University of Washington: Balancing Reliability and Sustainability with DRUPS

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De-Carbonizing the Campus: Planning, Tools & Technologies
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What's a DRUPS?

Short for **Diesel Rotary Uninterruptable Power System**

Similar to a battery powered UPS some of you may have at home or at work to protect your computer.

DRUPS =

UW Overview

- Founded in 1861 as the Territorial University of Washington
  - Seattle Campus moved to its current location in 1895
  - Composed of three campuses: Seattle, Tacoma and Bothell
  - 2022 Enrollment – 60,106
  - Square footage – 29.3 million
  - 7.5 miles of utility tunnels

UW Seattle Campus Facts and Energy Usage

- Campus Population- over 50,000 students and staff.
- Gross Floor Area- 17,933,923 Ft^2
- FY 21/22 Electrical Cost- $23.5 million*
- FY 21/22 Water Cost- $2.5 million
- FY 21/22 Sewer Cost- $5.7 million
- FY 21/22 Natural Gas Cost- $8.7 million

* FY = UW fiscal year, July 1 to June 30.

Source- Google Maps Photo

634 Acre UW Seattle Campus

Plant Overview

- The current facility is the third steam plant built by the UW
  - The first plant built in 1895 was replaced in 1901, which was then replaced by the 1908 plant, the site of the current plant.
  - Primary fuel - Natural Gas
  - Power purchased from Seattle City Light

University Sustainability Goals

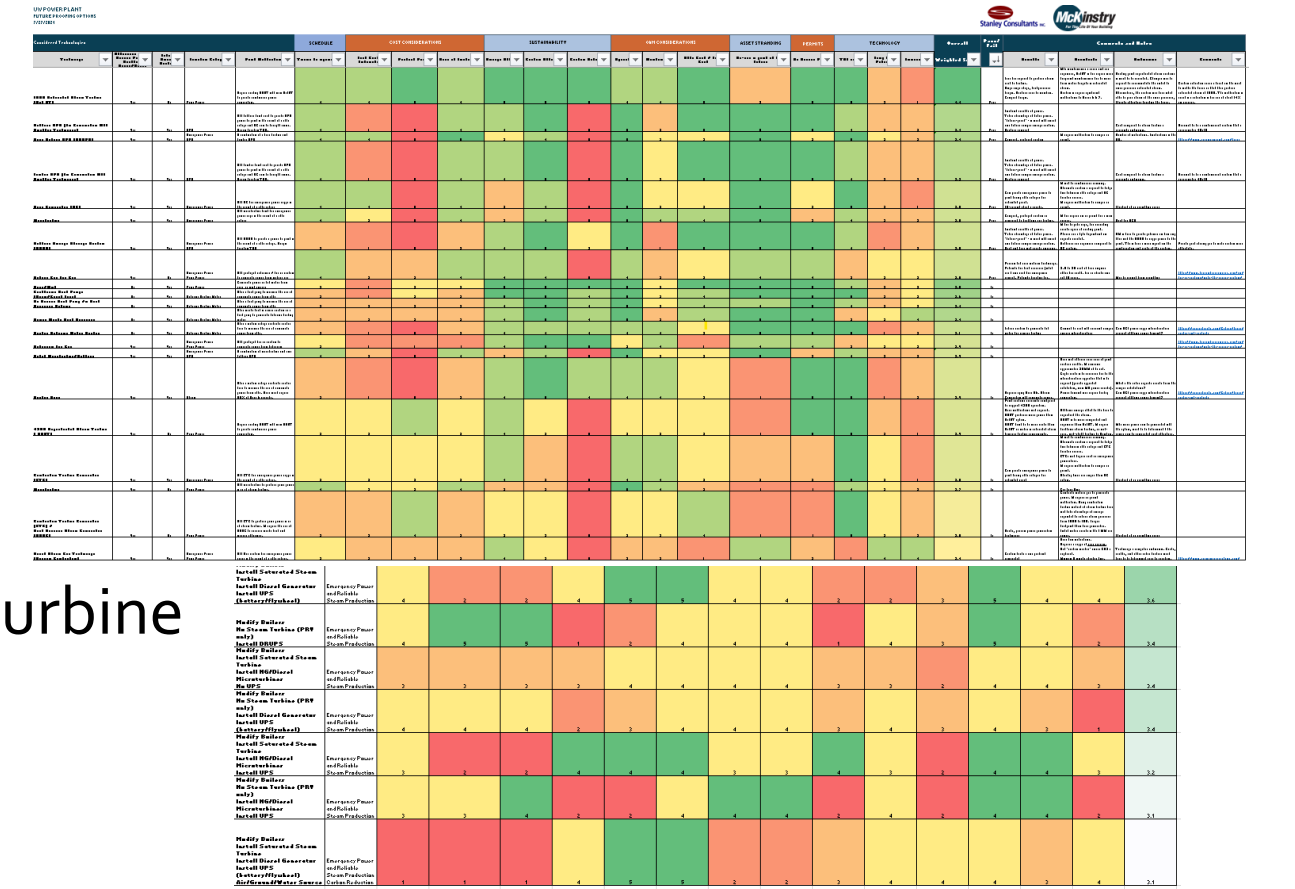
- Relevant Info from Sustainability Plan
  - Divest from fossil fuels
  - 15% energy use reductions
  - 45% GHG reduction
  - Any modernization of plant would have to involve a reduction in GHG.

Infrastructure Renewal Feasibility Study

- Project Goals
  - Uninterruptable Power Supply to Plant
  - Increased Plant Reliability / Plant Simplification
    - Single Steam Pressure
    - Update Legacy BMS and Boiler Instrumentation
    - Decommission Existing Turbine Generator
  - Maintain or Improve Plant Efficiency
  - Deliver Project In Line with Sustainability Goals
    - Sustainability Committee Buy-in

Infrastructure Renewal Feasibility Study

- Options Considered
  - Fuel Cells
  - Renewables
  - Heat Pumps
  - Sewer Waste Heat Recovery
  - Electric Boilers
  - Combustion Turbine / Microturbine
  - Combinations
  - Many Others



Infrastructure Renewal Feasibility Study

- Options Selected
  - Boiler Derate - Saturated Steam at 185 PSIG
    - Lower Heat Input per Pound of Steam (Sustainability)
    - Single Steam Header Pressure (Reliability/Redundancy/Simplicity)
  - New Backpressure Steam Turbine Generator- Saturated Steam, 185 psig to 10 psig
    - Coincidental Energy Recovery (Efficiency)
    - Does not Supply Plant in Blackout
  - Diesel Rotary UPS (DRUPS)
    - Uninterruptable Plant Power Supply (Reliability/Redundancy/Simplicity)
    - Operates on Electricity not Steam (Sustainability)

