

Engineering Procedure

SAEP-1135

29 February, 2004

On-Stream Inspection Administration

Document Responsibility: Inspection Dept.

Saudi Aramco DeskTop Standards

Table of Contents

1	Scope.....	2
2	Applicable Documents.....	3
3	Instructions.....	5
4	Responsibilities.....	14
5	OSI Program Reviews.....	16
6	Terminology.....	16
Appendix A - Corrosion Circuits, Classes And Service.....		17
Appendix B - Thickness Measurement Location (TML) Assignment.....		20
Appendix C - OSI Computer Program Calculations.....		24
Appendix D - Review of Other OSI Methods.....		25

1 Scope

This Saudi Aramco Engineering Procedure (SAEP) describes the steps necessary to plan and operate a program for the on-stream inspection (OSI) monitoring of fixed equipment. OSI Monitoring in this SAEP means the systematic monitoring of piping, pipelines, vessels and tanks for general loss of wall thickness and localized metal loss.

In addition to OSI Monitoring, an overall OSI Program should address several other types of inspection for fixed equipment while it is on stream or inaccessible for internal inspection. The other types of OSI, such as visual external inspection, corrosion probe monitoring, radiography and leak detection, are reviewed in Appendix D. The objective of an overall OSI Program should be to collect and integrate the different types of OSI data, particularly when preparing equipment for Test & Inspection (T&I) shutdowns.

It is the responsibility of all Operations Inspection groups to have an active OSI Program. The Inspection Unit Supervisor of each operations unit is responsible for planning and administering an OSI Program.

1.1 Equipment Scope

This procedure applies to piping and equipment for process fluids, hydrocarbon and similar flammable or toxic fluid services including fixed equipment contained in Community and Operations Support Facilities as stated in [SAEP-309](#). Basic types of this equipment include:

- Piping, Pipelines, and Fittings
- Shell & Tube and Fin-Fan Heat Exchangers
- Boilers
- Drums and Spheres
- Columns
- Storage Tanks and Spheroids
- Furnaces and Stacks

1.2 OSI Monitoring

The monitoring of equipment for wall thickness loss and for flaw development (such as pitting, erosion, gouging and cracking) is referred to as "OSI Monitoring." It is normally

conducted externally while equipment is operating (i.e., on-stream), under pressure, or inaccessible for internal inspection. Metal loss and flaw detection is usually done with ultrasonic instruments and radiographic equipment. Internal inspection of fixed equipment, particularly for internal conditions and associated

maintenance and test work during shutdowns, is referred to as "Equipment Inspection." This type of inspection, referred to in [SAEP-20](#), is not covered in this document. It should be noted that thickness monitoring during "Equipment Inspection" becomes a part of the total OSI Program.

1.3 OSI Objectives

The objective of an OSI Program is to provide reliable safeguards against unexpected failures and leaks that can jeopardize safety and production. This can be done efficiently by assigning OSI monitoring levels to match equipment corrosive service conditions. An OSI Program alone can not prevent all equipment failures, but when it is coordinated with other measures, such as proper maintenance support, the risk can be reduced to acceptable levels. Through predictive OSI reports, the following are realistic goals of an OSI Program:

1.3.1 Recommend Retirement or Corrective Action

OSI reports are issued to recommend equipment retirement or derating dates and to recommend repair or other corrective action, as a result of corrosion rates and remaining life.

1.3.2 Decrease Downtime

Prior to T&I shutdown, OSI reports can provide data to timely forecast the replacement of components that are at, or near, retirement thickness.

1.3.3 Increase Runtime

Reliable OSI information can contribute information to a Risk Based Assessment Program and allow safe extension of equipment runtimes when wall thickness loss conditions so indicate.

2 Applicable Documents

On-stream inspection shall comply with the latest edition of the references listed below, unless otherwise noted.

2.1 Saudi Aramco References

Saudi Aramco Engineering Procedures

[SAEP-20](#)

Equipment Inspection Schedules

[SAEP-309](#)

*Inspection of Community and Operations Support
Facilities Inspection*

<u>SAEP-122</u>	<i>Project Records</i>
<u>SAEP-308</u>	<i>Operation Inspection Unit Review</i>
<u>SAEP-343</u>	<i>Risk-Based Assessment for In-Plant Static Equipment</i>
<u>SAEP-1140</u>	<i>Qualification of Saudi Aramco NDT Personnel</i>
<u>SAEP-1142</u>	<i>Qualification of Non-Saudi Aramco NDT Personnel</i>
SAEP-1153	<i>Inspection Worksheet Procedure</i>

