Objectives
At the end of the lesson, the trainees will have a thorough understanding of the cleaning of heat exchangers and condensers tubes.

1.0 HEAT EXCHANGERS AND CONDENSERS MAINTENANCE

1.1 INTRODUCTION TO MAINTENANCE OF PLANT HEAT EXCHANGERS AND CONDENSERS

Nearly all heat exchanger maintenance problems are caused by either blockage or leakage. Therefore, the maintenance of heat exchangers in the plant can be discussed in terms of the general practices associated with

1. Cleaning out blockage and
2. Plugging leaks.

The purpose of this training unit is to explain how problems with heat exchangers affect their performance and to discuss the kinds of maintenance practices necessary to keep plant heat exchangers operating efficiently and safely. Specific attention is directed to identification of heat exchanger maintenance problems, preparation for maintenance operations, safety precautions, methods of cleaning large heat exchangers, procedures for stopping leaks in large heat exchangers, and maintenance of smaller heat exchangers.

1.2 OVERVIEW OF HEAT EXCHANGER MAINTENANCE

The two basic categories of heat exchanger maintenance problems are blockage and leakage. Blockage is an accumulation of foreign material, impurities, or buildup from chemical action within a heat exchanger that interferes with its operation. Leakage is generally internal leakage - one fluid leaking into the other; external leakage - leakage of fluid out of the heat exchanger - is rarely a problem with heat exchangers.

Blockage can interfere with heat exchanger operation in two ways:

1. As an accumulation on a heat exchanger’s heat transfer surfaces, blockage can prevent efficient heat transfer; and
2. As an accumulation that blocks the flow paths of the fluids in a heat exchanger, blockage can cause flow through the heat exchanger to be reduced.

Blockage is a common problem with both surface heat exchangers and direct contact heat exchangers. In a surface heat exchanger, blockage can affect both efficient heat transfer and flow through the heat exchanger. In a direct contact heat exchanger, however, only the flow through the heat exchanger is affected. Accumulation within a direct contact heat exchanger does not affect heat transfer, because heat is transferred directly between the two fluids - there is no medium between them.

Leakage problems are generally associated only with surface heat exchangers - condensers are shell-and-tube heat exchangers because leakage is usually internal leakage. Internal leakage within a surface heat exchanger allows the contamination of one fluid by the other fluid or by impurities that are present in the other fluid.

1.3 REMOVING BLOCKAGE

Blockage is removed from heat exchangers by thorough and careful cleaning. The procedure that is used to clean a particular heat exchanger depends on three factors:

1. The type of heat exchanger
2. The physical size of the heat exchanger and
3. The types of fluids flowing through the heat exchanger.

The type of heat exchanger determines the basic approach to cleaning it. For example, the main cause of blockage in a direct contact heat exchanger is scale formation. The high temperatures at which direct contact heat exchangers operate cause scale to form from the impurities in the incoming water. This scale must be brushed or scraped from the inlet nozzles of spray type or combination type direct contact heat exchangers to prevent a reduction in flow. Scale must also be removed from the trays of tray type or combination type direct contact heat exchangers to insure a thorough mixing of steam and water for proper removal of non-condensable gases.

Corrosion problems in direct contact heat exchangers come from some of the non-condensable gases that are released during heat exchanger operation. Because corrosion eats away and weakens trays and tray supports, they may occasionally need to be replaced or rewelded. Scale removal and work on trays are ordinarily the only maintenance operations performed on direct contact heat exchangers. For this reason, the remainder of this training unit will deal with maintenance of surface heat exchangers.
The method used for cleaning surface heat exchangers depends on the physical size of the heat exchanger and the types of fluids that flow through it. The size of the heat exchanger determines the basic tools needed for cleaning and can dictate whether the heat exchanger is cleaned in the plant or in another location, such as a workshop. The types of fluids flowing through the heat exchanger determine the type of blockage that generally occurs, and thus affect the choice of a cleaning method. For example, if river water is used for cooling, blockage may be caused by an accumulation of mud, water plants, and marine life. If pure water or steam flows through a heat exchanger, scale from corrosion or chemical deposits may accumulate.

The method chosen for cleaning a particular surface heat exchanger also depends on whether the tube side, the shell side, or both sides must be cleaned. Water boxes and tube sheets are generally cleaned by brushing or picking and scarping; sometimes, shoveling out water boxes is also necessary. Tubes are generally shot through with high-pressure water or a mixture of water and compressed air. For deposits that are harder to remove, rubber squeezes, wire brushes, or metal scapers can be shot through the tubes of straight-tube heat exchangers. The exact technique chosen depends on the metals used to make the tubes and the types of deposits to be removed. Care must be taken if these techniques are used in U-tube heat exchangers, because the cleaning implements used can get caught in the bends of the tubes.

