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IEEE Standard for Pad-Mounted Equipment—Enclosure Integrity

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IEEE Power and Energy Society

Developed by the
Transformers Committee

IEEE Std C57.12.28™-2023
(Revision of IEEE Std C57.12.28-2014)

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IEEE Standard for Pad-Mounted Equipment—Enclosure Integrity

Developed by the

Transformers Committee
of the
IEEE Power and Energy Society

Approved 6 December 2023

IEEE SA Standards Board

Recognized as an American National Standard

Abstract: Conformance tests and requirements for the coating integrity of above grade pad-mounted enclosures that contain apparatus energized in excess of 600 V and that may be exposed to the general public. These include, but are not limited to, the following types of equipment enclosures: pad-mounted capacitors or inductors, pad-mounted distribution transformers, pad-mounted junction enclosures, pad-mounted metering equipment, and pad-mounted voltage regulators.

Keywords: coating integrity, enclosure integrity, IEEE C57.12.28™, pad-mounted equipment, transformers, voltage regulators

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Introduction

This introduction is not part of IEEE Std C57.12.28-2023, IEEE Standard for Pad-Mounted Equipment—Enclosure Integrity.

The accredited standards committee on Transformers, Regulators, and Reactors (C57), originally developed and correlated standards on these products, together with the accredited Standards Committee on Power Switchgear (C37) through the Joint ASC C57/C37 working group on enclosures with Joseph Martin and then Robert C. Olen as chairman. This group is now the Enclosure Integrity working group of the IEEE Transformers Committee.

The data used in this work have been gathered from many sources, including the standards of the Institute of Electrical and Electronics Engineers and the National Electrical Manufacturers Association, reports of committees of the Edison Electric Institute, and others.

Significant changes in this revision of the standard are: the mandatory IEEE word usage clause was added, normative references were updated, carbon steel and gel coat definitions were removed, information was re-organized and separated into Enclosure design in Clause 4 and Coating system requirements in Clause 5, the pull and push tools (4.3.1.2 and 4.3.1.3) were updated, the purpose of each test was clarified, and each test was generally updated and clarified. The time frame of the simulated corrosive atmospheric breakdown (SCAB) procedure, Annex A, was clarified to call for one week to be one cycle. Two informative annexes were added: Annex B – Commonly used substrate steels and Annex D – Substrate surface preparation. Pad-mounted switchgear was dropped from the scope as IEEE PC37.75, *Draft Standard for Pad-Mounted, Pole-Mounted and Submersible Switchgear Enclosures and Associated Control Enclosures—Coastal and Non-Coastal Environmental Integrity*, is in the final balloting stages. A warning was added to 4.2.3 about the possibility of burns from publicly accessible metal surfaces.

Contents

IEEE Standard for Pad-Mounted Equipment—Enclosure Integrity

1. Overview

1.1 Scope

This standard covers conformance tests and requirements for the enclosure integrity of above-grade pad-mounted electrical equipment containing apparatus energized in excess of 600 V that may be exposed to the public including, but not limited to, the following types of equipment enclosures:

— Pad-mounted distribution transformers

— Pad-mounted capacitors or inductors

— Pad-mounted junction enclosures

— Pad-mounted metering equipment

— Pad-mounted voltage regulators

This standard does not cover installations that are under the exclusive control of electric utilities and that are located in such a manner that access to the equipment is controlled exclusively by the utility.

1.2 Purpose

The purpose of this standard is to describe the requirements for a comprehensive enclosure integrity system for pad-mounted equipment providing long service life with minimum maintenance and positive safety features.

1.3 Word usage

The word *shall* indicates mandatory requirements strictly to be followed in order to conform to the standard and from which no deviation is permitted (*shall* equals *is required to*).[6,7]

The word *should* indicates that among several possibilities one is recommended as particularly suitable, without mentioning or excluding others; or that a certain course of action is preferred but not necessarily required (*should* equals *is recommended that*).

[6] The use of the word *must* is deprecated and cannot be used when stating mandatory requirements; *must* is used only to describe unavoidable situations.
[7] The use of *will* is deprecated and cannot be used when stating mandatory requirements; *will* is only used in statements of fact.

The word *may* is used to indicate a course of action permissible within the limits of the standard (*may* equals *is permitted to*).

The word *can* is used for statements of possibility and capability, whether material, physical, or causal (*can* equals *is able to*).

2. Normative references

The following referenced documents are indispensable for the application of this document (i.e., they must be understood and used, so each referenced document is cited in text and its relationship to this document is explained). For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments or corrigenda) applies.

ASTM B117, Standard Practice for Operating Salt Spray (Fog) Apparatus.[8]

ASTM D523, Standard Test Method for Specular Gloss.

ASTM D610, Standard Practice for Evaluating Degree of Rusting on Painted Steel Surfaces.

ASTM D660, Standard Test Method for Evaluating Degree of Checking of Exterior Paints.

ASTM D661, Standard Test Method for Evaluating Degree of Cracking of Exterior Paints.

ASTM D714, Standard Test Method for Evaluating Degree of Blistering of Paints.

ASTM D1654-05, Standard Test Method for Evaluation of Painted or Coated Specimens Subjected to Corrosive Environments.

ASTM D2794, Standard Test Method for Resistance of Organic Coatings to the Effects of Rapid Deformation (Impact).

ASTM D3170, Standard Test Method for Chipping Resistance of Coatings.

ASTM D3359, Standard Test Methods for Rating Adhesion by Tape Test.

ASTM D3363, Standard Test Method for Film Hardness by Pencil Test.

ASTM D4060, Standard Test Method for Abrasion Resistance of Organic Coatings by the Taber Abraser.

ASTM D4585, Standard Practice for Testing Water Resistance of Coatings Using Controlled Condensation.

ASTM D4587, Standard Practice for Fluorescent UV-Condensation Exposures of Paint and Related Coatings.

UL 94, Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances.[9]

UL 746C, Polymeric Materials – Use in Electrical Equipment Evaluations.

[8]ASTM publications are available from the American Society for Testing and Materials (https://www.astm.org/).
[9]UL publications are available from Underwriters Laboratories (https://www.ul.com/).

3. Definitions, acronyms, and abbreviations

3.1 Definitions

For the purposes of this document, the following terms and definitions apply. The *IEEE Standards Dictionary Online* should be consulted for terms not defined in this clause.[10]

above grade: A term referring to an equipment use location above the high-water line not intended for partial or total submersion.

axial force: A force applied along the axis of the pry bar from its handle to its pry tip.

conformance tests: Certain performance tests are conducted to demonstrate compliance with the applicable standards. The test specimen is normally subjected to all planned routine tests prior to initiation of the conformance test program.

NOTE—The conformance tests may, or may not, be similar to certain design tests. Demonstration of margins (capabilities) beyond the standard requirements is unnecessary. [11]

design tests: Tests made by the manufacturer to determine the adequacy of the design of a particular type, or model of equipment or its component parts to meet its assigned ratings and to operate satisfactorily under normal conditions and under special conditions if specified. These tests are used to demonstrate compliance with applicable standards of the industry.

NOTE—Design tests, sometimes called *type tests*, are made on representative apparatus or prototypes to verify the validity of design analysis and calculation methods and to substantiate the ratings assigned to all other apparatus of basically the same design. These tests may also be used to evaluate the modification of a previous design and to verify that performance has not been adversely affected. Test data from previous similar designs may be used for current designs, where appropriate. In theory, the tests need not be repeated unless the design is changed so as to modify performance. However, experience has demonstrated that unintended change creeps into manufacturing processes and thus design tests should be periodically repeated.

dry film thickness: Thickness of any applied coating(s) measured after curing.

pad-mounted enclosure: An enclosure containing electrical apparatus, typically located outdoors at ground level where the general public has direct contact with the exterior surfaces of the equipment.

padlock: A locking device specified and supplied by the user that will prevent the disengagement of the pentahead device (e.g., key or combination lock, one time or twist lock, single use lock or similar device).

prying leverage: A force at right angles to the handle times the distance from this force to the point of insertion of the pry tip into a joint, crevice, or similar opening in enclosure.

routine tests: Tests made for quality control by the manufacturer on every device or representative samples, or on parts or materials as required to verify during production that the product meets the design specifications and applicable standards.

NOTE 1—Certain quality assurance tests on identified critical parts of repetitive high-production devices may be tested on a planned statistical sampling basis.

