TECHNICAL BULLETIN

EHE

# Using nitrogen or other gas to cool impeders.

## Background

*There are several high frequency welded tube products that require a dry ID but for a variety of reasons do not lend themselves to using conventional liquid cooled return flow impeders. Gas cooled impeders, using either air or preferably an inert gas have been suggested for years but the greatest obstacle is the enormous flow rates required to remove the heat generated in the ferrite. These flow rates can be reduced by lowering the temperature at which the cooling medium enters the impeder but there are limits to how far this can be taken.*

## Cooling Principles

Heat is generated within an impeder as a result of the electrical resistance & magnetic hysteresis losses that occur in the ferrite material. The amount of heat that the cooling medium must remove depends on many factors, with welder power level, frequency & coil position being the most important.

Normally water or mill coolant is used to cool the impeder, however if the total amount of heat produced is small, it may be possible to use air or nitrogen to cool the ferrite. Because gasses have much lower densities & lower specific heats than liquids, the volumetric flow rates required can be over 1000 times higher than those required with liquid cooling. This usually makes gas cooling uneconomical or impractical as a means of cooling impeders. As an example, a typical impeder to weld 1" O.D., 16 guage tube at 300 ft/minute requires approximately 1 GPM of liquid, but would need 15 cubic feet/minute of gas to achieve the same rate of cooling. In order to achieve this flow rate with a 1/2" O.D. (13mm) impeder, the nitrogen needs to be admitted through a 5/16" (8mm) line at 125 PSI (9 bar). The cost of such a flow rate is usually prohibitive unless an on-site nitrogen generator is available.

In most other cooling applications, it is possible to reduce the flow rate by admitting the cooling gas at a lower temperature, however this does not work very well with ferrite because the magnetic hysteresis losses are inversely related to temperature. This occurs because the magnetic domains in the ferrite have reduced mobility at lower temperatures, and more energy is required to change their polarization. The additional energy is dissipated as heat.

## Ferrite Performance

Ferrite manufacturers do not generally provide data for temperatures below 0°F, but by extrapolating their graphs downwards, it appears likely that most ferrites lose their magnetic properties at around -40°C. They also become very lossy at low temperatures because the magnetic domains require more energy to change their polarization. (coercivity & retentivity increase with lower temperatures). The graph below is from Neosid's data book for their F-59 material, & it is similar for other manganese/zinc ferrites.

(see graph on following page)

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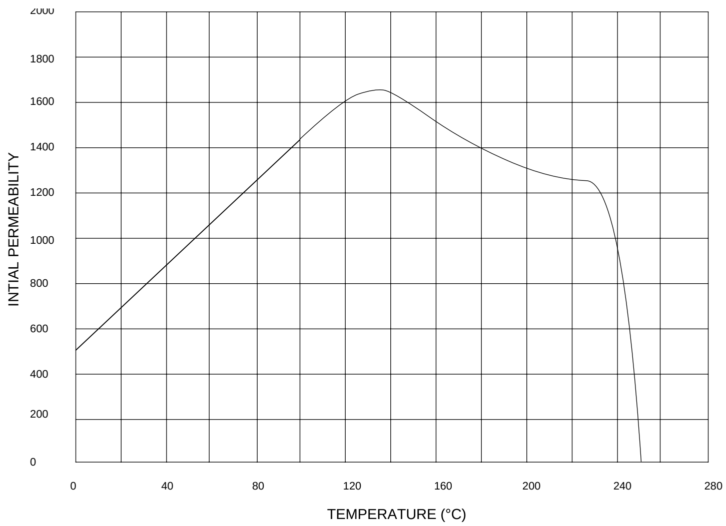



## Vortex Cooling

Vortex coolers are popular in many small industrial cooling situations but they are not an effective solution for cooling impeders. These devices work by splitting the gas stream into two - one hot & one cold. If any restriction is applied to one of the streams, the majority of the gas flows into the other, reducing the action of the vortex. These chillers only work properly for spot cooling of cutting tools & similar applications where there is little or no back pressure. Using a vortex tube to chill the gas also more than doubles the volume of gas required!

