GROWING CHALLENGES OF HEAT EXCHANGER'S OPERATION AND MAINTENANCE IN LNG PLANTS

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ABSTRACT

Malaysia LNG Group of Companies has three LNG Processing Plants located in Bintulu, Sarawak, Malaysia with a capacity of 23 million tones per annum. In LNG processing, natural gas are cooled down to liquid phase at -161˚C to reduce its volume to about 600 times at near normal ambient pressure for safe and economical transportation to customers. This cooling requires huge amount of heat removal. The heat can be removed through sea cooling water exchangers or air cooled exchangers or a hybrid of both.

The three LNG processing plants in PETRONAS LNG Complex uses all the three methods and incorporated different design technology based on the year of construction. Each of these methods and design technologies had its operational challenges. This paper will describe the experiences and challenges in the operation and maintenance of these heat exchangers in the complex. There are total of 126 sea cooling water exchangers and 298 fans exchangers used in removing the heat to convert the incoming gas into cold liquid LNG. 90% of the sea cooling water exchangers had been in operations for 25 years while the air cooled heat exchangers for 15 years. The performance of these heat exchangers is critical for the continuous LNG production.

With the ever changing environment both in the sea water and air conditions and increasing demand to squeeze the assets, some heat exchangers had experienced performance issues and failures during operations. The presence of dissolved chemical such as ammonia, silt, living sea organism and suspended solid in the changing sea water environment had caused tube leaks and threatened the operations of the plant.

Since start up in 1982, corrosion of tubes in heat exchangers has resulted in numerous tube failures. The phenomenon of tube failures due to tube erosion-corrosion and also flow induced vibration has caused several plant production interruptions. It had been identified that high concentrations of suspended solids as the source of deposits on the heat transfer surfaces and higher sea water velocities had caused tube leaks. High concentration of acidic species, especially chlorides and ammonia, caused corrosion under the deposits and stress corrosion cracking of copper alloy tubes. Over the years with ever changing sea water quality and higher production demand, the heat exchanger becomes more degraded and underperforming.

Changing tube materials from Aluminum Brass and Carbon Steel to copper nickel alloy with a specific percentage of iron content has shown an excellent performance since last ten years in operation. The specific iron content of copper nickel alloy has provided a better corrosion resistance behavior in sea water application. Installation of screens at the inlet of individual heat exchangers, improvement in chlorination control to reduce fouling, replacement of zinc anodes with a better material to improve layering of protective oxides in the tubes and operating within design tube sheet velocity ranges to

avoid deposits and erosion have also restored the performance of heat exchanger to its original design.

Fouling of the air cooled heat exchanger's fins due to atmospheric contaminants had reduced its efficiency and poses cleaning challenges. Fan belts, motors and bearings failures are other typical problems faced in the operation of air cooled heat exchangers. These require expanding resources, both parts and labor for proactive and reactive maintenance. Degradation of air quality has increased fouling rate of the air cooled heat exchangers. The tube fins are easily fouled within one year after cleaning. The air cooled heat exchanger fouled faster with a smaller tube pitch design. Online chemical foam cleaning, changing component materials and good maintenance practices have improved the performance of the air cooled heat exchangers.

Plant optimization to improve production capacity changes the operating conditions and cooling requirement. The changes of flow regime require resizing and material compatibility analysis for the affected heat exchangers. Mitigation and redesign of heat exchangers has been undertaken to ensure the exchangers meet the changing operating conditions.

The challenges faced over the years in operating and maintaining the heat exchangers has elevated engineering and design standard that is crucial for future design and construction consideration.

INTRODUCTION

Malaysia LNG Group of Companies has three LNG Processing Plants located in Bintulu, Sarawak, Malaysia with a capacity of 23 million tones per annum. In LNG processing, natural gas are cooled down to liquid phase at -161˚C to reduce its volume to about 600 times at near normal ambient pressure for safe and economical transportation to customers. This cooling requires huge amount of heat removal. The heat can be removed through sea cooling water exchangers or air cooled exchangers or a hybrid of both.

