Installation, Operation and Maintenance Manual for Shell and Tube Heat Exchangers

HEADQUARTERS:

410 Ohio Street
Lockport, NY 14094
Ph: 716-434-5585
Fax: 716-434-1757
www.dmimfg.com
Thank you for purchasing a DMI SHELL & TUBE HEAT EXCHANGER. This equipment has been carefully engineered and manufactured to perform to your requirements and provide long service life.

Prior to installation or maintenance the following tools and equipment should be on hand:

The final issue of the General Arrangement Drawing (GA) for your DMI SHELL & TUBE HEAT EXCHANGER.

Suitable lifting device. Your general arrangement drawing will indicate the dry weight of your new DMI SHELL & TUBE HEAT EXCHANGER.

Suitable chains or slings capable of supporting the weight of your DMI SHELL & TUBE HEAT EXCHANGER. Attach the chains or slings only at the lifting lugs or around the heat exchanger shell. Note that some lugs are designed only for lifting removable components such as heads. Only lugs intended for lifting the entire heat exchanger should be used for that purpose. Never lift the DMI SHELL & TUBE HEAT EXCHANGER by the nozzles as this can cause permanent damage to the vessel shell.

A properly prepared foundation. The DMI SHELL & TUBE HEAT EXCHANGER can be mounted directly on a concrete floor, on piers or directly on another piece of equipment, depending upon your requirements.

Note: It is the responsibility of the owner to prepare the foundation and provide the necessary anchor bolting for the DMI SHELL & TUBE HEAT EXCHANGER.

An appropriate set of tools with hex head sockets, pipe wrenches, Teflon tape (or other pipe thread sealant), torque wrench, pinch bars, carpenter’s level, metal shim stock, wire brushes, gasket sealant, etc.

All the required gaskets, nuts and studs needed to make all piping connections.

If water is being used as a coolant, the supply piping must be capable of delivering a sufficient quantity to the DMI SHELL & TUBE HEAT EXCHANGER. This information is found on the DMI SHELL & TUBE HEAT EXCHANGER thermal performance data sheet. Inadequate cooling water will result in reduced DMI SHELL & TUBE HEAT EXCHANGER performance.
The DMI SHELL & TUBE HEAT EXCHANGER should be installed in a location that permits walkways around the vessel. There should also be adequate floor space in front and behind to permit the removal of heads, replacement of tubes, and removal of the tube bundle if so equipped. Heat shielding and/or guard rails for personnel protection may be required, depending on the installation.

The DMI SHELL & TUBE HEAT EXCHANGER must be installed level to insure all flanged connections can be made without inducing stresses in the vessel weld joints. Misaligned flanges can induce extraneous stresses in the vessel walls and are subject to leakage as well.

The DMI SHELL & TUBE HEAT EXCHANGER has two (2) support cradles. The front cradle is to be bolted securely to the foundation. The rear cradle has slotted holes to permit thermal expansion of the shell so provisions must be made to allow this end of the DMI SHELL & TUBE HEAT EXCHANGER to move.

After the DMI SHELL & TUBE HEAT EXCHANGER has been bolted to the foundation, the shipping covers on the flanges are removed. Conduct a visual inspection to insure no foreign objects have fallen into the vessel during shipment or storage.

**INSTALLATION**

Process and utility piping is brought to the DMI SHELL & TUBE HEAT EXCHANGER, taking care to insure proper flow orientation. Refer to the GA drawing which will identify the inlets and outlets. It is recommended to install isolation valves in the utility and process fluid lines to facilitate future maintenance.

Protective screens or strainers are recommended in piping upstream of the heat exchanger. This prevents any dirt or debris from entering the exchanger and possibly plugging tubes.

Piping connections are made with the appropriate gaskets for the service intended. Exercise care to insure flat, full face contact with mating surfaces to eliminate leaks. All flange surfaces should be cleaned with a wire brush just prior to joining.

Care must be taken to insure foreign objects do no fall into the vessel during installation. Small parts, such as a hex nut, could be entrained by the fluid flow and expelled into the discharge piping, causing significant damage to downstream equipment.

