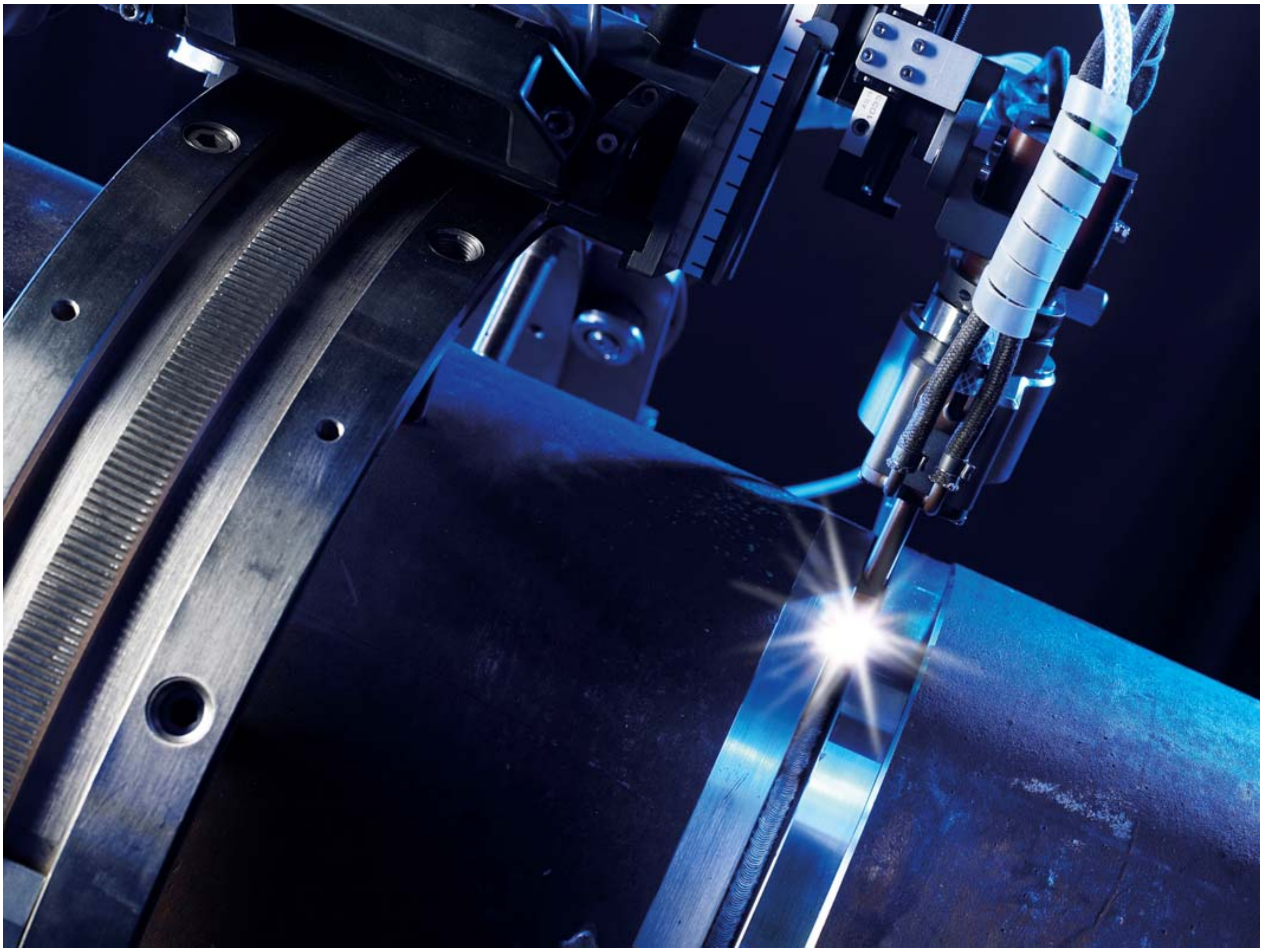
Press Release

# NARROW GAP WELDING OF HEAVY WALL THICKNESS MATERIALS IN NUCLEAR AND FOSSIL FUEL INDUSTRIES

## THE DIFFERENT VARIANTS: ADVANTAGES AND LIMITATIONS INDICATED BY EXAMPLES

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## Introduction

TIG welding of heavy wall thickness materials in an orbital configuration, or prefabricated on rotating work pieces is ever more common despite the many alternative technologies.
This process has proven that once all the constraints have been taken into account; TIG welding remains the best process for dealing with the many inconsistencies that have to be incorporated to make automation successful.