The three LNG processing plants in PETRONAS LNG Complex uses all the three methods and incorporated different design technology based on the year of construction. Each of these methods and design technologies had its operational challenges. This paper will describe the experiences and challenges in the operation and maintenance of these heat exchangers in the complex. There are total of 126 sea cooling water exchangers and 298 fans exchangers used in removing the heat to convert the incoming gas into cold liquid LNG. 90% of the sea cooling water exchangers had been in operations for 25 years while the air cooled heat exchangers for 15 years. The performance of these heat exchangers is critical for the continuous LNG production.

OVERVIEW OF SEA WATER COOLING SYSTEM IN LNG PLANTS

In early 80's, the cooling water system was designed to supply cooling water to the sea-water distiller, coolers and surface condensers in parallel nature of gas liquefaction trains and in common facilities. The cooling system uses sea water once through as the coolant. Each train gas four cooling water pump (one standby) with a capacity approximately 18,000 m3/ hr at the intake station, giving a capacity of 160,000 m3/hr. The water feed lines to the train sizes 2.8 m diameter and about 1km long are internally epoxy coated carbon steel lines with internal cathodic protection by aluminum anodes.

Most of the heat exchangers are shell and tubes type which are mostly Al-brass (C68700), tube sheet and header boxes are Cu-Al (C63000) or Cu-Ni (C70600) clad. Some exchangers are low finned tubes. Steel anodes (A283-C) are installed inside the header boxes. The sea water outlet temperature are below 42 degree C and the tube wall tubes skin temperature on the water side are below 52 degree C. The water velocities in the tubes are at the low end of the range of 1.0 to 2.2 m/s. Wire screen have been retrofitted in the inlet header boxes to prevent debris collecting on the tube sheets.

In early 90's, the plant was extended with trains 4,5 and 6. These trains are partly sea water cooled. The sea water cooling system for train 4,5 and 6 were connected to the existing sea water system of train 1,2 and 3 respectively. Cross over piping had been made as well to ensure supply of sea water to all the new trains incase of an old train would be shutdown. No additional pumping capacity was installed, but some modification to the existing sea water have been made with the normal supply rate with nine (9) pumps in operation became 170,000 – 180,000 m3/hr. Approximately about 70% of total sea cooling water is supplied to trains 1,2 and 3, 18% to trains 4,5 and 6 with the balance to the condenser of the steam turbine and the common facilities. Eleven pumps could be required depending on LNG production requirement.

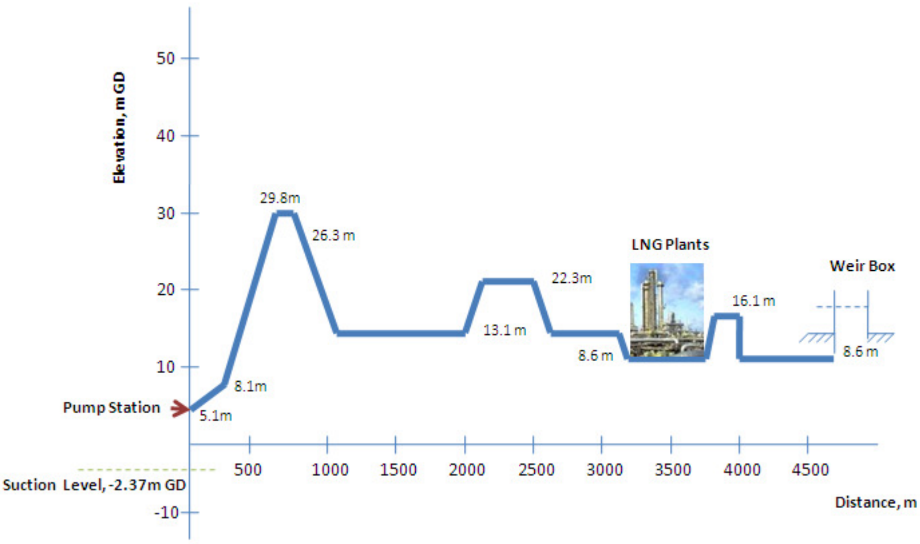

Figure 1 Sea Cooling Water Pipeline Profile

The new trains has six sea water cooler which all tubes are Al-Brass (C68700), tube sheet and header boxes are Al-brass D (C61400) clad. Steel anodes are installed inside header boxes. The sea water outlet temperature is between 42 degree C and the tube wall skin temperature on the water side is below 52 degree C. The water velocities in the tubes are in the range of 1.0 to 2.2 m/s.

