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ADVANCED UT TECHNIQUES UTILIZED AT SAMREF

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ABSTRACT:

This paper is prepared to share Saudi Aramco Mobil Refinery (SAMREF) experience during the elapsed few years with newly developed advanced UT techniques and to show how they are effective in assessing and identifying the problematic areas in the refinery equipment and piping without affecting the plant production and the Turnaround schedule.

The paper will discuss in particular, the UT Shear Wave Technique that is currently utilized for flange inspection to detect flange face corrosion, UT thickness measurements on hot piping and equipment for corrosion and erosion monitoring and Time of Flight Diffraction (ToFD) UT Technique for weld quality testing in lieu of Radiography Testing.

INTRODUCTION

Non Destructive Testing techniques are widely used in the industries aiming at the detection of corrosion on the existing equipment and piping and provide a tool for insurance of achieving the quality measures during new fabrication and construction. New NDT techniques are continuously developed and implemented for the purpose of reliability enhancement throughout the industries. Many of these methods could be performed without affecting the equipment or Unit operations.
Ultrasonic Testing (UT) Method is considered one of the most valuable methods that is heavily used and applied in the industries. This is because of its flexilibility to new invention based on the industrial needs. Such technique involves the basic UT Thickness Measurements, Straight Beam UT, Angle Beam or Shear-wave UT, Attenuation Testing, Time of Flight Diffraction, Internal Rotary Inspection System, Phased Array UT Scan, P-Scan, etc.
The present paper discusses the basic principles of the UT techniques mentioned above, useful applications, advantages and limitations and each UT technique will be discussed in a separate Section.

ON-LINE FLANGE FACE INSPECTION USING UT-SW TECHNIQUE

Summary

The On-Line Flange Gasket Face Inspection Technique is newly applied at SAMREF since year 2005. The subject technique utilizes the manual angle beam UT probe on the Weld-Neck flanges to perform on-line inspection. The technique is aimed at detection of flange face corrosion due to HF Acid attack on the Carbon Steel flanges. The main reason for this advanced UT technique is to reduce the turnaround schedule by the reduction of the inspection time during the turnaround and also to help cost effective turnaround planning by identifying the flanges that require definite repairs or replacement ahead of the turnaround start date.

Background

The Alkylation Unit is part of the FCC Complex in SAMREF. The unit main function is to produce high-octane gasoline blending stock and therefore is considered one of the most important units in SAMREF due to its high value products. It uses the Hydraufluoric (HF) acid as catalyst. HF acid exists as a fresh and pure process or dissolved in the process hydrocarbons (traced HF).

From safety point of view, the HF acid is considered one of the most toxic chemicals in SAMREF Refinery either in liquid or vapor phase. Extreme precaution is established to prevent the HF acid leak to the atmosphere by adequate design, operational control, extensive quality control measures during the construction and repairs in addition to continuous monitoring by the field operators.

Corrosion problems in the Alkylation Unit are mainly caused by the presence of HF acid which is a strong acid and could impose medium to extremely serious corrosion in almost no time, depending on the process flow conditions and locations. There is different attack mechanisms associated with the HF Acid, one of them which is related to the subject is HF acid crevice corrosion which is created in the tight gap areas such as flanged connections.

It is believed that the repeated leaks on the flanged connections are linked with HF acid crevice corrosion. By design, a gasket with a PTFE inner ring is selected. The purpose of this ring is to fill the void or gap area between the mating flanges and to minimize the acid intrusion between the flange faces, thus reducing the crevice flange corrosion. However, this could not be fully achieved as experience showed a number of flanges that had significant corrosion on the gasket flange face.

Due to piping complexity and the high number of piping flanged connections (around 1000 flanged connections in the Alkylation Unit), a special program was created in the year of 2002 aimed at preventing critical HF flange leaks by timely assessment and rectification of the flanged connections in compliance.

