Export Control				
U.S. Technology Content			Yes	No
			X	
Classification (ECCN)	US	EU	Swiss	Thai
	EAR99	X	X	X

This document is subject to United States Export Administration Regulations ("EAR," 15 C.F.R. Parts 730-774), United States International Traffic in Arms Regulations ("ITAR," 22 C.F. R. Parts 120-130), European Union, Swiss and/or other national export control regulations. Diversion contrary to United States and/or other applicable national law is prohibited. Dieses Dokument unterliegt der United States Export Administration Regulations („EAR", 15 C.F.R. Teile 730 bis 774), United States International Traffic in Arms Regulations ("ITAR," 22 C.F.R. Teile 120-130), Europäische Union, Schweiz und / oder anderen nationalen Ausfuhrkontrollbestimmungen. Eine Umleitung, die geltendem amerikanischen und / oder anderem nationalen Recht widerspricht, ist verboten.

Geothermal Power Generation

SPE 2025 GEOTHERMAL APPLICATIONS_ DONALD R LEGER

EthosEnergy

Portfolio

We provide a full range of independent and OEM approved solutions for turbine, generator and transformer products and services that are specific to the appropriate industry

Gas turbines

Full-service provider offering gas turbine solutions across a range of OEMs.

Steam turbines

Industry-leading engineered solutions and turnkey support to increase reliability and efficiency.

Generators

Services include manufacturing of stators and rotors to generator winding kits.

Compressors

Inspect, repair, reverse-engineer and re-build centrifugal, axial and integrally geared compressors.

Transformers

Design and manufacture new grid transformers, autotransformers, and generator step-up (GSU)..

Field services

24/7 turbomachinery field services, rapid mobilization and industry leading safety performance

Operations and maintenance

Comprehensive third-party facility operations and maintenance service for power plants.

