Mechanical equipment and operation and maintenance

Session VI

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Presentation overview

- Presentations presenting features of mechanical equipment used in geothermal power plants and their operation and maintenance
- Calculated example showing methods used for basic engineering within mechanical equipment design in geothermal energy
- Photographs of extreme conditions shown and discussed with solutions

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Mechanical equipment

- This session will present mechanical equipment used in geothermal power plants. Emphasis will be on different design considerations compared to conventional steam plants.

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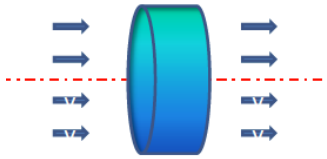
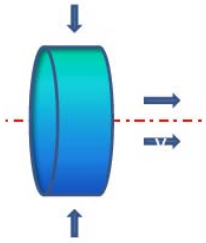
Binary power plant – turbine

dry vapour expansion, no erosion of blades

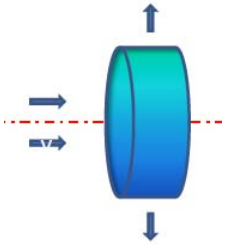
- <u>Axial, possibly multistage</u>
  most common



- <u>Radial, inflow</u>
  sometimes used



- <u>Radial, outflow, multistage</u>
  recently proposed again



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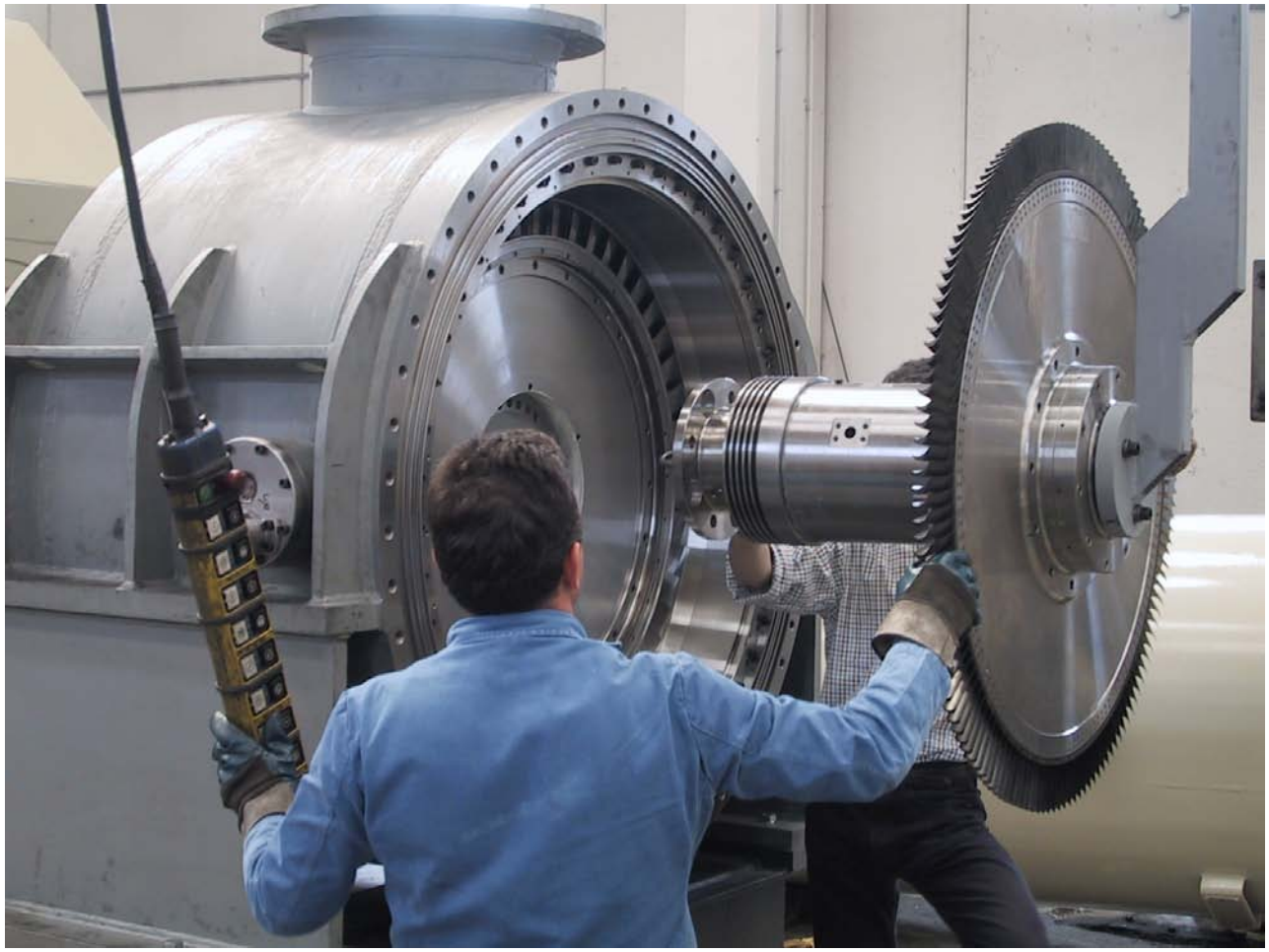
Turbine, axial, single stage



Low rotational speed
Low peripheral speed, low mechanical stress
No reduction gear

By courtesy of Turboden

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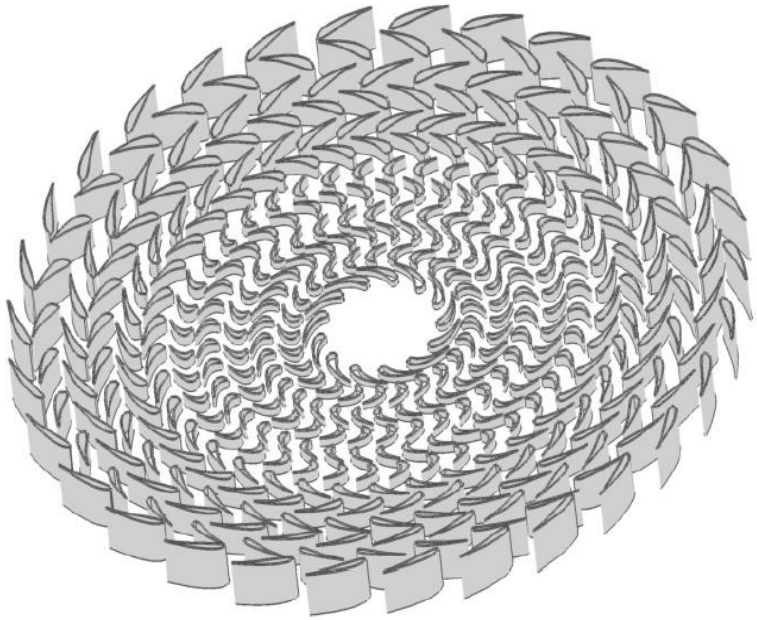
Binary power plant – turbine

radial, outflow, multistage



Advantages

• fluid passage area naturally increases along the expansion process
high efficiency and flexibility

Main disadvantage:

• low work extraction per stage (centrifugal force potential acts against work extraction) high number of stages required;

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Binary plant – power cycle pump

- Centrifugal, multistage pump
- Operated at variable speed

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Power Plant - Heat Exchangers

