The Geysers

November 29, 2023

An Overview of The Geysers

- Geysers – By the Number
- Geology: Why is it here?
- How was it developed?
- Exploration & Development
- The Geysers Sustainability
- Geysers Challenges
- Geysers Development
- Geysers Technology

The Geysers - by the Numbers

NORTHERN AMERICA'S LARGEST GEOTHERMAL OPERATIONS

THE GEYSERS BY THE NUMBERS

The Geysers Geothermal Field 2022 Statistics

The Geysers' 15 Geothermal Power Plants span two Northern California counties, Lake and Sonoma:
The Geysers, comprising 45 square miles along the Sonoma and Lake County border, is the largest complex of geothermal power plants in the world. Today, there are 15 geothermal power plants operating at The Geysers and Calpine Corporation, the largest geothermal power producer in the U.S., owns and operates 13 power plants with a net generating capacity of about 725 megawatts of electricity - enough to power 725,000 homes, or a city the size of San Francisco.

- Calpine's Sonoma County power plants: Aidlin U-1, McCabe U-5/6, Ridge Line U-7/8, Eagle Rock U-11, Cobb Creek U-12, Lake View U-17, Sulphur Springs U-14, Sonoma U-3, Grant U-20, Socrates U-18
- Northern California Power Agency's Sonoma County power plants: Unit 1 & Unit 2
- Calpine's Lake County power plants: Calistoga U-19, Big Geysers U-13, Quicksilver U-16

Calpine Geothermal Operations:

- 28,447 Acres, about 44 square miles
- 75 miles North of San Francisco
- 13 Operating Geothermal Power Plants
- 10 Power Plants in Sonoma County; 3 Power Plants in Lake County
- Steam Pipelines = 92.2 miles
- Injection Waterlines = 72 miles
- 21kV Power Lines = 75 miles
- Project Roads = Over 171 miles

Geothermal Wells:

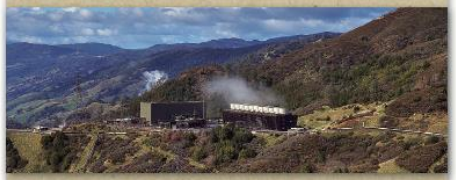
- Calpine Steam Wells: 319
- Calpine Injection Wells: 73
- Deepest Well: 12,900 ft
- Average Well Depth: 8,500 ft
- Total Calpine Geysers wells drilled to date: 601 with one injection well drilled in 2022
- Today's average grassroots drilling time: 85 days (75 days drilling + 10 rig up/down)
- 2022 Average Steam Production Per Well: 11,938 Pounds Per Hour
- Flow Rated Average Well Head Temperature: 370.9° Deg F
- Flow Weighted Average Well Head Pressure: 83.2 psig
- Most Recent Steam Well Drilled: Prati 24 on February 11, 2021
- Most Recent Injection Well Drilled: Davies Estate 11 completed November 10, 2022

Power Generation:

- First Exploratory Well Drilled in 1920; First Modern Well Drilled in 1955
- First Commercial Power Plant: PG&E Geysers Unit 1 in 1960
- Most Recent Power Plant Built: Aidlin U-1 in 1989
- 2022 Average Output: 630.94 Net Megawatts
- 2022 Generation: 5,543,878.10 Net Megawatt Hours
- 2022 Average Unit Availability: 91.17%

Geothermal – Clean, Reliable, Renewable Power

CALPINE®



About Calpine

Calpine Corporation is America's largest generator of electricity from natural gas and geothermal resources with operations in competitive power markets. Our fleet of 75 power plants and two battery storage facilities, including one under construction, represents nearly 26,000 megawatts of generation capacity. Through wholesale power operations and our retail businesses, we serve customers in 22 states, Canada and Mexico. Our clean, efficient, modern and flexible fleet uses advanced technologies to generate power in a low-carbon and environmentally responsible manner. We are uniquely positioned to benefit from the secular trends affecting our industry, including the abundant and affordable supply of clean natural gas, environmental regulation, aging power generation infrastructure and the increasing need for dispatchable power plants to successfully integrate intermittent renewables into the grid.

THE GEYSERS
GEYSERS POWER COMPANY, LLC

www.calpine.com
www.geysers.com

March 2023

GEYSERS OPERATIONS, MAINTENANCE, & SUPPORT

Geysers O&M:

Central Operations (Control 1):

- ✓ Steam Field Operations- Production Desk
- ✓ Power Plant Operations – Gen Desk
- ✓ Steam Field

Power Plant:

- ✓ Power Plant O&M

Central Maintenance:

- ✓ Shop Services
- ✓ 21 KV Team
- ✓ Paint
- ✓ Buildings and Grounds
- ✓ Vehicle Maintenance

Technical Services:

- ✓ Drilling
- ✓ Project Management

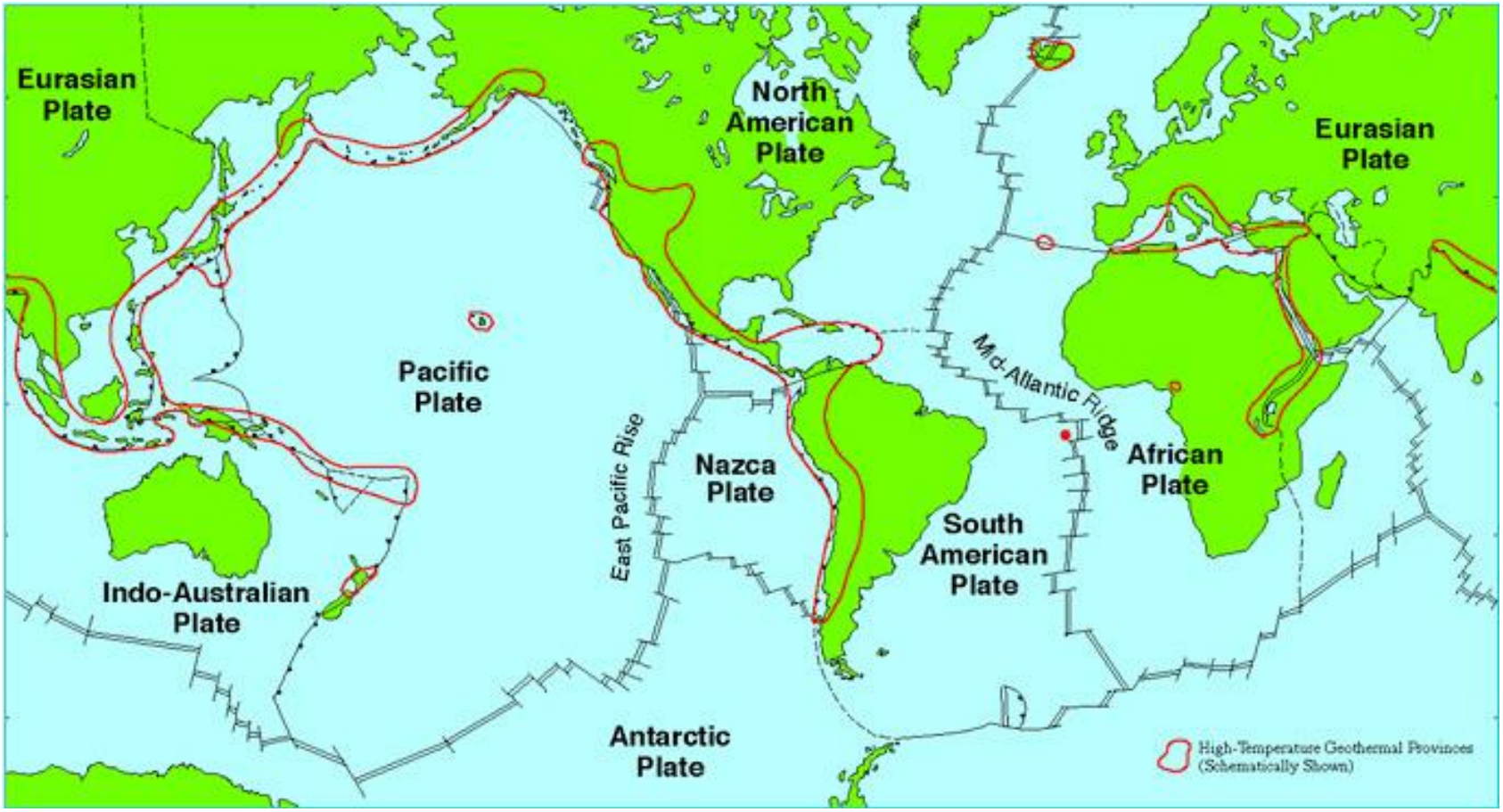
Resource Group:

