



STANDARD OVERHAUL PRACTICES MANUAL

PENETRANT METHODS OF INSPECTION

**PART NUMBER
NONE**

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Revision No. 24
Jul 01/2009

To: All holders of PENETRANT METHODS OF INSPECTION 20-20-02.

Attached is the current revision to this STANDARD OVERHAUL PRACTICES MANUAL

The STANDARD OVERHAUL PRACTICES MANUAL is furnished either as a printed manual, on microfilm, or digital products, or any combination of the three. This revision replaces all previous microfilm cartridges or digital products. All microfilm and digital products are reissued with all obsolete data deleted and all updated pages added.

For printed manuals, changes are indicated on the List of Effective Pages (LEP). The pages which are revised will be identified on the LEP by an R (Revised), A (Added), O (Overflow, i.e. changes to the document structure and/or page layout), or D (Deleted). Each page in the LEP is identified by Chapter-Section-Subject number, page number and page date.

Pages replaced or made obsolete by this revision should be removed and destroyed.

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Location of Change

Description of Change

NO HIGHLIGHTS

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HIGHLIGHTS

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INTRODUCTION

1. General

- A. The instructions in this manual tell how to do standard shop procedures during maintenance functions from simple checks and replacement to complete shop-type repair.
- B. This manual is divided into separate sections:
 - (1) Title Page
 - (2) Transmittal Letter
 - (3) Highlights
 - (4) Effective Pages
 - (5) Contents
 - (6) Revision Record
 - (7) Record of Temporary Revisions
 - (8) Introduction
 - (9) Procedures
- C. Refer to SOPM 20-00-00 for a definition of standard industry practices, vendor names and addresses, and an explanation of the True Position Dimensioning symbols used.
- D. The data is general. It is not about all situations or specific installations. Use it as a guide to help you write minimum standards.
- E. If the component overhaul instructions are different from the data in this subject, use the component overhaul instructions.

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INTRODUCTION

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PENETRANT METHODS OF INSPECTION

1. INTRODUCTION

- A. The data in this subject comes from Boeing process specification BAC5423 and Boeing specification support standard BSS7039. The airline has a copy of the Boeing Process Specification manual.
- B. The data is general. It is not about all situations or specific installations. Use this data to help you write minimum requirements.
- C. The Boeing Company will not test penetrant materials for the airlines or act as an intermediary between vendors and airlines, but Boeing will occasionally test new materials as they become available.
- D. Industry standard specifications AMS 2647 and ASTM E1417 are acceptable alternatives to this procedure.
- E. Refer to SOPM 20-00-00 for a full list of all the vendor names and addresses.

2. GENERAL

- A. Penetrant examination uses the property of a liquid to go into a defect that is open at the surface of the part. The liquid is applied to the surface and permitted to soak in. Unwanted liquid is removed from the surface, but some liquid stays in the defect. A developer is applied to pull the liquid out of the defect so it can be seen. Fluorescent penetrants are examined under ultraviolet light.
- B. Penetrants are usually used on nonferrous metals, but they can be used on all metals, ceramics, glass and plastics. With some special alloys or plastics, precautions must be used to prevent damage to the part.
- C. A penetrant inspection system is a group of penetrant materials used together to do the inspection. These systems are put into groups by penetrant type, removal method, developer type, and sensitivity level. The details of the systems are shown in Table 1.

Table 1: Penetrant Classifications per BSS7039 and QPL AMS 2644

Penetrant Type	Description
1	Fluorescent Dye
2	Visible dye (not for flight hardware)
Penetrant Method	Description
A	Water washable
B	Post emulsifiable, lipophilic
C	Solvent removable
D	Post emulsifiable, hydrophilic
E	Water washable, water base (Ref ASTM D2512)
Sensitivity Level ^{*[1]}	Description
1/2	Ultra low (not applicable to flight hardware)
1	Low
2	Medium
3	High
4	Ultrahigh

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Table 1: Penetrant Classifications per BSS7039 and QPL AMS 2644 (Continued)

Penetrant Type	Description
Developer Form	Description
a	Dry powder
b	Water soluble
c	Water suspendible
d	Nonaqueous wet Type 1
e	Nonaqueous wet Type 2
f	Special application
g	No developer
Solvent Remover Class	Description
1	Halogenated
2	Non halogenated
3	Special application

*[1] The sensitivity level classifications are for Type 1 penetrant systems only.

