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Oil and gas industries including lower carbon energy — Pipeline transportation systems — Pipeline geohazard monitoring processes, systems and technologies

Industries du pétrole et du gaz, y compris les énergies à faible teneur en carbone — Systèmes de transport par conduites — Processus, systèmes et technologies de surveillance des risques géologiques pour la conduite

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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 document 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).

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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.

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Introduction

In recognizing that pipelines transverse highly variable environments, this document provides an overview of available technologies and techniques to monitor and manage geohazards rather than providing prescriptive procedures. This document also recognizes that competent and appropriately qualified geohazard and pipeline stress experts are an integral part of the process because they are best suited to assess system-wide or site-specific needs for a geohazard monitoring program (GHMP).

Geohazards can adversely affect the operation or integrity of new and existing pipelines and their right-of-way (RoW), as well as the design and construction of proposed pipelines. Monitoring systems are commonly used for assessing and managing geohazard risk and the impact of geohazards on the integrity of pipelines. In comparison with geohazard engineering mitigation measures, monitoring systems have significant cost-benefit advantages in reducing economic, social, and environmental risks.

With the development of GHMP, this document brings about the following potential benefits:

— technical benefits: it helps operators, regulators, consultants, and third parties determine appropriate practices for monitoring geohazards and provides examples of current and emerging monitoring systems and techniques;

— risk reduction: it helps operators better assess the impact of the geohazard on the integrity of their pipeline asset, which then allows for an assessment of the resulting consequences;

— economic benefits: it helps operators define and develop physical intervention measures to prevent a pipeline integrity incident by making forecasts of impacts and evaluating consequences in cases where a pipeline system faces geohazards; it can help interested parties, especially operators of small- and medium-scale pipelines, to properly use their available economic and operational resources among the inventory of their geohazards;

— social and environmental benefits: it provides the pipeline operators with sufficient time for physical interventions by monitoring with early warning notifications; it can reduce the likelihood of integrity issues or loss-of-containment incidents, avoiding or reducing negative social and environmental impacts by early intervention.

Geohazard monitoring is part of a comprehensive geohazard management and pipeline integrity plan that should be developed as part of operating any buried pipeline. ISO 20074 and ISO 19345-1 provide information on preparing geohazard management plans and pipeline integrity requirements. Monitoring should not be performed in isolation of these plans and requirements.

Geohazard monitoring is typically used to initially identify and characterize geohazards. It is a means to confirm the presence of a geohazard and provide characterization of the feature so that engineering assessment of the geohazard impact to the pipeline can be performed, and engineering mitigations can be developed and implemented in a timely manner.

Geohazards include any natural feature, event, or process that can negatively impact the integrity of the RoW or pipeline. These can include but are not limited to earthquakes, landslides, debris flows, rockfalls, frost heave and thaw settlement, ground subsidence from karst collapse or underground mining, rock indentation, and hydrotechnical hazards, such as lateral or vertical erosion, scour, channel migration or avulsion, and others. Although the information in this document can be used for monitoring most geohazards, the focus herein is on ground movements (e.g. landslides or subsidence) impacting pipelines or their RoW.

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Oil and gas industries including lower carbon energy — Pipeline transportation systems — Pipeline geohazard monitoring processes, systems and technologies

1 Scope

This document provides requirements and guidance on planning, selecting, and implementing methods and strategies for monitoring geohazards that can interact with pipelines.

This document specifies requirements and recommendations for users regarding the development and initiation of monitoring processes throughout the pipeline life cycle, including the following stages:

a) preliminary engineering and route selection phase;

b) detailed design phase;

c) construction phase;

d) operation and maintenance phase.

This document also describes the processes and steps for developing a suitable geohazard monitoring program (GHMP).

This document applies to geohazard monitoring of new and existing onshore gathering and transportation pipelines and the right-of-way (RoW).

This document does not apply to monitoring geohazards that are temporary, such as the stability of spoil piles, temporary cut slopes to facilitate pipeline construction, stability of excavation or trench wall, and access roads.

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

ISO 20074, *Petroleum and natural gas industry — Pipeline transportation systems — Geological hazard risk management for onshore pipeline*

IEC 60529, *Degrees of protection provided by enclosures (IP Codes)*

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

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

3.1.1
aerial reconnaissance
reconnaissance activities of the pipeline RoW and surrounding terrain by means of aircraft (unpiloted drones, helicopters, or piloted airplanes) flying at relatively low heights above the ground to provide visual or video inspection and observation of the ground surface

3.1.2
aerial survey
broad category encompassing the collection of data by aerial platforms

Note 1 to entry: It includes *aerial reconnaissance* (3.1.1) and reconnaissance by piloted or unpiloted aircraft, airborne surveying platforms such as light detection and ranging (LiDAR), magnetic tomography, and airborne laser scanning (ALS) techniques.

