400 Series:
Process Safety

# EHS Mechanical Integrity

Standard Number: IVL EHS-415
Version: 2.0
Issue / Revision Date: 17 March 2025

Global Environmental, Health and Safety
Indorama Ventures

## Table of Contents

## 1. Purpose

This standard establishes Indorama Ventures process and minimum requirements for a Mechanical Integrity (MI) assurance program for all equipment.

## 2. Scope

This standard applies to all Indorama Ventures owned/operated sites. This standard does not apply to third-party warehouses and tollers. This standard also does not apply to joint ventures (JVs) in which Indorama Ventures is a minority owner, unless specifically requested by the related Segment EHS Leader. Refer to the IVL EHSG-1415E Scope of Equipment in MI Programs document for a listing of equipment types typically included in mechanical integrity programs.

For the purpose of this standard, the term 'EHS' includes process safety, transportation, and security, as well as environmental, health and safety.

This standard must be implemented by each site. Until implementation of this standard is complete, each site must at a minimum be in compliance with the local applicable regulations.

## 3. Responsibilities

Following is an overview of key responsibilities for this standard. Additional responsibilities, as applicable, are included in Section 4, Requirements.

3.1. Corporate EHS

3.1.1. Provide ongoing technical assistance related to this standard.

3.1.2. Periodically audit sites to determine compliance with this standard.

3.1.3. Review, update and communicate to all Indorama Ventures sites any updates or changes to this standard and associated documents and tools.

3.1.4. Periodically review this standard to ensure its continuing adequacy and suitability to Indorama Ventures operations.

3.1.5. Ensure this standard is consistently implemented from site-to-site within Indorama Ventures.

3.1.6. Communicate, as applicable, any lessons learned as a result of best practices identified or any non-compliances associated with implementation of this standard.

3.2. Site Head or Designee

3.2.1. Ensure implementation of and compliance with this standard including that it is adhered to and that all personnel receive the proper training, resources, and communications.

3.2.2. Assist with the implementation of this standard; in particular:

- Be thoroughly familiar with the requirements of this standard and any associated procedures and work practices.
- Provide support, resources and training needed to carry out the requirements of this standard.
- Ensure required records are maintained on file.
- Ensure compliance with this standard by personnel (as applicable), including conducting periodic compliance audits.
- Ensure Responsible Persons are assigned to the categories of equipment.

- Assign a Qualified Person(s) to oversee and manage the mechanical integrity activities.

3.2.3. Ensure that Mechanical Integrity assessments are carried out for the site and for any modifications to equipment once initial Mechanical Integrity assessments are complete.

3.3. Segment EHS

3.3.1. Ensure that any site or local standard or procedure related to the same topic follows the corporate requirements at a minimum.

3.3.2. Support the site on any technical point related to the standard, including implementation.

3.3.3. Periodically evaluate each site's level of compliance with this standard.

3.4. Program Owner

3.4.1. Be thoroughly familiar with the requirements of this standard and local regulatory requirements.

3.4.2. Develop and implement the requirements of this standard and any local/regional regulatory requirements.

3.4.3. Periodically review and monitor for compliance with the requirements of this standard, and per local regulatory requirements, at least every five (5) years.

3.4.4. Develop an action plan to correct any non-conformance with local regulatory or Indorama Ventures requirements.

3.5. Project Managers

3.5.1. For current and ongoing projects and associated equipment, the Project Manager shall ensure compliance with this standard for equipment within the defined project scope of work and is specifically responsible to ensure:

- Systems, procedures, and personnel are in place to meet the applicable requirements of this standard.
- Responsible Persons are assigned to the categories of equipment.
- Persons assigned to execute or manage tasks required by this standard are competent persons.
- Documentation required by this standard is developed and retained.
- Performance of tasks and activities required by this standard are completed as planned.
- Periodic audits are conducted to verify compliance with this standard.
- Required documents or evidence of compliance is in place and maintained.

3.6. Responsible Person

3.6.1. The Responsible Person shall ensure compliance with this standard for the specific categories of equipment within their assigned area of responsibility and is specifically responsible to ensure:

- Equipment items within their assigned category are identified.
- Maintenance and/or inspection plans are defined and maintained up to date with current information.
- Changes to equipment inspection intervals are reviewed and documented.

- Equipment deficiency records are reviewed and recommendations for approval of deferred inspections are provided.
- Determination of corrective actions, which may include removing deficient equipment from service if safe operation cannot be assured.
- Verification of completed corrective actions for reported repairs are conducted.
- Evaluation of reported deficiencies identified during operation, maintenance, or inspection activities is conducted.
- Supervise Fitness for Service (FFS) or other suitable engineering assessments for equipment.

3.7. Responsible Manager

3.7.1. The Responsible Manager shall work with the Responsible Person to execute corrective actions as necessary, including removal of deficient equipment from service if safe operation cannot be assured.

3.8. Employees and Contractors

3.8.1. All personnel must understand and follow the requirements of this standard including:

- Being aware of and trained on, as applicable, the legal, regulatory and other associated requirements.
- Immediately reporting any situations that may cause or have a potential to cause a non-compliance.
- Completing any assigned regulatory tasks or actions.
- Being aware of and trained on the process safety information relevant to the process(es) they operate and/or maintain.

3.8.2. Individuals experienced in the process under evaluation (e.g., operations specialist, maintenance associate, process engineer) shall be involved in the EHS criticality assessment as requested.

3.9. In addition to the roles and responsibilities detailed above, the site must define and document the roles and responsibilities for all personnel who play a role in implementing the standard, at a minimum:

- Supervisors
- Engineering and Maintenance
- EHS Personnel
- Other applicable functions, as staffed at individual site level

## 4. Requirements

The site shall implement the requirements of this standard, and any local regulatory requirements, and, at a minimum, address the following:

4.1. General

4.1.1. All facilities shall implement the elements of a mechanical integrity program in accordance with the requirements of this standard and all applicable local, national, or regional regulations.

4.1.1.1. A typical equipment life cycle is shown in Attachment B, which includes several of the key components of mechanical integrity assurance. Requirements for these components are included within this standard.

4.1.2. The program shall be documented as necessary to demonstrate compliance, including a description of the location of all required records. The Site Head shall assign appropriate resources to provide oversight or manage the mechanical integrity activities.

4.1.3. Equipment categories (e.g., fixed, rotating, controls, instrumentation, electrical, fire protection, structural, buildings, and civil works) shall be assigned to a Responsible Person. A single individual may act as Responsible Person for multiple equipment categories.

4.1.4. All tasks and activities required by this standard shall be performed by competent persons.

4.1.5. A list(s) of all equipment within the MI program shall be developed and maintained consistent with IVL EHSG-1415E, Scope of Equipment in MI Programs.

4.1.5.1. Unique numbers shall be assigned to each physical equipment item.

4.1.5.2. The assignment of equipment identification for piping is usually accomplished by dividing the system into a series of segments or circuits. The circuit is then assigned a unique identification.

4.1.5.3. Individual piping circuits should have common materials of construction, operating conditions, active damage mechanisms, and expected corrosion (damage) rates.

4.1.5.4. Isometric (iso) construction drawings are often used to define the segments since the iso drawings also contain relevant materials of construction, specifications, test pressures, supports, coating and insulation systems, and components.

4.1.6. A record (electronic or hardcopy file) of all documents required by this standard shall be maintained for each item of equipment. The documentation record shall include:

4.1.6.1. Relevant mandatory process safety information in accordance with IVL EHS-402 Process Safety Information.

4.1.6.2. Evidence of compliance with the requirements of this standard.

4.2. Refer to IVL EHSG-1415F Equipment Documentation Guidelines for a description of the documents associated with different equipment types.

4.2.1. All designs and specifications shall be completed by competent people.

4.2.2. Recognized and generally accepted good engineering practices (RAGAGEP) shall be used for the design of new or modified equipment. See Attachment C Inspection Codes, Practices, and References for potentially applicable RAGAGEP.

4.2.3. All required documentation shall be maintained in the equipment records.

4.3. Procurement

4.3.1. Procurement Specifications shall be defined to ensure the mechanical integrity aspects of the equipment are properly specified, including but not limited to the following.

4.3.1.1. A Quality Assurance/Quality Control process shall be utilized to ensure that the "as-delivered" equipment item conforms to design, purchase, and materials specifications.

4.3.1.2. Appropriate documentation shall be requested and provided for each equipment item procured, including operating, maintenance, and inspection specifications; certification as applicable; or other Process Safety Information.

4.3.2. Refer to IVL EHS-402 Process Safety Information as needed for additional guidance.

4.3.3. Systems and procedures should be in place to ensure goods and services are provided by approved contractors/suppliers.

4.3.4. An inspection plan for fabricated equipment shall be developed to define:

- Designated hold points and criteria to proceed;
- Witness requirements for any work-in-progress testing, verification, or analysis;
- Final factory acceptance inspection;
- Pre-shipment inspection; and
- Delivery receipt inspection.