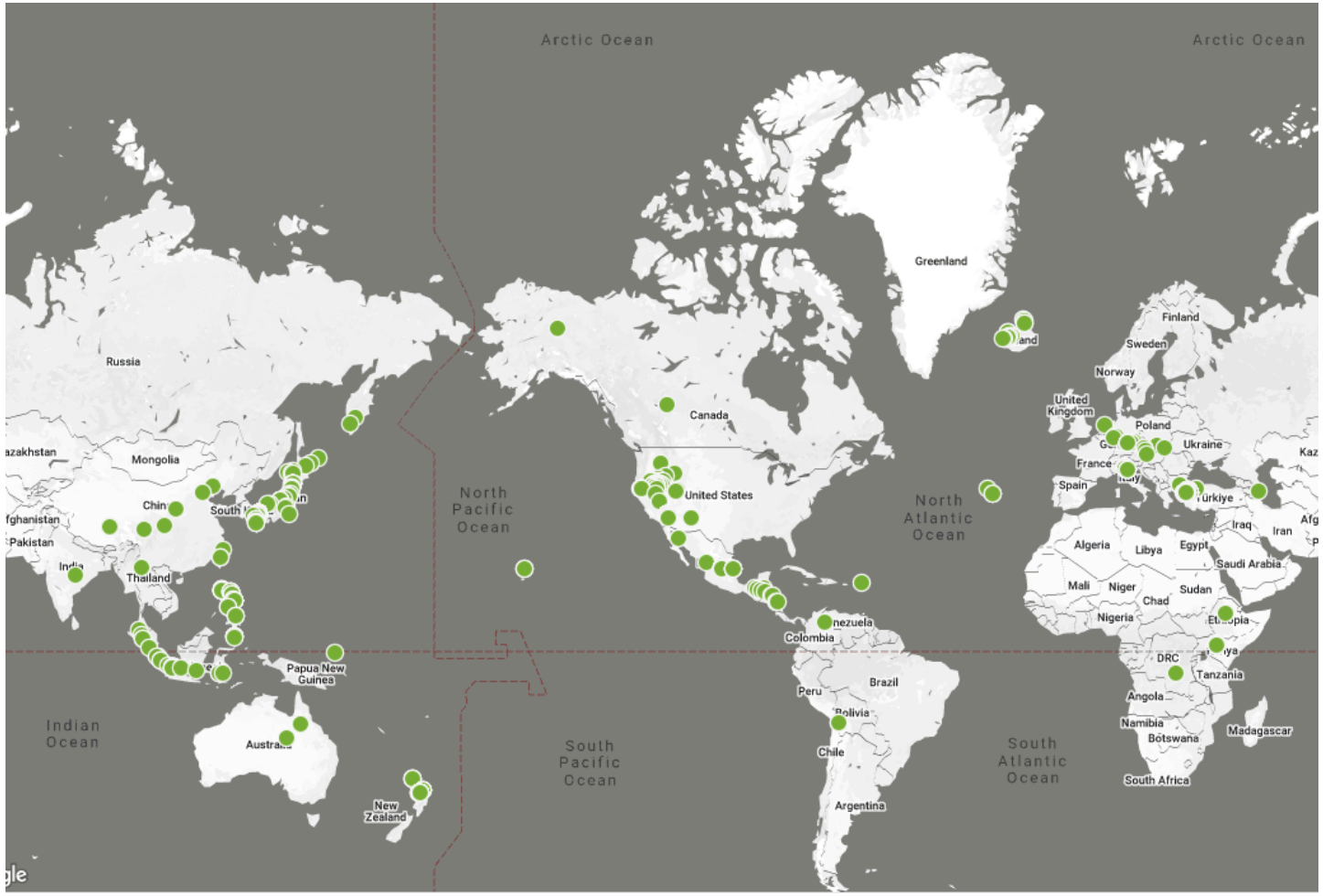
Supporting services

Steel construction, oilfield services and material handling in select geographical locations.

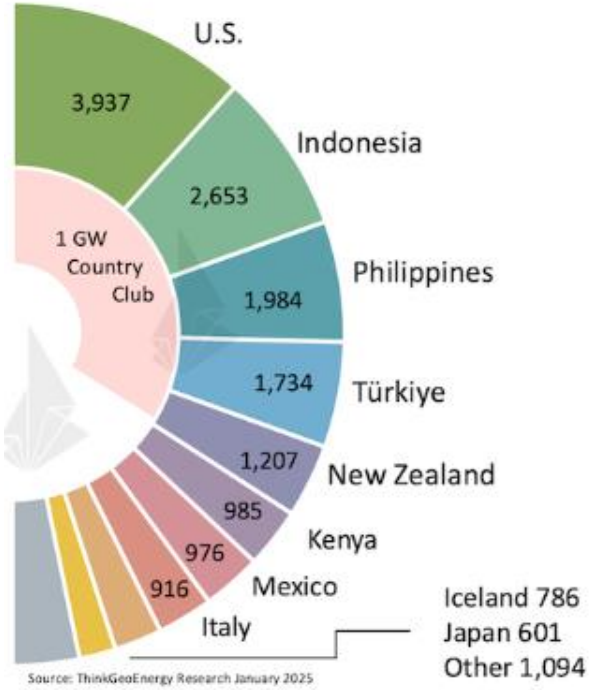
History of Geothermal Energy

- **First Geothermal unit – Experimental, 1904 – Larderello, Italy**
- First Geothermal unit – Commercial, 1914 – Larderello, Italy (installed by Prince Piero Conti to end his dispute with the local utility)
- **First Geothermal unit in the US – 1922, Geysers, CA**
- Soviet Union, Iceland, Hungary & New Zealand installed units in the 1950s.
- **1951-1960 Geysers (USA) developed to nearly 1 GW capacity**
- First water-dominated resource developed at East Mesa, CA, 1979
- **First flash plant developed at Brawley, CA in 1980 (10 MW)**
- First use of crystallizer/clarifier technology to manage high salinity brines – Salton Sea, CA – 1982
- **First binary plant in 1984 – Roosevelt Hot Springs, Utah (1.3 MW)**
- First dual-flash plant, Heber, CA – 1984 (50 MW)

