Mechanical Design
Mechanical Design

• Enclosures I
  – NEMA
  – IEC

• Bearing design

• Enclosures II
  – ABS and SOLAS
  – Hazardous Location
  – Electrical Housings

• Other Design Considerations
  – Coupling and Shaft Design
  – Typical Marine Designs
Enclosures: Standards

- NEMA MG 1-2006 Section 1 Part 1
- NEMA MG 1-2006 Section 1 Part 5
- IEC 60034-5, 2000-12
- IEC 60034-6
NEMA MG 1-2006 Section 1 Part 1

• Classification according to environmental protection and methods of cooling

• Most common classifications:
  – Dripproof guarded machine (ODP)
  – Weather-protected machine: Type I & Type II WPII
  – Totally enclosed fan-cooled guarded (TEFC)
  – Totally enclosed air-to-water-cooled (TEWAC, CACW)
  – Totally enclosed air-to-air-cooled (TEAAC, CACA)
NEMA MG1-2006 Section 1 Part 5 and IEC 60034-5, 2000-12

• IP Codes
  – Protection of persons against contact with hazards
  – Protection of machine against ingress of solid objects
  – Protection of machine against harmful effects due to ingress of water
NEMA MG1-2006 Section 1 Part 5 and IEC 60034-5, 2000-12

1st digit
- 2 = protected against 12 mm objects
- 4 = protected against 1 mm objects
- 5 = dust protected
- 6 = dust tight

2nd digit
- 1 = protected against dripping water
- 2 = protected against 15 degree from vertical water spray
- 3 = protected against 60 degree from vertical water spray
- 4 = protected against splashing water
- 5 = protected against water jets
- 6 = protected against powerful water jets

Common: IP21 (ODP), IP22, IP23, IP44, IP54, IP55, IP56
Just Another Day at the Beach
True Grit
Guarded Open Drip Proof (IP22)
Totally Enclosed Fan Cooled

- Internal air flows over the core and windings and is circulated by a shaft-driven fan. Heat is radiated through the enclosure.
- An external shaft-driven fan pushes ambient air over the cooling fins on the outside of the machine.
- Requires a larger machine due to the added losses associated with radiant cooling.
- Meets ingress protection ratings IP44-IP56
Totally Enclosed Air-to-Air Cooled

- TEAAC (CACA)

- Cooling air supplied by shaft-mounted fan or separate blowers.

- 50 to 100 CFM per kW of losses.

- Oversized for a typical 20º C rise over ambient for the internal cooling circuit. Example: 40º ambient + 30º C = 70º C internal air.

- Ambient air temp remains constant.

- Typically the internal generator inlet air temp will be ambient + 20º C so the generator needs 35 - 40% oversizing to equal an ODP.
TEAAC: Shaft-Mounted Fan
TEAAC: Shaft-Mounted Fan (cont.)
TEAAC: Separate Blowers
TEAAC: Separate Blowers (cont.)
Totally Enclosed Air-to-Water Cooled

• TEAWC (CACW).
• Has cooling water inlet and outlets.
• Flow; 1 gpm / kW loss.
  – Usual water = 32º C
  – Single tube = + 8º C = 40º C internal air
  – Double tube = +18º C = 50º C internal air
• For typical 32º C water there is no de-rate for single-wall application. Ex: 32º C water + 8º C = 40º C incoming air.
• With 32º C water we typically can provide 40º C air back to the inlet side of the generator, so they are sized similarly to an ODP machine.
Totally Enclosed Air-to-Water Cooled
Totally Enclosed Air-to-Water Cooled (cont.)
Weather Protected II

- Inlet air has three 90 degree direction changes and <600 fpm (<3 m/sec) air speed.
- Optional air filters.
- Inlet air temp remains unchanged so sizing is equal to an ODP.
Weather Protected II (cont.)
Air Filters

- A differential pressure safety switch is included.
IEC 60034-6 Classification

- Sequence of numbers and letters to identify cooling type, (e.g., TEWAC, TEAAC) and cooling medium (e.g., air, water, hydrogen)
  - A number is placed first, indicating the cooling circuit arrangement. It is applies to both primary and secondary circuits.
  - Each circuit is designed by a letter (indicating coolant), followed by a number (indicating coolant movement method).
  - The letter and number for the primary circuit (around windings) are placed first followed by those for the secondary circuit.

