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STANDARDS

Interface Practices Subcommittee

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Test Method for Dielectric Withstand of Coaxial Cable

NOTICE

Table of Contents

Title **Page Number**

1. Introduction

1.1. Executive Summary

This test method is intended for to the performance of Dielectric Strength Tests upon coaxial cables, in a laboratory setting. This is not a test intended for field application.

1.2. Scope

The purpose of this document is to provide a test standard for detecting flaws in the insulation (sometimes referred to as the dielectric) of a completed coaxial cable. This test, usually referred to as a Hipot or Dielectric Withstand Test, verifies that the insulation can withstand a specified voltage applied between the center conductor and outer conductor for a specified time interval, without resulting in a dielectric breakdown. Upon successful completion of this Hipot test, it can be concluded that the inner and outer conductors are properly insulated from each other.

Under normal operating conditions there will be a small amount of leakage current within the dielectric of any product (in this case the insulation between the center and outer conductors of a coaxial cable). However, if 2 conductors are not properly insulated from each other, the application of high voltage can cause dielectric breakdown. Dielectric breakdown results in excessive current flow that is substantially larger than the nominal leakage current for the dielectric material being tested.

Traditionally, either an AC or DC voltage may be used for the test. The DC voltage used should be the peak of the equivalent AC (RMS) voltage, or 1.414 times the AC (RMS) voltage.

1.3. Benefits

The Test Procedure for Dielectric Withstand of Coaxial Cables, when executed per this procedure, will yield confidence and assurance of the insulation properties of the dielectric medium used to separate the inner conductor and outer conductor components. Use of this test method provides user a means to verify design acceptance and reliability.

1.4. Intended Audience

The intended audience for this test method, are cable manufactures and end-users with proper laboratories and safety measures in place to safely perform test.

1.5. Areas for Further Investigation or to be Added in Future Versions

No further areas of investigation or versions are foreseen at this time.

2. Normative References

2.1. SCTE References

- No normative references are applicable.

2.2. Standards from Other Organizations

- No normative references are applicable.

2.3. Published Materials

- No normative references are applicable.

3. Informative References

The following documents might provide valuable information to the reader but are not required when complying with this document.

3.1. SCTE References

- No informative references are applicable.

3.2. Standards from Other Organizations

- EN50191 - Erection and Operation of Electrical Test Equipment
- NFPA 70E - Standard for Electrical Safety in the Workplace
- OSHA Standards for General Industry 29 CFR - Part 1910

3.3. Published Materials

- No informative references are applicable.

4. Compliance Notation

shall	This word or the adjective "***required***" means that the item is an absolute requirement of this document.
shall not	This phrase means that the item is an absolute prohibition of this document.
forbidden	This word means the value specified shall never be used.
should	This word or the adjective "*recommended*" means that there may exist valid reasons in particular circumstances to ignore this item, but the full implications should be understood and the case carefully weighted before choosing a different course.
should not	This phrase means that there may exist valid reasons in particular circumstances when the listed behavior is acceptable or even useful, but the full implications should be understood and the case carefully weighed before implementing any behavior described with this label.
may	This word or the adjective "*optional*" means that this item is truly optional. One vendor may choose to include the item because a particular marketplace requires it or because it enhances the product, for example; another vendor may omit the same item.
deprecated	Use is permissible for legacy purposes only. Deprecated features may be removed from future versions of this document. Implementations should avoid use of deprecated features.

5. Abbreviations and Definitions

5.1. Abbreviations

AC	alternating current

DC	direct current
GFI	ground fault interrupter
kV	kilovolt
Hz	hertz
mA	milliampere
µF	microfarad
pF	picofarad (capacitance)
Xc	total capacitive reactance of the cable
Ic	leakage current, capacitive
Ir	leakage current, reactance

5.2. Definitions

- No definition references are applicable.

6. AC vs. DC Hipot Testing

AC and DC Hipot tests have inherent advantages and disadvantages depending on the application they are used for. Some advantages of an AC Hipot test include: an AC voltage stresses a cable's insulation in both polarities; it is unnecessary to allow the coaxial cable to discharge; it is unnecessary to apply an AC voltage gradually. Some advantages of a DC Hipot test include: a DC Hipot doesn't need to have a high output current capacity; the application of a DC voltage allows the Hipot to clearly display true leakage current; a DC Hipot can be used to test highly capacitive products using far less power.

