IT
INSPECTION TRENDS
NOVEMBER 2024
THE MAGAZINE FOR MATERIALS INSPECTION AND TESTING PERSONNEL

Enhancing Weld Inspection with the Latest UT Techniques

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[**NOVEMBER 2024** | VOLUME 27 | NUMBER 4]

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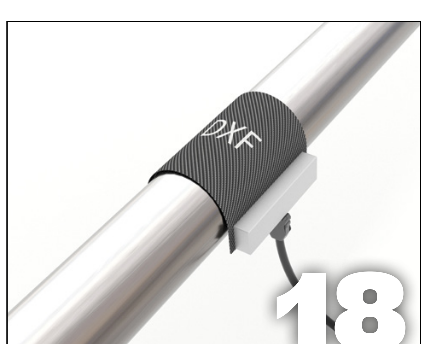
INSPECTION TRENDS (ISSN 1523-7168 Print) (ISSN 2689-0631 Online) is published quarterly by the American Welding Society. Editorial and advertising offices are located at 8669 NW 36 St., #130, Miami, FL 33166; telephone (305) 443-9353.

AWS MISSION STATEMENT: The mission of the American Welding Society is to advance the science, technology, and application of welding and allied joining processes worldwide, including brazing, soldering, and thermal spraying.

COVER PHOTO:
A phased array technician using a TFM scan to supplement a standard PAUT sectorial scan. (Credit: Sonatest)



2025 IEC: Performing Inspections to Perfection

BRENT E. BOLING

Over the years, AWS has promoted various successful conferences for many sectors of the welding industry. Beginning with its inaugural presentation in January 2020, the Inspection Expo & Conference (IEC) has become an outstanding opportunity for the inspectors involved in the quality of these varied production sectors.

The IEC has established itself as a premier event focused on the needs of inspectors from all sectors of the welding and joining industry. With event participants, speakers, and exhibitors from AWS, AISC, NDTMA, and AMPP, the event has something for everyone involved in piping, structural, nondestructive examination, coatings, energy, automotive, aerospace, bridges, and much more.

After a great start from its 2020 debut in Houston, Tex., the event hit a major stumbling block due to COVID-19 that delayed further conferences for three years.

In November 2023, the IEC finally had a resurgence in Austin, Tex., and it was another success. The location, venue, topics, and speakers were all a great fit for the gathering of inspectors who came expecting to learn from industry experts and perfect their ability to perform inspections.

Many aspects of IEC are still in flux as the organizing committee attempts to plan for an event that is convenient and high quality. We prioritize not having too many prominent events in close conflict with each organization's conference schedules. Our organizing committee takes into consideration the time of year, location, type of venue, cost of housing, local attractions, availability of speakers, and much more. This committee has members, many of whom are certified inspectors, from all participating organizations and others.

From the committee to the speakers to the participants, the event is truly by inspectors, for inspectors. What better way to be prepared to perform inspections to perfection than spending time with industry experts with amazing backgrounds? The networking opportunities are just as impressive. There are also professional development hours available for the time spent learning from industry experts. The benefits for guests make this a must-attend event.

The third IEC is scheduled for February 5–7, 2025, at the Marriott St. Louis Grand, St. Louis, Mo. You can find all the information by visiting ***aws.org/community-and-events/conferences-and-events/iec***. Looking forward to seeing you there. IT

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ASNT Certification Services and AWS Collaborate on Certification Initiatives

The American Society for Nondestructive Testing (ASNT) Certification Services, Houston, Tex., and AWS, Miami, Fla., have formed a relationship aimed at advancing the art, science, and technology of welding and nondestructive examination (NDE). This collaboration will focus on harmonizing requirements for certifications and expanding the global reach of both organizations through various training and certification programs.

This partnership allows for sharing of authorized training programs, examinations, and certification facilities, creating a more cohesive and integrated approach to certification. By working together, the two organizations aim to deliver enhanced value to their members and the broader industry.

Richard Arn, AWS vice president of welding technology, stated, "The American Welding Society is excited to partner with The American Society for Nondestructive Testing to develop certification products that will benefit the members of both associations. We look forward to collaborating with them closely over the course of the next few months to begin to materialize these opportunities."

Paul Lang, ASNT chief global strategy officer and ASNT Certification Services executive director, said, "This partnership represents a significant step forward in aligning our respective certification programs. By combining our expertise in welding and nondestructive testing, we can provide more comprehensive and globally recognized certifications. We are committed to fostering innovation and excellence within our industries, and this collaboration is a testament to that commitment."

Through this agreement, the focus will be on harmonizing certification program qualification requirements to ensure that professionals in both the welding and NDE fields have access to top-tier training and certification opportunities. By aligning their efforts, both organizations are setting a new benchmark for quality and consistency in the certification landscape.

Item-Writing Workshop Trains CWIs in Exam Question Development

AWS held a Certified Welding Inspector (CWI) Item-Writing Workshop August 27–29 at its World Headquarters in Miami, Fla. Six volunteer CWIs joined four AWS staff for two and a half days of training in item-writing strategies for certification exams, practice item writing, and collaborative item review.

The AWS assessment team's exam developers facilitated the event. Participants gained valuable knowledge in the science of assessment and question development and made substantial contributions by creating new questions for AWS Certification exams.

The volunteer subject matter experts bring real-world experience and up-to-date knowledge from the field, which helps ensure that exam content accurately reflects current industry practices and standards. Their expertise is important for maintaining exam content that is relevant and valid.

(From left) Mark Pidal (exam developer), William Marchant (exam developer), Brad Brewer, Shawn Barrett, Brian Wall, Elmer Duerte, Dale Hartsock, Daniel Balson, Kyle Holbert (welding consultant), and Andrew Henderson (exam developer) participated in the CWI Item-Writing Workshop.

Inspection Expo & Conference Explores Latest NDE Methods and More

The Inspection Expo & Conference (IEC) will be held February 5–7, 2025, in St. Louis, Mo. AWS, the American Institute of Steel Construction, the Association for Materials Protection and Performance, and the Nondestructive Testing Management Association are joining forces to deliver a comprehensive event designed by inspectors for inspectors.

Visitors will be able to engage with industry experts, gain valuable insights, and network with fellow professionals at the forefront of inspections and materials integrity. Presentations will delve into the latest methods in welding inspection, nondestructive examination (NDE), coating inspection, and structural steel inspection. Attendees can learn about specific applications across various sectors, get updated on the latest industry standards and certification processes, engage in thought-provoking discussions on ethics, and more.

Early bird pricing is available until December 20. Visit *aws.org/Community-and-Events/Conferences-and-Events/IEC* to learn more.

AWS Certification Exam Eligibility Period Reduced

The eligibility period to schedule AWS certification exams has been reduced from 120 days to 90 days after registration. This change only applies to registrations made in or after October 2024; any registrations before this date will still have a 120-day eligibility period.

This adjustment is designed to streamline the exam experience and make scheduling more efficient. AWS is offering support through this transition to ensure the process remains as straightforward as possible. For further assistance, visit *aws.org/Contact-Us*.

AWS Presents Welding Coordination and Quality Assurance Endorsement

AWS, Miami, Fla., now offers a Welding Coordination and Quality Assurance (WCQA) endorsement. This supplemental credential for Certified Welding Inspectors (CWIs) and Senior Certified Welding Inspectors (SCWIs) validates their specialized knowledge in welding quality assurance and coordination. Professionals with the WCQA credential demonstrate proficiency in establishing, auditing, and enhancing quality management systems within an organization to ensure high standards of quality and compliance. Candidates must hold a current CWI or SCWI certification. Familiarity with welding quality assurance practices and coordination processes is recommended before attempting the endorsement exam.

For more information, visit *aws.org/certification-and-education/professional-certification/welding-coordination-and-quality-assurance-endorsement*.

Phoenix International Divers Complete Underwater Inspection at Talos' Thunderhawk Platform

A dive crew from Phoenix International Holdings Inc., Largo, Md., recently completed an underwater inspection in lieu of drydocking for Talos Energy on the Thunderhawk platform in the Gulf of Mexico. The inspection took place June 3–July 12.

Phoenix International divers finished underwater inspection of almost 600 welds at the Thunderhawk platform in the Gulf of Mexico.

Over the course of 36 days, the company's dive crew, equipped with a deep air package, completed 164 dives. The crew, consisting of six divers, six tenders, and one supervisor, worked 16-hour days to complete magnetic particle inspection of 119 welds, close visual Inspection of 300 welds, and general visual inspection of 200 welds.

Jon Regh, Houston-area manager at Phoenix, stated, "We are pleased to have completed another successful project for long-term client Talos Energy. We have worked extensively on offshore oil and gas facilities all over the Gulf of Mexico for over two decades, and nondestructive testing is a core capability that Phoenix offers our clients to help maintain the quality of their assets."

