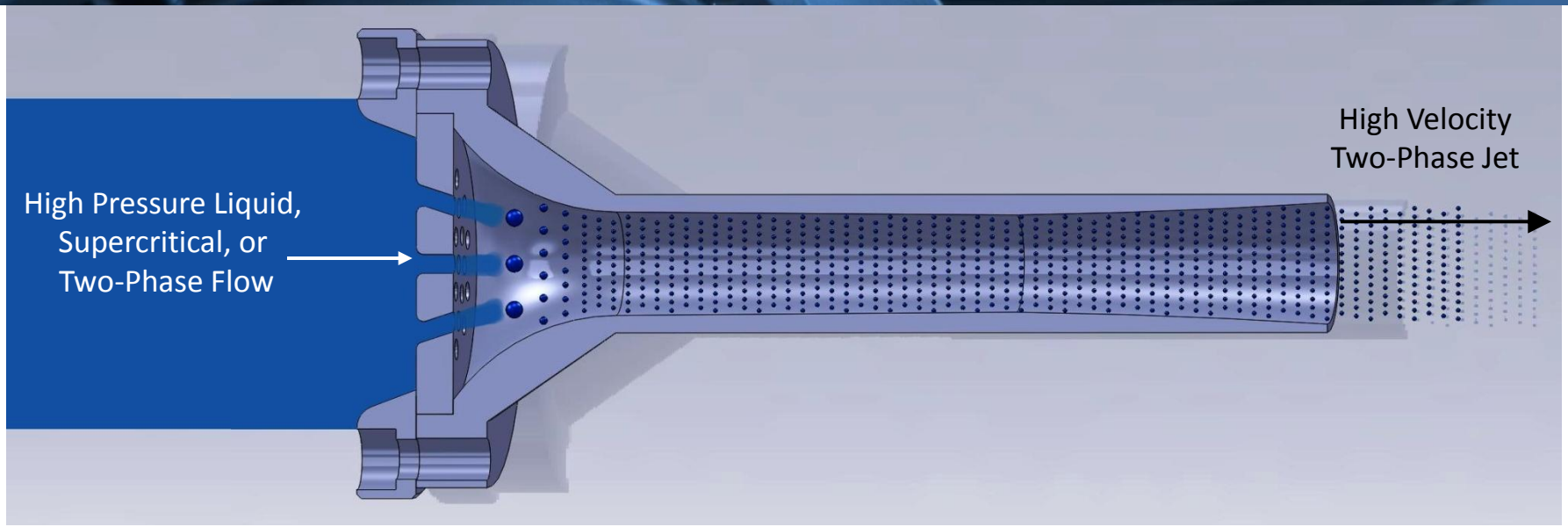
# Construction and Startup of Low Temperature Geothermal Power Plants

