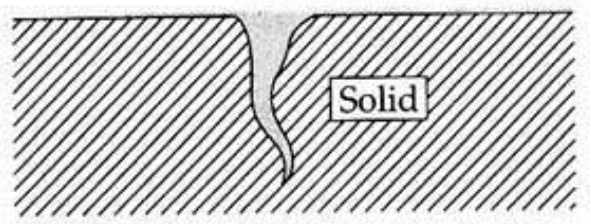
Non-Destructive Testing

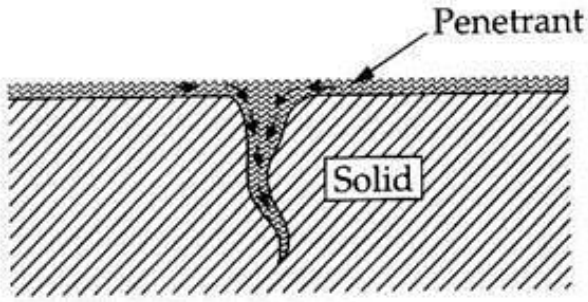
Module II

Asst. Prof. Vishnu Sankar
Department of Mechanical Engineering
Rajagiri School of Engineering & Technology (RSET)

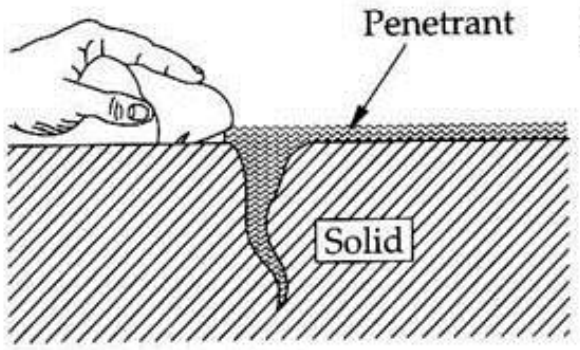
Liquid Penetrant Inspection (LPI)



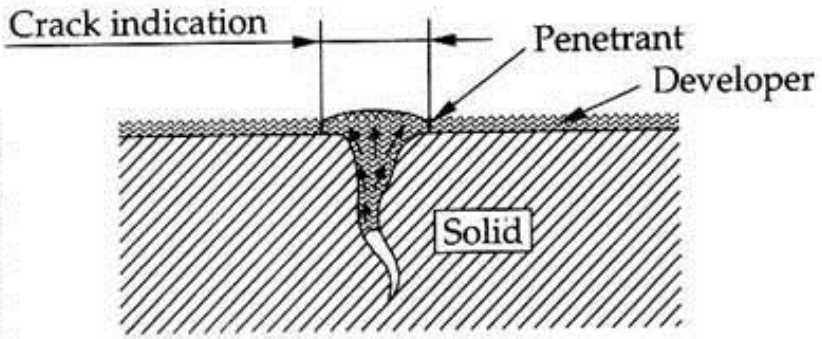
(a) Cleaning and drying of test surface



(b) Application of penetrant to test surface



(c) Removal of penetrant from test surface



(d) Application of developer

LPI – physical principles

- Depends on the ability of liquid to wet and flow over a surface and to penetrate in to cavities.
- Ability of a liquid to flow over a surface and enter cavities depends on surface tension and capillarity.
- The cohesive force between molecules of a liquid causes surface tension.
- Capillarity is the rise or depression of liquid in narrow cavities.

- Viscosity, affects the flowing ability of liquid.
- Highly viscous fluids are unsuitable as penetrants
- They don’t flow rapidly, and they require more time for penetration in to fine flaws.
- Visible light or UV light

Procedure for Penetrant testing (Steps of Liquid Penetrant Testing)

