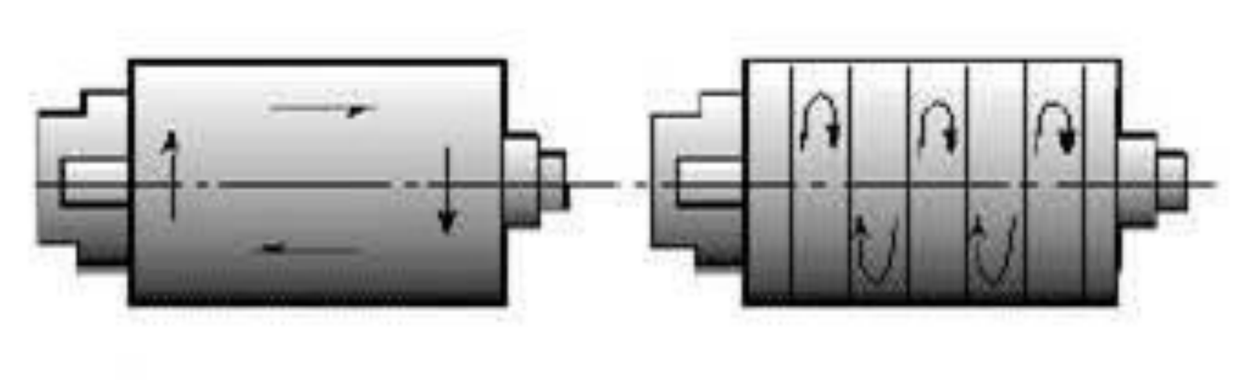
Why use Laminations?

