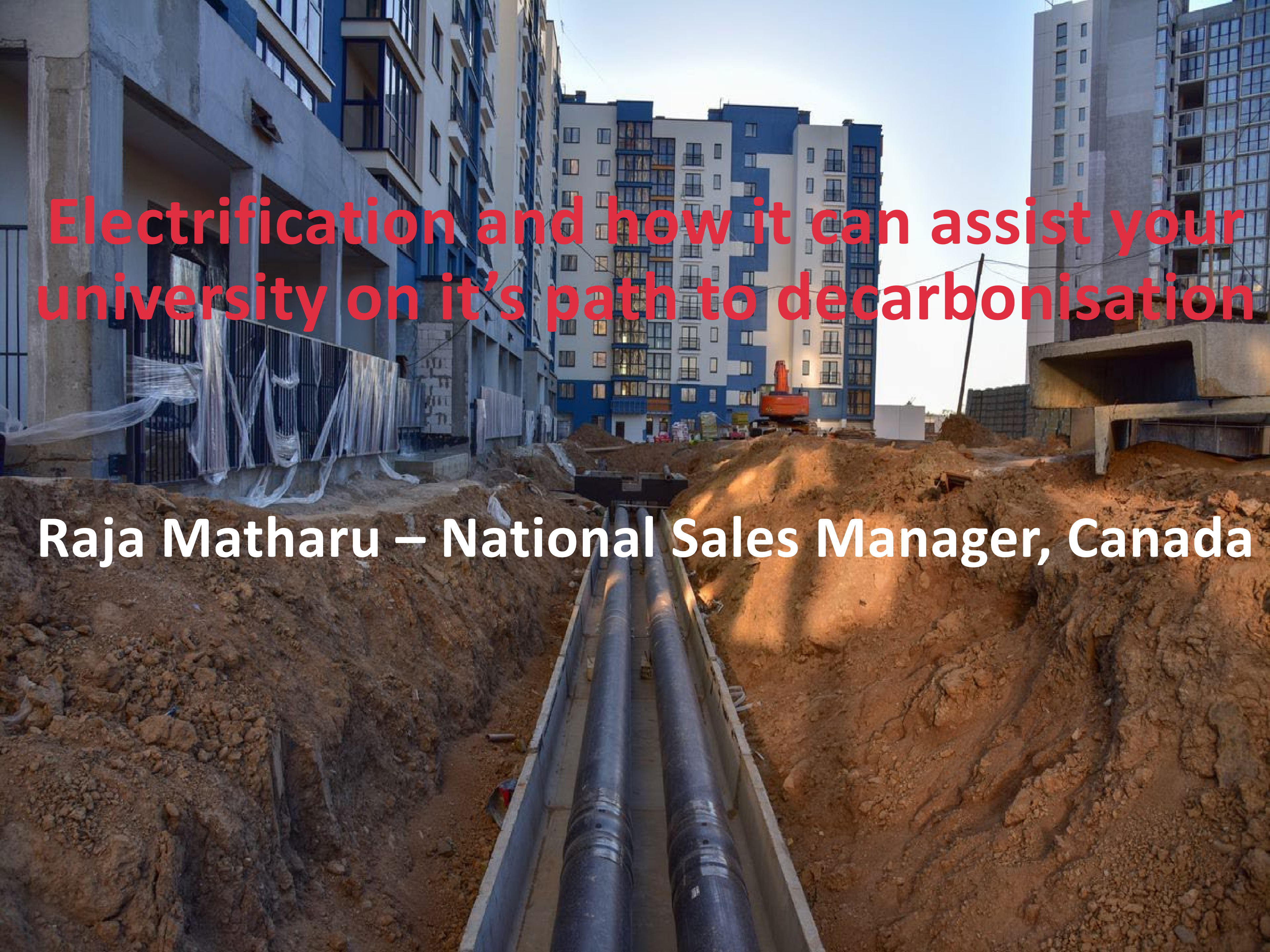


Electrification and how it can assist your university on it’s path to decarbonisation

Raja Matharu – National Sales Manager, Canada

Problem

Many universities rely on carbon-intensive systems for heating across campus buildings as well as for various laboratory devices, humidification systems, and washing appliances. Electric heating solutions provide ways for you to improve efficiency of existing systems while helping reduce energy consumption and lower carbon emissions. Electric heating solutions empower universities to meet their sustainability goals through zero emission electric process heat and steam generation on a scale beyond conventional limits.

