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**Petroleum and natural gas industry —  
Pipeline transportation systems  
— Pipeline integrity assessment  
specification**

*Industries du pétrole et du gaz naturel — Systèmes de transport par  
conduites — Spécification d'évaluation de l'intégrité des conduites*

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## Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see [www.iso.org/directives](http://www.iso.org/directives)).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see [www.iso.org/patents](http://www.iso.org/patents)).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see [www.iso.org/iso/foreword.html](http://www.iso.org/iso/foreword.html).

This document was prepared by Technical Committee ISO/TC 67, *Oil and gas industries including lower carbon energy*, Subcommittee SC 2, *Pipeline transportation systems*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at [www.iso.org/members.html](http://www.iso.org/members.html).

# Petroleum and natural gas industry — Pipeline transportation systems — Pipeline integrity assessment specification

## 1 Scope

This document specifies requirements and gives recommendations on the integrity assessment of pipelines of various applications as part of pipeline systems.

This document is mainly applicable to onshore pipeline systems, connecting wells, production plants, process plants, refineries and storage facilities, including any section of a pipeline constructed within the boundaries of such facilities for connection purpose, according to ISO 19345-1. The principles can also be used for offshore pipelines where applicable and practical.

This document applies to rigid, steel pipelines. It is not applicable for flexible pipelines or those constructed from other materials, such as glass-reinforced plastics.

This document does not cover all conditions which might be related to pipeline integrity. A competent pipeline integrity engineer can evaluate whether additional requirements are necessary.

This document does not cover the assessment of pipeline defect(s) found during fabrication/construction or installation, which would need to be done in accordance with the applicable standards of design, construction, material procurement and welding process applicable at that time. However, this document can be applied to the ongoing monitoring and assessment of known flaws from the time of construction.

## 2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 19345-1:2019, *Petroleum and natural gas industry — Pipeline transportation systems — Pipeline integrity management specification — Part 1: Full-life cycle integrity management for onshore pipeline*

## 3 Terms, definitions and abbreviated terms

### 3.1 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at <https://www.iso.org/obp>

— IEC Electropedia: available at <https://www.electropedia.org/>

#### 3.1.1

##### **alternating current attenuation survey**

##### **ACAS**

method of measuring the current attenuation along the pipeline to assess general quality of the coating by applying the electromagnetic field propagation theory

**3.1.2**

**comprehensive assessment**

evaluation using two or more separate integrity data sets

**3.1.3**

**corrosion**

deterioration of a material, usually a metal that results from an electrochemical reaction with its environment

[SOURCE: ISO 19345-1:2019, 3.1.5]

**3.1.4**

**crack**

planar flaw, or linear discontinuity, with a sharp tip radius

[SOURCE: ISO 19345-1:2019, 3.1.6]

**3.1.5**

**data transferability**

use of data from similar pipelines (in terms of geometry, material, service, environment) to supplement or replace data that cannot be obtained, or are difficult to obtain, on the pipeline being evaluated

**3.1.6**

**deformation**

change in shape of the pipe or component, such as a bend, buckle, dent, ovality, ripple, wrinkle, or any other change that affects the roundness of the pipe or original cross-section or straightness of the pipe or component

[SOURCE: ISO 19345-1:2019, 3.1.9]

**3.1.7**

**defect**

imperfection of a type or magnitude exceeding acceptable criteria

[SOURCE: ISO 19345-1:2019, 3.1.10]

**3.1.8**

**degradation modelling**

models to evaluate degradation of materials

**3.1.9**

**dent**

depression which produces a disturbance in the curvature of the pipe wall, caused by contact with a foreign body resulting in plastic deformation of the pipe wall

[SOURCE: ISO 19345-1:2019, 3.1.11]

**3.1.10**

**direct inspection**

methodology used to detect and characterize pipeline defects and condition at a specific location

**3.1.11**

**failure**

event in which a component or system does not perform according to its operational requirements

[SOURCE: ISO 19345-1:2019, 3.1.14]

**3.1.12****fitness for purpose****FFP**

quantitative engineering evaluation that is performed to demonstrate the structural integrity of an in-service component that can contain an imperfection, defect or damage

[SOURCE: ISO 19345-1:2019, 3.1.15]

**3.1.13****gouge**

surface damage to a pipeline caused by contact with a foreign object that has scraped (gouged) material out of the pipe, resulting in a metal loss defect or imperfection

[SOURCE: ISO 19345-1:2019, 3.1.16]

**3.1.14****in-line inspection****ILI**

inspection of a pipe wall from the interior of the pipe using specialized tools

[SOURCE: ISO 19345-1:2019, 3.1.19]

**3.1.15****integrity assessment**

process that includes the inspection and testing of a pipeline in order to determine physical characteristics and assess its integrity condition by combination of an analysis of data, use of reliability assessment methodologies of the structure and an evaluation of the safety state of the pipeline

[SOURCE: ISO 19345-1:2019, 3.1.20]

**3.1.16****magnetic flux leakage****MFL**

type of in-line inspection technology in which a magnetic field is induced in the pipe wall between two poles of a magnet

Note 1 to entry: Anomalies affect the distribution of the magnetic flux in the pipe wall. The magnetic flux leakage pattern is used to detect and characterize anomalies.

[SOURCE: ISO 19345-1:2019, 3.1.24]

**3.1.17****maximum allowable operating pressure****MAOP**

maximum internal pressure at which a pipeline system, or parts thereof, is allowed to be operated

Note 1 to entry: The MAOP is established by the maximum pressure achieved during testing (see ISO 13623).

[SOURCE: ISO 19345-1:2019, 3.1.27]

**3.1.18****metal loss**

pipe wall anomaly in which metal has been removed

Note 1 to entry: Metal loss is usually the result of corrosion, but gouging, manufacturing defects, erosion, or mechanical damage can also result in metal loss.

[SOURCE: ISO 19345-1:2019, 3.1.28]

**3.1.19**  
**non-destructive testing**  
**NDT**

analysis techniques used to evaluate the properties of a material, component or system without causing damage

Note 1 to entry: “Non-destructive inspection” (NDI) and “non-destructive evaluation” (NDE) are also commonly used to describe this technology.

[SOURCE: ISO 19345-1:2019, 3.1.29]

**3.1.20**  
**pressure test**

means of assessing the integrity of a new or existing pipeline that involves filling the pipeline with water, dry air or nitrogen, and pressurizing to a level reasonably in excess of the MAOP of the pipeline to demonstrate that the pipeline is fit for operating condition

[SOURCE: ISO 19345-1:2019, 3.1.34, modified — “dry air or nitrogen” “reasonably” added, “for a given time frame dependent on the identified integrity hazards” deleted and “service at the MAOP” replaced by “operating condition”; Note to entry deleted.]

