APPENDIX E – HYDROGEN SYSTEMS OPERATIONS

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E.1 HYDROGEN SYSTEM ALARMS

E.1.1 Process Alarm

A process alarm indicates that the process is deviating from the normal condition but does not represent a hazardous or incipient hazardous condition. An example would be a high-pressure switch on the PDC compressor that hits the high set point that shuts down the compressor as part of normal operation. Indicator lights will be on both the local (near the equipment) control panel(s) and at the remote control room panel.

E.1.2 Safety Alarm Level 1

A safety alarm level 1 (S-1) results from a condition that is not normal but does not require immediate response by local fire or emergency response teams. The condition does, however, require input from plant management. Plant management would be notified of an S-1 alarm by a paging system or cellular call out that would identify the type of alarm. The page would specify the alarm as an S-1 type, "Incipient Flame Detected in H2 Room." Examples of an S-1 alarm would be the UV/IR detectors detecting an "incipient" flame, which is one that may or may not be present and that requires investigation by trained personnel. An S-1 alarm can shut down part or all of the H_2 and CNG systems to the normally closed, safe condition.

E.1.3 Safety Alarm Level 2

A safety alarm level 2 (S-2) indicates a major deviation from normal process parameters and requires immediate notification of plant management and local fire and emergency response teams. Both would be notified by pager or cellular call outs that would identify the type of alarm. The page would specify the alarm as an S-2 type, "Flame Detected in H2 Room." An example of an S-2 is the UV/IR detectors detect a flame in the storage or dispensing area.

E.1.4 Alarm Actions

E.1.4.1 UV/IR Detects an Incipient Fire

This is an S-1 alarm. There may be a flame, or the detector may be fooled by another signal. There is no definite flame detected. This should generate an audible alarm (horn, tone 1) and a visual alarm (yellow light/beacon) in both the storage room and the control room. The alarm also generates a pager/cellular call out to plant management that describes the event as an S-1, "possible fire detected."

The alarm will:

1. Shut down the HOGEN 300, the PDC compressor, the dryer, and all fueling dispensers
2. Close all H_2 and CNG-actuated valves
3. Maintain power to the gas detectors, UV/IR detectors, sprinkler
4. Flow detection, all pressure and temperature transmitters, TIC, and SV-104 on the helium purge system.

E.1.4.2 UV/IR detects a fire

This is an S-2 type alarm, requiring immediate response by system controls, plant personnel, and local emergency teams. The alarm will generate a red flashing beacon and horn (tone type 2) in both the storage area and the control room. The system will send a page/cellular call out to plant management and emergency response teams, describing the type (S-2) alarm and the source, "Fire detected."

The alarm will:

1. Shut down the HOGEN 300, the PDC compressor, the dryer, and all fueling dispensers
2. Close all H_2 and CNG-actuated valves
3. Maintain power to the gas detectors, UV/IR detectors, sprinkler
4. Flow detection, all pressure and temperature transmitters, TIC, and SV-104 on Helium purge system.

E.1.4.3 Emergency Shutdown

When an emergency shutdown (ESD) is initiated, either at the control panel or by depressing any of the ESD pushbuttons, it will initiate an S-2 alarm, requiring immediate response by the system controls, plant personnel, and local emergency teams. The alarm will generate a red flashing beacon and horn (tone type 2) in both the storage area and the control room. The system will send a page/cellular call out to plant management and emergency response teams, describing the type (S-2) alarm and the source, "Fire detected."

The alarm will:

1. Shut down the HOGEN 300, the PDC compressor, the dryer, and all fueling dispensers
2. Close all H_2 and CNG-actuated valves
3. Maintain power to the gas detectors, UV/IR detectors, sprinkler
4. Flow detection, all pressure transmitters and temperature transmitters, TIC, and SV-104 on the helium purge system.

E.1.4.4 Combustible Gas Detector Detects Either CNG or H_2 at 25% of LFL

This is an S-1 alarm with response similar to the "incipient fire" shown in C.1.2 above.

E.1.4.5 Combustible Gas Detector Detects Either CNG or H_2 at 50% of LFL

This is an S-2 alarm with the same response as an ESD alarm or flame detection alarm.

E.1.4.6 High Low-Pressure Storage Tank Pressure Alarm

This is a two-level alarm. High pressure detected by PSH-104 initiates a P-1 alarm with no page outs. The alarm will close valves SV-101 and -103 on the inlet and outlet side of the LPS and will initiate a horn (tone 1) and an amber light beacon in the storage area and control room. If the pressure in the low-pressure storage continues to climb, then PT-104 high-high setpoint will trigger an S-1 alarm: horn tone 2, red flashing beacon, call out to plant management, and shutdown:

1. Shut down the HOGEN 300, the PDC compressor, the dryer, and all fueling dispensers
2. Close all H_2 and CNG-actuated valves
3. Maintain power to the gas detectors, UV/IR detectors, sprinkler

4. Flow detection, all pressure transmitters and temperature transmitters, TIC, and SV-104 on the helium purge system.

EF.1.4.7 PDC Leak Detected in Either Stage 1 or 2

This indicates there is a diaphragm leak in the compressor. The leak is captured within the leak detection system and vented to the H_2 vent stack at low pressure. The alarm is a process alarm, P-1. The alarm should initiate an amber indicator light and an audible tone in the storage area and the control room, shut down the PDC compressor, and close the inlet and outlet valves on the PDC, valves SV-101, -104, and -105.

