Risk-based Inspection

API RECOMMENDED PRACTICE 580
THIRD EDITION, FEBRUARY 2016

AMERICAN PETROLEUM INSTITUTE

Special Notes

API publications necessarily address problems of a general nature. With respect to particular circumstances, local, state, and federal laws and regulations should be reviewed.

Neither API nor any of API's employees, subcontractors, consultants, committees, or other assignees make any warranty or representation, either express or implied, with respect to the accuracy, completeness, or usefulness of the information contained herein, or assume any liability or responsibility for any use, or the results of such use, of any information or process disclosed in this publication. Neither API nor any of API's employees, subcontractors, consultants, or other assignees represent that use of this publication would not infringe upon privately owned rights.

API publications may be used by anyone desiring to do so. Every effort has been made by the Institute to assure the accuracy and reliability of the data contained in them; however, the Institute makes no representation, warranty, or guarantee in connection with this publication and hereby expressly disclaims any liability or responsibility for loss or damage resulting from its use or for the violation of any authorities having jurisdiction with which this publication may conflict.

API publications are published to facilitate the broad availability of proven, sound engineering and operating practices. These publications are not intended to obviate the need for applying sound engineering judgment regarding when and where these publications should be utilized. The formulation and publication of API publications is not intended in any way to inhibit anyone from using any other practices.

Any manufacturer marking equipment or materials in conformance with the marking requirements of an API standard is solely responsible for complying with all the applicable requirements of that standard. API does not represent, warrant, or guarantee that such products do in fact conform to the applicable API standard.

Users of this Recommended Practice should not rely exclusively on the information contained in this document. Sound business, scientific, engineering, and safety judgment should be used in employing the information contained herein.

Foreword

This recommended practice (RP) is intended to provide guidance on developing a Risk-Based Inspection (RBI) program for fixed equipment and piping in the hydrocarbon and chemical process industries. It includes:

a) what is RBI,

b) what are the key elements of RBI,

c) how to implement an RBI program,

d) how to sustain an RBI program.

It is based on the knowledge and experience of engineers, inspectors, risk analysts, and other personnel in the hydrocarbon and chemical industry.

Shall: As used in a standard, “shall” denotes a minimum requirement in order to conform to the specification.

Should: As used in a standard, “should” denotes a recommendation or that which is advised but not required in order to conform to the specification.

This RP is intended to supplement API 510, API 570, and API 653. These API inspection codes and standards allow an owner-user latitude to plan an inspection strategy and increase or decrease the code designated inspection frequencies and activities based on the results of an RBI assessment. The assessment shall systematically evaluate both the probability of failure (POF) and the associated consequence of failure (COF). The POF assessment should be evaluated by considering all credible damage mechanisms. Refer to the appropriate code for other RBI assessment requirements. This RP is intended to serve as a guide for users in properly performing such an RBI assessment.

The information in this RP does not constitute and should not be construed as a code of rules, regulations, or minimum safe practices. The practices described in this publication are not intended to supplant other practices that have proven satisfactory, nor is this publication intended to discourage innovation and originality in the inspection of hydrocarbon and chemical facilities. Users of this RP are reminded that no book or manual is a substitute for the judgment of a responsible, qualified inspector or engineer.

This document was produced under API standardization procedures that ensure appropriate notification and participation in the developmental process and is designated as an API standard. Questions concerning the interpretation of the content of this publication or comments and questions concerning the procedures under which this publication was developed should be directed in writing to the Director of Standards, American Petroleum Institute, 1220 L Street, NW, Washington, DC 20005. Requests for permission to reproduce or translate all or any part of the material published herein should also be addressed to the director.

Generally, API standards are reviewed and revised, reaffirmed, or withdrawn at least every five years. A one-time extension of up to two years may be added to this review cycle. Status of the publication can be ascertained from the API Standards Department, telephone (202) 682-8000. A catalog of API publications and materials is published annually by API, 1220 L Street, NW, Washington, DC 20005.

Suggested revisions are invited and should be submitted to the Standards Department, API, 1220 L Street, NW, Washington, DC 20005, standards@api.org.