Solid Core

Low resistance

Large eddy currents

Higher core losses

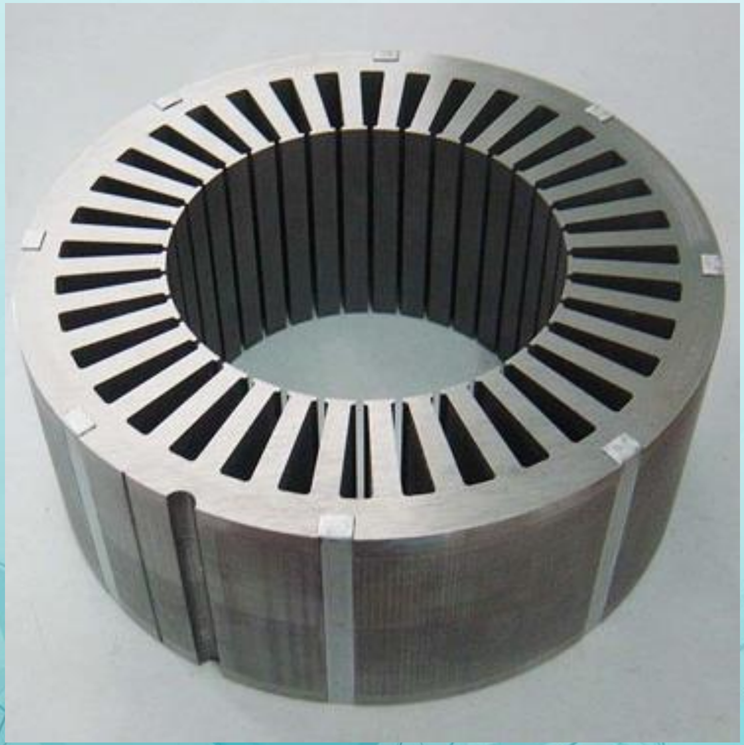


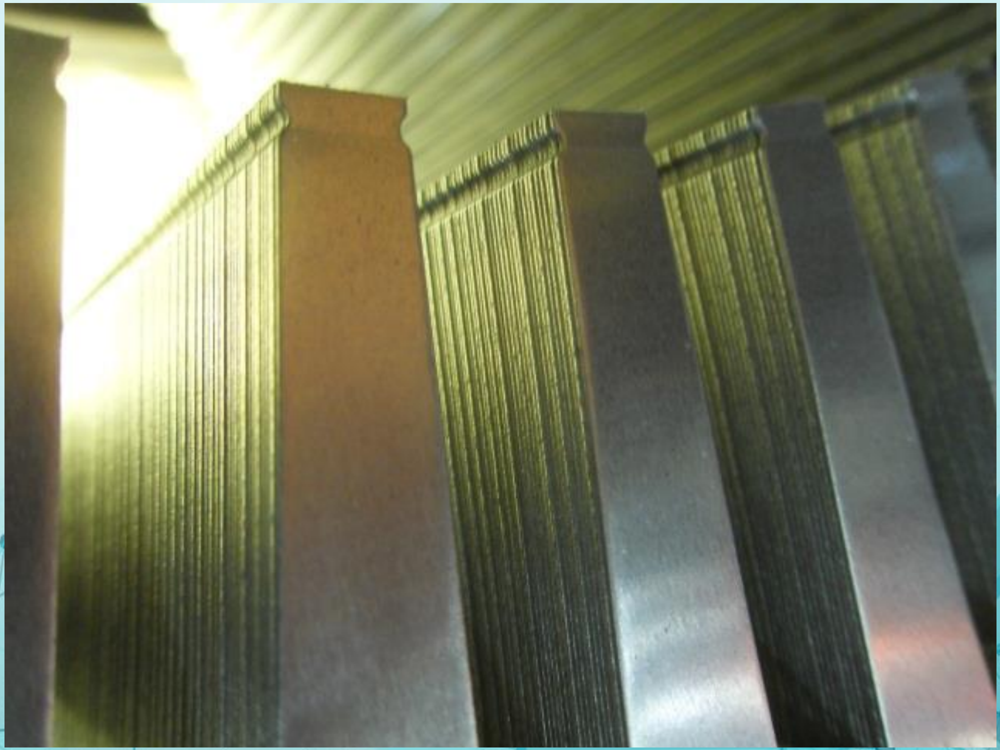
Laminated Core

High resistance

Small eddy currents

Lower core losses





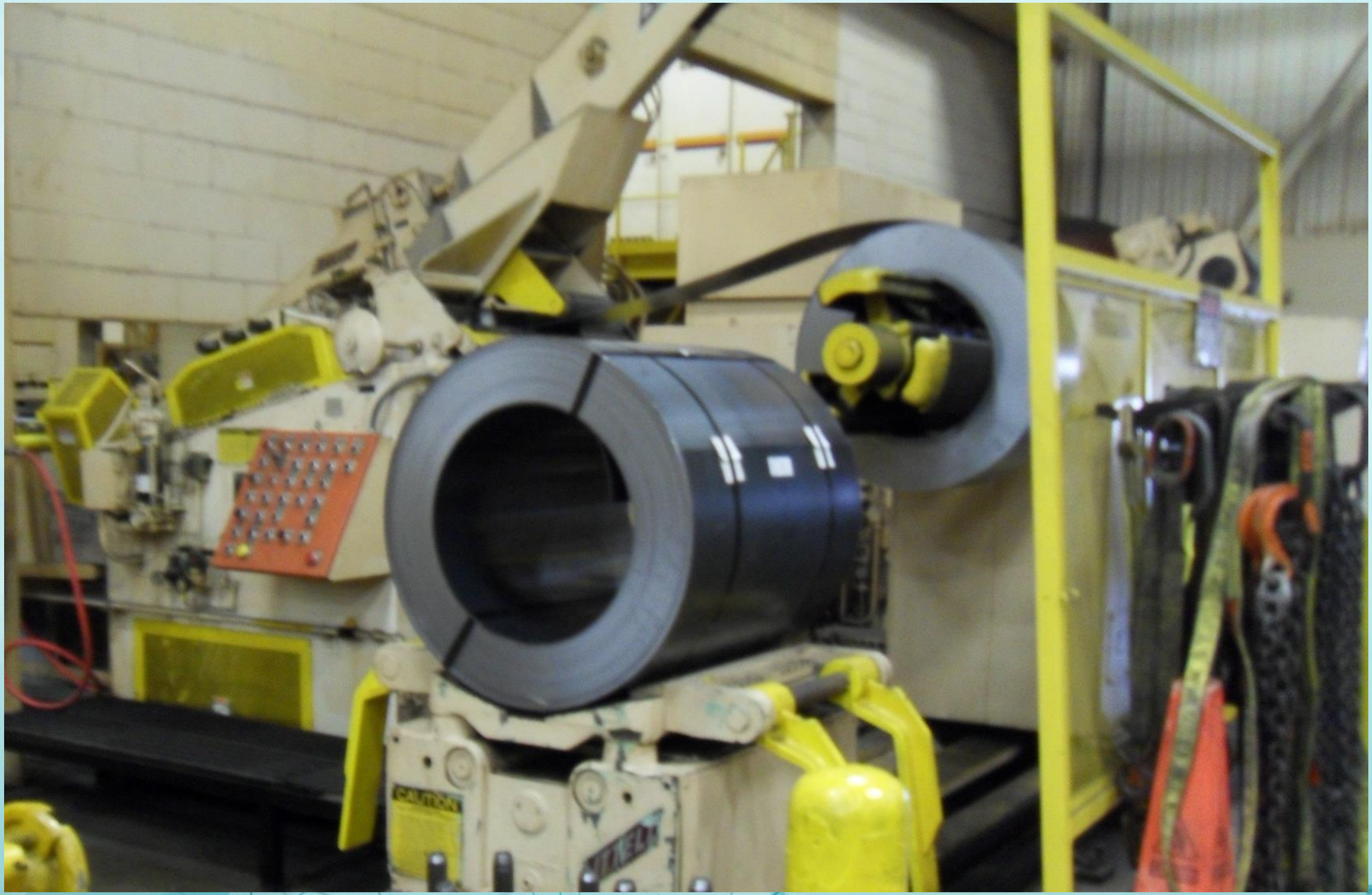
Steel Core Plates

- Core Plate C3
  - High Grade Varnish
  - Intended for Air-Cooled or Oil Immersed Cores
  - Approved for NEMA Class F Service*
  - Will Not Survive Lamination Annealing Process
  - Provides Less Resistance Between Laminations
- Core Plate C5
  - Oil and Heat Resistant Inorganic Coating
  - Suited for High Temperature Applications
  - Withstands Lamination Annealing Temperature, Welding Temperature and Typical Burn-Out Temperature