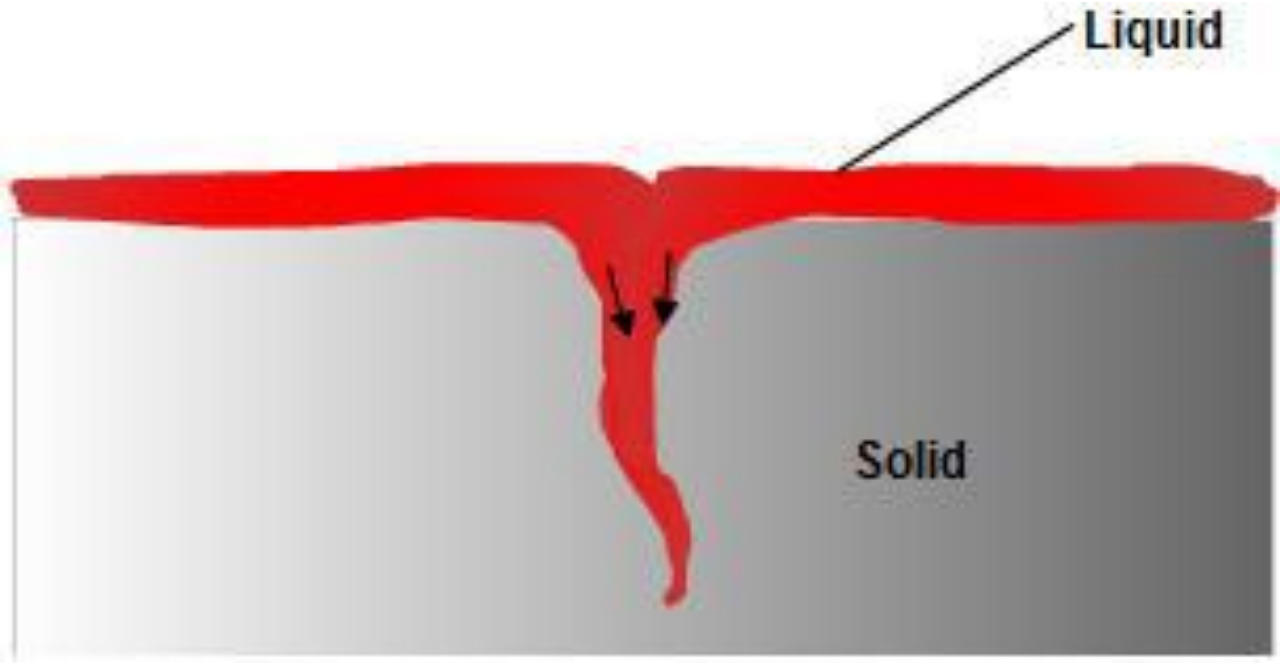
- The exact procedure for liquid penetrant testing can vary from case to case.
- Depends on several factors.
- The penetrant system being used.
- The size and material of the component being inspected.
- The type of discontinuities being expected in the component.
- The condition and environment under which the inspection is performed.