- ✓ Geologists
- ✓ Geophysicist

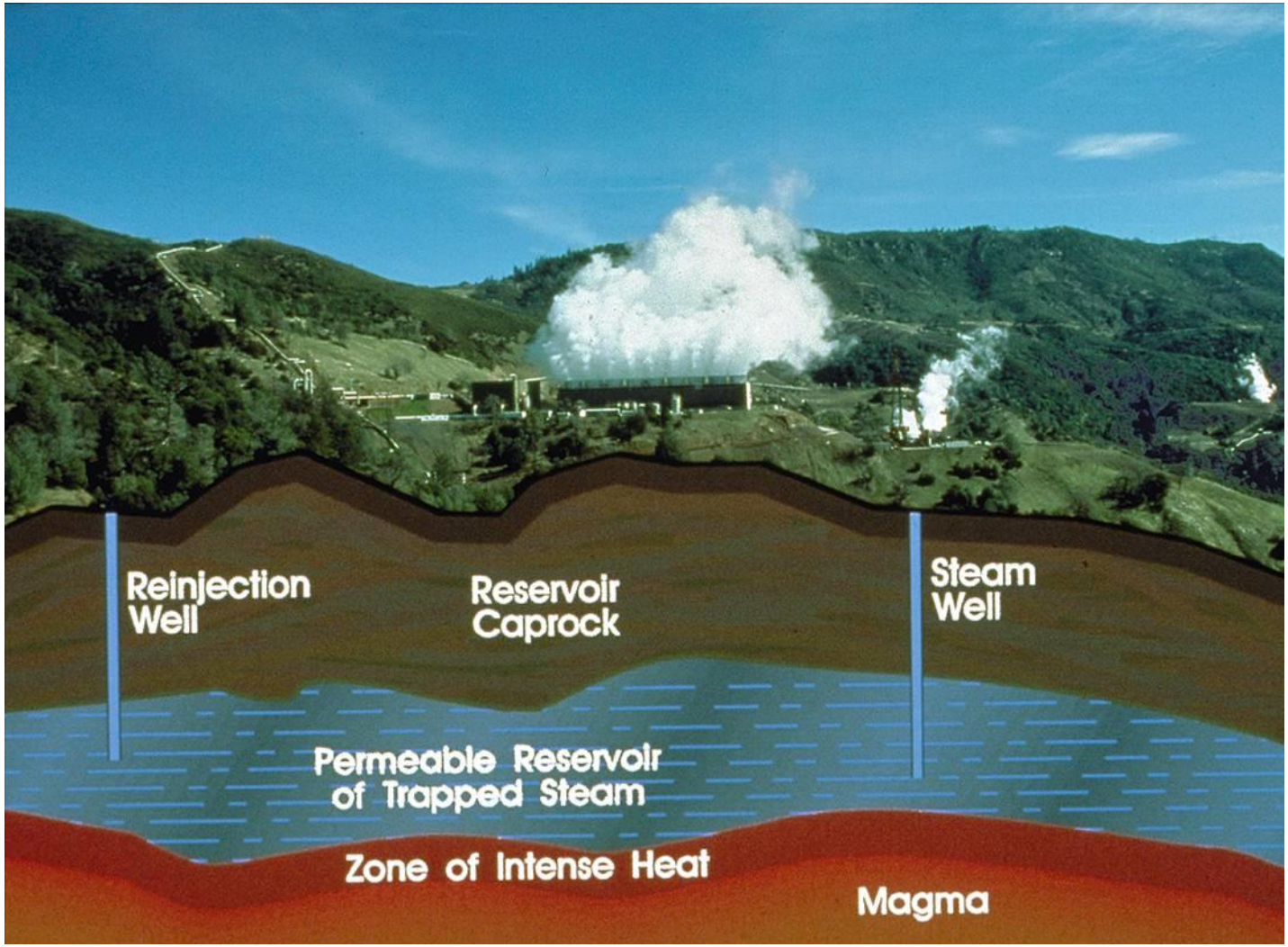
Geothermal Production Analytics:

GEOLOGY AT THE GEYSERS – WHY IS IT HERE?

- Found near plate boundaries (associated with volcanoes)
- Around the Pacific "Ring of Fire"
- About 65 geothermal power fields in operation (8,000 mws)



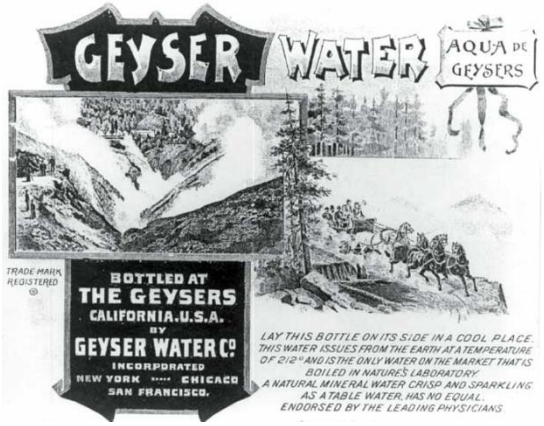
GEOLOGY AT THE GEYSERS – WHY IS IT HERE?



