Safety Alert 012 - ANP/SSM

CO_2 Stress Corrosion (SCC-CO_2)

This Operational Safety and Environment Superintendence alerts the oil, gas and other stakeholders about the occurrence of a corrosion mechanism called CO_2 Stress Corrosion (SCC-CO_2).

What happened?

Incidents of this nature occurred from 2016 in flexible gas injection and production pipelines, with high levels of CO_2, from the second year of operation, being that the equipment had a service life previously established by the manufacturer of 20 years.

Potential consequences

CO_2 Stress Corrosion can cause the unexpected and catastrophic failure of a flexible pipeline, leading to production losses and accidents with consequences to people, environment and property.

Identified causes

Three factors were identified as necessary for the occurrence of this phenomenon: the existence of water through annular flooding, the existence of stress/strain acting in the pipeline and CO_2 fugacity. Thus, CO_2 contents, pipeline stress levels and pipeline material should be considered to determine whether there is a reduction in affected pipelines lifespan. Regarding the stress in the pipeline tensile armors, residual stress and operating stress enough to activate the SCC mechanism were identified. In addition, the material of the tensile armor wires proved to be susceptible to the mechanism of corrosion assisted cracking (nucleation and propagation), under operational conditions of the design envelope (CO_2, stress and water) during exposure time.

Lessons learned

Operator has established several measures to mitigate the occurrence of the SCC-CO_2 phenomenon and reduce the consequences due to failures, which are presented below, applicable only to subsea systems that use flexible pipelines with potential occurrence of the SCC-CO_2 phenomenon:

SGSS Chapter 14: Incident Investigation

Deepening the scope of SCC-CO_2 in its facilities: considering pipelines operational history (CO_2 content, temperature, loads, etc.), establish a program to deepen the scope of the phenomenon, based on the removal of flooded pipelines in operation for dissections and investigation, as well as laboratory materials tests, under conditions that represent the pipelines in operation, aiming to identify the phenomenon occurrence envelope, based on evaluating corrosion cracks and pits and defining a period of SCC-CO_2 compatible operation for each type of pipeline. With these results, pipelines similar to those already dissected (e.g. same material, CO_2 content, temperature, loads, etc.) can be evaluated for the operational risk. Operator implemented a pipeline dissection program for pipelines with potential occurrence of the SCC-CO_2 phenomenon, including gas injection and

production pipelines. It is noteworthy that the evaluation of the lifespan of the top branches has shown lifespan values due to SCC-CO_2, in the flooded condition, appreciably higher than those of the other branches. This is because top *risers* have lower CO_2 pressures in the annular, due to the relief on the surface, which allows the continuous elimination of annular gases from the pipeline.

SGSS Chapter 16: Risk Analysis

Establishing a Centralized SCC-CO_2 Risk Management: being this a phenomenon which is not yet fully dominated by the industry, it is recommended that risk assessments be carried out periodically by specialists dedicated to the evaluation of the phenomenon and safety measures additional to those already implemented, and that the managing of the recommendations Implementation is also centralized.

Establishing measures to reduce the consequence in case of pipeline failure: evaluate and implement interlocking systems to detect pipeline rupture events and automatic closure of the surface shutdown valve (SDV) and the wet Christmas Tree in pipelines with potential occurrence of the phenomenon. Perform tests to confirm wells safeguards functionality (e.g. control mesh, actuation systems) and implement systems that allow the identification of leakages.

SGSS Chapter 20: Design

Establishing a fugacity envelope: for all high strength materials (1200 to 1500 MPa of UTS - Ultimate tensile strength) there may be a cracking threshold between 3 and 5 bar of CO_2. Lower mechanical strength steels have a lower susceptibility to SCC-CO_2. No cracking was identified at temperatures of 25 °C or lower and no cracking susceptibility was identified in oil production pipelines as it was in gas injection pipelines.

Including protective cover and abrasion cover on the outer cover in gas injection flowlines: in the risers to be manufactured, the inclusion of a double cover (outer cover and abrasion cover) or double cover and mechanical protection between outer cover and abrasion cover was established as a design requirement.

Including connectors that maximize tightness for the lines to be manufactured: the design was adjusted to reduce the number of connections, plug-in seals were replaced and facilities for testing were added.

SGSS Chapter 21: Manufacturing and Installation

Establishing an inspection procedure and issuing a report to identify any cover damage that has occurred during loading and/or installation.

Establishing installation procedures to include actions that prioritize the maintenance of the external cover integrity if any damage is identified.

Establishing damage repair recommendation by running an annular integrity test prior to pipeline installation.

Development by manufacturer of solutions that minimize CO_2 permeation for the annular for pipelines with composite pressure barrier (hybrid flexible pipe - HFP) or metal permeation barrier

solution (with tapes). As well as materials with corrosion resistant steels and methods to minimize and control manufacturing residual stresses.

SGSS Chapter 23: Integrity Management

Establishing a specific integrity management program for pipelines with potential occurrence of the phenomenon: qualify and hire tools for inspection of pipeline flooding to replace flooded pipelines/branches that are within the phenomenon occurrence envelope and prior to pipeline period of safe operation, determined from the dissections, laboratory tests and methodologies to estimate SCC-CO_2 lifespan. Intensify visual inspections in the pipelines to determine torsions or other apparent malfunctions, which may be indicative of structural integrity impairment.

Adequacy of inspections to identify any cover damage and torsions: for pipelines already installed and with potential occurrence of the phenomenon, perform inspections with special image takings to identify possible damage and forward actions in case of identification of damage.

SGSS Chapter 26: Deactivation and Decommissioning

Establishing specific criteria to determine a deadline for pipeline removal, as failure may occur in the hibernation phase after end of lifespan for a SCC-CO_2 subjected pipeline.

Contact

For additional information regarding this safety alert, please contact ANP's Operational Safety and Environment Superintendence at incidentes@anp.gov.br.