PALO VERDE
NUCLEAR GENERATING STATION

Mechanical Maintenance Training
Heat Exchanger Tube Maintenance
Classroom Lesson

Mechanical Maintenance Training	**Date: 6/15/2010 11:21:18 AM**
LP Number: NMD40C000303	**Rev Author: GARY KEENEN**
Title: Heat Exchanger Tube Maintenance	**Technical Review:** Kleinman, Dean W(Z56639) Digitally signed by Kleinman, Dean W (Z56639) DN: cn=Kleinman, Dean W(Z56639) Reason: I have reviewed this document Date: 2010.06.15 12:38:52 -07'00'
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INITIATING DOCUMENTS

Task Analysis of Tasks

REQUIRED TOPICS

None

CONTENT REFERENCES

Handbook of Heat Transfer, edited by Warren M. Rohsenow & James P. Hartnett, 1973, McGraw-Hill, NY, NY.

Heat Exchangers: Design and Theory Sourcebook, edited by N.H. Afgan & E. U. Schunder, 1979, McGraw-Hill, NY, NY.

Heat Exchanger Introduction, 1993, Williams Learning Network, Rockville, Maryland

M400-0301-00049; Tech Manual, Moisture Separator Reheater

31MT-9ZZ19: Tube Plugging of Secondary System Heat Exchanger Components.

CRDR 2625306 During a leaking tube search, the tube stabilizing cable came out of the tube and hit a platform about 20 ft. away.

CRDR 2625309 During U2 plant startup on 07/31/2003, personnel became overheated while working in the 2A condenser waterbox.

TCSAI 2740095 Include more specific info in lesson plan supporting review questions.

LESSON PLAN REVISION DATA

Jun 15, 2010	Mark Tague	Incorporated TCSAI 2740095.

Tasks and Topics Covered

The following tasks are covered in Heat Exchanger Tube Maintenance :

Task or Topic Number*	**Task Statement**
Lesson:	Heat Exchanger Tube Maintenance
HXCH001	Maintain Heat Exchangers

Total task or topics: 1

TERMINAL OBJECTIVE:

1 Given a heat exchanger maintenance activity the Maintenance Mechanic will , describe the methods used to locate leaking tubes, and to plug/rework/replace the heat exchanger tubes, as demonstrated by achieving a minimum score of 80% on a written examination.

1.1 Identify the common causes of heat exchanger tube leakage.

1.2 Describe the varied methods that can be used to locate leaking tubes heat exchanger.

1.3 Describe the general method used to plug leaking heat exchanger tubes.

1.4 Describe the method used to plug leaking Feedwater Heater tubes.

1.5 Describe the method used to plug leaking Main Condenser tubes.

1.6 Describe the method used to plug leaking Moisture Separator/Reheater tubes

1.7 Describe the methods of removing tubes from heat exchangers.

1.8 Describe the method used to replace tubes in heat exchangers

1.9 Describe the process of rolling tubes in tube sheets

1.10 Describe the general procedure to replace a heat exchanger tube bundle

CONTENT	METHODS & ACTIVITIES
I. Motivation	Focus student attention on "What's In It For Me".
II. Pre-Job Brief	
A. <u>Pre-job briefing</u> on the day's activities modeling the use of the ***Palo Verde Standards & Expectations, Preventing Events***	
B. Focus On Five (Task Preview) Familiarize worker with the scope of work, task sequence, and critical steps.	
1. Critical Steps (Terminal Objectives) Given a heat exchanger maintenance activity the maintenance mechanic will describe the methods used to locate leaking tubes, and to plug/rework/replace the heat exchanger tubes, as demonstrated by achieving a minimum score of 80% on a written examination	PVNGS Standards & Expectation book (Focus on five) Highlight the critical steps (Terminal Objectives) on the power point presentation.
2. Identify error likely situations (error traps) a. Discuss at least one specific error likely situation.	(Look at Error Precursors in S&E book)
3. Identify the Worst thing that can happen.	Apply to the setting you're in. (Lab versus Classroom)
4. Identify specific error prevention defenses to be used.	What defenses can we employ to prevent the "Worst thing that could happen"
5. Identify actions to assure proper configuration control.	This may not be applicable in every training setting.
C. Break policy	
1. Two Minute Drill - After lunch at a minimum	At Instructor's discretion, not to interrupt class flow.

CONTENT	METHODS & ACTIVITIES
III. Lesson Enabling Objectives	Read and/or discuss the lesson objectives

- EO01 Identify the common causes of heat exchanger tube leakage.
- EO02 Describe the methods used to locate leaking heat exchanger tubes.
- EO03 Describe the general method used to plug leaking heat exchanger tubes.
- EO04 Describe the method used to plug leaking Feedwater Heater tubes.
- EO05 Describe the method used to plug leaking Main Condenser tubes.
- EO06 Describe the method used to plug leaking Moisture Separator/Reheater tubes.
- EO07 Describe the methods of removing tubes from heat exchangers.
- EO08 Describe the process used to replace tubes in heat exchangers
- EO09 Describe the process of rolling tubes in tube sheets.
- EO10 Describe the general procedure to replace a heat exchanger tube bundle.