[10] *IEEE Standards Dictionary Online* is available at: http://dictionary.ieee.org. An IEEE account is required for access to the dictionary, and one can be created at no charge on the dictionary sign-in page.
[11] Notes in text, tables, and figures of a standard are given for information only and do not contain requirements needed to implement this standard.

NOTE 2—Routine tests are sometimes called production tests.

substrate: The uncoated material that provides structural integrity to the enclosure.

3.2 Acronyms and abbreviations

AWG	American wire gauge
SCAB	simulated corrosive atmospheric breakdown

4. Enclosure design, access, and security

4.1 General

The objective of this clause is to describe design and performance requirements for pad-mounted enclosures not situated in coastal or other severe environments. Other performance requirements may be needed to provide long service life in other environments.

4.2 Design requirements

In addition to passing the tests defined in this standard, the construction of pad-mounted enclosures shall comply with the requirements of 4.2.1 through 4.2.15.

4.2.1 Substrate

The substrate shall be a material which, when coated or otherwise processed, will maintain the structural integrity of the enclosure over the life of the apparatus.

4.2.2 Welds

All welds shall be treated to prepare the weld area and the heat affected zones for coating. Weld spatter shall be removed. All welds shall be made in accordance with appropriate industrial welding standards.

4.2.3 Exterior surface

The enclosure shall be designed such that all exterior surfaces are accessible for proper surface preparation and the application of a uniform amount of coating materials. Additionally, all exterior surfaces shall be accessible for the purposes of inspection and maintenance of the enclosure over the life of the equipment.

WARNING

Users should take care when deploying pad-mounted equipment in publicly accessible locations as operational and environmental factors may cause the equipment's exterior metal surfaces to reach temperatures which could result in burns to an individual who comes in contact with their surfaces.

4.2.4 Other exposed surfaces

Any surface, other than coated substrate, in the assembled equipment that is left exposed to the external environment (e.g., seals, gaskets, cables) must survive the same environment as the coated substrate.

4.2.5 Enclosure mounting

The bottom edge of the enclosure shall provide for flush mounting on a flat, rigid mounting surface.[12]

4.2.6 Contaminant accumulation

The enclosure shall be designed to shed water and minimize areas where corrosive elements can accumulate.

4.2.7 Water resistance

The enclosure shall restrict the entry of water (other than floodwater) into the enclosure so as not to impair the operation of the apparatus inside.

4.2.8 Sharp corners

External sharp corners and projections shall be minimized.

4.2.9 Panel assembly

Panels shall be fastened or hinged to resist disassembly, breaking, or prying open from the outside with the doors in the closed and locked position. Normal entry shall be possible only with the use of proper access tools. There shall be no exposed screws, bolts, or other fastening devices that are externally removable (with the exception of pentahead bolts provided for extra security) that would provide access to energized parts in the enclosure.[13]

4.2.10 Door hardware

Locking bolts and associated threaded receptacles, hinges, and hinge pins shall be AISI type 304 stainless steel[14] or material of equivalent corrosion resistance.

4.2.11 Handhole covers

If handholes are publicly accessible, a guard shall be applied over the handhole that is secured from inside the locked air compartment enclosure.

4.2.12 Locking/latching devices

The latching device(s) shall be designed and constructed of such a material so as to resist breaking or bending. The provision for locking device(s) on the enclosure door(s) shall be designed and located as to comply with the defined tests.

4.2.13 Attachments

Any attachments to the assembled equipment (e.g., sight glass, viewing window, gauge) that are exposed to the external environment must retain their intended functionality.

4.2.14 Fire resistance

The enclosure shall be constructed of fire-resistant material. Non-metallic enclosures shall be made from material having a “5V” classification per UL 94,[15] or the enclosure shall comply with the 127 mm (5 inch) flame test specified in UL 746C.

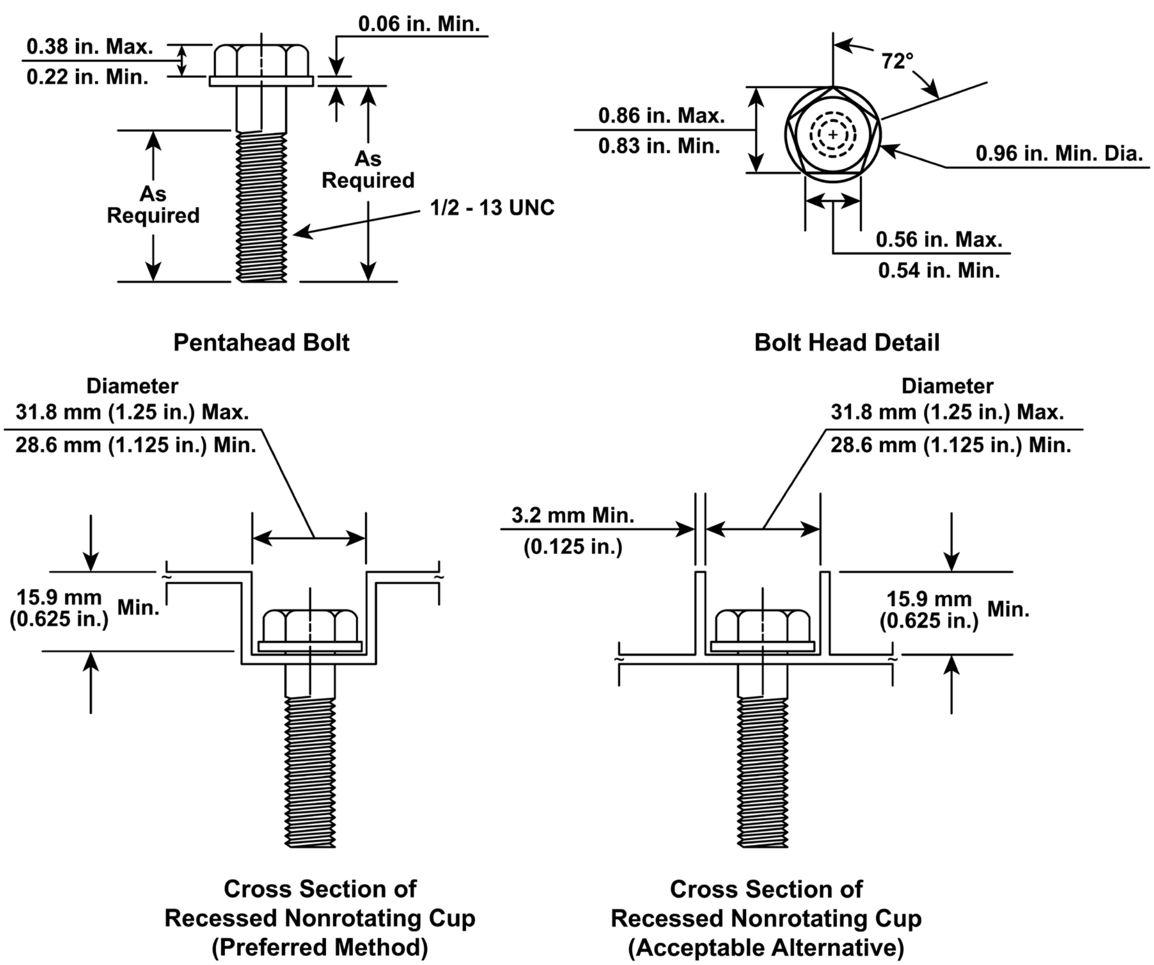
[12]The security of the interface between the mounting surface and the equipment is the responsibility of the installer/user.
[13]4.2.15 describes the design requirements for pentahead bolts.
[14]See Annex B.
[15]Information on references can be found in Clause 2.

4.2.15 Enclosure access

All access doors shall be fastened with a device that uses a pentahead tool to permit unlatching the door only after the padlock has been removed. This pentahead device or bolt shall be coordinated such that the padlock cannot be inserted into the hasp until the access door is fully latched and the pentahead device is securely engaged.

Enclosures without latches shall have padlock and pentahead bolt provisions and shall be coordinated to prevent insertion of a padlock until the access door is fully closed and the pentahead device or bolt is securely engaged. It shall not be possible to disengage the pentahead bolt until the padlock is removed.

