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**Surface
Discontinuities on
Bolts, Screws, and
Studs**

SAE Recommended Practice
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SURFACE DISCONTINUITIES ON BOLTS, SCREWS, AND STUDS

1. SCOPE:

This recommended practice defines, illustrates, and specifies allowable limits for various types of surface discontinuities that may occur or become apparent during the manufacture and processing of bolts, screws, and studs which are primarily intended for use in automotive assemblies subjected to severe dynamic stresses and necessitating use of high-strength fasteners having appropriate fatigue resistant properties.

- 1.1 The basic recommended practice does not include inspection sampling requirements. It is intended that the purchaser shall specify, in the original inquiry and purchase order, the inspection sampling requirements which the producer must satisfy to demonstrate the acceptability of bolts and screws with respect to surface discontinuities. Appendix outlines inspection sampling plans applicable when such requirements are not specified by the purchaser in the original inquiry, purchase order, or in related specifications.

2. TYPES OF SURFACE DISCONTINUITIES:

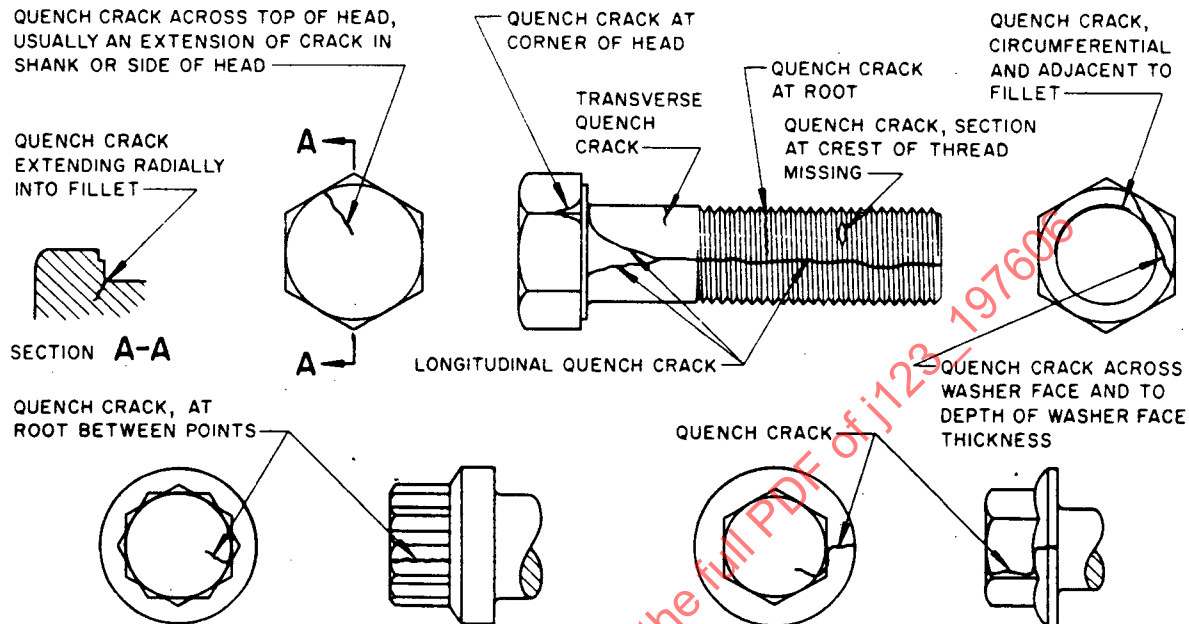
For the purpose of this recommended practice, surface discontinuities on bolts, screws, and studs are divided into 10 "types," defined as follows:

- 2.1 Crack: A crack is a clean (crystalline) fracture passing through or across the grain boundaries without inclusion of foreign elements. Cracks are normally caused by overstressing the metal during forging or other forming operation, or during heat treatment. Where parts are subjected to significant reheating, cracks usually are discolored by scale.

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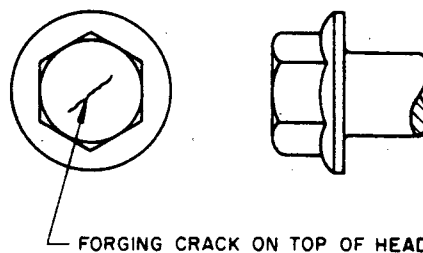
- 2.1.1 Quench Cracks: Quench cracks may occur during heat treatment due to excessively high thermal and transformation stresses. They usually traverse an irregular and erratic course on the surface of the fastener. Typical quench cracks are shown in Fig. 1.