Laser Photonics Lands Sale with Acuren

Laser Photonics Corp. (LPC), Orlando, Fla., a global developer of industrial laser systems for cleaning and other material processing applications, has completed a sale and is working on a partnership agreement with the U.S. division of Acuren, a provider of asset protection services through nondestructive examination and consulting.

LPC is to deliver its CleanTech Industrial Roughening Laser 3050 (CTIR-3050) to Acuren's U.S. operations in a sale that marks the beginning of the two companies' relationship. They are working together to have LPC join Acuren as a preferred partner for an ongoing purchasing program. This collaboration will provide Acuren with a smooth, expedited path for R&D and product customization processes.

"We are thrilled about working with Acuren — this order represents a major achievement for Laser Photonics as we venture into the nondestructive testing market," said Wayne Tupuola, CEO of LPC. "Our laser surface treatment technology is a sustainable and efficient solution for corrosion removal and the protection of critical infrastructures."

PNDE Builds 13,000-Sq-Ft Addition to Facility

Professional NDE Services Group (PNDE), Fairfield, Ohio, a provider of nondestructive examination (NDE) services throughout the Ohio, Indiana, Kentucky tri-state region, is expanding its facilities to enhance its service capabilities.

Targeted for completion by the end of 2024, the 13,000-sq-ft addition is located at the company's Fairfield headquarters. This additional space allows PNDE to further broaden its laboratory testing capacity and services, including advanced ultrasonic testing, radiographic testing, and digital x-ray inspection.

Mark Koehler, PNDE manager of business development, explained that the new facility is strategic to adding these services and resources in order to remain responsive to the demands of current and future customers.

Professional NDE Services' facility addition will include space for ultrasonic testing, radiographic testing, and digital x-ray inspection.

"This expansion represents not only physical growth but another step forward in our mission to deliver excellence in NDE services," Koehler said. "As the industry continues to evolve, this added space allows us to keep pace with advancing technologies, expanding current techniques, and best practices and remain a trusted partner for our clients seeking reliable NDE solutions."

The addition will also enhance the employee experience with climate control extending beyond office spaces throughout the entire facility.

BY CALVIN E. PEPPER

What the CWI Lifetime Achievement Award Means to Me

How does one say "thank you" to an organization that bestows such a weighty honor as the CWI Lifetime Achievement Award upon one of its members? I've wrestled with this since being honored by the CWI Lifetime Achievement Award Committee during FABTECH 2022 in Atlanta, Ga.

A lifetime of achievement would suggest that the individual has spent most, if not all, of their professional life pursuing this single endeavor. For me, it never seemed like a lifetime of pursuit. My years of working in inspection as both an AWS volunteer and an inspection professional have passed away with alarming speed. I had barely begun before I realized that I was approaching my fiftieth year of professional service to the AWS CWI program and the many industry sectors it has been my pleasure to serve.

The people I met and had the pleasure of working with at AWS and in different industries helped guide and instruct me in the intricacies of our profession, and any recognition that has come to me must be shared with them. We have all been blessed at AWS to have had access to mentors and instructors who set the standard for professionalism and dedication to the science and art of welding.

When coming to the end of a profession, it becomes harder than ever to declare an end to your life's work. I return to my own advice to my children: Find something you love and do it as well and for as long as possible. The end will take care of itself.

Thankfully, I retain a passion for inspection, education, consulting, and volunteerism and will continue to give back to the Society and its members in any way possible. Going forward, I will occasionally look over my shoulder and feel humbled and honored by a plaque and medal hanging prominently in my office. I will also feel a deep sense of pride and gratitude for the honor bestowed on me by my peers. IT

BY KRISTIN CAMPBELL AND CARLOS GUZMAN

Chloë Hudson: The Path to Becoming a CWI

Chloë Hudson is a specialty gas tungsten arc welding (GTAW) welder and a Certified Welding Inspector (CWI) in North Carolina. She was the first hire for Joe Gibbs Aerospace's aerospace program, and with a longstanding desire to work in aerospace welding, this opportunity allowed her to grow alongside a fledgling program from its inception. Her primary responsibilities include welding and fulfilling her role as a CWI.

In 2018, Hudson began her journey toward CWI certification by assessing whether she met the minimum requirements. To her disappointment, she discovered that she did not. During her first job, when she expressed her aspiration to become a CWI, colleagues scoffed at her ambition, dismissing it as unrealistic. Hudson had faced skepticism in the past; some individuals questioned her optimism, having experienced the complex process of becoming a CWI themselves.

As a dedicated professional, Hudson believes proficiency in her field was essential. A lifelong learner at heart, she felt it was crucial to challenge herself. She attended a week-long CWI seminar, recognizing its importance for hands-on learners like herself. Hudson emphasizes how crucial visual and practical explanations are to grasp the material thoroughly, and the seminar proved invaluable. She diligently documented her learning throughout the class, taking pictures of every slide and transcribing her notes into a comprehensive notebook. Surrounded by others who shared her interest in the subject matter, she found the experience enriching. The instructor's engaging teaching style ignited her enthusiasm for passing the CWI test, ultimately enhancing her skills as a welder, coworker, employee, and inspector.

Chloë Hudson

This image highlights a completed titanium airship hub.

Obtaining CWI certification was a significant milestone for Hudson. It gave her a nationally recognized credential that commands respect in any welding environment requiring specific codes. The achievement validated her efforts and brought positive feedback from her supervisors and managers. When her company had the opportunity to bid on a job with SpaceX, Hudson was integral to the sales pitch as an in-house CWI, a role she viewed as a testament to the value she added to her company.

Hudson's journey as a welder and CWI exemplifies her commitment to her craft and her desire to contribute meaningfully to her industry. Through perseverance and a passion for learning, she has advanced her career and positioned herself as a vital asset to her company's future success. A video about her journey is featured on AWS's YouTube channel.

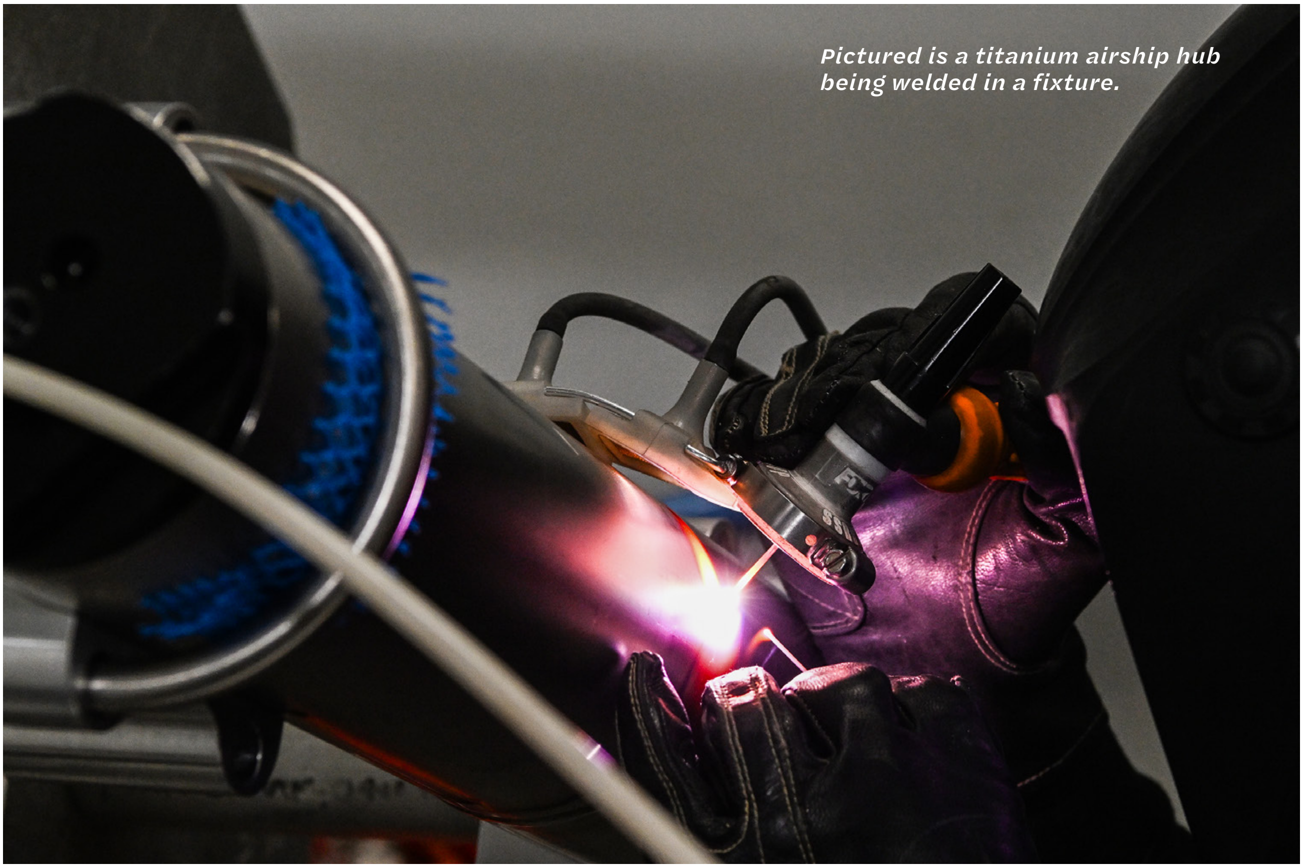
Recently, *Inspection Trends* asked Hudson about all aspects of her career, and below are her answers.

