Industrial Scale Enhanced Heat Recovery Fully Condensing Economizer

VICTORY ENERGY®
Full Steam Ahead!

SUSTAINABLE CERTIFIED SOLUTIONS

"Energy efficiency is a foundational cross-cutting decarbonization strategy, and it remains the most cost-effective option for near term GHG emissions reductions.."

US DOE Industrial Decarbonization roadmap, 2022

ECONOMIZERS

- Economizers improve thermal efficiency by recovering heat from the combustion flue gases exhausted from the boiler or other fired equipment.
- The recovered heat is used to heat colder streams (heat sinks). This recovered heat displaces the need to burn additional fuel to heat these same streams.
- Re-used waste heat is an emissions-free substitute for costly purchased fuels.

WASTE HEAT RECOVERY OPPORTUNITIES

Wherever Industrial quantities of fuel are being used

- Boilers
- Turbines
- Reciprocating Engines
- Oxidizers
- Ovens
- Furnaces
- Cement Kilns

- Manufacturing
- Chemicals & Refining
- Fertilizers
- Food processing
- Pulp & Paper
- Institutional
- Bio-renewable

CONDENSING ECONOMIZERS

- A large portion of energy consumed today comes from hydrocarbon fuel combustion, and one of the major combustion by-products is water vapor.

$$CH_4 + 2\ O_2 \rightarrow CO_2 + 2\ H_2O$$

- For natural gas combustion, ~ 12% by weight of exhaust gas is water.
- Every lb of moisture condensed releases ~ **1,000 btu of energy.**
- Condense the moisture out of the flue gas and recover the "**Latent heat**" by cooling flue gas below its "water dew-point "
- The water dew-point of natural combustion exhaust is ~ 140 F.
- If this flue gas contacts a surface below 140 F, the moisture in the flue gas will start condensing – releasing its latent heat.

CONVENTIONAL THINKING SAYS…

- Condensing Economizers are only for “clean” burning fuels like natural gas.
- They need exotic metallurgies or specialized coatings.
- Finned tubes are not suitable for condensing economizer applications.

This Case study disproves these notions.

- Significant energy recovery is available after a “conventional economizer” even with “dirty” flue gases.
- Condensing economizers can be designed with readily-available metallurgies.
- **Paybacks are very attractive even at current fuel prices.**
- Condensing economizers provide an easily installed solution towards Emissions reductions and other concurrent benefits.

OPERATING SCENARIOS

Partial Condensing

The flue gas outlet temperature is kept above water-dewpoint. There will be partial condensation and “sweating” on the tubes. Heat Recovery is not maximized however there is no significant condensate to be handled.

Full Condensing

The flue gas outlet temperature is taken well below water-dewpoint. There will be full condensation and “raining” inside the Economizer. Heat Recovery is maximized. There is significant condensate to be handled.

Note that the tube-wall temperature of the Economizer tubes are completely controlled by the water side temperature.

OPPORTUNITY STATEMENT

- Alberta Pacific Forest Industries - the largest single-line kraft pulp producer in North America as part of their sustainability initiatives engaged an Engineering Company to recover waste heat from the stack of their recovery boiler.

- Steam was being used to generate hot water required by the Mill.

- They were now looking to take some or all of the flue gas from the recovery boiler and direct it through one or more flue gas water heaters to heat LP feedwater and a separate hot mill water stream.

- This heat recovery application in this environment would arguably be the **first** of its kind in North America and arguably in the world.

“Nobody has done it before.. That what makes it real interesting… and pulp mills have been around for hundreds of years…”

