TECHNICAL SERVICES DEPARTMENT

BULLETIN

No. 113
June 2025

ANNULAR SPACE PROTECTION OF OPENINGS CREATED BY PENETRATIONS OF TUBULAR STEEL CONDUIT. A REVIEW OF UL SPECIAL SERVICES INVESTIGATION FILE NC546 PROJECT 90NK11650

Note: This report was published in August 1991. It was reviewed by NEMA RN, Steel Conduit and Electrical Metallic Tubing Committee, in June 2025 and was adopted as NEMA Engineering Bulletin.

Preface by NEMA's Steel Conduit Manufacturers

It has been long known that penetrations of fire-resistance-rated assemblies by different materials require different types of protection. A main consideration is the ability of the penetrating item to withstand the fire conditions without melting or burning. Steel conduit is unique in that its melting point is well above the 1850°F maximum temperature of the ASTM E119 time-temperature curve for a 2-hour fire test, as well as the 2000°F maximum for a 4-hour test. It is not just "noncombustible."

With regard to the size of the penetrating item, the maximum electrical conduit trade size produced is trade size 6 (aka 6"), and only a very small percentage of conduit and tubing used is larger than trade size 4. Trade sizes 1/2 and 3/4 are by far the most prevalent. Maximum penetration size is predetermined when considering electrical conduit and tubing; specifically, rigid metal conduit (RMC), intermediate metal conduit (IMC), and electrical metallic tubing (EMT).

There are many excellent through-penetration firestop systems on the market. A number of these can be used with steel conduit. The testing that the NEMA group sponsored at Underwriters Laboratories (UL) was to support the code recognized option of annular space filler protection. This helps to promote full code compliance and leaves no excuse for unsealed penetrations that would compromise safety. Both types of sealing methods, annular space filler and through-penetration systems, do the job with steel conduit and tubing. The UL Special Investigation reviewed in this document covered annular space filler materials.

These tests were performed as generically as possible, using materials purchased by UL from local supply houses. Construction was representative of ordinary field practice using good workmanship as expected by the codes. These are original results with no retesting to secure a passing result.

A review of the Special Services Investigation (File NC546 Project 90NK11650) made by UL follows:

The subject of the fire test investigation was various annular space protection materials installed in a concrete block wall, concrete floor assemblies, gypsum wallboard/wood joist/plywood deck floor-ceiling assemblies, and two variations of gypsum wallboard/steel stud wall assemblies. The purpose of the investigation was to determine if commonly available construction materials could be used as annular space protection materials in conjunction with tubular steel conduit products. Originally, the NEMA Rigid Steel Conduit and EMT Section sponsored this testing for the purpose of verifying that these combinations of products will meet the requirements contained in the following obsoleted Model Building Code Sections:

1) BOCA National Building Code, Sec. 915.7 of the 1989 Supplement to the 1987 Code.
2) ICBO Uniform Building Code, Sec. 4304 (e) and (f), and Sec. 4305 (c) of the 1990 Supplement to the 1988 Code.
3) SBCCI Standard Building Code, Sec. 1001.3.5 of the 1989/90 Supplement to the 1988 Code.

Although these building codes are no longer published, and have not been in some time, the requirements for filling an annular space between the assembly and the penetrant (a steel conduit) have not changed. Section 714.4.1 of the 2024 *International Building Code* (IBC) requires that the annular space between a noncombustible penetrating item and the periphery of the opening in a fire-resistance-rated assembly be filled with a material that will prevent the passage of flames and hot gases sufficient to ignite cotton waste when subjected to the time-temperature fire conditions of ASTM E119 under a minimum positive pressure of 0.01 in. of water column at the location of the penetration for a time period equivalent to the required fire resistance rating of the assembly penetrated.

