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Demystifying Metric: NEMA vs. IEC Motors

General Overview

- Fundamental motor operation is the same
  - Both are induction motors
- National Electrical Manufacturers' Association (NEMA)
  - Primary standards in the United States
    - Influential in Canada, Mexico as well
- International Electrotechnical Commission (IEC)
  - Most widely adopted standards worldwide
    - 67 member countries, including the US
  - IEC defined requirements issued as Directives by the EU
    - International standards frequently incorporated into local country specifications

Merging of Standards

- Harmonizing of standards required to create a truly global marketplace
  - IEC enclosure and ventilation codes (IC) are now in the NEMA MG standards
  - NEC incorporates IEC hazardous area zone classifications
  - Restriction of Hazardous Substances (RoHS) is an EU directive
    - Does not currently apply to motors
  - Efficiency calculations
    - IEC assumes a fixed value for stray losses, NEMA measures them
- US participation in standards writing is declining
  - Reasonable to expect further infusion of IEC specifications

Aspects for Comparison

- Insulation classes
- Ambient
- Altitude
- Efficiency classes
- Power ratings – kW vs. HP
- Service factor
- Cooling codes
- Ingress protection codes
- Impact protection codes
- Frame size designations

- Output characteristics
- Duty cycles
- Dimensional nomenclature
- Mounting positions
- Terminal box positions

Power Ratings

- NEMA motors rated in horsepower (HP)
  - 1 HP = power to lift 33,000 pounds 1 foot in 1 minute
- IEC uses kilowatts (kW)
  - HP x 0.746 = kW or kW/0.746 = HP
- Both NEMA and IEC assign specific power ratings to certain frame sizes according to speed
  - In general, output power ratings and frame sizes are comparable
    - There are some exceptions, and in these cases there can be frame size differences to be taken into consideration

Voltage, Frequency & Speed

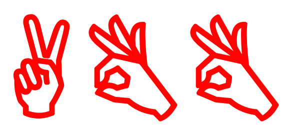
- Common voltages from around the world

50 HZ	220	240	380*	400*	415	500	660	690*
60 HZ	230	---	440	460	480	575	---	---

* Voltages occasionally seen at 60 HZ

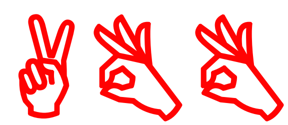
- Maximum voltage variation: NEMA ± 10%; IEC ± 5%
- Maximum frequency variation: NEMA ± 5%; IEC ± 2%
- Base speeds based on number of poles

Poles	2	4	6	8	10	12
RPM 60 HZ	3600	1800	1200	900	720	600
RPM 50 HZ	3000	1500	1000	750	600	500

