ASME PCC-3–2017

(Revision of ASME PCC-3–2007)

Inspection Planning Using Risk-Based Methods

AN AMERICAN NATIONAL STANDARD

The American Society of Mechanical Engineers

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Two Park Avenue • New York, NY • 10016 USA

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FOREWORD

ASME formed an Ad Hoc Task Group on Post Construction in 1993 in response to an identified need for recognized and generally accepted engineering standards for the inspection and maintenance of pressure equipment after it has been placed in service. At the recommendation of this Task Group, the Board on Pressure Technology Codes and Standards (BPTCS) formed the Post Construction Committee (PCC) in 1995. The scope of this Committee was to develop and maintain standards addressing common issues and technologies related to post-construction activities, and to work with other consensus committees in the development of separate, product-specific codes and standards addressing issues encountered after initial construction for equipment and piping covered by Pressure Technology Codes and Standards. The BPTCS covers non-nuclear boilers, pressure vessels (including heat exchangers), piping and piping components, pipelines, and storage tanks.

The PCC selects standards to be developed based on identified needs and the availability of volunteers. The PCC formed the Subcommittee on Inspection Planning and the Subcommittee on Flaw Evaluations in 1995. In 1998, a Task Group under the PCC began preparation of Guidelines for Pressure Boundary Bolted Flange Joint Assembly, and in 1999 the Subcommittee on Repair and Testing was formed. Other topics are under consideration and may possibly be developed into future guideline documents. The subcommittees were charged with preparing standards dealing with several aspects of the inservice inspection and maintenance of pressure equipment and piping.

This Standard provides guidance on the preparation and implementation of a risk-based inspection plan. Flaws that are identified during inspection plan implementation are then evaluated, when appropriate, using the procedures provided in API 579-1/ASME FFS-1, Fitness for Service. If it is determined that repairs are required, guidance on repair procedures is provided in ASME PCC-2, Repair of Pressure Equipment and Piping.

This Standard is based on API 580, Risk-Based Inspection. By agreement with the American Petroleum Institute, this Standard is closely aligned with the RBI process in API 580, which is oriented toward the hydrocarbon and chemical process industries. In the standards development process that led to the publication of this Standard, numerous changes, additions, and improvements to the text of API 580 were made, many of which are intended to generalize the RBI process to enhance applicability to a broader spectrum of industries.

This Standard provides recognized and generally accepted good practices that may be used in conjunction with Post-Construction Codes, such as API 510, API 570, and NB-23.

ASME PCC-3–2007 was approved by the American National Standards Institute on October 4, 2007.

This 2017 edition was approved by the American National Standards Institute on May 11, 2017.

ASME POST CONSTRUCTION COMMITTEE

(The following is the roster of the Committee at the time of approval of this Standard.)

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General. ASME Standards are developed and maintained with the intent to represent the consensus of concerned interests. As such, users of this Standard may interact with the Committee by requesting interpretations, proposing revisions, and attending Committee meetings. Correspondence should be addressed to:

Secretary, Post Construction Standards Committee
The American Society of Mechanical Engineers
Two Park Avenue
New York, NY 10016-5990
http://go.asme.org/Inquiry

Proposing Revisions. Revisions are made periodically to the Standard to incorporate changes that appear necessary or desirable, as demonstrated by the experience gained from the application of the Standard. Approved revisions will be published periodically.

The Committee welcomes proposals for revisions to this Standard. Such proposals should be as specific as possible, citing the paragraph number(s), the proposed wording, and a detailed description of the reasons for the proposal, including any pertinent documentation.

Interpretations. Upon request, the Post Construction Standards Committee will render an interpretation of any requirement of the Standard. Interpretations can only be rendered in response to a written request sent to the Secretary of the Post Construction Standards Committee.

Requests for interpretation should preferably be submitted through the online Interpretation Submittal Form. The form is accessible at http://go.asme.org/InterpretationRequest. Upon submittal of the form, the Inquirer will receive an automatic e-mail confirming receipt.

If the Inquirer is unable to use the online form, he/she may mail the request to the Secretary of the Post Construction Standards Committee at the above address. The request for an interpretation should be clear and unambiguous. It is further recommended that the Inquirer submit his/her request in the following format:

Subject:	Cite the applicable paragraph number(s) and the topic of the inquiry in one or two words.
Edition:	Cite the applicable edition of the Standard for which the interpretation is being requested.
Question:	Phrase the question as a request for an interpretation of a specific requirement suitable for general understanding and use, not as a request for an approval of a proprietary design or situation. Please provide a condensed and precise question, composed in such a way that a "yes" or "no" reply is acceptable.
Proposed Reply(ies):	Provide a proposed reply(ies) in the form of "Yes" or "No," with explanation as needed. If entering replies to more than one question, please number the questions and replies.
Background Information:	Provide the Committee with any background information that will assist the Committee in understanding the inquiry. The Inquirer may also include any plans or drawings that are necessary to explain the question; however, they should not contain proprietary names or information.

