Concrete Thermal Energy Storage Enabling Flexible Operation without Coal Plant Cycling

10 MWh-e Pilot Plant at Plant Gaston

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Acknowledgement and Disclaimer

Acknowledgement

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Agenda

- Background
  - Storage and TES
  - Material Testing
- CTES Pilot Plant
  - Objectives and Team
  - Operation
  - Anticipated Performance
  - TES Design
  - Layout
  - Construction
- Q&A

Project Background

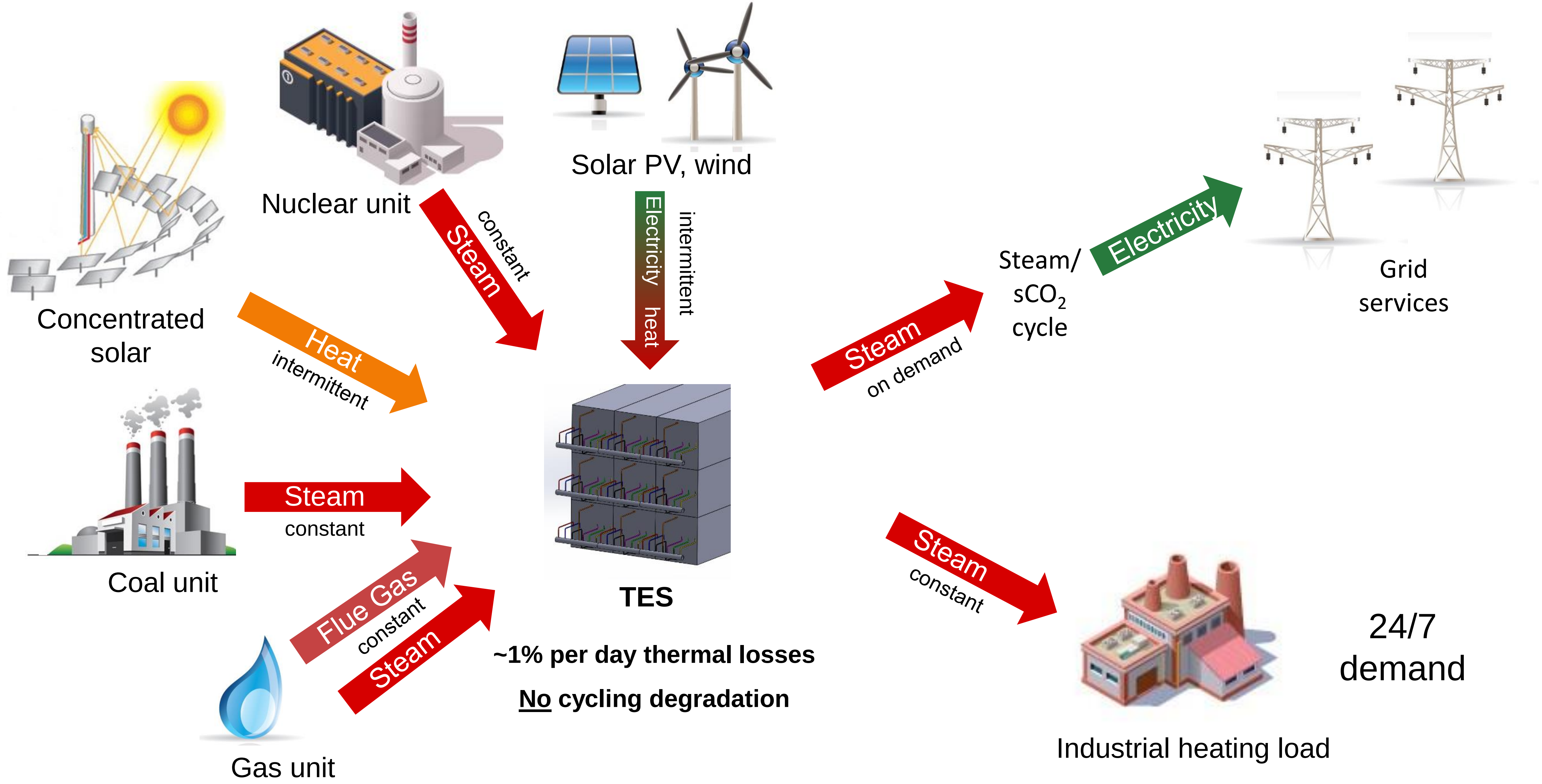
Background – Energy Storage Challenge

- Intermittent renewables are driving thermal plants to provide grid support causing:
  - Damage from cycling
  - Shorter lifetimes, higher emissions per kWh, and lower profitability
- If energy can be stored:
  - Plants can operate during low/negative pricing periods without exporting power
  - Batteries can be used; however, the cost of storage is high at **$1300–2100/kW** for a 4-hour system*; footprint and safety are also issues
  - Longer duration (e.g., 10+ hour storage) is also a challenge for batteries

**Energy Storage Technology and Cost Assessment. EPRI, Palo Alto, CA: 2018. 3002013957*

Thermal energy storage may deliver lower-cost options

Potential TES Applications



~1% per day thermal losses

No cycling degradation

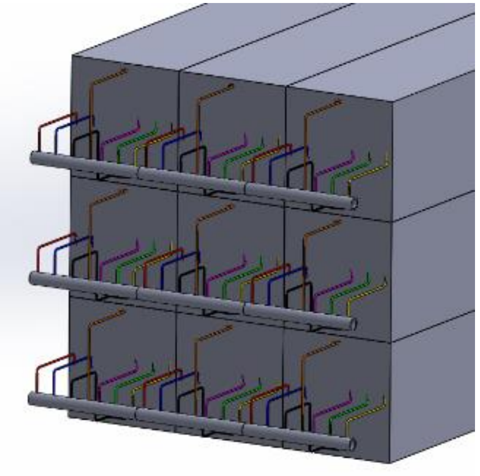
Why Concrete?

