AN INVESTIGATION OF PENETRANT TECHNIQUES FOR DETECTION OF
MACHINING-INDUCED SURFACE-BREAKING CRACKS
ON MONOLITHIC CERAMICS

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Date Published: February 1996

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Funded by
Propulsion System Materials Program
Office of Transportation Technologies
the Assistant Secretary for Energy Efficiency and Renewable Energy
U.S. Department of Energy
EE 51 05 00 00

for
OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee 37831
managed by
LOCKHEED MARTIN ENERGY RESEARCH CORPORATION
for the
U.S. DEPARTMENT OF ENERGY
under contract DE-AC05-96OR22464

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Table of Contents

<u>Topic</u>	<u>Page</u>
Abstract.....	v
1. Introduction	1
2. Purpose	2
3. Approach	2
4. Results	2
a. Literature Review	2
b. Experimental Results	3
Part 1: Gaseous diffusion, Charged Particle, and Visible Dye.....	3
Part 2: Fluorescent Penetrants	7
5. Recommendations	18
6. References.....	18
Appendix A. Product Sheets.....	21
A.1 Magnaflux.....	23
A.2 Sherwin.....	39
Appendix B. List of Dye Penetrant Suppliers.....	43

 

Abstract

The purpose of this effort was to evaluate penetrant methods for their ability to detect surface-breaking cracks in monolithic ceramic materials with an emphasis on detection of cracks generated by machining. There are two basic penetrant types, visible and fluorescent. The visible penetrant method is usually augmented by powder developers and cracks detected can be seen in visible light. Cracks detected by fluorescent penetrant are visible only under ultraviolet light used with or without a developer. The developer is basically a powder that wicks up penetrant from a crack to make it more observable.

Although fluorescent penetrants were recommended in the literature survey conducted early in this effort, visible penetrants and two non-standard techniques, a capillary gaseous diffusion method under development at the institute of Chemical Physics in Moscow, and the "statiflux" method which involves use of electrically charged particles, were also investigated. SiAlON ring specimens (1 in. diameter, 3/4 in. wide) which had been subjected to different thermal-shock cycles were used for these tests.

The capillary gaseous diffusion method is based on ammonia; the detector is a specially impregnated paper much like litmus paper. Advantages of this method were low after-test residuals and low environmental impact, while disadvantages included poor resolution power and poor-shape adaptability of the paper detector. As expected, visible dye penetrants offered no detection sensitivity for tight, surface-breaking cracks in ceramics. Although the non-standard statiflux method showed promise on high-crack-density specimens, it was ineffective on limited-crack-density specimens. The fluorescent penetrant method was superior for surface-breaking crack detection, but successful application of this procedure depends greatly on the skill of the user. Two presently available high-sensitivity fluorescent penetrants were then evaluated for detection of microcracks on Si₃N₄ and SiC from different suppliers. Although 50X optical magnification may be sufficient for many applications, 200X magnification provides excellent detectability.

Research sponsored by the U.S. Department of Energy, Assistant Secretary for Energy Efficiency and Renewable Energy, Office of Transportation Technologies, as part of the Ceramic Technology Project of the Propulsion Systems Materials Program, under contract DE-AC05-96OR22464 with Lockheed Martin Energy Research Corporation.

An Investigation of Penetrant Techniques for Detection of Machining Induced Surface-Breaking Cracks on Monolithic Ceramics

by

G. A. Forster and W. A. Ellingson

1. Introduction

Detection of surface breaking cracks by low-cost penetrant methods has been an accepted nondestructive evaluation method for use on metal for many years and has been shown to be especially useful for defect detection on castings and weldments. Application of penetrants to ceramic components is relatively new. The American Society for Testing Materials (ASTM) developed a penetrant standard, E165-91 covering generalized penetrant test methods. This is supplemented by other standards that cover specific penetrants and methods. These standards have also been adopted by the American Society of Mechanical Engineers (ASME). However, standard E165-91 specifically does not address environmental or other safety problems related to the use of any materials or solvents, leaving that responsibility to the user. There are many penetrant methodologies available, but there are two basic penetrant types, visible and fluorescent. However, recent work (1,2) has suggested that fluorescent penetrants are best for ceramics.

The visible penetrant method usually is augmented by powder developers and cracks detected can be seen in visible light. Cracks detected by fluorescent penetrant are visible only under stimulation by ultraviolet light. Fluorescent penetrant is used with or without a developer. The developer is basically a powder that wicks up penetrant from a crack to make it more observable.

Although fluorescent penetrants had been recommended in the literature, we briefly assessed visible penetrants as well as two unconventional crack detection "penetrant" methods. The two unconventional methods were: (a) "Statiflux", a method using a statically charged powder which adheres to cracks where there is a disruption of dielectric field and (b) a gaseous diffusion method under development in Russia wherein a gas (ammonia) diffuses into cracks and a detector utilizing treated paper is laid over the surface and changes color in

response to the gas coming from the cracks leaving a mirror image of any crack pattern.

2. Purpose

The purpose of this project was to evaluate penetrant methods for their ability to detect surface-breaking cracks in monolithic ceramic materials with an emphasis on detection of cracks generated by machining.

3. Approach

The approach used in this project was to first review the available literature and contact domestic ceramics suppliers to obtain the current status of penetrant application from their point of view. We also contacted manufacturers of dye penetrants and related materials. The second step was to conduct laboratory investigations to assess current approaches and to perhaps provide a direction for continued study should the results show promise.

4. Results

a. Literature Review

A review of the literature showed that there had been only limited publication on use of penetrants for ceramics materials. The most applicable and promising was the work of Horton (1), who demonstrated that use of fluorescent penetrants on highly polished ceramic ball bearings could detect critical cracks for rolling contact fatigue applications. What this work suggested was the apparent need for optical magnification when examining ceramics using fluorescent penetrants. All work here was on highly polished surfaces with surface finishes of $R_a < .5 \mu\text{m}$. Kölker, et al. (2), suggested that fluorescent penetrants could detect cracks with less than $0.1 \mu\text{m}$ opening and further, that these applications could be made on "green" bodies although "green" conditions were not specified. In 1993, Maling et al. (3), published an article which illuminated the concerns about environmental issues related to disposal of penetrants. Fluorescent penetrants use halocarbons (e.g., trichloroethylene) and the renewal of the Clean Air Act, the Clean Water Act and the Resources Conservation and Recovery Act

caused focus on the environmental "unfriendliness" of these halocarbons. Table 1 shows the environmental concerns as a function of the steps in the penetrant process and what is currently under study.

We also conducted a limited telephone survey. In this survey, ceramic component manufacturers indicated that they use fluorescent penetrant inspection (FPI) of their products on a routine basis. The materials and procedures used were considered proprietary. They also said they were addressing problem chemicals such as trichlorethylene in their procedures.

b. Experimental Results

Part 1: Gaseous diffusion, Charged Particle, and Visible Dye

Our exploratory effort to evaluate penetrant technologies included two non-standard techniques. These non-standard techniques were: (a) a capillary gaseous diffusion method (4) being developed at the Institute of Chemical Physics in Moscow, Russia, and (b) a charged particle method which involves use of electrically charged particles. This is a product produced by Stresscoat, Inc., of Upland, California.

Capillary Gaseous Diffusion

Very tight surface-breaking cracks in ceramics may be detectable by use of an appropriate gas instead of a liquid. Recently, a capillary gaseous diffusion method based on ammonia has been described by Marotta Scientific (4). In this method, a part under study is placed in a chamber with an environment containing gaseous ammonia. The overpressure is low, ≈ 0.1 atm. The "soak" time is dependent upon the part. The detector currently is a special impregnated paper similar in many respects to litmus paper. The rigidity of the paper detector limits the usefulness as complex contours cannot be followed by the "felt-like" paper detector. This method was studied at Argonne and the Russian scientists developing this technology visited Argonne and spent 2 days running tests. The obvious advantages are: a) low after-test residuals and b) low environmental impact. The current disadvantages are: a) the

Table 1. Environmental Issues in FPT Processes (from Malins et al.)

