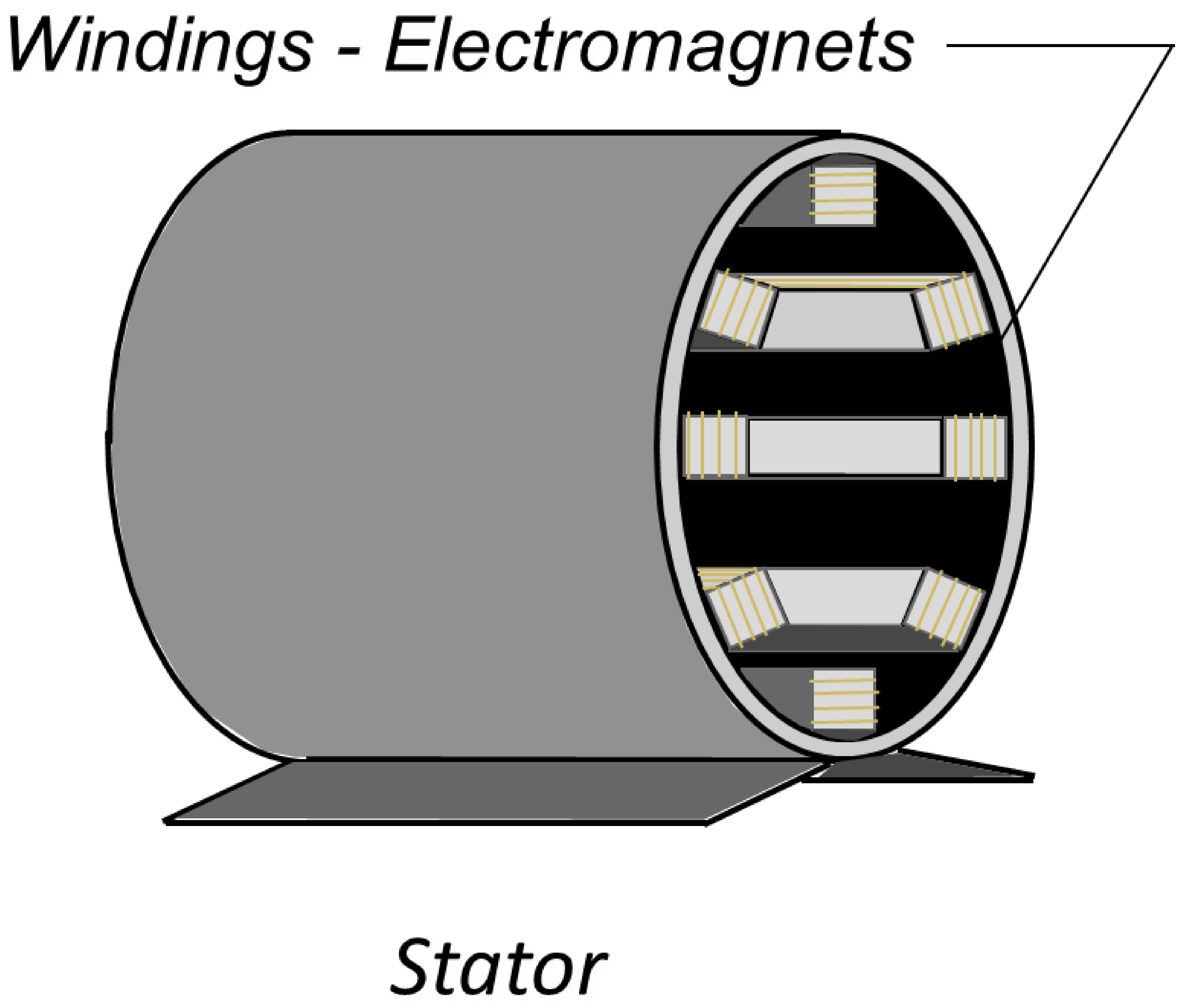
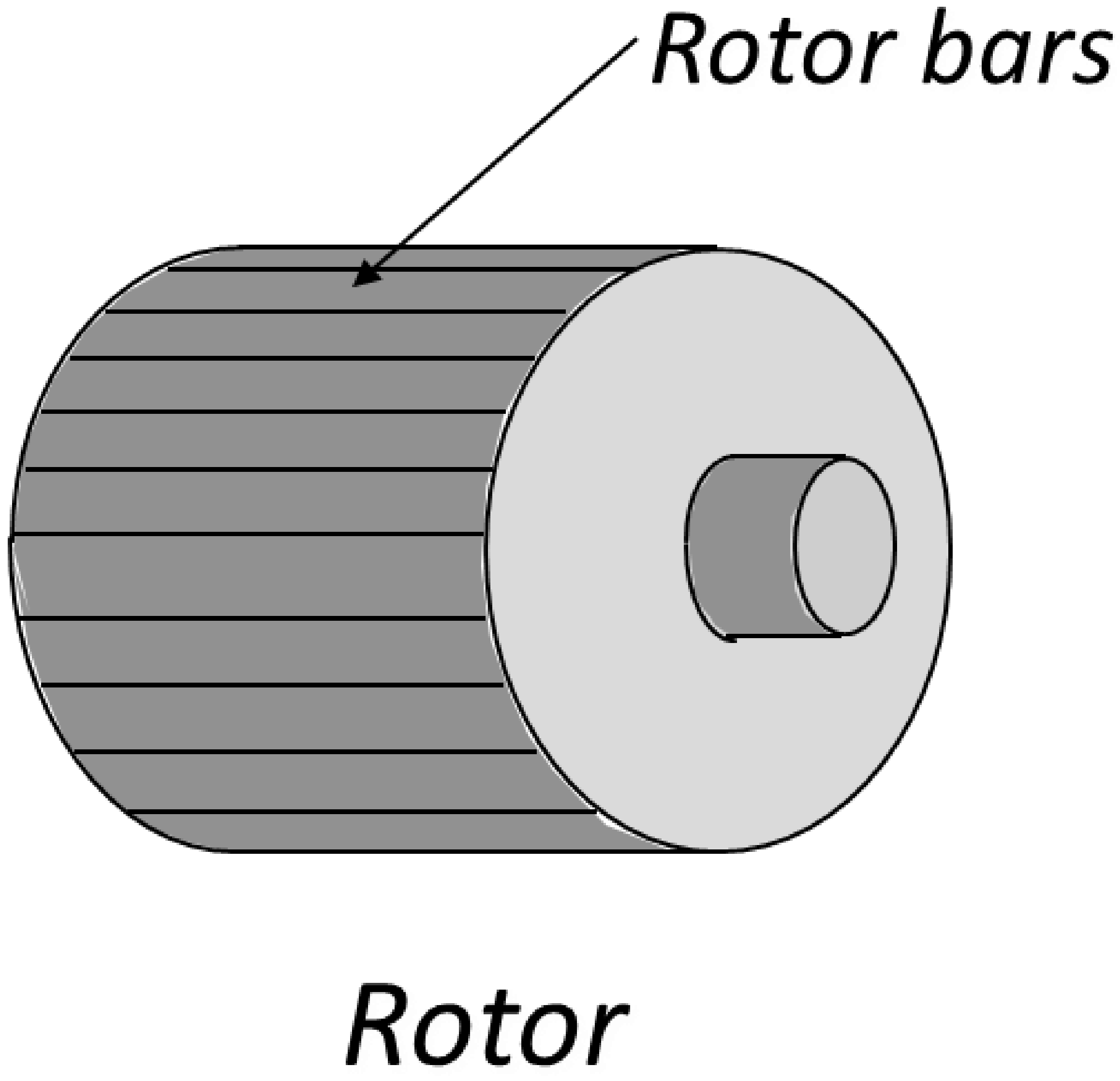
Electric Motors 101

Three Phase Motor Construction





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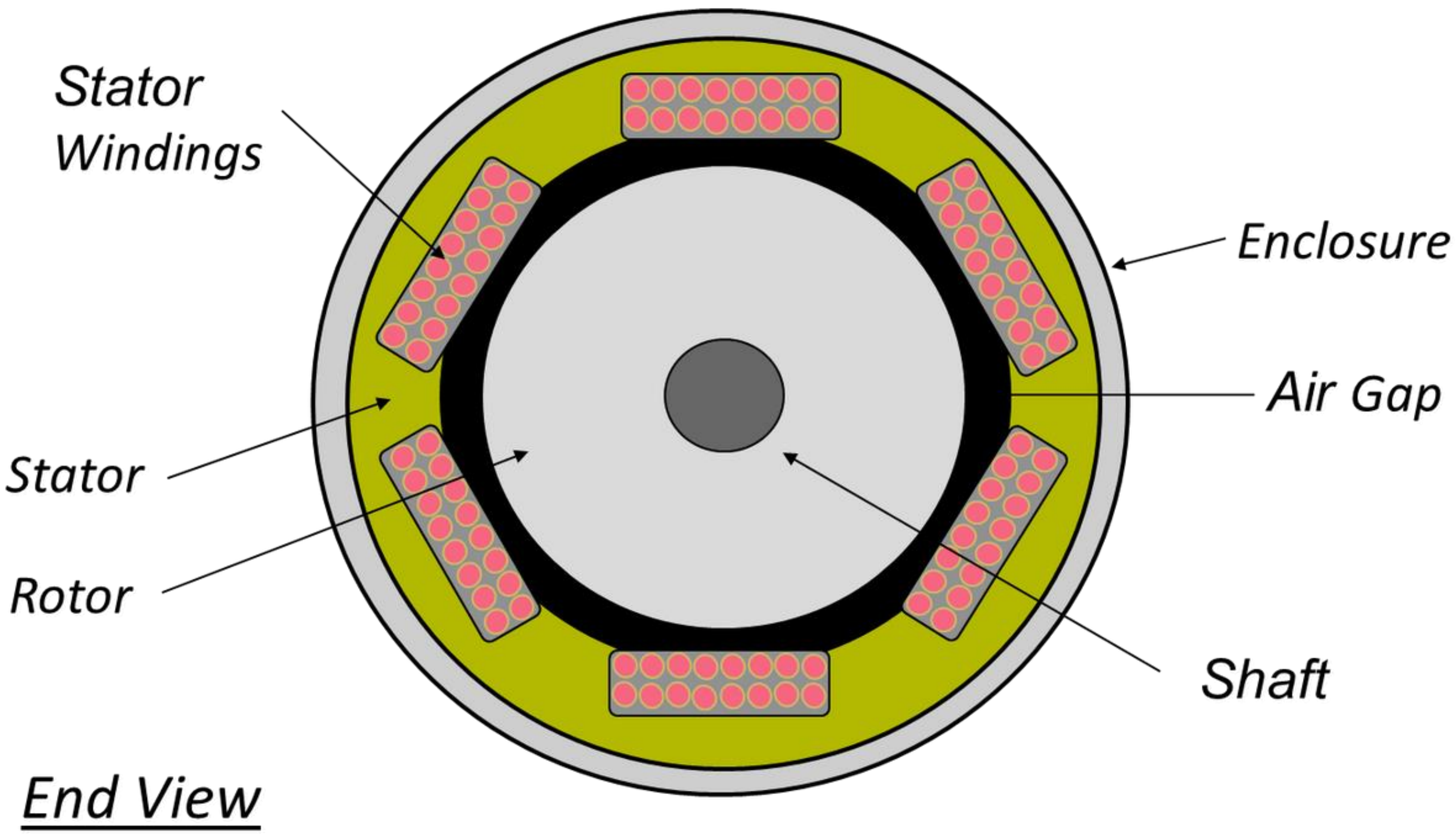
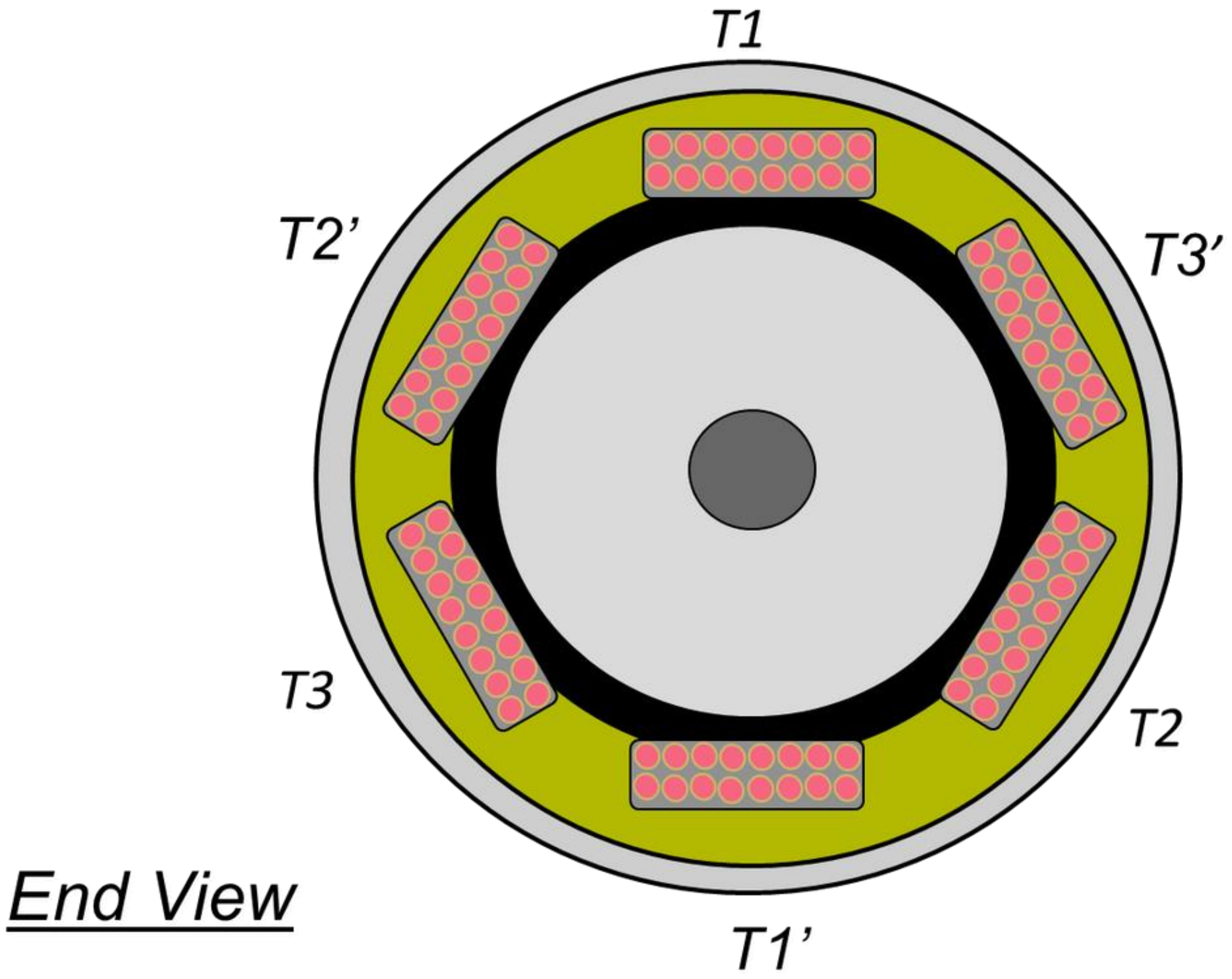
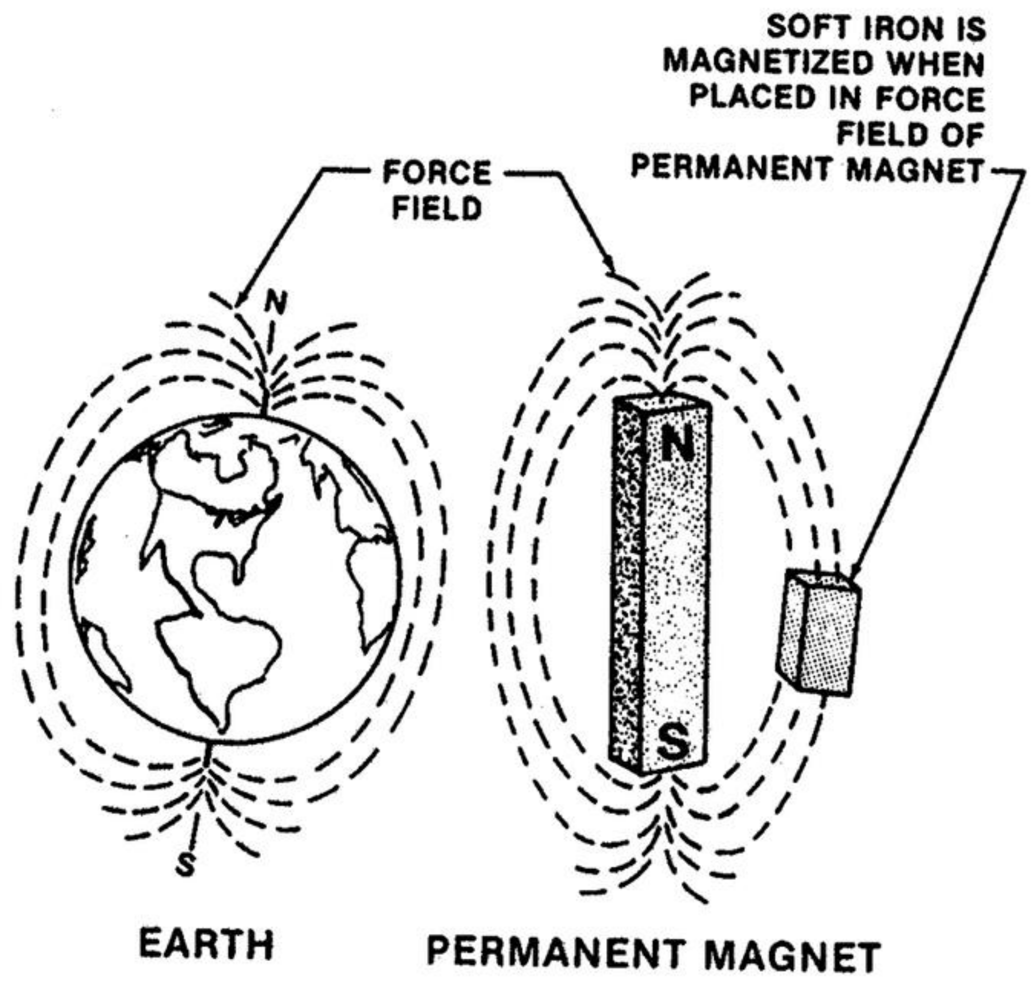
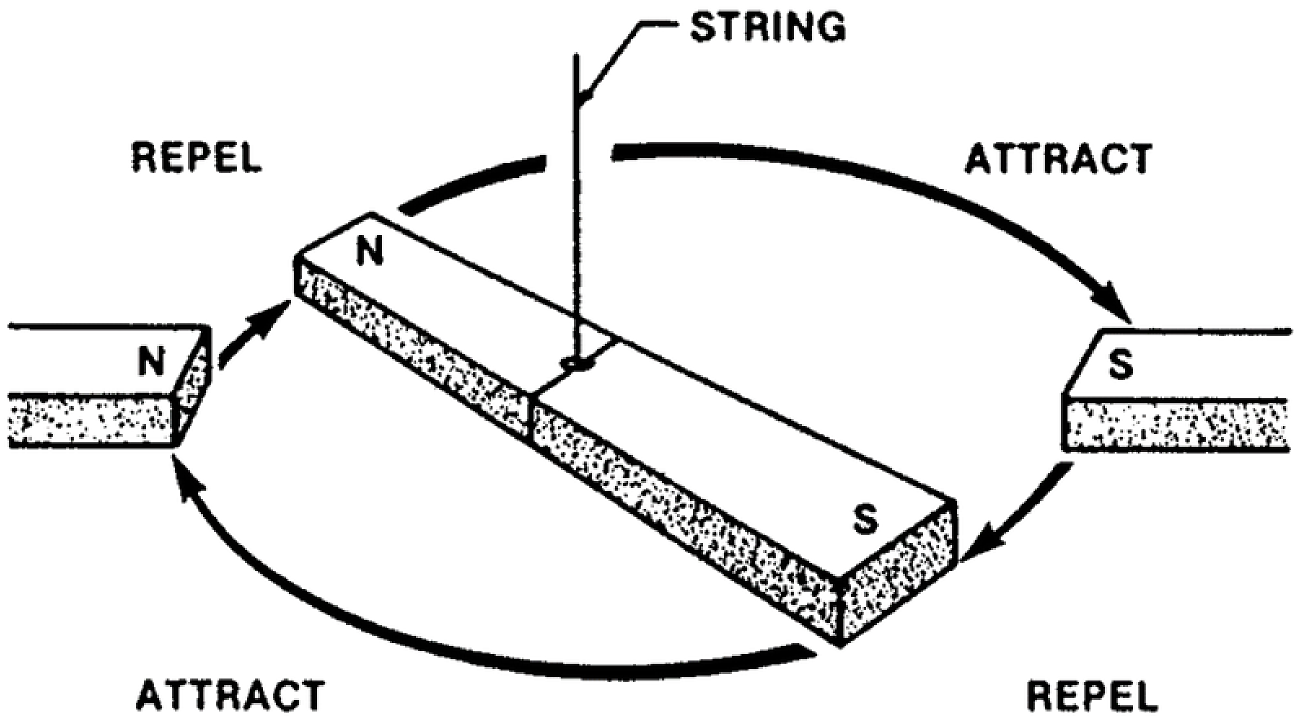