Very durable – see 2000-year old Pantheon in Rome, built of concrete!

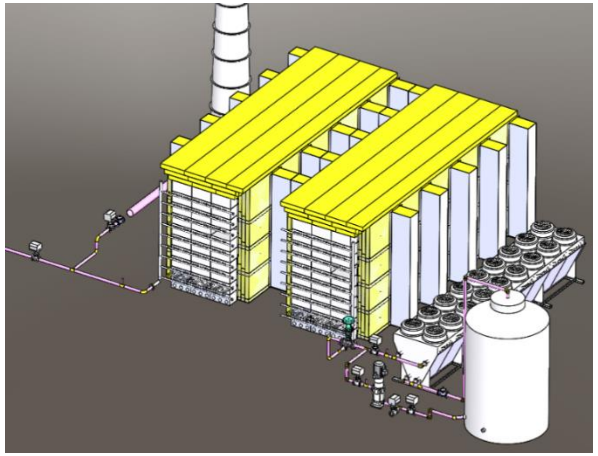
- Potential low-cost TES system
- Solid 'thermocline' structure used to store thermal energy
- Low-cost material ~**$68/tonne**
- Can be easily cast into any shape

3-block, flue gas-heated testing modules

- Steam tubes embedded into concrete monoliths – conductive heat transfer
- No moving parts
- Modular system (41' [12.5 m])
- Road/rail transportable



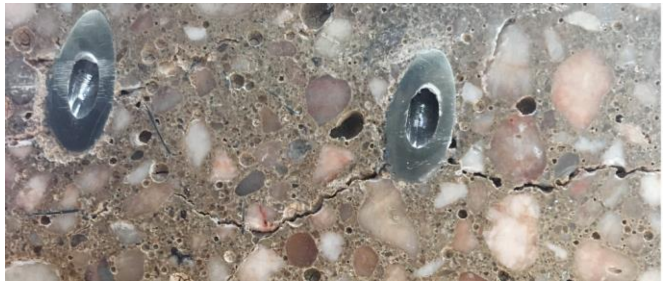
Stackable and scalable



10 MWh-e scale pilot concept

Concrete Material Investigations

- High temperature testing carried out by Storworks and EPRI to verify strength and thermal properties for multiple concrete recipes
- Multiple samples were:
  - soaked at 600°C for up to 5000h
  - cycled 1500 times between 400-600°C
- Properties tested throughout
- Parallel flow stability tested
- Pilot plant designed



Concrete TES Pilot

Project Objectives

“Demonstrate concrete thermal energy storage (CTES) integration with coal power plant to enable low-cost energy storage that will eliminate the need for excessive operational flexibility”

How to achieve this?

Design, construct and test a nominal 10 MWh-e CTES pilot plant at the Alabama Power’s Plant Gaston facility and conduct extensive testing of the system using supercritical steam heating and high-pressure steam generation

CTES thermohydraulic model validation and operating experience

Project Team

Prime

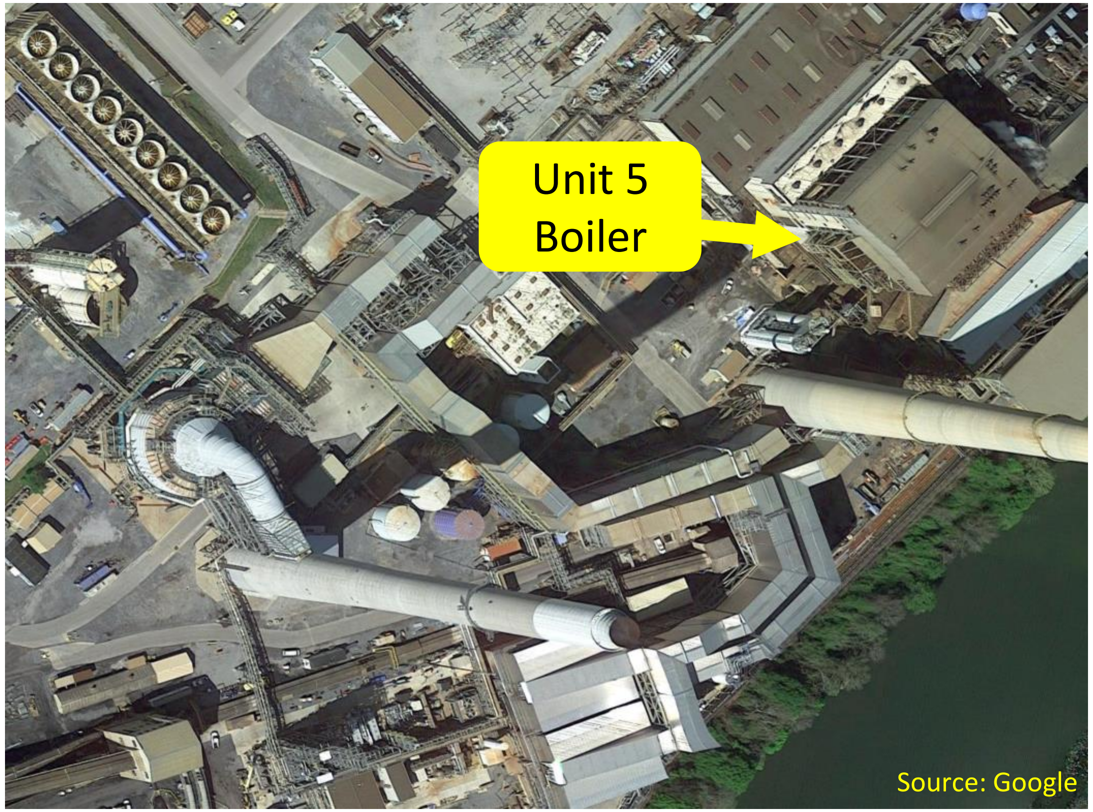
- Electric Power Research Institute, Inc. (EPRI)
  - Scott Hume (PI), Dr. Andrew Maxson, George Booras

