Mechanical equipment and operation and maintenance

Session VI

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Mannvit

Strasbourg, Nov. 8th, 2012

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Presentation overview

- Features of mechanical equipment used in geothermal power plants
- Example showing methods used for choosing a gas extraction system
- O&M with photographs of extreme conditions shown

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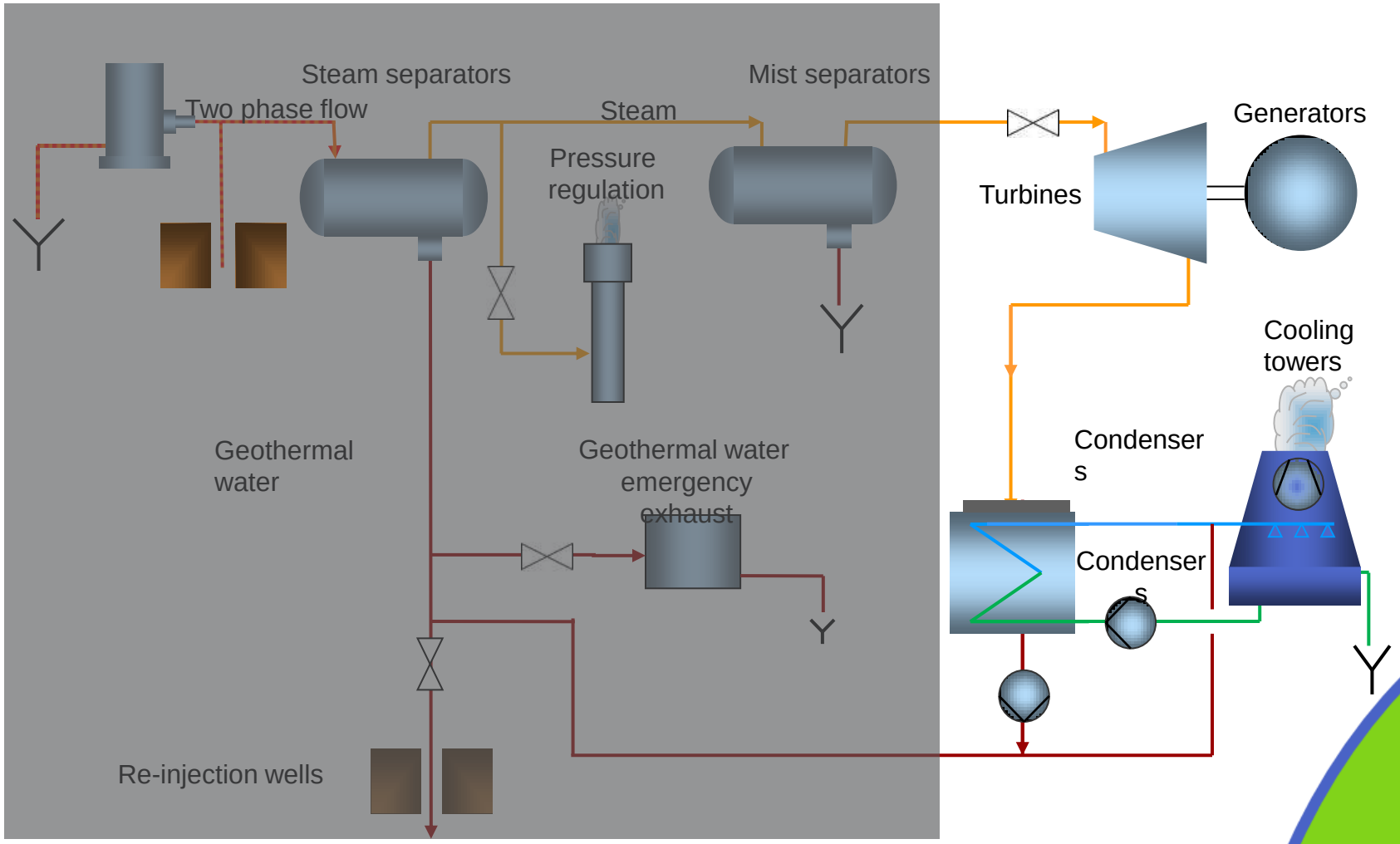
Power Plant Preliminary P&ID



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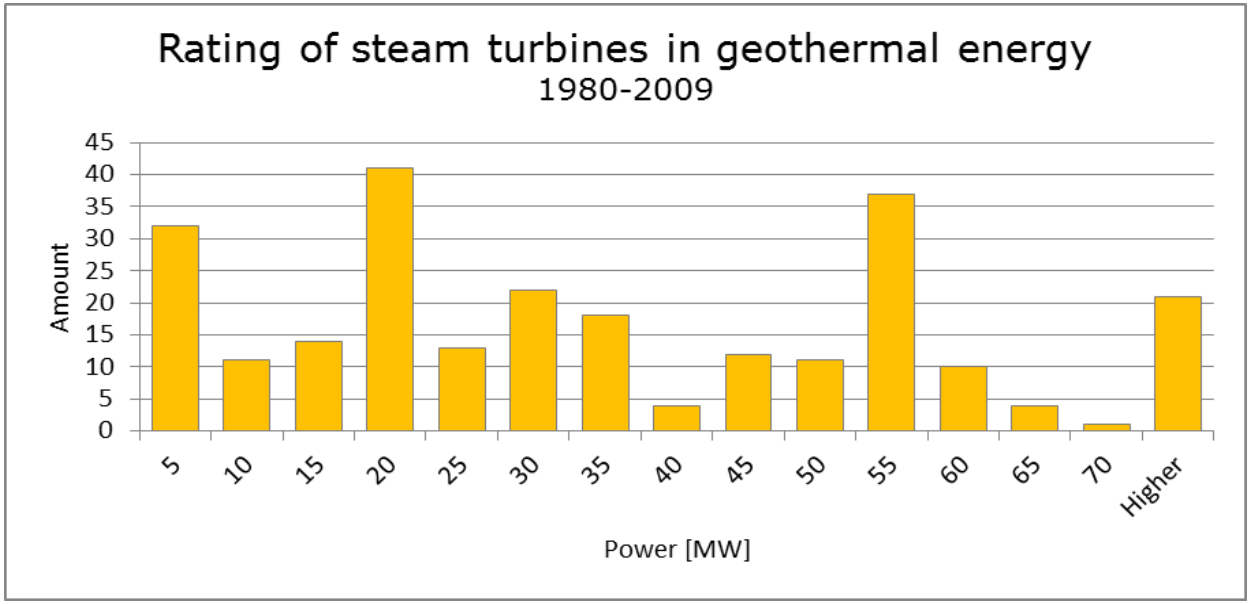
Power Plant - Turbine