Darcy Tangedal, Business Development Specialist, Alberta Pacific

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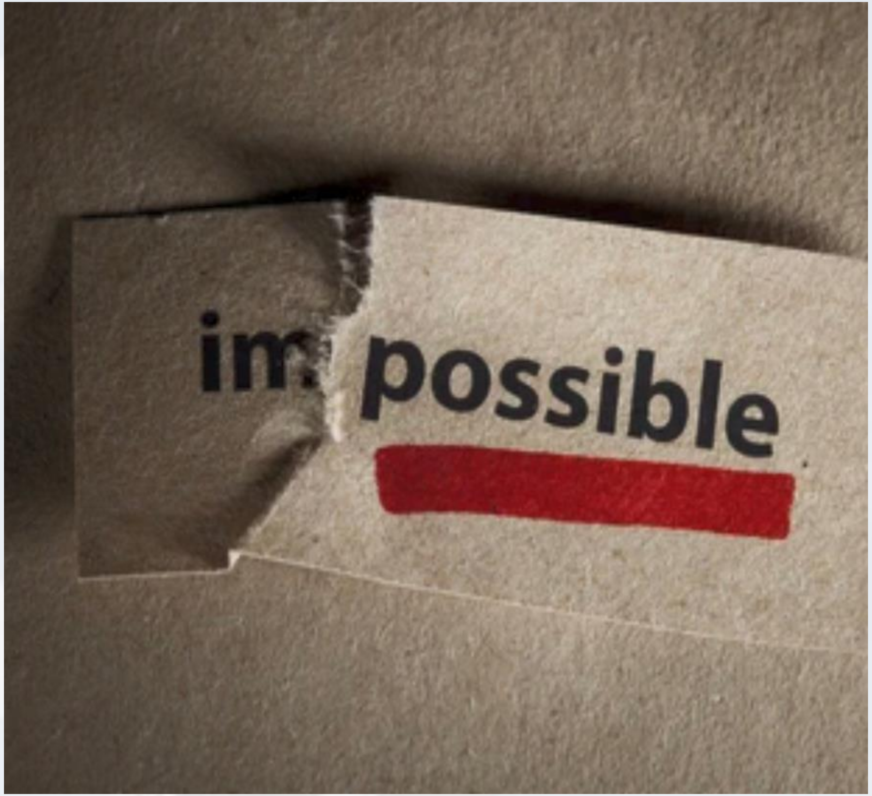
CHALLENGES

CORROSION - There are a number of chemical compounds in the flue gas from a recovery boiler. The primary concern is hydrochloric acid formation, however, sulphuric acid and nitric acid formation is also likely.

FOULING - Flue gas will have some particulate matter. Keeping the system clean.

THERMAL PERFORMANCE - Meeting thermal performance guarantees.

CONSTRUCTABILITY - Meeting space and installation constraints to make the project viable.



Challenges – CORROSION

- Uniform Attack
- Pitting Corrosion
- Crevice Corrosion
- Stress Corrosion Cracking

- Low pH, acid condensing environment
- PREn = %Cr + 3.3% Mo + 30%N
- Scale deposits
- Temperature range and chlorides

Solution

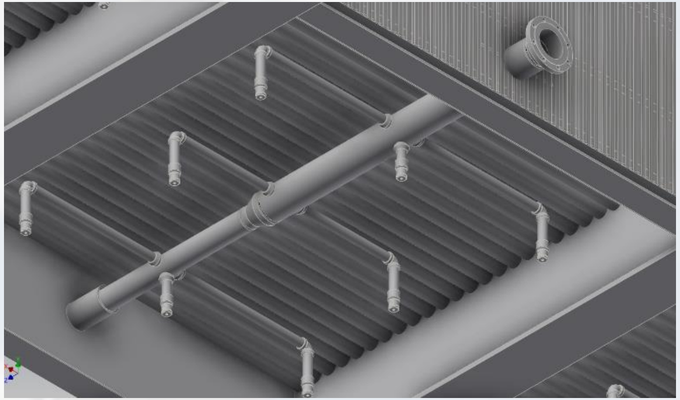
- Take the flue gas well below water dew-point to operate in the “full-condensing” mode - Condensate dilutes the corrosive constituents. This also maximizes heat recovery.
- Metallurgical solution for the pressure parts – Use the appropriate ASME approved pressure part metallurgy. Lab tests were done in a material test rig.
- Eliminate residual stresses in your economizer return bends – using hot forged bends
- Online Water-wash system to keep system clean.

Challenges – FOULING

- Flue gas has particulate matter. Using bare tubes in design will make the design un-economical.