4.4. Storage and Preservation

4.4.1. All equipment that is held in storage, including capital spares, spare parts, and replacement parts for equipment, shall be stored, preserved, inspected, and maintained in accordance with manufacturer's recommendations or RAGAGEP prior to installation. See Attachment C Inspection Codes, Practices, and References for potentially applicable RAGAGEP.

4.4.2. Any records for completion of the required preservation tasks and activities shall be maintained and retained in the equipment record.

4.4.3. When control transfers from one organization or team to another, the receiving organization or team must ensure that any on-going preservation requirements and procedures are continued.

4.5. Fabrication

4.5.1. Systems and procedures shall be in place to ensure:

4.5.1.1. Fabrication, installation, and construction of equipment is performed by approved contractors/suppliers.

4.5.1.2. A Quality Assurance/Quality Control process is utilized to ensure that the "as-installed" equipment items conform to installation and construction specifications.

4.5.1.3. Appropriate documentation and certification are requested and provided for each equipment item installed.

4.5.2. Refer to IVL EHS-402 Process Safety Information for additional guidance.

4.6. Materials of Construction

4.6.1. The materials of construction shall conform to the requirements and restrictions for the service and operating conditions.

4.7. Commissioning and Handover

4.7.1. Systems and procedures should be in place to ensure equipment is commissioned in accordance with written commissioning procedures or instructions.

4.7.2. A pre-start-up safety review shall be completed prior to start-up of the new or modified process equipment in accordance with IVL EHS-413 Pre-Start-Up Safety Review.

4.7.3. All required documentation shall be made available and accessible to the operating, maintenance, and other organizations as necessary.

4.8. Operation

4.8.1. The safe operating ranges shall be specified and included in the equipment file.

4.8.1.1. Operating procedures should also include these safe operating ranges for equipment. This may include pressure and temperature limitations established by the design, or limits set to prevent damage mechanisms that could affect equipment integrity and reliability. See the IVL EHS-412 Operating Procedure standard for more details about operating procedures.

4.8.2. Any change to the limiting operating range for an item of equipment shall be managed in accordance with IVL EHS-204 Management of Change.

4.9. Inspection and Maintenance - General

4.9.1. A maintenance strategy shall be defined and implemented for equipment covered by the requirements of this standard.

4.9.2. The written scheme of examination/inspection plan (WSE/IP) shall be based on a defined maintenance strategy. Refer to Attachment D for a decision tree depicting the maintenance strategy selection process.

4.9.3. WSE/IPs for equipment items shall be documented.

4.9.4. Use of a reactive or event triggered maintenance strategy as the primary or sole strategy requires that:

4.9.4.1. Prior to implementation, the equipment or component shall be assessed to determine if the possible failure mode could result in harm to people or the environment.

4.9.4.2. If the possible failure mode has the potential for harm to people or the environment, controls to mitigate the potential consequence shall be developed and implemented with the strategy.

4.9.5. The maintenance strategy shall consider the damage mechanisms, types of deterioration, possible failure modes, and remaining life assessment.

4.9.5.1. The remaining life of equipment shall be determined using methods specified by an inspection code or other RAGAGEP for the equipment type.

4.9.5.2. Refer to IVL EHSG-1415A Guidelines for Remaining Life Calculations for additional guidance.

4.10. Written Schemes of Examination and Inspection Plans

4.10.1. Equipment in the following categories shall utilize the WSE/IP strategy:

- Pressure Equipment
- Heat Exchangers
- Fired Equipment and Boilers
- Atmospheric Storage Tanks
- Process Piping and Components
- Relief Devices
- Flexible Hoses
- Structures
- Machines
- Rotating Equipment
- Instrumentation
- Electrical Equipment

4.10.2. An EHS risk assessment shall be used to justify any alternative approach to a WSE/IP required by this section and shall be documented with either a copy of the assessment maintained in the equipment record or in a central location with other EHS risk assessments.

4.10.3. Protective devices for equipment such as crash barriers, devices to prevent liquid hammer, or other devices, when installed to protect vulnerable pipework, shall be included in the WSE/IP.

4.10.4. The WSE/IP shall be based on an assessment to identify the specific damage mechanisms, types of deterioration, or failure modes applicable to the specific item of equipment based on the materials handled and process conditions; and the requirements, recommendations, or potentially applicable RAGAGEP guidelines defined in Attachment C for the type of equipment.

4.10.5. Prior to execution, an WSE/IP shall be prepared and documented and include the minimum following information:

a. Unique identification of the equipment or item(s) addressed by the WSE/IP
b. Identification of the minimum required activities including:
    - specific damage mechanism involved,
    - inspection methodology or testing technique,
    - extent of inspection coverage or the measurement points,
    - data to be recorded,
    - pass/fail criteria for the inspection/test
    - due date for the next required inspection

4.10.6. Inspection plans and/or maintenance tasks shall be defined and maintained up to date with current information by the Responsible Person.

4.10.6.1. Changes to the WSE/IP to eliminate or reduce the minimum required activities shall be performed by or under the direct supervision of the Responsible Person responsible for the equipment type.

4.10.6.2. The elimination of required inspection tasks and activities shall be approved and documented in accordance with IVL EHS - 204 Management of Change.

4.10.7. Any part of a WSE/IP for an item of equipment that is defined, managed, and executed by external inspectors, or compliance assessors, authorized in accordance with a regulatory agency or government organization shall be exempt from the specific requirements of this section.

4.10.8. WSE/IP for an item of equipment that is defined, managed, and executed by a third party (contract) inspector, or compliance assessor, that is not affiliated with a regulatory agency or government organization shall be subject to the requirements of this standard.

4.11. Inspection and Maintenance Intervals

4.11.1. The maximum allowed interval between inspections shall be defined and documented for each WSE/IP.

4.11.2. Intervals for inspections, examinations, or maintenance activities, shall be established based on the relevant national or international regulations, RAGAGEP (e.g., codes, standards, manufacturers' recommendations), operating history, operating experience, and risk assessments, for the category of equipment. Refer to the potentially applicable RAGAGEP references in Attachment C for additional guidance.

4.11.3. Inspection intervals shall not exceed the maximums specified by the relevant inspection code or by the national standard, unless justified by a Risk Based Inspection (RBI) assessment (see Attachment E), limited to the maximum allowed inspection interval stated by local regulation.

4.11.4. Changes to the maximum allowed interval (reduce or extend) between planned inspections tasks or activities shall be:

4.11.4.1. performed by or under the direct supervision of the Responsible Person responsible for the equipment type, and

4.11.4.2. approved and documented in accordance with the IVL EHS – 204 Management of Change standard for interval changes.

4.12. Maintenance or WSE/IP Execution

4.12.1. The site shall have an inspection management system(s) (IMS) in place for the management of WSEs, IPs, inspection/activity/task due dates, recording the results of inspections/activities/tasks, and analysis related to all inspection activities.

4.12.1.1. Inspection planning, including setting intervals, performing remaining life calculations, execution of plans, revising plans, and managing the deferral of inspections should be done in accordance with the guidelines in Attachment F.

4.12.2. Completion of tasks and activities required by the maintenance strategy shall be documented and include at least the following information:

a. Date of inspection, test, or activity
b. Name of person carrying out the inspection or test

c. Identification of the equipment items being inspected
    1) This shall include the model number and serial number of the device when applicable (i.e. for instrumentation, electrical equipment, etc.)
d. Type of inspection or non-destructive examination (NDE) technique and targeted damage mechanisms
e. Summary of measurement locations, or extent of area examined
f. Identification of any measurements that indicate a deficiency
g. Summary of the results, including (but not limited to) details of any recommended repairs - subsequent inspections and testing of repairs
h. Any restrictions to the equipment's safe operating limits due to the inspection findings
i. Date of the next planned inspection

4.12.3. A review of the WSE/IP should be performed after each inspection to ensure the tasks and activities remain relevant for the identified damage mechanisms.

4.12.4. The WSE/IP shall be periodically reviewed by the Responsible Person to ensure the tasks, activities, methods, locations, and intervals are appropriate for the current operating conditions, damage mechanisms, and results history.

4.12.4.1. The WSE/IP shall be updated to record any required changes identified during the review.

4.13. Inspector Qualifications

4.13.1. Inspections, tests, activities, and tasks shall be performed by persons with the training, knowledge, and experience for the tasks, techniques, methods, and equipment being utilized.

4.13.2. Inspectors may be individuals, organizations, contractors, or provided by third party agencies as allowed by local, national, or regional laws or regulations.

4.13.3. Any requirements for inspector certifications or the appointment of authorized inspectors shall be consistent with local, national, or regional laws or regulations.

4.13.3.1. Inspector certification by a national or international recognized organization is preferred.

4.14. Deferral of Planned Inspections

4.14.1. Each Facility shall have a system for the evaluation and management of inspection interval extensions (deferment of inspection).

4.14.2. A deferral request shall be documented and consider:

a. The service condition of the equipment
b. The EHS risk resulting from the likely failure mode(s)
c. The current rate of deterioration for each interval limiting damage mechanism(s)

4.14.3. Approval of a deferred inspection shall be contingent upon;

a. Recommendation from the Responsible Person that the equipment will not become deficient during the deferment period - If recommendation cannot be obtained, the deferral shall be managed as a deficiency.