**3.1.21**  
**sizing accuracy**

accuracy with which an anomaly dimension or characteristic is reported

Note 1 to entry: Typically, accuracy is expressed by tolerance and certainty.

EXAMPLE Depth sizing accuracy for metal loss using NDT methods, such as an ILI tool, is commonly expressed as +/-10 % of the wall thickness (the tolerance) and 80 % of the time (the certainty).

[SOURCE: ISO 19345-1:2019, 3.1.40]

**3.1.22**  
**stress corrosion cracking**  
**SCC**

cracking of a material produced by the combined action of corrosion and sustained tensile stress

**3.2 Abbreviated terms**

AC/DC	alternating current/direct current
ACVG	alternating current voltage gradient
CIPS	close interval potential survey
DCVG	direct current voltage gradient
EMAT	electromagnetic acoustic transducer
FFP	fitness for purpose
IMP	integrity management program
IMU	inertial measurement unit
LSM	large standoff magnetometry
POD	probability of detection
POI	probability of identification

SCT	stress concentration tomography
TEM	transient electromagnetic method
TFI	transverse flux inspection
USCD	ultrasonic crack detection
USCCD	ultrasonic circumferential crack detection
UT	ultrasonic compression wave tool

## 4 General

### 4.1 Key principles

Pipeline operators shall assess the integrity condition and safety state of their operated pipelines by using a suite of inspection, monitoring and evaluation techniques/methodologies. Local laws and regulations can apply for the integrity assessment. New technologies should be encouraged for application, when they are proved to be effective, safe and to follow industry practices. The key principles for integrity assessment are listed below.

- a) Threats and degradation modes shall be identified accurately for the integrity assessment.
- b) Relevant data shall be collected, as it constitutes the fundamental basis for a sound integrity assessment. Data sets shall be used to determine the defect types and failure mechanisms of the pipeline and to provide a basis for the selection of the most appropriate assessment methods. The pipeline assessment method shall be selected in accordance with the damage mechanisms, type, dimensions, distribution, expected activity and progression rates of defects affecting the pipeline and the purpose of the assessment.
- c) One or more assessment methods shall be selected based on data collected from ILI, direct inspection, pressure test or others. When ILI is applicable, it shall be selected as a priority.
- d) Historical records of past failures and executed repairs shall be considered for assessment method selection.
- e) The interval of pipeline integrity assessment shall be determined by previous assessment result. If leaks or ruptures occur in between integrity assessments, then, the interval shall be immediately re-evaluated based on the results of failure analysis (e.g. cause and contributing factors).
- f) Knowledge and ability related to integrity assessment shall be possessed by the practitioners.
- g) Relevant requirements of ISO 19345-1:2019 shall be applied, and other international practice standards should be considered as technical support.

### 4.2 Pipeline integrity assessment process

**4.2.1** The pipeline integrity assessment process shall be continuously improved. Experience obtained from each assessment assists in determining the most appropriate method for subsequent assessments.

**4.2.2** The pipeline integrity assessment process should follow the sequence shown in [Figure 1](#), including:

- a) data collection and analytics;
- b) pipeline condition inspection and monitoring;
- c) hazard identification;

- d) FFP assessment;
- e) assessment report.

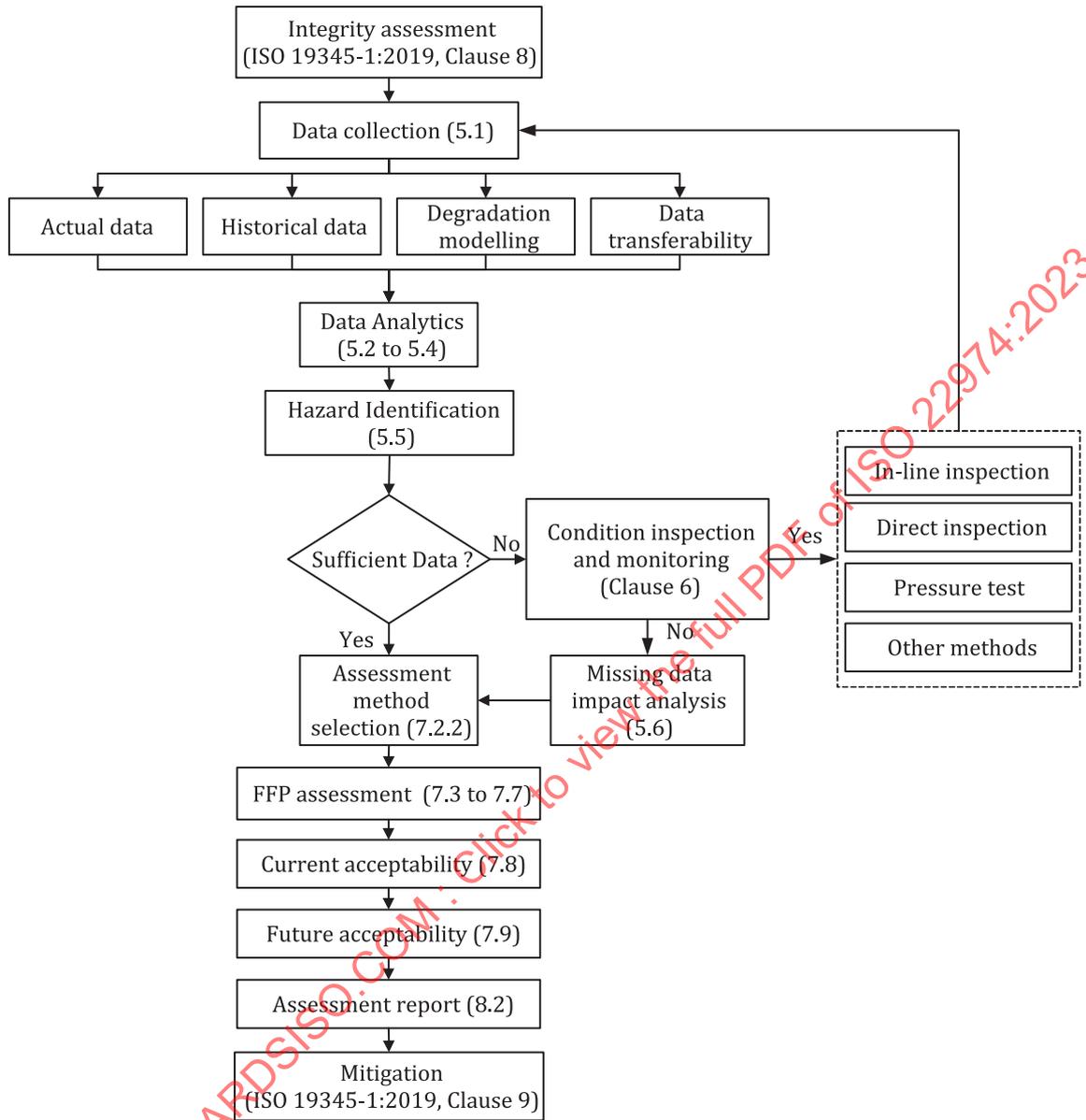


Figure 1 — Recommended pipeline integrity assessment process

4.2.3 The assessment of the remaining pipeline strength and remaining life affected by the presence and type of defects is the core of integrity assessment, and shall be carried out by considering factors related to service history and external environment.

