



Standard Practice for Fabrication of Neutron Radiographic Sensitivity Indicators¹

This standard is issued under the fixed designation E 2023; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This practice covers the fabrication of Sensitivity Indicators (SI), which can be used to determine the relative quality of radiographic images produced by direct, thermal neutron radiographic examination.

1.2 The values stated in inch-pound units are regarded to be standard. The SI equivalents given in parentheses in the text are for information only.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 ASTM Standards:

E 543 Practice for Evaluating Agencies Performing Nondestructive Testing²

E 545 Method for Determining Image Quality in Direct Thermal Neutron Radiographic Examination²

E 748 Practices for Thermal Neutron Radiography of Materials²

E 1316 Terminology for Nondestructive Examinations²

3. Terminology

3.1 *Definitions*—For definitions of terms used in this practice, see Terminology E 1316, Section H.

4. Summary of Practice

4.1 The Sensitivity Indicator (SI) is used for qualitative determination of the sensitivity of detail visible on the neutron radiograph. It consists of a step wedge containing gaps and holes of known dimensions. Visual inspection of the image of this device provides subjective information regarding total radiographic sensitivity with respect to the step-block material, as well as optional subjective data, regarding detrimental levels of gamma exposure.

4.2 Neutron radiography practices are discussed in Practices E 748. The neutron radiograph used to determine image quality using the SI shall meet the requirements of Method E 545.

5. Significance and Use

5.1 The only truly valid image quality indicator is a material or component, equivalent to the part being neutron radiographed, with a known standard discontinuity, inclusion, omission or flaw (reference standard comparison part). The SI is designed to substitute for the reference standard, providing qualitative information on hole and gap sensitivity in a single unit. Fabrication in accordance with this practice is vital for accurate and consistent measurements.

5.2 This practice shall be followed for the fabrication of all SIs to be used with Method E 545 to determine image quality in direct thermal neutron radiography.

6. Basis of Application

6.1 *Qualification of Nondestructive Agencies*—If specified in the contractual agreement, NDT agencies shall be qualified and evaluated as described in Practice E 543. The applicable edition of Practice E 543 shall be specified in the contractual agreement.

6.2 *Procedures and Techniques*—The procedures and techniques to be utilized shall be as described in this practice unless otherwise specified. Specific techniques may be specified in the contractual agreement.

6.3 *Reporting Criteria/Acceptance Criteria*—Reporting criteria for the examination results shall be in accordance with Sections 9 and 10 unless otherwise specified. Acceptance criteria, for example, reference radiographs, shall be specified in the contractual agreement.

6.4 Reexamination of repaired/reworked items is not addressed in this practice and, if required, shall be specified in the contractual document.

7. Sensitivity Indicator (SI)

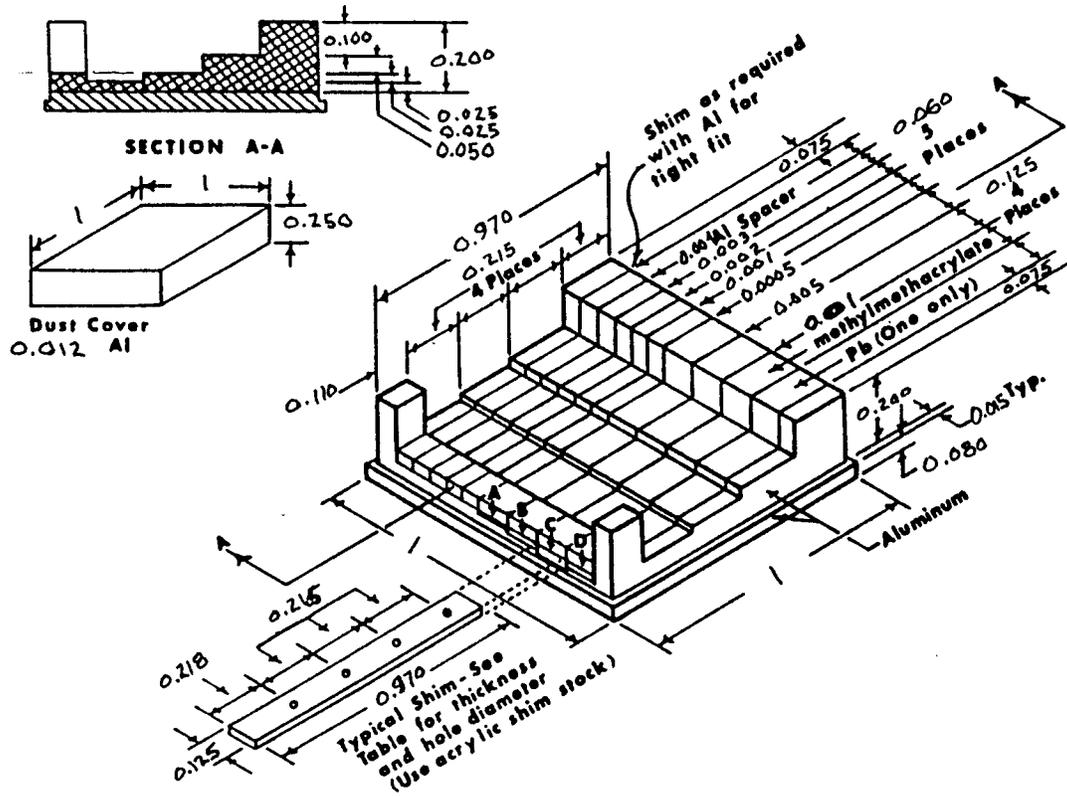
7.1 The Sensitivity Indicator (SI) shall be constructed of cast acrylic resin, lead (optional), and aluminum. The construction and dimensions are shown in Fig. 1.