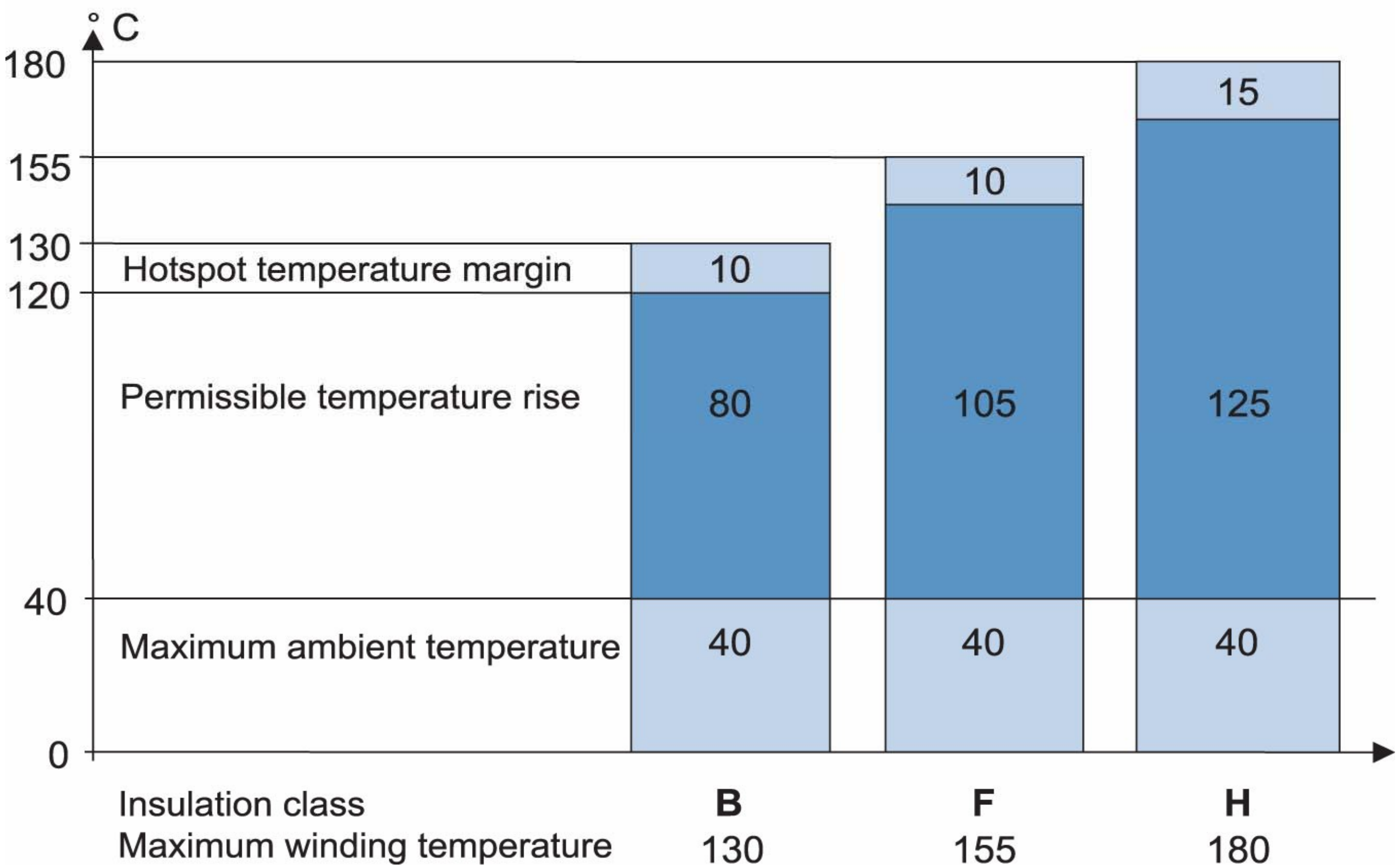


Service Factor

- Definition: Permissible amount of overload a motor will handle within defined temperature limits without overheating
  - Motor may be loaded according to value of rated power times service factor
  - Primary uses
    - Compensate for inaccuracy in predicting system power needs
    - Lengthen insulation life by lowering winding temperature at rated load
    - Handle intermittent overloads or unbalanced supply voltages
- Service factor is not recognized by IEC
  - Motors are designed to deliver rated power for an average lifetime
    - Size the motor to the application requirements

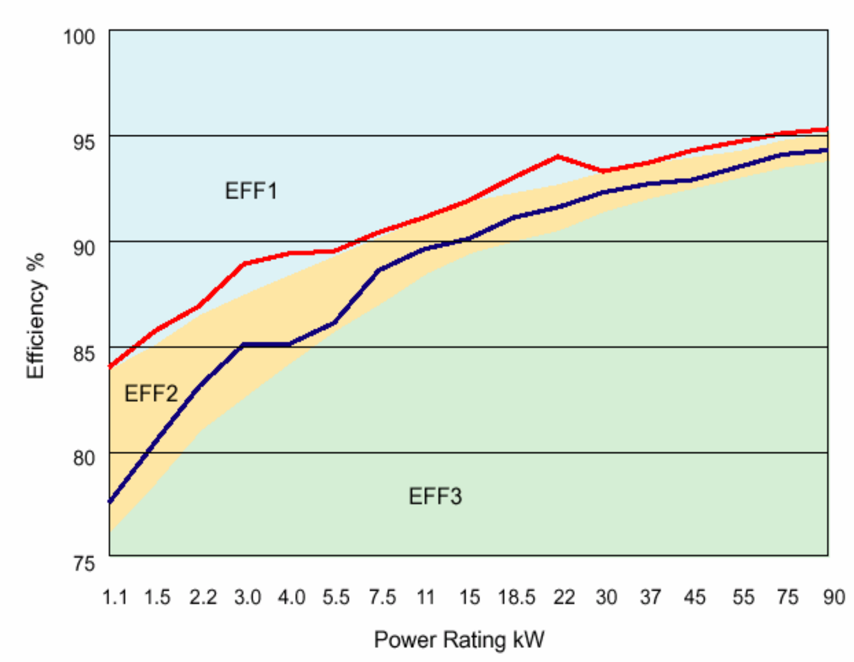


Insulation Classes



Efficiency Classes

- Efficiency definitions
  - EPAct, NEMA premium define specific points to be met by power and speed
    - EPAct 1 to 200 hp
    - NEMA Premium 1 to 500 hp
  - IEC defines efficiency ranges
    - Border lines are specified by power and speed
    - 1.1 to 90 kW
  - Mandatory minimum levels
    - EPAct in US
    - No minimum level in IEC



