WIND-TO-HYDROGEN ENERGY PILOT PROJECT: BASIN ELECTRIC POWER COOPERATIVE

Final Report

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U.S. Department of Energy
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Golden, CO 80401

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Prepared by:

Ron Rebenitsch
Randall Bush
Allen Boushee
Jeremy Woeste

Basin Electric Power Cooperative
1717 East Interstate Avenue
Bismarck, ND 58503

Brad G. Stevens, P.E.
Rhonda R. Peters
Kirk D. Williams

University of North Dakota
Energy & Environmental Research Center
15 North 23rd Street, Stop 9018
Grand Forks, ND 58202-9018

Keith Bennett

U.S. Department of Energy
1617 Cole Boulevard
Golden, CO 80401

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DISCLAIMERS

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EXECUTIVE SUMMARY

In an effort to address the hurdles of wind-generated electricity (specifically wind's intermittency and transmission capacity limitations) and support development of electrolysis technology, Basin Electric Power Cooperative (BEPC) conducted a research project involving a wind-to-hydrogen system. Through this effort, BEPC, with the support of the Energy & Environmental Research Center at the University of North Dakota, evaluated the feasibility of dynamically scheduling wind energy to power an electrolysis-based hydrogen production system.

The goal of this project was to research the application of hydrogen production from wind energy, allowing for continued wind energy development in remote wind-rich areas and mitigating the necessity for electrical transmission expansion.

Prior to expending significant funding on equipment and site development, a feasibility study was performed. The primary objective of the feasibility study was to provide BEPC and The U.S. Department of Energy (DOE) with sufficient information to make a determination whether or not to proceed with Phase II of the project, which was equipment procurement, installation, and operation.

Four modes of operation were considered in the feasibility report to evaluate technical and economic merits. It should be noted that all the modes studied represent hydrogen production efficiencies less than those achievable if the system were operated at full production on "grid" electricity. The modes of operation studied were the following:

- Mode 1 – scaled wind
- Mode 2 – scaled wind with off-peak
- Mode 3 – full wind
- Mode 4 – full wind with off-peak

In summary, the feasibility report, completed on August 11, 2005, found that the proposed hydrogen production system would produce between 8000 and 20,000 kg of hydrogen annually depending on the mode of operation. This estimate was based on actual wind energy production from one of the North Dakota wind farms of which BEPC is the electrical off-taker. The cost of the hydrogen produced ranged from $20 to $10 per kg (again depending on the mode of operation).

The economic sensitivity analysis performed as part of the feasibility study showed that several factors can greatly affect, both positively and negatively, the "per kg" cost of hydrogen. The study showed that in the best scenario the cost of production could be as low as $4.00 per kg.

During a September 15, 2005, meeting where representatives from DOE, BEPC, and other involved parties convened to evaluated the advisability of funding Phase II of the project. DOE concurred with BEPC that Phase I results did warrant a “go” recommendation to proceed with Phase II activities.

Following nearly two years of contract negotiations, system and site design discussions, and system and site construction activities, a hydrogen production and fueling facility was installed in northwestern North Dakota near Minot, North Dakota.

The hydrogen production system was built by Hydrogenics and consisted of several main components:

- Hydrogen production system
- Gas control panel
- Hydrogen storage assembly
- Hydrogen-fueling dispenser

The hydrogen production system utilizes a bipolar alkaline electrolyzer nominally capable of producing 30 Nm^3/h (2.7 kg/h). The hydrogen is compressed to 6000 psi and delivered to an on-site three-bank cascading storage assembly with 80 kg of storage capacity. Vehicle fueling is made possible through a Hydrogenics-provided gas control panel and dispenser able to fuel vehicles to 5000 psi.

A key component of this project was the development of a dynamic scheduling system to control the wind energy’s variable output to the electrolyzer cell stacks. The dynamic scheduling system received an output signal from the wind farm, processed this signal based on the operational mode, and dispatched the appropriate signal to the electrolyzer cell stacks.

BEPC had the option to select from three distinct wind farms for use in the project, one wind farm which it owns and operates and two others of which it is the electrical off-taker. For several reasons, BEPC chose to utilize output from the Wilton wind farm located in central North Dakota for the study.

Site design was performed from May 2006 through August 2006. In addition, a Hazard Identification and Risk Analysis and a Failure Modes and Effects Analysis were performed as part of the site and system design activities.

Upon completion of the site design work, site construction activities began in August 2006. Site construction involved necessary earthwork, infrastructure installation, and concrete slab construction and was completed by November 2006.

From April 2007 through October 2007, the system components were installed and connected. During this time period, high-pressure testing was also completed as well as other required inspections and approvals.

Beginning in November 2007, the system was operated in a start-up/shakedown mode. Because of numerous issues, the start-up/shakedown period essentially lasted until the end of January 2008, at which time a site acceptance test was performed.

Official system operation began on February 14, 2008, and continued through the end of December 2008, at which time the system was put into an "idle" state until consumption dictated production of hydrogen. Several issues continued to prevent consistent operation, resulting in operation of the system in fits and starts.

During the operational period, three ramp tests were performed on the electrolyzer cell stacks to evaluate cell stack degredation, if present. In addition, from December 23, 2008, through December 30, 2008, the hydrogen system was operated using Mode 1 protocol.

From February 14, 2008, through December 31, 2008, the system produced a total of just less than 26,000,000 liters (2320 kg), including approximately 3,300,000 liters (295 kg) of hydrogen during Mode 1 operation.

Unfortunately, the chronic shutdown issues prevented consistent operation and, therefore, did not allow for any accurate economic analysis as originally intended. With that said, much valuable experience was gained in the form of "lessons learned," and the project served as an extremely valuable platform for educating the public.

WIND-TO-HYDROGEN ENERGY PILOT PROJECT: BASIN ELECTRIC POWER COOPERATIVE

INTRODUCTION

In an effort to address the hurdles of wind-generated electricity and support development of electrolysis technology, the U.S. Department of Energy (DOE) awarded Basin Electric Power Cooperative (BEPC) a contract to investigate a wind-to-hydrogen system. Through this effort, BEPC, with the support of the Energy & Environmental Research Center (EERC), is evaluating the technical and economic feasibility of dynamically scheduling wind energy to power an electrolysis-based hydrogen production system.

The capital costs of electrolysis systems and the current fossil fuel-dominated electric mix in the United States have limited the widespread adoption of electrolysis technology for hydrogen production. Technology development of electrolysis systems and integration with low-cost, low-emission, or renewable energy sources will be necessary for the technology to be competitive with conventional fossil fuel energy production.

Advances in technology have reduced the cost of wind-generated electricity in many wind-rich areas of the United States; however, significant development of these resources has not occurred. Two factors, wind's intermittency and transmission capacity limitations, make it difficult to supply the wind-generated electricity to market, thereby slowing investment.

The goal of this project was to research the application of hydrogen production from wind energy. The economics and feasibility of dynamic scheduling were also to be addressed.

BACKGROUND

Site Location

The site chosen for the hydrogen system was the North Central Research Extension Center (NCREC), an agriculture research facility owned and operated under North Dakota State University (NDSU). The NCREC is located approximately 1 mile south of Minot, North Dakota, in north-central North Dakota (Figure 1). The 1200-acre research center was established in 1945 for agricultural field research. Today, it specializes in crop research, education activities, and foundation seed production.

Feasibility Study

Prior to expending significant funding on equipment and site development, BEPC hired the EERC to assess the feasibility of the project. The primary objective of the feasibility study, included in Appendix A, was to provide BEPC and DOE with sufficient information to make a determination whether or not to proceed with Phase II of the project, which was equipment procurement, installation, and operation.

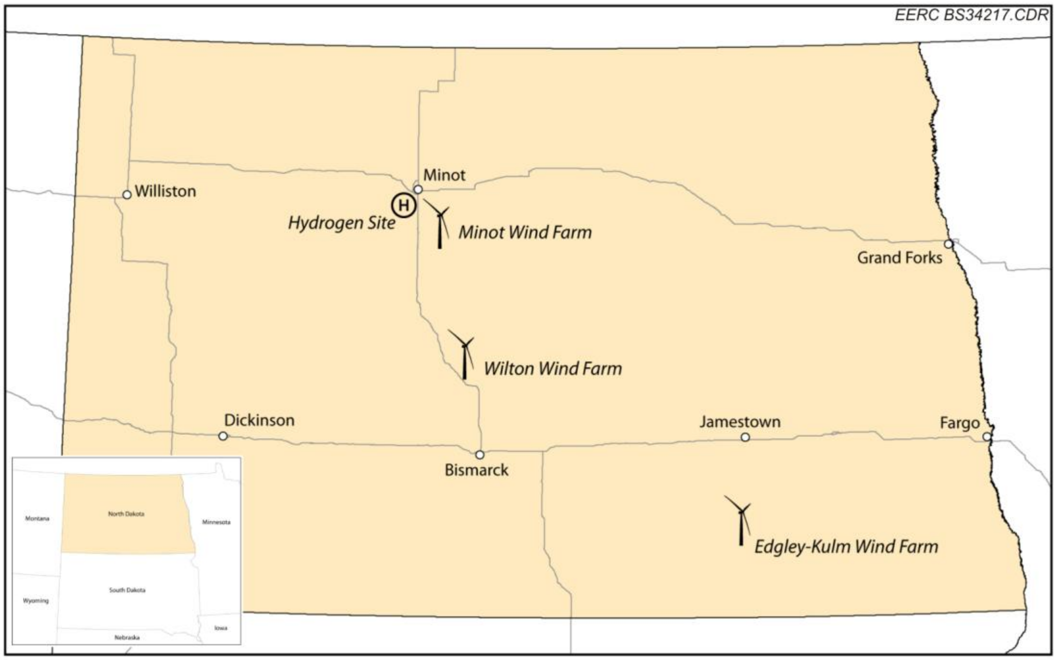

Figure 1. Site location.

As part of the Phase I/Feasibility Study, the EERC in consort with BEPC performed the following activities:

- Developed a framework for site layout and system design and operation. This information served as the basis for much of the request for quotation.

- Issued a request for quotation for the desired hydrogen generation system. The companies that received requests for quotation were Proton Energy Systems (Proton), Hydrogenics Corporation (formerly Stuart Energy Systems) (Hydrogenics), Norsk Hydro (Norsk), and Teledyne.

- Assisted BEPC in the selection of a vendor for the hydrogen generation system. BEPC selected Hydrogenics Corporation as the supplier of the hydrogen generation system.

- Performed a technical evaluation of theoretical wind energy and hydrogen production. This analysis estimated wind energy production and resulting hydrogen production from actual wind resource data at the existing wind farm locations.

- Performed an economic sensitivity analysis. This analysis evaluated the impact of several input costs on the cost of the produced hydrogen.

- Established a framework for development of a dynamic scheduling interface between the wind generation and the hydrogen facility. The dynamic scheduling programming was to be developed as part of Phase II activities.

- Prepared and submitted the initial National Environmental Policy Act documentation.

- Compiled information regarding pertinent national, state, and local code and permitting requirements.

- Performed an evaluation of available hydrogen end-use technologies and identified the most suitable technologies for application at the facility. The end-use technology chosen for implementation on the project was determined based primarily on availability and cost.

Four modes of operation were considered in the feasibility report to evaluate technical and economic merits. It should be noted that all the modes studied represent hydrogen production efficiencies less than those achievable if the system were operated at full production on “grid” electricity. The modes of operation studied were the following:

- Mode 1 – scaled wind
- Mode 2 – scaled wind with off-peak
- Mode 3 – full wind
- Mode 4 – full wind with off-peak

Mode 1 – Scaled Wind

As the mode name indicates, Mode 1 represented delivery of power to the electrolyzer scaled such that the maximum wind power is scaled to match the maximum load of the electrolyzer. This mode would imitate a scenario where the electrolyzer would be directly connected to a small wind turbine. For example, if the electrolyzer represents an electrical load of 150 kW and the dynamical scheduling software is monitoring wind turbine output of 1500 kW, the resulting maximum delivered power to the electrolyzer would be 150 kW, or the hourly delivered power would be the measured wind farm output in kW times 0.1. The power generation and delivery pattern would not be changed, only the magnitude. Because the electrolyzer requires a minimum input of 25% of rated power, when the scaled wind energy is less than this value, the electrolyzer will be run at the 25% minimum value. These values were used exclusively for the feasibility study based on input from Hydrogenics. The requirements of the actual system were 43% of the maximum electrolyzer load, which was 165 kW.

Mode 2 – Scaled Wind with Off-Peak

Mode 2 will consisted of operating the system under the Mode 1 (scaled wind) scenario with the addition of utilizing off-peak power to supplement the wind energy (if needed) during the hours of 11 p.m. to 7 a.m. Off-peak power will be delivered to the electrolyzer to supplement the wind energy up to the maximum electrolyzer load (150 kW).

Mode 3 – Full Wind

Mode 3 is the nonscaled version of Mode 1; that is, the actual power output from the wind farm was dispatched to the electrolyzer up to the maximum electrolyzer load (150 kW). Wind power greater than 150 kW will be delivered to the electrical grid as it normally would.

This mode mimicked a scenario where the electrolyzer is operated by a utility-scale wind turbine or wind farm. Unlike Modes 1 and 2, the wind turbine(s) in Modes 3 and 4 are not scaled to match the electrolyzer and, therefore, generate more electricity than can be utilized by the electrolyzer. As a result, Modes 3 and 4 produce two products, hydrogen and electricity.

Mode 4 – Full Wind with Off-Peak

Mode 4 can be thought of in two ways: either as the nonscaled version of Mode 2 or as Mode 3 with the addition of off-peak power. Mode 4 represents operating the electrolyzer in a "maximum utilization" scenario.

In summary, the feasibility report, completed on August 11, 2005, found that the proposed hydrogen production system would produce between 8000 and 20,000 kg of hydrogen annually depending on the mode of operation. This estimate was based on actual wind energy production from one of the North Dakota wind farms of which BEPC is the electrical off-taker. The cost of the hydrogen produced ranged from $20 to $10 per kg (again depending on the mode of operation).

The economic sensitivity analysis performed as part of the feasibility study showed that several factors can greatly affect, both positively and negatively, the "per kg" cost of hydrogen. Not surprisingly, the capital cost of the hydrogen production system had the largest impact on cost of production, representing approximately 70%. In addition, the size of the system had potential to significantly impact the cost of production. In this case, the system could have been double in size (and double in hydrogen output) for approximately a 30% increase in equipment cost. Other factors having the largest impact on cost of production were the amortization period and the cost of the electricity.

The study showed that, in the best scenario, where a larger system was purchased, operated in Mode 4, and amortized over a longer period than 10 years, the cost of production would likely be at or below $4.00 per kg.

A meeting was held on September 15, 2005, at BEPC's headquarters in Bismarck, North Dakota, to present and discuss the Phase I Feasibility Study results, receive DOE's stage gate decision, and if positive, plan the Phase II activities. Representatives from several agencies were either in attendance or on the conference call, including DOE, BEPC, the EERC, the city of Minot, NDSU, and Hydrogenics.

During the meeting, personnel from BEPC and the EERC presented the methodology and results of the feasibility study as well as recommendations for Phase II of the project. DOE concurred with BEPC that Phase I results did warrant a "go" recommendation to proceed with

Phase II activities. With a "go" decision in place, discussions followed to shape and kick off Phase II of the project.

PROJECT ACTIVITIES

Phase II activities began with BEPC initiating contract discussions with Hydrogenics, selected to provide the hydrogen generation and fueling equipment during Phase I. Concurrent with the system design, BEPC and the EERC began securing contractors to perform site design, perform site construction, and provide end-use vehicles.

System Design

The request for quotations to provide the hydrogen production system for the project specified a system capable of producing a minimum of 30 Nm^3/h of hydrogen that had to include compression, storage, and dispensing (at 5000 psi). The EERC submitted requests for quotations to Proton, Hydrogenics, Norsk, and Teledyne. Norsk declined to provide a bid, but all other bidders provided similar prices for a complete refueling station (approximately $1,000,000). Hydrogenics was the only company to offer a complete package. Proton and Teledyne would only supply the electrolyzer, with compression, storage, and dispensing provided by others.

Based on several factors, Hydrogenics was selected as the provider of the hydrogen system. In addition to demonstrated experience and the ability of the company to provide a complete package, Hydrogenics also provided contractual payment flexibility unique to the funding scenario for the project, which was not offered by other bidders.

Contract negotiations with Hydrogenics took the better part of the second half of 2005. The contract with Hydrogenics was finalized, and a kickoff conference call was held with Hydrogenics on January 10, 2006. From January 2006 through May 2007, BEPC, the EERC, and Hydrogenics discussed the design, construction, and operation of the hydrogen generation and fueling system.

The hydrogen production and fueling facility consisted of several main components:

- Hydrogen production system
- Gas control panel
- Hydrogen storage assembly
- Hydrogen-fueling dispenser

The hydrogen production system was built by Hydrogenics in Belgium (a change that occurred as a result of Hydrogenics acquiring Stuart Energy) and then was shipped to the Hydrogenics facility in Mississauga, Ontario, Canada, for initial testing and to undergo certification review by a nationally recognized testing laboratory (NRTL) for delivery and operation in the United States. The gas control panel and the dispenser were designed and built by Hydrogenics in Mississauga. The remaining major component, the storage assembly, was designed and built by CP Industries, Inc., in McKeesport, Pennsylvania, and delivered directly to the site by CP Industries.

System Overview

System Enclosure

With the exception of the storage and dispensing systems, the entire hydrogen production system consisting of an electrical control system, programmable logic controller system, electrical transformer-rectifier, uninterruptable power supply, water supply and purification system, hydrogen gas generation system (nominally rated at 30 Nm^3/h or 2.7 kg/h), electrolyzer cooling system, hydrogen purification system, instrument air system, hydrogen compression system, and ancillary equipment was contained in a 40-ft ISO shipping container (Figure 2). The container is portioned into three separate areas: the electrical area, the water process area, and the hydrogen production area.

The electrical and water process areas are separated from the process equipment by a gastight division. The hydrogen production area of the enclosure includes the gas generation equipment, gas purification equipment, and compression system. The container is equipped with gas detection sensors as well as a ventilation system.

Figure 2. Photo of hydrogen system enclosure.

Electrolyzer Input

Feed water was provided by North Prairie Rural Water and is of a potable water quality. Water is delivered to the system via underground piping and treated by a reverse osmosis (RO) purification system to obtain the water quality level required by the electrolyzer. The treated water is stored in a break tank and is automatically fed to the electrolytic cells through a series of control valves and separator/rinsing vessels. For each Nm^3 of hydrogen produced, approximately 1 liter of RO-purified water is required. The system output (at maximum capacity) is 30 Nm^3/h, therefore the required inflow of treated water is approximately 30 liters/h. A photo of the water treatment room is shown in Figure 3.

EERC BS34200.CDR

Figure 3. Photo of the water treatment room.

Input energy is required to initiate and maintain the electrolytic process. A transformer-rectifier is required to transform alternating current (AC) from the electrical grid to direct current (DC) required by the electrolyzer. The DC current is adjusted via automatic controls to allow for variable hydrogen production. The production output is dependent on user-initiated settings (which will mainly be determined by preprogrammed operational control scenarios and the amount of available wind energy). An uninterruptible power supply battery provides backup power to control the critical parameters of the system in the event of a power failure. If a power failure were to occur, hydrogen production would be stopped, and the electrolyzer would be put in “standby” mode. If power is not restored in 30 minutes, the remaining power of the battery would be used to gradually depressurize the machine and restore all parameters to a stabilized position.

Process Description

The electrolytic cells are bipolar (positive and negative charge on opposite sides) and convert the liquid water (H_2O) to hydrogen gas (H_2) and oxygen gas (O_2). The cell stack consists of circular electrolytic cells (90 cells in each stack), each containing two electrodes and an advanced proprietary alkaline inorganic ion exchange-type membrane (Figure 4).

The electrolyzer utilizes a potassium hydroxide (KOH) electrolyte to convert water to H_2 and O_2. The electrolyte solution in the electrolyzer is a water-based solution of approximately 30% KOH.

Figure 4. Photo of the electrolyzer cell stacks.

A separate closed-loop cooling system and a chiller reduce the need for external cooling water to zero. The cooling system is used to remove KOH and moisture from the hydrogen stream. This is done in two rinsing stages where gas flows through two small pressure vessels that are connected to the cooling loop. When the hydrogen gas flows through these pressure vessels, it is cooled down to allow the KOH and moisture to condense and be removed from the gas stream. The system is designed so that the KOH condensate is sent back by gravity to a condensate tank within the hydrogen production area.

Electrolyzer Output

The oxygen created in the electrolysis process is not stored but is vented to the air via system piping.

The hydrogen created in the electrolysis process is first passed through a gas/liquid separator and rinser. After gas-rinsing, the H_2 will be at 99.9% purity and is sent for further purification via a deoxo-dryer, where a catalytic purifier removes trace O_2 and a twin tower dryer removes moisture. The moisture content in the hydrogen stream is reduced to an atmospheric dew point of less than −75°C after exiting the dryer. The resulting product is hydrogen gas with a minimum purity of 99.998%. The remaining impurities are nitrogen (N_2) at less than 15 ppm (parts per million), O_2 at less than 2 ppm, water at less than 1 ppm, and carbon monoxide/carbon dioxide (CO/CO_2) at less than 1 ppm.

The separated hydrogen gas is pressurized to 414 bar (approximately 6000 psig) by way of an integrated diaphragm compression system and piped to the hydrogen storage assembly (located outside). The compression system includes a motor and controls and is housed in the hydrogen production area (Figure 5).

Hydrogen Storage

The hydrogen storage system is comprised of six cylinders in a three-bank cascade system giving a combined storage capacity of 80 kg. Vessels are ASME-rated and mounted to a frame suitable for seismic zone 1. The storage system operates at a maximum pressure of 414 bar (6000 psig), and includes safety release valves. The system also includes liquid-filled pressure gauges, one per bank, complete with block and bleed valves, located on the vessel side of the manual isolation valves and manual valves, one per bank to allow for evacuation of each bank on an individual basis. Dump valves are provided on each bank for manual evacuation of the system for purging purposes (Figure 6).

Dispenser

The gas-dispensing system contains a three-bank gas control panel (GCP) comprised of priority valves for directing hydrogen from the compression system into storage. Its sequencing control system directs filling of the cascading storage system and a dispenser priority panel controls cascading storage vessels for vehicle fueling at 5000 psi. A photo of the hydrogen dispenser is shown in Figure 7.

EERC BS34203.CDR

Figure 5. Photo of the hydrogen production area (hydrogen compressor in the foreground).

EERC BS34204.CDR

Figure 6. Photo of the hydrogen storage assembly.

EERC BS34205.CDR

Figure 7. Photo of the hydrogen dispenser.

Dynamic Scheduling Software

A key component of this project is the dynamic scheduling of the wind energy's variable output to the electrolyzer cell stacks. The dynamic scheduling system received an output signal from the wind farm, processed this signal based on the operational mode, and dispatched the appropriate signal to the electrolyzer cell stacks. With both systems connected to the electrical grid within BEPC's control area, several control scenarios could be utilized. These control scenarios were described as Modes 1 through 4 in the Feasibility Study section.

The Hydrogenics electrolyzer is always in one of three states, 1) cold: where the system is shut down and decompressed, 2) hot standby: where the cell stacks are energized, pressurized, and ready to produce hydrogen, and 3) operating: where the electrolyzer is producing hydrogen in relation to the electricity applied to the cell stacks. Since the electrolyzer took several minutes to start producing hydrogen from a cold state, and BEPC wanted the system to react quickly to the variability of the wind energy input, it was agreed that when the dynamic scheduling software was being utilized, the system would not be allowed to reach the cold state. To achieve this, the controlled variable load was limited to the 165-kW cell stack load. As another factor, Hydrogenics recommended a minimum operating level (43%) that had to be considered in the control scheme. All other electrical load (balance of plant) was considered as supplied from the grid and thus removed from variations considered in the development of the "follow-the-wind" control scheme.

The dynamic scheduling system, depicted in Figure 8, consists of an ION Enterprise SCADA (Supervisory Control and Data Acquisition) system manufactured by Schneider Electric. The ION components utilized are:

- One (1) 7550 RTU (Remote Terminal Unit)
- One (1) 8500 ION Meter with input/output (I/O) Extender
- One (1) 8600 ION Meter with I/O Extender
- One (1) computer server utilizing ION Enterprise Software - Version 5.5

A speed test was performed to measure the time required for passage of data. A clock seconds value was passed from the wind farm RTU through the system to the ION Meters at the electrolyzer and back again. The seconds value returned was then compared to the originating clock seconds value to determine the number of seconds for the communications signal round-trip. The average time for a round-trip communication was less than 3 seconds. Thus, the time for one-way communications through the system averaged less than 1.5 seconds.

The dynamic schedule program was developed using a combination of several standard ION logic modules. The Server polls the wind source data from the 7550 RTU located at the

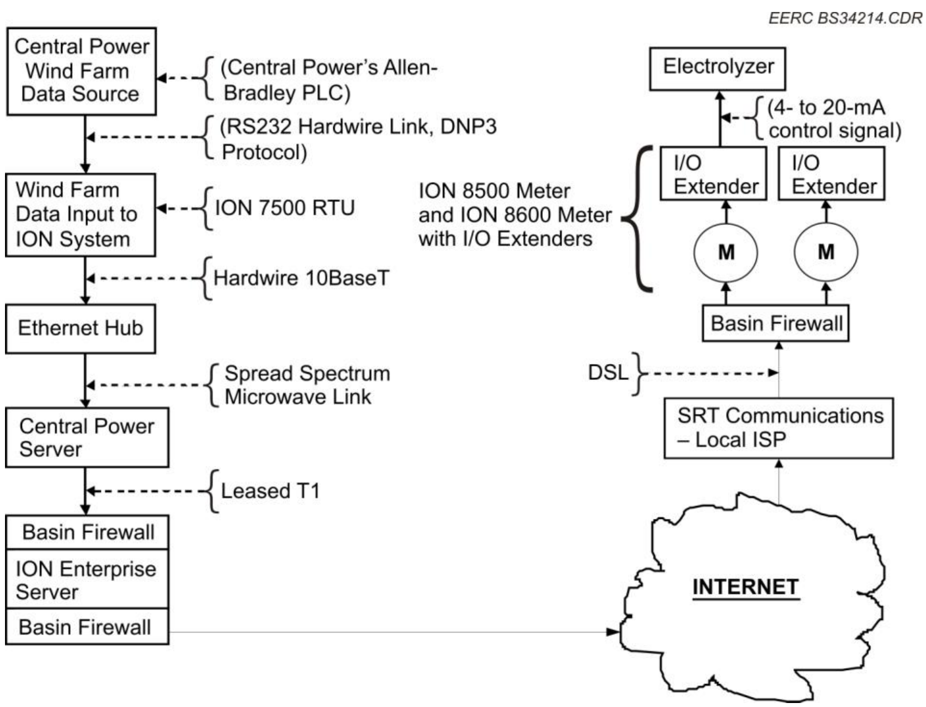

Figure 8. Dynamic scheduling process flow diagram.

Minot wind farm. Central Power Electric Cooperative, the electric transmission cooperative serving the study area, has an Allen-Bradley PLC (programmable logic controller) at that location which can pass the electric system wind farm data to the ION 7550 RTU using an RS232C connection and DNP3 protocol. The Allen-Bradley unit is the DNP3 master unit, the 7550 RTU is the slave unit.

The server then passes the polled data to the ION 8600 meter located at the electrolyzer site. The data are scaled in the server to a percentage value for the wind source. The ION 8600 meter then takes the wind source percentage value and scales a proportionate 4- to 20-mA control signal, which is then input to the electrolyzer control system.

Several logic modules are used to integrate the decisions necessary to operate the electrolyzer in accordance with the desired operating scenario and are described below.

ION Scheduler Module

This module allows the development of a 2-year calendar that can be programmed to define holidays, weekends, on-peak and off-peak times, and a means to input daylight savings time adjustments. The output of this module is a logical 1 when follow-the-wind should be implemented and a logical 0 when other control values should apply.

ION Counter (Status) Module

This module provides the means to select either follow-the-wind operation or operation based on an operator manually entered production value.

ION Arithmetic Module

These modules provided a means to implement the logic and scaling functions needed to determine the control/production request values in accordance with the wind source input signals and control operating mode selected.

ION Set Point Module

This module provided a means to determine the minimum production value that should be used when the wind source is below 43%. The electrolyzer is limited at the lower production level to either operating at a sustained 43% or larger value or to go to a zero production value. Proportionate operation below 43% was not recommended by Hydrogenics, the electrolyzer manufacturer. To moderate the impact of this limitation on production in this range, the 43% range was transformed into a step-function-type operation using an ION Setpoint Module. The set point module has a trigger value and a reset value. The set point module outputs a logical 1 when the input value increases beyond the trigger value. The output then remains at logical 1 for all values exceeding the reset value. Once the current value falls below the reset value, the output is then set to logical 0 and remains at logical 0 until such time as the trigger value is exceeded again.

The trigger value was set at 26%. The reset value was set at 17%. This allowed a 9% buffer operation zone or deadband to avoid unnecessary cycling of production between 0 and 43% when wind production was fluctuating around the halfway value (21.5%). Figure 9 is a graphical representation of this control strategy.

ION External Number Module

This module provides the wind source value from the ION system server. This module is necessary whenever data are passed from one source—through the server—to another source in order to implement proper data communication monitoring and alarming. The number provided by this module is the wind farm output value as scaled to a percentage of full farm output value in the server. (The wind farm used for the source is a nominal 49,500-kW nameplate. The actual percentage used was calculated using 50,000 kW as the wind farm full output value, as the actual wind farm output can reach and exceed 50,000 kW.)

