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# An Exploratory Study of Dielectric Breakdown Voltages for Residential Wiring

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Washington, D.C. 20234

October 1978

Sponsored by
**Office of Policy Development and Research**
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**U.S. DEPARTMENT OF COMMERCE, Juanita M. Kreps, *Secretary***

**Dr. Sidney Harman, *Under Secretary***

**Jordan J. Baruch, *Assistant Secretary for Science and Technology***

**NATIONAL BUREAU OF STANDARDS, Ernest Ambler, *Director***

## SI CONVERSION UNITS

In view of the present accepted practice in this country for building technology, common U.S. units of measurement have been used throughout this document. In recognition of the position of the United States as a signatory to the General Conference on Weights and Measures, which gave official status to the metric SI system of units in 1960, assistance is given to the reader interested in making use of the coherent system of SI units by giving conversion factors applicable to U.S. units used in this document.

| | |
|---|---|
| Length | 1 inch = 0.0254 meter (m) |
| Time | 1 hour = 60 minutes = 3,600 seconds |
| Frequency | 1 cycle per second = 1 hertz (Hz) |

## ACKNOWLEDGEMENTS

The authors appreciate the cooperation and efforts of David L. Hillhouse of the Electrosystems Division, Applied Electrical Measurements Section, NBS for design of special hardware used in these tests and of Walter J. Mangan for installation of hardware and assistance during tests.

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AN EXPLORATORY STUDY OF DIELECTRIC BREAKDOWN VOLTAGES FOR RESIDENTIAL WIRING

J.E.V. Raduan, R.W. Beausoliel, and W.J. Meese

## ABSTRACT

Residential electric circuits are subjected to surge voltages resulting from load switching in buildings, and from external causes such as lightning. Laboratory test data are presented on high voltage breakdown values for armored cable (type AC cable), nonmetallic-sheathed cable (type NM), flat conductor cable, and duplex receptacles. Dielectric withstand voltage test requirements in current standards for residential wiring and wiring devices vary over a wide range. In some cases, the standard test voltage values for both wiring and wiring devices are less than surge voltages recorded on wiring in residences. Also field recorded voltage wave forms and rates of their application are different from those used in standard withstand voltage tests.

Key words: Dielectric breakdown voltages; dielectric withstand voltage tests; residential wiring; surge voltages.

## 1. BACKGROUND

The Building Thermal and Service Systems Division, Center for Building Technology of the National Bureau of Standards (NBS), has an ongoing U. S. Department of Housing and Urban Development (HUD)-sponsored project involving the development of performance criteria and test methods for innovative branch circuit wiring for residences. The Service Systems Program of the Building Thermal & Service Systems Division participated in an NBS project to assist the Brazilian Government with the establishment of a testing laboratory for residential wiring and wiring devices.

During the electrical investigations and research activities, it was recognized that the existing high voltage withstand tests applied to branch circuit wiring and wiring devices have considerable differences from the standard test voltages applied to different wiring and wiring devices. The question arises as to what applied voltage will cause voltage breakdown in the dielectric materials of wiring and devices and what recommendations should be made relative to the test methods. Also, the requirements for voltage transients which wiring and devices should withstand in actual use are not well known. Such information is important because the high voltage breakdown of wires and devices is not only a function of the voltage but also is dependent on the frequency of the voltage wave. Existing standards for residential wiring and wiring devices require the application of 60 Hz constant voltage waves rather than surge voltage wave shapes which occur naturally in normal usage of installed wiring systems.

## 2. PURPOSE

The purpose was to determine the transient voltages expected in residential wiring through a literature search, and to determine the voltages that cause failure of wiring and devices through laboratory tests. Also, the intent was to identify the required values for development of performance criteria and test methods.

## 3. SURGE VOLTAGES IN RESIDENTIAL POWER CIRCUITS

The literature-search portion of this effort revealed that residential electric circuits are subjected to internally generated surge voltages resulting from load switching within the house, and externally generated surges that are likely to be caused by lightning [1]. The referenced paper presents surge voltage magnitudes and frequencies of occurrence in residential and industrial circuits. Table 1 shows recorded data at twenty-one locations [1]. This work was performed over a period of two years at more than 400 locations in 20 cities.

In those houses where frequent surges were found to occur, it was shown through deliberate switching of the devices that the operation of an oil burner, fluorescent lamp, pump, motor, refrigerator, or

TABLE 1 - Detailed Analysis of Recorded Surges

| House | Most Severe Surge | | | Most Frequent Surge | | | Average Surges per Hour | Remarks |
|---|---|---|---|---|---|---|---|---|
| | Type* | Crest (volts) | Duration (μs or cycles) | Type* | Crest (volts) | Duration (μs or cycles) | | |
| 1 | A-1.5 | 700 | 10 μs | A-1.5 | 300 | 10 μs | 0.07 | |
| 2 | A-2.0 | 750 | 20 μs | A-2.0 | 500 | 20 μs | 0.14 | fluorescent light |
| 3 | B-0.5 | 600 | 1 cycle | B-0.5 | 300 | 1 cycle | 0.05 | switching |
| 4 | B-0.5 | 400 | 2 cycles | B-0.5 | 300 | 2 cycles | 0.2 | |
| 5 | C | 640 | 5 μs | too few to show typical | | | 10 total | |
| 6 | B-0.3 | 400 | 1 cycle | B-0.3 | 250 | 1 cycle | 0.01 | |
| 7 | B-1 | 1800 | 1 cycle | B-1.0 | 800 | 1 cycle | 0.03 | lightning storm |
| 8 | C | 1200 | 10 μs | B-0.5 | 300 | 4 cycles | 0.1 | |
| 9 | B-0.25 | 1500 | 1 cycle | same as most severe | | | 0.2 | oil burner |
| 10 | B-0.25 | 2500 | 1 cycle | B-0.25 | 2000 | 1 cycle | 0.4 | oil burner |
| 11 | B-0.2 | 1500 | 1 cycle | same as most severe | | | 0.15 | water pump |
| 12 | B-0.2 | 1700 | 1 cycle | B-0.2 | 1400 | 1 cycle | 0.06 | oil burner |
| 13 | B-0.1 | 350 | 1 cycle | too few to show typical | | | 4 total | house next to 12 |
| 14 | C | 800 | 15 μs | | | | 1 total | lightning |
| 15 | B-0.25 | 800 | 3 cycles | B-0.25 | 600 | 3 cycles | 0.05 | rural area |
| 16 | B-0.15 | 400 | 15 μs | B-0.13 | 200 | 30 μs | 0.4 | surges |
| Street pole | B-0.5 | 5600 | 4 cycles | B-0.3 | 1000 | 1 cycle | 0.1 | lightning stroke nearby |
| Hospital | C | 2700 | 9 μs | C | 900 | 5 μs | 0.1 | lightning storm |
| Hospital | B-0.3 | 1100 | 1 cycle | too few to show typical | | | 4 total | |
| Department store | B-0.5 | 300 | 1 cycle | B-0.5 | 300 | 1 cycle | 0.5 | |
| Street pole | B-0.2 | 1400 | 4 cycles | B-0.2 | 600 | 4 cycles | 0.07 | lightning storm |

* A--long oscillation; B--damped oscillation; C--undirectional. Number shows frequency in megahertz

μs = microseconds ($10^{-6}$)

food mixer caused repeatable surges. Surges caused by load switching within houses in normal operation are likely to be repeated several times a day. Such surges can generally be associated with a specific device or appliance which may be operating erratically or exciting a natural frequency of the wiring system. However, such surges do not occur in all houses.

