ECET 4530

Industrial Motor Control

NEMA Ratings

1

NEMA Ratings

for the

3Φ Squirrel Cage

Induction Motor

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National Electrical Manufacturers Association

NEMA*

- **Trade association** whose 400+ member companies manufacture products used in the **generation**, **transmission**, **distribution**, **control**, and **end-use of electricity.**
- Provides a forum for the development of technical **standards** that relate to the design, installation and use of electrical equipment.

*** - Information about NEMA and NEMA Standards can be found at: www.NEMA.org**

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NEMA Divisions

Industrial Automation
Lighting Systems
Electronics
Building Equipment
Insulating Materials
Wire and Cable
Power Equipment
Diagnostic Imaging & Therapy Systems

4

NEMA Standards

NEMA standards relating to material presented in this course:

Industrial Control and Systems

- **ICS 1 – General Requirements**
- **ICS 2 – Contactors and Overload Relays**
- **ICS 5 – Control Circuit and Pilot Devices**
- **ICS 7 – Adjustable Speed Drives**
- **ICS 19 – Diagrams, Designations & Symbols**

MG 1 – Motors and Generators

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NEMA Rated Motors

NEMA Rated Motors must adhere to the uniform set of standards provided by NEMA.

The **standards** cover all aspects of a motor's design, testing, and operation, including the:

- operating efficiency & temperature
- ratings (voltage, current, frequency, speed, horsepower…)
- locked-rotor current & torque
- frame and mounting dimensions

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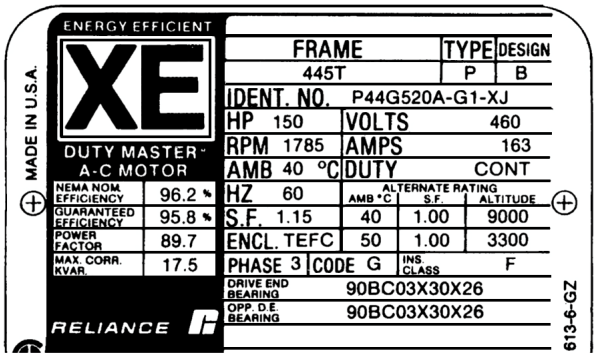
Motor Nameplates

A **nameplate** is attached to the frame of the machine and is used to display the motor's ratings and other key specifications:



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Nameplate Information

The **nameplate** may include a variety of information, including:

- **Manufacturer's Name** and **Logo**
- **Frame Designation** and **Type**
- **Rated Horsepower**
- **Rated Voltage**
- **Rated Frequency**
- **Rated Full Load Amps**
- **Number of Phases**
- **Rated Speed**

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Nameplate Information

The **nameplate** may include a variety of information, including:

- **Operational Efficiency**
- **Operational Power Factor**
- **Design Letter**
- **Rated Ambient Temperature**
- **Service Factor**
- **Duty Cycle**
- **(Locked-Rotor kVA) Code Letter**
- **Insulation Class Letter**

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NEMA Induction Motor Ratings

Descriptions for several of the **nameplate** items include:

Voltage – the nominal line-voltage magnitude that should be supplied to the terminals of to the machine

Full Load Amps – the expected line current magnitude (while driving rated load, provided that the motor is supplied at rated voltage & frequency, exposed to rated ambient temperature, …)

Speed – the expected rotational speed of the rotor (while driving rated load, provided that the motor is supplied at rated voltage & frequency, exposed to rated temperature, …)

Continuously exceeding the rated Full Load Amps will result in excessive heating of the motor.

Note that operating the motor at rated load but less-than-rated voltage can also result in increased currents and, in-turn, excessive heating of the motor.

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NEMA Induction Motor Ratings

Descriptions for several of the **nameplate** items include:

Horsepower – the maximum continuous (mechanical) power that the motor can provide to its shaft-connected load

Frame Designation – allows lookup of information regarding the shaft height and other machine dimensions

Service Factor – a multiplier that may be applied to rated load under certain operational conditions provided that rated voltage & frequency is maintained

Design Letter – the design class of the machine, which indicates the torque-speed performance characteristics

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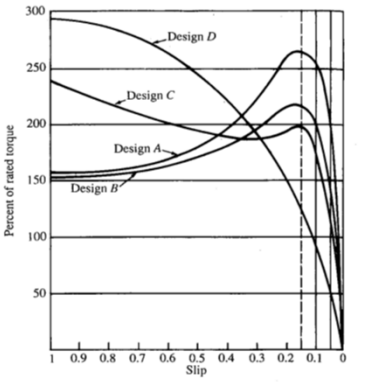
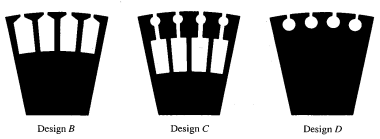
Design Class

The **design class** of an induction motor specifies the overall **torque-speed** characteristics for the motor.

