TUBE TO TUBESHEET WELDING OF TITANIUM FOR UREA STRIPPER

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INTRODUCTION

Urea stipper is one of the most important and critical equipment in urea plant. Tube to tubesheet welding is the single most critical activity in stripper fabrication. The joint involves welding of titanium and has a very difficult to weld configuration. Criticality in the selection of the material, welding of tube to tubesheet for procedures and implementation of the process on the job are explained in detail in this paper.

Urea Process

Urea is a nitrogenous fertilizer manufactured from ammonia and carbon dioxide. The reaction takes place in a reactor at high pressure (150-220 bar) and temperature (150-200°C). The solution leaving the reactor contains urea, ammonium carbamate, unreacted ammonla and carbon dioxide. The urea is seperated from other compounds either by stripping process or by total recycling process, In the Snamprogetti process, the reactor effluent is stripped with stripping agent ammonia in a stripper which is a falling film type of decomposer, the shell side of which is heated with steam. The decomposed vapour containing ammonia, carbon dioxide and water vapour is condensed in the carbamate condenser operating at the reactor pressure. The condensed product is recycled to the reactor. The urea solution passes unaffected through the stripper before being purified and concentrated. Severe service condition are encountered in stripper due to highly corrosive ammonium carbamate and high temperature. Hence, for successful production of urea operation of stripper becomes more critical.

Material Selection : Formely, standard 316L type stainless steel was used in the critical components of urea plants. However, in the modern processes, which have been optimized with regard to economy by increasing the temperature and pressure, the standard 316 L is severely attacked by the process solution. A range of other materials are available nowadays like 316L (modified), duplex stainless steels, titanium and zirconium. Although the price of titanium is much higher than that of austenitic stainless steel due to its high corrosion resistance properties, it is preferred to stainless steel grade in order to avoid premature unexpected shutdown resulting in loss of production and maintenance cost. The corrosion rates in urea/carbamate for various materials are given in Table 1.

Weldability of Titanium

Titanium is easily weldable like austenitic stainless steels. The primary differences between welding of austenitic stainless steel and titanium are that titanium must be completely shielded with inert gas at temperatures above 400°C and that cleanliness is more critical Titanium reacts with air to form oxides and at elevated temperatures it will readily oxidize and discolour. The colour of the welds can be used as an indication of the effectiveness of the shielding and resulting weld quality. Good shielding and cleaning will produce bright silvery welds, while straw, blue, gray and white indicate increasing amounts of weld contamination.

GTAW is the most widely used welding process for titanium. GTAW is well suited for titanium because it offers the greatest degree of control of the arc and heat input along with superior inert gas shielding.

Tube to tubesheet welding : Tube to tubesheet welding is the most critical activity in urea stripper fabrication. As strength weld is required between tube to tubesheet, a groove + fillet joint is chosen and it is shown in Figure 1 and Figure 2, 1892 tubes of ASME SB 338 Gr.3 with dimensions of 27.0 mm O.D.X3.5 mm (minimum) thick is fixed to the tubesheet material ASME SA 350 LF2 + ASME SB 265 Gr.1. Dimension of tubesheet is 2070 mm dia X 295 (285 + 10)mm thick. The tubes are placed at a triangular pitch of 35 mm and ligament is 8.0 mm approximately. The final projection of tubes required is 17.0 mm for fixing of ferrules. The problems associated with the welding tube to tubesheet are access and providing effective shielding. Necessity of wire feeding to obtain required fille' complicates the matter further. Tube to tube sheet welding requires effective shielding for weld, heat affected zone, inner diameter of tube and project portion of the tube.

Requirements for Tube to Tubesheet welding : The following requirements are to be met in tube to tubesheet welding as stipulated by Snamprogetti

- Penetrant examination should be cleared after each pass of welding.
- No welding defects should be seen in macro - examination at 10X.
- MLP should be greater than or equal to the tube wall thickness.
- Hardness difference between the weld and HAZ and the weld and base metal should be within the range of 70 VHN.
- The weld appearance should be bright silver in colour.

