

## LITERATURE ON BOILER TUBE FIT UP BY EXPANDING

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### INTRODUCTION

Boiler tubes are assembled by welding or by expanding. Expanding is mainly adopted in Boiler bank assembly. Expanding is resorted to, as it is the simplest way to fit the tubes in boiler bank. In this subject of tube expanding one may not find good literature regarding the % thinning to be adopted and the sequence to be adopted. Many have doubts whether a leaky joint can be seal welded or not. This article is brought out to clear the doubts of boiler users.

### A TUBE EXPANDER

A tube expander can be a roller type, which is widely used in Industry even today. It has a taper mandrel, when driven in, pushes out the three rolls. The tube is made to fill the gap between the tube and the tube hole. After the tube touches the tube hole, tube is further thinned to ensure a leak tight joint is established.

### LITERATURE ON TUBE EXPANDING

Tube expanding is in vogue for many years. Yet code regulations do not spell out enough on this subject. It has become necessary to reproduce the paragraphs of code regulations on this subject, for reader's interest. Further literature by some manufacturers is added here.

➤ *SOURCE: Steam / Its generation and use / Babcock & Wilcox: Pages 32.6 to 32.7*

### TUBE CONNECTIONS

Tubes may be attached to drums or headers by welding, expanding or a combination of both.

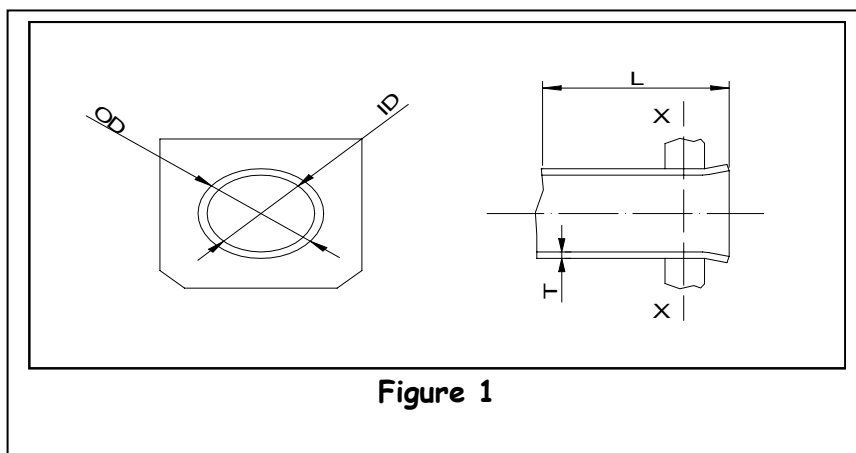


Figure 1

Welded connections may be made by joining the tube directly to the header, as in the case of membrane wall panels or by welding the tube to a stub (short length of tube) that is attached to the drum or header in the shop. This type of construction is used for the majority of connections.

In some applications, however tube expanding is a practical method of tube connections. Tube expanding or tube rolling is a process of cold working the end of the tube into contact with the metal of the drum or header containing the tube holes or seats. When a tube is expanded, the outside diameter, inside diameter and length increase and wall thickness decreases (*see figure 1*). The increase in length, called extrusion, occurs in both directions from some section X-X. The residual radial pressure between the tube and tube seat resulting from a properly expanded tube will provide a pressure tight joint of great strength and stability as shown in *figures 2 & 3*.

A typical roller expander contains rolls set a slight angle to the body of the expander causing the tapered mandrel to feed inward when it is rotated in a clockwise direction. As the mandrel feeds inward the rolls develop the internal force, which expands the tube.

The expanded joint presents a simple and economical way of fastening tubes into low-pressure boilers. Under axial loading, the expanded joint is as strong as the tube itself. However for conditions of widely fluctuating temperatures and bending loads, the expanded joint must be seal welded (*see figure 4*) or replaced by a shop attached tube stub. Generally, tubes above 1500-psi (105 kg/cm<sup>2</sup>g) range are either expanded and seal welded or attached to shop welded stubs. Selection of the type of tube end connection to be used is dictated by design, assembly, and operating characteristics.

### **SEAL WELDS**

Seal welds are used to make mechanical joints fluid tight. The strength of the connection is developed by the expanded joint, pipe threads or by the configuration as in the case of hand hole fittings. The throat dimension of seal weld is limited to 9.5 mm. Maximum, and post weld heat treatment is not required.

➤ *SOURCE: INDIAN BOILER REGULATIONS: Regulation no 152*

152: Attachment of Steel tubes

- a. Tubes shall be connected to the tube plates by one of the following methods. (1) Expanding (2) strength welding (3) Mechanical bolted bail joint.
- b. Drift or roller expanded tubes shall project through the neck or bearing part in the holes by at least a quarter of an inch and shall be secured from drawing out by being bell mouthed to an extent of 1/32 inch for each inch in diameter plus 2/32 inch.
- c. Tubes may be seal welded into fittings or headers for both boilers and super heaters after they have been expanded and flared provided the material into fitting or header does not contain carbon in excess of 0.35 %.
- d. In the case of drifted or roller expanded tubes, the tube holes in the tubes plates of drums, pockets or headers shall be formed in such a way that the tubes can be effectively tightened in them. Where tubes are normal to the plate, there shall be a neck or belt of parallel seating of at least ½ inch depth measure in plane parallel to the axis of the tube at the holes.