NOTE: Quench cracks of any depth, any length, or in any location are not permissible discontinuities.

FIGURE 1 - Typical Quench Cracks

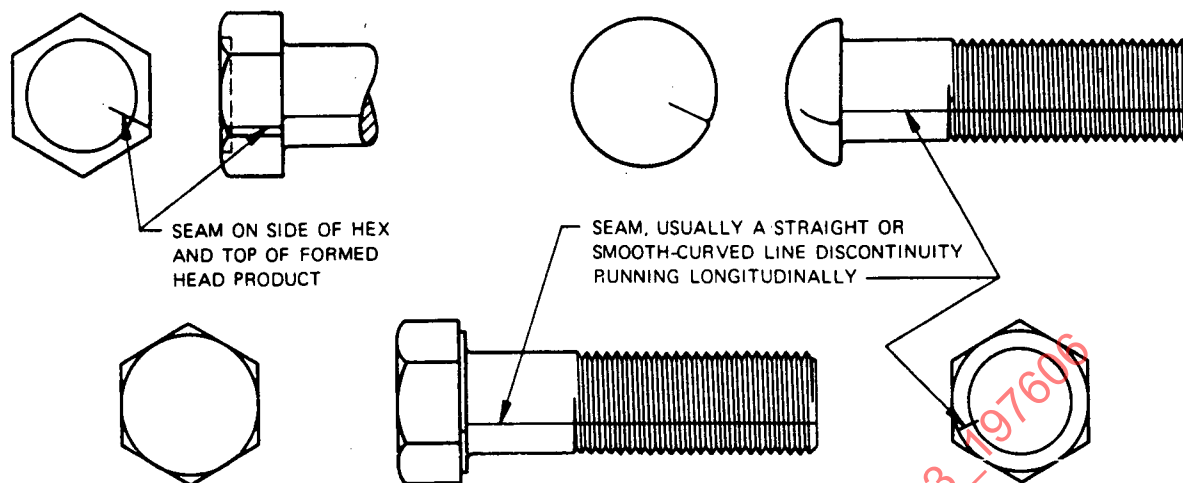
- 2.1.2 Forging Cracks: Forging cracks may occur during the cutoff or forging operations and are located on the top of the heads of screws and bolts. Typical forging cracks are shown in Fig. 2.



NOTE: Forging cracks are permissible discontinuities if within the limits specified in paragraph 3.5.

FIGURE 2 - Typical Forging Cracks

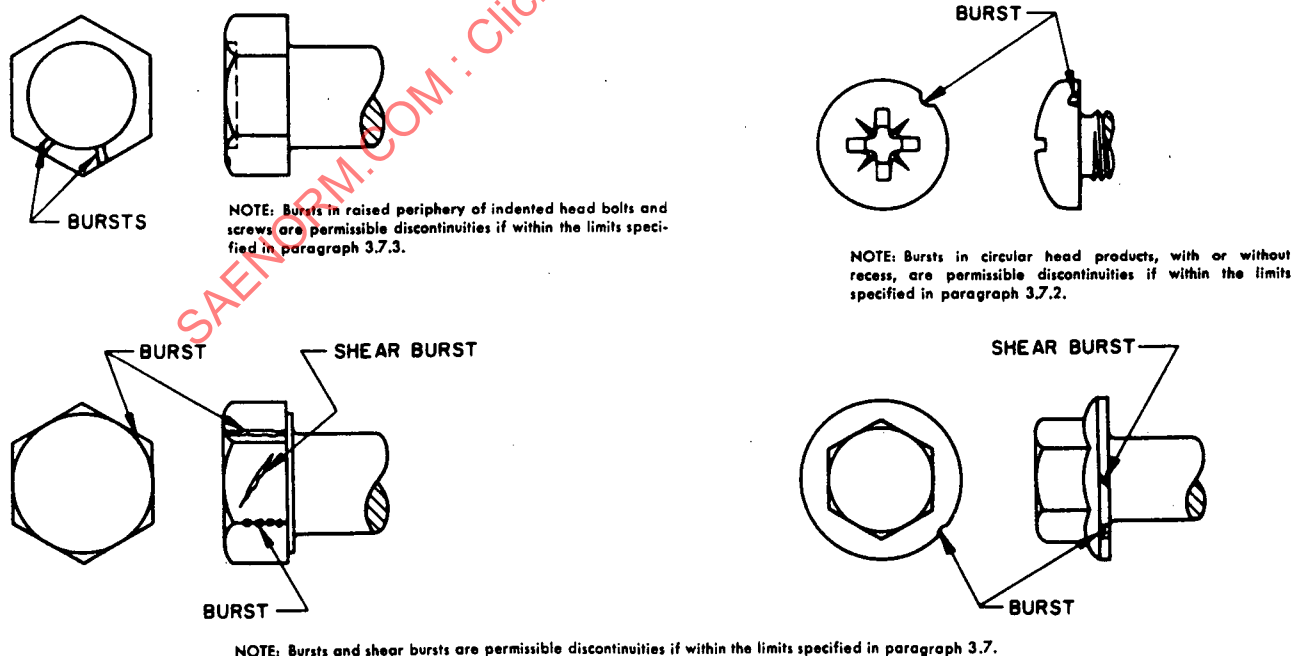
- 2.2 Seam: Seams are generally inherent in the raw material from which fasteners are manufactured. They are narrow, generally straight or smooth-curved line discontinuities, running longitudinally on the shank and/or thread. Seams may extend onto the tops of the heads of circular head products as well as being present at the periphery of the head. Seams may also extend into the chamfer circle, washer face, and wrenching flats of hex head products. Typical seams are shown in Fig. 3.



