JANA

AN OPERATIONS SOLUTION TO HEAVY HYDROCARBON PERMEATION IN GAS PIPELINES

A JANA White Paper **September 2021**

Executive Summary

Heavy hydrocarbon (HHC) permeation of plastic gas pipelines is a challenge affecting a growing number of gas distribution companies. Eliminating or reducing the ingress of the HHC can be an effective solution. In the meantime, gas distribution company field crews must continue to join to HHC pipe as part of normal operations, considering not only the immediate safety concerns but the long-term integrity of the pipeline system. To safely maintain plastic pipe systems without relying solely on mechanical fittings, it is necessary to ensure the fitness of fusions on HHC contaminated pipe.

Background

Heavy hydrocarbon (HHC) permeation has been a known potential threat since shortly after the introduction of PE pipe. Historically, the issue has been associated with very localized soil contamination (e.g., near gas stations, at sites of homeowners dumping hydrocarbons, etc.) that impacts a limited segment of pipe where localized mitigations can address the issue (e.g., replacement with steel pipe). Over the past several years, though, the gas distribution industry has observed HHC permeation in plastic gas pipelines more broadly within gas networks.

Based on discussions with operators and a detailed field study conducted by JANA, the more recently observed contamination is distinctly different than historical HHC permeations:

- The contamination is coming from the gas stream and not due to external contamination, as evidenced by its broadly distributed nature and higher HHC contamination on the inner pipe surfaces
- Contamination levels appear to be low to moderate and, while resulting in noticeable bubbling at the pipe surface on heating, contamination is generally not associated with any visible discoloration of the pipe (i.e., it is not possible to identify contaminated pipe by visual assessment)
- The broad scope of the issue within gas networks does not lend itself to traditional historical approaches (e.g., replacement with steel pipe)

Generally, the industry is employing mechanical fittings in areas of suspected HHC permeation. The use of these fittings introduces additional cost and time in field operations. Further, there is a potential risk of future leaks from these fittings.

The problem is not static as HHC permeation appears to be spreading within gas distribution systems.

HHC Source

Based on the reported widely-distributed nature of the contamination – supported by analysis of field samples that shows the contamination is highest on the inner pipe surface and not associated with local soil contamination – it is clear the contamination is coming from the gas stream. There is no definite scientific analysis of the source of HHC within gas pipelines; however, it is hypothesized (and supported anecdotally) that shale gas from the Marcellus region is accompanied, at some level, by HHC and is not being successfully removed prior to entrance into gas distribution systems.

Regardless of its specific source, this last point appears to be correct: there is a point of entry into multiple gas distribution companies' pipeline systems for HHC.

Approach Toward a Solution

There are two parallel avenues that can be taken to address the issue of HHC permeation:

1. Eliminate or reduce the ingress of HHC into the Distribution System
    - Identify ingress points into distribution system
    - Eliminate entry or reduce concentration of HHC into distribution system
    - Monitor HHC levels to ensure ingress has been mitigated
    - Give PE Pipe ability to "heal" once contamination has been removed
        - It has been verified by JANA that once the source of contamination is removed the HHCs will diffuse out of the pipe over time
2. Ensure Fitness for Fusions on Contaminated PE Pipe via an Engineering Assessment
    - Determine at what concentrations hydrocarbons affect fusion integrity
    - Develop method for measuring concentration of HHC or measuring the quality of field joints should that prove to be problematic in the field
    - Complete an Engineering Assessment to support using fusions on contaminated pipe, if applicable, in specified applications to reduce the use of mechanical joints

Ensuring Fitness for Fusions

The elimination or reduction of HHC in the gas supply is a laudable goal. In the meantime, and for some time thereafter, field operations will need to maintain the gas distribution system. This must be supported and facilitated by ensuring the fitness for fusions on contaminated PE pipe.

To ensure the fitness for fusions on HHC contaminated PE pipe, an Engineering Assessment is required. This Assessment establishes the process and constraints to effectively employ fusions on contaminated pipe and addresses three key components to ensure the suitability of fusion joints.

Component 1: Integrity of Fusion Joints

For a specific pipeline operator with a known level of HHC contamination, previous but limited JANA analysis determined that there were no apparent short-term strength reductions due to HHC contamination (i.e., lowering of pressure strength). The analysis also determined that the electrofusion joints met validation requirements and would survive long-term.