*The DMI SHELL & TUBE HEAT EXCHANGER was not designed to support the weight of the user’s piping. All user’s piping must be adequately supported by other means. The user/owner may consider expansion joints in the piping to eliminate thermal stresses. Additional loads induced by the user’s piping may result in an over stressed condition, violating the terms of the warranty.*
To insure a leak free system, the bolt tightening of all flanged joints should be performed in a diametrically opposed pattern, using a torque wrench in a minimum of two (2) equal steps. This will insure proper seating of the gaskets.

In the case of NPT connections, the use of TEFLON tape or other, compatible thread sealant is recommended to insure tight, leak free joints.

After all piping has been completed, the user can begin the start-up procedure.

**START-UP PROCEDURE**

If instrumentation will be employed, now is the time to add thermo wells, thermometers, pressure gauges, etc.

For heat exchangers in steam service, provision must be made to drain accumulated condensate prior to start-up. This is to guard against water hammer.

Vent valves should be opened before liquid is introduced to the heat exchanger. Start the flow of fluids gradually, introducing the cold fluid first. When the heat exchanger is filled and all air has been vented, the vent valves are closed.

Check the DMI SHELL & TUBE HEAT EXCHANGER for any leaks, tightening gasketed joints and packed joints if necessary.

*The DMI SHELL & TUBE HEAT EXCHANGER was hydrostatically tested before shipment but gasketed joints and packed joints may relax during transit and storage.*

*Gasketed joint leakage may be corrected by tightening the bolts of the headers. Use a diametrically opposed bolting pattern, in a minimum of two (2) equal steps.*

*Packed joint (TEMA type P rear head) leakage may be corrected by lightly tightening the packing gland with a hand wrench. This joint should never be over tightened. The packing gland should not have metal-to-metal contact with the shell flange.*

When the user is satisfied there is no tube side or shell side leakage, the DMI SHELL & TUBE HEAT EXCHANGER is ready for service.

**OPERATION PROCEDURES**

It is important the DMI SHELL & TUBE HEAT EXCHANGER is never operated at pressures and/or temperatures that exceed those stamped on the vessel’s nameplate. This same information will be found on the GA drawing.
Fixed tubesheet (TEMA type L, M and N rear heads) heat exchangers must not be subjected to thermal shock or premature failure may result. Thermal shock is a condition where excessive stress is created in heat exchanger components due to differential thermal expansion. Start the flow of both fluids gradually, introducing the cold fluid first. Reverse this sequence for shut-down: gradually stopping flow of both fluids, beginning with the hot fluid.

Fixed tubesheet exchangers have been evaluated for specific operating conditions, which are shown on the data sheet. The design should be re-evaluated before operating at conditions which differ substantially from the original.

Your DMI SHELL & TUBE HEAT EXCHANGER has been designed for years of trouble free service. After a successful start-up little attention is required. Maintenance logs of temperatures and pressure drops are your best guide to the health of your DMI SHELL & TUBE HEAT EXCHANGER.

If the utility fluid is cooling water it should be periodically monitored for quantity and quality. Tower water sources are usually maintained for quality and pose little threat to any heat exchanger.

If using untreated pond, river or well water, consideration must be given to both particulate matter as well as ph. Water filters should be employed and checked periodically to remove debris so the flow of cooling water is not reduced.

The required quantity of water flow is specified on the data sheet and must be available to the DMI SHELL & TUBE HEAT EXCHANGER. This will insure ample water flow to help keep the tubes clean as well as maintain the correct heat transfer coefficient.

MAINTAINANCE PROCEDURES

Your DMI SHELL & TUBE HEAT EXCHANGER will operate trouble free for extended periods of time but requires regular inspections like any other piece of plant equipment.

Regular monitoring of the “approach” temperature (difference between the hot side outlet temperature and the cold side inlet temperature) is the best way to determine if the DMI SHELL & TUBE HEAT EXCHANGER is performing as designed.

Regular monitoring of the process side and utility side pressure drop is another reliable measurement of performance.

Please refer to the DMI SHELL & TUBE HEAT EXCHANGER data sheet for the approach temperature and pressure drops.

While the shell side pressure drop should remain constant over time, it is sensitive to any changes in the volume of fluid flowing and changes in the inlet temperature of the fluid.
A sudden increase in pressure drop may indicate an upset condition in another part of the system.