Contents

Contents

Contents

Introduction

This recommended practice (RP) contains both minimum program requirements to qualify for establishing inspection intervals based on Risk-Based Inspection (RBI) analysis versus rule-based (e.g. 1/2 life) requirements, and provides additional suggested guidelines on using risk analysis to develop an effective inspection plan. The use of risk-based methodologies for inspection planning is not compulsory; they are optional, subject to the requirements and limitations of the other inspection codes (API 510, API 570, and API 653) and this RP. Inspection planning is a systematic process that begins with identification of facilities or equipment and culminates in an inspection plan.

The output of an RBI assessment conducted according to this RP is an inspection plan for each piece or group of equipment assessed, which should include the following:

a) identified risk drivers;

b) inspection methods that should be used;

c) extent of inspection (percent of total area to be examined or specific locations);

d) inspection interval or next inspection date (timing);

e) other risk mitigation activities;

f) residual level of risk after inspection and other mitigation actions have been implemented.

The RBI plan produced according to the guidance herein combined with a comprehensive set of integrity operating windows (IOWs) for each process unit and a rigorous management of change (MOC) program should provide the basis for sound management of the integrity of fixed equipment in the refining and petrochemical process industry.

RBI is synonymous with risk-prioritized inspection, risk-informed inspection, and with inspection planning using risk-based methods.

Purpose

General

The purpose of this document is to provide users with the basic minimum and recommended elements for developing, implementing, and maintaining a RBI program. It also provides guidance to owner-users, operators, and designers of pressure-containing equipment for developing and implementing an inspection program. These guidelines include means for assessing an inspection program and its plan. The approach emphasizes safe and reliable operation through risk-prioritized inspection. A spectrum of complementary risk analysis approaches (qualitative through fully quantitative) can be considered as part of the inspection planning process. RBI guideline issues covered include an introduction to the concepts and principles of RBI for risk management, and individual sections that describe the steps in applying these principles within the framework of the RBI process include:

a) understanding the design premise;

b) planning the RBI assessment;

c) data and information collection;

d) identifying damage mechanisms and failure modes;

e) assessing probability of failure (POF);

f) assessing consequence of failure (COF);

g) risk determination, assessment, and management;

h) risk management with inspection activities and process control;

i) other risk mitigation activities;

j) reassessment and updating;

k) roles, responsibilities, training, and qualifications;

l) documentation and recordkeeping.

The expected outcome from the application of the RBI process should be the linkage of risks with appropriate inspection, process control, or other risk mitigation activities to manage the risks. The RBI process is capable of generating:

a) a ranking by relative risk of all equipment evaluated;

b) a detailed description of the inspection plan to be employed for each equipment item, including:

   1) inspection method(s) that should be used (e.g. visual, ultrasonic, radiography, wet fluorescent magnetic particle),

   2) extent of application of the inspection method(s) (e.g. percent of total area examined or specific locations),

   3) timing of inspections/examinations (inspection intervals/due dates),

   4) risk management achieved through implementation of the inspection plan;

c) a description of any other risk mitigation activities, such as repairs, replacements, or safety equipment upgrades, equipment redesign or maintenance, IOWs, and controls on operating conditions;

d) the expected risk levels of all equipment after the inspection plan and other risk mitigation activities have been implemented;

e) identification of risk drivers.

Required Elements in RBI

General

This RP contains both minimum program requirements to qualify for interval extension beyond rule-based ($^1/_2$ life) requirements and provides additional suggested guidelines on using risk analysis to develop an effective RBI program. In general, the required elements/attributes of conducting an RBI analysis per this RP include the following.

Work Process Requirements (see Section 16)

Work process requirements include the following.

a) A documented management system to implement and sustain RBI program shall be developed and typically would include the following elements:

   1) procedures covering implementation, maintenance, and reassessment;

   2) roles/responsibilities, experience/training requirements;

   3) documented assumptions;

   4) timeframe for RBI analysis applicability;

   5) data requirements;

   6) risk targets;

   7) program audit requirements;

   8) scope and boundary limits;

   9) triggers for reassessment (e.g. process changes, equipment damage, failures, IOW exceedances, etc.);

   10) timeframe for reassessment.

b) Sufficient data shall be captured and maintained such that the assessment can be recreated or updated at a later time by others who were not involved in the original assessment (6.1).

c) The basis for both the POF and COF shall be documented (16.2).

d) The various inputs used to assess both the POF and COF shall be captured (16.5).

e) The POF, COF, and risk results shall be captured in the documentation (16.7).

