

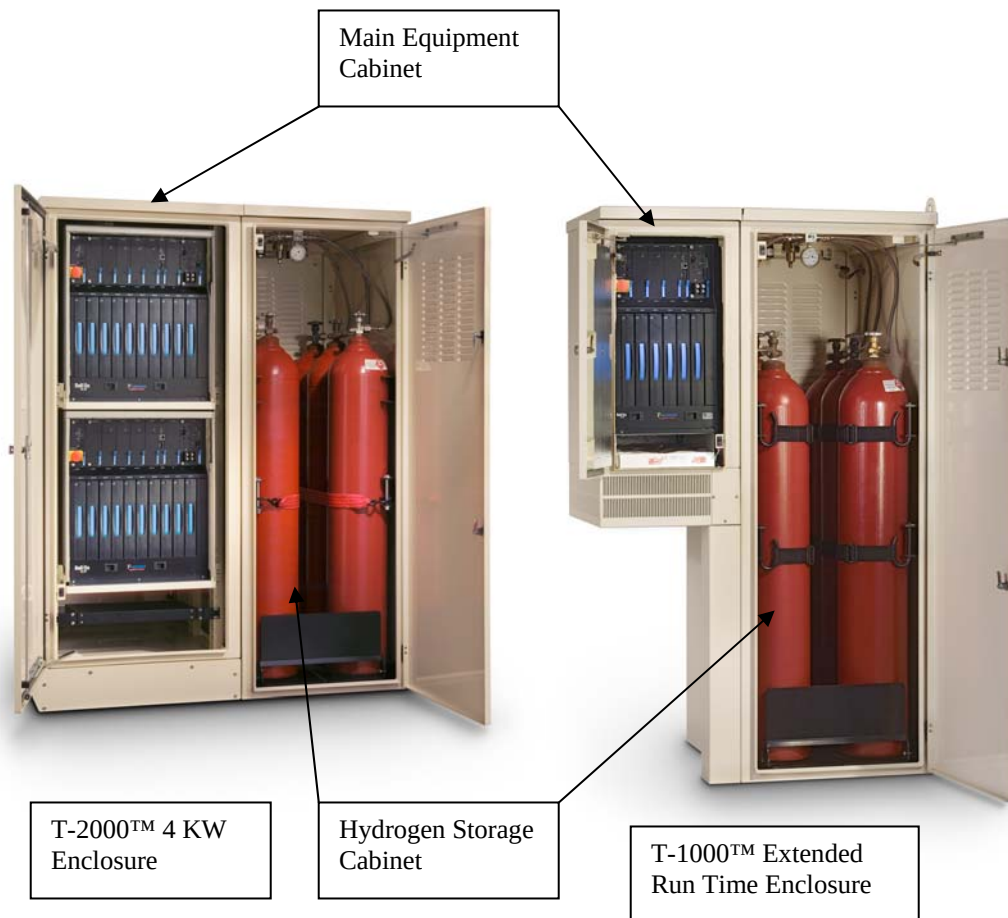
ReliOn Outdoor Enclosure Theory of Operations

Overview:

The ReliOn Outdoor Enclosure is a certified and listed, environmentally hardened enclosure system designed to accommodate ReliOn's T-1000™ and T-2000™ fuel cell systems. The ReliOn Outdoor Enclosure allows for the safe storage and delivery of hydrogen gas to the T-1000™ and T-2000™ fuel cell systems. The Outdoor Enclosure is modular and available in several different configurations. The standard configurations consist of one T-1000™ fuel cell system in a 'carapace' cabinet and six cylinders of compressed industrial grade hydrogen, or one to three T-2000™ fuel cell systems in a larger cabinet and six cylinders of compressed industrial hydrogen. Configurations are available that will accommodate up to six T-2000™ fuel cell systems and twelve hydrogen cylinders.

The Outdoor Enclosure provides an environment within which the ReliOn T-1000™ and T-2000™ fuel cells generate rated power through extreme external environmental conditions. Additionally, this system incorporates code-compliant hydrogen safety features for a solution eliminating the customer's need to develop or install a hydrogen system.