Wind Source Selection

BEPC has three wind farms located in the Central Power Electric Cooperative service territory. One wind farm is owned and operated by Basin and two are owned and operated by FPL Energy. Basin purchases 100% of the production from the two FPL Energy sites. Wind farm locations are shown in Figure 10, and details for each are as follows:

- Minot Wind Farm
  - Owned and operated by BEPC
  - Located south of Minot, North Dakota
  - Completed in 2002
  - Two (2) 1.3-MW Nordex N60 turbines, 60-meter hub height, 60-meter rotor diameter

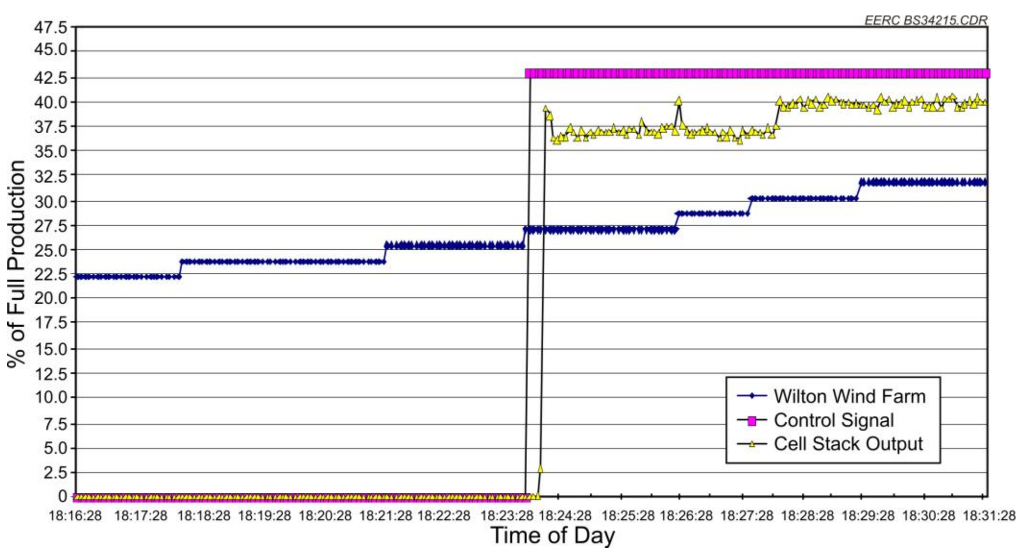

Figure 9. Graph of system control from start-up.

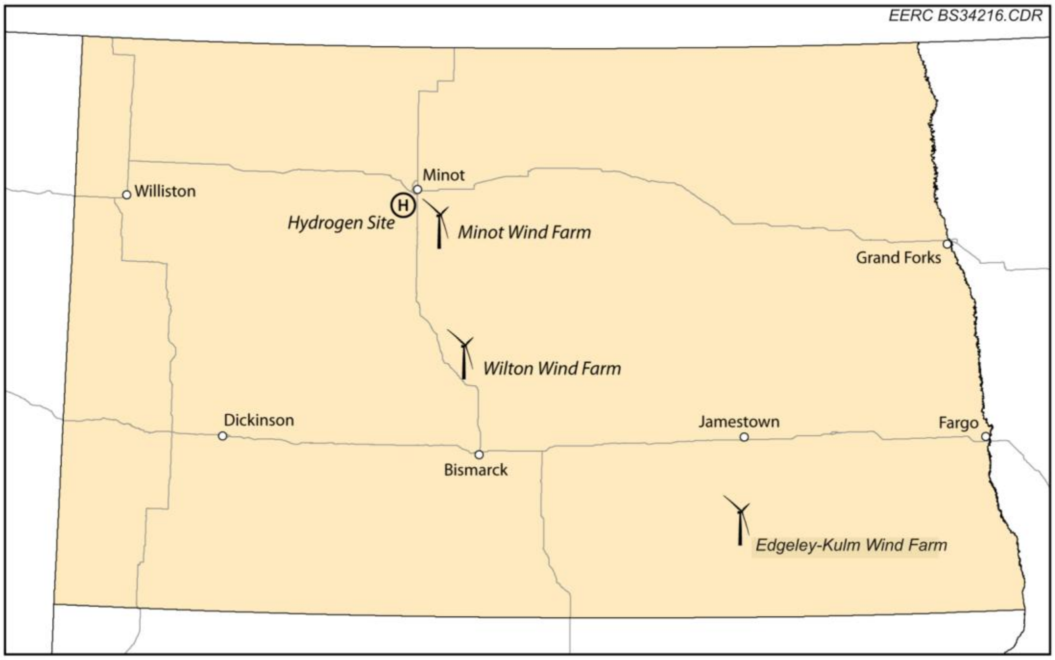

Figure 10. Wind farm locations.

- Edgeley–Kulm Wind Farm
  - Owned and operated by FPL Energy
  - Located west of Edgeley, North Dakota
  - Completed in 2003
  - Twenty-seven (27) 1.5-MW General Electric SE turbines, 64.7-meter hub height, 70.5-meter rotor diameter

- Wilton Wind Farm
  - Owned and operated by FPL Energy
  - Located southeast of Wilton, North Dakota
  - Completed in 2006
  - Thirty-three (33) 1.5-MW General Electric SLE turbines, 80-meter hub height, 77-meter rotor diameter

When determining a wind source to follow, options considered were to follow any of the farms alone or a combination of one or all of the wind farms. Wind sources considered were limited to those located in Central Power's service territory, as a typical future application of this program would usually be by a specific utility entity of that size utilizing this process on its system.

It was decided to use the Wilton Wind farm production as the wind source to follow for the following reasons:

1. It involved the newest technology, which provided a more moderated power output.

2. The number of turbines at the Wilton site allowed for diversity of production and moderation of the wind farm output variability.

3. Downtime of any one turbine would have minimal impact on wind source output and cause the least disruption to data collection.

4. Higher turbine hub heights and larger rotor diameters along with advanced control scheme provided optimum capture and best utilization of the wind resource.

5. On-site 24-hour, 7-day operation and maintenance support would provide maximum availability of the wind turbines.

Site Design

To perform the site design, BEPC solicited bids from qualified engineering firms having previous hydrogen-fueling facilities design experience. To perform the site design, BEPC selected the team of Albert Kahn Associates, Inc. (AKA), of Detroit, Michigan, and DMA Technical Services, Inc. (DMA), of Chatham, Ontario, Canada. AKA was responsible for traditional site design areas such as civil, electrical, and mechanical, and DMA was charged with designing the site safety-related design considerations.

In anticipation of the site design work, BEPC had the proposed site surveyed and contracted a geotechnical firm to perform subsurface drilling activities during May 2006. Upon selection of AKA/DMA as the site design contractors, BEPC provided the site survey and geotechnical information to them.

Based on the geotechnical results, system design information provided by Hydrogenics, and general site considerations provided by BEPC, AKA specified the necessary earthwork, the concrete slab to support the hydrogen system components, and the piping layout between components. AKA developed a specification package and site design figures. In addition, DMA performed a Hazard Identification and Risk Analysis (HIRA) and a Failure Modes and Effects Analysis (FMEA). The HIRA is a semiquantitative risk analysis intended to be a preliminary screening to determine priorities and identify risks worthy of more detailed quantitative risk analysis. The FMEA is a systematic method of identifying and preventing product and process problems before they occur. FMEAs are focused on preventing defects, enhancing safety, and increasing customer satisfaction. Site design drawings and safety-related documentation are included in Appendix B.

Site Construction

Upon the completion of the site design work, BEPC solicited bids from construction contractors to perform site construction work specified by AKA and DMA. The contractor selected to perform the site construction work was Industrial Contract Services (ICS) of Grand Forks, North Dakota. Figure 11 shows the site prior to site construction activities. Other contractors involved in the site construction were the following:

- Verendrye Electric Power Cooperative of Velva, North Dakota
  - Installation of main electrical service
  - Provider of electricity at the retail level

- Central Power Electric Cooperative
  - Provider of electricity at the wholesale level

- North Prairie Rural Water
  - Provider of water to the system

- Steen Construction of Minot, North Dakota
  - Installation of water supply piping
  - Installation of the discharge storage system

- Dakota Fence of Minot, North Dakota
  - Installation of the security fence

Figure 11. Hydrogen site prior to construction.

Site construction began in August 2006 with initial grade and earthwork and general site preparation. The site was excavated down to appropriate native material and backfilled with engineered fill that was compacted to a minimum of 95% Proctor.

Upon completion of the earthwork, the concrete slab and associated vehicle-refueling slab were formed, poured, and finished. The concrete slab was designed and constructed to support the weight of the hydrogen production system (ISO container), the hydrogen storage system, the gas control panel, associated piping, and two potential gensets. To do so the slab was 10 in. thick with metal reinforcement and thickened edges of an additional 1 ft 3 in. In addition, the entire slab was underlain by 4 in. of extruded polystyrene insulation to protect the slab from differential settling because of the expansive soils present at the site.

The vehicle-refueling slab, referred to as the low-ohm pad, was designed and constructed with special attention to static electrical discharge. The slab was 8 in. thick with an extensive reinforcement and grounding network embedded in the concrete. The low-ohm pad was designed so that the electrical resistance to ground of the overall slab ground system would not exceed 5 ohms.

By November 2006, the main site construction was complete and ready for placement of the hydrogen system components (Figure 12).

EERC BS34212.CDR

Figure 12. Photo of site after completion of site preparation.

System Installation

ICS was also awarded the contract to perform the installation of the hydrogen system as well as installation of the hydrogen piping. Other contractors involved in the system installation were the following:

- Main & Holmes Electric Company of Minot, North Dakota
  - Installation of system electrical and communication network

- C&C Plumbing and Heating of Minot, North Dakota
  - Installation of on-site HVAC retrofits

- Coritech Services of Royal Oak, Michigan
  - Installation and testing of flame detection system

- Engineering, Procurement, & Construction, LLC (EPC), of Lakewood, Colorado
  - Pressure testing of hydrogen piping network

- Praxair, Inc., of Minot, North Dakota
  - Provider of system gases

BEPC received the storage assembly, storing it until it was installed on the site in April 2007. The main electrical service to the site was also installed around this same time (Figure 13). The hydrogen production system arrived on-site in June 2007 and was set in place (Figure 14).

The gas control panel and hydrogen dispenser arrived on-site shortly after the ISO container and were also positioned on the slab immediately. ICS spent the next 3 months or so installing the piping connecting all the components as well as the necessary vents. Concurrently, Main & Holmes Electric installed the electrical and communications wiring. Figure 15 and 16 are photos of components and piping being installed. During this time, the underground discharge tank was installed, discharge from the system was connected to the underground tank, and the water supply line was connected to the system (Figures 17 and 18).

Since no sanitary sewer system was present at the site, the underground discharge tank was installed to store the RO reject stream and KOH condensate collected from the hydrogen system. The discharge tank is pumped out periodically, and water collected is taken for disposal at the city of Minot’s wastewater treatment plant, where it is blended with its incoming wastewater, treated, and discharged.

When ICS completed all the high-pressure piping, EPC performed the necessary pressure testing of the piping. EPC’s testing and certification report is included in Appendix C (Figure 19).

EERC BS34236.CDR

Figure 13. Photo of site with electrical service and storage assembly in place.

EERC BS34211.CDR

Figure 14. Photo of hydrogen system being set in place.

EERC BS34210.CDR

Figure 15. Photo of the gas control panel and hydrogen dispenser installed.

EERC BS34209.CDR

Figure 16. Photo of ICS personnel installing hydrogen piping.

Figure 17. Photo of discharge tank installed.

Figure 18. Photo of discharge tank access riser installed.

EERC BS34206.CDR

Figure 19. Photo during high-pressure testing.

During this time, Hydrogenics also performed modifications to the system on-site that were required to obtain certification on the system from a NRTL. For clarification, most people are familiar with Underwriters Laboratory (UL) and the phrase that something is UL-listed. In fact, UL is just one of several NRTLs. So it may be more appropriate to say that something is NRTL-certified instead of UL-listed, since the requirement is actually that it be NRTL-certified. BEPC contractually required Hydrogenics to provide a system that would be NRTL-certified. To meet this obligation, Hydrogenics hired QPS Evaluation Services, Inc. (QPS), a nationally-recognized Canadian testing laboratory, affiliated with SGS, and US-based NRTL, to certify the system when it arrived in Mississauga. QPS's inspection of the system resulted in numerous items to address prior to its certifying the system, so Hydrogenics performed many of these corrective actions on-site. QPS's report and final certification are included in Appendix D.

Once the on-site piping work was completed, Coritech Services installed and tested the site flame detection system. The flame detection system, installed in October 2007, is a stand-alone system interconnected with the Hydrogenics system consisting of a control panel, infrared detectors, emergency stop (E-stop) button, audible alarm, strobe light, and autodialer system. Utilizing two infrared detectors mounted on a column located at the north end of the system area, the flame detection system was configured to detect an invisible flame anywhere within the site area as well as the fueling area. Figure 20 shows a picture of the infrared detectors and Figure 21 shows the flame detection area. The flame detection system also incorporated one E-stop button at the north gate entrance. This E-stop is a manually activated alarm that can only be triggered by a person. In addition, the flame detection system was interconnected to the Hydrogenics system. The flame detection control panel was configured to respond to two types of alarms. A summary of the alarm protocols is included in Table 1.

Figure 20. Photo of the infrared flame detection sensors.

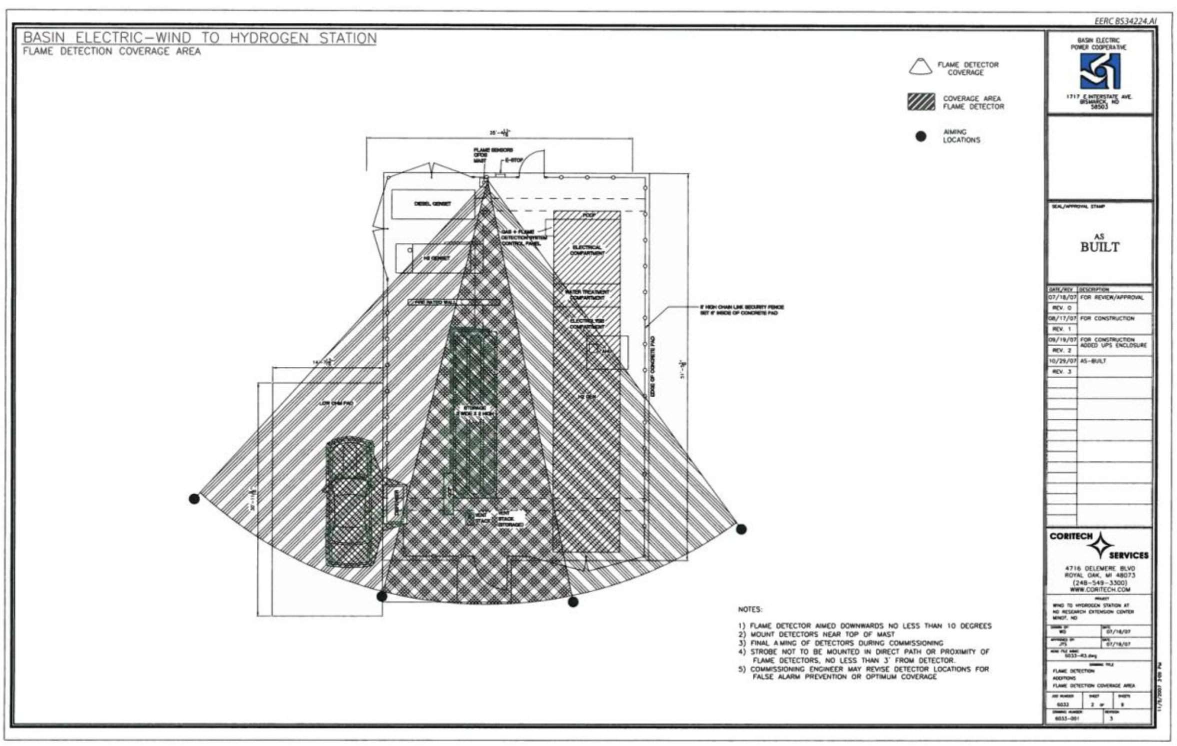

Figure 21. Drawing showing flame detection coverage area.

Table 1. Emergency Protocol for Alarm Conditions

Condition	Cause	Trigger	Location	System Response
Critical	Automated	Flame detection sensor	External	1. Call 911 2. Call BEPC Dispatch
Critical	Manual	E-Stop button	External	1. Call 911 2. Call BEPC Dispatch
Noncritical	Manual	ISO container stop button	ISO container	1. Call BEPC Dispatch
Noncritical	Manual	Dispenser stop button	Dispenser area	1. Call BEPC Dispatch
Noncritical	Automated – system alarm	Multiple	Internal	1. Call BEPC Dispatch
Noncritical	Automated hydrogen gas detected	Internal gas detection sensor	ISO container	1. Call BEPC Dispatch

By the end of October 2007, the system installation activities were complete, including the NRTL certification on the system. Figure 22 shows the completed system installation.

System Start-Up and Operation

System Start-Up

BEPC started operating the system at full capacity on November 1, 2007. It was anticipated that the start-up and shakedown period would take approximately 1 month but, because of numerous significant issues and the presence of several holidays, this period actually took until the end of January 2008.

Compressor Diaphragm Failure

Shortly after start-up, the first-stage diaphragm in the high-pressure compressor failed. This resulted in small amounts of hydrogen leaking by the diaphragm and forced the system to be shut down until the diaphragm could be replaced. Given the time of year and the workload of the vendor that provided the compressor, Power Product, Incorporated (PPI), the diaphragm replacement did not occur until January 22–26, 2008.

In June 2008, system measurements indicated a partial failure of the second-stage diaphragm in the high-pressure compressor. PPI was contacted, and a site visit was requested to repair the diaphragm. The hydrogen system was operated intermittently until the repair was done in November 2008. During the replacement of the diaphragm, PPI personnel noted scoring on the compressor plunger and indicated that it would also need to be replaced and would require another site visit. PPI personnel returned to the site on December 1, 2008, and replaced the plunger.

EERC BS34220.CDR

Figure 22. Photo of completed site.

Discharge Tank Leak

Although not as critical to the operation of the system, an apparent leak in the underground discharge tank was discovered. The existence of a leak was assumed because the tank appeared to fill up much faster than anticipated. The tank was pumped down, and a local diving company was hired to enter the tank and confirm the presence of a leak. The leak was confirmed, and water was observed entering the tank at the joint where the two pieces of the tank are put together. Since the two-piece concrete tank was buried several feet below ground level, BEPC chose to attempt to repair the leak in situ by using the same local diving company to go into the tank (with the tank full of water) and use a special compound to seal the joint. This may seem like an unusual remedy, but this diving company does similar work throughout the state diving in large tanks that cannot be emptied to repair leaks. The repair did reduce that inflow of groundwater into the tank but did not fully seal the tank. BEPC chose to take no further action to repair the leak and decided to pump the tank more frequently than originally planned.

Electrical Issues

There were two significant electrical issues that had to be addressed during the course of the project. The first issue was the tripping of the main breaker serving the site, and the second issue was the impact of harmonics affecting the ability of the local utilities to remotely read their meters.

The first problem (the tripping of the main breaker) was discovered when the unit was undergoing its initial test runs with various production levels and all processes working. The unit would run without problem and then periodically would trip the main breaker. Once the unit had tripped and the main breaker was reset, the unit could return to normal operation. The initial assumption was that there may have been an inrush from some piece of equipment that caused the trip, or there may have been a hidden cable or device fault. However, we could not positively correlate the tripping with any particular device operation nor find physical evidence of cable or equipment failure.

The first remedy tried was to adjust the main breaker's instantaneous trip setting to a maximum level to determine if it related to a fault or to equipment operation. Adjusting the trip setting stopped the breaker tripping while still maintaining a maximum tripping level below the fault current level that would be expected for a cable or equipment fault. Thus if the tripping was due to a fault, the breaker should continue to trip. This led us to suspect the tripping may be due to equipment operation inrush.

A power quality monitoring recorder was then installed on the equipment. The data were inconclusive as to correlation of data with any inrush currents. Some inrush current was observed but was not significant enough to cause a breaker trip. To check on the validity of the data collected, Hydrogenics applied a power quality monitor at a similar facility to see if any inrush current associated with system operation was evident there. No inrush was observed.

Both the BEPC and Hydrogenics power quality meters were then placed on the Minot unit, and normal operation tests were performed. No inrush was observed by the Hydrogenics power quality monitor and inconsistent data were observed by the BEPC power quality monitor.

The breaker itself was then reset to the original instantaneous trip level, and data were recorded with both power quality monitors. The main breaker tripped during normal test operations, but the data recorders did not record a correlating inrush current. It was then decided that the site main breaker itself might be the cause, and a replacement was ordered.

During installation of the replacement breaker, it was discovered that one of the bolted connections on the original unit was discolored, indicating heating and arcing. The circuit breaker has two components, a switch unit and a trip module. The two components are connected by a bolted bus connection. Unfortunately the bolted connection is hidden from casual observation, and therefore, the problem was not diagnosed immediately. Our conclusion was that the additional heating due to the bus connection caused the circuit breaker to trip during normal operation. Since replacement of the unit, no main breaker trips have occurred.

The second electrical issue observed was the presence of harmonics. The problem was brought to our attention by VEPC, the electric distribution cooperative that serves the site. VEPC advised that it was having difficulty reading its site meter remotely. VEPC's remote reading system utilizes a power line carrier signal which can be affected by the presence of harmonics.

The ION meters used to collect study data for the site have power quality monitoring capability including harmonics. The meters were programmed to monitor and record harmonic data, and the unit was test-operated at full rating.

As a condition of electrical service, consumer loads connected to VEPC's system (including the BEPC W2H2 system) are required to comply with IEEE standard 519. As applied specifically to this site, the standards are as follows:

Voltage (for the 480 volt system)
Maximum Individual Harmonic Component (%) ≤ 3.0%
Maximum Total Harmonic Distortion (%) ≤ 5.0%

Current – Individual Frequency Limits

Harmonic Range	Individual Frequency Limit (%)
h < 11	7.0
11 ≤ h < 17	3.5
17 ≤ h < 23	2.5
23 ≤ h < 35	1.0
35 ≤ h	0.5
Total Harmonic Distortion (THD)	8.0

The harmonic monitoring was done on the secondary side of the distribution transformer serving the site. Observing current values recorded on May 28th at 13:00 for near-full-load output (400 cell stack amperes), the 5th, 11th, 17th, 23rd, 29th, and THD current harmonics were outside of the above limits.

The harmonics issue was corrected by installing an MTE Matrix D harmonic filter on the low-voltage (480 volts) side of the transformer serving the site. The filter was installed just after the site main breaker. A more appropriate location would have been to intercept the circuits internal to the electrolyzer that serve the cell stack rectifiers. This was not feasible because of space limitations on the existing pad and in the system electric service room.

Valve and Sensor Issues

Clearly in a system of this type, numerous sensors and valves are necessary for proper and safe operation of the system. Since there was significant time passage between construction of the system in Belgium and start-up at the site, some of the gas detection sensors required replacement or recalibration almost immediately after start-up. Many of these sensors have a "shelf life" of 1 year.

Site Acceptance Test

On January 28, 2008, Hydrogenics personnel, along with BEPC personnel, performed the site acceptance test (SAT) of the hydrogen production system. The SAT consisted of testing several system operational and safety functions, witnessed by BEPC, and an acknowledgement of BEPC that the equipment performed satisfactorily. Since a few items required corrective action at the time of the SAT, BEPC's "sign-off" represented a partial SAT; full acceptance from BEPC would be granted at a time when the remaining "punch list" items were remedied. The full SAT was granted by BEPC on February 13, 2008, and this date represented the transition from the system start-up phase to full system operation phase.

System Operation

The system operation phase, beginning on February 14, 2008, was initiated with the hydrogen system being operated at full capacity and not from wind energy production. This was done to allow operators and engineers time to gain operational experience and be more proficient at operating, troubleshooting, and maintaining the system.

Beginning on February 14, 2008, the intention was to operate the system at full capacity until BEPC was satisfied that the system would operate as designed. Unfortunately, because of the equipment and sensor problems described in the previous section, BEPC was not able to operate the system as desired. In spite of the numerous shutdowns, BEPC did manage to produce approximately 19,780,000 liters (1766 kg) of hydrogen intermittently between February 14, 2008, and December 5, 2008, when the system was switched to Mode 4 operation.

On June 18, 2008, BEPC performed a ramp test on the electrolyzer cell stacks. The ramp test was performed to establish a baseline of performance of the cell stacks for comparison to later ramp tests performed on the cell stacks as a measure of cell stack degredation. To perform the ramp test, an input signal was sent via the dynamic scheduling software, thereby inducing DC current to the cell stacks at a controlled level. As shown in Table 2 and corresponding to Figures 23 and 24, the 125-minute ramp test involved applying current to the cell stacks and measuring the corresponding hydrogen production rate at each step in liters per hour. The ramp test began at the minimum current for these cell stacks (175 amps) and was ramped up to a maximum of 430 amps, then dropped back down to 175 amps, each step being approximately 10%. The resulting ratio of hydrogen output to current input for Ramp Test 1 for Cell Stacks 1 and 2 was 37.61 and 37.60 liter per hour per amp, respectively. This ratio was the benchmark for determining cell stack degradation in later ramp tests. At the time of Ramp Test 1, the cell stacks had produced approximately 6,000,000 liters (535 kg) of hydrogen each (12,000,000 liters total). Since the Hydrogenics system does not log runtime hours for system components, including the cell stacks, actual runtime hours on the cell stacks could not be determined. The only method of determining runtime hours on system components is to manually record the information from the operator control panel.

On December 5, 2008, a second ramp test was performed to determine if any degradation of the cell stacks had occurred (presumably from cycling the cell stacks up and down with the wind). At the time of Ramp Test 2, the cell stacks had logged approximately 1200 hours of runtime and had produced approximately 10,500,000 liters (950 kg) of hydrogen each (21,000,000 liters total). The input signal pattern from the first test was repeated for Ramp Test 2, and the hydrogen output was compared to the results of Ramp Test 1. The results of Ramp Test 2 are summarized in Table 3 and Figures 25 and 26.

Data from Ramp Test 2 showed that the hydrogen production ratio (liters per hour/amp of DC current) for Cell Stacks 1 and 2 was 37.61 and 37.55, respectively.

Beginning on December 5, 2008 (after ramp Test 2 was performed), the intention was to operate the hydrogen system using Mode 1 protocol as described in the feasibility study section

Table 2. Ramp Test 1 Data

Analog Signal to Stacks	Stack 1 Current (DC amps)	Stack 2 Current (DC amps)	Stack 1 H_2 Output (L/h)	Stack 2 H_2 Output (L/h)
0.76	175	175	6598	6593
0.76	177	173	6597	6584
0.80	214	216	8060	8174
0.80	215	214	8094	8109
0.84	259	260	9760	9765
0.84	260	258	9773	9793
0.88	303	303	11,401	11,339
0.88	305	303	11,462	11,242
0.92	343	346	12,922	13,054
0.92	345	347	13,025	12,872
0.96	386	388	14,539	14,483
0.96	391	388	14,691	14,660
1.00	432	430	16,249	16,167
1.00	426	432	16,052	16,239
0.96	391	387	14,576	14,555
0.96	386	390	14,627	14,594
0.92	344	345	12,926	12,972
0.92	343	347	12,896	13,043
0.88	301	304	11,318	11,330
0.88	305	303	11,485	11,517
0.84	260	261	9776	9753
0.84	260	259	9773	9695
0.80	217	216	8154	8079
0.80	216	214	8125	8163
0.76	175	176	6572	6581
0.76	176	174	6613	6574

of this report. Unfortunately, because of the issues with the heating system and other system sensors, the system was only operated in Mode 1 for approximately 7 days from December 23 through December 30, 2008.

During the 7 days of Mode 1 operation, the hydrogen system produced approximately 3,300,000 million liters (295 kg) of hydrogen. Figure 27 shows the hydrogen production profile during this period and its relationship with the Wilton Wind Farm output.

On December 30, 2008, the system was put into an idle state until consumption dictated production of hydrogen. Prior to “idling” the system on December 30, 2008, a third ramp test was performed using the same protocol and input signal pattern at the previous two ramp tests. Results from Ramp Test 3 are shown in Table 4 and Figures 28 and 29.

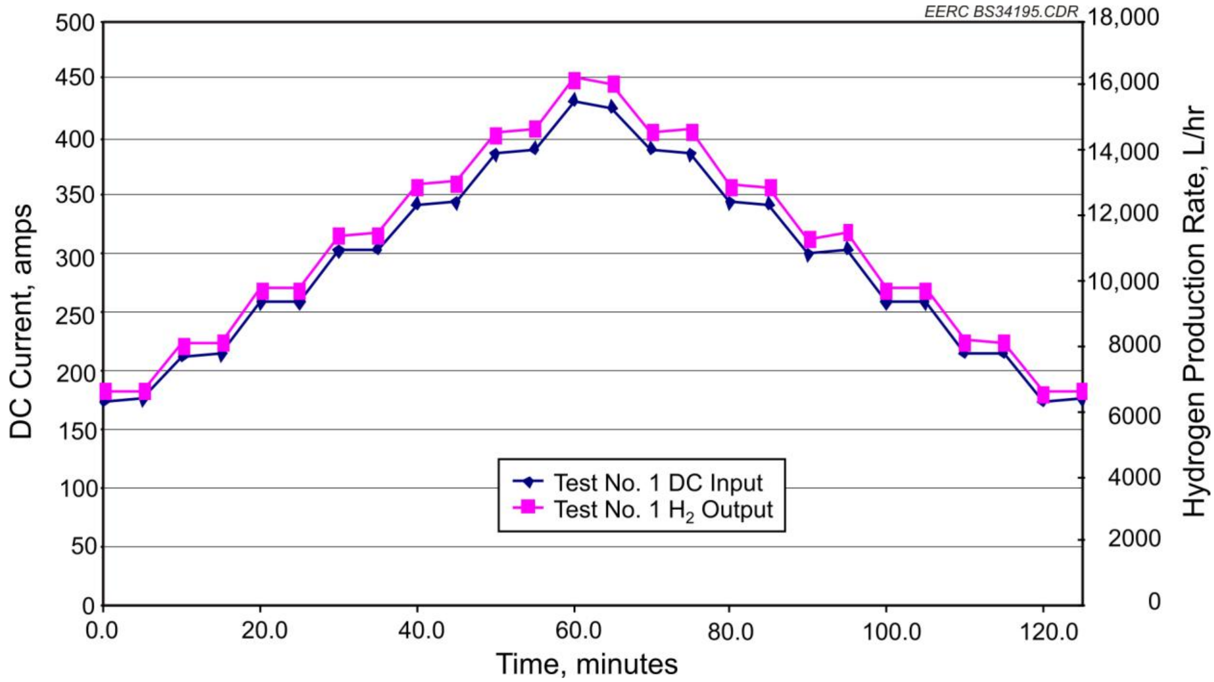

Figure 23. Ramp Test 1 results (Cell Stack 1).