Saudi Aramco Engineering Standards

<u>SAES-A-005</u>	<i>Safety Instruction Sheet</i>
<u>SAES-A-206</u>	<i>Positive Material Identification</i>

Saudi Aramco Inspection Procedures

<u>01-SAIP-01</u>	<i>Small Nipple Inspection Program</i>
<u>01-SAIP-02</u>	<i>Retirement Thickness of In-Plant Piping</i>

Saudi Aramco Forms and Data Sheets

2821-ENG	<i>On Stream Inspection Gauge Points</i>
9527-ENG	<i>Pressure Vessel Data Sheet</i>

2.2 Industry Codes and Standards

American Petroleum Institute

API STD 510	<i>Pressure Vessel Inspection Code: Maintenance Inspection, Rating, Repair, and Alteration</i>
API RP 570	<i>Inspection, Repair, Alteration and Rerating of In-Service Piping Systems</i>
API RP 572	<i>Inspection of Pressure Vessels</i>
API RP 574	<i>Inspection Practices for Piping Components</i>
API RP 578	<i>Material Verification Program for New and Existing Alloy Piping Systems</i>
API RP 579	<i>Fitness for Service</i>
API STD 653	<i>Tank Inspection, Repair, Alteration and Reconstruction</i>

American Society of Mechanical Engineers

ASME B31.3

Process Piping

American Society for Testing and Materials

ASTM E797

*Standard Practice for Thickness Measurement by
Manual Contact UT Method*

3 Instructions

This section outlines instructions to establish locations, quantity, and monitoring intervals for OSI Thickness Measurement Locations (TML) (details are presented in Appendices A & B). An OSI Program consists of six general activities for effective gathering and processing of OSI monitoring data. These six activities are described below and are:

- Circuit/Thickness Measurement Location (TML) Assignment
- Data Collection
- Scheduling
- Data Analysis
- Reporting
- Training

3.1 Circuit/TML Assignment

This activity covers the assignment of TML sampling units (called piping Corrosion Circuits or Equipment Circuits) and the TML positions and number of positions within each sampling unit. (See Appendix B for further information).

3.1.1 Corrosion Sectors

To assign corrosion sectors, divide the overall facility Process Flow Diagram into sections that represent large plant areas of common corrosion characteristics.(e.g., a large gas processing facility could be divided into Sour & Wet, Sweet & Wet, and Sweet & Dry corrosion sectors) As a convenience, each remote or isolated facility should be treated as a corrosion sector. Corrosion sectors can be helpful for the following tasks:

- a) Determine Corrosion Circuits, Corrosion Classes, and the manpower to monitor them.
- b) Schedule baseline surveys of new plants.

- c) Assign monitoring trips to small facilities in remote areas (since for logistical purposes, these facilities can be considered as corrosion sectors). Examples of these facilities would be onshore/offshore GOSPs and desalting units. Such facilities may contain several Corrosion Circuits that have different monitoring priorities. In order to ensure proper scheduling of monitoring visits, these facilities would be assigned corrosion sector monitoring priorities based on their most corrosive circuits.

3.1.2 Corrosion Circuit Assignment

Review Piping and Instrument Drawings (P&IDs) (see Section 3.1.3) and select Corrosion Circuits (see Appendix B) so that the smallest TML sample number, representing an entire circuit or problem zone, can be highlighted:

- a) Piping Corrosion Circuits -- On P&IDs trace with a different color each network of single alloy piping that sees the same process flow corrosion conditions. Usually a Corrosion Circuit can be identified as all of the continuous piping that connects two major pieces of equipment, such as a column and pump. It is advantageous to start and end corrosion circuits at numbered equipment.

Commentary Note:

Computer programs have been especially designed to accommodate piping Corrosion Circuits - see Appendix C.

- b) Equipment Corrosion Circuits -- Each piece of equipment is usually treated as a single Corrosion Circuit

Commentary Note:

Computer programs have been designed for vessels in addition to piping and they also can be used for tanks.

3.1.3 Process and Instrument Drawings

To simplify records, P&IDs may be redrawn into process flow diagrams that show one or more Corrosion Circuits. Additionally, isometric piping drawings must be developed for each circuit to indicate positions of the TMLs and limits of the circuit.

Commentary Note:

See Figure 33 in API RP 574 for typical isometric sketch.

