Assisting Transformation

Jens Voss, ROSEN Group, introduces the diagnostic solutions that are available for supporting future fuel pipelines.

Today's energy grid and the available pipeline network, in particular, will play a major role in the transition to net zero, connecting supply and demand. No pipeline is the same, and owners, operators and integrity engineers need to ensure that they understand and manage the integrity of the asset. Traceable, verifiable and complete manufacturing and construction records, as well as a thorough understanding of the anomaly population in the asset, are fundamental parts of integrity management.

State-of-the-art inspection technologies support the pipeline industry in managing threats such as geometry, metal loss, material properties and cracking, with a variety of solutions. This service portfolio will also be a key component when it comes to repurposing pipelines from natural gas to hydrogen under existing regulations and guidelines, including ASME B31.12.

Energy systems

The current carbon-based energy system is undergoing profound changes, driven by increased concerns over the longevity and security of fossil energy. Countries around the world are looking for ways to transform their energy systems. Initiatives such as the European Hydrogen Backbone illustrate and summarise the efforts to transform the current European energy systems, with the aim of ensuring the future security of energy supply, and lowering greenhouse gas emissions.[1]

Pipelines play a major role in the transformation of the energy system because of their ability to safely transport energy over long distances and act as storage at the same time. Compared to electrical power lines, pipelines can carry more energy and are already (or easily can be) directly connected to existing storage infrastructure, such as caverns. This integrated

set-up enables countries such as Germany to integrate imported energy via pipeline from sources with lower energy production costs. Especially with regard to international climate protection goals, the high energy density, and the established, partly global transport infrastructure (e.g. pipeline connections from Scandinavia or the Mediterranean, and new terminals to import LNG from overseas), it can be assumed that a global market for carbon dioxide (CO_2)-neutral gases (and fuels) will develop.[2]

A transformed energy landscape with significantly lower emissions will be based on the sector-coupling principle, providing greater flexibility to the energy system so that decarbonisation can be achieved in a more cost-effective way.[3] Figure 1 illustrates the different sources of energy (left) and highlights the various forms of energy that could be present in a pipeline.

With more focus on pipelines in the energy sector, it can be seen that the energy is transported via different carriers, such as hydrogen, ammonia, oxygen, biomethane or CO_2.[1] These carriers are called future fuels. Purpose-built pipeline networks transporting these fuels are already in use today – but in a significantly smaller volume than will be needed going forward.[1]

Low-carbon gases and their associated products can reliably and efficiently be transported, stored and distributed in existing and newly-built global pipeline network. Pipelines will also be used to assist carbon capture, utilisation and storage (CCUS) projects by transporting CO_2 safely from emission locations to permanent storage or end use locations. The transportation of these fuels through pipelines will require the consideration of both general and specific integrity threats and damage mechanisms in order to ensure safe and efficient operation.

These challenges can only be managed with a comprehensive integrity management system.[4] The transformation of the energy system will encompass the repurposing of existing infrastructure and the building of new pipelines according to latest design standards.[5]

Threats to manage in future fuel pipelines

If future fuels (or indeed any fuels) are to be transported through pipelines, pipeline integrity must be assured to allow for safe long-term operation. This concept of integrity management is not new to pipeline operators, as demonstrated by the long, proud and safe history of the existing pipeline network. Nevertheless, it is worth revisiting in the context of future fuels. In essence, the key points of interest for any pipeline integrity management system are:

- Pipeline condition: what are the time-dependent threats? Which types of defects should I tackle? Where? How severe?
- Integrity remaining life: how safe are my pipeline operations? For how long?
- Consequences: what are the consequences of loss of containment?
- Management: can I safely manage pipeline operations?

The introduction of different fluids into pipelines will not change how integrity management should be tackled, but it will introduce its own specificities and challenges. It is therefore necessary to consider each fluid in turn, identify the relevant threats, and outline how these can be monitored, inspected and managed. The management of these threats is best understood in the context of an integrity framework.[4,6] This is summarised in Table 1, which also provides an overview of the principal threats of interest.

The introduction of future fuels into a pipeline system will affect the assets. Assessment solutions to reliably detect, identify and size these threats during repurposing activities, as well as in future fuels operations, are critical for the safety and reliability of the asset from an economic perspective. A best practice in the energy industry is a full suite of assessment methods and measurement capabilities that include in-line inspection (ILI) solutions, pressure testing for pipelines, and direct assessments.

Integrity assessment methods

Regulators and industry groups are collaboratively working on rules and standards to safely transform oil and gas pipelines. Repurposing activities will be the focus of the industry for a large number of existing pipelines of different ages, diameters, material characteristics, and associated anomaly populations. Standards such as ASME B31.12 support these activities, and demand an in-depth understanding of the asset itself. Construction records, material certifications, and testing for future fuel operations, as well as updated threat assessments, are only a fraction of the efforts that need to be executed for a successful and cost-effective transformation process.[5]

At the core of these activities are pipeline integrity assessment methods, which can be split into four different categories:

- ILI.
- Pressure testing.
- Direct assessment (DA).
- Alternative methods.

ILI is a non-destructive inspection technique that can be used for pipeline integrity assessments. The type of ILI survey performed is dependent on the type of integrity threat that is being assessed.

Pressure testing is a destructive testing technique to detect/eliminate (by failing) the largest defect in the pipeline that can fail due to internal pressure (i.e. pressure-dependent defect) at the time of testing.

DA is a non-destructive assessment technique for classifying pipeline regions with common characteristics (i.e. pre-assessment) that may be experiencing the selected integrity threat (e.g. external corrosion, internal corrosion, or stress-corrosion cracking).