A minimum of one pentahead device or bolt and padlocking means shall be provided. The pentahead device or bolt shall be surrounded by a non-rotating guard or shall be recessed such that the pentahead device or bolt can be engaged only by the proper tool. The dimensions of the pentahead bolt and non-rotating recess shall comply with Figure 1. More than one door may be fastened with a single padlock and pentahead device or bolt. In the event that the pentahead bolt is missing, the design shall be such that the cabinet shall remain inaccessible through the bolt hole. The bolt hole shall be blocked from the back and all sides to prevent wire probe entry.



NOTE—The captive method is not shown.

Figure 1—Captive and recessed pentahead bolts

4.3 Security requirements

4.3.1 Test equipment

The tests for enclosure security shall be conducted with the following equipment or equivalent.

4.3.1.1 Pry bar

The pry bar shall be constructed with the pry tip shown in Figure 2. The pry bar shall be capable of accurately indicating the axial force and prying leverage specified in Table 1.

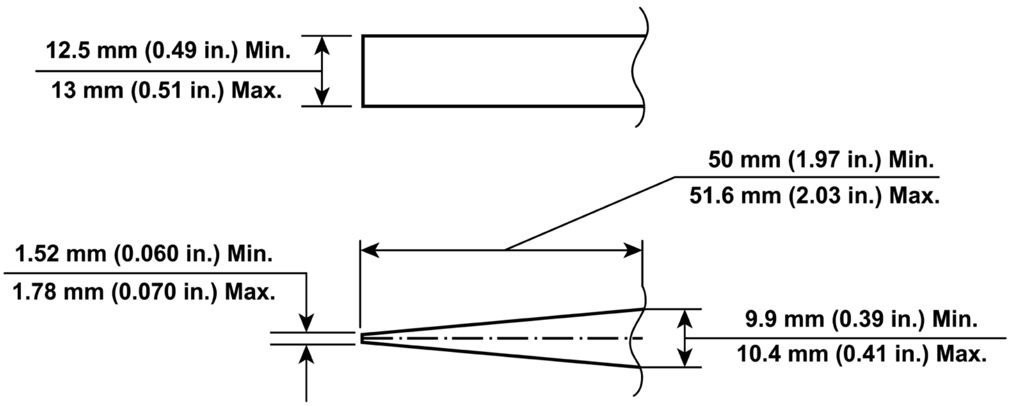


Figure 2—Pry bar tip

Table 1—Test values

Test	Value	Used in Clause
Inward axial force	222 N (50 lbf)	4.3.2.2
Prying leverage tests	102 N·m (900 lbf-inch)	4.3.2.2
Pull test	667 N (150 lbf)	4.3.2.3
Deflection test	445 N (100 lbf)	4.3.2.5

4.3.1.1.1 Tool

The axial force and prying leverage indication may be obtained from a variety of readily available or custom-made tools. Annex C includes a complete set of detail drawings for one set of such tools. Other pry bar designs complying with 4.3.1.1 are acceptable.

4.3.1.1.2 Measurement

The prying leverage applied can be measured indirectly by measuring the deflection of the pry bar. The indicator is mounted on the pry bar and set to measure the deflection of a certain length of the bar. A calibration can be made that will result in a table or curve showing prying leverage versus reading of the indicator.

4.3.1.2 Pull tool

A device that has a hook configuration as detailed in Figure 3 with associated indicator to measure pull force shall be used in the pull tests.[16]

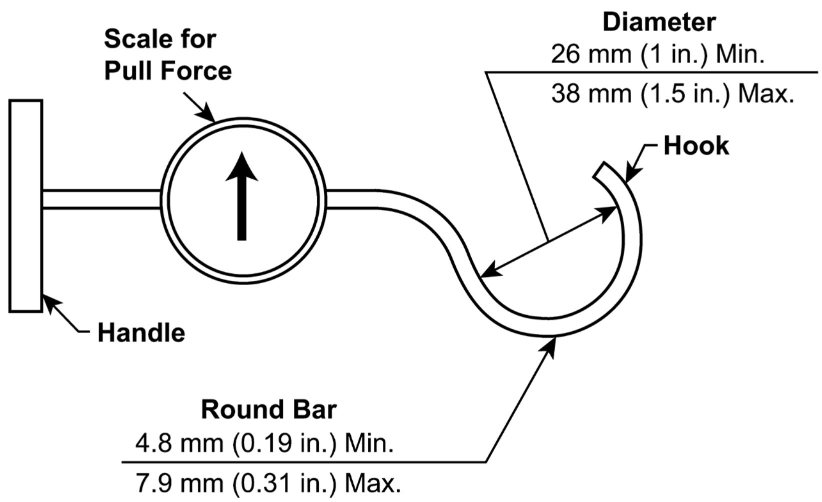


Figure 3—Pull hook

4.3.1.3 Push tool

A device that has a 12.7 mm × 12.7 mm (0.5 in × 0.5 in) square face as shown in Figure 4 with associated indicator to measure axial force shall be used to perform the deflection test (see Footnote 16).

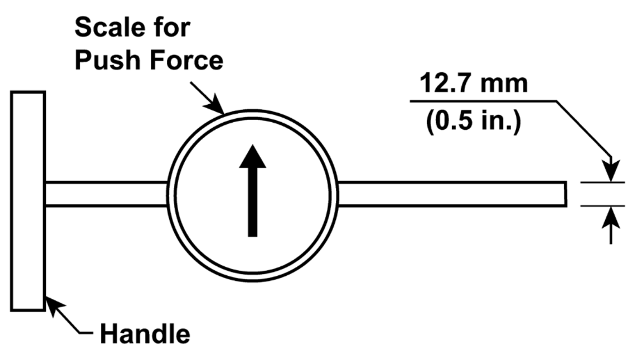


Figure 4—Push tool

4.3.1.4 Probe wire

The probing wire shall be bare number 14 AWG soft-drawn solid copper wire that is 3 m (10 ft) long.

4.3.2 Test methods

The following tests are to be performed on the enclosure. The enclosure shall resist the entry of foreign objects such as sticks, rods, or wires.

[16]Generic analog or digital scales can be configured to measure the push and pull forces for the tools in Figure 3 and Figure 4.

4.3.2.1 General

The pad-mounted enclosure shall be mounted on a flat surface according to the manufacturer's specification. With the access door(s) closed and locked using a padlock with an 8 mm (5/16 inch) diameter shackle, the following sequence of tests shall be performed:

a) Pry tests
b) Wire probe tests
c) Pull tests
d) Repeat wire probe tests
e) Deflection tests
f) Operation test

4.3.2.2 Pry tests

The pry bar shall be used on all joints, crevices, hinges, locking means and other objects that exist between the enclosure components, including the enclosure/pad interface. The pry bar shall be permitted to be placed at any angle to the enclosure surface. The tip of the bar shall first be inserted in the opening being tested using the value of axial force specified in Table 1. Then, with that axial force being maintained, the prying force specified in Table 1 applied alternatively first in one direction and then in the opposite direction (i.e., once in each direction). Application of either or both axial and prying force shall be maintained so long as relaxation is occurring. When relaxation ceases, or if no relaxation occurs, the pry bar shall be removed and the pry test reapplied at the same location. When relaxation ceases or no relaxation occurs after the second test, the pry bar shall be removed and applied at an untested location.

4.3.2.3 Pull tests

A pulling force shall be applied to the critical points of all enclosure parts that can be engaged by the pulling hook. A pulling force indicated in Table 1 shall be exerted at any angle to the enclosure surface. This force is to be maintained during any relaxation. When relaxation ceases, or if no relaxation occurs, the pull test shall be terminated. The hook shall then be inserted into any other part in which it can engage, and the test shall be repeated at the new location. All parts that can be engaged by the pull hook shall be tested once.

4.3.2.4 Wire probe tests

Following the pry tests and pull tests described in 4.3.2.2 and 4.3.2.3, an attempt to penetrate the enclosure with the probe wire shall be made. This penetration shall be attempted at all crevices and joints. The wire shall be straight with no pre-bends and shall be gripped by the tester with his or her bare hands. If the wire enters the joint, the wire shall be continually pushed and bent until either it can no longer be pushed, or it has entered the enclosure completely. This test is passed if no portion of the probing wire has entered the enclosure, or the probing wire is restricted by a barrier from intrusion into the enclosure to a point that does not reduce the clearance to energized parts of the equipment.

