Identifying Silent Power Loss in Induction Melting System Secondary Power Transmission and How to Correct It

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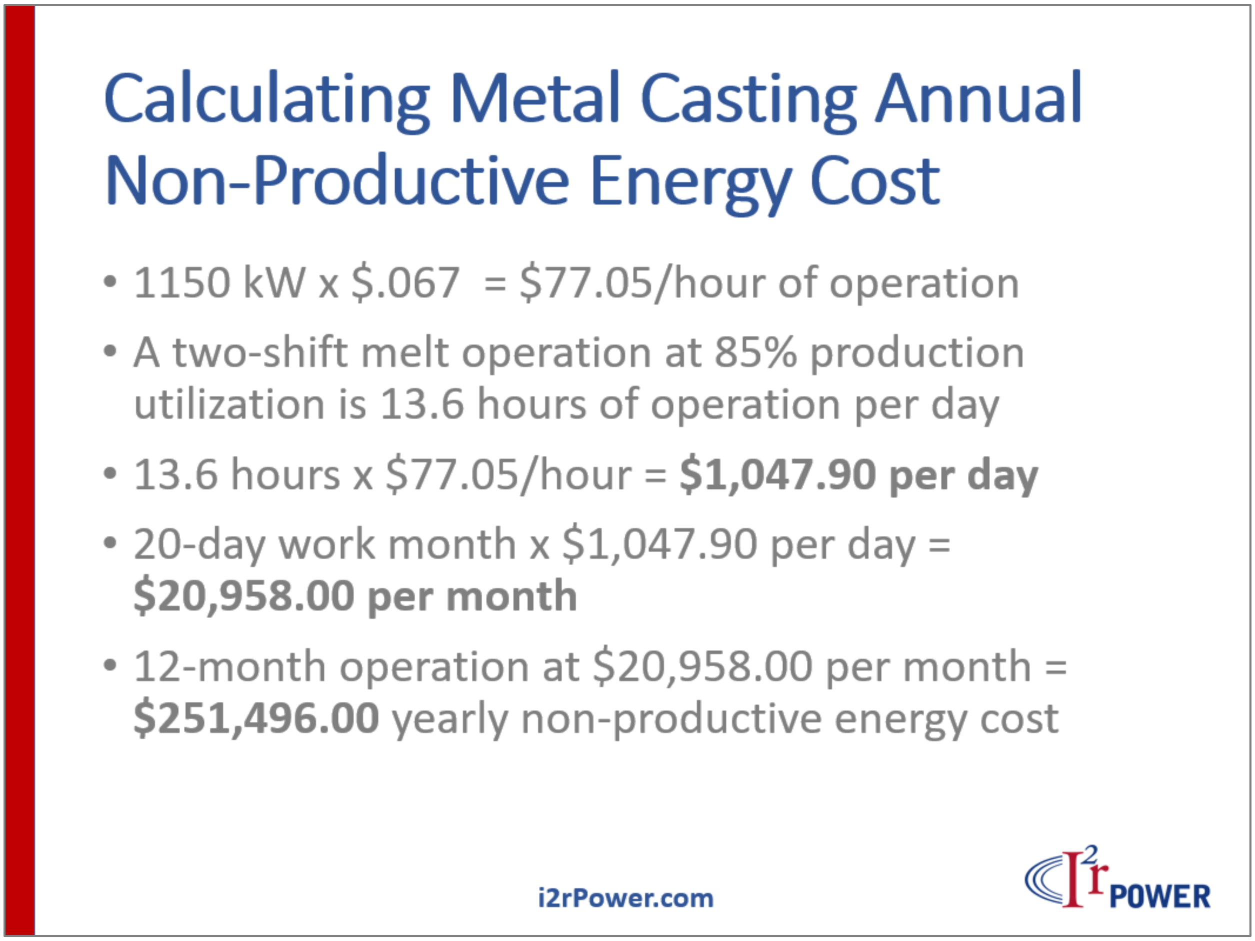
Every metal casting operation wants to reduce operational cost and enhance bottom line results. One of the greatest non-labor expenses, if not the greatest, is power consumption of induction melting systems. There are potential power losses that cannot be easily identified, unless you know where to look.

In 2020, the average power price for industrial customers in the United States was $.067 per kilowatt hour. A modern 5000-kilowatt induction melting furnace with a solid-state AC-DC rectifier/DC-AC inverter has power efficiencies of about 97%, with 3% losses. A well-designed induction furnace melting coil and furnace design with a well-designed refractory system is about 85% efficient, with 15% losses. A well-designed transmission of power between the power supply and furnace will have about 5% losses. In total, there can be as much as 23% power loss. Twenty-three percent (23%) losses on a 5000-kilowatt melting system equate to 1150 kilowatts of non-productive energy. Here's the concept illustrated:



Common and practical methods to reduce energy cost and improving melt time exist. Many well-run metal casting operations implement some, or all, of the following practices:

- Well-prepared scrap
- Pre-heating scrap
- Minimizing open cover times
- Good refractory practice
- Maintaining shunt/yoke on steel shell furnaces
- Proper cooling systems
- Maintaining designed power factor
- Maintaining proper melt coil geometries
- Efficient charge, alloying and tap procedures

All good operational practices improve melt times and energy consumption efficiencies. Every percentage point of loss that can be reduced during operation of high-power melt systems directly affects bottom line profitability.