FPT Process Station	Environmental Issues in Conventional Implementations	Environmental Improvement Approaches	Residual Environmental Issues
Station 1: Part Cleaning	<ul style="list-style-type: none"> Degreaser solvent wastes (organic or halocarbon solvents); health, safety, and environmental aspects of solvent vapor escape. Sludge, grease, coating debris removed from part (dispersed in degreaser solvent). 	Convert to non-solvent based cleaning and degreasing process such as steam cleaning or supercritical fluid cleaning (eliminates issues with solvent waste and solvent vapor escape).	Will still produce some form of aqueous-based oil or grease waste stream for treatment even if wash liquids (e.g., water for steam) are treated/recycled.
Station 2: Dye Applications	<ul style="list-style-type: none"> Waste organic solvent from dye solution; health, safety, and environmental aspects of solvent vapor escape. Toxic (possibly carcinogenic) dye compound (concentrated form and in solvent). 	For high sensitivity, probably cannot eliminate organic solvents. However, system can be changed to more benign solvents and equipment design can be adjusted to minimize vapor escape. Recycling solvent can limit waste output.	Dye will eventually degrade to point where it must be removed; with solvent recycling, volume can be minimized.
Station 3: Dye Rinsing	<ul style="list-style-type: none"> Rinse water contaminated with organic solvent. Rinse water contaminated with toxic (possibly carcinogenic) dye compound. 	Equipment design can be optimized to minimize the volume of rinse water required; rinse water can be treated/recycled to minimize volume fluid requiring disposal.	Some amount of organic contaminated waste water will require disposal even with treatment or recycling.
Station 4: Emulsifier Application	<ul style="list-style-type: none"> Used/aged emulsifier solution (surface penetrant in water) Wash water contaminated with emulsion of dye, dye solvent. 	Switch completely to aqueous systems to eliminate solvents and minimize organics in rinse output; treat/recycle wash water to minimize volume requiring disposal.	Some amount of organic contaminated waste water will require disposal even with treatment or recycling.
Station 5: Developer Application	<ul style="list-style-type: none"> Used/aged developer solution/dispersion (possibly made of an organic solvent) Biocides in developer solution/dispersion. 	Switch to water-based developer dispersions (or to dry developers); convert to biocides that degrade or can be removed during waste treatment.	Some amount of organic contaminated waste water will require disposal even with treatment or recycling.
Station 6: Flaw Detection	<ul style="list-style-type: none"> (Health and safety issues but no effluent environmental issues). 	NA	NA
Station 7: Part Cleaning	<ul style="list-style-type: none"> Possibly organic or halocarbon wash solvent for removing developer and dye. Rinse water contaminated with developer and dye/dye solvent. Possible health, safety, environmental issues of cleaning solution vapors. 	Convert to non-solvent based cleaning and degreasing process such as steam cleaning or supercritical fluid cleaning (eliminates issues with solvent waste and solvent vapor escape).	Will still produce some form of aqueous based oil or grease waste stream for treatment even if wash liquids (e.g., water for steam) are treated/recycled.

poor resolving power of the detector as the up-take of ammonia in the detector spreads giving a false crack width and b) the poor shape adaptability of the paper detector.

Charged Particle

A method previously explored several years ago by one of the investigators (G. Forster) for application to glass insulators, is a method called "Statiflux." In this method, electrostatically charged power is deposited on a non-conducting specimen and the charged particles tend to cluster at crack lines on the surfaces. This method was tested but soon eliminated because of poor detection on simulated crack specimens. The particle sizes were too large for the crack sizes under study.

Visible Dye

Just to check the reported poor detection of visible dye technology, an exploratory test was conducted. Indeed visible dye penetrants offer no detection sensitivity for tight surface breaking cracks in ceramics.

Test Specimens

The comparison of these test methods was done using a set of four 25 mm diameter, 18 mm wide SiAlON ring specimens which had been subjected to different thermal shock cycles: 0, 1, 2, 3 thermal shocks with the tests being done at 600°C using water as the quench.

The results of comparing crack detection of these three methods is shown in Fig. 1 where the same segment of the surface of one specimen is shown. From these results, statiflux was shown to have the superior detection based on visual observation. However, application of fluorescent penetrant on the same specimen gives the results shown in Fig. 2 which clearly provides sharper and better spatial definition.

Fig. 1. Comparison of dye penetrant methods. (a) visible dye penetrant, (b) gaseous diffusion and (c) statiflux, on the same piece of SiAlON 25 mm dia x 18 mm long.

Fig. 2. Same sample as in Fig. 1 but treated with fluorescent penetrant.

Part 2: Fluorescent Penetrants

The statiflux method, although promising on specimens with a network of cracks soon was shown to be ineffective when used on specimens with limited cracks. SiALON specimens were indented using a microhardness Vicker's indenter to produce specimens with few cracks. Figure 3 shows an optical photo micrograph of a crack emanating from one corner of the indent. The statiflux method did not detect this crack at all whereas fluorescent penetrant easily detected cracks of this size (see Fig. 5).

Fig. 3. Partial image of a Vicker's microhardness indent in SiAlON with a microcrack growing from the indent corner. The horizontal field of view is $\sim 125 \mu\text{m}$.

After the fluorescent penetrant method was verified for superior surface-breaking crack detection, a systematic study was conducted to evaluate two representative high sensitivity fluorescent penetrants; 1) RC-88 from Sherwin, Inc. and 2) ZL-37 from Magnaflux.^{a)}

These manufacturers produce a general line of dye penetrant inspection materials. Both companies produce a highly penetrating fluorescent dye and a water based emulsifier. We tested materials from both as representative of all suppliers.

Material Safety Data Sheets for the materials indicate that they are non-toxic, slightly irritating to skin and eyes, and are safe when handled in a controlled environment (see Appendix A).

The basic procedures for fluorescent penetrant crack detection is as follows:

^{a)} Other suppliers of dye penetrants are listed in Appendix B.

1. Clean the specimen.
2. Apply penetrant to the surface.
3. Allow penetrant to soak for a specified time (e.g., 10 minutes min.).
4. Remove excess penetrant from the surface with a suitable cleaner.
5. Apply ultraviolet (UV) light.
6. Visually scan surface for flaws with UV illumination using visual aids as appropriate.

Successful application of a procedure depends to a great extent on the skill of the user. For example, in Step 4, the removal technique must remove excess residual surface penetrant, but not remove penetrant from cracks. During inspection, the user must use judgment guided by experience as to what constitutes acceptable and unacceptable flaws.

As part of this study, we set up a penetrant laboratory (see Fig. 4) with venthood for venting the gases. We also modified an existing Nikon Optiphot Microscope (25-400X) with two additions: a) a special Hg-arc lamp and optical filter combination to allow UV illumination and b) a 512 x 480 x 8 bit CCD camera coupled to a computer with frame-grabber digitizer board. This allowed high magnification imaging and subsequent digital image archiving as well as digital image processing.

Test Specimens

Samples for microcrack studies using the two penetrants are listed in Table 2. The samples were identified by Roman numeral serial numbers because these could be scribed on the edges of the samples using a diamond marker.

Fig. 4. Photographs of the dye penetrant laboratory.

Procedures

The samples were first all ultrasonically cleaned with a biodegradable detergent (ALCONOX) in water and air dried by an air blower. Intentional cracks were then formed by indenting with a Vicker's microhardness indenter. The first indents were made at 20 kg on SiAlON. Indents made on silicon carbide (SiC) or silicon nitride (Si₃N₄) at 20 kg showed crushing at the edges of the indent. This made measurement of crack lengths difficult. The indent load was reduced to 5 kg and indent edges still were crushed. We compromised and set the load at 10 kg for reasonable crack lengths and the cracks were measured from tip to tip across the indent.

Table 2. Test Samples

Sample Number	Material	Sample Size	Supplier
-- Silicon Carbide --			
I	NT 230	3 x 4 x 27 mm	Norton Advanced Ceramics
II	"	3 x 4 x 30	"
III	Hexaloy SA	3 x 4 x 50	Carborundum
IV	"	3 x 4 x 50	"
-- Silicon Nitride --			
V	SN 253	3 x 4 x 26	Kyocera
VI	"	3 x 4 x 22	"
VII	GN 10	3 x 4 x 25	Allied Signal Ceramic Components
VIII	"	3 x 4 x 25	"
IX	NT 164	3 x 4 x 50	Norton Advanced Ceramics
X	"	3 x 4 x 50	"
XI	SN 88	4 x 6 x 45	NGK

The procedure for penetrant application with both penetrants was identical. After indenting, no cleaning was necessary because the cracks had been made on a clean surface and had not been exposed to contaminants. The specific procedure we followed was:

1. Brush or dip on penetrant and allow to stand for at least ten minutes.
2. Rinse in running tap water for one minute.
3. Dip in emulsifier solution and slowly agitate for one minute.
4. Rinse in running tap water, one minute.
5. Air dry surface at about 100°F with clean air until surface appears dry.
6. Inspect under microscope with UV light within 1 to 2 hrs as the fluorescence decays with time.

In Steps 2 and 4 the one minute is approximate and may be reduced for simple shapes. In step 3 the timing is more critical and is dependent on the strength of the remover solution. The one minute time is recommended by both suppliers when using their emulsifier at recommended strength. Too short a time in the emulsifier will leave a film of penetrant on surfaces. A glow from this film during inspection will be an indication to either increase the time or to check the concentration of the emulsifier. Too long a time in the emulsifier will begin to remove penetrant from cracks and reduce the detection sensitivity.

Figure 5 show the results of following this procedure on an indent on sample XI.

Since the purpose of this work was to detect cracks on machined specimens, each specimen was measured for surface roughness using a Rank-Taylor-Hobson Talysurf equipped with a wedge stylus. The surface data are given in Table 3.