Phil Welch, Patrick Boyle, Marc Sells, and Michelle Giron

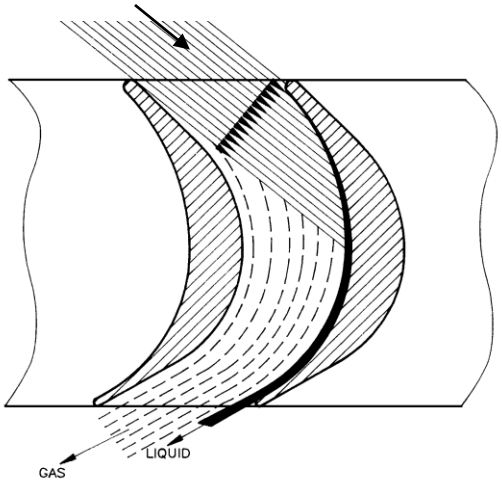
Energent Corporation

October 26th, 2011

# Two-Phase Turbine – Variable Phase Turbine (VPT)

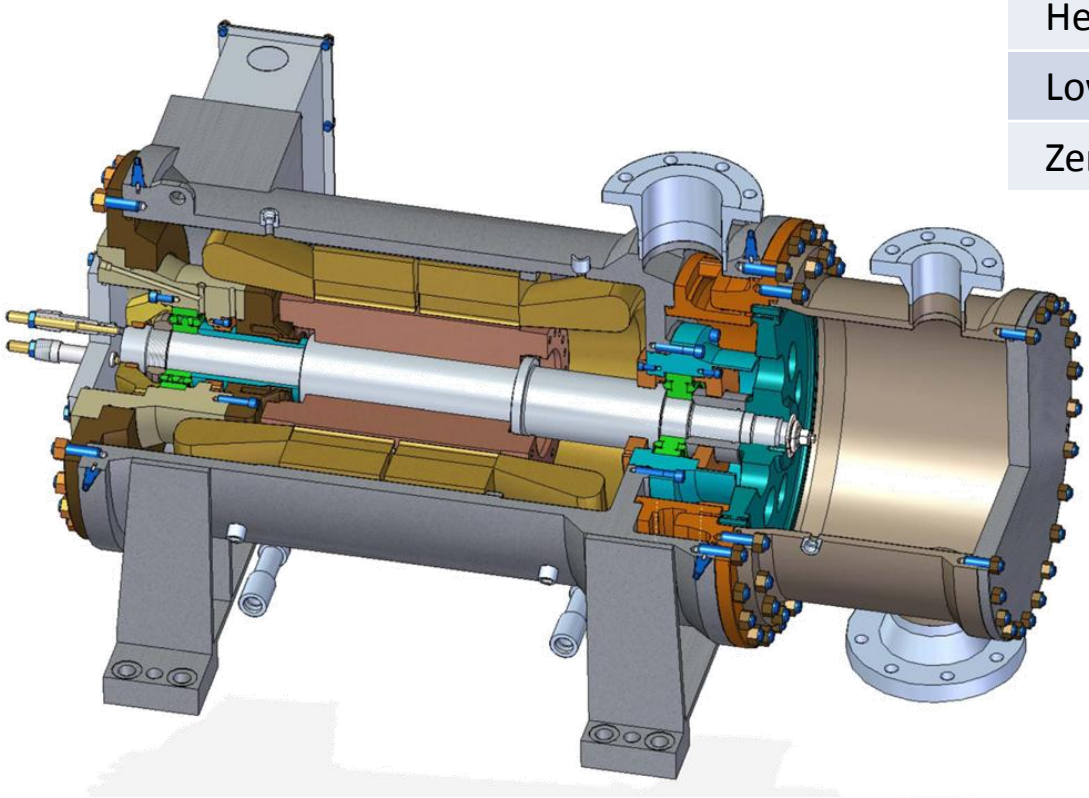



**TWO-PHASE JET FROM NOZZLE**



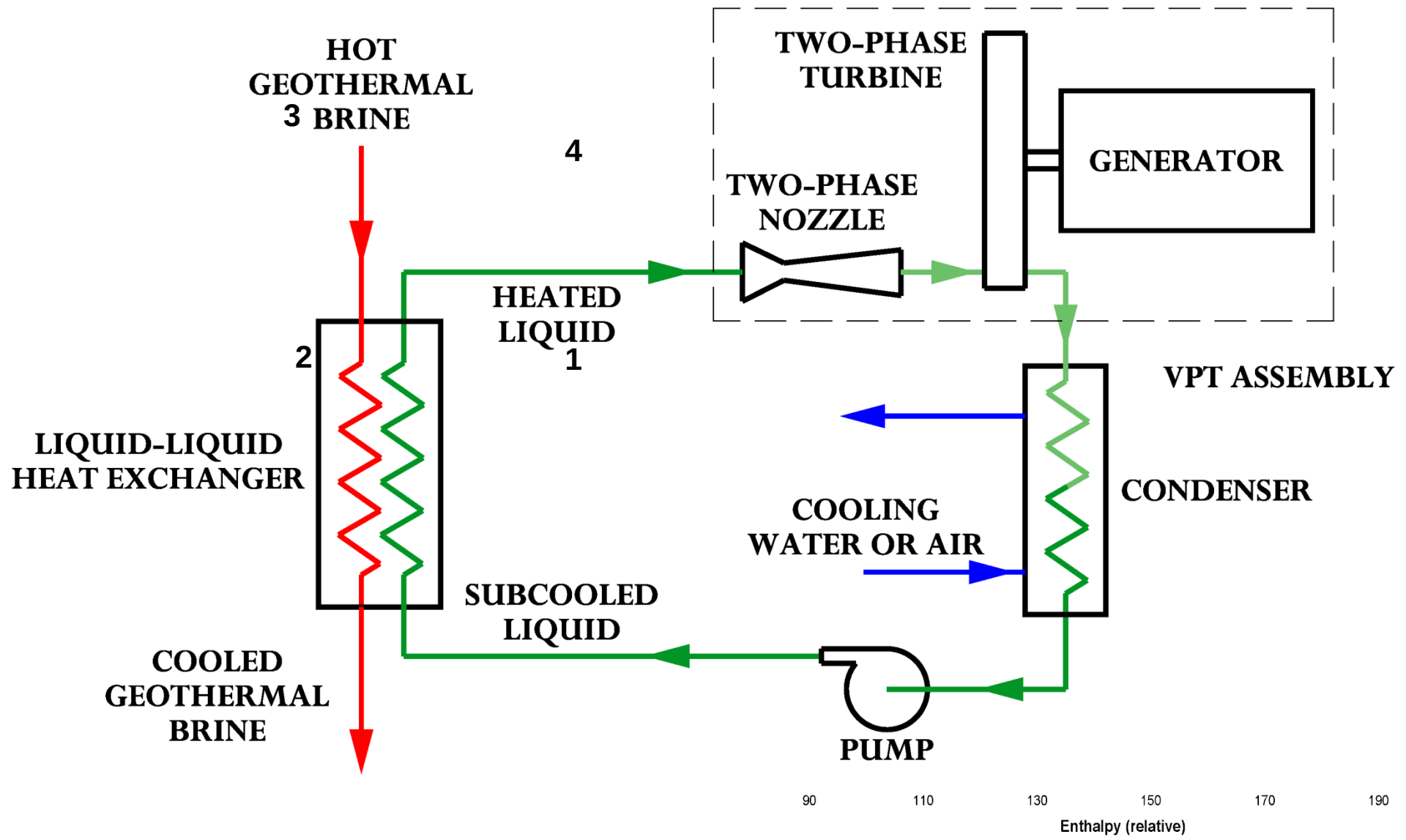

# Two-Phase Turbine – Variable Phase Turbine

| Variable Phase Turbine Benefits |
| --- |
| Can expand fluids into the two-phase region |
| Low speed eliminates gear box and lube oil |
| Hermetic turbine-generator available |
| Low runaway and thrust load |
| Zero erosion due to low jet velocities |

