INTERNATIONAL

Designation: F792 – 17

Standard Practice for
Evaluating the Imaging Performance of Security X-Ray Systems[1]

This standard is issued under the fixed designation F792; 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 applies to all X-ray-based screening systems with tunnel apertures up to 1 m wide × 1 m high, whether they are conventional X-ray systems or explosives detection systems, that provide a projection or projection/scatter image.

1.2 This practice applies to X-ray systems used for the screening for prohibited items such as weapons, explosives, and explosive devices in baggage, packages, cargo, or mail.

1.3 This practice establishes quantitative and qualitative methods for evaluating the systems. This practice does not establish minimum performance requirements for any particular application.

1.4 This practice relies upon the use of three different standard test objects: ASTM X-ray test object – HP, for evaluating human perception based performance parameters; ASTM X-ray test object – RT, for routine testing to assess operation; and ASTM X-ray test object – OE, for objective evaluation and scoring of the technical capability of the system. The specific test objects are subsequently described and referred to in this practice as the HP test object, RT test object, and OE test object.

1.4.1 *Part RT*—This part considers only the methods for routine and periodic verification of system operation and function, and therefore requires use of ASTM X-ray test object – RT.

1.4.2 *Part HP*—This part considers only the methods for, and use of, the ASTM X-ray test object – HP.

1.4.3 *Part OE*—This part considers only the methods for objective evaluation of the technical capabilities of a system, and therefore requires use of the ASTM X-ray test object – OE.

1.5 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.6 *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, health and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.7 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

B258 Specification for Standard Nominal Diameters and Cross-Sectional Areas of AWG Sizes of Solid Round Wires Used as Electrical Conductors

D6100 Specification for Extruded, Compression Molded and Injection Molded Polyoxymethylene Shapes (POM)

2.2 *ASTM Adjuncts:*

Adjunct to F0792 Drawings for Test Piece[3]

2.3 *Other Documents:*

IEC 60317-1:2010-03 Specification for Particular Types of Winding Wires – Part 1: Polyvinyl Acetal Enamelled Round Copper Wire, Class 105[4]

ANSI/NEMA MW 1000-2014 American National Standard, Magnet Wire (MW 80-C)[5]

ISO 12233-2000 Photography – Electronic Still-Picture Cameras – Resolution Measurements, Section 6.3 and Annex C

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

[1] This practice is under the jurisdiction of ASTM Committee F12 on Security Systems and Equipment and is the direct responsibility of Subcommittee F12.60 on Controlled Access Security, Search, and Screening Equipment.

Current edition approved April 1, 2017. Published August 2017. Originally approved in 1982. Last previous edition approved in 2008 as F792 – 08 which was withdrawn January 2017 and reinstated in April 2017. DOI: 10.1520/F0792-17.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from ASTM International Headquarters. Order Adjunct No. ADJF079217. Original adjunct produced in 2017.

[4] Available from International Electrotechnical Commission (IEC), 3, rue de Varembé, 1st Floor, P.O. Box 131, CH-1211, Geneva 20, Switzerland, http://www.iec.ch.

[5] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

3.1.1 *blocking material*—a thickness of material used to obscure the view of an object in an X-ray image by attenuating the X-ray beam used to form the image.

3.1.2 *boundary signal-to-noise ratio (BSNR)*—a metric for measuring the detectability of a boundary; the BSNR is computed by comparing the average pixel value between regions of interest on either side of the boundary; the significance of the difference in the pixel value is determined by measuring the consistency for repeated measurements for different images; see A3.1 for a complete technical definition.

3.1.3 *contrast sensitivity*—a measure of the minimum change in an object that produces a perceptible brightness change in the image on a display.

3.1.4 *effective atomic number* (Z_{eff})—the atomic number of a single hypothetical element that, for a particular x-ray spectrum, would exhibit essentially identical X-ray attenuation characteristics as the material under consideration.

3.1.5 *hue*—a property of a color that reflects the degree to which it can be classified as red, green, and blue; this property can be considered independently of the lightness of the color, for example, a red color and a pink color may have the same hue but different lightness and saturation.

3.1.6 *image quality metric (Part HP)*—a quantitative assessment of a capability of an imaging system; nine image quality metrics are defined in this practice along with the standard test object and methods necessary for their measurement.

3.1.6.1 *test 1: wire display*—the ability of an X-ray system to display images that can be used by an operator to identify metal wires.

3.1.6.2 *test 2: useful penetration*—the ability of an X-ray system to produce an image that allows for the detection, by an operator or algorithm, of wires that are hidden by different thicknesses of blocking material.

3.1.6.3 *test 3: spatial resolution*—the ability of an X-ray system to display closely spaced, high-contrast items as separate.

3.1.6.4 *test 4: simple penetration*—the ability of an X-ray system to display images that can be used by an operator to identify lead numerals that would otherwise be hidden by steel blocking material.

3.1.6.5 *test 5: thin organic imaging*—the ability of an X-ray system to display images that can be used by an operator to identify thin pieces of organic material.

3.1.6.6 *test 6: steel contrast sensitivity*—the ability of an X-ray system to display images that can be used by an operator to identify shallow circular recesses in steel.

3.1.6.7 *test 7: materials discrimination*—the ability of an X-ray system to display images that can be used by an operator to discriminate between materials with different effective atomic numbers.

3.1.6.8 *test 8: materials classification*—the ability of an X-ray system to display images that can be used by an operator to consistently identify a particular material over a range of different thicknesses.

3.1.6.9 *test 9: organic differentiation*—the ability of an X-ray system to display images that can be used by an operator to differentiate between organic materials of different effective atomic numbers.

3.1.7 *image quality metric (Part OE)*—a quantitative assessment of a capability of an imaging system; six image quality metrics are defined in this part of the practice along with the standard test pieces and methods necessary for their measurement.

3.1.7.1 *test 1: steel differentiation*—the ability of an X-ray system to provide an image that can be used to detect, using an objective algorithm, boundaries between different thicknesses of steel.

3.1.7.2 *test 2: useful penetration*—the ability of an X-ray system to produce an image that allows for the detection, by an operator or algorithm, of wires that are hidden by different thicknesses of blocking material.

3.1.7.3 *test 3: organic boundary signal-to-noise ratio*—a measure of the ability of an X-ray system to detect thickness changes in thin pieces of low atomic-number material.

3.1.7.4 *test 4: spatial resolution*—the ability of an X-ray system to display closely spaced, high-contrast items as separate.

3.1.7.5 *test 5: dynamic range*—the ratio between the largest and smallest usable grayscale values.

3.1.7.6 *test 6: noise equivalent quanta (NEQ)*—a spatial-frequency-dependent measure of the detection ability of an imaging system that is quantified in terms of the number of photons, or quanta, that would be required to achieve the same detection ability for an ideal imaging system; the NEQ is computed from measurements of the modulation transfer function, the noise power spectrum, and the average pixel value of uniformly illuminated noise images.

3.1.8 *modulation transfer function (MTF)*—a spatial-frequency-dependent measure of contrast reduction used to characterize an imaging system's spatial resolution, that is here derived from the system's edge-spread function.

3.1.9 *noise power spectrum (NPS)*—a spatial-frequency-dependent function that characterizes the noise properties of an image, computed using the Fourier transform of uniformly illuminated noise images.

3.1.10 *Nyquist frequency*—a frequency that is half the spatial sampling frequency; in units of cycles per pixel, it always has a value of 0.5 but in this practice it should be expressed in units of cycles per mm.

3.1.11 *operator*—the person operating the X-ray imaging device.

3.1.12 *region of interest (ROI)*—an area on the image of a specified size and position; an ROI is usually selected in order to compute some statistical quantity over the pixels it contains (for example, the mean value or the standard deviation).

3.1.13 *test image*—a grayscale digital X-ray image of the ASTM X-ray test object-OE to which the objective algorithms are applied.

3.1.14 *test object*—the physical object required to test a system using this practice; the test object includes various test pieces, the mounting board, a protective case, padding material, and fasteners.

3.1.15 *test piece*—a part of the test object that is used to measure the value of an image quality metric in this practice; for example, the POM step wedge used to evaluate the thin organic imaging test (test 5 of part OE).

3.1.16 *useful penetration*—the ability of an X-ray system to produce an image that allows for the detection, by an operator or objective algorithm, of wires that would otherwise be hidden by different thickness of blocking material.

4. Part RT

4.1 *Significance and Use:*

4.1.1 This practice applies to and establishes methods to measure the imaging performance of X-ray systems used for security screening. Such systems are typically used to screen for prohibited items such as weapons, explosives, and explosive devices in baggage, packages, cargo, or mail.

4.1.2 The most significant attributes of this practice are the design of test object and standard methods for determining the performance levels of the system.

4.1.3 In screening objects with X-ray systems, still images are the primary inputs provided to operators. It is assumed that the better the quality of these images, the better will be the potential performance of the operator.

4.1.4 This practice is intended to provide the ability to routinely assess the performance of a cabinet X-ray system. This routine assessment can be used to ensure that: the cabinet X-ray system is operational; the imaging performance nominally meets expectation; and any changes in imaging performance are tracked.

4.1.5 This practice is not intended to be used as the basis for system qualification or validation.

4.2 *Test Object:*

4.2.1 Images of the RT test object are shown in Fig. 1. Mechanical drawings for the test object that shall be used with this practice are given in A1.1.1.

4.2.2 The RT is fragile because of the polycarbonate substrate on which the wires and step wedge are mounted. Consequently, the RT shall be contained and scanned within a case with the following specifications:

Interior dimensions: at least (19.5 cm × 12.5 cm × 5 cm) ± 0.5 cm
Wall, top and bottom (largest surfaces of case):
Material: ABS plastic
Thickness: between 1.5 mm and 3 mm
Construction: single piece of ABS Plastic. No joints, fasteners, or foreign objects, other than fill material, shall be between the case and the RT test object. These surfaces shall be nominally flat (this is, exhibit a radius of curvature greater than about 10 m) over a nominally central area of at least 17 cm × 11 cm.
Fill:
Material: polyethylene foam
Thickness: sufficient to hold RT firmly in place and nominally centered within the case.

4.3 *Test Procedures:*

4.3.1 Obtain an image of the test object in its case using the standard operating procedure (for example, by placing the test object on the conveyor belt so that it is run through the scanning area). The location and orientation of the RT test object on the conveyor belt of the cabinet X-ray system is not critical. However, to maximize the accuracy and usefulness of image performance tracking, the position and orientation of the RT test object should be nominally the same each time it is used for this purpose, and this orientation and location shall be recorded. More than one location and orientation may be used, in which case each orientation and location pairing of the RT shall be recorded. Any image enhancement features provided by the cabinet X-ray system may be used, and the setting for these features shall be recorded.

4.4 *Evaluation Considerations:*

4.4.1 *General*—Use of this practice does not guarantee that the X-ray system is operating properly. It is not intended to replace the X-ray system's diagnostics. If problems are experienced with the X-ray system they must be resolved prior to operation.

4.4.2 *Training Requirements*—To effectively conduct the evaluation of an X-ray system, it is recommended that the evaluator be trained to operate the X-ray system under test.

4.4.3 *Result Interpretation and Significance*—A wire not under aluminum is considered to be seen if more than half of it is visible in the X-ray image. A wire under a particular step is considered to be seen if, in the X-ray image, more than half of it is visible under that step.

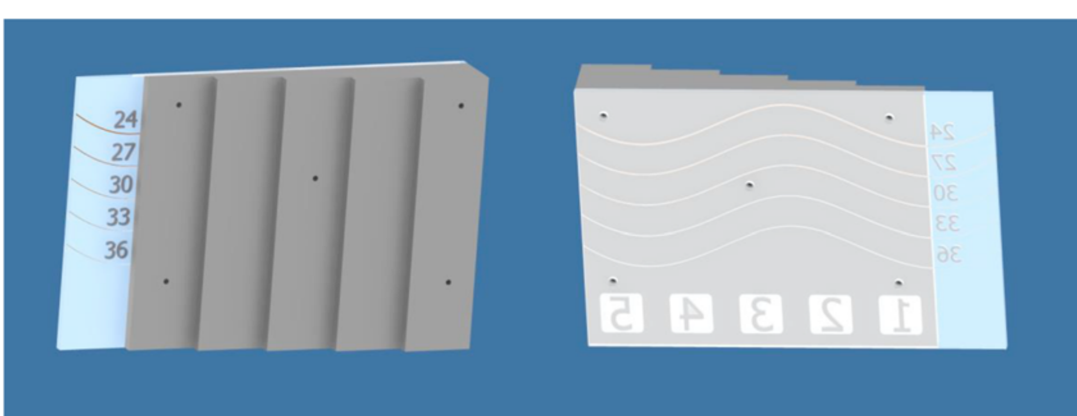


FIG. 1 An Image of the Front and Back of the Practice F792 – RT Test Object

4.4.4 *Log Sheet Use*—Table 1 is the log sheet that shall be completed by the evaluator each time an evaluation is conducted. Results shall be recorded on the log sheet for every location and orientation under test. Mark a ✓ in the box corresponding to each segment of wire that can be seen. The log sheet shall serve as a record of the results and observations regarding the tests. Log sheets shall be retained in the systems' log book for a set period, to be determined by the security administrator, so that results of tests can be compared to those of previous tests for that system.

5. Part HP

5.1 *Significance and Use:*

5.1.1 This practice applies to and establishes methods to measure the imaging performance of X-ray systems used for security screening. Such systems are typically used to screen for prohibited items such as weapons, explosives, and explosive devices in baggage, packages, cargo, or mail.

5.1.2 The most significant attributes of this practice are the design of test object and standard methods for determining the performance levels of the system.

5.1.3 In screening objects with X-ray systems, still images are the primary inputs provided to operators. It is assumed that the better the quality of these images, the better will be the potential performance of the operator.

5.1.4 The results produced by this practice reflect the performance of an X-ray system under the control of a particular operator or operators. Different operators may obtain different results for the same system.

5.1.5 Tests 7, 8, and 9 only apply to systems that have materials discrimination capabilities and use image hue to represent materials information (that is, effective atomic number).

5.2 *Test Object:*

5.2.1 The following describes the ASTM X-ray test object – HP (shown in Fig. 2) to be used throughout the test procedures to determine the performance levels of a system. A drawing index for the test object is provided in Table 2. Copies of the mechanical drawings listed in Table 2 are provided in A2.2.

5.2.2 The test pieces and mounting board are fragile, so they should be contained and scanned within a protective case with the following specification:

Interior dimensions: at least (45 cm by 28 cm by 12 cm)
Wall, top and bottom (largest surfaces of case):
Material: ABS plastic
Thickness: 3 mm ± 0.2 mm (in the regions directly above and below the test pieces).
Construction: single piece of molded ABS black plastic. No joints, fasteners or foreign objects, other than fill material, shall be between the case and the test pieces along the paths of the X rays that form the image. These surfaces shall be nominally flat (that is, exhibit a radius of curvature greater than about 10 m) over nominally a central area of at least 41.5 cm × 25 cm.
Fill: polyethylene foam with a thickness sufficient to hold the mounting board and test pieces in place within the case. The density of the foam should be less than 0.03 g/cm^3. No foam should be present in the region directly above the test piece for tests 7 and 8.

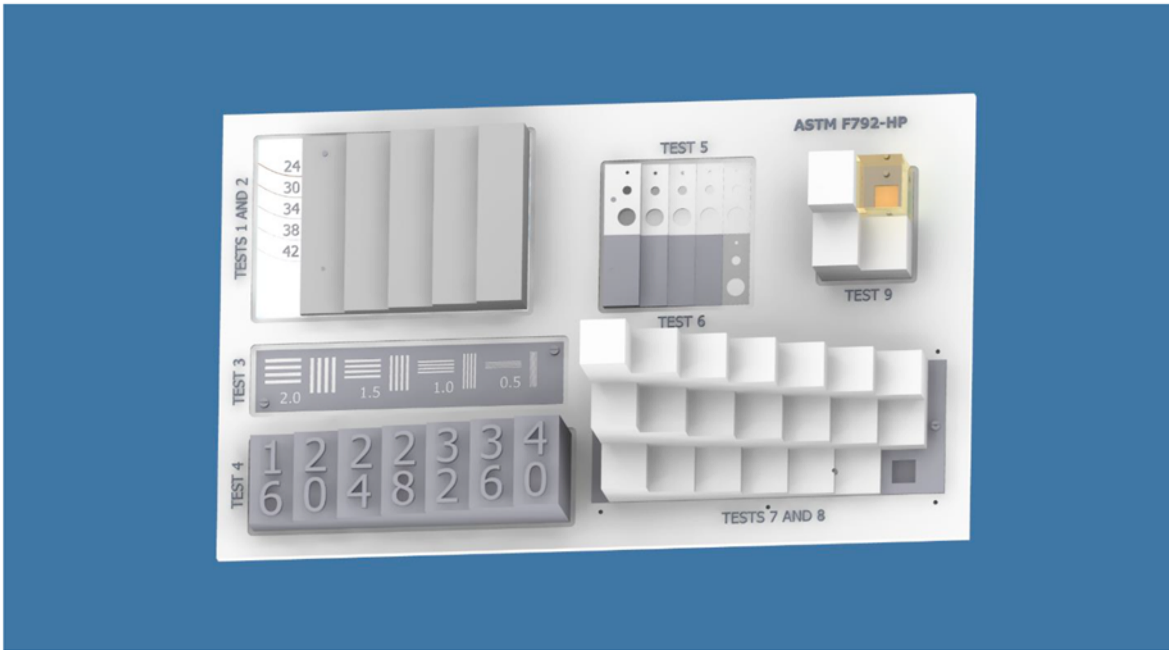
5.2.3 *Test 1–Wire Display*—To determine how well an X-ray system displays wires, the test object incorporates a set of unobstructed wires. The copper wires of AWG sizes 24, 30, 34, 38, and 42 are laid out on the test object in a sinusoidal pattern. The diameters of the wires of AWG sizes 24, 30, 34, 38, and 42 are 0.511 mm, 0.254 mm, 0.160 mm, 0.102 mm, and 0.064 mm, respectively.

5.2.4 *Test 2–Useful Penetration*—To determine the useful penetration of an X-ray system, the test object incorporates a set of five wires placed under aluminum steps that vary in thickness. The gauge of these wires and the thickness of the aluminum provides sufficient range to characterize the system's

TABLE 1 Imaging Performance Data

NOTE 1—This table is a log sheet for recording the results of testing a cabinet X-ray system using the RT test object. Dimensional details of the wire gauges are given in Specification B258.

Manufacturer					
Model					
Serial number					
Address					
Date					
Time					
Location of test object					
Orientation of test object					
Image enhancement features and settings					
Wire gauge / Step number	24	27	30	33	36
No step					
1					
2					
3					
4					
5					



The test pieces for all nine tests are labelled on the test object and are described in more detail in subsequent sections.

FIG. 2 An Image of the Practice F792 – HP Test Object

TABLE 2 Test Object Drawing Index

Note 1—See A2.2 for the complete set of drawings.

Item Number	Description	Test	Part Number	Drawing
	ASTM F792 – HP X-Ray Test Object		ASSY 1	1 of 20
	Mounting Board		BOARD	2 of 20
1A	Tests 1 and 2 Assembly	Tests 1 and 2	T1A-ASSY	3 of 20
1B	Tests 1 and 2 Step Wedge	Tests 1 and 2	T1B-WEDGE	4 of 20
1C	Tests 1 and 2 Wire Holder	Tests 1 and 2	T1C-HOLDER	5 of 20
3	Test 3 Pattern	Test 3	T3–PATTERN	6 of 20
4	Test 4 Steel Step Wedge	Test 4	T4–WEDGE	7 of 20
5	Test 5 POM Step Wedge	Test 5	T5–WEDGE	8 of 20
6A	Test 6 Steel Pattern Sheet	Test 6	T6A-PATTERN	9 of 20
6B	Test 6 Steel Step Wedge	Test 6	T6B-WEDGE	10 of 20
7A	Tests 7 and 8 Upper Assembly	Tests 7 and 8	T7A-ASSY1	11 of 20
7B	Tests 7 and 8 Steel Grid	Tests 7 and 8	T7B-GRID	12 of 20
7C	Tests 7 and 8 Thick POM Wedge	Tests 7 and 8	T7C-THICK	13 of 20
7D	Tests 7 and 8 Medium POM Wedge	Tests 7 and 8	T7D-MEDIUM	14 of 20
7E	Tests 7 and 8 Thin POM Wedge	Tests 7 and 8	T7E-THIN	15 of 20
7F	Tests 7 and 8 Lower Assembly	Tests 7 and 8	T7F-ASSY2	16 of 20
7G	Tests 7 and 8 Lower Base	Tests 7 and 8	T7G-BASE	17 of 20
9A	Test 9 Assembly	Test 9	T9A-ASSY	18 of 20
9B	Test 9 Organic Blocks	Test 9	T9B-BLOCK	19 of 20
9C	Test 9 Grid	Test 9	T9C-GRID	20 of 20

useful penetration. The copper wires of AWG sizes 24, 30, 34, 38, and 42 are laid out on the test object in a sinusoidal pattern under aluminum steps with thicknesses of 4 mm, 8 mm, 12 mm, 16 mm, and 20 mm.

5.2.5 *Test 3–Spatial Resolution*—To determine the spatial resolution of an X-ray system, the test object incorporates a set of narrowly spaced line-pair gauges. Four pairs of horizontal and vertical line-pair gauges are present on the test piece with spacings of 2 mm, 1.5 mm, 1.0 mm, and 0.5 mm.

5.2.6 *Test 4–Simple Penetration*—To determine the simple penetration of an X-ray system, the test object incorporates lead numerals placed on top of steel that varies in thickness. The thicknesses of the steel steps are 16 mm, 20 mm, 24 mm, 28 mm, 32 mm, 36 mm, and 40 mm.

5.2.7 *Test 5–Thin Organic Imaging*—To determine the thin organic imaging capability of an X-ray system, the test object incorporates a set of holes machined into plastic of various thicknesses. The plastic steps have thicknesses of 0.25 mm, 0.5 mm, 1.0 mm, 2 mm, and 5 mm and each step has holes of diameters 2 mm, 5 mm, and 10 mm cut through them.

5.2.8 *Test 6–Steel Contrast Sensitivity*—To determine the steel contrast sensitivity of an X-ray system, the test object incorporates a set of circular holes behind steel of various thicknesses. The steel steps have thicknesses of 0.5 mm, 1 mm, 2 mm, and 5 mm, and each step has holes, all of depth 0.1 mm, with diameters of 2 mm, 5 mm, and 10 mm.

5.2.9 *Test 7–Materials Discrimination*—To determine the materials discrimination capability of the X-ray system, the test object incorporates a grid of square attenuators. The effective atomic number and attenuation of each attenuator is controlled by varying the amount of steel and plastic in each. The effective atomic number of the attenuators varies in the horizontal axis and the total attenuation varies in the vertical axis, as viewed in Fig. 2. Details regarding the amount of steel and plastic in each attenuator in the grid are provided in the mechanical drawings of the test object in A2.2.

