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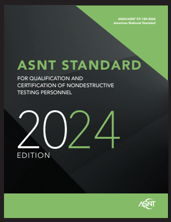

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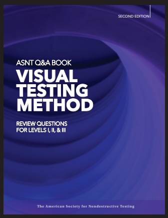

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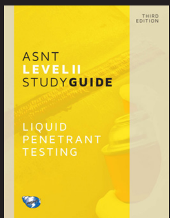

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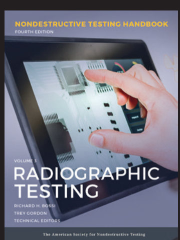

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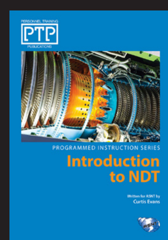

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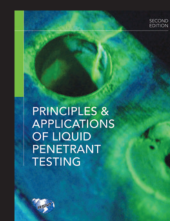

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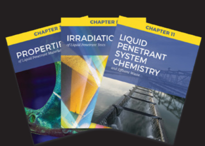

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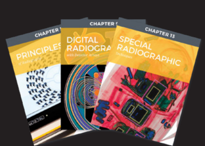

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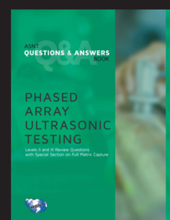

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MACHINE VISION-BASED TOOLS

for automotive service and repair

BY DANIEL LAU

Machine vision systems and other visual inspection methods are commonly used in the automotive industry for manufacturing, service, and repair. This article is focused on nondestructive visual testing methods for vehicle service and repair.

Introduction

Auto mechanics and vehicle owners can identify many issues through visual inspection. However, unaided visual inspections that rely on the visual acuity of the inspector may miss problem areas. Furthermore, while unaided visual inspections can often yield qualitative results, quantifying findings without advanced tools can pose significant challenges. For example, although an auto mechanic might recognize that a vehicle is misaligned during a visual inspection, without quantitative inspection tools, it's rare for them to precisely align the vehicle to meet the manufacturer's specifications.

This article focuses on the application of machine-vision systems for identifying vehicle issues and generating quantitative results, which subsequently guide prescriptive repair processes. Automotive mechanics rely on visual inspection for the following:

- **Making an initial assessment.** Technicians start with a visual inspection to get an overall understanding of the vehicle's condition and catch obvious problems such as leaking fluids or damaged parts.
- **Identifying leaks.** By visually inspecting the underside of a car, mechanics can spot leaks from the engine, transmission, brakes, or cooling system. The color and location of the fluid can indicate the source of the leak.
- **Checking wear and tear.** Components such as brake pads, belts, hoses, and tires are checked for wear and tear. Tires, for instance, are inspected for tread depth and wear patterns that might indicate alignment issues.

- **Spotting corrosion.** Rust and corrosion can compromise the structural integrity of a vehicle. Visual inspection helps in identifying areas of corrosion that need to be addressed to prevent further damage.
- **Conducting safety inspections.** Critical safety components such as seat belts, airbags, and lights are visually inspected to verify that they are functioning properly.
- **Examining the engine and exhaust system.** The engine and exhaust components are inspected for signs of damage, corrosion, or unusual deposits that might indicate underlying issues.
- **Evaluating the suspension and steering.** Visual inspection of the suspension and steering systems can reveal issues such as worn shocks, struts, or other suspension components that could affect the vehicle's handling capabilities.

Visual Inspection in Automotive Repair

Auto mechanics use visual inspection to identify a broad range of vehicle issues. Following is a short list of vehicle issues where visual inspection plays a crucial role in both identifying the problem and executing repairs: tire wear and tread depth assessment, detection of vehicle dents, and alignment evaluation. This article will discuss the application of machine vision methods by focusing on these issues and comparing typical inspection processes with and without machine vision systems.

Tire Tread Depth

In the US, the minimum legal tire tread depth is 2/32 in. (1.6 mm). This standard applies to all passenger cars, light trucks, and SUVs. The measurement should be taken in the major tread grooves of the tire and across different points along the tire's circumference to ensure accuracy, as tires can wear unevenly.

VISUAL INSPECTION CAPABILITIES AND LIMITATIONS

The 2/32-in. standard is based on the fact that tires significantly lose their ability to grip the road surface and effectively disperse water as their tread wears down. This increases the likelihood of hydroplaning and accidents, particularly in wet conditions. To easily check whether tires meet the minimum tread depth, the US has popularized the "penny test." Insert a penny into the tread groove as far as possible, with Abraham Lincoln's head facing down (Figure 1); if the top of Lincoln's head remains visible, the tire's tread depth is below the legal threshold, indicating the need for replacement.

Although the legal minimum tread depth is 2/32 in., numerous safety experts recommend replacing tires when they reach 4/32 in. (3.2 mm) of the remaining tread depth, especially for wet driving conditions—and even more so for winter driving conditions—to ensure optimal traction and safety on the road.

In much of the rest of the world, the legal minimum is 1.6 mm (approximately 2/32 in.).

Figure 1. Measuring tire tread depth with a Lincoln penny.

Figure 2. Measuring tire tread depth with a depth gauge.

The penny test is a common method for determining whether the remaining tread depth meets the minimum legal requirement. However, this method is highly dependent on the user. A more robust approach is to use a micrometer or depth gauge (shown in Figure 2).

Because tires wear unevenly, to properly assess if the remaining tread meets local legal requirements, multiple measurements should be taken at various circumferential positions around the tire and along each tread. Care must be taken to ensure that the depth gauge is properly positioned for accurate readings. Additionally, the depth gauge must be calibrated to eliminate any systemic bias that could affect the measurement results.

To determine if a measurement approach can be used to meet a specific requirement, a gauge study, specifically a Gage R&R (Repeatability and Reproducibility) study, should be conducted. A gauge study assesses the measurement system's overall performance via the following factors:

- **Repeatability (equipment variation).** This assesses whether the same operator can get consistent measurements using the same depth gauge on the same tire tread multiple times. Low repeatability suggests that the gauge itself or the measurement process introduces significant variability.
- **Reproducibility (operator variation).** This evaluates whether different operators can achieve consistent measurements using the same depth gauge on the same tire tread. High variability in this area indicates differences in how operators use the gauge or interpret its readings.
- **Overall measurement system variation.** This combines repeatability and reproducibility to assess the total variation introduced by the measurement system, encompassing both the depth gauge and the operators.

We conducted a gauge study on the use of a depth gauge for tire tread measurement and found that the operator contributed approximately 0.039 in. (1.0 mm) to the overall range of measurements for a given tread. Therefore, to ensure that the potential error introduced by the operator (the auto mechanic) does not result in tires worn beyond the legal limit being incorrectly assessed as passing, the pass-fail measurement result must be adjusted to account for this potential error (Figure 3).

To ensure a pass condition with a 95% confidence interval, where the minimum legal tread depth is 2/32 in., and considering the inherent variability in measurements, we must account for the uncertainty in the measurement process. This involves adjusting the nominal pass threshold to accommodate this measurement variability. By doing so, we can be 95% confident that the true tread depth does not fall below the minimum legal limit.

Figure 3. The impact of a visual inspection on the tread depth fail limit.

The calculation entails determining the standard deviation (σ) of a set of measurements and using the Z-score associated with a 95% confidence level. For a 95% confidence level, the Z-score is 1.96. Because the range of measurements is 0.0394 in., if we assume this range represents the total variability (six standard deviations in a normal distribution, as per the Six Sigma methodology), we can approximate the standard deviation as:

$$\sigma = \frac{\text{Range}}{6} \quad (1)$$

To ensure the measurement result meets the minimum legal tread depth with a 95% confidence interval, we adjust the threshold by adding the margin of error (MoE) to the fail criteria. The margin of error is calculated as:

$$\text{MoE} = Z \times \sigma \quad (2)$$

where

Z is the Z-score (1.96 for a 95% confidence level), and

σ is the standard deviation.

To ensure a pass condition with a 95% confidence interval, given a fail criteria of 2/32 in. and a range of measurements of 0.0394 in., the measurement result for tread depth must be at least 0.0755 in. This adjusted threshold accounts for measurement variability and ensures, with 95% confidence, that the true tread depth meets or exceeds the legal minimum tread depth.

While the above approach ensures that the tread of all tires measured with a depth gauge meets the legal minimum, the significant variance in the measurement process means that many tires with tread measurements shallower than 0.0755 in. may actually have true tread depths deeper than the legal limit of 2/32 in. This means that tires with remaining usable life might be discarded unnecessarily.

CURRENT MACHINE VISION CAPABILITIES AND OPPORTUNITIES

Much of the variability in the measurement process is a result of errors associated with visual inspection. Since the auto mechanic positions the depth gauge by eye, their visual acuity and patience are an integral part of the overall measurement process. While a depth gauge is a cost-effective tool, its use for this measurement might not be the most economically sound decision. The economic expense of discarding tires with usable life may outweigh the economic benefits of using an inexpensive depth gauge (or penny) for the assessment.

Tire tread depth can also be measured using 3D imaging approaches that incorporate structured light projection with machine vision systems. Structured light projection systems illuminate the object under inspection with a pattern of light, which can be either static or dynamic (time-varying). Machine vision systems are typically calibrated camera systems that acquire a high-fidelity image of the object under inspection. The most common method of structured light is laser line scanning. Laser line scanning is a simple form: the projected pattern is a line. In a laser line scanning system, a laser line is projected onto the surface of an object, and a machine vision camera captures the resulting image. From this image, the 3D profile of the surface can be determined. By capturing a series of profiles, the surface of an object can be reconstructed as a 3D digital model.

When measuring tread depth using a laser line scanning system, the tread depth can be calculated from the resulting 3D model. This is typically done by creating a reference surface from the tire's contact area (the part of the tire that touches the road) and using this reference surface to calculate the depth of the tread. With a sufficiently detailed 3D model, statistical variations in tread depth can be analyzed. These statistical variations in tread depth can provide valuable information regarding the safety of the vehicle. For instance, the wear pattern across the tire's surface can reveal alignment problems.

Gage R&R measures of laser line scanning systems exhibit significantly lower variances in repeatability and reproducibility compared to those associated with the use of depth gauges by operators. A typical measurement range for a laser line scanning system is 0.008 in. When compared to the earlier depth gauge results, this reduces the guard band from 0.0129 in. to 0.0026 in. (see Figure 4).

Because the resulting pass/fail limit has been reduced to 0.0651 in., compared to the earlier threshold of 0.0755 in., significantly fewer good tires will be discarded.

Figure 5. Laser line scanning system.

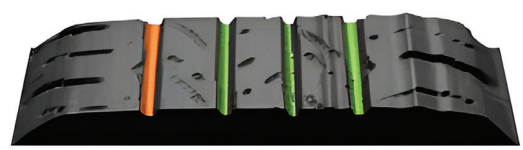

Figure 6. 3D model of a tire with tread depth measurement result.

For this application, the use of a machine vision–based 3D imaging system improves the accuracy of measurement results and reduces the economic waste associated with discarding tires that still have usable life.

Vehicle Dents

The identification and repair of dents in vehicle bodies are almost entirely reliant on visual inspection. Auto mechanics and dent repair specialists depend on their visual acuity to locate dents and determine if the repair has been successfully completed.

VISUAL INSPECTION CAPABILITIES AND LIMITATIONS

Although various techniques exist for repairing dents, we will focus on PDR (paintless dent repair) to illustrate the importance of visual inspection in the dent repair process. PDR is a popular method that typically does not require the removal of body panels or pounding out dents from the interior. Instead, the dent is pulled and pounded from the exterior of the damaged body panel. Dents in metal structures contain areas of both plastic and elastic deformation. To restore the metal to its undamaged

Figure 4. The impact of a machine vision system on the tread depth fail limit.

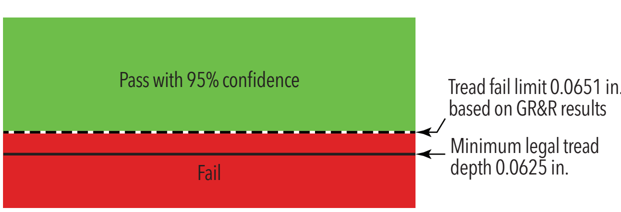

Figure 7. Dent repair: (a) Pulling and (b) pounding the dent.

condition, pressure must be applied precisely to the areas of deformation. Applying the right amount of pressure in the correct location is necessary to achieve a good result.

Applying the right pressure in the right direction along areas of the dent that are above the original surface can relieve the strain in these regions and cause other areas of the dent to move closer to their original, undamaged shape. Similarly, pulling areas of the dent (Figure 7) that are below the original surface has a comparable effect. By combining pressure at high points (dent pounding) with pressure at low points (dent pulling), the auto mechanic can restore the body panel surface to a close approximation of its original, undamaged state.

When repairing a dent, determining when to stop can be challenging. Specialists in dent repair often project lines onto the surface of the dent to aid in this process. By visually observing the lines, they can better estimate when the dent has been removed. Figure 8 shows how line projection is used to assess whether the dent has been removed. While this approach is an improvement over purely visual methods, the final determination of whether the dent has been removed still relies on visual inspection. Factors such as lighting conditions, object reflectance

Figure 8. Using a visual aid for determining the extent of the dent.

Figure 9. A dent repaired using PDR.

properties, inspector fatigue, and inspector visual acuity all influence the outcome. Figure 9 shows an example of a dent repaired using PDR.

CURRENT MACHINE VISION CAPABILITIES AND OPPORTUNITIES

3D imaging tools can create digital 3D models of the surface deformation of vehicle dents. These 3D models can be used to assess the extent of the damage and suggest the appropriate method of repair. Figure 10 shows an example of a 2D and 3D image of a dent on a vehicle.

When the original CAD data is available, the digital 3D model created from the 3D imaging tool can be directly compared to the CAD model. However, in most cases, CAD data is not available. In such instances, mathematical models of the object under inspection can be used to establish a reference surface against which the deformation can be measured. For the dent shown in Figure 10, the extent of the deformation was calculated from the 3D surface data using a

Figure 10. A structured light system for imaging dents.

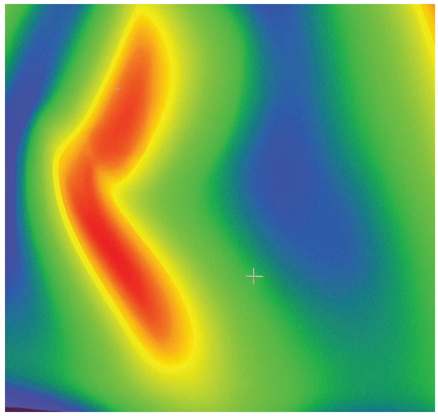

Figure 11. Deformation calculation for the dent shown in Figure 10.

reference surface that was mathematically derived directly from the data. The result is illustrated as a heat map in Figure 11.

Using the 3D data from a dent measurement, various representations can be calculated. A depth map with false color (Figure 11) can be used to identify the high points and low points of the dent, providing the auto mechanic with information to determine where to pound and where to pull on the dent. A more sophisticated approach involves using the dent depth information to calculate the dent strain (Figure 12). Relieving the dent strain is a key part of the PDR process. Deriving dent strain maps from the 3D data facilitates a digital workflow for dent repair. Figure 12 illustrates the locations of strain in a dent along with the dent depth.

3D data on a dent can also be used to generate strain maps, offering more precise guidance on where to pound or pull to restore the body panel to its original shape. Additionally, utilizing 3D data enables the identification of when the dent has been successfully repaired. This approach introduces a mathematical metric for determining dent repair, promoting better consistency among technicians and across various vehicles, taking the guesswork out of dent repair.

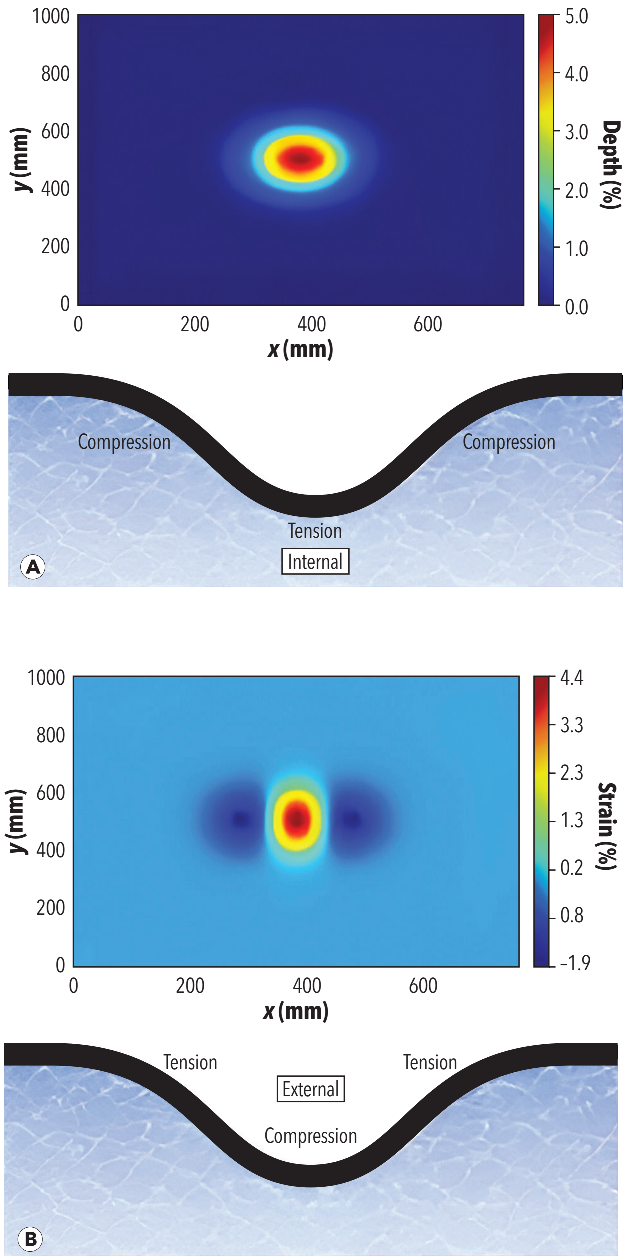

Figure 12. Locations of strain in a dent: (a) dent depth; (b) dent strain.

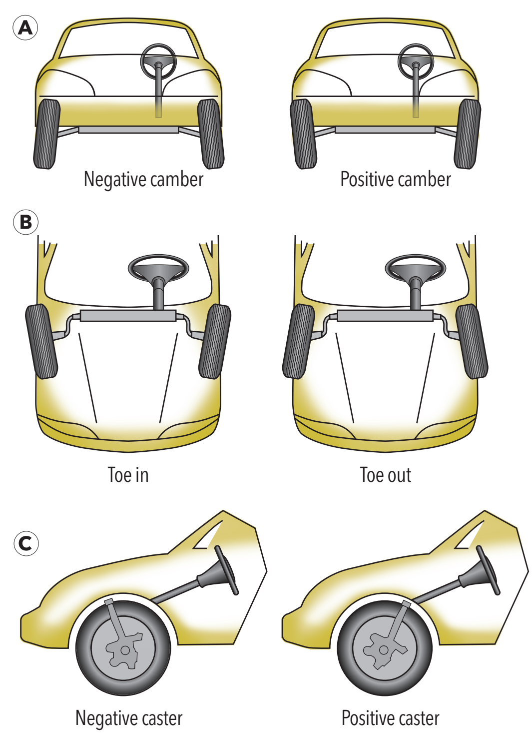

Figure 13. Vehicle alignment parameters: (a) camber; (b) toe; (c) caster.

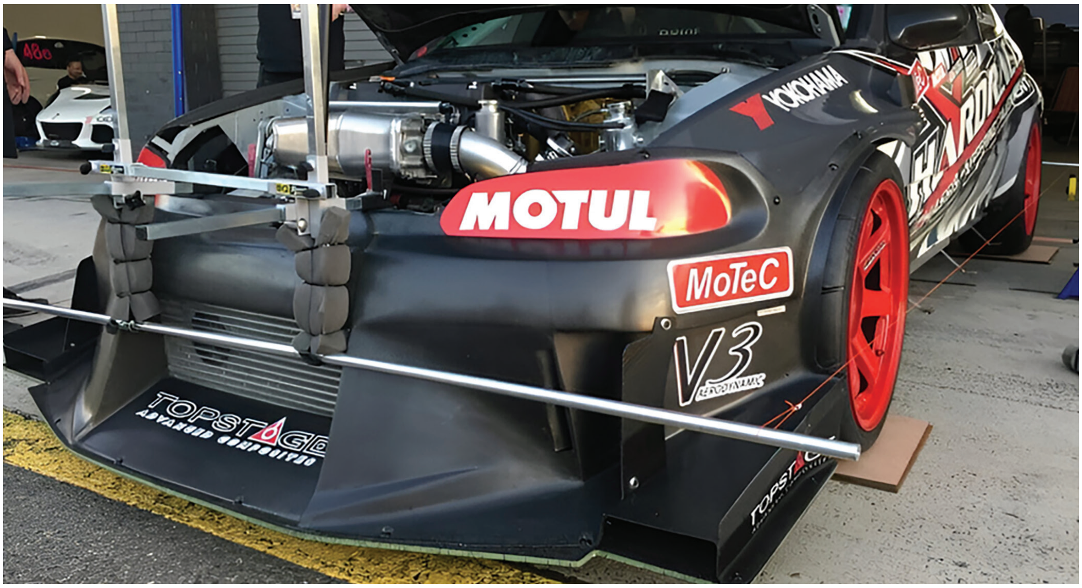

Figure 14. Visual alignment of a vehicle.

Vehicle Alignment

Safe and comfortable driving requires correct vehicle alignment. In addition to affecting safety, improperly aligned vehicles contribute to increased wear and tear. This is particularly evident in increased and uneven wear on tires. The three primary vehicle alignment parameters are camber, toe, and caster (Figure 13).

VISUAL INSPECTION CAPABILITIES AND LIMITATIONS

A well-trained auto mechanic using simple tools (Figure 14) can align a vehicle using visual methods. Following is a typical checklist used for visual inspection for alignment.