shell and tube or plate – possibly with phenolic coating

Soultz heat exchangers

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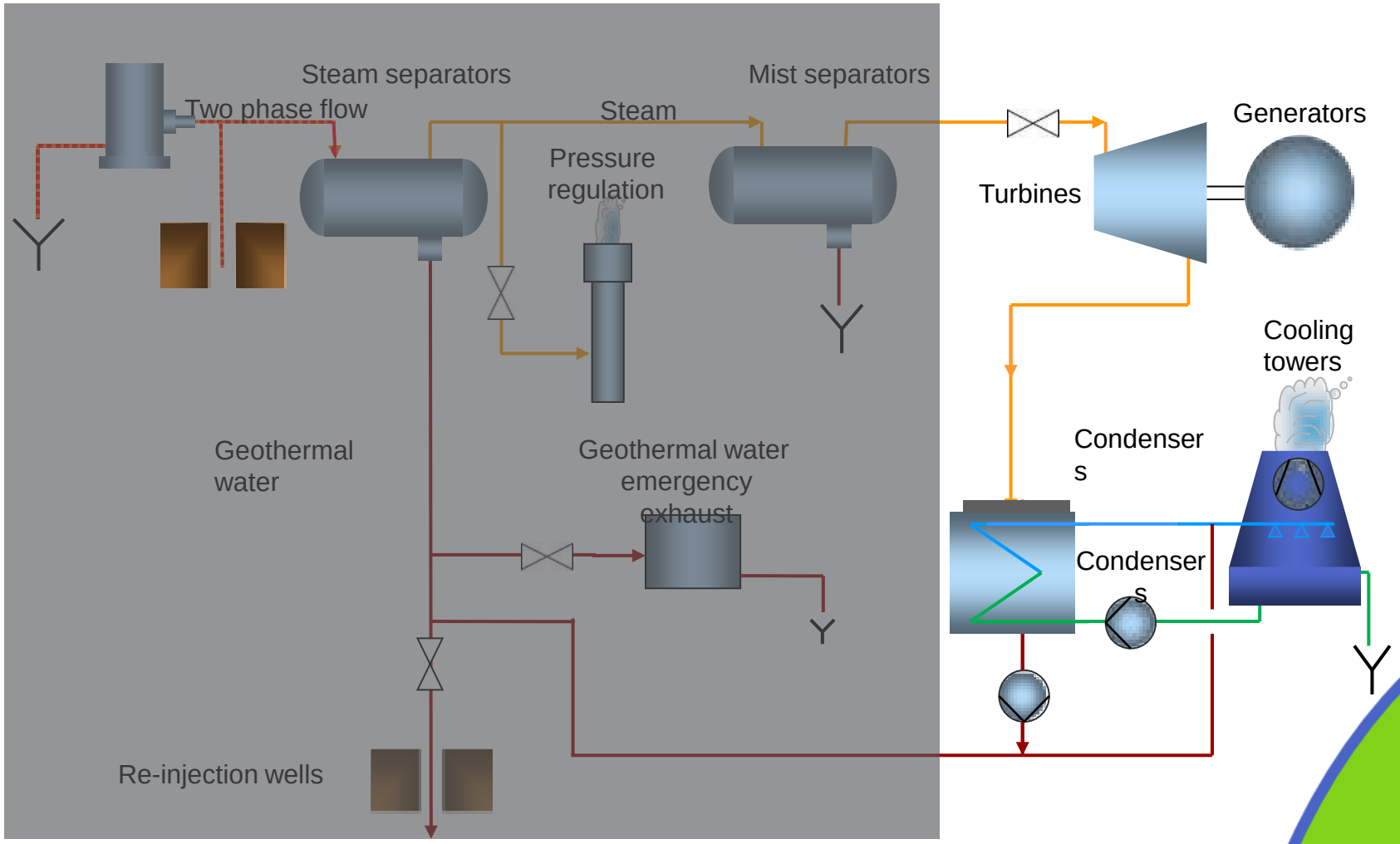
Power Plant Preliminary P&ID



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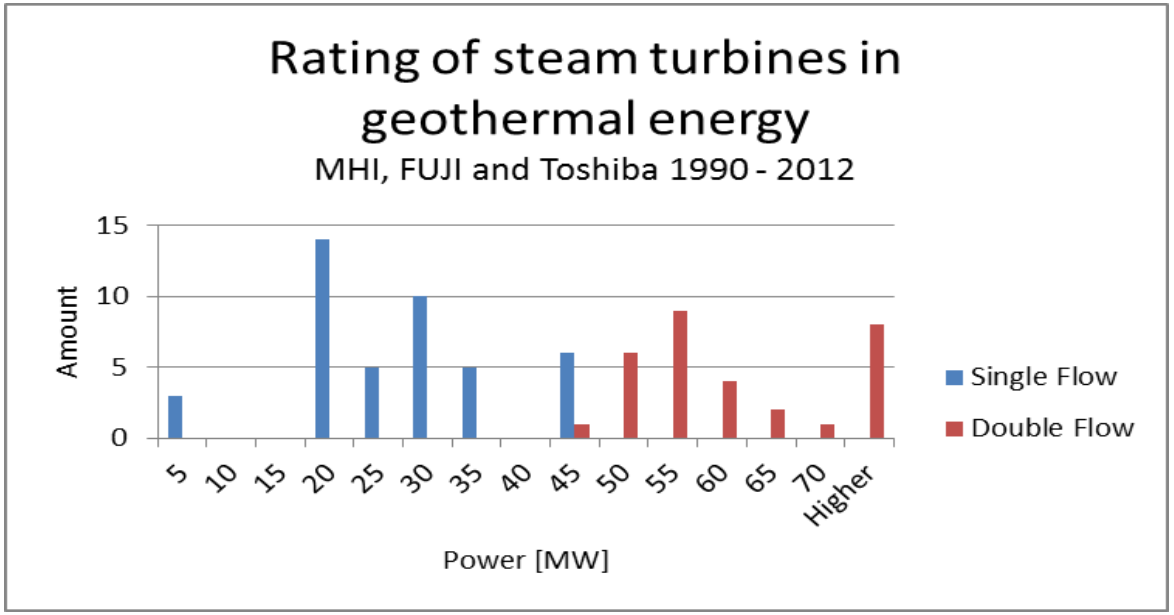
Power Plant - Turbine

- Axial flow
  - Single
  - Double
- Turbo expander



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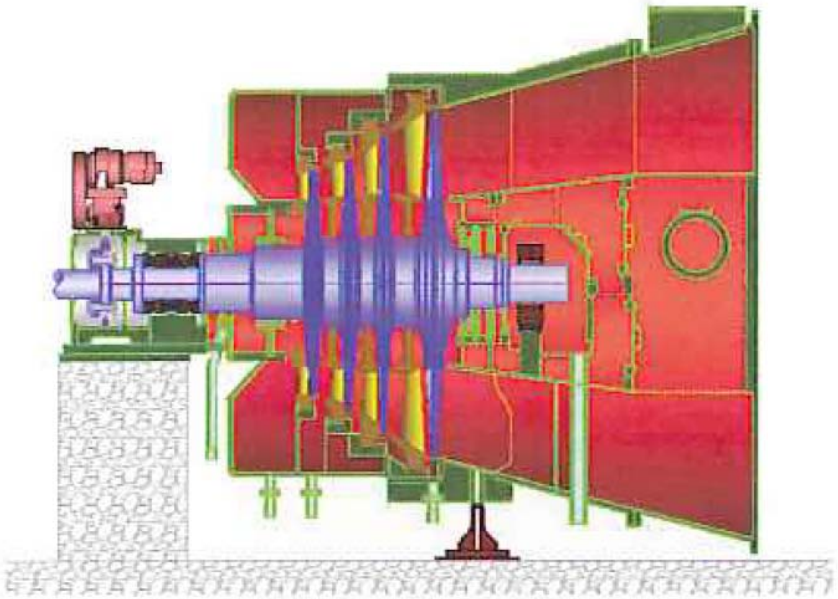
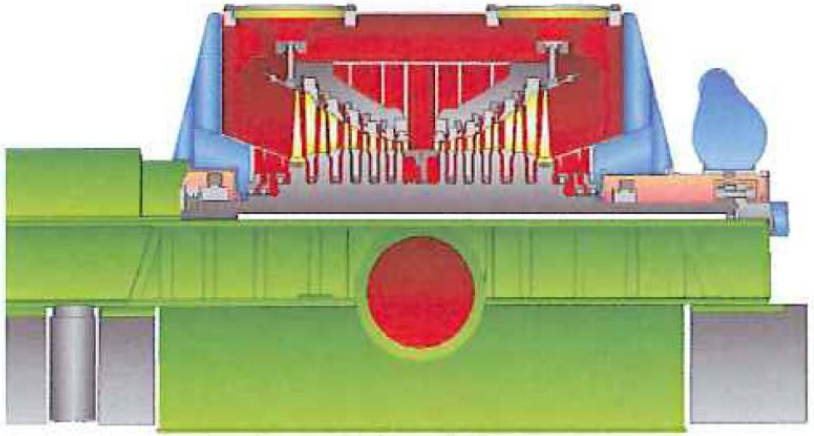
Single and double flow turbines





