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STRUCTURAL INTEGRITY MONITORING OF OFFSHORE STRUCTURES USING LIQUID PENETRANT TESTING

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ABSTRACT
The offshore inspection is an integral part of the Oil and Gas industry, due to the structural failures, a huge sum of money and resources have been invested into ensuring that offshore structures are built according to procedures and specifications that will guaranty the integrity and overall reliability for the complete life of the structure which is usually between 25 – 30 years.
The complex failure pattern of offshore structure's means they will be prone to hazards; hence consistent in-service inspection techniques are required to monitor the structural integrity of these structures, and as a result, offshore inspections have developed over the past years with the introduction of Non-Destructive Examination (NDE) inspection techniques such as "LIQUID PENETRANT TESTING".

Keywords: NDE; Inspection; POD; Solvent; Penetrant; Liquid; Testing; Developers; Offshore; Integrity.

INTRODUCTION
In recent times, liquid penetrant testing which is one of the Non-Destructive Examination techniques has become very effective in detecting tiny surface discontinuities, and this method can also be used to check the integrity of our fabricated materials and the detection of defects, imperfections, pinholes, and the propagation of fatigue cracks without damaging the asset.
Since the liquid penetrant inspection is easy to implement, it gives room for the inspection of various ranges of materials for defects that may arise from fabrication errors or develop during the life of the system. [1].
Liquid penetrant testing entails little skills when compared to other NDE techniques, thus close attention must be paid to details, procedures, and the processing time should be taken into consideration with detailed information on the various forms of defects that may occur in the specimen to be tested. [2].
Liquid penetrant inspection can be used to test both metallic and non-metallic materials which include welds, forgings, castings, plastic and ceramic and it's one of the most expedient NDE techniques employed by quality control personnel.
This research paper focuses on the liquid penetrant testing techniques of NDE, for areas with large volumes and complex shapes. It can be inspected using dye liquid penetrant testing at a low cost, and the material and

associated pieces of equipment used are relatively inexpensive, and this makes the techniques preferred when compared to all other NDE techniques.

Principles of Liquid Penetrant Testing

Liquid penetrant testing principles are due to its ability to detect and determine the severity of surface defects in materials, is based upon capillary action of the liquid and the capillarity depends on cohesion, adhesion, viscosity, and surface tension. [3].

The liquid penetrant is applied on the specimen (surface) and left for some period, which is referred to as dwell time, hence penetrating voids that are open to the surface. [4].

The method used in liquid penetrant testing is tailored to expedite the capillarity and to make the results of the same visible and capable of interpretation. But a good penetrant must have the ability to penetrate voids that are opened to the surface, have good wettability, and should be removed easily from the surface after each testing [5].

Definition / Types

The liquid penetrant testing is defined as a liquid that has the capillary to penetrate defects and is regarded as one of the major techniques of the Non-Destructive Examination, and it is used to determine surface defects such as flaws, pinholes, lamination, porosity, and cracks without causing harm (damage) to the structure. [5].

The various types of liquid penetrant testing are discussed below:

Fluorescent Penetrant (Brightness Contrast)

This type of penetrant testing is done under ultraviolet light. [5].

