Emerging fluids, data impacts and the future of pipelines

Paul Dickerson, Emerson, outlines the changes happening in pipeline transport, and how companies are preparing for a flexible energy future.

The energy transition and global push toward reducing emissions is opening a new era for pipelines and infrastructure development. From oil and gas and nuclear to wind, solar and emerging sources such as hydrogen, a broad energy mix is reshaping the energy landscape. Significant interest and investment are pouring into both carbon capture and sequestration projects as well as hydrogen transportation and storage. The ways people and businesses use and interact with energy are changing.

As grids are being diversified, pipeline companies are balancing calls for global energy security. Amid this proliferation of energy generation resource types and new decarbonisation technologies, companies must reconcile numerous complex variables. Among these complexities are specific models and thermodynamic equations required to determine the characteristics of emerging fluids that are being transported in pipelines under different operating conditions. Pipeline companies rely on the specificity of this data for planning.

Agile software tools enable companies to more reliably account for these complexities, with software becoming a high-priority strategic driver in the evolving energy sector.

A broad energy mix

What will future energy consumption trends look like? Commercially, what will become the best business model for long-term hydrogen transportation and storage solutions, and carbon capture, utilisation and storage (CCUS) initiatives?

The integration of technologies, being leveraged by oil and gas companies for better alignment of overall optimisation, increased following the 2014 - 2015 market downturn. More recently, there has been a tilt toward extensive use of advanced data analytics, putting companies in a position to improve efficiencies, in both facilities and operations.

What makes the ability to act deliberately on the most current information so crucial for dynamic pipeline design and operational environments? A different approach may be necessary, to utilise the data initialisation that supports accurate engineering and reliable delivery of various product types, amid the pioneering transformation technologies designed for energy operations.

Adopting agile pipeline design software solutions signals a proactive approach to streamlining efficiencies, enabling quick and accurate responses, and providing operators flexibility for any direction they need to go to satisfy evolving market demands.

CCUS and pipelines

Both CCUS and hydrogen transportation and storage are being explored heavily due to their ability to reduce emissions now and set the foundation for large-scale commercialisation.

As activities in the CCUS segment expand, pipelines will play an essential role in transporting captured CO_2, from industrial processes or direct air capture (DAC) facilities to permanent geological storage or sequestration sites. Captured CO_2 can be compressed into a concentrated stream of pressurised liquid or a dense phase, the latter exhibiting both liquid and gas characteristics, to enable efficient transportation via pipelines. This CO_2 is pumped back in reservoirs, salt domes and other sequestration sites for long-term storage or use in enhanced oil recovery (EOR) processes. Anthropogenic CO_2 does not generally need to be pure to store, and is commonly 90% or more CO_2 with the remaining industrial process waste gasses.

The design and operation of CO_2 pipelines are subjects of ongoing research to ensure safety and effectiveness at scale. Along corridors of industrial areas, plant-wide carbon capture systems will feed the captured anthropogenic CO_2 into trunklines that will provide transportation to storage locations.

In many ways, the trunklines will resemble gathering systems running in reverse. To accommodate large-scale CCUS in the US alone, according to Global CCS Institute reporting, the infrastructure will need to grow from over 5000 miles (8046 km) today – discontinuous across five geographic zones – to an estimated 20 000 miles to 96 000 miles (32 000 km to 155 000 km) in the future.

From crude oil back to CO_2, the ability to switch rapidly between product types, and demonstrate the ability to make high-value decisions, within minutes, is becoming increasingly relevant. Knowledge-based, data-driven simulation models for optimising design and operations are available to provide the most current intelligence and support integration of CCUS into pipeline systems and networks.

On hydrogen

Hydrogen, produced from a variety of net carbon neutral or carbon capture sources, is clean burning, produces only water vapour upon combustion, and can be stored in pipelines as a pressurised gas. Gaseous hydrogen has approximately one quarter the energy density of natural gas. Injecting a percentage of pure hydrogen into the gas stream has the net effect of a reduction in the energy content of the gas stream by volume, and a greater volume of the transported gas is required for compression.

