Tube To Tube Sheet Welds

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These are very critical welds in a heat exchanger since they are very difficult to make and sometimes even more difficult to inspect. They are critical because presence of even small defects could lead to leaking welds during service. Hence it is very essential that adequate inspection is laid down.

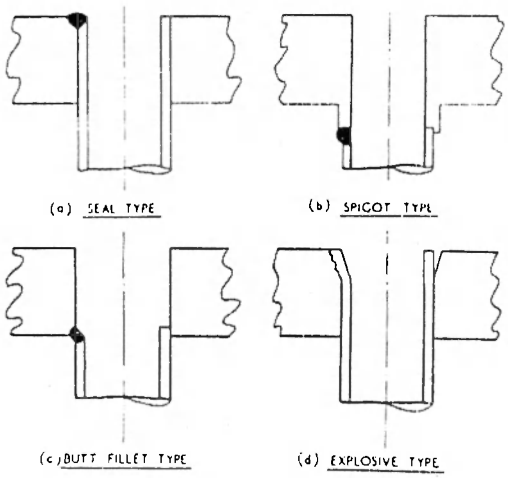

Fig.1 : Principal types of tube-to-tube plate-welded joints.

Four different types of weld are illustrated. A simple seal weld is essentially a fillet weld. Improved weld characteristics can be obtained by having a machined groove around it. The inside radius of the groove is generally equal to sum of tubesheet hole plus tube wall thickness. Tube is expanded into the tube sheet hole after welding.

The other weld is spigot type with a projection machined out from the extra thick tube plate or it may be a mechanical pull out by cold draw process. The latter process is metallurgically more attractive but it is not still widely employed. Automatic TIG welding is done by inserting the weld head through the tube bore. The weld is crevice free and bulk of tube sheet is isolated making it a butt weld rather than corner & fillet type.

The third alternative is also crevice free and a butt fillet type generally made by automatic TIG process only, by a similar bore- welding head.

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The final choice shows the explosion welded surface weld which extends only to part of the interface while retaining the crevice. This type is also still not used very widely.

Both RT and UT techniques are used for inspection of the first three welds

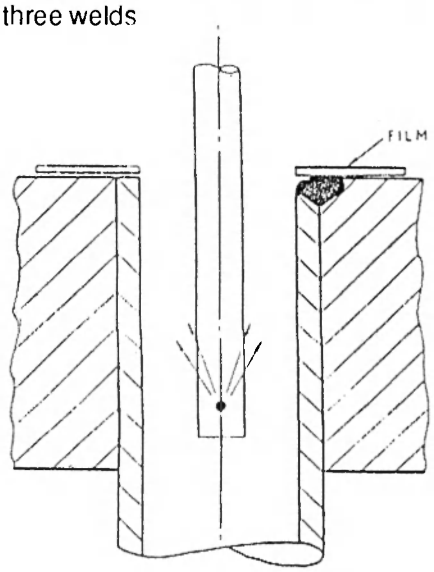


Fig. 2 : Alignment of source of radiation and film with respect to seal weld.