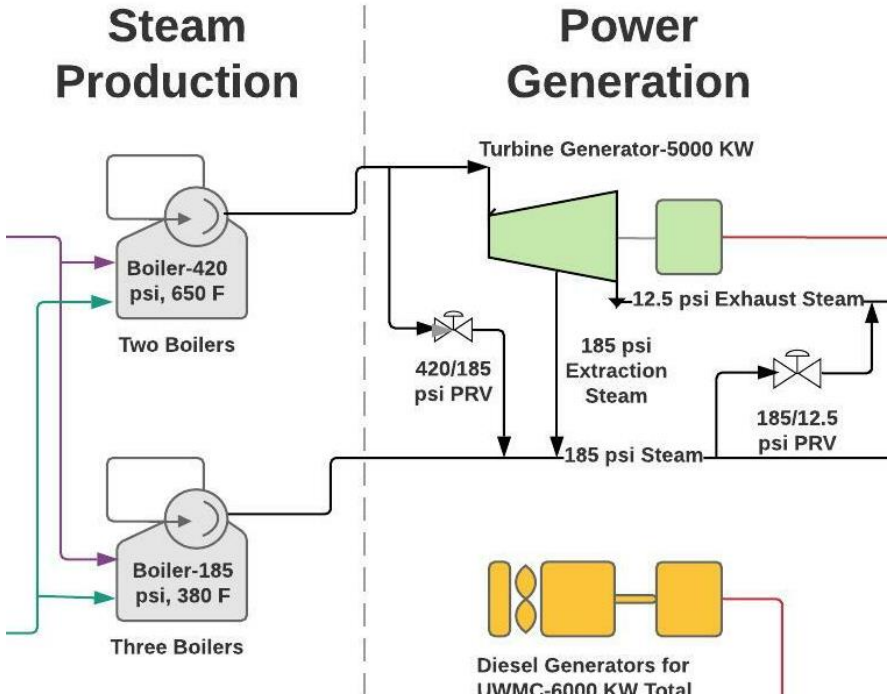
Existing Steam Cycle

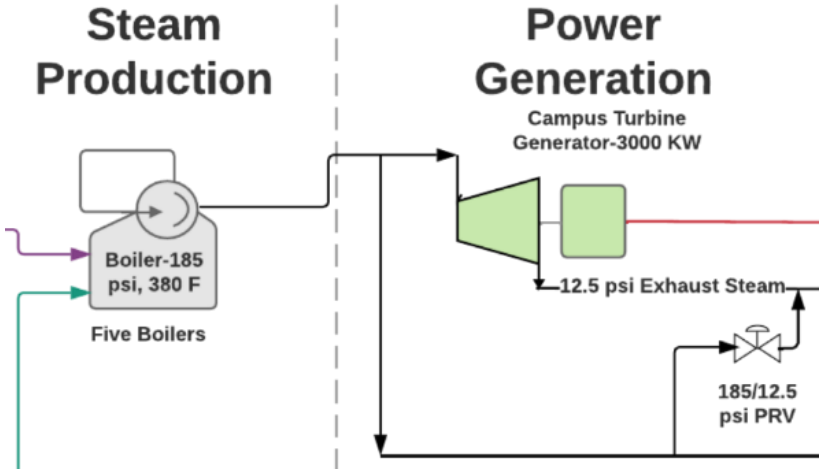
- Boilers 3 – 5
  - Dates: 1948-1994
  - 185 PSIG Saturated
  - Common FW and Steam Headers
- Boilers 6 & 7
  - Dates: 1968 & 2000
  - 425 PSIG Superheated
  - Common FW and Steam Headers
  - Connected to Existing Steam Turbine

Existing Steam Cycle

- Steam Turbine Generator
  - Installed 1968
  - 12.5 PSIG Backpressure with 185 PSIG Extraction
  - Dual Purpose
    - Combined Heat & Power
    - Emergency Plant Power Supply
  - No Longer Reliable

Steam Cycle Modifications





Boiler Modifications

- Contacted OEMs to Study Feasibility
  - Boiler 6: Indeck Power Equipment Company
  - Boiler 7: Amec Foster Wheeler (Wood PLC)
- Recommended Modifications

Boiler 6:

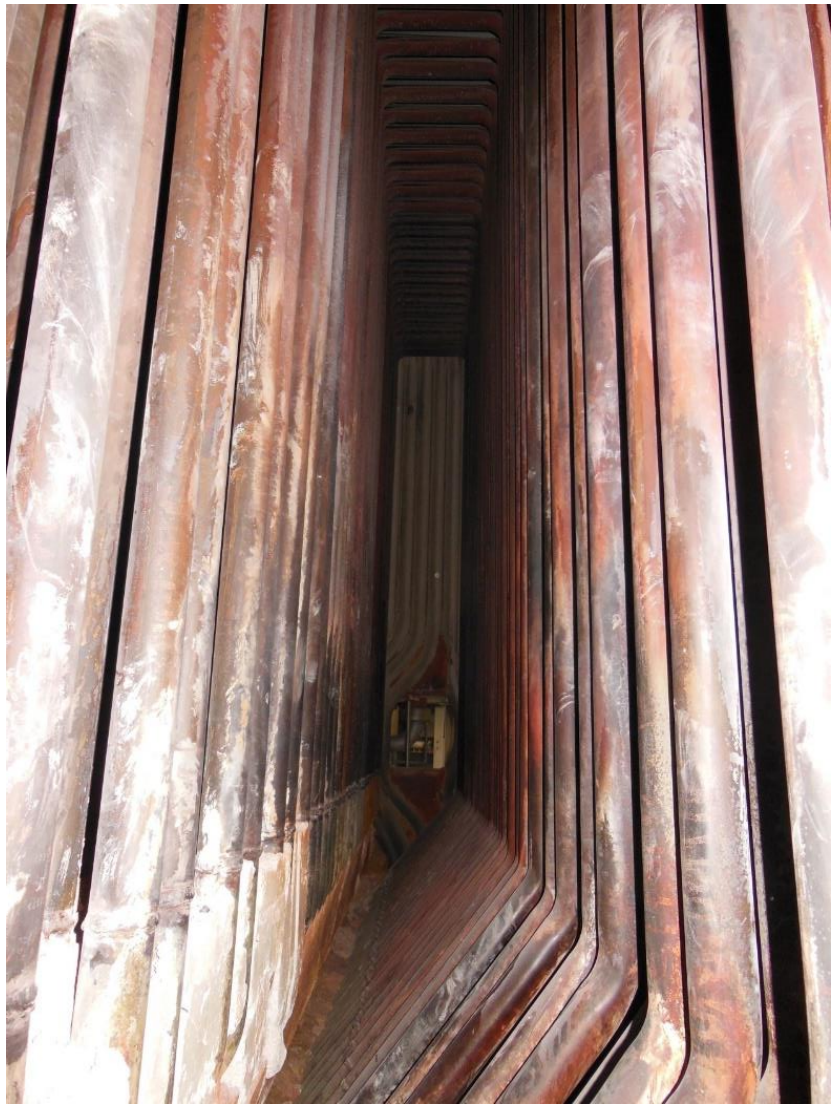
- Superheater Removal
- Installation of 12 Additional Reliever Tubes
- Replacement of Steam Drum Internals