The referenced report states that conditions such as pinched electrical insulation or reduced air clearances in wall outlet boxes and similar conditions can cause flashover with 60-Hz power following. One house was found in which a light fixture was sparking. Flashover at 1700 volts was observed in relationship with the start of an oil burner in the house. The defective light fixture was apparently acting as a voltage-limiting gap for the house.

Available statistics indicate that electrically caused fires are a real problem in this country. Not including electrical fires attributed to motors or other power-consuming appliances, the National Fire Protection Association statistics indicate that approximately 100,000 fires annually are caused by electrical wiring and general equipment. This is approximately 10 percent of all building fires. A more detailed breakdown pertaining to the causes of these 100,000 fires was not given [2]. It is conceivable that a portion of these fires could have been caused by high voltage flashover with 60 Hz power following in wiring, devices, or grounded building components; however, this hypothesis requires validation.

## 4. STANDARD HIGH VOLTAGE WITHSTAND TESTS

Dielectric withstand voltages are applied between insulated conductors or terminals or other elements of opposite polarity, often including the grounding conductor or terminal. The dielectric material of the cable or device is subjected to a voltage considerably in excess of the rated voltage but less than expected breakdown voltage. The withstand test voltage is intended to indicate dielectric capability to withstand rated voltage with superimposed momentary surge or transient voltage level resulting from circuit switching or lightning.

Examination of some standard withstand test methods has shown that a large range of withstand voltages is used for residential wiring and devices which may be subject to surge voltages. These voltages are shown in Table 2. A number of these voltages are less than surge voltages recorded in dwellings as shown in Table 1.

As a general rule, the standard withstand test voltages are applied at a uniform rate of voltage increase until the withstand voltage value is reached. The voltage at this value, is held constant for 60 seconds and then reduced to zero at the same rate used to increase the voltage. Breakdown any time during the test constitutes test failure.

## TABLE 2

## SUMMARY OF WITHSTAND TEST VOLTAGES

| WIRING METHOD OR DEVICE | WITHSTAND TEST VOLTAGE - VOLTS |
|---|---|
| Nonmetallic-sheathed cable[3] | 5000 |
| Armored cable[4] | 1500 |
| Flat conductor cable[5] | 2000 |
| Thermoplastic - insulated wires[6] types T, TW: | |
| Conductor sizes: | |
| 14-10 AWG | |
| 8-2 | 2000 |
| 1-4 | 2500 |
| 213-500 MCM | 3000 |
| 501-1000 MCM | 3500 |
| 1001-2000 MCM | 4000 |
| Receptacles/plugs[7] | 1250 |
| General use AC switch[8] | 1500 |

## 5. HIGH VOLTAGE BREAKDOWN OF RESIDENTIAL WIRING AND DEVICES

Selected wiring and some devices were subjected to breakdown voltages to determine the difference between existing withstand voltage requirements and actual voltage breakdown levels.

Breakdown tests were carried out with the cooperation and assistance of NBS's High Voltage Measurements Section (now the Applied Electrical Measurements Section). The high voltage test equipment and transformer arrangement is shown in Figure 1. The 100 kVA, 200 kV transformer was large enough to assure essentially sinusoidal 60 Hz output voltage as required by the ASTM D 149[9].

### 5.1 TEST PROCEDURE AND TEST RESULTS FOR NONMETALLIC-SHEATHED CABLE AND ARMORED CABLE TESTED IN OPEN AIR

Nonmetallic-sheathed cable (NMSC) having two #12 AWG copper conductors with equipment grounding conductor and armored cable having two #12 AWG copper conductors were tested using the test specimen configuration shown in Figure 2.

Nonmetallic-sheathed cable (type NM) and armored cable (type AC) were subjected to a designated rate of voltage rise until voltage breakdown occurred. At that time, breakdown voltage was recorded. The specimens were examined for positive indication of breakdown such as a burned hole in the conductor insulation or sheath after each test.

Test voltage rate applications in volts per second were respectively: 750, 1000, 2000, and 4000. These values were selected to determine the effect of rate of voltage rise on voltage breakdown values. These rates were applied to 12 nonmetallic-sheathed cable specimens and to 12 armored cable specimens with three specimens used at each rate. These rates are much lower than those recorded in Table 1. However, these lower rates show a trend of voltage breakdown level related to rates similar to those used in ASTM dielectric strength tests of electrical insulating materials at commercial power frequencies[9].

Results obtained from the tests are shown in Tables 3 and 4. In each case, failure occurred near the center of the specimen and was indicated by burned conductor insulation. Burned conductor insulation was usually visible only when the sheath was removed.

### 5.2 TEST PROCEDURE AND TEST RESULTS FOR NONMETALLIC-SHEATHED CABLE TESTED IN WATER

The NMSC test of section 5.1 using the test setup in Figure 3 was repeated with the specimen immersed in water. This test is similar to the dielectric withstand voltage test as it appears in the UL Standard 719, Nonmetallic-Sheathed Cables[3], except that the specimens were subjected to increasing rates of voltage rise until voltage breakdown occurred, and specimens were immersed in tap water at room temperature

