ECET 3500

Electric Machines

NEMA Ratings

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 <u>standards</u> that relate to the design, installation and use of electrical equipment**

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

Standards

Standards:

- **Enable customers to select from a range of safe, effective, and compatible electrical products**
- **Promote fair competition by defining products and processes, leading to economies in production and elimination of misunderstanding**
- **Promote the manufacturing of products that are available globally, delivered locally, competitively priced, able to perform predictably, and are safe and environmentally sound**

NEMA Divisions

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

NEMA Standards

NEMA standards relating to motor control include:

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 – General Purpose Industrial AC Small & Medium Squirrel-Cage Induction Motors

NEMA Rated Motors

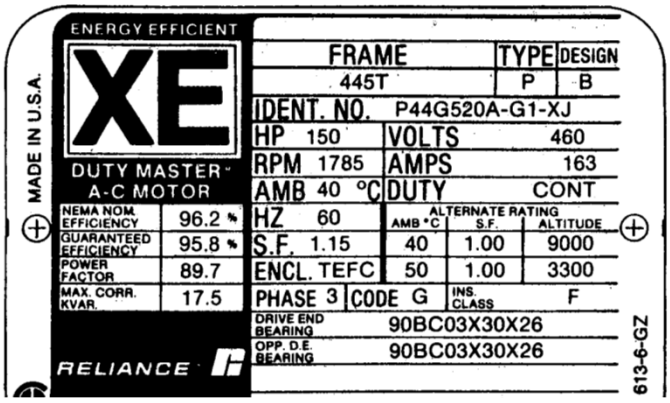
Motors must adhere to a uniform set of standards provided by NEMA in order to be called a "NEMA Rated Motor"

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

- **the frame/mounting dimensions**
- **the motor's ratings (voltage, current, frequency, speed, horsepower…)**
- **the locked-rotor current & torque**
- **the operating efficiency & temperature**

Motor Nameplates

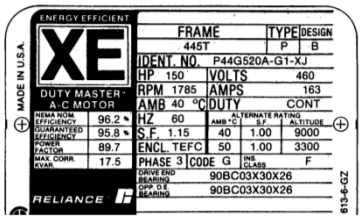
A motor's ratings and other key specifications are provided by means of a nameplate attached to the frame of the machine.



Motor Nameplates

A motor's ratings and other key specifications are provided by means of a nameplate attached to the frame of the machine.

Although the meanings of the ratings may appear to be self-evident by their names, the manner in which the rating information is provided often requires access to the look-up tables contained within the governing standard.



Nameplate Information

The nameplate typically includes the:

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

Nameplate Information

The nameplate typically includes the:

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

NEMA Induction Motor Ratings

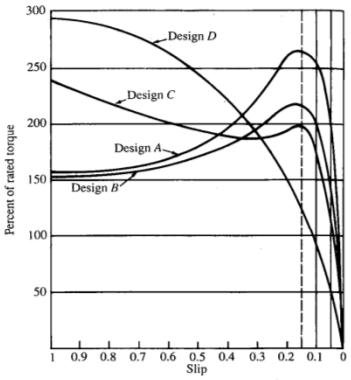
- **Frame Designation – information providing the shaft height / machine dimensions**
- **Horsepower – the maximum continuous load that the machine is able to drive**
- **Voltage – the expected operational "Line" voltage supplied to the machine**
- **Full Load Amps – the expected line current magnitude when supplied at rated voltage & frequency, driving rated load, and exposed to rated ambient temperature**

NEMA Induction Motor Ratings

- **Speed – the expected operational speed when supplied at rated voltage & frequency, driving rated load, and exposed to rated temperature**
- **Service Factor – a multiplier that may be applied to rated load under stated conditions provided that rated voltage/frequency is maintained**
- **Design Letter – indicates the torque-speed performance characteristics of the motor**

NEMA Induction Motor Designs

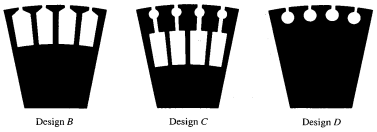
FIGURE 5–1
Torque-speed characteristics of basic NEMA-design squirrel-cage induction motors.



The torque-speed characteristics for motor designs A-D are shown in the figure to the right.

The torque-speed characteristic for a Squirrel-Cage Induction Motor can be adjusted by changing the size and depth of the motor's rotor conductors.

FIGURE 5–2
Representative cross sections of some NEMA-design rotors.



NEMA Induction Motor Ratings

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

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

are based upon the motor's ratings, and can be determined by utilizing the tables provided in the MG1 standard.

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

NEMA Induction Motor Ratings

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.

NEMA Induction Motor Ratings

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	—	—	—	—	—

NEMA Induction Motor Ratings

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	—	—	—	—	—

NEMA Induction Motor Ratings

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.