Advantages of Electrification

Lowered Safety Concerns

No open flames

Increased Efficiency

Nearly 100% of energy utilized is converted to heat energy

Minimal Maintenance

Combustion controls that need adjusting; easily replaceable, if needed

Clean Operation & Lower Installation Costs

No pollution stacks, fuel lines or holding tanks

Precise Temperature Control

Electric allows point of use installation with a power control input range of 0% to 100%, no wasted energy

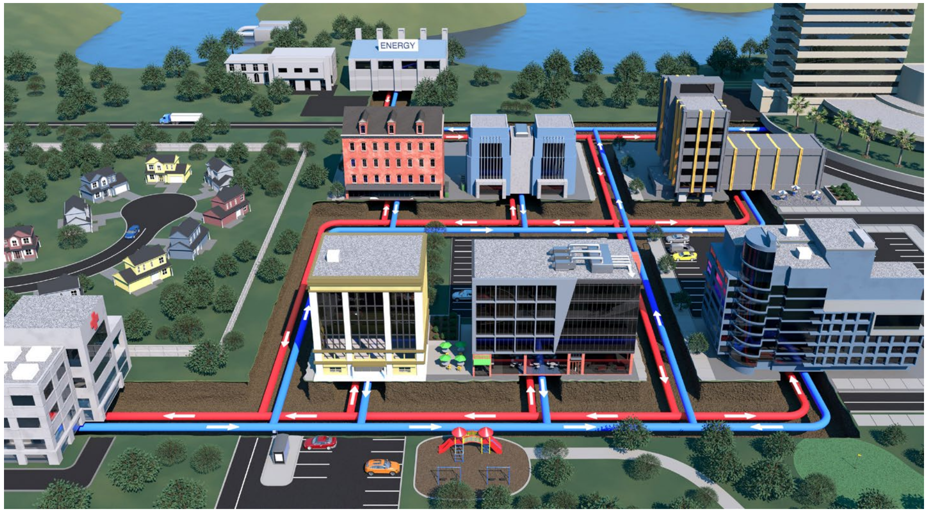
Controlled Costs

Low fluctuations in electricity prices and increased availability of low cost renewable energy

Campus Electrification

Applications

- Low Voltage (< 600V)
  - Electric heat trace for freeze protection on piping
  - "Booster" heat for long distance transfer of steam/hot water
  - Peak load heating
- Medium Voltage (> 1000V)
  - Peak load heating
  - Large scale electric steam/hot water generators for campus heat



LOW VOLTAGE (LESS THAN 600V) ELECTRIC SOLUTIONS

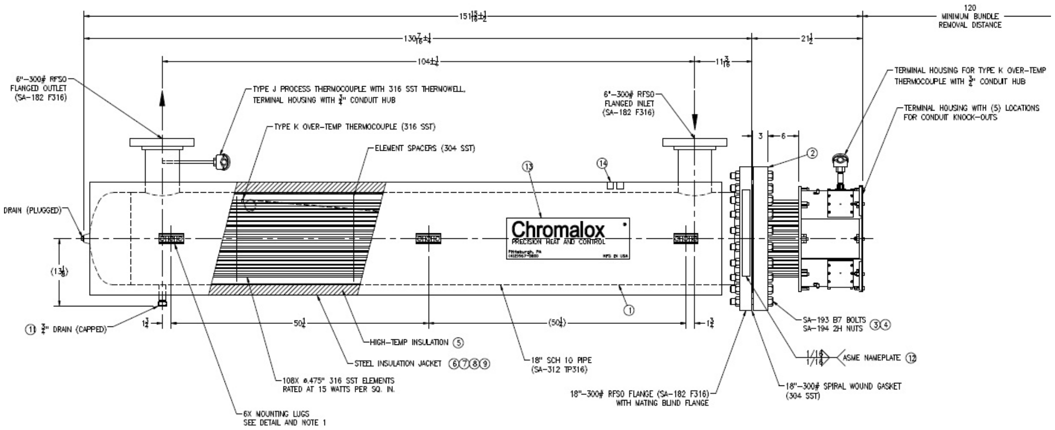
Pipe freeze protection

- Exposed piping
  - Potable water
  - Wet Fire sprinkler piping
  - Drum drips- dry fire sprinkler
  - Sanitary piping & traps
  - Storm piping
  - Cooling towers
  - Condensate & steam piping
  - Water tanks
  - Pumps & sumps