The Outdoor Enclosure is designed for installation at a customer's location on a stand alone concrete pad with connection to the customer's DC bus.



Applicable Codes and Standards:

The ReliOn Outdoor Enclosure system is based on several safety standards. The referenced standards are listed below:

NFPA 55	Standard for the Storage, Use, and Handling of Compressed Gases and Cryogenic Fluids in Portable and Stationary Containers, Cylinders, and Tanks 2005 Edition.
NFPA 853	Standard for Installation of Stationary Fuel Cell Power Plants, 2003.
NFPA 496	Standard for Purged & Pressurized Enclosures for Electrical Equipment, 1998.
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, 1997.
NFPA 70A	National Electric Code.
CGA E-11	Standard for Stationary Compressed Gas Cylinder Discharging Manifolds for Working Pressures up to 3000 PSI.
CGA – G-5.4	Standard for Hydrogen Piping Systems at Consumer Locations.
ASME/ANSI B31.3	Process Piping Code.
ANSI/CSA FC1-2004.....	Standard for Stationary Fuel Cell Power Systems.
Telcordia GR-63	NEBS Requirements – Physical Protection (sections as deemed applicable by RBOC)
Telcordia GR-1089	Electromagnetic Compatibility and Electrical Safety - Generic Criteria for Network Telecommunications Equipment (sections as deemed applicable by RBOC)
Telcordia GR- 487	Generic Requirements for Electronic Equipment Cabinets (sections as deemed applicable by RBOC)
EN 60204-1	Safety of Machinery - Electrical equipment of machines. Part 1: General Requirements
EN 50165	Electrical equipment of non-electric heating appliances for household and similar purpose clause 19.101 EMC phenomena only
EN 61000-6-2	Electromagnetic compatibility (EMC) – Part 6.2 Generic standards for industrial environments
EN 61000-6-3	Electromagnetic compatibility (EMC) – Part 6.3 Generic standards for residential, commercial and light industrial environments
98/37/EC	EU Machinery Directive
89/336/EEC	EU EMC Directive

This list is not all inclusive.

Enclosure Design:

The Outdoor Enclosure is designed to account for hazardous area classification and is constructed of rugged 1/8” thick aluminum with a baked on powder-coat finish that resists solar loading and heat build up within the cabinet. All access doors use standard telecommunications style hex ‘can wrench’ locking mechanisms to provide controlled access and will accommodate additional padlocks as well. When installed per factory specifications, the Outdoor Enclosure has been tested to withstand wind speeds up to 150 mph.

The Outdoor Enclosure is comprised of two separate compartments; the hydrogen storage cabinet and the main equipment cabinet. The hydrogen storage cabinet houses the hydrogen cylinders and hydrogen fuel delivery system. The main equipment cabinet houses a T-1000TM fuel cell or one to three T-2000TM fuel cells and a 1-U rack-mounted signal & control box (TSCB) for signal aggregation and I/O connectivity.

