Sustainable Energy
World-wide Motor Minimum Energy Performance Standards

Motors Drives and Automation Systems
Orlando, FL
2:15 PM March 14th, 2012

Richard E deFay
Project Manager, Sustainable Energy
Copper Development Association, Inc.
Who is the Copper Development Association?

- A US based not-for-profit association of the global copper industry, influencing the use of copper and copper alloys through: research, development, education, promotion, technical and end-use support. Helping people to use copper materials in safe, sustainable, efficient applications in business, industry and the home.

We have different & diverse specialties.
What is my Role?

To speak at:
  - Conferences
  - Trade Shows
  - Workshops
  - Seminars/CEU Credits
  - Conventions

About:
  - Energy Efficiency
  - Energy Efficient Motors
  - Motor Management Best Practices
  - MotorMaster+ Software
  - Transformers

And their relationship to copper
Overview

- A review of world-wide activity of motor efficiency programs, legislation and new technologies
- The changing motor world
  - Technologies
  - Problems
- Implications for US
- Pending regulations
Definitions

• IEC = International Electrotechnical Commission

• MEPS = Minimum Energy Performance Standards

• IEA = International Energy Association

• 4E = Efficient Electrical End-use Equipment

• EMSA = Electric Motor Systems Annex
<table>
<thead>
<tr>
<th>USA</th>
<th>EUROPEAN</th>
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<td>Old</td>
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<td>EFF3</td>
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<td>Standard Efficiency =</td>
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<td>NEMA Premium =</td>
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<td>Above NEMA Premium =</td>
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(Not an official designation)
Motor Sales: World - wide

Source: IEA-Draft CUB 2009
<table>
<thead>
<tr>
<th>Efficiency Levels</th>
<th>Efficiency Classes</th>
<th>Testing Standard</th>
<th>Performance Standard</th>
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<td>Global 2008</td>
<td>IEC 60034-30</td>
<td>IEC 60034-2-1 incl. stray load losses 2007</td>
<td>Mandatory MEPS</td>
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<td>Low Uncertainty</td>
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<td>Canada 2011</td>
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<td>Europe* 2015 (≥ 7.5 kW), 2017</td>
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<td>IE2</td>
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*Bold means in effect

*[IE3 or IE2+VSD]
Quick Walk Around the World

• Africa
• Japan
• S. Korea
• India
• Latin America
The current status of MEPS for 3-phase motors in South America could be summarized as following:

<table>
<thead>
<tr>
<th>Country</th>
<th>Current Status</th>
<th>Anticipated</th>
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<tbody>
<tr>
<td>Brazil</td>
<td>Mandatory IE2 / EPAct</td>
<td>IE3/NEMA Premium &gt;5 years – minimum</td>
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<tr>
<td>Chile</td>
<td>Mandatory (up to 10 HP)IE2/EPAct</td>
<td>IE2 / EPAct (&gt; 10 HP)2011/2012</td>
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<tr>
<td>Argentina</td>
<td>Voluntary IE1 / Standard</td>
<td>IE2 / EPAct &gt; 3 years</td>
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<tr>
<td>Peru</td>
<td>Voluntary IE2 / EPAct</td>
<td>IE2 / EPAct Mandatory &gt; 5 years</td>
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<tr>
<td>Colombia</td>
<td>Voluntary IE1 / Standard</td>
<td>IE2 / EPAct &gt; 3 years</td>
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New Technologies

- More is better
- Copper Rotor Motor
- Switched Reluctance Motors
- Permanent Magnet Motors
- Other Esoteric Developments
Induction Motors

• More is better
  o More copper in windings
  o Higher grade steel core
  o Improved bearings
  o Improved fan design
Copper Rotor Motor

- Technology behind the CRM
Switched Reluctance Motors

• The basic design elements

Courtesy Gil McCoy, WSU
Main Advantages

**Advantages**
- High efficiency
- High torque and speed
- High reliability and long lifetime
- Simple and robust construction
- Low cost
- Simple controller (1 power switch per phase)
- High power density
- Available in different sizes and shapes
Disadvantages

• Disadvantages
  o Ripple torque,
  o high vibration level
  o High acoustical noise
  o VSD always necessary
SR Applications

- Washing machines
- Vacuum pumps
- Centrifugal machines
  - Compressors
  - Pumps
- Vacuum cleaners
- HVAC
- VSD systems
- Automation
- Traction
- Machine tools
Permanent Magnet Motors

• A brief overview of the technology of the PM Motor

Courtesy Gil McCoy, WSU
Permanent Magnet Motor Advantages

• Main Advantages
  o Excellent torque-speed curve
  o Excellent dynamic response
  o High efficiency and reliability
  o Low maintenance
  o Longer lifetime
  o Low acoustical noise
  o High speed capability
  o High torque/volume ratio or high power density

• Main Disadvantages
  o High cost
  o Need for a VSD except for Low speed PM.
Product Line Efficiency Comparison
Latest IEEE 841 moving up to Premium Efficient

Gil McCoy, WSU
Typical Partial Load Efficiencies of 55 kW / 75 HP, TEFC, 1800 RPM Motors
What exactly are they?

