



JOINT CANADA-UNITED STATES
NATIONAL STANDARD

ANSI/CAN/UL 9540:2020

STANDARD FOR SAFETY

Energy Storage Systems and Equipment

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UL Standard for Safety for Energy Storage Systems and Equipment, ANSI/CAN/UL 9540

Second Edition, Dated February 27, 2020

Summary of Topics

This Second Edition of ANSI/CAN/UL 9450, Standard for Safety for Energy Storage Systems and Equipment, has been issued to reflect the latest ANSI and SCC approval dates, and to incorporate the proposals dated June 28, 2019, October 18, 2019, and December 20, 2019.

The new requirements are substantially in accordance with Proposal(s) on this subject dated June 28, 2019, October 18, 2019 and December 20, 2019.

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ANSI/UL 9540-2020

FEBRUARY 27, 2020



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ANSI/CAN/UL 9540:2020

Standard for Energy Storage Systems and Equipment

First Edition – October 25, 2018

Second Edition

February 27, 2020

This ANSI/CAN/UL Safety Standard consists of the Second Edition.

The most recent designation of ANSI/UL 9540 as an American National Standard (ANSI) occurred on February 27, 2020. ANSI approval for a standard does not include the Cover Page, Transmittal Pages, Title Page, Preface or SCC Foreword.

This standard has been designated as a National Standard of Canada (NSC) on February 27, 2020.

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Preface (UL)

This is the Second Edition of ANSI/CAN/UL 9540 Standard for Safety for Energy Storage Systems and Equipment.

UL is accredited by the American National Standards Institute (ANSI) and the Standards Council of Canada (SCC) as a Standards Development Organization (SDO).

This Standard has been developed in compliance with the requirements of ANSI and SCC for accreditation of a Standards Development Organization.

This ANSI/CAN/UL 9540 Standard is under continuous maintenance, whereby each revision is approved in compliance with the requirements of ANSI and SCC for accreditation of a Standards Development Organization. In the event that no revisions are issued for a period of four years from the date of publication, action to revise, reaffirm, or withdraw the standard shall be initiated.

In Canada, there are two official languages, English and French. All safety warnings must be in French and English. Attention is drawn to the possibility that some Canadian authorities may require additional markings and/or installation instructions to be in both official languages.

Comments or proposals for revisions on any part of the Standard may be submitted to UL at any time. Proposals should be submitted via a Proposal Request in UL's On-Line Collaborative Standards Development System (CSDS) at <http://csds.ul.com>.

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This Edition of the Standard has been formally approved by the UL Standards Technical Panel (STP) on Energy Storage Systems and Equipment, STP 9540.

This list represents the STP 9540 membership when the final text in this standard was balloted. Since that time, changes in the membership may have occurred.

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This Standard is intended to be used for conformity assessment.

The intended primary application of this standard is stated in its scope. It is important to note that it remains the responsibility of the user of the standard to judge its suitability for this particular application.

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INTRODUCTION

1 Scope

1.1 These requirements cover energy storage systems that are intended to receive and store energy in some form so that the energy storage system can provide electrical energy to loads or to the local/area electric power system (EPS) when needed. The types of energy storage covered under this standard include electrochemical, chemical, mechanical and thermal. The energy storage system shall be constructed either as one unitary complete piece of equipment or as matched assemblies, that when connected, form the system. This standard is a system standard, where an energy storage system consists of the an energy storage mechanism, power conversion equipment and balance of plant equipment as shown in [Figure 6.1](#). Individual parts (e.g. power conversion system, battery system, etc.) of an energy storage system are not considered an energy storage system on their own. This standard evaluates the compatibility and safety of these various components integrated into a system.

NOTE: Energy storage systems may include equipment for charging, discharging, control, protection, power conversion, communication, controlling the system environment, air, fire detection and suppression system, fuel or other fluid movement and containment, etc.

1.2 The systems covered by this standard include those intended to be used in a standalone mode (e.g. islanded) including "self-supply" systems to provide electrical energy and those used in parallel with an electric power system or electric utility grid such as "grid-supply" systems, or applications that perform ancillary operational modes associated with power generation such as voltage support and regulation, frequency support and regulation, volt-var, capacity reserve, energy shifting or other utility grid support services.

