FM Approvals

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Examination Standard for Dissolved Gas Analysis Monitoring Systems in Liquid-Immersed Transformers

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Foreword

This standard is 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 this standard is to present the criteria for examination of various types of products and services.

Examination in accordance with this standard shall demonstrate compliance and verify that quality control in manufacturing shall ensure a consistent and reliable product.

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1. INTRODUCTION

1.1. PURPOSE

1.1.1. This standard states testing and certification requirements for Dissolved Gas Analysis (DGA) continuous monitoring systems, for the detection of gas formation in liquid-immersed or liquid-insulated transformers.

1.1.2. Testing and certification criteria may include performance requirements, marking requirements, examination of manufacturing facility(ies), audit of quality assurance procedures, and a surveillance program.

1.2. SCOPE

1.2.1. This standard applies to any component intended for or for use in DGA monitoring for single gas or multiple gases within liquid-immersed transformers.

1.2.2. This standard contains requirements for DGA monitoring systems in liquid-immersed transformers. The liquid is typically mineral oil, natural ester oil, synthetic ester oil, or silicone oil. Other liquids shall require special investigation.

1.2.3. The fault gases that are measured to determine developing faults within liquid-immersed transformers are Acetylene (C2H2), Carbon Dioxide (CO2), Carbon Monoxide (CO), Ethane (C2H6), Ethylene (C2H4), Hydrogen (H2), and Methane (CH4). This standard verifies performance testing to all of these gases.

1.2.4. This standard does not apply to equipment monitoring gas within the headspace of a liquid-immersed transformer.

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 DGA monitoring systems for the purpose of obtaining certification.

1.4. BASIS FOR CERTIFICATION

Certification 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 for certification;
- the durability and reliability of the product.

1.4.2. An examination of the manufacturing facilities and audit of quality control procedures may be conducted to evaluate the manufacturer's ability to consistently produce the product, which is examined and tested, and the marking procedures used to identify the product. Subsequent surveillance may be required by the certification agency in accordance with the certification scheme to ensure ongoing compliance.

1.5. BASIS FOR CONTINUED CERTIFICATION

The basis for continual certification may include the following based upon the certification scheme and requirements of the certification agency:

- production or availability of the product as currently certified;
- the continued use of acceptable quality assurance procedures;
- compliance with the terms stipulated by the certification;
- satisfactory re-examination of production samples for continued conformity to requirements; and
- satisfactory surveillance audits conducted as part of the certification agency’s product surveillance program.

1.6. EFFECTIVE DATE

1.6.1. The effective date of this examination standard mandates that all products tested for certification after the effective date shall satisfy the requirements of this standard.

1.6.2. The effective date of this standard is eighteen (18) months after the publication date of the standard 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. Conversion of U.S. customary units is in accordance with ANSI/IEEE/ASTM SI 10.

1.8. NORMATIVE REFERENCES

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the cited edition applies.

ANSI/IEC 60529, *Degrees of Protection Provided by Enclosures (IP Code)*

ANSI/IEEE/ASTM SI 10, *American National Standard for Metric Practice*

ANSI/UL 61010-1, *Safety Requirements for Electrical Equipment for Measurement, Control, and Laboratory Use – Part 1: General Requirements*

ASTM D923, *Standard Practices for Sampling Electrical Insulating Liquids*

ASTM D3487, *Standard Specification for Mineral Insulating Oil Used in Electrical Apparatus* IEC 60068-2-6, *Environmental testing - Part 2-6: Tests - Test Fc: Vibration (sinusoidal)*

IEC 61326-1, *Electrical equipment for measurement, control and laboratory use - EMC requirements - Part 1: General requirements*

ISO 6142 - *Gas analysis – Preparation of calibration gas mixtures – Gravimetric method*

1.9. TERMS AND DEFINITIONS

For purposes of this standard, the following terms apply:

Term	Definition
Continuous monitoring	A test protocol in which a transformer is tested at very short time intervals (e.g., daily or several times per day) for characterization of abnormal gas formation, and very early warning of abnormal gas formation
Control unit	Equipment intended to provide display indication, alarm functions, output contacts, and/or alarm signal outputs when operated with remote sensors
Dissolved gas analysis (DGA)	A method of determining the quantities and type of gases that are dissolved within insulating fluids
Fault	An unplanned occurrence or defect in an item which may result in one or more failures of the item itself or of other associated equipment
Fault signal	An audible, visible or other type of output, different from the alarm signal, permitting a warning or indication that the equipment is not working as intended
Gas chromatography (GC)	A process of separating, analyzing, and identifying chemical compounds. GC relies on differences in partitioning behavior between a flowing mobile phase (an inert carrier gas and the sample under test) and a stationary phase to separate the components in a mixture. The components are identified, and their mass and quantity are known.
Gas concentrations	The concentration of a gas dissolved in insulating liquid as expressed in parts per million by volume (ppm v/v), expressed at standard temperature and pressure conditions (0°C and 101.325 kPa)
Indicated value	The representation of measured value of gas concentration by the equipment under test, by output signal and/or display.
Remote sensor	Sensor that is separated from the equipment body and is connected to a control unit or transmitter

Sensor	Assembly in which the sensing element is housed
Stabilization	A state where three successive readings of an equipment at a constant gas volume fraction, taken at 1-hour intervals, indicates no changes greater than ±1% of the measuring range
Standard test gas	Test gas with a composition specified for each item of equipment and gas to be used for all tests, unless otherwise stated
Test Gas	The gas or blend of gases for which the equipment is designed to detect

2. GENERAL INFORMATION

2.1. PRODUCT INFORMATION

DGA monitoring systems are intended to continuously monitor the concentration of gases absorbed within the insulating liquid of a liquid-filled transformer, which can occur as the transformer develops various deficiencies over its operational life. Prior to the development of DGA monitoring systems, gas concentrations were measured by extracting samples of the liquid periodically and having the liquid tested to determine which gases and their quantities were present in the liquid. The buildup of specific gases is an indication of faults occurring within the transformer. With DGA monitoring systems, a sensor is inserted into the cooling system containing the liquid, or the liquid is pumped to a nearby system for analysis where the concentration of gases is determined. Continuous monitoring provides real-time detection of the concentration and rate of rise of gases, allowing for action to be taken before potential catastrophic transformer failures occur. DGA monitoring provides the means to detect sudden gas formation or other intermittent gas formations that would typically be missed between periodic sampling of the liquid.

2.2. CERTIFICATION APPLICATION REQUIREMENTS

2.2.1. The manufacturer shall provide the following preliminary information with any request for certification consideration:

- a complete list of all models, types, sizes, and options for the products or services being submitted for certification consideration,
- general assembly drawings, complete set of manufacturing drawings, anticipated marking format, electrical schematics, nameplate / marking format
- brochures, sales literature, spec. sheets, installation, operation and maintenance procedures,
- the number and location(s) of manufacturing facilities.

2.2.2. All documents shall identify the manufacturer's name, document number or other form of reference, title, date of last revision, and revision level. All foreign language documents shall be provided with English translation.

2.3. REQUIREMENTS FOR SAMPLES FOR EXAMINATION

2.3.1. Following authorization of certification examination, the manufacturer shall submit samples for examination and testing based on the sample requirements to be determined by the certification agency.

2.3.2. Requirements for samples may vary depending on design features, results of prior or similar testing, and results of any foregoing tests.

2.3.3. The manufacturer shall submit samples representative of production.

2.3.4. It is the manufacturer's responsibility to provide any necessary test fixtures, such as those which may be required to evaluate the product with unique construction.

3. GENERAL REQUIREMENTS

3.1. PRODUCT INFORMATION

Where the manufacturer makes any claims in the instruction manual regarding special features of construction or performance specifications that exceed the requirements detailed in this standard, all such claims shall be verified and the test procedures carried out as stated in each clause and shall be extended or supplemented to verify the claimed performance. The performance criteria for each fault gas are detailed in ANNEX A .

3.2. REVIEW OF DOCUMENTATION

During the initial investigation and prior to physical testing, the manufacturer's specifications and details shall be reviewed to assess the ease and practicality of installation and use. The certification examination results may further define the limits of the final certification.

3.3. PHYSICAL OR STRUCTURAL FEATURES

3.3.1. The DGA monitoring equipment shall be able to withstand the normal environmental conditions encountered in manufacturing, storage, or the installation environment for which it is designed. Section 4 details these conditions.