A Hipot test is used to apply high voltage to the insulation of a coaxial cable and make sure that the leakage current produced is limited to an acceptable level. This leakage current is limited by the cable's shunt impedance resulting from the parallel capacitance and the insulation resistance between the two conductors.

A big advantage of the DC Hipot test is that the current due to the capacitance falls to zero when the cable is exposed to a constant DC voltage. Therefore, the Hipot measures and displays only the true resistive leakage current. Thus, the test operator can be assured that the capacitive reactance isn't coming into play when performing a DC Hipot test. However, there is another current component to consider when applying a DC voltage to a coaxial cable. As the DC voltage applied increases, there is a current needed to "charge" the capacitance of the cable up to the test voltage. This charging current will be much higher than the actual leakage current of the cable's insulation. So, it is necessary to ramp up the DC voltage slowly so that the charging current doesn't become so great as to cause a false failure of the Hipot. Once the cable is fully charged, the charging current will fall to zero and the only remaining current component will be the real leakage current.

When an AC Hipot is used, a capacitive current component is produced along with the resistive leakage current (the sum of which is known as the total current). An AC Hipot test will measure and display the total current. The reactive capacitance of a coaxial cable usually is much more significant than its resistance. Thus, the approximate total current can be assumed to be a good indication of the real leakage current.

7. Equipment

As discussed above, the Hipot or Dielectric Withstand Tester is the device needed to check for flaws in the insulation of coaxial cable. With a wide range of Hipot testers available, the test operator should make sure the equipment selected incorporates adequate safety provisions and be properly sized for the voltage, trip current, and timing function capabilities for the test to be conducted. Such features include, but are not limited to:

- 5 kV AC/DC maximum output voltage
- GFI (ground fault interrupter) protection
- 20 mA AC/5 mA DC adjustable trip current
- Adjustable Electronic Ramping
- Regulated output voltage

Audible/Visual failure indicator
Automatic voltage discharge
LCD Display
Adjustable Electronic Dwell Timer

An example of a commercially available Hipot tester that meets these specifications is the Associated Research HyPot III 3765, or equivalent.

Methods for determining the proper trip currents and voltage are to be conducted as part of verification of the equipment, before use. This is necessary to ensure the equipment settings are such, to indicated a failure at the prescribed trip This can be achieved via several methods. These methods are as follows, but not limited to:

- External resistor method
- External switch box method
- Internal verification checks – *more common to the latest Hi-Pot testers in the market.*

** Always refer to the manufacturer's literature and application notes as to how to perform these verification tests and checks. Lead connections can be confusing and varying from different manufacturers. The actual trip current is typically specified in the specification for the product under test and examples are provided in the Appendix, sections 11.2 and 11.3.*

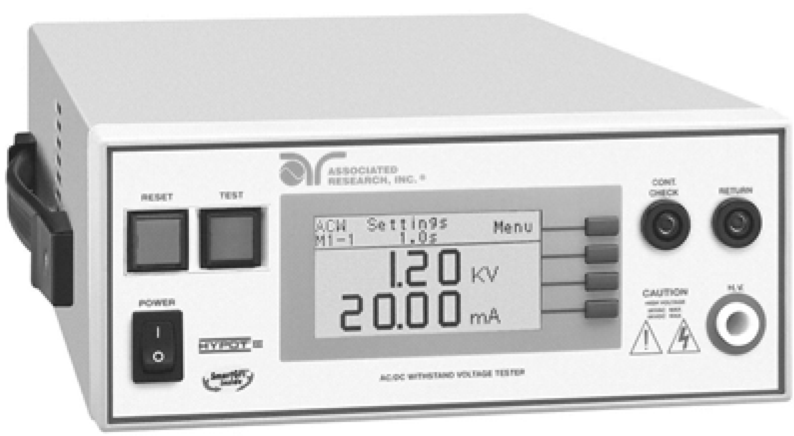

Figure 1 – Hipot Tester

Ensure that personnel are properly trained and instructed for the proper operation of the test device. For more information on this subject please refer to the following documents:

- ·EN50191 Erection and Operation of Electrical Test Equipment
- ·NFPA 70E Standard for Electrical Safety in the Workplace

Follow all safety instructions provided by manufacturer and applicable OSHA, or other regulatory requirements.

8. Test Samples

Unless otherwise specified, the test will be conducted on finished shipping lengths of coaxial cable or on master reels that will be cut into shorter lengths for shipping.