The shape of the torque-speed response curve of a motor can be adjusted by modifying the configuration of its rotor conductors, thus allowing for the design of motors suited to specific applications.





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Design Class Applications

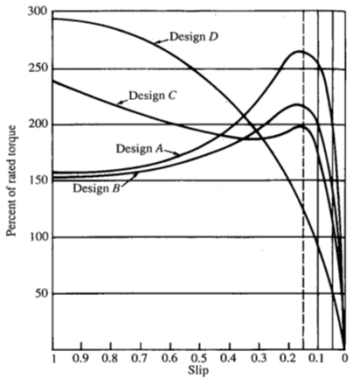
Design A – Fans, blowers, centrifugal pumps and compressors, etc… where starting torque requirements are relatively low

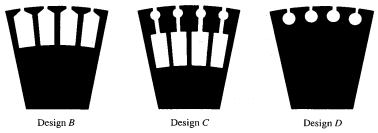
Design B* – Fans, blowers, centrifugal pumps and compressors, etc… where starting torque requirements are relatively low

Design C – Conveyors, crushers, agitators, reciprocating pump and compressors, etc… where starting under load is required

Design D – High peak loads with or without flywheels such as punch presses, shears, elevators, extractors, winches, hoists

*** – The most commonly utilized NEMA 3Φ IM is the Design B.**





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NEMA Induction Motor Ratings

Certain operational characteristics of a NEMA-rated induction motor, such as:

- **Rated Torque**,
- **Locked-Rotor Current**,
- **Locked-Rotor Torque**, and
- **Breakdown Torque**

are based upon the motor's ratings and can be determined by utilizing the **nameplate information** and either the **tables** in NEMA standard **MG-1** or by hand calculation.

Note – the torque values shown in the tables are often defined as a percentage of the machine's other rated values.

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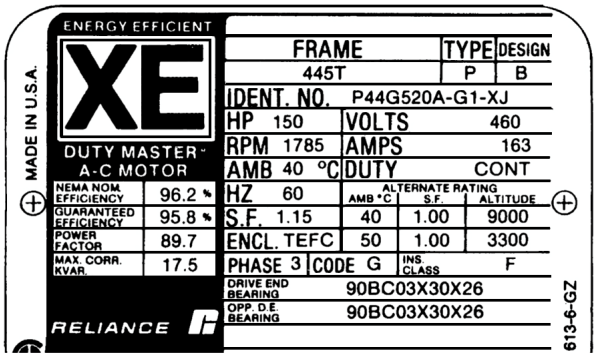
NEMA-Rated Motor Example

Example – Determine the **rated torque** for the 150 Hp Reliance Electric induction motor:

Key Nameplate Data – 150 Hp, 1785 rpm



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NEMA-Rated Motor Example

Example – Determine the **rated torque** for the 150 Hp Reliance Electric induction motor:

Key Nameplate Data – 150 Hp, 1785 rpm

Since: $$T_{D(lb\cdot ft)} = \frac{5252 \cdot P_{mech(hp)}}{n_{r(rpm)}}$$

then: $$T_{Rated(lb\cdot ft)} = \frac{5252 \cdot P_{Rated(hp)}}{n_{rated(rpm)}} = \frac{5252 \cdot 150}{1785} = 441.3\,(lb \cdot ft)$$

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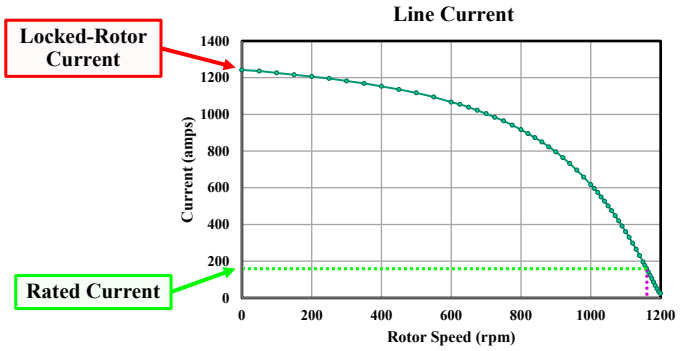
Locked-Rotor Current

Locked-Rotor Current is the amount of current that the motor will draw at standstill when supplied with rated voltage.



