Experience in Welding Tubes to Tube Sheet with Automatic Argon Arc Tube Sealer

By Y. P. BHATIA*

The connection between tube and tube-sheet is usually achieved by means of expanding the tube so that it fits tightly in the hole by means of radial pressure. In service, especially when there are fairly high temperature or pressure differentials, such a joint with expansions, only, may deteriorate. Seal welding avoids this condition. Seal welding with automatic argon arc is more favourable for many applications when compared with other welding processess. This process results in welds of exceptional quality together with low operating costs, completely automatic operation, consistent results and high productivity. This type of tube sealing represents a major breakthrough in the fabrication of boilers, heat exchangers, condensers and scrubbers. Until recently, joining tube to tube plates was a difficult manual operation occupying considerable production time. Experience indicates that expansion cannot be relied upon solely to provide a permanent and effective seal; alternative or supplementary welding of the joint is then often appropriate. The mothod which may be to utilize argon arc welding will now be examined against various other welding techniques, in vogue.

Welding Technique :

The choice of a suitable welding procedure and joint design is a matter which deserves close attention, because the geometry of these joints is usually not conducive to the production of high quality welds. Special consideration must be given to all permanent factors, often coupled with some degree of experimentation. Both the tungsten-arc and metal arc processes are used in tube to tube sheet welding while welding any stainless steel combinations with TiG process causes no problems. Care should be taken with the various carbon steels to ensure that the manganese content is maintained with in the specification of the steel to avoid problems.

Rolling and Welding

Although it can be demonstrated that the strength of seal welds of suitable proportions is more than adequate to withstand the service stresses encountered, views on correct sequence to be adopted in sealing of tubulars are sharply divided. Some favour full expansion before welding, some after welding. Others counsel that full expansion is undesirable either before or after welding, and favour merely a light rolling to ensure that the tube is in contact with the tube sheet. Each advances good reasons to support his point of view. Supporters of full expansion before welding consider that, as it is essential to provide some operation to fix the tubes in to the sheet prior to knifying and welding, it is economical to complete the full expansion operation at this early stage this avoids the duplication of effort which is bound to occur if

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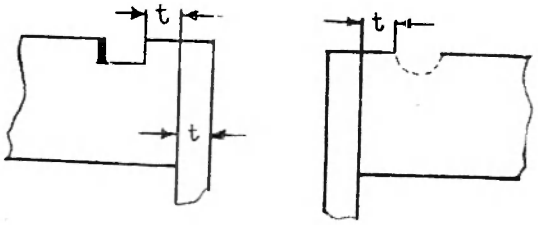
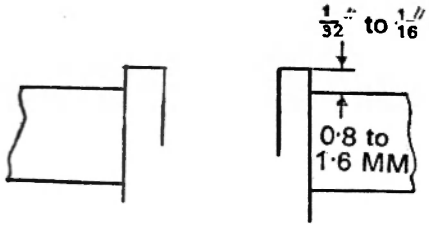
the first rolling operation is restricted merely to light expansion, sufficient only to grip the tube and ensure a close fit. The former also provides an opportunity to prove the efficiency of the rolled seal by hydrostatic or pneumatic testing before seal welding. A large number of test pieces and tube sheets have been welded adopting this procedure with the TiG process without encountering even problems such as porosity. Welding before rolling has the economical disadvantage of duplicating the rolling operation but enables the welds to be tested before finally expanding the tubes. There may be damage to the welds, if final expansion is not carefully controlled so as to avoid excessive deformation of the tube in the region of the welded joint. Furthermore, when joints are welded without prior rolling the end of the tube may be so deformed that it may be necessary to ream it out so as to avoid jamming of the rollers. When ligament sizes permit to flare the end of the tube and countersink the tube hole to match, this facilitates the final rolling process and reduces encroachment of the weld on the tube threshold.

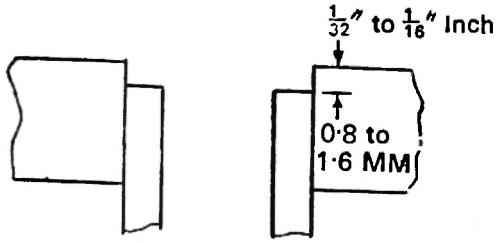
Joint Preparation :



Castellated Preparation



Plain Bore Preparation



Fillet Preparation

Cleaning and assembly :

Careful cleaning before welding with minute attention to detail is very necessary particularly when using inert gas process. It is possible to achieve this. Traces of oil or grease trapped between the tube and plate cause difficulties and must be excluded alongwith rust, scale and other foreign materials.