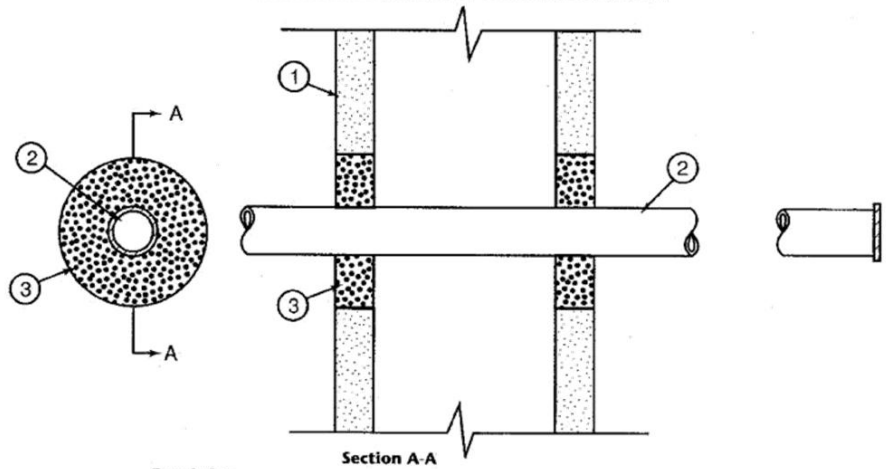
All materials that were tested passed the tests and maintained the fire-resistance rating for the time period specified for the assembly.

This includes joint compound used as annular space filler in a 2-hour gypsum wallboard/steel stud wall assembly.

Additionally, although not specifically required by the IBC, the test assemblies were subjected to the hose stream test, as specified in the standard *Fire Tests of Through-Penetration Firestops*, ANSI/UL 1479 (ASTM E814).

EXAMPLE OF PENETRATION OF 4 HR. CONCRETE BLOCK WALL

TEST ASSEMBLY NO. 1/TEST CONFIGURATION NO. 4



Section A-A

Item no.	Description
1	Nom. 8" thick Concrete Block Wall.
2	Nom. 1/2" Rigid Conduit centered in Nom. 4" opening. Conduit extended 12" & 36" beyond the exposed & unexposed surfaces, respectively. Nom. 1/8" thick steel plate welded to exposed end of conduit.
3	Nom. 2 1/8" Thickness of type M mortar installed within the annular space of both faces of block, flush with each surface of wall.

Ill. 6 NC546

TEST ASSEMBLY #1—4 HOUR FIRE EXPOSURE PERIOD
CONCRETE BLOCK WALL

Test Configuration No.	Opening Size	Penetrating Item(s)	Annular Space Protection Material(s)	Fire Exposure Results
1	Nominal 8 in. diameter	Nominal 4 in. diameter EMT	Nominal 2–1/8 in. thickness of Type M mortar on each side of wall.	Pass
2	Nominal 8 in. diameter	Nominal 4 in. diameter rigid conduit	Nominal 2–1/8 in. thickness of Type M mortar on each side of wall.	Pass
3	Nominal 6 in. diameter	Nominal 2 in. diameter EMT	Nominal 2–1/8 in. thickness of Type M mortar on each side of wall.	Pass
4	Nominal 4 in. diameter	Nominal 1/2 in. diameter rigid conduit	Nominal 2–1/8 in. thickness of Type M mortar on each side of wall.	Pass
5	Nominal 4 in. diameter	Nominal 1/2 in. diameter EMT	Nominal 2–1/8 in. thickness of Type M mortar on each side of wall.	Pass
6	Nominal 6 in. high by 10–1/2 in. wide	Nominal 1/2, 3/4, 1–1/2, 2 and 4 in. diameter EMT, spaced 3/4 in. apart	Nominal 2–1/8 in. thickness of Type M mortar on each side of wall.	Pass
7	Nominal 6–1/2 in. high by 11 in. wide	Nominal 1/2, 3/4, 1–1/4, 2 and 4 in. diameter rigid conduit, spaced 3/4 in. apart	Nominal 2–1/8 in. thickness of Type M mortar on each side of wall.	Pass

Test Assemblies

Concrete Block Wall Assembly with 4-Hour Fire-Resistance Rating
The concrete block wall consisted of a 54 in. wide by 66 in. high wall constructed with nominal 8 in. thick concrete blocks having a 4-hour fire endurance rating when tested in accordance with the standard *Fire Tests of Building Construction and Materials*, ANSI/UL 263 (ASTM E119). The blocks were assembled using Type M mortar.