(a)

(b)

Fig. 5. Typical image results obtained: (a) visible light and (b) UV after treatment with fluorescent penetrant. Corner to corner across the indent is $\sim 100\ \mu\text{m}$.

Table 3. Surface Roughness for Penetrant Studies

Sample Number	Ra, μm	Rq, μm
I	.056	.070
II	.054	.071
III	.089	.109
IV	.099	.126
V	.069	.109
VI	.186	.281
VII	.161	.201
VIII	.170	.214
IX	.122	.153
X	.124	.159
XI	.046	.060

Penetrant Comparison

With the limited number of samples, a comparison between the two penetrants was made by dividing the samples into two groups. Each sample was given three indents of 10 kg. Since the crack length was determined by measuring from tip to tip across a diagonal, this yields two cracks per indent or six cracks per sample. The first group, samples 2, 4, 6, 8, 10, were treated with ZL-37 and the second group, samples 3, 5, 7, 9, 11, were treated with RC-88 penetrant. The tip to tip crack length as seen using the penetrant were then measured, using the microscope.

To remove the penetrant the samples were then cleaned in an ultrasonic bath of distilled water and detergent (ALCONOX) followed by an ultrasonic bath in plain water and drying at $\sim 160^{\circ}\text{F}$. After this cleaning procedure none of the cracks were visible under UV light.

However, some of the crushed areas around the indents were faintly visible.

The samples were then reinspected but with the other penetrant. That is samples 2, 4, 6, 8, 10 were treated with RC-88, and samples 3, 5, 7, 9, 11, treated with ZL-37. The crack lengths were again measured. The results are given in Table 4. Several observations can be made: First, the crack lengths for the same sample measure the same within one standard deviation for the two penetrants; second, crack lengths for samples of the same materials matched closer than the crack lengths of different materials and third, crack lengths for silicon carbide averaged 372 μm while for silicon nitride the average was 283 μm .

One possible reason for the wide scatter in crack lengths even for the same indent on the same sample is the subjective nature of picking the end points of a crack.

Figure 6 illustrates an observation we saw frequently. Surrounding each indent is a "cloud" of fluorescence. Under visible light this surface appears undisturbed. After exposure to the penetrant, the image shows areas of fluorescence, that are not removed by the detergent action of the remover. The fluorescence must remain under the surface where the remover is not effective. The stress of the indent must open a network of micro-micro cracks through the material that allows penetration of the penetrant. The surface away from the indent is undisturbed.

This same phenomenon shows up on other areas than around indents. It appears randomly over the surface, many times around a pit or inclusion. Figure 7 shows the effect around a pit. Perhaps this is an indication of surface damage caused by heavy grinding, the damage being accentuated by the discontinuity. This phenomenon deserves further study.

Importance of Optical Magnification

After a limited study, we have concluded that 100X magnification provides excellent detectability. However, 50X may be sufficient for many applications. This is significant as the speed of inspection would be greatly reduced if 100X is needed.

Table 4. Optically Measured Crack Lengths Using Fluorescent Penetrant

Indenter Load: 10Kg
Optical Magnification: 100X

Sample #	Crack Length μm	Penetrant	Material Type
<u>Step 1</u>			
II	407 ± 24	ZL-37	NT 230 SiC
IV	372 ± 26	ZL-37	Hexaloy S.A. SiC
VI	275 ± 14	ZL-37	SN 253 Si ₃ N ₄
VIII	291 ± 24	ZL-37	GN 10 Si ₃ N ₄
X	262 ± 16	ZL-37	NT 164 Si ₃ N ₄
III	341 ± 32	RC-88	Hexaloy SA SiC
V	303 ± 48	RC-88	SN 253 Si ₃ N ₄
VII	277 ± 9	RC-88	GN 10 Si ₃ N ₄
IX	269 ± 10	RC-88	NT 164 Si ₃ N ₄
<u>Step 2</u>			
II	379 ± 36	RC-88	NT 230 SiC
IV	384 ± 10	RC-88	Hexaloy S.A. SiC
VI	282 ± 14	RC-88	SN 253 Si ₃ N ₄
VIII	278 ± 14	RC-88	GN 10 Si ₃ N ₄
X	264 ± 20	RC-88	NT 164 Si ₃ N ₄
III	346 ± 36	ZL-37	Hexaloy S.A. SiC
V	325 ± 18	ZL-37	SN 253 Si ₃ N ₄
VII	288 ± 27	ZL-37	GN 10 Si ₃ N ₄
IX	283 ± 10	ZL-37	NT 164 Si ₃ N ₄

Fig. 6. An indent in Sample I surrounded by a cloud of fluorescence (100X).

Fig. 7. Disturbed material on Sample I surrounding a void (400X). The void is $\sim 7 \mu\text{m}$ dia.

5. Recommendations

Based on the results of this limited study, we recommend the following:

1. Use only fluorescent penetrants for detection of surface-breaking cracks generated by machining.
2. The protocol to be followed should utilize high (>25X) optical magnification with UV light delivered to the test piece.
3. Verification of crack detection sensitivity should be established through a limited 1-year follow-on study whereby the Vicker's indent is polished away and crack length measured using fluorescent penetrant.
4. Automation of detection should be assessed as part of a limited one-year follow-on using the digital image data acquisition and new advanced digital image processing methods.

6. References

1. Horton, S. A. "Detection of Surface Defects in Ceramic Rolling Elements," in Fourth International Symposium on Ceramic Materials and Components for Engines, June 1991, Göteborg, Sweden, pp. 897-904.
2. Kölker, H., Henze, P., Schwetz, K. A. and Lipp, A., "X-ray Microfocus and Dye Penetrant Techniques for Crack Detection in Ceramics," in Third International Symposium on Ceramic Materials and Components for Engines, V. J. Tennery, et., Las Vegas, NV, USA, Nov. 1988, pp. 1122-1129.
3. Malins, R. J., McCall, D. and Rhodes, G. W., "Systems Level Considerations for Environmentally Responsive Fluorescent Penetrant Testing," Mat. Eval. Vol. 51, No. 3, 338-352, Mar. 1993.

4. Beriozkina, N. G., Larichev, M. N., Leipunsky, I. O., Eremin, G. L., and Dergunov, N. M., "Indicator Capillary-Diffusion Method for Nondestructive Defectoscopy of Composite Materials," in Moscow International Composites Conference (MICC), Nov. 14-16, 1990, Moscow, Elsevier Science, UK (1991), pp. 773-776.

Appendix A: Product Sheets

A.1 ZL-37/ZR-10B

A.2 RC-88/ER-83A

ZYGLO Post Emulsifiable Penetrant (ZL-37)

Product Data Sheet
ZY-PE-11

Effective: February 18, 1992
Supercedes: January 21, 1992

General Description

ZL-37 is a post emulsifiable fluorescent penetrant, used reliably for a wide range of ultrahigh sensitivity, critical applications.

ZL-37 is ideally suited for titanium turbine components, investment castings, and other high stress critical components where detection of fine, tight and broad open shallow discontinuities is a must.

ZL-37 is formulated to be impervious to water to assure against being overwashed from defects. ZL-37 requires the application of a lipophilic emulsifier or a hydrophilic emulsifier to render it washable with water, and the resultant mixture is biodegradable.

ZL-37 is formulated for rapid separation from water, for efficient effluent clean-up by coalescer, separation settling pond or charcoal filtration.

ZL-37 fluoresces a bright greenish-yellow color under ultraviolet radiation. Use blacklight sources with peak wavelength of 365 nanometers such as MAGNAFLUX® ZB-100. ZL-37 is formulated to produce heat stable fluorescent indications under normal drying conditions (140°F/60°C).

ZL-37 meets OSHA requirements for Class III B liquids due to its high flash point and can be used in open dip tanks.

Composition

ZL-37 is composed of alkyl aryl phosphate, high boiling petroleum oils, and fluorescent dyes.

Safety

ZL-37 is intended for industrial use by qualified personnel only.

Do not smoke or eat while using ZL-37. Wash hands thoroughly after use. To protect hands from staining and drying out, protective hand wear is recommended.

Store ZL-37 in closed containers away from open flame or heat.

Department of Labor Material Safety data sheets available.

02/18/92

ZYGLO Post Emulsifiable Penetrant
(ZL-37)

Product Data Sheet
ZY-PE-11a

Typical Properties (Not a Specification)

Viscosity @100°F	13.4 cs
Flash Point	Greater than 200°F (P.M.C.C.) (93.3°C)
Density	8.1 lbs./gal. (959 gms./L)
Sulfur	Less than 1000 ppm
Chlorine	Less than 1000 ppm
Sodium	Less than 100 ppm
Fluorine	Less than 50 ppm

Noncorrosive per MIL-I-25135

Compatible with titanium and high nickel alloys

Like all MAGNAFLUX® materials, ZL-37 is closely controlled to provide unique batch to batch consistency and uniformity to assure optimum process control and inspection reliability. Batch certification available upon request.

