Liquid Penetrant Test [7]

- **Introduction to Nondestructive Testing (NDT)**

The use of noninvasive techniques to determine the integrity of a material, component or structure

or

quantitatively measure some characteristic of an object or part without damaging it.

Methods of NDT

Visual

Thermography

Microwave

Magnetic Particle

Tap Testing

Acoustic Microscopy

X-ray

Acoustic Emission

Magnetic Measurements

Liquid Penetrant

Ultrasonic

Replication

Laser Interferometry

Eddy Current

Flux Leakage

Six Most Common NDT Methods

- **Visual**
- **Liquid Penetrant**
- **Magnetic**
- **Ultrasonic**
- **Eddy Current**
- **X-Ray**

Visual Inspection

Most basic and common inspection method.

Tools include fiberscopes, borescopes, magnifying glasses and mirrors.

Portable video inspection unit with zoom allows inspection of large tanks and vessels, railroad tank cars, sewer lines.

Robotic crawlers permit observation in hazardous or tight areas, such as air ducts, reactors, pipelines.

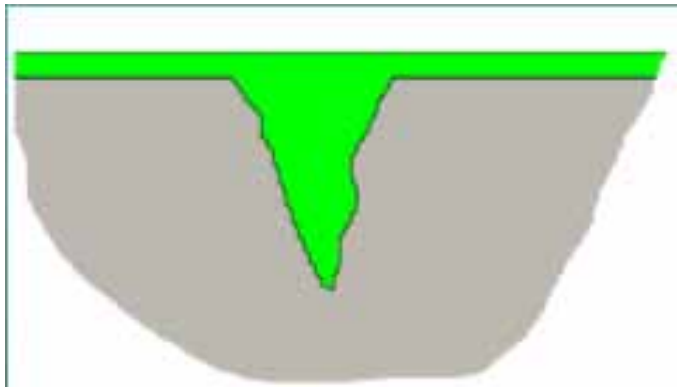
Liquid Penetrant Testing (LPT)

- **In penetrant testing, a liquid with high surface wetting characteristics is applied to the surface of a component under test.**
- **The liquid “penetrates” into surface breaking discontinuities via capillary action and other mechanisms.**
- **Excess penetrant is removed from the surface and a developer is applied to pull trapped penetrant back the surface.**
- **With good inspection technique, visual indications of any discontinuities present become apparent.**

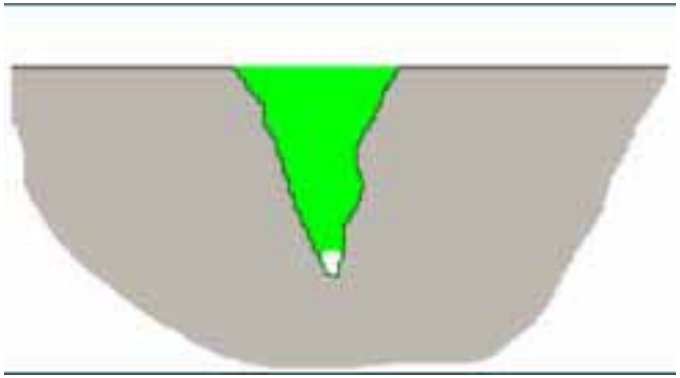
Basic Process of LPT

1) Clean & Dry Component

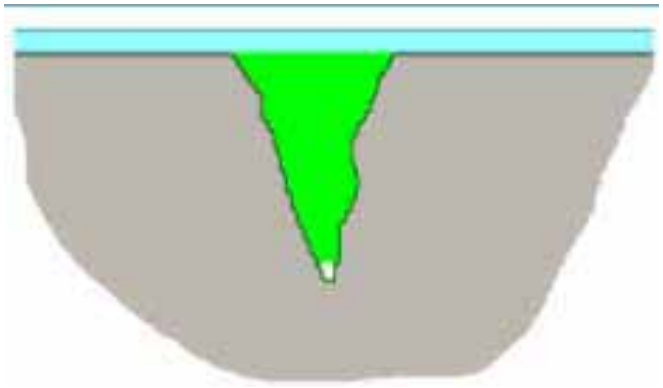
2) Apply Penetrant



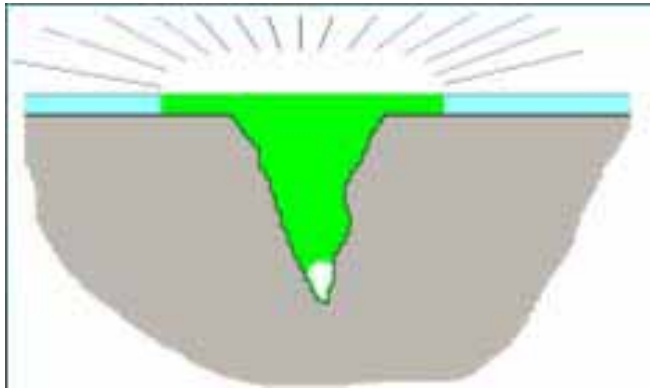
3) Remove Excess



4) Apply Developer



5) Visual Inspection



6) Post Clean Component

What Can Be Inspected by LPT?

