CHROMALOX
Advanced Thermal Technologies

ZERO-EMISSION STEAM GENERATION WITH ELECTRICITY

Advances in electric resistance technology have the capability to provide zero-emission clean steam or process heat for a truly sustainable solution.

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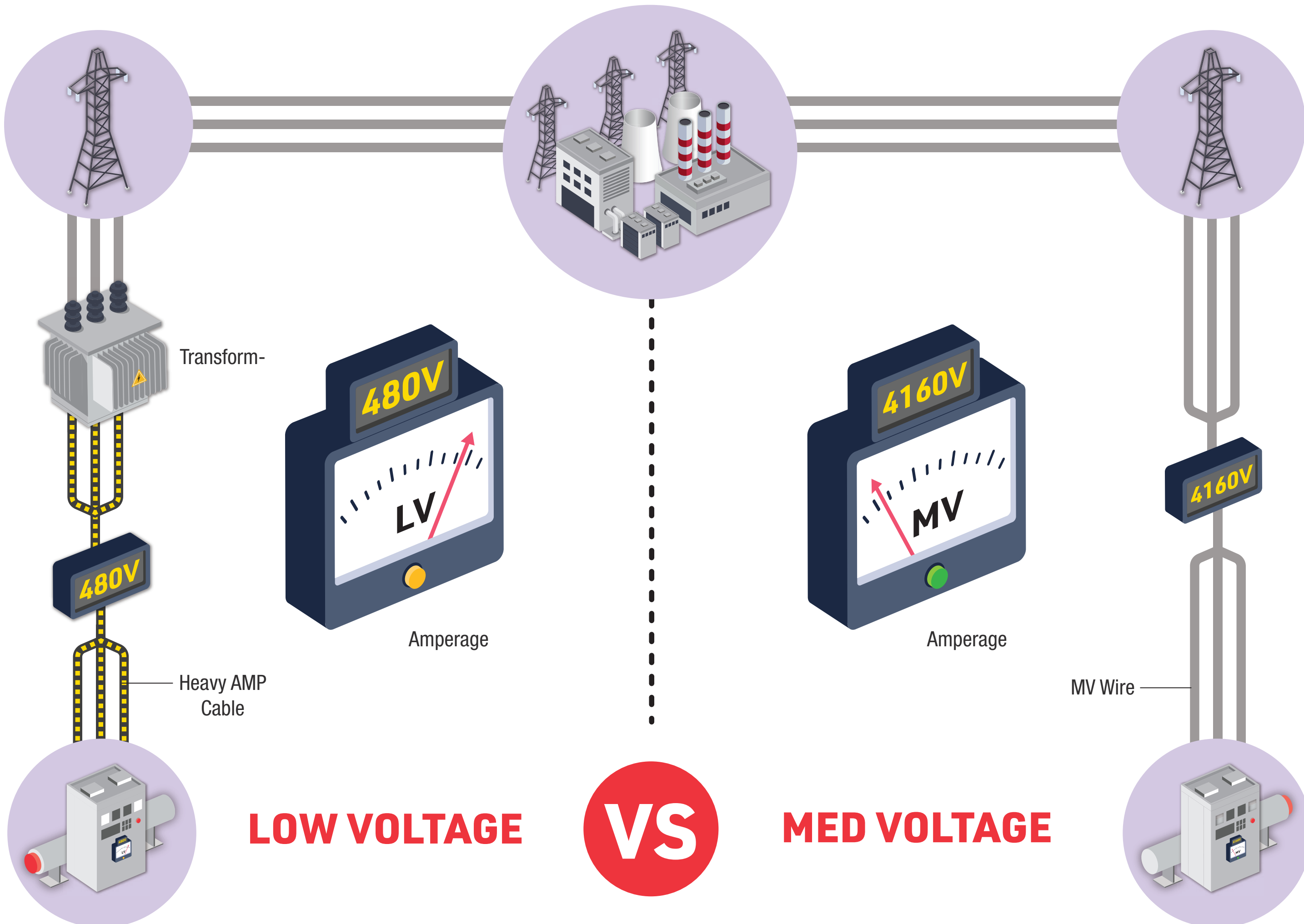
The fossil fuel age is well under way as our world has become heavily reliant on the finite supply of fossil fuel-based energy for everything from power generation and transportation to industrial process heating and steam generation. As energy demand continues to increase, fossil fuels can no longer be looked to for long-term reliability, and the effect of fossil fuel-based systems on the environment is becoming more apparent. For these reasons, the focus has been shifting to renewable energy generation at an increasing rate, and alternative fuel technologies revolving around hydrogen, ammonia, biogas and renewable fuels are also making a breakthrough. With alternative energy sources becoming more prevalent for regional energy generation as well as support from local and federal government legislation aimed at decarbonisation, utilisation of clean energy down to the local process level is also gaining traction to curb emissions, particularly in steam generation. Due to steam's excellent heat transfer properties and relative ease of use and abundant supply, it is used across multiple industries from residential and commercial building heat to medical sterilisation and industrial heating applications. Fuel fired steam generation has been the prevailing method for many years because electric technology has been generally dismissed due to its higher energy cost. However, with new developments in electric heating technology as well as government legislation aimed at regulating and decreasing emissions, the landscape is changing in favour of electric. Electric resistance heating elements have been used in the industry for over 100 years without significant change, as the overarching design is simple but effective. While electric heating elements are versatile in how they are designed and customised, the core technology has been intact for decades for low voltage applications to 690VAC.



