ANSI C37.85-2002
Revision of
ANSI C37.85-1989

American National Standard
For Switchgear—

Alternating-Current High-Voltage Power Vacuum Interrupters— Safety Requirements for X-Radiation Limits

Secretariat:

National Electrical Manufacturers Association
Institute of Electrical and Electronics Engineers

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American National Standards Institute, Inc.

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Foreword (This Foreword is not part of American National Standard C37.85-2002.)

This standard was developed initially by a task force of the NEMA Switchgear Section as a result of an industry study undertaken at the request of the Bureau of Radiological Health in order to meet the need as set forth in Public Law 90-602, identified as Radiation Control for Health and Safety Act of 1968.

Upon completion, the initial proposal was submitted to the American National Standards Committee C37 on Power Switchgear for further development and to obtain a consensus as an American National Standard. It was approved on April 28, 1972 as American National Standard for Safety Requirements for X-Radiation Limits for AC High-Voltage Power Vacuum Interrupters Used in Power Switchgear, ANSI C37.85-1972.

This standard set forth performance requirements relative to X-radiation emission and methods of test for high-voltage vacuum switching devices. The 1989 revision incorporated higher-voltage vacuum interrupters that have been developed, tested, and placed into service since the 1972 adoption of the standard. This revision incorporates editorial and minor technical changes from the 1989 version.

- "Dielectric withstand voltage test" (and similar phrases) have been changed to "power-frequency withstand voltage test" (or similar phrasing) throughout.
- ANSI/NBS 114-1974 has been superseded by ANSI N43.3-1993.
- Table 1 has been modified to add categories for 4.76kV, 8.25kV, and 15kV, so as to coordinate with the apparatus standards.
- Clause 7 has been modified to better conform to ANSI Z535.4, and to allow some latitude in the language and the placement of the label.
- Annex A incorporates some minor updates to reflect that this is now the third edition of the document, but nothing major was changed.
- The allowable limits for radiation are based on the occupational dose limits established by 10CFR835 for general employees, 5.0 rem (0.05 sievert) per year for the whole body. The limits for selected tissues and organs are much higher.
- Radiation exposures have been historically measured in rem units, and most of the references still use this unit of measure. Another unit of measure, the sievert (Sv) is coming into use as the SI unit of dose equivalent, but use of this unit is still not common. Therefore, it has been deemed reasonable to maintain all measures in terms of rem.
- For convenience, a few conversions among the more commonly used units are listed here:
  - 0.5 rem (roentgen equivalent man) = 5 mSv (millisievert) = 500 mR (milliroentgen)
  - 1 mR = 0.01 mSV
  - 1 R = 10 mSV

Suggestions for improvement of this standard will be welcome. They should be sent to the National Electrical Manufacturers Association, Inc, 1300 North 17th Street, Suite 1847, Rosslyn, VA 22209

This standard was processed and approved for submittal to ANSI by Accredited Standards Committee on Power Switchgear, C37. Committee approval of the standard does not necessarily imply that all members voted for its approval. At the time it approved this standard, the C37 Committee had the following members:

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This revision was prepared by a joint working group of the NEMA Power Circuit Breaker Technical Committee (SG-IV) and the NEMA Power Switchgear Assemblies Technical Committee (SG-V). The members of this working group were:

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Alternating-Current High-Voltage Power Vacuum Interrupters—

Safety Requirements for X-Radiation Limits

1 General

This standard specifies the maximum permissible X-radiation emission from alternating-current high-voltage power vacuum interrupters that are intended to be operated at voltages above 1000 volts and up to 38,000 volts when tested in accordance with procedures described in this standard.

NOTES—

The test procedures prescribed in this standard are not necessarily applicable for higher-voltage vacuum interrupters.

In this standard, the term “interrupter” signifies “high-voltage power vacuum interrupter,” unless qualified by other descriptive terms.

2 Related American National Standards

The following standards are listed for information only and are not essential to complete the requirements of this standard.