4.2.4 Comprehensive assessment should be carried out given multiple data generated from different sources, such as various inspection methods or time periods.

## 5 Data collection and analytics

### 5.1 Data collection

**5.1.1** The scope of data collection should be determined according to the pipeline properties, potential damage mechanism, assessment methodologies, etc. to evaluate threats, or potential threats, and damage mechanism(s) for the pipeline. Relevant data and information can be collected along the entire pipeline life cycle such as design, construction, operation and maintenance phases. When the pipeline data is deemed insufficient for the integrity assessment, other relevant data such as failure analysis and integrity assessment reports of pipelines with similar operating conditions should also be collected as reference. When data transferability is used to determine the FFP of a pipeline, the assessor should apply conservative factors or allowances to recognize the added uncertainty.

For example, the pipeline whose material properties cannot be obtained can refer to the test results of pipelines with similar construction years, same steel grade, same manufacturing processes, same pipe manufacturer, same quality control applied during construction and any other relevant information.

**5.1.2** The data used for pipeline integrity assessment should include:

- a) Pipeline attributes: steel grade, diameter, wall thickness, weld type, fluid type, coating type and cathodic protection, accessory infrastructures, burial conditions.
- b) Mechanical properties, such as tensile properties, engineering stress/strain curve, fracture toughness.
- c) Inspection reports and data, such as ILI, NDT, direct inspection and SCT.
- d) Design and operating parameters, such as fluid composition, maximum allowable operating pressure, maximum/minimum operating temperature.
- e) Construction data, such as welding records, pressure testing, welding procedure specifications, NDT results.
- f) Historical data, such as in-service pressure testing, excavation verification, repair, failure(s) and maintenance data.
- g) Load data, such as service load, environmental load, construction load or other additional load.
- h) Degradation modelling, such as corrosion growth model, fatigue model, crack extension model, SCC model.
- i) Environmental conditions, such as corrosiveness of the environment, crossing of railways, highways and rivers and as well as geotechnical and geographical information.
- j) Transferable data from similar pipelines.
- k) Other data, such as regional grades, critical consequence areas, risk assessment results.

### 5.2 Data quality

The quality of data available should be determined, including the allowance for varying data quality over historical events, and identify a confidence level that can be applied to the resulting assessment. It should be determined whether the data quality is sufficient to enable an FFP assessment to be completed to the required certainty according to the criticality of the system, which should conform to the dimensions outlined below, as applicable:

- a) Accuracy: Data accuracy should be examined by analysis and verified between different data sources.
- b) Completeness: It should be checked that all needed data is available.

- c) Consistency: The data should be free of internal contradictions.
- d) Precision: The data should be exact as required.
- e) Granularity: The data should be kept and presented at the right level of detail to meet the requirements of FFP assessment.
- f) Timeliness: The data should be as current as needed and should be retained no longer than required.

### 5.3 Data alignment

5.3.1 Data from different sources shall be aligned based on the data with higher accuracy.

5.3.2 The data alignment content shall be determined in accordance with the pipeline attributes and damage mechanism. For example, for external corrosion, the ILI data can be aligned with the pipeline attributes, coating, cathodic protection, stray current interference, soil corrosiveness, direct inspection and other relevant data. For internal corrosion, it can be compared with the data of pipeline elevation, including ILI data, data of pipeline evaluation by other methods, medium composition, flow, temperature, pigging products, etc.

5.3.3 For alignment of two or more ILI data sets, girth welds should be aligned prior to assessing the defects or features of interest. Inspection accuracy and defect growth should be subsequently analysed.

5.3.4 When data of ILI and other different inspection methods are available, other data should be aligned with the ILI data. If ILI has not been carried out, it should be carried out first. If the pipeline is unpiggable, other inspection method such as direct inspection at selected critical area should be adopted. The data should be then aligned to the ground mapping data.

### 5.4 Data analysis

5.4.1 A comprehensive analysis of the aligned data should be carried out to determine the cause of defect(s) and arresting mitigating measures.

5.4.2 A defect statistical assessment should be performed to determine the severity, distribution, and the relationship between different types of defects. The cause and initiation of the defect(s) should be determined.

5.4.3 The cause and rate of defect growth should be analysed using multiple sources of data when possible. If necessary, excavation can be used to verify the causes of actively growing defect(s).

### 5.5 Hazard identification

5.5.1 Hazards shall be analysed using integrated data from various sources.

5.5.2 Hazards should be delineated into time-related, time-independent and inherent factors categories as follows:

- a) Time-related hazards, including external corrosion, internal corrosion, SCC/hydrogen-induced cracking, fatigue damage, etc.
- b) Time-independent factors, including mechanical damage (dents, gouges), pipe deformation caused by soil movement or floods, etc.
- c) Inherent factors, including seam welds, mill defects, girth weld defects, buckles or wrinkles, etc.

Hazards shall be identified based on failure analysis and previous integrity assessment. It is also advisable to identify hazards from failure accidents and integrity assessment of pipelines with similar background.

## 5.6 Data sufficiency

**5.6.1** The sufficiency of data should be evaluated based on data quality, defect(s) cause analysis, assessment methods, maintenance requirements, etc.

**5.6.2** The impact on the assessment results due to data sufficiency should be determined. Data sufficiency is defined as:

- a) Identification of the degradation mechanism(s) are confirmed by appropriate inspection and supporting data;
- b) Inspection, testing or monitoring data that meets the reliability requirements of the assessment results;
- c) Mechanical properties data of pipe body or weld that are required for the FFP assessment;
- d) Loading data that are required for the FFP assessment;
- e) For time-related defects, the applicable defect growth rate can be obtained through multiple inspections, monitoring data, defect growth modelling or simulation test. Otherwise, the growth rate should be selected conservatively.

