



Engineering Procedure

SAEP-343

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Risk-Based Inspection (RBI)
for In-Plant Static Equipment

Document Responsibility: Inspection Department

Saudi Aramco DeskTop Standards

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1 Scope

This document establishes study procedures and responsibilities for a risk based inspection to optimize the use of inspection resources for static in-plant equipment such as vessels, exchangers and piping at Saudi Aramco's facilities. It provides details of key study management activities and the main tasks required to conduct such a study.

2 Conflicts and Deviations

- 2.1 Any conflicts between this Procedure and other applicable Saudi Aramco Engineering Procedures (SAEPs), Saudi Aramco Engineering Standards (SAESs), Saudi Aramco Materials System Specifications (SAMSSs), Saudi Aramco Standard Drawings (SASDs), or industry standards, codes, and forms shall be resolved in writing through the Manager, Inspection Department of Saudi Aramco, Dhahran.
- 2.2 Direct all requests for deviations from this Procedure in writing in accordance with SAEP-302 and forward such requests to the Manager Inspection Department of Saudi Aramco, Dhahran.

3 Applicable Documents

Except as modified by this SAEP, applicable requirements in the latest issues of the following industry Codes, Standards, and Practices shall be considered an integral part of this procedure.

3.1 Saudi Aramco Documents

Saudi Aramco Engineering Procedures

SAEP-20

Equipment Inspection Schedule

SAEP-302

*Instructions for Obtaining a Waiver of a
Mandatory Saudi Aramco Engineering
Requirement*

3.2 Industry Codes and Standards

American Petroleum Institute

API STD 510

*Pressure Vessel Inspection Code - Inspection,
Repair, Alteration, and Rerating*

API STD 530

*Calculation of Heater-Tube Thickness in
Petroleum Refineries*

<i>API RP 570</i>	<i>Piping Inspection Code - Inspection, Repair, Alteration, and Rerating of In-service Piping Systems</i>
<i>API RP 579</i>	<i>Fitness-for-Service</i>
<i>API RP 580</i>	<i>Risk-Based Inspection</i>
<i>API PUB 581</i>	<i>Risk-Based Inspection Base Resource Document</i>
<i>API STD 653</i>	<i>Tank Inspection, Repair, Alteration, and Reconstruction</i>
<i>API RP 750</i>	<i>Management of Process Hazards</i>
<i>API RP 752</i>	<i>Management of Hazards Associated with Location of Process Plant Buildings, CMA Manager's Guide</i>
<i>API RP 941</i>	<i>Steels for Hydrogen Service at Elevated Temperatures and Pressures in Petroleum Refineries and Petrochemical Plants</i>
British Standard	
<i>BS 7910</i>	<i>Guide on Methods for Assessing the Acceptability of Flaws in Fusion Welded Structures</i>
Det Norske Veritas	
<i>DNV RBI Procedure</i>	<i>Risk-Based Inspection, Version 7, 15 March 1999</i>
National Board of Boiler and Pressure Vessel Inspectors	
<i>NB-23</i>	<i>National Board Inspection Code</i>
U. S. Code of Federal Regulations	
<i>OSHA 29 CFR 1910.119</i>	<i>Process Safety Management</i>

4 Definitions and Abbreviations

4.1 Definitions

For purposes of this SAEP and the RBI process as a whole, the following definitions shall apply:

Consequence: Outcome from an event. There may be one or more consequences from an event. Consequences may be positive or negative. However, for the purpose of this document consequence will mean the negative

outcome of any event. Consequences may be expressed qualitatively or quantitatively.

Deterioration: The reduction in a material's ability to perform its intended purpose. This can be caused by various deterioration mechanisms (e.g., thinning, cracking, mechanical). Damage or degradation may be used in place of deterioration.

Event: Occurrence of a particular set of circumstances. The event can be singular or multiple. The probability associated with the event can be estimated for a given period of time.

External Event: An event beyond the direct or indirect control of management and staff at the facility. External events may result from forces of nature, acts of God or sabotage, or such events as neighboring fires or explosions, neighboring hazardous material releases, electrical power failures, tornadoes, lightning, earthquakes, and intrusions of external transportation vehicles, such as aircraft, ships, trains, trucks, or automobiles.

Failure: Termination of the ability of a system, structure, or component to perform its required function. Failures may be unannounced and undetected until the next inspection (unannounced failure), or they may be announced and detected by any number of methods at the instance of occurrence (announced failure).

Failure Mode: The manner of failure. For Risk-Based Inspection, the failure of concern is loss of containment of pressurized equipment items. Some examples of failure modes are pinhole, crack and rupture.

Hazard: A physical condition or a release of a hazardous material that could result from component failure and result in human injury or death, loss or damage, or environmental degradation. The hazard is the source of harm. Components that are used to transport, store, or process a hazardous material can be a source of a hazard. Human error and external events may also create a hazard.

Hazard and Operability (HAZOP) Study: A HAZOP study is a form of failure mode and failure effect analysis. HAZOP studies, which were originally developed for the process industry, use systematic techniques to identify hazards and operability issues throughout an entire facility. They are particularly useful in identifying latent hazards designed into facilities due to lack of information, or introduced into existing facilities due to changes in process conditions or operating procedures. The basic objectives of the techniques are:

- To produce a full description of the facility or process, including the intended design conditions,
- To systematically review every part of the facility or process to discover how deviations from the intention of the design can occur; and
- To decide whether these deviations can lead to hazards or operability issues.

Management of Change: is a procedural system of control supported by appropriate documentation to ensure that safeguards are in place to eliminate the possibility of hazard introduction as a result of changes, other than replacement in kind to equipment, fluid composition, operations, process parameters, control parameters, trip and alarm set points.

In RBI context it is a procedure supported by documentation to ensure that all key parameters, identified and used as a basis for the RBI study, are controlled to be within the study defined ranges. It also specifies that any change to those parameters requires a review by the appropriate expertise for impact on equipment deterioration or consequences.

Mitigation: Limitation of any negative consequences of a particular event.

Probability (Likelihood): The chance that a given event will occur. The mathematical definition of a probability is "a real number in the scale 0 to 1 attached to a random event". Probability can be related to a long-run relative frequency of occurrence or to a degree of belief that an event will occur. For a high degree of belief, the probability is near 1. Frequency rather than probability may be used in describing risk.

Proponent: The customer who can undertake the study or for whom the study is being undertaken.

Qualitative Risk Analysis: Methods that use engineering judgment and experience as bases for the analysis of probabilities and consequences of failure. The results of qualitative risk analyses are dependent on the background and expertise of the analysts and the objectives of the analysis. Failure Modes, Effects and Criticality Analysis (FMECA) and HAZOPs are examples of qualitative risk analysis techniques that become quantitative risk analysis methods when consequence and failure probability values are estimated along with the respective descriptive input.

Quantitative Risk Analysis: An analysis that:

- Identifies and delineates the combinations of events that, if they occur, will lead to a severe accident (e.g., major explosion) or any other undesired event.

- Estimates the frequency of occurrence for each combination, and
- Estimates the consequences.
- Estimates the risk of interest, which can be based on production loss, damage to the facility, population, environment or a combination of risk types.

The quantitative risk analysis integrates into a uniform methodology the relevant information about facility design, operating practices, operating history, component reliability, human actions, the physical progression of accidents, and potential environmental and health effects, usually in as realistic a manner as possible.

Quantitative risk analysis uses logic models depicting combinations of events that could result in severe accidents and physical models depicting the progression of accidents and the transport of a hazardous material to the environment. The models are evaluated probabilistically to provide both qualitative and quantitative insights about the level of risk and to identify the design site or operational characteristics that are the most important to risk.

Residual Risk: The risk remaining after risk mitigation.

Risk: Combination of the probability of an event and its consequences.

Risk Tolerance: A decision to tolerate a risk. Risk acceptance depends on risk criteria.

Risk Analysis: Systematic use of information to identify sources and to estimate the risk. Risk analysis provides a basis for risk evaluation, risk mitigation and risk tolerance. Information can include historical data, theoretical analysis, informed opinions and concerns of the proponent.

Risk-Based Inspection (RBI): A systematic tool for managing risk by prioritizing equipment for inspection activities. It can be used to plan, justify and aid the assessment of results from inspection, testing and monitoring systems. Note that RBI can result in inspection efforts increasing, decreasing or being re-directed to higher risk areas.

Risk Control: Actions implementing risk management decisions. Risk control may involve monitoring, re-evaluation, and compliance with decisions.

Risk Criteria: Terms of reference by which the significance of risk is assessed. Risk criteria may include associated cost and benefits, socio-economic and environmental aspects, priorities and other inputs to the study.

Source: Thing or activity with a potential for consequence. Source in a safety context is a hazard.

Source Identification: Process to find, list, and characterize sources. In the safety area, source identification is called hazard identification.

Team Leader: Specialist or Engineer assigned to coordinate and manage all activities involved in a RBI study.

4.2 Abbreviations

AIChE	American Institute of Chemical Engineers
API	American Petroleum Institute
ASME	American Society of Mechanical Engineers
ASNT	American Society of Nondestructive Testing
ASTM	American Society of Testing and Materials
BRD	Base Resource Document
CCPS	Center for Chemical Process Safety, part of AIChE
CMA	Chemical Manufacturers Association
COF	Consequence of Failure
CSD	Consulting Services Department (Dhahran)
CUI	Corrosion under Insulation
EIS	Equipment Inspection Schedule
ES	Engineering Services
ESA	Engineering Services Agreement
EPA	Environmental Protection Agency
FMEA	Failure Modes and Effects Analysis
HAZOP	Hazard and Operability Study
HIC	Hydrogen Induced Cracking
HTHA	High Temperature Hydrogen Attack
ID	Inspection Department (Dhahran)
ISO	International Standards Organization
LOF	Likelihood of Failure
LPD	Loss Prevention Department (Dhahran)
MOC	Management of Change

MPY	Mils Per Year
NDT	Nondestructive Testing
NFPA	National Fire Protection Association
OSHA	Occupational Health and Safety Administration
OSI	On-Stream Inspection
OSPAS	Oil Supply Planning and Scheduling
PFD	Process Flow Diagram
PHA	Process Hazard Analysis
POF	Probability of Failure
PSM	Process Safety Management
PWHT	Post-Weld Heat Treatment
P&ID	Process & Instrumentation Diagram
QA/QC	Quality Assurance and/or Quality Control
QRA	Quantitative Risk Assessment
RBI	Risk-Based Inspection
RCM	Reliability Centered Maintenance
RMP	Risk Management Plan
ROI	Return on Investment
SCC	Stress Corrosion Cracking
SOHIC	Stress Oriented Hydrogen Induced Cracking
SSC	Sulfide Stress Cracking
SIS	Safety Instruction Sheet
TML	Thickness Measurement Location
UT	Ultrasonic Testing

5 Instructions

5.1 RBI Methodology

The RBI methodology currently approved and implemented in this SAEP is the API RBI from the American Petroleum Institute. The documents associated with this methodology are referenced in Section 3. It is recommended that the latest version of this software be used for a study. The custodian of this software is ES (Inspection Department).

