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A SERVICE PUBLICATION OF LOCKHEED-GEORGIA COMPANY, A DIVISION OF LOCKHEED CORPORATION

Liquid Penetrant
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A SERVICE PUBLICATION OF
LOCKHEEDGEORGIA COMPANY
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Cover: A Royal Saudi Air Force C-130H makes an assault landing during the Volant Rodeo '84 competition. This was the first year that the RSAF participated in the Volant Rodeo exercises.

Focal Point

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M. M. HODNETT

The Hercules aircraft has now been in continuous production for over 30 years. It is the longest production run for any aircraft in the history of the aerospace Industry, a proud record. Of the more than 1700 Hercules aircraft that have been built, approximately 88% are still in operation. This fact is an impressive tribute to the outstanding durability of the Hercules aircraft, but it also says something significant about the quality of the product support that has been received by our customers through the years. The role of the supporting organizations has in fact been central to the success storyofthe Hercules airlifter. How well an aircraft flies IS a functlon of its design, but how well an aircraft performs is a function of its support.

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Sincerely,

M. M. Hodnett
Director of Customer Supply

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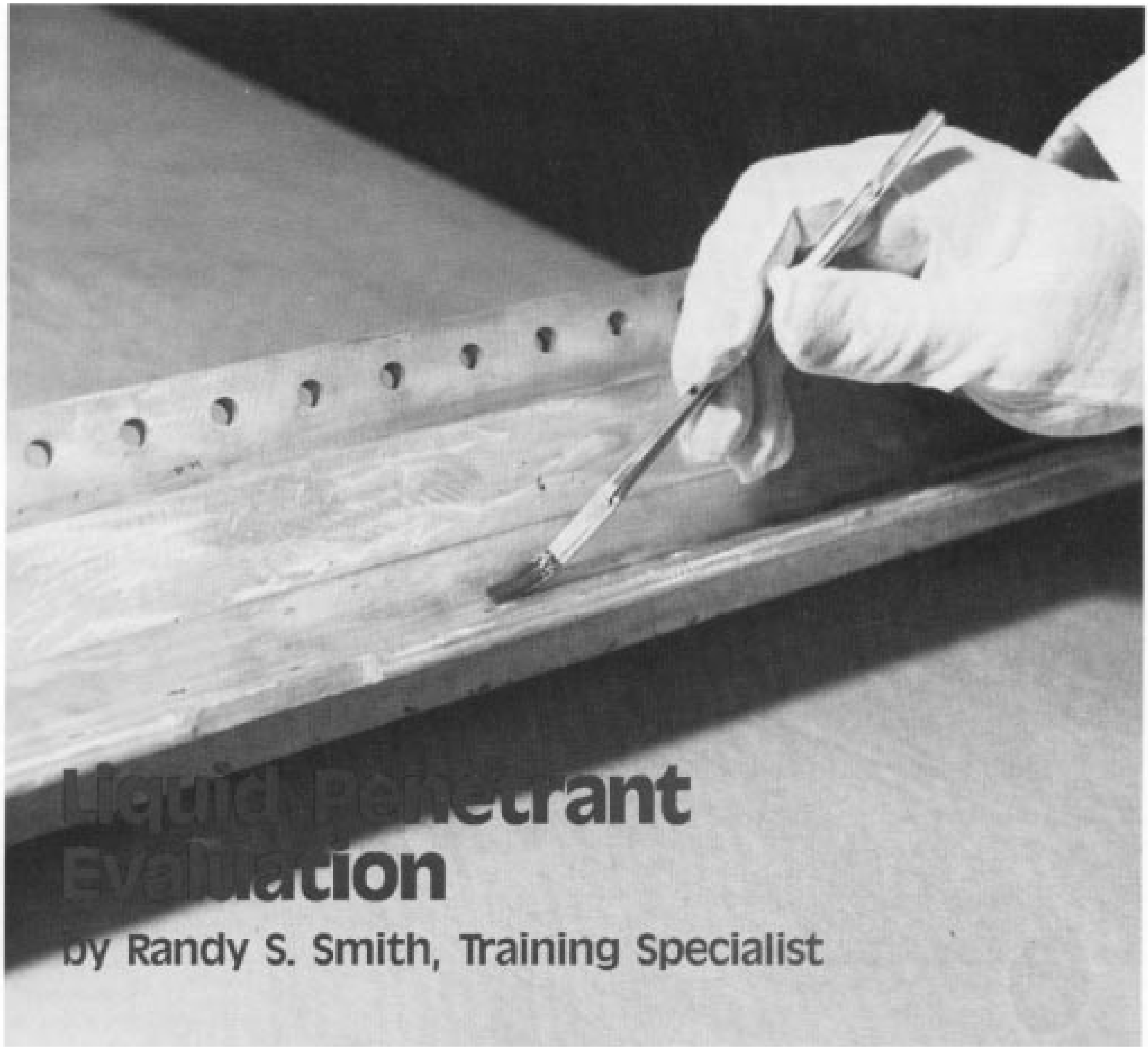

Liquid Penetrant Evaluation

by Randy S. Smith, Training Specialist

Volume 11, Number 2 of Service News magazine (April-June 1984), contained an article entitled "'An Introduction to Nondestructive Evaluation" in which many of the techniques used in aerospace applications of nondestructive evaluation are briefly described. In this article, one of the most important techniques, liquid penetrant evaluation, will be examined in greater detail.

Liquid penetrant evaluation is a quick and reliable nondestructive technique used for detecting various types of discontinuities which are open to the surface of a material. It can be used to inspect most nonporous materials such as metals and metal alloys, hard rubber, plastics, glass, and some ceramics. The types of discontinuities and defects which can be detected by this method include cracks, porosity, corrosion, seams, cold shuts, and forging laps (see glossary for definitions).

BASIC INSPECTION PRINCIPLES

The basic principle of liquid penetrant evaluation is to increase the visible contrast between a discontinuity and its background. This is accomplished by applying an oil-base liquid, called penetrant, to a surface to be inspected. Capillary action will cause the penetrant to enter any surface discontinuities that might exist (Figure 1).

After an adequate dwell time, the excess penetrant on the surface is removed with water, an emulsifier, or a solvent, depending on the particular inspection process employed. A developer, usually a white powder, is then applied to the surface of the material. This powder acts as a blotter and draws out the penetrant remaining in a discontinuity after the excess surface penetrant has

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GLOSSARY

Black Light – Ultraviolet radiation, approximately 3200 to 4000 angstroms in wavelength, essentially invisible to the human eye.

Capillary Action – The tendency of liquids to travel or climb when exposed to small openings such as cracks, pits, and fissures. It is due in part to such factors as surface tension, cohesion, adhesion, and viscosity.

Cold Shut – A discontinuity that appears on the surface of cast metal as a result of two streams of liquid meeting and failing to unite. Also, a portion of the surface that is partially separated from the main body of metal by oxide.