That all recently changed when Chromalox developed and patented the first true medium voltage element rated to a voltage of 7200VAC. Referred to as DirectConnect (see Figure 1), these medium voltage electric heating elements provide a significant advantage over conventional electric designs and bridge the gap from electric technology to fuel fired technology for steam generation and process heating.

BENEFITS OF ELECTRIC HEATING TECHNOLOGY

To appreciate the value of electric resistance steam generation over fuel fired steam generation, it is important to understand the benefits of medium voltage electric technology compared to conventional low voltage solutions. Firstly, no intermediate transformer is required to drop down a site's voltage into the lower voltage realm traditionally required by electric heaters. Even if low voltage were available, these systems would generally draw significant power, such that upgrades to the power infrastructure may still be needed. Beyond this aspect, the value of a medium voltage system is largely derived from the substantial decrease in the system's amperage due to the higher voltage level. Using the reference of a 4160V system compared to a 480V system, the associated amp draw is reduced almost nine times. This significantly reduces the amount of wiring, conduit, fusing and contactors required to support the system. Fewer components also mean less time to install, fewer parts to maintain and support, and less risk of failure.

Beyond reducing the physical components required with medium voltage systems, a further advantage is gained through improved operational efficiencies. Electric systems, regardless of voltage level, are 100% efficient at converting applied energy into heat. In other words, all energy that reaches the heater is converted into heat and driven into the process. Electric systems do, however, have some losses upstream from the heater by means of I2R losses through the power wiring and heat dissipation through the power control components. Even in low voltage systems, these attributed losses are relatively small and only account for approximately a 3-4% reduction in efficiencies. With medium voltage systems, the reduction in amp draw means less wiring and fewer power-control components, which in turn means fewer losses, resulting in 99%+ operational efficiency.

Taking all of this into account, we can see that a medium voltage electric resistance system can significantly simplify site management and infrastructure, installation, operation and maintenance over traditional low voltage systems. Framing up a similar look when comparing medium voltage to traditional fuel fired systems, we can see the total cost of ownership evaluation reveals a much different picture compared to the myopic cost of energy discussion that we typically see. Particularly with a changing landscape with local and federal legislation aimed at decarbonisation, the chips continue to stack in favour of electric resistance heating.

COST OF OWNERSHIP

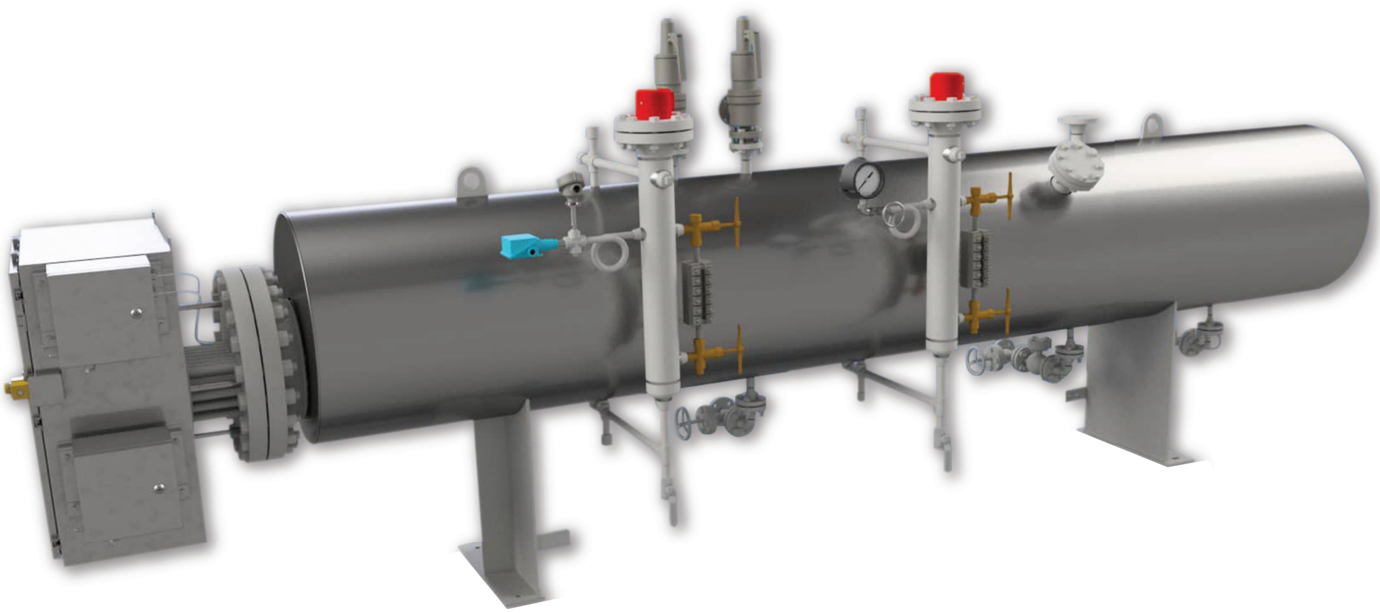
So how does a medium voltage electric system compare to a traditional fuel fired system when a full cost of ownership evaluation is performed? In addition to medium voltage systems having 99%+ total system efficiency, the inherent design of the electric heating element means the derived heat is surrounded by the medium to be heated, forcing that heat directly into the process. On the other hand, fuel fired systems advertise certain efficiencies but are only factoring in fuel conversion.

