

Inspection and Quality Control in Manufacturing
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Lecture – 07
Dye Penetrant Inspection

Hello my friends, now we are going to discuss about the non-destructive inspection, in that same topic our sub topic is the dye penetrant inspection.

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Dye Penetrant Inspection:

- Dye penetrant inspection (DPI), also called liquid penetrant inspection (LPI) or penetrant testing (PT).
- It is widely applied and low-cost inspection method used to locate surface breaking defects in all non-porous materials (*metals, plastics, or ceramics*).
- This technique is used to detect casting, forging and welding surface defects such as hairline cracks, surface porosity, leaks in new products, and fatigue cracks on in-service components.

History of Penetrant Testing:

Before 1900's:

- A very early surface inspection technique involved the rubbing of carbon black on glazed pottery, whereby the carbon black would settle in surface cracks rendering them visible.
- Later, it became the practice in railway workshops to examine iron and steel components by the "*Oil and Whiting*" method.

What is dye penetrant inspection, Generally the Dye penetrant inspection we are calling it as DPI is also called the liquid penetrant inspection LPI or penetrant testing PT. It is widely applied and low-cost inspection method used to locate surface breaking defects in all non-porous materials like the metals plastics or may be the ceramics. This technique is used to detect casting, forging and welding surface defects such as hairline cracks, surface porosity, leaks in new products and fatigue cracks on in service components.

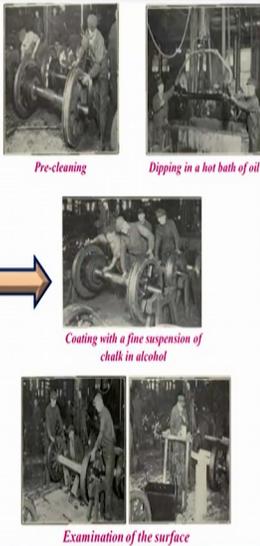
History of penetrant testing: before 1900, A very early surface inspection technique involved the rubbing of carbon black on glazed pottery, whereby the carbon black would settle in surface cracks rendering them visible. Sometimes it may happen that we are having anything object in white in color, it is very difficult to get the cracks over there, so now, if we rub anything black over black materials or the black color onto that, if we clean it, we can easily visualize the crack

line by that black nature. Later it became the practice in railway workshops to examine iron and steel components by the Oil and whiting method.

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1900's - Oil and Whiting Method:

- In this method, a heavy oil commonly available in railway workshops was diluted with kerosene in large tanks so that locomotive parts such as wheels could be submerged.
- After removal and careful cleaning, the surface was then coated with a fine suspension of chalk in alcohol so that a white surface layer was formed once the alcohol had evaporated.
- The object was then vibrated by being struck with a hammer, causing the residual oil in any surface cracks to seep out and stain the white coating.
- It is then carefully examined with magnifying glass.



Pre-cleaning *Dipping in a hot bath of oil*

Coating with a fine suspension of chalk in alcohol

Examination of the surface

1900s oil and whiting method generally, in this method, heavy oil commonly available in railway workshops was diluted with kerosene in large tanks so that locomotive parts such as wheels could be submerged. First, we are doing the pre-cleaning and dipping in a hot bath of oil. After removal and careful cleaning, the surface was then coated with fine suspensions of chalk in alcohol so that a white surface layer was formed once the alcohol had evaporated.

Coating with a fine suspension of chalk in alcohol is taking place. An last the the object was then vibrated by being struck with a hammer, causing the residual oil in any surface cracks to seep out and stain the white coating. Last it is then carefully examined with magnifying glass. Simple, first we are detecting that cracks and then we are seeing it properly.

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1940 - Visible Dye Penetrant Method:

- More effective penetrating oils containing highly visible dyes were then developed to enhance flaw detection capability. This method, known as the visible or colour contrast dye penetrant method, is still used quite extensively today.

1942 - Fluorescence Dye Penetrant Method:

- In 1942, fluorescent dyes were added to the liquid penetrant.
- These dyes would then fluoresce when exposed to ultraviolet light (sometimes referred to as "black light") rendering indications from cracks and other surface flaws more readily visible to inspectors.
- Many of these early developments were carried out by *Magnaflux* in Chicago, IL, USA in association with *Switzer Bros.*, Cleveland, OH, USA.

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Principle of Dye Penetrant Inspection:

- DPI is based upon capillary action, where low surface tension fluid penetrates into clean and dry surface-breaking discontinuities.

Capillary Action:

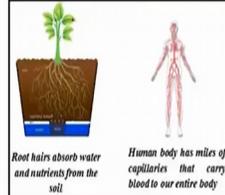
- ✓ Also known as capillarity, capillary motion, capillary effect, or wicking.
- ✓ It is the ability of a liquid to flow in narrow spaces without the assistance of, or even in opposition to, external forces like gravity.
- ✓ It occurs because of intermolecular forces between the liquid and surrounding solid surfaces.
- ✓ If the diameter of tube is sufficiently small, then combination of surface tension and adhesive forces between the liquid and container wall act to propel the liquid.



Capillary action in tubes of varying diameters

Examples from nature:

- ❖ Water movement in plants against the force of gravity
- ❖ Blood flow through the human body



Root hairs absorb water and nutrients from the soil

Human body has miles of capillaries that carry blood to our entire body

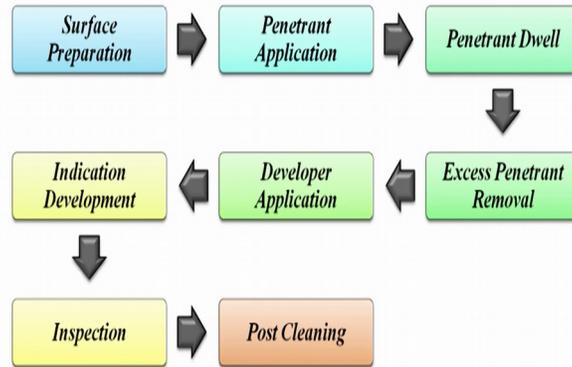
Now what are the principles of this dye penetrant inspections. Generally, DPI is based upon capillary action, where low surface tension fluid penetrates into clean and dry surface- breaking discontinuities, what is capillary action, also known as capillarity, capillary motion, capillary effect, or wicking, It is the ability of a liquid to flow in narrow spaces without the assistance of, or even in opposition to external forces like gravity.