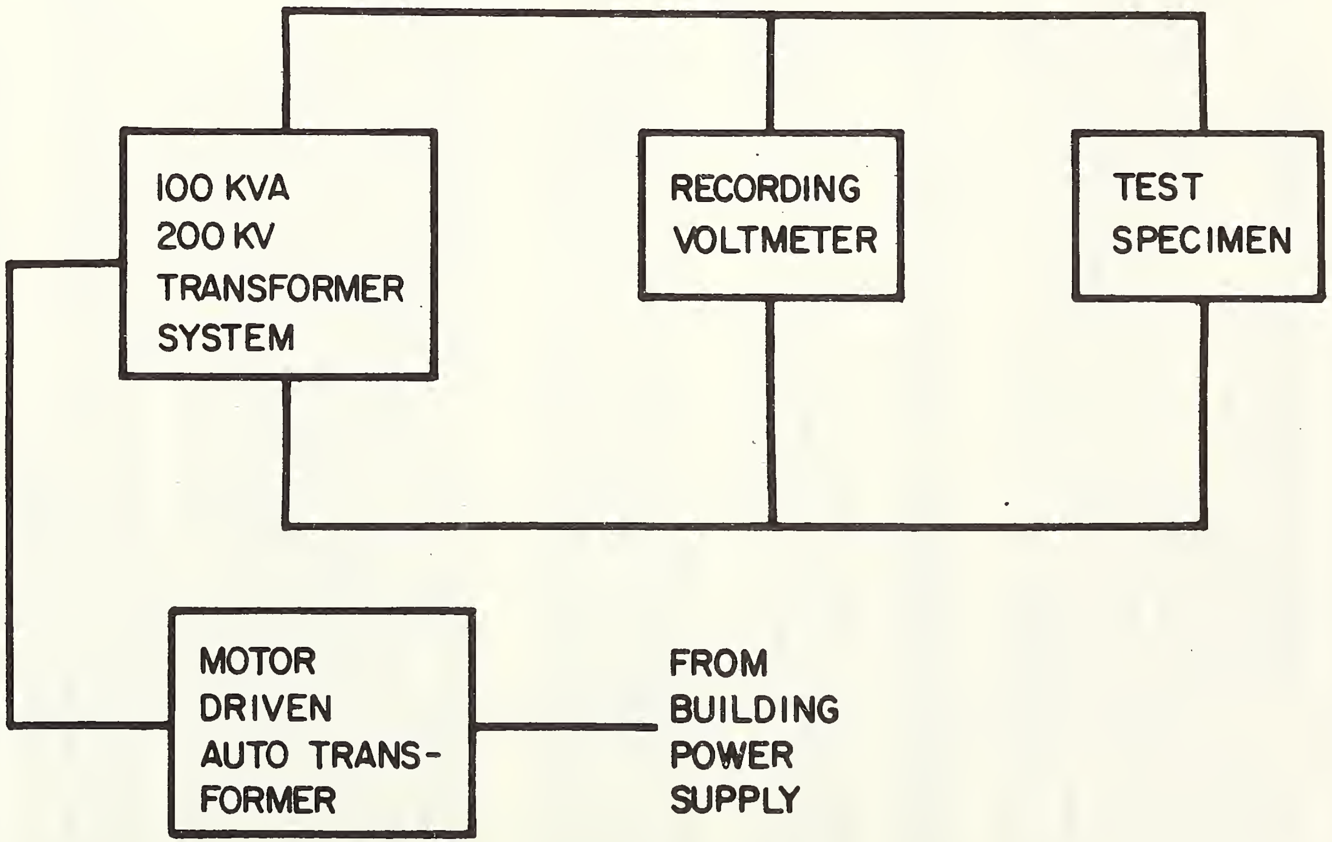


Figure 1. High Voltage Test Block Diagram

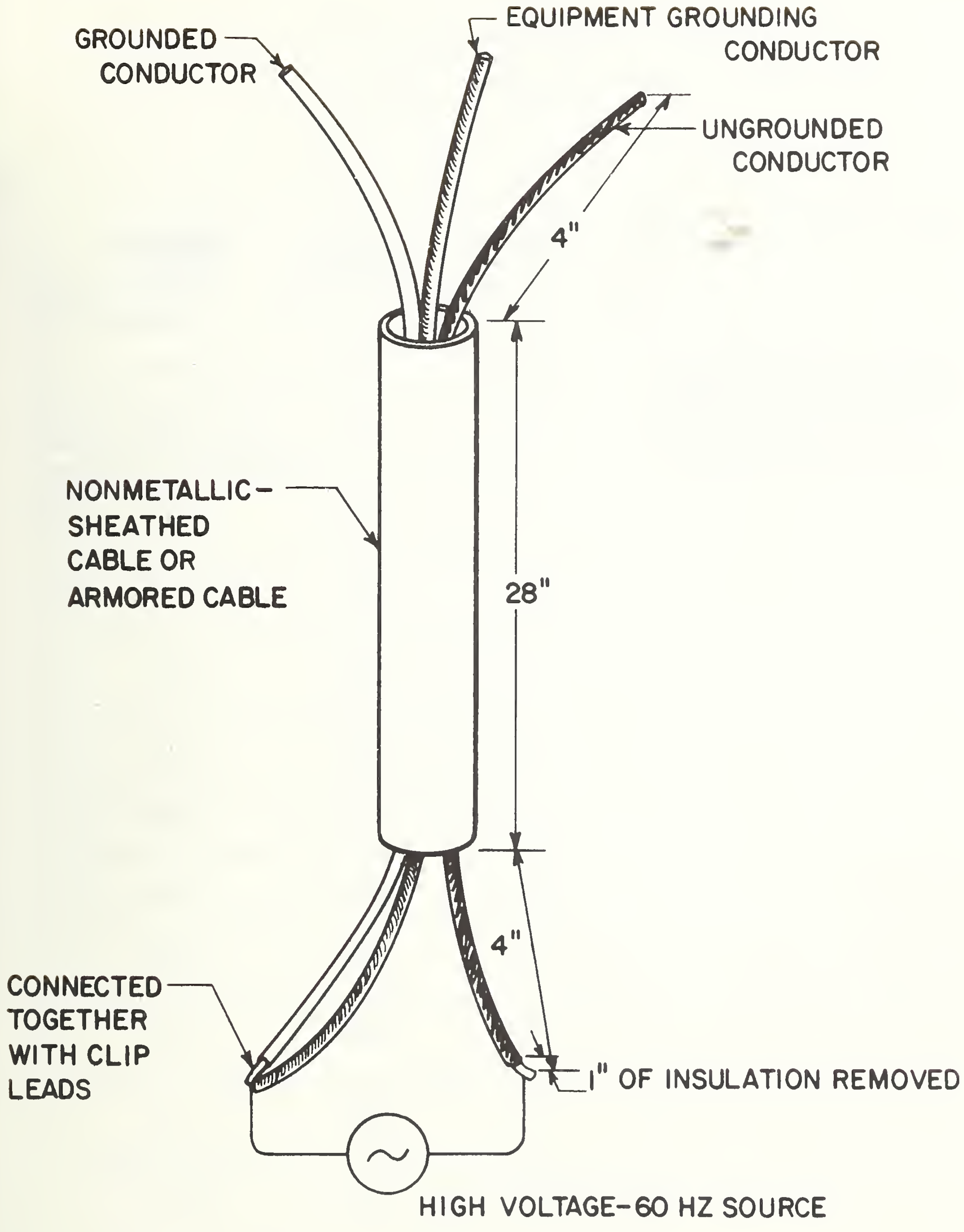


Figure 2. Nonmetallic-Sheathed Cable Test in Air at Room Temperature

TABLE 3

NONMETALLIC-SHEATHED CABLE IN AIR -

VOLTAGE BREAKDOWN VALUES

| DESCRIPTION OF TEST SPECIMEN | SPECIMEN NO. | RATE OF VOLTAGE RISE - V/s | BREAKDOWN VOLTAGE - kV |
|---|---|---|---|
| Nonmetallic-sheathed cable (two #12 AWG solid copper conductors with grounding conductor) tested in open air as shown in Figure 2. | 1 | 750 | 29.5 |
| | 2 | 750 | 29.5 |
| | 3 | 750 | 30.0 |
| | 4 | 1000 | 30.0 |
| | 5 | 1000 | 32.5 |
| | 6 | 1000 | 31.0 |
| | 7 | 2000 | 33.0 |
| | 8 | 2000 | 33.0 |
| | 9 | 2000 | 34.0 |
| | 10 | 4000 | 31.0 |
| | 11 | 4000 | 35.0 |
| | 12 | 4000 | 35.0 |

TABLE 4

ARMORED CABLE IN AIR -

VOLTAGE BREAKDOWN VALUES

| DESCRIPTION OF TEST SPECIMEN | SPECIMEN NO. | RATE OF VOLTAGE RISE - V/s | BREAKDOWN VOLTAGE - kV |
|---|---|---|---|
| Armored cable (two #12 AWG solid copper conductors) tested in open air as shown in Figure 2. | 13 | 750 | 27.0 |
| | 14 | 750 | 26.0 |
| | 15 | 750 | 21.5 |
| | 16 | 1000 | 29.0 |
| | 17 | 1000 | 29.0 |
| | 18 | 1000 | 30.0 |
| | 19 | 2000 | 31.5 |
| | 20 | 2000 | 31.5 |
| | 21 | 2000 | 32.5 |
| | 22 | 4000 | 31.0 |
| | 23 | 4000 | 32.5 |
| | 24 | 4000 | 33.0 |