Geothermal Power To Date

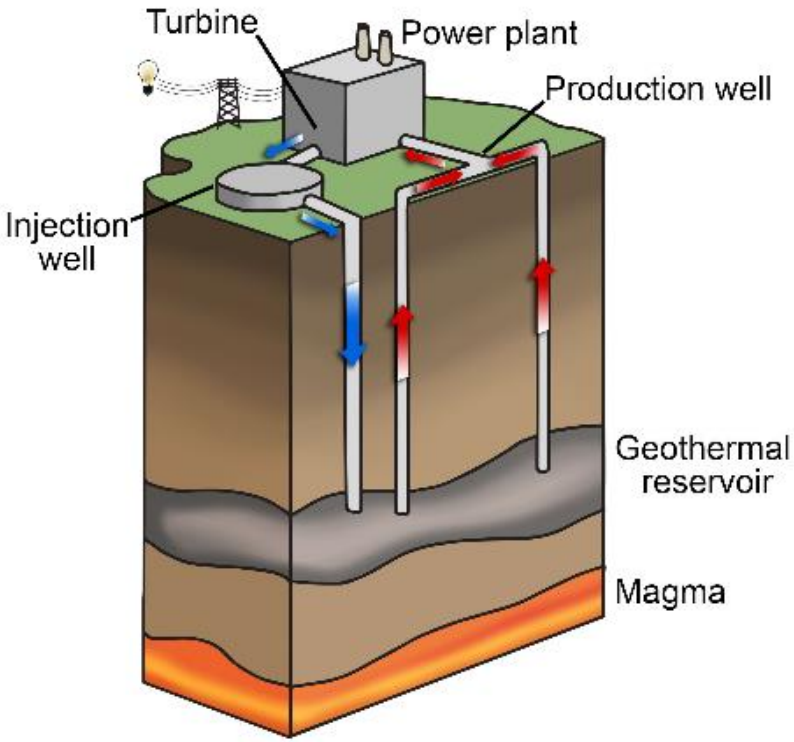


Global Geothermal Power Plant Map (ThinkGeoEnergy)