Solution

- Online Cleaning System - Use the condensate collected as the washing media.
- The spray water flow rate is about 288 kpph per section.
- Use a conductivity meter to monitor the sump condensate. High conductivity would indicate the water is getting too contaminated and the sump needs to be purged before washing continues.
- Washing sequence optimization. Washing would start at the top and work its way to the bottom on one side and then repeating the sequence on the other side. Flow would be used to control pressure since a constant flow to the nozzle assemblies should result in the same pressure for each nozzle assembly, regardless of elevation.

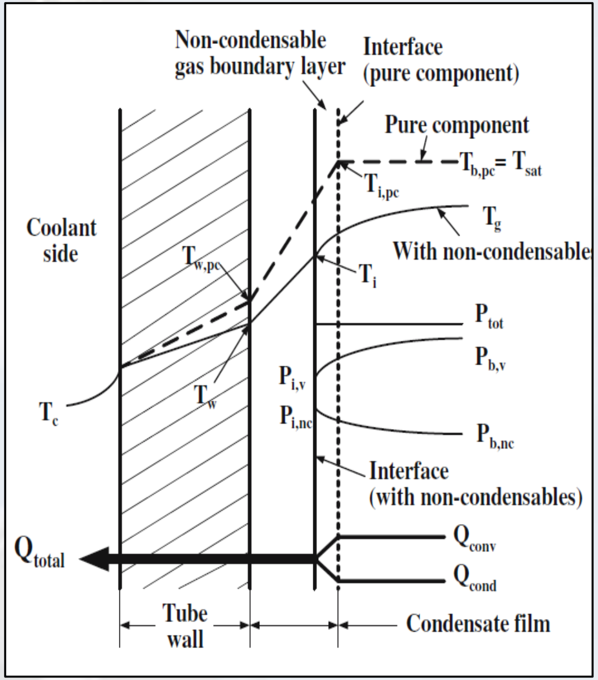


Challenges – THERMAL DESIGN

Guaranteeing Thermal Duty and pressure drop through the Economizer

Solution

- Engineering Expertise!
- Victory Energy proprietary condensing heat transfer co-relations developed using our experience from the Condensing Economizers we have designed were used.
- Flue gas mass flow rate of **1.31 MM lb/hr @ 280 F** entering the Economizer.
- Flue gas temperature to the stack of **130 F.**
- **Total heat recovery of 184 MMbtu/hr.**
- **Over 46% of the recovery derived from condensing heat transfer.**
- Condensate recovered is **82,266 lb/hr.**
- Flue gas side pressure of 6” w.c. through the Economizer.



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EXPLORER® series

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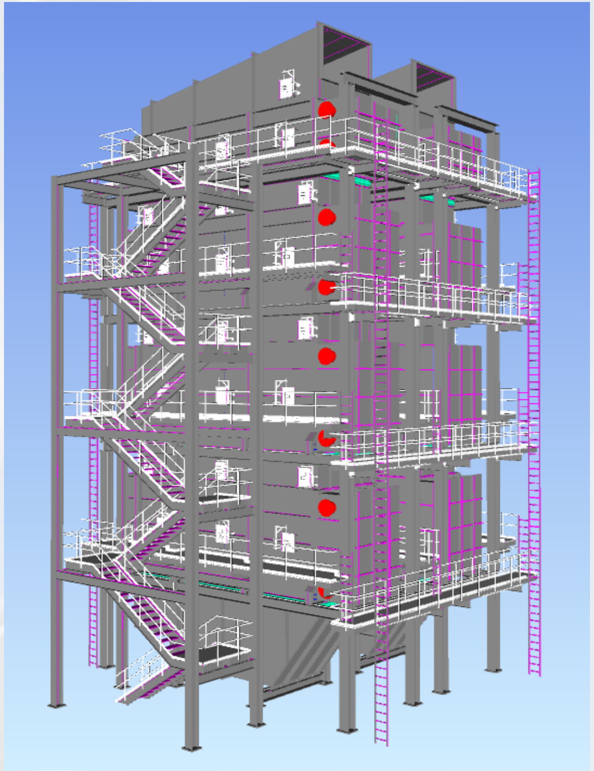
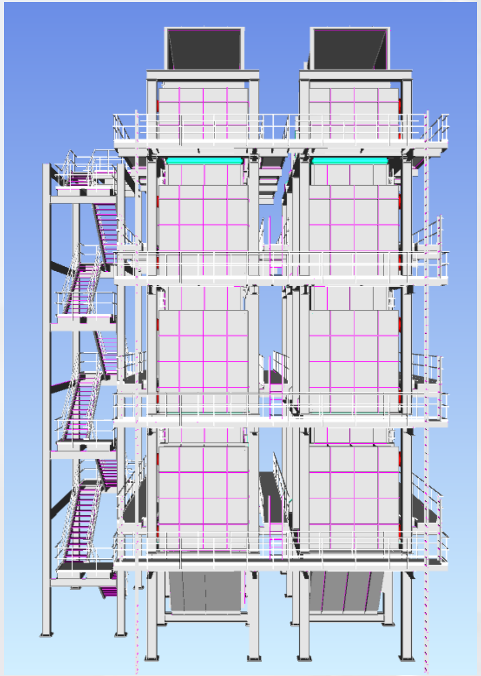
Design Concept