- a) Process flow diagrams (if employed) -- Each Corrosion Circuit is shown on master flow diagrams as having piping flow lines of a specific color or a specific line symbol. Common colors used are red, blue, and green; common symbols used are solid lines, dashed lines, and dotted lines. Each Corrosion Circuit may be further divided into circuit subsections. These subsections are identified by numbers placed in each Corrosion Circuit and refer to one or more isometric drawings.
- b) Isometric drawings -- Isometric drawings must be directly indexed to the P&ID or process flow diagram so that specific TMLs can be efficiently located. Isometric drawings must accurately display the position of TMLs and must be directly associated with data sheets that list the monitoring dates, thickness measurements, and design details for each TML. Isometric drawings should include specific process flow data and any special equipment access requirements. The best place to make isometric drawings is on site. An exception is where an OSI Program is being duplicated from one used on another plant of identical design.

3.1.4 Circuit Corrosion Classes

By using the method described in A3.2 of Appendix A, the inspection supervisor, OSI Coordinator, and responsible corrosion engineer can estimate and assign Corrosion Classes to each Corrosion Circuit.

Commentary Note:

Corrosion Classes are established for initial OSI frequencies only. Once data is input into the computer program, the program will flag high corrosion areas through the default settings in the program.

3.1.5 Selection of TMLs

After Corrosion Circuits and their Corrosion Classes have been determined, Paragraph B.2 of Appendix B should be used. Paragraph B.2 provides the basis for selecting the number, distribution, and location of TML sites.

3.2 Data Collection

3.2.1 TML Monitoring

The way TMLs are measured with ultrasonic probes on the equipment will have at least a near term bearing on how accurately the monitor zone is represented. These methods are described below.

3.2.2 Spot Monitoring

TMLs can be considered as a spot of about 0.75 to 1.5 inches (20 to 40 mm) in diameter, wherein the full area of the spot is scanned and the thinnest reading is recorded. TMLs of this type usually are identified by paint pen markings (or at least by paint scrape and grease marks left by ultrasonic probing). When indexed to points in isometric piping or equipment drawings (as kept in OSI hard copy records or computer memory files), precisely the same TML positions can be monitored repeatedly. This ensures that TML loss rates can be determined and located accurately. This method will give representative corrosion rates sooner than any other nonscanning method. The disadvantage of this method is that it most likely can miss spots of greatest corrosion development. When using the spot method, it is very important to scan areas nearby in order to be able to detect other places where deterioration may be significant. When using manual type ultrasonic probes without X-Y position scanners, spot zone type TMLs are recommended.

3.2.3 Scan Monitoring

TMLs are usually marked right on the equipment as a band around a pipe or a rectangular area on a vessel or tank. The whole area of the zone is scanned for the thinnest reading. Some type of instruments will actually save in its microprocessor memory the minimum thickness of the scan. Automated and computerized X-Y position scanners can provide the means to efficiently store tens of thousands of thickness readings to provide a wall thickness map. For regular OSI monitoring work, the advantage of this method is that it can provide a better chance than the spot method to find the greatest corrosion rates including pitting.

3.2.4 Grid Monitoring

TMLs represent the thinnest reading by taking scan or spot readings manually over a whole pipe portion (that can range over a few inches up to several feet long or about a whole fitting such as a large elbow or tee). There is no physical mark necessarily left on the equipment to indicate the spot of the thinnest reading. It is left to the inspector to find the thinnest wall locations and record them.

3.2.4.1 Advantage: The advantage of this method is that it promotes thorough scanning to increase the probability of finding the thinnest zones.

3.2.4.2 Disadvantages: One disadvantage of this technique is that there is the possibility that the thinnest reading will migrate

from one location to another between monitoring trips. This will greatly extend the time required to get a fix on corrosion rates and predict remaining equipment life. Another problem is that a fabrication-caused thin wall spot may be discovered during subsequent monitoring trips. This could cause confusion as to whether the thin spot is the result of deterioration or fabrication.

3.2.5 Record Keeping

All baseline and OSI monitoring data are kept in a computer database, record books or files in the inspection office. To safeguard against fire, back-up copies of the OSI records shall be kept in another building or in a fire proof cabinet. The inspection record system consists of the following information:

- a) Equipment Documents
 - General Equipment Inspection Record
 - Safety Instruction Sheets (SIS)
 - Vessel Design Data Sheets
 - Equipment Internal (T&I) Inspection Reports
 - Equipment External Inspection Reports
 - Equipment Inspection Schedules
 - Equipment Condition OSI Computer Reports
 - Equipment Remaining Life OSI Computer Reports
- b) Monitoring Data
 - Process Flow Diagrams
 - Piping Isometric Drawings
 - Vessel Drawings
 - TML Monitoring Sheets (Manual Records)
 - Line Designation Table
- c) TML Monitoring Computer Reports
 - TML General Computer Reports
 - TML Scheduling Computer Reports

Record books or files that contain this information are listed in a master cross-reference book or file so that data of any particular piping Corrosion Circuit or equipment unit can be readily located.