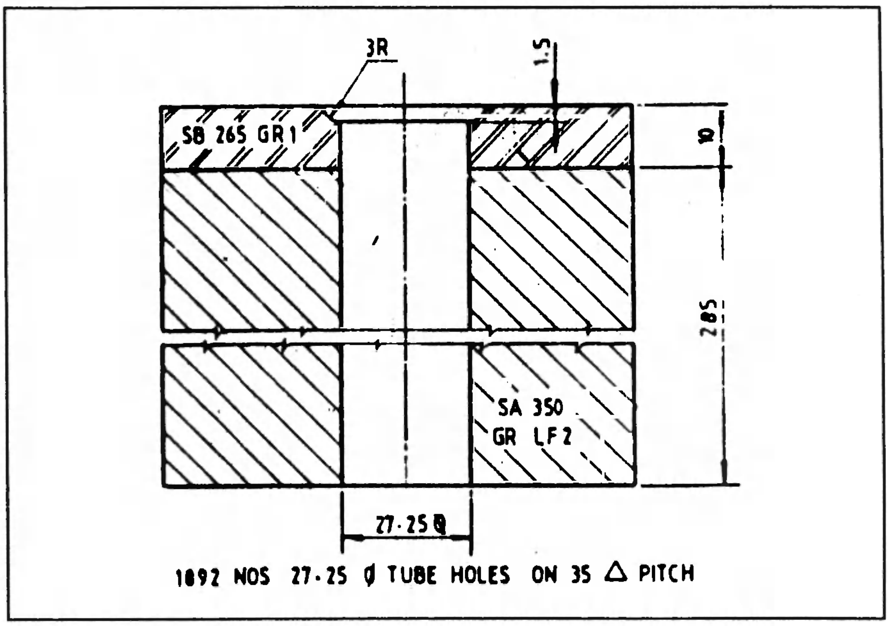

Fig 1 : Weld edge preperation on tube sheet

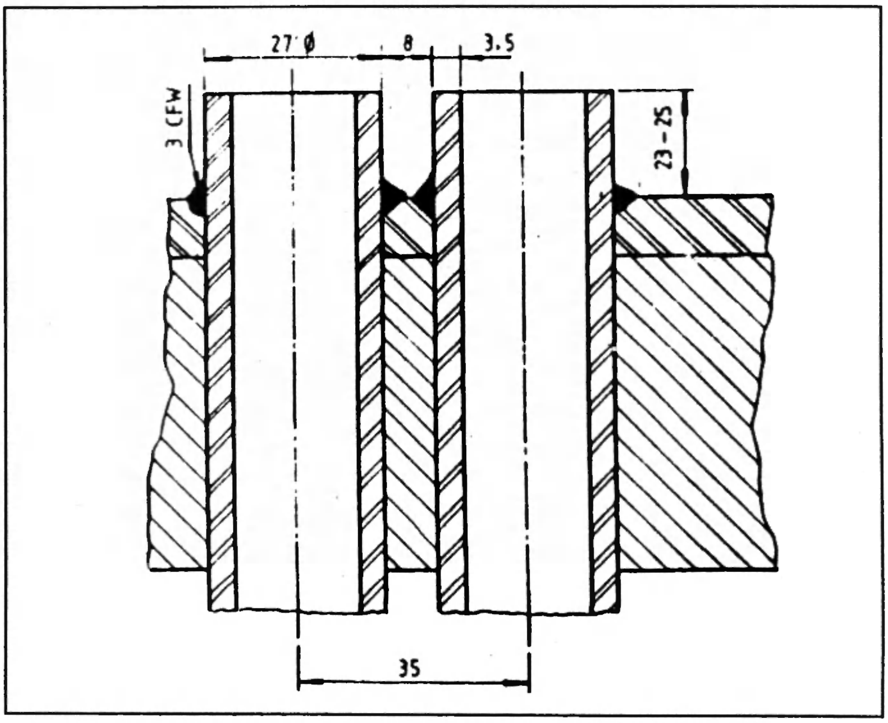

Fig 2 :Section showing welded joints tube projection & ligment

Planning of the trials

Welding trials were planned with manual and automatic GTAW process with tubesheet in horizontal position. The weld configuration and criticality of shielding made automatic GTAW an ideal choice. However, initially manual GTAW trials were planned.

