Met-L-Chek Company has been manufacturing penetrant inspection materials since 1952. Met-L-Chek Company products are sold under the Met-L-Chek® and Pen-Chek® trademarks. Met-L-Chek Company products are manufactured in the United States and under license in the Netherlands by NDT Europa B.V.

Penetrant inspection is a surface inspection method used to highlight fine cracks, porosity, and through leaks on most solid surfaces. It is usable on most metals, some plastics, composites, and synthetic materials. Penetrants are of principally two types, visible red dye or fluorescent. Visible penetrant inspection is performed in bright white light and fluorescent penetrant inspection is performed in a darkened area under UV-A illumination.

Fluorescent penetrants are available in sensitivity levels 1/2 to 4 with 4 being the highest. Visible penetrants are not generally classified by sensitivity level but are generally considered to be roughly equal to level 1 fluorescent penetrant inspection. Penetrants are further classified as to their surface removal method; water washable, post emulsifiable, solvent removable, and special application.

The other components of the process are emulsifiers, solvent cleaners and removers, and developers. Materials are available in bulk containers for production line operations, and portable aerosol cans and kits for remote and spot inspections. The typical use temperature range is 4.4°C to 51.6°C (40°F to 125°F).

In very simple terms the penetrant inspection process consists of several steps:
Step 1 - clean the inspection surface.
Step 2 - apply penetrant and allow it to penetrate the surface discontinuities.
Step 3 - remove surface penetrant and dry surface if water is used.
Step 4 - apply developer and allow time for indications to form.
Step 5 - inspect.
High quality inspection materials are qualified to AMS-2644 and listed on QPL-2644 (Qualified Products List). The sensitivity of a penetrant per AMS-2644 is established by Wright Patterson AFB Materials Laboratory, not by the penetrant material supplier. Another specification based on AMS-2644 but with some minor differences is ISO-3452-2, which finds use in Europe for generally non aerospace applications. All major aerospace OEM’s require a material be listed on the QPL for AMS-2644 before it may be considered for use.

There are numerous processing specifications for the penetrant inspection process, the major ones are ASTM E-165 and ASTM E-1417 for most general applications, AMS-2647 for aerospace applications, and the ASME Pressure Vessel and Boiler Code for nuclear and power generation applications. Many OEM’s have their own processing specifications which include portions of one or more of the above mentioned specifications. In aerospace, to try to simplify the number of individual OEM specifications a user would have to try to comply with, an organization called NADCAP was created as a central audit authority. A user is either working to an OEM’s specification, a consensus specification such as ASTM E-1417, a customers specification, NADCAP, or their own procedure. A written procedure should be available to anyone required to perform penetrant inspection.

### Penetrant Material Definitions

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<th>AMS-2644 and ASTM E-1417</th>
<th>ISO-3452-2</th>
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<td><strong>TYPE 1</strong> – Fluorescent Dye</td>
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<tr>
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<td><strong>TYPE III</strong> – Dual fluorescent &amp; visible</td>
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<tr>
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<td>Sensitivity per visible levels</td>
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<td>class 2 – Non-halogenated.</td>
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<td>“a” – dry powder.</td>
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<td>“d” – non-aqueous (solvent) for Type 1 penetrants.</td>
<td>“d” – non-aqueous for Type I.</td>
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<td>“e” – non-aqueous (solvent) for Type 2 penetrants.</td>
<td>“e” – non-aqueous for Type II &amp; III.</td>
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<tr>
<td>“f” – special application.</td>
<td>“f” – special application.</td>
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Choosing Fluorescent (Type 1) Water Washable (Method A) Penetrants

Water washable penetrants are the most widely used for general metal working and even low stress component aerospace applications. Water washable penetrants are composed of water washable ingredients. The penetrant covered part is simply washed after the prescribed penetration dwell time. Being water washable, excessive wash time or pressure must be avoided with Method “A” penetrants to avoid washing the penetrant from shallow open discontinuities.

The **FBP-911**, **FBP-912**, **FBP-913** and **FBP-914** series covers sensitivity levels 1-4 and was designed to be the most environmentally friendly possible. This series does not contain fats, oils, or greases (FOG’s), and is free of any volatile organic compounds (VOC’s). The constituents are considered biodegradable. This series is smooth washing, non-gel forming and will wash cleanly from rough surfaces.