Sub-Contractors

- Storworks Power (Bright Energy)
  - Mike Matson, Cully Little, John Kreuder
- Southern Company
  - Josh Barron, Scotty Westbrook (site)
- United E&C (formally AECOM)
  - Steven Mastrangelo, John Kulbaga

High Level Details

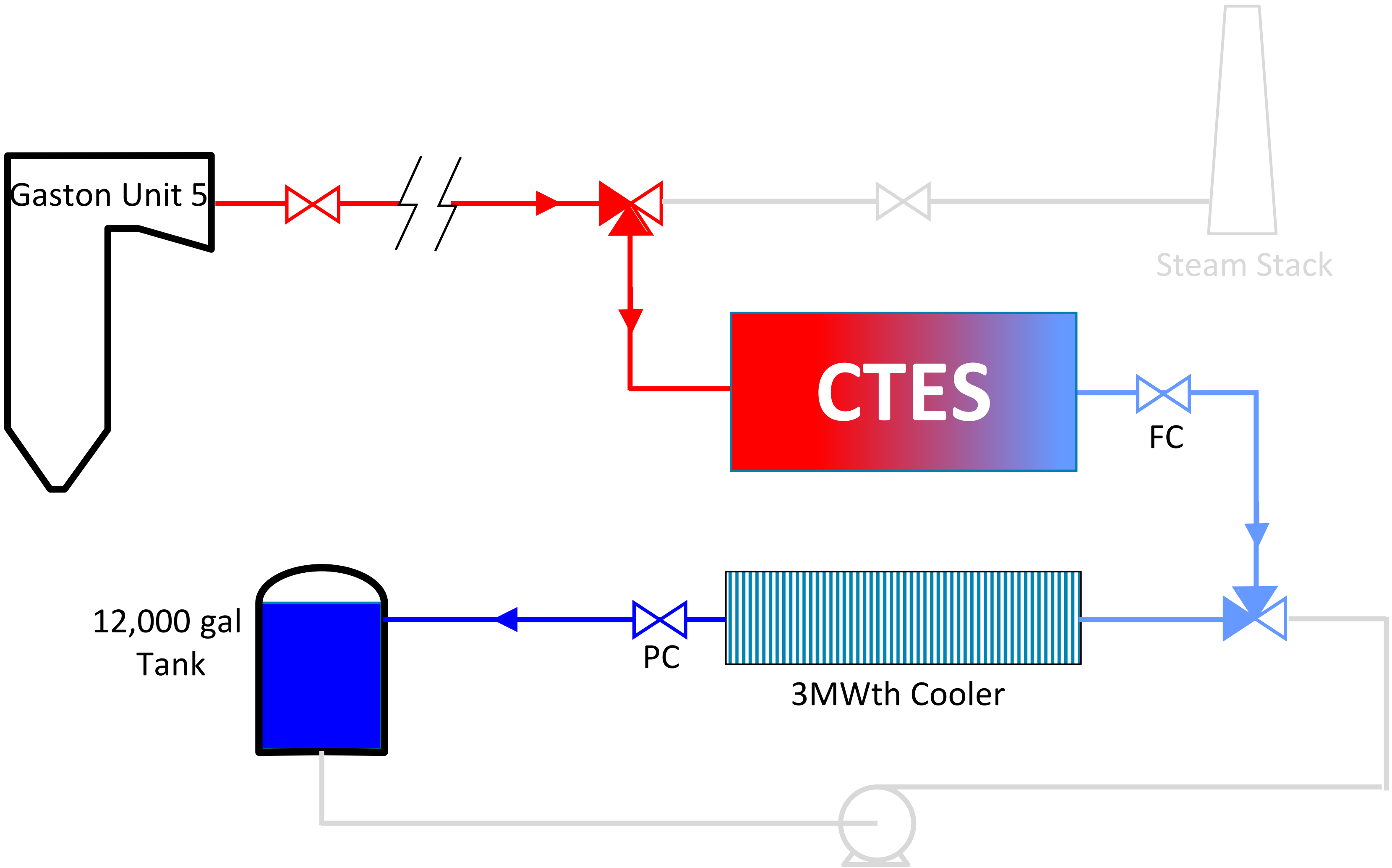
- 10 MWh-e scale (>30 MWh-th)
- Location – Plant Gaston
- Details (per block)
  - 0.24 MWh-e => 42 total needed
  - 7 m^3, 20 tonnes
  - 30”x 36”x 41’ (road/rail transport)
- TES Assembly
  - Arrangement: 7 high, 6 modules wide
  - Insulated/Cladding similar to HRSG
  - Overall size 20’ tall, 22’ wide, 42’ long



