UNDERSTANDING GENERATOR SET RATING DEFINITIONS

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MTU Onsite Energy
AGENDA

1. ISO Standard
2. Manufacturer Allowances
3. Exhaust Emissions
4. Specific Industry Ratings
5. Conclusion
ISO STANDARD

What does the ISO-8528-1 standard define?
ISO STANDARD
8528-1 INTRODUCTION

- What is ISO-8528?
  - International standard for reciprocating internal combustion engine driven alternating current generating sets

- Who uses it?
  - Nearly all generator set manufacturers worldwide
ISO STANDARD
8528-1 INTRODUCTION

• Where do our ratings come from?

8528-1: Applications, Ratings, & Performance:

✓ 8528-2: Engines
✓ 8528-3: AC generators for gensets
✓ 8528-4: Control gear & Switchgear
✓ 8528-5: Generating Sets
✓ 8528-6: Test Methods
✓ 8528-7: Technical Declarations for Specifications and Design
✓ 8528-9: Measurement and Evaluations of Mechanical Vibrations
✓ 8528-10: Measurement of Airborne Noise
✓ 8528-12: Emergency Power Supply to Safety Services
ISO STANDARD
8528-1 RATINGS

• What ratings does ISO-8528-1 define?
  Six types of ratings:
  
  1. Emergency Standby Power (ESP)
  2. Prime Power (PRP)
  3. Limited-Time Running Power (LTP)
  4. Continuous Power (COP)
  5. Data Center Power (DCP)
  6. Maximum Power for Low-Power Generating Sets (MAX) (Less than 12kWe)
ISO STANDARD
8528-1 RATING CRITERIA

• What criteria does ISO-8528-1 determine?
  • Annual Run-time Expectation
  • Load Variability
  • Load Factor
ISO STANDARD
CRITERIA # 1: ANNUAL RUN-TIME

<table>
<thead>
<tr>
<th>Rating Type</th>
<th>Emergency Standby Power (ESP)</th>
<th>Prime Power (PRP)</th>
<th>Limited-Time running Power (LTP)</th>
<th>Continuous Power (COP)</th>
<th>Data Center Power (DCP)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Expected Annual Run-time</td>
<td>≤ 200 hours</td>
<td>Unlimited</td>
<td>≤ 500 hours</td>
<td>Unlimited</td>
<td>Unlimited</td>
</tr>
</tbody>
</table>

The expected annual run-time criteria establishes the annual hourly usage expectation.
ISO STANDARD
CRITERIA # 2: LOAD VARIABILITY

<table>
<thead>
<tr>
<th>Rating Type</th>
<th>Emergency Standby Power (ESP)</th>
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<td>Unlimited</td>
<td>Unlimited</td>
</tr>
<tr>
<td>Load Variability</td>
<td>Variable</td>
<td>Variable</td>
<td>Undefined</td>
<td>Constant</td>
<td>Constant/Variable</td>
</tr>
</tbody>
</table>

The load variability criteria determines the load profile expectation.
### ISO STANDARD

#### CRITERIA #3: LOAD FACTOR

<table>
<thead>
<tr>
<th>Rating Type</th>
<th>Emergency Standby Power (ESP)</th>
<th>Prime Power (PRP)</th>
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</thead>
<tbody>
<tr>
<td><strong>Expected Annual Run-time</strong></td>
<td>≤ 200 hours</td>
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<td>≤ 500 hours</td>
<td>Unlimited</td>
<td>Unlimited</td>
</tr>
<tr>
<td><strong>Load Variability</strong></td>
<td>Variable</td>
<td>Variable</td>
<td>Undefined</td>
<td>Constant</td>
<td>Constant/Variable</td>
</tr>
<tr>
<td><strong>Average Load Factor</strong></td>
<td>≤ 70%</td>
<td>≤ 70%</td>
<td>≤ 100%</td>
<td>≤ 100%</td>
<td>Undefined</td>
</tr>
</tbody>
</table>

The actual average power ($P_{pa}$) is calculated as follows:

$$P_{pa} = \frac{P_1 t_1 + P_2 t_2 + P_3 t_3 + \ldots + P_n t_n}{t_1 + t_2 + t_3 + \ldots + t_n}$$

where $P_1, P_2, \ldots, P_n$ is the power at time $t_1, t_2, \ldots, t_n$.