- D. The latest revision of the Qualified Product List to AMS 2644 gives a full list of all approved penetrant materials. Other materials can be used if they become approved to be added to that list.
- E. In each penetrant inspection system, use the materials from only one manufacturer at a time. Do not use materials of one manufacturer with those from a different manufacturer unless tests make you sure the results will be satisfactory.
- F. If the overhaul instructions do not give the sensitivity level for penetrant inspection, use the data in Table 2 as a guide. This gives minimum sensitivity levels. Higher sensitivity levels can be used unless specified by overhaul instructions.

Table 2: Selection of Penetrant Sensitivity Level

TYPE	QPL-AMS-2644 SENSITIVITY LEVEL	USE FOR
1	1	Castings, other than precision or titanium, and parts made from such castings.
1	2	All materials and product forms not shown under another sensitivity level.
1	3	Portable Method C inspection of areas of possible damage and local areas of repair on flight hardware.
1	4	As specified by overhaul instructions.

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Table 2: Selection of Penetrant Sensitivity Level (Continued)

TYPE	QPL-AMS-2644 SENSITIVITY LEVEL	USE FOR
2	N/A	Inspection of ground handling or support equipment, tools and tooling.

G. Selection of penetrants for metallic parts

- (1) Unless specified differently, use the sensitivity levels in Table 2.
- (2) Examine aluminum-lithium alloys with Method B or Method D penetrants only.
- (3) Method C penetrants can be used to examine local areas.
- (4) On parts which will contain liquid oxygen, and which cannot be fully cleaned after the examination, use Method E penetrants.

H. Selection of penetrants for nonmetallic or composite parts

- (1) Make sure that the inspection materials will not damage the surface. The inspection materials must not cause cracks, crazing, pits, etching, or discoloration.
- (2) Phenolic and equivalent plastics can be safely examined with all Type 1 penetrants.
- (3) Nonmetallic materials can be examined with Type 1 Method E penetrants.
- (4) Teflon and equivalent plastics can be examined with Type 1, Method E penetrants. For these penetrants, QPL-25135 approval is not necessary.
- (5) Developer is not necessary when you penetrant examine plastics. If you use the developer with Method E penetrants, use only dry powder developer.

- I. Do not use visible penetrants. If visible penetrants are used before fluorescent penetrants, mixtures of visible penetrants with fluorescent penetrants will prevent fluorescence, and you will not see the defects. Also, visible penetrants can become hard, and when they get into thin cracks, the penetrant cannot be removed with the usual cleaning procedures.

3. MATERIALS

A. Chemical Etch

- (1) Sodium hydroxide flakes or pellets, technical grade
- (2) Nitric acid (20% solution of 40-42° Baume, technical grade acid) (BAC5765 solution 13A)
- (3) Nitric-fluoride etch solutions for titanium (BAC5753 Method II A)
- (4) Hydrochloric acid, concentrated
- (5) Hydrofluoric acid, concentrated
- (6) Hydrofluoric acid, 70%
- (7) Ammonium bifluoride

- B. Penetrants – Refer to the QPL of AMS 2644 for a full list of approved products. Other materials can be used if they become approved to add to that list.

- C. Aliphatic naphtha – TT-N-95 (SOPM 20-60-01)

- D. Thinner – TT-T-291, Grade I (SOPM 20-60-01)

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4. EQUIPMENT

- A. Set up the penetrant inspection equipment to keep to a minimum possible contamination of the penetrant materials by water, dust, or dirt. Include a good flow of air when you will use solvents, removers, developers which are not water-based, or if you spray the penetrants.
- B. For black light inspections
 - (1) Use bulbs to send out light in the 320-400 nanometer range, to give a minimum of 1000 microwatts per square centimeter at 15 inches (38 cm) from the bulb or filter face.
 - (2) Do tests of the black light intensity as follows:
 - (a) Weekly, if the intensity is more than 1500 microwatts per square centimeter at the 15 inch (38 cm) minimum distance.
 - (b) Daily, if the intensity is 1000-1500 microwatts per square centimeter at the 15 inch (38 cm) minimum distance.
 - (3) Black light intensity at the part surface – See Table 3.