It occurs because of intermolecular forces between the liquid and surrounding solid surfaces. If the diameter of tube is sufficiently small, then combination of surface tension and adhesive forces between the liquid and container wall act to propel the liquid. This is the capillary action in tubes of varying diameters, what are the examples, generally water movement in plant against the force of gravity, so root hairs absorb water and nutrients from the soil. Human body has miles of capillaries that carry blood to our entire body, by which the blood is taking place in our body.

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Test Procedure:

- Basic processing steps of dye penetrant inspection are as follows:

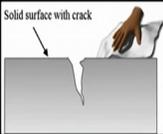


What are the test procedure? Basic processing steps of dye penetrant inspection are as follows; First is the surface preparation, then penetrant application and then penetrant dwell, then excess penetrant removal, developer application indication development, inspection, last one is the final one which is called as the post cleaning.

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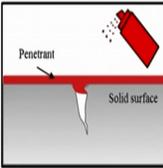
Step-1: Surface Preparation

- ✓ Most critical steps of a liquid penetrant inspection.
- ✓ The surface must be free of oil, grease, water, or other contaminants that may prevent penetrant from entering flaws.
- ✓ The sample may also require etching if mechanical operations such as machining, sanding, or grit blasting have been performed because these operations can smear metal over the flaw opening and prevent the penetrant from entering.



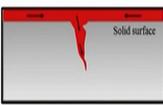
Step-2: Penetrant Application

- ✓ Once the surface has been thoroughly cleaned and dried, the penetrant material is applied by spraying, brushing, or immersing the part in a penetrant bath.



Step-3: Penetrant Dwell

- ✓ The penetrant is left on the surface for a sufficient time to allow as much penetrant as possible to be drawn from or to seep into a defect.
- ✓ Penetrant dwell time is the total time that the penetrant is in contact with the part surface.



First Surface penetration. Most critical steps of a liquid penetrant inspection, the surface must be free of oil, grease, water or other contaminants that may prevent penetrant from entering flaws. The sample may also require etching if mechanical operations such as machining, sanding or grit blasting have been performed because these operations can smear metal over the flaw opening and prevent the penetrant from entering. First, we have to clean the surface.

Second penetrant application, Once the surface has been thoroughly cleaned and dried, the penetrant material is applied by spraying, brushing, immersing the part in a penetrant bath. Next is the penetrant dwell, the penetrant is left on the surface for a sufficient time to allow as much penetrant as possible to be drawn from or to seep into a defect. Penetrant dwell time is the total time that the penetrant is in contact with the part surface.

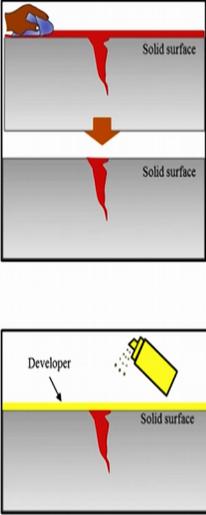
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Step-4: Excess Penetrant Removal

- ✓ This is the most delicate part of the inspection procedure because the excess penetrant must be removed from the surface of the sample while removing as little penetrant as possible from defects.
- ✓ Depending on the penetrant system used, this step may involve cleaning with a solvent, direct rinsing with water, or first treating the part with an emulsifier and then rinsing with water.

Step-5: Developer Application

- ✓ A thin layer of developer is then applied to the sample to draw penetrant trapped in flaws back to the surface where it will be visible.
- ✓ Developers come in a variety of forms that may be applied by dusting (dry powdered), dipping, or spraying (wet developers).



Next excess penetrant removal. This inspection procedure because the is most delicate part of the excess penetrant must be removed from the surface of the sample while removing as little penetrant as possible from defects. So, we have to take only the excess penetrant not that penetrant which has already entered the cracks or the pores.

Depending on the penetrant system used, this step may involve cleaning with a solvent, direct rinsing with water, or first treating the part with an emulsifier and then rinsing with water. Then next one is called the developer application; A thin layer of developer is then applied to the sample to draw penetrant trapped in flaws back to the surface where it will be visible. Developers come in a variety of forms that may be applied by dusting dry powdered, dipping or spraying wet developers. So now we are using the developer.

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Step-6: Indication Development

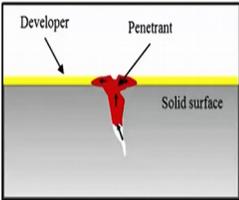
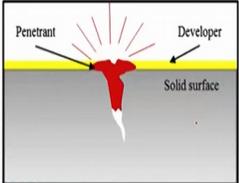
- ✓ The developer is allowed to stand on the part surface for a period of time sufficient to permit the extraction of the trapped penetrant out of any surface flaws.
- ✓ This development time is usually a minimum of 10 minutes. Significantly longer times may be necessary for tight cracks.

Step-7: Inspection/Evaluation

- ✓ Inspection is then performed under appropriate lighting to detect indications from any flaws which may be present.

Step-8: Post Cleaning

- ✓ The test surface is often cleaned after inspection and recording of defects, especially if post-inspection coating processes are scheduled.

Then indication development. The developer is allowed to stand on the part surface for a period of time sufficient to permit the extraction of the trapped penetrant out of any surface flaws. The development time is usually a minimum of 10 minutes significantly longer times may be necessary for tight cracks. Then next one is the Inspection or the evaluation.

