Russ Davis, MISTRAS Group, USA, outlines a roadmap for implementing a non-intrusive inspection programme.

EXTERNAL INSPECTION: AN INSIDE LOOK

Protecting the integrity of a pressure vessel is of the utmost importance, but abnormalities such as corrosion, cracking, hydrogen damage, and welding flaws on internal walls can be difficult to detect. Pressure equipment has traditionally called for external inspections, internal visual inspections, non-destructive examination (NDE), and thickness evaluations to assess a pressure vessel's suitability for continued service. These traditional inspection techniques have drawbacks, as they require internal entry into the asset, increasing costs, and safety hazards. By accessing equipment designed to store highly hazardous chemicals (HHCs), there is always a serious safety risk.

Many pressure vessel operators in the chemical, petrochemical, and refining industries are seeking more advanced techniques to maximise the effectiveness of pressure vessel inspections. One such technique is non-intrusive inspection (NII) programmes, or external inspections in-lieu of internal inspection analysis.

This comprehensive inspection strategy enables safe and effective inspections to be performed on

Figure 1. MISTRAS rope access technicians perform pressure vessel inspections for at-height and hard to reach access points, delivering a wide range of advanced techniques.

Figure 2. Advanced robotic scanner technology helps to preserve time and budget by providing faster, more accurate inspection results.

pressure equipment externally, therefore eliminating vessel entry during the inspection process. NDE technology has progressed to the point where inspectors and engineers are able to externally collect data on vessel integrity that is as good or better than data obtained from an internal inspection.

The implementation and execution of an effective non-intrusive inspection programme is complex, requiring a multi-disciplined team of subject matter experts (SMEs) in engineering analysis, advanced and traditional NDT techniques, condition monitoring, and data management. Operators can benefit by partnering with a company with expertise in a wide range of asset protection specialities, such as MISTRAS Group. Through such a partnership, operators can develop, implement, and manage an effective NII programme that enhances safety and productivity at their facilities.

NII inspections vs traditional techniques

NII programmes are proven to be a safer, more cost-effective, and quicker alternative to time-intensive internal inspection. In many cases, it is not necessary to remove the vessel from service to perform a comprehensive NII, which eliminates the requirements for cleaning, clearing, degassing, blinding, and opening the pressure vessel.

The rigid technical requirements for data and NDE selection are, in many cases, more stringent than those that are typically required for intrusive inspections. These requirements generally result in a greater understanding of the damage mechanisms that may adversely affect the vessel. The process of selecting NDE methods for the NII, which will be detailed later, results in a more comprehensive understanding of where and why damage is going to occur within the pressure boundary of the vessel. When used effectively, NII programmes ultimately result in enhanced safety and significant savings over a traditional, intrusive inspection programme.

Suitability review

When building an NII programme, the first element is the determination of whether the vessel is suitable for NII. Qualified personnel must evaluate the vessel and operating process to determine if an external inspection can be performed, and if the data would be as good or better than what could be collected by an internal inspection. The following factors should be considered:

Evaluation of background data

It is essential to gather and evaluate background data and documentation on the equipment being considered for NII. This information should contain all relevant equipment data and records, inspection and maintenance histories, operating conditions (including pressure, temperature, flow characteristics, and all chemicals contained within the vessel), and accessibility concerns.

Table 1. Inspection type descriptions

Type	Description
A	Damage mechanism is NOT expected to occur. Inspection is required to confirm there is no onset of the damage mechanism
B	Damage mechanism is expected, but with low-medium progression. Location of degradation can be predicted and not anticipated to impact on vessel integrity for at least two (2) outage periods. Inspection is required to confirm CRA predictions
C	Damage mechanism is expected with medium-high progression. The location of the damage mechanism cannot be predicted and MAY affect vessel integrity within two (2) outage periods. Inspection is required to confirm absence of critical-sized flaws

Based on DNV-RP-G103, Table 4-1

Table 2. Inspection effectiveness categories

Inspection effectiveness category	Inspection effectiveness description	Inspection methods will correctly identify the damage state...	Confidence percentage	Inspection type equivalent (per DNV-RP-G103)
A	Highly effective	...in nearly every case	80 – 100%	C
B	Effective	...in most cases	60 – 80%	C
C	Moderate effectiveness	...about half the time	40 – 60%	B
D	Limited/specific effectiveness	Validates lack of damage with limited/specific information	20 – 40%	A

Based on API 581, Risk-Based Inspection Methodology, Part 2, Table 2.C.2.1

Zone evaluation

When reviewing a vessel for NII suitability, it is important to determine whether different damage mechanisms can affect different areas within the vessel. An example of this is distillation columns, which may have three separate zones: upper vapour zone, middle two-phase zone, and lower liquid zone, each of which need to be evaluated differently.