1. **Prepare the vehicle.** Ensure the vehicle is parked on a level surface. Check that the tire pressure aligns with the manufacturer's specifications. Make sure there are no heavy items in the trunk or elsewhere that could impact the vehicle's stance. The vehicle should be in a neutral position, with the steering wheel centered.
2. **Inspect the tire condition.** Look for signs of uneven tire wear. Uneven wear on the inside or outside of the tires may indicate misalignment.
3. **Check the wheel toe alignment.** The "toe" refers to the angle of the wheels relative to the vehicle's centerline. Stand in front of the vehicle and look at the front wheels. They should appear parallel to each other and aligned with the car's body. Repeat the process from behind the vehicle, checking the rear wheels.
4. **Examine the camber angle.** The camber is the tilt of the wheel. When looking at the vehicle from the front or back, the wheels should be perpendicular to the ground. A visible tilt inward (negative camber) or outward (positive camber) could indicate a problem.
5. **Observe the steering wheel position.** Sit in the driver's seat and check if the steering wheel is centered when the wheels are pointed straight ahead. A misaligned steering wheel while driving straight can indicate alignment issues.
6. **Check the suspension components.** Inspect the suspension components for any signs of wear or damage. Worn parts can affect wheel alignment. Accurate measurements of toe and camber can be achieved by establishing reference points using string and a straight pipe (Figure 14). Key alignment parameters can be measured using these reference points, a tape measure, and a level. While the cost of the alignment tools is minimal, the procedure largely relies on visual inspection and requires a well-trained mechanic.

CURRENT MACHINE VISION CAPABILITIES AND OPPORTUNITIES

Currently, there is a shortage of well-trained mechanics, and frequent turnover at automobile service and repair shops increases training costs while diminishing the productivity of mechanics employed by these businesses. For automobile service and repair shops specializing in vehicle alignment, tools are required to enable mechanics with minimal training to perform the complex task of aligning a vehicle. Machine vision–based tools (Figure 15) automate the vehicle alignment process and generate digital records.

Using machine vision-based alignment tools eliminates the error associated with visual inspection. The standard deviation for a typical machine

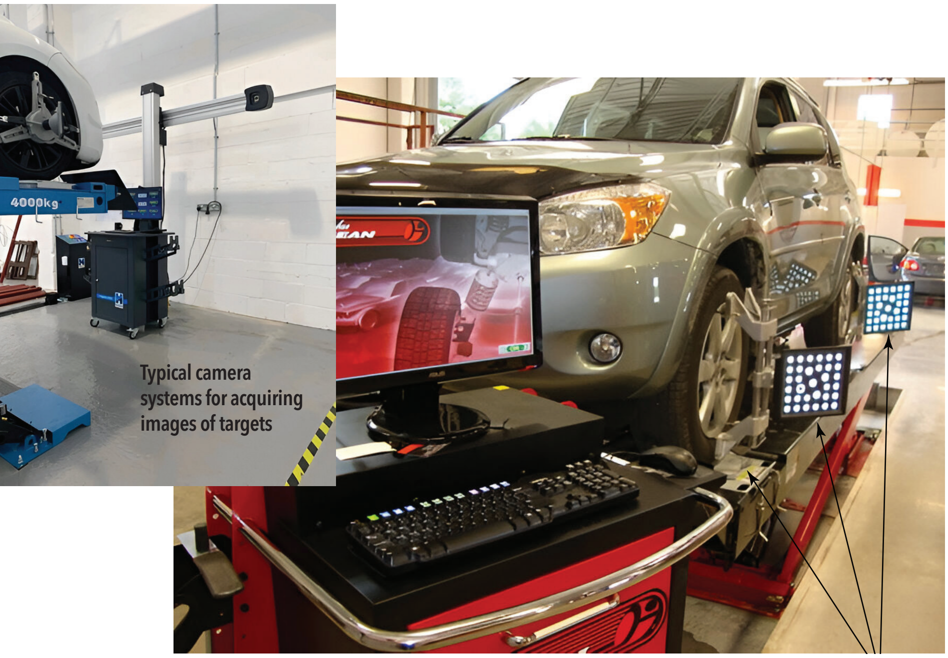

Figure 15. Tools for performing a machine vision–based alignment of a passenger vehicle.

vision–based system, for toe and camber measurements, is typically around 0.02 degrees. Achieving this level of accuracy through purely visual inspection is extremely challenging. Additionally, because the workflow is embedded in software, technician training requirements are reduced. The process is guided by the software, ensuring accurate results. Figure 16 shows results from a commercially available machine vision–based wheel alignment system.

A machine vision–based wheel alignment system calculates the orientation of the wheels by analyzing the alignment markers attached to each wheel. Typical results, along with the acceptable range for the specific vehicle under test, are shown in Figure 16. For instance, the camber specification includes a minimum of –1.75, a maximum of –0.25, and a preferred value of –1.00 (all values are in degrees).

Conclusion

For many years, automotive mechanics have relied on visual inspection to perform a variety of tasks, including tire inspection, dent repair, and wheel alignment. Visual inspection is crucial for determining whether tires need to be replaced, identifying and repairing dents and other damages in collision shops, and assessing vehicle alignment by auto mechanics. However, purely visual methods are susceptible to errors. Limitations in visual acuity, inadequate lighting, fatigue, and other human factors contribute to errors in visual inspections. These errors can range from minor, such as overlooking a small dent, to major, such as inaccurately assessing vehicle wheel alignment or tire tread depth.

Machine vision–based methods establish standard inspection and repair processes, mitigate measurement errors, reduce training requirements, and improve the overall efficiency of vehicle inspections and repairs. Today, automotive shops have access to a variety of machine vision–based tools. These tools include both 2D and 3D imaging for almost all aspects of vehicle inspection and repair that were previously done through purely visual techniques. As vehicle manufacturers continue to integrate advanced technologies into automobiles, the demand for advanced machine vision–based tools will increase. For instance, new tools are required to meet the need for calibration and repair of ADAS (Advanced Driver Assistance Systems) and other autonomous or semi-autonomous technologies. ME

AUTHOR

Daniel L. Lau, PhD: Databeam Professor and Certified Professional Engineer, Department of Electrical and Computer Engineering, University of Kentucky, Lexington, KY; dllau@uky.edu

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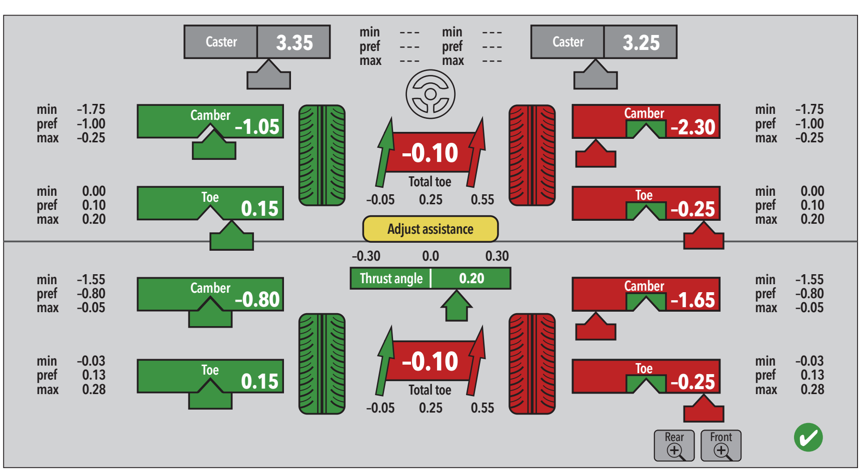

Figure 16. Typical measurement results from a machine vision-based wheel alignment system.

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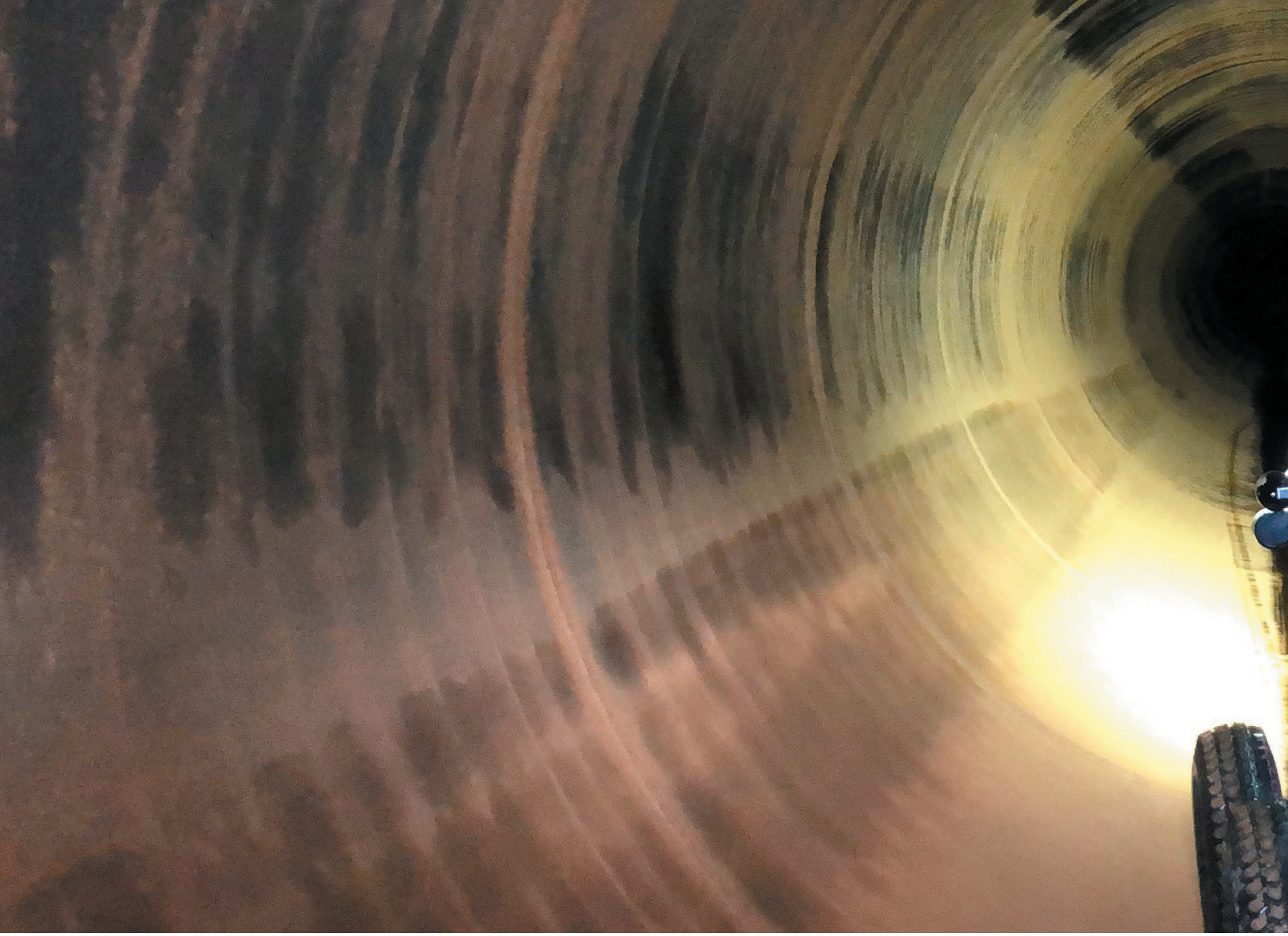

ROBOTIC CRAWLERS

BY RON KESSLER

Modern robotic crawlers provide a means of safe and effective remote data capture, reducing confined space entries, minimizing data collection times, enhancing inspection data quality, and optimizing overall inspection spend.

Introduction

Direct visual testing (VT) is a nondestructive testing method utilized for surface inspection and evaluation. The specifications of direct visual inspection are defined as placing the eye within 24 in. (600 mm) of the surface to be examined, at an angle of not less than 30°, supported by a white light source with a minimum intensity of 100 fc (1000 lux). For many industries, direct VT presents formidable challenges, as the costs to access the examination area are prohibitively expensive and

FOR VISUAL TESTING

inherently dangerous; hence, the advent of remote visual inspection (RVI).

RVI employs the use of remotely operated camera systems including videoprobes, tube cameras, robotic crawlers, pan-tilt-zoom (PTZ) cameras, uncrewed aerial systems (UASs/drones), and submersible remotely operated vehicles (ROVs). The remote nature of the data capture, sophistication of the tooling, and skill of the inspector drives safe, efficient, and cost-effective inspections in hazardous, inhospitable, and inaccessible plant systems and components. Moreover, many of these inspection instruments may be deployed with a wide array of payloads delivering manipulators, cleaning apparatuses, and varying sensor technologies to encompass a broader range of mission parameters.

Modern robotic crawlers are exceptionally well-suited for a wide variety of inspection tasks. As indicated in Figure 1, the assets, applications, industries, and methodologies can be extensive and far-reaching. These tools are becoming increasingly capable of capturing a myriad of inspection data while providing a significant reduction in peripheral inspection costs such as scaffolding, insulation removal, and confined space entry. The reduction or, oftentimes, elimination of these supporting activities also optimizes the safety profile of the inspection by reducing labor and minimizing high-risk activities. This article will examine common crawler platforms, deployment considerations, and offer a unique use case for review.

Crawler Platforms

Crawler platforms generally consist of a camera control unit (CCU), crawler body, camera(s), and a cable/cable reel. The CCU enables remote operation of system features such as crawler travel direction and speed, as well as camera articulation and operation. Furthermore, the CCU may provide critical feedback to the operator, such as travel distance and camera orientation. The CCU may also enable data

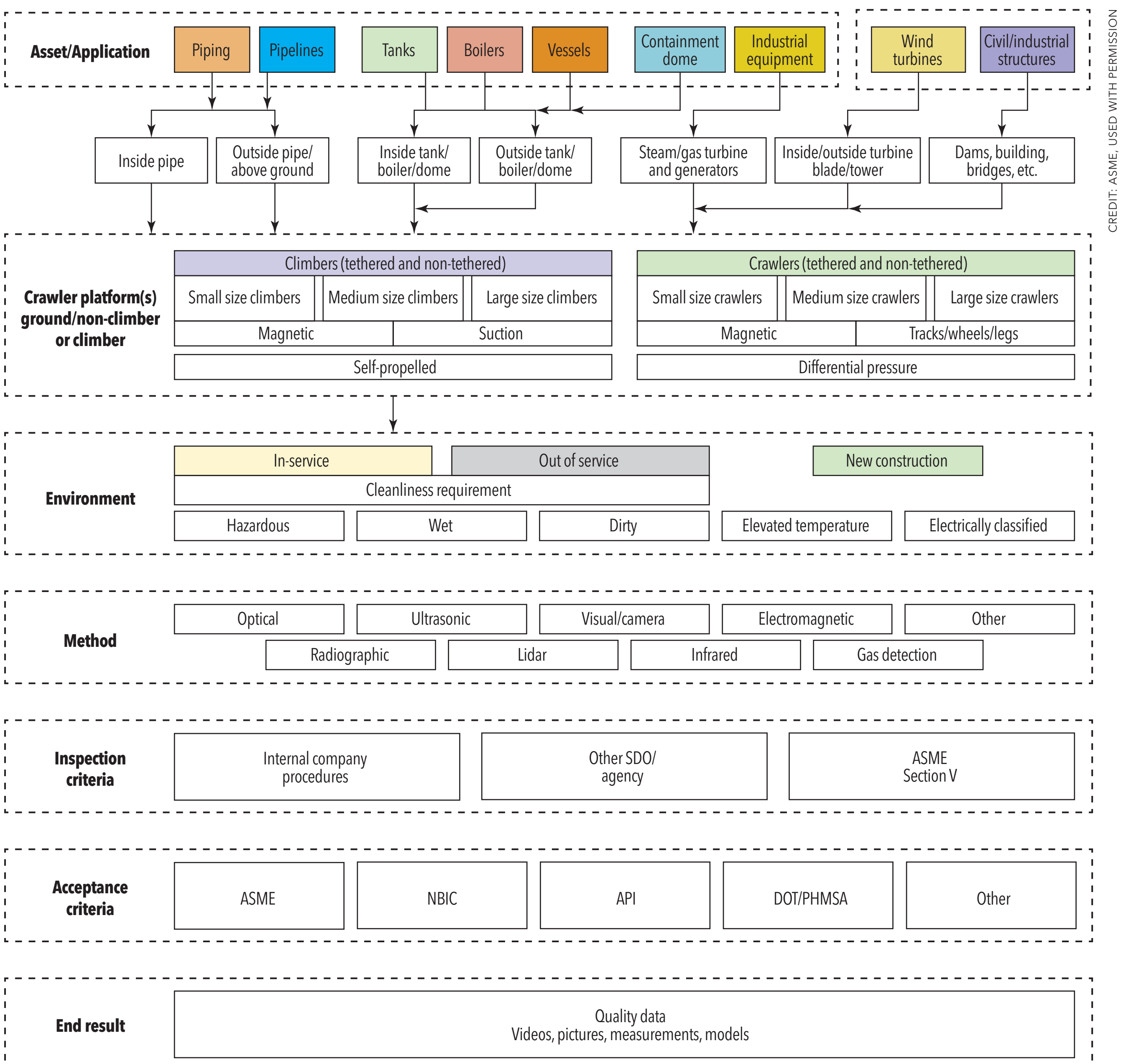

Figure 1. Crawlers for inspection by asset/application from ASME MUS-2.

Figure 2. Modular robotic crawler.

capture and system intelligence such as pitch, roll, and system pressurization levels.

Crawler bodies are often modular in nature and may be configured to accommodate a wide range of assets (Figure 2). Wheeled or tracked units can both be effective depending on the area to be traversed. Access to the asset to be inspected should also be considered, as confined launch areas, piping geometry, or other obstacles may impact the ideal wheel size, camera selection, or tooling configuration. Vertical travel may be achieved utilizing variable-geometry crawlers that leverage opposing force on pipe walls, or by using vacuum-based, magnetic-based, or magnetic-wheeled crawlers. Each maintain certain advantages in specific applications depending on access, geometry, cleanliness, material, contents, and line features.

Cameras and accompanying lighting are utilized for both navigation and inspection. Ideally, inspection cameras will offer PTZ features to enhance data capture efforts. Advanced camera features such as variable lighting control, aperture manipulation, and automated weld, joint, or feature scanning are invaluable to quality inspection efforts.

The cable reel functions as a means of communication between the CCU and crawler, and in case of an unplanned event such as a loss of power or change in atmospheric conditions, the safe removal of the tool. While some units may be operated without tethers, deployment in industrial applications typically requires a positive means of extraction. Automated cable reels can advance and retract the cable with the crawler movement to ease operation and lessen the burden on the inspection team. Care should be taken with cable tending when the crawler is navigating around obstacles so as not to destabilize the unit. Excessive slack or tension may inadvertently overturn the crawler.

Sensor payloads for inspection crawlers can be extensive. Tremendous industry investment has accelerated the advancement of remote operation tooling. Common accoutrements include lidar or laser scanning, ultrasonics, eddy current, radiography, and cleaning apparatuses or nozzles to facilitate hydrolazing (high-pressure water jetting) or CO_2 cleaning. Deployment of these tools and the associated cables and/or hoses may constrain crawler functionality, travel distance, and agility.

Deployment Considerations

Crawler selection should be suited for the mission objectives, inspection specifications, and line/asset features. Mission objectives should define the purpose and work scope. Key mission parameters may include distance to be traveled, what data is to be collected, and what method of testing is to be completed. Inspection specifications will underscore the applicable codes and standards to be utilized. Collectively, this information shapes equipment selection, technician suitability based on necessary experience or certifications, and inspection team makeup.

Operators should use care in evaluating the access point location, orientation, and obstacles for insertion. Common line feature considerations include pipe geometry such as the number of bends, bend radius, slope, and/or vertical sections of piping; system design features such as valves and their number, location, type, and orientation; and instrumentation such as thermowells. Additionally, obstacles such as vertical tees or downcomers to be traversed should also be evaluated. Fabrication and service-induced anomalies (including backing or chill rings) and excessive line exfoliation should also be considered. Atmospheric testing, temperature, and cleanliness will also impact crawler selection and mission planning.

While evacuated lines are more conducive to RVI, inspections can also occur with the line full or partially full. Clarity, turbidity, and flow rate may negatively impact inspection effectiveness. Care should be exercised as not to exceed the maximum depth rating or head pressure for the crawler. If the crawler is to be introduced to other compounds, the Safety Data Sheets (SDSs) should be thoroughly reviewed for possible hazards. This effort should go beyond the typical job safety analysis (JSA) and should evaluate hazards and chemical compatibility with the inspection crawler bill of materials. For example, the crawler and camera O-rings, crawler wheels or tracks, and the cable may all be susceptible to chemical-induced degradation.

Use Case

As a service provider, our RVI team experiences a broad spectrum of applications across a myriad of industries. The expansive nature of our work necessitates a mastery of RVI equipment deployment, utility, and manipulation. And while some exams can be rather mundane, we are often sought after for unique applications that challenge current technology limitations. These difficult inspections that challenge convention and technology limitations are often the most rewarding in terms of provoking thought and advancing inspection capabilities.

We recently devoted our efforts to assist a pipeline operator requesting assistance in validating several anomalies noted during a pipe pigging effort. The results of the pipe pigging inspection indicated that there were indentations in the line. Our inspection tasks were to conduct a general remote visual inspection, locate and identify the anomalies, and measure the relevant indications to support further engineering analysis.

The inspection presented a laundry list of formidable challenges for our team. Beyond the access point, the pipe was buried and inaccessible. The line geometry was not inspection-friendly, containing a tee joint at the access, several bends, and an elevation change. Furthermore, the line also changed in diameter. These obstacles made it difficult for an inspection crawler equipped with measurement tools to travel to the areas of interest, some at distances of more than 800 ft (243 m).

Crawlers that can accomplish this type of inspection are not readily available, so customization was necessary for a successful deployment. Our team liaised with several equipment manufacturers and technology providers to understand how we might "stack" various technologies for mission success. After a bit of research, we fitted, tested, and commissioned a remotely operated crawler coupled with a terrestrial 3D laser scanner. This package was able to fit in the smaller of the two pipe diameters, navigate around multiple bends, and capture high-fidelity measurements at great distances (Figure 3).