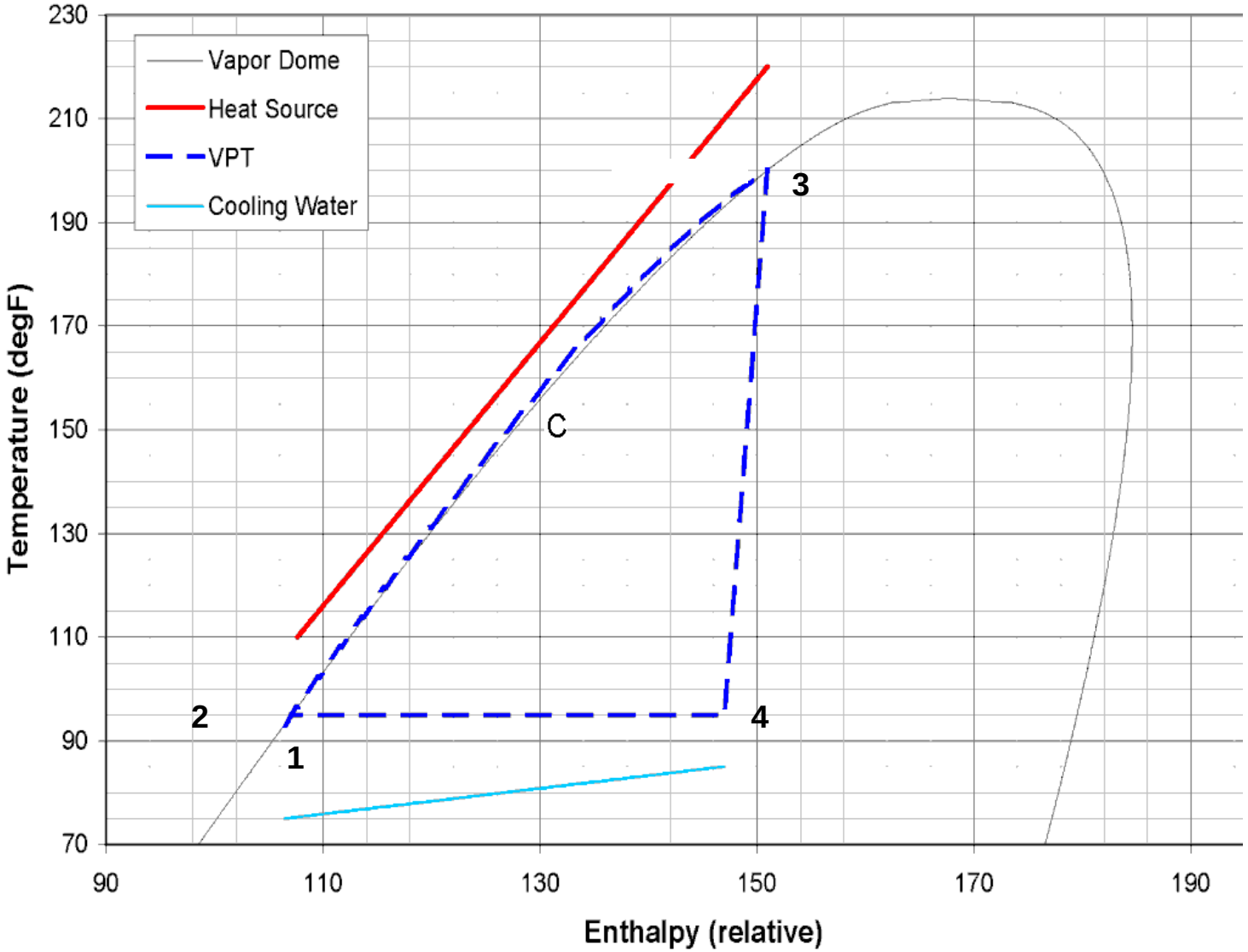


Hermetic 150 kW Variable Phase Turbine

# Variable Phase Cycle (VPC)



# Variable Phase Cycle (VPC)



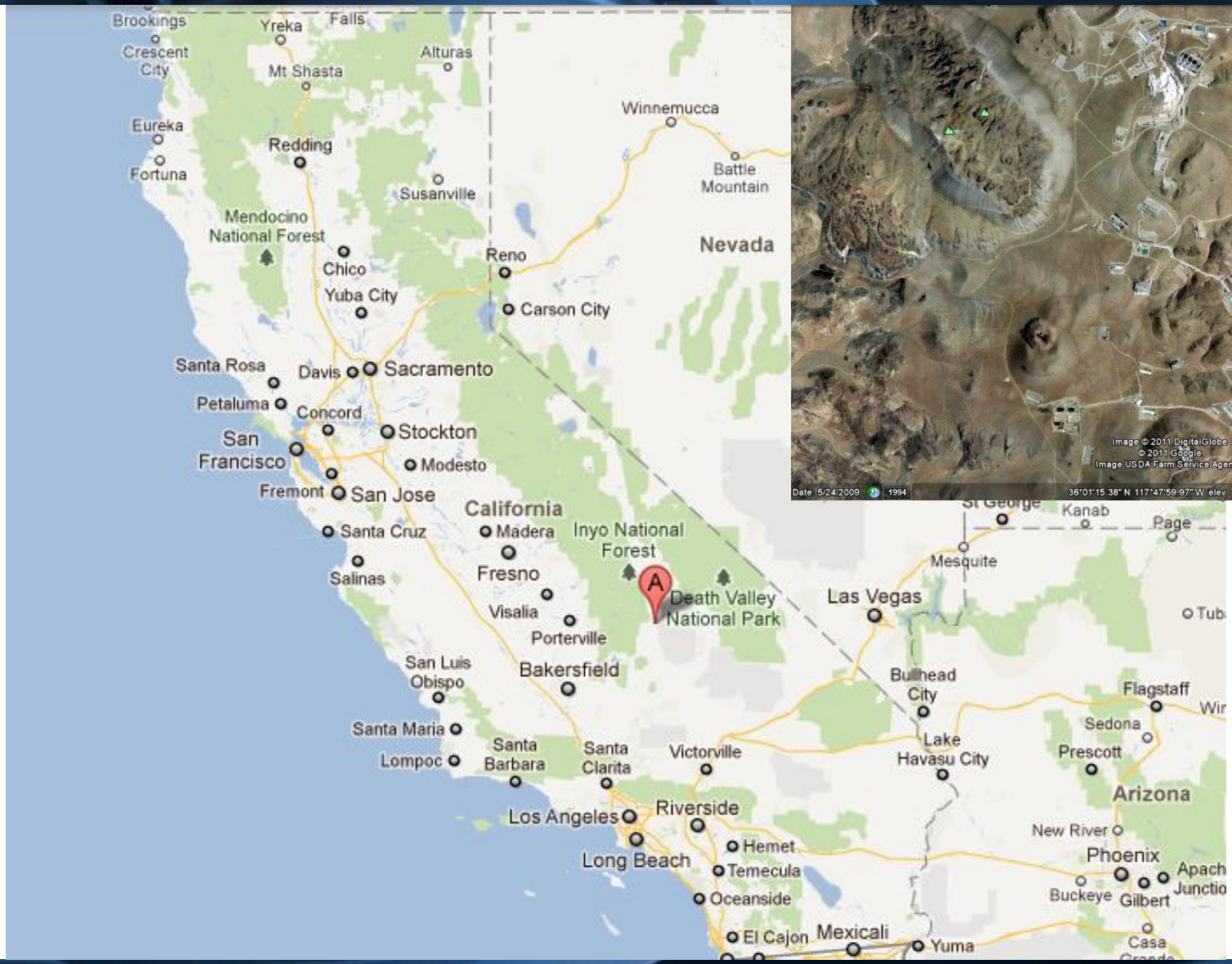
# 1 MW Variable Phase Cycle Power Plant

## SYSTEM SPECIFICATIONS

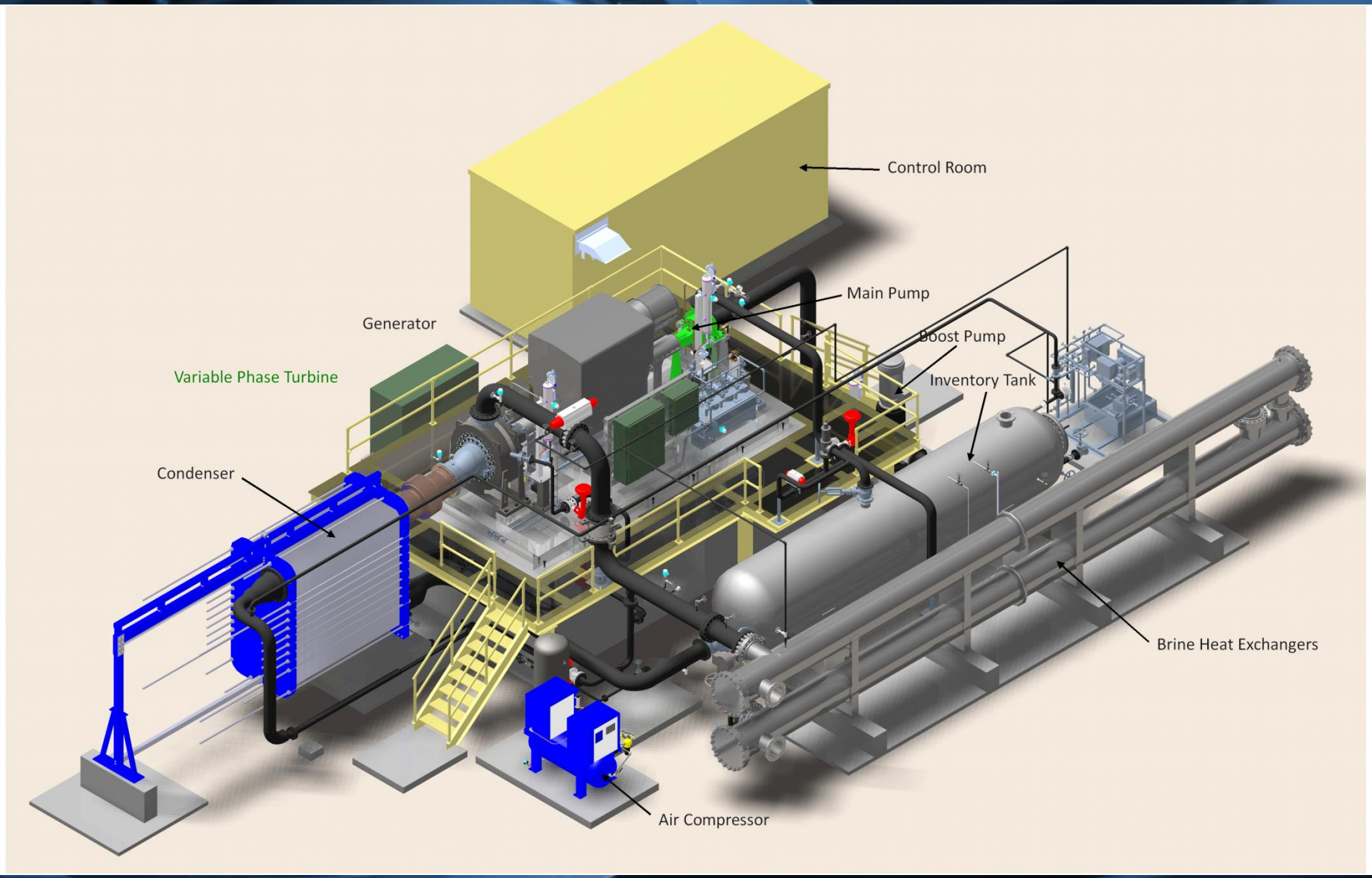
| | | |
|---|---|---|
| **Geothermal Brine** | Flow | 847,000 lb/hr |
| | Temperature | 234 °F (inlet) |
| | Temperature | 175 °F (outlet) |
| **Variable Phase Cycle Power System** | Working Fluid | R134a |
| | Cycle Type | Liquid – Variable Phase cycle |
| | Turbine Type | Two-Phase Axial |
| | Turbine Speed | 3,600 rpm |
| | Net Power | 1000 kW |

- A 1 MW VPC is currently being installed at the Coso Geothermal Field in California
- Energy is extracted from the warm brine reinjection line, which would be otherwise wasted
- World's largest trilateral flash cycle