1.3 Energy storage systems are intended for installation and use in accordance with the National Electrical Code, NFPA 70, the Canadian Electrical Code, Part I Safety Standard for Electrical Installations, CSA C22.1, the National Electrical Safety Code, IEEE C2, the International Fire Code, ICC IFC, the International Residential Code, ICC IRC, the National Fire Code of Canada, NRC NFC, the Fire Code, NFPA 1, and the Standard for the Installation of Stationary Energy Storage Systems, NFPA 855. Requirements for installation, with the exception of installation manuals and documents for installation provided with the system are outside the scope of this standard.

1.4 This standard covers energy storage systems for stationary indoor and outdoor installations. This standard also covers mobile energy storage systems as defined by this standard. The standard includes requirements for energy storage systems used in residential installations, non-residential installations and wall-mounted applications.

1.5 Systems using lead acid or Ni-cad batteries that fall within the scope of UL 1778 and only serve an uninterruptible power system (UPS) application are outside the scope of this standard.

1.6 The maximum energy capacity of individual electrochemical ESS shall not exceed the following values:

- a) Outdoor wall mounted electrochemical ESS shall not exceed 20 kWh (72 MJ);
- b) Residential use electrochemical ESS shall not exceed 20 kWh (72 MJ); and
- c) Non-residential use electrochemical ESS shall not exceed 50 kWh (180 MJ), except as allowed in [1.7](#) – [1.11](#).

1.7 With reference to [1.6](#), there is no maximum energy capacity limit for non-residential use electrochemical ESS that are tested in accordance with the Standard for Test Method for Evaluating

Thermal Runaway Fire Propagation in Battery Energy Storage Systems, UL 9540A in which the performance level criteria of the cell level test have been met.

1.8 With reference to [1.6](#), the maximum energy capacity of non-residential use electrochemical ESSs shall be permitted to be increased to the value of the unit which complies with the UL 9540A Unit Level Test.

1.9 With reference to [1.6](#), the maximum energy capacity of non-residential use electrochemical ESSs shall be permitted to be increased to the value of the unit which complies with the UL 9540A Performance criteria for the Installation Level test, and the ESS shall be marked in accordance with [41.13](#).

1.10 With reference to [1.6](#), there is no maximum energy capacity limit for non-residential use electrochemical ESS intended for use in remote outdoor locations as defined in the applicable installation code, provided they are marked in accordance with [41.15](#). The Standard for the Installation of Stationary Energy Storage Systems, NFPA 855 defines outdoor remote locations as being located more than 30.5 m (100 ft) from exposures.

1.11 With reference to [1.6](#), lead acid and Ni-Cad energy storage systems have exceptions to the capacity energy limits including, in some cases, no limits based upon specific telecom and utility installations as outlined in NFPA 855.

2 Components

2.1 A component or equipment of an energy storage system covered by this standard shall comply with the safety requirements for that component or equipment. See Appendix [A](#) for a list of standards covering components generally used in the energy storage systems covered by this standard. Components and equipment shall comply with the CSA and/or UL standards as appropriate for the country or countries where the energy storage system is to be installed.

3 Units of Measurement

3.1 Values and their respective units of measurement that are stated without parentheses constitute the requirement of the standard and those in parentheses constitute explanatory or approximate information.

4 Undated References

4.1 Any undated reference appearing in the requirements of this standard shall be interpreted as referring to the latest edition of the reference, including all revisions and amendments.

5 Normative References

5.1 The following standards are referenced in this standard, and portions of these referenced standards may be essential for compliance. Energy storage systems covered by this standard shall comply with the referenced installation codes and standards as appropriate for the country where the energy storage system is to be installed. When the energy storage system is intended for use in more than one country, the energy storage system shall comply with the installation codes and standards for all countries where it is intended to be used.