The program covers all piping flanges in the Main and Trace HF acid streams. The 1st Phase of the program was completed during the 2002 Turnaround through conventional method of breaking-down flanges, inspecting flange faces and repair or replace as required. This traditional approach imposed high cost and very slow progress of the program due to limited number of flanges that could be opened for inspection during the turnaround (majority of the flanges could not be opened on-stream). With this traditional approach and due to excessive number of flanges that has to be opened, the inspection works has to be completed after at least four (4) Turnaround timeframes (2002 through 2018 turnarounds). Therefore, SAMREF explored other alternative techniques and identified that the On-Line UT Shear Wave based technique to be a cost-effective and efficient mean to continue this critical inspection program based on the set time frame (2005 till 2010).

Another successful approach by SAMREF is that two SAMREF Saudi inspectors were trained to this technique and have been qualified by a certified training organization.

High priority flanges were started during the year of 2005. After the 2006 Major Turnaround, the success rate was calculated to be around 87% (i.e. 13% of the reported flanges to be in the fail criteria were found in good condition). Obviously, the accuracy is highly dependent on the operator capability and confidence and it is believed that more practicing and field work with this technique should further improve this success percentage in the future.

Technique Description

Technique description is summarized below;

1- Weld Neck configuration is shown in Figure -1. This type of flange is the only acceptable flange connection method for piping in the HF acid service (including hydrocarbon with HF acid traced, even for small piping such as ¾”). This design was selected as to minimize the chances of crevice corrosion which is typical for socket welded and slip on flanges