Requests that are not in the format described above may be rewritten in the appropriate format by the Committee prior to being answered, which may inadvertently change the intent of the original request.

Moreover, ASME does not act as a consultant for specific engineering problems or for the general application or understanding of the Standard requirements. If, based on the inquiry information submitted, it is the opinion of the Committee that the inquirer should seek assistance, the inquiry will be returned with the recommendation that such assistance be obtained.

ASME procedures provide for reconsideration of any interpretation when or if additional information that might affect an interpretation is available. Further, persons aggrieved by an interpretation may appeal to the cognizant ASME Committee or Subcommittee. ASME does not "approve," "certify," "rate," or "endorse" any item, construction, proprietary device, or activity.

Attending Committee Meetings. The Post Construction Standards Committee regularly holds meetings and/or telephone conferences that are open to the public. Persons wishing to attend any meeting and/or telephone conference should contact the Secretary of the Post Construction Standards Committee.

ASME PCC-3–2017
SUMMARY OF CHANGES

Following approval by the ASME Post Construction Committee and ASME, and after public review, ASME PCC-3–2017 was approved by the American National Standards Institute on May 11, 2017.

The 2017 edition of ASME PCC-3 includes revisions that are identified by a margin note, **(17)**. The following is a summary of the latest revisions and changes.

Page	*Location*	*Change*
3	2.3	Second paragraph revised
7	3.5	Revised
	3.6.1	Subparagraph (c) revised
12, 13	4.4.1.6	Added
	4.4.1.7	Added
17	6.3.3	Revised
18	7.2	Revised
19	7.2.3	Third paragraph revised
20	7.2.4.2	Revised
	7.2.5	Revised
21, 22	8.3.2	End of last sentence restored by errata
32–35	10	Revised in its entirety
	11.3	Revised
37	13.2	Title revised
38	13.2.3	Revised
40, 41	15.1	Definitions for *examination*, *examiner*, *holiday*, *inspector*, and *testing* added
42–44	Table 16-1	Added, replacing former Table 16
45, 46	Table 16-2	Added, replacing former Table 16
65	Nonmandatory Appendix C	Title revised
66–70	Table C-1	Title and Note (1) revised
73	D-4.5.4	Revised
80–82	Nonmandatory Appendix F	Added

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INSPECTION PLANNING USING RISK-BASED METHODS

1 SCOPE, INTRODUCTION, AND PURPOSE

1.1 Scope

The risk analysis principles, guidance, and implementation strategies presented in this Standard are broadly applicable; however, this Standard has been specifically developed for applications involving fixed pressure-containing equipment and components. This Standard is not intended to be used for nuclear power plant components; see ASME BPV, Section XI, Rules for Inservice Inspection of Nuclear Power Plant Components. It provides guidance to owners, 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 cost-effective inspection. A spectrum of complementary risk analysis approaches (qualitative through fully quantitative) should be considered as part of the inspection planning process.

1.2 Introduction

This Standard provides information on using risk analysis to develop and plan an effective inspection strategy. Inspection planning is a systematic process that begins with identification of facilities or equipment and culminates in an inspection plan. Both the probability[1] of failure and the consequence of failure should be evaluated by considering all credible damage mechanisms that could be expected to affect the facilities or equipment. In addition, failure scenarios based on each credible damage mechanism should be developed and considered.

The output of the inspection planning process conducted according to these guidelines should be an inspection plan for each equipment item analyzed that includes

(a) inspection methods that should be used

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

(c) inspection interval (timing)

(d) other risk mitigation activities

(e) the residual level of risk after inspection and other mitigation actions have been implemented

[1] *Likelihood* is sometimes used as a synonym for *probability*; however, *probability* is used throughout this Standard for consistency.

1.3 Purpose

This Standard presents the concepts and principles used to develop and implement a risk-based inspection (RBI) program. Items covered are

(a) an introduction to the concepts and principles of RBI

1 Scope, Introduction, and Purpose
2 Basic Concepts
3 Introduction to Risk-Based Inspection

(b) description of the steps in applying these principles within the framework of the RBI process

4 Planning the Risk Analysis
5 Data and Information Collection
6 Damage Mechanisms and Failure Modes
7 Determining Probability of Failure
8 Determining Consequence of Failure
9 Risk Determination, Analysis, and Management
10 Risk Management With Inspection Activities
11 Other Risk Mitigation Activities
12 Reanalysis
13 Roles, Responsibilities, Training, and Qualifications
14 Documentation and Record Keeping

1.4 Relationship to Regulatory and Jurisdictional Requirements

This Standard does not replace or supersede laws, regulations, or jurisdictional requirements.