POORLY INSULATED WATER MAIN

Circulation heaters (Booster/Peak heat)

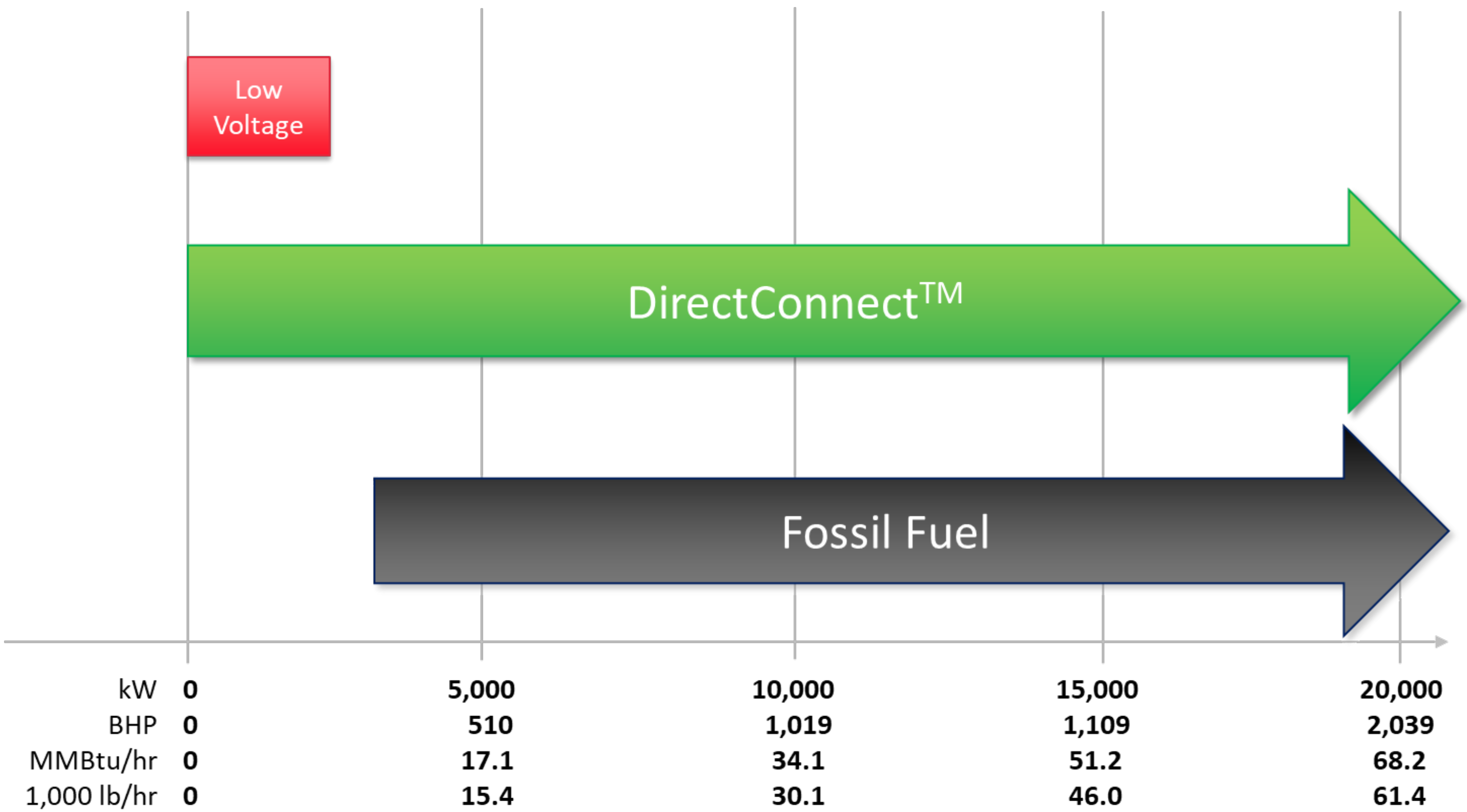
- In-line or Recirculating
- Water, Solutions, and Steam
- ASME/CRN/PED Certifications
- Custom and Standard Designs
- Low Pressure Drop Across Unit
- Skid Mounting w/ Integral Power Control Assemblies
- Process and High Limit Controllers
- BACnet Connectivity