   If the Responsible Person does not recommend or cannot justify approval of a deferral request, then operation beyond the inspection date requires more extensive evaluation and review.

b. Performing additional inspections as required to demonstrate the equipment will be safe to operate during the deferment period.
c. Confirmation that the deferral conforms with any local regulations or requirements, including approval by an authorized inspection agency or regulator if required.
d. Confirmation that the EHS risk level can be maintained within acceptable limits during the deferment period.
e. The deferment is approved by the Site Head or designee
f. The deferment is tracked through the site's Management of Change system for the evaluation and management of inspection interval extensions.
g. The deferment is only valid for a fixed time indicated by the revised inspection date.
h. The inspection becomes "overdue" if the inspection is not completed by the approved due date.

4.14.4. An inspection date may be deferred more than once so long as an analysis for each deferral indicates it is safe to do so and does not violate any regional, national, or local regulations.

4.15. Overdue Activities Management

4.15.1. The inspection date as recorded in the equipment record or Inspection Management System (IMS)shall be used as the basis for establishing whether an inspection is "overdue" for the purposes of reporting in accordance with IVL EHS-109 EHS Metrics and Reporting and IVL EHS-1109A EHS Metrics and Reporting Methodology.

4.15.1.1. The scheduled date for an WSE/Inspection Plan activity listed in the site's maintenance scheduling tool or application (SAP PM or other) may be sooner than that required by the IMS.

4.15.2. If the maintenance scheduling tool or application (SAP PM or other) is used as the IMS, then the scheduled date in the maintenance scheduling tool or application shall be used as the basis for establishing whether an inspection is "overdue" for the purposes of reporting in accordance with IVL EHS-109 EHS Metrics and Reporting and IVL EHS-1109A EHS Metrics and Reporting Methodology.

4.16. Deficiency Management

4.16.1. The deficiency management process is appropriate for ensuring the proper analysis and mitigating actions are performed. Any reported deficiencies identified during operation, maintenance, or inspection activities shall be:

a. Evaluated by the Responsible Person to determine the appropriate corrective actions necessary
b. Communicated to the Responsible Manager (Equipment/Operations Manager)

4.16.2. Deficient equipment shall be removed from service if safe operation cannot be assured.

4.16.3. A Fitness for Service (FFS) or other suitable engineering assessment shall be performed under the direct supervision of the Responsible Person to determine the equipment's suitability for continued operation.

4.16.4. The FFS analysis shall conform to the methodologies defined in the following documents as applicable for the equipment type.

a. API 579 – Fitness for Service
i. *Fitness for Service* is ideal for assessments of equipment designed to the ASME pressure codes; however, conversions to other codes can be done and coverage of the

failure modes common to the chemical process industry is adequate for most evaluations.

b. BS 7910 – Guide to methods for assessing the acceptability of flaws in metallic structures
   i. Guide to methods for assessing the acceptability of flaws in metallic structures is not based on a specific design code; however, the detailed analysis includes extensive use of fracture mechanics and provides generalized guidance for other damage mechanisms.

4.16.5. The FFS or engineering assessment shall be documented in the equipment record.

4.16.6. Continued operation of equipment with deficiencies shall be contingent upon:

a. Confirmation that the equipment can be managed and safely operated until the deficiencies can be corrected.

4.16.7. An engineering and/or safety analysis shall be completed to specify the conditions required for continued operation, including but not limited to,

a. additional inspections
b. restrictions on operating limits
c. temporary repairs (e.g., leak repair devices)
d. restricted access
e. any additional safeguards that may be required

4.16.8. The continued operation of deficient equipment shall be managed as a temporary change in accordance with IVL EHS 204 - Management of Change standard. Actions to address deficiencies shall be tracked to completion.

4.16.9. Leak Repair Devices (engineered enclosures) shall also be:

a. managed as a temporary change.
b. processed in accordance with IVL EHS – 204 Management of Change standard.
c. designed and installed in accordance with the requirements stated in Attachment G.
d. registered as an asset in the site's inspection management system unless the installation is in non-hazardous service and in place ≤ 180 days.
e. have an WSE/IP in place.
f. removed during the next scheduled plant or equipment outage.

4.17. Anomaly Management

4.17.1. Inspection results for equipment shall be reviewed for anomalies by the Responsible Person.

4.17.2. If the evaluation indicates inspection results are erroneous, such as finding thickness measurements that have increased over time, then the Responsible Person, in communication with the Responsible Manager, shall develop a plan of corrective action for the inspection.

4.18. Corrective Actions Management

4.18.1. Any reported repairs or other corrective actions identified during inspection activities shall be:

a. Entered into the equipment inspection management record
b. Corrected immediately or tracked until completed
c. Verified complete by the inspector or Responsible Person

d. Recorded as complete upon verification

4.19. Repairs and Restoration

4.19.1. Repairs shall meet or exceed the requirements to restore equipment to a functional state sufficient for continued safe operation.

4.19.1.1. Repairs should account for the expected amount of wear or degradation that may take place during operation and ensure sufficient strength remains until the next planned equipment outage, or opportunity for repair, is reached.

4.19.2. Materials of construction for repairs shall be verified to assure suitability for use in the specific process service.

4.19.3. Repairs to correct deficiencies shall be mandatory unless other action is taken to modify the equipment such that the deficiency is no longer relevant.

4.19.4. Any changes or modifications to the equipment shall be managed in accordance with IVL EHS – 204 Management of Change standard.

4.19.4.1. In this context, a modification is any alteration or change to the equipment design, ratings, materials, or components based on the original design or previously approved changes.

4.19.5. Repairs and changes, including welding, shall follow applicable RAGAGEPs and any standards a site has selected to use, including inspection and/or testing by qualified personnel. See Attachment C for potentially applicable RAGAGEP.

4.19.6. Restoration to “like new” condition is not mandatory unless necessary for continued safe operation.

4.19.7. Repairs to correct defects, flaws, blemishes, or other imperfections that do not limit the mechanical integrity of an equipment item or component are not mandatory.

4.20. Material Management

4.20.1. Systems and procedures shall be in place for the purchase, storage, preservation, security, identification, marking/tagging, and management of parts, components, assemblies, or other material goods used for the repair and restoration of equipment.

4.20.2. Positive materials identification should be performed in accordance with Attachment H.

4.21. Return to Service from Maintenance Activity

4.21.1. Systems and procedures shall be in place for the transition (turnover or handover) of individual items of equipment from the maintenance organization to the operating organization.

4.21.2. The procedures shall ensure:

a. All repairs are completed
b. The equipment is re-installed correctly
c. All items disconnected are re-installed correctly
d. Any temporary items installed for maintenance are removed
e. Any required tests and inspections are completed

f. There are no leaks

4.21.3. Refer to process safety standard IVL EHS-413 Pre-Start-up Safety Review for additional requirements that may apply.

4.22. Idled or Out of Service Equipment

4.22.1. Equipment designated as Idled, which is equipment not being used but is expected to be returned to service at a future date, including equipment temporarily mothballed (preserved for potential future use), shall be managed as active equipment requiring inspections to continue.

4.22.2. Equipment designated as Out of Service, which is equipment with no intention to be returned to service, shall be managed as active equipment requiring inspections to continue until the equipment is fully disconnected.

4.22.2.1. Once the equipment is fully disconnected the equipment may remain in place but should be removed from the process operating areas.

4.22.2.2. Fully disconnected requires an air gap at all piping, instrument, power, and utility connection points.

4.22.3. All idled or out of service designated equipment shall be drained, flushed, and decontaminated of all chemicals as early as practicable after the decision is made to remove an item of equipment from active service.

4.22.4. The inspection and maintenance plans may be revised for idled or out of service equipment if necessary to reflect the changed potential for exposure to degradation or damage mechanisms associated with being in active service.

4.22.5. Provisions for equipment preservation shall be implemented and included in the inspection and maintenance plan.

4.22.6. Equipment that is Out of Service and fully disconnected, with the intention of being removed from the mechanical integrity inspection program, shall:

a. Have an EHS risk assessment performed to ensure the necessary precautions are in place to protect personnel until the equipment is removed.
b. Have an inspection and maintenance plan in place to ensure the equipment has adequate structural integrity to prevent collapse until the equipment is removed.
c. Not be reused or returned to service unless a full inspection protocol is implemented to ensure the integrity of the equipment.

4.23. Additional Requirements for EHS-Critical Equipment in accordance with IVL EHS-405 EHS Criticality Assessment, PHA/LOPA Identified Independent Protection Layers (IPLs), and Consequence Mitigation Systems:

4.23.1. A corrective/reactive maintenance strategy shall not be used for EHS critical equipment, EHS critical structures, EHS critical PHA/LOPA identified independent protection layers (IPLs), or for consequence mitigation systems.

4.23.2. A corrective/reactive maintenance strategy may be used for any equipment listed as an initiating event cause within a PHA/LOPA.

