WORK INSTRUCTION
FOR
TUBE EXPANSION

BHARAT HEAVY ELECTRICALS LIMITED
POWER SECTOR - WESTERN REGION
TECHNICAL SERVICES
NAGPUR
# WORK INSTRUCTION
FOR
TUBE EXPANSION

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<th>Issue Date:</th>
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<th>Reviewed By:</th>
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WORK INSTRUCTION
FOR
TUBE EXPANSION

Bharat Heavy Electricals Limited
Power Sector - Southern Region
474, Anna Salai, Madras-600 035
WORK INSTRUCTION FOR TUBE EXPANSION

CONTROLLED / INFORMATION

ISSUED TO : 
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PROCEDURE FOR TUBE EXPANSION

1.0 Scope

This standard covers the tube expansion process carried out in Boiler, Condenser and other heat exchangers and coolers.

The tubes of condenser or beat exchanger or boiler are fixed in tube plate holes by means of roller expansion.

2.0 Guidelines

2.1 Guidelines for boiler tube expansion is enclosed in Annexure 1.

2.2 Guidelines for condenser tube expansion is enclosed in Annexure 2.

2.3 In case any specific instructions are given by the manufacturing unit the same shall be followed.

3.0 The Equipment

The area in charge shall inspect and ensure the adequacy of the equipment, tools and lubricants available / to be selected, for the tube expansion work.

3.1 Tube hole numbering system as given by manufacturing units to be followed. If not given, it may be decided and recorded.

4.0 Mock up test for selling of parameter

4.1 Purpose

Before starting the lube expansion (on actual job) a mock expansion shall be carried out to ensure that the design requirements can be adequately met.

4.2 Procedure

4.2.1 Obtain the mock lip trial pieces (of the same material with the same hole size as that of the main plate) from manufacturing unit or in case it is not available choose a few holes from the original tube plate on the equipment itself.

The test tubes shall be representative of the tubes to be expanded.

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4.2.2 Drive Equipment to be used shall be the same for the mock up test and for the main job.

**AMENDMENT NO. 1**

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4.2.3 Check for the tube holes of mock up plate. They are to be cleaned and free of burrs, scratches etc. running lengthwise.

The surface shall be metal clean, when examined without magnification under normal lighting. Surface shall be cleaned free of films and contaminants such oil, oil, water, paint and preservatives as determined by visual inspection or after cleaning with a solvent dampened white cloth or an equivalent alternate method. When there is a groove or separation in the tube sheet, particular attention to be paid to ensure that the groove is clean.

4.2.4 Check the tube end and tube holes. Measure OD & ID of Tube and ID of the plate hole. (As in Format I)

4.2.5 Based on the recommendation of the manufacturing unit, calculate the expansion and wall thinning to be obtained. And determine the range of tube II) after expansion.

4.2.6 Insert the tubes as required in the drawing furnished by supplier in the measured holes and expand. In case of electrical drive, the torque requirement is to be determined by means of trial expansion. The electrical drive unit controller Ammeter shall be checked for consistency. In case of Hydraulic and pneumatic drives, the pressure gauges, pressure switch set up, are to be checked for consistency.

Starting with lower values continue expansion till the required ID of the expanded tube, as recommended by the manufacturing unit is achieved.

4.2.7 Record the dimensions measured in the test as per Format 1.

4.2.8 If there is a specific requirement from the designer to carry out the pullout test, same shall be carried out. In such cases the
testing shall be done in the mock up test plate, by obtaining the required test procedure for pullout test from the designer concerned.

4.2.9 Airleak test will be conducted on the mockup test piece to pressure of 1.5 kg/cm² to ensure that these joints are leak proof and also to ensure the qualification of parameters. However, if the pull out test is done as per clause 4.2.8, the air leak test is not required.
# TUBE EXPANSION MOCK TEST REPORT

## Site:

## Type of Expander:

## Reference Document:

## Unit:

## S. No.:

## Area:

## Thinning %

### Specified ----------------------- --------------------------

<table>
<thead>
<tr>
<th>Tube Plate Hole No.</th>
<th>Tube Plate Hole ID</th>
<th>Before Expansion</th>
<th>After Expansion</th>
<th>Set Value/Remarks</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td>Tube OD</td>
<td>Tube ID</td>
<td>Thick</td>
</tr>
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</table>

Range of ID of Tube after expansion to meet specified

Current Range/Pressure setting

Certified that the process is adequate to meet the percentage thinning specified.

QAE

Area Manager

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RECORD OF TUBE HOLES & TUBE DIMENSIONS FOR
5% OF TOTAL HOLES PRIOR TO EXPANSION

(May be taken in parts daily or at any convenient intervals)

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Tube Plate Hole No.</th>
<th>Tube Plate Hole ID</th>
<th>Tube OD</th>
<th>Tube ID</th>
<th>Remarks</th>
</tr>
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Specification
Tube Plate hole ID
Tube OD
Tube ID

Area Manager

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Sr. Manager

Reviewed & Approved by: A. M. RAO
Head/Projects
RECORD OF PERCENTAGE THINNING AFTER EXPANSION

(RANGE OF ID OF TUBE AFTER EXPANSION AS OBTAINED FROM FORMAT: 1)

Site: Range of ID as per format 1
Unit: =
Area: Date:

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Tube Hole Number</th>
<th>Tube ID Measured</th>
<th>Acceptable Not Acceptable</th>
<th>Remarks</th>
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QAE

Area Manager

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Reviewed & Approved by: A. M. RAO
Head/Projects
4.2.10 After the mock up trial readings are obtained satisfying the recommended/specified results, the main job shall be taken up.