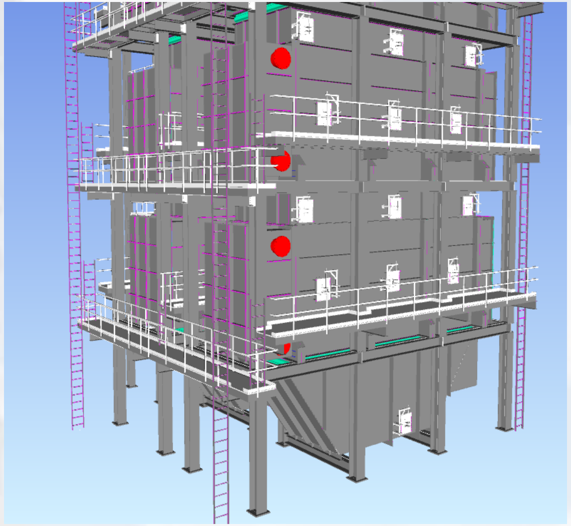
- Modular Design for easy constructability / effective cleanability.
- Four(4) independently supported modules.
- Expansion joints between modules.
- External support steel.

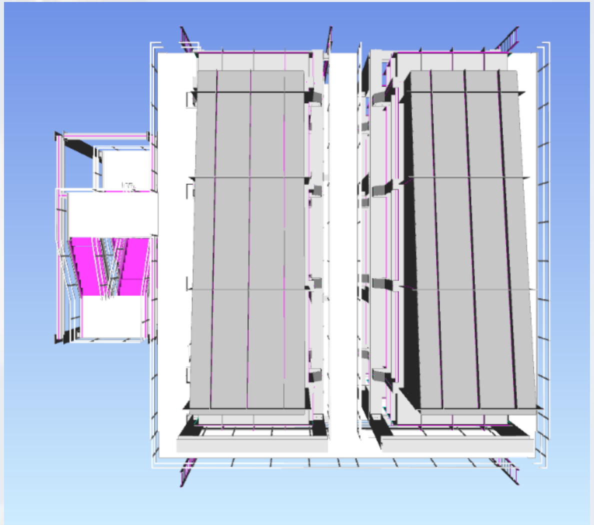
  - ✓ Configuration: Vertical Gas Down, Horizontal Tube
  - ✓ Code: ASME Section I
  - ✓ Tube Side Design Pressure: 100 PSIG
  - ✓ Tube Side Design Temperature: 500 F
  - ✓ Gas Side Design Pressure: 25” WC
  - ✓ Gas Side Design Temperature: 500 F