The data capture effort included complete video of the line, still image capture of points of interest (Figure 5), and 3D laser scanning of indentations and anomalies (Figures 4 and 6). Utilizing a terrestrial laser scanning provided 1 mm accuracy, which enabled enhanced engineering modeling and analysis. Perhaps most importantly, this data was captured without confined space entry and eliminated the time and cost of excavations and external data collection.

Figure 3. Crawler equipped with a 3D laser scanner. Also note the "bridge" utilized to drive over the exposed tee connection at the bottom of the line.

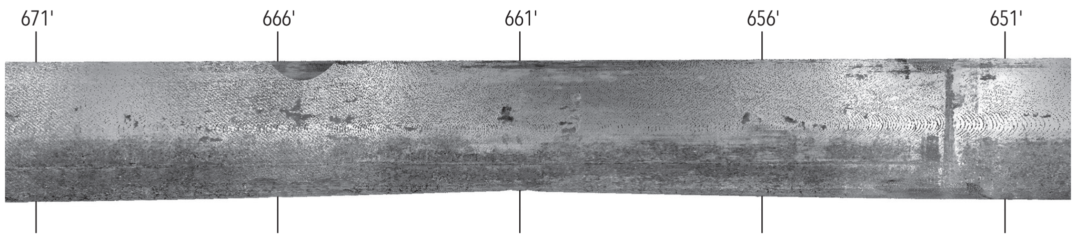

Figure 4. Point cloud view of indentation and surrounding piping.

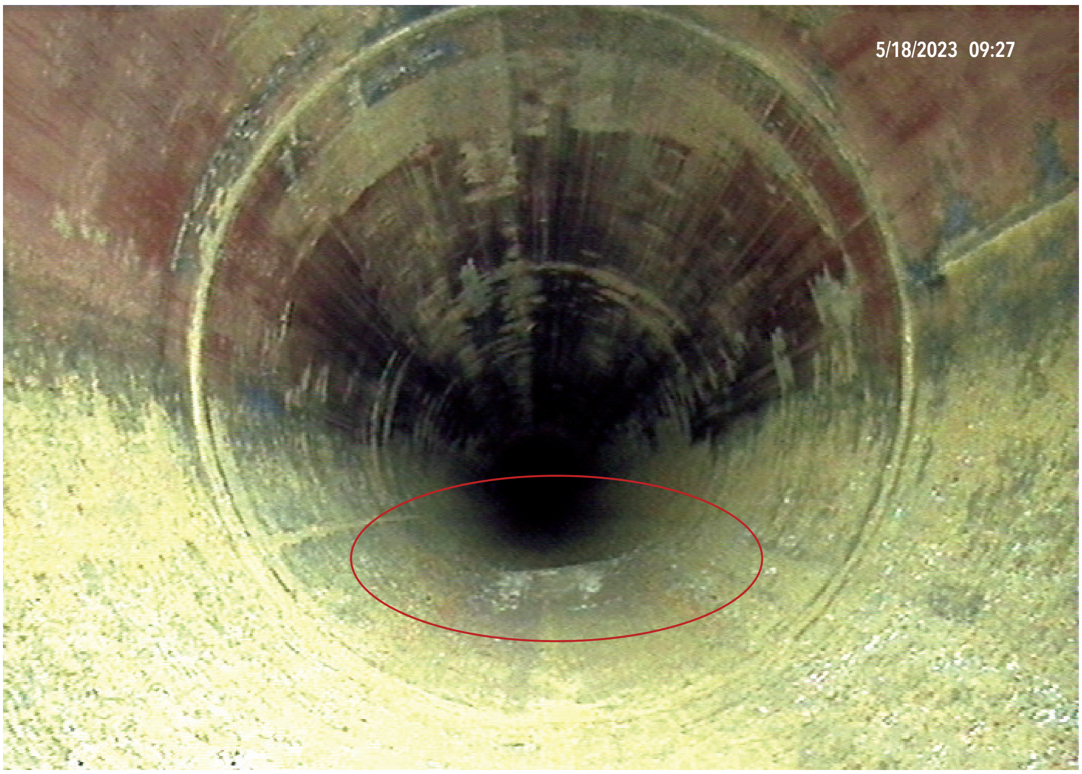

Figure 5. Crawler camera view.

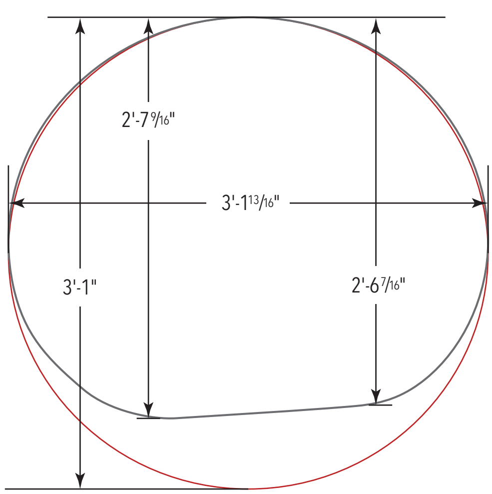

Figure 6. Best-fit oval due to indentation.

Conclusion

Effective utilization of remote crawlers begins with a clear understanding of mission objectives, inspection specifications, and line/asset features. Collectively, these critical areas create a framework for crawler selection, payloads, and inspection team attributes. When properly deployed, remote crawlers yield tremendous benefits including safe, expedient, and cost-effective data collection, excellent data quality, and minimization or elimination of excavation and confined space entries. This culmination of attributes can help to reduce outage or turnaround scope, optimize inspection budgets, and positively impact safety metrics. ME

AUTHOR

Ron Kessler: Vice President, Robotic Inspection Solutions, Team Inc., Sugarland, TX; rkessler2012@gmail.com

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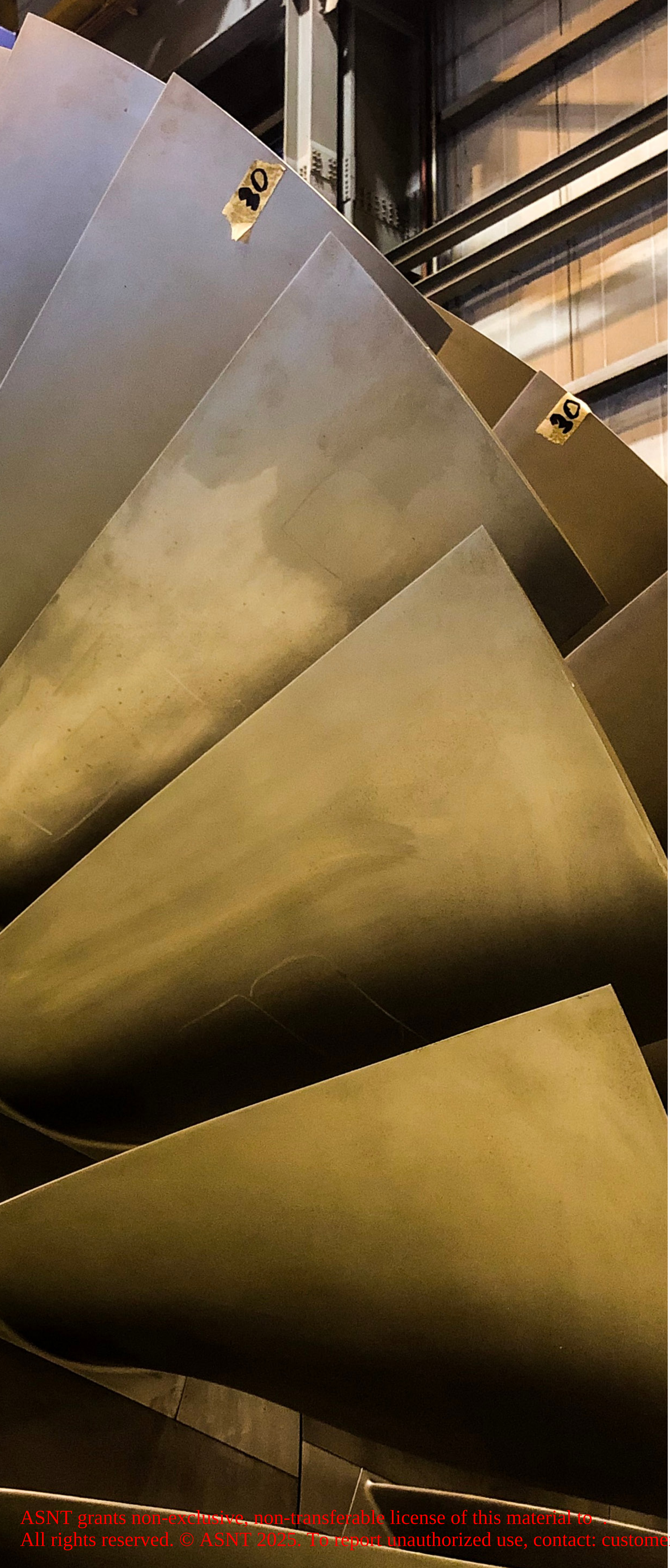
RVI FOR INTERNAL HEALTH MONITORING OF INDUSTRIAL GAS TURBINES

BY PAUL THOMPSON

INDUSTRIAL GAS TURBINES ARE ROBUST, DURABLE, AND DEPENDABLE, BUT THEY CAN DEVELOP PROBLEMS SUCH AS INTERNAL WEAR, LOSS OF THERMAL BARRIER COATINGS, AND PREMATURE PART FAILURES. IF LEFT UNDETECTED, THESE ISSUES CAN LEAD TO SIGNIFICANT UNPLANNED COSTS AND DOWNTIME. TO PREVENT PREMATURE FAILURES, AND AS AN AID IN FUTURE OUTAGE PLANNING, INTERNAL HEALTH MONITORING USING REMOTE VISUAL INSPECTION (RVI) CAN DETERMINE WHETHER COMPONENTS ARE IN GOOD CONDITION AND FIT FOR SERVICE, OR IF ADDITIONAL REPAIRS ARE NEEDED. THE USE OF RVI, WITH A VIDEO BORESCOPE CAPABLE OF ANALYZING AND QUANTIFYING INDICATIONS USNG 3D DATA DISPLAYED IN A POINT CLOUD, ALLOWS FOR MEASURING ANOMALIES WITH ACCURACIES OF 0.001 IN. (0.025 MM). IN SOME CASES, EARLY DETECTION AND 3D ANALYSIS OF INTERNAL ISSUES IN INDUSTRIAL GAS TURBINES HAVE SAVED OPERATORS MILLIONS OF DOLLARS, SOMETIMES EVEN DURING A SINGLE OUTAGE.



Introduction

Industrial gas turbines are the heart of operations where electric power generation, cogeneration of electricity and steam, gas compression, propulsion in marine applications, or a combination of these is necessary for a plant or vessel to operate. While these turbines are incredibly dependable, they have regular maintenance schedules and occasionally forced outages where remote visual inspection (RVI) is required to determine if industrial gas turbines are fit for service, or if additional repairs and maintenance are required. The nondestructive technique of RVI, which is a discipline within the visual testing (VT) method, allows for indirect visual inspections of areas of the fan, compressor, combustion section, and power turbine with minimal disassembly. Auxiliary components and balance of plant (BOP) items such as piping, valves, vessels, and machinery are also inspected with RVI during these outages. When surface indications or discontinuities are detected, extremely accurate indication sizing and 3D analysis are now possible with RVI. The benefits are minimized downtime, increased safety, and maximized return on investments for the operation. This article provides insights on how the proper implementation of RVI technology, and accurate interpretation of the data obtained during an RVI event, can provide valuable diagnostic information on the internal health of a gas turbine.

Direct visual examinations to determine the safety of a situation or the quality of assets have been around as long as eyesight. Visual testing (VT) is thought of as a foundation of nondestructive testing (NDT). VT in industrial applications began in the early 1920s. It was not until 1988 that VT became a certified testing method in ASNT's SNT-TC-1A. However, it was not widely accepted by industry until the European Union Standards Committee incorporated VT in the EN 473 certification standard in 2001. EN 473 was subsequently replaced by ISO 9712:2021(en): *Nondestructive Testing – Qualification and Certification of NDT Personnel*.

To perform effective direct visual examinations, the recommended distance and angle for viewing is to have the eye within 600 mm

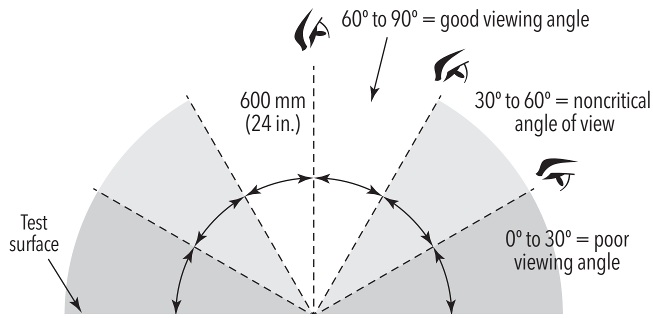


Figure 1. Direct visual testing viewing angle and distance.

(24 in.) of the object and positioned at an angle not less than 30° to the inspection surface, as shown in Figure 1 [1].

Making a direct visual examination to determine the condition of internal components in a gas turbine is physically impossible without significant amounts of downtime and disassembly. As seen in Figure 2, a technician can readily inspect the internal components of a large frame gas turbine. When knowing their internal condition is required, this is where RVI becomes indispensable. It is interesting to note that while RVI is a subdiscipline of VT in SNT-TC-1A and ISO 9712:2021(en) visual testing (methods), both direct unaided visual tests and visual tests conducted during the application of another NDT technique are excluded. This accentuates the importance and value of qualified and certified NDT personnel who are specifically using RVI.

RVI enables the visual inspection of otherwise inaccessible areas or surfaces. The earliest examples were endoscopes that began to be used for medical purposes in the early 18th century. With the advent of cannons, artillery operators would lower a candle on the end of a stick into a cannon bore to determine its condition prior to use. You might see why this could be problematic for the inspector! People soon realized they could only see in straight lines, but if mirrors or fiberoptics were used, the light and image could "go around" corners. From this discovery, the borescope and borescope technology have evolved.

Dr. George S. Crampton developed the first industrial borescope, which was used by the Westinghouse Co. for examining internal turbine components. Inspecting internal surfaces of a turbine rotor were some of the first RVI applications on industrial turbines. While Crampton was a mechanical "MacGyver" of sorts, he used optical instruments in his medical practice as an ophthalmologist and tinkered with optical instruments in his spare time. His work led to the founding of the Lenox Instrument Co. [2].

Today, typical RVI applications with borescopes are inspecting internal components on aviation and

Figure 2. Visual inspection of a GE Vernova large frame gas turbine's fuel lines.

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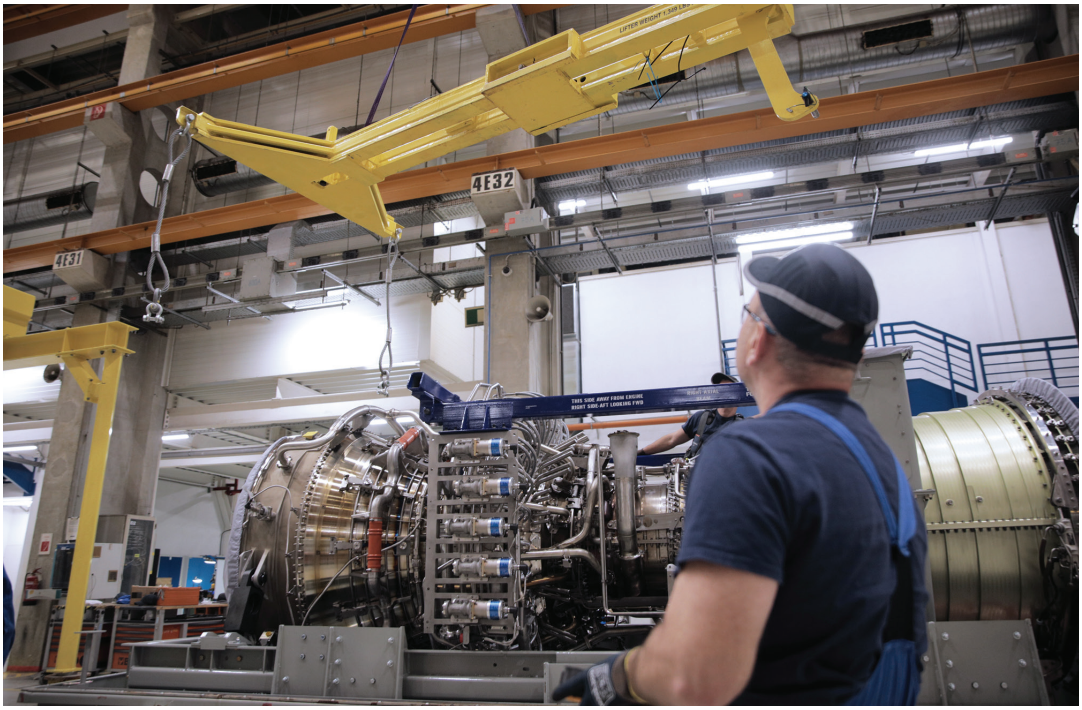

Figure 3. GE Vernova readies an LM6000 aeroderivative turbine for service.

industrial turbines, power cylinders, pipes, tubing, boilers, and heat exchangers, within numerous industrial applications.

Aerospace and power-generation gas turbine operators benefit from RVI procedures, commonly referred to as "borescope inspections." In fact, gas turbines in aerospace and industrial applications are among the largest industry segments that use borescopes. Small port plugs can be quickly removed from the external casing, and a borescope inserted by a technician allows for the inspection of internal stages or areas of the fan, compressor, combustor, power turbine, and related accessories. Borescopes for turbine inspections come in two basic configurations: one with a flexible insertion shaft and one with a rigid insertion shaft. Both types can be configured with or without video capability. This article focuses primarily on flexible video borescopes.

In some cases, industrial turbines were initially developed as aviation turbines. For instance, Pratt & Whitney's FT4000 is the aeroderivative industrial variant of the PW4000, and Rolls-Royce's RB211 is used in both aviation and industrial applications.

Similarly, the GE Vernova LM6000 (LM is a Land Marine designation) aeroderivative turbine shown in Figure 3 was developed from the CF6-80C2 aviation turbine platform. The CF6 has been in use for over 50 years on long-haul flights by Boeing and Airbus. A cut-away of the CF6 as shown in Figure 4 depicts the major section of a gas turbine.

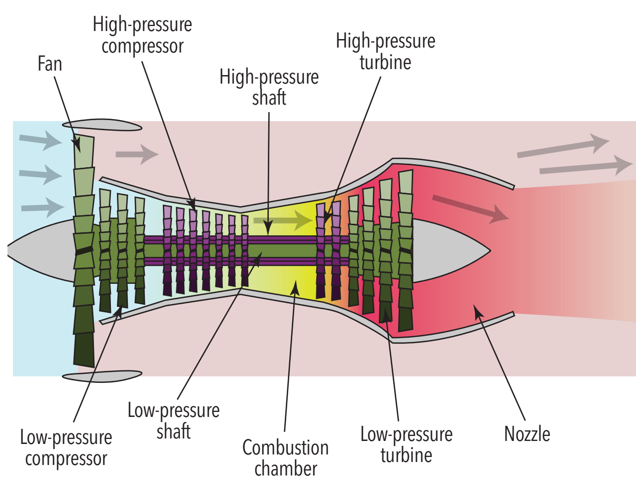

Figure 4. Cut-away view of the major section of a CF6 gas turbine used in aviation.

In power generation, there are also much larger and heavier frame turbines that have higher power output. However, both turbine types operate fundamentally the same, in that ambient air is compressed, mixed with fuel and heat in the combustion section, and then passes through a power turbine section where the energy is extracted. Notice the scale difference of the aeroderivative LM6000 in Figure 3 and the large frame 7HA.03 in Figure 5.

Therefore, it makes sense that RVI inspections on aeroderivative and large frame turbines would be comparable to those conducted on aviation turbines, and indeed they are. A significant difference is that aviation turbines are inspected on

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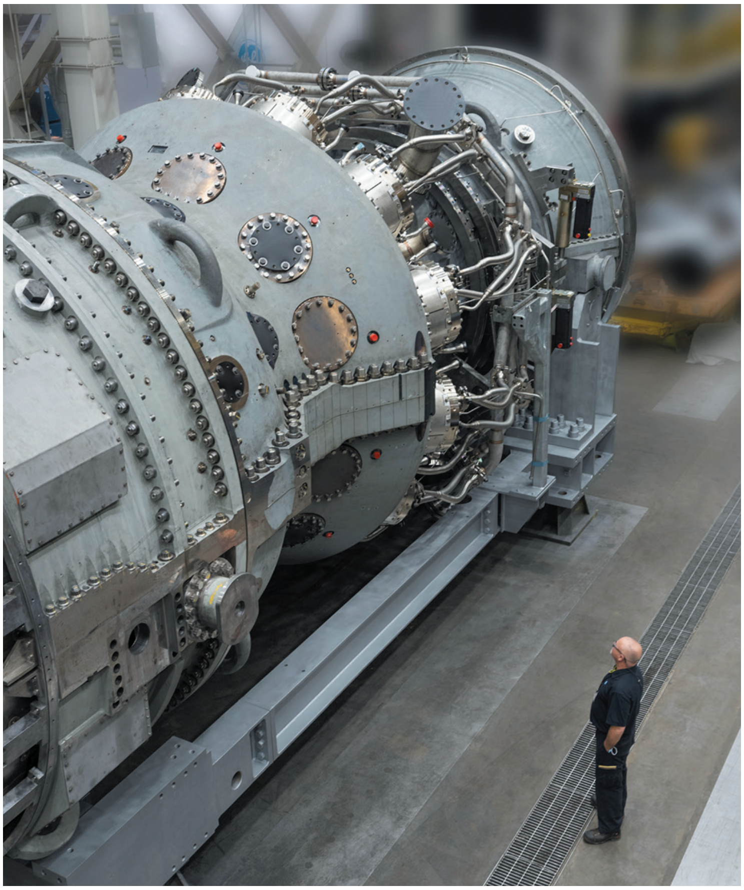

Figure 5. Large frame 7HA.03 GE Vernova gas turbine.

a more frequent schedule to ensure flight safety. Another critical aspect of RVI for both aviation and industrial turbines is determining whether a turbine can operate safely and efficiently until the next scheduled inspection, thereby ensuring maximum uptime and profitability. This often involves needing to make precise and accurate measurements of various types of surface indications. A thorough understanding of RVI techniques, and the equipment being used, is critical for collecting accurate image data to make these assessments.

