# Remote Internal Inspection – Keys to Success

Sean Peters

# Who am I?

- Worked around the globe on specialist RDVI campaigns for 16+ years
- Key part of planning teams with a focus on RDVI for multiple large campaigns/turnaround
- Worked with Oil & Gas Asset owners for the dedicated design and inspection procedures for new build LNG facilities
- Infield RDVI SME for various OEM’s when they are looking to develop new Visual Inspection tools for the market.
- Worked with Urban Search & Rescue using cameras and technology to help locate survivors 2011 Christchurch Earthquake

# The Importance of Screening – Remote Internal Inspection




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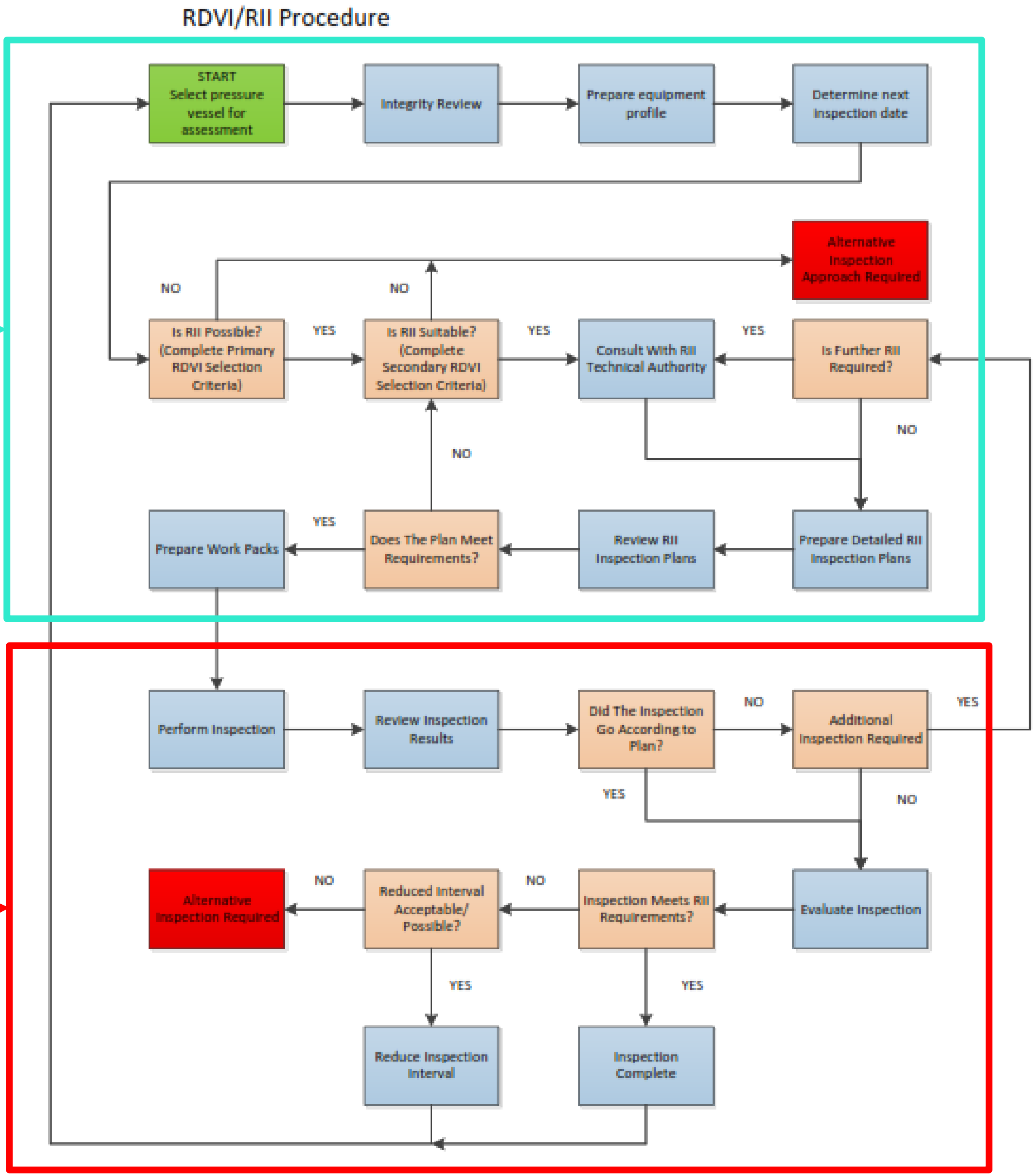
# Process of Assessment

All of this is to ensure…

To Achieve this; we need to the following;

- Suitable Experienced & trained personnel
- Validated and Verified camera equipment
- Dedicated selection/procedures (HOIS-RP-058 RII Recommended Practice)

That this step is efficient as possible and obtains the clients best outcome



# Basic Steps to Success

1. Defining the Goals
2. Review & Assessment
3. Planning & Workscope
4. Infield Execution
5. Reporting
6. Analysis

It is highly recommended that you include your chosen inspection service provider and Remote Internal Inspection Specialists as they can contribute and eliminate any issues long before they arrive

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# Starting off

Once we have our list of assets and information consolidated, we need to start look a few key questions for each asset;

- What is the Purpose or driver for this inspection?
- What do we need to achieve during this inspection for it to be a success?
- How are we going to achieve this?




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# Goals and Use of Inspection Data

## Project

- Incorporate lessons learnt from similar projects to eliminate legacy issues from fabrication and construction
- Ensure quality requirements are met
- Ensure requirements for operational production increases are met
- Ensure requirements for in-service inspection savings are installed in the correct locations, orientations etc
- Ensure that QA/QC requirements are met for long term operation reliability
- Provide conditional data and confidence for extending first In-Service inspection requirement