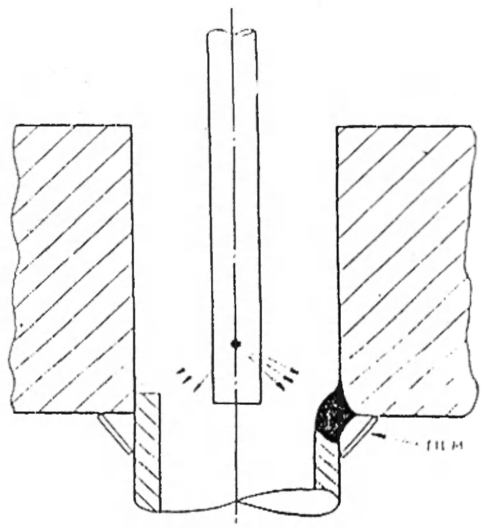


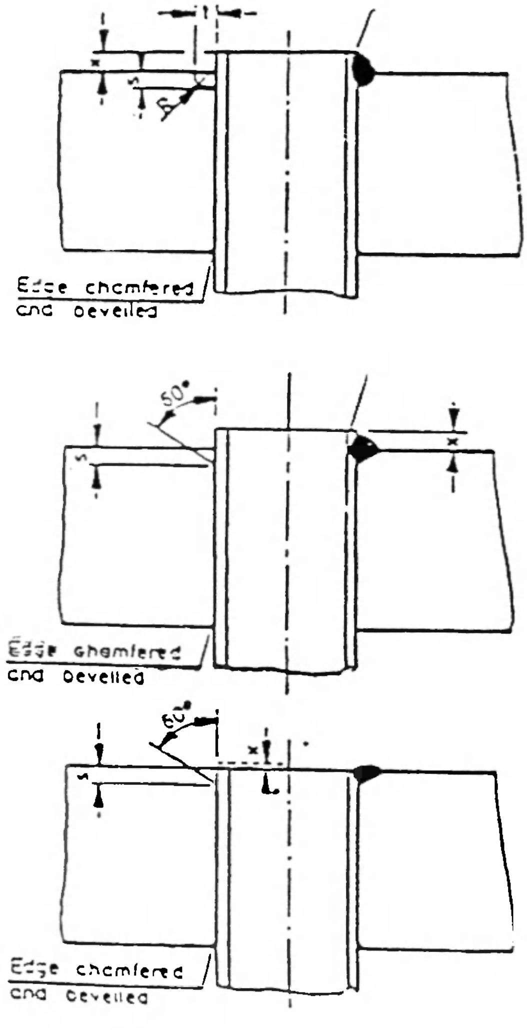
Fig. 3 : Alignment of source of radiation and film with respect to a butt fillet weld.

Highly specialised equipment having a microfocus rod anode x-ray set and miniature lower energy gamma sources are used to carry out the panoramic radiography. Since the size of the welds is small with their peculiar shape, a small source to film distance is necessary. In absence of such new developments the welds would normally be helium leak tested for internal soundness and surface checked by LPI for surface breaking defects.

The fourth type having explosion welded tubes has to be necessarily inspected by UT. This is also not totally satisfactory because if the surfaces are perfectly fitting like in high quality slip gauges, UT waves are transmitted well.

There are various ways in which the Indian workshops have been asked to weld tube to tubesheet weld joints. Basically these are imported designs with most of the technical and inspection requirements originating from the Country and industry where from the equipment designs have originated.

Many times the designs are indigenised later but in general it can be said that the requirements are made more rigid and difficult to fulfil in the given circumstances of equipment calibre and technological expertise. Some typical weld details are shown the typical testing is as below.



xmin = tube wall thickness
s = tube wall thickness
t = 3mm for s > 1.5 mm
t = 2mm for s < 1.5mm

x = 0 — 0.5 mm

Fig 4 : Welding is carried out in such a way that the inner side and the edges of the tube remain unchanged