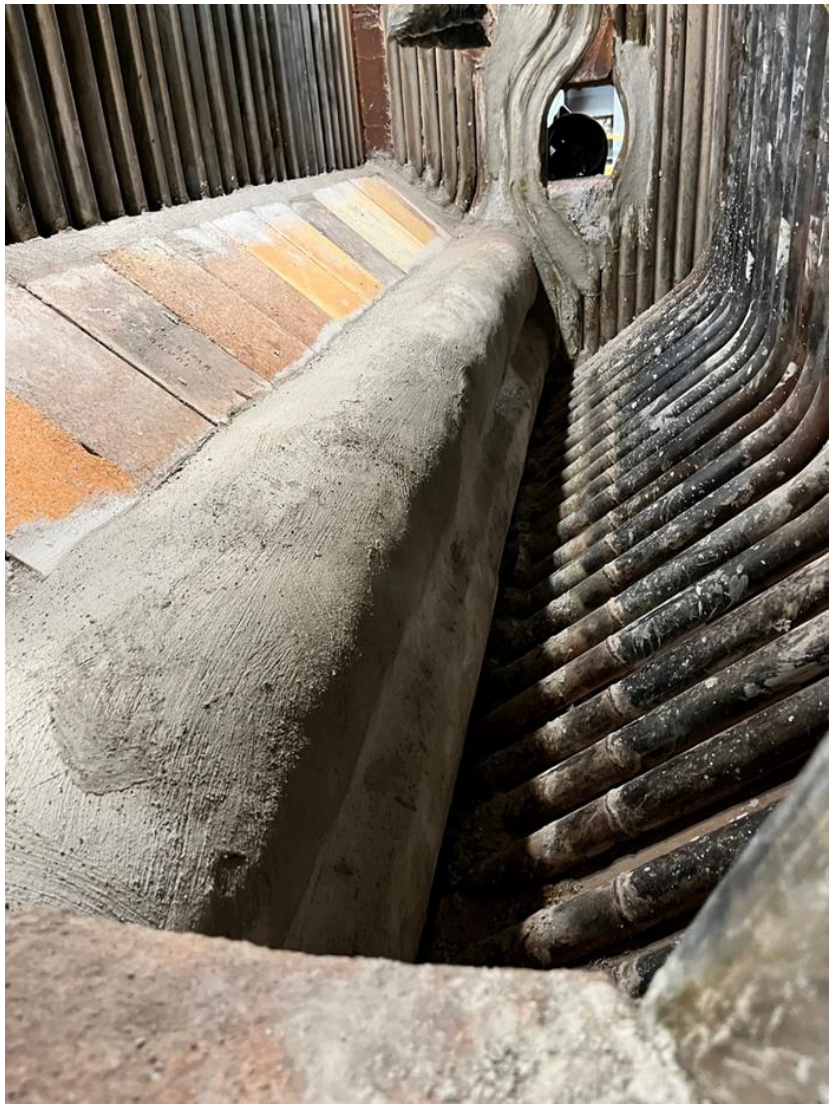
Boiler 7:

- Superheater Removal
- Economizer Tube Reduction
- Replacement of Steam Drum Internals

- Also Replacing Obsolete BMS and Boiler Instruments

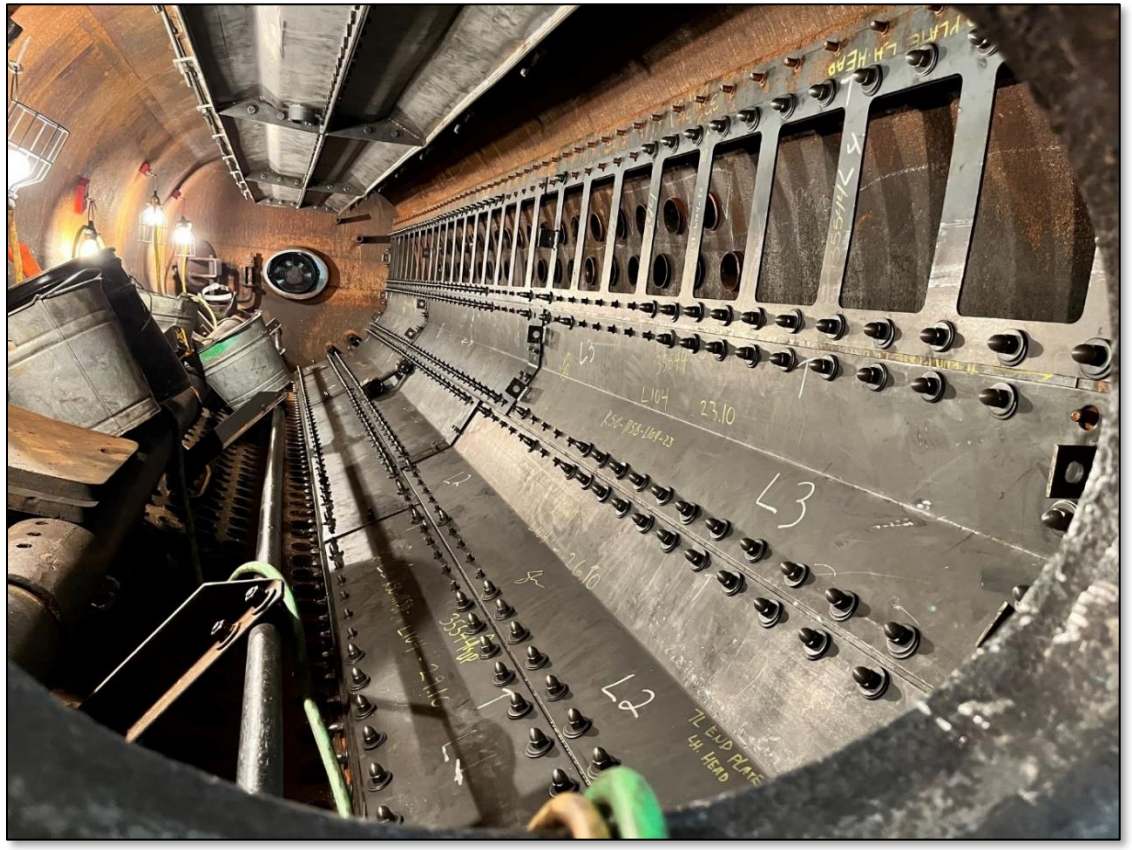
Boiler #6 Superheater Removal





Superheater Removal Before and After

Boiler #6 Modifications



Steam drum before and after modification

Piping Modifications

- Boiler 6
  - Steam Piping Rerouted to 185# header
  - Temporary Feedwater Regulating Valve Installed