Shell side cleaning is accomplished by withdrawing the tube bundle from the heat exchanger and then cleaning the outsides of tubes. Wire brushes, special solvents, or water may be used, depending on the type of fluid and what deposits must be removed. These same methods are used when it is necessary to remove deposits from the inside of the shell itself.

1.4 STOPPING LEAKS

Internal leakage in a surface heat exchanger - either a condenser or a shell-and-tube heat exchanger - generally occurs in one of two places:

1. Leaks develop in the tubes or
2. Leakage occurs through the joints where the tubes pass through the tube sheets.

Leakage within tubes is usually stopped by plugging both ends of leaking tubes so that there is no flow through them. Leakage where the tubes pass through the tube sheets can be stopped by welding the affected tubes to the tube sheet.

Only a certain percentage of the tubes in any heat exchanger can be plugged before heat transfer efficiency is significantly affected. In many cases, heat transfer efficiency is affected significantly when 10 - 20% of
the tubes are plugged, but this number may be as great as 50% for some components. When heat transfer efficiency is affected, the tubes should be replaced. As a general rule, all the tubes in a component are replaced at the same time. This work may be performed in-house, or the job may be contracted out - the size of the component determines where tube replacement is done.

Tubes are typically set into tube sheets in one of two ways:

1. Rolling or
2. Welding

Rolling tubes is a method of expanding the tubes into corrugated holes in the tube sheets. Welding is done when temperature, pressure, vibration, or a combination of these factors make rolling the tubes insufficient or impractical.

1.5 SACRIFICIAL ANODES

As explained in the heat exchanger training unit, sacrificial anodes are large pieces of zinc that are used in some heat exchangers to minimize corrosion of the metals that make up the heat exchanger. The zinc plates, which are more susceptible to corrosion than the heat exchanger metals, are called sacrificial anodes because they are gradually eaten away by the corrosive action of impurities in the water that passes through the heat exchanger.

Sacrificial anodes are bolted inside the water boxes of a heat exchanger. As they become eaten away, they become less and less effective, and they may cause damage to the heat exchanger if corrosion causes them to loosen and become detached from their mounts. A certain amount of judgment is needed to decide when sacrificial anodes should be replaced. One rule of thumb is to replace any sacrificial anodes that are more than 50% worn away. Sacrificial anodes should also be replaced if they are in danger of coming loose from their mounts.
2.0 MAINTENANCE PREPARATION AND SAFETY PRECAUTIONS

Preparation for performing work on heat exchangers involves two major elements:

1. Choosing the proper tools and equipment and
2. Observing the appropriate safety precautions

2.1 CHOOSING TOOLS AND MAINTENANCE EQUIPMENT

The tools and equipment needed to perform maintenance on heat exchangers can be divided into two general categories:

1. Working tools
2. Safety equipment

The first category includes the hand tools and power tools needed to do a maintenance job. The second category includes the equipment required to insure personal safety.

The working tools and equipment needed for a particular job may include wrenches, impact tools, cleaning devices such as high-pressure water guns, scrapers, brushes, squeegees, etc., shovels, trowels, buckets, and large containers. The equipment needed to seal or plug leaking tubes may include plugs, screwdrivers, wrenches, hammers, welding equipment, and equipment to roll tube ends into tube sheets.

The safety equipment needed for a particular job depends to a large extent on the type of component involved. For work on larger components, where work must be done in a wet environment or in a confined space, low-voltage safety lighting is needed. One example of this type of safety light is shown in Fig. 4-3-1. If high-pressure water guns will be used, or if a water box must be entered, rain suits, boots, and goggles or safety glasses are required. Eye protection and skin protection are especially important in situations where corrosion inhibitors, such as chemicals that contain chromates, may be present.

Fig. 3-1 Safety Lighting Equipment
The proper working tools and safety equipment for a particular job can best be chosen by someone who is familiar with the equipment and with the work that is to be done. Familiarity with the equipment is gained by examining the equipment and by studying the manufacturer’s manuals, specification sheets, and information bulletins. A person who is familiar with heat exchanger maintenance operations knows the specific tasks that are associated with each type of work and can select the tools and equipment that are likely to be needed. For example, the job of opening and inspecting a large heat exchanger includes the mechanical task of opening the component and, in most cases, also includes the task of cleaning out the component so that a thorough inspection can be conducted. Tools and equipment for both tasks should be taken to the work area.