Altitude

- The cooling affect of surrounding air is directly dependent on the density of the air
  - Air density diminishes as altitude increases, reducing the ability of the surrounding air to cool the motor
  - Standard ratings are based on 1000 meters asl (3300 feet)
  - Need to derate motor output if altitude is higher

Altitude m	1000	1500	2000	2500	3000	3500	4000
Altitude ft	3300	4900	6600	8200	9800	11500	13100
Derate Factor	100	96	92	88	84	80	76

Ambient

- Ambient temperature is the temperature of the medium surrounding the motor – air, water, etc.
  - Standard ratings are based on 40˚C (104˚F)
  - Need to derate motor output if ambient is higher

Ambient °C	40	45	50	55	60	65	70	80
Ambient °F	104	113	122	131	140	149	158	176
Derate Factor	100	96.5	93	90	86.5	83	79	70

International Cooling Codes

- IC codes are now included in NEMA enclosure type definitions

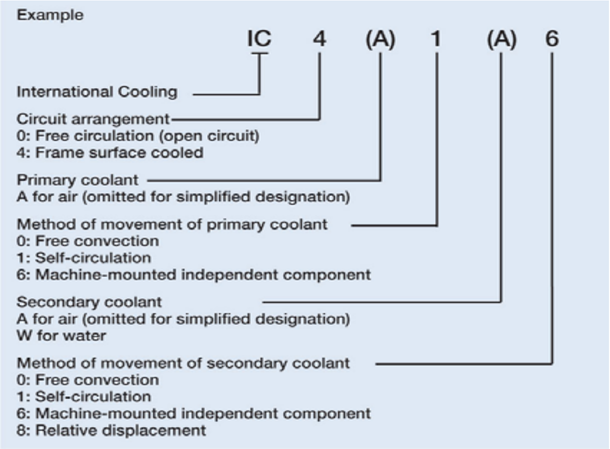
1.26.2 Totally Enclosed Fan-Cooled Machine

A totally enclosed fan-cooled machine is a frame-surface cooled totally enclosed machine equipped for self exterior cooling by means of a fan or fans integral with the machine but external to the enclosing parts.

1.26.3 Totally Enclosed Fan-Cooled Guarded Machine (IC411)

A totally-enclosed fan-cooled guarded machine is a totally-enclosed fan-cooled machine in which all openings giving direct access to the fan are limited in size by the design of the structural parts or by screens, grilles, expanded metal, etc., to prevent accidental contact with the fan. Such openings shall not permit the passage of a cylindrical rod 0.75 inch diameter, and a probe such as that shown in Figure 1-1 shall not contact the blades, spokes, or other irregular surfaces of the fan.

- IEC specifies detail using letter & number codes for definition
  - IC 410 – motor without fan
  - IC 411 – TEFC
  - IC 416 – TEBC
  - IC 418 – TEAO (airstream)
  - IC 01 – ODP



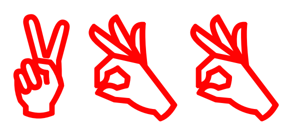
Ingress Protection (IP) Codes

- Ingress protection defines specific degrees of protection against persons getting in contact with moving parts inside the enclosure
  - Two digit code
    - First number defines the level of protection against solid objects
    - Second number defines protection against entry of water
  - Example

1.26.6 Water-Proof Machine (IP55)

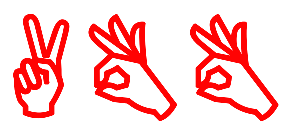
A water-proof machine is a totally enclosed machine so constructed that it will exclude water applied in the form of a stream of water from a hose, except that leakage may occur around the shaft provided it is prevented from entering the oil reservoir and provision is made for automatically draining the machine.

The means for automatic draining may be a check valve or a tapped hole at the lowest part of the frame which will serve for application of a drain pipe.