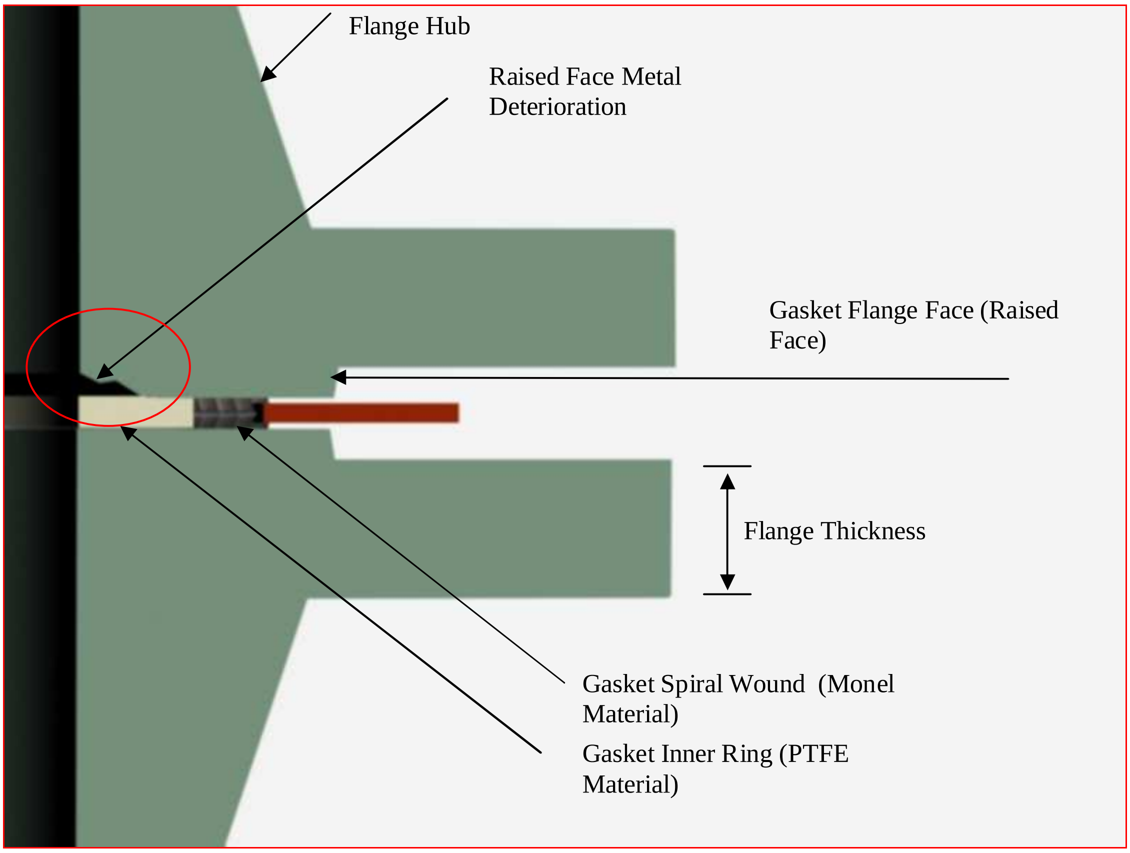

Figure – 1: A Close View for 2 WN Flanges Connected with Spiral Wound Gasket Showing a Metal Attack from Process Side (note: bolts are not shown)

2- Knowledge of flange configuration, dimensions and sketches is mandatory. Also, history of repairs or replacement would help proper evaluation of the corrosion problem.
3- The technique utilizes the angle probe only. Straight probe could not be used because that the area of interest could not be accessed by the straight beam method

4- The block calibration procedure is similar to the normal angle UT
5- The best beam angle (angle of refraction) should be selected using a transparent paper representing the available beam angles and the paper is placed on a 1:1 scaled drawing which represents the actual flange. The paper should be traced through the flange drawing and the best angle should be selected (refer to Figure 2 below).

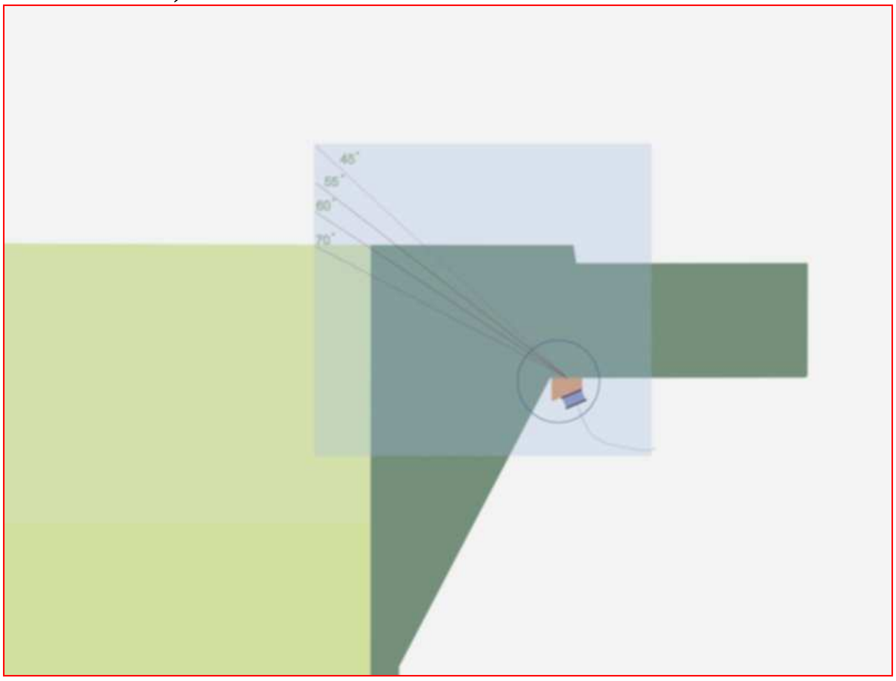

Figure -2: Beam Angle Selection using a Transparent Paper and 1:1 Scaled Flange Drawing

6- Similar to the UT Shear-Wave method, depth, surface distance and south path have to be determined as to approximately allocate the corrosion areas (refer to Figure 3)