ANSI N43.3-1993, General Radiation Safety - Installations Using Non-Medical X-Ray and Sealed Gamma-Ray Sources, Energies up to 10 MeV

ANSI/IEEE C37.100-1992, Definitions for Power Switchgear

3 Definitions

The definitions and terms contained in this standard, or in other American National Standards referred to in this standard, are not intended to embrace all legitimate meanings of the terms. They are applicable only to the subject treated in this standard. For additional definitions of terms used in this standard, see ANSI/IEEE C37.100-1992. An asterisk (*) following a definition indicates that, at the time this standard was approved, there was no corresponding definition in ANSI/IEEE C37.100-1992.

conformance tests: Those tests that are specifically made to demonstrate the conformity of switchgear or its component parts with applicable standards.

high-voltage power vacuum interrupter: An interrupter in which the separable contacts function within a single evacuated envelope and that is intended for use in power switchgear.*

maximum interrupter operating voltage: The highest steady-state alternating-current rms operating voltage that will appear across the open contacts of a vacuum interrupter in its application.*

NOTE—The maximum interrupter operating voltage is a function of the highest system voltage on which a switchgear device employing vacuum interrupters is to be applied, the number of interrupters used in series, and whether the device is single-phase or three-phase.

milliroentgen (mR): The amount of X-radiation that produces 2.58×10^{-7} coulombs per kilogram of air.*

power-frequency withstand voltage tests: Tests made to determine the ability of insulating materials and spacings to withstand specified rms overvoltages for a specified time without dielectric breakdown or puncture.

shielding: The barrier of attenuating material used to reduce radiation hazards.*

4 Performance Requirements

Interrupters, tested as specified in clause 5, shall be in compliance with this standard if the X-radiation emitted does not exceed the following:

1) 0.5 milliroentgen per hour at the maximum operating voltage shown in column 2 of Table 1.
2) 15.0 milliroentgens per hour at the power-frequency withstand test voltage shown in column 3 of Table 1.

Table 1 – X-radiation test voltages for interrupters applied without additional external shielding (Note 1)

Rated Maximum Voltage (kV rms) (Note 1) (column 1)	X-Radiation Test Voltages (Note 2)	
	Maximum Interrupter Operating Voltage (kV rms) (column 2)	Power-Frequency Test Voltage (kV rms) (column 3)
4.76	4.76	14.25
8.25	8.25	27.0
15.0	15.0	27.0
15.5	15.5	37.5
25.8 – 27.0	27.0	45.0
38.0	38.0	52.5 (Note 3)
38.0	38.0	60.0 (Note 4)

NOTES—
1 Table 1 will be expanded in future revisions of this standard as additional ratings become available.
2 Refer to Appendix B for the derivation of the test voltages.
3 For interrupters used in switchgear having a power-frequency withstand test voltage of 70 kV rms.
4 For interrupters used in switchgear having a power-frequency withstand test voltage of 80 kV rms.

5 Conformance Test Procedures for New Interrupters

5.1 General requirements

5.1.1 Condition of interrupter to be tested

When conformance tests to measure the X-radiation emission levels of vacuum interrupters are to be performed, the interrupter shall be new and in good condition and tests shall be performed before it is put into commercial service.

5.1.2 Mounting of specimen

The interrupter shall be mounted in a test fixture, designed so that the open contact spacing may be set at the recommended minimum distance, and which will permit the application of a test voltage to one terminal of the interrupter while the other terminal is grounded. Interrupters designed for operation in an

insulating medium other than air (such as oil or SF_6) may be tested in such a medium, if necessary, to withstand the test voltage.

The container for the insulating medium shall be of an insulating material having radiation attenuation no greater than that afforded by 9.5mm thick methyl methacrylate. The insulating medium between the interrupter and radiation instrument shall be the minimum required for dielectric purposes.

5.1.3 Test circuit

The interrupter shall be connected to a power source of alternating-current voltage with a means for varying the voltage across the open contacts of the interrupter. A sine wave voltage having a crest value not exceeding 1.414 times the rms value shall be applied.

5.1.4 Frequency

The frequency of the supply voltage shall be 50 Hz or 60 Hz. During the test, the frequency shall not vary by more than 3 Hz.

5.1.5 Radiation instrument

A radio frequency (RF) shielded radiation survey instrument having the following minimum specifications shall be used:

Accuracy: Capable of measuring 15 milliroentgens per hour with an accuracy of ± 25 percent with a response time not to exceed 15 seconds

Energy Response: 12 kiloelectron volts to 0.5 mega-electronvolts ± 15 percent

Sensitive Area: 100 cm^2, maximum.