➤ *SOURCE: BS 1113: 1999 Design and manufacture of water tube steam generating plant*

A. Connections to main pressure part

- 1) Expanded connections

The hole in the main pressure part shall provide a belt of parallel seating of not less than 13mm. It is permitted to seal weld internally or externally. The forming of holes, internal projection shall conform to B.

**B. Tubes and integral pipes.**

1) Scope and restrictions

It is permissible to attach tubes and integral pipes to main pressure parts, other than welding, by propulsive expanding and belling or by expanding and seal welding. It is also permitted to use other methods of expanding, but in such cases it shall be demonstrated that the method provided adequate leak tightness and will prevent tube withdrawal in service, unless documented evidence of satisfactory performance in service is produced. The outside diameter of the tube of pipe connected by expanding shall not exceed 114.3 mm.

2) Expanding of tubes and pipes

Tube holes for expanded tubes shall be formed in such a way that the tubes can be effectively tightened in them. The surfaces finish shall be no coarser than 6.3 microns (see BS 1134). The surface shall exhibit no spiral or longitudinal score marks which could form a leak path. Where the tube ends are not normal to the tube plate, there shall be a neck or belt of parallel seating in the tube hole at right angle to the axis of the tube. The belt shall be at least 10 mm in depth measured in a plane containing the axis of the tube at the hole.

Where pipes or tubes are fitted by propulsive expanding, they shall be belled out from the edge of the tube hole at an angle to the tube axis to resist withdrawal. In no such case shall the projection of the tube though the parallel tube seat shall be less than 6 mm and the belling shall be not less than given in table A

<b>Table A belling dimensions for tubes propulsively expanded</b>	
Dimensions in mm	
Outside diameter of tube	Minimum increase in diameter of belling over tube hole diameter
Upto and including 51	3
Over 51 and upto and including 82.5	4
Over 82.5 upto and including 101.6	5

➤ *SOURCE: Boiler repair manual by US Navy*

**FITTING TUBES**

When fitting tubes into drums or headers, be sure each tube extends far enough in to the header or drum. Tubes up to (but not including) 2 inches in OD should project 3/16 inch to 5/16 inch (4.7 mm to 7.9 mm) in to the drum or header. Tubes of 2 inches OD and larger should project 5/16 inch to 7/16 inch (7.9 mm to 11.1 mm) in to the drum or header.

In tube joints where the tube and hole measurements can be obtained, the correct amount of expansion can be found by using the following formula

- For tubes in drums: diameter of the tube hole minus OD of the tube, plus 0.012 inch (0.3048 mm) per inch OD of tube.
- For tubes in headers for boiler design pressure less than 500 Psi (35 kg/cm<sup>2</sup>g): Diameter of tube hole minus OD of tube plus 0.015 inch (0.381mm) per inch OD of tube.
- For tubes in headers for boiler design pressure over 500 Psi (35 kg/cm<sup>2</sup>g): Diameter of tube hole minus OD of the tube, plus 0.02 (0.508mm) inch per inch OD of tube.

The figure arrived by the using above formula should be added to OD of the tube as measured to give the required OD of the tube after rolling.

If it is impossible to reach OD of the tubes in drums to gauge them, the inside diameter of the tube must be measured. Since plastic deformation of the tube wall varies with the tube wall thickness, the ID of the tube for different wall thickness will vary. Where the outside of the tube is not accessible the following formula is used to in the expansion of the tube.

The ID of the tube, plus the tube hole diameter minus the OD of the tube plus the expansion increase factor.

➤ *SOURCE: Tool selection guide by VERNON TOOL COMPANY CA*

Tube expanding (also referred to as tube rolling) is the cold working of the metal of the tube ends into contact with the tube sheet holes to achieve a pressure tight joint. A tube expander is used to increase the circumference of the tube ends until a proper joint is produced.

This can be related to the rolling of steel, since the steel sheet is made thinner and longer. The tube is an endless sheet and the tube expander enlarges the outside and inside diameter of the tube.

A completed tube joint must have the tube larger than the containing metal in the tube sheet hole. The expanded tube joint contains a force trying to make the tube smaller and a force trying to make the tube hole in the tube sheet larger. As the tube is expanded, the tube wall is thinned and the tube circumference is increased. The tightness at the tube joint will be measured by the increase of the inside diameter or the tube. The following variables determine the proper expansion of a tube.