The sea water intake station, is about 3.6km away from the process area, contains a series of screens to remove debris and jellyfish (the final screen having 1.7mm opening) and 4 submerged pumps for each train of first plant. The seawater is chlorinated before it is pumped via three 112" main cooling water lines to processing plants.

THE HISTORY OF TUBE FAILIRES AND HEAT EXCHANGER PERFORMANCE

In early operation of heat exchangers in PETRONAS LNG Complex, there had been more than 150 documented cases of tubes failures corrurred due to pin hole perforations initiated from the inside tubes (seawater). Since 1985, Eddy Current Testing (ECT) was used on selected heat exchanger to detect deteriorated tubes prior to perforations. Most of the tubes were found experiencing wall thinning which was greater than 35% weight loss.

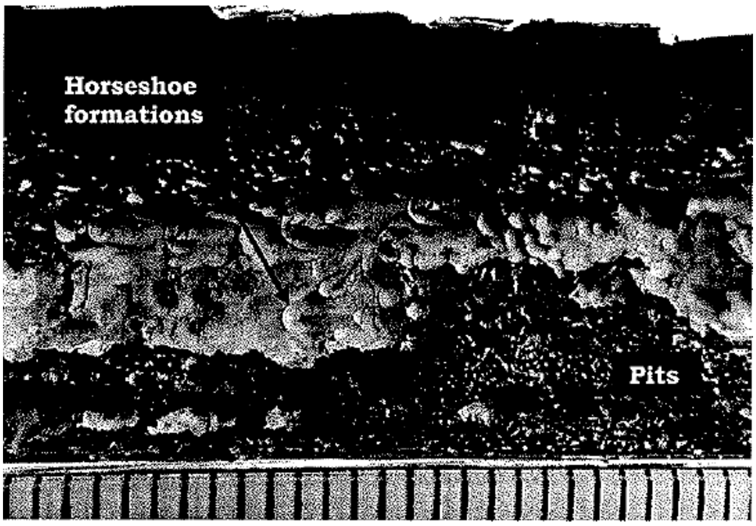

Figure 2 Horseshoes Formation of Al-Brass Tube

All failed tubes of on aluminum brass tubes. Subsequently several heat exchangers which used the aluminum brass tubes were changed to Cupro Nickel tubes (70/30) to provide a better corrosion resistance for the sea water application. As Figure 2 indicates several 'horseshoe' formation was observed on the failed tubes which is an indication of metal removal due to the erosion.

The tube material Al-Br (ASTM B111 C687000) and Cu Ni (ASTM B111 C71500) which commonly used for heat exchangers in sea water application subjected to several failures modes. Investigations has revealed that the key source of problem leading to the tubes leaks of sea cooling water heat exchangers are dominantly caused by following failure modes.

- Stress corrosion cracking
- Galvanic corrosion
- Dealloying
- Sulfide attack
- Pitting/Crevice corrosion
- Erosion-corrosion.

It was also revealed that there are three major causes which resulted to the tube failures are as follows:

- Leaks related to high water flow velocity, air ingress via SCW standpipe and varying internal tube diameter leading to erosion corrosion.
- Leaks related to severe fouling caused by barnacles, foreign material and anode material and leading to under deposit corrosion
- Leaks related to inherent design that is, the top down design leading to erosion corrosion and under deposits corrosion.

With the ever changing environment both in the sea water and increasing demand to squeeze the assets, some heat exchangers had experienced performance issues and failures during operations. The presence of dissolved chemical such as ammonia, silt, living sea organism and suspended solid in the changing sea water environment had caused tube leaks and threatened the operations of the plant.