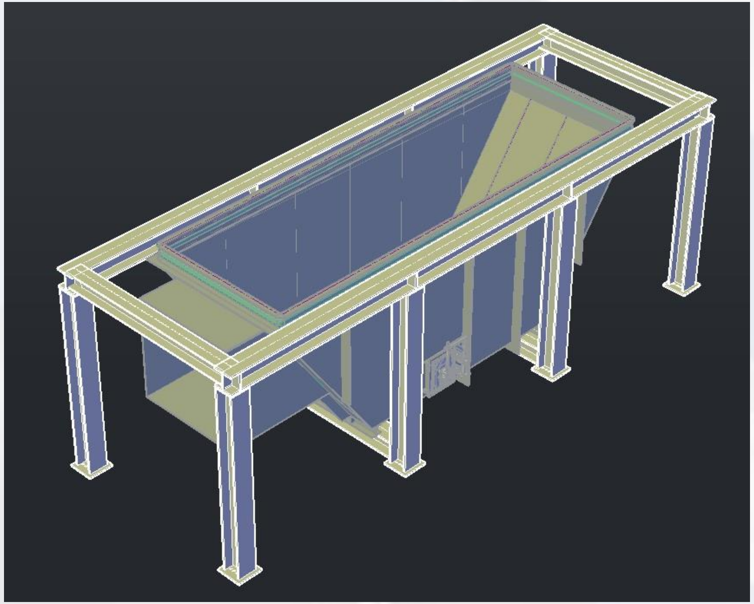
Design Concept

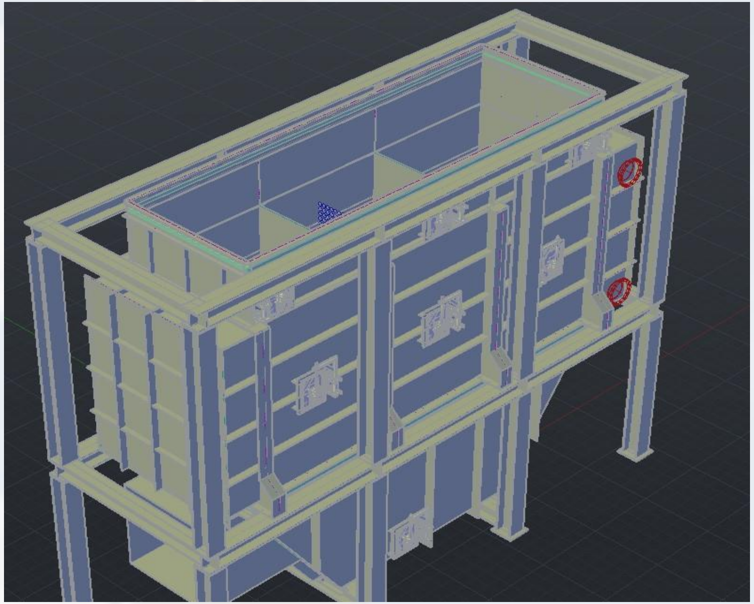






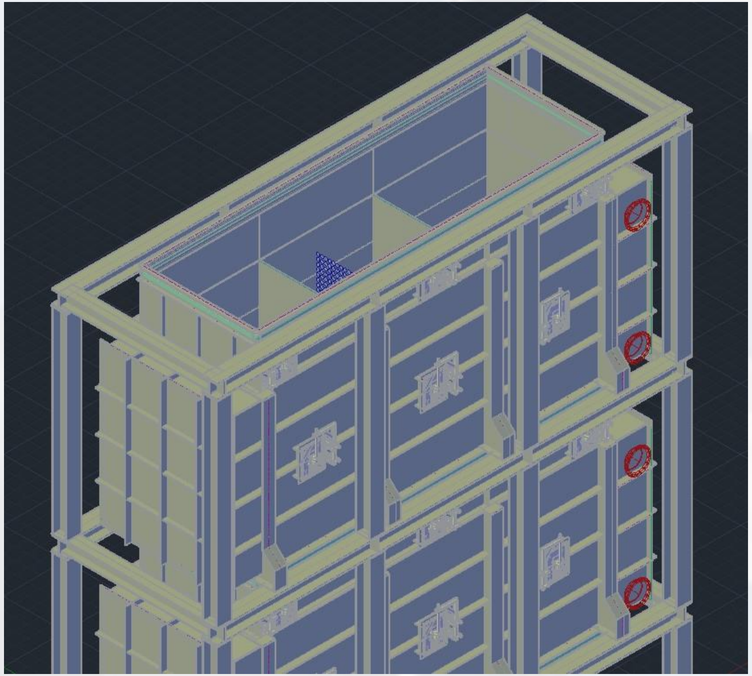