- Clearance between the OD of the tube and tube sheet hole
- Original tube I.D.
- Amount of expansion after tube-to-tube sheet contact
- Pre-thinning of tube wall before tube-to-tube sheet contact

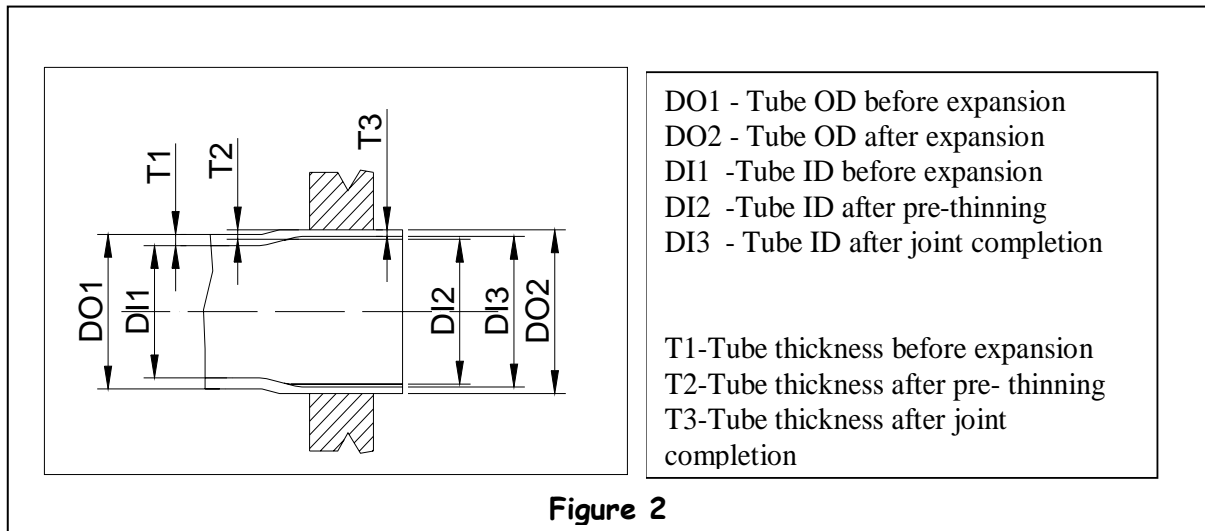
Each of these factors can be measured and determined before the rolling operation begins.

### ***IMPROVED TUBE EXPANDING***

The tube of a tube joint must be larger than the tube hole. The tube joint contains equal forces trying to make the tube larger and the tube hole smaller. These forces are always equal.

A “Best” tube joint is one in which the weaker member is stressed to give a maximum expanding or shrinking force. The equal and opposite force in the other member could be greater.

Expanding beyond the point that develops maximum force in the weaker member of the tube joint is over-rolling. Over-rolling thins the tube more than necessary making a weaker tube joint, and produces excessive stressing and growth of the tube sheet.



Excessive working of the tube also causes undesirable changes in its grain structure, creates excessive work hardening, and may even produce cracks in the tubes. Flaking of the tubes usually indicates over-rolling. Flakes are thin layers of the tube metal being sheared from the inner surface of the tube by excessive working of the tube. Expanding tubes thins the tube wall and increases its circumference. If the tightness of the tube joint is measured by an increase in the tube I.D., it is necessary to consider and compensate for pre-thinning the tube wall. Pre-thinning is defined as “tube wall-thinning produced when a tube is enlarged to make it exactly fit in its tube hole.” Pre-thinning varies with the initial tube-to-tube sheet clearance and with the tube wall thickness.

The tube wall is additionally thinned when the tube is enlarged beyond the metal-to-metal fit in the tube hole to create the interference fit condition of the tube joint. This additional thinning is a constant amount when each tube joint is made to have the same amount of interference-fit beyond the metal-to-metal condition of its members.

The following formulas may be used to figure the amount of Pre-thinning produced in any tube joint and with any amount of initial clearance between the tube OD and the tube hole ID.

The tube cross-section has a specific area. The area remains constant when the tube is enlarged; therefore, the tube I.D. must increase.

The ID after establishing the contact with the tube hole is calculated as below.

1.  $A1, \text{ Tube c/s area} = 3.142 * \{(DO1)^2 - (DI1)^2\} / 4$
2.  $A2, \text{ Inner area of DI2} = \{ (3.142 * (DO2)^2 ) - A1$
3.  $D12, \text{ Tube inner dia after pre-thinning} = \text{Sqrt} [4 * A2 / 3.142]$
4.  $M1, \text{ Pre-thinning} = \{(DO1 - DI1) - (DO2 - DI2)\}$

Now final ID is the sum of initial tube-to-tube hole clearance, Pre-thinning & interference required. The table in the below page shows the calculation for typical convection bank tubes.

➤ *SOURCE : ASME Section 1 Part PWT*

### ***PWT –11 TUBE CONNECTIONS***

Tubes, pipe and nipples may be attached to shells, heads, headers and fittings by one of the following methods.

#### ***PWT –11.1***

Tubes may be attached by expanding, flaring, beading, seal welding in the following combinations illustrated in Fig PW –11.

- a. Expanded and flared (sketch (a)),
- b. Expanded and beaded (sketch (b)),
- c. Expanded, flared, seal welded, and re expanded after welding (Sketch (c)) or
- d. Expanded, seal welded, and reexpanded after welding or seal welded and expanded after welding (sketch (d)).

