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Basic Principles of Tube Expanding

Tube Expanding is the art of reducing a tube wall by compressing the O.D. of the tube against a fixed container . . . such as rolling tubes into tube sheets, drums, ferrules or flanges. To assure a proper tube joint, the tube wall must be reduced by a predetermined percentage. The following chart can be used for determining the correct tube wall reduction.

This chart shows a typical 3/4" – 16 gauge tube. Before rolling this tube you would find the proper rolling dimension as shown.

- | | |
|---|--|
| <p>A. First determine the tube hole size.</p> <p>B. Then determine the tube outside diameter.</p> <p>C. Subtract the tube outside diameter from the tube hole dimension.</p> <p>D. With a Tube Gauge, determine the inside diameter of the tube before rolling.</p> <p>E. By adding the dimension found in "D" to the clearance between the tube O.D. and the tube hole, you will then know the tube's inside diameter at metal to metal contact.</p> | <p>F. Roll the tube to what you feel is a good tube joint. This example was rolled and then the I.D. of the tube was checked with an accurate Tube Gauge.</p> <p>G. By subtracting "E" from the rolled diameter you determine the actual amount of expansion (tube wall reduction) on the inside diameter of your tube. This can be converted to a % of wall reduction by dividing the actual wall thickness ("B minus D") .130" into the amount of roll .009.</p> |
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You can use this chart to your advantage by predetermining both the % of wall reduction required and the actual inside diameter which should be rolled. After the completion of "E" you realize any additional increase of the inside diameter of the tube will result in actual wall reduction. Since the amount of wall reduction greatly determines the quality of the tube joint, you should arrive at the % required for your application prior to tube rolling.

By subtracting the tube inside diameter "D" from "B", you determine actual wall thickness. This example would therefore be .130". If you then take the 7% wall reduction times the wall thickness, you arrive at .0091". Adding .0091" ("G") to .627" ("E") we get "F" the inside diameter of the tube after rolling (.636").

Test Chart For Determining Proper Amount Of Tube Expansion

	Tube Test Number	1	2	3	4	5	6
A	Tube Sheet Hole Size	.757					
B	Tube Outside Diameter	.750					
C	Clearance (A Minus B)	.007					
D	Tube Inside Diameter	.620					
E	Tube Inside Diameter When Metal-To-Metal Contact is Reached (D Plus C)	.627					
F	Tube Inside Diameter After Rolling	.636					
G	Actual Amount of Roll on Diameter (F Minus E)	.009					

- Note:
- 1) Take all measurements in thousands
 - 2) Take "A" in middle of area to be rolled
 - 3) Take "B", "D" and "F" in same position as No. 2
 - 4) Take both horizontal and vertical diameters as tubes may be out of round show mean diameter

Customer: _____
 Location: _____
 Unit: _____
 Tube Alloy: _____
 Date: _____

Tube Expanders

Basic Principles of Tube Expanding

This technique is an excellent way to set torque rolling devices. Once you have arrived at the rolled dimension for four or five tubes, you can roll them and very simply determine if more or less wall reduction is required. Knowing how to determine wall reduction is important; however it is equally important to know the characteristics of the popular tubing materials. We should know the proper wall reduction which would apply to each metal. A simple rule of thumb is the harder the material, the less wall reduction is required to obtain a tube joint. For example, you can assign these as approximate percentages of wall reduction when rolling pressure vessels:

Tubing Material:

Copper & Cupro Nickel	8 - 10%
Steel, Carbon Steel & Admiralty Brass	7 - 8%
Stainless Steel & Titanium	4 - 5%

These materials and percentages can be your guideline to rolling tubes of like materials.

Here is a summary of important factors in rolling certain alloys: When rolling 3003 or 4004 Aluminum you should not reduce the walls over 5%. When rolling 6061-T Aluminum, which is one of the most popular materials used in aircraft fittings, you can reduce the wall 10 to 12% for a mechanical joint.

There is a tube process called Alonizing. It is stated that Alonized steel combines the heat and corrosion resistant properties of the iron aluminum alloy with the strength and rigidity of steel. When rolling this tubing it is extremely important to lubricate each tube end and make certain that the tube expanders are kept clean. Remove all particles of the tubing materials from the expanders to decrease tool fatigue. When rolling Alonized tubing, abrasive particles are removed from the inside diameter of the tubing and gathered in the expander. It is recommended that two expanders be used. One should be cleaned and lubricated while the other is being used.

