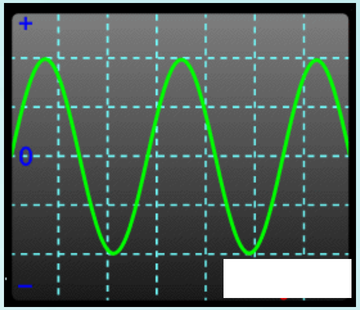
NEMA vs. IEC Motor Standards

Comparison and Contrast of the Two Design Practices

NEMA Standards vs. IEC Standards

- Overview/Objectives:
  - Voltage and Frequency
  - Service Factory / Duty Type
  - Insulation Classes
  - Efficiency Measurements
  - Altitude and Ambient Temperature
  - Frame Size Designations
  - Construction Comparisons

Voltage, Frequency



Nominal Voltages @ 50 Hz		Nominal Voltages @ 60 Hz	
NEMA	IEC	NEMA	IEC
220		115	
	230		120/208
	230/400	200	
380	500*		240
	400/690	230	230/400
	1000		277/480
			347/600
		460	
		575	
			600

NEMA

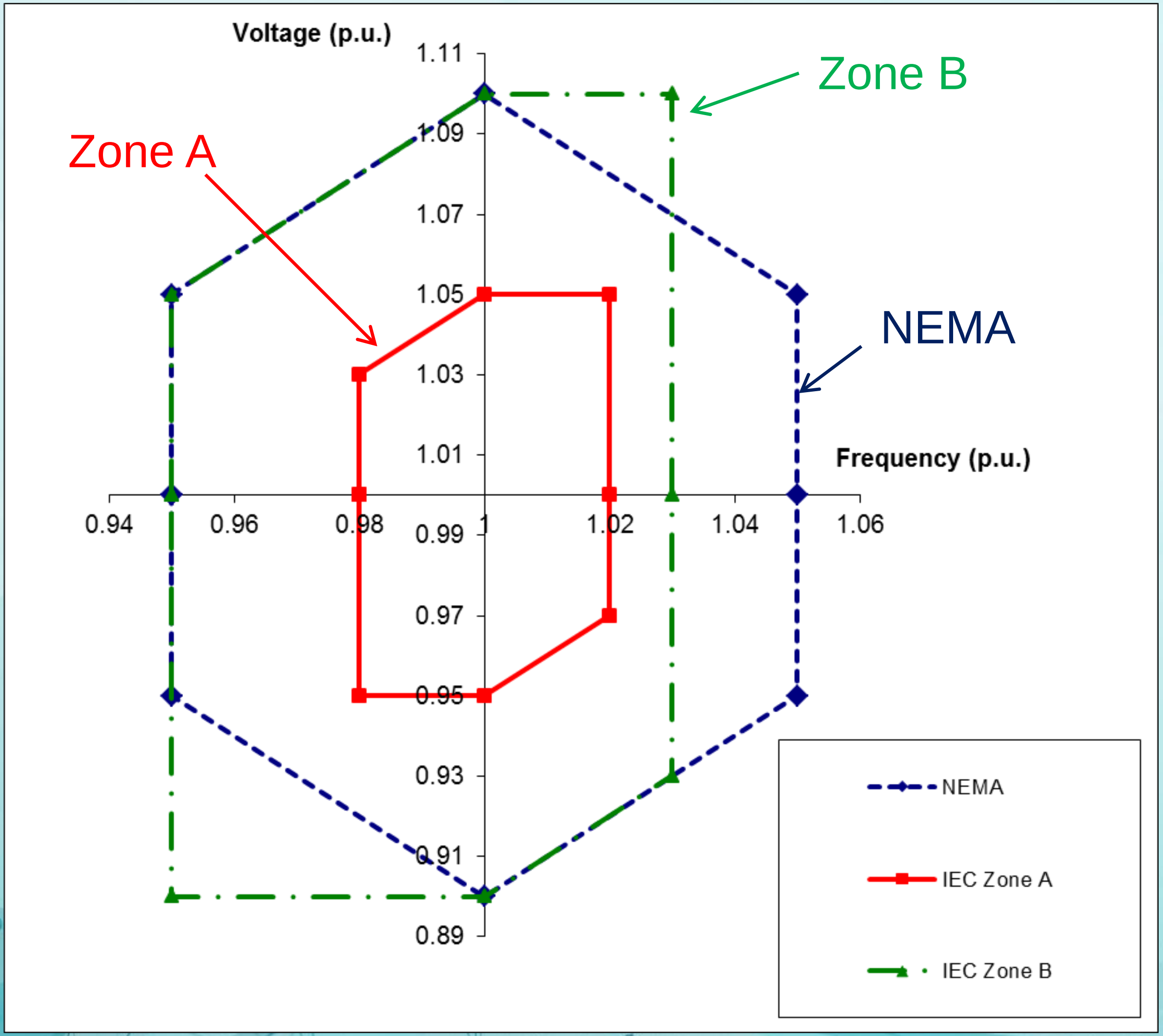
Voltage, Frequency

	Voltage	Frequency
NEMA	+/- 10%	+/- 5%
IEC, zone A	+/- 5%	+/- 2%
IEC, zone B	+/- 10%	+3% / -5%

NEMA/IEC Allowable Voltage
and
Frequency Variations for Motors

NEMA

Voltage, Frequency



Service Factor/Duty Type

- Service Factor = NEMA MG 1 definition
- Example: 400 HP with 1.15 SF can be run continuously at   400 x 1.15 = 460 HP
- May be employed for several reasons
  - Uncertainty in the load HP requirement
  - Intermittent overloads
  - Unbalanced supply voltages
  - Comfort factor for user
- Motor runs hotter – reduced insulation/bearing life

NEMA

Service Factor/Duty Type

- IEC - does not recognize the use of service factor
- IEC - specifies a "Duty Type" for each motor design
- Purchaser of machine must specify duty
  - Numerically
  - As a time sequence graph
  - By selecting a predefined duty (S1-S10)

Service Factor/Duty Type

Duty Type	Description
S1	Continuous
S2	Short time
S3	Intermittent periodic
S4	Intermittent periodic with starting
S5	Intermittent periodic with electric braking