The ends of all tubes that are flared shall project through the tube sheet or header not less than ¼ inch (6 mm) nor more than ¾ inch (19 mm) before flaring. Where tubes enter at an angle, the maximum limit ¾ inch shall apply only to the point of least projection. Tubes that are expanded and flared without seal welding shall be flared to an outside diameter of at least 1/8 inch (3.2 mm) greater than the diameter of tube hole. For tubes that are seal welded, the maximum throat of seal weld shall be 3/8 inch (10 mm).

➤ *SOURCE: HYDRO PRO Inc*

Hydraulic expansion is another technology of fitting tubes in tube holes. In this relatively high hydraulic pressure is used for expanding the tubes in place. The hydraulic pressure makes the tube metal to flow into the tube hole and thus creates a perfect seal. The following is a comparison of the hydraulic expanding versus mechanical roller expanding as projected by the tool manufacturer.

### ***HYDRALIC EXPANSION vs. MECHANICAL ROLLING METHODS***

1. Hydraulic expanding, or Hydro-expanding, is an innovation in expanding tubes into tube sheet. It is completely different from roller expanding, whether the tube expanders are driven electrically, by air, or hydraulically.
2. In Hydro-expanding, the degree of expanding is directly related to the preset expanding procedure. The pressure is exactly repeatable and does not vary from tube to tube, no matter what shape the tube is in. But, in mechanical rolling, whether you use torque setting or apparent percent tube wall reduction, the degree of expanding cannot be directly correlated. Furthermore, torque controllers measure only the power drawn by the rolls, which can vary with the condition of the rolls and mandrel, lubrication, operator fatigue and other factors.
3. Mechanical rolling reduces the tube wall by; a) stretching the tube radially, and b) imposing high unit rolling forces that cause the tube to extrude axially. Hydro expanding, however, only stretches the tube radially. The amount of wall reduction is barely measurable and, in fact, the tube end pulls in slightly as the tube is bulged out rather, than extruding.
4. Hydro expanding produces no surface effects on the tube and almost no work hardening. You never get bell shaped or hourglass shaped tube ends. Therefore, the tube-to-wall contact is always uniform.

5. When you roller-expand tubes into grooved holes, tube metal extrudes into the grooves. But, when you Hydro-expand tubes into grooved holes, the tube bulges into the groove, providing additional tightness at the contact of the groove edges with the tube.
6. Mechanical rolling may cause tube-end fatigue, depending upon the frequency and amplitude of the stresses the rollers apply. The frequency is far more effective in producing fatigue than the amplitude. That is why five or seven roll expanders are used when the tube material is subject to fatigue. From the fatigue standpoint, Hydro-expanding is like having an infinite number of rolls.
7. The high contact stresses imposed by rolling make it more likely that stress corrosion will cause tube-end failure. The transition from the reduced wall is a possible trouble source in rolled tubes.
8. You can Hydro-expand the tubes to the exact rear face of the tube sheet, thereby reducing the chance of crevice corrosion at the rear. This is accomplished by the uniformity of pressure being applied to the entire tube length at the same time. With mechanical rolling methods you are pushing the tube material out the rear of the tube sheet and because of this; you create a very noticeable rear crevice, resulting in premature tube failure.
9. The extreme ease of operation of the HydroPro requires almost no training.
10. If tube rollers cease and stall, the rolling motor may spin and injure the worker. HydroPro is completely safe.
11. To roll tubes into tube sheet thicker than 2", you have to step roll. This is time consuming and requires a tremendous amount of skill. You can Hydro-expand tubes into any thickness of tube sheet with one pass of the mandrel per tube.
12. When you re-roll leakers after hydro testing, you further reduce the tube wall. Also, you may move the ligaments enough to start other leaks and may even cause ligament damage around the other tubes. This can also create problems in having to chase the leaks completely around the tube sheet, creating even more problems, and so on. With Hydro-expanding, because you can accurately control the exact expansion pressure, you can eliminate the problem of having to re-expand leakers. If you do have a leaker, you know exactly which pressure will provide a seal without disturbing any of the adjacent holes.
13. Expansion time depends on the tube material and averages from 2 to 5 seconds per tube. Only one worker is needed to do the work. Tube ends are prepared in the same way as for roller expanding. Note that tubes would tear up rolls and cages or break mandrels will damage o-rings and backups.
14. Hydro-expanding is successful in out-of-round holes and in holes distorted by tube plugging. However, axial scratches in the hole or tube material will cause leaks in any expanded tube to tube sheet joints, regardless whether expanding by rolling, near contact explosions, compressing a rubber expander, or by hydro-expanding. Therefore, it is recommended that scratched holes be burnished free of axial scratches or a groove be cut into the tube sheet. It might be further noted that because of the uniformity of hydraulic expansion, it does further reduce the probability of axial scratches when retubing. The extraction of hydro-expanded tubes will be extremely even and uniform, thereby producing cleaner tube holes ready for re-tubing.