Corrosion – The deterioration of metal by chemical or electro-chemical reaction with its environment or other materials.

Crack – A discontinuity which has a relatively large cross-section in one direction and a small or negligible cross-section when viewed in a direction perpendicular to the first.

Forging Lap – A surface defect, appearing as a seam, caused by folding and then rolling or forging hot metal fins or sharp corners onto a surface without welding.

Porosity – Random pits or holes in the surface of an object caused by gases being liberated as the material solidifies.

Seam – A discontinuity caused by a void or crack in rolled material which although closed is not welded.

Water Break-Free Surface – A chemically clean surface upon which water, when applied, will momentarily remain in an even, continuous film.

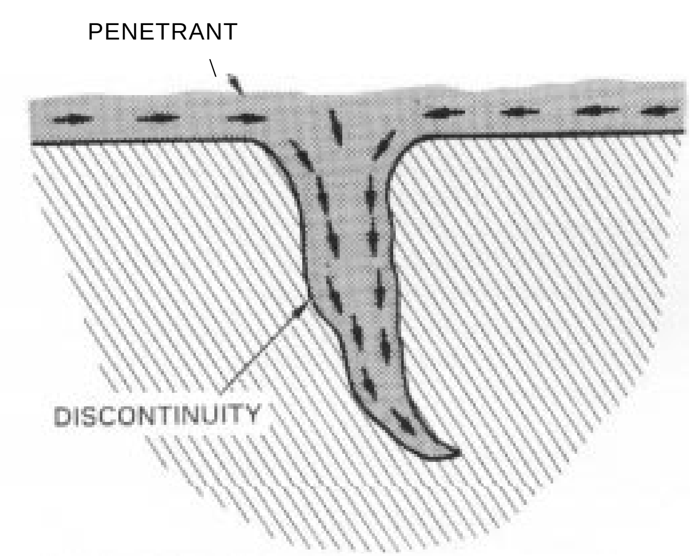

Figure 1. Penetrant enters a discontinuity by capillary action.

been removed. After sufficient developer dwell time, the part is inspected and any discontinuities evaluated in accordance with the appropriate repair manuals and inspection documents.

GENERAL PROCEDURES

There are six different processes that can be used for liquid penetrant evaluations. Three of the processes involve fluorescent dye penetrants and three involve visible dye penetrants. The fluorescent dye processes are identified as type I, methods A, B, and C; and the visible dye processes are identified as type II, methods A, B, and C. The following basic procedures are common to all liquid penetrant evaluations:

- Step l-Selecting the appropriate inspection process.
- Step 2-Precleaning the test article.

- Step 3-Predrying the test article.

- Step 4-Applying penetrant to the test article.

- Step 5-Removing the excess surface penetrant and drying the test article.

- Step h-Applying the developer to the test article.

= Step 7-Inspecting and evaluating the test article.

- Step 8-Postcleaning the test article.

Selection of the Inspection Process

The selection of the appropriate liquid penetrant evaluation process is very important and is dependent on seven basic factors:

- Inspection sensitivity required.

- Surface conditions of part or area to be tcstcd.

. Configuration or geometry of part to be tested.

- The number of parts to be tested.

- Testing facilities and equipment available.

- The effect of penctrant chemicals on materials being tested.

- Requirements previously established by applicable technical orders, inspection documents, and drawings.

Precleaning

The detection of a discontinuity in a material depends upon the flow of penetrant into the discontinuity. It is apparent that such a flow cannot take place if a discontinuity is filled with contaminants such as oil, grease, engine residue, corrosion, or water; or covered with paint or plating. It is, therefore, essential that the area being inspected be thoroughly clean and free of foreign materials. A small amount of contamination may not prevent penetrant from entering a discontinuity, but it could mask or cause misinterpretation of the indications.

There are several methods of cleaning available to the inspector. The selection of the best cleaning method depends on the type of material being inspected, the type of contamination present, and the type of surface coating on the material. Note that mechanical cleaning procedures such as scraping, wire brushing, grinding, and sand blasting should never be employed. These cleaning methods can cover up or mask discontinuities and prevent penetrants from entering.

Alkaline Cleaning

Alkaline cleaners are nonflammable water solutions containing specially selected detergents **for** wetting, penetrating, and emulsifying various types of contamination. After being thoroughly removed by rinsing, they leave a water break-free surface which is chemically and physically clean. Alkaline cleaners are generally used for removing inorganic contamination.

Water Cleaning with Detergents

Machines using hot water and detergents may be used to clean parts. After the part is cleaned and rinsed, it must be dried by heat to ensure evaporation of rinse water that may be trapped in a discontinuity. If the part is not heat-dried, water remaining in the discontinuity can prevent penetrant from entering. Drying temperatures should be limited to between 150 degrees F and 180 degrees F. This method is not recommended for cleaning oily or greasy parts.

Vapor Degreasing

Vapor degreasing is the preferred method of cleaning parts being prepared for liquid penetrant evaluation, especially those **covered with** oil, grease, and most other types of organic contamination. Vapor degreasers generally use a solvent, such as trichloroethylene, which will vaporize as it is heated. This method cleans out discontinuities better than any other cleaning procedure. Vapor degreasing not only cleans a part but also heats it so that no moisture remains in any discontinuities. Care should be taken when vapor degreasing aluminum or aluminum alloys. It is possible to actually heat-treat a part if it is left in the degreasing tank too long.

Solvent Cleaning

Solvent cleaning is probably the most widely used method of cleaning a part prior to liquid penetrant evaluation. Solvent-type cleaners are generally used for hand-cleaning when the equipment needed for alkaline cleaning, water and detergent cleaning, and vapor degreasing is not available. Solvent cleaners are usually supplied in pressurized spray cans and are especially useful for inspecting small areas and for flight line use. The most widely used solvents are those that contain trichloroethylene or trichloroethane. Manufacturer's instructions should be carefully observed at all times. Some solvents used for this purpose are flammable and all must be used in well-ventilated areas.

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Figure 2. Recirculating hot air dryer.

Paint Removal

Paint must be removed from a test article before liquid penetrant testing by applying an approved paint stripper. The kinds of strippers that can be used include bond release-type, solvent-type, and hot tank-type. It is recommended that vapor degreasing or solvent cleaning be done after the paint has been removed from the area to be inspected. When stripping aluminum or magnesium, special care must be taken. Many paint strippers are not suitable for these metals.

Predrying

All parts must be completely dry before application of penetrant. This is to ensure that all water and cleaning agents have been removed from any discontinuities.

There are several acceptable methods of drying a part. They include hand wiping with a dry, lint-free cloth, compressed air drying, warm air drying, oven drying, and recirculating hot air drying. Of these methods, recirculating hot air drying provides the best overall coverage and evaporation. Figure 2 shows a typical recirculating hot air dryer. When using either oven or recirculating hot air drying, care should be taken not to overheat the part. Drying ovens and recirculating dryers should have the temperature maintained between 150 degrees F and 180 degrees F. Under no circumstances should the temperature exceed 225 degrees F.