4.3.2.5 Deflection tests

The deflection test shall be applied to all sides and walls of the enclosure. This test is passed if the specific force (see Table 1) applied perpendicularly to the surface of the enclosure does not impair the dielectric, mechanical or corrosion performance of the equipment.

4.3.2.6 Operation test

Following all of the above tests, the unit shall be lifted at least 1 m in accordance with manufacturer's standard lift instructions and then set again on the flat surface. The doors shall be easily opened, closed, latched and locked without requiring adjustments to the cabinet, latch mechanism and/or enclosure door(s). All of the door latch points must fully engage when the door is closed.

4.3.2.7 Test repetition

These design tests shall be repeated whenever the enclosure design is changed so as to modify performance, or at least every five years, whichever occurs first.

4.3.3 Test values

The minimum test values for which entry shall be prevented are provided in Table 1.

5. Applied coating system requirements

5.1 General

All coated surfaces on the exterior or interior of the enclosure that may be exposed to the atmosphere shall be capable of meeting the performance tests required by this standard. Each different combination of substrate(s) and coating(s) shall meet these design tests. If more than one substrate/coating system combination is used for different areas of the enclosure, the areas in which each is used shall be identified. The laboratory test performance data of each substrate/coating system shall be submitted for approval upon request.

5.2 Test repetition

Test data shall be resubmitted whenever there are changes in the production method and/or materials, or at least every five years, whichever occurs first.

5.3 Enclosure color

Unless otherwise specified, the topcoat color shall be Munsell number 7GY 3.29/1.5 high gloss or 7GY 3.29/1.5 SG semi-gloss pad-mount green. The color variation of the coated product shall not exceed the Munsell color standard by more than a ΔE^* (CIELAB) value of two.[17]

NOTE—CIELAB uses ΔE^* to distinguish CIE 1976 L*a*b* scale in 1976 (Supplement No. 2 to CIE Publication No. 15, Colorimetry) from previous versions. CIELAB is more commonly used rather than Hunter.

5.4 Test specimens

Test specimens shall consist of panels of the same material composition used in production. Test specimens shall be fabricated in accordance with Figure 5, Figure 6, Figure 7, and Figure 8 as to size and design. Quantity and type of panels in each test are identified under the specific test. If more than one substrate and coating combination is used on an enclosure, all variations shall be tested in accordance with 5.5. All panels shall be prepared using the production coating system.[18] Coated test panels shall be conditioned at room temperature and humidity for a minimum of 7 days prior to any testing.

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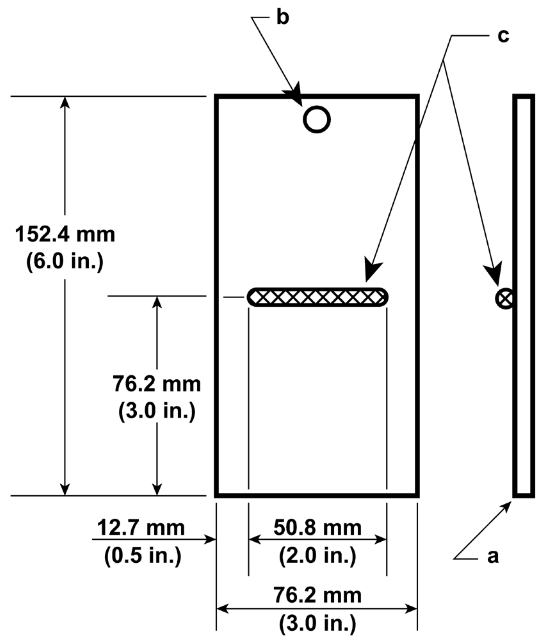
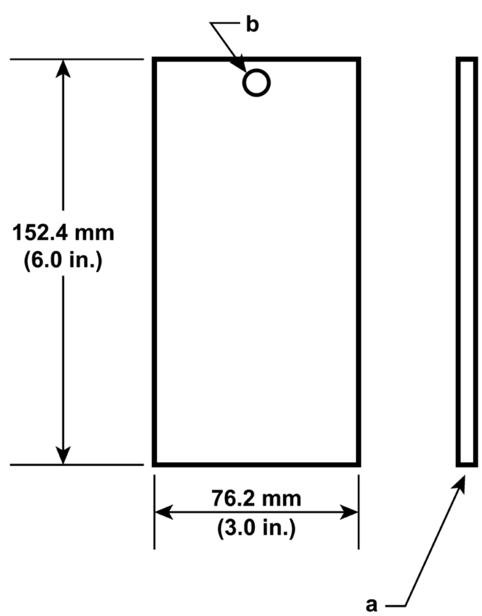
[17] *Munsell Color Standards*, X-Rite, Inc. 4300 44th Street S.E. Grand Rapids, Michigan 49512 (https://munsell.com/).
[18] See Annex D.



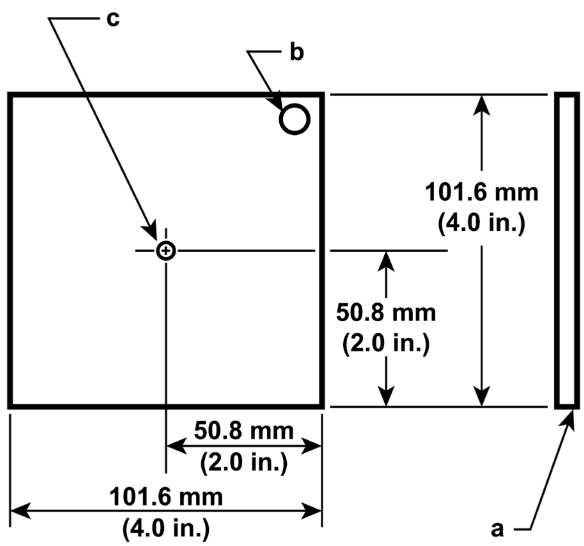
a. Test panels shall be made from typical production stock of the same material type and thickness used in the construction of the device for which the specified test is intended.
b. Hole may be placed in panel for hanging for coating operations if required. Locate centered on short dimension and 3.2 mm (1/8 inch) to edge of hole on long dimension. Recommended maximum hole size 14.3 mm (9/16 inch) in diameter.
c. Weld bead shall be the same type of metal composition as the panel. Weld bead shall be 6.4 mm (1/4 inch) wide and 3.2 mm (1/8 in.) high.

Figure 5—Weld-bead coating test panel



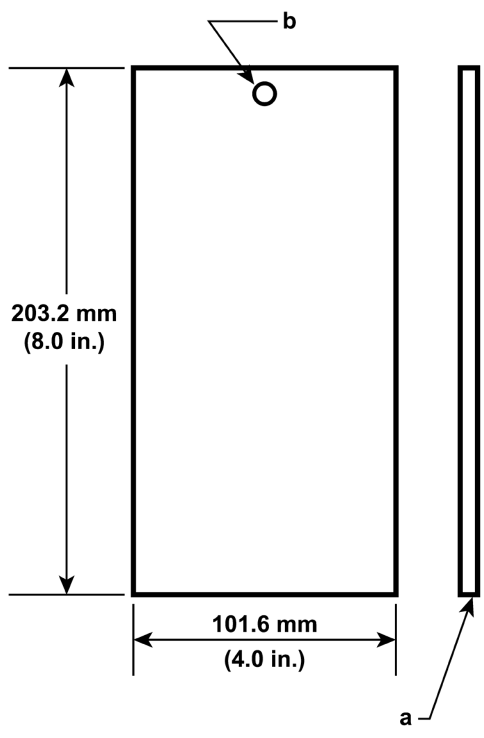
a. Test panels shall be made from typical production stock of the same material type and thickness used in the construction of the device for which the specified test is intended.
b. Hole may be placed in panel for hanging for coating operations if required. Locate centered on short dimension and 3.2 mm (1/8 inch) to edge of hole on long dimension. Recommended maximum hole size 14.3 mm (9/16 inch) in diameter.

Figure 6—Plain coating test panel



a. Test panels shall be made from typical production stock of the same material type and thickness used in the construction of the device for which the specified test is intended.
b. Hole may be placed in panel for hanging located in one corner. Recommended maximum hole size 14.3 mm (9/16 in.) in diameter.
c. 7.9 mm (5/16 in.) diameter hole required to fit the ASTM D4060 test fixture post.