- 3.2.6 Temperature Correction. High-temperature materials, up to about 540°C can be measured with specially designed instruments with high temperature compensation, search unit assemblies, and couplants. Normalization of apparent thickness reading for elevated temperatures is required.

The following equation makes a correction of 1% per 100°F temperature change for ferritic steel:

$$T_a = T_m \times [1.007 - (0.0001 \times T)] \quad (1)$$

T_a = the corrected thickness of the part (actual thickness)

T_m = the measured thickness of the part at temperature (apparent thickness)

T = the surface temperature of the part in °F.

3.3 Scheduling

After Corrosion Circuits have been baseline-measured, noted for flaws, and the circuit Corrosion Class has been estimated, the first monitoring dates can be determined. This allows the initial monitoring dates to fit the expected corrosion conditions as shown by the Corrosion Class.

3.4 Data Analysis

- 3.4.1 Once two or more successive thickness readings are available, OSI TML and equipment/circuit information can be calculated manually or obtained automatically by computer (see Appendix C). It must be kept in mind that the capability of obtaining accurate measurements with most ultrasonic gauging instruments is limited to a minimum of about 0.01 inch (0.25 mm). Therefore, corrosion rates usually must be over 10 mpy (250 µm/a) before they can be measured within a one year period. Items that should be calculated (manually or by computer) for each TML and equipment/circuit are:

TMLs

- Long Term Corrosion Rate
 - Short Term Corrosion Rate
 - Archive Corrosion Rate
-

- Representative TML Corrosion Rate
- TML Retirement Date
- TML Recommended Inspection Date
- Action TML Calculation
- Remaining Life Calculation
- MAOP Calculation (optional)

Equipment/Circuit (EQ/CIRC)

- Representative Corrosion Rate (RCR)
- Predicted Equipment/Circuit Retirement Due Date
- Equipment/Circuit Remaining Life
- Recommended Equipment/Circuit Inspection Due Date
- Equipment/Circuit MAOP (optional)

3.4.2 The information obtained from paragraph 3.4.1 is then employed to assess the TMLs and equipment/circuits. The three most important items of the list are, corrosion rate, retirement date, and the recommended inspection due date. Appendix C details each item of paragraph 3.4.1 and how it is calculated.

3.5 Reporting

3.5.1 A quarterly OSI status report should be prepared to show progress made during base lining and regular OSI monitoring. The report shall be issued to plant or facility management. An updated master list of all circuits due for retirement within five (5) years should be included in the report.

3.5.2 Once OSI data has been gathered and analyzed, reports can be prepared by computer into one or more of the following types of reports.

3.5.2.1 New Survey

This report lists wall thickness measurements for each TML for a given EQ/CIRC and monitoring period. Also, this report is designed to be printed out and used as a form to collect data on the next monitoring trip.

3.5.2.2 EQ/CIRC ID Analysis

This report lists corrosion rates for each TML that has been monitored on at least two different occasions (so that sufficient time has elapsed to calculate a rate). When three or more successive wall-thickness measurements are made, this report will provide short term, long term and archive corrosion rates. This report also provides statistical analysis of the EQ/CIRC including formula adjusted corrosion rates, maximum average corrosion rates, representative circuit corrosion rates, TML retirement dates and TML inspection dates. Included in the report are the thicknesses and dates for the first, short and last readings taken plus the retirement thickness. A special feature of this report is that it flags increasing and decreasing trends in corrosion rates.

3.5.2.3 EQ/CIRC ID Summary

This report summarizes all circuits within a specific area and identifies the EQ/CIRC, service, circuit corrosion rate, remaining life, number of TMLs, number of action TMLs, retirement date, last inspection date and inspection due date.

3.5.2.4 EQ/CIRC ID Inspection Due

This report can be generated for a specific time frame to show what circuits or vessels are due to be monitored (e.g., a report could be generated to show what circuits are due to be monitored during a specific month/year.)

3.5.2.5 TML Inspection Due

This report can be generated for a specific time frame to show what TMLs for various circuits or vessels are due to be monitored (e.g., a report could be generated to show what TMLs for various circuits are due to be monitored during a specific month/year.) The next OSI should not be longer than half the remaining life of the equipment.

3.5.2.6 EQ/CIRC ID Retirement Due

This report can be generated for a specific time frame to show what circuits or vessels are due to be retired (e.g., a report could be generated to show what circuits are due for retirement

during a specific month/year) The report includes the circuit retirement date and the next inspection due date.

