

Approval Standard

for

Less or Nonflammable

Liquid-Insulated

Transformers

Class Number 3990

June 1997

Foreword

FM Approvals are intended to verify that the products and services described will meet stated conditions of performance, safety and quality useful to the ends of property conservation. The purpose of FM Approval Standards is to present the criteria for FM Approval of various types of products and services, as guidance for FM Approvals personnel, manufacturers, users and authorities having jurisdiction.

Products submitted for Approval shall demonstrate that they meet the intent of the Approval Standard, and that quality control in manufacturing and/or applications shall ensure a consistently uniform and reliable product or service. FM Approval Standards strive to be performance-oriented and to facilitate technological development.

For examining equipment, materials and services, FM Approval Standards:

- a) must be useful to the ends of property conservation by preventing, limiting or not causing damage under the conditions stated by the Approval listing; and
- b) must be readily identifiable.

Continuance of Approval and Listing depends on compliance with the Approval agreement, satisfactory performance in the field, on successful re-examinations of equipment, materials, and services as appropriate, and on periodic follow-up audits of the manufacturing facility or service/application.

FM Approvals LLC reserves the right in its sole judgement to change or revise its standards, criteria, methods, or procedures.

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1. INTRODUCTION

1.1 Purpose

1.1.1 This standard states FM Approval criteria for transformers insulated with less or nonflammable liquids.

1.2 Scope

1.2.1 This standard sets performance requirements for liquid insulated distribution and power transformers rated from 5 to 10,000 kVA (upper limit applies to naturally cooled (OA) class only) and 35 kV class or lower.

1.2.2 This standard also applies to any component intended for use as a protective device and that is normally provided as part of the transformer assembly. Use of components previously Approved as individual protective devices shall not automatically result in an Approved transformer assembly.

1.3 Basis for Requirements

1.3.1 The requirements of this Standard are based on experience, research and testing, and/or the standards of other organizations. The advice of manufacturers, users, trade associations, jurisdictions and/or loss control specialists was also considered.

1.3.2 The requirements of this Standard reflect tests and practices used to examine characteristics of less or non flammable liquid-insulated transformers for the purpose of obtaining FM Approval. Transformers having characteristics not anticipated by this Standard may be Approved if performance equal, or superior, to that required by this Standard is demonstrated, or if the intent of the Standard is met. Alternatively, transformers which meet all of the requirements identified in this Standard may not be Approved if other conditions which adversely affect performance exist or if the intent of this Standard is not met.

1.4 Basis for FM Approval

FM Approval is based upon satisfactory evaluation of the product and the manufacturer in the following major areas:

1.4.1 Examination and tests on production samples shall be performed to evaluate

- the suitability of the product
- the performance of the product as specified by the manufacturer and required by FM Approvals; and as far as practical,
- the durability and reliability of the product.

1.4.2 An examination of the manufacturing facilities and audit of quality control procedures is made to evaluate the manufacturer's ability to produce the product which was examined and tested, and the marking procedures used to identify the product. These examinations are repeated as part of FM Approvals' Product Follow-Up Program.

1.5 Basis for Continued Approval

Continued Approval is based upon:

- production or availability of the product as currently Approved;
- the continued use of acceptable quality assurance procedures;
- satisfactory field experience;
- compliance with the terms stipulated in the Approval Agreement;
- satisfactory re-examination of production samples for continued conformity to requirements; and
- satisfactory Facilities and Procedures Audits (F&PAs) conducted as part of FM Approvals' product follow-up program.

Also, as a condition of retaining Approval, manufacturers may not change a product or service without prior authorization by FM Approvals.

1.6 Effective Date

The effective date of an Approval standard mandates that all products tested for Approval after the effective date shall satisfy the requirements of that standard. Products Approved under a previous edition shall comply with the new version by the effective date or forfeit Approval.

The effective date of this Standard is June 1998 for compliance with all requirements.

1.7 System of Units

Units of measurement used in this Standard are United States (U.S.) customary units. These are followed by their arithmetic equivalents in International System (SI) units, enclosed in parentheses. The first value stated shall be regarded as the requirement. The converted equivalent value may be approximate. Appendix A lists the selected units and conversions to SI units for measures appearing in this standard. Conversion of U.S. customary units is in accordance with the ANSI/IEEE/ASTM SI 10-97, *Standard for Use of the International System of Units (SI): The Modern Metric System*.