Applying Penetrant

There are two types of penetrant used in liquid penetrant evaluation-fluorescent dye and visible dye. Penetrant can be applied to a test article by flow-on, dipping, brushing, or spraying. Any of these methods of application can be employed provided that the area to be inspected is completely covered with penetrant. The penetrant is allowed to remain on the test article for a

MATERIAL	FORM	TYPE OF DISCONTINUITY	WATER-WASHABLE PENETRATION TIME (MINUTES)*	POST-EMULSIFIED PENETRATION TIME (MINUTES)*
Aluminum	Castings	Porosity	5to 15	5**
		Cold shuts	5to 15	5**
	Extrusions and forgings	Laps	N/R	10
	Welds	Lack of fusion	30	5
		Porosity	30	5
	All	Cracks	30	10
		Fatigue cracks	N/R	30
Magnesium	Castings	Porosity	15	5 ”
		Cold shuts	15	5**
	Extrusions and forgings	Laps	N/R	IO
	Welds	Lack of fusion	30	IO
		Porosity	30	IO
	All	Cracks	30	10
	All	Fatigue cracks	N/R	30
Steel	Castings	Porosity	30	IO**
		Cold shuts	30	IO**
	Extrusions and forgings	Laps	N/R	10
	Welds	Lack of fusion	60	20
		Porosity	60	20
	All	Cracks	30	20
	All	Fatigue cracks	N/R	30
Brass and bronze	Castings	Porosity	10	5**
		Cold shuts	10	5””
	Extrusions and forgings	Laps	N/R	10
	Brazed parts	Lack of fusion	15	10
		Porosity	15	IO
	All	Cracks	30	10
Plastics	All	Cracks	5 to 30	5
Glass	All	Cracks	5 to 30	5
Carbide-tipped tools		Lack of fusion	30	5
		Porosity	30	5
		Cracks	30	20
Titanium and high tempera-ture alloys	All		N/R	20 to 30
All metals	All	Stress or inter-granular corro-sion	N/R	240

*For parts having a temperature of 60” F or higher
**Precision castings only
N/R – Not Recommended

Figure 3. **Typical liquid penetrant evaluation dwell times table.**

specific dwell time as determined by a dwell times table (Figure 3).

Removing Excess Surface Penetrant

After the penetrant has remained on the test article for the specified time, the excess penetrant must be removed from the surface. There are three methods of removing excess surface penctrant. They are water spray, emulsifier followed by water spray, and solvent-moistened cotton cloth. The method to be used depends on the inspection process employed.

Applying Developer

After the excess surface penetrant has been removed, developer is applied to the surface. The developer acts as a blotter to draw out penetrant from a discontinuity and provides a color contrast background for the penerrant.

There are three general types of developers: wet, dry, and nonaqueous. Developers are usually applied by dipping, dusting (dry developers only), or spraying.

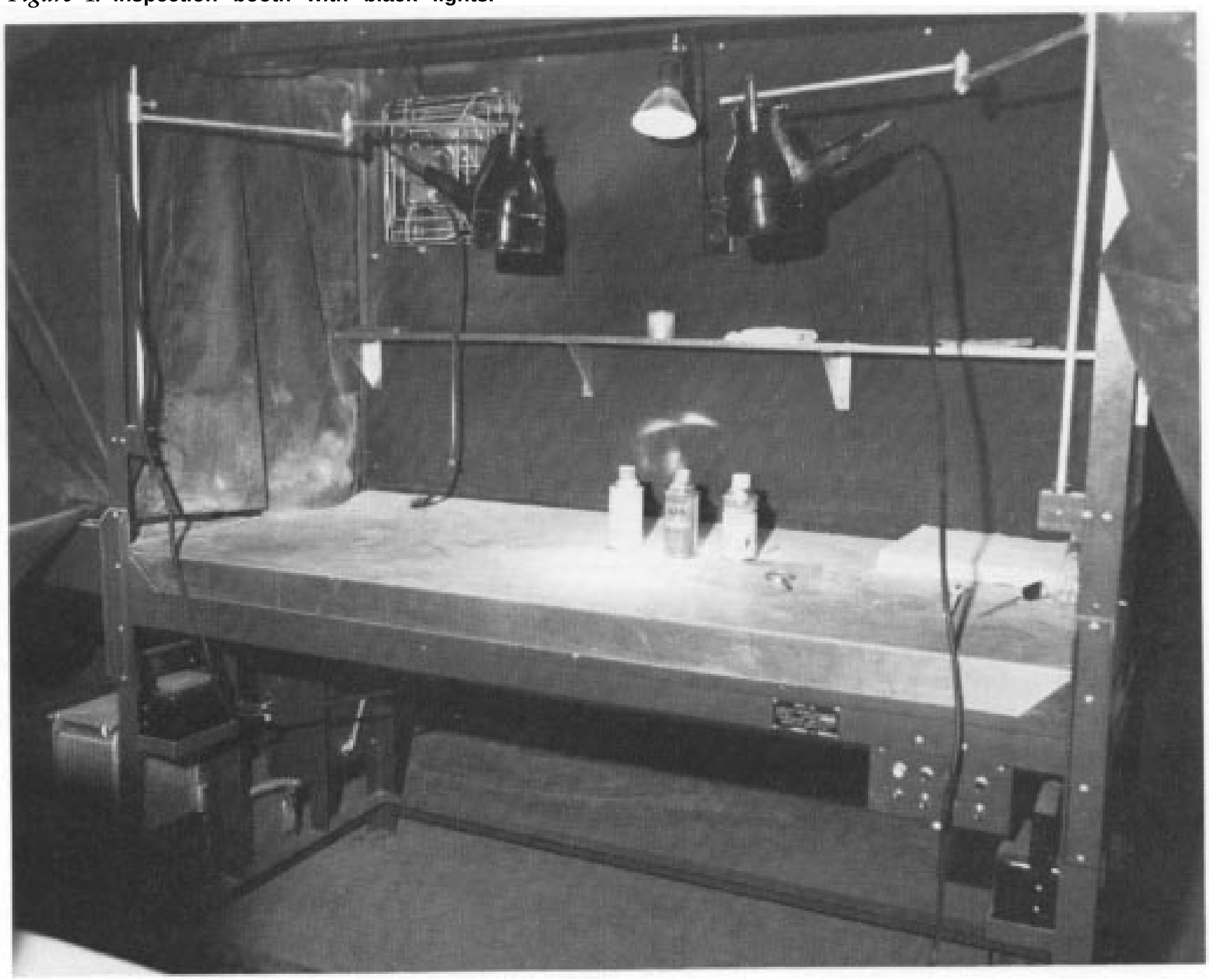
Inspecting and Evaluating

Inspecting and evaluating a part is **done** with either a high-intensity white light or an ultraviolet light, depending on the type of penetrant used for the inspection. If fluorescent penetrant is used, the inspection must be carried out in a darkened booth (Figure 4) or under a dark hood. Evaluations of the indications must be done using applicable inspection documents and maintenance manuals. Optical equipment such as magnifying glasses and microscopes are often used as inspection aids.