Example: I C 8 A 1 W 7
IEC 60034-6 Classification (cont.)

- Circuit arrangement (machine construction and cooling medium routing)

<table>
<thead>
<tr>
<th></th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Free circulation</td>
</tr>
<tr>
<td>1</td>
<td>Inlet pipe or outlet duct circulated</td>
</tr>
<tr>
<td>2</td>
<td>Outlet pipe or outlet duct circulated</td>
</tr>
<tr>
<td>3</td>
<td>Inlet and outlet pipe or duct circulated</td>
</tr>
<tr>
<td>4</td>
<td>Frame surface cooled</td>
</tr>
<tr>
<td>5</td>
<td>Integral heat exchanger (using surrounding medium)</td>
</tr>
<tr>
<td>6</td>
<td>Machine-mounted heat exchanger (using surrounding medium)</td>
</tr>
<tr>
<td>7</td>
<td>Integral heat exchanger (using remote medium)</td>
</tr>
<tr>
<td>8</td>
<td>Machine-mounted heat exchanger (using remote medium)</td>
</tr>
<tr>
<td>9</td>
<td>Separate heat exchanger using surrounding or remote medium</td>
</tr>
</tbody>
</table>
### IEC 60034-6 Classification (cont.)

#### Coolant Type

<table>
<thead>
<tr>
<th>Coolant Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Air</td>
</tr>
<tr>
<td>F</td>
<td>Freon</td>
</tr>
<tr>
<td>H</td>
<td>Hydrogen</td>
</tr>
<tr>
<td>N</td>
<td>Nitrogen</td>
</tr>
<tr>
<td>C</td>
<td>Carbon dioxide</td>
</tr>
<tr>
<td>W</td>
<td>Water</td>
</tr>
<tr>
<td>O</td>
<td>Oil</td>
</tr>
<tr>
<td>S</td>
<td>Any other</td>
</tr>
<tr>
<td>Y</td>
<td>Reserved</td>
</tr>
</tbody>
</table>
IEC 60034-6 Classification (cont.)

- Method of circulation

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Free convection</td>
</tr>
<tr>
<td>1</td>
<td>Self-circulation</td>
</tr>
<tr>
<td>2-4</td>
<td>Reserved</td>
</tr>
<tr>
<td>5</td>
<td>Integral independent component (independent of machine rotational speed)</td>
</tr>
<tr>
<td>6</td>
<td>Machine-mounted independent component</td>
</tr>
<tr>
<td>7</td>
<td>Separate and independent component or coolant system pressure</td>
</tr>
<tr>
<td>8</td>
<td>Relative displacement</td>
</tr>
<tr>
<td>9</td>
<td>All other components</td>
</tr>
</tbody>
</table>
IEC 60034-6 Classification (cont.)

• Kato code TEWAC (CACW), IP44, IP54 = IC8A1W7
  – 8 = Machine-mounted heat exchanger with remote medium
  – A = Primary circuit cooling medium is air
  – 1 = Self circulation of medium
  – W = Secondary cooling medium is water
  – 7 = Separate circulation not mounted to machine.

• Kato code TEAAC (CACA), IP44, IP54 = IC6A1A1
  – 6 = Machine-mounted heat exchanger using surrounding medium
  – A = Primary circuit cooling medium, air
  – 1 = Self circulation of medium
  – A = Secondary cooling medium, air
  – 1 = Self circulation of medium
Mechanical Design

- Enclosures I
  - NEMA
  - IEC
- Bearing design
- Enclosures II
  - ABS and SOLAS
  - Hazardous Location
  - Electrical Housings
- Other Design Considerations
  - Coupling and Shaft Design
  - Typical Marine Designs
Bearing Design: Which ones and why?