The **FP-921**, **FP-922** and **FP-923** series covers sensitivity levels 1-3. These materials are bright yellow green fluorescent penetrants that are smooth washing, with controlled removal without gelling. They have low viscosities, which aids in spraying and reduced drag out in immersion applications. The materials use biodegradable surfactants. They are approved by **GE, Pratt & Whitney**, and **Rolls-Royce** for non rotating turbine engine component inspection.
FLP-1 is a special water based leak detector penetrant which may be used as supplied or diluted with water for special applications in through-leak detection, use on plastics and other chemically sensitive materials.

Guide to Method “A” (water washable) Processing per ASTM E-1417

Pre-Clean Surface
Part must be clean, dry and at a temperature of 4.4° - 52°C (40° - 125°F) before penetrant is applied. Use Met-L-Chek® 300LF aqueous alkaline degreaser; immersion or spray application. Use Met-L-Chek® E-59A, R-503 or R-504 solvent cleaners for spot inspection cleaning applications.

Apply Met-L-Chek® Type 1 or Type 2 Penetrants (Method A)
Use spray, immersion, or wipe on application.

Dwell
Wait a minimum of 10 minutes; 20 minutes if temperature is 4.4°-10°C (40-50°F). Reapply penetrant if dwell is over 2 hours to prevent drying prior to removal.

Wash
Water temperature 10°-38°C (50°-100°F). Water pressure < 275kPa (< 40 psi); if a hydro-air nozzle is used limit pressure to < 172kPa (< 25 psi). Distance >30cm (>12 inches). Time- only long enough to remove surface fluorescence under UV-A or color under bright visible light.

Dry
Temperature <71 °C (<160 °F) Time- only long enough to dry surface

Apply Nonaqueous Developer (forms “d” or “e”) or Dry Developer (form “a” Type 1 only) Met-L-Chek® D-70 or D-72A (Type 1 only)

Apply Aqueous Developer (form “c”) Immersion, flow on, or spray.
Met-L-Chek® D-78B

Dry
Temperature <71 °C (<160 °F) Time- only long enough to dry surface

Dwell
Wait a minimum of 10 minutes before inspection. Maximum time is 1 hour for forms “d & e” (nonaqueous) maximum 2 hours for form “c” (aqueous), and maximum 4 hours for form “a” (dry powder). If times are exceeded, clean part and reprocess.

Inspect
For fluorescent Type 1 penetrants use UV-A illumination of >1000 μw/cm² @ 15inches (38.1 cm) in a darkened area of < 21 lux visible light (< 2 foot candles). For visible Type 2 penetrants use lighting of 1100 lux/m² (100 footcandles) minimum.

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Guide to Methods “B” & “D” (post emulsifiable) Processing per ASTM E-1417

Pre-Clean Surface
(see Method “A” details)

Apply Method “B” or “D” Penetrant
(see Method “A” details)

Dwell
(see Method “A” details)

Method “B”

Method “D”

Pre-Rinse
Water temperature 10˚-38˚C (50˚-100 °F).
Water pressure < 275kPa (< 40 psi).
only long enough to remove bulk of surface penetrant.

Method “D” Hydrophilic Emulsifier
Agitated Dip: 17-20% concentration; < 2 minutes
Spray: 1-5% concentration; < 2 minutes.
Met-L-Chek® E-58D

Wash

Water temperature 10˚-38˚C (50˚-100 °F).
Water pressure < 275kPa (< 40 psi); if a hydro-air nozzle is used limit pressure to < 172kPa (<25 psi).
Distance >30cm (>12 inches).
Time- only long enough to remove surface fluorescence under UV-A or color under bright visible light.

Dry
Temperature <71˚C (<160 °F)
Time- only long enough to dry surface

Apply Aqueous Developer (form “c”)
Immersion, flow on, or spray.
Met-L-Chek® D-78B

Dry
Temperature <71˚C (<160 °F)
Time- only long enough to dry surface

Apply Nonaqueous Developer (forms “d” or “e”) or
Dry Developer (form “a” Type 1 only)
Met-L-Chek® D-70 or D-72A (Type 1 only)

Dwell
Wait a minimum of 10 minutes before inspection. Maximum time is 1 hour for forms “d & e” (nonaqueous),
maximum 2 hours for form “c” (aqueous), and maximum 4 hours for form “a” (dry powder).
If times are exceeded, clean part and reprocess.