Alabama Power’s Plant Gaston

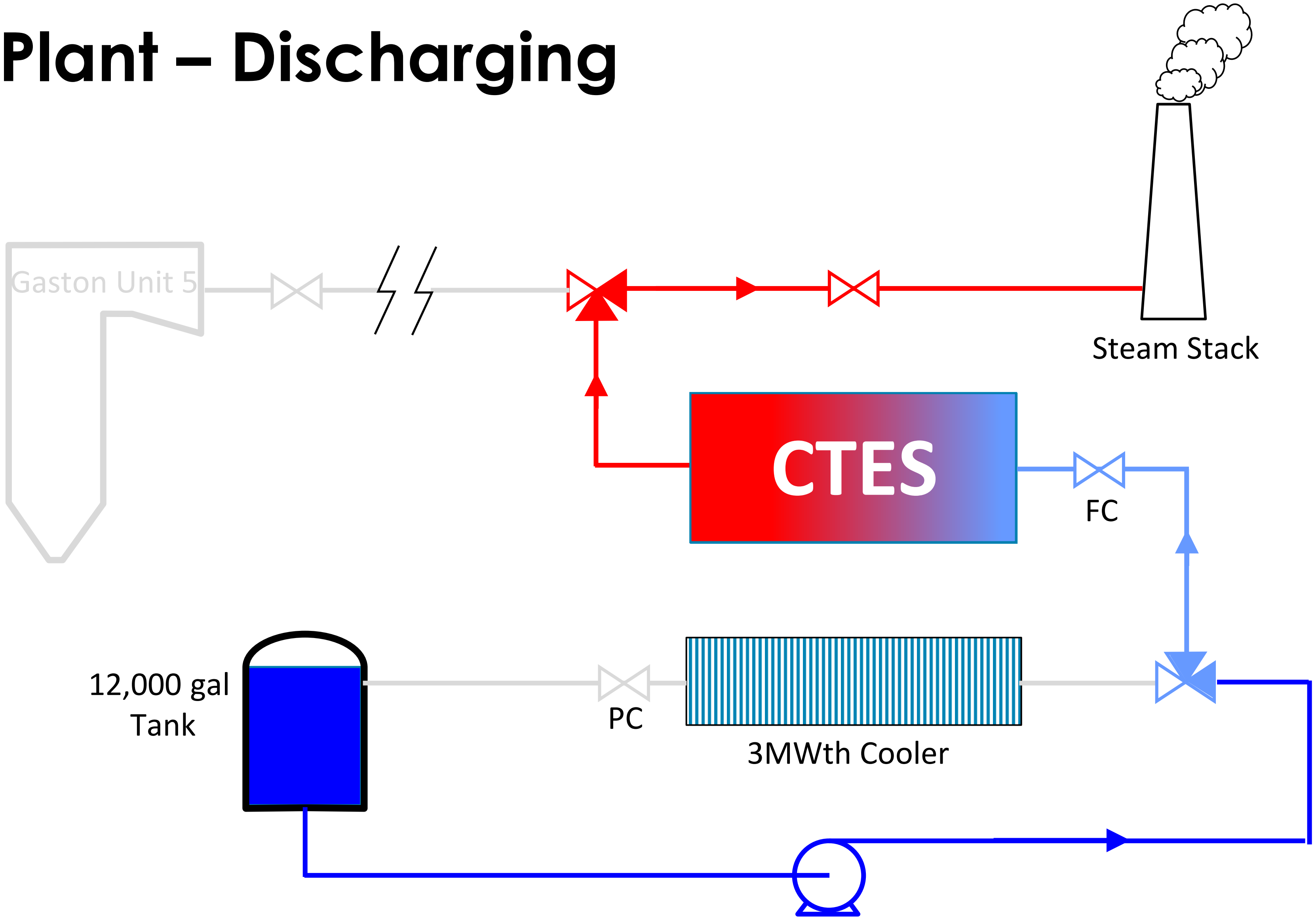
Supercritical steam source – representative of full scale