Depending on their merits, it is possible that other RBI methodologies may be approved by ES. Appropriate procedures will be developed by ES to cater for these methodologies if required.

Usage of non-approved RBI methodologies shall invalidate such RBI studies. The results derived from RBI studies could lead to potential EIS deviation / extension / revision requests which are subject to approval by ES (ID) and Loss Prevention Department.

The level of RBI study that shall be used is as follows:

- Qualitative or Semi-Quantitative RBI - for plant screening
- Quantitative RBI such as Level III API-RBI - for detailed analysis as a basis for an EIS change request

5.2 Screening and Boundary Identification

5.2.1 Establishing Objectives and Goals of a RBI study

This section sets out the scope and the priorities for a RBI study. Screening is done to concentrate areas of pursuit. Boundary limits are identified to determine what is vital to include in the study. The organizing process of aligning priorities, screening risks, and identifying boundaries improves the efficiency of conducting the study and its end-results in managing risk.

An RBI study is a team-based process. At the beginning of the exercise, it is important to explain the following points to participants unfamiliar with the process:

Why the RBI is being done?

How the RBI study will be carried out?

Who is on the RBI team?

What are the roles of the team members?

Who is responsible and accountable for what actions?

Which facilities, assets, and components will be included?

What data is to be used in the study?

When the study will be completed?

How long the study will remain in effect and when it will be updated?

What will be done with the end result, i.e., inspection workscope reduction, increase or status quo?

These items should be addressed during the preassessment preparation (Phase 1) activity and during the workshop (Phase 2, Task 2). See 5.10.

An RBI study should be undertaken with clear objectives and goals that are fully understood by all members of the RBI team and by management. Some examples are listed below.

5.2.2 Understand Risks

An objective of the RBI study may be to better understand the risks involved in the operation of a plant or unit and to understand the effects that inspection, maintenance and mitigation actions have on the risks. From the understanding of risks, an inspection program may be designed that optimizes the use of inspection and plant maintenance resources.

5.2.4 Reduce Risks

When risks are identified, inspection actions and/or other mitigation that have a positive effect in reducing risk to an acceptable level may be undertaken. These actions may be significantly different from the inspection actions undertaken during a statutory or certification type inspection program. The results of managing and reducing risk include improved safety, avoidance of breaches and commercial losses.

5.2.5 Reduce Costs

Reducing inspection costs is usually not the primary objective of an RBI study, but it is frequently a side effect of optimization. When the inspection program is optimized based on an understanding of risk, one or more of the following cost reduction benefits may be realized:

- a) Unproductive inspection activities may be eliminated or reduced.
- b) Inspection of low risk items may be eliminated or reduced.
- c) On-line or non-invasive inspection methods may be substituted for invasive methods that require a plant shutdown.
- d) More effective infrequent inspections may be substituted for less effective frequent inspections.

5.2.6 Sort Mitigation Alternatives

The RBI study may identify risks that may be mitigated by actions other than inspection. Some of these actions may include:

- a) Modification of the process to eliminate damaging conditions.
- b) Modification of operating procedures to avoid damaging situations.
- c) Chemical treatment of the process to reduce damage rates.
- d) Change metallurgy of components with a high Likelihood of Failure (LOF) to reduce this parameter.
- e) Removal of unnecessary insulation to reduce likelihood of corrosion under insulation.
- f) Reduce inventories to reduce Consequence of Failure (COF).
- g) Upgrade safety or detection systems.
- h) Change fluids to less flammable or toxic fluids.
- i) Use of coatings and/or cathodic protection.

The data within the RBI study can be useful in determining the optimum economic strategy to reduce risk. The strategy may be different at different times in a plant's life cycle. For example, it is usually more economical to modify the process or change metallurgy when a plant is being designed than when it is operating.

5.2.7 End-of-Life Strategies

Equipment approaching the end of their useful service life are a special case where application of RBI can be very useful. The end of life case for plant operation is about gaining the maximum remaining economic benefit from an asset without undue personnel, environmental or financial risk.

End-of-life strategies focus the inspection efforts directly on high-risk areas where the inspections will provide a reduction of risk during the remaining life of the plant. Inspection activities that do not impact risk during the remaining life are usually eliminated.

End-of-life RBI inspection strategies may be developed in association with a fitness-for-service assessment of damaged components using methods described in API RP 579, BS 7910 and other state-of-the-art techniques.

5.3 Initial Screening

5.3.1 Establish Physical Boundaries of an RBI Study

Boundaries for physical assets included in the study are established consistent with the overall objectives. The level of data to be reviewed and the resources available to accomplish the objectives directly impact the extent of physical assets that can be assessed. The screening process is important in centering the focus on the most important physical assets so that time and resources are effectively applied.

5.3.2 Facilities

At the facility level, RBI may be applied to all types of plants including but not limited to:

- a) Oil and gas production facilities
- b) Oil and gas processing plants and transportation terminals
- c) Refineries

Screening at the facility level can utilize high-level qualitative RBI study and also by using one or some of the following criteria:

- a) Strategic importance to company
- b) Joint decision with OSPAS Department and Proponent organizations
- c) Asset value
- d) History of problems/failures at each facility
- e) PSM/non-PSM facilities
- f) Age of facilities
- g) Proximity to the public
- h) Current equipment inspection intervals

5.3.3 Process Plants

If the scope of the RBI study is a multi-plant facility then the first step in the application of RBI is screening of entire process plants to rank relative risk priorities based on combined LOF and COF. Naturally, plants representing highest risk are then scheduled for immediate RBI study. The screening also provides insight about the level of study that may be required for operating systems and equipment items in the

various plants. Qualitative RBI studies are recommended for plant screening.

Priorities may be assigned based on one of the following:

- a) Relative LOF of the plants
- b) Relative economic impact of the plants
- c) Relative COF of the plants
- d) Relative reliability of the plants
- e) T&I schedule

In addition to above, it is worth noting that plant/facility selection for a RBI study may be guided by the results of risk-ranking exercises carried out by the RBI Team in conjunction with OSPAS and representatives from proponent organizations.

Key questions to answer at the Plant level are similar to the questions at the facility level:

- a) How much funding is spent maintaining and inspecting static equipment at the plant per year on a T&I cycle?
- b) Does the plant have a significant impact on the operation of the facility?
- c) What is the replacement cost for the plant?

5.3.4 Systems within Process Plants

When a process plant is identified for an RBI study and overall optimization is the goal, it is usually best to include all systems within the plant. Practical considerations, such as resource availability, may require that the RBI study is limited to one or more systems within the plant. Selection of systems may be based on:

- a) Relative LOF of systems
- b) Relative COF of systems
- c) Relative reliability of systems

5.3.5 Expected Benefit from Applying RBI to a System

It is recommended to group equipment within a process plant into systems or circuits (sometimes referred to as corrosion circuits or loops) where common environmental operating conditions exist based on process chemistry, pressure and temperature, metallurgy, equipment

design and operating history. By dividing a process plant into systems, the equipment can be screened together suggesting operating parameters that need to be included, areas within the plant that are more likely to experience damage, and save time in having to treat each piece of equipment separately.

A common practice utilizes block flow or process flow diagrams for the plant to identify the systems. Information about metallurgy, process conditions, potential damage mechanisms and historical problems should be identified on the diagram for each system to aid in screening which systems to include in the study.

5.3.6 Equipment Items

In most plants, a large percentage of the total plant risk will be concentrated in a relatively small percentage of equipment items. These potential high-risk items may require greater attention in the risk study. An objective of screening is to identify which equipment poses this higher risk. An RBI study may be applied to all pressure containing equipment such as:

- a) In-plant piping
- b) Pressure vessels (columns, drums, etc.)
- c) Reactors
- d) Heat exchangers and fin fans
- e) Furnaces
- f) Tanks

Generally, the study would cover all equipment (of the type above) within the plant. If required, the following issues may be considered in screening the equipment to be included:

- a) Which types of equipment have had the most reliability problems?
- b) Which pieces of equipment have the highest COF if there is a pressure boundary failure?
- c) Which pieces of equipment are subject to most degradation that could affect pressure boundary containment?
- d) Which pieces of equipment have lower design safety margins and/or lower corrosion allowances that may affect pressure boundary containment considerations?

- e) Will the integrity of safeguard equipment be compromised by damage mechanisms?
- f) Which pieces of equipment are operating at or above design conditions?
- g) Which pieces of equipment were included in a debottle-necking project?

5.4 Establishing Operating Boundaries

The RBI study normally includes review of both LOF and COF for normal operating conditions. Start-up and shutdown conditions as well as emergency and non-routine conditions may also be reviewed for their potential effect on LOF and COF.

The operating conditions, including any sensitivity analysis, used for the RBI study should be recorded as the operating limits for the study. Any change in operating conditions outside the operating limits may require a review of the RBI study as per the facility MOC document.

5.4.1 Start-up and Shutdown

Process conditions during start-up and shutdown can have a significant effect on the risk of a plant. A good example is polythionic acid SCC. The LOF for susceptible plants is controlled by whether mitigation measures are applied during shutdown procedures. Start-up lines are often included within the process piping and their service conditions during start-up and subsequent operation should be considered.

5.4.2 Normal Operation

The normal operating conditions for the plant or system may be most easily provided if there is a process flow model or mass balance available for the plant or process unit. The following data should be provided:

- a) Operating temperature and pressure including variation ranges.
- b) Process fluid composition including variation with feed composition ranges.
- c) Flow rates including variation ranges.
- d) Systems with cyclic operation such as reactor regeneration systems should consider the complete cyclic range of conditions.