S6	Continuous operating periodic
S7	Continuous operating periodic with electric braking
S8	Cont. operating with related load/speed changes
S9	Duty with non-periodic load and speed variations
S10	Duty with discrete constant loads and speeds

NEMA

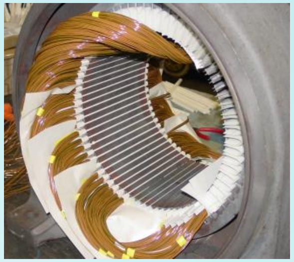
Insulation Classes

- NEMA identifies four insulation classes: A, B, F & H
- Temperature rise by resistance limits for low voltage, random wound shown – based on 40°C ambient

Note	Class A (105°C)	Class B (130°C)	Class F (155°C)	Class H (180°C)
1	60	80	105	125
2	70	90	115	--
3	65	85	110	130
4	65	85	110	--

Note 1: Motors with a 1.0 SF, other than in notes 3 & 4
Note 2: All motors with a 1.15 SF or higher
Note 3: Totally enclosed non-ventilated motors with a 1.0 SF
Note 4: Motors with encapsulated windings and with a 1.0 SF

Insulation Classes



- IEC identifies many thermal classes
- Maximum allowable total temperature (°C)

IEC Thermal Class Designation	Letter Designation
90	Y
105	A
120	E
130	B
155	F
180	H
200	N
220	R
250	-

Efficiency – Measurement Harmonization

- Under the old IEC standard, 0.5% of input power at rated load was used to calculate the additional load (stray) losses
- New standard uses same method as IEEE 112 method B
  - Stray losses “indirectly” measured
- This method is employed by majority of motor manufacturers

Efficiency – NEMA Standard MG1

- Nominal efficiency values in defined in Part 12
- Nameplate efficiency selected from Table 12-10

  ≤ average efficiency of a large population

  of the same design
- For an individual motor: efficiency ≥ the minimum value associated with the nominal value in Table 12-10

