OMI-SC-0401

Surface Condenser

Operation, Maintenance and Installation Manual

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ENGINEERING ANSWERS

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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 operating back pressure while condensing steam. The condensate generated is usually recirculated back into the boiler and reused. Both of these operations are accomplished at the best efficiency consistent with the ever-present problem of economy.

1.2 Design Description

(Refer to Figure II, page 6, for a general cross-section with labeled parts and pages 7 and 8 for description of parts.)

Steam enters the condenser shell through the steam inlet connection usually located at the top of the condenser. It is distributed longitudinally over the tubes through the space designated as dome area. When the steam contacts the relatively cold tubes, it condenses. This condensing effect is a rapid change in state from a gas to a liquid. This change in state results in a great reduction in specific volume and it is this reduction in volume that creates the vacuum in the condenser. The vacuum produced by condensation will be maintained as long as the condenser is kept free of air. A vacuum venting system is utilized to support the condenser vacuum by continually removing any air entering the system. The tubes are kept cold by the circulation of water which removes the heat given up by the condensing steam. This heat is known as the latent heat of vaporization and is sometimes termed “heat of condensation,” in conjunction with the discussion of condensers. The condensate is continually removed from the hotwell by condensate pump(s), and is discharged into the condensate system.

With the exception of the saturation component of air present in the system, all the steam entering the condenser is condensed. The air in the system, generally due to leakage in piping, around shaft seals, valves, etc., enters the condenser and mixes with the steam. The air saturated with water vapor passes through the air cooling zone where the air-vapor mixture is cooled below the condensing temperature of the entering steam. The air cooling zone is designed and located to utilize the coldest section possible of the tube bundle. The saturated air is removed from the condenser by the vacuum venting equipment such as steam jet air ejectors, liquid ring vacuum pumps, or a combination of both.

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. <u>Do not loosen or remove the stake studs and double nuts on the shell side.</u>

(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*, then the waterboxes are not removable. The waterbox covers can be removed by simply removing all of the through bolts.

