Technical Challenges of Goethermal Energy Utilisation

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Hitaveita Suðurnesja Geothermal Power Plants

- Svartsengi 1: 2 x 1 MWe og 50 MJ/s (decommissioned)
- Svartsengi 2: 75 MJ/s
- Svartsengi 3: 1 x 6 MWe
- Svartsengi 4: 7 x 1,2 MWe
- Svartsengi 5: 1 x 30 MWe og 75 MJ/s
- Svartsengi 6: 1 x 30 MWe
- Reykjanes: 2 x 50 MWe

» Total: 324,4 MWe and MJ/s
High-temperature system

1226 Year of historic lava flow
Geothermal Power Plant Main Parts

- Geothermal wells
- Well piping
- Separator station
- Steam piping
- Power station
- Steam turbine – Generator
- Cooling system
- Substation, switchyard
- High voltage line
Design tasks

- Mechanical (in approximate time sequence)
  - Preliminary Design: Concept design, dialogs between owner, designers and main machine producer
  - Process Flow diagram (PFD): Showing main equipment, connecting pipelines, valves, and flowrates
  - Process Instrument Diagram (PID): Similar to PID but with all instruments and their codes for function
Design tasks

• Mechanical, continued
  – Piping: Pipe dimensions, Pressure ratings, Design codes and standards, Safety, Pressure drop criteria and calculations
  – Power station Layout
  – Equipment submitted for tendering
  – Detail design
Design tasks

• Electrical equipment
  – High Voltage
    • Single line diagram
    • Transformer specifications
    • Breakers specifications
    • Protection system specifications
  – Low voltage
    • Distribution cubicles
    • Cabling
Design tasks

- Control system
  - Control loops
  - Control equipment
    - Regulators
    - PLC computers
  - Remote monitoring
    - SCADA system
- Civil engineering
- Architectural drawings
- Landscape design
Design of a well

- Casing head flange, weld-neck 12"x300 ANSI RF
- 22 1/2" Surface casing (67.06mm x 12mm)
  117.00 lbs/ft. (169.41 Kg/m) welded connections, X42
- 13 3/8" Top casing (11m) extra heavy wall
  - (255.9mm x 20.12mm) 113.0 lbs/ft. (193.62 Kg/m)
  - Grade X75, Steel 35Cr-3B
- 21" Drilling
  - 18 5/8" Anchor casing (473.1mm x 11.05mm)
  - 87.5 lbs/ft. (125.91 kg/m), H40, welded connections, R3
  - Centralizers every third joint
- Float collar for inner string cementing 18 5/8"
  - Float shoe 18 5/8"
  - 17 1/2" Drilling
- 13 3/8" Production casing (339.7mm x 12.14mm)
  - 68 lbs/ft. (98.46 kg/m), K55, Antares HS, R3
  - Centralizers every third joint
  - Float collar for inner string cementing 13 3/8"
- Liner hanger for 9 5/8" cas.
  - Float shoe 13 3/8"
- 12 1/4" Drilling
  - 9 5/8" Spotted liner (241.3mm x 10mm)
  - 40 lbs/ft. (58.00 kg/m), K55, Antares HS, R3

- 820 mm x 8 holes
- 80 mm
- 103 mm

Grout shoe
Geothermal wells
Problems in operation

- Scaling
- Corrosion
- Casing collapse
- Liner break
- Leaks
- Gas
Two Phase Pipelines

- Avoid slug flow
  - Incline two phase pipes down
  - Calculate the dimension of condensate pipe lines to ensure there is space for flash steam

- Keep them anchored
Rankine Cycle

- Boiler
- Condenser
- Turbine
- Condensate
- Feedwater pump
- Cooling
Svartsengi – Single Line Diagram
Equipment design choices

- Separators: Vertical Cyclone or horizontal gravity?
- Separators on each wellpad or two phase flow pipeline to a central separator station?
- Length of main steam pipe?
- Impulse or reaction steam turbine?
- Cooling tower or natural cooling-water?
- Vacuum pumps: Steam ejectors, water ring pumps, or hybrid?
Reykjanes Principles

• High separator and inlet pressure to reduce scaling in separators
  – Steam wetness in low pressure stages is high, danger of erosion
• Double flow reaction turbines
  – Lower steam velocity reduces danger of erosion
• Seawater cooled condenser
  – Minimum steam and vapour plumes
• Remote monitoring and control
  – Lowers operation cost
• Environmentally benign power plant
Design Principles for Reykjaness

- Independent system for each unit, one separator, one moisture separator, one cooling system.
- Easy maintenance
- Ample maintenance space in power station
- Remote operation
- Quality steam
**Reykjanes 2 x 50 MW Geothermal Flash Steam Power Plant**

- **Steam fraction**: 0.2207
- **Enthalpy**: $h_1 = 2798$ [kJ/kg]
- **Pressure**: $P_{\text{steam}} = 19$ [bar]
- **Steam flow rate**: $m_{\text{steam}} = 163.8$ [kg/s]
- **Number of wells**: 11
- **Well flow rate**: $m_{\text{well}} = 70$ [kg/s]
- **Geothermal Well**
  - **Temperature at wellhead**: $T_{\text{downhole}} = 295$ [°C]
  - **Enthalpy**: $h_0 = 1316$ [kJ/kg]
- **Steam**
  - **Mass flow rate**: $m_{\text{in}} = 770$ [kg/s]
  - **Steam washing**
- **Separator**
  - **Mass flow rate**: $m_{\text{liq}} = 600.1$ [kg/s]
  - **Temperature**: $T_2 = 209.8$ [°C]
  - **Enthalpy**: $h_2 = 896.9$ [kJ/kg]
  - **Brine**
- **Brine Cooler**
  - **Temperature**: $T_{\text{chilled}} = 32$ [°C]
  - **Mass flow rate**: $m_{\text{brine}} = 4134$ [kg/s]
- **Disposal to Ocean**
- **Seawater Pumps**
  - **Mass flow rate**: $m_{\text{cooling water}} = 3364$ [kg/s]
- **Steam Dryer**
  - **Power output**: $P_{\text{turb}} = 105368$ [kW]
  - **Wetness**: $y_3 = 0.1698$
  - **Temperature**: $T_3 = 45.79$ [°C]
  - **Enthalpy**: $h_3 = 2178$ [kJ/kg]
- **Steam Turbine**
- **Condenser**
  - **Heat removed**: $Q_{\text{cond}} = 337459$ [kW]
  - **Pressure**: $P_{\text{cond}} = 0.1$ [bar]
  - **Condensate**
- **Gas**
- **Generator**
Silbersulfid-Kristalle auf Chip-Widerstand
Reykjanes Power Station
Inside a condenser
Gas exhaust system: Steam ejectors and intercondensers
It was difficult to get quality gaskets when asbestos had been banned.
Hydrogen sulphide can cause cracks in high manganese steel.
50 MW turbine, 80 kg/s, 18,0/0,1 bar
Drops from silencers are bad for glass and glossy car surfaces.
GRP (Glass Reinforced Plastic) piping must be handled with care.
Svartsengi 6 cooling tower. Ice may be a problem.
Remember

- Preserve exergy
- Avoid scaling
- Silica scaling starts at $T_{\text{reservoir}} - 100^\circ C$
- Vertical separators can be over-/underloaded
- Direct contact condenser can cause sulfur scaling in cooling tower and condensers
- Consult operating and maintenance staff
Everything clear?