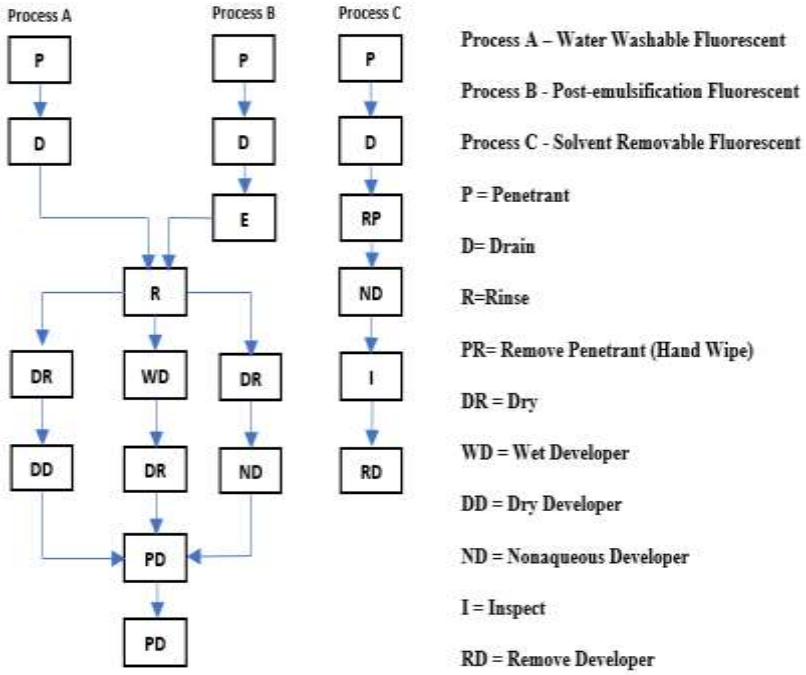

Fig. 1 Shows the fluorescent penetrant method. [5].

Visible or Dye Penetrant (Color Contrast)

Hence a good penetrant should have a high visibility medium that will act as a defect indicator and a fluid carrier that will distribute same over the surface of the material and into the depths of the defects (Mix, 2005).

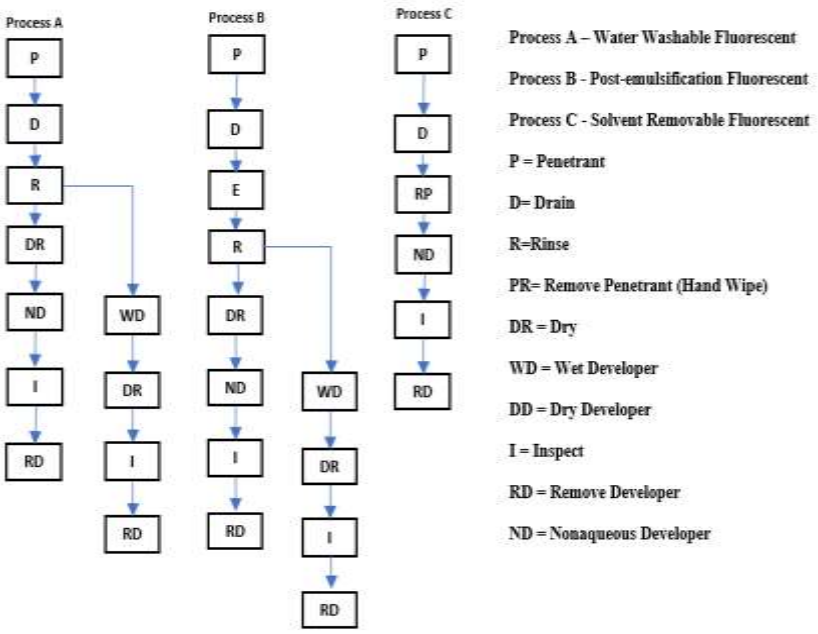

Fig. 2 Shows the visible penetrant method. [5].

Characteristics of a Good Penetrant

Below are the desirable characteristics of liquid penetrant testing and they are as follows:

•Should exhibit low toxicity.

•They should have good color contrast and fluorescence.

•Slow evaporation and slow dry.

•It should be easy to remove from the surface.

•Ability to penetrate small defects.

Test Method

Liquid penetrants are usually classified (A – D) based on the test methods used in the removal of surplus penetrant and these procedures are outlined as follows:

The Water Washable Method, the Post-Emulsifiable Lipophilic Method, the Solvent Removal Method, and the Post Emulsifiable Hydrophilic Method. [4].

•**The Water Washable Method:** As the name implies, water washable can be solely used in the removal of penetrants and it's sometimes called the self-emulsifying method.