Concrete Floor Assembly with 3-Hour Fire-Resistance Rating
The concrete floor assembly consisted of a 48 in. by 48 in. by 4-1/2 in. thick lightweight concrete slab having a 3-hour fire-resistance rating.

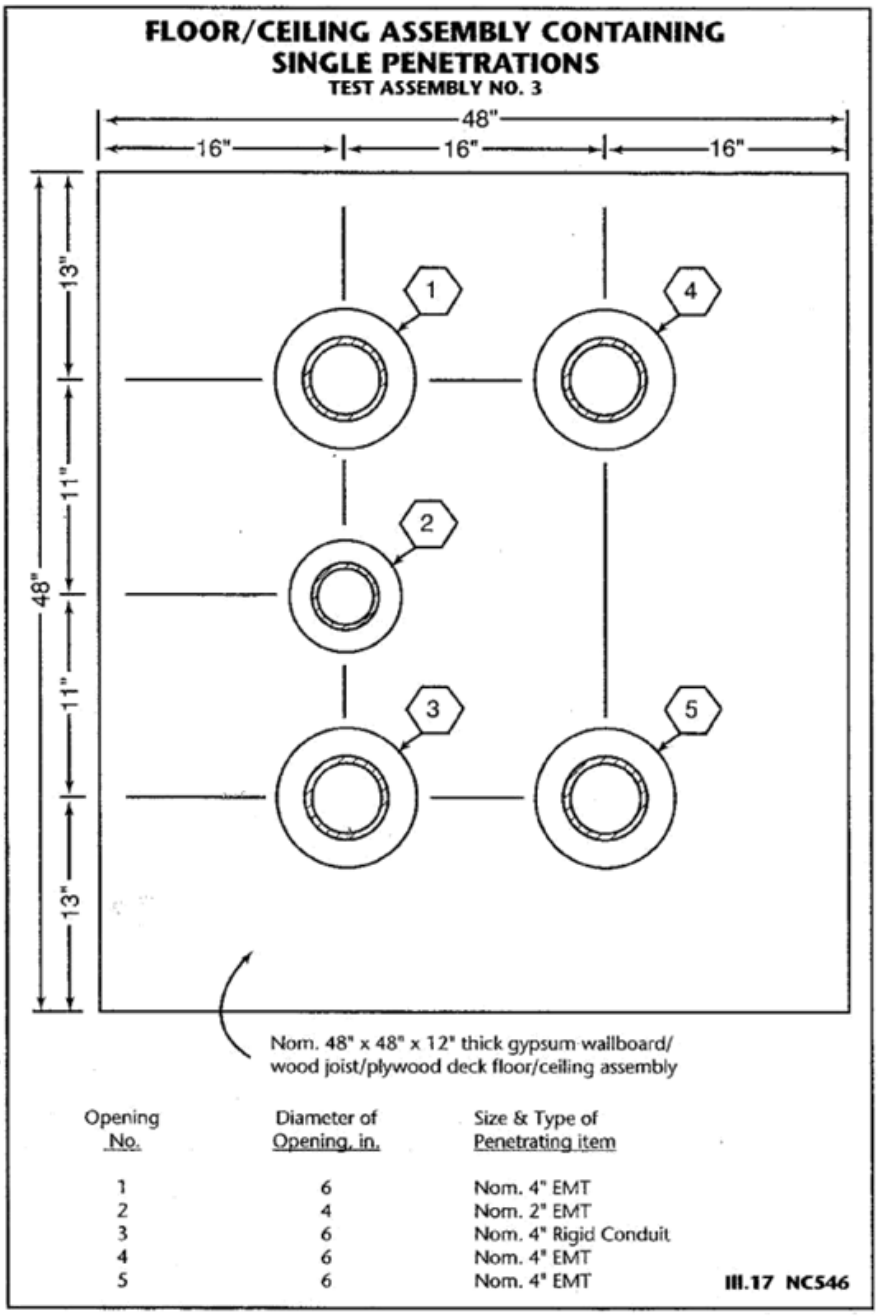
Wood Joist Floor-Ceiling Assembly with 2-Hour Fire-Resistance Rating
The wood joist floor-ceiling assembly consisted of a 48 in. by 12 in. thick assembly constructed with nominal 2 in. x 10 in. wood joists protected on the ceiling side with two layers of 5/8 in. thick gypsum wallboard separated by 5/8 in. thick resilient channel and on the floor side with 3/4 in. thick plywood. The floor-ceiling assembly constructed in this manner has a 2-hour fire-resistance rating.