5.2.10 *Test 8–Materials Classification*—To determine if the X-ray system consistently identifies a given material over a range of thicknesses, the same test piece is used as for Test 7.

5.2.11 *Test 9–Organic Differentiation*—This practice is intended for use at both the point of manufacture and where the system is operated. The latter includes locations such as security checkpoints of transportation terminals, nuclear power stations, correctional institutions, corporate mailrooms, government offices, and other security areas.

5.3 *Test Procedures:*

5.3.1 Acquire an image of the test object in its case using the X-ray system.

5.3.1.1 This test method specifies how to test a particular view in which the test object is placed at a particular position in the screening area. The test object shall be in its case and oriented in the imaging system such that the face of the thickest attenuator of test 7 and 8 is perpendicular to the X-ray beam for the X-ray view being tested. If the test object is misaligned by more than 3° then any test results are not valid (see A2.1 for more details on ensuring proper alignment). It is acceptable to tilt the test object (for example, by using a foam wedge) to orient it properly. The normative position of the test object shall be on the belt so that it is roughly centered between the edges of the belt and facing in the direction of the detector. Testers of multiview systems should apply these test methods to all views offered by the system. The view being tested should be recorded on the log sheet (Figs. 3 and 4). The tester may also elect to measure the position dependence of the image quality metrics throughout the inspection volume. The position and orientation of the test object should be recorded on the log sheet.

5.3.1.2 All nine tests should be scored based on a single captured X-ray image and on the perception of one person. This captured image will be presented to the tester on the X-ray system's display. To achieve the best image for each test, it may be necessary to use enhancement features such as zoom as well as brightness and contrast enhancements, etc. This is an acceptable practice, but for each test, the enhancement features used must be recorded on the log sheet (given in Figs. 3 and 4). The tester should record the temperature and humidity on the log sheet and ensure they are within the manufacturer recommended operating range. The results of the tests are to be retained as part of the X-ray system's performance/testing record.

5.3.2 *Test 1–Wire Display*—Using the image obtained in 5.3.1.2, record the *Test 1* wires that can be seen on the display (that is, the wires not under the aluminum step wedge). A wire is considered to be visible if more than half of its length can be seen. Record a ✔ in the box on the log sheet next to each wire that is visible.

5.3.3 *Test 2–Useful Penetration*—Using the image obtained in 5.3.1.2, record all the *Test 2* wires (that is, the wires under the aluminum step wedge) that can be seen on the displayed image. A wire is considered to be visible under a particular step if more than half of its length under that step can be seen. Record a ✔ in the box on the log sheet along each segment of wire that is visible under the step wedge.

5.3.4 *Test 3–Spatial Resolution*—Using the image obtained in 5.3.1.2, record which sets of vertical and horizontal slots in the displayed image of the *Test 3* test piece can be resolved. Vertical and horizontal slots are considered to be resolved if and only if all four slots can be seen and there is visible separation between each slot. Record a ✔ in the log sheet box above each set of vertical and horizontal slots that is resolved.

5.3.5 *Test 4–Simple Penetration*—Using the image obtained in 5.3.1.2, record the thicknesses of steel through which the lead numerals in the displayed image of the *Test 4* test piece can be seen on the monitor. Each lead numeral consists of a series of line segments. A lead numeral is considered visible if more than half of the total length of the line segments can be seen and the numeral can be uniquely identified. Record a ✔ in the log sheet box on each step for which both lead numerals are visible.

5.3.6 *Test 5–Thin Organic Imaging*—Using the image obtained in 5.3.1.2, record which circular holes are visible in the displayed image of the thin plastic of the *Test 5* test piece. A hole is considered to be visible if it at least half of its area or edge can be differentiated from the surrounding area. Record a ✔ in the log sheet box on each hole that is visible.

5.3.7 *Test 6–Steel Contrast Sensitivity*—Using the image obtained in 5.3.1.2, record which holes can be seen in the displayed image of the steel piece of the *Test 6* test piece. A hole is considered to be visible if at least half of its area or edge can be differentiated from the surrounding area. Record a ✔ in the log sheet box on each hole that is visible.

5.3.8 *Test 7–Materials Discrimination*—Using the image obtained in 5.3.1.2, study the displayed image of the test piece for *Test 7* and record if there is a difference in hue between horizontally-neighboring squares. Neighboring squares are considered differentiated if they are displayed with a perceptibly different hue. If the squares differ only in brightness, then they are not considered differentiated. Record a ✔ in the log sheet box between each of the differentiated squares.

5.3.9 *Test 8–Materials Classification*—Using the image obtained in 5.3.1.2, study the displayed image of test piece for *Test 8* and record if the squares in each column show a consistent hue. A materials misclassification is considered to have occurred in a column if any two squares in that column are displayed with a perceptibly different hue. Mark a ✔ in the log sheet box for each of the columns in which all materials have been classified with a consistent hue.

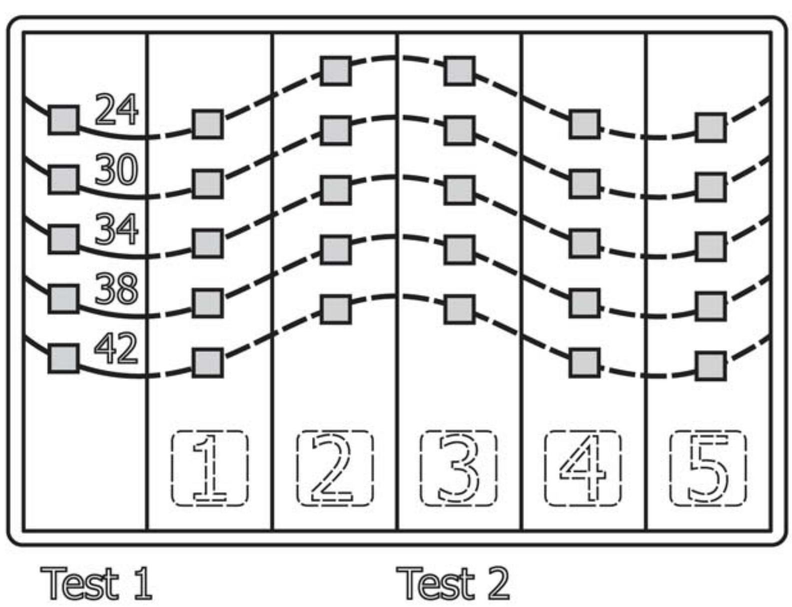
5.3.10 *Test 9–Organic Differentiation*—Using the image obtained in 5.3.1.2, study the displayed image of the test piece used for *Test 9*. Observe if there is a difference in hue between the four organic samples. Samples are considered differentiated if they are displayed with a perceptibly different hue. If the samples differ only in brightness, then they are not considered

Operator: ______________________ Date: ________ Time: ________
X-ray make and model: ______________ Serial no: ________ Software version: ________
Display make and model: ______________________ Serial no.: ________
Position on belt (left, middle or right): ______________________
Temperature: ______________ Humidity: ______________
Other notes (*e.g.* test article orientation, tilt, etc.): ______________________

Record all image enhancements used in the evaluation of the tests:

Test	Imaging options used
1. Wire display	
2. Useful penetration	
3. Spatial resolution	
4. Simple penetration	
5. Thin organic imaging	
6. Steel contrast sensitivity	
7. Materials discrimination	
8. Materials classification	
9. Organic differentiation	

Use the scoresheets below to record the results of the system for each test. The images should be strictly interpreted based on the guidelines in section 5.3 of the ASTM F792-HP test method.



Tests 1 and 2: Mark a ✓ in each box (□) associated with a wire segment that is considered visible according to the criteria in sections 5.3.2 and 5.3.3 of ASTM F792-HP.

FIG. 3 Practice F792 – HP Log Sheet Page 1

ASTM F792-HP Log Sheet Page 2

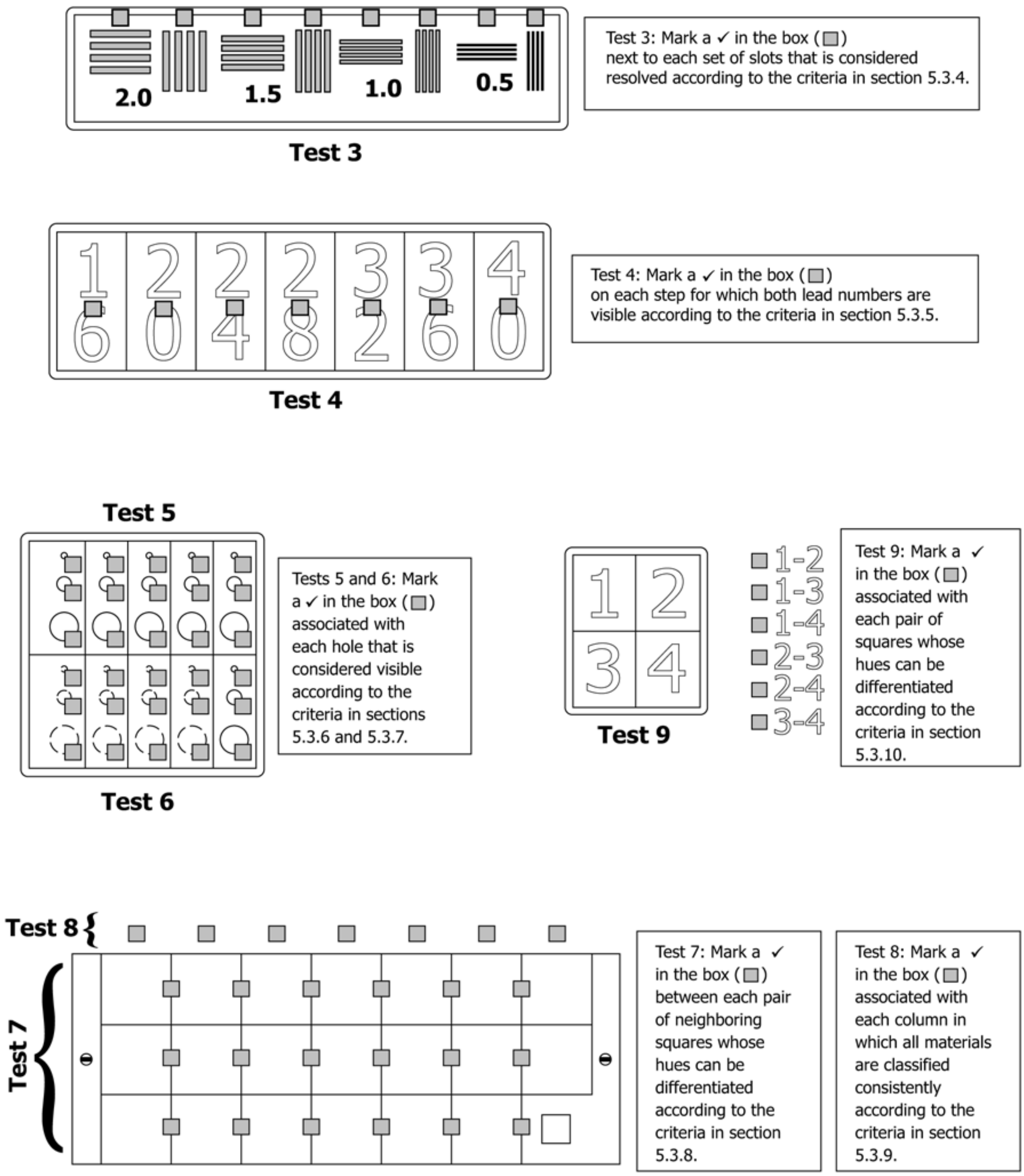


FIG. 4 Practice F792 – HP Log Sheet Page 2

differentiated. Mark a ✓ in the log sheet box between each pair of differentiated squares.

5.4 *Evaluation Considerations:*

5.4.1 *General*—Use of this practice does not guarantee that an X-ray system is operating properly. It is not intended to replace the X-ray system's diagnostics. If problems are experienced with the X-ray system, they must be resolved prior to operation.

5.4.2 *Training Requirements*—To effectively conduct the evaluation of an X-ray system, it is recommended that the evaluator possess system-specific training. The evaluator must be able to use all of the X-ray system's features to optimize performance and present the best image practical.

5.4.3 *Test Object Location and Orientation*—The location and orientation of the test object greatly affects performance. Ensure and record that these are consistent with previous tests.

5.4.4 *Log Sheet Use*—A copy of the log sheet (Figs. 3 and 4) shall be completed by the system operator/evaluator each time an evaluation is conducted. The log sheet shall serve as the record of results and observations regarding the tests. All completed log sheets shall be appropriately archived so that results of tests can be compared to previous tests for that system.

6. Part OE

6.1 *Significance and Use:*

6.1.1 This practice applies to and establishes methods to measure the imaging performance of X-ray systems used for security screening. Such systems are typically used to screen for prohibited items such as weapons, explosives, and explosive devices in baggage, packages, cargo, or mail.

6.1.2 The most significant attributes of this practice are the design of test object and standard methods for determining the performance levels of the system.

6.1.3 This practice applies to and establishes methods to measure the imaging performance of X-ray systems used for security screening. Such systems are typically used to screen for prohibited items such as weapons, explosives, and explosive devices in baggage, packages, cargo, or mail.

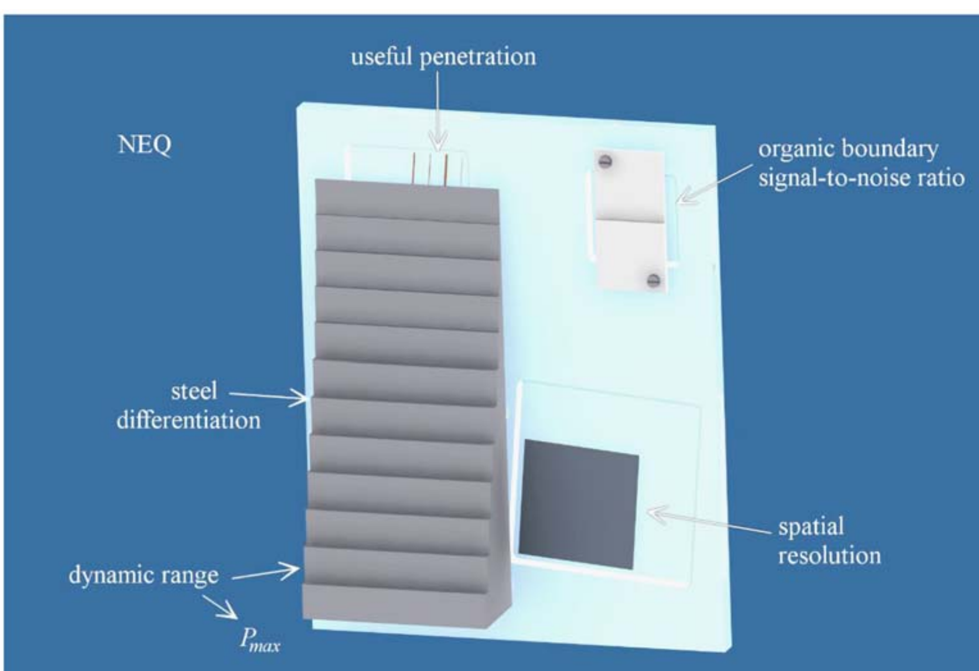
6.1.4 This practice is intended for use by manufacturers to assess the performance of contraband screening X-ray systems to verify imaging performance, and by users of these X-ray security systems to periodically verify the relative performance of the system.

6.1.5 This practice is intended to establish whether an X-ray system meets the manufacturer's specification or if the system's performance has changed over time, or both.

6.1.6 This practice may be used for manufacturing control, specification acceptance, service evaluation, or regulatory statutes.

6.2 *Test Object:*

6.2.1 Part OE was developed to objectively assess an X-ray-based screening system's image quality using six independent metrics. An image of the OE test piece is shown in Fig. 5. The OE test object consists of test pieces mounted to a polycarbonate base. Details of the construction of the test object as well as mechanical drawings are given in A3.2 of this practice. The test pieces and mounting board are fragile, so they should be contained and scanned within a protective case with the following specification:



Arrows indicate which pieces of the test object are used to compute the useful penetration, organic boundary signal-to-noise ratio, spatial resolution, and steel differentiation metrics. The dynamic range is computed based on the regions of the image with the highest and lowest pixel values. The NEQ metric is computed based on a noise image where the test object is not present in the image.

FIG. 5 A Diagram of the Practice F792 – OE Test Object

Interior dimensions: at least (20 cm by 25 cm by 7 cm) ± 0.5 cm
Wall, top and bottom (largest surfaces of case):
Material: ABS plastic
Thickness: 3 mm ±0.5 mm
Construction: single piece of molded ABS plastic. No joints, fasteners, or foreign objects, other than fill material, shall be between the case and the test pieces. These surfaces shall be nominally flat (that is, exhibit a radius of curvature greater than about 10 m) over nominally central area of at least 20 cm × 25 cm
Fill: polyethylene foam with a thickness sufficient to hold the mounting board and test pieces in place and centered within the case.

6.2.1.1 *Test 1–Steel Differentiation*—To determine the ability of a system to differentiate between different thicknesses of steel. This test uses the steel step wedge to determine the thickest step that can be discerned from adjacent steps. A step is discerned from adjacent steps, as defined here, if the BSNR is greater than five at its boundaries.

6.2.1.2 *Test 2–Useful Penetration*—To measure the ability of a system to detect wires under different thicknesses of steel blocking material. The test uses the steel step wedge to determine the thickest step under which thinly enameled wires of AWG[6] sizes 20, 24, and 30 can be detected.

6.2.1.3 *Test 3–Organic Boundary Signal-to-Noise Ratio*—To measure the ability of the X-ray system to image thin pieces of low atomic number material, such as organic materials. In practice, the organic boundary signal-to-noise ratio describes the ability of the X-ray system to provide images that can be used to distinguish different thicknesses of organic material.

6.2.1.4 *Test 4–Spatial Resolution*—To determine the spatial resolution of an X-ray system. The spatial resolution of the X-ray system shall be defined as the lowest spatial frequency at which the modulation transfer function (MTF) drops to value of 0.2. The MTF of an X-ray system will be measured using the slanted edge method using an X-ray image of the slanted lead foil.

6.2.1.5 *Test 5–Dynamic Range*—To determine the dynamic range of the system. The dynamic range of the system is the ratio between the largest and smallest usable signals.

6.2.1.6 *Test 6–Noise Equivalent Quanta (NEQ)*—To measure the NEQ of a system, which describes the frequency dependence of the imaging ability of a system.

6.3 *Test Procedures:*

6.3.1 The OE test methods contained herein shall be applied to the test images produced by the checkpoint X-ray security screening system being tested. Care should be taken to preserve for evaluation the full information content of the test image. In most cases this precludes, for example, evaluating screen captured images or data formats that employ compression. This test method specifies how to test a particular view in which the test object is placed at a particular position in the screening area. The normative position is with the test object, in its case, on the belt (though tilted slightly with a foam wedge, if necessary, to be perpendicular to direction of the X-ray beam), and roughly centered laterally in the inspection volume. Testers of multiview systems may wish to apply these test methods to all views offered by the system. The tester may also elect to measure the position dependence of the image quality metrics throughout the inspection volume. If operational decisions are made based on evaluation of a composite image, that is, of an image formed by combining multiple images (or frames) produced using different X-ray spectra, then it is advisable to apply the standard to these composite images; the OE test methods may also be applied to each frame separately. In the absence of manufacturer instructions on how to natively export or produce a grayscale image from a colorized composite image, it is acceptable to impose a grayscale using the following method: with the image represented in RGB color space, calculate the grayscale value for each pixel by summing the R, G, and B channels for that pixel and then dividing by three. The location and orientation of the test object in the following procedures depends upon the X-ray source and detector arrangement. The test object shall be oriented in the imaging system such that the face of the thickest step of the step wedge is perpendicular to the X-ray beam for the X-ray view being tested and facing in the direction of the detector. Maintaining this perpendicularity, acquire eight images of the test object: four images with the long axis of the test object oriented parallel to the belt direction and four images with the long axis of the test object oriented perpendicular to the belt direction. The file format, types of images analyzed, and export methods shall be reported on the log sheet (see Fig. 6).

6.3.2 *Steel Differentiation:*

6.3.2.1 This test is scored using the eight images collected in 6.3.1.

6.3.2.2 In each image, identify the lines that correspond to the boundaries between the steps of the steel step wedge. There are twelve of these lines (including the boundary between the thinnest step and the area with no steel blocking material).

6.3.2.3 In each image, and for every boundary, select ROIs on both sides of the boundary. The ROIs should contain the smallest number of pixels that bound an area that is nominally 10 mm × 15 mm (these dimensions should be measured in the plane of the test object). The long edge of the ROI should be oriented parallel to the long edge of the step, as seen in Fig. 7. The center of the ROI should be 7.5 mm ± 1 mm away from the step discontinuities (that is, the center of the step).

6.3.2.4 For each boundary, compute the BSNR using the method described in A3.1 and record this value as $BSNR_j$, where *j* is the boundary index. Identify the thickest step on the step wedge for which the BSNR at both boundaries of this step is greater than five, and report the thickness of this step as the value for steel differentiation metric.

6.3.3 *Useful Penetration:*

6.3.3.1 This test is scored using the eight images collected in 6.3.1.

6.3.3.2 In each image orientation and for every step, select an ROI that is as wide as possible and 10 mm deep that also nominally includes the wires and whose borders also avoid all step-wedge edges, interfaces, and fasteners by at least 2 mm. Here, the ROI "width" is the transverse spatial dimension and "depth" is the direction normal to a step boundary, as illustrated in Fig. 7.

[6] Dimensions for the wires are given in Specification B258. The wires should be enameled according to IEC 60317-1 or NEMA MW 80C in order to prevent corrosion.