American Society of Mechanical Engineers (ASME) Codes

ASME B31 (all applicable parts), *Power Piping*
ASME BPVC, *Boiler and Pressure Vessel Code*

ASTM International

ASTM D4169, *Standard Practice for Performance Testing of Shipping Containers and Systems*

CSA Group Standards

CSA C22.1, *Canadian Electrical Code, Part I Safety Standard for Electrical Installations*
CAN/CSA-C22.2 No. 0, *General Requirements – Canadian Electrical Code, Part II*
CSA C22.2 No. 0.15, *Adhesive Labels*
CAN/CSA-C22.2 No. 0.17, *Evaluation of Properties of Polymeric Materials*
CSA C22.2 No. 0.2, *Insulation Coordination*
CSA C22.2 No. 0.8, *Safety Functions Incorporating Electronic Technology*
CSA C22.2 No. 14, *Industrial Control Equipment*
CSA C22.2 No. 94.2, *Enclosures for Electrical Equipment, Environmental Considerations*
CSA C22.2 No. 100, *Motors and Generators*
CSA C22.2 No. 107.1, *Power Conversion Equipment*
CAN/CSA-C22.2 No. 107.2, *Battery Chargers*
CSA C22.2 No. 139, *Electrically Operated Valves*
CSA C22.2 No. 301, *Industrial Electrical Machinery*
CAN/CSA-C22.2 No. 60079-2, *Explosive Atmospheres – Part 2: Equipment Protection By Pressurized Enclosure "p"*
CAN/CSA-C22.2 No. 60950-1, *Information Technology Equipment – Safety – Part 1: General Requirement*
CAN/CSA-C22.2 No. 60529, *Degrees of Protection Provided By Enclosures (IP Code)*
CAN/CSA-C22.2 No. 62109-1, *Safety of Power Converters for Use in Photovoltaic Power Systems – Part 1: General Requirements*
CAN/CSA C22.2 No. 62368-1, *Audio/Video, Information and Communication Technology Equipment – Part 1: Safety Requirements*
CSA B51, *Boiler, Pressure Vessel, and Pressure Piping Code*
CSA B52, *Mechanical Refrigeration Code*
CSA B149.1, *Natural Gas and Propane Installation Code*
CSA FC 1, *Fuel Cell Technologies – Part 3-100: Stationary Fuel Cell Power Systems – Safety*
CSA Z462, *Workplace Electrical Safety*
CSA Z662, *Oil and Gas Pipeline Systems*
CAN/CSA-E60730-1, *Automatic Electrical Controls for Household and Similar Use – Part 1: General Requirements*

International Code Council (ICC)

ICC IFC, *International Fire Code*
ICC IRC, *International Residential Code*

International Electrotechnical Commission (IEC) Standards

IEC 60068-2-52, *Environmental Testing Part 2: Tests – Tests Kb, Salt Mist, Cyclic (Sodium Chloride Solution)*
IEC 60364-4-41, *Low-Voltage Electrical Installations – Part 4-41: Protection for Safety – Protection Against Electric Shock*
IEC 60364-6, *Low-Voltage Electrical Installations – Part 6: Verification*
IEC 60417 Database, *Graphical Symbols for Use on Equipment*
IEC 60529, *Degrees of Protection Provided by Enclosures (IP Code)*
IEC 60664-1, *Insulation Coordination for Equipment Within Low-Voltage Systems – Part 1: Principles, Requirements and Tests*
IEC 60812, *Failure modes and effects analysis (FMEA and FMECA)*
IEC 60896-11, *Stationary Lead-Acid Batteries Part 11: Vented Types General Requirements and Methods of Tests*

IEC 60896-21, Stationary Lead-Acid Batteries Part 21: Valve Regulated Types Methods of Test
IEC 60980, Recommended Practices for Seismic Qualification of Electrical Equipment of the Safety System for Nuclear Generating Stations
IEC 61000-4-2, Electromagnetic Compatibility (EMC) – Part 4-2: Testing and Measurement Techniques – Electrostatic Discharge Immunity Test
IEC 61000-4-3, Electromagnetic Compatibility (EMC) – Part 4-3: Testing and Measurement Techniques – Radiated, Radio-Frequency, Electromagnetic Field Immunity Test
IEC 61000-4-4, Electromagnetic compatibility (EMC) – Part 4-4: Testing and Measurement Techniques – Electrical Fast Transient/Burst Immunity Test
IEC 61000-4-5, Electromagnetic Compatibility (EMC) – Part 4-5: Testing and Measurement Techniques – Surge Immunity Test
IEC 61000-4-6, Electromagnetic Compatibility (EMC) – Part 4-6: Testing and Measurement Techniques – Immunity to Conducted Disturbances, Induced by Radio-Frequency Fields
IEC 61000-4-8, Electromagnetic Compatibility (EMC) – Part 4-8: Testing and Measurement Techniques – Power Frequency Magnetic Field Immunity Test
IEC 61000-6-2, Electromagnetic Compatibility (EMC) – Part 6-2: Generic Standards – Immunity Standard for Industrial Environments
IEC 61025, Fault Tree Analysis (FTA)
IEC 61508 (all parts), Functional Safety of Electrical/Electronic/Programmable Electronic Safety-Related Systems
IEC 62040-1, Uninterruptible Power Systems (UPS) – Part 1: Safety Requirements