4.23.3. Positive Materials Identification (PMI) in accordance with Attachment H shall be required for equipment that is an alloy material and is one of the following:

4.23.3.1. Piping and components under pressure (including valves, fittings, flanges, bolts, gaskets, expansion joint bellows, and welds)

4.23.3.2. Pressure containing components of instrument systems

4.23.3.3. Pressure containing components of machinery

4.23.3.4. Relief valves

4.23.3.5. Control valves

4.23.4. The remaining life of EHS Critical Equipment shall be determined in accordance with IVL EHSG-1415A Guidelines for Remaining Life Calculations and applicable recognized and generally accepted good engineering practices.

4.23.4.1. Where equipment is subject to (highly) unpredictable damage mechanisms and the end-of-life determinations may not be possible, this shall be documented in the equipment file and another means of determination shall be used, typically manufacturers recommendations, historical performance, condition monitoring and trend analysis and direct measurement.

4.23.5. For all critical pipework and sample points, A labelling, tagging, color-coding, or other scheme shall be developed and implemented by the site to make these systems easy to identify.

## 5. Training

Training requirements must be defined for the site-specific mechanical integrity program. At a minimum, all training must be documented with the training date, the names of personnel trained, the names of the trainer(s), the content of the training (or reference to content) and other site-specific/business segment requirements, when applicable.

5.1. Initial

Training on the requirements of this standard and the site-specific/regulatory requirements must be provided to Indorama Ventures personnel based on their relevant responsibilities and shall be provided in the local language. At a minimum, personnel and/or management with direct responsibilities for this standard and site-specific/regulatory requirements must read and understand this standard prior to conducting activities associated with this standard.

5.2. Refresher

Refresher training shall be provided periodically by reviewing this standard and any site-specific /regulatory requirements at appropriate intervals (e.g., changes to regulatory requirements, observed user deficiencies), or at least once every three (3) years.

## 6. Recordkeeping

Records associated with this standard and/or site-specific regulatory requirements and Mechanical Integrity must be controlled and retained in accordance with regulatory or site business segment record retention requirements, whichever is more stringent. Examples of records to be maintained include but may not be limited to maintenance plans, leak repair device records, deferment of planned inspections, as well as all data required to be documented for the equipment.

## 7. References

These references are in addition to those listed in Attachment C.

7.1. IVL EHS-107 Management of Actions

7.2. IVL EHS-109 EHS Metrics and Reporting

7.3. IVL EHS-204 Management of Change

7.4. IVL EHS-208 Risk Management Standard and Matrix

7.5. IVL EHS-320 Electrical Safety and Electrical Equipment Integrity (to be issued at a future date)

7.6. IVL EHS-402 Process Safety Information

7.7. IVL EHS-405 EHS Criticality Assessment

7.8. IVL EHS-408 Area Classification & Management

7.9. IVL EHS-409 Design & Maintenance of SIFs

7.10. IVL EHS-410 Pressure Relief Systems Design (to be issued at a future date)

7.11. IVL EHS-412 Operating Procedures (to be issued at a future date)

7.12. IVL EHS-413 Pre-Start-Up Safety Review

7.13. IVL EHSG-1415A Guidelines for Remaining Life Determination

7.14. IVL EHSG-1415B Guidelines for the Detection and Management of Corrosion Under Insulation

7.15. IVL EHSG-1415C Guidelines for Bolted Flanged Joints

7.16. IVL EHSG-1415D Flexible Hose Guidelines

7.17. IVL EHSG-1415E Scope of Equipment in Mechanical Integrity Programs

7.18. IVL EHSG-1415F Equipment Documentation Guideline

**Note**: Access to most of the industry codes, standards, and references are available through an online subscription service.

## 8. Terms and Definitions

See IVL EHS Glossary and Attachment A.

## 9. Revision History

| Version | Date | Summary of Update | Owner | Approver | Next Review Date |
|---|---|---|---|---|---|
| Original | 22 June 2023 | Initial Release | Chad Wyble, Global Process Safety Program Director | Todd Hogue, VP, Global Head of EH&S | 22 June 2026 |
| 1.0 | 09 August 2024 | Updated implementation timeframe (Section 2) and Responsibilities (Section 3); made minor editorial updates. | Chad Wyble, Global Process Safety Program Director | Todd Hogue, VP, Global Head of EH&S | 09 August 2029 |
| 2.0 | 17 March 2025 | Added “EHS critical structures” to 4.23.1 and added a new 4.23.2. | Chad Wyble, Global Process Safety Program Director | Todd Hogue, VP, Global Head of EH&S | 17 March 2030 |

## Attachment A: Definitions and Glossary

A.1 Active Equipment

Equipment that not “fully disconnected” – includes “in service”, idled, off-line, installed spares, and isolated/blinded equipment.

A.2 Alloy

Any metal (including welding filler materials) that combine two or more metallic elements to enhance mechanical properties, physical properties, or corrosion resistance.

A.3 Ancillary Equipment

Any supporting equipment or systems that are necessary to ensure the continued functionality of a primary equipment item.

A.4 Approved Contractors and Suppliers

Contractors and suppliers that have demonstrated acceptable performance by way of experience, industry reputation, and any qualifying criteria determined by the project team and Corporate Purchasing.

A.5 Basis for Design

A specification of design conditions required of an equipment item. A specification of the industry standard, design code, RAGAGEP, or manufacturer’s information that defines the engineering basis for the specific design features of an equipment item.

A.6 Breakdown Maintenance

See Corrective Maintenance or Reactive Maintenance

A.7 Controlled Equipment

As defined in IVL EHS Glossary

A.8 Corrective Maintenance

Maintenance that is identified after a failure has occurred – also known as reactive or breakdown maintenance.

A.9 Defect

With respect to Mechanical Integrity, an area where corrosion, deterioration, and/or erosion/abrasion has started to occur, or where the original insulation or protective coating is no longer intact but metal loss is within the minimal corrosion allowance. Additionally, fabrication errors may result in an equipment defect.

A.10 Deficiency

Deviation outside the acceptable tolerance from the as designed and as-built conditions of the equipment such that it can no longer operate within the documented safe upper and lower limits.

A.11 EHS Critical

As defined in the Global EHS Glossary and in accordance with IVL EHS-405 EHS Criticality Assessment.

A.12 EHS Risk Assessment

An evaluation or assessment of the EHS risk in accordance with IVL EHS-208 Risk Management Standard and Matrix.

A.13 Engineered Enclosure

See Leak Repair Device

A.14 Equipment

“Equipment” (including non-electrical equipment) means machines, electrical apparatus, fixed or mobile devices, control components and instrumentation thereof and detection or prevention systems which, separately or jointly, are intended for the generation, transfer, storage, measurement, control and conversion of energy and/or the processing of material.

A.15 Equipment Item

A part within a complete unit of equipment that has a specific purpose or function and is necessary for the complete unit to function properly.

A.16 Equipment Records

Data and information containing specific information about the design, fabrication, inspection, and repair of equipment. The records may be in electronic format or printed media and comprised of drawings, specification sheets, checklists, photographs, radiographs, narratives, or manufacturer provided information. Some records may not be specific to an individual item of equipment.

A.17 Event Triggered Maintenance (ETM)

Maintenance to correct defects or deficiencies that is scheduled and executed after a triggering event. The trigger event may be based on forecasted equipment availability (such as a planned shutdown or turnaround), loss of performance, loss of function, observed need for maintenance, an outcome of executing one of the other maintenance strategies, or other method.

A.18 Feasible

For the purposes of selecting a maintenance strategy: the expected results to be achieved by conducting a task or activity are known to be reliable and effective, the methodology or technology employed is proven to be effective, and the locations for measurements are accessible.

A.19 FMEA

Failure modes and effects analysis – a reliability analysis process that identifies failure modes, their effects, and maintenance activities to prevent them.

A.20 FMECA

As FMEA with the addition of a criticality step to rank multiple failure modes for the same equipment item.

A.21 Fully Disconnected

Equipment that is physically removed from the process or that is left in place with all sources of power, utilities, or process piping physically disconnected. The use of switches, blinds, or isolation valves as isolation points is not acceptable as a substitute for physical disconnection.

A.22 Hazardous Materials

As defined in the IVL EHS Glossary

A.23 In Service

Active equipment that is not idled, off-line, an installed spare, or isolated/blinded.

A.24 Inspection Plans (IP)

Detailed tasks defined in accordance with an inspection code or standard – also known in some regions as a Written Scheme of Examination (WSE) – typically comprised of one or more non-destructive tests or examination techniques (*NDT/NDE*).

A.25 Leak Repair Device (LRD)

Repair using clamps or sleeves – alternative features may include external load bearing capability, non-metallic leak sealants, and/or an extended design life span – used to restore the functional integrity of a pressure containment system.

A.26 Maintenance Plans

Detailed tasks defined in accordance with manufacturers recommendations, experience, or RAGAGEP for the equipment type – also known in some regions as a Written Scheme of Examination (WSE) – typically comprised of one or more methods defined by a maintenance strategy.