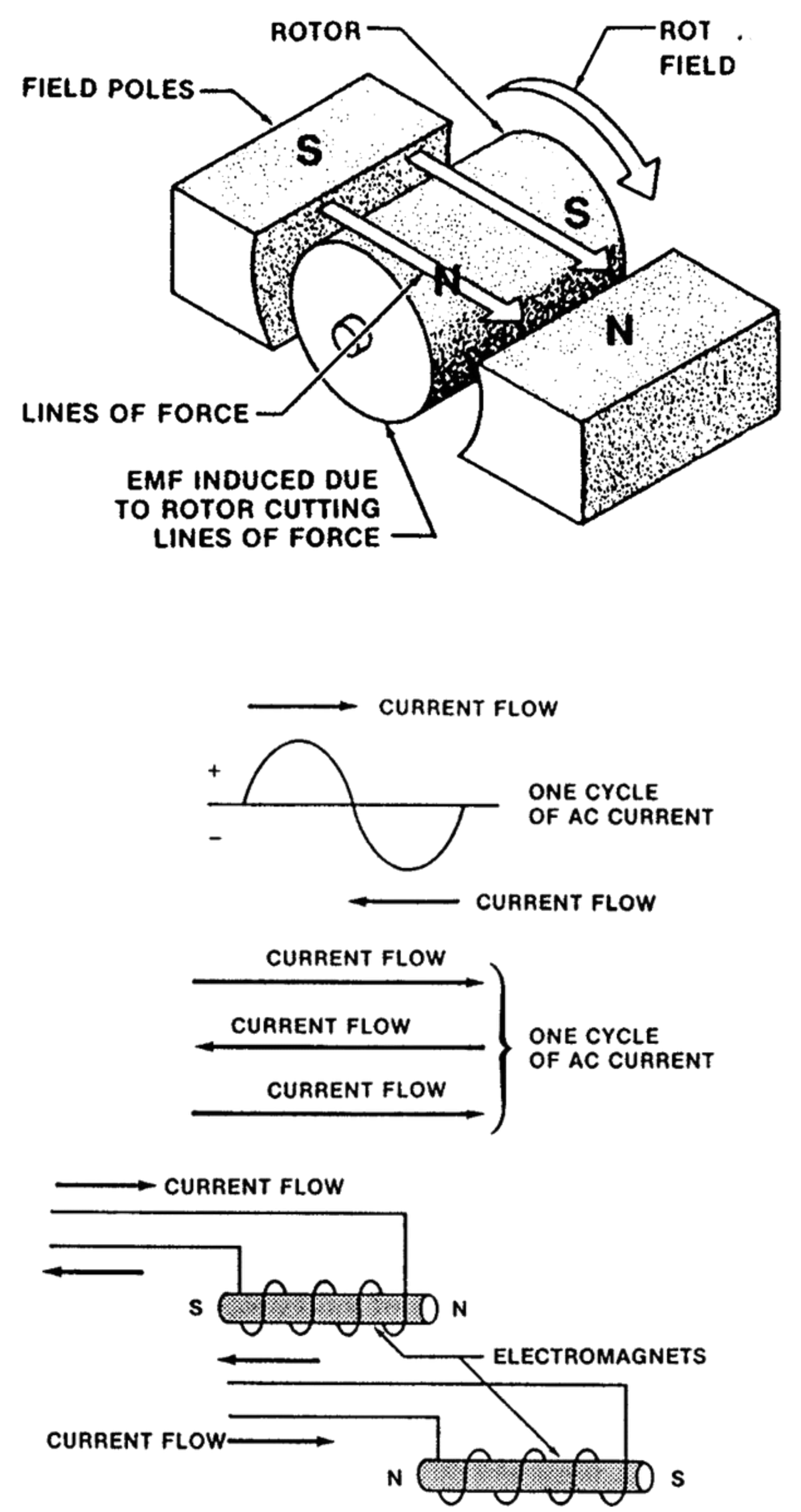


Motor Operation

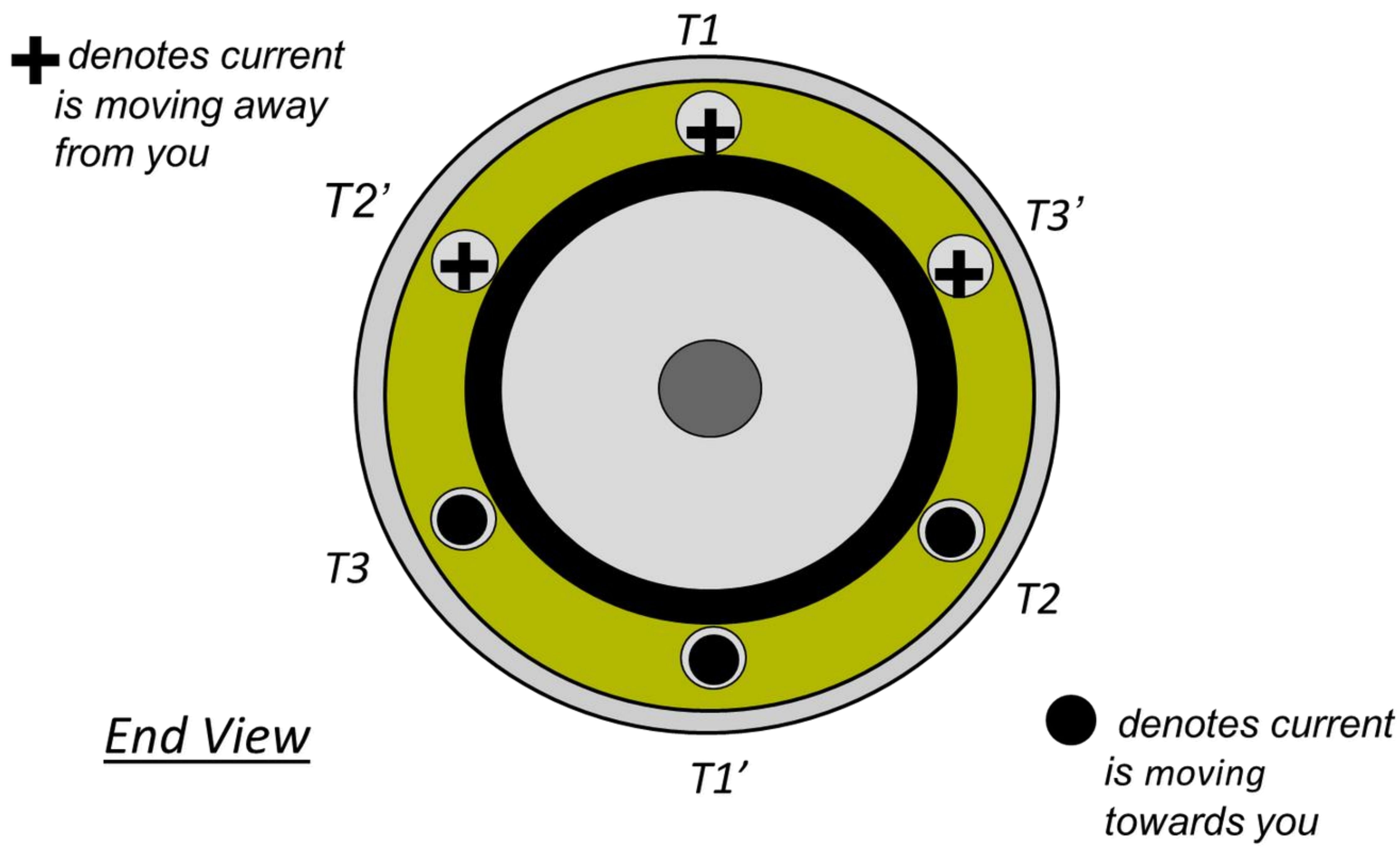




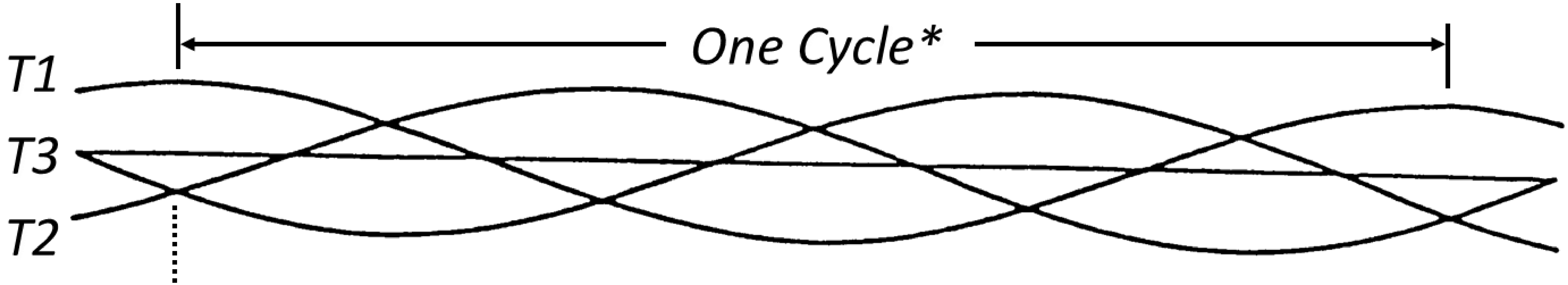
Motor Operation

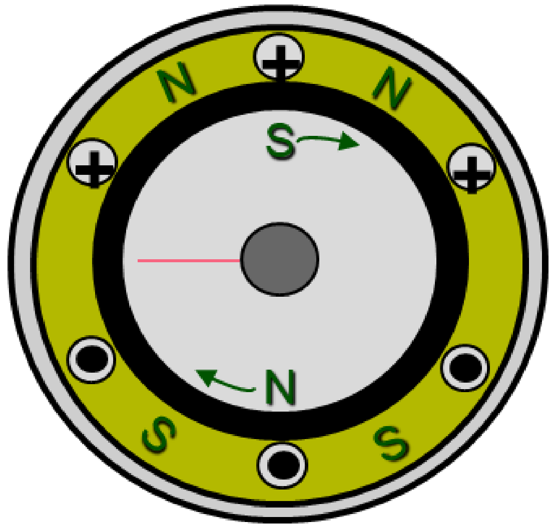


Three Phase Motor Construction

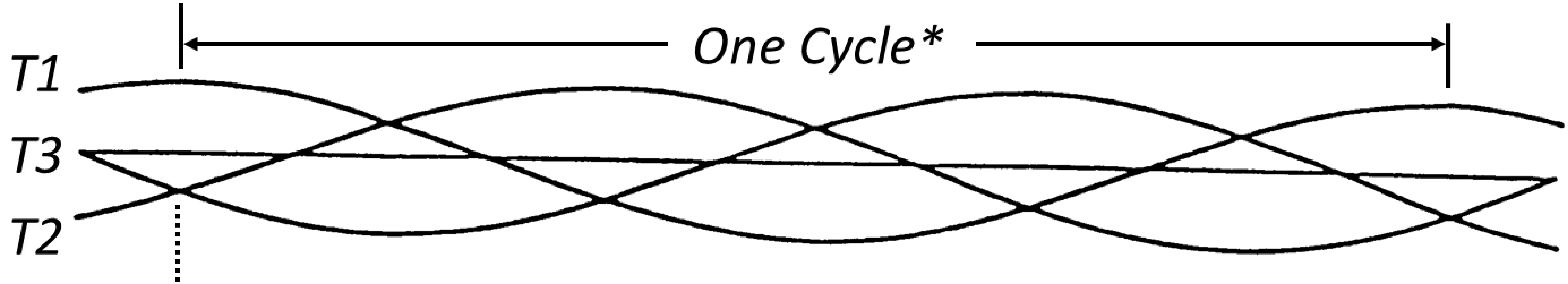


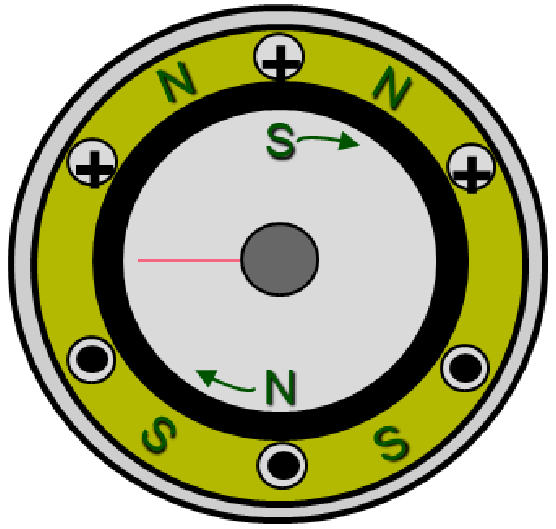
Rotation of the Motor

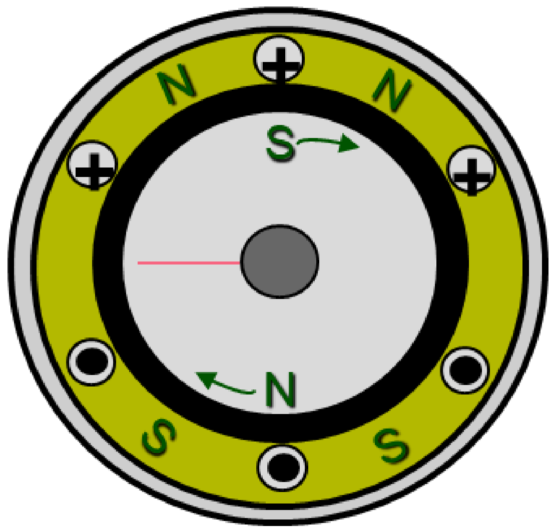




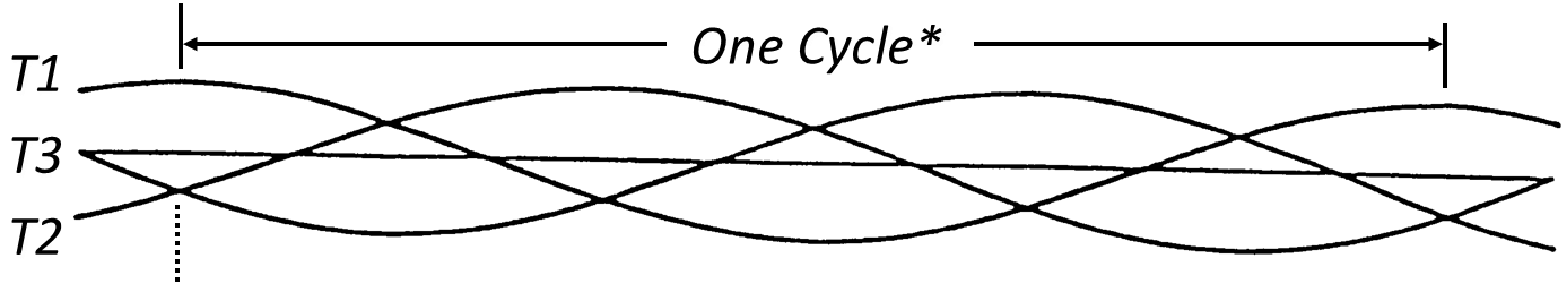