A gradual increase in pressure drop across the shell side indicates a decrease in flow area through the tube bundle. This is usually caused by particulate matter accumulating between the tubes, which may be indicative of dirty or inoperative filters. Once the tube bundle has been contaminated with particulate matter, it must be cleaned and/or replaced.

If the thermal performance of the DMI SHELL & TUBE HEAT EXCHANGER starts to decrease, the health of the tube side is the first area to check. Heat exchanger performance is sensitive to changes in tube side fluid temperature and quantity as well as tube side fouling activity. If the tube side supply temperature and quantity has not changed then the operator must consider tube side fouling as the cause of deteriorating performance.

Tube side fouling manifests itself in three ways;

- **Biological growth** such as algae.
- **Chemical processes** where dissolved minerals precipitate out of the water and accrete on the tube walls.
- **Mechanical fouling**, such as suspended particulate matter accumulating in the tube side passages.

Regardless of the type of fouling, the tube side pressure drop and approach temperature will tend to increase and they all require the same corrective treatment. The tube side of the DMI SHELL & TUBE HEAT EXCHANGER must be cleaned. This is accomplished by a partial disassembly of the DMI SHELL & TUBE HEAT EXCHANGER.

**PARTIAL DISASSEMBLY**

Prior to disassembly collect all the required materials and tools needed to perform the task. The following will be required:

- The final issue of the General Arrangement Drawing (GA) for your DMI SHELL & TUBE HEAT EXCHANGER.
- A suitable lifting device, capable of supporting the weight of the headers.
- Appropriate size hex wrenches, torque wrench, wire brushes, gasket cement and a gasket scraping tool.
- Test covers for tube side nozzles (optional).
- Replacement gaskets. These can be obtained direct from DMI parts department. Always reference the serial number of the DMI SHELL & TUBE HEAT EXCHANGER when ordering parts.
Suitable wire brushes for cleaning the inside of the tubes.

Follow the equipment manufacturer’s shut down procedure. Once the hot fluid has stopped flowing through the DMI SHELL & TUBE HEAT EXCHANGER, cold fluid flow is continued until the heat exchanger is no longer hot to the touch. The coolant flow is then stopped and the vent valves opened. The drain plugs are then removed, allowing both sides to drain. Tube side supply piping is then removed.

*If deemed necessary, this is the ideal time to perform a pressure test of the tube side. Replace all vent/drain plugs and install the test covers on the tube side header nozzles. One test cover will have an NPT fitting to mount a pressure gauge; the other will have a suitable fitting to mount a pressure regulator.*

*Pressurize the tube side to line pressure psi using shop air. Never exceed the name plate design pressure.*

*The pressure gauge indication should hold steady, indicating there are no leaks.*

*A slow decrease in pressure indicates a bad tube joint(s).*

*If the bundle can not be pressurized the problem is most likely a split tube.*

To correct a split tube problem, refer to the section on FINDING AND PLUGGING A SPLIT TUBE at the end of this manual.

To correct bad tube joints the shell side must be pressurized. If you suspect bad tube joints, go to the TUBE JOINT TEST PROCEDURE section located at the end this manual.

Once the tube side has been drained, the headers should be matched-marked to ease reassembly. The heads are then unbolted and removed. Before proceeding farther it is a good idea make a sketch showing the orientation of any pass ribs, which will aid in re-assembly. The interior of the heads should be cleaned with wire brushes to remove any scale, accumulated particulate matter and/or biological growth.

The tube interiors are cleanable by a number of methods. The least aggressive is flushing with water to remove accumulated particulate matter and biological growth. Precipitated solids require more aggressive cleaning methods such as rotary wire brushes or pressure washing with cold water. The use of steam or very hot water is not recommended as either of these may loosen the rolled tube joints. Any chemical cleaning solutions must be compatible and safe with the tube material metallurgy.

After the tube side has been cleaned and all the tube interiors are clear of biological growth, precipitated and particulate matter, the DMI SHELL & TUBE HEAT EXCHANGER is ready for reassembly.
**REASSEMBLY PROCEDURE**

Using a new gasket, install the front head, aligning the match marks made during the disassembly procedure. If the front head gasket has ribs, they are to be oriented exactly as the original gasket. Bolt the header in place.