POLYSOUDE has paid close attention to the various manufacturing conditions which, due to their complexity, require a specific solution almost every time. It brings accommodation of the technical procedure and the welding equipment to reach the most apposite compromise.

## The Determining Variables

The approach to setting up a Narrow Gap welding procedure specification requires precise analysis of certain essential variables. These variables will be the main factor in determining whether or not it is truly possible to perform Narrow Gap welding within the financial or technical constraints of the project environment, especially in the nuclear industry.

Let us review the main points and associated considerations.

- Dimensional characteristics of the workpieces

Of course, this is fundamental key as the relevance will increase as the thickness increases.
Consideration must be given to the fact that the Narrow Gap technique is trickier to develop and will only be of benefit and be cost-effective when the thickness is consistent. As a general rule, Narrow Gap welding will not be cost-effective or technically efficient for thicknesses of less than 25 mm.

For thicknesses of 60 mm and above, optimisation of welding time may achieve a factor of between 5 and 10 in relation to conventional TIG welding. This takes into account the combined effect of the reduction in the quantity of metal deposited and of the rate of deposition in the process.

❖ Preparation and alignment conditions

The machining and alignment tolerances are used as the first significant criteria to confirm that a Narrow Gap TIG technique can be used.
In the most critical cases, with full penetration root pass, the alignment precision and clearance values between the two root faces, associated with machining tolerances will allow the Welding Specialist to evaluate the compatibility between the welding conditions and the automatic TIG process.

The lack of accessibility for manual welding due to the width of the weld groove only allows a small amount of flexibility and generally excludes situations wherein machine tools or alignment tooling cannot correct a poor alignment less than 75% of the thickness of the root face to be achieved with a gap which does not exceed 0.5 to 0.8 mm.

These decision-making criteria are, of course, relaxed for welding without full penetration, backing, sealing run, etc.).

❖ Grades and Operating Constraints

The grade(s) to be welded are essential when considering Narrow Gap welding. The ensuing weldability will determine the level of constraint to be considered for the equipment (thermal insulation, thermal screen, additional cooling system, specific saddles, etc.)

The mechanical characteristics of the materials and their behaviour in terms of welding shrinkage will be used to determine the profile of the  weld groove  (the angle of the weld groove will be chosen according to the grade and thickness to be welded) (fig 1).

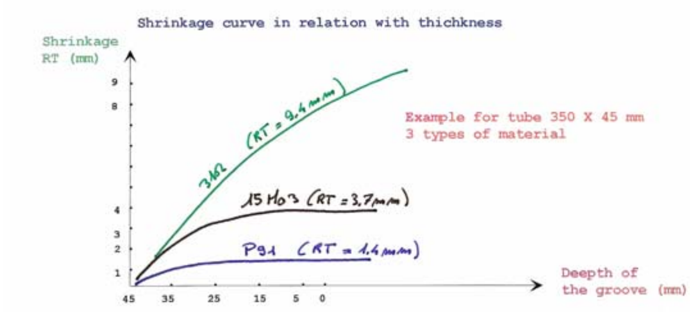
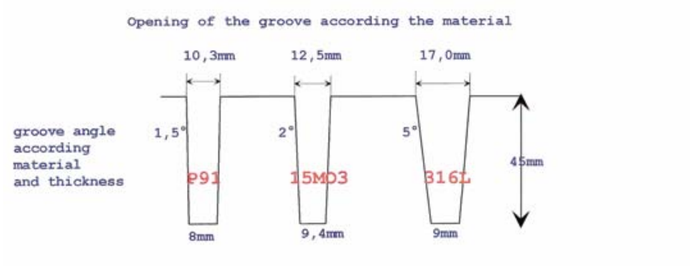



*Fig. 1 :*
*Shrinkage curve in relation to the thickness*




*Opening of the groove according to the material*

Then, it is advisable to ensure that the materiel is not susceptible to cracking which could prove to be more or less incompatible with either the stresses caused by solidification or with the level of energy needed to avoid compactness defects, (mainly from lack of fusion).