MEDIUM VOLTAGE (GREATER THAN 1000V) ELECTRIC SOLUTIONS

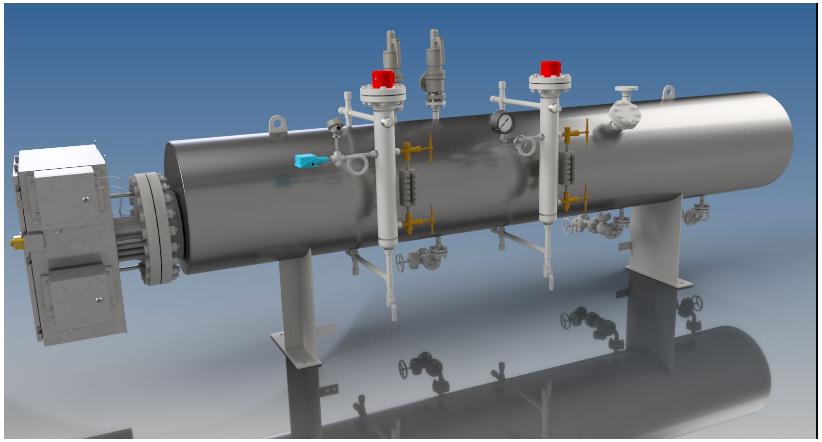
Optimal Choice for Steam/Hot Water Generation

- By utilizing medium voltage, electric provides a cost-effective solution for large heating demands
- Medium voltage provides all the same “green” benefits as low voltage heating



Medium voltage steam/hot water generators

- Up to 6900V operation
- Standard sizes from 1.1 MW to 10.9 MW
- Custom sizes up to 20 MW available
- ASME Designed & Certified
- 250 & 450 PSIG designs standard, up to 1000 PSI available
- Full SCR, contactor, and hybrid control options
- BACnet Connectivity



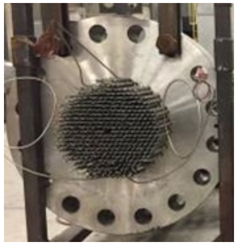
Standard Size Specifications

Voltage	kW	Steam Lbs / hr	Mbh	bhp	Boiler Dimensions (In / mm)*			Dry Weight (lbs./Kg)
					W	L	H	
4160	1151	3,469	3,927	117	46 / 1168	217 / 5512	77 / 1956	4,200 / 1,905
4160	2303	6,941	7,858	235	55 / 1397	218 / 5537	87 / 2210	8,300 / 3,765
4160	4606	13,882	15,716	469	66 / 1676	220 / 5588	101 / 2565	16,200 / 7,350
4160	6909	20,823	23,574	704	76 / 1930	222 / 5639	115 / 2921	23,800 / 1,100
6600	1827	5,506	6,234	186	55 / 1397	218 / 5537	87 / 2210	7,200 / 3,300
6600	3654	11,013	12,467	372	66 / 1676	220 / 5588	101 / 2565	14,000 / 6,350
6600	7308	22,025	24,935	745	76 / 1930	228 / 5791	121 / 3073	27,400 / 12,426

Benefit of Medium Voltage Elements vs. Low Voltage

Low Voltage

- Up to 1,000V (690V)
- 95.7% efficient
- 12 mm diameter elements
- 0.7 mm sheath thickness
- 2,928V hi pot for 480V
- 3rd party certs: UL, CSA, ATEX, IECex
- 1MW @415V = 1,493 amps
- 1.4MW SCR Panel Dimensions: 285cm W x 51cm D x 229cm H




Medium Voltage

- 1,000 to 7,200 Volts
- 98.8% efficient
- 25 mm diameter elements
- 1.27 mm sheath thickness
- 15,400V hi pot for 6600V
- 3rd party certs: UL, ETL, ATEX, IECex
- 1MW @ 6600V = 88 amps
- 1.4MW SCR panel dimensions: 229cm W x 76cm D x 235 cm H