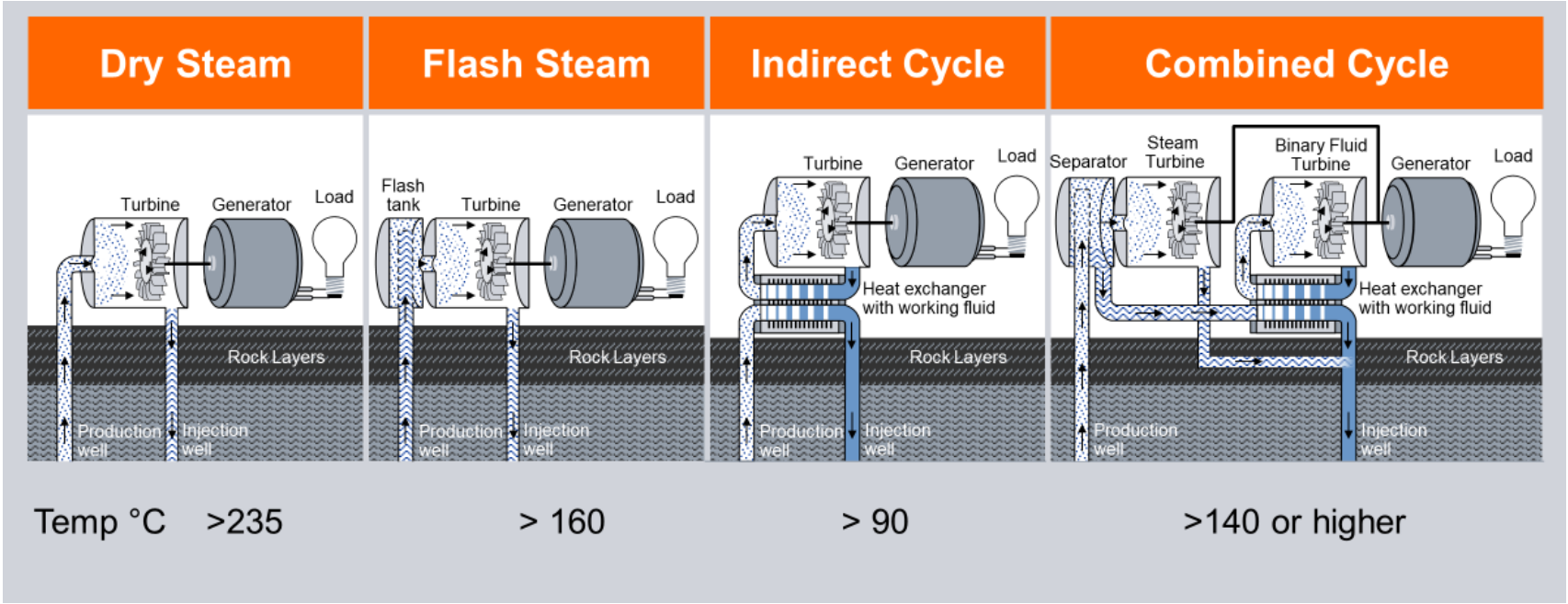
Geothermal Drilling

Deep Drilling Could Change the Potential



Geothermal Power Cycles

Geothermal Power is Base Load Generation



The Cause and Effect of Wet and Corrosive Geothermal Steam Must be Addressed

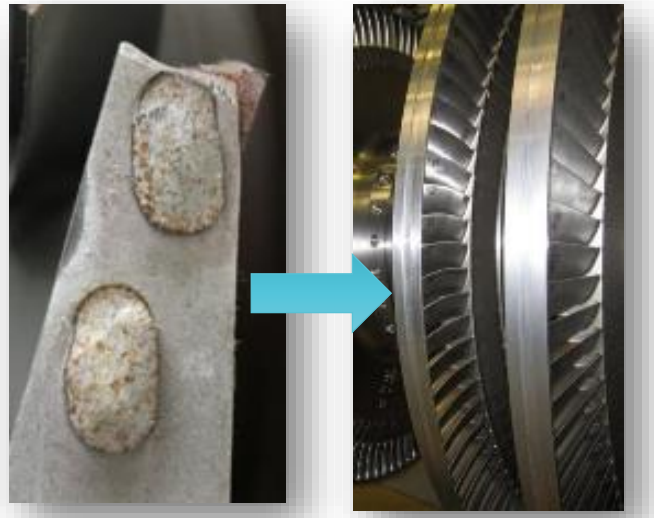
Best practice for geothermal turbines

- Material selection MUST be based on steam conditions and chemistry
- Proper shutdown and moisture removal during outage is also critical
- Periodic monitoring of steam path condition and repairs if needed
- Strict control of steam chemistry
- Geothermal resources can consume conventional materials
- Small variation in hardness and chemistry can be important
- Short term spikes in low Ph can be very damaging