A.27 Maintenance Strategy

An approach or methodology employed to preserve the functionality of equipment through condition assessments, monitoring, life extension activities, degradation rate reduction activities, failure avoidance, or restoration activities.

A.28 NDT/NDE

Non-destructive testing/examination. Activities carried out to check a piece of equipment for deficiencies without affecting its integrity.

A.29 Pipe Clamp or Sleeve

See Leak Repair Device.

A.30 Piping Component

A mechanical element suitable for joining, or assembly into, a pressure tight, fluid containing piping system – Components include pipe, fittings, flanges, gaskets, bolts, valves, and devices such as expansion joints, flexible joints, pressure hoses, traps, strainers, in-line portions of instruments, and separators.

A.31 Piping System

A defined section of pipework including piping, fittings, flanges, bolting, gaskets, valves, bellows, piped-in flexible components, hangers, anchors, linings, insulation, protection and pipe supporting elements but not including support structures.

A.32 Planned Component Replacement (PCR)

Based on cumulative operating hours, fixed passage of time, multiples of repair or operating cycles, or other replacement plan that does not require loss of functionality or actual condition as a replacement criterion.

A.33 Positive Materials Identification (PMI)

The process of assuring the correct alloy materials of construction are verified for equipment prior to installation.

A.34 Preventive Maintenance (PM)

Activities or tasks that reduce or minimize the degradation rate of equipment or components.

A.35 Predictive or Condition Based Maintenance (PdM/CM)

Vibration analysis, oil analysis, motor winding resistance, thermography, acoustic monitoring, process control and trending analysis, emissions monitoring, and similar technology-based examination techniques used to assess the current state of equipment and establish trends to forecast the need for maintenance in advance of a failure.

A.36 Pressure Equipment

Equipment or equipment items designed to operate with liquid or vapor contents under pressure (may include columns, vessels, exchanger shells, tube bundles, reactors, pressurized tanks, filters, separators, etc.).

A.37 Reactive Maintenance

Maintenance carried out at the time a deficiency or loss of performance is detected.

Also referred to as Corrective Maintenance or Breakdown Maintenance.

A.38 Responsible Person

As defined in IVL EHS Glossary.

A.39 Shall

Compliance with the requirements is mandatory.

A.40 Should

Compliance with the requirement is recommended and alternatives are acceptable.

A.41 Temporary Repair

A repair to an item of equipment or a component that restores functionality but has a finite design life and does not conform to the original design specification or construction – A temporary repair is not necessarily a temporary change as defined in the IVL EHS Glossary.

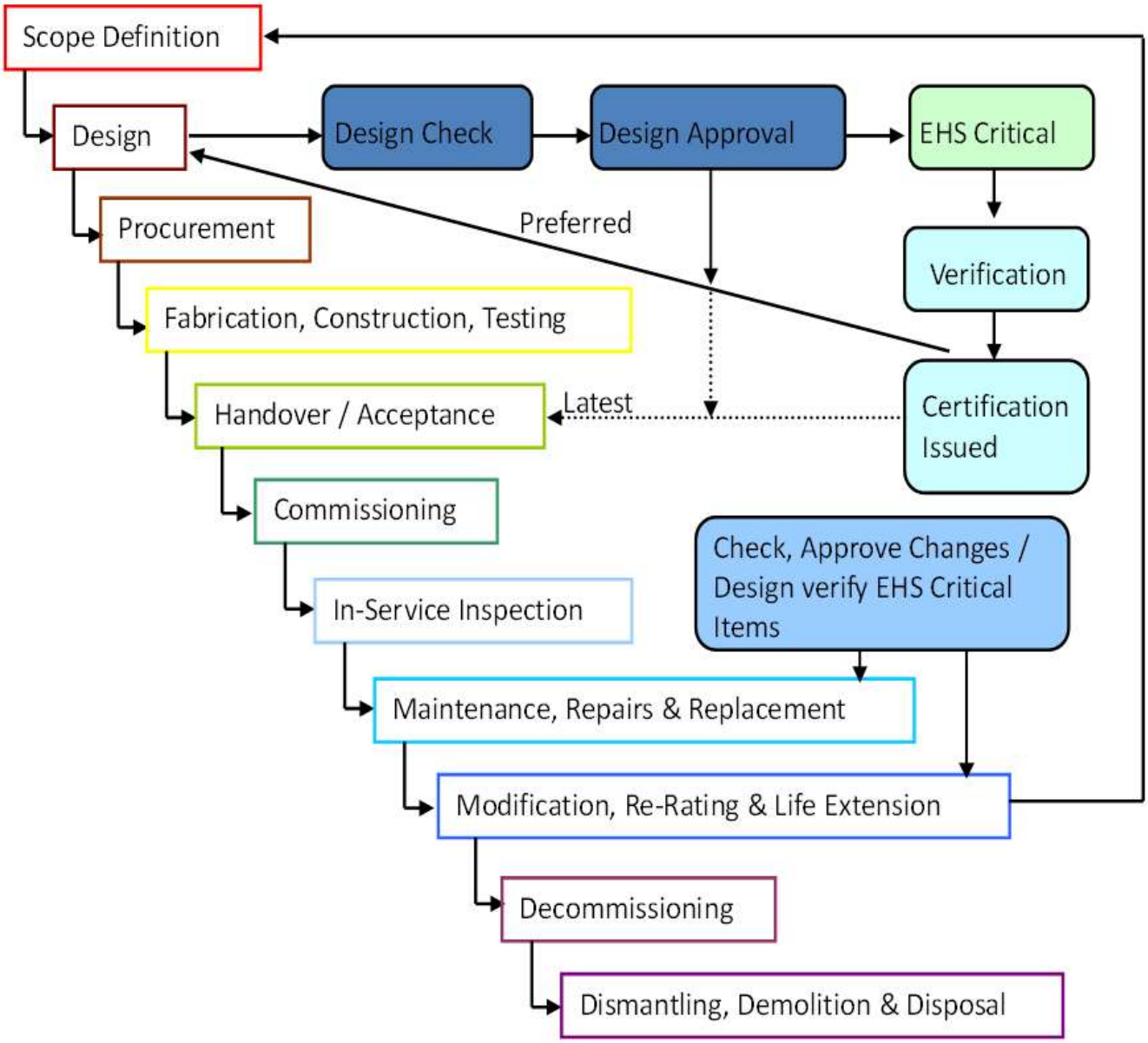
A.42 Visual Inspection

A non-destructive, non-intrusive technique generally using only hand tools and the unaided eye for the detection of readily observable defects.

A.43 Written Scheme of Examination

See Inspection Plan or Maintenance Plan.