TO: 1 **Given a heat exchanger maintenance activity the Maintenance Mechanic will , describe the methods used to locate leaking tubes, and to plug/rework/replace the heat exchanger tubes, as demonstrated by achieving a minimum score of 80% on a written examination.**

EO: 1.1 Identify the common causes of heat exchanger tube leakage.

Main Idea

CONTENT	METHODS & ACTIVITIES

I. Leak Locations

  A. Most common is at or near the tube-to-tubesheet junction

    1. Most turbulent flow at inlet of the tubes

    2. Dissimilar metals between tube and tube sheet

    3. Seal weld, packing, or rolling may not seal completely

  B. Also in an area where the outside fluid (if high velocity) could erode the tubes where it enters the shell side

  C. Foreign material could cause leakage anywhere along the tubes

  D. Shock (like water hammer) could create a leak anywhere in the heat exchanger

II. Erosion of the tube by the fluid flow in the heat exchanger

  A. Shell sides if baffles are not in place or have been broken

CONTENT	METHODS & ACTIVITIES

B. Tube side due to turbulent flow

Example:

1. In the main condenser, Westinghouse welded **stainless steel plates** to the **carbon steel support stanchions** to deflect the incoming high energy fluid from directly impinging on the tubes
2. The **dissimilar thermal expansion rates** of the carbon and stainless steels caused the welds to break
3. **Pieces of plate were blown into the tubes** puncturing them and the high-energy fluid then directly eroded the tubes causing more damage

III. Corrosion of the tubes

A. Improper chemistry control

B. Excessive stresses

1. Example: We are experiencing linear crack failures in the feedwater heater tubes.
2. It is stress corrosion cracking caused in part by the different thermal expansion of the stainless steel tubes and the carbon steel shell of the heaters.

C. Failure or inadequate cathodic protection

1. Failure to maintain sacrificial anodes

CONTENT	**METHODS & ACTIVITIES**
IV. Mechanical shear	
A. Shear caused by failed structural members	
Example:	
1. Low pressure feedwater heaters in the top of the condenser originally had stainless steel lagging on them held away from the surface by spot welded studs	
2. Their purpose was to provide some insulation to prevent heat loss from the heater	
3. Vibration loosened them and then the studs started puncturing them allowing more vibration	
4. The weakened and perforated pieces started breaking off and sheared tubes in the main condenser	
B. Shear caused by foreign objects in heat exchanger	SOER 82-12 Steam Generator Tube Ruptures
1. R. E. Ginna Plant. On January 25, 1982, a steam generator tube rupture occurred at full power conditions	
a. Reactor coolant system pressure decreased rapidly, causing a reactor trip on low pressure and initiating safety injection	
b. The “B” SG safety valve opened five times during the event, once for approximately an hour	
c. Finally, operators managed to cool down the RCS using the ADV’s on the good SG.	
d. CAUSE: A loose metal object caused the tube rupture	

CONTENT	**METHODS & ACTIVITIES**

e. This rupture had an estimated leak rate of 630 GPM through a ¾” by 4” long axial fishmouth that was approximately 3” above the tube sheet.

2. Prairie Island 1. On October 2, 1979, while operating at power a steam generator tube rupture event occurred

   a. A steel coil spring punctured the tube

   b. Resulted in a leak rate of 390 GPM through a ¾” by 1 ½” long fishmouth that was also located approximately 3” above the tube sheet

3. Both of these incidents occurred from loose metal objects in the secondary side of the steam generator, introduced by

   a. Failed mechanical components from the feed and condensate systems being carried into the SG

   b. Tooling or other foreign objects left in the system after maintenance

V. Vibration induced mechanical failure

A. The main condenser tube support stanchions are spaced about three feet apart

B. This is too far to prevent vibration

1. The vibration causes thinning of the tubes at the tube support plates

2. To prevent tube failures, plastic cushions have been inserted between the tubes to dampen vibrations

CONTENT	**METHODS & ACTIVITIES**
VI. Tube to tube sheet leaks	
A. Packing leaks on heat exchangers with packed tubes	PPT Slide # 58
B. Leaks from rolled tubes	
1. Tubes rolled less than optimum amount of tube wall reduction do not have sufficient holding power	Briefly describe here and mention that the how to of rolling tubes will be covered later in the lesson.
2. Tubes over rolled have excessive tube wall reduction and have experienced excessive work hardening	
C. Weld failures or cracks	
1. Heat exchangers with welded tubes may experience weld failures due to:	
a. Excessive stresses both mechanical and thermal at the welded joint	
b. Corrosion – stress cracking corrosion at the weld	
VII. Leaks from floating tube sheet connections	
A. Gasket or O-ring failures	
B. Scale/foreign material	
VIII. Generic indications of a leaking tube in a heat exchanger	
A. Increasing or decreasing inventory for one of the fluids	

CONTENT	METHODS & ACTIVITIES
B. Alarm indication if associated with any of the fluids under leak detection	
1. Nuclear cooling water has a radiation monitor to detect leakage	
2. TDS alarm in feedwater in case of main condenser leak	
IX. Indications of minor tube leakage in steam generators	PPT Slide #59
A. Main steam line radiation high	
B. Condenser off gas radiation high	
C. Steam generator blowdown radiation high	
D. Charging/letdown flow mismatch	
E. Decreasing VCT level	
F. Secondary side sample activity high	
X. Indications of leak in main condenser	These indications will be seen in the control room. PPT Slide #60
A. An increase on any hotwell sodium indication	
B. A corresponding increase in hotwell cation conductivity	
C. An auto isolation of the condensate reject valve due to conductivity	
D. There may be an increase in the hotwell level depending on the size of the tube leak	
XI. Besides internal leakage in heat exchangers, external leakage may occur	