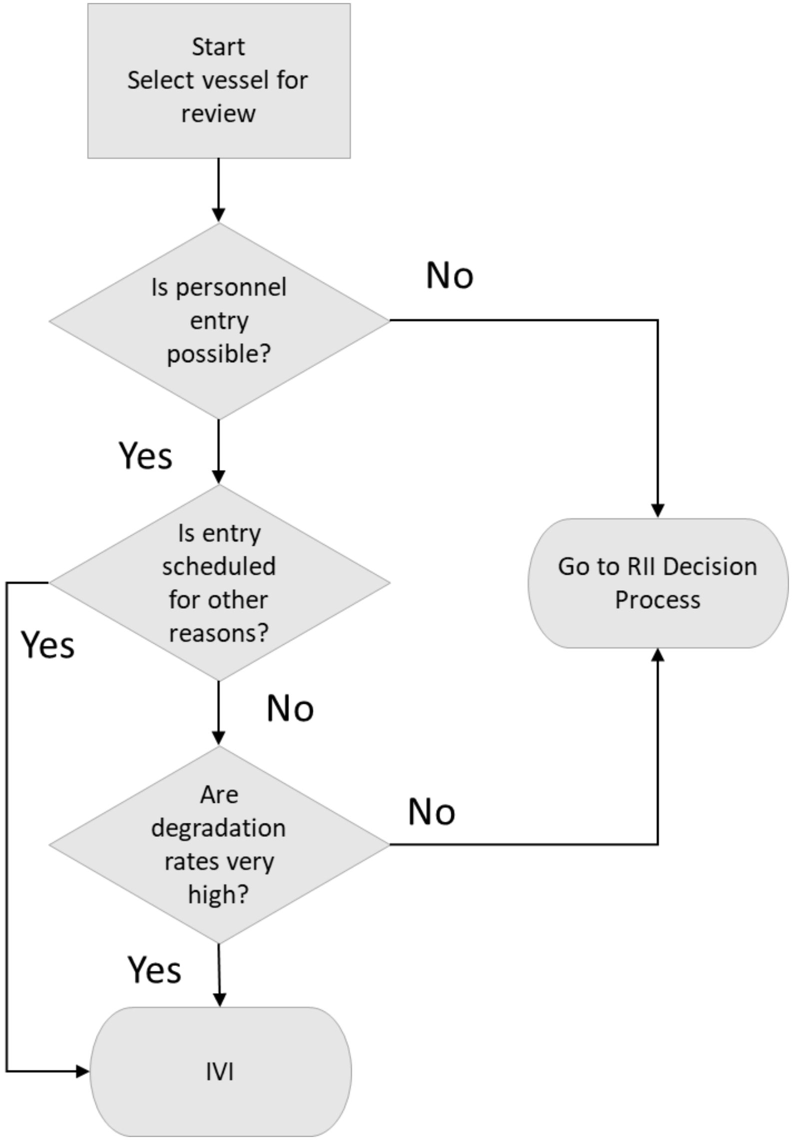
## Operational

- Increase available production days per annum
- Increase data from inspections pertaining to plant integrity
- Decrease shut down durations
- Decrease mechanical shut down costs
- Decrease resources and logistics costs per shut down
- Decrease high risk activities (HSE)
- Decrease sim-ops conflicts during shut downs
- Enable On-Line inspections of selected pressure equipment, Tanks and Holds
- Provide higher levels of confidence in plant condition to extend in-service inspection intervals

## Regulatory

- To extend first in-service shut down
- To extend intervals between in-service shut downs or tank entries
- To provide high levels of data to ensure confidence in plant safety for operation (containment and process)
- Ensure that the facility is safe to operate

# 2 – Asset Review




Once we know what the Goals of the inspection is for, we need to start to review the asset to determine HOW we are going to achieve these and collect the required data.

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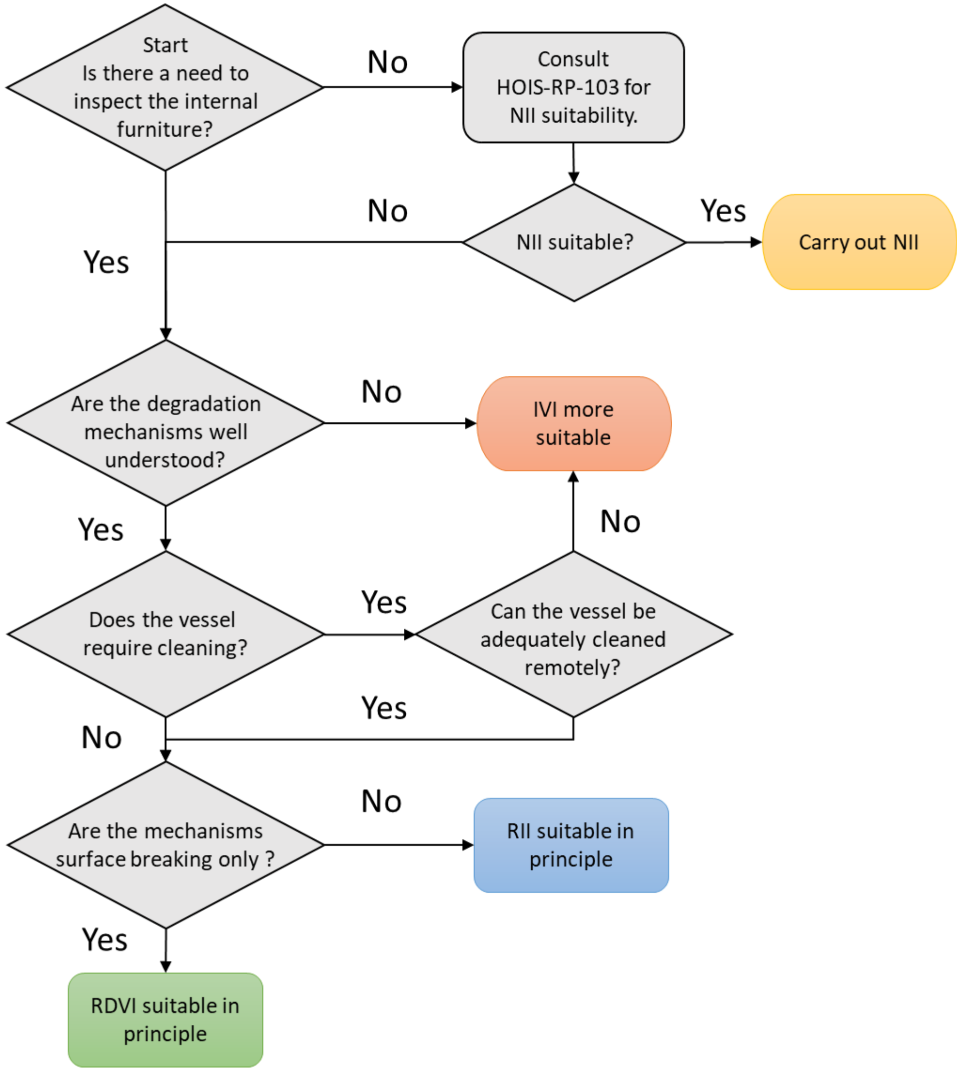
# Questions we need to Ask

- What is the vessel made from?
- Is cleaning required for this inspection?
- What is my access point size?
- How big is the inspection area?
- How far away from the access point are my inspection targets?
- What is the time frame for this inspection?
- What access points can we utilize?
- What internal fitment is present in the vessel?
- Is there likely to be FOSAR required?
- Is there an issue with O2 entering the vessel? (pyrophoric chemicals present)
- What is the vessel process and service? (CO2 removal, chemical. Gas cracking etc)
- Is Non-Intrusive Inspection methods being applied (HOIS-RP-103)

Is NDT Reqd?

- Is it a cryogenic service or is water allowed in the vessel?
- What NDT Method is required?
- Where is the NDT required?

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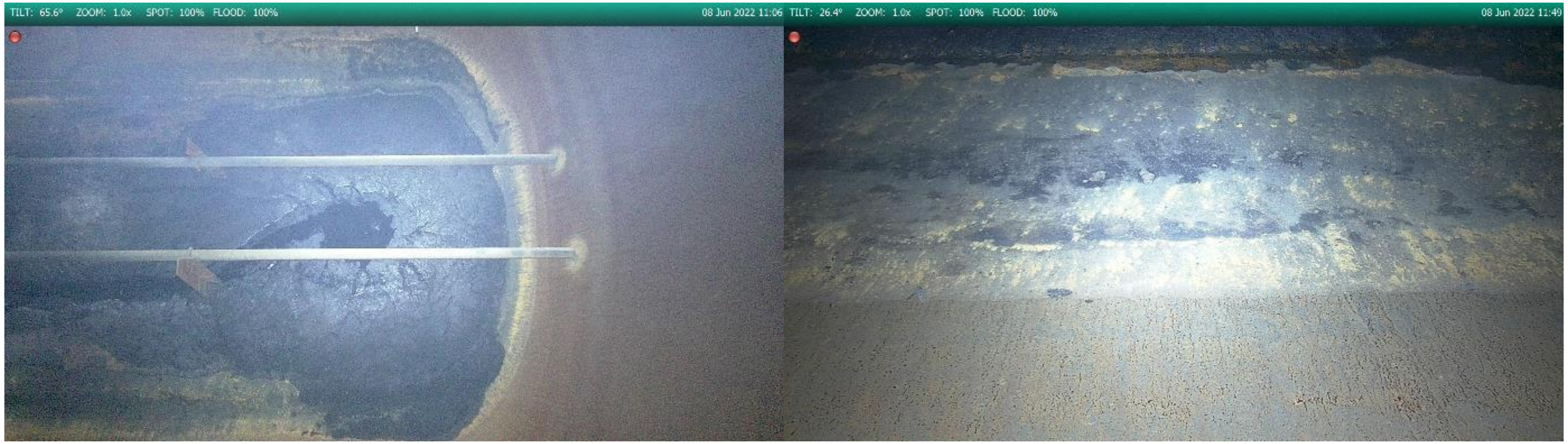
# Vessel Cleanliness Concerns