**TABLE : 1 SAMPLE CALCULATION**

TABLE SHOWING THE PRE-THINNING, % FINAL THINNING, INTERFERENCE REQD,FINAL THK,FINAL ID.		with interference of 0.024 inches	with interference of 0.024 inches	with interference of 0.040 inches	with interference of 0.040 inches	Final thk of tube due to 12 %	Final thk of tube due to 12 %
DO1	Tube OD	50.8	50.8	50.8	50.8	50.8	50.8
T1	Tube thk	3.66	3.66	3.66	3.66	3.66	3.66
DI1	Tube ID	43.48	43.48	43.48	43.48	43.48	43.48
A1	Tube area	542.03	542.03	542.03	542.03	542.03	542.03
DO2	tube hole dia	51.60	51.90	51.60	51.90	51.60	51.90
A2	tube hole area	2091.17	2115.56	2091.17	2115.56	2091.17	2115.56
A3	Area of of enlarged tube	1549.14	1573.53	1549.14	1573.53	1549.14	1573.53
DI2	ID of the tube after contact	44.41	44.76	44.41	44.76	44.41	44.76
M1={DO1-DI1)-(DO2-DI2)}	prethinning	0.13	0.18	0.13	0.18	0.13	0.18
M2=DO2-DO1	Clearance	0.80	1.10	0.80	1.10	0.80	1.10
M3	Interference	0.61	0.61	1.02	1.02	0.86	0.86
M4=(M1+M2+M3)	Total increase in Id	1.54	1.89	1.95	2.30	1.79	2.14
DI3=DI1+M4	Final ID	45.02	45.37	45.43	45.78	45.27	45.62
T2=(DO2-DI2)/2	Thk after prethinning	3.59	3.57	3.59	3.57	3.59	3.57
T3	Final thk of tube	3.29	3.27	3.09	3.06	3.16	3.14
100*(T2-T3)/T2	% thinning	8.48	8.54	14.13	14.23	12.00	12.00



➤ *SOURCE: WWW.SCHLECHTRIEM.DE – German vendor for tube expander*

### **EXPANSION LIMIT FOR EXPANSION OF TUBES**

Tube expansion can be compared to the cold rolling of steel sheets. The tube to be expanded can also be equated with an endless steel sheet, which, during the rolling process, has been lengthened or enlarged to a point when the external diameter of the tube equals the diameter of the tube sheet hole. This first stage is called 'metal to metal contact'. Note that the expansion at this stage is not yet leak proof.

Further rolling is necessary to increase the expansion and reach the point when the material is deformed. This creates tension because of the compression between the tube and the tube sheet. A leak proof expansion is assured if the pressure tension is greater than the service pressure, which arises from the heating, the lengthening and finally the tension of the medium. The difference of expansion between the 'contact' and the final expansion is called 'expansion limit'.

This 'expansion limit' must never cause a rupture in the cohesion of the molecules of the tube material by an exaggerated deformation of the material. If this were the case the tube material could become damaged – it could crack or break – and this would create the danger of explosions etc. when the tube comes under high pressure.

It could then happen that, though the tests had turned out positive, the tube would prove useless after a few days in service.

### **EXAMPLE**

Tube dimension	:	30 X 3 mm
Tube sheet hole	:	30.4 mm
Less 2 X 3 mm tube wall thickness	:	- 6.0 mm
<hr/>		
Theoretical internal diameter of the tube at 'metal to metal contact'	:	24.4 mm
Plus expansion limit i.e. 20% of the tube wall thickness	:	+ 0.6 mm
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Theoretical ID of tube after having reached the expansion limit	:	25.0 mm

Recommended expansion range:

Metal to Metal contact: about 3 -5 % of tube wall thickness

Expansion limit: about 15 - 20% of tube wall thickness

➤ *SOURCE: TRISTAR TUBE EXPANDERS*

### **WHAT IS CORRECT EXPANSION OF TUBES?**

Correct expansion of tubes is the forming of a 100% bond between the tube and tube sheet, a result of reducing the tube wall by 4 to 5%. Anything less or more will result in under- or over- expansion. By using controlled rolling motors with the proper tube expander, correct expansion can be assured automatically.

The basic purpose of tube expansion is to obtain a good hydraulic and mechanical joint. A secondary, but equally important, purpose is to obtain a seal that is durable, resistant to corrosion and essentially

free of longitudinal stress. During tube expansion we must take care of “Over Expansion” and we do take care of “Under Expansion”. The under expansion is detected during hydraulic test and can be corrected by re-expanding. But, over expansion cannot be detected easily and it imposes excessive stresses in the material of the tube and tube sheet. This results in damage to the ligament and a poor joint.

The optimum expansion is the one that develops a tight joint with adequate strength and with minimum stress. The Torque needed for achieving optimum tube expansion varies with the tube diameter, tube thickness, tube sheet thickness, tube material and tube sheet material. Obviously we must determine some relation between the amount of tube expansion and the amount of torque required to achieve that. Many feel that the manufacturer should specify the torque needed for particular combination of various conditions. Since many preferential factors come into play like the desired amount of expansion, the lubricant used, the expansion length set on expander etc. it has to remain with the user to arrive at the torque figure. It is recommended that a group of about five tubes be expanded, measuring the results after every expansion. Comparison of the measurements with the calculated figures will enable decision making on the increase or decrease of the torque to be applied. Once the correct torque is determined the same has to be repeatedly applied for all tubes.