A ½" minimum length of center conductor and outer conductor of each cable end is exposed to facilitate connection to the Hipot test leads.

To decrease the occurrence of arcing (or a visible spark) from the center conductor to the outer conductor, the outer conductor may be removed approximately ¼ inches to expose the insulation. If braid ends are present, they should be folded back over the jacket and away from the center conductor. Refer to the following connection diagram:

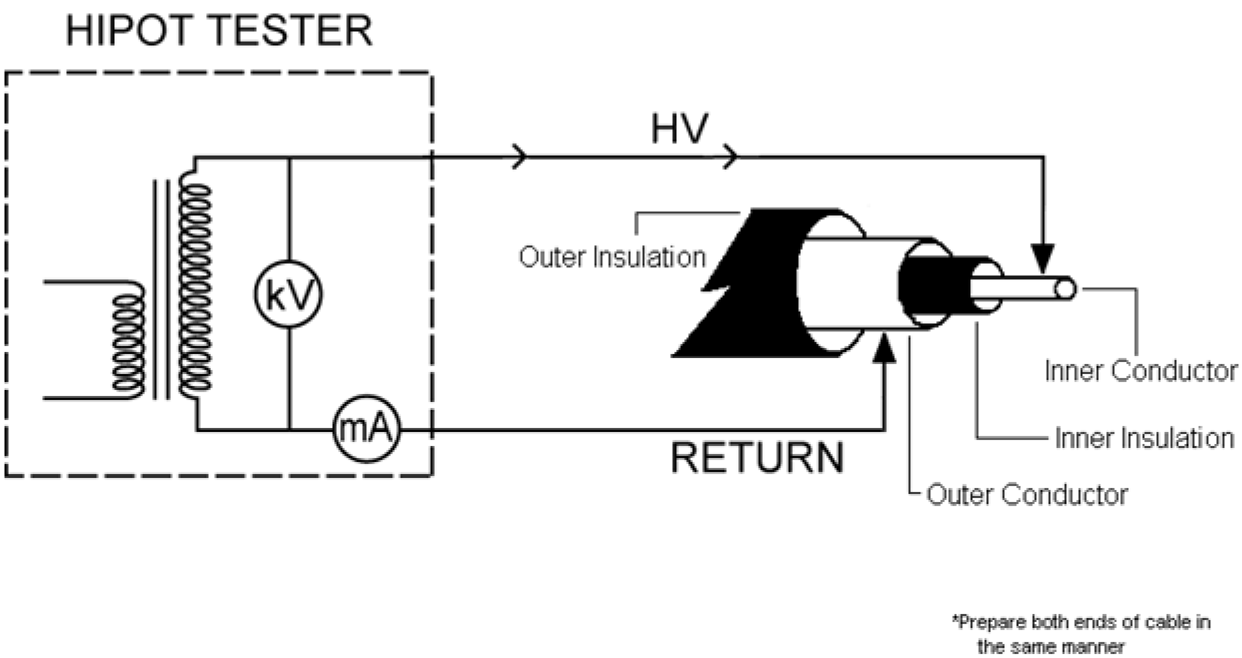

Figure 2 - Connection Diagram

Note: Most Hipot testers are now equipped with arc detection circuits. In order to prevent false failures, make sure that arc detection is enabled. If this feature isn't available and/or is disabled and a spark is seen or heard at either of the ends of the cable during the test, re-prepare the cable to expose additional dielectric and repeat the test.

9. Test Method

CAUTION: Care must be taken not to allow anyone near the exposed ends of the test leads and both ends of the cable during the application of the test voltage. Safety measures must comply with all recommendations supplied by the equipment manufacturer and any federal, state and local codes that may apply. Reference should be made to OSHA Standards for General Industry 29 CFR Part 1910 including but not limited to paragraph 1910.335 with regards to protective equipment and alerting techniques.

In order to perform the Hipot test correctly, connect the RETURN lead of the tester to the exposed portion of the outer conductor and the HOT lead of the tester to the exposed center conductor.