Efficiency - IEC

- IEC defines International Energy-efficiency classes

  (IE Codes) in IEC Standard 60034-30
- IEC motor nameplate efficiency is the rated efficiency assigned by the manufacturer
- For a particular IE code, the rated efficiency must not be less than the value given in 60034-30 for that rating
- For IEC motors, the rated efficiency and IE code shall be marked on the nameplate (IE2-84,0%)

Efficiency – NEMA/IEC

Portion of NEMA MG1 Table 12-10 EFFICIENCY LEVELS	
Nominal Efficiency	Minimum Efficiency Based on 20% Loss Difference
98.5	98.2
98.4	98.0
98.2	97.8
98.0	97.6
97.8	97.4
97.6	97.1
97.4	96.8
97.1	96.5
96.8	96.2
96.5	95.8
96.2	95.4
95.8	95.0
95.4	94.5

Efficiency – NEMA/IEC

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96.8	96.2
96.5	95.8
96.2	95.4
95.8	95.0
95.4	94.5

Manufacturer's Calculated Efficiency	Nameplate Efficiency	
	NEMA	IEC
96.1%	95.8%	96.1%

IEC nameplate efficiency would be 0.3% higher than NEMA motor of same design

Efficiency - Harmonization

- IEC IE2 and IE3 levels for 60 Hz motors were adopted directly from MG 1 Tables 12-11 and 12-12

NEMA Level	IEC Level
--	IE1
Energy Efficient	IE2
Premium Efficiency	IE3

Efficiency Levels for 60 Hz Motor Designs

- NEMA 50 Hz efficiency values found in Table 12-14 were derived directly from IEC 60034-30

Altitude/Ambient

- Interrelated and considered together
- 3300' (1000 m) maximum altitude without need for compensation for both NEMA & IEC
- 40°C maximum allowable ambient without compensation for both NEMA & IEC

Altitude - NEMA

- Above 3300’, NEMA – two options
  - Reduction in ambient
  - Reduction in permissible rise at sea level

TRSL = TRA [1-(ALT-3300)/33000]

Where:

TRSL = temperature rise limit in degrees C when tested at sea level

TRA = standard permissible temperature rise limit at sea level for the insulation class

ALT = altitude above sea level in feet at which machine is to be operated

Altitude - NEMA

Reduction in ambient required by NEMA at high altitude to avoid reduction in permissible temperature rise

Maximum Altitude, Feet (Meters)	Ambient Temperature (°C)
3300 (1000)	40
6600 (2000)	30
9900 (3000)	20

Altitude - IEC

- Above 3300 ft. (1000 meters), IEC
  - Between 1000 and 4000 meters: assumes ambient reduction will compensate for higher temperature rise

Altitude, Meters	Thermal Class		
	130 (B)	155 (F)	180(H)
	Ambient Temperature (°C)		
1000	40	40	40
2000	32	30	28
3000	24	19	15
4000	16	9	3

  - For altitudes above 4000 meters, the IEC says the temperature rise shall be adjusted “by agreement”

Ambient

- For ambient temperatures above 40°C:
  - NEMA specifies the temperature rise be reduced by the amount over 40°C
  - IEC specifies the temperature rise be reduced by the amount over 40°C (40-60°C only)
  - Above 60°C, IEC specifies the temperature rise be adjusted “by agreement”

Ambient (0°C ≤ A ≤ 40°C)

- For ambient temperatures between 0° & 40°C:
  - Both NEMA and IEC use an equation to determine the allowable increase in permissible temperature rise
  - There are slight differences to be aware of

Ambient (0°C ≤ A ≤ 40°C)

NEMA

- For Δ in ambient of ≤ 5°C, add Δ to allowable rise
- For Δ in ambient > 5°C use the following formula:

  Increase in Rise = (40°C-marked ambient)(1-[reference temperature – (40°C + temperature rise limit)]/80°C)

Where reference temperature is from following table:

	Class of Insulation System			
	A	B	F	H
SF < 1.15	105	130	155	180
SF ≥ 1.15	115	140	165	190

Ambient (0°C ≤ A ≤ 40°C)