Addressing Moisture Problems

Tall blade erosion protection: Stellite shield

Solid Stellite coupon



Design solution to tenon erosion is to change to integral covers

Material Options for Tall Blades in Geothermal Flash/Direct Steam Plant Service

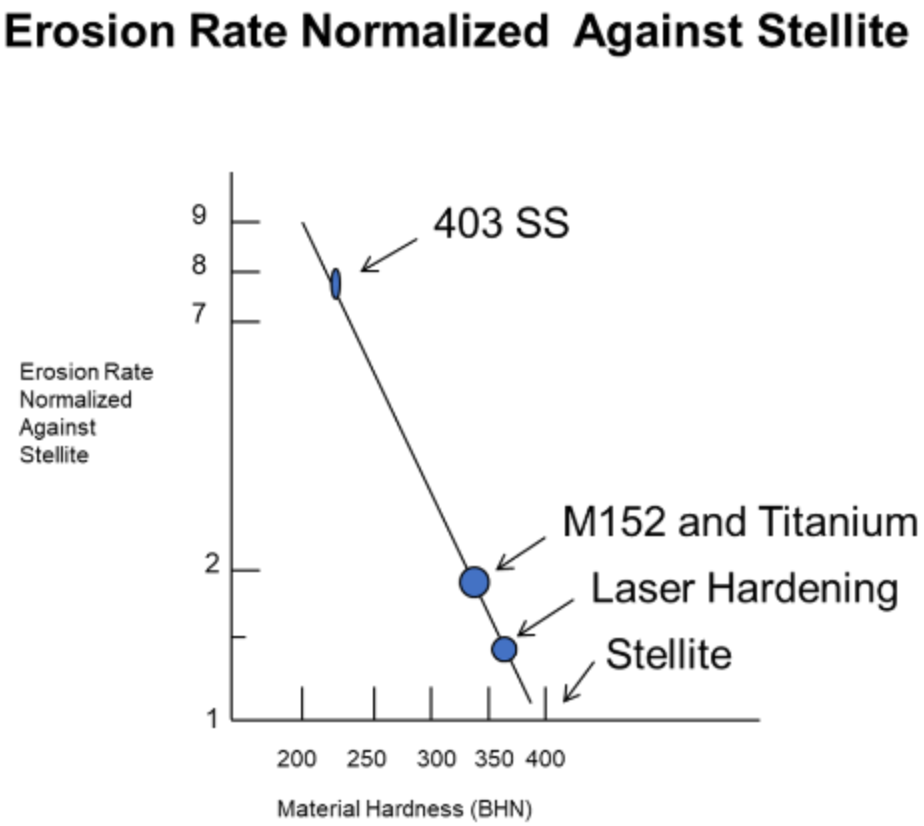
Addressing Blade Erosion

Material Options:

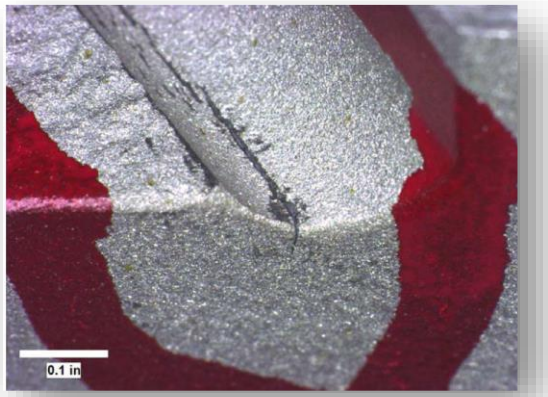
- 403 SS (Also called X15)
- M152 (Also called Jet Heat)
- 17-4 PH
- Titanium

Other Treatments:

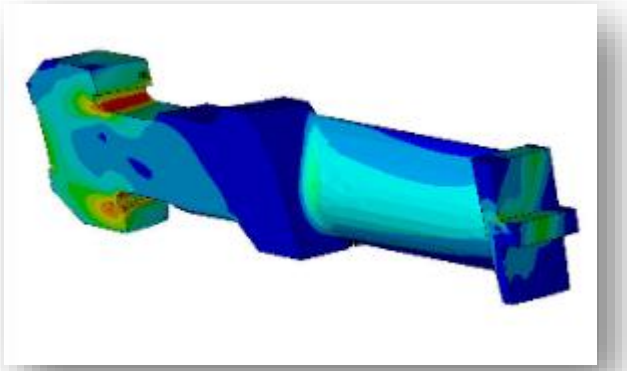
- Laser Hardening
- Flame Hardening
- Coatings