- Axial turbines
  - Single flow
  - Double flow
- Turbo expander



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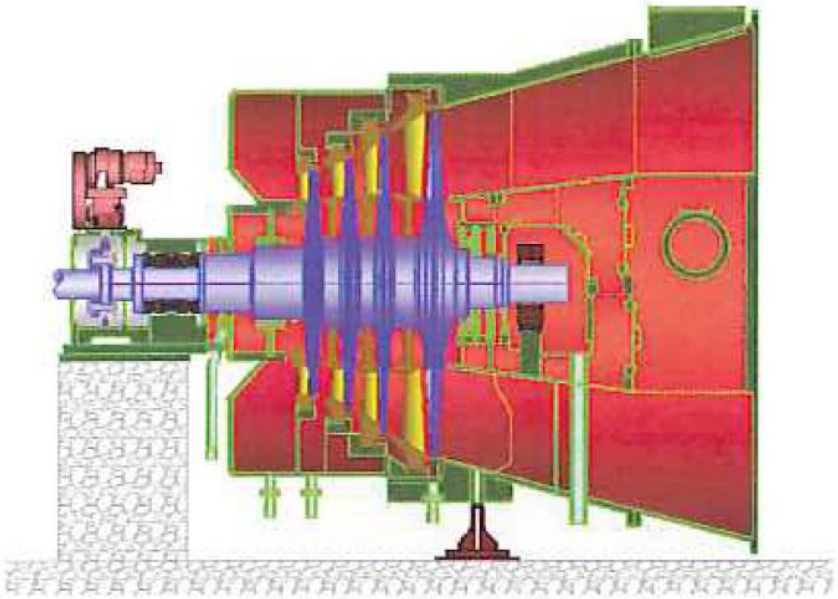
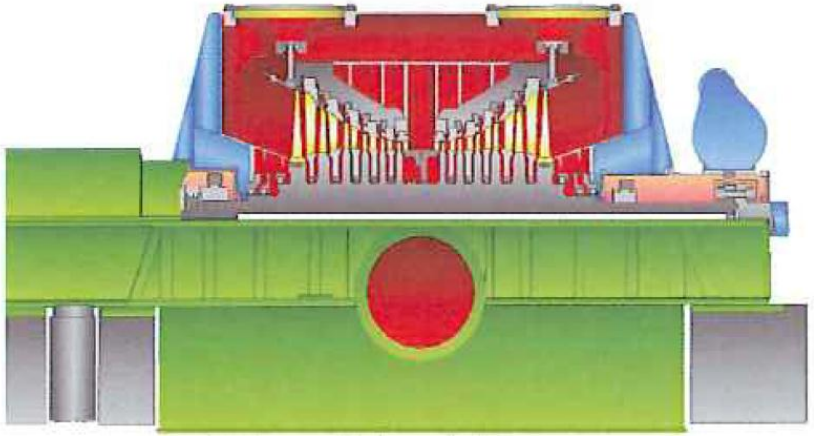
Single and double flow turbines

single flow 20 - 70 MW Double flow 40 - 140 MW





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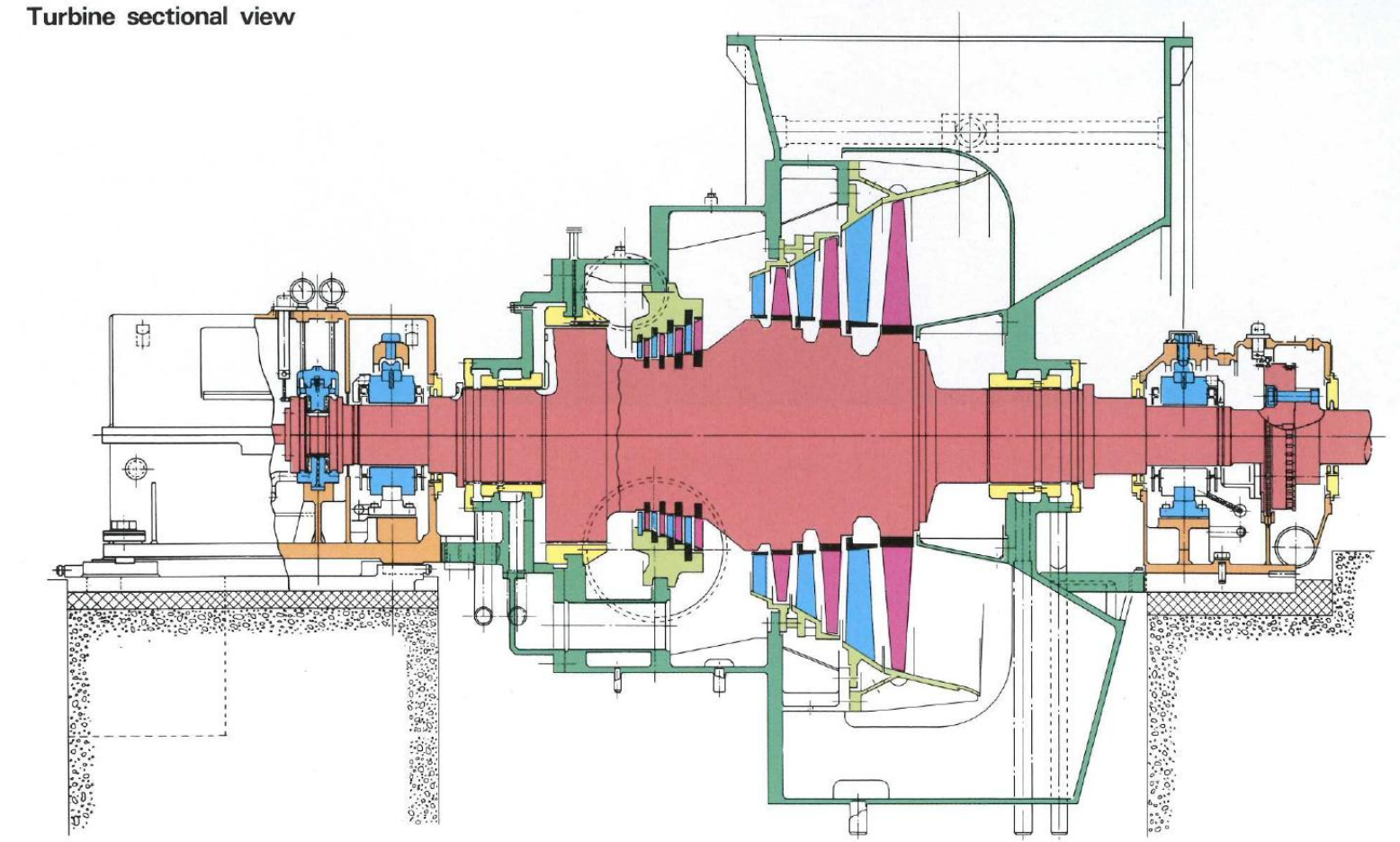
Double pressure

6,3/1,4 bara -> 0,1 bara



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Power Plant – Turbine / generator

- Rotor
  - Turbine blade size is over 30”
  - Corrosion protection on the last stages
- Turbine drain
- Double steam inlet – Stem free test
- Generator
  - Overpressure in generator housing

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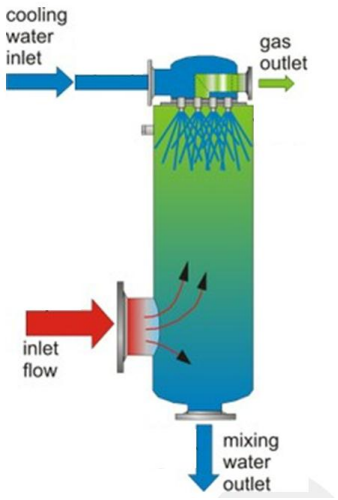
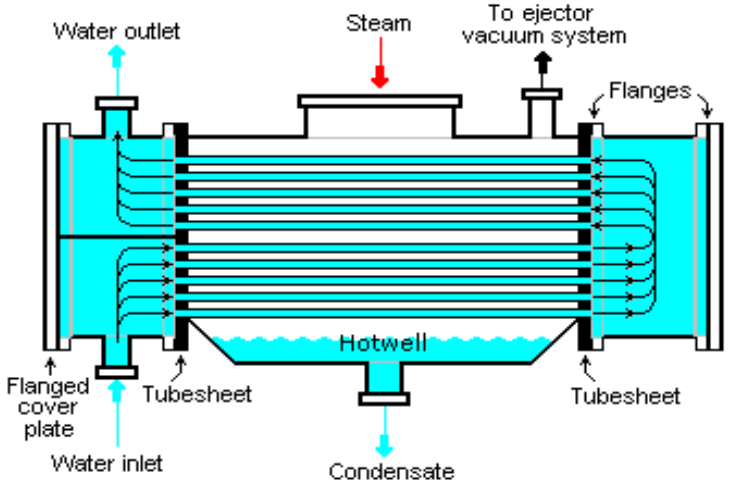
Power Plant - Heat Exchangers

- Evaporators/recuperators
  - Conventional shell and tube or plate heat exchangers
  - Hybrid
- Condensers
  - Direct contact
  - Indirect contact
    - Shell and tube
  - Special cooling section for gas