Finally, the ability to weld without filler wire will be important to evaluate the "adaptability" to Narrow Gap welding (management of starts and stops, re-melting passes…)

❖ <u>Welding Position</u>

The welding position is also fundamental in selecting the operating process. The need to weld in position will substantially reduce the level of productivity of the process which is characterised by different weld pass thicknesses.

It should be noted that, depending on the materials and chemical analysis involved, there are applications where welding in and upward or downward direction cannot be performed.

❖ Manufacturing Context

Some related factors could be influential when deciding on the operating process or simply disqualify the Narrow Gap approach.

Examples:

- Backing accessibility or non-accessibility (raises the question of the possibility either to strike the root off level or to weld inside with X preparation.
- Control and traceability of supplies, management of base materials and filler wire products, the possibility to develop with materials coming from the same processing or the same melt for filler wire products is recommended.
- With regard to non-routine maintenance or maintenance related to a large number of welds to be made. The development time and means are substantial in order to carry out tests to establish the parameter limits.
- Whether the company has a team of welding technicians and resources compatible with the required technical skills.

## Selection of operating procedure

Analysis of the initial variables will help to determine the appropriate operating procedure and equipment adapted for various applications.

Every technique varies significantly for each different field of use. Mastering this set of variables guarantees the best compromise whilst minimising risks.

## Narrow Gap TIG welding, straight single-pass layer by layer

This technique offers the best productivity gains while remaining simple for operators to carry out.

On the other hand, developing the welding process specification can be most tedious since every aspect must be taken into account:

- Weld shrinkage
- operating weldability

The technique would be relatively simple since it consists of making a single-pass layer by layer and then including the weld shrinkage by adjusting the angle of the weld groove profile so that the width to be welded remains constant and between 8 and 10 mm
(fig 2).

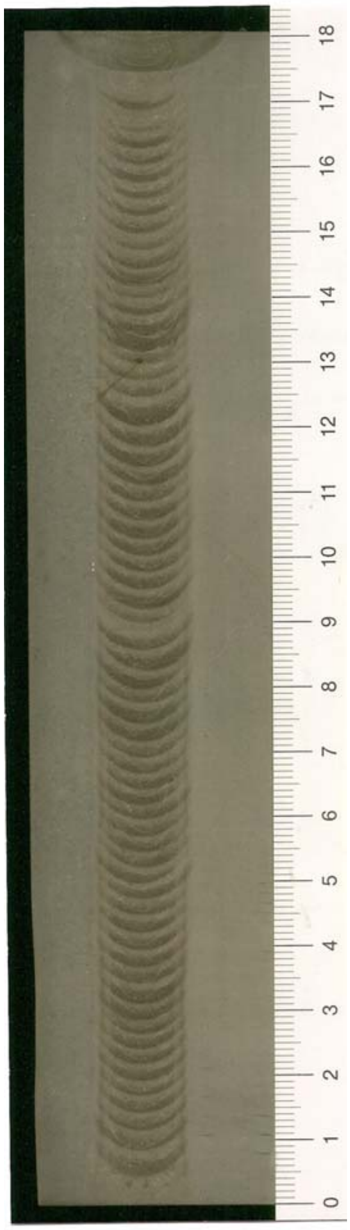


*Fig. 2*
*Hot wire narrow gap weld. One pass per layer.*
*Wall thickness 180 mm, base material: low alloy steel P91.*

Thicknesses of less than 40 mm do not need a specific torch (fig 3).