The Post Emulsifiable Lipophilic Method: This method is an oil soluble-based process that interrelates well with the oil-based emulsifier to aid removable.

•**The Solvent Removal Method:** This method is often used for small parts or vessel welds and penetrants can be removed from the surface by solvent.

•**The Post Emulsifiable Hydrophilic Method:** This method uses a cleansing agent which lifts the surplus penetrant from the specimen (structure) with a water wash.

Benefits and Limitations of Various Test Methods

The table below shows the various benefits and limitations of using liquid penetrant testing methods according to [5].

Table 1. Benefits of Liquid Penetrant.

Benefits of Liquid Penetrant				
Variable	Water Washable Fluorescent	Post-emulsification Fluorescent	Water Emulsification Visible	Solvent Clean Visible
High Sensitivity		x	x	
High Visibility	x	x		
High Speed	x	x		
Good Retest		x		x
Portability			x	x
Intricate Parts	x			
Shallow Defects		x		
Large Parts			x	x
Contaminated Parts			x	

Table 2. Limitations of Liquid Penetrant.

Limitation of Liquid Penetrant				
Variable	Water Washable Fluorescent	Post-emulsification Fluorescent	Water Emulsification Visible	Solvent Clean Visible
Black Light Required	x	x		
Poor Retest	x			
High Staff Power			x	x
Rinsing Aid Required		x	x	
Low Speed			x	x
Poor on Shallow Defects	x		x	x
Poor on Rough Surface		x	x	x

Application of Liquid Penetrant Testing

The liquid penetrant testing authenticity amounts for its prevalent application, though the process may appear simple, a detailed procedure must be followed to achieve dependability for critical application. [5].

Liquid penetrant testing can be applied in various industries namely:

•Used for the inspection of tools and can also be applied in the inspection of pressure vessels, pumps, reactors, and tanks in the processing industries.

•Can be used in the inspection of aircraft engines, propellers, and wing fittings.

•The inspection of field rigs, pipe, and drilling equipment.

The ability of liquid penetrant to detect tiny flaws and prevent same from propagating into major cracks makes it one of the most desired techniques, these preventive measures will help mitigate against accidents happening in our facilities and as such ensure the safety of personnel on board. [1].

There are six basic steps for performing liquid penetrant testing which includes:

•Surface Preparation, Application of Penetrant, and removal of surplus penetrant, Application of developer, Inspection & Evaluation, and Surface Post Cleaning. [4].

The removal of surplus penetrant and the application of the developer are the most critical steps in the process) The various inspection stages when performing liquid penetrant testing are illustrated below.

Various Inspection Stages Explained Below:

A. Surface Preparation: The quality of our test results will be greatly affected by the standard of our surface preparation, hence proper surface preparation has become very important before commencing our inspection activities and the surface must be free from grease, oil, and any other contaminant and this will then ease the flow of the penetrant into the defects. (The surface should be dried before commencing the test). [4].

B. Application of penetrant: In this stage of the inspection, after thorough surface preparation, our penetrant is applied onto the crack by capillary force, and this flows freely into the cracks while considering temperature and maintaining the dwell time of a maximum of 30 min. [4].

C. Removal of surplus penetrant: This process will remove all the surplus penetrant from the surface, allowing the defects to retain the penetrants that have entered it. One must be mindful not to remove the penetrant completely hence the developer might not meet the penetrant whereby giving an invalid result. [4].

D. Application of the developer: After the removal of the surplus penetrant, the developer is applied and it helps to make the defect visible, when applied it creates a color that increases the visibility of the defect. [4].

E. Inspection & Evaluation: Inspection and evaluation of our result are done to ascertain the result of our test, and this will be done with good visibility condition and the interpretation will mostly be by the human eye. The acceptance and rejection will be based on the specification. [4].

F. Surface Post Cleaning: As the name implies, post-cleaning of the specimen will be done at the end of the final test. [4].