Figure 3 Blockage of Heat Exchanger Mesh Screen by Foreign Material

In the past ten years of operation records, the sea cooling water heat exchangers had experienced several tube failures due to high sea water flow which resulted to tubes erosion-corrosion. Upon completion of rejuvenation and revamp project in 2003, the sea water velocity has increased and exceeded the maximum range of tube tubes material velocity. With increasing sea water flow rates, corrosion rates remain low due to the resilience of the protective layer of the tubes. However the velocity for a given geometry of the tubes exceeds a critical value of the velocity, at which shear stresses are sufficiently high to strip off the protective corrosion film, damage in the form of impingement attack may occur.

With the increasing number of plugged tubes over the years, it was noted that the extreme turbulence of flow has caused to the faster tubes wall thinning that lead to tube failures. Beside the higher flow velocity during operation, the formation of calcium deposits under low flow condition is the most cause of the pitting and crevice corrosion of the tubes.

Besides trains shutdown, low or non flow conditions exist during operation due to:

- Blockage of tubes to debris being lodged against the tubesheet
- Internal blockage by foreign material
- Insufficient water supply to heat exchanger which resulted to fouling

Figure 4 An Individual Small Pit Displays at Hemisphere Shape

Above figure reveals that small pits are hemispherical in shape and very likely start to merge with one another to form larger and deeper pits as the surface metal is further eroded.

Tube blockages by debris and other external particles and corrosion product of carbon steel sacrificial anodes have been found to varying degrees in all the heat exchangers. Prior to 1990, barnacle's growth in the channel boxes of various exchangers had also been found.

In 2007, it was also found that the blockage of the inlet of tube sheet (mesh screen which was installed in 1982) caused by out specification of saw dust injected to upstream of heat exchangers. The blockage of the tubes is subjected to low flow or no flow, thus corrosion initiated due to local concentrations of chlorides or the formation of calcium deposits.

Figure 5 Tube Fouling due to Calcium Carbonate Growth

It was noted that the flow rate of the tubes had exceeds the max. tube velocity of aluminum brass and copper nickel tubes. Based on ultrasonic flow meter check on the tubes flow velocity, the flow rate crossed the tubes of the heat exchangers recorded to >3 m/s. Within five years after revamp project completion, the tube failures has increased to about >10% due to flow accelerated failures and severe tubes erosion.

Based on Energy Dispersive Spectrometer (EDAX) Analysis, it was indicated that sulfur and chlorine were present at the pit surfaces which are not part of element that forms copper tube's protective layer. These elements, which are commonly found as sulphide and chloride ions such as environments, are known to cause severe corrosion in copper alloys. Furthermore, sulphide can also from a weak film which is easily removed through erosion.

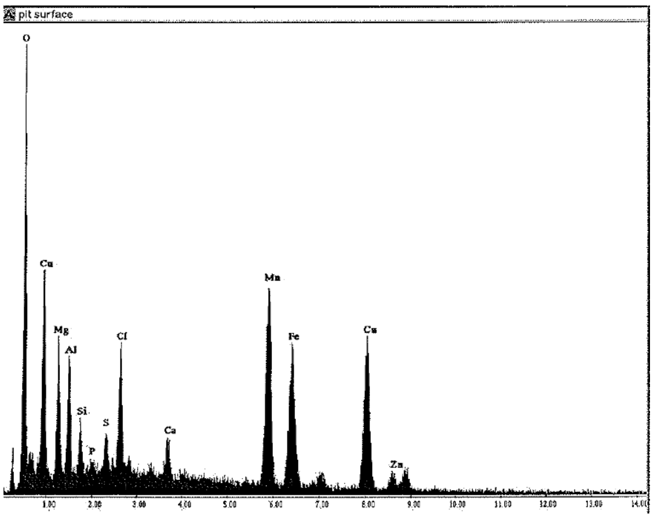

Figure 6 EDAX Analysis on Pit Surfaces

Based on Figure 5, EDAX confirms that the presence of sulfur on the tube surface. This presence of sulfur leads to the formation of weak, porous, sulphine containing film as observed in Figure 6 instead of a stable oxide layer. The weak oxide layer can be easily damaged and become preferred pit surface for pits initiation. As damage become more severe, the effect of local turbulence and erosion become more significant.