Rotation of the Motor

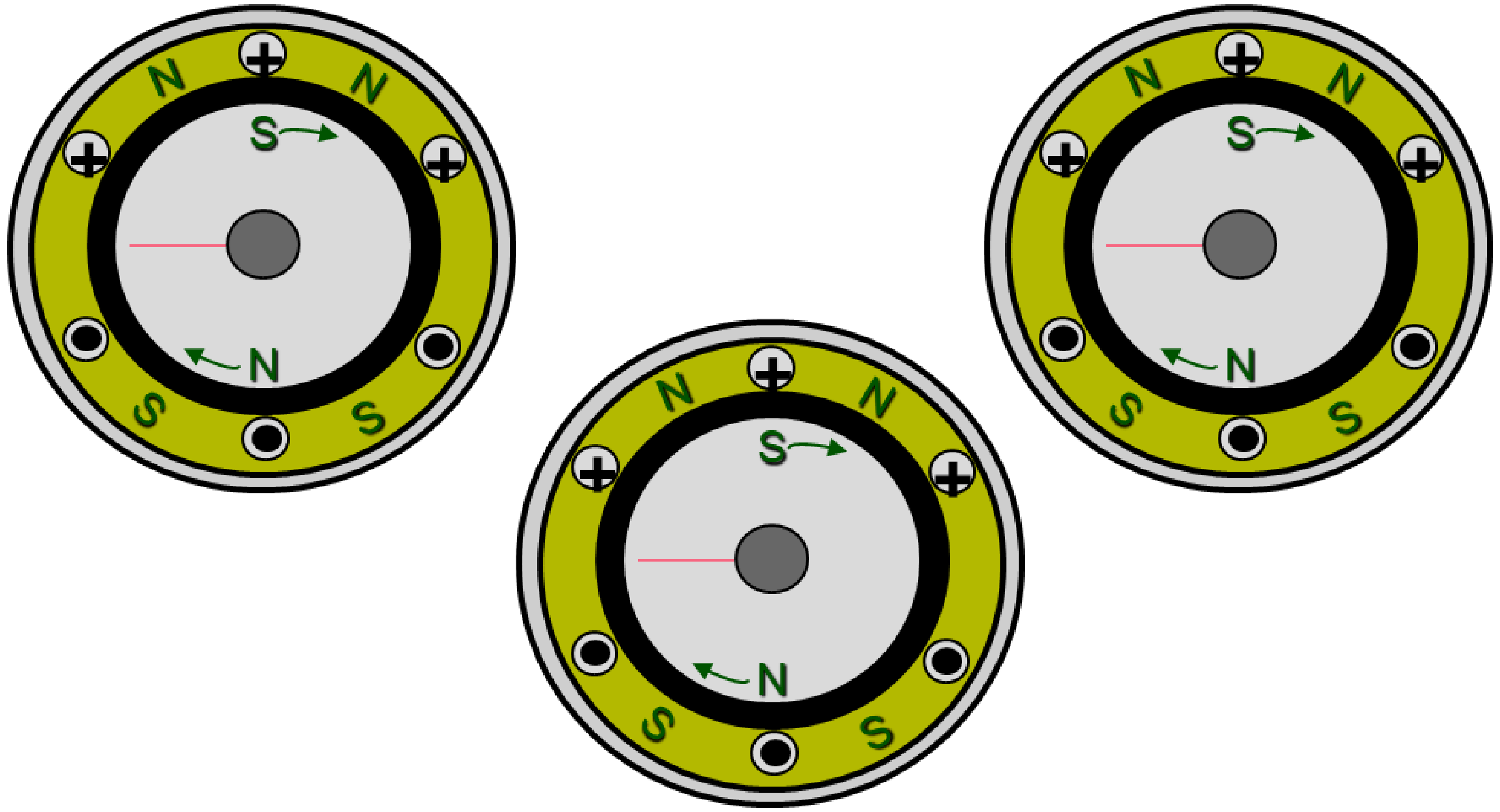




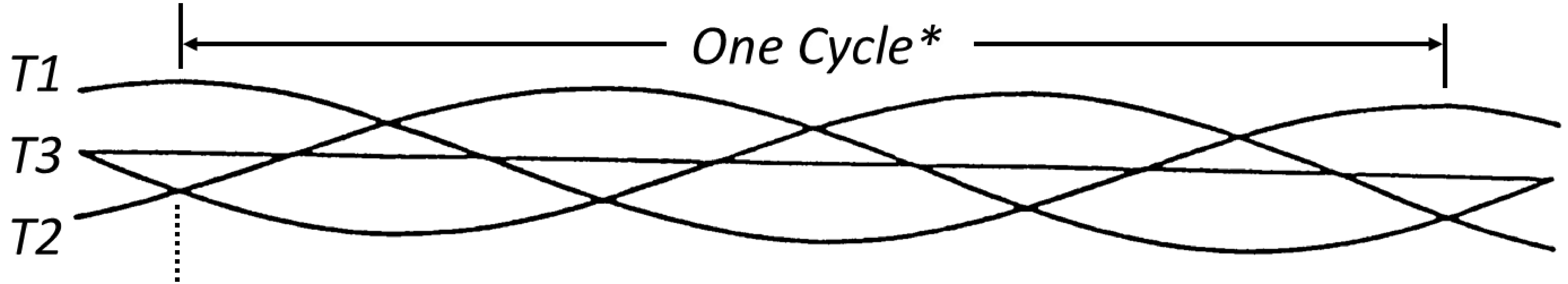


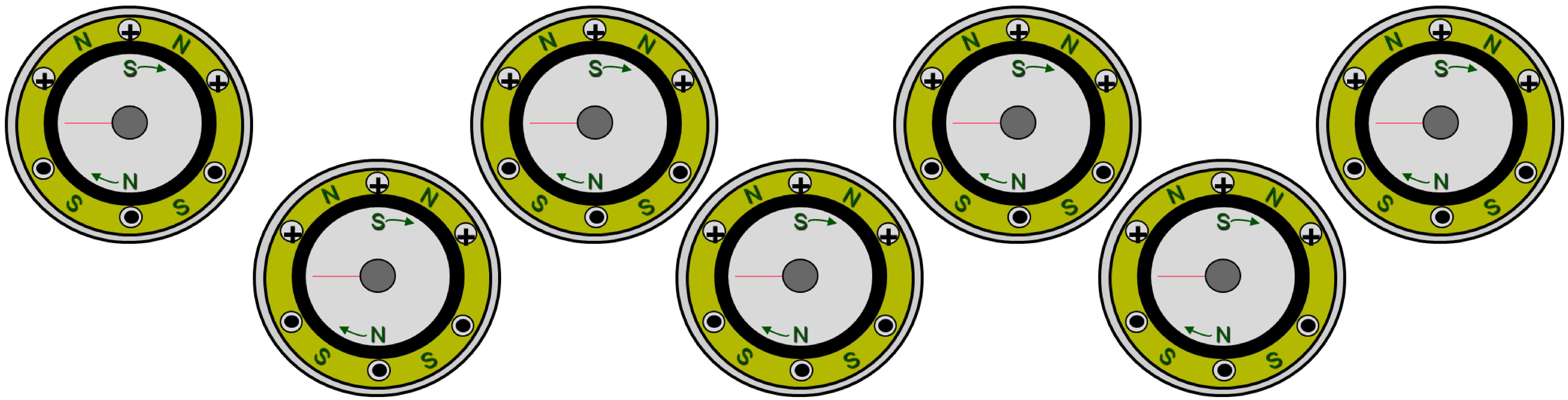
Rotation of the Motor





Rotation of the Motor





Synchronous Speed of Motor

$$N_0 = \frac{120f}{P}$$

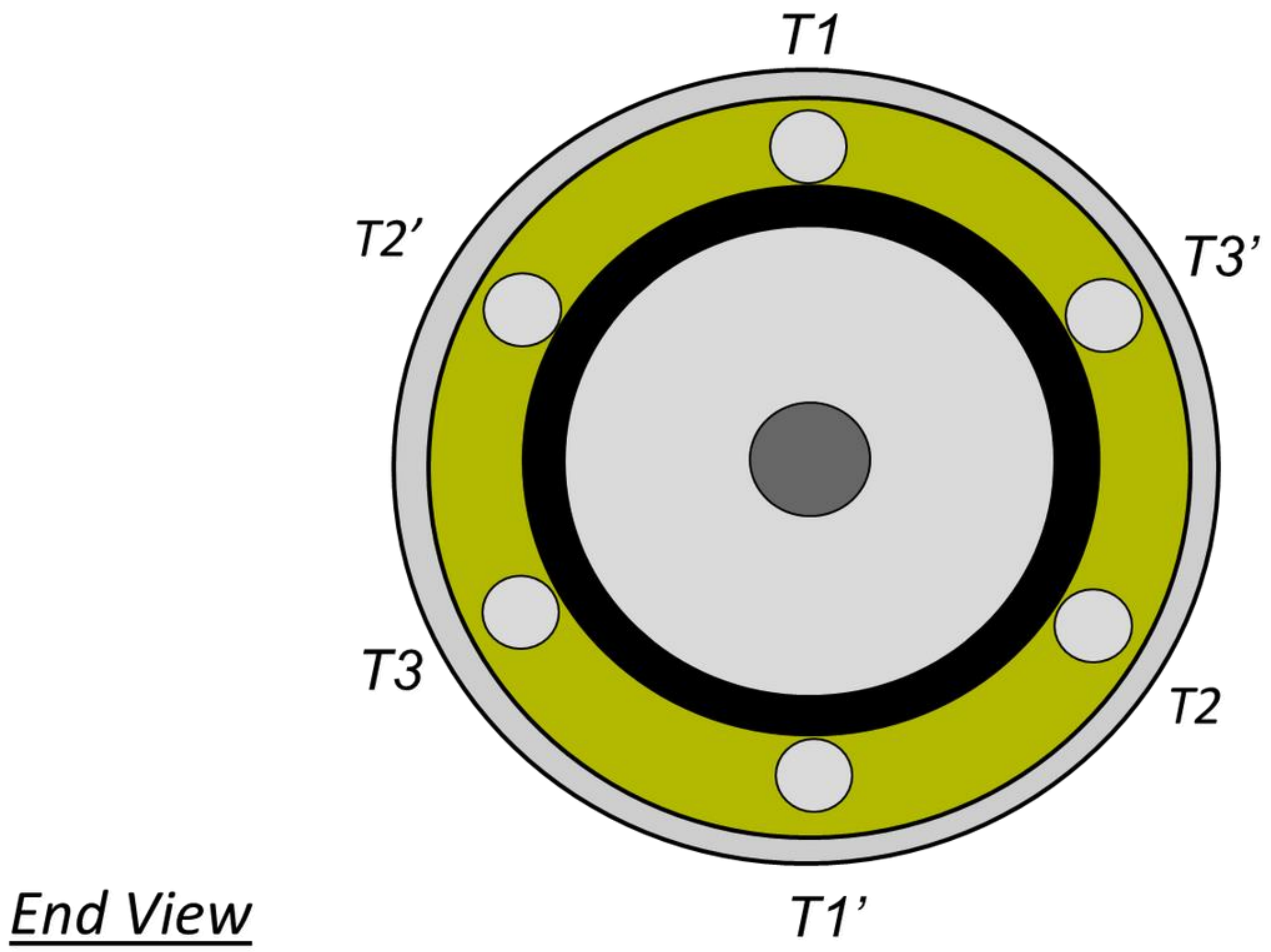
Poles & Sychronus RPM @ 60HZ

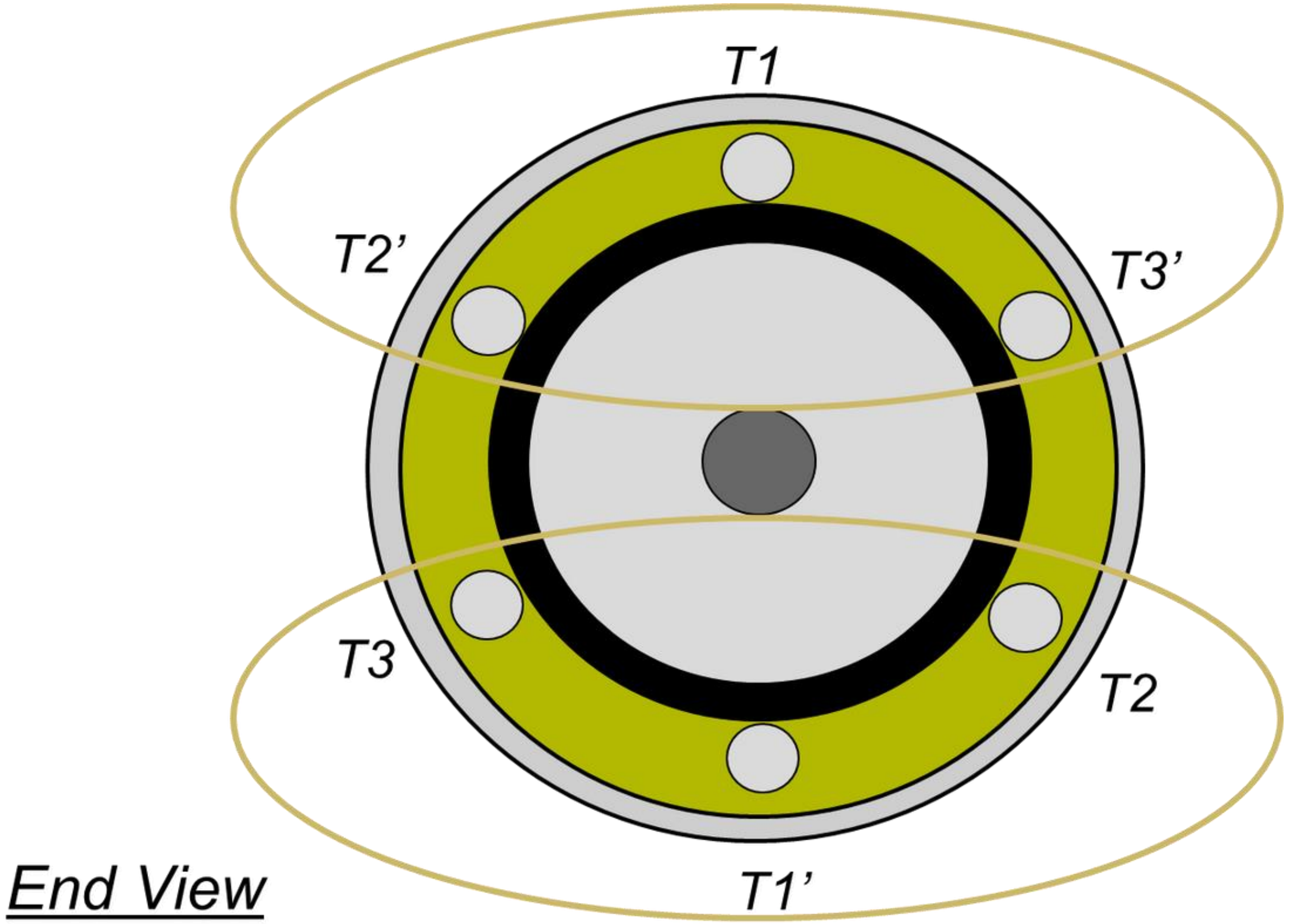
Magnetic Poles	Synchronous RPM
2	3600
4	1800
6	1200
8	900