5.4.3 Emergency and Non-routine Operations

Plants have systems and equipment installed for emergency and non-routine operations. Examples of these include flare systems and emergency shutdown systems. When these are included in the RBI study, their service conditions during both routine operations and their duty cycle should be considered.

5.4.4 Operating Time Period

The operating time period of the selected plants/equipment is an important limit to consider. The RBI study may include the entire operational life, or may be for a selected period. For example, process plants often are shut down for maintenance activities and the associated run length may depend on the condition of the equipment in the plant. An RBI analysis may focus on the current run period or may include the current and next-projected run period. The time period may also influence the types of decisions and inspection plans that result from the study such as inspection, repair, replace, operating, and so on. Future operational projections are also important as part of the basis for the operational time period.

5.4.5 Off-Plot and Utilities Included

Whether or not utilities and off-plot systems should be included depends on the planned use of the RBI study and the current inspection requirements of the facility. Possible reasons for inclusion of off-plot and utilities are:

- a) The RBI study is being done for an overall optimization of inspection resources and environmental and business COF are included.
- b) There is a specific reliability problem in a utility system. An example would be a cooling water system with corrosion and fouling problems. An RBI approach could assist in developing the most effective combination of inspection, mitigation, monitoring, and treatment for the entire facility.

5.5 Resources and Time Required

The resources and time required to implement an RBI study will vary widely between organizations depending on a number of factors including:

- a) Implementation strategy/plans.
 - b) Knowledge and training of implementers.
-

- c) Availability and quality of necessary data and information.
- d) Availability and cost of resources needed for implementation.
- e) Amount of equipment included in each level of RBI analysis and physical boundary selection.

The estimate of scope involved in completing an RBI study might include the following:

- a) Number of facilities, plants, equipment items, and components to be evaluated.
- b) Time and resources required to gather data for the items to be evaluated.
- c) Training time for implementers.
- d) Time and resources required for RBI study of data and information.
- e) Time and resources to document and evaluate RBI study results and develop inspection, maintenance, and mitigation plans.

RBI requires data gathering from many sources, specialized analysis, and then risk management decision-making. Generally, one individual does not have the background or skills to conduct the entire study. It is generally accepted that RBI be conducted by a team of people with the requisite skills and background. Some team members may be part-time due to limited input needs. It is also possible that not all the team members described in Section 5.5.1 below may be required if other team members have the required skill and knowledge of that discipline.

5.5.1 Team Makeup, Roles, and Responsibilities

The RBI Team shall comprise individuals as follows:

- RBI Engineer (ID, CSD or Proponent)
- Inspectors (Proponent Inspection Engineer and ID Inspection Engineer)
- Materials and Corrosion Engineer (Proponent and CSD)
- Process Engineer (Proponent)
- Operation Representative (Proponent, as required)
- Maintenance Engineer (Proponent, as required)
- Loss Prevention Engineer (LPD, as required)

5.5.2 Team Leader

The Team Leader shall be proposed by either the Proponent's Management, i.e., an engineer attached to the plant or facility, or the Manager of Inspection Department, Engineering Services, Dhahran. In each case, he must fulfill the following requirements:

- Excellent skills in team leadership and project management
- Adequate training in RBI methodology and software navigation, i.e., having attended at least one API RBI workshop
- Excellent report-writing skills
- Excellent presentation skills

The team leader may be any one of the above-mentioned team members. He is a full-time team member and he is responsible for the following:

- a) Initiating and closing any needed Engineering Services Agreement.
- b) Formation of the team and ensuring the team members have the necessary skills and knowledge.
- c) Preparation of a Gantt chart depicting study tasks, activities, appropriate durations and assigned resources.
- d) Ensuring the study is conducted adequately:
 - Data gathered is correct.
 - Assumptions made are logical and documented.
 - Appropriate personnel are utilized to provide data or assumption.
 - Appropriate quality checks are employed on data gathered and on the data analysis.
- e) Preparing all reports (preliminary and final) on the RBI study and ensuring the report is distributed to the appropriate personnel and management.
- f) Ensuring the timescales and study planning are adhered to, or timescales are modified as needed, and the study is completed on schedule.
- g) Following up to ensure that the appropriate risk mitigation actions have been implemented.

- h) Agreeing to a time-frame period with the proponent for a repeat analysis.
- i) Finalizing the ESA to document study completion.

5.5.3 Plant Inspector

The plant inspector is responsible for gathering data on the condition of equipment in the study. This condition data should include the new/design condition and current condition. Generally, this information will be located in equipment inspection files. If condition data is unavailable, the inspector, in conjunction with the materials and corrosion Engineer, should provide predictions of the current condition. The inspector and materials and corrosion Engineer are also responsible for assessing the effectiveness of past inspections. The plant inspector and his management are responsible for implementing the recommended inspection plan derived from the RBI study.

5.5.4 Materials and Corrosion Engineer

This Engineer is responsible for assessing the types of damage mechanisms and their applicability and severity to the equipment considering the process conditions, environment, metallurgy, age, etc., of the equipment. This Engineer should compare this assessment to the actual condition of the equipment, determine the reason for differences between predicted and actual condition, and then provide guidance on damaging mechanisms, rates or severity to be used in the RBI study. Part of this comparison should include evaluating the appropriateness of the inspections in relation to the damage mechanism. This Engineer also should provide recommendations on methods of mitigating the likelihood of failure (such as changes in metallurgy, addition of inhibition, addition of coatings/linings, etc.). The materials and corrosion engineer should provide operating windows and ranges for the parameters to be monitored. These ranges of the parameters shall be controlled through the facility's management of change (MOC) written procedure. Changes that fall outside the range shall trigger a study update.

5.5.5 Process Engineer

The process Engineer is responsible for providing process condition information such as pressure, temperature, flow stream composition, etc. This information generally will be in the form of process flow sheets. The process Engineer is responsible for documenting variations in the process conditions due to normal occurrences (such as

start-ups and shutdowns) and abnormal occurrences. The process Engineer is responsible for describing the composition and variability of all the process fluids as well as their toxicity and flammability. The process Engineer should evaluate and recommend methods of risk mitigation through changes in process conditions.

5.5.6 Operations and Maintenance Personnel

These personnel are responsible for verifying that the facility / equipment is being operated within the parameters set out in the process design. They are responsible for providing data on occurrences when the process deviated from the limits of the process condition and for obtaining the number and causes of emergency shutdowns and tripping of equipment. They are also responsible for verifying that equipment repairs/replacements/additions have been included in the equipment condition data supplied by the equipment inspector. Operations and maintenance and their management are responsible for implementing recommendations that pertain to process or equipment modifications.

5.5.7 Management

Management's role is to provide sponsorship and resources (personnel and funding) for the RBI study. They are responsible for making decisions on risk management or providing the framework/mechanism for others to make these decisions based on the results of the RBI study. Finally, Management is responsible for providing the resources and implementing RBI recommendations and risk mitigation decisions. Management should ensure that a management of change (MOC) program controlling the RBI study parameters is in place and effective.

5.5.8 RBI Engineer

This person(s) is responsible for assembling all of the data and carrying out the RBI analysis. This person(s) is responsible for defining data required from other team members, defining accuracy levels for the data, verifying through quality checks the soundness of data and assumptions, inputting or transferring data into the computer program and running the program (if one is used), quality control of data input/output, manually calculating the measures of risk (if a computer program is not used), displaying the results in an understandable way and preparing a report on the RBI analysis. Further, this person(s) should be a resource to the team to conduct "Cost Benefit Analysis" if it is deemed necessary.

5.5.9 Loss Prevention Specialist

This person(s) is responsible for providing data on safety systems and regulations. He also is responsible for assessing and recommending ways to mitigate the consequence of failures. He is called upon to address all consequence aspects of the RBI study.

5.5.10 T&I Engineer

This person(s) is responsible for providing data on the cost of the facility/equipment being analyzed and the business interruption impact of having pieces of equipment or the facility shut down.

5.6 Training and Qualifications

5.6.1 Risk Based Inspection Personnel

This person(s) needs to have a thorough understanding of risk analysis either by education, training, or experience. He should have received detailed training on the RBI methodology and on the program(s) being used.

Contractors who provide RBI personnel for conducting RBI analysis should have a program of training and be able to demonstrate their personnel are suitably qualified and experienced to ES. The qualifications of the RBI personnel should be documented.

5.6.2 Other Team Members

It is recommended that the other team members receive basic training on RBI methodology and on the program(s) being used. This training should be geared primarily to an understanding of RBI. This could be provided by the personnel on the RBI Team or by another person knowledgeable on RBI methodology and on the program(s) being used. This requirement is fulfilled during a 1-day workshop, i.e., Phase 2, Task 2. See 5.10.

5.7 RBI Documentation and Record Keeping

5.7.1 General

It is important that sufficient information is captured to fully document the RBI study. As a minimum, this should include the following data:

- a) The level of the analysis as defined in this document.
 - b) Team members performing the study.
-

- c) Timeframe over which the study is applicable.
- d) The inputs and sources used to determine risk.
- e) Assumptions made during the study.
- f) The risk study results.
- g) Follow-up mitigation strategy, if applied, to manage risk.
- h) The mitigated risk levels, i.e., residual risk after mitigation is implemented.
- i) References to codes or standards that have jurisdiction over extent or frequency of inspection.

Ideally, sufficient data should be captured and maintained such that the study can be recreated or updated at a later time. To facilitate this, it is preferable to store the information in a computerized database. This will enhance the analysis, retrieval, and stewardship capabilities. The usefulness of the database will be particularly important in stewarding recommendations developed from the RBI study, and managing overall risk over the specified timeframe.

Responsibility for ensuring that all RBI study-related data and reports are preserved is assigned to the Team Leader. Copies of the data from all studies are to be submitted to Inspection Department for future use and manipulation. Overall responsibility for data storage and management belongs to the proponent organization.

5.7.2 Methodology

The methodology used to perform the RBI analysis should be documented so that it is clear what level of analysis was performed. Qualitative RBI studies are recommended for plant screening. Quantitative RBI such as Level III API-RBI is required for detailed analysis. The basis for both the likelihood and consequences of failure should be documented. The specific software program and version used to perform the study should also be documented.