Power transmission loss between the inverter and melt furnace

As a result of our familiarity with of hundreds of induction melt systems, we are able to identify a significant slow bleed of energy–the power transmission between the inverter and melt furnace. A properly designed target for transmission loss is typically 3%. When studied, it is common to find actual losses are two to three times the 3% target. There are a number of causes of excessive power losses in power transmission.

An understanding of fundamental laws of electricity will help illustrate how these losses are created, and can facilitate further investigation of wasted energy during the operation of your induction melting unit. Use the calculations below to establish basic power efficiency formulas:

- Watt loss = I^2R calculations ($I^2 * R * L$) Current squared x Resistance x Length
- Voltage drop = IR drop ($I * R * L$) Current x Resistance x Length)

In addition, there are considerations to incorporate during your analysis. Be aware of the following physical laws of electricity:

- Higher temperature of a conductor increases resistivity by disorganizing the crystal structure of a conductor (vibrating atoms) making the passage of electrons more difficult
- Higher frequencies will increase the skin and proximity effects of a conductor. Solid copper bus or flexible power cables cannot defy the physical law of increased resistance and voltage drop.

Electrical handbooks publish resistance of a conductor operating at a Direct Current (DC). Determining power losses by I^2R calculations at 60 cycles, the effective resistance can be determined relative to the resistance of DC transmission. As AC frequency increases, many variables such as proximity, orientation, and conductor construction all determine effective resistance.

A quick rule to determine transmission resistance of a conductor performing at a higher than 60 cycle frequency, is to use generalized basic multipliers to determine effective resistance. I^2R calculation multipliers determining effective resistance of a conductor at higher frequencies other than 60 Hz are:

- 60 Hz – 1.00
- 200 Hz – 1.1
- 500 Hz – 1.15
- 1000 Hz – 1.20
- 3000 Hz – 1.50
- 4500 Hz – 1.7
- 9600 Hz – 2.0

Once the basic understanding of the calculating methods determining watt loss is understood, the opportunity to discover unnecessary power loss can be investigated.

Points of investigation to improve busbar efficiency

Problem-solving for power efficiency requires multiple facets of consideration. The following are guide points to assist during your investigation of busbar power efficiencies:

- Perform heat loss calculation of the existing bus bar to determine baseline operating system efficiency. If the busbar is operating hot–money and energy is being lost.
- Is the busbar spaced properly between adjacent phase?
- Can increased copper cross section and/or surface area be improved?
- Is water-cooling the bus a consideration?
- Is spacing of busbar optimizing efficiency considering skin effect, polarization, proximity and inductance?
- Is the bus trench layout achieving the most direct route?
- Can the busbar run be lengthened prior to interconnection with the power cable?
- Does the bus interconnection operate hot? If so, is proper hardware, bolt pre-load, contact pressure, and contact condition optimal?

Points of investigation to improve power cable efficiency

Problem-solving for power transmission loss requires full system consideration. The following are guide points to assist during your investigation of power cable efficiencies:

- Calculate existing watt and voltages losses of the existing power cable configuration for baseline operating system efficiency.
- Are the cables oriented to maximize efficiency through cross polarization and tight bundling?
- Is the cable bundle too long–transferring energy further than necessary?
- Is the cable sized with the proper copper conductor cross section?
- Does the power cable have proper cooling volume and unobstructed flow?
- Are the terminals properly designed for efficient interconnection between the busbar or power supply and the furnace coil?
- Is the cable designed for the proper bend radius to maintain power and enhance efficiency life?
- Are all of the power cables dedicated to a power section of the coil in the optimal condition?

Few melting systems have identical characteristic and often systems with the same power supply and furnace arrangement have the same power transmission path. This is why there is no one answer to every melting system power transmission layout. Often within the same melt shop, separate melt systems have different paths of distributing energy to the melt coil.

A little detective work into an existing system, often with inexpensive corrective actions, can reduce energy consumption and offer significant ROI. Contact your induction system service center or power cable provider for an initial baseline evaluation to determine how many KWh of consumption can be reduced on an annual basis. Then you will know to continue melting with confidence money is not being silently lost, or formulate corrective action improvements to reduce unnecessary losses and improve productivity.

AUTHOR BIOGRAPHY

Michael G. Pinney, President of I^2r POWER in the US, has more than 30-years of experience in multiple capacities serving melting and thermal processors, including the construction and design of water-cooled power cables for metal casting, steel making and materials melting industries worldwide. Pinney has worked extensively with furnace systems including induction, electric arc, controlled atmosphere, and remelt furnaces including design, construction, and service. Founded in 2005 by Pinney, I^2r POWER specializes in the aftermarket repair, rebuilding and design of air- and water-cooled power cables for all thermal processing industries. The company's product lines have grown to include bus systems, vacuum pass-through chamber and electromagnetic stirring device design/build, retrofit and custom applications. The company has more than 100 years of collective experience in the repair and rebuilding of electromagnetic stirring devices. For more information, visit www.i2rPower.com