Method of Application

Test parts must be clean, free of all oil, grease or other foreign contaminating substances, and dry, before penetrant is applied. ZL-37 can be applied by immersion dip, brush or flow on, conventional or electrostatic spray. Area to be inspected must be completely covered with penetrant.

Penetration Time and Temperature

The generally accepted minimum penetration time is 2 to 5 minutes. Some specifications may require longer dwell times. ZL-37 is generally used between 50°F to 125°F

Penetrant Removal

ZL-37 requires the use of a Zyglo lipophilic emulsifier or hydrophilic emulsifier to render it water washable.

When using ZL-37 with hydrophilic emulsifier it is advantageous to prerinse the ZL-37 covered part with plain water spray (50°F - 100°F) (20 - 40 psig) before the emulsifier application. The prerinse removes the bulk of the surface penetrant but leaves a thin film, sufficient for quality inspection. The purpose of the prerinse is to lower the amount of penetrant entering the emulsifier tank (dip application), contaminating it and lowering its activity. The prerinse effluent can be treated to separate the penetrant and water to the extent that the water can be reused in the prerinsing operation.

Recommended emulsifiers for use with ZL-37 are:

ZE-3

ZE-4B

ZR-10B

ZYGLO Post Emulsifiable Penetrant (ZL-37)

Product Data Sheet
ZY-PE-11b

Penetrant Removal (Continued)

For inspection of small areas the solvent wipe technique is commonly employed, using SKC-NF or SKC-S Cleaner/Remover. Moisten a clean wiping media with SKC-NF or SKC-S and wipe inspection area free of surface penetrant. Do not flood surface with cleaner/remover as sensitivity may be impaired.

Developer Application

Zyglo developers should be used to maximize the sensitivity of ZL-37. Aqueous developers are applied prior to drying; dry powder and nonaqueous developers after drying (140°F/60°C).

Recommended developers for use with ZL-37 are:

ZP-4B	ZP-9F	SKD-NF
ZP-5B	ZP-13A	SKD-S
ZP-9E	ZP-14	SKD-S2

MIL-I-25135 Classification

"E" Revision - Type I, Method B, Level 4 Penetrant with ZE-3 or ZE-4B emulsifier.

"E" Revision - Type I, Method D, Level 4 Penetrant with ZR-10B emulsifier (20%).

Specification Compliance

MIL-I-25135	ASTM E-165
MIL-I-6866	ASME B & PV Code, Sec. V
MIL-STD-271	AMS-3157
Boeing BAC 5423 PSD 6-46 or 8-4	McDonnell Douglas PS-21202
Garrett EMS 52309E	AECL
Pratt & Whitney	MIL-STD-2132
PMC 4354-2	

How Supplied

1 gallon can	20 gallon drum
5 gallon pail	55 gallon drum

Coverage

1 gallon approximately 900 square feet

Warning:

Penetrants attack and even dissolve many kinds of plastic pipe. Polyvinyl chloride (PVC) pipe is especially vulnerable, and can crumble after only a few days of exposure. Even diluted penetrant rinsings attack it rapidly. ABS plastic pipe is nearly as sensitive. When installing plumbing to handle penetrant rinsings, use metal pipe.

02/18/92

MAGNAFLUX® MATERIAL SAFETY DATA SHEET ZYGLO® PENETRANT ZL-37

1. IDENTIFICATION

Company: MAGNAFLUX®
Address: 7301 West Ainslie Avenue, Harwood Hts., Illinois 60656
Telephone No.: (708) 867-8000 (Off-Hour Emergency Number - CHEMTREC - 1-800-424-9300).
Product Use: Fluorescent inspection penetrant
Packages: 1 gallon cans, 5 gallon pails, 20 gallon and 55 gallon drums
NFPA Rating: Health 1, Flammability 1, Reactivity 0
PIN: None
Revision Date: June 4, 1993

2. HAZARDOUS INGREDIENTS

Ingredient	Wt./Wt. %	CAS #	TLV	PEL	LD ₅₀	LC ₅₀
Severely hydrotreated heavy naphthenic distillates (petroleum)	30-60	64742-52-5	not avail.	not avail.	not avail.	not avail.
Isodecyl diphenyl phosphate	15-40	29761-21-5	not avail.	not avail.	15.8 g/kg (oral/rat)	2.2 mg/l [6 hr/(rat(2/5))]
Poly(oxy-1,2-ethanediyl), α - (nonylphenyl)-ω-hydroxy	3-7	9016-45-9	not avail.	not avail.	2g/kg (oral/rat)	not avail.

3. HAZARDS IDENTIFICATION

EMERGENCY OVERVIEW

Bland, oily liquid which may irritate the skin and eyes. Difficult to ignite, but will burn vigorously, if engulfed in fire.

POTENTIAL HEALTH EFFECTS

Skin Contact: Can irritate by removing natural skin oils on long or repeated exposures.
Eyes: May cause irritation.
Inhalation: Not significant at room temperatures. When heated or sprayed, ZL-37 vapors may cause dizziness and nausea.
Ingestion: Not significant in small (mouthful) amounts.
Medical conditions known to be aggravated by exposure to product: None

4. FIRST AID

Skin Contact: Wash off with soap and water. Use soothing lotion.
Eyes: Rinse carefully under upper and lower eyelids using plenty of water.
Inhalation: Remove to fresh air if dizzy or nauseated.
Ingestion: Do not induce vomiting. Accidental ingestion of a small mouthful is not expected to cause significant harm.
NOTE: In all severe cases, contact physician immediately. Local telephone operators can furnish number of regional poison control center.

5. FIRE HAZARD

Conditions of flammability: Heating above 200°F (93°C) in presence of ignition sources.
Flash point: Min. 200° F (93° C) (Pensky-Martens closed cup)
Flammable limits in air: 1% to 6%
Extinguishing media: Carbon dioxide, foam
Special fire fighting procedures: Keep containers cool with water spray. Do not spray water directly on burning ZL-37. It may float and spread the fire.
Hazardous combustion products: Smoke, soot, oxides of carbon and nitrogen.
Unusual fire hazards: None

6. ACCIDENTAL RELEASE MEASURES

Mop up or sweep up with absorbent. (For disposal, see Section 13.)

7. HANDLING AND STORAGE

Avoid breathing spray mist.
 Avoid eye contact.
 Avoid repeated or prolonged skin contact.
 Store away from heat source.

8. EXPOSURE CONTROLS/PERSONAL PROTECTION

Controls: None, unless applied as spray. Use where ventilation will carry spray mist away from occupied areas.
Personal protection: Wear safety glasses to protect eyes. Wear nitrile rubber gloves if hand exposure is unavoidable. Respirator with filter if sprayed in enclosed, unventilated space.

9. **PHYSICAL PROPERTIES**

<i>Initial boiling point (bulk):</i>	Min. 455°F (235°C) (ASTM D-86)	<i>Vapor pressure:</i>	< 0.10mm @ 70° F (21° C)
<i>Percent volatile:</i>	None	<i>Vapor density:</i>	Heavier than air
<i>Density/sp. gravity:</i>	0.96	<i>Evaporation rate:</i>	Negligible
<i>Water solubility:</i>	0%	<i>Appearance:</i>	Green oily liquid
<i>pH:</i>	Neutral	<i>Odor:</i>	Mild odor

10. **STABILITY AND REACTIVITY**

<i>Stability:</i>	Stable
<i>Incompatibility:</i>	None
<i>Hazardous decomposition products:</i>	Soot, oxides of carbon if heated to combustion temperatures.
<i>Reactivity:</i>	None

11. **TOXICOLOGICAL INFORMATION**

<i>Carcinogenicity:</i>	Contains no known or suspected carcinogens listed with OSHA, IARC, NTP, or ACGIH.
<i>Threshold limit value:</i>	5 mg/m ³ for oily mist
<i>WHMIS information (Canada):</i>	According to available information, the ingredients have not been found to show reproductive toxicity, teratogenicity, mutagenicity, skin sensitization, or synergistic toxic effects with other materials.

12. **ECOLOGICAL INFORMATION**

No data is available on ZL-37. It floats on water and can be skimmed off. Its low vapor pressure may exempt it from VOC restrictions.

13. **DISPOSAL**

As a non-hazardous oily waste, incinerate or send to waste handler who can blend it into secondary fuels.	
<i>RCRA:</i>	Not a hazardous waste
<i>U.S. EPA Waste Number:</i>	None

14. **TRANSPORTATION**

U.S. DOT: 49 CFR 172.101 Hazardous Materials Table

	<u>Bulk</u>
<i>Proper shipping name:</i>	None, not restricted
<i>Hazard class or division:</i>	None
<i>Identification No.:</i>	None
<i>Packing Group:</i>	None

15. **REGULATORY INFORMATION**

<i>TSCA:</i>	All ingredients are listed in TSCA inventory.
<i>CERCLA:</i>	Not reportable
<i>SARA TITLE III, Section 313:</i>	No reportable ingredients
<i>California Proposition 65:</i>	Contains nothing on this list
<i>WHMIS Class (Canada):</i>	D-2B

Note: This MSDS has been prepared to meet WHMIS (Canada) requirements with the exception of using 16 headings.