## Making Gas Cooling Work

The few tube producers we are aware of that use nitrogen or other forms of gas cooling use this only on very light-walled tubing, where all other parameters are optimized, and where the nitrogen is required anyway for some other purpose such as internal spray painting or bright annealing. They typically require 50% to 100% higher weld power levels, because the high operating temperature of the ferrite greatly reduces its effectiveness.

Several manufacturers of small diameter tubing now use gas cooling. The gas is normally nitrogen from cryogenic storage but may include up to 15% hydrogen for stretch reducing mills with in-line bright annealing. Nitrogen may ract with the hot metal in the weld to form nitrides. In some cases these may form inclusions causing weld defects. Argon or Helium  are considered inert, so they will not normally react with the metal, but both have much lower specific heat than nitrogen so a greater volume must be used. They are also more costly both to buy and to store.

When designing impeders for gas cooled applications, it is critically important to use the lowest loss ferrite available. TDK’s IP-H grade has total losses of 3.5kW/kg. at 400 kHz & 200mT. This is less than half the loss of the next best material that we have tested. Using this material, a typical impeder for welding 1/2” OD x 0.040” WT (13mm OD x 1mm WT) tubing generates around 100 watts of heat due to losses in the ferrite. Additional heating occurs due to proximity of the impeder to the hot metal. This amount of heat can be removed using chilled nitrogen or other gas, provided that sufficient flow can be achieved.

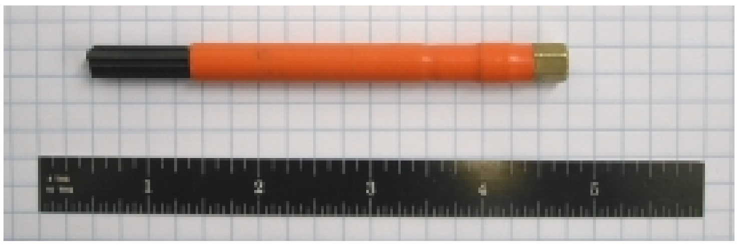
## Recent Work

EHE has developed several impeder designs specifically for gas cooling. The most successful use TDK IP-H fluted ferrite in a high flow PTFE case which maximizes the cross section of ferrite that can be accomodated within the welded tube. Liquid nitrogen is metered & allowed to evaporate before entering the impeder. Up to 15% hydrogen may be added as a reducing gas for bright annealing.

The gas flow rate should be adjusted so that the ferrite core operates at its optimum temperature. Saturation flux density falls with rising temperature, so if the ferrite is too hot, it will saturate earlier, reducing the total flux supported by the impeder.

Reducing the core temperature too far lowers magnetic permeability, which also reduces the amount of flux in the impeder. In addition, hysteresis losses are increase as temperature is lowered, placing more burden on the cooling system

It is also important to protect the ferrite core from thermal shock and from excessive thermal gradients. Both will cause the material to fracture, reducing its effectiveness.



Gas cooled impeder with exposed ferrite for stretch reduced automotive & refrigeration tubing

## Optimising Impeder Operation

Various means can be applied to minimize the magnetic flux in the impeder & thus the amount of heat which must be removed. By far the most important is minimizing the area of the weld vee. This entails using a short vee length & a narrow approach angle. It is essential to keep the weld roll diameter as small as possible when producing small diameter induction welded tube. Ideally the weld roll diameter should be no more than 2-1/2 times the tube OD. Because small diameter tubing is usually produced at high linear speeds, using such small rolls results in high RPM & reduced bearing life. One novel approach to the bearing problem is to use ceramic rolls running on water cooled hollow carbide shafts.

Frequency also plays a part in determining the success of welding small diameter tubing. A higher frequency results in less flux in the impeder for a given amount of weld power, however losses in the ferrite increase with frequency. Good results have been achieved on small diameter carbon steel tubing at 400-600kHz. Non ferrous materials and austenitic stainless steels may be induction welded without the use of an impeder, or with a smaller mass of ferrite in the impeder.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