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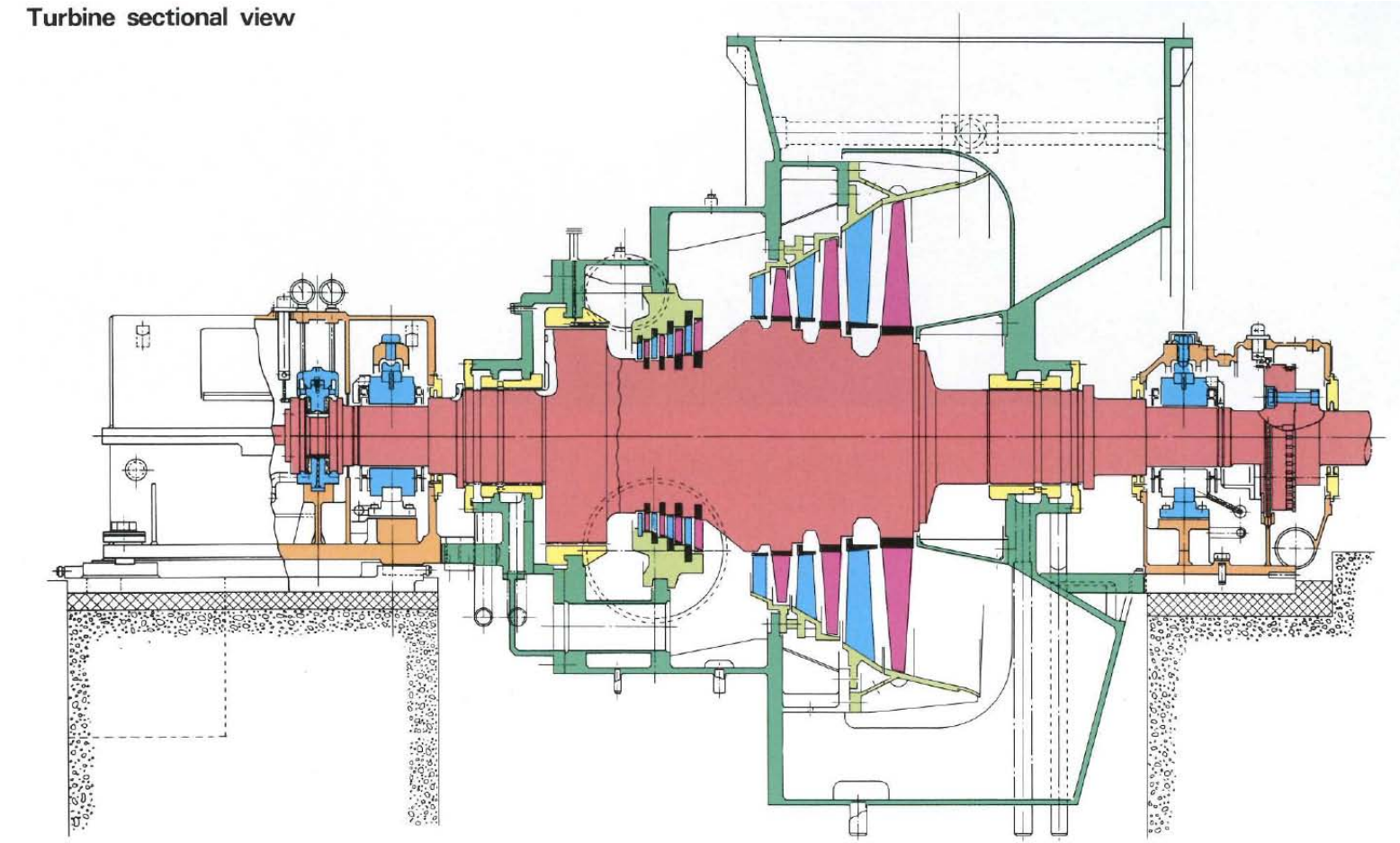
Double flash

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



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Power Plant – Turbine / generator

- Rotor
  - 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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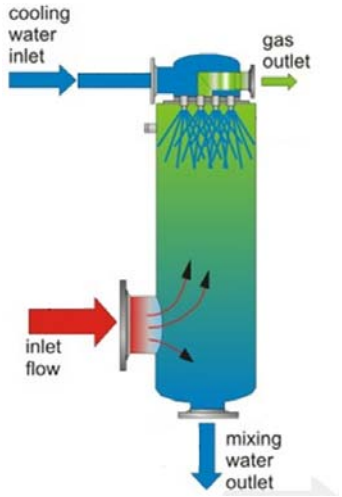
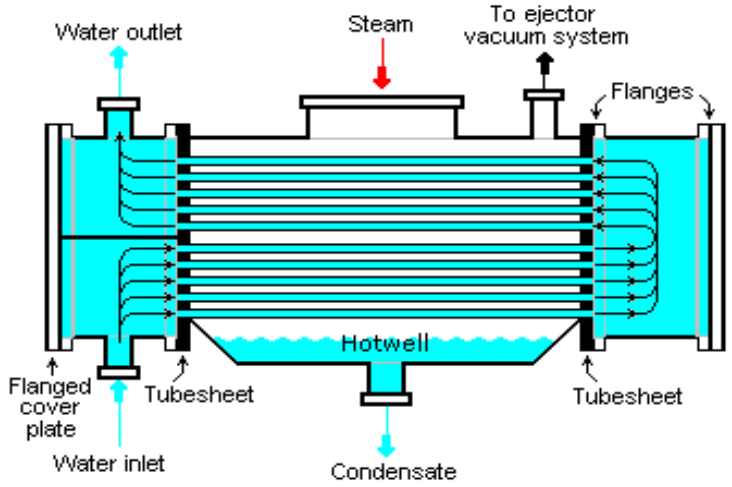
Power Plant - Heat Exchangers

- Condensers
  - Direct contact
  - Indirect contact
    - Shell and tube
  - Special gas cooling section





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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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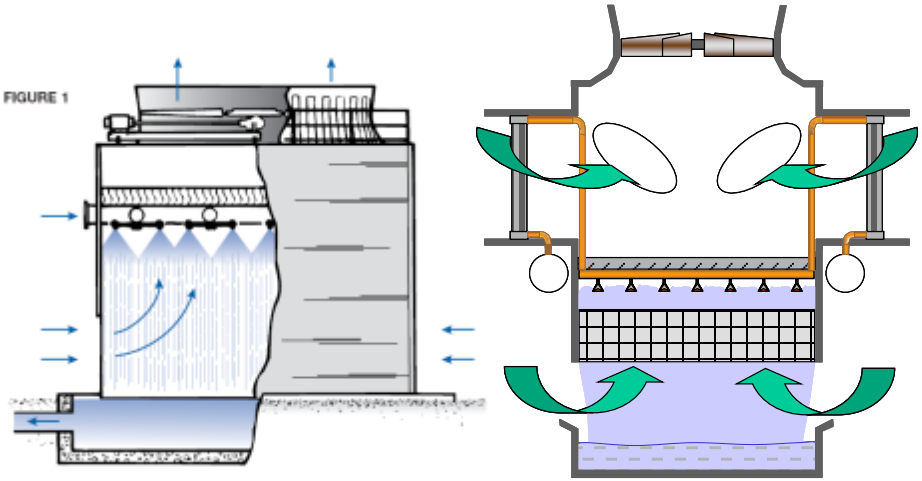
Power Plant - Cooling Tower

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



Conventional Hybrid

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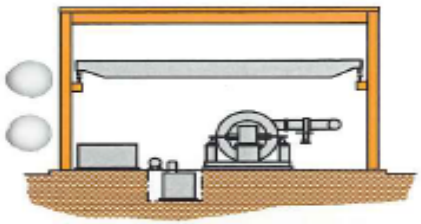
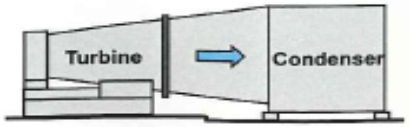
Power Plant - Layout

Axial Exhaust

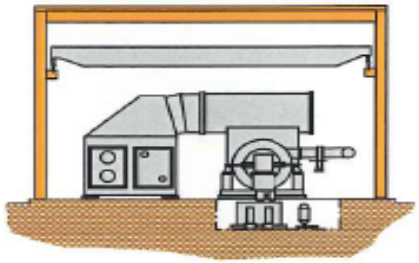
- *Total concrete required and complexity of the foundation design are also significantly reduced*



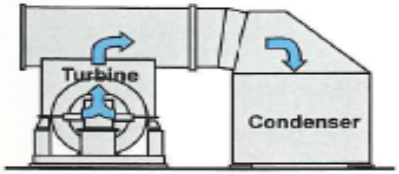
- *Axial diffuser effectively transforms exhaust velocity into pressure, thereby minimizing exhaust loss*



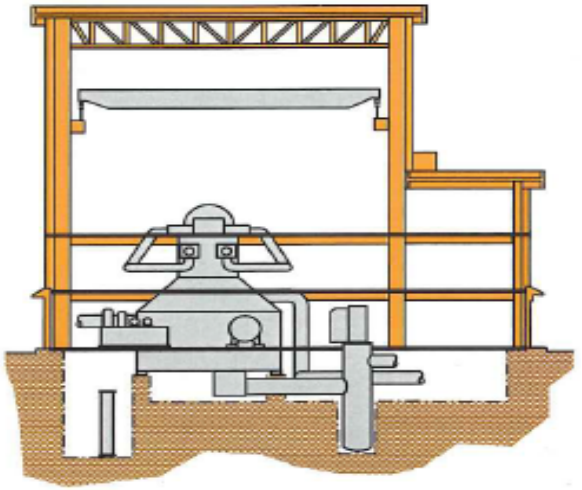
Top Exhaust



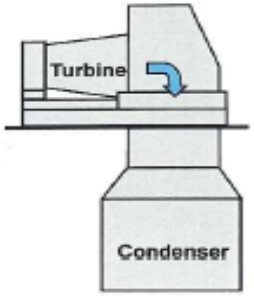
- *Triple turning of the exhaust flow creates the biggest loss*