Table 3: Type 1 Inspection Light Requirements

AMBIENT WHITE LIGHT ^{*[1]}	INSPECTION CONDITIONS	MINIMUM BLACK LIGHT μ W/cm2 ^{*[1]}
0-2 foot candles (0-20 lux)	Darkened Inspection Area With Developer	1000
0-2 foot candles (0-20 lux)	Darkened Inspection Area Without Developer	3000
More than 2 foot candles (20 lux) ^{*[2]}	Subdued Lighting With Developer	5000

*[1] Light intensity at the inspection surface.

*[2] If possible, decrease ambient light to less than 2 foot candles (20 lux). Do not do black light inspections with white light levels more than 10 foot candles (100 lux).

5. SEQUENCE OF OPERATIONS

- A. Penetrant examine parts after heat treatment, welding, final machining operations, or other procedures that could cause defects or make them come to the surface.
- B. Penetrant examine parts before surface treatments that will smear metal, close surface openings or get into the defects any contamination which cannot be removed or which will cause a problem with the penetrant. Some of these operations are:
 - (1) Application of conversion coatings such as anodize, chemical treatment, chromate treatment, and passivation
 - (2) Peening
 - (3) Impregnation, plating, painting, and application of solid film lubricant
 - (4) Abrasive cleaning, blasting, sanding, buffing, burnishing, honing, and grinding. For machine-ground bushings, penetrant examine after machining but before final grinding.
- C. If the surface has a conversion coating (anodize, chemical treatment, chromate treatment or passivation), coating removal before you penetrant examine is not necessary unless there is a high penetrant background.

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- D. If the surface has smeared metal, chemical etch per Paragraph 6. to remove a minimum of 0.0002 inch from the surface. The etch is not necessary before a penetrant check of an operation that forms or straightens a part after the operation that smeared the metal.
- E. Do not penetrant examine shot-peened surfaces unless the overhaul instructions are different.
- F. Remove impregnations, plating, paint, or solid film lubricant before you penetrant examine.

6. CHEMICAL ETCH

- A. Use this procedure to chemically remove smeared metal when necessary.
- B. When necessary and to prevent changes to important dimensions, give holes with small tolerances the protection of masks or plugs before the etch. Remove this protection after the etch and before the penetrant examination.
- C. For Aluminum Alloy
 - (1) Solutions

CAUTION: THESE CHEMICALS ARE VERY CORROSIVE AND POISONOUS. DO NOT BREATHE THE VAPORS OR MISTS. DO NOT GET THE CHEMICALS IN THE EYES, ON THE SKIN OR ON CLOTHING. DO NOT LET THE CHEMICALS TOUCH MATERIALS THAT CAN BURN. WHEN YOU MIX THESE CHEMICALS WITH WATER, ALWAYS ADD THE CHEMICAL TO THE WATER. DO NOT ADD WATER TO THE CONCENTRATED CHEMICAL, BECAUSE THE WATER WILL BOIL AT AN EXPLOSIVE RATE AS YOU ADD IT.

- (a) Method 1 (Sodium Hydroxide etch) – Make a solution of 10 grams sodium hydroxide in 90 ml tap water.
 - (b) Method 2 (Flicks etch) – Add 10 ml concentrated hydrofluoric acid and 15 ml concentrated hydrochloric acid to 90 ml tap water. Mix fully.
 - (2) Carefully clean the surfaces to remove all grease, oil, dirt and other contamination.
 - (3) Apply the solution with swabs to the surfaces for 2-5 minutes. Be careful not to let the solution get into faying surfaces. This etch solution will make black smut.
 - (4) Rinse with a good flow of water.
 - (5) Remove the black smut with the 20% nitric acid solution applied with swabs.
 - (6) Rinse with a good flow of water. This step is very important, because etchant that stays on the surface can cause intergranular corrosion.
 - (7) Dry fully with a hot air dryer. The surface must be completely dry before you apply the penetrant.
 - (8) If the amount of etch is not sufficient, do Paragraph 6.C.(3) thru Paragraph 6.C.(7) again.
 - (9) Let the surface cool to below 100°F (38°C) before you apply the penetrant.
- D. For Magnesium Alloy
 - (1) Solution – Use Solution 2 of BAC5769.
 - (2) Carefully clean the surface to remove all grease, oil, dirt and other contamination.
 - (3) Alkaline clean and rinse per SOPM 20-30-03.
 - (4) Apply the solution with swabs to the surface for not more than 90 seconds.
 - (5) Rinse with a good flow of water. This step is very important, because etchant that stays on the surface can cause intergranular corrosion.
 - (6) Dry fully with a hot air dryer. The surface must be completely dry before you apply the penetrant.

