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SECTION I - GENERAL INFORMATION

1.1 Introduction

The function of a surface condenser is to create the lowest possible turbine or process

It is necessary to continuously remove air from the system in order to maintain the desired vacuum. An increasing amount of air in the condenser would reduce its capacity and cause the pressure to rise. In order to reduce the amount of water vapor present in the air (saturation component) it is necessary to cool the air prior to entering the vacuum venting equipment. This optimizes the size and utilities of the vacuum venting equipment. If proper air cooling is not accomplished, the venting equipment will be overloaded and the required vacuum will not be maintained.

It is important to maintain a vacuum tight system. Therefore, efforts must be made to reduce the air leakage by checking all connections, seal glands, relief valves, etc. during the initial startup and at periodic inspections during operation.

1.3 Mechanical Description

The tubes in the condenser are normally expanded into the tubesheets at both ends. The tubes are supported by properly located support plates to help prevent deflection, vibration and chafing of the tubes. The tube holes in the supports are de-burred on each side to prevent damage to the tubes.

The waterbox / tubesheet / shell joints are fastened together in three ways, depending upon the tubesheet design.

- (A) *If the tubesheet is flanged to the shell, the waterboxes on either end of the shell are bolted to the tubesheets and shell flanges utilizing staked studs per Sketch A and stud bolts per Sketch B of Figure I. Stake studs can be identified by the double nuts included on the shell side. The stake studs are threaded into the tubesheet. The stud bolts are through bolts with no threads in the tubesheet. The staked studs permit the operator to remove the waterboxes without disturbing the seal between the tubesheets and shell flanges.*

It is important not to break this seal between tubesheet and shell flange. The tubes are expanded into each tubesheet holding them firmly in place, and the shell seal cannot be replaced without retubing the entire condenser. To prevent breaking the joint, it is important that all nuts be removed from the waterbox flange side and not from the shell flange side. Do not loosen or remove the stake studs and double nuts on the shell side.

- (B) *If the tubesheet is welded to the shell, and the tubesheet outside diameter is larger than the shell, it extends to form a flange. In this case, the waterbox is simply bolted to the tubesheet with through bolts. All of the through bolts must be removed in this type of design in order to remove the waterboxes.*

- (C) *If the tubesheet is welded to the shell and to the waterbox*

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Figure II

Description of Parts - Refer to Figure I

Steam Inlet Exhaust connection for turbine. Connection is flanged or welded and may be round, rectangular or oval. There may be more than one exhaust connection on a unit. This connection can also be located on the side of the condenser for axial exhaust turbines.

Impingement Protection.....

Hotwell.....	Storage area with volume sufficient to contain all the condensate produced in the condenser in a given time period. Normally one minute retention time is specified under design operating conditions. Bathtub or cylindrical types may be used, depending upon the volume and deaeration requirements.
Condensate Outlet(s).....	Connection(s) for piping to condensate pump(s).
Support Saddles	

SECTION II - INSTALLATION

2.1 *Initial Inspection*

Inspect the equipment including all protective covers for shipping damage. If damage is evident, check for any contamination internally and replace the protective covers if the unit is going to be placed in storage. If unit is damaged, *notify the carrier immediately* and then Graham Corporation.

2.2 *Installation*

Sufficient clearance should be provided at one end of condenser to permit removal and replacement of tubes and at the other end to permit tube expanding.

The unit is typically supplied with two support saddles, one of which will have elongated holes to permit movement due to thermal expansion. The unit should be secured to the foundation by bolting to the support saddles. The condenser must be installed level and square so that all connections can be made without being stressed.

Remove all shipping covers and bags of desiccant (if supplied) prior to installation of unit. **Caution** - If the unit was purged with nitrogen for shipment, do not allow personnel to enter any part of the unit until it has been properly vented with fresh air.

After piping is complete, inspect the foundation bolts in the support cradle having the elongated holes, making sure they are loose enough to allow for movement.

Careful attention should be given to the location of the vacuum venting equipment in relation to the main condenser. The first consideration in regard to pressure drop should be to limit the physical distance required to connect the vapor or air outlet on the condenser to the venting equipment. This distance should be limited to approximately 30 feet or less with no loop or "U" type piping runs. If longer distance pipe runs are unavoidable, consideration should be given to increasing the pipe size to limit the pressure drop.

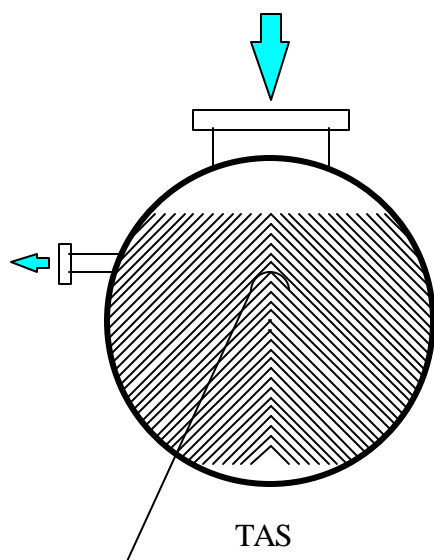
The second consideration involves condensate removal from the inter and after condensers if steam jet ejectors are utilized as the venting equipment. The condensate drain piping must allow for the sub-atmospheric operating pressure on the shell side of intercondenser (under vacuum). Condensate removal must be accomplished by a trap, loop seal, barometric leg, or a condensate pump. When a trap or loop seal is utilized, the condensate outlet connection of the inter/aftercondenser should be located a minimum of 18" above the condensate inlet connection located in the main condenser hotwell. Refer to Figure III.