Postcleaning

Cleaning the test article must be accomplished after liquid penetrant evaluation. If it is not, the residue from

Figure 4. **Inspection booth with black lights.**



the **penetrant may** promote corrosion. Penetrant residue will also prevent the proper adhesion of paint on those parts or inspection areas that must be repainted after the inspection. Vapor degreasing or solvent cleaning are adequate for the postcleaning process.

PENETRANT TESTING TYPES AND METHODS

There are two basic types of liquid penetrant evaluations. Type I employs the use of fluorescent penetrants (normally green) and type II employs the use of visible dye penetrants (normally red). Within each type, there are three inspection methods, referred to as methods A, B, and C. Each method within a type uses a specific group of materials: method A materials consist of a water-washable penetrant and developers; method B materials consist of a postemulsified penetrant, an emulsifier, and developers; and method C materials consist of a solvent-removable penetrant, a penetrant remover, and developers.

Type 1 penetrants are oil-base liquids that contain a fluorescent dye. Fluorescent penetrants are normally used in the inspection of aircraft parts and components because of their higher sensitivity than visible dye penetrants. Indications from fluorescent penetrants will show up as brilliant yellow or green lines or spots which will take the form of the discontinuity. The indications will glow or fluoresce when subjected to ultraviolet radiation from a “black” light.

Type II penetrants are also oil-base liquids, but they contain a visible dye instead of a fluorescent one. Visible dye penetrants are normally used in industrial applications such as power plants, mills, and automobile factories. Indications from visible dye penetrants show up red the same way as do fluorescent penetrants except that a high-intensity white light is used to illuminate the surface. Type 11 penetrant evaluations are not normally used in the aircraft industry, and Lockheed engineering does not recommend their use on the Hercules aircraft. For this reason the following discussion describing inspection processes will cover only the **fluorescent penetrant** processes. It should be remembered, however, that methods A, B, and C of type I evaluation are virtually the same as methods A, B, and C of the type II process as far as the procedures themselves are concerned.

Type I, Method A Inspection Process

Type I, method A liquid penetrant materials consist of a water-washable fluorescent dye penetrant and dry, wet, and nonaqueous developers. These materials are classified as group IV materials as outlined in specification MILI-25135. The penetrant has an emulsifying agent that makes it removable with water.

Following precleaning and drying, penetrant is applied to the inspection area by flow-on, dipping, brushing, or spraying. The penetrant is allowed to remain on the inspection area for the time specified in the dwell times table (Figure 3).

After the penetrant has been on the surface for the appropriate amount of time, the excess surface penetrant is flushed from the area by spraying cold water at 20 to 30 psi across the surface. A black light should be used in conjunction with the rinsing process to ensure that all the excess surface penetrant has been removed. However, care should be taken not to “overwash” the inspection area. Figure 5 shows a typical rinse station equipped with a black light.

After the excess surface penetrant has been removed, the developer is applied. If a wet developer is to be used, it may be applied immediately after rinsing off the excess penetrant If a dry or nonaqueous developer is to be used, the part or inspection area must first be dried in a drying oven or with a blow dryer. Maintain the temperature **in** the drying oven to the same temperaturc range as **that** given in the section on predrying; i.e. 150 degrees F to 180 degrees F.

Developer dwell time is usually between 10 and 20 minutes. After the appropriate dwell time, the area is inspected in a darkened booth with a black light (Figure 4), and any discontinuities are evaluated. After the part has been inspected and evaluated, it should be postcleaned.

Type I, Method B Inspection Process

Type I, method B liquid penetrant materials **consist** of a fluorescent penetrant, an emulsifier, and dry, wet, and nonaqueous developers. These materials are classified as groups V and VI materials per specification MIL I-25135. The primary difference between group V and group VI is that group VI materials have greater sensitivity.

This inspection process is essentially the same as the type I, method A process except that an emulsifier is applied to the part or inspection area after the appropriate penetrant dwell time. The purpose of the emulsifier is to make the penetrant water washable. The emulsifier can be applied to the part by dipping, spraying, or flow-on. Emulsifier dwell time for normal tests is 1 to 3 minutes with a maximum of 5 minutes. Optimum emulsification time should be determined by test. After emulsification, the process continues as in method A.