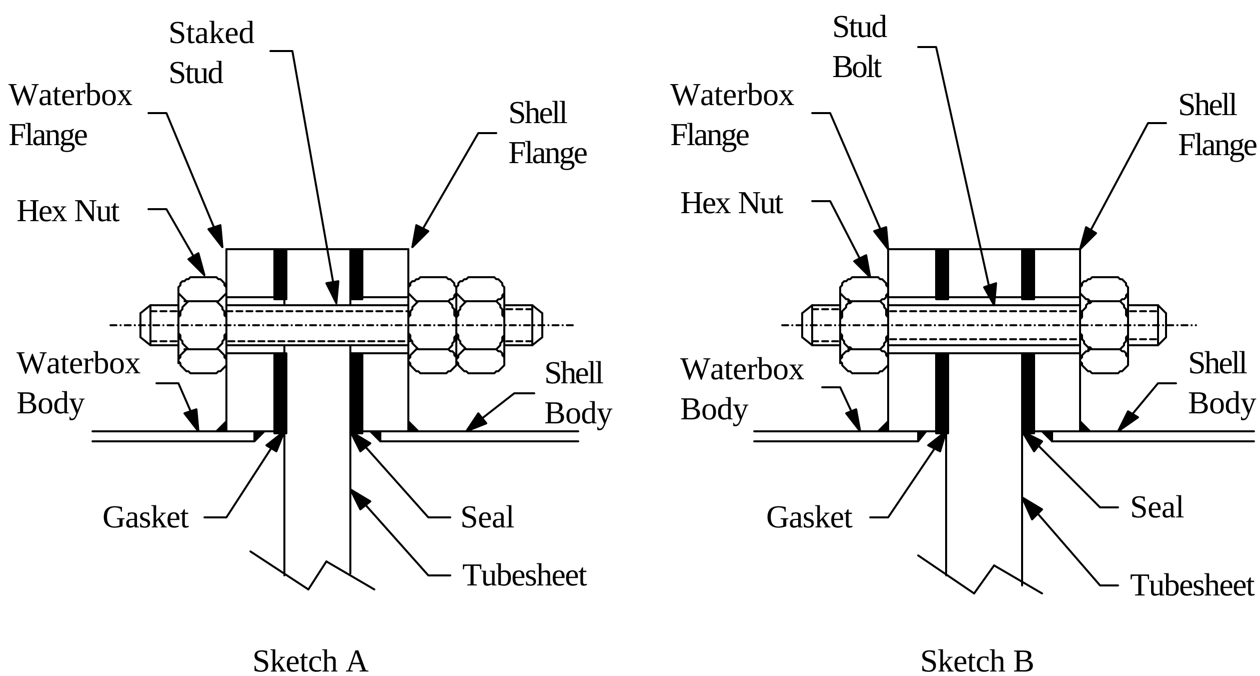


Figure I

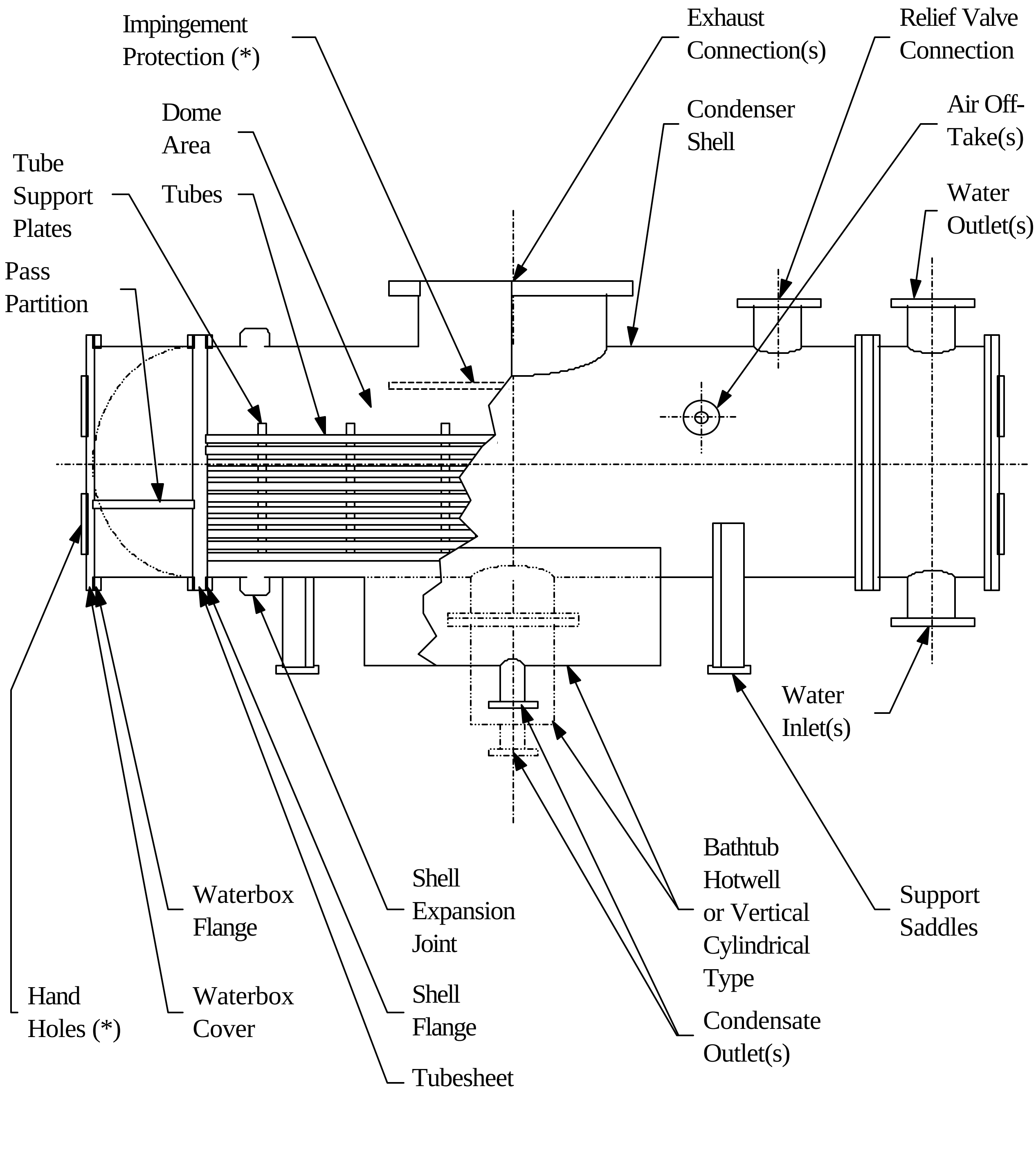

Impingement
Protection (*)
Exhaust
Connection(s)
Relief Valve
Connection
Dome
Area
Condenser
Shell
Air Off-
Take(s)
Tube
Support
Plates
Tubes
Water
Outlet(s)
Pass
Partition
Water
Inlet(s)
Bathtub
Hotwell
or Vertical
Cylindrical
Type
Shell
Expansion
Joint
Waterbox
Flange
Support
Saddles
Hand
Holes (*)
Waterbox
Cover
Shell
Flange
Condensate
Outlet(s)
Tubesheet
(*)-As Required by Design

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..........................	A plate (perforated or solid), dummy tubes or solid rods used to protect the tubes against high entrance impingement velocity. Supplied as required by design.
Condenser Shell.....................................	Cylindrical or rectangular "body" which contains the vacuum space around the tubes.
Tube Support Plates	Provide intermediate support for the tubes between the tubesheets.
Shell Expansion Joint..............................	Used to reduce the stresses caused by differential expansion between the tubes and the shell. Only required when this differential expansion creates an over stressed condition as defined by calculations.
Tubes...	Contain the cooling medium (usually water) - separates the condensing side from cooling side.
Dome Area...	An open area above the tubes which permits the steam to easily distribute throughout the length of the bundle without dead or overloaded zones.
Shell Flange	Point for bolting tubesheets to the shell body.
Air Offtake(s)..	Connection(s) for piping to vacuum venting equipment - one or two used depending upon design.
Pressure Relief Connection....................	Connection for either a water sealed relief valve or other relief device that will prevent the condenser from being over pressurized. The device must be sized in accordance with HEI Standards for Steam Surface Condensers latest edition.

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...................................	Cradles for attaching the condenser to customer's structure or concrete foundation.
Tubesheets	Flat plate used to hold the tubes in place and separate the steam and cooling fluid. The tubes are normally roller expanded inside the tubesheet, but can also be seal welded.
Waterbox..	Commonly referred to as inlet-outlet waterbox, inlet waterbox, outlet waterbox, return waterbox, return bonnet - provides a directional pathway for circulating water through the tube bundle.
Waterbox Cover...................................	Flat plate bolted to the ends of channel type waterboxes.
Waterbox Flanges.................................	Point for bolting waterbox to tubesheet or waterbox to waterbox cover.
Pass Partitions	Plates used to divide the water path into the required number of tube passes.
Water Inlet	Connection for bolting to the cooling water supply.
Water Outlet..	Connection for bolting to the cooling water return.
Handholes	Inspection ports in waterbox covers or bonnets for inspecting a portion of the face of tubesheet and tube ends. These are optional and are supplied as required by the design.

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.