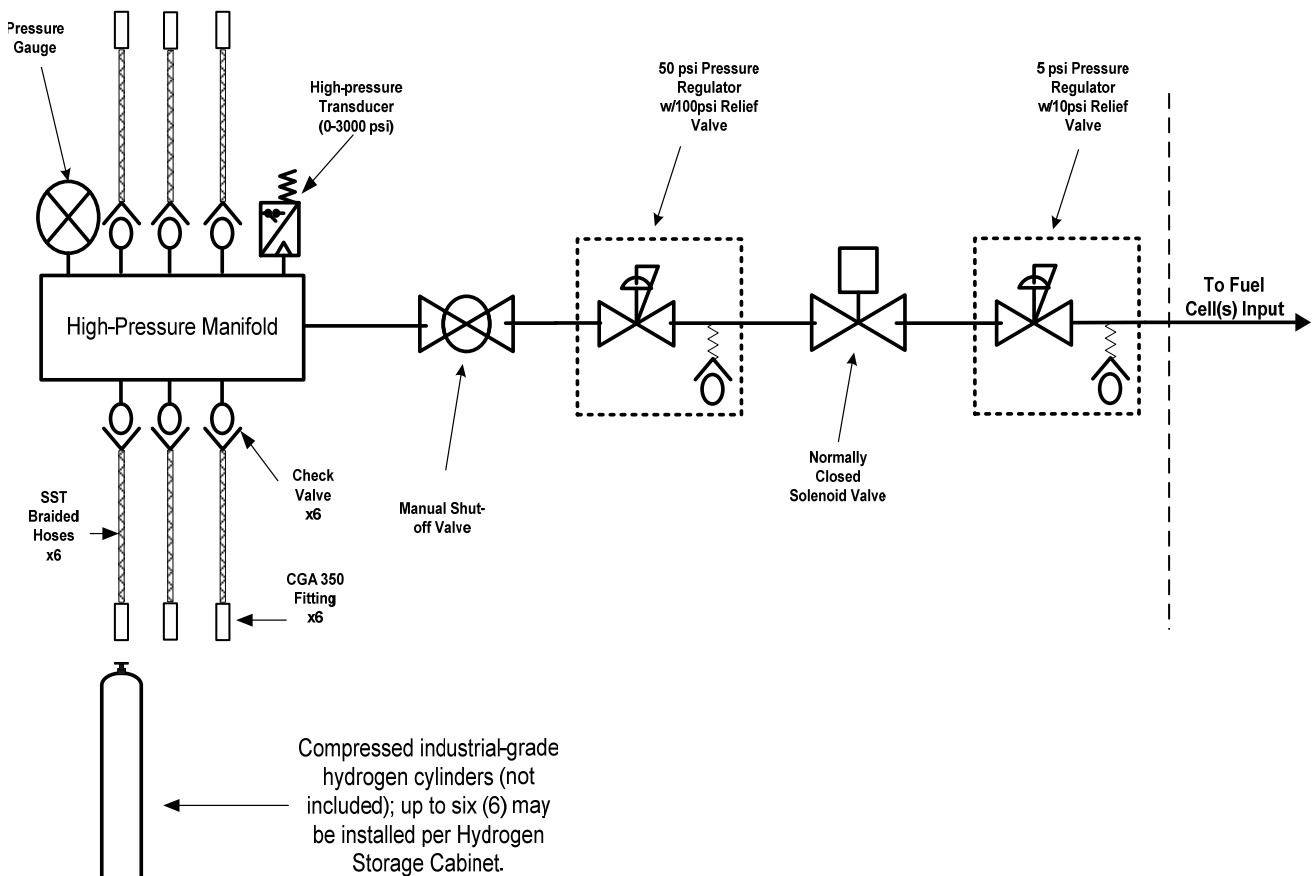
Hydrogen Storage Cabinet:

The hydrogen storage cabinet houses the hydrogen cylinders, high pressure hydrogen feed hoses, check valves, high pressure manifold, 2 ea. single-stage regulators with pressure relief valves, manual shut off valve, high-pressure transducer (0-3000 psi), and normally-closed fuel control solenoid. Details are shown in the following section.

The hydrogen storage cabinet is classified as a Class 1, Div 2 location due to the potential for the presence of hydrogen. As such, the normally-closed solenoid installed on the feed line and the high-pressure transducer installed on the high pressure manifold are both Class I, Div 2 certified components and they are the only powered electrical components installed in the hydrogen storage cabinet. The cabinet doors are louvered and promote passive ventilation which prevents a build up of hydrogen gas should a minor leak occur in the high-pressure hydrogen fuel delivery system.

Each hydrogen storage cabinet contains six hydrogen cylinders which are secured in place with restraining straps. Each cylinder is plumbed to a common manifold and each hydrogen feed hose incorporates a check valve to prevent reverse flow to the cylinders. This safety feature provides the user the ability to replace a cylinder while the system is pressurized and running, without interruption of service. The common manifold is attached to a high-pressure, single-stage regulator which steps the delivery pressure to 50 PSI. Integral to this single-stage regulator is a pressure relief valve that will operate at 100 PSI which prevents possible damage to downstream devices should a regulator fail internally. Downstream is a low-pressure, single-stage regulator which steps the delivery pressure to 5 PSI. Integral to this single stage regulator is a pressure relief valve that will operate at 10 PSI. At this point the hydrogen piping enters the main equipment cabinet providing fuel at 5 psi to the fuel cell(s).