Manual GTAW : Welding trials were conducted in dust free enclosure. The power source used was a thyristorized one with provision for up slope/down slope for welding current. Titanim being prone to oxidation particular care was taken for improved shielding. In addition to normal shielding from the ceramic shield, an auxiliary shield developed in-house was used. A backing shield which was placed inside the tube was used to protect the tube inner diameter. The welding system is shown in Figure 3. Due to excessive projection and less ligament, welding has become very difficult initially. Arcing used to take place on the tube walls surrounding the tube being welded. It can be seen from Figure 3 that if the angle between tungsten and tube increases above 17, then arcing takes place on surrounding tubes. Hence control of tungsten movement is very critical. This required extensive practice to welders. Necessity to obtain the required size of fillet complicated matter further. The welding was completed in three passes with 1.6 mm dia ER Ti-1 filler wire for achieving 3.5 mm throat length. The parameters are given in Table 2.

As some bow was observed on tubesheets received for the job, further trials were conducted with tube projection of 23 mm. At the same time welding trials were planned with tubesheet in vertical position to increase productivity on the job. Change of position and increased projection in the tube made the welding much more difficult compared to earlier case in terms of shielding and control of weld pool. Feasibility of the welding in two passes instead of three passes was checked and confirmed. First pass was welded with 1.6 mm dia ER Ti-1 filler wire and second pass was welded with 2.4 mm dia filler wire. The parameters are given in Table 2.

Commercial grade argon gas was tried out for auxiliary shelding and tube inner diameter purging and positive results were achieved. However, since the cylinders are not certified for purity, they were tested before use.

Automatic GTAW : Trails were conducted for tube to tubesheet welding. The details of welding are given below.

Equipment details : The power source, which is controlled by a microprocessor based system, has a facility for programming and storage for all the welding parameters. The power source is designed for a maximum output of 250 amps and can be used in linear or pulsed current modes with a duty cycle of 60%. The welding head consists of a rotating central housing which includes the rotary seals for the distribution of cooling water, shielding gas, welding current, the gear motor for rotation and cable connections to the control system. The motor fitted with an encoder

Table 1 : Corrosion Resistance of Materials to UREA / Carbamate solution

Material	Corrosion Rate(mpy)
316 L	--
316 L(mod)	6.9
25/22/2 L Mn	3.2
Pure Titanium	2.6
Pure Zirconium	0.1