The inspection is then performed under appropriate lighting to detect indications from any flaws which may be present. And the last one is the Post cleaning, the test surface is often cleaned after inspection and recording of defects especially if post-inspection coating processes are scheduled.

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Penetrant Materials:

- The penetrants are mixtures of organic solvents, which are characterized by their ability to wet materials, spread rapidly and penetrate into minute.
- These materials used today are much more sophisticated than kerosene and whiting first used by railroad inspectors near the turn of 20th century.
- Today's penetrants are carefully formulated to produce the level of sensitivity desired by the inspector.

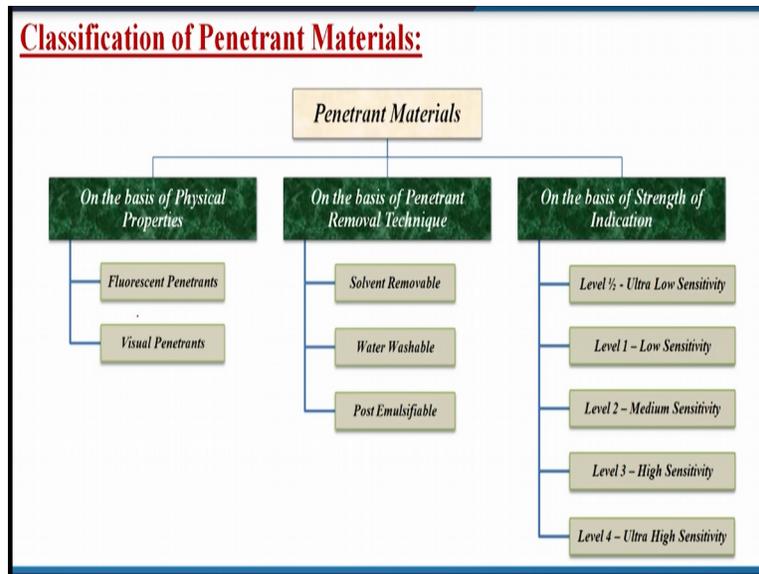
Characteristics of Liquid Penetrants

- ❖ To perform well, a penetrant must possess a number of important characteristics.
 - ✓ It should spread easily over the surface being inspected.
 - ✓ It should be easily drawn into discontinuities by capillary action.
 - ✓ It should not be harmful to the inspector or the material being tested.
 - ✓ It should possess high indicating capability & less dwell time.
 - ✓ It should remain in fluid state.
 - ✓ It should not affect the physical and chemical properties of the testing material.
 - ✓ It should be cohesive, adhesive and relatively low in cost.

Now what are the penetrant materials? The penetrants are mixtures of organic solvents which are characterized by their ability to wet materials, spread rapidly and penetrate into minute. These materials used today are much more sophisticated than kerosene and whiting, first used by rail road, inspectors near the turn of 20th century. Today's penetrants are carefully formulated to produce the the level of sensitivity desired by the inspector.

What are the characteristics of liquid penetrants? To perform well a penetrant must possess a number of important characteristics, it should spread easily over the surface being inspected, It should be easily drawn into discontinuities by capillary action, It should not be harmful to the inspector or the material tested, it should possess high indicating capability and less dwell time, it should remain in fluid state, It should not affect the physical and chemical properties of the testing material, it should be cohesive, adhesive and relatively low in cost.

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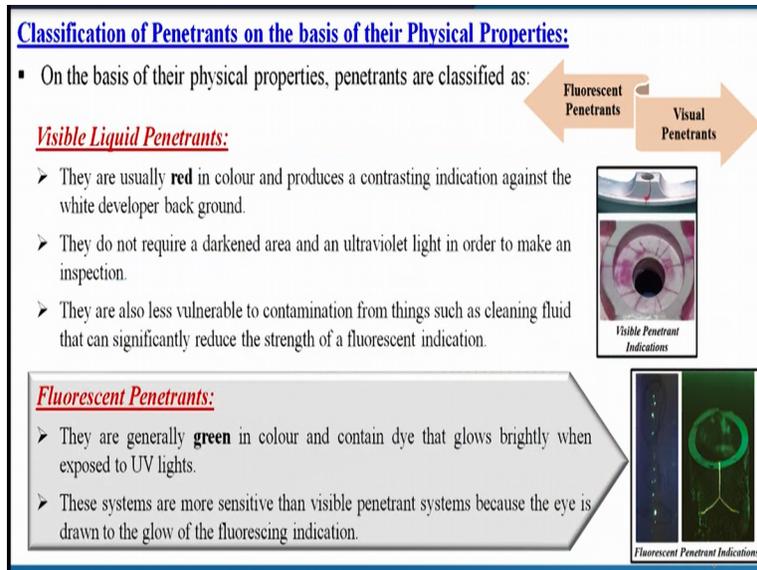


Now what are the classification of penetrant materials? on the basis of physical properties, generally fluorescent penetrants and the visual penetrants, on the basis of penetrant removal technique, solvent removable, water washable and post emulsifiable, on the basis of strength of indication: level half-ultra-low sensitivity, level 1-low sensitivity, level 2- medium sensitivity, level 3-high sensitivity, level 4-ultra high sensitivity.

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Classification of Penetrants on the basis of their Physical Properties:

- On the basis of their physical properties, penetrants are classified as:
 - Visible Liquid Penetrants:**
 - They are usually **red** in colour and produces a contrasting indication against the white developer back ground.
 - They do not require a darkened area and an ultraviolet light in order to make an inspection.
 - They are also less vulnerable to contamination from things such as cleaning fluid that can significantly reduce the strength of a fluorescent indication.
 - Fluorescent Penetrants:**
 - They are generally **green** in colour and contain dye that glows brightly when exposed to UV lights.
 - These systems are more sensitive than visible penetrant systems because the eye is drawn to the glow of the fluorescing indication.