Down Exhaust



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



Source: Toshiba

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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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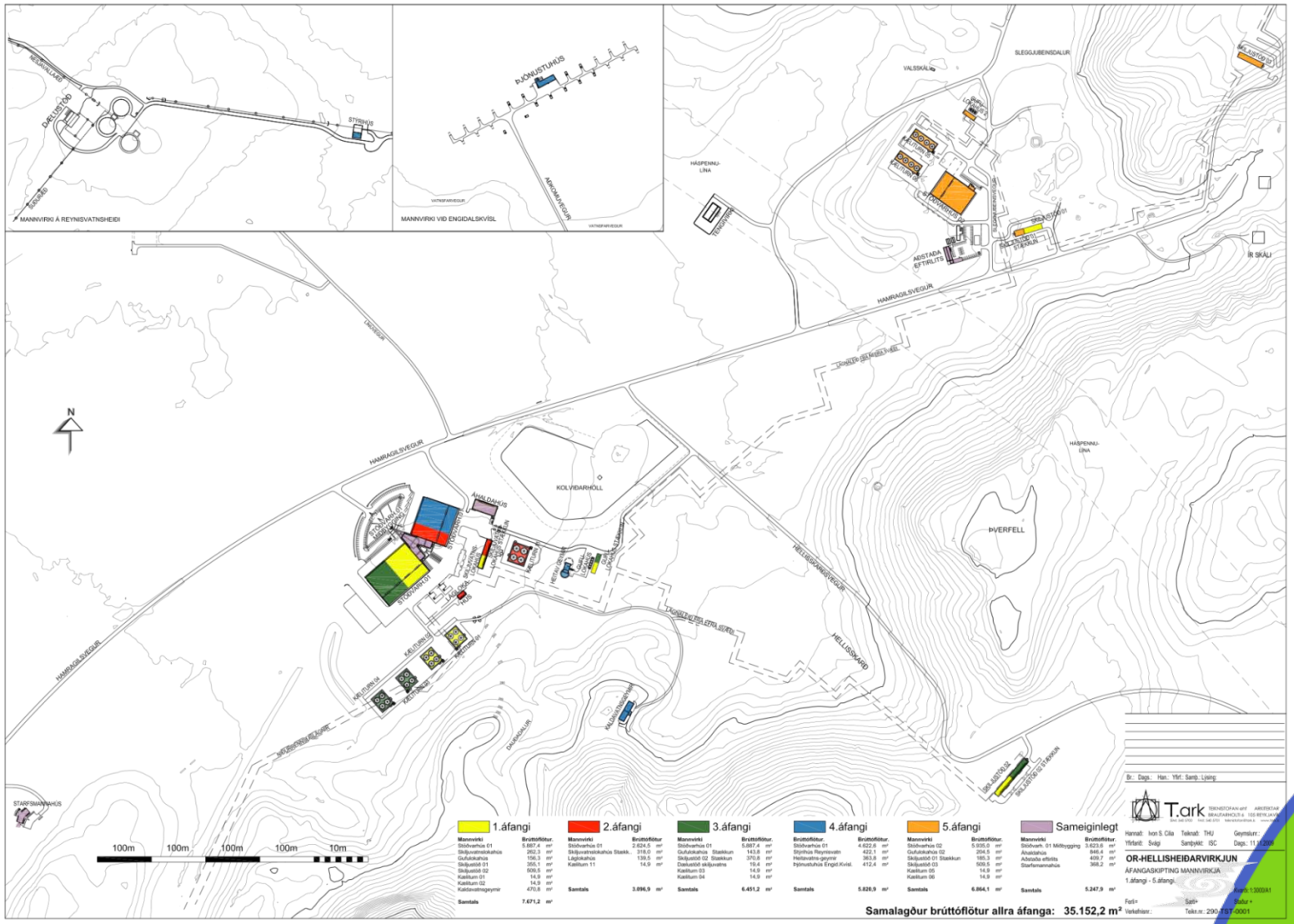
Hellisheiði layout, 220 000 m^2 footprint



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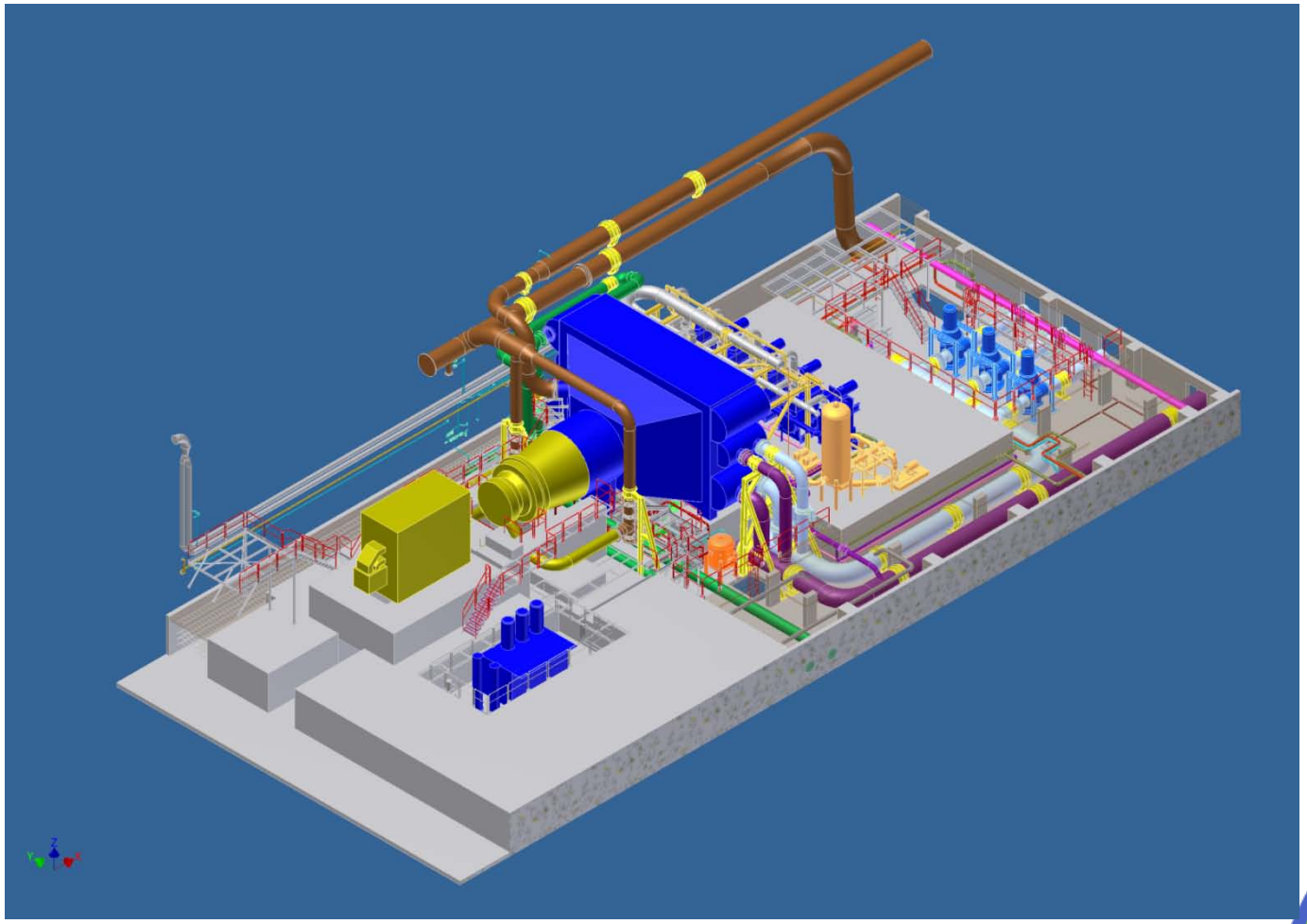
Layout – 45 MW unit at Hellisheiði



