Genuine Determination of Electrofusion Fitting Joint Integrity

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For buried gas distribution pipelines, the majority of the future risk profile is set when the pipelines are installed. In effective Pipeline Safety and Asset Management Systems, it is critical to ensure the integrity of new pipeline installations. 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 joints. At AGA's 2017 Operations Conference and Biennial Exhibit, JANA demonstrated a novel approach for non-destructive evaluation of electrofusion coupling and saddle joints that uses ultrasound to determine joint quality. An update on the development of the technology is presented, including results from industry sponsored blind tests, field trials and beta testing. Also outlined are the many ways the technology has been found by users to integrate within their operations.

Background

Electrofusion fittings are seeing increased use in gas distribution pipelines. While electrofusion (EF) joints can be highly reliable, quality components and installation techniques are necessary for ensuring the long-term integrity of the joints[1]. The Plastic Pipe Database Committee (PPDC) has identified an elevated number of leaks associated with new pipe or appurtenances installations within the first five years and operators have reported the cause of these leaks as installation error[2]. In 2017, the PPDC reported that 44% of all failures/leaks occurring within the first 5 years were due to installation error[3].

Similarly, a comprehensive study of electrofusion joints in the UK[4] found that 20% of sampled field joints failed in destructive testing. The primary causes of failure in this study were identified as:

- Inadequate clamping or misalignment: 34%
- Contamination: 29%
- Poor scraping: 26%
- Other: 11%

The PPDC[3] has suggested that

- *"operators remain vigilant in their efforts to maintain their operator qualification programs, training programs, installation procedure reviews and inspection efforts to assure the integrity of their systems."*

A major characteristic of EF joints is that the fusion between the pipe and fitting is completely hidden from the operators view. There are few visual indicators of what has happened during the fusion process so it can be challenging to know the quality of the fusion.

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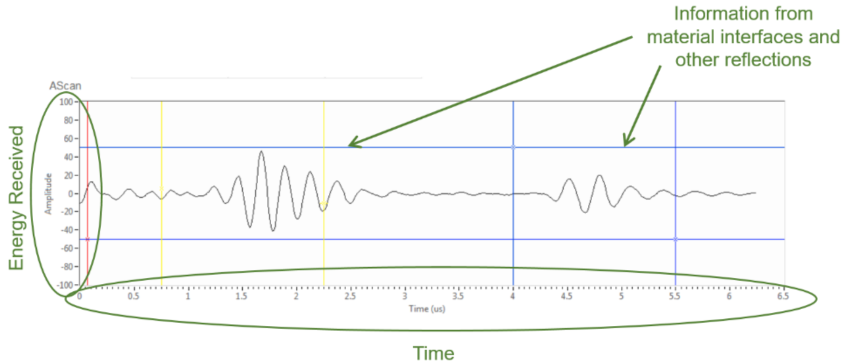
[1] NTSB Safety Alert – Safety Through Reliable Fusion Joints, June 2015.
[2] Plastic Piping Data Collection Initiative Status Report, August 2014.
[3] Plastic Piping Data Collection Initiative Status Report, August 2017.
[4] UK WIR Report Ref No 10/WM/08/43, "Leakage from PE Pipe Systems", 2011.

Ultrasonic Inspection of Electrofusion Joints

The goal of ultrasonic inspection is to "see" the hidden regions of electrofusion coupling and saddle joints in order to assess joint quality. The simplest method is a pulse-echo system, using a single probe transducer and presentation of results in the form of an A-Scan (time domain trace). It is also the least expensive system using only one probe and modest electronics. Figure 1 shows a typical A-Scan trace – an X, Y plot showing energy received (Y axis) vs time (X axis). Information from the material interfaces and other reflections are contained in the sinusoidal wave shape.

Figure 1: Typical A-Scan Trace



A simple-to-use, cost-effective and highly accurate tool based on A-scan technology has been developed. The key to this methodology was the development of a novel approach for analysis of the sound waves. The sinusoidal wave form output from an A-scan contains a significant amount of information about the substrate through which the sound passes. Good welds with no defects produce a very distinctive sinusoidal trace where the 'ring down' from the wires is overlaid by the various weld reflections, resulting in slight changes to peak height and received frequency.

The various defects that are found in EF joints produce distinct changes from a typical good weld trace. These can be identified by both the operator and, with the appropriate algorithms implemented, automatically by the computerized tool, providing a go-no go output.

Based on input from gas distribution operators, the tool was developed to be:

Simple to Use and Rugged

- The tool is designed for use by regular operators and inspectors, not a dedicated NDT specialist
- The tool is simple to use as it automatically detects a full range of anomalies for the operator
- The tool leads the operator through each step of the analyses and operators can be trained in using the tool quickly
- Designed and tested for use in the ditch.

Cost Effective

- A very cost effective method. This, coupled with the ease of use, provides a viable means of achieving 100% joint inspection, even to the point of enabling each fusion crew to have joint inspection capabilities
- A low per-unit cost, the tool can be employed widely in the field. Lost cost hardware that can take advantage of most existing field computers.
- Rapid joint inspection. A 4" electrofusion tapping tee takes 5 – 15 minutes
- Full and automated data capture, traceability and reporting.

High Accuracy and Flexibility

- A key feature is a high level of accuracy in identifying issues within EF joints
- Excellent correlation has been achieved for detection of all typical EF defects.
- Works with all major brands of EF coupling and saddles
- Sizes 1" through 20" diameter.