LR current, which is typically 4-10x larger than rated current, in indicative of the current that the motor will draw at startup.

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NEMA-Rated Motors

Table: **Locked-Rotor Current** of 3Φ, 230V, 60Hz Motors

Table 31
LOCKED-ROTOR CURRENT OF 3-PHASE 60-HERTZ SMALL AND MEDIUM SQUIRREL-CAGE INDUCTION MOTORS RATED AT 230 VOLTS [MG 1-12.35.1]

HP	LOCKED-ROTOR CURRENT, AMPERES	DESIGN LETTERS	HP	LOCKED-ROTOR CURRENT, AMPERES	DESIGN LETTERS
1/2	20	B, D	60	870	B, C, D
3/4	25	B, D	75	1085	B, C, D
1	30	B, C, D	100	1450	B, C, D
1-1/2	40	B, C, D	125	1815	B, C, D
2	50	B, C, D	150	2170	B, C, D
3	64	B, C, D	200	2900	B, C,
5	92	B, C, D	250	3650	B
7-1/2	127	B, C, D	300	4400	B
10	162	B, C, D	350	5100	B
15	232	B, C, D	400	5800	B
20	290	B, C, D	450	6500	B
25	365	B, C, D	500	7250	B
30	435	B, C, D			
40	580	B, C, D			
50	725	B, C, D			

NOTE—The locked-rotor current of motors designed for voltages other than 230 volts shall be inversely proportional to the voltages.

*** – Table from NEMA Standards Condensed MG 1-2007**

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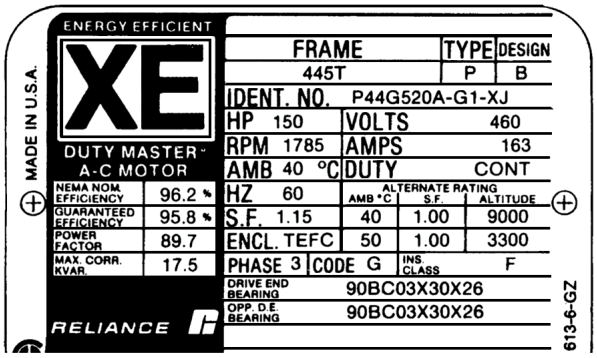
NEMA-Rated Motor Example

Example – Determine the **locked-rotor current** for the 150 Hp Reliance Electric induction motor:

Key Nameplate Data – 150 Hp, 460 V, 163 A, Design B



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NEMA-Rated Motor Example

Example – Determine the **locked-rotor current** for the 150 Hp Reliance Electric induction motor:

Key Nameplate Data – 150 Hp, 460 V, 163 A, Design B

Table 31 → 150 Hp / 230 V / B → 2170 LR amps

Table 31
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HP	Locked-Rotor Current, Amperes	Design Letters	HP	Locked-Rotor Current, Amperes	Design Letters
1/2	20	B, D	60	870	B, C, D
3/4	25	B, D	75	1085	B, C, D
1	30	B, C, D	100	1450	B, C, D
1-1/2	40	B, C, D	125	1815	B, C, D
2	50	B, C, D	150	2170	B, C, D
...	...	...	...	...	...
20	290	B, C, D	450	6500	B
25	365	B, C, D	500	7250	B
30	435	B, C, D			
40	580	B, C, D			
50	725	B, C, D			

NOTE—The locked-rotor current of motors designed for voltages other than 230 volts shall be inversely proportional to the voltages.

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NEMA-Rated Motor Example

Example – Determine the **locked-rotor current** for the 150 Hp Reliance Electric induction motor:

Key Nameplate Data – 150 Hp, 460 V, 163 A, Design B

Table 31 → 150Hp / 230V / B → 2170 LR amps

Note – LR amps are inversely proportional to voltage

$$\therefore \textbf{ LR Amps} = 2170 \cdot \frac{230}{460} = 1085 \text{ A}$$

The LR amps are **6⅔x greater** than the FLA (I_{Rated})!!!