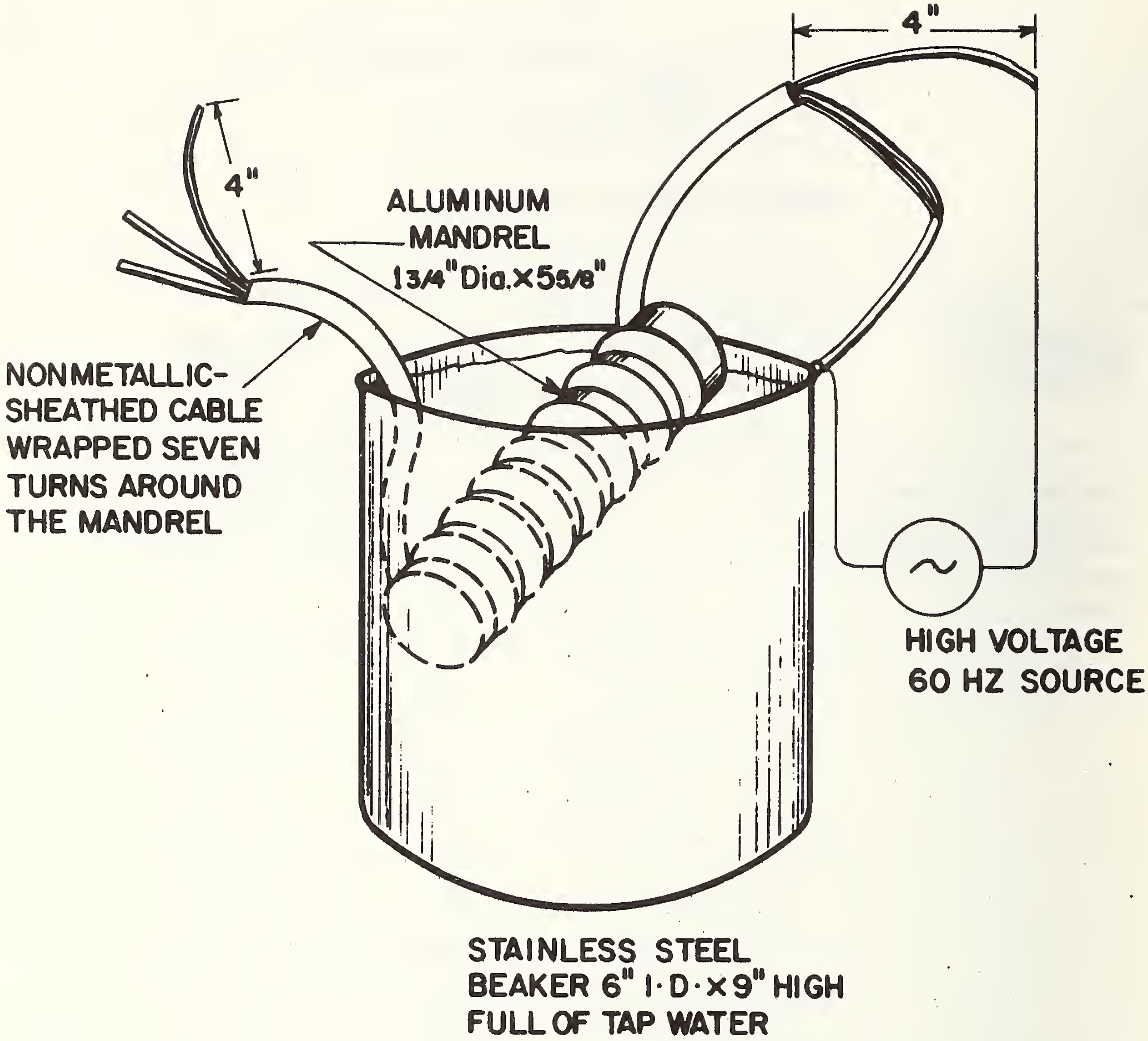


Figure 3. Nonmetallic-Sheathed Cable Test in Water at Room Temperature

for 48 hours instead of the 24-hour immersion required by the UL 719. No particular water quality is required by the referenced standard. Test results are given in Table 5. These results show very little difference from the results in Table 3 for tests in open air. In each case, the conductor insulation was burned, which indicated a positive break. This break was usually visible only when the sheath was removed.

## 5.3 TEST PROCEDURE AND TEST RESULTS FOR FLAT CONDUCTOR CABLE

The National Aeronautics and Space Administration (NASA) developed flat conductor cable (FCC) for aerospace applications. As a part of their technology spin-off program, FCC was introduced by NASA as a proposed surface-mounted wiring system for residential and commercial general purpose branch circuits using 120 V, 20 A single-phase current.

The residential application uses FCC in a baseboard configuration. This configuration has three solid copper conductors each 0.0125 inch thick and 0.4 inch wide. The overall width of the cable is 2 inches. The individual conductors are insulated with polyhetylene terephthalate (Mylar) insulation [10,11,12].

The commercial application uses FCC in an "under-carpet" configuration in office spaces to serve convenience outlets[5]. The FCC is applied directly to the floor by way of a double backed adhesive tape which is slightly wider than the flat cable. An 0.008-inch thick by 5-inch wide grounded steel sheet or top shield is placed on top of the FCC and secured by the tape. The under-carpet FCC is similar to that used in the baseboard except that it uses conductors which are 0.009 inch thick and 0.6 inch wide and the overall FCC width is about 2.5 inches. The cross-sectional areas of baseboard and under-carpet conductors are approximately the same as #12 AWG round conductors rated at approximately 20 amperes. FCC of the baseboard system and under-carpet system types were tested in open air using the configurations shown in Figures 4 and 5. Rates of voltage rise in volts per second were applied to configurations as follows: 750, 1000, 2000, and 3500. Three specimens were tested at each rate of voltage rise. Breakdown voltage was recorded. Voltage breakdown in all FCC specimens was indicated by a burned track in the insulation between conductors. Voltage breakdowns for baseboard and under-carpet specimens are shown in Tables 6, 7, and 8.

## 5.4 TEST PROCEDURE AND TEST RESULTS FOR PARTIAL BRANCH CIRCUITS

Side-wire (wire-binding screw) and back-wire (push-in) receptacles were tested in the configuration shown in Figure 6. Voltage application rates of 750 volts/second and 3500 volts/second were applied to three specimens at each voltage rate until breakdown occurred, as shown in Tables 9 and 10. It appeared that the dielectric material in the receptacle was damaged.

TABLE 5

NONMETALLIC-SHEATHED CABLE IN WATER -

VOLTAGE BREAKDOWN VALUES

| DESCRIPTION OF TEST SPECIMEN | SPECIMEN NO. | RATE OF VOLTAGE RISE - V/s | BREAKDOWN VOLTAGE - kV |
|---|---|---|---|
| Nonmetallic-sheathed cable (two #12 AWG solid copper conductors with grounding conductor) tested in water as shown in Figure 3. | 25 | 750 | 28.0 |
| | 26 | 1000 | 29.0 |
| | 27 | 2000 | 26.0 |
| | 28 | 3500 | 37.0 |
| Nonmetallic-sheathed cable (two #14 AWG solid copper conductors with grounding conductor). | 29 | 750 | 31.0 |
| | 30 | 1000 | 30.0 |
| | 31 | 2000 | 35.5 |
| | 32 | 3500 | 37.5 |