16. **OTHER INFORMATION**

<i>Revision Statement:</i>	The MSDS format has been altered to conform to WHMIS (Canada) requirements in Sections 1, 2, 5, 9, 11, 13, 15, 16
<i>Supersedes:</i>	MSDS dated 1/20/93

Signed by:

Bruce C. Graham, Chief Chemist

MAGNAFLUX

ZYGLO Hydrophilic Emulsifier (ZR-10B)

Product Data Sheet
ZY-E-6

Effective: April 15, 1988
Supersedes: November 15, 1985

General Description

ZR-10B is a biodegradable, pinkish, slightly viscous liquid. ZR-10B is a 100% active concentrate which is diluted in water when used as an emulsifier for Zyglo PE penetrants. ZR-10B is very low in sulfur, holoogens and sodium content.

Utilization of ZR-10B Hydrophilic Emulsifier affords such advantages as: minimization of fluorescent background on rough surfaces, minimization of bleedout from hollow parts, reduced consumption of expendable materials, ease of use in close loop systems and reduced effluent pollutants. ZR-10B Hydrophilic Emulsifier yields the most reliable and reproducible test results due to its controlled Zyglo PE penetrant removal.

Composition

ZR-10B is composed of polyols and surface active agents.

Safety

ZR-10B is intended for industrial use by qualified personnel only.

Do not smoke or eat while using NDT materials. Wash hands thoroughly after use. Protective hand wear is recommended to prevent drying of skin. If ZR-10B solution is sprayed, avoid breathing mist, either by using adequate ventilation or by wearing respirator with mist filter.

Department of Labor Material Safety data sheets available upon written request.

Typical Properties (Not a Specification)

Color	Pinkish Red
Viscosity @ 100°F	42.3 Centistokes
Flash Point	Greater than 200°F (93°C) P.M.C.C.
Density @ 60°F	8.35 lbs./gallon (1003 gms/L)
Water Tolerance	Infinite
Corrosion	Non-corrosive per MIL-I-25135
Sulfur	Less than 1000 ppm
Chlorine	Less than 1000 ppm
Sodium	Less than 100 ppm
Fluorine	Less than 50 ppm

Like all Magnaflux Corporation materials ZR-10B is closely controlled to provide unique batch to batch consistency and uniformity to assure optimum process control and inspection reliability. Batch certification available upon request.

04/15/88

ZYGLO Hydrophilic Emulsifier
(ZR-10B)

Product Data Sheet
ZY-E-6a

Pre-Rinse

The pre-rinse step is recommended before the application of a hydrophilic emulsifier like ZR-10B. Pre-rinse is a water spray employed to mechanically reduce the film of PE penetrant on a part before entering the emulsifier bath. This process step prolongs the emulsifier bath life by lowering the amount of penetrant contaminating the bath. The pre-rinse and hydrophilic emulsifier process are ideally suited for closed loop low pollution systems.

Application and Emulsification

ZR-10B concentrate is diluted in water before it is used as an emulsifier/remover. The hydrophilic emulsifier is generally employed as a spray or an immersion dip. The concentration used will determine the amount of contact time required to remove the surface penetrant.

Spray Method

If the spray method of emulsifier application is used, an injector or metering pump is used to control the concentration. The general spray concentration range is 0.1% to 0.5% remover. Higher concentrations up to 5% may be used but care is required to avoid over removal. Spray removal should be employed under blacklight illumination to control removal of penetrant from the surface. A clean water rinse is recommended to eliminate emulsifier/penetrant residues.

Immersion Method

If the immersion dip method is employed the general concentration range is 5% to 33% remover to water. The recommended concentration range is 20% to 33% which optimizes remover activity, bath life, economics and process rate. The penetrated part is immersed in the bath, which is gently agitated by mechanical or air means. The length of time the part is in the bath will vary with the concentration of the bath, the type penetrant being used, specification requirements and the desired results. At 20% concentration the immersion contact time generally ranges between 30 - 180 seconds.

The immersion dip is followed by a clean water spray to remove any penetrant/emulsifier residues.

The use of foam, created by heavy agitation of the emulsifier bath, as a remover method is possible. The foam will act as a remover, however it is not as effective overall for maximum performance. The foam does not enter hollow parts as readily as the liquid immersion and will therefore be less effective.

04/15/88

ZYGLO Hydrophilic Emulsifier
(ZR-10B)**Product Data Sheet**
ZY-E-6b**Concentration Control**

The concentration of hydrophilic remover baths can be monitored using a refractometer and the charts provided (Figures 1 and 2). The water content of the bath can also be determined using the procedure described in ASTM D-95.

Specification Compliance

MIL-I-25135
MIL-STD-6866
MIL-STD-271
Bechtel Matl. Proc. Guide SS-10
ASME B & PV code, Sec. V
ASTM E-165
Stone & Webster QAD 9.24

McDonnell Douglas P . 21202
Garrett EMS 52309
Boeing BAC 5423 PSD 6-46 or 8-4
FPL SQAD 1005
RDT F3-6T
AECL
Pratt & Whitney PMC 4355-2

How Supplied

1 gallon can
5 gallon pail
20 gallon drum
55 gallon drum

References: Zyglo Process Data Sheets ZY-4, ZY-5

For price information, refer to Price Page.

04/15/88

MAGNAFLUX®

AO REFRACTOMETER UNITS

Figure 1. Remover Concentration Chart
Using a Portable Hand-Held Refractometer (MAGNAFLUX P/N 513829)

Figure 2. Remover Concentration Chart
Using a Laboratory Precision Refractometer

MAGNAFLUX

MAGNAFLUX® MATERIAL SAFETY DATA SHEET ZYGLO® EMULSIFIER ZR-10B

1. IDENTIFICATION

Company: MAGNAFLUX®
Address: 7301 West Ainslie Avenue, Harwood Hts., Illinois 60656
Telephone No.: (708) 867-8000 (Off-Hour Emergency Number - CHEMTREC - 1-800-424-9300).
Product Use: Penetrant remover
Packages: 1 gallon can, 5 gallon pail, 20 gallon and 55 gallon drums
NFPA Rating: Health 1, Flammability 1, Reactivity 0
PIN: None
Revision Date: November 24, 1993

2. HAZARDOUS INGREDIENTS

<u>Ingredient</u>	<u>Wt./Wt. %</u>	<u>CAS #</u>	<u>TLV</u>	<u>PEL</u>	<u>LD₅₀</u>	<u>LC₅₀</u>
Poly (oxy-1,2-ethanediyl), <i>n</i> (nonylphenyl)- <i>w</i> -hydroxy	60-100	9016-45-9	not avail.	not avail.	2 g/kg (oral/rat)	not avail.
2-methyl-2,4-pentanediol	30-60	107-41-5	25 ppm (ceiling)	25 ppm (ceiling)	2.8 g/kg (oral/guinea pig)	not avail.

3. HAZARDS IDENTIFICATION

EMERGENCY OVERVIEW

Bland, oily liquid which may irritate the skin and eyes.
 Difficult to ignite, but will burn vigorously if engulfed in fire.

POTENTIAL HEALTH EFFECTS

Skin Contact: Can irritate by removing natural skin oils on long or repeated exposures.
Eyes: Irritating.
Inhalation: Not significant at room temperatures. When heated or sprayed, ZR-10B vapors may cause dizziness and nausea.
Ingestion: Not significant in small (mouthful) amounts.
Medical conditions known to be aggravated by exposure to product: None

4. FIRST AID

Skin Contact: Wash off with soap and water. Use soothing lotion.
Eyes: Rinse carefully under upper & lower eyelids using plenty of water.
Inhalation: Remove to fresh air.
Ingestion: Do not induce vomiting. Accidental ingestion of a small mouthful is not expected to cause significant harm.
NOTE: In all severe cases, contact physician immediately. Local telephone operators can furnish number of regional poison control center.

FIRE HAZARD

Conditions of flammability: Heating above 200°F (93°C) in presence of ignition sources.
Flash point: Min. 200° F (93° C) (Pensky-Martens closed cup)
Flammable limits in air: 1% to 6%
Extinguishing media: Carbon dioxide, foam
Special fire fighting procedures: Keep containers cool with water spray. In use, ZR-10B is dissolved into water, nearly eliminating its ability to burn.
Hazardous combustion products: Smoke, soot, oxides of carbon
Unusual fire hazards: None

5. ACCIDENTAL RELEASE MEASURES

Mop up or sweep up with absorbent. (For disposal, see Section 13.)

7. HANDLING AND STORAGE

Avoid breathing spray mist.
 Avoid eye contact.
 Avoid repeated or prolonged skin contact.