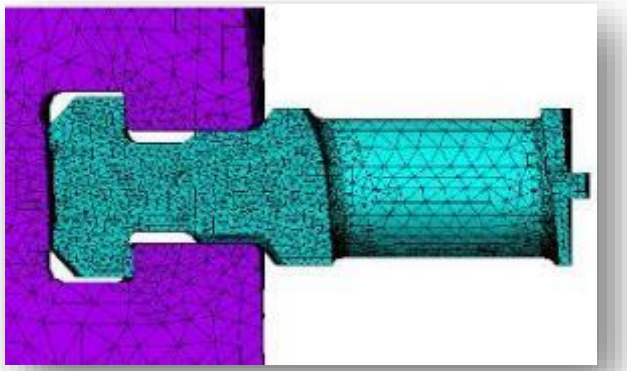


“T” Root Blade and Rotor Stress



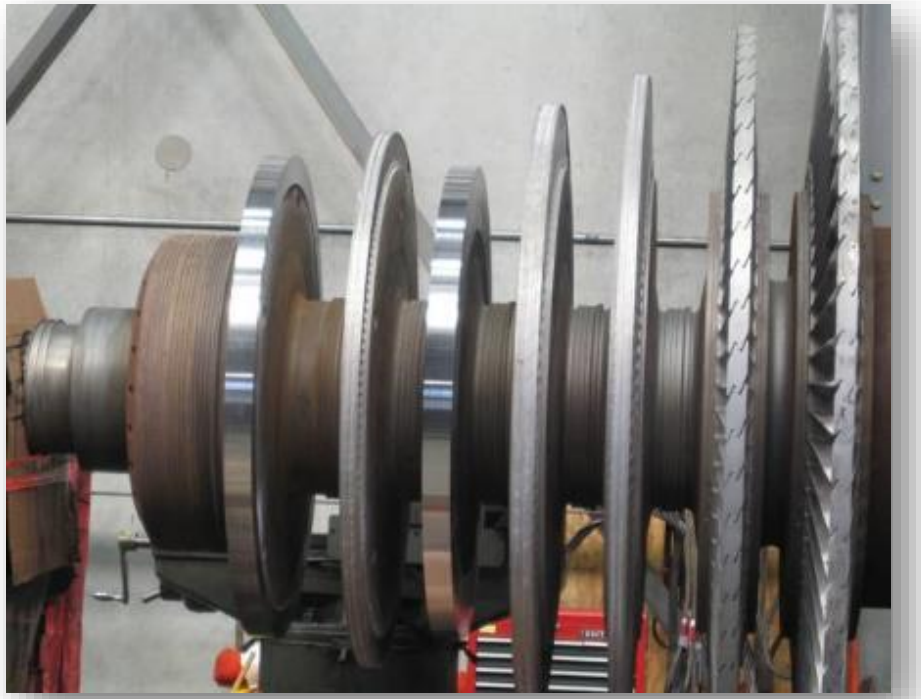
Blades and Rotor subject to high stress concentrations