7.2 The optional lead step in the SI may be replaced with a blank, cast acrylic resin step. The lead provides a visual indication of beam gamma content; however, the lead image is not used for any of the SI calculations of Method E 545.

¹ This practice is under the jurisdiction of ASTM Committee E-7 on Nondestructive Testing and is the direct responsibility of Subcommittee E07.05 on Radiology (Neutron) Method.

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² Annual Book of ASTM Standards, Vol 03.03.



Material — Methacrylate

Shim	Thickness	Hole Diameter
A	0.005	0.005
B	0.010	0.010
C	0.020	0.020
D	0.010	0.010

NOTE 1—All dimensions are in inches.

NOTE 2—The lead step may be replaced with a methacrylate strip with the D shim eliminated.

FIG. 1 Sensitivity Indicator

7.3 The acrylic resin shall be methacrylate.

7.4 All dimensional tolerances are as noted on the figures.

7.5 Aluminum shims and strips shall be 99.9 % pure elemental material.

7.6 The SI may be encased in a 6061 aluminum dust cover, 0.012-in. (0.305-mm) thick.

7.7 When used, the optional lead shim shall be at least 99.9 % pure elemental material.

8. Fabrication³

8.1 Components:

8.1.1 *Mill a Channel*, 0.850-in. (21.6-mm) wide × 6.5-in. (165-mm) long from an aluminum block, 1-in. (25.4-mm) wide × at least 0.303-in. (7.70-mm) high × 6.5-in. (165-mm) long. The channel should begin 0.075-in. (1.90-mm) from edge A and leave 0.103-in. (2.62-mm) aluminum in the bottom of the channel (see Fig. 2).

8.1.2 *Mill the A Channel* (see Fig. 1), within this channel, 0.125-in. (3.18-mm) wide × 0.005-in. (0.127-mm) deep ×

6.5-in. (165-mm) long. The near edge of channel A should be 0.450-in. (11.4-mm) from edge A (see Fig. 3).

8.1.3 *Mill the B Channel*, adjacent to the A channel, 0.125-in. (3.18-mm) wide × 0.010-in. (0.254-mm) deep × 6.5-in. (165-mm) long. The near edge of channel B should be 0.325-in. (8.26-mm) from edge A (see Fig. 3).

8.1.4 *Mill the C Channel*, adjacent to the B channel, 0.125-in. (3.18-mm) wide × 0.020-in. (0.508-mm) deep × 6.5-in. (165-mm) long. The near edge of channel C should be 0.200 in. (5.08 mm) from edge A (see Fig. 3).

8.1.5 *Optional*—Mill the D channel adjacent to the C channel, 0.125-in. (3.18-mm) wide × 0.010-in. (0.254-mm) deep × 6.5-in. (165-mm) long. The near edge of channel D should be 0.075-in. (1.90-mm) from edge A.

NOTE 1—The D channel is not required and shall not be milled if the lead shim is not to be used.