- Types
  - Ball
  - Spherical roller
  - Split roller
  - Sleeve

- Considerations
  - Size
  - Initial cost
  - Life cycle cost
  - Orientation: radial and axial loading
  - Certification agency preference
  - Customer preference
Initial Cost

- Bearing type
- Oil system requirement (sleeve bearings)
  - Cooling
  - Hydrostatic jacking for slow roll
  - Redundancy of oil lube system
  - Black Start
- Grease auto lubricator (anti-friction) used for extended lubrication intervals
Size

- \( L_{10} \) calculation (anti-friction)
- Loads: axial and radial
  - Orientation
  - Generator rotor weight
  - Magnetic forces
- Torque on the bearing ID (i.e. shaft size)
  - RPM
  - kW rating
  - Shaft material
- Shock loads
- Maximum speed rating (anti-friction)
- Minimum load capability (anti-friction)
Life Cycle Costs

• Grease (anti-friction)
  – Interval VS sealed/shielded
  – Grease “valve”

• Oil change interval (sleeve) and cooler requirements
  – Oil operating temperature
    • Ambient temperature
    • Oil viscosity
  – Rotor weight
  – Oil type
    • Mineral
    • Synthetic
Orientation

- Land based
- Ship board
- Oil platform
- High shock

Photo: Royal Navy/MOD
Certifying Agency

- ABS
- API
- DNV
- US Navy
- Others
Ball Bearing

• Pros
  – Low cost
  – Grease lubricated
  – Thrust capable
  – Intermediate maintenance cycle (~2000 hours)
  – Good for black start as no pre-lube is required

• Cons
  – Speed limited as size increases
  – Life limited as load and speed increases
  – Maintenance
  – Replacement requires coupling removal
  – High shock
Spherical Roller Bearing

• Pros
  – Low cost
  – High load capacity
    • High thrust capacity
    • High radial load capacity
  – Grease lubricated
  – Self aligning

• Cons
  – Speed limited as size increases
  – Life limited as load and speed increases
  – Short maintenance cycle (~200 hours)
  – Requires removal of coupling for replacement
  – High shock
Split Roller Bearing

- **Pros**
  - Split for “easy” disassembly (no coupling removal)
  - Cost effective for medium-sized generators (5 to 6-inch diameter shafts)
  - Grease lubricated (extended cycle with “Auto-Lube”)
  - High radial load capacity
  - Labyrinth seals standard
  - Self aligning

- **Cons**
  - Speed limited as size increases
  - Life limited as load and speed increases
  - Short maintenance cycle (~200 hours)
  - “Low” thrust capability
  - High shock
Sleeve Bearing

• Pros
  – Long life
  – Long maintenance intervals (8000 hours or more)
  – High thrust capability
  – Cost effective for large sizes (6-inch diameter shafts and up)
  – Split for “easy” disassembly (no coupling removal)
  – Capable of high shock loading without damage
  – Self aligning
  – Available with integral insulation
  – “Self lubricating” in some applications
Sleeve Bearing (cont.)

• Cons
  – May require supplemental cooling method
    • High speed
    • High ambient temperature
    • High loads
  – May require forced lubrication (High thrust load or hydrostatic jacking for slow roll)
  – High cost for smaller sizes
  – Susceptible to oil leaks
  – Dependent on circulating oil system in some applications
Bearing Temperature Detectors

- Two types of RTDs available:
  - Platinum (100 ohm)
  - Copper (10 ohm) optional

- Recommended for high-hour applications.
Oil Life (in Sleeve Bearings)

- Temperature dependent
  - Applications
  - Certifying agencies
  - Shipboard
- Totally enclosed
- Life decreases by 1/2 for every 10º C above 85º C
- Mineral oil - 8000 hour oil life at ~85º C
- Synthetic oil - 16,000 hour oil life at ~95º C
Factors Affecting Temperature

• Viscous shear of oil
  – Speed dependent
    • RPM
    • Diameter of journal
  – Width of journal
  – Viscosity of oil (ISO VG46)
  – Thrust load
  – Radial load
  – Bearing clearance
How to Keep Temperature Under 85° C

• Decrease bearing losses
  – Reduce oil viscosity
  – Decrease journal diameter
  – Decrease thrust load
  – Decrease radial load

• Increase heat dissipation
  – Use larger bearing housing
  – Increase air velocity across bearing housing
  – Use mid-mount housing (EM); increases surface area
  – Minimize insulating materials in heat conduction path

• Use an oil cooler
Oil Cooler

- Oil cooler
- Filter
- Pump
- Motor
- Hoses and fittings
Mechanical Design

• Enclosures I
  – NEMA
  – IEC

• Bearing design

• Enclosures II
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  – Hazardous Location
  – Electrical Housings