CTES Pilot Plant – Charging



Supercritical steam condensed, cooled and stored

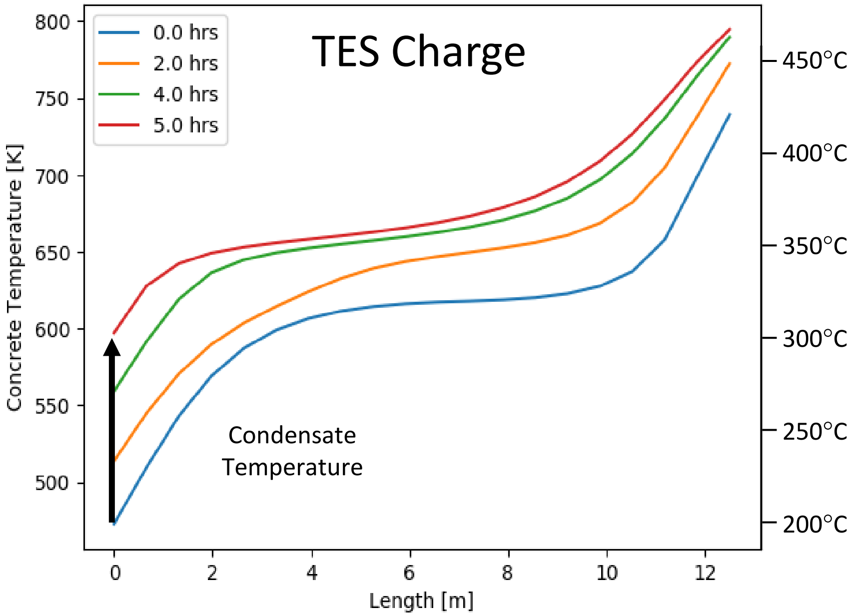
CTES Pilot Plant – Discharging

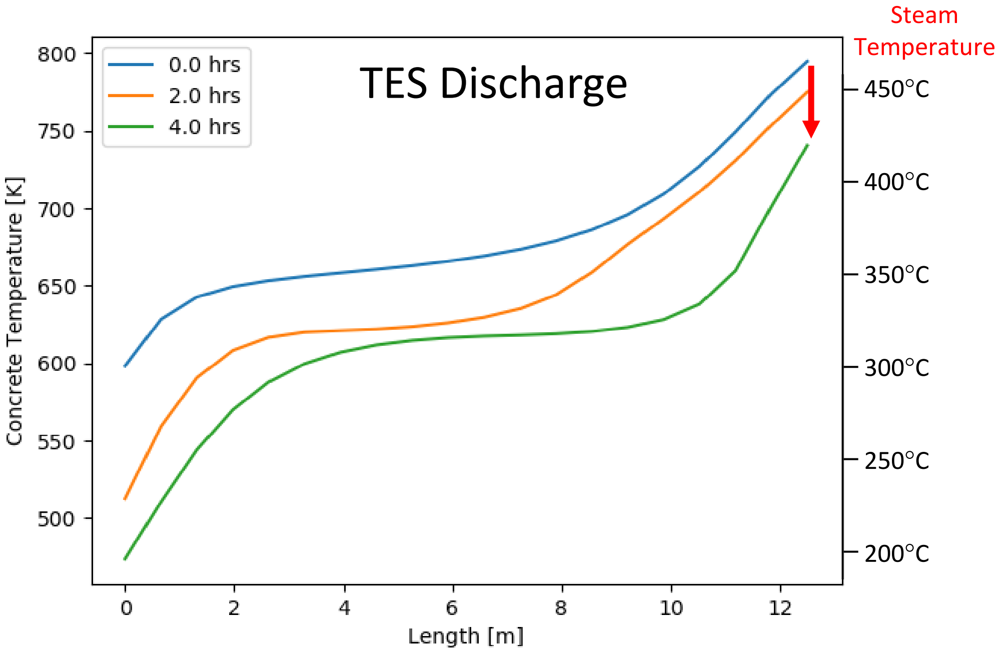


Generated steam measured and disposed

Anticipated Performance

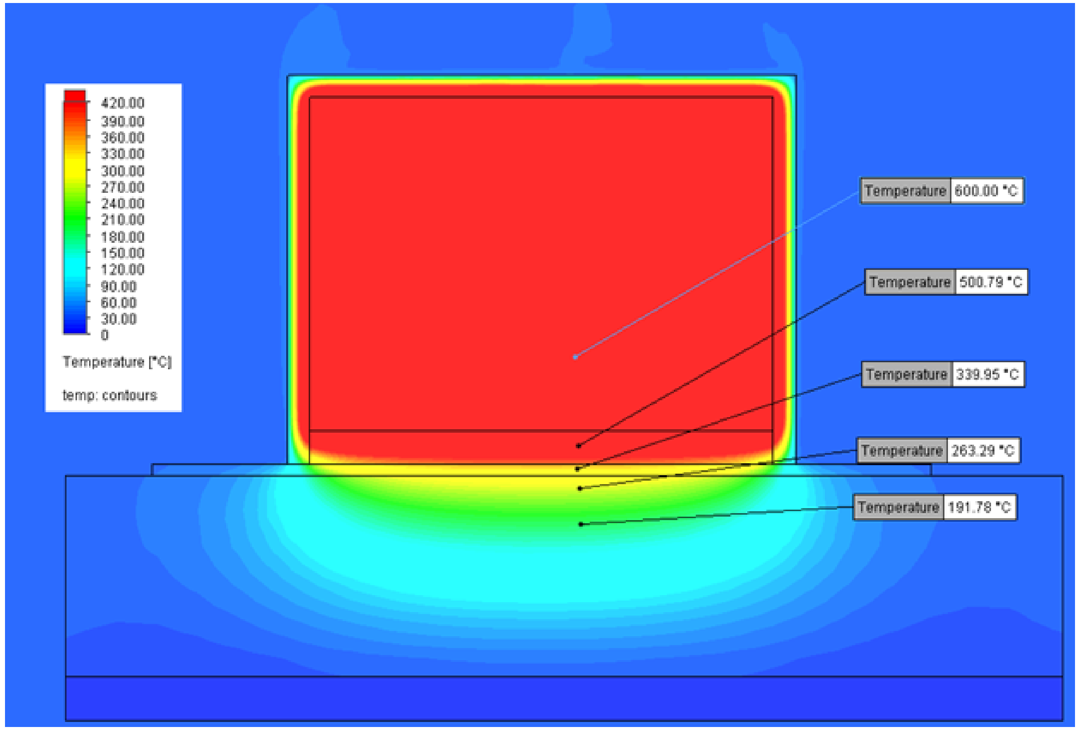
- Supercritical steam heats TES, cooling to high pressure condensate
- For discharge, lower pressure and temperature steam generated
- Effective 'Round Trip Efficiency' is the lost work potential

