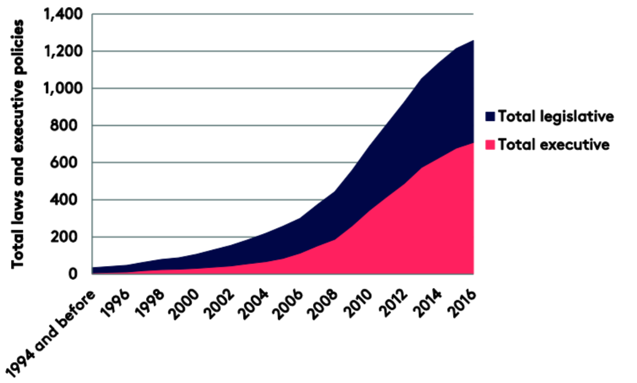
Wherever Thermal is Critical

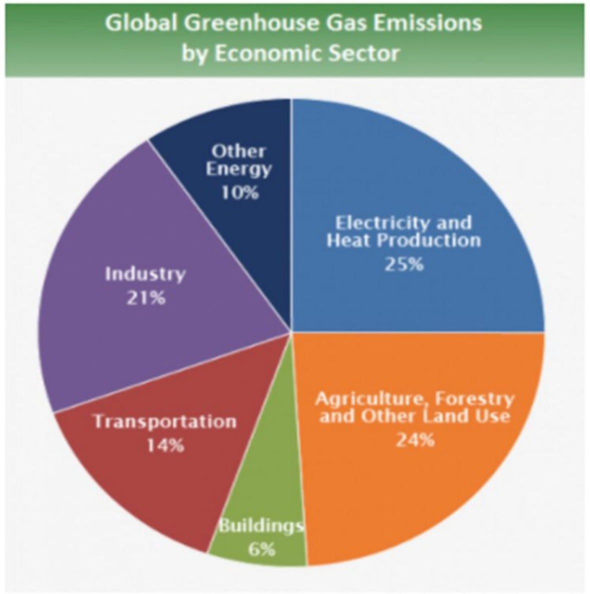
100 years of solving the world's most demanding thermal problems

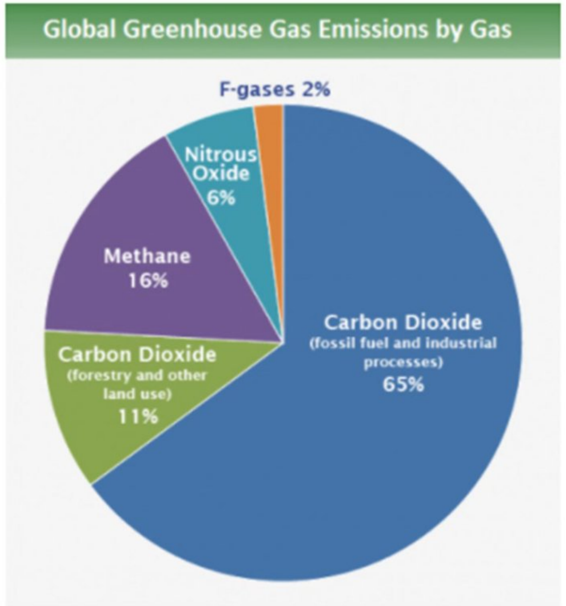
THE DRIVE FOR DECARBONIZATION – FOCUS ON THE INDUSTRIAL SECTOR

- Paris Climate Agreement
- GHG Global Emissions by Gas
- GHG Global Emissions by Sector
- Increase in Climate Legislation
- Diesel NOx reduction legislation:
  - CARB 2024-2027
  - US EPA 2027
  - EU VII 2027 (est.)
- The Energy Transition will require different approaches



Climate change laws around the world. Legislative laws are passed by parliaments, whereas executive laws or policie are enacted by governments. Source: Global trends in climate legislation and litigation, 2017 update.





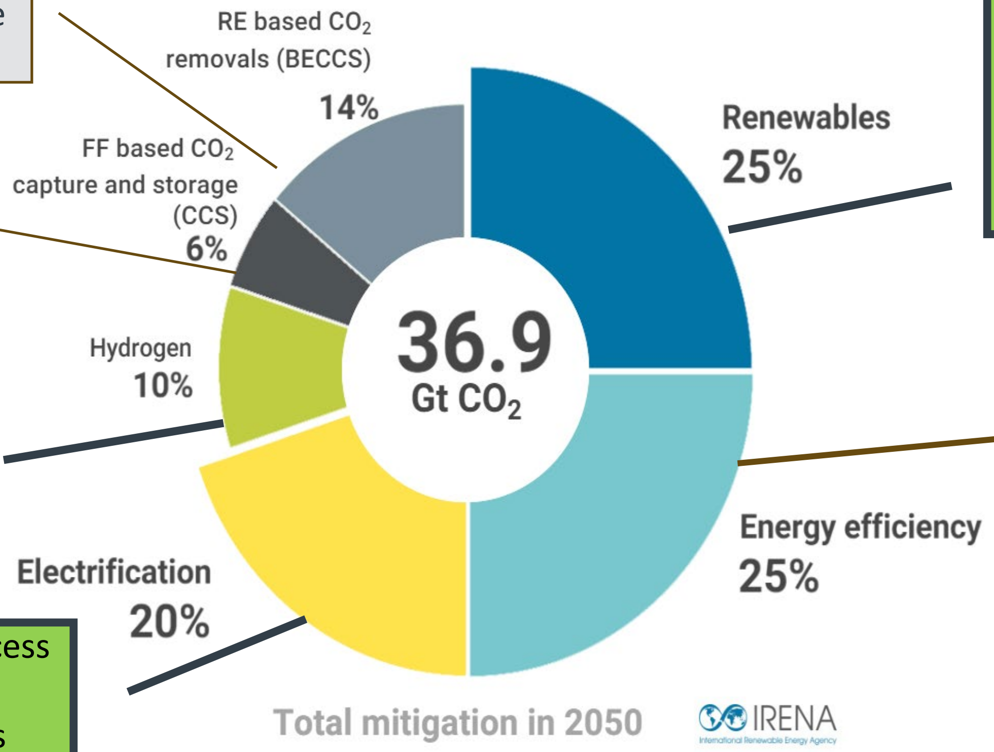
6 MAJOR AVENUES FOR DECARBONIZATION

Renewable energy-based CO2 capture and storage.

Fossil Fuel based CO2 capture and storage.

Use of hydrogen as a replacement for hydrocarbon fuels

Electrification of process heat and other electrification such as heat pumps.



Wind, solar and similar power generation and renewable fuels such as renewable diesel.

Energy conservation through insulation and similar.

Electrification of Industrial Processes is a critical piece in building a global climate strategy.

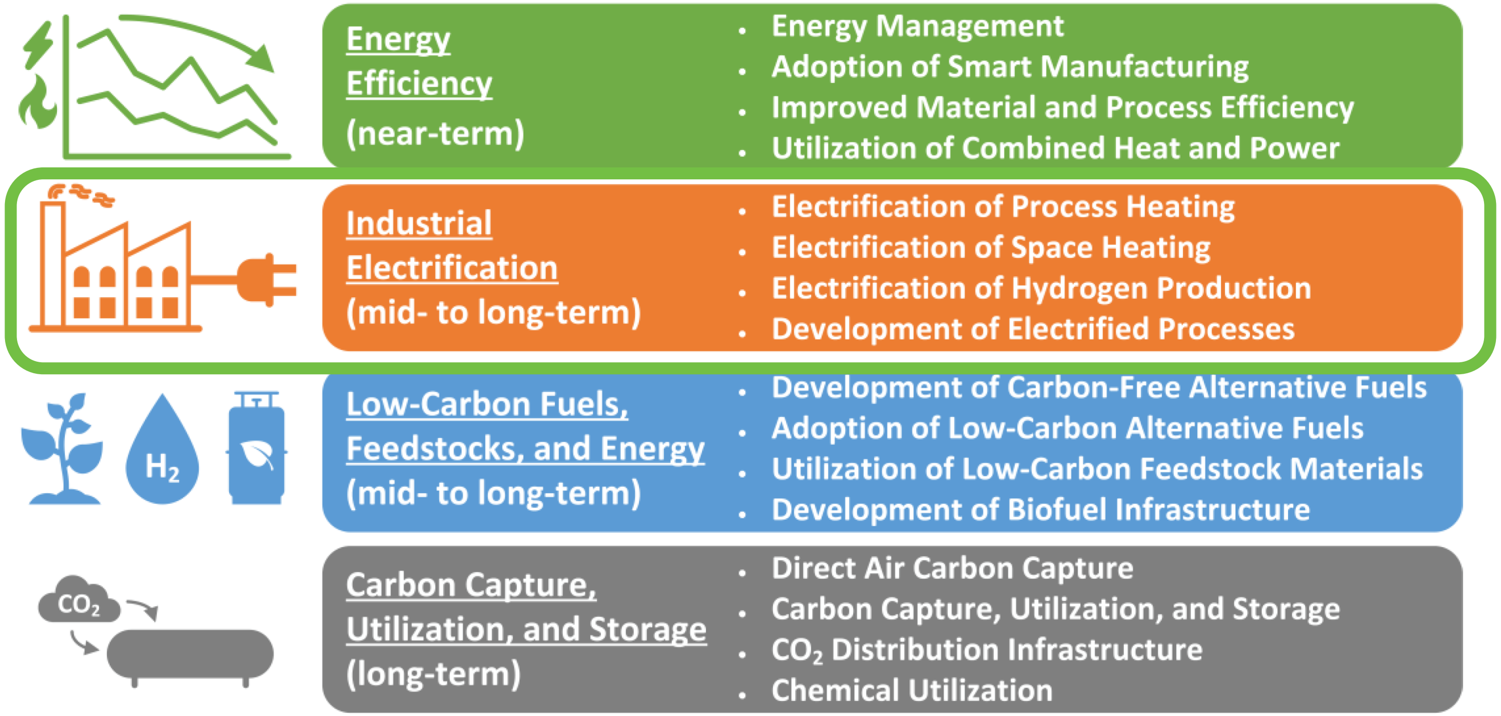
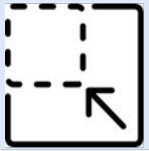