Figure 7—Abrasion coating test panel



a. Test panels shall be made from typical production stock of the same material type and thickness used in the construction of the device for which the specified test is intended.
b. Hole may be placed in panel for hanging for coating operations if required. Locate centered on short dimension and 3.2 mm (1/8 in.) to edge of hole on long dimension. Recommended maximum hole size 14.3 mm (9/16 in.) in diameter.

Figure 8—Gravelometer coating test panel

5.5 Applied coating system performance requirements

5.5.1 Adhesion test

This test demonstrates proper adhesion of the coating system to the substrate.

This test requirement shall apply to all coating systems applied to the enclosure.

One coated test panel, per Figure 6, shall be scribed to bare substrate in accordance with ASTM D3359. Method A shall be used for films thicker than 0.13 mm (5 mil or 0.005 inch). Method B shall be used for films less than or equal to 0.13 mm (5 mil or 0.005 inch). There shall be 100% adhesion to the substrate and between layers. A rating of 5A for Method A and 5B for Method B per ASTM D3359 is required.

5.5.2 Humidity test

This test evaluates the performance of the coating system under controlled condensation conditions. Condensation may cause deterioration of the coating system impacting the useful service life of the equipment.

This test requirement shall apply to all coating systems applied to the enclosure.

Two coated panels, per Figure 5, shall be tested for 1000 h in accordance with ASTM D4585, except that the test shall be conducted at 45 °C ± 1 °C (113 °F ± 2 °F). Upon completion of the test, panels shall be evaluated for the following:

— Blistering—There shall be no blistering observed per ASTM D714 on the surface of the panels when inspected within 15 min after removal from the cabinet.
— Softening—After removal from the cabinet, allow the panels to air dry for 24 h ± 1 h. There shall be no more than one pencil hardness change when tested per ASTM D3363.
— Any color change shall be noted.

5.5.3 Impact test

This test demonstrates how the substrate/coating system stands up to deformation from impacts.

This test requirement shall apply to all coating systems applied to the enclosure.

One coated panel per Figure 6, shall be impacted on a concrete floor per ASTM D2794 at a value of 9 N·m (80 in-lb force, intrusion) utilizing a hemispherical indenter with a diameter of 15.875 mm (5/8 inch).

When the substrate is a material that visibly rusts when exposed to salt spray, the test panel shall be exposed to 24 h of salt spray per ASTM B117. There shall be no visible rust or corrosion product in or around the impact (intrusion) area of the panel.

When the substrate is a material that does not visibly rust when exposed to salt spray, the test panel shall be visually inspected under 10× magnification. No bare substrate shall be present in or around the impact (intrusion) area of the panel.

5.5.4 Insulating fluid resistance tests (for fluid-filled equipment only)

This test demonstrates proper adhesion of the coating to the substrate and chemical resistance to the insulating fluid whether gaseous or liquid.

This test requirement shall apply only for coated surfaces on the interior of the enclosure and that come into direct contact with insulating fluids.

Partially immerse one coated panel, per Figure 6, in the insulating fluid for 72 h at the top fluid rise temperature plus 40 °C ± 2 °C (104 °F ± 4 °F). On the immersed portion of the panel, there shall be no loss of adhesion per ASTM D3359, no blisters per ASTM D714, no streaking, and no more than one pencil hardness change when tested in accordance with ASTM D3363, using either method. Any color change shall be noted.

Example: For 65 °C (149 °F) rise transformers the test temperature is 105 °C ± 2 °C (221 °F ± 4 °F), while for 75 °C (167 °F) rise transformers the test temperature is 115 °C ± 2 °C (239 °F ± 4 °F).

When multiple types of insulating fluid may be used in the equipment, a separate test is required for each type of insulating fluid.

5.5.5 Ultraviolet accelerated weathering test

This test demonstrates how the substrate plus the coating system survives exposure to ultraviolet light.

This test requirement shall apply only for coated surfaces on the exterior of the enclosure or that may routinely be exposed to sunlight.

Two panels prepared, per Figure 6, shall be tested per ASTM D4587, cycle 2 (ultraviolet accelerated weathering) for 500 h utilizing either the FS-40 bulb, or using UVB-313EL lamps with an irradiance control system, with a cycle of 4 h ultraviolet at 60 °C ± 2 °C (140 °F ± 4 °F), followed by 4 h condensation at 50 °C ± 2 °C (122 °F ± 4 °F). For chambers utilizing an irradiance control system, the irradiance shall be set at 0.48 W/m^2 at 310 nm. Loss of gloss shall not exceed 50% of original gloss per ASTM D523. The coating shall not exhibit cracking per ASTM D661 or checking per ASTM D660 under unaided visual inspection.

5.5.6 Simulated corrosive atmospheric breakdown (SCAB)

This test demonstrates how the substrate plus the coating system stands up to corrosion in a cyclic environment, which is more representative of natural corrosive environments.

This test requirement shall apply to all coating systems applied to the enclosure.

Three coated panels shall be prepared per Figure 5 and then tested in accordance with the procedure described in Annex A. The scribe shall be prepared for evaluation using ASTM D1654-05, procedure A, method 2. Upon completion of three week-long cycles of SCAB, the scribe line shall be divided into 14 zones, 6.4 mm (0.25 inch), and the worst spot in each zone will be evaluated by measuring the amount of creepage away from the scribe line [except the first 6.4 mm (0.25 inch) of the scribe at each end of the scribe line]. The average of the 14 readings shall be rated per ASTM D1654-05, Table 1. Scribe creepage shall include discoloration and pitting caused from corrosion as well as loss of coating adhesion, blistering, film undercutting, and removal of coating around the scribe line. After a rating has been set for each of the three panels, the average rating of the three shall not be less than a rating of six. The area away from the scribe shall have no blisters per ASTM D714 and no rust per ASTM D610.

5.5.7 Abrasion resistance

This test demonstrates how the substrate plus the coating system stands up to abrasion and handling.

This test requirement shall apply only for coated surfaces on the exterior of the enclosure.

One coated panel, per Figure 7, having the minimum dry film thickness of the total coating system shall be tested using a CS-10 wheel and 1000 g weight, in accordance with ASTM D4060. A total of 3000 cycles shall be run with the wheels resurfaced before testing and after each 500-cycle run.

When the substrate is a material that visibly rusts when exposed to salt spray, the test panel shall be exposed to 24 h of salt spray per ASTM B117. There shall be no visible rust or corrosion product in the abraded area.

When the substrate is a material that does not visibly rust when exposed to salt spray, the test panel shall be visually inspected under 10× magnification. No bare substrate shall be present.

5.5.8 Chipping resistance test

This test demonstrates how the substrate plus the coating system stands up to chipping commonly caused by shipping, storage, and installation.

This test requirement shall apply only for coated surfaces on the exterior of the enclosure.

Two coated panels per Figure 8 are to be tested per ASTM D3170 at room temperature using 410 kPa (60 psig) gauge air pressure.

When the substrate is a material that visibly rusts when exposed to salt spray, the test panel shall be exposed to 24 h of salt spray per ASTM B117. Remove from salt spray, rinse, and dry the panels. Evaluate the panels for chip size, including only the chips that rusted. No chip shall be greater than 3.0 mm (0.12 inch) in diameter.

When the substrate is a material that does not visibly rust when exposed to salt spray, evaluate the panels for chip size, including only chips that expose bare substrate. No chip shall be greater than 3.0 mm (0.12 inch) in diameter.

6. Labels

6.1 Purpose

Labeling can be an important aspect of pad-mounted enclosure integrity. Labeling can alert or inform an individual of potential hazard. Pad-mounted enclosures should be designed to achieve a high degree of integrity. When labels are attached to pad-mounted enclosures, they should be located as near the hazard as practicable. Labels should be concise and simple to understand and should accurately communicate the type and degree of hazard.

6.2 Application

The application of any labels, whether intended for interior or exterior use, shall be subject to an agreement between the purchaser and the manufacturer.

7. General

7.1 Shipment

The manufacturer shall provide a method of shipment that will allow the enclosure to be received by the purchaser such that it still meets the performance tests required by this standard.

7.2 Coating repair procedure

A coating system repair procedure shall be recommended by the manufacturer.

7.3 Coating touch-up prior to shipment

Touch-up, when required, shall be done at final inspection before any equipment is shipped. In areas where the integrity of the coating system is violated, the touch-up shall blend smoothly and meet all performance criteria of this standard.