The diagram features a central box with two arrows pointing outwards. The left arrow is labeled 'Fluorescent Penetrants' and points to a grey box containing text and a small image of a glowing green crack. The right arrow is labeled 'Visible Penetrants' and points to a white box containing text and a small image of a red crack. The overall layout is enclosed in a blue border.

Classification of the penetrants on their physical properties. On the basis of their physical properties' penetrants are classified as, Fluorescent penetrants and visual penetrants. What is visible liquid penetrants? They are usually red in color and produces a contrasting indication against the white developer back ground.

They do not require a darkened area and an ultraviolet light in order to make an inspection, this is the biggest example that I am using this particular pen on this white board, that is also red in color, so it is give a clear indication that where I am pointing out, They are also less vulnerable to contamination from things such as cleaning fluid that can significantly reduce the strength of a fluorescent indication.

Then come to the fluorescent penetrants: They are generally green in color and contain dye that glows brightly when exposed to UV lights from this particular image you can see, that we can clearly see the cracks or may be the pores, these systems are more sensitive than visible penetrant systems because the eye is drawn to the glow of the fluorescing indication.

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Classification of Penetrants on the basis of Removal Technique:

- On the basis of method used to remove the excess penetrant from the part. There are four methods:



- ❑ Method A: Water Washable
 - Also called as self-emulsifying systems, can be removed from part by rinsing with water alone.
 - These penetrants contain an emulsifying agent (detergent) that makes it possible to wash the penetrant from the part surface with water alone.
- ❑ Method B: Post-Emulsifiable, Lipophilic
 - In this, lipophilic systems (Method B), penetrant is oil soluble and interacts with oil-based emulsifier to make removal possible.
- ❑ Method C: Solvent Removable
 - Solvent removable penetrants require the use of a solvent to remove the penetrant from the part.
- ❑ Method D: Post-Emulsifiable, Hydrophilic
 - Post-Emulsifiable, hydrophilic systems (Method D), used an emulsifier that is a water soluble detergent which lifts the excess penetrant from the surface of part with a water wash.

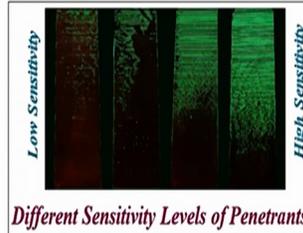
Now on the basis of method used to remove the excess penetrants from the parts there are four methods, one is called method A water washable, method B post emulsifiable lipophilic, method C Solvent removable, method D post emulsifiable hydrophilic. Method A, also called as self-emulsifying systems, can be removed from part by rinsing with the water alone.

These penetrants contain an emulsifying agent, detergent, that makes it possible to wash the penetrant from the part surface with water alone. Method B, in this lipophilic systems penetrant is oil soluble and interacts with oil-based emulsifier to make removal possible. Method C. Solvent removable penetrants require the use of a solvent to remove the penetrant from the part. Method D, Post emulsifiable hydrophilic systems used an emulsifier that is a water soluble detergent which lifts the excess penetrant from the surface of part with a water wash.

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Classification of Penetrants on the basis of their Strength of Indication:

- Penetrants are also formulated to produce a variety of sensitivity levels.
- The higher the sensitivity level, the smaller the defect that the penetrant system is capable of detecting.
- The five sensitivity levels are:
 - ✓ *Level ½ - Ultra Low Sensitivity*
 - ✓ *Level 1 - Low Sensitivity*
 - ✓ *Level 2 - Medium Sensitivity*
 - ✓ *Level 3 - High Sensitivity*
 - ✓ *Level 4 - Ultra-High Sensitivity*
- As the sensitivity level increases, so does the number of non-relevant indications.
- Therefore, a penetrant needs to be selected that will find the defects of interest but not produce too many non-relevant indications.



Classification of penetrants on the basis of their strength of indication. Penetrants are also formulated to produce a variety of sensitivity levels, the higher the sensitivity level the smaller the defect that the penetrant systems is capable of detecting. The five sensitivity levels are Level half – ultra low sensitivity, Level 1 – Low sensitivity, level 2- medium sensitivity, Level3-high sensitivity, Level 4-Ultra high sensitivity.

In this particular case you can understand low sensitivity means, we are not getting that much of effect. But while we are talking about high sensitivity, we can clearly see all the defects over there. If it is more tiny also we can clearly see. So, every sensitivity level is having their own limitation, as the sensitivity level increases, so does the number of non-relevant indications.

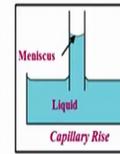
Therefore a penetrant needs to be selected that will find the defects of interest but not produce too many non-relevant indications, so it depends, if we need a very a high quality inspection, if the parts very essential or may be very costly in that case we need to take care all the cracks or pores, in this case we need the high sensitivity penetrants over there, and if we need only the ordinary testing, so that we can go for the low sensitivity penetrants.

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Properties of Good Penetrant:

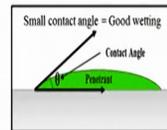
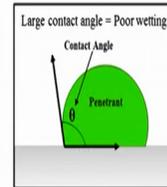
1) Capillarity:

- It is the ability of a liquid to flow in narrow spaces without the assistance of external forces. This property helps the penetrant to fill a void.



2) Surface Energy (Surface Wetting Capability):

- One of the important characteristics of a liquid penetrant material is its ability to freely wet the surface of the object being inspected.
- One way to quantify a liquid's surface wetting characteristics is to measure the **contact angle** of a drop of liquid placed on the surface of an object.
- The contact angle is the angle formed by the solid/liquid interface and the liquid/vapour interface measured from the side of the liquid.
- Liquids wet surfaces when the contact angle is less than 90 degrees.
- For a penetrant material to be effective, the contact angle should be as small as possible. In fact, the contact angle for most liquid penetrants is very close to zero degrees.