Modular installation

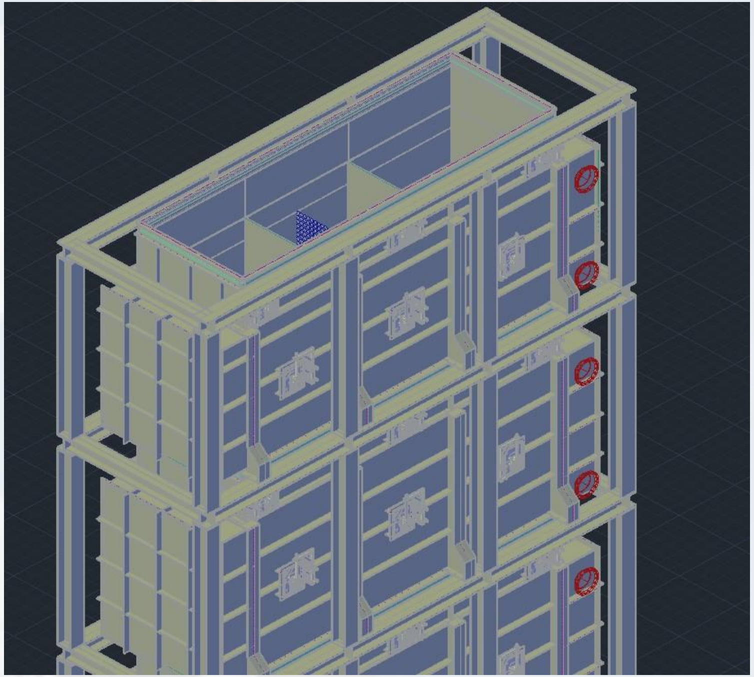




Individual modules will be set in place after support steel is set per module.