4.2.11 In case the drive unit is to be changed either during mock trial or during the actual expansion, the mock up test shall be repeated.

5.0.0 **Procedure for tube expansion on actual job**

5.1.0 Clean the tubes and tube plate holes as per the cleaning, procedure indicated in clause 4.2.3

5.1.1 Take random measurements for 5% of tube holes and 5% of tubes to ensure that the dimensions are as specified. Record the same as per Format 2. This may be done in parts also on daily basis or at convenient intervals. Average value may be taken for tube expansion calculation.

5.2.0 The length of cleaning to be done for the tube shall be based on site requirement and application.

5.3.0 Ensure that the final cleaning of tubes and tube plate holes are done not earlier than one day prior to their expansion.

5.4.0 Determine the sequence of tube expansion as per the recommendation of the manufacturing unit.

5.5.0 Determine the sequence of tube insertion, tack rolling, cutting off ends, flaring, expansion etc as required.

5.6.0 Insert all tubes, Ensure tube projection as per drawing.

5.7.0 After insertion of the tube, the rolling will be done at the earliest to avoid the formation of rust and ingress materials in the annular space between the tube and tube plate.

5.7.1 Every day at the start of the work, first 10 expansion done shall be checked (or correct expansion, before proceeding with further expansion.

5.8.0 After the final expansion, for the day, measure 10% of the tubes expanded, to ensure results are obtained as per the required range and record the same as per format. In case the result is under
expansion, in 10% of the tubes, continue examination for another 10% or the tubes expanded. In this case if the expansion is below the range specified, expand the earlier 10% tubes with under expansion, to the specific range. While examining the additional 10% of tubes also, if under expansion is noted, all 100% tubes expanded that day should be checked. Wherever under expansion is noted, the same shall be expanded further to get the results desired.

In case or over expansion in the first 10% tubes examined, the cause is to be analysed and process corrected if required even by going in for another mock up test and the matter shall be referred to the manufacturing units for opinion.
1.0 Instruction for Condenser Tube Expansion

These instructions are issued for guiding tube expansion process at site in KWU design of Condensers. These are also to be used as reference document for heat exchangers manufactured at shop.

1.1 Introduction

Condenser being huge equipment it is dispatched in different assemblies/sub-assemblies and various loose parts. It is built at site before the stage of tubing comes. Tubing in Condenser is done after welding/fitting all internals in lower half. Trouble-free and safe operation of Condenser depends mainly on subject operation. Improper expansion of tubes may result into tube joint failure which may lead to water entry in steam space resulting in contaminated condensate, hence interruption in power generation and expensive repair due to likely damage to other equipments.

1.2 Expanded Joint

Tube expansion into the tube plate is a process in which the tube is expanded mechanically to provide metal to metal contact with the hole surface. In this process, outer surface of the tube first touches with the inner surface of tube hole and on further expansion, ductile material of tube flows into the cavities of the tube hole surface undergoing plastic deformation thereby providing leak-tight joint. Normally roller expanders are used for above purpose. In this type of expansion, taper mandrel is inserted between three high finish rollers. With the rotation of mandrel by torque controlled motor, all rollers rotate. While feeding the mandrel inwards, diameter over rollers increases which expands the tube making the leak-proof joint.

Expanded tube to tube plate joint obtained with above process is pressure-tight joint with strength and stability. This type of tube plate joint is most popular in Heat Exchangers.
1.3 Cleaning of tube hole surfaces in main tube plates find tube ends

All contact surfaces in the expanding operation should be clean. No foreign material is allowed to be entrapped between the tube and tube hole mating surfaces, as it will result in a poor joint, which may ultimately lead to leakage. Foreign material will fill in the cavities of holes in which tube material must have down. Remove all rust, dust scale, oil, dirt, protective coating and other foreign matter from tube plate holes and inside and outside surfaces of tube ends.

Foreign matter on the inside of tube will tend to become embedded into the tube wall and may cause flaking and falling of rollers and mandrel. Cleaning of tube hole may be done by the application of suitable light oil or solvent like carbon tetrachloride etc. Tube ends can be cleaned by using rough cloth and if necessary very fine emery paper may also be used avoiding scratches over the tube surface.

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1.4 Tube Hole Surface Inspection

Before insertion of tubes, holes should be inspected visually: after cleaning. Hole should not have longitudinal or spiral-through tool marks. Such marks should be smoothened before tube insertion.

1.5 Tube Insertion

The tubes are to be threaded through various intermediate support plates while positioning the same between two main tube plates at either ends. Depending upon the number of supports and tube length, requisite number of persons should be employed between different compartment to guide the tubes in right holes with proper care to avoid scratches on the tubes. Burrs, if any, should be cleaned from support plate holes before tube insertion.

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1.6 Torque / Current Setting

Before starting actual expansion torque should be set to achieve required thinning. Normally for condenser, thinning is kept between 7% and 10%. Calculation procedure of tube thinning is shown in Annexure-I

1. Select 10 holes in different zones in the tube nest representing various roughness and various hole sizes and note the same in log sheet.

2. Measure tube, outside and inside diameter of corresponding tubes and note the same in log sheet.

3. Set the torque based on experience.

4. Insert the tubes in 2 holes with their dimensions; duly recorded. Expand the inlet end, keeping 1.5 mm protrusion for bell mouthing, if required.
5. Measure internal diameter of the tube after expansion.