Background

It is crucial to have RVI equipment that meets examination requirements, can accurately measure indications and anomalies on demand when needed, and is standardized to provide indication size analysis traceable to precision measurement standards like those at the National Institute of Standards and Technology (NIST). This ensures accurate decision-making data can be obtained.

Even with the best equipment in the world, training—or lack of training—of RVI technicians significantly impacts the quality of the inspection data obtained. Training for RVI technicians is no less critical than it is for technicians in other NDT disciplines such as ultrasonics, radiography, and electromagnetics.

When preparing for a borescope inspection, some critical factors must be considered to help ensure success. Ask yourself:

- Is the camera and entire video borescope system serviceable and standardized to provide indication size analysis traceable to precision measurement standards like those at the National Institute of Standards and Technology (NIST)?
- Does the RVI technician know how to inspect the cleanliness of the camera and optical tip adapters, with both fixed and removable optical lenses?
- Is the technician trained and qualified to use the equipment, and do they understand the inspection requirements?
- Is their training complete on both the RVI system and the asset to be inspected?
- Has the performance of the technician and RVI equipment been evaluated with a Probability of Detection study, or has a Gage Repeatability and Reproducibility (Gage R&R) [3] been completed on assets requiring accurate detection and measurement analysis?
- Does the technician know the necessary diameter and length of the flexible camera shaft to ensure access through all borescope ports and to reach the farthest inspection points?
- What is the required travel path of the camera to the inspection area? Are guide tubes, push poles, or other accessories required to deliver the camera to the inspection site?
- Does the technician know what to do and what *not* to do if the camera becomes stuck in a turbine?
- What is the internal environment in the inspection area? Is it hot, cold, toxic, explosive, or corrosive?

Each of these are key factors to be aware of when performing an RVI task, and they should all be addressed in a training program. One must understand the benefits—and risks—of performing RVI with the proper equipment and trained technicians versus best-in-class equipment and inadequately trained technicians.

RVI Data Collection and Analysis

In these examples, you will see where RVI measurements were taken, and that the measurement data obtained was accurate. However, the measurement data was also very wrong. How can measurement data in the same image obtained with best-in-class RVI equipment be both accurate and wrong at the same time?

There are caveats one can learn to mitigate with training. Two critical ones are that the XYZ data points used to achieve measurement data must exactly map the shapes and contours of the surface to be analyzed, and the measurement cursors must be accurately placed on these data points.

First, a measurement image captured with a video borescope must accurately depict the underlying measurement data determined by the calculated XYZ coordinates, ensuring that each camera pixel correctly maps the surface points. If the point cloud data—all XYZ data points which are stitched together to form a point cloud—precisely matches the surface points, accurate measurements can be made using the XYZ coordinates in that point cloud. Note that in Figure 6 the point cloud data on the image's right side accurately depicts the surface points as seen in the white light image on the left. Using point cloud image data for measurements can result in more accurate and precise measurement data.

Pivoting a point cloud image on the X, Y, and Z axes allows the technician to evaluate the point cloud's health; in other words, does the point cloud data exactly portray the surface being viewed? This can be done by pivoting the point cloud image on the video borescope's display or doing the same in PC-based remeasurement software.

If the point cloud data quality is low, it will not accurately depict the actual surface geometry. There may be holes, or missing data, and there may be wavy or extremely lumpy areas in the point cloud even when the surface being imaged is flat. The point cloud data must accurately represent the area of an image that is to be measured. Accurate placement of the measurement cursors is also critical and can be validated, and relocated if needed, in the point cloud.

Here are examples of two separate RVI tasks showing how, even with good image data quality, obtaining accurate measurement data yielded the wrong measurement data. More importantly, we will see how to resolve these errors.

In the first example, Figure 7 shows a stereo measurement of a tip-to-shroud clearance being used to determine the wear of a power turbine's blade tips. The measurement type being used is referred to as a *depth* measurement. It can be thought of as measuring the distance to or from a reference plane established by placing three cursors on a reference surface. Then, by placing a fourth cursor on a point, one can calculate the distance of that fourth cursor above (+) or below (–) the reference plane. Blade tip-to-shroud clearance is important data for decision-making regarding the efficiency of the power turbine and assessing the need for repairs.

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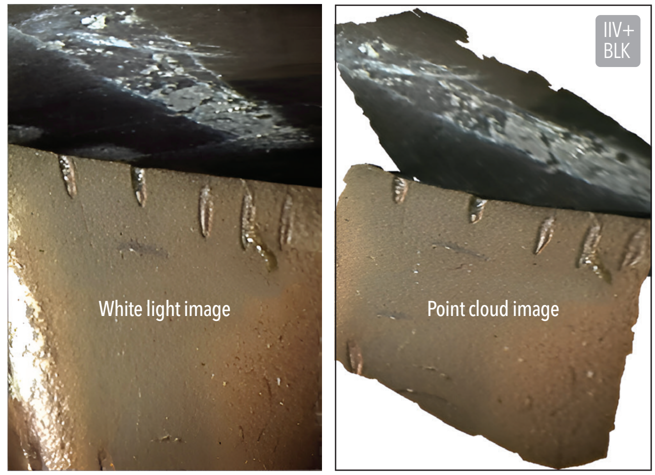

Figure 6. Power turbine shroud (darker top part of image) and blade tip (bronzish lower part of image) as seen in a white light image (left) and an XYZ 3D point cloud (right).

As seen in Figure 7, three points of a mathematical reference plane *appear* to be on the shroud's surface: the cursors labeled 1,2, and 3. (Pay particular attention to the plane's cursor labeled 3.)

The fourth cursor, labeled 4, is placed on the tip of the blade and provides a measurement from the reference plane on the shroud to the blade tip.

In Figure 7, the measurement data of 0.031 in. (0.787 mm) may be considered accurate because cursors 1, 2, and 3 for a reference plane appear on the shroud (the darker surface in the upper portion of the image), and the measurement cursor (cursor 4) appears to be placed on the tip of the blade (the bronze-colored surface in the lower portion of the image).

When the stereo measurement system does not have the capability to generate a viewable 3D point cloud, moving the fourth cursor around the measurement plane can help establish a valid placement of the reference plane, as indicated by minimal, if any, distance variations from the reference plane. This step is often overlooked in stereo measurements that do not offer a point cloud view.

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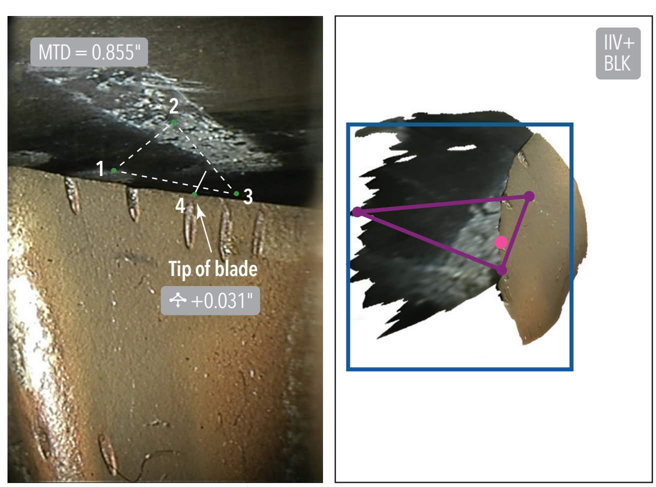

Figure 7. Power turbine blade tip-to-shroud, measured with a stereo image–reference plane data was not validated. The darker top part is the shroud of the combustor; the bronzish lower part is a power turbine blade.

However, when observing the cursor placement in a fully surfaced point cloud image, it becomes evident whether the point cloud has low data quality and if cursors have been accurately positioned on the data. Reviewing both metrics in the point cloud can help increase accuracy and precision of the collected measurement data.

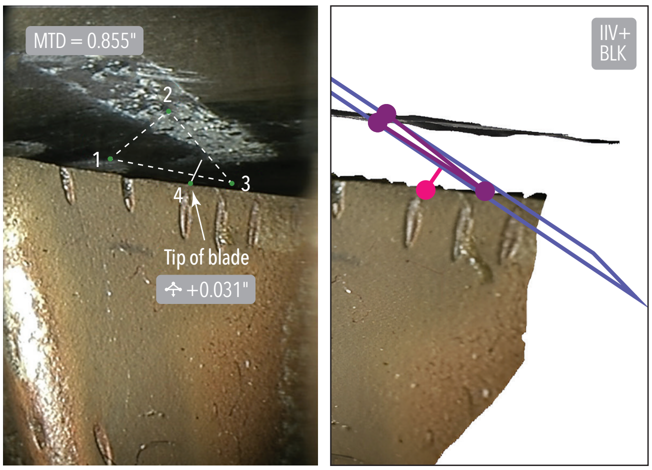

Figure 8. Power turbine blade tip-to-shroud, measured with stereo. Measurement data found to be in error by reviewing the point cloud.

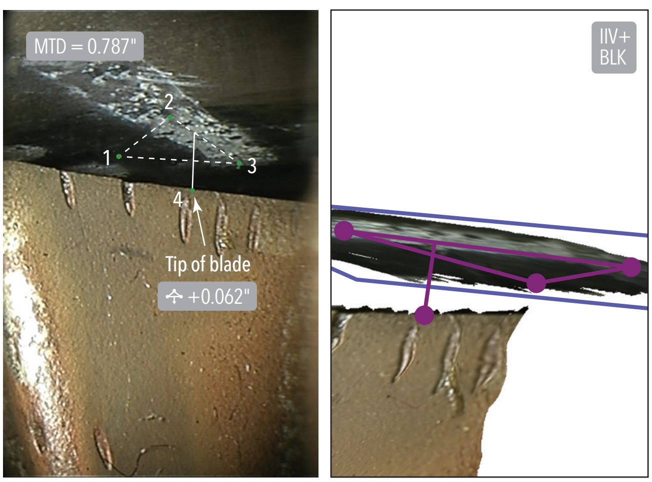

Figure 9. Power turbine blade tip-to-shroud, measured with stereo. Measurement data error corrected by correctly placing the reference plane's cursors on the shroud while reviewing the point cloud.

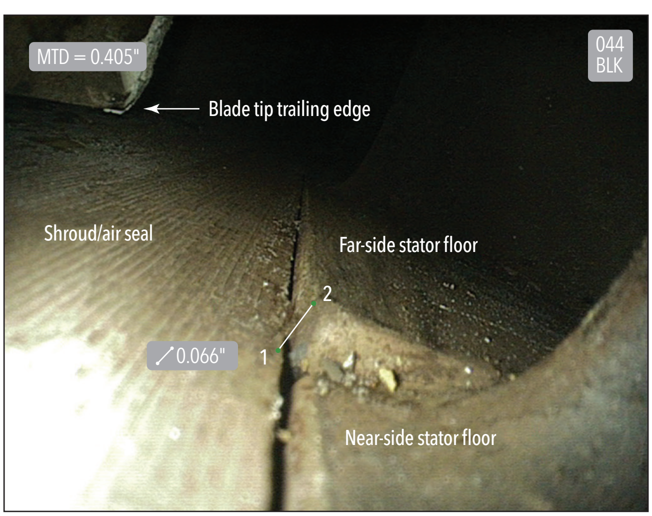

Figure 10. White light image of compressor section with stator section to be measured for rocking.

In the example in Figure 7, the technician was not trained in how to validate the measurement data in a stereo image, nor were they trained to review the point cloud data and the cursor placement upon the data. This led to providing a blade tip-to-shroud clearance data of 0.031 in. (0.787 mm).

When a measurement system's point cloud is reviewed and pivoted in X, Y, and Z onscreen, it immediately becomes obvious that a common measurement error has been made. Note in Figure 8 that when viewing the 3D data in the point cloud image, the cursor labeled 3 of the measurement's reference plane (the lower, far-right magenta cursor) was placed on data from the tip of the blade, not on reference plane data for the shroud.

Note that the reference plane's blue lines are an extension of the three cursors used to establish the reference plane. When that plane is tilted away from the actual surface of the shroud, the tip-to-shroud gap measurement appears smaller than it actually is. Because the data quality in the point cloud is extremely high, this presented an accurate measurement. Because cursor 3 of the reference plane was inaccurately placed on the tip of the blade, and not on the shroud, the results obtained are also wrong. This exemplifies a scenario where good measurement image data quality resulted in an accurate measurement but also produced incorrect measurement data.

To correct this error, the reference plane cursor labeled 3 has been moved in the point cloud in Figure 9 and placed on the shroud, which yields a different result of 0.062 in. (1.57 mm). This 0.031 in. (0.787 mm) discrepancy may seem small, but using this incorrect measurement data can cost the asset owner hundreds of thousands of dollars if the equipment is taken out of service prematurely for unneeded repairs. Also, leaving erroneous measurement data unaddressed while the asset remains in service can lead to efficiency losses in the power turbine, impacting proper operations and resulting in revenue losses.

The RVI image used in the second example is in the compressor section of a large frame gas turbine used to turn a massive electricity generator at a power plant. In this type of industrial gas turbine operation, downtime can bring losses of millions of dollars a day and may also result in penalties and fines, sometimes as much as US$1 million [4].

This power plant was in a planned outage. An RVI task was scheduled to evaluate if the stationary vanes in the compressor section were properly fixed in place or if they were becoming loose and beginning to tilt, or "rock." Some stator rock is allowed, though significant damage and unplanned forced outages can result when limits are exceeded.

As previously discussed, to increase accuracy and precision of RVI measurement data, the XYZ point cloud data must exactly replicate the data points on the surface being observed. Proper placement of the cursors is critical.

In Figure 10 we see one measurement cursor, labeled 1, on the shroud on the left, and the second cursor, labeled 2, on the shoulder of the far-side stator yielding measurement data of 0.066 in. (1.676 mm).

In Figure 11, notice that the geometry of the point cloud exactly matches the surface geometry as observed in Figure 10. The data integrity of the point cloud would allow for accurate measurements. Also note the placement of the cursors in the point cloud. The RVI task requires measuring the offset of the stator floors, not the offset of the stator floors to the shroud.

Even if shroud-to-stator were the required measurement, the measurement in Figure 11 is not taken perpendicular to the shroud's shoulder, nor is it entirely on the stator floor. It would be close to impossible to measure perpendicularly from the stator floor to the next stator floor using a two-cursor length measurement.

In addition, the data was not validated in the point cloud prior to providing the operator with the results. Repairs were being discussed prematurely, which could have resulted in additional outage days and the loss of millions of dollars per day in revenue, along with reduced availability of electricity for the grid.

Once more, this illustrates a situation where the measurement data is perfectly accurate but also yields incorrect measurement results.

To resolve the measurement data errors, the technical guidance for making this stator rock measurement with RVI was reviewed. The best measurement type to use would again be the *depth* measurement. This measurement type measures the perpendicular distance to or from the reference plane. The reference plane would be placed on one of the stator floors, and the fourth measurement cursor would be placed on the other stator floor.

In Figure 12, a three-cursor depth reference plane (depicted as a dotted-line triangle and labeled 1, 2, and 3) was placed on top of the far-side stator floor, and the fourth measurement cursor, labeled 4, was placed on top of the near-side stator floor. This is seen in the white light image on the left half of the image.

The resulting measurement data was 0.029 in. (0.736 mm), a difference of 0.037 in. (0.939 mm) from the original measurement data provided to the plant manager. Having the correct data allowed the plant to come back online without extending the outage, while also saving millions of dollars.

A magnified view of the point cloud image depicted in Figure 13 enables validation of the

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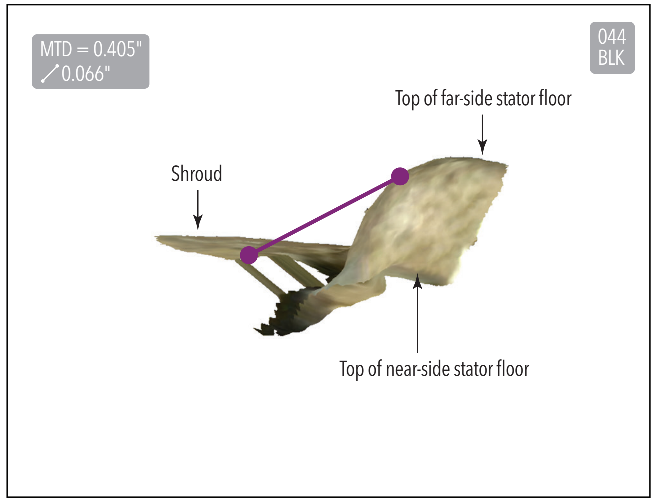

Figure 11. White light image of compressor section with incorrect measurement type and cursor placement.

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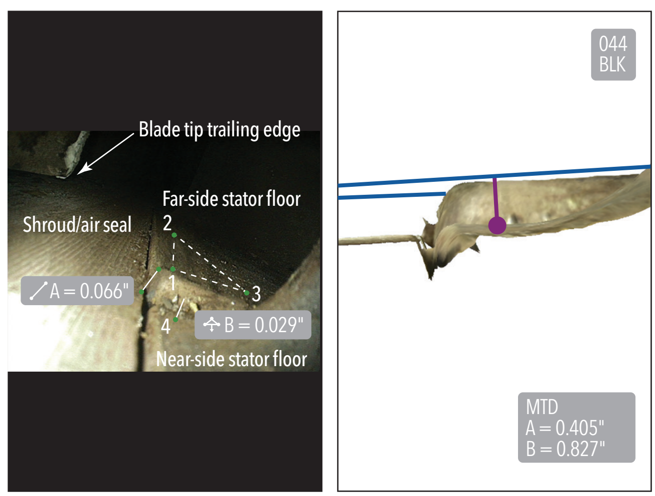

Figure 12. On the left side of the image is the white light image of compressor section with depth measurement. On the right is the point cloud image of depth measurement.

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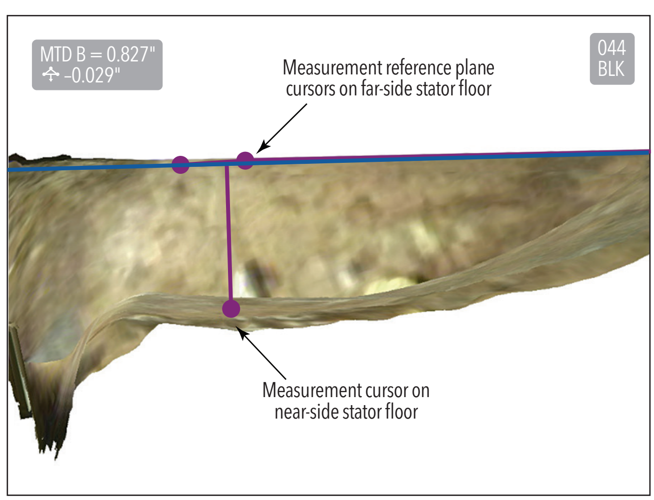

Figure 13. Full point cloud image of area being measured. Point cloud data depicts exactly the geometry of the surfaces being measured.

correct placement of cursors on the surfaces and confirms that the point cloud data precisely replicates the surface being measured.

Summary

In summary, RVI using video borescopes can assess the internal health of industrial gas turbines and help avoid false calls that could lead to increased downtime and significant unplanned expenses.

Although current generation video borescopes require a significant initial investment, they can deliver a substantial return on investment (ROI) even after just one inspection event.

The results provided can be more accurate, leading to safer and more efficient operations with lower ownership and operational costs.

The key to achieving this is to have the proper equipment operated by trained and qualified technicians, certified by their employers to perform specific RVI tasks on a particular asset.

AUTHOR

Paul Thompson: Managing Director, REVEAL RVI, Savannah, GA; revealrvi@icloud.com

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ROBOTIC VISUAL INSPECTION IN CONFINED SPACES

BY EKKEHARD ZWICKER, BRANDON DEBOER, MARKUS WEISSMANN, AND ANTOINE CHEVALEYRE

Robotic visual inspection presents a promising solution to the challenges posed by confined space inspection, offering enhanced efficiency, accuracy, and safety.

Introduction

The latest advancements in robotic visual inspection technology—including the generation of digital twins, the tagging of inspection data within asset models, and the implementation of semi-autonomous control—demonstrate how robotics can effectively tackle the challenges of inspecting confined spaces. Localization technologies such as lidar (light detection and ranging) and 3D modeling are key for effective confined-space navigation. Maintaining image quality in robotic visual inspections is also important, to ensure compliance with industry standards.

The experimental validation that follows evaluates the technical capabilities of robotics and pole cameras for confined space inspection. This includes visual examination, ultrasonic thickness readings, and 3D surface scans. The integration of digital twin technology streamlines data management and facilitates post-inspection analysis.

Robotic visual inspection ultimately offers numerous benefits, including high-quality and reproducible data, reduced outage time and costs, process improvement through automation, and increased safety by minimizing human entry into confined spaces.