### 2.2 MAINTENANCE SAFETY PRECAUTIONS

The safety precautions associated with heat exchanger maintenance depend largely on the nature of the heat exchanger involved, but some safety precautions apply to all work on heat exchangers. For example, work should never be done on a heat exchanger until the system that includes the heat exchanger is shut down and isolated, and equipment such as valves, motors, pumps, switchgear, and controls are tagged out so that they will not be operated while maintenance is going on. The heat exchanger should be drained and vented before it is opened. In addition, all tools should be carefully inspected before each use to make sure that they are in safe working condition.

The nature of some heat exchangers necessitates additional safety precautions. Work on large heat exchangers, for example, often requires working in confined work spaces. In such situations, air quality checks are performed to make sure that there is enough oxygen to breathe and that no dangerous gases are present. The two-man rule is always followed in confined areas so that help is available if a worker encounters trouble: one worker always stays outside of the confined work space and keeps steady contact with the worker on the inside.

Additional ventilation may be necessary in some areas for two reasons:

1. To remove dangerous gases and provide fresh air with enough oxygen to breathe
2. To cool a confined space if work is being done on hot equipment, such as a condenser being run under partial load.

If, for any reason, a confined space cannot be adequately ventilated, special precautions might be required to protect personnel from breathing hazards or heat. These precautions can include respiratory protection to insure safe breathing air or reduced work cycles to
prevent the danger of heat exhaustion or heat stroke. Individual plant safety procedures may call for other specific measures.

The safety precautions associated with the rigging of large, heavy parts, such as a large heater Tank, as illustrated in Fig. 4-3-2, must be carefully observed when large components are moved. Good lifting practices must also be observed when smaller pieces of equipment are moved by hand. Proper handling of tools and adherence to accepted maintenance practices further assures the safety of workers involved in heat exchanger maintenance operations.

Fig. 3-2 Rigging a Large Heater Tank

3.0 CLEANING LARGE HEAT EXCHANGERS AND CONDENSERS

3.1 BLOCKAGE OF HEAT EXCHANGER AND CONDENSER TUBES

Blockage in large heat exchangers is usually caused by impurities in the fluids passing through them or by the corrosive action of gases or chemicals. An example of the first type of blockage is the accumulation of mud, water plants, and marine life in the water boxes and tubes of heat exchangers that use river water as a source for cooling water. This accumulation may become quite heavy. The corrosive action of gases in fluids or chemical deposits due to additives in fluids causes lighter blockage, such as the scale that forms in the tubes of a high-temperature, high-pressure heat exchanger. This scale accumulation may be so light that it does not affect flow through the heat exchanger, but the buildup of deposits can severely affect the transfer of heat, because these deposits cannot conduct heat effectively.

3.2 TUBE SIDE CLEANING OF HEAT EXCHANGER AND CONDENSERS
The methods used to clean the tube side of a large heat exchanger depend on several factors, including the following:

1. The amount of work space available - cleaning must often be done in confined areas.

2. The tube configuration - U tubes in a shell-and-tube heat exchanger may limit the choice of cleaning techniques.

3. The kind and amount of deposits - different approaches are required for cleaning heavy accumulations of mud and debris than for removing light scale buildup.

Cleaning out the tube side of a component such as a condenser typically includes the following steps:

1. Raking, scraping, or picking accumulated blockage off of the tube sheets

2. Shoveling or troweling accumulations out of the water boxes

3. Shooting the tubes with a high-pressure water gun to clear them of built-up slime, silt, and crusted deposits

Rakes, scrapers, and picks are typically used to remove heavy accumulations from the tube sheets. Fig. 4-3-3 shows a worker using a pick to remove debris. However, accumulated blockage must be removed carefully from tube sheets and the mouths of tubes. The tubes in many heat exchangers are made of soft, malleable metals that can be easily damaged if cleaning is done too vigorously with sharp picks or scrapers.

Fig. 3-3 Picking Debris from Tube sheet
After blockage is removed from the tube sheets, the next step is usually shoveling or troweling any heavy accumulation out of the water boxes. It is usually practical to clean out the bottom of the water box after buildup has been removed from the tube sheets so that the area only has to be cleaned out one time. If a slippery accumulation inside could cause a worker to fall, it might be a good idea to clear out the water box first.

Several methods can be used to shoot the tubes to clear them of blockage. All the methods use a high-pressure water gun such as the one shown in Fig. 4-3-4(a). If the buildup is relatively soft and not too heavy, the tubes may be shot through with high-pressure water alone. Sometimes, compressed air mixed with water is used to churn off deposits that are harder to remove. A variety of implements can be forced through the tubes by the water from the gun; the choice of implements depends on what has to be removed. These implements (Fig. 4-3-4(b) are often referred to as “bullets”; they may be hard rubber squeegees that just fit the insides of the tubes, wire brushes with rubber squeegees on each end, or metal-bladed scrapers, depending on the hardness of the deposits and the strength of the tube materials.