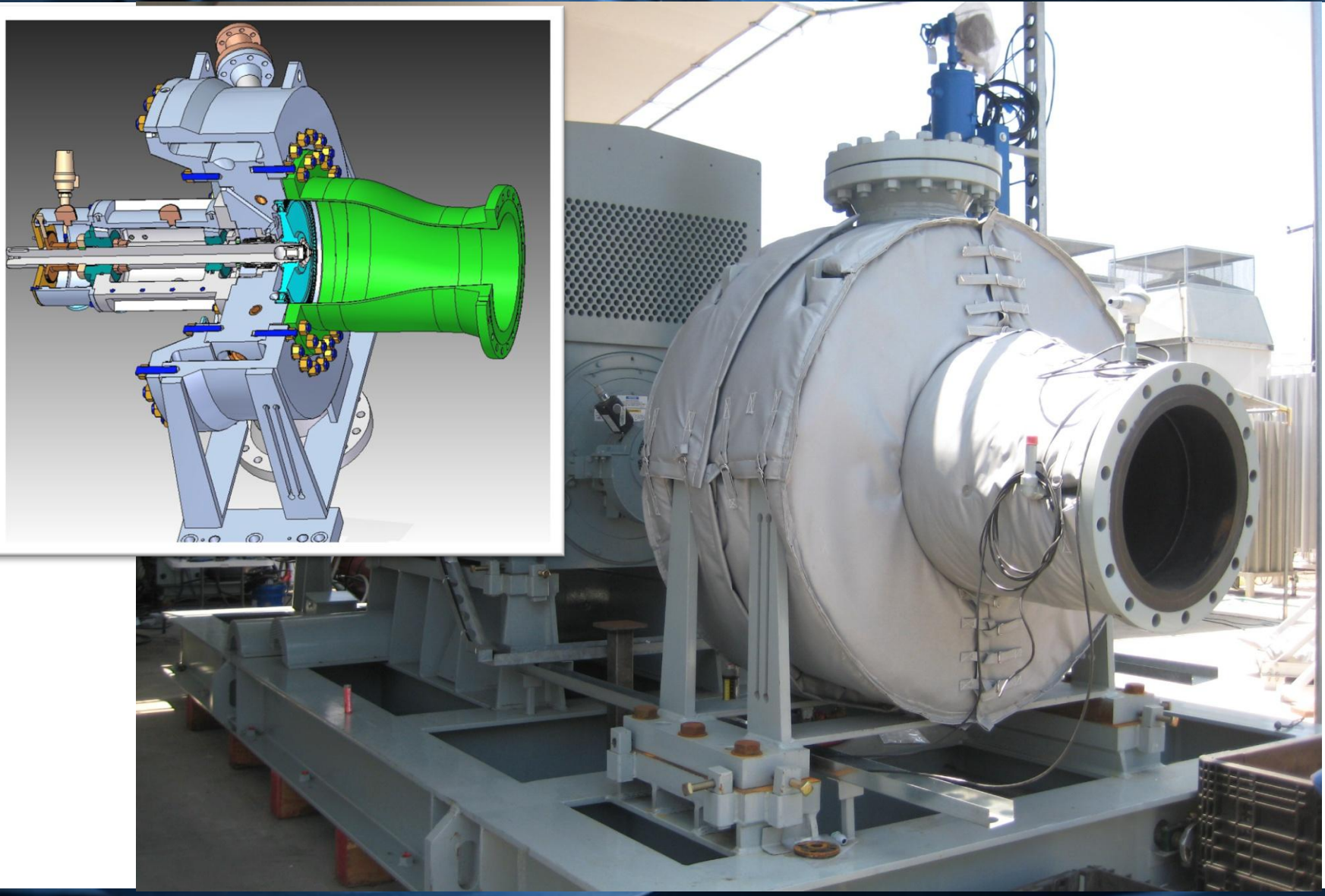
# Coso Geothermal Site – China Lake



# Coso Geothermal System Layout



# Coso Geothermal – Variable Phase Turbine



# Turbine-Generator-Pump Assembly

- Turbine, generator, and pump are coupled along a single shaft
- Assembly rotates at 3,600 rpm (synchronous) with no gear reductions
- Entire assembly is mounted on a single skid