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- (7) If the amount of etch is not sufficient, do Paragraph 6.D.(4) thru Paragraph 6.D.(6) again.
 - (8) Let the surface cool to below 100°F (38°C) before you apply the penetrant.
- E. For 300-series CRES, A-286 CRES, Nickel and Cobalt Alloys

(1) Solutions

CAUTION: THESE CHEMICALS ARE VERY CORROSIVE AND POISONOUS. DO NOT BREATHE THE VAPORS OR MISTS. DO NOT GET THE CHEMICALS IN THE EYES, ON THE SKIN OR ON CLOTHING. DO NOT LET THE CHEMICALS TOUCH MATERIALS THAT CAN BURN. WHEN YOU MIX THESE CHEMICALS WITH WATER, ALWAYS ADD THE CHEMICAL TO THE WATER. DO NOT ADD WATER TO THE CONCENTRATED CHEMICAL, BECAUSE THE WATER WILL BOIL AT AN EXPLOSIVE RATE AS YOU ADD IT.

- (a) Method 1 – Add 40 ml of 40-42° Baume nitric acid and 4 ml of 70% hydrofluoric acid to 56 ml tap water. Mix fully.
 - (b) Method 2 – Add 40 ml of 40-42° Baume nitric acid and 3 grams ammonium bifluoride to 57 ml tap water. Mix fully.
- (2) Carefully clean the surfaces to remove all grease, oil, dirt and other contamination.
- (3) Apply the solution with swabs to the surfaces for 2-5 minutes. Be carefully not to let the solution get into faying surfaces. This etch solution will make a black smut.
- (4) Rinse with a good flow of water.
- (5) Remove the black smut with the 20% nitric acid solution applied with swabs.
- (6) Rinse with a good flow of water. This step is very important, because etchant that stays on the surface can cause intergranular corrosion.
- (7) Dry fully with a hot air dryer. The surface must be completely dry before you apply the penetrant.
- (8) If the amount of etch is sufficient, do Paragraph 6.E.(3) thru Paragraph 6.E.(7) again. If too much smut is made, make and use a solution with less water.
- (9) Let the surface cool to below 100°F (38°C) before you apply the penetrant.
- F. For titanium alloys, etch by the Method IIA procedure of BAC5753.

7. SURFACE PREPARATION

- A. The parts to be examined must be clean, dry, and free of grease, oil, grinding compounds, rust, scale, acids or alkalis, fluxes, burrs, feather edges, smeared metal, paint (primer, enamel), layout dye, or any other material which could hide defects and result in irrelevant indications or which will interfere with the examination procedure.
- B. If parts, platings or coatings were removed or chemically etched, the parts must be rinsed and dried before the penetrant examination. Make sure that chemicals do not go into faying surfaces. If you gave holes the protection of masks or plugs before the etch, remove this protection before the penetrant examination.
- C. Carefully wash with water and dry the parts that were treated with acids or alkalis. Chemicals and moisture that could be caught in the defects must be removed. Chemicals in the defects could react with the penetrant and prevent good indications of defects. Ultrasonic cleaning can help.
- D. The surface must be fully dry before you apply the penetrant. If you think there is moisture in defects, heat the surfaces to 225°F (107°C) maximum until the moisture is gone or the surface is dry. Let the surface cool to 100°F (38°C) or less before you apply the penetrant.

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- E. Removal of anti-friction bearings and disassembly of parts is recommended before penetrant inspection. If bearings are not removed, or parts are not disassembled, they must be completely masked to prevent contamination by penetrant fluid.