1. How did you get into the welding field, and why have you made it your career?

I initially cut my teeth in the industrial sector with my first job in maintenance for nuclear shutdowns. During this time, I noticed that specialized trades made a far better living. I had welded in high school and found myself proficient enough to continue my education to become a master of a specific trade rather than just a jack of all trades. Returning to a full immersion in a specified skill was the spark I needed to engulf myself in the passion that welding has become.

2. Why did you want to become a CWI, and what did earning this distinction mean?

I wanted to challenge myself with something difficult. I am a forever student and always hungry for a challenge. This was the natural next step to add value to what I bring as an employee.



Pictured is a titanium airship hub being welded in a fixture.

3. How was that goal achieved in addition to studying and taking a one-week seminar?

I studied for six months, using every single moment of downtime. I wanted to do the most difficult CWI course (D1.1). I read that code book cover to cover, made flashcards, and did everything I could to prepare. I am extremely proud to wear that badge. It's one of the most difficult things I've ever accomplished.

4. What are your current jobs?

I work part-time at Joe Gibbs Aerospace and full-time at Tony Stewart Racing. I also recently started my own company and work from my shop at home during the offseason.

5. What parts do you inspect on the job now, what are your inspection responsibilities, and what are you looking for to ensure quality? Also, what AWS codes are followed in doing so?

I inspect titanium hub parts and operate under AWS D17.1, *Specification for Fusion Welding for Aerospace Applications* (this project is considered experimental). The guidelines for this project require parts that are near perfect every time. There are very small margins for error, and I am both a welder and an inspector, so the pressure is on for each part produced.

My main focus is visual inspection. After each visual inspection, we also do a penetrant test using a Zyglo machine,

This view shows a butt joint for the start of a titanium airship hub.

looking for surface cracks and ensuring proper fusion at each welded junction.

6. What's both challenging and cool about your position?

There's a lot of pressure to perform, which is incredibly stressful and challenging. Perfection is demanded because of the cost of each part, but the finished product and the airships they go toward building are incredibly rewarding. This project is based on a humanitarian effort to deploy these airships to disaster areas to aid those affected.

7. What advice do you have for individuals who want to become a CWI?

Commit yourself to the process. It's not something to be taken lightly and can't be put on the back burner. It requires dedication and focus, but the pride that comes with accomplishment is worth any trials and tribulations faced in the process.

8. What are your future plans?

I have committed myself to achieving my pilot's license in the coming weeks, and gearing myself to be more immersed in the aerospace, Federal Aviation Administration, and aviation sectors will be the next challenge on the horizon. I also plan on taking on more of a consulting role as far as being a CWI goes from my personal business. But all things considered, I am extremely happy where I am currently, and if nothing changes in the next five or ten years, I will be content. IT

Above is an airship docked to a mooring mast. Numerous airship parts and components as well as the mooring mast itself were built. Everything was welded from 12-in. I-beams to 0.035-in.-wall titanium tubes.

KRISTIN CAMPBELL (*kcampbell@aws.org*) is managing editor and **CARLOS GUZMAN** (*cguzman@aws.org*) is editor of *Inspection Trends*.

A phased array technician using a TFM scan to supplement a standard PAUT sectorial scan. (Credit: Sonatest.)

Enhancing Weld Inspections with Advanced Ultrasonic Techniques: FMC, TFM, and TFMi

BY WILL HAWORTH

Ultrasonic testing (UT) has long been essential for inspecting welds, particularly in industries where structural integrity is crucial. Recent advancements, such as full matrix capture (FMC) and total focusing method (TFM), have pushed the boundaries of weld inspection, offering improved capabilities over conventional phased array ultrasonic testing (PAUT).

FMC and TFM address limitations in traditional PAUT, particularly in detecting, sizing, and characterizing complex flaws. The latest development, Intermodal TFM (TFMi), enhances these methods by combining multiple propagation modes, offering even greater accuracy.

While PAUT remains the standard in many inspection codes, including AWS D1.1, *Structural Welding Code — Steel* and AWS D1.5, *Bridge Welding Code*, FMC and TFM provide valuable supplementary tools for enhancing inspection quality. Though not yet universally accepted, these techniques offer superior imaging and flaw characterization, making them indispensable where higher precision is required.

This article explores how FMC, TFM, and TFMi improve weld inspections, offering clearer imaging and more reliable flaw detection that position these techniques as key advancements in UT.

Full Matrix Capture

Full matrix capture (FMC) is a significant advancement in UT that captures raw data from all elements in an ultrasonic array. Unlike traditional PAUT, which focuses at a predetermined distance, FMC records every A-scan signal between each combination of transmitting and receiving pairs of elements, creating a comprehensive data set that can later be postprocessed into highly detailed images.

How FMC Works

During FMC acquisition, each element of the phased array probe transmits a pulse one at a time while all the other elements receive the returning signals. This process is repeated for each element in the array, so if you have a 64-element transducer, each element pulses once, and every other element receives the signals, generating a total of 4096 A-scans (64 × 64). These A-scans are stored and later processed to reconstruct detailed images of the weld.

This comprehensive data collection enables flexibility during postprocessing, allowing advanced imaging techniques like TFM to be applied. By capturing data from every possible transmit-receive combination, FMC gives inspectors a complete view of the weld, providing improved flaw detection and characterization compared to conventional PAUT methods, which rely on fewer data points — Fig. 1.

Total Focusing Method

TFM is a postprocessing technique that converts FMC data into fully focused images across the area of interest. Unlike PAUT, which focuses only on specific points using preset focal laws, TFM provides high-resolution images by calculating the behavior of the ultrasonic wave for each pixel in the inspection area — Fig. 2. However, TFM relies on a single propagation mode selected by the inspector before scanning. This mode could be direct, reflected, or mode-converted, concentrating on a single leg or skip of the ultrasonic beam's travel path.

How Propagation Modes Work

Propagation modes describe ultrasonic waves' paths as they travel through a material, including how they interact with defects and material boundaries. A direct wave travels through the material and echoes back from the flaw, while reflected waves bounce off surfaces like the backwall. Mode-converted waves switch from one wave type to another, such as from longitudinal (L) to transverse (T) or vice versa, when they encounter a defect or boundary, like the crown or root of a weld.

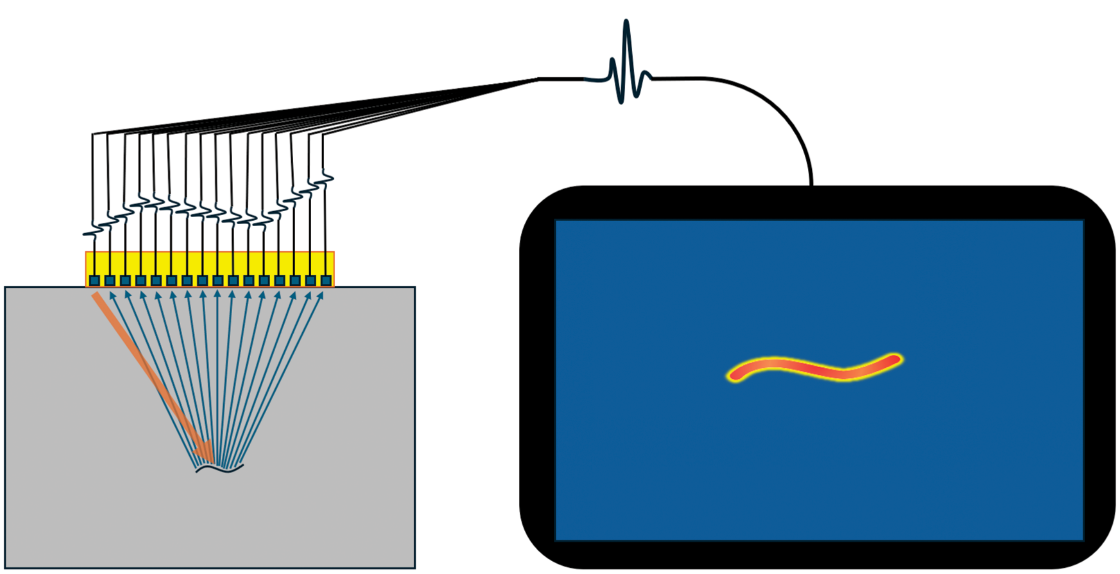
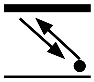


Fig. 1 — FMC data acquisition with TFM processing. (Credit: Sonatest.)

