Risk-based Machinery Management

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Introduction

The origins for the development of this recommended practice came from the recognition among responsible companies that more effective machinery risk management requirements are needed in view of:

— major accidents occurring within the industry;

— new manufacturing centers having difficulty in consistently achieving acceptable levels of quality;

— new applications and services that involve unproven design envelopes;

— larger fleets of aging machinery operating in process and pipeline facilities;

— limited experienced resources operating and maintaining machinery.

These and other drivers have influenced the content of the pages that follow, including understanding of the following.

1) Machinery risk is context dependent. It may be quite different among companies operating identical machinery within the same process service. Therefore, to be truly effective, the API Subcommittee on Mechanical Equipment (SOME) determined that prescriptive design requirements, as seen in machinery base standards, such as API 610, could not be imposed upon the industry by API 691. Since every company has unique engineering specifications, process requirements, worker competencies, work processes, risk tolerances, etc., API 691 allows internal risk criteria and methodologies to be utilized by individual operating companies for the purpose of identifying and managing high-risk machinery applications within the context of their own operating regimes.

2) Machinery risk is systemic. As such, the recommended practice sets minimum requirements for operating companies, selected designated responsible parties (DRPs), and vendors. Depending on the companies within this system, risk levels may either rise or fall for any given machinery asset. Each company is encouraged to map the API 691 processes outlined herein to their internal work process to the extent possible. The vendor is required to maintain on file design failure mode and effects analysis (DFMEA) as specified by the operating company. They are also responsible to track the technology readiness levels (TRL < 7) of components and subcomponents whose failure may lead to a loss of containment and/or a loss of functionality that could lead to a potential process safety event and to define integrity operating window (IOW) as required. Any other risk management requirement placed upon the vendor is considered outside the scope of this recommended practice. The DRP is required to perform all tasks and activities required by the operating company to enable safe and environmentally compliant machinery.

3) Machinery risk is dynamic. It changes over time and, therefore, API 691 is organized by machinery life cycle phase, including feasibility and concept selection; front end engineering design; detailed design; installation and commissioning, and operations and maintenance. There are periodic risk assessments that are required in each of these phases. The recommended practice requires the operating company to put in place a management system to track and mitigate risks where required over time, develop machinery standard operating procedures, define safe operating limits (SOLs), and provide adequate training for operating and maintenance personnel working on high-risk machinery, hereafter referred to as “API 691 Machinery.”

While not required, the user of this recommended practice is encouraged to utilize the Informative annexes where internal requirements are either lacking or found to be insufficient. The operating company and/or their DRP will find that issuing both the base API machinery datasheet (e.g. the API 618 datasheet) concurrently with the API 691 data sheet (Annex H) at the proposal stage is a useful way to define and communicate all API 691 requirements to ensure these are properly addressed and in the most timely manner.

A bullet (•) at the beginning of a section or subsection indicates that either a decision is required or further information is to be provided by the operating company. When such decisions and actions are taken, they may be specified in company documents (e.g. requisitions, change orders, datasheets, and drawings).

Risk-based Machinery Management

1 Scope

1.1 General

1.1.1 This recommended practice defines the minimum requirements for the management of health, safety, and environmental (HSE) risks across the machinery life cycle. It shall be applied to the subset of operating company and/or vendor defined high-risk machinery.

1.1.2 Unless otherwise specified, the following criteria shall be used for initial risk screening to identify potential high-risk machinery for which this recommended practice will be applied:

a) hazardous gas or liquid services as defined by jurisdiction, appropriate regulatory body, and/or operating company standards or specifications,

b) services operating at temperatures >350 °F (177 °C) and having design or specified off design operating pressures >80 % maximum allowable working pressure (MAWP),

c) services operating at temperatures >400 °F (204 °C),

d) components and subcomponents having technology readiness levels (TRLs) < 7 whose failure may lead to a loss of containment and/or a loss of functionality that could lead to a potential process safety event (see Table 1),

e) liquid services operating at pressures in excess of 600 psig (41.4 bar),

f) liquid services having specific gravities less than 0.5.

It is acknowledged that most operating companies and vendors may have existing risk management processes. This recommended practice is not written to replace or invalidate company practices but is meant to supplement them to provide safe working and living environments for facilities and surrounding communities. Operating companies (i.e. Sections 5, 6, 7, and 8 for design, installation, and operating purposes) or vendors [i.e. in Section 4 for research and development (R&D) and product development purposes] can use their own initial risk screening criteria where these have been found to be effective or the criteria recommended above.

NOTE 1 Typically only between 10 % and 20 % of machinery falling within any given initial risk screening will be considered API 691 Machinery. This can include a subset of “critical,” “unspared,” “special purpose,” “prototype,” and/or worst actor machinery. Risks can include loss of containment of hazardous fluids, loss of functionality, high energy releases, etc.

NOTE 2 Applicable international (e.g. GHS [1]) or national (e.g. OSHA 1910.119, API 570 [2], Class 1, etc.) hazardous service classifications are typically defined within operating company specifications.

NOTE 3 Operating companies and vendors can choose to apply this recommended practice to machinery not covered by existing API standards (e.g. hyper compressors).

1.1.3 The following machinery protection and safety standards shall be applied to new API 691 Machinery where applicable:

a) API 670;

b) IEC 61508-1, IEC 61508-2, and IEC 61508-3;

c) IEC 61511 (Parts 1, 2, and 3) or ANSI/ISA-84.00-2004 (Mod IEC 61511);

d) IEC 62061 or ISO 13849-1 and ISO 13849-2.