NOTE: Seams are permissible discontinuities if within the limits specified in paragraph 3.6.

FIGURE 3 - Typical Seams

2.3 **Burst:** A burst is an open break in the metal (material). Bursts may occur on the flats or corners of the heads of bolts and screws, at the periphery of flanged or circular head products, or on the raised periphery of indented head bolts and screws. Typical bursts are shown in Fig. 4.



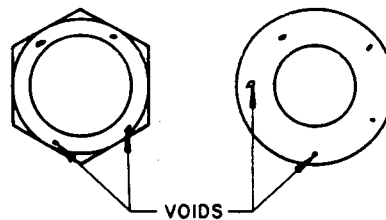
NOTE: Bursts in raised periphery of indented head bolts and screws are permissible discontinuities if within the limits specified in paragraph 3.7.3.

NOTE: Bursts in circular head products, with or without recess, are permissible discontinuities if within the limits specified in paragraph 3.7.2.

NOTE: Bursts and shear bursts are permissible discontinuities if within the limits specified in paragraph 3.7.

FIGURE 4 - Typical Bursts and Shear Bursts

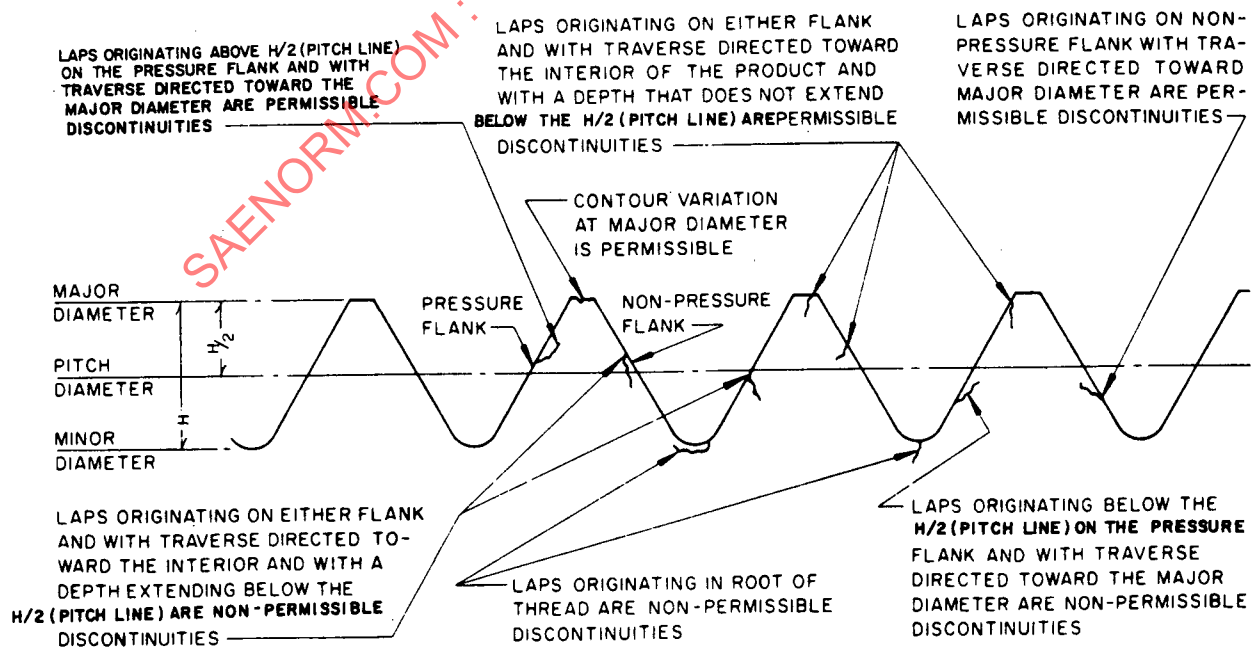
- 2.4 Shear Burst: A shear burst is an open break in the metal, occurring most frequently at the periphery of products having circular or flanged heads and are generally located at approximately 45 deg to the product axis. Shear bursts may also occur on the sides of hex head products. Typical discontinuities of this type are shown in Fig. 4.
- 2.5 Void: A void is a shallow pocket or hollow on the surface of the bolt or screw due to nonfilling of metal during forging or upsetting. Typical voids are shown in Fig. 5.