Challenges with Confined Space Inspection

Inspecting confined spaces presents several challenges and risks due to the unique nature of the environment, including [1, 2]:

- **Limited access.** Confined spaces are typically difficult to reach and may have restricted entry points, making it challenging for inspectors to thoroughly examine the area.
- **Poor visibility.** Many confined spaces have limited lighting or may be completely dark, hindering the ability to see potential hazards or defects.
- **Restricted movement.** Inspectors may face difficulties maneuvering within confined spaces due to narrow passages, obstacles, or equipment obstructions.
- **Communication challenges.** Communication between workers inside a confined space and those outside can be challenging due to physical barriers or poor reception, increasing the risk of accidents or delays in emergency response.
- **Time constraints.** Inspections in confined spaces often require careful planning and coordination to ensure the safety of personnel. Time constraints may arise due to limited availability of access or the need to complete inspections quickly to minimize disruption to operations.
- **Training requirements.** Inspecting confined spaces requires specialized training and expertise to identify potential hazards and implement safety protocols effectively. Lack of proper training can increase the likelihood of accidents or errors during inspections.
- **Documentation and reporting.** Proper documentation of confined space inspections is crucial for regulatory compliance and risk management. However, maintaining accurate records can be difficult, especially in remote or hazardous environments.
- **Emergency preparedness.** In the event of an accident or emergency inside a confined space, rescuing workers can be complex and time-consuming. Inspectors must be adequately trained in emergency procedures and have access to the appropriate rescue equipment.
- **Regulatory compliance.** Confined space inspection must adhere to stringent safety regulations set by authorities such as OSHA (the Occupational Safety and Health Administration) in the US. Failure to comply with these regulations can result in legal repercussions and jeopardize worker safety.

Addressing these challenges requires careful planning, appropriate training, and the use of advanced technologies and safety measures to ensure the effectiveness and safety of confined space inspections.

Limitations of Remote Visual Inspection

Remote visual inspection (RVI) conducted in confined spaces such as pressure vessels, reactors, and boilers, whether using a remote-controlled crawler or a camera mounted on a pole, often relies heavily on manual control. The crawlers are piloted remotely, data is captured manually, and reports are subsequently created by transferring this information into predesigned templates. This disconnected approach presents several challenges. First, there is no direct link between the captured data and its specific location within the asset. Second, this manual process (Figure 1) demands significant additional effort to leverage the data for internal processes and integrate it with the digitalization strategies of asset owners and operators.

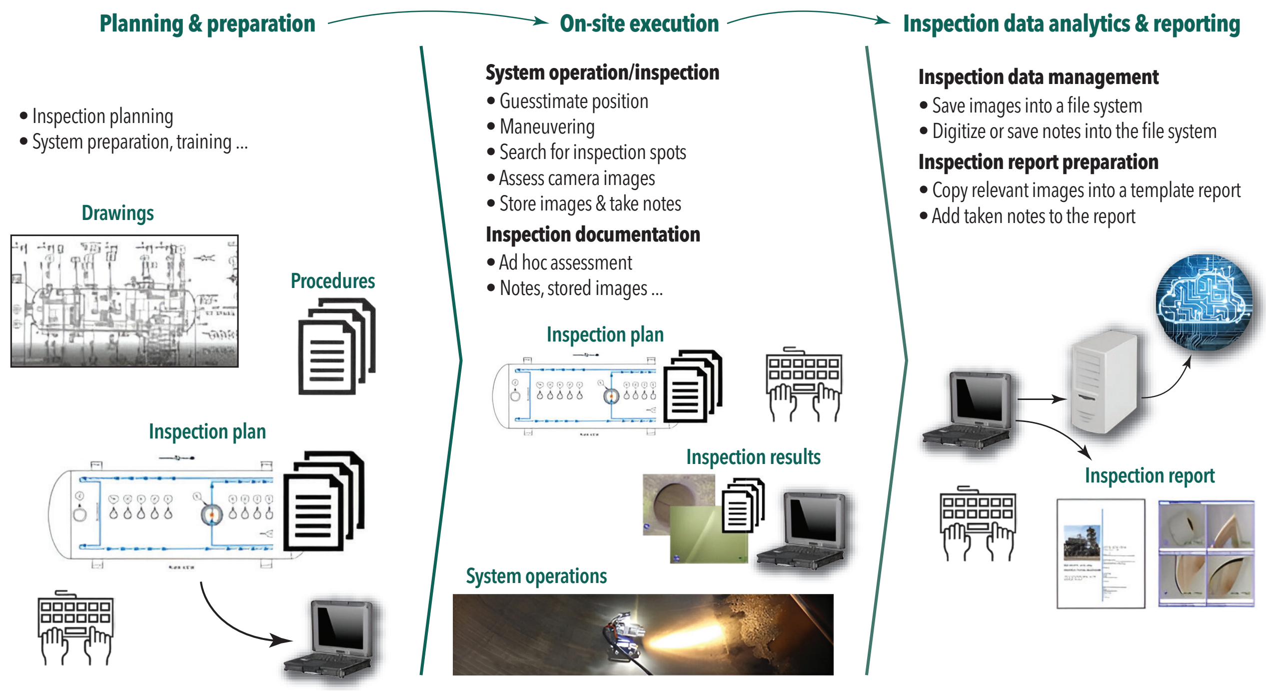

Figure 1. Remote visual inspection (RVI) process involving manual preparation, inspection, and documentation.

Advantages of Robotic Visual Inspection

The latest state-of-the-art robots create digital twins, tag inspection data positions within the asset model, and provide 3D semi-autonomous control. These robots then generate inspection reports automatically and directly upload the data into asset performance management systems. Recent technology is moving toward refining this new process of robotic visual inspection while supporting a seamless integration into asset owners' digital strategy. By using the latest robotic technology, inspections are now semi-automated, data is automatically stored, and asset inspections can be compared over time.

Robotics visual inspection offers several compelling advantages for inspecting confined spaces, including:

- **Enhanced visibility.** Robotic systems equipped with high-definition cameras can provide superior visual inspection capabilities compared to human inspectors. These cameras can capture detailed images and videos of the interior of confined spaces, allowing for thorough examination of equipment, structures, and components. The enhanced visibility offered by robotic visual inspection ensures that potential defects, damage, or anomalies are detected with precision.
- **Consistency in inspection.** Robotic visual inspection systems can follow predefined inspection paths and parameters consistently, ensuring uniform coverage of the entire confined space. Unlike human inspectors, robots do not suffer from fatigue or distractions, which can compromise the thoroughness and accuracy of inspections. This consistency in inspection results in high-quality data for analysis and decision-making.
- **Safe accessibility to hazardous environments.** With the use of robotics, human entry into confined spaces can be eliminated, and the related efforts and challenges as previously described (limited access, restricted movement, communication challenges, required confined space training, emergency planning and measures) are reduced.
- **Real-time monitoring and feedback.** Robotic visual inspection systems can provide real-time monitoring and feedback during inspections. As the robot navigates through the confined space, operators can view live video feeds and data from onboard sensors, allowing them to assess the condition of assets immediately. Any abnormalities or issues identified can be addressed promptly, minimizing downtime and reducing the risk of potential failures.
- **Comprehensive documentation and reporting.** Robotic visual inspection systems can automatically capture and store visual data, creating comprehensive documentation of inspections. These records can include images, videos, timestamps, and annotations, providing a detailed history of the condition of assets over time. Additionally, automated reporting features enable the quick and accurate generation of inspection reports, facilitating compliance with regulatory requirements and internal quality standards.

- **Integration with data analysis tools.** Visual data captured by robotic inspection systems can be integrated with data analysis tools and software for further analysis. Advanced image-processing algorithms can detect patterns, anomalies, or defects in visual data, supporting predictive maintenance and asset management strategies. By leveraging the power of data analytics, companies can optimize maintenance schedules, extend asset lifespan, and reduce operational costs.

These advantages make robotic visual inspection a valuable solution for industries seeking efficient, accurate, and safe methods of assessing confined spaces and maintaining critical assets.

Key Technology: Localization and Data Geotagging

Robotic localization technology for autonomous operation and reporting is available and is used by both drones and mobile robots on the plant level. However, most modern localization technology cannot be applied to confined spaces due to the lack of GPS reception, weakly textured surfaces, asset size, and complex geometries.

Current robotic practice in GPS-restrictive areas is simultaneous localization and mapping with lidar remote sensing technology. By using a lidar, a point cloud of the environment is created, and a mesh is stitched together simultaneously while the robot is moving. By comparing the point clouds and mesh, the absolute distance between positions can be computed, and the robot can be located within an asset.

Another much simpler approach is to provide a 3D model of the asset as input, measure the distance from the robot to a specific point on the asset, and compare this with the distance calculated using the corresponding position in the 3D model. To increase accuracy and repeatability, additional navigation sensors are integrated into the localization process. These include an inertia measurement unit (IMU), odometry (distance measured by the driving wheels), and kinematic constraints. All this data is combined using a particle filter and/or a Kalman filter. This allows for the calculation of the robot's 3D pose (position and orientation within the asset) and the specific location in the 3D model where the inspection camera is directed (Figure 2).

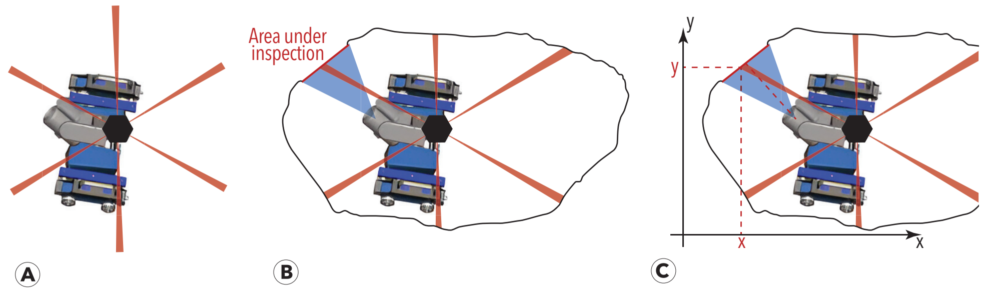

Figure 2. The approach to calculate the 3D pose of a robotic system in a confined space and to localize the inspection camera view on the asset being observed: (a) robot with distance sensors (lidar), IMU, and odometry; (b) confined environment; (c) localization of robot and inspection data.

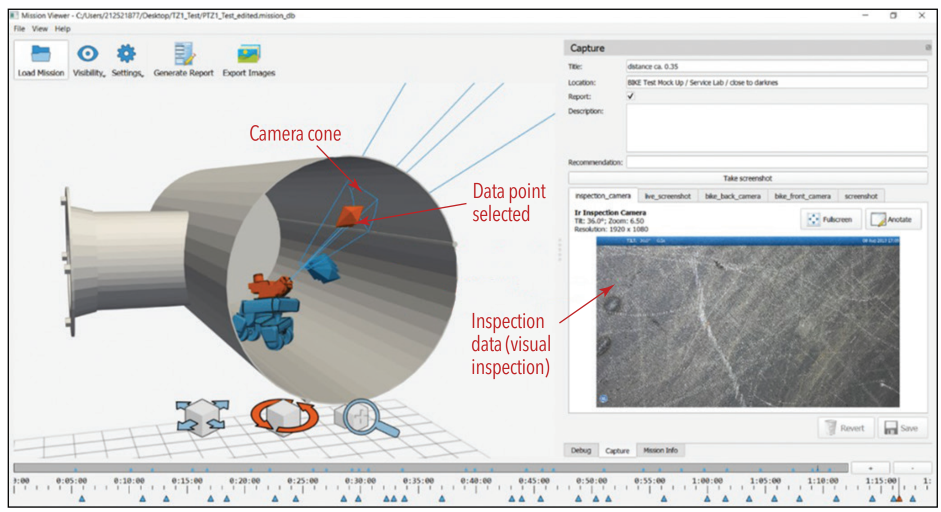

Figure 3. 3D digital twin software calculates the view cone of an inspection camera and automatically links the captured image with the correct asset coordinates. The data can be edited and amended with comments and sketches.

As a result, the system can geotag all images to the 3D model and store them in a database along with the camera settings at the time of capture, such as zoom level, lighting, and resolution (Figure 3).

Notes—either as text or created with a drawing editor—can be added to the images during the inspection or later when creating the documentation. These annotated images are then stored in the database. The inspection report can be generated automatically using templates (Figure 4).

A primary goal is to minimize the time spent on-site and inspecting the asset. The planning of the inspection, based on the inspection plan, can be completed before the mission by utilizing a 3D model and a virtual representation of the robot and inspection camera system. This can be achieved through a sophisticated simulation tool, which enables running the inspection scenario to assess technical feasibility

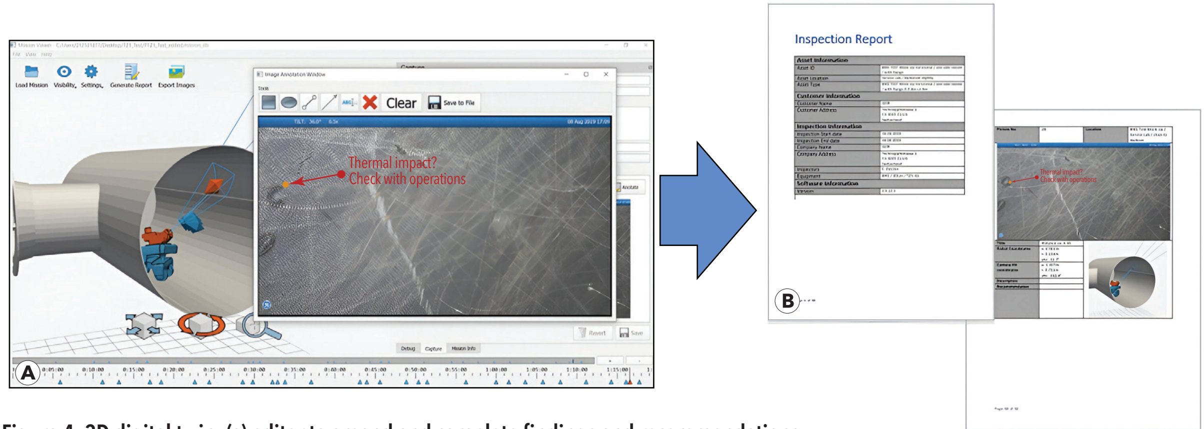

Figure 4. 3D digital twin: (a) editor to amend and complete findings and recommendations, possibility to annotate inspection data; (b) automatically generated inspection report.

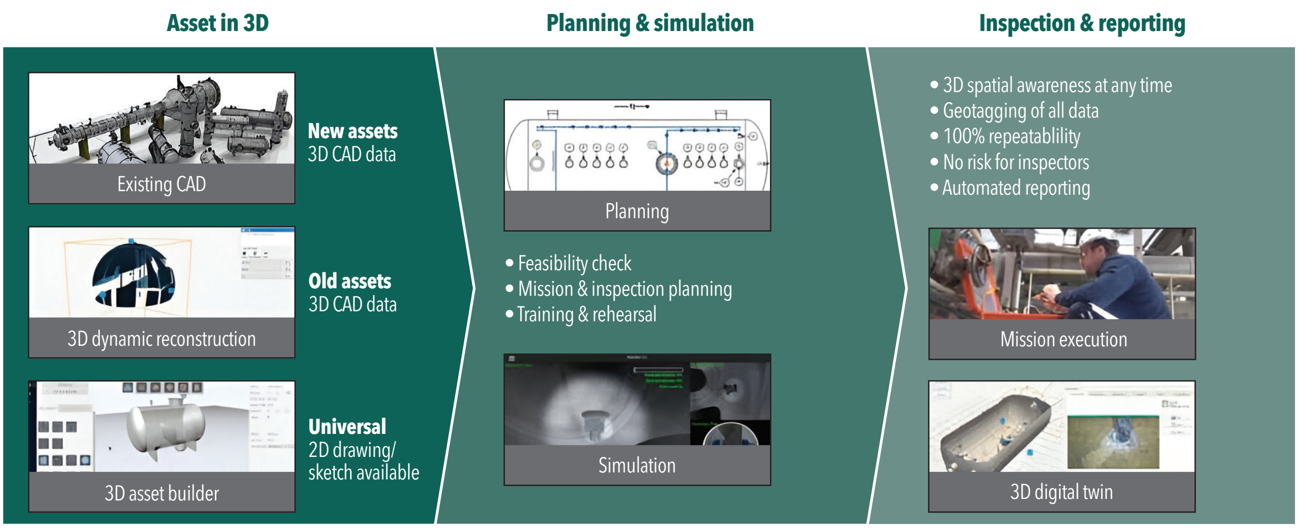

Figure 5. Integrating planning and simulation, using the 3D virtual representation of the asset and the kinematic representation of the robot with the camera and the cables.

and provides an opportunity to train and rehearse the inspection (Figure 5).

Recommended Practices for Robotics-Based Remote Visual Inspection

Close visual inspection is a top priority for robotic applications, but there are discussions about whether robotics-based remote visual inspection (RVI) can fully replace close visual inspection (CVI) performed by a human. Several RVI limitations have been identified, including the robot's distance from the inspection surface, limited viewing angles, lack of tactile feedback, absence of surface preparation or deployment of inspection aids, and challenges with artificial lighting. Due to these limitations, it is advised not to claim robotics-based RVI as a complete replacement for human CVI. Instead, robotic inspection should complement conventional CVI by identifying areas that require further examination.

Standards such as ASME V Article 9 [6] and BS EN 17637 [7] specify spatial resolution requirements for CVI and direct visual inspection (DVI), typically around 3 line pairs per millimeter (lp/mm) under optimal viewing conditions, based on human eye acuity. Although ASME V Article 9 also references the visibility of fine lines, this is not considered a reliable measure of spatial resolution. To comply with ASME V Article 9, robotics-based RVI images should demonstrate a spatial resolution of approximately 3 lp/mm, equivalent to that of CVI and DVI.

The "HOIS Guidance on Image Quality for UAV/UAS–Based External Remote Visual Inspection in the Oil & Gas Industry" [5] provides detailed guidance on maintaining image quality during uncrewed aerial vehicle (UAV) inspections within the oil and gas sector. Its goal is to ensure that the images obtained are of sufficient quality for engineering assessments of component integrity, aiding asset operators in making critical decisions about continued operation. While the HOIS guidance focuses exclusively on

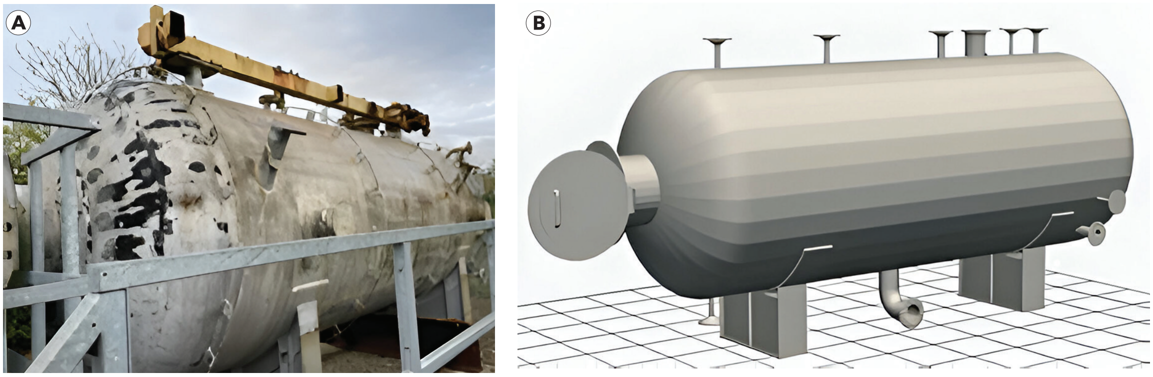

Figure 6. Digital twin created from asset drawings: (a) photo of asset; (b) digital twin.

image quality, it does not address safety and operational aspects of UAV deployment, which are covered in separate publications.

The same guidelines for an UAV-based visual inspection can be applied to robotic crawlers.

The guidance identifies three priority applications for UAV and robotics-based RVI among members of the HOIS organization [8]: achieving CVI resolution, assessing coatings to ISO 4628 standards, and inspecting flare tips/stacks. While both still images and videos are considered, the document places more emphasis on still images, as they are typically more common in final inspection reports.

Specific guidance is also provided regarding spatial resolution requirements for each of the priority applications, along with methods for verifying that the achieved resolution meets these standards. Additionally, the importance of image signal-to-noise ratio (SNR) is highlighted as a critical quality criterion, with recommendations for minimum SNR values and maximum ISO settings for cameras. Information on these settings can often be obtained from resources such as the DxOMark website or estimated based on the camera's sensor element area.

General advice covers various aspects of UAV and robotics-based RVI, including considerations for viewing direction, ambient light levels, and camera settings. It also addresses file formats and post-processing software for both still images and videos.

Overall, the document serves as a comprehensive guide for ensuring adequate image quality in UAV-based RVI within the oil and gas industry. It offers specific recommendations for key quality criteria and priority applications while providing general guidance on related aspects.

Experimental Validation

To validate the technical capabilities of both robotics and pole cameras for confined space inspection, we conducted an extensive visual examination of a test vessel. In addition to visual inspection, we took ultrasonic thickness readings at designated spots on the hull and conducted 3D surface scans on sections affected by corrosive pitting. All this data was geotagged (localized) in a digital twin optimized for inspection, which was built from customer drawings (Figure 6).

The test was conducted using an ultra-mobile robotic platform that allows it to climb over obstacles [8]. The robot is equipped with a visual inspection camera, an ultrasonic probe, and a structured white light–based surface scanning system. Utilizing 3DLOC technology, it can calculate the robot's pose within the vessel and geotag the images to the 3D virtual model (as described previously in the "Key Technology: Localization and Data Geotagging" section).

To assess image quality, an USAF 1951 resolution chart was utilized within the vessel, with measurements taken from a distance of 1.8 m. Figure 7 depicts the camera's capabilities, serving as an example of the output obtained from the localization data, images, and other key notes from the inspection. Typically, a report of this nature would include:

- a picture captured with the HD camera
- the coordinates of the robot within the 3D model
- the coordinates of the camera hit point on the surface
- a screenshot of the crawler's position and stance at the time the image was captured
- descriptions and recommendations as necessary.

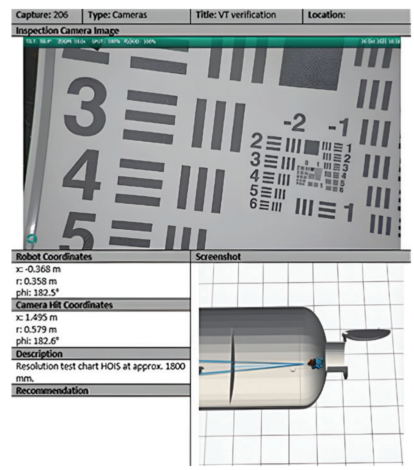

Figure 7. USAF test chart at 1.8 m distance and typical reporting structure.