6. Compare above expanded diameter with theoretical diameter as per Annexure I.

7. a) If expanded internal diameter is more than the theoretical, this would mean that the tube is over-expanded. Lower setting of torque current and repeat above with two fresh holes and tubes.

   b) If expanded internal diameter is less than the theoretical, this would mean that the tube under-expanded. Increase setting of torque/current and repeat above with two fresh holes and tubes.

8. Finally set the controller to the torque/current where actual expanded internal diameter is achieved within the theoretical range of expansion.

9. Re-expand the tubes where under expansion has taken place.

1.7 **Sequence of expansion**

1. Expand about 6 rows vertical and horizontal at centre to avoid distortion of tube plate.

2. Complete the entire tube expansion with right torque/current setting and if necessary with selective torque/current setting for selective holes.

1.8 **General Precautions Before Expansion**

1. At a few places, measure distance between outer faces of tube plates and keep the record of the same.

2. Measure the tube length and see that margin is about 10 mm. No tube should be used having margin less than 3 mm over the dimension measured at 1 above.

3. Slacken the set screw on the thrust collar of the expander and adjust it, by moving the collar body along the screwed body, to suit the length of expansion as per the drawing.
Lock the collar in the set position by tightening the set screw at required position.

4. Inlet end should be expanded first find then outlet end should be expanded. Proper collar washer should be used while expanding individual ends of the tube. While expanding inlet end, collar washer should be used not to allow axial movement of lube beyond tube plate on water box side (See rig.1 of Annexure-II). While expanding outlet end, collar washer should not be used so as to allow axial movement of tube beyond lube plate towards water box end (see fig. 2 of Annexure-II) necessary two different tube expanders may be used to meet this requirement.

5. After expansion, inlet end should be bell mouthed by light blow of hammer, using belling tool if recommended in the drawing.

6. Protrusion of tube at outlet end should be between 1 mm and 10 mm. or as per drawing. Excess length should be cut after expansion.

7. Suitable oil or glycerin may be used for lubrication of rollers.

1.9 Do's

1 Cool and clean the expander in a mixture of soap solution and glycerin at regular intervals. It is better to use two expanders so that one Gill be cooled and deemed when the other expander is in service.

2 Inspect the rollers, mandrel and expander cage at regular intervals for wear / scratches.

3 Check torque/current setting whenever rollers and mandrel are changed.

4 Measure rolling length of tube at regular interval and see that expansion does not exceed beyond tube plate.
5 Expanders should be rotated at a speed proportionate to the tube size, gauge (thickness), depth of expansion, tube material, tube plate material and hole ligament. Ideal speed will keep minimum mandrel slippage and will prevent overheating of mandrel, rollers find cage assembly.

1.10 Don'ts

1. Do not use expander with overflowing coolant/lubricant. This will overflow into the gap of tube and lube hole in lower rows and will create film between tube and tube plate causing weak joint of these lower rows. Coolant/lubricant should be just sufficient to prevent overheating of rollers and mandrel.

2. Never expand the tube beyond tube plate face.

3. Never use worn out rollers / mandrel / cage. This will dig on tube material.

4. Never change only rollers or mandrel. Complete set of rollers and mandrel should be changed.

5. Do not expand the lube at any end if lube is suspected to fall short of either tube plate face.

Enclosures: Annexure I & II
ANNEXURE: I

BONDING EXPANSION AND ITS DETERMINATION

LEgend

D — Hole Diameter
A — Tube Outside Diameter
B — Tube Inside Diameter
C — Tube Inside Diameter After Expansion
T — Tube Expansion Depth
L — Tube Plate Thickness
T1 — Tube Thickness Before Expansion
T2 — Tube Thickness After Expansion
E — Percentage Thinning

ALL DIMENSIONS ARE IN MM

THICKNESS BEFORE EXPANSION

\[ t_1 = \frac{A - B}{2} \]

THICKNESS AFTER EXPANSION

\[ t_2 = \frac{D - C}{2} \]

PERCENTAGE THINNING

\[ E = \left(1 - \frac{t_2}{t_1}\right) \times 100 \text{ \%} \]

\[ E = \frac{A + C - (D + B)}{A - B} \times 100 \text{ \%} \]

\[ C = \frac{E}{100} \left( A - B \right) + \frac{E}{100} (A - B) \]

\[ D - \left( A - B \right) + \frac{E}{100} (A - B) \]

\[ D - \left( \frac{100 - E}{100} \right) (A - B) \]

EXAMPLE:

BRASS TUBES OF Ø 13 X 1

D = 13.28 mm
A = 19 mm
B = 17 mm
E = 10 \%

THEORETICAL INTERNAL DIAMETER AFTER EXPANSION

\[ C = 19.28 - \left( \frac{100 - 10}{100} \right) (19 - 17) \]

\[ = 19.28 - 18 \]

\[ = 17.46 \text{ mm} \]

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ANNEXURE-II

**Fig. 1**

**Fig. 2**
BOILERS

1.0 Purpose

1.1 To provide general instruction and establish recommended procedures for rolling boiler tubes and seal welding boiler tubes in the field.

1.2 To furnish background information on the theory of tube expanding, and to highlight the factors which can influence the quality of a rolled joint.

1.3 These guidelines reflect what have been found over many years, to be a successful method of tube rolling. It should be stressed that by far the greatest percentage of problems experienced during tube rolling in the field are attributable to lack of attention to the most basic demands (or cleanliness, careful handling of components and proper equipment selection).

1.4 For specific data on given contracts, the Area in change should consult the engineering drawings, bills of material and other documents for that contract. These instructions are intended for use in erecting industrial boilers, but certain sections are adaptable for other types of work.