One of the widest methods of determining tube expansion is to determine the percentage of wall reduction of the tube being expanded. The wall reduction is due to thinning of the tube wall after the tube outer diameter comes into contact with the tube sheet bore during Tube Expansion. Tube walls of non-ferrous tubes in condensers are reduced by 3 to 4 % to get an optimum joint. A wall reduction of 8 to 10% in the case of ferrous tubes in Heat Exchangers is considered optimum, whereas non-ferrous tubes require to be reduced by 8 to 12% due to the pressure involved.

## ***AUTHOR'S EXPERIENCE***

### ***❖ TUBE EXPANDING OF BOILER BANK TUBES FOR BIDRUM BOILERS.***

In the following paragraphs the experience of the author in the field of boiler is brought out. Bank tubes become a design requirement in case of boilers with main steam pressure of 44 kg/cm<sup>2</sup> and below. This due to the fact that the evaporator duty is more at lower pressures and sufficient heat transfer surface can be provided in less space only with bidrum bank tube design. Bank tubes are necessarily expanded in to the tube holes provided in steam & lower drum. To erect boiler bank tubes, the lower drum is usually erected first as the slinging will be easier. A temporary steam drum lifting structure has to be used for erecting the steam drum. Both the drums are aligned and relatively positioned as per the design requirement. Now in the following paragraphs, the care to be taken for tubes expanding is brought out.

#### ***1. Cleanliness and surface condition***

When installing and rolling tubes, it is extremely important that both the tube and tube holes be clean and relatively smooth and maintained in this condition until the joint is rolled. Any foreign matter on either surface can prevent a tightly rolled joint. Particular attention must be given to the cleanliness of these items. Once the tubes have been stuck in the drum, the tube should be rolled immediately. Tack rolling now and final rolling later is a bad practice. Immediate final rolling will minimize the chance of rust or foreign matter from accumulating in the annular space between the tube and tube hole. Both the tube and tube hole should have a slight chamfer on their edges to minimize the chance of them scratching each other.

## *2. Tube ends preparation*

Prior to installing the tubes in the drum, the outside of the tube ends must be cleaned and free of burrs and shall not have chatter marks, tears, drags, scratches, etc running length wise. Swaged tube ends must be thoroughly prepared with emery paper or by puffing. The surface roughness shall not exceed 125 microns. The surface shall be free from films or contaminant such as oils, water, paint and preservatives as determined by a visual examination or a solvent dampened white cloth.

The tubes should be clean for about 300 mm on one end to be stuck first and 150 mm on the other end. This will prevent any foreign matter from rubbing off the tube onto the tube hole when the tubes are stuck.

The inside of the tube ends must be free from contamination such as sand, mud, metal chips, weld slag, etc for the full depth of the tube expander.

## *3. Tube holes preparation*

The tube holes in the drum where the tubes are to be stuck must also be clean and free of burrs and shall not have chatter marks, tears, drags, scratches, etc running lengthwise. The surface roughness shall be 200 - 300 micro inches as per ANSI B 46.1 the surface shall appear metal clean when magnified under normal lighting. Sharp edges shall be removed. The surface shall be free from films or contaminant such as oils, water, paint and preservatives as determined by a visual examination or a solvent dampened white cloth.

When a visual examination is not possible and the surfaces are inaccessible, a dry white cloth wipe shall be done. If either cloth exhibits indications of contaminant, the system shall be re-cleaned or the specific contaminant shall be determined and evaluated as to its potential deleterious effect.

When there is a groove or serration in the tube sheet, particular attention should be paid to insuring that the groove is clean. The diameter of the tube hole is based on the following:

Diameter of tube hole = Nominal dia of the tube plus 0.8 mm. Tolerance shall be +0.000 mm and – 0.300 mm

## *4. Sequence of tube installation and expansion*

The sequence in which tubes are expanded is critical. Using the wrong sequences can cause the drums to go out of roll and level. Another important aspect is to insure the tube is parallel with the tube hole. If the tube is slightly crooked relative to the tube hole, it is virtually impossible to get a properly rolled joint. The angle the tube hole is drilled at, the angle the tube is bent at, the length of the tube stock and the ovality of the drum will all affect the parallelism.

### *4.1 Master tubes*

Due to several factors such as drum ovality, error in drilling angle, error in tube bending angle are going to contribute to varying length of tube projection inside the drums. Hence bank tubes are fabricated with an additional allowance in length this additional length is trimmed off at site. Now insitu cutting can be adopted if the required portable facing machine is available. A better way is to take a set of tubes called master tubes. A set of tubes is inserted in to the drums, aligned, and drum inner contour is marked and removed. These tubes are sized keeping the beelling allowance of 10

mm on both ends. Now these tubes can be used as master tubes. The balance tubes can be now sized as per the master tubes, at ground before lifting to position. This saves considerable time.

#### *4.2 Torque control for tubes expansion.*

Electrical drive is extensively used in INDIA. The amount of tube thinning can be controlled by the torque control unit manufactured for this purpose. The torque values are to be set using the mock up tube sheet & trial tube lengths. Two mock up tube sheets are required matching the steam drum & water drum thickness. The tube holes are drilled as per steam drum / water drum. The trial tube lengths should be of the same diameter & thickness as per the bank tubes. If the tube ends are swaged, then the trial tubes should also be the same. The torque required is set to achieve the design % thinning. The ID of the hole prior to rolling is recorded. The tube ID required after rolling is calculated based on the thinning required. Now the torque is set on trial and error method by gradually increasing the torque values until the desired thinning is achieved. The mock up tube sheet shall have at least 9 holes for this purpose. The desired thinning for Boiler tubes is 8 to 10 %.