## Attachment B: Typical Life Cycle of Equipment



## Attachment C: Some Equipment Inspection Codes, Practices, and References

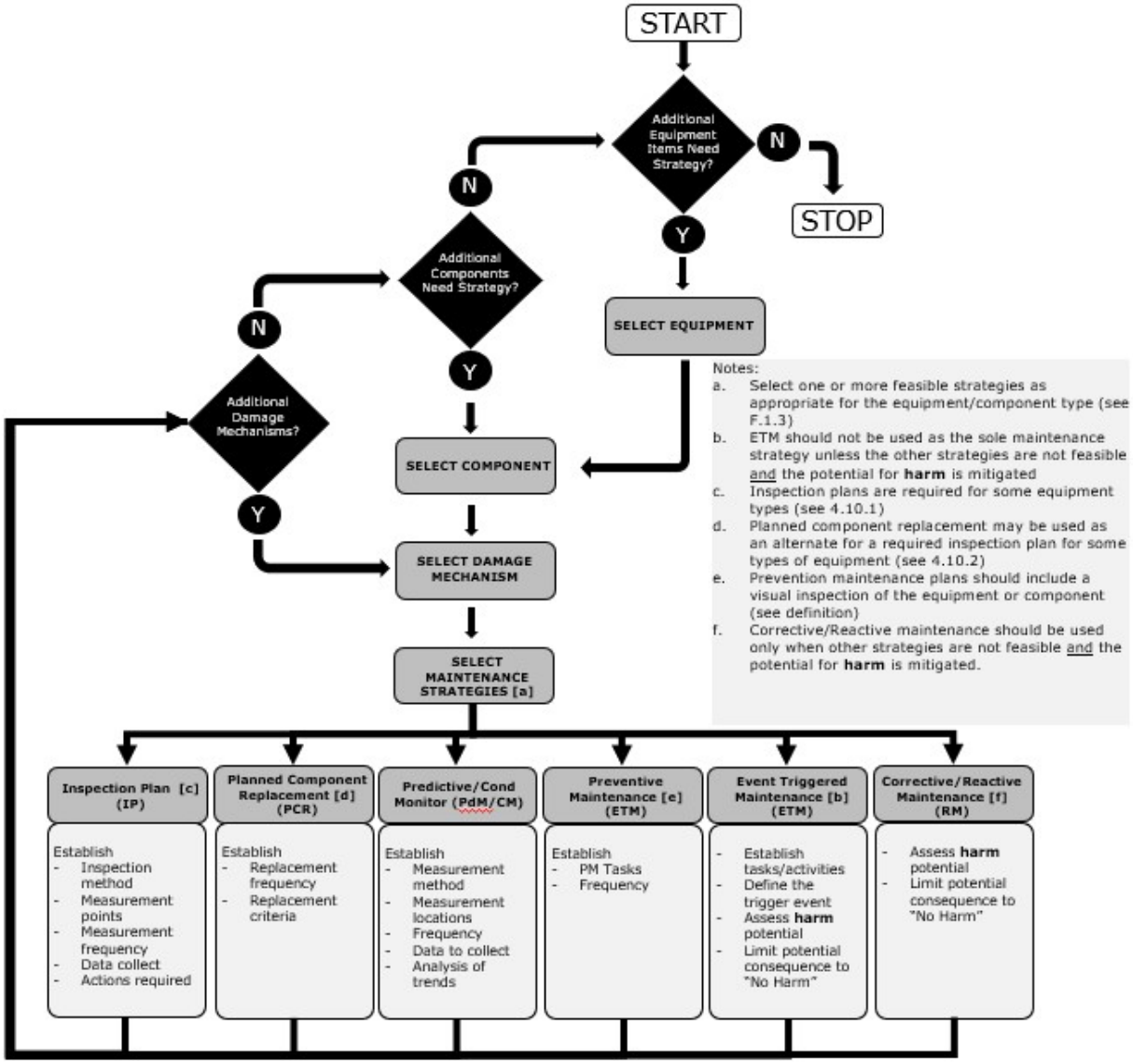
| Equipment Type or Topic | Common Codes and Internal Global IVL EHS Standards (This is not a complete list. Use Codes applicable to your Region/Location) |
|---|---|
| Relief and Vent Systems | — API STD 526 – Flanged Steel Pressure Relief Valves<br>— API STD 527 – Seat Tightness of Pressure Relief Valves<br>— API 576 - Inspection of Pressure Relieving Devices<br>— Also consult IVL EHS-410 Pressure Relieving Systems (to be issued at a future date) |
| Pressure Vessels | — API STD 510 – Pressure Vessel Inspection Code<br>— API RP 572 – Inspection Practices for Pressure Vessels<br>— UK Health and Safety Executive: Latest revisions of the Pressure Equipment Regulations (PER) and Pressure Systems Safety Regulations (PSSR)<br>— EU: Pressure Equipment Directive – (latest revision) |
| Rotating equipment | — ISO 10816 – Mechanical Vibration Parts 1-8, and 21<br>— PIP REEE002 – Reliability Indicators for Rotating Machinery<br>— IEEE 43 – Recommended Practice for Testing Insulation Resistance of Rotating Machinery<br>**Note:** Consult specific equipment manufacturer guidelines and recommendations for inspection, testing, condition monitoring, and routine maintenance tasks necessary to ensure equipment integrity |
| Piping Systems | — ASME B31.3 Process Piping Code<br>— API STD 570 – Piping Inspection Code<br>— API RP 574 – Inspection Practices for Piping System Components<br>— API STD 598 – Valve Inspection and Testing<br>— ASME PCC2 Repair Pressure Equipment and Piping<br>— UK Health and Safety Executive: Latest revisions of the Pressure Equipment Regulations (PER) and Pressure Systems Safety Regulations (PSSR)<br>— EU: Pressure Equipment Directive – (latest revision) |
| Bolted Flanged Connections | — Energy Institute: Guidelines for the management of the integrity of bolted joints in pressurized systems<br>— ASME PCC-1 Guidelines for Pressure Boundary Bolted Flange Joint Assembly |
| Structures | — All load bearing steel, concrete, and wood structures and foundations should be inspected at regular intervals by qualified personnel to ensure the load bearing capacity is not diminished by degradation using an inspection plan or written scheme of examination defined in Section 4.10 |
| Civil Works | — All permanent steel, concrete, wood, and earthen civil works designed to accommodate site security, site drainage, water retention, traffic, or occupancy should be inspected at regular intervals by qualified personnel to ensure the design function of the civil works are not diminished by degradation using an inspection plan or written scheme of examination defined in Section 4.10 |
| Emergency shutdown systems | **Note:** Consult specific equipment manufacturer guidelines and recommendations for inspection, testing, condition monitoring, and routine maintenance tasks necessary to ensure equipment integrity |
| Instrumentation and Controls | **Note:** Consult specific equipment manufacturer guidelines and recommendations for inspection, testing, condition monitoring, and routine maintenance tasks necessary to ensure equipment integrity |
| Safety Instrumented Functions | — IVL EHS-409 Design & Maintenance of SIFs |

| Equipment Type or Topic | Common Codes and Internal Global IVL EHS Standards (This is not a complete list. Use Codes applicable to your Region/Location) |
|---|---|
| | **Note:** Consult specific equipment manufacturer guidelines and recommendations for inspection, testing, condition monitoring, and routine maintenance tasks necessary to ensure equipment integrity |
| Electrical Systems | — IVL EHS-320 Electrical Safety and Electrical Equipment Integrity (to be issued at a future date)<br>**Note:** Consult specific equipment manufacturer guidelines and recommendations for inspection, testing, condition monitoring, and routine maintenance tasks necessary to ensure equipment integrity |
| Coatings, Insulation, and Fireproofing Systems | — European Federation of Corrosion Working Party 13 (WP 13) Corrosion in Oil and Gas Production<br>— European Federation of Corrosion Working Party 15 (WP 15) Corrosion in the Refinery Industry<br>— PIP CTEG1000 Guidelines for Use of Coatings Practices |
| Corrosion Under Insulation | — API RP 583 Corrosion Under Insulation and Fireproofing<br>— NACE SP0198 - The Control of Corrosion under Thermal Insulation and Fireproofing Materials – A systems approach.<br>— NACE: Corrosion Under Insulation (CUI) Guidelines: (EFC 55) [Book] |
| Materials, Corrosion, and Damage Mechanisms | — API RP 571 – Damage Mechanisms Affecting Fixed Equipment in the Refining Industry.<br>— Energy Institute: External corrosion awareness handbook: A guide for visual recognition of external integrity threats to upstream oil and gas production plant (A5)<br>— Energy Institute: External corrosion awareness handbook: A guide for visual recognition of external integrity threats to upstream oil and gas production plant (A6)<br>— EEMUA Pub No. 149: Code of Practice for the Identification and Checking of Materials of Construction in Pressure Systems in Process Plants |
| Risk-based Inspection Practices | — HSE COMAH: Assessment and Inspection Procedure<br>— ASME PCC3 Inspection Planning Using Risk-Based Methods<br>— API RP 580 – Risk-Based Inspection<br>— API RP 581 – Risk-Based Inspection Methodology<br>— API RP 577 – Welding Inspection and Metallurgy |
| Pollution control devices | **Note:** Consult specific equipment manufacturer guidelines and recommendations for inspection, testing, condition monitoring, and routine maintenance tasks necessary to ensure equipment integrity |
| Storage Tanks | — Basle Chemical Industry (BCI) Tank Farm - Guidelines for the Chemical Industry 2009 (Europe)<br>— API STD 653 – Tank Inspection, Repair, Alteration, and Reconstruction<br>— API RP 575 – Inspection Practices for Atmospheric and Low-Pressure Storage Tanks<br>— AS 1940-2004 – The Storage and Handling of Flammable and Combustible Liquids (Australia)<br>— EEMUA Pub No. 159 – Above Ground Flat Bottomed Storage Tanks – A Guide to Inspection, Maintenance, and Repair (Europe) |
| Hazard Mitigating Devices | **Note:** Consult specific equipment manufacturer guidelines and recommendations for inspection, testing, condition monitoring, and routine maintenance tasks necessary to ensure equipment integrity |
| Hazardous Area Equipment | IVL EHS-408 Area Classification & Management<br>**Note:** Consult specific equipment manufacturer guidelines and recommendations for inspection, testing, condition monitoring, and routine maintenance tasks necessary to ensure equipment integrity |

| Equipment Type or Topic | Common Codes and Internal Global IVL EHS Standards (This is not a complete list. Use Codes applicable to your Region/Location) |
|---|---|
| Secondary/emergency scrubbing systems | **Note:** Consult specific equipment manufacturer guidelines and recommendations for inspection, testing, condition monitoring, and routine maintenance tasks necessary to ensure equipment integrity |
| Emergency power supply systems (e.g. back-up generators, Uninterruptible Power Supplies [UPS]) | **Note:** Consult specific equipment manufacturer guidelines and recommendations for inspection, testing, condition monitoring, and routine maintenance tasks necessary to ensure equipment integrity |
| Buried drains, bunds/levees/secondary containment structures and lagoons | Refer to Civil Works |
| Fixed and portable gas sensors or detectors | **Note:** Consult specific equipment manufacturer guidelines and recommendations for inspection, testing, condition monitoring, and routine maintenance tasks necessary to ensure equipment integrity |
| Fired Equipment/ Boilers | – API RP 573 – Inspection of Fired Boilers and Heaters<br>**Note:** Consult specific equipment manufacturer guidelines and recommendations for inspection, testing, condition monitoring, and routine maintenance tasks necessary to ensure equipment integrity |
| Transportation containers | **Note:** Consult specific equipment manufacturer guidelines and recommendations for inspection, testing, condition monitoring, and routine maintenance tasks necessary to ensure equipment integrity |
| Flexible hoses | – Materials Technology Institute (MTI) Reliability Guidelines for Flexible Hoses 2015<br>**Note:** Consult specific equipment manufacturer guidelines and recommendations for inspection, testing, condition monitoring, and routine maintenance tasks necessary to ensure equipment integrity |
| Utilities necessary for safe operation or shutdown | Refer to specific equipment categories |

**Note:** All the listed references are available directly from the Indorama Venture's Engineering Subscription service or directly from the authoring organization.

