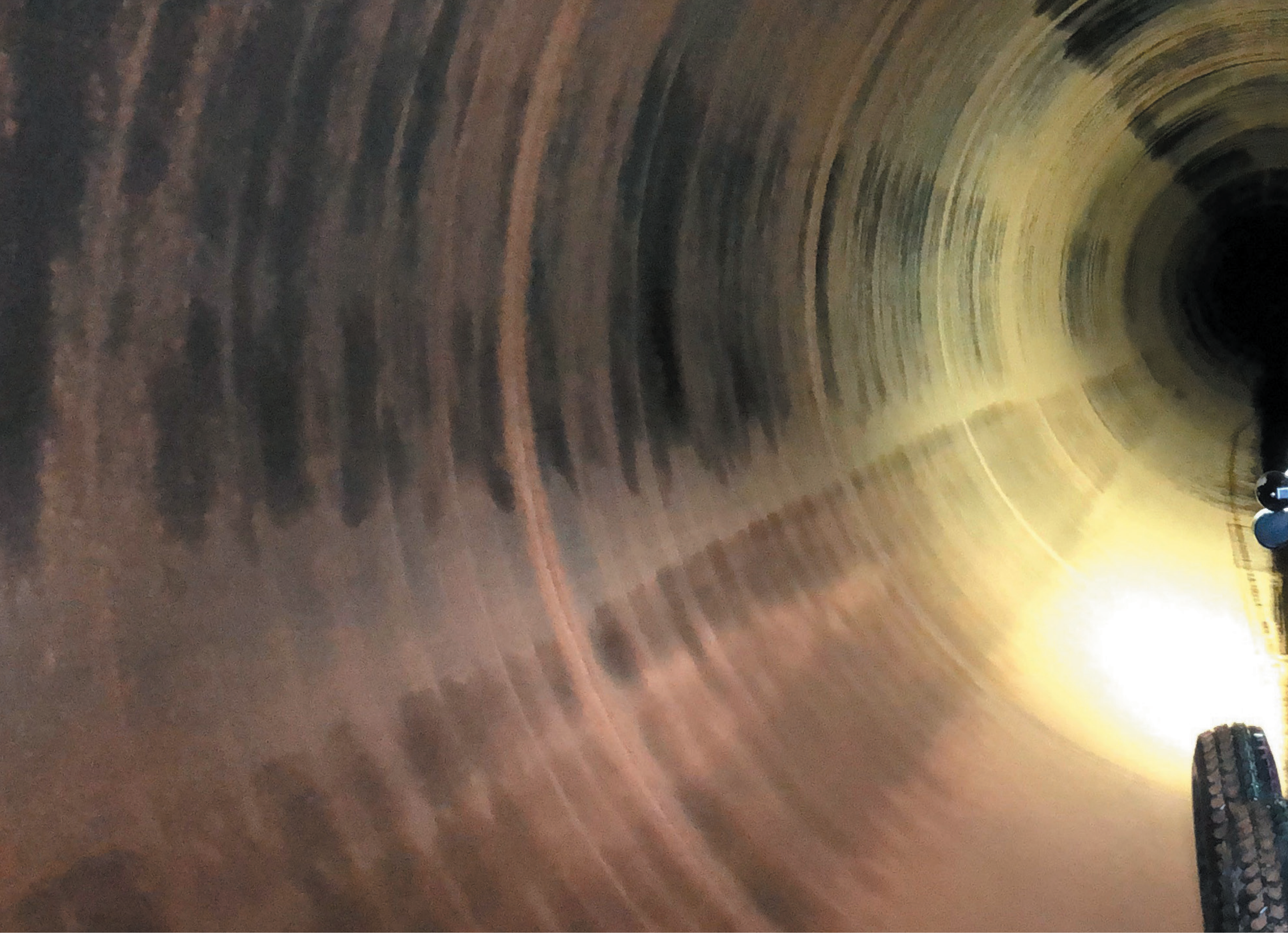

# ROBOTIC CRAWLERS

### 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

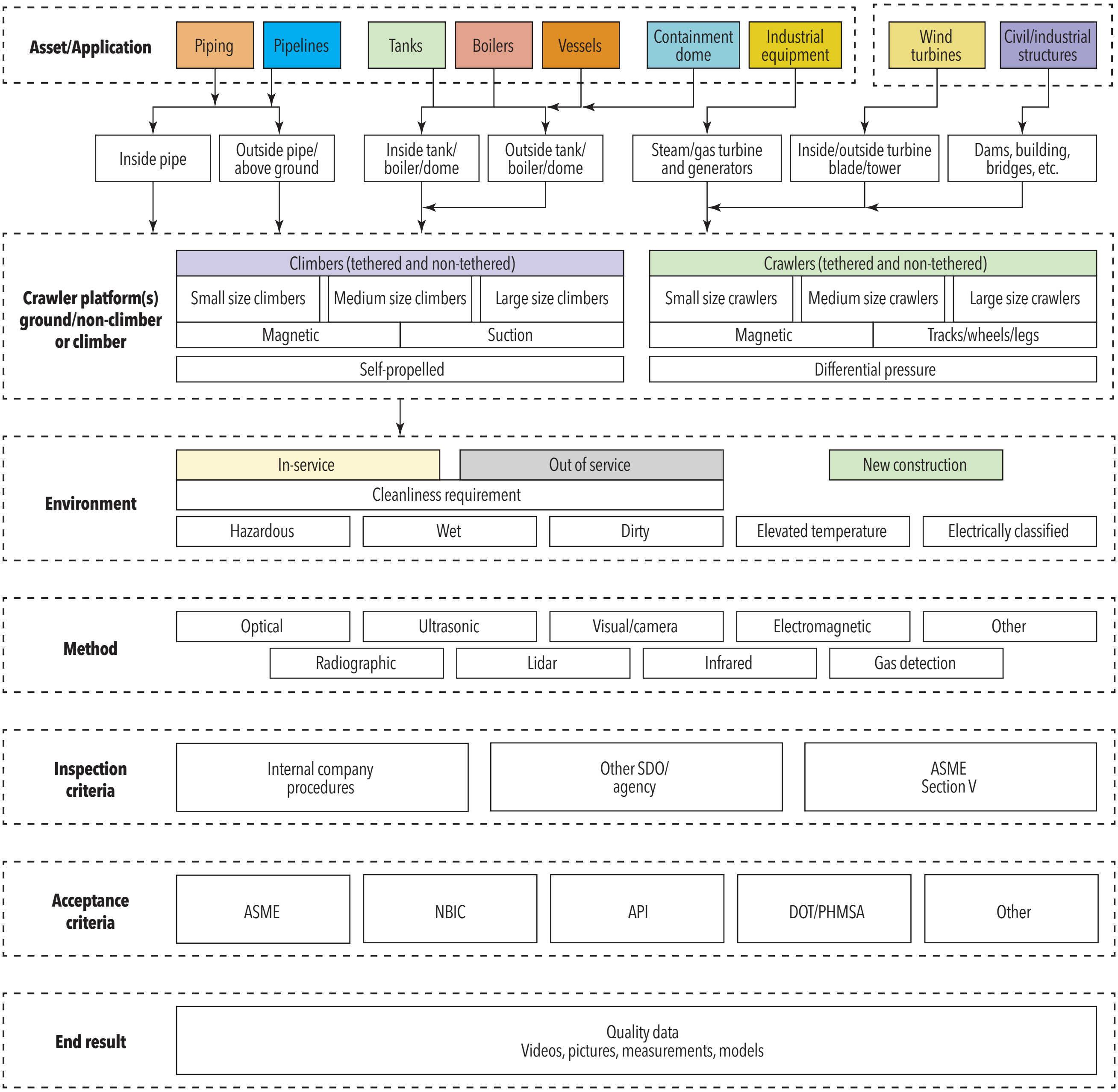

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Figure 1. Crawlers for inspection by asset/application from ASME MUS-2.

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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.

**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.

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.