Inspect
For fluorescent Type 1 penetrants use UV-A illumination of >1000 µw/cm² @ 15 inches (38.1 cm)
in a darkened area of < 21 lux visible light (< 2 foot candles).
For visible Type 2 penetrants use lighting of 1100 lux/m² (100 footcandles) minimum.
Choosing Fluorescent (TYPE 1) Post Emulsifiable (Methods B & D) Penetrants

Post emulsifiable penetrants are the choice for hot section rotating turbine engine components and other critical high stress applications. Post emulsifiable penetrants require the use of an emulsifier to render the penetrant water washable. Post emulsifiable penetrants and emulsifiers are qualified to the AMS-2644 specification together and must be used as a family of materials. Method B (Lipophilic) employs E-57 as the emulsifier, which is used as supplied. Method D (hydrophilic) uses E-58D, which is used diluted in water to a concentration of 17 - 20 % for immersion applications and < 5 % for spray. Most aerospace engine OEM’s use, or recommend the use of Method D. Met-L-Chek Company’s level 2, 3, & 4 Method D materials are approved by GE, Pratt & Whitney, and Rolls-Royce turbine engine groups.

<table>
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<th>Method B Systems</th>
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<td>Sensitivity Level 2 - FP-93A(M) with E-57</td>
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<td>Sensitivity Level 3 - FP-95A(M) with E-57</td>
<td>Sensitivity Level 3 - FP-95A(M) with E-58D</td>
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<tr>
<td>Sensitivity Level 4 - FP-97A(M) with E-57</td>
<td>Sensitivity Level 4 - FP-97A(M) with E-58D</td>
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The key processing differences between the two approaches are in the emulsification techniques. When using Method B the penetrant covered part is immersed in the emulsifier, removed, and allowed to drain for a specified time before the part is washed. For Method D the penetrant covered part is given a short water pre-rinse, then immersed in the diluted emulsifier for a specified time, removed and washed. The Method D emulsifier bath is generally under gentle agitation during the immersion step. The Method D emulsifier may also be applied as a spray remover, in which case the water pre-rinse is not generally required.
Guide to Method “C” (wipe) Processing per ASTM E-1417

**Pre-Clean Surface**
Part must be clean, dry and at a temperature of 4.4˚-52˚C (40˚- 125˚F) before penetrant is applied. Use Met-L-Chek® E-59A, R-503 or R-504 solvent cleaners for spot inspection cleaning applications.

**Apply Met-L-Chek® TYPE 1 or TYPE 2 Penetrants (Method “C”)**
Use spray, immersion, or wipe on application

**Dwell**
Wait a minimum of 10 minutes; 20 minutes if temperature is 4.4˚-10˚C (40-50˚F). Reapply penetrant if dwell is over 2 hours to prevent drying prior to removal.

**Wipe Removal of Surface Penetrant**
Moisten cloth with remover and wipe penetrant from surface.
Do not spray remover on surface to remove penetrant, as sensitivity will be impaired.
A cloth moistened with water may be used with Method “A” penetrants but surface will need to be dried before developer application.

Apply Met-L-Chek® E-59A, R-503 or R-504

**Apply Nonaqueous Developer (forms “d” or “e”)**
Spray thin even film
Met-L-Chek® D-70

**Dwell**
Wait a minimum of 10 minutes before inspection. Maximum time is 1 hour for forms “d & e” (nonaqueous), maximum 2 hours for form “c” (aqueous), and maximum 4 hours for form “a” (dry powder).
If times are exceeded, clean part and reprocess.

**Inspect**
For fluorescent Type 1 penetrants use UV-A illumination of >1000 µw/cm² @ 15inches (38.1 cm) in a darkened area of <21 lux visible light (<2 foot candles).
For visible Type 2 penetrants use lighting of 1100 lux/m² (100 footcandles) minimum.