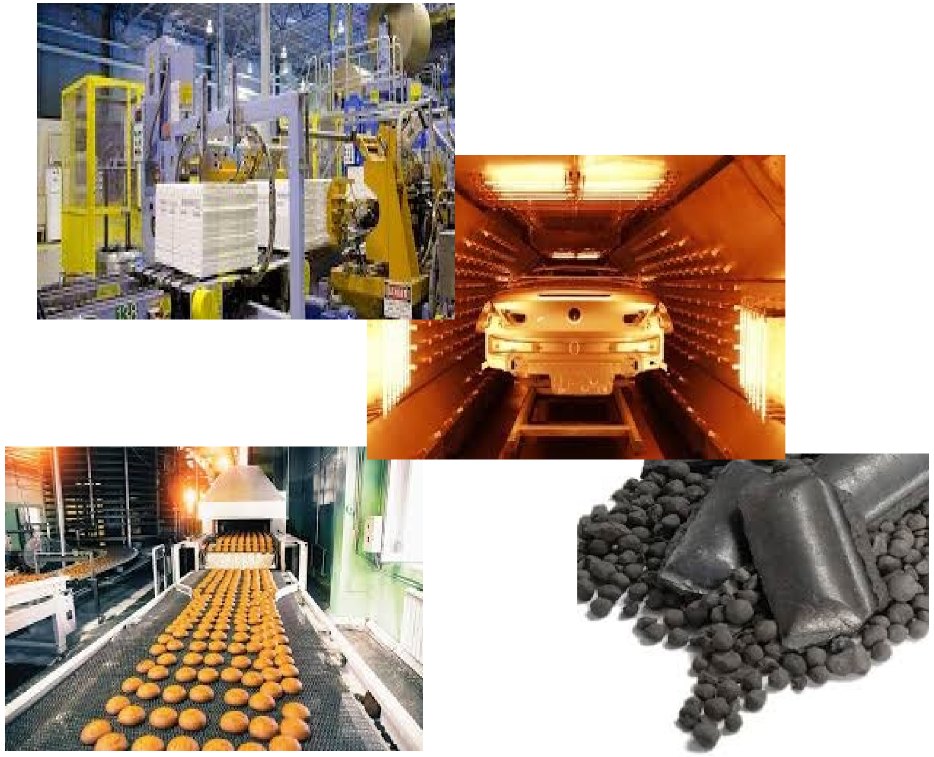
Image from MDPI Article: *"Energy Efficiency as a Foundational Technology Pillar for Industrial Decarbonization."*

ELECTRIC THERMAL SYSTEM ADVANTAGES

	Less thermal lag:	Temperature is controlled through direct application of electricity
	Safer and clean operation:	No fossil fuels to burn or combust
	Smaller overall footprint:	Constant heat flux capability results in smaller footprint as compared to the non-constant heat flux in shell and tube heat exchangers
	Lower operating cost:	Capable of remote unmanned operations with proper sensors and controllers

INDUSTRIES ELECTRIFYING PROCESS HEAT AND THEIR POSSIBLE APPLICATIONS

- Food and Beverage (Drying and Hot Oil Heating)
- Wood, Paper, and Pulp (Drying Processes)
- Petrochemical and Oil Refining processes (Column Reactor Reboilers, Feed and Regen Heaters)
- Renewable Fuels (Regen Heaters and Reboilers)
- Automotive (Coatings and Paint Drying)
- Green Steel (Process Heat for Direct Reduced Iron)



We would love to hear more from your other processes in Oil & Gas, Petrochem being considered for electrification

FOSSIL FUELS TO ELECTRIC HEATERS: WHAT IS POSSIBLE?

HISTORICAL APPLICATIONS FOR ELECTRIC HEATERS IN OIL & GAS

- TEG/MEG Glycol Reboiler Heater
- Gas/Instrument Heater
- Fuel Gas Heater
- Knock-Out Drum Heater
- Seawater heater
- Caisson heater
- Air Line Heater
- Fuel Gas Superheater
- Knock Out Drum
- Lube Oil Heater

HISTORICAL APPLICATIONS FOR FIRED HEATERS IN OIL & GAS

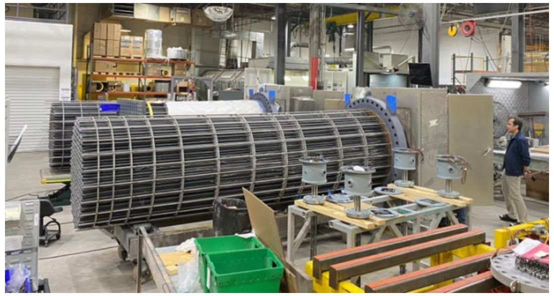
- Feed/Product Exchanger
- Glycol Reboiler
- Dehydration Inlet Preheater
- Fuel Gas Heater
- Mole Sieve Regen
- Waste Gas Heater
- Crude Oil Heater
- LNG Vaporizer
- FCC Heaters

- **Electric process heaters are in use for 75+ years**
- **Until recently most have been 250kW or less**
- **Package sizes range from 5MW to 200MW**
- **Last 2 to 3 years many processes are being evaluated for conversion to electric process heaters**

PRINCIPLE OF ELECTRIC HEATING

Electric current is pass through a resistor which creates vibration of atoms to produce heat. This can come in various configurations:

Mineral Insulated Resistors



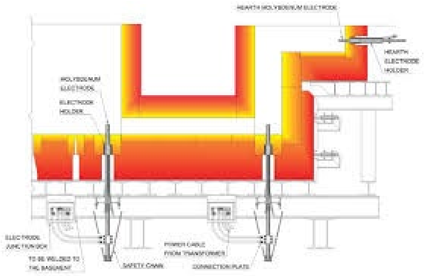
Metal Base Resistors like NiChrome

Coil

Ribbon/Strips

Rods

Electrode Heating



In electrode heating, the medium is the resistor

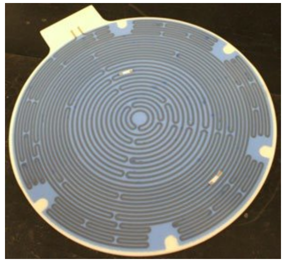
Refractory Materials Resistors

SiC

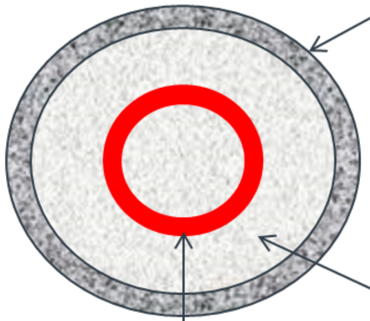
MoSiC2

Graphite

Ceramic Heaters



FOCUS ON MINERAL INSULATED ELECTRIC HEATERS FOR OIL/GAS & PETROCHEM

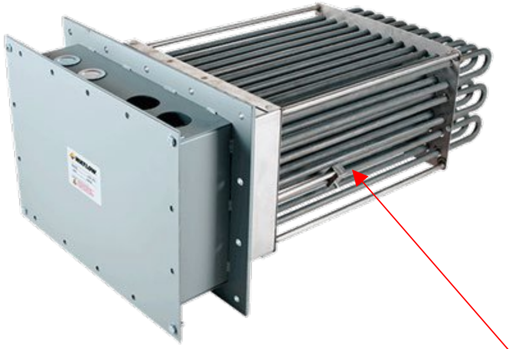


Process fluid removes heat from the heater surface by convection (or other form of heat transfer). If heat flux is too high, the sheath temperature will be high (in some cases can damage the fluid… i.e coking in oil)

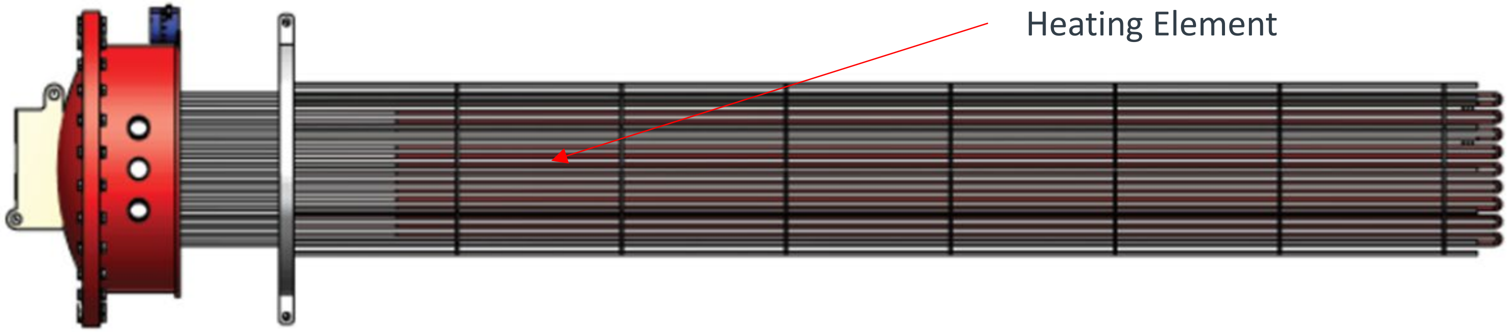
MgO (Magnesium Oxide) acts as an electrical insulator and thermal conductor. When properly compacted, MgO conducts heat from the resistance wire to the heater sheath and at the same time prevents the electrical current to go to ground (sheath)

NiChrome wire (resistor) generates the heat when electrical current is pass through. Long life of the heater depends on how fast this resistor will decay over time (by oxidation). Temperature is the main driver for long life