ASTM F792-OE Test Object Log Sheet

Tester: ______________________ Date: ________________ Time: __________

System manufacturer: ____________________ Model: ______________________

Serial no.: ______________________ Software version: ______________________

File format, image type and export method: ______________________________

____

Position (e.g. centered on the belt): ____________________________________

Other notes: ____

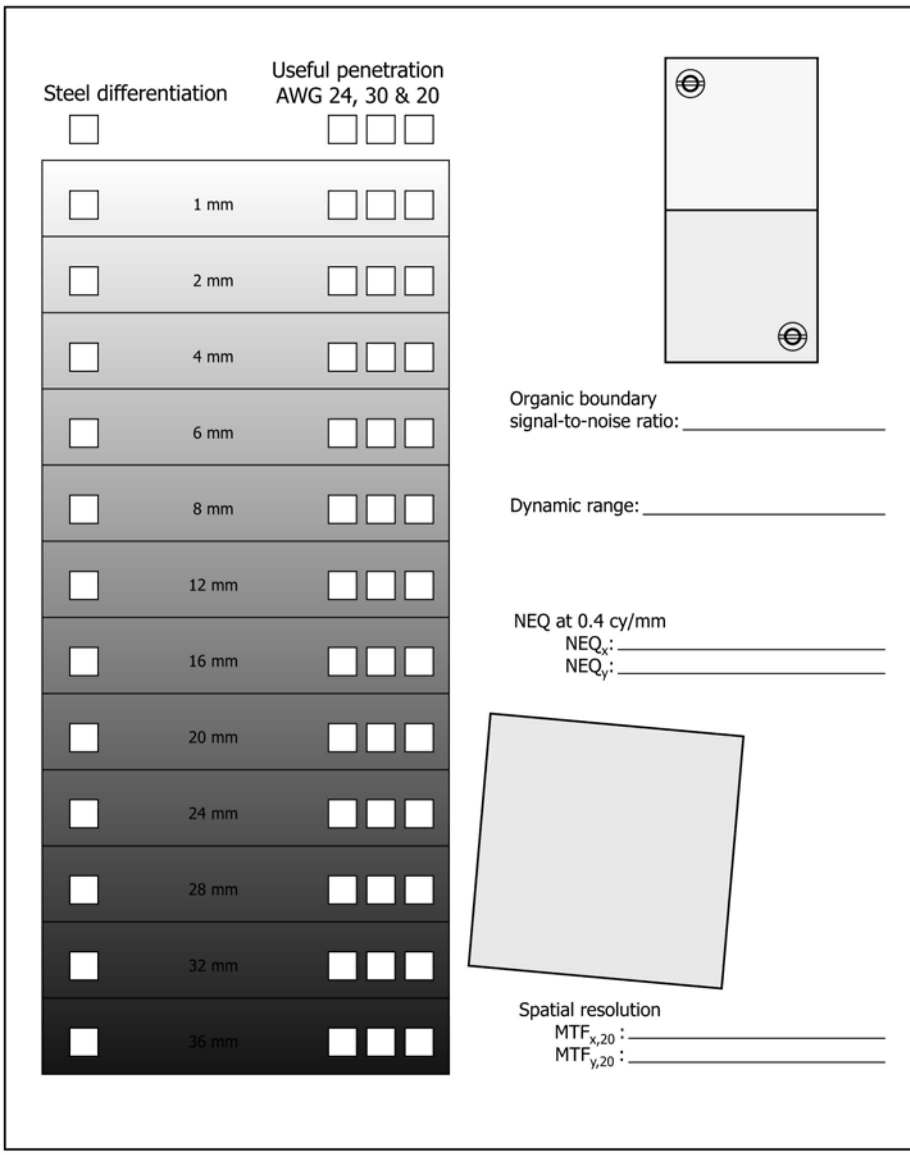


FIG. 6 A Log Sheet for Recording the Final Results of Practice F792 – OE

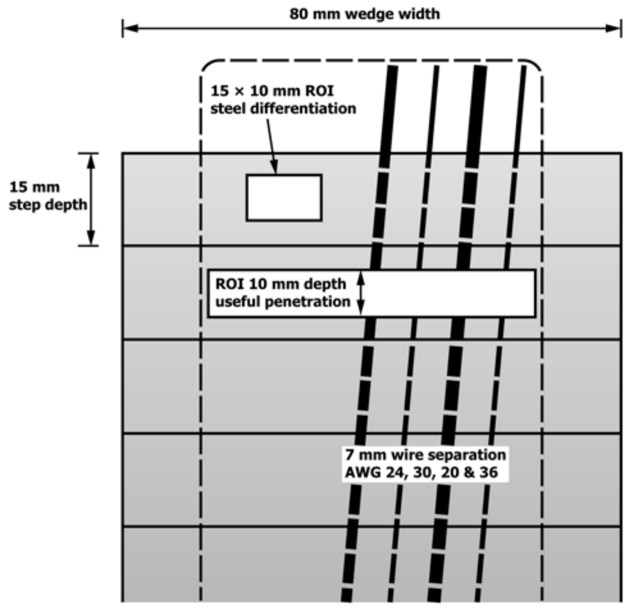


FIG. 7 A Schematic of the Top Part of the Steel Step Wedge along with Example ROIs for the Steel Differentiation and Useful Penetration Tests

6.3.3.3 For each ROI, compute a Wire Profile Function (WPF) as follows. Determine and record the median pixel value of the ROI. Perform a discrete Radon transform on the ROI minus its median.

$$R(\rho,\theta) = \text{Radon}[g(i,j) - \text{median}(g(i,j))] \quad (1)$$

where $g(i,j)$ are the pixel values in the ROI. The discrete Radon transform, $R(\rho,\theta)$, should be computed with an angular step size of 1° and a step size in the variable ρ of 1 pixel. The Radon transform of the I column, J row image, $g'(i,j)$ shall be computed using:

$$R(\rho,\theta) = \begin{cases} \frac{1}{|\sin\theta|}\sum_{i=1}^{I} g'(i,j'), & |\sin\theta| > \frac{1}{\sqrt{2}} \\ \frac{1}{|\cos\theta|}\sum_{j=1}^{J} g'(i',j), & |\sin\theta| \le \frac{1}{\sqrt{2}} \end{cases} \quad (2)$$

where $g'(i,j)$ is equal to $g(i,j)$ minus its median. The values of i' and j' are given by:

$$i' = [i_c + (j_c - j)\tan\theta + \rho\cos\theta + \rho\sin\theta\tan\theta] \quad (3)$$

$$j' = \left[j_c + \frac{i_c - i}{\tan\theta} + \rho\left(\sin\theta + \frac{\cos\theta}{\tan\theta}\right)\right] \quad (4)$$

where (i_c, j_c) is the position of the origin about which the Radon transform will be computed (for example, the center of the ROI). The square brackets indicate that the value should be rounded to the nearest integer (that is, the nearest-neighbor approximation).

6.3.3.4 Determine the coordinates of the minimum value of $R(\rho,\theta)$ for the 0 mm thick step and record its coordinates $(\rho_{min},\theta_{min})$. This θ_{min} should be used for analyzing the ROIs of all other steps in the same image.

6.3.3.5 The WPF shall be taken to be the column of $R(\rho,\theta)$ where $\theta = \theta_{min}$. Discard the outer d pixels of the WPF, because their value(s) may be affected by artifacts. d is calculated using $d = ceil\{h|\tan\theta_{min}|\}$, where h is the ROI height in pixels and the function ceil{} rounds its argument up to the nearest integer.

6.3.3.6 Select a representative background region of the WPF. This region should be at least 7 mm away from the known location of any wire, contiguous, and span at least 15 mm. Calculate the mean μ_{bkg} and sample standard deviation σ_{bkg} of the background region.

6.3.3.7 Define the test region as being those parts of the WPF that are not designated to be background in 6.3.3.6.

6.3.3.8 For each point in the test region of the WPF, calculate and record the t-statistic:

$$t_i = \frac{\mu_{bkg} - WPF_i}{\sigma_{bkg}} \quad (5)$$

where WPF_i is the i^{th} value in the WPF.

6.3.3.9 For each t_i value from the test region, calculate and record the associated p_i value using the formula.

$$p_i = \frac{1}{2}\left[1 - erf\left(\frac{t_i}{\sqrt{2}}\right)\right] \quad (6)$$

Here, $erf(\ )$ is the usual error function.

6.3.3.10 Determine and record N_{tot}, the total number of p values that were calculated.

6.3.3.11 For each WPF_i, if $p_i < 8.8 \times 10^{-5}/N_{tot}$ and if WPF_i is consistent with an *a priori* known location of a wire, then that wire is scored as visible.[7] Only a single WPF_i is required to satisfy these two conditions for a wire to be scored positively on a given step. False negatives are not recorded.

6.3.3.12 Record the thickness of the thickest step for which the wire is visible in at least three of the four images in both the

[7] The threshold value of $8.8 \times 10^{-5}/N_{tot}$ was chosen so that the wire detection sensitivity of the algorithm was consistent with the performance of human operators, see "*An Objectively-Analyzed Method for Measuring The Useful Penetration of X-ray Imaging Systems*," J. L. Glover and L. T. Hudson, *Meas. Sci. Technol.* **27** 065402 (2016).

parallel and perpendicular orientations. Tabulate these values for the wires of AWG sizes 20, 24, and 30.

6.3.4 *Organic Boundary Signal-to-Noise Ratio:*

6.3.4.1 This test is scored using the eight images collected in 6.3.1.

6.3.4.2 In each image, select a rectangular ROI with the smallest number pixels that bound an area of nominally 5 mm × 15 mm (these dimensions should be measured in the plane of the test object). The center of the ROI should be 7.5 mm ± 1 mm on each side of the step discontinuity between the two thicknesses of plastic.

6.3.4.3 Using the ROIs described in 6.3.4.2, measure the *BSNR* and record and report this value as the value for organic boundary signal-to-noise ratio.

6.3.5 *Spatial Resolution:*

6.3.5.1 This test is scored using the eight images collected in 6.3.1.

6.3.5.2 Select two ROIs nominally centered on the top and left edges of the lead foil. The ROIs should be nominally 40 by 40 mm (measured in the plane of the test object).

6.3.5.3 Compute the MTF_x and MTF_y of the ROIs selected in 6.3.5.2 according to ISO 12233-2000, Section 6.3 and Annex C. The MTF_x and MTF_y should be plotted up to the Nyquist frequency and their values listed in a table.

6.3.5.4 Linearly interpolate MTF_x and MTF_y to determine the lowest spatial frequency at which their values would nominally equal 0.2, and record these values as $MTF_{x,20}$ and $MTF_{y,20}$. If the values are larger than the Nyquist frequency, then report the value of the Nyquist frequency.

6.3.5.5 Repeat 6.3.5.2 through 6.3.5.4 for each of the images. Record and report the mean and sample standard deviation of the $MTF_{x,20}$ and $MTF_{y,20}$ values.

6.3.6 *Dynamic Range:*

6.3.6.1 This test is scored using the eight images collected in 6.3.1.

6.3.6.2 In each image, select a rectangular ROI on the step with the lowest mean pixel value that has no zero-value pixels. The ROI should have the smallest number pixels that bound a region of 5 mm × 15 mm (measured in the plane of the test object). The long edge of the ROI should be oriented parallel to the long edge of the step. The center of the ROI should be 7.5 mm ± 1 mm away from the step discontinuities.

6.3.6.3 Compute and record the sample standard deviation of the pixels in the ROI, σ.

6.3.6.4 Compute and record the maximum pixel value in the image, P_{max}.

6.3.6.5 Compute and record the dynamic range of the image, P_{max}/σ.

6.3.6.6 Repeat 6.3.6.2 through 6.3.6.5 for each of the images and report the mean value and sample standard deviation of the dynamic range.

6.3.7 *Noise Equivalent Quanta:*

6.3.7.1 Acquire eight images without the test object in place. Make sure that the images are not saturated. If necessary, a thin, uniform attenuator can be used to unsaturate the image.

6.3.7.2 For the images obtained in 6.3.7.1, establish an ROI of approximately 100 mm by 100 mm that is nominally centered in the image (measured in the plane of the belt). The ROI consists of an *MxN* array of *M* rows and *N* columns of pixel values, $n[x,y]$, where *x* and *y* correspond to the horizontal and vertical axes (rows and columns) of the image.

6.3.7.3 Compute the complex-valued discrete spatial-frequency spectrum, $\hat{n}_y[f_x]$, of each of the *M* rows of the image obtained in 6.3.7.1 using:

$$\hat{n}_y[f_x] = \mathrm{DFT}\{n_y\,[x]\}, \tag{7}$$

where DFT is the discrete Fourier transform and $n_y[x]$ are the pixel values for a fixed image row of noise (denoted by the subscript "*y*").

6.3.7.4 Compute the complex-valued discrete spatial-frequency spectrum, $\hat{n}_x[f_y]$, of each of the *N* columns of the image obtained in 6.3.7.1 using:

$$\hat{n}_x[f_y] = \mathrm{DFT}\{n_x\,[y]\}, \tag{8}$$

where $n_x[y]$ is the noise for a fixed image column (denoted by the subscript "*x*").

6.3.7.5 Compute NPS_{f_x} for the ROI using:

$$NPS_{f_x} = \frac{1}{M}\sum_{y=1}^{M}|\hat{n}_y[f_x]|^2, \tag{9}$$

where *y* is an index.

6.3.7.6 Compute NPS_{f_y} for the ROI using:

$$NPS_{f_y} = \frac{1}{N}\sum_{x=1}^{N}|\hat{n}_x[f_y]|^2, \tag{10}$$

where *x* is an index.

6.3.7.7 Compute the mean pixel value, S_{out}, within the ROI.

6.3.7.8 If necessary, linearly interpolate the values of MTF_x and MTF_y computed in 6.3.5.4, so that MTF_x and MTF_y each has values that have the same frequencies as NPS_{f_x} and NPS_{f_y}.

6.3.7.9 Compute the NEQ_x using:

$$NEQ_x = \frac{S_{out}^2 MTF_x^2}{NPS_{f_x}}. \tag{11}$$

6.3.7.10 Compute the NEQ_y using:

$$NEQ_y = \frac{S_{out}^2 MTF_y^2}{NPS_{f_y}}. \tag{12}$$

6.3.7.11 Repeat 6.3.7.1 through 6.3.7.10 for each of the images collected in 6.3.7.1, labeling each measurement with an index, such as $NEQ_{x,i}$ and $NEQ_{y,i}$ with $1 \le i \le 8$.

6.3.7.12 Compute the means, $\overline{NEQ_x}$ and $\overline{NEQ_y}$, and sample standard deviations σ_{NEQ_x} and σ_{NEQ_y}, of the data obtained in (*11*) and record these values.

6.3.7.13 Report the $\overline{NEQ_x}$ and $\overline{NEQ_y}$ values as well as the σ_{NEQ_x} and σ_{NEQ_y} values at a frequency of 0.4 cycles/mm.

6.4 *Evaluation Considerations:*

6.4.1 *General*—Use of this practice does not guarantee that the X-ray system is operating properly. It is not intended to replace the X-ray system's diagnostics. If problems are experienced with the X-ray system, they must be resolved prior to operation.

6.4.2 *Training Requirements*—To effectively conduct the evaluation of an X-ray system, it is recommended that the evaluator be trained to operate the X-ray system under test.

6.4.3 *Test Object Location and Orientation*—The location and orientation of the test object greatly affects performance. Ensure and record that these are consistent with previous tests.

6.4.4 *Result Interpretation and Significance*—The purpose of this test method is to objectively measure the performance of the system for the purpose of comparison and to measure changes in system performance with time. The OE test method does not have minimum performance requirements. A completed example log sheet with typical details and results is given in Fig. A3.6

6.4.5 *Log Sheet Use*—The final scores for the six metrics shall be recorded on the log sheet provided in Fig. 6. The evaluator shall record all relevant details of the X-ray system, software versions, test object positioning and orientation, as well as details of the image format and how the images were extracted from the X-ray system. The evaluator shall provide full plots of the *MTF* and *NEQ* up to the Nyquist frequency.

7. Keywords

7.1 bulk explosives detection; contrast sensitivity; dynamic range; effective atomic number; explosive device; explosives; image quality metrics; imaging; materials classification; materials discrimination; noise-equivalent quanta; organic boundary signal-to-noise ratio; organic differentiation; security system; simple penetration; spatial resolution; steel contrast sensitivity; steel differentiation; thin organic imaging; useful penetration; weapons; wire display; X-ray

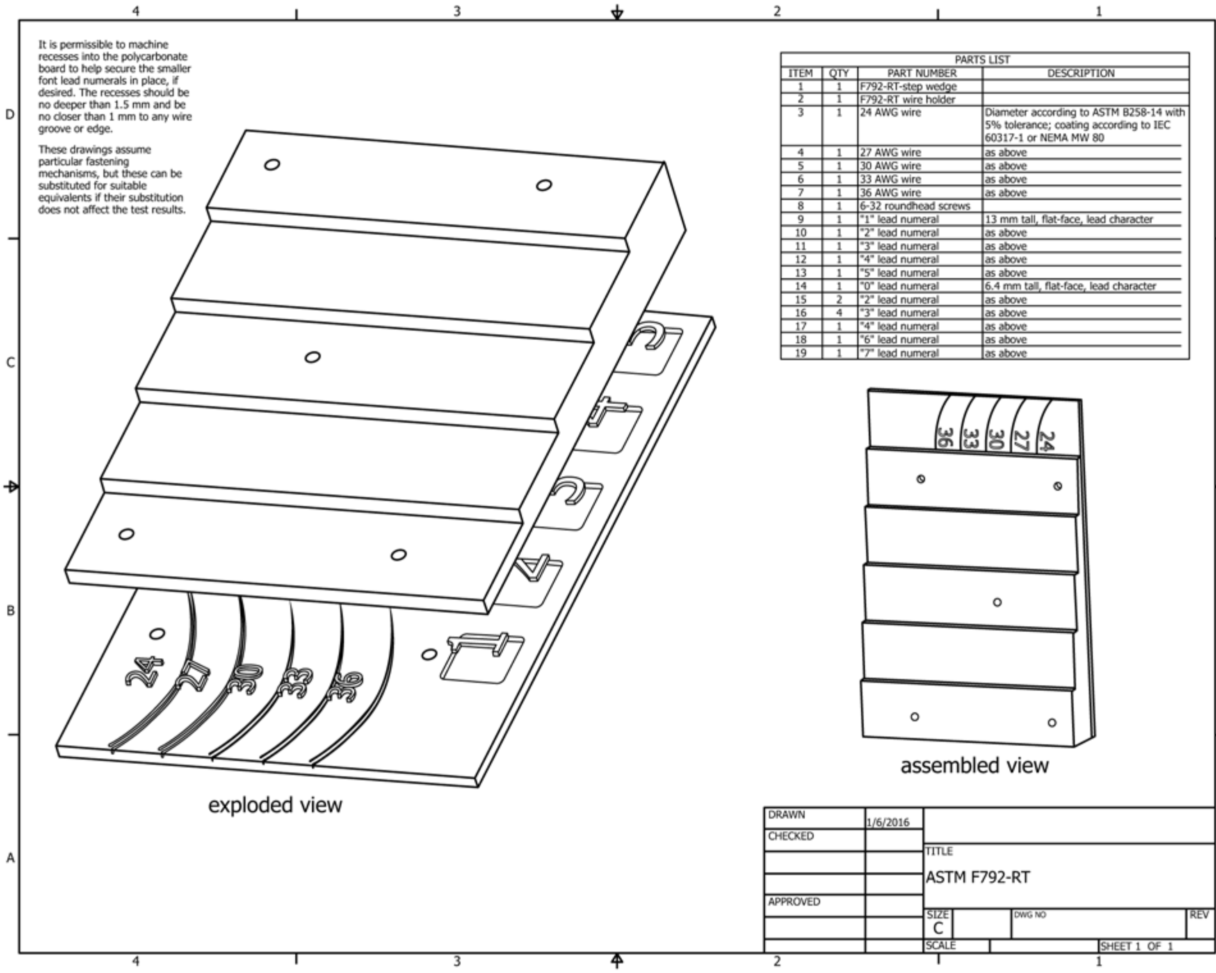
ANNEXES

(Mandatory Information)

A1. PART RT

A1.1 Mechanical Drawings for ASTM X-ray Test Object – RT

A1.1.1 The test object drawings (see Figs. A1.1-A1.3) are included in this documentary standard to facilitate the reader's understanding regarding the use of these test objects. To manufacture a test object, please refer to the full quality final drawings that are included in ASTM Adjunct ADJF079217.[3]



PARTS LIST

ITEM	QTY	PART NUMBER	DESCRIPTION
1	1	F792-RT-step wedge	
2	1	F792-RT wire holder	
3	1	24 AWG wire	Diameter according to ASTM B258-14 with 5% tolerance; coating according to IEC 60317-1 or NEMA MW 80
4	1	27 AWG wire	as above
5	1	30 AWG wire	as above
6	1	33 AWG wire	as above
7	1	36 AWG wire	as above
8	1	6-32 roundhead screws	
9	1	"1" lead numeral	13 mm tall, flat-face, lead character
10	1	"2" lead numeral	as above
11	1	"3" lead numeral	as above
12	1	"4" lead numeral	as above
13	1	"5" lead numeral	as above
14	1	"0" lead numeral	6.4 mm tall, flat-face, lead character
15	2	"2" lead numeral	as above
16	4	"3" lead numeral	as above
17	1	"4" lead numeral	as above
18	1	"6" lead numeral	as above
19	1	"7" lead numeral	as above

FIG. A1.1 A Mechanical Drawing of the Practice F792 – RT Test Object with Assembled and Exploded Views