Procedure

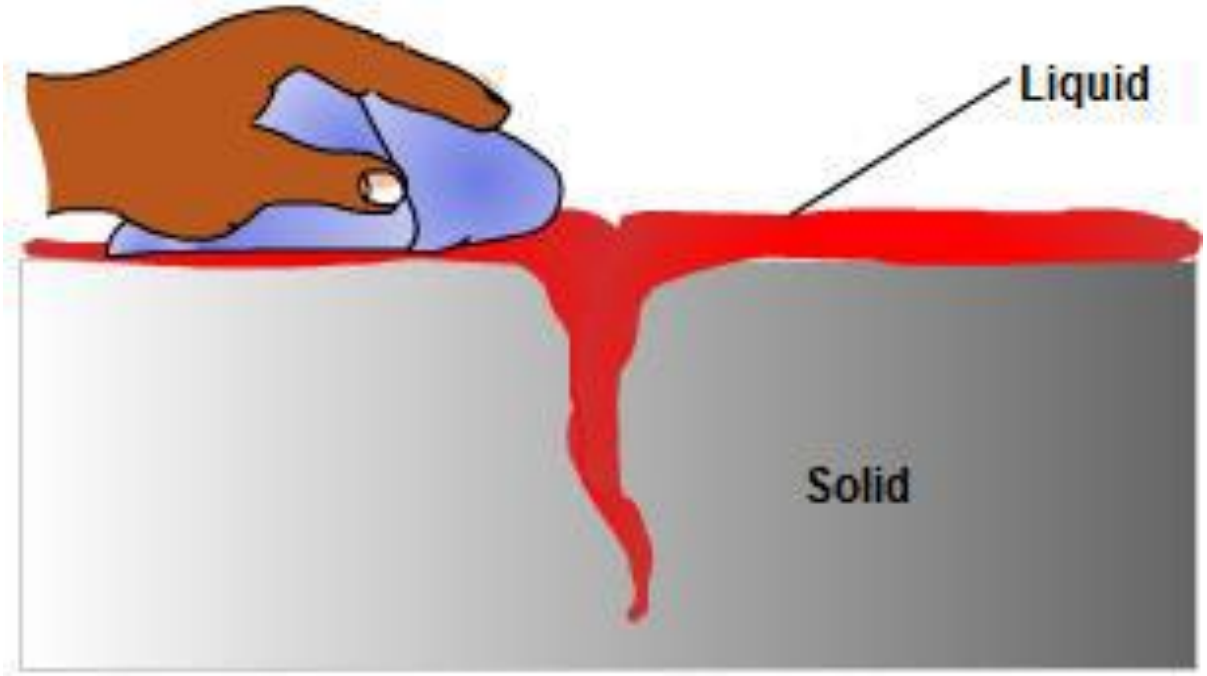
- 1) Cleaning
- One of the most important steps
- The defect must be open to the surface for the penetrant to enter.
- Scale, flakes, paint, dirt, grease etc
- Tend to accumulate the penetrant.
- Leads to either masking of real indications or creation of false indication.
- Solvents, brushes, rags, etchants, etc
- The cleaned surface should be properly dried before applying penetrant.

- 2) Penetrant application
- Spraying, brushing, or immersing the part in a penetrant bath.
- The fluid should spread freely and evenly over the surface and move in to the crack.

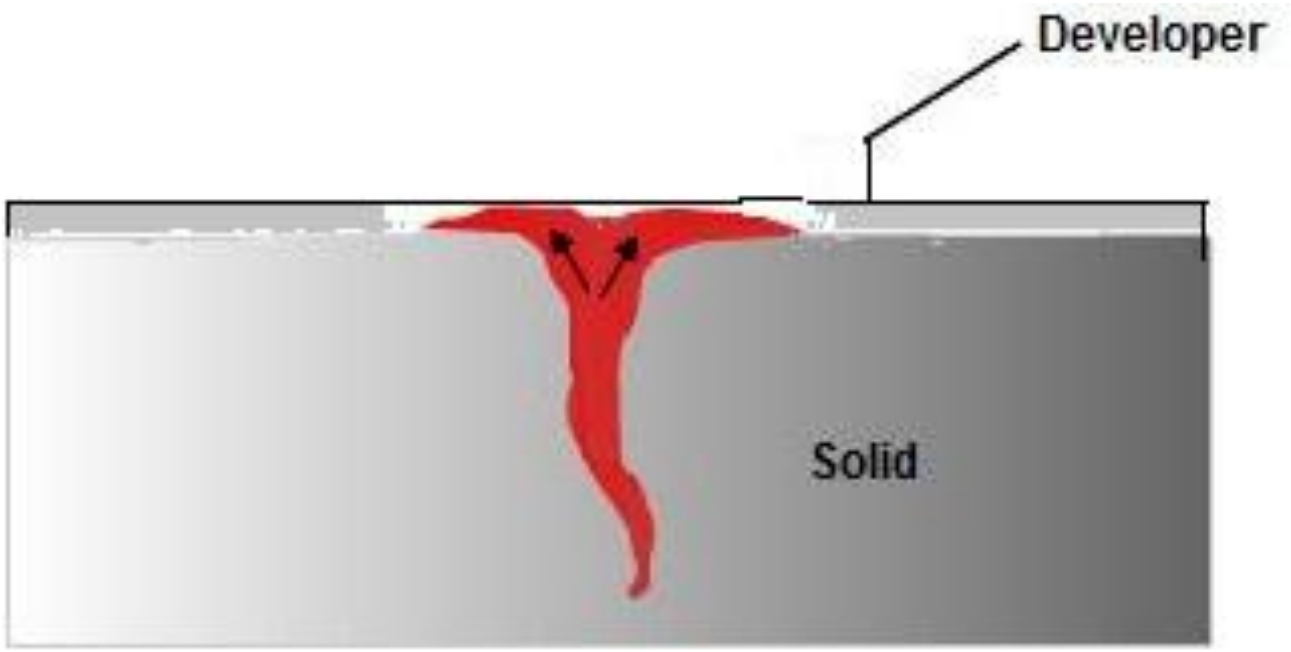
- 3) Penetrant Dwell - total time that the penetrant is in contact with the part surface.
- The penetrant is left on the surface for a sufficient time.
- Allow as much penetrant as possible to be drawn into a defect.
- Dwell time depends on crack size and shape characteristics and also environmental conditions.
- 20 to 30 minutes
- No harm in using a longer penetrant dwell time as long as the penetrant is not allowed to dry.