EF.1.4.8 PDC Loss of Chilled Water Flow

This is a process alarm, P-1. It will shut off the PDC compressor, close valves SV-103, -104, and -105, and provide a tone and amber light at the control panel.

E.1.4.9 PDC High Outlet Pressure

This condition is initiated by PSH-203 and is the normal sequence to shut down the PDC compressor when the outlet pressure reaches 6,000 PSIG. The signal should also close SV-103 and -104, feeding H_2 to the PDC.

E.1.4.10 PDC High-High Outlet Pressure

This condition is initiated by PSHH-203, set at 6,100 PSIG. This is also a process alarm, P-1, and will shut down the PDC. It will also close SV-103 and -105.

E.1.4.11 High-Pressure in H_2 Process Line from PDC to HPS Tanks

This alarm is initiated by PSH-112, set at 6,500 PSIG, and is an S-1 type alarm. It will shut down the PDC, initiate an audible and visual alarm, and close SV-103 and -105.

E.1.4.12 Low Pressure in H_2 Process Line from PDC to HPS Tank

This alarm is initiated by PSL-112. The alarm indicates a possible leak from the H_2 line, which should be operating at 4,000–6,000 psig. If the pressure drops below 4,000 psig, it is possible that the line has a leak. This is a P-1 or S-1 type alarm that initiates an audible and visual alarm in the control room. Operators should take steps to check for leaks through system diagnostics and by visual checks of the line with portable gas detectors.

E.1.4.13 HPS Tanks 1 and 2 High-Pressure Detected by PT-113 and -114

There are two high alarm set points for each transmitter. The high-pressure alarm is set at ~6,200 psig. When this set point is reached, it will illuminate an indicator light on the control panel, and it will close SV-109 and -107 and shut off the PDC compressor. If the pressure continues to increase and reaches the second, or high-high pressure alarm set point at ~6,500 psig, then the system will initiate an S-1 alarm and keep SV-107 and -109 deenergized and the PDC shut down.

E.1.4.14 High H_2 Pressure to the Dispenser

This alarm will be initiated by PT-110 and will have two set points: high and high-high. The high-pressure alarm will be set at ~5,200 psig, which will initiate a process alarm, P-1, warning the operators that the dispenser feed pressure is high. This alarm will not shut down any equipment or close any valves. The alarm will be an amber indicator light and a tone. When the pressure increases to ~5,500 psig at PT-110, then the system will initiate an S-1 alarm, and will close SV-106, -110, -111, -112, thereby preventing H_2 flow to the dispenser.

E.1.4.15 High CNG Pressure to the Dispenser

This alarm will be initiated by PT-111 and will have two set points: high and high-high. The high-pressure alarm will be set at ~5,200 psig, which will initiate a process alarm, P-1, warning the operators that the dispenser feed pressure is high. The alarm will not shut down any equipment or close any valves. It will be an amber indicator light and a tone. When the pressure increases to ~5,500 psig at PT-111, then the system will initiate an S-1 alarm and will close SV-113, thereby preventing CNG flow to the dispenser.

E.1.4.16 High H_2 Flow from the High-Pressure System

This alarm indicates there is a likely break in the H_2 line between the HPS tanks and the dispenser. The alarm is actuated by flow switch FSH-101. This is an S-2 type alarm, generating a red beacon light and horn (tone 2). The alarm shuts down the HOGEN, dryer, PDC, and compressor. It also closes all actuated valves

E.2 INITIAL STARTUP OR STARTUP AFTER EXTENDED SHUTDOWN

E.2.1 Sensors/Detectors

1. Run a test of the UV/IR flame detectors to ensure that they are operating properly. Initiate a manual built in test (BIT) by pressing in momentarily on push button "BIT Manual Test" on the central control panel. The UV/IR detectors will run through a manual diagnostic test, checking the electrical circuitry, the sensors, and the sensing window cleanliness. A successful manual BIT activates the following: the fault relay is closed, the alarm relay activates for 3 s, the accessory relay is activated for 3 s, the 4–20-mA output will go to 20 mA (or 16 mA if only SW1-7 = on and SW1-6 = off). An unsuccessful BIT activates the following: fault relay is released, and the 4–20-mA output goes to zero. If the BIT is unsuccessful, the plant operators *must* determine why it was unsuccessful and correct the problem. The BIT must be run again until a successful test is completed.
2. *Warning*: Failure to complete a successful BIT means that the flame detection system is not working properly, and it will not detect a flame. Failure of the flame detectors will put personnel and property at risk and may result in injury or death to personnel. Do not proceed with the hydrogen system startup until the flame detector system is fully operational and has passed a successful BIT test.
3. If the BIT test is successful (4 to 20-mA output goes to 20 mA), then the detector status returns to normal, and the flame detector system is ready to scan the area and detect a flame. Each detector must be tested and pass a successful BIT before starting the hydrogen or CNG systems. The UV/IR system must pass the BIT before you proceed.
4. Run a check of the flammable gas detection system. Ensure that the detector(s) is properly calibrated and that the alarm output is functioning properly. The detector should initiate a visual and audible alarm (S-1 type alarm) at 25% of the hydrogen LFL and initiate a system shutdown and alarm (S-2 type) at 50% LFL of the hydrogen LFL.