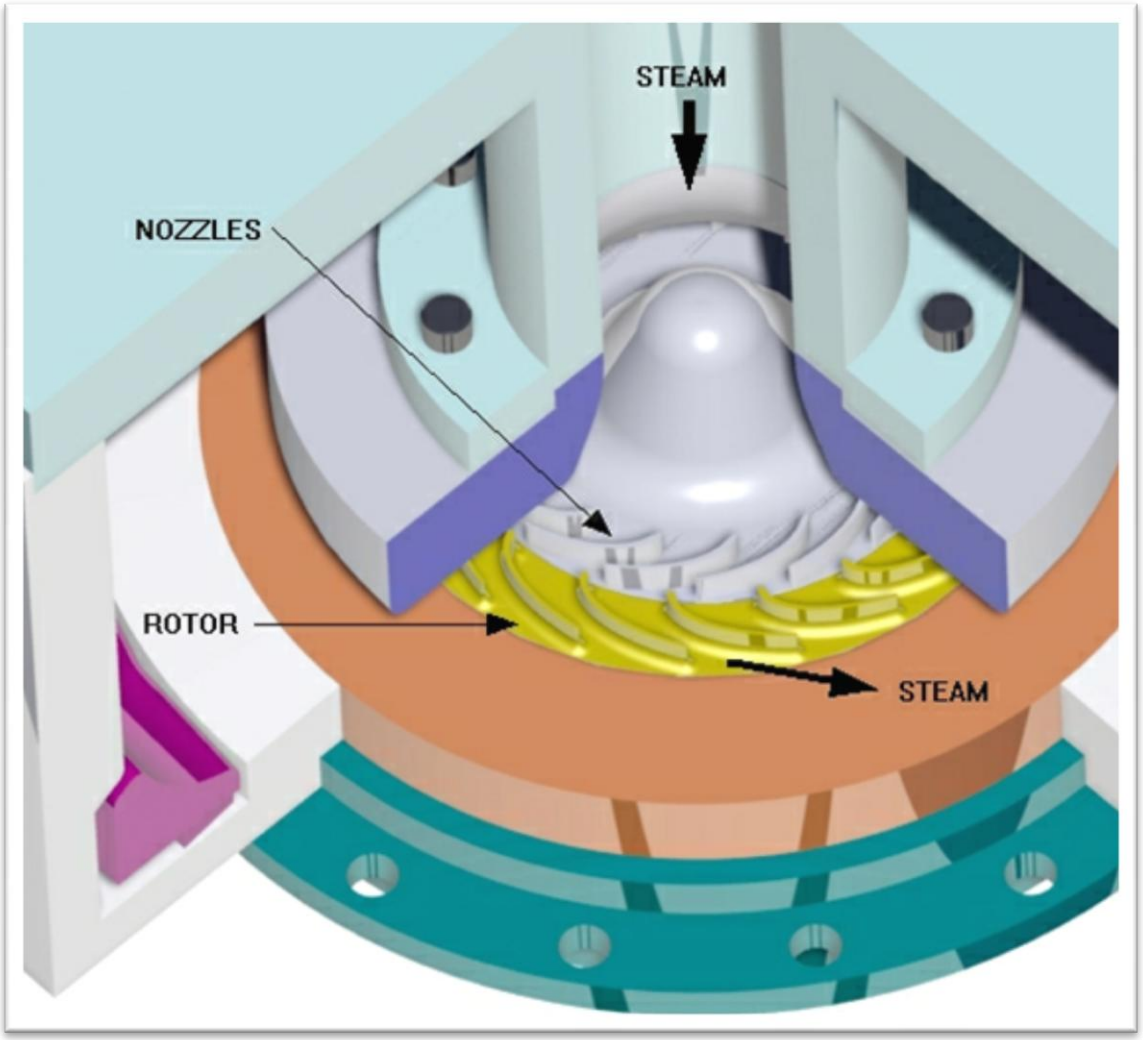
# Heat Exchanger

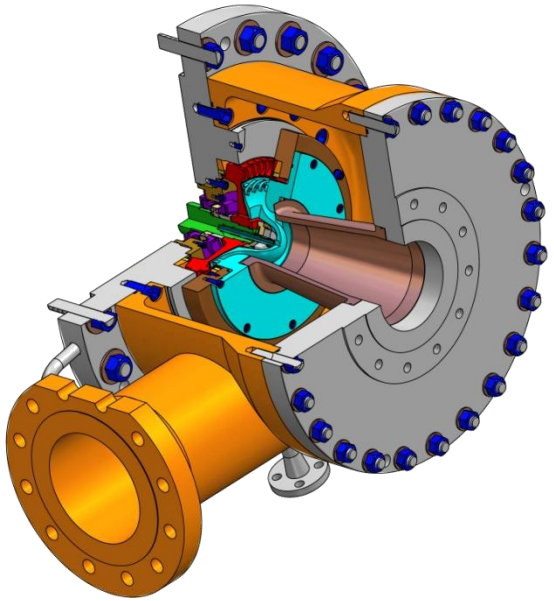

- 40’ shell and tube type heat exchanger
- Fluid does not boil in the VPC → liquid-to-liquid heat exchanger
- 352 tubes per shell

# Condenser

- Plate and frame type condenser
- Uses water from existing cooling towers
- 330 semi-welded plate cassettes

# Radial Outflow Turbine – Euler Turbine



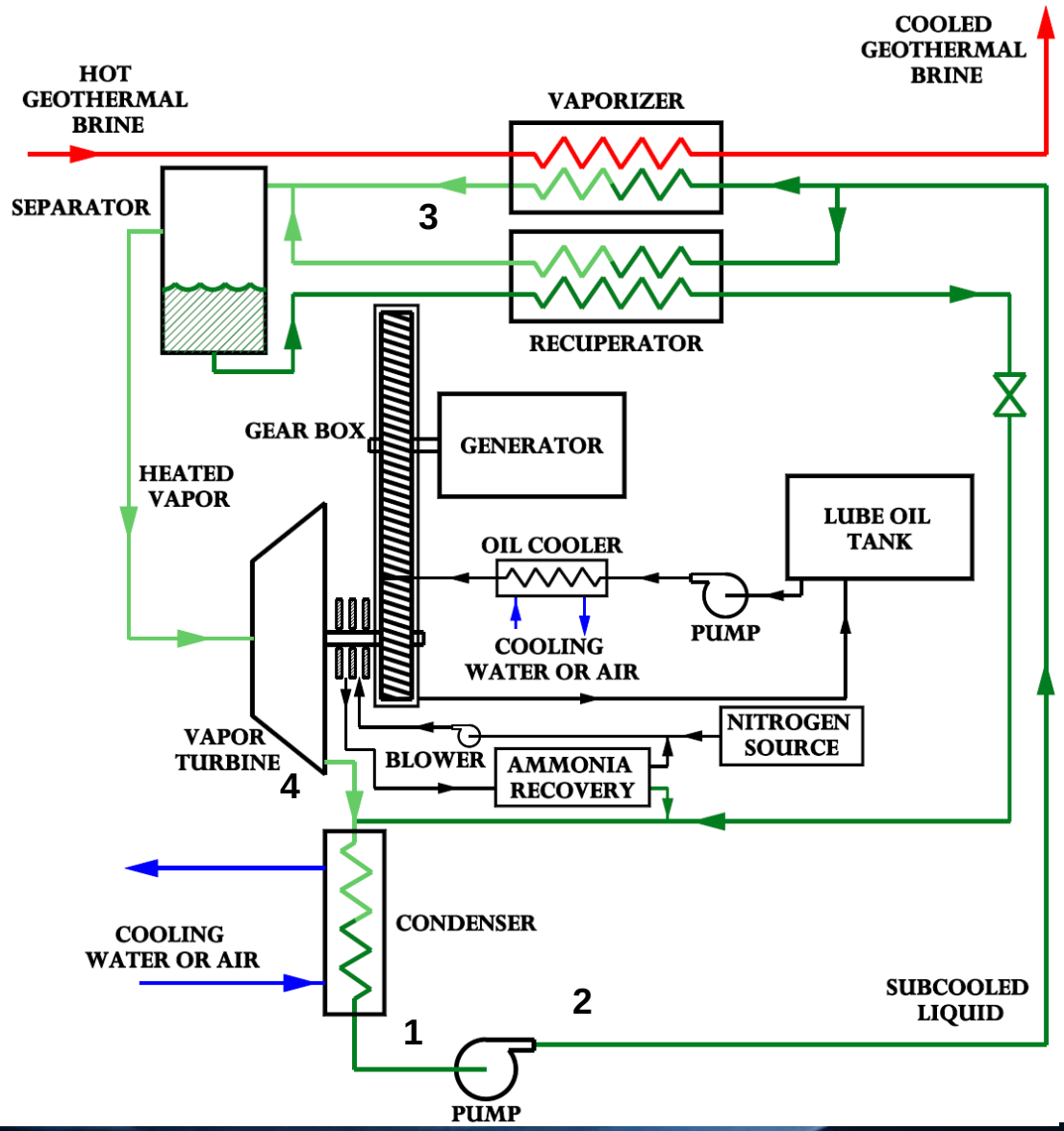



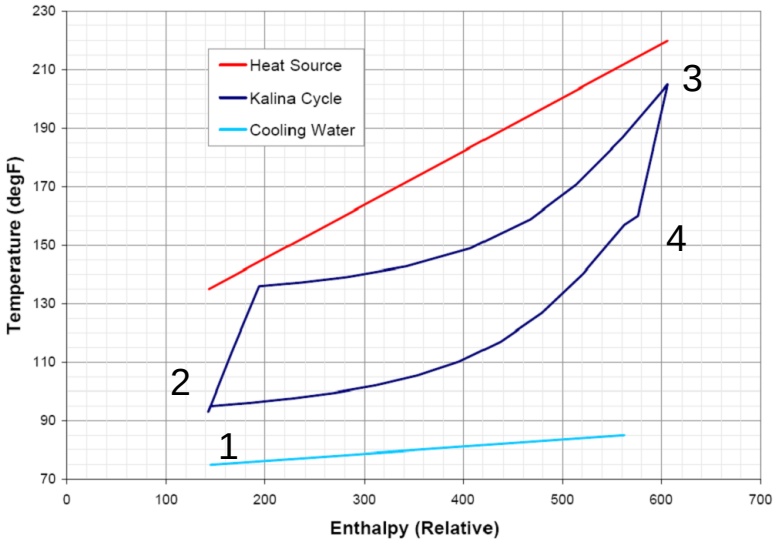
# Radial Outflow Turbine – Euler Turbine