2.0 Tube Expanding:

2.1 The Theory of Tube Expanding:

2.1.1 The Process of Tube Expanding:

Tube expanding or rolling can be defined as the process of cold working the tube ends by means of a tool, usually a rotating expander, until that tube end has increased in size enough to fill a given space. Applied to boiler erection, tube rolling is performed with the intention of creating a strong mechanical bond and a pressure tight hydraulic seal between the tube end and the drum or header to which it is joined.

The operation of expanding a tube into a tube sheet or boiler drum consists of two stages. First, cold expanding the end of the tube...
until the outside surface of the tube is in contact with inside surface of the tube hole. This step merely serves to remove the commercial tolerance between the tube and tube hole, and adds very little to the final strength or hydraulic seal of that joint.

As the rolling action continues during the second stage of expanding, a further increase in the diameter is opposed by the metal of the tube sheet or drum with the result that a slight elastic deformation is imparted to the tube hole and a permanent or plastic deformation imparted to the metal of the tube. These changers provide the rolled joint with the following characteristics.

1. As the pressure of the expander is removed from the inside of the tube, the elastic properly of the tube hole metal tries to force the tube hole back to its original size.

   This action is resisted by the permanent deformation of the tube diameter, and thus a pressure is established between the two surfaces.

   The finish of the two surfaces determines the coefficient of friction, and this coupled with the pressure between the tube end and the tube hole determines the holding strength of the joint. A joint rolled to the maximum friction pressure possible, coupled with a maximum coefficient of friction is best able to withstand the stresses imposed upon it by the constantly changing operating conditions of a steam boiler in service.

2. With further increases of the tube end diameter resisted by the metal of the tube sheet, and the metal of the tube walls being displaced by the expander rolls, the voids and irregularities ever present in the contacting surfaces become filled and ideally form a water tight joint capable of withstanding test and operating pressures. The increasing rolling diameter of the expander rolls causes a further reduction in wall thickness of the tube and only a small
portion of the metal thus displaced can be accommodated radially in the tube wall and by the yielding of the tube hole metal. The excess portion causes the metal in the tube wall to now axially and manifests itself as an increase in length of the tube end metal in contact with the lube shed and cold worked by the action of the expander, thus pushing the tube proper along with it. For a practical example, suppose two headers me to be connected by straight tubes. Picking anyone of the tubes in position with both ends projecting say 3/8" through the header walls and making provisions at one end of the tube to measure any end movement, it will be found that expanding the other end will cause the loose end of the tube to move further into the header, the increase in tube length depending on the degree of rolling imparted to the rolled end. If the expanding should cease when this axial movement has reached say 1/16", the loose tube end will project 3/8" + 1/16" a total of 7/16". Measuring the tube projection at the rolled end will disclose, providing a parallel expander is used (non-flaring in this (else to make measuring possible) that this end projects 7/16" through the header wall also. This is an increase of 1/16", the same increase noted at the loose end, indicating that the axial movement of the tube metal of a rolled joint is due to the expanding operation and that the movement is in both directions and about equal the flow of metal in the middle of the lube sheet thickness being zero. This plastic axial flow of the tube metal has been termed "elongation".

2.1.2 Requirements of a Properly Rolled Joint

The major requirement of any joint is that during the life of the boiler it does not leak and it resists the stresses imposed by and incident to boiler operation.

An equally important, but often neglected requirement, is that all joints between two tube sheets be expanded uniformly.
It has been demonstrated that the same degree of expansion in a series of tube ends will produce joints of uniform strength provided that all other factors affecting joint strength remain equal. Also, once tube sheet spacing has been fixed, the elongation that must occur as a tube end is rolled tight causes stress to develop in that tube as well as others that the permanently fixed at both ends to the tube sheet.

The magnitude of the stress varies with the amount of elongation and if adjacent tubes are rolled to significantly different elongations, initial stresses may be set up which will exceed the holding strength of the joints affected.

The sequence in which tubes are rolled can also cause stresses to accumulate in other tubes, particularly short straight tubes or tack tubes resulting in premature failure. A boiler bank erection procedure should recognize that these stresses will develop and provide an installation sequence that will neutralize the accumulative effect of these stresses.

To develop the maximum holding strength from a joint, it must be first determined what amount of rolling is required to develop that strength. Destructive testing of rolled joints has shown that continued expanding of a tube after it has made contact with tube sheet causes the holding strength of the joint to rise quickly to its maximum, and then decline steadily with additional rolling. A joint rolled to its maximum strength will also be water-tight. Over-rolling a joint will significantly reduce its holding strength whereas hydraulic tightness mayor may not be affected. Having a minimum number of leaks at hydro is generally taken to indicate a good rolling in spite of the fact that the tubes may be rolled ill such a manner that many may give way at any time. Likewise, if the test discloses many leaks, it is considered poor rolling even though the leaks may be attributable to another problem.

Assuming that a boiler has been rolled uniformly to the proper degree of expansion, leaks discovered during hydro should
disappear with only a light re-rolling. Continued rolling will lead to a reduction in holding strength and should not be permitted. If a leak persists, seal welding might be advisable.

2.1.3 Measuring and Controlling Tube Expansion

As energy is expended during the rolling of a tube end, a number of changes take place to that tube which can be seen, and sometimes measured accurately. These changes include elongation of the tube, swelling of the lube just outside the area of roller-contact, flaking of mill scale around the tube hole and reduction in tube wall thickness.