E.2.2 Nitrogen Generator

1. Start the nitrogen generator (N-20). Turn the main power switch on the nitrogen generator control panel to the OFF position. Turn on the compressed air supply, following the air compressor's operating instructions. Check that the air pressure out of the compressor is 90–150 psig. Open the air supply valve to the nitrogen gas generator. Turn on the power circuit for the nitrogen generator at its disconnect box. Turn the main power switch on the generator control panel to the ON position. The power indicator light should be lit ON. Pressure (90–150 psig) should show on the Peak Pressure gauge. Nitrogen should begin to flow into the product tank. Initially, the product tank is filled with air. The air must be purged out of the product tank by the product nitrogen. This is accomplished by opening the drain valve on the bottom of the product tank and venting the air/nitrogen mix to the atmosphere until the product reaches 97% nitrogen (<3% oxygen as measured using an oxygen detector on the product venting from the drain valve).
2. When the product pressure reaches 75 to 80 psig, the amber light on the N-20 control panel will illuminate, and nitrogen production will stop until the product pressure falls below 55 to 60 psig. Check the product purity using the integral oxygen analyzer. Purity should be >97% nitrogen before the nitrogen is used as a purge gas. If the purity is less than 97%, vent the product from the storage tank until 97% purity is achieved. Once purity is reached and the product pressure has reached 75–80 psig, the nitrogen may be used to purge the hydrogen production, compression, and storage system.

> WARNING: Nitrogen purity must be >97% (<3% oxygen) for the gas to be used as a safe purge gas. If purity is less than 97%, a flammable mix can occur when the purge gas mixes with the hydrogen gas.

E.2.3 Hydrogen System Inert Purging

E.2.3.1 Vent Stack Nitrogen Purge

1. As part of the APS HAZOP, it was recommended to maintain a constant nitrogen purge on the vent stack. This purge is normally a low-flow purge of about 10 scfh, which will generate a nitrogen velocity in the vent stack of about 0.1 ft/s. The purge will keep ambient air from diffusing into the vent stack.
2. First, purge the hydrogen dryer. Connect the nitrogen source to valve V-169 on the inlet side of the dryer. Open valves V-104 ,-105, -107, and -108. Connect an oxygen monitor onto valve V-106 and open this valve. Flow nitrogen through both adsorber beds in the dryer. Monitor the oxygen level at V-106 until the oxygen reads 3%. At this point, the dryer has been adequately purged with inert nitrogen. Close V-169 and disconnect the nitrogen source from this valve. Replace the cap on the end of valve V-169. Close V-169 and –106, then disconnect the nitrogen source from V-169 and remove the oxygen detector from V-106.
3. Purge the remainder of the hydrogen system with the nitrogen generated by the nitrogen generator. Connect the nitrogen supply to V-109. Close V-103. Connect the oxygen detector to valve V-111, and open it to sample the contents of the LPS. Open V-109, allowing nitrogen into the piping system. Open manual valves (V-104, -105, -107). Open actuated valve SV-101, using the control system PLC (programmable logic controller) to force the outputs to the ON or OPEN status for this valve. With the manual and solenoid valves open, the LPS can be purged with the nitrogen gas. Open V-109 to start nitrogen flow into the low-pressure storage (LPS) tank.

4. Allow the nitrogen to flow into the low-pressure storage tank (Note that this tank must be purged of all hydrogen before being moved to the new hydrogen production location). The nitrogen generator can generate about 300 scfh of 97% nitrogen (3% oxygen). At this production rate, it will take about 5 days to fill the low-pressure tank to 90 psig. This amount of nitrogen is needed to purge the high-pressure storage tubes. Continue to fill the LPS with nitrogen. Connect the oxygen analyzer to valve V-111 on the LPS. Open V-111 and monitor the oxygen content of the LPS tank. The LPS should eventually reach 3% oxygen. It may be necessary to vent some of the tank content to the vent stack by opening V-110 and SV-102.

5. Once the LPS tank reaches 3% oxygen, the remainder of the hydrogen system can be purged with the nitrogen contained in the LPS. Open valves V-103, -116, -127, -128, -136, -138, -140, -141, -144, and -145 and energize actuated valves SV-103, -105, -106, -107, -109, -110, and –111, using the PLC control system. Continue to operate the nitrogen generator to keep the LPS filled with nitrogen.

6. Open valves V-132 and -133 on the chilled water supply for the PDC compressor. Allow chilled water to begin flowing through the compressor. Turn on the PDC compressor. This will pull low-pressure nitrogen out of the low-pressure storage tank and boost the nitrogen to about 6000 psig. The high-pressure nitrogen will flow to the high-pressure storage tanks (HPS) and to the process piping between the HPS tubes and the fueling dispensers. The high-pressure tubes will fill with nitrogen. These tubes have a storage capacity of about 8,900 scf per tube. They are shipped with air inside the tubes. The air must be purged out of the tubes until the oxygen level reaches 3% before hydrogen is introduced into the tube. To reduce the oxygen level in the tubes to a level that will not allow a reaction between the hydrogen and oxygen, the tubes need to be filled to at least 2000 psig with nitrogen gas. Monitor the fill pressure on PT-113 and -114. This fill pressure requires a minimum of 3,000 scf per tube to properly inert the storage tubes. The PDC compressor is capable of delivering 300 scfh of 6,000-psig gas. The flow rate of nitrogen will be somewhat lower, due to its material properties. At this flow rate, it will take a minimum of 10 hours per hydrogen storage tube to fill the tubes to 2,000 psig of nitrogen.