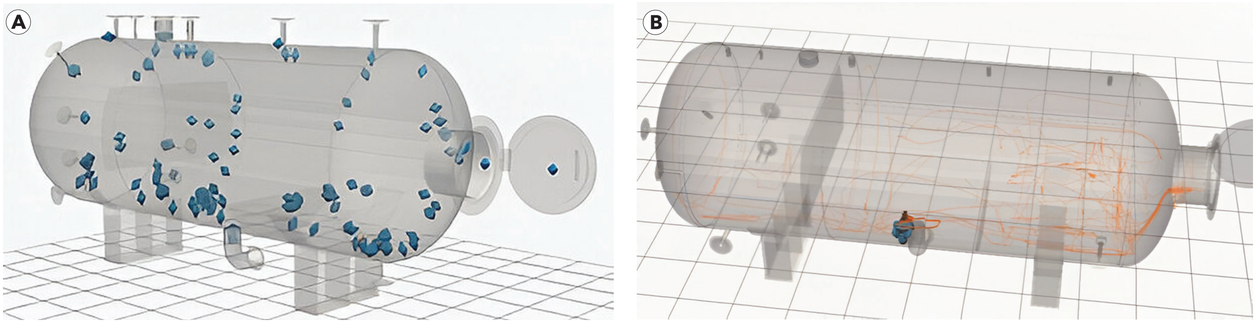

Figure 8. Overview of the (a) complete inspection locations and (b) path driven by the robotic crawler.

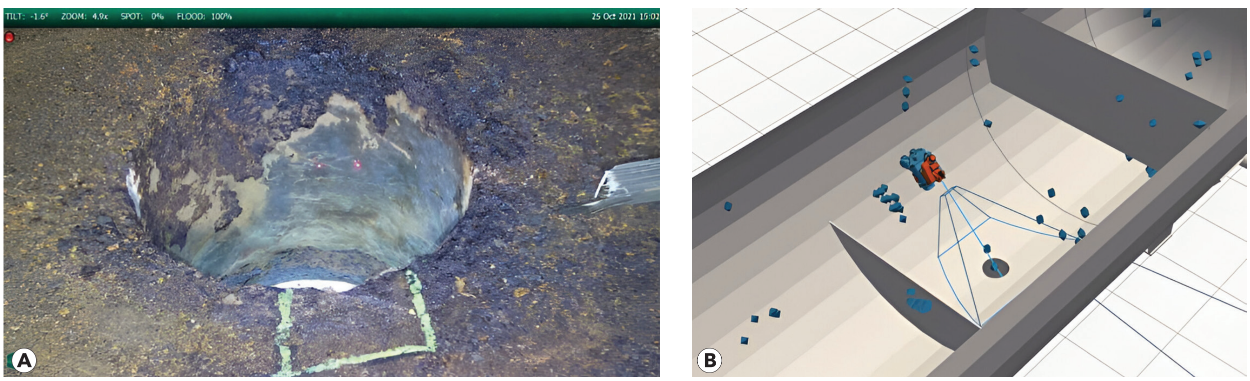

Figure 9. Close-up of (a) nozzle and (b) its positioning in the digital twin.

Figure 10. Close-up of the shell surface.

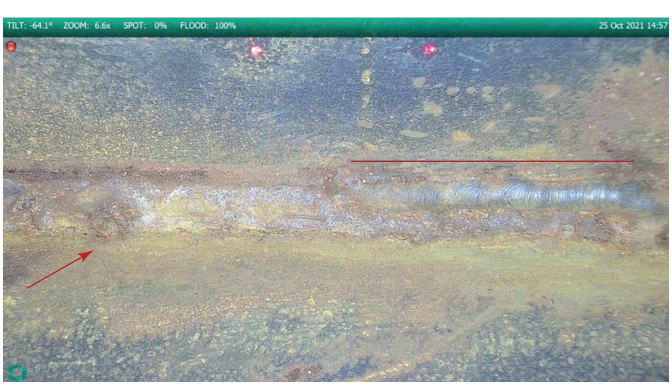

Figure 11. Close-up of a support weld with some annotations. Note the two laser dots that allow a rough dimension of findings.

The comprehensive examination of this vessel involved a detailed focus on crucial zones such as nozzles, supports, and welds (Figure 8). Each photograph captured during the inspection has been precisely marked within the 3D model, indicating their specific positions (Figure 9). Additionally, a complete video feed of the inspection was recorded.

During the meticulous examination of the vessel, significant internal corrosion and clusters of pits were identified (Figures 10 and 11). Relevant findings were recorded in the report, prompting further investigation using 3D surface scanning techniques to accurately determine the dimensions and depths of the affected areas (Figure 12).

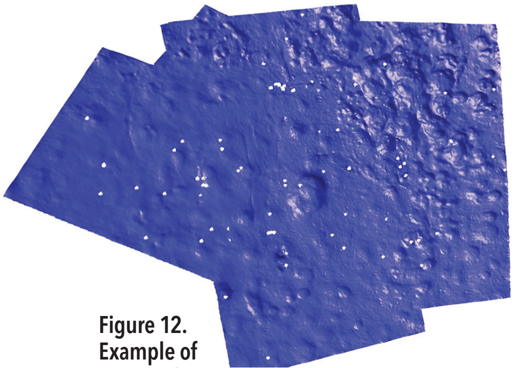

Figure 12. Example of a 3D surface scan of the shell.

Results and Discussion

The comprehensive test conducted on the vessel, coupled with a direct comparison with a manual inspection carried out by an inspector entering the vessel, met the requested standards for inspection quality. The creation of a digital twin streamlined the handling and management of inspection data, facilitating easier analysis post-mission. The automatic generation of the inspection report also significantly reduced the time required for post-inspection tasks.

The trials demonstrated that robotics-based RVI can effectively detect various damage mechanisms in vessel shells and internal structures. However, factors such as lighting angles, camera positions, and automated settings can impact image quality and the detectability of pitting. Localized pitting detection with zero-degree ultrasonic inspection proves ineffective in heavily corroded vessels, with external ultrasonic testing showing greater success. RVI, structured light, and stereoscopic imaging can measure anomaly width, length, and depth, although the accuracy may vary depending on inspection conditions.

Vessel cleanliness plays a crucial role in achieving optimal inspection results, and while high coverage is attainable, it relies on the inspector's estimation. Although calibration charts may aid in assessing camera performance, their direct correlation with overall inspection effectiveness remains unclear. Utilizing a plastic test piece offers a cost-effective method to validate RVI capabilities, and the integration of 3D mini-digital twins enhances reporting compared to traditional PDF formats.

For more detailed information on the conducted test and comprehensive results analysis, refer to the HOIS report "HOIS-R-070 C20-03 RII Practical Trials Report" [3].

Conclusion

In summary, the benefits of using robotic visual inspection for confined spaces in industry include:

- **High-quality, reproducible inspection data** tagged with the asset's position and stored in a database.
- **A 3D virtual model tagged with inspection data**, known as a "digital twin," which serves as an IoT (Internet of Things) building block and supports digital integration strategies (such as asset performance management systems and data analytics). The digital twin acts as the front end for these tools, allowing for comparison of repeat inspections with previous ones to calculate trends and predictions.
- **Reduced outage time and costs** through offline preparation using virtual planning and training. Safe and simple operation of the robotic tools is supported by full 3D spatial awareness and 3D interactive control, along with automatic inspection report generation.
- **Process improvement through task automation** (such as automatically repeating missions) and autopilot functionality, enabling inspectors to focus more on the inspection and less on system operation.
- **Increased safety** by avoiding human entry into confined spaces.

These benefits apply to both asset owners and service companies.

AUTHORS

Ekkehard Zwicker: Waygate Technologies; ekkehard.zwicker@bakerhughes.com

Brandon DeBoer: Waygate Technologies; brandon.deboer@bakerhughes.com

Markus Weissmann: Waygate Technologies; markus.weissmann@bakerhughes.com

Antoine Chevaleyre: Waygate Technologies; antoine.chevaleyre@bakerhughes.com

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VISUAL TESTING METHOD PERSONNEL QUALIFICATION AND CERTIFICATION: AN OVERVIEW

BY MIKE ALLGAIER

Most major nondestructive testing (NDT) personnel qualification and certification (PQ&C) schema address visual testing (VT) as a standalone NDT method. However, there are significant differences between the details of these elements. Various codes, standards, and specifications delineate various requirements for personnel education, experience, training, and examination of the candidates for certification. This article addresses the common elements needed for PQ&C across different codes, standards, and guidelines.

Introduction

Visual testing (VT) has long been integral to other NDT methods, as it historically has served as a prerequisite for those methods. It was a prerequisite to liquid penetrant testing (PT), magnetic particle testing (MT), ultrasonic testing (UT), and radiographic testing (RT) when it was stated in those methods that "surface conditions that would interfere with the examination should be evaluated and removed." Level I/II certification took for granted that the prerequisite to PT and MT included the VT knowledge and skills.

The VT method has gained its own method status over the last 50 years. Early VT tools included the human eye, a magnifying glass, a dental mirror, a 6-in. steel scale, a 12-in. wooden ruler, and maybe a 50-ft tape measure. Today, how to examine an object has changed. The advent of digital imaging has offered a great expanse in the variety of instruments available to capture digital images and allow analysis of the part condition, including measurement techniques that are more and more sophisticated. Remote visual inspection, also known as RVI, can be used to inspect areas of infrastructure from a distance that are too dangerous, remote, or inaccessible for direct visual inspection. RVI technologies include remotely operated cameras, borescopes, videoscopes, fiberscopes, and drones.

Background

When exploring PQ&C schema for VT, we discover two major categories. The first is direct VT (DVT) and the second is indirect VT, more commonly referred to as RVI.

The DVT examination definition taken from the *ASME Boiler and Pressure Vessel Code,* Section V: *Nondestructive Examination*, Article 9, *Visual Examination,* states that the eye should be within 24 in. of the surface to be examined and at an angle not less than 30°. This can include aids such as a magnifier or mirror. The term "aid" implies that the surface can be inspected without these tools, hence the direct method of VT.

RVI is used when the above criteria for DVT cannot be met—for example, when the surface under inspection is *only* accessible with a mirror, a magnifying glass, a series of lenses in a borescope, a bundle of fibers, a charge-coupled device transmitting the image to a monitor (such as a videoscope), or a telescope for long-distance inspections.

With either category for evaluating hardware, there are three pillars, or goals:

- to acquire an acceptable image,
- to evaluate the part, component, or system test results, and
- to disposition those test results to the appropriate acceptance or recording criteria.

To perform these steps, the inspector or examiner needs to possess the core knowledge and basic skills for common applications. In addition, industry-specific knowledge and skills unique to various industries, products, or VT techniques are also required. These are called industry specific segments (ISS). When comparing various industry PQ&C requirements, we observe overlaps, omissions, and unique criteria across different programs. Some VT requirements are common across all industries, while others are unique to certain ISS.

Elements of Personnel Qualification and Certification

Proper execution and evaluation of any VT application requires the inspector or examiner to be qualified in the VT method using the applicable techniques. Compliance with those qualifications, along with written documentation and a summary sheet, is known as certification. Following are a few of the common schema for VT PQ&C used in the NDT industry.

American Society for Nondestructive Testing (ASNT)

The original recommendations for NDT PQ&C date back to 1968 with the publication of ASNT Recommended Practice No. SNT-TC-1A: *Personnel Qualification* *and Certification in Nondestructive Testing.* Its main distinction is that it is a guideline, not a standard. It provides guidelines for employers to establish in-house certification programs for the qualification and certification of NDT personnel and provides education, experience, and training recommendations for each NDT method. Therefore, the primary driver is the employer's written practice, which can vary across individual companies.

When an employer has a contract with a customer, the customer's specification will call out the primary standards, codes, and regulations that must be complied with to satisfactorily complete the contract. Originally, SNT-TC-1A had its own body-of-knowledge outline referenced for each NDT method as a supplement, but it was up to the employer to modify the program to suit their needs. Training content and duration would be especially subject to customization by each employer. SNT-TC-1A provides the recommended number of training hours in a table (see Table 1 for VT recommendations).

Today, ANSI/ASNT CP-105: *ASNT Standard Topical Outlines for Qualification of Nondestructive Testing Personnel* specifies the body of knowledge to be used as part of a training program qualifying and certifying NDT personnel. It applies to personnel whose tasks or jobs require knowledge of the technical principles underlying the NDT methods for which they have responsibility. These tasks include performing, specifying, reviewing, monitoring, supervising, and evaluating NDT work. These outlines are approved by the American National Standards Institute (hence the ANSI in its title).

ANSI/ASNT CP-189: *ASNT Standard for Qualification and Certification of Nondestructive Testing Personnel* is a standard for qualification and certification of NDT personnel. Its main distinction is that it is a standard, not a recommended practice. It builds on SNT-TC-1A by providing comprehensive minimum requirements for personnel certification, such as requirements for NDT instructors and employer certification of Level I, II, and III personnel as well as a requirement for the ASNT NDT Level III certification of Level III personnel. This standard is approved by ANSI and also references CP-105 for training outlines. When CP-189 is referenced in a contract, the vendor, contractor, or prime must meet the requirements listed therein.

The common certification elements addressed in both the guideline (SNT-TC-1A) and the standard (CP-189) include education, training, experience, and exams. Exams include three types: physical (visual acuity) exams, written exams, and practical exams.

American Petroleum Institute (API)

API has its own requirements for vessel inspection, including VT. API 510, API 570, API 653, and API 1169 (note: this list is not exhaustive) each have their own checklists of what to inspect for in internal and external visual inspections. Vessels, piping, new piping construction, tanks, and the like have broader scope inspection requirements than surface conditions alone. Licensed inspectors must be utilized to prevent catastrophic failures or unexpected operational issues. This article does not address the petrochemical specifics for inspection PQ&C.

TABLE 1

Recommended initial training and experience levels for VT*

Examination method	NDT level	Training hours	Minimum hours in method or technique	Total hours in NDT
Visual testing (VT)	I	8	70	130
	II	16	140	270

*per SNT-TC-1A (2024), excerpted from Table 6.3.1A

American Welding Society (AWS)

Prior education typically does not decrease the requirements for VT Level I or II in terms of experience, training, physical exams, written exams, or practical exams (proficiency demonstrations). However, the AWS certification for Certified Weld Inspector (CWI) does adjust the experience requirements based on an individual's education. The more education one has, the less experience is needed to obtain CWI certification. In this comparison, CWI is treated as equivalent to SNT-TC-1A or CP-189 Level II.

Table 2 shows the minimum education and work experience required to become a CWI per AWS.

TABLE 2

Education and work experience required to become a CWI, per AWS

If the candidate has:	The amount of experience required is:
4-year bachelor's degree	1 year
2-year associate degree	2 years
Eng/tech courses	3 years
Vo-tech courses	4 years
High school	5 years
8th grade	9 years
<8th grade	12 years

Note: This concept also applies to NDT Level IIIs in SNT-TC-1A, where higher education levels can reduce the required amount of experience.

Training

All these PQ&C programs require training. NDT requires skilled and qualified personnel to perform, interpret, and evaluate the tests. Training and certifying NDT personnel can help ensure the accuracy, reliability, and validity of NDT results. Moreover, training and certifying NDT personnel can help company owners reduce the risk of errors, accidents, and liabilities. Furthermore, training and certifying NDT personnel can help improve their competence, confidence, and motivation.

The industry can choose from various NDT training and certification programs, such as those offered by ASNT, the British Institute of Non-Destructive Testing (BINDT), or the International Organization for Standardization (ISO).

Most government and industry regulations include references to NDT qualification and certification standards. These documents outline the education, training, and experience requirements that must be met before completing the certification examination process.

Training topics are addressed in outlines found in ANSI/ASNT CP-105. This body of knowledge for VT is the basis for visual examination training course outlines and curriculums. (Note: As of this writing, ASNT is working to achieve compatibility with ISO TS 25107.)

The training requirements listed for both SNT-TC-1A and CP-189 state that 24 hours is the required amount of training hours needed for Level II (8 hours for Level I plus 16 hours for Level II). This includes both classroom training for knowledge transfer and laboratory training sessions for skills transfer. A significant portion of this time is spent learning about material discontinuities and defects—essentially, understanding what to look for when performing VT.

Learning how to perform VT for DVI and RVI takes less time if the equipment is basic, such as a dental mirror, flashlight, and 6-in. scale. In the past, RVI typically involved using borescopes (lens or fiber) for image transfer. However, if training on videoscopes, telescopes, or remote cameras is required, significantly more time must be allocated for training in these techniques.

The required training for CWI certification used to be a 40-hour course. Now, a CWI must complete 80 professional development hours (PDHs) through seminars, courses, or online courses such as those found on the AWS Education Portal. These courses must meet the requirements of the *AWS Specification for the Certification of Welding Inspectors* (AWS QC1:2016-AMD1).

ISO 9712: *Nondestructive Testing – Qualification and Certification of NDT Personnel* is an international standard that specifies requirements for principles for the qualification and certification of personnel who perform industrial NDT. In this standard, VT training is measured in days, not hours. This is a change in the 2021 standard, which was adopted by ASNT in 2023 (ASNT CP-9712, identical adoption) (see Table 3).

TABLE 3

ISO 9712 requirements for VT training

Level	Training requirement
VT Level 1	3 days
VT Level 2	2 days
VT Level 3	3 days

Note: One day = 7 h. "Limited" and "unlimited" terms used in ISO 9712 (2012) have been deleted from the 2021 edition. Reduced training is allowed if reduced curriculum and allowed by certification body (e.g., if limited to direct VT only, then less training is required).

The nuclear power generation industry developed visual examination requirements, as outlined by the Electric Power Research Institute (EPRI) in the 1980s, to address the unique needs of the *ASME BPVC*, Section XI, for in-service inspections. The total training hours for Level I, II, and III visual examiners through EPRI is 104 hours. Distinct techniques within the Visual Examination certification address general surface conditions (VT-1), leak testing (VT-2), and a third category for hangers, snubbers, restraints, supports, and reactor vessels internals (VT-3). Level I and II training is 40 hours each for a total of 80 hours to become a Level II. An additional 24 hours are needed for Level III.

Compared to these examples from AWS and ISO 9712, the 24-hour training specification for VT Level II in SNT-TC-1A is noticeably lower.

Experience

SNT-TC-1A Level I and II experience started off as measured by months (one and two, respectively). This unit of time measurement was replaced with experience requirements expressed in hours. This calculation was based on approximately 40% of three months' worth of experience, equating to 210 hours.

AWS, as stated previously, required five years of experience if the candidate was high school educated. How to gain credit for those years of experience is not clarified.

ISO 9712 requirements for experience in VT are shown in Table 4.

Exams

Physical. Visual acuity is the primary physical attribute that must be examined for PQ&C in VT. Per SNT-TC-1A, "near vision" is one of the visual acuity requirements. According to SNT-TC-1A, an NDT technician must have the ability to read the Jaeger No. 2 test chart, at a distance of no less than 12 in. (30 cm), with or without corrective lenses, in at least one eye. This requirement applies to all levels of NDT personnel.

Color perception requirements are determined according to the specific demands of the job and are set by the employer. A special color perception test may be administered if abnormal color perception exists. The candidate must demonstrate the ability to see the appropriate colors needed for the specific exam to be performed.

TABLE 4

ISO 9712 requirements for VT experience

Level	Experience
VT Level 1	15 days
VT Level 2 (with Level 1)	45 days
VT Level 2 (directly)	60 days
VT Level 3 (with Level 2 and higher education)	180 days
VT Level 3 (with Level 2 only)	240 days
VT Level 3 (directly and higher education)	360 days

Note: One day = 7 h.

Written. Written exams are used to assess a candidate's understanding of the subject matter contained in the appropriate syllabus or outlined requirements. SNT-TC-1A and CP-189 both refer to the training outlines in CP-105 for theory. The topics of the questions contained in the general examination are found there. The number of general questions ranges from 30 (minimum) to typically 50 on the basic principles and theory applicable to the VT method. The number of specific questions is determined by the codes, specifications, and procedures applicable to the inspections mandated by customer specifications, which the inspector must adhere to during their work for the employer.

Practical. A demonstration of practical proficiency is called the practical exam. The primary requirement is to follow a 10-point checklist, though specific details of the checklist are not explicitly provided.

Table 5 shows a typical example of a practical exam's 10-point checklist.

TABLE 5

Typical practical exam checklist example

Observation item	Unsatisfactory	Satisfactory
1. Surface condition		
2. Procedure compliance		
3. Equipment usage		
4. Adequate coverage		
5. Attribute identification		
6. Discontinuity/attribute evaluation		
7. Disposition and evaluate discontinuity/attributes		
8. Report/document results		
9. Comply with safety cautions		
10. Health		

Each item on the list carries a value of 10 points. A minimum score of 70% is required to pass.

When each of the 10 checklist points carries equal weight at 10 points each, failing the practical exam becomes unlikely. Generally, with this scoring system, most candidates score 90% or higher, resulting in a pass.

An alternate is a checklist like shown in Table 6. In this scenario, mandatory elements must be successfully completed with a score of 80% or higher, otherwise the entire practical exam is considered failed. Performance, evaluation, and disposition should be mandatory checklist items where a pass or fail decision is required. The points assigned to other listed items can be discretionary.