3.1.3
automatic monitoring
monitoring of in-place instruments by use of an automated data acquisition system such as a data logger

3.1.4
internal calliper tool
type of in-line inspection (ILI) device that measures and records changes in the physical geometry of the pipeline (e.g. ovality, dents, wrinkles) and other physical features

3.1.5
data cleaning
process used to improve data quality by detecting, flagging, or correcting (or filtering and removing) the erroneous or noisy data from instrumentation

3.1.6
data management system
system that receives the instrumentation data through the *data transfer protocol* (3.1.8) in a specific server or cloud and processes and presents the data

Note 1 to entry: The data can be accessible or viewable with access privileges. *Data cleaning* (3.1.5) and processing, storage, and visualization as well as early notification system can be part of the data management system.

3.1.7
data processing
process used to convert the quality data to engineering units (such as elevation, deformation, strain) by processing the collected data obtained from instrumentation using mathematical equations or algorithms

Note 1 to entry: It can be performed in a specified server or cloud.

3.1.8
data transfer protocol
common set of rules to transfer the monitoring data from a data acquisition system to a specified server or a cloud repository

3.1.9
early warning information system
manual or automated system to perform *data processing* (3.1.7), data management, and data evaluation with the intent of issuing or transmitting a warning message to the operators if predefined threshold limits are exceeded

3.1.10
fibre optic sensing
FOS
use of small-diameter fibre optic cables that are attached to a buried pipeline or installed within the trench backfill and are capable of indirectly detecting various attributes, such as ground movement, loss of containment, backfill loss due to erosion and more

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3.1.11
geographic information system
GIS
computer program that stores and retrieves information concerning a geographical area or feature

Note 1 to entry: It is a platform for storing and cataloguing data about a linear feature such as a pipeline, including geohazard inventory along the pipeline *right-of-way(RoW)* (3.1.24) or the characteristics of the pipeline, physiology of the pipeline route, geology, land use, ownership, etc.

3.1.12
geohazard monitoring program
GHMP
program for assessing the spatial evolution of geohazards, the temporal evolution of geohazards, and triggering events, and other physical quantities, which includes monitoring objectives, methods, frequency, threshold levels, response to threshold exceedance, operation and maintenance, and program termination and abandonment

3.1.13
global navigation satellite system
GNSS
satellite navigation system with global coverage, essentially providing global position system (GPS) coverage

Note 1 to entry: It is a unified designation for single satellite navigation orientation systems including Global Positioning System (GPS-USA), BeiDou Navigation Satellite System (BDS-CHN), Global Navigation Satellite System of Russia (GLONASS-RUS), Galileo Satellite Navigation System (GALLIEO-EUR), etc., and also for their augmentation system, as well as a combination of those satellite navigation and position systems and their augmentation systems, such as Wide Area Augmentation System (WAAS-USA), European Geostationary Navigation Overlay Service (EGNOS-EUR), and Multi-Functional Satellite Augmentation System (MASS-JPN) and also covers other satellite navigation systems in process and to be established in the future.

[SOURCE: ISO/IEC 18038:2020, 3.10, modified — GPS has been emphasized and note 1 to entry has been added.]

3.1.14
in-line inspection
ILI
inspection of a pipeline from the interior of the pipeline using specialized physical or electronic tools

Note 1 to entry: Device or equipment that is inserted into the pipeline and will travel along the pipeline collecting information on the physical state and geometry of the pipeline. Data collected can include information on ovality, bends, curvature, dents, physical deformation, horizontal and vertical position, wall thickness, bending, and axial strain.

[SOURCE: ISO 19345-1:2019, 3.1.19, modified — "pipe wall" and "pipe" have been replaced by "pipeline"; "physical or electronic" has been added; note 1 to entry has been added.]

3.1.15
inertial measurement unit
IMU
in-line pipeline tool that measures and records the physical geometry and position of the pipeline

3.1.16
light detection and ranging
LiDAR
terrestrial or airborne system to collect data to develop ground elevations or profiles using lasers

3.1.17
magnetic flux leakage
MFL
in-line inspection (ILI) (3.1.14) tool used to detect and size both internal and external metal loss features in a pipeline wall

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3.1.18
monitoring network
network of instruments established for monitoring the behaviour of a geohazard and its impact on the pipe or other environmental factors such as rainfall or stream discharge or flow

3.1.19
monitoring point
site designated for monitoring geohazard behaviour or other characteristics

Note 1 to entry: The monitoring point can be located on the ground surface, within or on the periphery of geohazards, on the ground surface of the pipeline or *right-of-way (RoW)* (3.1.24), or other locations to monitor groundwater, environmental or meteorological elements, forced pipeline deformation, and other change.

3.1.20
pipeline monitoring
process of planned or real-time measurement, information analysing and processing on displacement, strain, cross sectional geometry of the pipeline with instruments, equipment, and technical means

3.1.21
pipeline geohazard risk management program
PGMP
set of processes and procedures for guiding operating companies or operators to carry out coordinated activity for guiding and coping with issues related to pipeline geohazard risk

Note 1 to entry: It is a comprehensive program as described in ISO 20074 that details the identification, assessment, and mitigation of geohazards that can negatively impact the integrity of buried pipelines or the *right-of-way (RoW)* (3.1.24).