According to Australian Pipelines and Gas Association (APGA) analysis of a new study, energy storage in hydrogen pipelines costs up to 37 times less than battery energy storage systems and up to 10 times less than pumped hydro energy storage.

Published in 2023, a scientific review of 11 hydrogen production and various storage and transport options compared the energy, environmental footprint and eco-cost analysis of technologies. Researchers noted an estimated 38 - 85% lower energy footprint associated with transporting gaseous hydrogen in pipelines, compared to alternative storage and transportation options.

Relating to challenges, existing natural gas networks can store small volumes of hydrogen with little to no effect on performance. In higher concentrations, hydrogen can cause embrittlement of steel pipes, creating weakness in the pipes structure which could lead to infrastructure damage.

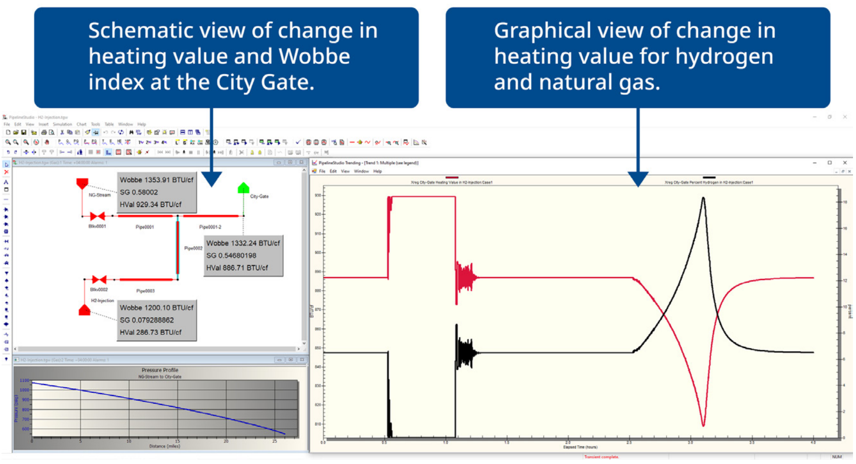

Figure 1. Engineers use modelling software to simulate the effects of a hydrogen injection into a natural gas pipeline.

Support for DAC, carbon markets

A Congressional Budget Office (CBO) report in 2023 showed that CCUS facilities with a combined capacity of 134 million tpy of CO_2 were under construction or are being developed in the US. If all of those facilities came online today, the nation's total CO_2 capture capacity would increase approximately sevenfold – to 156 million tpy, or 3% of current annual CO_2 emissions in the US. Supported by billions of dollars in government funding from the 2021 Infrastructure Investment and Jobs Act, regional DAC hubs are being designed around enhancing CO_2 transportation efficiency and cost reductions, through consolidating capture sites and shared pipeline networks.

With rising interest in negative emissions from technologies such as bioenergy with carbon capture and storage (BECCS) and DAC, the voluntary carbon market has additionally emerged as an opportunity for pipeline companies. As businesses look beyond energy supply, interest in federal tax incentives and carbon credits are indicative of the way some are working to monetise emission reductions. From 2010 to 2019, companies claimed a total of US$1 billion in section 45Q tax credits for carbon sequestration, according to the CBO. The incentive programme was expanded following passage of the 2022 Reconciliation Act.

Adapting for transition

The energy transition will be affected by the availability of new CO_2 and hydrogen transportation infrastructure and expansions in traditional oil and gas, having an impact on the decarbonisation potential and business outcomes.

OPEC's 2023 World Oil Outlook estimated cumulative investment requirements in the oil sector between 2022 and 2045 would amount to US$14 trillion, or approximately US$610 billion/y on average. It was estimated that investments of US$1.7 trillion and US$1.2 trillion, respectively, would be required to meet downstream and midstream requirements, hedging against challenges and risks to market stability and energy security.