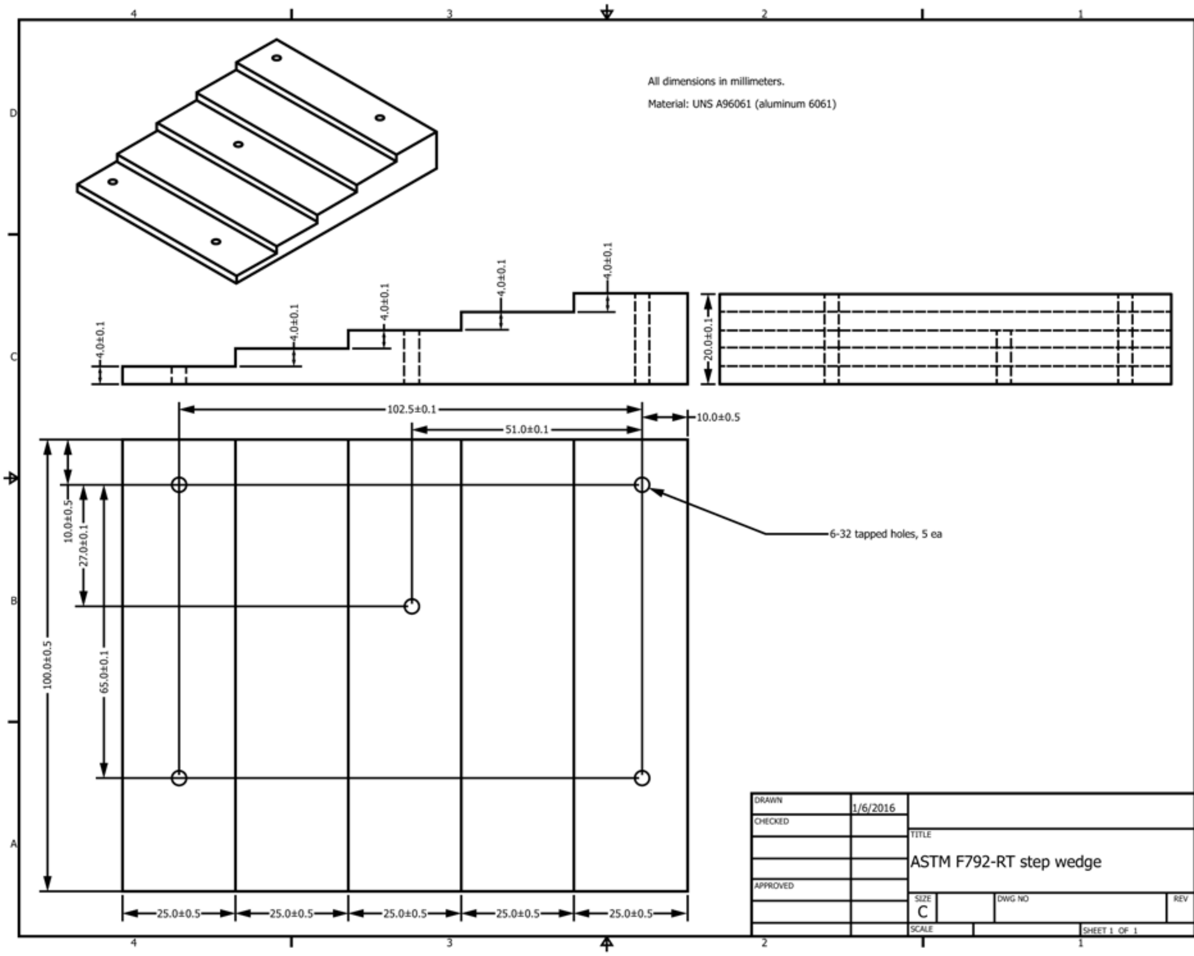


FIG. A1.2 Mechanical Drawing of the Practice F792 – RT Step Wedge

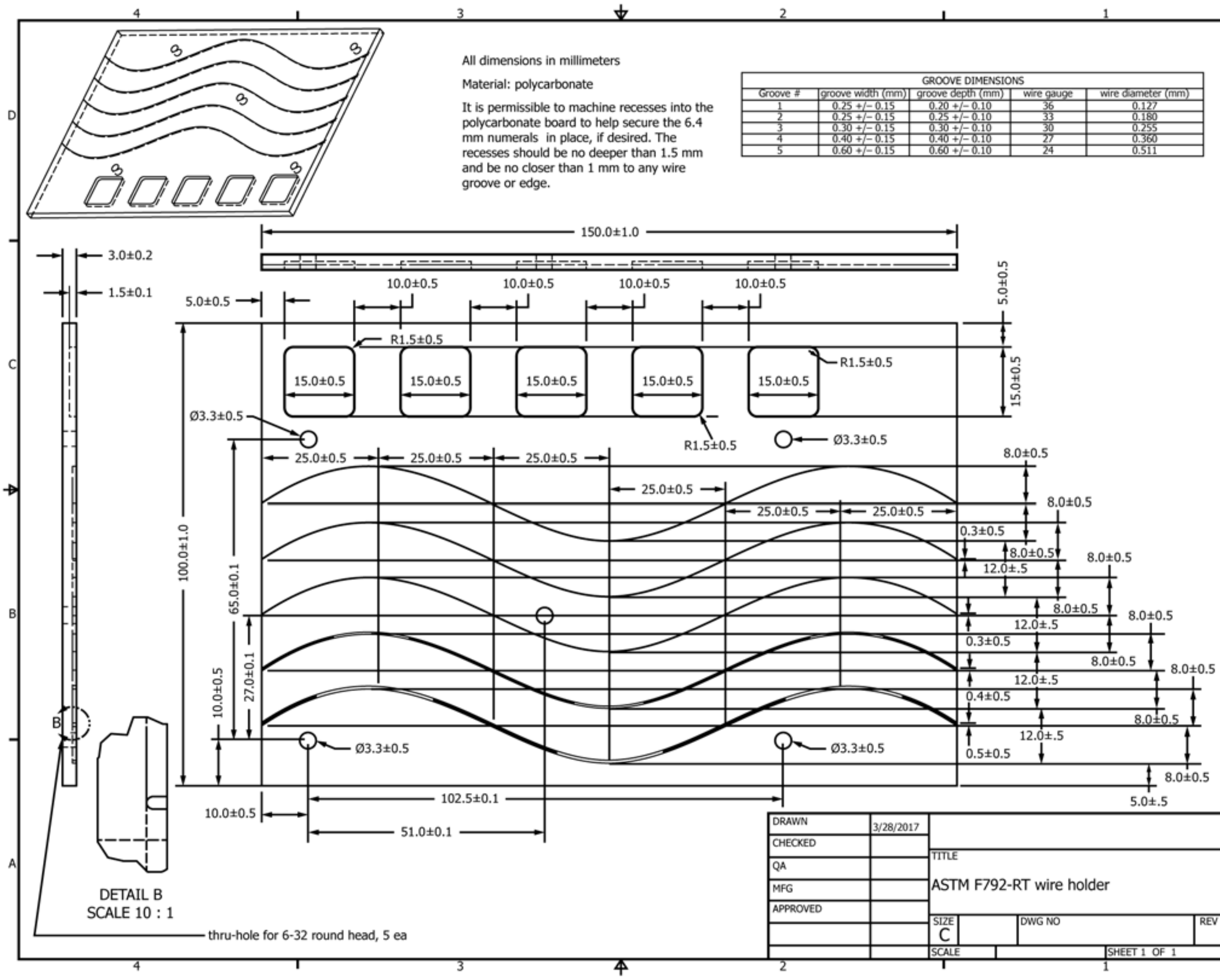
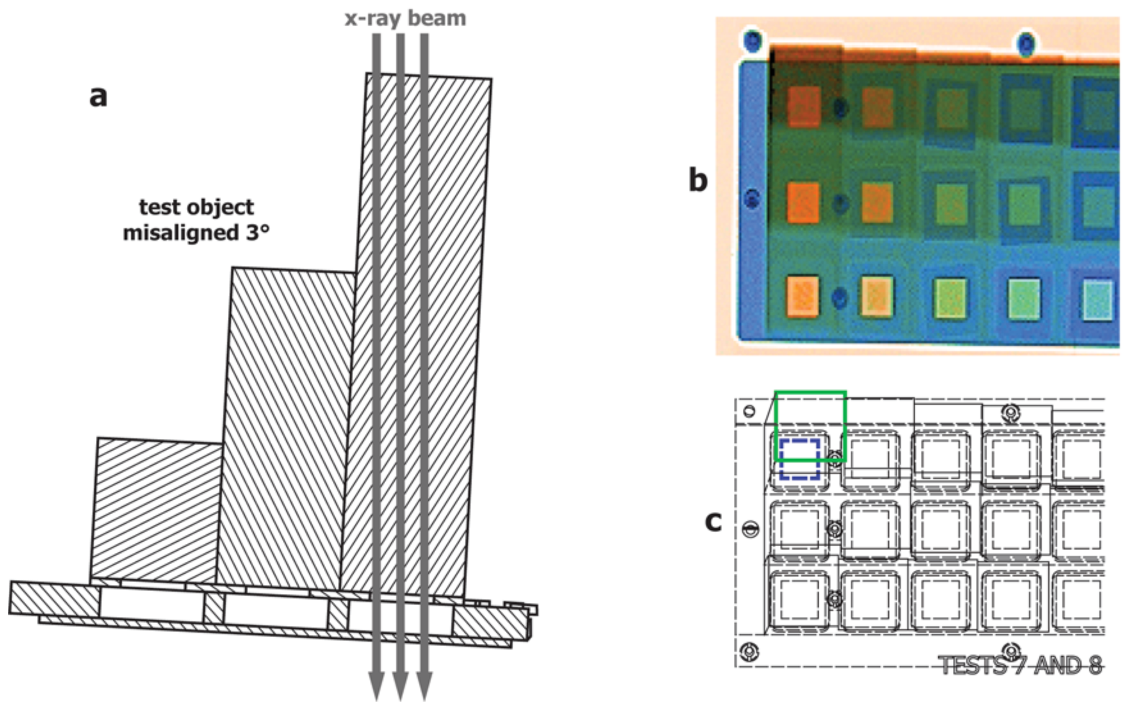


FIG. A1.3 Mechanical Drawing of the Practice F792 – RT Wire Holder

A2. PART HP

A2.1 Alignment of the Practice F792 – HP Test Object

A2.1.1 This annex provides guidance on how to ensure the F792 – HP test piece is aligned correctly. The test object should be aligned so that the X-ray beam is as close as possible to perpendicular to the face of the thickest square of *Test 7* and *Test 8* (the top left square). This may necessitate tilting the test object. It is acceptable to orient the suitcase at an angle using other objects (for example, a foam wedge) provided they do not alter the test results. When the test piece is improperly aligned, the color visible in the square holes in the steel grid may have discontinuities. For example, the upper left square in Fig. A2.1(b) is dark orange in color except for the bottom edge, where the color is noticeably lighter. This color difference is caused by the X-ray beam not being normal to the top surface of the POM test piece and, consequently, not travelling through the full thickness of the POM that sits above the hole in the steel. Fig. A2.1(c) represents the misalignment as seen from the X-ray source. If the test piece is aligned so that the angle between the normal to the POM test piece and the X-ray beam direction is less than 3°, then any X-ray that travels through the square hole in the steel grid (highlighted in blue in Fig. A2.1(c)) will also travel through the full thickness of the POM piece (highlighted in green in Fig. A2.1(c). Fig. A2.1(a) shows the X-ray paths when the angle between the normal of the POM and the X-ray beam direction is slightly less than 3°. Therefore, to ensure that the test piece is aligned satisfactorily,



(a) a cross section through the left-most column of the test piece for *Test 7* and *Test 8* when the test object has been misaligned by slightly less than 3°. The path taken by the X-ray beam is also shown. (b) An X-ray image of the misaligned test piece. (c) A wireframe representation of the test object is shown when it is misaligned by more than 3°. The square hole in the steel grid is outlined as a dashed blue line and the top face of the POM piece is outlined in green.

FIG. A2.1 Alignment of the F792 – HP Test Object

make sure that the top of the POM piece (green in Fig. A2.1(c)) is aligned over the square hole in the steel mask (blue in Fig. A2.1(c)) in the X-ray image and the color in the square has no discontinuities.

A2.2 Mechanical Drawings for ASTM X-ray Test Object – HP

A2.2.1 The test object drawings (see Figs. A2.2-A2.21) are included in this documentary standard to facilitate the reader's understanding regarding the use of these test objects. To manufacture a test object, please refer to the full quality final drawings that are included in ASTM Adjunct ADJF079217.[3]