## Attachment D: Maintenance Strategy Selection



## Attachment E: Risk-Based Inspection Methods

A risk-based inspection (RBI) program is a risk management methodology. The RBI methodology provides a structured process for the analysis of equipment to determine specific damage mechanisms and their associated failure modes. The failure modes are further evaluated to determine the potential consequence along with a determination of the likelihood of occurrence to attain a risk rating. The risk rating is then used to establish a prioritization scheme for conducting inspections. The results of the inspections are used to assess the equipment condition and the likelihood of occurrence for a failure mode. The continual process of assessment, risk ranking, prioritization, and measurement is repeated over the life of the equipment. Refer to Figure 1.

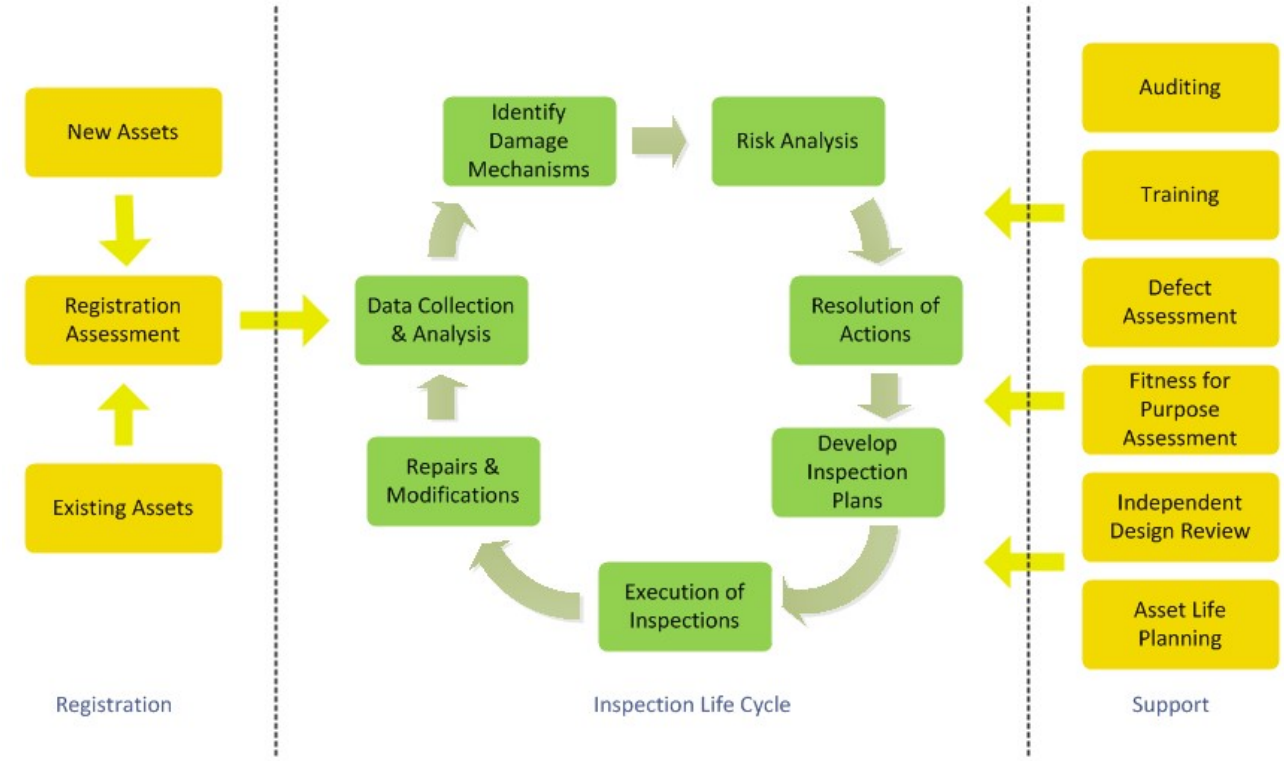



*Figure 1: Risk-based Inspection Program Overview*

E.1 Purpose

E.1.1 A Risk-Based Inspection (RBI) system will provide:

a. planned inspection for equipment based on risk of failure,
b. compliance with regulatory requirements,
c. compliance with recognized and generally accepted good engineering practices,
d. training and qualification for personnel who take part in the maintenance work,
e. quality assurance for new and replacement equipment and spare parts,
f. continuous improvement of the maintenance system

E.2 Principles

E.2.1 A maintenance system should be designed using elements that work together as a quality system. If any of the elements are missing or are poorly designed, the performance of the maintenance system will suffer and will not be as effective as it could be.

E.2.2 RBI is a maintenance system in which the controlling elements are designed to integrate smoothly with the maintenance process. The resultant output is reliable equipment with continuously improving performance. Some special features of RBI include:

a. criticality rating developed for each equipment item based on the effect equipment performance has on the key business indicators and used to recommend maintenance tasks,
b. precisely defined procedures for performing tasks,
c. maintenance data in a format easy to evaluate for compliance with the maintenance plan and with regulatory requirements,
d. an update step that continuously improves the maintenance plan for each equipment item as well as the entire system that drives both toward optimum performance, and
e. information that can be used to eliminate unplanned equipment failures and make step improvement toward optimum performance.

E.3 Information Required

The quality of any risk-based inspection program will depend on the quality of the information input. Information required will include:

a. existing equipment histories, including any repairs,
b. known deterioration mechanisms / failure modes for the technology / materials,
c. detailed design information.

E.4 Output

The risk-based assessment should produce a specific maintenance and inspection plan for each item of equipment, based on its likely deterioration and consequences of failure.

## Attachment F: Inspection Planning, Execution, and Management Guidelines

F.1 Inspection and Maintenance – General

F.1.1 A good practice is to also define and implement a maintenance strategy for equipment that is not covered by this standard, as well as equipment that is covered.

F.1.2 A single maintenance plan document may be used to address multiple equipment items if the plan is appropriate to all the items addressed and it is clear which equipment items are addressed by the plan.

F.1.3 The maintenance plan should be consistent with one or more of these common strategies:

a. Inspection Plans (IP)
b. Planned Component Replacement (PCR)
c. Predictive or Condition Based Maintenance (PdM/CM)
d. Preventive Maintenance (PM)
e. Event Triggered Maintenance (ETM)
f. Corrective/Reactive Maintenance (RM)

F.1.4 Refer to Attachment D for a decision tree depicting the maintenance strategy selection process.

F.1.5 These strategies can be applied at the equipment assembly or component level and it is not necessary for all components within an equipment assembly to have the same strategy.

F.1.6 Event triggered maintenance should be used in combination with one or more of the other strategies and is not preferred as the primary or as a sole strategy.

F.1.7 Availability of spare parts, time in service, age, and operating history of the equipment or component should also be considered.

F.1.8 Inspection and maintenance of equipment items and components should be in accordance with the original equipment manufacturers (OEM) recommendations, instructions, or manuals specific to the item of equipment modified in accordance with local operating experience. Refer to IVL EHSG-1415C Guidelines for Bolted Flanged Joints and IVL EHSG 1415D for additional guidance on equipment component mechanical integrity.

F.1.9 If specific OEM information is not available then OEM information from a similar model of equipment should be consulted; otherwise, generally accepted inspection and maintenance practices should be used.

F.1.10 The following information should be consulted in the determination of damage mechanisms, types of deterioration, or failure modes:

a. Process service, operating parameters, and potential for upsets
b. Corrosion control studies or other metallurgical analysis
c. Consultation with metallurgist, corrosion engineer, or materials specialist
d. Equipment manufacturer operating manuals, maintenance manuals, and reference materials
e. Organizations, consortiums, and other knowledge sharing forums
f. Equipment inspection, maintenance, and repair history
g. Equipment operating in similar service
h. Use of a damage mechanism screening tool such as ASME PCC-3 ‘Inspection Planning Using Risk-Based Methods’ Attachment B

i. Use of damage mechanism references such as API-571 Damage Mechanisms Affecting Fixed Equipment in the Refining Industry
j. Failure Modes and Effects Analysis (FMEA)
k. Failure Mode, Effects, and Criticality Analysis (FMECA)
l. Potential for Corrosion Under Insulation

F.1.11 Equipment, components, or parts that cannot be inspected or tested due to limitations in access, mode of failure, or available examination techniques should be evaluated to determine level of risk associated with the failure mode in accordance with IVL EHS-208 Risk Management Standard and Matrix and appropriate action taken to ensure an acceptable risk level is achieved.