3.3.2. The DGA monitoring equipment shall be able to operate reliably according to the maintenance cycle as specified by the manufacturer. The system components shall be capable of withstanding ambient temperature ranges of -10°C to +40°C for indoor applications, or -25°C to +70°C* for outdoor applications, and be able to operate at normal conditions at these temperature ranges or otherwise specified by the manufacturer.

*NOTE: This upper temperature limit is intended to account for the effects of solar radiation on outdoor metal enclosures. For such installations, an allowance of +15°C has been applied.

3.3.3. Electrical components shall conform to the applicable national and international electrical codes.

3.3.4. Electromagnetic Compatibility (EMC) shall ensure reliable operation of the DGA monitoring equipment and other systems in the vicinity.

3.3.5. Means shall be provided to mechanically or magnetically mount and adequately secure system components in their location of installation. The intended mounting methods shall be compatible with the monitored equipment in its intended environment without compromising functionality. The mounting methods shall be identified in the operating instructions.

3.4. CYBER SECURITY

3.4.1. For systems that are to be connected to the internet via the asset owner's network to facilitate communication and reporting, the equipment shall be ICSA Core Certified to IEC 62443-4-2 and ICSA extinctions for IIoT or shall employ a gateway that meets the identical requirement.

3.4.2. For systems that are to be connected to the SCADA network, the equipment shall be CSA or SSA Certified to IEC 62443-4-2 or IEC 62443-3-3 with a minimum of SLC 2.

3.5. MARKINGS

3.5.1. Marking on the product or, if not possible due to size, on its packaging or label accompanying the product, shall include the following information:

- name and address of the manufacturer or marking traceable to the manufacturer;
- date of manufacture or code traceable to date of manufacture or lot identification;
- model number, size, rating, capacity, etc., as appropriate;
- electrical ratings; and
- FM 6520.
- When hazard warnings are needed, the markings shall be universally recognizable and permanent.

3.5.2. The model or type identification shall correspond with the manufacturer's catalog designation and shall uniquely identify the certification agency’s mark of conformity.

3.5.3. The certification agency's mark of conformity shall be displayed visibly and permanently on the product and/or packaging as appropriate and in accordance with the requirements of the certification agency. The manufacturer shall exercise control of this mark as specified by the certification agency and the certification scheme.

3.5.4. All markings shall be legible and permanent.

3.6. MANUFACTURER'S INSTALLATION INSTRUCTIONS

The manufacturer shall:

- prepare instructions for the installation, maintenance, and operation of the product;
- provide facilities for repair of the product and supply replacement parts, if applicable;
- provide services to ensure proper installation, inspection, or maintenance for products of such nature that it would not be reasonable to expect the average user to be able to provide such installation, inspection, or maintenance;
- provide equipment ratings, including supply voltage or voltage range, frequency or frequency range, and power or current rating;
- provide environmental ratings, temperature range, relative humidity; and
- identify the gas(es) and the range(s) for which the equipment is approved for performance.

3.7. CALIBRATION

3.7.1. Each piece of equipment used to verify the test parameters shall be calibrated within an interval determined on the basis of stability, purpose, and usage. A copy of the calibration certificate for each piece of test equipment is required.
The certificate shall indicate that the calibration was performed against working standards whose calibration is certified and traceable to an acceptable reference standard and certified by an ISO/IEC 17025 accredited calibration laboratory.
The test equipment shall be clearly identified by label or sticker showing the last date of the calibration and the next due date. A copy of the service provider's accreditation certificate as an ISO/IEC 17025 accredited calibration laboratory should be available.

3.7.2. When the inspection equipment and/or environment is not suitable for labels or stickers, other methods such as etching of control numbers on the measuring device are allowed, provided documentation is maintained on the calibration status of the equipment.

3.8. ELECTROMAGENTIC COMPATIBILITY

The equipment their components, and remote detector heads must be constructed to be resistant to, or protected against, electromagnetic interference. Testing shall be verified and documented in accordance with IEC 61326-1 by an ISO/IEC 17025 accredited test laboratory.

4. NORMAL CONDITIONS FOR TEST

4.1. GENERAL

4.1.1. The test conditions specified in the clauses below shall be used for all tests, unless otherwise stated. Where the manufacturer makes claims of performance specifications that exceed the requirements in this standard, all such claims shall be verified and the test procedures carried out as stated in each clause and shall be extended or supplemented to verify the claimed performance.