5.7.3 Personnel

The assessment of risk will often depend on the experience and judgment of the personnel or team performing the analysis. Therefore, a record of the team members involved should be captured. This will be helpful in understanding the basis for the risk if recreating the analysis becomes necessary at a later time.

5.7.4 Timeframe

The level of risk may often be a function of time. This is either due to the time dependence of a degradation mechanism, or simply the potential for changes in the operation of equipment. Therefore, the time period over which the RBI analysis is applicable should be defined and captured in the final documentation. This will permit tracking and management of risk effectively over time. Note that plant changes (physical, operational, etc.) may invalidate the study results and a repeat study may thus be required. The responsibility for tracking whether the RBI study is still valid belongs to the proponent organization.

5.7.5 Assignment of Risk

The various inputs used to assess both the likelihood and consequence of failure should be captured. This would include, but not be limited to, the following information:

- a) Basic equipment data and inspection history critical to the study, e.g., operating conditions, materials of construction, service exposure, corrosion rate, inspection history, etc.
- b) Operative degradation mechanisms.
- c) Criteria used to judge the severity of each degradation mechanism.
- d) Anticipated failure mode(s) (e.g., leak or rupture).
- e) Key factors used to judge the severity of each failure mode.
- f) Criteria used to evaluate the various consequence categories, including safety, health, environmental and financial.
- g) Criteria used to evaluate the acceptability of the risks.

5.7.6 Assumptions Made to Assess Risk

Risk analysis, by its very nature, requires that certain assumptions be made regarding the nature and extent of equipment degradation. Moreover, the assignment of failure mode and the severity of the contemplated event will invariably be based on a variety of assumptions - regardless of whether the analysis is quantitative or qualitative. To understand the basis for the overall risk, it is essential that these factors be captured in the final documentation. Clearly documenting the key assumptions made during the analysis of likelihood and consequence will greatly enhance the capability to either recreate or update the RBI study.

5.7.7 Risk Based Inspection Results

The likelihood, consequence and risk results should be documented as well as the recommendations made for optimized inspection plans. For items that require mitigation, the results after mitigation should be documented as well.

5.7.8 Mitigation and Follow-up

One of the most important aspects of managing risk through RBI is the development and use of mitigation strategies. Therefore, the specific actions required to mitigate either likelihood or consequence should be documented in the study. The degree of "credit" assigned to a particular action should be captured along with any time dependence.

5.7.9 Codes and Standards

Since various codes and standards cover the inspection for most pressure equipment, it is important to reference these documents as part of the RBI study. This is particularly important where implementation of RBI is proposed to relax either the extent or frequency of inspection. Note that any inspection relaxation will require approval from several Departments in accordance with SAEP-20.

Refer to Section 3 for a listing of relevant codes and standards.

5.8 Reassessment and Updating RBI Studies

5.8.1 Using an "Evergreen" RBI Program

RBI is a dynamic tool that can provide current and projected future risk evaluations. However these evaluations are based on data and knowledge at the time of the study. As time goes by, changes are inevitable and the results from the RBI study should be updated.

It is important to maintain and update an RBI program to ensure the most recent inspection, process, and maintenance information is included. The results of inspections, changes in process conditions beyond the specified limits covered in the RBI studies, and implementation of maintenance practices can all have significant effects on risk and can trigger the need to perform a reassessment.

5.8.2 Why Conduct a RBI Reassessment

There are several events that will change risks and make it prudent to conduct an RBI reassessment. It is important that the RBI study is

linked to a Management of Change written procedures that identifies when a reassessment is necessary. Guidance on some key factors that could trigger an RBI reassessment is given in Section 5.8.7.

5.8.3 Degradation (Damage) Mechanisms and Inspection Activities

Many degradation mechanisms are time-dependent. Typically the RBI study will project degradation at a continuous rate. In reality, the degradation rate may vary over time. Through the inspection activities, the average rates of degradation may be better defined.

Some degradation mechanisms are independent of time, i.e., they occur only when there are specific conditions present. These conditions may not have been predicted in the original study but have subsequently occurred.

Inspection activities will increase information on the condition of the equipment. When inspection activities have been performed, the results should be reviewed to determine if an RBI reassessment is necessary.

5.8.4 Process and Hardware Changes

Changes in process conditions and hardware changes, such as equipment modifications or replacement, frequently can significantly alter the risks, and dictate the need for a reassessment. Process changes, in particular, have been linked to equipment failure from rapid corrosion or cracking. This is particularly important for degradation mechanisms that depend heavily on process conditions. Typical examples include chloride stress corrosion cracking of stainless steel, wet H₂S cracking of carbon steel and sour water corrosion. In each case, a change in process conditions can dramatically affect the corrosion rate or cracking tendencies. Hardware changes can also have an effect on risk. For example:

- a) The likelihood of failure can be affected by changes in the design of vessel internals that increase velocity-related corrosion effects.
- b) The consequence of failure can be affected changing the fluids characteristics inside a vessel.

5.8.5 RBI Study Premise Change

The premises for the RBI study could change and have a significant impact on the risk results. Some of the possible changes could be:

- a) Increase or decrease in population density.

- b) Change in materials and repair/replacement costs.
- c) Change in product values.
- d) Revisions in safety and environmental laws and regulations.
- e) Revisions in the users Risk Management Plan (such as changes in risk tolerance criteria).

5.8.6 The Effect of Mitigation Strategies

Strategies to mitigate risks, such as installation of safety systems, repairs, etc., should be monitored to ensure they have successfully achieved the desired mitigation. Once a mitigation strategy is implemented, a reassessment of the risk may be performed to update the RBI program. Note that these mitigation measures should always be implemented with due consideration to Management of Change aspects; they should also be reviewed in terms of hazard identification, e.g., HAZOP.

5.8.7 When to Consider Conducting an RBI Reassessment

After Significant Changes

As discussed previously, significant changes in risk are possible by several events. Each significant change should be evaluated by qualified personnel to determine the potential for a change in risk. It is recommended to conduct an RBI reassessment after significant changes in process conditions, degradation mechanisms/rates/severities or RBI premises.

After a Set Time Period

Although significant changes may not have occurred, over a period of time, many small changes may occur and cumulatively cause significant changes in the RBI study. It is recommended that a default time period for reassessment, typically coinciding with T&I interval, or when changes occur but no longer than a maximum of 10 years, is used. The governing inspection codes (such as API STD 510, API RP 570 and API STD 653) and corporate procedures such as SAEP-20 should be reviewed in this context.

After Implementation of Risk Mitigation Strategies

Once a mitigation strategy is implemented, it is prudent to determine how effective the strategy has been in reducing the risk to an acceptable level. This should be reflected in a reassessment of the risk

and appropriate update in the documentation. It is noted that mitigation measures should not be implemented unless there is reasonable certainty about their reliability and cost-effectiveness.

Before and After Maintenance T&Is

As part of the planning before a maintenance T&I, it could be useful to perform an RBI reassessment. This can become a first step in planning the T&I to insure the work effort is focused on the equipment items at unacceptable risk levels.

Since a large amount of inspection, repairs and modifications are performed during a maintenance T&I, it is also necessary to perform an update of the study after the T&I to reflect the new risk levels.

5.9 RBI Study Typical Timescales

The typical total duration of an RBI takes about 6 weeks. A proposed schedule is outlined below:

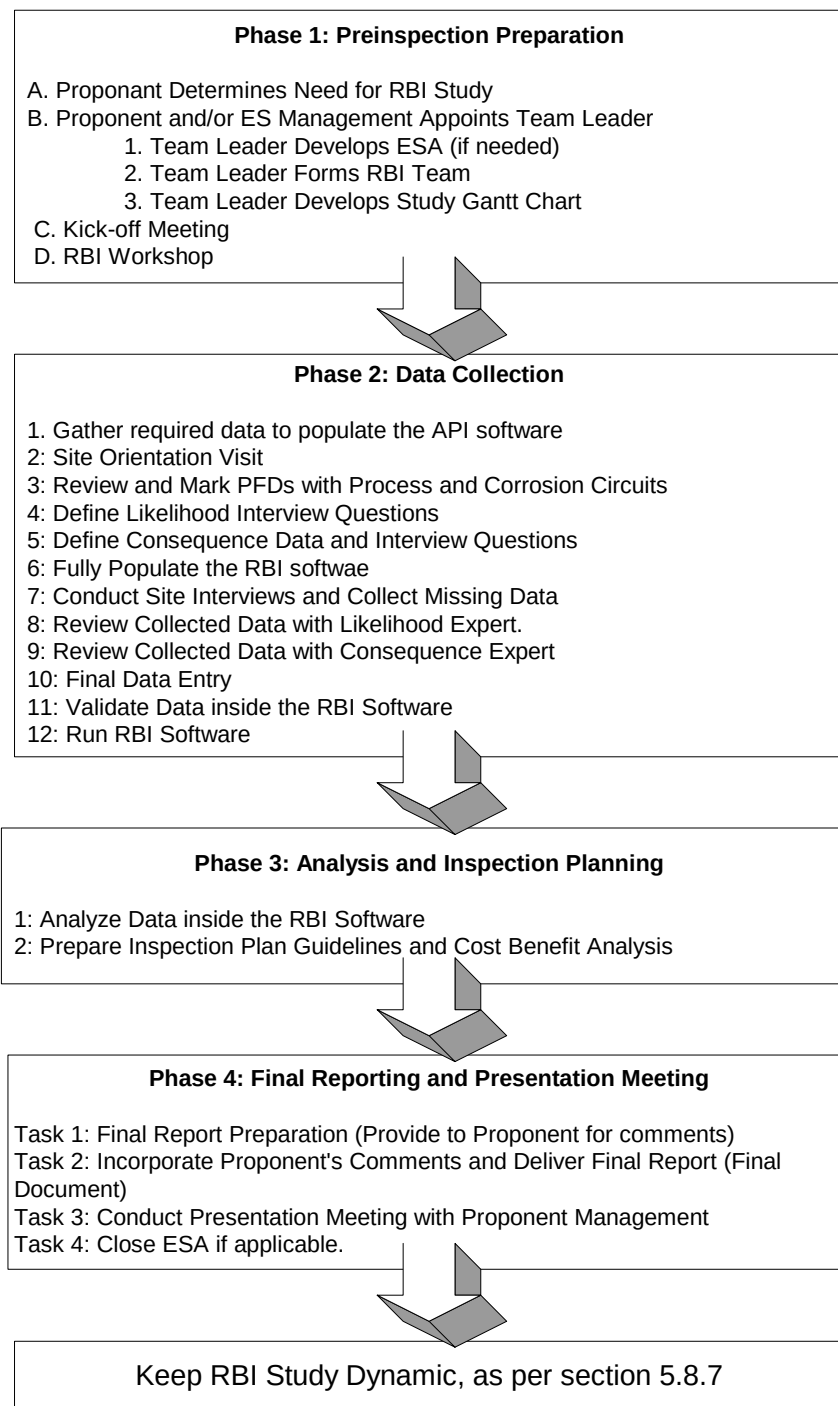
Phase 1 – Preassessment Preparation:	One week
Phase 2 – Data Collection:	Two weeks
Phase 3 – Data Analysis and Inspection Planning Guidelines:	One week
Phase 4 – Final Reporting and Presentation Meeting:	Two weeks

5.10 RBI Study Phases

Details of the Phases and Tasks comprising an RBI study are given in Appendix 1, Typical API RBI Procedure.