**5.6.3** Additional data collected as per [Clause 6](#) shall be re-analysed in accordance with [5.2](#).

**5.6.4** The additional data shall be integrated with the original data in accordance with [5.3](#), and the hazard identification and cause analysis shall be updated.

## 6 Condition inspection and monitoring

### 6.1 Data collection method

Data collection method includes ILI, direct inspection, pressure test, SCT monitoring, excavation verification, failure analysis, material sampling test and informative data collection, etc. and should be selected based on the type and accuracy of data required for the assessment.

### 6.2 In-Line inspection

**6.2.1** Selection of proper ILI technology should be based on the threat and expected defects, risk assessment and inspection history of the pipeline. For pipelines with multiple inspections, it is recommended to use the same type or selecting complementary ILI techniques as per [Figure 2](#). For more information on the ILI methods available, see ISO 19345-1:2019, Table 2.

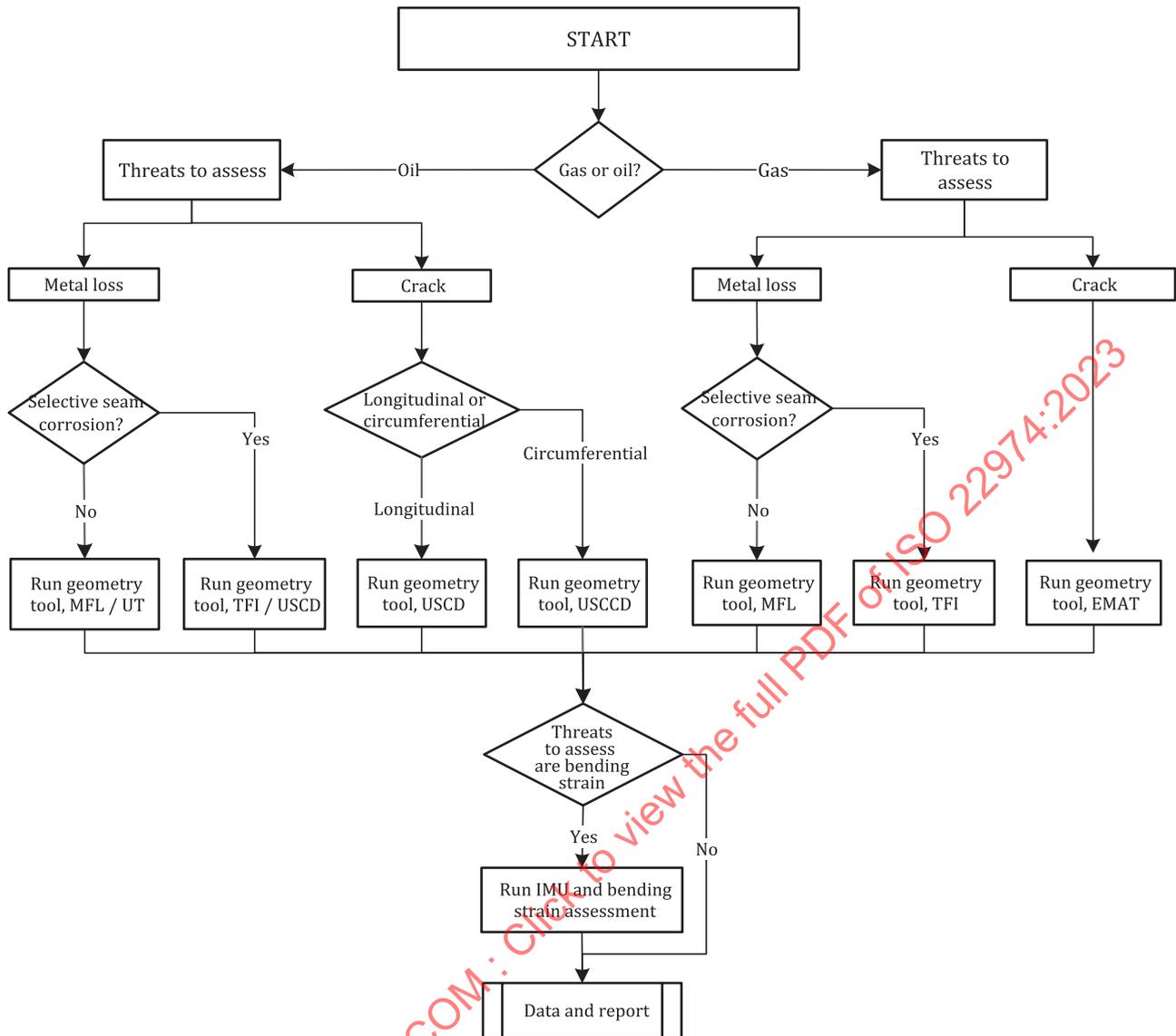


Figure 2 — A general ILI tool selecting procedure diagram

- a) For metal loss threats, MFL and UT provide good detection of volumetric defects while TFI should be deployed in addition to MFL when it is suspected that axially aligned metal-loss defects present.
- b) For crack threats (including crack and crack-like features in the pipe body, seam welds and, girth welds), USCD can be used to detect longitudinal features, USCCD is able to detect circumferentially aligned cracks or crack-like features. EMAT is a special solution for crack inspection in gas lines. TFI is able to detect some axially aligned cracks, but excluding SCC.
- c) Deformation or geometry tools are often used for detecting damage in the pipeline involving deformation of the pipe cross section.
- d) IMU can be adopted to identify segments subject to bending strain and location of defects in conjunction with other ILI data sets, such as metal loss or crack inspection.

6.2.2 When inspection data has been obtained, performance specifications such as inspection threshold, POD, POI and sizing accuracy should be verified statistically considering the ILI tool tolerance, errors in dig verification measurement method and confidence level.

**6.2.3** The ILI performance should be verified based on historical data, pull tests or dig verification. The subsequent FFP assessment shall be executed only after the inspection data are verified to be acceptable.

**6.2.4** The most recent ILI data should be used when executing an assessment based on ILI. Corrosion growth rate assessments can be performed based on two (or more) ILI datasets. Dig verification should be performed to determine if the growth rate of time-dependent defects is consistent with previous prediction.

### **6.3 Direct inspection**

**6.3.1** Direct inspection should include methods for external corrosion, internal corrosion, SCC, stress concentration inspection, and could include methods as described in [6.5](#) and [6.6](#), as per [Figure 3](#). The flow chart outlined in [Figure 3](#) can be used for degradation mechanisms that are predictable and not explicitly outlined herein.

**6.3.2** Direct inspection should be confirmed to be feasible before conducting a survey. The following conditions are not suitable for direct inspection:

- a) External corrosion direct inspection should not be conducted on pipelines under electric shielding caused by coating disbonding or with underground metal structures nearby,
- b) Internal corrosion direct inspection should not be conducted on pipelines with internal coating or lining.