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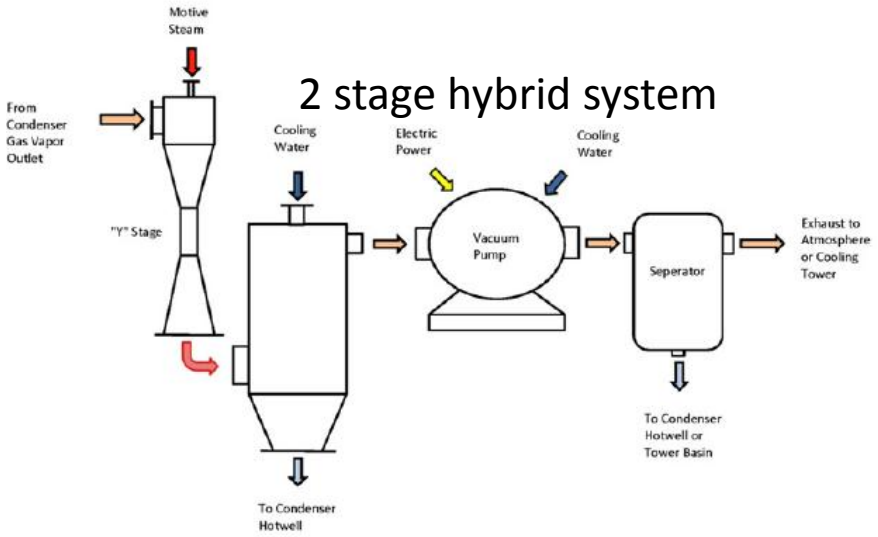
Power Plant - Gas extraction system

- Type
  - Compressors
  - Vacuum pumps
  - Ejectors
- Selection
  - Gas content
  - Condenser pressure
  - Cost evaluation
    - Price of electricity/steam



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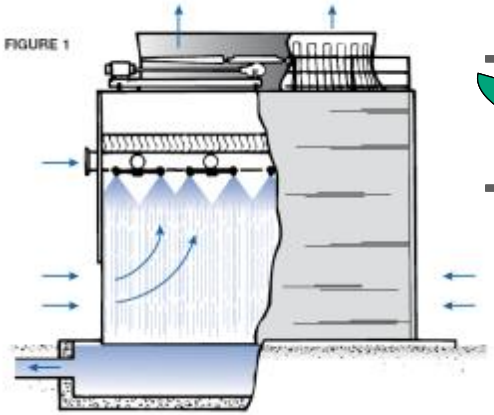
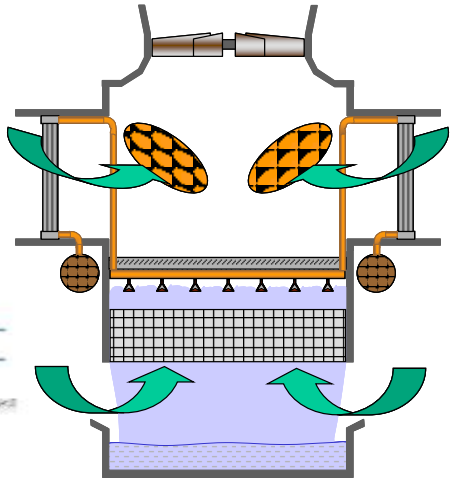
Power Plant - Cooling Tower

- Type
  - Wet
  - Hybrid
  - Dry
- Selection
  - Cost efficiency
  - Availability of water
  - Visual impact



Wet CT



Hybrid CT

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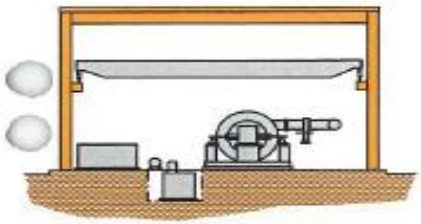
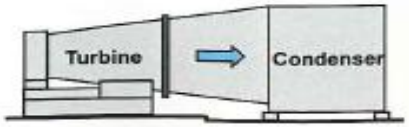
Power Plant - Layout

Axial Exhaust

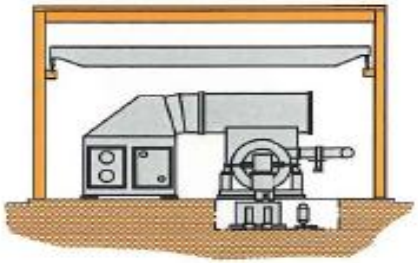
- *Total concrete required and complexity of the foundation design are also significantly reduced*



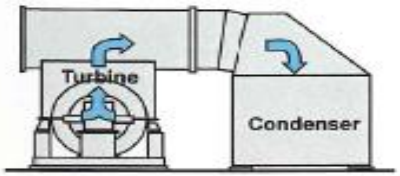
- *Axial diffuser effectively transforms exhaust velocity into pressure, thereby minimizing exhaust loss*



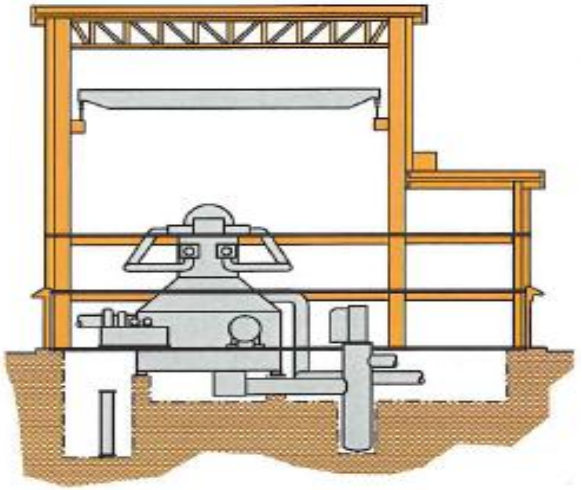
Top Exhaust



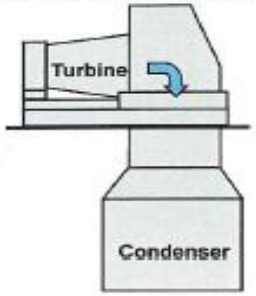
- *Triple turning of the exhaust flow creates the biggest loss*



Down Exhaust



-*Conventional design with single turning produces moderate exhaust loss*



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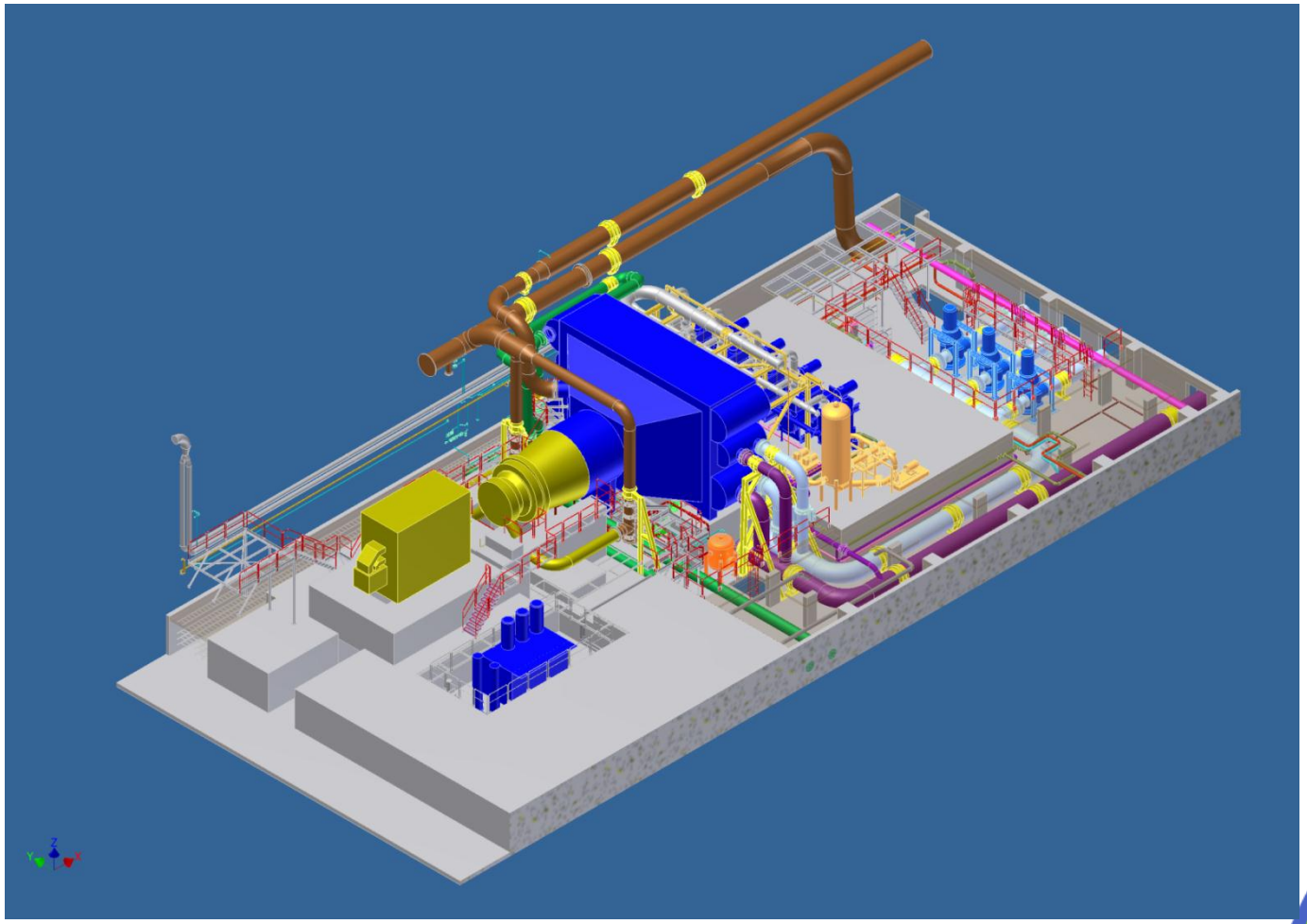
Layout – 45 MW unit at Hellisheiði



