Module 2

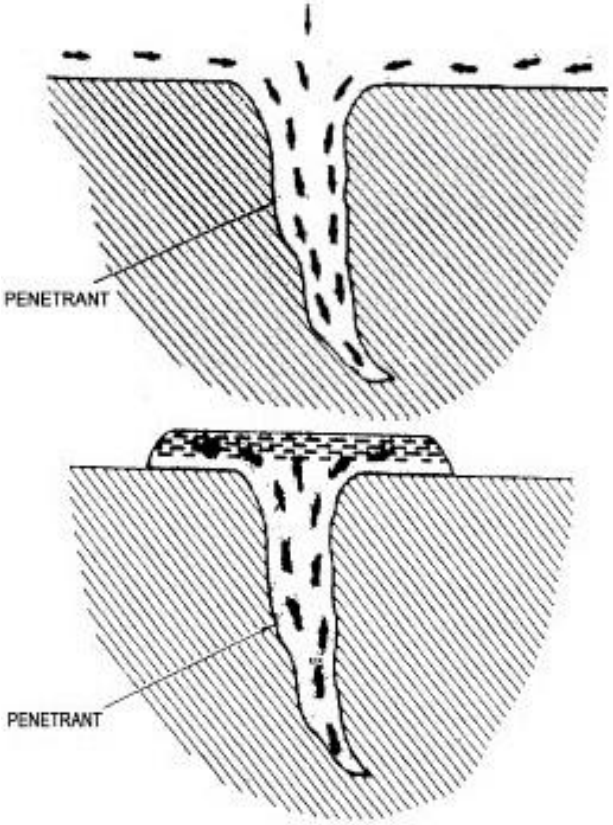
Liquid Penetrant Testing

Introduction

Liquid Penetrant inspection is a technique which can be used to detect defects in a wide range of components, provided that the defect breaks the surface of the material.

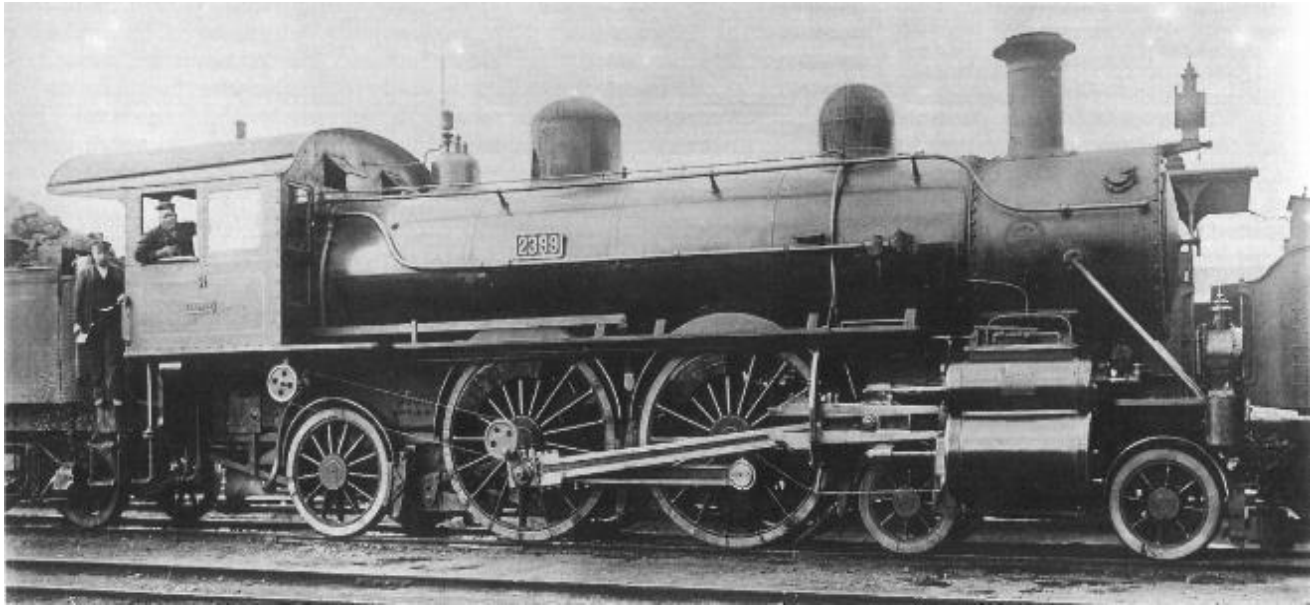
The principle of the technique is that a liquid is drawn by capillary attraction into the defect and, after subsequent development, any surface-breaking defects may be rendered visible to the human eye. In order to achieve good defect visibility, the penetrating liquid will either be colored with a bright and persistent dye or else contain a fluorescent compound.