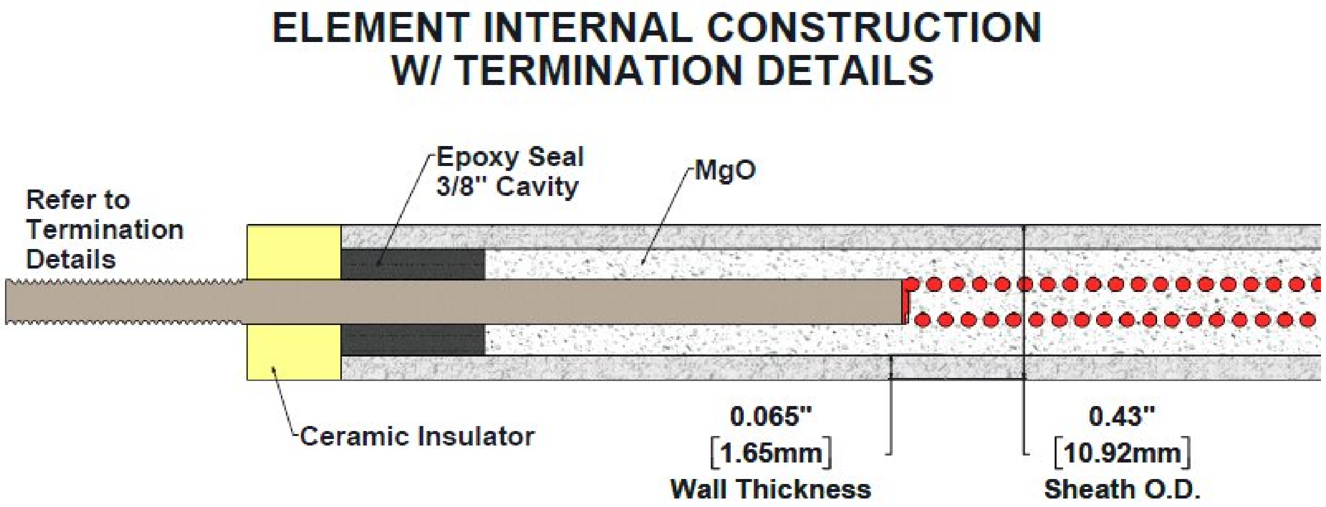
Mineral Insulated Resistors

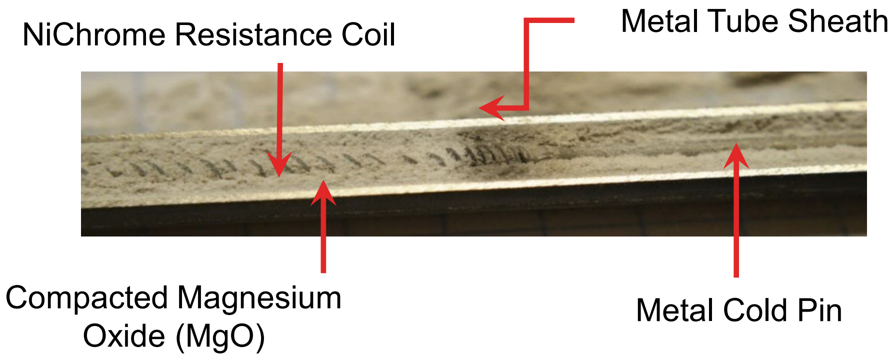


Heating Element

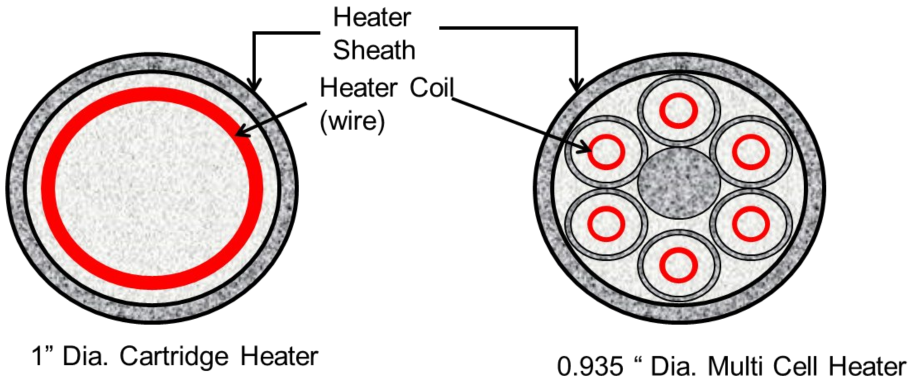


CONSTRUCTION OF BASIC ELECTRIC HEATER (Tubular, Cartridge and Multicell)





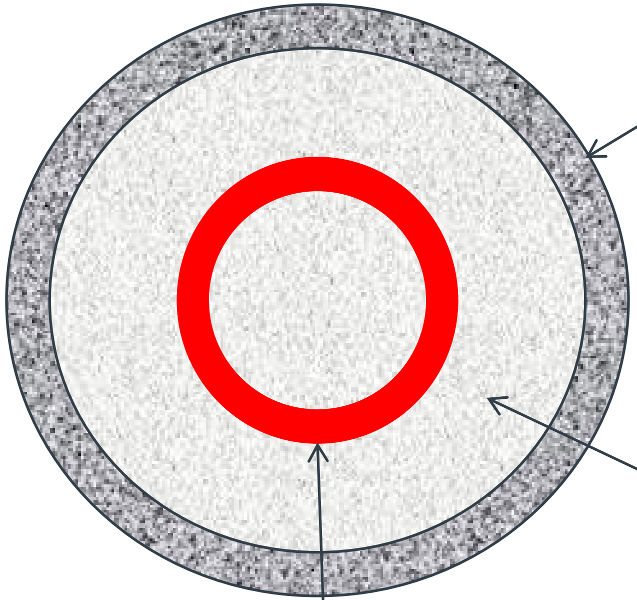
This are relative construction and how the internal construction of these heaters are essential to the specific applications intended for



Mineral insulated heaters varies in construction to meet different performance needs of the applications.

Cartridge heaters are constructed such that the coils are closer to sheath to enable faster heat transfer of heat to media. For this reason, cartridge heaters can operate at much higher watt density (heat flux) in water immersion

MINERAL INSULATED HEATING ELEMENT (Watrod… Industry Workhorse)

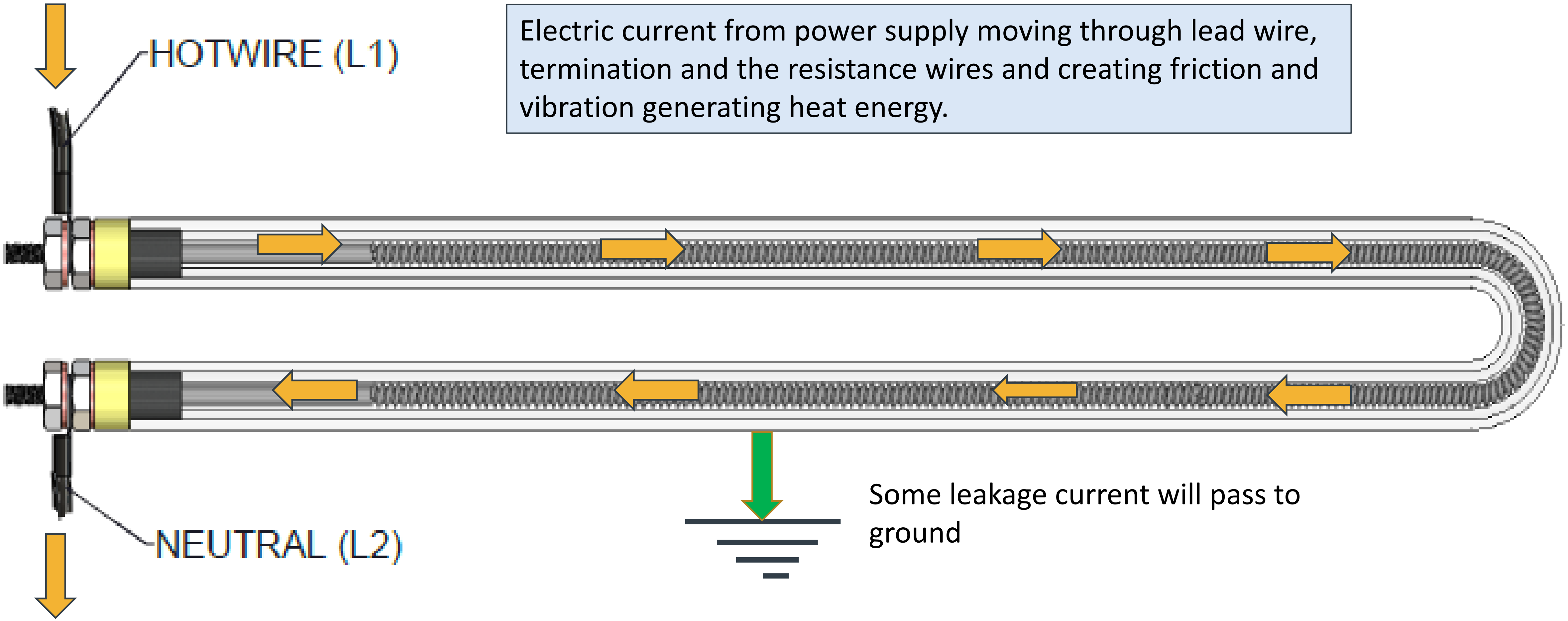


Process fluid removes heat from the heater surface by convection (or other form of heat transfer). If heat flux is too high, the sheath temperature will be high (in some cases can damage the fluid… i.e coking in oil)

MgO (Magnesium Oxide) acts as an electrical insulator and thermal conductor. When properly compacted, MgO conducts heat from the resistance wire to the heater sheath and at the same time prevents the electrical current to go to ground (sheath)

NiChrome wire (resistor) typically 80 Ni 20 Chromium, generates the heat when electrical current is pass through. Long life of the heater depends on how fast this resistor will decay over time (by oxidation). Temperature is the main driver for long life

HOW THE ELECTRIC HEATER WORKS

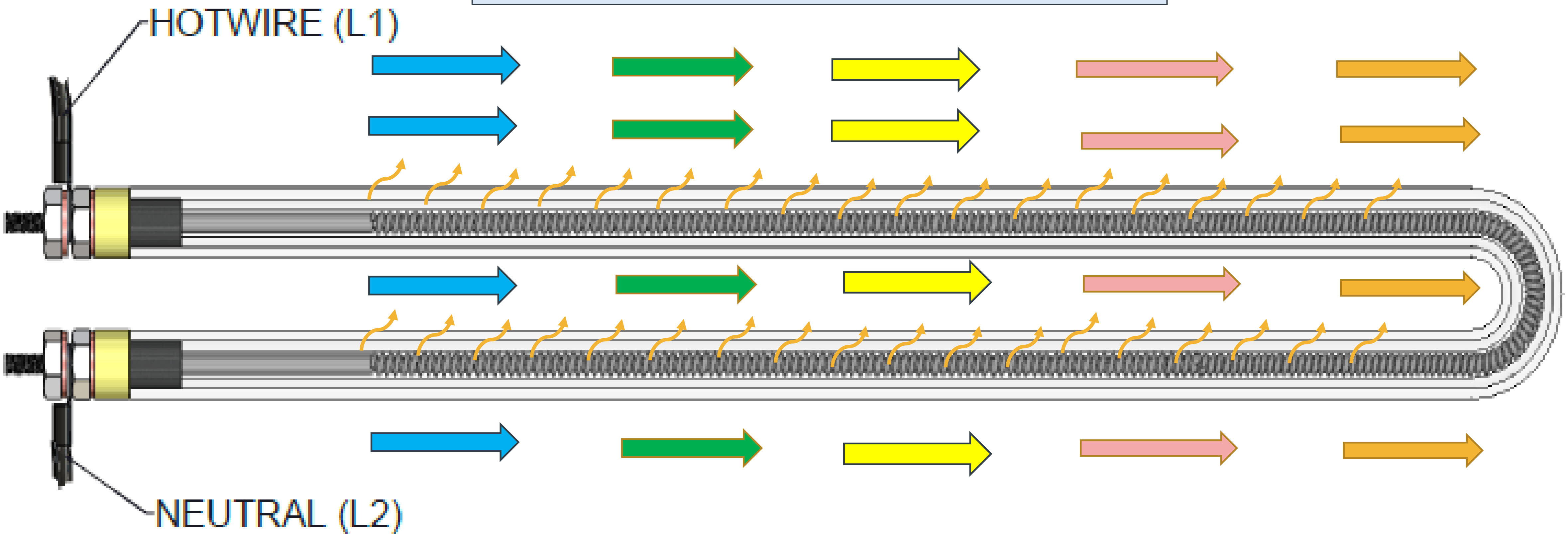


Electric current from power supply moving through lead wire, termination and the resistance wires and creating friction and vibration generating heat energy.