Ingress Protection Codes

First Number		Second Number	
Protection Against Solid Bodies		*Protection Against Liquid*	
0	No protection	0	No protection
1	Objects > 50 mm	1	Vertically dripping water
2	Objects > 12 mm	2	75º to 90º dripping water
3	Objects > 2.5 mm	3	Sprayed water
4	Objects > 1 mm	4	Splashed water
5	Dust protected	5	Water jets
6	Dust-tight	6	Heavy seas
7		7	Effects of immersion
8		8	Indefinite immersion

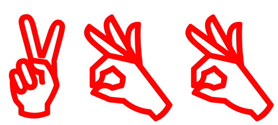


Mounting Positions

	Code I/Code II						Product code pos. 12
Foot-mounted motor.	IM B3 IM 1001	IM V5 IM 1011	IM V6 IM 1031	IM B6 IM 1051	IM B7 IM 1061	IM B8 IM 1071	A = foot-mounted, term.box top R = foot-mounted, term.box RHS L = foot-mounted, term.box LHS
Flange-mounted motor, large flange	IM B5 IM 3001	IM V1 IM 3011	IM V3 IM 3031	*) IM 3051	*) IM 3061	*) IM 3071	B = flange mounted, large flange
Flange-mounted motor, small flange	IM B14 IM 3601	IM V18 IM 3611	IM V19 IM 3631	*) IM 3651	*) IM 3661	*) IM 3671	C = flange mounted, small flange
Foot- and flange-mounted motor with feet, large flange	IM B35 IM 2001	IM V15 IM 2011	IM V36 IM 2031	*) IM 2051	*) IM 2061	*) IM 2071	H = foot/flange-mounted, term.box top S = foot/flange-mounted, term.box RHS T = foot/flange-mounted, term.box LHS
Foot- and flange-mounted motor with feet, small flange	IM B34 IM 2101	IM V17 IM 2111	IM 2131	IM 2151	IM 2161	IM 2171	J = foot/flange-mounted, small flange
Foot-mounted motor, shaft with free extensions	IM 1002	IM 1012	IM 1032	IM 1052	IM 1062	IM 1072	

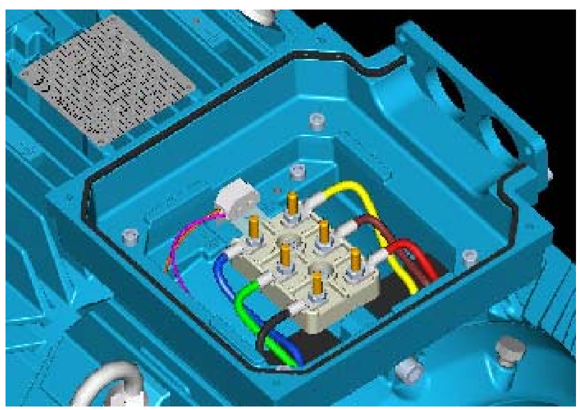
*) Not stated in IEC 60034-7.

- Every combination of orientation, feet and/or flanges has a specific designation
- Two different codes
  - Short form
    - One letter, two numbers
  - Full code according to IEC standards
    - IM x yy z => IM 1001
      - x = construction type
      - yy = mounting arrangement
      - z = # of shaft extensions



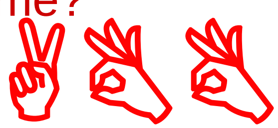
Terminal Boxes

- NEMA standard location is on left hand side facing output shaft (F1)
  - Optional positions on right hand side (F2) and on top (F0)
  - Flying leads require extra space to connect and contain inside
- IEC standard is on top
  - Optional locations on either side – left (F1) or right (F2)
  - Terminal box can generally be rotated 4 x 90 degrees
  - Terminal posts make for easy connection of leads



Frame Size Designations

- First two (2) digits of NEMA frame size designation represent four (4) times the actual shaft height in inches
  - EX: 11 inch shaft height x 4 = 44_ frame size
- IEC motors use actual shaft height in millimeters
  - EX: 280 mm shaft height = 280 frame
- Most frame sizes in either NEMA or IEC have a comparable equivalent in terms of shaft height
  - EX: 280 mm/(25.4 mm/in) = 11.02 inches
  - EX: 11 in x 25.4 mm/in = 279.4 mm
  - One exception – there is a 100 frame IEC motor which has no comparable NEMA counterpart
    - [100 mm/(25.4 mm/in)] x 4 = 15.7 inches => NEMA 160 frame?