- If the asset is unable to be cleaned thoroughly without a CSE, then a few simple processes can be applied with further NDT techniques employed to help remove the CSE requirement.
  - Complete Corrosion mapping in areas of heavy deposition or NDT inspection & Engineering Assessments as per HOI-RP-103 Non-Intrusive Inspection (can be done while online)
  - Deploy PTZ via conventional poles/smart pole for internal Visual inspection.
  - Deploy robotics in areas where it is clean surfaces only





Not every vessel needs to be 100% clean. Minor deposition & oil is ok in many cases.
In some instances, understanding where the deposition is built up can help determine process efficiency and potential degredation

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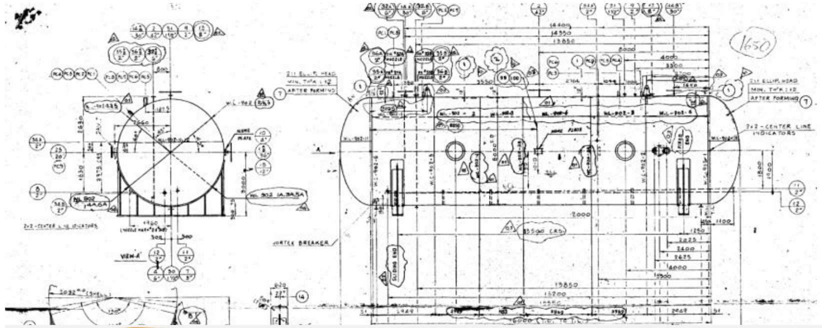
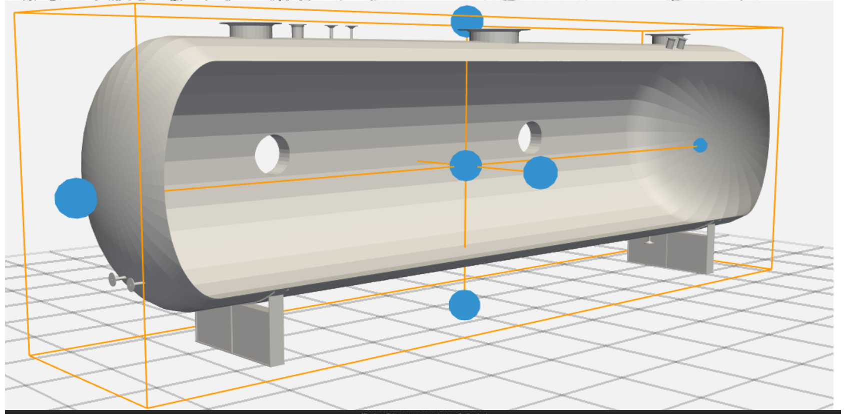
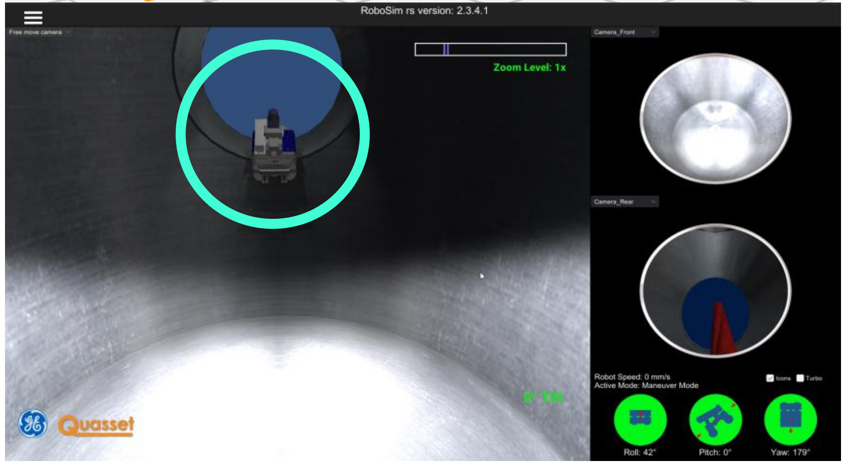
# 3 – Planning & Scope Development

- Create the Digital Twin from the supplied Drawings
- Develop a Remote Inspection Drive Plan (incorporate any NDT & Other data capture methods in this)
- Perform a simulated inspection of the asset if required.
- Identify any key areas that we may be unable to reach during the simulation
- Develop additional strategy or re-review the asset to identify other access points or inspection methods for areas unable to be inspected using remote internal inspection methods





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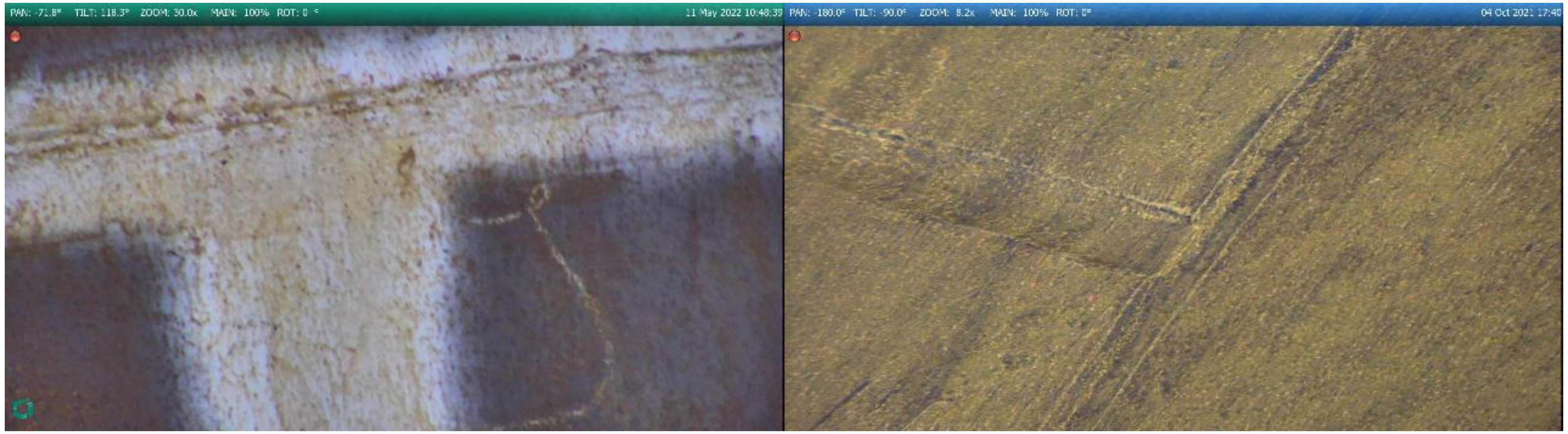
# Our Goals – What we need to do

- To help assess the condition of the plant for safe and reliable operation (safety and process)
- Record and document the condition of the plant accurately
- To provide clear and concise data of the condition of the plant
- To provide multiple images and data sets of the condition for assessment and future analysis
- To provide fine detail and extent of any degradation (credible and non credible)
- To have enough clear and concise images captured that enables communication to the condition un-deniable and indisputable




Out of Focus X

In focus

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# Validating Camera Performance

- There is no silver bullet or system that does everything. Each manufacturer of PTZ, Robotic Crawler, UAV or Videoscope has an optimal working range and area that they excel at.