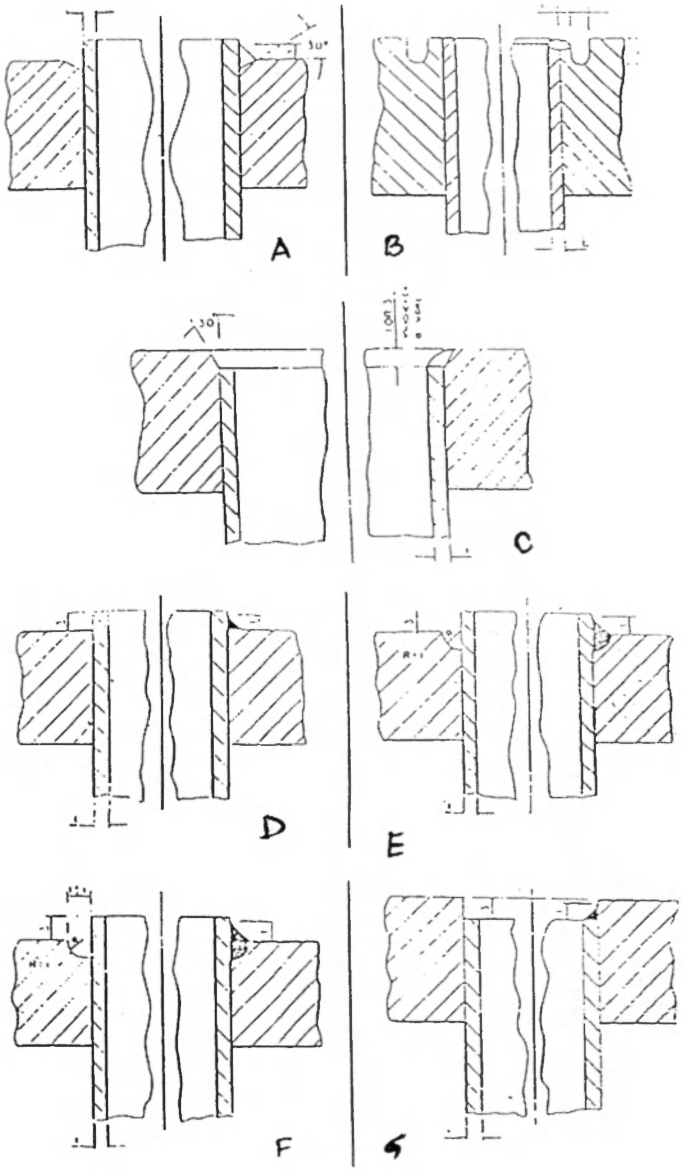


Figure 5

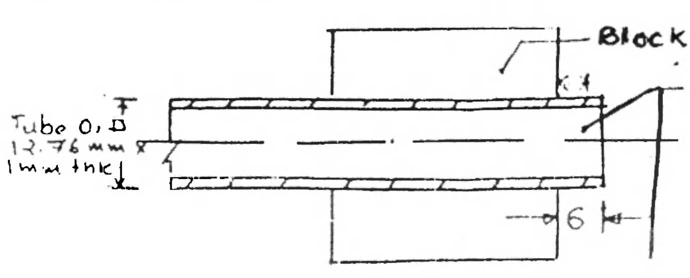
1) DPT after root run
2) Air leak test at 0.5 barg min using soap solution
3) DPT after final run
4) Leak test at 0.5 barg minimum with soap solution.

This is in lieu of radiography which is normally not possible and done in India. The welding is specified to be done normally by GTAW only but in two runs using fillerwires.

In some specifications we also find a stipulation that TIG manual is preferred in two runs with filler wire and if automatic TIG is to be used it will be only permitted on the root pass. It is rather difficult to understand or agree with this stipulation. Strength of welding is always specified and reference of TEMA-R or ASME appendix A are given and a throat or minimum leak path of tube thickness is laid down. For a few tubes or as a minimum, 0.8. or 0.7 times the tube thickness is also allowed.

It is essential to carry out procedure approval tests as well as individual welder performance qualification test blocks on which the laid down destructive and non-destructive tests are carried out to establish the reliability of the procedure and the manual skills in using the same. It is natural that down hand welding procedure is preferred when manual TIG process is preferred. At times when the heat exchangers are long ones this condition becomes tough to meet as suitable deep pits have to be dug or proper supporting arrangements are necessary to hold the job as well as the welding paraphernalia at a height. Among destructive tests the normal requirement is various radial sections of the weld to be macroetched to confirm absence of nonacceptable defects of planer type and within acceptability, levels of inclusions and porosities.

A very specific design in a nuclear vessel called end shield has the depicted trijunction joint between tube and tubesheet with the baffle plate making up the permanent backing plate.



Tube contact rolled upto 4mm tube sheet face
Fig 6 : Grove designed for Test Coupon
(For combination qualifications, the deposited weld metal thickness shall be recorded for each filler metal or process used)

