

Risk-based Inspection

API RECOMMENDED PRACTICE 580
THIRD EDITION, FEBRUARY 2016



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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.

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

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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),