THE GEYSERS – THE RESORT DAYS: 1854 -1980

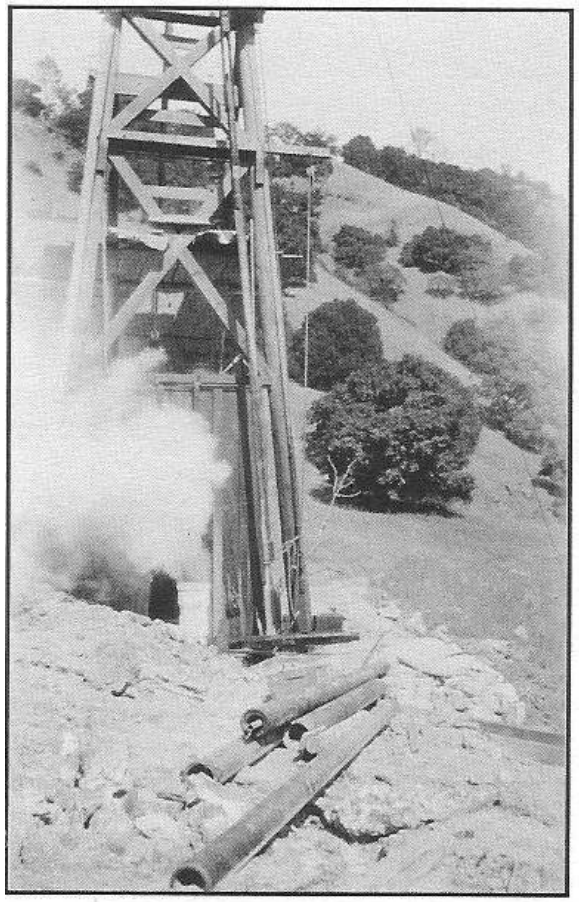
The Big Geysers: 'Eighth Wonder of the World'

VIP Visitors: Pres. Grant, Taft, Teddy Roosevelt.



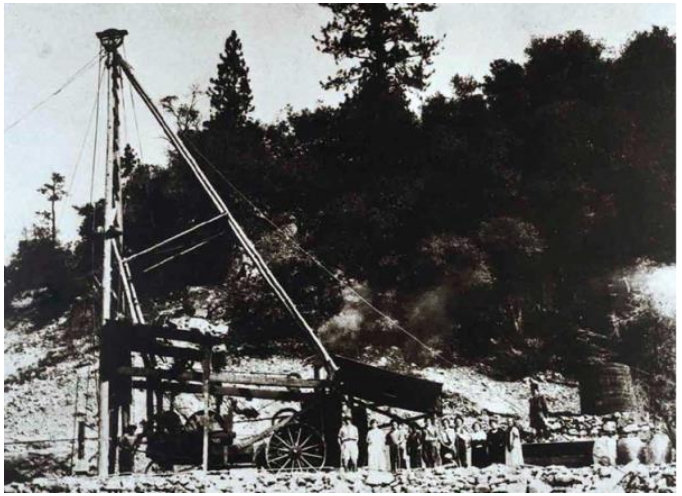
Geysers Canyon, in its natural state.

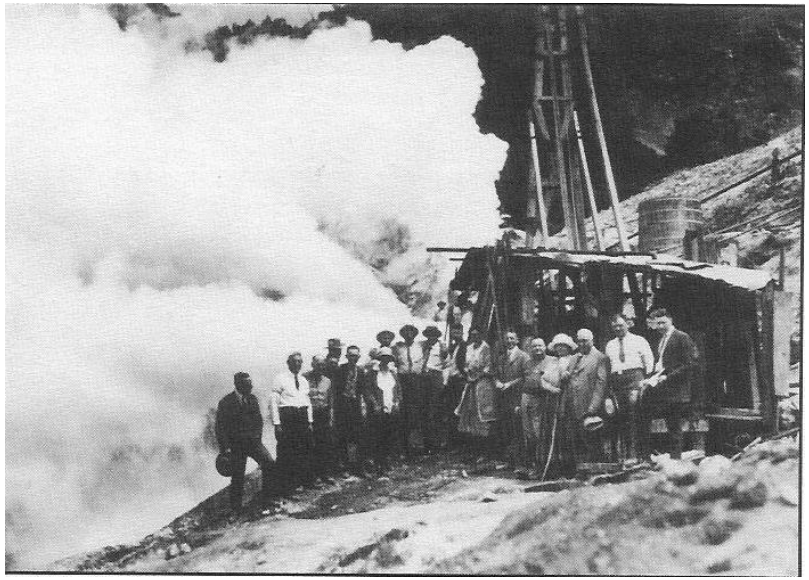
1920's –Exploratory Drilling



Rig on Well
Number 3

First Exploratory Well Drilled in 1920.

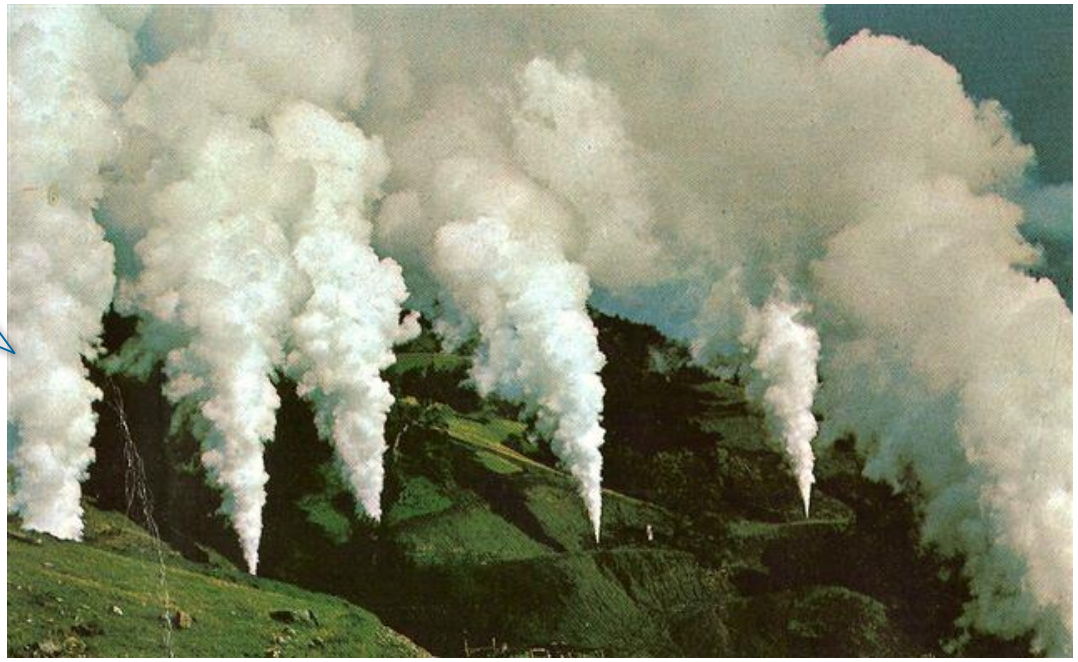




Development Starts, 1950's - Drilling

First modern well drilled in 1955 – still producing today!

6-month(!) flow test.