7200/P = Synchronous RPM

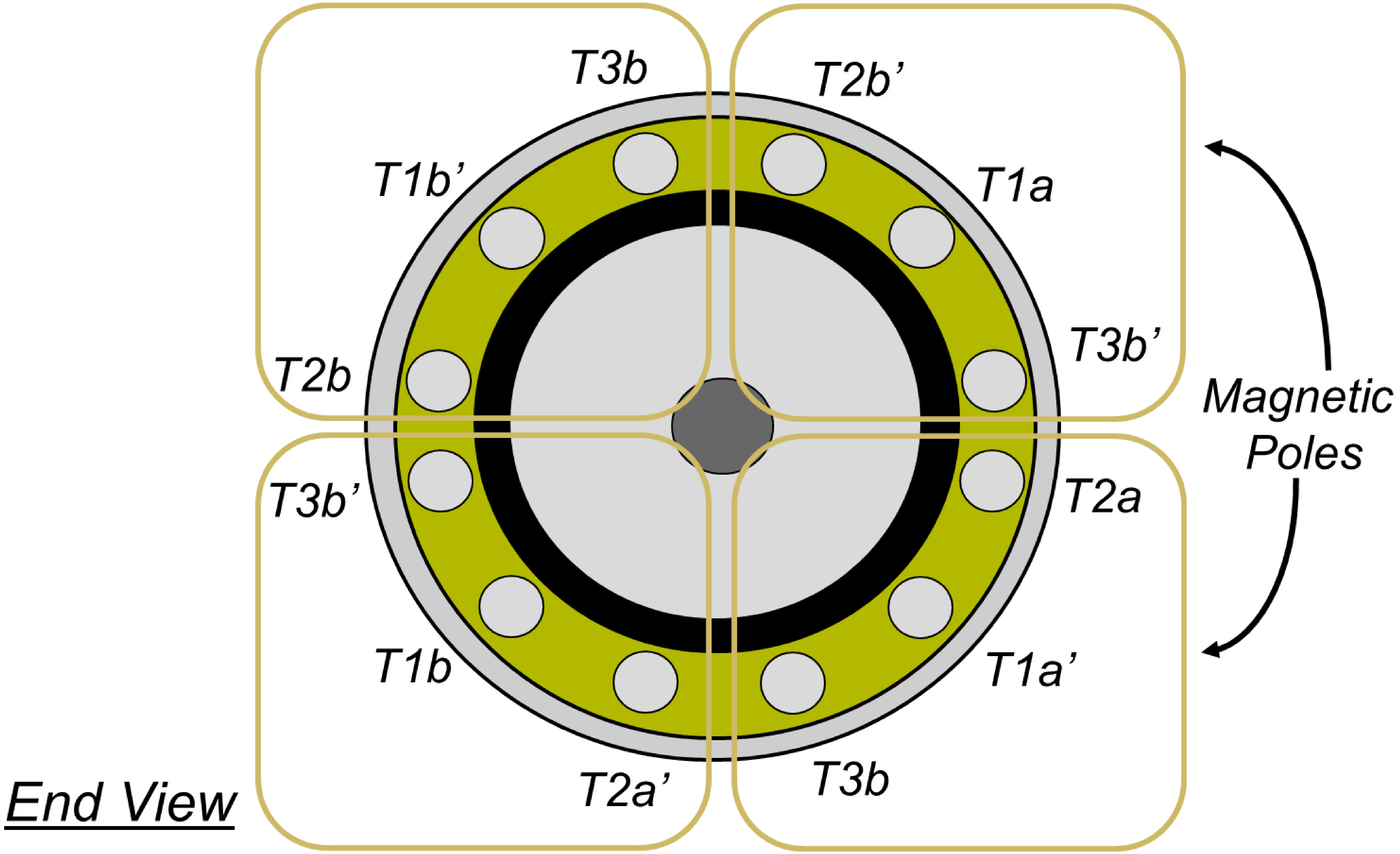
7200/Synchronous RPM = P

Three Phase Motor Construction



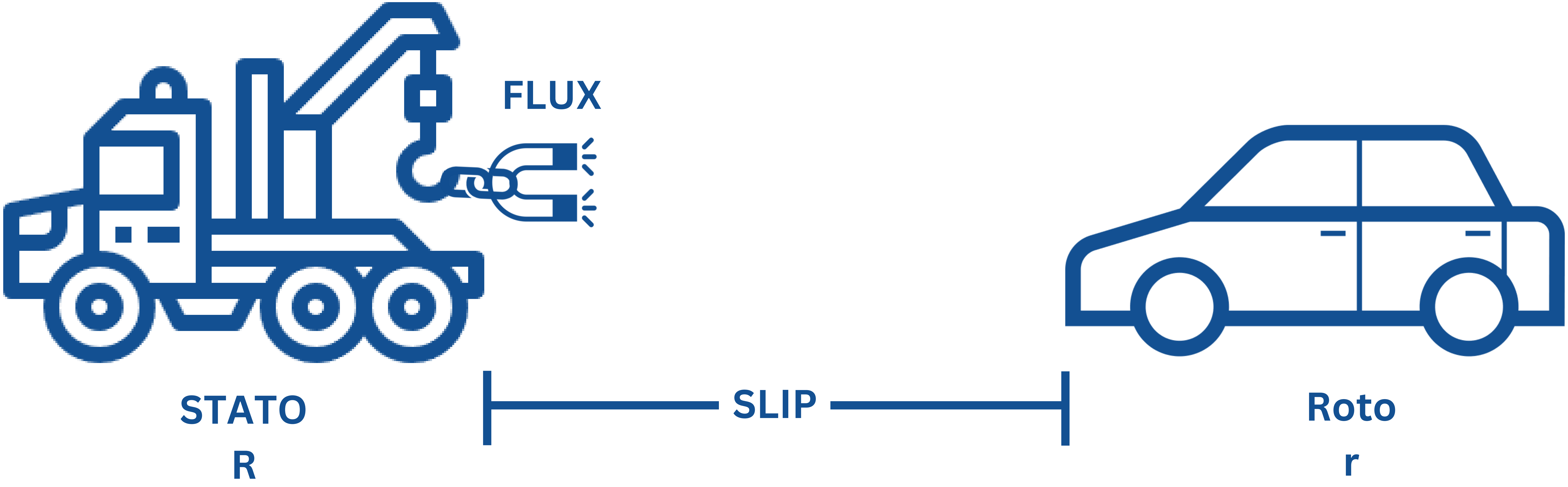


Three Phase Motor Construction



What is slip?

- To produce torque in an induction motor, currentmust flow in the rotor.
- To induce current flow in the rotor, the rotorspeed must be slightly slower than thesynchronous speed.
- The difference between the synchronous speedand the rotor speed (rated speed) is called the slip.



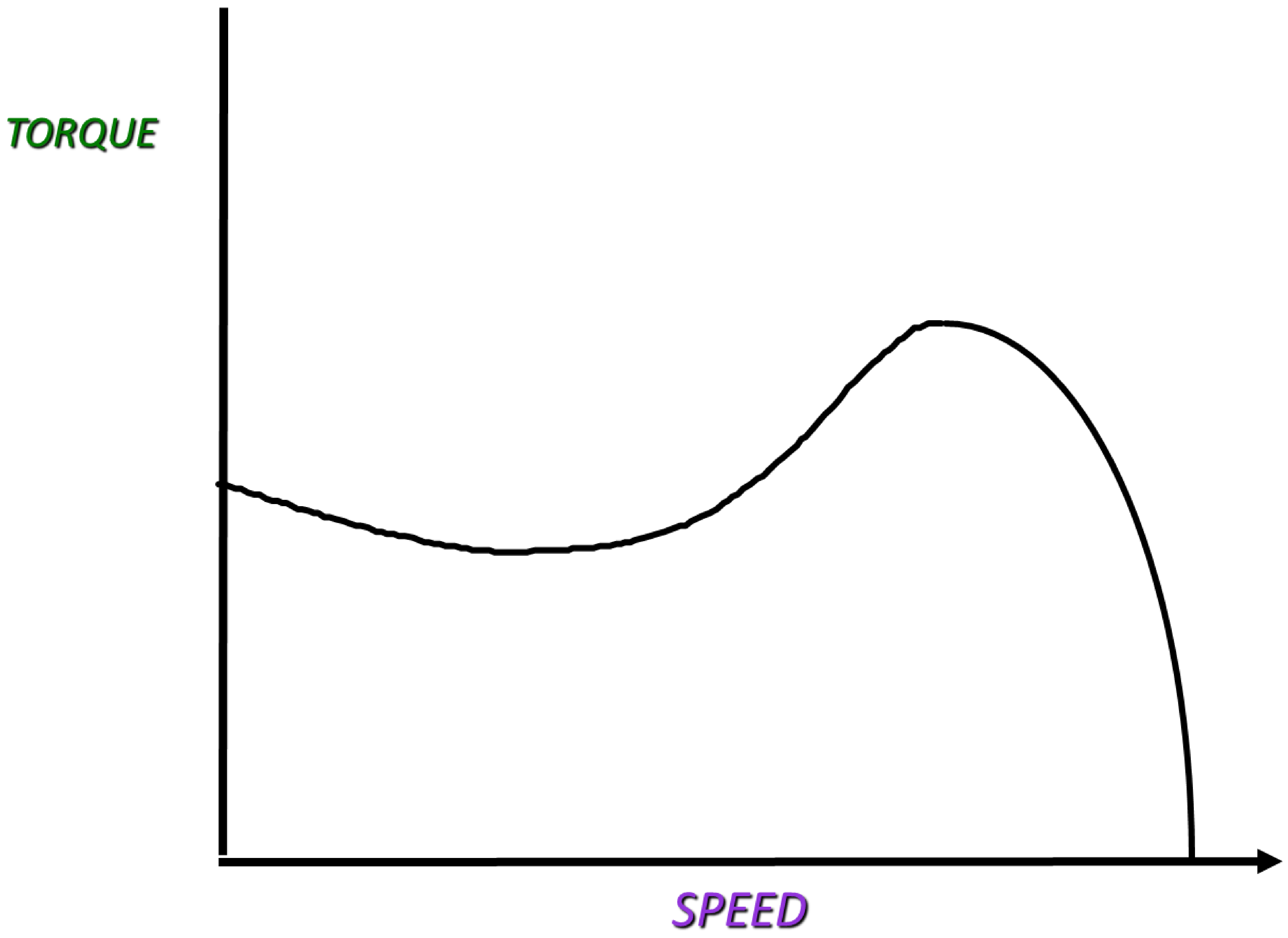
Motor Rated Speed

$$N_0 = \frac{120f}{P} \quad (1\text{-}s)$$

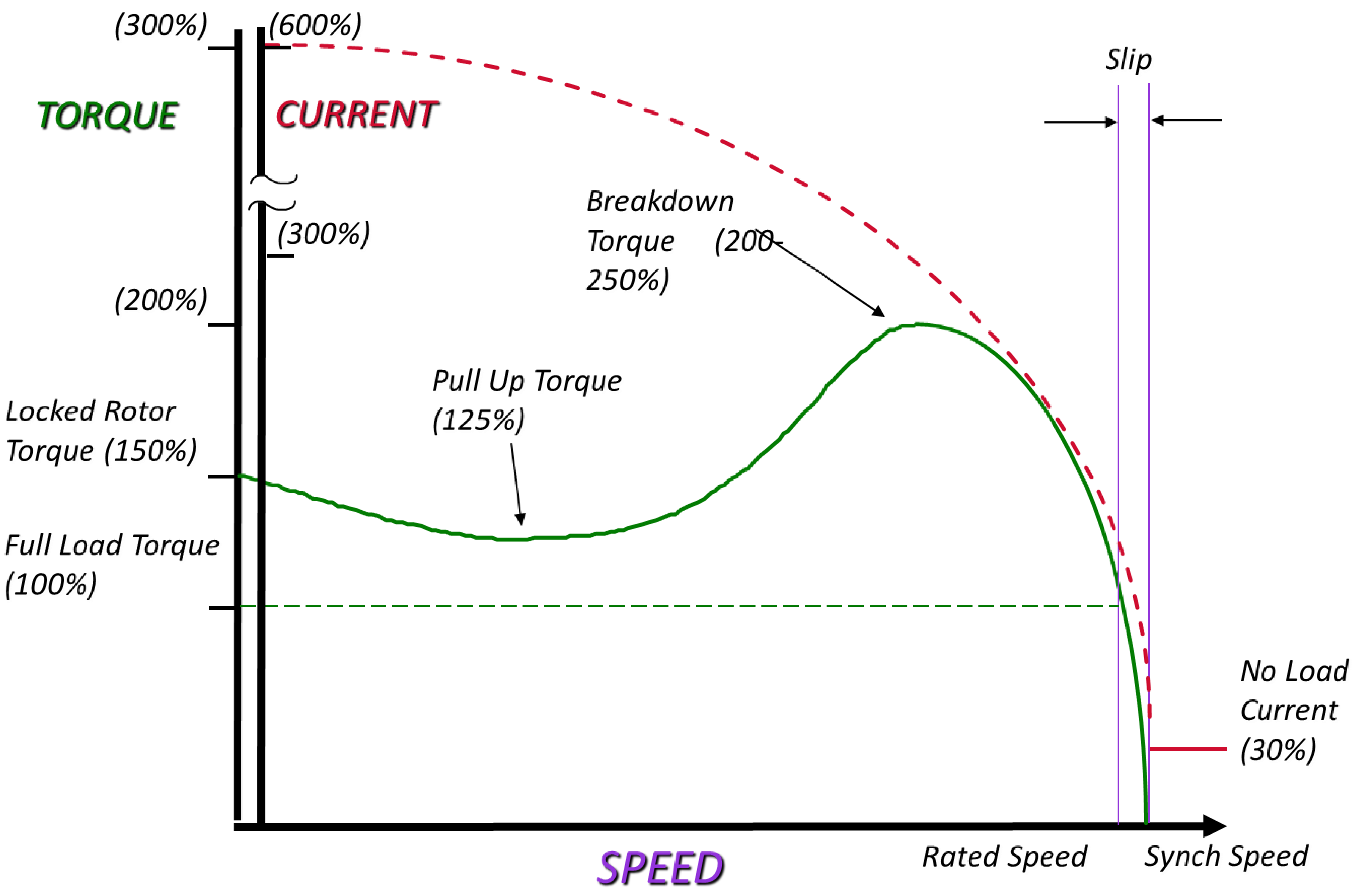
Where:

- N: RPM of the Motor
- f: Frequency in Hz
- P: Number of Poles of the motor
- s: (No-N)/No

Torque Curve



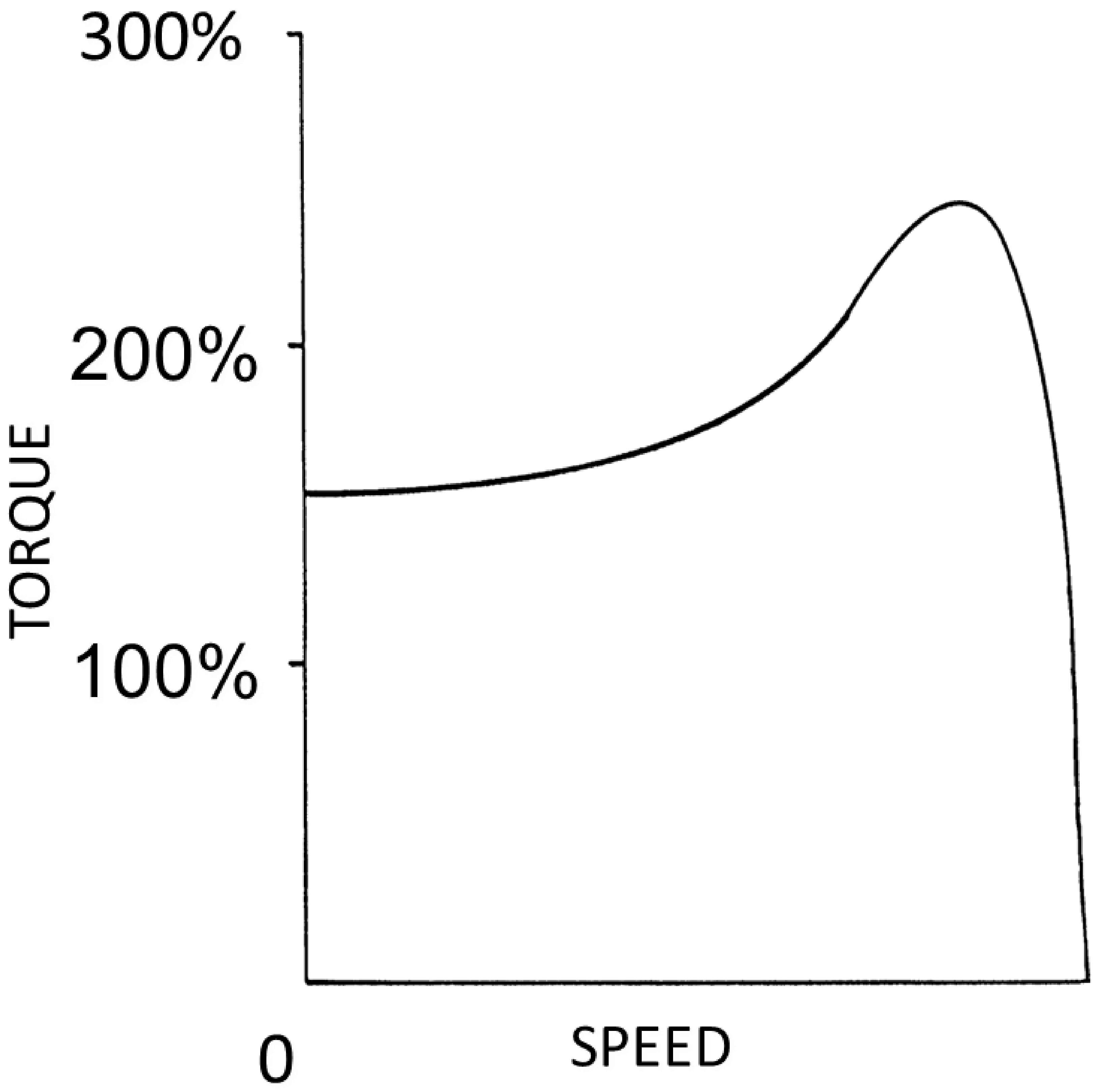
Torque Curve



Nema Design Characteristics

NEMA Design A

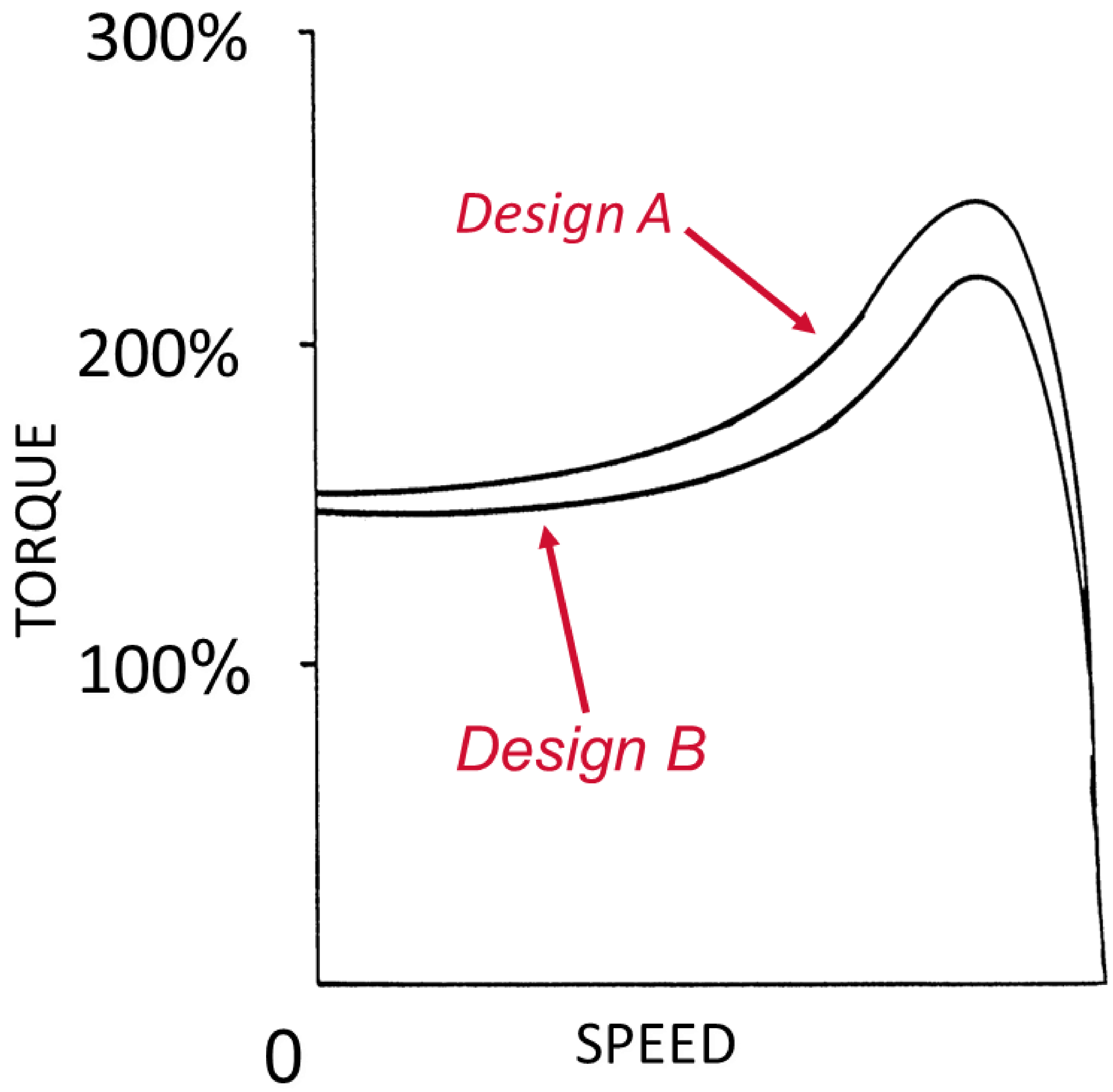
- High breakdown torque
- Normal Starting Torque
- High Starting current
- Low Full load slip
- Used in applications that require
  - Occasional Overloads
  - Better Efficiency