1.1.4 Other standards and technical reports may be used to further assist in the application of this standard including:

a) ISO 12100, [3]

b) ISO/TR 14121, [4]

c) VDMA 4315, [5]

d) IEC 60812, [6]

e) IEC 64244-3. [7]

1.1.5 This recommended practice is intended to be used by operating companies, their designated responsible parties (DRP), and vendors that are identified as potentially operating at high risk. It is applicable to both new (Sections 4 to 8) and existing (Section 8) installations.

NOTE This can include some supporting process equipment, for example, knockout drums, instrumentation, etc. that are located off-skid.

1.2 Machinery Risk Management

1.2.1 General

The term "API 691 Machinery" is used in this recommended practice to identify machinery that warrants a comprehensive machinery risk management system. Using risk ranking to prioritize machinery for further study and/or action provides a focus that maximizes the risk reduction of ongoing activities and improves the effectiveness of machinery risk management systems.

1.2.2 Management System

A management system to implement and sustain risk management programs for machinery should include:

1) procedures covering implementation, program maintenance, and reassessment (including reassessment triggers),

2) roles/responsibilities, training, and competence testing to ensure employment of qualified personnel,

3) documentation requirements of the risk analyses (e.g. scope, boundaries, assumptions, and mitigation actions),

4) data requirements including validation requirements,

5) acceptable risk limits and thresholds,

6) management of change (MOC) process,

7) program audit traceability requirements.

1.2.3 Risk Assessments

Assessment of probability and consequence can be done by a variety of approaches at the operating company or vendor's option. Refer to Annex A for further information. This recommended practice allows flexibility in assessment approaches (various qualitative, semi-quantitative, or quantitative methods) and defines only the deliverables needed at each stage to determine appropriate mitigations.

1.2.4 Risk Mitigation

Risk mitigation is typically accomplished by:

a) identifying risk levels above owner-defined limits,

b) identifying both the probability of failure (POF) and consequence of failure (COF) to understand the risk drivers,

c) identifying scenarios in sufficient detail to provide the specified deliverables at each life cycle stage,

d) identifying potential mitigations for either or both probability and consequence,

e) selecting and testing mitigations for sufficient risk reduction,

f) documenting and implementing the selected mitigations.

NOTE All of the steps above may not be appropriate at every life cycle stage.

1.2.5 Integration with Other Risk Assessments

The risk assessment methodologies within this recommended practice encompass approaches that enhance those conducted as part of a typical process hazard analysis (PHA) or reliability centered maintenance (RCM) program, both of which tend to focus on only a portion of the equipment life cycle. Integration of the various methodologies across the machinery life cycle (and its organizational supply chain) is key to a successful machinery risk management program.

Operating companies or their designated responsible party (DRP) may perform initial screening of machinery as part of routine process safety management (PSM) and/or hazard and operability (HAZOP) studies. These may also be useful in providing information on risk (e.g. consequence and/or operating scenarios).

1.2.6 Risk Assessment and Mitigation Activities by Life Cycle Stage

1.2.6.1 General

Risk assessment is used at different stages of the life cycle in different ways. These typically include two stages: a screening to identify machinery warranting further review and a more detailed assessment to identify needed mitigation.

For screening assessments, consequence alone may be used to trigger the need for further, more detailed risk assessments (e.g. better screening and evaluate risk management activities).

The following outlines the risk assessment and mitigation activities at each of the life cycle phases. It should be noted that API 691 Machinery can be declassified at any phase by the operating company if it is deemed that machinery or machinery components and subcomponents are not considered high risk and do not require mitigation.

1.2.6.2 Feasibility and Concept Selection (Section 4)

A screening assessment is performed early to identify machinery with potential high risks principally in the research, development, new applications, or manufacturing activities. Technical risk categorization (TRC) and technical readiness level (TRL) assessments aid in risk assessment and the definition and application of mitigation in this phase.

1.2.6.3 Front-end Engineering Design (FEED) (Section 5)

A preliminary risk assessment is performed in this stage to:

a) identify API 691 Machinery with potential high risks,

b) define a list of supplementary protective measures that should be within the scope for detailed design.

1.2.6.4 Detailed Design (Section 6)

A more detailed risk assessment with the additional information available as design progresses (or as changes occur) is performed in this stage to:

a) confirm that the risk level is high enough to warrant continued mitigation,

b) define available mitigations in design or in operation and maintenance activities.

NOTE These would typically include detail to the maintainable item level for failure mode and effects analysis (FMEA) and task selection.

1.2.6.5 Installation and Commissioning (Section 7)

This section covers requirements, recommendations, and considerations for the installation and commissioning phase including:

a) use of API 686 [8],

b) recommendations on the review of deviations in the process and/or the machinery,

c) recommendations on the verification of mitigations (including functional safety tests),

d) recommendations and considerations on commissioning operational tests,

e) pre-start-up safety reviews (PSSRs),

f) installation and commissioning documentation.

1.2.6.6 Operation and Maintenance (Section 8)

An initial screen is performed to identify API 691 Machinery leveraging available HAZOPs, incident reports, and other HSE related documentation. A field risk assessment is then conducted for machinery found to meet specific criteria defined within the recommended practice. The results of the field risk assessment should provide actionable mitigation activities that, after technical review, are required to be implemented per this recommended practice.

1.2.6.7 Guidelines for Risk Assessment Methodology (Annex A)

Annex A (informative) provides detailed background information and guidance on risk assessment and management methodologies.

1.3 Limitations

This recommended practice is based on machinery risk assessment methodologies commonly used within the petroleum, chemical, and gas industries.

Nonetheless, it will not compensate for:

a) inaccurate or missing information,

b) inadequate designs or faulty equipment installation,

c) operating outside defined and acceptable limits,

d) not effectively executing defined equipment activities,