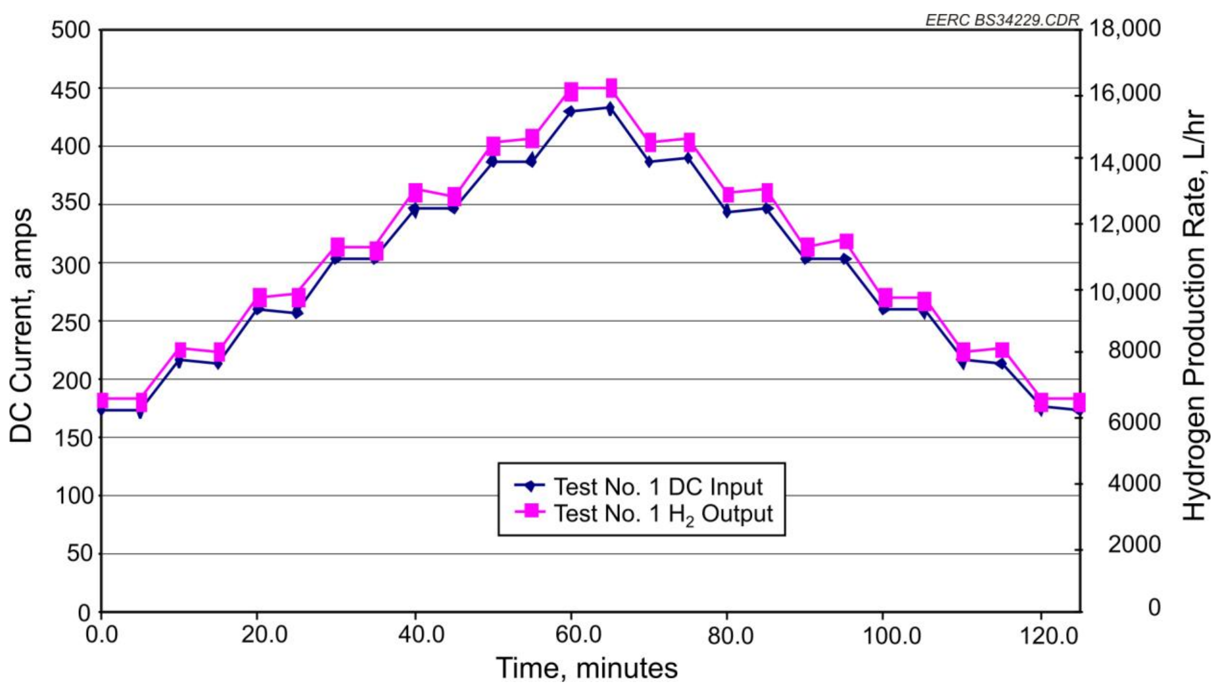

Figure 24. Ramp Test 1 results (Cell Stack 2).

Table 3. Ramp Test 2 Data

Analog Signal to Stacks	Stack 1 Current (DC amps)	Stack 2 Current (DC amps)	Stack 1 H_2 Output (L/h)	Stack 2 H_2 Output (L/h)
0.76	177	177	6593	6551
0.80	176	177	6680	6638
0.84	220	220	8197	8184
0.88	263	263	9901	9947
0.92	305	306	11,540	11,506
0.96	350	350	13,150	13,163
1.00	393	392	14,797	14,928
0.96	426	394	16,052	14,817
0.92	393	394	14,811	14,863
0.88	350	349	13,141	13,113
0.84	306	307	11,489	11,521
0.80	263	263	9874	9903
0.76	220	220	8304	8239
0.76	177	177	6685	6602

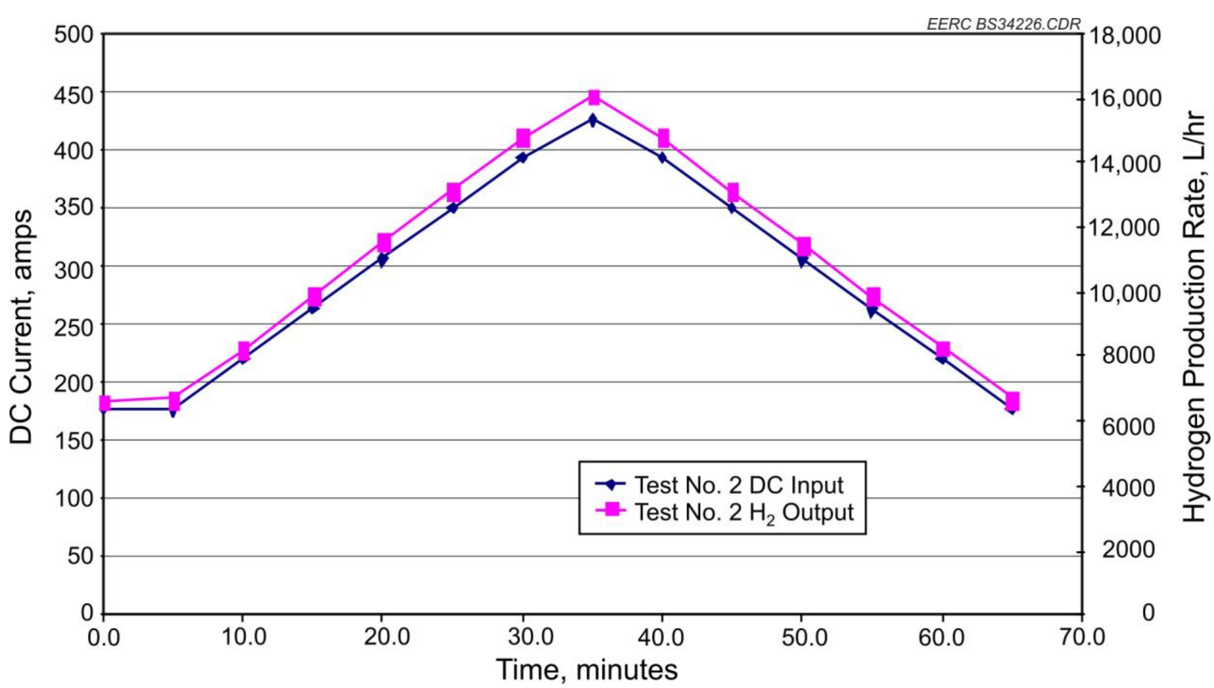

Figure 25. Ramp Test 2 results (Cell Stack 1).

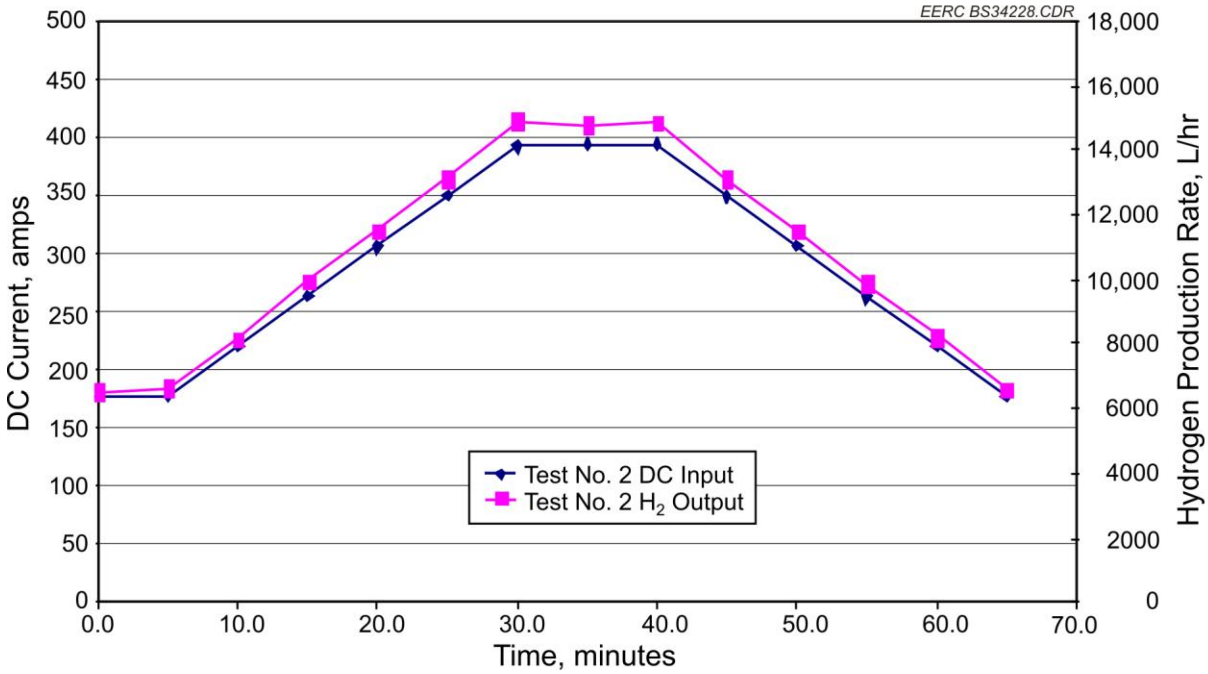

Figure 26. Ramp Test 2 results (Cell Stack 2).

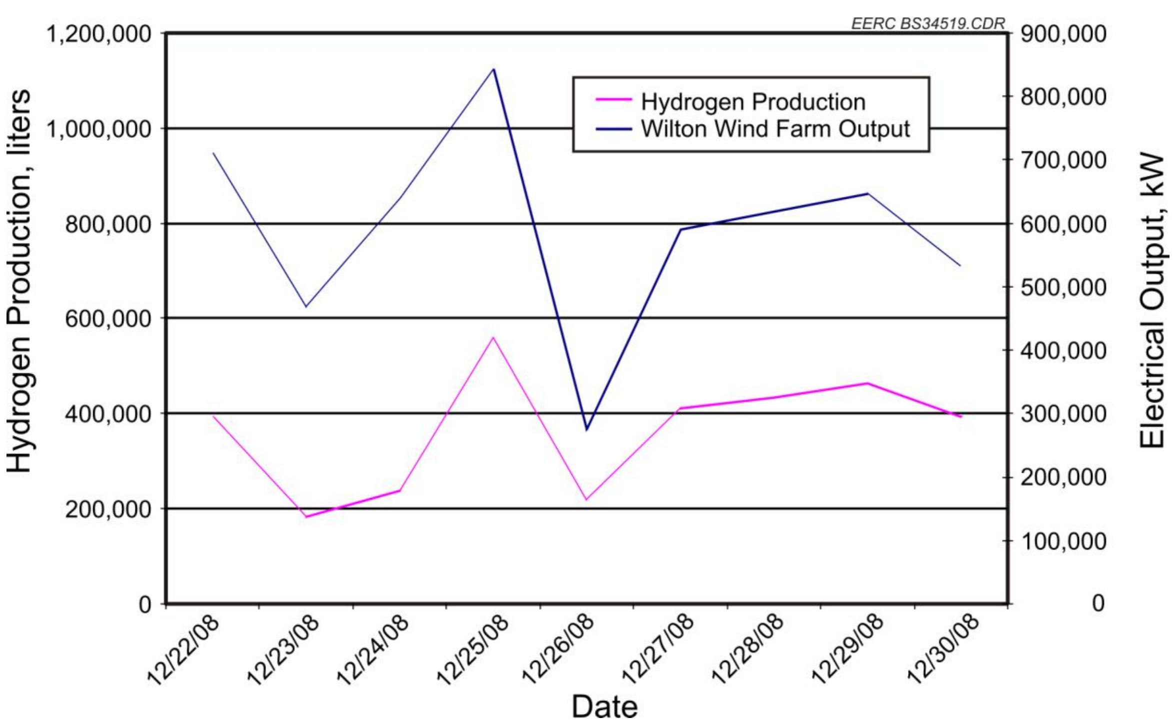

Figure 27. Graph of wind farm output to corresponding hydrogen production.

Table 4. Ramp Test 3 Data

Analog Signal to Stacks	Stack 1 Current (DC amps)	Stack 2 Current (DC amps)	Stack 1 H_2 Output (L/h)	Stack 2 H_2 Output (L/h)
0.76	174	176	6615	6592
0.80	216	218	8238	8124
0.84	263	263	9884	9852
0.88	307	306	11,466	11,478
0.92	347	348	13,058	13,105
0.96	392	393	14,770	14,770
1.00	430	426	16,157	16,123
0.96	392	393	14,722	14,738
0.92	346	348	13,095	13,155
0.88	304	303	11,449	11,452
0.84	260	262	9836	9800
0.80	219	218	8270	8196
0.76	175	174	6622	6538

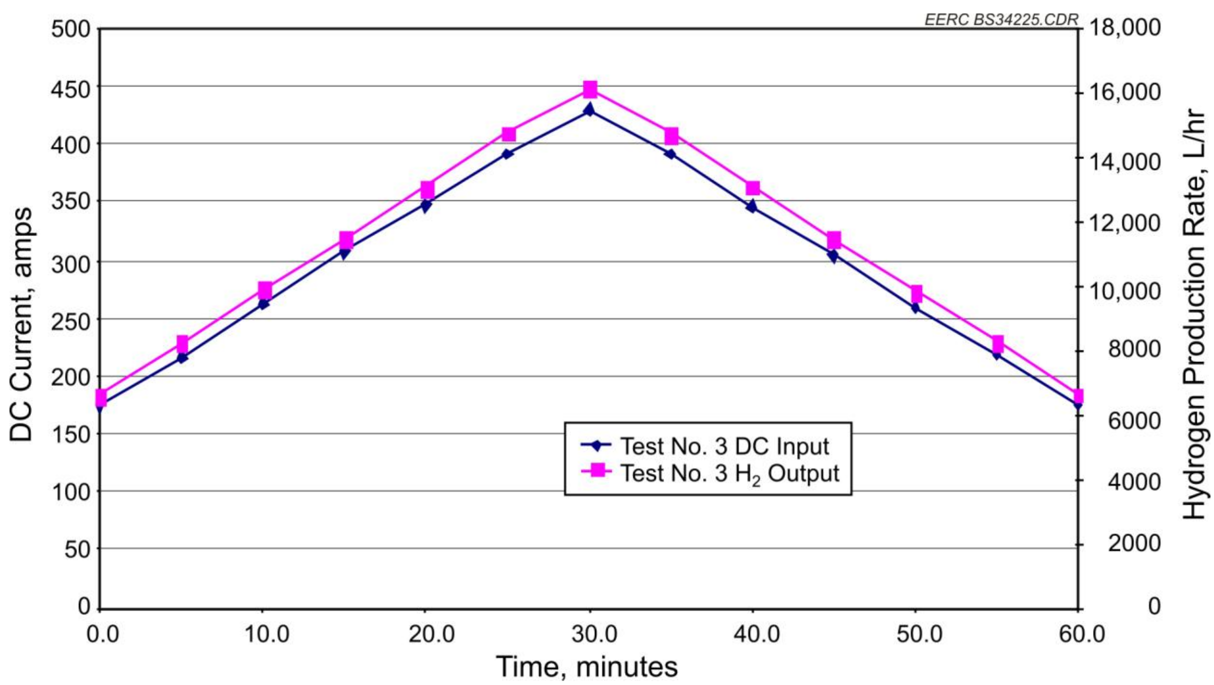

Figure 28. Ramp Test 3 (Cell Stack 1).

Data from Ramp Test 3 showed that the hydrogen production ratio (liters per hour/amp of DC current) for Cell Stacks 1 and 2 was 37.73 and 37.57, respectively.

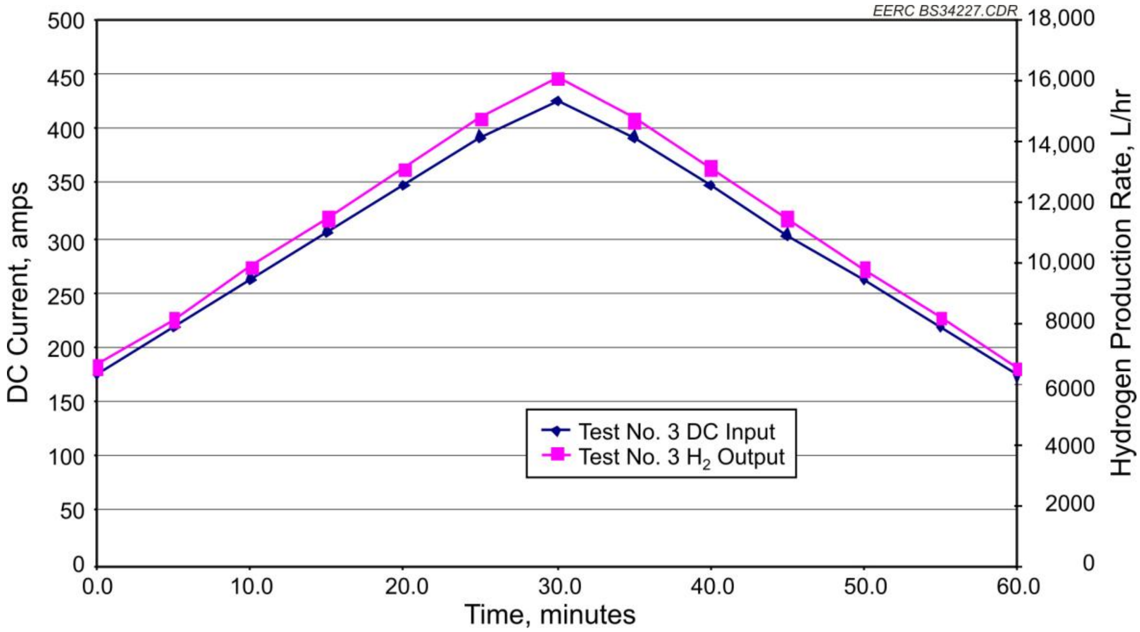

Figure 29. Ramp Test 3 results (Cell Stack 2).

Upon completion of Ramp Test 3 and in anticipation of "idling" the system, the hydrogen system was operated at full output on December 31, 2009, to fully fill the on-site storage so fueling of project vehicles could continue to be performed. Once on-site storage was filled to capacity, the system was put into the "idled" state.

To summarize the total system production during the project, Figures 30 and 31 are provided and represent hydrogen production in both liters and kilograms from the start of operation through December 2008. From February 12, 2008, through December 31, 2008, the system produced a total of just less than 26,000,000 liters (2320 kg). A chronological summary of the hydrogen production is provided in Appendix E.

As the graphs show, the hydrogen production system saw limited operation during the project year, primarily because of equipment malfunction, component failure, and system alarming.

Education and Outreach Activities

Given a project of this novelty, it was not surprising that many occasions existed for providing the general public, as well as more technically inclined individuals, with an opportunity to understand the many facets of this project.

Over the course of the project, both EERC and BEPC personnel participated in numerous events showcasing the project and the hydrogen-capable pickups, described in the End-Use Activities section, such as the North Dakota State Fair, the dedication of the EERC's National Center for Hydrogen Technologies building, and local energy workshops and electric cooperative events.

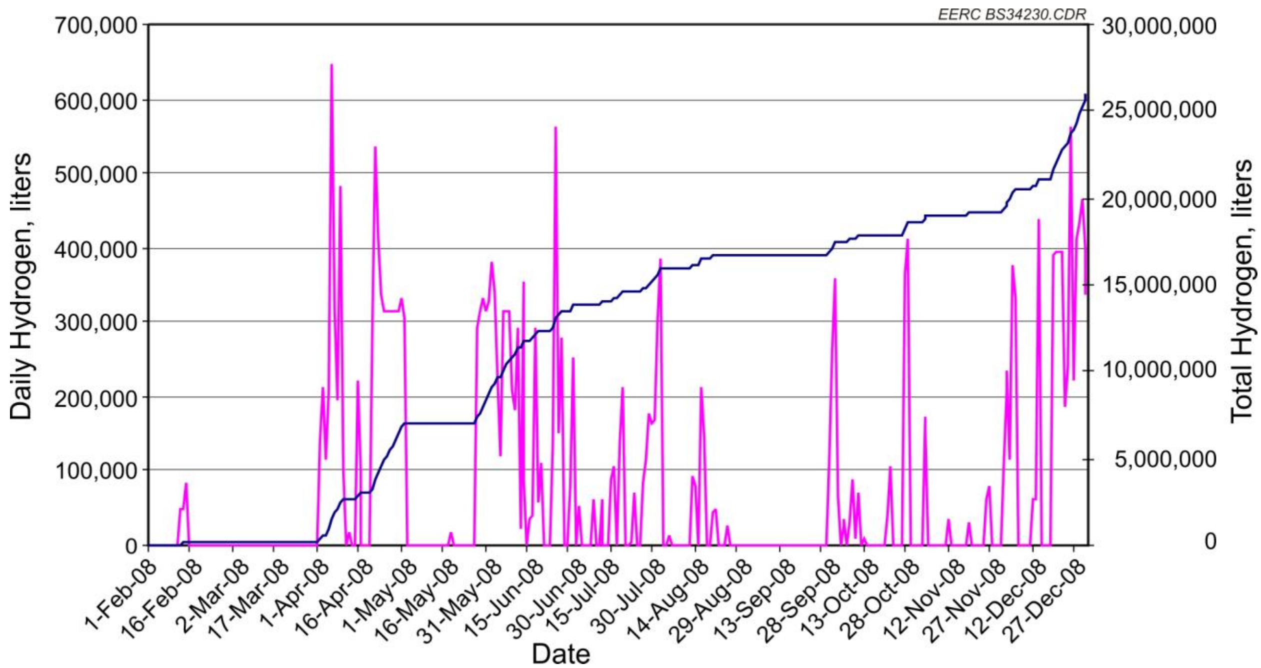

Figure 30. Total hydrogen production in liters.

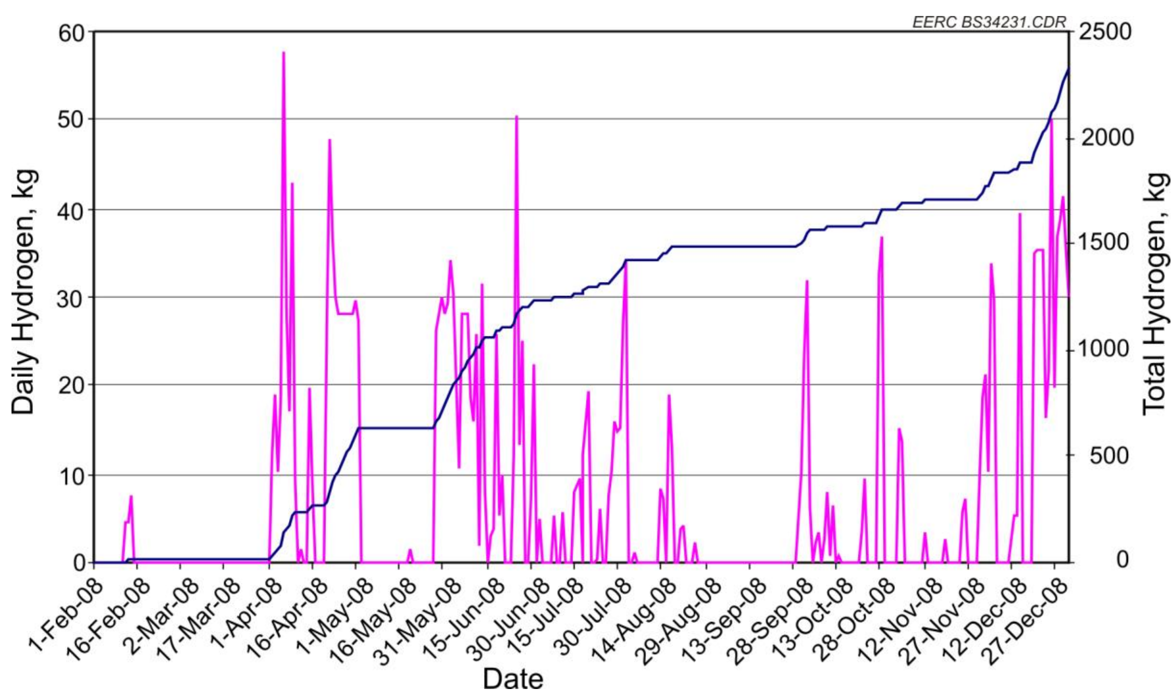

Figure 31. Total hydrogen production in kilograms.

In most cases, the hydrogen pickups were either trailered or driven on gasoline to the events and idled on hydrogen at the events to increase people's awareness of hydrogen-related technologies.

End-Use Activities

On-Road Platform

Although not a part of the original project scope, procurement and operation of end-use vehicles was the chosen alternative to venting or flaring the hydrogen produced.

For this end-use purpose, BEPC and the EERC evaluated both internal combustion engine (ICE) conversion and fuel cell technologies. Based on cost, availability, and platform flexibility, BEPC chose to pursue the ICE conversion vehicle platform. BEPC selected AFVTech, Incorporated (AFVTech), of Phoenix, Arizona, to perform conversions on three Chevrolet Silverado 1/2-ton pickups (Figure 32).

Two of the converted pickups were purchased by BEPC. The other pickup is owned by the state of North Dakota, which donated its use for the project.

The BEPC-owned pickups are utilized as corporate vehicles and are typically driven daily. The state-owned pickup is stationed at the NDSU NCREC and is used for education and outreach and, to a limited extent, for daily running.

The conversion of the pickups (performed by AFVTech) involved the addition of eight gas injectors to the intake manifold and custom programming of the factory powertrain control

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Figure 32. Photo of one of the converted pickups.

module (PCM). The AFVTech system used the factory-installed PCM to maintain correct operational standards. The PCM programming was modified to accept this new calibration, which allowed the engine to operate on gasoline, E85, or hydrogen. AFVTech did not install a secondary PCM because the complexity of the program structure within the factory-installed PCM far exceeds any aftermarket unit. OBD2 compliance, transmission function, and body control functions would be affected if a secondary PCM were installed. AFVTech used sequential fuel injection (one injector per cylinder) as the basis for introducing fuel into the engine. Fuel injection allows for precise air fuel control. No factory-installed sensors on the converted vehicle were disconnected, and no signal was created to defeat the check engine light.

Hydrogen was stored in three tanks (located in the pickup box), each having a storage capacity of 2.2 kg at 5000 psi resulting in a total onboard storage capacity of 6.6 kg at 5000 psi. Unfortunately, at the time of the vehicle retrofits, the only available pressure relief valves were only rated for 3500 psi. For this reason, the project vehicles were only filled to a pressure of 3500 psi. The storage tanks were purchased from Structural Composite Industries and were constructed of aluminum and wrapped with carbon and fiberglass. Hydrogen is delivered to the engine at a lesser pressure through regulators and stainless steel piping. For safety reasons, two hydrogen gas detectors were installed, one in the engine compartment and one in the pickup box. Figure 33 shows the hydrogen storage tanks and associated regulators and piping.

Off-Road Platform

In addition to the three pickups, Butler Machinery Company of Minot, North Dakota, provided a Caterpillar Challenger MT525B tractor to NDSU for engineering students to convert

EERC BS34223.CDR

Figure 33. Photo of the hydrogen storage in the pickup box.

to operate on a hydrogen/diesel blend. The engine in the tractor was a 3056E Caterpillar, six cylinder, direct fuel injection with electronic over mechanical control, and was turbocharged with air-to-air charge air cooler. Figure 34 is a photograph of the tractor and Figure 35 shows the hydrogen piping and flow control.

The NDSU students used one storage tank (located at the front of the tractor) of the same construction as the pickups and delivered the hydrogen to the engine via the air intake. Since a diesel engine operates by compression ignition as opposed to spark ignition, the hydrogen must be fumigated into the engine with the air intake.

PROJECT SUMMARY AND LESSONS LEARNED

General Observations

Hydrogen production facilities require unique siting considerations to both operate a safe system and satisfy often uninformed local officials and the general public. The siting requirements and safety codes and standards are new and evolving, and anyone planning to install a hydrogen system should spend sufficient time becoming familiar with not only the codes and standards but also local requirements.

Because some of the components of the hydrogen production system, specifically the ISO container and storage assembly, were extremely heavy, and significant funds were spent on the design and construction of the site, mainly the concrete slab.

EERC BS34219.CDR

Figure 34. Photo of the converted NDSU tractor.

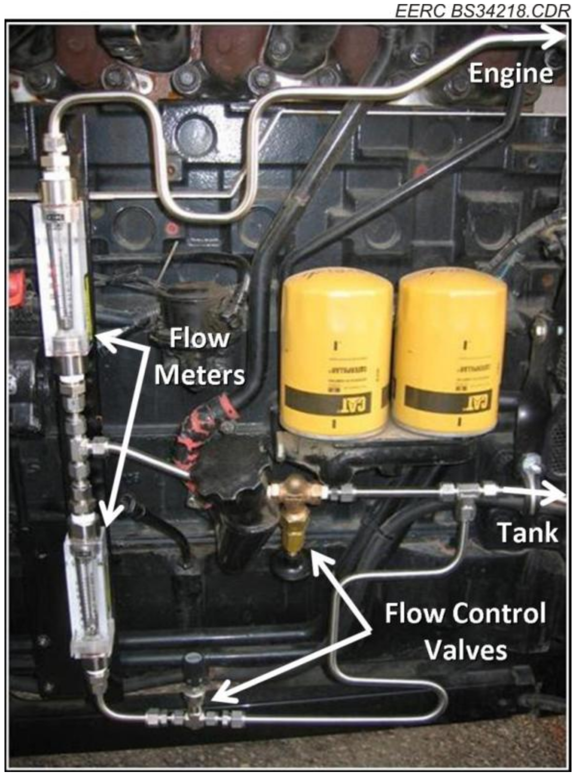

Figure 35. Photo of tractor piping and flow control.

