Hydrogen Purity and Moisture Monitoring in Hydrogen Cooled Generators

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Overview

SAFETY • INCREASED EFFICIENCY • RISK MITIGATION

- Hydrogen as a cooling medium
- Importance of purity monitoring
- Dew point monitoring
Hydrogen Cooled Generators

- First H\textsubscript{2} cooled generators became operational in late 1930’s
- Larger generators require more efficient cooling methods
- Helium too costly compared to H\textsubscript{2}
Why Hydrogen?

- Less windage / frictional losses
- Better heat transfer characteristics
- More megawatts per pound of iron
- Lower moisture levels
Why Hydrogen?

- 14 times more efficient at removing heat than air
- Relative density is 4 times less than air
- Approximately 90% lighter than air
# Cooling Medium Characteristics

<table>
<thead>
<tr>
<th>Cooling Medium</th>
<th>Molecular Weight</th>
<th>Specific Heat Capacity</th>
<th>Density</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air</td>
<td>28.95</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>2.02</td>
<td>14.30</td>
<td>0.07</td>
</tr>
<tr>
<td>Hydrogen @ 30 psig</td>
<td></td>
<td>14.30</td>
<td>0.21</td>
</tr>
<tr>
<td>Hydrogen @ 45 psig</td>
<td></td>
<td>14.30</td>
<td>0.26</td>
</tr>
<tr>
<td>Water</td>
<td></td>
<td>4.18</td>
<td>1000.00</td>
</tr>
</tbody>
</table>
Additional Benefits

- Sealed environment: prevents contamination
- Pressurized vessel: suppresses partial discharge and increases level of voltage required to breakdown components
- Is not an oxidizing agent
- Pure hydrogen: will not support combustion
Typical Shaft Seal
The hydrogen dilemma ...
... the morning after.
Gas Purity Monitoring

- Why do we monitor hydrogen purity?
  - Safety, explosive range 4 to 75% H₂ in air
  - Most explosive at 13% H₂ in air
  - Efficiency

- Performed during gassing, de-gassing and normal operation of the generator
Hydrogen Purity and Efficiency

![Graph showing the relationship between Hydrogen Purity and Financial Loss for 800 MW and 400 MW units.](image-url)
Typical Generator Arrangement
Methods of Measuring Gas Purity

- Manometer
- Gas density blower
- Thermal conductivity
- Vibrating element
Considerations

- Accuracy, stability, ranges and redundancy
- Sampling location, filtering and flows
- Area classification, form of protection
  - Different countries have different specifications
Why Monitor Dew Point?

- Component and insulation failure
- Efficiency
Increased Dew Point

• Could support insulation failure (electrical tracking)

• Corrosive effects
  - Retaining rings – most highly stressed mechanical component in the generator

• Cyclic generator operation
Retaining Ring Failure
Shorted Turns
Mixture Density

Mixture Density Change at 30 PSIG and 60 C
H2 in Air vs H2 Dew Point

H2 Dew Point (°C)

H2 Mixture Density (g/m³)

H2 in Air (%)
Where Does Moisture Come From?

- Primary source — seal oil and seals
- Hydrogen coolers
- Stator cooling water (clip leaks)
- Thermal cycling of generator
Methods of Monitoring Dew Point

- Ceramic
- Silicon based
- Aluminum oxide
- Chilled mirror
- Measuring a change in the electrical properties
  - Capacitance, resistance or impedance
Considerations

- Accuracy, stability, pressure compensation, ranges
- Effects of temperature, pressure
- Sampling location, filtering, flows
- Area classification, form of protection
  - Different countries have different specifications
Summary

• Hydrogen as a cooling medium
• Importance of purity monitoring
• Dew point monitoring

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THANK YOU

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