NOTE: Voids are permissible discontinuities if within the limits specified in paragraph 3.8.

FIGURE 5 - Typical Voids on Bearing Surface

- 2.6 Lap: A lap is a fold-over of metal in the threads of screws, bolts, and studs. If laps occur, they generally show a pattern of consistency between the product, that is, laps will be identically located and with the same direction of traverse between all product. Typical laps in external threads are shown in Fig. 6A.



NOTE: These requirements apply to all bolts and screws except tapping screws with spaced threads.

FIGURE 6A - Surface Discontinuities in External Screw Threads

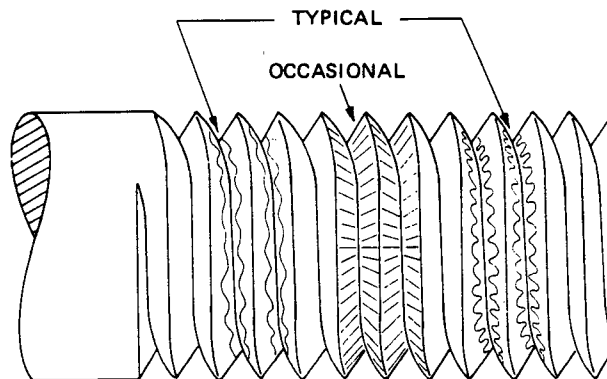
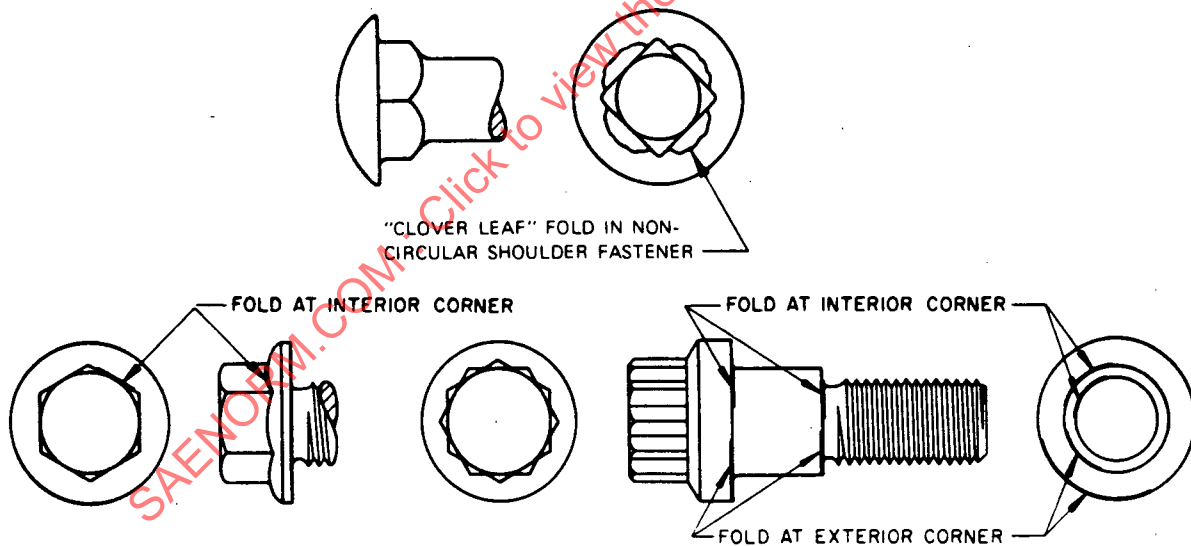