- When selecting an RII tool, we need to look at the performance of the system in its given the target inspection area.

- To help ensure that we understand exactly what the visual tools can see and define, we should be testing them against a known test piece as each system has an optimum range for clarity, light which all leads to better image quality. A higher MP rating does not necessarily equal a better or clearer image. Lighting, contrast and image processing software all plays a big part in RDVI images.

- A good way to assess the parameters and optimal ranges of any RDVI tool is to take a test sample and place it inside a pressure vessel and perform mock inspections and tests to see what defects you can detect under different conditions. This testing should also include lighting and lens/tip configurations

  This data from these tests help provide an understanding for Degradation assessments and detectability further on or provide justification to lower our inspection escalation points from Remote inspection to CSE Inspection.


**Figure 4-3: Lloyd's Register test piece**

 

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# RII Tooling Basics

| Inspectable Areas | Robotics (Crawlers / ROV's) | PTZ & Poles | Videoscopes | CSE UAV's |
|---|---|---|---|---|
| Pressure Vessel Internals | Yes | Yes | Yes | Yes |
| Tower Internals (Manway Access) | Yes | Yes | Yes | Conditional |
| Tower Internals (Between Trays) | No | Yes (if access allows) | Yes (if access allows) | No |
| Kettle Type Heat Exchangers | Yes | Yes | Yes Inc Tube Internals | Yes |
| Shell & Tube Heat Exchangers | Yes, If tube bundle is removed | Yes, if bundle removed Requires custom tooling | Yes inc Tube Internals | Yes, If tube bundle is removed |
| Fin Fan Heat Exchangers | No | No | Yes | Tube Externals only |
| Pipe Internals | Yes | Requires custom tooling | Yes | Conditional |
| Storage Tanks | Yes | Yes | No | Yes |
| FPSO / Ship Tanks / Hulls | Conditional | Conditional | No | Yes |
| NDT Payloads | Yes | No | Stereo Measurement / Phase measurement (Conditional) | No |

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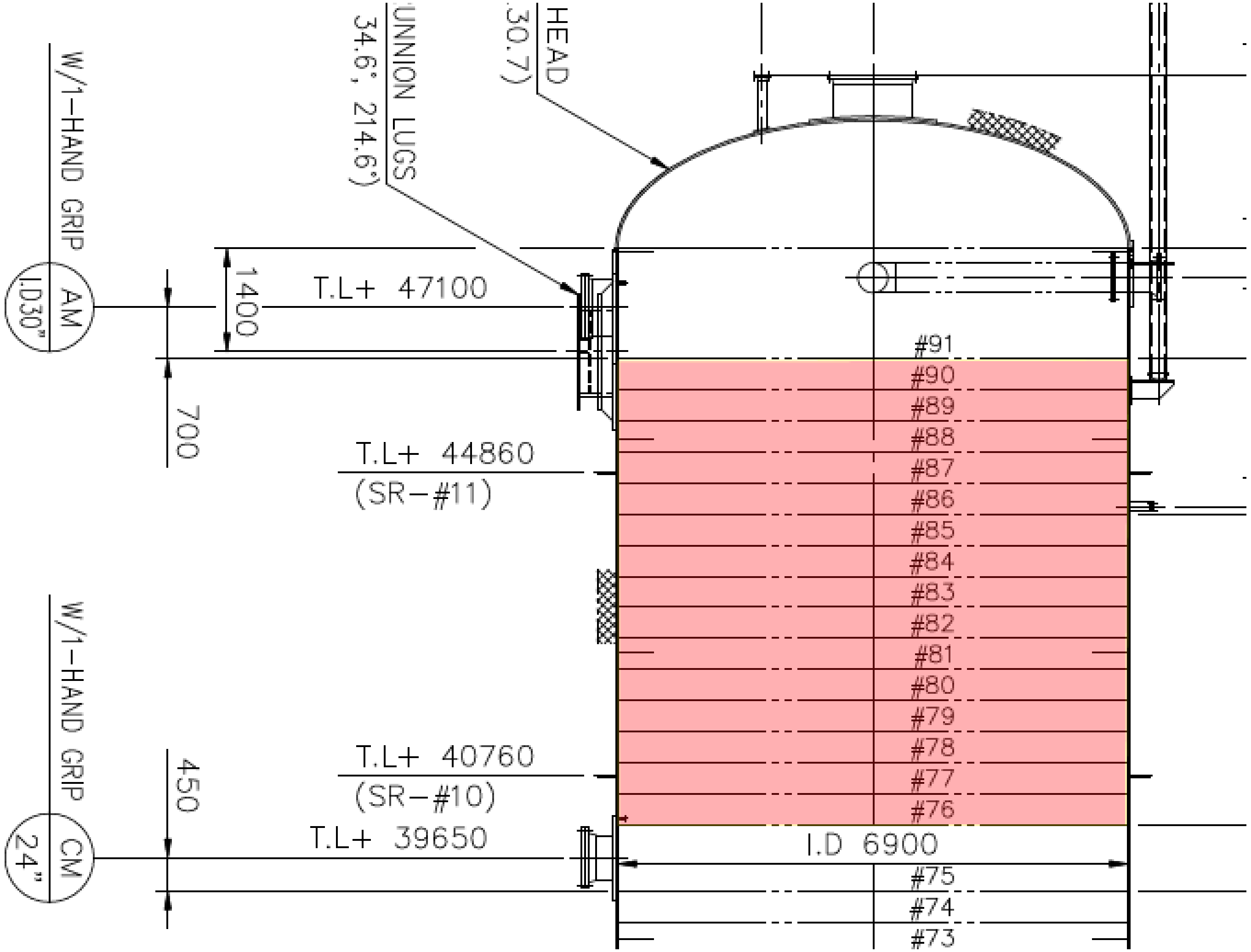
# Note: Towers or similar internal arrangements

- Towers can be difficult due the number of trays and other internal fitment present.
- While it may appear that the outcome is good based on the access table (Table A-1-1) , internal fitment limits our ability to achieve our inspection strategy targets (Table 4-1)
- These trays and location of access points can limit the areas that we can get RII technology too.  In these cases, NII as per HOIS-RP-103 should be the preferred the method of inspection with RII as a supplementary technique.
- External cladding can also be an issue with this, and as such further RII should be applied where possible to ensure asset integrity and confidence.
- NII should be performed on the RED Section if no CSE is to be undertaken.
- Assessment about tray damage can be taken form Process data such as pressure differentials, depositions, liquid/gas carry over etc.