CONTENT	METHODS & ACTIVITIES
A. External leakage may result in flooding as covered in SOER 85-5	Operating Experience
1. Crystal River 3 – With the unit at 100% power, one of the service water heat exchangers was opened up for maintenance. A solenoid valve failed, which failed a fourteen-inch air actuated heater supply valve open. The flooding from the disassembled heat exchanger was estimated at 65,000 GPM and flooded the turbine building to a level of six inches in approximately five minutes.	
B. Palo Verde has had its share of flooding incidents	Operating Experience
1. August 14, 1986, Unit 1 – The main circulating water system was being returned to service following some condenser inspections and repairs. The manways on the south side of condenser 1A had been verified secured; however, when the system was started an estimated 50,000 – 100,000 gallons poured out of the manways flooding the turbine building to a level of four to five inches. It was believed that the manways were not properly secured.	
C. Flooding is a safety concern because it can disable safety equipment needed to safely shut down the plant	
1. The damage caused by flooding can be wide spread and occur over a short period of time.	
2. Ensure permits in place <u>for the correct side of the heat exchanger</u> prior to opening Prevent Events – Ensure permit is for the correct side of the condenser.	

CONTENT	METHODS & ACTIVITIES
D. Personnel need to be aware of the impact flooding could have on the plant	
1. Could affect the safe operation of the plant	
2. Which evolutions increase the vulnerability to flooding	
3. Areas and equipment susceptible to flooding	
4. Methods to reduce the risks and effects of flooding	
5. Operator actions to prevent/control flooding	

EO: 1.2 Describe the varied methods that can be used to locate leaking tubes heat exchanger.

Main Idea

CONTENT	METHODS & ACTIVITIES

I. General information

A. The method of locating tube leaks depends on the system and the characteristics of the fluid that is leaking and the size of the leak.

B. Test procedures for locating leaks may be implemented during the course of normal operations at prescribed times in the life of the plant

C. PVNGS uses several methods of monitoring and locating heat exchanger tube leaks

1. Ops engineering uses eddy current testing

2. Systems engineering uses methods that include helium monitoring

3. Major leaks in the condenser tubes can be found just by listening, you can hear it whistling.

4. Plastic film

5. Soap bubbles

CONTENT	**METHODS & ACTIVITIES**
6. Rubber duckies in the Main Condenser	
7. Caution:	
a. If plugs (or ducks) are used to identify leaking holes, they can be blown off when pressure increases in the tubes Prevent Events- Stand clear when pressuring and keep others away from plugged tubes.	Ask them to identify a tool they would use to prevent this from happening
b. Leak location will no longer be identified	
c. Ensure the identification process matches the conditions	
II. Helium testing	
A. General	
1. This is the use of an inert gas introduced into the system and then monitored by some device.	
2. The usual monitoring is by gas spectroscopy to determine the presence of the inert gas that is used to detect the leak	
3. Helium leak detection of main condenser tube leaks is commonly performed with the unit running but downpowered and vacuum in the condenser	
B. Set up	
1. The detector is connected to the vacuum pump discharge	
2. A small syringe of helium is injected in a valve connection on the shell side of the condenser (test shot)	

CONTENT	METHODS & ACTIVITIES
3. This tests the detector and gives an indication of the time delay of detection	
a. Usually there is a 30 second or more delay from the test shot until detection	
C. Enter water box and start wide area testing	
1. Set up communications with personnel at the helium detector	
2. Start at the top and start spraying the tubes going in a pattern and shooting every tube.	
3. As soon as the detector sees something:	
a. Stop, mark the area shot in the last 30 seconds or so, and let the detector clear.	
b. Mark is not by a plug because it is under pressure and could dislodge the plug Hazard Assessment- Plug could become a projectile.	
c. It usually takes a while for the detector to clear, so it is a good time to come out of the water box and cool off.	
4. Once the detector has cleared, start again by shooting one tube at a time in the area marked and waiting approx. 30 seconds for detection.	
5. When the leaking tube is found, double check it being careful that only the tube being tested gets helium.	The detector is very sensitive and may pick up background helium from adjacent tubes.
a. Good ventilation with copus blowers helps clear out background helium.	

CONTENT	METHODS & ACTIVITIES
6. Mark the tube and start the rapid detection process again	
a. Continue until all the tubes have been checked	
b. Again, mark is not by a plug Prevent Events – Do not disturb any plugs when marking a tube as this might cause the plug to dislodge.	SME Identified Prevent Events tool – identify tool
III. Some systems have alarms associated with them to detect a leak across the heat exchangers.	
A. Radiation monitors on the main steam system	
B. Sodium monitoring on the main condensers	
IV. Eddy current testing	
A. The manufacturer recommends that testing of the steam generator tubes be done periodically	Note that because of faults found, we do it every outage
B. The test is performed by the use of an electronic test device that has a probe	
C. The probe is mechanically pushed through the tubes and an electrical signal is generated (eddy current) and monitored to give a graphic indication of the tube	
D. The graphic interpretation of the tube is compared to a series of test standards that were made on the same type of material as the tubes being tested	
E. This will determine the amount of wear, erosion or damage to the tubes	