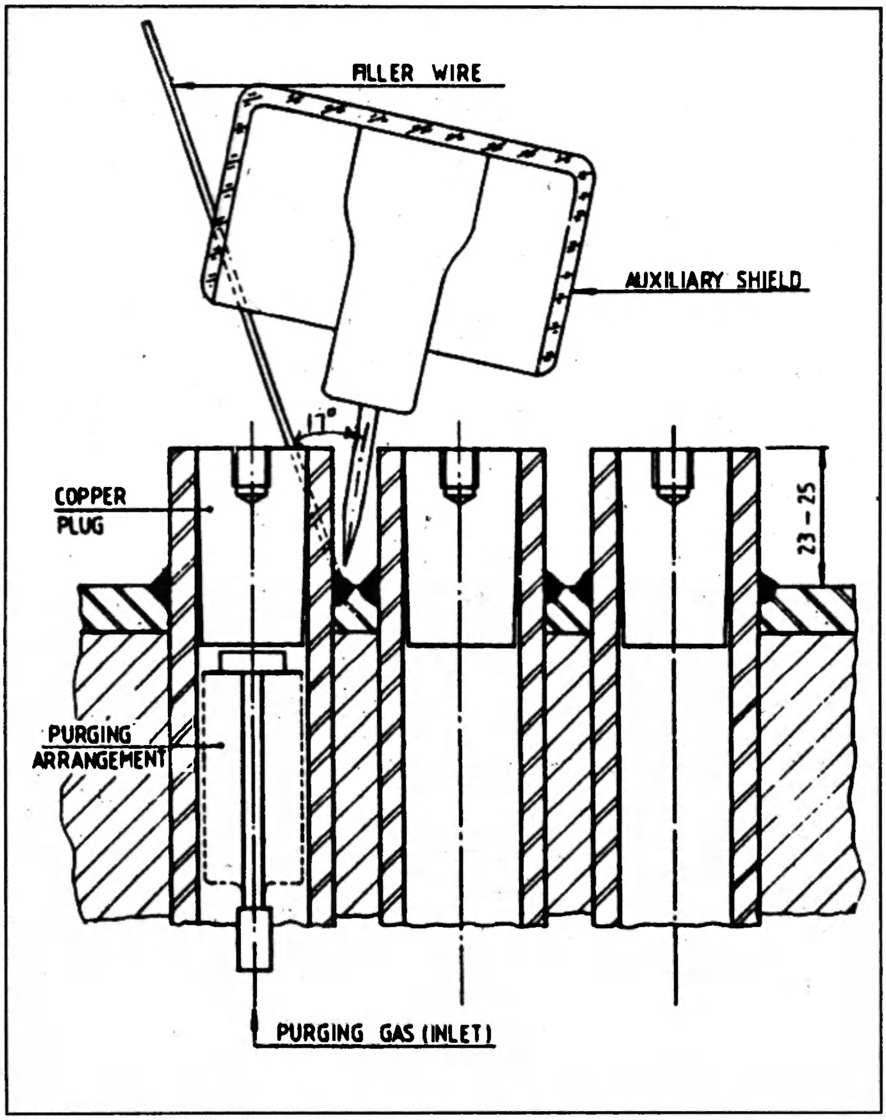

Fig 3 :Schematic sketch showing shielding arrangement regulates the speed and controls the welding sequence as a function of actual torch position through the power source. The motor drive assembly guides the tool and supports all other components. The head has provision for wire feeder assembly. The welding is carried out by inserting the sensor of the head into the tube. The sensor guides the welding head along the weld joint. The sensor has the provision for gas purging the tube. A specially disigned chamber support is placed on the tubes and a chamber is positioned for auxillary shielding. The welding head is mounted on the X-Y slide which is fixed on a fixture assembly. The welding system is shown in Fig 4.

Welding trials : Welding trials were conducted with 0.8 mm dia ER Ti-1 filler wire. The welding parameters are given in Table 3. The welding cycle is divided into four sectors for two passes. For first pass of welding this is not required due to high rotation speed, whereas for second pass rotation speed is kept low to achieve required fillet size. Due to excessive heat buildup, tube and some times weld, used to become blue. Starting position of the weld is very inportant to achieve a smooth weld. After extensive trials starting position of the weld is fixed at 11.30 position and rotation is in clockwise direction. Overlap of weld is approximately 45.

Criticality in the location of tungsten electrode and wire : It was observed that the location of tungsten electrode and wire are very important in achieving a proper weld profile and fillet. If the tungsten is close to tube and near the tube sheet (-1mm) then there is every possibility of short circuting of the arc and tungsten contamination of the weld. If the tungsten electrode is away from tube sheet and towards the tube side, weld metal deposition would be on tube only. If tungsten electrode is away from tube (-3mm) then weld metal would fall down from 1 to 5 O'Clock position. Hence an optimum position of 1,5 mm to 2 mm between tungsten electrode and tube is fixed. The m/c. has provision for AVC or programmed height control. Generally for projected tube end joints programmed height is preferred and hence for welding trials it was used. In this mode the tungsten will retract to a preset height after touching the tubesheet face after sequence is initiated and no corrective action will be taken.

Table 2 : Manual GTAW Parameters for Titanium tube to tubesheet

Parameter	Tubesheet horizonaltal	Tubesheet vertical
Current (A)	135 - 145	135 - 160
Voltage (V)	15 - 22	14 - 22
Filler dia.(mm)	1.6	1.6 & 2.4
Polarity	DCEN	DCEN
Tungstan dia.(mm)	3.2	3.2
Gas :		
Shielding	Argon	Argon
Auxilary	Argon	Argon
I.D.Purge	Argon	Argon
No. of passes	3	2

