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Fuel Cell Vehicle Terminology

RATIONALE

The technical report covers technology, products, or processes which are mature and not likely to change in the foreseeable future.

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1. ***Scope***—This SAE Information Report contains definitions for hydrogen fuel cell powered vehicle terminology. It is intended that this document be a resource for those writing other hydrogen fuel cell vehicle documents, specifically, Standards or Recommended Practices.

1.1 **Purpose**—The purpose of this document is to provide a record of commonly used terminology established by the technical community involved in writing practices and information reports for hydrogen fuel cell powered vehicles.

2. ***References***

2.1 **Related Publications**—The following publications are provided for information purposes only and are not a required part of this specification.

2.1.1 ANSI PUBLICATION—Available from American National Standards Institute, 1819 L Street NW, Washington, DC, 20036.

ANSI Z21.83—American National Standard For Fuel Cell Powered Plants.

2.1.2 JAPAN ELECTRIC VEHICLE ASSOCIATION PUBLICATION (JEVA)—Available from Japan Electric Vehicle Association, Toranomon NS Building, 1-22-15, Toranomon, Minato-Ku, Tokyo, 105-0001, Japan.

Glossary of Terms Relating to Fuel Cell Electric Vehicles, Working Draft dated April 25, 2001

2.1.3 LOS ALAMOS NATIONAL LABORATORY PUBLICATION—Available from Los Alamos National Laboratory, Los Alamos, NM or www.education.lanl.gov/resources/fuelcells.

#LA-UR-99-3231—Fuel Cells - Green Power

2.1.4 U.S. FUEL CELL COUNCIL PUBLICATION—Available from the U.S. Fuel Cell Council, 1625 K Street NW, Suite 725, Washington, DC, 20006 or www.usfcc.com.

Fuel Cell Glossary, Second Edition - MAY, 2000, U.S. Fuel Cell Council – Moving to Market, Fuel Cell Glossary, 2nd Edition – May, 2000

2.1.5 EUROPEAN FUEL CELL GROUP LTD PUBLICATION—Available from European Fuel Cell Group Ltd, Pascalstraat 12, 2811 EL Reeuwijk, The Netherlands or www.fuelcell-eur.nl/status.htm.

Status of Fuel Cell Technology

3. Basic Fuel Cell Description—The basic theory of the hydrogen fuel cell was first published in Philosophical Magazine in 1839 by Christian Friedrich Schonbein in the January, 1839 edition and by Sir William Grove in the February, 1839 edition. 160 years later, the practical application of fuel cells to general transportation needs is close to reality.

A fuel cell is an electrochemical conversion device that converts a hydrogen fuel and air into electricity. As an example, in a Proton Exchange Membrane Fuel Cell, humidified hydrogen is fed into the anode (negative electrode). A platinum catalyst facilitates the separation of the hydrogen gas into two electrons and two positively charged hydrogen ions, or protons. The hydrogen ions migrate across the electrolyte. The electrolyte is sometimes in the form of a membrane designed such that it can not conduct electrons, therefore, the electrons must travel through an external circuit which contains a motor or other electrical load, which consumes the power generated by the fuel cell. At the same time, humidified air is supplied to the cathode (positive electrode). After the hydrogen ions migrate across the membrane, they are combined at the positive electrode with the electrons and humidified air to form water. The water is then emitted from the fuel cell. A single fuel cell produces only a small output (typically about 0.7 volts), but when the cells are stacked in series, the output voltage is multiplied by the number of cells stacked.

While water is a product of the fuel cell reaction, both the air and fuel entering the fuel cell must be humidified. This additional water keeps the membrane hydrated. The humidity of the gases must be carefully controlled, too little water in the hydrogen fuel prevents the membrane from conducting the hydrogen ions, and too much water in the air supplied to the cathode cause the cathode to flood. Flooding of the cathode prevents the air from reaching the cathode catalyst sites and forming the water to be emitted.

4. Fuel Cell Electric Vehicle Terminology

4.1 General—Terms used to describe the common components and characteristics of fuel cell vehicles.

4.1.1 AIR UTILIZATION—The fraction of the oxidant that enters the cell that reacts electrochemically.

NOTE— Also known as Oxygen Utilization.