**Key**

- $t$: time
- $P$: power
- $P_t$: Prime Power (100%)
- $P_{pp}$: Permissible average power during a 24 h period ($P_{pa}$)
- $P_{pa}$: Actual average power over a 24 h period ($P_{pa}$)
- Stop

**NOTE**

$t_1 + t_2 + t_3 + \ldots + t_n = 24$ h

- The load factor criteria determines the expected average load over any 24 hour operating period.
ISO STANDARD LOAD FACTOR EXAMPLE

- 1000kW STB rated unit
- 24 hour load profile shown
- 15,600 kW *hrs. accumulated

<table>
<thead>
<tr>
<th>Power Output (kW)</th>
<th>Time (hours)</th>
<th>kW / hrs</th>
</tr>
</thead>
<tbody>
<tr>
<td>1000</td>
<td>0.0</td>
<td>0</td>
</tr>
<tr>
<td>700</td>
<td>12.5</td>
<td>8750</td>
</tr>
<tr>
<td>650</td>
<td>8</td>
<td>5200</td>
</tr>
<tr>
<td>500</td>
<td>3.0</td>
<td>1500</td>
</tr>
<tr>
<td>300</td>
<td>0.5</td>
<td>150</td>
</tr>
<tr>
<td>Totals</td>
<td>24</td>
<td>15,600</td>
</tr>
</tbody>
</table>

Average Load = \( \frac{15,600 \text{ kW} \times \text{hrs.}}{24 \text{ hrs.}} \) = 650 kW

Average Load Factor = \( \frac{650 \text{ kW}}{1000 \text{ kW}} \) = 65%
MANUFACTURER ALLOWANCES

How do manufacturers differ from each other?
MANUFACTURER ALLOWANCES

NET POWER vs. GROSS POWER

What is the difference?

• Net Power Rating: The maximum amount of power from the genset available, after subtracting electrical power it uses during operation

• Gross Power Rating: The maximum amount of power from the genset available, without consideration for electrical power it uses during operation
MANUFACTURER ALLOWANCES
NET POWER vs. GROSS POWER EXAMPLE

Gross Power Output with electronically powered cooling fans
MANUFACTURER ALLOWANCES
NET POWER vs. GROSS POWER EXAMPLE

Net Power Output with electronically powered cooling fans
MANUFACTURER ALLOWANCES
NET POWER vs. GROSS POWER EXAMPLE

Net Power Output with belt driven cooling fans
MANUFACTURER ALLOWANCES
OVERLOAD CAPABILITY

What is overload?

- Overload in the power generation industry is defined as additional power available for a short amount of time.
- Commonly offered as 110% of the PRP rating.
- Typically utilized for load fluctuations.
MANUFACTURER ALLOWANCES
OVERLOAD CAPABILITY DIFFERENCES

How do manufacturer's differ?

1. How often it can be utilized:
   - 1 hr. / 12 hrs. ➔ mtu
   - 1 hr. / 24 hrs. ➔ Others

2. Annual operation limit at 110%:
   - ≤ 25 hours ➔ Others
   - ≤ 87 hours ➔ (1% of year)
How are gensets sized?

*The inherent nature of different electrical loads needs to be understood.*

- Motors & Transformers have a large current demand (referred to as in-rush) for a short period of time when initially connected
- Most other loads do not incur the same in-rush demand
Scenario # 1

Started in one step across the line

- Lowest cost starting method
- Minimum Genset Size: 550kW
- 50% Average Load Factor

Loads:
- (6) 25hp NEMA code G motors
- 150kW of LED Lighting
Scenario # 2

Started in two steps across the line

- Increased cost starting method
- Minimum Genset Size: 400kW
- 69% Average Load Factor