Are they rare?

How are they used?

Where can they be found?

Where does the market stand now?
Just What are Rare Earth Materials?

- Scandium
- Lanthanum
- Praseodymium
- Promethium
- Europium
- Terbium
- Holmium
- Thulium
- Lutetium
- Yttrium
- Cerium
- Neodymium
- Samarium
- Gadolinium
- Dysprosium
- Erbium
- Ytterbium
Applications

- Computer Hard Drives
- Audio Speakers
- Headphones
- Bicycle dynamo’s
- PM Motors in cordless tools
- Self powered flashlights
- Mag-lev trains
- Solar panels/Wind Turbines
- Hybrid vehicle motors
- Air conditioning units
- Washing machines
- Medical Equipment (MRI’s)
- Green phosphors for Flat screens
- HE fluorescent lamps
- Industrial motors

Nickel plated neodymium magnet on a bracket from a hard drive
Global Production of Rare Earth Oxides, 1950 - 2000

Production, kt

Monazite-placer era
Mountain Pass era
Chinese era

China
USA
Other
Total


Courtesy-Wikipedia
World Mine Production and Reserves (2009 Data)

- **Country Production (Metric Ton) Reserves (Metric Ton)**
  - United States: insignificant - 13,000,000
  - Australia: insignificant - 5,400,000
  - Brazil: 650 - 48,000
  - **China: 120,000 - 36,000,000**
  - Commonwealth of Independent States: not available - 19,000,000
  - India: 2,700 - 3,100,000
  - Malaysia: 380 - 30,000
  - Other countries: not available - 22,000,000
  - World total: (rounded) 124,000 - 99,000,000
And the Problem is?

• Low Supply
• Increased Demand
• = Skyrocketing Prices
• Countries around the world will be forced to develop their own production capabilities to meet the growing demands for rare earth metals.

Most of the scandium used in the US goes into aluminum bats and other sports equipments.
Toyota Tries to Break Reliance on China

Company Seeks to Develop Electric Motor Without Costly, Tightly Controlled Rare Earth Metals

BY MIKE RAMSEY

Toyota Motor Corp. is striving to develop a new type of electric motor to escape a simmering trade conflict involving China's grip on a rare mineral. The Japanese auto maker believes it is near a breakthrough in developing electric motors for hybrid cars that eliminates the use of rare earth metals, whose prices have risen sharply in the past year as China restricted supply. The minerals are found in the magnets used in the motors.

All electric motors rely on magnets to make them work. The new motor Toyota is working on is based on the very common and inexpensive induction motor, found in such devices as kitchen mixers. Induction motors use electromagnets—magnets that only have their magnetic attraction when power is applied to them.

Most motors used in electric and hybrid cars today use a different type of motor that relies on permanent magnets. These magnets always have a magnetic field—akin to the magnets used to attach things to refrigerator doors. But the permanent magnets found in electric-car motors, unlike those that hold up the school lunch menu, are made from neodymium, a rare-earth mineral that is almost entirely mined and refined in China.

As car companies race to improve electric and hybrid vehicles, their reliance on metals like neodymium and lithium—used in batteries found in electric and hybrid cars—is raising a host of new geopolitical issues over access to the minerals. The supply of many of these minerals is controlled by China.

Toyota has taken several steps to reduce its dependence on China for the materials, including investing in a lithium venture in Argentina and launching a joint venture in Vietnam to prospect for rare metals like neodymium.

The auto industry purchases 40% of the world's supply of neodymium and Toyota buys more than any other company, said Jack Lifton, a rare earth materials expert and founder of Technology Metals Research in Carpentersville, Ill. There is about a kilogram (2.2 pounds) of neodymium in every Prius, he said. Toyota declined to comment on this figure.

"It would be a big change in demand for neodymium" if Toyota switched to an induction motor, said Mr. Lifton.

General Motors Co., which launched its Volt electric car last month, also is looking into alternative types of motors. "We have ongoing development in those
• Advanced Research Project Agency - Energy

  o Seeking rare earth alternatives in critical technologies (REACT)

  o Announced $31.6 Million

  o To develop substitute materials for rare earth permanent magnets.

  o Fourteen projects split the 31.6M
Summary of Projects

• **Case Western Reserve University**
  “Transformation Enabled Nitride Magnets Absent Rare Earths”
  - Investigators will use micro-alloying of iron-nitride alloys with the goal of demonstrating a new magnet system, containing no rare earths, in a prototype **electric motor**.