4.1.2 AUXILIARY BATTERY—A battery provided separately from the primary energy source for operating an instrument such as a vehicle control device (peripheral devices).

NOTE— The auxiliary battery is generally charged by the propulsion battery of fuel cell via a DC-DC converter or the like.

4.1.3 CAUTION LABEL—A label displaying information relating to cautions, warnings, and dangers for the purpose of preventing hazardous handling of the fuel cell system.

4.1.4 COLD START—Start-up that occurs after a sufficient soak at the normal ambient temperature.

NOTE— For a test procedure, it is recommended that the soak period should be between 12 hours (minimum) and 36 hours (maximum), and that the vehicle should not be started and should remain in a temperature controlled area during this soak period.

4.1.5 COOLANT—A fluid used for effecting heat transfer in the thermal management system.

NOTE— The fluid is preferably non-electrically conductive and has a low freezing point.

4.1.6 DEFUEL—The process of eliminating fuel from a tank or vessel.

4.1.7 DEPRESSURIZE—The process of reducing the internal pressure in a tank or vessel to near ambient pressure.

4.1.8 DIRECT INTERNAL REFORMING—Production of hydrogen within a fuel cell from a hydrocarbon based fuel (*methanol, gasoline, etc.*) fed to the fuel cell or stack.

4.1.9 EXTERNAL REFORMING—The production of hydrogen from a hydrocarbon fuel (*methanol, gasoline, natural gas, propane, etc.*) prior to entry to the fuel cell or stack.

4.1.10 FLAMMABILITY LIMIT—The range of vapor concentration of flammable gas that will result in propagation from a flame in air.

NOTE— Hydrogen: 4-75%, carbon monoxide: 12.5-74.2%, methane: 5-15%, n-pentane: 1.5-7.8%, acetylene: 2.5-100%, ammonia: 15-28%.

4.1.11 FLAME VISIBLE GLASSES—Glasses which makes it possible to detect a colorless flame by making the flame visible.

4.1.12 FUEL CELL—Electrochemical energy conversion device in which fuel and an oxidant react to generate electricity without any consumption, physically or chemically, of its electrodes or electrolyte.

4.1.13 FUEL CELL VEHICLE (FCV)—A vehicle that receives propulsion energy from an onboard fuel cell power system.

4.1.14 FUEL UTILIZATION—The fraction of the fuel that enters the cell that reacts electrochemically.

4.1.15 GAS CLEANUP—Removal of a contaminant from gaseous feed streams by a mechanical or chemical process.

4.1.16 HEAT CYCLE TEST—A fuel cell endurance test under repeated ambient temperature change within a prescribed range.

4.1.17 HOT START—Start-up after a shut-down while the temperature of the fuel cell equipment is still within the fuel cell equipment's normal operating temperature range.

4.1.18 HYDROGEN EMBRITTLEMENT—Phenomenon causing metal to lose ductility due to occlusion of hydrogen atoms in the metal.

4.1.19 HYDROGEN PERMEATION—Permeation of hydrogen through a material of normal construction, resulting in the release of hydrogen.

4.1.20 LOAD FOLLOWING—A mode of operation where the fuel cell system is generating variable power depending on the load demand.

4.1.21 LOWER FLAMMABILITY LIMIT (LFL)—The minimum concentration of a flammable gas/vapor in air in which flame is propagated.

4.1.22 MAXIMUM ALLOWABLE WORKING PRESSURE (MAWP)—The maximum gauge pressure at which a part or system may be operated.

NOTE— It is the pressure used in determining the setting of pressure-limiting / relieving devices installed to protect the part or system from accidental over pressuring.

4.1.23 MAXIMUM OPERATING PRESSURE (MOP)—The normal (non-failure) transient or steady-state gauge pressure at which a part or system may be operated.

NOTE— It shall not exceed the allowable working pressure, and is usually kept at a suitable level below the setting of pressure limiting / relieving devices to prevent their frequent functioning.

4.1.24 MAXIMUM OPERATING TEMPERATURE (MOT)—The normal (non-failure) transient or steady-state gauge temperature at which a part or system may be operated.