For comparative tests of maximum holding strength to be of practical value, they must include a means to indicate the relationship existing between the degree of expanding imparted to a joint and the holding strength. To be acceptable for test purposes, any of these measuring methods must give reasonably accurate results, and to be of practical value, must also permit the easy duplication of such results in commercial tube rolling.

Measuring means in common use, follow two directions, namely, measuring power applied to obtain a particular degree of expansion or measuring work done.

The power required to expand a tube is affected by varying commercial tolerances in the tube wall thicknesses, variations in tube hole dimensions, and variances in the hardness of the tube and tube sheet.

The power may be measured by some means at the source or at the expander mandrel direct. Torque measurements are the most common method of measuring the motor power.

This will be discussed in more detail below.

Means to measure the work done consist of measuring the reduction in wall thickness, measuring the bulge at the edge of the roller contact area and measuring the elongation. In many cases, we do not expand the tube for full thickness of the tube sheet, thus
measuring the bulge at the edge of the roller contact area cannot be used.

The other two methods, either measuring the reduction in tube wall thickness or tube elongation are both recognized as valid measurements and will be discussed in detail below.

1.3.1 Percent Wall Thickness Reduction

During the process of tube rolling, the mandrel, while being driven deeper into the expander body, causes the rolls to compress the tube material tighter into the tube sheet. This results in thinning of the tube wall, which is better known as "wall reduction".

The percentage of wall thickness reduction can be determined very accurately by taking a series of measurements on both the tube end and the tube hole before and after rolling. Although less than practical for field use, this method is probably the closest to being a definitive rolling standard since it can be stated at what degree of expansion a lube has achieved maximum holding strength, and at what point a tube has been over-rolled. This method is recommended by a number of tool manufacturers and is generally used in scientific studies.

The percent of wall reduction can be calculated by using the following formulae:

\[ \text{ID} + (\text{TOD} - \text{OD}) + \%\text{WR} \times (2\text{t})/100 = \text{FID} \] (1)

Where

- \( \text{ID} \) = Initial inside diameter of tube
- \( \text{TOD} \) = Tube hole diameter, measured before insertion of tube
- \( \text{OD} \) = Outside diameter of lube, initial
- \( \%\text{WR} \) = Percent wall reduction
- \( \text{t} \) = Tube thickness, initial
- \( \text{FID} \) = Final inside diameter of lube
Further development of formula:

\[ \text{OD} - \text{ID} = 2t \]

Therefore, formula (1) becomes:

\[ \frac{\%WR}{100} + \text{TOD} - 2t = \text{FID} \]  

(2)

Solve formula (2) for wall reduction:

\[ \%WR = \frac{\text{FID} + 2t - \text{TOD}}{2t} \times 100 \]  

(3)

Tests have shown a wide range of wall thickness reductions to be acceptable, and that an inverse ratio exists between the wall thickness and needed percent reduction in wall thickness to obtain a properly rolled joint, i.e., as the tube wall becomes thicker, the necessary percent reduction in wall thickness becomes smaller.

For carbon steel boiler tubes in the thicknesses we are accustomed to dealing with, a wall thickness reduction of 7 or 8% is recommended to obtain optimum joint strength and hydraulic tightness.

A reduction of 20%, or greater will result in a joint of reduced holding strength with the possibility of leaking - an over-rolled joint. For production rolling, a wall thickness reduction of 10% ± 5% is considered acceptable.

This method has been described primarily to illustrate the relationship between joint strength and excessive rolling, and to present the accepted limits for an optimum and over-rolled joint. It is not recommended for frequent field use due to the time consuming and therefore expensive measurements that are required.

If, however, torque controlled equipment is to be used for rolling, the wall thickness reduction measurement is an excellent means to determine the job torque setting.
2.1.3.2 The Elongation method for Measuring

Measuring the elongation, or the amount the tube grows axially as the walls are thinned during expansion, also has a wide range of acceptable values. The factors affecting elongation are the tube wall thickness, the presence or lack of a serration or groove in the tube sheet, and the depth of roll. Elongation is a manifestation of the actual work done to produce the friction pressure between tube and tube hole contacting surfaces, and since actual work only is measured and the above variables are known prior to the start of expanding, all variable factors inherent in other means for controlling tube expanding are eliminated.

There is no need to take measurements prior to starting the work, and the elongation can be measured while the work is being performed. This we feel elongation is the most economical means available for field use of satisfactorily determining when a joint is properly expanded. Curves indicating the correct elongation have been established through experimentation and empirical work. Use of the elongation curves in actual practice has confirmed the validity of these curves. Thus, we feel elongation is for field use the most practical measure of the tube expanding and the use of elongation eliminates guess work rind individual preference.

As with the percent wall thickness reduction method, if torque controlled rolling equipment is to be used on the job, elongation measurements provide an excellent means to determine the proper torque setting.

2.1.3.3 Torque Control Tube Rolling

The principle behind torque control rolling is simple. When a given torque input is supplied to an expanding tool for a series of uniformly sized tube ends, the same amount of work is performed at each tube end, and the same degree of expansion is obtained. To obtain more expansion on any of the tube ends, torque input must be increased.
In practice, torque control techniques provide rolled joints of a very consistent quality and protection against over-rolling.

High quality electric torque control motors capable of rolling 4" OD tubes have been available since 1950, but for reasons that will be discussed later, electric equipment is not recommended for field use inside a boiler drum.

For condenser or heat exchanger tube rolling, however electric torque control equipment will produce excellent results and are recommended. There are also several mechanical clutch type or magnetic drive torque control rolling motors available from the expander manufacturers that will work very well.