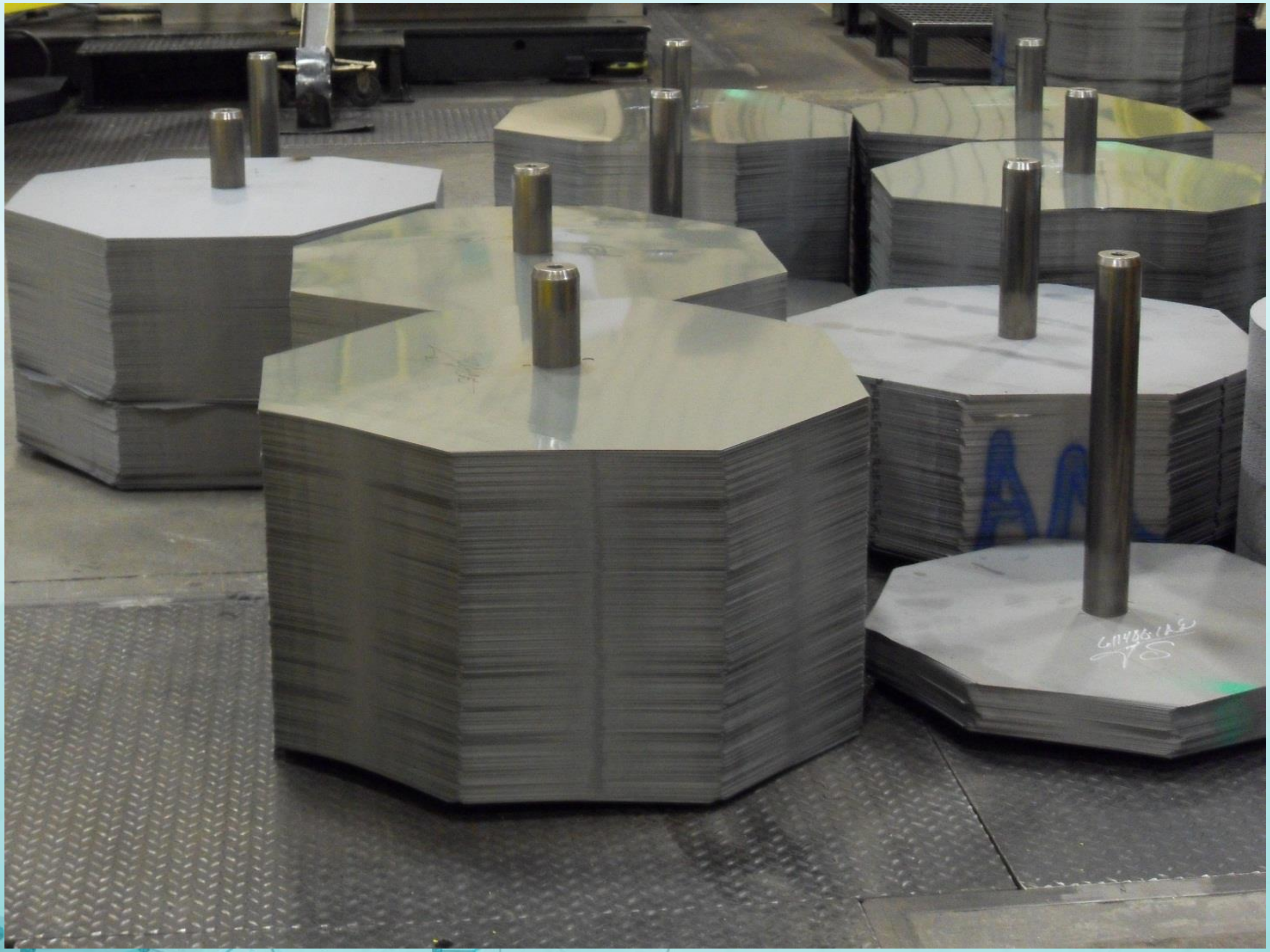
* Per NEMA Standard MG-1

Coil Steel

Punch Press

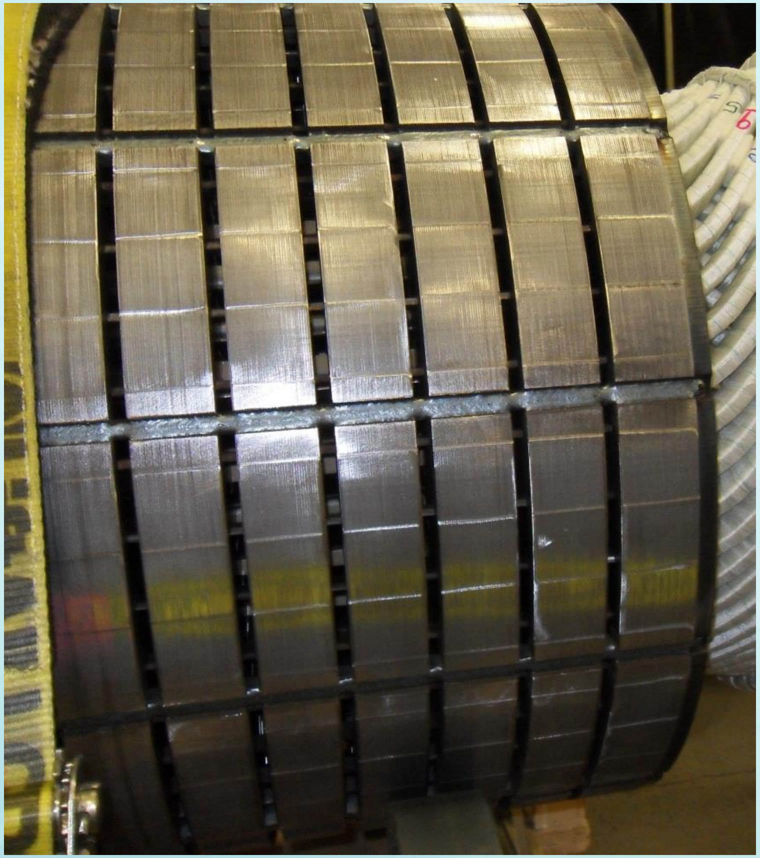


Lamination Blanks



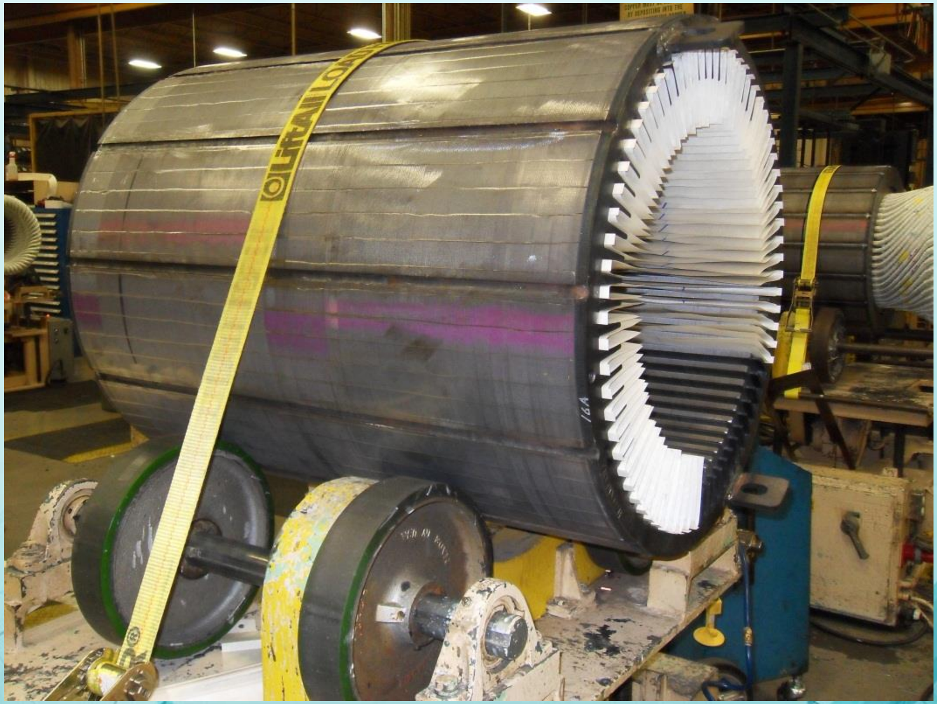
Stator Laminations and Rotor Blanks

Stator Core



Ducted

Solid