8.1.6 Prepare five methacrylate strips, 0.060-in. (1.52-mm) thick × at least 0.200-in. (5.08-mm) wide × 6.5-in. (165-mm) long. These strips will be used in 8.2.11.

8.1.7 Prepare four methacrylate strips, 0.125-in. (3.18-mm) thick × at least 0.200-in. (5.08-mm) wide × 6.5-in. (165-mm) long. One of the methacrylate strips may be

³ The instructions in Section 8 assume the simultaneous fabrication of five units for practical reasons. Units may be fabricated singly, if desired.

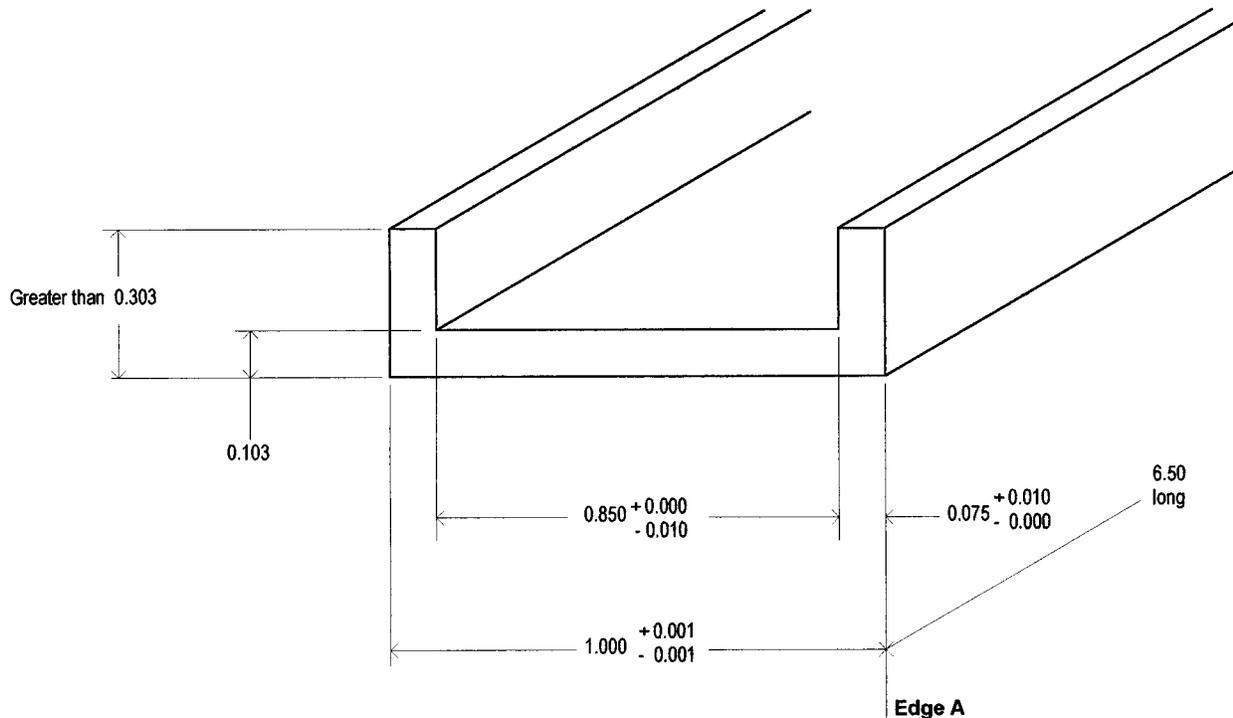


FIG. 2 Main Channel in Aluminum Block

NOTE 1—Unless otherwise specified, use the following:
Dimensions are in inches.
Tolerances on machined dimensions: .XX = ± .01 .XXX = ± .002.

replaced with an optional lead strip of the same dimensions. These strips will be used in 8.2.5.

8.1.8 Prepare one each strip from aluminum shim stock, at least 0.200-in. (5.08-mm) wide × 6.5-in. (165-mm) long, with the following thickness:

- 0.0005 in. (0.0127 mm)
- 0.0010 in. (0.0254 mm)
- 0.0020 in. (0.0508 mm)
- 0.0030 in. (0.0762 mm)
- 0.0040 in. (0.102 mm)
- 0.0050 in. (0.127 mm)
- 0.0100 in. (0.254 mm)

8.1.9 Prepare one each methylmethacrylate strip to fit snugly in the 0.125-in. (3.18-mm) wide × 6.5-in. (165-mm) long with the following thickness:

- 0.0050 in. (0.127 mm) (Shim A)
- 0.0100 in. (0.254 mm) (Shim B)
- 0.0200 in. (0.508 mm) (Shim C)
- 0.0100 in. (0.254 mm) (Shim D) (If used, this strip is to be fabricated from lead stock (see Fig. 4). These strips will become Shim A through Shim D in 8.1.10.)