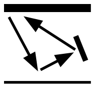
Fig. 2 — Example of TFM imaging. (Credit: Sonatest.)

In TFM, the inspector selects a specific propagation mode before scanning, and that mode determines the wave path being analyzed. The mode's name indicates the number of reflections and mode conversions. For example:

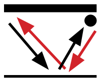
- TT means the sound travels as a transverse wave to the defect and then directly back to the probe.



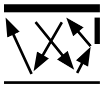
- TTT indicates the wave bounces off the backwall, then the defect, and returns to the probe, or vice versa.



- TTTT involves a reflection from the backwall, then the defect, another reflection from the backwall, and then back to the probe.



- TTL means the wave travels as a transverse wave, reflects off the backwall, mode converts to longitudinal at the defect, and returns to the probe.



More complex modes exist, such as 5T, 6T, and 7T, as well as various longitudinal modes, but are less commonly used in weld inspections. These propagation modes provide critical insight into the location and nature of flaws by capturing how the ultrasonic waves behave as they travel through the material.

Advantages and Limitations of TFM

TFM offers clearer, more detailed images compared to sectorial scans, making it excellent for flaw characterization. However, the need to choose a single propagation mode limits its ability to detect all flaws. For example, selecting a direct wave may miss flaws that are better detected through mode-converted waves or vice versa. Since the chosen mode focuses on a specific part of the beam's travel, defects like off-axis or transverse flaws can go undetected, reducing the overall effectiveness of TFM for complex inspections.

Intermodal TFM

TFMi, developed by Sonatest in collaboration with Holloway NDT, addresses the limitations of TFM by combining multiple propagation modes into a single scan view. Instead of relying on a single mode like TFM, TFMi integrates up to four modes, allowing inspectors to simultaneously visualize flaws from multiple perspectives — Fig. 3.

How TFMi Works

TFMi, available exclusively on the Sonatest Veo3, eliminates the need for the inspector to choose a single mode. TFMi provides a complete picture of the weld's integrity by combining multiple propagation modes into a unified image. For example, a transverse crack that might appear acceptable with a single-mode TFM scan due to low amplitude or limited visibility could be rejected when seen with multiple modes combined in TFMi. This approach ensures critical defects are more easily identified, characterized, and sized, making TFMi a valuable advancement for comprehensive weld inspections.

FMC, TFM, and TFMi in the Context of PAUT and AWS Standards

PAUT in AWS D1.1 and D1.5

Phased array is widely accepted in industry standards, including AWS D1.1 and AWS D1.5, which govern the inspection of structural welds. These standards allow PAUT sectorial scans to assess weld acceptability by measuring the size and location of flaws. However, these scans primarily focus on the amplitude of indications and may struggle to provide the necessary characterization for more complex or subtle defects. This is where advanced techniques like FMC/TFM and TFMi can offer significant advantages.

Importance of Flaw Characterization

While sectorial scans are effective for initial detection, weld inspectors often face situations where further flaw characterization is necessary. In AWS codes, some types of flaws may be accepted or rejected depending on their amplitude, but others require more detailed evaluation. TFM and TFMi provide the additional clarity needed to differentiate between various flaw types, helping to avoid unnecessary weld repairs or ensuring that critical defects are not overlooked. This enhanced characterization is crucial, as small differences in flaw type can significantly impact weld integrity.

Accurate Sizing with TFM and TFMi

Another key benefit of TFM and TFMi is their ability to provide more accurate flaw sizing compared to PAUT sectorial scans. Since TFM creates a fully focused image at every point in the inspection volume, it allows for precise measurements of flaw dimensions. Accurate sizing

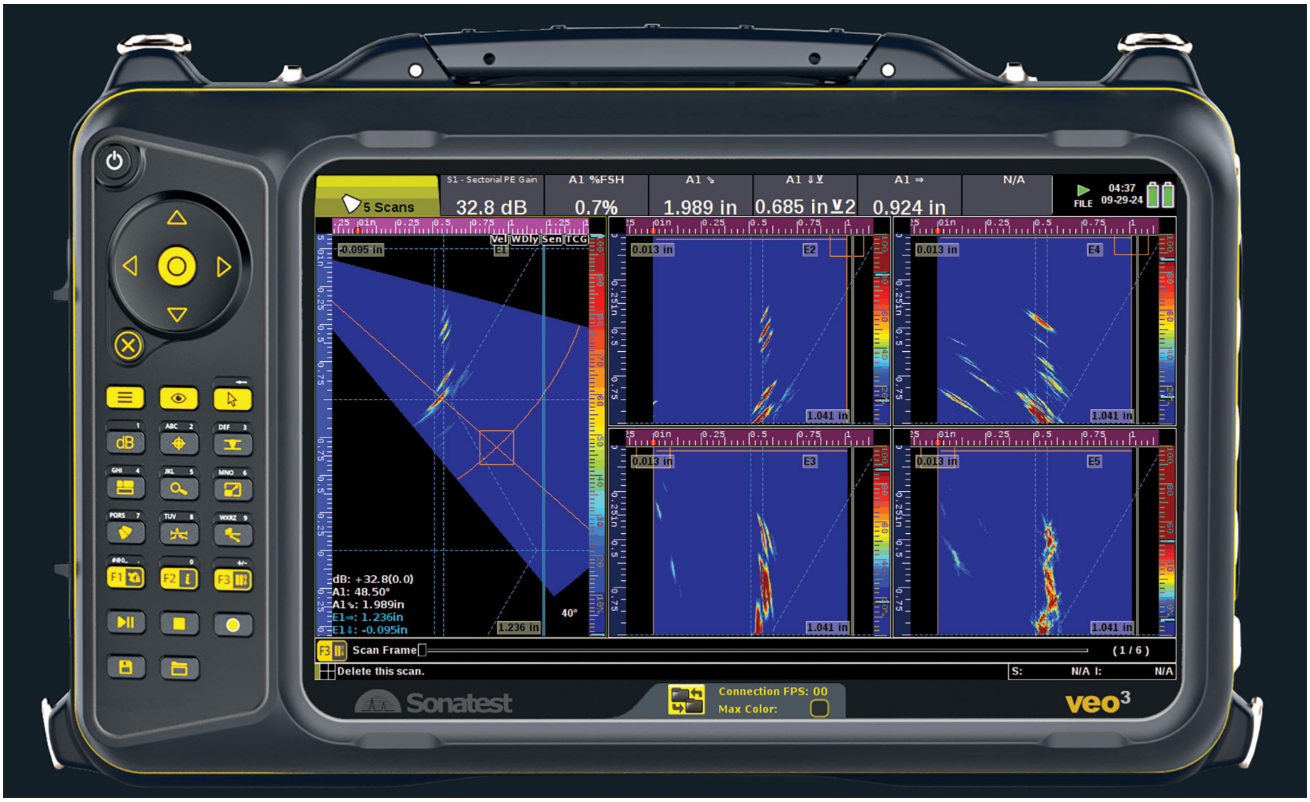


Fig. 3 — PAUT sectorial scan (left), TFM TT (top middle), TFM TTT (bottom middle), TFM 4T (top right), TFMi TT, TTT, 4T and TTL (bottom right). (Credit: Sonatest.)

is especially important for making informed decisions about weld repairs, as improperly sized flaws can lead to unnecessary rework or missed defects that could compromise the weld's performance.

Detection of Off-Axis and Transverse Flaws

Off-axis or transverse flaws are particularly challenging for sectorial scans to detect because of their orientation relative to the probe. Although time-of-flight diffraction (TOFD) is commonly used to detect these defects, TFM and TFMi offer an alternative that uses the same transducers as PAUT rather than requiring a subsequent TOFD scan with a separate set of specialized probes. By incorporating multiple wave modes, TFMi is more effective at discovering these flaws, which might otherwise go unnoticed, making it a valuable supplement to standard sectorial scans.

Practical Application: Integrating FMC, TFM, and TFMi in Weld Inspections

Workflow Integration

FMC, TFM, and TFMi can seamlessly integrate into existing inspection workflows alongside traditional PAUT. A common approach involves starting with a PAUT sectorial scan to detect and locate indications. Once a potential defect is detected, TFM or TFMi is used for enhanced flaw characterization and accurate sizing. This method combines the speed of PAUT with the detailed imaging capabilities of TFM and TFMi, offering inspectors more comprehensive insights without compromising efficiency.