1.8 Applicable Documents

The latest versions of the following standards, test methods, and practices are referenced in this standard:

- A. ANSI/IEEE C57.12.00 General Requirements for Liquid-Immersed Distribution, Power, and Regulating Transformers.
- B. ANSI/IEEE C57.12.90 Test Code for Liquid-Immersed Distribution, Power, and Regulating Transformers.
- C. ANSI/ASME Boiler and Pressure Vessel Code (BPV) Code, Section VIII, Pressure Relief Devices.

1.9 Approval Application Requirements

To apply for an Approval examination the manufacturer, or its authorized representative, should submit a request to the Electrical Group Manager at FM Approvals, 1151 Boston-Providence Turnpike, PO Box 9102, Norwood, MA 02062, U.S.A.

2. GENERAL REQUIREMENTS

2.1 Markings

- 2.1.1 An Approved transformer shall be labeled in accordance with the requirements of ANSI C57.12.00 pertaining to ratings and other essential operating data.
- 2.1.2 A separate durable corrosion-resistant metal label(s) carrying the information noted below shall also be attached to the transformer.
- Tank withstand pressure.
 - Pressure relief device(s) type/model/part number(s) and manufacturer.
 - Fuse type(s), rating, model/part number(s), and manufacturer.
 - Type of insulating liquid (either FM Approved Class 6933 less-flammable or Class 6934 nonflammable transformer fluid) and fluid volume.

The label shall also carry the following text:

- Replacement fuses must be exact duplicates of those initially provided.
- Secondary containment equal to the liquid volume of the transformer is required for all indoor installations. Secondary containment for transformers containing 660 gal (2.5 m³) or more is required of outdoor installations.
- Indoor installation site requirements:
 - For Type 1 and Type 2 buildings the transformer must be located at least 3 ft (0.9 m) from building walls.
 - For combustible buildings the transformer must be located at least 3 ft (0.9 m) from building walls and protected by an automatic fire suppression system or must be installed in a 3 hour fire rated vault.
- Outdoor installation site requirements:

The transformer must be located at least 3 ft (0.9 m) from building walls and 5 ft (1.5 m) from doors, fire escapes and windows.

Note: The requirements in items 3 and 4 pertain to non-network transformers only. Requirements for network transformers will be determined on a case by case basis.

- 2.1.3 When applicable (per Section 2.3.6), a tag shall be attached to the low voltage neutral bushing stating: "Secondary ground fault protection, or equivalent, must be installed unless specifically prohibited by the authority having jurisdiction."
- 2.1.4 The transformer shall also bear the FM Approval mark (reproduction art formats are shown in Appendix B). The location, material, and application method will be by mutual agreement between FM Approvals and the manufacturer.

2.2 Instructions

- 2.2.1 The manufacturer shall provide instructions and/or illustrations for proper installation, maintenance, and operation.
- 2.2.2 Upon request, the manufacturer shall furnish time/current curves of the fusing or protective relay schemes provided with the transformer. This applies whether the devices are of in-house manufacture or purchased.

2.3 Physical or Structural Features

2.3.1 Transformers shall be designed in accordance with the requirements of ANSI/IEEE C57.12.00 and the requirements of this FM Approvals standard. Where the FM Approvals requirements exceed or are more specific than those of C57.12.00, the FM Approvals requirements shall be used to determine Approval. Approved ratings shall not be less than 5 nor more than 10,000 kVA. (OA cooling class)

Note: 10,000 kVA limit applies to class OA at lowest nameplate temperature rise rating. Approved ratings can be higher for other classes.

2.3.2 Rectangular and cylindrical transformer tanks shall be designed for a minimum withstand pressure of 7 psi (48 kPa) without permanent distortion. Rectangular tanks shall be designed for a minimum withstand pressure of 15 psi (105 kPa) without rupture; cylindrical for a minimum of 20 psi (140 kPa) without rupture.

2.3.3 Transformers shall be provided with a pressure relief device of sufficient capacity to limit internal pressure, under low current arcing fault conditions, so that tank rupture does not occur. The nominal opening pressure of the relief device shall be 10 psi (69 kPa) and the minimum nominal flow rates shall be as follows:

<i>kVA Rating 3-Phase (1-Phase)</i>	<i>Flow Rate SCFM @ 15 psi (103 kPa)</i>
112.5 (37.5)	35
150 (50)	50
300 (100)	100
1000 (333)	350
2000 (667)	700
10000 (3333)	5000

Note: Table interpretation is, for example, kVA >150 and ≤ 300 requires flow rate of 100 SCFM.

2.3.4 Transformers shall be insulated with an FM Approved less or nonflammable transformer fluid. Less flammable fluids shall have a fire point not less than 572°F (300°C) as determined by the ASTM D92—Open Cup Method.