Microsteam Turbine – 275 kW Euler Turbine

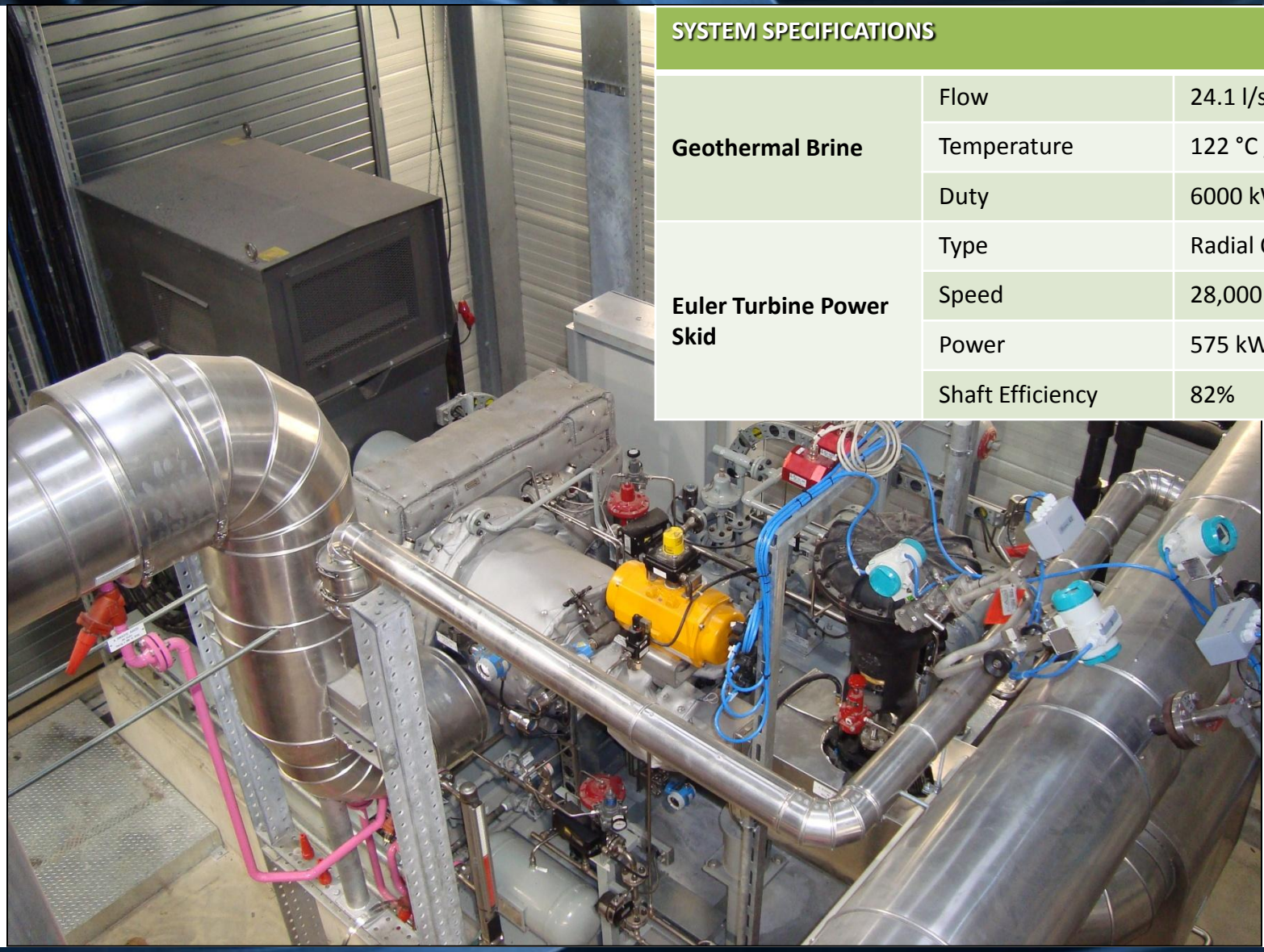
| Euler Turbine Benefits |
| --- |
| High Efficiency |
| Single Stage Gearbox |
| Titanium Alloy Construction |
| Erosion and Corrosion Resistant |
| Rugged 2D Blade Design |
| Moisture Resistant – Expand Saturated Vapor |

# Kalina Cycle for Low Temperature Geothermal



# Euler Turbine – 575 kW Kalina Cycle



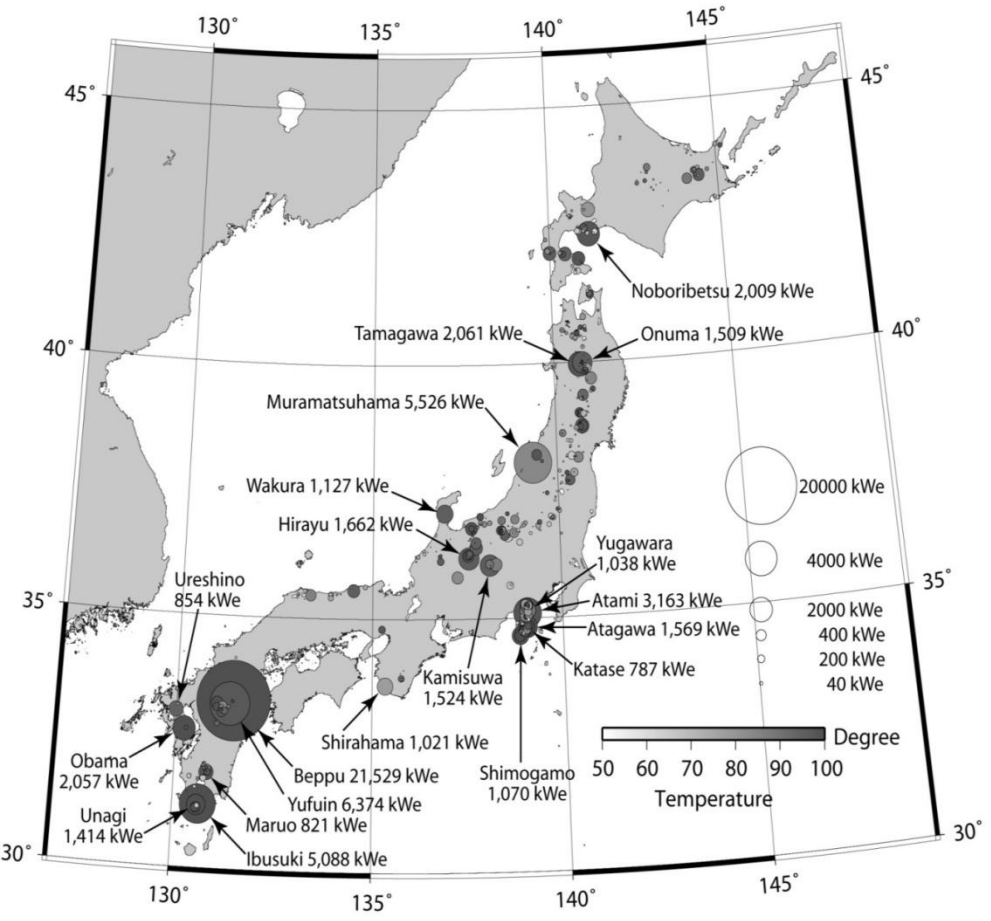
| SYSTEM SPECIFICATIONS | | |
|---|---|---|
| **Geothermal Brine** | Flow | 24.1 l/s |
| | Temperature | 122 °C / 63 °C |
| | Duty | 6000 kWth |
| **Euler Turbine Power Skid** | Type | Radial Outflow |
| | Speed | 28,000 rpm |
| | Power | 575 kW |
| | Shaft Efficiency | 82% |

# Taiwan Kalina Cycle in Chingshui, Taiwan


- Competition to determine best geothermal technology for this resource
- Taiwan's first Kalina cycle – featured a modified Microsteam Turbine

