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Faults Diagnosis and Their Remedies in the Manufacturing of Heat Exchangers: A Case Study

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Abstract (10pt)

We devoted our attention towards improved engineering techniques in the field of manufacturing and inspection of shell and tube type heat exchangers after collecting design data from B.P.C.L. (Bharat Pumps and Compressors Ltd), Naini, Allahabad (U.P.), India. In this paper remedial steps /procedures/improved techniques have been proposed for all the manufacturing /assembly/heat treatment operations. The main objective of this paper is to prepare a useful guide to the manufacturers and quality control people.

Keywords:

Heat exchanger; Tube bundle assembly, baffle plate.
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1. Introduction

The author visited BPCL industry at Allahabad and tried to know the faults / operations taking more time in the manufacturing of the shell and tube type heat exchangers. The author suggested the diagnosis of the time taking/ poor operations with the help of the reference [1-10].The major problems faced by manufacturers were found in the following operations.(i) Drilling of tube sheets,(ii) Drilling of baffle plates, (iii) Tube bundle assembly, (iv) Tube expansion,(v) Tube to tube sheet joints,(vi) Exchanger shell assembly, (vii) Exchanger assembly, (viii) Heat treatment (ix) Testing,(x) Shipment,(xi) Removal and plugging of holes during servicing. Etc.

2. Suggested Diagnosis and Remedial Steps

The remedial steps are prepared with the help of several references including [1-11] and several meetings with engineers, foreman, supervisor and skilled worker of the plants. I feel that they people know the problems and to a large extent solution also. But time factor is a crucial one for them. Everyone is busy to achieve one's target. The suggested remedial steps for various operations are as follows.
2.1 Drilling of Tube-Sheet
(i) A thin aluminum sheet template Printed with the required tube layout with hole centers accurately marked should be used. (ii)Punch marks should be marked with red pen to avoid drilling of unwanted holes. (iii) Similarly the tie rod holes should be marked with paint to indicate the operator that these types of holes and eye bolt holes are not to be drilled through full thickness of the tube sheet. (iv) Table-1 and Table-2 would serve as a guide line for manufacturer.

Table-1: Speeds and feeds for drilling

HOLE SIZE mm	PIOLET DRILLING			PREDRILLING			FINAL DRILLING		
	DIA mm	R.P.M mm/rev	FEED mm/rev	DIA mm	R.P.M mm/rev	FEED mm/rev	DIA. mm	R.P.M mm/rev	FEED mm/rev
10.15	6.0	450/600	0.12	8.0	300/400	0.3	9.75	350/450	0.5
16.20	6.0	450/600	0.12	14.0	300/400	0.3	15.75	350/450	0.5
20.20	6.0	450/600	0.12	18.0	250/350	0.3	19.75	300/350	0.5
25.25	6.6.	450/600	0.12	23.0	200/300	0.3	24.75	250/300	0.5
38.35	6.0	450/600	0.12	25.0	200/300	0.3	37.50	80/600	0.5

Table-2: Speeds and feeds for reaming

HOLE SIZE mm	REAMER DIA mm	FAST HELIX REAMER		SOLID REAMER	
		RPM	FEED mm/rev	RPM	FEED mm/rev
10.15	10.15	200/300	0.2-0.30	80/100	0.2
16.20	16.20	200/300	0.2-0.30	80/100	0.2
20.20	20.20	200/300	0.2-0.30	60/80	0.2
25.25	25.25	200/300	0.2-0.30	60/80	0.2
38.25	38.25	80/100	0.2-0.30	40/60	0.2

2.2 Drilling of Baffle Plates

Assemble all the baffles in the same sequence as they would be fitted inside the exchanger. Baffle should be welded at its periphery at few places to act as a single unit. Punch serial number (S.No) on outside diameter of each and every baffle such as S. No. I, 3, 5 … for bunch 'A' and 2, 4, 6. … for bunch 'B' and arrange the baffles as they would be in actual exchanger. Pass the exchanger to through baffle holes. Mark the segment to be cut from full diameter baffle (except supported baffle) to get the desired shape of the segmental baffle as per drawing.