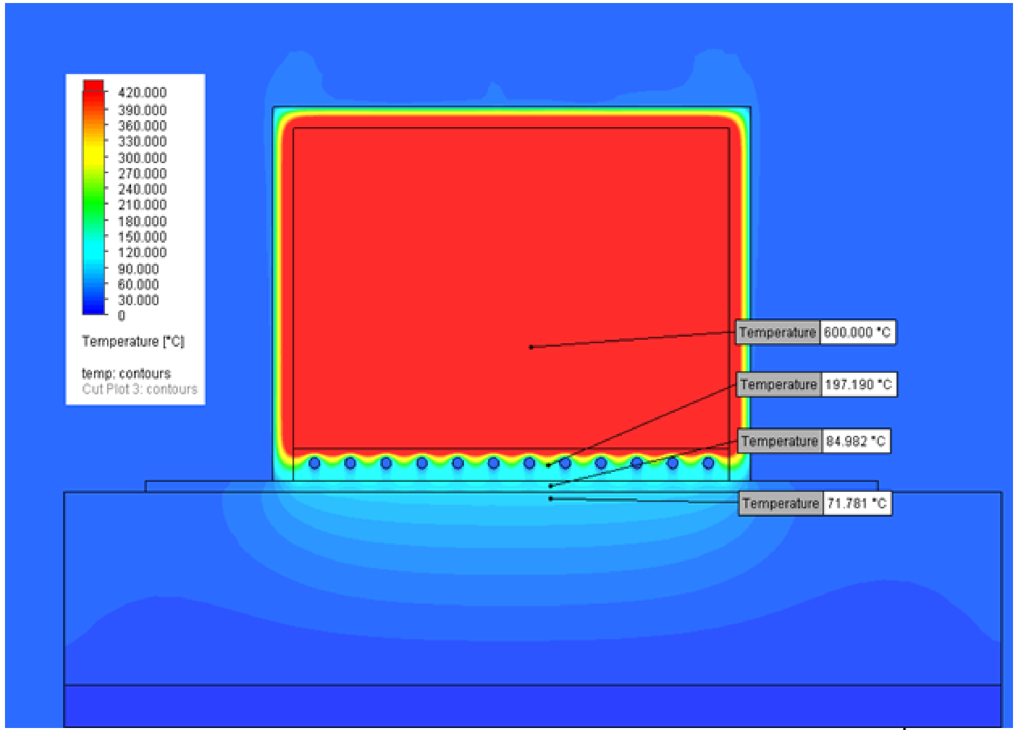




Protecting the CTES foundation

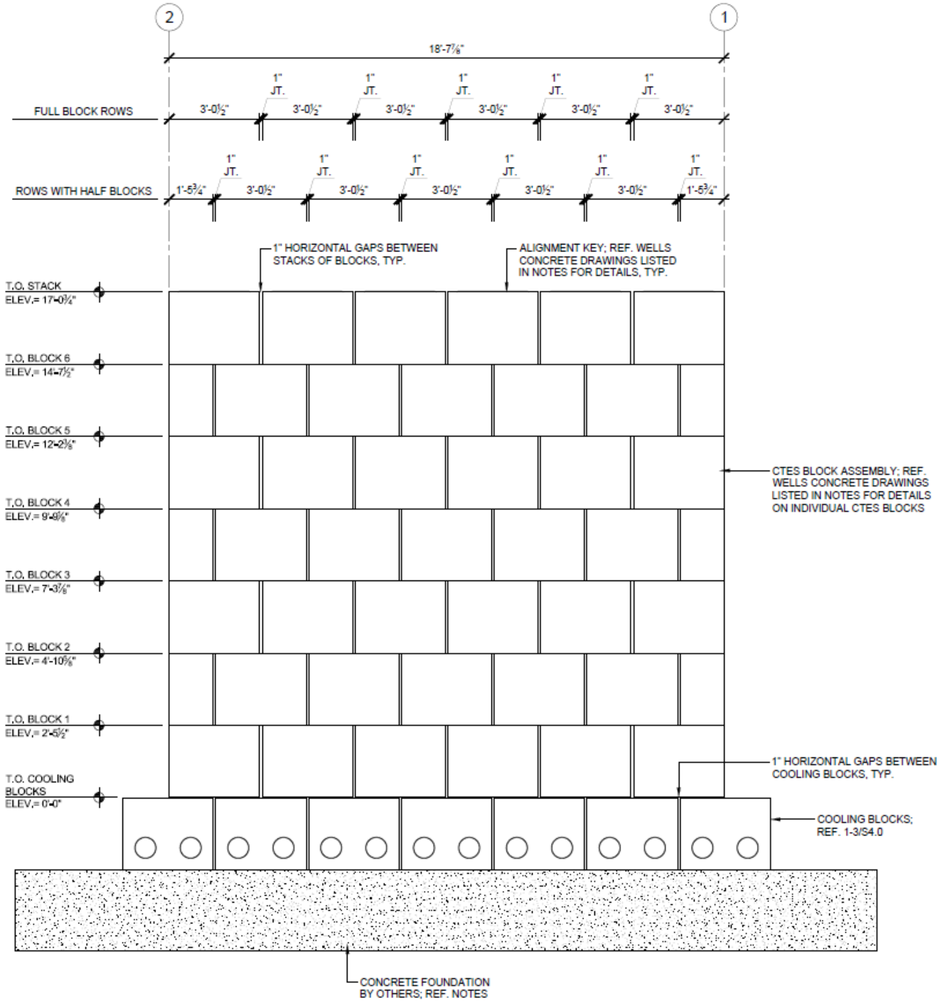
- Finite element conduction model showed extensve thermal energy transmission to foundation
- Actively cooled blocks designed to intercept the heat conduction, limiting the maximum foundation temperature to <75°C (167°F)