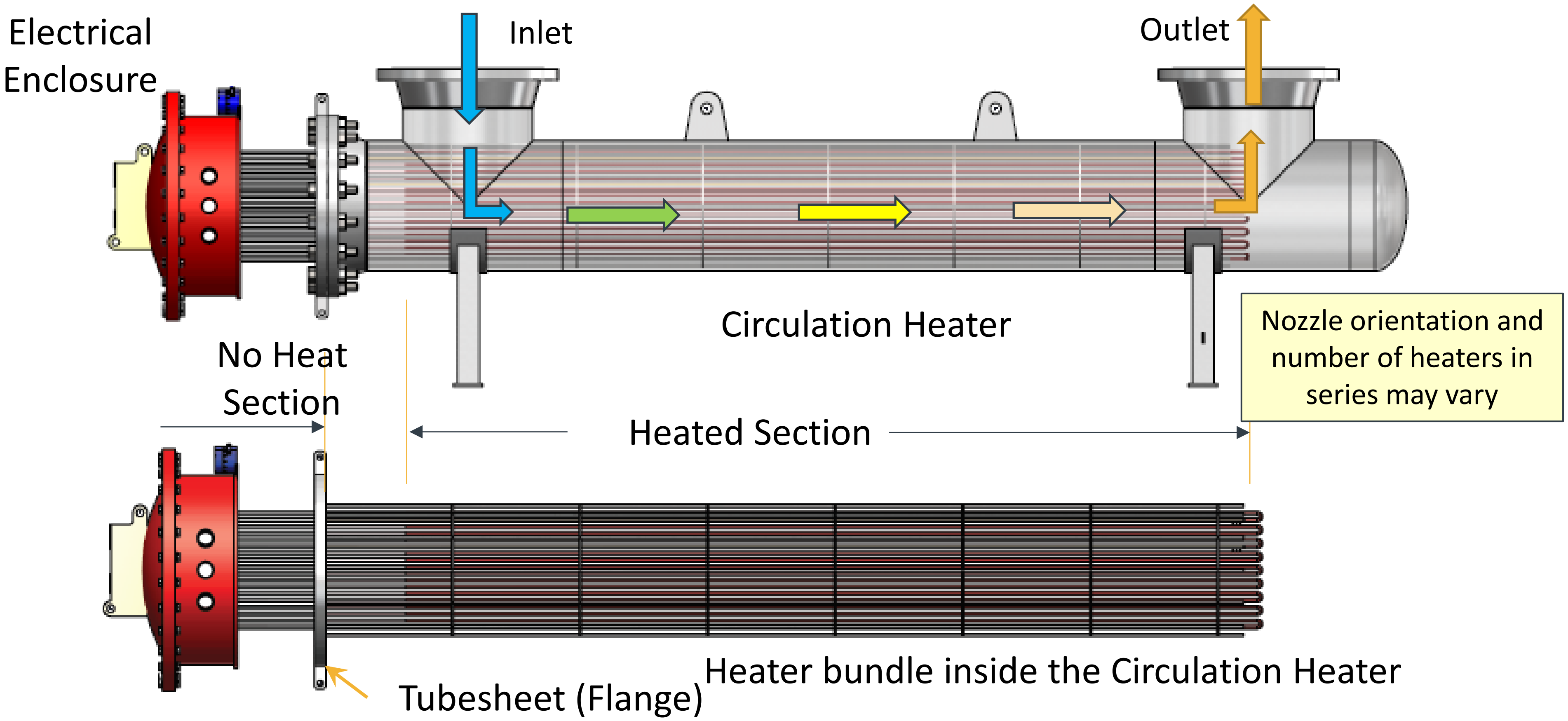
Some leakage current will pass to ground

PROCESS FLUID IS HEATED BY CONVECTION HEAT TRANSFER (HEAT FLUX)

Process fluid picks up the heat from heater sheath



TRADITIONAL CIRCULATION HEATER



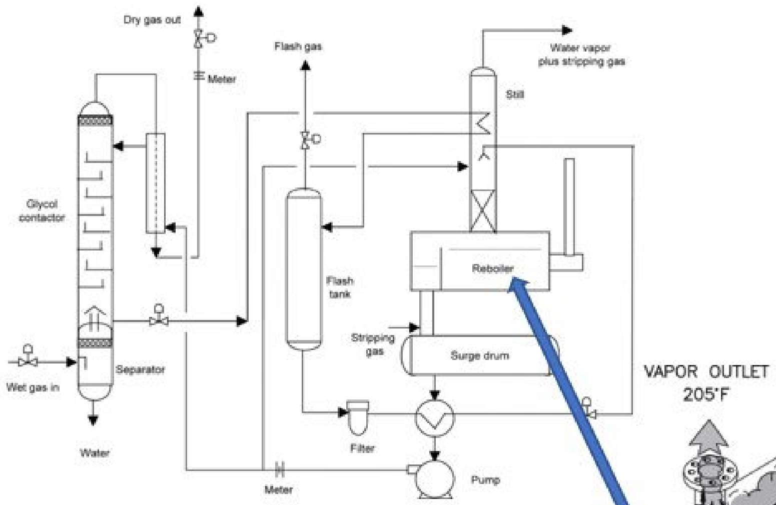
Heat Transfer predominantly convection heat transfer

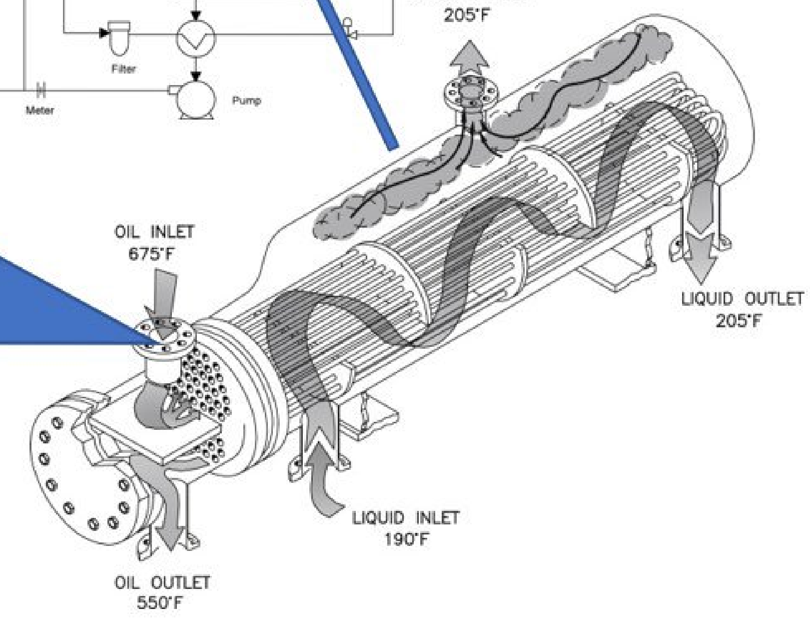
WATLOW CIRCULATION HEATER MIXING TECHNOLOGIES

1- Worst
4 - Best

		hc	ΔP
 Traditional	Use for immersion applications (TEG, MEG, Amine, Liquid Immersion) processes that requires very minimal pressure drop (CCR, PDH heaters, ASU) Limited or not the best for convection heat transfer.	1	4
 Optimax	Use for gas and some liquid applications that can accept higher. Can be used for CCR, PDH, ASU if pressure drop is acceptable. Better than traditional heater for convection heat transfer.	2	3
 Segmental	Use for gas or liquid applications that requires much improved convection heat transfer (higher WSI) but can accept higher pressure drop. Ideal for process where fouling may not be an issue (i.e Fuel gas heaters, crude oil distillates, etc) Better than Optimax for convection heat transfer.	3	1
 Helimax	Use for flow applications that requires better pressure drop than segmental baffles and less fouling compared to segmental baffles. When mixing can't achieve the improved convection offered by Optimax.	4	2