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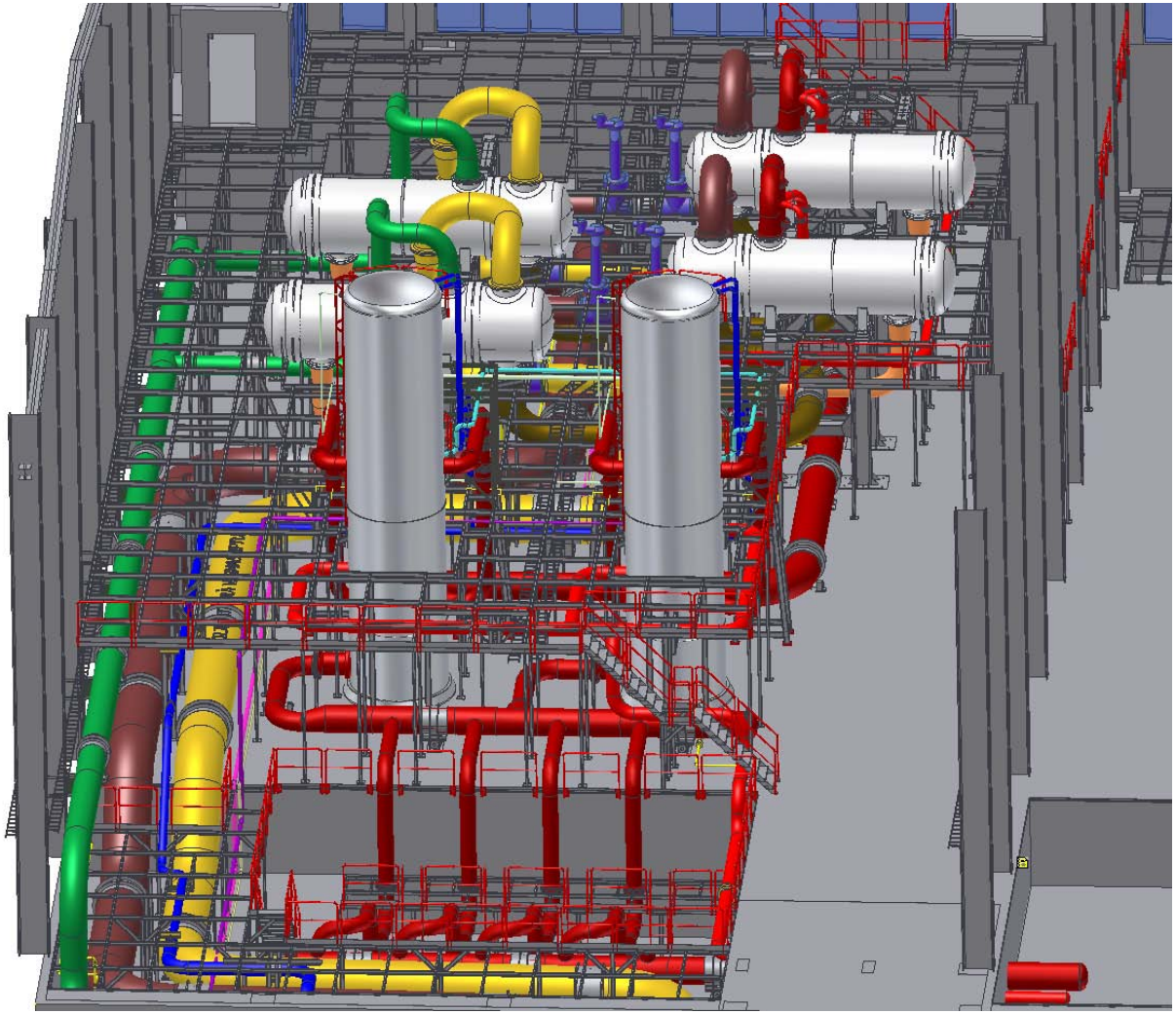
Layout – 133 MW hot water plant at Hellisheiði



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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 and discussed with solutions.

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

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Geothermal Power Plants

Operation & Maintenance

- Lower T & P than conventional power plants gives less age dependence (no creep)
- Large makeovers at certain time intervals
- Rotor renewal and generator maintenance every 10-15 years
- Drilling for maintaining steam depends on the geothermal field

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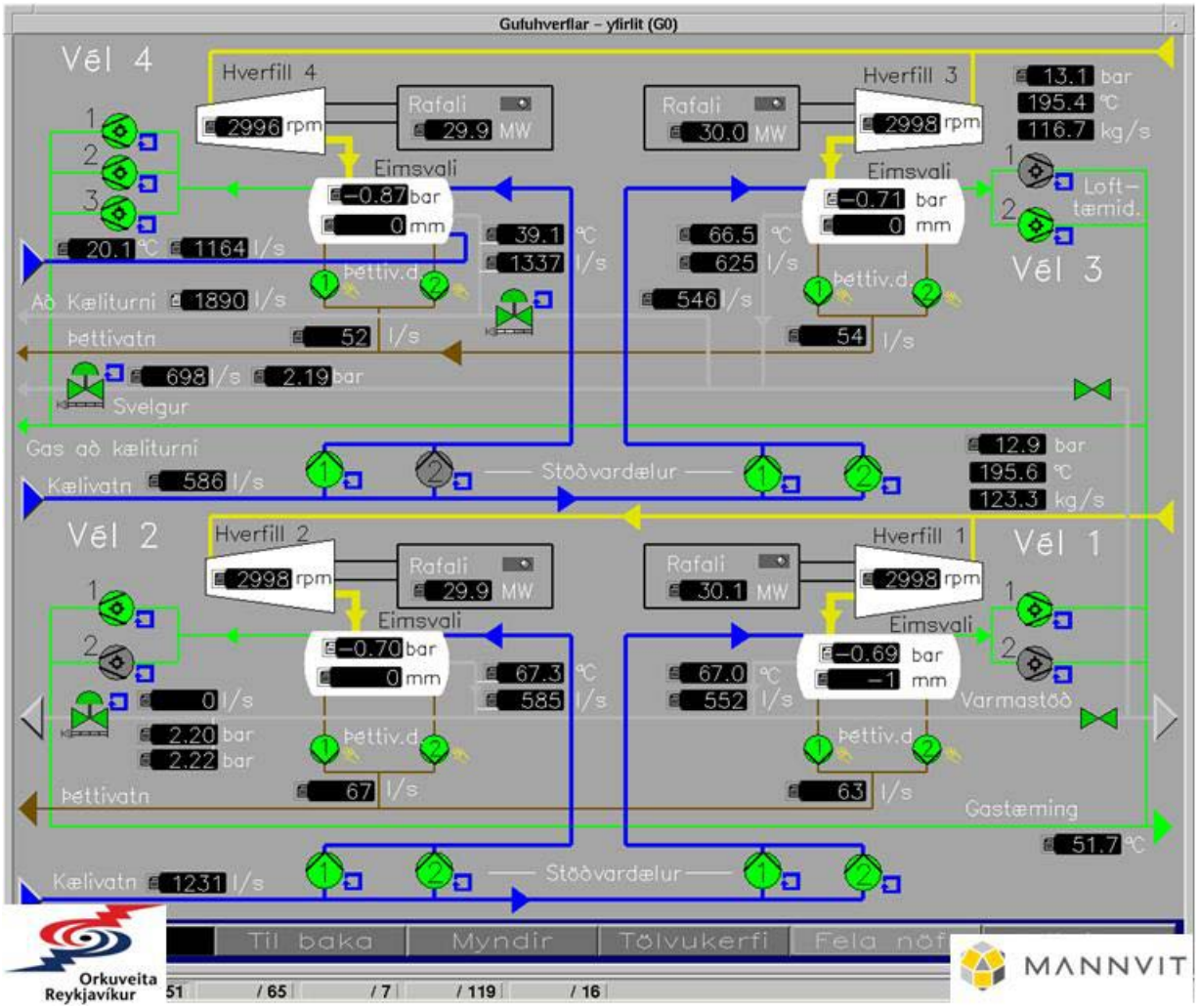
Operating Console