NOTE—Victoreen Instrument Company Model 440RF was used during the development of this standard.

5.1.6 Location of radiation instrument

The sensing element of the radiation instrument shall be positioned in the plane of the separable contacts and pointed at the contacts from a distance of 1 meter from the nearest external surface of the interrupter (see Figure 1). When electrical safety requires the instrument to be located at a distance greater than 1 meter, the instrument reading shall be adjusted by applying the inverse square law as follows:

$R\ (1\ \text{meter}) = R\ (d) \times (d)^2$

Where R (d) is the radiation level measured, at the distance d (in meters) from the external surface of the vacuum interrupter.

5.1.7 Precautions

If distances normally required for electrical safety are maintained, the exposure to test personnel will generally not exceed established dose limits (see ANSI N43.3-1993). Nevertheless, adequate precautions such as shielding or distance should be used to protect test personnel against possible higher X-radiation occurrences due, for example, to incorrect contact spacing, or to the application of voltages in excess of those specified in 5.2.

5.2 Test voltage and measurement procedure

With the interrupter mounted in a test fixture, with the contacts blocked open at the minimum contact spacing specified, and with the radiation instrument in place (see Figure 1), a voltage shall be applied across the interrupter contacts equal to the maximum interrupter operating voltage shown in Column 2 of Table 1. After a minimum of 15 seconds, the X-radiation level on the radiation instrument shall be read.

Next, the voltage across the interrupter contacts shall be raised to a value equal to the power-frequency insulation withstand test voltage shown in Column 3 of Table 1. After a minimum of 15 seconds, the X-radiation level on the radiation meter shall be read.