Gypsum Wallboard/Steel Stud Wall Assembly with 2-Hour Fire-Resistance Rating
The first gypsum wallboard/steel stud wall assembly consisted of a nominal 52 in. wide by 62 in. high wall constructed with nominal 3-1/2 in. wide No. 25 MSG steel studs spaced 24 in. OC. The steel studs were faced with two layers of 5/8 in. thick gypsum wallboard on each side. The wall assembly constructed in this manner has a 2-hour fire-resistance rating.

Steel Reinforcement
The steel reinforcement for the concrete floor slabs was a 6 by 6 in. welded wire mesh of No. 10 SWG uncoated steel wire (6x6 – W1.4xW1.4).

Wood Joists
The wood joists were nominal 2 by 10 in. Douglas Fir-Larch lumber supplied in 12 ft. lengths.

Plywood Deck
The plywood deck was nominal 3/4 in. thick standard interior grade plywood conforming with PSI-66.



Gypsum Wallboard
The 5/8 in. thick “Type C” and “Type X” UL Classified gypsum wallboard was supplied in 4 by 8 ft. sheets weighing approximately 2.3 psf. and was manufactured by the United States Gypsum Co., Chicago, IL.

Joint Compound
The joint compound was a premixed ready-to-use compound manufactured specifically for use as a gypsum wallboard joint treatment material.

Resilient Channels
The resilient channels were fabricated from 0.021 in. thick (No. 25 gauge) galvanized steel and measured 1-1/2 in. wide by 5/8 in. deep and were supplied in 10 ft. lengths.

Fasteners
Fasteners for the floor assembly were 16d and 8d common nails and 1 in. long Type S self-drilling, self-tapping bugle-head steel screws. Fasteners for the wall assemblies were 1/4 in. 20 hex-head steel bolts with nuts into strut channels, 1/2 in. long Type S-12 self-drilling, self-tapping pan head steel screws, and 1 in. and 1-5/8 in. long Type S self-drilling, self-tapping bugle head steel screws.

Floor and Ceiling Runners
The channel-shaped runners were fabricated from 0.022 in. thick (No. 25 gauge) electrogalvanized steel and measured 3-5/8 in. wide by 1-3/8 in. deep and were supplied in 10 ft. lengths.

Steel Studs
The steel studs were fabricated from 0.024 in. thick (No. 25 gauge) electrogalvanized steel and measured 3-1/2 in. wide by 1-1/4 in. deep with 5/16 in. folded back return flange legs. The studs were supplied in 10 ft. lengths.

Joint Tape
The 2 in. wide joint tape was made of a porous 0.010 in. thick paper with numerous pin-hole perforations throughout.

Conduit and Tubing
The galvanized steel conduit and tubing ranged from trade size 1/2 EMT and RMC to trade size 4 EMT and RMC. All conduits and tubing were sealed on the fire-exposed end with a 1/8 in. thick steel plate welded to the end.