Liquid
Solid

- 4) Removal of excess Penetrant
- This is the most delicate part of the inspection
- Excess penetrant must be removed from the surface while removing as little penetrant as possible from defects.
- Excess cleaning may remove the penetrant from the upper region of the defect
- Developer doesn’t reach the penetrant and no defect is indicated.
- Insufficient cleaning will leave a background of penetrant on the surface.
- Affects contrast.


Liquid
Solid

- 5) Application of developer
- A thin layer of developer is applied to the sample to draw penetrant trapped in flaws back to the surface where it will be visible.
- Another important function of the developer is, it provides good visual contrast.
- Developers come in a variety of forms that may be applied by dusting (*dry powders),* dipping, or spraying *(wet developers).*


Developer
Solid

- 6) *Indication Development: The developer* is allowed to stand on the part surface for a period of time.
- To permit the extraction of the trapped penetrant out of any surface flaws.
- This development time is usually a minimum of 10 minutes.
- Significantly longer times may be necessary for tight cracks.

- 7) Inspection and Evaluation
- The last step is scanning of the surface for indications.
- the scanning may be carried out under visible light conditions or with UV or laser incident light.
- The defect recognition may be made with human eye or with automated optical scanners.
- After inspection, acceptance or rejection of the component is made based on the applicable specifications and standards

Advantages of penetrant test

- High sensitivity (small discontinuities can be detected).
- Few material limitations.
- Portable to use.
- Easy to inspect large areas and volumes.
- Low cost.
- Complex parts can be inspected.
- Proper visualization is provided.
- Further examination of indication may be done.

Limitations of penetrant test

- Defects must be open to the surface.
- Only materials with a relatively nonporous surface can be inspected.
- Pre-cleaning is critical since contaminants can mask defects.
- The inspector must have direct access to the surface being inspected.
- Surface finish and roughness can affect inspection sensitivity.
- Multiple operations in a controlled mode is required.
- Post cleaning of acceptable parts or materials is required.
- Proper chemical handling and its disposal is required.

Characteristics of good penetrant

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

Types of penetrants

- Penetrant materials come in two basic types:
- Type 1 - **Fluorescent Penetrants**: they contain a dye or several dyes that fluoresce when exposed to ultraviolet radiation.
- Type 2 - **Visible Penetrants**: they contain a red dye that provides high contrast against the white developer background.

Comparison of Flourescent and Visible penetrants

Flourescent Penetrants

- Consists of dyes that flouresce when exposed to UV radiations.
- More sensitive.
- Requires darkened area and UV radiations
- More vulnerable to contamination

Visible penetrants

- Consists of red dye, which gives fine contrast against white developer background.
- Less sensitive.
- Doesn’t require dark area or UV radiations
- Less vulnerable to contamination

Cleaners and Emulsifiers

- A cleaning fluid must act as a solvent for the material to be removed.
- For water based penetrants, a simple water wash or rinse is suitable.
- For petroleum based penetrants, there are two methods
- The most direct approach is to use an oil or chlorine based solvent.
- Another method is to use an emulsifier
- It reacts with the oil based penetrant to form a water-soluble substance.
- Two types of Emulsifiers: Lipophilic and Hydrophilic.