• Other Design Considerations
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  – Typical Marine Designs
Enclosures: ABS and SOLAS

• ABS Rules for Classing and Building Steel Vessels 2014, Part 4, Chapter 8, Section 3, Para 1.11.2

Equipment in areas affected by a local fixed pressure water-spraying or a local water-mist fire extinguishing system in machinery spaces (2014):

Electrical and electronic equipment within areas affected by local fixed pressure water-spraying or local water-mist fire extinguishing systems are to be suitable for use in the affected area. See 4-8-3/Figure1. Where enclosures have a degree of protection lower than IP44, evidence of suitability for use in these areas is to be submitted to ABS, taking into account:

1) The actual (water spraying or fire extinguishing) system being used and its installation arrangement and,

2) The equipment design and layout (inlets, filters, baffles vents, etc. to prevent or restricted water ingress. The cooling airflow must be maintained).
Enclosures: ABS and SOLAS (cont.)

- Figure 1. Example of area affected by local fixed pressure water spraying or local water-mist fire extinguishing system in machinery spaces. (2014)
Hazardous Location

- Hazardous Location Class I Div or Zone II / EEEx nA
  - NEC 500 and 505 plus UL 1836 (USA)
  - CEC and CSA applicable standard (Canada)
  - EN 50021 and 50014 (European Union) Kato has generator range certified by BASEEEFA, UK
  - IEC 60079-15, 60079-00

- Hazardous Location EEEx P II T3

- Applications must be submitted to our Engineering Dept. for quotation!
Hazardous Location Markings

Kato product:
Class 1 Zone 2 A Ex n IIA&B T3 Class 1
Zone 2 A Ex p IIA&B T3

Kato Product:
EEEx n IIA&B T3
EEEx p IIA&B T3

Kato product: Class 1 Div 2 Groups C&D T3
Hazardous Location: Zones

- **Zones**
  - Zone 0: Gaseous hazard continuously present.
  - Zone 1: Gaseous hazard intermittently present.
  - **Zone 2**: Gaseous hazard abnormally present.
  - Zone 20: Dust hazard continuously present.
  - Zone 21: Dust hazard intermittently present.
  - Zone 22: Dust hazard abnormally present.
Hazardous Location: Divisions

• Divisions (For USA and existing Canadian sites)
  – Division 1: Explosive atmosphere is normally or intermittently present.
  – Division 2: Explosive atmosphere is present only abnormally.
  – Division 2: A gas hazard is present only abnormally.
  – Division 1: A gas hazard is normally or sometimes present.
Hazardous Location: Gas Grouping

### HazLoc Hand Chart
#### Gas Groupings

<table>
<thead>
<tr>
<th>IEC Canada (CEC)</th>
<th>USA (NEC 505)</th>
<th>EU (Europe)</th>
<th>Canada (CEC) USA (NEC 500)</th>
<th>Gas, Dust, Fiber</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group IIC</td>
<td>Class I, Group IIC</td>
<td>Group IIC</td>
<td>Class I, Group A</td>
<td>Acetylene</td>
</tr>
<tr>
<td>Group IIB</td>
<td>Class I, Group IIB</td>
<td>Group IIB</td>
<td>Class I, Group C</td>
<td>Ethylene</td>
</tr>
<tr>
<td>Group IIA</td>
<td>Class I, Group IIA</td>
<td>Group IIA</td>
<td>Class I, Group D</td>
<td>Propane</td>
</tr>
<tr>
<td>Group I</td>
<td>Group I</td>
<td>Group I</td>
<td>Not within IEC / NEC</td>
<td>Methane</td>
</tr>
<tr>
<td></td>
<td>Class II, Group E (Div 1 Only)</td>
<td>T2A</td>
<td>Class II, Group F</td>
<td>Coal Dust</td>
</tr>
<tr>
<td></td>
<td>Class II, Group G</td>
<td>T2C</td>
<td>Class II, Group G</td>
<td>Grain</td>
</tr>
<tr>
<td></td>
<td>Class III</td>
<td>T2B</td>
<td></td>
<td>Fibers</td>
</tr>
</tbody>
</table>

