**11.1 Objective**

To visualize cracks which are not visible to naked eye, using liquid penetrant inspection

**11.2 Apparatus**

* Cleaner
* Developer
* Penetrant
* Samples (steel rod, metal sheet cupping test, rod bend tested, welded plate having beads)

**11.3 Introduction**

Liquid Penetrant Inspection is a nondestructive method of revealing discontinuities that are open to the surfaces of solid and essentially nonporous materials. Indications of a wide spectrum of flaw sizes can be found regardless of the configuration of the work piece and regardless of flaw orientations. Liquid penetrants seep into various types of minute surface openings by capillary action. Because of this, the process is well suited to the detection of all types of surface cracks, laps, porosity, shrinkage areas, laminations, and similar discontinuities. It is extensively used for the inspection of wrought and cast products of both ferrous and nonferrous metals, powder metallurgy parts, ceramics, plastics, and glass objects.

In practice, the liquid penetrant process is relatively simple to utilize and control. The equipment used in liquid penetrant inspection can vary from an arrangement of simple tanks containing penetrant, emulsifier, and developer to sophisticated computer-controlled automated processing and inspection systems. Establishing procedures and standards for the inspection of specific parts or products is critical for optimum end results.

The liquid penetrant method does not depend on ferromagnetism (as does, for example, magnetic particle inspection), and the arrangement of the discontinuities is not a factor. The penetrant method is effective not only for detecting surface flaws in non-magnetic metals but also for revealing surface flaws in a variety of other nonmagnetic materials. Liquid penetrant inspection is also used to inspect items made from ferromagnetic steels; generally, its sensitivity is greater than that of magnetic particle inspection.

The major limitation of liquid penetrant inspection is that it can detect only imperfections that are open to the surface; some other method must be used for detecting subsurface flaws. Another factor that can limit the use of liquid penetrants is surface roughness or porosity. Such surfaces produce excessive background and interfere with inspection.

**11.3.1 History**

The exact origin of liquid penetrant inspection is not known, but it has been assumed that the method evolved from the observation that the rust on a crack in a steel plate in outdoor storage was somewhat heavier than the rust on the adjacent surfaces as a result of water seeping into the crack and forcing out the oxide it had helped to produce. The obvious conclusion was that a liquid purposely introduced into surface cracks and then brought out again would reveal the locations of those cracks.

The only material that fulfilled the known criteria of low viscosity, good wettability, and ready availability was kerosene. It was found, however, that although wider cracks showed up easily, finer ones were sometimes missed because of the difficulty of detecting, by purely visual means, the small amounts of kerosene exuding from them. The solution was to provide a contrasting surface that would reveal smaller seepages. The properties and availability of whitewash made it the logical choice. This method, known as the kerosene-and-whiting test, was the standard for many years. The sensitivity of the kerosene-and-whiting test could be increased by hitting the object being tested with a hammer during testing. The resulting vibration brought more of the kerosene out of the cracks and onto the whitewash. Although this test was not as sensitive as those derived from it, it was quick, inexpensive, and reasonably accurate. Thus, it provided a vast improvement over ordinary visual examination.

The first step leading to the methods now available was the development of the fluorescent penetrant process by R.C. Switzer. This liquid, used jointly with a powder developer, brought penetrant inspection from a relatively crude procedure to a more scientific operation. With fluorescent penetrant, minute flaws could be readily detected when exposed to ultraviolet light (commonly called black light). This development represented a major breakthrough in the detection of surface flaws.

Switzer's work also included the development of the visible-color contrast method, which allowed for inspection under white light conditions. Although not as sensitive as fluorescent penetrant inspection, it is widely used in industry for noncritical inspection. Through the developments described above, liquid penetrant inspection has become a major nondestructive inspection method.

**11.4 Penetrant Methods**

Because of the vast differences among applications for penetrant inspection, it has been necessary to refine and develop the two types of penetrants (type I, fluorescent, and type II, visible) into four basic methods to accommodate the wide variations in the following principal factors:

* Surface condition of the work piece being inspected
* Characteristics of the flaws to be detected
* Time and place of inspection
* Size of the work piece
* Sensitivity required

The four methods are broadly classified as

* Water washable, method A
* Postemulsifiable lipophilic, method B
* Solvent removable, method C
* Postemulsifiable hydrophilic, method D

**11.5 Basic Processing Steps of a Liquid Penetrant Inspection**

Liquid penetrant inspection depends mainly on a penetrant's effectively wetting the surface of a solid work piece or specimen, flowing over that surface to form a continuous and reasonably uniform coating, and then migrating into cavities that are open to the surface. The cavities of interest are usually exceedingly small, often invisible to the unaided eye.

**11.5.1 Surface Preparation**

One of the most critical steps of a liquid penetrant inspection is the surface preparation. 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. Use cleaner to clean the surface. These and other mechanical operations can smear metal over the flaw opening and prevent the penetrant from entering.

**11.5.2 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.

**11.5.3 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. Dwell times are usually recommended by the penetrant producers or required by the specification being followed. The times vary depending on the application, penetrant materials used, the material, the form of the material being inspected, and the type of defect being inspected for. Minimum dwell times typically range from five to 60 minutes. Generally, there is no harm in using a longer penetrant dwell time as long as the penetrant is not allowed to dry. The ideal dwell time is often determined by experimentation and may be very specific to a particular application.

Figure 1: application of penetrant

**11.5.4 Excess Penetrant Removal**

Figure 2cleaning of excess penetrant

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.

**11.5.5 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)

**11.5.6 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.

Figure 3: developer applied

**11.5.7 Inspection**

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

**11.5.8 Clean Surface**

The final step in the process is to thoroughly clean the part surface to remove the developer from the parts that were found to be acceptable.

**11.6 Result**

In different specimens crack was clear with red stain.

**11.7 Advantages and Disadvantages of Penetrant Testing**

Like all nondestructive inspection methods, liquid penetrant inspection has both advantages and disadvantages. The primary advantages and disadvantages when compared to other NDE methods are summarized below.

**11.7.1 Primary Advantages**

* The method has high sensitivity to small surface discontinuities.
* The method has few material limitations, i.e. metallic and nonmetallic, 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.

**11.7.2 Primary Disadvantages**

* Only surface breaking defects can be detected.
* Only materials with a relatively nonporous surface can be inspected.
* Precleaning is critical since contaminants can mask defects.
* Metal smearing from machining, grinding, and grit or vapor blasting must be removed prior to LPI.
* 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 and controlled.
* Post cleaning of acceptable parts or materials is required.
* Chemical handling and proper disposal is required.

**References**

* Nondestructive Evaluation and Quality Control was published in 1989 as Volume 17 of the 9th Edition Metals Handbook 2nd edition.
* http://www.ndt-ed.org