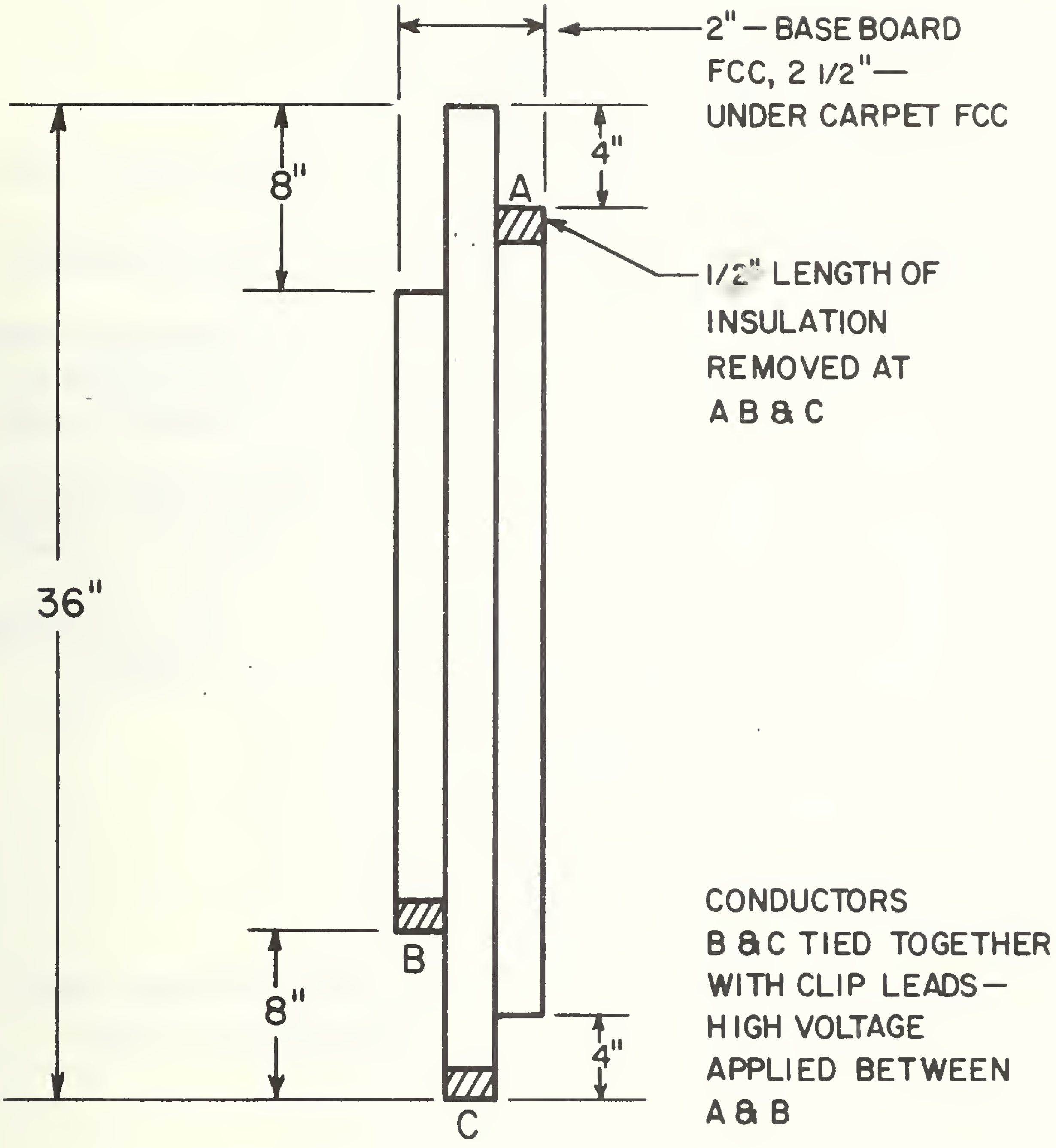


Figure 4. Flat Conductor Cable Baseboard or Under-Carpet Specimens

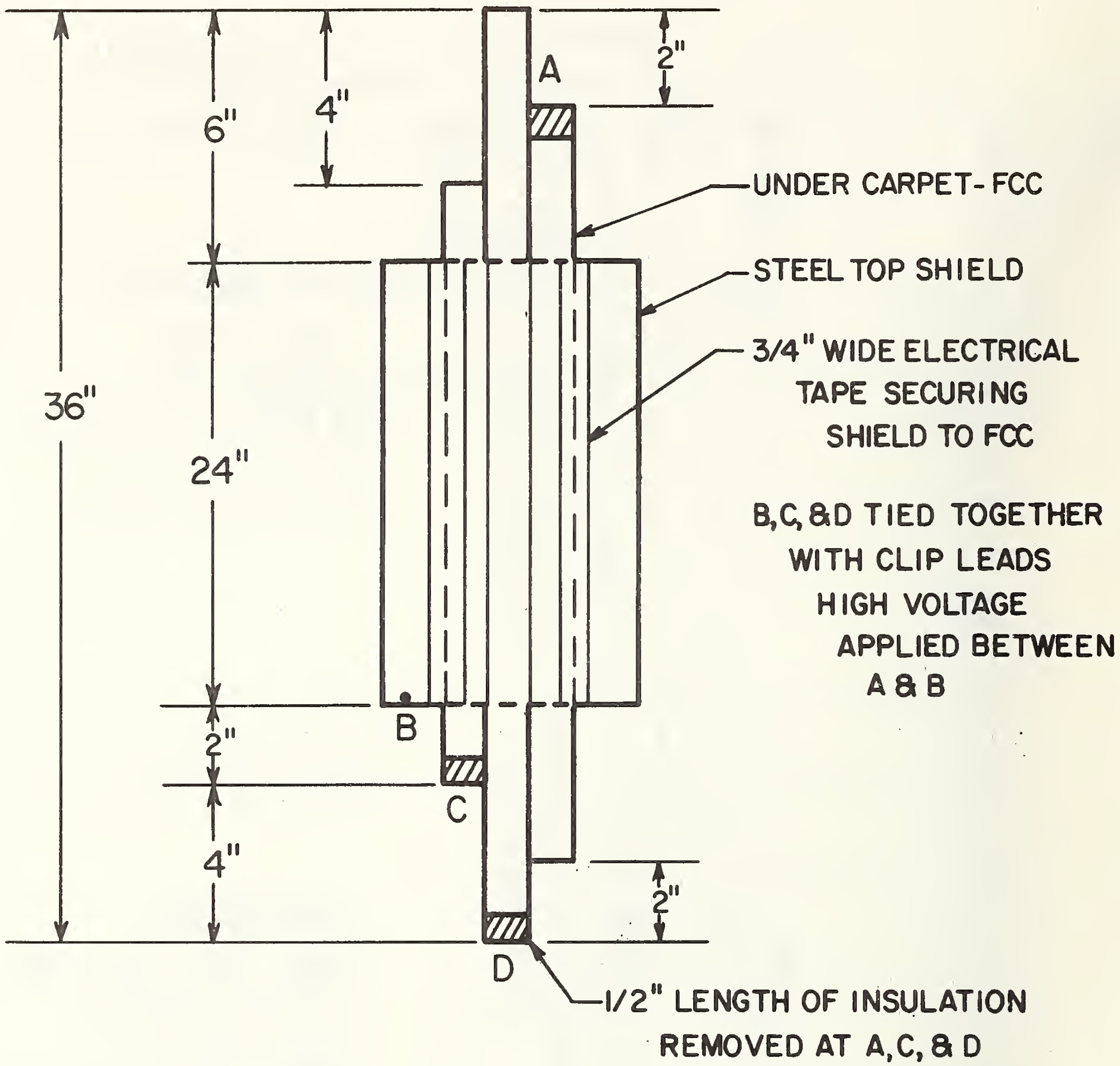


Figure 5. Flat Conductor Cable Under-Carpet Specimen with Top Shield

TABLE 6

FLAT CONDUCTOR CABLE-BASEBOARD

VOLTAGE BREAKDOWN VALUES

| DESCRIPTION OF TEST SPECIMEN | SPECIMEN NO. | RATE OF VOLTAGE RISE - V/s | BREAKDOWN VOLTAGE - kV |
|---|---|---|---|
| Flat conductor cable (0.4 inch wide by 0.0125 inch thick conductors) of the type used in the baseboard system tested in open air as shown in Figure 4. | 33 | 750 | 19.0* |
| | 34 | 750 | 20.0 |
| | 35 | 750 | 21.0 |
| | 36 | 1000 | 19.5 |
| | 37 | 1000 | 22.0 |
| | 38 | 1000 | 22.0 |
| | 39 | 2000 | 22.5 |
| | 40 | 2000 | 23.5 |
| | 41 | 2000 | 23.0 |
| | 42 | 3500 | 23.0 |
| | 43 | 3500 | 23.0 |
| | 44 | 3500 | 23.0 |

* No hole or material decomposition was found.