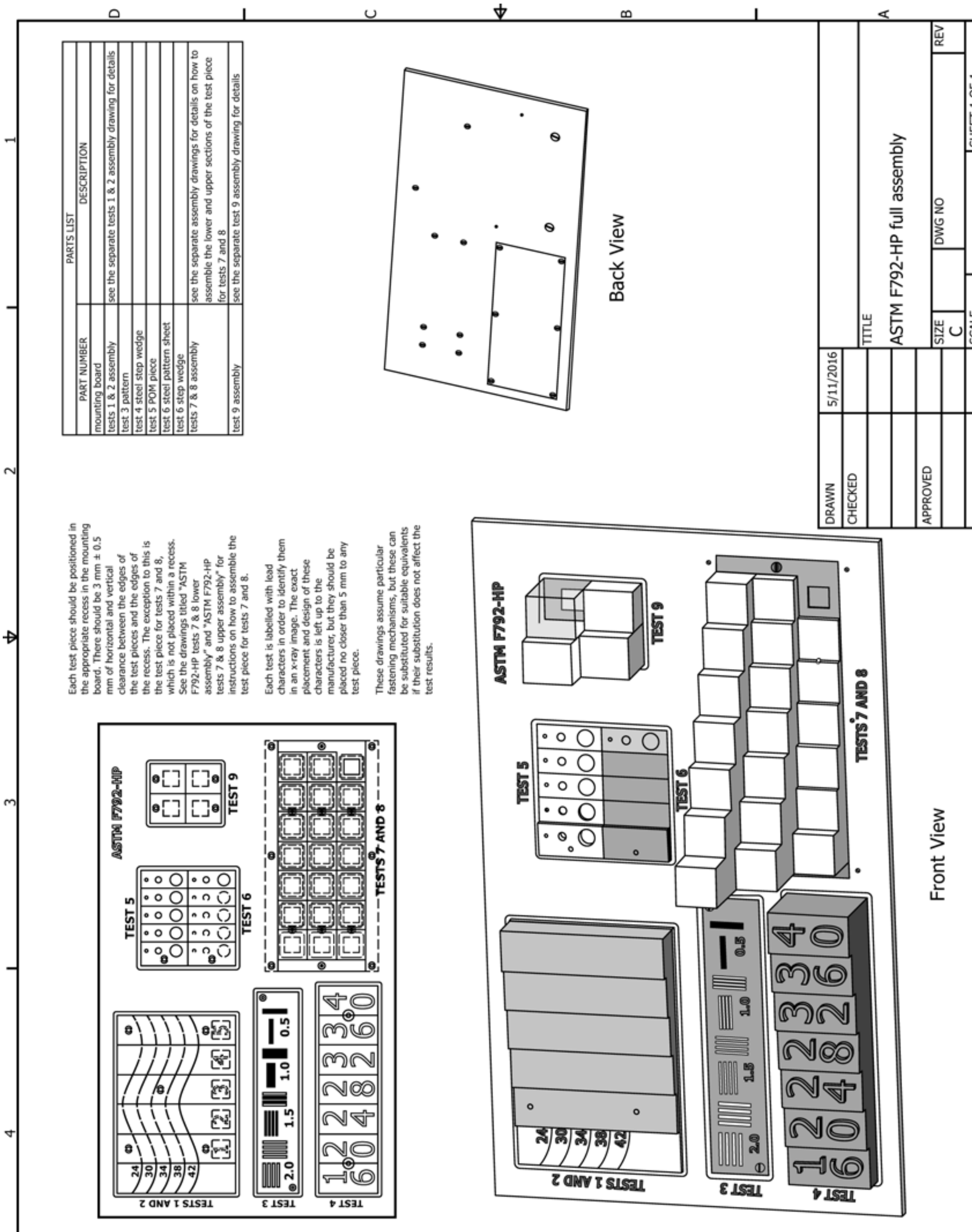


FIG. A2.2 Practice F792 – HP Mechanical Drawing

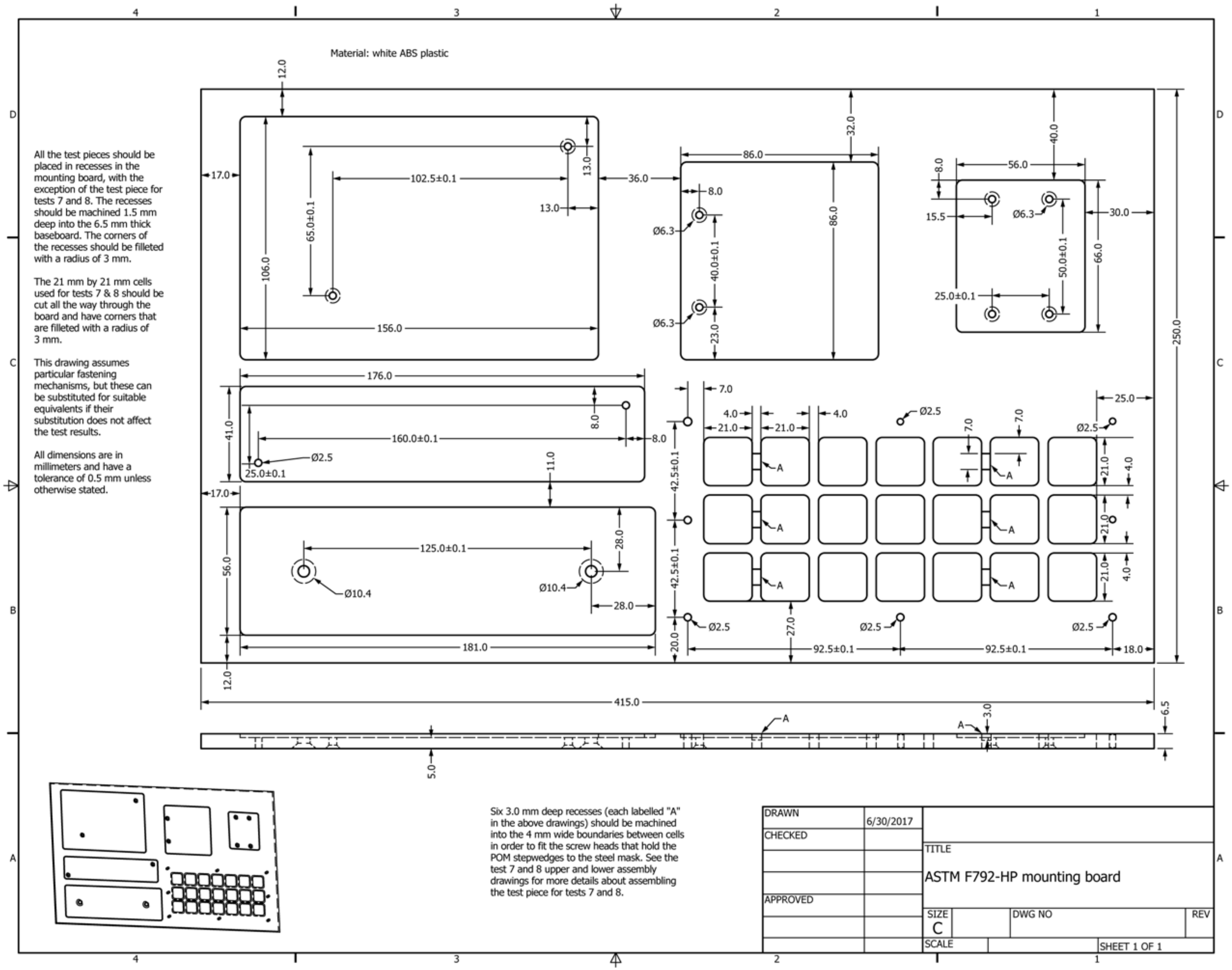


FIG. A2.3 Practice F792 – HP Mechanical Drawing

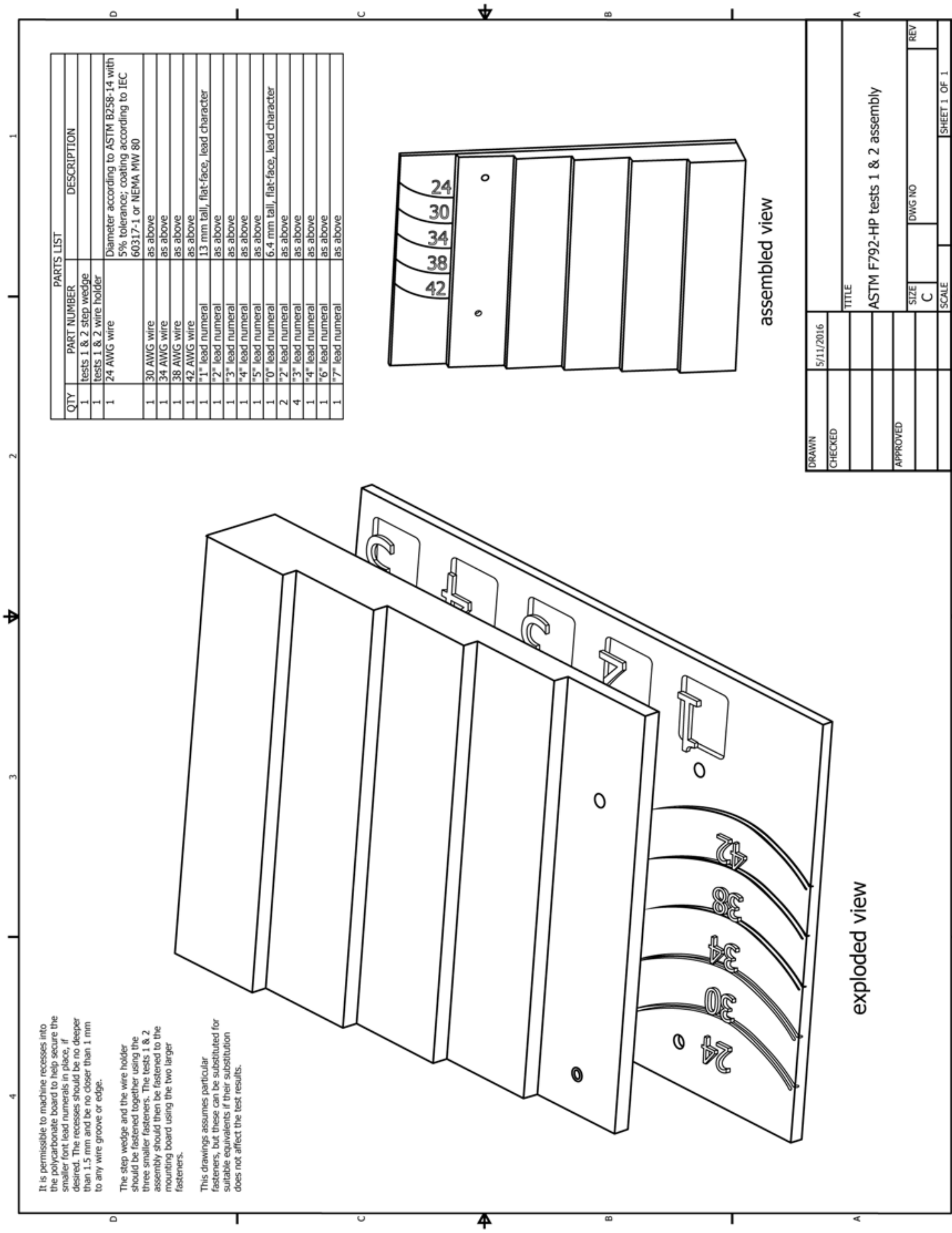


FIG. A2.4 Practice F792 – HP Mechanical Drawing

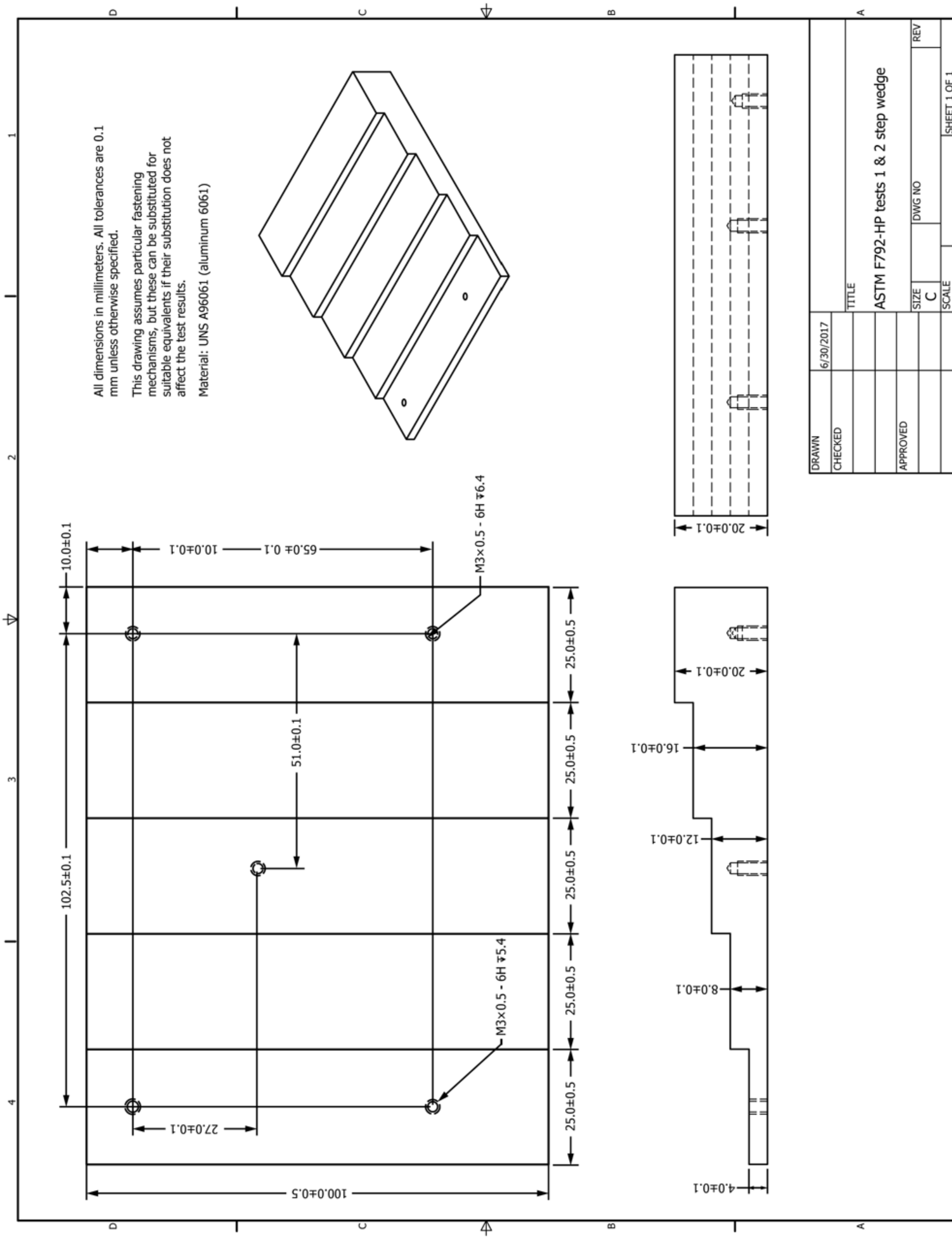
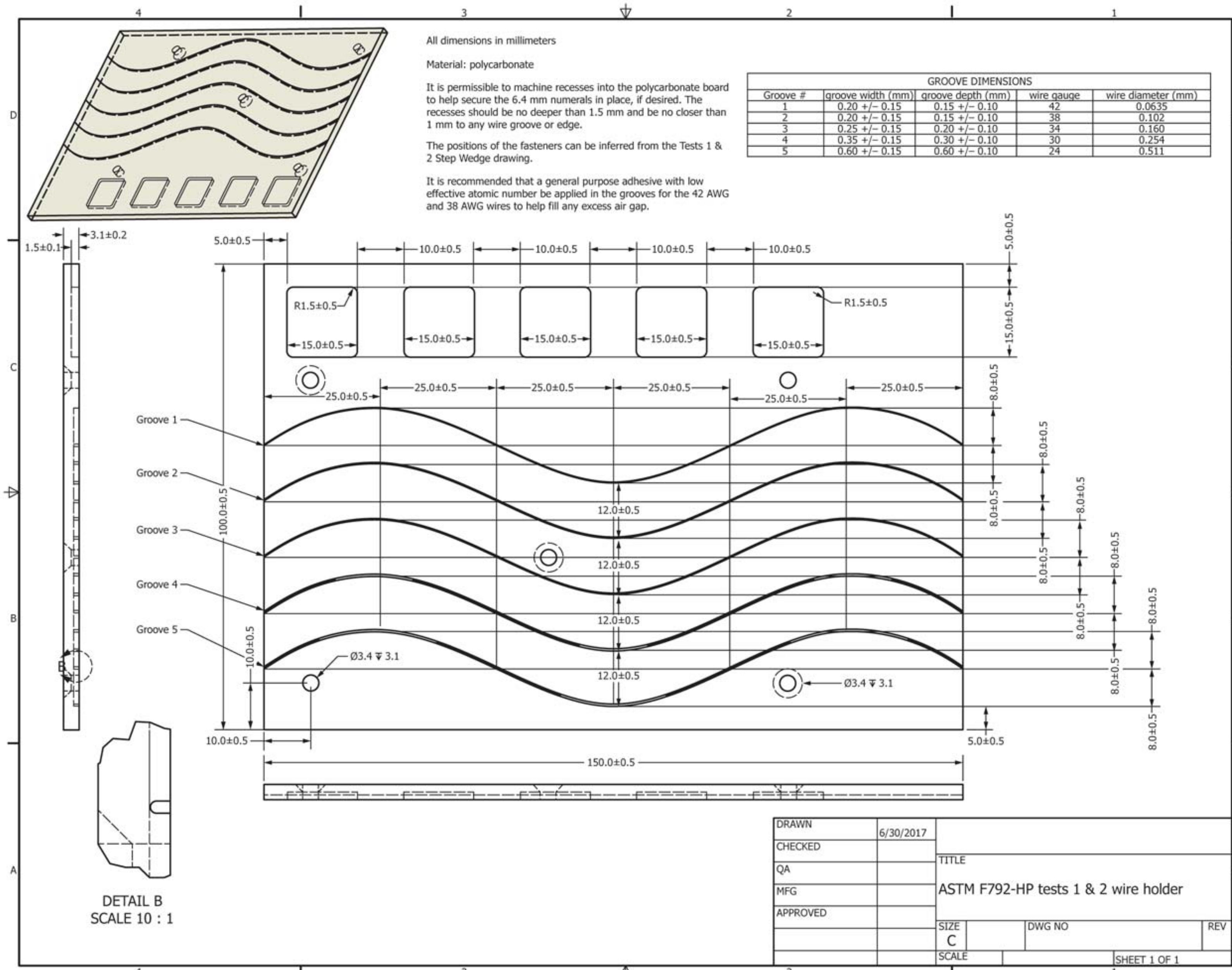


FIG. A2.5 Practice F792 – HP Mechanical Drawing



GROOVE DIMENSIONS

Groove #	groove width (mm)	groove depth (mm)	wire gauge	wire diameter (mm)
1	0.20 +/– 0.15	0.15 +/– 0.10	42	0.0635
2	0.20 +/– 0.15	0.15 +/– 0.10	38	0.102
3	0.25 +/– 0.15	0.20 +/– 0.10	34	0.160
4	0.35 +/– 0.15	0.30 +/– 0.10	30	0.254
5	0.60 +/– 0.15	0.60 +/– 0.10	24	0.511

