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OUTLINE OF INVESTIGATION
FOR
PORTABLE WATER ELECTROLYSIS TYPE HYDROGEN GENERATORS

Issue Number: 1

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Summary of Topics

This is the first issue of the Outline of Investigation for Portable Water Electrolysis Type Hydrogen Generators, which covers portable generators and component generators for installation in products rated 250 V maximum.

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INTRODUCTION

1 Scope

1.1 This outline covers portable water electrolysis type gaseous hydrogen generators and component water electrolysis type gaseous hydrogen generators for use in portable equipment.

1.2 This outline applies to hydrogen generators rated 250 V maximum that are for installation in products intended for indoor and outdoor residential and commercial use.

1.3 This outline also covers portable hydrogen generators used for refueling of hydrogen absorbing metal alloy fuel cartridges, which are limited in size to a maximum of 100 g of hydrogen storage and a maximum volumetric capacity of 1 L, and which comply with Annex B of IEC 62282-6-100.

1.4 These products are not intended for use in classified locations.

1.5 The generators covered by this standard do not include hydrogen storage pressure vessels.

2 Glossary

2.1 For the purpose of this outline, the following definitions apply.

2.2 AMBIENT TEMPERATURE AND PRESSURE – For testing purposes of this outline, ambient temperature is 25°C (77°F) and ambient pressure is 1 atm.

2.3 CLASSIFIED LOCATION – Location where the concentration of flammable vapors, liquids or gases are, or may be, present in quantities sufficient to produce explosive or ignitable mixtures.

2.4 HYDROGEN EMBRITTLEMENT – Deleterious changes in the physical properties of metals produced by contact with hydrogen.

2.5 LOWER EXPLOSION LIMIT (LEL) – The lowest volume percentage of flammable gas in air that will explode.

Note: The range of volume ratio of hydrogen in air that will form a flammable atmosphere is more extensive than the range that will form an explosive atmosphere. The flammability limits are used in this outline to provide the maximum protective measures.

2.6 LOWER FLAMMABILITY LIMIT (LFL) – The lowest volume percentage of flammable gas in air that will ignite.

Note: The range of volume ratio of hydrogen in air that will form a flammable atmosphere (4 - 75 volume %) is more extensive than the range that will form an explosive atmosphere (18.3 - 59 volume %). Therefore the flammability limits are used in this outline to provide the maximum protective measures.

2.7 MAXIMUM ALLOWABLE WORKING PRESSURE (MAWP) – The maximum gauge pressure that a part or system is allowed to operate at, and is the operating pressure of the pressure relief devices installed to protect the part or system against overpressure.

2.8 MAXIMUM OPERATING PRESSURE (MOP) – The maximum pressure developed in a part under normal operating conditions. This value is typically controlled by limit controls, such as pressure switches, and is set to a maximum value of 10% less than the start-to-discharge pressure of the pressure-relief device for that part.

2.9 PORTABLE – Not secured in place or physically attached and able to be moved about.

2.10 PRIMARY SAFETY CONTROL – A control whose failure would affect the safety of the hydrogen generator as determined by the safety analysis.

2.11 RESIDENTIAL – An occupancy that provides sleeping accommodations for purposes other than health care or detention and correctional.

2.12 ZONE SYSTEM OF CLASSIFICATION – The means for classifying areas within the hydrogen generator system in accordance with Article 505 of the National Electrical Code, ANSI/NFPA 70, and the methods outlined in Electrical Apparatus for Explosive Gas Atmospheres Part-10: Classification of Hazardous Areas, IEC 60079-10. The potential zones of this system are:

- Class I, Zone 0 – A location in which ignitable concentrations of flammable gases or vapors are present continuous or ignitable concentrations of flammable gases or vapors are present for long periods of time.
- Class I, Zone 1 – A location:
 - a) In which ignitable concentrations of flammable gases or vapors are likely to exist under normal operating conditions; or
 - b) In which ignitable concentrations of flammable gases or vapors may exist frequently because of repair or maintenance operations or because of leakage; or
 - c) In which equipment is operated or processes are carried on of such a nature that equipment breakdown or fault operations could result in the release of ignitable concentrations of flammable gases or vapors and also cause simultaneous failure of electrical equipment in a mode to cause the electrical equipment to become a source of ignition; or
 - d) That is adjacent to a Class I, Zone 0 location from which ignitable concentrations of vapors could be communicated, unless communication is prevented by adequate positive pressure ventilation from a source of clean air and effective safeguards against ventilation failure are provided.
- Class I, Zone 2 – A location:
 - a) In which ignitable concentrations of flammable gases or vapors are not likely to occur in normal operation and if they do occur, will exist only for a short period; or
 - b) In which volatile flammable liquids, flammable gases or flammable vapors are handled, processed, or used, but in which the liquids, gases or vapors normally are confined within closed containers or closed systems from which then can escape only as a result of accidental rupture or breakdown of the containers or system or as a result of abnormal operation of the equipment with which the liquids or gases are handled, processed, or used; or
 - c) In which ignitable concentrations of flammable gases or vapors normally are prevented by positive mechanical ventilation, but which may become hazardous as result of failure or abnormal operation of the ventilation equipment; or

d) That is adjacent to a Class I, Zone 1 location from which ignitable concentrations of flammable gases or vapors could be communicated, unless such communication is prevented by adequate positive-pressure ventilation from a source of clean air and effective safeguards against ventilation failure are provided.

3 Components

3.1 Except as indicated in 3.2, a component of a product covered by this outline shall comply with the requirements for that component. See Appendix A for a list of standards covering components used in the products covered by this outline.

3.2 A component is not required to comply with a specific requirement that:

- a) Involves a feature or characteristic not required in the application of the component in the product covered by this outline, or
- b) Is superseded by a requirement in this outline.

3.3 A component shall be used in accordance with its rating established for the intended conditions of use.

3.4 Specific components are incomplete in construction features or restricted in performance capabilities. Such components are intended for use only under limited conditions, such as certain temperatures not exceeding specified limits, and shall be used only under those specific conditions.

4 Units of Measurement

4.1 Values stated without parentheses are the requirement. Values in parentheses are explanatory or approximate information.

5 Undated References

5.1 Any undated reference to a code or standard appearing in the requirements of this outline shall be interpreted as referring to the latest edition of that code or standard.

CONSTRUCTION

6 General

6.1 A hydrogen generator shall employ materials found by investigation to be acceptable for the intended application.

7 Fluid Containing Parts

7.1 Materials

7.1.1 Fluid containing parts shall be suitable for the application.

7.1.2 A part employed to contain flammable and hazardous fluids shall be resistant to the action of the fluid being handled.

7.1.3 Metallic parts containing hydrogen gas shall be resistant to hydrogen embrittlement as outlined in Basic Considerations for the Safety of Hydrogen Systems, ISO 15916. If employing a material other than as outlined in ISO 15916, an evaluation for susceptibility to hydrogen embrittlement will need to be conducted in accordance with the Standard Test Method for Determination of Susceptibility of Metals to Embrittlement in Hydrogen Containing Environments at High Pressure, High Temperature, or Both, ASTM G 142, or the Standard Test Method for Determination of the Susceptibility of Metallic Materials to Gaseous Hydrogen Embrittlement, ASTM F 1459. Results of testing done in accordance with ASTM G 142 shall be at least one. Ratios below one indicate a susceptibility to hydrogen embrittlement with the test method outlined in ASTM G 142. Ratios above two indicate a susceptibility to hydrogen embrittlement with the test method outlined in ASTM F 1459.

7.1.4 When corrosion of a metallic part containing liquid interferes with its intended function or permits external leakage of a the liquid and a potential hazard, the part shall be made of corrosion-resistant material or be provided with a corrosion-resistant protective coating in accordance with the corrosion resistance requirements in the Standard for Enclosures for Electrical Equipment, UL 50.

7.1.5 An elastomeric part, relied upon for safety of a liquid containing part, such as a seal between electrical and wetted parts, shall be suitable for the application as determined by the tensile strength and elongation after oven aging and volume change and extraction after immersion tests outlined in the Standard for Gaskets and Seals, UL 157.

7.1.6 The immersion shall be for 168 h in liquids representative of intended application with no volume change limits greater than $-1/+25$ % and no extraction (weight loss) greater than 10% of the original values.

7.1.7 Thermoplastic parts (other than elastomeric parts) in contact with liquids, whose deterioration would create a hazard, shall be subjected to an immersion test in accordance with the Standard Practices for Evaluating the Resistance of Plastics to Chemical Reagents, Practice A, Immersion Test, Procedure I – Weight and Dimension Changes, ASTM D543. As a result of the immersion, there shall be no volume change greater than 2% or weight change in excess of $-10/+25$ % of the original values.