8.1.10 Drill four holes in the shims from 8.1.9, starting 0.218 in. (5.54 mm) from one end and centering the other three holes 0.215 in. (5.46 mm) from the first hole. Repeat the process along the rest of the 6.5-in. (165-mm) length (see Fig. 4). The diameter of the holes are as follows:

- Shim A 0.005-in. (0.127-mm) diameter
- Shim B 0.010-in. (0.254-mm) diameter
- Shim C 0.020-in. (0.508-mm) diameter
- Shim D 0.010-in. (0.254-mm) diameter, if optional Shim D is to be used.

To verify that the various shims have the proper holes drilled into them, a certified hole measurement report is required.

8.1.11 To keep the SI intact during use, it is highly recommended that a dust cover be kept on the unit. One dust cover for each SI may be prepared from aluminum shim stock, 0.012-in. (0.305-mm) thick × 1.50-in.² (38.1-mm²) by cutting out a 0.250-in.² (6.35-mm²) from each corner and folding the aluminum to form a cover, 1-in.² (25.4-mm²) × 0.250-in. (6.35-mm) high (see Fig. 1).

8.2 Assembly:

8.2.1 Insert Shim C into the C channel milled in 8.1.4 (see Fig. 5).

8.2.2 Insert Shim B into the adjacent B channel milled in 8.1.3 (see Fig. 5).

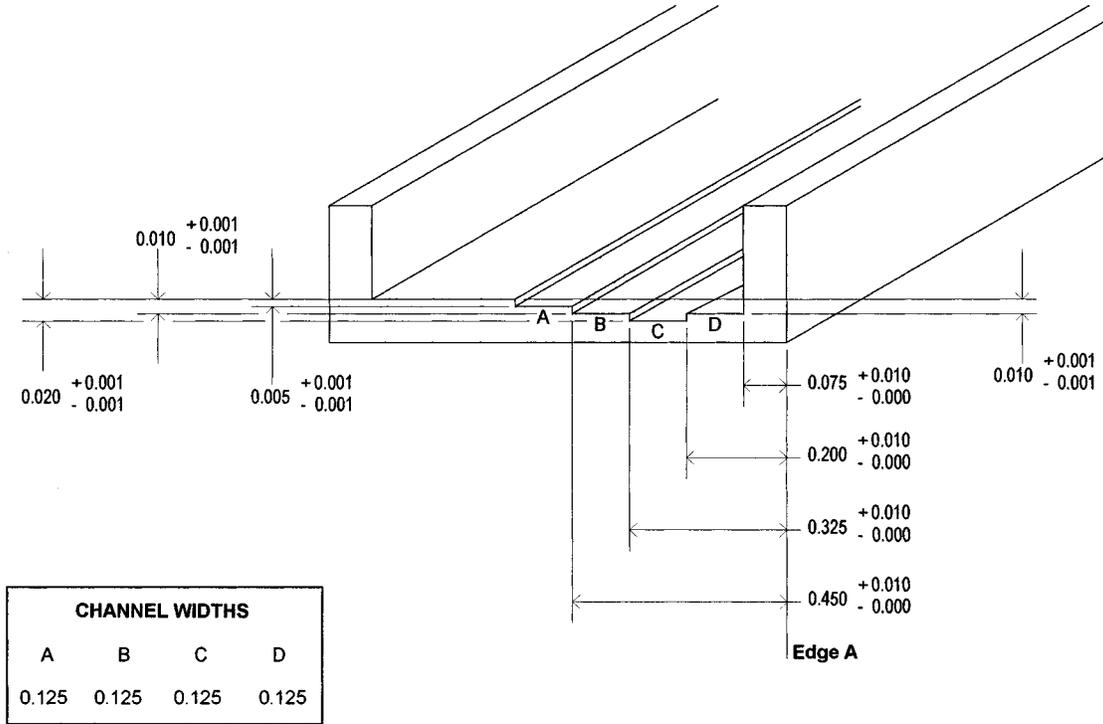
8.2.3 Insert Shim A into the adjacent A channel milled in 8.1.2 (see Fig. 5).

