Impedance Pipe Heating – What is it? How does it work?

By Patrick S. Morris

Impedance pipe heating. What is it? How does it heat? These questions are asked far too often for a technology that has been around for over a hundred years. While in essence the simplest and most elegant way to heat a pipeline, impedance heating technology is often viewed incorrectly and misunderstood as a method to heat pipe. Thankfully, once people learn how impedance heating works and the benefits its use brings, they are more than willing to adopt impedance heating technology and leave behind other pipe heating methods.

At its core, impedance pipe heating is done by applying a low voltage source to a pipe and allowing electric current to pass through the pipe. While technically any voltage can be utilized, without special isolation and containment provisions the National Electric Code (NEC) limits impedance system designs to a maximum secondary voltage of 80V. By keeping the secondary voltage under 80V the designer ensures the system will be safe for personnel working on and around the energized pipe. In addition, impedance systems utilizing a secondary voltage over 30V must also have a ground fault protection system. Use of ground fault protection further heightens safety should the energized pipe become grounded. So we know what an impedance system is, but how does it work?

The purpose of an impedance pipe heating system, quite simply, is to provide heat to contents flowing in a pipe. How does it do this? In actuality, it does it in several ways at once. We've said that the core of an impedance system is applying a low voltage source to a pipe and allowing an electric current to pass through the pipe. Electric current is composed of electrons moving from atom to atom in the pipe material. As the electrons move, they encounter resistance from the material around them, and from their own inertia. It takes energy to force the electrons to switch from atom to atom, and this energy is released into the pipe in the form of heat. This portion of an impedance system is the resistive heating element, and follows the simple formula of $P = I^2R$, which means the (P) power produced is equal to the (I) current squared multiplied by the (R) resistance of the pipe. Anyone who has taken any type of course dealing with electricity will be familiar with this formula. But while resistive heating provides the majority of the heating, it is not the only source.

Impedance pipe heating uses the word impedance for a reason: there is more to the heat produced than just resistive losses. The voltage applied to an impedance heated pipe is generally from a transformer designed to lower standard 480V, 60 cycle power to something less than 80V. This secondary transformer voltage produces an alternating current in the pipe, with a frequency of 60 Hz. As the current changes direction in the pipe, it will encounter a magnetic resistance within the pipe. The more magnetic the pipe material, the larger the resistance that will be encountered. This resistance reduces the depth to which the current can penetrate the pipe wall thereby reducing the cross sectional area apparent to the current. As a result the effective electrical resistance of the pipe is increased. This is called the 'skin effect'. This increase in resistance results in additional heat loss from the $P=I^2R$ effect. This is most prominently seen in carbon steel pipe applications, and has a side effect of isolating the inside surface of the heated pipe from the current and voltage. This gives impedance pipe heating the ability to heat pipes containing highly conductive materials, such as molten lead, without concern for stray currents entering the material. While an important part of the heating process, there remains still one more component to discuss.

The final heat producing component in an impedance pipe heating system is a surprising source: the cables connecting the transformer to the pipe. Most any impedance system you will find will have the secondary cables from the supply transformer running the length of the pipe, strapped to the outside of the pipe's insulation. While it is often not the shortest path to run the wire, it does serve two important purposes. First, it reduces any interference to sensitive equipment that might be caused by the electrical currents in the pipe. And second, it is a source of heat for the pipe. How does it produce heat? All electrical currents produce a circular magnetic field perpendicular to the path of the current. In the case of impedance heating, by running the cable along the pipe, this magnetic field will induce small eddy currents in the surface of the pipe, similar to how the copper windings in a transformer produce a current in the iron core. The eddy currents experience friction in the pipe surface, and thus release power in the form of heat. Like the 'skin effect' discussed earlier, the more magnetic the pipe's material, the more pronounced the heating effect of the eddy currents will be.

So here we have all three components that come together in an impedance system to produce heat: the resistive heat, the 'skin effect', and the magnetic induction. When applied to a pipe, the result is an even heat over the entire surface of the pipe. This even heat is unique of all the current methods used to heat pipe lines, and is the combination of elements that come together to produce it.

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