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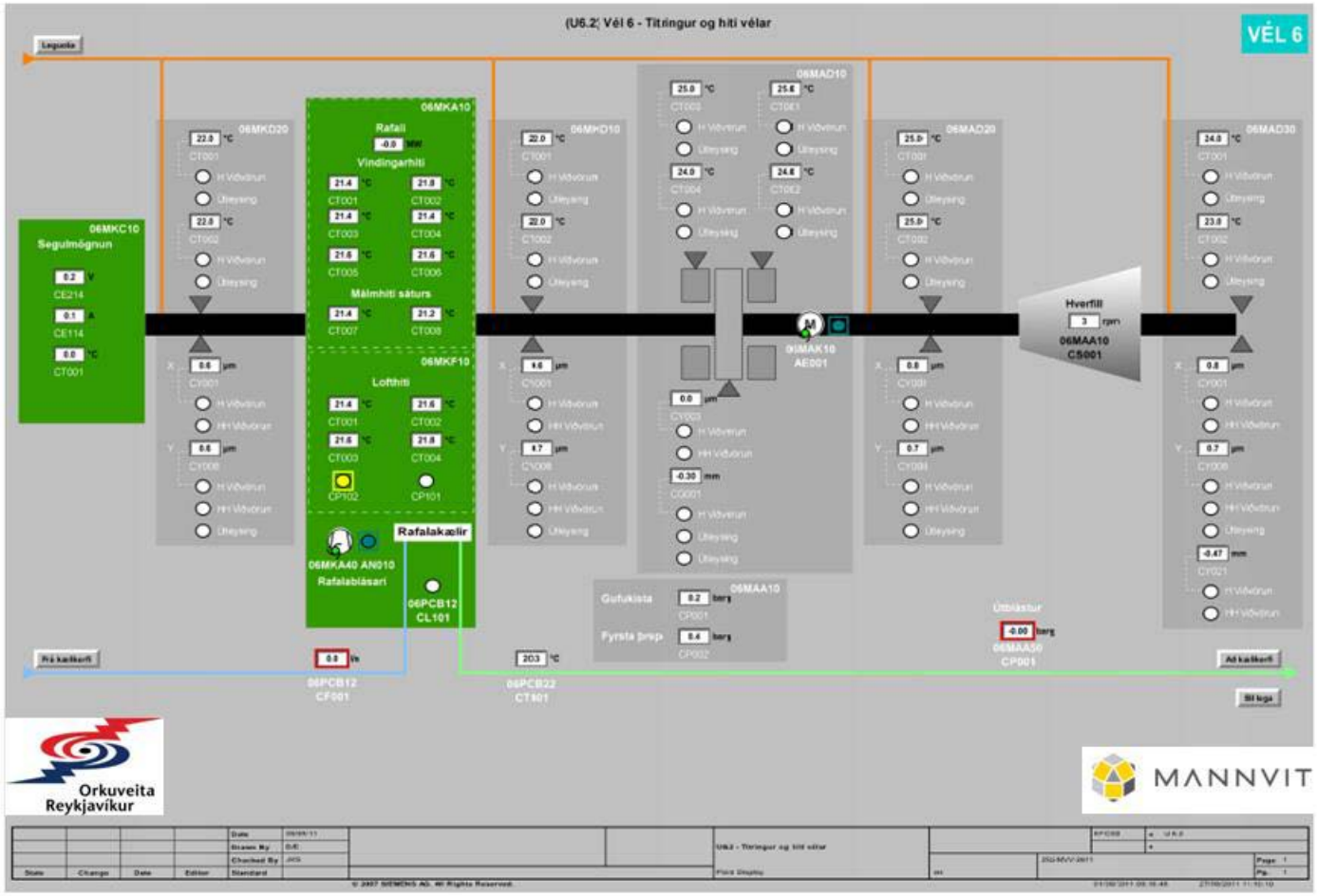
Turbine Monitoring



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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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Leakage in Wellhead

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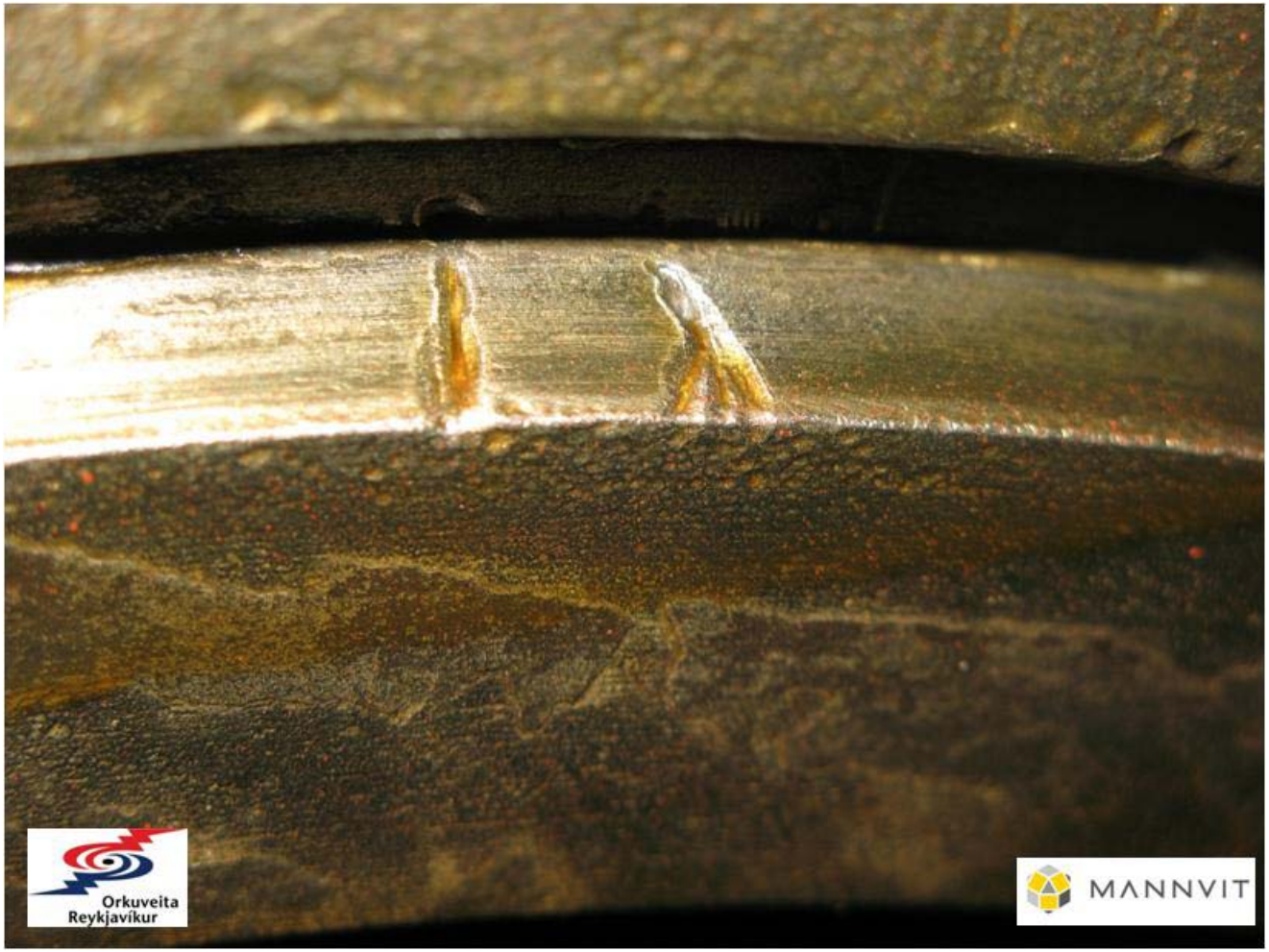
Leakage in Wellhead



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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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Steam Separator for 60 kg/sek

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Well Cleaning during Discharging

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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 of Rotor

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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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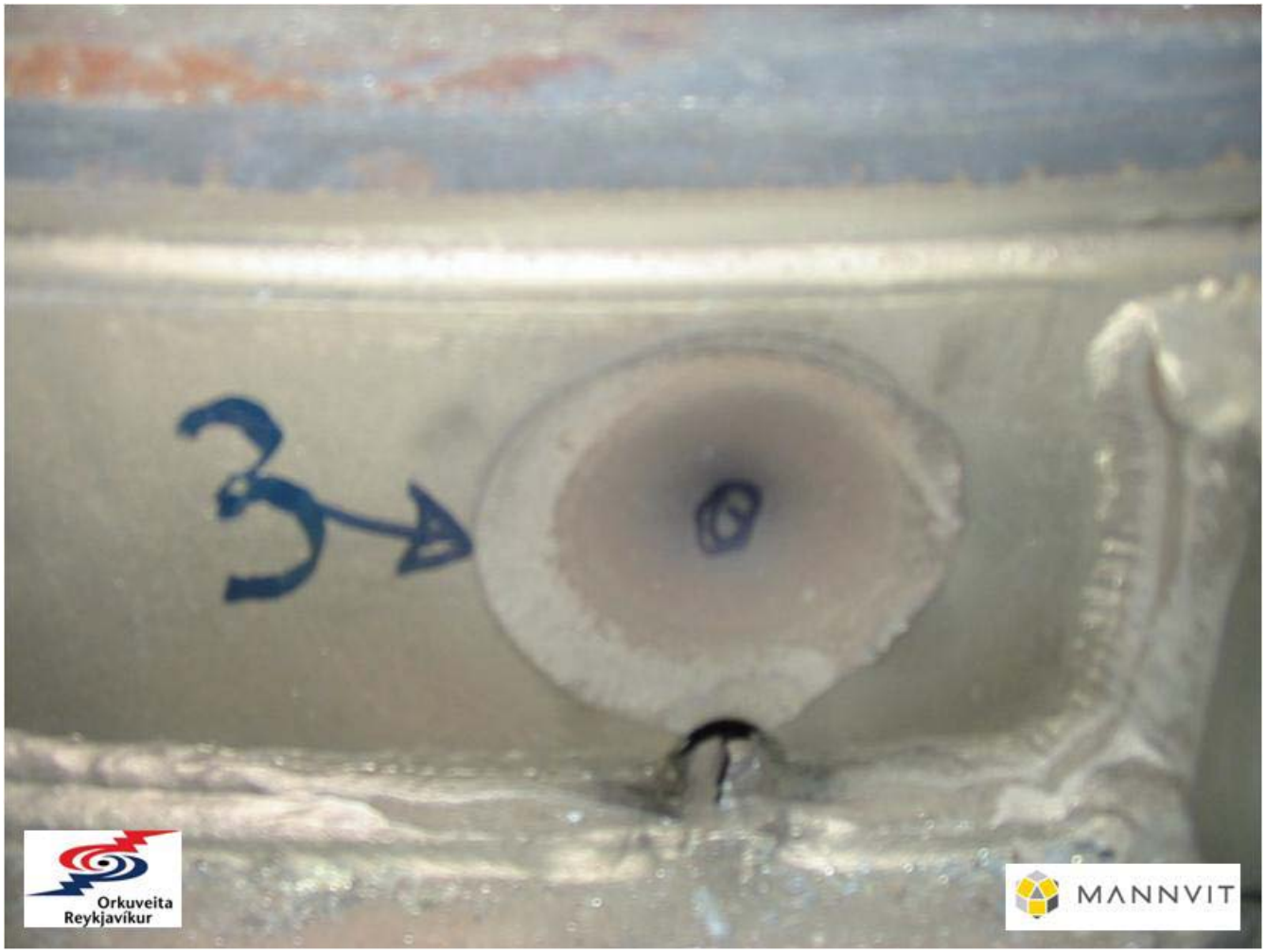
Damages Caused by Drainage