TABLE 7

FLAT CONDUCTOR CABLE UNDER-CARPET

VOLTAGE BREAKDOWN VALUES

| DESCRIPTION OF TEST SPECIMEN | SPECIMEN NO. | RATE OF VOLTAGE RISE - V/s | BREAKDOWN VOLTAGE - kV |
|---|---|---|---|
| Flat conductor cable (0.6 inch wide by 0.009 inch thick conductors) of the type used in the under-carpet wiring system tested in open air as shown in Figure 4. | 45 | 750 | 9.5 |
| | 46 | 750 | 10.5 |
| | 47 | 750 | 9.5 |
| | 48 | 1000 | 10.0 |
| | 49 | 1000 | 10.5 |
| | 50 | 1000 | 10.0 |
| | 51 | 2000 | 15.0 |
| | 52 | 2000 | 15.0 |
| | 53 | 2000 | 12.5 |
| | 54 | 3500 | 16.0 |
| | 55 | 3500 | 12.0 |
| | 56 | 3500 | 12.5 |

TABLE 8

UNDER-CARPET FCC TESTS INCLUDING TOP SHIELD

VOLTAGE BREAKDOWN VALUES

| DESCRIPTION OF TEST SPECIMEN | SPECIMEN NO. | RATE OF VOLTAGE RISE - V/s | BREAKDOWN VOLTAGE - kV |
|---|---|---|---|
| Flat conductor cable (0.6 inch wide by 0.009 inch thick conductors) including 5 inch wide by 0.008 inch thick steel top shield as used in the under carpet wiring system tested in open air as shown in Figure 5. | 57 | 750 | 6.5 |
| | 58 | 750 | 5.3 |
| | 59 | 750 | 4.6 |
| | 60 | 1000 | 6.0 |
| | 61 | 1000 | 5.6 |
| | 62 | 1000 | 5.1 |
| | 63 | 2000 | 6.0 |
| | 64 | 2000 | 6.3 |
| | 65 | 2000 | 8.4 |
| | 66 | 3500 | 6.5 |
| | 67 | 3500 | 6.4 |
| | 68 | 3500 | 5.6 |

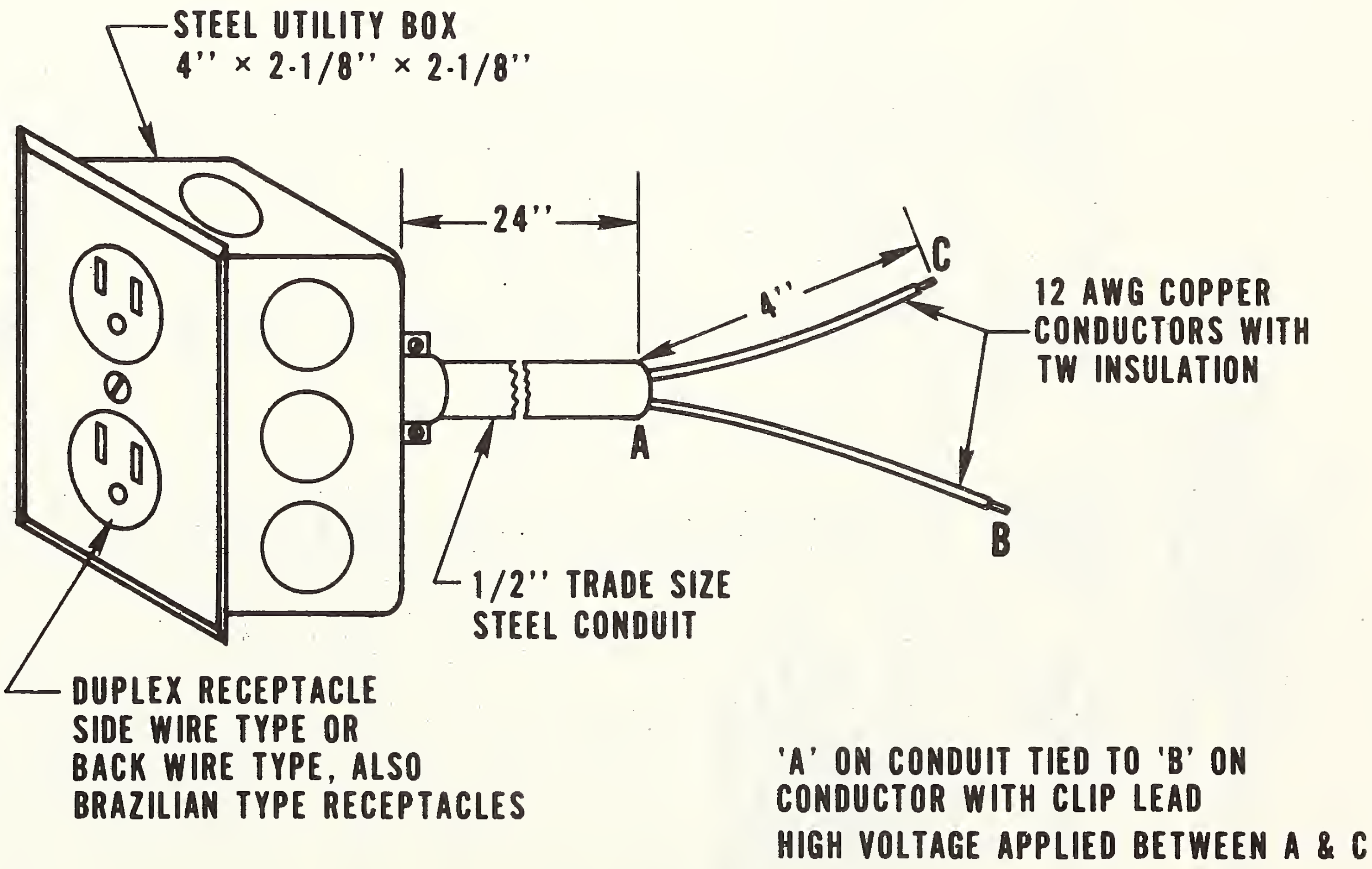


Figure 6. Partial Branch Circuit

6. TEST SUMMARY

1. The voltage breakdown for nonmetallic-sheathed cable (NMSC) and armored cable (BX) test specimens greatly exceeded the standard voltage withstand test voltage values used by industry.

| Cable | Breakdown Voltage Range (kV) | Standard Voltage Withstand (kV) |
|---|---|---|
| NMSC | 26 - 37.5 | 5 |
| BX | 21.5 - 33 | 1.5 |

Figure 7 shows the trend of increasing breakdown voltage values as voltage application rate increases.