Nema Design Characteristics

NEMA Design B

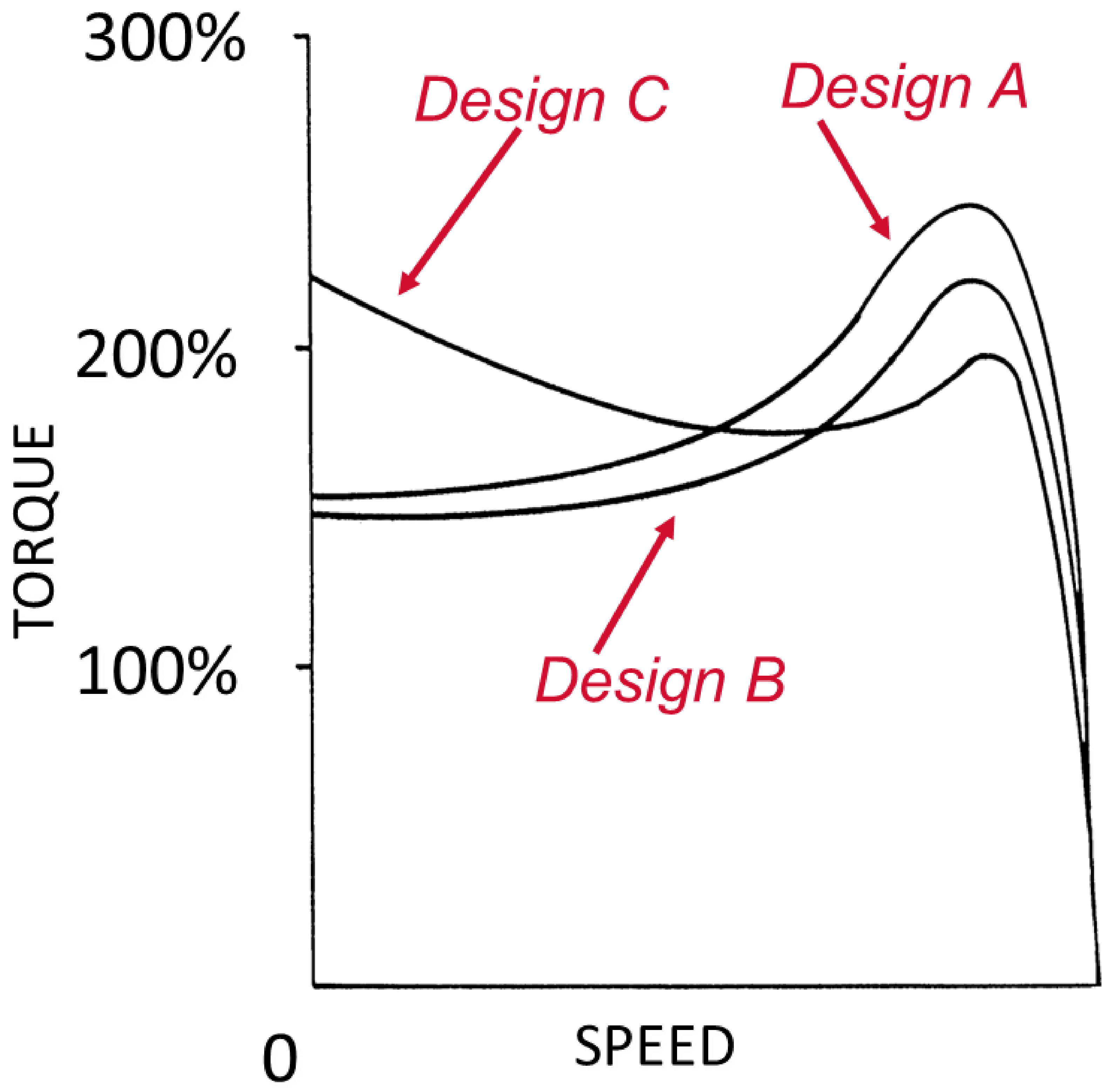
- Normal breakdown torque
- Normal Starting Torque
- Low Starting current
- Normal Full load slip
  - Less than 5%
- General Purpose Motor



Nema Design Characteristics

NEMA Design C

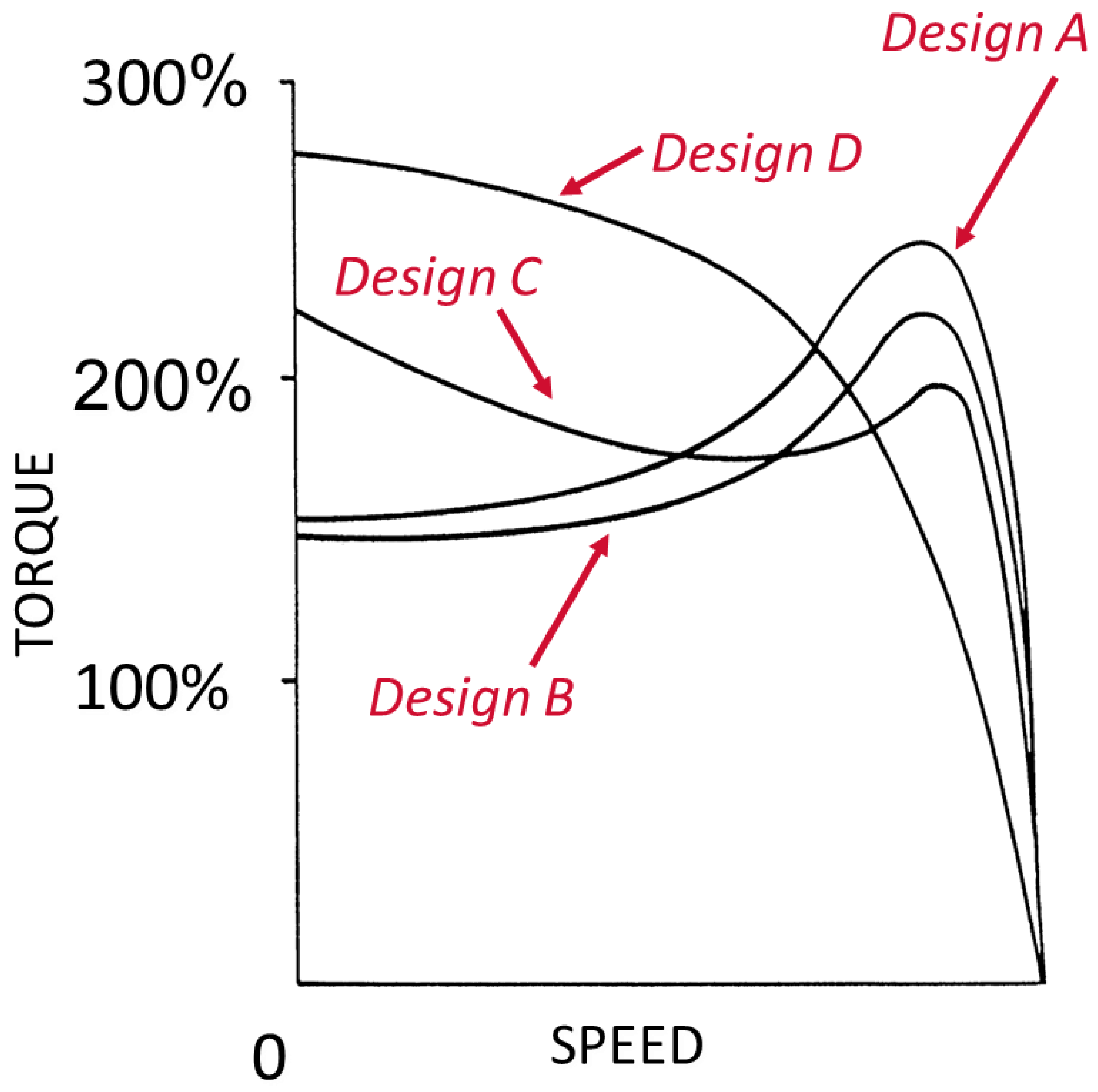
- Low breakdown torque
- High Starting Torque
- Low Starting current
- Normal Full load slip
  - Less than 5%
- Used in applications that require
  - High Breakaway Torque



Nema Design Characteristics

NEMA Design D

- High breakdown torque
- High Starting Torque
- Normal Starting current
- HIgh Full load slip
  - 5-13%
- Used in applications that require
  - High Breakaway Torque



Rotational Horsepower Formula

$$HP = \frac{Torque \times RPM}{5250}$$

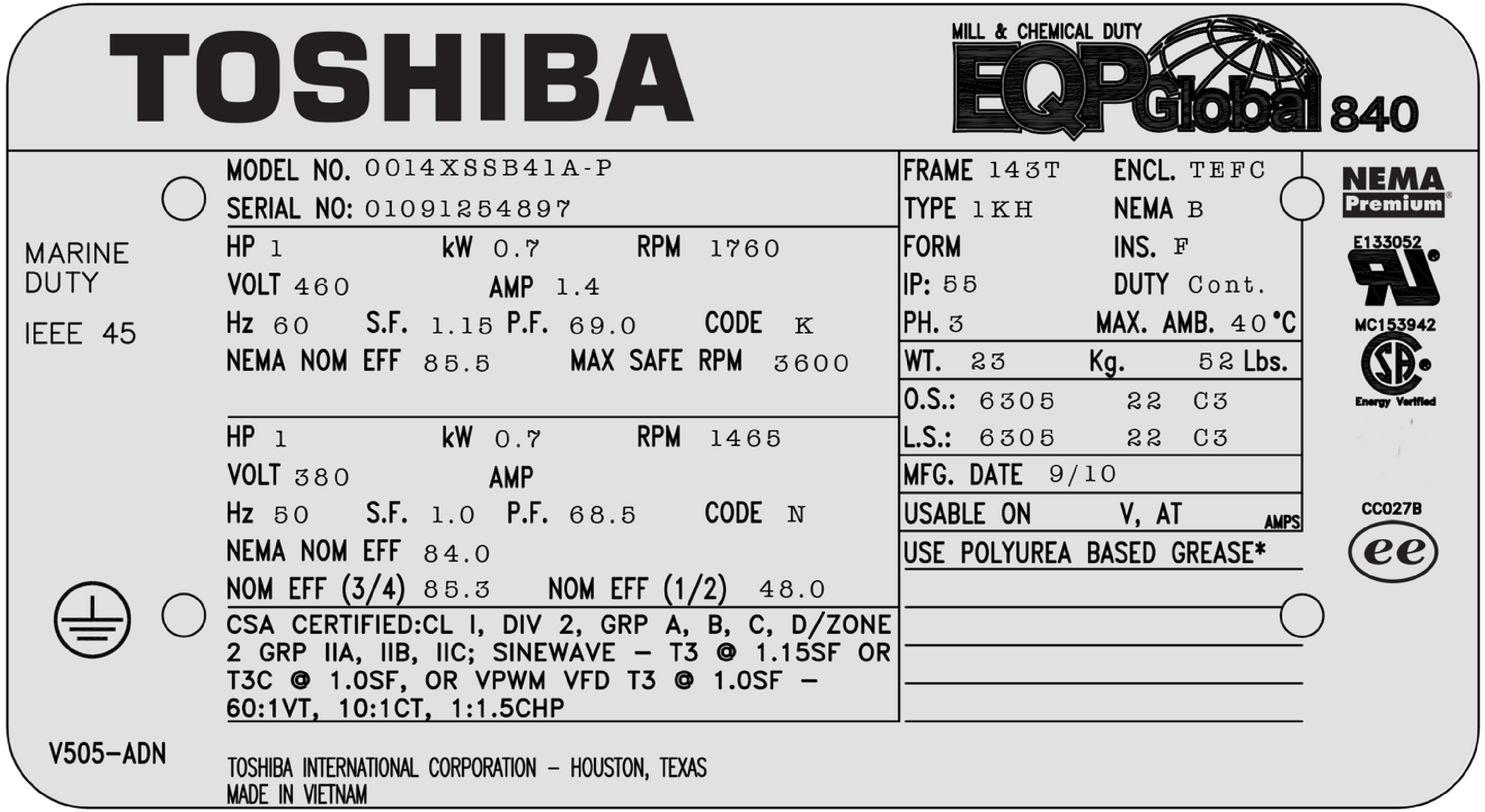
OR

$$Torque = \frac{HP \times 5250}{RPM}$$

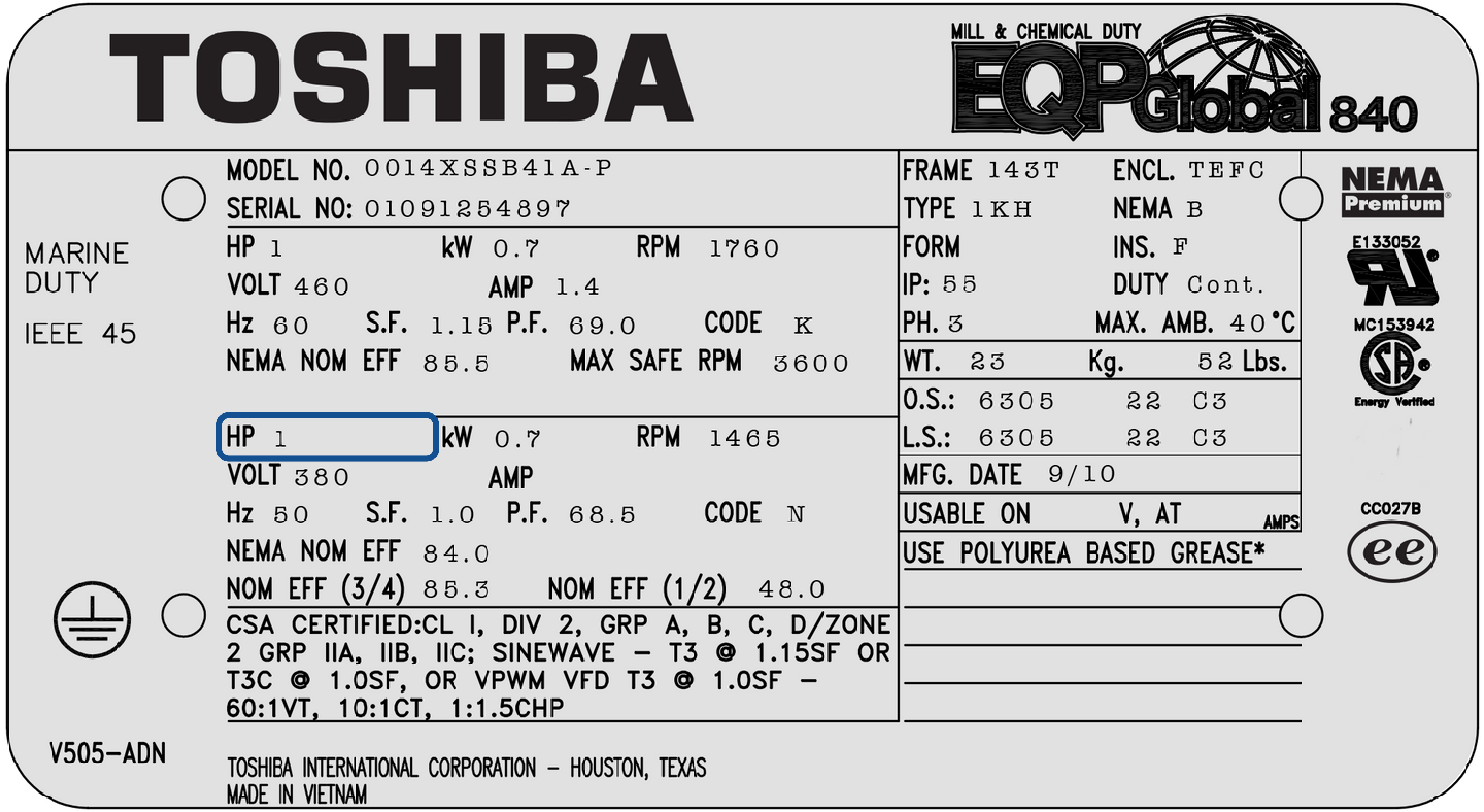
Where:

- Torque - Amount of torque in lb. ft.
- RPM - RPM of the motor
- 5250 - Constant obtained by dividing 33,000 by 6.28