If torque control rolling is to be used on a job, it is recommended that the specific job torque setting be established at least once a day for each device in use. A group of tubes should be expanded to the degree desired, and the torque selling on the machine producing that expansion would then be the job torque selling. Either the elongation or wall thickness reduction methods are used to determine that the proper amount of expansion has been reached.

2.2 Equipment Selection

2.2.1 Expander Selection

Various types of expanders are commercially available; however, those in common use in field assembled boilers are the parallel, self feeding type surfaces of the rolls in contact with the tube inside diameter are parallel and the individual rolls are mounted on the expander cage at a feed angle which allows the mandrel, at it is routed, to spiral deeper into the expander. As the tapered mandrel moves deeper, the rolls are forced further apart, thus increasing the effective diameter of the expander.

The expander, rolls, and mandrel for lube rolling are selected by considering the ID of the tube, the depth of roll or expanding length and whether the tube will be flared or not. in general, only
those tubes which will be seal welded are not flared. Expanders with odd number of rolls are preferred. They can adjust to minute differences in the tube thickness and any out of roundness of the tube inside diameters. When flare rolls are used, there should be at least two rolls.
**METHOD FOR DETERMINING EXPANDER LENGTH**

<table>
<thead>
<tr>
<th>Drum Thickness</th>
<th>Straight roll Expander</th>
<th>Flared Roll Expander</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upper Drum</td>
<td>Less than 2 1/2&quot;</td>
<td>Not Required</td>
</tr>
<tr>
<td></td>
<td>2 1/2&quot; or Greater</td>
<td>Drum Thickness</td>
</tr>
<tr>
<td>Lower Drum</td>
<td>Less than 3&quot;</td>
<td>Not Required</td>
</tr>
<tr>
<td></td>
<td>3&quot; or Greater</td>
<td>Drum Thickness</td>
</tr>
</tbody>
</table>

- It is recommended that a minimum of 1/4" be added to the expander length to compensate for tube protrusion into the drum.
- When the lower drum is between 2 1/2" and 3" thick, the same flared roll expander may be used in both the upper drum and the lower drum. The intent here is to reduce the number of different length expanders on a job when this condition is present.
- When the lower drum is more than 3" thick, a two step expanding procedure is used in the Lower Drum: the first steep requires a deep roll expander, without flare rolls, to close the annular space between the tube and tube hole. When the tube stops vibrating, the annular space is closed up. The second step is the final roll alone with a conventional expander with a 2 1/2" depth of roll and the usual flared rolls.

**Note:** Care should be taken not to flare tube end all the way to drum or tube sheet surface. Observe detail and dimensions on contract drawing.

Once the expander length and tube ID are known, the proper expander body, rolls, and mandrel can be selected from the expander vendors catalogue. Expanders with an odd number of rolls are preferred since they can adjust to minute differences in the
tube thickness and any out-of-roundness of the tube inside diameters. Tubes over 2 1/2" OD should use expanders with more than three rolls.

2.2.2 Expander Accessories
When expanding tubes in headers or other confined areas, various accessories may be necessary to drive the expander.

2.2.3 Drive Motor
Expander Driving Motors come in three basic categories air (pneumatic), electric, and hydraulic. When selecting your motor, consider the thickness of the tube wall and the OD of the tube. Also keep in mind the fact that expander drive sizes may vary (usually 3/4" or 1" and the motor chuck size selected should be compatible.

Air motors are generally preferred for field application. They are available for expanding tube to 5 inch diameter. These motors are heavy and require two people to operate. They do not overload as electric motors do; therefore, maintenance is reduced. The air supply to the motor must be adequate, dry, lubricated, and clean. Motor rotation will stop rapidly in an emergency and may be started much more smoothly them electric.

The exhaust of the motor should be arranged so it does not blow water and oil into the surface of the drum.

By selecting the properly sized rolling motor (or a specific application, it is possible to greatly reduce the chances of an over-rolled condition. Use the following chart to select a motor having torque output range that is compatible with the job. If, due to a large variance in tube size, it becomes necessary to order motors of different power outputs, restrict motor use to the size tube it is intended for.

The following is a general guide to the reversible air motors usually used.
<table>
<thead>
<tr>
<th>Motor Torque Ft. Lb.</th>
<th>Tube Wall thickness</th>
<th>Maximum Tube OD</th>
<th>Motor RPM</th>
<th>Motor Weight in lb</th>
</tr>
</thead>
<tbody>
<tr>
<td>200**</td>
<td>Under .200 to 2 1/2'</td>
<td>120</td>
<td>25</td>
<td></td>
</tr>
<tr>
<td>310</td>
<td>Under .200 to 3</td>
<td>150</td>
<td>36 1/2&quot;</td>
<td></td>
</tr>
<tr>
<td>400</td>
<td>.200 to .220 to 4</td>
<td>150</td>
<td>38</td>
<td></td>
</tr>
<tr>
<td>445</td>
<td>.200 to .220 10 4 1/2'</td>
<td>150</td>
<td>57</td>
<td></td>
</tr>
<tr>
<td>1225</td>
<td>Over 0.25 over 4</td>
<td>60</td>
<td>69</td>
<td></td>
</tr>
</tbody>
</table>

* With 90 lb. Air Pressure

** Corner-type molars for use in areas of limited access.

Electric Motors are available that will expand tubes up to 4 inch OD. However, we feel these motors are unsatisfactory for extended use in erecting boilers for the following reasons:

- Electrical shock hazard exists.
- Motor rotation will not stop immediately on release of the run button.
- Motors become overloaded on 3 inch high pressure tubes causing overheating of the motor and excessive downtime due to maintenance.
- Hydraulic motors will roll up to 5 inches in diameter and are available in two basic designs: one in which the motor is taken into the boiler drum and another in which the molar is mounted outside the drum and power is transmitted by a shaft into the drum.