Institute of Electrical and Electronics Engineers (IEEE) Standards Association

IEEE C2, National Electrical Safety Code
IEEE 693, Recommended Practice for Seismic Design of Substations
IEEE 1547, Interconnecting Distributed Resources with Electric Power Systems
IEEE 1547.1, Conformance Test Procedures for Equipment Interconnecting Distributed Resources with Electric Power Systems

International Standards Organization (ISO) Standards

ISO 7010, Graphical Symbols – Safety Colours and Safety Signs – Registered Safety Signs
ISO 13849-1, Safety of Machinery – Safety-Related Parts of Control Systems – Part 1: General Principles for Design
ISO 13849-2, Safety of Machinery – Safety-Related Parts of Control Systems – Part 2: Validation
ISO 26262 (all parts), Road Vehicles – Functional Safety

National Electrical Manufacturers Association (NEMA)

NEMA Z535.1, Safety Colors
NEMA Z535.2, Environmental and Facility Safety Signs
NEMA Z535.3, Criteria for Safety Symbols
NEMA Z535.4, Product Safety Signs and Labels
NEMA Z535.5, Safety Tags and Barricade Tape (for Temporary Hazards)
NEMA Z535.6, Product Safety Information in Product Manuals, Instructions, and Other Collateral Materials

National Fire Protection Association (NFPA) Codes and Standards

NFPA 1, Fire Code
NFPA 70, National Electrical Code
NFPA 70E, Electrical Safety in the Workplace
NFPA 79, Electrical Standard for Industrial Machinery
NFPA 286, Standard Methods of Fire Tests for Evaluating Contribution of Wall and Ceiling Interior Finish to Room Fire Growth

NFPA 497, Recommended Practice for the Classification of Flammable Liquids, Gases, or Vapors and of Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas
NFPA 855, Standard for the Installation of Stationary Energy Storage Systems

National Research Council of Canada

NRC NFC, National Fire Code of Canada

Occupational Safety and Health Standards (OSHA)

29 CFR 1910.1200, Toxic and Hazardous Substances

Telcordia

GR-63-CORE, Network Equipment Building System (NEBS) Requirements: Physical Protection

UL Standards

UL 50E, Enclosures for Electrical Equipment, Environmental Considerations
UL 252, Compressed Gas Regulators
UL 429, Electrically Operated Valves
UL 508C, Power Conversion Equipment
UL 746C, Polymeric Materials – Use in Electrical Equipment Evaluations
UL 840, Insulation Coordination Including Clearances and Creepage Distances For Electrical Equipment
UL 842, Valves for Flammable Fluids
UL 991, Tests for Safety-Related Controls Employing Solid-State Devices
UL 1012, Power Units Other Than Class 2
UL 1564, Industrial Battery Chargers
UL 1741, Inverters, Converters, Controllers and Interconnection System Equipment for Use With Distributed Energy Resources
UL 1778, Uninterruptible Power Systems
UL 1971, Signaling Devices for the Hearing Impaired
UL 1973, Batteries for Use in Stationary, Vehicle Auxiliary Power and Light Electric Rail (LER) Applications
UL 1998, Software in Programmable Components
UL 2200, Stationary Engine Generator Assemblies
UL 2416, Audio/Video, Information and Communication Technology Equipment Cabinet, Enclosure and Rack Systems
UL 5500, Remote Software Updates
UL 9540A, Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems
UL 60079-2, Explosive Atmospheres – Part 2: Equipment Protection by Pressurized Enclosures "p"
UL 60730-1, Automatic Electrical Controls for Household and Similar Use, Part 1: General Requirements
UL 60950-1, Information Technology Equipment – Safety – Part 1: General Requirements
UL 62109-1, Safety of Power Converters for Use in Photovoltaic Power Systems – Part 1: General Requirements
UL 62368-1, Audio/Video, Information and Communication Technology Equipment – Part 1: Safety Requirements