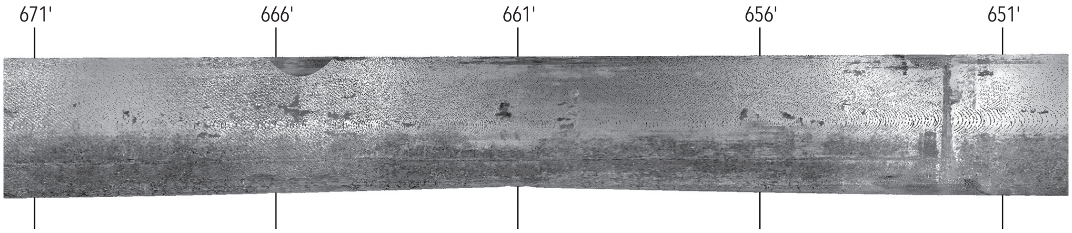

Figure 4. Point cloud view of indentation and surrounding piping.

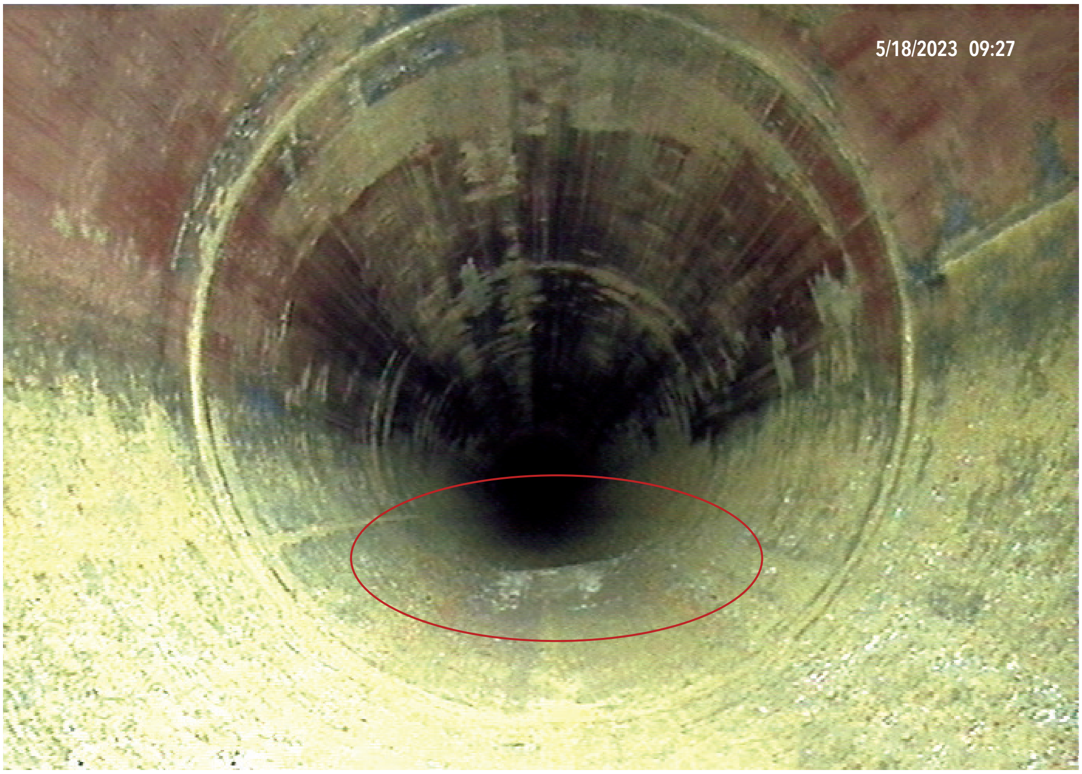

Figure 5. Crawler camera view.

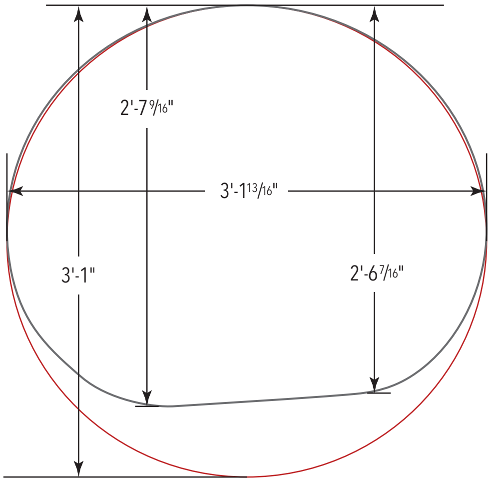

Figure 6. Best-fit oval due to indentation.

## 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

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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.