An overview of the RBI Study Phases is presented in Figure 1 below.

Figure 1 - Overview of the RBI Study Tasks



5.11 RBI Team (Dhahran)

Name	Department	Telephone
Moraya S. Al-Gahtani	Inspection	874-7226
Nasser M. Balhareth	Inspection	874-5018
Patrick T. McGhee	Inspection	873-6486
Abdullah M. Al-Subaii	Inspection	874-7225
Abdou Kermad	MEU/ME&CCD/CSD	874-6121
Mohammed Notaifee	Loss Prevention	872-9641
Wajdi Sadat	Loss Prevention	872-9647
Tariq Hassan	Loss Prevention	872-9646

Revision Summary

14 December 2005	Revised the "Next Planned Update". Reaffirmed the contents of the document, and reissued with no other changes.
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Appendix 1 – Typical API RBI Activities

These activities are organized sequentially as follows:

Phase 1 – Preassessment Preparation

Task 1 – Develop ESA if needed

The proponent organization shall develop an ESA if necessary to secure ES commitment. This ESA shall include the objective(s), scope of work and expected deliverables. It shall also include details of the proponent's representative who will act as main contact to the Team Leader throughout the duration of the study.

Task 2 – Form RBI Team

Once an ESA is developed and approved by both ES and the proponent's management, the Team Leader will immediately undertake the task of RBI Team formation. This activity is accomplished by a formal written request to the appropriate Department Managers. These requests should specify the following items:

- The nature and objective of the study
- The location of the study
- The input and responsibilities required from the engineers/specialists requested to participate in the study
- The duration of the study

The Team Leader shall also specify the extent of the involvement of the team members requested, i.e., whether it is part-time or full-time and whether any additional involvement is required before and after the study, e.g., for report writing, data gathering, etc.

Department Managers are required to confirm the availability of the engineers requested (or suitable replacements) for the duration requested, by a formal written memorandum to the Team Leader.

Task 3 – Develop Gantt Chart

The Team Leader shall compile a Gantt chart showing all study activities described in the RBI Study Activities Section above. He shall specify the required milestones, the assigned resource(s) and duration. This chart may be compiled using software tools such as Microsoft Project 98 or similar. This document is to be submitted, in the first instance, to the Proponent for approval, then to the team members for information.

Task 4 – Kick-off meeting

Objectives

- To confirm and clarify study deliverables and schedule.
- To establish contacts between the RBI Study Team members.
- To establish the mechanics and protocols of transferring information between the RBI Study Team and plant personnel.
- To clearly define the proponent's goals and motivations for the study.

Motivation

It is important to reinforce both the RBI Study Team's and the proponent's understanding of the study goals.

By focusing on some of the questions outlined in the safeguards section (see below), the RBI Study Team can begin to understand the plant's inspection philosophy, driving forces and expectations for the results of the study. Once the RBI Study Team has a clear understanding of these motives, it will be possible for the team to focus on effective methods for data collection and inspection planning that will meet the proponent's goals.

Activities

The Team Leader will organize a meeting grouping all members of the RBI Study Team. It is the Team Leader's responsibility that all necessary personnel from Engineering Services and the plant are able to attend.

The Team Leader will develop an agenda for the meeting. The safeguards section gives some guidance on the issues that the kick-off meeting could address.

The scribe for the kick-off meeting shall be appointed by the Team Leader. The minutes compiled shall be reviewed by the RBI Study Team members for completeness before submission to the proponent.

Resources

- Data: Basic information on plant under study.
- Personnel: The RBI Study Team
- Proponent Input: Attendance and contribution to kick off meeting by proponent representative and other relevant personnel (plant manager, inspection supervisor, maintenance manager, etc.)

Results

- Meeting agenda
- Meeting minutes

Safeguards and Quality Checks

The meeting agenda could focus on some of the following issues:

- Confirmation and consensus of study's scope, aims, and schedule.
- Requests for additional data. PFDs, P&IDs and the equipment list to be included in the study should have been provided for the Engineering Services Agreement (ESA) preparation. If these were not provided, they should be collected early on the study, along with other required data as indicated on task 1, Task 3 "Request Data"
- Who in the proponent organization can provide the different types of data?
- How and in what form will the data be transferred to the Team Leader?

Task 5 – Conduct RBI Workshop

Objectives

- Provide team members with an insight into RBI methodology
- Emphasize key features and expected benefits.

Activities

This workshop shall be carried out at proponent's offices and shall group RBI Study Team members only. Either the Team Leader or another member familiar with the RBI concept and methodology shall lead the presentation or demonstration. This exercise provides an excellent opportunity to clarify to the team members their expected contribution to the study and the role throughout the study duration.

Resources

- Data:
 - A standard PowerPoint presentation
 - API RBI software
- Engineering Services and/or Proponent Personnel: Team Leader and RBI engineers
- Proponent Input: Remainder of team members; conference room of adequate size with presentation facilities. The conference room should be close to the inspection files room

Task 6 – Site Orientation Visit

Objective

To familiarize RBI Study Team with the site and the facilities.

Motivation

This task involves visiting the facility to gain an understanding of the process, its operation, layout and inspection practices.

Activities

The study personnel should ask the proponent to walk them through the process following the process flow and discussing the inspection activities and experience they have had on the equipment. The study personnel should be looking for information and asking questions which relate to:

- Ease of inspection and access.
- Evidence of corrosion.
- Susceptibility to corrosion.
- Potential consequences (hazards, business interruption, etc.).
- Historical frequency of incidents.

The RBI Study Team should visit the control room, and walk through the plant. These all can have an influence on the consequence and likelihood of failures. A general understanding of the facilities as a whole, therefore, aids in the consequence classing.

Resources

- Data: Scope of work agreed upon and the PFDs.
- Engineering Services and/or Proponent Personnel: Team Leader and RBI engineers.
- Proponent Input: Proponent staff familiar with each process plant, their operation, maintenance, and inspection should be available to help the team become familiar with the site.

Results

- Notes from site visit.
- Confidence to proponent that knowledgeable persons are addressing concerns.

Safeguards and Quality Checks

This orientation visit may take place in conjunction with the kick-off meeting or may take place during the site interviews and collection of missing data visit (Phase 2, Task 9. See 5.10.

Phase 2 – Data Collection

Task 1 – Request Required Data

Objective

To provide the proponent a complete list of the data needed by RBI Team for the RBI study.

Motivation

The success of an RBI study depends strongly on the accuracy of the data and information that is based on. And, as such, it is the RBI Study Team's responsibility to clearly define the data needed to analyze the equipment so that the results meet the study goals and the proponent expectations.

Activities

Create a list of data required. The type of data required will vary depending on the type of study (Qualitative vs. Quantitative). See type of data required below. Note that for the majority of studies, **a quantitative approach will be adopted**.

Item	Qualitative	Quantitative	Electronic	Comments
PFDs	✓	✓	✓	Current and up to date
P&IDs	✓	✓	✓	Current and up to date
Flow and mass balances	✓	✓	✓	Often found on the PFDs.
Piping specifications	✓	✓	✓	Including insulation and coating information.
Piping designation tables	✓	✓	✓	
Equipment data sheets or Safety Instruction Sheets (SIS)		✓		
MSDS (Materials Safety Data Sheets) for process fluids or Chemical Hazard Bulletins (CHB)		✓		
Equipment history files including OSI data and corrosion rates for piping		✓	✓	
Operating data			✓	If different from PFD data.
Written process description	✓	✓		

Site Safety case (or equivalent) and associated study reports				HAZOP, QRA, Hazard Assessments and Reliability and Availability studies
Current Inspection Plans		✓		Refer to EIS and SAEP-20

Appendix 2 - contains full details of data and information that can be edited and sent to the proponent.

Resources

- Data: Scope
- Engineering Services and/or Proponent Personnel: Team Leader and RBI engineers
- Proponent Input: Data
- Tools: PCs

Results

- List of data / information requirements

Safeguards and Quality Checks

The request for information should be sent as early as possible so that all the documents and other information are made readily available prior to the first meeting, e.g., Phase 1, Task 4. (See 5.10). If an ESA is needed, the data (documents/information) requirement list can be appended to and submitted with the ESA request.

Where possible, all data, including PFDs, should be provided to the Team Leader in electronic format. Data in electronic format saves time when assembling the RBI database and reduces the chances for data entry errors.

Task 2 – Review and Mark Process Flow Diagrams with Process and Materials of Construction Information

Objectives

- To create a set of marked process flow diagrams specifically designed for visualizing and checking the data needed for RBI analysis.
- To become familiar with the chemical process under study and to undertake a first check for missing information.

Motivation

A large part of the expert solicitation with plant personnel, Engineering Services' consequence and likelihood experts is based on how plant information is summarized on the simplified PFDs created in this task.