Almost any material that has a relatively smooth, non-porous surface on which discontinuities or defects are suspected.

What Can NOT be Inspected by LPT?

- Components with rough surfaces, such as sand castings, that trap and hold penetrant.
- Porous ceramics
- Wood and other fibrous materials.
- Plastic parts that absorb or react with the penetrant materials.
- Components with coatings that prevent penetrants from entering defects.

- **Defect indications become less distinguishable as the background “noise” level increases.**

Penetrant Materials

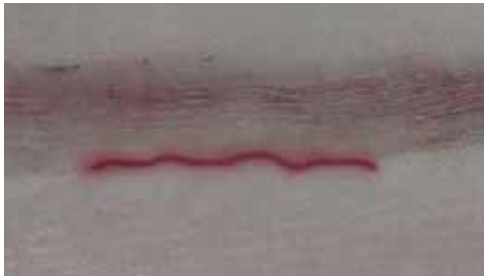
Penetrants are formulated to possess a number of important characteristics. To perform well, a penetrant must:

- **Spread easily over the surface being inspected.**
- **Be drawn into surface breaking defects by capillary action or other mechanisms.**
- **Remain in the defect but remove easily from the surface of the part.**
- **Remain fluid through the drying and developing steps so it can be drawn back to the surface.**
- **Be highly visible or fluoresce brightly to produce easy to see indications.**
- **Not be harmful to the inspector or to the material being tested.**

Penetrant Removal Method

- **Penetrants are also classified by the method of removing the excess penetrant.**
  - **Solvent Removable** penetrants are removed by wiping with a cloth dampened with solvent. They are supplied in aerosol cans for portability and are primarily used for spot checks.
  - **Water Washable** penetrants are removed with a course spray of water. They are the easiest to employ and most cost effective when inspecting large areas.
  - **Post-Emulsifiable** penetrants are water-washable only after they have reacted with an emulsifier solution. A post-emulsifiable system is used when washing the penetrant out of the defect is a concern. The emulsifier is given time to reacts with the penetrant on the surface but not the penetrant trapped in the flaw.

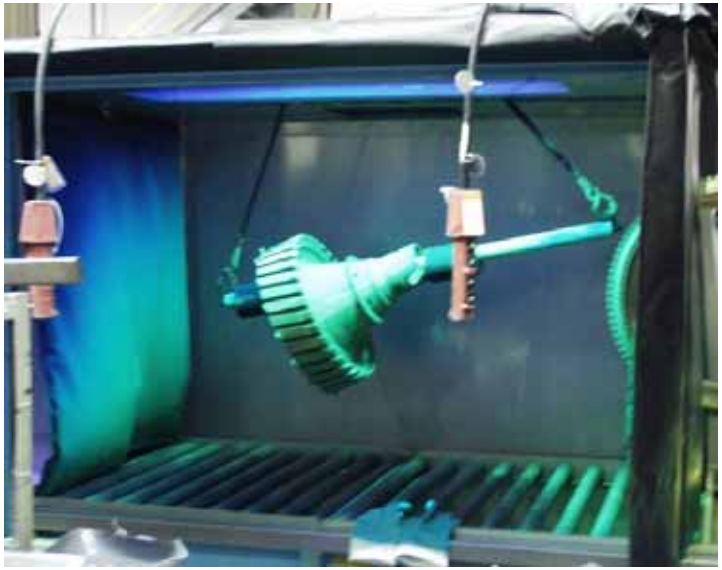
Developers



- **The role of the developer is to pull trapped penetrant out of defects and to spread it out on the surface so that it can be seen. Also provides a light background to increase contrast when visible penetrant is used.**
- **Developer materials are available in several different forms**
  - **Dry Powder** is a mix of light fluffy powder that clumps together where penetrant bleeds back to the surface to produces very defined indications.
  - **Wet, Water Suspendable** is a powder that is suspended in a water that covers the surface with a relatively uniform layer of developer when the water is evaporated. The solution is somewhat difficult to maintain as the powder settles out over time.
  - **Wet, Water Soluble** is a crystalline powder that forms a clear solution when mixed with water. The solution recrystallizes on the surface when the water is driven off. Indications sometimes lack definition and look milky. Not recommended for use with water-washable penetrants.
  - **Wet, Non-Aqueous** - is supplied in a spray can and is the most sensitive developer for inspecting small areas. It is too costly and difficult to apply to large areas.