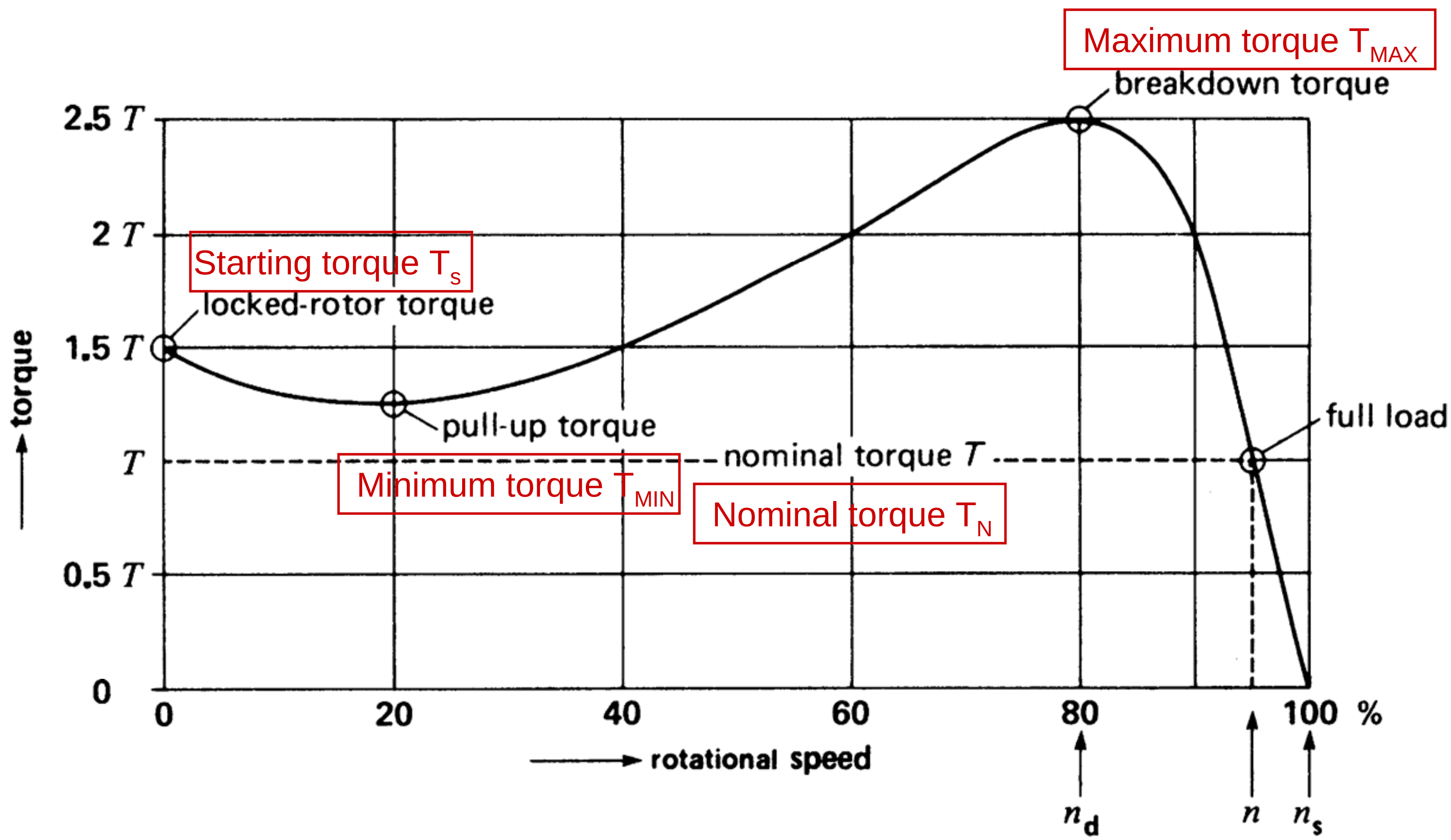
Frame Size Comparisons

- IEC defines a wider range
  - 56 through 900 mm shaft heights
  - No NEMA equivalents for all of them
    - NEMA technically stops with 440 frame series