Dynamic Scheduling System

The distance between the wind energy source and the hydrogen facility had no significant impact on ability to follow wind energy production: Communication times for the entire communications path were typically 2 seconds or less. This time was determined by sending a clock signal from the wind data source terminal to the electrolyzer and back to the wind data source location. The difference between the time value returned and the current time of the sending clock was calculated then divided by 2 to determine the communication time for a one-way signal transmission. This time included server processing time, time through the Internet and Internet service provider, time for communications to pass through a leased T1 line, and the utility internal communications links. The actual physical distance for the communication path from the utility data source to the server to the electrolyzer site was in excess of 200 miles.

VPN Internet connection worked well and was reliable with no downtime: No downtime for the VPN Internet connection was observed during the study. We were aware of only one event related to the Internet service during the study period. The local Internet provider e-mail system did not forward e-mails (alerts and alarms) from the ION meter located at the hydrogen site for a time period estimated at approximately a week. The VPN communications link itself remained in service throughout that time period.

Response and communications were within requirements necessary to be considered real-time operations: The total time between receipt of wind production information from the source to proportionate hydrogen production level/energy utilization requested was typically less than 9 seconds. The electric system area operator's, Western Area Power Administration's WAPA's, requirements for considering data communications as real time depends on the size of the unit being monitored. For larger plants, 10 MW or larger, real-time data systems are required to poll and update data every 4 seconds or less. For smaller plants, less than 10 MW, real-time data systems are required to poll and update data every 1 minute or less. The electrolyzer load was approximately 200 kW with approximately 165 kW of that as schedulable. Thus communications and response complied with WAPA's real-time requirements for that size schedulable load.

System Operation

Minimum cell stack operation limited the reality of operating on wind energy: At the direction of Hydrogenics, the electrolyzer was not operated below 43% of full load or approximately 71 kW (at full production the cell stack power requirement is approximately 165 kW). This requirement somewhat defeated the concept of operating the electrolyzer on wind energy, in that at times maintaining the cell stack at 43% required significant supplemental power from the grid. Lowering the minimum requirement would allow a wider range for controllable production scheduling and a more legitimate claim of "renewable hydrogen." The main concern regarding lowering the minimum cell stack requirement was to eliminate or minimize the potential for hydrogen to be present in the oxygen stream, causing nuisance alarms to shut down the system.

Electrolyzer output response to control signal input was linear and consistent: The electrolyzer hydrogen production output and associated power consumption followed the input control signal quite well with only moderate delay between the sending of a new control level and response of the unit. The output responded to the control signal within 3 to 7 seconds with a typical response of 4+ seconds. Consistent output values were observed. Figure 36 shows a typical pattern of control signal and system response.

Balance-of-plant loads varied considerably depending on climate control requirements: Balance-of-plant loads for the electrolyzer site (i.e., all electric loads other than the electrolyzer stacks) included the auxiliary processes for hydrogen production as well as compressing and storing hydrogen. This also included auxiliary heating and cooling for the electrolyzer site, heat tracing for water supply and drainage lines, the fire detection and alarm system, ship-to-shore connection to the standby generator, and miscellaneous site needs such as lighting.

Although the entire balance-of-plant load was a variable load, the heating system represented the most significant variation (Figure 37).

No apparent cell stack degradation took place as a result of following the wind: In an attempt to measure cell stack degradation, if it occurred, three ramp tests were performed. The ratio of hydrogen produced in liters per hour to current input in amps was the benchmark used to determine the existence and magnitude of cell stack degradation. Based on the ramp tests, no significant reduction in the hydrogen production ratio could be ascertained.

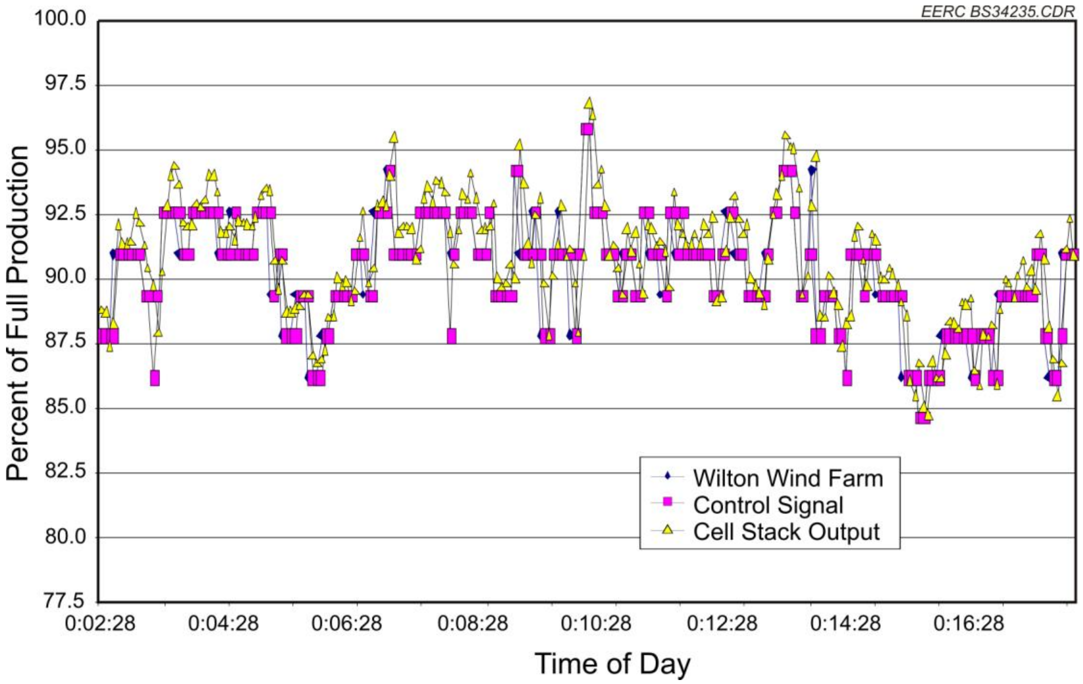

Figure 36. Example of wind farm output control signal and hydrogen production (as a % of full output).

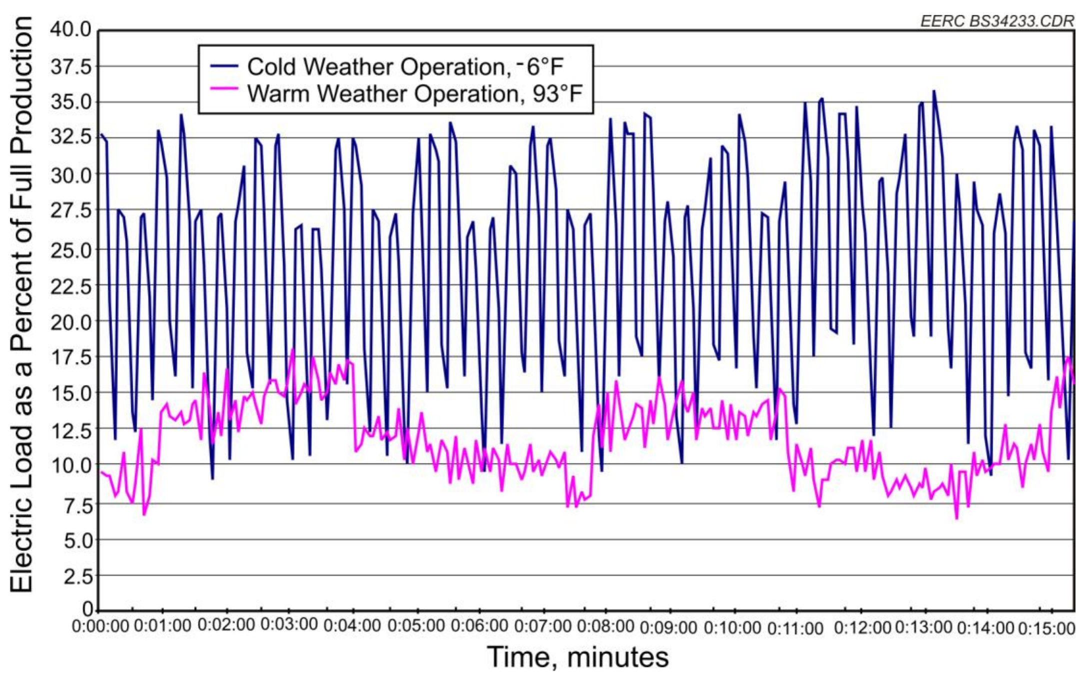

Figure 37. Comparison of balance-of-plant electrical load during summer and winter.

Additional logging of system operation data would have enhanced the research results: Both BEPC and EERC were disappointed in the lack of data collected and stored. Two specific areas were the most missed:

1. Hydrogenics as part of its normal programming, does not included runtime hours and cycle counts as part of the stored information data sets. In past experience, these data are very useful to evaluate system performance, troubleshoot equipment failures, and proactively perform component maintenance. The only method available on this system was to manually record runtime hours from the operator interface on-site. This proved to be an inefficient solution since the system was for the most part operated unattended. In future systems, it would be useful to not only make available runtime hours and cycle counts at the operator interface but also record that information for long-term reference and analysis.

2. Communication between the dispenser and the main system PLC was achieved with a pseudo local area network. This allowed access to the dispenser when remotely connecting to the main PLC, but no long-term information from the dispenser was recorded or stored. An additional complication was that the dispenser PLC and the main PLC were not of the same make. BEPC attempted to find a retrofit solution to be able to pass the dispenser information to BEPC's server, but concern was expressed about installing and tying in an additional piece of equipment in the dispenser, which was a classified area. Therefore, BEPC did not pursue a solution any further. In the future, it would be useful to be able to store pertinent dispenser-related information long term.

In retrospect, these two issues would have best been mitigated by installing a PC on-site to use as a local network server.

End-Use Platforms

Converted ICE vehicles were chosen over fuel cell-based vehicles primarily based on cost. A secondary consideration was availability. Our experience regarding both ICE and fuel cell vehicles is that availability, performance, and reliability were being overstated by the industry at the time the project was pursuing vehicle purchases.

Specifically regarding converted ICE vehicles, the project team found that several companies offered vehicles, but upon requesting pricing and availability information, many could not deliver a vehicle in any reasonable time frame.

Although most reasonably priced, the ICE vehicle conversions were not without issue. The converted ICE vehicle is expected to operate on a gaseous fuel with far different combustion characteristics than its native fuel, liquid gasoline. Project vehicles exhibited significant power loss, most of which could be gained back with the installation of a supercharger. In addition, the vehicles experienced predetonation under certain driving conditions.

CONCLUSIONS

Although the project experienced tremendous delays that resulted in less than desired operational time, several conclusions can be made:

- The equipment sector of the hydrogen industry (based on project and experience and discussions with others procuring equipment) needs to improve most facets of their product, including delivery of product on time, delivery of a product consistent with market expectations, providing a product requiring less operator attendance, and continuing to find ways to reduce the capital cost of equipment.

- The hydrogen production system operated during this project required considerable operator presence to maintain a high hydrogen production rate. Justified or not, both BEPC and EERC personnel had expectations that this system would require limited operator attendance, which was not our experience.

- The dynamic scheduling system, as proposed and briefly used, will work on a utility-scale application with due considerations given to the electrolyzer design operating condition restrictions.

- The electrolyzer response (both in rate of hydrogen production and in power usage) in relation to the input control signal was predictable and rapid enough to act as a counterpart to mitigate most of the intermittent and variable energy characteristics associated with a wind energy source.

- The dynamic scheduling system would work best with multiple unit wind farms using newer technology wind turbines. The electric production variations from this type of source would be moderated by the diversity associated with multiple units and by the kinetic energy management capabilities available in newer wind turbine technology. Older technology turbines would present larger and more frequent variations to follow. Figure 38 shows the production pattern of the three wind farms considered for the wind source.

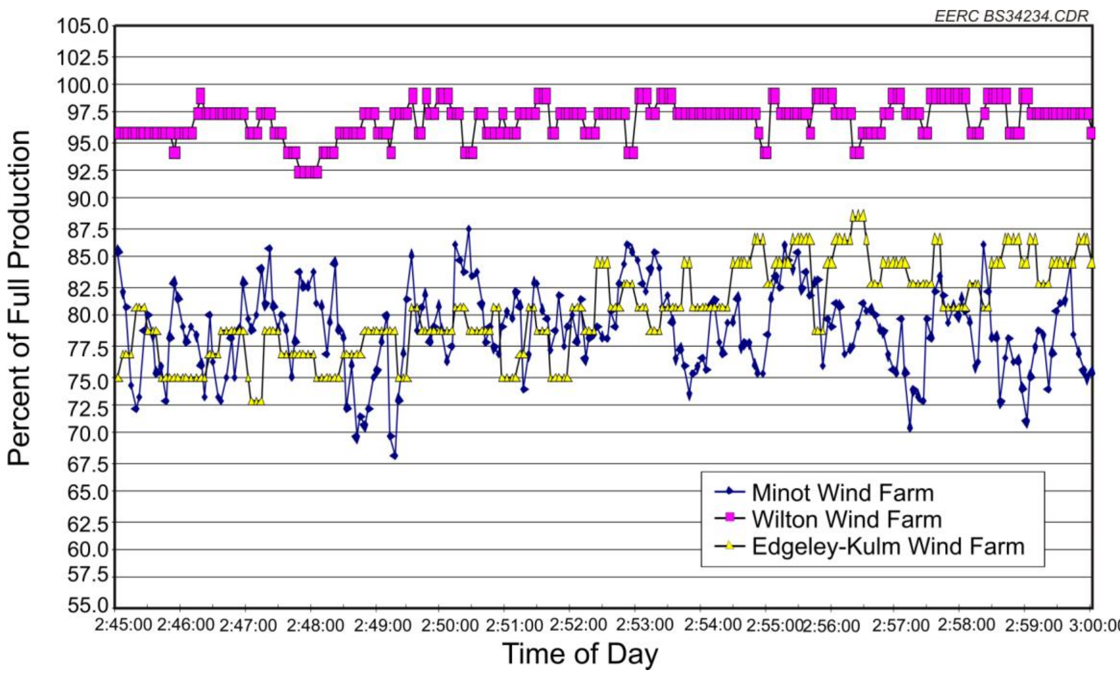

Figure 38. Comparison of the output of the three wind farms.

APPENDIX A

WIND-TO-HYDROGEN FEASIBILITY STUDY

APPENDIX A

WIND-TO-HYDROGEN FEASIBILITY STUDY

Wind-to-Hydrogen Feasibility Study

August 11, 2005

Mr. Ron Rebenitsch
Manager, Member Marketing
Basin Electric Power Cooperative
1717 East Interstate Avenue
Bismarck, ND 58503

Dear Mr. Rebenitsch:

Subject: Final Report Entitled "Wind-to-Hydrogen Feasibility Study"

Enclosed please find the subject final report. If you have any questions, please call me at (701) 777-5120, fax at (701) 777-5181, or e-mail at dschmidt@undeerc.org.

Sincerely,

Darren D. Schmidt
Research Manager

DDS/jlb

Enclosure

WIND-TO-HYDROGEN FEASIBILITY STUDY

Final Report

Prepared for:

Mr. Ron Rebenitsch

Manager, Member Marketing
Basin Electric Power Cooperative
1717 East Interstate Avenue
Bismarck, ND 58503

Prepared by:

Darren D. Schmidt
Chad A. Wocken
Kerryanne M. Leroux
Bradley G. Stevens
Kirk D. Williams
Rhonda R. Hill

Energy & Environmental Research Center
University of North Dakota
PO Box 9018
Grand Forks, ND 58202-9018

2005-EERC-08-06 August 2005

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WIND-TO-HYDROGEN FEASIBILITY STUDY

EXECUTIVE SUMMARY

A feasibility study was conducted to assess the potential for a wind-to-hydrogen project to provide a platform for the development of dynamic scheduling of wind power for hydrogen production and provide a working example to help facilitate the future development of renewable-based hydrogen energy. The project is proposed to be installed at the North Dakota State University (NDSU) North Central Research Extension Center located near Minot. Electrolytic hydrogen production is proposed for refueling vehicles. The electric power is dispatched from various wind turbine sites owned by Basin Electric Power Cooperative. Operation will include testing and experimentation of "real world" operational scenarios given wind scheduled power. Stuart Energy was the selected vendor for the hydrogen refueling station technology. The unit is sized to provide 30 Nm^3/hr and includes 100 kg of storage capacity. The station would have the capacity to fuel a regularly operated bus or a small fleet of vehicles. Utilization of North Dakota state fleet vehicles for hydrogen retrofit will most likely be pursued. AFV Tech was identified as the most likely supplier for hydrogen vehicle technology. Retrofits for Chevrolet 3500 express vans are estimated to cost $40,000. Hydrogen fumigation technology options are a lower-cost second choice. All other hydrogen-based vehicle options are significantly more expensive. Vehicle operation will include automatic switch-over capability to gasoline.

Study for dynamic scheduling was determined and economics evaluated. Four modes of operation were selected. Mode 1 includes a relative zero-net effect on the grid by the scaling of hydrogen production with power production from the turbines. Mode 2 is a modification of Mode 1 to include utilization of off-peak power to supplement wind-generated power. Mode 3 includes improved economics by the operation of the electrolyzer at full capacity and only curtained when wind-generated power is unavailable; Mode 4 is Mode 3 modified to accept off-peak power. The software and hardware required to conduct the testing will include a Power Measurement ION® Enterprise system. The economics for the wind-generated power at 30 Nm^3/hr equate to approximately $20/gallon equivalent to gasoline for Mode 1 and $10/gallon equivalent to gasoline for Mode 4. Certainly, a larger-scale electrolyzer could produce economics closer to $3/gallon; however, the capital costs for such a unit are not within the budgetary scope for this project. A sensitivity analysis revealed that the best-case scenario costs could yield a production price for hydrogen of $4.06/kg and a worst-case of $46.54/kg.

The project will comply with all relevant safety standards, and procedures for construction approvals have been identified and are in process. A case is justified to follow National Fire Protection Association Standard 52 and recommendations from the U.S. Department of Energy (DOE) provided in Table ES1. A National Environmental Policy Act permit is currently in process with DOE. Formal approval has been granted to construct on the property of NDSU. Zoning has been reviewed with the adjacent city of Minot. The local fire marshall has been notified, even though a permit is not required. Underwriters Laboratories and Occupational Health and Safety Administration requirements have been reviewed with the local electrical inspector and provisions are being made to assure that Stuart Energy will deliver equipment that

complies with the inspector's requirements. Adequate electric, water, and sewer utilities are currently available at the project site.

The logistics, economics, process description, and operation are described in this feasibility study. The project is positioned to provide an excellent platform for the development of dynamic scheduling of wind power for hydrogen production and provide a working example to help facilitate the future development of renewable-based hydrogen energy.

Table ES1. Annual Hydrogen and Oxygen Production

Operational Mode	Total Input Power to Electrolyzer, kWh/year	Estimated Annual Hydrogen Production, kg	Estimated Annual Oxygen Production, kg
1	504,191	8,129	65,032
2	760,042	12,990	103,920
3	1,021,408	18,228	145,824
4	1,104,733	19,719	157,752

WIND-TO-HYDROGEN FEASIBILITY STUDY

INTRODUCTION/BACKGROUND

In an effort to address the hurdles of wind-generated electricity and support development of electrolysis technology, the U.S. Department of Energy (DOE) awarded Basin Electric Power Cooperative (BEPC) a contract to investigate a wind-to-hydrogen system. Through this effort, BEPC, with the support of the Energy & Environmental Research Center (EERC), is evaluating the technical and economic feasibility of dynamically scheduling wind energy to power an electrolysis-based hydrogen production system.

The capital costs of electrolysis systems and the current fossil fuel-dominated electric mix in the United States have limited the widespread adoption of electrolysis technology for hydrogen production. Technology development of electrolysis systems and integration with low-cost, low-emission or renewable energy sources will be necessary for the technology to be competitive with conventional fossil fuel energy production.

Advances in technology have reduced the cost of wind-generated electricity in many wind-rich areas of the United States; however, significant development of these resources has not occurred. Two factors, wind's intermittency and transmission capacity limitations, make it difficult to supply the wind-generated electricity to market, thereby slowing investment.

This project will demonstrate an application of hydrogen production from wind energy. The economics and feasibility of dynamic scheduling will be addressed, and outreach from the fueling of vehicles will be completed. This report outlines the feasibility of the project for future implementation.

PROJECT GOAL AND OBJECTIVES

The goal of this program is to research and demonstrate the production of a hydrogen stream from an electrolysis system using dynamically scheduled wind power and to quantify the savings associated with dynamically scheduled wind utilization. The result of successful completion of the demonstration would include improved energy self-sufficiency, economic development in rural areas with high wind resources, technology advancements in electrolysis and hydrogen delivery systems, and the creation of a local hydrogen supply to support further hydrogen end-use technology development, including fuel cell fleet vehicles. Further, if a new wind energy source can be utilized locally to create end-use products such as hydrogen or fertilizer, than costly interstate transmission lines to move power from remote wind generation projects can be avoided. New wind projects can then be completed based on local demand for end-use products and not impacted by siting, permitting, and construction of transmission lines.

A specific objective of this program is to develop a better understanding of the advantages, challenges, and technical hurdles related to dynamically scheduling wind power from geographically disparate locations to power a hydrogen production facility. Another objective is to evaluate the operational considerations of hydrogen production and delivery systems, especially under non-steady-state operating conditions induced from dynamic scheduling. Further research into the marketing and use of the resulting hydrogen is also part of this endeavor.

Feasibility Report Objectives

This feasibility study provides the preliminary design and economic analysis from which to evaluate the merit of proceeding with the design, construction, and operation of the demonstration system. Based on the data provided in this report, DOE will have sufficient data to authorize BEPC to proceed with acquisition of major equipment to expedite the construction of the wind-to-hydrogen facility.

This report is a working document and will be revised as information becomes available from detailed system design and economic analysis. A revised feasibility study will be prepared in advance of construction to provide for appropriate review by DOE.

PROJECT DESCRIPTION AND CONCEPT

The wind-to-hydrogen pilot project is a multiphase effort. The first phase is ongoing and consists of the technical and economic feasibility study. The primary components of this Phase 1 investigation include the following:

- NEPA analysis/determination – BEPC will complete the National Environmental Policy Act (NEPA) requirements. The feasibility study includes NEPA submittal and environmental review of the proposed system. This project will initially accomplish conceptual design, preliminary design, and NEPA determination for the proposed demonstration project large-scale development.

- Equipment selection – A firm cost estimate will be developed for the electrolyzer, hydrogen-fueling station, and building structures (if necessary) and telecommunications needs/equipment for dynamically scheduling power. The optimum equipment will be selected to maximize efficiency of cost and production. Alternative experimental storage will be pursued if economically viable.

- Detailed design – Site, building, fueling station, storage, and telecommunications designs will be developed for the components and subsystems. Emphasis will be placed upon design of a durable and reliable system, assuming a 10-year project life.

- Economic sensitivity – An economic sensitivity analysis will be performed to evaluate various project approaches and variances for performance of the final design.

BEPC continues to proceed with the engineering documentation and verification for dynamic scheduling of wind power to the electrolyzer. The EERC is developing the predesign necessary to verify that the proposed electrolyzer, hydrogen-fueling station, and wind turbine comply with the project objectives. Additionally, the EERC is developing general design criteria for performance and cost estimates. Experimental forms of storage are being explored and evaluated. In general, the study evaluates options in terms of cost and physical application, thereby providing documentation of project decisions for future planning.

Upon approval from DOE, the second phase of the program will include equipment acquisition, construction, and demonstration of the full-scale, dynamically scheduled hydrogen production facility. In general, the project consists of dynamically scheduling wind from two wind farms in North Dakota plus a possible third wind project now planned near Bismarck, North Dakota. Two turbines (2.6-MW nameplate capacity) are located south of Minot, North Dakota, along U.S. Highway 83. The second wind farm is located near Edgeley, North Dakota, and consists of 27 turbines (40-MW nameplate capacity). The third wind project would consist of 33 turbines with a nameplate of 49.5 MW. A hydrogen production system will be located at the North Dakota State University (NDSU) North Central Research Extension Center (NCREC) south of Minot, North Dakota, capable of producing hydrogen at a rate of 30 Nm^3/hr at maximum rating. A map illustrating the location of the wind turbines and hydrogen production system are provided in Figure 1. The system consists of an electrolysis unit, water treatment, chiller, hydrogen storage, control system, and fuel-dispensing station. A plan view of the NDSU NCREC, where the hydrogen production system will be located, is provided in Figure 2. Conceptual plan view, elevation, and three-dimensional drawings of the equipment are provided in Figures 3–5, respectively.

Initial equipment design and specification have been coordinated with Stuart Energy. It is anticipated that their responsibility to the project will include supply of the hydrogen production system and technical support for installation and operation. A general process block flow diagram of the system is provided in Figure 6.

System Operation

One of the main objectives of the wind-to-hydrogen demonstration project is to gain operational experience with the electrolyzer system with a variable electrical energy source (in this case, wind energy). This will be achieved by dispatching, in near-real time, electricity from BEPC's existing wind turbines in North Dakota to the electrolyzer located south of Minot.

The hydrogen fueling system will be assembled and tested off-site at the vendor's facility and then delivered to our prepared project site for installation. Upon completion of system installation, the hydrogen-fueling system will be operated for a period of time to perform start-up and shakedown procedures as well as provide operational training to project personnel. This phase is anticipated to require no more than 2 weeks.

Once the vendor and operational personnel are satisfied that personnel have been sufficiently trained and the start-up and shakedown period has been completed, the hydrogen fueling system operation will be transitioned into one of several operational modes. Each operational mode represents a unique but representative "real-world" scenario.

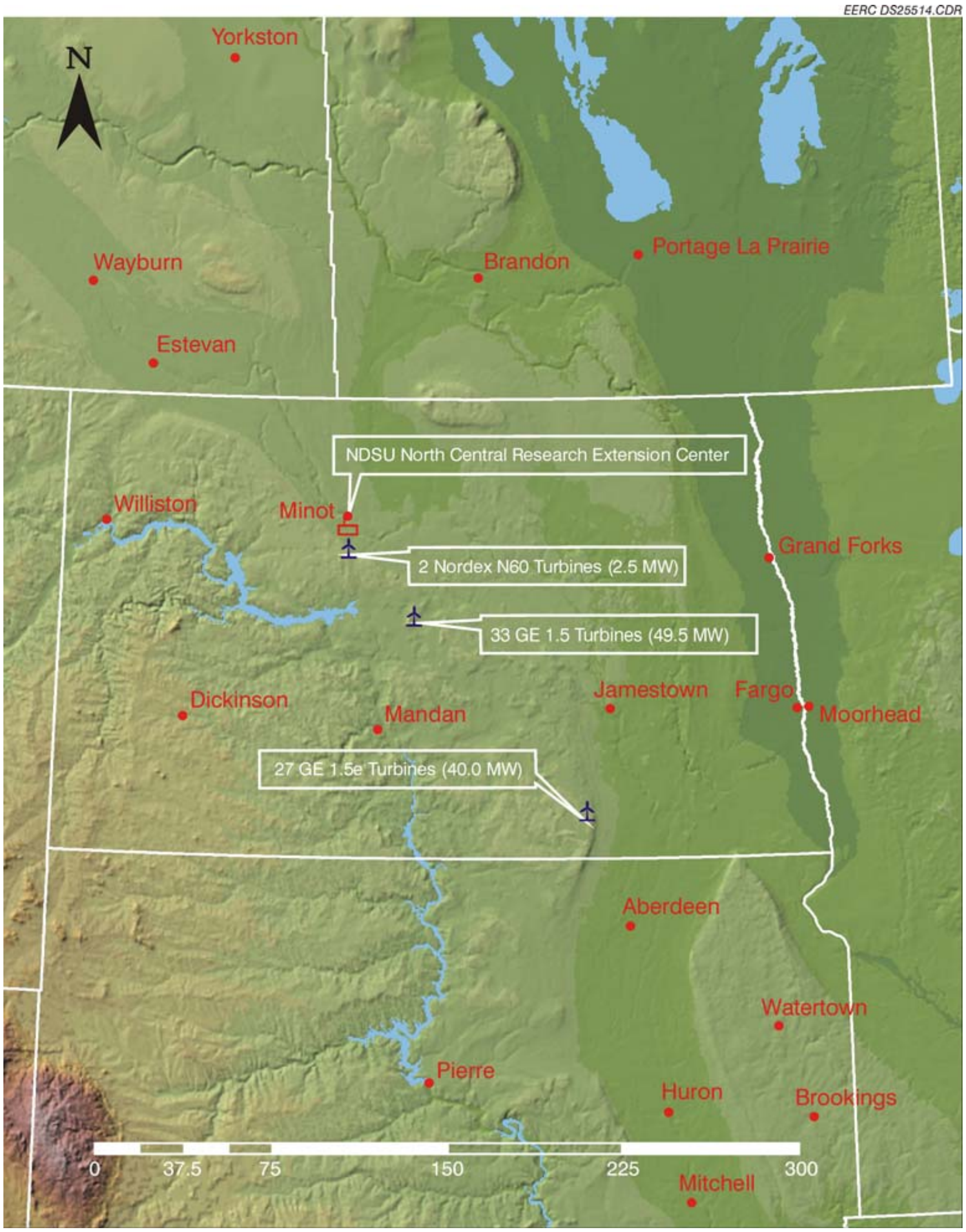

Figure 1. Project map.