2.2.1 U- Tube Bundle Assembly

Follow U- tube assembly break down diagram as shown in Fig.1. Components required for tube bundle assembly are shown in Table-3.

2.3 Tube Expansion

It is suggested that the expansion of tubes should be done hydraulically in place of mechanically as it is the latest technique for expanding tube. In this technique, tube sheet employs hydraulic pressure instead of rollers. Sufficient hydraulic pressure is applied to improve tensile stresses in the tube wall about 115% of the yield stress and thus expand the tube firmly into the tube sheet. This technique has the advantage that it is applicable to any thickness of tube sheet, can be controlled accurately and tube thickness are accommodated. Pressure as high as 483 MPa are employed for thick walled tubes.

2.4 Tube to Tube Sheet Joints

The criteria for selection of joints are given in the Table-4 and Table-5. In the present study the material of shell and tube type heat exchanger is carbon steel. So rolling in plain holes and strength welded joints are recommended. There should be no grooved holes in the tube sheet because retubing in grooved holes is not possible as the holes invariably become oversized when leaking tubes are removed.

2.5 Exchanger Shell Assembly

Follow the suggested shell assembly break down diagrams shown in Fig.2, Fig.3. and Fig.4. Sub assembly and components required are shown in Table-6 and Table-7 respectively

Table-3: Components for Tube Bundle Assembly

Item no.	Description	Quantity
301	Tube sheet.	01
302	U-Tubes.	as per design
303	Baffle Plates.	as per design
304	Tie rods.	as per design
305	Spacers pipes.	as per design
306	Sliding rod	02
307	Eye bolts	02
308	Jack screw	06 or as required
309	Hex nut	as required
310	Lock nut	as required
311	Stopper plate	03
312	Plug for eye bolt hole	02