In the former type the dye is generally red and the developed surface can be viewed in natural or artificial light, but in the latter case the component must be viewed under ultra-violet light if indications of defects are to be seen.



Penetrant Testing History

- Penetrant first used in 1900s to detect cracks in locomotive parts
- The method was called oil and whiting. The carbon black was held by the cracks, and hence, their outline was readily visible.
- The method used dirty lubricating oil that was thinned with kerosene followed by application of chalk coating which absorbed oil from the cracks.
- In 1940s fluorescent or visible dye was added to the oil
- Nowadays, liquid Penetrant inspection is an important industrial method and it can be used to indicate the presence of defects such as cracks, laminations, laps and zones of surface porosity in a wide variety of components.

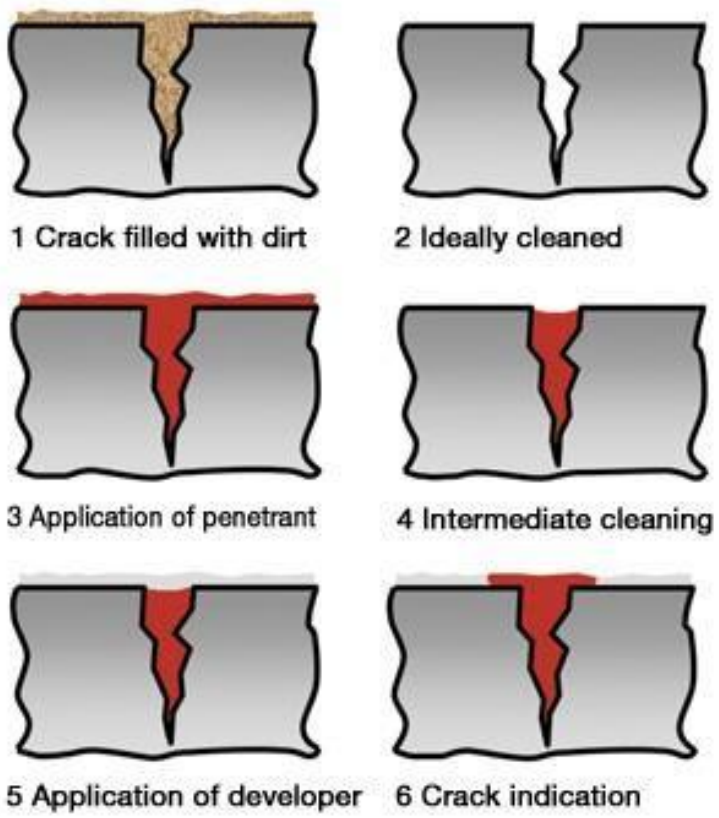


Liquid Penetrant Testing

- Penetrant testing can be applied to most of materials including metallic and non metallic objects
- Metallic materials include aluminum, magnesium, titanium, cast iron, stainless steel, powdered metal products, copper, brass, bronze, etc.
- Non metallic materials include ceramics, plastic, molded rubber, composites, glass, etc.
- Penetrant testing can’t be applied on a porous surface

Principles

- Clean & dry test object
- Apply penetrant and let it penetrate
- Remove excess penetrant
- Apply developer
- Evaluate indications
- Post clean test object



Surface preparation

- All surfaces of a component must be thoroughly cleaned and completely dried before it is subjected to inspection.
- It is important that any surfaces to be examined for defects must be free from oil, water, grease or other contaminants if successful indication of defects is to be achieved.

Application of penetrant

- After surface preparation, liquid Penetrant is applied in a suitable manner, so as to form a film of penetrant over the component surface.
- The liquid film should remain on the surface for a period sufficient to allow for full penetration into surface defects.