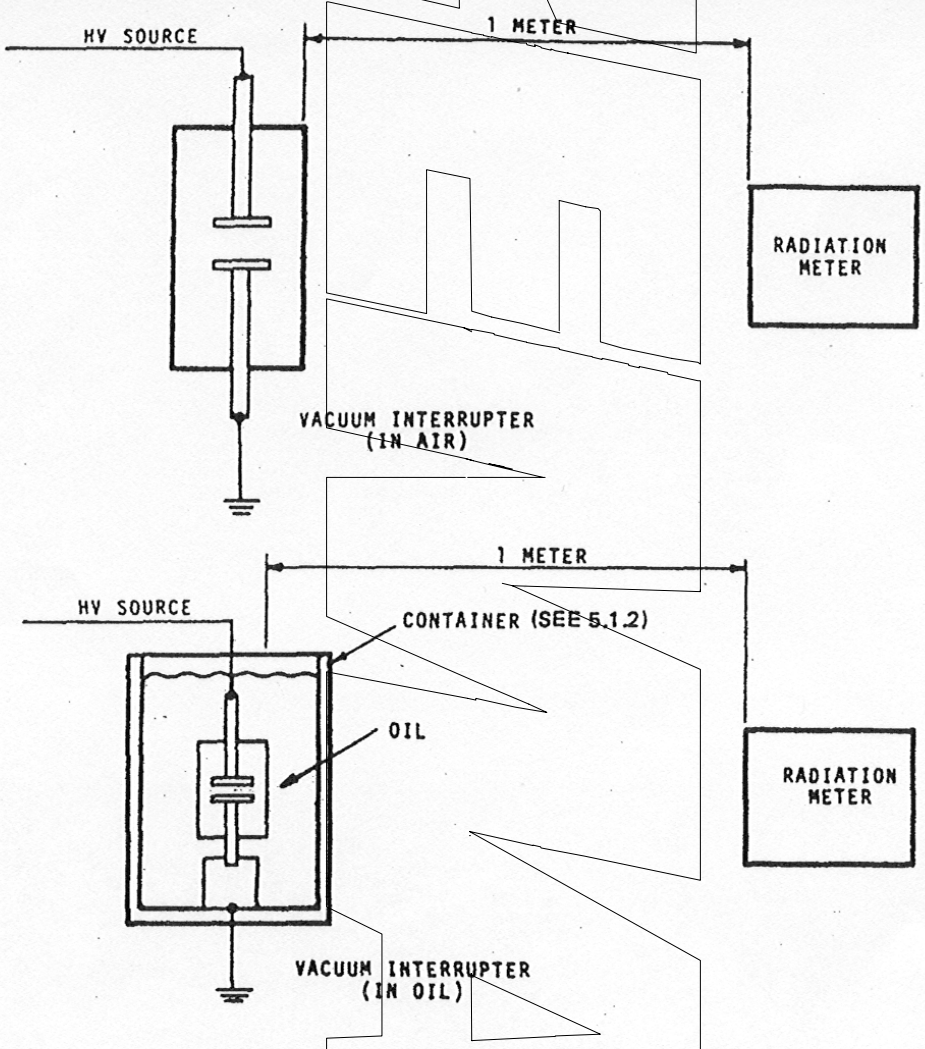

Figure 1 – Test location of radiation meter

6 Power-Frequency Withstand Voltage Tests on Used Interrupters

Power-frequency withstand voltage tests should be performed by users of switchgear devices to prove the ability of insulating materials and spacings to withstand specified overvoltages for specified times without dielectric breakdown or puncture. The test voltage levels used for field tests are typically 75 or 80 percent of the levels used on new equipment by the suppliers. Such tests should be conducted as commissioning tests before new equipment is placed into service, as tests before recently maintained equipment is returned to service, and in general, as part of a comprehensive preventive maintenance program.

Power-frequency withstand voltage tests may also be used to establish the vacuum integrity of vacuum interrupters. Suppliers shall prescribe the test procedures, including gap settings and test voltages, for conducting power-frequency withstand voltage tests on used vacuum interrupters or switchgear utilizing vacuum interrupters.

When power-frequency withstand voltage tests are performed on used vacuum interrupters, or on switchgear components utilizing vacuum interrupters (including contactors, switches, circuit breakers, and the like), precautions shall be taken for the safety of test personnel. If distances normally required for electrical safety are maintained, X-radiation exposure to test personnel generally does not exceed established dose limits (see ANSI N43.3-1993). Nevertheless, adequate precautions such as shielding or distance should be used to protect personnel against possible higher X-radiation occurrences due, for example, to incorrect contact spacing, or to the inadvertent application of voltages in excess of the values prescribed in Column 3 of Table 1.

7 Labeling

Each interrupter prepared for shipment shall have an appropriate label on its outer surface, or alternatively, in an appropriate location on the product assembly into which the interrupter is incorporated. The label shall conform to ANSI Z535.4 requirements. An example of an acceptable label is:

CAUTION **Vacuum interrupters may emit X-radiation that may be hazardous to your health.**

X-rays can be produced when high voltage withstand test levels are placed across open contacts.

Keep personnel more than 2 meters (6 feet) from vacuum interrupter during tests.

Annex A
(informative)
Report on the basis of derivation of the maximum permissible levels of X-radiation emitted by high-voltage power vacuum interrupters

(Annex A is not part of American National Standard C37.85-2002, but is included for information only.)

The known United States manufacturers of vacuum interrupters initiated a test program during 1968 (as a Task Force of the NEMA Switchgear Section) to determine the present levels of X-radiation, if any, being emitted from high-voltage power vacuum interrupters, and to suggest permissible levels of radiation from such interrupters on the basis of their recognized application.

Each manufacturer conducted a series of tests on new vacuum interrupters taken from stock and recorded the X-radiation levels, if any, under the following conditions:

1) Power-frequency withstand test voltage applied to new interrupters
2) Fault current interruption (where applicable)
3) Load current interruption
4) Power-frequency withstand test voltages after fault current interruption
5) Power-frequency withstand test voltages after load current interruption

As a result of evaluating the results of the aforementioned tests, the manufacturers concluded that neither the general public nor users will be subjected to harmful X-radiation due to normal application and operation of 15.5kV rated vacuum interrupter devices when applied within their assigned ratings and when the voltage applied across the open contacts of the interrupter is 15.5kV or less.

The manufacturers also concluded that at the permissible user power-frequency withstand test voltage of 37.5kV, radiation levels are negligible for vacuum interrupters rated 15.5kV. Normal electrical safety precautions require the user to be at a distance from the interrupters that provides sufficient protection.