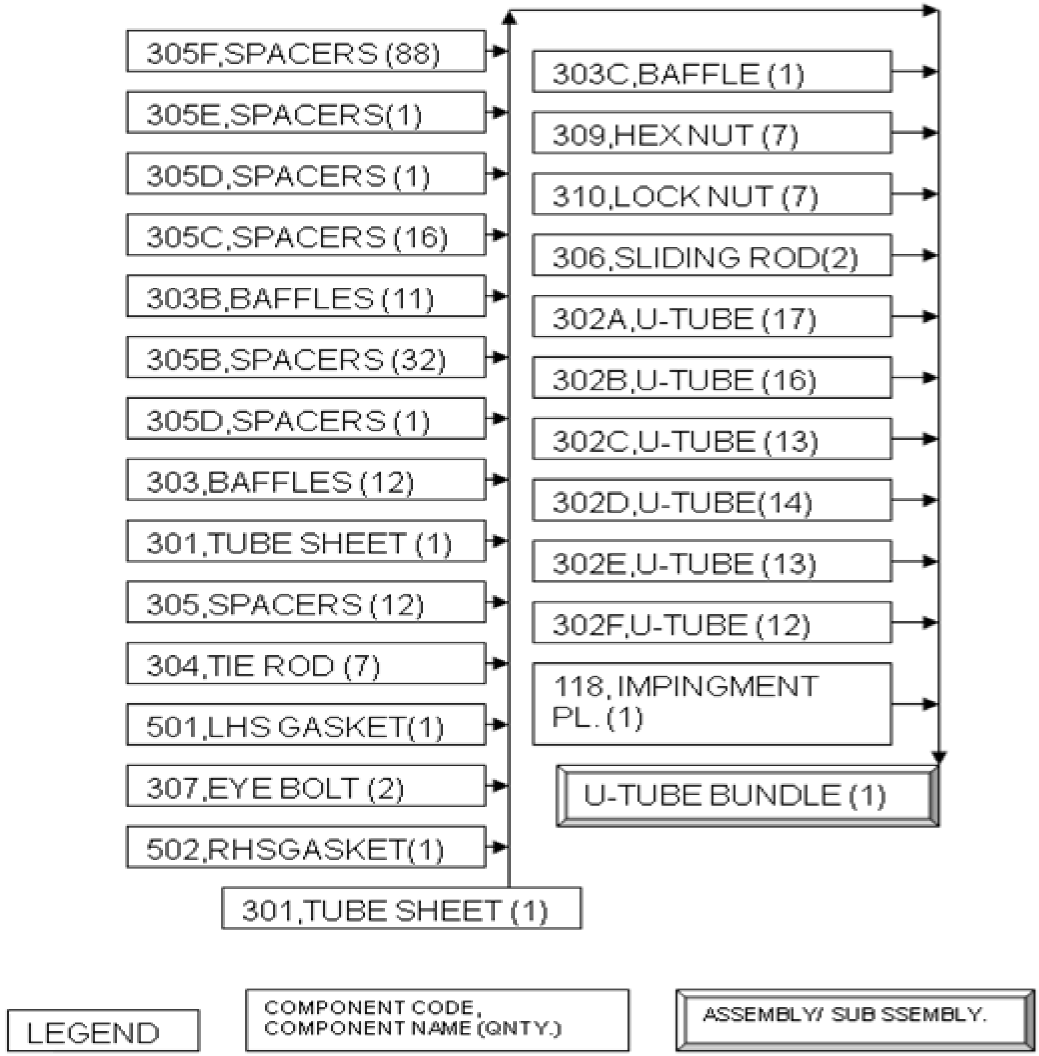

Fig.1: U-TUBE BUNDLE ASSEMBLY BREAK DOWN DIAGRAM

Table-4: Joints for Carbon steel and alloy steel

S. No	Pressure Kg/cm²	Temp^r °C	Fixing arrangement	Remarks
1	<=6	<=175 , <=350	Roll in plain holes seal welds Roll in grooved holes only	when Intermixing is dangerous
2	<6<= 40	<=350	Roll in grooved holes only.	Intermixing not dangerous
3	>6<=40	<=350	Roll in grooved holes & seal weld.	Intermixing angerous
4	<.40<=8 0	<=350	Roll in grooved holes& seal weld	-----
5	<=350	<=350	Roll in plain holes and strength weld	-------
6	All Prs.	<=350	Rolling plain holes& strength weld	------

Table-5: Joints for stainless steel

S. No	Pressur eKg/cm 2	Temper °C	Fixing arrangement	Remark
1	<=6	<=175 <=350	Roll in plain holes and seal welds Roll in grooved holes Seal weld	------ if intermixing dangerous
2	<=6 =80	<=350	Roll in grooved holes and seal weld	--------
3	>80	<=350	Roll in grooved holes and seal weld	-----
4	All Prs.	<=350	Roll in grooved holes and seal weld	------

Table-6: Components required for shell assembly

NOZZLE	DESCRIPTION	QNY
N1	SHELL INLET	01
N2	SHELL OUTLET	01
N3	CHANNEL INLET	01
N4	CHANNEL OUTLET	01
V1	VENT (SHELL)	01
V1	VENT(CHANNEL)	01
D	DRAIN (SHELL)	01
C1	PRESSURE.CON.	04
C2	THERMO.CON.	04