FEA Modeling – High Stress in fillets on blades and rotor

Wheel Weld Repair and Reblading



1st & 3rd stage wheel weld

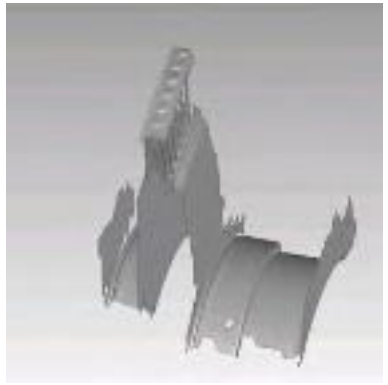
1st & 3rd stage reblading completed

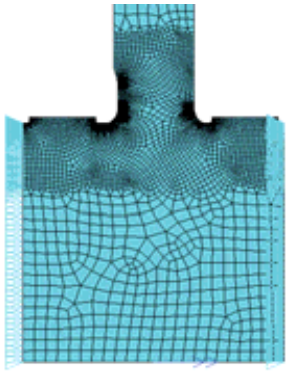
Wheel and Shaft Erosion Repairs

Severe wheel erosion

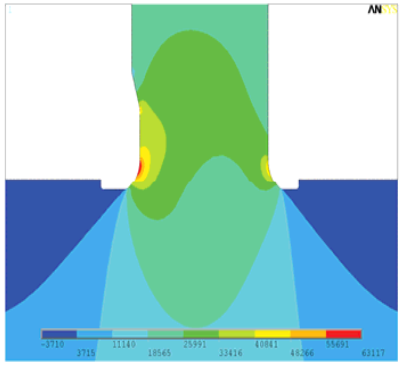
Severe shaft erosion

Finished photo of wheels machined and Inconel inlay in shaft seal area

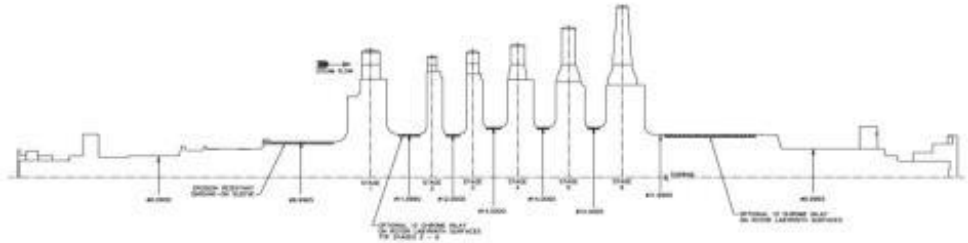




Model to evaluate wheel profile modification



Analysis to validate wheel profile modification



All seal areas are typically upgraded with Inconel inlay on geothermal repairs

Blade and Wheel Dovetail Inspection

Visual inspection of blading to look for:

- Blade and shroud physical damage
- Visual surface crack indications
- Rubs
- Erosion
- Corrosion

Corrosion

Shroud Rubs

Erosion

- Magnetic particle inspection to look for cracks which can indicate stress corrosion cracking damage or metal fatigue
- For geothermal applications, removal of blades to inspect the dovetails of the rotor and blades is sometimes done depending on operational history and blade visual condition
- Phased array NDT of the dovetails is sometimes an option if surface is not badly corroded

Change Diaphragm to Stainless Steel Inner and Outer Rings

- 12 Cr Inner and outer rings
- 12 Cr Spacer bands
- 12 Cr or Inconel nozzles

Minimum requirements for high moisture:

- Stainless steel inlay at steam face
- Stainless steel inlay at horizontal joint
- Inconel weld repairs

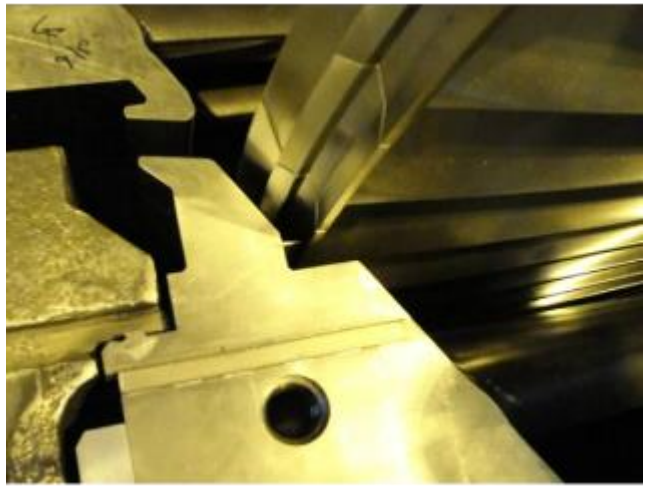
Improved Moisture Separation Feature

- Appendages on the diaphragms to draw moisture from the steam
- Moisture collected must be removed from the bottom of the casing for each stage

