# UPGRADING TO MEDIUM VOLTAGE TECHNOLOGY FOR MULTI-MEGAWATT ELECTRIC HEATING SYSTEMS

***Mark Wheeler and***
***Christopher Molnar***
***Chromalox, Inc.***
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**Medium voltage technology greatly reduces installation, operating, and maintenance cost for a multitude of thermal processes throughout an entire facility.**

Most industries use low voltage systems, typically less than 1000V, for electric heating applications. These were practical for most of the 20th century. Now, however, certain applications in such heavy industries as power generation, oil and gas, petrochemical, chemical, and others demand much higher power output. These applications require multi-megawatt (MW) electric heating systems. At low voltages, such requirements lead to challenges with power distribution, process design and costs.

A viable solution: moving to medium voltage. A safe and reliable technical design for metal-sheathed electric process heating and power controls now exists for heating systems operating at medium voltages. These patent-pending, third-party certified Chromalox DirectConnect medium voltage electric heating systems allow heavy industries to capture all the advantages of electric process heat while minimizing the disadvantages of low voltage, high amperage designs. This white paper discusses the benefits and cost savings associated with heating systems operating at 4160 volts relative to traditional low voltage designs.

## Installation Savings

Medium voltage technology permits operation of process heat equipment directly off of an existing 4160V distribution system, potentially eliminating the installation of dedicated step-down transformers for low voltage duty. When operating multi-megawatt systems, this cost avoidance can be substantial, conservatively estimated in the neighborhood of $25,000 per MW installed.

Additionally, medium voltage technology for electric process heating drastically reduces the amperage draw for the same heat output. For example, operating process heating equipment at an industry standard 4160V reduces amperage by a factor of nine. This allows the end user to reduce both the wire diameter and number of wires necessary for installation when compared to a low voltage source. At 4160V, a conservative estimate of the material savings on wire alone can equal $1.50 per amp per foot of run. A multi-megawatt system operating at 4160V installed several hundred feet from the main distribution bus can instantly save the end user close to $200,000.

Finally, the higher voltage decreases the labor cost necessary for installation. Using fewer wires of smaller diameter greatly reduces the time and effort for installation. At 4160V, the estimated labor savings on wire installation costs about $0.15 per amp per foot of run. Although dollar savings based on a conservative situation yield about $15,000, installation time drops by a factor of 10, decreasing wire and conduit labor time from weeks to only days. This obviously helps to decrease the overall project timeline and cost.

**Operating Savings**

Operating at medium voltages increases the efficiency of power distribution and consumption. Although electric process heat and control solutions have much higher efficiencies than fuel-fired systems, especially at reduced duty cycles, they are still not perfectly 100% efficient. Energy losses occur in the form of heat generation, often designated as $I^2R$ losses. A typical low voltage system will operate at about 96% efficiency, with 4% energy loss coming from heat generated by current transmission across wire, bussing, connections and instrumentation.

However, the lower amperage associated with medium voltage technology minimizes heat loss for a given power output. This is why electric power transmission lines operate at hundreds of thousands of volts -- for high efficiency line loss reduction. For example, a multi-megawatt process heating solution operating at 4160V will run at almost 99% efficiency. That 3% improvement in efficiency translates into operating cost savings for the life of the system. For example, assuming a cost of $0.05/kWh from your utility, an end user will save tens of thousands of dollars every year of operation. With a life expectancy of 20 years or more, this is significant.

Another possible advantage results from incentives by many electric utilities that reward reduced consumption. These incentives permit the end user to receive a lower price rate from the utility, or a grant or rebate to help pay the capital costs for the investment of the medium voltage equipment.

**Maintenance Savings**

One key advantage of electric process heat in general is the low cost of maintenance. With no moving parts and a robust design, electric process heaters will often operate for decades with minimal maintenance relative to fuel-fired equipment. And although the major parts of an electric process heater do not require regular adjustments, routine inspections of electrical connections help to ensure safety and minimize inefficiency from losses. The fact that medium voltage technology requires fewer wires and connections simplifies inspection time.

**Life-Cycle Savings**

Often electric heaters in heavy industry operate in process-critical situations where downtime can cost hundreds of thousands of dollars, if not millions, a day. So failure of a heating element can be a major cost factor. Regardless of the cause, the impact to an end user's operation can be catastrophic. End users must make decisions regarding their source of replacement heating bundles: whether sourced as needed or stocked for emergencies.

For critical process situations, the end user may choose to purchase a spare heating bundle along with the original equipment. This can add as much as 50% to 60% to the entire system cost. The alternative is to source a heating bundle as needed, which can result in a significant lead time and/or cost for expediting. These alternatives can be costly, time consuming, and unpredictable.

The system that incorporates replaceable medium voltage elements, like that designed by Chromalox, mitigates that cost and risk. The end user can purchase a low cost set of spare elements for on-site storage. Should an emergency arise, the cost and production downtime for replacing the failed elements is greatly reduced. For a typical multi-megawatt system, the cost savings associated with replaceable elements can reach $100,000 per incident. Downtime may drop to a matter of days as opposed to many weeks for a sourced replacement bundle.