Activities

- Review the PFDs and understand the process system. If necessary, simplify these PFDs to include only the primary process piping.
- Using the P&IDs, mark the equipment and lines to be included in the study and the isolation devices. Based on this, identify the equipment to be included in each inventory group.
- Create three working copies of the PFDs. Each working copy will be titled and used for one of the following set of parameters:
 - Operating temperatures and pressures.
 - Consequence information, representative fluids, phases, and the location and type (A, B or C) of isolation devices. See Table below:

Type	Description
A	Isolation or shutdown systems activated directly from process instrumentation or detectors, with no operator intervention.
B	Isolation or shutdown systems activated by operators in the control room or other suitable locations remote from the leak
C	Isolation dependent on manually operated valves

- Damage mechanisms susceptibility (high, medium or low), corrosion rates, materials of construction, type of cladding, and PWHT or no PWHT.
- In preparation for the initial interview with the Engineering Services Likelihood and Consequence Experts, the operating temperatures and pressures and materials of construction should be marked next to the vessels and piping on the appropriate set of PFDs.

Resources

- Data: Plant data
- Engineering Services and/or Proponent Personnel: RBI Engineers and Consequence and Likelihood Experts
- Proponent Input: Proponent supplied PFDs and P&IDs

Results

Three sets of simplified PFDs marked as follows: The first set with operating conditions, the second with consequence factors, and the third with materials and damage mechanisms. Expert solicitation shall be used when marking these PFDs.

Safeguards and Quality Checks

- The name and date of any interview conducted with an Expert must be documented for the final report of the RBI study.
- On the bottom right hand side of each page include the ESA number, site name, plant name, initials (of applicable team member), date and page X of Y.
- Missing information should be highlighted for later collection. In lieu of missing data, appropriate assumptions may be made.
- Assumptions should be made throughout the study using, wherever possible, the defaults indicated in the BRD. Whenever any assumptions are made, they shall be documented and they shall be designed to provide a conservative result, i.e., to increase the risk associated with the item.
- Throughout the study, the RBI Engineers shall keep the redrawn PFDs updated with the latest information, as well as the assumptions written on a separate sheet of paper. The marked up PFDs and P&IDs, and the written assumptions become essential RBI Study records. Outdated versions of these study records should be discarded. It is noted all study records are kept with the Team Leader who shall be responsible for safekeeping and adequate filing of all RBI study documentation.

Task 3 – Define Likelihood Interview Questions

Objective

- To collect data necessary for the correct assignment of suspected damage mechanisms.

Activities

The Team Leader shall consult with the likelihood expert to determine what data is needed from each section of the plant to confirm the suspected damage mechanisms. This data may include parameters such as pH, %H₂S, Chlorine, Kp factors, velocities, sulfur by %wt, inspection history, etc. The likelihood expert will need the P&IDs and the Marked PFDs from Phase 2, Task 4 (See 5.10) as reference material. In addition, The Team Leader, the likelihood expert or corrosion engineer shall define the interview questions that would allow for the collection of this data.

Resources

- Data: P&IDs and Simplified PFDs
- Engineering Services Inspection Department and/or Proponent Personnel: The RBI Engineers and the Likelihood Expert.

Results

- List of interview questions for damage mechanisms.

Task 4 – Define Consequence Data and Interview Questions

Objective

- To define the consequence data applicable to the plant.

Activities

The Team Leader shall consult with the consequence expert to define the detection and mitigation system entries, the temperature, pressure, representative fluid and phase entries, the inventory group and isolation type entries, the toxic model and toxic percentage entries. Where significant, both summer and winter conditions shall be provided.

The Consequence Expert shall define any proponent interview questions that would allow for the collection of any missing consequence data. For this task, he would require the P&IDs and the marked PFDs from Phase 2, Task 4 (See 5.10) as reference material.

The consequence data should be marked on the applicable simplified PFDs.

Resources

- Data: P&IDs and Simplified PFDs.
- Engineering Services and/or Proponent Personnel: The RBI Engineers and the Consequence Expert.

Results

- Simplified PFDs with information regarding detection and mitigation system entries, the temperature, pressure, representative fluid and phase entries, the inventory group and isolation type entries, and the toxic model and toxic percentage entries.

Safeguards and Quality Checks

The Consequence Expert and the RBI Engineer should identify any missing data to be collected during proponent interviews.

Task 5 – Populate the RBI Software

Note that a first attempt to populate the software with 80% of data should have already been carried out during Phase 1, Task 4 (See 5.10). The current task will entail

populating the remaining 20% of data and ensuring that the Export Template is fully populated.

Objective

- To initialize the electronic database of equipment information in an Excel workbook file using the Export Template.

Activities

- Create the equipment list in the latest version of the Export Template. The purpose of creating the equipment list is to define the boundaries of the systems included, and the actual equipment items to be analyzed.
- From the information collected and assembled, fill in the required information in the Export workbook.

Resources

- Data:
 - Simplified PFDs
 - Information requested in Phase 1, Task 4. See 5.10.
- Engineering Services and/or Proponent Personnel: RBI Engineers
- Tools: Export Template

Results

- Completed Excel workbook with the basic information needed for RBI study.
- List of assumptions made to complete database.
- List of questions and issues that must be addressed with the proponent to complete database.

Safeguards and Quality Checks

Equipment item issues:

- In all cases, the vessel ID and description should match those marked up on the PFDs and P&IDs. To avoid cluttering the PFDs, the piping ID and description do not have to be marked up on the PFDs.
- Use the P&IDs and PFDs and list by process flow.
- Note any discrepancies between the PFDs and P&IDs for future clarification.
- All equipment should be included as a single item. For example, exchangers 38E-23A/B/C and D, should be listed separate, i.e., 38E-23A, 38E-23B, 38E-23C and

38E-23D, giving a total of four equipment items.

- Be consistent with the Equipment Type used. Remember that Equipment Type assigns the generic failure frequency. Use Exchanger for tubular exchanger shells, Exchanger-TS for exchanger tubes, Condenser for condenser shell side and Condenser-TS for condenser tube side.
- Valves, flanges and reducers are not included in the analysis. However, they may become important inspection objects in high-risk circuits, especially reducers.
- In many cases, there will be inadequate records documenting when a piping segment was replaced. On these situations, agree with the proponent on the best number for years in service, and the best number, date and effectiveness of each inspection to be applied globally for all piping.
- Piping coming off the equipment is classed as a part of the piping to which it connects.
- Piping runs (including piping off the equipment) are classed as single components for the analysis, provided that the material type is the same and the diameter and/or thickness do not vary.
- If the diameter or the material changes, each section must be defined as a unique item.
- If the thickness changes but the pipe identification and diameter remain the same, you may include only the one with the lowest thickness.
- Normally, the final inspection plan must consider all components and yet, there may be occasions when this would make the data assembly process excessively time consuming, making it necessary to make simplifications. An example of this is a P&ID containing many small fuel gas lines; in this case instead of entering each pipe, it is useful to enter a typical pipe for that P&ID or service.
- Some equipment will be modeled in two or more parts to account for the large differences in process conditions and damage mechanisms found between them. For example, heat exchanger tube and shell side, fin fan tubes, fin fan inlet header, and fin fan outlet header, column top and bottom, etc.
- One may use the Asset ID column in the export template to record the main piping ID without the diameter, or the main equipment ID after separating it into parts such as top or bottom for columns, shell side or tube side for heat exchangers, etc.

Documenting Assumptions:

With the available data, populate all applicable sheets and columns of the Export Template. If data is not available, make assumptions so that the final risk result is on the conservative side. Document these assumptions in a word document and in the Export Template using blue font. These assumptions should be discussed with the

proponent during the interview visit. Use the assumptions indicated in the BRD wherever possible.

Remember to keep your List of Assumptions in a separate document and keep them updated at all times. You will need to review these assumptions with the proponent.

Task 6 – Conduct Site Interviews and Collect Missing Data

Objectives

- To complete basic data collection.
- To verify information.
- To collect detailed consequence, damage mechanism and inspection information.
- To meet with plant personnel to discuss and get consensus on assumptions made.

Motivation

- To finalize the data collection process with accuracy and completeness.

Activities

If possible, prior to this task, send all likelihood and consequence related questions to the appropriate personnel at the plant.

While at the plant, the following activities must be completed:

- Complete the collection of basic data
 - Meet with plant personnel to collect detailed damage mechanisms, inspection and consequence calculation input data needed. These meetings can be done individually or in-groups depending on the issues that must be resolved. Assignment of roles and duties shall be the responsibility of the Team Leader.
 - Collect missing data in the Export Template.
 - Meet with the HAZOP/Process engineer to confirm the location of block valves for inventory grouping, detection systems, injection points, type of toxic (H₂S), % of toxic, mitigation systems, representative fluids and phases, pH, contaminants (H₂S, Chlorine, Kp factors, velocities, etc.), temperatures and pressures.
 - Hold a meeting with the inspector and corrosion engineer (together or individually) to review past inspection history, repair/replace history, contaminants, damage mechanisms, and assumptions made.
 - Review the inspection files and collect the inspection information.
 - Collect the measured corrosion rates for piping and vessels. Before doing this manually, consult with the proponent to see if this information is available in
-

electronic form.

Resources

- Data: Equipment files, proponent interviews
- Engineering Services and/or Proponent Personnel: Team Leader and/or RBI Engineers
- Proponent Input: Participation in interviews

Results

- Verified complete basic data set for RBI model. This data includes consequence information, inspection data, corrosion rates, and damage susceptibilities.
- Reach a consensus with plant personnel on assumptions.

Safeguards and Quality Checks

The date and names of all those participating in the interview meetings must be documented for the final report of the RBI study.

When reviewing the inspection files, it is important to record the nature of inspection carried out on each piece of equipment. This shall include the type of damage mechanism inspected for, the method of inspection applied, the number of inspections, the coverage and the date of each inspection.

When assigning the inspection effectiveness, use the Inspection Effectiveness look up tables found in the API Base Resource Document (BRD) as well as any inspection criteria agreed with the proponent.

INSPECTION HISTORY REVIEWS

A Pitting

It is important to note the concentration (widely scattered, scattered, concentrated on certain vessel or pipe locations, etc.), and depth if these have been recorded. The proponent and the Likelihood Expert and/or Corrosion Engineer should be consulted in this regard to determine an applicable corrosion rate and determine if damage should be considered localized or general.

B Measuring Corrosion Rate

This is measured in mils per year (MPY). 1 mil = 0.001". Most Thickness Measurement Location (TML) readings are only read to two decimal places (10-mil accuracy), i.e., a change in thickness from 0.50" to 0.49" is a 10-mil change in thickness.