The following cleaning procedure indicates acceptable technique. Having completed machining of tubes and plates, the faces of all the components should be examined for rough edges, scratches, pitting etc., which may entrap lubricant or other undesirable foreign material.

The whole tube plate should be thoroughly degreased making copious use of suitable solvents to leach away all foreign matter.

Carbon tetrachloride or trichlorethylene are common use but other solvents may also be used with relative advantages. Undue economy often results in recontamination of cleaned surface through the volatile solvent leaving behind an oily residue as it evaporates. Particular attention should be given to the end of the tubes, which should be degreased both inside and outside for a length at the very least equal to the thickness of the tube plates.

It is best to avoid the use of any lubricant for rollers during expansion, but if, because of undue wear or heating of the rolls, lubrication is thought necessary then it must be applied with discreation. The fear of contamination is less with vegetable oils than with mineral oils, and excellent results may be obtain by using solf soap or detergent solution. In any case., only the absolutely necessary amount of lubricant should be used, and it should be applied with great care so that it is not allowed to penetrate into the gap between the tube and plate.

On completion of assembly, expansion, etc. the localised areas around the joint should be cleaned again with solvent so as to remove the final traces of lubricants. The sheet may be slightly warmed before welding is commenced to assist in the removal of any last traces of oil or solvent which might have escaped the cleaning cycle : Whatever sequence in rolling and welding is chosen, the precauting which must be taken with regards to joint preparation cleanliness etc. remains the same.

Experimental Data :

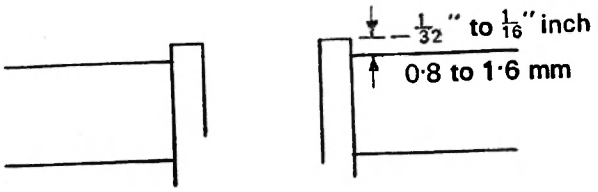
You will find results of different mock up tests carried out with Agron arc tube sealing machine,

Manual argon arc welding with a filler wire and with coated electrodes. Different joint Geometry have been considered. It will be observed that automatic argon arc welding is definitely superior than manual welding, as shown by the results of mechanical testing required as per various codes.

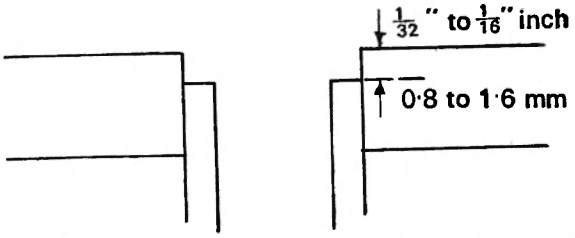
Tube sheet material A-285 Gr. C. Tube material A-179($\frac{3}{4}$"%×14 Gauge).

Tube up/plain bore preparation

1) Light expansion
No. of runs=2
No re-expansion
Pull out test 5.2 Tonnes.



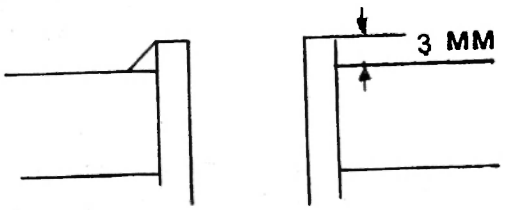
2) *Tube down/Fillet preparation.*
Light expansion
No of run=1
No re-expansion
Pull out test 4.8 Tonnes.



The above mock up was done with Automatic Argon arc tube sealer having the following condition.

Current=120 Amps.
Voltage=11-12 volts.
Time setting=55 seconds.
Argon flow=12 cuft/h.

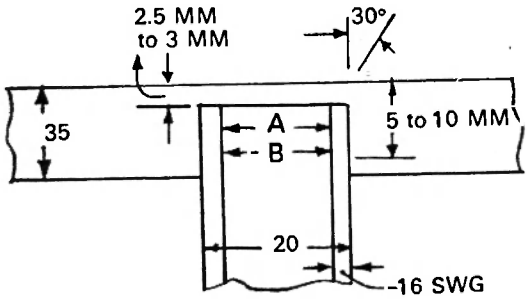
3) Tube up 3 mm by manual arc welding using.
E 6012 class of electrodes
Light expansion
Welded will 12Swg coated electrodes.
No re-expansion
Pull out test 3.7 Tonnes.



The following tests were carried with Tube Sealer on the following combination having the following Joint Geometry and procedures.

Test procedure No. 1.