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Power Plant – Building

- Turbine hall
  - Conventional steel structure
- Connecting buildings
  - Housing electrical rooms
  - Concrete building to achieve higher tightness
- Earthquake requirements

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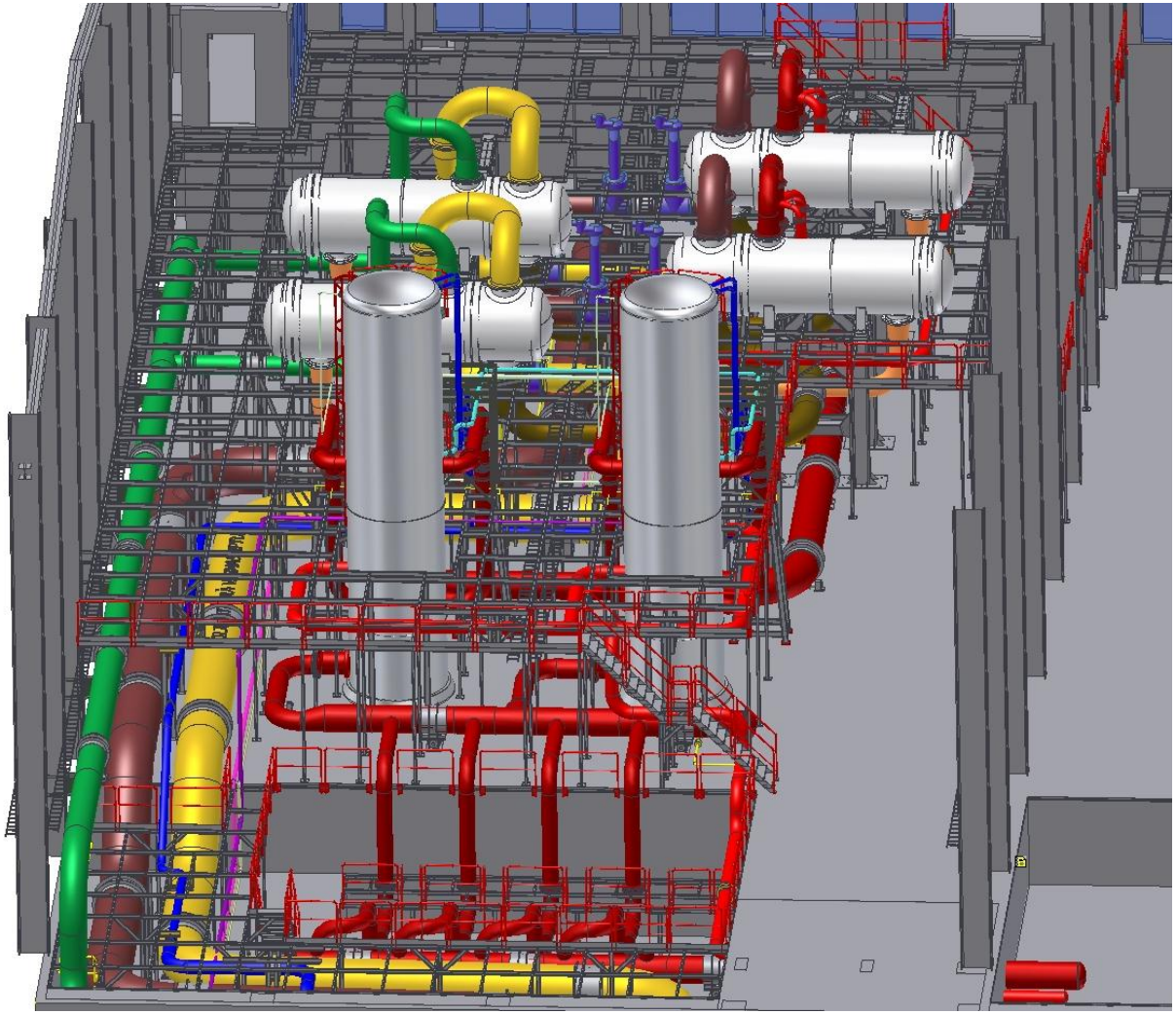
Layout – 133 MW hot water plant at Hellisheiði



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Example

- Selection of gas extraction system
- Assumptions
  - Gas content 1% gas
  - Steam consumption 83 kg/s
  - Price of steam 500.000 EUR/kg/s
  - Price of electricity 300.000 EUR/100 kW

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Example, continued

- Vacuum pumps
  - Electrical consumption 1200 kW
  - Capital cost 400.000 EUR
- Ejectors
  - Steam consumption 5 kg/s
  - Capital cost 100.000 EUR
- Hybrid system
  - Electrical consumption 300 kW
  - Steam consumption 2 kg/s
  - Capital cost 200.000 EUR

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Example, continued

- Evaluation formula
  - CC+EC*PE+SC*PS
    - Capital Cost (CC)
    - Electrical Consumption (EC)
    - Price of Electricity (PE)
    - Steam Consumption (SC)
    - Price of Steam (PS)

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- Vacuum pumps:
  - 400.000 + 1200*300.000/100 = 4.000.000 EUR
- Ejectors
  - 100.000 + 5*500.000=2.600.000 EUR
- Hybrid system
  - 200.000+2*500.000+300*300.000/100=2.100.000 EUR

- Hybrid system would be selected.

  Please note that numbers are fictive.

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Operation and maintenance

- In this session operation and maintenance of geothermal power plants with emphasis on the geothermal part of the plant is introduced. Photographs of extreme conditions will be shown.

