Impedance Pipe Heating System Components

In past issues, we have most often presented applications for impedance pipe heating and how it is being used throughout industry today. With this issue we step back and review the primary components of an impedance pipe heating (IPH) system. At the center of an IPH system are three key elements. The following paragraphs describe and discuss these key elements: isolation, power and control.

Isolation:
First and foremost, the proper isolation of an impedance pipe heating system is critical to its successful operation. Without proper isolation, the impedance system current that should be moving through the pipe finds alternate paths, resulting in poor and uneven heating of the pipe. The first step to successful isolation focuses on the selection of the support method for the pipe. The entire length of the impedance heated pipe must be isolated from ground, and often the best method to achieve isolation at the support points is to support the pipe from outside the insulation. This ensures contact cannot occur between the pipe and a grounded metallic support point. After the supports are sufficiently isolated, all the other related connection points to the pipe must be examined to verify there are no unexpected or unforeseen paths to ground. Such connection points include the impedance system piping limits, pumps, control valves, etc. It is necessary for all of these devices to be electrically isolated from earth ground in that they are to be heated by the impedance system.

Next, the path of the impedance system's current flow must be defined. Remember, impedance heating pipe systems are about current flowing through the wall of a pipe. The electric current flow of an impedance system is much like the water flow of a river. At any point, a river has a specific volume of water. When the river takes a single path, the flow is constant at any point along the river. If however, the river breaks into multiple paths, the water is divided, and each path will carry a different volume of water. The same is true with an electrical current, and each path with a different volume, (i.e.: resistance), will produce a different amount of heat in the pipe defining its path. Not a desirable trait for a pipe heating system.

This challenge is addressed by using Insulated Pipe Joints, or IPJ's. IPJ's are located such that a multi-path river is re-configured into a single path. At any break in the path where multiple paths are created, an IPJ is inserted, forcing the impedance system current down one side of the break. Once the current reaches the end of the forced path, a cable is installed to connect the end point of the path to the other side of the original break, on the opposite side of the IPJ isolation flange. This ensures a single path for current flow and even heating along both branches of the pipe run. An IPJ consists of a flange, assembled using a non-conductive full face gasket, and Nylon, Teflon or other appropriate material bolt isolators. The selection of gasket and bolt insulators will be dictated by the process the piping system is serving, the system's operating temperature and pressure, and the size of the IPJ flange. Use of IPJ's provides proper impedance system isolation and helps ensures its proper circuitization and operation.

IPJ Isolating a Manual Valve

Power:
The power for most impedance systems will typically start with a standard 480V, single phase, AC source. While any primary voltage can be utilized, 480 VAC is common standard in most plants. The 480 VAC is connected to a specially designed dual winding isolated transformer. This transformer, which can range from 1 kVA up to 100 kVA and larger, is sized and designed specifically for a given impedance pipe heating application. The transformer will take the 480 VAC and produce a low voltage secondary, usually under 30 VAC, but always under 80 VAC. By keeping the voltage below 80 VAC, we stay within the limits dictated by NEC Code article 427.27. The low voltage secondary of the transformer is then attached to the pipe by means of cables. The cables vary from size #1 wire all the way to 750 MCM type THHN, with single or multiple cables per connection, dictated by the system current required and pipe size. It is important to note, that the secondary cable is not sized based solely on its ability to handle the system current, but on its electrical resistance as well. Incorrect sizing of the secondary cables can result in higher cable power losses, which means less system heating power is applied to heat the pipe. Finally, the cables are connected to the pipe by the use of cable lugs and weld plates. The use of weld plates ensures a good connection to the pipe, and further reduces any unwanted power losses.

Impedance Transformer with Disconnect

Control:
The controls of an impedance system allows for significant variation. The basic parts of the control system are a temperature sensor (usually an RTD), a temperature controller, and a method to control the application of 480 VAC to the impedance system power transformer. The temperature controller can vary from a simple thermostatic switch for on/off control, to a complete PLC system controlling multiple impedance systems and process parameters at the same time. Most commonly used is a digital temperature controller designed with a single temperature sensor input and an output to match the selected power control method. The power control method will typically be a simple power contactor, allowing for on/off control. When precise temperature control (+/- 1 ºF) is required, a silicone controlled rectifier, or SCR, is employed. Whether on/off, or SCR control, the style of controller, the temperature tolerances, and the duty cycle will be unique to each system application.

Each system control has its advantages and disadvantages.

On/Off Control

Advantage:
The main advantage of an on/off system is its simplicity. The control components and programming needed are minimal: turn the system on below "x" temperature and off above "y" temperature. On/off control system are also relatively inexpensive. Typical freeze protection systems are a good on/off control application.

Disadvantage:
The disadvantages to the on/off control system are of course a result of its simplicity. Alternating a system from full on to full off continually can impose high duty cycle conditions and can be hard on the component parts not properly selected. As a result, the hysteresis has to be set to accommodate the duty cycle limits of the control system components. Failing to do so will result in control component failures from excessive cycling wear. In addition, large hysteresis can result in undesirable product and process temperatures swings. Also, most impedance systems are designed to not only maintain a pipe's temperature, but to heat it and its contents from a cold ambient condition to operating temperature prior to process startups. With on/off control, this results in putting a much higher load on your power system during "ON" times and higher duty cycle rates than are necessary to maintain pipe temperature during normal process operating conditions.

SCR Control

An alternative to on/off is the SCR control system. An SCR, silicone controlled rectifier, is another form of control common with impedance heating systems. Unlike an on/off control system, with the use of an SCR the power level applied to a system can be varied from 0% to 100%. This is accomplished by controlling how much current is applied to the primary side of the impedance system transformer.

Advantage:
The obvious advantage to the SCR system is its heightened controllability. Using an SCR, the impedance system's output is controlled to only what is required at any specific pipe heating load condition. With no switching from full on to full off, the load on the plant power system is smoothed, and the wear and tear on control component parts is greatly reduced. Also, the temperature tolerance for the pipe can be lowered significantly to as little as +/- 1° F. This allows for the use of impedance systems with materials and processing that require exacting temperature control, with little or no variation. Heating lines containing temperature sensitive oils or liquid sugars often require the precise temperature control made possible by use of an SCR system.

Disadvantage:
The down side to SCR control system is cost and to a degree increased complexity. An SCR is more expensive than the simple contactor of a on/off system. Also the digital controller needed to control the SCR is more complex than that of an on/off controller as it must be configured with an analog output.

In the end, the choice between an on/off and a SCR control system is dependent on your specific application needs. No matter what the system requirements are, there is no one right answer. The temperature requirements of the process and material, the acceptable temperature tolerances, and the system cost all come together to direct a user to one control type or another.

Conclusion:
From the outside, an impedance pipe heating system may seem complex, but once it is broken down into its individual parts, the simplicity, and some would say elegance of this pipe heating method can be recognized. An isolated piping system, with a low voltage power source applied to it, and a control system to apply the power source as needed. The individual details of each component will change from system to system, with each tailored to fit the specific requirements of the piping and product being heated. In the end, the basic purpose of each component from system to system is the same. This basic simplicity makes impedance pipe heating the successful pipe heating solution that it is.