2.3.5 Electrical protection shall be provided to prevent tank rupture due to high current faults. This protection shall limit the electrical energy input to the transformer. The protection shall be in the form of current-limiting fuses or other technology of demonstrated equivalent or greater effectiveness.

When current limiting fusing is used, under-fluid expulsion fuses may be used in series in accordance with the manufacturer’s recommended protection scheme.

If protection is designed to vent or emit gas during operation (such as is the case with expulsion fuses without current limiting fusing in series), this protection shall be located external to the transformer tank.

If lightning arrestors are provided with single phase pad, single phase pole, or three phase pole round tank transformers they shall be located external to the tank.

The maximum I^2t let through for current limiting fuses and other types of protection shall not exceed the values shown in the table below.

Maximum I^2t Let Through

<i>kVA Rating 3 Phase (1 Phase)</i>	<i>Current Limiting Fusing</i>	<i>Other Protection</i>
45 (15)	500000	700000
75 (25)	500000	800000
112.5 (37.5)	550000	900000
150 (50)	600000	1000000
225 (75)	650000	1200000
300 (100)	750000	1400000
500 (167)	900000	1900000
750 (250)	1100000	2200000
1000 (333)	1250000	3400000
1500 (500)	1500000	4500000
2000 (667)	1750000	6000000
2500 (833)	2000000	7500000
3000 (1000)	2250000	9000000
3750 (1250)	2500000	11000000
5000 (1667)	3000000	14000000
7500 (2500)	3000000	14000000
10000 (3333)	3000000	14000000

Note: Table interpretation is, for example, kVA ≥ 500 and < 750 is limited to 900,000.

- 2.3.6 Electrical protection shall also be provided to clear sustained low current faults. For units up to 2,500 kVA, fuse protection is acceptable as a minimum. For indoor installations, units above 500 kVA shall be equipped with alarm contacts on the pressure relief device. Units rated above 2,500 kVA, in all locations, shall be equipped with alarm contacts on the pressure relief device and sudden pressure relays or other technology having a demonstrated equivalent or greater effectiveness. Transformers with wye connected secondaries of 150V or more, to ground, and rated at 1000 A or more, shall be provided with a ground fault sensing current transformer (CT) in the low voltage circuit unless prohibited by the authority having jurisdiction.
- 2.3.7 All transformers, except pole mount and single phase padmount, shall be equipped with a liquid level indicator. Transformers rated at 750 kVA or higher shall also be equipped with a liquid temperature indicator and a pressure-vacuum gage.
- 2.3.8 Transformers shall be capable of tolerating, as a minimum, a 1.5° tilt from vertical without affecting their Basic Lightning Impulse Insulation Level (BIL).

2.4 Drawings/plans/specifications

The manufacturer shall provide assembly drawings, component drawings, material lists, labeling format, brochures, sales literature, specification sheets, etc. for FM Approvals examination.

3. PERFORMANCE REQUIREMENTS

Note: Due to the physical size and/or the need for specialized test equipment, examination and tests of transformer assemblies will normally be conducted at the manufacturer's facility. Evidence shall be provided that all test equipment used is in calibration and that there is an established recalibration program for this equipment.

3.1 Examination

Sample transformers shall be examined to verify that they are constructed in accordance with the manufacturer's drawings and specifications, ANSI/IEEE C57.12.00 requirements and FM Approvals requirements.

3.2 Pressure Capability

3.2.1 Requirement

- A. Transformer assemblies shall be capable of withstanding an internal pressure of 7 psi (48 kPa) without leakage, permanent distortion, or rupture.
- B. Rectangular transformer tanks shall be capable of withstanding an internal pressure of 15 psi (105 kPa), cylindrical tanks 20 psi (140 kPa) or their design pressure, whichever is greater, without leakage or rupture.

EXCEPTION

Cylindrical tanks with venting covers.

3.2.2 Test/Verification

- A. A complete transformer assembly, with all components that would normally penetrate the tank walls installed, shall be pressurized, to the level noted in 3.2.1.A above, for a period of one minute. There shall be no evidence of leakage, permanent distortion, or rupture.
- B. A transformer tank, with all openings plugged, shall be pressurized, to the level noted in 3.2.1.B above, for a period of one minute. There shall be no evidence of leakage or rupture of the tank itself or displacement of the components. Minor leakage at gasketed or other sealing surfaces is allowed.