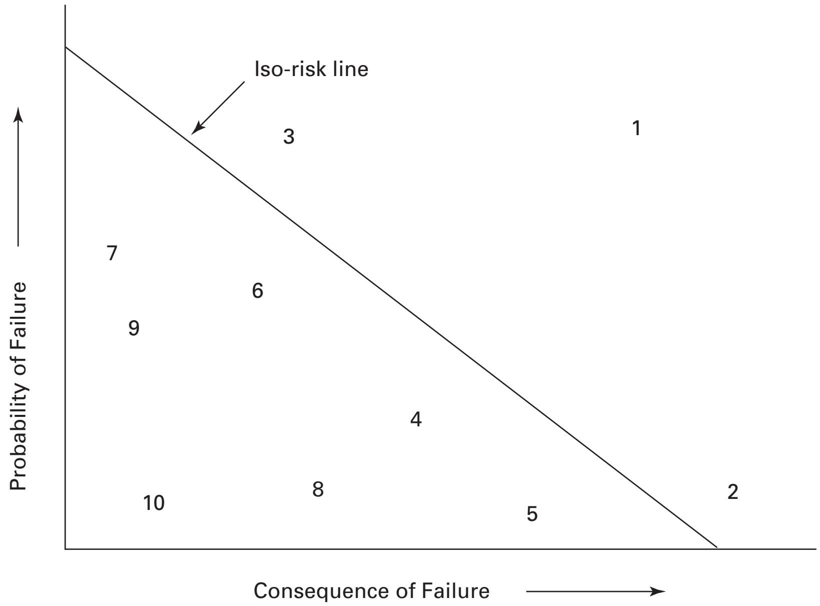
2 BASIC CONCEPTS

2.1 Risk

Everyone lives with risk and, knowingly or unknowingly, people are constantly making decisions based on risk. Simple decisions such as whether to drive to work or walk across a busy street involve risk. Bigger decisions such as buying a house, investing money, and getting married all imply an acceptance of risk. Life is not risk-free and even the most cautious, risk-averse individuals inherently take risks.

For example, when driving a car, an individual accepts the possibility that he or she could be killed or seriously injured. The risk is accepted because the probability of being killed or seriously injured is low while the benefit realized (either real or perceived) justifies the risk taken. Influencing the decision is the type of car, the safety

Fig. 2.1 Risk Plot



features installed, traffic volume and speed, and other factors such as the availability, risks, and affordability of alternatives (e.g., mass transit).

Risk is the combination of the probability of some event occurring during a time period of interest and the consequences (generally negative) associated with that event. Mathematically, risk should be expressed as

$$\text{risk} = \text{probability} \times \text{consequence}$$

Understanding the two-dimensional aspect of risk allows new insight into the use of risk analysis for inspection prioritization and planning. Figure 2.1 displays the risk associated with the operation of a number of equipment items. Both the probability and consequence of failure have been determined for ten equipment items, and the results have been plotted. The points represent the risk associated with each equipment item. An "iso-risk" line, representing a constant risk level, is also shown on Fig. 2.1. A user-defined acceptable risk level could be plotted as an iso-risk line. In this way the acceptable risk line would separate the unacceptable from the acceptable risk items (i.e., if the iso-risk line on the plot represents the acceptable risk, then equipment items 1, 2, and 3 would pose an unacceptable risk that requires further attention). Often a risk plot is drawn using log-log scales for a better understanding of the relative risks of the items assessed.

Risk levels or values may be assigned to each equipment item. This may be done graphically by drawing a series of iso-risk lines and identifying the equipment items that fall into each band or it may be done numerically. Either way, a list that is ordered by risk is a risk-based ranking of the equipment items. Using such a list, or plot, an inspection plan may be developed that focuses attention on the items of highest risk.

2.2 Overview of Risk Analysis

The complexity of a risk analysis is a function of the number of factors that can affect the risk and there is a continuous spectrum of methods available to assess risk. The methods range from a strictly relative ranking to rigorous calculation. The methods generally represent a range of precision for the resulting risk analysis (see para. 3.3.6).