Admiralty Brass is widely used in condensers. This material should be well lubricated. The tube wall is reduced approximately 7% to 8% for optimum tube joints. In general, only a 4% to 10% reduction in wall thickness is necessary to produce a tight tube in a serrated hole. On the other hand, reduction in excess of 15% may cause leaking, splits or flaked tubes.

Carbon Steel is used in almost every type of pressure vessel built today. Tube wall reduction should be approximately 7% to 8%. Heavy lubrication is a must. If the tube is cracking or tooling shows excessive wear, tube hardness should be checked. Carbon Steel tubes should be 90 to 120 Brinnel hardness for rolling. It is possible to roll tubes up to 150 Brinnel; however, flaking and cracking are more likely to occur as the tube hardness increases.

When rolling Copper and Cupro Nickel, consider approximately 8 - 10% wall reduction to be a proper tube joint. Copper, since it is one of the softer tubes used in pressure vessels, can be easily rolled. Use plenty of lubrication because copper has an abrasive action on tube expanders.

When rolling Stainless Steel and Titanium, approximately 4 to 5% wall reduction is sufficient to produce a tight tube in a serrated hole. When rolling these alloys the entire wall reduction should be done quickly. These materials have a greater tendency to work harden; therefore, minimal or no rerolling should be done. Motor speeds should be 400 to 750 RPM.

When rolling Titanium, it is recommended to use an expander with four rolls or more. This will decrease diaphragm of a thin wall and help eliminate tube end cracking. There are, however, exceptions to the above rule.

This discussion of alloys has been related to those used in pressure vessels such as boilers, heat exchangers, and condensers. These factors would be approximately the same in a mechanical joint for industrial use. However, a greater percent of wall reduction is usually considered when making a mechanical joint. Higher quality tubes are used in industrial applications.

Major Causes of Tube Leaks

Tube rolling leakage is usually caused by one of the following: under-rolling, over-rolling, improper preparation of tube sheets and differential thermal expansion. Improper expansion can lead to serious difficulties for both the manufacturer and the repair service men.

Tube Expanders

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Under-Rolling

Under-Rolling as the word would imply is when the tube is not expanded to fill the tube sheet hole and the proper amount of wall reduction is not obtained. **It is better to under-roll than to over-roll.**

Over-Rolling

Over-rolling is when the expansion of the inside diameter of the tube surpasses the expansion required for the proper percentage of wall reduction for the ultimate tube joint. **Over-rolling can do considerable damage to a vessel.** Over-rolling will decrease the dimensions of the ligament between tubes and weaken this bridge. Once a ligament is weakened, it will cause a reaction in all ligaments surrounding that weak ligament. If we decrease the strength of the ligament the tube next to the tube being rolled will leak.

Over-rolling also causes distortion in tube sheets or drums, such as egg-shaped holes. It will also cause diametrical expansion which is the overall increase of a tube sheet or drum. Over-rolling has been known to cause a tube sheet to bow or warp to the point where the standard length tube could not be used in the vessel until the bowing or warpage is returned to normal. This is usually corrected by placing stay rods in the vessel and pulling the tube sheets back to their original position.

Improper Preparation of Tube Holes

Improper preparation of tube holes is another major cause in tube leakage. If the tube sheet or drum is gouged, it is extremely hard to expand the tube to fill these gouges or tears without over-rolling. The smoother the tube seat or tube hole the easier it is to roll an optimum tube joint. The ligaments and light tube walls make it more important that the finish of the tube hole be in the low micro range. We find many manufacturers today are drilling, reaming and sizing or burnishing to get the microfinish desired for tube holes.

Differential Thermal Expansion

Differential thermal expansion can result with thicker tube sheets. When the expansion due to heat varies noticeably between the thinner tube and tube sheet, a shift of the tube results. One of the most important steps for ensuring a safe and permanent tube joint is to thoroughly clean the surfaces of the tube end and the tube hole wall. These two surfaces must be clean and free of all dust, mill scale and pits or scratches. It is extremely important to eliminate any longitudinal scoring in the tube hole wall. These longitudinal lines will cause leaky tubes.