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# The Workscope

- Inspection targets point and inspection Methods
- Previous inspection History
- Inspection Tool Deployment Methodology
- Inspection Tool safety Information
- Inspection & Test Plant
- Vessel Drawings & Information
- Inspection Methodology and process
- Specific instructions for the Remote inspection team
- Recommended Drive Plan (Robotics)





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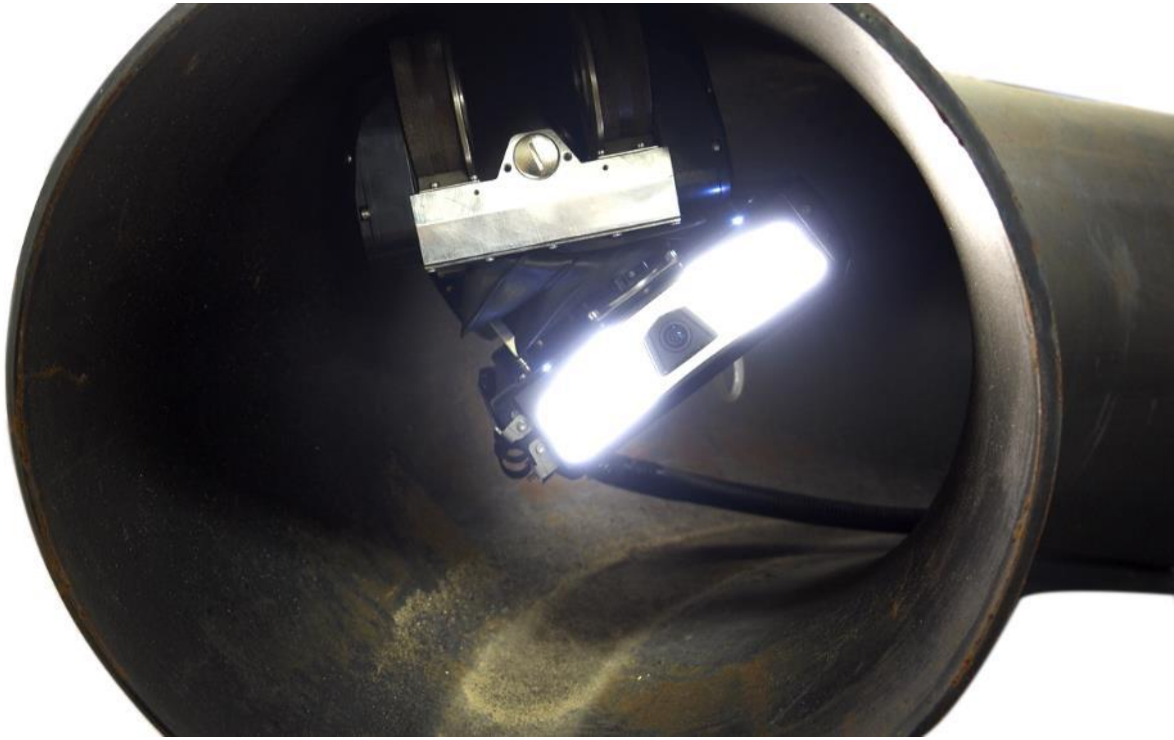
# 4 - Infield Execution

- All infield techs to be briefed on inspection criteria and familiarize themselves with the work scope./Inspection & Test Plans

- Inspections to be witnessed live by person of authority where required (API, AMSE, AICIP Engineer etc).

- Work scopes to be followed and any restrictions to be clearly noted in the work pack and be incorporated in the final report



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# Keys to Success

## Experienced and Trained Personnel

- Completing remote inspections
- In camera selection and operation (Inc Lenses)
- Defect detection and identification
- Selection and deployment of support/access tooling
- Recording and safe storage of conditional data
- Report generation and communication of results
- Relevant codes and applied standards

## Procedures to be used:

- All inspections undertaken
- Equipment start up and calibration checks
- Condition recording and interpretation
- Sizing and extent of degradation
- Data security
- Managing deliverables and expectations
- Escalation planning

## Equipment

- Correct for type for the inspection
- Capable of likely defect/degradation detection
- Working within operable ranges (validated and verified to the appropriate standard)
- Have the correct support tooling to position the cameras




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# 5 – Reporting

- Reports and all documents issued to the client should be clear, methodical and concise.
- All data points should be clearly identifiable and be linked to a location within the asset.
- Detailed reports contain:
  - Target areas/items with comments & interpretation
  - All Raw Data (images, NDT screenshots & Videos etc)
  - Issued electronically with all data points indexed for easy reference and compliance


This is one of the most crucial things during the inspection process.

If left inaccurate, or data omitted or glossed over, important details pertaining to the safety of the vessel can be missed.




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# 6 – Analysis

- We want to ensure that any future inspections can be completed more efficiently and with less restrictions.

- All lessons learnt need to be incorporated in to work packs so that future works don’t have the same pitfalls or encountered issues.

- Review
  - All areas of Concern for potential future remedial actions
  - All areas in ‘acceptable condition’ to ensure confidence for safe & reliable plat operations
  - Work packs to be updated with additional target areas based on inspection history & key findings
  - Lessons learnt to remove any pain points and to create greater efficiency, repeatability & accuracy.
  - Degradation has been reviewed and assessed for further inspection & testing
  - All Inspection results have bene uploaded into the client RBI or engineering assessment program.

Upon issue of report and inspection close out, a review for the inspection process and data gathered should be under taken. Any restrictions should be addressed and to help find further efficiencies in the inspection process identified.

Changes to tools, deployment methods, tools, access point & Deployment methodologies are not uncommon.

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# Summing Up

- We need to define inspection goals and requirements
- Inspections need to be planned & assessed as a team
- Execution in the field to the plans developed
- Ensure reports and data captured is clear, concise and contain high levels of detail
- Review and analyze all results and complete further assessments where required

We get one chance to get it right




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# Example
# – V-001 Gas Separator

 

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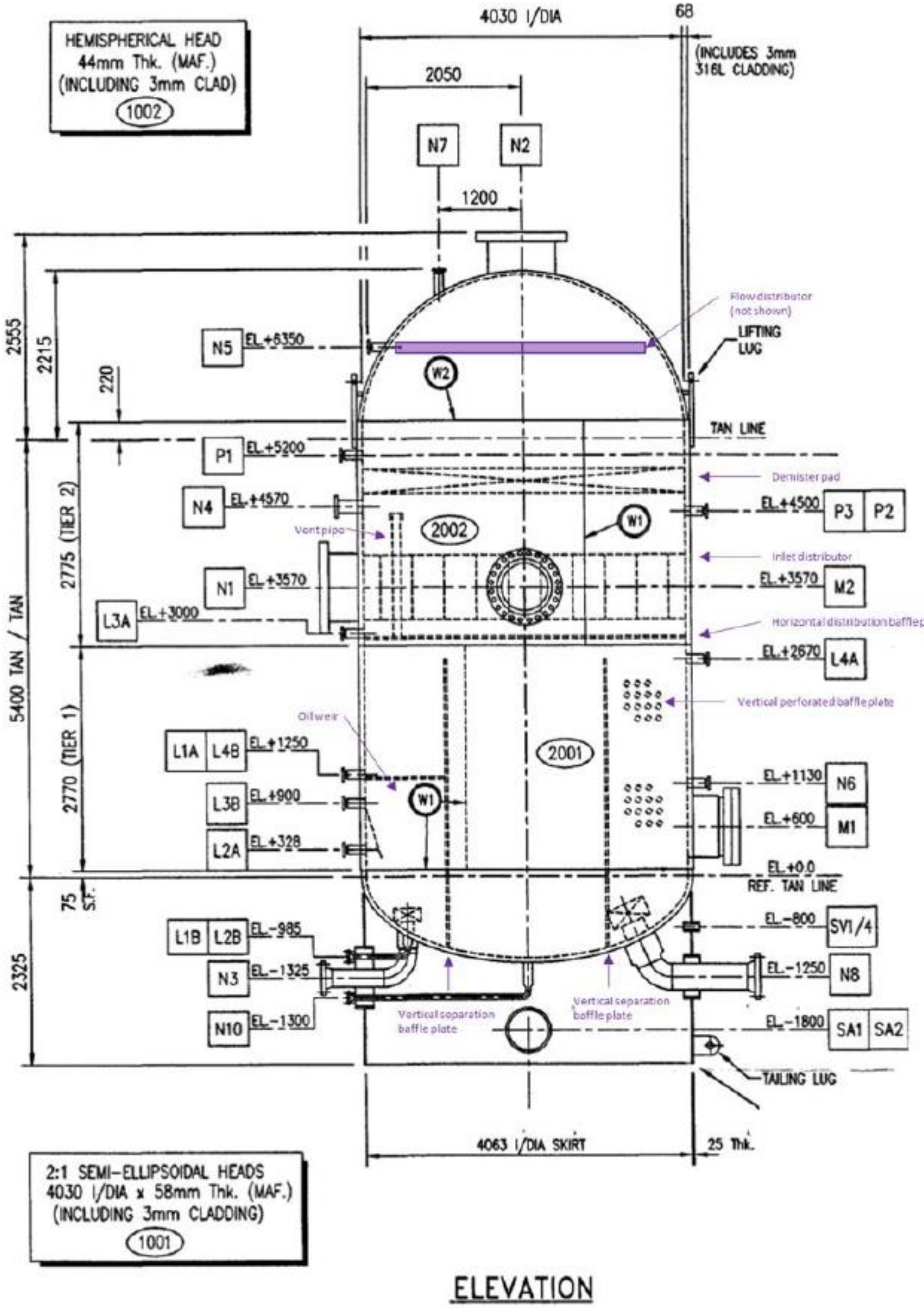
# Example – V-001 Gas Separator