Since the factors of time and distance are involved, the manufacturers proposed that 15 milliroentgens per hour for 1 minute or 0.25 milliroentgen per test be considered as a reasonable and safe maximum level of radiation in uncontrolled areas for user personnel engaged in testing vacuum interrupters of the type and rating covered by the foregoing test program.

The 15 milliroentgen-per-hour radiation level is measured at a distance of 1 meter from the vacuum interrupter. When a power-frequency withstand test voltage of 37.5kV is applied, it would be highly unlikely that any individual would be within 1 meter of the interrupter being tested since the individual could reach out and touch the energized bare conductor. For reasons of electrical safety, all persons are normally required to remain at least 2 to 3 meters from any device which is being tested with voltages such as those listed in Table 1.

Assuming a maximum permissible cumulative exposure for an uncontrolled area not to exceed:

- 500 milliroentgens/year
- 100 milliroentgens/7 days
- 2 milliroentgens/one hour

and a maximum radiation rate of 15 milliroentgens per hour for a 1-minute test (0.25 milliroentgen per test) from each interrupter at a distance of 1 meter, 33.3 hours of exposure would be permitted in a single year. Two thousand 1-minute power-frequency withstand voltage tests would have to be performed in a year to accumulate a maximum permissible dosage. Since this test is performed only during maintenance, which normally occurs only once in a 1-year to 3-year period, 2000 1-minute tests per year exceeds by a factor of 10 or more the number of interrupters a large user (such as a utility) would be expected to test in a year.

Concerning the 50kV 1-minute power-frequency withstand test voltage applied by the switchgear manufacturer during his factory test, the manufacturers believe that the level of possible emitted X-radiation could be injurious to personnel. Therefore, the manufacturers recommended that they take the appropriate precautions to protect personnel and meet local codes by using monitoring devices and safety measures as required.

Since the original 1972 adoption of this standard, manufacturers have conducted tests on interrupters rated through 38kV, and data for these higher voltage interrupters was reflected in 1989 edition of this standard. This testing and concurrent field experience has demonstrated that these higher voltage ratings meet the requirements of this standard.

The 2002 revision of this document also adds data for interrupters rated below 15.5kV, to coordinate with the ratings of available apparatus.

Annex B
(informative)
Testing in assembled switchgear

(Annex B is not part of American National Standard C37.85-2002, but is included for information only.)

B.1 General

This standard is intended for use by vacuum interrupter manufacturers to ensure that interrupters produced do not emit X-radiation in excess of prescribed limits under specified conditions. The test procedures call for the interrupters to be tested in fixtures. The procedures, therefore, are not readily applicable to interrupters installed in assembled switchgear.

Assembled switchgear, however, is subject to periodic power-frequency withstand voltage tests by users, usually as part of a preventive maintenance program. The purpose of the power-frequency withstand voltage test is to prove the quality of the insulation system. The test is not intended for X-radiation measurements. However, since interrupters may be subjected to power-frequency withstand voltage tests, they should be designed so as not to emit radiation in excess of the levels specified in this standard at the test voltage level.

Power-frequency withstand voltage tests may also be used, under prescribed conditions, to verify that vacuum interrupters have maintained their vacuum integrity.

The two voltage levels to which a vacuum interrupter is subjected in its application are:

1) The maximum interrupter operating voltage (see clause 3.)
2) The field power-frequency withstand test voltage

B.2 Determination of the power-frequency withstand test voltage

The power-frequency withstand test voltage shown in Column 3 of Table 1 is 75 percent of the factory power-frequency withstand test voltage for each of the rated maximum voltages shown in Column 1. This test voltage is typically used by users performing power-frequency withstand voltage tests on switchgear devices.

Manufacturers test assembled switchgear at the factory test level. This procedure may cause the interrupter to emit X-radiation in excess of the amount prescribed in (2) of clause 4. Manufacturers should have the necessary facilities and take the necessary precautions to protect workers against accidental radiation exposures.

Users conduct such tests less frequently and apply a lower value of test voltage (75-80 percent of the value used to test new equipment). This procedure makes the use of special facilities unnecessary. Nevertheless, the precautions specified in 5.1.7 should be observed.