TEST ASSEMBLY #3—2 HOUR FIRE EXPOSURE PERIOD
PLYWOOD/WOOD JOISTS/GYPSUM WALLBOARD FLOOR–CEILING ASSEMBLY
(DESIGN NOS. L505, L511, OR L536)

Test Configuration No.	Opening Size	Penetrating Item(s)	Annular Space Protection Material(s)	Fire Exposure Results
1	Nominal 6 in. diameter	Nominal 4 in. diameter EMT	Upper level: nominal 3/4 in. thickness of caulk Lower level: nominal 5/8 in. thickness of caulk, flush with exposed surface, topped with nominal 2 in. thickness of mineral wool	Pass
2	Nominal 4 in. diameter	Nominal 2 in. diameter EMT	Upper level: nominal 3/4 in. thickness of caulk Lower level: nominal 5/8 in. thickness of caulk, flush with exposed surface, topped with nominal 2 in. thickness of mineral wool	Pass
3	Nominal 6 in. diameter	Nominal 4 in. diameter EMT	Upper level: nominal 3/4 in. thickness of caulk Lower level: nominal 1–7/8 in. thickness of caulk	Pass
4	Nominal 6 in. diameter	Nominal 4 in. diameter EMT	Upper level: nominal 3/4 in. thickness of mineral wool, covered with 30 mil thickness of paint Lower level: nominal 2 in. thickness of mineral wool, covered with 30 mil thickness of paint	Pass
5	Nominal 6 in. diameter	Nominal 4 in. diameter EMT	Upper level: nominal 3/4 in. thickness of joint compound Lower level: nominal 1–7/8 in. thickness of joint compound	Pass

Annular Space Filler Descriptions

Mineral Wool

The mineral wool insulation used in the test configurations was manufactured by Partek Insulations, Inc., Phoenix City, AL. The mineral wool was supplied in nominal 24 by 48 by 2 in. thick batts having a nominal density of 4 pcf. The actual density of the batts was 4.4 pcf.

Caulk

The one-part RTV silicone caulk material used in the test configurations was manufactured by Dow Corning Corp., Midland, MI, and was designated “Silastic 732 RTV Adhesive/Sealant.”

Mortar

The mortar used in the test configurations was a Type “M” mortar, as defined in Table 24-A of the 1988 Edition of the U.B.C. The mortar was composed of 1 part Type I Portland cement, 1/4

part hydrated lime, 2-1/2 part No. 4 mason's sand, by bulk volume, mixed with water as needed to achieve a workable mixture.

Hydraulic Cement
The hydraulic cement used in the test configurations was a prepared dry mixture manufactured by Thoro System Products, Miami, FL, and was designated "Thorite." The dry mixture was mixed with water as needed to achieve a workable mixture.

Hose Stream Test Information

Although not required where annular space protection materials are permitted by the referenced code sections, the conduit producers requested the hose stream test be conducted. This supplemental information on the hose stream performance of the test configurations responds to the concerns of those who attach importance to this test.

All hose stream tests were conducted in accordance with Section 5 of the standard ANSI/UL 1479 (ASTM E814). Paragraph 5.1 of this standard provides for use of a duplicate test assembly for hose stream testing. The duplicate assembly is subjected to a fire exposure of one-half the original rating period, but not more than 60 min. For some test configurations, this duplicate test assembly was not utilized because the original assembly, after fire exposure for the full rating period, passed the hose stream test, thus far exceeding the requirements. As an example, concrete block, with mortar as the annular space protection, passed after being subjected to four times the required fire exposure.

The duplicate test for hose stream was performed only for those test configurations that did not pass after fire exposure for the full rating period.

Construction was identical to the original test assemblies. Slight changes were made in annular space filler as shown in notes (1), (2), and (3) in Table H-1.

The configurations that passed the hose stream test after being subjected to the full rating fire exposure period are contained in column (a) of Table H-1.

Results of the duplicate assembly testing are contained in column (b) of Table H-1.