Any particular analysis may not yield usable results due to a lack of data, low-quality data, or the use of an approach that does not adequately differentiate the risks represented by the equipment items. Therefore, the risk analysis should be validated before decisions are made based on the analysis results.

A logical progression for a risk analysis is

(a) collect and validate the necessary data and information (see section 5)

(b) identify damage mechanisms and, optionally, determine the damage mode(s) for each mechanism (e.g., general metal loss, local metal loss, and pitting) (see section 6)

(c) determine the probability of failure over a defined time frame for each damage mechanism (see section 7)

(d) determine credible failure mode(s) (e.g., small leak, large leak, and rupture) (see section 7)

(e) identify credible consequence scenarios that will result from the failure mode(s) (see section 8)

(f) determine the probability of each consequence scenario, considering the probability of failure and the probability that a specific consequence scenario will result from the failure (see section 9)

(g) determine the risk, including a sensitivity analysis, and review risk analysis results for consistency/reasonableness (see section 9)

(h) develop an inspection plan and, if necessary, other mitigation actions, and evaluate the residual risk (see sections 10 and 11)

If the risk is not acceptable, consider mitigation. For example, if the damage mode is general metal loss, a mitigation plan could consist of onstream wall thickness measurements, with a requirement to shut down or to repair onstream if the wall thickness measurements do not meet predetermined values or fitness-for-service acceptance criteria.

(17) 2.3 Inspection Optimization

When the risk associated with individual equipment items is determined and the relative effectiveness of different inspection techniques in reducing risk is estimated or quantified, adequate information is available for developing an optimization tool for planning and implementing an RBI program. Inspection affects perceived risk; physical actions such as mitigation activities performed as a result of an inspection affect actual risk.

Inspections may affect the calculated risk by reducing uncertainty. When there is uncertainty about the risk associated with operating equipment items, the default action should be to make reasonably adverse (conservative) or even "worst-case" assumptions resulting in relatively high calculated risk. For example, during an initial analysis one assumption may be that the only credible damage mechanism for a component is general corrosion (i.e., general metal loss). If examination reveals that no measurable metal loss has actually occurred, then the probability of failure may be reassessed to a lower level with a corresponding reduction in the calculated risk.

Figure 2.3 presents stylized curves showing the reduction in risk that should be expected when the degree and frequency of inspection are increased. The upper curve in Fig. 2.3 represents a typical inspection program. Where there is no inspection, there may be a higher level of risk, as indicated on the *y*-axis. With an initial investment in inspection activities, risk generally is significantly reduced. A point is reached where additional inspection activity begins to show a diminishing return and, eventually, may produce very little additional perceived risk reduction. Any inspection activity beyond this point may actually increase the level of risk. This is because invasive inspections in certain cases may cause additional damage (e.g., introduction of oxygen into boiler feedwater, water contamination in equipment with polythionic acid, damage to protective coatings or glass-lined vessels, or improper reclosing of inspection openings that may result in leakage of harmful fluids). This situation is represented by the dotted line at the end of the upper curve.

Fig. 2.3 Management of Risk Using RBI

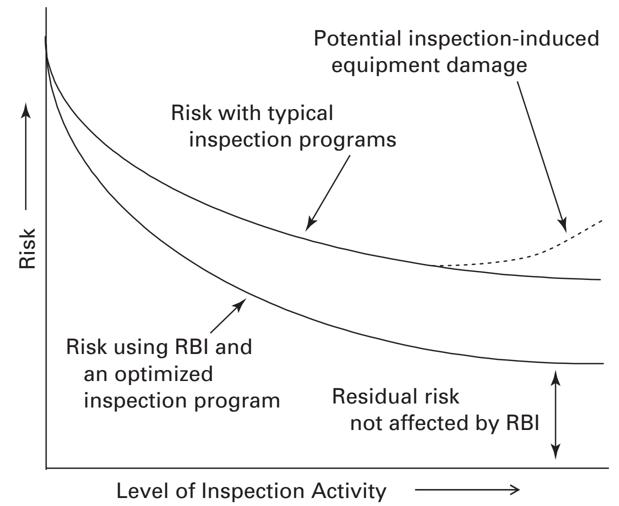


Table 2.3 Factors Contributing to Loss of Containment

Category of Failure	Contribution to Losses
Mechanical failure	41%
Operational error	20%
Unknown	18%
Process upset	8%
Natural hazard	6%
Design error	4%
Sabotage/arson	3%

RBI provides a consistent methodology for assessing the optimum combination of methods and frequencies. Each available inspection method may be analyzed and its relative effectiveness in reducing failure probability estimated. Given this information and the cost of each procedure, an optimization program may be developed. The key to developing such a program is the ability to assess the risk associated with each equipment item and then to determine the most appropriate inspection techniques for that equipment item. A conceptual result of this methodology is illustrated by the lower curve in Fig. 2.3. The lower curve indicates that, with the application of an effective RBI program, lower risks can be achieved with the same level of inspection activity. This is because, through RBI, inspection activities are focused on higher risk items and away from lower risk items.