Equipment Selection

Equipment selection is driven by economics, conversion efficiency experience of the supplier, and an ability to provide a complete refueling station. The primary equipment and cost for the wind-to-hydrogen project is the electrolytic hydrogen production system. The goal of the project is to demonstrate the feasibility of producing a hydrogen stream from an electrolysis system using dynamically scheduled wind power. Since the project will focus on research

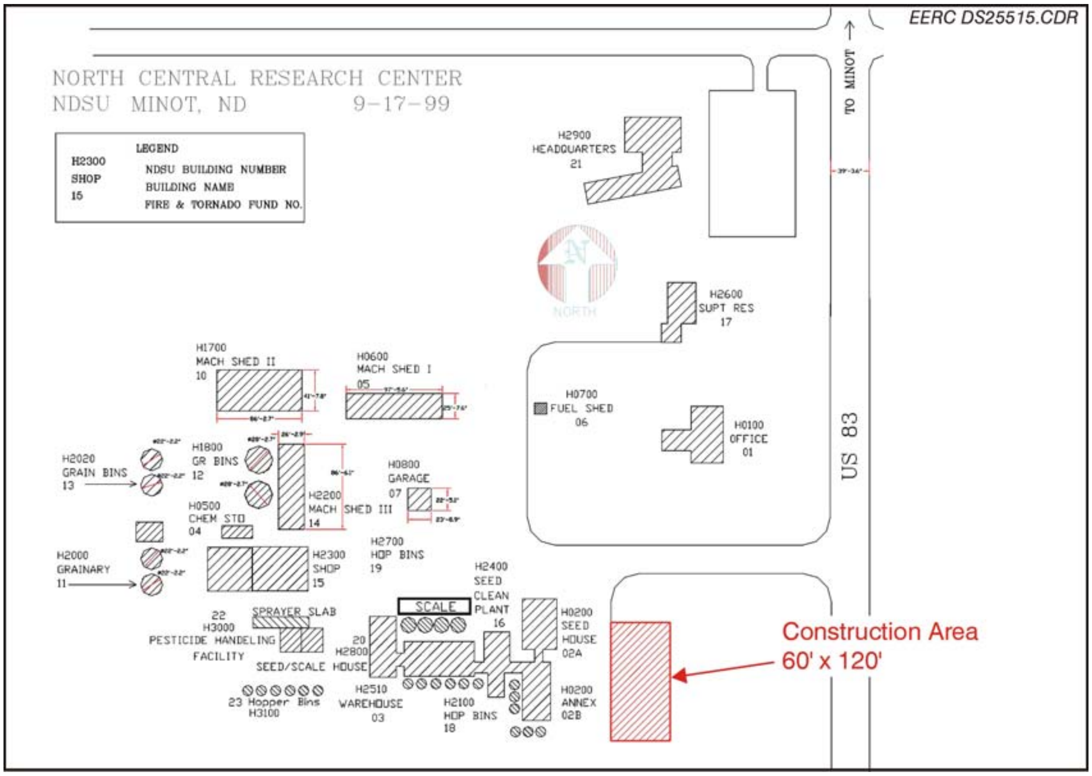

Figure 2. Hydrogen production facility at NDSU NCREC.

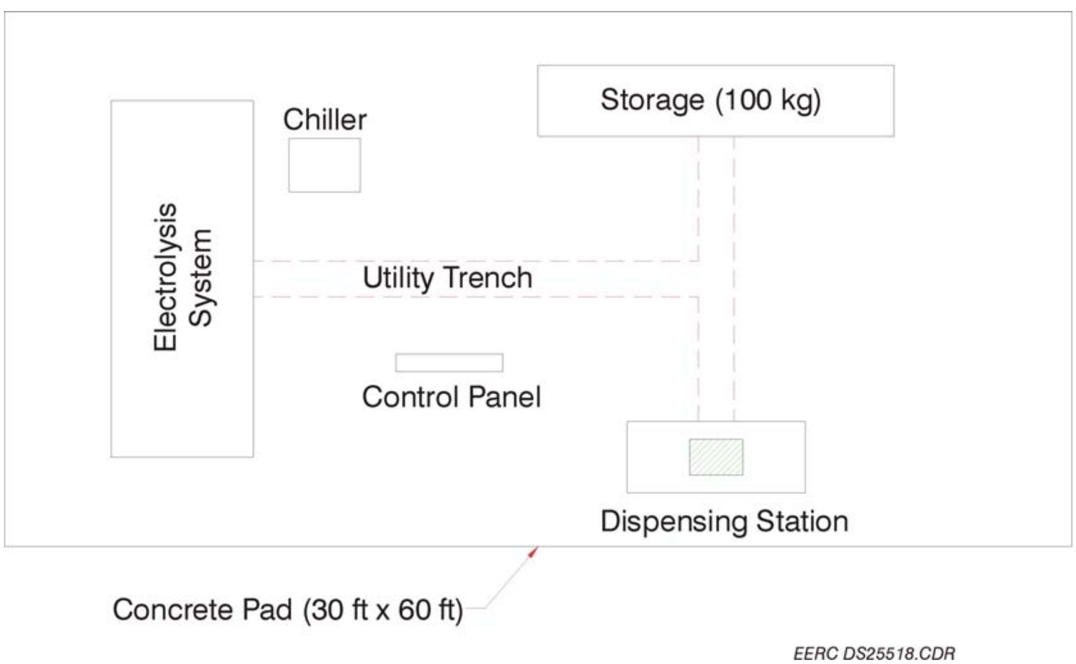

Figure 3. Hydrogen production system plan view.

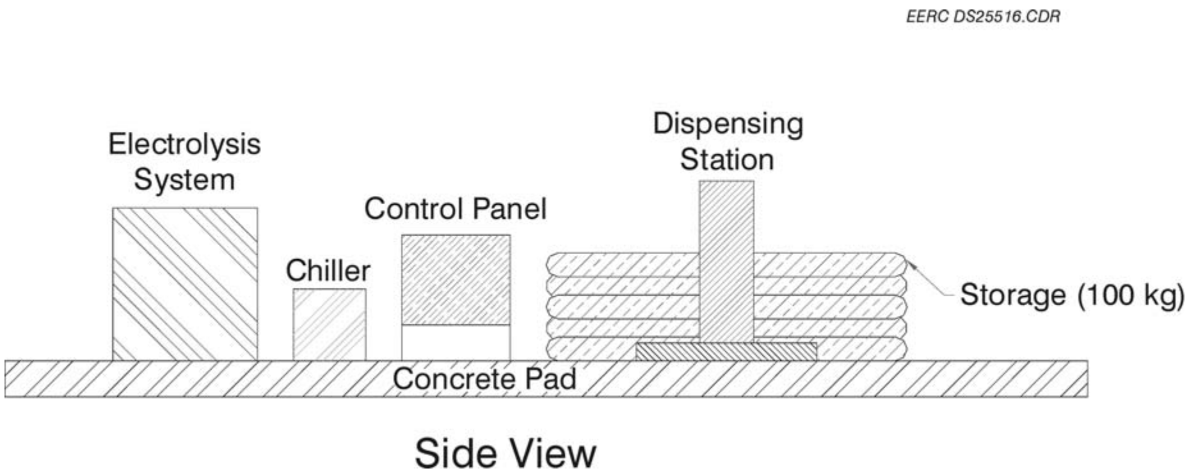

Figure 4. Hydrogen production system elevation.

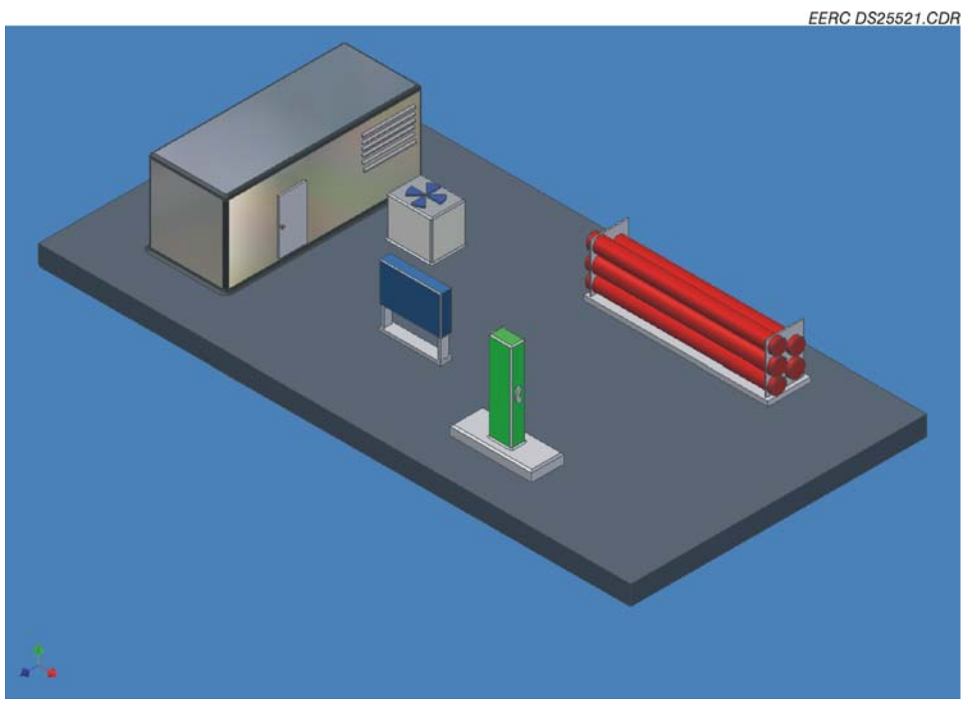

Figure 5. Hydrogen production system three-dimensional.

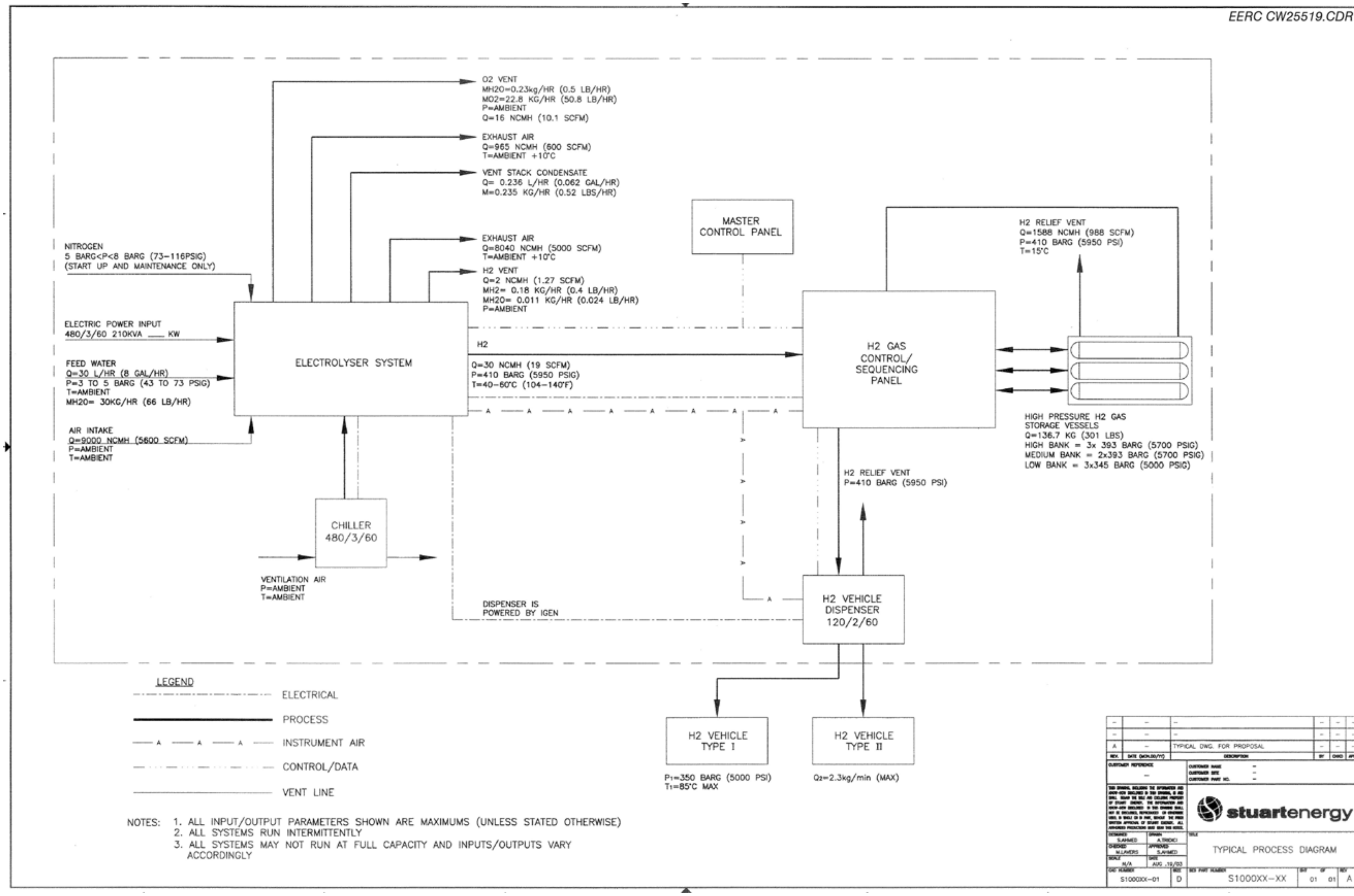

Figure 6. Process flow diagram.

regarding the dynamic scheduling of wind and vehicle fleet fueling, a commercial electrolytic hydrogen production system is desired that will prove reliable. High reliability of the electrolyzerfueling station will enable project activities to focus on the economic study for scheduling wind power and enable successful vehicle fueling activities while avoiding hydrogen production maintenance. Also, within estimated funding, the largest hydrogen production module was sought to document the most favorable economies of scale.

Equipment suppliers were selected based on the ability to provide at least 30 Nm^3/hr of hydrogen. A request for quotation (RFQ) was prepared and sent April 15, 2005, with responses provided within 2 weeks. The companies targeted and responding to the RFQ included Proton Energy Systems, Stuart Energy, Norsk Hydro, and Teledyne. Submitted quotations are confidential; therefore, only general information can be reported. All of the above-referenced companies were listed in an overview of electrolytic hydrogen production technology provided by National Renewable Energy Laboratory (NREL) (Archer Energy Systems, 2005). The NREL summary provided background information on commercial suppliers, performance, and economics. Norsk declined to bid, but all other bidders provided prices within a similar range (approximately $1,000,000) for a complete refueling station. Stuart was the only company to offer a complete package, where Teledyne and Proton would only supply the electrolyzer, with compression, storage, and dispensing provided by others. Stuart was found to have a significant number of refueling station installations compared to Teledyne and Proton. Proton was the only company to propose more than one electrolyzer to meet the output requirement. Also, Proton is the only company building large solid-polymer electrolyte electrolyzers. Stuart and Teledyne offer bipolar alkaline electrolyzer technology.

Stuart Energy was selected as the preferred technology supplier. The quotations showed little difference in price or major technology components; therefore, the basis for selecting Stuart was the demonstrated experience—Stuart's systems being the most efficient performers—and the ability of the company to provide a complete package. Stuart also provided contractual payment flexibility unique to the funding scenario for the project, which was not offered by other suppliers.

Dynamic Scheduling

A key component to the successful demonstration of this project is the dynamic scheduling of the wind energy's variable output to the electrolyzer. The dynamic scheduling system will receive an output signal from the wind farm, process this signal based on the operational mode, and dispatch the appropriate amount of power to the electrolyzer. When both systems are connected through the local power grid, multiple distinct control scenarios can be utilized. The system design currently contains four control "modes" and has the potential to add additional modes as needed. The four modes chosen for this demonstration project are based on anticipated needs of larger-scale development projects that might be initiated as a result of this study.

The four operational modes being considered for use during the demonstration are:

- Mode 1 – scaled wind
- Mode 2 – scaled wind with off-peak

- Mode 3 – full wind
- Mode 4 – full wind with off-peak

Mode 1 – Scaled Wind

As the mode title indicates, Mode 1 represents delivery of power to the electrolyzer scaled such that the maximum wind power is scaled to match the maximum load of the electrolyzer. This mode would imitate a scenario where the electrolyzer would be directly connected to a small wind turbine. For example, if the electrolyzer represents an electrical load of 150 kW and the dynamical scheduling software is monitoring wind turbine output of 1500 kW, the resulting maximum delivered power to the electrolyzer would be 150 kW, or the hourly delivered power would be the measured wind farm output in kW times 0.1. The power generation and delivery pattern would not be changed, only the magnitude. Because the electrolyzer requires a minimum input of 25% of rated power, when the scaled wind energy is less than this value, the electrolyzer will be run at the 25% minimum value. In this demonstration project, the electrolyzer has a much smaller energy requirement than even a single wind turbine, so to simulate this scenario, the maximum wind energy can be multiplied by a scale factor of k ($k < 1$) to correspond to the maximum electrolyzer energy input. A time delay is shown between the time the analog output signal is updated and the value when the available turbine power is read. This value can be set based on the response time of the electrolyzer to changes in hydrogen production levels. Figure 7 displays the software decision flowchart for Mode 1.

Mode 2 – Scaled Wind with Off-Peak

Mode 2 will consist of operating the system under the Mode 1 (scaled wind) scenario with the addition of utilizing off-peak power to supplement the wind energy (if needed) during the hours of 11 p.m. to 7 a.m. Off-peak power will be delivered to the electrolyzer to supplement the wind energy up to the maximum electrolyzer load (150 kW). Figure 8 displays the software decision flowchart for Mode 2.

Mode 3 – Full Wind

Mode 3 is the nonscaled version of Mode 1; that is, the actual power output from the wind farm will be dispatched to the electrolyzer up to the maximum electrolyzer load (150 kW). Wind power greater than 150 kW will be delivered to the electrical grid as it normally would.

This mode will mimic the scenario where the electrolyzer is operated by a utility-scale wind turbine or wind farm. Unlike Modes 1 and 2, the wind turbine(s) in Modes 3 and 4 are not scaled to match the electrolyzer and, therefore, generate more electricity than can be utilized by the electrolyzer. As a result, Modes 3 and 4 produce two products, hydrogen and electricity. Figure 9 displays the software decision flowchart for Mode 3.

Mode 4 – Full Wind with Off-Peak

Mode 4 can be thought of in two ways: either as the nonscaled version of Mode 2 or as Mode 3 with the addition of off-peak power. Mode 4 represents operating the electrolyzer in a "maximum utilization" scenario. Figure 10 displays the software decision flowchart for Mode 4.

Minimum Required Electrolyzer Energy Input

The Stuart SESF electrolyzer requires a minimum input energy for proper operation. When wind levels are below this value, the electrolyzer can be run either at no output or be provided its required minimum input value from integrated system energy sources, regardless of whether off-peak pricing is available. The minimum electrolyzer input value is approximately 25% of its rated full input energy. Because the electrolyzer has a relatively long warm-up time, it is generally not practical to shut it down, so for this demonstration project, the electrolyzer will be run at a minimum of 25% rated power (standby mode) at all times possible.

Control Software

The software chosen for the supervisory control and data acquisition (SCADA) system used for dynamic scheduling, control, and monitoring of the electrolyzer is the Power Measurement (PWRM) ION Enterprise® 5.5. BEPC will provide support and maintenance of the system because it has dedicated support staff experienced with this product. A server separate from other BEPC systems will be utilized for this project. Remote access to the server and

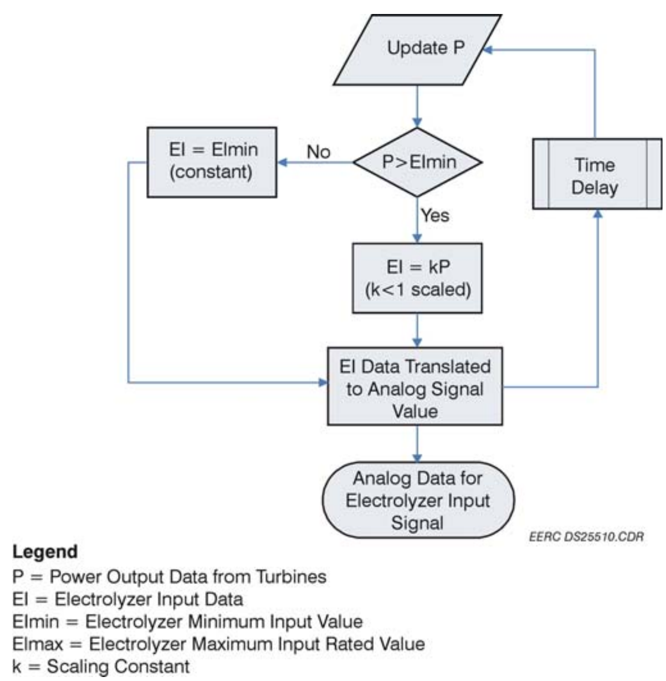

Figure 7. Mode 1 – scaled wind.

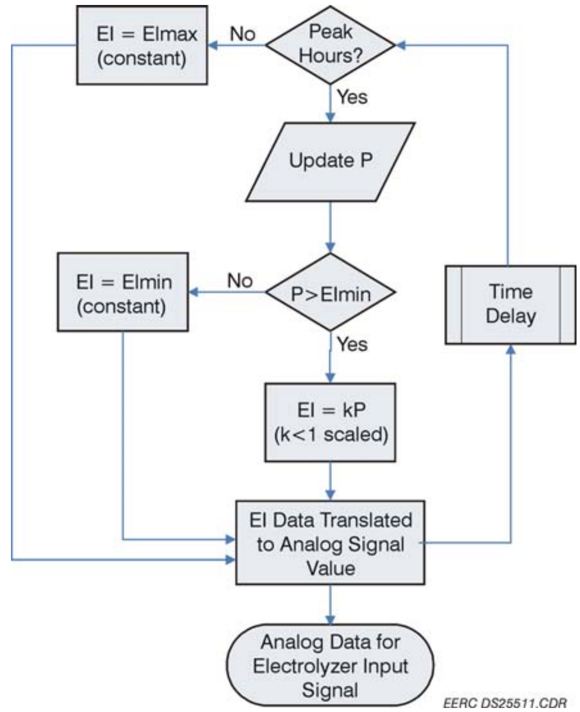

Figure 8. Mode 2 – scaled wind with off-peak.

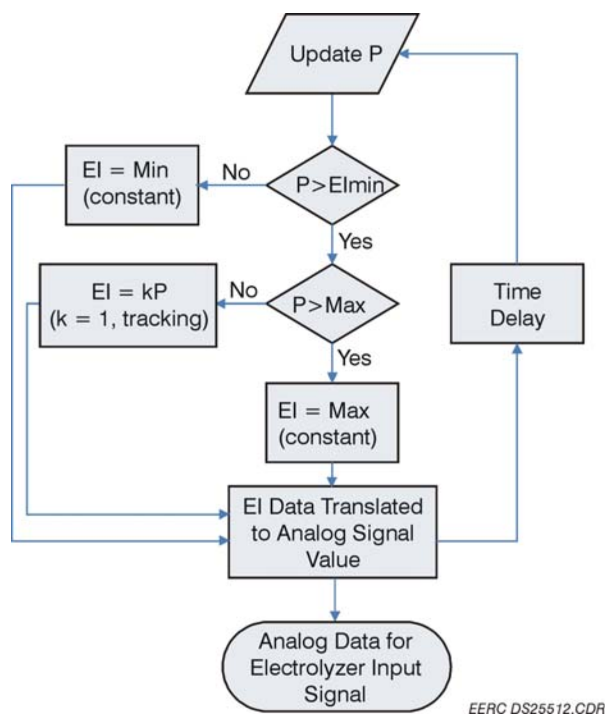

Figure 9. Mode 3 – full wind.

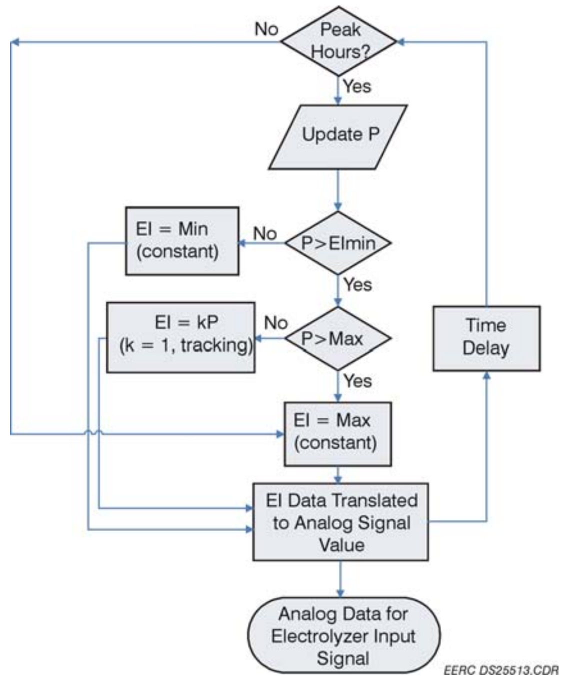

Figure 10. Mode 4 – full wind with off-peak.

software will be provided to the EERC to facilitate development of dynamic scheduling programming, data analysis, and future control and monitoring of the system.

The PWRM ION Enterprise 5.5 software collects and analyzes data, provides communication and control regarding dynamic scheduling, and interfaces with other energy management and SCADA systems through multiple communication channels and protocols. A primary function of the SCADA system is to accept digital data from the wind turbines and the electrolyzer and provide output data that is used to set the power input level of the electrolyzer. Data monitoring will be done in real time, and historic data can be stored in an structured query language (SQL) database. Graphical data reports are produced in Microsoft Excel™ format for energy consumption and power quality as well as customized user-defined quantities. Alarms can be created and set to alert via a variety of methods, including an operator's workstation, pager, or e-mail.

Control Hardware

A PWRM ION meter/remote terminal unit (RTU) will be used at the electrolyzer site for control, measurement, and communication. It will be Web-enabled and integrate with ION Enterprise 5.5, as well as other energy management and SCADA systems. It will have multiple communication channels and protocols and will be capable of accepting digital inputs and providing digital output and analog output signals.

Wind Energy Analysis

To develop hydrogen production estimates for each of the operational modes, wind energy production estimates had to first be generated. Actual production data were available and were used to estimate both wind energy and hydrogen production.

Actual wind farm production data for 2004 was used from the wind farm located near Kulm and Edgeley, North Dakota. This wind farm will likely be the wind energy generation source for the demonstration. The wind farm production data was provided by BEPC in the form of total hourly output in kW for the wind farm which consists of 27 wind turbines. The total hourly output was divided by the number of wind turbines (27) to obtain a nominal single turbine hourly output.

In 2004 the Kulm/Edgeley wind farm produced 5,041,928 kWh, resulting in a capacity factor of 38%. Following the operational protocol described in the System Operation section, the estimated electric energy delivered ranges from approximately 500,000 kWh/year in Modes 1 and 2 to 1,020,000 kWh/year in Modes 3 and 4, with an additional 83,000 kWh/year in Mode 4 and 256,000 kWh/year in Mode 2 being provided as off-peak electric energy. As a result, it is estimated that the total electric energy delivered to the electrolyzer will range from approximately 500,000 kWh/year in Mode 1 to 1,100,000 kWh/year in Mode 4. Table 1 summarizes the estimated annual power supplied to the electrolyzer by wind energy and off-peak energy for each operational mode.

Traditionally for this type of analysis, a wind-monitoring site would be used to derive the wind energy production estimates. This monitoring data would then be used to extrapolate the 40-m wind speed up to the wind turbine hub height for use in estimating the hourly wind turbine output in kW. Using the wind turbine power curve, the estimated wind turbine output is derived for each hour by using the wind turbine power at the corresponding 65-m wind speed. Once the hourly wind turbine output for each hour is estimated, the output values are totaled to obtain an estimated annual wind turbine production in kWh. This number is then reduced by 5% to adjust to 95% availability.

Monitoring data from the monitoring site at Edgeley was used to support the results coming from the actual wind farm data. Using the method described above, the 2004 data from the Edgeley monitoring site resulted in an estimated wind turbine power production of 4,989,685

Table 1. Annual Wind Energy Production and Electrolyzer Power Requirement

Operational Mode	Input Power to Electrolyzer from Wind, kWh/year	Input Power to Electrolyzer from Off-Peak, kWh/year	Total Input Power to Electrolyzer, kWh/year
1	504,191	NA	504,191
2	504,191	255,851	760,042
3	1,021,408	NA	1,021,408
4	1,021,408	83,326	1,104,733

kWh annually. The estimated generation very closely corroborated the estimates based on actual wind farm production data.

Gas Production Analysis

Based on the energy production of each mode, both hydrogen and oxygen production was estimated assuming a linear relationship between power input to the electrolyzer and gases generated. Estimated annual hydrogen production ranged from approximately 8,000 kg in Mode 1 to 20,000 kg in Mode 4, and estimated annual oxygen production ranged from approximately 65,000 kg in Mode 1 to 158,000 kg in Mode 4. Table 2 summarizes the estimated annual hydrogen and oxygen production for each operational mode.

Economic Analysis

The economics of this feasibility study were based on the potential cost of producing hydrogen in comparison to the current price of gasoline, estimated at $2/gal in the Midwest (Energy Information Administration, 2005b). It is generally accepted that 1 kg H_2 is approximately equal to 1 gal of gasoline in its available energy content (Archer Energy Systems, 2005). Therefore, all costs were estimated on a per-kg-H_2 basis. Table 3 summarizes the cost of hydrogen production calculated for each mode.

As described in the Dynamic Scheduling and Wind Energy Analysis Sections, the electrolyzer, which represents a 150 kW load, will be operated in concert with available wind energy and will likely consume between 500,000 and 1,100,000 kWh per year. The balance of the hydrogen fueling system (i.e. balance of plant) will include but not be limited to the compression system, heaters, lights, and system controls and will be operated on grid power. The balance of plant is approximately 20 kW at full load. To derive an electrical usage, the assumption was made that the balance of plant would consume approximately 100,000 kWh annually and that usage would be divided evenly between peak and off-peak times.