Structural integrity assessment

The extent to which a vessel can withstand damage must be evaluated by knowledgeable engineers to determine the suitability of NII. If the vessel is presumed to be past its usable life or if any major internal repairs are needed, NII may be useful as a pre-turnaround inspection, but will not prevent the need to open and repair a vessel.

NII inspection planning

After determining that NII will provide suitable inspection data, operators must work with qualified engineers and NDT experts to devise a cost-effective inspection plan prior to any field performance of the NDE. This comprehensive plan will serve as the field road map, and must take into consideration:

- When the inspection should be scheduled and how long it will take.
- Inspection methodology and gathered data precision.
- Areas and components of the vessel to be inspected.
- Inspectors, qualifications, and equipment accessibility.
- Reporting requirements.
- Plant operations and maintenance requirements (e.g. shutdown, scaffolding, etc.)
- Safety requirements pertaining to equipment and personnel.
- Whether the inspection will be performed on or off-stream.
- The temperature during inspection.
- Comparison with previous inspections.
- Cost and time restraints.

Choosing an effective inspection methodology

An external inspection method must be suitable for the detection of all potential damage mechanisms identified in the NII decision process and suitability assessment. Risk-based inspection (RBI) is an effective solution for evaluating damage mechanisms, and for the selection of NDE methods suitable for the detection of damage and subsequent quantification. Visual inspections are a necessary component of the NII plan as well. See Tables 1 and 2 for examples of classifying inspection methods based on expected damage mechanisms and expected methodology effectiveness.

Having a complete understanding of all potential damage mechanisms helps to identify what type of inspection method is required. Damage mechanism/corrosion analysis must be performed by qualified personnel, and the selection and execution of suitable NDE methodology must be determined by SMEs fully aware of the limitations of each NDE method. In this regard, it is essential to implement an NII programme with a third-party service provider with expertise in engineering analysis and NDE methodology to guide the planning and decision-making process.

Inspection execution

Inspectors and technicians should adhere as closely as possible to the inspection plan developed for the NII process. Any deviations must be documented and communicated to the project manager, engineer, or inspector performing the analysis of the vessel and executing the field tests. It is critical that data quality

should adhere to the effective analysis and that corrective measures are taken, or additional data is acquired while the inspection team is on-site.

Analysing inspection results and determining inspection frequency

Following the execution of the inspection plan, the results are analysed to establish future inspection intervals. An NII may be considered acceptable if the actual inspection performed achieved total compliance with the overall inspection plan. The same is true in cases where there is a minor deviation in the actual inspection as compared to what was mapped out in the inspection plan, but the minor deviation does not impact the effectiveness of the inspection.

In these cases, non-intrusive inspections may be considered as a replacement for the internal inspection and in support of the planned deferment period, and no follow-up internal inspection is required. The next inspection date will be established as half the remaining life of the vessel, based on corrosion rate, not to exceed 10 years or as required by local regulations. Additional monitoring may be determined as a good practice between the established NII intervals. In this event, the inspector will identify effective intermediate inspection methods and the recommended frequency. In all cases where NII is accepted in lieu of internal inspections, an external inspection should be performed every five years.

However, if there is a significant decrease in what was achieved in comparison to the inspection plan, then further investigation is necessary, and the inspection interval will need to be determined by other means. If the actual inspection did not meet the requirements of the inspection plan, then the NII cannot be the basis for continued operation of the equipment, and additional action must be taken to ensure the integrity of the equipment.

Reporting inspection results

A complete final report should be developed regarding the NII inspection and will include, at a minimum:

- All vessel documentation utilised for the NII evaluation.
- Inspection/test plan, including all drawings.
- Results of all inspection and testing performed.
- Evaluation of the inspection and testing results indicating if the NII was acceptable.
- The next inspection due date and the basis for the establishment of the next due date.

Final thoughts

External non-intrusive inspections, instead of internal inspections, are a safe, viable, and effective option to traditional internal inspections. Recognised and generally accepted good engineering practices (RAGAGEP) identify NII methodology as acceptable. As effective as NII can be, the process requires significant technical analysis, both to meet codes and to ensure the effectiveness of external NDE methods. Vessel operators can realise significant benefits in partnering with a service provider with expertise in all phases of the process to help them plan, coordinate, and ultimately execute a successful NII process for keeping assets safe and online.