NEMA Induction Motor Ratings

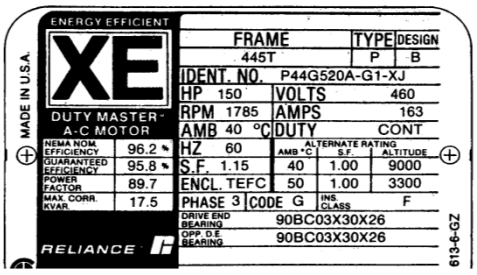
Winding Temperature Based on Insulation Class

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

Induction Motor Rating Example

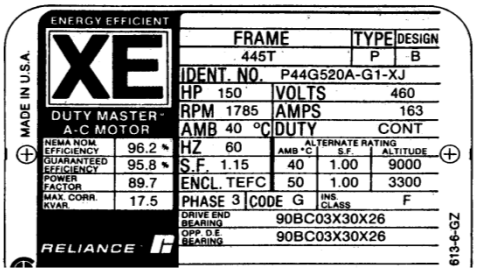
<u>Example</u> – Determine the <u>locked-rotor (starting) current</u> for the 150Hp induction motor shown below:



Induction Motor Rating Example

Example – Determine the <u>locked-rotor (starting) current</u> for the 150Hp induction motor shown below:

<u>Key Nameplate Data</u> – 150Hp, 460V, 163A, Design B



Induction Motor Rating Example

Example – Determine the <u>locked-rotor (starting) current</u> for the 150Hp induction motor shown below:

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

<u>Table 31</u> → 150Hp / <u>230V</u> / B → <u>2170</u> L-R amps

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
...			...		
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.

Induction Motor Rating Example

Example – Determine the locked-rotor (starting) current for the 150Hp induction motor shown below:

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

Table 31 → 150Hp / 230V / B → 2170 L-R amps

Note – L-R amps are inversely proportional to voltage

$$\therefore \textbf{L-R Amps} = 2170 \cdot \frac{230}{460} = 1085A$$

Induction Motor Rating Example

Example – Determine the locked-rotor (starting) current for the 150Hp induction motor shown below:

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

Table 31 → 150Hp / 230V / B → 2170 L-R amps

Note – L-R amps are inversely proportional to voltage

$$\therefore \textbf{L-R Amps} = 1085\,\text{A} = 6.67 \text{ x } 163\,\text{A}$$

The L-R amps are 6⅔x greater than the FLA!

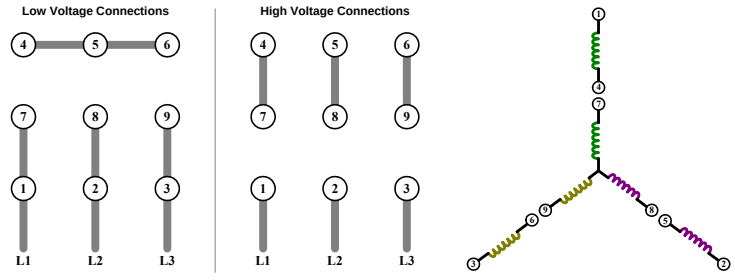
Dual-Voltage Induction Motors

Some 1Φ and 3Φ induction motors have dual-voltage ratings, the selection of which is based on the wiring configuration of the motor.

The rated voltages of both 1Φ and 3Φ, dual-voltage motors typically have a 1:2 ratio.

Dual-Voltage Induction Motors

Dual-voltage motors with a 1:2 voltage ratio contain two sets of windings that can be wired together in either a parallel (low-V) or a series (high-V) format.



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

Dual-Voltage Induction Motors

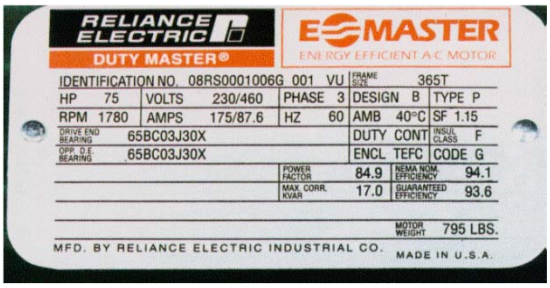
Dual-voltage motors with a 1:2 voltage ratio contain two sets of windings that can be wired together in either a parallel (low-V) or a series (high-V) format.

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

The other ratings of the 1:2 motor are independent of the wiring format (i.e. – 1:1) provided that the appropriate rated voltages are applied.

Dual-Voltage Induction Motors

The nameplate for a 230/460V motor is shown below:



Note that the rated voltages and currents have the expected inverse relationship:

230V-175A / 460V-87.6A