Motor Nameplate Data



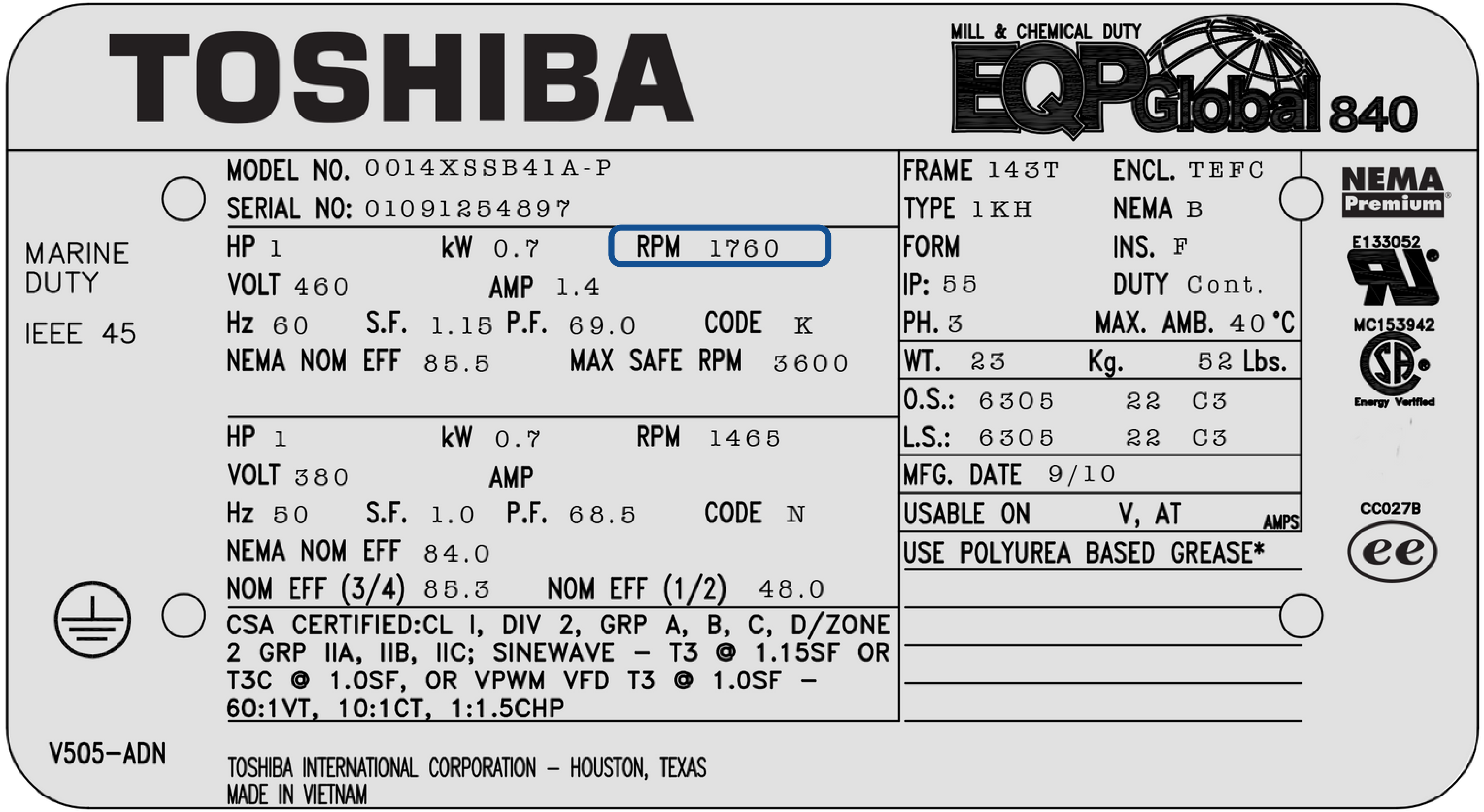
Understanding the Nameplate



HP- Horsepower

The horsepower figure stamped on the nameplate is the horsepower the motor is rated to develop when connected to a circuit of the voltage, frequency and number of phases specified on the motor nameplate.

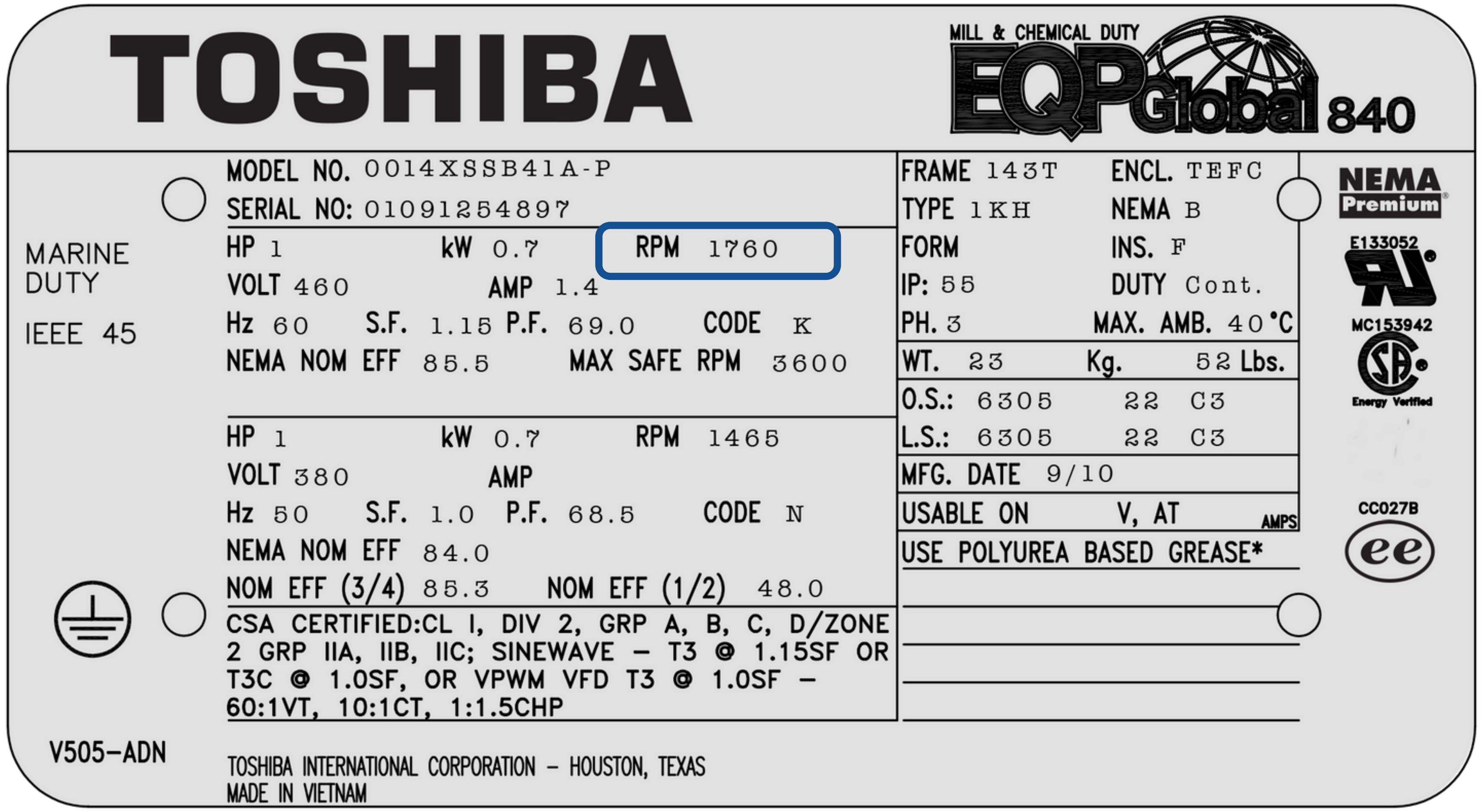
Understanding the Nameplate



Revolutions per Minute

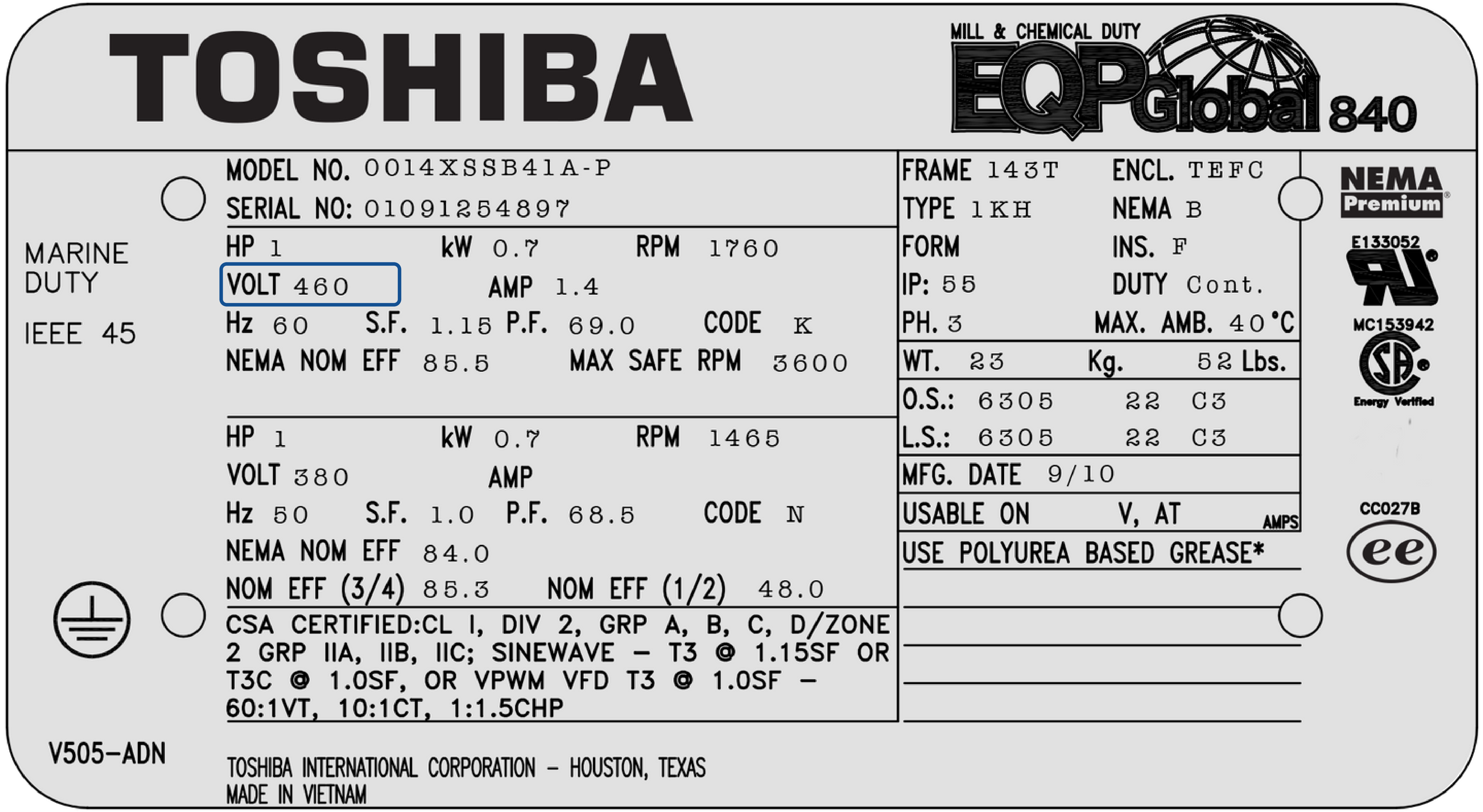
The RPM value represents the approximate speed at which the motor will run when properly connected and delivering its rated output.

Understanding the Nameplate



Poles	Synchronous RPM	Typical Nameplate RPM
2	3600	3450
4	1800	1725
6	1200	1140
8	900	850

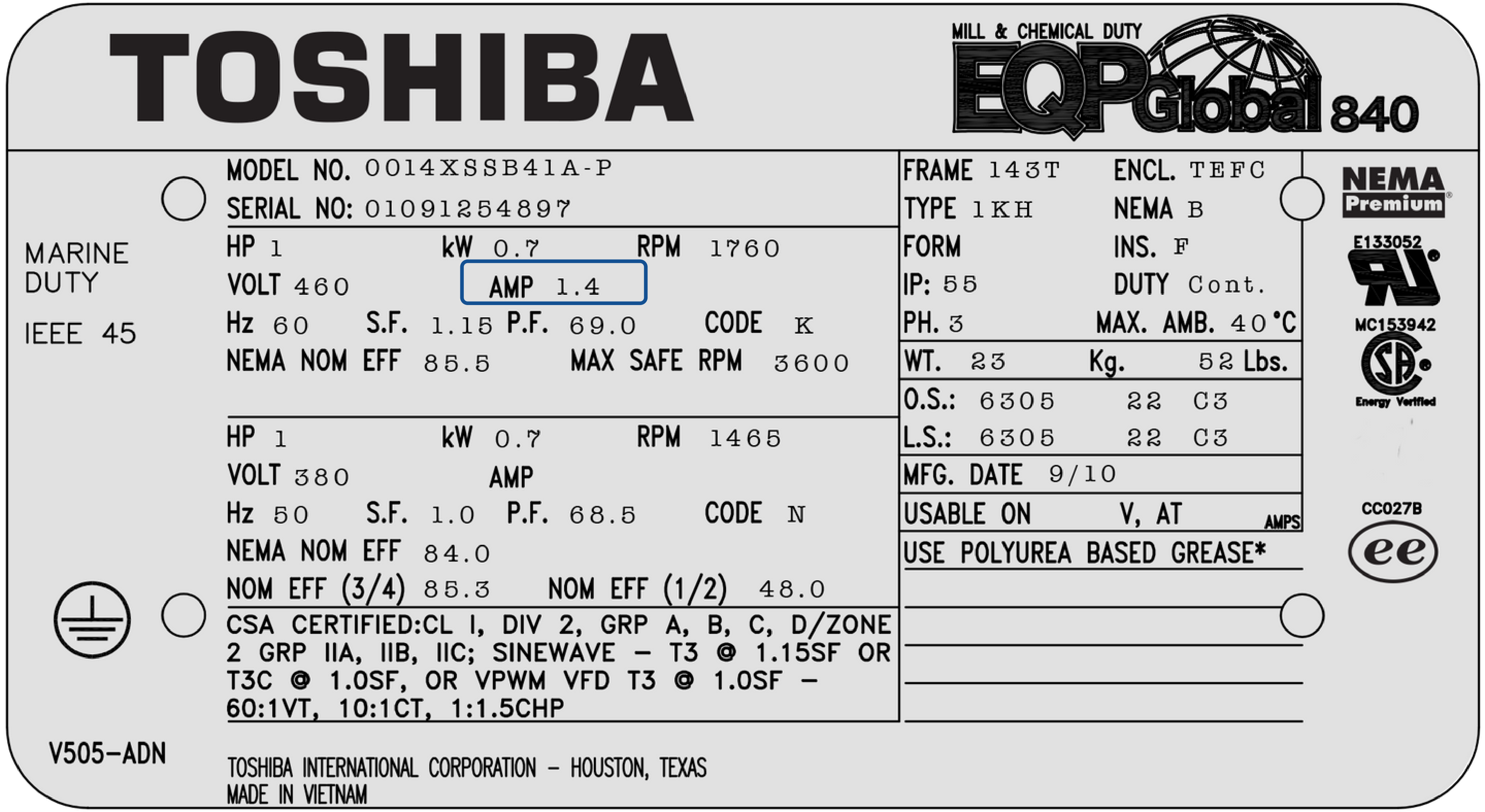
Understanding the Nameplate



Voltage

The rated voltage figure on the motor nameplate refers to the voltage of the supply circuit to which the motor should be connected, to produce rated horsepower and RPM.

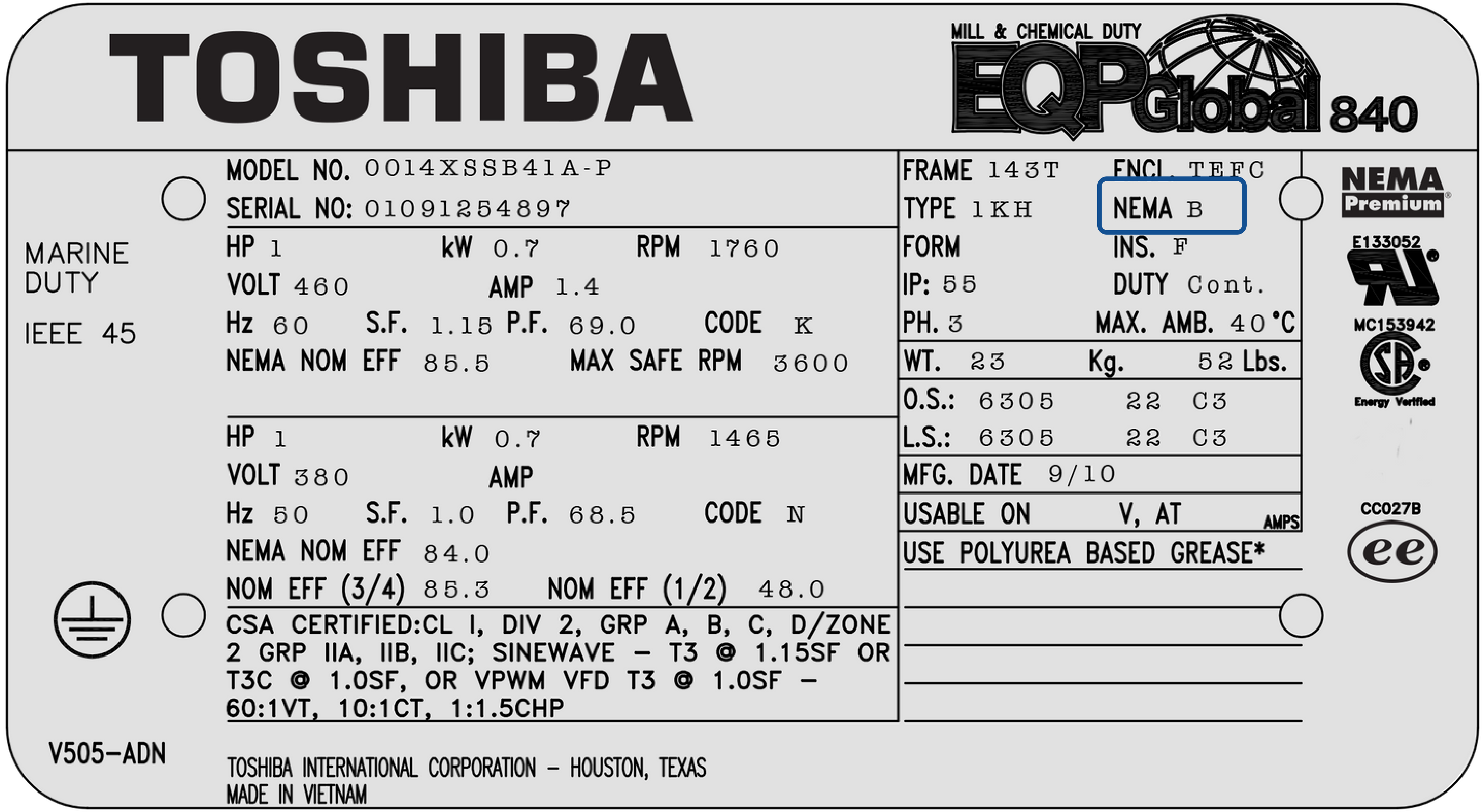
Understanding the Nameplate



Amps

The amp figure on the motor nameplate represents the approximate current draw by the motor when developing rated horsepower on a circuit of the voltage and frequency specified on the nameplate.