4.2. LIQUID

4.2.1. All testing is performed in clean mineral oil meeting the specifications of ASTM D3487, unless otherwise specified. All testing performed within a test program shall use oil from the same batch.

4.3. SAMPLING

4.3.1. The mineral oil shall be extracted with a gas-tight syringe via the oil sampling port of the test fixture. See ASTM D923, *Standard Practices for Sampling Electrical Insulating Liquids* for procedures for oil extraction.

4.4. TEST GAS

4.4.1. The gas mixture may be prepared by any suitable method, for example in accordance with the methods outlined in ISO 8142 or ISO 6145, or by commercially produced certified gas mixtures.

4.5. STANDARD TEST GAS

4.5.1. The volume fraction of the standard test gases shall consist of concentrations after absorption in liquid as noted in the Standard Test Gas Value column in ANNEX A for each gas being performance tested. Refer to table G.1 of C57.104-2019, IEEE Guide for the Interpretation of Gases Generated in Mineral Oil-Immersed Transformers, or table 3 of IEC 60599, Mineral oil-filled electrical equipment in service – Guidance on the interpretation of dissolved and free gases analysis, for determining the required amount of gas needed to achieve the absorbed concentration.

4.6. ACCURACY

4.6.1. Each indicated value taken for performance testing in Section 5 shall be compared against a sample of the liquid analyzed by gas chromatography, to be drawn simultaneously.

4.7. VOLTAGE

4.7.1. Mains-powered or fixed DC powered equipment shall be operated within ±2% of the manufacturer's rated voltage and frequency.

4.7.2. Battery-powered equipment shall be equipped with new or fully charged batteries at the commencement of each series of tests. The temperature test shall be carried out with all batteries specified in the instruction manual.

4.8. TEMPERATURE

4.8.1. Unless otherwise specified, the ambient air and gas shall be held at a temperature constant to ±2°C within the range of +15°C to +25°C throughout the duration of each test.

4.9. PRESSURE

4.9.1. The tests shall be performed at a prevailing ambient pressure between 85 kPa and 108 kPa.

4.10. ACCLIMATION TIME

4.10.1. In each instance where the equipment is subjected to a difference test condition, the equipment shall be allowed to stabilize under these new conditions and the manufacturer’s specified stabilization time shall be observed before measurements are taken.

4.11. ORIENTATION

4.11.1. The equipment shall be tested in each orientation specified by the manufacturer.

4.12. COMMUNICATIONS

4.12.1. The equipment shall be tested with all methods of communication connected and active. The equipment shall operate at the maximum transaction rate, cabling characteristics, and activity level specified by the instrument's manufacturer.

4.13. ALARMS

4.13.1. Equipment with alarm capabilities shall be fixed or adjustable only within the measuring range.

4.13.2. Equipment with multiple configurable alarms for a single gas shall document the order and range(s) for the alarms from most sensitive to the least sensitive. A more sensitive setpoint shall only be configurable to a value greater than a less sensitive setpoint.

5. PERFORMANCE REQUIREMENTS

5.1. GENERAL

5.1.1. The equipment tested shall be fully representative of equipment intended for commercial production.

5.1.2. The performance tests shall be carried out on the same sample except for tests 5.13 through 5.18, which may be conducted on separate samples.

5.1.3. The unpowered storage test (5.2), initial preparation of equipment (5.3), and vibration test (5.4) shall be conducted prior to all remaining tests except for tests 5.13 through 5.18. All remaining tests shall be performed to a schedule agreed upon between the manufacturer and the test laboratory.

5.1.4. For equipment being certified for use in more than one liquid, the full test program shall be performed using mineral oil. For the second and subsequent liquids, the accuracy test (5.5) shall be performed in these liquids with any correction factors applied.

5.1.5. Unwarranted or false alarms shall be considered failure of the tests described below.

5.1.6. Calibration of the equipment, if applicable, shall be performed between tests, or as the manufacturer specifies in the instruction manual.

5.1.7. All indicated values from the equipment readings are verified and compared against liquid drawn samples analyzed via Gas Chromatography following practice detailed in ASTM D3612.