3.5.2.7 TML Retirement Due

This report can be generated for a specific time frame to show what TMLs for various circuits or vessels are due to be retired. (e.g., a report could be generated to show what TMLs for various circuits are due for retirement during a specific month/year.) The report includes the TML retirement date for each circuit and the next inspection due date.

3.5.2.8 Archive

This report illustrates all thickness readings and the dates taken for each TML by Area and EQ/CIRC.

3.5.2.9 MAOP Analysis (Piping)

This report specifies the MAOP for each TML of an Area and EQ/CIRC. It also flags the lowest reading for the EQ/CIRC and indicates the flange rating for the piping circuit.

3.5.2.10 EQ/CIRC ID Hydro

The report can track last hydrostatic testing performed on the piping circuit.

3.5.2.11 EQ/CIRC Info

This report provides the general information for a specific EQ/CIRC that for each TML number includes, , location description, component code, material code, retirement thickness, and the first, short and last thickness reading and dates taken. Also, a summary at the bottom of the report indicates the analytical settings.

3.5.2.12 EQ/CIRC ID External Corrosion Repairs

The report indicates the external TML, location , inspector, pit depth, inspection date, repair date and critical date for an Area and EQ/CIRC.

3.5.2.13 T-Min. Calculations

This report generates minimum thickness calculations for an EQ/CIRC TML employing the design code for the specific EQ/CIRC. These calculation can be for pipe, vessel heads or tank shells.

3.5.2.14 EQ/CIRC Notes

This report will print all notes associated with an Area and EQ/CIRC.

3.6 Training

For maintaining effective administration of an OSI Program, a training program is required to ensure availability of long term, competent personnel. Instructions on how to start and run an OSI Inspector training program is beyond the scope this document. Help with initial inspector training can be obtained from the Operations Inspection Division of the Inspection Department. However, the Inspection Unit of the Operating Department is responsible for proper training of its' personnel.

4 Responsibilities

- 4.1 The Operations Inspection Unit Supervisor shall be responsible for the following:
 - 4.1.1 Assure the availability of an active OSI program and all unit personnel have an access to t he program for the required action.
 - 4.1.2 Assure the availability of training program to maintain effective administration of the OSI Program.
 - 4.1.3 Issue a quarterly OSI Progress Report to the plant management and the annual equipment condition reports to the plant maintenance and operation superintendents.
 - 4.1.4 In case the Unit has no assigned Corrosion Engineer, the Unit Supervisor shall be assigned the duties in 4.2.
 - 4.2 Corrosion Engineer with assistance from the Process Engineer shall be responsible for the following:
 - 4.2.1 Determine corrosion sectors from process flow diagrams.
 - 4.2.2 Assign corrosion circuits from P&IDs.
-

- 4.2.3 Estimate corrosion rates for each piping corrosion circuit.
- 4.2.4 Assign TMLs to corrosion circuits so that the quantity and location will match the expected corrosion class.
- 4.2.5 Review of corrosion rates greater than 5 mpy or equipment with remaining life less than twice the OSI interval.
- 4.2.6 Review of process changes for impact on OSI Program and adjust the TML's or intervals as required.
- 4.3 OSI Administrator shall be responsible for the following:
 - 4.3.1 Planning and running of the OSI Program.
 - 4.3.2 Issue the required OSI progress reports and OSI TML overdue reports to the unit supervisor.
 - 4.3.3 Coordinate for NDT actions between the area inspectors and the NDT technicians.
 - 4.3.4 Issue report with criteria in 4.2.5 to the Corrosion Engineer.
- 4.4 Field Supervisor shall be responsible for the following:
 - 4.4.1 Assure all plant static equipment is monitored by OSI program.
 - 4.4.2 Review OSI data with the responsible area inspector and advise accordingly.
 - 4.4.3 Assure OSI program data is being reviewed, analyzed, and added to the equipment per T&I reports.
- 4.5 Area Inspector shall be responsible for the following:
 - 4.5.1 Conduct baseline survey to obtain original wall thickness measurement of new, modified or previously unmonitored equipment.
 - 4.5.2 Obtain wall thickness measurement of the monitored plant equipment as per OSI due reports.
 - 4.5.3 Prepare OSI isometric drawings of added piping and equipment.

4.6 Project Management Team (PMT) or construction contractor shall:

Assign TML locations as detailed in Appendix B of this procedure and conduct baseline survey to obtain original wall thickness of new equipment and piping as required in [SAEP-122](#).

5 OSI Program Reviews

All OSI Programs shall be audited annually by the proponent operation Inspection management. Representatives of the Inspection Department will review the OSI program during the unit review in accordance with [SAEP-308](#). This review will be aimed at providing constructive comments and suggestions.