- Boiler 7
  - New Low Pressure Feedwater Header Serving Boilers 6 and 7

Boiler #6 Returned to Service November 2022

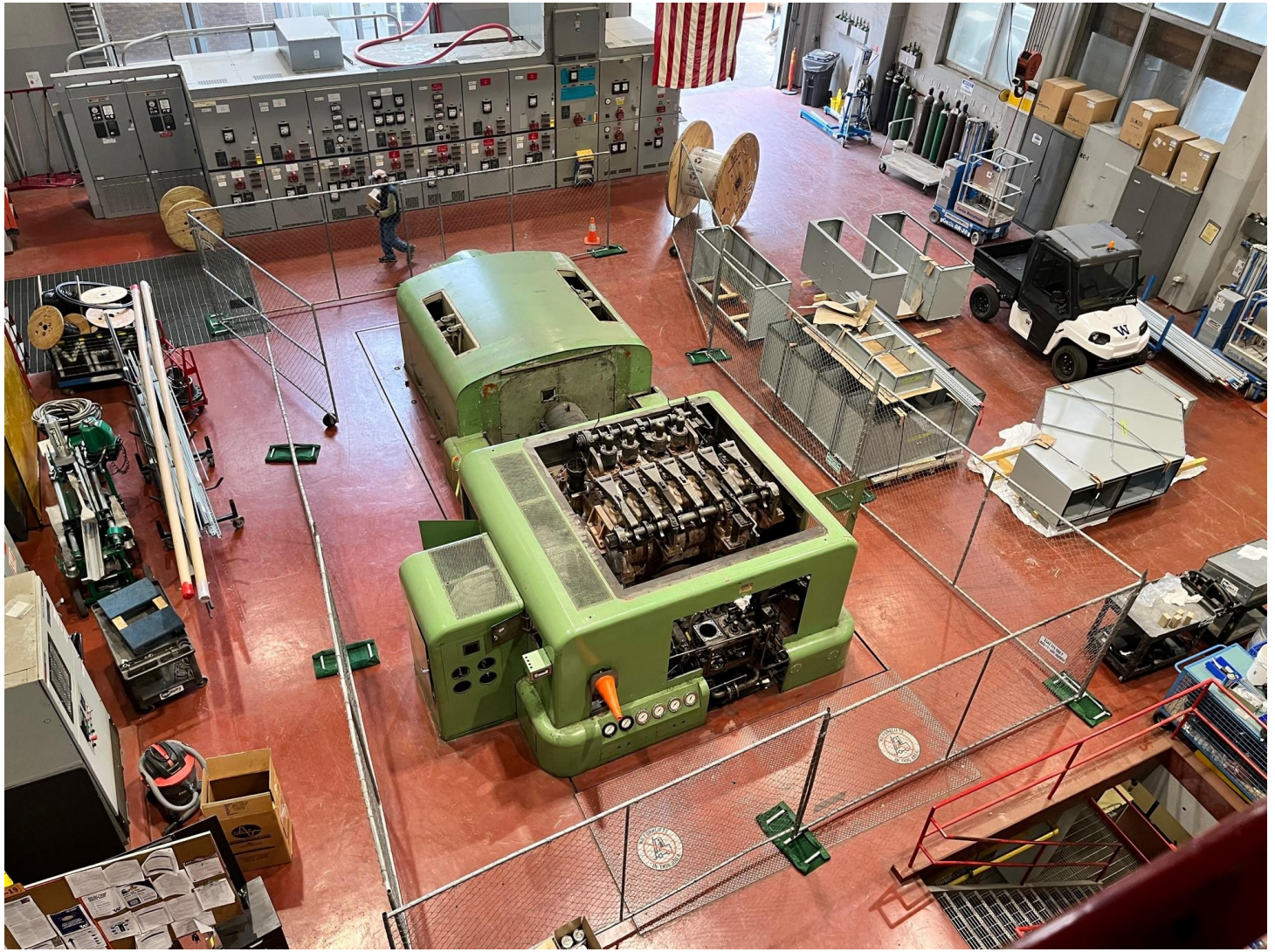
New Steam Turbine Selection

- Single Stage, Backpressure Unit
- Saturated Steam
- 185 PSIG to 12.5 PSIG
- 3 MW Maximum Capacity
- Compact Modular Form Factor