LV vs MV cost savings

- Elimination of costly step-down transformers
- Reduced installation labor hours: 1,270 hours for LV compared to only 70 hours for MV design
- Conduit Runs: 380V = 50, 6600V = 9
- Wired Circuits: 380V = 63, 6600V = 3 circuits
- Increased Operational Efficiency: 95.7% at 380V, 98.8% for 6600V
- Reduced maintenance costs: $238K compared to $40K for MV design

COST OF OWNERSHIP	380 V	6,600 V	SAVINGS
Installation	$1,752,900	$907,500	$845,400
Operating	$4,070,400	$220,100	$3,850,300
Maintenaince	$179,600	$17,100	$162,500
10 yr Life Cycle Repacements	$237,900	$39,900	$198,000
20 Year Costs	$6,24,800	$1,184,600	$5,056,200
Annualized Costs	$312,040	$59,230	$252,810

500KW 4160V / 480V Wire

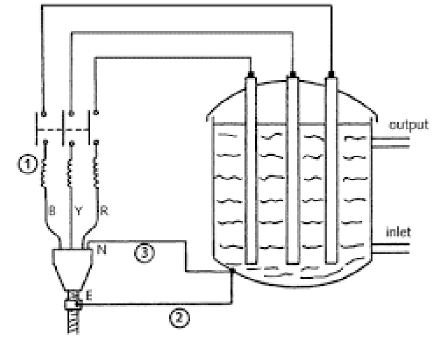
MV ELECTRIC HEATING TYPES

ELECTRIC RESISTANCE
VS.
ELECTRODE

Electrode Boilers

Electrode boilers utilize the conductivity of water to carry electric current and generate steam and/or hot water. An alternating current flows from the electrode of one phase to an electrode of another phase using the water as the conductor. The resistance of the water to current flow produces heat directly. The heat generated is proportional to current flow.

Simplified Electrode Boiler Drawing



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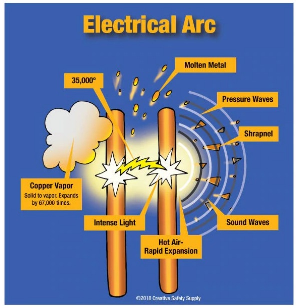
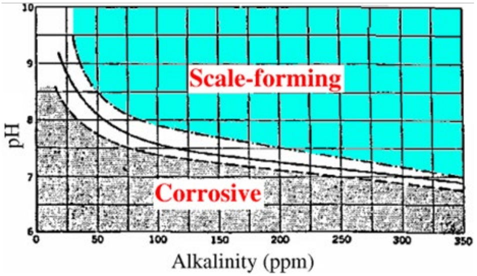
Electrode Boilers – Maintenance / Operational Factors

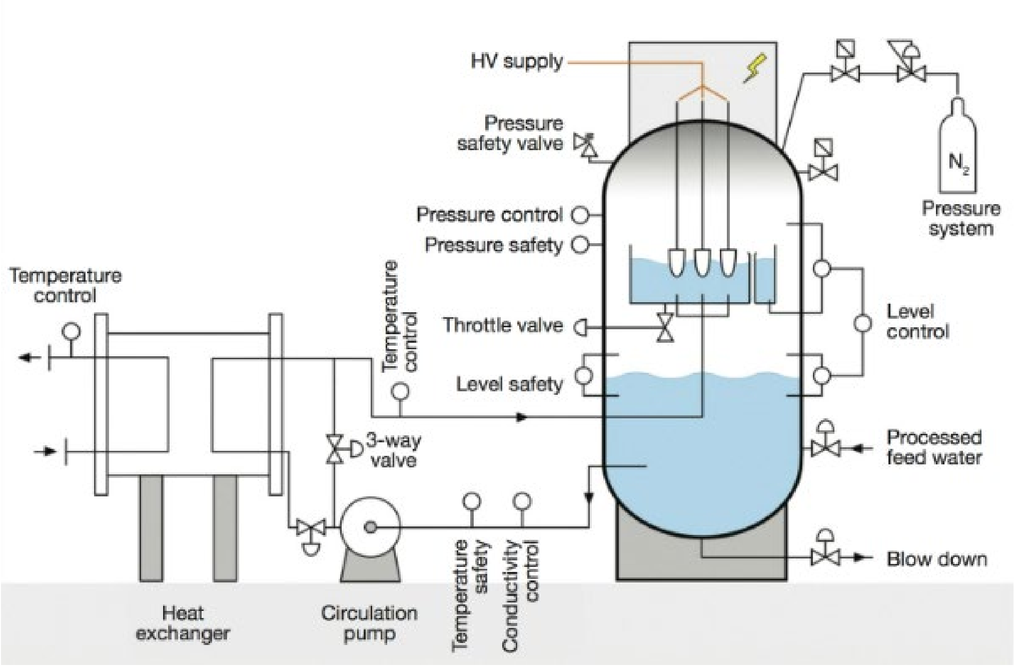
- Water quality/conductivity issues
- Foaming issues with water inside the boiler vessel
- Scale deposition on the electrodes
- Corrosion and fouling of the spray nozzles
- Corrosion concern with fragile electrical power insulators
- Arc-over concerns
- Disruption in electrical power supply and switchgear
- Complex control scheme
- Multiple moving parts/components