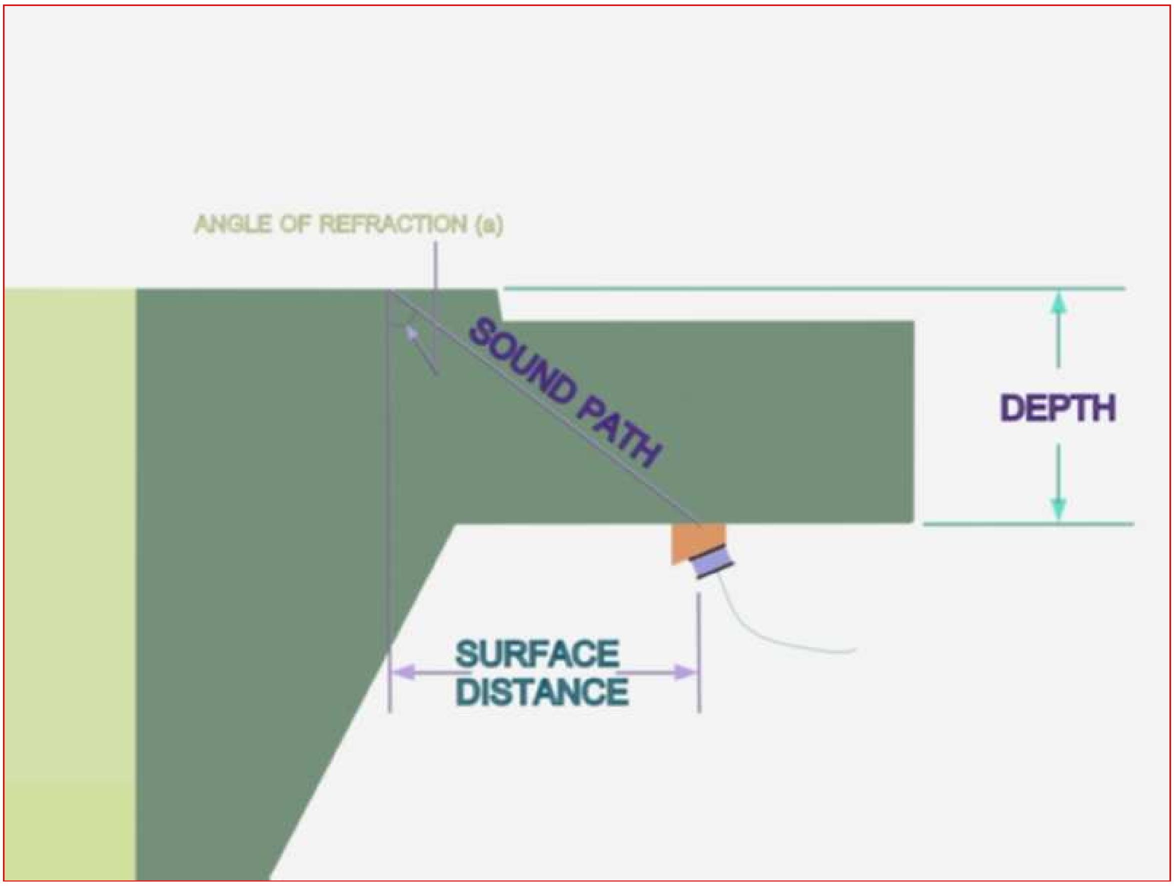

Figure – 3: A 2D Drawing Showing Required Dimensions to be Identified

7- It should be noted that this technique could be only used to inspect the flange area that is located between the bolt holes.
8- As the corrosion source is from the process stream, the technique would focus on the internal side of the face, i.e. the inner 50% of the flange face should be inspected first. The outer 50% of the flange face should be inspected only if a moderate corrosion is detected. By this approach, considerable inspection time saving could be achieved.
9- Acceptance criteria is summarized to have a rejected flange when the corrosion exceeds 50% of the inner side of the flange face and the rejected flange has to be repaired or replaced based on the repair economics, refer to Figure 4.