Case Examples

In a typical scenario, a sectorial scan detects a small indication in a weld. Due to the flaw's low amplitude and small size, it is deemed acceptable under AWS standards. However, when a supplementary FMC/TFM scan is performed, the inspector suspects the defect may be more serious. Unfortunately, because the defect appears differently in the two TFM propagation modes, it is still difficult to accurately size or characterize.

At this point, a TFMi scan is employed, combining the two modes into a single view. This reveals the flaw's accurate size and shape, clearly visualizing a transverse crack that is now recognized as a rejectable defect. Thanks to the precise imaging provided by TFMi, the inspector can confidently recommend repair, demonstrating the critical role of these advanced techniques in ensuring weld integrity — Fig. 4.

In another instance, a sectorial PAUT scan detects an indication, and based on its amplitude, it is deemed acceptable, provided it is not a crack. The sectorial and A-scan readings disguise the flaw as a slag inclusion, an acceptable defect. However, when performing a TFMi scan, the geometrical detail clearly shows a planar crack-like flaw. With TFMi's superior imaging, the flaw can now be accurately identified as a crack, leading to its rejection and necessary repair. This highlights how TFMi's precise imaging can prevent serious defects from being overlooked, ensuring better weld integrity — Fig. 5.

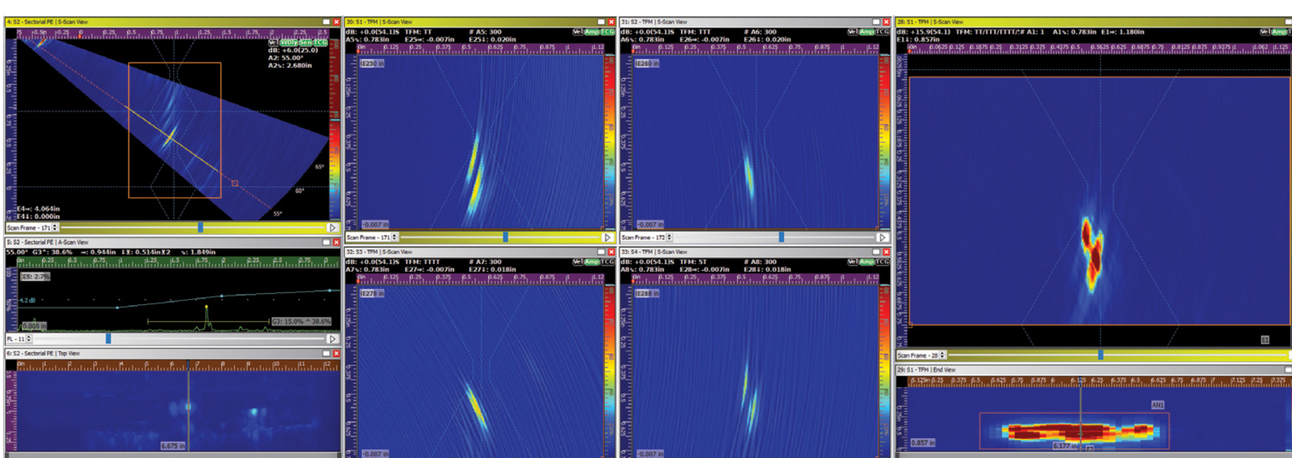


Fig. 4 — Scan of transverse crack in a weld. PAUT sectorial (left), four separate TFM Modes (middle), four combined modes in TFMi (right). (Credit: Sonatest.)

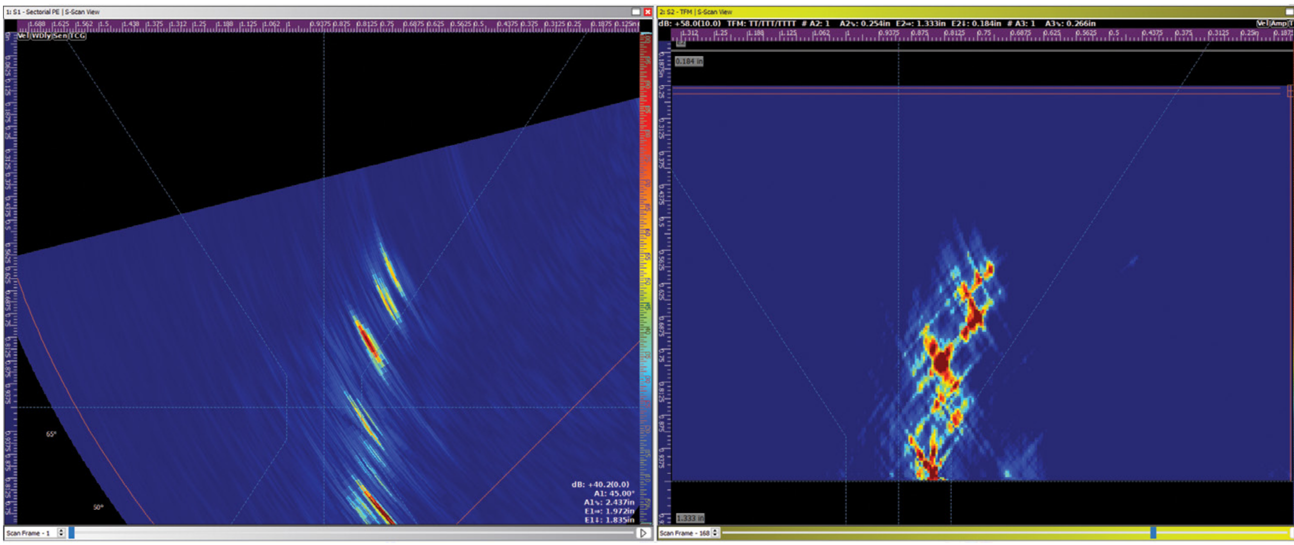


Fig. 5 — Branched crack in a weld. PAUT sectorial scan (left), three-mode TFMi (right). (Credit: Sonatest.)

Challenges and Considerations

Regulatory and Acceptance Issues

While FMC, TFM, and TFMi offer significant advancements in weld inspection, one of the main challenges is that these techniques are not yet universally accepted in formal inspection standards. Codes like AWS D1.1 and AWS D1.5 currently allow the use of PAUT sectorial scans for weld acceptability, but the adoption of FMC and TFM remains limited. This lack of universal acceptance can make it challenging to use these techniques in regulated environments where adherence to established standards is mandatory.

Training and Equipment

Another challenge is the need for specialized training to effectively interpret the data produced by FMC, TFM, and TFMi. These advanced techniques provide more detailed information than traditional PAUT, but inspectors may find it difficult to extract meaningful insights from the scans without proper training. Moreover, advanced equipment capable of capturing and processing FMC data is required, which could represent a significant investment for inspection teams.

Despite these challenges, the benefits of integrating FMC, TFM, and TFMi into weld inspection workflows are clear. As more inspectors become trained in these techniques and the technology becomes more widespread, it's likely that regulatory acceptance will follow, making these tools an even more integral part of the inspection process.

Conclusion

As industries recognize the benefits of FMC, TFM, and TFMi for improving weld inspections, these advanced techniques are gaining momentum. Their ability to offer superior flaw characterization, accurate sizing, and better detection of off-axis defects makes them invaluable tools, especially in scenarios where conventional PAUT may fall short. While current standards, such as AWS D1.1 and AWS D1.5, primarily rely on sectorial scans, the advantages of these methods are sparking interest in their broader adoption. As technology continues to advance, these techniques are becoming more accessible, thanks to improvements in data processing, equipment, and ease of use.

Despite the challenges of regulatory acceptance and the need for specialized training, the future of ultrasonic testing is clear. FMC, TFM, and TFMi provide critical supplemental insights for weld inspections, ensuring more comprehensive evaluations. As more inspectors adopt these tools, they will likely become integral components of routine workflows, driving higher standards for flaw detection and weld integrity.

Works Consulted

- AWS. 2020. D1.1, *Structural Welding Code — Steel.*
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BY NORMAN STAPELBERG

Advancing Radiographic Inspection:

The Promise of Digital X-Ray Film

The potential benefits of this technology make it an attractive prospect for the NDE industry

The field of nondestructive examination (NDE) has long relied on radiographic film for inspecting welds in pipes, vessels, and other complex structures. Despite significant technological advancements, the industry has been waiting for a more flexible digital alternative that could better replace traditional film while maintaining its unique advantages.

With the rapid development of flexible electronics, particularly in consumer devices such as foldable smartphones and curved monitors, the possibility of a flexible digital gamma/x-ray detector (digital x-ray film [DXF]) seems closer to reality.

DXF represents significant progress in flexible digital gamma and x-ray detector technology. Designed to serve as a digital replacement for radiographic film or computed radiography (CR) plates, DXF combines the versatility of film with the efficiency and accuracy of digital imaging. This innovation could significantly reduce the time and cost associated with radiographic inspection of welds and castings — Fig. 1.