Now properties of a good penetrant. First one is called the capillarity, it is the ability of a liquid to flow in narrow spaces without the assistance of external forces. This property helps the penetrant to fill a void. When we are using the meniscus over there and dipping into the liquid due to that capillary rise, the meniscus is filled, the liquid is going inside the meniscus itself, so this is known as the capillarity.

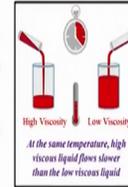
Second is the surface energy, surface wetting capability: One of the important characteristics of a liquid penetrant material is its ability to freely wet the surface of the object being inspected. So, one way to quantify a liquid's surface wetting characteristics is to measure the contact angle of a drop of liquid placed on the surface of an object. The contact angle is the angle formed by the solid/liquid interface and the liquid/vapor interface measured from the side of the liquid.

Liquids wet surfaces when the contact angle is less than 90 degrees. For a penetrant material to be effective, the contact angle should be as small as possible. In fact the contact angle for most liquid penetrant is very close to zero degrees. So, in this particular case, larger contact angle means poor wetting, so small contact angle is good wetting means the penetrant is homogeneously dispersed onto the surface.

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3) Viscosity:

- It is the internal resistance of a liquid to flow.
- A fluid that is highly viscous has a high resistance and flows slower than a low-viscosity fluid. e.g. Liquids such as water that flow easily, have a lower viscosity than do liquids such as honey.
- It has little effect on the ability of a penetrant material to enter a defect but it does have an effect on the speed at which the penetrant fills a defect.
- The penetrants with less viscosity fill the cracks in less time.



4) Specific Gravity:

- It is the ratio of density of a substance to the density of distilled water at 40°F (4°C).
- Most commercial penetrants have a specific gravity of less than one, primarily because they are made up of organic materials having low specific gravities.
- For this reason, water contamination sinks to the bottom of the penetrant tank.

5) Water Washable Penetrant Thermal Stability:

- It is the ability of water washable penetrants to resist physical changes under normal operating conditions.

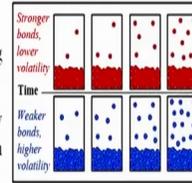
Next come to the viscosity, it is the internal resistance of a liquid to flow, A fluid that is highly viscous has a high resistance and flows slower than a low viscosity fluid Example liquid such as water that flow easily, have a lower viscosity than do liquids such as honey. It has little effect on the ability of a penetrant material to enter a defect but it does have an effect on the speed at which the penetrant fills a defect, yes of course, if the viscosity is higher, the movement of that particular penetrant is also higher, the penetrants with less viscosity fill the cracks in less time, that is quite obvious.

Next one is called the specific gravity: it is the ratio of the density of a substance to the density of the distilled water 40-degree Fahrenheit or 4 degree centigrade. Most commercial penetrants have a specific gravity of less than one primarily because they are made up of organic materials having low specific gravities. For this reason, water contamination sinks to the bottom of the penetrant tank. Next one is the water washable penetrant thermal stability: It is the ability of water washable penetrant to resist physical changes under normal operating conditions

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6) Volatility:

- Volatility is characterized by the vapour pressure or boiling point of a liquid.
- It is associated with the evaporation rate of liquids and it is desirable for penetrant materials to have a low volatility i.e. a high boiling point.
- High volatility results in a loss of penetrant in open tanks.
- A high volatile material will dry on the part during the penetrant dwell, leaving a film that is difficult to remove.
- Entrapped penetrant having high volatility would also have a tendency to dry or lose its liquid properties, resulting in failure to bleed back out of a discontinuity to produce an indication.



7) Fluorescent Dye Thermal Stability:

- The dye used in fluorescent-dye penetrants lose their brightness or colour when subjected to elevated temperature. This loss is termed "heat fade".
- Aerospace Material Specification (AMS) 2644 specifies the maximum allowable brightness loss as a function of penetrant sensitivity.
- Thermal stability is an important consideration during hot air drying before or after developer application.

Sixth is the volatility: Volatility is characterized by the vapor pressure or boiling point of a liquid, it is associated with the evaporation rate of liquids and it is desirable for penetrant materials to have a low volatility that is a high boiling point. High volatility results in a loss of penetrant in open tanks. A high volatile material will dry on the part during the penetrant dwell, leaving a film that is difficult to remove.

Entrapped penetrant having high volatility would also have a tendency to dry or lose its liquid properties, resulting in failure to bleed back out of a discontinuity to produce an indication. In this particular case stronger bonds, lower volatility if the time is increased in this direction, in this case the weaker bonds and higher volatility.

Fluorescent dye thermal stability: The dye is used in fluorescent dye penetrants lose their brightness or color when subjected to elevated temperature. This loss is termed heat fade. Aerospace Material specification AMS 2644 specifies the maximum allowable brightness loss as a function of penetrant sensitivity, Thermal stability is an important consideration during hot air drying before or after developer application.

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8) Flash Point:

- Flash point is the temperature at which sufficient flammable vapour is given off a liquid to form an explosive mixture in air over the liquid.
- The flash point does not affect the performance of a penetrant.
- High flash points are desirable to reduce the hazard of fire.

9) Removability:

- This term describes two conflicting requirements for a penetrant:
 - a. The ability to be removed from a surface leaving little or no residual background.*
 - b. Resistance to being removed from discontinuities.*
- In order to meet the first requirement, the penetrant must maintain the dyes in solution even when in the form of a thin film on the surface of a part and without its more volatile components that have been lost during the dwell time.
- The second requirement is met by the penetrant in discontinuities resisting the removal process.

Next is the flash point. Flash point is the temperature point at which sufficient flammable vapor is given off a liquid to form an explosive mixture in air over the liquid. The flash point does not affect the performance of a penetrant. High flash points are desirable to reduce the hazard of fire. Next one is the removability; this term describes two conflicting requirements for a penetrant.

The ability to be removed from a surface leaving little or no residual background. Resistance to being removed from discontinuities. In order to meet the first requirement, the penetrant must maintain the dyes in solution even when in the form of a thin film on the surface of a part and without its more volatile components that have been lost during the dwell time. The second requirement is met by the penetrant in discontinuities resisting the removal process.