EXPOSURE CONTROLS/PERSONAL PROTECTION

Controls: None, unless applied as spray. Use where ventilation will carry spray mist away from occupied areas.
Personal protection: Wear safety glasses to protect eyes. Wear nitrile rubber gloves if hand exposure is unavoidable.
 Respirator with filter if sprayed in enclosed, unventilated space.

PHYSICAL PROPERTIES

<i>Initial boiling point (bulk):</i>	Min. 385°F (196°C) (ASTM D-86)	<i>Vapor pressure:</i>	< 0.10mm @ 70° F (21° C)
<i>Percent volatile:</i>	None	<i>Vapor density:</i>	Heavier than air
<i>Density/sp. gravity:</i>	0.9	<i>Evaporation rate:</i>	Negligible
<i>Water solubility:</i>	100%	<i>Appearance:</i>	Pink viscous liquid
<i>pH:</i>	Neutral	<i>Odor:</i>	Mild odor

9. STABILITY AND REACTIVITY

<i>Stability:</i>	Stable
<i>Incompatibility:</i>	None
<i>Hazardous decomposition products:</i>	Soot, oxides of carbon if heated to combustion temperatures.
<i>Reactivity:</i>	None

10. TOXICOLOGICAL INFORMATION

<i>Carcinogenicity:</i>	Contains no known or suspected carcinogens listed with OSHA, IARC, NTP, or ACGIH.
<i>Threshold limit value:</i>	5 mg/m ³ for oily mist
<i>WHMIS information (Canada):</i>	According to available information, the ingredients have not been found to show reproductive toxicity, teratogenicity, mutagenicity, skin sensitization, or synergistic toxic effects with other materials.

11. ECOLOGICAL INFORMATION

No data is available on ZR-10B. It dissolves into water and is biodegradable. Its low vapor pressure may exempt it from VOC restrictions.

12. DISPOSAL

As a non-hazardous oily waste, incinerate or send to waste handler who can blend it into secondary fuels.

<i>RCRA:</i>	Not a hazardous waste
<i>U.S. EPA Waste Number:</i>	None

13. TRANSPORTATION

U.S. DOT: 49 CFR 172.101 Hazardous Materials Table

	<u>Bulk</u>
<i>Proper shipping name:</i>	None, not restricted
<i>Hazard class or division:</i>	None
<i>Identification No.:</i>	None
<i>Packing Group:</i>	None

14. REGULATORY INFORMATION

<i>TSCA:</i>	All ingredients are listed in TSCA inventory.
<i>CERCLA:</i>	Not reportable
<i>SARA TITLE III, Section 313:</i>	No reportable ingredients
<i>California Proposition 65:</i>	Contains nothing on this list
<i>WHMIS Class (Canada):</i>	D-2B

Note: This MSDS has been prepared to meet WHMIS (Canada) requirements with the exception of using 16 headings.

15. OTHER INFORMATION

<i>Revision Statement:</i>	Section 2 - TLV and PEL values were corrected.
<i>Supersedes:</i>	MSDS dated 6/1/93

Signed by:
Bruce C. Graham, Chief Chemist

RC-88 FLUORESCENT PENETRANT

Approved Type I, Methods B C & D, Level 4, MIL-I-25135 Rev. D & E

PRODUCT INFORMATION

Description: RC-88 is a nonwater-washable, ultra-high sensitivity (Level 4), fluorescent penetrant, formulated for super critical inspections. It is a grade above Sherwin RC-77 fluorescent penetrant. It is an OSHA Class IIIB material. Flash point over 200°F. Complies with low-sulfur and low-halogen requirements. Excellent heat and UV stability.

Special Features: RC-88 can be considered a special purpose material; formulated with a single objective:

To find the dangerous microscopic flaw, which other penetrant systems overlook!

To do this, RC-88 is charged with a near maximum quantity of heat stable dyes. As a result, the visibility of dangerous microscopic crack indications is at a high level. Flaws, barely observable, or not visible at all, with other Level 4 penetrants are fully apparent with RC-88.

RC-88 was invented primarily for evaluating the critical components of turbine engines—discs, compressor blades, fan blades. It gives added assurance that flaws conducive to catastrophic failures will be detected, *not overlooked*.

Additionally, RC-88 provides a higher degree of heat and UV stability, which are especially important when detecting microscopic flaws, giving further assurance that extremely microscopic flaw indications will not be lost in the drying oven, but will remain visible for detection.

Considering the cost of one overlooked catastrophic failure causing crack, RC-88 is not just cost effective, it is indispensable. In some areas, there is no excuse for not using the best material and process available.

While RC-88 is approved for use with both hydrophilic (Method D) and lipophilic (Method B) emulsifiers, only Method D (hydrophilic emulsifier) is recommended for highly critical inspections.

Companion Materials:

Developers -	Sherwin D-90G Dry Powder (form a) Sherwin D-100 Nonaqueous (form d) Sherwin D-100NF Nonaqueous (form d) Sherwin D-110A.1 Nonaqueous (form c) Sherwin D-113G.1 Water Soluble (form b) equivalent QPL-25135-listed developers
Emulsifiers -	Sherwin ER-83A Hydrophilic Emulsifier (method D) Sherwin ER-85 Lipophilic Emulsifier (method B)
Removers -	Sherwin DR-61 (Class 1) Sherwin DR-60 (Class 2) equivalent QPL-25135-listed removers

Container Sizes: one-gallon cans
case of 4 one-gallon cans
five-gallon pail
55-gallon drum

Basic Instructions: (These instructions describe the basic process, but they may be amended by the user to comply with applicable specifications and/or inspection criteria provided by the contracting agency.)

- Application:** Apply RC-88 only to clean, dry surfaces by spraying, flowing, brushing or dipping.
- Dwell-Time:** A 10 minute minimum dwell time is suggested. When particularly tight cracks are suspected, or the part is especially critical, the dwell time may be extended to 30 minutes, or longer.

revised 14 April 1993

SHERWIN
INCORPORATED

5530 Borwick Ave.
South Gate, CA 90280
(310) 861-6324
FAX (310) 923-8370

Do not soak the part. To increase sensitivity, as well as conserve material, allow the penetrant to drain from the part surface back into the penetrant tank.

3. Removal

A. Hydrophilic Dip Method

- a. **pre-wash:** following dwell, use a plain water rinse to remove 90-99% of the undrained penetrant from surface. Use a coarse spray at 20-50 psi; use ambient temperature —not heated— water. Do not over wash.
- b. **immersion:** immerse and agitate the part in 20-30% hydrophilic emulsifier solution. Immersion time and agitation will vary with part geometry and surface condition.
- c. **rinse:** remove part from tank; clean with coarse, plain water spray

B. Hydrophilic Spray Method

- a. **wash:** inject a 0.1-5.0% emulsifier solution into pressurized rinse water; spray the part. Use a coarse spray at 20-50 psi; use ambient temperature —not heated— water. Use very dilute emulsifier solutions since spraying "scrubs" the penetrant from part. Wash time and solution concentrations vary with part geometry and surface conditions.
- b. **rinse:** use coarse plain water spray to remove all traces of emulsified penetrant.

C. Lipophilic Method

- a. **emulsification:** dip part into undiluted lipophilic emulsifier, remove part, and allow excess emulsifier to drain back into tank. During drain time, the emulsifier will mix with surface penetrant. Parts with rough surfaces require longer drain times.
- b. **rinse:** use coarse, plain water spray to remove all traces of emulsified penetrant.

4. **Drying:** A recirculating oven no higher than 160°F (71°C) is suggested. Leave part in oven just long enough to evaporate surface moisture. Drying is improved by using pressurized air to disperse and remove excess water before placing part in oven.

5. **Developing:** RC-88 is self-developing and flaw marks are usually apparent almost immediately after the part is dry. However, since RC-88 is used on critical components to find microscopic and incipient cracks, using a developer is mandatory. Sherwin D-90G or D-99A, both dry powders, are recommended for production inspection. Sherwin D-100 or D-100NF, both nonaqueous, are suggested for small areas. (Always apply nonaqueous developers in a light coat.)

Applicable Specifications:

MIL-I-25135 Rev's. D & E
ASME Code NDT, Sec. V
Navships 250-1500
Lockheed
BAC 5423
RDT-F3-6T
ASTM-E-165

Northrup
MIL-STD-271 E
AMS-3155
GE-DFO
General Dynamics
Sikorsky Aircraft

AECL
MIL-STD 6866
AMS-2647
Garrett EMS 52309
AMS-3157
MIL-STD-2132

RC-88 lends itself to heat assisted penetrant methods, and is especially conducive to inspecting in-service parts, e.g., turbine engine parts. Write for heat assisted method particulars.

PRECAUTIONARY INFORMATION

RC-88 is a combustible liquid. Use with adequate ventilation and away from sparks, fire or open flame. Avoid prolonged or repeated contact with skin. Do not take internally. Avoid prolonged or repeated breathing of vapors. Read the label on the container for additional precautionary information.