The Evolution of Flexible Electronics

Over the past decade, the flexible semiconductor industry has made remarkable progress. The commercial availability of foldable screens on devices such as Samsung smartphones and the proliferation of curved monitors and televisions highlight how far this technology has come.

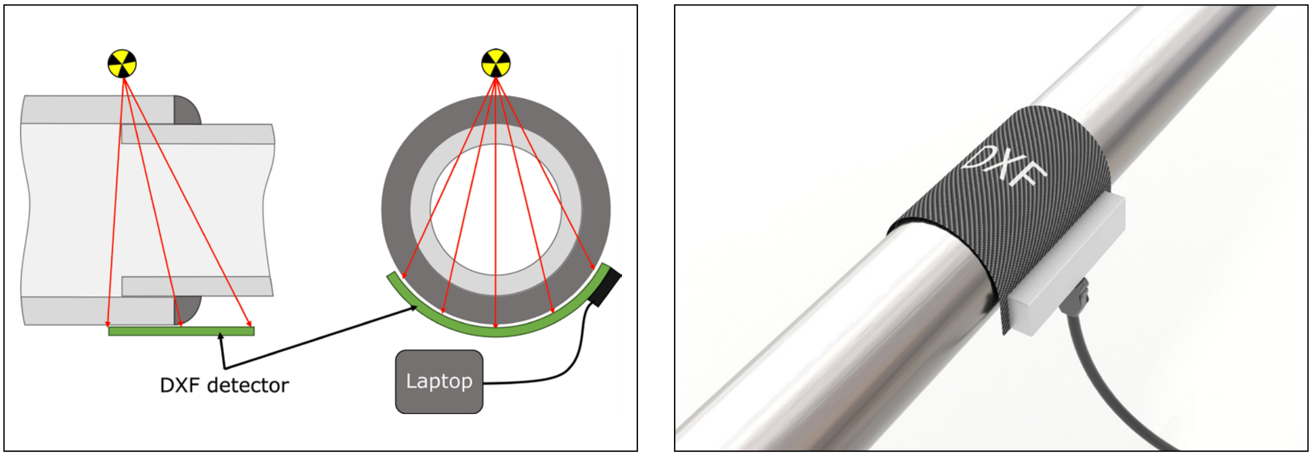

Fig. 1 — Pipe joint inspection using digital x-ray film (left) and digital x-ray film wrapped around a pipe (right).

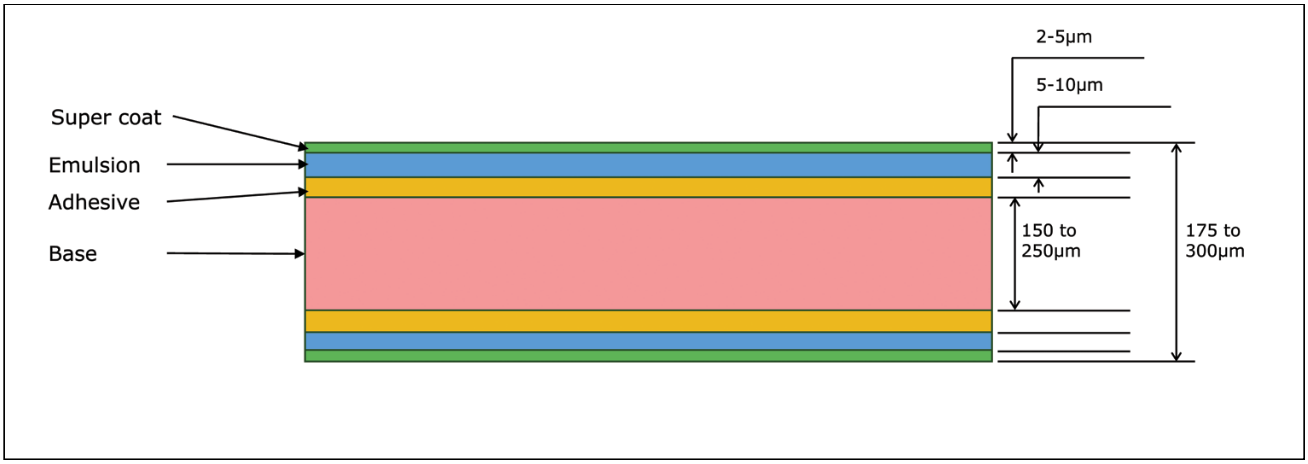

Fig. 2 — Double-layer radiographic film features layers mirrored on the opposite side of the base layer, effectively doubling the film's sensitivity to x-rays and gamma rays.

These advancements hinge on the same basic technology that underpins the pixelated backplanes used in digital x-ray flat panel detectors (FPDs) — also called digital radiography (DR). By integrating flexible pixelated backplanes with x-ray-sensitive semiconductor inks, we are on the brink of achieving a truly flexible digital equivalent to traditional x-ray film. But is this a practical development or just wishful thinking? To answer this, it is worth examining the current landscape of radiographic inspection technologies.

Traditional Radiographic Film: A Trusted Method

Radiographic film has been a cornerstone of weld inspection since it was first used by Yale University in 1896. Over the years, its performance has improved dramatically in terms of resolution and speed, but the fundamental components have remained relatively unchanged. Modern radiographic film typically consists of multiple layers: a semirigid polyester base layer glued to an emulsion layer of gelatine loaded with silver halide crystals. These crystals, usually silver bromide or chloride, determine the film's speed and resolution. The emulsion layer is then covered by a protective gelatine layer. In double-layer films, these layers are mirrored on the opposite side of the base layer, doubling the film's sensitivity to x-rays and gamma rays, thereby reducing exposure times — Fig. 2.

When exposed to radiation, the halide crystals in the film interact with x-ray or gamma-ray photons, releasing negative ions that are then collected by silver molecules. During the development process, these silver molecules form black metallic silver suspended in the gelatine to create the final image. Larger halide crystals capture images more quickly but at the expense of resolution, while smaller crystals offer higher resolution but require longer exposure times.

Despite its limitations, radiographic film is valued for its thinness and flexibility, which allows it to be wrapped around pipes or other complex shapes and held in place during imaging. However, the process is labor-intensive, requiring the film to be loaded into light-proof envelopes in dark rooms and developed manually or automatically. These images must then be digitized for archiving or stored physically — often for decades — in environmentally controlled chambers, which is costly.

Digital X-ray Inspection with FPDs

FPDs originated in the medical industry, which remains the largest market for x-ray imaging technology. FPDs used in NDE are adapted from those designed for medical use. They typically feature square, flat, rigid, and often heavy panels encased in protective housings that add to their weight and cost. While these panels produce high-quality images quickly, their rigidity limits their applicability in weld inspections, particularly for pipes and other complex shapes.

FPDs are relatively thick, making it difficult to position them in tight spaces where they are often needed. Despite these challenges, FPDs offer significant advantages in terms of image quality and speed. The software accompanying these detectors simplifies image analysis, with advancements in artificial intelligence (AI) poised to further enhance this capability.

Most FPDs are indirect conversion x-ray detectors. These detectors use a scintillator material to convert x-rays or gamma rays into visible light, which is then captured by a pixelated backplane, typically made of amorphous silicon (A-Si) or, more recently, indium gallium zinc oxide (IGZO). Each pixel on the backplane contains a photodiode that converts the visible light into an electrical signal, which is processed to generate a digital image. While indirect conversion detectors are well-established in medical imaging, they do have some drawbacks:

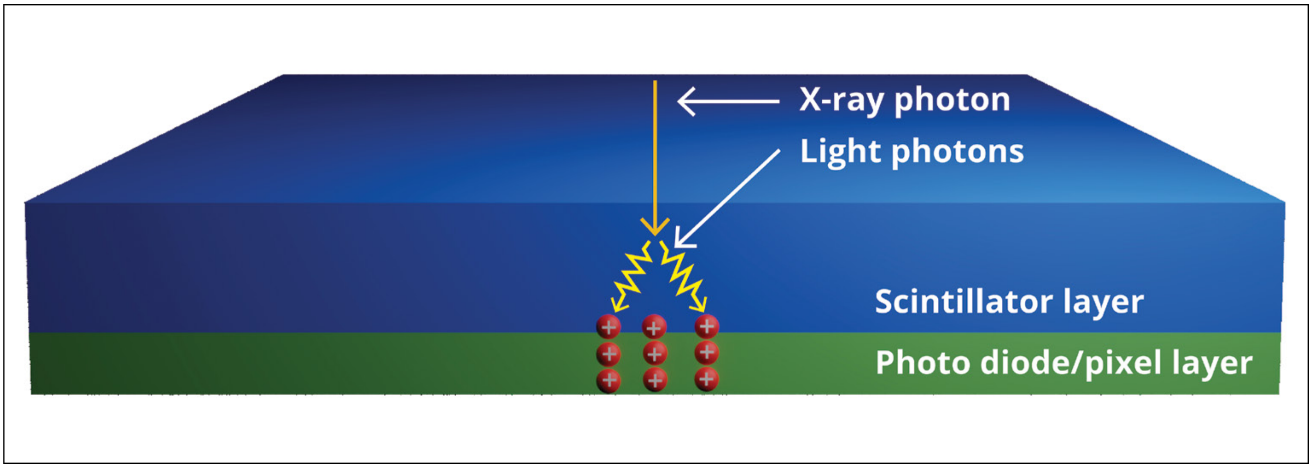

Fig. 3 — Indirect conversion process of digital x-ray flat panel detectors.