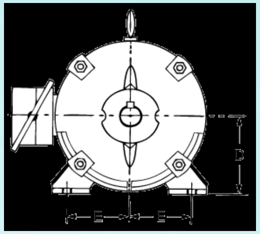
IEC

- For any ambient between 0° & 40°C, use the following formula:

  Increase in Rise = (40°C-marked ambient)(1-[thermal class– (40°C + temperature rise limit)]/80°C)

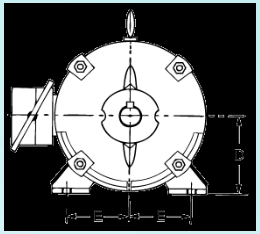
  – IEC does not take service factor into account, as service factor is not recognized by the IEC

Frame Size Designations



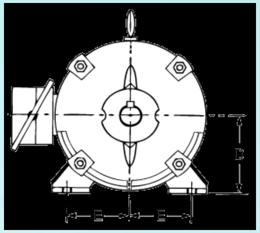
- NEMA MG 1 assigns a frame size based on enclosure, HP and rpm for 60 Hz operation
- IEC does not associate any specific output power and speed to a specific frame size
  - CENELEC harmonization document HD231 does
  - This document covers totally enclosed squirrel cage motors at 50 hz, 56 to 315M frames, up to 132 kW

Frame Size Designations



NEMA			IEC		
Frame	Shaft Height (in)	Shaft Height (mm)	Frame	Shaft Height (in)	Shaft Height (mm)
			63	2.480	63
42	2.625	66.675	71	2.795	71
48	3.0	76.200	80	3.150	80
56 / 140T	3.5	88.900	90	3.543	90
			100	3.937	100
180T	4.5	114.300	112	4.409	112
210T	5.3	133.350	132	5.197	132
250T	6.3	158.750	160	6.299	160
280T	7.0	177.800	180	7.087	180
320T	8.0	203.200	200	7.874	200
360T	9.0	228.600	225	8.858	225
400T	10.0	254.000	250	9.843	250
440T	11.0	279.400	280	11.024	280
5000	12.5	317.500	315	12.402	315
5800	14.5	368.300	355	13.976	355
			400	15.748	400
6800	17.0	431.800	450	17.717	450
			500	19.685	500

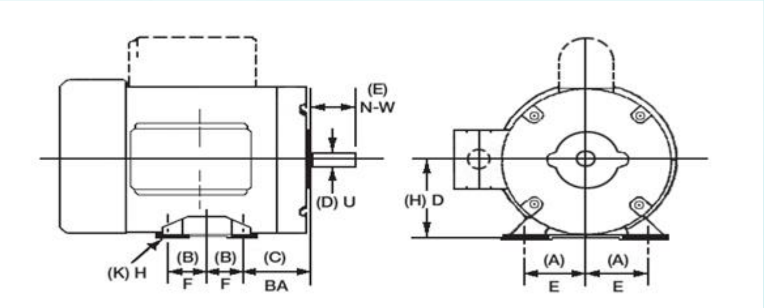
Frame Size Designations



- IEC measurement labels tend to be more logically defined

  Length: NEMA = C, IEC = L
  Shaft height: NEMA = D, IEC = H
  Shaft diameter: NEMA = U, IEC = D

- IEC in mm, NEMA in inches
- Many dimensions are very close
  - NEMA output shafts tend to be longer
  - Shaft heights, foot spacing and shaft diameters generally within 3 or 4 mm



Merging of Standards

- IEC enclosure (IP) & cooling (IC) codes are included in NEMA MG 1
- NEC incorporates IEC hazardous area zone classifications
- IEC 60034-2-1 contains a test method essentially equivalent to IEEE 112 (method B) and CSA 390-10
- NEMA 50 Hz efficiency values found in Table 12-14 were derived directly from IEC 60034-30
- IEC IE2 and IE3 levels for 60 Hz motors were adopted directly from MG-1 Tables 12-11 and 12-12

North American participation in global standards writing is becoming more widespread – it is reasonable to expect further infusion of IEC specifications as U.S. manufacturers expand into global markets