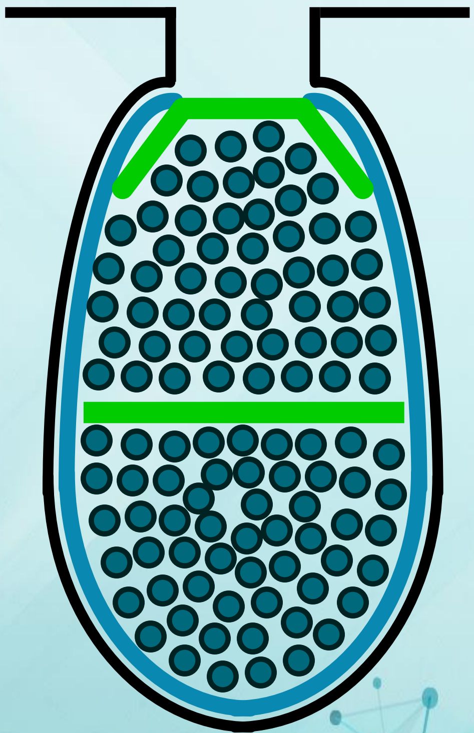


Stator Windings

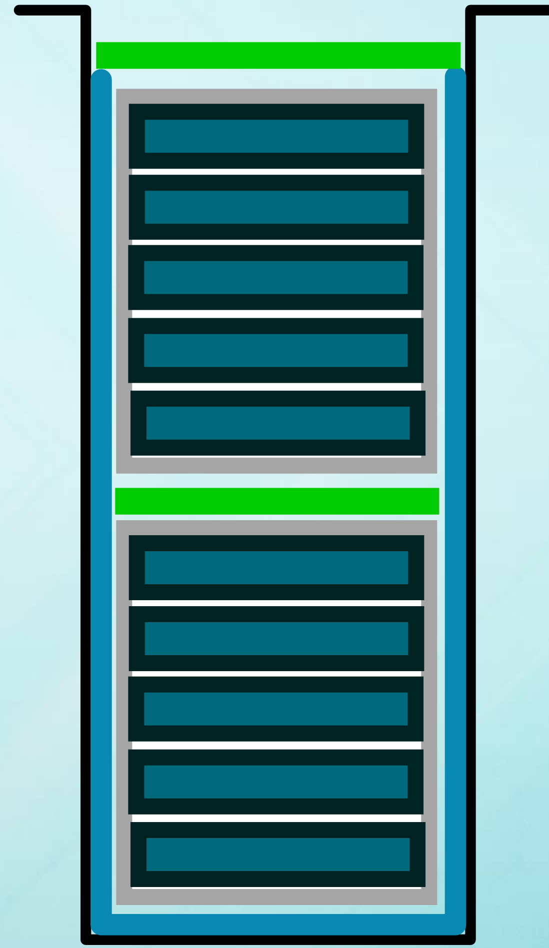
- All coils are manufactured with insulated copper wire.
- Form Wound or Random Wound
  - Number of Turns
  - Size/Shape of Wire
  - Insulation
    - Class F or Class H
    - Enamel or Glass over Enamel