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Developer:

- It's role is to 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.
- It also provide a light background to increase contrast when visual penetrant is used.
- Fine developer particles both reflect and refract the incident ultraviolet light, allowing more of it to interact with the penetrant, causing more efficient fluorescence.
- Developers also create a white background so there is a greater degree of contrast between the indication and the surrounding background.



- It should have good absorption characteristics.
- It should be chemically inert with test material.
- It should be able to uniformly cover the surface with thin smooth coating.
- It should provide a good contrast background for bright and clean indications.
- It should be non-toxic.
- It should be easy to remove after inspection.

Next come to the developer: Its role is to 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. It also provides a light background to increase contrast when visual penetrant is used. Fine developer particles both reflect and refract the incident ultraviolet light, allowing more of it to interact with the penetrant, causing more efficient fluorescence.

Developers also create a white background so there is a greater degree of contrast between the indication and the surrounding background. What are the characteristics of good developer, it should have good absorption characteristics, it should be chemically inert with test material, it should be able to uniformly cover the surface with thin smooth coating, it should provide a good contrast background for bright and clean indications, it should be non-toxic, it should be easy to remove after inspection?

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Classification of Developers:

- Developer classification is based on the method that the developer is applied.
- There are four forms of developers in general use:
 - i. *Water Soluble Developers*
 - ii. *Dry Powder Developers*
 - iii. *Water Suspendable Developers*
 - iv. *Non-aqueous Developers*
- *Water Soluble Developers:*
 - They 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, pouting, or brushing the solution on to the surface is sometimes used but these methods are less desirable.

What are the classification of developers? Developer classification is based on the method that the developer is applied. There are four forms of developers in general use. First one is the water-soluble developers, then comes the dry powder developers, then water suspendable developers, the forth one is the Non-aqueous developers.

Now what is water soluble developers : They consist of a group of chemicals that are dissolved in water and form a developer layer, when the water is evaporated away, so that means we are using the water that particular developer, the best method for applying water soluble developer is by spraying it on the part, dipping or may be the brushing the solution on to the surface is sometimes used but these methods are less desirable.

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Dry Powder Developer:

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

Advantage:

- ❖ When a dry developer is used, indications tend to stay bright and sharp since the penetrant has a limited amount of room to spread.



Dry powder developer application using spray gun.

Applications:

- ✓ The developer can be applied by:
 - ❖ Dipping parts in a container of developer.
 - ❖ Using puffer to dust parts with developer.
 - ❖ Using electrostatic powder spray guns.
 - ❖ Placing part in a dust cabinet where developer is blown around and allowed to settle on the part.

Limitations:

- ❖ Since dry powder developers only stick to the area where penetrant is present, the dry developer does not provide a uniform white background as the other forms of developers do.
- ❖ Having a uniform light background is very important for a visible inspection to be effective and since dry developers do not provide one, they are seldom used for visible inspections.

What is dry powder developer? Dry powder developer is generally considered to be the least sensitive but it is inexpensive to use and easy to apply, Dry developers are white, fluffy powder that can be applied to a thoroughly dry surface in a number of ways. What are the advantages, When a dry developer is used, indications tend to stay bright and sharp since the penetrant has a limited amount of room to spread?

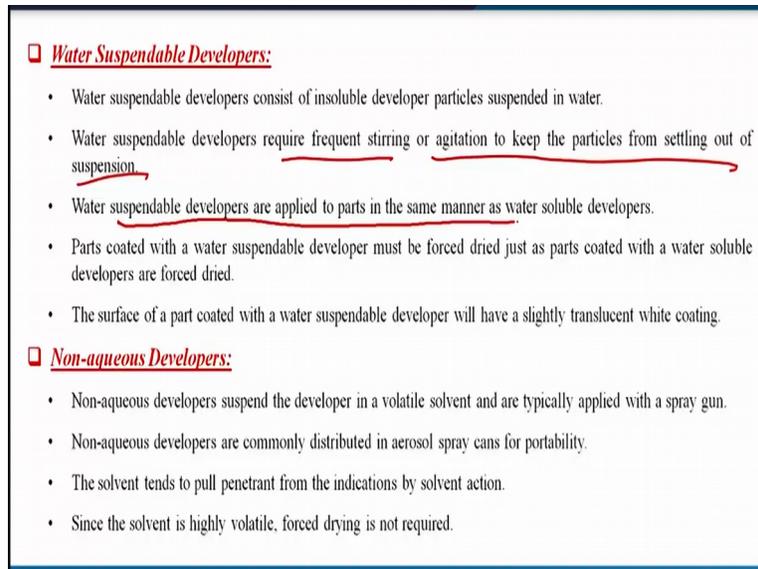
What are limitations, since dry powder developers only stick to the area where penetrant is present the dry developer does not provide a uniform white background as the other forms of developers do. Having a uniform light background is very important for a visible inspection to be effective and since dry developers do not provide one, they are seldom used for visible inspections.

What are applications, It can be used for dipping parts in a container of developer, it can be used for puffer to dust parts with developer, using electrostatic powder spray guns, Placing part in a dust cabinet where developer is blown around and allowed to settle on the part. So these all are the applications.

Next water suspendable developers: Water suspendable developers consist of insoluble developer particles suspended in water, Water suspendable developers require frequent stirring

and agitations to keep the particles from settling out of the suspension. Yes, it should not settle down at the bottom, so continuous stirring is required.

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Water Suspending Developers:

- Water suspendable developers consist of insoluble developer particles suspended in water.
- Water suspendable developers require frequent stirring or agitation to keep the particles from settling out of suspension.
- Water suspendable developers are applied to parts in the same manner as water soluble developers.
- Parts coated with a water suspendable developer must be forced dried just as parts coated with a water soluble developers are forced dried.
- The surface of a part coated with a water suspendable developer will have a slightly translucent white coating.