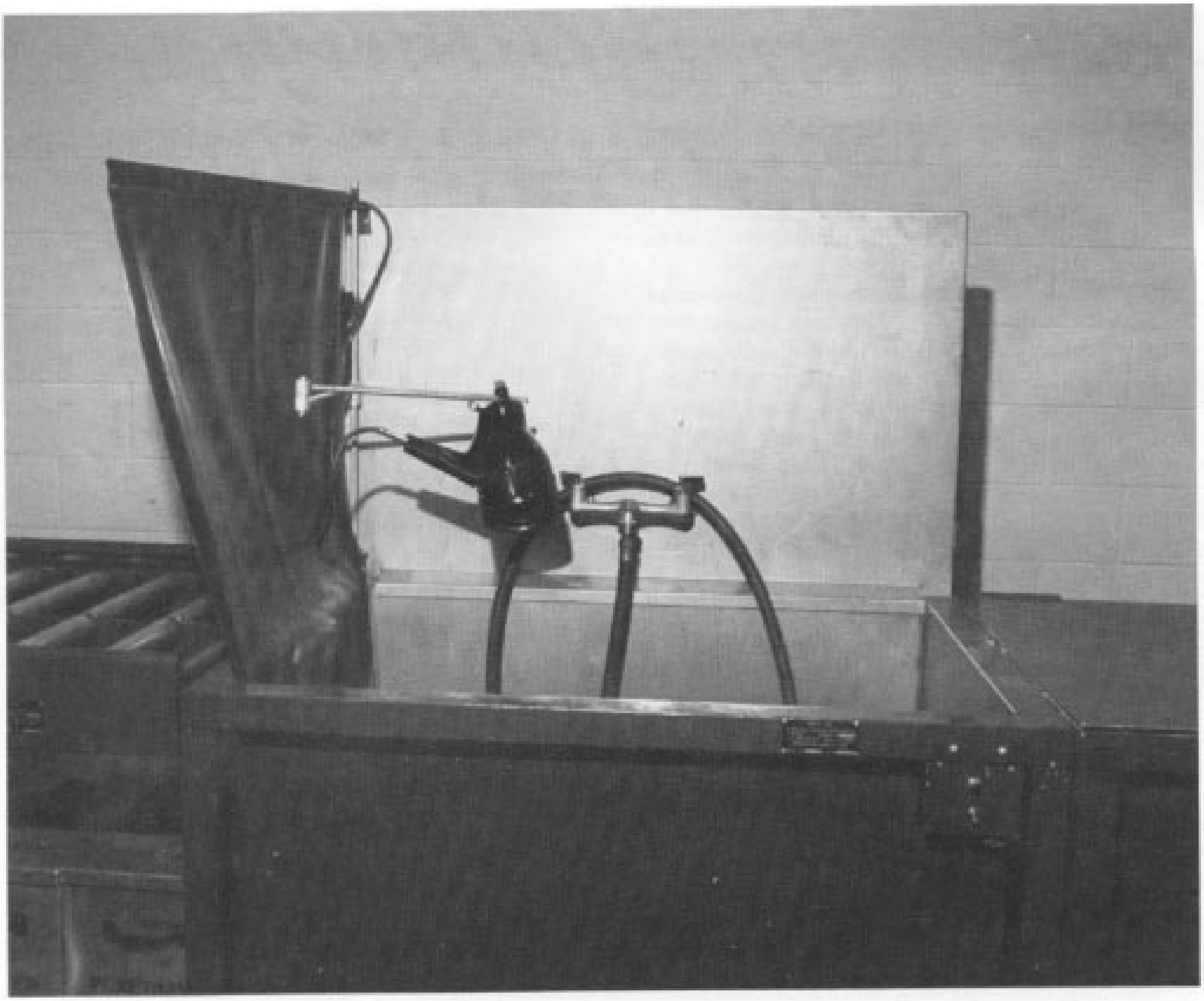


Figure 5. Typical rinse station equipped with a black light.

Type I, Method C Inspection Process

The materials for this process consist of a solvent-removable fluorescent penetrant, a penetrant remover, and dry and nonaqueous developers, all of which are classified as group VII materials.

The type 1, method C inspection process does not include an emulsification or water rinse, which makes this process highly portable. After the appropriate penetrant dwell time, the excess surface penetrant is removed by hand wiping the surface with a clean, lint-free dry cloth saturated with an approved penetrant remover. The solvent should never be applied directly to the inspection area and wiping should be in one direction only to avoid streaking. After the surface is clean, the developer is applied. The part is then inspected and any discontinuities evaluated. After evaluation, the part is postcleaned.

Type II, Methods A, B, and C Inspection Processes

Type II, methods A, B, and C liquid penetrant materials are essentially the same as for type I, methods A, B, and C except that a visible dye penetrant is used in lieu of a fluorescent penetrant. Type II, method A, B, and C materials are classified as groups III, II, and I materials, respectively, as outlined in specification MILI-25135.

PENETRANT DWELL TIMES

Adequate penetrant dwell times are a vital step in liquid penetrant evaluations. An inadequate dwell time may not allow a discontinuity to be fully indicated. Optimum penetration times should be determined and established by trial on identical parts or materials when possible. Otherwise use the dwell times table (Figure 3), which indicates the minimum dwell times for a number of materials with respect to different types of discontinuities. Longer penetration time or additional penetrant application may be necessary for questionable parts to ensure full indication of discontinuities.

LIQUID PENETRANT EVALUATION EQUIPMENT

Black Light

The fluorescent penetrants used in the type I inspection processes fluoresce (glow) brilliantly when exposed to ultraviolet (UV) radiation from a "black" light. Black light is a term applied to invisible radiant energy in that portion of the electromagnetic spectrum having a wavelength of approximately 3200 to 4000 angstroms. Black light assemblies consist of a 100-watt mercury vapor bulb, a filter, and a current-regulating transformer (Figure 6).

The purpose of the filter is to allow passage of only those wavelengths of near UV radiation that will cause type I penetrants to fluoresce, and to block the passage of very harmful UV radiation below 3000 angstroms.

The intensity of the UV radiation is a very important factor in obtaining optimum response from a type I penetration indication. The recommended intensity for black lights is 800 microwatts per square centimeter at a distance of 15 inches from the test specimen.

Extreme caution must be observed when working with a black light. The operator must be careful not to touch the light when it is on because the bulb and filter assembly get very hot when in use. Also, the filter must be clean and in good condition at all times. The operator must never look directly into a black light. A scratched or broken filter will permit the passage of UV radiation that is harmful to the skin and eyes.

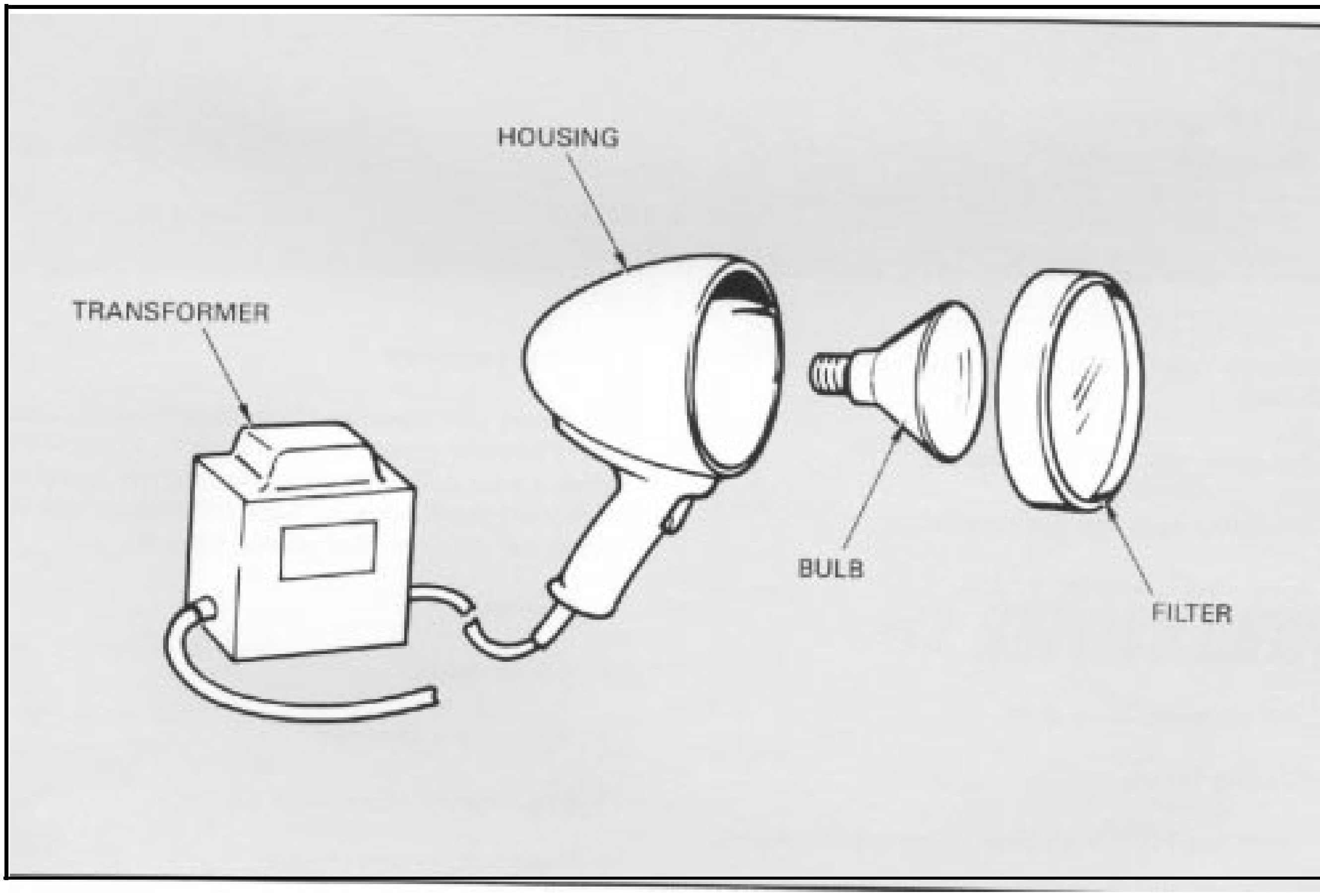
Normal procedure for using a black light is to leave it on for the duration of the inspection and evaluation. Normal warm-up time is 5 to 10 minutes. If the unit is turned off, a 10- to 15-minute wait is required to allow the bulb to cool sufficiently before turning the light back on.