Loads:
- (6) 25hp NEMA code G motors
- 150kW of LED Lighting
MANUFACTURER ALLOWANCES
LOAD FACTOR – REAL WORLD ADVANTAGE

Scenario # 3

- Soft-started in one step
  - Most costly starting method
  - Minimum Genset Size: 350kW
  - 79% Average Load Factor

Loads:
- (6) 25hp NEMA code G motors
- 150kW of LED Lighting
MANUFACTURER ALLOWANCES
LOAD FACTOR – REAL WORLD ADVANTAGE

Scenario 1. 550 kW generator set, 50% Load Factor, 25 HP motors (6) started across the line with 150kW resistive loads, all in one step.

Scenario 2. 400 kW generator set, 69% Load Factor, 25 HP motors (6) and 150kW resistive loads started in separate steps.

Scenario 3. 350 kW generator set, 79% Load Factor, 25 HP motors (6) soft-started with 150kW resistive loads in same step.

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### Scenario #1
- Peak Power: 525kW
- Running Power: 275kW
- Load Factor: 50%
- Genset Size: 550kW

### Scenario #2
- Peak Power: 375kW
- Running Power: 275kW
- Load Factor: 69%
- Genset Size: 400kW

### Scenario #3
- Peak Power: 275kW
- Running Power: 275kW
- Load Factor: 79%
- Genset Size: 350kW

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GET CONNECTED.
POWER UP.

POWER GENERATION SYMPOSIUM 2017
MANUFACTURER ALLOWANCES
LOAD FACTOR – REAL WORLD ADVANTAGE

$15,000

$5,000
MANUFACTURER ALLOWANCES
LOAD FACTOR – REAL WORLD ADVANTAGE

As more efficient starting methods are utilized:

- Size of the genset is decreased due to decreased in-rush
- Costs go down significantly
- Genset load factor is increased

(if allowed by manufacturer)

<table>
<thead>
<tr>
<th>Rating</th>
<th>ESP</th>
<th>PRP</th>
<th>COP</th>
</tr>
</thead>
<tbody>
<tr>
<td>MTU Load Factor</td>
<td>85%</td>
<td>75%</td>
<td>100%</td>
</tr>
<tr>
<td>ISO-8528-1 Minimum</td>
<td>70%</td>
<td>70%</td>
<td>100%</td>
</tr>
</tbody>
</table>
MANUFACTURER ALLOWANCES
MAXIMUM ANNUAL ESP RUN-TIME

- No **limit** defined by ISO-8528-1 for Emergency Standby Power
  - 200 hour annual recommendation
- Some genset manufacturer’s give a 50-200 hour annual limit
- MTU OE gensets have a 500 hour annual recommendation
  - With no annual **limit**
  - Just follow the standard maintenance program
MANUFACTURER ALLOWANCES
TIME BEFORE OVERHAUL (TBO)

- No TBO defined by ISO-8528-1 for any rating
- Some manufacturer’s do not publish a defined maintenance schedule with time before overhaul clearly shown
  - Without TBO defined, products, quality, and ratings cannot be compared
- MTU OE engines are initially designed with defined TBO requirements

<table>
<thead>
<tr>
<th>Rating</th>
<th>Hours</th>
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<tbody>
<tr>
<td>ESP</td>
<td>8000</td>
</tr>
<tr>
<td>PRP</td>
<td>10,000-15,000</td>
</tr>
<tr>
<td>COP</td>
<td>21,000</td>
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</tbody>
</table>
EXHAUST EMISSIONS

How do exhaust emissions impact the generator set rating?
USA Exhaust emission requirements for gensets come from three different levels:

- Federal
- Regional
- Facility

The federal emissions are the starting point for consideration.
Environmental Protection Agency (EPA)

Requirements for gensets can be broken into three categories:

1. Stationary Emergency
2. Stationary Non-Emergency
3. Non-Road Mobile Machinery
Exhaust emission requirements are commonly thought to be officially related to the genset ratings

- Not true!
- Genset ratings are based on ISO-8528-1 & the genset manufacturer's guidelines