Non-aqueous Developers:

- Non-aqueous developers suspend the developer in a volatile solvent and are typically applied with a spray gun.
- Non-aqueous developers 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.

Water suspendable developers are applied to parts in the same manner as water soluble developers. Parts coated with a water suspendable developer must be forced dried just as parts coated with a water-soluble developers are forced dried. The surface of a part coated with a water suspendable developer will have a slightly translucent white coating

Next one is called the non-aqueous developers: Non-aqueous developers suspend the developer in a volatile solvent and are typically applied with a spray gun. Non-aqueous developers 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.

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Common Uses of Dye Penetrant Inspection:

- Dye penetrant inspection is one of the most widely used non-destructive evaluation methods.
- Its popularity can be attributed to two main factors: its relative ease of use and its flexibility.
- DPI offers flexibility in performing inspections because it can be applied in a large variety of applications ranging from automotive spark plugs to critical aircraft components.
- DPI can be used to inspect almost any material provided that its surface is not extremely rough or porous.
- Materials that are commonly inspected using DPI include the following:
 - Metals (aluminium, copper, steel, titanium, etc.)
 - Glass
 - Many ceramic materials
 - Rubber
 - Plastics

Now, Common uses of Dye penetrant inspection. Generally, dye penetrant inspection is one of the most widely used non-destructive evaluation methods. It is popular in nature and it can be attributed to two main factors, its relative ease of use and its flexibility. DPI offers flexibility in performing inspections because it can be applied in a large variety of applications ranging from automotive spark plugs to critical aircraft components, so there are N number of applications of this technique.

DPI can be used to inspect almost any material provided that its surface is not extremely rough or porous. It is not I am putting any kind of penetrant or may be developer and it is absorbing the same that time it is not possible. Materials that are commonly inspected using DPI include the following. Metals Like aluminum, copper, steel titanium etc. Glass, Rubber, and also the plastics.

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Types of Discontinuities that can be Detected via DPI:

- Dye penetrant inspection can detect all discontinuities that are open to the surface.
 - ❖ **Rolled products**- cracks, seams, laminations.
 - ❖ **Castings**- cold shuts, hot tears, porosity, blow holes, shrinkage.
 - ❖ **Forgings**- cracks, laps, external bursts.
 - ❖ **Welds**- cracks, porosity, undercut, overlap, lack of fusion, lack of penetration, pin holes.
 - ❖ **Others**- Fatigue cracks, quench cracks, grinding cracks, overload and impact fractures.



Different types of defects detected by dye penetrant testing

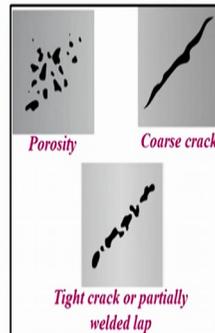
Now, types of discontinuities that can be detected via DPI. Dye penetrant inspection can detect all discontinuities that are open to the surface. Rolled products like cracks, seams, laminations, Castings cold shuts, hot tears, porosity, blow holes, shrinkage. Forgings- cracks, laps, external bursts. Welds- cracks, porosity, undercut, overlap, lack of fusion, lack of penetration, pin holes.

Others- Fatigue cracks, quench cracks, grinding cracks, overload and impact fractures. So, these kinds of defects we can easily find out by this technique. Here all are all examples that how we are detecting this cracks

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Typical Penetrant Indications:

- The size of the indication, or accumulation of penetrant, will show the extent of defect and the brilliance will be a measure of its depth.
- Deep cracks will hold more penetrant and will be broader and more brilliant.
- Very fine openings can hold only small amounts of penetrants and will appear as fine lines.



<i>Defect</i>	<i>Penetrant Indications</i>
Casting porosity	Spherical surface indications
Casting cold shut	Dotted lines
Cracks	Straight continuous surface lines
Hot tears	Ragged line of variable width
Heat treat cracks	Multiple irregular lines
Thermal cracks	Interconnecting lines
Lack of fusion	Broken line of varying width
Fatigue cracks	Continuous line in parts
Very tight crack	Series of very small dots in continuous form

Now, Typical penetrant indications: The size of the indication or accumulation of penetrant, will show the extent of defect and the brilliance will be a measure of its depth. Deep cracks will hold more penetrant and will be broader and more brilliant, very fine openings can hold only small amounts of penetrants and will appear as fine lines. For defects casting porosity, so generally spherical surface indication, so this is the example. Casting cold shut generally dotted lines.

Cracks- straight continuous surface lines, so this is the example. Hot tears- ragged line of variable width. Hot treat cracks – Multiple irregular lines. So, for different defects there are different types of penetrant indications accordingly. Last one is the very tight crack- series of very small dots in continuous form. So, this is the example.

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False Indications:

- It is an accumulation of penetrant caused by a drop of penetrant left on the workpiece.
- There are two conditions which may create accumulations of penetrant that are sometimes confused with the true crack and discontinuities.

1) *Indications due to inadequate removal of penetrant during rinse process or contamination from work area or hands.*

2) *Non-relevant indications caused by actual surface discontinuities that are present by design (e.g. raised lettering to identify part, press fit parts, etc.)*

- These types of indications can be identified since they are regular in form and shape.

False indications: It is an accumulation of penetrant caused by a drop of penetrant left on the work piece. There are two conditions which may create accumulations of penetrant that are sometimes confused with the true crack and discontinuities. First one indication due to inadequate removal of penetrant during rinse process or contamination from work area or hands.

Second, non-relevant indications caused by actual surface discontinuities that are present by design example, raised lettering to identify part, press fit parts etc. sometimes we are making some kind of impressions writing some names, some numbers or may be parts number. So that

time also you can give some kind of false interpretations. These types indications can be identified since they are regular in form and shape.