FIG. A2.6 Practice F792 – HP Mechanical Drawing

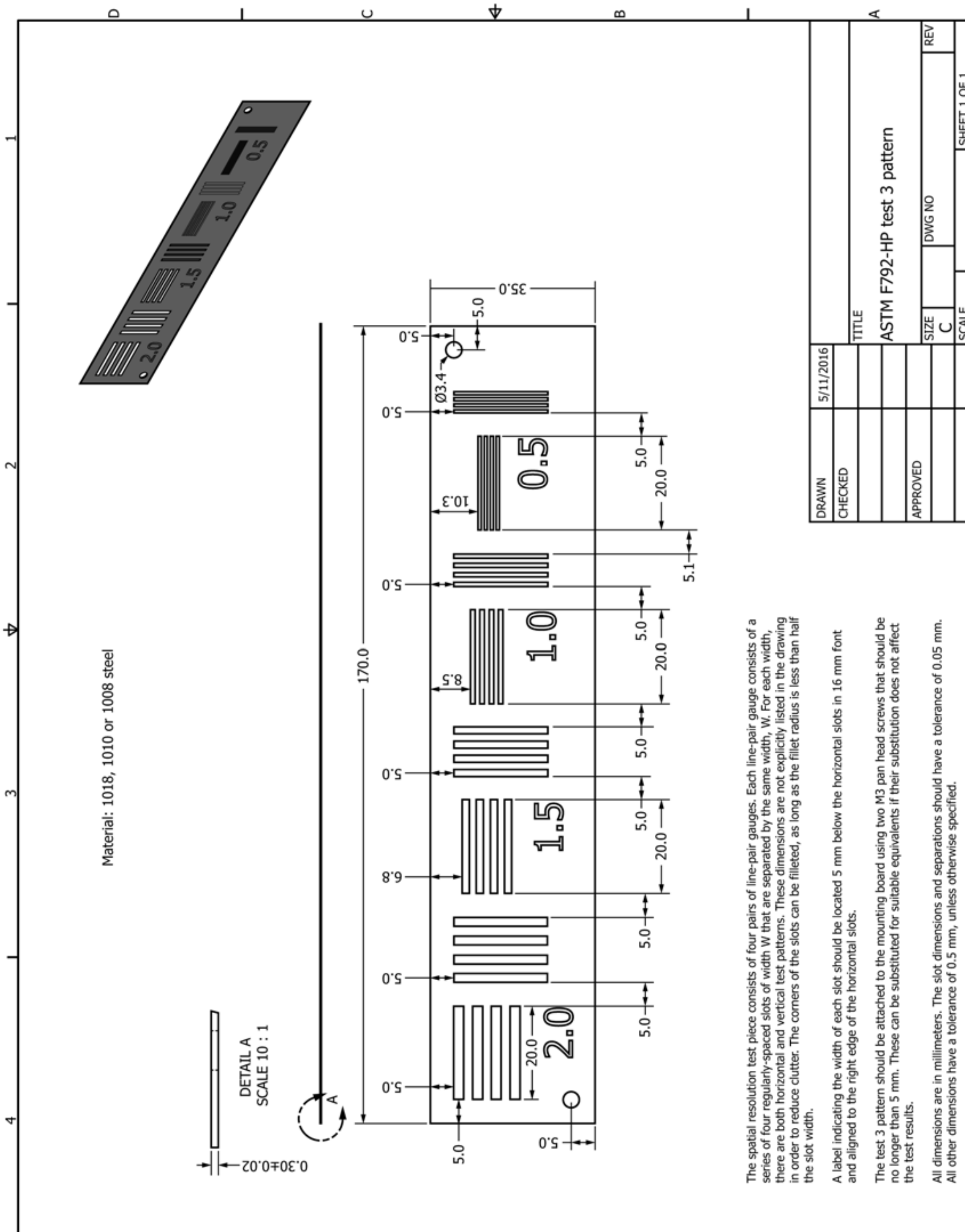


FIG. A2.7 Practice F792 – HP Mechanical Drawing

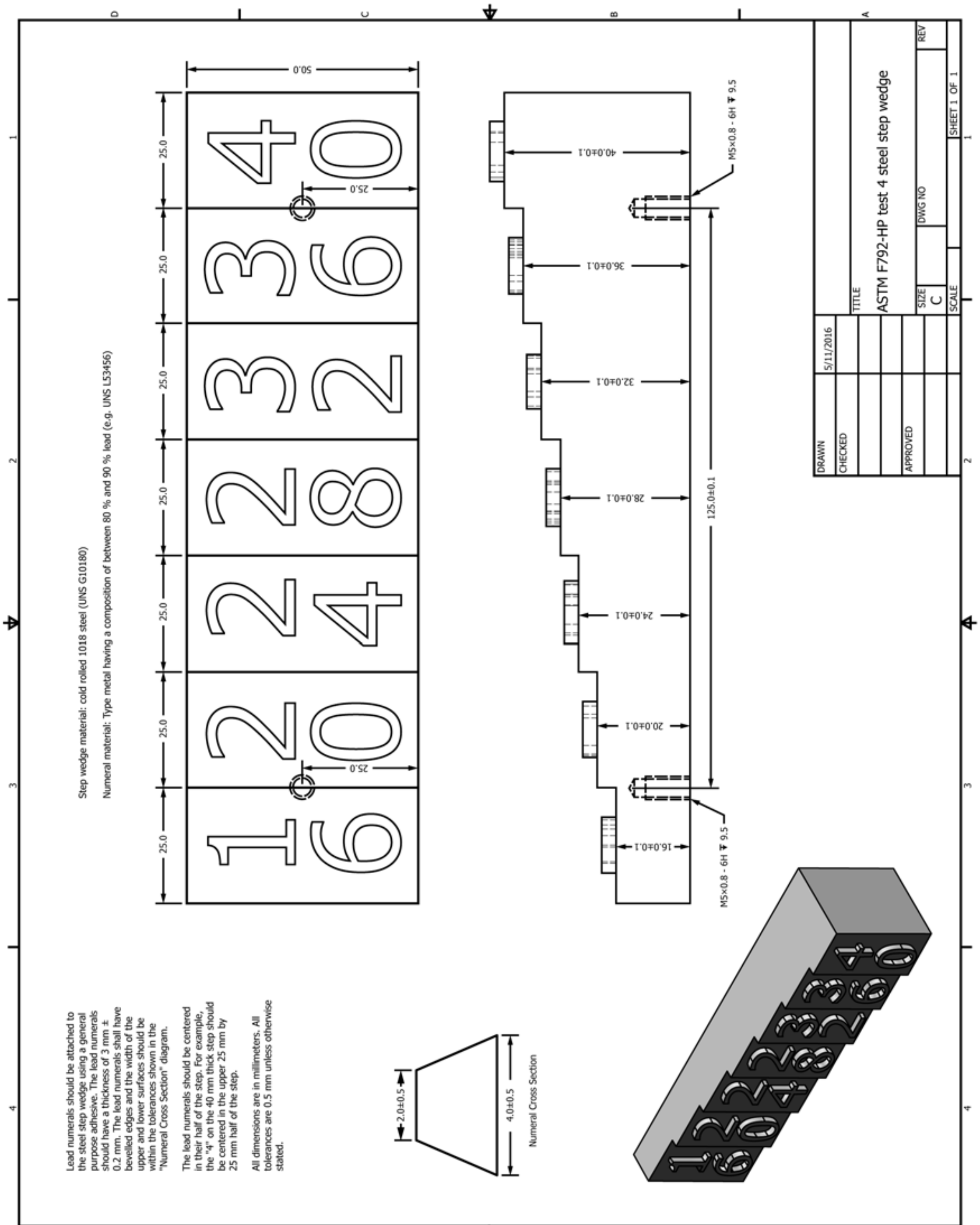


FIG. A2.8 Practice F792 – HP Mechanical Drawing

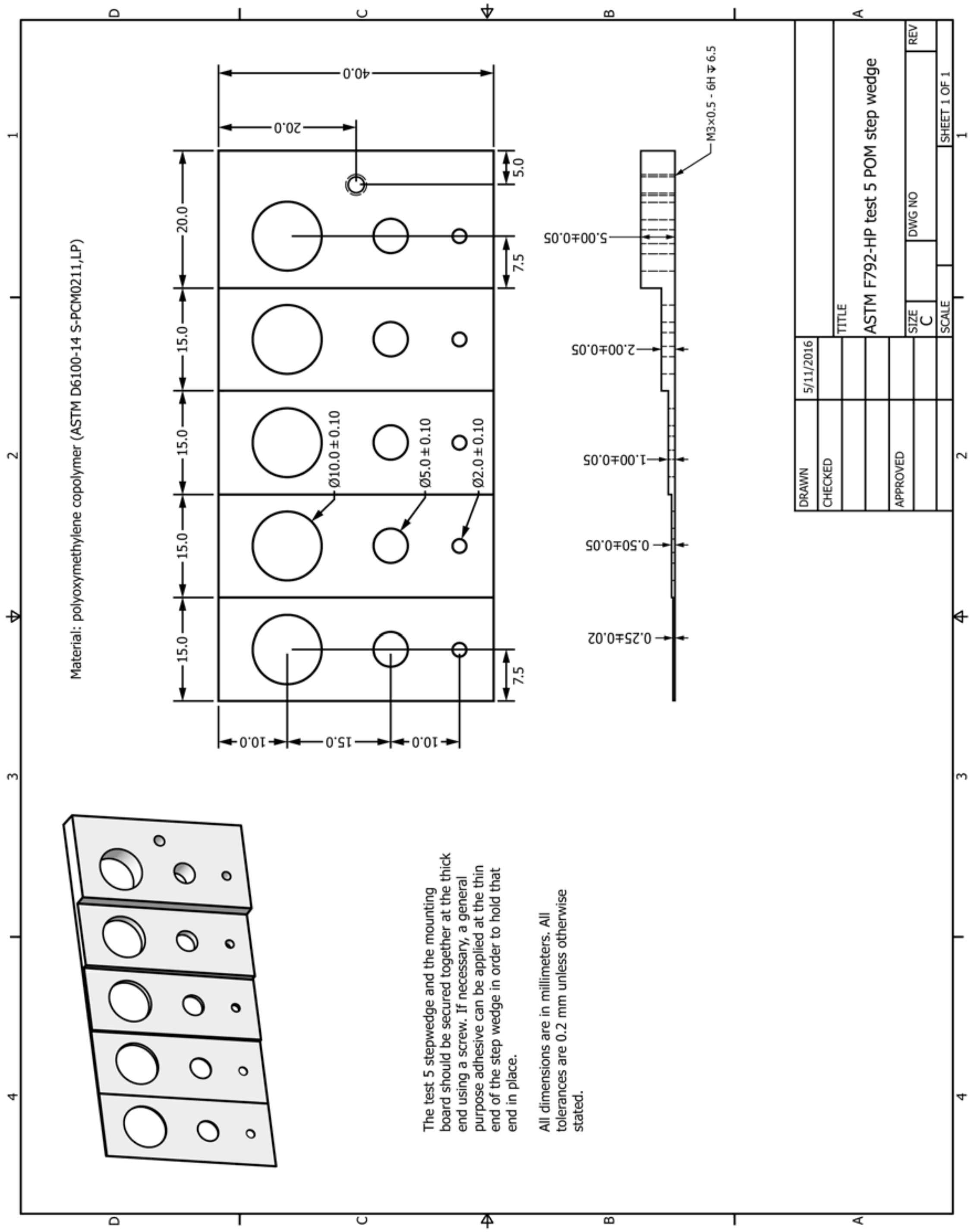


FIG. A2.9 Practice F792 – HP Mechanical Drawing

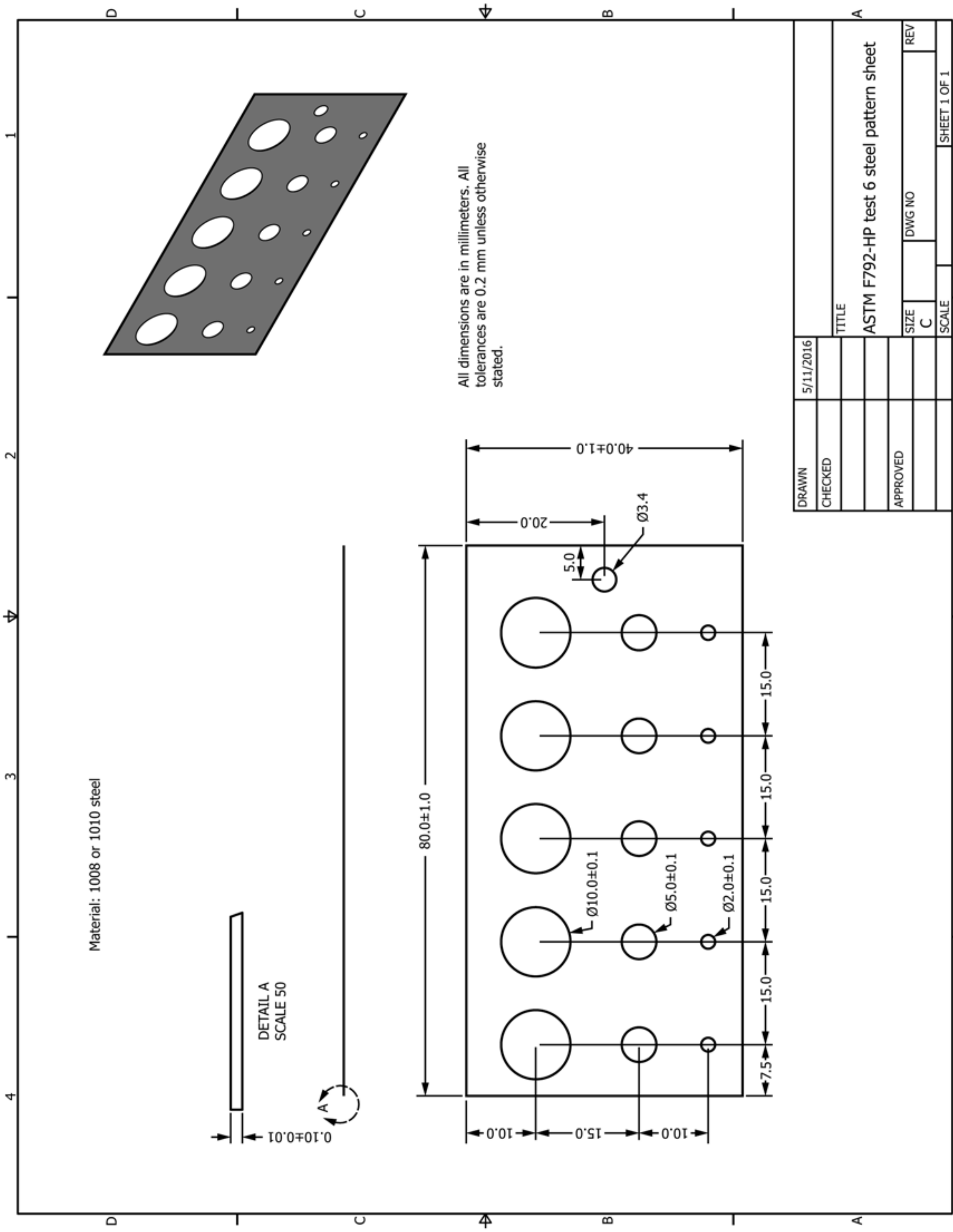


FIG. A2.10 Practice F792 – HP Mechanical Drawing

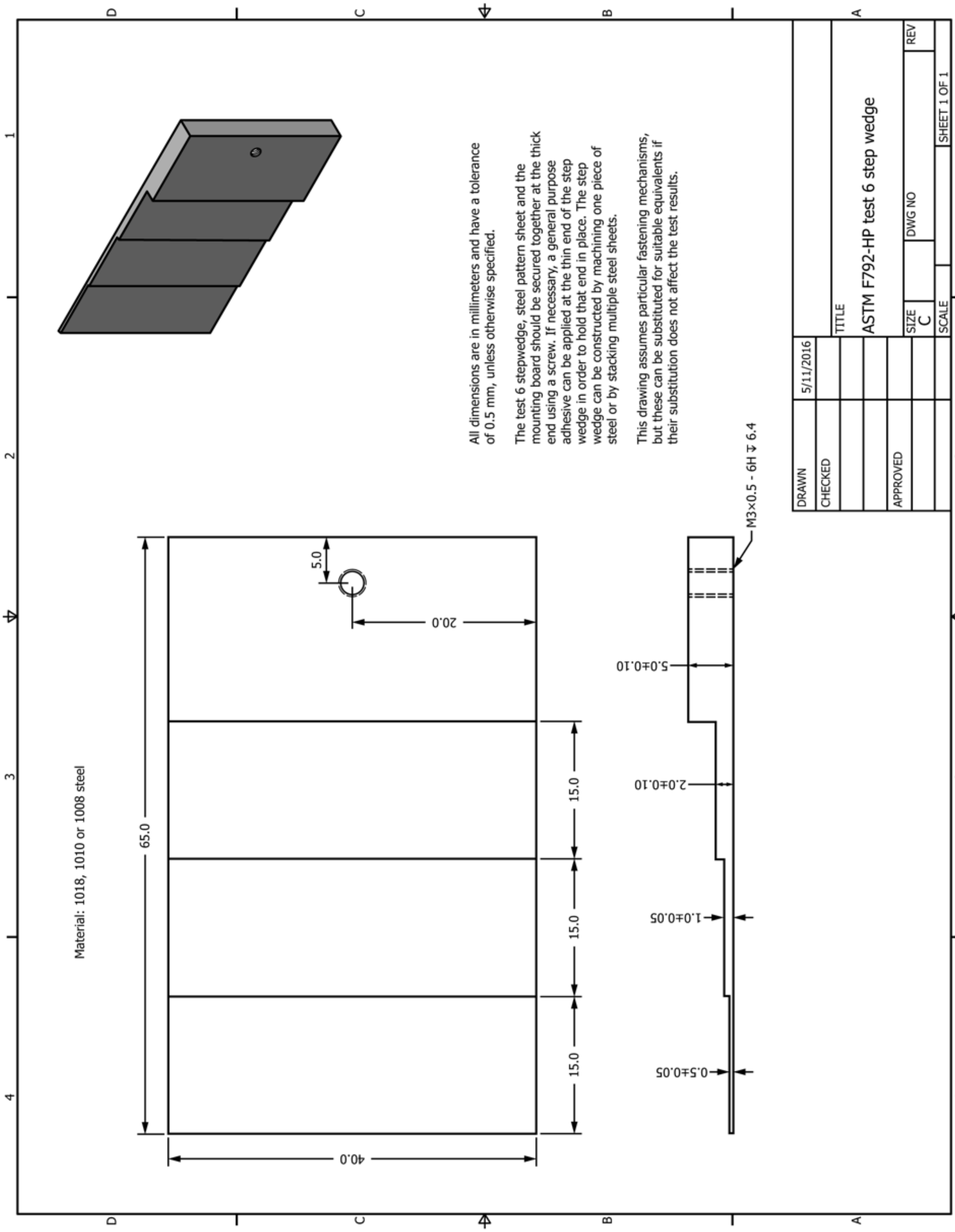


FIG. A2.11 Practice F792 – HP Mechanical Drawing

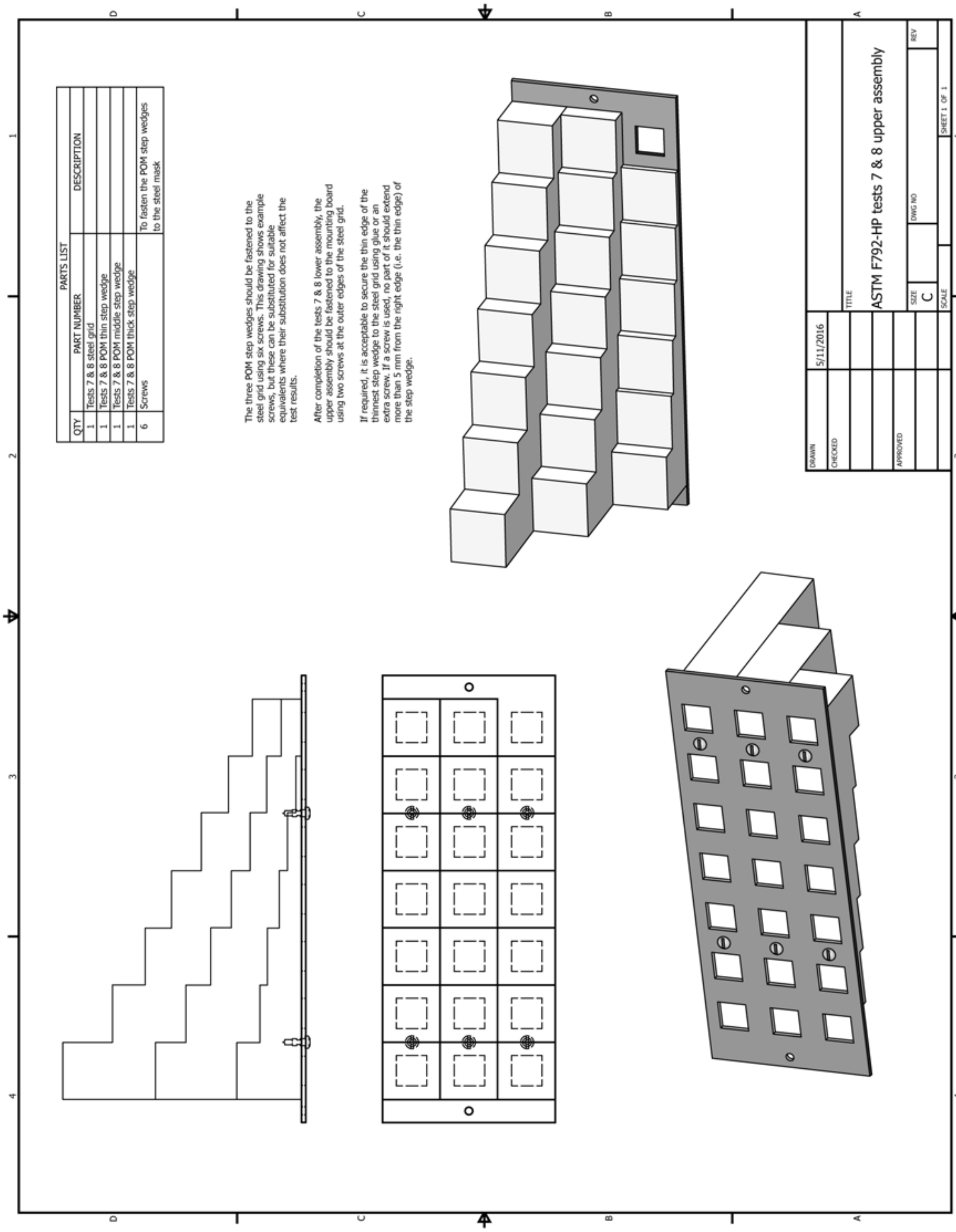


FIG. A2.12 Practice F792 – HP Mechanical Drawing

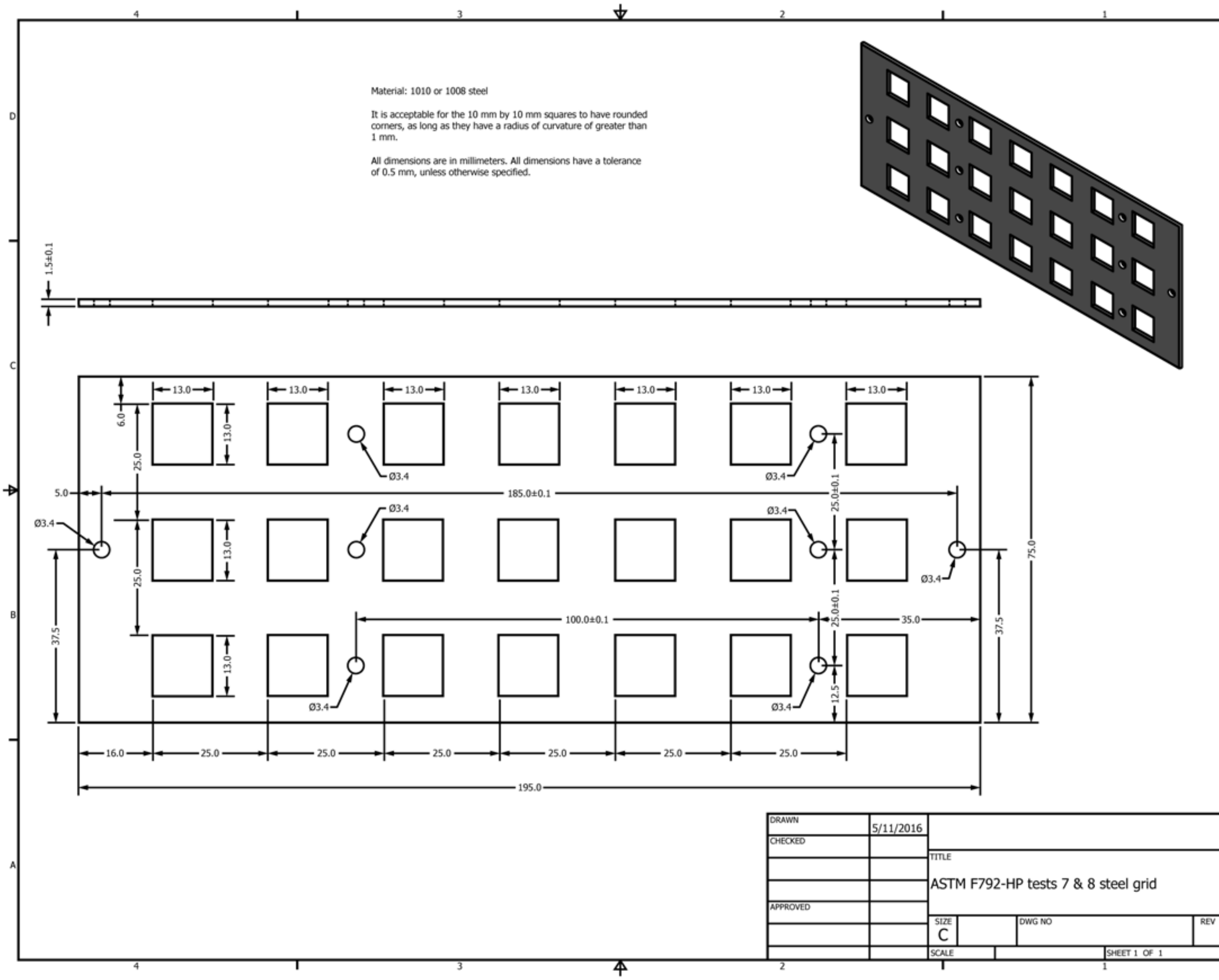


FIG. A2.13 Practice F792 – HP Mechanical Drawing

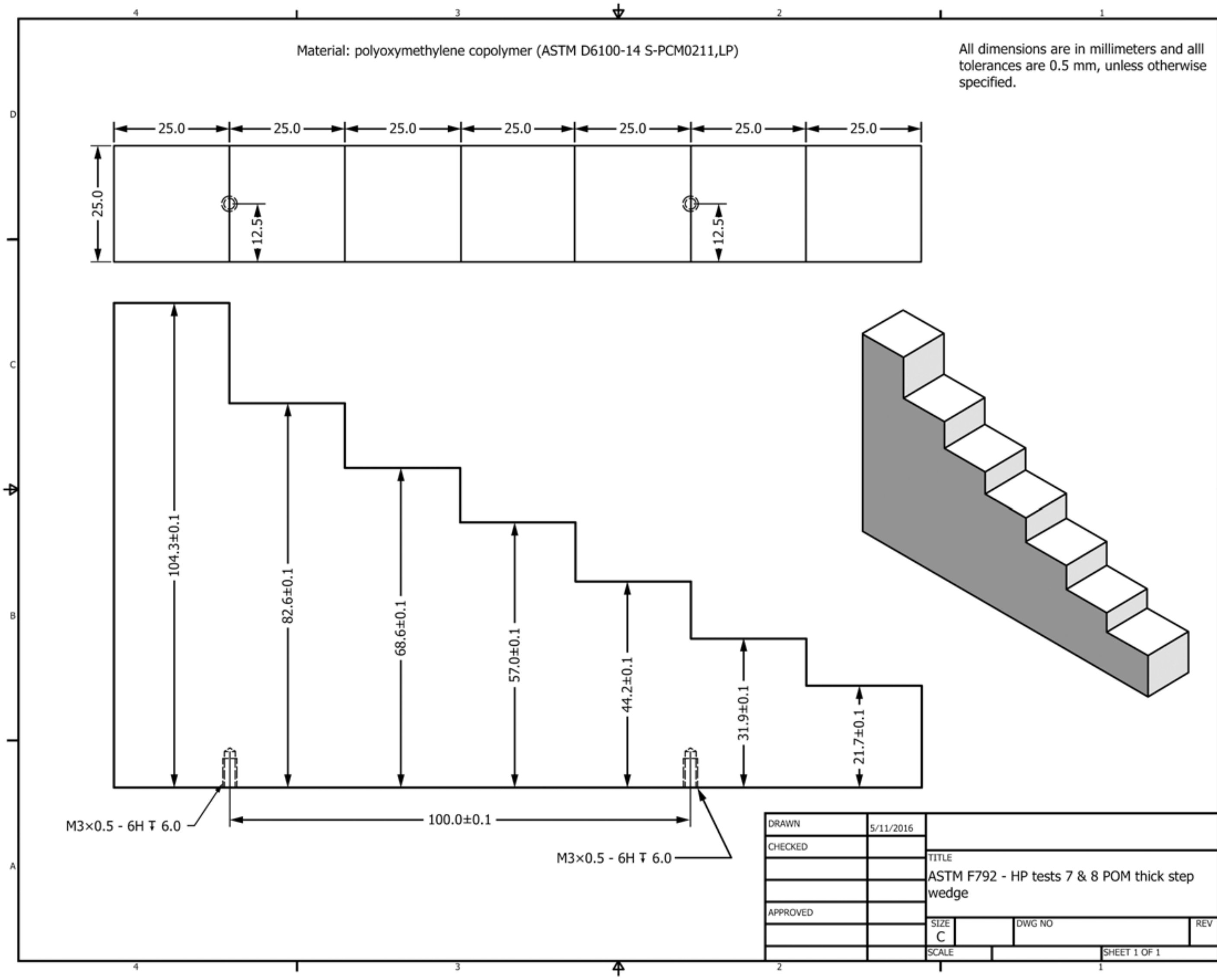


FIG. A2.14 Practice F792 – HP Mechanical Drawing

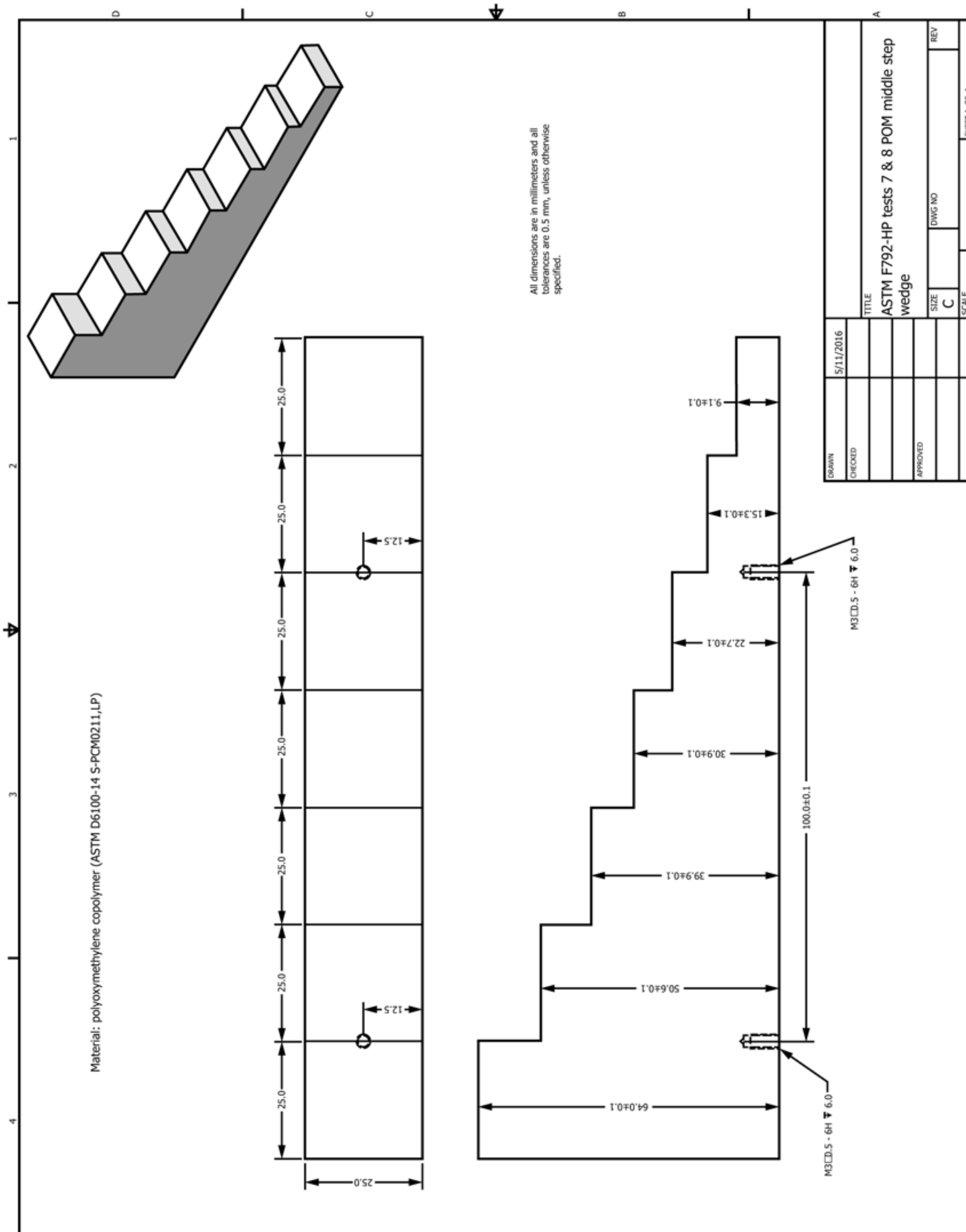


FIG. A2.15 Practice F792 – HP Mechanical Drawing

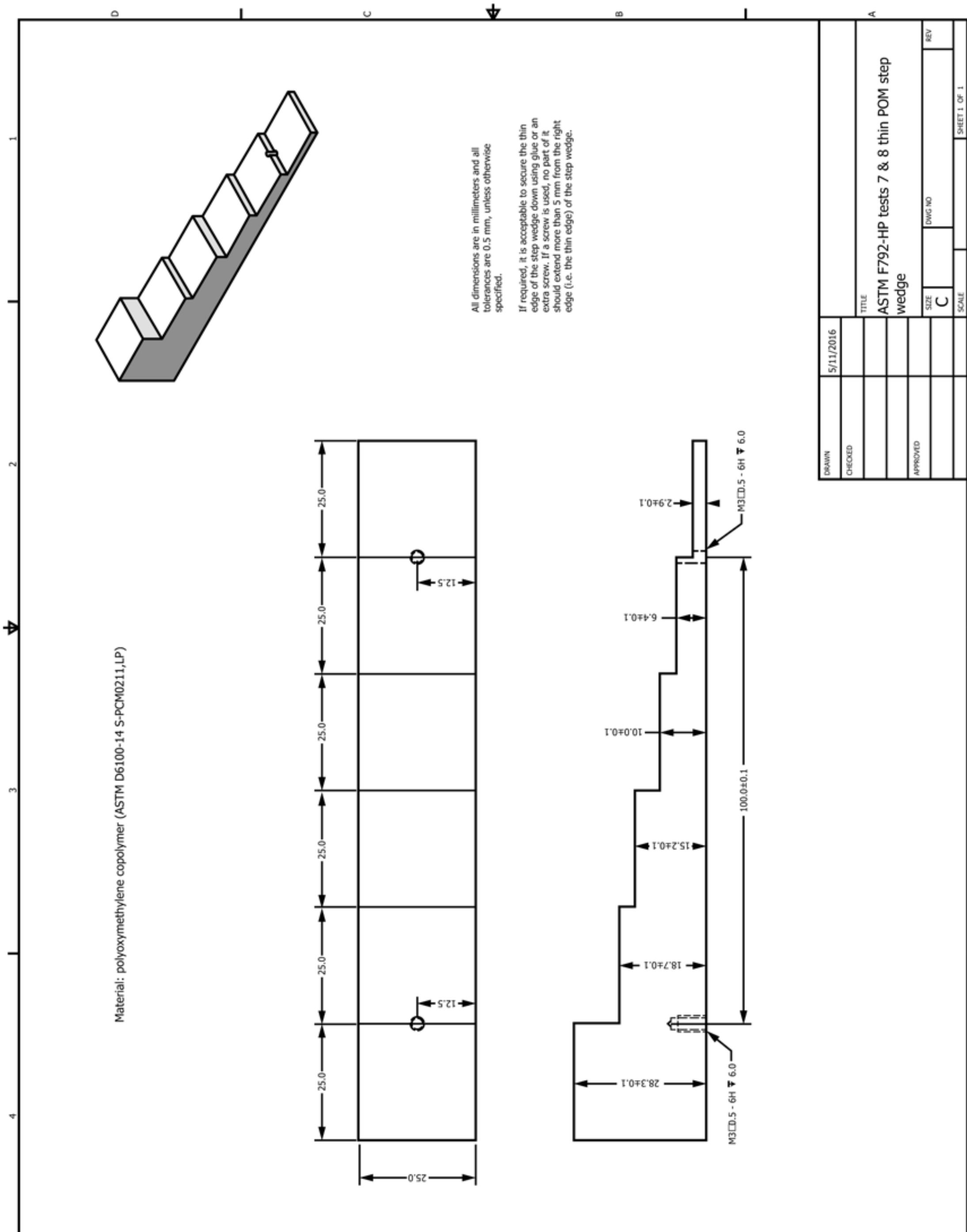
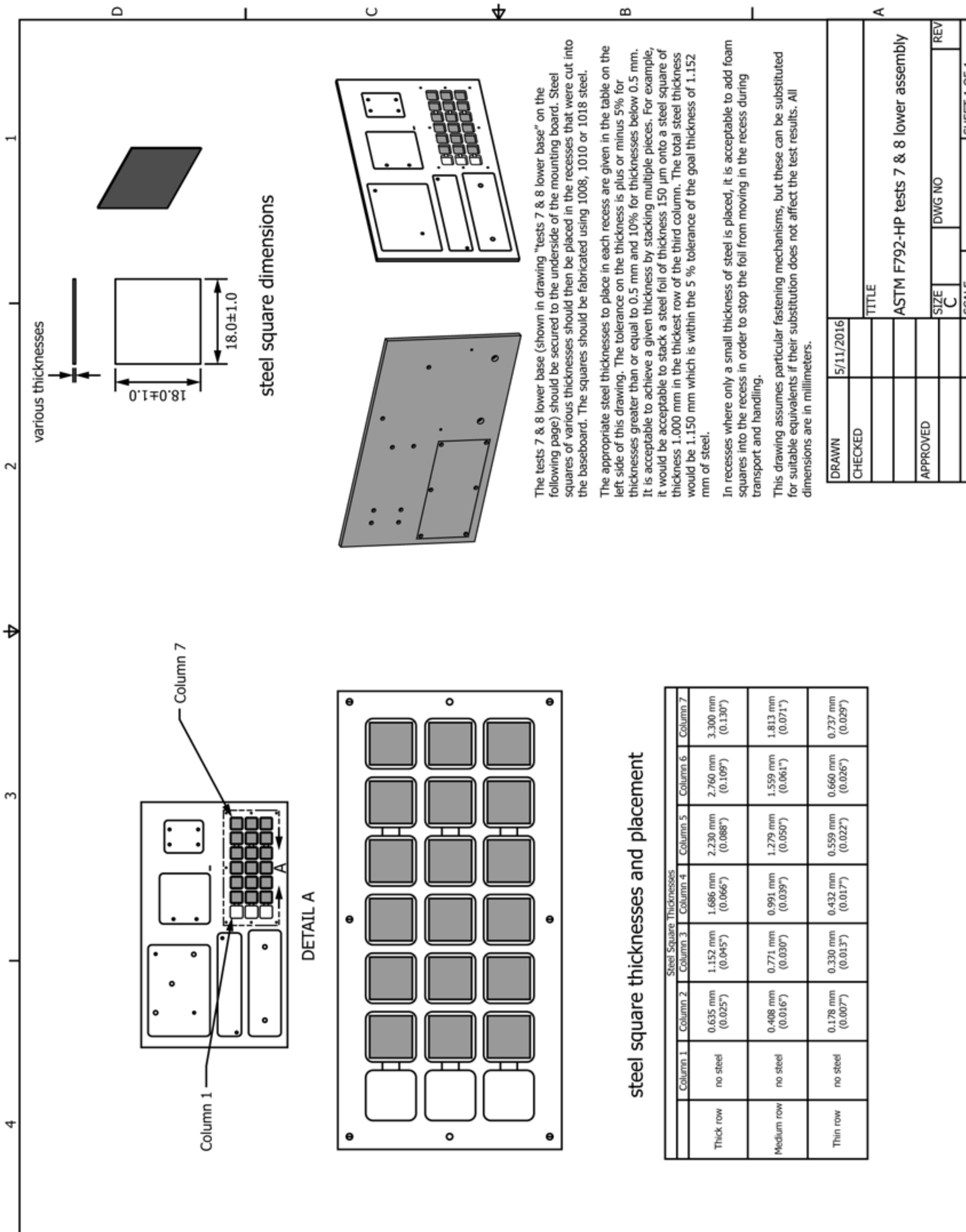