The minimum flow requirement for copper nickel alloy and aluminum brass tubes is 1 m/s. The sea water supply to an exchanger could be insufficient during the operation during these conditions:-

- When a LNG train is on standby, sea water pumps were shutdown and reduced the water supply taken from 24" crossover line from the main supply header of the operating train, and

- During the early start up or shutdown of the trains, only one cooling water pump is operated.

The average tube velocity is 0.3m/s when using crossover only. The design of tube velocities is 1.5m/s – 2.2m/s and average 1.8m/s with three pumps in operation. This average tube velocity is reduced to about 1.2m/s with two pumps operating below 95% LNG production.

With the practice of injecting the saw dust to minimize the impact of tube leaking during operation, the out of specification of saw dust injected to the heat exchanger had caused blockage to the mesh screen and accelerated the tubes flow rate throughout the heat exchangers. During train shutdown in year 2008, it was found that about 40% of the tubesheet blocked by out of spec saw dust which resulted to tube failures. This blockages has also resulted to a deposition of solids generally occurs below a tube velocity of 1 m/s.

Exposing to polluted water with certain degree ammonia and chloride content or any sulfides present can interfere with the surface film protection of then tubes, producing a black film containing cuprous oxides and sulfide. Based on analysis and investigation carried out in 2000 and 2003, it was highlighted that some tubes of sea water application failed due to corrosion under the protective layer caused by ammonia attacks. The source of ammonia was found in steam condensers originated from the hydrazine dosed to the Boiler Feed Water. The hydrazine reacts with oxygen to form nitrogen and water which potential caused to partial breakdown to ammonia. The major suspected sources of the ammonia are from sea water intake. It is known that ammonia levels of the sea water increase over the years and no monitoring was done to measure the level of ammonia of sea water. It was noted that the ammonia plant is nearby from the sea water intake station.

CHLORINATION UNIT PERFORMANCE

In order to minimize the growth of marine and other organism, a low level of Free Residual Chloride (FRC) is maintained throughout the cooling water system. The Cooling Water Intake Station (CWIS) has the facility to inject a solution of Sodium Hypochlorite (NaOCl) into the incoming sea water. Sodium Hypochlorite solution is produced in the electro-chlorination unit, using electrolysis of sea water by passage of a D.C current. The Sodium Hypochlorite solution produced in the electro- chlorination unit flow by gravity via a GRE transfer line to the dosing points at the CWIS. The purpose of the unit is to maintain a level of 0.2 – 0.5 ppm FRC at the cooling water out fall at all trains end so as to ensure that no marine or organic growth inside the cooling water system.

The CWIS has four inlet bays and during normal operation, only three bays are in service and the Hypochlorite storage tanks are bypassed and spaded. Although the purpose of the unit is to have a FRC level of 0.2- 0.5ppm in the cooling water out fall of each trains, from the loads record of four chlorinator units over the period of 2000 – 2009, it is found that three out of chlorinators don’t meet the design capacity and even demonstrated a constant decline in chlorination load (kA). As a consequence it is found that the FRC in the cooling water out fall of each trains only in 30% - 40% of the operational time is in line with the specification of a FRC of 0.2-0.5ppm. In addition, with the increase of LNG carries which is resulted to quality of sea water to be taken Additional test (e.g. TOC, Ph and amount of sediment/solids) to be analyzed during quite and busy periods at bay.

CORRECTIVE MEASURE TAKEN

Air Ingress

Maintaining good discharge pressure at the SCW pumps to avoid possibility of air ingress via the 112” SCM standpipe. One 36” common crossover header was installed at the discharge of the SCW pump to balance SCW between the three 112” SCM lines.