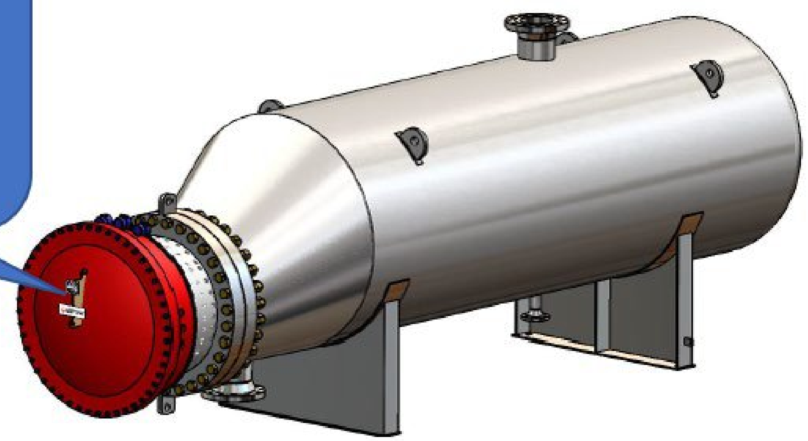
ELECTRIFICATION OF GLYCOL REBOILERS

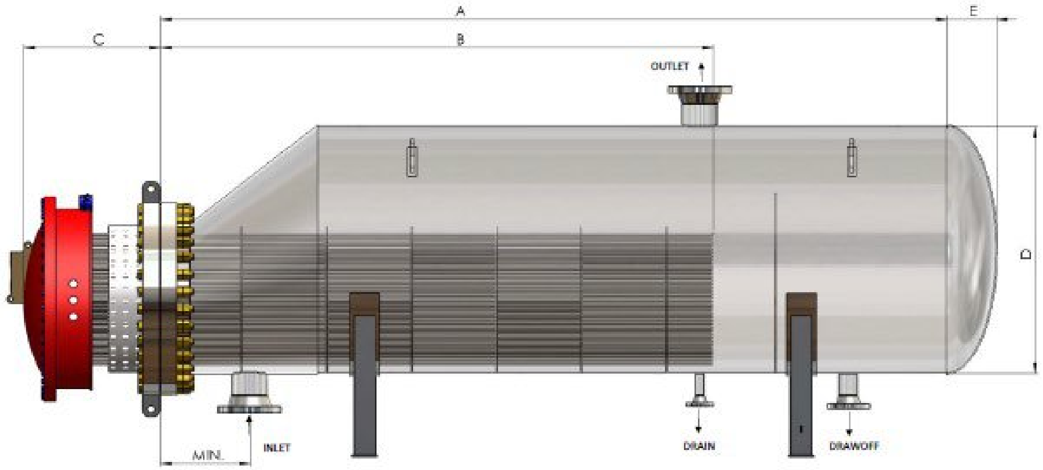




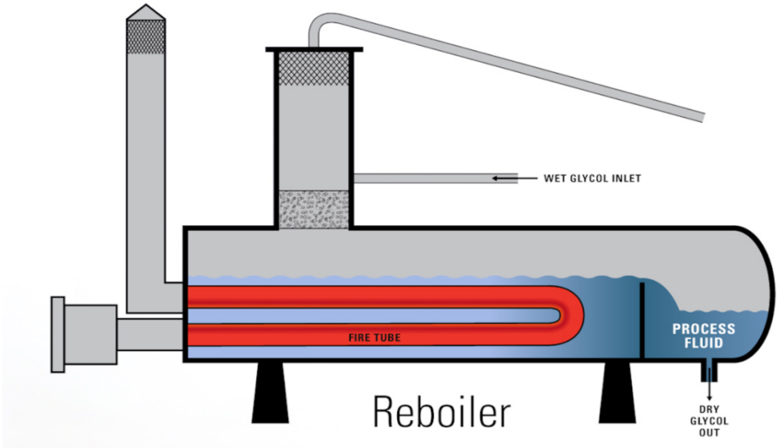
Hot oil source glycol reboiler heat exchanger

Electrically heated glycol reboiler heat exchanger. Sizes to 15MW in single vessel have been developed.

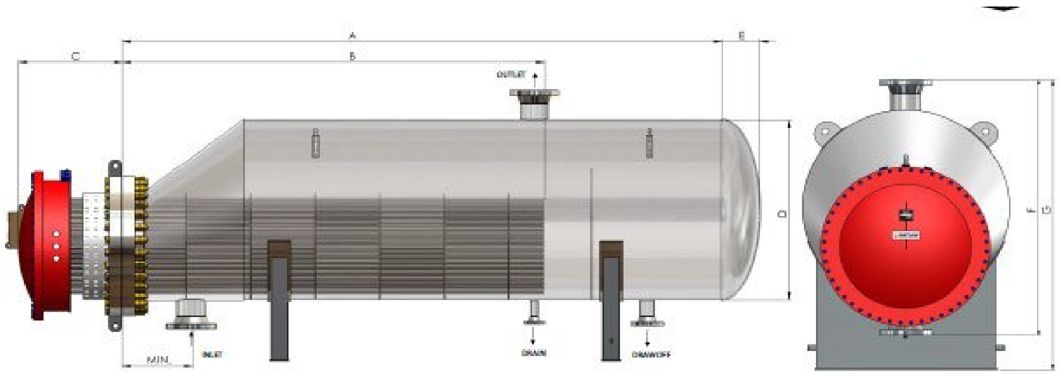




ELECTRIC HEATER REBOILERS



Gas fired reboilers fire tube are susceptible to uneven heating which causes corrosion, foaming and breakdown of glycol or amine



Electric Heater reboilers have constant heat flux thus avoiding surface overheating

HEAT ENERGY (CALCULATION TO CONVERT GAS FIRED HEATERS TO ELECTRIC HEATERS)

Process Heat Energy: BTU/hr can be converted to equivalent electric heat energy (watts, KW, MW) by using this conversion:

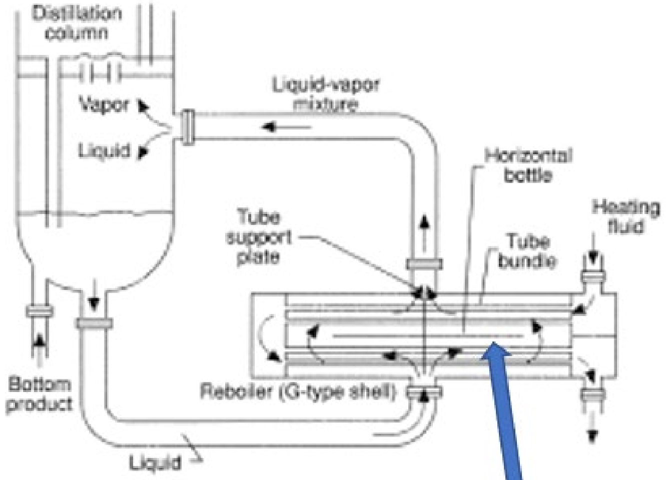
BTU/Hr by furnace* heat exchanger efficiency /3412 = KW equivalent (electric)/0.95

Typical losses through cables and power controllers is about 4%

<u>Example:</u>

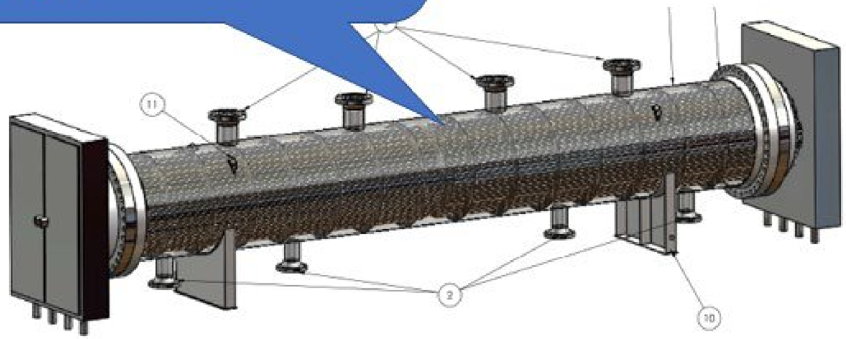
Hot Oil System: Heat Exchanger BTU consumption= 6.0 MMBTU/hr
Electric Heater Equivalent = 6.0 MMBTU*293.078*0.85/0.96 = 1557 KW Electric Heater
Note: 0.85 is the heat exchanger efficiency
0.96 is the electric heater efficiency

2 PHASE REBOILERS

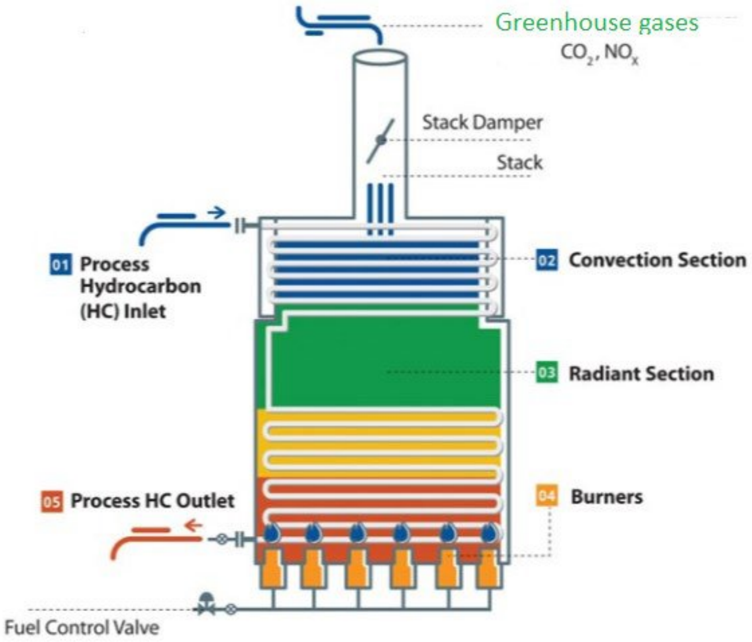


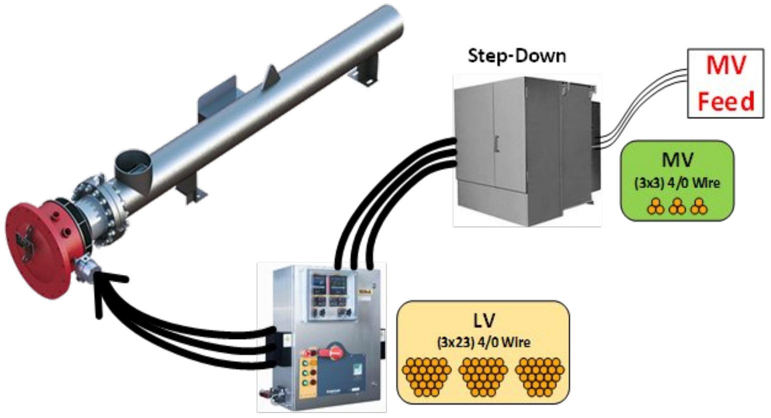
Steam source horizontal reboiler

Electrically heated 12MW 2 phase distillation column reboiler

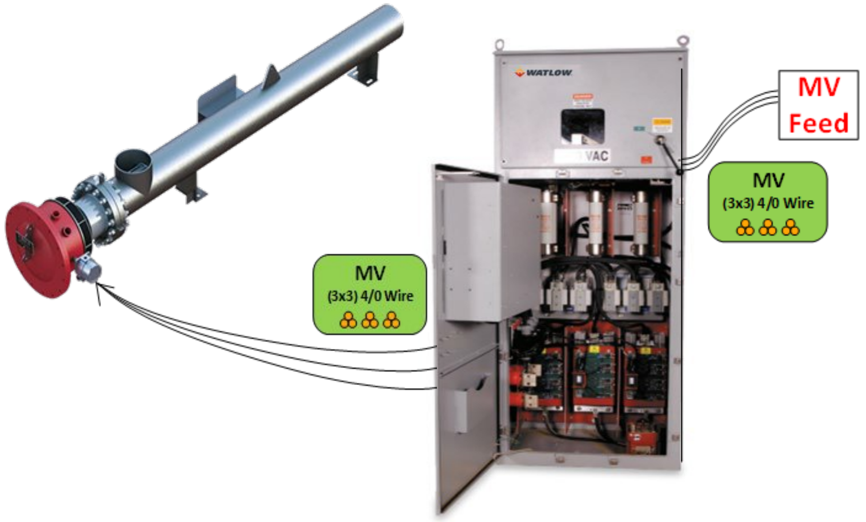


THE TRANSITION TO MEDIUM VOLTAGE





Heated Section



Current Fired Solution

- Gas Fired
- Emits greenhouse gases

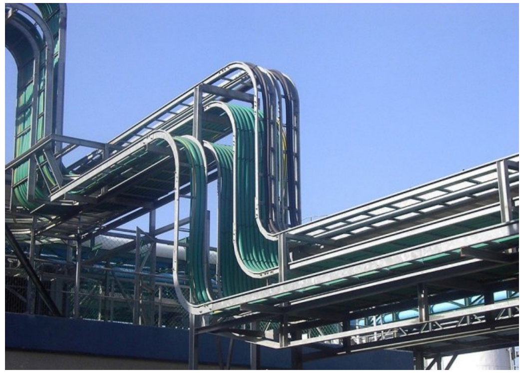
Low Voltage Electric Solution

- Large step-down transformer
- High amperage control panel
- Many large interconnection cables