Install a new gasket to the rear tubesheet, holding the gasket in place with small pieces of tape or gasket cement. If the rear head gasket has ribs, they are to be oriented exactly as the original gasket.

Install the rear head, aligning the match marks made during the disassembly procedure. Bolt the head in place.

*To insure a leak free system, the bolt tightening of all flanged joints should be performed in a diametrically opposed pattern, using a torque wrench and in a minimum of two (2) equal steps. This will insure proper seating of the gaskets.*

Remake the tube side connections, using new gaskets.

The DMI SHELL & TUBE HEAT EXCHANGER is now ready to be placed into service. Return to the START-UP PROCEDURE section of this manual.

**TUBE JOINT TEST PROCEDURE**

Locating leaking rolled joints can be a time intensive process as there are twice as many rolled joints as there are tubes and a large DMI SHELL & TUBE HEAT EXCHANGER bundle may have hundreds of tubes. It is not unusual for the owner to sub-contract this procedure and should be considered as the equipment required to test and re-roll tube joints may not be available locally.

To test and find leaking rolled tube joints, the tube side of the tubesheet faces must be exposed and the shell must be pressurized. In order to pressurize the shell, it must be isolated from the rest of the system. This means the removal of some of the shell side piping.

Once the shell side piping has been removed, fit test covers/NPT plugs to the shell side nozzle connections. Use new gaskets or TEFLON tape to insure a tight seal. One test cover will have a fitting to mount a pressure gauge; the other test cover will have a fitting for introducing air into the shell.

The procedure is:

Remove tube side headers as described in the PARTIAL DISASSEMBLY section of this manual.
Remove shell side piping and add test covers/NPT plugs to the shell side connections.

Using shop air, pressurize the shell gradually to full line pressure or design operating pressure, whichever is less.

Using a soapy water solution or commercially available leak detector, bathe both tubesheet faces. Bubbles will identify the leaking tube joint(s).

Re-roll the leaking joints using the correct pneumatic, three pin tube expanding tool and re-test.

*Tube expanding, while not difficult, does take practice to do correctly. The three pin roller expander tool is commercially available from numerous sources.*

Continue until all of the leaking joints have been identified and re-rolled and the leak detecting solution no longer bubbles. The pressure gauge reading should remain constant.

When satisfied with the rolled tube joint repair, bleed off the shell side pressure and remove the test covers from the shell side nozzles.

Re-make all shell side piping, using new gaskets.

Proceed with the re-installing the tube side headers.

**FINDING AND PLUGGING A SPLIT TUBE**

Locating split tubes can be a time intensive process. A large DMI SHELL & TUBE HEAT EXCHANGER bundle may have hundreds of tubes and each has to be tested individually. It is not unusual for the owner to sub-contract this testing and should be considered as the equipment required to test for a split tube may not be available locally.

To test and find split tubes, the tube side of the tubesheet faces must be exposed. This entails the removal of both headers. Refer to the PARTIAL DISASSEMBLY section of this manual.

The equipment required to locate and replace split tubes is:

*A pressure gun with gauge and correct adaptors to match the tube ID and gauge.*

*Reusable, removable tube plugs.*

*Single use, tapered tube plugs of compatible metallurgy.*

*Mallets, crescent wrench, shop air line.*
Chalk or other marking device to identify split tubes.

The locating of split tubes is usually a two man job, one at each end of the bundle.

NOTE: Every tube in the bundle must be tested.

The procedure is:

Starting with the tube in the uppermost right corner of the rear tubesheet, a removable plug is expanded securely in the tube opening.

The pressure gun with gauge is inserted in the opposite end of the same tube.

Pressure is applied and the gauge monitored. Steady pressure indicates a good tube. Steadily decreasing pressure indicates leakage around the test fittings or a split tube. Insure the test fittings are secure. If the pressure continues to decrease or if the tube is unable to hold pressure, the tube is faulty and must be plugged.

Remove the expandable plug from the rear tubesheet.

Mark the tube at both ends with chalk or other suitable marking device.

Proceed to the tube immediately adjacent to the tube just tested.

Continue this procedure row by row until all of the tubes have been tested.