The V-001 Gas Scrubber is a vertical, three phase separator. It receives process fluids via nozzle N1. The inlet distributor slows and spreads the incoming flow, causing some fluids to drop out into the liquid compartment at the bottom through the horizontal distribution baffle plate.

The gas travels upwards in the vessel with residual entrained liquids removed on passing through the demister pad. The gas exits the vessel through nozzle N2 at the top of the vessel.

The liquids collect in the liquid compartment before passing through a series of vertical perforated baffles that change the direction of the fluids and encourage the water and oil to separate with the oil floating on the top of the water. Oil flows over the oil weir plate into the oil compartment and exits via the oil outlet nozzle N8. The water is removed via nozzle N3.

Gas continues to be released as the liquids are separated. A vent in the horizontal baffle plate allows passage of gas to the upper part of the vessel.



# V-001 Gas Separator – A History

The last comprehensive inspection included internal and external visual inspection. Visual inspection for the vessel flanges and bridle pipework flanges raised no concerns. Dye penetrant inspection (DPI) was carried out on 25% of the internal attachment welds, nozzle welds, longitudinal welds, circumferential welds, and shell internal surface. No surface breaking indications were noted.

Visual inspection of the internal 316L stainless steel weld overlay on the top and bottom of the vessel found no areas of concern. Inspection of the vessel internals (baffle plates, hatch cover, vortex breaker, demister pad, flow distributor, and inlet distributor) found no areas of concern.

Ultrasonic thickness (UT) inspection was completed on a 200 mm wide band around the bottom circumferential weld. The minimum reading was found at the 3 o'clock (OC) position and was 67.8 mm compared to the nominal of 68 mm.

Figures 4 to 6 show examples of the vessel condition.

**Figure 4 Bottom domed end, good condition**

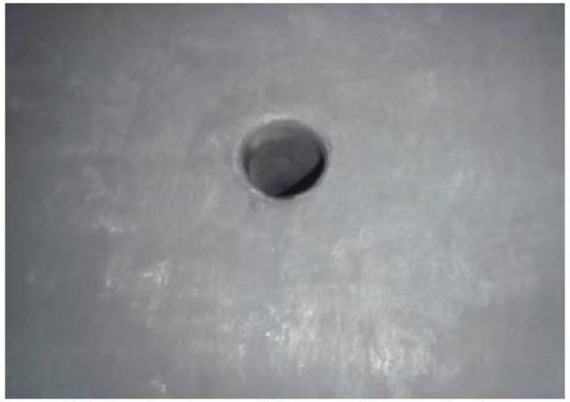


**Figure 5 Typical condition of nozzle internals**

**Figure 6 Demister pad, good order**

# V-001 Gas Separator – What damage Mechanisms are present? (Degradation Threat Assessment)

For the purposes of the RII, the consequence of failure (COF) for V-001 is High. The DTA zones the vessel into three different degradation risk areas: Gas, Oil and Water.

Corrosion is not expected in V-001 due to presence of the internal cladding of stainless steel, i.e. there are no credible threats listed in the DTA.

Corrosion resistant alloys normally do not suffer from general corrosion due to the presence of the protective passive layer, but they may be susceptible to pitting corrosion and crevice corrosion under certain circumstances such as when extraneous ions are present (e.g. chlorides).

The pitting process has been described as random, sporadic, and stochastic and the prediction of the time and location of events remains extremely difficult. It is, however, unlikely that a single isolated breakdown of the passive layer will occur and as such, if pitting were to initiate, it is likely to be relatively homogenous across the affected zone.

Chloride stress corrosion cracking (Cl-SCC) is one of the most common reasons why austenitic stainless steel pipework and vessels deteriorate. Cl-SCC initiates from sites of localised pitting or crevice corrosion. Cracking is therefore also likely to be relatively homogenous across the affected zone. The majority of reported practical instances of Cl-SCC have occurred at temperatures >60°C.

V-001 operates at temperatures up to 45°C. As can be seen in Figure 7, at this temperature, stainless steel 316L is expected to be highly tolerant to sulphide stress cracking (SSC), and Cl-SCC, in CO2/chloride environments provided oxygen and H2S are absent. If oxygen is present, pitting (and hence Cl-SCC) can occur at very low temperatures. Similarly, if H2S or elemental sulphur is present in a chloride environment, pitting can readily initiate [5].

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# V-001 Gas Separator – Primary Screening

| | Yes/No | Comment |
|---|---|---|
| **Is personnel entry possible?** | Yes | But scaffolding and internal fitment removal is required |
| **Is entry scheduled for other reasons?** | No | No, based on past inspection findings |
| **Are degradation rates very high** | No | No, due to the S/S cladding |
| **Outcome:** | Yes | Suitable for RII in upper and lower vessel |