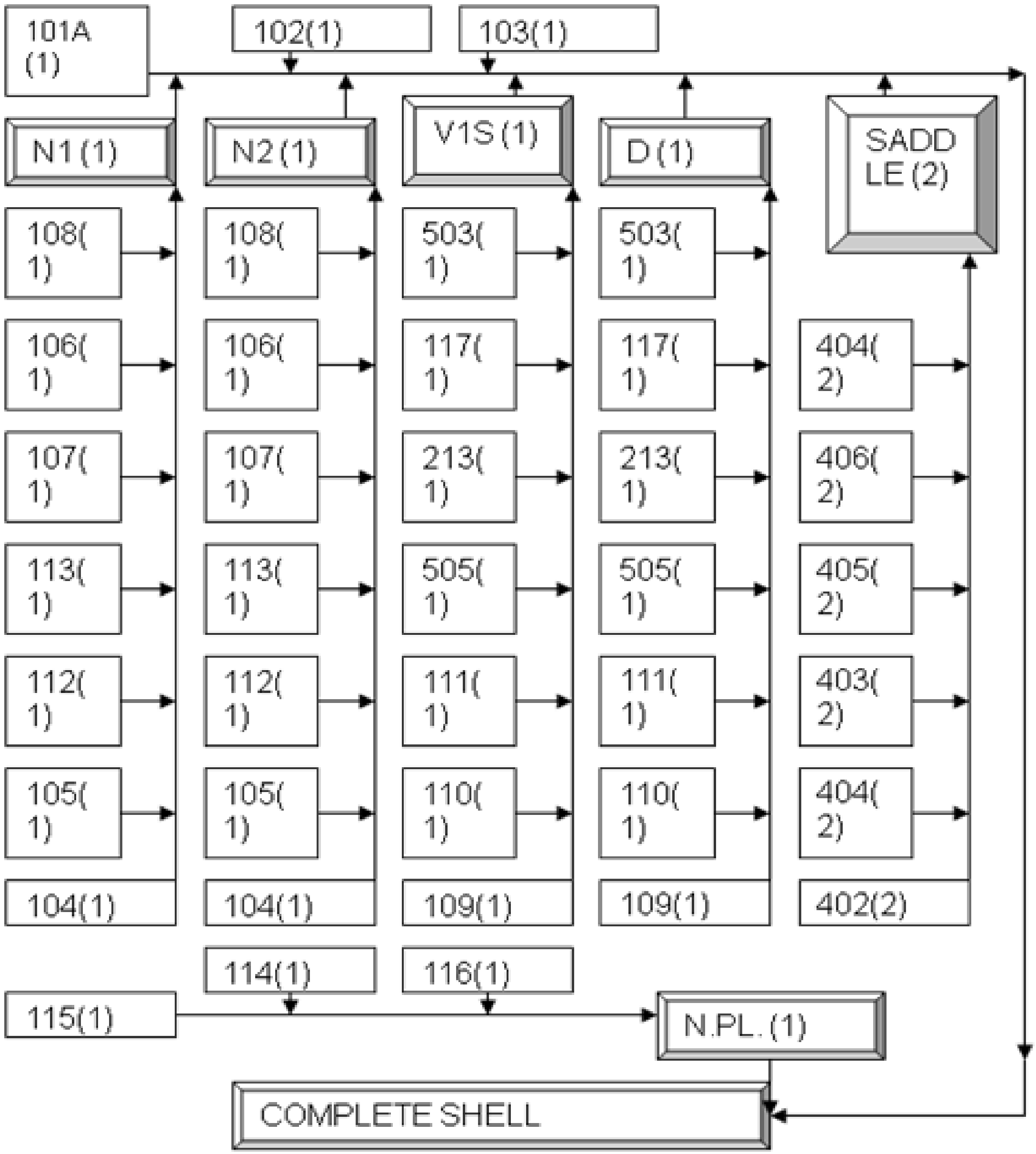

Fig.2: Exchanger Shell Assembly Breakdown Diagram

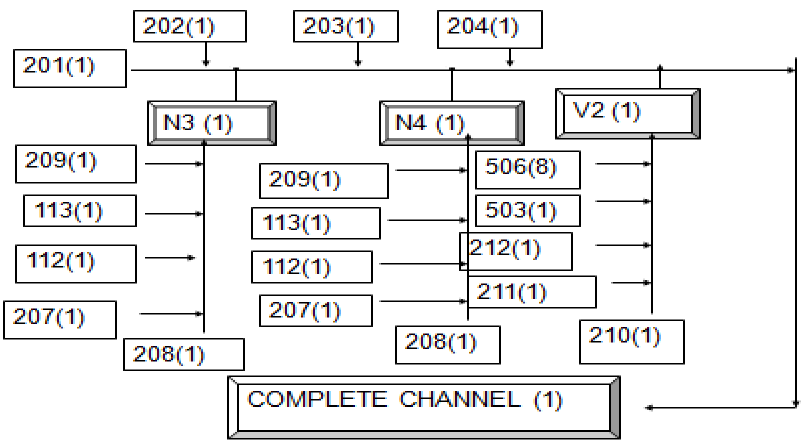

Fig.3: Channel Assembly Break down Diagram

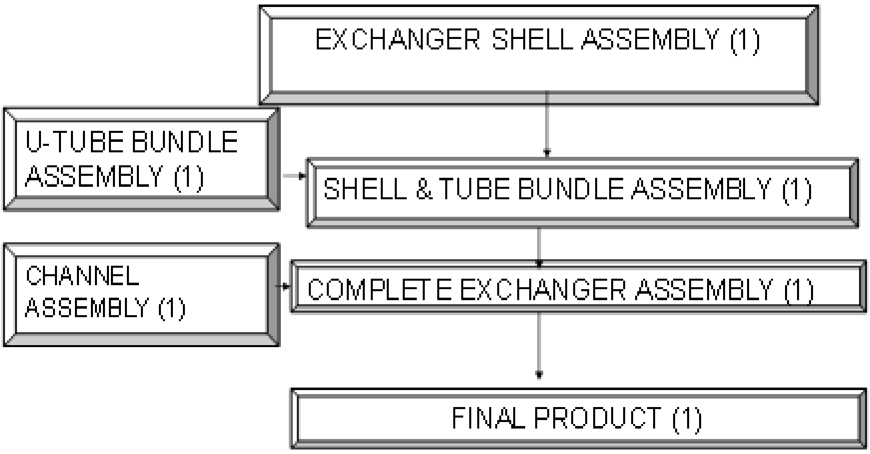

Fig.4: Exchanger Assembly Break down Diagram

2.6 Heat Treatment

Weld the tube with tube sheet. Stress relieves the exchanger by leaving the tubes free in the baffles and the tie rods. The circulation of nitrogen is recommended to protect the tubes and tube sheet holes from oxidation during heating. The valves besides air discharge and nitrogen, feed serve to regulate the pressure inside within acceptable values during heating and cooling. All air should be driven out from exchanger before heating the shell. The rate of heating and cooling should be maximum 50˚C/hour

2.7 Testing of Joints

Pneumatic test should be adopted after hydraulic test.

2.8 Removal of Defective Tubes

Relieve the tube to tube sheet weld with taper end mill. Mill the hole down to 5 mm from the tube sheet face. Drill the tube with spiral fluted end mill up to expanded length of the tube. Use lubricating oil freely. Knock out tube from the tube sheet. Expanded portion will automatically collapse. Now, tube sheet holes should be examined carefully of surface condition and cleanliness of grooves and necessary steps should be followed.

2.9 Shipment

Internal and external surface should be free from loose scale and other foreign materials. All external carbon steel surfaces should be painted with red lead primer. Water, oil or other liquids used for cleaning shall be drained before shipment. All exposed machined contact surfaces should be coated with a removable rust preventive and protect against mechanical damage by suitable covers. All threaded connections shall be suitably plugged. The exchanger and any spare parts should be suitably protected to prevent damage during shipment.

2.10 Plugging of Holes

In many cases, it is impossible to replace tubes after failure has occurred, when leakage between a tube wall and tube sheet has developed to such an extent that the tube sheet material has been badly eroded than the tube hole must be permanently plugged by welding.