IEC	56	63	71	80	90	100	112	132	160	180	200
NEMA	---	42	48	56	140	---	180	210	250	280	320

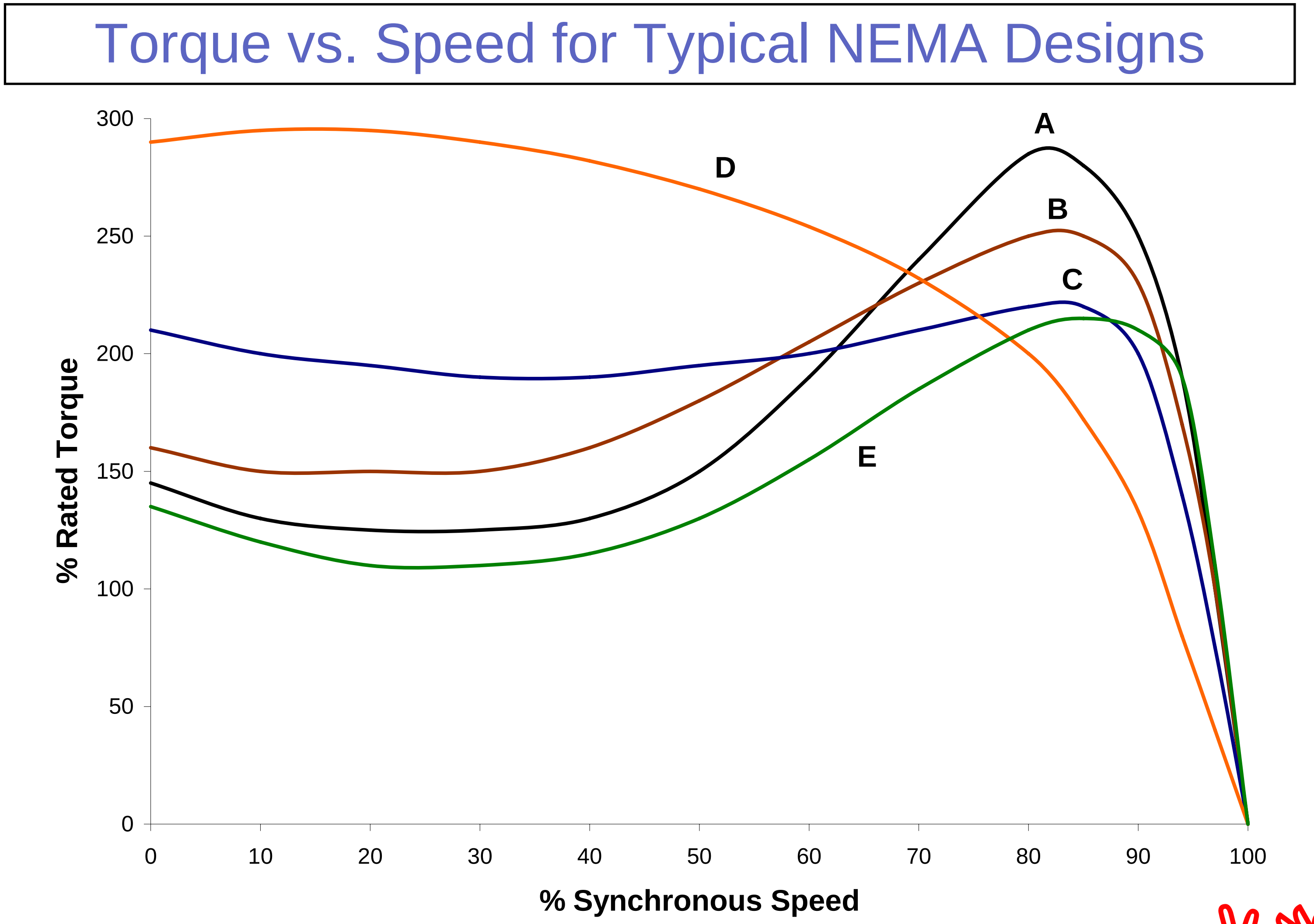
IEC	225	250	280	315	355	400	450	500	560	630	710
NEMA	360	400	440	500	580	680	700	800	---	---	---

AC Motor Torque Characteristics



IEC designations

AC Motor Torque Characteristics



Output Characteristics

- Standard torque profile for IEC most like NEMA design A
  - Higher starting torque and starting current than design B
  - Results in higher efficiencies, lower audible noise
    - Also higher starting currents
- IEC motors are not designed to handle thrust loads
  - No normal or high thrust designs
  - No hollow shaft designs
  - European pump companies design the thrust load capability into the pumps