- Note:**
- 1. For test A., venting through the pressure relief device shall be prevented by blocking the relief mechanism, plugging its outlet port, or removal of the device and plugging the tank port.
 - 2. For test B., components may be left installed if it is more convenient and if they are capable of withstanding the test pressure.
 - 3. Tests A and B may be conducted without windings installed unless their installation requires penetration of tank walls.

3.3 Electrical Capability

3.3.1 Requirement

Completed transformer assemblies shall be subjected to applicable electrical tests specified in ANSI/IEEE C57.12.00, Table 16, entitled "Routine, Design, and Other Tests for Liquid-Immersed Transformers". All Approval sample transformers shall be subjected to the routine tests. Design tests are required only for prototypes.

3.3.2 Test/Verification

- A. All tests shall be conducted in accordance with ANSI/IEEE C57.12.90 Test Code for Liquid-Immersed Transformers.
- B. Required Tests:
 1. Temperature rise at minimum and maximum ratings (new design only).
 2. Winding ratio at all connections.
 3. Polarity and phase relation.
 4. Full and reduced wave impulse for verification of basic lightning impulse insulation levels (BIL).
 5. Dielectric for insulation strength; coil to core, high to low voltage winding, and terminals to ground; at the voltage levels specified in ANSI/IEEE C57.12.00.
 6. No-load losses and excitation current at rated voltage and frequency.
 7. Overexcitation for turn-to-turn and layer-to-layer insulation strength.

3.4 Insulating Fluids

3.4.1 Requirement

Less flammable transformer fluids shall be in conformance with FM Approval Standard 6933. Nonflammable fluids shall be in conformance with FM Approval Standard 6934.

3.4.2 Tests/Verification

Any fluid, submitted as a component of a transformer assembly, which is not Approved shall be evaluated for conformance to the requirements of Standard 6933 or 6934 as a prerequisite to its use.

3.5 Level Pressure, and Temperature Protective Devices

3.5.1 Physical Features

3.5.1.1 Requirement

Protective devices shall be practicably useable, shall not present unreasonable hazards in their normal use, shall not be capable of being assembled or installed improperly, and shall not be easily defeated or bypassed. They shall be protected from environmental conditions that could impair their operation.

3.5.1.2 Test/Verification

Protective devices shall be assembled, installed, removed, operated, and/or serviced in accordance with the manufacturer's instructions and responsible trade practices. There shall be no evidence of failure to comply with the above noted requirements.

3.5.2 Pressure Relief Devices

3.5.2.1 Requirement

Pressure relief devices shall meet the requirements of the ANSI/ASME BPV Code, Section VIII, Division 2 as it pertains to release pressure. They shall have a rated working pressure equal to or greater than the tank rated pressure. A means of annunciating overpressure alarms shall be provided for transformers rated above 2,500 kVA.

3.5.2.2 Test/Verification

- A. These devices shall be subjected to ten operational cycles. Relieving pressure shall remain within the manufacturer's stated tolerance or ± 2 psi (14 kPa) whichever is less.
- B. The devices shall be held closed and subjected to a pressure equal to 1.5 times their rated pressure for one minute. There shall be no evidence of leakage or damage.

EXCEPTION

This test is not required if the device cannot be held closed by ordinary means such as plugging of the vent port or wedging of the relief mechanism.

- C. The manufacturer shall provide data pertaining to the flow capacity of the device.

3.5.3 Level Indicators

3.5.3.1 Requirement

A level indicator shall have, as a minimum, the same pressure capability as the tank as described in Section 3.2.1.A above.

3.5.3.2 Test/Verification

The indicator shall be subjected to the same test as described Section in 3.2.2.A above.

3.5.4 Pressure/Temperature Indicators and/or Switches

3.5.4.1 Requirement

- A. Accuracy of indication shall conform to the manufacturer's specification.
- B. Switching (trip) point shall repeat within the manufacturer's specification. Reset, automatic or manual, shall not occur until the input is below the trip point.

Note: When applicable, the devices shall comply with the above requirements over a range of 85 to 110 percent of nominal supply voltage.

- C. Devices that have adjustable trip points shall be configured so as prevent adjustment by means readily accessible to an operator. Typically, a special tool, removal of an access cover, or a password for electronic devices shall be required.
- D. These devices shall be capable of conforming to the requirements noted in A and B over a temperature range of 32–120°F (0–49°C) or their specified operating (ambient) temperature range, whichever is greater.