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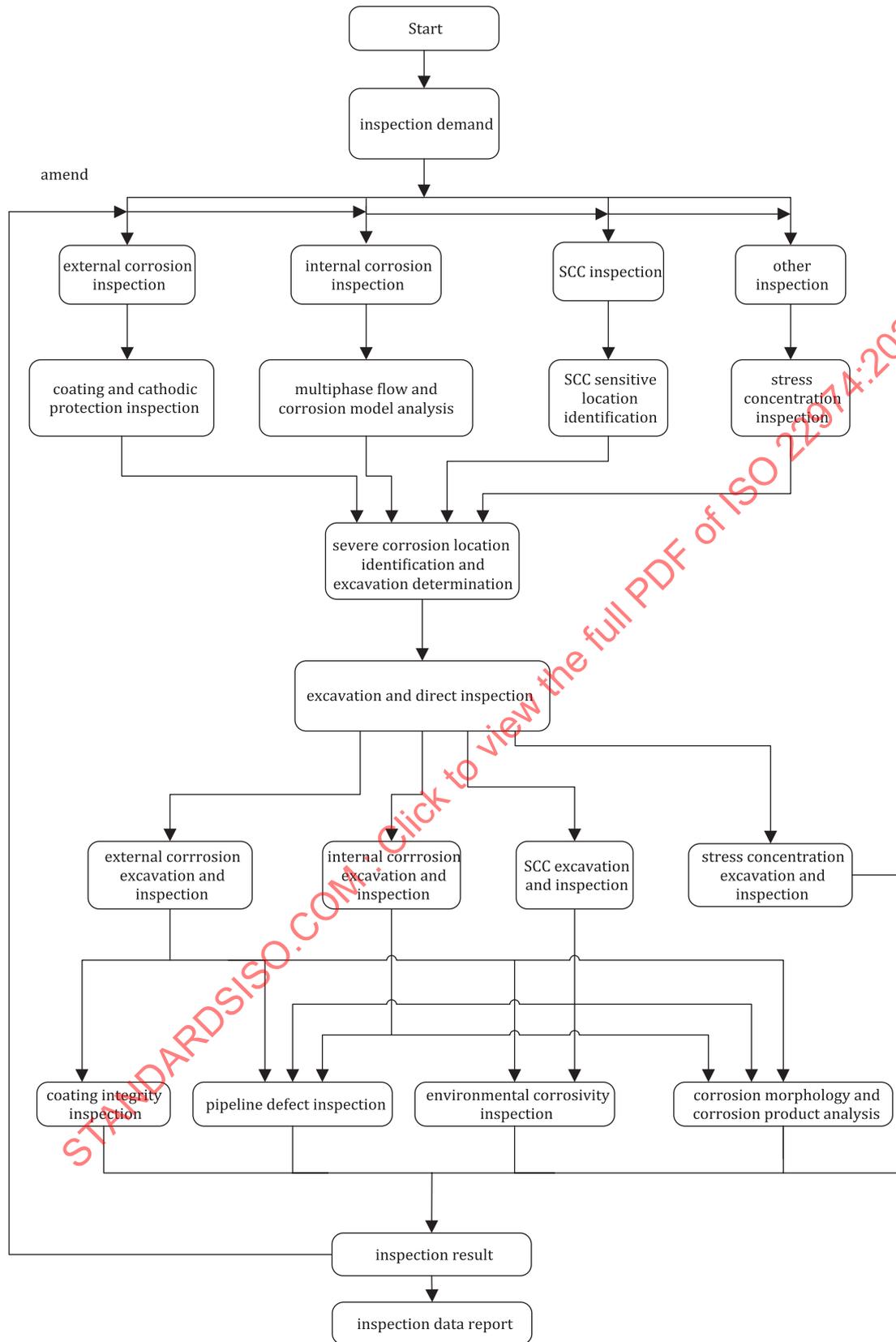


Figure 3 — Direct inspection flow chart

**6.3.3** External corrosion direct inspection should be carried out through the inspection of coating/insulation, cathodic protection of pipelines, AC/DC interference and current drainage and pipeline defects.

- a) For pipelines with external coating, inspection for the effectiveness of cathodic protection, coating integrity, analysis of the soil corrosiveness, etc. should be included.
- b) For pipelines without external coating or with poor quality coating, an inspection for the presence of corrosion should be conducted.
- c) The coating/insulation inspection should be carried out through aboveground inspection methods such as Pearson survey, ACVG, DCVG, ACAS, coating resistivity measurement, and some direct examination methods for coating thickness, adhesion and degradation measurement at the excavation site.
- d) The effectiveness of cathodic protection should be inspected by aboveground inspection methods such as CIPS along the pipeline, coupon instant-off potential survey, and on/off potential survey.
- e) The AC/DC interference data of pipelines should be obtained by monitoring/detecting the interference current, interference voltage, corrosion rate and other related parameters of the pipeline or at the area with severe interference.

**6.3.4** Internal corrosion direct inspection should be conducted by establishing the flow or/and corrosion models to predict the corrosion risk and examination at the site excavation.

- a) The models should be established by primarily considering the transferred fluid, topography and flow rates.
- b) The flow and corrosion models should consider the historical operation of the pipeline.
- c) During internal corrosion direct inspection, the prediction of the distribution of internal corrosion risk location and the high-risk internal corrosion sites should be determined.

**6.3.5** Identification and inspection of susceptible sections of external SCC on pipelines at excavation sites should be carried out for SCC direct inspection. Historical data and above ground inspection methods can be used. The location where SCC has occurred or with the same SCC characteristics as similar pipelines should be of priority.

**6.3.6** Stress concentration inspection can be used to identify pipeline damage by aboveground and non-intrusive method, which include LSM, SCT and the TEM.

**6.3.7** Excavation sites should be proposed for the external corrosion, internal corrosion, and SCC inspection verification. The type and size of the defect(s) can be obtained through appropriate inspection methods (e.g. ultrasonic guided wave, ultrasonic thickness measurement or X-ray, etc.)

## **6.4 Pressure test**

**6.4.1** A pressure test is the process of proving the structural integrity of the pipeline for a given test pressure.

**6.4.2** The test pressure and duration should be determined by the potential threats on the pipeline, the highest pressure in historical operation, the altitude difference of the pipeline, and the surrounding environment of the pipeline.

