

# **Choosing the Right HF Welding Process for API Large Pipe Mills**

Dr. Paul Scott, Thermatool Corp, East Haven, Connecticut, USA

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## **Introduction**

For over fifty years high quality API pipe has been produced with both the contact and induction weld processes. Each of these processes has distinct advantages and disadvantages, which must be weighed when producing large diameter API, pipe over 16 inches (406 mm) in diameter. The decision regarding the appropriate choice of welding process becomes more difficult as the wall thickness and pipe diameter increase.

Above 16 inches in diameter, the HF contact welding process has historically dominated pipe and tube production for many good reasons. While recently there has been a trend towards using the HF induction welding process for the large pipe and tube sizes, there are many good reasons why the HF contact welding process can still be the better choice for this pipe range. Depending on the mill design and the steel coils available, the HF contact welding process may well be the best practical choice!

This paper will discuss the differences in the two processes so as a proper evaluation can be made on whether contact or induction welding should be used to produce pipe above 16 inches (406 mm) in diameter.

## **Weld Quality**

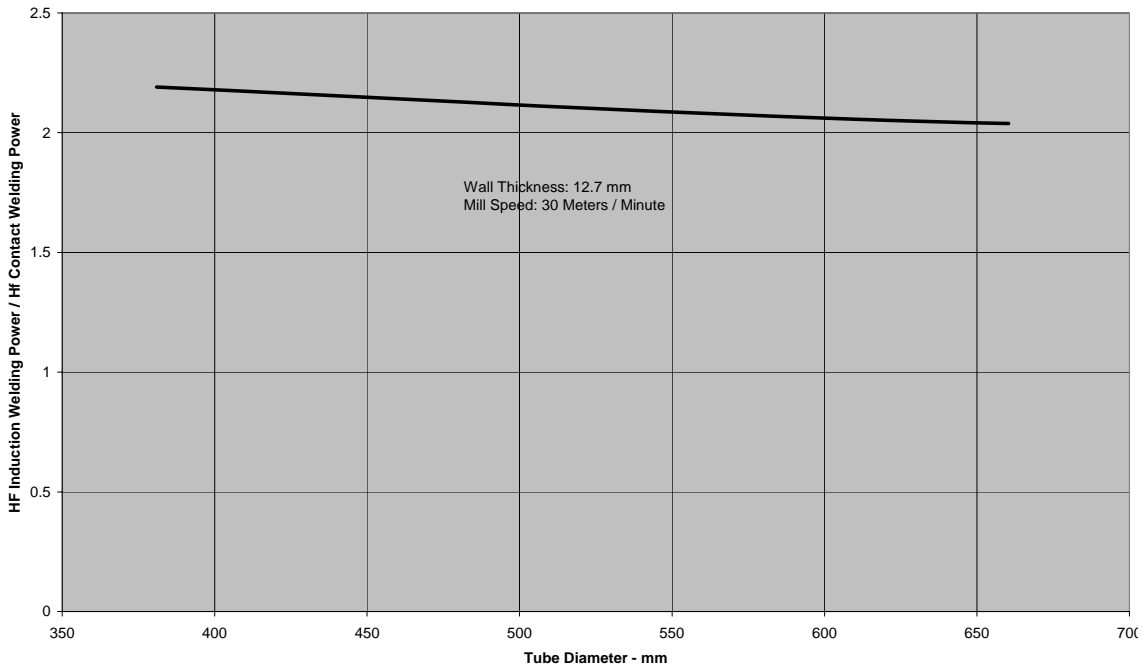
There is a myth worth dispelling that the HF induction process somehow produces a better or higher quality weld than the HF contact process. The fact is that weld samples produced under identical conditions by the HF induction and the HF contact welding processes are indistinguishable. The API Institute and producers of API pipe worldwide can verify this fact. The major advantage that the HF induction process has over the HF contact process is that you will not produce "arc marks" on the pipe with an induction coil. For pipe made for the oil and gas industry, any arc marks must be removed in a separate operation to meet API specifications. Arc marks tend to be more pronounced when welding hot rolled steels with heavy scale. It is possible to produce arc mark free pipes with contacts; it takes more care in set-up and operation. For the very high tensile materials used in API pipe production, the contact process has the advantage of a much shorter weld area. If the pipe strip material being formed cannot be controlled over the longer weld area length required by the HF induction process, the weld quality could be severely compromised. While strictly this is not a "welding problem", poor control of the strip edges due to the longer weld area required by the HF induction welding process would greatly hamper achieving acceptable weld quality.