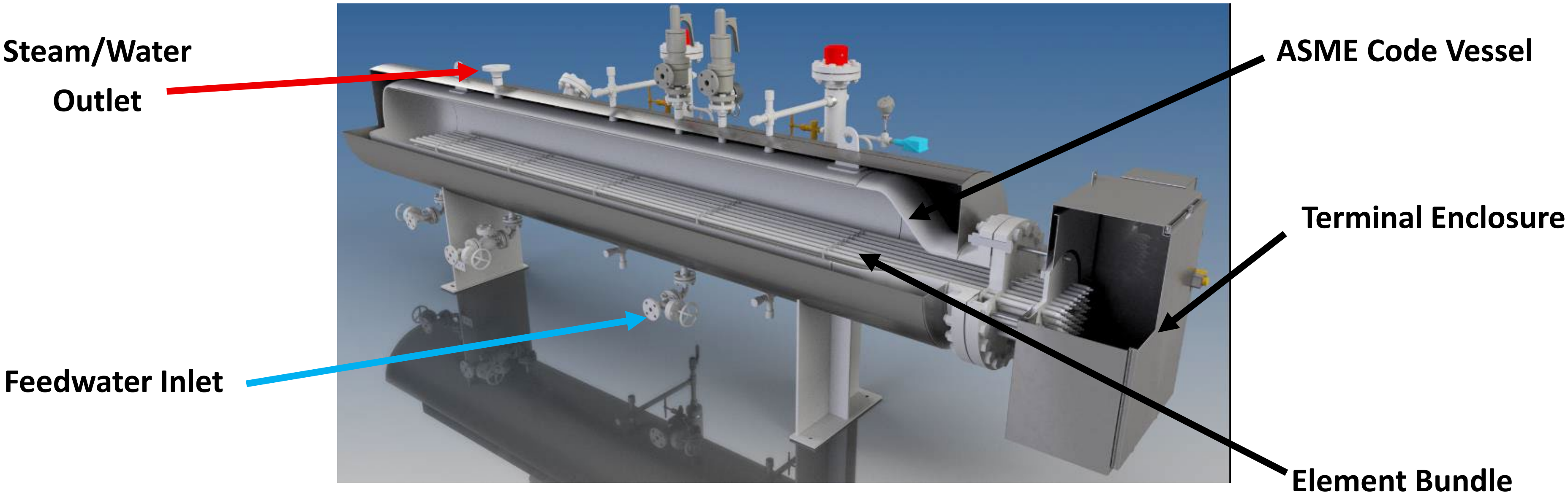


Electrode Boilers – Complex Control Systems

- Additional large circulating pump required for internal flow
- Hydraulic pump required to constantly adjust stream/water flow and electrode output alignment
- Water quality requires constant monitoring which requires interlocks with additional chemical feed pumps



Resistance Element Design Steam/Hot Water Generator



- The heating elements use a sealed resistance wire to convert electric energy to heat
- The heating bundle is immersed directly in the water providing 100% heat transfer
- Electrical components are isolated from the water/steam chamber

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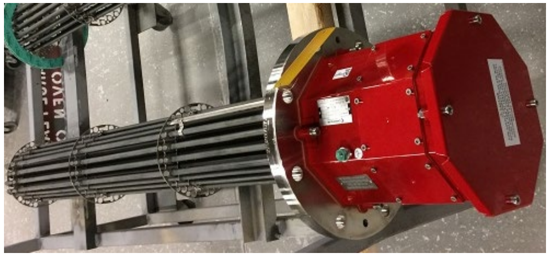
Steam/Hot Water Generation with Resistance Heaters

