

ADVANCED NATURAL GAS PIPELINE MATERIALS



NETL

NATIONAL ENERGY TECHNOLOGY LABORATORY

NETL's Natural Gas Infrastructure Program strengthens the reliability, public safety, operational efficiency, and flexibility of the nation's natural gas infrastructure pipelines. We use the most modern and effective leakage mitigation technologies, including the development of advanced materials for our natural gas pipelines.

The Laboratory works on ways to improve midstream operations systems that actively connect production fields with local distribution systems. Natural gas transmission pipelines require a long lifespan. Population growth can encroach on the lines over time, putting new communities at potential risk. Our leakage mitigation technologies aim to protect those communities.

One of the possible sources of leakage is internal corrosion of the pipeline principally due to the presence of incidental water and CO_2 . While the gas is nominally dried prior to introduction to the pipeline, water can accumulate in low areas of the line. CO_2 , as a natural gas impurity, is a significant issue because it will dissolve in residual water to form corrosive carbonic acid. This situation can be further exacerbated by the high partial pressure of CO_2 in the pipeline

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Presently, internal corrosion is assessed through regular inspection during pipeline pigging, which is the practice of using pipeline inspection devices, generally referred to as pigs or scrapers, to perform maintenance operations. However, preventive maintenance is costly and may require the venting of natural gas prior to inspection. Natural gas leaks caused by corrosion can be prevented by applying protective coatings and liners to pipelines. This can be accomplished by developing advanced materials that block the permeation of corrosive species to pipelines substrates.

Key focus areas of the program's research are:

- Polymer-Metal-Polymer Composite Barrier Liners
- Metallic Coatings
- Multilayer Barrier Coatings with High Chemical Stability
- Joining Methodologies for Composite Liners

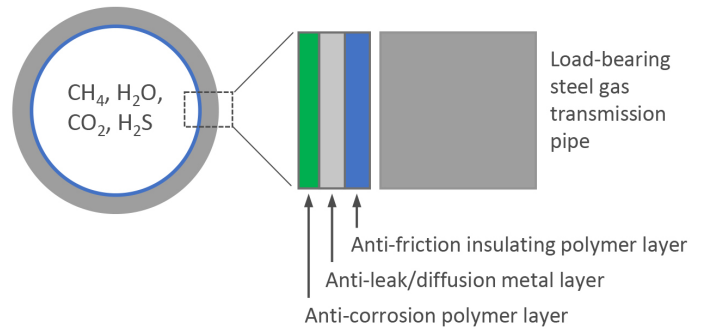
POLYMER-METAL-POLYMER COMPOSITE BARRIER LINERS

Water and CO_2 react to form carbonic acid that can corrode the inside of steel pipes. NETL is developing composite liners to investigate the use of impermeable barriers to reduce or eliminate carbonic acid corrosion of steel. Successful commercialization of the technology can save money and lives by reducing the rate of pipeline failure due to internal corrosion.

Polymer-metal-polymer composite barrier films have been shown to be effective in preventing carbonic acid corrosion of steel in the laboratory; however, much work remains to be done to go from the lab bench to testing a prototype composite liner in the field.

NETL is also investigating the feasibility of using composite barrier liners in pipelines that carry gases other than natural gas (e.g., CO_2 and hydrogen). A liner that is resistant to wet CO_2 enables the use of existing pipelines to transport the gas for enhanced oil recovery or carbon sequestration. This project, which is ongoing, provides an avenue for pipeline transport of hydrogen through the existing natural gas infrastructure without embrittling the steel pipes.

NETL's High-Pressure Immersion and Reactive Transport Lab and Severe Environment Corrosion Erosion Research Facility enable the testing of gas permeation and corrosion under pure and mixed gas environments at pipeline relevant pressures and temperatures.

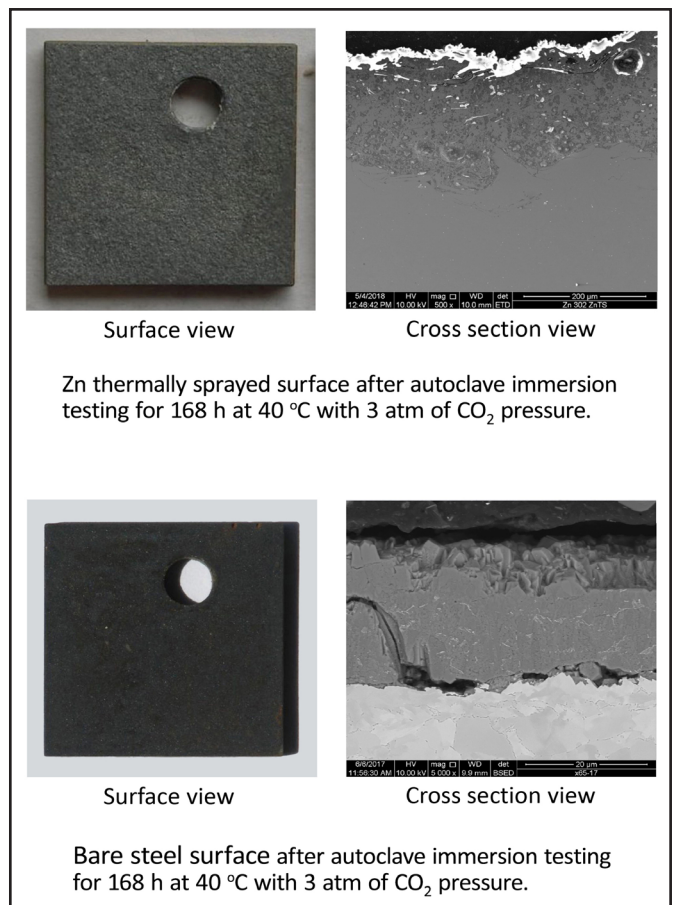


Gas permeation reduction with metal-composite barrier liners.