7.1.8 An elastomeric part employed as a seal for hydrogen, shall be suitable for that application as noted in Annex C of Basic Considerations for the Safety of Hydrogen Systems, ISO 15916. The material shall be evaluated for tensile strength and elongation as received and after oven aging (based upon service temperatures) in accordance with the Standard for Gaskets and Seals, UL 157. If employed in outdoor use equipment, it shall be subjected to a low temperature evaluation in accordance with UL 157.

7.1.9 Valves, compressors, pumps, piping and other components such as gauges, pressure and/or float switches and check valves located in the hydrogen or electrolyte system shall be determined suitable for the application as outlined in 7.2 – 7.7 and 12 and comply with the appropriate component standards identified in those sections and Appendix A.

7.2 Piping and joints

7.2.1 Piping and joints employed for flammable or other hazardous fluids and non-hazardous fluids above 15 psi (103.4 kPa) and above 186°C (366.8°F) or below minus 29°C (minus 20.2°F) in a hydrogen generator shall comply with the applicable sections of the Process Piping, ASME B31.3. The piping shall be constructed of materials resistant to deterioration from the fluids that they contain in accordance with Fluid Containing Parts, Section 7.

Note: A hazardous fluid, in accordance with the use in this outline, is any fluid where an unintended leak could create a hazard such as flammable vapors, and corrosive or toxic chemical leaks.

7.2.2 Piping and joints containing non-flammable or non-hazardous fluids at pressures of 15 psi (103.4 kPa) or less and temperatures between minus 29°C (minus 20.2°F) through 186°C (366.8°F) are considered outside the scope of the Standard for Process Piping, ASME B31.3. Piping systems for these applications shall be constructed of materials in accordance with Fluid Containing Parts, Section 7.

7.2.3 Thermoplastic piping, tubing and fittings for conveying flammable fluids shall comply with 7.2.1 with the additional considerations as follows:

- a) They shall be protected within a ventilated enclosure where they will not be subject to mechanical or physical stresses, and
- b) They shall be either conductive to avoid static discharge with a maximum resistance of 1 MΩ per meter as outlined in the Continuity Test of 36.2, or comply with the Test for Accumulation of Static Electricity in 36.3.

7.3 Pressure vessels

7.3.1 A pressure vessel shall be constructed in accordance with the ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, Rules for Construction of Pressure Vessels, and shall be marked with the appropriate ASME symbol.

7.4 Storage tanks

7.4.1 Integral non-pressurized vessels storing liquids for hydrogen processing, etc., shall be constructed of materials that shall be resistant to deterioration from direct contact with the particular liquids. The storage vessels shall be designed and located and secured within in the system so that there is no leakage that could create a hazardous condition.

7.4.2 Storage vessels for liquids that require replenishment of the liquid shall be designed so that they can be easily refilled without introduction of a hazard. Compliance shall be determined by the Overfill Test, Section 30.

7.5 Pressure-relief valves

7.5.1 Pressure-relief devices shall comply with the ASME Boiler and Pressure Vessel Code, Section VIII, Part 1, or Section 9 of the Standard for Cylinder Valves, UL 1769, whichever applies.

7.5.2 The operating pressure of a relief valve shall not exceed the maximum allowable working pressure (MAWP) of the pressure vessel or the part it is protecting.

7.5.3 The flow rating of a pressure-relief valve shall comply with the ASME Boiler and Pressure Vessel Code, Section VIII, Part 1, or Section 18.3 of the Standard for Cylinder Valves, UL 1769, whichever applies.

7.5.4 A pressure-relief valve shall have its discharge located so that operation of the device does not result in a hazardous situation such as flammable fluids escaping to an unclassified or confined area or depositing moisture on live parts.

7.6 Valves

7.6.1 Valves shall be rated for the application, including pressure, temperature, fluids contained, and electrical ratings, if applicable.

7.6.2 Electric shut-off valves shall be evaluated as a safety shut-off valves in accordance with Standard for Electrically Operated Valves, UL 429.

7.6.3 Electrical and other automatically operated valves such as shut-off valves, shall fail in a safe position.

7.6.4 Electrical valves located in classified zones within the system shall be rated for that classification.

7.6.5 Non-electric valves for use with flammable fluids shall comply with the Standard for Valves for Flammable Fluids, UL 847.