Developers

The application and removal of the developer is an essential part of our results evaluations, a well-applied developer will produce clear defects definition.

The aim is to spray a light coat of the developer to enable quick evaporation of the penetrant in the flaw and to speed the return of the penetrant to the surface.

There are various types of developers used in liquid penetrant testing, these are as follows Dry, Soluble, Suspended, and Non-Aqueous developer (preferred).

Detectability

The importance of liquid penetrant cannot be over-emphasized, it makes defects visible for inspection, and such surface cracks when it's repaired will prevent catastrophic failures and reduce costly shut down of our facilities. (Saipem, 2012)

•Liquid penetrant testing can detect defects with tinny openings at the surface.

•It equally can detect defects on smooth surfaces than rough defect surfaces

Note: Liquid penetrant can detect ranges of defects.

Probability of Detection (POD)

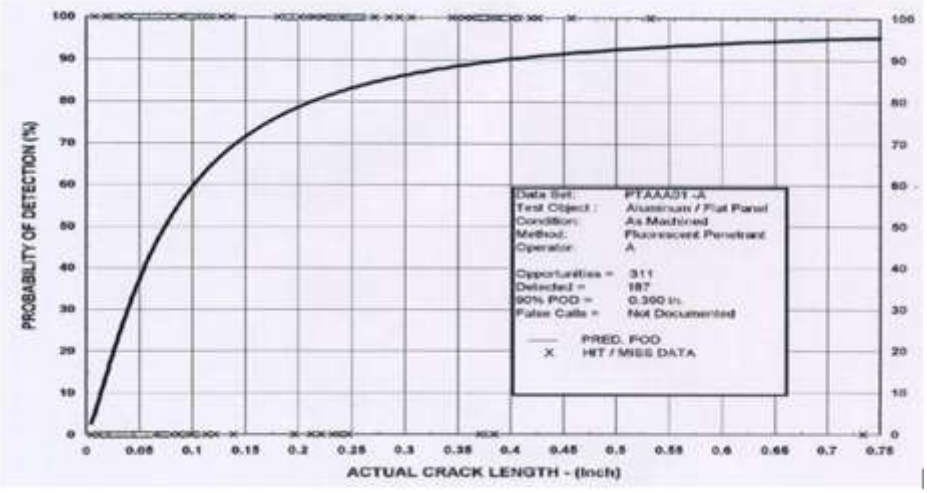

Fig. 3. Probability of Detection Curve

Typical POD curve – shows 90% POD = 0.39 in for specific test and POD also depends on the width of flaws, which must be wide enough to bleed dye into developer to be seen and end of crack may show more clearly than center- capillary pumping" [7].

Benefits and Limitation of Liquid Penetrant Testing

Benefits of Liquid Penetrant Testing

- Suitable for a wide range of sizes and shapes of test specimens that are not easily accessed.
- Indications can reveal the relative size, shape, and depth of the flaw.
- Best for the detection of surface-breaking cracks.
- Easy inspection of parts with complex shapes
- The equipment is user-friendly hence simple in terms of procedure and interpretation.
- Very sensitive to minor flaws.
- Does not require a power source.

Limitation of Liquid Penetrant Testing

- Restricted to surface-breaking defects alone.
- Uses a significant number of consumables.
- Environmental and safety concerns.
- Examiner must have direct access to the surface being examined
- Removal of the coating before commencing the test.
- False indication from sharp corners and scratches
- Post cleaning required.
- Flaws must be open to the surface

Procedure Used in the Offshore Industry

The procedure (process) used in the industry is outlined below:

Pre – Cleaning: Cleaning of the surface is very important, to remove all contaminants and it's aimed at making defects visible to the surface. (The use of acid etching is still in practice)

Application of Penetrant: The penetrant is then applied and left for between 5 to 30 min.

Removal of Excess Penetrant: The removal of surplus penetrant is done (water washable)

Application of Developer: After the removal of surplus penetrant, a developer is applied to the surface.