2. The flat conductor cables of under-carpet type without shield experienced voltage breakdown at voltages less than half the voltage breakdown values for nonmetallic-sheathed cable and armored cables, and FCC baseboard failed at about the lowest armored cable voltage level.

| Breakdown Voltage Range (kV) | | | |
|---|---|---|---|
| NMSC | BX | FCC Under Carpet | FCC Baseboard |
| 26 - 37.5 | 21.5 - 33 | 9.5 - 16 | 19.5 - 23 |

The baseboard FCC failed at about twice the voltage level of the under-carpet system FCC.

The addition of the top shield to the under-carpet FCC reduced the voltage breakdown of this FCC by about one-half.

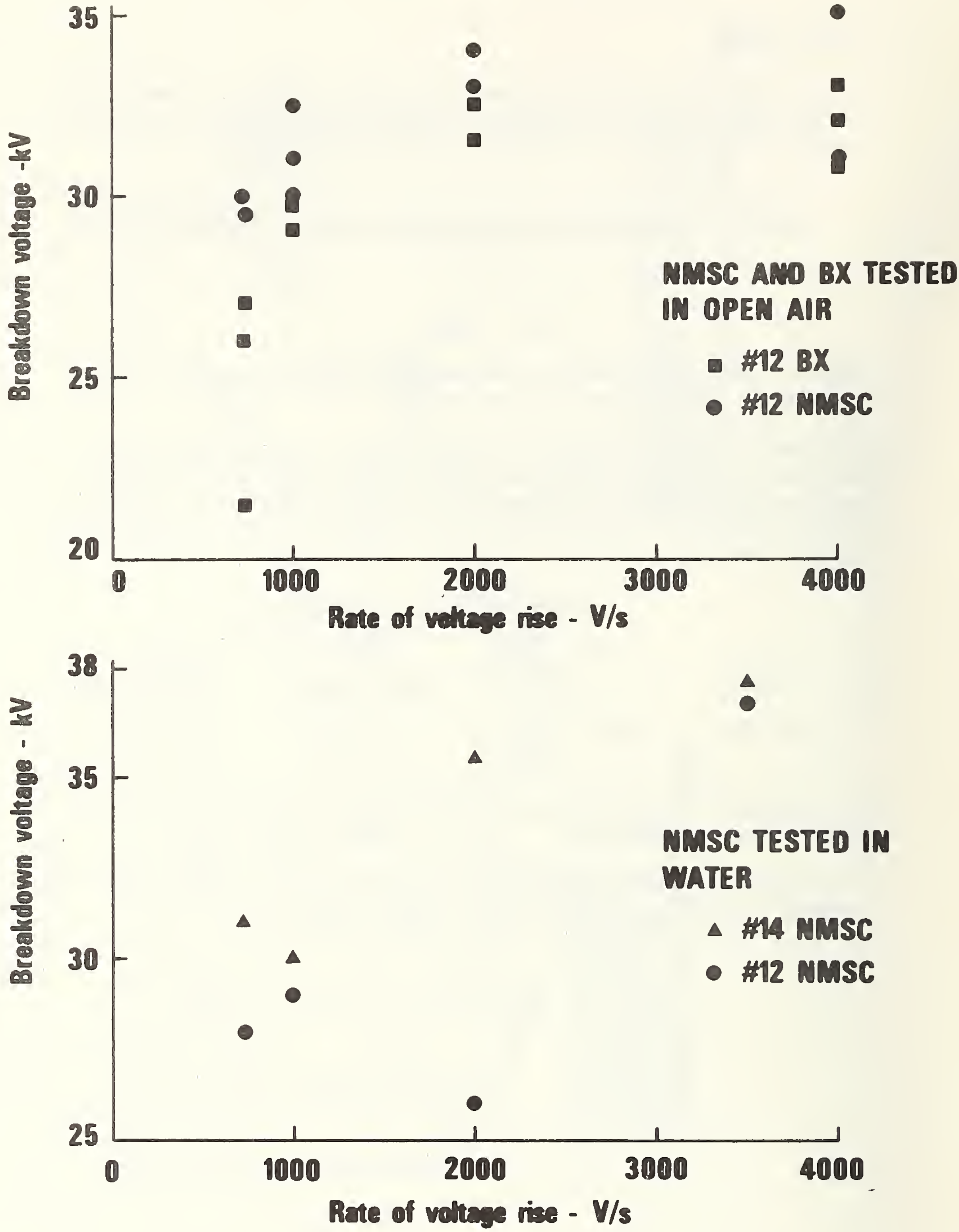


Figure 7. Breakdown-voltages for Nonmetallic Sheathed Cable (NMSC) and Armored Cable (BX)

Breakdown Voltage Range (kV)

| FCC Under Carpet Without Shield | FCC Under Carpet With Shield |
|---|---|
| 9.5 - 16 | 4.6 - 8.4 |

Figure 8 illustrates voltage breakdown values and voltage application rates for the flat conductor cables.

3. American back-wire receptacles broke at considerably lower voltage levels than American side-wire receptacles.

Breakdown Voltage Range (kV)

| Back-wire | Side-Wire (American) | Side Wire (Brazilian) |
|---|---|---|
| 5.8 - 6.5 | 7.7 - 8.6 | 4.5 - 7.7 |

With increasing rate of voltage application, cable breakdown voltage increased, but the breakdown voltage of receptacles tended to decrease with increasing rate. See Figure 9.

4. All wiring and devices broke at voltages in excess of the highest surge voltage recorded in a house [1].

| Highest Voltage Recorded in a House (kV) | Lowest Cable Breakdown Voltage (kV) | Lowest Receptacle Breakdown Voltage (kV) |
|---|---|---|
| 2.5 | 4.6 (Under carpet with top shield) | 4.5 (Brazilian receptacle) |