7.7 Pumps and compressors

7.7.1 Air compressors and air vacuum pumps employed in the system shall be suitably rated for the application and shall comply with the Standard for Motor-Operated Air Compressors, Vacuum Pumps and Painting Equipment, UL 1450.

7.7.2 Water pumps shall be rated for the application and shall comply with the Standard for Motor-Operated Water Pumps, UL 778.

7.7.3 Pumps handling liquids (other than water) shall comply with the Outline of Investigation for Power-Operated Chemical Pumps, UL 1861, and be evaluated for use with the intended fluid.

7.7.4 Compressors for handling flammable gases and vapors shall comply with the endurance (with external leakage), blocked outlet, and hydrostatic strength tests of the Standard for Power-Operated Pumps for Petroleum Dispensing Products, UL 79. Materials in contact with the gases and vapors shall be resistant to deterioration in accordance with Fluid Containing Parts, Section 7.

7.7.5 The following shall be provided for compressor systems for flammable fluids as determined necessary from the safety analysis of 18.5:

- a) Pressure-relief devices to limit each stage pressure to the MAWP for the pressurized parts. Pressure-relief devices shall comply with 7.5 and shall be vented safely;
- b) An automatic shutdown control for high discharge and low suction pressure;
- c) An unloading devices that captures and recycles contained gas for re-use and/or safe venting after a shutdown of the compressor;
- d) Vibration isolation on inlet or outlet lines; and
- e) A pressure limiting device to avoid over pressurization at the inlet.

7.7.6 Electric pumps for flammable fluids shall be provided with the following as determined from the safety analysis of 18.5:

- a) Pressure-relief devices limiting the inlet and outlet pressure to the MAWP of the parts protected. The relief devices shall comply with 7.5, and released fluids from operation of the pressure-relief devices shall be safely routed;
- b) An automatic shutdown control for high discharge pressure; and
- c) Suction and discharge lines shall be protected from damage due to vibration.

8 Protection for Flammable and Explosive Fluids Hazards

8.1 General

8.1.1 Compartments housing flammable fluid containing parts within hydrogen generators shall be classified according to Article 505 of the National Electrical Code, ANSI/NFPA 70, or the Standard for Electrical Apparatus for Explosive Gas Atmospheres – Part 10: Classification of Hazardous Areas, IEC 60079-10. They shall not produce a classified area outside of the enclosure, except within ducting that leads to a safe location.

8.1.2 Equipment within classified zones shall use appropriate protection as outlined in the National Electrical Code, ANSI/NFPA 70, and shall be rated for the zone classification. The surface temperatures within classified zones shall not exceed 80% of the auto-ignition temperature of the flammable concentration. The potential for static discharge sufficient to cause ignition shall be eliminated by material selection and bonding and grounding of metal parts. There shall be no parts or components that produce arcs or sparks capable of igniting a flammable concentration of gas.

8.1.3 Hydrogen generators intended for use in repair garages shall have all electrical components either located 450 mm (18 in) above the floor level or the electrical equipment shall be rated for use in Class I Division 1 locations. Components includes such devices as switches and controls, motors, receptacles, connectors and other components which could ignite flammable concentrations of vapors.

8.2 Alternative methods of protection

8.2.1 Protection methods not covered in 8.2.2 shall comply with 8.1.2.

8.2.2 Protection shall be provided by passive or active means such that flammable gas mixtures remain below 1% hydrogen within the generator enclosure, except within the dilution volumes. Methods to determine the boundaries of the dilution volume and ventilation requirements can be found in the Standard for Electrical Apparatus for Explosive Gas Atmospheres – Part 10: Classification of Hazardous Areas, IEC 60079-10.

8.2.3 Passive methods may include, but are not limited to:

- a) Pipe orifice and similar methods of flow restriction to restrict the maximum release rate to a predictable value; and
- b) Use of joints that are permanently secured and constructed so that they limit the maximum release rate to a predictable value.