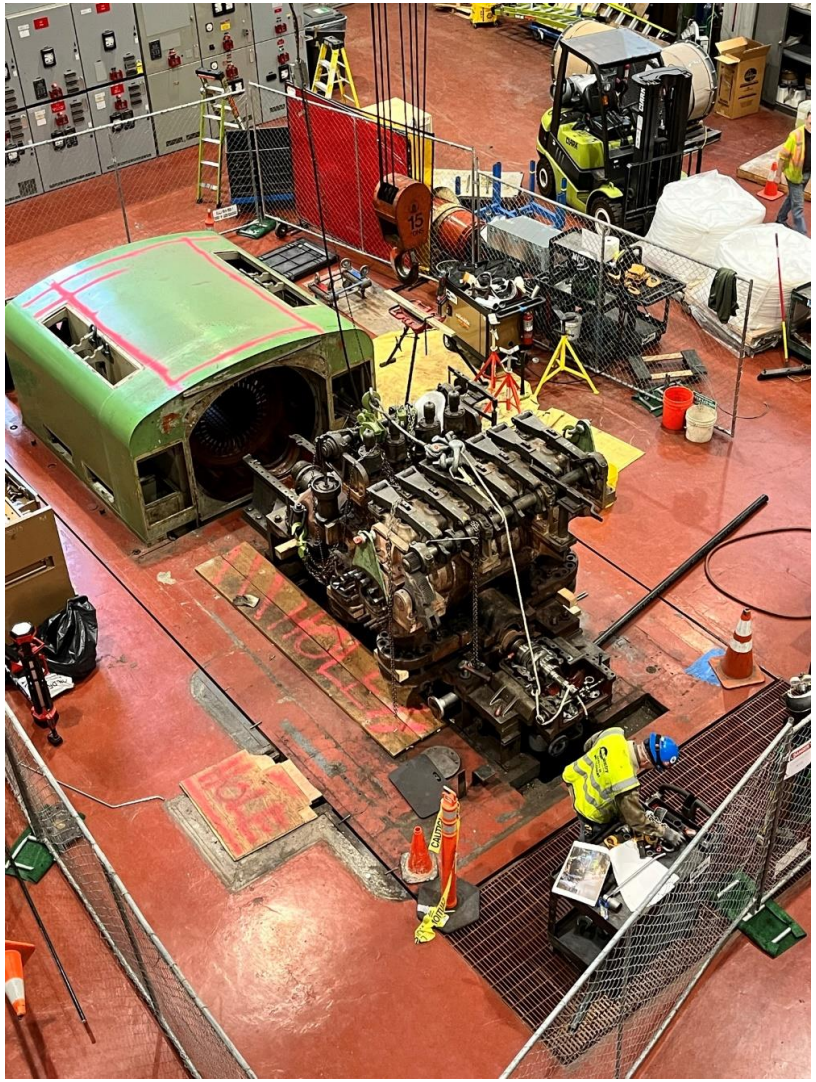
New generator arrives in Washington State 1-27-2023

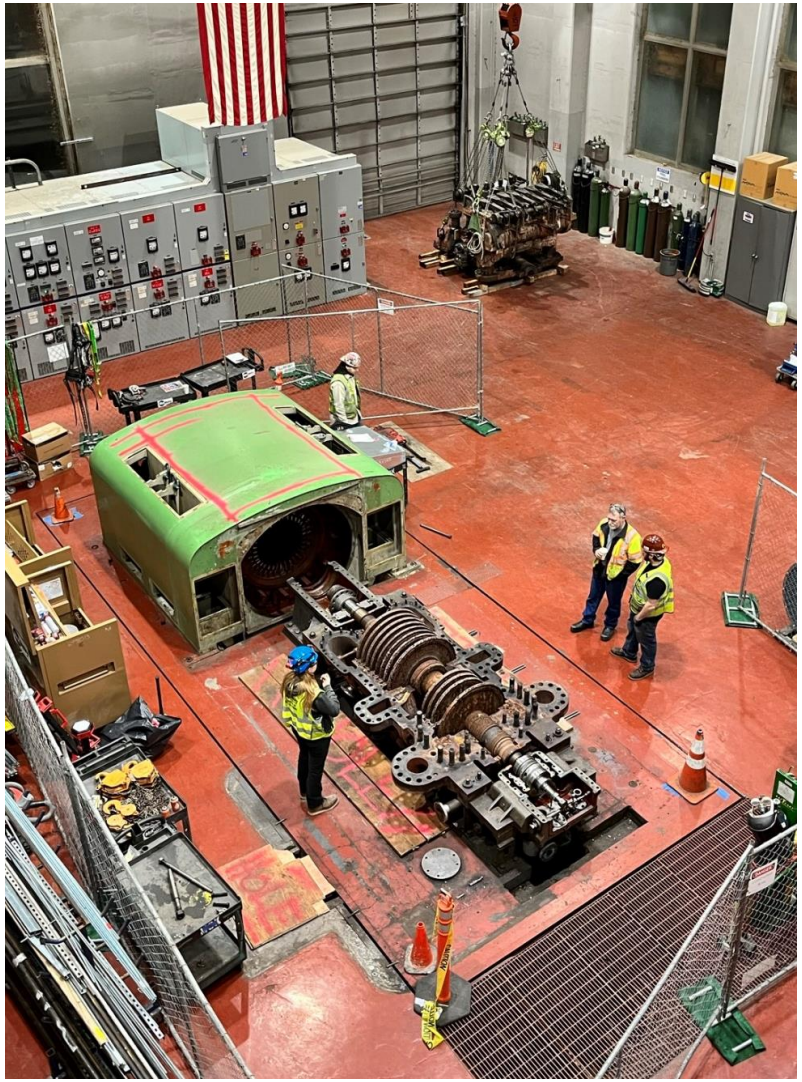
New turbine arrived in Washington State 2-23-2023