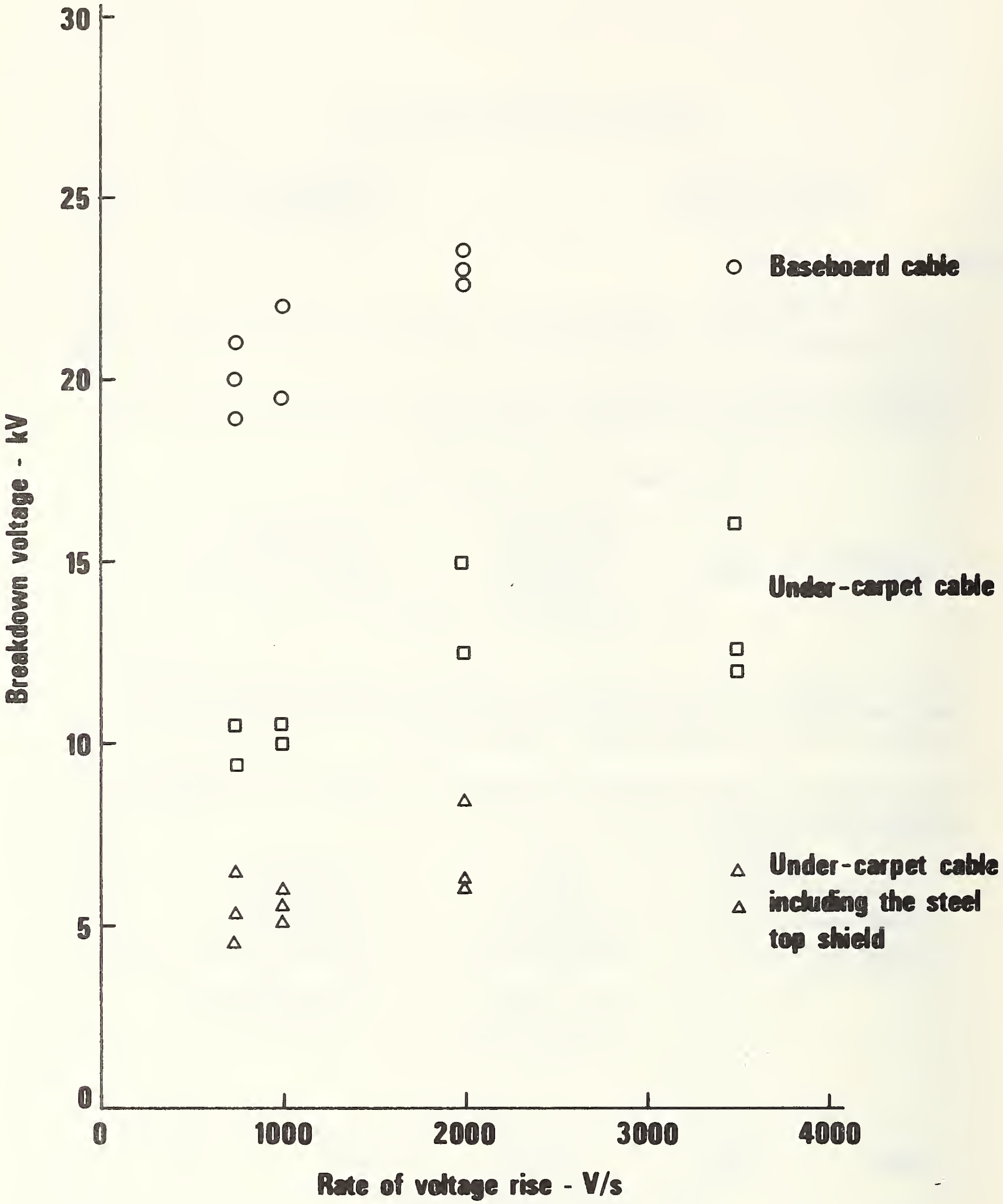


Figure 8. Comparison of Flat Conductor Cable Breakdown Voltages

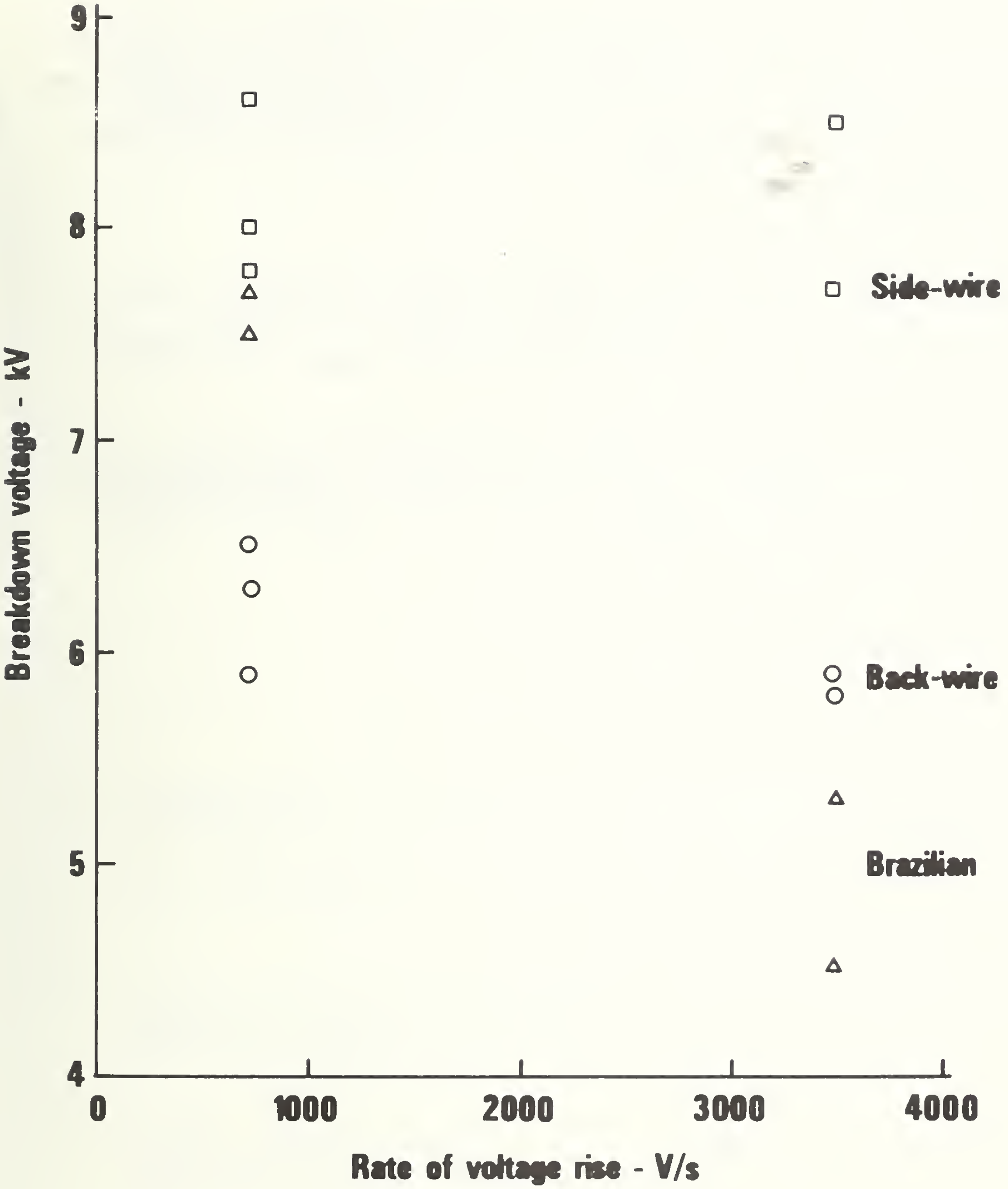


Figure 9. Comparison of Receptacle Breakdown Voltages

## 7. CONCLUSIONS

Standard voltage withstand test methods may not simulate the rate of rise of voltage surges that wiring and devices may encounter during actual performance within dwellings. Breakdown voltages for receptacles tended to decrease with increasing voltage rate of rise; therefore, voltage withstand test methods for receptacles may imply better performance than exists in dwellings.

## 8. RECOMMENDATIONS

Waveforms of the type recorded in houses should be applied to cable specimens and devices under laboratory conditions to determine a more realistic simulation of voltage breakdown levels. See Table 1, page 2. The results may also indicate whether new withstand test methods and voltages are required.

The effects of high voltage breakdown of residential wiring and devices with 60 Hz power following should be investigated. Tests should be performed under various environmental conditions to study the effects of temperature, sea air, and aging.

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4. TITLE AND SUBTITLE

AN EXPLORATORY STUDY OF DIELECTRIC BREAKDOWN VOLTAGES FOR RESIDENTIAL WIRING

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16. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)*

Residential electric circuits are subjected to surge voltages resulting from load switching in buildings, and from external causes such as lightning. Laboratory test data are presented on high voltage breakdown values for armored cable (type AC cable), nonmetallic-sheathed cable (type NM), flat conductor cable, and duplex receptacles. Dielectric withstand voltage test requirements in current standards for residential wiring and wiring devices vary over a wide range. In some cases, the standard test voltage values for both wiring and wiring devices are less than surge voltages recorded on wiring in residences. Also, field-recorded voltage wave forms and rates of their application are different from those used in standard withstand voltage tests.



17. KEY WORDS *(six to twelve entries; alphabetical order; capitalize only the first letter of the first key word unless a proper name; separated by semicolons)*

Dielectric breakdown voltages; dielectric withstand voltage tests; residential wiring; surge voltages.


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