Not all risks are affected by inspection. Table 2.3 shows seven categories of factors that have contributed to loss of containment events resulting in major insurance losses in petrochemical process plants.

Table 2.3 shows that, in a typical petrochemical plant, only about half of the causes of loss of containment can be influenced by inspection activities (the 41% of mechanical failures plus some portion of the "unknown" failures). Other mitigation actions should be used to manage the other factors contributing to risk.

As shown in Fig. 2.3, risk cannot be reduced to zero. Residual risk factors include, but are not limited to, the following:

(a) human error

(b) natural disasters

(c) external events (e.g., collisions or falling objects)

(d) secondary effects from nearby units

(e) consequential effects from associated equipment in the same unit

(f) deliberate acts (e.g., sabotage)

(g) fundamental limitations of inspection method

(h) design errors

(i) unknown mechanisms of damage

See Marsh & McLennan report, *The 100 Largest Losses 1974-2015.*

3 INTRODUCTION TO RISK-BASED INSPECTION

In most facilities, a large percentage of the overall risk is concentrated in a relatively small number of equipment items while a large percentage of the equipment items may pose minimal risk. The equipment items having higher risk will require more attention in an inspection plan based on a risk analysis (commonly referred to as risk-based inspection or RBI) and the associated increased inspection costs may be offset by reducing or eliminating inspection of equipment items that pose minimal risk. RBI will allow users to

(a) define, measure, and use risk for managing important elements of facilities or equipment

(b) manage safety, environmental, and business-interruption risks in an integrated, cost-effective manner

(c) systematically reduce the overall facility risk by making better use of inspection resources and timely follow-up action

3.1 Items RBI Will Not Compensate for

RBI is based upon sound engineering and management principles; however, RBI will not compensate for

(a) inaccurate or missing information

(b) inadequate design or faulty equipment

(c) improper installation and/or operation

(d) operating outside the acceptable design envelope

(e) not effectively implementing the inspection plan

(f) lack of qualified personnel or team work

(g) lack of sound engineering or operational judgment

(h) failure to promptly take corrective action or implement appropriate mitigation strategies

3.2 Consequence and Probability for Risk-Based Inspection

The objective of a risk analysis should be to determine what incident would occur (consequence) in the event of an equipment failure, and how likely (probability) it is that the incident could happen. For example, if a pressure vessel subject to damage from corrosion under insulation develops a leak, or if a crack in the heat-affected zone (HAZ) of a weld results in a rupture, a variety of consequences could occur. Some possible consequences are

(a) formation of a vapor cloud that could ignite, causing injury and equipment damage

(b) release of a toxic chemical that could cause health problems

(c) a spill that could cause environmental damage

(d) a rapid release of superheated steam that could cause damage and injury

(e) a forced unit shutdown that could have an adverse economic impact

(f) minimal safety, health, environmental, and/or economic impact

Combining the probability and the consequence of each applicable scenario will determine the risk to the operation. Some failures may occur relatively frequently without significant adverse safety, environmental, or economic impacts. Similarly, some failures have potentially serious consequences, but the probability of the incident is low. In either case, the risk may not warrant immediate action; however, if the probability and consequence combination (risk) is high enough to be unacceptable, then mitigation action(s) to reduce the probability and/or consequence of the event should be implemented. In addition, some failures that occur frequently may accumulate a high economic impact when examined over time.

Past inspection planning methods have traditionally focused solely on the consequences of failure or on the probability of occurrence without systematic efforts to tie the two together. They have not considered how probable it is that an undesirable incident will occur. Only by considering both factors can effective risk-based decision making take place. Typically, acceptance criteria should be defined recognizing that not every failure will lead to an undesirable incident with serious consequence (e.g., water leaks) and that some serious consequence incidents have very low probabilities.

3.3 Risk Analysis Methodology

The risk analysis that supports the RBI program may be qualitative, quantitative, or a combination of the two. In each case, the risk analysis approach should be used to systematically screen for risk, identify areas of potential concern, and develop a prioritized list for more in-depth inspection or analysis. Use of expert opinion will typically be included in most risk analyses. The choice of approach depends on many factors such as

(a) objective of the analysis

(b) number of facilities and equipment items to assess

(c) available resources