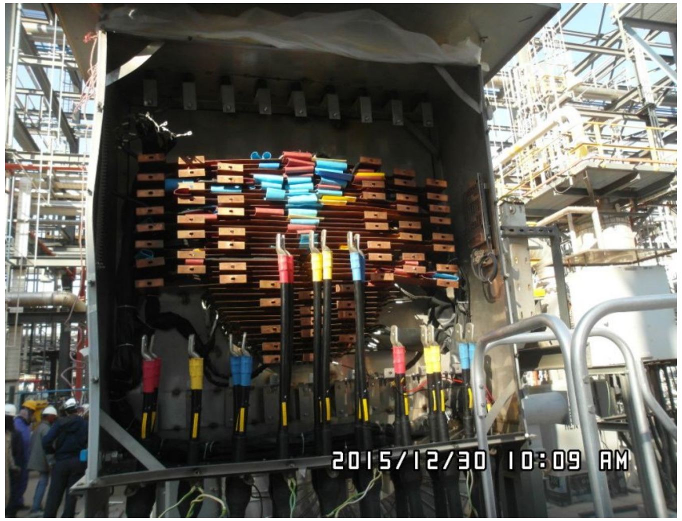
Medium Voltage Electric Solution

- No step-down transformer
- Low amperage control panel
- Few small interconnection cables

MEDIUM VOLTAGE IS AN ENABLER FOR LARGE MW SYSTEMS



It is almost impractical or not possible to electrify large MW systems using low voltage heaters because of cable limitations and wiring challenges



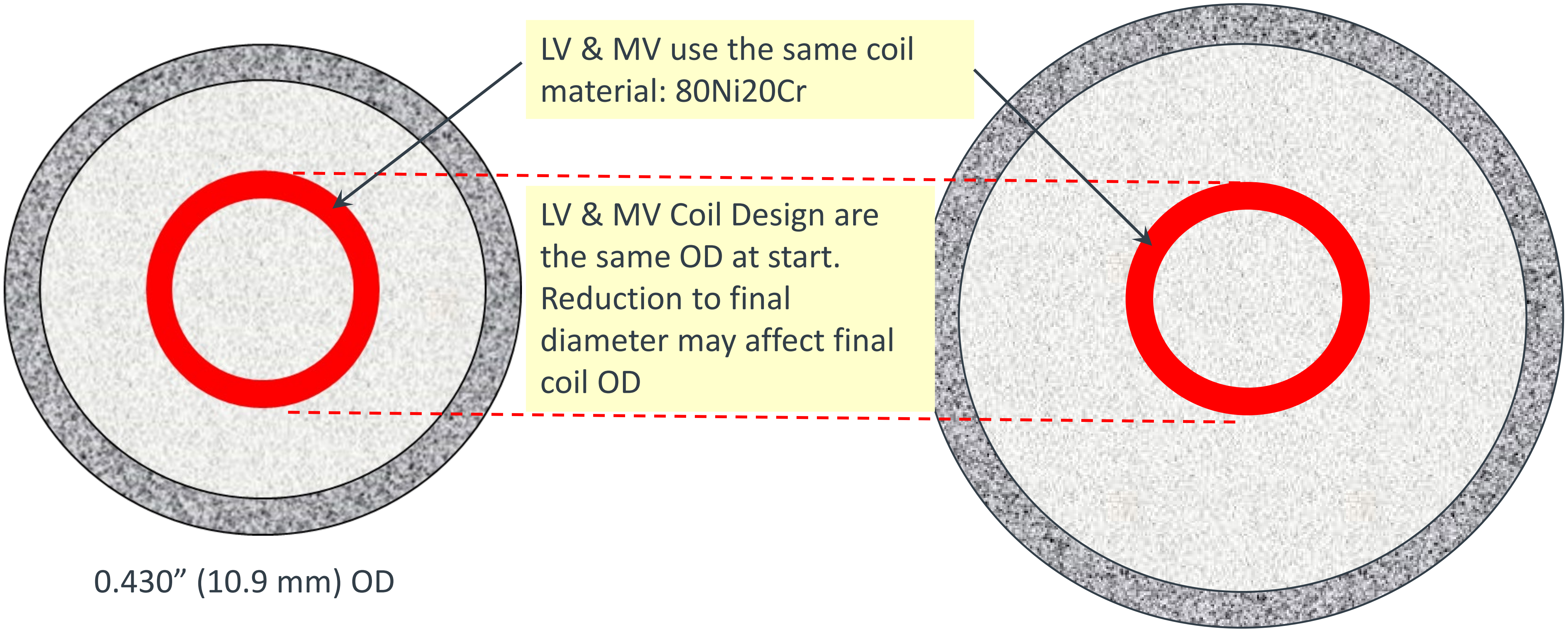
~1 MW Low Voltage Heater
(460V)

~1 MW medium Voltage Heater
(4160V)

INTERNAL CONSTRUCTION DIFFERENCE (LV vs MV)

LV Heater up to 690V

MV Heater up to 7200V

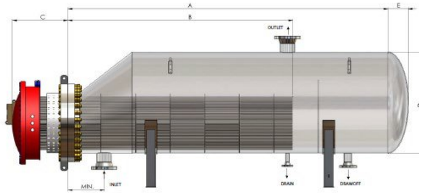


0.430” (10.9 mm) OD

0.5625” (14.29 mm) OD

SCALABILITY OF TUBULAR TYPE ELECTRIC HEATERS

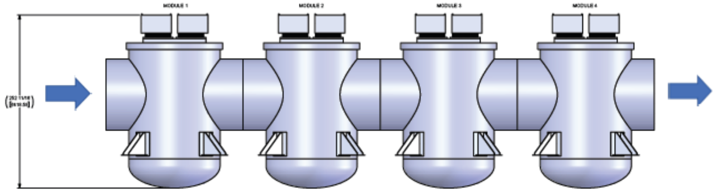
6.0 MW



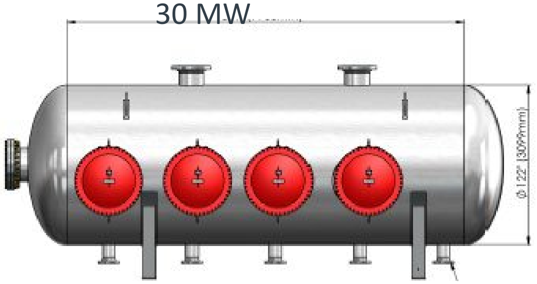
5.0 MW

4.0 MW

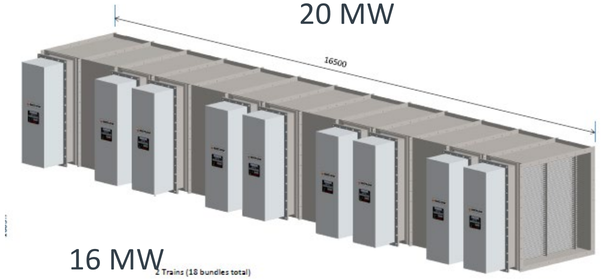
3.0 MW



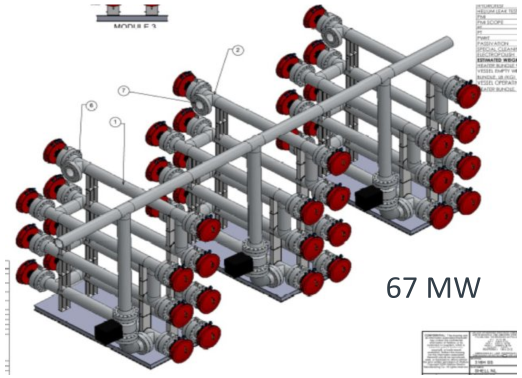
30 MW



20 MW



16 MW



67 MW

Tubular Type (MI) heaters are easily scalable to meet large scale electrification

PROVEN PERFORMANCE AND RELIABILITY OF ELECTRIC HEATERS

Electric Heaters are widely use in Oil & Gas, Petrochem. Regeneration of catalysts for CCRs and PDH systems had proven track records with required reliability of 100,000 hrs of continuous service

Regen Heaters for Alkyllation, Chevron El Segundo, CA

Heaters for Acrylic Acid process, LG Korea

Heating syStems are designed and manufactured to stringent industry standards and third-party agencies like UL, CSA, ASME, ATEX, IEC. NACE and more.

They are installed in hazardous and nonhazardous environment.