ULC Standards

ULC/ORD-C842, Guide for the Investigation of Valves for Flammable and Combustible Liquids

US Department of Defense (DOD) Standards

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MIL-STD-882E, System Safety

6 Glossary

6.1 For the purpose of this standard, the following definitions apply.

6.2 **ARC FLASH BOUNDARY** – The area within which a hazardous arc could occur, and which requires the use of special protective equipment (PPE). See [10.12](#).

6.3 **COMMISSIONING** – The process by which an energy storage system, upon installation, is tested and otherwise evaluated to verify that it functions according to its design objectives and specifications.

6.4 **DECOMMISSIONING** – The act of removing an energy storage system from service, which includes shutting it down, typically some level of dismantling, and then finally removing it from the site of installation.

6.5 **DUT** – Device under test.

6.6 **ELECTRIC POWER SYSTEM (EPS)** – Equipment or facilities that deliver electric power to a load. The most common example of an EPS is an electric utility.

6.7 **ELECTRIC SHOCK HAZARD** – A potential for exposure of persons to hazardous voltage circuits through direct contact from openings in protective enclosures and/or insufficient insulation between hazardous voltage circuits and accessible parts.

6.8 **ENCLOSURE** – The outer cover of the Energy Storage System that provides protection to its contents.

6.9 **ENERGY STORAGE SYSTEM (ESS)** – Equipment that receives energy and then provides a means to store that energy in some form for later use in order to supply electrical energy when needed. See [Figure 6.1](#). An ESS utilizes one of the following technologies:

a) **ELECTROCHEMICAL ESS** – Consists of a secondary (rechargeable) battery, electrochemical capacitor, flow battery or hybrid battery-capacitor system that stores electrical energy and any associated controls or devices that can provide the stored electric energy upon demand.

b) **CHEMICAL ESS** – Consists of hydrogen storage, the hydrogen generator to supply the hydrogen for storage, and a fuel cell power system to provide electric energy upon demand.

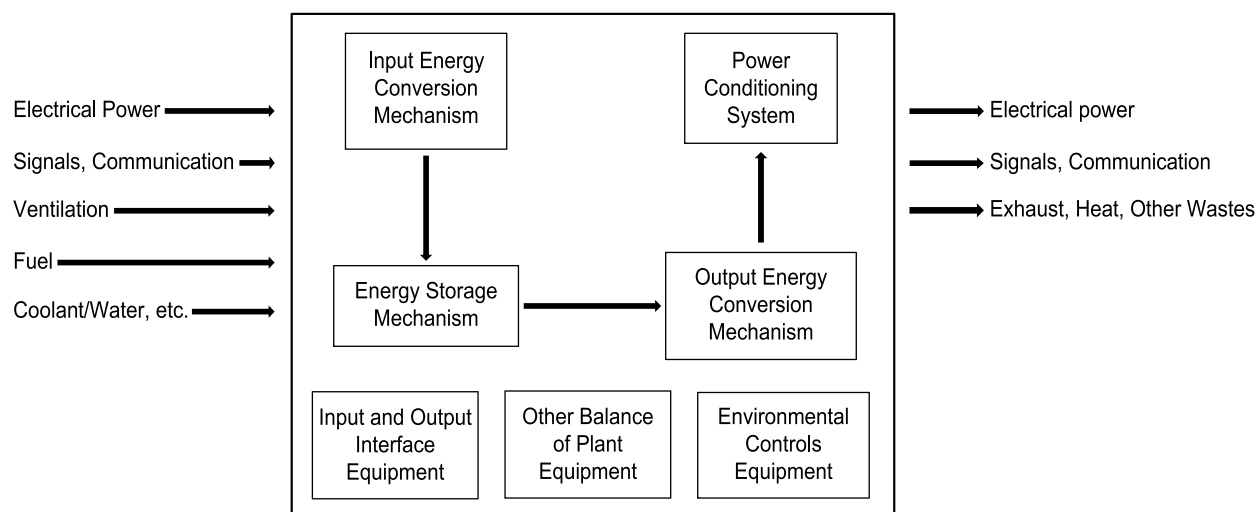
c) **MECHANICAL ESS** – Consists of a mechanical means to store energy such as through compressed air, pumped water or fly wheel technologies and associated controls and systems, which can be used to run an electric generator to provide electric energy upon demand.