8.2.4 If the D channel was milled in 8.1.5, insert the lead shim (see Fig. 5).

8.2.5 Insert a 0.125-in. (3.18-mm) methylmethacrylate strip (previously prepared in 8.1.7) into the channel so that the second strip is positioned over Shim C. Over Channel D, insert either the optional lead strip or a 0.125-in. (3.18-mm) methylmethacrylate strip (see Fig. 6).

8.2.6 Insert the 0.010-in. (0.254-mm) thick aluminum strip next to the methylmethacrylate strip between the B and C channels (see Fig. 6).

8.2.7 Insert another 0.125-in. (3.18-mm) methylmethacrylate strip next to the aluminum strip (see Fig. 6).



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FIG. 3 Channels A Through D in Main Channel

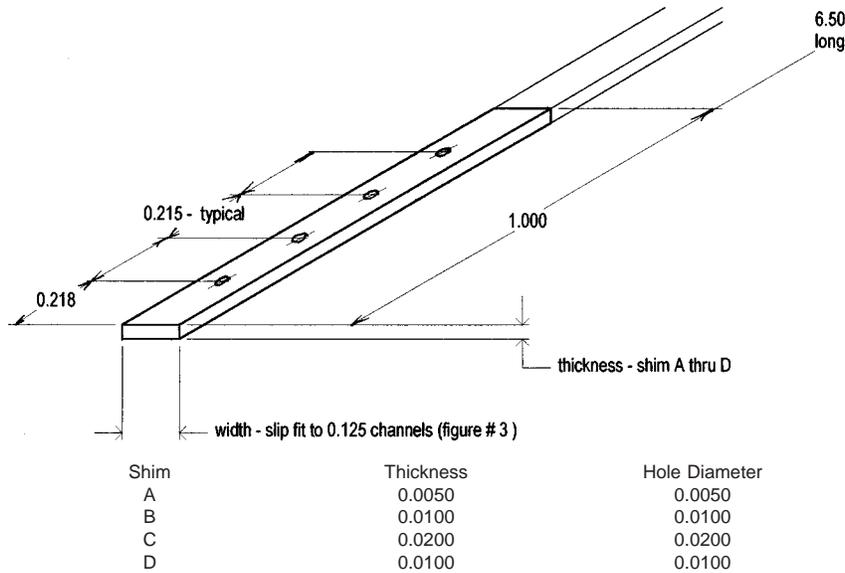


FIG. 4 Shims

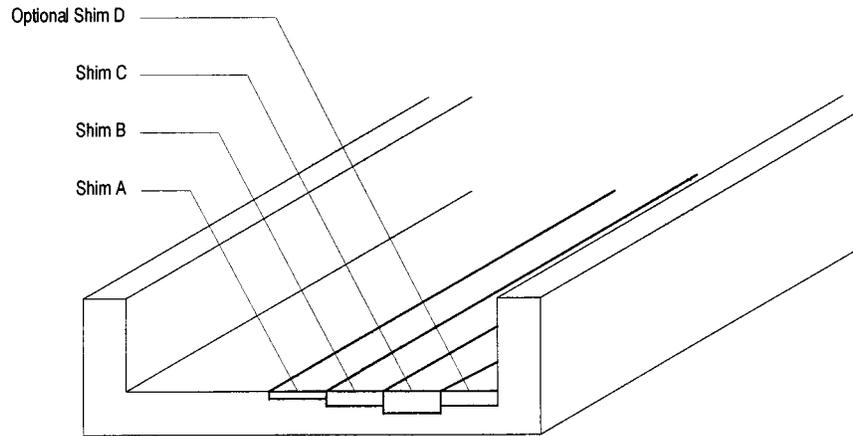
8.2.8 Insert the 0.005-in. (0.127-mm) thick aluminum strip (see Fig. 6).

8.2.9 Insert the last 0.125-in. (3.18-mm) methylmethacrylate strip next to the previously inserted aluminum strip (see Fig. 6).