Program the Hipot tester for the correct voltage, current, and test duration settings. Unless otherwise specified, the test voltage will be 1000 VAC or 1414 VDC and the test duration will be 1 minute (60 seconds). The appropriate current trip point should be set higher than the approximate calculated leakage current of the cable being tested. As the majority of the impedance of the cable is capacitive, the test operator can perform a calculation to determine the approximate nominal leakage current of the cable under test during an AC Hipot test. The formula for the approximate total capacitive reactance of the cable under test is as follows:

$$Xc = 1 / (2f\pi C)$$

Where Xc is the total capacitive reactance of the cable, C is the total capacitance of the cable (capacitance per foot multiplied by the total number of feet being tested) and f is the frequency of the AC voltage applied. Once the capacitive reactance has been calculated, it is easy to find the nominal leakage current using the formula below:

$$I \approx V / Xc$$

Where I is the approximate nominal leakage current, V is the applied test voltage (usually 1000 VAC) and Xc is the total capacitive reactance.

Once the nominal leakage current of the cable under test has been approximated, it can be used to provide settings for the current trip point of the Hipot.

Once all the appropriate settings have been programmed into the Hipot and the correct connections have been made, the test operator can execute the Hipot test.

10. Pass/Fail Criteria

Once the test is performed the Hipot will indicate whether the cable under test has passed or failed. A good cable will have enough insulation to withstand the applied voltage for the full duration of the test. In this case the leakage current will not exceed the Hipot’s current trip point and the Hipot will give a PASS indication. If the leakage current of the cable under test exceeds the current trip point setting of the Hipot, the Hipot will give a FAIL indication and the test operator can conclude that the cable is bad.

*The operator should make sure that no sparks are present during the test. As stated above, the presence of a spark indicates that arcing has occurred and may cause a false failure.

11. APPENDIX

11.1. Relevant AC Equations

Total current of a coaxial cable:

$$It = Ir + Ic$$

*In the case of a coaxial cable, Ic can be assumed to be much larger than Ir therefore:

$$It \approx Ic$$

Approximate capacitive reactance of a coaxial cable:

$X_c = 1 / (2f\pi C)$

Approximate total leakage current:

$I_t \approx I_c = V / X_c$

11.2. AC Hipot Test Example

A test operator needs to perform an AC Hipot test on 1000 feet of coaxial cable. After connecting the Hipot to the ends of the cable to be tested, the operator needs to determine the appropriate trip point for the Hipot test. The test operator determines that cable has a rated capacitance of 15 pF/ft and the test will be performed at 1000 VAC at a frequency of 60 Hz.

First, the test operator needs to find the total capacitance of the cable. For 1000 feet of cable, with a capacitance of 15 pF/ft., the total capacitance of the cable is:

$(1000 \text{ ft.}) * (15 \text{ pF/ft.}) = 0.015\ \mu F$

Once the total capacitance is found, the test operator can find the approximate total capacitive reactance of the cable using the formula above. Knowing that the test will be performed on a cable with a capacitive reactance of 0.015 µF at a frequency of 60 Hz, the equation will look as follows:

$X_c = 1 / [(2)*(60)*(\pi)*(0.000000015)] = 176{,}838\ \Omega$

Knowing the capacitive reactance of the coaxial cable under test and assuming the resistance of the cable to be infinite, the operator can now find the approximate total current of the cable.

$I \approx (1000) / (176{,}838) \approx 5.65 \text{ mA}$

Since the approximate leakage current the test operator expects is 5.65 mA, the Hipot trip current should be set slightly higher. The test operator sets the trip current for a level of 10 mA. As long as the leakage current of the cable under test remains lower than 10 mA, the test operator can determine that the cable has passed the Hipot test.

11.3. DC Hipot Test Example

A test operator needs to perform a DC Hipot test on 1000 feet of coaxial cable After connecting the Hipot to the ends of the cable to be tested, the operator needs to determine the appropriate trip point for the Hipot test. The test operator determines that cable has a rated capacitance of 15 pF/ft and the test will be performed at 1414 VDC.

Since the test is applying a DC voltage, the capacitive reactance of the cable isn't a factor of the total current. Therefore it isn't necessary to calculate the capacitance of the cable under test. The Hipot will measure and display the true leakage current of the cable under test.

A good rule of thumb is to use the equivalent AC Hipot test's current trip point as a basis for the trip point in the DC test. Otherwise, just use the maximum output current level of the Hipot. This standard calls for the maximum output current of a DC Hipot to be 5 mA DC. As long as the leakage current of the cable under test remains lower than 5 mA, the test operator can determine that the cable has passed the Hipot test. In order to prevent false failures due to the charging current of the capacitance of the cable, the test operator sets up a 10 second ramp time so the voltage applied increases gradually.