d) **THERMAL ESS** – Consists of a system that uses heated fluids such as air as a means to store energy along with associated controls and systems, which can be used to run an electric generator to provide electrical energy upon demand.

NOTE: The ESS may be a single unit or composed of multiple parts. The ESS may include equipment for charging, discharging, control, protection, power conversion, communication, controlling the system environment, air, fire detection and suppression system, fuel or other fluid movement and containment, etc. as shown in [Figure 6.1](#).

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Figure 6.1
Block Diagram of Energy Storage System



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Examples:

Technology	Input Energy Conversion Mechanism	Energy Storage Mechanism	Output Energy Conversion Mechanism
Electrochemical	Charger	Battery System	Converter
Chemical	Water Electrolysis Hydrogen Generator	Hydrogen Storage	Combustion Generator Fuel Cell
Mechanical	Air Compressor	Flywheel	Motor Generator
Thermal	Heat Pump	Thermal Storage	Heat Generator or Heat Exchanger

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6.10 ENERGY STORAGE SYSTEM INTEGRATOR – The entity typically responsible for ensuring the various parts of the ESS work together, and that the ESS works with the external systems that either supply energy into the ESS or use energy from the ESS.

6.11 FAILURE MODES AND EFFECT ANALYSIS (FMEA) – a rigorous and systematic methodology for analyzing reliability and the impact the failure of any one component associated with a technology and its installation has on safety. For the purposes of this standard, only the impact to safety is considered.

6.12 FUEL CELL POWER SYSTEM – Equipment that converts chemical energy in the form of a fuel and oxidant into electrical energy with heat and by-products from the reaction.

6.13 HAZARDOUS ARC – An electrical arc with sufficient energy to result in physical hazards to someone coming in contact with it. See [10.12](#).

6.14 HAZARDOUS FLUID – A hazardous material (e.g. toxic, combustible, etc.) that is either a liquid or a gas.

6.15 HAZARDOUS MATERIAL – A hazardous material is a substance, which has the potential to cause harm to humans, animals, or the environment, either by itself or through interaction with other factors. Hazardous materials are further defined in 29 CFR 1910.1200.

6.16 HAZARDOUS VOLTAGE – Voltage exceeding 30 Vrms/42.4 Vac peak or 60 Vdc is considered hazardous.

6.17 HVAC – Heating, ventilation and air-conditioning.

6.18 INSULATION LEVELS – The following are levels of electrical insulation:

a) BASIC INSULATION – A single level of insulation that is intended to provide protection against electric shock when the insulation has not failed.

b) DOUBLE INSULATION – Insulation comprising both basic insulation and supplementary insulation.

c) FUNCTIONAL INSULATION – Insulation that is necessary only for the correct functioning of the equipment that can reduce the likelihood of ignition and fire, and that does not protect against electric shock.

d) REINFORCED INSULATION – Single insulation system that provides a degree of protection against electric shock equivalent to double insulation under the conditions specified in this standard. The "insulation system" consists of one homogeneous piece, or several layers that cannot be tested as basic insulation and supplementary insulation.

e) SUPPLEMENTARY INSULATION – Independent insulation applied in addition to basic insulation in order to reduce the risk of electric shock in the event of a failure of the basic insulation.

6.19 MOBILE ENERGY STORAGE SYSTEMS (MESS) – An ESS that is not portable, but has a means so that it can be moved (e.g. mounted on a wheeled trailer or skid) to a site to provide power on a temporary basis.

6.20 NON-COMBUSTIBLE DIELECTRIC MEDIUM – A transformer fluid that does not ignite, burn, give off flammable vapors or support combustion in air.

6.21 NON-COMBUSTIBLE MATERIAL – A material that will not ignite or burn when subjected to fire or excessive heat.