CTES Structural Aspects

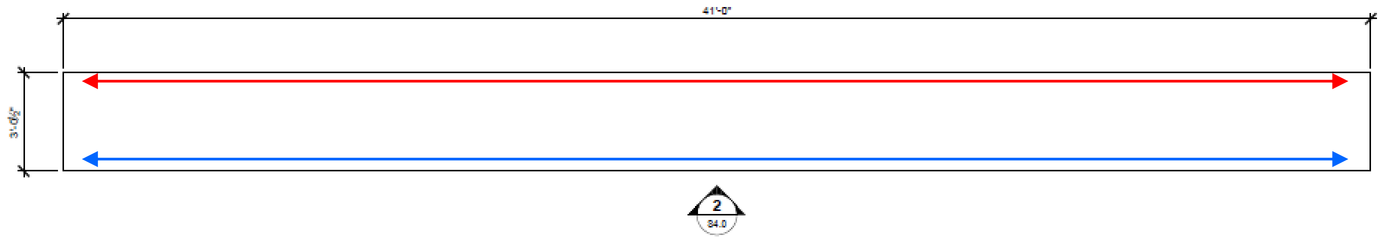
- Original design used column stacks
- For seismic structural requirements, a brick wall approach was introduced
- 6 ‘half blocks’ needed
- 1” gap between adjacent blocks
- Cooling blocks extended to increase stability



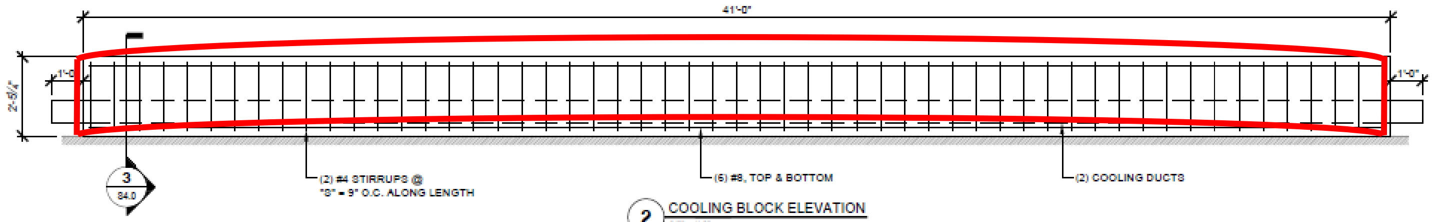
1 CTES BLOCK ASSEMBLY: FRONT ELEVATION
3/8" = 1'-0"

Cooling Block Structural Design

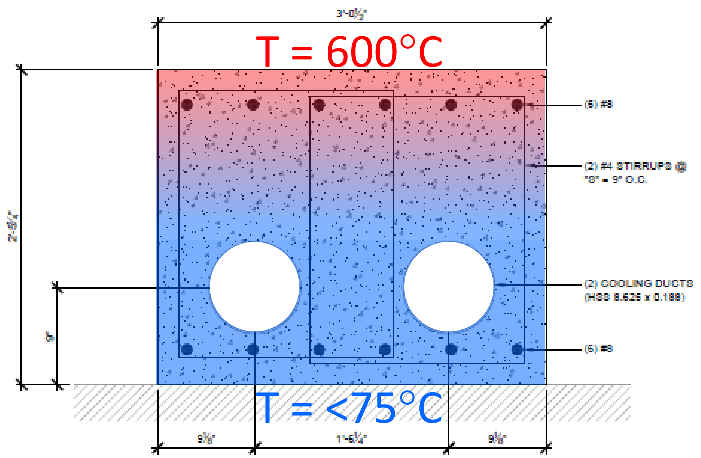
- Cooling block undergoes substantial temperature gradient during operation
- Block tendency to ‘bow’
- Rebar used to hold block down to avoid uneven forces on the center of the TES modules