For the purposes of the economic analysis, the costs for electricity were assumed to be $0.066/kWh for on-peak energy and $0.035/kWh for off-peak energy. These values were determined based on supply chain cost input from BEPC and by BEPC's member cooperatives Central Power Electric Cooperative (CPEC) and Verendrye Electric Cooperative (VEC). The electricity pricing assumptions reflect actual cost that would apply to service provided to an

Table 2. Annual Hydrogen and Oxygen Production

Operational Mode	Total Input Power to Electrolyzer, kWh/year	Estimated Annual Hydrogen Production, kg	Estimated Annual Oxygen Production, kg
1	504,191	8,129	65,032
2	760,042	12,990	103,920
3	1,021,408	18,228	145,824
4	1,104,733	19,719	157,752

Table 3. Calculation of H_2 Production Cost

	Item	Unit	Mode 1 Scaled	Mode 2 Scaled and Off-Peak	Mode 3 Maximum	Mode 4 Maximum and Off-Peak
Wind Energy Generation/ H_2 Fueling System Usage	Peak price	$/kWh	0.066	0.066	0.066	0.066
	Scaled power	kWh/yr	504,191	504,191	1,021,408	1,021,408
	Balance of plant	kWh/yr	50,000	50,000	50,000	50,000
	Scaled cost	$/yr	36,577	36,577	70,713	70,713
	Off-peak price	$/kWh	0.035	0.035	0.035	0.035
	Off-peak power	kWh/yr	–	255,851	–	83,326
	Balance of plant	kWh/yr	50,000	50,000	50,000	50,000
	Off-peak cost	$/yr	1,750	10,705	1,750	4,666
H_2 Generation	H_2 fueling system	$, installed	1,300,000	1,300,000	1,300,000	1,300,000
	Service life	yr	10	10	10	10
	Conversion cost	$/yr	130,000	130,000	130,000	130,000
	H_2O required	gal/yr	24,386	38,969	54,684	59,156
	H_2O cost	$/yr	417	481	496	511
	H_2	kg/yr	8,129	12,990	18,228	19,719
	O_2	kg/yr	65,032	103,920	145,824	157,752
Cost	Power	$/kg H_2	4.71	3.64	3.98	3.82
	Conversion	$/kg H_2	15.99	10.01	7.13	6.59
	Water	$/kg H_2	0.05	0.04	0.03	0.03
	Total	$/kg H_2	20.76	13.68	11.13	10.44

industrial customer having a comparably sized electric load in VEC's service area near Minot. BEPC and its member cooperatives each serve different roles in the delivery of electric energy:

- BEPC serves as the generator of electricity and delivers this electricity through the high-voltage electrical transmission system to regional delivery point substations.

- CPEC is responsible for taking delivery of electricity at the regional substations and provides the sub-transmission "wheeling" of the wholesale electricity to the local distribution system delivery point substation.

- VEC in turn provides the local distribution system delivering the electricity to the retail customer.

The capital cost of the hydrogen fueling system and the utility cost of water consumed were incorporated into the analysis as well. The hydrogen fueling system cost, derived from a price quote provided by Stuart Energy, as well as site preparation and installation will total $1.3

million. A 10-year service life is assumed, resulting in an annual cost of $130,000 to produce hydrogen from water via electrolysis. Rural water rates in Minot (Minot Area Development Corporation, 2003) were used in estimating water requirement costs.

The price of electrolysis has the most influence on the hydrogen production cost, constituting 65%–80% for all modes. Peak electricity comprises 20%–35% of the production cost. The off-peak electricity is 5% the cost of hydrogen for Mode 2 and 1% for Mode 4. Water usage contributes less than 0.3% to the final cost of hydrogen. Figure 11 gives a graphical representation of each mode for estimated hydrogen production cost and quantity of hydrogen produced. It shows the influence of large capital and small operating costs, as the price to generate hydrogen becomes more economical with increased annual production.

Sensitivity analyses were performed to illustrate the effect of peak electricity price, hydrogen fueling system price, and hydrogen fueling system service life on the cost of producing hydrogen. Hydrogen production costs were studied over a range of $0.025/kWh to $0.100/kWh for the peak electricity price, shown in Figure 12. Changes in cost deviated −21% to 18% from baseline values given in Table 2 for all modes. The capital hydrogen fueling system price was varied over a range of $1.0 million to $1.6 million, Figure 13. The range of deviation in the cost of producing hydrogen was +/−18% from the baseline.

The economics amortize the price of the hydrogen fueling system over the span of expected service life. For this analysis a baseline service life of 10 years was recommended by the supplier because of the research nature of the project. However, it is expected that through proper equipment operation and maintenance that a significantly longer service life could be realized, thereby improving the economics of hydrogen production, as illustrated in Figure 14. Based on this sensitivity analysis, a service life of 5 years resulted in an increase in hydrogen cost of approximately 71% from the baseline. Should the service life be extended out to 20 years, the hydrogen production cost could be reduced from baseline values by an average of 36%. Under these conditions, the cost of hydrogen for Mode 4 could be reduced to $6.88/kg H_2.

SAFETY CODES AND STANDARDS

The codes and standards necessary to regulate hydrogen usage are in a very early stage of development, much earlier than is the case for natural gas or gasoline, according to an Idaho National Engineering and Environmental Laboratory (INEEL) report (Cadwallader and Herring, 1999). The report further stated that the standard most similar to compressed hydrogen storage and dispensing was National Fire Protection Association (NFPA) Standard 52 for compressed natural gas (CNG). Therefore, hydrogen codes and standards can be built upon those in place for methane as a transportation fuel, since these are both lighter-than-air gases with low spark ignition energies for deflagration. Hydrogen codes and standards will have to take into account the unique physical, ignition, and combustion characteristics of hydrogen gas. For example, 40CFR68 Chemical Accident Prevention Provisions, the release point and the explosion end point distance are compared to the release point/site boundary distance to determine if the public could be exposed to the explosion end point’s 1 psi overpressure.

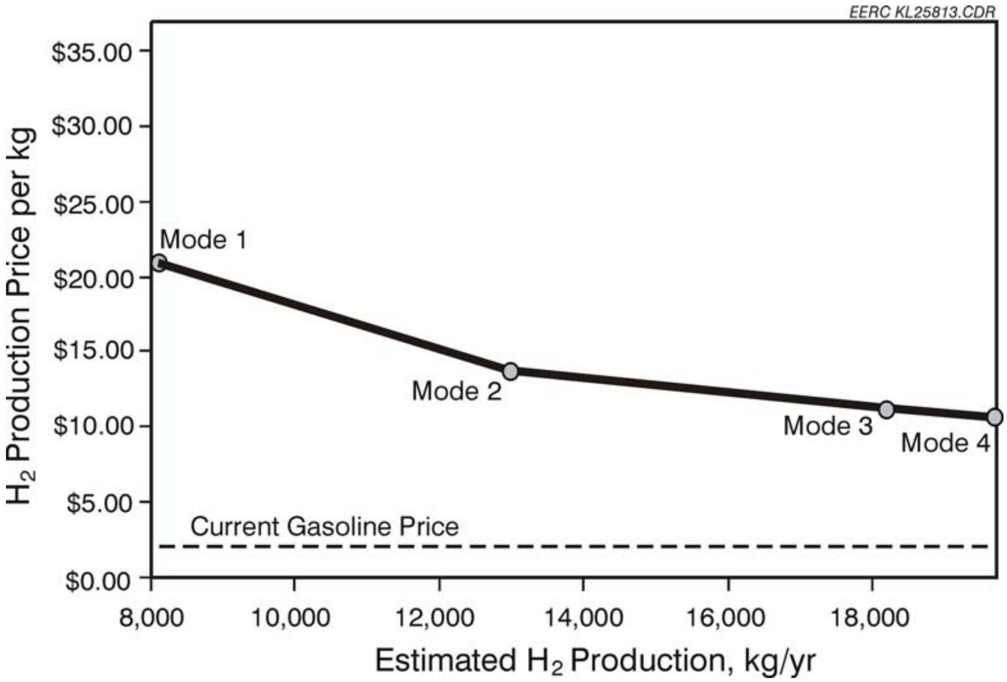

Figure 11. Estimated H_2 cost and H_2 produced for each mode.

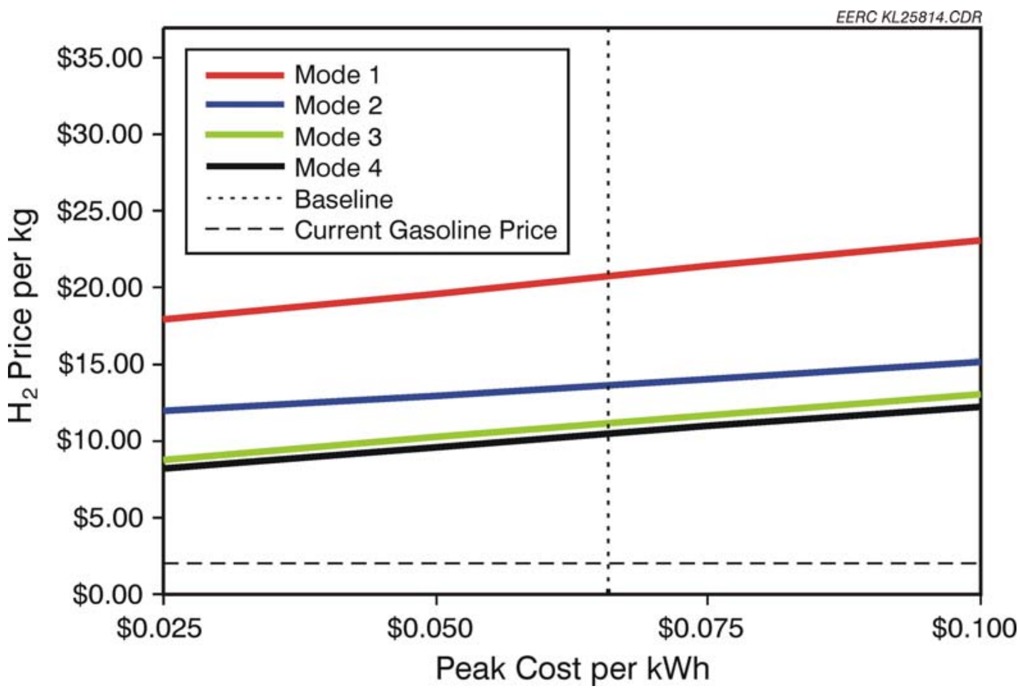

Figure 12. Sensitivity of H_2 production cost to peak electricity price.

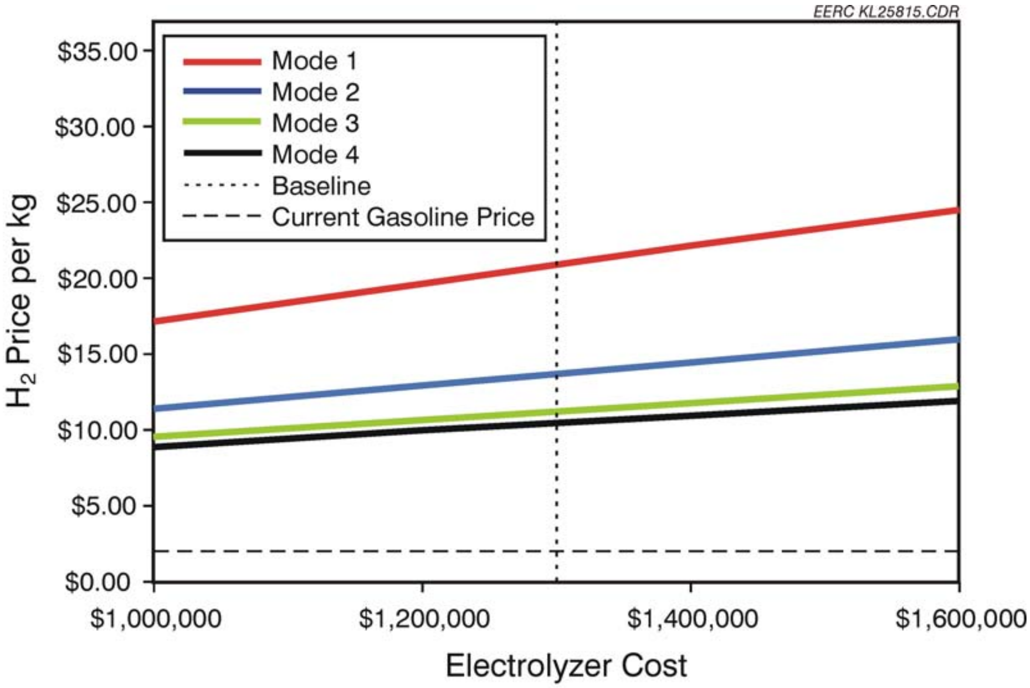

Figure 13. Sensitivity of H_2 production cost to electrolyzer price.

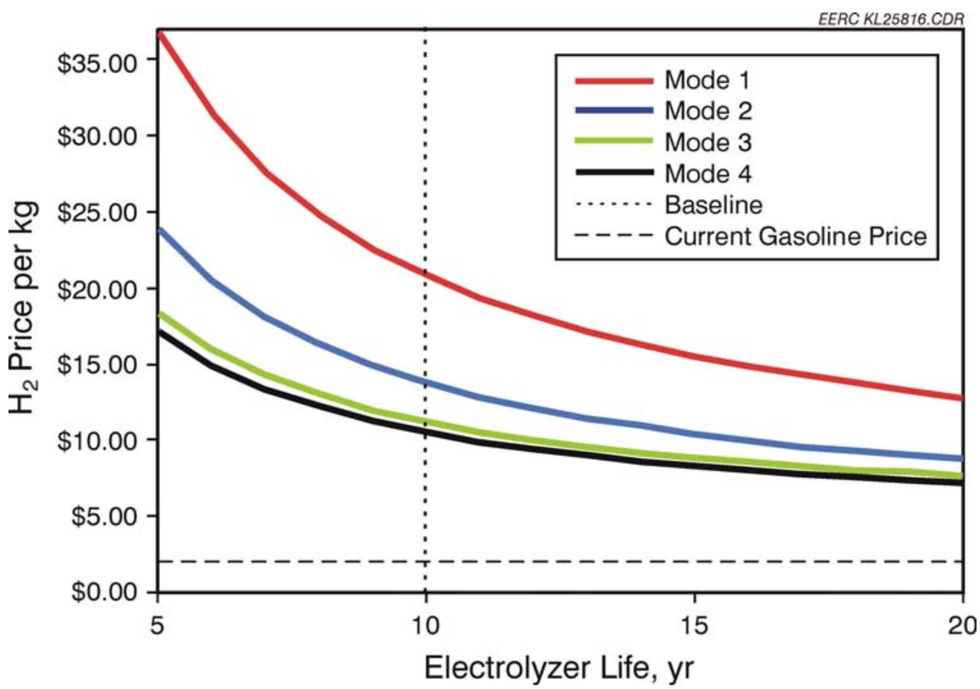

Figure 14. Sensitivity of H_2 production cost to electrolyzer life.

A guide was generated by the DOE Office of Energy Efficiency and Renewable Energy (EERE) addressing the need for hydrogen codes and standards (Energy Efficiency and Renewable Energy, 2004). Within the guide, EERE provides a list of existing codes and standards both generalized and specific to hydrogen that affect the current design, installation, and operation of a hydrogen facility. The codes or standards particular to this project are summarized in Table 4.

Table 4. Derived Codes and Standards for Hydrogen Systems (Energy Efficiency and Renewable Energy, 2004)

Issue Fuel Supply and Storage	Requirement Description
Identification and Labeling of Storage Containers	Manifold gaseous hydrogen supply units shall be marked with the name "HYDROGEN" or a legend such as "This unit contains hydrogen" in accordance with CGA.[a]
Structural support	Permanently installed containers must be provided with substantial supports, constructed of noncombustible material securely anchored to firm foundations of noncombustible material. Compressed gas containers, cylinders, tanks, and systems shall be secured against accidental dislodgement.
Shutoff Valves	A shutoff valve is required for containers and piping to equipment.
Protection from Impact	Guard posts or other approved means shall be provided to protect storage tanks and connected piping, valves, fittings; dispensing areas; and use areas subject to vehicular damage. Container valves shall be protected from physical damage.
Security and Access by Authorized Personnel	Areas used for the storage, use, and handling of compressed gas containers, cylinders, tanks, and systems shall be secured against unauthorized entry and safeguarded in an approved manner.
Containers	Hydrogen storage containers shall be designed, constructed, and tested in accordance with applicable requirements of the ASME[b] Boiler and Pressure Vessel Code and DOT[c] regulations.
Separation from Hazardous Conditions	Aboveground storage of flammable and combustible liquids or liquefied oxygen shall be located on ground higher than the hydrogen storage, except where diking, diversion curbs, grading, or a separating solid wall is provided to prevent liquids accumulation within 50 ft of the hydrogen container.
Fueling Station Piping and Equipment Location	Refueling station systems and equipment shall not be located beneath or where exposed to failure of electric power lines or to piping containing any class of flammable or combustible liquid, other flammable gases, or oxidizing materials.
Bonding and Grounding	Equipment, containers, and associated piping shall be electrically bonded and grounded. Containers and systems shall not be located where they could become part of an electrical circuit nor used for electrical grounding.

[a] Compressed Gas Association.
[b] American Society of Mechanical Engineers.
[c] U.S. Department of Transportation.

continued . . .

Table 4. Derived Codes and Standards for Hydrogen Systems (Energy Efficiency and Renewable Energy, 2004) (continued)

Issue	
Fuel Supply and Storage	Requirement Description
Materials	Materials shall be approved for hydrogen service in accordance with ASME B31.3 for the rated pressure, volume, and temperature of the gas transported. Gray, ductile or malleable cast-iron pipe, valves and fittings shall not be used.
Joints	Joints on piping and tubing shall be listed for hydrogen service, including welded, brazed, flared, socket, slip, or compression fittings. Soft solder joints are not permitted. Threaded or flanged connections shall not be used in areas other than hydrogen cutoff rooms or outdoors.
Valve, Gauge, Regulator, and Piping Component Materials	All valves, gauges, regulators and other piping components shall be listed or approved for hydrogen service for the rated pressure, volume, and temperature of the gas or liquid transported. Cast-iron valves and fittings shall not be used.
Testing	After installation, all field-erected piping, tubing, and hose and hose assemblies shall be tested and proved hydrogen gas-tight for the rated pressure, volume, and temperature of the gas or liquid transported in that portion of the system.
Cleaning	Before placing into hydrogen service, piping systems shall be cleaned.
Pressure Relief Devices (PRDs)	Containers and portions of the system subject to overpressure shall be protected by PRDs.
Temperature-Corrected Fill Pressure Flow Shutoff	A shutoff device shall be required for stopping fuel flow automatically when a fuel supply container reaches the temperature-corrected fill pressure.
Connector Depressurization	Transfer systems must be capable of depressurizing to facilitate disconnection and bleed connections leading to a safe point of discharge.
Compressed Gas Controls	Controls shall be designed to prevent materials from entering or leaving process systems. Automatic controls shall be fail-safe.
Operating and Maintenance	
Vehicle Access	Storage containers shall be accessible to mobile supply equipment at ground level and to authorized personnel.
Ignition Source Control	Ignition sources shall be identified and kept out of the fueling area. Storage and refueling areas must be kept clean and free of combustibles.
Warning Signs	A warning sign with the words "STOP MOTOR, NO SMOKING, FLAMMABLE GAS" shall be posted at the dispensing station and in compressor areas.
Fire Prevention and Emergency Planning	A written fire prevention and emergency plan is required based on the size and location of the refueling station.
Regular Inspections	Stationary containers shall be tested every 5 years, and cylinders shall be examined at each refilling. When containers are filled, PRDs shall be periodically examined externally for corrosion, damage, plugging of external channels, mechanical defects, and leakage.

[a] Compressed Gas Association.
[b] American Society of Mechanical Engineers.
[c] U.S. Department of Transportation.

As mentioned previously, few official standards currently exist for hydrogen use in vehicles. Therefore, standards for CNG were identified. The general CNG and equipment qualifications apply to pressurized system components handling CNG (National Fire Protection Association, 2002). Standards not mentioned in the EERE report focus on compression, storage, and dispensing systems as follows:

- General requirements
  - The fueling connection shall prevent the escape of gas where the connector is not properly engaged or becomes separated.
  - Compression equipment shall incorporate a means to minimize liquid carryover to the storage system.
- Equipment installation
  - Containers shall be protected by painting or other equivalent means where necessary to inhibit corrosion. Horizontally installed containers shall not be in direct contact with each other.
  - PRDs shall have a set pressure not to exceed 125% of the service pressure of the fueling nozzle it supplies.
  - Regulators shall be designed, installed, or protected so that their operation is not affected by outdoor elements.
  - Gauges shall be installed to indicate compression discharge pressure, storage pressure, and fuel supply container fill pressure.
  - Manifolds connecting fuel containers shall be fabricated to minimize vibration and shall be installed in a protected location or shielded to prevent damage from unsecured objects.
  - A bend in piping or tubing shall be prohibited where such a bend weakens the pipe or tubing.
  - A joint or connection shall be located in an accessible location.
  - The use of hose shall be limited to a vehicle fueling hose, inlet connection to compression equipment, and a section of metallic hose not exceeding 36 in. in a pipeline to provide flexibility where necessary. Each section shall be installed to protect against mechanical damage and readily visible for inspection.
  - At public fueling stations, provision shall be provided to recycle gas used for calibration and testing.

- Installation of emergency equipment
  - The fill line on a storage container shall be equipped with a backflow check valve to prevent discharge of gas from the container in case of rupture of the line, hose, or fittings.
  - Where excess-flow check valves are used, the closing flow shall be less than the flow rating of the piping system that would result from a pipeline rupture between the excess-flow valve and the equipment downstream of the excess-flow check valve.
  - An emergency manual shutdown device shall be provided at the dispensing area and also at a location remote from the dispensing area. This device, when activated, shall shut off the power supply and gas supply to the compressor and the dispenser.
  - Emergency shutdown devices shall be distinctly marked for easy recognition with a permanently affixed legible sign.
  - Breakaway protection shall be provided in a manner that, in the event of a pullaway, gas ceases to flow at any separation.
  - A breakaway device shall be installed at every dispensing point. Such a device shall be arranged to separate using a force <150 lb when applied in any horizontal direction.
- Vehicle fueling appliances (VFAs)
  - VFAs shall be listed.
  - VFAs shall not exceed a gas flow of 10 scf/min or be installed within 10 ft of any storage.

The NFPA and the Occupational Safety and Health Administration (OSHA) specifically address hydrogen system requirements. The National Electrical Code (NEC), NFPA 70, focuses on electrical wiring from the meter to the load site. Hydrogen systems are classified as NEC Class I, Group B and require explosion-proof electrical systems. The NFPA 50A standard for gaseous hydrogen systems (National Fire Protection Agency, 1999) covers the requirements for installation where the hydrogen supply to the consumer originates outside the consumer premises and is delivered by mobile equipment. Requirements not mentioned in the EERE guide are as follows:

- Pressure relief devices – PRDs or vent piping shall be designed or located so that moisture cannot collect and freeze in a manner that would interfere with proper operation of the device.
- Equipment assembly – Installation of hydrogen systems shall be supervised by personnel familiar with proper practices with reference to their construction and use.

- Operating instructions – For installations that require any operation of equipment by the user, instructions shall be maintained at operating locations.

- Maintenance – Each hydrogen system installed on consumer premises shall be inspected annually and maintained by a qualified representative of the equipment owner.

- Clearance to combustibles – The area within 15 ft of any hydrogen container shall be kept free of dry vegetation and combustible material.

- Caution – Personnel should be cautioned that hydrogen flames are practically invisible.

NFPA standards are primarily a repetition of OSHA requirements. However, several specifications for gaseous hydrogen systems not mentioned previously are worthy of note as follows (Occupational Safety and Health Administration, 2005):

- Safety relief devices shall be arranged to discharge upward and unobstructed to the open air in such a manner as to prevent any impingement of escaping gas upon the container, adjacent structure, or personnel.

- For this system, a special room or inside buildings, exposed to other occupancies, is permissible; however, it is preferred that gaseous hydrogen systems are located outside or in a separate building.

- The minimum distance from a hydrogen system of indicated capacity located outdoors, in separate buildings, or in special rooms to any specified outdoor exposure shall be in accordance with Table 5 specific to this system.

PERMITTING AND SITE LOGISTICS

As with any construction-type project, several permitting and inspection requirements must be met. In addition, this project required that utilities be brought to the system location. Appendix A contains permit approvals received at the time of this writing.

Permits

NEPA

The EF1 Environmental Checklist was submitted online on March 23, 2005, for review by DOE. At the time of this writing, no results from DOE were available regarding the NEPA.

Table 5. Hydrogen System Distance Requirements for Outdoor Exposure

Type of Outdoor Exposure		Minimum Distance, ft[a]
Building or Structure	Wood frame construction	10
Wall Openings	Not above any part of a system	10
	Above any part of a system	25
Flammable Liquids Above Ground	0–1000 gallons	10
	In excess of 1000 gallons	25
Flammable Liquids Below Ground (0–1000 gallons)	Tank	10
	Vent or fill opening of tank	25
Flammable liquids below Ground (>1000 gallons)	Tank	20
	Vent or fill opening of tank	25
Flammable Gas Storage, Either High Pressure or Low Pressure	0–15,000 ft^3 capacity	10
Oxygen Storage	12,000 ft^3 or less	Refer to NFPA 51[b]
Fast-burning solids such as ordinary lumber, excelsior, or paper		50
Slow-burning solids such as heavy timber or coal		25
Open flames and other sources of ignition		25
Air compressor intakes or inlets to ventilating or air-conditioning equipment		50
Concentration of people in congested areas such as offices, lunchrooms, locker rooms, time-clock areas.		25

[a] These distances (except for wall openings, air compressors, and concentrations of people) do not apply where protective structures such as adequate fire walls are located between the system and the exposure.
[b] NFPA 51: Standard for the Design and Installation of Oxygen–Fuel Gas Systems for Welding, Cutting, and Allied Processes.

NDSU

A formal request was submitted on May 10, 2005, to Mr. Bruce Bollinger of NDSU for approval to construct a concrete slab and place the hydrogen fueling station at the NDSU NCREC near Minot. Formal approval was granted by NDSU on June 9, 2005, via e-mail notification. A copy of the e-mail is included in Appendix A. Contractual details regarding property access and insurances are being negotiated between NDSU and BEPC.

Local

The city of Minot does have a permitting process under which jurisdiction for this project falls. The subject property is zoned as “Public.” The city of Minot planning requirements dictate that the Minot Planning Commission review and approve any planned construction. A planning review document was submitted July 1 for review by the Planning Commission at its July 25 meeting. The City of Minot Planning Commission approved the permit request for the proposed hydrogen fueling system during the July 25 meeting.

Inspections

Fire

Mr. Ray Lambert with the of North Dakota Fire Marshall's Office was notified and provided with details regarding the project on March 11, 2005. Mr. Lambert indicated that the Fire Marshall's Office does not issue permits but appreciated being informed about the project.

Electrical

On March 11, 2005, Mr. Ron Ihmels, District 4, North Dakota Electrical Inspector, was informed of the proposed project. Mr. Ihmels indicated that a qualified electrical contractor would need to be hired and the contractor would need to acquire the appropriate electrical permits. In addition, the hydrogen system will be required to have an Underwriters Laboratory certification or equivalent obtained from a nationally recognized testing laboratory (NRTL) as designated by OSHA. Stuart Energy will be utilizing Entela, Inc., an OSHA-approved NRTL, to perform the electrical certification on the hydrogen fueling system prior to delivery of the hydrogen fueling system.

Logistics

Utilities

In association with the proposed system, three utilities needed to be addressed: electrical service, water supply, and waste discharge.

Electric

Electrical service will be brought to the site from the existing electrical service in accordance with electrical codes. The system electrical load requirements are 480-V AC nominal, 60-hertz, 3-phase power.

Water

The electrolyzer/hydrogen fueling system requires water as a feed source to the electrolyzer. For this reason, rural water will be brought to the system site. The nominal feed water requirement at 100% capacity is 15 gal/min at a pressure between 20 and 50 psi gauge. The proposed system will only operate at 100% periodically.

Sewer

The system being proposed has several discharge options, one of which is a zero-discharge option. Each discharge scenario has advantages and disadvantages. For this application, the zero-discharge option is the most appropriate to eliminate the need for sewer service and to limit the associated permitting requirements. This is because a sewer system is unavailable and because issues associated with environmental permitting must be minimized.

PRODUCT END USE

This section reports the results for obtaining hydrogen-powered vehicles (or equipment) that use either fuel cell technology, hydrogen hybrid (coupled to an electric motor) internal combustion engine (HH-ICE) or hydrogen internal combustion engines (H-ICE), or multifuel (hydrogen/gasoline, hydrogen/diesel, or hydrogen/ CNG engine conversion units. In an effort to understand the details of using dry gaseous fuels in an ICE, CNG/gasoline conversion kits were also investigated. The options are delineated in Table 6.

Most of the details for each option investigated were obtained through conversations with technical personnel from product manufacturers. Some of the individuals contacted also submitted informal proposals for review. These written proposals were received from Hydrogen Car Company (HCC) in California, Ford Motor Company in Michigan, AFVTech in Arizona, and Alternative Energy Products Laboratory Division of the Saskatchewan Research Council (SRC) in Saskatchewan.

With the exception of the fuel cell-powered vehicles and the Ford E-450 Shuttle Bus, all conversions would be performed on customer-supplied vehicles. For warranty validation, this would necessitate transporting the vehicle to and from the manufacturer's shop or a facility designated by the supplier of the conversion kit. The summary of results for the feasibility of vehicle procurement is included in Table 7.