Fouling by Water Based Deposits

Since 1983, barnacle growth on the channel boxes of the exchangers had always been found. In 1987, chlorination of the seawater was reviewed and comparison was made on past Free Residual Chlorine (FRC) levels at all heat exchangers’ outlet and the inspection record during turnaround. It was concluded that a continuous chlorine level of 0.2 – 0.5ppm FRC would be required to keep the heat exchangers free from marine fouling. Shock dosing (3ppm FRC at pump intake station) is required if chlorine level at outfall is less than 0.1ppm for 3 consecutive days.

With the above chlorination guideline, it has proven that no barnacle growth was observed at all heat exchangers in all trains.

Chlorination of sea water however has adverse effects on the exchanger tubes. Aluminum brass and 70/30 Copper Nickel tubes are susceptible o attack at all level of chlorination. In the presence of chlorine, the protective oxide layer will not form on the tube surfaces. Thus, to ensure formation of this protective layer and the reformation of the film damaged during maintenance, it was decided that there should be no chlorination during start ups for the first 24 hours with water flow at least one cooling water pump. Due to aging and under performance of the existing old chlorination unit, the unit was revamped to a new bipolar cell. Close monitoring and tight control of the free residual chlorine at the intake station of the SCW as well as the outfall of the SCW in order to reduce marine fouling.

Fouling by Foreign Material

Responding to the high degree of tube blockage found the early days, the stainless steel screens were fitted in front of a number of inlet tube sheet commencing in 1985. This was to prevent debris from entering the tubes during operation.

The screen was fitted to above 25mm of the tubesheet as the tapered anchor plugs are not fully driven in. Debris caught on the screens are now 25 mm above the tubes ends. Consequently the tubes do not suffer from conditions of low or no flow as the debris do not directly cover all the tube ends.

Figure 7 Foreign Material Blocked Tubes

These screens somehow potential add risk of galvanic corrosion in this part of the heat exchangers. Since the installation in 1985, no galvanic corrosion was noted and this is resulted to the sacrificial anodes which continue to catholically protect the tube plates and tube ends.

Fouling by Anode Material

Where pitting/crevice corrosion are found, these are related to the breakdown of protective films. A ready supply of fresh rust or ferrous ions in solutions to reform the protective layer wills thus slowdown the corrosion process.

Figure 8 Anode Metal Loss

Zinc anodes were noted experiencing corrosion in sea water and the replacement was done to change all zinc anodes and steel anodes to soft iron anodes which provide a better performance. Steel anode shows the typical exfoliation type of rust that is often seen on iron anodes. This corrosion product is a cause of fouling, but also prevents the ferrous ion to dissolve in the water. By using soft iron (Armco ion) anodes to obtain even dissolution of the anodes without rusts built up leading to under deposit corrosion.

Tube Cleaning

Tube cleaning is carried out to avoid sedimentation on the inner tube surface and it is being carried out during train's shutdown either using mechanical or chemical cleaning method. It has found that a poor tube cleaning may result to presence of scaling which was not removed properly which later on may results to tube erosion – corrosion.

Chemical cleaning is carried out at minimum controlled flow rates to ensure that blockages due to the cleaning elements cannot occur. The selection of chemical product for cleaning shall be evaluated and analyzed to ensure no adverse impacts on the performance of tube material after cleaning.

Tube Material Selection

While all failures are of aluminum brass, both aluminum brass and 70-30 copper nickel alloys have been corroded on the basis of Eddy current checks, Corrosion appears confined to a small group of heat exchanger.

The choices of aluminum brass and copper nickel (70-30) tubes are therefore; on a system wide basis is appropriate. On the affected exchangers, an upgrade to a more resistance type has been evaluated. Titanium, super duplex stainless steel and copper nickel with additional iron content are alternatives for replacement.

Extensive analysis and study on the material selection has resulted to the selection of copper nickel alloy with a specific content of iron to provide a better corrosion resistance in sea water application. Copper Nickel alloy (ASTM B111 C71640 with 1.83% iron) has proven excellent with sea water application. The first heat exchanger using this new material was put on trial in year 1998 and after almost ten years in operation, no tubes failures was found during every train shutdown. Copper nickel alloy with 1.83% iron content provided a higher mechanical strength and corrosion resistance as compared to standard copper nickel alloy with 2% iron content. The new tubes material is also noted that capable to withstand the tube flow velocities exceeds 3.5m/s at a certain condition on the short term period. The retubing of all affected heat exchangers has initiated in year 2008 by replacing all aluminum brass and copper nickel tubes with copper nickel alloy with 1.85% iron content tubes. About 4,000 tubes have been replaced with this tubes material and for another 50,000 tubes of aluminum brass tubes will be replaced in year 2009.