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Geothermal Power Plants

Included in Operation & Maintenance

- Central operation centers
- Observation of machinery
- Security
- Operation supplies (chemical for cooling water, inhibitors, oil, filters for air cleaning, cleaning products, binary fluid)

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Geothermal Power Plants

Operation & Maintenance

- Maintenance – work (rotor and generator every 15 years)
- Maintenance – supplies
- Monitoring of the reservoir and area
- Drilling for maintaining steam

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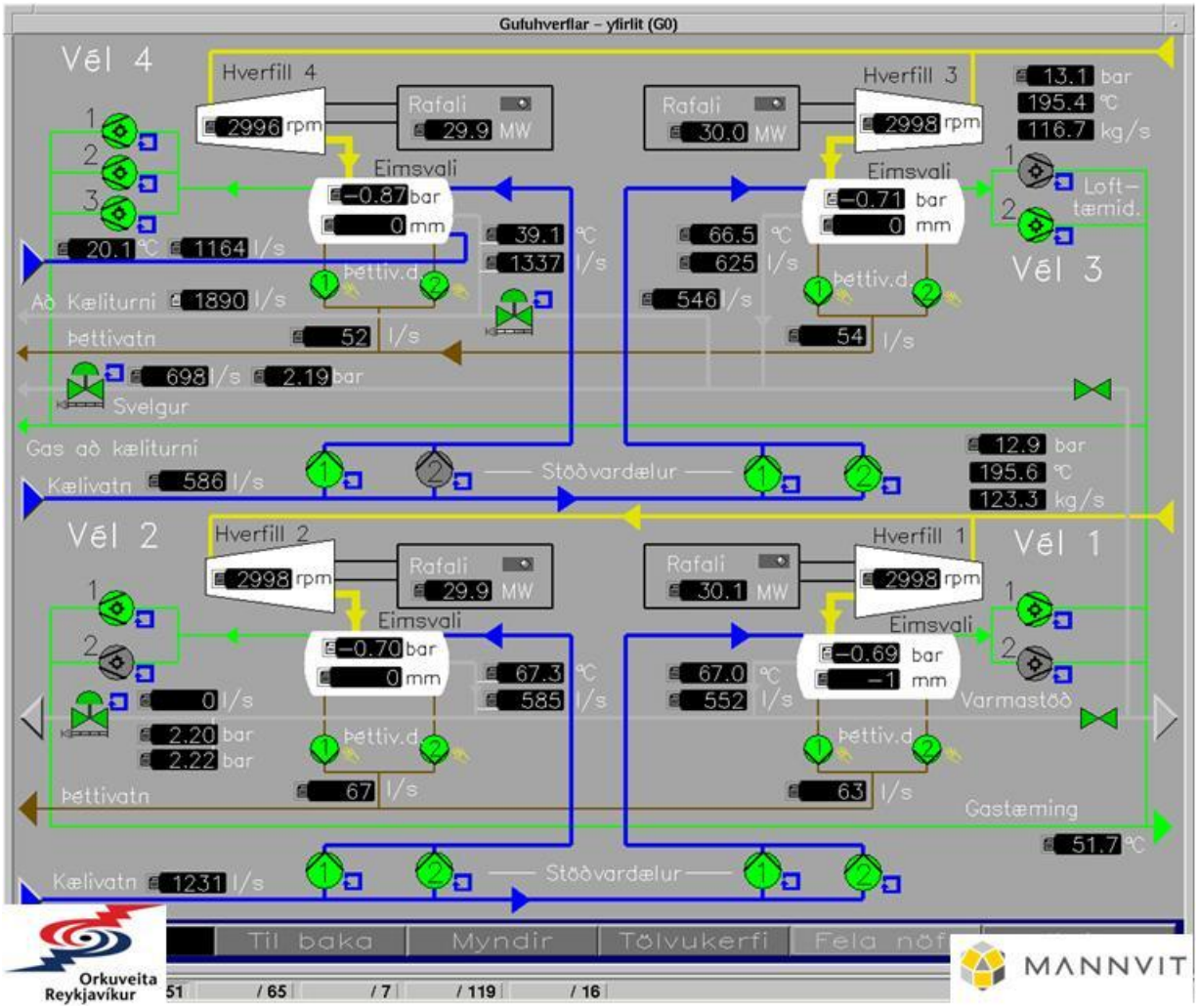
Operating Console



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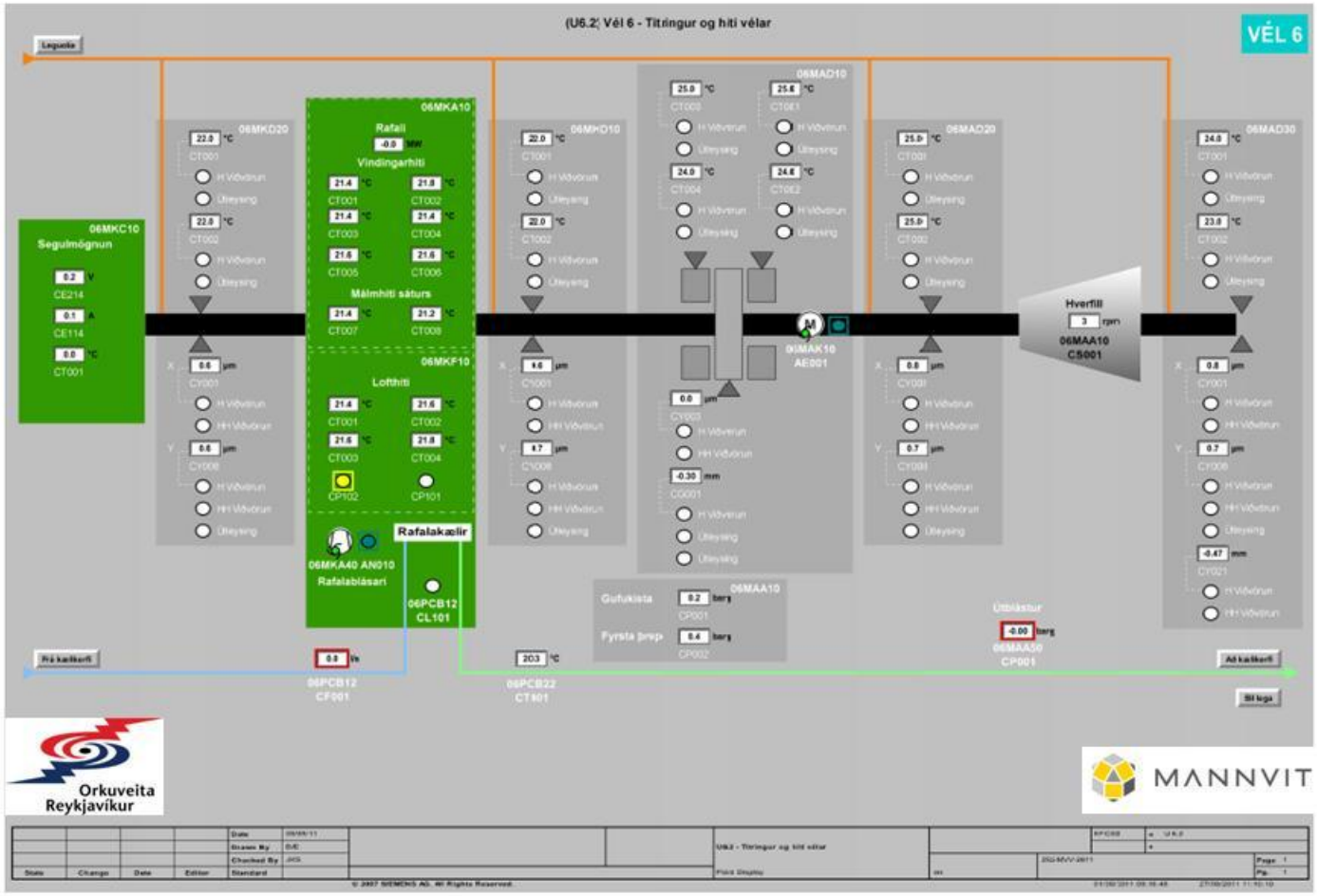
Turbine Monitoring



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Wellhead

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Enclosure Wellheads

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Leakage in Wellhead

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Leakage in Wellhead

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Leakage in Wellhead

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Well Discharge in Winter

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Well Discharge in Winter

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Wellhead Master Valve

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Well Cleaning during Discharging

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Steam Separator for 60 kg/sek

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Cooling Tower in Winter

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Turbine Rotor

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Cleaning of Rotor

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Scaling on Rotor

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Scaling in Stationary Diaphragms

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Erosion in Stationary Diaphragms