Ratings & EPA emission class can be **cross-applied**
### EMERGENCY DIESEL ENGINES

#### Current requirements breakdown into three Tiers:

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<tbody>
<tr>
<td>&lt;50-750hp</td>
<td></td>
<td></td>
<td>Tier 3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt;750hp</td>
<td></td>
<td></td>
<td>Tier 2</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **<50-750hp**: Engines: Tier 3
- **>750hp**: Engines: Tier 2
EXHAUST EMISSIONS
NON-EMERGENCY REQUIREMENTS

Stationary Non-Emergency Category:

Tier 4

NON-EMERGENCY DIESEL ENGINES

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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>50-750hp</td>
<td></td>
<td></td>
<td>Tier 4i</td>
<td></td>
<td>Tier 4i</td>
<td></td>
<td>Tier 4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt;750hp</td>
<td>Tier 2</td>
<td></td>
<td></td>
<td>Tier 4i</td>
<td></td>
<td></td>
<td>Tier 4</td>
<td></td>
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</tr>
</tbody>
</table>
EXHAUST EMISSIONS
MOBILE REQUIREMENTS

NON-ROAD MOBILE DIESEL ENGINES

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</tr>
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<tbody>
<tr>
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<td></td>
<td></td>
<td>Tier 4i</td>
<td></td>
<td></td>
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<td>Tier 4</td>
<td></td>
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<td>Tier 2</td>
<td>Tier 4i</td>
<td></td>
<td></td>
<td></td>
<td>Tier 4</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Mobile Classification

Current requirements:

✔ Tier 4
# EXHAUST EMISSIONS

## FEDERAL CATEGORY EXCEPTIONS

<table>
<thead>
<tr>
<th>Class</th>
<th>Stationary</th>
<th>Non-Road Mobile Machinery</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Emergency</td>
<td>Non-Emergency</td>
</tr>
<tr>
<td>General Usage</td>
<td>When normal source (utility) is not available</td>
<td>Unlimited</td>
</tr>
<tr>
<td>Exceptions &amp; Notes</td>
<td>100 hours maint. &amp; testing</td>
<td>Requires inducement**</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Must move facilities once per year to be considered mobile</td>
</tr>
</tbody>
</table>

**Inducement**: Situation where engine must reduce power or shut down when emission requirements are not met due to product malfunction, tampering, and poor quality or low diesel emission fluid, etc.
EXHAUST EMISSIONS
NON-EMERGENCY DECISION

Should I buy just what I need? (Tier 2)

Or should I spend more for a Tier 4 certified genset so I can do utility programs?

Why does a customer want a Tier 4?

1. Participate in utility programs
2. Run where no utility power exists
3. Party influenced specification to require Tier 4 (even though not required)
What else could the customer do with a certified Tier 4 product?

1. Comply to local requirements (if aligned)

2. Meet Best Available Control Technology (BACT) requirements

3. Promote a “green” reputation
EXHAUST EMISSIONS
NON-EMERGENCY DECISION

Why might a customer not want a certified Tier 4 product?

1. Price
   ✓ Competitor market price levels 50-70% above Tier 2

2. Inducement Concerns
   ✓ EPA **required** shut-downs **add risk** to mission critical applications

**Should I buy just what I need?**

(Tier 2)

**Or should I spend more for a Tier 4 certified genset so I can do utility programs?**
Non-Attainment Areas

- Non-Attainment Areas are defined as counties that do not meet the National Ambient Air Quality Standards (NAAQS)
- 44 of 50 (88%) states have designated Non-Attainment Areas
- As population density grows, Non-Attainment Areas will increase
Non-Attainment Areas

- The Clean Air Act requires that any State with Non-Attainment Areas must develop a State Implementation Plan (SIP) to correct the problem.

- SIP’s may include:
  - Reduced Facility limits (for Title V permitting)
SPECIFIC INDUSTRY RATINGS

What are some examples of rating requests that do not fit into the ISO standard definitions?
Data Centers and other mission critical applications must have reliable emergency backup power in case of outages.