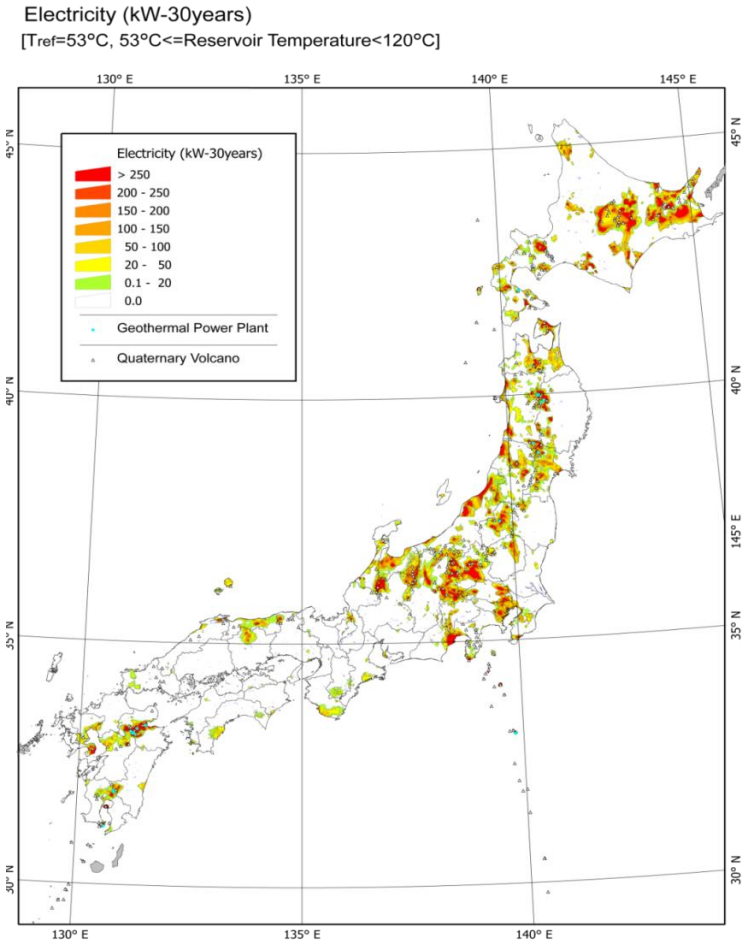
# Japan – Low Temperature Geothermal Potential

Total 723 MW from existing hot springs
Temperature <120 deg.C



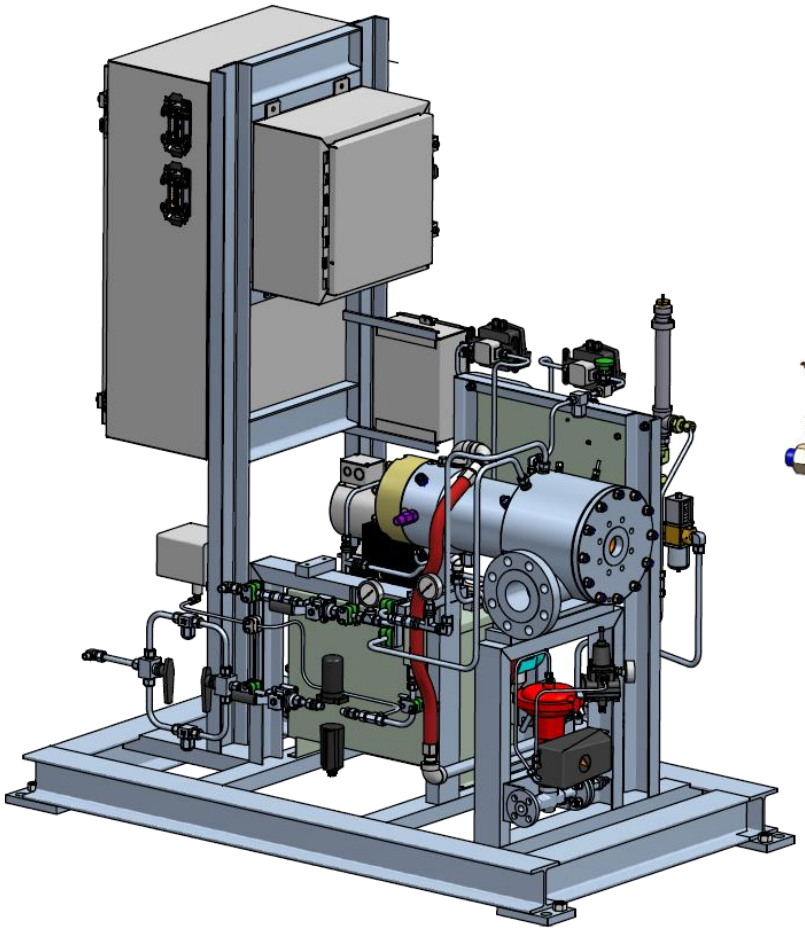

Muraoka (2007)

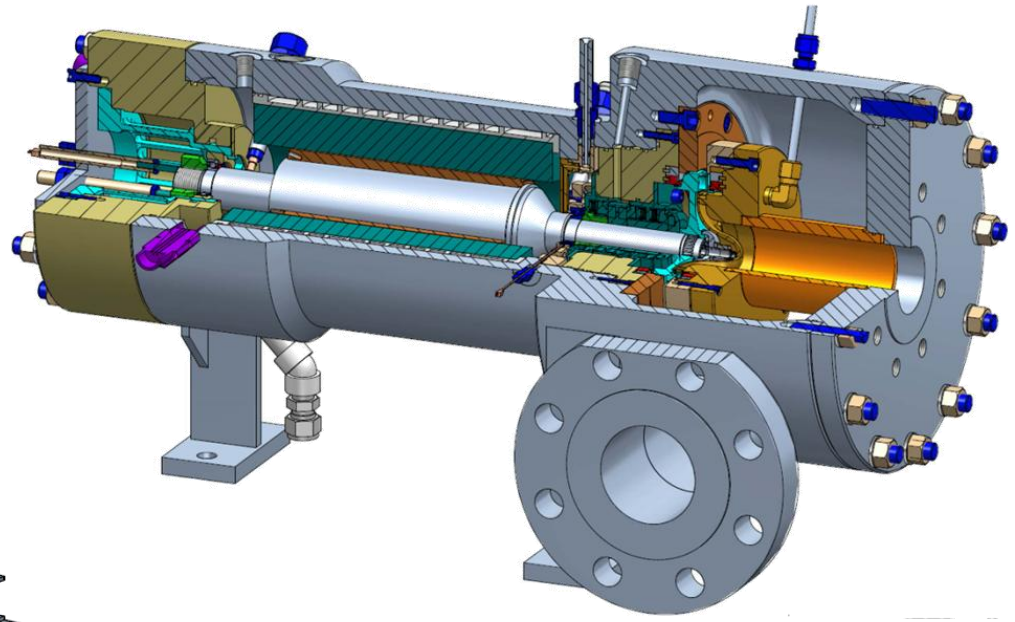
Total potential of all resources 8,330MW
(Temperature <120 deg. C)




Muraoka (2008)

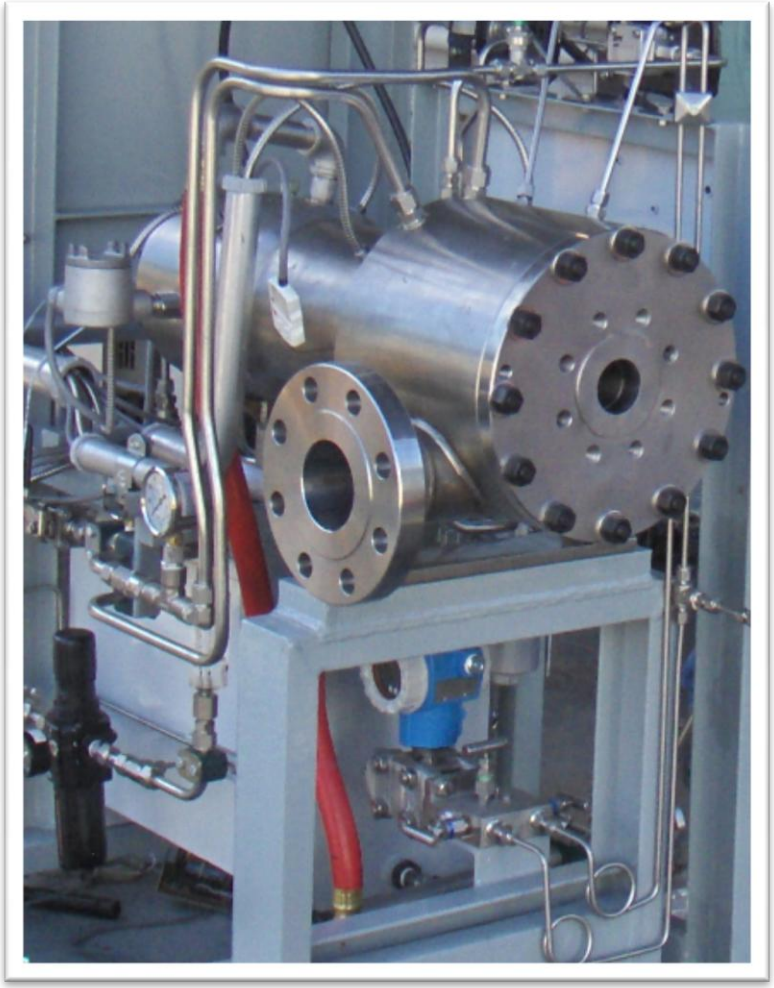
# Nanosteam Turbine – 100 kW Euler Turbine