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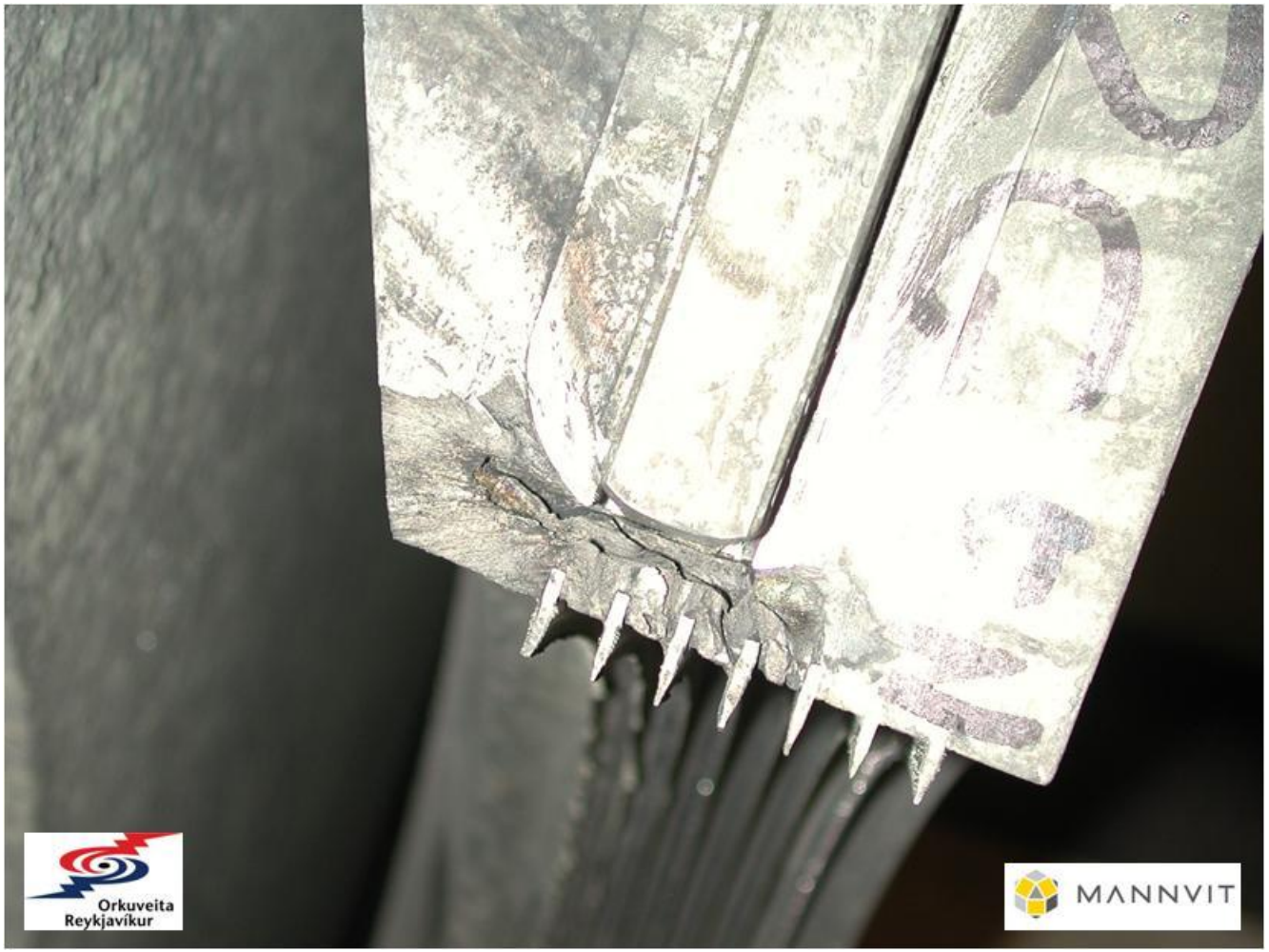
Erosion in Stationary Diaphragms



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Erosion in Stationary Diaphragms

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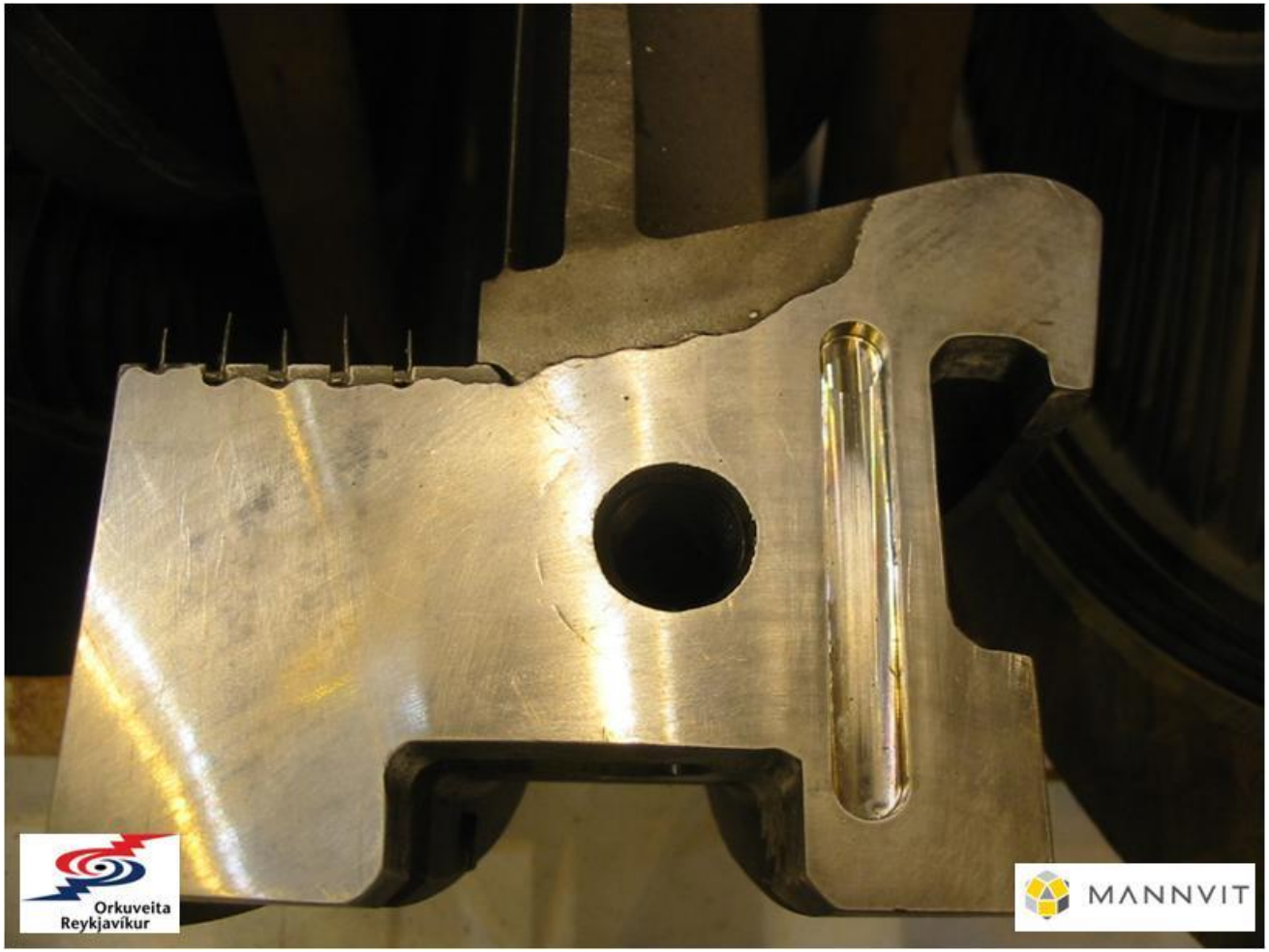
Diaphragm Repaired by Welding



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Diaphragms Repaired by Welding