8.2.4 Active methods include, but are not limited to:

- a) Hydrogen flow or pressure controls which may initiate safety measures such as de-energization of non-classified electrical equipment and initiation of ventilation when normal limits are exceeded;
- b) Continuous and reliable ventilation which maintains an average hydrogen gas concentration below 1% within the enclosure, except in dilution volumes; and

Note: Ventilation values are based on the maximum anticipated hydrogen gas leak rate in the enclosure as determined by analysis methods such as those outlined in the Standard for Electrical Apparatus for Explosive Gas Atmospheres – Part 10: Classification of Hazardous Areas, IEC 60079-10.

c) A hydrogen gas detection system within the enclosure that initiates ventilation at 0.4% hydrogen. If hydrogen/air mixtures exceeding 1% hydrogen are detected, hydrogen generation shall be stopped and non-classified electrical equipment shall be de-energized.

8.2.5 The reliability of the active methods shall be determined in accordance with Safety Controls, Section 18.1.

8.2.6 When mechanical ventilation is relied upon as a protection means, proper operation of the ventilation system shall be confirmed by measuring either airflow or pressure or by the use of redundant ventilation methods. Failure of ventilation shall cause a shutdown of gas generation. Equipment that must remain energized during ventilation shutdown, for example, shall be suitable for the area of classification.

8.2.7 The enclosure and internal component layout shall be designed and constructed to preclude trapping of hydrogen gas that may leak from components.

8.2.8 Enclosures that rely on ventilation for protection against accumulation of ignitable mixtures shall be purged with a minimum of 5 air-changes prior to the energizing of any electrical devices that are not suitable for the classification. All electrical equipment, which must be energized prior to or during purging, must be suitable for the classification. Purging is not required if the atmosphere within the enclosure can be demonstrated to be non-hazardous prior to energizing of any non-classified electrical equipment.

8.3 Hydrogen gas detection

8.3.1 Hydrogen gas detectors relied upon as a safety critical component shall comply with the Standard for Gas and Vapor Detectors and Sensors, UL 2075, and shall be installed in locations based upon the manufacturer's classification analysis in accordance with Electrical Apparatus for Explosive Gas Atmospheres – Part 10: Classification of Hazardous Areas, IEC 60079-10, and safety analysis of Section 18.5.

8.3.2 The reliability of the hydrogen gas detection systems employed for safety control purposes such as ventilation in accordance with 8.2.1 shall be evaluated in accordance with Safety Controls, Section 18.1, and self-verification means shall be provided.

9 Electrical Insulation

9.1 Polymeric and other non-metallic parts relied upon for electrical insulation including polymeric enclosures shall be made of materials that meet the requirements for electrical insulation as outlined in the Standard for Polymeric Materials - Use in Electrical Equipment Evaluations, UL 746C.

10 Enclosures

10.1 Hydrogen generators shall be provided with enclosures for protection from access to electrical parts, safety circuits, hazardous moving parts, hot surfaces and other parts of the generator that are hazardous. Outdoor-use hydrogen generators shall be provided with a protective cabinet for parts adversely affected by weather.

10.2 Openings in enclosures of hazardous parts shall be located and sized to provide adequate protection from access to hazardous parts in accordance with 10.1. Hydrogen generators shall be provided with a minimum IP2X or IPXXB rating from access to hazardous parts as outlined in Degrees of Protection Provided by Enclosures (IP Code), IEC 60529.

10.3 Openings in outdoor-use hydrogen generator enclosures or cabinets shall be located and sized to prevent parts from being adversely affected by rain in accordance with Outdoor-Use Generators – Rain Test, Section 25.

10.4 Metallic enclosures of hazardous parts shall have strength and rigidity to resist impact. Compliance shall be determined by the Impact Test of Section 35. Metallic enclosures shall be corrosion resistant through the use of corrosion resistant materials or protective painting or plating.

10.5 Polymeric materials employed for enclosures for electrical equipment and other sources of ignition shall comply with the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C, and shall be suitable for the mechanical stresses, environment and temperatures encountered. Compliance is determined by the Impact Test of Section 35 and Mold Stress Tests of Section 31 of this standard.

11 Guards and Protection Against Injury

11.1 A moving part that may cause risk of injury to persons shall be enclosed, guarded, located or otherwise arranged to reduce the likelihood of unintentional contact. Compliance is determined in accordance with 10.2.

Exception: A part or portion of a part that is exposed to perform the work function is not required to be enclosed but, when necessary, guarding shall be provided.

11.2 A moving part that may involve a risk of injury to persons shall be considered with respect to degree of exposure necessary to perform the intended function, the sharpness of the moving part, the likelihood of unintentional contact and the speed of the moving part.