- Penetrants are then classified by the method used to remove the excess penetrant from the part. The four methods are:
- Method A - Water Washable
- Method B - Post-Emulsifiable, Lipophilic
- Method C - Solvent Removable
- Method D - Post-Emulsifiable, Hydrophilic

Method A - Water Washable

- Penetrants can be removed from the part by rinsing with water alone.
- These penetrants contain an emulsifying agent (detergent).
- This makes it possible to wash the penetrant from the part surface with water alone.
- Sometimes referred to as self-emulsifying systems.

Advantages of method A

- High sensitivity
- Less cost
- Large surface discontinuities can be visualized.
- Easy removal of penetrant.

Limitations of method A

- Dark environment is required
- Insensitive to shallow discontinuities
- Quality of penetrant is degraded by contamination

Method B- *Post-Emulsifiable, Lipophilic*

- The penetrant is oil soluble and interacts with the **oil-based emulsifier** to make removal possible.
- Lipophilic emulsifiers diffuse in to the penetrant, breaking down the structure so that the penetrant may be rinsed away with water

Method C - Solvent Removable

- They require the use of a solvent to remove the penetrant from the part.

Method D - Post-Emulsifiable, Hydrophilic

- Hydrophilic Emulsifiers are composed of materials similar to common detergents.
- It lifts the excess penetrant from the surface of the part with a water wash.

Classification of penetrants based on sensitivity of indication produced by flaws

- Based on the strength or detectability of the indication that is produced for a number of very small cracks.
- The five sensitivity levels are:

1. Level ½ - Ultra Low Sensitivity
2. Level 1 - Low Sensitivity
3. Level 2 - Medium Sensitivity
4. Level 3 - High Sensitivity
5. Level 4 - Ultra-High Sensitivity

- The procedure for classifying penetrants into one of the five sensitivity levels uses specimens with small surface fatigue cracks.
- The brightness of the indication produced is measured using a photometer.

Developers

- The role - pull the trapped penetrant material out of defects and spread it out on the surface of the part so it can be seen by an inspector.
- Developers used with visible penetrants create a white background
- So there is a greater degree of contrast.
- Developers used with fluorescent penetrants both reflect and refract the incident ultraviolet light,
- allowing more of it to interact with the penetrant, causing more efficient fluorescence.

Classification

- Developers are classified based on the method that the developer is applied:
- The six standard forms of developers are:
- ***Form A - Dry Powder***
- ***Form B - Water Soluble***
- ***Form C- Water Suspendable***
- ***Form D - Nonaqueous Type 1: Fluorescent (Solvent Based)***
- ***Form E - Nonaqueous Type 2: Visible Dye (Solvent Based)***
- ***Form F - Special Applications***

Dry Powder

- Dry powder developers are generally considered to be the least sensitive.
- but they are inexpensive to use and easy to apply.
- Dry developers are white, fluffy powders
- can be applied to a thoroughly dry surface in a number of ways.

a. by dipping parts in a container of developer
b. By using electrostatic powder spray guns
c. by using a puffer to dust parts with the developer powder
d. placing parts in a dust cabinet where the developer is blown around

Advantages and Limitations

- Advantages

a. Inexpensive

b. Easy to apply

- Limitations

a. Less sensitive to indications

b. Powder is only stuck to the area where penetrant is present

Water soluble

- Consist of a group of chemicals that are dissolved in water,
- and form a developer layer when the water is evaporated away.
- The best method for applying water soluble developers is by spraying it on the part.
- Dipping, pouring, or brushing the solution on to the surface is sometimes used but these methods are less desirable.
- Drying is achieved by placing the part in a warm air dryer with the temperature 21°C .
- Properly developed parts will have an even, pale white coating over the entire surface.

Water Suspendable

- Consist of insoluble developer particles suspended in water.
- They require frequent stirring or agitation to keep the particles from settling out of suspension.
- They are applied to parts in the same manner as water soluble developers.
- Then the parts are dried using warm air.

Nonaqueous

- Nonaqueous developers suspend the developer in a volatile solvent,
- and are typically applied with a spray gun.
- These are commonly distributed in aerosol spray cans for portability.
- The solvent tends to pull penetrant from the indications by solvent action.
- Since the solvent is highly volatile, forced drying is not required.