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Erosion of Rotor

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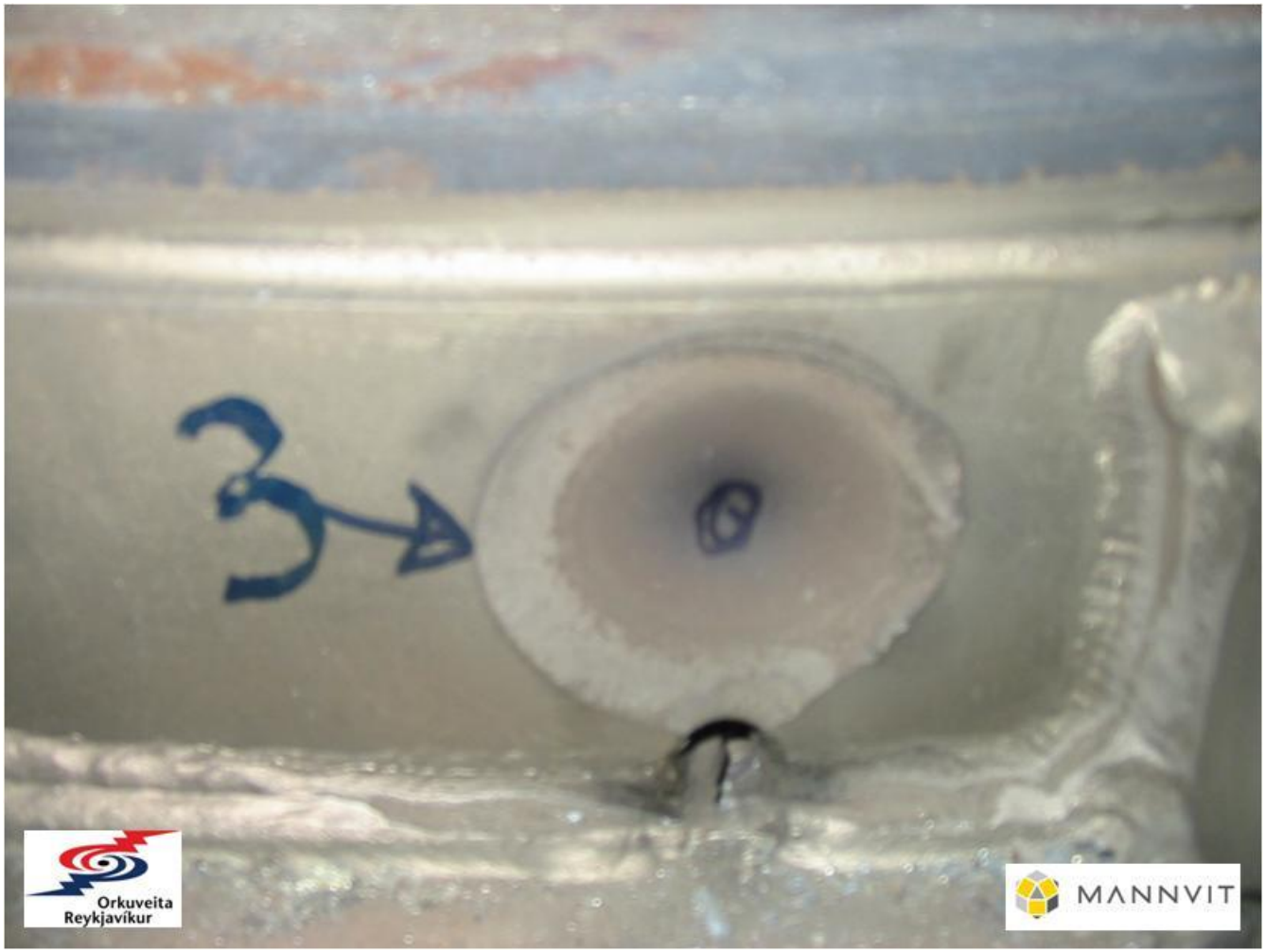
Damages Caused by Drainage



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Improvement of Drains in Turbine

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Drains in Turbine

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Shut Down Valve Axle

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Shut Down Valve End Bearing

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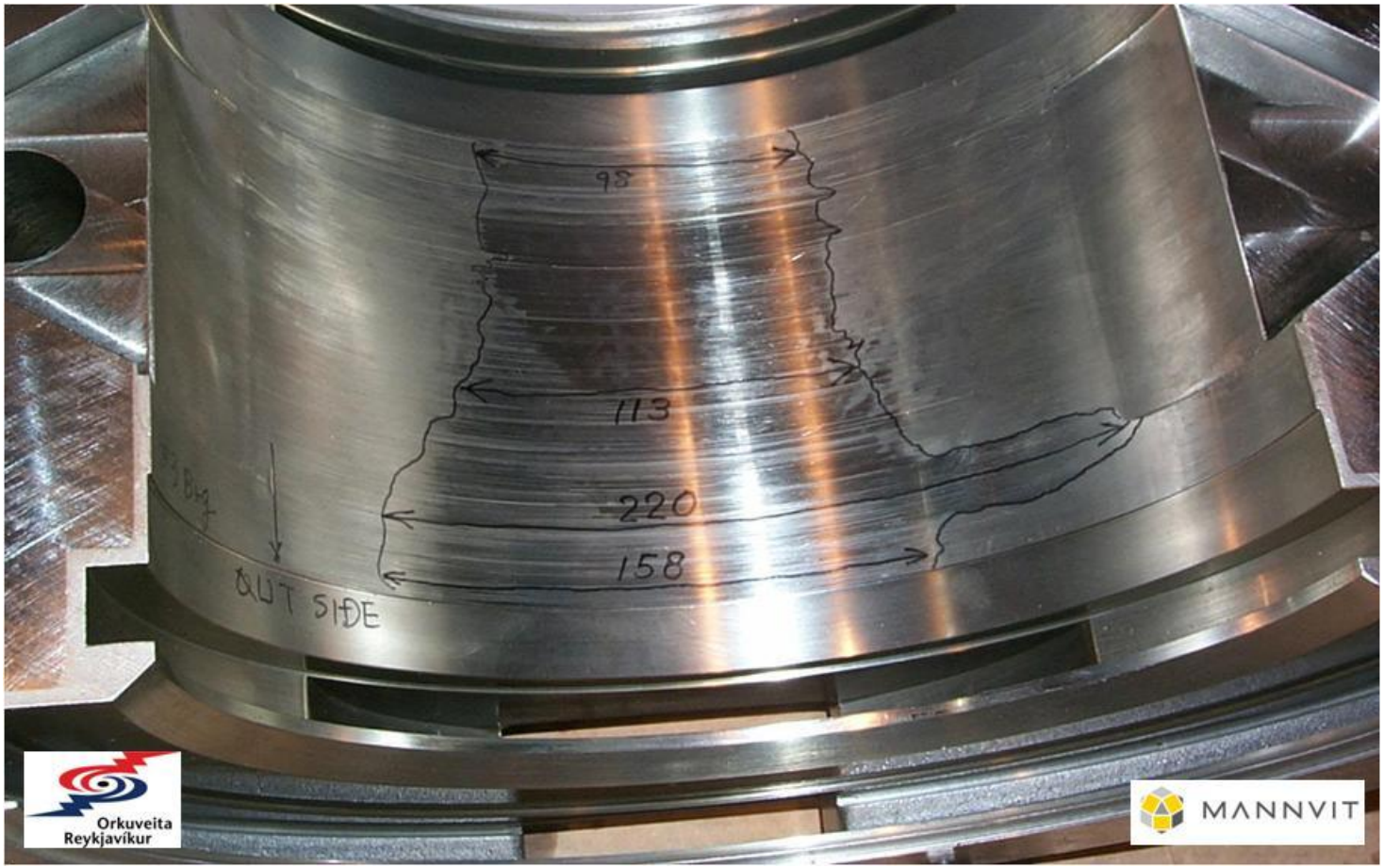
Turbine and Generator Bearings