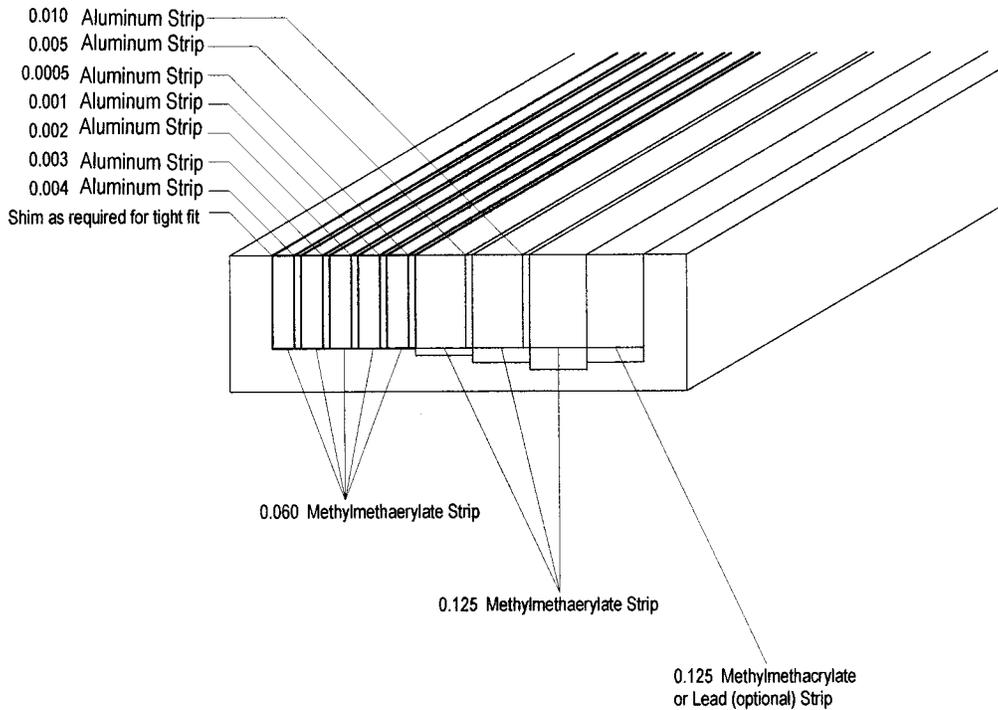
8.2.10 Insert the 0.0005-in. (0.0127-mm) thick aluminum strip next to the previously inserted methylmethacrylate strip (see Fig. 6).

8.2.11 Insert a 0.060-in. (1.52-mm) thick methylmethacrylate strip next to the previously inserted aluminum strip (see Fig. 6).

8.2.12 Repeat the steps described in 8.2.10 and 8.2.11, alternating increasing aluminum strip thickness with 0.060-in. (1.52-mm) thick methylmethacrylate strips (see Fig. 6), that is:



NOTE 1—See Fig. 4.
FIG. 5 Shims in Channels



Unless otherwise specified, use the following:
 Dimensions are in inches.
 Tolerances on machined dimensions: .XX = ± .01 .XXX = ± .002.

FIG. 6 Strips in Main Channel

- 0.001-in. (0.0254-mm) thick aluminum strip
- 0.060-in. (1.52-mm) thick methylmethacrylate strip
- 0.002-in. (0.0508-mm) thick aluminum strip
- 0.060-in. (1.52-mm) thick methylmethacrylate strip
- 0.003-in. (0.0762-mm) thick aluminum strip
- 0.060-in. (1.52-mm) thick methylmethacrylate strip
- 0.004-in. (0.102-mm) thick aluminum strip
- 0.060-in. (1.52-mm) thick methylmethacrylate strip