- For electrofusion joints, in general, a more robust assessment of HHC contaminated pipe with known levels of contamination is required
  - This Assessment should include appropriate testing to verify the performance of electrofusion joints: ring tensile, hydrostatic testing (elevated temperature testing to validate long-term performance using Popelar Shift) and fusion evaluation testing (FET)
- For butt fusion joints, a similar test program is required
  - This Assessment should include similar testing as that required for electrofusion joints, replacing FET with bent strip testing
- The Engineering Assessment should also identify any differences in fusibility considerations based on pipe manufacturer and pipe vintage

Component 2: Risk Associated with Fusion Joints vs. Mechanical Joints

The risk associated with fusion joints and the risk associated with mechanical joints for HHC contaminated pipelines should be quantified based on historical leak rates in the gas company's system and historical industry leak rates, combined with previous JANA analyses and the assessments detailed it Component 1: Integrity of Fusion Joints.

Component 3: Field Procedures to Confirm Joint Quality

Field procedures should be developed by field operations personnel to assess the suitability of conducting a fusion based on a preliminary assessment (e.g., estimating HHC saturation level in contaminated pipes with a trial fusion)

Additional Tool

At conditions replicating those identified in the field – including typical, worst case to-date and higher contamination levels – the ability of jaNaDeTect to identify fusion quality for electrofusion tees and butt fusion joints can be verified.

Field Trials

Implementation of jaNaDeTect* includes the execution of field trials of both the process and the tools, with targeted Operations engagement for practical optimization and validation.

- To ensure operational functionality of the process developed for assessing fusibility and ensuring fusion quality, field trials will be conducted with two (2) gas company field crews

**For detail on the Field version of jaNaDeTect™, see Appendix A*

APPENDIX A: JANADETECT

General Product Profile

With the excellent projected longevity of current generation PE gas piping, a key component of ensuring future pipeline integrity must be centered on ensuring the integrity of the joining techniques. JANA's approach to non-destructive evaluation of joints uses technology that is based on ultrasound; this process is more effective than previous ultrasonic methods due to JANA's unique approach to analyzing the sound waves.

The objective of jaNaDeTect is to equip gas distribution companies with the ability to detect anomalies of joints on polyethylene pipe, thus improving the quality of the installed pipe and lowering the overall risk associated with its operation.

After significant end-user trials, JANA has developed the technology to a point whereby a 94% level of accuracy in finding anomalies has been achieved. To further support this technology, JANA led the development of an ASTM standard via the ASTM E07 Committee on Nondestructive Testing. The standard was published as *ASTM E3044: Standard Practice for Ultrasonic Testing of Polyethylene Butt Fusion Joints.*