#### *4.3 Sequence of expansion*

##### *4.3.1 Stage 1*

After the drums have been properly aligned, central two of tubes, and expanded to maintain drum alignment. The two center longitudinal rows R9 & R10 should be installed as per the sequence shown in figure 4.

##### *4.3.2 Stage 2*

Then two sets of circumferential columns tubes (C1, C2 and C25, C26) near the end of the drum should be installed. The sequence shall be as per the figure 5. By this clockwise and counterclockwise sequence the twisting of the drum can be prevented.

##### *4.3.3 Stage 3*

The tubes in rows R8 & R11 are erected as per the sequence shown in figure 6. In the same way rest of the bank tubes are erected. The longitudinal and circumferential reference tubes erected in stage 1 & 2 are used for aligning the all the rest of the tubes. Here again the clockwise and anticlockwise rotation will help in preventing twisting of drum axes.

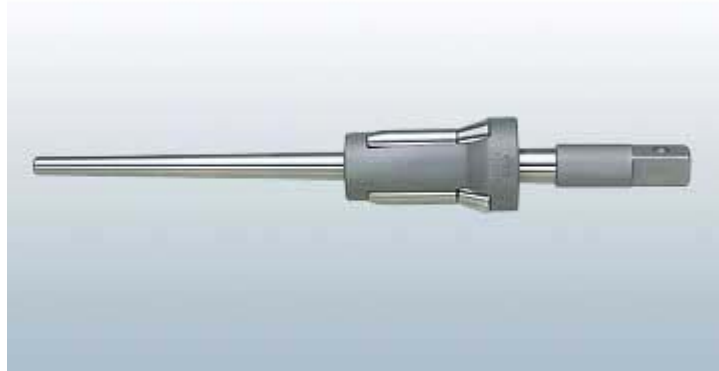
##### *4.3.4 Stage 4*

The loading sequence of the tubes is not important, while full rolling of the tubes should be as per the sequence suggested. Tube to tube spacings is maintained by wooden spacers. Piano wires are used for checking the alignment of tubes. Simultaneous expansion in upper and lower drums must be practised. While expanding tubes care should be taken not to spill lubricants inside the tube to drum joint. The cleanliness inside the drums will help in preventing leaky joints.

### **SUMMARY**

As far as the tube expansion of boiler tubes are concerned one may not find enough literature. Over expansion of boiler tubes are frequently encountered in many cases. The reason is mostly the insufficient knowledge on the part of the personnel who execute the job. Tube expansion is as an art

and only few take serious steps to maintain the quality of workmanship. It is hoped that the above article is useful to the readers.



**Figure 1 TUBE EXPANDER**

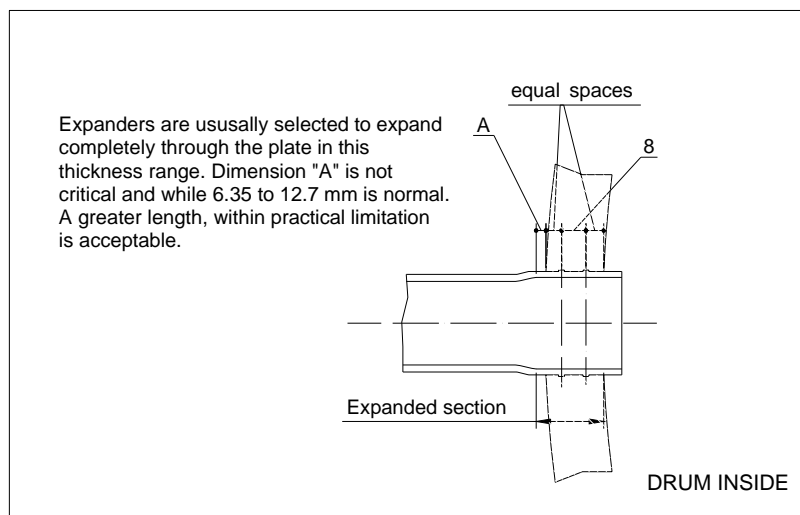
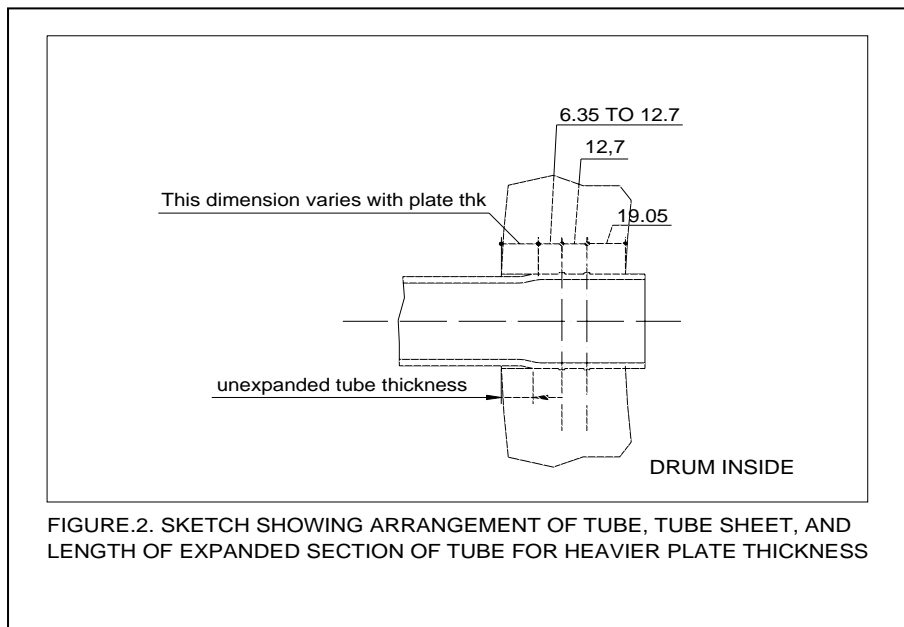