CONTENT	METHODS & ACTIVITIES
V. Soap film	
A. A soap solution or other high surface tension solution is applied to tube ends	
1. Both ends of the tube must be painted at the same time	
2. Soap film is only reliable for about five minutes	
3. Recognize the additional slippery footing conditions when using the soap bubbles	
Hazard Assessment- Pay attention to the area as this is an opportunity to experience a slip or fall.	
B. The shell side of the heat exchanger is then pressurized or placed under a slight vacuum	
C. The bubble film on leaking tubes will be disturbed	
1. A burst bubble or sucked in film is not a positive indication of tube leak.	
2. This type of test has to be repeated to verify that the film was disturbed by a leak and not other causes	STAR self checking
VI. Plastic film material testing	
A. A slight vacuum is applied to the shell side of the heat exchanger	
B. A plastic film material is placed on the tube sheet	
1. The thin slick brown trash bags used here are made of the type of plastic that works very well	
C. A leaking tube will be indicated by a depression of the film material	

CONTENT	METHODS & ACTIVITIES
D. This method does not work well on the main condensers because the tubes are not flush with the tube sheet.	
VII. Ultrasonic testing	
A. This is the use of ultrasonic sound to get a graphic picture of the tube	
B. This system works on the concept that sound will travel through the material of the tube	
C. Imperfections or flaws in the tube will change the sound transmission	
D. The changes in the sound are compared to a standard and the status of the tube can be determined	
E. This type of testing requires qualified personnel and test standards for comparisons	
1. Test personnel must be able to interpret the test results	
2. Questionable results have to be retested	
VIII. Mark identified leaking tubes	STAR
A. Marking of the leaking tubes will have to be done to ensure the correct tubes are plugged	
Prevent Events- Do not disturb other plugs when marking any given tube.	
B. Method of marking will be controlled by several factors	
1. Materials of the tubes and tube sheet	
2. Fluids used in the heat exchanger	
3. System cleanliness requirements	

CONTENT	METHODS & ACTIVITIES
4. Chemical use permit	
5. Pressures	
C. Examples of marking materials	
1. Oil-based paints	
2. Water based paints	
3. Chalk	
D. Use of templates	
1. Grid markings or the use of a template can help to ensure the correct tube is marked on <u>both</u> ends of the heat exchanger	STAR, PPT Slide #59
2. These are also necessary for U-tube heat exchangers	
E. Mechanical means for marking tubes	
1. A temporary plug (rubber stopper) can be inserted in the tube	
a. Cannot be used where a potential for shell side pressure to increase exists	SME Identified Prevent Events tool - Ask them to identify a tool they would use
b. Could blow out plug	
2. The use of a prick punch to mark the tube sheet at the ends of the tubes	
3. Etch marks can be placed on the tube surface	

EO: 1.3 Describe the general method used to plug leaking heat exchanger tubes.

Main Idea

CONTENT	METHODS & ACTIVITIES

I. Concerns for plugging tubes in heat exchangers

  A. Plugging tubes reduces the operational capacity of the heat exchanger by reducing the heat transfer area

  B. The manufacturer has a specification for the percentage of tubes that can be plugged without a major degradation of heat exchanger efficiency

  C. When tubes are plugged in a shell and tube heat exchanger, care must be taken if hydrostatic testing of the shell side must be done

    1. Plugs may be blown out if they are subjected to high differential pressure

II. When tubes are plugged, both ends of the tube must be plugged to isolate the tube from the fluids

  A. Several methods are available to ensure that the correct tube is plugged at both ends

  Prevent Events caution – self and peer checking

    1. For straight tubes, one end of the tube sheet can be marked and a light source can be utilized to ensure that the correct tube is plugged at the other end

    2. Grid marking sheets or templates can be used to correspond the tubes in a U-bend heat exchanger

CONTENT	METHODS & ACTIVITIES
a. Marking templates can be verified during eddy current testing by noting the position of the eddy current probes on both ends	
b. The templates can also be verified during tube lancing	
3. The use of low pressure air can be utilized to verify the tubes	
B. Ensure proper size plug	
Use Self Check/ Peer Check to verify proper plug size.	
1. The same equipment in different units may not have the same size tubing and plugs	
2. Use current drawings, not previous experience from another unit	
III. There are other methods of tube repair available	
A. Sleeving	Note that sleeving only works on straight sections of tube
1. This is the installation of a short piece of tube into the weakened or leaking tube	
2. This is for tubes that are weakened or leaking at the shell side of the tube sheet/tube interface	
3. The tube sleeves are rolled into place for the seal	
4. The ends of the sleeves can be seal welded at the tube I.D. and tube sheet face for a positive seal	
5. This is considered as only a stop gap measure, and replacement options should be considered when practical	

EO: 1.4 Describe the method used to plug leaking Feedwater Heater tubes.