FUEL CELL-POWERED VEHICLES (FCVs)

Fuel cell research is presently being conducted by most of the automotive or transportation manufacturers worldwide. Only a small percentage of these developers have progressed to the point of offering this technology for sale in the near term. Others are not as optimistic and are simply claiming ongoing development. In all cases, where a product is either available

Table 6. Commercial Hydrogen Vehicle Options and Capabilities

Power Plant Type	Fuel Capability	Vehicle Platforms
Fuel Cell	Hydrogen only	All lift trucks and smaller vehicles more available than buses or cars.
HH-ICE	Hydrogen only and electric	Bus
H-ICE	Hydrogen only	Shuttle bus, trucks, cars
Multifuel, CNG	CNG, HCNG (hythane), switch-over to gasoline capability	Shuttle van, trucks
Multifuel, gasoline	Hydrogen with switch-over to gasoline capability	GM 2500 truck
Multifuel, diesel	Hydrogen with switch-over to diesel capability	GM 2500 truck
Multifuel, CNG/gasoline	Hydrogen with switch-over to CNG or gasoline capability	Chevrolet Express Van
Conversion Kits	CNG/gasoline automatic switching	GM and Ford engines

Table 7. End-Use Vehicle Report

Option	Manufacturer/Supplier	Description	Cost	Delivery Time
Fuel Cell (these vehicles operate using 100% hydrogen-powered fuel cells only)	Hydrogenics Corp./ GEM	Neighborhood Electric Vehicle	$25K–$30K	6 months
	Hydrogenics Corp./ ePower Synergies, Inc.	Commercial transports, lift trucks, and ice refinishers; 4×6 Gator Delivery van	Lift truck: $150K Gator: $150K–$200K Delivery van: $250K $500K	3–6 months
	Astris Energi, Inc.	Golf cart (alkaline fuel cell)	$30K	3 months
	Quantum Technologies	Electric golf-cart style	$25K plus cost of base vehicle	6 months
	Clean-Tech LLC	Quad ATV/light duty on- or off-road vehicle	$25K–$30K	3 months
	Renewable Power Solutions	Quad/ATV (PEM[a]) Island golf cart (PEM) Reva (FCV[b])	$25K $20K $32.5K	1 month 1 month 3–4 months
	TransTeq LLC	12–22 passenger Ford FAST cutaway shuttle bus 45-foot, 60-passenger shuttle bus	$1M $1.2M	6–9 months
	ISE Corporation	60-passenger full-size bus	$2M+	6–8 months
HH-ICE (these vehicles operate using a 100% hydrogen-fueled ICE/electric motor hybrid system only)	ISE Corporation	60-passenger full-size bus	$850K	6 months
H-ICE (these vehicles operate using a 100% hydrogen-fueled ICE only; no switch-over fuel options are possible)	Ford Motor Company	8–12-passenger shuttle van	$250K for 2–3-year lease	9–12 months
	TransTeq LLC	15–22-passenger FAST cutaway Ford shuttle van	$300K–$400K	6–9 months
	Quantum Technologies, Inc.	Toyota Prius Shuttle Bus	$60K plus cost of vehicle $200K–$250K for shuttle	6 months 12 months

[a] Proton exchange membrane.
[b] Fuel cell vehicle.

continued . . .

Table 7. End-Use Vehicle Report (continued)

Option	Manufacturer/Supplier	Description	Cost	Delivery Time
	ETEC	GM 1500 HD Series Pickup	$120K–$130K plus cost of truck	6 months
	HCC	Ford Ranger, Explorer, Freestar, F-150, Expedition SUV, or Econoline van	$50K–$55K plus cost of vehicle	3 months
	PowerTech Labs	GM 1500 HD Series Pickup	Lease for $1.5K–$2K per month	9-12 months
CNG/HCNG/ Gasoline Conversions (these vehicles operate on a variable mixture of 100% CNG, or HCNG blend, and 100% gasoline with an automatic switch-over)	Collier Technologies, Inc.	Ford 5.4-L CNG platform; GM platform in work	$12.5K plus cost of CNG vehicle	1 month
	TransTeq LLC	15–22 passenger FAST cutaway Ford shuttle van	NA	NA
Hydrogen/Gasoline Conversions (these vehicles operate on a variable mixture of 100% hydrogen and 100% gasoline, or diesel, with an automatic switch-over)	Alternative Energy Products Laboratory (a division of SRC)	GM 2500 or HD pickup trucks with 6.0-L (modifications for diesel are in progress); capable of switching between both fuel sources automatically	$305K plus cost of vehicle (cost of two vehicles is $170K each)	1 month
Hydrogen/CNG Conversions (these vehicles operate on a variable mixture of 100% hydrogen and 100% CNG, or gasoline, with an automatic switch-over)	AFVTech	2005/2006 Chevrolet Express Van with KL-5 heads; capable of switching between either fuel sources automatically	$21K plus cost of vehicle and hydrogen storage tanks, which are $15K–$20K. Total cost is $36K–$41K plus cost of vehicle	1-3 months

[a] Proton exchange membrane.
[b] Fuel cell vehicle.

continued . . .

Table 7. End-Use Vehicle Report (continued)

Option	Manufacturer/Supplier	Description	Cost	Delivery Time
CNG/Gasoline Conversions (these vehicles will cold start on gasoline and can automatically or manually switch-over to CNG. After the CNG source is depleted, the vehicle will autoswitch to gasoline)	DRV/ECO Fuel Systems	Basic underhood conversions for select GM and Ford engines	\$4.5K for basic kit plus CNG tanks (\$3K–\$5K each) all plumbing and installation (\$2K–\$3K)	1 month
	Baytech Corp.	Basic underhood fumigation conversion for older GM engines; direct, sequential-port injection for GM engines with KL-5 heads	Fumigation: \$3.5K Injection: \$5K–\$6K for CNG and \$7K–\$8K for HCNG, plus cost of storage tanks and all plumbing	1 month
	Clean-Tech LLC	Uses DRV/ECO and Baytech underhood CNG kits	\$10K plus cost of storage tanks and all plumbing	1 month
	Technocarb Equipment Ltd.	Basic underhood fumigation conversion for some GM engines; direct, sequential-port injection for some GM engines with KL-5 heads	Fumigation: \$1.7K–\$3K. Injection: \$3K–\$4K plus cost of storage tanks and all plumbing	< 1 month
	Hybrid Fuel Systems, Inc.	Simple underhood CNG delivery system for heavy-duty diesel engines only	\$4.5K plus cost of storage tanks and all plumbing	< 1 month
	Parnell USA, Inc.	Basic underhood conversions for select Ford (5.4-L) engines	\$8K–\$10K with 16–18-GGE tanks, \$10K–\$13K with 24–26-GGE tanks, plus cost of all plumbing	1 month

[a] Proton exchange membrane.
[b] Fuel cell vehicle.

(0–6 months) or will soon become available (6 months to less than 1 year), the current projected costs are very high depending on the intended application of the vehicle.

Small, short-range neighborhood type vehicles, golf carts, or scooters, can range between \$25K and \$50K. Hydrogenics Corporation in Canada and Global Electric Motorcars (GEM) in North Dakota have developed a demonstration neighborhood electric vehicle (NEV) that may be available soon for extended site demonstrations through ePower Synergies, Inc. (ePSI), of Illinois. Astris Energi, Inc., of Canada has placed alkaline fuel cell technology in a golf cart-type vehicle that is currently available for about $30K, lower if ordered in quantity. Various European manufacturers claim to have fuel cell-powered scooters available for the local home market. ePSI claims to be familiar with at least four models that were displayed at the European EVS-21 Conference earlier this year; however, no current pricing or availability could be confirmed.

The cost for material-handling equipment, delivery vehicles, and special purpose vehicles (lawn mowers, commercial transports, lift trucks, and ice refinishers) can range between $150K and $500K. Information from ePSI states the John Deere 4×6 Gator could be available for lease through Hydrogenics by the end of 2005 at a cost of $150K to $200K; a Hyster Class I lift truck would be available in 3 to 4 months at a cost of around $150K, also through Hydrogenics; TORO has developed a Greens Mower, but there is no current pricing or availability information; small delivery step-van-type vehicles are presently being demonstrated by Purolator Package Delivery Service in Toronto and within a year may be offered for sale at a cost between $250K and $500K; and based on conversations between the EERC and ePSI, a fuel-cell powered ePower-Olympia ice refinisher may soon find its way to North Dakota. Other types of fuel cell-powered equipment (backhoes, garbage trucks, and trolleys) are planned through ePSI and Hydrogenics; however, the funding sources are still being secured.

Quantum Technologies is offering a fuel cell-powered utility vehicle that is suggested for use in an airport or university setting. A base electric, golf cart-type vehicle would be provided to Quantum Technologies, and for about $25K, Quantum Technologies will convert the vehicle to use a fuel cell. This conversion process is scheduled to be available by the end of 2005. Quantum Technologies has also developed a fuel cell-powered all-terrain, off-road vehicle. No further details are available on this vehicle.

Clean-Tech LLC in California will soon be offering (end of summer 2005) a fuel cell-powered Quad ATV/light-duty vehicle for on- and off-road use at an estimated cost of $25K to $30K.

Renewable Power Solutions (RPS), also in California, is offering two hybrid electric FCVs that target the personal outdoor activities market. The first vehicle is a four-wheel off-road all-terrain vehicle (ATV) that uses a PEM fuel cell combined with lithium or nickel metal hydride batteries. The cost of this vehicle is $25K, and it can be delivered in about 1 month after receiving the order with a deposit. The second FCV is known as a Special Edition Island Golf Cart that also uses a PEM fuel cell, costs just under $20K, and can be delivered in 4 weeks after receiving the order with a deposit. RPS is just beginning to enter into the highway vehicle market by introducing the Reva Car. This FCV is also a battery/electric hybrid manufactured in India and will be considered a low-speed vehicle in the United States, even though it is considered a highway vehicle in most other countries. The introductory price for this vehicle will be $32.5K free-on-board (FOB) Los Angeles and is expected to be available for delivery in 3 to 4 months.

For full-sized, heavy-duty 12–60-passenger buses, the cost is extremely variable, ranging from $1M to $2M (or more). All FCVs being developed by the major automotive manufacturers are either no longer offered for sale or have strict conditions related to how and where the vehicle can be used. In the passenger bus industry ISE and TransTeq offer to sell a fuel cell-powered bus. TransTeq currently has a fuel cell version of the 12-to 22-passenger Ford FAST cutaway shuttle bus available for around $1M, and a 45-foot, 60-passenger shuttle bus for $1.2 M. Delivery on either of these vehicles is 6 to 9 months from receipt of purchase order. ISE Corporation offers a large heavy-duty passenger fuel cell bus for $2M+; however, it is not yet available in large quantities, and delivery is in the 6- to 8-month time period.

HYDROGEN HYBRID INTERNAL COMBUSTION ENGINE (HH-ICE OR H2-ICE)

Very few possibilities were found for this configuration. ISE Corporation (in combination with New Flyer and SunLine Transit) was the only manufacturer that has an engine/vehicle platform currently offered for sale. This configuration uses a hydrogen-powered ICE (the Ford Power Products V-10) to generate electrical power that runs electric motors to power the vehicle. ISE offered a hydrogen hybrid full-sized bus for $850K with a 6-month delivery. This cost decreases to $700K with quantities of 10 or more and to $620K with 100 or more.

HYDROGEN INTERNAL COMBUSTION ENGINE (H-ICE)

This engine/vehicle system has a few more possibilities to offer than the other engine options previously discussed. The primary goal of this category is to bridge current gasoline ICE technology to FCVs. This concept will put hydrogen-powered vehicles on the road in the shortest time frame and in a more cost-effective manner than fuel cell technology alone.

Ford is the only major automotive original equipment manufacturer (OEM) to offer a dedicated (100%) hydrogen-powered ICE/vehicle system, which is built as an E-450 shuttle bus. These shuttles would remain the property of Ford Motor Company because of their prototype status and would be made available only by a lease agreement for customer use during a period of 2 or 3 years. Ford will also retain all intellectual property. The shuttle bus cost is $250K for the entire 2-to 3-year lease term as determined by Ford and the customer. It is expected that 50% of the vehicle price will be payable within 30 days of the agreement signing, and the remainder will be due upon delivery. All hydrogen system-related maintenance will be the responsibility of Ford Motor Company. Ford will provide training on use of the hydrogen system and on diagnostics for the system. During the lease period, the customer will be responsible for all normal vehicle maintenance and upkeep as defined by the standard Ford warranty. The customer will be required to have special tools on hand, cost for which will be shared 50–50 with Ford. These tools will remain the property of Ford. Ford Motor Company will monitor all vehicle performance and usage during the lease period to ensure ongoing customer satisfaction and satisfactory vehicle operating performance. All of the vehicles will be equipped with a telematics system allowing monitoring of vehicle function and system function from a remote location. It is expected that the fleet customer will work with a third party to install and operate a hydrogen-fueling infrastructure. Ford's experience with similar demonstration projects has shown that fleet customer facilities with central fueling, storage, and maintenance are the key to a successful program. To keep operating and maintenance costs low, Ford is further requesting a minimum of five vehicles be leased in close proximity to each other. The final details of this portion of the request are not clear at this time, and Ford indicated it will not rule out any discussions by potential customers.

TransTeq is offering its version of a FAST cutaway Ford-chassis shuttle van that would seat 15 to 22 passengers in a dedicated hydrogen-powered ICE for between $300K and $400K based on a single, demonstration-class vehicle. Delivery is expected 6 to 9 months from receipt of the order, depending on the availability of parts.

In addition, three non-OEM vehicle/engine developers were found to offer complete H-ICE systems for sale. These developers would be provided a specific vehicle/engine family package, and they would retrofit a complete, dedicated hydrogen combustion system to the base vehicle.

Quantum Technologies, Inc., is currently producing 36 dedicated hydrogen-powered Toyota Prius vehicles for use across southern California. The cost of this platform is $60K excluding the base price of the new Toyota Prius (which is approximately $30K), and delivery would be anticipated for late 2005. Quantum Technologies has also indicated it may have the ability to offer a shuttle bus for sale in mid-2006 at a unit cost ranging from $200K to $250K. No further details were disclosed at this time.

Electronic Transportation Engineering Corporation (ETEC) is currently offering a GM 1500 HD series full-size crew-cab pickup truck conversion to dedicated hydrogen power. The cost for this complete conversion, which would be done on a new or customer-supplied, 6.0-L V-8 vehicles, is between $120K and $130K with an estimated delivery by the end of 2005. This conversion is actually performed by Rouch Industries in cooperation with ETEC. Further investigation has shown that PowerTech Labs in Vancouver, British Columbia, could offer this same package as a lease for between $1500 and $2000 a month with an expected availability by the end of 2005, and delivery by early to mid-2006.

Hydrogen Car Company (HCC) is currently working with the Ford engine/vehicle platform. Their currently developed platforms include the Ford Ranger, Explorer, Freestar, F-150 pickup truck, Expedition SUV, and Econoline van. HCC replaces the stock engine with a naturally aspirated 5.7-L V-8, modifies the existing computer program, and adds the hydrogen storage tanks and all associated electronics and hardware to make it run on a dedicated hydrogen fuel source. This conversion would be performed on a customer-supplied vehicle, and the proposed cost of converting one of these vehicles with a 5-gallon gasoline equivalent (GGE) would be between $50K and $55K. The project vehicle delivery is anticipated 3 months after receiving the order.

CONVERSIONS

CNG/HCNG/Gasoline

The systems investigated under this option use CNG, a blend of hydrogen and CNG known as HCNG or Hythane®, or gasoline. Hythane® is a trademarked term referring to either a 70/30 of 80/20 blend of CNG and hydrogen and is commonly referred to as HCNG. The CNG is blended with hydrogen at the pump station before the on-vehicle tank is filled, and this gas mix tank is usually at the standard CNG pressure, which is around 350 psi. A vehicle converted to run on HCNG can be done for a lower cost than for pure hydrogen; however, in addition to a hydrogen source, a source of CNG is also required as is a mechanism to do the actual blending at the refueling site. The cost of the CNG and blending equipment was not obtained at this time.

Most of Collier Technologies, Inc.'s (Nevada) current experience is with the Ford 5.4-L CNG engine. Collier Technologies' technical people indicate they can convert any Ford vehicle with the 5.4-L dedicated CNG engine to run on CNG or HCNG. The single kit cost is $12.5K with the expected delivery about 1 month after the order is received. Since the base vehicle is already CNG-prepared, fuel storage tanks compatible with CNG/HCNG are part of the vehicle package and are on the vehicle. The HCNG conversion would use the same tanks since it does not require special storage tanks because of the low pressure of the blended gas. Collier Technologies further indicated it is currently working with Baytech Corp. to offer a CNG/HCNG/gasoline conversion kit for GM vehicles. At this time, no further information on this kit is available.

TransTeq indicated that it would be able to offer its FAST cutaway Ford-chassis shuttle van in a CNG/HCNG-powered ICE at a lower cost than the dedicated hydrogen vehicles. However, at this time, no further information was obtained for this option.

Hydrogen/Gasoline or Diesel

The Alternative Energy Products Laboratory Division of the SRC in Saskatoon, Saskatchewan, is currently offering a hydrogen/gasoline (or diesel) retrofit system that is designed for installation in GM 2500 series pickup trucks with a 6.0-L gasoline engine and also claims to be working on a similar system for the Duramax diesel engine if development can be successfully completed by the end of summer 2005. Either of these vehicles, on average, will substitute from 30% to 50% hydrogen for gasoline (or diesel), depending on the load. At idle and very light cruise, the vehicles operate on up to 100% hydrogen, while maximum power is supplied on 100% gasoline (or diesel), they are automatically switched to 100% gasoline (or diesel) upon depleting the hydrogen fuel tanks. These conversions would be done on customer-supplied late model (2003–2006) GM 2500 or 2500HD trucks equipped with a 6.0-L gasoline (or 6.6-L diesel) ICE. Each vehicle ordered would be equipped with a storage tank assembly (3.5-kg storage tank rated for 5 ksi fueling probe, quarter-turn valve, and a high-pressure regulator), tank enclosure, under-hood assembly (injectors, low-pressure regulator, and ground fault indicator valves), electronic control module, safety and instrumentation system (four hydrogen detectors, pressure, temperature, manifold pressure, and engine speed), and wiring harness (for 16 injectors, gas detection system, and safety shutdown system). The cost of this conversion would be approximately $305K (plus the cost of the vehicle) and would be completed about 1 month after receipt of the customer vehicle. Conversion of two vehicles lowers the cost to approximately $170K each, and delivery would be one a month.

Hydrogen/CNG

AFVTech in Arizona is offering a hydrogen/CNG conversion on a customer-supplied 2005 or 2006 Chevrolet 3500 Express Van with a 6.0-L engine with the KL-5 cylinder head option. This conversion can be done on any van meeting the specifications given by AFVTech with less than 30,000 miles or 1000 hours of operation. In addition to the vehicle, the customer must also supply the hydrogen storage tanks equivalent to a 6 or 7 GGE. Approximate cost for these tanks and configuring the tanks to the vehicle is $15K to $20K, with delivery of the tanks and modifications to the vehicle taking up to 2 months. AFVTech will supply the conversion system, pollution control module reprogramming, fuel injectors, all high-pressure plumbing and regulators, wiring, fuel selector switch and secondary fuel gauge, laptop computer with diagnostic programming, spark plugs and wires, and technician training. The cost of the conversion with components specified above is about $21K, and delivery would be within 1 month after receipt of the vehicle at AFVTech in Arizona.

CNG/Gasoline

The systems discussed in this section are either underhood or complete conversion kits. The underhood kits consist of all hardware, plumbing, and electronics necessary to make the system functional. These kits do not include the low-pressure CNG fuel storage tanks, quarter-turn shutoff valves, plumbing to engine, or fueling probes with valves. The complete kits include everything needed to make the system fully functional. Most of the conversion kits offered start the engine on gasoline and switch to CNG after 90 seconds or until the induction system has reached a preset temperature. Two of the manufacturers (Technocarb Equipment and Baytech Corporation) offer both a fumigation system and a sequential, direct port injection system. The others offer only the sequential systems. The fumigation system introduces the CNG either before or after the carburetor, and the gas is drawn into the cylinders during the intake part of the ICE cycle. These systems are lower in cost and easier to install but suffer from several problems, including backfires and poor performance. The sequential direct-port systems inject the gas directly into each cylinder and are carefully metered and monitored by the onboard vehicle computer system. Performance is vastly improved, and backfires are virtually eliminated; however, installation is complex, and the kits are more costly. Most of the CNG conversion companies that were queried have tried some type of hydrogen injection or fumigation system and either stopped pursuing it or indicated they may return to hydrogen later.

DRV Energy in Oklahoma combined with ECO Fuel Systems in British Columbia offers conversion kits for five GM engines (4.3-L, 5.3-L, 6.0-L, 6.8-L, and 8.1-L) and three Ford engine platforms (4.6-L, 5.4-L, and 6.8-L). The basic underhood kit costs $4500, and tanks cost anywhere from $3000 to $5000. Labor for installation by DRV Energy is about $1500. Turnaround time can be up to 1 month after receipt of the customer-supplied vehicle.

Baytech Corporation in California offers the fumigation system conversion kits for older GM engines and the direct-port, sequential injection kits for GM engines with the KL-5 heads. Either conversion system is sold only to GM-certified shops. The fumigation system is sold as an underhood system only (without storage tanks and all the other components needed to make the system functional) and costs $3500. For the sequential system, the underhood system cost is $5000 to $6000 for CNG fuel and $7000 to $8000 for HCNG fuel. The estimated installed cost for a complete sequential system with tanks, valves, and plumbing is around $20K. Baytech technical staff claims its program can be optimized for only two fuels: either gasoline and CNG or CNG and HCNG. Thus a system using either of these two fuel combinations can be specified. Turnaround time can be up to 1 month after receipt of the customer-supplied vehicle.

Clean-Tech LLC in California uses DRV/ECO and Baytech CNG conversion kits for the specific GM engine platform. The installed cost of its underhood CNG conversion is around $10K plus the cost of the tanks, plumbing, and valves (shutoff and refill). Turnaround time can be up to 1 month after receipt of the customer-supplied vehicle.

Technocarb Equipment Ltd. in British Columbia offers the CNG underhood fumigation system conversion for most GM vehicles at a cost of $1700 to $3000 and an underhood direct, sequential injection system for specific families of GM vehicles at a cost of $3000 to $4000. They do not offer any of the other parts needed to complete the system (storage tanks, fuel lines, refill valve, and quarter-turn shutoff valve). Availability of these kits is 1 to 2 weeks. A full system design with detailed costs for targeted GM vehicles would be available by contacting Carburetor and Turbo Systems in Minnesota.

Hybrid Fuel Systems, Inc., in Georgia primarily offers an underhood CNG fuel delivery system designed for use on diesel engines. At this time, the engine platforms are heavy-duty diesel engines including Mack, Cummins, and International. The cost for an underhood kit would be about $4500 without storage tanks, fuel lines, refill valve, and quarter-turn shutoff valve. Turnaround time for converting the engine would be 2 to 3 weeks. This manufacturer expressed an interest in the possibility of developing an HCNG/diesel conversion system in the near future.

BAF Technologies in Texas is offering complete CNG conversion kits on the Ford 5.4-L and 6.8-L and the GM 8.1-L engine platforms. Cost for the complete conversion system on a customer-supplied Ford vehicle is between $10K and $11K for 12- to 15-GGE tanks and around $17K to $18K for 30-GGE tanks. The GM 8.1-L with 50- to 60-GGE tanks would cost around $25K. Turnaround time can be up to 1 month after receipt of the customer-supplied vehicle.

Parnell USA, Inc., in Arizona offers a complete CNG conversion kit for the Ford 5.4-L engine platform. The cost for a complete conversion depends on the basic tank storage capacity. A 16- to 18-GGE tank system would cost between $8000 and $10K, while a 24- to 26-GGE system would cost between $10K and $13K. Turnaround time can be up to 1 month after receipt of the customer-supplied vehicle.

CONCLUSIONS

It is anticipated that the wind-to-hydrogen project will provide an excellent platform for development of dynamic scheduling of wind power for hydrogen production and provide a working example to help facilitate the future development of renewable based hydrogen energy. The project has been fully described regarding equipment, layout, and concepts for testing. The location in Minot, North Dakota, will utilize electrolytic hydrogen production for refueling vehicles with electric power dispatched from various wind turbine sites owned by BEPC. Operation will include several shakedowns, and “real-world” operational scenarios given wind scheduled power. Stuart Energy was selected to provide the hydrogen refueling station sized to provide 30 Nm^3/hr and including 100 kg of storage capacity. Regarding utilization, the capacity could fuel a regularly operated bus or a small fleet of vehicles. The most likely approach regarding vehicle fueling will be to retrofit North Dakota state fleet vehicles for hydrogen operation with switch-over capability to gasoline. AFV Tech was identified as the most likely supplier for hydrogen fueling technology with the capability to retrofit Chevrolet 3500 express vans for approximately $40,000. Fumigation technology options would be a lower-cost second choice for fleet vehicles. All other hydrogen-based vehicle options were significantly more expensive.

Study for dynamic scheduling was determined and economics evaluated. Four modes of operation were selected. Mode 1 includes a relative zero-net effect on the grid by scaling of hydrogen production with power production from the turbines. Mode 2 is a modification of Mode 1 to include utilization of off-peak power to supplement wind generated power. Mode 3 includes improved economics by operation of the electrolyzer at full capacity and only curtained when wind generated power is not available, and Mode 4 is Mode 3 modified to accept off-peak power. The software and hardware required to conduct the testing will include a PWRM ION Enterprise system. The economics for the wind-generated power at 30 Nm^3/hr equate to approximately $20/gallon equivalent to gasoline for Mode 1 and $10/gallon equivalent to gasoline for mode 4. Certainly, a larger-scale electrolyzer could produce economics closer to $3/gal; however, the capital costs for such a unit are not within the budgetary scope of this project. A sensitivity analysis revealed that best-case scenario costs could yield a production price for hydrogen of $2.32/kg and a worst-case of $29.84/kg.

The project will comply with all relevant safety standards, and procedures for construction approval have been identified and are in process. A case is justified to follow NFPA Standard 52, and recommendations from DOE are provided in Table 2. A NEPA permit is currently in process with DOE. Formal approval has been granted to construct on the property of NDSU. Zoning has been reviewed with the adjacent city of Minot. The local fire marshall has been notified, even though a permit is not required. UL and OSHA requirements have been reviewed with the local electrical inspector and provisions are being made to assure that Stuart Energy will deliver equipment that complies with the inspector's requirements. Adequate electric, water, and sewer utilities are currently available at the project site.

The logistics, economics, process description, and operation are described in this feasibility study. The project is positioned to provide an excellent platform for development of dynamic scheduling of wind power for hydrogen production and provide a working example to help facilitate the future development of renewable-based hydrogen energy.

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APPENDIX A

PERMIT APPROVALS

Stevens, Brad

From:	Bruce Bollinger [bbolling@ndsuext.nodak.edu]
Sent:	Thursday, June 09, 2005 9:19 AM
To:	bstevens@undeerc.org
Cc:	k.grafton@ndsu.nodak.edu; gina.a.haugen@ndsu.nodak.edu; bruce.bollinger@ndsu.nodak.edu; jay.fisher@ndsu.nodak.edu
Subject:	Approved Request of your proposal dated May 10, 2005

Brad,
Dr. Ken Grafton, Dean and Director of the Agricultural Experiment Station has approved your project request. Your request was also approved by the Office of the V.P. for Business and Finance at NDSU.
Upon approval from Jay Fisher. Please proceed with your plan on locating the piece of equipment at the North Central Research Extension Center.
Bruce Bollinger

Bruce Bollinger
Director Ag Budget Office
North Dakota State University
P.O. Box 5437
Fargo, ND 58105-5437
Phone 701/231-8116 Fax 701/231-7510
Bruce.Bollinger@ndsu.nodak.edu

MEETING RESUME

Planning Commission
Regular Meeting
July 25, 2005
Page 1

SUMMARY OF ACTION

Members Present:

Arneson, Berning, Dammen, Eggen, Hoffart, Curl-Langager, Langseth, Miller, Schempp and Semrau

Members Absent:

Conway, Hight and Volk

Others Present:

City Planner, City Engineer, City Attorney, City Assessor, Building Official, Public Works Director, Fire Marshal, Airport Director, Damon Druse, Rolly Ackerman, Alan Estvold, John Coughlin , Dean Feist, Bruce Walker, Mike Probst, Greg Oase, Aldermen Somerville, Boen and Krabseth

Approval of Minutes:

The minutes of the June 27, 2005 and July 11, 2005 meetings were approved by unanimous vote.

1. **That the City Council pass a motion approving the request by George McLaughlin to subdivide the unplatted portion of SW1/4SE1/4, Section 33-156-83 to be known as Outlot 3, Section 33-156-83. Also, to pass an ordinance to change the zone from AG (Agricultural District) to R-A (Agricultural Residence District) on proposed Outlot 3, Section 33-156-83. This property is located north of County Road 10 and west of 30th Street NW.**

   Approval of this item is subject to the following conditions:
   1. **That a rural sanitary sewer study be required prior to issuance of a building permit, and**
   2. **Driveway access to highway must be approved by County Engineer.**

The above motion by Langseth, seconded by Miller and carried unanimously.

SUMMARY OF ACTION

2. That the City Council pass an ordinance approving the request by Gene Krebs to change the zone from C-2 (General Commercial District) to M-1 (Light Industrial District) on Lots 11 & 12, North Side Addition, for the purpose of constructing mini-storage units. This property is located west of Main Street North and south of 36th Avenue NW.

The above motion by Langseth, seconded by Miller and carried unanimously.

3. That the City Council pass a motion approving the request by the City of Minot – Airport to subdivide the unplatted portion of W1/2SW1/4NW1/4 and W1/2NW1/4SW1/4, Section 12-155-83 to be known as Minot International Airport Second Addition. This property is located at 25 Airport Road.

The above motion by Langseth, seconded by Miller and carried unanimously.

4. That the City Council consider without recommendation the request by Brad Beeter and Sharon Morey to subdivide Lots 3 & 4, Block 1, Oens Addition, into 2 lots to be known as Lots 1 & 2, Oens 2nd Addition. Also, to change the zone from R-1 (Single-Family Residence District) to C-2 (General Commercial District) on proposed Lot 2, Oens 2nd Addition. This property is located at 502 7th Street NE.

Bob Goodwin explained that the house on the property would be remodeled by Mr. Beeter. He indicated that Ms. Morey wanted to keep the storage building for private storage for herself. Semrau read a letter of protest from the Public Works Director. The letter indicated that the storage building will be out of compliance with the zoning rules if the subdivision is allowed. Goodwin indicated that the building was already non-conforming. Bye stated that the Board of Adjustment approved a variance in 1994 for a reduced front yard setback from 25 feet to 20 feet and a variance for the square footage of accessory building. She indicated that if the request were approved the rear setback for the building would be required to be 25 feet when abutting a residential property. Also, the Commission discussed a variance to create one non-conforming C-2 zoned lot in respect to front and rear yard setbacks. Following due consideration, motion by Curl-Langager, second by Dammen to deny the request. Motion does not pass due to a tie in voting. Motion by Schempp, second by Langseth to pass the item on to City Council without a recommendation from the Planning Commission. Motion passed unanimously.