# Case Study

The following is a real-world case study conducted for a U.S. refinery in need of a 2.4 MW electric hot oil process heating system:

**Installation**

The refinery had a 450-foot span between the main power distribution system and the hot oil system. The following table compares the installation components and labor costs of a Chromalox DirectConnect 4160V system versus a traditional low voltage installation:

| **Low Voltage** | |
|---|---|
| 480V Construction – 24 Circuits | |
| 2,400kW Heater | $214,550 |
| Power Control Panel | $126,525 |
| Start-Up Service | $8,600 |
| Product Sub-Total | $349,675 |
| | |
| Transformer | $101,500 |
| 150 ft. Wire to Panel | $94,025 |
| 300 ft. Wire to Heater | $188,050 |
| 240 Labor Hours | $20,400 |
| Install Sub-Total | $403,975 |
| | |
| **Total Cost** | **$753,650** |

| **Medium Voltage** | |
|---|---|
| 4160V Construction – 2 Circuits | |
| 2,400kW Heater | $305,370 |
| Power Control Panel | $173,950 |
| Start-Up Service | $8,600 |
| Product Sub-Total | $487,920 |
| | |
| Transformer | $25,325 |
| 150 ft. Wire to Panel | $4,570 |
| 300 ft. Wire to Heater | $9,140 |
| 20 Labor Hours | $1,700 |
| Install Sub-Total | $40,735 |
| | |
| **Total Cost** | **$528,655** |

**An installation savings of $224,995 was realized using 4160V electrical supply.**

**Operation**

The reduced amperage of the medium voltage system minimizes $I^2R$ losses in the wires, heater bussing, and panel heat losses. For the refinery, these factors can contribute to a significant cost savings for the new 2.4 MW application. The operation runs 24 hours per day with electric utility costs of $0.05 per kWh. The following table shows their annual energy savings by switching away from the traditional low voltage design:

| **System** | **Low Voltage** | **Medium Voltage** |
|---|---|---|
| | 480V | 4160V |
| $I^2R$ Losses (Wattage) | 103,670 | 28,564 |
| Efficiency Rating | 95.7% | 98.8% |
| **$I^2R$ Operating Cost** | **$43,697** | **$12,040** |

**An annual operating savings of $31,657 realized using 4160V electrical supply.**

**Maintenance**

The smaller number of 4160V circuits allows inspection time to be reduced proportionally. The following table compares Chromalox medium voltage and low voltage systems assuming a monthly inspection program with annualized costs.

| System | Low Voltage | Medium Voltage |
|---|---|---|
| | 480V | 4160V |
| Number of Circuits | 24 | 2 |
| Monthly Inspection | 3 hours | 0.5 hours |
| **Maintenance Cost** | **$3,060** | **$510** |

**An annual operating savings of $2,550 can be realized using 4160V electrical supply.**

**Life Cycle**

Process heating equipment installed in a refinery, with a proper maintenance program, should have a life expectancy of 20 years. However, it's likely that at least one element bundle replacement will be required over the life of the heating system. For this refinery, a traditional low voltage system would include a large heating bundle using 480V welded-in elements.

By taking advantage of the Chromalox DirectConnect 4160V system with individual replaceable heating elements, the refinery can cut downtime and save repair costs. The following table shows the refinery's anticipated failed element replacement cost savings by avoiding a traditional low voltage design.

| System | Low Voltage | Medium Voltage |
|---|---|---|
| | 480V | 4160V |
| Replace Contactors/SCR | $25,500 | $17,450 |
| Replace Expired Heating Elements | $108,554 | $41,540 |
| Labor | $29,600 | $10,508 |
| **Maintenance Cost** | **$163,654** | **$69,498** |
| **Downtime** | **14-21 days** | **< 5 days** |

**A life cycle savings of $94,156 can be realized using 4160V electrical supply.**

Note that the above savings does not include the potential cost of lost production avoided from the minimized downtime of less than a week versus much longer for a traditional solution.

**Case Study Summary**

The table below summarizes the costs expected by the refinery as a result of this hot oil system project (assuming a 20-year life span). Despite the higher capital costs for a medium voltage system, the installation and life cycle savings amount to $319,151, while the annual operating and maintenance savings amount to $684,140.

| **Cost of Ownership** | **Low Voltage** | **Medium Voltage** |
|---|---|---|
| | 480V | 4160V |
| Installation | $753,650 | $528,655 |
| Operation | $873,940 | $240,800 |
| Maintenance | $61,200 | $10,200 |
| 10-Year Life Cycle Replacements | $163,654 | $69,498 |
| **20-Year Costs** | **$1,852,444** | **$849,153** |

**A total cost of ownership savings of $1,003,291 was realized through the choice of a Chromalox DirectConnect 4160V system versus a low voltage system.***

The following analysis shows that the refinery is in a far better financial position by choosing Chromalox DirectConnect medium voltage system over the traditional low voltage design. In this particular case, the installation cost savings more than paid for the incremental capital spend for the medium voltage equipment, making the payback period immediate. In general, the payback on almost all installations will be less than one year.

**Conclusion**

The innovative Chromalox DirectConnect medium voltage electric heating systems represent a technological breakthrough that offers the potential to drastically cut costs while increasing efficiency, productivity, and profitability for industries requiring multi-megawatt process heating solutions.

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* *Estimations were used for unknown factors (such as length of wires). The intent is to best model the cost comparison of using either a 480V or 4160V electrical supply from known data. The information is intended to help the user understand the total cost of ownership and make an educated decision.*

**About Chromalox, Inc.**

Chromalox is a heating and control technology company that delivers Enterprise Thermal Solutions for our energy and industrial customers. We provide Temperature Maintenance Solutions for piping systems, valves and tanks, Process Heating Solutions for revenue-generating industrial processes, and Component Heating Solutions for industrial equipment manufacturers. Drawing upon a century of experience, a global footprint, and the most comprehensive set of technologies in our industry, no thermal control project is too large or complex for us anywhere in the world.

**Chromalox, Inc.**
103 Gamma Drive
Pittsburgh, PA 15238
1-800-443-2640
www.chromalox.com