6 Terminology

Remaining Corrosion Allowance (RCA): is equal to the actual wall thickness minus the minimum design thickness.

Measurements

μm = micrometer = 0.001 mm = 0.03937 mil. More accurate representation is:
1 mpy = 25.4 $\mu\text{m}/\text{a}$ (or $\mu\text{m}/\text{year}$), 3 mpy = 76.2 $\mu\text{m}/\text{a}$, 6 mpy = 152.4 $\mu\text{m}/\text{a}$, etc.
The approximate values of 25, 75, 150 $\mu\text{m}/\text{a}$, etc., are presented as practical usage.

Mil = 0.001 inch

mpy = mils per year

μm = micrometer or 0.001 millimeter

$\mu\text{m}/\text{a}$ = micrometers per annum (per year)

Appendix A – Corrosion Circuits, Classes, and Service

A.1 Corrosion Circuit Principle

A piping Corrosion Circuit can be defined as a corrosion-oriented division of piping where a single alloy is exposed to a common corrosion environment. Corrosion Circuits can also refer to non-piping equipment units or any particular corrosion problem zone. The purpose of the assignment of Corrosion Circuits is to group related data so that they can be more efficiently sampled or to highlight problem zones.

A.2 Corrosion Class

Corrosion Classes are assigned to Corrosion Circuits so that initial OSI frequencies can be determined. Corrosion Classes are also used to determine TML distribution in piping Corrosion Circuits. Corrosion Classes must initially be based on estimated corrosion rates.

A.2.1 Corrosion Class Numbering

Corrosion Class number decreases with decreasing remaining life as follows:

Corrosion Class	Remaining Life
0	Less than or equal to 4 years (or Special Schedule)
1	4 to 10 years
2	10 to 20 years
3	Greater than or equal to 20 years

A.2.2 Remaining Life

Remaining equipment life is based on the existing corrosion allowance divided by OSI generated corrosion rates or historical corrosion rates. [e.g., A 3 mpy (75 $\mu\text{m/a}$) average corrosion rate would require 0.060 inches (1.5 mm) extra metal thickness to last twenty years. A twenty year design life is often used for equipment accounting schedules.]

A.3 Corrosive Service Criteria

As a rule of thumb, corrosion can be considered under control when the corrosion rate is 1 mpy (25 $\mu\text{m/a}$) or less--see Section 5.2. This criterion does not address pitting or flaw type corrosion, where coatings, special alloys, or other corrosion control measures are taken. When corrosion rates exceed 3 mpy (75 $\mu\text{m/a}$), corrosion control rather than corrosion allowance measures also may be used.

From the above criteria, the following guidelines are developed:

A.3.1 Corrosive Service Assignment

For OSI monitoring purpose, Corrosive Service is defined to cover fixed equipment corrosion conditions where weight loss (or uniform attack) corrosion rates exceed 1 mpy (25 $\mu\text{m/a}$). All fixed equipment that falls in this category shall be included in an OSI monitoring program. Equipment corrosion rates less than 1 mpy should not be placed initially in an OSI program. Noncorrosive service equipment is subject to inspection during T&I shutdown to see if any problems justify including them for future OSI monitoring.

A.3.2 Corrosion Class Estimating

Initial Corrosion Classes are important since they establish priorities for gauging of new or ungauged Corrosion Circuits. When the value three mils per year is multiplied by the 20 years design life, the suggested minimum corrosion allowance of 60 mils (1.5 mm) is obtained. As previously shown, Corrosion Classes are based on remaining life. When a plant is new or unmonitored, no corrosion rates are available. Therefore for these plants, Corrosion Classes must be estimated by experience with similar systems or by knowledge of the process. For example, by dividing the estimated rates into the 60 mils (1.5 mm) Corrosion Allowance, the following corrosion rate ranges, or Corrosion Services, can be developed for each Corrosion Class:

Corrosion Class	Remaining Life	Corrosion Service
0 Performance Alert	Less than or equal to 4 years	380 mm/a (15 mpy) and up
1 Corrosive Service	4 to 10 years	150 to 350 mm/a (6 to 14 mpy)
2 Mild Corrosive Service	10 to 20 years	75 to 125 mm/a (3 to 5 mpy)
3 Low Corrosive Service	Greater than or equal to 20 years	Less than 75 mm/a (3 mpy)

A.3.3 Corrosion Class Assignment

Initial Corrosion Classes or Corrosion Services can be assigned from the expected corrosion rate of each Corrosion Circuit. These initial categories should be used only as required during the planning of Corrosion Circuits and scheduling of baseline gauging work. Once wall thicknesses are gauged, remaining lives are obtained by the computer program for the TMLs and the corrosion circuits.