7. Start the vacuum venting or hogging equipment. If hogging equipment is supplied it should be started first. Its purpose is to rapidly evacuate the condenser and associated piping (including the turbine casing) in a short period of time (usually 30 to 60 minutes). (Refer to the instruction manual for the vacuum venting equipment for specific startup instructions.)
8. When the proper vacuum has been achieved start the steam turbine. (Refer to the instruction manual supplied by turbine manufacturer for specific startup instructions.)

3.2 *Shutting Down the Condenser*

The turbine or process steam to the condenser must be shut off in advance of shutting down the condenser. (Refer to the instruction manual supplied by turbine manufacturer for specific shut down instructions.)

1. Shut off the vacuum venting equipment. (Refer to the instruction manual for the vacuum venting equipment for specific shut down instructions.)
2. Open vacuum breaker if supplied.
3. Shut off the condensate pump.
4. Shut off the circulating water pump and close the isolating valves to the main condenser. If the vacuum venting equipment is raw water cooled, close the isolating valves to this unit.
5. Open the necessary vents and drains. Depending on the length of the shutdown, it may be necessary to fully drain and dry the equipment to prevent damage and corrosion. In addition, in cold climates freeze protection must be considered.



Typical Tube Fields

Figure IV

SECTION VI - TROUBLESHOOTING

4.1 *Detecting a Leaky Tube*

A tube leak can be detected in two ways. The most common method is to check for contamination of the boiler feed water. This contamination will appear as an increase in conductivity of the condensate. If the leak is severe enough, a continual rise in the water level of the hotwell will be observed.

When a leak is suspected, it should be checked (at the first opportunity) by performing a hydrostatic test. To perform the hydrostatic test remove the handhole covers in the waterbox covers or, if handholes were not supplied, remove the waterbox covers and *flood* the condenser shell side with fresh water. **Important** - Leave the waterboxes bolted on to the shell to reinforce the tubesheets. (See paragraph 1.3, reference shell to tubesheet seal.)

Examine the face of tubesheets for any leaks. Water running out of a tube end indicates that the tube is ruptured inside the condenser. If immediate replacement of the tubes can be made, the procedure outlined below should be followed. As a temporary measure, leaking tubes can be plugged. An appropriate tube plug must be placed in both ends of the tube to stop the leak. Use care when plugging tubes to insure that the tube sheet is not damaged. If the water is leaking out between the tube and tubesheet joint, it can usually be stopped by re-expanding the tube. Check the tube end for cracks before and after the expanding process. If a tube end is cracked the tube must be replaced.

4.2 *Removing and Replacing Defective Straight Tubes*

The suggested procedures listed below should only be used for units with tubes expanded at both ends of condenser and only one tubesheet at each end of the condenser. When removing tubes, the tube metal must be completely loosened from each tubesheet and then the tube will pass easily out through the tubesheet holes and baffle / support plates. **Warning** - Any attempt to drive the tube(s) out before it is properly loosened will result in deformation of the tube(s) so that it will not pass through the holes in the baffles and/or support plates and could cause permanent damage to the tubesheet.

Removing Tubes:

A. Manual Method (not intended for large retubing jobs):

1. Remove waterbox covers and waterboxes as necessary.
2. Clean all dirt and obstructions from the ends of tube(s) to be removed.
3. If tube protrudes past the face of the tubesheet, trim flush with the use of a tube end facing tool or tube trimmer.
4. Thread a manual puller mandrel into one end of tube, until at least five (5) teeth are engaged. Slip on spacer(s) as required. Next, screw nut onto the mandrel and seat on spacer. Simultaneously, while the nut is being torqued down at one end, the other end of the tube should be lightly tapped with a tube knock-out tool. Once the tube is loosened from both tubesheets, it is fairly easy to completely remove by hand. **Warning** - Be extremely careful that the tube holes are not scratched or gouged. All holes should be carefully examined for surface condition and, if necessary, a reamer of slightly larger diameter should be used to remove imperfections (check expanding tolerances before reaming the tube holes).

B. Hydraulic Tube Puller Method:

1. Refer to Steps 1 and 2 of Method A.
2. Thread the tube “spear” into the adapter. Be sure the proper size “spear” is used based upon the tube O.D. and gauge (BWG).
3. Using either a hand or impact wrench, turn the spear into the tube until it bites firmly.
4. Place the hydraulic tube puller over the spear and attach. Keep cylinder end square against the face of tubesheet and clear of other tube ends.
5. Place the horseshoe lock into the adapter groove.
6. Apply light pressure with the pump (snug up) and, at the same time, the other end of the tube should be lightly tapped with a tube knockout tool. If the tube protrudes, trim flush with face of tubesheet.