NOTE— It shall not exceed the allowable working temperature, and is usually kept at a suitable level below the setting of temperature limiting / relieving devices to prevent their frequent functioning.

4.1.25 MAXIMUM ALLOWABLE VOLTAGE—The maximum voltage higher than the rated voltage allowable for the equipment or apparatus.

4.1.26 MAXIMUM POWER—The maximum power output which equipment or apparatus can generate according to the specifications indicated by the manufacturer.

4.1.27 MAXIMUM VOLTAGE—The maximum voltage generated by equipment or apparatus.

4.1.28 MINIMUM ALLOWABLE VOLTAGE—The minimum voltage lower than the rated voltage which is allowable for the equipment or apparatus.

4.1.29 MINIMUM IGNITION ENERGY—The minimum spark energy necessary for flammable gas to ignite.

4.1.30 MODEL—Model is a reference individually given by manufacturers to distinguish their fuel cells.

4.1.31 MODULE—A self-contained unit that serves as a building block for the overall structure of a power source or a subsystem thereof.

4.1.32 NO-LOAD VOLTAGE—See Open Circuit Voltage.

4.1.33 OFF GAS—A gas discharged from the fuel cell stack containing unreacted gas, generated gas, and / or inert gas.

4.1.34 OPEN CIRCUIT VOLTAGE—The voltage measured at the stack terminals when a fuel cell is disconnected from an external circuit. Also called no-load voltage.

4.1.35 OPERATING PRESSURE—The variable pressure at which a system operates in response to changes in operating conditions.

4.1.36 PARTIAL OXIDATION—The process of oxidizing a fuel with a deficiency of oxygen to form a gaseous mixture containing hydrogen.

4.1.37 POISONING—A degradation of the fuel cell performance caused by the contamination of the fuel cell components such as the membrane and/or electrodes.

4.1.38 POST-CONSUMER MATERIALS—Those products or other materials that have served their intended end uses and that have been recovered from or otherwise diverted from the waste stream for the purpose of recycling.

4.1.39 POWER DENSITY (kW/LITER)—In the context of a single cell, the power density is measured in terms of power/unit area of active cell, e.g., kW/m^2; in the context of a complete cell stack, the power density is defined in terms of power/unit stack volume, e.g., kW/m^3.

4.1.40 PRE-CONSUMER MATERIALS—Those materials generated during any step in the production of a material or product that have been recovered from or otherwise diverted from the waste stream for the purpose of recycling.

4.1.41 PURGE—To displace the fuel in the fuel tank and / or fuel system to a safe level.

4.1.42 RATED CURRENT—Current level (or levels) in amperes at which a device is designed to operate for a specified duty cycle.

4.1.43 RATED POWER—The manufacturers specification for power capacity for a cell or stack under specified conditions.

4.1.44 RATED VOLTAGE—Voltage range at which a device is designed to operate.

4.1.45 RECYCLABLE—Products or materials that can be recovered from or otherwise diverted from the waste stream for the purpose of recycling.

4.1.46 RECYCLE—The series of activities, including collection, separation, and processing, by which products or other materials are recovered from or otherwise diverted from the waste stream for use in the form of raw materials in the manufacture of new products.

4.1.47 RECYCLED CONTENT—The portion of a material's or product's weight that is composed of materials that have been recovered from or otherwise diverted from the waste stream either during the manufacturing process (pre-consumer/post-industrial) or after consumer use (post-consumer).

4.1.48 REFORMING—The conversion of a non-hydrogen fuel, such as hydrocarbons or alcohols, into a gaseous mixture suitable for operating fuel cells.

4.1.49 SPECIFIC POWER (kW/kg)—The rated power divided by the cell or stack mass.

4.1.50 STACK LIFE—The cumulative period of time that a fuel cell stack may operate before its output deteriorates below a specified minimum value.

4.1.51 STACK RATED PRESSURE—The air pressure at the entrance of the stack at the time of rated power.

NOTE— ISO recommends using absolute pressure. If gauge pressure is used, it should be so noted.

4.1.52 STACK TEST—Experiment where an electrical load is applied to a stack of fuel cells to determine its ability to perform.

NOTE— Normally, the output is two pieces of information. First is a current output at a specific cell voltage point. Second is a continuous voltage versus current curve (polarization curve).