### 2.2.4 Maintenance of Equipment

2.2.4.1 Before using an expander, wash all parts thoroughly, in any commercial solvent, making sure all dirt, grease, and girt is...
removed. It is desirable to keep all petroleum based lubricants off the inside surface of pressure parts since they are very difficult to remove during chemical cleaning.

2.2.4.2 Lubricate expander properly before using. Use a commercial lube rolling lubricant.

2.2.4.3 Wash expander thoroughly after each rolling operation with any commercial solvent or light non-petroleum oil.

2.2.4.4 Allow expander to cool in a solvent or light non-petroleum oil bath when it becomes hot. Whenever possible, use at least two expanders during a rolling operation. This makes it possible to have one cleaned of all foreign matter and to be cooling in a solvent or light non-petroleum oil bath for immediate use. This procedure will speed up the rolling job and at the same time, insure long service life for the expanders.

2.2.4.5 Replace scarred or chipped rolls or mandrels immediately. One small chip in a roll can cause a complete set of rolls and the mandrel to be damaged in a single rolling operation.

2.2.4.6 When the rolling job is completed, wash the expanders thoroughly and lubricate generously to prevent rusting while in storage. Prior to re-using, this lubricant must be removed.

2.2.4.7 The air motor should be inspected and put in proper operating condition prior to shipment to the job. Equipment, such as these air motors, designed to produce a torque of 200 fl - lb. or over, must be well maintained to sustain this type of performance.

2.2.4.8 Before using an air motor, ensure that you have an ample supply of clean dry air, with 90 psi pressure at the tool. Manufacture's literature about the motor you are using will list the proper air flow and hose size needed.

2.2.4.9 Moisture in compressed air lines can be damaging to air tool performance. It pays to take steps to remove it. Water in the air supply tends to wash away lubricants in air motors. It also can cause corrosion of internal parts. In cold weather, moisture in the...
air can form ice in the tool’s air passages which slows down or completely stops an air tool. Use of excessively wet air results in water shooting out of the air tool’s exhaust. This is unpleasant to the operator and can be damaging to the work.

Individual moisture separators should be installed at the end of each pipe line connected to an air tool hose.

Most of the moisture can be removed at the compressor before it enters the piping system. This is done by installing an after cooler and a moisture separator in the air compressor discharge line between the compressor and the air receiver tank. The after cooler should cool the compressed air to a temperature just below the lowest temperature anywhere in the distribution piping system. This cooling will condense the moisture out of the air. The condensed moisture and compressed air then pass through the moisture separator which removes most of the water and delivers relatively dry air to the air receiver and distribution lines. After coolers and moisture separators are not standard equipment on most air compressors but can be obtained from all air compressor manufacturers.

2.2.4.10 Individual lubrication requirements of air tools vary widely, and specific instructions for each type tool should be followed. In general, most rotary vane type motors require the use of a light oil similar to SAE #5 or #10W or good grade of spindle or turbine oil. Heavier oils, unless specifically recommended, will cause sticking and sluggish performance. Many air tools have built in oil reservoirs to provide continuous lubrication; however, it is often difficult to provide adequate supervision to assure that these reservoirs are kept filled.

A widely used and highly recommended method of measuring proper air tool lubrication is to install air line lubricators at the end of each pipe line leading to an air tool hose. This line lubricators mixes a small amount of oil with the compressed air.
This adequately lubricates all parts of most air tools except portions of a tool requiring a grease type lubricant.

Its permanent location makes it easy to find, and it is more likely to be kept filled by the person assigned to oiling. Care must be taken not to over-lubricate, such that the lubricant is exhausted on to the pressure parts inner surface.

2.3 Expanding Instructions

2.3.1 Practice

2.3.1.1 The actual mechanics of tube expanding is more nearly an art than a science. The only way to assure a properly rolled tube is by having qualified supervision directing experienced mechanics who have developed a feel for a properly rolled joint. As an aid to developing and maintaining this feel, we recommend that a dial indicator be used to measure the elongation on about 10% of the tubes (Step 2.3.2.). The mechanic should be monitored (or consistency by measuring elongation on a group of tubes, in the morning.

After the tubes have been installed and proper stock set, expanding may proceed. When a deep roll is required to close the annular space, a deep roll expander with a stop flange is set in the tube with the stop flange about 1" to 1 1/2" away from the tube end. When the tube has been expanded sufficiently to close the annular space, the tube will stop vibrating and the rolling motor will start to slow down and the expander should have fed in enough to cause contact between the stop flange and the tube end. Reverse the rolling motor and back out the expander.

Caution: Do not continue to roll after the tube has stopped vibrating. This is an indication that the annular space has been closed and the first stage of rolling is complete. This is a touch roll only, excessive rolling at this time may interfere with elongation measurements and the next stage of rolling.

2.3.1.2 When the tube is tight in the tube hole, i.e., it has stopped vibrating, the dial indicator, should be set to measure the
elongation. It is recommended that about 10% of the tubes be checked by elongation.

2.1.3 The hard roll is performed by inserting the expander so the bottom of the flare rolls are about 3/4" from the tube end. The tube is then expanded to the correct degree. The flare rolls should have engaged the end of tube and created a flare on the tube so the outside diameter of the flare is at least 1/8" greater than the diameter of the tube hole. If the tube was fully expanded before the flare rolls engaged, reset the expander so the flare rolls are at the end, and roll the flare onto the tube end.