Developers convince PG&E…

PLANT CONSTRUCTION, COD 1960 - 1989

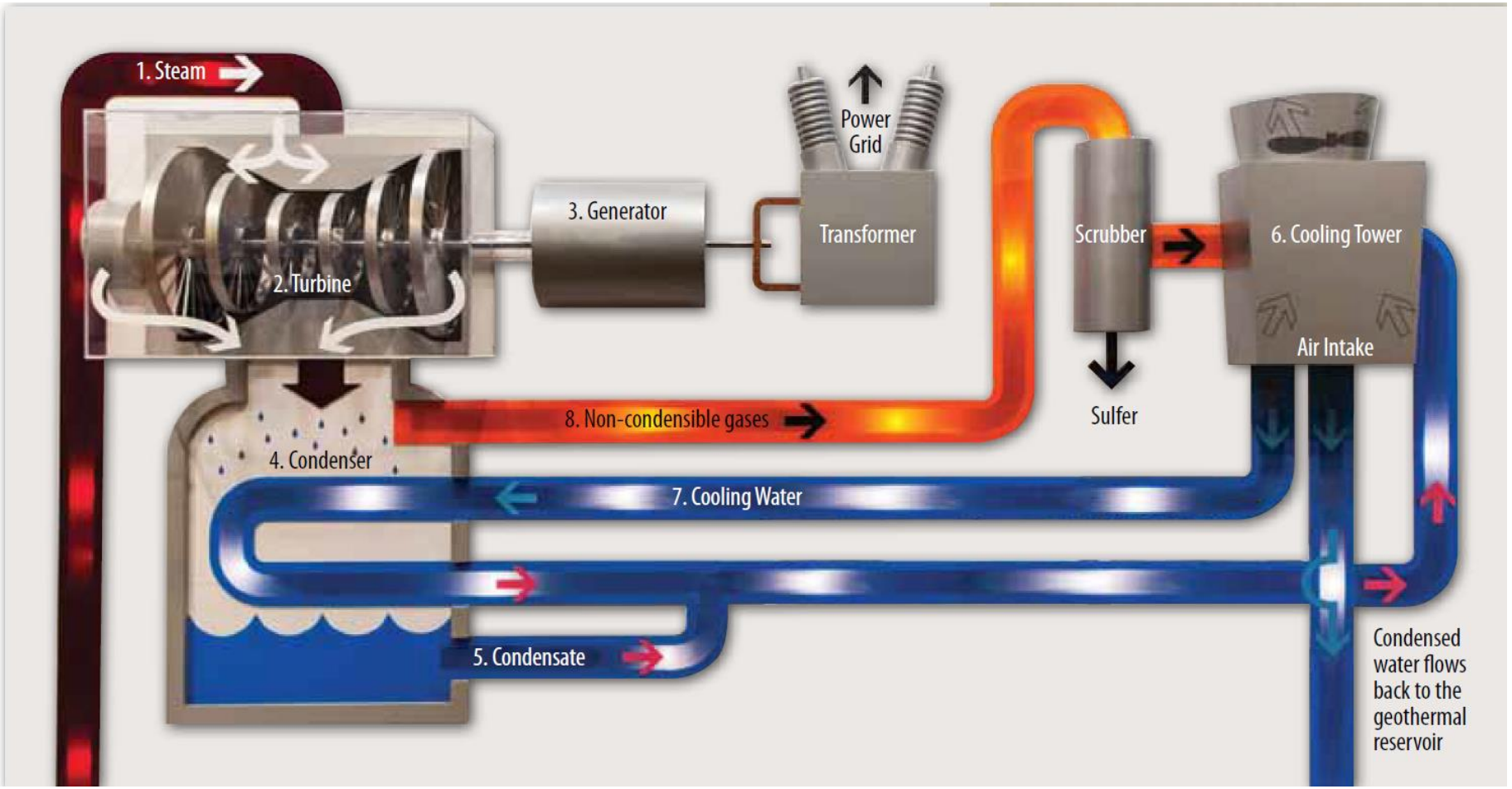
U1&2, 1960-63, 12 & 14 MW_{gross}

GEYSERS EXPLORATION AND DEVELOPMENT BOOM

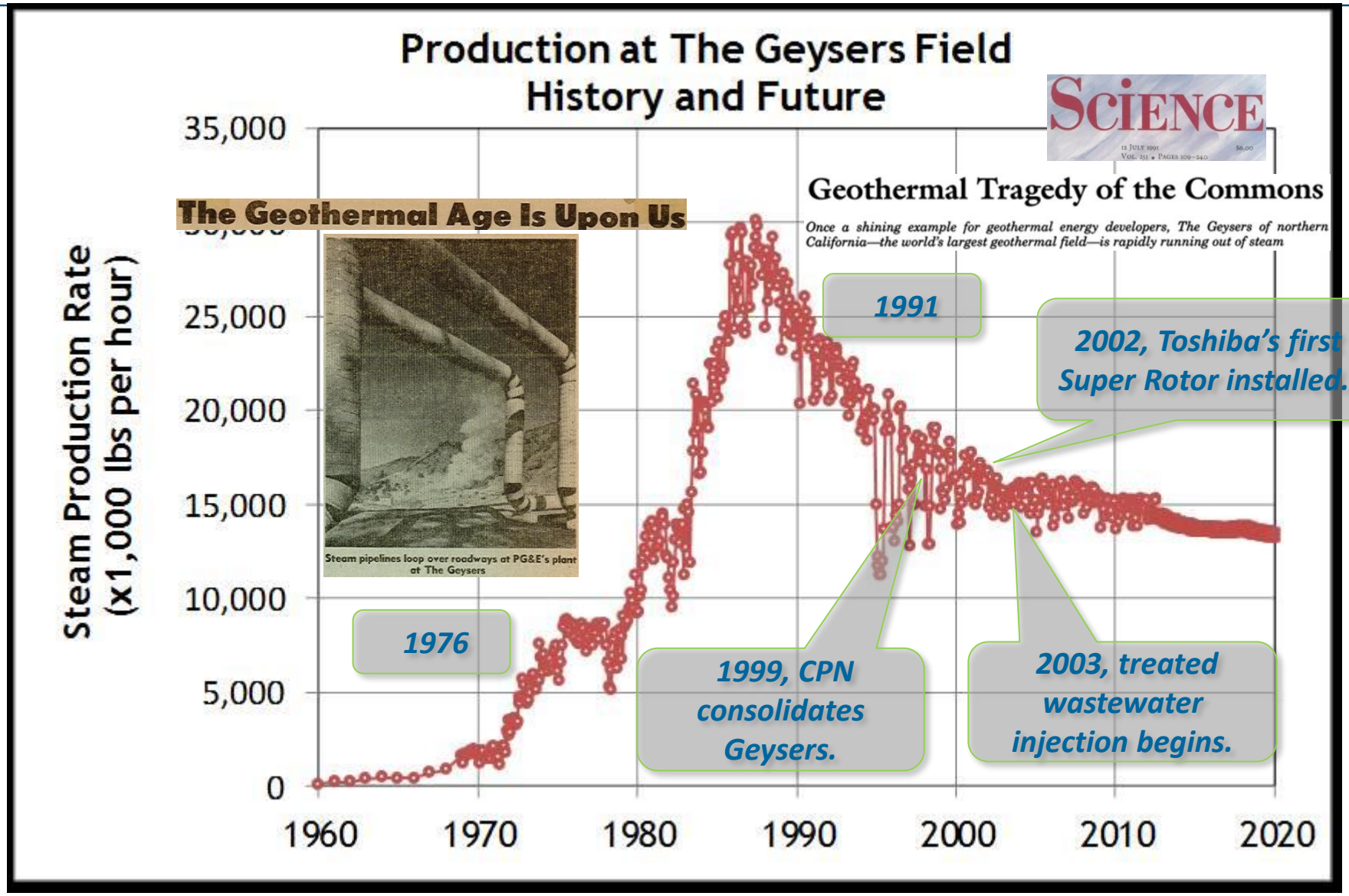
- Development boomed in the late 1970s and expanded significantly in 1980s
- 1960 – 1989: 22 power plants had been built at The Geysers, with first 20 years of development in Sonoma County
- 1987: Steam production peaked and then began to rapidly decline
- Calpine purchases a 1-megawatt interest in Aidlin, located in the northwest fringe of the geothermal reservoir. Built in 1989, it was the last power plant built at The Geysers, to date

Aidlin, Calpine Unit 1
Sonoma County, CA

How do Power Plants at The Geysers Work?