The technique and order of conducting a practical proficiency demonstration

TABLE 6

Proposed example of 10-point checklist for VT practical exam Level II (VT or RVI)

Categories	Point weight
1. Procedure selection	3
2. Surface preparation/cleanliness	2
3. Method application—satisfactory technique	10
4. Equipment and material selection	10 (min 8 pts req'd)
• Equipment	
• Material (cleaning; pre and post)	
5. Adequate area of interest coverage	10
6. Interpretation of indications and disposition	40 (min 32 pts req'd)
• Complete coverage for interpretation	
• Determination of relevance	
• Appropriate application of acceptance criteria	
• Appropriate disposition of part, component, or system	(min 80% accurate)
7. Standard practice codes or procedure usage	10
• Familiarity	
• Compliance	
8. Records	10
• Completeness	
• Appropriate data entry	
• Control of records	
• Compliance with routing requirements	
9. Health factors	3
• Site procedures familiarity	
• Adherence	
• Compliance	
10. Safety factors	2
• Volatile liquids	
• Electrical hazards	
• Light and infrared radiation	
80% min required total and for Sections 4 and 6 as noted	100 pts possible

only require a test piece and a 10-point checklist. However, the scoring protocol or the value assigned to each point is not specified. It is up to the method Level III and the employer's written practice to provide such details.

Conclusion

Visual inspection has come a long way from a few decades ago. Recent developments have brought us to new frontiers. Given this, the industry now has an opportunity to standardize the key elements of qualifying DVT and RVI NDT personnel.

Additional ISS can address written and practical exams as needed, in addition to minimum core knowledge and skills common to all DVT/RVI inspectors. The same goes for the training curriculum. There can—and should—be a core of knowledge and skills common to all VT inspectors/examiners. Each industry can produce Industry Segment Qualifications (ISQ) with subtechniques delineated.

Further discussion is necessary to cover the specific visual examination requirements outlined in various codes, standards, and specifications. Visual examination techniques and equipment vary in VT, DVT, and RVI. Industry-specific qualifications are required to tailor the education, training, and experience necessary for certification in this distinct field. ME

REFERENCES

ANSI/ASNT CP-105: *ASNT Standard Topical Outlines for Qualification of Nondestructive Testing Personnel.* American Society for Nondestructive Testing.

ANSI/ASNT CP-189: *ASNT Standard for Qualification and Certification of Nondestructive Testing Personnel.* American Society for Nondestructive Testing.

ANSI/ASNT CP-9712: *Nondestructive Testing for Qualification and Certification of NDT Personnel (2023)*, Identical Adoption of ISO 9712:2021(e). American Society for Nondestructive Testing.

ASME Boiler and Pressure Vessel Code, Section V: *Nondestructive Examination*, Article 9, *Visual Examination*. American Society of Mechanical Engineers.

ASNT Recommended Practice No. SNT-TC-1A: *Personnel Qualification and Certification in Nondestructive Testing.* American Society for Nondestructive Testing.

AWS D1.1: *Structural Welding Code – Steel.* American Welding Society.

ISO 9712: *Nondestructive Testing – Qualification and Certification of NDT Personnel.* International Organization for Standardization.

AUTHOR

Mike Allgaier is a professional training executive and instructor best known for his ethical, energetic, and committed efforts to develop NDT personnel. His ASNT honors include ASNT Fellow, Mentoring Award, and Tutorial Citation Awards. He is currently chair of the VT Committee in ASNT's Technical & Education Council and can be reached at mwallgaier@outlook.com.

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ASNT Events are where the NDT World comes together!

ASNT organizes events to promote NDT knowledge and international collaboration and provide educational opportunities. Attend to learn, network with academic and industry experts, demonstrate achievements, and contribute to the NDT community.

FROM THE WAY-BACK MACHINE

NEAL J. COUTURE, CAE
ASNT CEO
NCOUTURE@ASNT.ORG

The following excerpt was taken from an article titled "A Look Ahead at Nondestructive Testing," authored by NDT giant Robert C. McMaster and published in *Materials Evaluation* in April 1986:

> Past experience has shown that more than one type of nondestructive test may be needed to detect various types and locations of defects and to provide assurance of quality based upon confirming or additive evidence obtained from these different test indications. A major problem arises when the test records produced by different test methods are not compatible. Today, many human inspectors have the training and experience needed to provide such correlations between X-ray, ultrasonic, magnetic particle, liquid penetrant, eddy current, and other commonly used types of tests. Robotic or computer-controlled nondestructive test systems will typically require consistent forms of test records, possibly bitmapped graphic images which can be enlarged, reduced, rotated, and rectified to fit new coordinate systems. Fortunately, these techniques have been well developed for use in aerial mapping of the Earth's surface and in "Landsat" images recorded by satellites in space. Three-dimensional analyses of defect locations, shapes, sizes, and planes of view feasible with computer graphics today offer examples of the programs and techniques required. Contrast enhancement, as well as color identifications of types or severity of defects (similar to those widely broadcast in television weather shows today), can also be used for defect identification, locations, shapes, and analyses of the severity of hazards they could present in service. Coincidence of defect indications obtained from different types of tests, or from tests made on the same test objects at different points during manufacture, or at different times during service, or whenever test evaluations are required for legal or other purposes, could be demonstrated by sequences of such rectified images (just as the movements of air masses, fronts, and jet streams are shown on television nationwide as time-lapse maps of the weather movements over the Earth's surface). Even when the test object moves about on the Earth's surface, at sea, in the air, or in outer space, its defect images could still be correlated after transmission of test data to earth stations at fixed locations. For critical applications, such images could be reproduced at highly qualified analysis facilities, such as national or international standards laboratories. The system reliability attainable by these means could far exceed that obtainable today from repeated inspections by certified human operators.

"We are often reminded that those organizations and individuals who do not know their own history are forced to live it again."

–ROBERT C. MCMASTER

LEADERSHIP FROM P. 65

Interestingly, ASNT's Strategic Management Committee is addressing the very issue McMaster highlighted almost 40 years ago. Currently, the NDT industry lacks a standardized file format, resulting in significant inefficiencies. Although formats like DICONDE exist, they have limitations including inflexible metadata structures, and they primarily support image data, excluding other data types such as waveforms. This lack of standardization leads to difficulties with data sharing, increased costs, and errors. Additionally, it complicates the management of digital NDT data, results in growing file sizes, and creates issues with converting proprietary formats.

ASNT plays a crucial role in setting standards, providing certifications, and promoting best practices. NDT is essential in various industries, including aerospace, construction, and automotive. It ensures the integrity and reliability of materials and structures without causing damage. Look to *Materials Evaluation* and other ASNT communication channels in the coming months as we work to address the persistent challenges facing NDT.

And with only a touch of irony, I quote McMaster from the introduction to his article: "We are often reminded that those organizations and individuals who do not know their own history are forced to live it again." ME

ASNT ELECTS NEW

The American Society for Nondestructive Testing (ASNT) is pleased to announce the addition of five distinguished professionals to its Board of Directors, each serving a three-year term starting 1 July 2024. Michael Childers, Joshua de Monbrun, Roger Engelbart, and John Derrick McCain were elected by their fellow members in the general election held 15 March–15 April, and Wade Jenstead was nominated by the ASNT Leadership Development Committee and was appointed as a director at the June 2024 meeting of the ASNT Board of Directors. Each new director brings a wealth of expertise and a shared commitment to advancing the field of nondestructive testing (NDT). Their collective experience and leadership are set to drive ASNT's mission forward, fostering innovation, education, and industry excellence. Read on to meet them!

MICHAEL CHILDERS

Michael Childers has been a member of ASNT since 2010. His professional certifications include API RP 578 for XRF and OES technologies, and he is also a certified instructor by the American Society for Training and Development.

Childers is a graduate of Glendale Community College where he studied business administration, psychology, and English. He brings a wealth of experience from his 28-year tenure at Southwest Gas Corp., where he has held multiple positions, including specialist/corporate engineering staff/operations, corporate supervisor/operations staff, technical instructor, welding crew leader, and welder.

Within ASNT, Childers has actively served in several leadership roles, including chair, vice chair, and treasurer of the Arizona Section, and as a member of the Engineering Council and the NDE Engineering Education Committee. Childers has chaired the API/AGA Joint Committee/API 1104 for six years and has been an active member of the API and AGA for 15 years, serving as a voting member on several committees. Additionally, he has been involved with the Gas Technology Institute, Pipeline Research Council International, Western Regional Gas Conference, Western Energy Institute, American Welding Society, and the National Petroleum Council, contributing his expertise and leadership to advance the industry.

As a newly elected director, Childers's goal is to promote and advance safety, technology, education, and opportunity for ASNT members and their respective industries. In addition, he aims to represent ASNT within the oil and natural gas industry and to be a part of shaping the future of NDT under the direction of ASNT executive leadership, for current and future members.

DIRECTORS

JOSHUA DE MONBRUN

Joshua de Monbrun, CEng, has been a member of ASNT since 2015. He holds multiple certifications, including ASNT NDT Level III in ET, MT, PT, RT, UT, and VT, as well as AWS CWI. De Monbrun is also an API 570 Pipeline Inspector, a DCBC Surface Supplied Supervisor, a DCBC Air Diver, a NACE Coating Inspector, and has completed EMI ICS-200/NIMS 700 training.

De Monbrun's educational background includes a bachelor of science degree in Engineering (Nondestructive Testing) from the University of Northampton. His professional experience is extensive, having spent 10 years with MISTRAS Group Inc. in various roles, from commercial diver to project manager. He has served as Technical Authority since 2021. His military service includes time as a Non-Destructive Inspection Specialist (SRA) in the US Air Force and as an Aviator (W01) in the US Army.

Within ASNT, de Monbrun has served as chair of the ASNT Underwater NDT Committee and co-technical editor of the upcoming NDT Handbook on Ultrasonic Testing, as well as a member of the Technical & Education Council, Engineering Council, and Certification Management Council. His involvement in other industry organizations includes serving on the AWS B2 and D3.6 Committees and the ASME BPV Code Working Group.

De Monbrun's career in NDT spans over two decades. His professional journey has provided him with a deep appreciation for the integration of new technologies into traditional sectors. With the accelerating pace of digitalization, automation, machine learning, and artificial intelligence, he is a staunch advocate for embracing innovation to keep ASNT at the cutting edge of the industry. He is passionate about bridging the gap between traditional methodologies and modern advancements, ensuring that ASNT remains a leader in NDT.

In his pursuit of this vision, in his role on the Board of Directors de Monbrun aims to promote the incorporation of emerging technologies into ASNT's practices and standards, believing that the inclusion of younger, tech-savvy professionals is vital for a dynamic and progressive approach. He is dedicated to attracting a new generation to the field of NDT by highlighting the exciting opportunities for innovation and problem-solving.

ROGER ENGELBART

Roger Engelbart has been a member of ASNT since 1978 and is an ASNT NDT Level III in MT, PT, RT, UT, and VT. His early professional journey began in the US Air Force, where he served as a flightline mechanic and avionic specialist, laying the groundwork for his technical expertise.

Engelbart holds a master of science degree in Mechanical Engineering and Materials Science from Washington University in St. Louis and a bachelor of science degree in Metallurgical Engineering from Missouri University of Science & Technology. His professional experience includes positions at Boeing Research and Technology as an Associate Technical Fellow in NDT, at McDonnell Douglas Astronautics Co. (which later merged with Boeing), and at Emerson Electric's Electronics and Space Division.

For more than 35 years, Engelbart has been an active participant in ASNT, serving the Society and its members at the national level for the past 17 years, including previous key positions of Secretary/Treasurer, Vice President, President, and Chair of the Board. In his most recent term as Director (ending 30 June 2024), Engelbart played a crucial role in developing and executing ASNT's Strategic Plan for 2022–2026 through his work on the Strategic Management Committee. Engelbart has also served and/or held leadership positions on the Advocacy Committee, Technical & Education Council, Research Council, and the Aerospace Committee.

Beyond ASNT, Engelbart is active in other professional organizations, including the ASTM E07 Committee on Nondestructive Testing, the ASTM F42 Committee on Additive Manufacturing, and the British Institute of NDT.

Engelbart's extensive experience and dedication to advancing the NDT field underscore his commitment to the Society and its mission. He has witnessed the Society launch its certification program, expand its business ventures internationally, and become a powerful advocate for the NDT profession. Engelbart is enthusiastic about continuing to contribute to ASNT's future success as one of its directors.

WADE JENSTEAD

Wade Jenstead began his career in 1992 after attending Hutchinson Technical College (now Ridgewater College). The associate of applied sciences program provided him training in all NDT disciplines as well as welding and metallurgy. Jenstead was an active member in the Minnesota Student Section of ASNT. During his early years in the industry, he was also active with the ASNT sections throughout the Southeast as a territory salesman. He was fortunate to be mentored by several members during those years.

Jenstead has spent the last 25+ years working with advanced NDT solutions such as phased array ultrasonic testing, full matrix capture/total focusing method, eddy current array, digital radiography, computed tomography, and advanced remote visual inspection. He has held sales leadership positions for the last approximately 15 years with GE Inspection Technologies (now Waygate Technologies), Zetec, and Eddyfi Technologies. He spent around 10 years in global sales roles while working for GE Inspection Technologies, where he traveled internationally. He has worked to provide NDT solutions in most industry sectors including aviation/space, nuclear, fossil and renewable power, transportation, oil and gas, and manufacturing.

As the current Vice President of Sales (Americas) for Eddyfi Technologies, Jenstead continues his passion of helping to solve the industry's toughest challenges while striving for the best customer experiences.

Jenstead's interest in serving as a director on ASNT's board is for the opportunity to give back to an organization that has provided so much to him and the industry as a whole. Jenstead sees the NDT industry continuing to expand and transform at the same time as technologies are advancing. This is concurrent with an aging workforce, which will require fortification by bringing in new/additional personnel and members. He is looking forward to collaborating with fellow ASNT members to further the advancement of this amazing industry, one that truly makes the world a safer place.

JOHN (DERRICK) MCCAIN

John (Derrick) McCain has been a member of ASNT since 2002. He holds numerous certifications, including ASNT NDT Level III in MFL, MT, PT, RT, UT, and VT, as well as GUL Level III, API 510, API 570, API 653, and AWS CWI.

McCain holds a bachelor of science degree in business administration and management with a minor in economics from California State University. His professional experience spans five years at TEAM Inc., where he has held key leadership roles. Since 2020, he has served as Vice President of Asset Integrity and Inspection.

Within ASNT, McCain founded and chaired the California Central Valley Section in 2018, demonstrating his leadership and commitment to the Society. His involvement extends beyond ASNT to active participation in API, where he leads committees, forums, and summits.

McCain is particularly inspired by the six pillars of ASNT's current Strategic Plan, recognizing the need for focused execution in these areas to meet industry demands. In his term on the Board, he hopes to focus on the importance of educating the next generation of practitioners, maintaining agility and relevance, and achieving global leadership. ME

MOMENTS

On 27 May 2024, at the opening ceremony of the 20th World Conference on NDT in Incheon, South Korea, the International Committee for Non-Destructive Testing (ICNDT) presented the Havercroft Award to ASNT. ASNT CEO Neal J. Couture, CAE, accepted the award on behalf of ASNT.

The Havercroft Award is a prestigious recognition named in honor of Dr. Peter Havercroft, a notable figure in the field of nondestructive testing (NDT). The purpose of the Havercroft Award is to acknowledge significant contributions and outstanding service to the global NDT community. The award aims to honor individuals or organizations who have made substantial contributions to the advancement and dissemination of NDT knowledge and practices. The winners are chosen by secret ballot by the members of the ICNDT Advisory Committee (IAC), from nominations submitted by member societies.

SOCIETY ELECTIONS

ASNT is a member-driven association, meaning that its members are responsible for governing the organization. This involves making and enforcing decisions through policy. Once a year, an election is held where members can vote for candidates for the Board of Directors, who then oversee the association's governance, leadership, and strategic planning. Following are some frequently asked questions about ASNT's election process.

Q: How are candidates for the Board of Directors selected?

A: ASNT revamped its selection process three years ago by creating a Leadership Development Committee (LDC). The LDC assesses the current Board's competencies, identifies gaps, and publishes a call for interest. The LDC also reaches out to members with demonstrated skills and leadership potential, inviting them to apply.

Q: When is the call published?

A: The call for interest is posted by 1 December each year. Applicants are invited to answer a few questions and share their experience via an online application, which is due by 1 January. The Committee may also directly solicit interest from qualified members. To be considered as a candidate, applicants must be members in good standing, have the support of their employer, sign a conflict-of-interest disclosure, and agree to fulfill the duties outlined in Policy J-03, "ASNT Board of Directors Job Description," available on asnt.org.

Q: What criteria are used to select Board candidates?

A: The LDC conducts a gap analysis to determine the knowledge, skills, and abilities needed on the Board. They focus on competencies required to lead ASNT toward its strategic goals. Competencies such as financial acumen are always needed, regardless of specific objectives.

Q: How does the nomination process work?

A: The LDC reviews candidate applications based on criteria designed to fill competency gaps, and subsequently recommends at least four candidates to the current ASNT Board of Directors by 31 January. The Board reviews these recommendations, formally completes the nomination process, and places the nominees on a ballot for members.

Q: How often are elections held?

A: Per Policy G-01, "Nominations, Appointments, and Elections," elections are held every year for the ASNT Board of Directors. Elections are held online from 15 March to 15 April. Four directors are elected by the members to serve three-year terms.

Q: What if there are still competency gaps after the election?

A: If there are still gaps after the nomination and election process, the Board is authorized to appoint one Director each year to address these needs. This is a recent addition to the governance system and was used for the first time in 2024.

Q: Are write-in candidates allowed?

A: Per ASNT policy, write-in candidates are not allowed.

Q: How are officers of the Society selected?

A: The Board of Directors is responsible for electing the Vice President. The positions of President, Chair of the Board, and Immediate Past Chair of the Board are filled through a succession process. Officer terms are for one year.

Q: How can members get involved in ASNT's governance?

A: Members interested in leading ASNT are encouraged to get involved at various levels, including sections, committees, councils, and working groups. Volunteering in these areas allows members to learn about ASNT and demonstrate their skills. Opportunities can be found on the Volunteer Portal on ASNT's website at volunteer.asnt.org.

Q: How can I learn more about ASNT elections?

A: To learn more about ASNT's election process, please refer to Policy G-01, "Nominations, Appointments, and Elections," available at asnt.org. ME

***Q&A** is a column intended to answer questions about ASNT's programs, publications, events, certification, and other happenings.*

CLEVELAND

CLEVELAND, OH
15 APRIL 2024
14 ATTENDING

▶ The Cleveland Section held a meeting at Mavis Winkles Restaurant in Twinsburg, Ohio. Speaker Peter Pelayo, Met-L-Chek Product Manager at McGean, presented the modern history of liquid penetrant inspection from a penetrant materials manufacturer's perspective. His talk included the changes in the test method from visible to fluorescent dyes and included the transition from mercury vapor UV lamps to LED UV lamps. Also addressed was the question, "How small of a crack can be found with penetrant inspection?"

COLORADO

DENVER, CO
11 APRIL 2024
8 ATTENDING

▶ The Colorado Section met at EVRAZ North America in Pueblo, Colorado. The meeting consisted of a tour and overview of the EVRAZ "Rail Weld Line," where rail is electrically flash butt welded to provide continuously welded rail to the railroad industry.

CONNECTICUT YANKEE

GROTON, CT
15 MAY 2024
24 ATTENDING

▶ A joint meeting of the Connecticut Yankee Section and the AWS was held at the Elks Lodge in Groton, Connecticut. Max Richardson, a student in the Nuclear Engineering Technology program at Three Rivers Community College, was awarded a US$500 scholarship for his essay on nondestructive testing in a nuclear power plant. This was followed by Martin Dahl of Rad Source Technologies, who delivered a presentation focusing on the company's new digital imaging inspection system.

MINNESOTA

MINNEAPOLIS, MN
18 APRIL 2024
15 ATTENDING

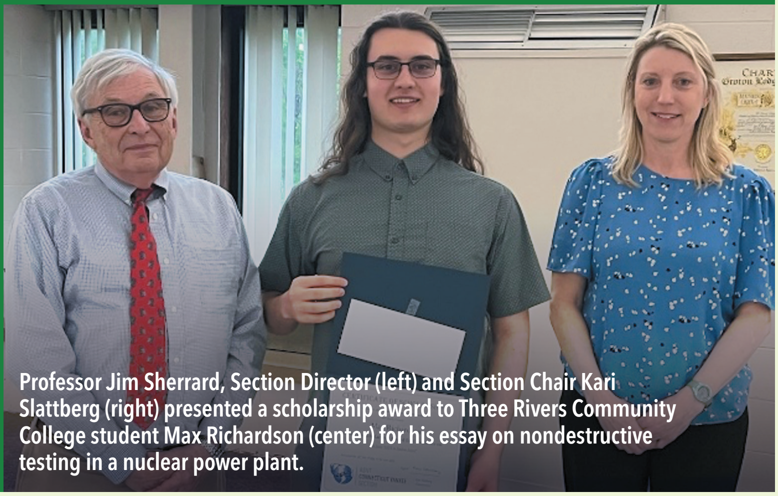
▶ "Weld Failure Analysis" was the focus of this Minnesota Section event and facility tour, held at Materials Evaluation and Engineering Inc. in Plymouth, Minnesota, and hosted by CEO and Principal Engineer Larry Hanke and Principal Materials Engineer Dan Grice. The event covered various failure analysis scenarios in a variety of materials and included a tour of their material characterization and testing laboratory and its capabilities.

SAUDI ARABIAN

DHAHRAN, SAUDI ARABIA
17 APRIL 2024
95 ATTENDING

▶ The Saudi Arabian Section held its sixth technical dinner meeting for the 2023-2024 program year at the Mercure Hotel Khobar in Al Khobar. Gareth Mugford, Product Manager for NDT Scanners & Solutions at Eddyfi Technologies, delivered a presentation on "Turnkey Phased Array Solutions." ME

SPOTLIGHTCONNECTICUTYANKEE



Professor Jim Sherrard, Section Director (left) and Section Chair Kari Slattberg (right) presented a scholarship award to Three Rivers Community College student Max Richardson (center) for his essay on nondestructive testing in a nuclear power plant.

PARTICIPATE

SAVE THE DATE: SECOND ANNUAL ASNT FOUNDATION GOLF TOURNAMENT

Location: Wildhorse Golf Club, Henderson, NV
Date: 19 October 2024

Get ready to swing into action at ASNT's exciting charity golf tournament! Whether you're a pro or just starting out, come join the fun and support a great cause before our annual conference kicks off.