Removal of excess penetrant

- It is now necessary·to remove excess penetrant from the surface of the component.
- Some penetrants can be washed off the surface with water, while others require the use of specific solvents.
- Uniform removal of excess penetrant is necessary far effective inspection.

Development

- The development stage is necessary to reveal c1early the presence of any defect.
- The developer is usually a very fine chalk powder. This may be applied dry, but more commonly is applied by spraying the surface with chalk dust suspended in a volatile carrier fluid.
- A thin uniform layer of chalk is deposited on the surface of the component Penetrant liquid present within defects will be slowly drawn by capillary action into the pores of the chalk.
- When a dye penetrant is used the dye colour must be in sharp contrast to the uniform white of the chalk-covered surface. The development stage may sometimes be omitted when a fluorescent penetrant is used.
- After an optimum developing time has been allowed, the component surface is inspected for indications of penetrant 'bleedback' into the developer.
- Dye penetrant inspection is carried out in strong lighting conditions, while fluorescent penetrant inspection is performed in a suitable screened area using ultra-violet light.
- The latter technique causes the penetrant to emit visible light, and defects are brilliantly outlined.

Penetrants

- The Penetrant’s are mixture of organic solvents, which are characterized by the ability to wet materials, spread rapidly and penetrate into minute defects and dissolve dyes, so that the indications produce a definite colours as contrasted to the white background of the developer.
- Penetrants are either coloured (mostly red, sometimes blue) or fluorescent under black light or both at the same time.
- Types of penetrants
  - Based on physical properties
  - Based on removal techniques
  - Based on strength of indication.

Types of Penetrants

1. Based on Physical Properties

i) Fluorescent Penetrants

Fluorescent penetrants are generally green in colour and they contain dye that glow brightly when exposed to UV lights

ii) Visual penetrants

Visual penetrants are usually red in colour that provide high contrast against the white developer background.

2. Based on removal technique

i. Solvent removable
ii. Water washable
iii. Post emulsifiable

1. Solvent Removable

In this method , Penetrants are removed by wiping with a cloth dampened with solvent.

2. Water washable

- Have a built in emulsifier, easily removed by water rinse
- Typical rinse procedure are (refer to manual):
  - Pressure < 40 psi
  - Temperature 10^{o} - 38^{o} C
  - Angle 45^{o} - 75^{o}

iii) Post Emulsifiable / PE

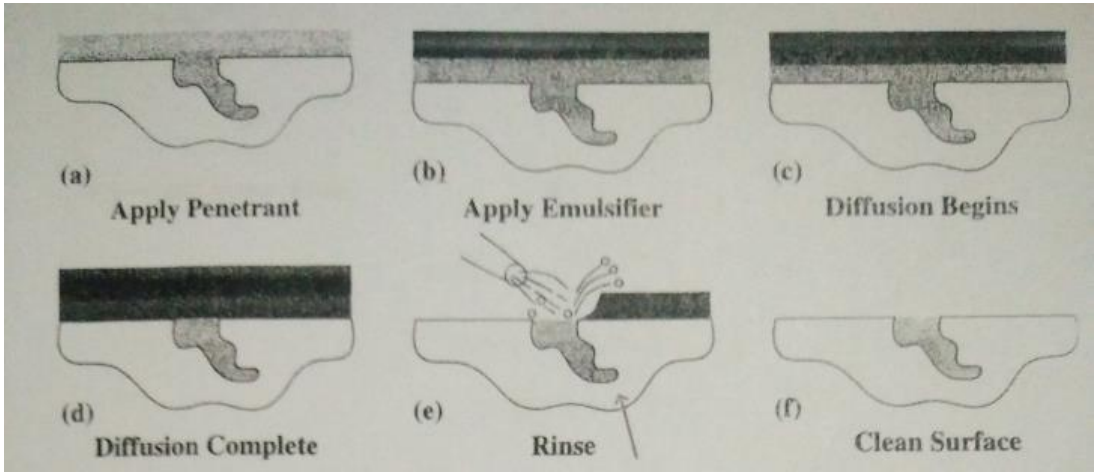
- Not contain emulsifying agent, not soluble in water
- Emulsifier applied to remove excess penetrant by dipping, spraying, or flowing
- Emulsifier dwell time is 1 - 4 minutes