THE GEYSERS: RESERVOIR DECLINE

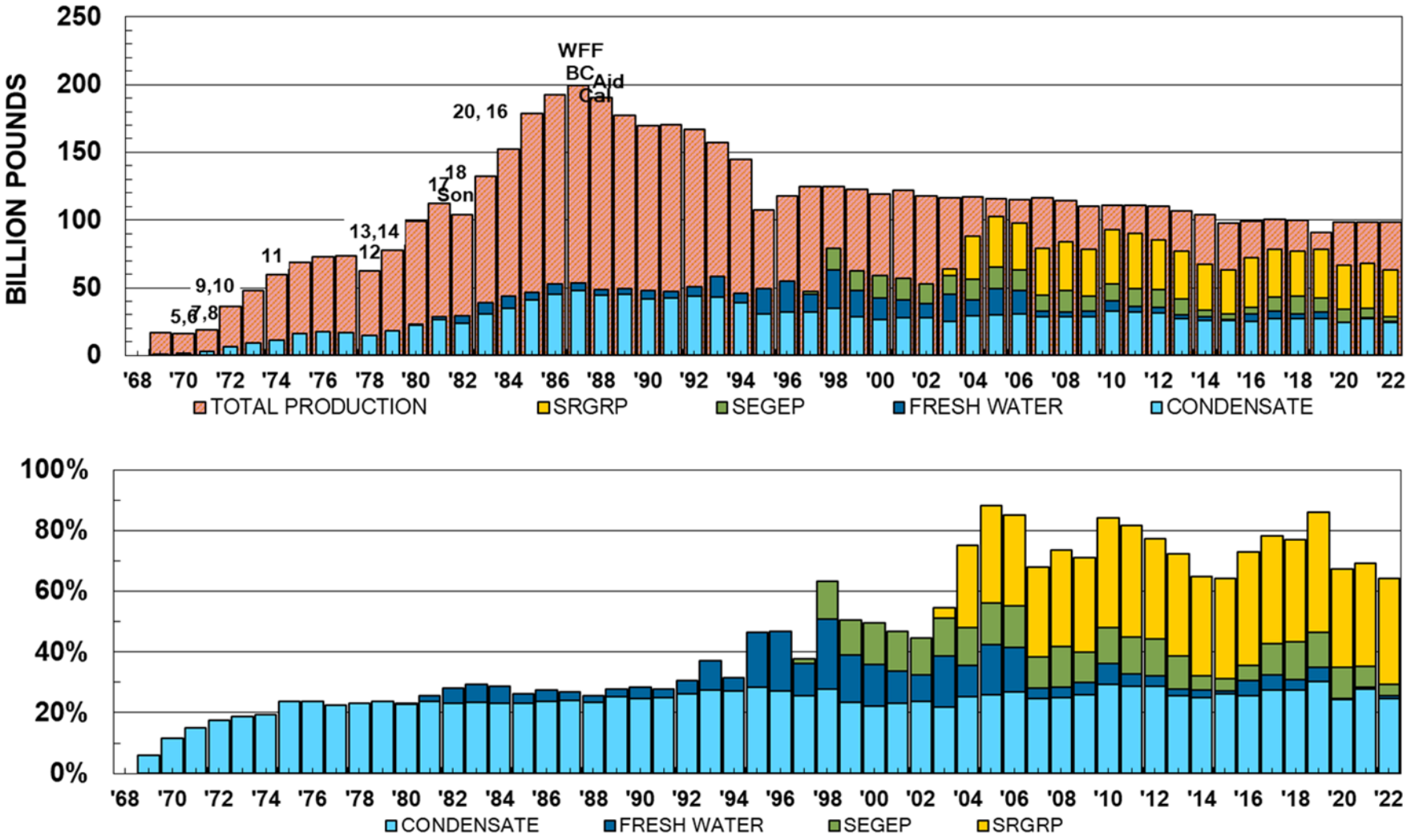


How is The Geysers Sustained?

Clean Energy from Recycled Water

- **Santa Rosa Geysers Recharge Project (SRGRP): Since 2003**
  - 40 miles of 48” pipe
  - 2017: 11.69 MGD
  - Avoids discharge into Russian River
- **South East Geysers Effluent Pipeline (SEGEP): Since 1997**
  - 30 miles of 20” pipe
  - 2017: 7 MGD (NCPA/CPN)
  - Avoids discharge into Clear Lake

How is The Geysers Sustained?



GEYSERS CHALLENGES:

1. Steam Field corrosion

2. Steam Turbine steam path corrosion/degradation

Corrosion Executive Summary

93,462 MWh Stranded due to Corrosion in 2022

Not all wells are created equal

- 27% > 0.5 ppmw [Cl-]
- 36% < 30°F Superheat

Condensate + Cl = Corrosion

Heat sinks create condensate

Transient conditions create excessive condensate

- DECs and INCs
- PG&E PSPS events (21kV shut-down)
- All Outages
- Wildfires
- Pipeline repair -> line shut-in
  - Additional stranded load
  - Causes corrosion elsewhere

Improved thickness monitoring in 2018

- Proactive repairs

Steam Line Corrosion Prevention

- Active Mitigation
  - CMF, DSHT
  - Other strategies in development
- Passive Mitigation
  - Insulation
  - Segregate steam by temperature