Modular installation





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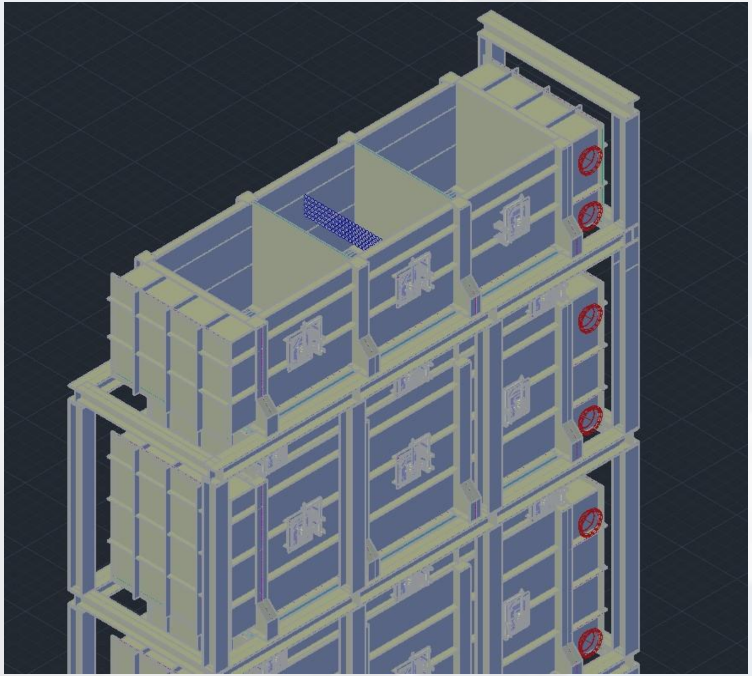
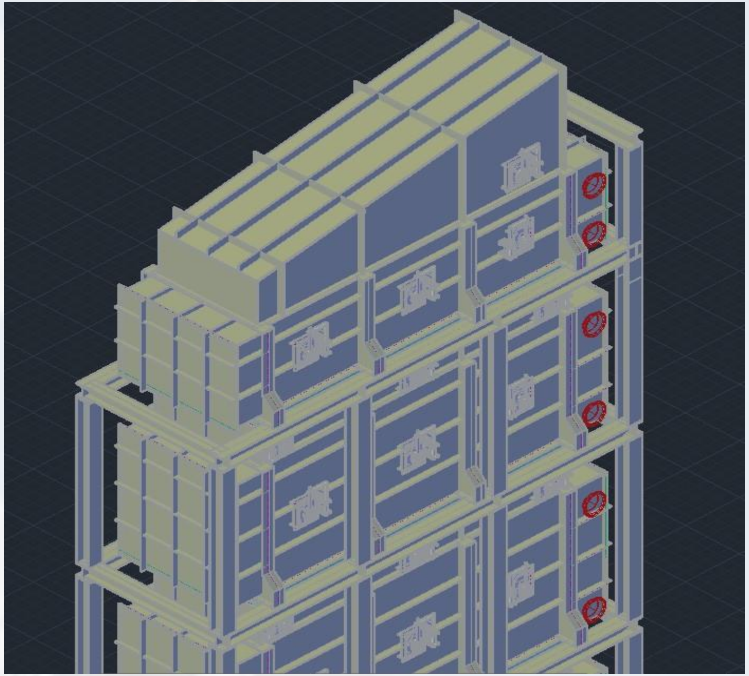
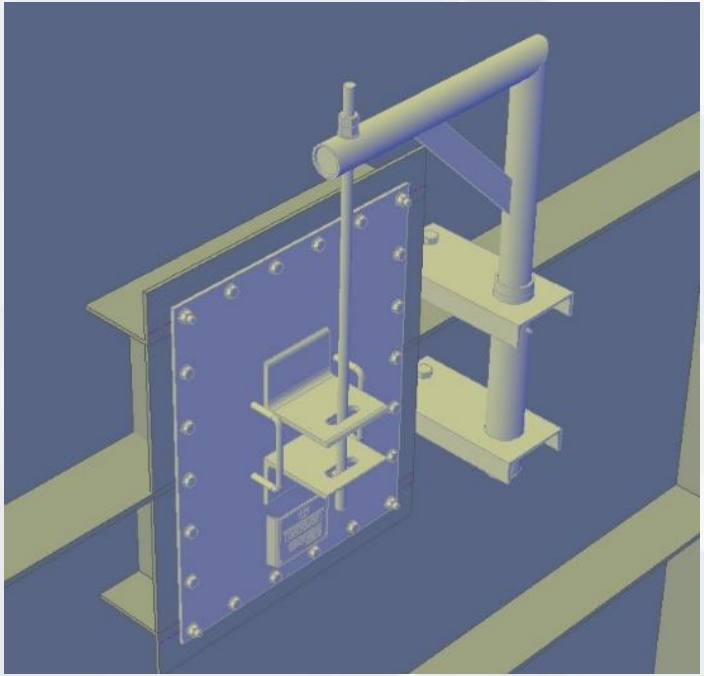




Ease of access for maintenance



- Support feet resting on slide plates (not shown)
- Davited access doors
- End-panels designed for easy access

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Owner's Engineer assessment of the commissioned unit…

- The flue gas moisture content measured in the new SHR Stack appears to be accurate and indicates the flue gas stream is fully saturated.

- The total energy absorbed by the LP Feedwater Heaters and the Hot Water Heaters combined is the same as design. The combined overall heat transfer is essentially the same as the combined overall Victory Energy predicted performance.

Owner's assessment of the unit… (after four years of operation)

" The Waste Heat Recovery Unit has proved to be an impressive addition to our site and is definitely creating the value we had hoped for. "

Darcy Tangedal, Alberta Pacific

Summary

- GHG reductions of 20,000 tCO2e per year.
- Over 40 tons/hr of moisture that was exhausted up the stack with the flue gas is now condensed and re-used.
- The waste heat is now accounting for 70,000 MW hours per year of incremental energy being generated..
- The Condensing Economizer is also reducing particulate emission by capturing particulate matter in the condensate.

Thank you!

QUESTIONS

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