1. Conversion losses: The process of converting x-rays to visible light and then to an electrical signal results in some loss of sensitivity.

2. Image blurring: The visible light generated by the scintillator can scatter across multiple pixels, especially in detectors with thick scintillators, leading to blurred images (see Fig. 3).

A Step Toward Digital

CR plates offer a partial solution to the limitations of DR panels, more closely mimicking traditional x-ray film. CR plates are flexible, x-ray-sensitive phosphor plates available in various sizes and resolutions. When exposed to x-rays, the phosphor crystals in the plates release electrons, which are trapped in a higher energy state. This stored charge is later stimulated by a helium-neon laser in a developing station, emitting blue light proportional to the stored image. This light is captured by a photomultiplier tube and converted into an electrical signal, which is then processed into a digital image. After the image is captured, the plate can be cleared by exposure to intense light, making it ready for reuse — Fig. 4.

However, CR plates have their limitations. They are often used in harsh environments where contamination by sand or other materials can damage the plate and affect image quality. Scratches or kinks in the plates can also leave artifacts on the x-ray image, sometimes rendering the plate unusable. Although CR plates are designed for around 1000 exposures, they are often damaged much sooner, and up to 50% of the resolution can be lost during the digitization process.

The Future of Radiographic Inspection

While the market has seen incremental improvements in resolution and software over the past decade, recent

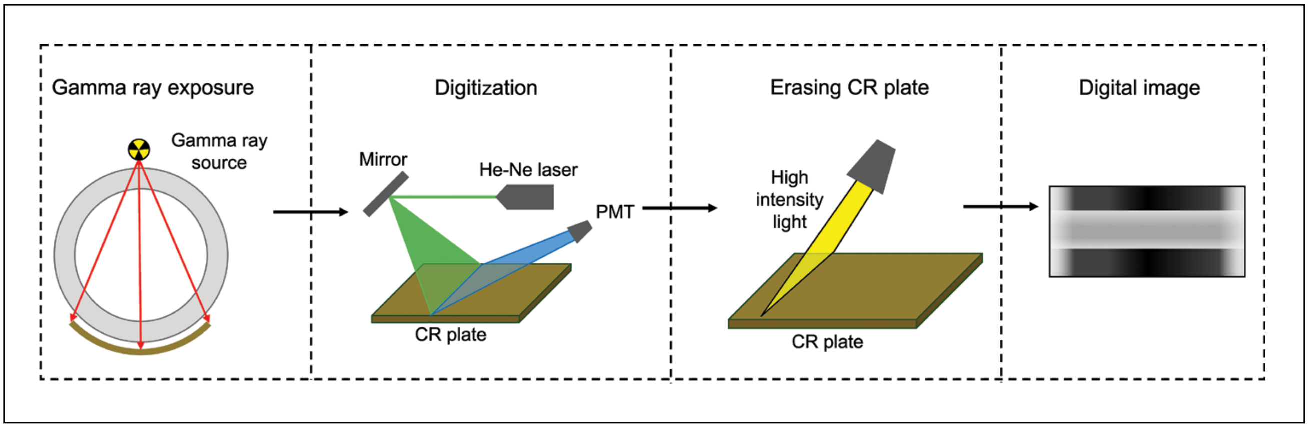

Fig. 4 — CR plate image capturing process.

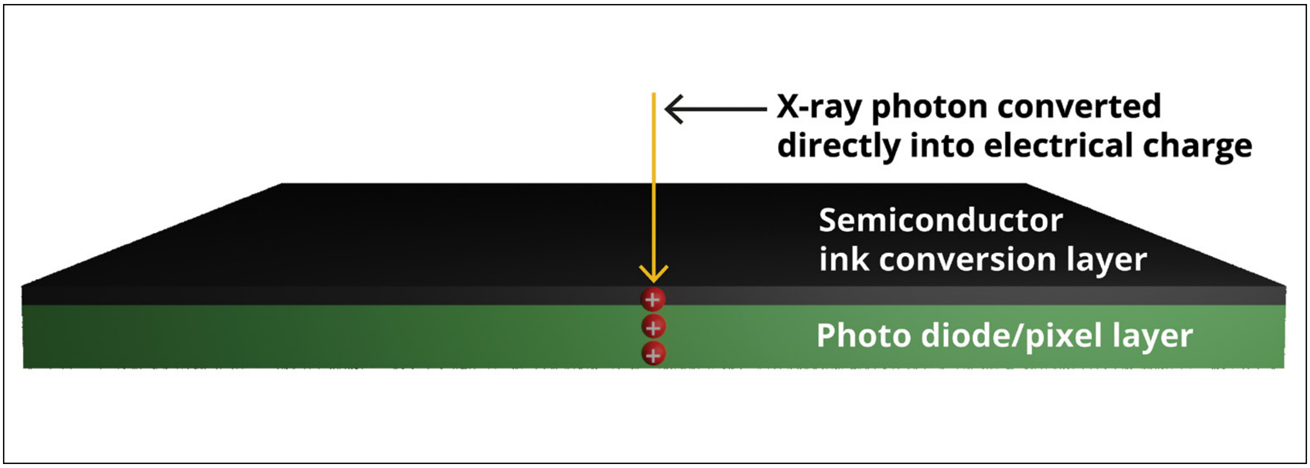

Fig. 5 — Representation of a direct-conversion, flexible, ultra-thin x-ray detector.

innovations have begun to push the boundaries of what is possible in digital radiographic inspection. One such advancement is the development of direct conversion detectors using materials such as cadmium telluride (CdTe) and amorphous selenium (A-Se). These detectors convert x-ray photons directly into electrical signals, eliminating the need for a scintillator and resulting in higher spatial resolution and sensitivity without blurring. However, these detectors have their limitations. CdTe, for example, is a single-crystal structure that is slow to grow, making it expensive and limited in size. These factors, combined with their rigidity, restrict the use of CdTe detectors in NDE. Furthermore, both CdTe and A-Se detectors are typically limited to applications below 200 keV.

More recently, flexible DR detectors have been introduced, which use flexible scintillators on flexible A-Si backplanes. While these offer some flexibility, they remain heavy, thick, and expensive, limiting their potential to replace traditional x-ray film in most applications.

The Promise of Digital X-ray Film

The future of radiographic inspection lies in the continued development of flexible semiconductor technologies. As has been seen with consumer electronics, advancements in flexible displays using IGZO and low-temperature polysilicon (LTPS) thin-film transistor panels have enabled higher resolutions and smaller pixel sizes. These flexible backplanes are now being adapted for use in x-ray detectors. Moreover, the solar photovoltaic industry has spurred the development of flexible organic semiconductor materials as an alternative to Si in solar panels. These materials can create an x-ray-sensitive semiconductor ink when combined with high-attenuation nanoparticles. Coating these inks or polymers onto an A-Si, IGZO, or LTPS pixelated backplane could result in a direct conversion x-ray detector that is both flexible and ultrathin — Fig. 5.

A digital x-ray film made from a flexible pixelated backplane, coated with a direct conversion semiconductor ink, and protected by carbon fiber layers could be less than 1 mm thick and offer the same flexibility as traditional radiographic film. Such a detector would be more resistant to scratches and kinks, making it a viable alternative for weld inspection. The cost of manufacturing these detectors would need to be low enough to make them semidisposable, ensuring that the total cost of ownership remains competitive with traditional film.

Conclusion

While digital x-ray film is not yet commercially available, the technology is rapidly advancing and may soon become a reality. The potential benefits of DXF — including reduced inspection time, lower costs, and improved image quality — make it an attractive prospect for the NDE industry. As flexible semiconductor technology continues to evolve, further innovations are expected that will revolutionize the way radiographic inspection is approached, ultimately leading to more accurate and efficient inspections of critical infrastructure.