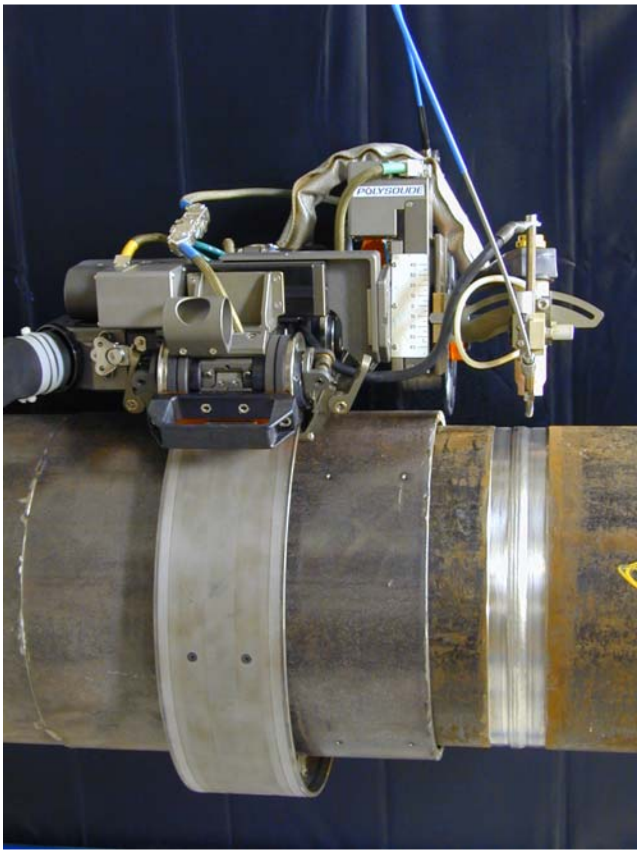
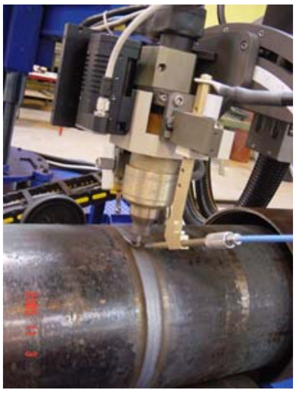



*Fig. 3 :*
*Polycar MP orbital carriage weld head and standard torch for narrow gap preparation up to 40 mm wall thickness*.

The adjustment of electrode stick-out is sufficient to ensure an effective level of gas protection for a majority of materials. It should be noted that POLYSOUDE has developed a motorised programmable device to make automation management easier, with fully automatic control of the length of the electrode, the diameter to be welded and the welding parameters without intervention by the operator. The most frequent use of this would be continuous rotating tube welding to avoid stopping between passes or orbital welding in harsh environments to control the electrode stick-out by remote control.

For the heaviest wall thicknesses engineering design involves, on the one hand, finding the best compromise to design sturdy torches but also compatible with the minimum width of weld grooves (i.e. a thickness of 7 mm for the torch body) and, in the other hand, to develop mechanical seam tracking to avoid collisions between torches and weld groove sides (fig. 4).



*TIG hot wire standard torch with motorized electrode stick-out and seam tracker.*