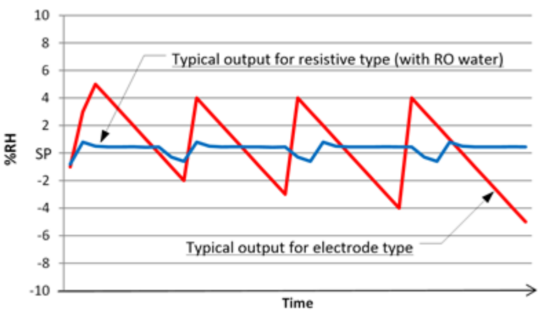
<u>Benefits of using resistance heating to generate steam/hot water</u>:

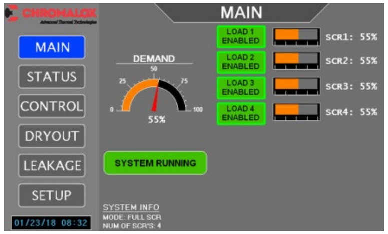
- Very little to zero water treatment required
- Able to utilize DI or de-min feedwater sources
- Electrical connections isolated from internal boiler vessel
- Simple control scheme based on outlet pressure sensor
- Corrosion resistant Incoloy sheathed heating elements
- Minimal maintenance due to zero moving parts required for operation
- Nearly 100% efficient
- 450 PSIG standard designs, up to 1000 PSIG custom designs



Resistance Heaters – Operational Control

- Resistance heater response instantaneously to process control input
- Response is not dependent on pump flow, water conditions, or electrical conductor scale conditions
- Pressure / temperature control has significantly tighter deadband





Steam/Hot Water Generation Technology Comparison

Functional Area	Features	Elements / Resistance	Electrode	Fossil Fuel
Power Supply	Wiring / Amperage	Low	Low	Low
	Fuel Lines	None	None	Yes
	Fuel Pump	None	None	Yes
	Fuel Burner	None	None	Yes
	MV Electrical Terminations	External	Internal	None
Feed / Return Water	Water Quality Maintenance	Low	High	Average
	Water Treament	Low	High	Average
	Impact of Water Supply Variations	Low	High	Average
	Capable of Clean Steam Generation	Yes	No	Average
Safety	Fire Risk	Low	Low	High
	MV Shock Hazard Risk	Low	High	Low
	Third Party Standards - Mechanical	ASME/PED	ASME	ASME/PED
	Materials Thermal Stress	Low	No	No
Performance / Operation	Heat Up Time	Fast	Fast	Slow
	Operation Complexity	Low	High	High
	Load Variation Response Time	Excellent	Average	Low
	Load Variation Efficiency	Excellent	Excellent	Poor
Maintenance	Maintenance Inspections Time	Low	High	High
	Maintenance Service Time	Low	High	High
	Labor specialization	Low	High	High
Sustainability	Use Renewable Fuel Source	Yes	Yes	No
	Act as Energy Storage Module	Yes	Yes	No
	Operational Efficiency over 20 years	Excellent	Poor	Poor
	DC Power Capability (Renewables)	Yes	No	No
Installation	Footprint	Med	High	High
	Horizontal / Vertical (high ceiling)	Low	High	Average
	Shock & Vibe / Seismic Event Resistant	Yes	Low	Average
Other	Industry Knowledge / Usage	Established	Specialized	Established

Resistance heater designs score higher than electrode and fossil fuel fired steam generation in:

- Water treatment requirements
- Safety
- Efficiency
- Maintenance
- Sustainability

Footprint Electric vs Electrode

- Dimensions of actual boilers are similar
- Electrode is vertical where electric an be vertical or horizontal
- Element/electrode replacement clearances
- Electric units can be placed outdoors

MV ELECTRIC HEATING CASE STUDY

Emissions Reduction at McGill University's Downtown Powerhouse

PROJECT BACKGROUND AND MARKET DRIVERS:

McGill University received $1.8M CAD in funding from the Low Carbon Economy Fund (Low Carbon Economy Fund - Canada.ca) for three projects aimed to reduce the universities carbon footprint. One of those projects was to replace gas fired boilers in the downtown powerhouse.