8. APPLICATION OF PENETRANT

- A. Before you start, make sure the penetrant and part temperature is 40-120°F (4-49°C).
- B. Under black light, apply a layer of penetrant on all of the surfaces to be examined. You can apply the penetrant with a spray, swabs, a flow of liquid, or you can put the part in the penetrant.
- C. Do not let penetrant collect in holes, recesses, or pockets. Put the part in a rack or turn or move it as necessary to let the penetrant drain equally from all surfaces.
- D. Let the penetrant soak in for these minimum times (which include drain times):
 - (1) Oil-base, water-washable penetrants – 10 minutes
 - (2) Post-emulsifiable penetrants – 20 minutes
 - (3) Solvent-removable penetrants – 20 minutes
 - (4) Water-base, water-washable penetrants – 10 minutes
- E. These penetration times are applicable for penetrant or part temperatures 60-120°F (15-49°C). For penetrant or part temperatures 40-60°F (4-15°C), multiply these times by 2.

9. REMOVAL OF UNWANTED PENETRANT

- A. After the applicable soak and drain time, remove the penetrant from the surfaces by water spray, emulsifier-water spray, or solvent, as applicable. Do this under black light of 100 microwatts per square centimeter minimum at the work surface, and visible light no stronger than 10 foot candles. Remove the penetrant until the background fluorescence is gone. This will let the remaining penetrant be only in the defects. Be careful not to remove too much penetrant, or you will not be able to find the defects.
- B. Remove the unwanted penetrant before it dries too much, or it will not be easy to remove it from the surfaces. If the penetrant does get too dry, completely clean the parts and apply the penetrant again per Paragraph 7., Paragraph 8. above.
- C. Water washable penetrant
 - (1) Rinse with a water spray, with 50-100°F (10-38°C) water at 40 psi maximum pressure.
- D. Post emulsifiable penetrant with lipophilic emulsifier

CAUTION: EMULSIFICATION TIME STARTS WHEN THE EMULSIFIER OR REMOVER IS APPLIED TO THE PART. THEREFORE, THE PART MUST BE COMPLETELY COVERED AS QUICKLY AS POSSIBLE.

- (1) Put the part in the emulsifier.
- (2) Let the part drain for 5 minutes maximum.
- (3) Rinse with a water spray, with 50-100°F (10-38°C) water at 40 psi maximum pressure.
- E. Post emulsifiable penetrant with hydrophilic remover. Use one of these procedures:

CAUTION: EMULSIFICATION TIME STARTS WHEN THE EMULSIFIER OR REMOVER IS APPLIED TO THE PART. THEREFORE, THE PART MUST BE COMPLETELY COVERED AS QUICKLY AS POSSIBLE.

- (1) Put the part in the remover.

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- (a) Rinse with a water spray to remove unwanted penetrant, with 50-100°F (10-38°C) water at 40 psi maximum pressure.
 - (b) Put the part in the remover for 3 minutes maximum. Shake the part or the remover while the part is in the remover.
 - (c) Rinse with a water spray to remove the remaining penetrant, with 50-100°F (10-38°C) water at 40 psi maximum pressure.
- (2) Spray on the remover
- (a) Rinse with a water spray to remove unwanted penetrant, with 50-100°F (10-38°C) water at 40 psi maximum pressure.
 - (b) Use a water spray, with metered hydrophilic remover no stronger than 5 percent (0.25 percent is recommended) to remove the remaining penetrant.
 - (c) Rinse with a water spray to remove the remaining penetrant, with 50-100°F (10-38°C) water at 40 psi maximum pressure.
- F. If parts are on an automatic line, do not let the line stop with emulsifier on the part surface. If the emulsification time is longer than the limit, clean and dry the parts and start over again. Parts on an automatic line can be rinsed without black light if the procedure is controlled to be sure the rinse is sufficient to remove the penetrant.
- G. If a water rinse could cause corrosion because the water could make puddles or be slow to dry, use this Method C procedure:
- (1) Wipe the area with a clean, dry, lint-free cloth. Turn the cloth to use a clean surface for each wipe. Wipe until most of the penetrant is removed.
 - (2) Wipe the area with a clean, lint-free cloth lightly moist with a cleaner approved by the QPL to AMS 2644. Turn the cloth to use a clean surface for each wipe. Wipe until the penetrant is removed.
 - (3) When the penetrant is removed, immediately apply a very thin layer of non-aqueous wet developer.