- Penetrant – emulsifier mixture is removed by water rinse

Two types of emulsifier, lipophilic and hydrophilic

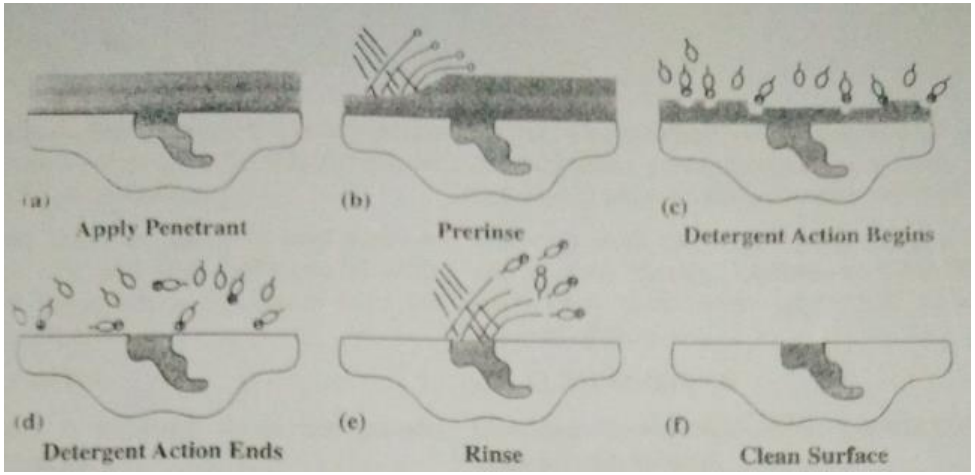
Lipophilic Emulsifier

- Mechanism of lipophilic emulsification is by diffusion
- Both molecules of emulsifier and penetrant penetrate each other to form a washable mixture
- Rate of diffusion increases as concentration and temperature raised



Hydrophilic Emulsifier

- Is a water based solution, mixture of chemical called surfactant
- Works based on principle of peeling the penetrant
- Need pre-rinsing prior to emulsifier application to help remove 60 – 80 % penetrant and provide an even surface
- Applied by immersion or spraying



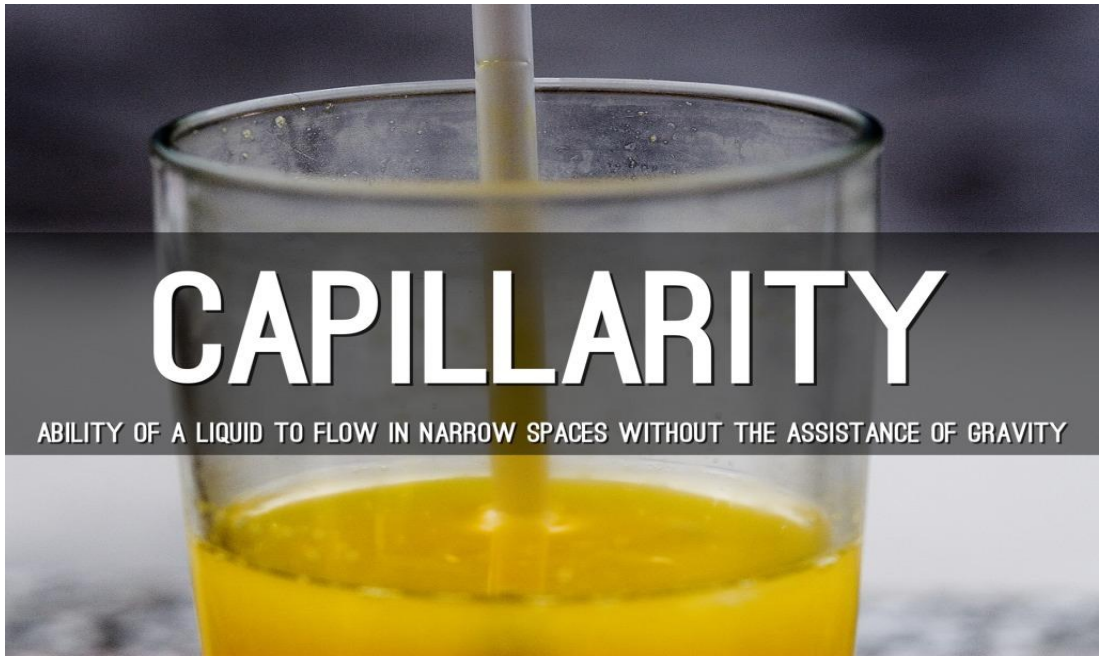
3 Based on Strength Indication

- i) Level ½- Ultra Low sensitivity
- ii) Level 1- Low Sensitivity
- iii) Level 2- Medium Sensitivity
- Iv) Level 3- High Sensitivity
- V) Level 4- Ultra High Sensitivity