CUSTOMER ISSUE:

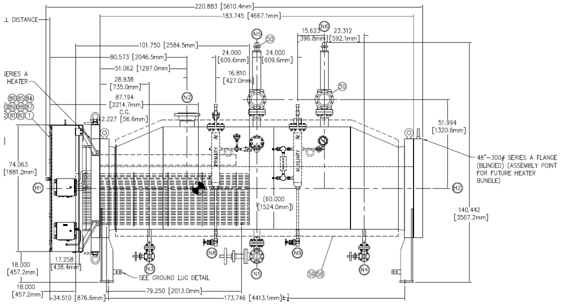
McGill University project and engineering team were tasked with removing existing gas fired boilers and replacing with 20MW of electric steam generation. Limited modifications to the existing boiler house were permitted and a custom electric solution was required.

OFFERING DEVELOPMENT:

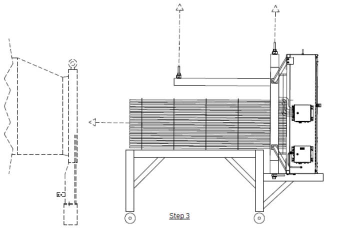
Chromalox and Provan worked with McGill University and their engineering firm BPA to custom design (2) 10MW MVSGI electric steam generators. The design has (2) 5MW heater bundle assemblies installed from opposite ends of the ASME/CRN boiler vessel. This allows for easy integration with Hydro Quebec 5MW 6600V power supply feeders.

SUSTAINABLE OUTCOME ACHIEVED:

When fully installed the 20MW electric steam generators will eliminate 30,000 ton/yr of scope 1 & 2 CO_2 emissions since the electric supply is provided by a hydro-electric power generation station.



Initial 5MW Installation

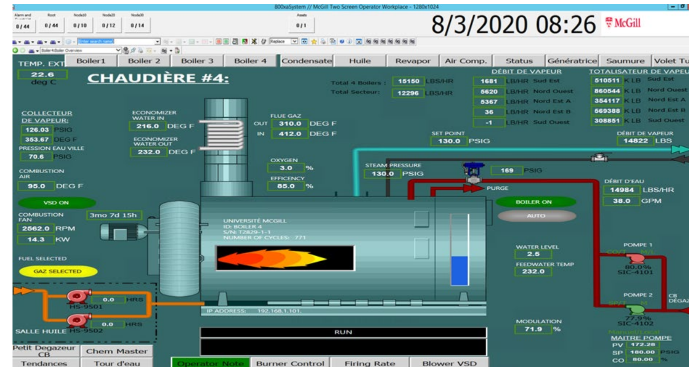


Future 5MW Heater Bundle Install

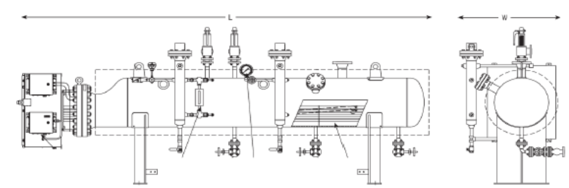
Emissions Reduction at McGill University’s Downtown Powerhouse

<u>Chromalox Offering - Value Creation & Differentiation</u>:

- Design engineering team in TN able to incorporated McGill’s boiler house controls and integrate with their standardized ABB PLC systems and programming
- Electrode boilers were initially being considered, but McGill heard from Montreal University about the operation and maintenance headaches they experienced with electrode boiler design and electrode was ruled out by McGill.
- Vendor was able to meet the entire McGill specification of 6.6kV with no design modifications
- Collaboration with local sales representatives allowed vendor to proceed with the order as is.
- Throughout the project the local sales representative and vendor maintained close contact with the end user which has allowed excellent collaboration.



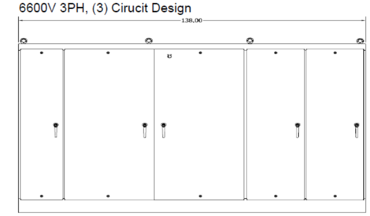
10,000 KW Steam Boiler Sample Drawing - 6600V Design



Approx Dimensions: 240"L x 80"W x 136"H

5,000 KW Boiler Control Panel Sample Drawing

6600V 3PH, (3) Cirucit Design



Approx Dimensions: 138"W x 92.5"H x 36"D

Close