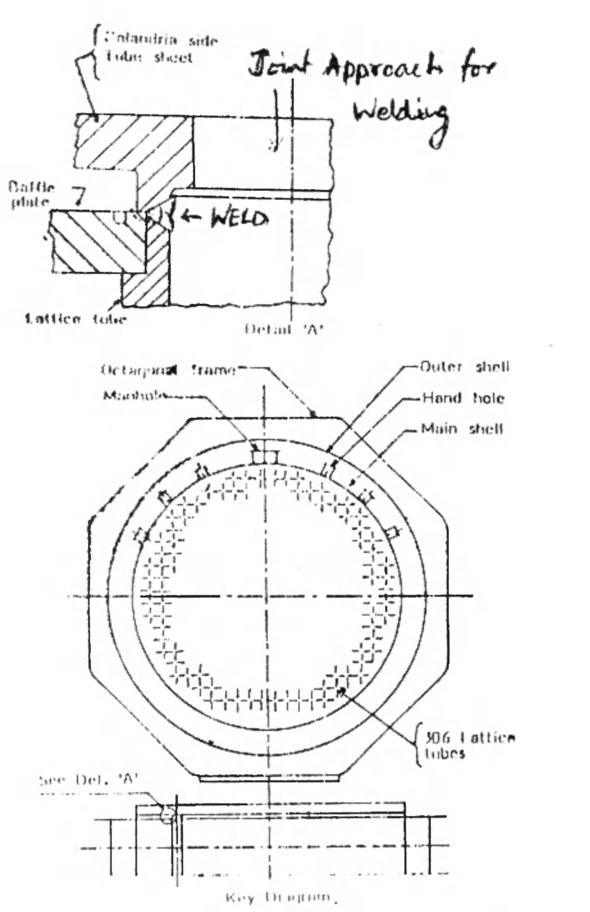


Fig. 7 : Joint configuration for welding SCTS baffle plate lattice tube

It was a very complicated joint successfully developed and made by only a couple of fabricators in India. Cudos to the engineers who conceived such joint and the ones who developed the welding technique with fully indigenous equipments. The joint was made in horizontal (2G) position and totally hidden from sight besides having approach only through the tubesheet holes of 114.00 mm. Being nuclear welds and developmental stage the quality requirements were very high and non-destructive testing procedures had to be evolved from scratch. Only possible methods were PT and UT for surface faults and internal soundness respectively. Use of austenitic stainless steel of type 304L SS adds to the difficulty of ultrasonic check. Yet testing from the top surface of calandria side tube plate was developed and carried out in addition to the check over the machined surface of the welds. A full but controlled penetration joint had to be ensured and a combination process of root TIG plus SAW in horizontal position was adopted. These kind of weld joints have added significantly to the welding expertise and understanding in India.

This joint has also found its way into the welding treatise authored by Shri S.V.Nadkarni, where further details can be found. Use was made of preplaced insert of different chemical composition to ensure adequate ferrite content in the solidifying root run as well as to help in giving reproduceable and consistent penetration pattern more easily.

Now we will discuss another critical tube to tubesheet weld in a nuclear heat exchanger which presented very peculiar and almost unsurmountable problems.

1) No roughness, weld craters, cracks, porosity, slag inclusion or fuse through beyond acceptable level.
2) Air leak test at each pass.
3) PT for second pass.
4) Helium Leak test after second pass
5) Average MLP should be 1.25 mm and individual leak path 1mm.
6) No porsity larger than 0,254 mm is acceptable.

Many difficulties came together in this weld joint for practical execution.

- The tubes were small diameter ID 10.00 mm and thickness was also quite small 1.00 mm. materials used : ss type 316L.
- The tubes were projecting outside the tubesheet surface not little, but 6 mm.
- The weld had to be a fillet weld built up in two runs minimum with one run using filler wire, the fillet leg was 3 mm although normal throat of 1 mm could be ensured by even 1.5 mm leg fillet.
- The specification laid down a further condition that not only the tube wall should remain intact but no fusion or burnthrough should appear on the inside wall of the tube. This necessitated a highly controllable procedure in which the fusion with tube wall will be positive but the fusion surface must lay within a narrow tube was band of say o.4 to 0.8 mm only.

The last one was really a big hurdle in producing acceptable and repeatable weld joints with conventional automatic tube to tubesheet welding tig torches.

Ultimately a changed design of the welding torch and supporting system was able to deliver the goods with considerable delays in fulfilling the contract. Meanwhile a reputed foreign make machine had to be rejected since it could not deliver the results even though promised. There was further complication in the technical specifications wherein statistical quality control has to be exercised . This was another grey area where the learning graph of all concerned had to be accommodated. When the job was completed which comprised more than 12000 joints of this kind almost everyone closely or remotely concerned with this welding heaved a sign of relief. All said and done a few questions came up in my mind.

- Whether such highly complicated weld designs can be postponed till our welding & NDT expertise reaches the required level ? As an alternative the technology could be directly transferred from foreign and learnt by Indians for implementation.
- If a similar design has been already implemented at one fabrication workshop in India why the know-how and do-how cannot be transferred to other workshops where the job is loaded? I think these two questions will give rise to many more sub-questions and we can be totally lost in trying to find an answer.In the meanwhile let me say that we will keep on progressing in our own Indian way.

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2) Technical Specifications of Tube to Tubesheet welds
3) Modern Welding Technology - S.V.Nadkarni

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