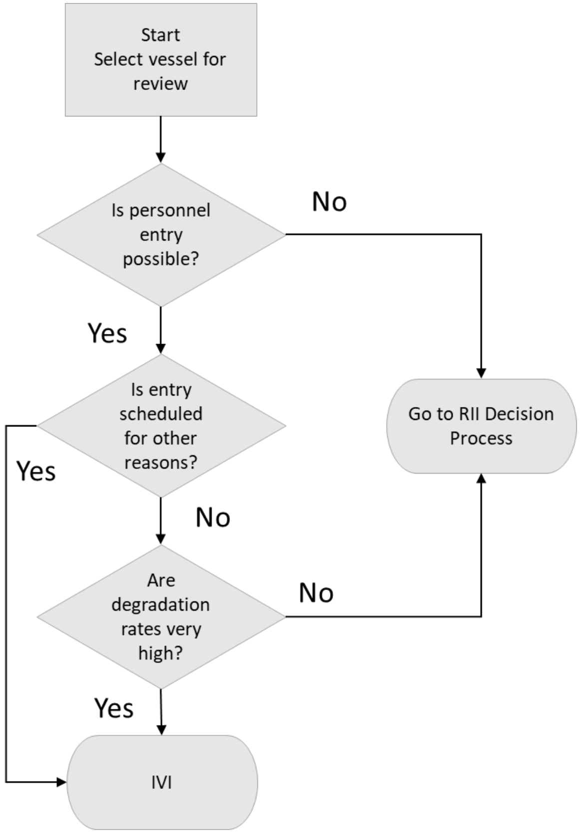
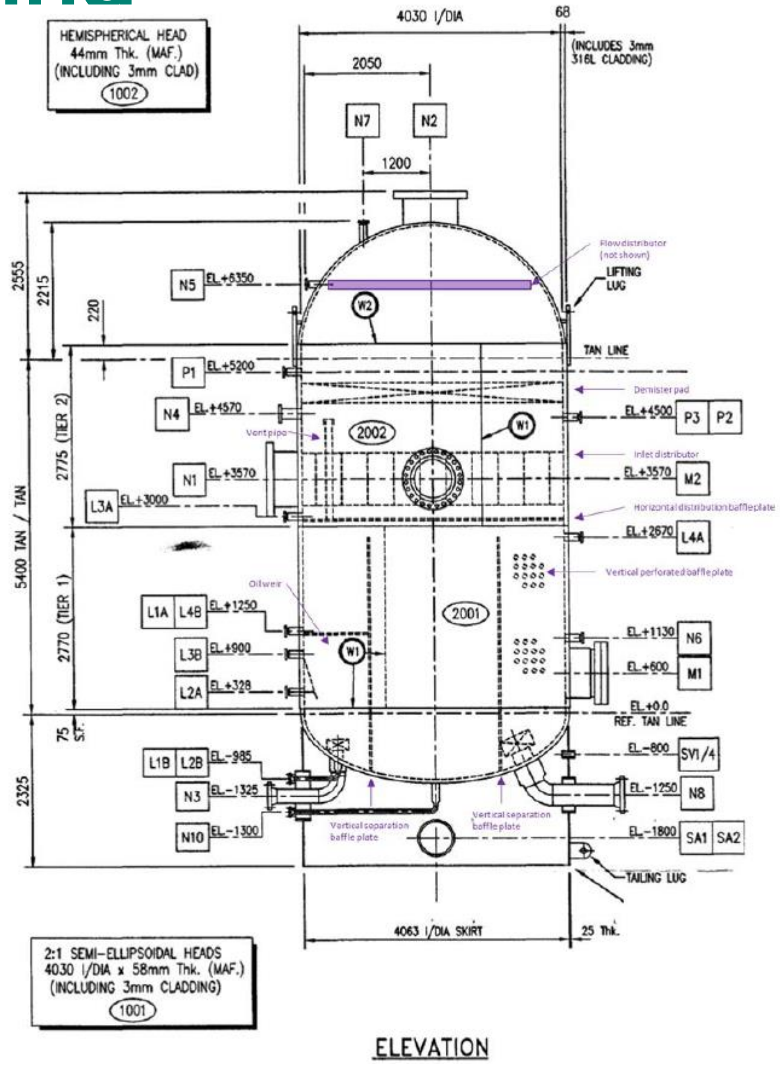



**Figure 3-1 from [1]**







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# V-001 Gas Separator – Primary Screening

| From Figure 3-3 | Yes/No | Comment |
|---|---|---|
| **Is there a need to inspect the internal furniture?** | Yes | There are elements critical to process integrity, additionally localised attachments points can fracture that would have an adverse effect on the pressure envelope. |
| **Are the degradation mechanisms well understood?** | Yes | Well understood in the details provided and align with the gas/liquid compositions provided. |
| **Does the vessel require cleaning** | No | Some remote cleaning may be required in the centre of the lower dome and can be done via M1 easily |
| **Can the vessel be adequately cleaned remotely?** | Yes | As above |
| **Are the mechanisms visually detectable only?** | Yes | Typically breakdown of the cladding will leave tell take signs of Fe staining in the localised area, additionally light reflection of cracking will be obvious |
| **Outcome:** | Yes | Suitable for RII |

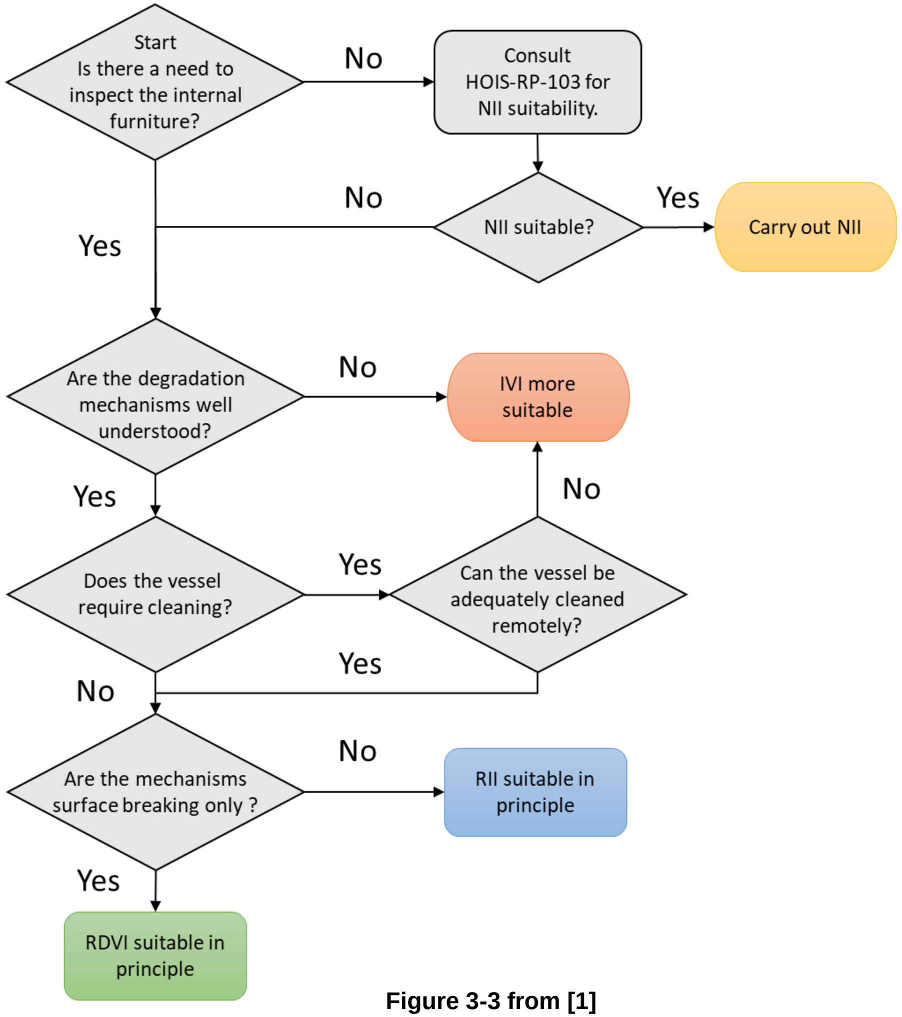


**Figure 3-3 from [1]**




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# Inspection Strategy

Based on the information gathered during the Primary Screening and the table to our left; we can determine that the inspection strategy is a Type A

| Type | Definition |
|---|---|
| A | Degradation mechanism is NOT expected to occur.<br>Inspection is required to confirm there is no onset of the degradation mechanism. |
| B | Degradation mechanism expected, with low / medium progression.<br>Location of degradation can be predicted.<br>Degradation mechanisms are wall loss only, i.e. not cracking.<br>Not anticipated to impact on vessel integrity in the medium term (typically at least 2 outage periods).<br>Inspection required to confirm DTA predictions. |
| C | Degradation expected with medium/high progression.<br>Locations of degradation cannot be predicted. (Internally lined or coated asset)<br>May impact on vessel integrity in the medium term (two-outage timeframe).<br>Inspection required to confirm absence of flaws of defined limiting sizes. |