Data Requirements (Section 7)

Data requirements include the following.

a) Data inputs and assumptions shall be validated by qualified personnel such as process engineer/operator to review operating parameters used (7.3).

Damage Mechanisms and Failure Modes (Section 8)

Requirements for damage mechanisms and failure modes include the following.

a) The RBI team shall consult with a corrosion specialist to define the equipment damage mechanisms, damage modes (optional), and potential failure modes (8.1.2).

   1) Equipment design (pressures, temperature, and materials of construction) and current condition shall be considered. Data used and assumptions made shall be validated and documented.

   2) All process conditions, e.g. start-up, shutdown, idle, anticipated abnormal and normal, as well as planned process changes shall be considered. Identifying trace constituents (ppm) in addition to the primary constituents in a process can be very important as trace constituents can have a significant effect on the damage mechanisms.

   3) Considering the materials, methods, and details of fabrication, a list of the credible damage mechanisms that may have been present in past operation, be presently active, or may become active shall be developed including the rate of deterioration for primary damage mechanisms and the tolerance of the equipment to the type of damage.

b) A qualified corrosion specialist shall be responsible for assessing the types of damage mechanisms and their applicability and severity to the equipment considering the process conditions, environment, metallurgy, age, and other relevant data pertaining to of the equipment (15.2.4).

POF Analysis (Section 9)

POF analysis requirements include the following.

a) The POF analysis shall address all credible damage mechanisms to which the equipment being reviewed is or can be susceptible. Further, it shall address the situation where equipment is or can be susceptible to multiple damage mechanisms (9.1).

b) Combinations of process conditions and existing materials of construction for each equipment item shall be evaluated to identify active and credible damage mechanisms (9.4.2).

c) Inspections shall be evaluated to determine the effectiveness in finding the identified mechanisms (9.4.4).

COF Analysis (Section 10)

COF analysis requirements include the following.

a) COF calculations steps shall be performed to estimate the consequences that are likely to occur due to a failure mode typically resulting from an identified damage mechanism(s) (10.1.1).

b) The major factors to consider in evaluating the consequences of failure shall include (10.5.1):

   1) flammable events (fire and explosion),

2) toxic releases,

3) releases of other hazardous fluids.

Evaluation of Risk (Section 11)

Requirements for evaluation of risk include the following.

a) Risk shall be determined by combining the POF (results of work done as described in Section 9) and the COF (results of the work done as described in Section 10). The general form of the risk equation shall be as follows (11.1):

risk = probability × consequence

b) Overall risk shall include the probability of loss of containment (11.2.3).

Output (Section 12)

Output requirements include the following.

a) Items with unacceptable risk to the owner-user shall be assessed for potential risk management through inspection plans or other risk management strategies. In addition, higher risk items should also be prioritized for potential risk management (12.2).

b) The inspection strategy shall be a documented, iterative process to assure that inspection activities are continually focused on items with higher risk (12.3).

c) Inspection results such as the identification of damage mechanisms, rate of deterioration, and equipment tolerance to the types of deterioration shall be used as variables in assessing remaining life and future inspection plans (12.6).

RBI Reassessment and Updating (Section 14)

Requirements for RBI reassessment and updating include the following.

a) Changes are inevitable and the results from the RBI assessment shall be updated (14.1).

b) When inspection activities have been performed, the results shall be reviewed to determine if an RBI reassessment is necessary (14.2.2).

c) The governing inspection codes (such as API 510, API 570, and API 653) and jurisdictional regulations, if any, shall be reviewed in this context (14.3.2).

RBI Benefits and Limitations

The primary work products of the RBI assessment and management approach are plans that address ways to manage risks on an individual equipment level. These equipment plans highlight risk from a safety/health/environment perspective and/or from an economic standpoint. RBI plans should include cost-effective actions along with projected risk mitigation.

Implementation of these plans provides one of the following:

a) an overall reduction in risk for the facilities and equipment assessed;

b) an acceptance/understanding of the current risk.