2.11 Plugging the Tube Holes by Removing the Tubes

(i) Remove tube as described earlier. (ii)Machine the plug. Material of the plug should be same as that of the tube sheet. (iii)Clean the holes free from all dirt and pitting and push fit the plug with light hammering. (iv)Complete the welding of the plugs to tube sheets,

2.12 Plugging the Hole with Tubes in Position

Mill cut the tubes to tube sheet welding using taper end mill. Push fit the plugs after cleaning I.D. of the tubes of all dirt etc. Complete welding of the plugs to the tube sheet. After completing welds, apply hydraulic test on shell side using full permissible test pressure. Keep test on shell side using full permissible test pressure. Keep test pressure for few hours to check the soundness of welds.

3. Results and Discussion

The data regarding faults were collected for a period of 8 months from the rejection and rectification register, the components returned back by the customers for repair and maintenance purpose and on the basis of customer’s complaints. The special causes of the faults have been observed. It is sometimes difficult to determine the source of the special cause variability, but elimination of these problems is necessary to obtain a stable manufacturing process. The speeds and feeds for drilling and reaming suggested from the references are shown in Table-1 and Table-2. The components for tube bundle assembly are shown in Table-3. Table-6 and Table-7 show the sub-assembly and components of a shell respectively. The proposed assembly break down diagrams is presented by Fig.1, Fig2, Fig3 and Fig.4 respectively. The guide lines for selection of joints are shown in Table-4 and Table-5 respectively.

Table -7: COMPONENTS SHELL ASSEMBLY

ITEM NO	DESCRIPTION	QTY
101A	PLATE FOR SHELL	03
102	PLATE FOR SHELL'D' END	01
103	GIRTH FLANGE FOR SHELL	01
104	W.N.FLANGE FOR N1&N2	02
105	NOZZLE FOR N1&N2	02
106	NOZZLE FOR N1&N2	02
107	BEND FOR N1&N2	02
108	R.F.PADFOR N1&N2	02
109	NOZZLE FOR N1&D	02
110	W.N.FLANGE FOR V1&D	02
111	BLID FLANGE FOR V1&D	02
112	COUPLING FOR C1&C2	04
113	PLUG FOR C1&C2	04
114	NAME PLATE BRACKET	01
115	NAME PLATE	01
116	SCREWS	04
117	STIFFNERS	01
118	IMPINGMENT PLATE	01
201	PLATE FOR CHANNEL	01
202	PL.FOR CHANNEL 'D'END	01
203	GIRTH FLANGE CHANNEL	01
204	PASS PARTITION PLATE	01
207	NOZZLE FOR N37N4	02
208	W.N.FLANGE FOR N3&N4	02
209	R.F.PAD FOR N3&N4	02
210	NOZZLE FOR V2	01
211	W.N.FLANGE FOR V2	01
212	BLIND FLANGE FOR V2	01
213	STIFFNERS	02
401	WRAPER PLATE	02
402	BASE PLATE	02
403	STIFFNER FOR SADDLE	02
404	ROB FOR SADDLE	04
405	RIB FOR SADDLE	02
101B	PLATE FOR SHELL	05
501	L.H.SIDE GASKET	05
502	R.H.SIDE GASKET	05
503	GASKET FOR V1,V2&D	15
504	STUD & 2 NUT FOR G.FLG.	32
505	STUD & 2 NUT FOR V1&D	12
506	STUD WITH 2 NUT FOR V2	08

4. Conclusions

From the above case study, it can be clearly noted that there is a tremendous difference between the traditional methods and implementation of the proposed improved techniques. By applying the proposed techniques in the manufacturing of the shell and tube type heat exchanger, the 20 % overall improvement may be there. This study may be used as a guide by the manufacturers as well as quality control personnel of heat exchangers.

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