4.1.53 STACKING—The process of placing individual fuel cells adjacent to one another to form a fuel cell stack.

4.1.54 START-UP TIME—The time required for a fuel cell to generate a useable output after initiation of the start-up procedure.

NOTE— Warm starting time and cold starting time are included.

4.1.55 STEAM REFORMING—The process of reacting a hydrocarbon fuel in the presence of steam to form a gaseous mixture containing hydrogen.

4.1.56 SUBSTACK—Typically a group of stacked fuel cells that makes up the base repetitive unit number of cells per full stack.

NOTE— Substacks may form an intermediate step in manufacturing and may be used to test new stack concepts prior to scale-up to full size stacks.

4.1.57 THERMAL CYCLE—Repetition of temperature change of equipment during the cycle of start → drive → stop.

NOTE— A process consisting of cooling a fuel cell including a cell stack to a temperature close to ambient temperature from driving temperature and heating again to driving temperature.

4.1.58 VOLTAGE-CURRENT CHARACTERISTICS—Characteristics which represent the relationship between voltage and current in a fuel cell.

NOTE— In many cases, the current is indicated by the current density in the fuel cells. Also known as polarization curves or IV/VI curves.

4.2 Fuel Cell Types—Terms describing different types of fuel cells for automotive applications

4.2.1 ALKALINE FUEL CELL (AFC)—A type of hydrogen/oxygen fuel cell in which the electrolyte is concentrated KOH and hydroxide ions (OH^-) are transported from the cathode to the anode.

NOTE— Temperature of operation can vary from <120 °C to approximately 250 °C depending upon electrolyte concentration.

4.2.2 CLASSIFICATION—Fuel cells are identified in accordance with the type of electrolyte unless otherwise indicated.

NOTE— The electrolyte types include alkaline, polymer, phosphoric acid, molten carbonate, solid, etc.

4.2.3 DIRECT HYDROGEN FUEL CELL (DHFC)—A type of fuel cell using hydrogen as a raw fuel.

4.2.4 DIRECT FUEL CELL—A type of fuel cell directly using a raw fuel.

4.2.5 DIRECT METHANOL FUEL CELL (DMFC)—A type of fuel cell in which the fuel is methanol (CH_3OH), in gaseous or liquid form.

NOTE— The methanol is oxidized directly at the anode with no reformation to hydrogen. The electrolyte is typically a PEM.

4.2.6 FUEL REFORMING FUEL CELL—A type of fuel cell using hydrogen obtained by reforming a raw fuel.

NOTE— The raw fuel may be methanol, gasoline, or another hydrocarbon-based fuel.

4.2.7 PHOSPHORIC ACID FUEL CELL (PAFC)—A type of fuel cell in which the electrolyte consists of concentrated phosphoric acid (H_3PO_4) and protons (H^+) are transported from the anode to the cathode.

NOTE— The operating temperature is generally 160 °C ~ 220 °C.

4.2.8 PROTON EXCHANGE MEMBRANE FUEL CELL (PEMFC OR PEFC)—A type of acid based fuel cell in which the exchange of protons (H^+) from the anode to the cathode is achieved by a solid, aqueous membrane impregnated with an appropriate acid.

NOTE— The electrolyte is called a proton-exchange membrane (PEM). The fuel cells typically run at low temperatures (<100 °C) and pressures (<5 atm).

4.2.9 SOLID OXIDE FUEL CELL (SOFC)—A type of fuel cell in which the electrolyte is a solid, nonporous metal oxide, typically ZrO_2 doped with Y_2O_3, and O^{2-} is transported from the cathode to the anode.

NOTE— The operating temperature is generally 800 °C ~1000 °C

4.3 Fuel—Terms describing fuel cell fuels and fuel storage

4.3.1 CLEANLINESS FACTOR—DEGREE OF FUEL PURITY

NOTE— Fuels or raw fuels used in a fuel cell require stringent quality control with respect to substances such as sulfur which may poison the reaction catalysts.

4.3.2 COLORING AGENT—Chemicals to provide hydrogen with color so that leakage of hydrogen gas which is a colorless and odorless substance may be detected by color.