Stator Windings

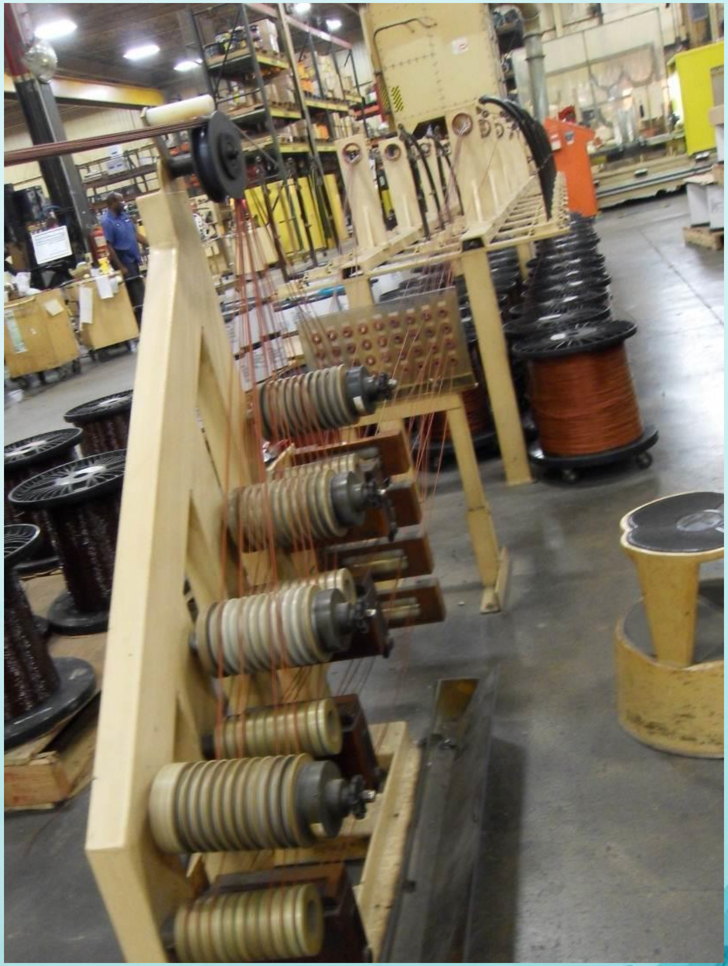
Random

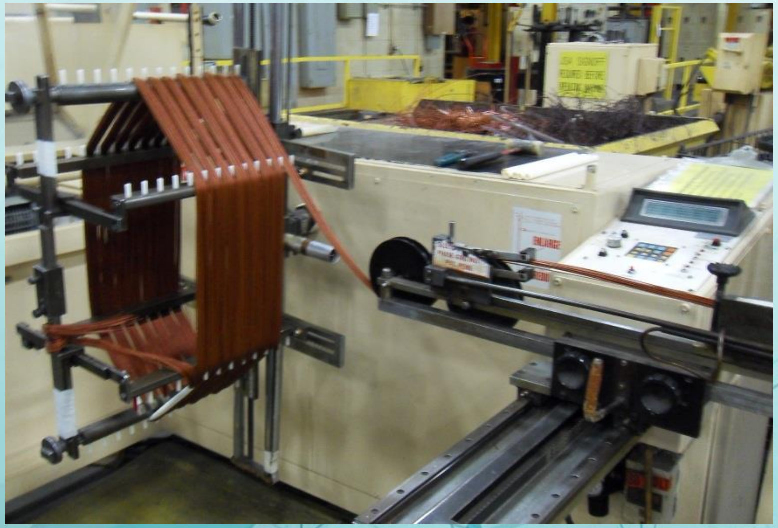


Form



Stator Windings - Random Wound





Stator Windings
Random Wound

Stator Windings
Form Wound

Stator Windings
Form Wound

Stator Windings Manufacturing Process

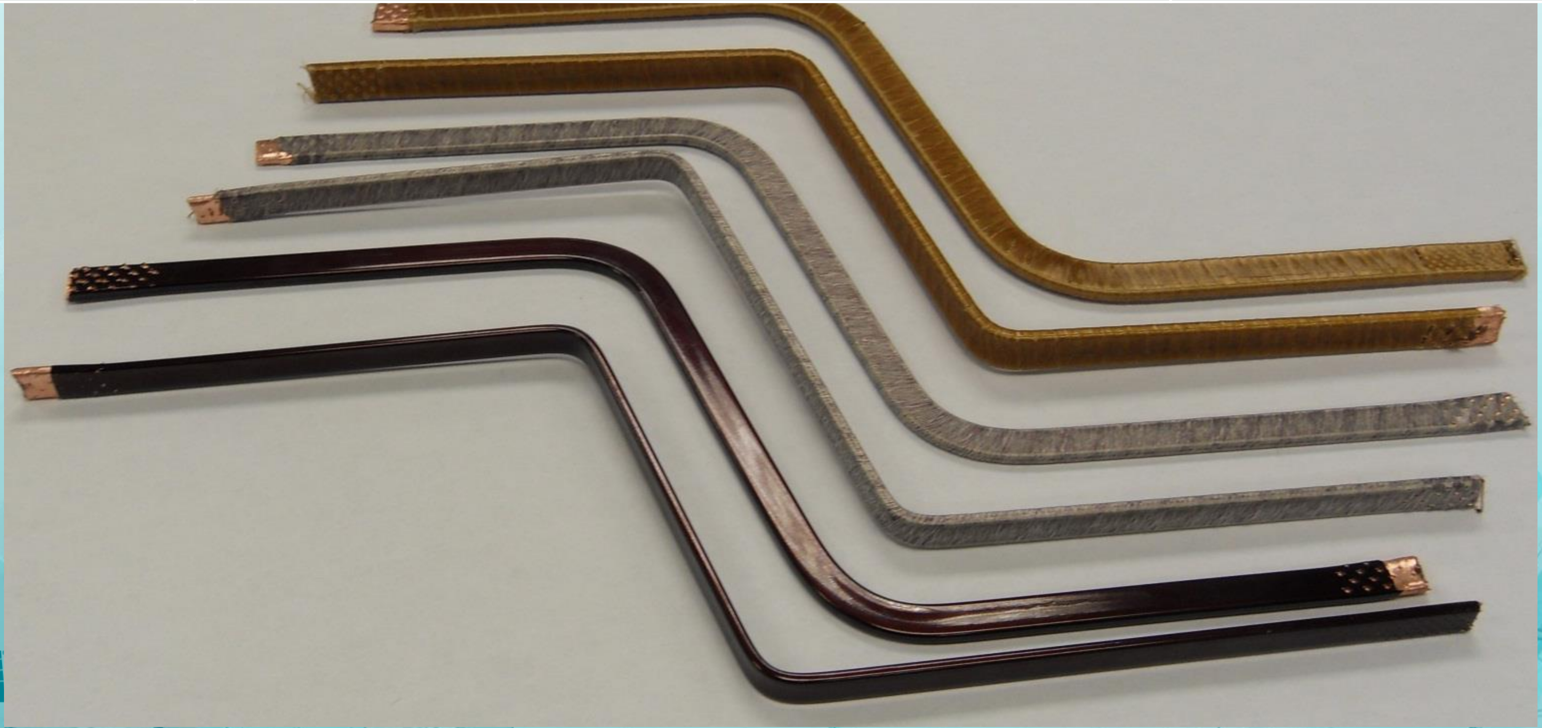
Stator Windings

Random Wound (Round Wire)
- Wind Wire in Phase Groups
- Insulate Stator Slot
- Insert Windings

Form Wound (Rectangular Wire)