TG2 Retired September 2022



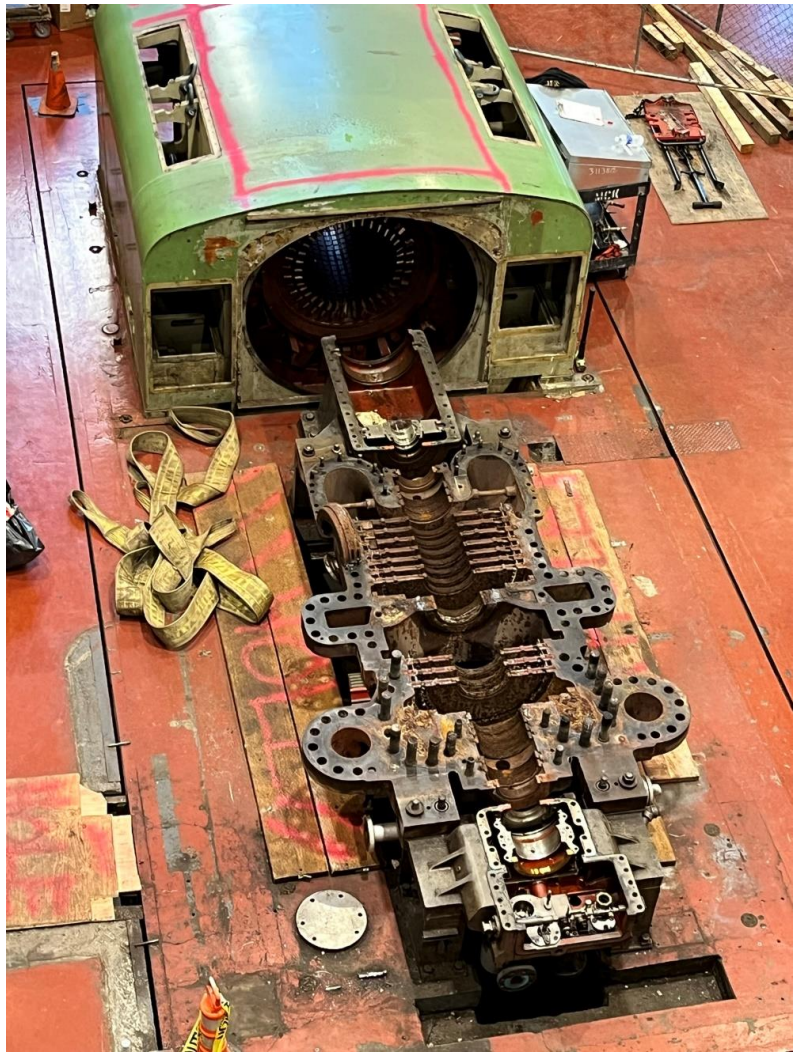
TG2 Demolition

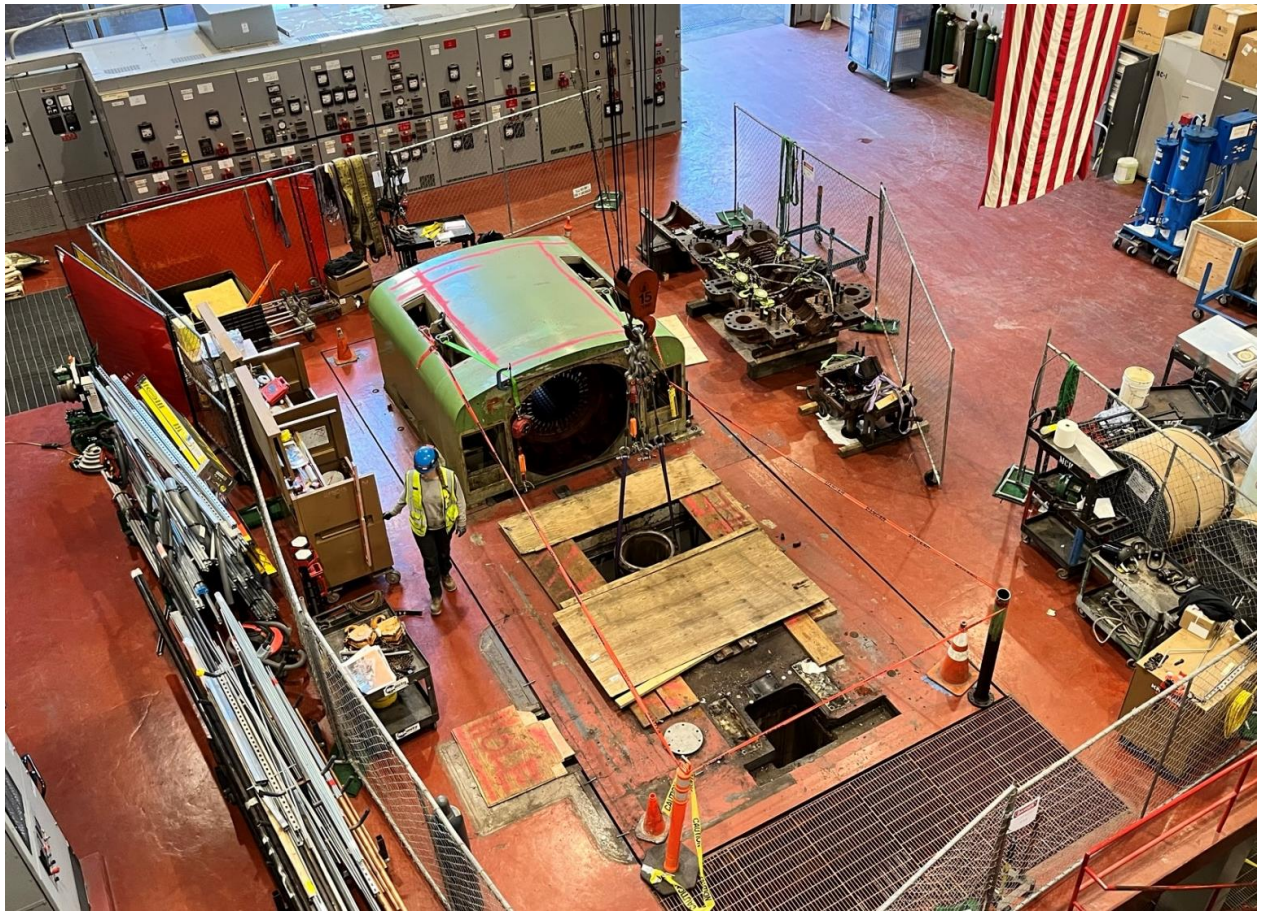




Removal of the upper half of the turbine case.

TG2 Demolition





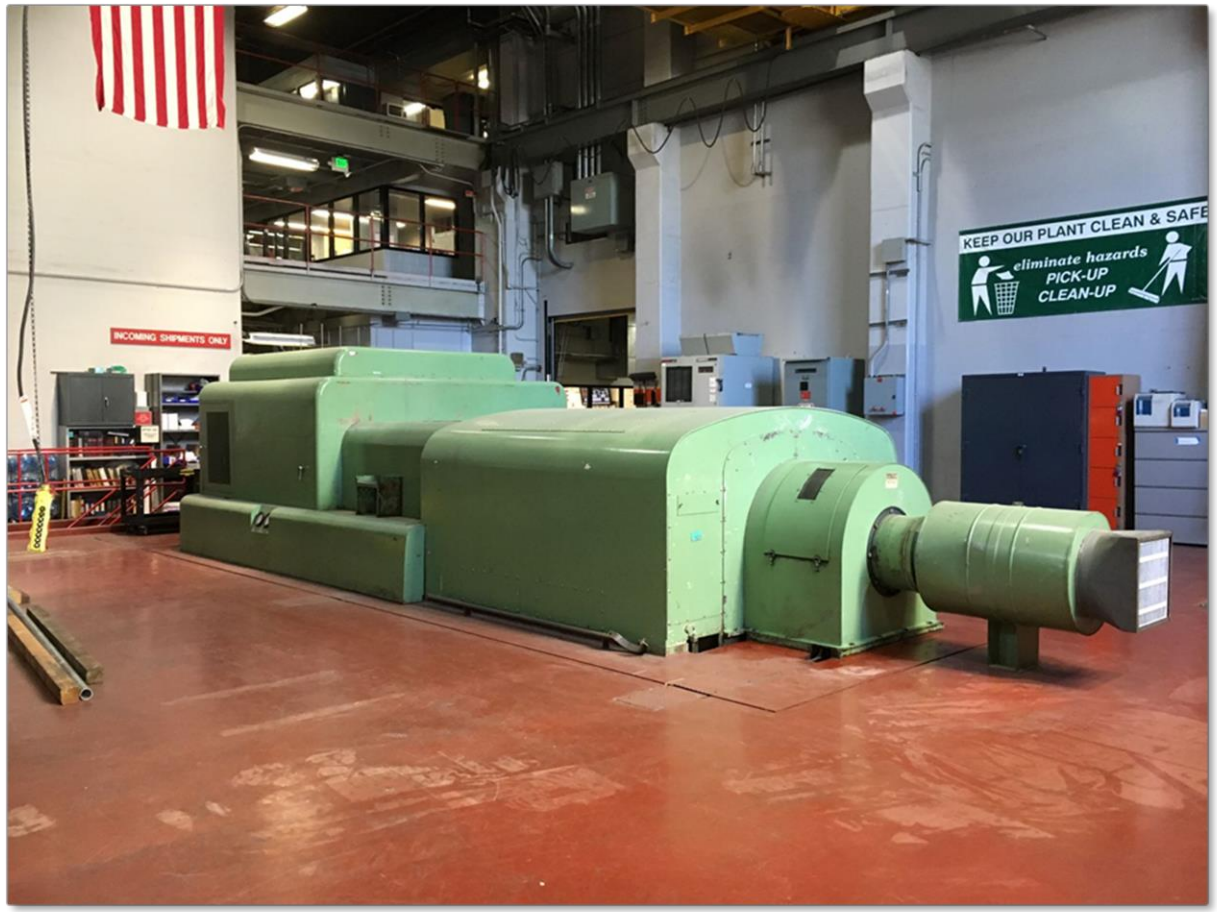
Turbine lower half and exhaust pipe removal.