Main Idea

CONTENT	METHODS & ACTIVITIES
I. Feedwater heater tech manual contains a procedure for plugging tubes	
A. Follow safety rules	
1. Permits Use Self Check/Peer Check to ensure permit is established and adequate.	
2. 3-leg communication to plug the right hole	
3. Remember the mirror image concept	
B. Tube is prepared to ensure the plug will seal properly	
1. Leaking tube is drilled out to the tube sheet diameter to a depth of 1.125”, preferably with a four fluted drill	
2. Clean and dry the tube sheet hole with an approved solvent to ensure all lubricants and metal particles are removed	
3. Wire brush the tube hole and remove any oxidation from the tube sheet around the hole	
C. Clean and prep the thimble plug	PPT Slide # 61
1. The plug may have to be machined to length, to recess the tube 1.125” below the tube sheet surface	
2. The thimble is belled such that there is a good fit to the tube hole ID	

CONTENT	**METHODS & ACTIVITIES**

D. Install plug

1. Drive the plug into the tube sheet

2. Weld in place using an approved welding procedure

II. LP Feedwater Heaters use a different plug type

A. Solid, tapered, stainless steel plug

B. Drilled and tapped on the backside

C. Allows using a driving tool to insert it

D. Allows for removal at a later date

III. Use of other types of tube plugs, welded or non-welded, must be approved through engineering

IV. Palo Verde Event [CRDR 2625306]

A. Unit 2 LP FW heater 2C was opened for leaking tube search. On 8/1/2003 at about 1:00 AM, employees were getting ready to test north side of tubesheet with smoke to detect leak.

1. RP just surveyed the internals of the heater.

2. Air blower was turned on to establish conditions for confined space. The heater was hot as a few hours prior the unit was synchronized to grid.

B. The air blower's yellow hose was put inside the heater to cool off the space a little. Hot air was being expelled from the north side of the heater when the hose was put inside the heater.

C. A few seconds later pop was heard and stream of steam come out of the heater. When noise abated it was realized that tube stabilizing cable come out of the tube, too.

CONTENT	**METHODS & ACTIVITIES**
D. The cable went straight out of the heater and hit a platform about 15-20 feet away. The cable was expelled from tube 47-16. It is suspected that the plug in tube 47-16 was leaking slightly and water accumulated in the tube during operating cycle.	
E. The tube is exposed to pressure of about 450 psig, and it probably had this kind of pressure when heater was opened.	
F. The north plug was barely "hanging on" in the tube, and when it cooled off a little, it shrunk and was expelled. The cable was expelled with the stream of water and steam.	
G. This incident is reported as a close call.	

EO: 1.5 Describe the method used to plug leaking Main Condenser tubes.

Main Idea

CONTENT	METHODS & ACTIVITIES

I. Follow all safety precautions

   STAR-Use Prevent Event tools to verify conditions are safe to work.

   A. Permits

      Use Self Check/ Peer Check to ensure Permit is established and adequate.

   B. Changing plant evolutions

II. Following tech manual instructions, the plug to be used is driven into the tube/tube sheet joint

   A. Westinghouse recommends using a thimble plug

   B. Use light hammer blows to tap the plug firmly into place

III. Engineering has approved the use of rubber expansion plugs

   A. The older style of rubber plug (reddish brown) has not held up very well

   B. Being replaced by the newer long black plugs

EO: 1.6 Describe the method used to plug leaking Moisture Separator/Reheater tubes

Main Idea

CONTENT	METHODS & ACTIVITIES
I. Follow all safety precautions	
A. Permits	
Use Self Check/Peer Check to ensure permit is established and adequate.	
B. Changing plant evolutions	
Ensure communications are clear and thorough so all involved are aware of plant conditions.	
II. General Information	
A. The tech manual contains a recommended procedure for plugging the tubes; however, the approved process will be provided in the work order	
B. The MSR tubes must be severed behind the tube sheet to prevent plugged cold tubes from interfering with the thermal expansion of the remaining tube bundle	
C. Because of the shape of the tube bundle header, a segmented tube severing tool may be needed, GE supplies a special tool for this purpose that includes:	
1. An air motor for operating the tool	
2. A reamer attachment	
3. Extra cutters	TO09
4. Extensions	

CONTENT	METHODS & ACTIVITIES

5. A hand taper reamer

III. Set up the severing head

A. The tool head is inserted in the tube and the next segment is screwed to it

B. Each segment is attached and inserted until the tool extends past the tube sheet ¼” to ½”

C. Remove severing head to prep tubing

IV. Prep tubing

A. Use the taper reamer to clean up any weld roll over at the tube sheet/tube I.D.

B. Check the fit of the tube plug, it should insert fully in the tube.

1. This is necessary as the plug must perform two functions

a. The plug has to plug the tube

and

b. It must also hold the tube in place after the tube is severed.