- Wind Wire Into Individual Coils
- Shape Coils to Fit Stator Core
- Insulate Coils w/Nomex Tape
- Insulate Stator Slot
- Insert Windings
- Connect Coils in Phase Groups

Stator Windings
Magnetic Wire Types

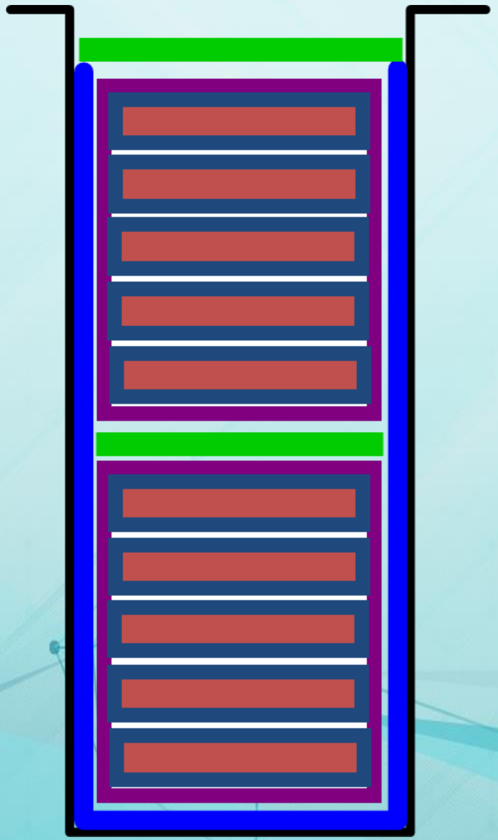
NEMA Class	Description	Insulation Thickness
H	Heavy Film, Single Glass, Epoxy Saturant, Copper Wire	0.013”
F	Heavy Film, Single Glass, Copper Wire	0.013”
F	Dual Film, Copper Wire	0.005”