Alternative methods such as inferred condition technologies and data analytics may be used when operational (e.g. pipeline system configuration), technological (e.g. small diameters), and environmental (e.g. water availability and disposal) conditions do not permit the other three main types of pipeline integrity assessment methods.[7]

ILI technology can be of significant value in repurposing activities, as it is highly utilised in today's pipeline integrity management. The support of integrity decisions with measurement data has improved over recent decades, and technological developments in other industries (telecommunication, defence, IT, etc.) will further enhance these abilities. ILI tools can be classified by integrity threat type or technology principle; widely used principles are mechanical calipers, magnetics, eddy current, ultrasound and electromagnetic acoustics. Knowing pipeline integrity threats related to hydrogen and other future fuels, it is possible to acknowledge that different kinds of ILI

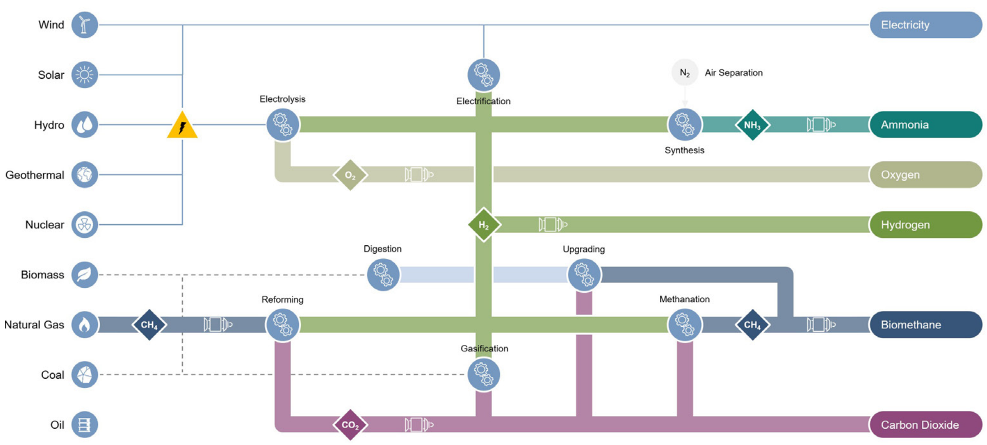

Figure 1. Sector-coupling principle with different forms of energy in pipeline transport.

technologies can support the integrity management of such pipelines. Those ILI technologies could be for the detection of deformations, mapping or corrosion, for example. Technologies could also include those that are particularly applicable to future fuels, such as determination of material properties or detection of cracks and crack-like anomalies in gas pipelines.[4]

Today's in-line diagnostic portfolio delivers solutions from simple cleaning applications to high-resolution crack detection services. It is important that all of these applications are also available in future fuel assets. Therefore, ROSEN is creating solutions to adapt its fleet of inspection tools, readying it for future fuels. Initial inspections in smaller-diameter product lines for hydrogen, ammonia and CO_2 have already been conducted in the past[4], and utilisation of the lessons learned and use of the solutions in larger diameters and for longer inspection lengths are under development.

The inspection tools need to be modified to withstand the environment in future fuels pipelines, which can be very different compared to oil and natural gas. Products such as ammonia, CO_2 and hydrogen pose specific challenges for the materials on the inspection tools, and intense upfront testing and understanding of deterioration processes is key for inspection vendors to be able to deliver a high-quality service.

Table 1. Integrity threats in future fuel pipelines

Name of threat	Threat	Feature type
General	External corrosion	Metal loss
	Third-party damages	Dents, gouges
	Geohazard	Bending strain
	Manufacturing/construction (materials and welding)	Crack-like/cracks
	External enviromentally-assisted cracking (EAC)	Cracks
Hydrogen	Material embrittlement	Low fracture toughness under hydrogen environment
	Hydrogen cracking damages	Cracks
	Additional considerations	Hard spots, geometry anomalies, bending strain
CO_2	Ductile fracture	Low material toughness
	Internal corrosion	Metal loss
	Internal SCC	Cracks
Ammonia	Internal SCC	Cracks
	Internal corrosion	Metal loss

Table 2. Applications and technologies

Application	Technology principles	Services
Cleaning	Mechanical scrapers, brushes	RoClean
Deformation/ movement	Calipers, eddy current, gyroscope	RoGeo
Metal loss	Magnetic flux leakage, eddy current, ultrasound	RoCorr
Material properties	Magnetic flux, eddy current	RoMat
Cracking	Ultrasound, electromagnetic acoustic transducer, eddy current	RoCD

Another key aspect of ILI is the ability to gather a high-quality data set under the harsh conditions in pipelines. Solutions such as speed control valves and low-flow/low-pressure set-ups enable a constant flow velocity without speed excursions or tool stops. With the lower density of hydrogen compared to natural gas, these solutions hugely aid success.

The safety regulations for operations of ILI solutions might change with the introduction of more hydrogen into the pipeline networks. Existing ATEX certificates might need to be updated to ensure proper consideration of the lighter hydrogen in onsite safety procedures.

Conclusion

Existing pipeline infrastructure will play a major role in the transformation process of the energy industry. In practice, this means that ageing pipelines must be converted to transport fluids that are very different from those for which they were originally designed. A comprehensive, integrity-led approach is required to maintain safety during this transition.

The service life and compatibility of the ILI tool parts strongly depend on the tool run conditions, the chemical composition of the fluid, and the exposure time. Available solutions are suitable to enable ILI in hydrogen, CO_2, ammonia, and other future fuels. The proposed inspection technologies for pipelines that are transporting future fuels will need to be assessed for each pipeline within the context of an integrity framework; however, it appears likely that high-resolution corrosion services, crack-detection services, and material properties services will be required. ROSEN is conducting work to provide these services in the environment of future fuels.

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