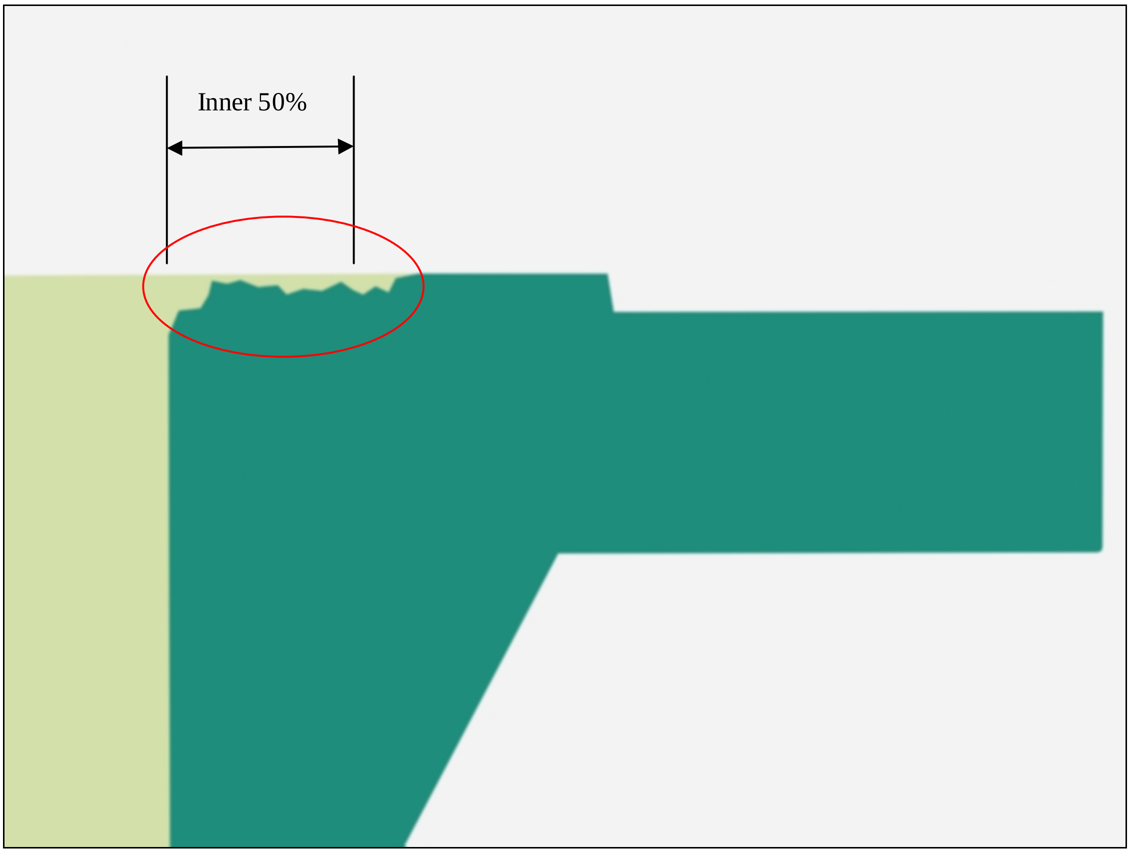

Figure – 4: Rejected Flange due to Corrosion more that 50% of the Flange Face

Technique Advantage:

1- Cost effective inspection technique allowing on-line inspection and also utilizing the available UT flaw detectors
2- Cheap inspection method compared to Phased Array
3- Not very complicated.

Technique Limitations

1- The technique requires a skilled UT Personnel (Level II or Level III, with a specialized training on the technique)
2- The technique does not fully scan the flange face. The probe could not inspect the area behind the bolt holes
3- No permanent record is obtained

ON-LINE HOT UT THICKNESS MEASUREMENTS

Summary

The on-line UT thickness measurement at elevated temperatures is not a new UT technique but it had major contributions to SAMREF Refinery as an effective cost saving inspection tool which could assess the piping integrity under high temperatures without the need to shutdown the process unit. As defined by UT probe manufacturers, the hot temperature ranges from 65^{o} C to the maximum temperature that the probe or couplant could handle.

Background

SAMREF first use of the technique was in the year of 1997 to identify the elevated temperature piping replacement scope without the need to shut down the process unit (operating above 300C).