*Finished weld / Capping pass*

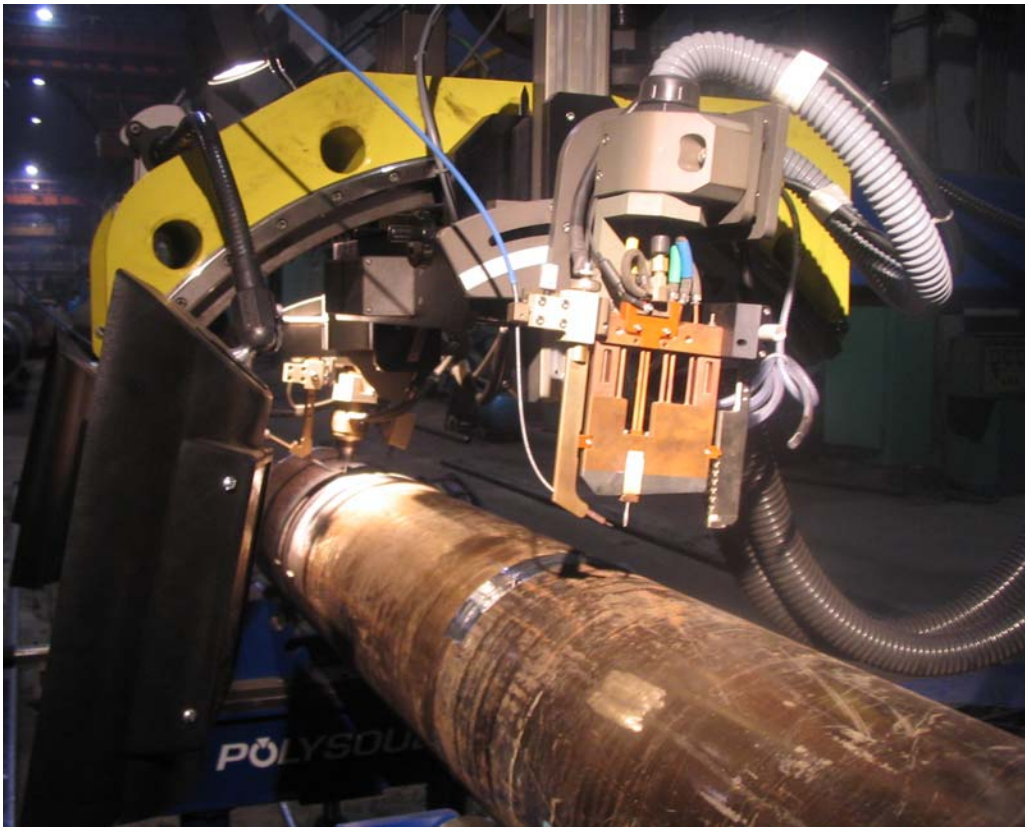



*Fig 4 :*
*Double torch assembly for mechanised welding : Narrow gap torch and standard torch with motorized electrode stick-out*

The purpose of this device will be to centre the torch in the axis of the joint to be welded or to guide the torch with respect to one reference side.

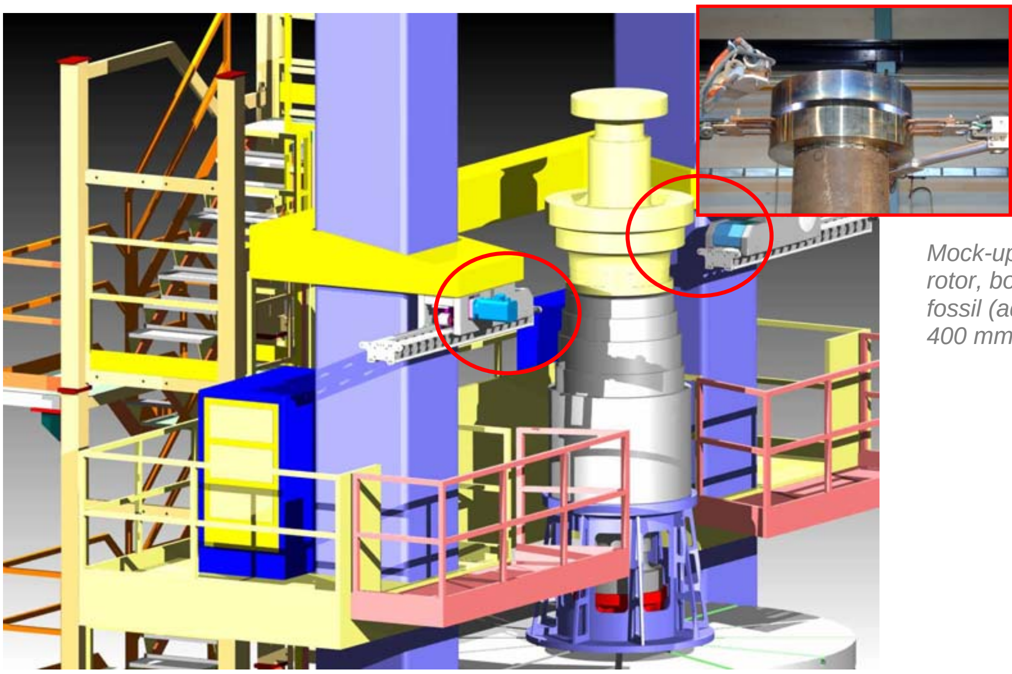
The self-centring sensor system is used mainly in orbital welding. It enables corrections to be made in 3 dimensions (lateral position, orientation in the axis of the weld groove and trim correction.

The lateral sensor device is more suitable for continuous welding applications on machines where the workpieces are rotating.

This system is very simple to use, but requires manual intervention to fine tune the position of the electrode in the centre of the weld groove being filled.
Unlike the self-centring system, offsets are possible and a gap is permitted (if materials are dissimilar or of a thermal non-equilibrium.

**Narrow Gap TIG welding, dual-pass weld Layer by Layer**

This technique is an alternative to the single-pass weld by layer technique. It is used when the thickness is consistent and the financial or technical savings of the TIG process continue to be substantial despite welding times two or three times greater than the method used in the single-pass layer by layer process (fig. 5).



*Mock-up for turbine rotor, both nuclear and fossil (add fuel). Up to 400 mm wall thickness*

*Fig 5*
*Turbine Rotor welding station using TIG hot wire narrow gap double torch. Mono or multi-pass per layer.*

The key factors for selecting this alternative are primarily related to:

- Problems of preparation or alignment where the precision is incompatible with the single pass process
- Sensitive materials which need either limited constraints or limited welding heat input.