Properties of Good penetrant

1. Capillarity

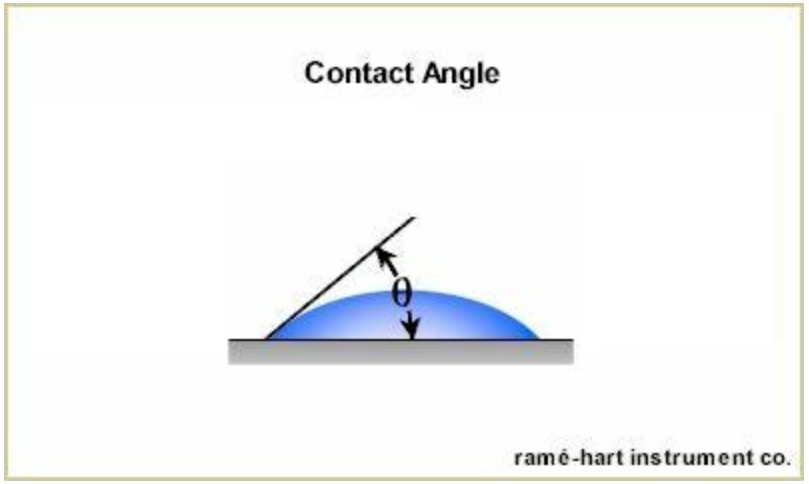
It is the ability of a liquid to flow in narrow spaces without the assistance of external forces. This property helps the penetrant to fill a void.



2. Contact Angle

Angle formed by the solid-liquid interface and liquid – vapour interface measured from the side of a liquid is called contact angle.

Mostly the liquid penetrant has contact angle of 0deg



3. Viscosity

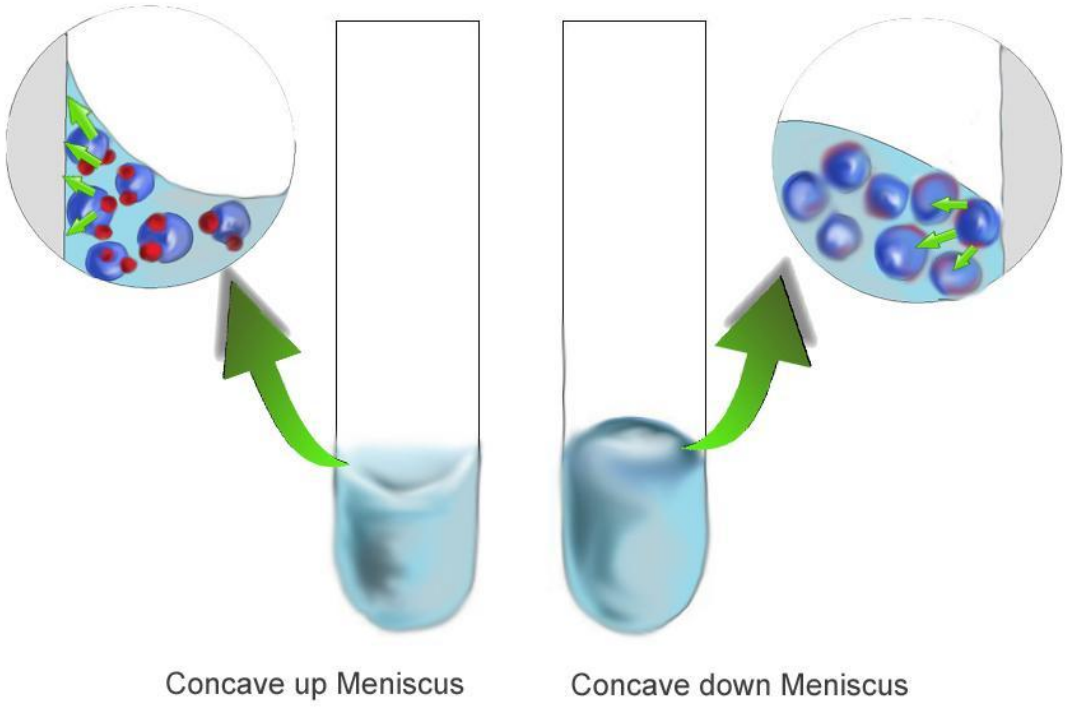
- Viscosity is the internal resistance of a liquid to flow. The penetrants with less viscosity fill the cracks in time