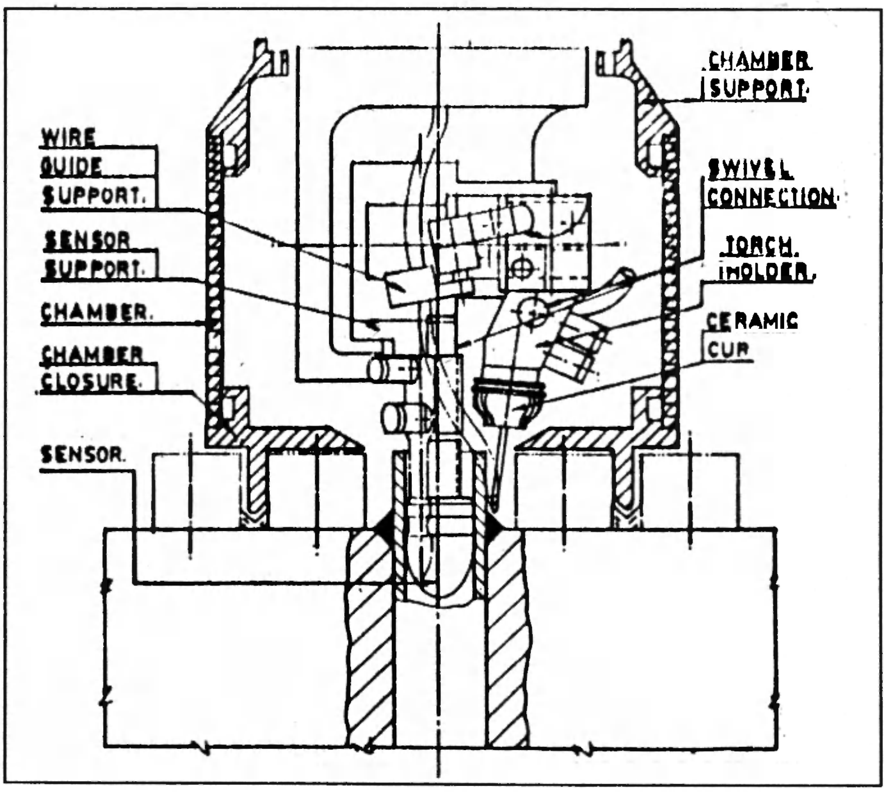

Fig 4 : Automatic Welding System

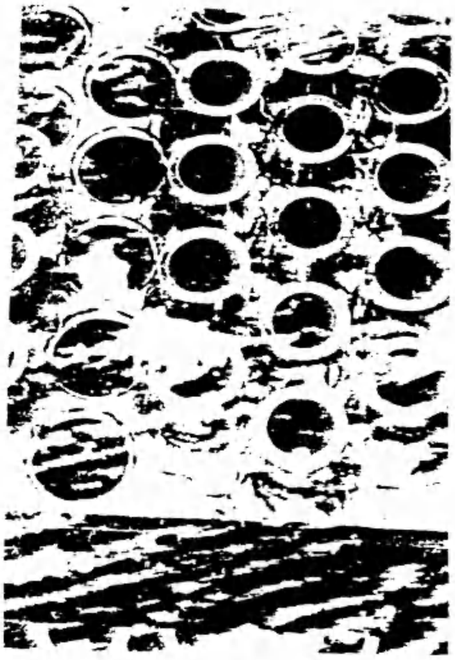

Fig 5 Photograph of a Tube to Tubesheet welded block & sectioned view

Fig 6 : Macro-photograph of Titanium tube to tubesheet weldment

Fig 7 : Manual GTAW of Titanium Tube to Tubeheet on the job

Fixture Development : During trials it was observed that the visibility of the arc is not proper with the chamber closure supplied by equipment manufacturer adjustments of parameters (or stopping the weld if any abnormalities occur during welding) was not possible. Hence a new chamber was designed and made with stainless steel strip. Quality of welds was found to be excellent with this new fixture. The equipment manufacturer had supplied and acrylic closure for auxillary shielding of the weld. It was noticed that whenever tungsten shorting occurred either in the weld or with the tube tungsten rod removal became very difficult due to the closed chamber. A glass chamber made into two halves was tried out and found to be very useful.

Procedure Qualification

Manual GTAW procedure : Based on parameters as given in Table 2, tube to tubesheet welding procedures were qualified with tubesheet in horizontal and in vertical position respectively. All the requirements were met satisfactorily. The hardness values are given in Table 4. Photograph of a tube to tubesheet welded block and a sectioned view is shown in Figure 5.

Automatic GTAW procedure : A procedure was qualified based on the parameters given in Table 3. Hardness values are given in Table 4. Macro photograph of the weld at 5X is shown in Figure 6.