Heaters for Stabilizer column

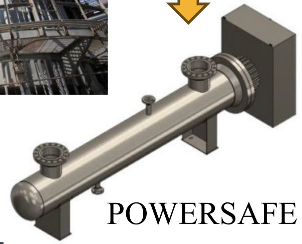
Heaters for PDH Reactors PTT, Thailand

CASE STUDIES:
WHAT IS POSSIBLE AND HAS BEEN DONE

RENEWABLE FUELS PRODUCTION - REACTOR CHARGE HEATING

MV Case Study	
Project	Hot Oil System Upgrade
Site	Refinery - Singapore
Application	Renewable Diesel Fuel Production
Current Process Heat Source	2MW Gas-fired Heat Exchanger – Hot Oil System
Watlow Solution	POWERSAFE® Medium Voltage Electric Heating System including vessel directly heating reactor feedstock
Case for Change	Avoid massive increase in CO_2 tax and reduce emissions; better process safety, reliability, operation flexibility
Watlow Value Proposition	Lower total cost of ownership, more precise process control, reliability

Gas Fired Furnace



POWERSAFE

SINGAPORE BUDGET 2022

cna

Carbon tax increase

Currently	S$5 per tonne
2024 & 2025	S$25 per tonne
2026 & 2027	S$45 per tonne
By 2030	S$50 to S$80 per tonne

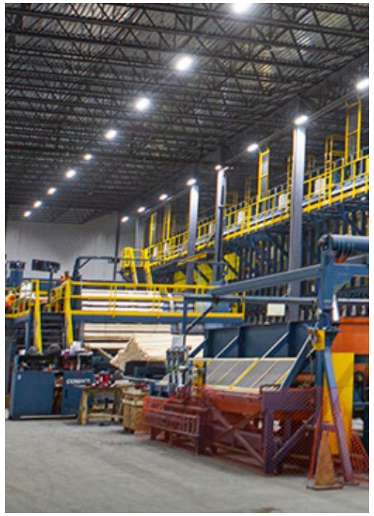
POWERSAFE™

Watlow Medium Voltage Heat Exchanger System

WOOD, PULP, PAPER APPLICATION AND CASE STUDY

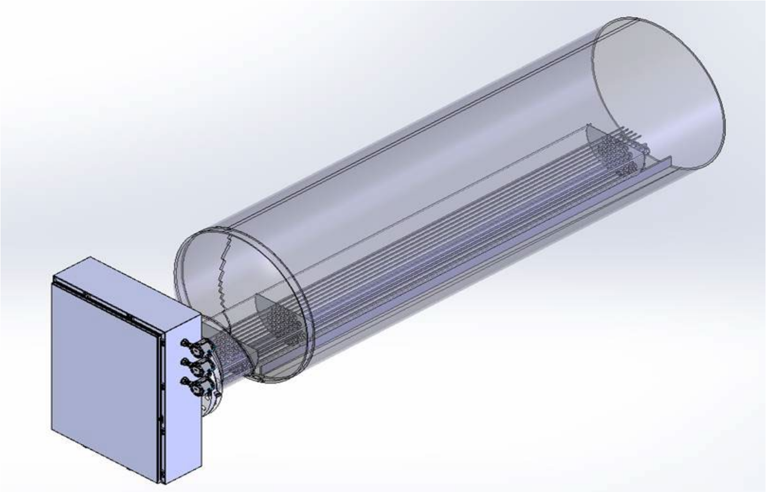
Wood Paper Pulp Case Study	
Project	Electric Lumber Kiln
Site	Canada
Application	Drying of softwood lumber
Previous Process Heat Source (New Source)	Combusted fossil fuel (600 VAC Electric) Brownfield
Watlow Solution	Duct heaters (20) and WATCONNECT XL Control Panels (4)
Case for Change	Corporate sustainability goals. Available low-cost electricity from Hydro.

Eco-friendly lumber



TEG APPLICATION – LOW VOLTAGE

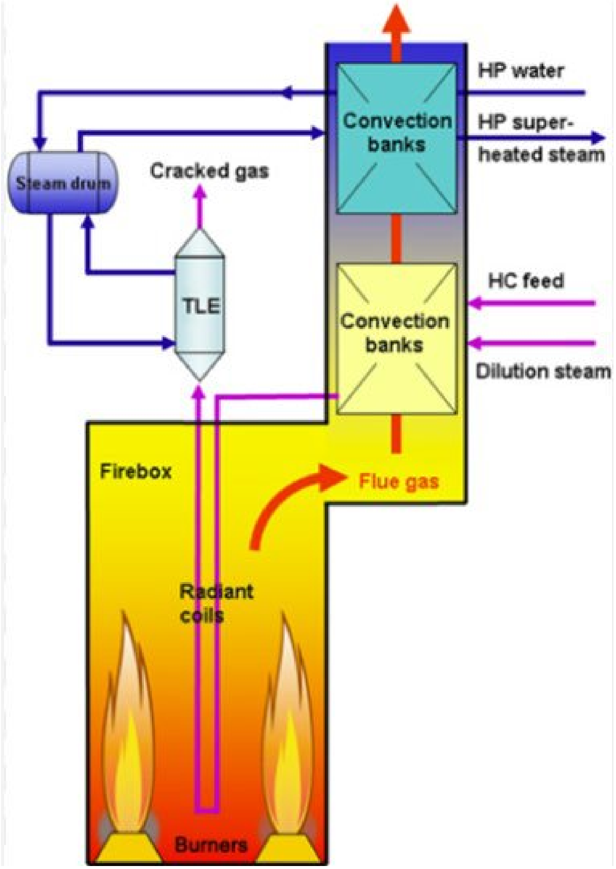
Wood Paper Pulp Case Study	
Project	Heat exchanger upgrade to electric
Site	Gulf of Mexico
Application	TEG Reboiler
Previous Process Heat Source (New Source)	Shell and tube converted to electric heater bundle with WATCONNECT Panel
Watlow Solution	100kW, 480
Case for Change	Reduce carbon footprint and gain experience with electric heaters. Full capacity from previous shell and tube was no longer necessary.
Watlow Value Proposition	Full thermal solution with pre-designed, standard products that fit the application and requirements

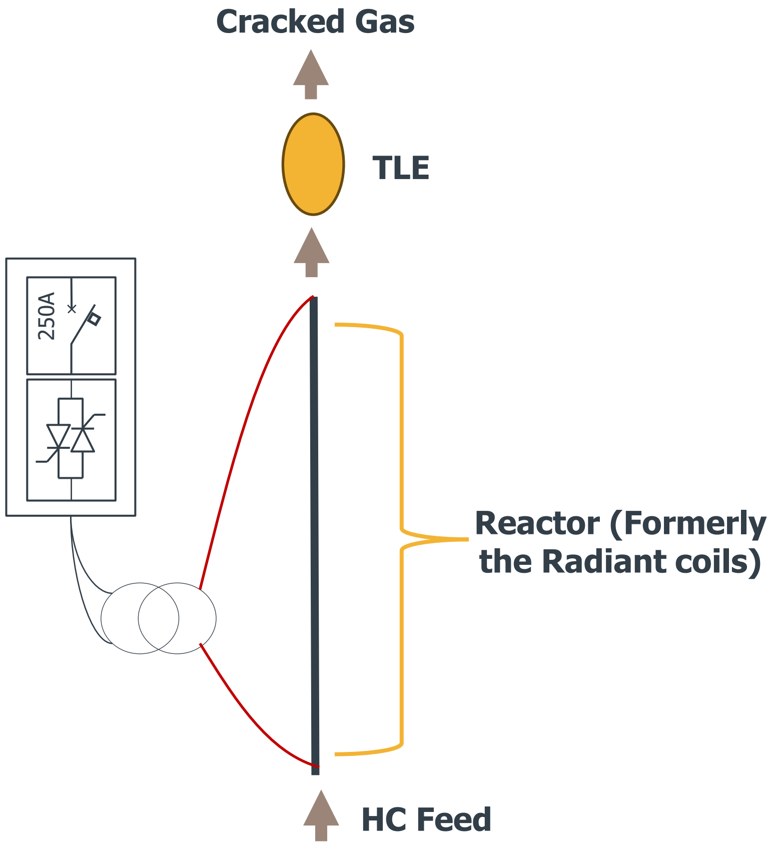


REFINERY

Refinery Upgrade Case Study	
Project	Refinery Upgrade
Site	France
Application	Hot Oil System for Bitumen
Current Process Heat Source	Steam generated by fossil fuel, Brownfield
Watlow Solution	Direct Heat Exchanger (PowerSafe)
Case for Change	• The bitumen logistics hot oil circuit is heated by 3 HP steam exchangers. They can be replaced by electrical heaters with a power of 4.8MW, resulting in a yearly saving of 13,5kT CO_2 and 4.9 kta Natural Gas. This represents around 1% of the refinery's CO_2 emissions and 19% of CO_2 reductions plan.
Watlow Value Proposition	• Our technical capability to provide medium voltage solutions, our responsiveness

Direct Heating - a groundbreaking solution





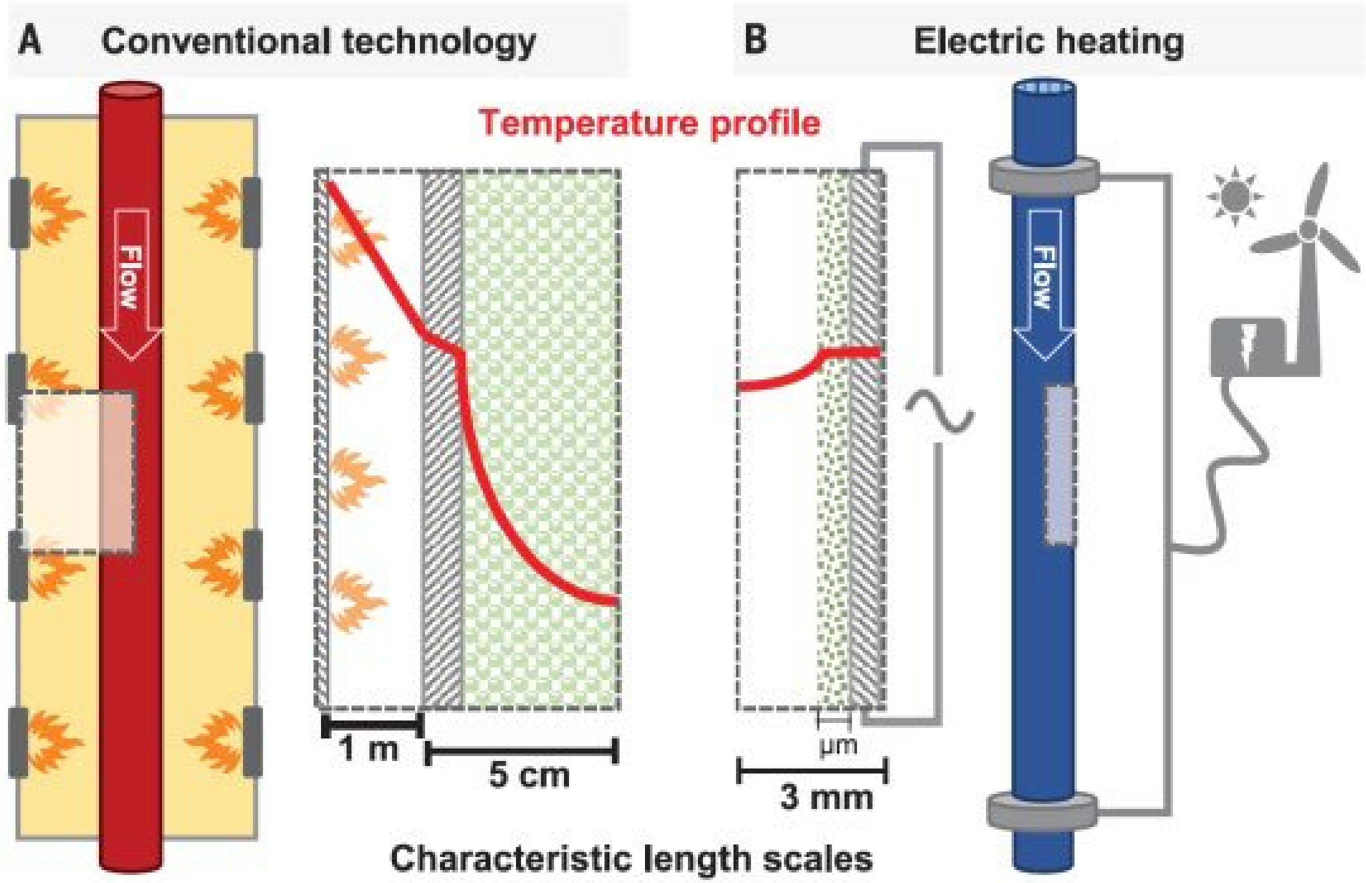
- **Typical Fossil Fired Ethylene Cracker**
  1. Complex
  2. Inefficient (Firebox efficiency 40-45%)
  3. Not accurate control and ultra long response.