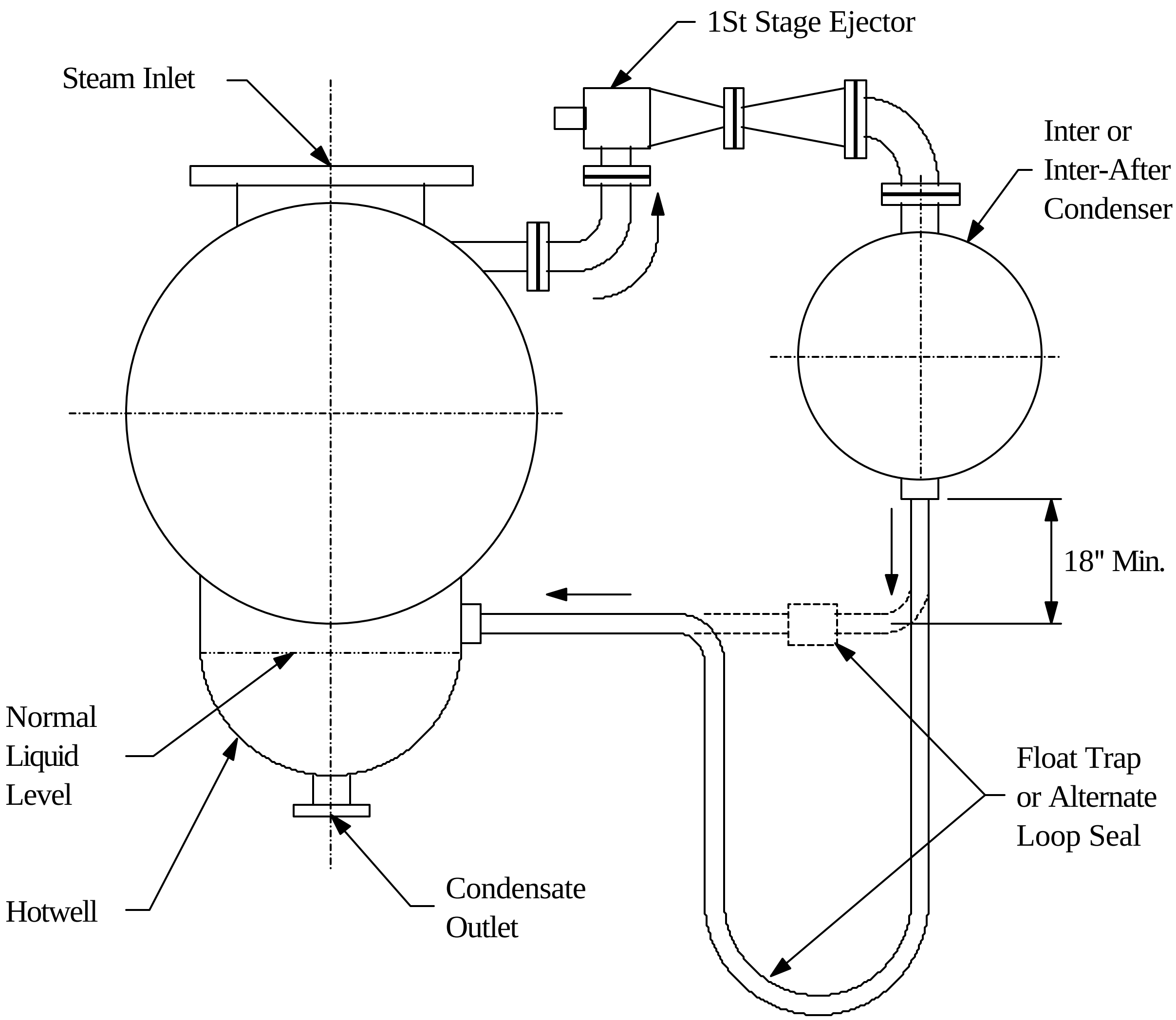

1St Stage Ejector
Steam Inlet
Inter or
Inter-After
Condenser
18" Min.
Normal
Liquid
Level
Float Trap
or Alternate
Loop Seal
Condensate
Outlet
Hotwell

Figure III

SECTION III - OPERATION

3.1 Starting the Condenser

Start the condenser in advance of the turbine and any other equipment that exhausts into the condenser according to the following procedure:

1. Check all atmospheric vent valves on the shell side (steam side) of the condenser to make sure they are closed. Make sure the atmospheric relief valve is operable and properly sealed with water.