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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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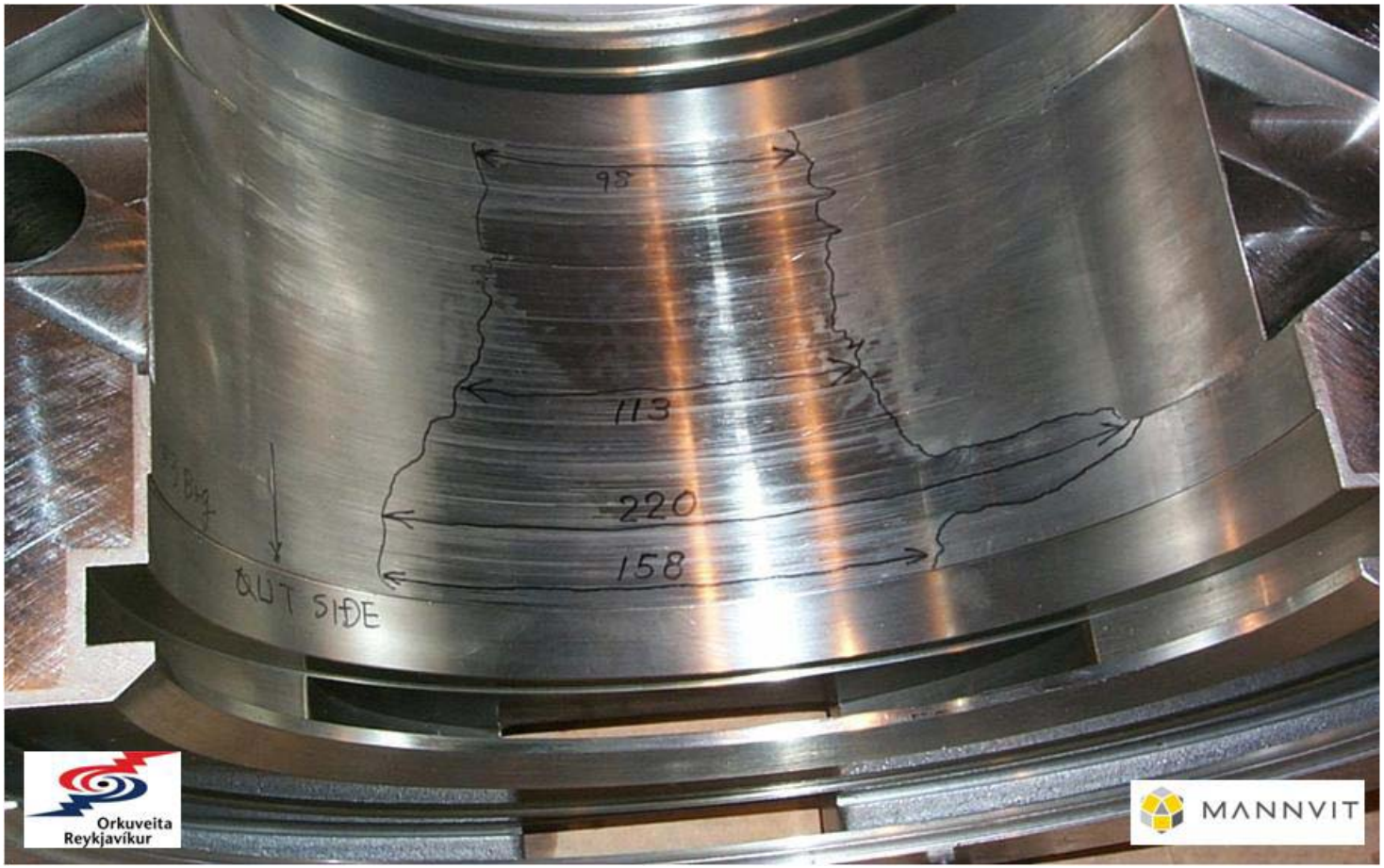
Turbine and Generator Bearings



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Oil filter

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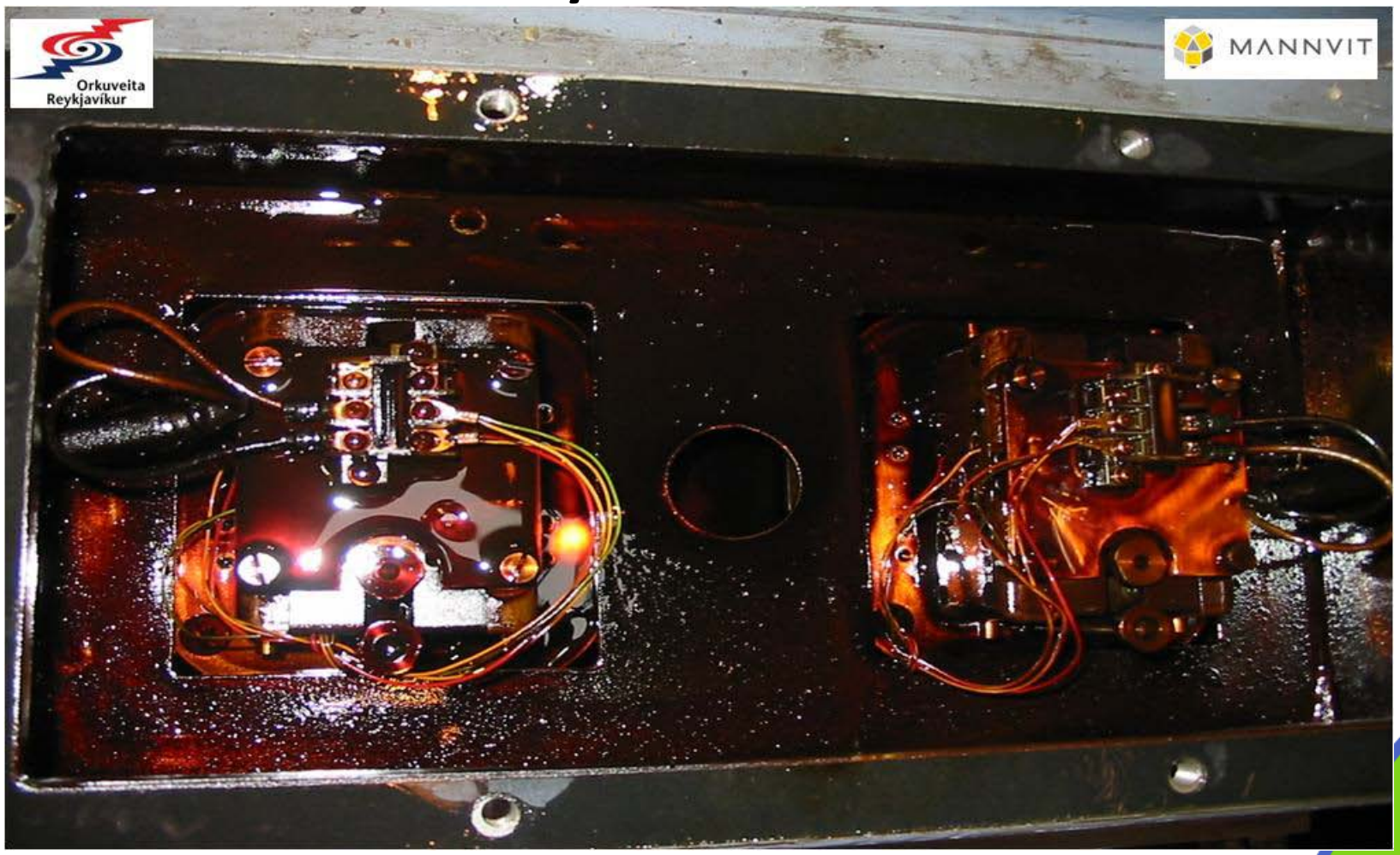
Oil System