7. Once the high-pressure tubes are filled with nitrogen to ~2,000 psig, the PDC compressor can be shut down manually by pressing the STOP button, SW-1, on the PDC control panel. This will stop the flow on high-pressure nitrogen to the high-pressure storage tubes. Use the control system PLC to force solenoid valves, SV-101, -103, -104, -105, -107, and -109 to the closed position by deenergizing the outputs to these valves. Connect the oxygen detector to purge valve V-161. Open V-142 and adjust PCV-115 to match the inlet pressure required by the detector (2–15 psig). Close V-144 and SV-110. Begin to vent the nitrogen from the high-pressure tubes by opening manual valve V-159 and -139. Vent HPS tank 1 by opening the solenoid valves and SV-106, -108 and -111. Allow the pressure in the high-pressure storage to decrease to about 30–45 psig, then close the vent solenoid valve SV-108 and close the manual valves SV-110 and V-144. Use an oxygen detector to validate that the oxygen concentration in the gas in tube 1 is not greater than 3%. If the gas has 3% oxygen or less, the storage tank has been properly purged and is ready to be filled with flammable hydrogen. If the oxygen level is >3%, the tubes must be filled with nitrogen again and the purge/vent procedure repeated until the oxygen level is <3%. Repeat this procedure for tube 2. Close V-145 and SV-111. Open V-144 and SV-110. Energize SV-108 to the open position and begin venting the gas in tube 2 into the vent stack. Monitor the oxygen level with the oxygen detector. If the oxygen level is <3%, the tank is adequately purged. If the level is >3%, repeat the fill, purge, and vent procedure. Once tube 2 reaches <3%, vent the pressure to 30–45 psig. De-energize SV-108 to close this actuated vent valve. Close valves V-139, -142, and V-159.

E.2.3.2 Dispenser Purging

Close V-142. Connect the nitrogen supply to V-161 and open this valve. Open V-148 and -149, which supply gas to the dispenser. Open the lower door on the dispenser and adjust PR-1 to allow

N2 flow through the dispenser. Slowly (3–5 s), open PCV-3 on the instrument air supply. Open BV-1 and -2. Use the dispenser control system (DCS) to open ABV-1, -3, and -4 on the hydrogen flow run in the dispenser and allow nitrogen to flow through the dispenser and fueling hose/nozzle. Use the oxygen detector to check the oxygen level of the purge gas exiting the fueling nozzle. Continue to purge until the oxygen level is <3%. Close BV-1 and -2. Use the DCS to close ABV-1, -2, -3, -4. Adjust PR-1 to zero psig. Repeat this process for the CNG flow line in the dispenser.

E.2.3.3 Low-Pressure Storage Venting

Release the nitrogen purge from the LPS by closing V-104, -105, -109, and -116. De-energize SV-101, -103 to close these valves. Open V-110 and energize SV-102 to vent the tank to the vent stack. Watch the LPS tank pressure on OI-104 and PT-104. Allow the LPS tank pressure to drop to 15–25 psig of nitrogen. Close SV-102 and V-110 when the pressure reaches 15–25 psig. Recheck the oxygen level in the LPS by sampling at V-111. Close V-111 when sampling is completed.

E.2.4 Starting Hydrogen Generation

1. Start the Proton HOGEN 300 hydrogen generator. Switch the HOGEN's power disconnect to the ON position. Check that valves V-101 and –102, which supply instrument air and nitrogen to the HOGEN, are open. Set the pressure regulators on these supply lines by adjusting PCV-101 and -102. Open the deionized water valves that feed DI water into the HOGEN 300. Initiate start of the HOGEN by resetting the controller. Press the RESET switch on the control panel on the HOGEN. Start the generator by pressing the START button on the HOGEN panel. The generator begins an automated 5-minute start up sequence that includes an enclosure air purge for 180 s, fluids level check, ramp up of operating current to 1000 amp, start of electrolysis current and vent for 120 s, and start and check of the circulating pump for 30 s. Once this 5-minute sequence is complete, the generator will produce 300 scfh of hydrogen gas at 150 psig.
2. Start the hydrogen dryer by pressing the ON button on the dryer control panel. The dryer will set the actuated switching valves to the initial position. Saturated hydrogen from the HOGEN will enter the primary adsorber vessel, where moisture will be removed from the hydrogen.
3. Open V-104, -105, -107, -108 to the LPS. Begin hydrogen flow into the inerted low-pressure storage by opening SV-101 (initiate the START H_2 FLOW sequence or force SV-101 open with the PLC). Allow hydrogen to flow into this tank until the tank pressure (PI-104) reaches about 150 psig. At this point, the operator chooses whether to continue generating hydrogen or to shut down the generator. The HOGEN automatically begins to ramp down production as the outlet pressure nears 150 psig and will automatically shut down hydrogen production at 150 psig. The operator can continue to generate gas by starting the PDC compressor and drawing some hydrogen (300 scfh) out of the low-pressure tank. Removing this amount of hydrogen will keep the tank pressure below 150 psig and will allow the HOGEN to continue to generate (~300 scfh) hydrogen. If the operator does not start the PDC compressor, the HOGEN will automatically shut down when the tank pressure reaches 150 psig. If the operator chooses to stop the production of hydrogen, solenoid valve SV-101 should be closed (de-energized).