Stalionary Penetrant Inspection Units

Stationary inspection units are normally used for conducting penetrant evaluations using methods A and B of both type I and type II processes. These units arc capable of handling parts of various sizes and shapes.

Figure 7 shows a typical stationary inspection unit

Figure 6. Black light assembly.



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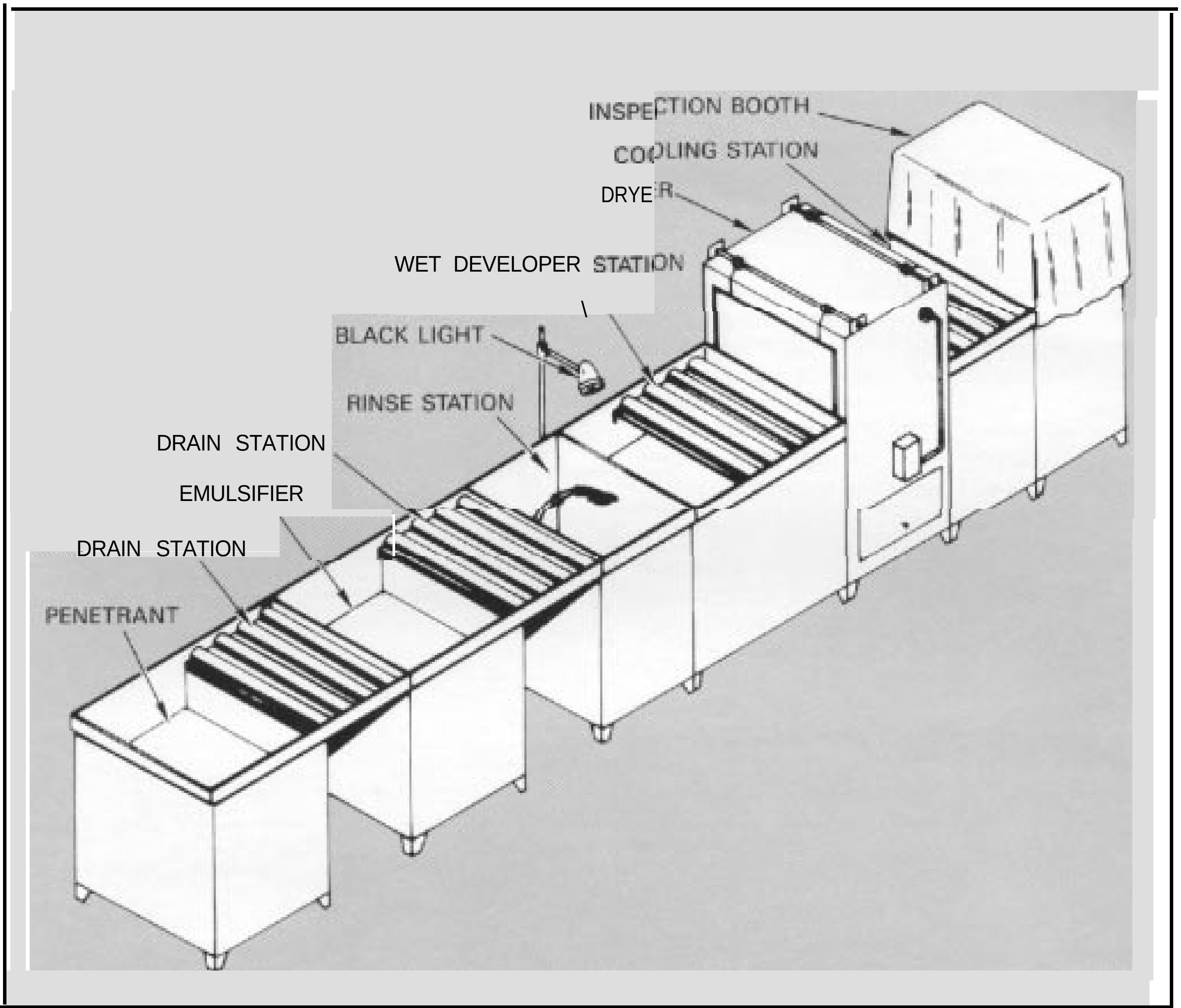


Figure 7. Type I, method B stationary inspection unit.

used in the type I, method B process. It consists of the following:

- Penetrant tank and drain station.
- Emulsifier tank and drain station.
- Rinse station with black light.
- Wet developer station.
- Hot air recirculating dryer.
- Cooling station.
- Inspection booth with black lights and an exhaust fan.

