Water Mist Fire Protection for a 35 Megawatt Steam Turbine Generator

ORR Protection Systems
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Steam Turbine Generators

- Uses superheated steam to rotate a shaft
- Shaft turns generator to make electricity
- Size range – 5 Kilowatt to 1.5 Gigawatt
- Heavy and spins fast
  - 50 Hz – 3,000 RPM
  - 60 Hz – 3,600 RPM
Generator Fire Problem

- Combustible oils used for turbine operation
  - Flash points of 375°F to 500°F

- Lube oil pumping skids support turbine
  - Lubricate bearings along shaft
  - Prevent metal-to-metal contact
  - Help operate control valves

- Uncontrolled sprays can ignite on hot surfaces and create LARGE fires

- Lube oil must be available to the bearings and seals until the shaft stops spinning – 20-30 Minutes
“During a recent 15-year period, 17 large turbine building fires resulted in more than $400 million in gross loss. Lost generating capacity was in excess of 20 million MWh, which is roughly the equivalent of a mid-sized investor-owned utility in the United States. The average loss was $24 million and the average outage was more than 24 weeks.”

- FM Global

- The risk is real
- Resulting in large losses
  - Extended outages
  - Significant property damage
  - Lost revenues
FM Global Large Scale Fire Tests

- Testing occurred:
  - January - February 2004
  - Large Burn Laboratory (West Glocester, RI)

- Tested performance of sprinklers

- Oil fire results
  - Pool fires
    - Extinguished from overhead
  - Spray and Vertical Surface fires
    - Not extinguished from overhead
    - Controlled only by local application
  - Shut off oil flow as soon as possible
    - Skilled operators must decide

“The turbine test fires produced the most powerful fires yet recorded in the new FM Global burn laboratories.” – FM Global
FM Global Recommendations

- FM Global Property Loss Prevention Data Sheet 7-101 *Fire Protection for Steam Turbines and Electric Generators*

- Recommends water sprinkler systems for protection
  - Automatic wet or deluge
  - 10’ x 10’ spacing
  - 8.0 K-Factor, 50 psig minimum pressure
Considering Water Mist

- **Ultra-fine droplets...**
  - Fast evaporation cools flame and surrounding gases
  - Locally displaces oxygen
  - High density effectively blocks radiant heat

- **Proven use for flammable and combustible liquids fires**
  - Pool, spray, and vertical surface fires
  - Works with fires in combination modes

- **Commonly used for protection of combustion turbines and generators**

- **Manufacturer fire testing data...**
  - Many to reference and well documented
  - Similar to steam turbine fires
  - Indicate good performance
Case Study

- 35 Mw Steam Turbine Generator at Fertilizer Plant
- Plant refines mined phosphates into phosphoric acid
  - Waste steam from refining process used to make electricity
  - Turbine installed in hi-bay building
  - Owner currently uses water mist for protection of other hazards
Turbine Building
Turbine Building
Considerations:

- **Total flooding**
  - Volume too large for total flooding.
  - Building not fully enclosed.

- **Local application**
  - Access over bearings
  - Diked area around lube oil skid
High Pressure Water Mist System

- Design Basis – Local Application High Pressure Water Mist
  - MSC/Circ.913, 4 June 1999 - Guidelines for the Approval of Fixed Water-Based Local Application Fire-Fighting Systems for use in Category A Machinery Spaces.
    • International Maritime Organization Maritime Safety Committee
  - Test Report No. RTE11160/99 Evaluating the Extinguishing Capabilities of the HI-FOG Local Application Fire Protection System in Machinery Spaces According to IMO MSC/Circ.913 VTT.
    • Marioff testing conducted at VTT Technical Research Center of Finland
Marioff Local App. Water Mist

System Design:

- Followed Marioff HI-FOG® Systems (GPU) for Local Application Fire Fighting in Machinery Spaces – DIOM
- Total system flow 35.7 GPM (135 LPM)

- 2 water mist zones – 6 Nozzles each
  - Zone 1 – Turbine Bearings
  - Zone 2 – Lube Oil Skid

<table>
<thead>
<tr>
<th>Design Value</th>
<th>IP</th>
<th>SI</th>
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<tbody>
<tr>
<td>Nozzle K-Factor</td>
<td>0.124 @ ≥ 1450 psi 0.078 @ 290 psi</td>
<td>6.8 lpm/bar^{1/2} @ ≥ 100 bar 4.3 lpm/bar^{1/2} @ 20 Bar</td>
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<tr>
<td>Max. Water Flow Rate</td>
<td>0.29 gpm</td>
<td>11.1 lpm</td>
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<tr>
<td>Max. Spacing</td>
<td>16’ 4”</td>
<td>5 m</td>
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<tr>
<td>Max. Coverage Area</td>
<td>269 ft²</td>
<td>25 m²</td>
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<tr>
<td>Max. Distance from Hazard</td>
<td>17’ 3”</td>
<td>5.25 m</td>
</tr>
<tr>
<td>Min. Distance from Hazard</td>
<td>4’ 11”</td>
<td>1.5 m</td>
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</table>
Zone 1 – Turbine Bearings

- Four bearings on turbine. One wetted by steam.
- Two water mist nozzles per bearing.
Zone 1 – Turbine Bearings
Zone 1 – Turbine Bearings
Zone 2 – Lube Oil Skid

- Nozzle array over top of diked area containing skid
- Protects lube oil and control oil skids
Zone 2 – Lube Oil Skid
Water Mist Pump

- Nitrogen Driven Gas Powered Pump
- 24 N\textsubscript{2} cylinders for 40 minutes of discharge time
- Two zones of protection – Manual remote releases
Detection and Control System

- Dedicated suppression control panel
- Multiple manual release stations
- Four video image smoke and fire detection cameras
- Remote monitoring from plant operator’s station
Turbine Operator’s Station
Detection Camera Video
Conclusions

Steam turbines are a fire risk

Lube oil fires are a high-challenge hazard

Water mist is a suitable fire protection solution

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References


International Maritime Organization (1999) MSC/Circ.913, 4 June 1999 - *Guidelines for the Approval of Fixed Water-Based Local Application Fire-Fighting Systems for use in Category A Machinery Spaces.* Note: This standard has been revised as MSC/Circ. 1387 10 December 2010