The true boiler operational efficiency is more complex to derive. While the burners may be capable of combustion efficiencies into the 90% range, this number is based on factors like excess air percentage and fuel specification. This is also specifically aimed at how well the boiler converts fuel to heat, but does not indicate whether that heat is driven into the process. This is where the true efficiency of a fuel fired boiler presents a much different story. Once the fuel has been burned, a percentage of that heat is immediately vented off through the flue stack.

COST OF OWNERSHIP	480 V	4160 V	SAVINGS
Installation	$753,650	$528,655	$224,995
Operation	$873,940	$240,800	$633,140
Maintenance	$61,200	$10,200	$51,000
10 year life cycle replacement	$163,655	$69,500	$94,155
20 year costs	$1,852,445	$849,155	$1,003,290
Annualized costs	$92,622	$42,458	$50,165

*Representative of 2.4MW

The heat that does pass through the boiler's exchange system also faces challenges of its own, specifically how well that heat is transferred from the tubes into the process. As these boilers operate over time, soot from combustion will begin to coat onto components, reducing effective heat transfer.



3D Model of Chromalox DirectConnect™ MVSGI Series electric steam generator

The higher advertised efficiency of the boiler to convert fuel to heat is short-sighted, considering the amount of heat generated from fuel that is introduced where it is truly needed, the process medium, is much lower. Fuel fired steam systems are inherently more complex as well, requiring additional fuel line infrastructure, economisers, oxygen metering, and flue stack treatment in addition to the basic components needed for steam production such as a blowdown vessel and water and steam lines. This requires more upfront capital expenditure in order to support these installations. Add in permitting costs, administrative fees and newly adopted carbon taxes or cap and trade credit costs, and the upfront and annual fees associated with fuel fired systems begin to pile up.

MAINTENANCE

The cost evaluation of the system goes beyond just capital costs, though, as these parts must also be maintained. This is perhaps the most significant factor to consider when looking at fuel fired systems. More complex systems are more prone to failed components, which may compound to other parts of the system or cause boiler shutdown altogether. Planned and unplanned shutdowns are an often overlooked aspect of the total cost of ownership, but can be substantial when you factor in the rippling effect of an offline boiler. Planned shutdowns at least allow coordination, but the complexity of these systems requires more frequent maintenance and tuning to keep the boilers at their peak efficiencies. Unplanned shutdowns, on the other hand, come with a much higher price. These types of event have multiple aspects that contribute to the total cost, including detection costs, containment costs, recovery costs, incidental expenses, productivity loss, business interruption and, perhaps most importantly, loss of revenue. While all systems have the potential for unplanned shutdown, the more complex they are, the greater potential exists. This, again, is a significant advantage of DirectConnect, as electric systems are inherently straightforward and require little to no auxiliary equipment to function at peak efficiency. Components most susceptible to failure, namely contactors or fuses, are generally commodity parts that can be replaced quickly and easily.

CARBON NEUTRAL SOLUTION

Financial considerations aside, the greatest asset that electric steam generation systems have is producing zero emissions locally. These electric systems can also be powered by electricity generated from renewable energy sources, energy storage systems, or excess grid energy. As renewable energy sources and energy storage means become more prevalent and capable, the use of electric heating systems at the process level means a truly carbon neutral solution from generation to application. The use of medium voltage electric heating solutions offers many advantages over fuel fired systems when factors beyond just the cost of energy are considered, such as the total cost of ownership. As our world struggles to release the clench that fossil fuels have, advances in emerging electric technology have now presented the capability to provide zero emission clean steam or process heat for a truly sustainable solution.

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THREE STAGES TO NET ZERO

Achieving any long term sustainability target is not a linear process. It takes careful planning, especially when it comes to critical thermal solutions, ensuring they are designed for the future, improve processes and reduce long term costs. Chromalox's eMissionZero model explores how through decentralization, optimization and decarbonization, organizations around the world can develop a robust roadmap to zero carbon emissions.

Partnering with organizations through a Decarbonization Assessment, Chromalox can provide the tools, guidance and expert support to ensure any thermal solution has a pathway to success. Click here to find out more about the Decarbonization Assessment and eMissionZero model.