Annex A

(normative)

Simulated corrosive atmospheric breakdown (SCAB) procedure

The SCAB procedure is as follows:

Prepare three panels in accordance with 5.5.6.

For coatings applied to the interior of an enclosure, proceed directly to step a).

For coatings applied to the exterior of an enclosure test the panels in accordance with ASTM D4587, cycle 2 (ultraviolet accelerated weathering) for 504 h utilizing either FS-40 or UVB-313EL lamps with a cycle of 4 h of ultraviolet at 60 °C ± 2 °C (140 °F ± 4 °F), followed by 4 h of condensation at 50 °C ± 2 °C (122 °F ± 4 °F). For chambers utilizing an irradiance control system, the irradiance shall be set at 0.48 W/m^2 at 310 nm. No evaluation is necessary at this point as this is a conditioning step, continue to step a) as follows:

a) Scribe the panels in accordance with ASTM D1654–05 to create an approximately 102 mm (4 inch) long scribe across the weld.

b) Place the test panels (scribed side facing up) in a non-conductive panel rack with the scribe line in a vertical position. The rack shall hold the panels at a 15° ± 5° angle from the vertical. Panels in the test rack shall not touch one another.

c) Expose the panels for the specified number of cycles.

   1) Monday – cycle begins.

      i) 60 min in oven at 60 °C ± 2 °C (140 °F ± 4 °F)
      ii) 30 min in freezer at −23 °C ± 2 °C (−10 °F ± 4 °F). Panel shall be transferred into freezer within 1 min after removal from the oven.
      iii) Remove the panels from the freezer and immerse in a 5% (w/w)[19] NaCl solution by weight for 15 min. The NaCl solution shall be at room temperature. The panel transfer time from freezer to the NaCl immersion shall be less than 1 min.
      iv) Remove the panels from the NaCl bath and allow the test panels to age at room temperature and humidity for 75 min.
      v) Place the panels in humidity cabinet at 60 °C ± 2 °C (140 °F ± 4 °F) and 85% ± 3% relative humidity for 21 h.

   2) Tuesday through Friday

      i) Immerse the panels in 5% (w/w) NaCl solution for 15 min. The NaCl solution shall be at room temperature. The panel transfer time from the humidity cabinet to the NaCl immersion shall be less than 1 min.
      ii) Remove the panels from the NaCl bath and allow the test panels to age at room temperature and humidity for 75 min.
      iii) Place the test panels in humidity cabinet at 60 °C ± 2 °C (140 °F ± 4 °F) and 85% ± 3% relative humidity for 22 h and 30 min.

   3) Saturday and Sunday

      i) Leave the test panels in the humidity cabinet at 60 °C ± 2 °C (140 °F ± 4 °F) and 85% ± 3% relative humidity.

   4) Monday

      i) Cycle ends and next cycle begins until the specified number of week-long cycles has been completed.

d) Once the specified number of cycles has been completed, evaluate the test panels per 5.5.6.

[19] w/w indicates fraction by weight.

Annex B

(informative)

Commonly used substrate steels

carbon steel: Steel alloy with carbon (C), sulfur (S), and phosphorus (P) as the principal elements, restricted amounts of manganese (Mn) < 1.65%, silicon (Si) < 0.60%, and copper (Cu) < 0.60%, and negligible amounts of other elements. Carbon steels can be categorized as low-carbon (C ≤ 0.30%), medium-carbon (0.30% < C ≤ 0.60%), or high-carbon (0.60% < C ≤ 1.00%).

copper bearing steel: (Also known as weathering steel) High-strength low-alloy steel with approximately 0.15% carbon, 0.05% maximum sulfur, and a minimum of 0.2% copper content, exhibiting a minimum yield strength of 345 MPa and suitable for welding. ASTM A242 and ASTM A588 describe such steels in detail.

stainless steel: A steel alloy with chromium (Cr) as the main alloying element. Specific alloys have varying alloy compositions using carbon (C), nickel (Ni), manganese (Mn), phosphorus (P), sulfur (S), silicon (Si), nitrogen (N), and sometimes molybdenum (Mo) or titanium (Ti).

— **AISI** 304 (UNS S30400): 18.0% ≤ Cr ≤ 20.0%, C ≤ 0.08%, 8.0% ≤ Ni ≤ 10.5%, Mn ≤ 2.00%, P ≤ 0.045%, S ≤0.03%, Si ≤1.00%, N ≤ 0.10%

— **AISI** 304L (UNS S30403): 18.0% ≤ Cr ≤ 20.0%, C ≤ 0.03%, 8.0% ≤ Ni ≤ 12.0%, Mn ≤ 2.00%, P ≤ 0.045%, S ≤0.03%, Si ≤1.00%, N ≤ 0.10%

— **AISI** 316 (UNS S31600): 16.0% ≤ Cr ≤ 18.0%, C ≤ 0.08%, 10.0% ≤ Ni ≤ 14.0%, Mn ≤ 2.00%, P ≤ 0.045%, S ≤0.03%, Si ≤1.00%, N ≤ 0.10%, 2.0% ≤ Mo ≤ 3.0%

— **AISI** 316L (UNS S31603): 16.0% ≤ Cr ≤ 18.0%, C ≤ 0.03%, 10.0% ≤ Ni ≤ 14.0%, Mn ≤ 2.00%, P ≤ 0.045%, S ≤0.03%, Si ≤1.00%, N ≤ 0.10%, 2.0% ≤ Mo ≤ 3.0%

— **AISI** 409 (UNS S40900): 10.50 ≤ Cr ≤ 11.75%, C ≤ 0.08%, Ni ≤ 0.50%, Mn ≤ 1.00%, P ≤ 0.045%, S ≤ 0.045%, Si ≤ 1.00%, N ≤ 0.03%, and minimum Ti of 6 times %C with a max of 0.75%

NOTE 1—AISI – American Iron and Steel Institute, AISI Publications are available from the American Iron & Steel Institute, 25 Massachusetts Avenue, NW, Suite 800 Washington DC 20001.

NOTE 2—UNS – Unified numbering system.

NOTE 3—The "L" designation indicates a "low carbon" version – thus 304L is a low carbon version of 304.

NOTE 4—409 is a ferritic stainless steel and is magnetic, while 304, 304L, 316, and 316L are austenitic stainless steels and are not magnetic.

Annex C

(informative)

Pry bar

C.1 General

The pry bar, Figure C.1, depicted in this informative annex is just one design intended to meet the functional requirements of 4.3.1.1 Other pry bar designs complying with 4.3.1.1 are acceptable.

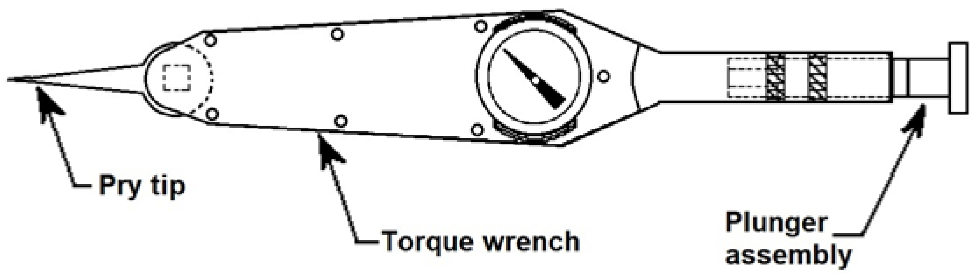


Figure C.1—Assembled pry bar

The pry bar consists of three parts: pry tip (Figure C.2), torque wrench, and axial force plunger (Figure C.3). The pry tip is designed for installation on a half-inch drive of a torque wrench. The plunger is designed to be inserted into the handle of a torque wrench with a hollow handle that has an interior stop for the plunger to fit into and press against.