TG2 Demolition

Removal of the 15 ton generator Stator assembly

DRUPS Installation

- DRUPS Background
  - Existing turbine (5MW)
    - Constant Source of Power
  - No diesel generator for plant
  - Options considered
    1. Diesel generator
    2. Battery
    3. Integrated Diesel Rotary UPS (DRUPS)
       - Electrically coupled
       - Mechanically coupled



Diesel Generator Option

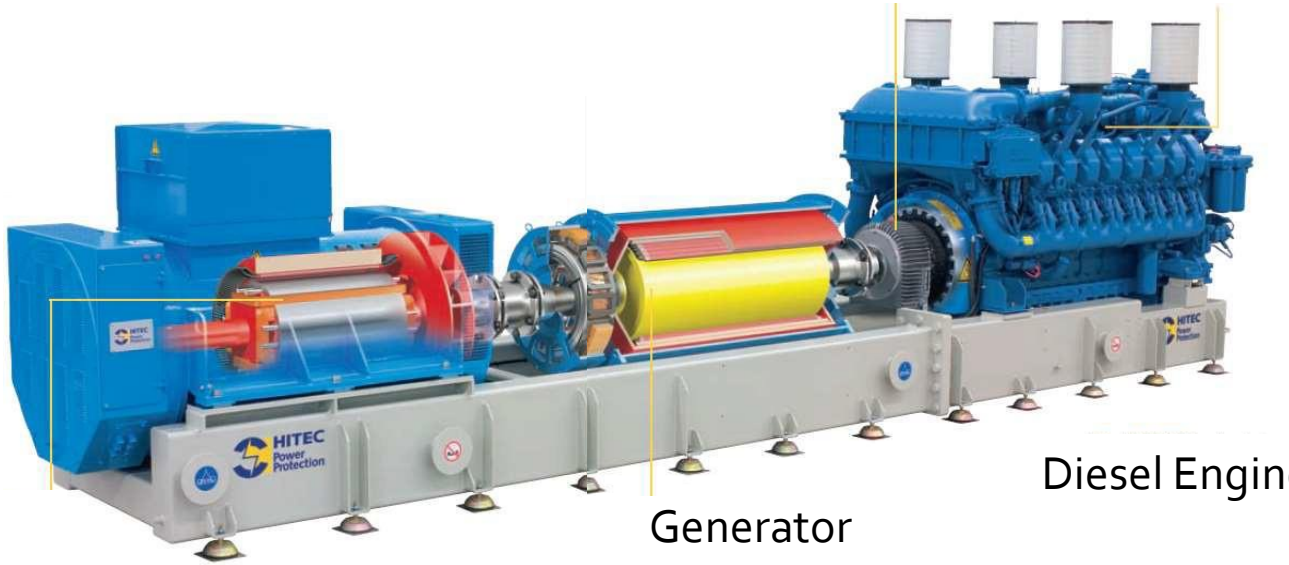
UW Seattle Campus 2 MW Diesel Generator

Battery Option

Snohomish PUD 2MW Lithium Battery Energy Storage System

Electrically Coupled UPS with Mechanical Energy Storage

Mechanically Coupled



DRUPS Installation

- DRUPS Benefits
  - Advantages of DRUPS (mechanically coupled)
    - Excellent ride through capability
    - Single point of supply
    - Physical space available

DRUPS Installation

- DRUPS physical integration
  - Location, location, location
  - Structural – existing structure(s)
    - 64,000 lbs (28,920Kg)
  - Access for installation
    - 8.9’ H x 6.6’ W x 27.3’ L
  - Interface Points
    - Cooling/ventilation
    - Exhaust
    - Radiator
    - Fuel supply
    - Electrical

DRUPS Installation

- DRUPS electrical integration
  - Interconnection to existing 4160V system
  - New electrical equipment
    - Medium voltage switchgear (arc duct exhaust)
    - Low voltage equipment
    - Interconnection of DRUPS equipment
    - Interconnection to existing equipment