FIG. A2.16 Practice F792 – HP Mechanical Drawing



	Steel Square Thicknesses						
	Column 1	Column 2	Column 3	Column 4	Column 5	Column 6	Column 7
Thick row	no steel	0.635 mm (0.025")	1.152 mm (0.045")	1.686 mm (0.066")	2.230 mm (0.088")	2.760 mm (0.109")	3.300 mm (0.130")
Medium row	no steel	0.408 mm (0.016")	0.771 mm (0.030")	0.991 mm (0.039")	1.279 mm (0.050")	1.559 mm (0.061")	1.813 mm (0.071")
Thin row	no steel	0.178 mm (0.007")	0.330 mm (0.013")	0.432 mm (0.017")	0.559 mm (0.022")	0.660 mm (0.026")	0.737 mm (0.029")

FIG. A2.17 Practice F792 – HP Mechanical Drawing

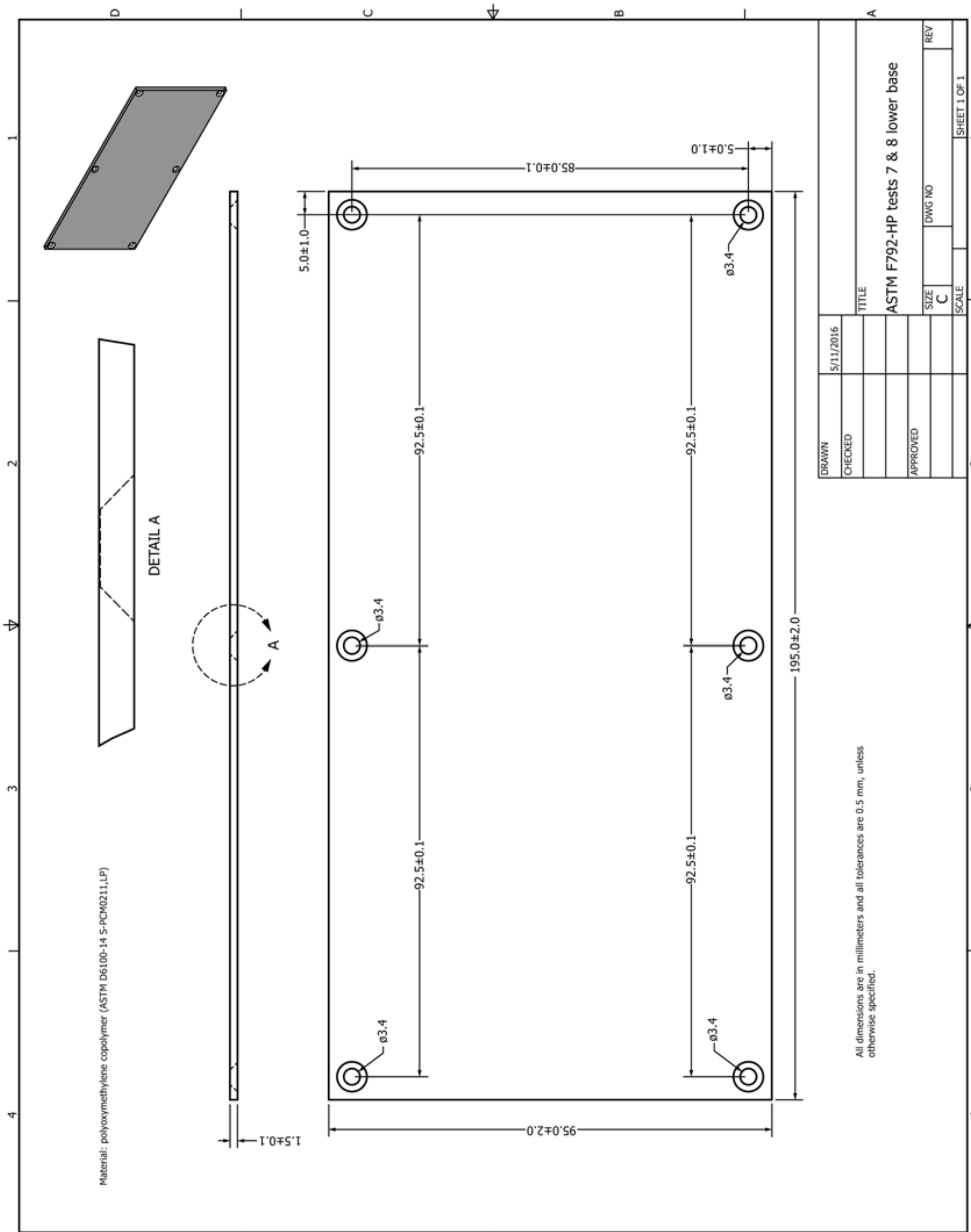


FIG. A2.18 Practice F792 – HP Mechanical Drawing

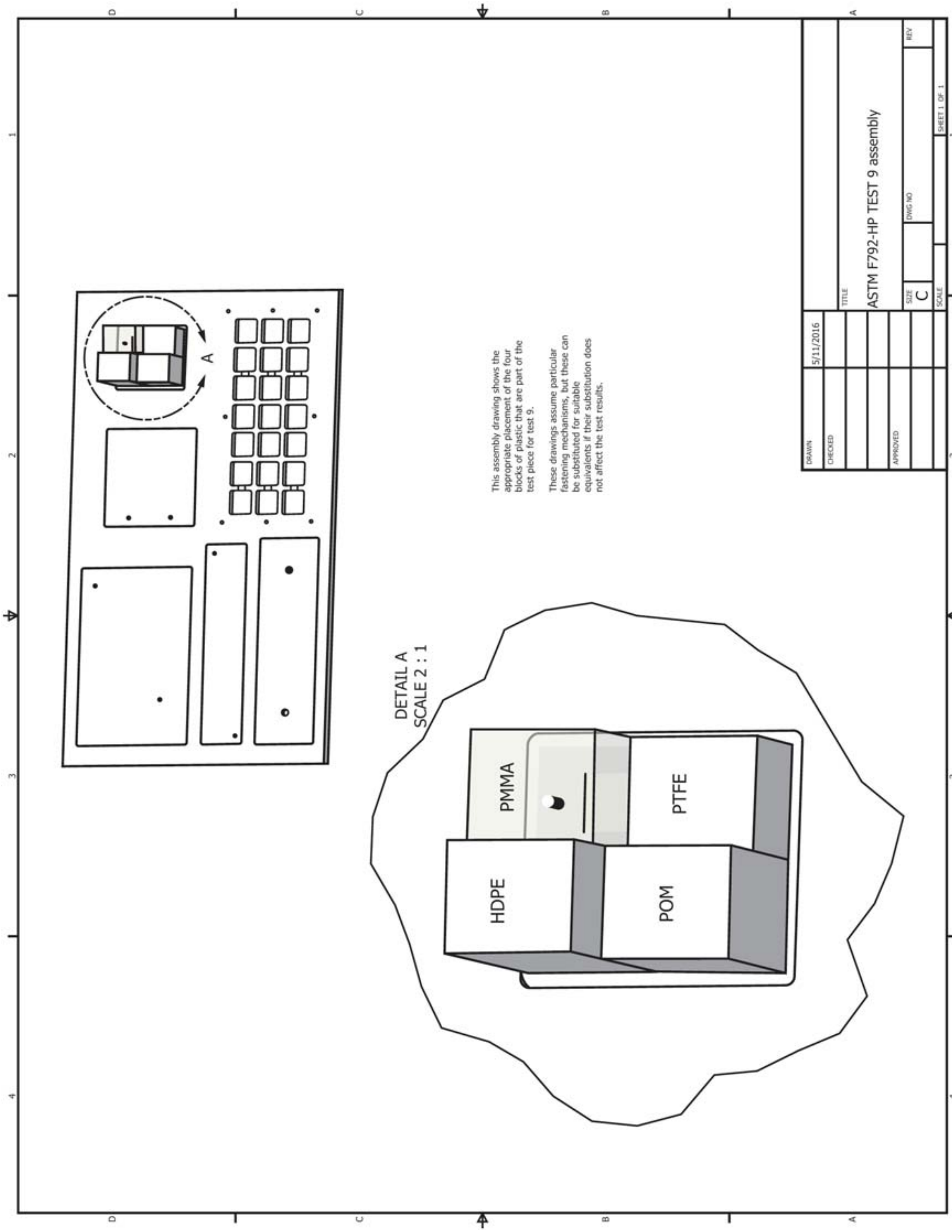


FIG. A2.19 Practice F792 – HP Mechanical Drawing

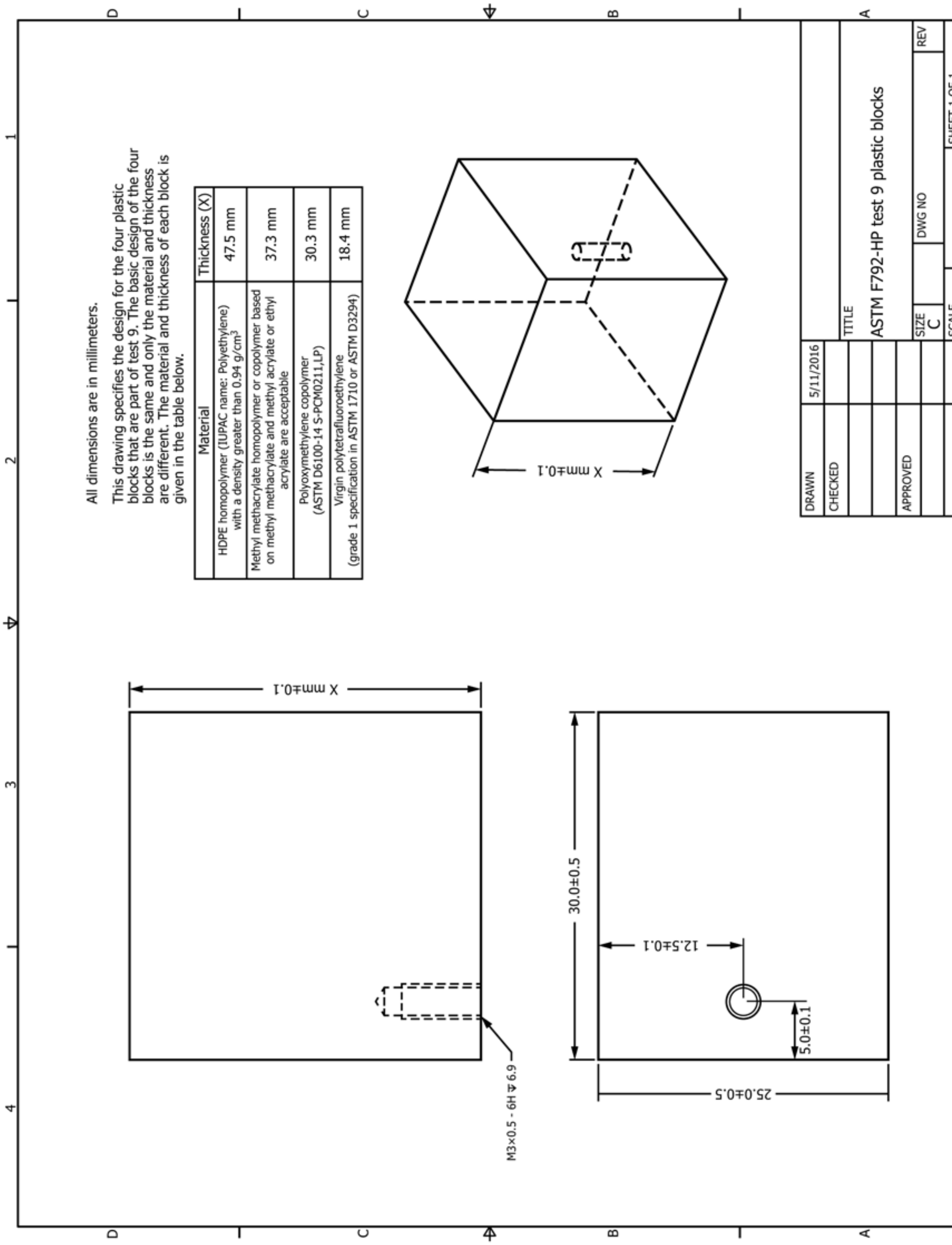


FIG. A2.20 Practice F792 – HP Mechanical Drawing

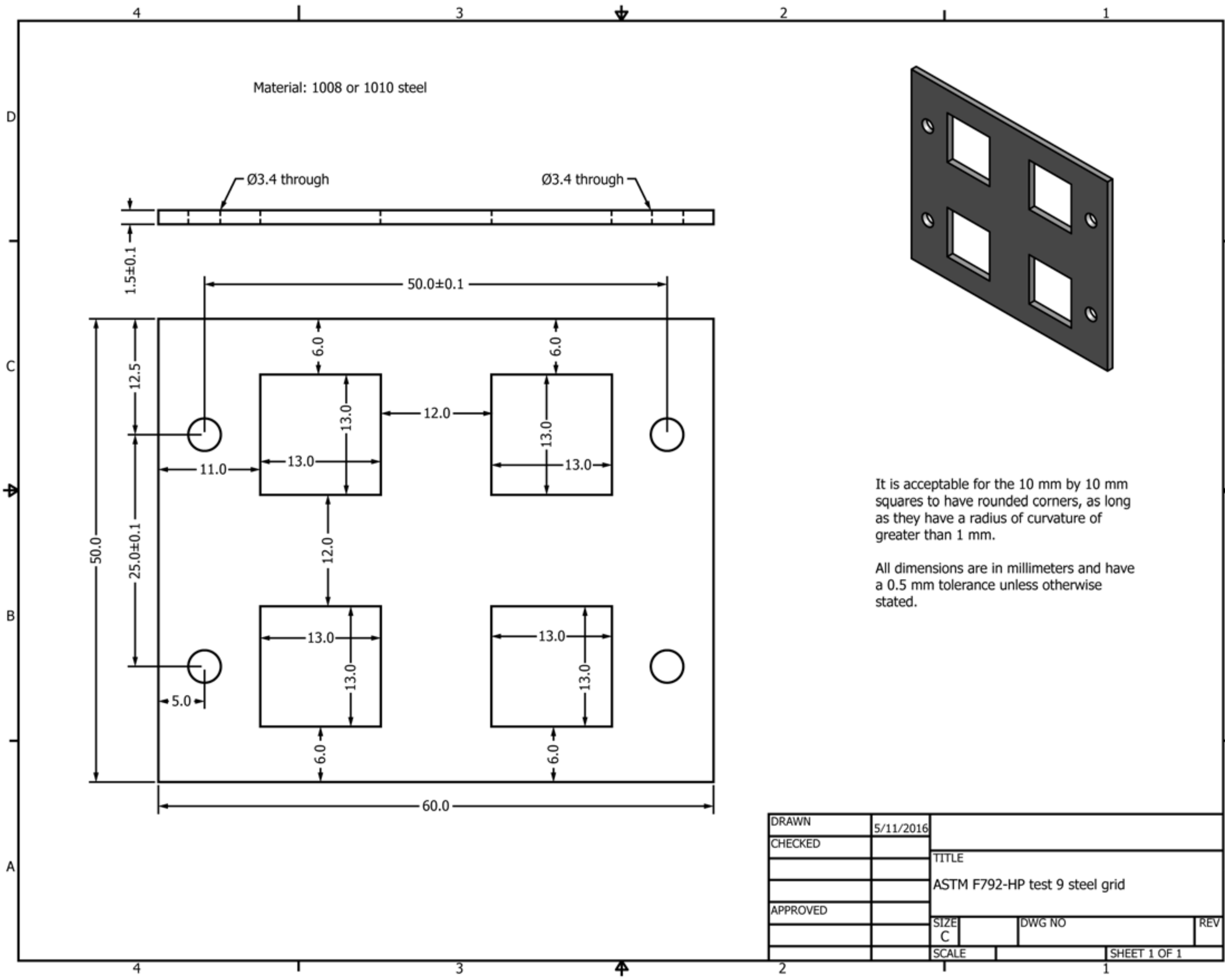


FIG. A2.21 Practice F792 – HP Mechanical Drawing

A3. PART OE

A3.1 Calculating the Boundary Signal-to-Noise Ratio, *BSNR*

A3.1.1 The *BSNR* is computed using the following process, which requires a number, *M*, of images, of the test object.

A3.1.1.1 Compute the mean value, $\overline{B_{-,i}}$, of the pixel values from one side of the boundary in the ROI for the i^{th} image of the test object, where the "–" subscript denotes the thicker side of the boundary.

A3.1.1.2 Compute the mean value, $\overline{B_{+,i}}$, of the pixel values from the other side (side not used in A3.1.1.1) of the boundary in the ROI for the i^{th} image of the test object, where the "+" subscript denotes the other side of the boundary.

A3.1.1.3 Compute the detectability of the boundary using:

$$S_i = 1 - \frac{\overline{B_{-,i}}}{\overline{B_{+,i}}}. \qquad \text{(A3.1)}$$

A3.1.1.4 Compute the mean, $\bar{S}$, and sample standard deviation, σ_s, of the set of S_i values from the *M* image orientations.

A3.1.1.5 The boundary signal-to-noise ratio, *BSNR*, is computed using:

$$BSNR = \frac{\bar{S}}{\sigma_s} \quad \text{(A3.2)}$$

A3.2 Mechanical Drawings

A3.2.1 The Practice F792 – OE test object is shown fully assembled but without its protective case in Fig. A3.1. Mechanical drawings of the individual parts follow in subsequent figures, Figs. A3.2-A3.5. The 36 AWG wire is not used explicitly in the practice, but can be used for stretch goals and testing of very high resolution systems.