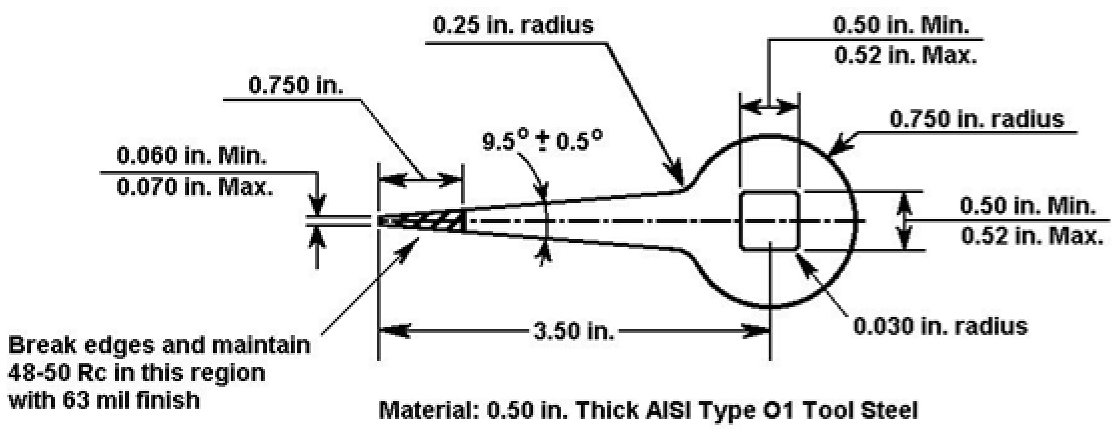


Figure C.2—Pry tip

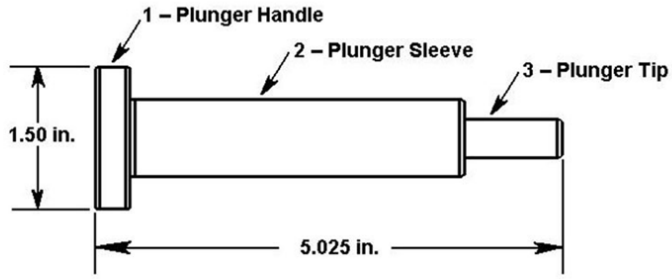


Figure C.3—Plunger assembly

C.1.1 Pry tip calibration

The addition of a pry tip to the torque wrench increases the moment arm of the tool. Consequently, the tool must be re-calibrated to account for the longer moment arm. Calibration is accomplished as follows:

a) Clamp approximately one inch of the pry tip to a workbench or other rigid surface.

b) Select a point on the torque tool handle to apply force.

c) Measure the distance (in inches) from this point to the end of the pry tip.

d) Divide 900 inch-lb by this distance to determine the force (in pounds) to be applied during calibration.

e) Using a calibrated force measurement tool, apply the calculated force to the handle and record the torque indicated on the torque wrench dial.

f) This value becomes the target prying leverage force to be used during the pry test.

C.1.2 Plunger calibration

The plunger is a simple spring force measurement tool made from machined steel parts. The plunger must be calibrated and marked to indicate when the desired force has been reached. The plunger fits into the hollow pipe handle of the torque wrench and must be installed into the torque wrench prior to calibration. Calibration is accomplished as follows:

a) Apply force to the plunger using a calibrated force measurement tool.

b) As force is applied, the plunger body moves into the torque wrench handle. When the desired force is obtained (50 lb) mark the plunger body at the torque wrench handle rim.

c) During the pry test, depress the plunger until the mark aligns with the wrench handle rim.

C.2 Drawings

All dimensions are in inches. All tolerances are ± 0.03 unless otherwise stated.

C.3 Assembly instructions

a) Insert plunger tip (Figure C.4) from threaded end of plunger sleeve (Figure C.5).

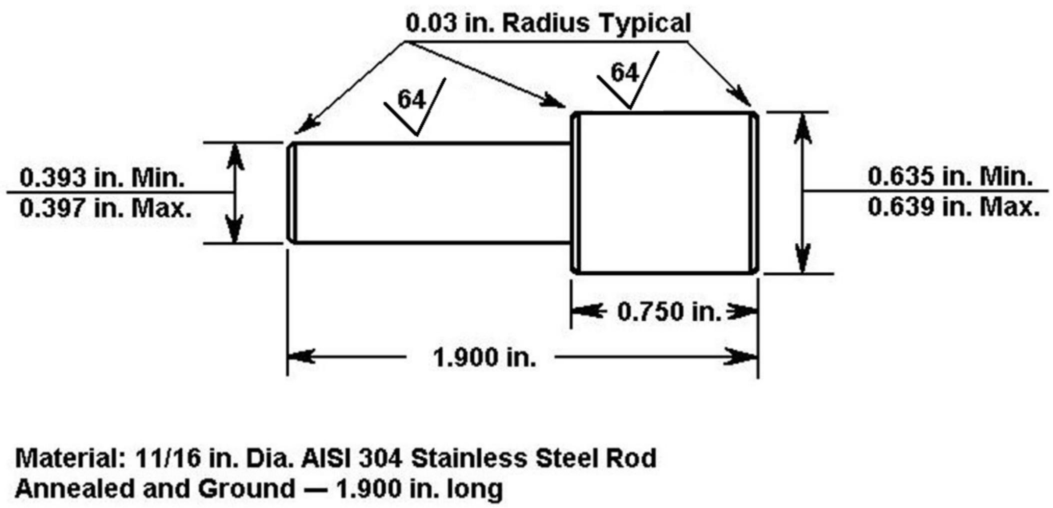


Figure C.4—Plunger tip

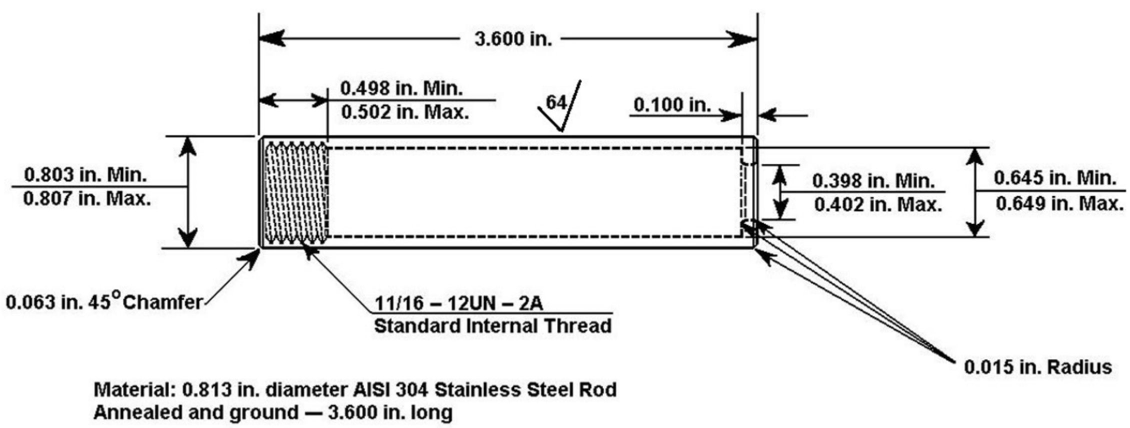
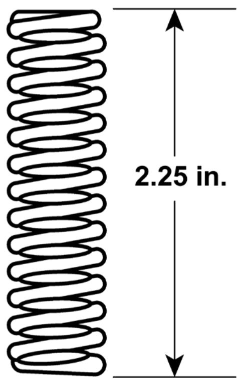


Figure C.5—Plunger sleeve

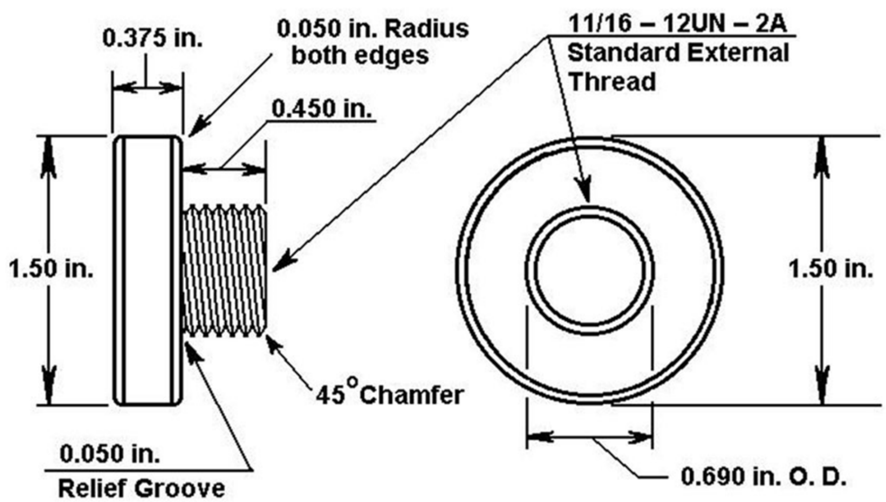
b) Insert plunger spring (Figure C.6) from threaded end of plunger sleeve.