2. If it doesn’t, use the straight reamer to size the tube

3. The reamer head replaces the severing head for reaming operations

V. Reassemble the severing head

A. Assemble the drive shaft with the double male thread shaft attached to the mandrel and cutter head

1. Hand tighten joints

CONTENT	METHODS & ACTIVITIES
2. excessive tightening will make it harder to disassemble	
B. Assemble the body sections by sliding them over the mandrel drive shaft and lightly tighten them	In tight areas the cutter may have to be assembled in the tube
C. The hex driver end, spring and thrust collar are assembled as a unit last	
D. Ensure the cutter length from the thrust collar is correct, by checking the tube sheet dimension at the tube location in the tech manual	STAR
E. Check the tool operation by pushing on the hex drive	
1. See that the cutters extend	
2. Release the drive and ensure they retract	
3. The cutter must be set to cut the tube ¼” to ½” behind the tube sheet	
VI. Cut the tubing	
A. Insert the tool fully	
B. Attach the air motor	
C. Start cutting	
1. Operating the motor while pressing against the spring loaded driver	
2. The applied pressure extends the cutters	
D. Tube severing will be noticed when the load on the motor decreases and the motor speeds up	
E. After severing the tube, release the pressure and withdraw the tool. Check tube and cutter for correct sever and condition	

CONTENT	METHODS & ACTIVITIES
F. Prep the tube sheet by grinding the tube weld down flush with the tube sheet	PPT Slide #60
VII. Repeat the prep/severing operation on the other end of the U-tube. Ensure the correct tube is prepped and marked on the tube map	STAR
VIII. Install plugs	PPT Slide #61 & 62
A. Insert the plug, ensuring that it engages the severed tube, and set with a hammer approximately 1/16” to 1/8” below the surface of the tube sheet	
B. In tight areas, the tube plug is in screwed segments which are screwed and welded as they are inserted in the tube	
C. Apply a single pass fillet weld that completely covers the original tube weld	
D. Perform visual and dye penetrant tests on plug weld	

EO: 1.7 Describe the methods of removing tubes from heat exchangers.

Main Idea

CONTENT	METHODS & ACTIVITIES

I. General information

A. Complete removal of the tube can only be done on straight plain tubes

1. U-tubes are replaced by pulling the tube bundle and disassembling (not normally done)

B. Many vendors supply various tools for tube removal/replacement

C. General processes

1. One process reams the tube roll to weaken the rolled joint and then uses a tube driver to break the rolled joint and drive the tube out

2. Another process uses a tube jack that threads into the tube I.D. and uses a hydraulic jack to jack the tube free from the roll

3. On welded tubes, cutters are available to cut the weld and prepare the tube sheet for a new tube installation

4. Make certain that you're using the right tools and methods and follow the manufacturer's recommendations. Using the wrong tools can damage or destroy the heat exchanger.

CONTENT	METHODS & ACTIVITIES
II. Preparation of tubing	
A. Use of reamers to remove tube from tubesheet	
1. Ream the ends of the tube in the tube sheet to remove them	
a. The tube is usually reamed to a size that is 0.010 inch less than the outside diameter of the tube	
b. Do not ream or cut away the tube sheet material	
2. Size of reamer	
a. Actual reamer size should be obtained from the heat exchanger tech manual	
b. Reamer should be provided with pilot which closely fits inside bore of tube	
c. Ensure that the reamer does not touch or mar surfaces of tube holes in tube sheet	
3. It is usually recommended that the tube be reamed about 1/32" past the rolling ridge of the tube	
a. Reaming past this point or past the tube sheet may cause the tube to split when using a tube knockout tool	
B. Tube drill	PPT Slide #64
1. Similar to tube reamers in purpose and use	
2. Usually come with tube knockout tools	
3. Commonly four fluted drills	

CONTENT **METHODS & ACTIVITIES**

C. Tube cutters (severing tools)

1. Designed to cut the tube on the back side of the tube sheet

2. May simplify tube removal by permitting each tube sheet's rolled joint to be broken individually

3. Many times the channel head will not allow removal of a full length of tube

D. Tube collapsing tool

1. The collapsing tool collapses the tube into itself, thereby breaking the tube roll joint

2. A hard chisel or spear shaped tool designed to be driven in between the tube and the tube sheet hole

   a. It is used by starting the opening between the tube and tube sheet with a small chisel where the tube hole webbing is the strongest

   b. Drive the well lubricated collapsing tool in between the tube and tube sheet parallel to the tube

   c. Be careful not to scratch or damage the tube sheet hole during the driving and removal process

3. Check the condition of the collapsing tool and tube hole after each tube is extracted, clean up any burrs

4. After collapsing the tube with the collapsing tool, then the tube can be driven out

CONTENT	**METHODS & ACTIVITIES**

III. Removing tubing

A. Tube knockout tool (pusher)

1. Must be properly sized to tube and tube hole in tube sheet

2. Commonly comes with the tube drill or reamer

3. Can use pneumatic impact driver or be manually driven with a hammer

B. Tube Jacks (hydraulic tube pulling equipment)

1. The spear or tube jack has cutting threads similar to a bottom tap on one end and serrations on the other, sized approximately the same as the tube O.D.

2. It is used in conjunction with a hydraulic power unit and a tube gripper, (the jacking device)

3. The tools needed and procedure used will be stated in the work order and may include:

a. Use of the cutter to cut the tube behind the tube sheet, and using a tube collapsing tool to collapse the tube stub in the tube sheet, then using a tube pusher to drive the other length of tube out of the heat exchanger

b. Use a reamer or tube drill to reduce the tube wall at each tube sheet, and use a tube pusher and pneumatic driver to drive the tube out

c. Use a tube jack (gripper and spear) to jack the tubes out

CONTENT **METHODS & ACTIVITIES**

4. Operation

   a. The spear is commonly threaded into the tube by hand or using an air impact driver

   b. The hydraulic power unit hoses are connected to the tube gripper

   c. The gripper slides over the spear and the unit is actuated

   d. The gripper jaws clamp down on the spear

   e. The gripper thrusts up against the tube sheet and pulls, breaking the tube roll and pulling the tube and spear out as one

   f. At the end of each stroke, the jaws retract, stroke in and repeat, as long as the unit as actuated

   g. The tube and spear are pulled out of the heat exchanger through the tube gripper as a single unit

   h. Some of the better units have safety switches built in to prevent the operator from having his hands in the wrong place

      1) These units generate thousands of pounds of thrust

      2) You don’t want your fingers to be in the wrong place when it is actuated.