FIGURE 6B - Starting Serration Marks

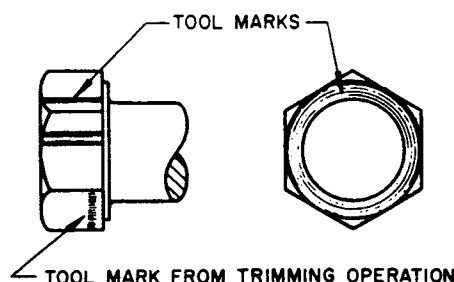
- 2.7 **Fold:** A fold is a doubling over of metal which may occur during the forging operation. Folds may occur at or near the intersection of diameter changes and are especially prevalent with noncircular necks, shoulders, and heads. Typical folds are shown in Fig. 7.



NOTE: Folds in interior corners at or below the bearing surface are not permissible discontinuities. Folds at exterior corners are permissible discontinuities if within the limits specified in paragraph 3.4

FIGURE 7 - Typical Folds

- 2.8 **Tool Marks:** Tool marks are longitudinal or circumferential grooves of shallow depth produced by the movement of manufacturing tools over the surface of the fastener. Typical tool marks are shown in Fig. 8.



NOTE: Tool marks are permissible discontinuities if within the limits specified in paragraph 3.9.

FIGURE 8 - Typical Tool Marks

2.9 Nick or Gouge: A nick or gouge is an indentation on the surface of the fastener, produced by forceful abrasion or the impact of product coming into contact with other product or manufacturing equipment during manufacture.

3. LIMITS FOR SURFACE DISCONTINUITIES:

3.1 Letter Definitions: Throughout the following requirements, D designates the nominal size (basic major diameter of thread) of bolts, screws, and studs, except for bolts and screws with shoulders, in which case D designates the largest shoulder diameter. F designates the nominal flange diameter or head diameter of products having circular heads. For metric-series products, use millimeter; for inch-series products, use inch.

3.2 Quench Cracks: Quench cracks of any depth, any length, or in any location, are not permitted. (See 2.1.1 and Fig. 1).

3.3 Laps in Screw Threads: Laps of any depth and any length which (a) are present in the root of the screw thread, or (b) originate on the flank, traverse toward the interior, and extend in depth below the pitch line of the bolt, screw, or stud, or (c) originate below the pitch line on the pressure flank and traverse toward the major diameter, are not permitted. (This requirement is not applicable to tapping screws having spaced threads.) (See 2.6 and Fig. 6A.) When approved by the purchaser, marks on threads caused by the serrations on thread rolling dies (see Fig. 6B) shall be excluded from these requirements.

3.4 Folds:

3.4.1 Folds located in internal corners at or below the bearing surface, for example, in the fillet at the junction of head and shank, are not permitted.

3.4.2 Folds located at the intersection of the flange periphery and bearing surface, are not permitted (See 2.7 and Fig. 7.)

3.5 Forging Cracks: Forging cracks on the top of head bolts and screws shall not exceed a length of 1 D or a width or depth of 0.20 mm (0.008 in) ± 0.010 D.

- 3.6 Seams: For metric-series bolts, screws and studs, seams in the shanks shall not exceed (a) an open width at the surface of 0.13 mm for sizes 6.3 to 12 mm, inclusive, and 0.25 mm for sizes 14 mm and larger, and (b) a depth of $0.015 D + 0.10$ mm for sizes 6.2 to 16 mm, inclusive, and $0.030 D$ for sizes over 16 mm. (See 2.2 and Fig. 3)

For inch-series bolts, screws and studs, seams in the shanks shall not exceed (a) an open width at the surface of 0.005 in for sizes 1/4 to 7/16 in, inclusive, and 0.010 in for sizes 1/2 in and larger, and (b) a depth of $0.015 D + 0.004$ in for sizes 1/4 to 5/8 in, inclusive, and $0.030 D$ for sizes over 5/8 in. (See 2.2 and Fig. 3.)

Seams extending into the heads and flanges of fasteners which do not open beyond the limits specified for bursts are acceptable.