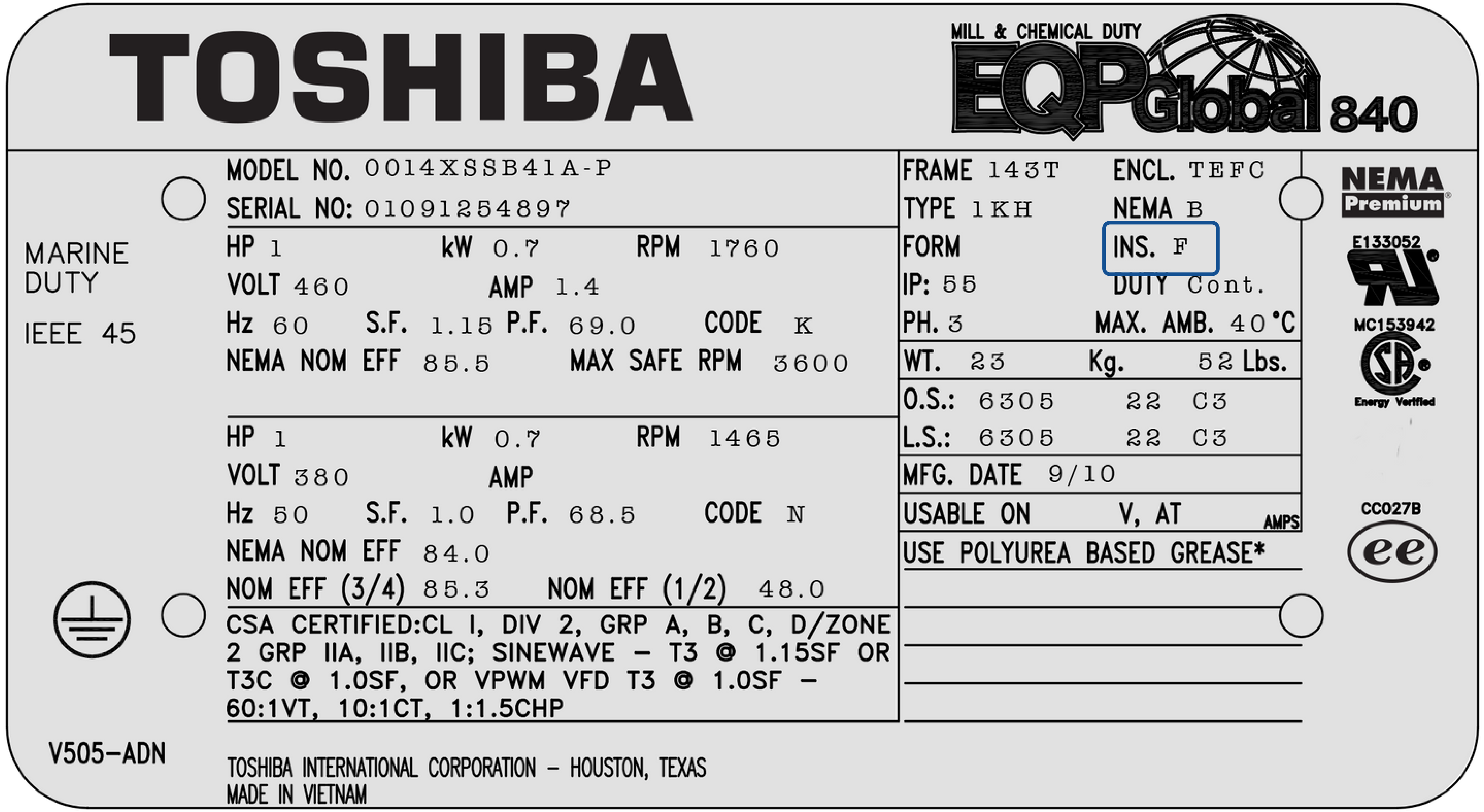
Understanding the Nameplate



NEMA Design

The NEMA Design rating specifies the speed torque curve that will be produced by the motor.

Understanding the Nameplate



Insulation Class

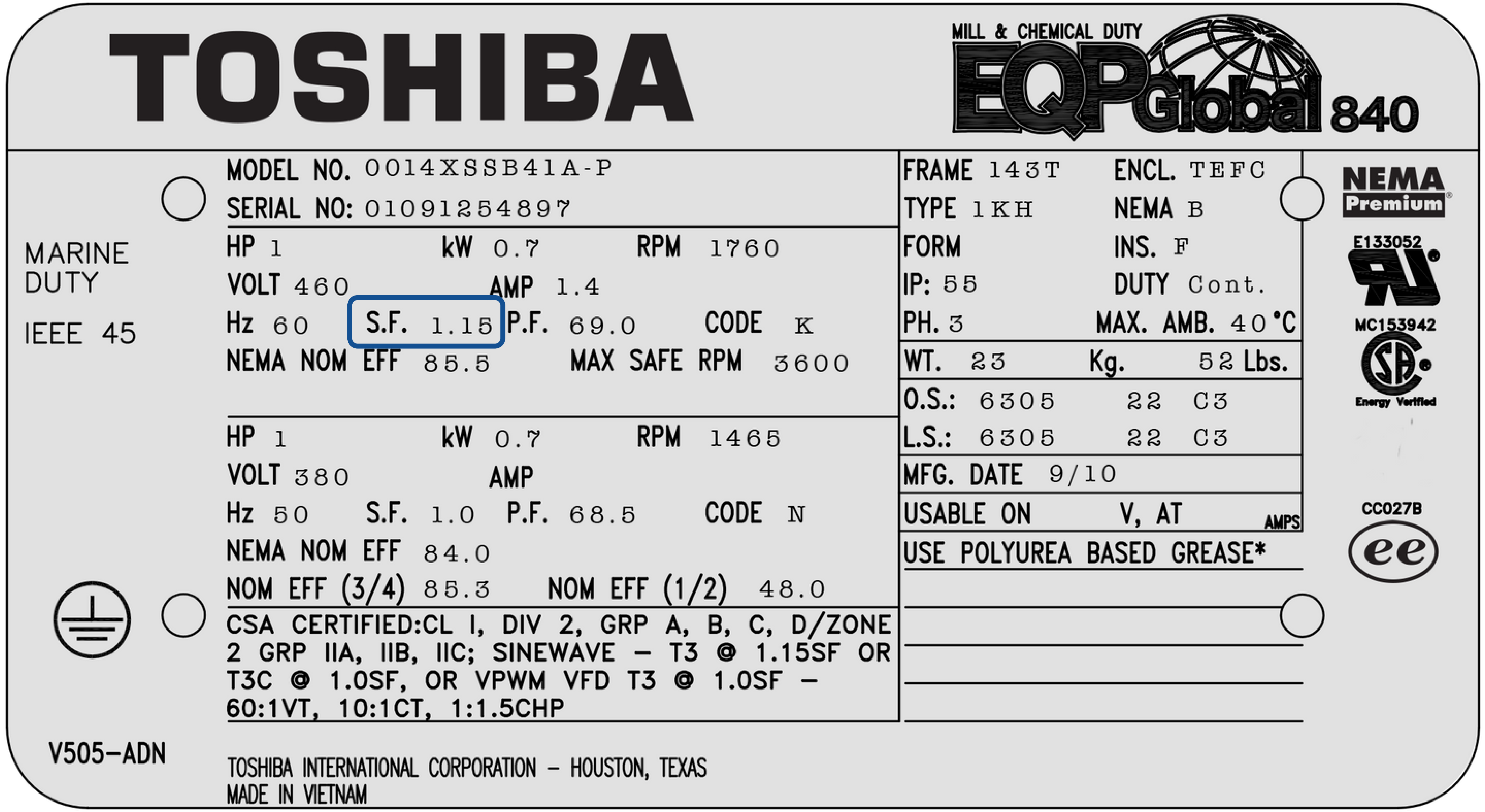
Insulation Class letter designates the amount of allowable temperature rise based on the insulation system and the motor service factor.

Insulation Class Information

Insulation Class	Ambient Temp.	Temp. Rise	Total Temp.
A	40 C	65 C	105 C
B	40 C	90 C	130 C
F	40 C	115 C	155 C
H	40 C	140 C	180 C

**Most common insulation classes are class B & F*

Understanding the Nameplate

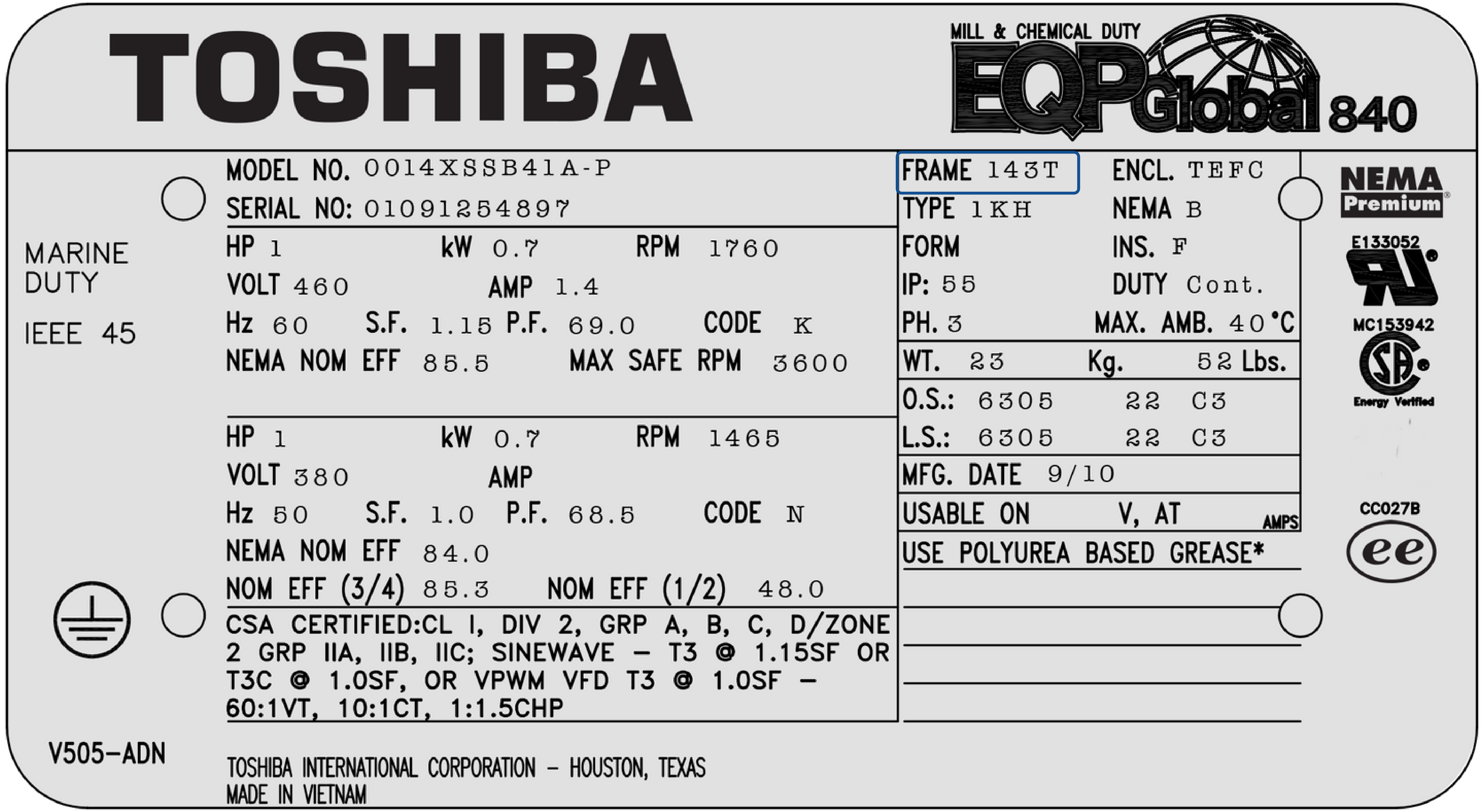


S.F. - Service Factor

The number by which the horsepower rating is multiplied to determine the maximum safe load that a motor may be expected to carry continuously.

Example: A 10 HP Motor with a service factor of 1.15 deliver 11.5 horsepower continuously without exceeding the allowabe temperature rise of the insulation class.

Understanding the Nameplate



Frame

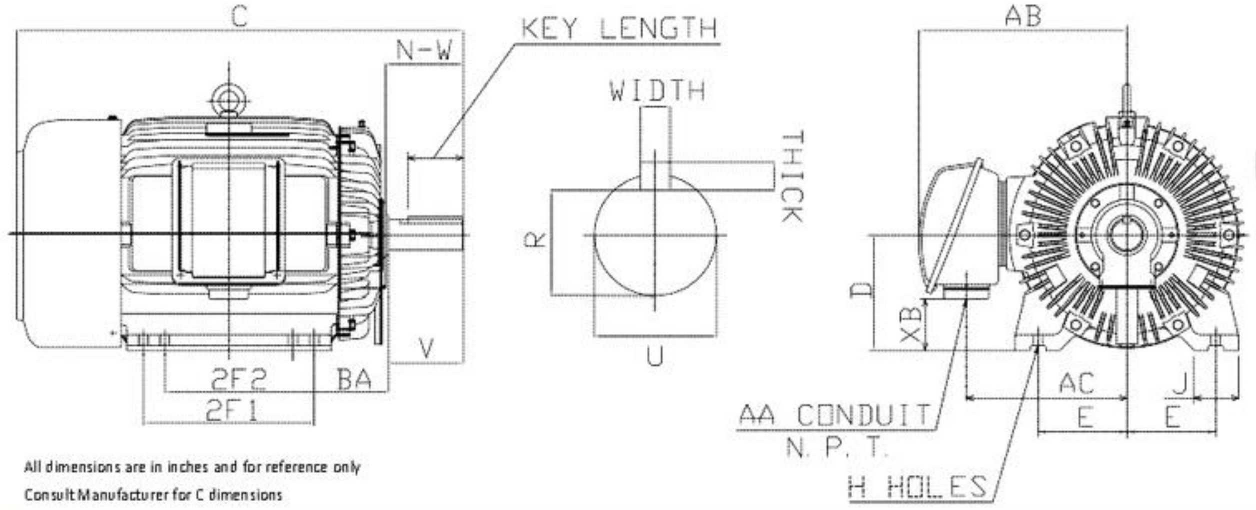
The frame designation refers to the physical size of the motor as well as certain construction features such as the shaft and mounting dimensions.

NEMA
Frame Chart

DYKMAN

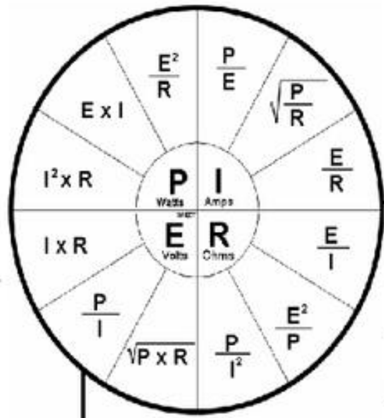
AC NEMA T-Frame Motor Dimensions

Dimensions for Foot-Mounted Motors with a Single Straight-Shaft Extension



All dimensions are in inches and for reference only
Consult Manufacturer for C dimensions

FRAME SIZE	MOUNTING						SHAFT EXTENSION			KEY & KEYSEAT			
	D	E	2F1	2F2	H	BA	N-W	U	V	WIDTH	THICK	LENGTH	R
143T	3.50	2.75	4.00	—	0.34	2.25	2.25	0.875	2.20	0.188	0.188	1.410	0.771
145T	3.50	2.75	5.00	4.00	0.34	2.25	2.25	0.875	2.20	0.188	0.188	1.410	0.771
182T	4.50	3.75	4.50	—	0.41	2.75	2.75	1.125	2.70	0.250	0.250	1.780	0.986
184T	4.50	3.75	5.50	4.50	0.41	2.75	2.75	1.125	2.70	0.250	0.250	1.780	0.986
213T	5.25	4.25	5.50	—	0.41	3.50	3.38	1.375	3.30	0.312	0.312	2.410	1.201
215T	5.25	4.25	7.00	5.50	0.41	3.50	3.38	1.375	3.30	0.312	0.312	2.410	1.201
254T	6.25	5.00	8.25	—	0.53	4.25	4.00	1.625	3.90	0.375	0.375	2.910	1.416
256T	6.25	5.00	10.00	8.25	0.53	4.25	4.00	1.625	3.90	0.375	0.375	2.910	1.416
284T	7.00	5.50	9.50	—	0.53	4.75	4.62	1.875	4.50	0.500	0.500	3.280	1.591
284TS	7.00	5.50	9.50	—	0.53	4.75	3.25	1.625	3.20	0.375	0.375	1.930	1.416
286T	7.00	5.50	11.00	9.50	0.53	4.75	4.62	1.875	4.50	0.500	0.500	3.280	1.591
286TS	7.00	5.50	11.00	9.50	0.53	4.75	3.25	1.625	3.20	0.375	0.375	1.930	1.416
324T	8.00	6.25	10.50	—	0.66	5.25	5.25	2.125	5.15	0.500	0.500	3.910	1.845
324TS	8.00	6.25	10.50	—	0.66	5.25	3.75	1.875	3.65	0.500	0.500	2.030	1.591
326T	8.00	6.25	12.00	10.50	0.66	5.25	5.25	2.125	5.15	0.500	0.500	3.910	1.845
326TS	8.00	6.25	12.00	10.50	0.66	5.25	3.75	1.875	3.65	0.500	0.500	2.030	1.591
364T	9.00	7.00	11.25	—	0.66	5.88	5.88	2.375	5.75	0.625	0.625	4.280	2.021
364TS	9.00	7.00	11.25	—	0.66	5.88	3.75	1.875	3.65	0.500	0.500	2.030	1.591
365T	9.00	7.00	12.25	11.25	0.66	5.88	5.88	2.375	5.75	0.625	0.625	4.280	2.021
365TS	9.00	7.00	12.25	11.25	0.66	5.88	3.75	1.875	3.65	0.500	0.500	2.030	1.591
404T	10.00	8.00	12.25	—	0.81	6.62	7.25	2.875	7.15	0.750	0.750	5.650	2.450
405T	10.00	8.00	13.75	12.25	0.81	6.62	7.25	2.875	7.15	0.750	0.750	5.650	2.450
405TS	10.00	8.00	13.75	12.25	0.81	6.62	4.25	2.125	4.15	0.500	0.500	2.780	1.845
444T	11.00	9.00	14.50	—	0.81	7.50	8.50	3.375	8.00	0.875	0.875	6.890	2.880
444TS	11.00	9.00	14.50	—	0.81	7.50	4.75	2.375	4.50	0.625	0.625	3.030	2.021
445T	11.00	9.00	16.50	14.50	0.81	7.50	8.50	3.375	8.00	0.875	0.875	6.890	2.880
445TS	11.00	9.00	16.50	14.50	0.81	7.50	4.75	2.375	4.50	0.625	0.625	3.030	2.021
447T	11.00	9.00	20.00	16.50	0.81	7.50	8.50	3.375	8.00	0.875	0.875	6.910	2.880
447TZ	11.00	9.00	20.00	16.50	0.81	7.50	10.12	3.375	9.62	0.875	0.875	8.500	2.880
447TS	11.00	9.00	20.00	16.50	0.81	7.50	4.75	2.375	4.50	0.625	0.625	3.030	2.021
449T	11.00	9.00	25.00	20.00	0.81	7.50	8.50	3.375	8.00	0.875	0.875	6.910	2.880
449TZ	11.00	9.00	25.00	20.00	0.81	7.50	10.12	3.375	9.62	0.875	0.875	8.500	2.880
449TS	11.00	9.00	25.00	20.00	0.81	7.50	4.75	2.375	4.50	0.625	0.625	3.030	2.021