Depending on the materials and problems with weldability, mainly dependent on chemical analysis of the base metals and wire feed products, the dual-pass technique is frequently limited to ½ pass advance (generally downward for filling). This technical constraint becomes very significant in terms of the design of the welding equipment which must include two wire feed units and make provision for the welding torches to be symmetrical (Fig. 6a and 6b).

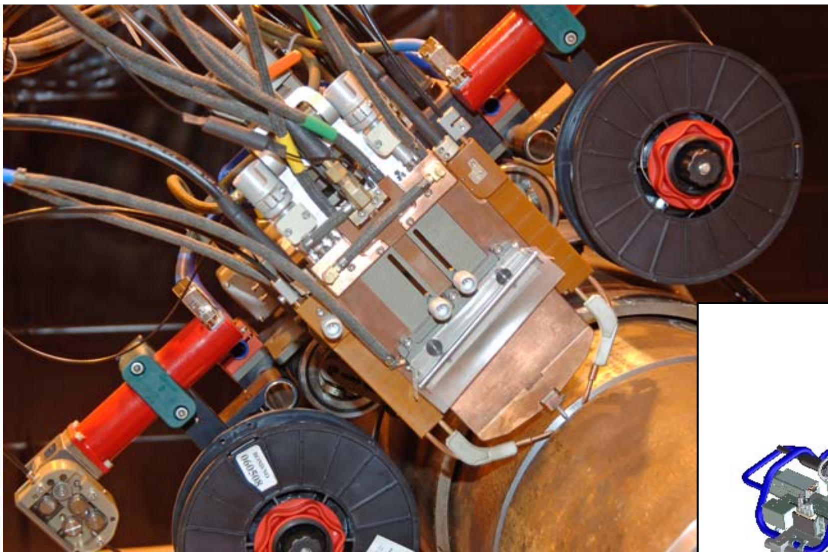


*Fig. 6a :*
*5 GT symmetric double downhill TIG hot wire narrow gap welding with Polycar MP*

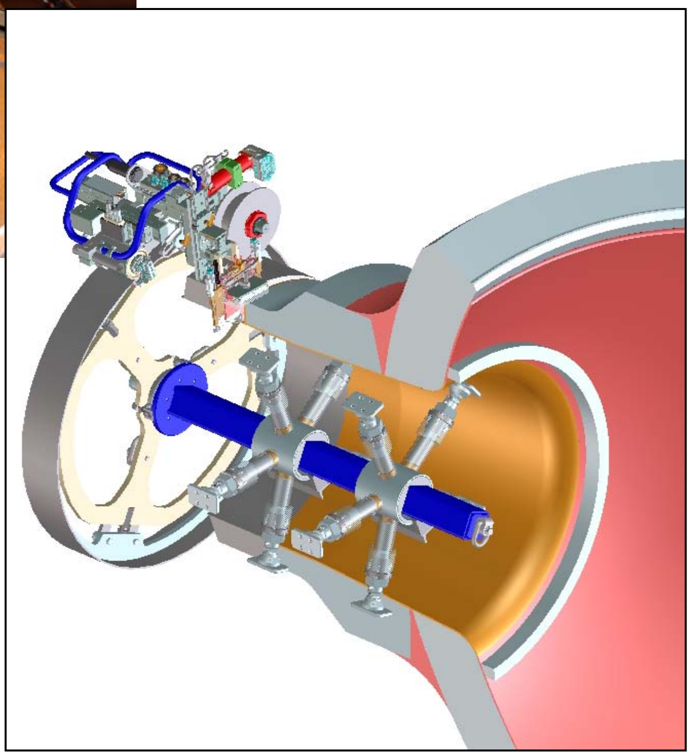


*Fig. 6b*
*TIG hot wire safe end narrow gap welding for nuclear steam generator and reactor.*

The relative increase in the width of the weld groove in dual-pass welding does not however affect the definition of the angle of the weld groove which does not permit the inclination of the torch any more than in single-pass. Nevertheless, since the lack of heavy arc pressure does not make it possible to ensure good side wall fusion, dual-pass welding requires other methods of ensuring that the fillet welds are fused. Two techniques are commonly used; either replace the traditional straight electrode by a bevelled electrode or use a bent electrode.