Latest useful application for the technique was in April 2006 and after the completion of the 2006 Major Turnaround. Significant catalyst losses were observed for a Major Process Unit (FCC Unit). The reason for the problem was un-known yet and troubleshooting was carried out and identified many causes but all of these causes are related to internal problems of major pressure vessels in the unit. As a result and in order to fix the problem, the unit has to be shutdown in an urgent basis due to catalyst significant losses.

Manpower resources at that time were extremely difficult due to the engagement of the local contractors to other industrial turnarounds and the need to postpone the shutdown is required. Due to the significant erosive environment of the catalyst, a safety concern was raised for the piping and equipment integrity. The need to inspect the piping is mandatory to answer the question "could the unit be operated safely until then next emergency outage?". Hence, Hot UT was introduced and extensive UT was performed on susceptible erosion areas. The results showed that the unit could be postponed for a few weeks safely and saved Samref at least US $ 1,000,000.

Due to the hot and elevated temperature associated with this application, the Hot UT Thickness measurements is used only when it is required and not made as a routine inspection method.

Technique Description

The Hot Temperature UT thickness measurement technique is different than the Cold Temperature technique by a few items including equipment and procedure. The Hot UT Technique uses a special probe and couplant but uses the same UT device as the cold UT thickness measurement device. A few items that describe the Hot UT Technique are outlined below;

1- Safety during the UT measurements at the elevated temperatures must be evaluated carefully due to the difficult environment for the NDT Technician. Reason is that radiant heat will fatigue the technician and there is a potential for burns if appropriate Personal Protective Equipment (PPE) not worn. Items that must be considered shall include evaluation for the need to conduct Job Safety Analysis (JSA), UT scope shall be minimum, insulation removal should be kept to a minimum (UT through insulation holes is mostly recommended), considering that the couplant has a self ignition temperature and consider alternate NDT techniques if the work cannot be performed safely (i.e. permanently mounted UT probes or radiography)

2- A qualified procedure and personnel for the testing must be established and approved by a Level III NDT Personnel in UT. A summary of the procedure (using Kratkramer Type DA 305 & ZGM Couplant) is included below;

   a. Calibrate the UT device at ambient temperature on a step block which includes the thickness of interest.
   b. Prepare the examination surface by removing rust scale and coating if any, before every measurement.
   c. The service temperature of the examined pipe must be checked before conducting of the physical job and during the execution of the job. Frequency and tools required (such as pyrometer, skin thermocouple, etc.) should be specified in the procedure.
   d. Clean the probe prior to every measurement to remove residue from decomposed couplant.
   e. The required couplant should be selected in the early stage depending on the service temperature of the tested component.
   f. Apply the couplant to the transducer's face and not on the tested surface. The probe shall be applied for a short duration of time.
   g. After each measuring sequence, the probe is to be cooled immediately in cold water.
   h. The contact face (transducer's face) is to be cleaned adequately before taking another measurement.
   i. The couplant residues must be removed completely from the tested material as it may corrode the material.

Due to the difficulties in obtaining accurate hot UT measurements, the hot UT personnel must be tested frequently. The technician shall be able to demonstrate an accuracy of + / - 0.25 mm difference between the hot and cold measurements. A Curved Step Wedge is used for this verification (refer to Figure 5). It should be noted that the wedge has to be heated to the operating temperature of the actual pipe.