Material Safety Data Sheet

May be used to comply with
 OSHA's Hazard Communication Standard,
 29 CFR 1910.1200. Standard must be
 consulted for specific requirements.

U.S. Department of Labor

Occupational Safety and Health Administration

(Non-Mandatory Form)

Form Approved

OMB No. 1218-0072

IDENTITY (As Used on Label and List)
 DUBL-CHEK PENETRANT RC88

Note: Blank spaces are not permitted. If any item is not applicable, or no
 information is available, the space must be marked to indicate that.

Section I

Transportation Emergency: CHEMTREC 800/424-9300

Manufacturer's Name Sherwin Incorporated	Emergency Telephone Number (310) 861-6324
Address (Number, Street, City, State, and ZIP Code) 5530 Borwick Ave. South Gate, CA 90280	Telephone Number for Information (310) 861-6324
	Date Prepared 9 March 1992
	Signature of Preparer (optional)

Section II — Hazardous Ingredients/Identity Information

Hazardous Components (Specific Chemical Identity; Common Name(s))	OSHA PEL	ACGIH TLV	Other Limits Recommended	% (optional)
Mixture esters, phosphate/phthalate plasticizing agents.	Unlisted	Unlisted		
CAS Nos. 27961-21-5 & 68515-49-1			While exposure limits are not established, a general guideline for products of this type is 5 mg/m ³ (8-hour time-weighted average)	

HMS - F-1, H-2, R-0, S-0

Section III — Physical/Chemical Characteristics

Boiling Point	440°F	Specific Gravity (H ₂ O = 1)	0.9050
Vapor Pressure (mm Hg.)	N/A	Melting Point	N/A
Vapor Density (AIR = 1)	N/A	Evaporation Rate (Butyl Acetate = 1)	N/A

Solubility in Water

Not soluble, slightly miscible

Appearance and Odor

Yellow, green liquid.

Petroleum Odor

Section IV — Fire and Explosion Hazard Data

Flash Point (Method Used)	200°F	ASTM D 93	Flammable Limits unknown	LEL N/A	UEL N/A
Extinguishing Media	CO-2	Foam	Dry Chemical		

Special Fire Fighting Procedures

Do not use direct stream of water; it spreads the fire. Product
 may float and reignite on surface of water.

Unusual Fire and Explosion Hazards

On burning, this product can release toxic fumes and vapors. Firefighters should
 wear self-contained breathing apparatus and full protective clothing.

Section V — Reactivity Data

Stability	Unstable		Conditions to Avoid	Open flames	1 hazards normally incompatible
	Stable	X		with petrole	oils

Incompatibility (Materials to Avoid) Oxidizing materials.

Hazardous Decomposition or Byproducts

Carbon monoxide and other unidentified organic compounds may be found upon combustion.

Hazardous Polymerization	May Occur		Conditions to Avoid
	Will Not Occur	X	

Section VI — Health Hazard Data

Route(s) of Entry: Inhalation? Skin? Ingestion?

Primary routes of entry skin and eye contact.

Health Hazards (Acute and Chronic) Not known

Carcinogenicity: NTP? No IARC Monographs? No OSHA Regulated? No

Signs and Symptoms of Exposure

Eyes - severe irritation. Skin - Irritation. Inhalation - light headiness.

Medical Conditions

Generally Aggravated by Exposure Unknown

Emergency and First Aid Procedures

Eyes-flush with water. Skin- Wash, remove contaminated clothing. Inhalation-Fresh Air

Ingestion-Do not induce vomiting. Eyes & Ingestion - Medical Attention Essential.

Section VII — Precautions for Safe Handling and Use

Steps to Be Taken in Case Material is Released or Spilled

Extinguish all flames. Make dike.

Waste Disposal Method:

Take up with an absorbent material and dispose of in compliance with all local, state and federal regulations.

Precautions to Be Taken in Handling and Storing

Handling - do not splash or create mists or vapors.

Storage - Store away from high temperatures and open flames. Keep containers closed.

Other Precautions

Emptied container retains vapor and product residues. Do not cut or weld on or near this container.

Section VIII — Control Measures**Respiratory Protection (Specify Type)**

Use NIOSH-approved respirator if vapors or mists are generated.

Ventilation	Local Exhaust	Advisable.	Special	none
	Mechanical (General)	Usually not necessary.	Other	none

Protective Gloves

Chemical resistant

Eye Protection

Chemical Safety when possibility of splash

Other Protective Clothing or Equipment**Work/Hygienic Practices**

Wash before eating. Do not smoke.

ER-83A HYDROPHILIC EMULSIFIER

Approved Method D, Type I, MIL-I-25135 Rev. D
Approved Group V & VI, MIL-I-25135 Rev. C

PRODUCT INFORMATION

Description: ER-83A is a concentrated "detergent" used diluted with water to emulsify Sherwin's fluorescent penetrants, such as the company's "RC-" designated products. ER-83A removes surface, non-water-washable penetrants by spray or immersion following a pre-wash step. The product meets low-sulfur, low-halogen, and low-sodium requirements, has a flash point over 200°F, and is an OSHA Class IIIB material.

Special Features: ER-83A is low in solvent properties and relies primarily on surfactants (surface active agents) for its removal action. This minimizes the risk of "over-emulsification," or dissolving of flaw-entrapped penetrant, due to extended emulsifier dwell times, or to over concentration arising from water evaporation.

ER-83A works well on smooth or rough surfaces as well as on machined or coated surfaces.

Companion Materials:

Penetrants -	Sherwin RC-29
	Sherwin RC-50
	Sherwin RC-65
	Sherwin RC-77
Developers -	Sherwin D-90G Dry Powder (form a)
	Sherwin D-100 Nonaqueous (form d)
	Sherwin D-100NF Nonaqueous (form d)
	Sherwin D-113G Water Soluble (form b)
	equivalent QPL-25135 developers

Container Sizes: one-gallon cans
case of 4 one-gallon cans
five-gallon pail
55-gallon drum

Basic Instructions: (These instructions describe the basic process. They may need to be amended by the user to comply with applicable specifications and/or inspection criteria provided by the contracting agency.)

There are two ways to apply ER-83A: by direct spraying or by immersing the part in a diluted emulsifier solution. Either method is employed after the part has been drained of as much penetrant as possible and has undergone a pre-wash step. Pre-washing removes most excess, undrained penetrant, thereby permitting lower strength solutions and shorter dwell times as well as reducing penetrant carry-over to the emulsifier tank.

Pre-wash Step: Once the penetrant dwell and drain step is complete, and prior to applying the ER-83A solution, spray the part at an angle with plain, ambient temperature water to mechanically remove ninety to ninety-nine percent of the remaining surface penetrant. Do not use hot water. A coarse spray of 20-40 p.s.i. is preferred. Perform this operation under black light to insure that only a microscopic film of penetrant continues to adhere to the part surface before spraying or immersing the part in the emulsifier solution. Do not over wash.

Spray Application: Use very dilute solutions when spraying ER-83A Emulsifier, since spraying in itself helps remove the penetrant. The solution strength, which may vary from as low as 0.1% to as high as 5.0% is regulated by several factors: (1) pre-wash thoroughness, (2) surface texture, (3) force of the spray, and (4) solution contact time during and following spray application. A solution strength less than 0.2% (i.e., 1 part emulsifier to 500 parts water) may suffice for parts having smooth surfaces, even when using a brief spray cycle.

SHERWIN
INCORPORATED

5530 Borwick Ave.
South Gate, CA 90280
(310) 861-6324
FAX (310) 923-8370

Maintaining the strength of **ER-83A** spray solution is not as critical as with competitive hydrophilic emulsifiers which rely on solvent action; nevertheless, in order to minimize over-emulsifying, an upper concentration limit should be established and the solution checked regularly with a refractometer. Excess foaming indicates increased solution concentration.

For economy as well as maximum sensitivity, use the lowest strength solution that is consistent with reasonably brief application time. Excessive background fluorescence or the need for prolonged spraying indicate the need to increase the solution strength.

Prolonged water scrubbing, with or without emulsifier, can erode penetrant from wide flaws. If possible, the emulsifier should be rinsed under black light to insure against over-washing.

Immersion Application: The immersion technique for applying **ER-83A** requires a stronger solution — 20% to 30% — than the spray technique. On particularly difficult parts, accelerate the solution's action with mild agitation by moving the parts up and down in the solution or by using devices such as mixers or air stirrers.

A thorough, clear-water rinse follows the immersion. An inadequate final rinse will interfere with developer action; emulsifier solution should not be allowed to dry on the surface.

Use a refractometer to monitor the **ER-83A** solution for evaporative water loss, which can occur rapidly in hot, dry conditions. Water loss leads to an over-active emulsifier solution. Restore proper solution strength by simply adding water.

The **ER-83A** solution must also be monitored for penetrant contamination. While the pre-wash step minimizes carrying penetrant to the solution tank, eventually penetrant contamination will require recharging the solution tank.