IEEE 841 Construction Norms & Expectations

Electrical Features	841 NEMA
Service Condition	Division II Normal
Service Factor	1.0 (1.15 is normal)
Cooling	TENV & TEFC
Efficiency Standard	Nominal per NEMA MG 1, table 12-12 with minimums from 12-10
Connection	3-lead with flying leads
Starting Method	Line start
Inverter Capable?	Yes

NEMA

IEEE 841 Construction Norms & Expectations

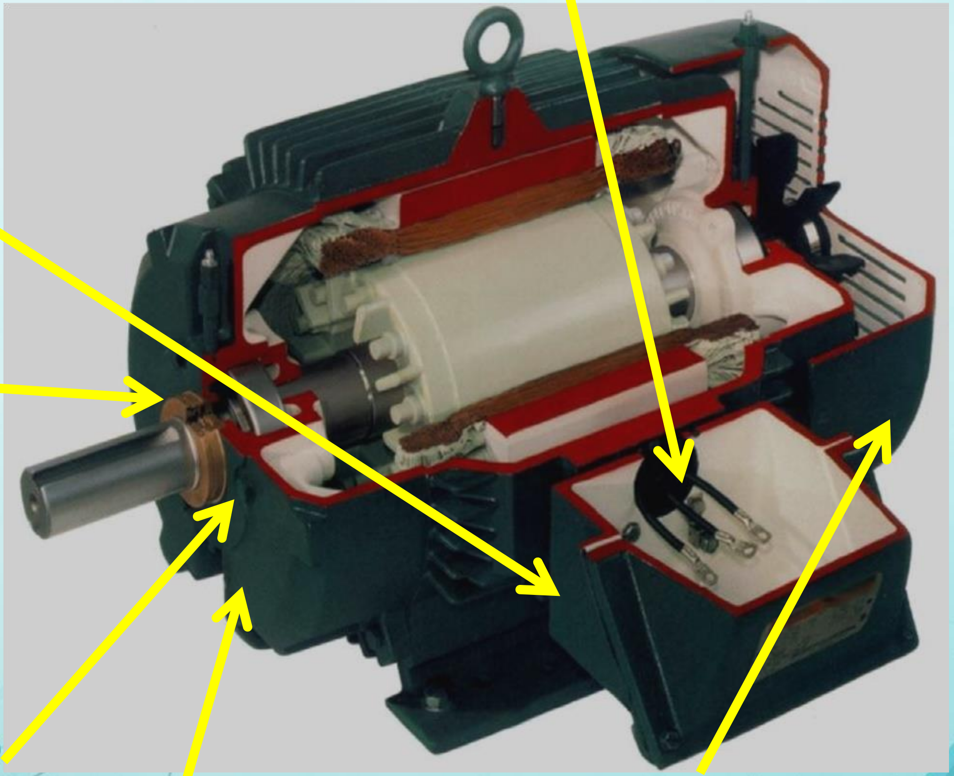
Mechanical Features	841 NEMA	Std. IEC
Conduit Box	Center- side mount, rotatable in 90° increments, diagonally split lid	Drive-end top mount cast to frame with flat cover
Shaft Seal	Non-contact labyrinth seal both ends	Contact seal on drive end of shaft
Level of Protection	IP55 or IP56	Same
Bearings Retainers	Cast iron both ends	Usually on drive end only
Grease Provisions	Extended greasers with relief each end	Grease provisions
Thrust Loading	Optional thrust bearings for pumps	Not normal in IEC motors as European pumps usually handle the thrust load

Typical IEEE-841 Motor Construction

3 Flying leads

Side mounted conduit box

Rotating labyrinth seal



Cast iron frame ,endplates and Bearing retainers

Cast iron fan cover

IEEE 841 Construction Norms & Expectations

Motor testing	NEMA
IEEE 841 Tests	Measurement of winding resistance
	No-load readings of current, power and nominal speed at rated voltage and frequency
	Mechanical vibration check – 2 perpendicular on radial and one on axial plane
	High potential test

Conclusion

- A wide variety of electric motors are available in either IEC or NEMA design
- An understanding of these differences and similarities of the design standards will help you select the correct design requirements for a new installation or field replacement
- Once you can detail the design and performance requirements for your application, you can identify acceptable motors to choose from whether they are NEMA design or IEC design