F.2 Inspection Plans

F.2.1 Inspection plans may be utilized for other types of equipment in addition to those specified

F.2.2 A fixed replacement schedule for a relief device or piping component is an acceptable alternative to the inspection plan required by this section

F.2.3 An alternative to the WSE/IP approach may be used provided the alternative approach is not in violation of any regulatory or corporate policy requirements

F.2.4 The WSE/IP should be in accordance with the key principles of the appropriate national codes, manufacturer's recommendations, or other recognized and generally accepted good engineering practice (RAGAGEP) for the equipment type. Refer to Attachment C for guidance on potentially applicable RAGAGEP.

F.2.5 Risk-based inspection methodologies may be used to complement the requirements of this standard. Refer to the Risk-based Inspection Practices listed in Attachment C and the guidance in Attachment E.

F.2.6 Covered surfaces that are susceptible to Corrosion Under Insulation (CUI) should be incorporated into the WSE/IP for the equipment or piping system. Refer to IVL EHSG-1415B Guidance on the Detection and Management of CUI for guidance.

F.2.7 The WSE/IP may include non-mandatory supplemental tasks or activities at the discretion of the Responsible Person. The WSE/IP should designate which tasks or activities are supplemental. Any tasks or activities that are not so designated should be considered mandatory components of the IP.

F.2.8 Supplemental activities or tasks (either one-time or recurrent) may be included in the inspection plan or inspection work package to be performed coincident to the IP. Supplemental activities or tasks are not necessarily related to the on-going mechanical integrity.

F.2.9 Changes to the WSE/IP to add tasks or activities should be performed by or under the direct supervision of the Responsible Person responsible for the equipment type.

F.2.10 The changes, and reason for the change, should be documented in the IP, approved in writing by the Responsible Person and should be communicated to the site management team members.

F.2.11 The addition of tasks or activities to the WSE/IP generally does not increase the process safety risk to the equipment; however, changes to the WSE/IP should be communicated to avoid misunderstanding.

F.2.12 The elimination or reduction of activities should be based on an evaluation to demonstrate that overall effectiveness of the WSE/IP will not be adversely impacted by the planned elimination or reduction.

F.2.13 Changes to an inspection plan governed by an external authorized inspector should be communicated in accordance with IVL EHS – 204 Management of Change standard.

F.3 Inspection and Maintenance Intervals

F.3.1 The interval between inspections (periodicity between examinations) should ensure that sufficient inspections or examinations are carried out to identify at an early stage any deterioration or malfunction which is likely to affect the safe operation of the system. Different parts of the system may be examined at different intervals, depending on the degree of risk associated with each part.

F.3.2 A general criterion is that inspection or examination intervals should not exceed one-half the calculated remaining life.

F.3.3 The interval between planned maintenance activities should be determined based on measured or estimated wear rates, known or potential deterioration or damage mechanisms, generally accepted industry practice, or manufacturers recommendations. Different parts of the system may be examined at different intervals, depending on the degree of risk associated with each part.

F.3.4 Risk-based inspection (RBI) programs that meet the requirements of the relevant inspection code, national standard, or applicable local regulation and allow for extended maximum intervals may be employed.

F.3.5 Changes to execute the planned inspection or maintenance tasks and activities earlier than required should be performed by or under the direct supervision of the Responsible Person responsible for the equipment type.

F.3.6 The changes to the inspection interval, and reason for the change, should be documented in the IP, approved in writing by the Responsible Person and the sites maintenance, engineering, and/or production management should agree.

F.3.7 The reduction of the WSE/IP interval generally does not increase the process safety risk to the equipment; however, changes to the WSE/IP interval should be communicated to avoid misunderstanding.

F.3.8 Changes to an inspection interval governed by an external authorized inspector should be communicated in accordance with the IVL EHS – 204 Management of Change standard.

F.4 Remaining Life Calculations

F.4.1 Remaining life calculations should be determined for all equipment covered by the requirements of this standard as necessary to establish or revise inspection or planned maintenance intervals.

F.4.2 Remaining life calculations for pressure vessels, heat exchangers, storage tanks, and piping should conform to the methods listed in the relevant national or international regulations, inspection codes, industry standards, or practices for the category of equipment.

F.4.3 Remaining life calculations for pressure vessels, heat exchangers, storage tanks, and piping should be recorded in the equipment record.

F.4.4 Remaining life calculations for all other categories of equipment should be determined using available equipment specific information and engineering analysis or judgment.

F.5 Maintenance or Inspection Plan Execution

F.5.1 The results of routine periodic visual surveillance associated with an event triggered maintenance strategy do not require documentation of the occurrence unless follow-up action is required.

F.5.2 The maintenance or inspection plan should be reviewed upon completion of tasks or activities to determine if revisions are needed to:

a. The current tasks or activities
b. The addition of new tasks or activities
c. The frequency of the tasks or activities
d. The specific types of measurements, observations, or examination techniques
e. The locations of the measurements

## Attachment G: Leak Repair Devices

G.1 Leak repair devices (LRD) are engineered enclosures installed to stop an active leak or prevent a potential leak.

**CAUTION**: Leak sealing involves working on a live system that is in a deficient state and working on or disturbing the affected area could lead to further deterioration or failure during installation.

G.1.1 This type of repair is not a substitute for a permanent repair.

**Note:** Mechanical clamps and engineered composite repair systems are examples of leak repair devices

**Note:** Refer to Clause 4.16.9 for specific requirements.

G.1.2 This guideline excludes any leak repair devices that require welding to in-service equipment, piping, or components.

G.2 The use of an LRD should be limited to situations where shutdown of the equipment is not practical.

G.3 A full evaluation of the area where the LRD will be installed shall be performed.

G.3.1 The evaluation should assess the extent of deterioration including confirmation of the damage mechanism(s), extent of the affected area, effective wall loss, and any geometric anomalies (out of roundness, bulging, dents) that could affect the integrity of the installed LRD.

G.3.2 The evaluation should specifically address safety measures and precautions for equipment, piping, or component that are leaking, or may leak, during the installation process.

G.4 Refer to ASME PCC-2 Articles 3.6 and 4.1 for best practices guidance on risk assessment, design, materials of construction, fabrication, and inspection/examination requirements.

G.4.1 The LRD design and installation should comply with any applicable local, national, or regional regulatory requirements.

G.5 LRDs shall be engineered by a competent person.

G.5.1 The LRD shall be designed with sufficient strength for the operating conditions (temperature, pressure, vibration, live loads, dead loads) and any loads that may occur during installation.

**Note:** The forces generated during the sealant injection can be significant. Note that the rate of sealant injection can have a significant effect on the pressure/force generated.

G.5.2 The weight of the LRD may impose dead loads on the piping system such that additional supports are required.

G.5.3 Any loss of structural capacity of the equipment, piping or components resulting from the deterioration should be mitigated with additional external structural supports or bracing or incorporated into the LRD design.

G.5.4 Where NDE methods are unable to detect the condition of the underlying equipment, piping, or components after the LRD is installed, the design should assume a full loss of structural capacity.

G.5.5 All sealing compounds and elastomeric materials shall be compatible with the process fluid.

G.5.6 All metallic components shall be compatible with the process fluid.

G.5.7 LRDs should not be insulated (to eliminate the potential for CUI) unless necessary to ensure process stability, product quality, or to meet personnel protection requirements.

G.5.7.1 Where insulation is required, it should be designed such that it can be readily removed and replaced to facilitate LRD inspections.

G.6 Documentation for each LRD installed shall include:

- Management of Change (MOC) documentation and approval
- Date of installation
- Unique identifier (serial number or tag number)
- Location (physical location and orientation within the process flow)
- Process service, operating temperature and pressure
- Size, material, and rating for the equipment
- Thickness measurements of the component in the area adjacent to the LRD
- Materials of construction for the LRD
- Sealant type and its curing temperature range, if applicable
- Rated pressure and temperature for the LRD
- Design code applicable to repaired component, and design calculations for custom designs
- Manufacturer

Positive Materials Identification

G.7 These requirements intend to ensure that the materials used for EHS critical equipment are verified to be correct prior to installation.

G.8 If the use of an alloy for an item is optional or discretionary, then it should be sufficient to document this in the equipment record for auditing purposes and forgo the PMI testing.

G.9 Vendor provided material certifications shall be provided or Positive Materials Identification (PMI) testing shall be performed using one of the following methods:

a. portable X-ray fluorescence (when carbon content measurement is not required)
b. portable optical emission spectroscopy (when carbon content measurement is required)
c. laboratory chemical analysis
d. portable Fourier-transform infrared spectroscopy, for non-metallics

G.10 A materials verification process shall be established in accordance with any applicable RAGAGEP such as the following references:

a. EEMUA Pub No. 149: Code of Practice for the Identification and Checking of Materials of Construction in Pressure Systems in Process Plants
b. PIP VESPMI01 Positive Material Specification
c. API RP 578 Material Verification Program for New and Existing Alloy Piping Systems