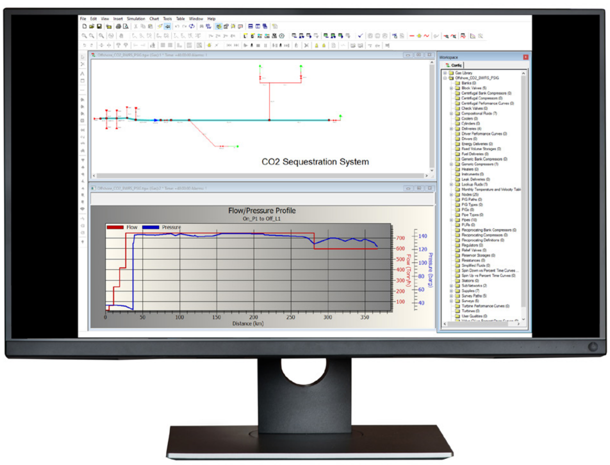

Figure 2. **Emerson's user interface displays a CO_2 sequestration configuration and a steady-state hydraulic profile that illustrates the impact of compression on dense phase CO_2.**

The pipeline industry is being presented with new opportunities as entire transportation networks are being planned around diverse energy transport and storage solutions. Rigorous precision is relied on for moving divergent product types to sites where they can flow to meet day-to-day energy market needs, or be safely stored or effectively disposed of.

The ability to design for switching among products within the same pipeline system will become indispensable, alongside addressing changing infrastructure needs and enabling quick responses to trends in energy consumption.

Enhancements to pipeline network design tools

Digital transformation has always been about more than advanced sensors and monitoring equipment. Listening to the voice of the industry necessitates experience and equilibrium. Development of advanced technology including software is enhanced when users, agencies and regulators provide feedback and collaborate.

Ensuring the most current pipeline intelligence can be made available to operators is crucial in dynamic energy markets where conditions can change rapidly, and high dollar value decisions are being made increasingly on the fly.

Data utilisation is the backbone of software applications for pipeline design and optimisation requiring interchangeability and flexibility. A convergence of technologies is empowering the interchangeability of simulation data between operational and engineering environments. A complete pipeline design and engineering simulation software tool streamlines the workflow by delivering rapid and accurate offline pipeline management design, planning and hydraulic analysis.

Innovative just-in-time analysis has been added, enabling users to start an engineering simulation from up-to-the-minute information on the hydraulic state. New and improved viscosity correlations are now being implemented, alongside interactive transient simulation to handle emerging energy transformation technologies – as they are being developed – proving to facilitate the design process.

With hydraulic data feeding directly into the model – such as current line fill, current temperatures, pressures and flows – engineering assessments can be based on a reflection of actual pipeline conditions, rather than relying on outdated or estimated figures.

The ability to use more current data enables companies to meet the evolving critical energy storage and infrastructure needs and stay in front of changes in day-to-day market demands. Immediate insights can be obtained into the current state of the pipeline. As conditions change, the ability to start with a contemporary analysis – not only the state that is being used as just a basic initialisation – allows for rapid model adjustment. Engineers can evaluate different configurations and operational strategies to optimise the performance of designing pipelines and modifying existing systems, whether for natural gas, oil, refined products, or other fluids.

This advancement additionally provides native support for commonly used industry-standard equations of state,