Omh's Law & Electrical Equations

Power AC Circuits

$$\text{Efficiency} = \frac{746 \times \text{Output Horsepower}}{\text{Input Watts}}$$

$$\text{Three Phase KW} = \frac{\text{Volts} \times \text{Amperes} \times \text{Power Factor} \times 1.732}{1000}$$

Three Phase Amperes = Volt Amperes x 1.732

$$\text{Three Phase Power Factor} = \frac{\text{Input Watts}}{\text{Volts} \times \text{Amperes} \times \text{Power Factor} \times 1.732}$$

$$\text{Three Phase Efficiency} = \frac{746 \times \text{Horsepower}}{\text{Volts} \times \text{Amperes} \times \text{Power Factor} \times 1.732}$$

$$\text{Three Phase Amperes} = \frac{746 \times \text{Horsepower}}{1.732 \times \text{Volts} \times \text{Efficiency} \times \text{Power Factor}}$$

$$\text{Single Phase KW} = \frac{\text{Volts} \times \text{Amperes} \times \text{Power Factor}}{1000}$$

$$\text{Single Phase Amperes} = \frac{746 \times \text{Horsepower}}{\text{Volts} \times \text{Efficiency} \times \text{Power Factor}}$$

$$\text{Single Phase Efficiency} = \frac{746 \times \text{Horsepower}}{\text{Volts} \times \text{Amperes} \times \text{Power Factor}}$$

$$\text{Single Phase Power Factor} = \frac{\text{Input Watts}}{\text{Volts} \times \text{Amperes}}$$

$$\text{Horsepower (3 Phase)} = \frac{\text{Volts} \times \text{Amperes} \times 1.732 \times \text{Efficiency} \times \text{Power Factor}}{746}$$

$$\text{Horsepower (1 Phase)} = \frac{\text{Volts} \times \text{Amperes} \times \text{Efficiency} \times \text{Power Factor}}{746}$$

For Pumps

$$\text{Horsepower} = \frac{\text{GPM} \times \text{Head(ft)} \times \text{Specific Gravity}}{3960 \times \text{Efficiency of Pump}}$$

For Fans and Blowers

$$\text{Horsepower} = \frac{\text{CFM} \times \text{Pressure (lbs./sq.ft)}}{33{,}000 \times \text{Efficiency}}$$

Motor Application Equations

$$\text{Torque(lb.-ft.)} = \frac{\text{Horsepower} \times 5250}{\text{RPM}}$$

$$\text{Horsepower} = \frac{\text{Torque(lb.-ft.)} \times \text{RPM}}{5250}$$

Time for Motor to Reach Operating Speed (Seconds)

$$\text{Seconds} = \frac{WK^2 \times \text{Speed Change}}{308 \times \text{Avg. Accelerating Torque}}$$

WK^2 = Inertia of Rotor + Inertia of Load (lb.-ft.^{2})

$$\text{Average Accelerating Torque} = \frac{[(\text{FLT} + \text{BDT})/2] + \text{BDT} + \text{LRT}}{3}$$

$$\text{Load } WK^2 \text{ (@ Motor Shaft)} = \frac{WK^2 \text{(Load)} \times (\text{Load RPM})^2}{(\text{Motor RPM})^2}$$

$$\text{Shaft Stress (lbs. per sq. inch)} = \frac{\text{HP} \times 321{,}000}{\text{RPM} \times (\text{Shaft Diameter})^3}$$

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Boise, ID	888.336-3988	**Seattle, WA**	206.708.1796
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Phoenix, AZ	866.725.3395	**Vancouver, OR**	877.267.9900
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North America's Most Complete Stock of Motors, Drives, Controls & Reducers

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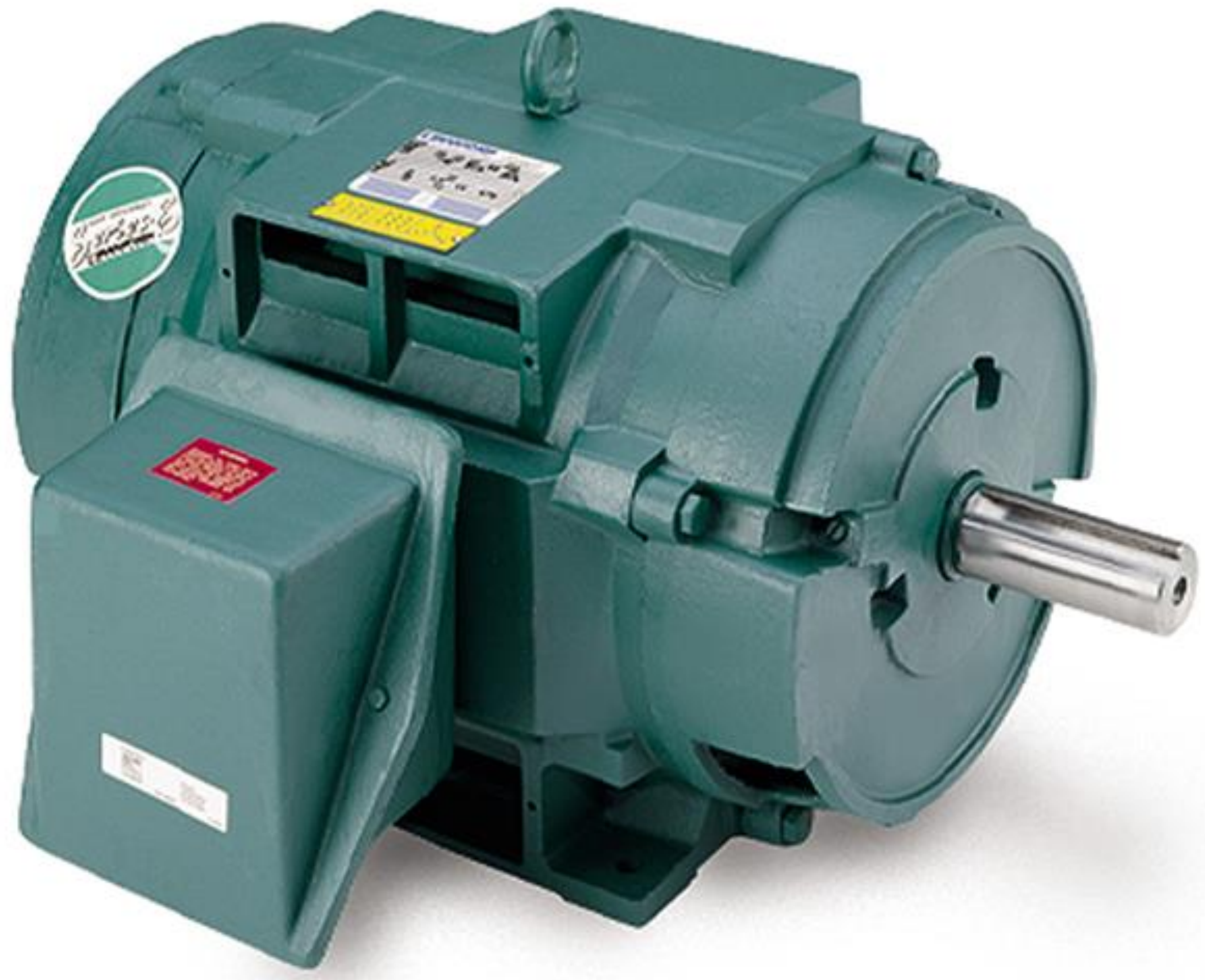
Common types of Motor Enclosure

- Open Drip-proof (ODP)
- Totally Enclosed non-ventilated (TENV)
- Totally enclosed fan cooled (TEFC)
- Totally Enclosed blower code (TEBC)

Types of Motor Enclosures



ODP

- Open drip-proof
- Ventilating openings permit passage of external cooling air over and around the windings of the motor. Small degree of protection against lquid or solid particles entering the enclosure.

Types of Motor Enclosures

TENV

- Totally enclosed non ventilated
- Totally enclosed enclosure with no means of external cooling.

Types of Motor Enclosures

TEFC

- Totally enclosed fan-cooled
- Totally enclosed enclosure with external cooling means, such as a shaft connected fan

Types of Motor Enclosures

TEBC

- Totally enclosed blower-cooled
- Totally enclosed enclosure with external cooling means such as a separately controlled motor power.

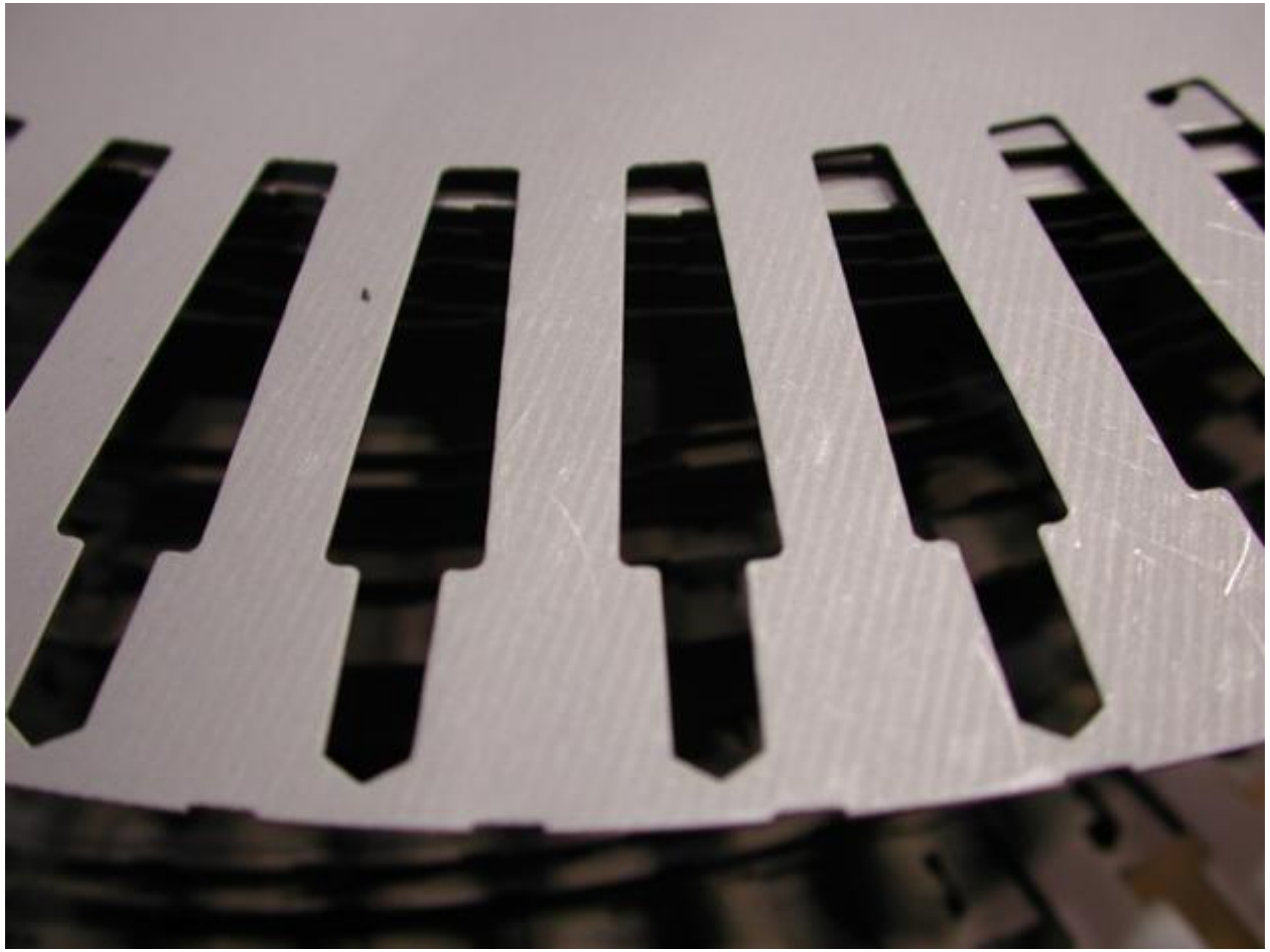
Application Driven Enclosures

- Washdown
- Stainless Steel
- Explosion Proof
- Totally Enclosed Air Over
- Weather Protected
    - Type I
    - Type II

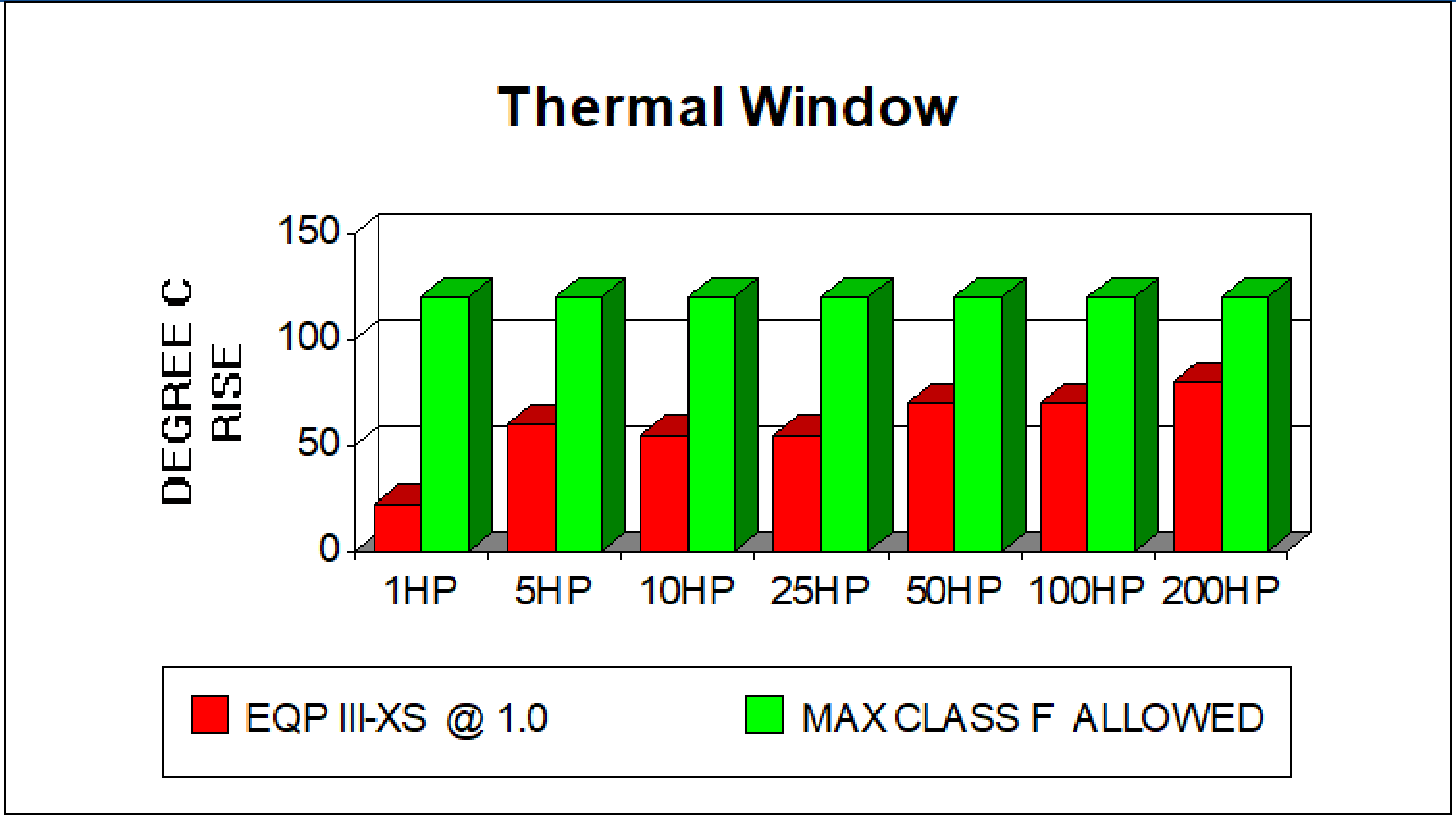
Something you cannot see...

Stator & Rotor Laminations

- C5 or C3 Lamination Steel
  - C5 rated for 1000 degrees F
  - C3 rated for 750 degrees F



How does everything add up?



Questions?