NCPA Ansaldo Unit – Rerate/Life Extension

EthosEnergy scope

- New diaphragms
- New blades
- New seals
- Weld and re-machine casing on site
- Added inlets on site
- Support controls retrofit
- Disassembly & reassembly



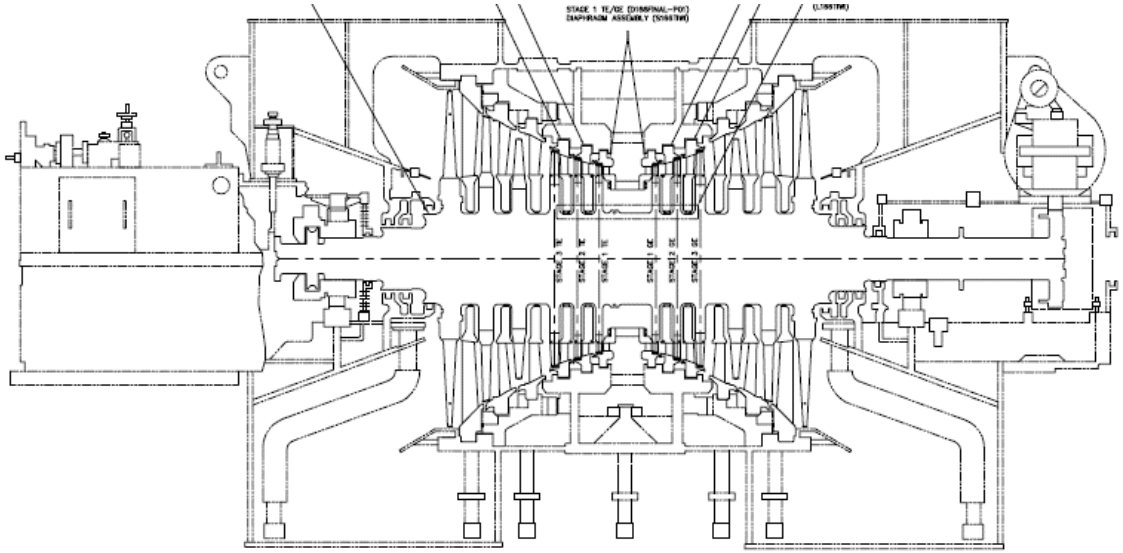
Steam Path Modernization 49 MW Dual Flash

- Complete replacement steam path
- Advanced Aero-bowed blades and nozzles
- 12 Cr steam path for geothermal application
- Integral covered blades

Derate Due to Steam Field Depletion

Toshiba

- Single Flash
- 6 Stage Double Flow
- 660 mm Tall L0 Blades

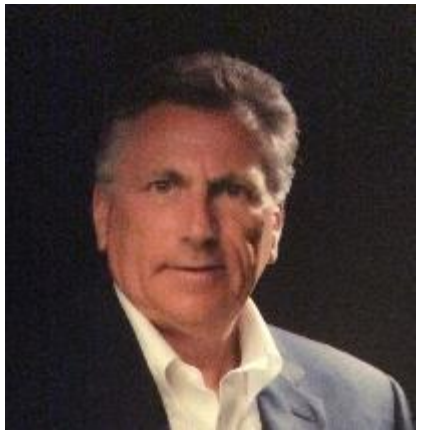


14%
Efficiency Improvement

10%
Steam Rate Improvement

Measurement	Units	Original Design	De-rated Conditions
Inlet Pressure	Kg/cm² abs	7.86	6.04
Inlet Temperature	deg C	168.9	165.7
Condenser Vacuum	mmHg	585	678
Turbine Speed	3600	3600	3600
Rated Output	kW	57,000	32,200

Thank you for your time, any questions?



Don Leger
Manager-Steam Turbine Application Engineering
Donald.Leger@ethosenergy.com
M: +1 978-549-1304

EthosEnergy