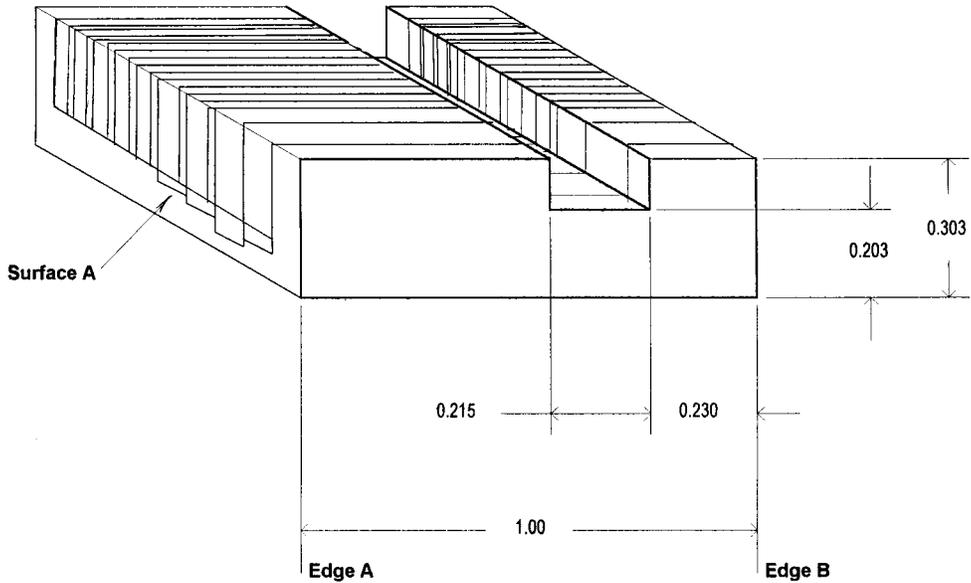
8.2.13 Cut and insert aluminum shims sized as required for a tight fit between the last 0.060-in. (1.52-mm) methylmethacrylate strip and the wall of the channel to wedge all the strips in place (this step is important for later machining of the unit) (see Fig. 6).

8.3 Fabrication:

8.3.1 Mill off a 1.0-in. (25.4-mm) long section of the stacked channel from the 6.5-in. (165-mm) length.

8.3.2 Mill the top surface of the sectioned unit to a height of 0.303 in. (7.70 mm). This height is equivalent to the first step of 0.200 in. (5.08 mm) of methylmethacrylate (see Fig. 7).

8.3.3 Mill a 0.215-in. (5.46-mm) wide channel, 0.230-in. (5.84-mm) from Edge B (as shown in Fig. 7) across the full width of the stacked assembly, including the aluminum walls. The bottom of the channel should be 0.203 in. (5.16 mm) from the bottom of the block.



Unless otherwise specified, use the following:
 Dimensions are in in.
 Tolerances on machined dimensions: .XX = ± .01 .XXX = ± .002.

FIG. 7 First Milled Step

8.3.4 Mill another 0.215-in. (5.46-mm) wide channel, 0.445-in. (11.30-mm) from Edge B (as shown in Fig. 8) across the full width of the stacked assembly, including the aluminum walls. The bottom of the channel should be 0.153 in. (3.89 mm) from the bottom of the block.

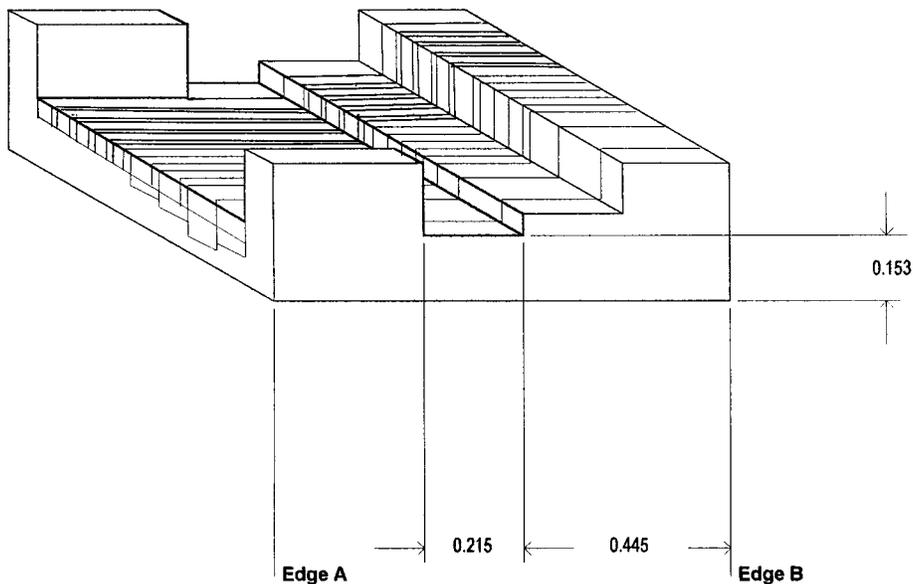
8.3.5 Finish milling all stock between the aluminum walls from the last channel to Surface C to a height of 0.153 in. (3.89 mm) from the bottom of the block, as shown in Fig. 7. Do not remove material from the aluminum walls. After completion, the block should look as shown in Fig. 8.