2. Check to insure that all waterbox vent valves on the tube side (water side) are open to bleed the system of air.

3. Slowly open the isolating valves in the main condenser circulating water line(s) to permit flow through the unit. The circulating water pump(s) should be running at this time. When water flows from the waterbox vent lines, they should be closed. It is important to make sure the condenser waterboxes remain completely full of water. Often an air pocket will develop especially during start up and it must be vented to insure proper performance of the condenser.

4. Check the hotwell water level. This should be approximately midway in the hotwell gauge glass. Refer to the setting plan drawing supplied for specific details. (When starting the condenser for the first time, fresh water will need to be introduced into the hotwell to obtain a starting level and to prime the condensate pump system.)

5. If condensate is being used as a cooling medium in the vacuum venting equipment, open the valve in the condensate recirculation line to the recycle startup connection located in the upper half of the condenser shell and close the valve to the recycle connection in the hotwell. After the unit is started and the steam turbine is running, switch back to the recycle connection in the hotwell. If raw water is being used, no change is required in the recycle line. Slowly open the water supply line and verify that water is flowing through the vacuum venting equipment.

6. Start the condensate pump. Check to insure that the automatic level controls are maintaining the hotwell water level. The normal level will be shown on the drawing supplied. As a general guideline, the level should be halfway up the hotwell gauge glass. (Refer to the instruction manuals for the level controller and condensate pumps for specific startup instructions.)

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.)

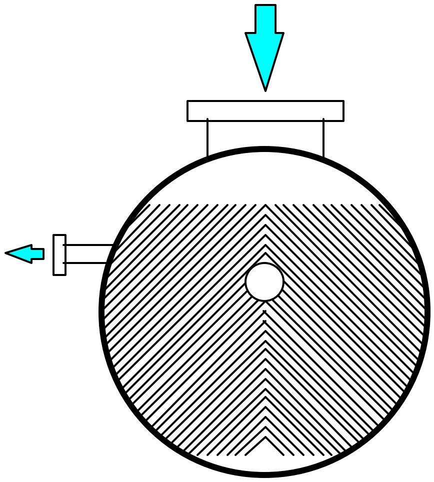
1. Shut off the vacuum venting equipment. (Refer to the instruction manual for the vacuum venting equipment for specific shut down instructions.)

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.



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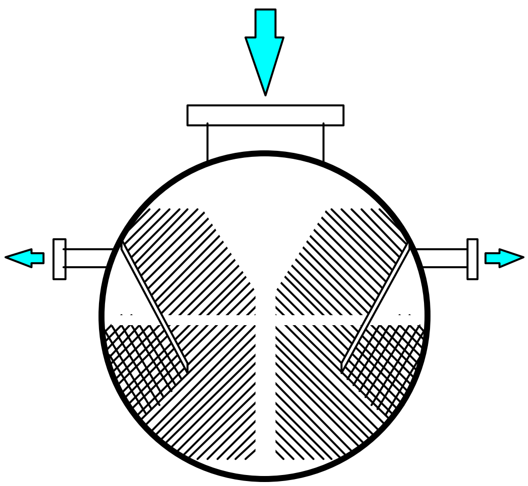

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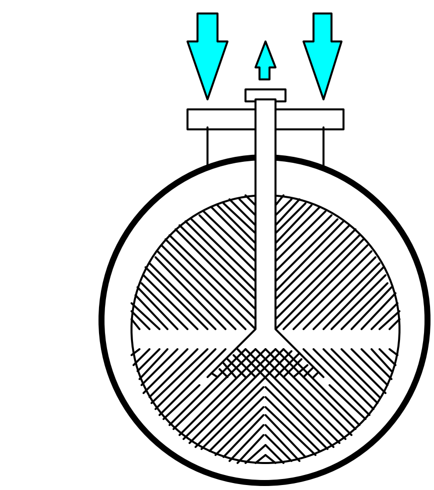