The corrosion rate is usually derived from software tools used within the company to manage OSI data. These currently include Pipe+, IDDEAL and FARIS. These programs usually provide short and long-term corrosion rates. In addition, these rates are further statistically modified (invariably increased) by the software tool to provide "representative" values. The corrosion engineer together with the materials engineer and inspection engineer shall carefully examine the historical data gathered and decide on the most applicable corrosion rates being experienced by the various plant items. Scientific judgment and historical plant experience shall both play a major role in determining the applicable corrosion rates. Note that the selected rates will have a significant effect on the criticality of the plant items under study.

C Documenting Environmental Cracking Inspections

It is important to note the extent of environmental cracking inspection performed, the location and the findings derived. Note that metallurgy, PWHT, and hardness are all key factors in determining the susceptibility of plant equipment to SCC, SSC, HIC and SOHIC. The corrosion and materials engineers shall provide the required input with respect to environmental susceptibility and shall pay due regard to current company standards, guidelines and procedures relevant to these damage mechanisms.

It is noted that H₂S is usually quantified in ppm. Note also that 1% (mass or weight) = 10,000 ppm or 0.1%=1000 ppm.

PFDs normally provide H₂S and other components in moles (lb-mol/hr). To obtain a mole% (volume%), divide the moles/hr of the specific component, e.g., H₂S, by the total moles/hr. To obtain a mass or weight % for H₂S, use the formula:

$$\text{Mass \% } H_2S = [(\text{lb-mol/hr } H_2S) \times 34] / [(\text{lb-mol/hr Total}) \times (\text{total mol wt})]$$

D Furnace Tube Data

The radiant tubing is usually considered the most troublesome item in a fired heater. It is this (process) tubing that should be given particular attention. Convection tubing is usually used for steam raising and tube failures in this section are generally rare and do not usually have a significant impact on process operations.

The physical parameters (diameter, thickness, material, etc.) are usually obtained from the Safety Instruction Sheets (SIS). Visual and thickness survey reports can be obtained from the inspection files. Design temperature and pressure are also obtained from the SIS. Operating data can be obtained from the control room. The process or operations engineer can assist in determining

the relevant data. If infrared surveys are available, these should be examined for accuracy and reliability by the materials engineer or other heater specialist from ES. Note that metal temperatures provided by skin thermocouples or infrared scans have a major impact on heater tube serviceability and remaining life.

Diameter measurements for creep monitoring are sometimes recorded by some plants if creep is an issue. This data is usually kept in the equipment file.

E Heat Exchanger Data

The length of tubing of finfans for RBI is taken as tube length x # of tubes.

The exchanger channel length is taken as 2 x channel length (on U-1 or SIS) for U-tube exchanger and 3 x channel length (on U-1 or SIS) for straight tube.

Fin-tube exchangers normally have a flange as a channel. Hence, there is no need to enter any data in the API RBI software for the channel.

For plate and frame exchangers, it is advised to enter the dimensions that would best model any thinning present.

Task 7 – Review Collected Data with Likelihood Expert

Objective

- To ensure that the data being entered into the RBI Export Template is accurate and makes sense.

Activities

The corrosion, inspection and materials engineers shall jointly review the inspection, corrosion rates and damage mechanism data collected from the files and interviews. A decision will also be made by this group to set the Export Template to measured or estimated corrosion rates. This may reduce the analysis time later in the RBI software.

Resources

- Data: P&IDs and Simplified PFDs, all data collected
- Engineering Services and/or Proponent. Personnel: The materials, corrosion and inspection engineers.
- Proponent: Inspection engineer

Results

- Verified data prior to final data entry.

Task 8 – Review Collected Data with Consequence Expert

Objective

To ensure that the data being entered into the RBI Export Template is accurate and makes sense.

Activities

The Consequence Expert shall review any changes to the location of block valves for inventory grouping, detection systems, injection points, type of toxic (H₂S), % of toxic, mitigation systems, representative fluids and phases, pH, contaminants (H₂S, Chlorine), Kp factors, velocities, temperatures and pressures.

Resources

- Data: P&IDs and Simplified PFDs, all data collected in any other form
- Engineering Services and/or Proponent Personnel: The RBI Engineer and the Consequence Expert.

Results

- Verified data prior to final data entry.

Task 9 – Final Data Entry

Objective

Finalize the data entry process.

Activities

Once the review steps described in Phase 1, Tasks 10 and 11 are complete, all data shall be entered into the Export Template.

It is noted that data is gradually entered and verified for accuracy in the Export Template and that this task will ensure that all data has been collected.

Resources

- Data: P&IDs and Simplified PFDs, all data collected.
- Engineering Services and/or Proponent Personnel: The RBI Engineer.
- Tools: RBI Export Template.

Results

Populated Export Template.

Task 10 – Validate Data inside the RBI Software

Objective

- Validate and ensure accuracy of Excel workbook.

Activities

A qualified RBI Engineer not involved with the study should review every column in the Export Template and verify the validity and accuracy of the data entered. If this engineer is not available, the team leader shall assign an appropriate team member to carry out this task. Any assumptions made are to be updated; if required, sensitivity to final results shall be evaluated.

Resources

- Data:
 - The populated software
 - The three sets of PFDs
 - List of assumptions
 - Proponent information vs. defaults used
 - Inspection history and findings
 - Contaminants
 - Damage mechanisms
- Engineering Services and / or Proponent Personnel: RBI Engineer, Likelihood and Consequence Experts
- Tools: RBI software

Results

- Validated data in software
- Updated list of assumptions

Safeguards and Quality Checks

- Verify that there are no duplicate items in the Export Template. The RBI software will delete the second in order.
- Verify that all data brought from the pull down menus in the Export Template did come from these pull-down menus.
- Check that all data entered makes sense. Check for unusually large or small operating temperatures, pressures, length, diameter, thickness, etc.

- Check that the thickness and diameter of every pipe is in accordance with the piping specifications.
- Check for consistency with the Equipment Type used. Note that Equipment Type assigns the generic failure frequency. Use Exchanger for tubular exchanger shells, Exchanger-TS for exchanger tubes, Condenser for condenser shell and Condenser-TS for condenser tube side.
- Check if the Design Temperature is greater than Operating. If not, investigate.
- Check if the Design Pressure is greater than Operating. If not, investigate.
- Run a filter for all items running at 400°F or higher. If Carbon or Low Alloy Steels are used, investigate. Are these refractory lined? Clad? Is the corrosion rate chosen high enough? Is the proponent using the wrong material for these temperatures?
- Run a filter for all items showing HIC/SOHIC. Use the Steam Tables and make sure water is present, if not, there should be no HIC/SOHIC present.
- Run a filter for all items showing no damage mechanisms and make sure you agree with what you see. Is this in accordance with the inspection history and findings?
- For every damage mechanism identified, print a list from the Export Template showing the Equipment Name, Equipment Description, Operation Temperatures and Pressures, Materials of Construction, Corrosion Rates used, the damage mechanism identified and the severity chosen. The Likelihood Expert shall review these lists for final verification.
- Print another table showing the Equipment Name, Equipment Description, the location of block valves for inventory grouping, detection systems, injection points, type of toxic (H₂S), % of toxic, mitigation systems, representative fluids and phases, pH, contaminants (H₂S, Chlorine), Kp factors, velocities, temperatures and pressures. The Consequence Expert shall review this list for final verification.
- Check that all the information written in the three sets of PFDs matches what was written in the Export Template.

Task 11 – Export Data to API-RBI Software

Objective

- To export data collected to API-RBI software

Activities

- Export data to RBI software
- Document and label RBI analysis file with the following information:
 - Plant name

- Plant name
 - Current date
 - If file represents current or future (give date) risk, before or after a recommended inspection T&I.
 - Measure of risk used for the ranking: maximum settings, equipment damage area, or toxic area.
- Run RBI calculations inside the software.

Resources

- Data: Export workbook
- Inspection Department and/or Proponent Personnel: RBI Engineers
- Tools: API RBI, Export Template

Phase 3 – Analysis and Inspection Planning

Task 1 – Analyze Data inside the API RBI Software

Objective

- To analyze the data inside the software.

Activities

The detailed use of the software is covered in the BRD, i.e., API PUB 581. The major steps to follow when analyzing data in the RBI software are:

- Consult with the Likelihood Expert, corrosion engineer and the proponent on whether to set the RBI Thinning Module to "estimated," "measured," or "calculated" (supplement) for the corrosion rates entered. The supplements normally yield very conservative calculated corrosion rates. They do not have to be used for every piece of equipment. Instead, use the supplements to provide a reference rate for a corrosion group or system. The corrosion rates from the three settings (estimated, measured, or calculated) should be used where appropriate to determine the best representative value.
- Consult with the Likelihood Expert and the proponent on whether to set the other RBI modules under Predicted or Calculated (Supplement). Again, the supplements do not have to be used for every piece of equipment. Instead, use the supplements to provide a reference factor for a corrosion group or system. The Likelihood Expert should look at both the Predicted and the Calculated factors and determine which one best represents the damage susceptibility level.

- Consult with the Consequence Expert and the proponent and validate the size of the inventories calculated by the software.

Resources

- Data: Populated Software
- Engineering Services and/or Proponent Personnel: RBI Engineers, Likelihood Expert, Consequence Expert
- Tools: API RBI

Safeguards and Quality Checks

- If any parameters are altered as you review the applicable likelihood supplements and consequence information inside the software, run the pertinent batch calculations again, i.e., Thinning, CUI, Consequence, etc. The Auto Calculate should be set every time a change is made in the API RBI software.
- Determine what is driving the high likelihood items. Is it the remaining wall thickness? The age? The material of construction used? The lack of inspection? This information shall be documented for inclusion in the final report.
- Determine what is driving the high consequence items. Is it the representative fluid used? phase? toxicity? size of the inventory? This information shall be documented for inclusion in the final report.
- If the existing software does not properly model a certain damage mechanism or a critical equipment item that the proponent wishes to address, then these shall be analyzed outside the software. Any methodology used to address these issues shall be adequately referenced and documented in the final report.

Task 2 – Prepare Inspection Plan Guidelines and Cost Benefit Analysis

Objective

- To prepare an inspection planning and cost benefit analysis

Motivation

There are several ways of mitigating risk cost effectively. The likelihood aspect of risk may be reduced by:

Adding an inspection.