## **The Cost of Energy**

In most parts of the world, the cost of energy is a serious consideration and energy costs can be expected to increase over time. The HF contact process is far more energy efficient than the HF induction process. As the relative efficiency of the two processes decreases as pipe or tube diameter increases, this statement is particularly true for large pipe and tube production. The chart below compares the energy required to weld the same tube with 12.7 mm wall thickness at 30 Meters per minute with the HF contact and the HF induction processes for tube diameters from 380 mm to 660 mm. In

this tube diameter range, the HF induction process requires over twice the energy compared to the HF contact process. Very significant power cost savings can be realized when welding large diameter pipe with the contact process.

Relative Efficiency between the HF Contact and HF Induction Welding Processes



## Large Mills and the Impact of the HF Induction or HF Contact Welding Processes

There are several factors particular to pipe mills designed to make pipe and tubing above 16 inches in diameter that influence the choice between the HF induction and HF contact welding processes.

The first consideration was cited in the paragraph above. The weld area length, the distance between the vee apex (the weld point) and the last constraining point of the pipe or tube before welding (generally the last fin pass), is significantly longer for the HF induction welding process than for the HF contact welding process. When welding with HF induction, this length is determined by the vee length (the distance from the vee apex to the downstream edge of the induction coil), the length of the induction coil (typically on the order of the tube diameter) and the distance required upstream of the induction coil which is needed to supply sufficient impeder length to complete the magnetic path around the induction coil (ideally not less than one and half tube diameters). To this must be added the distance required by the seam guide and its distance to the last fin pass. The vee length in the HF induction situation can be greatly influenced by the design of the weld box. For instance, if the weld box is of the traditional two side roll design, sufficient clearance at the bottom of the weld box must be provided to accommodate the bottom of the induction coil. If the clearance between the induction coil and the weld box base is too small, significant heating of the weld box will result and to alleviate this, the vee length will have to be increased until sufficient clearance can be obtained. This problem is often found with weld boxes originally designed for sole use with the HF contact process where no bottom clearance is required.

The HF contact process results in a much shorter weld area because the contacts can be often placed within the radii of the weld rolls and the seam guide can be placed relatively close behind the contact head assembly. The length of the weld area is important to getting good edge presentation in the weld vee, particularly when welding the high yield strength materials used in API pipe production. If these high yield strength materials are not sufficiently constrained, then significant “spring back” of the material will occur as it passes from the last fin pass to the vee apex and this will cause an uncontrollably wide vee angle, poor vee shape, and in the limit, wavering vee edges. All of these conditions can cause poor weld quality and in the extreme, the inability to achieve a weld at all!

In addition to the length of the weld area, other factors that influence the choice between the HF induction and HF contact processes are:

- Whether an accumulator is present in the mill line.
- Whether the accumulator can hold sufficient material to prevent starting and stopping of the mill during pipe and tube production.
- Whether long enough strip coils are available for the largest tube sizes so that there is sufficient time to reliably make the butt weld before depleting the accumulator.
- Additional tooling expense for impeder material and induction coils for each pipe diameter required by the HF induction process.

The HF induction welding process works well only when the mill production is continuous. This means that an accumulator must be provided in the mill design and that it must supply strip continuously to the mill throughout the mill run. If this is not possible, then the work coil used in the HF induction process must be rethreaded each time the strip is run out through the mill. This can be extremely difficult since through practical necessity the clearance between the strip and the coil is typically less than 2 inches (50 mm). During the rethreading operation the strip has not yet been constrained at the vee apex by the weld box and “spring back” will cause a very wide cross section of the strip to be presented at the entrance of the induction work coil. As large strips with heavy wall thicknesses are almost impossible to control, the induction work coil most likely will have to be removed and replaced each time the mill is rethreaded, leading to substantial down time and extra work. If the strip edge collides with the work coil during the rethreading process, the work coil will probably be irreparably damaged.