8.3.6 Mill the final 0.215-in. (5.46-mm) wide channel, 0.660-in. (16.76-mm) from Edge B, including the aluminum walls. The bottom of the channel should be 0.128 in. (3.25 mm) from the bottom of the block (see Fig. 9).

8.3.7 Machine a base in the completed unit by cutting 0.015 in. (0.381 mm) from all four sides. The machining should leave a 0.080-in. (2.03-mm) thick base (see Fig. 9).

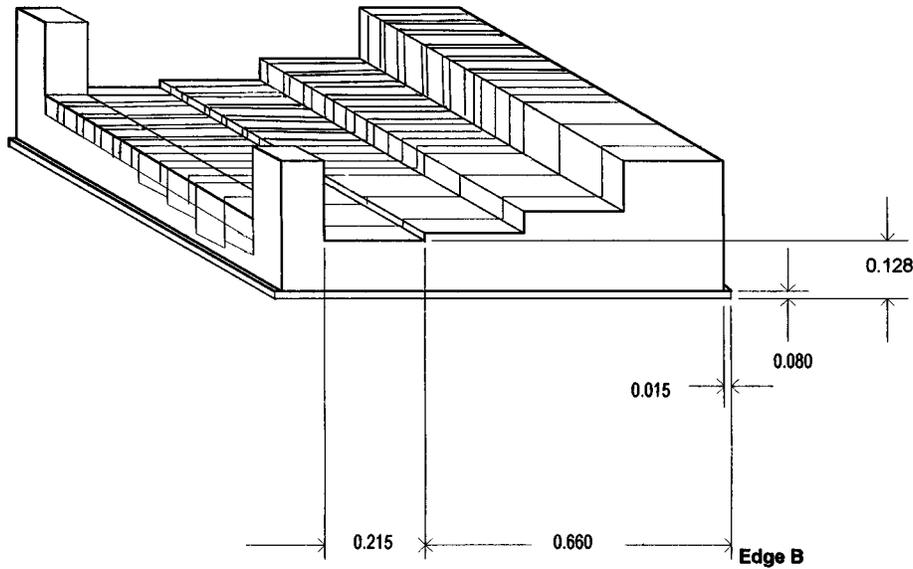
8.3.8 The SI is complete and should look identical to the SI shown in Fig. 1.

8.3.9 Slip-fit the dust cover from 8.1.11. Do not use glue.



Unless otherwise specified, use the following:
 Dimensions are in inches.
 Tolerances on machined dimensions: .XX = ± .01 .XXX = ± .002.

FIG. 8 Second Milled Step



Unless otherwise specified, use the following:
 Dimensions are in inches.
 Tolerances on machined dimensions: .XX = ± .01 .XXX = ± .002.

FIG. 9 Finished Block

9. Certification

9.1 Upon request of the purchaser by contract or purchase order, any fabricator of the SI described in this practice shall provide materials certification. To verify the details of construction, a measurement certification of individual components and assembly to verify correct location and sizes and a comparison thermal neutron radiograph of the assembled SI with that of a reference standard SI (preferably on a single neutron radiograph) shall be provided.

9.2 All dimensions should be measured with a micrometer or an optical comparator to determine the SI dimensions.

9.3 The comparison thermal neutron radiograph of the assembled SI, along with a reference standard SI, shall show the following:

9.3.1 All shims and strips are in place and aluminum strips are vertical (no blurred edges).

9.3.2 A minimum of six or seven holes should be visible, identical to those in the reference SI.

9.3.3 Using a magnifier with a calibrated scale, measure the size of the gaps and visible holes. If the measured dimensions

match those in the reference standard SI's image, the unit(s) are acceptable and can be certified.

9.4 The comparison thermal neutron radiograph of the assembled SI with the reference standard SI shall meet quality level Category I, specified in the latest edition of Method E 545.

9.5 Any SI certified under Method E 545-81, -86, or -91 is assumed to be a reference SI, unless there is known to be a disqualifying deficiency.

10. Records

10.1 Complete records of the fabrication details shall be maintained by the manufacturing facility for three years or as specified in the basis of purchase.

11. Keywords

11.1 direct method; image quality indicator; neutron radiography; sensitivity indicator (SI)

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