5.1.8. When extracting liquid for analysis, the procedures detailed in ASTM D923 shall be applied.

5.2. UNPOWERED STORAGE

5.2.1. The equipment shall be exposed sequentially to the following temperatures in clean air, or to the minimum/maximum storage temperatures specified by the manufacturer, whichever is more severe:

	For sensors or probes immersed in liquid:	**For control equipment, remote equipment, or any equipment not immersed in liquid for indoor use:**	**For control equipment, remote equipment, or any equipment not immersed in liquid for outdoor use:**
Step 1	-20°C ± 3°C	-10°C ± 3°C	-25°C ± 3°C
Step 2	+21°C ± 3°C	+21°C ± 3°C	+21°C ± 3°C
Step 3	+70°C ± 3°C	+40°C ± 3°C	+70°C ± 3°C
Step 4	+21°C ± 3°C	+21°C ± 3°C	+21°C ± 3°C

5.3. INITIAL PREPARATION OF THE EQUIPMENT

5.3.1. The equipment shall be installed, calibrated, and adjusted to obtain correct indications in accordance with the manufacturer's instructions.

5.4. VIBRATION

5.4.1. The vibration test shall be carried out in accordance with IEC 60068-2-6. The equipment shall be energized and mounted on the vibration test machine and vibrated successively in each of the three planes respectively parallel to each of the three major axes of the equipment.

5.4.2. The equipment shall be vibrated for a period of at least 1 hour in each of the three planes. The frequency shall continuously change exponentially with time, and the rate of change of frequency shall be one octave per minute. The vibration shall be 10 Hz to 31.5 Hz, 0.5 mm displacement amplitude (1.0 mm peak-peak total excursion) and 31.5 Hz to 100 Hz, 19.6 m/s^2 acceleration amplitude.

5.4.3. The equipment shall remain energized throughout the test. The equipment shall not give indication of alarm. The equipment shall not give a false indicated value of the presence of the test gas.

5.4.4. For testing on sensors or probes immersed in liquid, the indicated value shall meet the Acceptance Criteria in ANNEX A of the original stabilized indicated value throughout the test.

5.5. ACCURACY

5.5.1. The equipment shall be tested with the liquid that has absorbed the test gas in concentrations of 0%, 25%, 50%, 75%, and 90% of either the upper measurement range or the Pre-Failure Limit specified in ANNEX A , whichever is lower, in ascending order from the lowest to the highest concentration. Indicated values shall be taken after stabilization. After all readings are taken, the liquid shall be purged with Nitrogen until the equipment reading is stable. The equipment shall indicate a value within the Acceptance Criteria in ANNEX A . For DGA Systems monitoring multiple gases, the sequence shall be repeated for each remaining gas being tested for performance.

5.5.2. For DGA Systems specifying test gases with measuring ranges exceeding the limits of the Pre-Failure Limit in ANNEX A , the accuracy test shall be performed with gas concentrations of 0%, 25%, 50%, 75%, and 90% of the measuring range, ascending from lowest to highest concentration.

5.6. REPEATABILITY

5.6.1. The equipment shall be exposed to three applications of the liquid having absorbed the standard test gas(es), with each application maintained until a stable indicated value is measured, followed by purging with Nitrogen. Indicated values shall be taken at the end of each application of standard test gas(es) and the purging of Nitrogen. All indicated values shall meet the Acceptance Criteria in ANNEX A for the gas(es) applied.

5.7. ALARM SET POINT(S)

5.7.1. Fixed alarms shall be tested with the liquid that has absorbed the test gas in concentrations equal to the set point minus twice the Acceptance Criteria in ANNEX A and shall not activate the alarm.

5.7.2. Fixed alarms shall be tested with the liquid that has absorbed the test gas in concentrations equal to set point plus twice the Acceptance Criteria in ANNEX A and shall activate the alarm.

5.7.3. Configurable alarms shall have the tests of 5.7.1 and 5.7.2 repeated at the minimum and maximum setpoint for each alarm.

5.7.4. Equipment with more than one configurable alarm for a single gas shall be tested to verify that the less sensitive alarm cannot be set equal to or above a more sensitive alarm and the more sensitive alarm cannot be set equal to or below a less sensitive alarm.

5.8. TEMPERATURE

5.8.1. For sensors or probes immersed in liquid:

a. The test shall be performed in a fixture having the capability of holding the liquid at the specified temperature within ±2°C, or at the manufacturer's claimed maximum temperature if greater. The temperature of the liquid shall be adjusted in the sequence as specified below for 2 hours after internal thermal stability of the liquid.