Stopping and restarting the mill when the strip end reaches the butt weld point is also not a very practical option. This will cause random sections of unwelded tube that will have to be removed and scrapped and these will occur randomly with respect to the butt welds so that the “good” pieces of pipe will be of random length. With API pipe production, starting and stopping the mill is further complicated by the seam annealing process. The sections of pipe that are not properly seam annealed will also have to be marked and removed as scrap. While some strategies have been proposed for minimizing the problems associated with starting and stopping the mill to perform the butt weld, these are practically awkward, at best.

On the other hand, the HF contact welding process is well suited to “coil to coil” mill operation and is almost exclusively used in large mills without an accumulator. This is because the contact head can be easily lifted clear of the strip when the mill is rethreaded and because with the HF contact process, the tail of the strip can be welded to within a few inches from the end. With the HF contact process, each strip can be converted almost completely into a pipe whose length is nearly the length of the strip. Thus expensive scrap is minimized and the pipe lengths produced are directly controlled by the strip lengths. This is why the HF contact process is both practical and provides the highest probability of achieving the greatest overall manufacturing yield off of the pipe mill. In the API market, this is the most important factor in determining a mill line’s success.

For large diameter pipe and tube welding, the HF contact process requires little or no impeder material inside the pipe or tube. On the other hand, the HF induction process requires large, complex and very expensive consumable impeder clusters when welding large diameter pipes and tubes. In addition to the tooling expense, these clusters are time consuming to change, contributing to mill down time. They also complicate the design of the ID scarfing mandrel, making it less easy to maintain and adjust, and have a serious cooling water requirement.

Finally, one set of contacts will weld the complete size range while individual expensive induction coils are required for the majority of the pipes produced with an induction coil. The contact tips are the only parts which need to be replaced and the replacement of contacts can be accomplished in a very short time.

## **Dual Welders**

A practical solution to many of the problems cited above is the “Dual Welder”. The Dual Welder is designed so that it can weld using either the HF induction or the HF contact process. Conversion between welding processes is very straightforward with the induction work coils and the contact head mounting to the welder in changeable “cartridge type” assemblies. In cases where an accumulator is available, but the mill’s weld box has not been designed to accept the induction work coils for the largest pipe or tube sizes, Dual Welders can allow the smaller pipe sizes to be welded with the HF induction process and the largest sizes to be welded by the HF contact process. This strategy can also be employed to reduce the length of the weld area to get good control of the strip for the larger pipe sizes. The HF induction process can then weld the smaller diameter pipes, which require shorter weld areas.

Dual Welders also make sense if the accumulator is only used to produce the smaller diameter pipes, while “coil to coil” operation is used to produce the larger diameter pipes. This complicates the mill line design, as the accumulator cannot be mounted directly at the entry end of the mill. In this situation, the accumulator can be constructed in a “basement” below the mill or in the space directly above the mill. While these accumulators pose their own specific operational problems, there are many examples of both types of accumulators in successful operation on mill lines around the world. The advantage of this approach is the versatility of mill operation.

## **Conclusion:**

To summarize the contact weld process offers the following advantages when producing HF welded pipe above 16 inches in diameter.

- A very high quality weld.
- An expensive accumulator is not required when welding with contacts.
- When pipe is welded coil to coil, contact welding results in significant increases in production and reduced scrap over the induction process.
- Contact welding results in very significant energy cost savings.
- Expensive induction coils and large, complex impeder assemblies are not required.
- Simplified design and maintenance of the ID scarfing mandrel.
- Overall there is less downtime for changing coils and impeders with the contact process.
- Significantly shorter weld vee lengths are achieved, which can result in a shorter weld area making it easier to control strip and to produce a quality weld.
- Overall, significantly less scrap pipe is produced with the contact process.