Concerning the seam tracking, dual-pass welding only requires a reference on one of the two fusion faces, this together with the possible requirement to make more or less pronounced offsets to modify the stacking of the passes.

**Narrow Gap TIG welding, single-pass with oscillated electrode**

This is an interesting variant for very heavy wall thicknesses, (of the order of 150 to 200 mm), where use of the technique in one pass per layer imposes technological constraints which may be at the limit of what is reasonable, (accuracy of the weld groove controlling shrinkage, proportion and technological limitation for design of the torch, etc.).
For this reason, and mainly for non-orbital applications, the oscillated passes technique can make it possible to combine the benefit of a single-pass weld layer by layer, while still having more flexibility with regards to width tolerance, (oscillation amplitude of the electrode can still be adjusted), with transverse shrinkage constraints which are much more moderate than in pulled passes (single-pass weld layer by layer type).

The equipment will be more complex, (motorised, controlled and programmable oscillation of the wire and the electrode), more bulky and usually, mounted on imposing installations (fig. 7)

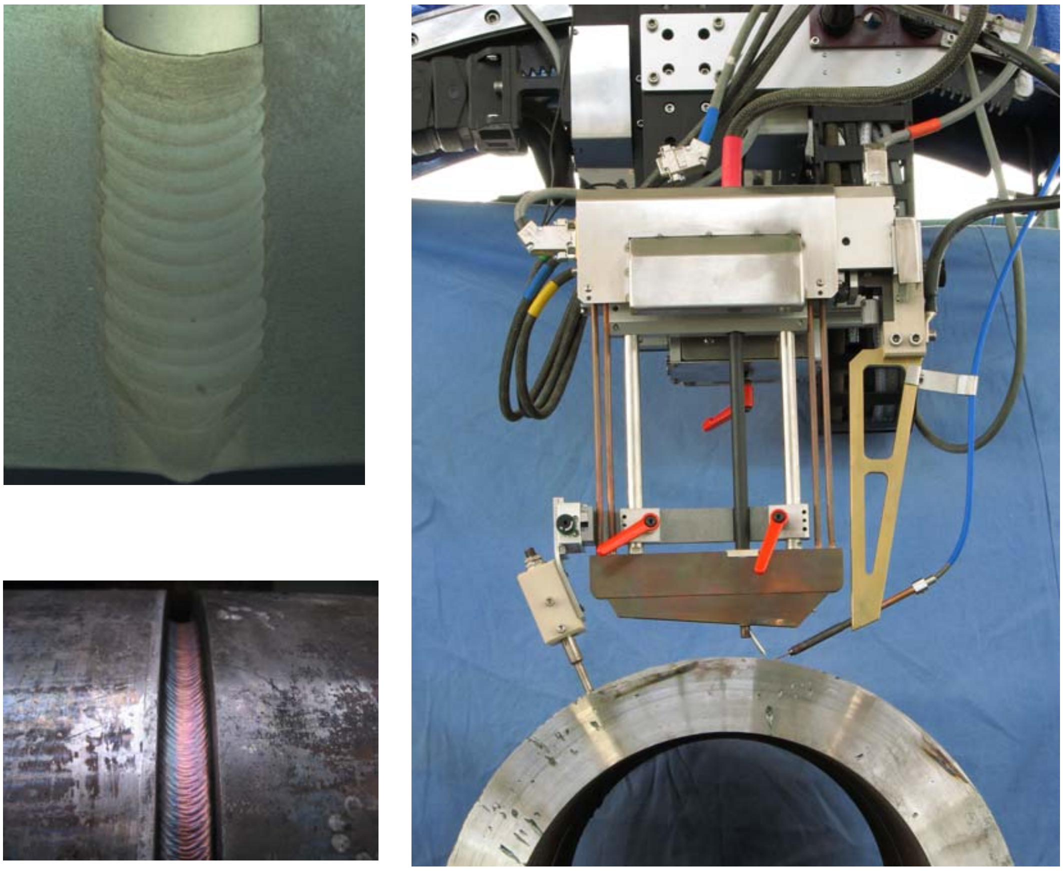


*Fig. 7 : Narrow gap TIG hot wire welding. Torch with oscillating electrode and wire for wall thickness from 80 to 160 mm.*

*In the present case: base material P91 low alloy steel.*

Additional features are provided to make automatic centring of the torches easier before and/or during welding. The principle of seam tracking by measuring the arc voltage may be used in this case instead of the mechanical sensing systems required by fixed electrode torches.