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 in Random Wound Motors

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

Insulation Systems Random Wound

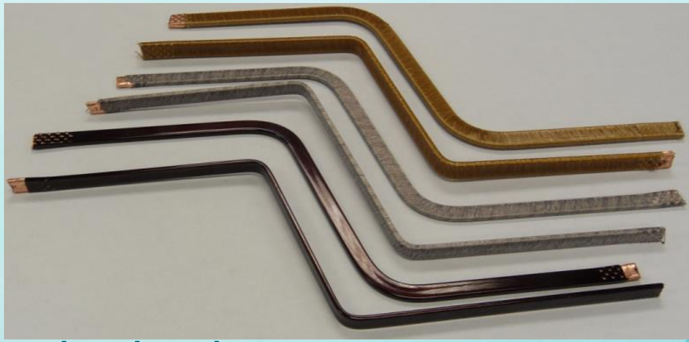
Insulation Systems in Form Wound Motors

- 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 Standard MW1000)
- Surge (IEEE Standard 522)
  - Individual Coils
  - Wound Stator Before Connect
  - Wound Stator After Connect
- High potential test (NEMA Standard MG1-20,
  IEEE Standard 112)
- Added Testing for Enduraseal
  - One Minute Megger Dry @ 500VDC (IEEE Standard 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
    - Standard for RPM AC motors

* Ref. NEMA Standard MG-1

Temperature Rise per NEMA MG1-2011

20.8.1 Machines with a 1.0 Service Factor at Rated Load

Item	Machine Part	Method of Temperature Determination	Temperature Rise, Degrees C Class of Insulation System 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

Item	Machine Part	Method of Temperature Determination	Temperature Rise, Degrees C Class of Insulation System 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.)