### Temperature Class

<table>
<thead>
<tr>
<th>Surface (°C) Temp</th>
<th>IEC, EU (Europe)</th>
<th>USA (NEC 505)</th>
<th>USA (NEC 500)</th>
<th>Canada</th>
</tr>
</thead>
<tbody>
<tr>
<td>450 (842 F)</td>
<td>T1</td>
<td>T1</td>
<td>T1</td>
<td></td>
</tr>
<tr>
<td>300 (572 F)</td>
<td>T2</td>
<td>T2</td>
<td>T2</td>
<td></td>
</tr>
<tr>
<td>280 (536 F)</td>
<td>T2A</td>
<td>T2B</td>
<td>T2C</td>
<td></td>
</tr>
<tr>
<td>260 (500 F)</td>
<td>T2B</td>
<td>T2C</td>
<td>T2D</td>
<td></td>
</tr>
<tr>
<td>230 (446 F)</td>
<td>T2D</td>
<td>T2D</td>
<td>T2D</td>
<td></td>
</tr>
<tr>
<td>200 (392 F)</td>
<td>T3</td>
<td>T3</td>
<td>T3</td>
<td></td>
</tr>
<tr>
<td>190 (374 F)</td>
<td>T3</td>
<td>T3</td>
<td>T3</td>
<td></td>
</tr>
<tr>
<td>165 (329 F)</td>
<td>T3</td>
<td>T3</td>
<td>T3</td>
<td></td>
</tr>
<tr>
<td>160 (320 F)</td>
<td>T3</td>
<td>T3</td>
<td>T3</td>
<td></td>
</tr>
<tr>
<td>135 (275 F)</td>
<td>T4</td>
<td>T4</td>
<td>T4</td>
<td></td>
</tr>
<tr>
<td>120 (248 F)</td>
<td>T4</td>
<td>T4</td>
<td>T4</td>
<td></td>
</tr>
<tr>
<td>100 (212 F)</td>
<td>T5</td>
<td>T5</td>
<td>T5</td>
<td></td>
</tr>
<tr>
<td>85 (185 F)</td>
<td>T6</td>
<td>T6</td>
<td>T6</td>
<td></td>
</tr>
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</table>
## Hazardous Location: Protection

### Protection Concepts [North America]

<table>
<thead>
<tr>
<th>Type of Protection</th>
<th>USA</th>
<th>Permit Use</th>
<th>Canada</th>
<th>Basic Concept of Protection</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>NEC® 500</td>
<td>NEC® 505</td>
<td>Existing</td>
<td>New</td>
</tr>
<tr>
<td><strong>Increased Safety</strong></td>
<td>NA</td>
<td>Zone 1, 2</td>
<td>AEx e</td>
<td>NA</td>
</tr>
<tr>
<td><strong>Non-Incentive</strong></td>
<td>Div 2</td>
<td>Zone 2</td>
<td>AEx n</td>
<td>Div 2</td>
</tr>
<tr>
<td><strong>Flameproof</strong></td>
<td>NA</td>
<td>Zone 1, 2</td>
<td>AEx d</td>
<td>NA</td>
</tr>
<tr>
<td><strong>Explosionproof Powder Filled</strong></td>
<td>Div 1, 2</td>
<td>Zone 1, 2</td>
<td>NA</td>
<td>AEx q</td>
</tr>
<tr>
<td><strong>Intrinsic Safety</strong></td>
<td>Div 1, 2</td>
<td>Zone 0, 1, 2</td>
<td>AEx ia</td>
<td>NA</td>
</tr>
<tr>
<td><strong>Pressurized (Purged)</strong></td>
<td>Div 1, 2</td>
<td>Zone 1, 2</td>
<td>AEx p</td>
<td>Div 1, 2</td>
</tr>
<tr>
<td><strong>Encapsulation</strong></td>
<td>NA</td>
<td>Zone 1, 2</td>
<td>AEx m</td>
<td>NA</td>
</tr>
<tr>
<td><strong>Oil Immersion</strong></td>
<td>Div 2</td>
<td>Zone 1, 2</td>
<td>AEx o</td>
<td>Div 2</td>
</tr>
</tbody>
</table>

**Note:** NEC® Article 501.1 permits the use of zone-rated equipment in Class I Division 2 locations.

Kato can comply with this AEx p or Ex P Pressurized system.
Kato can comply with this Div 2 or AEx n code (non-sparking)
Hazardous Locations: Markings