A3.3 Part OE Log Sheet with Example Data

A3.3.1 The test object drawings (see Fig. A3.6) are included in this documentary standard to facilitatte the reader's understanding regarding the use of these test objects. To manufacture a test object, please refer to the full quality final drawings that are included in ASTM Adjunct ADJF079217.[3]

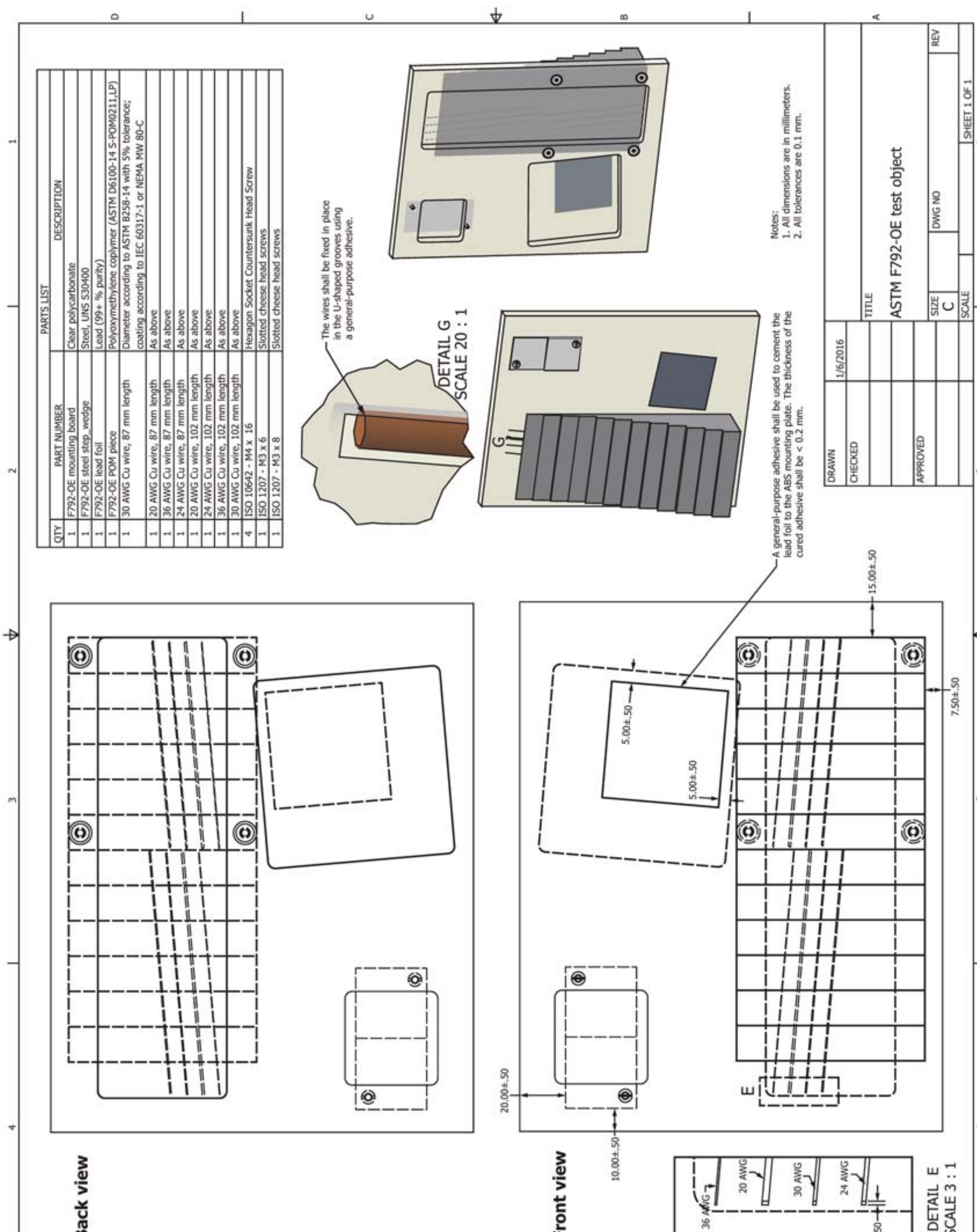


FIG. A3.1 Practice F792 – OE Test Object

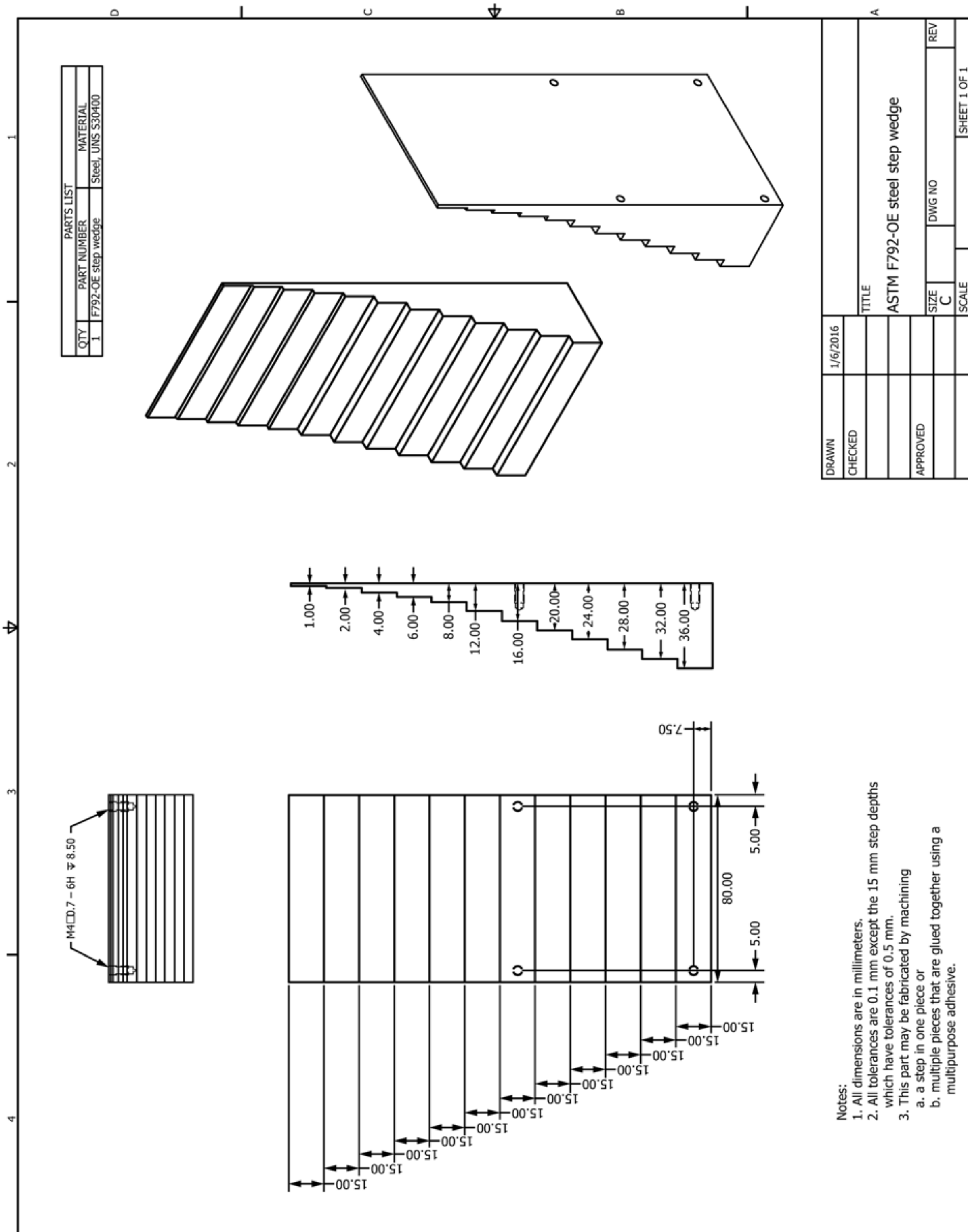


FIG. A3.2 Mechanical Drawing of the Practice F792 – OE Steel Step Wedge

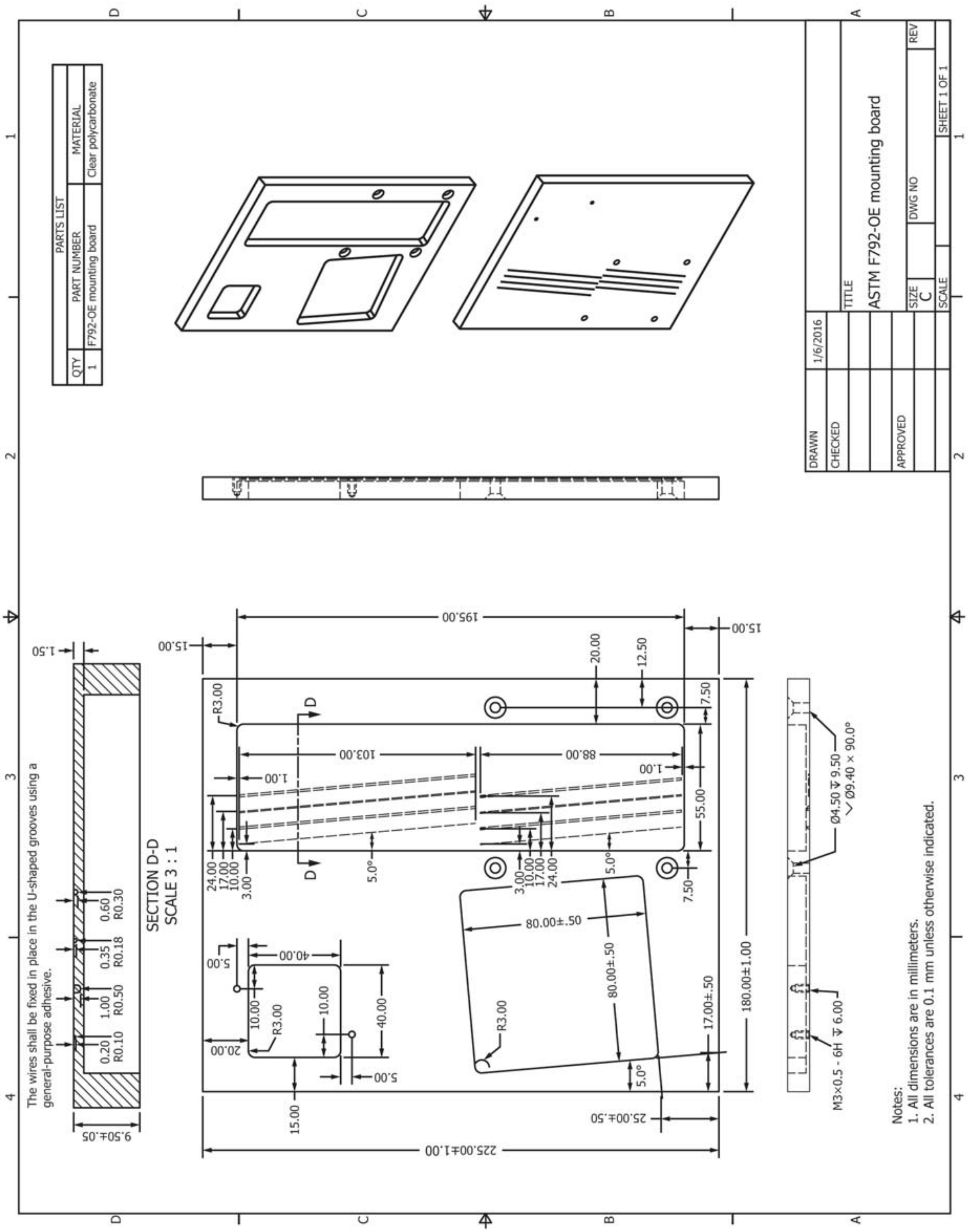


FIG. A3.3 Mechanical Drawing of the Polycarbonate Practice F792 – OE Mounting Board

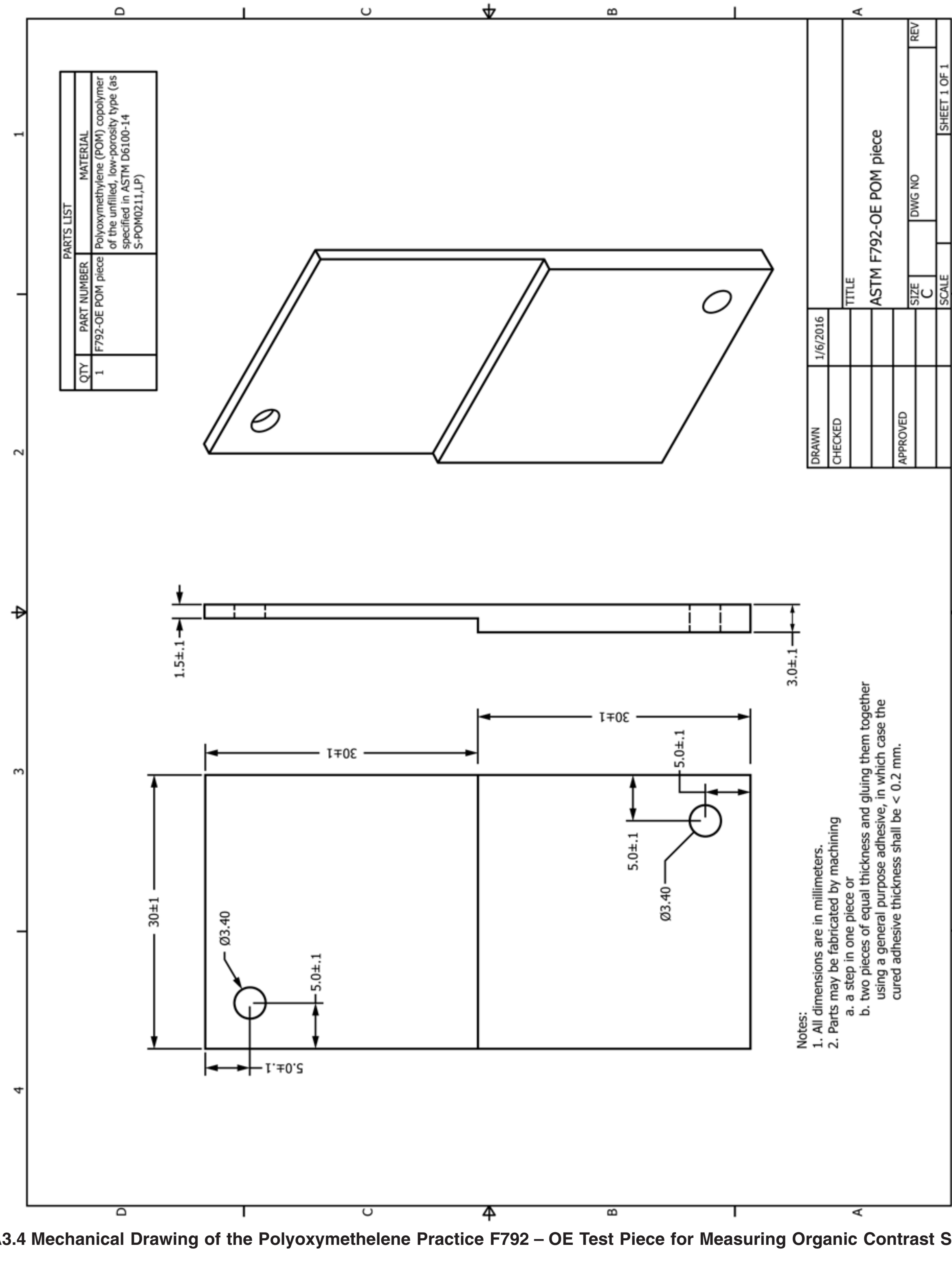


FIG. A3.4 Mechanical Drawing of the Polyoxymethelene Practice F792 – OE Test Piece for Measuring Organic Contrast Sensitivity

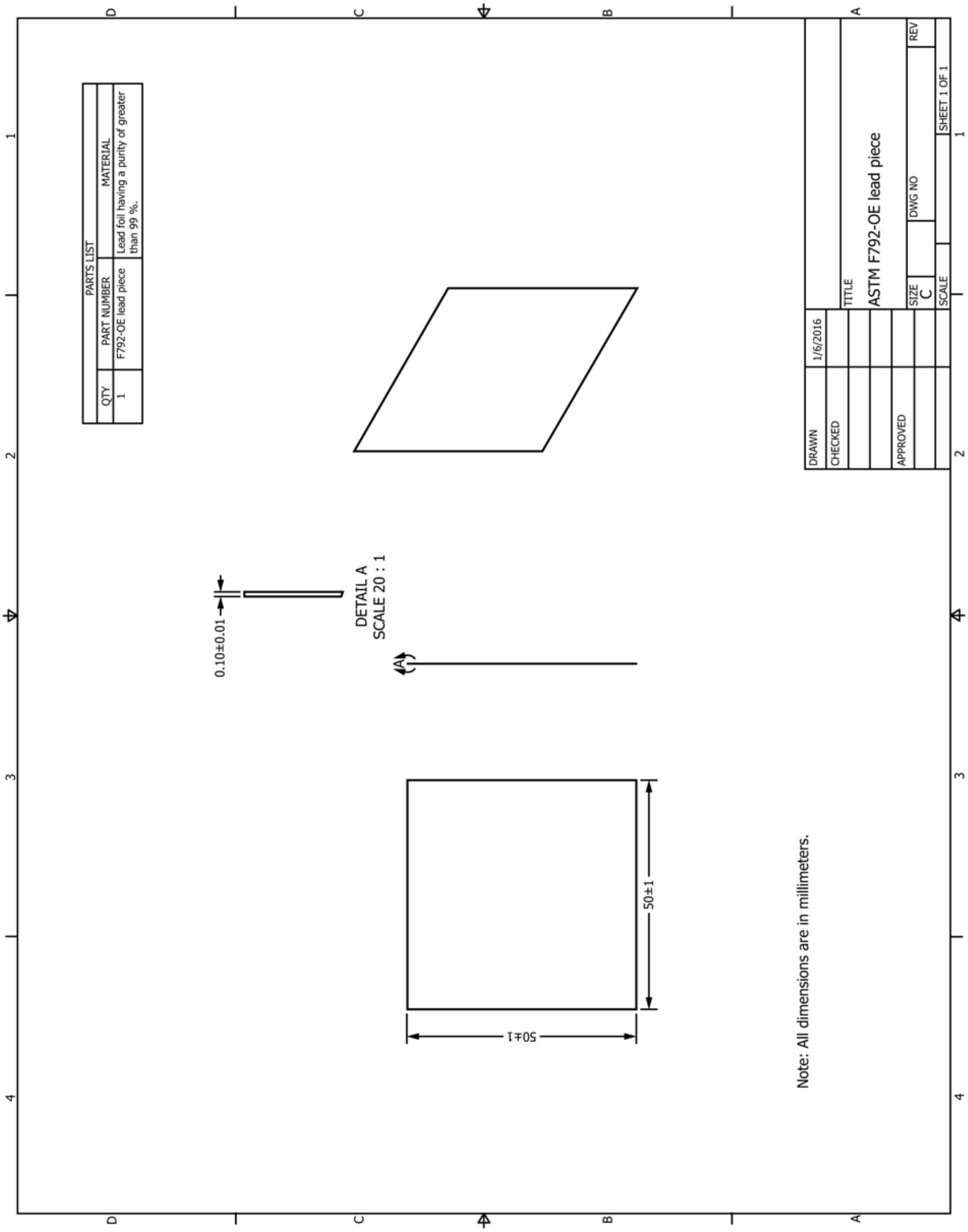
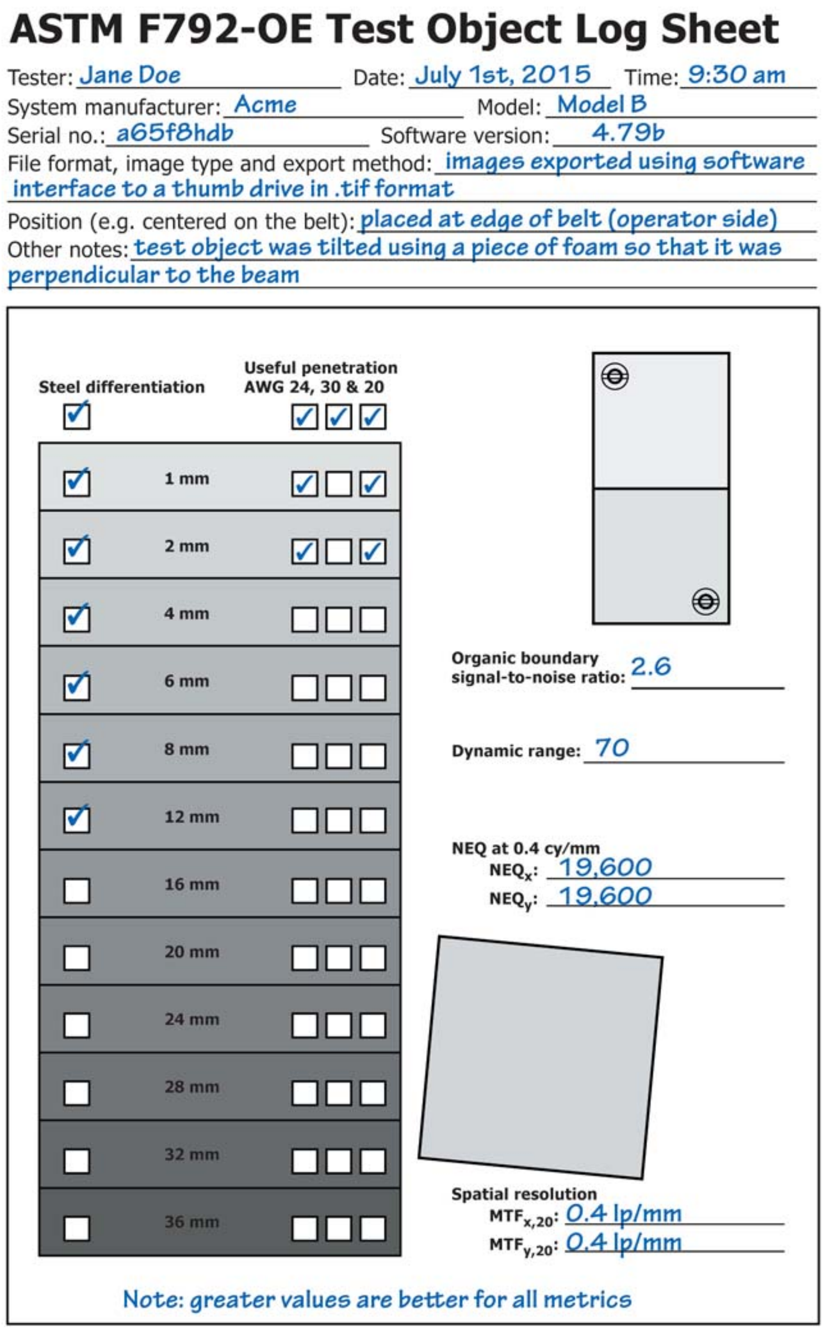


FIG. A3.5 Mechanical Drawing of the Practice F792 – OE Lead Test Foil Test Piece



ASTM F792-OE Test Object Log Sheet

Tester: Jane Doe Date: July 1st, 2015 Time: 9:30 am

System manufacturer: Acme Model: Model B

Serial no.: a65f8hdb Software version: 4.79b

File format, image type and export method: images exported using software interface to a thumb drive in .tif format

Position (e.g. centered on the belt): placed at edge of belt (operator side)

Other notes: test object was tilted using a piece of foam so that it was perpendicular to the beam

Steel differentiation ☑ Useful penetration AWG 24, 30 & 20 ☑☑☑

Steel differentiation	Step	AWG 24	AWG 30	AWG 20
☑	1 mm	☑	☐	☑
☑	2 mm	☑	☐	☑
☑	4 mm	☐	☐	☐
☑	6 mm	☐	☐	☐
☑	8 mm	☐	☐	☐
☑	12 mm	☐	☐	☐
☐	16 mm	☐	☐	☐
☐	20 mm	☐	☐	☐
☐	24 mm	☐	☐	☐
☐	28 mm	☐	☐	☐
☐	32 mm	☐	☐	☐
☐	36 mm	☐	☐	☐

Organic boundary signal-to-noise ratio: 2.6

Dynamic range: 70

NEQ at 0.4 cy/mm
NEQ_x: 19,600
NEQ_y: 19,600

Spatial resolution
$MTF_{x,20}$: 0.4 lp/mm
$MTF_{y,20}$: 0.4 lp/mm

Note: greater values are better for all metrics

FIG. A3.6 An Example of a Filled-Out Practice F792 – OE Log Sheet