Improved Water Tube Velocity

All heat exchangers should be operated with seawater velocities between tube material velocity's range to avoid deposits and erosion-corrosion. The seawater flow velocities are closely monitored to ensure the operating velocities is in range of tube material velocities. Operating within the design tube velocities by throttling the common outlet valve (MOV) of three condensers to avoid erosion corrosion. The flow distribution has been measured by using portable ultrasonic flow meter to ensure that the flow through the heat exchangers are within the acceptable tube velocity limits.

Mitigate Inherent Design Problem

Besides all the corrective measures, a series of Computational Fluid Dynamic (CFD) calculations was conducted to determine possibility in improving the system by having a better understanding on the impact of the hydraulic leading to maldistribution inside the heat exchanger's channel boxes. The CFD studies of the flow through the inlet piping and water box into heat exchanger showed that there were fluid flow turbulence problem based on the current design at selected heat exchangers. The results further showed that the problem with the current piping design is that the fluid must flow through closely coupled elbows; through a reducer, through a sudden expansion, and then having to make a 90 degree turn in order to find its way to the tube sheets. Example of design issues are illustrated in the figures below.

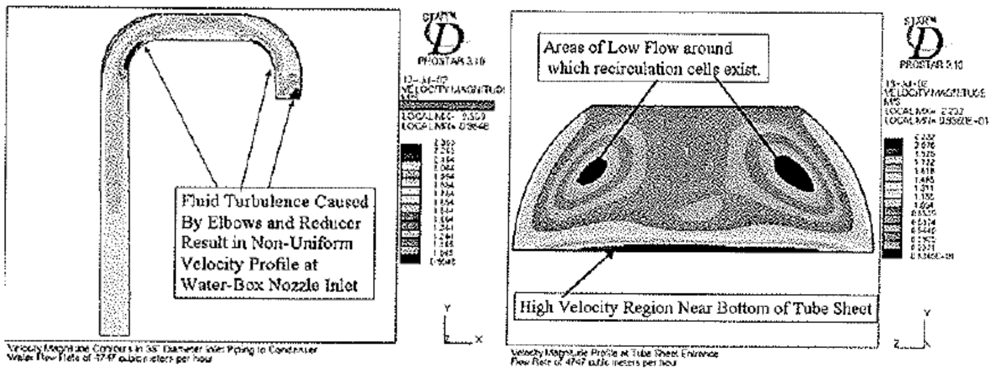

Figure 9 CFD Results of Heat Exchanger Inlet Piping and Water Box

Based on these findings, it was decided to mitigate the problem by installing the bottom section of the tubes in the first pass with a better tube material instead of Al-Br which are more resistance to high velocity and erosion effects.

Other factors to consider in reducing SCW heat exchangers failures are as below:

1) **Water Quality Improvement**

   a) **Cleanliness** - It is crucial to ensure cleanliness of water supply for heat exchangers. Debris, sediments and any other external particles that are passed through heat exchanger is to be screened and filtered.

   b) **Dissolved oxygen and sulfides** to be properly controlled or eliminated to ensure no failures of copper nickel alloy. Copper alloy tubes do not stand up well in severely polluted water that dissolved oxygen has been consumed in decay process and sulfides are present.

   c) Residual **chlorine** from sea water to be within the limit of operation and it shall be kept within the range of 0.3 – 0.4ppm at the inlet tube sheet.

   d) **Acidity-** In aerated water of PH less than 5, a protective film does not easily form on copper nickel tubes, so they corrode and thin rapidly. For Al Br tubes, which tend to corrode under highly alkaline conditions.

   e) **Temperature** of sea water to be controlled and monitored to ensure a protective film readily forms on copper nickel alloy in warm water but forms very slow in cold water.