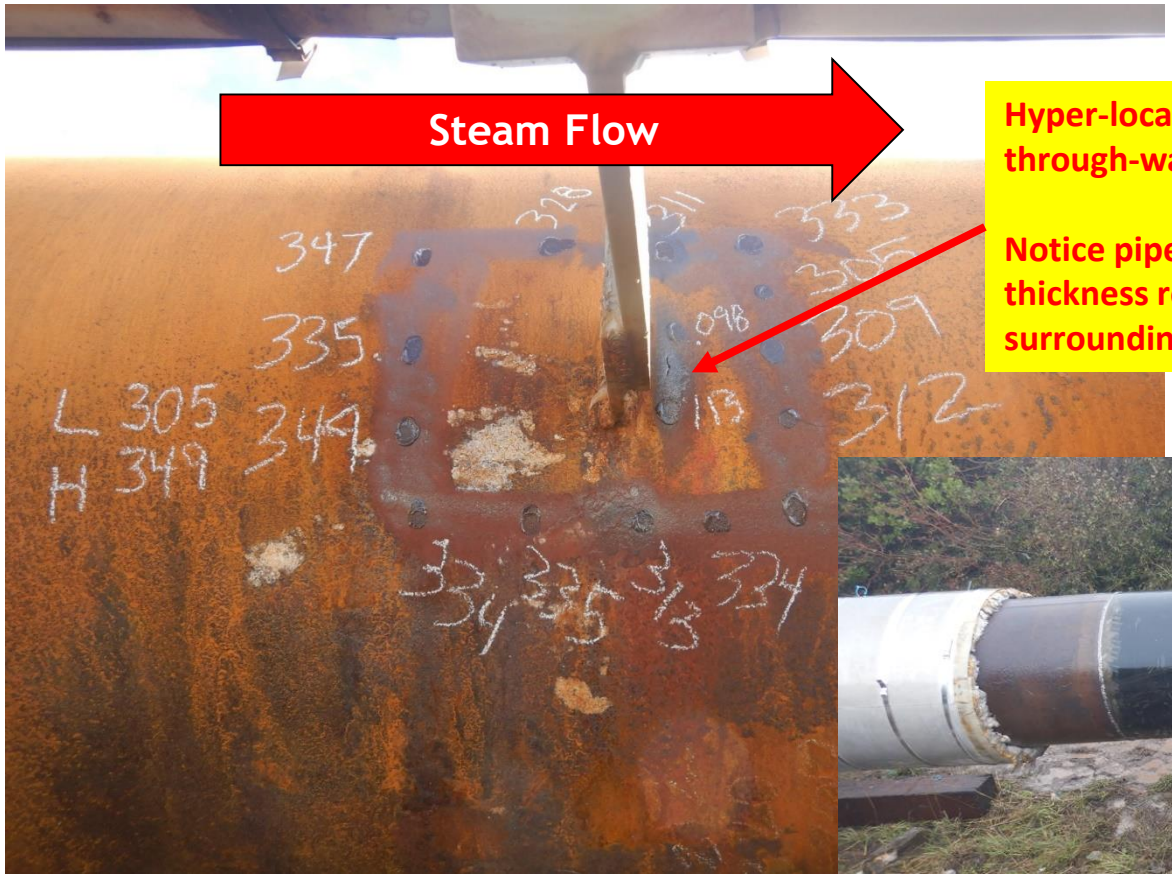
Transient Control

- Turbine Bypass
  - U05-MC issues
- Steamfield configuration control
  - Root line control valves
  - Auto crossover valves
- Generators and transfer switches

Transient Response

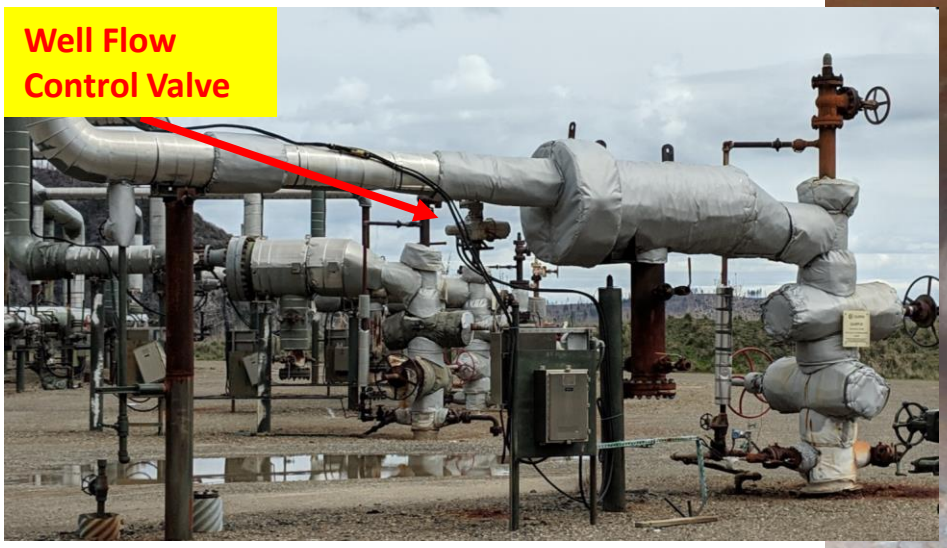
- Load-following DSHT system
  - Only protects plant

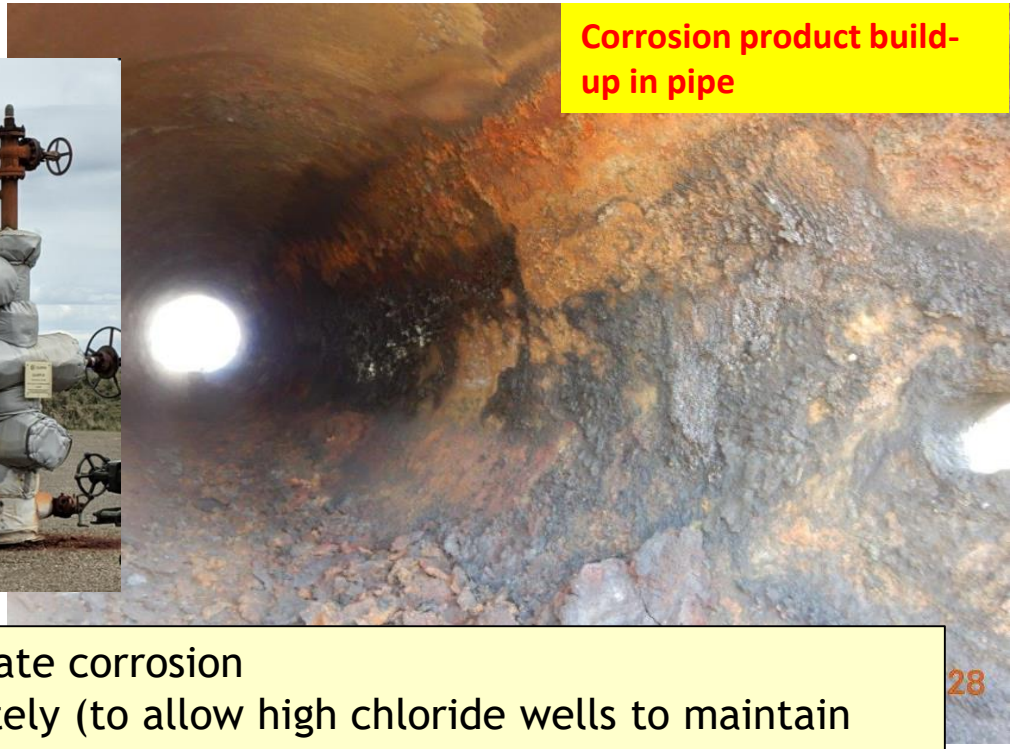
Major Corrosion Contributor – Heat Sinks



- Corrosion requires liquid (e.g. steam condensate)
- Condensate forms at heat sinks and absorbs **chlorides** from steam to form hydrochloric acid
- This acidic condensate moves downstream and evaporates, concentrating the acid

Major Corrosion Contributor – Transient Conditions





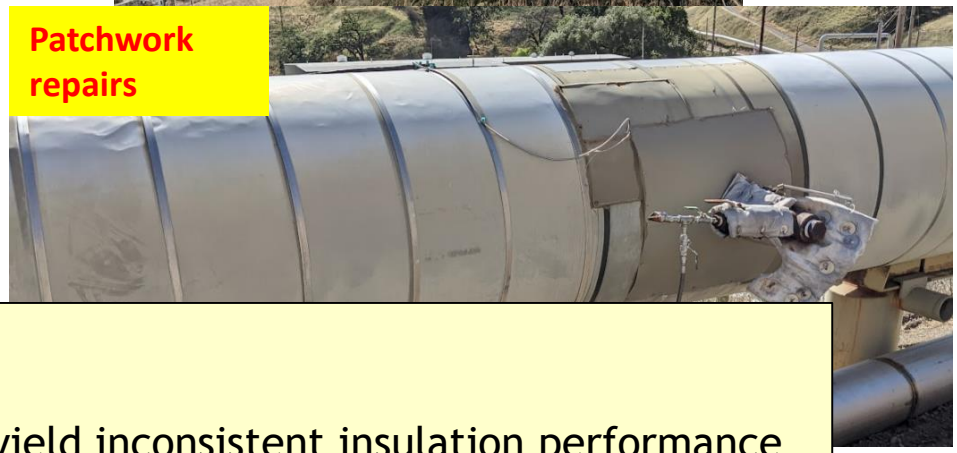
- Transient process conditions exacerbate corrosion
- Most wells cannot be throttled remotely (to allow high chloride wells to maintain steady flow)
- High chloride wells experience most of their corrosion during start-up/shut-in and when throttled
- Low steam velocity and dead legs allow more condensate to form
- Crossovers create low-velocity sections and dead legs, and these migrate during transient conditions
- Most crossover valves are not operable remotely, limiting response to moving dead legs