Final Inspection: The certified inspector will perform the final inspection.
Post Cleaning: Post cleaning is usually done, and the defects are recorded.

Duration of Inspection

The intervals for inspection (liquid penetrant testing) vary, the inspection is done to determine the integrity of our structures, to avoid catastrophic failures and damage in our facilities.
The interval for our inspections is as follows:
Older structures are inspected between 4 – 6 months while newer structures are inspected between 2-3 years. [6].
Note: Qualified Personnel: In an industry-based application, only qualified personnel who is certified as level II dye penetrant by document SNT-TC-1A of ASNT can perform and evaluate the results.
Reference Document: The reference documents used are as follows.
•API 1104 – Standard for welding of pipeline and related facilities
•ASME-V Art. SE 165 – Boiler and pressure vessel code – NDE: Standard Practice for liquid penetrant inspection method.
•ASNT SNT TC 1A – Recommended practice for NDT personnel, Qualification, and certification.

Industry Precaution

•Thorough cleaning is necessary to guarantee the absence of contaminants
•Compatibility of test materials before performing test is required.

Why Liquid Penetrant Testing is Needed

•Despite its limitation as explained above, liquid penetrant testing when compared to other NDE techniques it's still the most preferred in terms of topside inspection.
•Liquid penetrant testing is essential because it's cost-effective and very versatile, it can detect defects at the surface level before propagation will occur.
•The importance of liquid penetrant testing cannot be over-emphasized, it makes defects visible for inspection, and such surface cracks when it's repaired will prevent catastrophic failures and reduce costly shut down of our facilities.
•For areas with large volume, parts, and complex shapes this can be inspected using dye liquid penetrant testing at a low cost, and the material and associated equipment used are relatively inexpensive this makes the techniques preferred in terms of cost when compared to all other NDE techniques.
•The usage of aerosol spray cans makes the application of liquid penetrant more convenient and makes it possible to perform liquid penetrant testing inside the pressure vessel, boilers, down into pits, and into very tight places.
•The ability of liquid penetrant to detect tiny flaws and prevent same from propagating into major cracks makes it one of the desirous techniques, these preventive measures will mitigate against accidents happening in our facilities and as such ensure the safety of personnel on board.

CONCLUSION

This research on liquid penetrant testing exposed the in-depth knowledge of the procedures, inspection stages, and application of liquid penetrant testing in the offshore industry.

The liquid penetrant testing technique is one of the viable NDE methods employed for surface cracking detection and is cost-effective when compared to all other NDE techniques and therefore is the technique of choice for topside inspection.

When compared to other NDE techniques, liquid penetrant testing is a valuable tool during the construction phase and in-service inspection, thus for low-cost examination.

Conclusively, this research has shown that liquid penetrant testing is still one of the major and trusted NDE techniques and it is a very useful tool when it comes to surface crack detection.

REFERENCES

1) Shull, P. J., 2002. Non-Destructive Evaluation: Theory Techniques and Application. New York: Marcel Dekker.
2) Obot, E. I., 2013. OFFSHORE INSPECTION TECHNIQUES. Cranfield University, School of Applied Sciences United Kingdom: Unpublished MSc Thesis.
3) Beril, T. A., 1997. Capillarity effect analysis for alternative liquid penetrant chemicals. NDT & E International, 30(1), pp. 19-23.
4) Raj, B., Jayakumar, T. & Thavasimuthu, M., 2007. Practical Non-Destructive Testing. Third ed. Oxford: Alpha Science International Ltd.
5) Mix, P. E., 2005. Introduction to Nondestructive Testing. Second Edition New Jersey: John Wiley & Sons, Inc.
6) Saipem, N., 2012. Training Manual on Penetrant Testing. Port Harcourt: Unpublished Training Manual.
7) Yapp, D., 2014. Introduction to NDE Techniques Lecture Note. Cranfield University, School of Energy United Kingdom: Unpublished Lecture Note.