     => Lower availability and shorter lifetime

- **Direct Heated Ethylene Cracker**
  1. Smart and Simple
  2. High-efficient (80 – 90%)
  3. Very precise and ultra-fast control

     => Better availability and longer lifetime

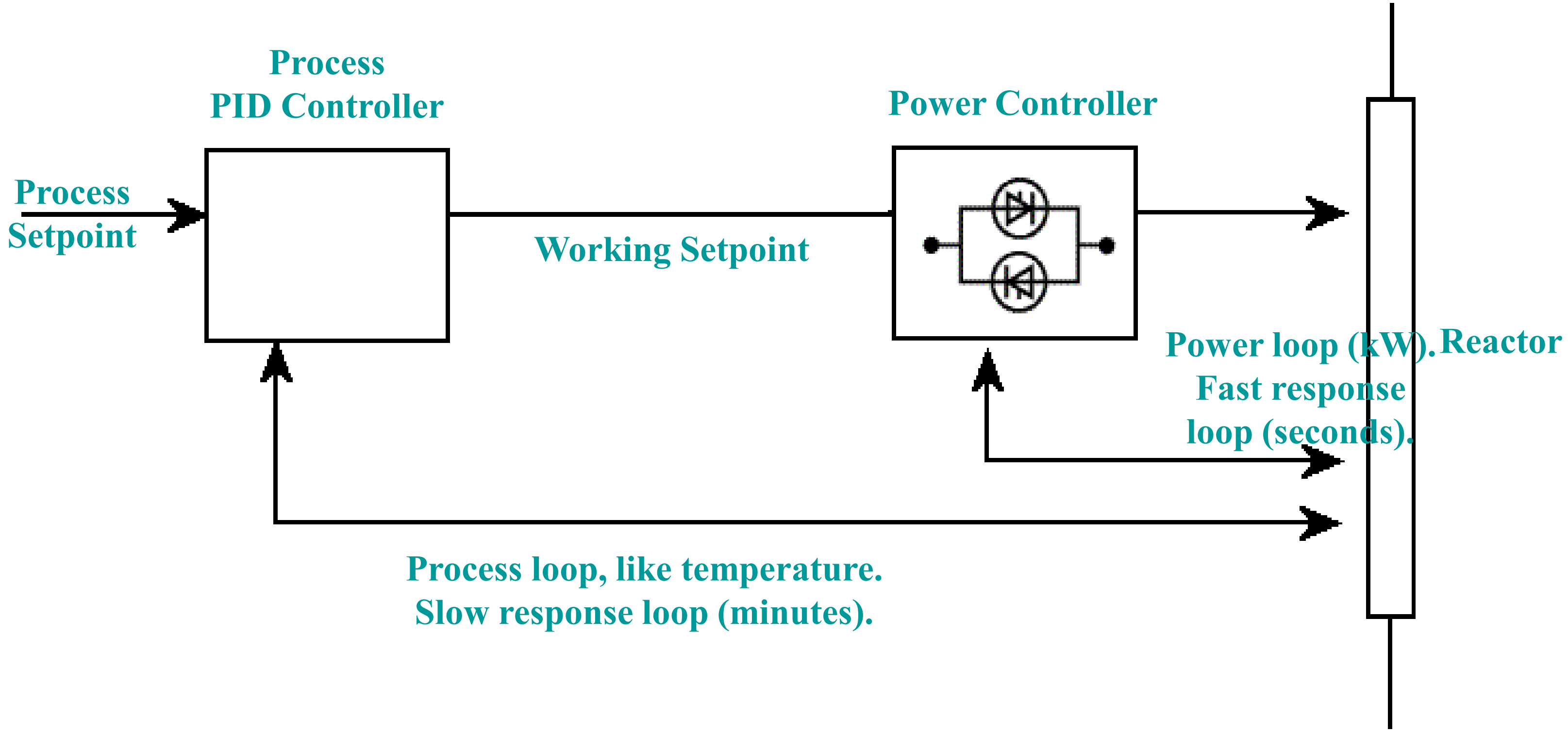
Direct Heating - a groundbreaking solution



- **Direct Electrically Heated Ethylene Cracker versus Radiant Technologies (both electric and burner)**
  1. Better/lower skin temperature => longer lifetime, better availability and more cost effective.
  2. Higher temperature homogeneity => better yield and higher furnace availability (less maintenance and downtime).

The advantages of a Direct Power Control Loop

- **It makes the process control loop more stable and faster, thanks to its accurate control and fast acting response.**

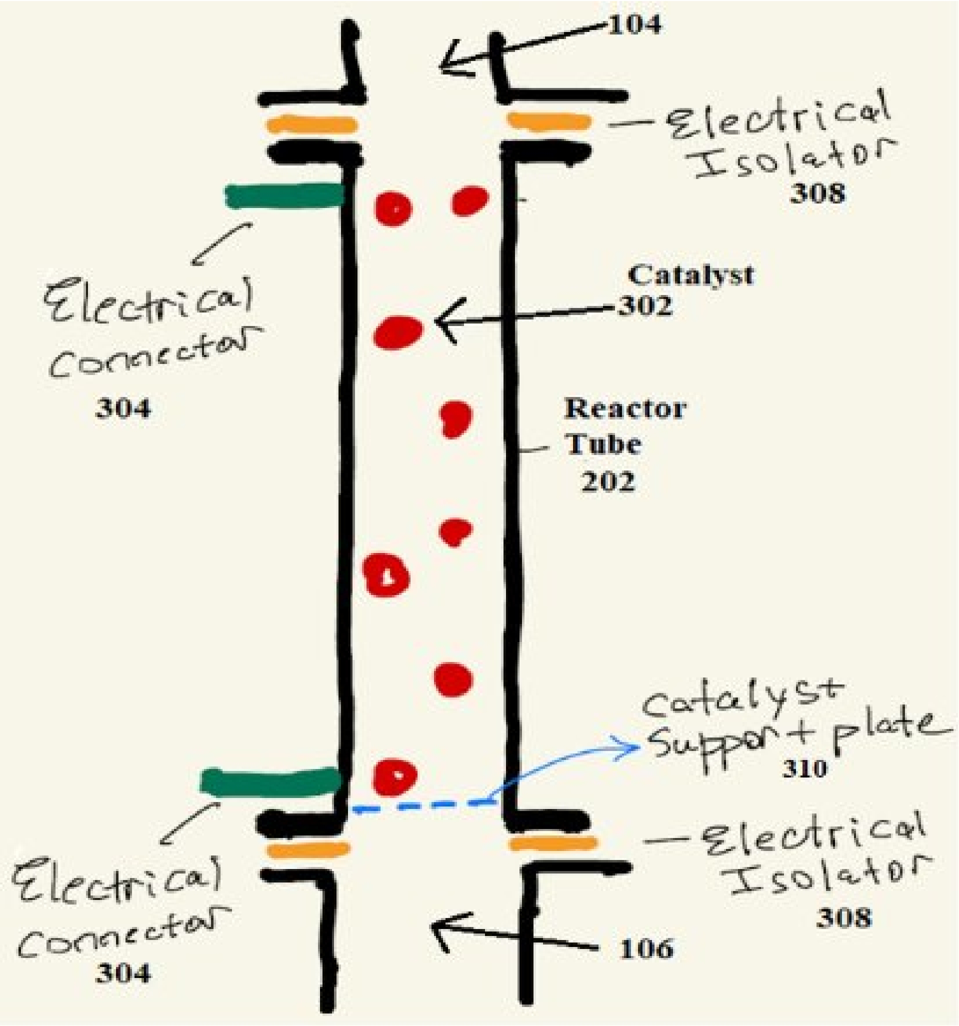


The advantages of a Direct Power Control Loop

- **The temperature control loops are always slow response loop (minutes), and it is due to multiple factors.**
  - The thermal inertia of the reactor.
  - The heat transfer to the reactor, when indirect (flame control) is made of convection, radiation and diffusion, and each mode has a different heat transfer function.
  - The time response of the temperature sensor itself is quite long (thermocouple).
  - The PID set up of the process controller must be softer in order to integrate the instabilities of the combustion, like flame instability, gas calorific value and flow variations, exhaust gas flow variations in the chamber…and so on.
- **By introducing inside the temperature control loop an accurate and direct power control loop (in kW, Volt or Ampere), we improve greatly the stability, accuracy and speed of the temperature control loop:**
  - The heat transfer to the reactor is much simpler with a quite constant heat transfer function (no more convection and radiation transfer modes). It gives also the opportunity to create a model of the heat transfer function and implement a predictive model-based temperature control loop, making the process control loop much faster than a typical PID control.
  - The time response of the direct Power Control loop is extremely accurate and fast (sampling every 20msec).
  - As we have eliminated the combustion instability, the gas calorific value variation and the exhaust flow instabilities in the combustion chamber, the PID control loop, can already be improved.

The advantages of a Direct Power Control Loop applied on a Catalytic or Non-Catalytic Reactor

- We inject the electrical energy between the two electrical connectors on the reactor tube.
- Thanks to the joules effect the heating is applied at the reactor tube itself, directly in contact with the catalytic reaction.
- As the heat generation is well known (reactor tube resistance), the heat transfer can be easily modeled and will give a faster and more accurate control.
- This solution will improve the yield, the energy efficiency and the lifetime of the complete reactor.



Thanks for your attention!

Roly Juliano

Principal Engineer

rjuliano@watlow.com

Gregoire Quere

Global Power Applications Manager

gregoire.quere@watlow.com

WATLOW®

Powered by Possibility

Thank you for your attention !