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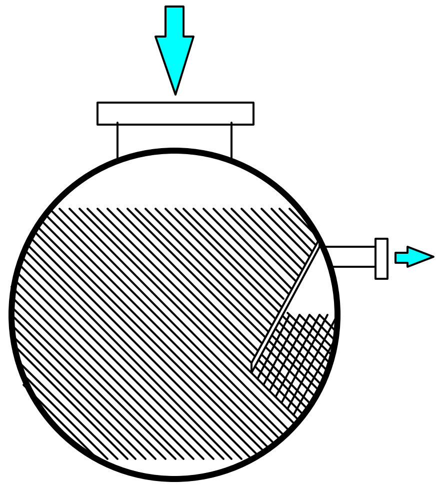

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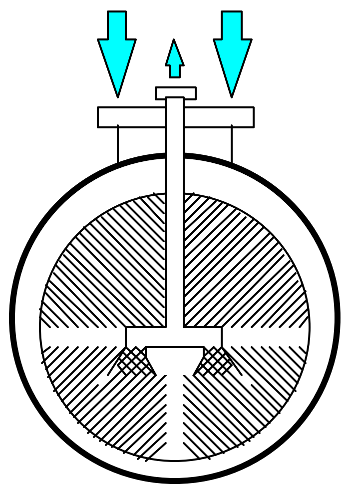

TBTD

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.

7. When the seal is broken and the tube is completely loosened from both tubesheets, the hydraulic unit can be used to finish removing the tube. ***Warning*** - Care should be taken to not scratch the tube holes in the tubesheet. 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.)

Replacing Tubes:

1. Twist the new tube as it is being pushed forward through the tubesheets and baffles for ease of insertion. The use of a tube guide speeds the assembly operation and prevents tube end damage.

2. Expand both ends of the new tube(s).

3. Apply a water test as described in paragraph 4.1 to make sure the new tube(s) is tight before replacing the waterbox covers. Use new gaskets in reassembly.

NOTE: Tube removal tools may be purchased if not included with order. Refer to Section 6 for address.

4.3 Fouling of the Condenser Tubes

When the inside or outside of the condenser tubes become covered with a foreign material, the unit is considered fouled. This is normally evidenced by a rise in operating pressure on shell side or an increase in pressure drop across the tube side and/or shell side of the condenser.

Under these conditions, the waterbox covers or the waterboxes should be removed (see section 1.3) and the tubes thoroughly cleaned. In most cases, the procedure for cleaning the tube side would be to either wire brush or hydroblast the tubes. Chemical cleaning methods are also available and can be used on either side of the unit, but are more often used to remove fouling on the shell side of the condenser. A number of automatic cleaning systems are also available that will allow the inside of the tubes to be cleaned while the condenser is in service.

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).

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

GPM	=	gallons per minute of cooling water
PPH	=	pounds per hour of steam condensed
T_2	=	cooling water outlet temperature, ºF
T_1	=	cooling water inlet temperature, ºF

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

When it is necessary to obtain spare parts, please address your communication to:

GRAHAM CORPORATION
20 Florence Avenue
Batavia, New York 14020

Telephone:	716 / 343-2216
	800 / 828-8150
Fax:	716 / 343-1097
E-MAIL:	equipment@graham-mfg.com
WEBSITE:	http://www.graham-mfg.com

IMPORTANT - The following information should be given in order to identify the spare parts required:

1. Serial number of unit (stamped on nameplate),
2. Name or description of part required,
3. Method of shipment (i.e. freight, express, etc.).

Graham Corporation presents the information in this manual as good engineering practice. We cannot be held responsible for any damage to equipment that may result from mal-operation nor for any personal injuries should they occur during normal or abnormal operation.

Graham engineers analyze your specific vacuum and heat transfer requirements to maximize the efficiency and performance of your process. Because it's not just about engineering products, it's about **engineering answers.**

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