**6.4.3** A pressure test should be conducted with water, however, dry air or nitrogen can also be used as the test medium, if the pipeline has been evaluated and safety measures have been implemented. Air pressure tests should not be used in high-density of population areas and oil pressure test should not be used for pipelines crossing important water bodies and environmentally sensitive areas. When

liquid is used as the pressure test medium, the air content in the pipeline should be tightly controlled, and the pressure-volume curve should be used for judgment and control.

**6.4.4** When carrying out a pressure test with transmission medium, the test pressure should not exceed the highest operating pressure in the past three years. For pipelines that have leaked and been repaired, a step-by-step method should be used where the maximum test pressure for the first step of testing should not exceed 0,8 times the operating pressure at the time of pipeline leak.

**6.4.5** The pipeline integrity should be pre-estimated according to the surrounding environment, transmission medium, operating pressure, previous operation status and failure and repair records of the pipeline. A preliminary pipeline integrity assessment can be made based on the pre-estimated results, and then the target method or step-by-step method pressure test scheme and other proven pressure test methods can be selected to formulate a detailed pressure test scheme.

**6.4.6** For pipelines with low leak risk, the target method pressure test scheme should be selected, and a certain target test pressure (maximum allowable operating pressure  $\times$  safety factor) should be set. Once the pipeline leaks or ruptures during the pressure test, the failure causes should be analyzed. After the repair, the test pressure should be reduced to the failure pressure or continue with the target test pressure, and the pressure test should be taken again until successful. The target method usually adopts the water medium for pressure test.

**6.4.7** For pipelines with high risk, a step-by-step method pressure test should be adopted. First, a conservative pressure should be determined for the first step pressure test according to the pipeline defect(s) repair, risk mitigation, FFP, and the historical operating pressure, and the target test pressure should also be set. Once the test pressure is successful, the next step test pressure should be continued with higher pressure until the target pressure is reached. If a failure occurs during pressure testing, the pressure test should be terminated and failure analysis and repairs should take place.

**6.4.8** The speed of pressure rise and the duration of pressure stabilization should be controlled, data such as the position and elevation of the pressure test terminal, type of medium, test pressure and ambient temperature change with time, stabilization time, position of the leakage point, leakage volume, the leakage time, leakage pressure shall be collected, and the leakage cause analysis shall be carried out.

**6.4.9** For pipelines that leak during the pressure test, an excavation shall be conducted to analyze the cause of the leakage and to clarify the hazard factors of the pipeline. Accuracy in determining the location of the leakage can be improved by segmenting the pressure test pipeline, injecting dye, odorant or tracer into the pressure test medium and utilizing acoustic monitoring equipment.

**6.4.10** The main steps of pressure test include identifying potential threats, integrity pre-estimation, pressure test methodology, pipeline filling and pigging, pressure rise, pressure stabilization, leakage cause analysis, repair, depressurization, displacement and disposal of water, pipeline drying and repeated pressure test in case of leakage. See the process in [Figure 4](#).

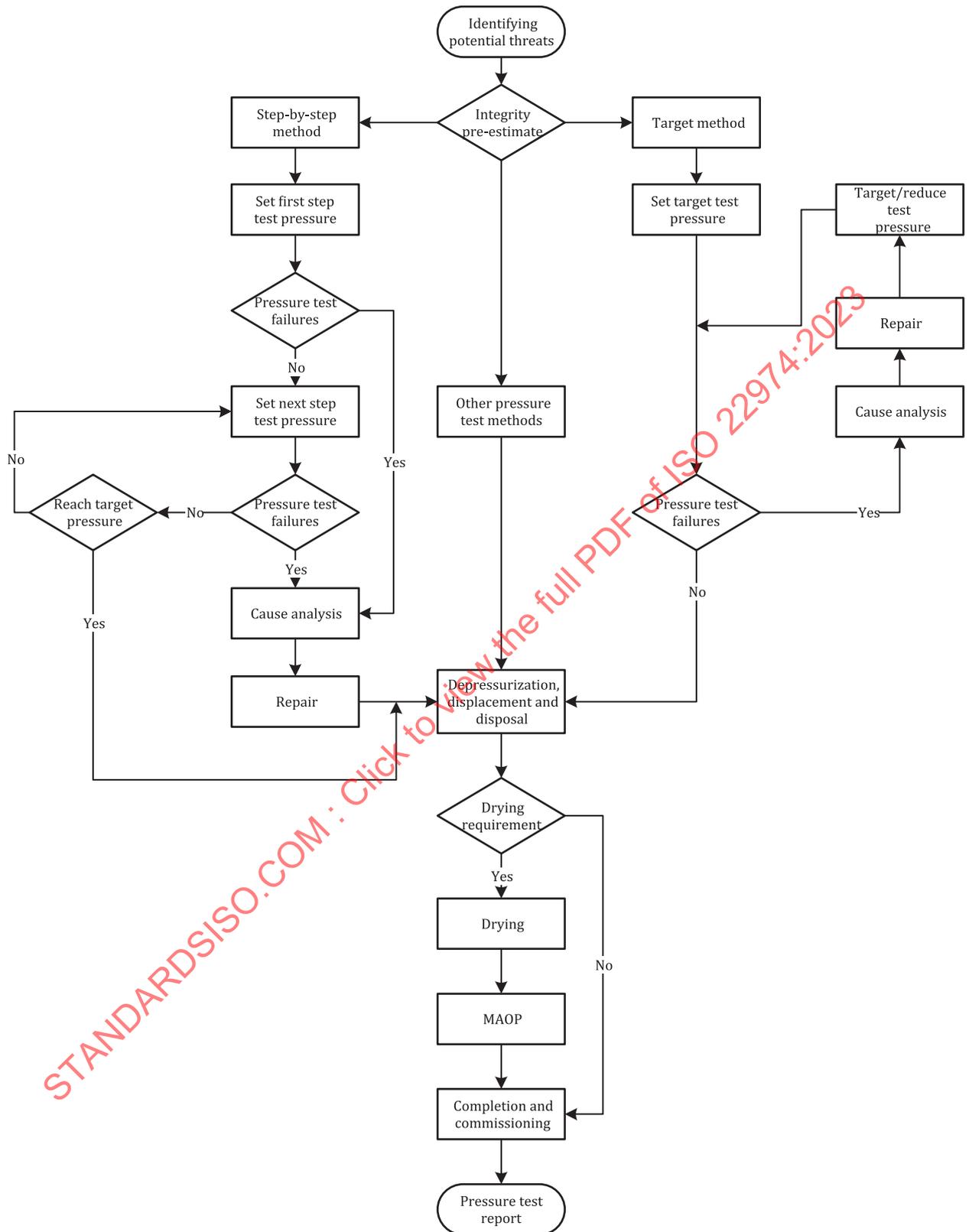


Figure 4 — Flow chart of pressure test

### 6.5 Material property testing

If the material properties are unknown or the assessment requires actual measured data, sampling or non-destructive/micro-destructive methods can also be used for testing.