2.3.1.4 During the assembly of the boiler and particularly during the rolling operation most important to keep the internal surface as clean as possible. Special care should be taken not to introduce dirt, petroleum-based products or other foreign substances to accumulate inside tubes, headers or drums. Keep openings closed at all times when not required for working areas.

2.1.2 Measuring Elongation

Since elongation takes place axially in both directions, it may be measured relative to the tube sheet and at either side of same. However, the rotating expander usually precludes any measuring at the front and elongation measurements are therefore preferably taken at the back of the joint which is the gas side of the drum on water tube boilers. Various measuring means may be employed, but perhaps the simplest is an ordinary dial indicator clamped to the tube with the point of the spindle in contact with the boiler drum. It must be remembered that the elongation pushes the tube proper along with it, thus the axial movement of the tube relative to the tube sheet registered by the dial indicator will coincide with and will therefore represent the elongation. Holding the tube in its correct position, expanding is then started. During the first stage of the expanding process, the tube is loose in the tube hole, consequently the operation of the expander causes the tube to vibrate, the vibration being transmitted through the spindle to the
needle on the dial indicator. The instant that the outside surface of the tube contacts firmly with the inside of the tube hole, the needle of the indicator becomes quiet and remains so until the irregularities of the tube and the tube hole surface are wholly or partially filled. Any movement of the indicator needle after the beginning of this period of quiet represents the elongation or axial flow of the tube metal. This axial tube movement or elongation varies with and is a measure of the degree of expanding.

Some selected elongation figures are given below.

<table>
<thead>
<tr>
<th>Tube OD</th>
<th>Depth of Roll</th>
<th>Tube Wall Thickness</th>
<th>Recommended Elongation</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.00&quot;</td>
<td>2 1/2&quot;</td>
<td>.110</td>
<td>.019</td>
</tr>
<tr>
<td></td>
<td></td>
<td>.125</td>
<td>.022</td>
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<tr>
<td></td>
<td></td>
<td>.135</td>
<td>.023</td>
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<td></td>
<td></td>
<td>.150</td>
<td>.026</td>
</tr>
<tr>
<td></td>
<td></td>
<td>.165</td>
<td>.029</td>
</tr>
<tr>
<td></td>
<td></td>
<td>.180</td>
<td>.032</td>
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<td></td>
<td></td>
<td>.200</td>
<td>.035</td>
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<tr>
<td></td>
<td></td>
<td>.220</td>
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</tr>
<tr>
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<td></td>
<td>.240</td>
<td>.044</td>
</tr>
<tr>
<td></td>
<td></td>
<td>.260</td>
<td>.047</td>
</tr>
<tr>
<td>2.50&quot;</td>
<td>2 1/2&quot;</td>
<td>.120</td>
<td>.021</td>
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<td>.035</td>
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<td></td>
<td></td>
<td>.240</td>
<td>.046</td>
</tr>
<tr>
<td></td>
<td></td>
<td>.260</td>
<td>.048</td>
</tr>
</tbody>
</table>

Prepared by: C. P. Giri
Sr. Manager

Reviewed & Approved by: A. M. RAO
Head/Projects
Selected Elongation Figures

2.2.3.1 A properly expanded joint Gill fail in operation due to many external forces. Since the drum's tube sheet and the tubes have substantially different thicknesses, the tube heats up and cools down much quicker than the drum. A rapid change of temperature, such as that caused by a lower water casualty or spraying a hot drum with a fin hose to hasten cooling, can cause the tube to cool more quickly than the drum, thermally contract faster than the drum, break the seal between the surfaces and leak. Vibrations, puffs and externally applied leads can also break the tube to tube sheet seal.

3.0 Seal Welding of Boiler Tubes to Tubesheet

3.1 When to Use

Seal Welding is not normally performed during the erection of new units, and should never be attempted without prior approval from Engineering. In some cases, however, as noted below, seal welding may become necessary or even desirable.

3.1.1 Customer Request

Based on a customer's past experience with his own unique operating conditions, or solely on performance, that customer may specify that all boiler tubes be seal welded. In this case, the tube rolling diagram will also contain the necessary welding information.

3.1.2 Defective or Poorly Rolled Joint

It is not unusual during the hydrostatic pressure test to find a few rolled joints that "weep" or leak a small amount of water, but this situation is normally corrected by re-rolling the leakers. If the water loss can not be stopped by re-rolling, or if there is a danger of over-rolling, it may become necessary to seal weld those joints only.

When a pre-assembled boiler is shipped to a job site, it is likely that stresses or vibration suffered during loading or
transportation will have caused some of the rolled joints to loosen. If these cannot be repaired by re-rolling, then seal welding will be required.

3.1.3 Tube Repair on Maintenance

When, for some reason, it becomes necessary to remove a rolled joint from either a new or operating boiler, there is an increased likelihood of the replacement joint leaking and thus requiring seal welding. This is a result of striations left on the surface of the hole while pulling the end of the tube through, or possible deformation of the tube hole during the initial rolling.

3.2 Instructions for Seal Welding

3.2.1 Seal welding can be performed on either the inside or outside surface of the drum.

3.2.2 Tubes that mare to be seal welded on the inside drum surface should be hard rolled first, and then seal welded. Do not flare those tube ends.

Tubes to be seal welded on the outside drum surface should be hard rolled, flared, and seal welded. In both cases, the joint should be lightly re-rolled after seal welding.