Hydrogen Fuel Delivery System:



Main Equipment Cabinet:

The main equipment cabinet houses the low-pressure hydrogen piping delivery system, the fuel cell(s), and a 1U rack-mounted signal & control box (TSCB) for signal aggregation and I/O connectivity (T-2000™ based systems only). This electrical equipment is not required to be certified for a Class I, Div 2 environment. The following components and measures are employed to ensure safety.

- Normally-closed hydrogen feed solenoid valve
- Low H₂ pressure (5 psi gas in a system designed for 3000+ psi)
- System compliant with ASME/ANSI B31.3 Process Piping Code
- Stainless steel plumbing with compression fittings and/or SAE connectors (No NPT threaded connections)
- Hydrogen sensor which interlocks the hydrogen feed solenoid (one in the T-1000™ and two in each T-2000™)
- No AC power brought into either cabinet (DC power only)
- No arcing or sparking components in either general purpose enclosure
- Low temperature pad heaters keep cartridges above freezing levels

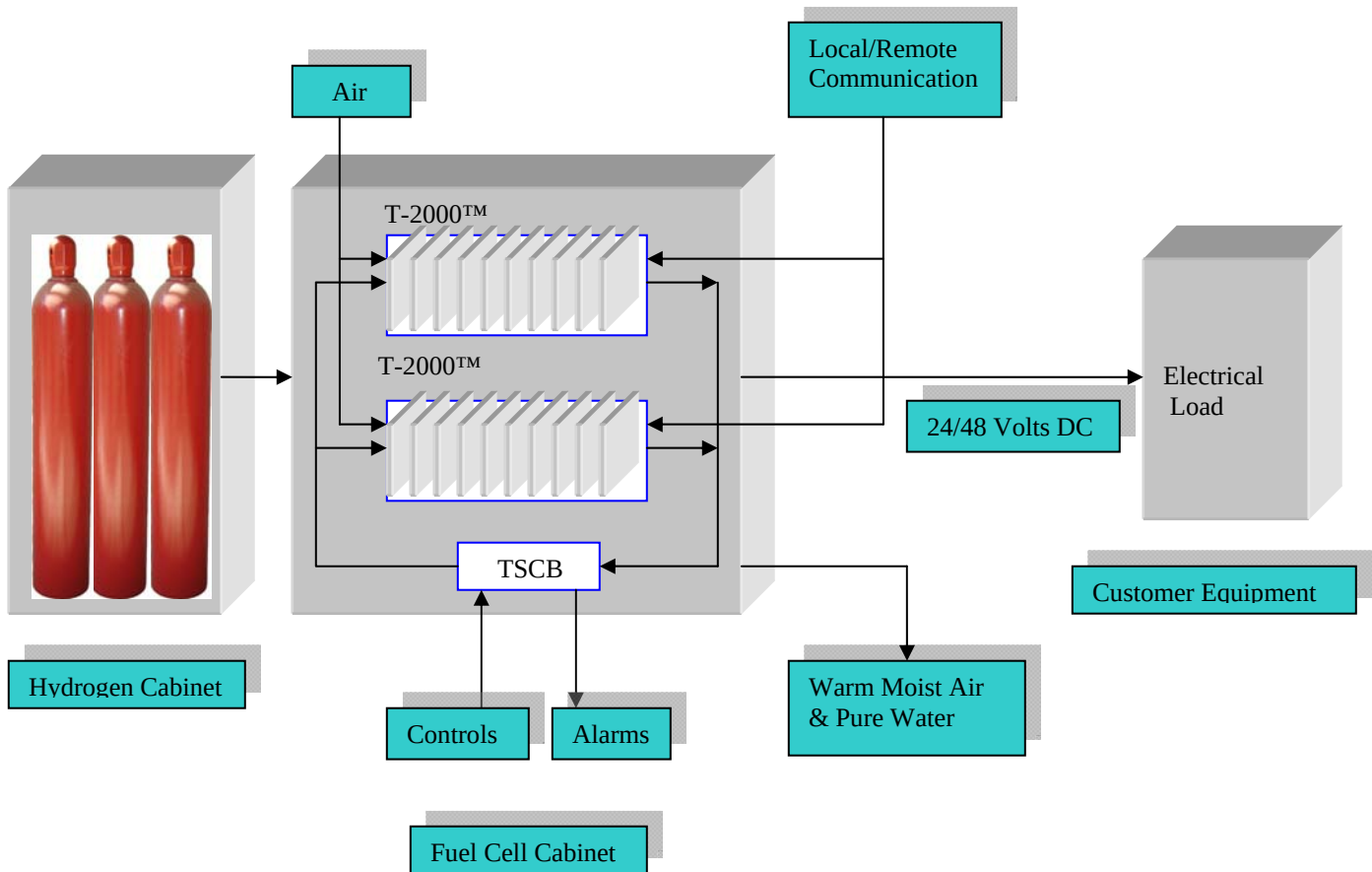
Operation:

In the standby state, the T-1000™ and T-2000™ fuel cell(s) are not operational. In this state, the normally-closed hydrogen feed solenoid is de-energized and closed and fuel is only present in the piping up to this point.

When the T-1000™ or T-2000™ fuel cell(s) are activated, they provide a signal which energizes the hydrogen feed solenoid. As mentioned above, there is a hydrogen sensor installed in each T-1000™ and two hydrogen sensors in the T-2000™. When the fuel cells are operational, the system is utilizing air drawn into the equipment cabinet and is exhausting this air out of the cabinet. All air drawn into the Outdoor Enclosure is filtered to remove dirt, insects, and other possible contaminants. The air pulled into the fuel cells is exposed to the internal hydrogen sensor(s). As mentioned in other related documents, the lower flammability limit (LFL) for hydrogen is 40,000 ppm in air which equates to a 4% concentration. If the system detects a very small hydrogen leak (4000 ppm for 20 minutes), then the system will issue a minor alarm but continues to operate. If the system detects a more substantial leak (7500-10,000 ppm), then the system will shut down and issue a major alarm which in turn deactivates power to the hydrogen feed solenoid and shuts down the flow of hydrogen fuel. This ensures that if a leak were to occur, the concentration of gas could not exceed 20-25% of the LFL which provides for a safety factor of 4-5.

During operation the fuel cell consumes hydrogen fuel and a small amount of oxygen from the ambient air stream. The fuel cell produces electricity and its byproducts are simply warm moist air and a small amount of pure liquid water which evaporates as it exits the bleed system. Signal and control wires can be connected to the TSCB to receive alarms and to provide control through contact I/O. Local and remote communications are supported at each fuel cell.

One-Line Representation of System:



Conclusion:

The T-1000™ and T-2000™ fuel cells serve as the cornerstone of the Outdoor Enclosure's design. The T-1000™ and T-2000™ have been certified to ANSI/CSA FC1-2004 Stationary Fuel Cell Power systems by CSA, and are also UL listed. The T-1000™ and T-2000™ have been approved for the CE Mark. These certifications are independent, 3rd party verification of the safety and reliability of the T-1000™ and T-2000™. Additionally, the Outdoor Enclosure system (including the T-1000™ and T-2000™) has completed NEBS – Network Equipment Building Standards, Level 3 compliance testing. This stringent testing regime includes brush fire testing, seismic zone IV earthquake testing, gunfire-withstand testing, EMI/RFI testing, salt fog testing, atmospheric contaminants exposure, solar loading, UV resistance of polymers, grounding and several other stringent criteria. The ReliOn Outdoor Enclosure system is a safe, economic means for hydrogen & hydrogen fuel cell installation, storage and delivery.