## 6.6 Other new methods

With the development of technology, any method that can detect or monitor the performance parameters related to pipeline safety and integrity should be used as a data source for new integrity assessment.

## 7 Fitness for purpose

### 7.1 General

**7.1.1** The FFP assessment shall determine whether the pipeline has sufficient structural strength within the specified safety limits to withstand various loads encountered during operation. The types, severity, sizes and causes of reported pipeline defects should be investigated. The FFP assessment shall determine if the defect is acceptable under the MAOP and other loads applicable to the defect area. If the defect is not acceptable, the MAOP shall be re-determined or the defect repaired.

**7.1.2** The FFP assessment should include: damage mechanism, selection of assessment method, remaining strength assessment, remaining life prediction and re-inspection intervals, remedial measures and recommendations. The process of FFP assessment is illustrated in [Figure 5](#). Assessment methods shall be selected in accordance with the collected pipeline condition detection information.

**7.1.3** Safe operation and maintenance recommendations shall be given in the FFP assessment based on analysis of high critical areas, medium temperature, pressure change and soil stress.

**7.1.4** Generally, time effectiveness and reliability of the results should be given in the FFP assessment report.

**7.1.5** The users shall select the assessment method based on defect information, load condition, assessment objective, quality and type of the assessment data. Conservative data and assessment methods should be used to assess the acceptability of defects, and more precise (less conservative) methods should only be used when required.

**7.1.6** Re-assessment shall be carried out when the operating conditions of the pipeline changes.

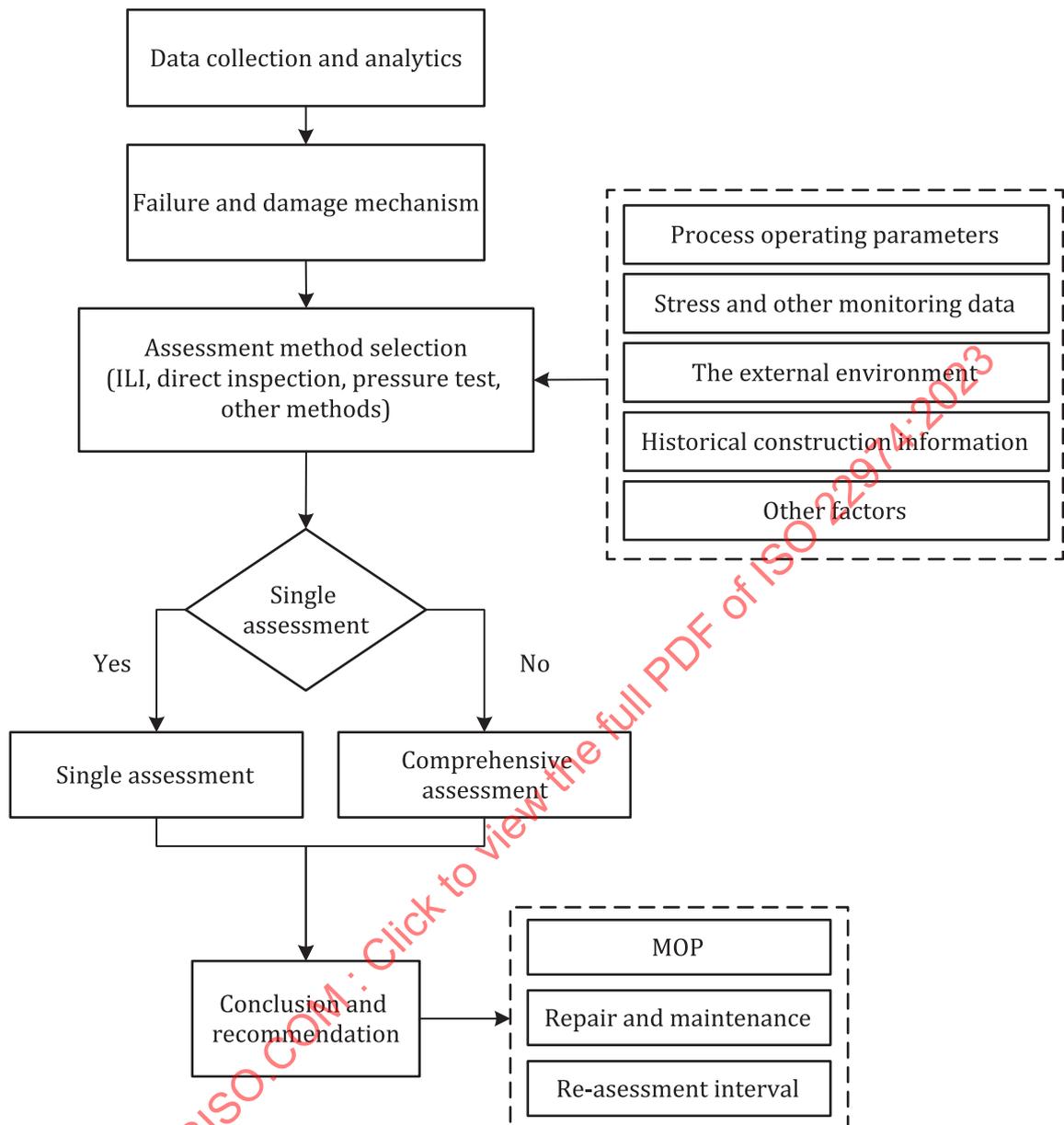


Figure 5 — FFP assessment process

## 7.2 Establishing acceptable FFP assessment

### 7.2.1 Failure and damage mechanism

- a) Failure or defect(s) cause analysis shall be carried out to determine the pipeline damage mechanism and assessment method.
- b) The following types of failure and damage mechanisms should be considered based on the available data. Each damage mechanism occurs under specific combinations of materials, surrounding environments, and operating conditions. The possible interaction between the various damage mechanisms should be considered.
  - 1) brittle and/or ductile fracture;
  - 2) plastic collapse;

- 3) fatigue damage;
- 4) leakage failure;
- 5) corrosion (internal and external) and/or erosion damage;
- 6) environmentally assisted cracking;
- 7) failure by instability (buckling);
- 8) mechanical damage (e.g. dent, etc.).