[SOURCE: ISO 20074:2019, 3.1.20, modified — "pipeline geohazard risk management" has been replaced by "coordinated activity for guiding and coping with issues related to pipeline geohazard risk"; note 1 to entry has been added.]

3.1.22
pipeline geohazard monitoring
activity that tracks the evolution of or characterizes the behaviour of a geohazard that can impact a pipeline or *right-of-way (RoW)* (3.1.24)

Note 1 to entry: These activities refer to the data with regard to geohazards, pipeline and its relevant factors at different times and under various states intermittently or continuously acquired with sensors, instruments, and other technical means.

3.1.23
remote sensing
acquisition of data or information on some property of an object or phenomenon by a sensor that is not in contact with the object

Note 1 to entry: In the common usage, it usually refers to collecting information using airborne or satellite platforms, although near-field, noncontact sensing can also be referred to as remote sensing.

3.1.24
right-of-way
RoW
corridor of land within which the pipeline operator has the right to conduct activities in accordance with the agreement with the pipeline owner and the landowner and the regulator, if required

[SOURCE: ISO 13623:2017, 3.1.19, modified — The abbreviated term "RoW" has been added; mentioning of "the pipeline owner" and "the regulator" has been added.]

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3.1.25
shape accel array
SAA
device that is permanently placed in a casing installed to a specific depth to provide intermittent or continuous monitoring of lateral ground movement with depth

3.1.26
slope inclinometer
SI
device lowered into a casing with internal grooves that measures the tilt in the casing that can be converted to lateral ground displacement with depth

3.1.27
strain capacity
amount of strain that a pipeline segment can tolerate before a limit state is reached (either code-based, serviceability or ultimate)

3.1.28
strain demand
amount of strain that is imposed on a pipeline segment by pipeline operation or external forces

EXAMPLE A landslide that is moving will impose external load on the pipeline segment resulting in additional imposed strain.

3.1.29
strain monitoring
process in which fit-for-purpose instruments, equipment, and technical means are applied for periodic or real-time measurement, analysis, and process of stress or strain information of a pipeline(s)

3.1.30
subject matter expert
SME
practitioner experienced with evaluating and managing geohazards

Note 1 to entry: The qualifications for a subject matter expert vary by location but they generally include a degree in geology, geomorphology, hydrogeology, geotechnical engineering, geological engineering, civil engineering, or related degree and at least 10 to 15 years of practical experience working with geohazards.

[SOURCE: ISO 20074:2019, 3.1.27, modified — The years of practical experience have been extended in note 1 to entry.]

3.2 Abbreviated terms

ALS airborne laser scanning

CORS continuously operating reference station

FBG fibre bragg grating

GPS global positioning system

HDD horizontal directional drill

InSAR interferometric synthetic aperture radar

MEMS micro electromechanical system

RTK real time kinematic

TLS terrestrial laser scanning

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TSS total station survey

UAV unpiloted aerial vehicle

4 Key objectives and principles

4.1 Objectives of geohazard monitoring

The objectives of geohazard monitoring shall be clearly defined before developing GHMPs or initiating geohazard monitoring processes. The main purpose of geohazard monitoring is ensuring the safe operation of a pipeline passing through territories with corresponding geohazards. The following aims or activities can effectively support this objective:

— characterize the geohazard and its relationship and potential threat to a pipeline and RoW;

— make a forecast of geohazard development and provide probabilistic assessment of the geological risks based on the forecast;

— allow pipeline operators to manage resources relative to geohazard mitigations and interventions according to the threat posed by the geohazard to a pipeline and RoW;

— provide evidence for mitigation measures or technical solutions to prevent the threat of geohazards;

— provide early warning information to allow for pre-emptive intervention before the pipeline's strain capacity or allowable strain demand as represented by a threshold ground movement limit is exceeded;

— confirm that previously completed mitigation or remediation measures are functioning as intended;

— quantify ground movement caused by natural extreme events, such as an earthquake or storm event;

— provide necessary monitoring information to enable decision-making by long-, mid-, and short-term forecasts to minimize negative consequences due to natural extreme events.

The monitoring process (4.2) provides the framework requirements and guidance for initiating, managing and designing monitoring projects throughout the entire lifecycle of a pipeline. GHMPs should be designed and implemented under the framework of the monitoring process.

A GHMP (4.3) is the compliance document for designing and implementing monitoring projects. A GHMP shall be prepared for each monitoring project.

4.2 Monitoring process

4.2.1 General

Monitoring processes shall be established within the management framework of ISO 20074.

NOTE 1 ISO 20074 provides a high-level framework for developing, implementing, and improving geohazard management programs for onshore pipelines. ISO 20074 is applicable to all geohazards and includes a complete life-cycle approach, meaning that an operator's pipeline geohazard risk management program (PGMP) covers the entire lifespan of the pipeline from conception and design to construction, operation, and decommissioning. A PGMP covers four interlinked processes that are performed through the pipeline life cycle:

a) identification of geohazards;

b) evaluation of geohazards;

c) long-term management of geohazards through monitoring and periodic re-evaluation;

d) mitigation of geohazard threats.

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