Portable Equipment

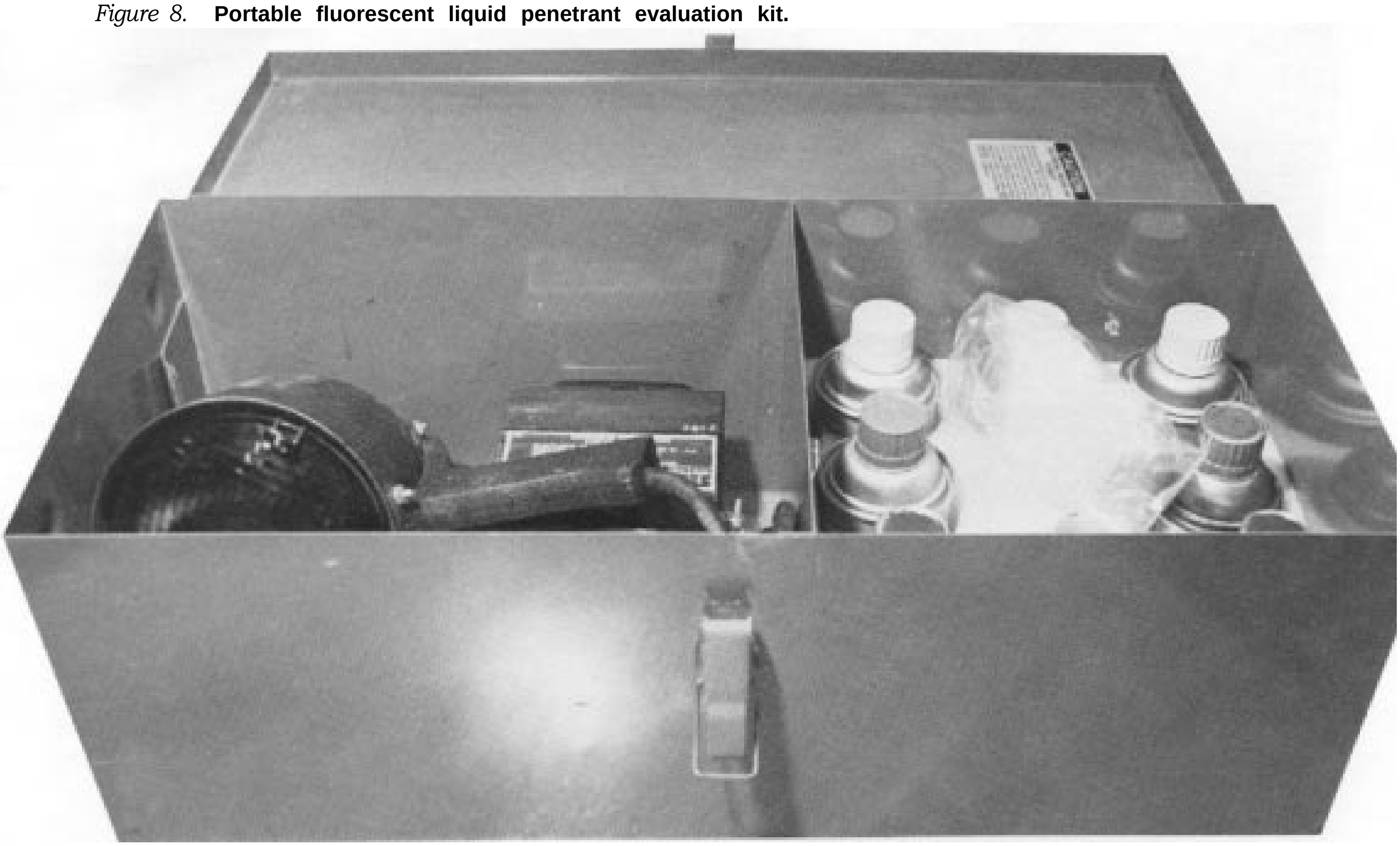
Method C of types I and II are usually accomplished using portable penetrant kits (Figure 8). Portable kits allow a great deal of flexibility and are very useful for inspecting small areas on large components and for flight line use. The kits typically contain:

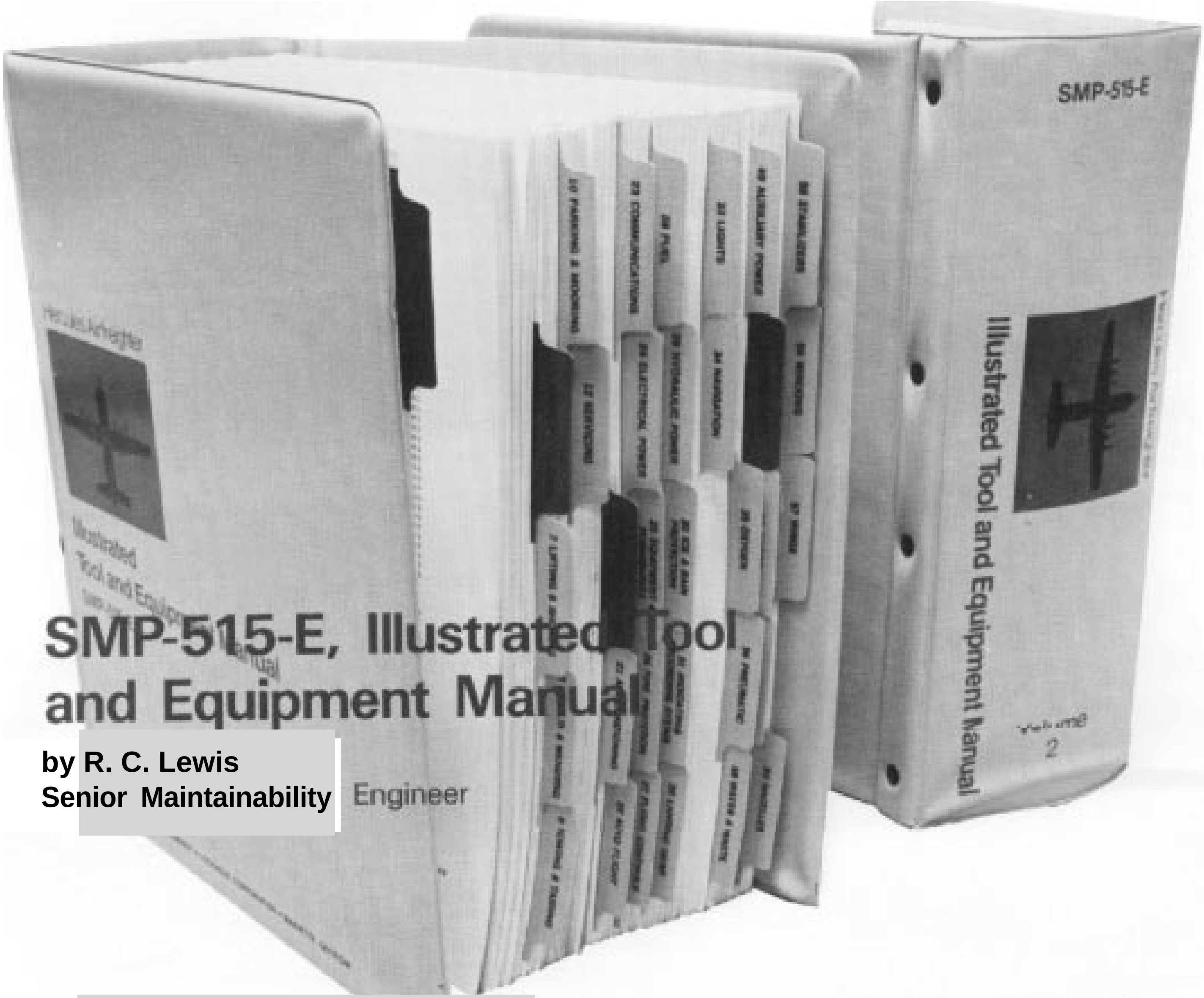
- Penetrant.
- Solvent cleaner.
- Nonaqueous developer.
- Dry developer (fluorescent kit only).
- Wiping cloths and brushes.