4.3.3 FLAME-COLORING AGENT—Chemicals to provide flame with color so that a colorless flame of hydrogen may be detected by color.

4.3.4 FUEL TANK—A device for storing a raw fuel for the fuel cell.

NOTE— When the raw material is hydrogen, the storage method differs according to the state of the hydrogen. In the case of gaseous hydrogen, a metal hydride storage device or a high-pressure cylinder is used. In the case of liquid hydrogen, an insulated storage tank is used.

4.3.5 HIGH PRESSURE HYDROGEN STORAGE—A device for storing hydrogen gas or liquid under high pressure.

NOTE— Hydrogen is stored and transported in the form of a gas or liquid using a high pressure container.

4.3.6 LOW TEMPERATURE HYDROGEN STORAGE—The storage of liquid hydrogen at low temperatures.

NOTE— To be stored as a liquid, hydrogen must be cooled to –253 °C (–423 °F).

4.3.7 METAL HYDRIDE HYDROGEN STORAGE—The storage of hydrogen absorbed in hydrides.

NOTE— The hydrogen is released when the hydride is heated or the pressure is reduced.

4.3.8 ODORIZING AGENT—Chemicals to provide hydrogen with an odor so that the leakage of hydrogen may be detected.

4.3.9 RAW FUEL—The fuel supplied to a fuel cell vehicle from an off-board source.

4.3.10 REFORMATE GAS—The fluid that exits the fuel reformer and acts as feed to the fuel cell stack.

4.3.11 REFUELING—Operation of supplying a raw fuel from off-board the vehicle.

4.4 Fuel Cell Components—Terms describing the components of fuel cells.

4.4.1 ANODE—The electrode at which oxidation occurs.

4.4.2 BIPOLAR PLATES—Conductive plate in a fuel cell stack that is in electrical contact with the anode for one cell and a cathode for the adjacent cell.

NOTE— The plate may be made of metal, a material such as graphite, or a conductive polymer that may be a carbon-filled composite. The plate usually incorporates flow channels for the fluid feeds and may also contain conduits for heat transfer.

4.4.3 CATALYST COATED MEMBRANE (CCM)—Term used to describe a membrane (in a PEM fuel cell) whose surfaces are coated with a catalyst layer to form the reaction zone of the electrode. (See also Membrane Electrode Assembly [MEA])

4.4.4 CATHODE—The electrode at which reduction occurs.

4.4.5 CELL—A basic fuel cell unit formed from a fuel electrode, an air electrode, and electrolyte.

4.4.6 CELL DEGRADATION RATE—The rate at which a cell's performance deteriorates over time.

NOTE— The degradation rate can be used to measure both recoverable and permanent losses in cell performance. The typical unit of measure is volts (DC) per unit time.

4.4.7 CELL INTERNAL RESISTANCE LOSS—The decrease in cell performance due to resistance losses caused by internal structures that create resistance to electron or ion flow.

NOTE— The most noticeable impact is seen in the cells operating region that occurs after activation, but before concentration polarization occurs.

4.4.8 CELL POWER DENSITY—The amount of power produced per unit measure.

NOTE— For a single cell, this is typically measured as Watts per square centimeter or kW per square meter.

4.4.9 CELL PRESSURE DIFFERENTIA—The difference in pressure across the electrolyte as measured from one electrode to the other.

4.4.10 CURRENT COLLECTOR—Term used to describe the conductive material in a fuel cell that collects electrons (on the anode side) or disburses electrons (on the cathode side).

NOTE— The current collectors are microporous (to allow for fluid flow through them) and lie in between the catalyst/electrolyte surfaces and the bipolar plates. Also referred to as Gas Diffusion Layer (GDL).

4.4.11 DESULFURIZER—A component for removing sulfur from the raw or reformed fuel.

4.4.12 ELECTRODE—The conducting body that contains active materials and through which current enters or leaves a cell.

4.4.13 ELECTROLYTE—The medium that provides ion transport between the positive and negative electrodes of a cell.

4.4.14 FUEL CELL STACK—An assembly of cells, separators, cooling plates, manifolds, and a supporting structure that electrochemically converts hydrogen rich gas and air reactants to dc power, heat, water, and other byproducts.