6 Steps of Liquid Penetrant Testing

1. **Pre-Clean**
2. **Penetrant Application**
3. **Excess Penetrant Removal**
4. **Developer Application**
5. **Inspect/Evaluate**
6. **Post-clean**



Pre-cleaning – Step 1

- **Parts must be free of dirt, rust, scale, oil, grease, etc. to perform a reliable inspection.**
- **The cleaning process must remove contaminants from the surfaces of the part and defects, and must not plug any of the defects.**

- **Pre-cleaning is the most important step in the LPT process!!!**

Penetrant Application – Step 2

Many methods of application are possible such as:

- **Brushing**
- **Spraying**
- **Dipping/ Immersing**
- **Flow-on**
- **And more**

Dwell Time

- **The penetrant solution must be allowed to “dwell” on the surface of the part to allow the penetrant time to fill any defects present.**
- **The dwell time vary according to penetrant type, temperature, material type and surface finish.**

Excess Penetrant Removal – Step 3

The removal technique depends upon the type of penetrant used, as stated earlier…

- **Solvent Removable**
- **Water Washable**
- **Post Emulsifiable**

Developer Application – Step 4

The method of developer application is is dependent on the type of developer used. The primary methods for the following main developer types will be covered in the following slides.

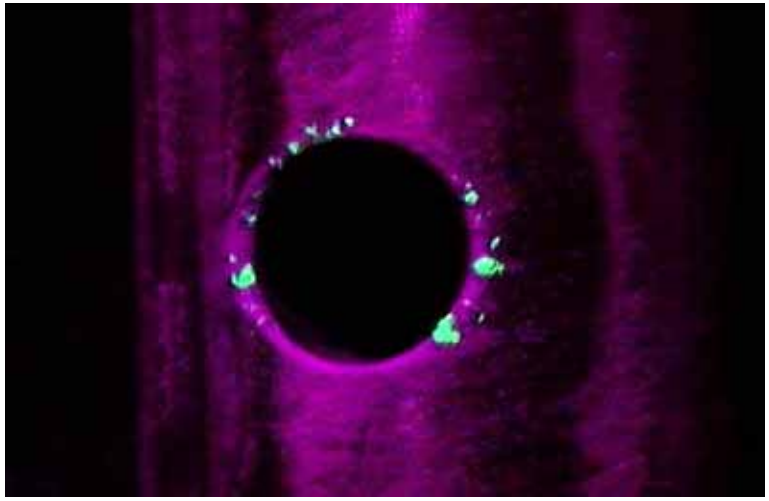
- **Dry**
- **Wet**
- **Nonaqueous Wet**

Inspection/Evaluation – Step 5

In this step the inspector evaluates the penetrant indications against specified accept/reject criteria and attempts to determine the origin of the indication.

The indications are judged to be either relevant, non-relevant or false.

Non-relevant weld geometry indications



Relevant crack indications from an abusive drilling process

Post Clean – Step 6

- **The final step in the penetrant inspection process is to thoroughly clean the part that has been tested to remove all penetrant processing materials.**
- **The residual materials could possibly affect the performance of the part or affect its visual appeal.**

Advantages of Liquid Penetrant Testing

- **Relative ease of use.**
- **Can be used on a wide range of material types.**
- **Large areas or large volumes of parts/materials can be inspected rapidly and at low cost.**
- **Parts with complex geometries are routinely inspected.**
- **Indications are produced directly on surface of the part providing a visual image of the discontinuity.**
- **Initial equipment investment is low.**
- **Aerosol spray cans can make equipment very portable.**

Limitations of Liquid Penetrant Testing

- **Only detects surface breaking defects.**
- **Requires relatively smooth nonporous material.**
- **Pre-cleaning is critical. Contaminants can mask defects.**
- **Requires multiple operations under controlled conditions.**
- **Chemical handling precautions necessary (toxicity, fire, waste).**
- **Metal smearing from machining, grinding and other operations inhibits detection. Materials may need to be etched prior to inspection.**
- **Post cleaning is necessary to remove chemicals.**

Standards relating to Liquid Penetrant Testing

- **American Society for Testing and Materials (ASTM):**

- **ASTM E165 - Standard Test Method for Liquid Penetrant Examination (2012).**
- **ASTM E433 - Standard Reference Photographs for Liquid Penetrant Inspection (2013).**
- **ASTM E1417 - Standard Practice for Liquid Penetrant Examination (2013).**
- **ASTM E1316 - Standard Terminology for Nondestructive Examinations (2016).**

Dye Penetrant Inspection Video

https://www.youtube.com/watch?v=xEK-c1pkTUI

References

- https://en.wikipedia.org/wiki/Dye_penetrant_inspection
- NDT Resource Center. https://www.nde-ed.org/index_flash.htm
- The American Society for Nondestructive Testing. www.asnt.org
- ASTM International. ASTM E165 - Standard Test Method for Liquid Penetrant Examination. West Conshohocken, 2012. (DOI: 10.1520/E0165_E0165M-12)
- ASTM International. ASTM E433 - Standard Reference Photographs for Liquid Penetrant Inspection. West Conshohocken, 2013. (DOI: 10.1520/E0433)
- ASTM International. ASTM E1417 - Standard Practice for Liquid Penetrant Examination. West Conshohocken, 2013. (DOI: 10.1520/E1417_E1417M)
- ASTM International. ASTM E1316 - Standard Terminology for Nondestructive Examinations . West Conshohocken, 2016. (DOI: 10.1520/E1316-16)
- ASM International. ASM Handbook, Volume 17: Nondestructive Evaluation and Quality Control. ASM, 9th edition, 795p., 1989. (ISBN: 978-0-87170-023-0)