	Sensors or probes immersed in liquid
Step 1	+21°C with liquid purged with Nitrogen
Step 2	+21°C with liquid having absorbed standard test gas(es)
Step 3	+70°C with liquid having absorbed standard test gas(es)
Step 4	+70°C with liquid purged with Nitrogen

b. Indicated values shall be taken after stabilization. All indicated values shall meet the Acceptance Criteria in ANNEX A for the gas(es) applied.

5.8.2. For control equipment, remote equipment, or any equipment not immersed in liquid:

a. The test shall be performed with the equipment installed in a thermal chamber capable of holding the specified temperature within ±2°C, or at the manufacturer's claimed minimum/maximum temperatures if greater. The liquid and the sensor or probe immersed in liquid shall be at ambient temperature. The temperature of the equipment shall be adjusted in the sequence as specified below for 2 hours after internal thermal stability.

	Control equipment, remote equipment, or any equipment not immersed in liquid for indoor use	**Control equipment, remote equipment, or any equipment not immersed in liquid for outdoor use**
Step 1	+21°C with liquid purged with Nitrogen	+21°C with liquid purged with Nitrogen
Step 2	+21°C with liquid having absorbed standard test gas(es)	+21°C with liquid having absorbed standard test gas(es)
Step 3	-10°C with liquid having absorbed standard test gas(es)	-25°C with liquid having absorbed standard test gas(es)
Step 4	+40°C with liquid having absorbed standard test gas(es)	+70°C with liquid having absorbed standard test gas(es)

b. Indicated values shall be taken after stabilization. All indicated values shall meet the Acceptance Criteria in ANNEX A for the gas(es) applied.

5.9. ORIENTATION

5.9.1. The equipment shall be tested with the liquid having absorbed the standard test gas(es) and the liquid purged with Nitrogen in the orientation limits stated in the manufacturer's instruction. Indicated values shall be taken after stabilization. All indicated values shall meet the Acceptance Criteria in ANNEX A for the gas(es) applied.

5.10. CROSS-SENSITIVITY

5.10.1. The equipment shall be exposed to liquid having absorbed all fault gases indicated in ANNEX A , with a concentration of the Standard Test Gas Value defined for each gas. The liquid shall be saturated for a period of no less than 24 hours. Indicated values shall be taken for the gases being tested for performance. The indicated values meet the Acceptance Criteria in ANNEX A for the specified gases being tested for performance. The liquid shall then be saturated with standard test gas for the gases being tested for performance. The indicated value shall meet the Acceptance Criteria in ANNEX A .

5.11. HIGH CONCENTRATION ABOVE RANGE

5.11.1. The equipment shall be subjected to liquid having absorbed one test gas at a concentration of twice the measuring range specified by the manufacturer. The gas shall be applied until a stable value is reached, a fault is indicated, or indication of an upper alarm is given. The liquid shall then be purged with Nitrogen until a stable indicated value is reached or fault is cleared. The test shall be repeated for each remaining gas being tested for performance. After exposure to all applicable gases, the equipment shall then be exposed to liquid having absorbed the standard test gas(es). All indicated value shall meet the Acceptance Criteria in ANNEX A for the gas(es) applied.

5.12. BATTERY

5.12.1. Equipment powered by batteries shall be capable of continuous operation for a period of at least 24 hours, including 1 hour of maximum load (e.g. continuous alarm, lights, etc.) without replacement or recharge of batteries.

5.13. VOLTAGE VARIATION

5.13.1. The equipment shall be configured for maximum load and tested with liquid having absorbed one standard test gas, followed by testing with the liquid purged with Nitrogen at both 115% and 80% of nominal voltage or the maximum and minimum values of the rated voltage. In all cases, the indicated values shall meet the Acceptance Criteria in ANNEX A for the gas(es) applied.

5.14. FAULTS

5.14.1. Fault signals shall be validated as follows:

- Fixed and externally powered equipment shall provide a fault signal in the event of failure of power to the equipment.
- A short or open-circuit in connections to any remote sensor or transmitter shall be indicated by a fault signal.
- For equipment where the sensor can be disconnected without opening the housing, the equipment shall provide a fault signal in the event of a disconnection of the sensor.