E.2.5 Hydrogen Fill to the High-Pressure Storage System

1. Open valves V-116, -103, -127, -128, -136, -140, -141, -144, and -145. Start the PDC compressor by pressing the START button, SW-2, on the PDC control panel. Open solenoid valves SV-103, -105 (PDC inlet and outlet) and inlet valves SV-107 and -109 on the high-pressure tubes. At this point, hydrogen will begin to flow into the high-pressure storage tubes. The pressure indicated on PI-113 and -114 and on PT-113, -114 will begin to increase. During the first fill with hydrogen, the tubes should only be filled to 150 psig. Then shut off the PDC compressor. Vent the HPS tubes to the

vent stack until the tube pressure drops to 30–45 PSIG. The vented gas will be a mix of nitrogen and hydrogen and therefore must be vented safely to the hydrogen vent stack. *Do not fill the tubes with hydrogen beyond 150 psig at first fill. The tube contains a low (3%) oxygen content. Mixing low-percentage oxygen in high-pressure hydrogen (>300 psig) can be hazardous.* Refill the tubes to 150 psig and again purge out to the vent stack. Repeat a third cycle to reduce the nitrogen content to below 1%. As the tubes are then filled to 6,000 psig with hydrogen, the nitrogen content will drop below 0.1%.

2. Once the initial hydrogen fill is completed, continue to operate the PDC to fill the tubes to 6000 psig. The PDC compressor will continue to operate and deliver high-pressure hydrogen to the storage tubes until the pressure in the tubes reaches 6,000 psig. Pressure switch PSH-203 (6,000 psig) and PSHH-203 (6,100 psig) on the compressor skid will shut off the PDC when the pressure at the outlet of the compressor reaches 6,000–6,100 psig. PSH-112 and PT-112 provide additional shutoff for the PDC at 6500 psig. PSH-112 will initiate an S-1 alarm if the pressure reaches 6,500 psig. PT-113 and PT-114 will also shut down the PDC compressor at 6,200 psig. Once the HPS tubes have reached 6,000 psig, the system is ready to deliver hydrogen to the dispenser.

E.2.5.1 Initial Hydrogen Dispensing

As with the HPS tubes, the dispenser and piping to the dispenser must be carefully filled and purged with low-pressure hydrogen to flush the nitrogen and 3% oxygen from the process lines. Open V-142 and -145 and energize SV-111. Adjust the pressure at PCV-115 to 150 psig. Open V-148 and -149 and SV-112. Start the dispenser and allow hydrogen to flow to the dispenser and out the vent line to the vent stack. Allow the hydrogen to flow for about 5 minutes at 10 scfm. This flow and duration should be adequate to flush the line of nitrogen and trace oxygen. Shut down the dispenser. The dispenser is now ready for the first vehicle fill.

E.3 STEADY-STATE OPERATION

When the system is operating at steady state, the HOGEN produces ~300 scfh of saturated hydrogen. The dryer produces 270 scfh of -80°F dew point hydrogen, and vents 30 scfh of wet hydrogen to the hydrogen vent stack. The PDC compressor delivers ~270 scfh of high-pressure hydrogen to the high-pressure storage tubes. This steady state will continue until the high-pressure tubes reach 6,000 psig. At this point, the PDC compressor will shut down. The HOGEN will continue to produce hydrogen and refill the low-pressure storage until this tank reaches ~150 psig, at which pressure the HOGEN will ramp down its production of hydrogen.

E.4 DISPENSER OPERATION

The hydrogen-fueling dispenser has two fueling hoses. One hose is set to deliver only 100% hydrogen at a maximum pressure of 5,000 psig. The second hose is set to deliver a blend of hydrogen and CNG. The driver/fueler can select either a low-hydrogen blend (H_2/CNG) or a high-hydrogen blend (H_2/CNG) for a 3,600-psig-vehicle CNG tank. The blend ratios are programmable within the control panel PLC to deliver a 5 to 50% H_2/CNG blend. Only authorized system operators can program the two (high and low) blend ratios. Once programmed, the selector switch on the fueling dispenser will only allow the driver/fueler to deliver a low or a high-hydrogen blend to the vehicle. The driver/fueler cannot change the preprogrammed H_2/CNG blend ratios at the fueling dispenser but can only select LOW or HIGH on the dispenser. This design is similar to a conventional gasoline dispenser—the driver can select the grade of gasoline desired (high test or regular) but cannot change the octane rating of the selection.

Fueling can be accomplished while the PDC compressor is operating. Hydrogen can be delivered to the fueling dispenser from either the high-pressure storage tube, from both tubes at the same time, or from the PDC compressor. Normally, the system operates as a *priority sequencing* system. The HPS tubes are filled by the PDC compressor in priority, with tube 2 filled first through SV-109, then tube 1 is filled through SV-107. In this way, tube 2 is maintained at the highest pressure to ensure sufficient high-pressure hydrogen is available to complete the vehicle fill to 5,000 psig. Sequencing valves SV-110 and -111 control the flow of hydrogen from the HPS to the dispenser. The PDC will continue to fill whichever tube is not dispensing hydrogen to the fuel dispenser until the 6,000-psig pressure switch trip point is reached. The sequencing valves are pneumatically actuated and are controlled by the dispenser control system (DCS). The selection of tube 1 or 2 depends on the flow rate required and pressure available in each tube. The system also allows direct supply of hydrogen from the PDC compressor to the dispenser through SV-106.