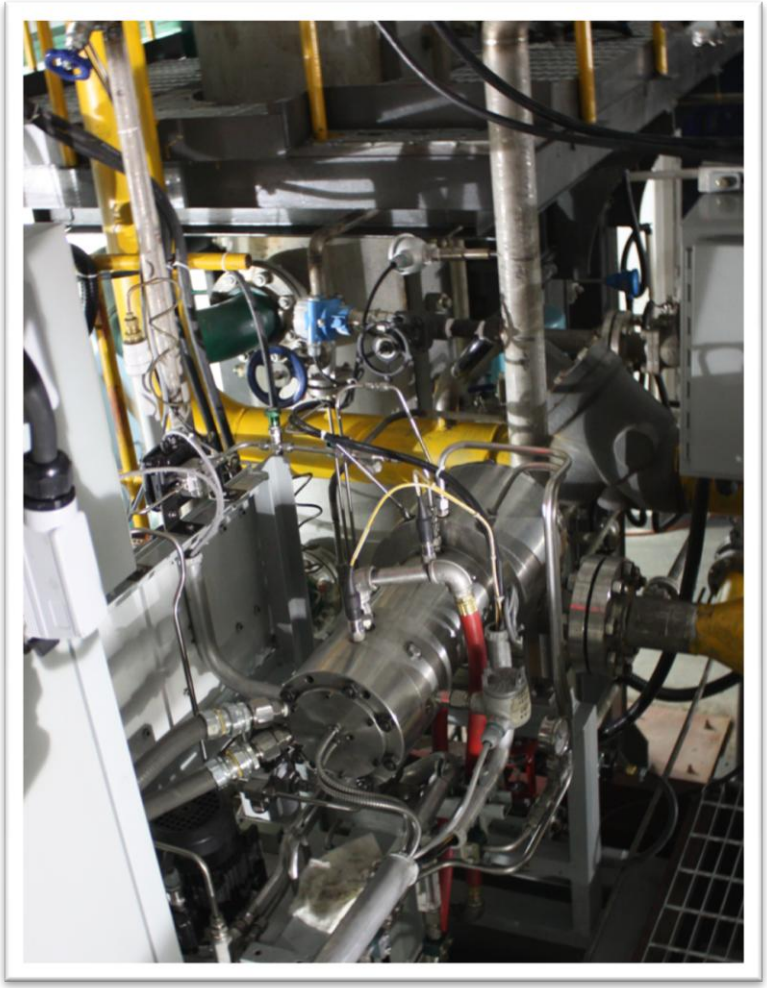




The Nanosteam Turbine is based on the Euler Turbine technology and utilizes a high-speed generator and power electronics in place of a traditional gear box.

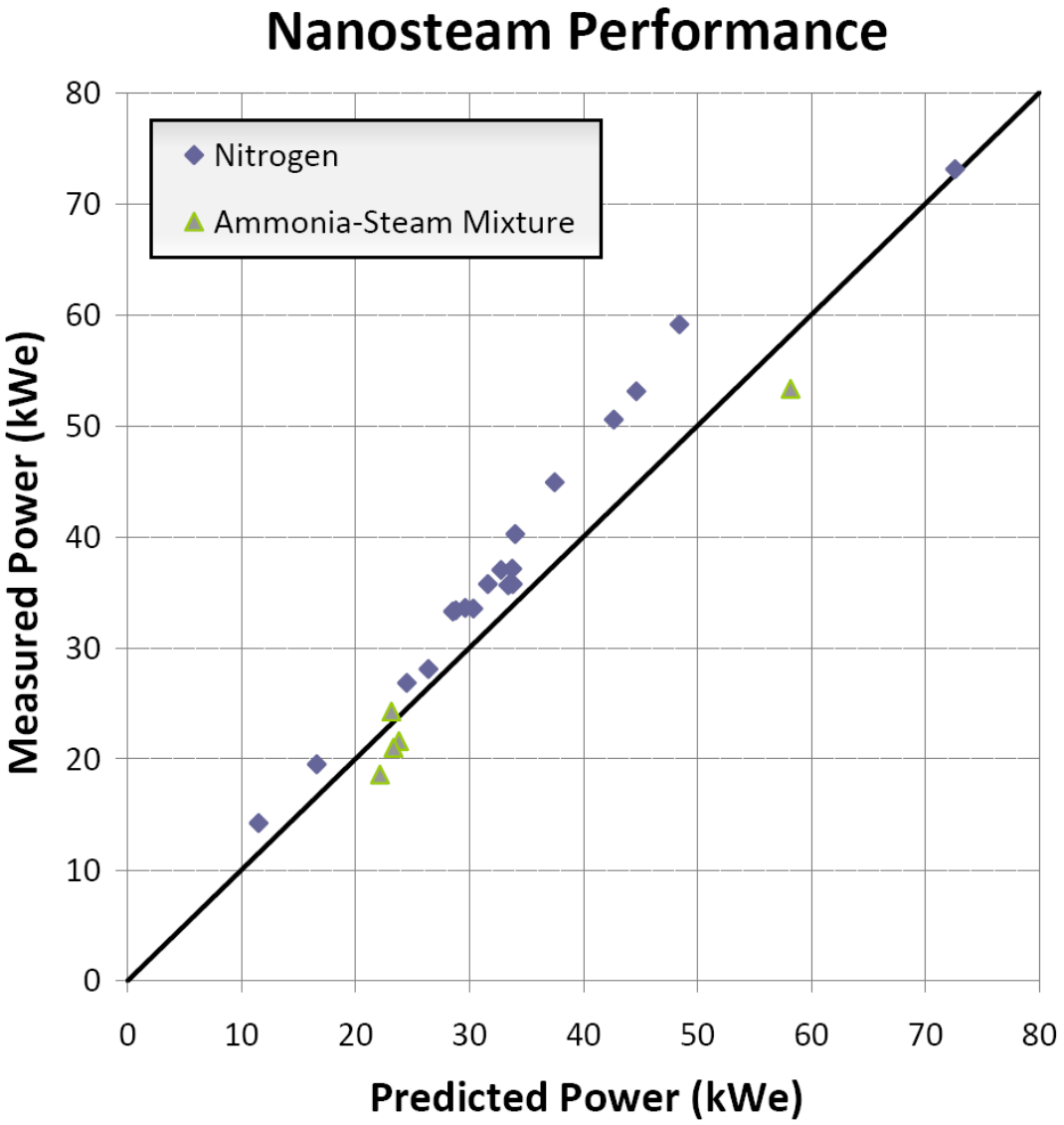
# Nanosteam Turbine Installations and Testing





Nanosteam Turbines have been delivered for Kalina cycles in Japan and China. Both units were extensively tested at Energent's factory and a full scale Kalina cycle laboratory in Shanghai.

# Nanosteam Turbine Performance Results



# Discussion

**Construction and Startup of Low Temperature Geothermal Power Plants**

More information at:

www.energent.net