How Does Impedance Pipe Heating Heat a Pipe?

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. At its core, impedance pipe heating is done by applying a low voltage AC 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.

The purpose of an impedance pipe heating system, quite simply, is to provide heat to contents flowing in a pipe and it does this 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.

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 surface resistance encountered. 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 encounter will have the secondary cables from the supply transformer running the length of the pipe, strapped to the outside of the pipe's insulation. 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. 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. The eddy currents experience friction in the pipe surface, and thus release power in the form of heat. The more magnetic the pipe's material, the more pronounced the heating effect of the eddy currents.

So here we have the three properties of impedance that contribute together in an impedance system to produce heat: the resistive heat, the surface friction and the magnetic induction. When applied to a pipe, the result is an extremely even heat over the entire surface of the pipe. The even heat of impedance pipe heating is uniquely different from all the methods currently used to heat pipe lines, and it's this combination of elements that come together to produce it.

An impedance heating system is a wonderful method to maintain temperature in a pipe, but it can also be used efficiently as a method to heat a pipe from ambient temperatures to a desired use temperature or to add heat to a product flowing through a pipe. What performance is needed from the system is a crucial part of the initial design phase. A system that needs to only maintain temperature will require different control and power than one that must heat a product as it flows through the pipe. Even if the system is meant to maintain temperature, does it also need to be able to warm the system from ambient on a cold startup and if so, how fast does it need to do it? Generally, if someone is looking for a heating solution they know what their heating requirements are, and it is just a matter of engineering a system that meets the needs of the user. Let's look at the application of simple temperature maintenance.

Basically, with a temperature maintenance system a product enters the pipe at a specific temperature. The product flows through the pipe and out the other end. When it gets to the other end, we want to be sure it is the same temperature as when it entered into the system. A system designed for temperature maintenance will be efficient, and exert the lowest possible load on the plant's power system. It will also be the most limited in scope of performance. Generally, this system will use a simple on/off control scheme, and require the least amount of control hardware. On the downside, if the system is ever turned off, what happens? Unless the line is drained, the result will be a line full of product that has cooled. If the product will flow at ambient, cooling may not be a significant problem. But if it becomes too thick at ambient another method of heating the pipe and the product back up to operating temperature will be required. If one is not found the pipe will need to be cleaned before an extended shut-down can occur. An alternative impedance system design is to combine warming/thawing in addition to maintaining product temperature.

An impedance system can be designed that will maintain the product temperature in normal operation, but also has the capability to warm the pipe from ambient when required. For this type of system, we first consider the temperature maintenance needs, as above, but then we consider how much power is needed to warm the system from ambient to operating temperature with a full pipe of product. Once we know how much power is required, the question becomes how fast does it have to get up to temperature. A system can be designed to heat from ambient to use in anywhere from a few minutes to several days. The design is dependant on the requirements of the customer and the temperature limits of the product.

As a system is designed, a balance must be achieved between the desire to simply maintain a product temperature and the desire to heat a product from ambient. Does the system need to be able to heat-up, or is temperature maintenance enough? Impedance system designs can be very flexible, with pros and cons to consider for every application. In the end, the designer and the customer need to ask themselves:

- What are the key performance objectives of the impedance pipe heating system?
- What does our process require, and what would be of most benefit to us?"

By asking themselves these questions, they can pinpoint their needs, and get a system design that will meet their process performance objectives for many long years of operation.