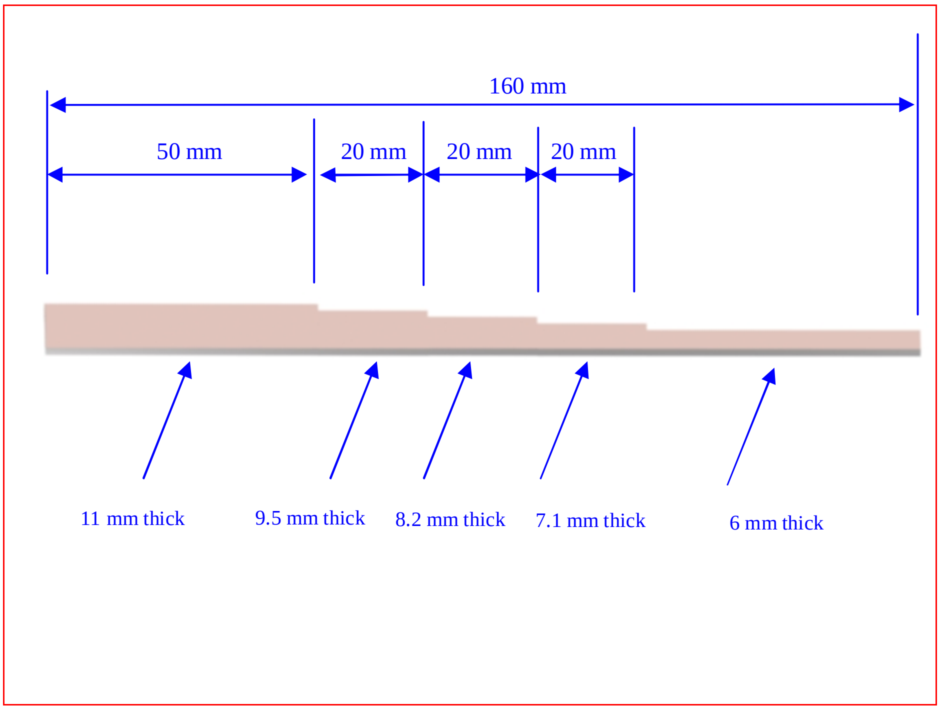

Figure - 5: Side View of the Curved Step-Wedge with Dimensions

Technique Advantage:

1- Cost effective technique that could eliminate the need to shutdown the process unit and hence saving the plant overall production
2- Simple and could be performed by the normal NDT technicians after qualification testing

Technique Limitations:

1- Safety concerns due to the risk of heat exposure and burns which require a Job Safety Analysis in some cases.
2- Very slow process due to the high temperature environment which strain the technician and require him to frequently take a rest more than the normal applications.
3- The probe could be wear-out while performing hot UT measurements. Hence, the probe has to be frequently tested and the supply of spare probes are to be considered

ALTERNATIVE UT TECHNIQUES IN LIEU OF RT

Summary

This section will discuss SAMREF successful journey in the use of NDT techniques as substitution to Radiography Testing. These techniques include ToFD and UT-SW (Visual Inspection (VI) was also used but will not be discussed in the paper). In comparison to RT, these techniques could be executed during the normal working hours without affecting the work field progress. The selection of the required UT technique for a particular joint depends on many factors which are listed in the table below.

Background

Radiography Testing (RT) is considered one of the most effective NDT methods that could find and allocate volumetric internal discontinuities and defects and also has the feature of recorded results. On the other hand, it has serious effects on the human bodies due to its radiation properties. As a result, no field works and human presence are allowed to be within the radiation exposure area during the execution of the RT. During turnarounds, RT scope is usually performed only during the lunch or shift changes where the field activities are stopped. Except for special cases, it is not allowed conduct RT during the working hours as not to affect the turnaround schedule.

Radiography Testing scope has a major impact on the turnaround schedule when significant number of piping joints are to be examined which was the case for SAMREF Refinery during the 2006 Major Turnaround. Hence, SAMREF had managed to have alternate UT techniques to replace the majority of the RT scope. Time of Flight Diffraction (ToFD), was utilized for large bore piping (from 12” to 36”) and UTSW was used for many joints where some relaxation was made based on non critical service, easy welding and good welder records. The RT scope was reduced to to be around 35% of the field welded joints instead of 100% and covered the joints of small to medium bore piping (2” to 10”) that handle critical service (such as LPG, hydraufluoric acid, etc.), tie-in joints and joints that have crack tendency due to service hydrogen charging. As a result, SAMREF turnaround goal was achieved by completion of the turnaround with the desired quality without a delay that could be the case if RT scope was only utilized.