Dimensional 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 dimensions are in mm, NEMA in inches
- Many dimensions are very close to the same
  - NEMA output shaft lengths tend to be longer
  - Shaft heights, foot spacings, shaft diameters within 3 or 4 mm

ATEX Directive

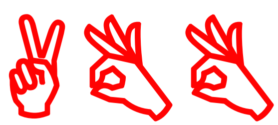
Product Directive 94/9/EC (ATEX 100a*/ ATEX 95**)

- Concentrates on the duties of the manufacturers for appropriate products
- Describes the Essential Healthy and Safety Requirements (EHSRs) for the products with regard to design, manufacturing process, testing, documentation and maintainability

Worker Protection Directive 1999/92/EC (ATEX 118* / ATEX 137**)

- Concentrates on the duties of the end users for safe operation
- Describes the “minimum requirements” for improving the health and safety protection of workers potentially at risk
  - Risk analysis and description, zone definition, maintenance practices in relation to safety on site

(*) *Reference to Article 100a/118 of the Treaty of Rome (1957)*
(**) *Reference to Article 95/137 of the Treaty of Amsterdam (1997)*



Equipment Classifications - Groups

- **Group I** -Apparatus for coal mines susceptible to firedamp (underground applications)
- **Group II** - Apparatus for explosive atmospheres other than mines (surface industries)
- Group II is further subdivided according to the nature of the gas or vapor present
  - **Group IIA** – Acetone, ammonia, ethyl alcohol, gasoline, methane, propane
  - **Group IIB** – Acetaldehyde ethylene
  - **Group IIC** – Acetylene, hydrogen

NEC 500 Explosive Atmosphere Classifications

- **CLASS I**
  - **Group A:** Acetylene
  - **Group B:** Butadiene, ethylene oxide, hydrogen, propylene oxide, manufactured gases containing more than 30% hydrogen by volume
  - **Group C:** Acetaldehyde, cyclopropane, diethyl ether, ethylene
  - **Group D:** Acetone, acrylonitrile, ammonia, benzene, butane, ethanol, ethylene dichloride, gasoline, hexane, isoprene, methane (natural gas), methanol, naphtha, propane, propylene, styrene, toluene, vinyl acetate, vinyl chloride, xylene
- **CLASS II**
  - **Group E:** Aluminum, magnesium and other metal dusts with similar characteristics
  - **Group F:** Carbon black, coke, charcoal or coal dust
  - **Group G:** Flour, wood, plastic, chemical, starch or grain dust
- **CLASS III**
  - Easily ignitable fibers, such as rayon, cotton, sisal, hemp, cocoa fiber, oakum, excelsior and other materials of similar nature

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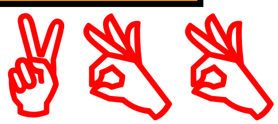
Apparatus Grouping Comparison

Typical Gas/Dust/Fiber	NEC 500 Classification	Division 1 Zone 1/21 & 22 C	Division 2 Zone 2/22 NC
Acetylene	Class I, Group A	Flameproof Ex d IIC T4	Non-Sparking Ex nA II T3
Hydrogen	Class I, Group B	Flameproof Ex d IIC T4	Non-Sparking Ex nA II T3
Ethylene	Class I, Group C	Flameproof Ex d IIB T4	Non-Sparking Ex nA II T3
Propane	Class I, Group D	Flameproof Ex d IIA T4	Non-Sparking Ex nA II T3
Methane	Mining*	Group I*	---
Metal dust	Class II, Group E	DIP IP 65 Ex tD A21	DIP IP 55 Ex tD A22
Coal dust	Class II, Group F	DIP IP 65 Ex tD A21	DIP IP 55 Ex tD A22
Grain dust	Class II, group G	DIP IP 65 Ex tD A21	DIP IP 55 Ex tD A22
Fibers	Class III	---	---