Appendix B – Thickness Measurement Location (TML) Assignment

B.1 TML Types

Internal metal loss (and in some cases external attack) occurs by corrosion and erosion, and at elevated temperatures by oxidation. For effective monitoring of this loss (and also flaws), TMLs are assigned to either piping Corrosion Circuits or vessels as three basic types:

B.1.1 Single Points

Single TMLs are assigned locations where corrosion and/or erosion are most likely to occur.

B.1.2 Grid Points

Multiple TMLs are used for monitoring localized flaw and aggressive wall thinning attack. TMLs of this type are often arranged in clusters or grids to ensure thorough coverage of the zone or area of concern. Sufficient measurements also are required to map wall thicknesses for a permanent graphic record.

B.1.3 Scan Points

Scanning points are normally employed for pitting corrosion where isolated wall thinning is of concern. A band, usually no less than 6 inches wide, around the entire circumference of the pipe (360 degrees) is scanned and the lowest thickness reading (i.e., pit) is recorded.

B.2 TML Location Assignment

An OSI program requires TMLs that are assigned to locations that best represent where deterioration is most active in the equipment. This section describes where to assign these locations.

B.2.1 Non-Piping Fixed Equipment

External TML locations are determined for non-piping equipment from knowledge of the particular system and corresponding internal problem areas found during T&I shutdown.

B.2.2 Piping Systems

Piping and heat exchanger tubing systems are more vulnerable than related fixed equipment to corrosion failure because of the thinner wall construction. Heat exchanger tubing units are not usually accessible for external on-stream inspection, but are handled as vessel components and more readily shut down, tested, and replaced than piping systems. Since an overwhelming vulnerability to corrosion failure may be associated with piping, the majority of TMLs are assigned to these systems at the following locations:

B.2.2.1 Flow change points

High loss is most likely to occur where high fluid velocity, turbulence, and impingement conditions are imposed by fittings and equipment such as:

Elbows

U-Bends

Tees

Reducers

Nipples

Branches

Headers

Pumps

Compressors

Internal Obstructions

Fabrication Defects

Weld Reinforcements

Weld Root Excess Penetration Instrument Probes

Chemical Injection Points

Mixing Locations

B.2.2.2 Water stagnation points

High loss sites are also most likely to occur where steam condenses, water collects and/or rivulets, entrapped pockets, water-oil interface and water-air tidal zones form. Areas where these conditions prevail are in deadlegs, drains, piping sag or low points, level gauges, scale or sludge deposits, and where there are significant drops in gas pressure or flow (50% or greater).

B.2.2.3 Corrosion monitoring points

High loss sites are assigned near on-stream corrosion probe and chemical sampling points to serve as a reference for the associated probe and sampling data.

B.3 TML Quantity

Non-piping systems are assigned TMLs to represent component zones (such as nozzles, shells, heads, roofs, etc.) and process zones where internal corrosion is most likely to occur. Piping Corrosion Circuits require more widespread representation and therefore must be assigned TMLs at high loss sites in quantities to best represent corrosion and remaining life conditions:

B.3.1 Original number (or baseline quantity) of TMLs recommended for piping Corrosion Circuits based on the Corrosion Service:

Corrosion Service	Quantity of TMLs (Recommended Minimum)
LOW CORROSIVE	Greater of 12 or 4% of High Loss Sites
MILD CORROSIVE	Greater of 24 or 10% of High Loss Sites
CORROSIVE	Greater of 48 or 15% of High Loss Sites
PERFORMANCE ALERT	Complete Area Scan of All Alert Zones

B.3.2 Quantity of TMLs recommended to be monitored for each corrosion circuit after the baseline TMLs (above) have been established:

Corrosion Class	Quantity of TMLs (Recommended Minimum)
Class 3	Greater of 3 or 1% of High Loss Sites
Class 2	Greater of 12 or 5% of High Loss Sites
Class 1	Greater of 32 or 12% of High Loss Sites
Class 0	Complete Area Scan of All Alert Zones

B.3.3 Reclassification of TMLs

When localized attack becomes distinctly greater in one or more zones than the rest of the corrosion circuit or vessel, the affected TMLs should be reclassified as an Alert Zone. The host circuit or vessel records must refer to any Alert Zones. Once TMLs have been reclassified to a new Alert Zone, other TMLs should be added so that the zone boundary is well defined and the localized attack is well mapped or characterized. Statistical procedures can be used (as shown in Appendix D) to determine what TMLs should be employed for qualification to Alert Zone status.