• **QM Power**
  “Advanced Electric Vehicle Motors with Low or No Rare Earth Content”
  - The team will develop a **motor** that uses no rare earth materials, is light and compact, and potentially delivers more power with greater efficiency at less cost. Key innovations will include a new motor design, emerging materials and advanced manufacturing techniques to reduce costs.

  - Courtesy American Ceramic Society
Summary of Projects cont.

• **University of Alabama**
  “Rare-Earth-Free Permanent Magnets for Electrical Vehicle Motors and Wind Turbine Generators:
  o Hexagonal Symmetry Based Materials Systems Mn-Bi and M-type Hexaferrite”
  The team will demonstrate advanced magnetic properties of new magnetic composite materials.

• **Argonne National Laboratory**
  “Nanocomposite Exchange-Spring Magnets for Motor and Generator Applications”
  o ANL will create a new class of permanent magnets based on a metal composite magnet design containing a blend of very small particles embedded in a matrix in aligned arrays.

  o Courtesy American Ceramic Society
• **Baldor Electric Company**  
  "Rare Earth-Free Traction Motor for Electric Vehicle Applications"  
  o The project goal is to develop a new type of electric motor with the potential to efficiently power a next generation class of electric vehicles. Key innovations include an innovative motor design, a unique cooling system, and development of advanced materials manufacturing techniques.

• **General Atomics**  
  "Double-Stator Switched Reluctance Motor Technology"  
  o This project will focus on improving the performance and enhancing the manufacturability of the unique "double stator" motor design, initially investigated at UT-Dallas, for transportation applications

  o Courtesy American Ceramic Society
Small Motor Regulation Status

- Process began early 2010
- Completed last year – 2011
- Takes effect 2015
Typical Small Motor Applications

- Residential compressors
- Exhaust fans
- HAC
  - Both air and liquid moving
- Door openers
- Conveyors
- Swimming pool pumps
- Jetted tubs
- Food processing
- General Machinery

Average hours of operation, less than 1,000 hours/year

Source: NEMA statistical
How DOE created small motor rule

- Tested one motor that did not meet the EPACT definition of a small motor
  - Ignored some points of definitions in statutes while picking others to re-define covered product

- Used consultant software design program that was not correlated to actual motor test results

- Extrapolated efficiency from a single test example to three speeds, eight power levels and three motor types

- Left definition of a small motor vague

- Created confusion and enforcement issues

Source NEMA statistical
Summary Of Small Motor Rule

• Product covered
  o ¼ through 3 HP
    • 2/4/6 pole
  o 42 through 56 frame
  o Polyphase
  o Cap start cap run
  o Cap start induction run

• General purpose
  o Without final definition

• Implementation in five years

• Result ---NEMA filed a lawsuit and lost

Source: NEMA statistical
Result of Lawsuit

- The recent decision by the court in favor of the DOE will move the process forward with final regulations completed 12/2011 and implementation by 2015.
What next?

• DOE required by law to consider amending existing standards to continue improved efficiency standards.

• Also authorized to increase scope.
The Motor Coalition Members

• American Council for an Energy-Efficient Economy
• Alliance to Save Energy
• Appliance Standards Awareness Project
• Copper Development Association
• Earthjustice
• Natural Resources Defense Council
• Northeast Energy Efficiency Partnerships
• Northwest Energy Efficiency Alliance
• National Electrical Manufactures Association
• Pacific Gas and Electric
• Determine and document a plan to improve the efficiency of the greatest number of units providing the greatest savings impact while reducing potential enforcement issues within the least amount of time.

• Deliver a plan to DOE as a platform for a consensus rule that can be acted upon within the least amount of time delivering large net benefits.
2 options

• 1- Increase nominal efficiency level for the existing scope of covered motors.

• 2- Expand scope of covered motors using existing efficiency levels.
Motor Coalition Proposed Approach

• Base future regulations on existing Epact 92 and EISA test standards, labeling, lab accreditation, compliance certification requirements

• Expand the scope of covered products to more than double the number of motors regulated

• Maintain the nominal efficiency levels at the current NEMA 12-12 (12-11 for some motors)

• Simplify how “coverage” is defined in order to ease compliance and enforcement.
MC’s Proposed Expanded Scope

- Partial motors
- \( \frac{3}{4} \) motors
- Gear motors
- Integral shafts
- Definite purpose
- Special shafts
- Special flanges
- Special purpose
- Vertical
- 56 or 90 Frame motors
- TENV
- NEMA or IEC

More effectively capture motors imported as a component or finished good for both general purpose and the new categories.
MC Expanded Product Scope

Total 4.4 million units USA per year

- Type 1 and 2
- Partial & Gearmotor
- Definite & Special
- Imported motors or component
- 56 Frame
Thank You

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