Specifically, this NDT technique can identify the following type of defects, giving a green/red light (pass/fail) indication:

- Non-fused
- Incomplete fusion
- Voids (various causes including moisture, hydrocarbon permeation, etc.)
- Contamination (e.g., oil, dirt, mud)
- Under-insertion
- Movement before cooldown
- Misalignment
- Over- or under- scraping
- Pipe ovality

Industry Blind Testing

A blind Proof of Concept trial was conducted with NYSEARCH with the purpose of demonstrating the technology's detection capabilities. Multiple member companies from NYSEARCH provided coupling and tapping tee joints with unidentified defects for assessment. Twenty-six samples with 28 joints were prepared using different materials, sizes and manufacturers for the pipe and fittings. NDT assessments were conducted on each joint.

Overall, the NDT technology achieved a 93% correlation rate between the observed anomalies and joint quality. There were 22 joints of poor quality and 6 joints of good quality in the study. The technology successfully detected anomalies in all joints of poor quality (22/22). The technology successfully detected no anomalies in the fusion zone of 4 of the good quality joints. The NDT detected anomalies in 2 of the good quality joints

Interestingly, two joints in the study that were intended to be prepared as poor quality joints were determined to be of good quality through the NDT assessment. Additionally, two joints that were intended to be good quality joints were determined to be of poor quality through the NDT assessment and verification by destructive testing. These results were confirmed through by destructive testing.

Field Trials

As initial design verification, JANA sent a technician into the field of a gas utility to test the feasibility, durability and practicality of the technology in the real application. Testing was done in conjunction with a major utility in 2 locations, in northern and southern US for a total of 3 weeks, as part of their regular construction.

During those 3 weeks, 27 joints were inspected ranging from 2" – 8" coupling and tapping tee EF joints. From the 27 joints, 6 were identified as having a significant level of anomalies, one of which blew off during a subsequent pressure test.

The high rate of joints with significant anomalies (22%) led to a quick investigation as to the cause. The technician and utility engineer were able to use the NDT technology as a tool for a root cause analysis to determine that the observed voiding was a result of clamping issue with the tapping tees.

These trials demonstrated that the technology was practical and robust enough to be used within typical gas installation/maintenance environments and proved a very useful tool to determine joint quality before the joint is buried. The findings resulted in rapid acceptance of the NDT results by the field crews. There had been some concern that the inspections would affect the work pace but it was found that this wasn't really the case. With some logistics, the inspections could be done without impacting the productivity of the crews.

Beta Program

To further validate the technology and drive development, JANA initiated a 1-year beta test programs with 5 major gas utility companies. The purpose was gain critical feedback from real users based on extended field trials. The companies were provided with NDT hardware/software and 3-9 inspectors per company were trained. The software was configured to accommodate the range of products used by the companies which included couplings and saddle tees from 0.5" to 12" from +GF+ Central Plastics®, Friatec®, Innogaz® and M.T. Deason®.

The beta program is still in progress. Users have found that a couple of days of classroom and hands-on training gets them fully operational and independent in the field: this is expected to be significantly improved as further automation is introduced into the software.

Inspections have been done in multiple environments, ranging from -20°C to +30°C. Two of the five companies have shared anecdotal results from their field inspections. The initial results showed that Company 1 found 3/30 (7%) joints with significant anomalies and Company 2 found 2/20 (10%) joints with significant anomalies. These are joints that had passed normal visual inspection.

The beta test companies are using the technology in different but complementary ways as discussed below under Potential Uses. The main challenge for those using it in the field was planning which joints to inspect and working with contracting crews to coordinate this, due to the novel nature of the project. However, delays can be avoided or minimized with careful planning and coordination.

The beta program has been critical in setting the future product roadmap. Already, based on operator feedback, significant improvements in the usability of the software have been implemented including a redesign of the software to enable touchscreen technology, auto-calibration, automation of data gathering, and automation of decision making. This has significantly reduced setup time and allows the focus to be on conducting the inspections.

Potential Uses

One major learning that came out of the beta program was the multiple ways this technology can be beneficially applied:

Second Inspections
In addition to the operator's visual inspection, the technology can be used as a second inspection, for some or 100% of joints. The operator's knowledge that more in-depth inspection capabilities could be deployed at any time has the added benefit of driving quality practices at all times.

Critical Inspections
The technology can be specified for certain critical joint types or joints in certain critical locations. For example, large diameter joints which are difficult to make or joints in high consequence areas (e.g., high density areas).

Quality Assurance/Quality Control
The technology can be used as part of the Quality Assurance program.. Current practice is typically to dig up and visually inspect joints without destructive testing. Visual inspections on EF joints provide little insight whereas the NDT method can provide substantially more and valuable information.

As part of a structured sampling program, the performance of the electrofusion program can be measured to determine an reliability of the operator qualification programs, training programs, installation procedures and inspection efforts. This can also be done on a complete range of fittings, or on a subset of fittings such as tapping tees, without interrupting gas flow.

Contract Pipeline Acceptance
It can be used to monitor contractor performance or as part of an pipeline acceptance criteria. Again, this approach has the added benefit of providing a driver of quality of every contractor.

Operator Qualification/Training
The technology can be incorporated into operator training, qualification, and requalification program to replace or supplement destructive tests saving time and providing immediate feedback. Per US DOT, test joints can be verified using NDT methods or through destructive tests. Additionally, OQ requalification can be done in the field using actual joints under real conditions without removal of the joints.

Post Installation Verification
Where operator workmanship may have been called into question, samples of their work can be excavated and the technology can be used to determine joint quality of without the need for interrupting gas flow or removal of the joint.

Dispute Resolution
Where the visual inspection results are ambiguous, or in instances of disputes, the technology can provide timely and cost effective additional information to make a final determination, potentially avoiding removal and repair of the joint.

Potential Future Developments

It is clear that the technology has numerous beneficial uses and can lead the industry to a higher level of joint quality and integrity. The product roadmap promises on-going improvements in usability with an increase in the scope of applications.