These factors need to be considered for the selection of tube metallurgy for sea water application.

2) **Operation and Maintenance**

   a) **Passivation** - Ferrous Sulphate injection has became of the preventive measures to minimize tube erosion during operation. When adding iron – sulphate solution to oxygen-containing water (sea water), the formation of the protective layer on copper alloys is enhanced. The solution is added at upstream of the heat exchanger to avoid the formation of trivalent iron because Fe+++ is ineffective and mat even react adversely. It has been a practice for ferrous sulphate injection for all sea cooling water heat exchangers.

   b) **Preventive Maintenance -** Preventive maintenance is also carried out at every regulatory shutdown. All heat exchangers are cleaned to remove all deposits and to ensure cleanliness of heat exchangers. Eddy Current Testing (ECT) are carried out on selected heat exchangers and tube which show > 30% loss in wall thickness are plugged. It has been a industrial practices where the retubing work to be executed if the number of plugged tubes has exceeded 10% of total tubes population.

3) **Heat Exchanger Design**

   The principal of heat exchanger design that influence tube performance to be evaluated and analyzed properly to ensure no tube failures during operation.

   a) **Velocity -** At velocities of less than 1m/s, sediment deposits, debris buildup and biological fouling in and on tubes can be excessive, which can cause copper nickel alloy and stainless steel tubes to fail permanently due to under deposit corrosion

   b) **Tube diameter**- Tube of large diameter are preferred for heat exchanger because any solids that pass through the screens will also flow through tubes

   c) **Shape** - The selection of tube shape either once through of U tubes to properly selected based on type of service or application. U tubes bundle must be avoided if the bundle prone to such corrosion if sediment and debris are not removed from their bends.

   d) **Orientation** of heat exchangers must follow TEMA standards recommendation for corrosive services and applications.

   e) **Venting-** Exchanger are normally fitted with vent cocks so they can be purged to clear gas or air pockets. Condensers, particularly when chlorine used as a biocide, tend to suffer corrosion when gases are not vented.

   f) **Tube sheet material**- selection of tube sheet material which is matching with tube material is necessary to avoid possibility of galvanic corrosion

g) **Channel** Boxes Material – Corrosion product from water box due to wrong choice of material matching between water box and the tubes and tube sheet can cause adverse galvanic corrosion.

PLANT THERMAL EFFICIENY AND OPTIMIZATION PROGRAM

Plant optimization to improve production capacity changes the operating conditions and cooling requirement. The changes of flow regime require resizing and material compatibility analysis for the affected heat exchangers. Mitigation and redesign of heat exchangers has been undertaken to ensure the exchangers meet the changing operating conditions.

The challenges faced over the years in operating and maintaining the heat exchangers has elevated engineering and design standard that is crucial for future design and construction consideration.

The alternative for the cooling system using air cooled heat exchanger is one of the options to mitigate the issues of sea water for cooling system. However, air cooled heat exchangers provides different characteristic of failures and issues. Fouling of the air cooled heat exchanger's fins due to atmospheric contaminants had reduced its efficiency and poses cleaning challenges. Fan belts, motors and bearings failures are other typical problems faced in the operation of air cooled heat exchangers. These require expanding resources, both parts and labor for proactive and reactive maintenance. Degradation of air quality has increased fouling rate of the air cooled heat exchangers. The tube fins are easily fouled within one year after cleaning. The air cooled heat exchanger fouled faster with a smaller tube pitch design. Online chemical foam cleaning, changing component materials and good maintenance practices have improved the performance of the air cooled heat exchangers in LNG plants

The increase number of open burning nearby the plants, and change of air quality has accelerated the fouling rate of air cooled heat exchangers. The fin fans were found easily fouled after one year in service. The reduction of air flow cross the tube bundles has resulted to underperforming air cooled heat exchanger and resulted to inefficiency of heat exchangers.

CONCLUSION

The challenges faced over the years in operating and maintaining the heat exchangers has elevated engineering and design standard that is crucial for future design and construction consideration.

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