E.4.1 Initializing the Hydrogen Dispenser

1. Set the H2/CNG blend ratios in the control panel PLC logic. This ratio set point is password protected, so only authorized operators may change the setting.
2. Open valves V-144 and -142 and solenoid valve SV-110. This allows hydrogen to flow to PCV-115. PI-115A should read ~6,000 psig. Set the delivery pressure on PI-115 by adjusting PCV-115 to about 5,200 psig.
3. Remove the lower door on the dispenser and adjust PR-1 to 5,000 psig. Open the pneumatic ball valve (PCV-3) on the instrument air supply slowly (3 to 5 s to full open), allowing instrument air to enter pneumatic valves ABV-1, -2, -3, and -4. Replace the door and turn power to the dispenser to ON.

E.5 VEHICLE FUELING

1. Swipe the credit card through the credit card reader and wait for acknowledgement that the card has been read. Once the card is read, the control system will open solenoid valve SV-112. This allows hydrogen to flow from both storage tubes to the hydrogen fueling dispenser. (Note that the control system PLC can be programmed to draw hydrogen from one or both tubes or directly from the compressor.)
2. The card reader will verify what type of fuel the operator is authorized to use and will only enable refueling for the fuel specified. No other dispensers or nozzles will be enabled.
3. Select either the 100% H_2 nozzle or the H_2/CNG blend nozzle from the dispenser and connect the nozzle to the vehicle fueling port. If the fuel is H_2/CNG blend, select either the LOW or HIGH HYDROGEN position on the dispenser selector switch.
4. Move the ON/OFF lever to the ON position. The dispenser will sense the pressure in the fuel tank and measure the ambient temperature. The system will calculate the criteria for each fill based on the initial measurements. The dispenser then initiates the purge cycle through the fill nozzle. The blended fuel hose also opens a solenoid valve to deliver a fuel sample to the blended gas FUEL GAS ANALYZER, which checks the composition and fuel value of the blend. Once the nozzle purge sequence is completed, hydrogen or H_2/CNG starts to flow to the vehicle. The dispenser continuously monitors the pressure and temperature of the gas as it enters the fuel tank to ensure that the right amount of fuel is delivered.
5. Once the vehicle is filled to the required pressure, the dispenser will shut off the gas flow and will purge the fill nozzle. A signal from the dispenser controls also de-energizes SV-112 in the hydrogen feed line from the high-pressure storage to the dispenser. The vehicle operator may then disconnect the fill hose. The vehicle operator will then cap the fill port and hang up the hose.

E.6 STARTUP AFTER NORMAL SHUTDOWN

1. Run a test of the UV/IR flame detectors to ensure they are operating properly. Initiate a manual built in test (BIT) by pressing momentarily on push button BIT Manual Test on the central control panel. The UV/IR detectors will run through a manual diagnostic test, checking the electrical circuitry, the sensors, and the sensing window cleanliness. A successful manual BIT activates the following: fault relay is closed, the alarm relay activates for 3 s, the accessory relay is activated for 3 s, the 4 to 20-mA output will go to 20 mA (or 16 mA if only SW1-7 = on and SW1-6 = off). An unsuccessful BIT activates the following: the fault relay is released, and the 4 to 20-mA output goes to zero. And if the BIT is unsuccessful, the plant operators *must* determine why it was unsuccessful and correct the problem. The BIT must be run again until a successful test is completed.
2. Warning: *Failure to complete a successful BIT means that the flame detection system is not working properly and it will not detect a flame. Failure of the flame detectors will put personnel and property at risk and may result in injury or death to personnel. Do not proceed with the hydrogen system startup until the flame detector system is fully operational and has passed a successful BIT test.*
3. If the BIT is successful (4 to 2-mA output goes to 20 mA), the detector status returns to normal, and the flame detector system is ready to scan the area and detect a flame. Each detector must be tested and pass a successful BIT before starting the hydrogen or CNG systems. The UV/IR system must pass the BIT before you proceed.
4. Run a check of the flammable gas detection system. Ensure that the detector(s) are properly calibrated and that the alarm output is functioning properly.
5. Start up the nitrogen generator. Turn on the compressed air supply, following the air compressor's operating instructions. Check that the air pressure out is 90 to 150 psig. Open the air supply valve to the generator. Turn the main power switch to the OFF position. Turn on the power circuit for the nitrogen generator at its disconnect box. Turn the main power switch on the generator control panel to the ON position. The power indicator light should be lit ON. The pressure should show on the *peak pressure* gauge. Nitrogen should begin to flow into the product tank.
6. When the product pressure reaches 75 to 80 psig, an amber light will illuminate, and nitrogen production will stop until the product pressure falls below 55–60 psig. Check product purity, using the integral oxygen analyzer. Purity should be >97% nitrogen before the nitrogen is used as a purge gas. Once the purity is reached and product pressure has reached 75–80 psig, the nitrogen may be used to purge the hydrogen production, compression, and storage system.
7. Start the Proton HOGEN 300 hydrogen generator. Switch the HOGEN's power disconnect to the ON position. Check that valves V-101 and –102, which supply instrument air and nitrogen to the HOGEN, are open. Set the pressure regulators on these lines by adjusting PCV-101 and -102. Open the de-ionized water valves that feed DI water into the HOGEN 300. Initiate start up of the HOGEN by resetting the controller. Press the RESET switch on the control panel on the HOGEN. Start the generator by pressing the START button on the HOGEN panel. The generator begins an automated 5-minute start up sequence that includes an enclosure air purge for 180 s, fluids level check, ramp up of operating current to 1000 amps, start of electrolysis current and vent for 120 s, and start and check of the circulating pump for 30 s. Once this 5-minute sequence is complete, the generator will produce 300 scfh of hydrogen gas at 150 psig.
8. Start the hydrogen dryer by pressing the ON button on the dryer control panel. The dryer will set the actuated switching valves to the initial position. Saturated hydrogen from the HOGEN will enter the primary adsorber vessel where moisture will be removed from the hydrogen.