Preparation of Tube Holes

Preparation of tube holes in heat exchangers and condensers is as follows:

1. Drill and ream tube sheet holes to .007" to .010" over the outside diameter of the tube to be used.
2. Be certain the ligaments are sufficient to guarantee a safe and permanent tube joint.
3. When conditions permit, utilize a sizing or burnishing tool to further assure a good finish in the tube hole. This will also increase the tensile strength of the ligament.
4. The serrations or grooves to be used will determine the holding power of the tube.
5. It is extremely important when retubing that the grooves be cleared of all metals or any foreign material.

Preparation of Tube Seats

Preparation of tube seats in drums, tube sheets, and headers are as follows:

1. Tube holes are normally drilled and reamed to approximately 1/32" larger than the nominal outside diameter of the tubes.
2. It is extremely important during this operation that there are no longitudinal scorings left in the tube seat.
3. In cases where out-of-roundness is extreme, prerolling of the tube holes is advised.
4. Be certain that the tube hole walls and the grooves in the tube walls are cleaned down to bare metal before tubes are inserted. Be certain all foreign material such as oil, grease, rust, or just plain dirt are removed. Special attention during this cleaning will prevent serious trouble later.

After tube holes have been prepared they are usually coated with a rust preventative compound. Before inserting any tube it is important to remove all traces of this coating. It is extremely important that great care be taken in handling the tubes for insertion in all of the vessels discussed above. Be certain that the tube ends are clear of any foreign material. Be especially certain that there are no chips on the tubing which may gouge the tube sheet or tube seat when the tube is placed in the vessel.

In some cases it will be necessary to force a tube into a tube hole. This should be done with extreme care. It is better to spring the tube than to try to force it with a hammer. If a tube end is kinked or damaged before rolling, the expanded end will be damaged and a leaky roll joint will result. Attention at this time to the tube ends and the tube alignment will prevent future troubles.

RECOMMENDED EXPANSION OF TUBES FOR OPTIMUM JOINT STRENGTH IN HEAT EXCHANGERS AND CONDENSERS

Use expansion listed in tube expansion column plus clearance between tube O.D. and sheet hole I.D.

Recommended expansion may be plus or minus .001".

O.D. Size	GA	Tube Expansion	O.D. Size	GA	Tube Expansion	O.D. Size	GA	Tube Expansion
1/2"	14	.006"	3/4"	10	.008"	1-1/4"	8	.010"
1/2"	15	.006"	3/4"	11	.008"	1-1/4"	10	.010"
1/2"	16	.006"	3/4"	12	.008"	1-1/4"	12	.009"
1/2"	17	.005"	3/4"	13	.008"	1-1/4"	14	.008"
1/2"	18	.005"	3/4"	14	.008"	1-1/4"	16	.007"
1/2"	19	.004"	3/4"	15	.007"	1-1/4"	18	.006"
1/2"	20	.004"	3/4"	16	.006"			
1/2"	21	.004"	3/4"	17	.005"	1-1/2"	8	.012"
			3/4"	18	.005"	1-1/2"	10	.012"
5/8"	12	.006"	3/4"	19	.005"	1-1/2"	12	.010"
5/8"	13	.006"	3/4"	20	.005"	1-1/2"	14	.010"
5/8"	14	.006"	3/4"	21	.004"	1-1/2"	16	.008"
5/8"	15	.006"				1-1/2"	18	.008"
5/8"	16	.006"	1"	8	.009"			
5/8"	17	.005"	1"	9	.009"	2"	8	.012"
5/8"	18	.005"	1"	10	.009"	2"	10	.012"
5/8"	19	.004"	1"	11	.009"	2"	12	.011"
5/8"	20	.004"	1"	12	.009"	2"	14	.010"
5/8"	21	.004"	1"	13	.008"	2"	16	.008"
			1"	14	.008"	2"	18	.008"
			1"	15	.007"			
			1"	16	.006"			
			1"	17	.005"			
			1"	18	.005"			

ADDITIONAL SIZES

1/4" O.D. tube - expand all gauges .003" after contact with tube sheet hole

3/8" O.D. tube - expand all gauges .004" after contact with tube sheet hole

EXAMPLE

3/4" O.D. x 14 gauge tubes

Recommended expansion008"

Tube sheet hole760"

Therefore, expand as follows:

Tube I.D. before expanding584"

Recommended expansion008"

Clearance between tube & tube sheet hole010"

FINISH I.D.602"

The above recommendation is based on our experience. However, this does not constitute a guarantee because of the great variety of materials, tubes and tube sheets used. Some conditions will require experimental rolling to be certain that the rolled joints will be satisfactory.