Fig. 2-4 Water Gun and Bullets

Whenever tubes are being shot in a heat exchanger, communications among all members of the maintenance crew are extremely important. To avoid the possibility of an accident, every member of the crew must understand what is being done. Even if only water or water with compressed air is being used, the force of the water in combination with the accumulation that comes out of the tubes can cause serious injury to anyone in the way, so no one should ever be in the water box on the receiving end while tube shooting is being done.

When water or water with compressed air is used to clear out tubes, the gun is held in the month of each tube, as shown in Fig. 4-3-5. The trigger of the gun is squeezed to operate it. The person holding the gun can feel a recoil of the gun from the pressure of the water going through the tube; this is due to the resistance within the tube. A tube can usually be cleared out in a few seconds.
Occasionally, blockage in a tube is so heavy that it cannot be shot through. When this happens, the pressure of the water causes the gun to recoil enough to spray the person holding it. It is for this reason that protective equipment such as rain suits and goggles or safety glasses are worn. Protective equipment is particularly important where corrosion inhibitors may have been used in the water going through the component. Corrosion inhibitors often contain chromates, which are especially hazardous to vision and can also present skin and respiratory hazards.

When implements such as squeegees, brushes, or scrapers are used to shoot tubes, the implements are usually packed into many tubes at once - often hundreds at a time. They are then shot through one at a time. After a number of implements have been shot through, a helper can collect them from the opposite water box while more tubes are being packed with bullets. However, the helper must be notified to get out before any more shooting of tubes occurs.

If blockage is relatively light, such as scale from corrosion or chemical deposits, cleaning is typically accomplished by brushing the tube sheets with wire or bristle brushes and then shooting the tubes. Even though blockage from corrosion or chemical deposits may appear to be light, it still must be removed so that it does not adversely affect heat transfer. Also, such deposits can, in time, cause contamination in the relatively clean water flowing through the heat exchanger.

### 3.3 SHELL SIDE CLEANING OF THE HEAT EXCHANGER AND CONDENSERS

Shell side cleaning is ordinarily done only on shell-and-tube heat exchangers. It is not generally done on condensers, because the arrangement of a condenser usually does not allow access to the tube bundle for cleaning purposes. In most cases, in order to clean the
outside of the tubes, the tube bundle must be removed from the shell. Large shell-and-tube heat exchangers frequently have the tube bundle supported within the shell on rails or slides so that the tube bundle can be withdrawn far enough for cleaning. The tube bundle is attached to the tube sheet, which is part of the header or water box.

Rigging for tube bundle removal involves separating the large flanged connection between the shell and the header. Flanged pipe connections must also be removed, and the pipes must be rigged to allow movement of the tube bundle and header. The flanged connection of the header is shown in Fig. 4-3-6. The studs shown in place are threaded at both ends for the large retaining nuts. The circular gasket shown lifted away is typically replaced by a new gasket that is cut from a large sheet of gasket material.

Fig. 3-6 Flanged Connection

In some instances, the shell is movable, and the tube bundle is left in place. There are also other details of construction and disassembly that vary from one heat exchanger design to another. For this reason, the manufacturer’s manual should be consulted for detailed information on removal of the tube bundle for cleaning and other maintenance.

The methods used for cleaning shell sides are relatively simple. The outsides of tubes may be wire-brushed to remove scale or chemical deposits. Solvents may be used to remove oil from tube surfaces. It may also be necessary to clean deposits from within the shell, using the same cleaning methods.

3.4 METHODS OF AUTOMATIC CLEANING
Automatic cleaning systems operate while heat exchangers are in service to reduce the accumulation of deposits. These systems can be divided into two general categories:

1. Mechanical systems and
2. Chemical systems

In one mechanical system, sponge balls with rough outer surfaces are circulated through the tubes in a condenser. These balls remove deposits from inside the tubes. The balls are caught by a screen trap and pumped back to the inlet for recirculation. A very simplified diagram of such a system is shown in Fig. 4-3-7. These mechanical systems are not operated continuously, but are used periodically when accumulation may be heavy enough to affect the component’s efficiency.

![Fig. 3-7 One Type of Mechanical Automatic Cleaning System](image)

Automatic chlorination is one type of chemical cleaning system. Chlorine is periodically introduced into the incoming water to kill algae and thus prevent the buildup of algae growth on tube walls. Automatic cleaning systems - mechanical and chemical - are used to keep manual cleaning jobs at a minimum for components that are especially vulnerable to heavy accumulations from unpurified water.