Benefits of jaNaDeTect

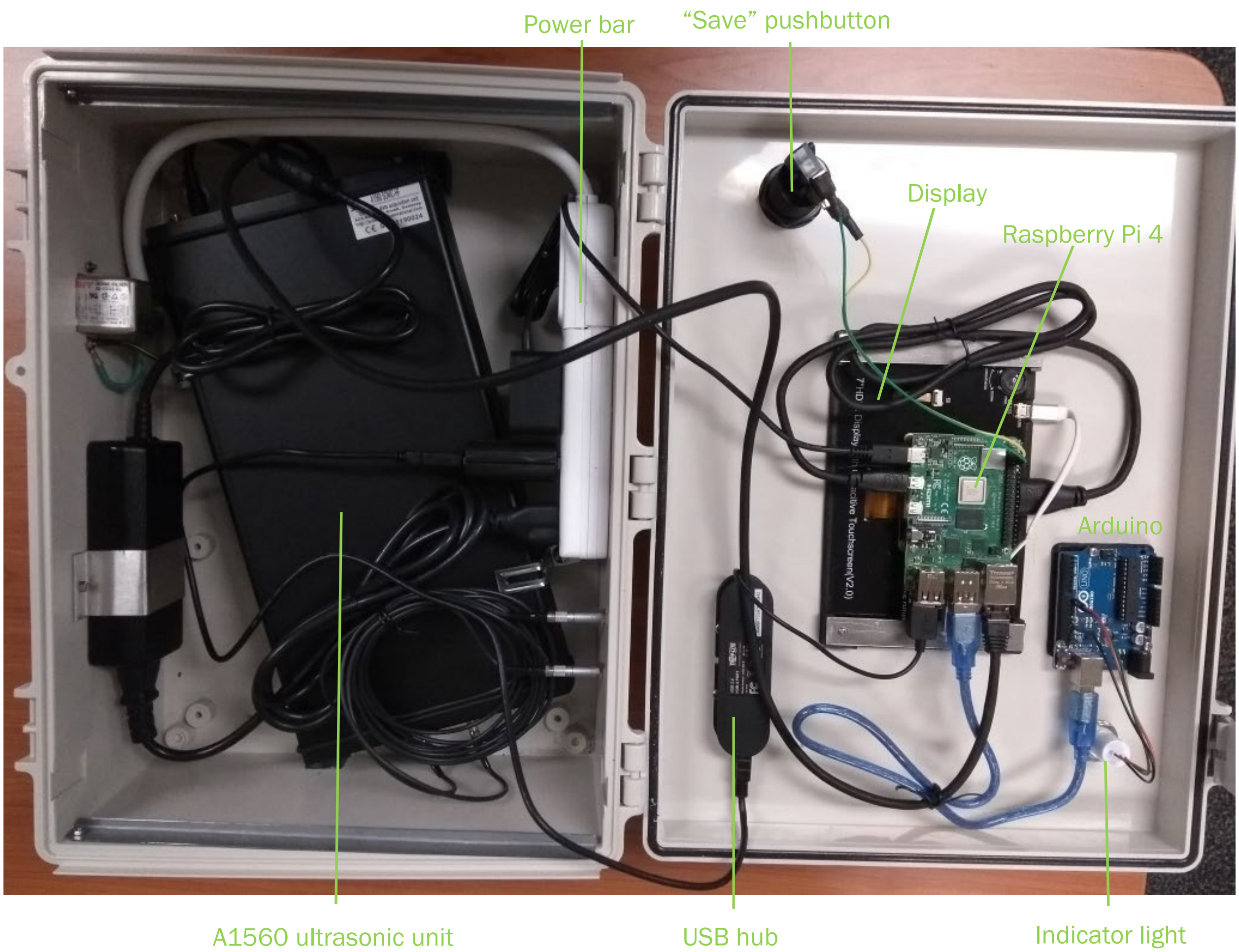
Simple to Use

The jaNaDeTect tool is simple to use as it is compact, provides a green/red pass-fail output and its patented technology ensures that accurate readings are taken. Analysis of a 4" electrofusion coupling takes 5 – 15 minutes.

The developed tool is hand-held, rugged and portable (Figure A2). Given the very low profile of the end of the probe, it can be used in very tight areas and measure right up to shoulders, nipples and other molding irregularities. The probe needs to be in direct contact with the surface, which is achieved using a coupling gel.

The A-Scan output – a string of numbers representing the power received by the receiver in time increments – is processed to provide a green/red light for a pass or fail of the joint. It is also possible to determine the type of void and, hence, the most likely cause of the joint failure so that corrective action can be taken. Roughly thirty readings are taken each second. Repeatability is excellent so averaging of the spectra is not required.

Figure A1: jaNaDeTect Hardware



Highly Accurate

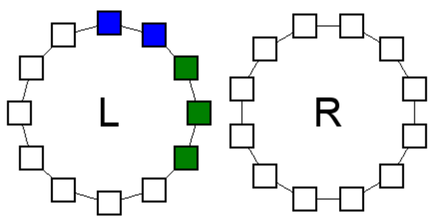
The key feature of the jaNaDeTect technology is the high level of accuracy in identifying all failure modes observed in the field. The system has now been verified through testing of over 1000 pipe joints of various sizes between 1" and 20" in diameter. Excellent correlation has been achieved for voids, cold zones and contamination detection. The recent developments in spectral processing enabled identification of defects with 100% accuracy on the latest set of welds run.

To verify and calibrate the jaNaDeTect system, an extensive testing program was initiated on a wide range of joints (different sizes and manufacturers) with a range of defects both intentionally created and from actual field specimens. The NDT results were correlated with the results of destructive testing.

For each inspection session, jaNaDeTect provides the following:

Joint Map

The Joint Map is a .png image file which shows the joint map for the left side (L) and right side (R) from the perspective of the inspector.

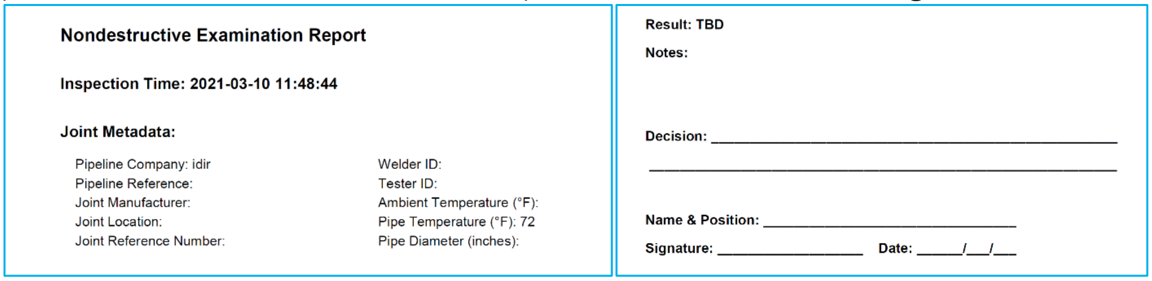


Each position in the joint map is colored according to classification result:

- Green: Clean
- Blue: Contamination
- Red: Cold Fusion

Inspection Report

The Inspection Report is a .pdf file which summarizes the results of the inspection session. It contains metadata regarding the inspection session, the Joint Map, results, notes from the visual inspection, places for handwritten decision rationale, and places for the decision-maker to sign and date



Nondestructive Examination Report

Inspection Time: 2021-03-10 11:48:44

Joint Metadata:

Pipeline Company: idir
Pipeline Reference:
Joint Manufacturer:
Joint Location:
Joint Reference Number:

Welder ID:
Tester ID:
Ambient Temperature (°F):
Pipe Temperature (°F): 72
Pipe Diameter (inches):

Result: TBD

Notes:

Decision: ____

____

Name & Position: ______________________________

Signature: __________________ **Date:** ______/___/___

Session Details

The Session Details are captured via a text file in JSON format and contain human-readable session metadata.

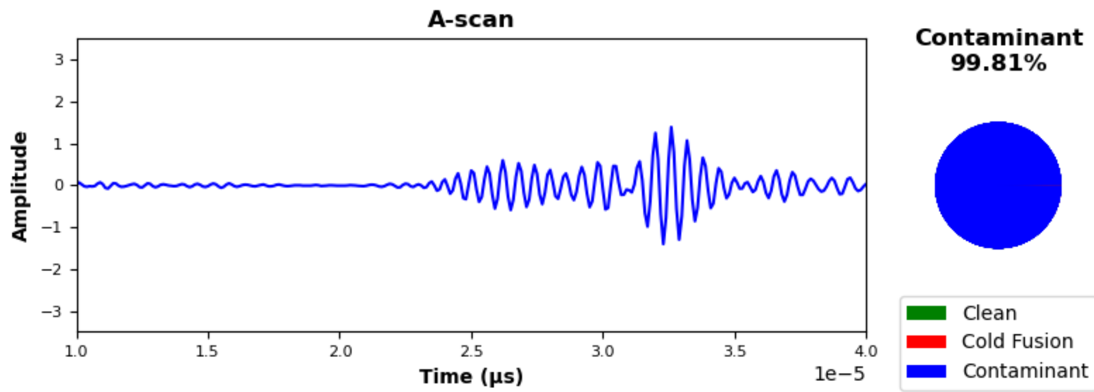
A-scan Data and Waveform Images

When an ultrasonic measurement is saved, the program creates two files: (1) A-scan Data and (2) Waveform Image.

The A-Scan Data is a .csv file that includes the following Data:

- Session Metadata in JSON format
- Class Result (i.e., clean, contaminant, cold fusion, etc.) and numerical scores for each Class
- A-scan Time Series, including time and wave

The Waveform Image is a .png file that captures the exact waveform which was shown on the screen when the ultrasonic measurement was saved, along with its class breakdown pie chart.



jaNaDeTect Equipment

The jaNaDeTect technology is based on A-scan ultrasonic analysis coupled with a spectral analysis algorithm. The hardware consists of the following as a minimum spec (specifics may be altered to address supply disruptions associated with the COVID pandemic):

- ACS 1560 HF ultrasonic unit with power supply
- Raspberry Pi 4 with power supply
- 7" HDMI Display with touchscreen DFR0506
- Arduino UNO
- USB hub with power supply
- Power strip with switch and surge protector
- Pushbutton
- Two-color indicator light
- Ethernet cable
- Cable HDMI – microHDMI
- Cable USB A male – USB miniB
- Cable USB A male – USB B male
- Two LEMO 00 through panel couplers
- Two LEMO 00 – LEMO 00 RF cables
- Plastic carrying case

jaNaDeTect includes a high-frequency A1560-SONIC-HF ultrasonic unit. Data digitized through an ethernet connection are transferred into a Raspberry Pi 4 computer for processing and storage. Estimation of joint quality is done by AI algorithm using the Arduino platform.

For butt fusion joints, the transducer itself is a special custom design through transmission where the wedge is enclosed and a pulser receiver is placed on one side. The receiver and emitter have 1.8 MHz frequency.

For electrofusion joints, the transducer utilizes the pulse/eco method with 0.25” diameter and 2.25 MHz frequency.

Figure A2: jaNaDeTect Components