1085 A = 6.67 x 163 A

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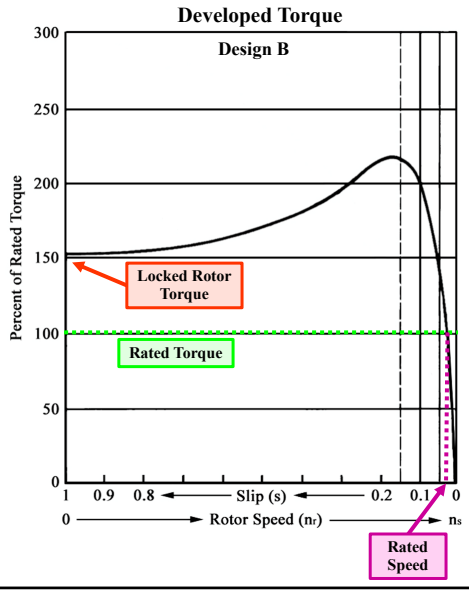
Locked-Rotor Torque

Locked-Rotor Torque is the amount of torque that the motor will develop at standstill when supplied with rated voltage.



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NEMA-Rated Motors

Table: **Locked-Rotor Torque** of Design A and B Motors

Table 32
LOCKED-ROTOR TORQUE OF DESIGN A AND B MOTORS [MG 1-12.38.1]

	Synchronous Speed, Rpm						
60 Hertz	3600	1800	1200	900	720	600	514
HP 50 Hertz	3000	1500	1000	750	—	—	—
1/2	—	—	—	140	140	115	110
3/4	—	—	175	135	135	115	110
1	—	275	170	135	135	115	110
1-1/2	175	250	165	130	130	115	110
2	170	235	160	130	125	115	110
3	160	215	155	130	125	115	110
5	150	185	150	130	125	115	110
7-1/2	140	175	150	125	120	115	110
10	135	165	150	125	120	115	110
15	130	160	140	125	120	115	110
20	130	150	135	125	120	115	110
25	130	150	135	125	120	115	110
30	130	150	135	125	120	115	110
40	125	140	135	125	120	115	110
50	120	140	135	125	120	115	110
60	120	140	135	125	120	115	110
75	105	140	135	125	120	115	110
100	105	125	125	125	120	115	110
125	100	110	125	120	115	115	110
150	100	110	120	120	115	115	—
200	100	100	120	120	115	—	—
250	70	80	100	100	—	—	—
300	70	80	100	—	—	—	—
350	70	80	100	—	—	—	—
400	70	80	—	—	—	—	—
450	70	80	—	—	—	—	—
500	70	80	—	—	—	—	—

*** – Table from NEMA Standards Condensed MG 1-2007**

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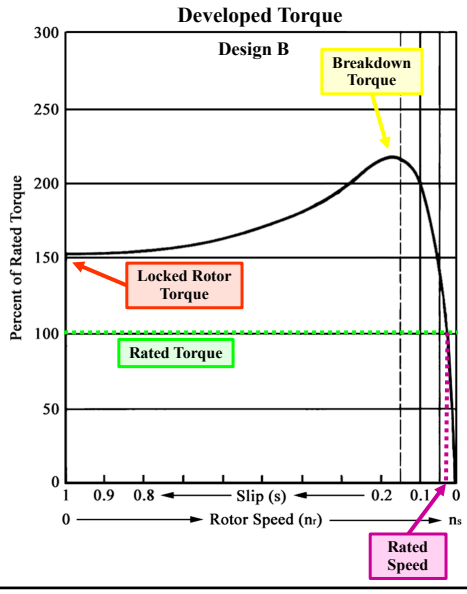
Locked-Rotor Torque

Locked-Rotor Torque is the amount of torque that the motor will develop at standstill when supplied with rated voltage.

Breakdown Torque is the maximum instantaneous torque that the motor can develop during normal operation without stalling.