Once all of the split tubes have been tested and identified, they must be plugged or be replaced.

When plugging split tubes, use tapered metal plugs of similar metallurgy and firmly drive the plug into the identified tube hole using a mallet. Two plugs per tube are required as both ends of a split tube must be plugged.

Tapered plugs just for this purchase are commercially available from many sources. Tube plugs of other designs are available as well. The type of plug used is up to the owner.

Continue until all identified split tubes have been plugged.

After all identified split tubes have been plugged, photograph or make a rubbing of the tubesheet for the maintenance file. The location of the split tubes may offer a clue as to the cause of the splitting.

If the split tubes are randomly distributed this may indicate a chemical attack. Shell side and tube side fluid samples should be analyzed for compatibility with tube metallurgy.
It is important to note the plugging of tubes effectively reduces the amount of surface available for heat transfer. If more than 5% of the tubes have been plugged the thermal performance may be degraded to the point where downstream processes are affected. If that is the case, a replacement shell should be ordered.

**REPLACEMENT OF INDIVIDUAL TUBES**

The replacement of individual tubes can be a difficult process and requires specialized tooling and mechanical skills. In addition to having the required three pin rolling tool and the necessary operator skills to effectively use the tube roller, the split tube must be removed from the bundle.

For tube removal, specialized tube pulling equipment is available and may be obtained by renting the tooling from a suitable mechanical supply house. If the tube pulling equipment is not available, the split tube can be removed by drilling out the ends of the tube that are rolled into the tubesheets. Caution must be used as over drilling will enlarge the tube hole to the point where the ligament between adjacent tubes is destroyed, effectively ruining the tube bundle.

Once the rolled ends of the tube have been drilled out, the tube is then forced out of the bundle. The exact method of this varies but the split tube may be driven out by using a new tube as a driver. The problem of this method is the end of the new tube may become “mushroomed” and may not pass through all of the baffles or the tubesheet.

> **A typical heat exchanger bundle will have many baffles and each baffle presents a large frictional load to a tube being pushed out.**

When the end of the split tube extends past the face of the tubesheet, its removal can be aided by pulling the tube as well as pushing.

A new tube is then installed. To aid in this process, a tapered plug is inserted in the new tube’s leading end. The tapered plug will center the tube in the tube holes of the baffle. The new tube is driven in by tapping the exposed end with a mallet.

Once the new tube has been installed, the three pin tube roller is used to seal the tube to tubesheet joint.

To be thorough, replaced tubes must be hydro tested to insure proper tube rolling.

If numerous tubes are split and need replacing, this may be a job best left to a sub-contractor that specializes in heat exchanger repair.
DISCLAIMER

This installation, operation and maintenance manual is to be used by experienced maintenance personnel only. While Diversified Manufacturing Inc has developed this manual with personal safety in mind it must rely upon the installation/maintenance personnel to use good judgment and exercise all due caution.

Maintenance personnel should always wear suitable protective clothing such as steel toed safety shoes and hard hats and use their facility’s established procedures when handling cranes, davits and tools. It is the responsibility of the user/owner to insure the safety of the maintenance personnel when entering confined spaces. It is the responsibility of the user/owner to insure the procedures described herein are followed.

Diversified Manufacturing Inc. can not be held responsible for any damages caused by owner/user initiated modification to the equipment.

Diversified Manufacturing Inc. can not be held responsible for damages caused by misuse of this equipment nor can Diversified Manufacturing Inc. be held liable for any personnel injuries caused by deviations from the procedures outlined in this manual.
Typical configuration of a multi-pass floating tubesheet (TEMA type W rear head) heat exchanger. Both tube side connections are on one end of the exchanger. The tube bundle is removable.

![Diagram of a multi-pass floating tubesheet heat exchanger.]

Typical configuration of a one pass fixed tubesheet (TEMA type M rear head) heat exchanger. Tube side connections are on both ends of the exchanger. The tube bundle cannot be removed.

![Diagram of a one pass fixed tubesheet heat exchanger.]

**Torque Values for Compressed Fiber Gaskets.** Contact factory for other types of gaskets. Gasket information can be found on the GA drawing.

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Recommended bolt tightening sequence.