1 COOLING BLOCK PLAN



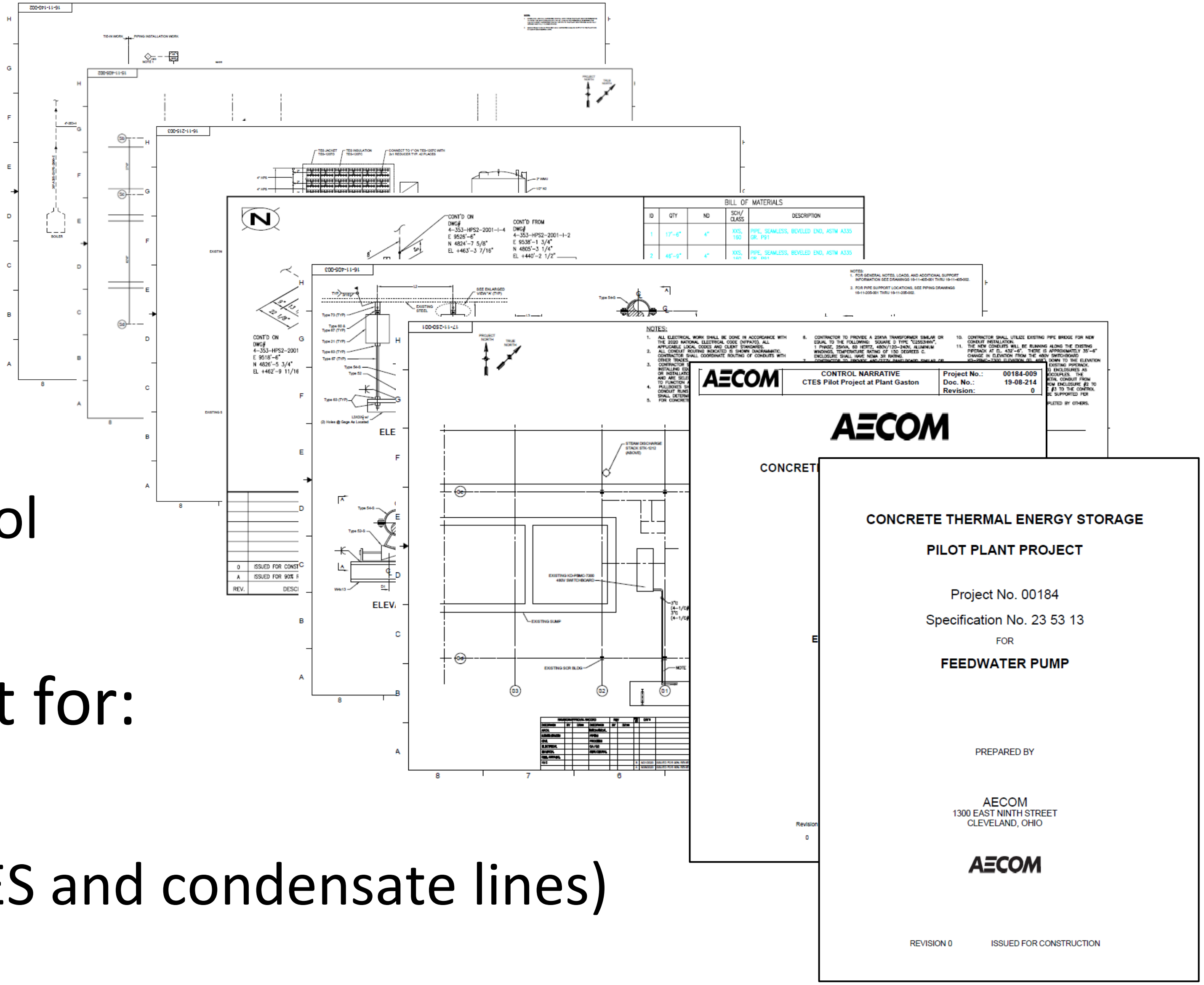
2 COOLING BLOCK ELEVATION



3 COOLING BLOCK SECTION

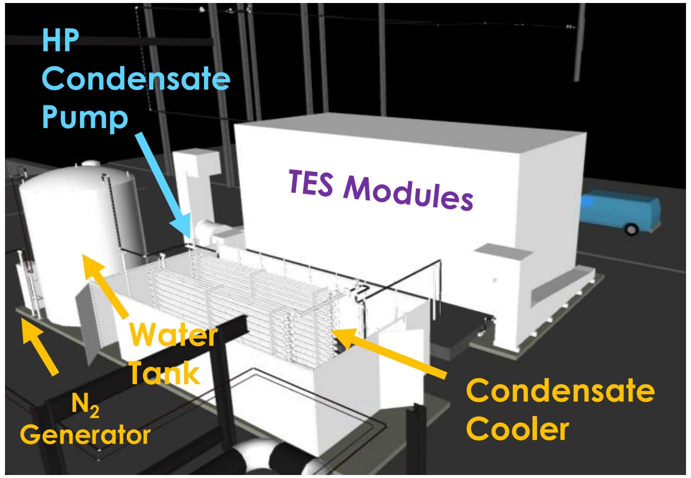
Detailed Design

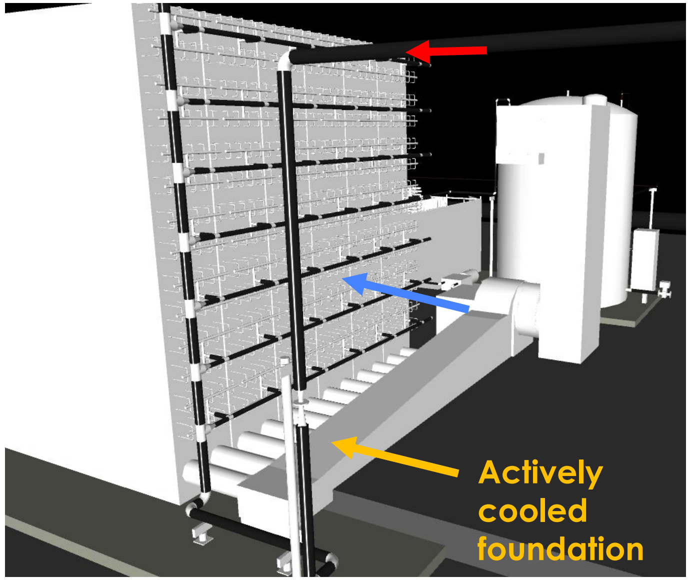
- 76 documents produced
  - Process
  - Mechanical
  - Piping
  - Electrical
  - Instrumentation and Control
  - Specifications and Lists
- Some redesign carried out for:
  - Steam interface relocated
  - Reduced piping costs (at TES and condensate lines)



Pilot Plant Layout

- Compact design next to Unit 5 SCR
- Two main foundation pads
  - Main TES blocks, cooling fan
  - Balance of plant (condensate cooler, water tank, nitrogen blanketing, feedwater pump)
- 800 ft of 4” P91 steam pipework needed
- Local DCS with feedback to Unit 5
- Convenient access to power and boiler water





Construction Progress

- Long lead item procurement started
- Foundation scope contacted
- TES blocks 100% manufactured
- Cooling blocks underway

Commissioning expected by the end of 2021, testing 2022

Q&A

Special thanks to Steven Markovich for his support during this endeavor!

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