10. DRYING

- A. Part surfaces must be fully dry before you apply dry developer or developer which is not water-based. Water based developers must be applied while the surface is wet, and then the surfaces must be fully dried.
- B. Dry parts with warm air up to 160°F (71°C). The recommended temperature is 120°F (49°C). If a drier is not available, let the parts dry in air or use a fan. Do not dry parts longer than 30 minutes. Too high a temperature or too long a time will decrease the sensitivity of the penetrant.
- C. For plastic parts, dry the surfaces with clean, lint-free cheesecloth or equivalent wipers or with a good flow of air up to 100°F (38°C).

11. APPLICATION OF DEVELOPER

- A. Developer must be used for all parts unless the overhaul instructions are different.
- B. Development time for wet developers is measured from the time the developer is completely dry to the time you examine the surface. For dry developers, development time is measured from the time you apply the developer to the time you examine the surface. For all developers, use a minimum of 10 minutes development time. More development time could be necessary for some types of defects or to help you find out how important the indications are.
- C. Dry Developers

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- (1) Sift, dust, or spray the developer on the parts or put the parts in the developer to make sure you apply the developer to all surfaces.
 - (2) Do not shake or spray too much, or the developer could rub off some of the penetrant that shows indication of defects.
- D. Wet Developers – Aqueous (water) Suspendible and Aqueous (water) Soluble
- (1) Immediately after you remove the unwanted penetrant, spray the developer on the surfaces or put the parts in the developer. Do not apply this developer with a brush. Make sure you apply the developer as a continuous, fully-mixed suspension or solution that wets all of the surfaces to be examined.
 - (2) Do not let the developer collect in puddles. Use low air pressure or suction, or move the parts, to remove unwanted developer.
 - (3) Immediately after you apply the developer to all of the surfaces, dry the surface with warm air per Paragraph 10.
- E. Wet developers – Nonaqueous (not water-based)
- (1) Shake the developer container to fully mix it before you apply it.
 - (2) For best results and best sensitivity, a thin smooth layer of the developer is necessary. To get a thin layer, spray the developer with a very fine nozzle and constant movement of the spray. Two or three thin coats are better than one thick coat.

12. INSPECTION OF THE PARTS

- A. Examine the parts in a booth with the black light per Paragraph 4.
- B. Before you examine under black light and each time your eyes are open to visible light, let your eyes adjust to the darkness for at least 3 minutes. Special scales are available from penetrant manufacturers to help you know if your eyes are sufficiently adapted to the darkness.
- C. Do not use corrective lenses or spectacles which are photochrome, photogray, or equivalently sensitive to light. Under black light, when there is no white light, this type of eyewear can decrease visual sensitivity.
- D. Do not look directly at the source of the black light, or your eyeballs will fluoresce and temporarily decrease visual sensitivity. Correctly filtered black light is not dangerous to the eyes, but if the filter is defective, it could let dangerous short-wave ultraviolet light through from the bulb. Replace defective or cracked filters immediately.
- E. Examine the surfaces as carefully as your eyes will permit. This is the practical limit of penetrant inspection. If this is not sufficiently satisfactory, the overhaul instructions will give other inspection procedures to make sure the part is serviceable.
- F. When you examine castings which were in service, reject parts only if they have signs of cracks or corrosion caused by the period of service, unless the overhaul or service bulletin instructions are different. Do not reject the parts if there are only indications of porosity.
- G. Reject parts that have surface defects which are more than permitted limits. If the limits are not specified, reject parts that have shrinkage cracks or porosity, cold shuts, fatigue cracks, forming cracks, grinding and heat-treat cracks, seams, laps, and bursts. Refer to BAC5423 for more details.
- H. If permitted by the overhaul instructions, repair the defects and penetrant examine the part again to see if it became serviceable.

13. CLEANING OF PARTS AFTER PENETRANT INSPECTION

- A. Clean the accepted parts in 4 hours or less after you applied the developer.

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- B. Penetrant material remaining on the part could cause corrosion or can be a problem for subsequent machining and inspection. Remove the remaining developer as follows:
 - (1) Dry powder developer – Blow with an air hose. If necessary, alkaline or solvent clean.
 - (2) Wet developer – Use a brush or wipe with a dry cloth. Rinse or spray with water. If necessary, alkaline or solvent clean.
- C. After you clean the parts, examine them under black light to make sure all of the penetrant and developer is gone.

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