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Oil filter

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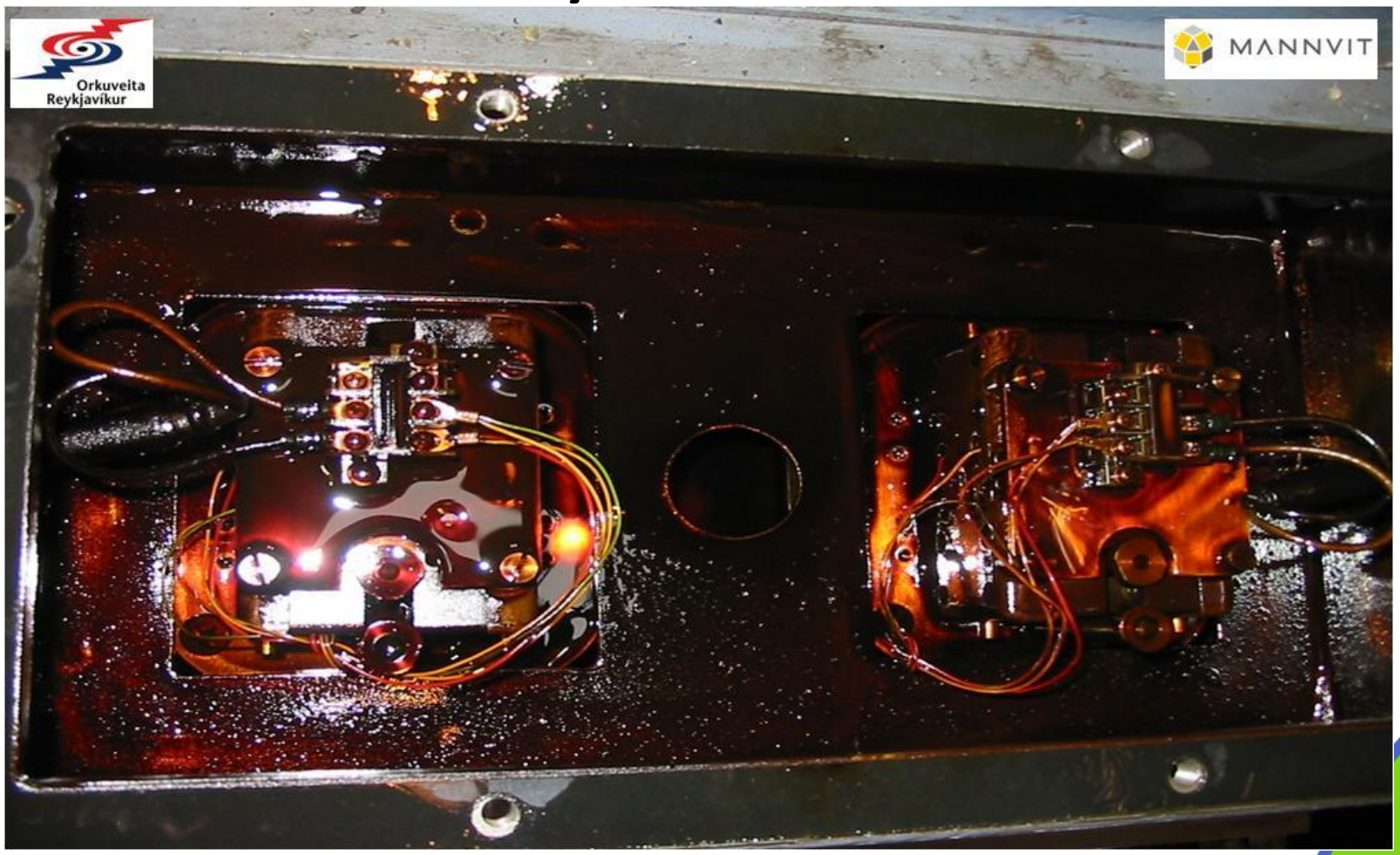
Oil System



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Broken turbine blades

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Damaged turbine housing

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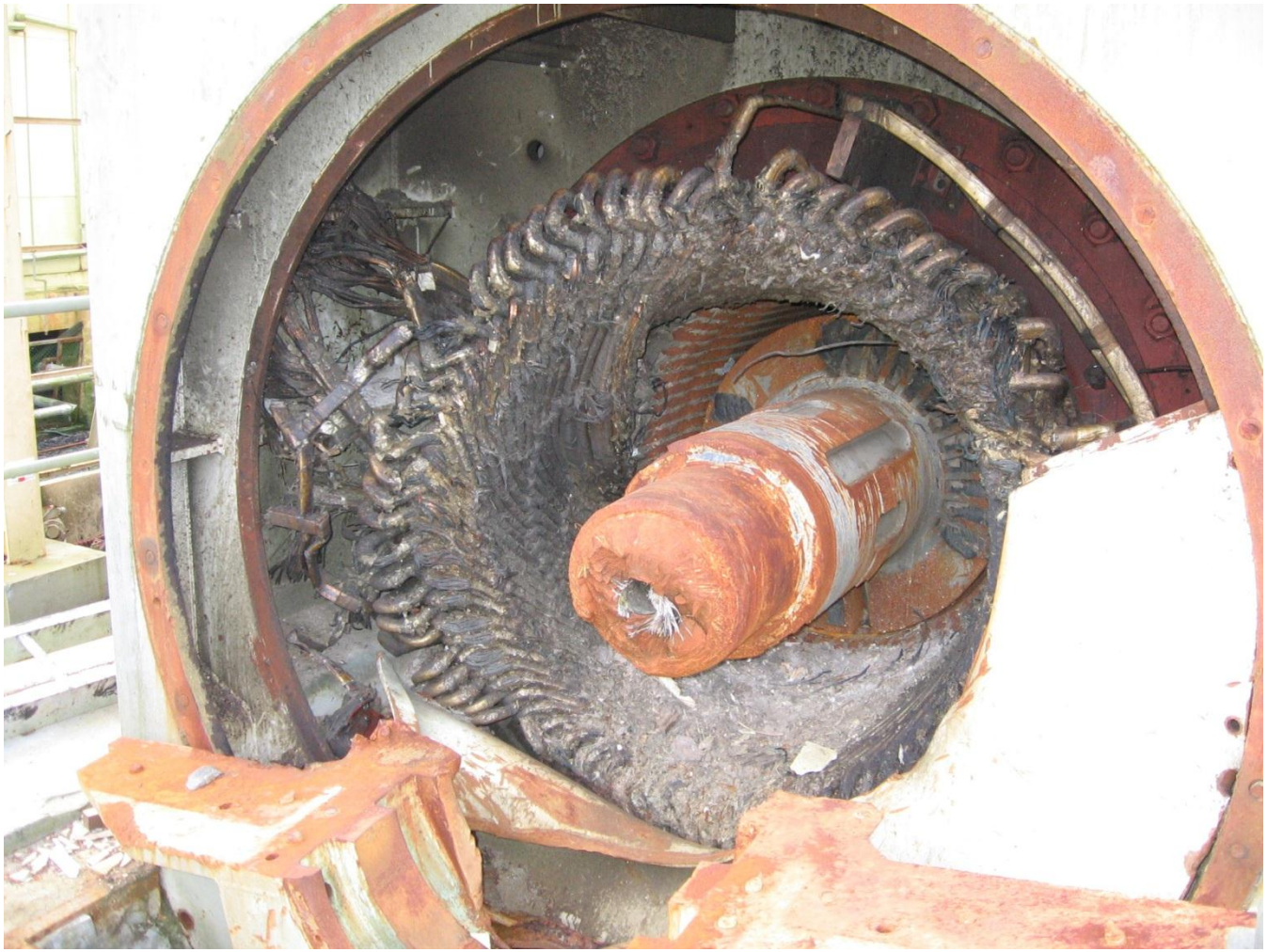
Generator broken



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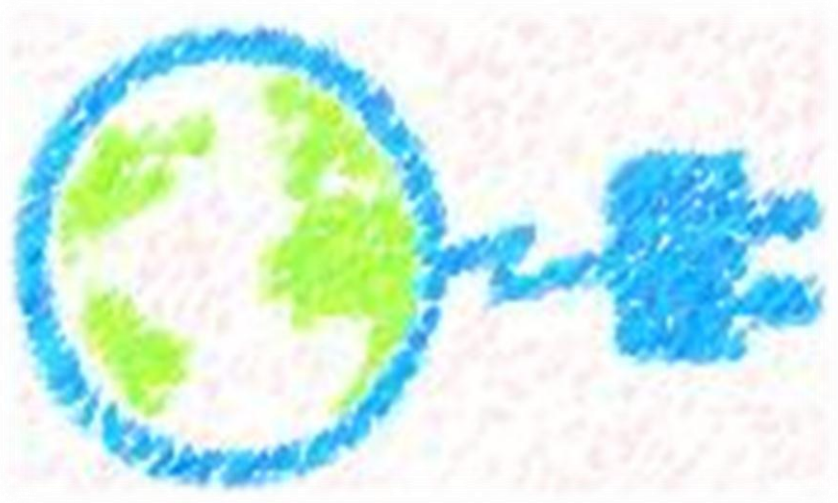

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