- Replacing equipment close to its end of life. The new item will have fewer years in service.
- Removing the source of corrosion or damage mechanism.

- Repairing the coating or insulation if CUI is a driver.
- Improved monitoring, i.e., adding Hydrogen Probes or Key Process Monitoring if SCC is a concern.

Modifications to the operating procedures may reduce the consequence side of risk by:

- Reducing the toxic and / or flammable inventory
- Adding isolation devices
- Improving detection systems
- Reducing manning
- Building blast walls or dykes

It is cautioned that any mitigation measures considered for risk reduction shall be reviewed by the relevant experts before implementation. It is noted that, for risk reduction inside the software, an inspection may be added. It is not possible to treat the remainder of the mitigation measures inside the software. Rather, these shall be addressed separately in the final report.

Activities

- It is advised to address the inspection plan guidelines or the cost benefit analysis only until the RBI file has been analyzed and validated.
- Prepare the Inspection Plan Guidelines following the Risk Reduction Criteria agreed with the proponent.
- Discuss and agree with the proponent the cost savings derived from the RBI Study.
- Prepare the Cost Benefit Analysis of the RBI study.
- Present the Inspection Plan Guidelines and Cost Benefit Analysis to the proponent. Once the proponent has accepted the Inspection Plan Guidelines and Cost Benefit Analysis, these should then be incorporated into your Draft Report.

Resources

- Data: Use the Inspection Risk Criteria defined with the proponent. These criteria should have been defined early in the study, preferably during the Kick off meeting. The default API Risk Reduction Criteria can be obtained from the BRD.
- Inspection Department and/or Proponent Personnel: RBI Engineers
- Tools: API RBI Software

Safeguards and Quality Checks

The Cost Savings from an RBI study may include the following:

- Reduction of inspections costs as a result of equipment being removed from upcoming scheduled T&Is.
- Reduction of maintenance costs as a result of equipment being removed from upcoming scheduled T&Is.
- Increased production time or run length as a result of inspecting less equipment (i.e., shorter T&Is).
- Use of non-intrusive inspections instead of intrusive ones.

The Cost Benefit Analysis should include the Return on Investment (ROI) calculation for the study. The ROI represents the net financial benefit calculated and expressed as a percent annual return on investment.

Task 3 – Prepare Draft Report (Draft 1)

Objective

- To prepare the Draft 1 report and document the preliminary findings

Activities

The Cost Benefit Analysis and Inspection Plan Guidelines shall be documented in the form of a Draft 1 Report. This document shall include a description of the work carried out, the results and the ensuing recommendations. At least 2 copies of this report shall be made, one to be submitted to the proponent and the other to ES team members.

Resources

- Data: Inspection Plan Guidelines and Cost Benefit Analysis from Phase 2, Task 2.
- Inspection Department and/or Proponent Personnel: RBI Engineers
- Tools: API Software

Results

This draft document shall follow the format of a Saudi Aramco Engineering Report (SAER) format and shall contain the following:

- A one page executive summary describing the work performed, the major findings, conclusions, recommendations and cost benefits resulting from the study.
 - Introduction
 - Objective
 - List of electronic and hard copy deliverables
 - A description of the analysis performed and how we arrived at the cost benefits
-

presented

- List of Assumptions and Marked PFDs
- Cost Benefit Analysis
- Conclusions
- Recommendations
- An Appendix with the Inspection Plan Guidelines. The standard format of these guidelines should, as a minimum, include the following information:
 - Likelihood, consequence, and overall risk factors before and after the recommended inspections.
 - The effectiveness and year of the recommended inspection for each of the damage mechanisms identified.
 - Inspection plan guideline reports for the different types of damage mechanisms or concerns.

Task 4 – Conduct a Final Review of the Deliverables

Objective

- The aim from this review is to determine whether the Draft 1 Report, Cost Benefit Analysis and The Inspection Plan Guidelines describe the work carried out with sufficient clarity.

Activities

- A senior engineer who has not been involved in the study shall review the Draft 1 Report. This engineer should be knowledgeable about the RBI methodology and Likelihood and Consequence drivers. Alternatively, the Team Leader can assign this responsibility to an appropriate team member.
- The Team Leader, in consultation with selected team members, shall implement all relevant changes made.
- The proponent shall, in conjunction with ID inspection engineer and the plant inspection engineer, review the resulting inspection planning guideline and check for any conflict with current inspection schedules requirements. Where conflicts or discrepancies have been identified, the RBI Team shall resolve these conflicts on site and update the inspection planning accordingly.
- The Draft 1 Report is then submitted on-site to the proponent for their review.

Resources

- Data: Draft 1 report and Inspection Plan Guidelines.

- Inspection Department and/or Proponent Personnel: A senior engineer knowledgeable about Likelihood and Consequence drivers

Safeguards and Quality Checks

The name of the engineer performing the review of the Draft 1 Report and the date of the review must be documented in all subsequent reports issued.

Task 5 – Present Preliminary Findings to Proponent (on-site)

Objective

- Provide the proponent with the preliminary findings from the study, as described in the Draft 1 Report.

Activities

- The Team Leader or another team member (assigned by the Team Leader) shall provide a PowerPoint presentation to the proponent. This exercise shall be carried out prior to the departure of the team from site and shall focus on the preliminary findings derived from the study.
- It is important that the proponent senior management attend this meeting
- Comments made by management and other attendees shall be documented and considered for future incorporation in the Final Report as appropriate.

Resources

- Data: Draft 1 report and Inspection Plan Guidelines.
- Inspection Department Personnel: Team Leader
- Proponent: Proponent team members and senior management

Phase 4 – Final Reporting and Presentation Meeting

Task 1 – Prepare Final Report (Draft 2)

Preparation of this document shall be the responsibility of the Team Leader. This Draft 2 report shall incorporate all comments made during the presentation meeting (Phase 3, Task 5) in addition to any other changes. The document shall follow the same outline as Draft 1, i.e., Phase 3, Task 3. At least two copies of this report shall be made, one to be submitted to the proponent and the other to be used by ES team members for review.

Task 2 – Prepare Final Report (Final)

Preparation of this document shall again be the responsibility of the Team Leader. All Draft 2 Report revisions received from the proponent and other team members shall be

considered for incorporation.

The result of this Task is the Final Report with the Cost Benefit Analysis and Inspection Plan Guidelines.

Safeguards and Quality Checks

- A copy of the final RBI Software files should be archived in Inspection's RBI LiveLink folder.
- This folder is also divided into multiple sub-folders named after the proponent's facility, e.g., Ras Tanura Refinery, Abqaiq Plants, etc.
- All correspondence, databases, reports, etc., are to be stored in the respective subfolder.
- The custodian of this folder shall be the RBI team leader, Operations Inspection Division, ID. He will assign access rights to the relevant RBI team members.
- The team leader for each study is responsible for placing relevant study data on LiveLink.
- All PFDs, P&IDs, team correspondence and hard copies of all reports are to be stored with the inspection department secretary. The Team Leader is responsible for transferring all this information to the inspection department secretary upon completion of the study.

Task 3 – Presentation Meeting with Proponent Management

Upon submission of the Final Report (SAER), the Team Leader shall convene a presentation meeting at the proponent's offices. Participants of this meeting shall include all team members, proponent management and/or ES management. The Team Leader shall be responsible for the preparation of this presentation. He shall enlist the assistance of selected team members to compile this document and ensure all study items are highlighted. It is important that any economic benefits derived from the study are duly emphasized.

This presentation meeting should take no later than one week following delivery of the Final Report (SAER), i.e., Phase 4, Task 2.

Task 4 – Closing the ESA (if applicable)

This is the last task for the study. If there is an ESA involved, the Team Leader shall complete the closure form, obtain approval from ID Manager and provide to the proponent management for counter signature. Upon receipt from the proponent, this form is then filed by the Team Leader with the remainder of the study documentation, i.e., with inspection department secretary.

This form should be dealt with no later than one week following the presentation meeting, i.e., Phase 4, Task 3.

Appendix 2 – Sources of Site Specific Data and Information

Information for RBI can be found in many places within a facility. It is important to stress that the preciseness of the data should match the sophistication of the RBI method used. The individual or team must understand the sensitivity of the data needed for the program before gathering any data. It may be advantageous to combine RBI data gathering with other risk/hazard analysis data gathering (e.g., HAZOP) as much of the data overlaps.

Specific potential sources of information include and are not limited to:

1. Design and Construction Records / Drawings
 - a) Safety Instruction Sheets
 - b) P&IDs, PFDs, etc.
 - c) Piping Isometric Drawings
 - d) Engineering Specification Sheets
 - e) Materials of Construction Records
 - f) Construction QA/QC Records
 - g) Codes and Standards Used
 - h) Protective Instrument Systems
 - i) Leak Detection and Monitoring
 - j) Isolation Systems
 - k) Inventory
 - l) Emergency Depressurizing and Relief Systems
 - m) Safety Systems
 - n) Fire-Proofing and Fire Fighting Systems
 - o) Layout
 2. Inspection Records
 - a) Schedules and Frequency (EISs)
 - b) Amount and Types of Inspection
 - c) Repairs and Alterations
 3. Process Data
 - a) Fluid composition analysis including contaminants or trace components
 - b) Process flow diagrams
 - c) Distributed control system data
 - d) Operating procedures
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- e) Start-up and shutdown procedures
 - f) Emergency procedures
 - g) Operating Logs and Process Records
 - h) PSM, PHA, RCM and QRA data or reports
- 4. Management of change (MOC) Records
- 5. Off Site data and information - if consequence may affect off site areas
- 6. Failure Data
 - a) Generic failure frequency data. This data may have a significant effect on likelihood of failure where it is used as a basis for calculation. In-house generic failure frequency data may be developed and used.
 - b) Industry specific failure data
 - c) Plant and equipment specific failure data
 - d) Reliability and condition monitoring records
 - e) Company incident records
- 7. Site Conditions
 - a) Climate / Weather records
 - b) Seismic activity records
- 8. Equipment Replacement Costs
 - a) Project cost reports
 - b) Industry databases
 - c) T&I costs, maintenance costs
- 9. Hazards Data
 - a) PSM studies
 - b) PHA studies
 - c) QRA studies
 - d) Other site-specific risk or hazard studies