• Black light and hood to provide darkened area for viewing indications (fluorescent kit only).

It is the intention of this article to give Service News readers a useful **overview of** the various liquid penetrant evaluation techniques that are available to the NDE technician. Please note, **however, that there** is much more involved in carrying out the procedures described safely and successfully than can be contained in a discussion of this scope. Be sure that any and all NDE procedures undertaken in your organization are carried out only by qualified NDE technicians following the applicable instructions and safety precautions contained in the appropriate maintenance manuals.

Figure 8. **Portable fluorescent liquid penetrant evaluation kit.**





SMP-515-E, Illustrated Tool and Equipment Manual

by R. C. Lewis
Senior Maintainability Engineer

The SMP-515-E Illustrated Tool and Equipment Manual is a Lockheed-Georgia Company service manual, published and distributed by the Support Equipment Design Department for use by all Hercules aircraft (L-lOO and C-130) maintenance personnel and operators.

The recipients of SMP-515-E are 78 LlOO/C-130 operators located in some 47 countries, as well as Lockheed-Georgia Company's domestic representatives and Lockheed-Georgia International Services offices world-wide.

SMP-515-E is a catalog of special tools and support equipment which is keyed to L-lOO/C-130 maintenance operations. It is arranged, as nearly as possible, by systems as defined in Air Transport Association Specification 100, Section 1-2-O. A commercial, rather than military, arrangement was selected because the application is predominantly commercial. Additional chapters have been added as necessary to include support equipment for functions not covered in Section 1-2-O.

Each item of support equipment is presented in a format adapted from that used in the MILHDBK-300, Technical Information File of Ground Support Equipment. Major emphasis is placed on clarity and accessibility of the information covering each entry in the manual. Included arc a functional description, full technical data, and an illustration of the item under discussion.

There are approximately 600 support equipment items included in the manual, ranging from small hand tools to powered ramp sweepers and aircraft loading/unloading vehicles. Many of the items listed are applicable to

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other aircraft, or can be adapted to other aircraft and aircraft applications.

With the equipment selected from SMP-515-E, line and shop support can be provided for each system on the aircraft. System and component overhaul capability can also be provided when required, but the vast number of items involved in programs of this type prohibit the inclusion of all of them in the manual. Based on customer needs, entire facilities can be designed and equipped to accommodate any degree or level of maintenance.

One of the charters of the Support Equipment Design Department is to provide L-lOO/C-130 operators with the latest state-of-the-art equipment. Each new or proposed piece of equipment is analyzed for its application, utilization, ease of service and repair, component parts availability and commonality, overall impact on the maintenance program, and economic feasibility. Operation, maintenance, and parts handbooks for each piece of equipment are reviewed for accuracy, comprehensibility, and completeness. Existing support equipment in SMP-515-E is likewise reexamined and reviewed on a regular basis as part of the ongoing manual updating effort.

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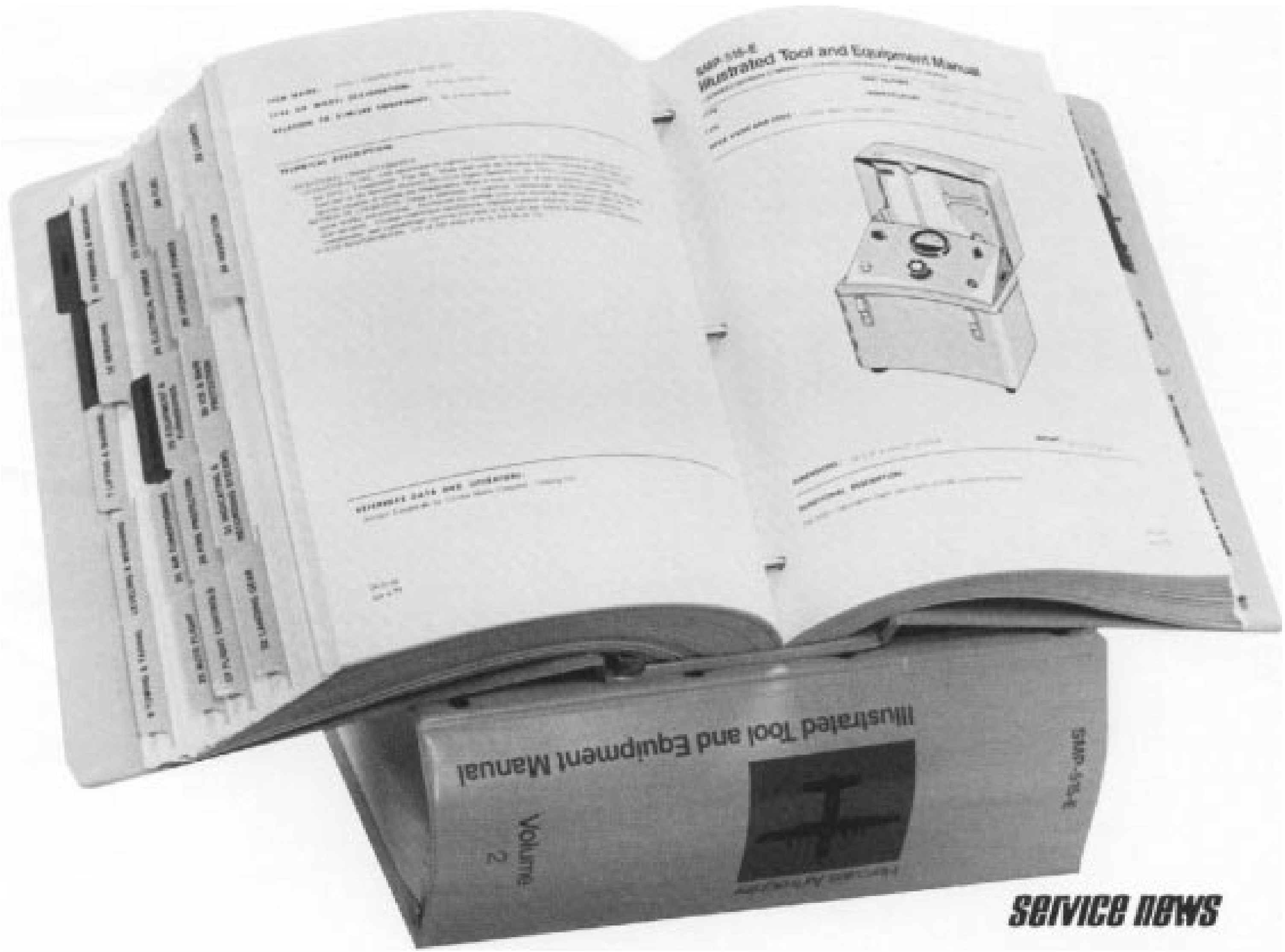

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