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Safety Precautions in DPI:

- When proper health and safety precautions are followed, liquid penetrant inspection operations can be completed without any harm to inspection personnel.
- Some of the most common safety concerns are:

<i>Chemical Safety</i>	<i>Ultraviolet Light Safety</i>
<ul style="list-style-type: none"><input type="checkbox"/> Flammability:<ul style="list-style-type: none">• Use exhaust fans to disperse vapours.• Ignition sources must be avoided.<input type="checkbox"/> Skin Irritation:<ul style="list-style-type: none">• Wear gloves to protect hands.• Wear safety glasses to protect eyes from splashing.	<ul style="list-style-type: none"><input type="checkbox"/> Lamps get hot:<ul style="list-style-type: none">• So be cautious.<input type="checkbox"/> Report missing or cracked filter on lamps.<ul style="list-style-type: none">• UV rays can cause sunburn and eye damage if filters not used or not functional.

Safety precautions in DPI: when proper health and safety precautions are followed. Liquid penetrant inspection operations can be completed without any harm to inspection personnel. Some of the most common safety concerns are, Chemical safety: like flammability, use exhaust fans to disperse vapors, ignition sources must be avoided. Like skin irritation – wear gloves to protect hands, wear safety glasses to protect eyes from splashing.

Ultra violet light safety: lamps get hot, so be cautious, Report missing or cracked filter on lamps. UV rays can cause sunburn and eye damage if filters not used or not functional

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Typical Applications of DPI:

1. **Aerospace:**

- ✓ Typical components that are checked by this method include turbine, rotor disc, blades, aircraft wheels, castings, forgings and welded assemblies.

2. **Automobiles:**

- ✓ Many automotive parts particularly aluminium, castings and forging including pistons and cylinder heads are subjected to this form of quality checks before assembly.

3. **Railways:**

- ✓ DPI to detect fatigue cracking is also used for the regular in service examination of the bogie frames of railway locomotive and the rolling stock.

4. **Tools and dies:**

- ✓ Drill bits, drill pipes, castings and drilling equipment are inspected by this method.

5. **Inspection on reactors and tanks:**

- ✓ Tanks, vessels, reactors, piping, dyers in the chemical and petro-chemical industries.

Typical applications of of DPI for aerospace industry. Typical components that are checked by this method include turbine, rotor disc, blades aircraft wheels castings, forgings and welded assemblies. Automobiles: Many automotive parts particularly aluminum castings and forging including pistons and cylinder heads are subjected to this form of quality checks before assembly.

For Railways, generally it detects the cracking is also used for the regular in-service examination of the bogie frames of railway locomotive and the rolling stock. For Tools and dies: Drill bits, drill pipes, castings and drilling equipment are inspected by this method. Inspection on reactors and tanks: Tanks vessels, reactors, piping dyers in the chemical and petro-chemical industries.

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Advantages of DPI:

- ❖ This method has high sensitivity to small surface discontinuities.
- ❖ The method has few material limitations, i.e. metallic and non-metallic, magnetic and nonmagnetic, and conductive and nonconductive materials may be inspected.
- ❖ Large areas and large volumes of parts/materials can be inspected rapidly and at low cost.
- ❖ Parts with complex geometric shapes are routinely inspected.
- ❖ Indications are produced directly on the surface of the part and constitute a visual representation of the flaw.
- ❖ Aerosol spray cans make penetrant materials very portable.
- ❖ Penetrant materials and associated equipment are relatively inexpensive.

What are the advantages of DPI? This method has high sensitivity to small surface discontinuities. This method has few material limitations, that is metallic and non-metallic, magnetic and non-magnetic and conductive and non-conductive materials may be inspected. That is why we are using this technique for various materials, so it is having a very wide application.

Large areas and large volumes of parts, materials can be inspected rapidly and at low cost. Parts with complex geometric shapes are routinely inspected. Indications are produced directly on the surface of the part and constitute a visual representation of the flaw. Aerosol spray cans make penetrant materials are very portable. Penetrant materials and associated equipment are relatively inexpensive.

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Limitations of DPI:

- Only surface breaking defects can be detected.
- Only materials with a relatively nonporous and smooth surface can be inspected.
- Pre-cleaning is critical since contaminants can mask defects.
- Metal smearing from machining, grinding, and grit or vapour blasting must be removed prior to DPI.
- The inspector must have direct access to the surface being inspected.
- Surface finish and roughness can affect inspection sensitivity.
- Multiple process operations must be performed under controlled conditions.
- Post cleaning of acceptable parts or materials is required.
- Chemical handling (due to toxicity and flammability) and proper disposal is required.

If there are certain limitations, what are those? Only surface breaking defects can be detected. So, it cannot go inside the material which we cannot see from the outside, only materials with relatively non-porous and smooth surface can be inspected. Pre-cleaning is critical since contaminants can mask defects. Metal smearing from machining, grinding and grit or vapor blasting must be removed prior to DPI.

The inspector must have direct access to the surface being inspected. Surface finish and roughness can affect inspection sensitivity. Multiple process operations must be performed under controlled conditions. Post cleaning of acceptable parts or materials is required. Chemical handling due to toxicity and flammability and proper disposal is required.

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Summary:

- Dye penetrant inspection is the one of the most widely used low cost inspection method.
- It can be used to locate all kinds of surface breaking flaws in all non-porous materials (metals, plastics, or ceramics).
- Penetrants are classified on the basis of their physical properties, removal techniques, and their strength of indication.
- Developers are classified on the basis of the method of their application.
- Proper health and safety precautions must be followed while performing this test.

Now we have come to the last slide of this particular lecture. In summary we can say, the dye penetrant inspection is one of the most widely used low cost inspection method. It can be used to locate all kinds of surface breaking flaws in all non-porous materials like metals, plastics or ceramics. Penetrants are classified on the basis of their physical properties, removal techniques and their strength of indication. Developers are classified on the basis of the method of their application. Proper health and safety precautions must be followed while performing this test.

Thank you very much.