3.5.4.2 Test/Verification

- A. Input signals, equal to 0, 25, 50, 75, and 100 percent of the operating range, shall be applied to the device. Indication shall comply with the manufacturer's accuracy specification.
- B. An input signal shall be applied slowly, until the switch actuates, for ten successive operations. The device shall conform to the requirements noted in 3.5.4.1.B above.
- C. When applicable, the above tests shall be repeated at 85 and 110 percent of nominal operating voltage.
- D. The set point adjustment instructions and the device shall be examined in order to verify compliance with the requirement noted in 3.5.4.1C above.
- E. The devices shall be conditioned at the operational temperature extremes noted in 3.5.4.1D above for a period of at least 24 hours at each temperature. Accuracy and repeatability shall be tested as noted in A and B above and results shall comply with stated requirements.

3.6 Transformer Tilt

3.6.1 Requirement

A transformer shall be capable of being tilted, as a minimum, 1.5° from vertical without affecting its Basic Lightning Impulse Insulation Level (BIL) as determined in Section 3.3.2 B.4 above.

3.6.2 Test/Verification

Note: For this test, fluid in the transformer, shall be set at a level equivalent to the minimum contracted fluid volume at a temperature of -4°F (-20°C).

The tilt will be simulated by reducing the fluid level to the equivalent depth caused by physically tilting the transformer. The BIL shall not be less than that determined in Section 3.3.2 B.4 above and there shall be no evidence of internal flashover.

4. OPERATIONS REQUIREMENTS

A quality assurance program is required to assure that subsequent transformers produced by the manufacturer shall present the same quality and reliability as the specific transformers examined. Design quality, conformance to design, and performance are the areas of primary concern.

- Design quality is determined during the examination and tests, and is documented in the Approval Report.
- Continued conformance to this Standard is verified by the Facilities and Procedures Audits (F&PA).
- Quality of performance is determined by field performance and as necessary by periodic re-examination and testing.

4.1 Demonstrated Quality Control Program

4.1.1 The manufacturer shall demonstrate a quality assurance program which specifies controls for at least the following areas:

- existence of corporate quality assurance guidelines
- incoming quality assurance, including testing
- in-process quality assurance, including testing
- final inspection and tests
- equipment calibration
- drawing and change control
- packaging and shipping
- handling and disposition of discrepant materials.

4.1.2 Documentation/Manual

There should be an authoritative collection of procedures/policies. It should provide an accurate description of the quality management system while serving as a permanent reference for implementation and maintenance of that system. The system should require that sufficient records are maintained to demonstrate achievement of the required quality and verify operation of the quality system.

4.1.3 Records

To assure adequate traceability of materials and products, the manufacturer shall maintain a record of all quality assurance tests performed, and shall maintain this record for a minimum period of two years from the date of manufacture.

4.1.4 Drawing and Change Control

- The manufacturer shall establish a system of product configuration control that shall allow no unauthorized changes to the product. Changes to critical documents, identified in the Approval Report must be reported to, and authorized by, FM Approvals prior to implementation for production.
- The manufacturer shall assign an appropriate person or group to be responsible for, and require that, proposed changes to Approved or Listed products be reported to FM Approvals before implementation. The manufacturer shall notify FM Approvals of changes in the product or of persons responsible for keeping FM Approvals advised by means of FM Approvals Form 797, Approved Product Revision Report or Address/ Contact Change Notice.

4.2 Facilities and Procedures Audit (F&PA)

4.2.1 An audit of the manufacturing facility is part of the Approval investigation to verify implementation of the quality assurance program. Its purpose is to determine that the manufacturer's equipment, procedures, and quality program are maintained to insure a uniform product consistent with that which was tested and Approved.

4.2.2 These audits shall be conducted periodically but at least annually by FM Approvals or its representatives or more frequently dependent on jurisdictional requirements.

4.2.3 FM Approved products or services shall be produced or provided at or from the location(s) audited by FM Approvals and as specified in the Approval Report. Manufacture of products bearing the FM Approval Mark is not permitted at any other location without prior written authorization by FM Approvals.

4.3 Installation Inspections

Field inspections may be conducted to review an installation. The inspections are conducted to assess ease of application, and conformance to written specifications. When more than one application technique is used, one or all may be inspected at the discretion of FM Approvals.

APPENDIX A**UNITS OF MEASUREMENT**

PRESSURE: psi – “pounds per square inch”; (kPa – “kilopascals”)
kPa = psi \times 6.895

bar – “bar”; (kPa – “kilopascals”)
bar = kPa \times 0.01
bar = psi \times 0.06895

TEMPERATURE: °F – “degrees Fahrenheit” (°C – “degrees Celsius”)
°C = (°F – 32) \times 0.556