4. Surface Tension

- Surface tension is nothing but wetting capability of a liquid. Penetrant should have good wetting capability to spread over the su

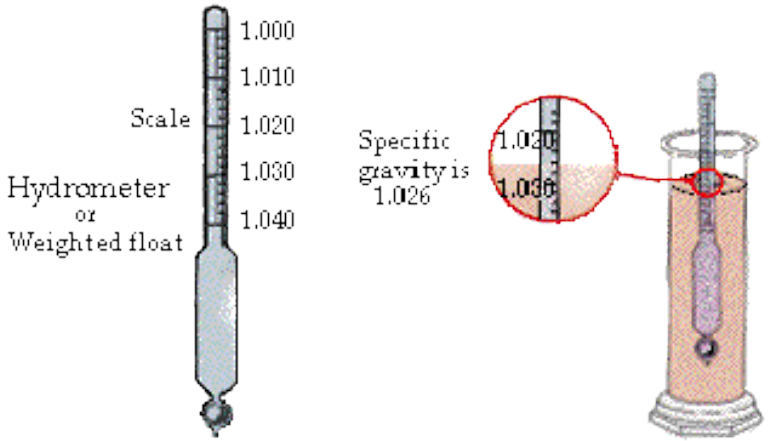
5. Cohesiveness and Adhesiveness

- The attractive force between like molecules and unlike molecules called cohesiveness and Adhesive forces respectively



6. Specific Gravity

- Specific gravity is the ratio of the density of a liquid to the density of the standard liquid. Penetrant have Sp Gravity less than one



7.Non-Flammable

8.Volatility

Tendency of a substance to evaporate at normal temperature is called volatility

9. Removability

Characteristics of Good Penetrants

- 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
- It should remain in fluid state
- It should Possess less dwell time
- It should not affect the physical and chemical properties of the testing material
- It should be cohesive, Adhesive and relatively low in cost

Properties of Good developer

- It should have good absorption characteristics
- It should have a good contrast background
- It should be able to uniformly cover the surface with the thin smooth Coating
- It should be chemically inert with test material
- 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

Types of Developers

1. Dry Powder Developers
2. Water Suspendable developers
3. Water soluble developers
4. Non-aqueous developers

1 Dry Powder Developers

- It is a mix of light feathery powder that clumps where penetrant bleeds back to the surface in order to produce very defined indications

2 Water- Suspendable Developer

- Water suspendable developers consist of insoluble developers particles suspended in water. Water suspendable developers require frequent stirring to keep the particle from setting out of suspension

3. Water Soluble developer

- Water soluble developer is a crystalline powder that forms a clear solution when mixed with water.
- The solution recrystallizes on the suraface when the water is drained

4. Non Aqueous

- Non Aqueous developer suspend the developer in a volatile solvent.
- It is supplied by a spray gun or aerosol can and it Is most sensitive developer for inspecting small areas

Classification of Testing Products

Table 4-1: Classification of testing products (EN ISO 3452-2)

Penetrant		***Excess penetrant remover***		***Developer***	
Type	Denomination	Type	Denomination	Type	Denomination
I	fluorescent penetrant	A	water	a	dry
II	colour contrast penetrant	B	lipophilic emulsifier 1 oil-based emulsifier 2 rinsing with running water	b	water-soluble
III	dual purpose (fluorescent colour contrast penetrant)	C	solvent (liquid) class 1: halogenated class 2: non-halogenated class 3: special application	c	water-suspendable
		D	hydrophilic emulsifier 1 optional pre-rinse (water) 2 emulsifier (water-diluted) 3 final rinse (water)	d	solvent-based (non-aqueous for type I)
		E	water and solvent	e	solvent-based (non-aqueous for types II and III)
				f	special application