4.4 *General Air Leakage*

The condenser and venting system is designed to handle the air leakage into the turbine and other parts of a commercially tight system.

A common cause for poor condenser vacuum is excessive air leakage. The best method to determine if air leakage is a problem is to check the vent of the air ejector aftercondenser or separator vapor outlet as any air in the vacuum system must exit at this point. Common places to find air leakage are around valves, valve stems, gauge glasses, flow control apparatus, flange gaskets, and shaft seals. An air leakage meter located at the vent of the aftercondenser or on the separator vapor outlet is an extremely helpful device in detecting this problem. When checking for leaks it is important to remember that the vacuum extends back into the turbine casing.

4.5 *Insufficient Condenser Cooling Water*

The amount of cooling water used should be equal to the design quantity. A shortage of cooling water will affect the performance of the condenser. The following formula can be used to determine the amount of cooling water being circulated in gallons per minute (GPM).

$$\text{GPM} = \frac{\text{PPH} \times 950}{(T_2 - T_1)500}$$

GPM	=	gallons per minute of cooling water
PPH	=	pounds per hour of steam condensed
T ₂	=	cooling water outlet temperature, °F
T ₁	=	cooling water inlet temperature, °F

At the design condensing steam load, the difference between the outlet water temperature and the inlet water temperature should not exceed design. If the temperature difference (ΔT) exceeds design then the amount of cooling water may be lower than design. The cooling water system should be checked to determine if it is the cause of the deficiency. Another possible cause of a higher than design ΔT is that the steam load may be higher than design. The quantity of steam entering the condenser should be checked to determine if this is the cause.

NOTE: Any obstructions in the condenser tubes, refuse covering a portion of the face of tubesheet or partially plugged strainers in the water system would increase the pumping head required and reduce the quantity of water being circulated.

4.6 *Miscellaneous Piping and Equipment Problems*

If condensate is utilized as the cooling medium for the condensers on the vacuum venting equipment, the condensate recycle piping going from this equipment back to the main condenser should be carefully reviewed. There are two condensate recycle connections located on the main condenser shell. One is located in the upper half of the shell which is used for startup only, while the other is in the hotwell and is used for normal operation. If the ejectors are used during startup, the water in the hotwell is being continuously recirculated and must be cooled. If this water is not cooled, the temperature going to the vacuum venting equipment will continue to rise and not allow the required vacuum to be obtained. This water is cooled by using the startup recycle connection which allows the water to spill over the condenser tubes. As soon as a continuous flow of steam is exhausted from the turbine the startup recycle connection should be closed and the normal recycle connection should be opened. If raw water is used for the cooling medium of the vacuum venting equipment, there will be one recycle connection located in the hotwell. Regardless of the type of water used, water must be flowing to the condensers before the ejectors are started.

An automatic overboard and recycle valve are usually present. Their purpose, along with the liquid level controller, is to maintain the proper level in the condenser hotwell. When the level in the hotwell rises condensate flows through the overboard valve back to the condensate system. The automatic valves should be checked during startup for proper sequencing.

If the condenser is a divided waterbox design, it utilizes two internal air cooling sections and two separate air off-takes are included on the unit. Refer to Figure III which shows some of the typical tube layouts that are available. Both of the air off take connections must be connected to the vacuum venting equipment and both isolating valves must be open. If one of the valves is closed, that section of the tube bundle could be blanketed with air which could cause a loss of vacuum.

If an ejector type vacuum venting system is used, check the piping from the inter/aftercondenser condensate outlet to main condenser hotwell for leaks, malfunctioning traps, or any obstructions. Refer to Section 2, paragraph 2.2 for proper piping. If there is a problem in this piping, the ejector system may become flooded and affect the main condenser performance.

All strainers, whether permanent or temporary startup type, should be checked, cleaned, removed and/or replaced before permanently placing the equipment on line. A partially plugged strainer causes excessive pressure drop and could result in problems during normal operation. All lines should be flushed or blown down prior to placing them in service.

SECTION V - MAINTENANCE

5.1 *Operator's Maintenance*

Every 30 Days: Inspect all pump glands for leakage. If leakage is evident, glands should be tightened to prevent excessive air leakage. Check water seal on relief valve.

Every 3 Months: If anode plates are installed, inspect and replace if necessary.

Every 12 Months: Inspect the tubes of the condenser for deposits and possible tube deterioration. Clean and replace the tubes as warranted.

NOTE: Refer to inspection points listed in auxiliary equipment manuals such as the vacuum venting equipment, turbine, and condensate pumps.

SECTION VI - REPAIR AND REPLACEMENT ORDERS

**heat transfer requirements to
maximize the efficiency and**