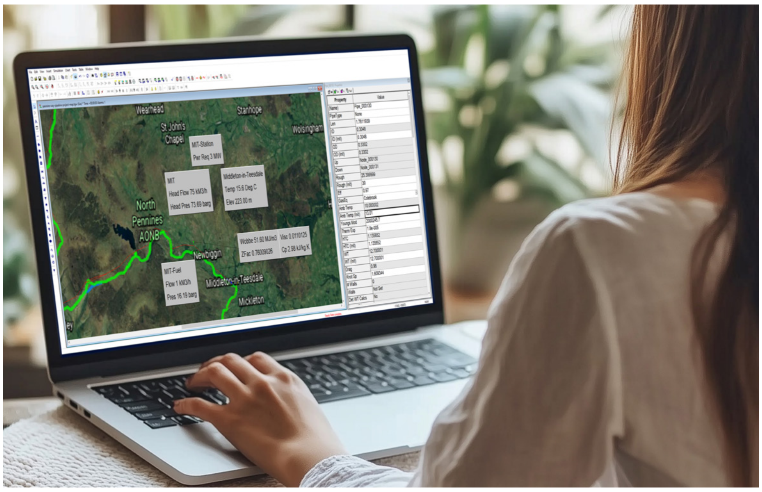

Figure 3. **Emerson's software allows users to incorporate maps and GIS information into configurations to enhance geo-referencing.**

such as European Gas Research Group (GERG) support, and other calculations, without depending on a third-party application. This includes energy transition fluids such as carbon dioxide, and both pure and natural gas enriched hydrogen and ammonia, and support for any fluid in liquid, gas, dense or supercritical phase.

Rapid data initialisation and modelling

Project lead times and efficiency are impacted by the ability to obtain accurate, analytics-backed simulation information. This information supports interpretation – through the integration of engineering and operational environments during the pipeline design and analysis phases.

It can be difficult to recover if engineers get too far down the wrong path. Propagations of revisions can potentially affect other business areas. The ability to pivot quickly without extensive rework makes it easier to manage constraints, allowing for more agile and adaptable operations.

Rather than having to collect and process new data or rely on assumptions, software that can quickly integrate data between the engineering and operational environment minimises requirements for additional data collection efforts and associated costs. Interactive transient simulation functionality allows data from a prior interactive state, or a saved state, to be utilised for initialising simulations. Users of enhanced simulation tools can also jump to a specific time in the simulation.

Such initialisation of engineering models results in more precision during pipeline design and engineering analysis, reducing the risk of errors and potentially lessening the need for unnecessary iterations. A hard job is made easier as this step enables rapid decision-making, producing more predictable, scalable outcomes.

Flexible energy future

Pipeline companies can be flexible and responsive, even with limited resources, when deploying enhanced simulation tools. The pace for learning and overall efficiency can be boosted when training is required for only one piece of software.

Applications with intuitive guided workflows are quick to learn and easy to use – limiting the time to ramp up and ensuring rapid implementation. From design scenarios and analysis to logs of simulations, tables, graphics and detailed reports, these all can be easily accessed in a single software tool, with interfaces providing an integrated and consistent user experience.

The software removes any guesswork and all the complexity from getting data in and out of non-formatted files such as spreadsheets and working with various data formats. Compatibility with other engineering and operational software used in the industry ensures smooth integration into existing workflows and systems.

Operators are able to switch quickly, one day to the next, among what they can calculate, model and simulate, without having to acquire an additional resource or separate tools. Designs can be put into procurement and created using intuitive configuration. If adjustments are required later in the project, the need for costly backtracking is reduced or eliminated.

Future-proofing design capabilities

Future-proofing pipeline design and operational capabilities, while providing the flexibility to manage emerging energy transformation needs, is about more than just allowing for accurate simulations of potential issues such as pressure drops, temperature changes, or flow irregularities. The ability to create a canvas for engineering simulation and modelling that leverages industry expertise is helping accelerate the speed at which people can get work done.

Decision-making for designing and optimising the performance of pipeline systems – for efficiency, cost, and safety from the outset – is more fully enabled by built-in analytics tools. Users can efficiently simulate operational changes, identify potential issues, and plan for interoperability.

Effective integration will hinge on robust design and engineering tools and sophisticated control systems capable of accommodating shifting energy needs and requirements for transporting varied products, including traditional oil and gas and transitional energy fluids. A turnkey approach may be warranted when considering adoption of advanced software that models the supply chain to drive business – leading to effectiveness in a challenging market environment and swiftly changing industry landscape. Up-to-the minute data initialisation combined with the ability to use a single hydraulic state to initialise engineering models provides a direct path to the most accurate simulations, reducing time to market and increasing delivery reliability, regardless of product type.

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