Special Applications

- Plastic or lacquer (a liquid made of shellac dissolved in alcohol) developers are special developers
- Primarily used when a permanent record of the inspection is required.

Advantages and disadvantages of the various developer types.

Developer	Advantages	Disadvantages
Dry	Indications tend to remain brighter and more distinct over time	Does not form contrast background so cannot be used with visible systems
	Easily to apply	Difficult to assure entire part surface has been coated

Advantages and disadvantages of the various developer types.

Soluble	Ease of coating entire part White coating for good contrast can be produced which work well for both visible and fluorescent systems	Coating is translucent and provides poor contrast (*not recommended for visual systems*) Indications for water washable systems are dim and blurred

Advantages and disadvantages of the various developer types.

Suspendable	Ease of coating entire part Indications are bright and sharp White coating for good contrast can be produced which work well for both visible and fluorescent systems	Indications weaken and become diffused after time

Advantages and disadvantages of the various developer types.

Nonaqueous	Very portable Easy to apply to readily accessible surfaces White coating for good contrast can be produced which work well for both visible and fluorescent systems Indications show-up rapidly and are well defined Provides highest sensitivity	Difficult to apply evenly to all surfaces More difficult to clean part after inspection

General characteristics of a good Developer

- High absorption to secure max blotting action.
- Easily spread to expose the defect.
- Provide a contrast background.
- Easily, evenly and readily applied.
- Form a thin uniform coating over the surface.
- Easily wet to allow penetrant to spread over the area.
- Non flourescent when used with flourescent penetrant.
- Easily removed after inspection.
- Inert to materials being inspected.
- Non toxic.
- Inexpensive.

Interpretation and Evaluation of indications

- Mechanical discontinuities at the surface will be indicated by bleeding out of the penetrant.
- However, localized surface imperfections, may produce similar indications which are non-relevant to the detection of unacceptable discontinuities.
- Any indication which is believed to be non-relevant must be regarded as a defect and will be further examined.

- Visual examination or another examination method may be used for verification of non-relevant indications.
- Surface conditioning may precede the reexamination.
- Inadequate cleaning may leave an excessive background, making interpretation difficult.
- When using color-contrast penetrants, indications with a light pink color may indicate excessive cleaning.

- Linear indications are indications in which the length is more than three times the width.
- Round indications are indications which are circular or elliptical with length less than three times the width.
- An indication of a defect may be larger than the defect that caused it;
- however, the size of the indication and not the size of the defect is the basis of acceptance or rejection.
- All indications will be evaluated in terms of the appropriate acceptance standards

Health and Safety Precautions in LPI

- When proper health and safety precautions are followed, LPI operations can be completed without harm to inspection personnel.
- There is a number of health and safety related issues that need to be taken into consideration.
- ***Chemical Safety & Ultraviolet Light Safety***

Chemical Safety

- Certain precautions must be taken, while handling chemicals.
- Material Safety Data Sheets (MSDS) for chemicals.
- Some of the penetrant materials are flammable and, therefore, should be used and stored in small quantities.
- Should only be used in a well ventilated area and ignition sources avoided.
- Eye protection should always be worn to prevent contact of the chemicals with the eyes.
- Gloves and other protective clothing should be worn to limit contact with the chemicals.

Ultraviolet Light Safety

- wavelengths ranging from 180 to 400 nanometers.
- These wavelengths place UV light in the **invisible** part of the electromagnetic spectrum between visible light and X-rays…***Blacklight***
- The most familiar source of UV radiation is the sun and is necessary in small doses for human body.
- Too much exposure can be harmful to the skin and eyes.

- The individual is generally unaware that the damage is occurring.
- There is usually no pain associated with the injury until several hours after the exposure.
- Skin and eye damage occurs at wavelengths around 320 nm and shorter,
- which is well below the 365 nm wavelength, where penetrants are designed to fluoresce.
- UV lamps deliver UV light with more intensity.
- UV lamps used in LPI are always filtered to remove the harmful UV wavelengths.

Air pollution

- Developing powders are considered non toxic, but excessive inhalation must be avoided.
- Exhaust fans should be installed in confined areas.