Major Corrosion Contributor - Insulation Condition

Damage from equipment, wildlife, and environment

Separation of insulation

Patchwork repairs



- No condensate = no corrosion
- Insulation has a limited life span
- Patchwork of varied age and condition yield inconsistent insulation performance
- Cold weather and rain result in increased condensation due to insulation issues
- Replacing all insulation on 18” – 42” pipe: $129,800,000 (materials and labor, excluding scaffolding cost)

THE GEYSERS – "SUPER ROTOR" PROGRAM

ERA-10645
CUSTOMER: PACIFIC GAS AND ELECTRIC COMPANY
PLANT : GEYSERS GEOTHERMAL POWER PLANT UNIT #8

CRACKING AND EROSION PROBLEM OF TURBINE ROTOR

AND NOZZLE DIAPHRAGMS

AUGUST 1979
DEVELOPMENT DEPT., TURBINE WORKS

TOSHIBA CORPORATION

What Problem Are We Trying to Fix?

Solution: Super Rotor Program

U5, Super Rotor Installation, COD 2009

THE GEYSERS – "SUPER ROTOR" PROGRAM

Optimization for Decreased Steam Deliverability Reliability and Efficiency Improvements

Applied reliability improvement technologies

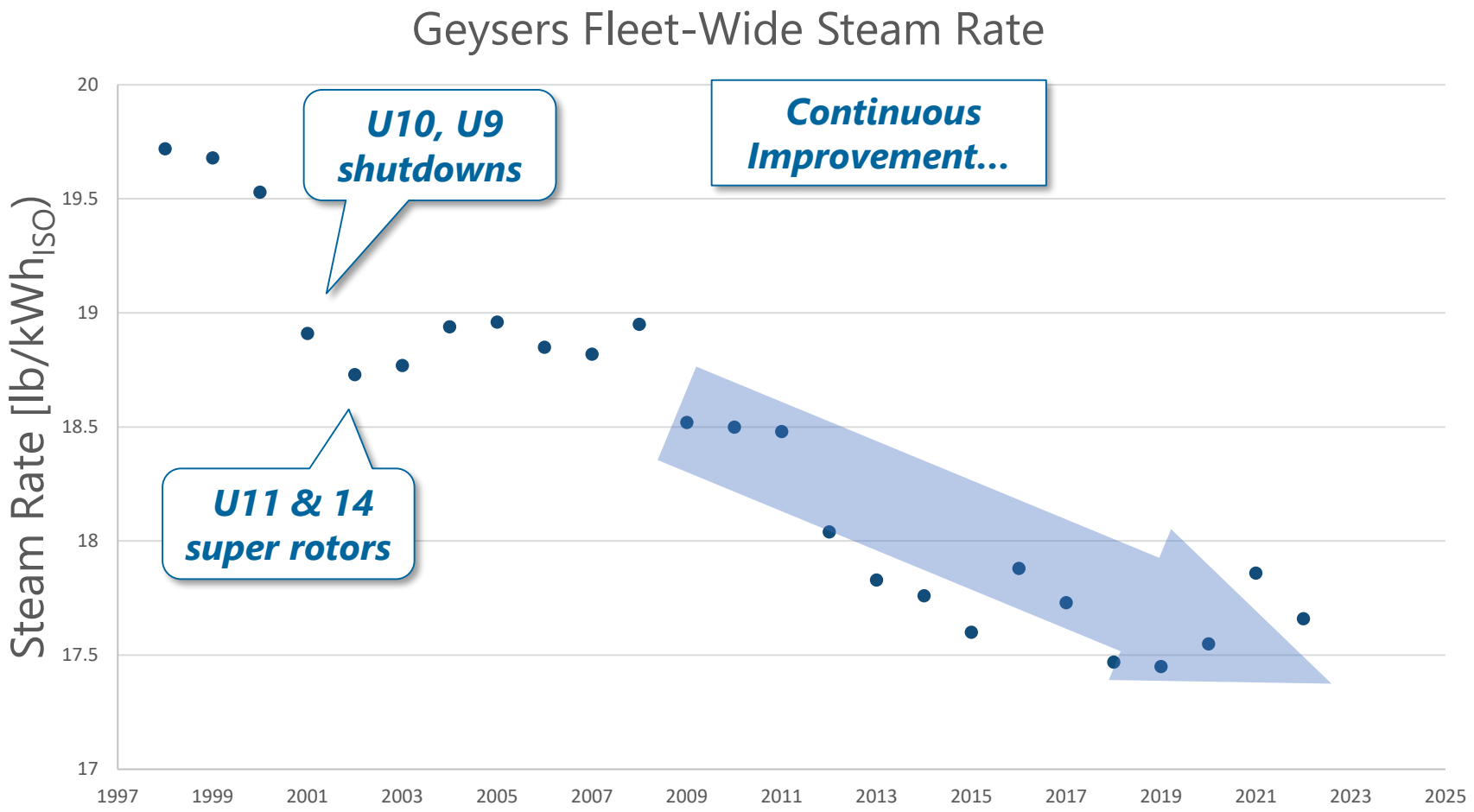
- Special coating technologies for turbine components
- Optimized design and material selection to prevent SCC
- Optimized stress controlled design
- Optimized design for outages works at geothermal units
- Design to extract drainage from steam path to improve turbine efficiency
- etc...

Realized Performance Optimization and 14+ Years to Date of Operation Without Opening Casing

The Geysers – "Super Rotor" Program

Unit	Plant	Date
U14	Sulphur Springs	5/16/2002
U11	Eagle Rock	6/20/2002
U5	McCabe5	1/2/2009
U6	McCabe6	2/28/2009
U7	RidgeLine7	6/19/2009
U8	RidgeLine8	6/22/2009
U17	LakeView	5/4/2011
U18	Socrates	5/7/2012
U19-2	Calistoga19-2	6/28/2013
U20	Grant	11/15/2014
U13	Big Geysers	6/26/2017
U12	Cobb Creek	6/26/2018
U19-1	Calistoga19-1	7/17/2021
U16	Quicksilver	6/15/2022