Spring Specifications:
MW Components / Century Spring Corp Stock #2672
Outside Diameter = 0.625 inch
Inside Diameter = 0.415 inch
Free Length = 2.25 inch
Rate = 113 lbf/inch.
Total Active Coils = 13
Wire Diameter = 0.105 inch
Solid Length = 1.37 inch
Max. Deflection = 0.51 inch
Max. Load = 58 lbf
Material = Spring Steel
Ends = Closed and Ground
Finish = Zinc Plated

Figure C.6—Plunger spring

c) Screw plunger handle (Figure C.7) into plunger sleeve.



Material: 1.50 in. Diameter AISI 304
Stainless steel Rod, Annealed
0.825 in. Long

Figure C.7—Plunger handle

Annex D

(informative)

Substrate surface preparation

D.1 General

Coating adhesion to the substrate material is highly dependent on proper surface preparation and proper cleaning of the substrate material. The surface preparation methods listed below and the technical data sheets for the coating to be applied should be considered to ensure the appropriate surface profile prior to applying a protective coating. Proper cleaning is also essential in ensuring the best performance of the protective coating systems.

Listed below are SSPC (Society of Protective Coatings), NACE (National Association of Corrosion Engineers), BS (British Standards), ISO (International Standards Organization), and ASTM (American Society for Testing and Materials) standards associated with cleaning and surface preparation.

D.2 Iron and carbon steel and copper bearing steel substrates

— SSPC-SP1/ISO 8504 [B18][20] – Solvent Cleaning

— SSPC-SP2 [B19] – Hand Tool Cleaning

— SSPC-SP3 [B20] – Power Tool Cleaning

— SSPC-SP11 [B25] – Power Tool Cleaning to Bare Metal

— SSPC-SP7/NACE 4 [B23] – Brush-Off Blast Cleaning

— SSPC-SP14/NACE 8 [B27] – Industrial Blast Cleaning

— SSPC-SP6/NACE 3 [B22] – Commercial Blast Cleaning

— SSPC-SP10/NACE 2 [B24] – Near-White Blast Cleaning

— SSPC-SP5/NACE 1 [B21] – White Metal Blast Cleaning

— SSPC-VIS 1 [B29] – Pictorial Surface Standard Dry Blast Cleaning

— SSPC-SP12/NACE 5 [B26] – High- and Ultrahigh-Pressure Water Jetting Prior to Recoating

— ISO 8501 [B17] – Pictorial Appearance of Different Rust Grades at Various Levels of Cleanliness

— ASTM D4417-11 [B4] – Standard Test Methods for Field Measurement of Surface Profile of Blast Cleaned Steel

— ASTM D2200-08/ASTM D2200-17 [B3] – Pictorial Surface Preparation Standards and Guides for Painting Steel Surfaces

[20]The numbers in brackets correspond to those of the bibliography in Annex E.

D.3 Stainless steel and non-ferrous substrates

— SSPC-SP1 [B18] – Solvent Cleaning

— SSPC-SP7/NACE 4 [B23] – Brush-Off Blast Cleaning

— SSPC-SP17 [B28] – Thorough Abrasive Blast Cleaning of Non-Ferrous Metals

— BS 7079 [B6] – Surface Roughness and Cleanliness Grade of Stainless Steel

— ASTM B254-92 [B2] – Standard Practice for Preparation of and Electroplating on Stainless Steel

Annex E

(informative)

Bibliography

Bibliographical references are resources that provide additional or helpful material but do not need to be understood or used to implement this standard. Reference to these resources is made for informational use only.

[B1] ANSI C2, Accredited Standards Committee C-2, National Electrical Safety Code® (NESC®).[21,22]

[B2] ASTM B254–92, Standard Practice for Preparation of and Electroplating on Stainless Steel.[23]

[B3] ASTM D2200–08/ASTM D2200–17, Standard Practice for Use of Pictorial Surface Preparation Standards and Guides for Painting Steel Surfaces.

[B4] ASTM D4417–11, Standard Test Methods for Field Measurement of Surface Profile of Blast Cleaned Steel.

[B5] Bringas, J. E., and M. L., Wyman, The Metals Black Book: Ferrous Metals, 3rd Ed. Edmonton, Alberta: CASTI Publishing Inc., 1998.

[B6] BS 7079, Surface Roughness and Cleanliness Grade of Stainless Steel.

[B7] IEEE Std C57.12.20™, IEEE Standard for Overhead-Type Distribution Transformers 500 kVA and Smaller; High Voltage, 34 500 V and Below; Low Voltage, 7970/13 800Y V and Below.[24,25]

[B8] IEEE Std C57.12.23™, IEEE Standard for Submersible Single-Phase Transformers:250 kVA and Smaller; High Voltage 34 500 GrdY/19 920 V and Below; Low Voltage 600 V and Below.

[B9] IEEE Std C57.12.24™, IEEE Standard for Submersible, Three-Phase Transformers, 3750 kVA and Smaller: High Voltage, 34 500 GrdY/19 920 V and Below; Low Voltage, 600 V and Below.

[B10] IEEE Std C57.12.29™, IEEE Standard for Pad-Mounted Equipment—Enclosure Integrity for Coastal Environments.

[B11] IEEE Std C57.12.30™ IEEE Standard for Pole-Mounted Equipment—Enclosure Integrity for Coastal Environments.

[B12] IEEE Std C57.12.31™, IEEE Standard for Pole-Mounted Equipment—Enclosure Integrity.

[B13] IEEE Std C57.12.32™, IEEE Standard for Submersible Equipment—Enclosure Integrity.

[B14] IEEE Std C57.12.34™, IEEE Standard Requirements for Pad-Mounted, Compartmental-Type, Self-Cooled, Three-Phase Distribution Transformers, 10 MVA and Smaller; High-Voltage, 34.5 kV Nominal System Voltage and Below; Low-Voltage, 15 kV Nominal System Voltage and Below.

[21]The NESC is available from the Institute of Electrical and Electronics Engineers (https://standards.ieee.org/).
[22]ANSI C63 publications are available from the Institute of Electrical and Electronics Engineers (https://standards.ieee.org/) and the American National Standards Institute (https://www.ansi.org/).
[23]ASTM publications are available from the American Society for Testing and Materials (https://www.astm.org/).
[24]The IEEE standards or products referred to in Annex E are trademarks owned by The Institute of Electrical and Electronics Engineers, Incorporated.
[25]IEEE publications are available from The Institute of Electrical and Electronics Engineers (https://standards.ieee.org/).

[B15] IEEE Std C57.12.35™, IEEE Standard Bar Coding for Distribution Transformers and Step-Voltage Regulators.

[B16] IEEE Std C57.12.38™, IEEE Standard for Pad-Mounted-Type, Self-Cooled, Single-Phase Distribution Transformers 250 kVA and Smaller: High Voltage, 34 500 GrdY/19 920 V and Below; Low Voltage, 480/240 V and Below.

[B17] ISO 8501, Pictorial Appearance of Different Rust Grades at Various Levels of Cleanliness.[26]

[B18] SSPC-SP1/ISO 8504, Solvent Cleaning.

[B19] SSPC-SP2, Hand Tool Cleaning.

[B20] SSPC-SP3, Power Tool Cleaning.

[B21] SSPC-SP5/NACE 1, White Metal Blast Cleaning.

[B22] SSPC-SP6/NACE 3, Commercial Blast Cleaning.

[B23] SSPC-SP7/NACE 4, Brush-Off Blast Cleaning.

[B24] SSPC-SP10/NACE 2, Near-White Blast Cleaning.

[B25] SSPC-SP11, Power Tool Cleaning to Bare Metal.

[B26] SSPC-SP12/NACE 5, High- and Ultrahigh-Pressure Water Jetting Prior to Recoating.

[B27] SSPC-SP14/NACE 8, Industrial Blast Cleaning.

[B28] SSPC-SP17, Thorough Abrasive Blast Cleaning of Non-Ferrous Metals.

[B29] SSPC-VIS 1, Pictorial Surface Standard Dry Blast Cleaning.

[26]ISO publications are available from the International Organization for Standardization (https://www.iso.org/) and the American National Standards Institute (https://www.ansi.org/).

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