9. Begin hydrogen flow into the low-pressure storage by opening manual valves V-4, -5, -7, and -8 and actuating valve SV-101 (initiate the START H_2 FLOW sequence or force SV-101 open with the PLC). Hydrogen will begin to flow out of the HOGEN and through the dryer adsorber bed and then into the LPS tank. Allow hydrogen to flow into this tank until the tank pressure (PI-104) reaches about 150 psig. At this point, choose whether to continue generating hydrogen or to shut down the generator. The HOGEN automatically begins to ramp down production as the outlet pressure nears 150 psig and will automatically shut down hydrogen production at 150 psig. You can continue to generate hydrogen gas by starting the PDC compressor and drawing some hydrogen (300 scfh) out of the low-pressure tank. Removing this amount of hydrogen will keep the LPS tank pressure below 150 psig and will allow the HOGEN to continue to generate hydrogen (~300 scfh). If you do not start the PDC compressor, the HOGEN will automatically shut down when the LPS tank pressure reaches 150 psig. If you choose to stop the production of hydrogen, then close solenoid valve SV-101 (to de-energize).

10. Open valves V-116, -103, -127, -128 , -136, -140, -141, -144, and -145. Start the PDC compressor by pressing the START button, SW-2, on the PDC control panel. Open solenoid valves SV-103, -105 (PDC inlet and outlet) –107, and -109 (the inlet valves on the high-pressure tubes. At this point, hydrogen will begin to flow into the high-pressure storage tubes. The pressure indicated on PI-113 and -114 and on PT-113 and -114 will begin to increase.

11. The PDC compressor will continue to operate and deliver high-pressure hydrogen to the storage tubes until the pressure in the tubes reaches 6,000 psig. Pressure switch PSH-203 (6,000 psig) and PSHH-203 (6100 psig) will shut off the PDC when the pressure at the outlet of the compressor reaches 6,000–6,100 psig. PSH-112 provides an additional shut off for the PDC at 6,000 psig. PSH-112 and PT-112 provide an additional shutoff for the PDC at 6,500 psig. PSH-112 will initiate an S-1 alarm if the pressure reaches 6,500 psig. PT-113 and -114 will also shut down the PDC compressor at 6,200 psig. Once the HPS tubes have reached 6000 psig, the system is ready to deliver hydrogen to the dispenser.

E.7 EMERGENCY SHUTDOWN

1. Emergency shutdown (ESD) can be initiated from the control room or from any of the remote ESD red mushroom head ESD buttons located throughout the facility

2. When an emergency shutdown is initiated, it will:

   - De-energize and close all actuated valves in the hydrogen system, isolating and capturing the hydrogen within the storage vessels and process piping.
   - Stop the PDC compressor drive motor (if operating).
   - Shut off the fueling dispenser, closing all valves in the dispenser.
   - Shut off the air compressor feeding the nitrogen generator.
   - Shut down the HOGEN 300 by interrupting the signal into the unit on terminal/port J102. This will cause the generator to shut down and vent the hydrogen out of the unit into the vent stack.
   - Keep the UV/IR flame detectors energized and operating.
   - Keep all visual and audible alarms operating.
   - Keep the flammable gas detector operating.
   - Maintain all pressure transmitters and switches, temperature transmitters and switches, flow transmitters and switches operating, so that the operators in the control room can monitor the process conditions in the hydrogen system.

- Maintain the data output from the HOGEN 300 through data port J101.
- Maintain power to the nitrogen generator except for the feed air compressor. The nitrogen generator may be shut down by turning the main power switch on the generator to the OFF position.
- Maintain lighting in the area.
- Maintain power to the control room panel and communication system.
- Initiate an S-2 alarm with callouts to APS plant management and local emergency response personnel. See Alarms above (Section C.1.4).

In the event of an emergency shutdown, plant personnel should attempt to determine its cause and then determine what emergency response actions are required. This may include evacuation of the site and surrounding areas if deemed necessary by plant personnel. The ESD will initiate an immediate emergency response by Arizona Public Service security and plant personnel to assist emergency response teams into the facility and provide them with information regarding the nature of the cause for the ESD.