5.15. DROP TEST

5.15.1. Portable or transportable equipment shall be subjected to a drop test, while operating, from a height of (1.0 ± 0.05) m above a concrete surface and allowed to free fall. Transportable equipment with a mass less than 5 kg shall be dropped, while not operating, from a height of (0.3 ± 0.03) m above a concrete surface and allowed to free fall. All heights are measured from the lowest point of the equipment. The test shall be performed three separate times, the portable equipment being dropped each time with a different side (surface) facing down at the time of release and the transportable equipment to be in an orientation for normal transport. The equipment shall be considered to have failed this test if there is a loss of function after the test.

5.16. IMPACT TEST

5.16.1. For control units, remote equipment, or any equipment not immersed in the liquid, the equipment shall be subjected to the impact test, with satisfactory results, as required by ANSI/UL 61010-1.

5.17. DIELECTRIC TEST

5.17.1. The equipment shall be subjected to dielectric strength tests, with satisfactory results, as required by ANSI/UL 61010-1.

5.18. ENVIRONMENTAL TESTS

5.18.1. For equipment marked to indicate an environmental rating for protection against the ingress of dust or water, testing shall be performed as defined by the stated standard (e.g. ANSI/IEC 60529, UL 50E, etc.). After environmental testing, the equipment shall be tested with liquid having absorbed the standard test gas(es). Indicated values shall be taken after stabilization. The equipment shall meet the Acceptance Criteria in ANNEX A for the gas(es) applied.

6. MANUFACTURER'S REQUIREMENTS

6.1. DEMONSTRATED QUALITY CONTROL PROGRAM

6.1.1. A quality assurance program is required to assure that subsequent products produced by the manufacturer shall present the same quality and reliability as the specific products 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 certification report.
- Continued conformance to this standard is verified by the certifier's surveillance program.
- Quality of performance is determined by field performance and by periodic re-examination and testing.

6.1.2. 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; and
- handling and disposition of non-conforming materials.

6.1.3. 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.

6.1.4. Records

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.

6.1.5. 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 certification report, may be required to be reported to, and authorized by the certification agency prior to implementation for production.

Records of all revisions to all certified products shall be maintained.

6.2. SURVEILLANCE AUDIT PROGRAM

6.2.1. An audit of the manufacturing facility may be part of the certification agency's surveillance requirements 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 ensure a uniform product consistent with that which was tested and certified.

6.2.2. Certified products or services shall be produced or provided at, or provided from, location(s) disclosed as part of the certification examination. Manufacture of products bearing a certification mark is not permitted at any other location prior to disclosure to the certification agency.

6.3. PRODUCT MODIFICATION

6.3.1. The manufacturer shall notify the certification agency of changes in product construction, components, raw materials, physical characteristics, coatings, component formulation or quality assurance procedures prior to implementation.

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ISO 6145-10, Gas analysis – Preparation of calibration gas mixtures using dynamic volumetric methods – Part 10: Permeation method

UL 50E, Enclosures for Electrical Equipment, Environmental Considerations

ANNEX A - GAS SPECIFIC PERFORMANCE TEST AND ACCEPTANCE CRITERIA

Gas	Acceptance Criteria	Standard Test Gas Value	Pre-Failure Limit
Acetylene C_2H_2	±1 ppm or ±15% of reading	200 ppm	450 ppm
Carbon Dioxide CO_2	±15 ppm or ±15% of reading	25,000 ppm	50,000 ppm
Carbon Monoxide CO	±10 ppm or ±15% of reading	1,000 ppm	2,100 ppm
Ethane C_2H_6	±15 ppm or ±15% of reading	400 ppm	900 ppm
Ethylene C_2H_4	±10 ppm or ±15% of reading	400 ppm	800 ppm
Hydrogen H_2	±25 ppm or ±20% of reading	400 ppm	725 ppm
Methane CH_4	±10 ppm or ±15% of reading	200 ppm	400 ppm

Note 1: Multi-gas DGA Monitoring Systems may monitor Oxygen (O_2) and Nitrogen (N_2) levels. As these gases are present but are not fault by-products, the accuracy of these gases is not required to be verified for performance.

Note 2: The pre-failure criteria is determined from data compiled in CIGRE TB 771 and IEC 60599. The ppm values are an average of the gas concentration levels of transformers entering a pre-failure state.