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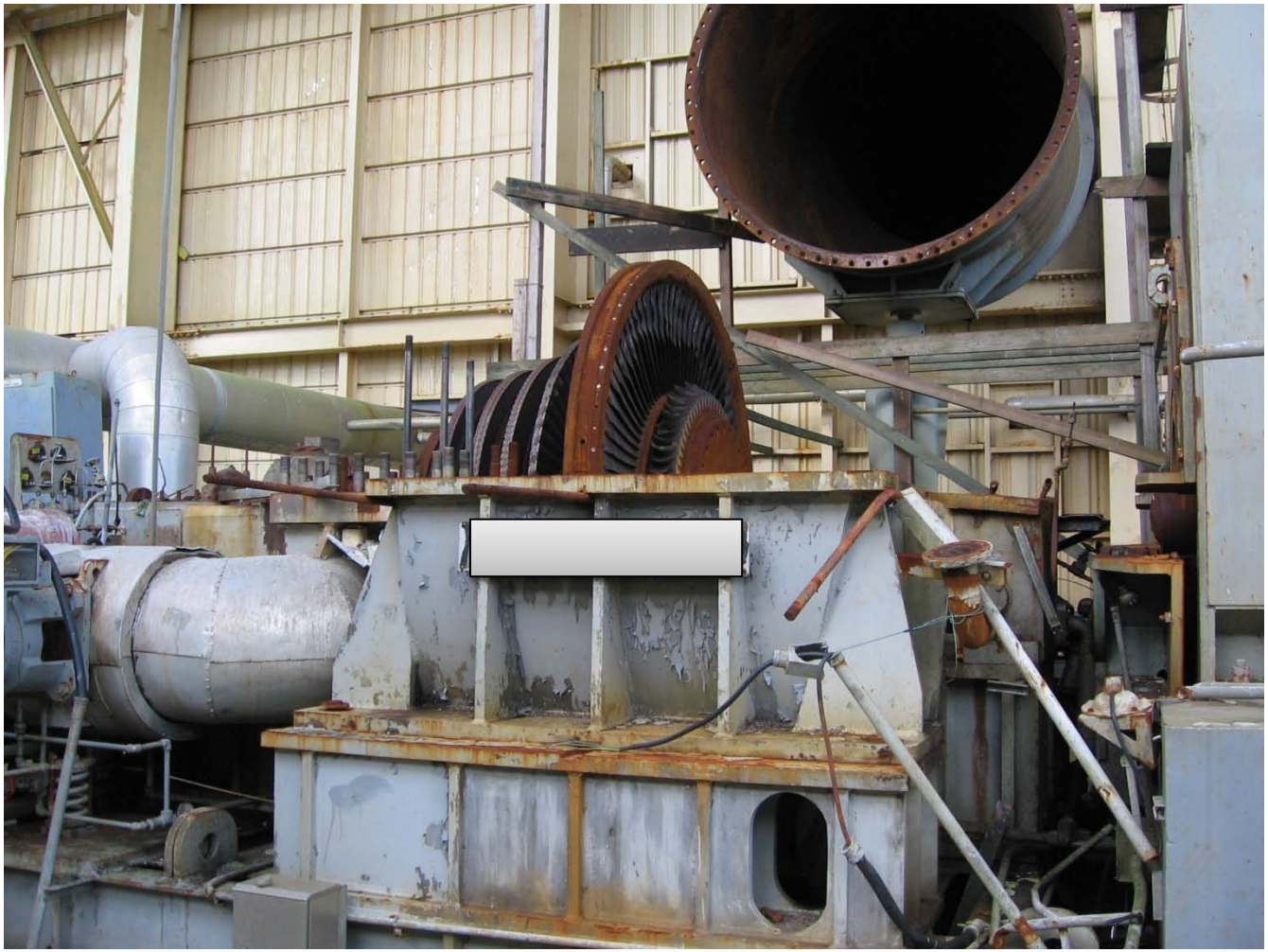
Broken turbine blades



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Damaged turbine housing

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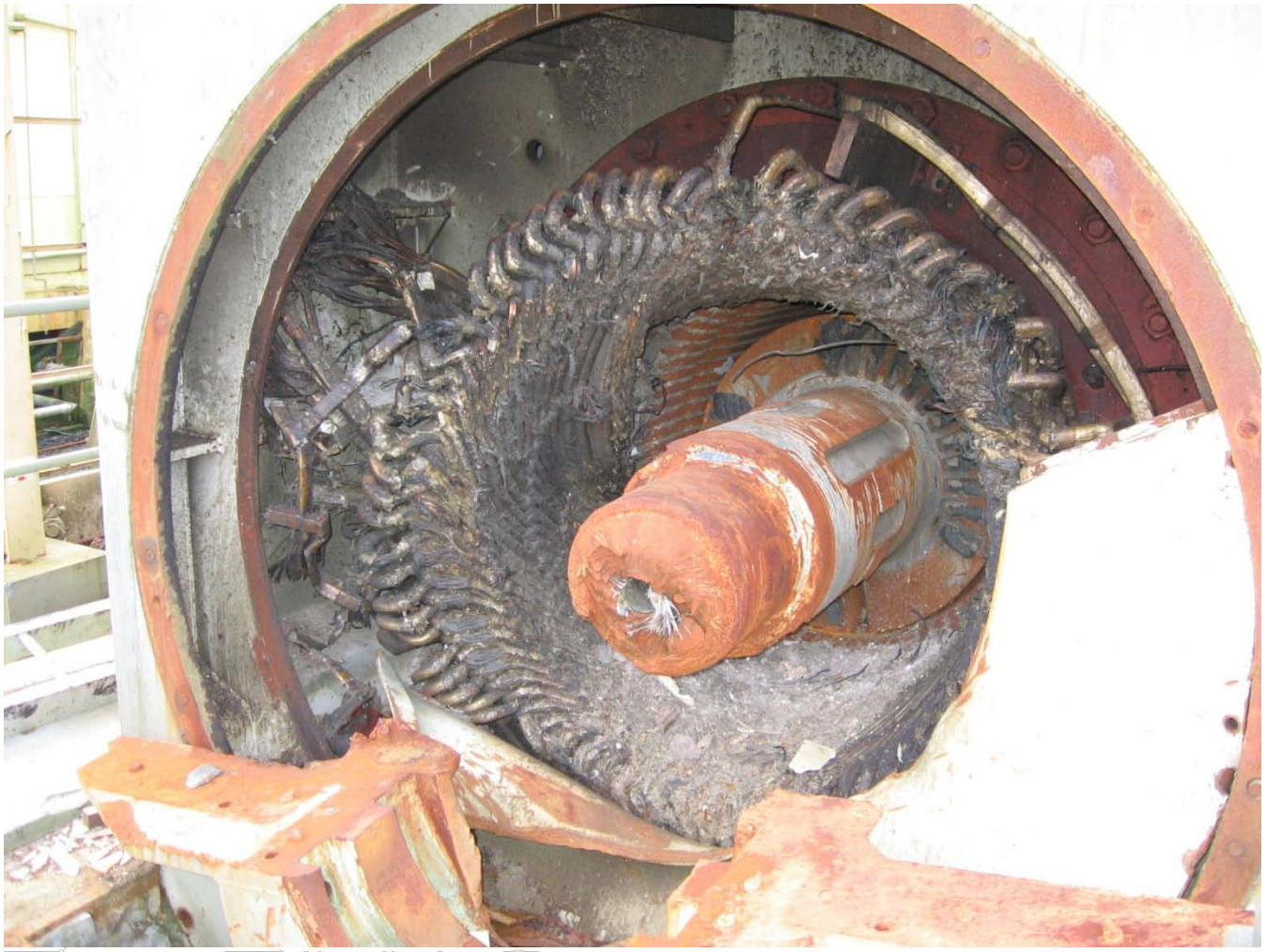
Generator broken



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