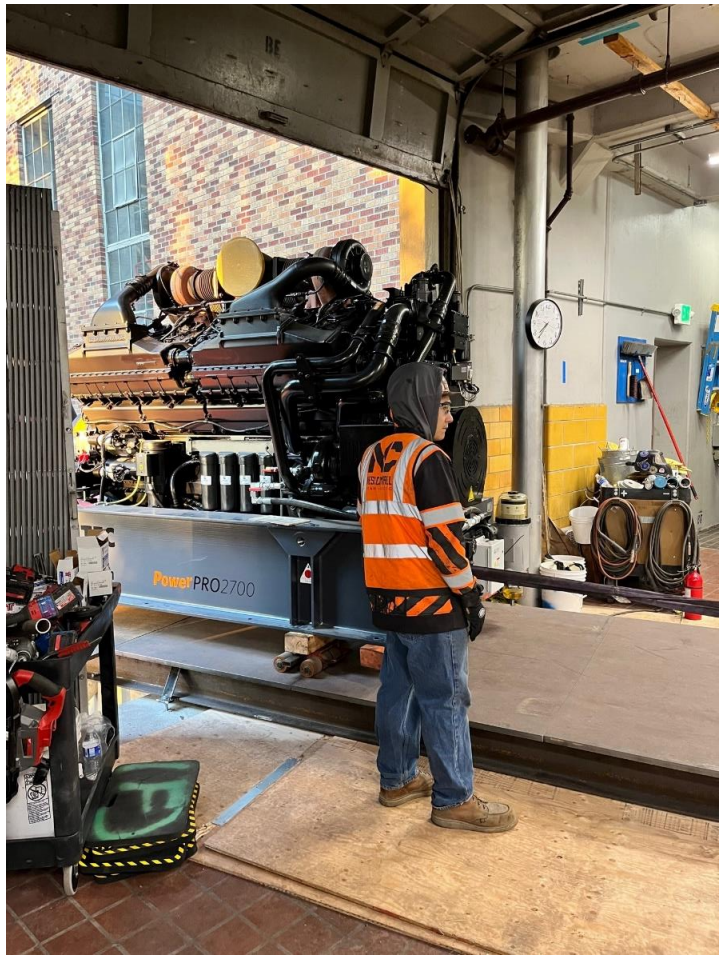
DRUPS Installation

- DRUPS electrical integration
  - Existing switchgear modifications
    - Condition of existing documentation
    - Knowledge of plant personnel
  - Existing control panel modifications
  - Control integration

DRUPS Installation

- Results
  - On-line and operating
  - Tested, minus switchgear blackout
  - Operated during Seattle Ice Storm

DRUPS Site Arrival 9-21-2022



DRUPS diesel engine skid rolled into position.

DRUPS Site Arrival 9-21-2022

The 20 ton DRUPS generator and Kinetic Energy Module skid rolled into position.

DRUPS Site Arrival 9-21-2022

DRUPS generator and Kinetic Energy Module skid bolted to engine skid.

DRUPS Switchgear and Control Panel

DRUPS Radiator and Exhaust System

DRUPS roof top radiator and exhaust stack.

DRUPS coolant lines and exhaust silencer.

2 MW DRUPS Commissioned November 2022

Lessons Learned

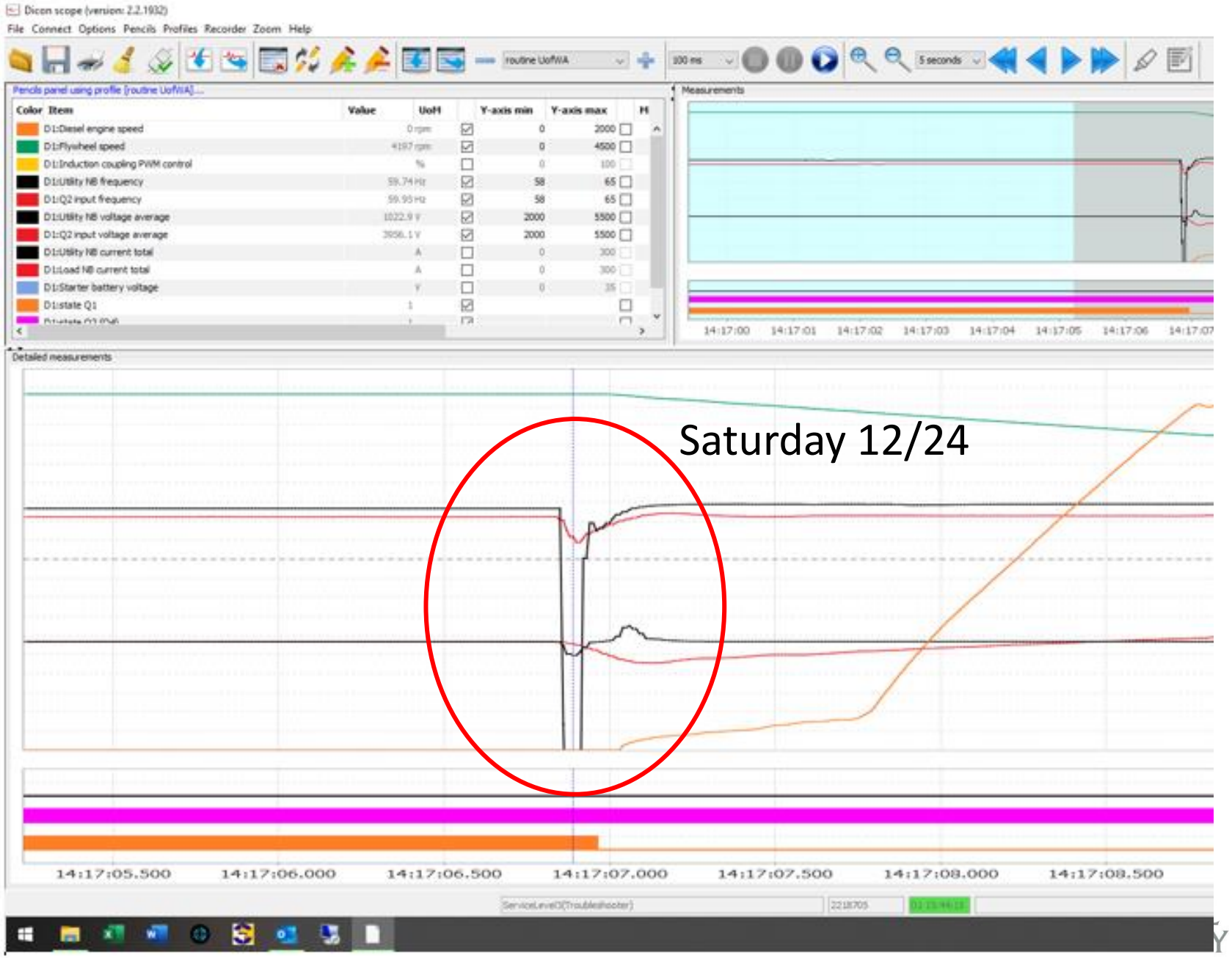
- Underestimated the noise generated by the DRUPS. The generator and kinetic energy module assembly (always running) is as noisy as the diesel engine.
- Several vendors were Europe based. Budget extra time working with European vendors due to time zones, holiday schedules.
- Changing the pressure of a boiler requires a significant amount of study and can require a variety of modifications.
- Closely coordinate demolition/construction activities between plant and contractor.
- Boiler #7 – Lessons to be Determined

It Works!

At the end of the ice storm on Christmas Eve the campus experienced a large power sag.

Voltage dropped from 4200 to 1020, 75% below normal.

No issues at the plant!



Questions?

Thank You!

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A Special Thank You to Our Construction Partner

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