Increasing the width of the weld groove (from 13 to 18 mm as required) allows further constraints to be taken into account when adapting the torch to very hostile environments (such as insertion in pre-heated environments with temperature limitations which can reach 400°C.)

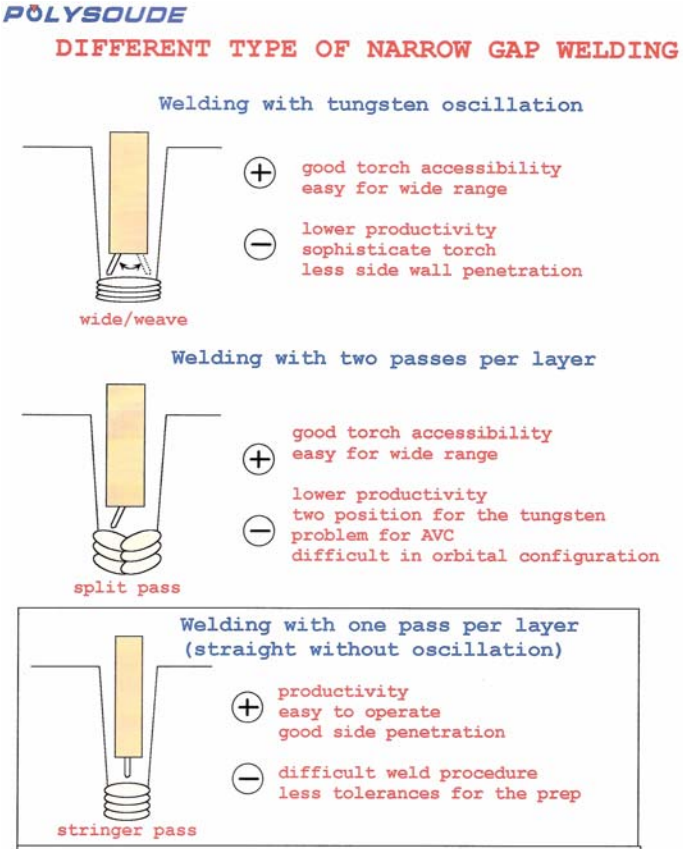
## Different variants

Based on the techniques and associated equipment described above, there are several variations possible.

- Hot wire TIG or cold wire TIG welding.
- Multi-pass layer by layer Narrow Gap welding. This is where the weld groove widths are more or less well-controlled or where the well grooves exist but cannot be modified.
- Oscillated multi-pass layer by layer Narrow Gap welding. The situation is the same as with the fixed electrode technique.

Note: The selection of one of the variants often corresponds to intermediate situations which need compromises between the environment, human resources or the equipment available.

## Conclusion




Many options can be used for Narrow Gap TIG welding of material thicknesses between 45 and 250 mm. In this range of thickness the choice of technique will influence how the welding equipment is defined.

*Fig. 8 :*
*Different variants of narrow gap welding*

Single-pass layer by layer welding represents the best compromise regarding performance and the ease with which it can be implemented by operators. Polysoude has focused its efforts in order to master the various narrow gap welding techniques in order to allow making the process more accessible. (fig. 8).

The other side of the coin can be seen during development wherein all the constraints have to be included, (operative weldability, approaching tolerances, machining tolerances, shrinkage variation, etc.). All the constraints referred to mean that a high level of manufacturing control of the environment is required, together with the compatibility and sensitivity of the materials, which must be carefully evaluated.

The alternative technique of dual-pass layer by layer can permit to guarantee the use of the Narrow Gap technique in cases wherein the welding of metals or control of workpieces is not compatible with single-pass welding. This solution is to some extent a fallback option in which productivity is increased by a ratio of 2 to 3, but which nevertheless proves to be competitive for orbital applications on heavy wall thicknesses.

In the case of rotating workpieces, use of the oscillated passes technique often proves to be the best compromise for heavy wall thicknesses in terms of the equipment and preparation of the workpieces. Of course, many variants are possible, and the final choice remains with manufacturers who must ensure they have all the influential factors.

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He joined POLYSOUDE in 1992 and has been Director of the Technology Department since 2001, after having spent many years on developing heavy wall thickness applications.