Kato product:
Class 1 Zone 2 A Ex n IIA&B T3
Class 1 Zone 2 A Ex p IIA&B T3

Kato Product:
EEEx n IIA&B T3
EEEx p IIA&B T3

Markings for North America

Markings for EU (European Union)

Kato product: Class 1 Div 2 Groups C&D T3
# Hazardous Locations: Future Marking

<table>
<thead>
<tr>
<th>Classification</th>
<th>Class 1, Zone 2</th>
<th>Class 1, Division 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geographic location</td>
<td>Europe (mandatory per European directive)</td>
<td>Worldwide per IEC EX</td>
</tr>
<tr>
<td>Kato selected certifying body</td>
<td>Self compliance</td>
<td>BASEEEFA</td>
</tr>
<tr>
<td>Main marking on main nameplate</td>
<td>Exit 3G Ex nA IIB T3 + CE marking</td>
<td>Ex nA IIB + IEC certificate # given by notified agency</td>
</tr>
<tr>
<td>Certification to customer</td>
<td>Self declaration</td>
<td>BASEEEFA 04 ATEX 0361 X CE marking</td>
</tr>
</tbody>
</table>
Electrical Housings

- NEMA 250-2003 Enclosures up to 1000V
- IEC 60529:2001-02 (IP Codes)
## NEMA 250-2003

### Table 1
**COMPARISON OF SPECIFIC APPLICATIONS OF ENCLOSURES FOR INDOOR NONHAZARDOUS LOCATIONS**

<table>
<thead>
<tr>
<th>Provides a Degree of Protection Against the Following Conditions</th>
<th>Type of Enclosure</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 *</td>
</tr>
<tr>
<td>Access to hazardous parts</td>
<td>X</td>
</tr>
<tr>
<td>Ingress of solid foreign objects (falling dirt)</td>
<td>X</td>
</tr>
<tr>
<td>Ingress of water (Dripping and light splashing)</td>
<td>...</td>
</tr>
<tr>
<td>Ingress of solid foreign objects (Circulating dust, lint, fibers, and flyings **)</td>
<td>...</td>
</tr>
<tr>
<td>Ingress of solid foreign objects (Settling airborne dust, lint, fibers, and flyings **)</td>
<td>...</td>
</tr>
<tr>
<td>Ingress of water (Hosedown and splashing water)</td>
<td>...</td>
</tr>
<tr>
<td>Oil and coolant seepage</td>
<td>...</td>
</tr>
<tr>
<td>Oil or coolant spraying and splashing</td>
<td>...</td>
</tr>
<tr>
<td>Corrosive agents</td>
<td>...</td>
</tr>
<tr>
<td>Ingress of water (Occasional temporary submersion)</td>
<td>...</td>
</tr>
<tr>
<td>Ingress of water (Occasional prolonged submersion)</td>
<td>...</td>
</tr>
</tbody>
</table>

* These enclosures may be ventilated.

** These fibers and flyings are nonhazardous materials and are not considered Class III type ignitable fibers or combustible flyings. For Class III type ignitable fibers or combustible flyings see the National Electrical Code, Article 500.
# NEMA 250-2003 (cont.)

## Table 2
**COMPARISON OF SPECIFIC APPLICATIONS OF ENCLOSURES FOR OUTDOOR NONHAZARDOUS LOCATIONS**

<table>
<thead>
<tr>
<th>Provides a Degree of Protection Against the Following Conditions</th>
<th>Type of Enclosure</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3</td>
</tr>
<tr>
<td>Access to hazardous parts</td>
<td>X</td>
</tr>
<tr>
<td>Ingress of water (Rain, snow, and sleet **)</td>
<td>X</td>
</tr>
<tr>
<td>Sleet ***</td>
<td>...</td>
</tr>
<tr>
<td>Ingress of solid foreign objects (Windblown dust, lint, fibers, and flyings)</td>
<td>X</td>
</tr>
<tr>
<td>Ingress of water (Hosedown)</td>
<td>...</td>
</tr>
<tr>
<td>Corrosive agents</td>
<td>...</td>
</tr>
<tr>
<td>Ingress of water (Occasional temporary submersion)</td>
<td>...</td>
</tr>
<tr>
<td>Ingress of water (Occasional prolonged submersion)</td>
<td>...</td>
</tr>
</tbody>
</table>

* These enclosures may be ventilated.