Training of welders : Number of welders were trained and quali-

Table 3 : Automatic GTAW Parameters for titanium tube to tubesheet (tubesheet in vertical position)

Parameter	I pass	II Pass
Peak current (A)	135 - 125	135 - 125
Back ground current (A)	60	60
Peak time (ms)	250	250
Back ground time (ms)	100	100
Wire feed rate (mm/s)	15 - 18	21 - 25
Wire dia (mm)	0.8	0.8
Rotarian speed (mm/s)	1.1 - 1.3	0.9 - 1.0
Voltage (V)	8-12	8-12
Gas :		
Shielding	Argon	Argon
Auxillary	Argon	Argon
I.D.Purge	Argon	Argon
Tungsten dia (mm)	2.0	2.0
Tungsten type	EW Th-2	EW Th-2

fied to weld titanium tube to tubesheet by manual GTAW process. Three welding operators were trained and qualified for automatic GTAW.

Implementation on the job

Dentist tools (grinders/Drills) and indigenously made tools were procured in anticipation of some repairs on the job like tungsten contamination of the weld etc. Observations made during implementation of manual as well as automatic GTAW process are given below. Photographs of manual and automatic GTAW of titanium tube to tubesheet on the job are shown in Figure 7 and Figure 8 respectively.

Manual GTAW : Except for minor discolouration of some of the welds no major problems were faced during manual GTAW process. The discolouration was removed by stainless steel wire brushes specially procured for the job. Wherever tungsten contanination was there (mostly on tube ends), it was removed by grinding.

Automatic GTAW : No major problems were faced during automatic GTAW except for tungsten contamination of some of the welds due to mismatch in tube projection. These were removed by griding and further welding was done. As welders were new to automatic system, production was on lower side. Automatic GTAW was implemented on the job to gain some experience for future jobs. However, the advantages of uniform bead profiles, relative absence of stray arcing were apparent. The overall appearance of welded joints were excellent.

Table 4 : Average hardness values in VPN (*Load 10 Kg.*) Titanium Tube to Tubesheet Welds

	Manual GTAW	Automatic GTAW
Weld	177	146
Tubesheet	143	109
Tube	211	234
Tubesheet (HAZ)	168	130
Tube (HAZ)	225	219

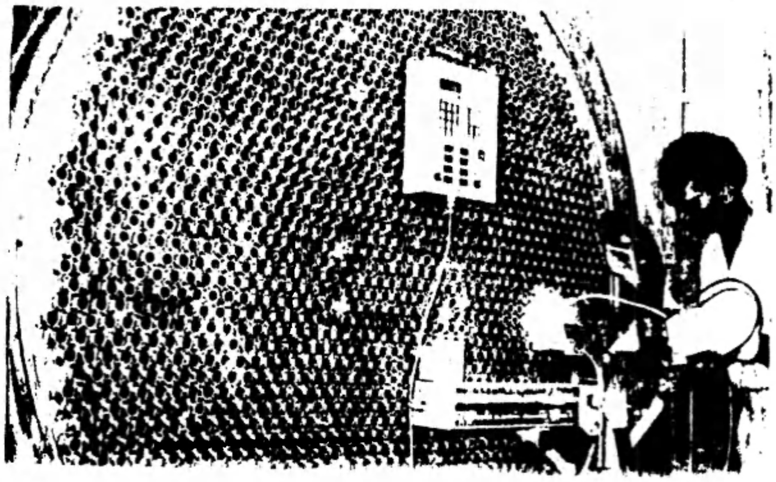

Fig 8 : Automatic GTAW of Titanium Tubesheet on the job

Tests and Results on the Job : Visual examination was done after completion of the welding. Dye penetrant examination was carried out on the job and found satisfactory. After penetrant examination, pneumatic test at 0.5 Kg/cm2 followed by helium leak test at same pressure was carried out and found satisfactory.

CONCLUSION

1. Manual GTAW procedures were developed for Ti tube to tube to tubesheet welding with tubesheet in horizonal and in vertical position.
2. Automatic GTAW procedure was developed with tubesheet in vertical position.
3. Both the welding techniques were implemented on the job with total success.
4. Chamber for auxilary shielding, sensing finger were developed in house and fixtures were modified.