EO: 1.8 Describe the method used to replace tubes in heat exchangers

Main Idea

CONTENT	METHODS & ACTIVITIES

I. Prior to installing new tubes in heat exchangers:

A. Check the condition of the tube sheet and tube holes and the webbing

B. Look for cracks in the webbing between tube holes

C. Check for elongated or egg shaped tube holes caused by excessive or improper tube rolling

1. Rolling the tube hole may correct out-of-roundness

D. Check the size of the tube hole and any other critical dimension called out by the tech manual

1. The tube hole should be approximately .007 to .010" over the size of the tube O.D.

E. Inspect the tube hole surface and prep in accordance with the work control document

II. Installing the new tube

A. This is commonly the most tedious step in the retubing process if you don't use the proper tools and procedures

B. Starting at the bottom of the tube bundle and working up can help by using previously installed tubes to guide the next tube

Caution: take care not to scratch or gouge the tube hole

EO: 1.9 Describe the process of rolling tubes in tube sheets

Main Idea

CONTENT	METHODS & ACTIVITIES
I. Basic description	
A. Tube rolling is the process of forming a tight mechanical joint by expanding a tube into the tube sheet hole	
B. Tube holes generally have one or more grooves or serrations (seat grooves)	
1. These increase the holding power of the expanded tube joint	
2. For a proper seal, these grooves should be thoroughly cleaned out with all burrs removed	
II. Description of tube expander rolls	
A. Different numbers of rolls	PPT Slide #65
1. Three roll, four and five roll expanders are commonly used	
2. The number of rolls is determined by the size of the tube and the quality of the joint	
3. The more rolls, the more even expansion and less stress and work hardening of the tube	
B. Rolls should be tapered	
1. To correspond with taper of expander mandrel	
2. Ensures parallel expansion of tube walls	

CONTENT	**METHODS & ACTIVITIES**

C. Inner ends of rolls

1. Rounded off to form torpedo shaped end

2. This prevents ridging and cutting of tubes at inner end of expanded joint

III. Proper set up of tube expander

A. Tube rollers must be adjusted to the proper depth

1. Counterbored tube sheets and/or steel and stainless steel tubes 3/16” to ½” greater than the thickness of tube sheet

2. On heat exchangers with non-ferrous tubes:

a. Adjusted so expanded portion of tube does not extend through tube sheet

b. About 1/16” to 1/8” of tube at inner end of tube hole left unexpanded

c. Example: main condenser roll depth approx. 1.375”

d. If expanded completely through the tube sheet the soft tube will bulge and subsequent removal of tubes will be extremely difficult

e. This also can cause stress cracking corrosion of the tube at the back side of the tube sheet

3. The depth of the expander is set with the thrust collar

4. The thrust collar must be recessed style if used on tube that extend out of the tube sheet

CONTENT	**METHODS & ACTIVITIES**

B. The expander should be adjusted to achieve the proper amount of tube rolling (wall reduction)

1. The amount of tube expansion depends on the tube material

2. Tube material classified in order of decreasing amount of tube wall reduction

   a. Copper and arsenical copper

   b. Red brass

   c. Muntz metal

   d. Admiralty alloy

   e. Aluminum brass

   f. Cupro-nickel and super nickel

   g. Monel metal

   h. Carbon steel and stainless steel

3. Based on hardness and strength of metal. Softer metal is expanded more and requires less torque to achieve the proper tube wall reduction

   a. Standard percents of wall reduction are:

   b. Copper and cupro-nickel 10%

   c. Steel, carbon steel &admiralty brass 7-8%

   d. Stainless steel & titanium 4 –5%

   e. Exception: main condenser titanium tubes, tech manual calls for 11-13% wall reduction

CONTENT	METHODS & ACTIVITIES
4. Rough hole produces mechanically stronger joint	
5. Adjustment method varies depending on the type of tube rolling equipment used	
6. Some units have torque controls	
a. Length of expanded tube section directly affects torque requirements for proper expansion	
7. Electric torque controls	
a. Used on electrically driven rolling equipment	
b. The current draw of the motor, being proportional to the torque,	
c. Torque is proportional to the amount of wall reduction	
8. Mechanical torque controls	PPT Slide #66
a. These can be used on both electrical and pneumatic rolling equipment	
b. These function off of a mechanical slip or friction cam arrangement,	
c. The slip is proportional to the torque, and the amount of wall reduction	
9. A pressure sensor on an air cylinder that pushes the mandrel through the rollers	
a. When a predetermined pressure is reached a timer is started that deactivates the expander	
b. By adjusting the timer you can adjust the amount of tube rolling	

CONTENT	**METHODS & ACTIVITIES**

10. All of these systems are nice and help roll the tubes uniformly; however, they must be set/calibrated and usually require four to five tubes to be rolled and checked to find the required settings