METALLIC COATINGS

NETL is developing a metallic coating system to protect the integrity of natural gas transmission pipelines from corrosion, thereby extending their safe operating lifespan for decades. After successful deposition and laboratory testing, at least two metallic coatings are to be tested in natural gas gathering lines, which tend to have shorter lifespans than transmission lines.

NETL has built an electrochemical reaction autoclave – a unique tool for studying corrosion in high-pressure conditions like a pipeline.



Zn coatings deposition of protective Zn carbonate.

MULTILAYER BARRIER COATINGS WITH HIGH CHEMICAL STABILITY

The safety of our citizens and their property is our number one priority, and our new initiatives are designed to enhance that safety. A significant portion of gas pipeline leaks over the past 20 years have been related to the internal corrosion of steel pipelines caused by salt water and gaseous impurities contacting bare steel. New innovations will change that. By fine-tuning the composition, molecular interaction, and structure of layer-by-layer (LbL) assemblies, NETL is developing multilayer barrier coatings that can remain chemically stable in CO₂-saturated salt water.

An LbL assembly uses complementary interactions, such as ionic, hydrogen, or covalent bonding, between components to deposit materials one layer at a time. Researchers can design the structure of these multilayer coatings with nanometer precision to achieve a high oxygen barrier and a reasonable water vapor barrier. NETL is depositing multilayer coatings produced through LbL assembly on the inner surfaces of steel pipelines. Their barrier and corrosion resistance are being characterized and then used to interpret anti-corrosion properties.

NETL has world class, in-house test facilities to measure the pure gas, mixed gas or water vapor permeance of multilayer

coatings. Our facilities include an advanced electrochemical impedance spectroscopy for estimating the rate of electrochemical corrosion. Furthermore, we maintain a suite of advanced materials laboratories across the country for the fabrication and characterization of polymer/clay multilayer coatings.

JOINING METHODOLOGIES FOR COMPOSITE LINERS

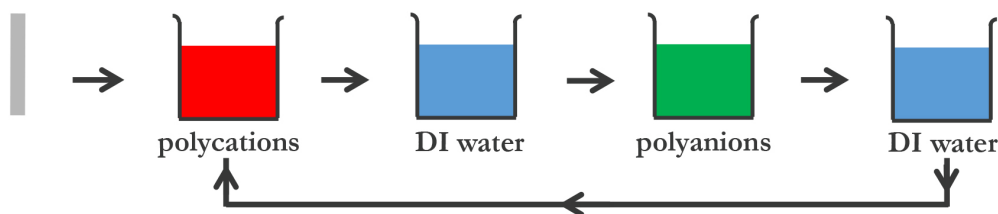
A barrier impermeable to water and methane, lining the interior of the pipeline walls, can prevent emissions and corrosion resulting in improved reliability for natural gas pipelines.

A metal foil liner coated with polymer on both sides will be impermeable to both water and methane molecules. Polymer coating on the metal foil will increase the robustness of the liner, which is especially needed during the installation and pigging processes. NETL is working to identify and demonstrate a viable joining technology for a metal thin foil layer of composite liners for natural gas pipelines. This technology is required to join metal thin foils in a defect-free and continuous manner.

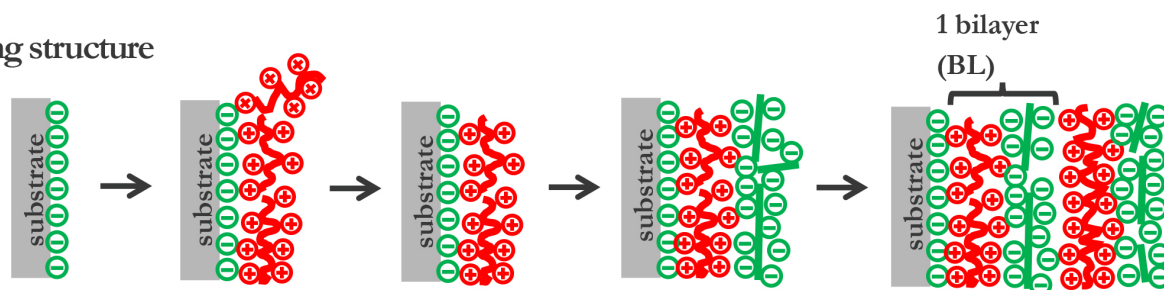
NETL maintains mechanical testing facilities and microstructural characterization laboratories for joining microstructure characterization.

LbL Assembly

Process



Corresponding structure



Decher G. *Science* **1997**, 277, 1232.

In a typical layer-by-layer (LbL) assembly process, positively and negatively charged components are alternately deposited to produce layered composite membranes.



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