B.4 Assignment of TMLs to New Equipment

New piping circuits should be applied to new sections of piping and associated fittings, after they are installed. The new TMLs will be required to provide original (or baseline) thicknesses for new sections. New sections (or spools) are best commissioned as new piping circuits since their start-up dates are usually much more recent than the parent circuits, and therefore they require separate analyses.

Appendix C – OSI Computer Program Calculations

- C.1 OSI mainframe and PC based computer programs are available for conducting OSI Program calculations. Most of the computer calculations used to process OSI are covered in the manuals. Some of the basic calculations performed by computer programs are identified in this section.
- C.2 Calculations Made for Each TML
- Long Term Corrosion Rate
 - Short Term Corrosion Rate
 - Archive Corrosion Rate
 - Representative TML Corrosion Rate
 - TML Retirement Date
 - TML Recommended Inspection Date
 - Remaining Life Calculation
 - MAOP Calculation
- C.3 Calculations Made for the Complete EQ/CIRC ID
- Representative Corrosion Rate
 - Predicted EQ/CIRC Retirement Due Date
 - EQ/CIRC Remaining Life
 - Recommended EQ/CIRC ID Inspection Due Date
 - EQ/CIRC MAOP
- C.4 T-min calculations are performed for Piping, Vessels, Power Boilers and Tanks. These calculations are based on formulas from the industry standards governing their design.
- C.5 Structural T-min calculations are not performed by the computer programs since these are user developed and input.

Appendix D – Review of Other OSI Methods

D.1 General

The scope of this SAEP has been limited to OSI Monitoring. Other types of OSI are reviewed here so that awareness of the critical need for properly balanced overall OSI effort will not be diminished by undue preoccupation with just OSI Monitoring:

D.2 Visual Inspection

Visual inspection encompasses the surveillance for the physical and operating appearance of equipment. Physical damage or distortion can be detected by such visual features as dents, creases, bulges, fractures, and cracks as caused by some force, burial, or subsidence. Also, physical deterioration can easily be seen on coatings, linings, laggings, claddings, electrical conduits, etc. These types of damages or conditions must be recorded when discovered as repair or correction may be necessary. Operating symptoms include apparent excess vibration, noise, or telltale signs of leaks (such as can be heard or smelled or can be seen by wavy appearing air, mist, smoke, condensation, frost, foreign deposits, etc.). Operating symptoms also must be reported for repair or change of operating mode.

D.3 Temperature Surveillance

Temperatures of external surfaces of operating equipment can be measured with contact and optical pyrometers, tempil sticks, and infrared detection instruments. Real time temperature maps and printed or photographed maps of hot or cold surfaces can be provided with infrared thermographic equipment.

D.4 Corrosion Probe Monitoring

Weight loss, electric resistance, impedance, pH, and hydrogen probes are monitored while the equipment is operating. Inspectors or Corrosion Engineers usually collect the data from these probes. Corrosion probe reports should be reviewed by inspection personnel and integrated or filed with the OSI Monitoring reports. This can serve to validate both OSI and corrosion probe data.

D.5 Chemical Sampling

On-line and isolated process streams are routinely monitored (through sampling valves) for oxygen, carbon dioxide, pH, iron, etc. Results of this type of OSI can be used to direct inspectors to new or intensified areas of OSI Monitoring.

D.6 Leak Detection

Chemical sniffer and ultrasonic noise detectors are used by inspectors to find small leaks that otherwise could not be detected. This type of OSI usually is not done routinely unless some problems develop to justify it.

D.7 Vibration Monitoring

OSI of operating equipment with hand held accelerometers, in-place transducers, special portable vibration analysis equipment, etc., usually is not performed by inspectors at Saudi Aramco. Data from this type of OSI usually is not important to OSI inspectors unless it involves piping systems or vessel components and thereby poses the possibility of developing fatigue cracks.

D.8 On-Site Process Monitoring

Operators and anyone else that happens to read gages for temperature, pressure, level, etc., must report any readings that may indicate any instrument malfunction, process excursion, or process upset. This type of OSI data may be useful to the OSI inspector if it indicates that there could be an introduction or increase of corrosion or other type of deterioration. Daily checks of the Operations Logbook will assist in identifying any process upsets or equipment malfunctions.

D.9 Radiography

This type of monitoring can be used to visually view the extent of internal corrosion or pitting in such areas as deadlegs. Film can be correlated to actual thickness measurements for assessing OSI monitoring areas. Also, small piping and fittings can be monitored using profile radiography.