3.7 Bursts and Shear Bursts:

- 3.7.1 Bursts in the flats of hex bolts and screws shall not exceed a width or an open depth of 0.25 mm (0.010 in) $+0.025 D$. In addition, no burst shall extend into the bearing surface, nor shall any burst occurring at the intersection of two wrenching flats reduce the width across corners below the specified minimum. (See 2.3 and 2.4 and Fig. 4.)
- 3.7.2 Flanges of bolts and screws and peripheries of circular head products may have two or more bursts or shear bursts providing that only one has a width greater than 0.13 mm (0.005 in) $+0.020 F$ or an open depth greater than 0.08 mm (0.003 in) $+0.012 F$; in addition, this one burst shall not have a width exceeding 0.25 mm (0.010 in) $+0.040 F$ or an open depth of 0.15 mm (0.006 in) $+0.024 F$.
- 3.7.3 Bursts in the raised periphery of indented head bolts and screws shall not exceed a width of 0.25 mm (0.010 in) $+0.020 D$, or have a depth greater than the height of the raised periphery. (See 2.3 and Fig. 4.)

- 3.8 Voids on Bearing Surface: Voids on the bearing surface of bolts and screws shall not exceed a depth of 0.25 mm (0.010 in) and the combined area of all voids shall not exceed 5% of the specified minimum area of the bearing surface. The method for determining area of voids shall be as agreed upon by purchaser and producer.

- 3.9 Tool Marks: Tool marks on the bearing surface shall not exceed surface roughness measurement of $2.8 \mu\text{m}$ (110 μin) determined as the arithmetic average deviation from the mean surface. (See 2.8 and Fig. 8.)

- 3.10 Nicks and Gouges: Nicks and gouges located in the threaded length shall not be of size and number which will interfere with assembly of the proper GO thread gage on the thread with the application of not more than 0.06 times $DN \cdot m$ (12 times $D \text{ in-lb}$) of torque, where D is the nominal bolt, screw, or stud size in inches. The manufacturer shall exercise due care during the manufacture and handling of parts to minimize the number and magnitude of nicks and gouges.

4. INSPECTION PROCEDURE

Bolts, screws and studs shall be inspected in accordance with the procedures outlined in 4.1 and 4.2, unless otherwise specified by purchaser.

4.1 Visual Inspection: A representative sample¹ shall be picked at random from the lot. The sample shall be examined visually for quench cracks, bursts, shear bursts, forging cracks, folds, tool marks, seams, voids on the bearing surface, and nicks and gouges.

4.1.1 If any part is found with quench cracks or with folds at internal corners at or below the bearing surface, the lot shall be subject to rejection.

4.1.2 If any part is found with seams, bursts, shear bursts, forging cracks, tool marks, voids, or nicks and gouges which exceed the allowable limits as specified for the applicable type of discontinuity under paragraph 3, the lot shall be subject to rejection.

4.2 Seam and Lap Inspection: The same sample (if acceptable by visual inspection) shall then be further examined for laps in threads and seams by deep (surface) acid-etch or magnetic-inspection techniques (Magna-glo, Magna-flux, eddy current, etc.). (NOTE: Other examining procedures may be used providing they have an equivalent ability to detect discontinuities of the size specified in 3.3 and 3.6.)

4.2.1 All parts showing indications which could be interpreted as seams shall be set aside. From this group, a secondary sample¹ shall be picked at random and each part in this sample sectioned through the shank perpendicular to the axis and etched for microscopic examination. The section should be through the unthreaded body adjacent to the thread runout. For bolts and screws which are threaded to the head, the section should be taken where the seam indication intersects the root of the thread at a distance of approximately one D from the underside of the head, where D is nominal size of bolt or screw. (A recommended procedure is outlined in ASTM E 3, Methods of Preparing Metallographic Specimens.) If during the microscopic examination any part is found having a seam with a depth in excess of the limit specified in 3.6, the lot shall be subject to rejection.

¹See Appendix.

4.2.2 Laps in Screw Threads: All products showing indications of laps in the threads shall be set aside. If the original sample examined in 4.2 was inspected using magnetic techniques, this same sample (if acceptable by inspection in 4.1) shall again be examined by magnetic inspection techniques but with the direction of flow of magnetization current changed so as to detect discontinuities located transverse to the bolt or screw axis. (NOTE: During this inspection, attention should also be given to examining the product for indications showing transverse quench cracks or folds in internal corners as these discontinuities are sometimes not readily seen in visual examination.) From the products set aside, five specimens shall be selected at random, surface etched, and examined visually to determine that the pattern of laps is reasonably consistent between products. One of the five specimens shall be sectioned longitudinally on the center line of the part and on a plane passing through the point at which any lap extends closest to the minor diameter of the thread and the section etched for microscopic examination. If during the microscopic examination any lap is found with a location and direction of traverse which classifies the lap as nonpermissible, the lot shall be subject to rejection.

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