Network with industry pals, enjoy delicious food and drinks, and grab some cool swag. Plus, there are fantastic prizes up for grabs!

All proceeds benefit the ASNT Foundation, helping to advance nondestructive testing (NDT) through scholarships, grants, research, and workforce development.

Don't miss out! Make plans to join us for a day of golf, camaraderie, and giving back. More information will be posted on asntfoundation.org as it becomes available.

Save the date and see you on the green!

AGUSTIN HARTE

2024 ASNT Foundation Engineering Undergraduate Scholarship winner Agustin Harte is a junior at Penn State University, studying Engineering Science and Energy Engineering. Harte holds leadership positions in the Society of Hispanic Professional Engineers and the Society of Engineering Science.

Harte also participates as an active undergraduate researcher in the Argüelles Research Group, which broadly concerns itself with using ultrasound for the nondestructive characterization of materials. Harte recently traveled with the group to the 186th Meeting of the Acoustical Society of America and gave a presentation on the use of ultrasonics in dairy processing. Harte plans to pursue graduate studies and continue research in the field of nondestructive testing (NDT), relating evaluations to the renewable energy sector.

NADIA LAFONTANT

2024 ASNT Foundation Engineering Undergraduate Scholarship winner Nadia Lafontant is an undergraduate in the School of Computing at Southern Illinois University at Carbondale (SIUC). She is currently working in the Intelligent Measurement and Evaluation Laboratory, where she studies nondestructive evaluation (NDE). Lafontant is also a teaching assistant for the "Engineering Learning Skills" course.

By developing AI models capable of detecting faults in metals with unprecedented precision, Lafontant seeks to address longstanding challenges in NDT, such as limited inspection speed and human error.

BROOKE LASTINGER

2024 ASNT Foundation Engineering Undergraduate Scholarship winner Brooke Lastinger is a junior at the University of Florida, pursuing combined bachelor's and master's degrees in Materials Science and Engineering. Lastinger is the treasurer for Material Advantage, the Materials Science and Engineering student society, and a team lead for the club's design team, Ceramic Mug Drop. Lastinger conducts undergraduate research in the university's Quantum Materials Design Group, with the goal of developing a practical and nondestructive method of measuring oxygen diffusion in oxide thin films for nano-ionic technologies.

In 2023, Lastinger interned at Naval Air Station Jacksonville's (NAS JAX) Materials Engineering Laboratory in their nondestructive inspection branch, where she gained hands-on experience in five NDT methods and performed service life assessment protocols and material engineering service requests on structural components of the Navy's aircraft. This summer, Lastinger returned to NAS JAX where she is an intern for both the nondestructive inspection and metallurgy branches, working on failure analysis and engineering investigations.

STUART KLEVEN

2024 Charles N. Sherlock Meritorious Service Award winner Stuart Kleven is a Quality Engineer and Responsible Level III at Acuren-Alloyweld Inspection, an NDT laboratory and metal finishing and welding shop in Bensenville, Illinois, serving critical industries including aerospace, electronics, medical devices, and forensics. He is an ASNT NDT Level III in four test methods—radiographic testing (RT), ultrasonic testing (UT), magnetic particle testing (MT), and liquid penetrant testing (PT)—as well an ASNT Fellow and Mentoring Award recipient and an AWS CWI (American Welding Society Certified Weld Inspector). He has 51 years of NDT experience in the commercial laboratory, welding and fabrication, forging, and nuclear power industries. Currently, he serves on the ASTM (American Society for Testing and Materials) E7 Committee for RT, PT, MT, and UT. He also serves on the board for the Chicago Section of ASNT.

ABOUT THE ENGINEERING UNDERGRADUATE SCHOLARSHIP

The Engineering Undergraduate Scholarship is a cash award given by the ASNT Foundation, currently US$3000 per award, that provides an incentive to undergraduate students enrolled in accredited US colleges and universities who are pursuing NDT/E as their field of specialization.

ABOUT THE CHARLES N. SHERLOCK MERITORIOUS AWARD

The Charles N. Sherlock Meritorious Service Award, given by ASNT, recognizes an individual's outstanding voluntary service to the Society, through a single or aggregate activities, though not necessarily in any single year.

The US Department of Commerce's National Institute of Standards and Technology (NIST) has named **Kathryn L. Beers** as the new director of the agency's Material Measurement Laboratory (MML).

MML, one of NIST's six research laboratories, conducts measurement science research in the chemical, biological, and material sciences and contributes technical expertise to the development of standards. MML has more than 850 staff members and visiting scientists performing fundamental and applied research to advance measurement science in ways that promote innovation, protect health and safety, and improve quality of life.

A polymer chemist by training, Beers joined NIST as a National Academies/National Research Council (NRC) postdoc in 2000 after earning a PhD from Carnegie Mellon University. She later served as director of the Combinatorial Methods Center in the Polymers Division and led the Renewable Polymers Project in the Polymers Division and the Polymers and Complex Fluids Group in the Materials Science and Engineering Division.

Beers also served as deputy division chief of the Polymers Division at NIST and as the assistant director for physical sciences and engineering in the White House Office of Science and Technology Policy. In 2020, she became manager of the Circular Economy Program, which focuses on standards and technologies needed to support a more sustainable economy.

The British Institute of Non-Destructive Testing (BINDT) has announced the appointment of **Corinne Mackle** to Deputy CEO, alongside her current responsibilities as Head of Publishing, Media, and Marketing and Editor of the Institute's publications. In her new role, Mackle will deputize for CEO David Gilbert both internally and externally as appropriate.

Mackle has been a member of the Institute's senior management team since 2012 and regularly attends meetings of the Institute's key committees and working groups, including Council, to assist and inform as the committees develop, refine, and implement their strategic objectives. She joined the Institute's publishing department in 2005 and has been instrumental in the continual development and improvement of all publications, communications, and promotional activities. She has served as editor of the Institute's publications, including its journal, *Insight*, and *NDT News*, since January 2018.

NDT Global introduced **Aly M. Marson** as the latest addition to their team of commercial account executives in the US region. With over seven years of experience at NDT Global, Marson brings a wealth of knowledge to the industry and a passion for educating companies on ultrasonic inline inspections.

Ahmed Al-Dadah has departed his position as Senior Vice President of Integrated Solutions at KBR Inc. after six years with the company. "At Integrated Solutions, we grew our team to over 7000 strong across the globe over the past few years," Al-Dadah said, "and through implementing the Reimagine KBR strategy, together we delivered outstanding results through the team's exceptional performance and dedication."

APPOINTMENTS

Barry Schieferstein, CAE, CMP, DES, has been promoted to Chief Operating Officer (COO) of ASNT. Schieferstein joined ASNT in 2018 and served over six years as Director of Events, playing a key role in planning and executing significant events that boosted the organization's industry presence. As COO, he will oversee and optimize daily operations and revenue-generating activities, excluding ASNT's subsidiary companies.

Before joining ASNT, Schieferstein spent most of his adult life in retail sales management. In 2013, he transitioned to conference planning, discovering a passion for orchestrating large-scale events. His career in conference planning included positions with the Ohio Department of Higher Education and The Ohio State University, providing valuable experience and a solid foundation for his role at ASNT. He is a Certified Association Executive (CAE), Certified Meeting Professional (CMP) by the Events Industry Council, and certified Digital Event Strategist (DES) by the Professional Convention Management Association (PCMA).

Nealy Wheat, CAE, SPHR, took on the role of Chief Financial and Administrative Officer (CFAO) at ASNT starting this month. In this expanded position, she is responsible for providing strategic financial guidance, ensuring robust financial management, and overseeing the administrative operations of ASNT and its subsidiaries. Her oversight extends to finance, human resources, marketing and communications, business development, and information technology functions.

Wheat joined the ASNT team in January 2024, bringing over 20 years of experience in association management across a variety of sectors including statewide trade and professional organizations, international charities, and chambers of commerce. She is a Certified Association Executive (CAE) and Senior Professional in Human Resources (SPHR).

Dalton Vidosh was promoted to Director of Finance at ASNT beginning this month. Vidosh joined ASNT in 2018 as an Accountant, then in 2022 transitioned into the role of Senior Accountant, where he excelled in managing complex financial tasks. He was promoted to Accounting Manager in 2023, where he played a pivotal role in streamlining financial processes and fostering team cohesion. Reporting to the CFAO, Vidosh will collaborate on strategic financial planning and budgeting and oversee monthly financials, the annual financial audit, and tax preparation.

Debbie Segor, CAE, has been promoted to Director of Marketing and Communication at ASNT. Prior to this role, she worked as the Marketing and Communication Manager responsible for developing and executing email marketing strategies to drive engagement, conversions, and brand loyalty. In her new role, Segor will oversee the creation and implementation of strategic marketing initiatives, manage the organization's brand and messaging, and lead the marketing team in driving engagement and growth. She has worked at ASNT for nearly nine years, spending her first five years in the membership and engagement department.

Garra Liming has stepped into the role of Director of Public Relations and Government Affairs for ASNT. Liming has been a dedicated ASNT staff member for 17 years, serving as the Director of Marketing and Communications for the past decade. In this new position, she will oversee the society's advocacy and legislative affairs agenda. Reporting directly to the CEO, she will be instrumental in shaping and executing ASNT's public relations strategies, managing government relations activities, and advocating for the organization's mission and interests to external stakeholders, including policymakers, government agencies, the media, and ASNT volunteers and members.

New Associate Editor **Stefanie Laufersweiler** joined the ASNT publishing department in May. As part of the publishing team, her focus will largely be on contributing to ASNT's journals, *Materials Evaluation* and *Research in Nondestructive Evaluation*. Laufersweiler brings years of publishing experience to her role at ASNT. She began her career at *Columbus Monthly* magazine in Columbus, Ohio, before transitioning to F+W Media, a global publisher of fine art, craft, and sewing books. There, she advanced to the role of Senior Editor. After leaving F+W Media, she focused on her family and pursued a freelance writing and editing career. Laufersweiler lives in Cincinnati, Ohio, with her husband, Matt, and their four children, and she still enjoys writing about artists when she has time.

Paul Lang has taken on the role of Chief Global Strategy Officer in addition to his continuing roles as Executive Director of ASNT Certification Services LLC and Director of Global Certification and Accreditation for ASNT.

Kelly Florian was promoted from Digital Marketing Specialist at ASNT to Digital Marketing Manager effective 1 July 2024.

Jesus "Jesse" Hernandez was recently named Facility Manager of the ASNT Houston facility, after serving as its Lead NDT Technician since January 2023.

RECOGNITIONS

The International Committee for Non-Destructive Testing (ICNDT) recognized several members of ASNT for making major contributions in the field of NDT. The following awards were presented by ICNDT on 27 May 2024 at the opening ceremony of the 20th World Conference on Non-Destructive Testing (WCNDT) in Incheon, Korea:

- Pawlowski Award, for the promotion of NDT internationally: **David Gilbert**
- Roentgen Award, for NDT science and technology: **Shant Kenderian, PhD**
- Sokolov Award, for NDT research: **Roman Maev, PhD**

In addition, the Committee recognized **Misty Haith, PhD**, and **Hojeon Seo, PhD**, with the Young Achiever Award, for achievement of young people in NDT.

RETIREMENT

Aqueos, who specializes in marine construction, commercial diving, vessel contracting, and ROV (remotely operated vehicle) services, announced the retirement of **Travis Detke**, effective 31 May 2024. Detke worked for Aqueos the past 12 years, serving as its VP of Operations for 10.5 years and as VP of Sales for the remaining 1.5 years. He is retiring with over 50 years of oilfield experience, including 47 in the offshore diving industry. Detke, known for his focus on safety and his support of the diving industry, began his offshore career with Subsea International in the North Sea, came ashore with Subsea in various positions, and subsequently worked with Global Industries, TransCoastal Marine, Aquatica/Cal Dive International, and Aqueos.

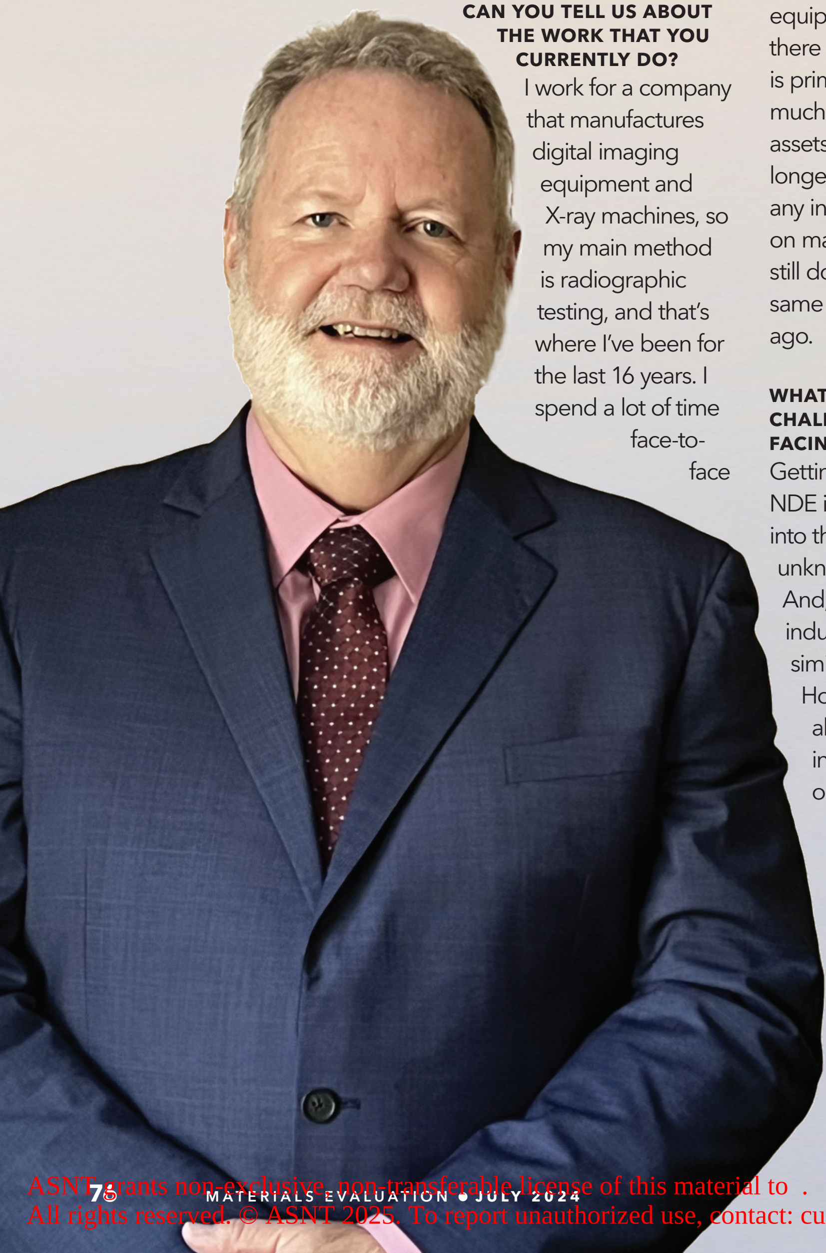
***Do you have news** you'd like to share with the NDT community? **People Watch** publishes notices of ASNT members' promotions, retirements, honors, and other milestones. Please send notices to the ASNT press release inbox at press@asnt.org.*

CLYDE MAY

ASNT President (2024–2025)
Senior Director, Varex Imaging
HOUSTON, TX

HOW DID YOU BEGIN YOUR CAREER IN NONDESTRUCTIVE TESTING (NDT)?
Probably like most people who are in NDT: by accident. I was in my second year at Marshall University, pursuing an accounting degree. I ran into a friend from high school who told me, "If you're bored, come see what we do." I started working for a company that did in-house nondestructive evaluation (NDE) for a company that built power plants. That was 1978.

CAN YOU TELL US ABOUT THE WORK THAT YOU CURRENTLY DO?
I work for a company that manufactures digital imaging equipment and X-ray machines, so my main method is radiographic testing, and that's where I've been for the last 16 years. I spend a lot of time face-to-face with customers, doing training, applications development, and helping with techniques and procedures. I travel probably 40 weeks out of the year. I've been to every continent except Antarctica, and every state in the US. I've had the opportunity to see so many places.



HOW HAS THE NDT INDUSTRY CHANGED THROUGHOUT YOUR CAREER?
Until the mid '90s, we were very focused on construction and equipment fabrication. But then there was a big shift in what NDE is primarily used for. Today it's so much more in-service NDE, since assets are being required to last longer. Bridges, airplanes—you pick any industry, and the NDE focus is on maintaining existing assets. We still do construction, but not on the same scale as we did 30–40 years ago.

WHAT ARE SOME OF THE BIGGEST CHALLENGES CURRENTLY FACING THE INDUSTRY?
Getting people to know what NDE is about and bringing them into the profession. It's such an unknown field, but so important. And, at least in the US, the industry is so understaffed, very similar to every skilled trade. How do we get the word out about NDE and its importance in day-to-day life? I think that's our biggest challenge.

WHAT ADVICE WOULD YOU GIVE SOMEONE CONSIDERING A CAREER IN NDE?
Learn as many different things as you can. While it's great to be really good at one thing, it's also important to have a working knowledge of everything in NDE, because it changes, right? The hot button of today may be gone tomorrow, so the more you can learn and get exposed to, the better.

YOU'RE ABOUT TO START YOUR TENURE AS ASNT PRESIDENT. IS THERE ANYTHING IN PARTICULAR THAT YOU'RE EXCITED TO WORK ON?
I'm fortunate to be involved with the ASNT Strategic Management Committee, and we've got a lot of things teed up. Certainly, drawing more people into the industry is very important. Also, reviewing our legacy programs and models for training and certification—they work, but they're 60 years old. The industry and much of what we do has changed. What is the workforce of tomorrow, what are the skills needed, and how do we prepare people for it? That's my primary focus for the next couple of years.

DO YOU HAVE A FAVORITE QUOTE THAT INSPIRES YOUR LIFE?
Particularly in our business, you see the catastrophes that can happen if we fail to do NDE or fail to do it correctly. My go-to saying is, "There's never a wrong time to do the right thing." ME

TO LISTEN TO THE EXPANDED INTERVIEW, SCAN THE QR CODE OR GO TO ASNT.ORG/PODCAST.

CALL FOR ABSTRACTS ON BIO-INSPIRED ROBOTICS AND SENSING FOR NDT

Materials Evaluation invites interested researchers to contribute to our upcoming Technical Focus Issue on Bio-Inspired Robotics and Sensing for NDT, to be published in January 2025. To submit an abstract for consideration, please contact Ehsan Dehghan-Niri, PhD, guest technical editor, at nde@asu.edu. Final manuscripts for invited papers must be submitted no later than 1 September 2024.

CALL FOR ASNT WEBINAR SPEAKERS

ASNT is recruiting speakers for its 2024 webinar series, and we invite you to submit your topic for consideration. ASNT webinars can be hosted by one speaker or a panel of speakers depending on the topic. Webinars are 1 h long with 10 min embedded for Q&A, and are typically held at 12:00 or 1:00 pm (ET). We're open to webinars hosted in English and Spanish (with a moderator provided by the speaker), and we may be open to other languages depending on topic and interest.

Do you have a technical topic you'd like to submit for consideration? Please email education@asnt.org with the following details:

- Your name
- Email address
- Proposed webinar title
- Proposed webinar description and 3–5 learning objectives
- Intended audience
- Availability to present virtually

Topics of interest include:

- PAUT
- TOFD
- AR/AI in NDT
- Eddy current
- Thermography
- Digital radiography
- NDT in aerospace
- Unique NDT applications
- Level I/II introductory topics
- Safety in NDT
- Business management of NDT

SPEAK TO AN ASNT SECTION

ASNT Sections are required to host a minimum of three technical meetings per year. Our sections need speakers to deliver NDT-related technical presentations at their meetings. ASNT has created a Section Speaker's Directory as a resource to help sections find speakers. Respond to this opportunity at volunteer.asnt.org to be added to the Section Speaker's Directory so sections can easily find you. ME

NEWCERTIFICATIONS

ACCP Level II CWI

Daniel Acevedo
Chase Bailey
Terrance Beaker
Matthew Benoit
Kyle Brock
Matthew Bulls
Bryan Cardenas Patlan
David Chambers
James Chitwood
Donnie Choplin
James Collins
Edward Conley
Diomedes Cordova
Joseph Cox
Will Cripps

ASNT 9712 Level II

Christopher Crites
Megan Davey
Shane Duhon
Ahmed Eltehawy
Kenneth Emnott

ASNT NDT Level III

Oscar Escobedo
Jeremy Farmer
Trent Farnsworth
William Fassbender
Zachary Floyd
Gokul G
Jorge Uriel Gonzalez Hurtado
June Grinnell
Albert Guajardo
Uriel M. Gutierrez
Bradley Hardy
Jahis Jeya Dharma Dhas Helen
Joseph Jones
Ramachandra Rao Kandregula
Kevin Keller
Kasey Kelley
Harjeet Khare
Paramjeet Kumar
Landon Kyle
Jacob Lee
Dylan Lennox
Adam Logan
Vinothkumar M
Jacob Mack
John Matthews
Matthew McClelland
Jonathan McClure
Kai-Han Mei
Efrain Mendoza
Bridget Mix

IRRSP

Jeremy Moreno
Charles Morin
Kiley Nail

ISQ – Oil & Gas

Duston Nelson
Charles Newkirk
Giscard Nuriady
Christopher O'Neal
Jose Oseguera Hernandez
Adesh Pal
Sargunabharathy R
Karthikeyan Ramasamy
Jacob Reed
Raymond Richoux
John Riley
Ivan Rodriguez
Clifton Sheldon
Cesar Sifuentes
Ashish Silori
Joni Sitio
Jamison Standley
Richard Stanley
Dabbar Taher
Jerod Taylor
Ryan Treece
Joe Trevino
Robert Trimble
Edwin Vasquez
Heath Vester
Franklin Webb
Braxton Williams
Anthony Ybarra

Naval Shipbuilders

Menelio Antonio Zarate Jara