Discussions

Throughout the pre-turnaround and turnaround fabrication and erection activities in SAMREF, there were clear signs of quality concerns by a major construction contractor. The deficiencies primarily ranged from shortage of resources, non-skilled manpower, lack of appropriate quality control personnel and NDT tools as well as shortcoming in the overall quality supervision and follow-up. The sub-standard quality was also obvious through the high welders rejection rate (as high as 12%) and significant schedule delays. Accordingly, the contractor request to reduce the high number of RT on field welded piping (originally, all field welds has to 100% RT inspected) could not be accepted. As to satisfy both, job execution completion date and job quality, SAMREF searched available volumetric NDT methods to replace the RT in an attempt to expedite the NDT activities associated with the construction of the piping. The following table summarizes the selected NDT Methods and techniques with its applications and examples.

Applicable NDT Method/Technique	Condition	Example

UT – SW	1- Moderate consequence piping which has a minor effect of the SHE (Safety, Health and Environment) 2- Good welder's records 3- Easy welding	1- Low temperature hydrocarbon 2- Less than 4% rejection rate 3- 6" butt weld on a non congested area
ToFD	Critical service and large bore piping	20", LPG service
Visual Inspection (not covered in this paper)	1- Weld could be inspected from the ID 2- Non critical and low pressure piping	1- 6" WN flange to pipe weld 2- Cooling water service

It is not simple to calculate the time saving and associated cost by the exchanged NDT methods taking into account that more than 300 welded joints were UT-SW inspected and more than 30 joints were ToFD inspected in different areas of the Refinery.

This is the 1st time that SAMREF had accepted that UT-SW to be an alternative NDT method to RT for a large number of welded joints. On the other hand, SAMREF does believe that UT-SW does not have reliable results in some instances. This is because that it is operator dependent and does not have a permanent record for future references. Also, lack of adequate and professional manpower as experienced during the present days would be a major concern with regard to the testing quality. For this reason, it was requested that all UT-SW are to be carried out under the witness of SAMREF Quality Control representative and to cover only the listed conditions above.

During the 2006 Major Turnaround, SAMREF utilized ToFD Technique to be a reliable volumetric inspection method for piping weld integrity inspection. The technique was used earlier in SAMREF with existing pressure vessels particularly for assessment of crack associated defects. ToFD is a field-proven advanced UT technique which was developed in 1970s for crack sizing of nuclear plants. ToFD examinations rely on the time of flight, rather than the amplitude of the ultrasound signal to size the defect and are therefore not as sensitive to defect orientation which is the case for the UT-SW. It has the feature of permanent records (computerized image and record of the inspection results). One major advantage of ToFD is that it can inspect large bore piping and eliminate the RT requirements for those piping. It was experienced that one RT shot for a 30" pipe would take a few hours to complete one joint and therefore, no other work activities shall be done during that period inside the barricaded area. Also, SAMREF utilized a UT Level III Technician to perform the job and the results were very successful. It should be noted that ToFD should not be carried out on tie-in joints. This is due to the fact that a small misalignment (Hi-Lo) would show lack of fusion defects by the ToFD. The technique is very sensitive to weld misalignment and a number of joints were rejected because of this and the same joints were tested again by RT and accepted as no Lack of Fusion were noticed.

Technique Advantage:

UT-SW

1- Provides a reliable volumetric testing under the condition that the job is performed by a dedicated and experienced technician
2- Could substitute RT for non critical service
3- Simple and portable technique

ToFD

1- Provides a reliable volumetric testing and could substitute RT for critical service, particularly for large bore piping

Technique Limitations:

UT-SW

1- Cannot be used as substitution to RT for critical service
2- Cannot be performed on piping less than 6” nominal pipe and thin piping
3- No permanent records

ToFD

1- Expensive technique that do require computerized equipment plus specialized and qualified personnel
2- Very sensitive to discontinuities and it is not recommended to be performed on tie-in joints

CONCLUSION

The paper is prepared to encourage the main petroleum industries that NDT is a wide field and inventions are newly developed for the sake of servicing the industry. This does require a two-way communications. Regardless of the available products that could be searched easily through the internet, manufacturers or suppliers are to present their new technologies and products to the industry and the industry personnel are to share their problems with the suppliers or manufacturers.