Tube sheet material SA240 TP 316 :—P8
Tube material SA213 TP 316 :—P8
Tube sheet thickness=35 mm thick.
Tube size : 20 mm O.D. × 16 SWG.
Expansion % before seal welding 4%
(i.e.) I.D. of Tube 17.224 mm
Loss of expansion due to seal welding
at A I.D.=16.9 to 17
at B I.D.=17.1 to 17.2
Welding parameters
Current=80 Amp volts 10/11 volts.
Argon flow 12 cft/hour.
Diameter of Thoriated Tungsten used 3/32"
Crater time=3 seconds.
Welding time=55 seconds.
Argon delay= 5 seconds.



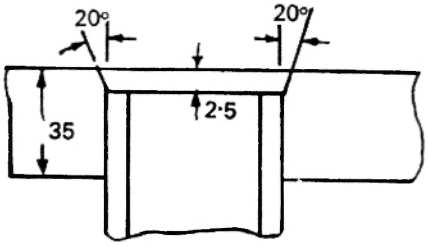
Test Results :

Macro examination after sectioning and acid etching=satisfactory
Hardness on tube 42 Rockwell B
Hardness on weld 49 Rockwell B
Hardness on HAZ 46 Rockwell B

Pull out test valve (without re-expansion)=5000 Kgs. (failed on H'A'Z.)
Pull out test valve (after re-expansion—to 4%) =5200 Kgs.
failed on tube outside Tube-sheet.

Test procedure No. 2 :

Tube sheet Material =IS 2002 Grade 2A—PI
Tube material =SA 179—PI
Tube sheet thickness =35 mm
Tube size =20 mm O.D.×2 mm. thick
Weld detail



Tube sheet hole dia=20.2 mm
Expansion % before seal welding 4%
(i.e.) Tube I.D. 15.8 mm.
Loss of expansion due to seal welding=complete loss.

Welding parameters :

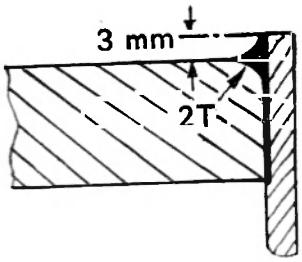
current=95 amp. Volts=12 to 13 volts.
Argon flow=12-15 cuft/hour.
Argon delay=5 second.
Welding time=55 seconds.
Diameter to Thoriated Tungsten used 3/32"
Creater time=3.25 seconds.

Test results :

Macro examination after sectioning and acid etching=satisfactory.
Pull out test valve (without re-expansion) 4700 kgs. (failed on pipe outside tube sheet)
Pull out test valve (after re-expansion)=4500 kgs.

The following tests were carried out to compare the tube sealing with automatic tube sealer and manual argon arc welding.

Tube sheet material M.S. Commercial.
Tube material SA-179 ($\frac{3}{4}$" O.D.×14 gauge.)



Light expansion.

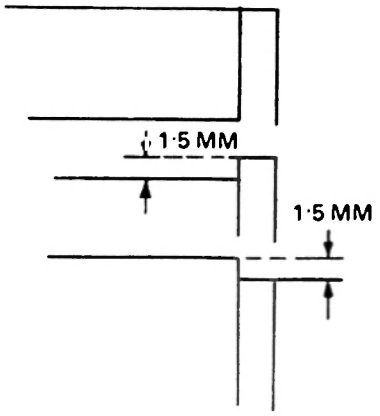
Welding with Manual TiG Welding process using the Silicon manganese filler wire confirming to B.S. 1453 A2 (IS 1278 type 4-2)

Re-expansion to 1% having 12 mm from tube sheet face.

Pull out test 3.5 Tonnes, Tube failed outside the region of tube Sheet.

The following experimental work done with automatic Tube Sealer Argon arc welding.

1) Tube Flush with Tube Sheet face
2) Tube up by 1.5 mm
3) Tube down by 1.5 mm.



Tube sheet materials M.S. Commercial.
Tube material SA 179 ($\frac{3}{4}$" OD×14 BWG)

Tubes-expanded lightly.
No. of runs=2.
Using 120 amp. × 12 volts × time takes 55 seconds.

Re-expanded back to 1%
Thinning having 12 mm from the fact of tube sheet.
Pull out tests were carried out=3.5 Tonnes.

In all the cases tube failed outside the region of Tube sheet.

Conclusions :

Seal Welding as a means of preventing leaks in heat exchangers and condenser tube connection is widely used either to supplement rolling or by itself as a reliable strentgh connection and seal. In the process explained the use of TiG welding together with the automatic tube sealer proves very economical specially for large heat exchangers where a large number of tubes are involved. Reduction in production time and avoiding the use of costly electrodes especially in the case of stainless steel together with good quality weld can be claimed as the achievement of the process. Experience shows that quality of welding can be achieved for both stainless steel and carbon steel with this process.

Reference : 1 British welding Journal—May 1963.
2 B.O.C. Tube Sealer T.C. 307 March, 1965.