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Fixed Camera Kit Enables Video Capabilities for Crawlers

The RECON fixed camera kit adds video monitoring to the NAVIC and TERAX crawlers. Users can view live video from one or two cameras simultaneously, record inspections for later review, catalogue, and share notable clips. A satellite camera provides a second viewing angle when required. Both cameras capture high-definition video and can take high-quality still images while recording video using the included RECON • Studio software. The cameras have very low latency, which means virtually no video recording and viewing delays. LED lights are built into the cameras to illuminate the foreground. The video software can control LED brightness; record video and capture still photos; activate and adjust guides on the video screen; and play back, organize, and share videos and photos. Single- and dual-adjustable camera brackets allow users to point the camera where they want. A long cable length allows the crawler to travel as far as 98.4 ft while maintaining clear video monitoring and control.

JIREH
jireh.com

Portable Digital X-Ray Detector Series Inspects a Variety of Welds

The D-DR flat panel detector series covers a wide range of industrial radiographic testing applications, such as circumferential welds on pipes, small tubes, large objects, and more. The basic spatial resolution is 80 µm for the small and medium detectors and 100 µm for the bendable and large detectors. With weights ranging from 4.4 to 13.2 lb, the detectors are light and are easy to handle. Further advantages of the detector series are long battery runtime, hot-swap functionality, and IP 67 protection class. In addition to wireless operation, all detectors can also be operated by wired data transmission and power supply. The detectors' integrated shielding makes them suitable for x-ray sources up to 450 kV and, depending on the model, for gamma sources, with a maximum frame time of 180 seconds. The digital x-ray systems are used with D-Tect X inspection software. Special functions such as multigain calibration ensure high image quality. Intelligent tools, such as one-click wall thickness analysis and image optimization filters, make image evaluation simple and efficient.

DÜRR NDT
duerr-ndt.com

BY ALBERT J. MOORE JR.

Q Maybe you can help me with a problem we are having on our production floor. We are using an oxyacetylene torch to preheat the steel before welding. The torch is popping and hissing and making everyone uncomfortable. What's going on?

A I think I can help you based on what you described. The torch is starving for fuel, i.e., acetylene.

Acetylene is not stable at pressures above 15 lb/in.^{2}. The good folks who refill the acetylene cylinders are well aware of the problem, so they take steps to stabilize the gas. The acetylene cylinder is not just an empty tank pumped full of gas. The cylinder is filled with a porous material, so the acetylene molecules are separated within the pores of the media. In addition, the acetylene gas is dissolved in acetone, much like carbon dioxide is dissolved in the water in a bottle of seltzer. These precautions stabilize the acetylene while it is pressurized in the cylinder.

Now, to your problem: The acetylene must come out of the solution; that is, the acetylene must separate from the acetone before being conducted to the pressure-reducing regulator and then to the hose supplying the torch. If there is an attempt to withdraw too much acetylene from the cylinder, the gas doesn't have time to separate from the acetone, and both the acetylene and acetone come out of the cylinder. You see the same thing if one suddenly pops the cap off a bottle of seltzer. Both the water and carbon dioxide gush out as foam. So, to prevent the seltzer from foaming, the cap is removed slowly to limit the volume of carbon dioxide escapes. The withdrawal rate of the acetylene has to be slow enough to ensure the acetylene has sufficient time to separate from the acetone. The goal is for only the acetylene to be delivered to the pressure-reducing regulator. The idea is to leave the acetone in the cylinder.

When it is first lit, the torch operates as intended, but as the acetylene is depleted, the volume of acetylene remaining in the cylinder diminishes, and the volume of acetylene that can safely be provided is reduced. After a short while, "pop, bang, hiss," the flame goes out with a pop. What do we do? What's happening?

Normally, the combustion of the oxygen and acetylene occurs at the torch tip, just beyond the end of the heating tip. With the drop in acetylene pressure, combustion can occur inside the heating tip. When using a large heating tip, the demand for fuel gas may easily outstrip the ability of the cylinder to deliver the quantity of acetylene required. As a result, the delivery pressure drops, and acetylene and acetone are pulled from the cylinder, as well as acetylene. One will see sparks in the torch's flame, and it will start to "pop" or backfire. In a worst-case scenario, the combustion can take place inside the torch handle, melting the torch and burning the operator's hand. The telltale hissing and black smoke are indications that the torch is about to self-destruct.

One solution is to use an alternative fuel gas, i.e., liquefied petroleum gas, MAPP gas, etc. Another solution is to use a larger acetylene cylinder or connect a couple of acetylene cylinders to increase the volume of acetylene available for delivery to the acetylene regulator.

Occupational Safety and Health Administration (OSHA) 29CFR 1910.102, 1910.102(a), 1910.253, and *CGA G-1-2009* are the standards where one will find the rules established by OSHA for the safe delivery of acetylene. *CGA G-1* states a withdrawal rate of 1⁄7 of the cylinder's content is generally safe. However, it states, "to minimize the withdrawal of liquid solvent in applications that are more sensitive to solvent carry-over, acetylene should be withdrawn from the cylinder at a rate not to exceed 1⁄10 the capacity of the cylinder per hour during intermittent use." For a permanent installation (think burning tables), the maximum withdrawal rate is 1⁄15 the acetylene cylinder volume or cylinders connected using a manifold.

Let's look at how this works.

- Volume of heat required — 140,000 BTU/hr (the bigger the torch tip, the greater the volume of acetylene needed)
- Volume of the acetylene cylinder — 350 ft^3 (when full)
- Volume of acetylene required — 87 ft^3/h
- Portable/Intermittent use of 350 $ft^3 \times 10\% = 35\ ft^3/h$ (three 350 ft^3 cylinders connected to a manifold would safely supply 105 ft^3/h of acetylene to the torch when first lit)
- The weight of acetylene remaining in the cylinder diminishes over time. Thus, it seems reasonable that as the cylinder nears depletion, it may not be able to deliver the volume of fuel needed to maintain the proper operating pressure.

While one can withdraw more acetylene than the quantity permitted by *CGA G-1* (based on the volume of the cylinder), remember as the withdrawal rate increases, the probability acetone will be pulled from the cylinder increases because the acetylene and acetone cannot properly separate. Acetone does nothing beneficial to the regulator or hoses!

The bottom line is that it sounds like you need to provide a sufficient volume of acetylene gas to the torch based on the size of the heating tip you are using. Here are a couple of suggestions:

1) Use a larger cylinder of acetylene,

2) Use multiple cylinders of acetylene connected with a manifold, or

3) Switch to LP gas or another alternative to acetylene. This would require a different pressure-reducing regulator for the fuel gas and a different style of

heating tip (must be compatible with LP fuel).

Be aware that if you switch to LP fuel, very cold winter days can present a problem. It takes heat to cause the liquefied petroleum gas to change from a liquid to a gas. If the LP tanks are inside a heated shop, it should not be a problem. However, if the work is outside in the weather, those cold winter days may prevent enough gas to boil off to properly supply the heating torch. You won't get a satisfactory flame.

I hope I have explained the problem sufficiently to satisfy your curiosity and offered some solutions to cure the problem.

Any article on using and handling gases contained in high-pressure cylinders deserves a few words on safety. Once again, OSHA and CGA provide some direction on the safe handling of gas cylinders. Let's review a few safety rules that come to mind. Keep in mind, this list is not all inclusive:

- Gas cylinders are to be transported, stored, and used while in the vertical upright position.
- Gas cylinders are to be secured using a metal chain. Nonmetallic straps should not be used to secure gas cylinders.
- High-pressure cylinders, other than fuel gases, are supposed to be opened all the way to ensure the double-seated valve reseats in the open position to prevent leakage around the valve stem.
- Fuel gas cylinders should be opened only about ½ turns to allow them to be closed quickly when necessary.
- Acetylene should never be used at a pressure greater than 15 lb/in.^{2}.
- Valves must be closed completely when the torch is not being used, or the cylinder is empty.
- Relieve the pressure on the diaphragm by backing the pressure adjustment screw of the pressure-reducing regulator out when the torch is not in use.
- Crack the cylinder valve to clear it of dust and debris before closing it and attaching the pressure-reducing regulation.
- Fuel gases are supposed to be stored separately from other gases except when secured in a cart and in use.
- Secure all cylinders from egress paths or pathways used by forklifts and other material handling equipment. Do not allow anything to run over the hoses.
- Never lift gas cylinders by their caps. The holes or slots are not intended to be used for lifting the cylinder.
- Use a cart to move cylinders from one location to another.
- Do not use magnetic lifting devices for lifting or moving gas cylinders.
- Never use a gas cylinder as a roller.
- Never throw a cylinder or slam them down when handling the gas cylinder.
- Never allow the gas cylinder to become part of the electrical circuit or come in contact with live currents. Arc strikes against the cylinder wall can lead to catastrophic outcomes.
- Never apply lubricants to the threads on the cylinder valve or the pressure-reducing regulator.
- Do not light the torch with anything other than a spark lighter.
- Do not use oxygen as a substitute for compressed air. IT

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