E.7.1 OPERATION OF THE HELIUM PURGE SYSTEM

The helium purge system is used for fire suppression in the event a fire occurs in the hydrogen vent stack. System operation can be initiated from a remote location by pressing the Helium Purge ON button on the control panel. This will open the actuated valve on the purge system, allowing helium to flow into the vent stack. This inert gas purge will suppress the hydrogen flame. There is also a backup nitrogen purge that can be manually opened to maintain an inert purge to the stack.

E.7.2 OPERATION OF THE FIRE SPRINKLER SYSTEM

The gas building and the adjoining auxiliary equipment room are equipped with a water sprinkler system in the event of a fire. A fusible link in the sprinkler head ensures automatic flow of water into the area of a fire. This system is not intended as a fire fighting measure but rather provides a means to keep equipment and storage vessels cool until the supply of fuel is exhausted. If the system is tripped, it will initiate an automatic call to local fire companies.

E.7.3 CONNECTIONS FOR FIRE DEPARTMENT HOOKUPS

There are two fire hydrants available to the fire department. The first hydrant is about 100 ft east of the gas building and about 50 ft east of the dispensing station. This hydrant is located on Arizona Public Service property within the 501 facility yard area. A second hydrant is located on 2nd Avenue, immediately south of the gas building.

E.8 NORMAL SHUTDOWN

Normal shutdown is defined as a system shutdown conducted in a managed, controlled fashion to bring the hydrogen system to a static condition in which the HOGEN is not generating hydrogen, the PDC compressor is not operating, and the storage and dispensing systems are inactive. In normal shutdown, the sensing devices and control circuits remain active so that the operators in the control room can monitor the status of the hydrogen system and the flame and flammable gas detectors. In normal shutdown, the active elements of the subsystems will be shut down (hydrogen cell stack, dryer, compressor, fuel dispenser).

In normal shutdown, follow this sequence:

1. Shut down the HOGEN 300 hydrogen generator by depressing the red STOP button on the control panel of the generator (or from a remote location by interrupting the J102 terminal). This will remove all dc power from the cell stack, preventing generation of any hydrogen. The hydrogen gas in the generator will vent to atmospheric pressure through the hydrogen vent stack. The water in the generator will drain if the ambient temperature is below 40ºF. All valves in the generator will revert to their unpowered state, resulting in venting and depressurization of the HOGEN.
2. Allow the HOGEN to complete its shutdown and cool down (about 15 to 30 minutes); then, turn off the chiller.
3. Close all solenoid valves in the hydrogen process piping by de-energizing these valves. Close select manual valves if the shutdown is for an extended time (weekend) such as V-103, -108, -110, -111, -116, -127, -142, -148, -149. These valves will isolate the storage tanks and the fuel dispenser.
4. Turn off the power to the fueling dispenser by turning the power switch on the dispenser to the OFF position (note that this will de-energize all electrical items in the dispenser and will de-energize the electrical output from the sensors in the dispenser.
5. Shut down the PDC compressor by pressing the STOP button. This will allow all controls and sensors to remain active in the compressor skid. *You may completely de-energize the PDC by switching the electrical disconnect for the PDC to the OFF position.*
6. Turn off the feed air compressor to the generator. Turn off the nitrogen generator by turning the main power switch to the OFF position.
7. Turn off the hydrogen dryer by pressing the STOP button on the control panel.

E.9 EXTENDED SHUTDOWN

An *extended shutdown* is one that will persist for an undetermined length of time but greater than 2 weeks. It is not a shutdown for weekends or holidays. Generally, in an extended shutdown the storage tanks and tubes that contain hydrogen will be de-pressurized to about 10–15 psig of hydrogen gas. For a very long shutdown period, or for major maintenance, the storage tubes/tanks should be de-pressurized and then purged with nitrogen until the atmosphere in the process piping and tanks/tubes is below 3% oxygen and below 25% of the LEL for hydrogen. The nitrogen pressure in the system should be set at about 10–15 psig.

All safety systems, UV/IR detectors, and flammable gas detectors should remain active during the extended shutdown until or unless the hydrogen system is completely shut down and purged with nitrogen. Only then should the safety systems, flame detectors, and flammable gas detectors be decommissioned (note that if the CNG system is still active, all of the safety systems, flame detectors, flammable gas detectors must remain active. It is recommended that these systems remain active even if the hydrogen and CNG systems have both been shut down and nitrogen purged. Operators must make an informed decision as to whether to shut off the safety systems, gas detectors, and flame detectors).

1. Turn off power to each subsystem.
    - Turn the main power switch on the nitrogen generator to OFF. Switch the power disconnect to OFF.
    - Turn the power switch on the fueling dispenser to OFF. Switch the power disconnect to OFF.
    - Press the STOP button on the PDC compressor. Switch the control panel power disconnect handle to OFF. Switch the main power disconnect to OFF.

- De-energize all solenoid valves.
- De-energize all process gas sensors, transmitters, and switches.

2. Close all manual valves. Check the pressure in each subsystem by looking at the local gauge and reading the pressure on the transmitters at the control panel. If there is excess pressure, then safely bleed the pressure to vent until the pressure is 10–15 psig.
3. Lock out and tag out all electrical disconnects.
4. Lock out select manual valves.
5. Secure the area.