The hose stream test is intended as a measure of structural stability, and not as an indicator of resistance to fire extinguishing activity. It is significant to note that when original testing of assembly No. 4 (Gypsum Wallboard/Steel Stud Assembly with 2-hour fire-resistance rating) was initiated, an explosion occurred in the furnace. Examination of the exposed side of the wall assembly revealed the following:

The top edge of the wall assembly had moved outward approximately 1/16 in. with respect to the test frame. In Penetration Nos. 1, 2, 4, and 5, the wall assembly was pushed out between 1/32 and 1/4 in. with respect to the test configurations. A small crack existed in the gypsum wallboard emanating from the lower edge of Penetration No. 1; in Penetration No. 5, a crack existed in the joint compound from the trade size 1/2 EMT to the adjacent corner.

The decision was made to continue with the test. Even after this physical insult, ALL TEST CONFIGURATIONS MAINTAINED THE RATING OF THE ASSEMBLY AND PREVENTED THE IGNITION OF COTTON WASTE.

Summary of Performance Relative to the Referenced Building Code Sections

All test configurations prevented the passage of flame and hot gases sufficient to ignite cotton waste when subjected to the ASTM E119 time-temperature fire conditions under a minimum positive pressure differential of 0.01 in. of water at the location of the penetration for the time period equivalent to the fire endurance rating of the assembly penetrated.

HOSE STREAM TEST RESULTS

Table H-1

Test Assembly No.	Penetration No.	Penetrating Item(s)	Annular Space Protection Material(s)	Fire Exposure Test	(a) Passed Hose Stream (Full Rating Period)	(b) Passed Hose Stream (Duplicate Assembly)
4 Hr. Asmbly.						
1	1	4 in. EMT	Mortar	Pass	Yes	
1	2	4 in. Rigid	Mortar	Pass	Yes	
1	3	2 in. EMT	Mortar	Pass	Yes	
1	4	1/2 in. Rigid	Mortar	Pass	Yes	
1	5	1/2 in. EMT	Mortar	Pass	Yes	
1	6	Mult. EMT	Mortar	Pass	Yes	
1	7	Mult. Rigid	Mortar	Pass	Yes	
3 Hr. Asmbly.						
2	1	4 in. EMT	Mineral wool	Pass	See (b)	(1)
9	1	4 in. EMT	(2) 1 in. caulk over mineral wool	Pass		Yes
2	2	4 in. EMT	Caulk	Pass	See 9 (b)	
9	2	4 in. EMT	Caulk	Pass		Yes
2	3	4 in. EMT	Mortar	Pass	Yes	
9	3	4 in. EMT	(2) 1–1/2 in. caulk over mineral wool	Pass		Yes
2	4	4 in. EMT	Hydraulic cement	Pass	Yes	
9	4	4 in. EMT	(2) 2–1/2 in. caulk over mineral wool	Pass		Yes
2	5	4 in. EMT	Grout over mineral wool	Pass	See 9 (b)	
9	5	4 in. EMT	Grout over mineral wool	Pass		Yes
2 Hr. Asmbly.						
3	1	4 in. EMT	Caulk and mineral wool	Pass	See 8 (b)	
8	1	4 in. EMT	Caulk and mineral wool	Pass		Yes
3	2	2 in. EMT	Caulk and mineral wool	Pass	See 8 (b)	
8	2	2 in. EMT	Caulk and mineral wool	Pass		Yes
3	3	4 in. EMT	Caulk	Pass	See 8 (b)	
8	3	4 in. EMT	Caulk	Pass		Yes
3	4	4 in. EMT	Paint over mineral wool	Pass	See 8 (b)	
8	4	4 in. EMT	Paint over mineral wool	Pass		Yes
3	5	4 in. EMT	Joint compound	Pass	See 8 (b)	
8	5	4 in. EMT	(3) Joint compound	Pass		Yes
2 Hr. Asmbly.						
4	1	4 in. EMT	Joint compound	Pass	See 6 (b)	
6	1	4 in. EMT	Joint compound	Pass		No
4	2	4 in. EMT	Caulk	Pass	See 6 (b)	
6	2	4 in. EMT	Caulk	Pass		Yes
4	3	4 in. EMT	Paint over mineral wool	Pass	See 6 (b)	
6	3	4 in. EMT	Paint over mineral wool	Pass		No
4	4	4 in. Rigid	Caulk	Pass	See 6 (b)	
6	4	4 in. Rigid	Caulk	Pass		Yes
4	5	Mult. EMT	Joint compound over mineral wool	Pass	See 6 (b)	
6	5	Mult. EMT	Joint compound over mineral wool	Pass		Yes