### 7.2.2 Assessment method selection

If only one type of data of ILI, pressure test or direct inspection is collected, integrity assessment based on ILI shall be selected in accordance with the ILI data as described in 7.3. Integrity assessment based on pressure test shall be carried out as described in 7.4 in accordance with the pressure test data. According to the direct inspection data, direct assessment of external corrosion, internal corrosion, stress corrosion or stress concentration shall be carried out as described in 7.5. New integrity assessment methods can be used given new inspection methods.

If multiple types of data are collected, such as ILI data and direct inspection data, comprehensive assessment shall be selected. If ILI data available, it shall be mainly considered for comprehensive assessment. The comprehensive assessment with pressure test can be directly used as the basis for operation pressure adjustment.

### 7.2.3 Acceptance criteria of FFP assessment

The potential damage mechanisms causing each type of defects should be assessed and possible defect growth by the degradation mechanism and/or loading conditions should be determined. The level of conservatism of an assessment depends on available data.

Acceptance criteria shall be determined in accordance with the pipeline design, defect type, surrounding environment and damage mechanism, etc., based on the risk.

## 7.3 FFP assessment based on in-line inspection

### 7.3.1 Defect data statistics and causation analysis

Causation analysis should be conducted on defect data from various inspections to identify the possible causes of any detects including the defect type, location on the pipe, distribution along the length of the pipe, coating type and external influences, such as topography, soil type, elevation profile and other relevant attributes identified from the inspection or similar assessment results. Such analysis where required should include but not be limited to:

- a) statistical analysis on overall defects;
- b) statistical analysis on specific defects;
- c) distribution statistics and causation analysis;
- d) statistical analysis of changes between two or multiple time periods.

### 7.3.2 Assessment method selection

- a) Appropriate defect assessment methods shall be selected in accordance with the type and characteristic of the pipeline defect(s), the type of load at the defect location and the properties of the pipeline. Assessment methods for types of defects can be determined according to ISO 19345-1:2019, Table 3 or according to standards of operating companies approved in accordance with the established procedure.

- b) The following factors shall be considered when selecting the defect assessment methods, including but not limited to:
- 1) Defect type and pipe properties;
  - 2) The type of load undertaken by the pipeline at the defect location;
  - 3) The applicable scope and limitations of the assessment method;
  - 4) Excavation verification information and historical failure analysis.
- c) Other considerations
- 1) Appropriate inspection tolerances should be added to the measured dimensions of a defect when assessing the static or fatigue strength of a defect.
  - 2) The validity of the inspection and integrity assessment shall be considered. The defect repair time limit shall be counted from the time when the on-site inspection is completed.
  - 3) The accuracy of the growth rate prediction for time-dependent defects should be corrected according to the excavation verification results, and the assessment report should be revised.

### 7.3.3 Assessment conclusions

The assessment conclusions shall include but not be limited to:

- a) list of defects to be repaired immediately;
- b) schedule of defects planned to be repaired;
- c) maximum allowable operating pressure;
- d) re-assessment interval and method.

## 7.4 Applicability analysis of pressure test

**7.4.1** The pipeline integrity shall be evaluated in accordance with information including the maximum test pressure, pressure stabilization time, whether there is failure under the pressure test condition, failure pressure value, etc., combined with the existing pipeline parameters and historical operating pressure. For pipelines that leak during pressure test, failure analysis shall be carried out to identify the hazard factors and characteristics of these factors, identify the types of defects, determine whether the defects are related to time, and estimate the development speed of defects. For pipelines without leakage during pressure test, the maximum allowable operating pressure and the maximum time interval for the next pressure test or other integrity assessment shall be confirmed in accordance with the data collected from the pressure test, estimated defect characteristics and pipeline surrounding environment.

**7.4.2** The MAOP of a pipeline should be determined according to the maximum test pressure, failure pressure value, design coefficient and safety margin requirements. The MAOP of oil pipelines is usually 0,8 times of the maximum test pressure or failure pressure, and de-rating at highly sensitive areas should also be considered. The MAOP of gas pipelines should be calculated according to the location class and the distribution of highly sensitive objects near the pipeline;

**7.4.3** The interval for the next pressure test or other integrity assessment shall be confirmed and determined in accordance with the combined factors of the existing pipeline wall thickness, test pressure, pipeline operating parameters, estimated defect growth characteristics, geological and environmental changes and pipeline maintenance level.

**7.4.4** The conclusion of a pressure test report shall include but not be limited to:

- a) MAOP;
- b) next assessment time and suggested method;
- c) recommendations for maintenance and operation to ensure integrity.

## **7.5 FFP assessment of direct inspection**

**7.5.1** The results of external corrosion aboveground inspection shall be classified in accordance with the field inspection and prior corrosion. The assessment of classification should consider but not be limited to, soil corrosivity, cathodic protection, the size and density of coating holiday and AC/DC interference.

- a) The results of inspection obtained by each single method, including soil corrosivity, cathodic protection and coating, shall be rated, according to which, an assessment shall be performed.
- b) AC/DC interference should be treated as a relatively independent assessment factor, and it should be evaluated separately at the specific section where serious AC and DC interference/induced corrosion has occurred.

**7.5.2** The internal corrosion risk along the pipeline should be classified based on the model results and examination results at the excavation site.

- a) For pipelines without a continuous water layer, the internal corrosion high risk location should be identified by analysing where the free water layer may form deposit.
- b) For pipelines with a continuous water layer, the internal corrosion high risk locations should be identified by analysing where the circumstance can induce more severe corrosion, including temperature, pressure, CO<sub>2</sub>, H<sub>2</sub>S, pH, Cl<sup>-</sup>, salinity, velocity (or shear stress), bacteria, etc.

**7.5.3** For the external corrosion and internal corrosion, the wall thickness should be quantitatively measured at severely corroded sites and the corrosion rate should be calculated. If the wall thickness loss exceeds 10 %, the remaining strength of the pipeline should be assessed.

**7.5.4** The direct inspection report shall clarify the validation and limitations of the inspection methods, include remaining service life calculations, re-assessment intervals, and recommendation of appropriate maintenance and repair methods if required.

## **7.6 Other methods of FFP assessment**

Based on the development of new technologies, pipeline integrity can be assessed by other new methods. Such methods should have sufficient data and test validation to evaluate and predict the integrity of pipelines, such as the possible new technologies of industrial internet plus various condition monitoring.

## **7.7 Comprehensive assessment**

**7.7.1** If data of two or more integrity assessment methods are available, they shall be aligned and analysed with the aim of understanding the causes of defects and loads. In addition, consideration should be given to pipeline operation conditions, changes in surrounding environment and stress and/or strain monitoring, etc.

**7.7.2** The comprehensive assessment shall be carried out by the FFP method preferentially based on ILI, if available, combined with the data from other inspections, monitoring and surrounding environment assessments.