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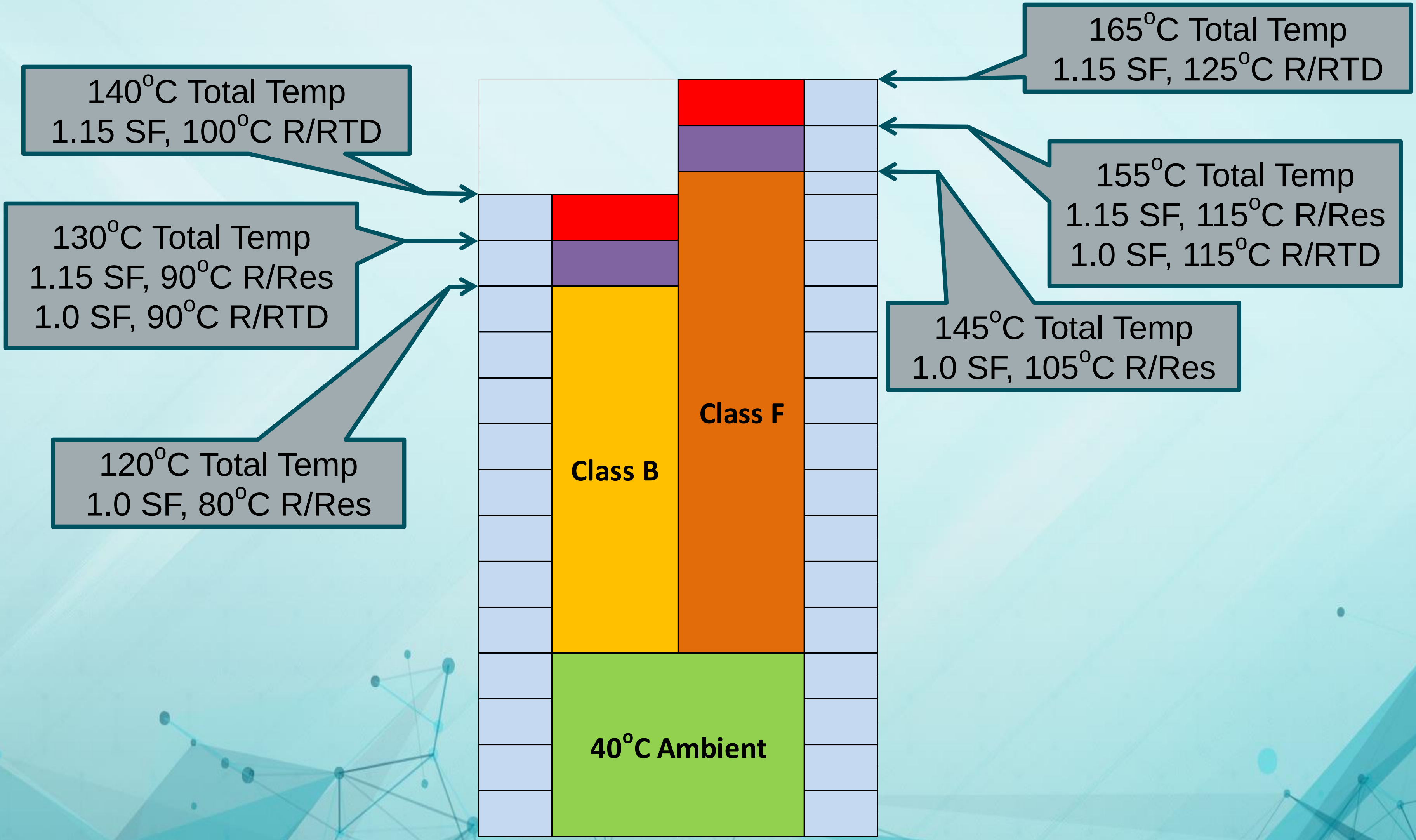
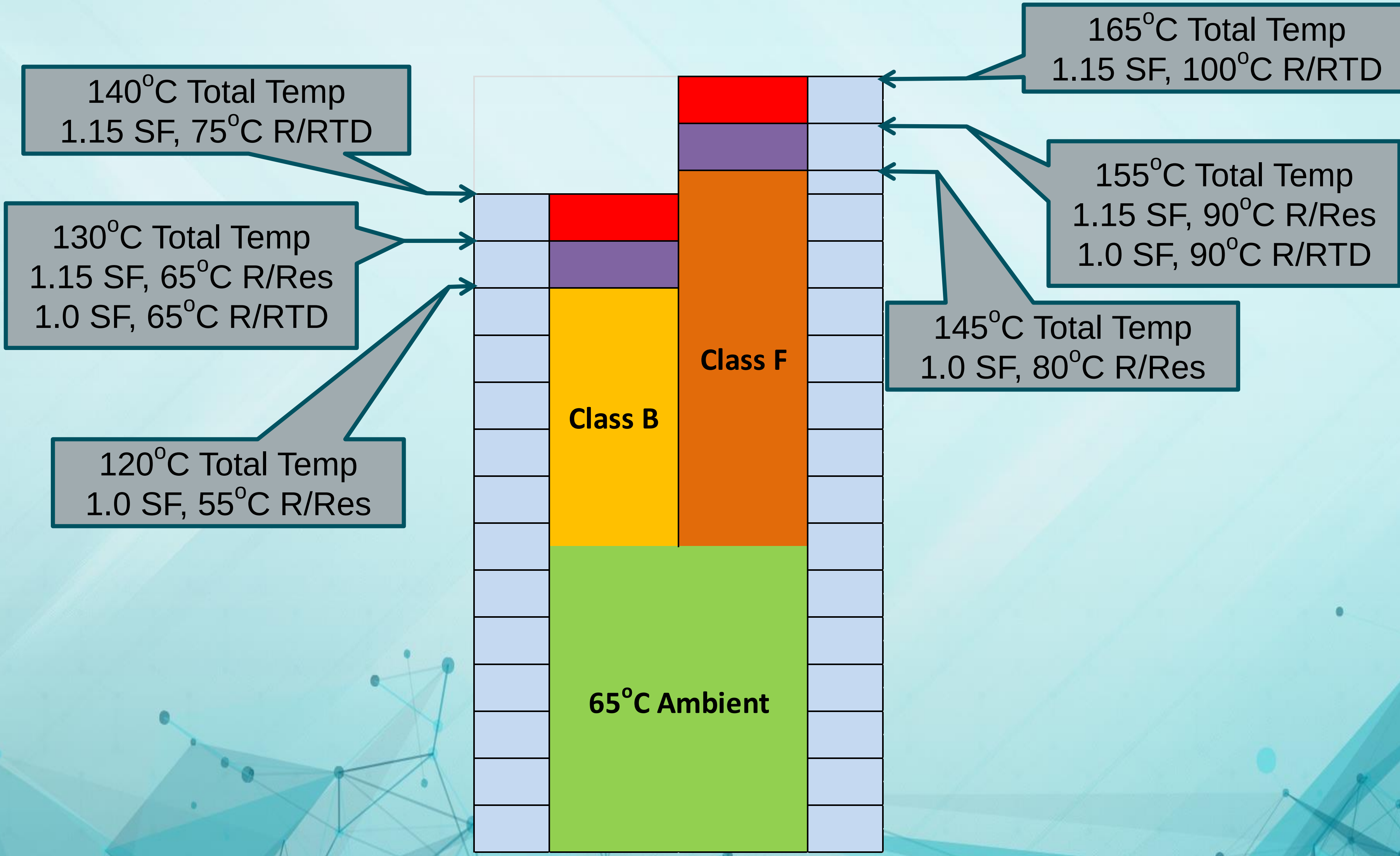
Temperature Rise & Insulation Class Summary



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

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

$$\mathbf{80 \times 0.9 = 72}$$

Therefore, motor must be sized for 72^{o}C Rise by Res at full load for B Rise

Temperature Effect on Motor Life

- Insulation life
  - Heat is the #1 cause of reduced insulation life
  - For every 10^0 C above rated temperature cuts life by 50%
  - Common overheating sources beyond basic design
    - Overload
    - Inadequate ventilation
    - Dirt buildup
    - Phase unbalance
    - High/Low voltage
- Bearing life
  - Bearing temperatures are typically 50-75% of winding temperature
  - Temperature impact (+ 10^0 C = 50% life)

NEMA

Quiz

- How are starting capacitor circuits typically disconnected once the motor starts?
- Why are rotors and stators typically made of laminated steel?
- What are the two common types of stator windings?
- Every 10^0C reached above rated temperature decreases motor life by what %?

- Centrifugal switch
- Lower electrical losses than solid
- Form wound, random wound
- 50%