**Table 4-1 inspection strategy type definitions**




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# Example - Access Point

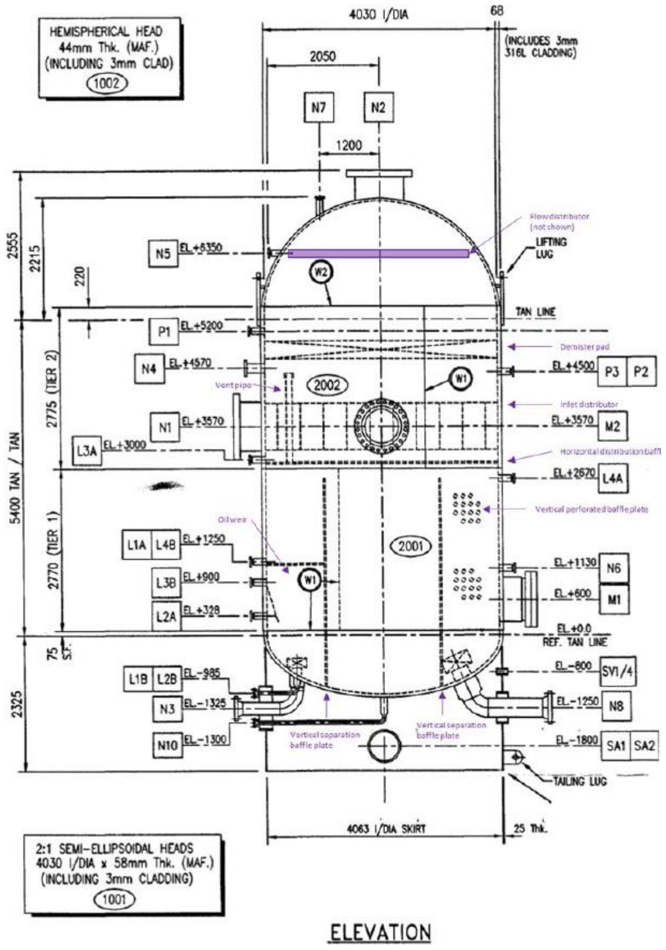
This is defined as a pressure vessel between a medium to a Large (more towards the Medium.

As we have two manways and have more than 2x 4" or greater access points we can consider our Access to be Type 1

Nozzle N7 – 150NB – only a valve & not having to do massive disconnections with N2

M2 manway – 600NB Only Nozzle that is suitable to deploy suitable inspection camera to look at the weld overlay.

M1 manway – 600NB Only Nozzle that is suitable to deploy suitable inspection camera to look at the weld overlay.




| Item | Size | Size | Type 1 | Type 2 | Type 3 |
|---|---|---|---|---|---|
| Pressure Vessel | Small | 1m x 4m | 2 x 2" access points or greater (and or manways) | 1 x 2" access points or greater | 1 x 1" access points or greater |
| | Medium | 3m x 8m | 2 x 4" access points or greater (and or manways) | 1 x 4" access points or greater | 1 x 2" access points or greater |
| | Large | 6m x 30m | 4 x 6" access points or greater (and or manways) | 3 x 6" access points or greater | 2 x 4" access points or greater |
| Exchanger Kettle | Small | 1m x 4m | 2 x 2" access points or greater (and or manways) | 1 x 2" access points or greater | 1 x 1" access points or greater |
| | Medium | 2m x 8m | 4 x 2" access points or greater (and or manways) | 2 x 2" access points or greater | 1 x 2" access points or greater |
| | Large | 5m x 30m | 6 x 2" access points or greater (and or manways) | 4 x 2" access points or greater | 1 x 1" access points or greater |
| Exchanger Shell & Tube | Small | 1m x 4m | 2 x 2" access points or greater (and or manways) | 1 x 2" access points or greater | 1 x 1" access points or greater |
| | Medium | 3m x 8m | 4 x 2" access points or greater (and or manways) | 2 x 2" access points or greater | 1 x 2" access points or greater |
| | Large | 6m x 30m | x 2" access points or greater (and or manways) | x 2" access points or greater | 2 x 2" access points or greater |
| Exchanger Fin Fan | N/A | N/A | Use Tube Plugs | N/A | N/A |

**Table A 1-1: Accessibility type based on type of vessel, size of vessel, and openings**

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# Degradation Assessment / Detectability Rating

As we know from our process analysis, engineering inputs, inspection history, we know that our degradation threats are low and that we are not expecting any form of degradation due to the construction materials chosen.

As SCC and subsequently Pitting from this mechanism is the most likely degradation assessment, we can determine that our Detectability rating is Cat 1

We are looking for the indications of pitting to assess Cl-SCC, not Cl-SCC directly.
Remember Cl-SCC has been ENGINEERED out of the vessel through material selection

| Degradation Mechanism | Definition | Cat |
|---|---|---|
| Generalised Loss of Wall Thickness | This covers corrosion or erosion where loss of wall thickness (LOWT) is uniform or varies slowly within the area under consideration. While corrosion will be visible with the human eye (e.g. rusting), the LOWT may not be obvious with visual inspection, and it may require NDT to measure the level of the loss. | Cat 2 |
| Localised Loss of Wall Thickness | This covers corrosion or erosion where the loss of wall is localised or irregular within the area under consideration. For the purposes of this recommended practice, localised loss of wall thickness is also intended to include pitting. | Cat 1 |
| Localised Cracking | This covers crack like flaws that are typically isolated and do not merge with surrounding flaws. A fatigue crack initiated in a region of stress concentration would typically be considered as localized cracking. Narrow cracking may not be obvious with visual inspection, and may be better classified as non-surface breaking, thus the morphology of the degradation must be considered. | Cat 2 |
| Generalised Cracking | This covers crack like flaws which are numerous and closely spaced in the region under consideration. Narrow cracking may not be obvious with visual inspection, and may be better classified as non-surface breaking, thus the morphology of the degradation must be considered. | Cat 3 |
| Blistering | This covers situations where the vessel material blisters showing deformation within the inner surface of the vessel (e.g. hydrogen blistering), or where the lining of the vessel delaminates from the vessel material. Small blisters may not be obvious with visual inspection. | Cat 3 |
| Mechanical Failure | This covers damage to the internals that results in the process efficiency being affected and requires repair, or damage to the vessel itself due to the physical failure of the internals (e.g. dropped objects). | Cat 1 |
| Mechanical Distortion | This covers damage to the internals or to the vessel such as when overpressure has caused the shell to bulge. | Cat 1 |
| Lining Failure | Specific to polymeric coated vessels, this covers various failures of the lining such as delamination, flaking, degradation etc. | Cat 1 |
| Porosity | This covers surface breaking holes that have formed in a weld, as trapped gas has been released during cooling. | Cat 1 |
| Incomplete welds | This covers welds that have simply not been completed (e.g. furniture is not fully attached to the vessel), or where fusion between the base metal and weld filler has not occurred properly at the weld cap. | Cat 1 |

**Table A 1-2: RDVI Detectability Rating Table (surface breaking mechanisms)**




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# Outcome - RII

| Using Figure A1-1 | Answer | Comment |
|---|---|---|
| **Accessibility Type** | 1 | Good access via M1, M2 and N7 |
| **RDVI Detectability Rating** | 1 | Typical degradation is detectable using visual methods |
| **Inspection Strategy Type** | A | |
| **Outcome:** | High | Use of RDVI as a screening tool to detect degradation is present.<br><br>Note if degradation is found further inspection and NDT may be required.<br><br>This can include external Scanning and/or NII methods |


**Figure A 1-1: RDVI practicality flowchart**




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