The RBI plans also identify equipment that does not require inspection or some other form of mitigation because of the acceptable level of risk associated with the equipment's current operation. In this way, inspection and maintenance activities can be focused and more cost-effective. This can result in a significant reduction in the amount of inspection data that is collected. This focus on a smaller set of data should result in more accurate information. In some cases, in addition to risk reductions and process safety improvements, RBI plans may result in cost reductions.

RBI is based on sound, proven risk assessment and management principles. Nonetheless, RBI will not compensate for:

a) inaccurate or missing information;

b) inadequate design or faulty equipment installation;

c) operating outside the acceptable IOWs;

d) not effectively executing the plans;

e) lack of qualified personnel or teamwork;

f) lack of sound engineering or operational judgment.

Using RBI as a Continuous Improvement Tool

Utilization of RBI provides a vehicle for continuously improving the inspection of facilities and systematically reducing the risk associated with pressure boundary failures. As new data such as inspection results and industry experience with similar processes becomes available, or when changes occur in operating conditions, a reassessment of the RBI program can be conducted to provide an updated view of risk. RMPs should be adjusted appropriately.

RBI offers the added advantage of identifying gaps or shortcomings in the effectiveness of commercially available inspection technologies and applications. In cases where technology cannot adequately and/or cost-effectively mitigate risk, other risk mitigation approaches can be implemented.

RBI as an Integrated Management Tool

RBI is a risk assessment and management tool that addresses an area of risk management not completely addressed in other organizational risk management efforts such as process hazards analyses, IOWs, or reliability centered maintenance. Integration of these risk management efforts, including RBI, is the key to a successful risk management program.

RBI produces equipment inspection and maintenance plans that identify the actions that should be taken to provide reliable and safe operation. An RBI effort can provide input into an organization's annual planning and budgeting to define the staffing and funds required to maintain equipment operation at acceptable levels of performance and risk.

RBI should be integrated with a management system to define and maintain IOWs as well as a robust MOC process as a basis to manage and control damage mechanisms in fixed equipment.

Risk-based Inspection

1 Scope

1.1 Industry Scope

Although the risk management principles and concepts that Risk-Based Inspection (RBI) is built on are universally applicable, this recommended practice (RP) is specifically targeted to the application of RBI in the hydrocarbon and chemical process industry.

1.2 Flexibility in Application

Because of the broad diversity in organizational size, culture, and federal and/or local regulatory requirements, this RP offers users the flexibility to apply RBI methodology within the context of existing corporate risk management practices and to accommodate unique local circumstances. The document is designed to provide a framework that clarifies the minimum and recommended attributes of a quality risk assessment without imposing undue constraints on users. This RP is intended to promote consistency and quality in the identification, assessment, and management of risks pertaining to material deterioration that could lead to loss of containment.

Many types of RBI methods exist and are currently being applied throughout industry. This document is not intended to single out one specific approach as the recommended method for conducting an RBI effort. The RP instead is intended to identify and clarify the minimum essential elements of an RBI analysis and program as well as to provide guidance on the recommended work process for conducting a successful RBI program. The best RBI programs will not only be in compliance with the minimum essential elements in this RP but will also adhere to the entire work process contained herein.

1.3 Mechanical Integrity Focused

The RBI process is focused on maintaining the mechanical integrity of pressure equipment items and minimizing the risk of loss of containment due to deterioration. RBI is not a substitute for a process hazards analysis (PHA) or hazard and operability assessment (HAZOP). Typically, PHA risk assessments focus on the process unit design and operating practices and their adequacy given the unit's current or anticipated operating conditions. RBI complements the PHA by focusing on the mechanical integrity related damage mechanisms and risk management through inspection. RBI also is complementary to reliability centered maintenance (RCM) programs in that both programs are focused on understanding failure modes, addressing the modes and therefore improving the reliability of equipment and process facilities.

1.4 Equipment Covered

The following types of equipment and associated components/internals are covered by this document:

a) pressure vessels—all pressure-containing components;

b) process piping—pipe and piping components;

c) storage tanks—atmospheric and pressurized;

d) rotating equipment—pressure-containing components;

e) boilers and heaters—pressurized components;

f) heat exchangers (shells, floating heads, channels, and bundles);

g) pressure-relief devices.