** External operating mechanisms are not required to be operable when the enclosure is ice covered.

*** External operating mechanisms are operable when the enclosure is ice covered. See 5.6.
IEC 60529:2001-02

- IP codes (same as NEMA MG-1)
  - Protection of persons against contact with hazards
  - Protection of machine against ingress of solid objects
  - Protection of machine against harmful effects due to ingress of water
IEC 60529:2001-02 IP Codes

1\textsuperscript{st} digit
\begin{itemize}
  \item 2 = protected against 12 mm objects
  \item 4 = protected against 1 mm objects
  \item 5 = dust protected
  \item 6 = dust tight
\end{itemize}

2\textsuperscript{nd} digit
\begin{itemize}
  \item 1 = protected against dripping water
  \item 2 = protected against 15 degree from vertical water spray
  \item 3 = protected against 60 degree from vertical water spray
  \item 4 = protected against splashing water
  \item 5 = protected against water jets
  \item 6 = protected against powerful water jets
\end{itemize}

Common: IP21 (ODP), IP22, IP23, IP44, IP54, IP55, IP56
Mechanical Design

- Enclosures I
  - NEMA
  - IEC
- Bearing design
- Enclosures II
  - ABS and SOLAS
  - Hazardous Location
  - Electrical Housings
- Other Design Considerations
  - Coupling and Shaft Design
  - Typical Marine Designs
Coupling Examples
ABS Requirements and Certification

- American Bureau of Shipping
- Typical temperature rating; 90° C rise over 50° C ambient.
- Certified shaft and coupling material required.
- Overspeed test required on all units.
- IP23 terminal box (minimum; IP44 terminal box when above 1000 V).
- Black start / emergency power units preferred to be rolling element bearings to avoid external pre-lube system.
- Generally frames larger than 9.6 require sleeve bearings with external pre-lube system.
ABS Requirements and Certification (cont.)

- Pitch (fore-and-aft/trim) and roll (athwartship/list) requirements - mobile offshore drilling units (MODU)

<table>
<thead>
<tr>
<th>Condition</th>
<th>Static</th>
<th>Dynamic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Column-stabilized units</td>
<td>15° in any direction</td>
<td>22.5° in any direction</td>
</tr>
<tr>
<td>Self-elevating units</td>
<td>10° in any direction</td>
<td>15° in any direction</td>
</tr>
<tr>
<td>Surface units</td>
<td>15° list and 5° trim simultaneously</td>
<td>7.5° pitching simultaneously</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Angle of Inclination</th>
<th>Athwartship</th>
<th>Fore-and-Aft</th>
</tr>
</thead>
<tbody>
<tr>
<td>Installations, components</td>
<td>Static</td>
<td>Dynamic</td>
</tr>
<tr>
<td>Propulsion and auxiliary machinery</td>
<td>15</td>
<td>22.5</td>
</tr>
<tr>
<td>Emergency power installation</td>
<td>22.5</td>
<td>22.5</td>
</tr>
<tr>
<td>Emergency fire pumps and their drives</td>
<td>22.5</td>
<td>22.5</td>
</tr>
<tr>
<td>Electrical and electronic appliances and control systems</td>
<td>22.5</td>
<td>22.5</td>
</tr>
</tbody>
</table>
Platform/Floater Recognition Chart

- Fixed-leg platform
- Compliant tower
- Spar
- Tension leg platform (TLP)
- Semi-submersible
- Floating production, storage & offloading (FPSO)

Considered floating

Considered land-based with offshore rules
API Requirements

• American Petroleum Institute
  – Bus bar lead construction for sealing lead connections
  – 6 kV and up to be TEEAC or TEWAC unless otherwise specified.
  – Space heater max temp 200° C
  – Forged rotor shaft with proximity probe surfaces for sleeve bearings
  – Specific balancing procedure
  – Additional machining requirements for mounting holes, parallel mounting surfaces
  – Insulated bearings on both ends
  – IP55 shaft seals on sleeve bearings
  – NEMA 4 (IP55) terminal boxes
  – Stainless steel plumbing, air screens, and external hardware
  – Water immersion testing
Customer Interface Drawings: 102