To standardize performance classes of data center “uptime”, an organization was created-

The Uptime Institute performance standard is the globally accepted design standard for data centers.
# SPECIFIC INDUSTRY RATINGS

## UPTIME INSTITUTE TIER CLASSIFICATION

<table>
<thead>
<tr>
<th>Tier Requirement</th>
<th>Tier I</th>
<th>Tier II</th>
<th>Tier III</th>
<th>Tier IV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Source</td>
<td>System</td>
<td>System + System</td>
<td></td>
<td></td>
</tr>
<tr>
<td>System Component Redundancy (power &amp; cooling)</td>
<td>N</td>
<td>N+1</td>
<td>Multiple N+1</td>
<td></td>
</tr>
<tr>
<td>Distribution Paths</td>
<td>1</td>
<td>1 active and 1 alternate</td>
<td>2 active</td>
<td></td>
</tr>
<tr>
<td>Concurrently Maintainable</td>
<td>No</td>
<td>Yes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fault Tolerance (single event)</td>
<td>No</td>
<td></td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Compartmentalization</td>
<td>No</td>
<td></td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Continuous Cooling</td>
<td>Load Density Dependent</td>
<td></td>
<td>Yes (Class A)</td>
<td></td>
</tr>
<tr>
<td>Availability</td>
<td>99.67%</td>
<td>99.75%</td>
<td>99.98%</td>
<td>99.99%</td>
</tr>
</tbody>
</table>

The Uptime Institute tier certification refers to the data centers' infrastructure that directly affects the computer room operation & uptime.

The certifications are awarded in four “Tier” levels.
## SPECIFIC INDUSTRY RATINGS
### TIER COMPARISON TO ISO RATINGS

<table>
<thead>
<tr>
<th>Rating Type</th>
<th>ISO 8528-1 Ratings</th>
<th>Uptime Institute Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Emergency Standby Power (ESP)</td>
<td>Tier I &amp; II</td>
</tr>
<tr>
<td>Expected Annual Run-time</td>
<td>≤ 200 hours</td>
<td>≤ 200 hours</td>
</tr>
<tr>
<td>Load Variability</td>
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<td></td>
<td>≤ 100%</td>
<td>≤ 100%</td>
</tr>
</tbody>
</table>

- **Tier I & II**: Unlimited
- **Tier III & IV**: Unlimited

**ISO 8528-1 Ratings**

- Emergency Standby Power (ESP)
- Data Center Power (DCP)
- Prime Power (PRP)
- Limited-Time running Power (LTP)
- Continuous Power (COP)

**Uptime Institute Requirements**

- Tier I & II
- Tier III & IV

- **Emergency Standby Power (ESP)**: ≤ 200 hours
- **Data Center Power (DCP)**: Unlimited
- **Prime Power (PRP)**: Unlimited
- **Limited-Time running Power (LTP)**: ≤ 500 hours
- **Continuous Power (COP)**: Unlimited

- **Expected Annual Run-time**: ≤ 200 hours
- **Load Variability**: Variable
- **Average Load Factor**: ≤ 70%
SPECIFIC INDUSTRY RATINGS
DATA CENTER CONTINUOUS POWER (DCCP)

// Power Rating
- Data Center Continuous Power (DCCP) rating is optimized for data center applications
- Uptime Institute compliant for Tier III and IV data centers
- No runtime limitation
- 100% Load Factor
- 10% Overload Available

DIESEL GENERATOR SET
MTU 20V4000 DS3000
7800 kW / 60 Hz / Data Center Continuous Power
380 - 13.8kV
MTU 20V4000 DS3000 (2009) M4 for Prime Rating Technical Data
CONCLUSION

How do all of these factors impact one another?
CONCLUSION
THE BALANCING ACT

Specific Industry Ratings
Manufacturer Allowances
ISO-8528-1 Standard
EPA Exhaust Emissions

Genset Purchaser
Customers

The key to supporting the customer is an understanding of all factors!
THANK YOU.