Applicable Specifications:

MIL-I-25135 Rev's. C & D
ASME B & P Vessel Code
Navships 250-1500
Lockheed
BAC 5423
MIL-STD-2132
MTU
Snecma

Allison Gas Turbine
MIL-STD-271 E
AMS-2647
AMS-3157
General Dynamics
ASTM-E-165
Rolls Royce
Sikorsky

AECL
MIL-STD 6866
RDT-F3-6T
Garrett EMS 52309
Northrup
General Dynamics
P & W FPM
GE-DFO

PRECAUTIONARY INFORMATION

ER-83A is a combustible liquid as supplied. Use with adequate ventilation and away from sparks, fire or open flame. Avoid prolonged or repeated contact with skin. Do not take internally. Avoid prolonged or repeated breathing of vapors. Highly Detergent. **DANGER!** Causes eye burns. **First Aid:** flush eyes with water; call a physician. Read the label on the container for additional precautionary information.

Material Safety Data Sheet

May be used to comply with
 OSHA's Hazard Communication Standard,
 29 CFR 1910.1200. Standard must be
 consulted for specific requirements.

U.S. Department of Labor

Occupational Safety and Health Administration
 (Non-Mandatory Form)

Form Approved

OMB No. 1218-0072

IDENTITY (As Used on Label and List)

Sherwin Dabl-Chek Emulsifier ER83A

Note: Blank spaces are not permitted. If any item is not applicable, or no
 information is available, the space must be marked to indicate that.

Section I

Transportation Emergency: CHEMTREC 800/424-9300

Manufacturer's Name

Sherwin Incorporated

Emergency Telephone Number

(310) 861-6324

Address (Number, Street, City, State, and ZIP Code)

5530 Borwick Ave.

Telephone Number for Information

(310) 861-6324

South Gate, CA 90280

Date Prepared

9 March 1992

Signature of Preparer (optional)

Section II — Hazardous Ingredients/Identity Information

Hazardous Components (Specific Chemical Identity; Common Name(s))	OSHA PEL	ACGIH TLV	Other Limits Recommended	% (optional)
Hexylene Glycol CAS No. 107-41-5	25 ppm	25 ppm		

(ceiling limit) (ceiling limit)

ACGIH states: "In order to prevent eye irritation
 it is recommended that the ceiling limit of 25 ppm
 be adopted."

HMS - F-1, H-2, R-0, S-0

Section III — Physical/Chemical Characteristics

Boiling Point	390°F	Specific Gravity (H ₂ O = 1)	0.98
Vapor Pressure (mm Hg.) not volatile	<.1	Melting Point	N/A
Vapor Density (AIR = 1)	4	Evaporation Rate (Butyl Acetate = 1)	not volatile N/A

Solubility in Water

completely soluble

Appearance and Odor

pink liquid, detergent odor

Section IV — Fire and Explosion Hazard Data

Flash Point (Method Used)	> 200°F ASTM D 93	Flammable Limits	LEL N/A	UEL N/A
Extinguishing Media	CO-2	Foam	Dry Chemical	

Special Fire Fighting Procedures

Do not use direct stream of water. It spreads the fire.

Firefighters should wear self-contained breathing apparatus and full protective clothing.

Unusual Fire and Explosion Hazards

On burning, this product can release toxic fumes and vapors.

Section V — Reactivity Data

42

Stability	Unstable		Conditions to Avoid	Open flames and hazards normally incompatible with petroleum oils
	Stable	X		

Incompatibility (Materials to Avoid) Oxidizing materials.

Hazardous Decomposition or Byproducts

Carbon monoxide and other unidentified organic compounds may be found upon combustion.

Hazardous Polymerization	May Occur		Conditions to Avoid
	Will Not Occur	X	

Section VI — Health Hazard Data

Route(s) of Entry: Inhalation? Skin? Ingestion?
Primary routes of entry skin and eye contact.

Health Hazards (Acute and Chronic) Not known

Carcinogenicity: NTP? No IARC Monographs? No OSHA Regulated? No

Signs and Symptoms of Exposure

Eyes - severe irritation. Skin - Irritation. Inhalation - light headiness.

Medical Conditions

Generally Aggravated by Exposure Unknown

Emergency and First Aid Procedures

Eyes-flush with water. Skin- Wash, remove contaminated clothing. Inhalation-Fresh Air
Ingestion-Do not induce vomiting. Eyes & Ingestion - Medical Attention Essential.

Section VII — Precautions for Safe Handling and Use

Steps to Be Taken in Case Material Is Released or Spilled Extinguish all flames. Make dike.

Waste Disposal Method

Take up with an absorbent material and dispose of in compliance with all local, state and federal regulations.

Precautions to Be Taken in Handling and Storing

Handling - do not splash or create mists or vapors.

Storage - Store away from high temperatures and open flames. Keep containers closed.

Other Precautions

Emptied container retains vapor and product residues. Do not cut or weld on or near this container.

Section VIII — Control Measures

Respiratory Protection (Specify Type)

Use NIOSH-approved respirator if vapors or mists are generated.

Ventilation	Local Exhaust	Advisable.	Special	none
	Mechanical (General)	Usually not necessary.	Other	none

Protective Gloves

Chemical resistant

Other Protective Clothing or Equipment

Work/Hygienic Practices

Wash before eating. Do not smoke.

Appendix B: List of Dye Penetrant Suppliers

The following is a list of manufacturers of fluorescent penetrant materials as listed on the U.S. Military QPL-25135-17, Feb. 1995.

1. American Gas and Chemical Co. Ltd.
220 Pegasus Ave., Northvale, NJ 07647
2. Ardrex Inc.
16961 Knott Ave., LaMiranda, CA 90638
3. Chem-Trend Inc.
1445 W. McPherson Park Drive, Howell, MI 48844-0860
4. Magneflux Division of Illinois Tool Works
7301 W. Ainslie Ave., Harwood Heights, IL 60656
5. Met-L-Chek
1639 Euclid St., Santa Monica, CA 90404
6. Sherwin Inc.
5530 Borwick Ave., South Gate, CA 90280-7402
7. Turco Products Inc.
PO Box 272, Avon, NJ 07717

INTERNAL DISTRIBUTION

Central Research Library (2)
Document Reference Section
Laboratory Records Department (2)
Laboratory Records, ORNL RC
ORNL Patent Section
M&C Records Office (3)
L. F. Allard, Jr.
L. D. Armstrong
P. F. Becher
R. F. Bernal
T. M. Besmann
P. J. Blau
R. A. Bradley
K. Breder
C. R. Brinkman
V. R. Bullington
G. M. Caton
S. J. Chang
A. Choudhury
D. D. Conger
R. H. Cooper, Jr.
S. A. David
J. L. Ding
M. K. Ferber
R. L. Graves
D. L. Greene
H. W. Hayden, Jr.
E. E. Hoffman
C. R. Hubbard

M. A. Janney
D. R. Johnson (5)
D. Joslin
R. R. Judkins
M. A. Karnitz
B. L. Keyes
H. D. Kimrey, Jr.
W. Y. Lee
K. C. Liu
E. L. Long, Jr.
W. D. Manly
R. W. McClung
D. J. McGuire
T. A. Nolan
A. E. Pasto
K. P. Plucknett
M. H. Rawlins
M. L. Santella
A. C. Schaffhauser
E. J. Soderstrom
D. P. Stinton
R. W. Swindeman
T. N. Tiegs
B. H. West
S. G. Winslow
J. M. Wyrick

EXTERNAL DISTRIBUTION

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Wilmington DE 19880-0302

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Materials Research Laboratory
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Yokosuka 237
JAPAN

Mufit Akinc
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Ames IA 50011

Ilhan A. Aksay
Princeton University
A313 Engineering Quadrangle
Princeton NJ 08544-5263

Charles Aldridge
Heany Industries, Inc.
249 Briarwood Lane
Scottsville NY 14546

Joseph E. Amaral
Instron Corporation
Corporate Engineering Office
100 Royale Street
Canton MA 02021

Edward M. Anderson
Aluminum Company of America
N. American Industrial Chemical
P.O. Box 300
Bauxite AR 72011

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Ceradyne, Inc.
Ceramic-to-Metal Division
3169 Redhill Avenue
Costa Mesa CA 92626

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BCL
Thermal Power Systems
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580 Monastery Drive
Latrobe PA 15650-2698

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St. Paul MN 55144-1000

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 Detroit Diesel Corporation
 Mechanical Systems Technology
 13400 Outer Drive West
 Detroit MI 48239-4001

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 S-12680
 Stockholm Lerkrogsvagen 19
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 Lincoln LN2 5DJ
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 Vesuvius McDanel
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 Box 560
 Beaver Falls PA 15010-0560

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 Babcock & Wilcox - LRC
 P.O. Box 11165
 Lynchburg VA 24506-1165

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 ASM International
 Advanced Materials & Processes
 Materials Park OH 44073-0002

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 Peoria IL 61656-1875

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Shell Research Limited
Thornton Research Centre
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