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NEMA-Rated Motors

Table: **Breakdown Torque** of Design A and B Motors

Table 34
BREAKDOWN TORQUE OF DESIGN A AND B MOTORS [MG 1-12.39.1]

	Synchronous Speed, Rpm						
	60 Hertz	3600	1800	1200	900	720	600	514
HP	50 Hertz	3000	1500	1000	750	—	—	—
1/2		—	—	—	225	200	200	200
3/4		—	—	275	220	200	200	200
1		—	300	265	215	200	200	200
1-1/2		250	280	250	210	200	200	200
2		240	270	240	210	200	200	200
3		230	250	230	205	200	200	200
5		215	225	215	205	200	200	200
7-1/2		200	215	205	200	200	200	200
10-125, inclusive		200	200	200	200	200	200	200
150		200	200	200	200	200	200	—
200		200	200	200	200	200	—	—
250		175	175	175	175	—	—	—
300-350		175	175	175	—	—	—	—
400-500, inclusive		175	175	—	—	—	—	—

*** – Table from NEMA Standards Condensed MG 1-2007**

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NEMA Induction Motor Ratings

Table: **Locked-Rotor kVA** based on Code Letter

Table 12
CODE LETTERS (FOR LOCKED-ROTOR KVA)—NAMEPLATE MARKING [MG 1-10.37.2]

Letter Designation	kVA per Horsepower*	Letter Designation	kVA per Horsepower*
A	0-3.15	K	8.0-9.0
B	3.15-3.55	L	9.0-10.0
C	3.55-4.0	M	10.0-11.2
D	4.0-4.5	N	11.2-12.5
E	4.5-5.0	P	12.5-14.0
F	5.0-5.6	R	14.0-16.0
G	5.6-6.3	S	16.0-18.0
H	6.3-7.1	T	18.0-20.0
J	7.1-8.0	U	20.0-22.4
		V	22.4-and up

*Locked kVA per horsepower range includes the lower figure up to, but not including, the higher figure. For example, 3.14 is designated by letter A and 3.15 by letter B.

*** – Table from NEMA Standards Condensed MG 1-2007**

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NEMA Induction Motor Ratings

Table: **Winding Temperature** based on Insulation Class

Table 46
WINDING TEMPERATURES UNDER RUNNING LOAD CONDITIONS [MG 1 Table 12-8]

Insulation System Class	Maximum Winding Temperature, Degrees C
A	140
B	165
F	190
H	215

*** – Table from NEMA Standards Condensed MG 1-2007**

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Dual Voltage 3Φ Squirrel Cage Induction Motors

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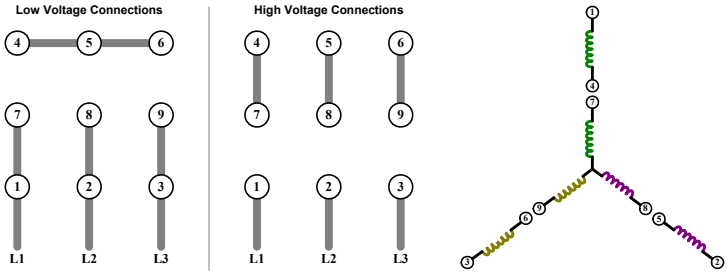
Dual-Voltage Induction Motors

Some 1Φ and 3Φ induction motors have **dual-voltage ratings**, the selection of which is based on the wiring configuration of the motor [parallel (low-V) or a series (high-V)].



Terminal Connections for 9-Terminal Dual-Voltage Y-Connected 3Φ Motor

Dual-voltage motors' rated voltages typically have a 1:2 ratio.

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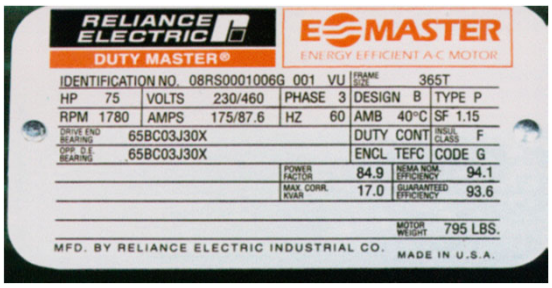
Dual-Voltage Induction Motors

Motors with a 1:2 rated-voltage ratio will have an **inverse ratio** of 2:1 for their **rated-current**.

The other ratings of the motor are independent of the wiring format.



Note that the rated voltages and currents for the motor shown to the left have the expected inverse relationships:

230V-175A / 460V-87.6A

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