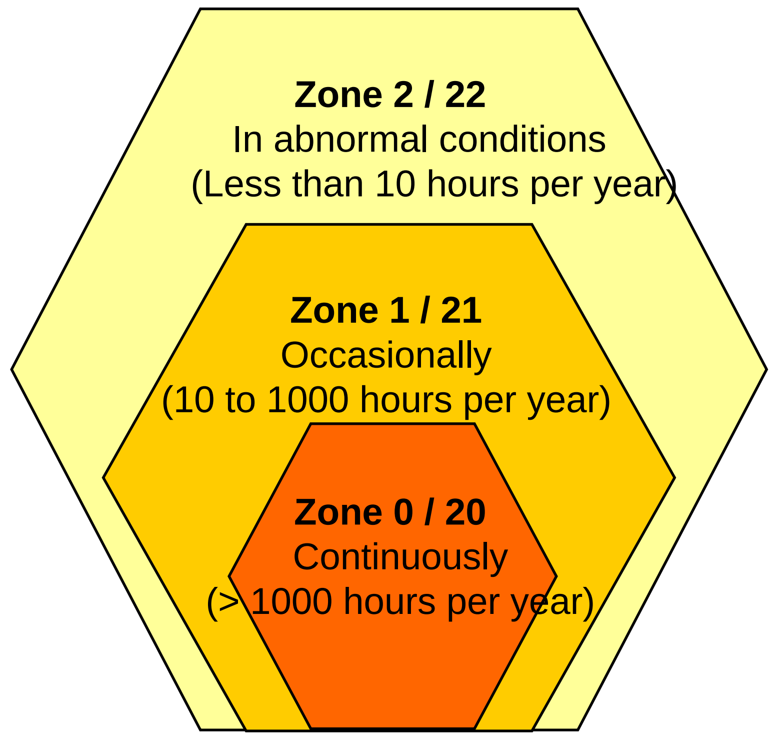


* Not within the scope of NEC, falls under the jurisdiction of MHSA

Equipment Classifications - Zones

- Hazardous areas are classified in terms of zones based on the potential frequency and duration of the occurrence of an explosive atmosphere of gas, vapor or combustible dust
- Zone 0 / 20
  - Present continuously, typically more than 1000 hours per year
- Zone 1 / 21
  - Present occasionally, typically between 10 and 1000 hours per year
- Zone 2 / 22
  - Present in abnormal conditions, typically less than 10 hours per year

Zones 0, 1 and 2 refer to gas
Zones 20, 21 and 22 refer to dust



No motors are allowed in Zone 0 / 20

Flameproof (Ex d)

- Motor enclosure shall be designed in such a way that no internal explosion can be transmitted to the explosive atmosphere surrounding the motor
- The enclosure must withstand, without damage, any pressure levels caused by an internal explosion
- The shape, length and gap of part assembly joints, at shaft opening, cable entries, etc., shall be designed to allow for throttling and cooling of hot gases escaping outside
- The standards emphasize the impact of an explosive atmosphere (for instance, explosion pressure) over constructional requirements of such apparatus
- Ex de variant
  - Increased Safety terminal box

Increased Safety (Ex e)

- Prevents the occurrence of sparks, arcs or hot spots in service (including starting and locked rotor situation), that could reach the self-ignition temperature of the surrounding, potentially explosive atmosphere, in all inner and outer parts of the machine
- The maximum stall time “t_E” allowed for the motor is stamped on name plate. This t_E time reflects a minimum value depending on the ratio I_S/I_N as given by the standards
- To reduce the temperature rise, this type of motor typically has a special winding that effectively de-rates the motor
  - Requires selection of a bigger motor compared to a flameproof motor for the same application

Non-Sparking (Ex nA)

- Motor must be designed in such a way that no sparks can occur in normal operation
- Ex nA motors are not flameproof motors. They have no flame path, and thus the enclosure groups A, B and C have no relevance
- Ex nA motors in cast iron frame can also be used for combustible dust applications
  - Gases penetrate this protection, however the ingress of dust is prevented

Dust Ignition Proof (Ex tD)

- Two potential conditions for dust ignition
  - Combustible dust can form a potentially explosive atmosphere when dispersed in the air
  - Layers of combustible dust may ignite and act as an ignition source for an explosive atmosphere
- This protection prevents explosive transmission of dust
  - The motor itself is dust ignition proof which means no potentially explosive atmosphere can penetrate inside the motor
  - The ingress of dust into the motor is prevented by the IP protection, being either IP 55 or IP 65
  - The maximum surface temperature outside the motor must not exceed the temperature class for which the motor is certified
  - No sparks may occur outside the motor enclosure

Summary

- IEC motors are becoming more prevalent in the US
- Basic operating principles are the same
  - Squirrel cage induction motors
- IEC definitions are more comprehensive and specific
  - Differences in rating and sizing approaches
    - IEC sizes per the application requirements
    - NEMA ratings have more conservative approach
- General and hazardous area definitions are starting to merge
- There is a perception in some circles that IEC motors are somehow inferior to NEMA designs
  - What do you think?

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