FIGURE. 3. SKETCH SHOWING ARRANGEMENT OF TUBE, TUBE SHEET, AND LENGTH OF EXPANDED SECTION OF TUBE FOR THINNER PLATE THICKNESS

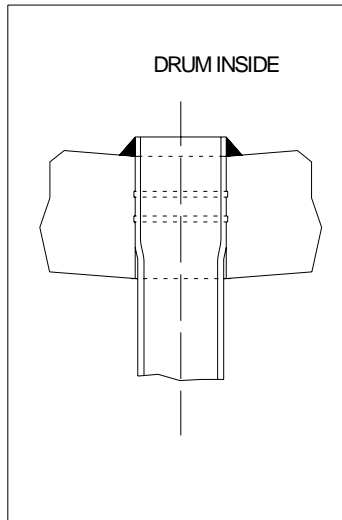


FIGURE.4. INSIDE SEAL WELD ( DRUM,

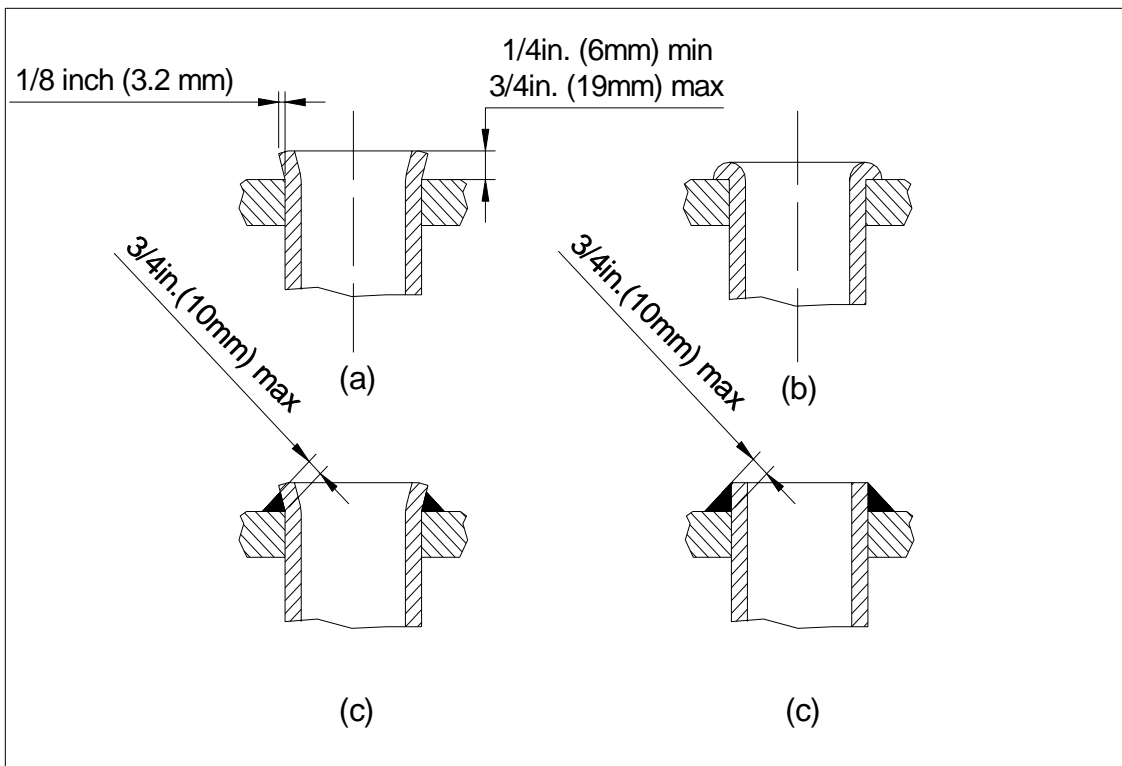


FIG PWT-11 EXAMPLES OF ACCEPTABLE FORMS OF TUBE ATTACHMENT