IV. Before using the expander

A. Wash in commercial solvent to remove anti-rust coatings, dirt, grease and other foreign matter

B. Inspect it to make sure that rolls and mandrel are free and in good condition

C. Lubricate expander with pressure resistant lubricant

1. For small diameter and light tube gauges, immerse expander in light bodied oil such as SAE 10 or 20

2. For large diameter and heavy gauge tubes, swab or brush expander with a mixture of SAE 40 and graphite

V. Rotating speed

A. Expanders should be rotated at a speed proportional to

1. Tube size

2. Tube gauge

3. Length of tube seat

B. Tube metal must also be taken into consideration when determining proper speed

1. Will provide safe cold working of tube metal without crystallization or flaking

2. Ensure maximum expander life without undue roll or mandrel breakdown

CONTENT	METHODS & ACTIVITIES

3. Ideal speed will keep mandrel slippage and heating to a minimum

VI. Lubrication and maintenance of tube expanders

A. Service demanded of tube expanders is severe

B. These precision tools should be given a reasonable amount of care

C. For long, trouble free and economical service, follow recommended guidelines

1. Remove all rust, mill scale and other foreign matter from inside and outside of tube

a. Foreign material may cause flaking or galling of rolls and mandrel

b. Mill scale or grit can cause damage to tube and tube seat

VII. After rolling each tube

A. Clean and cool expander in solvent or light oil

B. Properly lubricate expander

C. Inspect rolls and mandrel after rolling each tube

1. Replace any chipped rolls or mandrels immediately

2. A small chip in a roll can damage entire set of rolls and mandrel if not replaced at once

D. It is a good practice to use two expanders

1. One can cool and be inspected while the other is in use

EO: 1.10 Describe the general procedure to replace a heat exchanger tube bundle

Main Idea

CONTENT	METHODS & ACTIVITIES

I. General information

A. Not all tube bundles are replaceable

B. Many U-tube heat exchangers have replaceable tube bundles

1. Some have tube sheets that unbolt from the shell

2. Some you have to cut the shell off the tube bundle

3. The HP feedwater heaters are designed to allow cutting the shell off the tube bundle

a. It has a guard around the tubes just behind the tube sheet

b. Protects the tubes from the cutting torch flame

C. Some straight tube heat exchangers have tube bundles that are removable

1. A common style uses a floating tube sheet that can be pulled through the heater shell

II. Removing the tube bundle

A. Ensure permits are in place

Prevent Events Use Self Check/Peer Check to ensure clearance is established and adequate.

B. Remove channel heads and interference piping

CONTENT	METHODS & ACTIVITIES

C. Jack tube bundle away from shell

D. Rigging is commonly required to pull the tube bundle

1. Withdraw the bundle from the shell while properly supporting it

2. Many tube bundles are not rigid enough to support their own weight if rigged off of a single point

3. Cribbing is required to support the bundle as it is removed

4. A wide nylon sling or choker rigged from an I-beam and a monorail trolley can also be used to support the bundle during extraction

5. Support tube bundle from tube sheets, baffles and tube support plates

    a. Don’t rig directly off the tubes

    b. Care must be used when attaching rigging to the bundle not to damage the tubes or tube sheet

6. Threaded rods can be inserted through the tubes as strongbacks across the floating tube sheet

7. Steel cable may be used on heaters with large enough tubes to pass the cable through, with wooden softeners to prevent damage to the tubes or tube sheet

E. Some tube bundles use jacking bolts to break the tube sheet to shell seal, then on smaller heaters the bundle can be pulled by hand

CONTENT	METHODS & ACTIVITIES

F. On many designs the floating tube sheet sits in a machined bore

1. Once the tube sheet is pulled out of this bore it is much easier to pull

III. Reinstall new tube bundle

A. Clean and inspect the shell and ensure tube bundle gasket sealing areas are in good condition

B. Prepare the new bundle and gaskets

C. Install the new tube bundle

1. Depending on the heater design, the floating tube seal is installed either before the bundle is inserted or after

2. On the emergency diesel generator lube oil cooler, the two seal rings and a lantern ring are installed after the bundle and are captured by the return head

3. On heaters that use elastomer O-rings or quad rings on the floating tube sheet, lube the packing rings with an approved lubricant

D. Reinstall the channel heads and gaskets, torque in accordance with work order instructions

E. Reinstall the interference piping and conduct post maintenance testing

SUMMARY OF MAIN PRINCIPLES

The following items are things to consider in your lesson summary. They are not mandatory. You should develop your own summary.,

Objectives Review

Review the Lesson Objectives

Topic Review

Restate the main principles or ideas covered in the lesson. Relate key points to the objectives. Use a question and answer session with the objectives.

Questions and Answers

Oral questioning

Ask questions that implement the objectives. Discuss students answers as needed to ensure the objectives are being met.

Problem Areas

Review any problem areas discovered during the oral questioning, quiz, or previous tests, if applicable. Use this opportunity to solicit final questions from the students (last chance).

Concluding Statement

If not done in the previous step, review the motivational points that apply this lesson to students needs. If applicable, end with a statement leading to the next lesson.

You may also use this opportunity to address an impending exam or practical exercise.

Post Training (Job) Critique

Use Standards & Expectations Book Why, When, & How (page 74)