TABLE H–1 continued

Test Assembly No.	Penetration No.	Penetrating Item(s)	Annular Space Protection Material(s)	Fire Exposure Test	(a) Passed Hose Stream (Full Rating Period)	(b) Passed Hose Stream (Duplicate Assembly)
1 Hr. Asmbly.						
5	1	4 in. EMT	Joint compound	Pass	See 7 (b)	
7	1	4 in. EMT	Paint over joint compound	Pass		No
5	2	4 in. EMT	Caulk	Pass	See 7 (b)	
7	2	4 in. EMT	Caulk	Pass		Yes
5	3	4 in. EMT	Paint over mineral wool	Pass	See 7 (b)	
7	3	4 in. EMT	Paint over mineral wool	Pass		No (4)
5	4	4 in. Rigid	Caulk	Pass	See 7 (b)	
7	4	4 in. Rigid	Caulk	Pass		Yes
5	5	Mult. EMT	Joint compound over mineral wool	Pass	See 7 (b)	
7	5	Mult. EMT	Joint compound over mineral wool	Pass		No

(1) At the request of the submitter, duplicate testing was omitted.

(2) At the request of the submitter, this new test configuration was incorporated in the assembly. It was obvious from the original test that mineral wool would require some other filler to hold it in place during the hose stream application. Three different thicknesses of caulk were tested for this purpose.

(3) At the request of the submitter, the joint compound was domed approximately 1-1/4 in. above surface of plywood deck. This represents an alternate configuration from that evaluated in Test Assembly No. 3, Penetration No. 5.

(4) In Test Configuration No. 3, the painted mineral wool was still adhered to the gypsum wallboard. However, the paint had separated from the penetrating item, creating a hairline crack. Based upon the flexible nature of the painted mineral wool, it was judged that this separation would allow a through projection of water.

Distribution List

Codes and Standards Committee
NEMA Technical & Industry Affairs Department

Disclaimer

The standards or guidelines presented in a NEMA technical publication are considered technically sound at the time they are approved for publication. They are not a substitute for a product seller's or user's own judgment with respect to the particular product referenced in the standard or guideline, and NEMA does not undertake to guarantee the performance of any individual manufacturer's products by virtue of this standard or guide. Thus, NEMA expressly disclaims any responsibility for damages arising from the use, application, or reliance by others on the information contained in these standards or guidelines.

Special Notes

We repeat here, verbatim, the standard UL caveat:

"Information conveyed by this Report applies only to the specimens actually involved in these tests. UL Solutions (previously Underwriters Laboratories Inc). has not established a factory follow-up service program to determine the conformance of subsequently produced material nor has any provision been established to apply any registered mark of Underwriters laboratories Inc.

The issuance of this Report in no way implies Listing, Classification or other Recognition by UL Solutions and does not authorize the use of UL Solutions Listing, Classification or Recognition Marks or any other reference to Underwriters laboratories Inc. on or in connection with the product or system.

In no event shall UL be responsible to anyone for whatever use or nonuse is made of the information contained in this Report and in no event shall UL, its employees, or its agents incur any obligation or liability for damages, including but not limited to, arising out of or in connection with the use or inability to use the information contained in this report."

The full UL Special Investigation File NC546 Project 90NK11650 is available upon request from:

National Electrical Manufacturers Association
1812 North Moore St. Suite 2200
Arlington, VA 22209
www.makeitelectric.org

§