1- pre-clean surface
2- apply penetrant
3- dwell
4- wipe penetrant from surface
5- apply developer
6- inspect for cracks and porosity
Choosing Visible (TYPE 2) Penetrants

Visible inspection penetrants are used primarily for field applications where darkening the inspection area and the use of a black light (UV-A) is impractical, such as maintenance weld repair and safety checks. They are used to locate repair work areas on large rough castings and for through leak testing of heat exchangers and tanks where penetrant is applied to one side and developer to the other. Discontinuities in the range of 50µ are routinely detectable and under the right conditions even smaller discontinuities may be highlighted. Special high temperature visible penetrant materials are available which permit inspection of surfaces at temperatures up to 177˚C (350˚F). The majority of the applications use the solvent wipe off (Method C) technique of processing because most applications are spot or localized inspections. Production or full part inspection may be performed with visible penetrants using Methods “A”, “B” or “D”.

VP-30 - Water washable, low viscosity, low in sulfur and halogen, meets EdF, RCC-M nuclear specifications.
VBP 300 - Water washable, high viscosity, biodegradable, free of fats, oils, greases and solvents.
VP-31A - Post emulsifiable, low viscosity, low in sulfur and halogen, meets nuclear specification requirements.
VP-302 - Special high temperature penetrant used with R-502 remover and D-702 developer

Choosing a Solvent Cleaner/Remover

All penetrants that are approved for use to Methods “A”, “B”, & “D”, are approved for Method “C”, solvent wipe off.

Evaporation rate should be considered when choosing a cleaner/remover. When wiping the penetrant residue from a rough surface the slower evaporating remover will keep the wiping media moist and more effective at helping the removal of the penetrant. In the case of verifying a fluorescent indication by wiping the indication with a cotton swab or brush moistened with the remover, the slow evaporating material will make the indications blurry and bleed excessively. In this case a very fast drying cleaner is the right choice. When used as cleaners for pre-cleaning the inspection surface, the slow material will not evaporate readily from the part and could interfere with penetration of the discontinuity by the penetrant. The faster drying cleaners are also better solvents for oils and greases improving their removal from the part.
All of the cleaners are flammable and should not be used in confined areas without proper ventilation. They should not be used near open flames or sparks. Nonflammable solvents, have been used in past years, but have been found to be carcinogens or are banned as Ozone Layer Depleting Substances.

Tam Panel or star burst indication cleaning is best achieved with the directional spray tube applicators used on R-503 and R-504. Both are approved by Pratt & Whitney.

- E-59 - Slow evaporating used as a penetrant remover.
- E-59A - Moderate evaporation rate, residue free, petroleum solvent cleaner/remover.
- R-502 - Special high temperature penetrant (VP-302) remover.
- R-503 - Moderate rate, residue free, non-petroleum solvent cleaner/remover.
- R-504 - Fast evaporating, residue free, solvent cleaner/remover.

**Choosing a Developer**

The use of a developer is required by most testing specifications. The developer draws the penetrant from the flaw site and creates a uniform surface on which to view the penetrant indication.

D-70 nonaqueous developer (forms “d” & “e”) is developer powder suspended in a volatile solvent. This type of developer is most commonly used in aerosol cans, but may also be bulk sprayed using a paint sprayer. It is applied after the surface penetrant has been removed and the inspection surface dried. The solvent action of this type of developer helps bring the penetrant to the surface enhancing the detectability of the flaw. Low in Sulfur and Halogens it is widely used for nuclear component inspection. It is approved by Boeing, Edf, GE, Pratt & Whitney and is the qualification standard for AMS-2644.

D-72A dry powder developer (form “a”) is the most commonly employed developer form with fluorescent penetrants. It is not used with visible penetrants. It is applied by dusting it onto the part after the drying process. It is approved by Boeing, GE, Pratt & Whitney, and Rolls-Royce.

D-76B water soluble developer (form “b”) is a powder that is dissolved in water and applied to the part after the surface penetrant is removed and prior to drying. It is used with post emulsifiable fluorescent penetrants.

D-78B water suspendible developer (form “c”) is a powder that is mixed with water (does not dissolve) and applied to the part after the surface penetrant is removed and prior to drying. It is used with both fluorescent and visible penetrants. The developer must be continually mixed to prevent it from settling out of solution.

D-702: high temperature developer (form “f”) used with VP-302 penetrant.