THE GEYSERS – "SUPER ROTOR" PROGRAM



10% Reduction or improvement in steam rate since 2000

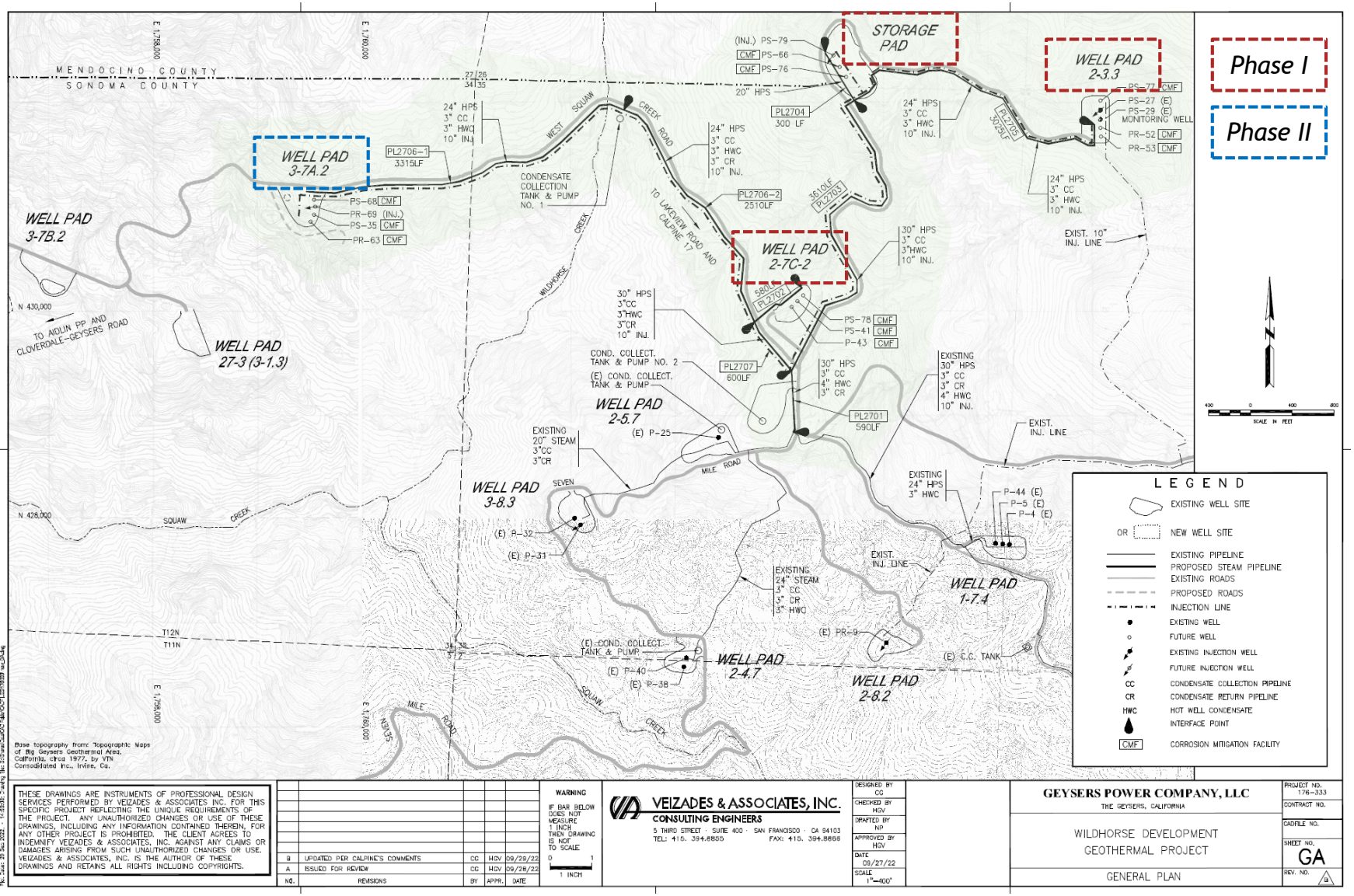
Geysers Development:

I. North Geysers Incremental Development:

- 25 MW's of Incremental Capacity
- 13 Greenfield Wells (11 Production/2 Injection)
- U11 Upgrades – Super Rotor, NCG removal enhancements
- 2 Counter party 20yr PPA's
- Full COD 2026

II. West Ford Flat/Bear Canyon Energy Storage

Incremental Geysers - Drawing for Phase I & II



Geysers Battery Storage Projects

West Ford Flat	*Bear Canyon*
*Energy Storage **25 MW***	*Energy Storage **13 MW***

1. Supports CPUC's reliability target, adding a combined 38 MW of incremental stand-alone storage
2. Projects will be in front of the meter and charge from the Grid – not impacting the Geysers energy output
3. Signed two RA PPAs with PG&E; Delivery date - 7/1/2024.

Projects are in advanced development for 2023 construction and Summer 2024 operation

- ✓ Batteries secured via executed Purchase Agreement with Tesla
- ✓ Site control secured via leasehold agreements
- ✓ Interconnection agreements are in place for the energy storage repower of the sites with point of interconnection at PG&E's Fulton Substation

Tesla MegaPack 2 XL

Safety

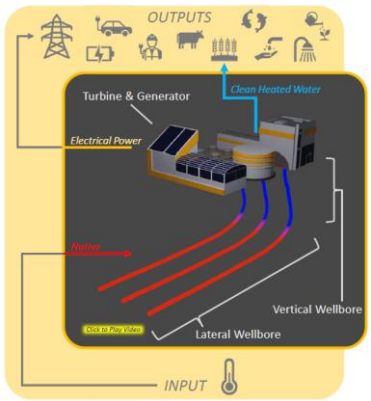
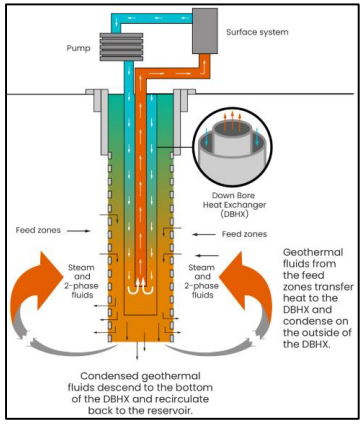
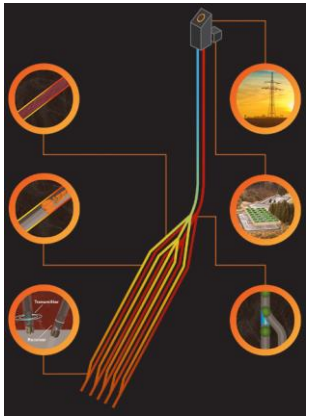
- Tesla leverages its operational experience (5+ GWh deployed) for continued reliability testing and engineering improvements
- MegaPack 2 utilizes LFP (Lithium-Iron-Phosphate) battery chemistry which is a more stable chemistry with less risk of thermal runaway and flammability compared to NMC battery technology

Operation

- Calpine expects to be the Scheduling Coordinator and is contracted with Tesla for the annual maintenance and augmentation through 2039

Targeted Closed-Loop Technology: Overview

Technology Depth

	ICARUS	GreenFire Energy	Eavor™
			
TECH	• Heat exchange within wellbore using casing inner liner	• Downhole heat exchanger	• Chemically sealed well radiator
+/–	+ Removes heat only; Installation above reservoir limits potential impacts to existing generation – POC needed to evaluate overall capacity factor and cost	+ Removes heat only; Steam condenses in well – Concepts not proven; Convert to ORC Systems; Impact to Existing Resource; Scalability (due to <MW/pad)	+ Removes heat only; No interaction with reservoir – Drilling to 21,000 feet through reservoir; Connecting Loop at Depth

QUESTIONS?