SUMMARY OF ACTION

5. **That the City Council pass a resolution to approve a request by Bruce & Diane Walker for a special use permit to offer apartment garages to people for rent other than apartment tenants, on Block 1, Lakeside Addition, less the north 185' and less Lot A. This property is located at 900 21st Avenue NW.**

 Approval of this item subject to the following condition:
 1. That no signage be allowed advertising the storage facilities.

Bruce Walker passed out pictures of the garages. He indicated that they would be regular residential garages and would not look like mini storage buildings. He stated that he has made many improvements to the property over the last 10 years. He stated that a special use permit to rent out some of the garages would be the best fit for the situation. He indicated that there would be minimal effect on traffic in the area. The City Attorney asked if Mr. Walker would be willing to have it written into the special use permit that signage would not be allowed for advertising the storage facility. Mr. Walker was in agreement. Following due consideration motion by Schempp, second by Curl – Langager to approve the request. Motion passed 9 yes votes to 1 no vote with Semrau voting no.

6. **That the City Council pass a motion to approve a request by Feist Construction to subdivide a portion of Blocks 4, 5, & 6, Edgeview Estates 1st Addition and a portion of Lot 2, Duchsherer Addition into 71 Lots to be known as Edgeview Estates 3rd Addition. Also, to pass an ordinance to change the zone from R-3 (Multiple Residence District) and C-2 (General Commercial District) to R-1 (Single-Family Residence District) on all proposed lots in Blocks 1,2,4, & 5 and from R-1 (Single-Family Residence District) and C-2 (General Commercial District) to R-3 (Multiple Residence District) on proposed Lots 1-8, Block 3.This property is located north of US 2 & 52 Bypass West and east of 18th Street West behind Countryside Homes.**

 Approval of this item subject to the following conditions:
 1. Approval of a stormwater management plan; and
 2. Sidewalks are required.

Rolly Ackerman indicated that the City would be involved in constructing one of the roads as a second access to the Cottonwoods area. Alan Estvold indicated that he is

SUMMARY OF ACTION

working on the storm water management plan and stated that there would be a small retention pond somewhere in the vicinity. Dean Feist indicated that he would purchase additional land from the City so the detention pond would be on property owned by him. Following due consideration motion by Eggen, second buy Hoffart to approve the request. Motion passed 9 yes votes to 1 no vote with Dammen voting no.

7. **That the City Council pass a motion to approve a request by Sunrise Investments Inc. to subdivide a portion of Blocks 4, 5, 6 & 7, Norton's Addition and portions of 3rd and 4th Streets SE and Norton Drive, into one lot to be known as Norton's Second Addition. Also, to pass an ordinance to change the zone from C-2 (General Commercial District) to M-1 (Light Industrial District) on proposed Norton's Second Addition for the purpose of constructing mini-storage units. This property is located east of 2nd Street SE and north of US Highway 2 & 52 Bypass.**

   Approval of this item is subject to the following conditions:
   1. **Approval of a stormwater management plan, and**
   2. **That City Council determines if sidewalks are required.**

John Coughlin indicated that he and his partner Jim Meyer had plans to construct mini storage buildings on the proposed plat. He indicated that he was requesting reduced front yard setbacks due to the narrowness of the lots and that other buildings in the area have reduced front yard setbacks. He also requested that the condition of sidewalks be required be waived as there are no other sidewalks in the area and the zoning of the property would be M-1 (Light Industrial). Also, a request for a variance to reduce the front yard setback from 25 feet to 15 feet along 21st Avenue SE was requested and approved. Following due consideration, motion by Schempp, second by Langseth to approve the request and let City Council determine if sidewalks should be required. Motion passed unanimously.

8. **That the City Council pass a motion to approve a request by MADC and Biodiesel Holding to subdivide the S1/2NE1/4, south of the Great Northern right of way, and a portion of Lot 7, Burlington Northern Industrial Park, Section 22-155-82 into four lots to be known as MADC First Addition. Also, to pass an ordinance to annex into city limits proposed MADC First Addition, Lot 7, Burlington Northern Industrial Park; and highway right of way. This property is located north of Highway 2 East and west of 72nd Street NE.**

SUMMARY OF ACTION

Approval of this request is subject to the following conditions:

1. **Approval of a stormwater management plan,**
2. **An additional copy of the stormwater management plan submitted to the County Engineer to be coordinated with the drainage basin study; and**
3. **Access to public right of way be approved by the County Engineer.**

Jerry Chavez, President of MADC, indicated that the project would be a 55 million dollar project and bring approximately 40 jobs to the area. Greg Oase explained the storm water management plan. He indicated that the drainage would be split along a ridge and that each site may be fenced independently. Bye indicated that the County Engineer is requesting that the storm water management plan be reviewed by his office prior to approval. Following due consideration, motion by Schempp, second by Eggen to approve the request. Motion passed unanimously.

9. **That the City Council pass a resolution to approve a request by Minot Seed & Meal, Inc. along with MADC, for a special use permit to process canola seeds for canola oil to manufacture premium grade biodiesel fuels which includes the storage of 1B flammable liquids including methanol and hexane on proposed MADC First Addition. This property is located north of Highway 2 East and west of 72nd Street NE.**

   Approval of this request is subject to the following conditions:

   1. **Approval of a stormwater management plan,**
   2. **An additional copy of the stormwater management plan submitted to the County Engineer to be coordinated with the drainage basin study.**

Schempp question if everything was submitted for the special use permit. Bye stated yes, unless there are any changes, then a resubmittal would be necessary. Motion by Schempp, second by Arneson to approve the request. Motion passed unanimously.

GENERAL INFORMATION

1. **A public hearing was held on a request by NDSU– North Central Research Extension Center and UND - EERC Energy & Environmental Research Center for a public zone plan review in regards to a hydrogen fueling**

SUMMARY OF ACTION

station on the NE1/4NE1/4, Section 11-154-83. This property is located west of US Highway 83 and south of 54th Ave SE.

The above motion by Langseth, seconded by Miller and carried unanimously.

2. An application was considered for Timbers construction to subdivide Outlot 4, Section 15-155-83 and lots 7-12, Lloyds Rearrangement of Block 5, Bel Air Addition and 26th ½ Street NW into 14 Lots to be known as Lots 1-14 Cobblestones at Bel Air. Also, to change the zone from AG (Agricultural District) to R-1 (Single Family Residence District) on proposed Lots 1-8 13 & 14, and from AG (Agricultural District) to R-2 (Two-Family Residence District) on proposed Lots 9-12, all Cobblestones at Bel Air. Also, to annex into city limits proposed Lots 1-14, Cobblestones at Bel Air. This property is located north of 4th Avenue NW and east of 27th Street NW.

Rolly Ackerman stated that lots 1-8 and lot 13 would be for single-family dwellings and that lots 9-12 would be for townhouses. He stated that lot 14 would be for a private park with a playground. Alan Estvold stated that the storm water management plan would have a small detention pond on the southwest corner of proposed Lot 14.

Bob Bossart, 425 26th Street NW, indicated that he was not in favor of the detention pond and that he is opposed to townhouses being in the area. Rich Fonder, 2708 5th Avenue NW, stated that he is opposed to annexation. He stated that he received a quote from the city of $33,000 to receive sewer and water services to his lot. There was some discussion on annexation. Fonder stated that he would be left as an island and if annexation is forced he felt that all islands around Minot should be forced to annex as well. George Franklin, 401 26th Street NW, questioned where the retention pond would drain. Estvold stated that it would drain to the triple culverts that are currently there. Schempp questioned if the detention pond should be located on lot 13 closer to the triple culverts. Estvold indicated that proposed Lot 14 is designated green space. There was discussion regarding unbuildable lots and taxes not being paid. Mike Probst indicated that proposed Lot 14 would be owned by everyone who purchases Lots 1-13. Following due consideration, motion by Schempp second by Eggen to hold the item until the drainage issue is resolved. Motion passed unanimously.

3. Application was considered for Liechty Homes, Inc. to subdivide a portion of Outlot 9 and the unplatted portion of NE1/4, Section 2-154-83 into 2 lots

SUMMARY OF ACTION

to be known as Liechty Homes 3rd Addition. Also, to change the zone from AG (Agricultural District) to C-4 (Planned Commercial District) on proposed Liechty Homes 3rd Addition. Also, a C-4 Plan Review and Approval to construct a retail sales facility on proposed Liechty Homes 3rd Addition. Also, to annex into city limits proposed Liechty Homes 3rd Addition. This property is located at 4030 Highway 83 South.

Doug Bercu, Timber Development, explained the proposed project. He indicated that there would be a 35,000 sq ft strip mall adjacent to the new Wal-Mart store. He stated that the project would bring in approximately 50-70 new full time jobs for the community. Alan Estvold indicated that there would be a detention pond on proposed Lot 2. He indicated that a storm water management plan was being designed. Schempp questioned access to the lot. Estvold indicated that access would be from South Broadway to 40th Avenue SW. Bercu also indicated that they had made a request for an additional curb cut from Wal-Mart but it has not been finalized. Bye indicated that as the area develops to the west, there is the possibility of more access points. The Public Works Director stated that the item should be held until the final plans can be reviewed. Following due consideration, motion by Schempp, second by Dammen to hold the item until the specific C-4 plans are submitted for review. Motion passed unanimously.

Meeting adjourned at 8:50 pm.

APPENDIX B

SITE DESIGN DRAWINGS AND SAFETY-RELATED DOCUMENTS

APPENDIX B

SITE DESIGN DRAWING AND SAFETY-RELATED DOCUMENTS

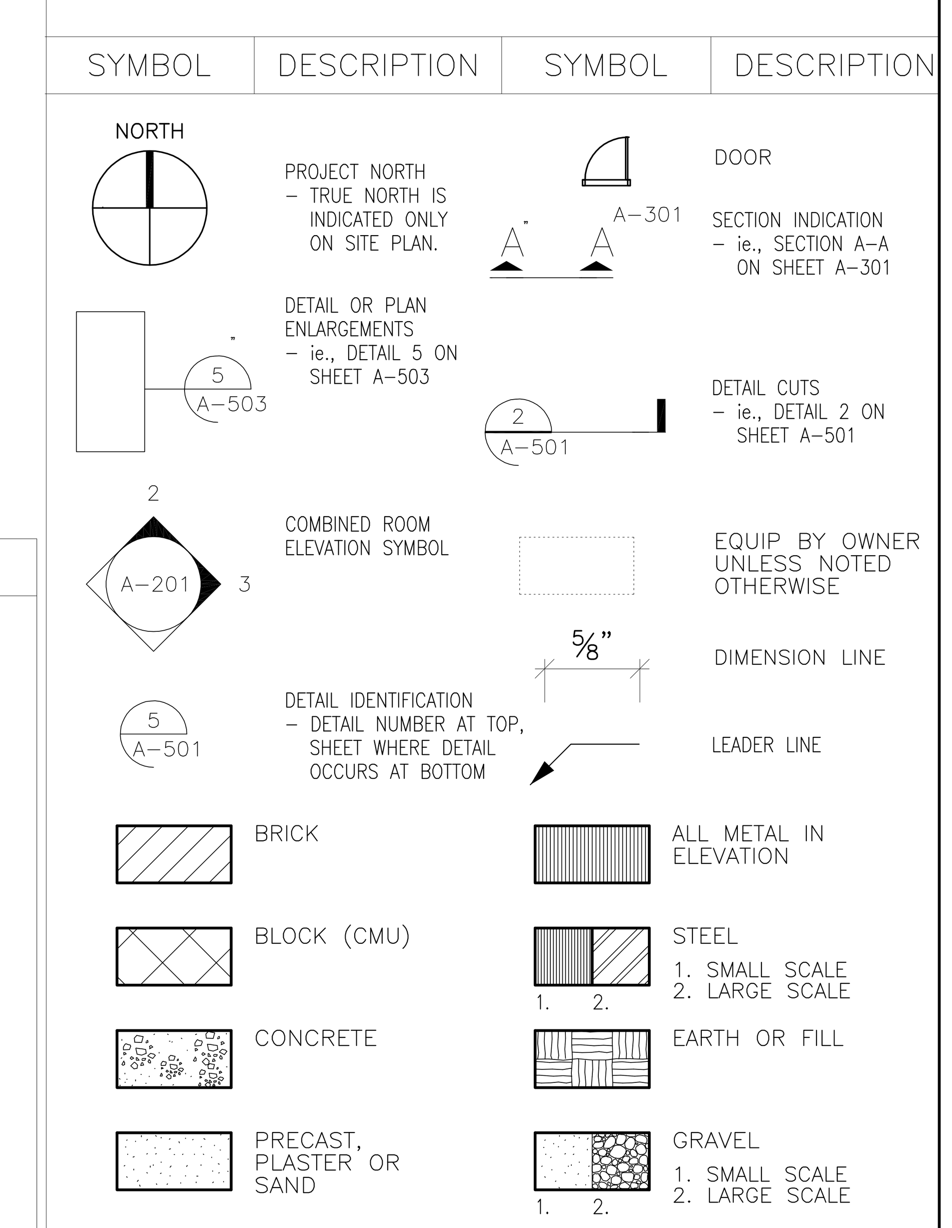
Title	Drawing No.	Description
Abbreviations and Symbols	OAI-0001	Summary of abbreviations and symbols
Specifications	OGI-0001	Summary of general specifications
Site Plan	OGA-0001	Drawing of overall site
Grading and Foundation Plan	OCC-0001	Drawing of grading and foundation plan
Sections and Details	OCC-0002	Drawing of foundation details
Floor Plan and Details	OAA-0001	Drawing of site layout and pertinent details
Mechanical Specifications	OMI-0001	Summary of mechanical specifications
Signs	OMI-0002	Drawing of required site signage
Process Flow Diagram	OMF-0001	Drawing of overall system process flow
Process and Integration Diagram	OMF-0002	P&ID of overall system
Process and Integration Diagram Schedule	OMF-0003	P&ID schedule
Mechanical Utilities Trench Layout	OMP-0001	Drawing of system utility trench
Mechanical Utilities Details	OMP-0002	Drawing of system utility details
Classified Zones and Physical Setbacks General Notes	OGI-0002	Summary of classification zones and physical setbacks
Physical Setbacks Elevations	OAI-0002	Drawing of physical setbacks in elevation view
Physical Setbacks Plan	OAI-0003	Drawing of physical setbacks
Gas and Flame Detection Coverage Requirements	OGI-0003	Drawing of gas and flame detection coverage requirements
Electrical Specifications	OED-0001	Summary of electrical specifications
Electrical Specifications	OED-0002	Summary of electrical specifications (continued)
Hydrogen Fueling System Grounding Plan	OEG-0001	Drawing of electrical grounding layout
Power Plan	OEA-0001	Drawing of overall site electrical layout
Hydrogen Refueling Station Equipment		
Flame Detection Additions Riser Diagram	6033-001	Control schematic of flame detection system
Flame Detection Additions Flame Detection Coverage Area	6033-002	Drawing of flame detection system coverage area
Flame Detection Additions Flame Detector Mounting	6033-003	Drawing of flame detector details
Flame Detection Additions Electrical Ladder	6033-004	Ladder diagram of the flame detection electrical system
Flame Detection Additions Instrumentation Wiring	6033-005	Drawing of flame detector wiring
Flame Detection Additions Light-Horn Assembly	6033-006	Drawing of light and horn wiring
Flame Detection Additions Enclosure Layout	6033-007	Drawing of flame detection system control panel
Failure Modes and Effects Analysis Report		
Hazard Identification & Risk Assessment Report		

ARCHITECTURAL AND STRUCTURAL ABBREVIATIONS

A/E	ARCHITECT–ENGINEER
AB	ANCHOR BOLT
ABR	ABBREVITION ABBREVIATED
AC&V	AIR CONDITIONING & VENTILATION
ACOUS	ACOUSTIC
ACP	ACOUSTICAL CEILING PANEL
ACT	ACOUSTICAL CEILING TILE
AD	ACCESS DOOR
ADDL	ADDITIONAL
ADDM	ADDENDUM
ADDN	ADDITION
ADJ	ADJACENT
AFF	ABOVE FINISHED FLOOR
AGGR	AGGREGATE
AHU	AIR HANDLING UNIT
AISC	AMERICAN INSTITUTE OF STEEL CONSTRUCTION
ALM	ALARM
ALT	ALTERNATE
ALUM	ALUMINUM
ANC	ANCHOR
ANES	ANESTHESIA, ANESTHESIOLOGY
ANOD	ANODIZED
ANSI	AMERICAN NATIONAL STANDARDS INSTITUTE
AP	ACCESS PANEL
APPROX	APPROXIMATE
ARCH	ARCHITECTURAL
ASPH	ASPHALT
ASTM	AMERICAN SOCIETY OF TESTING MATERIALS
AUTO	AUTOMATIC
AUX	AUXILIARY
AVG	AVERAGE
AWP	ACOUSTIC WALL PANELS
AWS	AMERICAN WELDING SOCIETY
B/B	BACK–TO–BACK
BC	BOTTOM CHORD
BD	BOARD
BETW	BETWEEN
BEV	BEVELED
BF	BARRIER–FREE
BIT	BITUMINOUS
BLDG	BUILDING
BLK	BLOCK
BLKG	BLOCKING
BOS	BOTTOM OF STEEL
BOT	BOTTOM
BP	BASE PLATE
BRCG	BRACING
BRKT	BRACKET
BRZ	BRONZE
BS	BOTH SIDES
BSMT	BASEMENT
BT	BENT
BUBR	BUILT–UP BITUMINOUS ROOFING
BULLN	BULLETIN
C	CONDUIT
C/C	CENTER TO CENTER
C/F	CENTER TO FACE
CA	COMPRESSED AIR
CAB	CABINET
CAP	CAPACITY
CATH	CATHETERIZE, CATHETER, CATHERISATION
CBD	CHALKBOARD
CCTV	CLOSED CIRCUIT TELEVISION
CCW	COUNTER CLOCKWISE
CEM	CEMENT
CER	CERAMIC
F/C	FACE TO CENTER
CF/CI	CONTRACTOR FURNISHED/CONTRACTOR INSTALLED
CFMF	COLD FORMED METAL FRAMING
CG	CORNER GUARD
CHKD	CHECKERED
CHL	CHORD LENGTH
CI	CAST IRON
CIRC	CIRCLE, CIRCULAR, CIRCULATION
CIRCUM	CIRCUMFERENCE
CJ	CONTROL JOINT
CL	CENTER LINE
CLG	CEILING
CLIN	CLINICAL
CLK	CLOCK
CLO	CLOSET
CLR	CLEAR
CM	CENTIMETER
CMU	CONCRETE MASONRY UNIT
CO	CLEANOUT
CO2	CARBON DIOXIDE
COEF	COEFFICIENT
COL	COLUMN
COMP	COMPRESSIBLE, COMPRESSED
COMPO	COMPOSITION
COMPR	COMPRESSOR
CONC	CONCRETE
COND	CONDENSATE, CONDUIT
CONDR	CONDENSER
CONF	CONFERENCE
CONN	CONNECTION
CONST	CONSTRUCTION
CONT	CONTINUATION, CONTINUE, CONTINUOUS, CONTROL
CONTR	CONTRACTOR
COORD	COORDINATE
COR	CORRIDOR
CORR	CORRUGATED
CP	CONTROL PANEL
CPS	CARPET, SHEET
CPT	CARPET TILE
CPW	CARPET, WALL
CR	CARD READER, COLD ROLLED
CRIT	CRITICAL
CRS	COURSE(S)
CSK	CUP SINK
CSS	CLINIC SERVICE SINK
CT	CERAMIC TILE, COMPUTED TOMOGRAPHY
CTB	CERAMIC TILE BASE
CTR	CENTER, CENTRAL
CTRD	CENTERED
CTSK	COUNTERSUNK
CTW	CERAMIC TILE WALL
CU	CUBIC
CUH	CABINET UNIT HEATER
CW	CLOCKWISE (MECH)
CW	COLD WATER
DA	DOUBLE–ACTING
DD	DUTCH DOOR
DECON	DECONTAMINATION
DEG	DEGREE
DEMO	DEMOLISH, DEMOLITION
DEPT	DEPARTMENT
DET	DETAIL
DEV	DEVELOPER
DF	DRINKING FOUNTAIN
DI	DEIONIZED
DIA	DIAMETER
DIAG	DIAGONAL
DIFF	DIFFUSER
DIM	DIMENSION
DISC	DISCONNECT
DIST	DISTANCE
DIV	DIVISION
DL	DEAD LOAD
DN	DOWN
DO	DOOR OPENING, DATA OUTLET, DITTO
DPFG	DAMPPROOFING
DR	DOOR
DR	DRAIN (MECH, CIVIL)
DRW	DECAY RETARDANT WOOD
DS	DOWNSPOUT
DT	DRAIN TILE
DWC	DRINKING WATER COOLER
DWG	DRAWING
DWL	DOWEL
DX	DIRECT EXPANSION
E	EAST
EA	EACH
EEW	EMERGENCY EYE WASH
EF	EACH FACE
EF	EXHAUST FAN (MECH)
EIFS	EXTERIOR INSULATION AND FINISH SYSTEM
EJ	EXPANSION JOINT
EKG	ELECTRO–CARDIOGRAM
EL	ELEVATION
ELEC	ELECTRICAL, ELECTRONIC
ELEV	ELEVATOR
EMER	EMERGENCY
EMSH	EMERGENCY SHOWER
EMSH/EW	EMERGENCY SHOWER/EYE WASH
ENCL	ENCLOSURE, ENCLOSED
ENTR	ENTRANCE
EO	ELECTRICAL OUTLET, ELECTRONICALLY OPERATED
EPSR	ELASTOMERIC/PLASTOMERIC SHEET ROOFING
EQ	EQUAL
EQUIP	EQUIPMENT
ER	EMERGENCY ROOM
ETC	ELAPSED TIME CLOCK
ETR	EXISTING TO REMAIN
EVAC	EVACUATION
EW	EACH WAY
EXCAV	EXCAVATE, EXCAVATION
EXGR	EXISTING GRADE
EXH	EXHAUST
EXIST	EXISTING
EXP	EXPANSION
EXPS	EXPOSED
EXT	EXTERIOR, EXTERNAL
EXTNG	EXTINGUISHER
EXTR	EXTRUDED
F/F	FACE–TO–FACE
FD	FLOOR DRAIN, FIRE DAMPER (MECH)
FDN	FOUNDATION
FE	FIRE EXTINGUISHER
FEC	FIRE EXTINGUISHER CABINET
FH	FUME HOOD
FHC	FIRE HOSE CABINET
FHSP	FIRE HOSE STAND PIPE
FIN	FINISH, FINISHED
FIXT	FIXTURE
FJ	FALSE JOINT
FLASH	FLASHING
FLEX	FLEXIBLE
FLG	FLANGE
FLR	FLOOR
FM	FACTORY MUTUAL
FOC	FACE OF COLUMN
FR	FIRE RATED
FRPFG	FIREPROOFING
FRW	FIRE RETARDANT WOOD
FRZ	FREEZER
FS	FAR SIDE
FSP	FIRE STANDPIPE
FT	FOOT, FEET
FTG	FOOTING
FURN	FURNITURE, FURNISH
FUT	FUTURE
GA	GAUGE, GAGE
GALV	GALVANIZED
GB	GRADE BEAM
GCW	GLAZED CURTAIN WALL
GENL	GENERAL
GENR	GENERATOR
GFI	GROUND FAULT INTERRUPTER
GHT	GLAZED HOLLOW TILE
GL	GLASS, GLAZING
GR	GRADE
GYP	GYPSUM
H	HIGH
H2	HYDROGEN
HB	HOSE BIBB
HD	HEAVY–DUTY
HDW	HARDWARE
HEX	HEXAGON
HT	HEIGHT
HORIZ	HORIZONTAL, HORIZONTALLY
HOSP	HOSPITAL
HP	HORSEPOWER
HP	HIGH POINT
HSS	HOLLOW STRUCTURAL SECTION
HT	HIGH TENSILE
HTG	HEATING
HTR	HEATER
HVY	HEAVY
HW	HOT WATER
HWY	HIGHWAY
HYD	HYDRANT
HZW	HAZARD WASTE
ID	INSIDE DIAMETER
IE	INVERT ELEVATION
IF	INSIDE FACE
ILLUM	ILLUMINATOR PANEL (FILM)
IN	INCH, INCHES
INCL	INCLUDING, INCLUSIVE
INDL	INDUSTRIAL
INFO	INFORMATION
INSUL	INSULATION, INSULATED
INT	INTERIOR, INTERNAL
INTRM	INTERMEDIATE
INV	INVERT
IV	INTRAVENOUS
JB	JUNCTION BOX
JC	JANITOR'S CLOSET
K	KIP (1000 POUNDS)
KG	KILOGRAM
KIT	KITCHEN
KP	KICK PLATE
KS	KEY SWITCH
L	LENGTH, LONG
LAB	LABORATORY
LAM	LAMINATED
LAV	LAVATORY
LBS	POUNDS
LDRY	LAUNDRY
LEV	LEVEL
LH	LEFT–HAND
LHR	LEFT–HAND REVERSE
LHS	LEFT–HAND SIDE
LIN	LINEAR
LKR	LOCKER
LL	LIVE LOAD
LLH	LONG LEG HORIZONTAL
LLV	LONG LEG VERTICAL
LO	LOUVER OPENING
LP	LOW POINT
LR	LONG RADIUS
LT	LIGHT
LTG	LIGHTING
LTWT	LIGHTWEIGHT
LVR	LOUVER
M	MOTOR, MOTORIZED
MACH	MACHINE
MAG	MAGNET, MAGNETIC
MAN	MANUAL
MAR	MARBLE
MAS	MASONRY
MATL	MATERIAL
MAX	MAXIMUM
MCA	MEDICAL COMPRESSED AIR
MCL	METAL CEILING – LINEAR
MCP	METAL CEILING – PAN
MECH	MECHANICAL
MED	MEDICINE, MEDICAL, MEDICATION
MEMB	MEMBRANE
MET	METALLIC, METAL
MEZZ	MEZZANINE
MF	METAL FABRICATIONS
MFG	MANUFACTURING
MFR	MANUFACTURER
MH	MANHOLE
MIN	MINIMUM
MISC	MISCELLANEOUS
MM	MILLIMETER
MO	METHOD OF OPERATION, MASONRY OPENING
MOD	MODIFIED
MR	MOISTURE RESISTANT, MAGNETIC RESONANCE
MRI	MAGNETIC RESONANCE IMAGING
MT	MARBLE THRESHOLD
MTD	MOUNTED
MULL	MULLION
MVAC	MEDICAL VACUUM
N	NORTH
N2	NITROGEN
N2O	NITROUS OXIDE
NARC	NARCOTICS
NATL	NATIONAL
NC	NURSE CALL, NOISE CRITERIA
NE	NORTHEAST
NFPA	NATIONAL FIRE PROTECTION ASSOCIATION
NG	NATURAL GAS
NIC	NOT–IN–CONTRACT
NL	NIGHT LIGHT
NO	NUMBER
NOM	NOMINAL
NOUR	NOURISHMENT
NS	NEAR SIDE
NS	NURSE STATION
NSF	NATIONAL SANITARY FOUNDATION
NTS	NOT–TO–SCALE
NUCL	NUCLEAR
NW	NORTHWEST
O	OXYGEN
O/O	OUT–TO–OUT
OA	OUTSIDE AIR
OBS	OBSERVATION
OC	ON CENTER
OD	OUTSIDE DIAMETER
OF	OUTSIDE FACE
OFF	OFFICE
OF/CI	OWNER FURNISHED/CONTRACTOR INSTALLED
OF/OI	OWNER FURNISHED/OWNER INSTALLED
OHDR	OVERHEAD DOOR
OPG	OPENING
OPP	OPPOSITE
OPER	OPERATOR, OPERATED
OR	OPERATING ROOM
ORIG	ORIGINAL
ORN	ORNAMENTAL
OSHA	OCCUPATIONAL SAFETY AND HEALTH ADMINISTRATION
OTO/OPH	OTOSCOPE/OPHTHALMOSCOPE
OVRS	OVERFLOW ROOF SUMP
PACU	POST ANESTHESIA CARE UNIT
PASS	PASSENGER
PAVT	PAVEMENT
PB	PUSH BUTTON
PC	PIECE (STRUC), PERSONAL COMPUTER
PCS	PIECES
PEND	PENDANT
PERF	PERFORATED
PERM	PERMANENT
PET	POSITRON EMISSION TOMOGRAPHY
PH	PHASE
PHYS	PHYSICAL, PHYSIOLOGICAL
PL	PLATE (STRUCT)
PL	PROPERTY LINE
PLAM	PLASTIC LAMINATE
PLAS	PLASTER
PLBG	PLUMBING
PLT	PLATE, PLATED
PLYWD	PLYWOOD
PMF	PERMANENT METAL FORM
PNL	PANEL
POL	POLISHED
PORC	PORCELAIN
PORT	PORTABLE
POS	POSITION
PP	PANEL POINT, PUSH PLATE
PR	PAIR
PREFAB	PREFABRICATED
PREP	PREPARATION
PRES	PRESENT
PRI	PRIMARY
PROC	PROCESS, PROCESSOR, PROCESSING
PROJ	PROJECT, PROJECTION
PROP	PROPERTY
PRTN	PARTITION
PT	PAINT (ARCH)
PTME	PATCH TO MATCH EXISTING
PTUBE	PNEUMATIC TUBE
PVG	PAVING
PW	PLANE OF WEAKNESS
PWP	POWER POLE
PWR	POWER
QC	QUALITY CONTROL
QUAD	QUADRUPLE
QT	QUARRY TILE
R	RADIUS
R	RISER (ARCH, MECH)
RAD	RADIOGRAPHIC, RADIATOR, RADIATION
RB	RESILIENT BASE
RC	ROOF CONDUCTOR
RCVG	RECEIVING
REC	RECESS, RECESSED
RECEP	RECEPTACLE
REF	REFERENCE
REFRIG	REFRIGERANT, REFRIGERATION, REFRIGERATOR
REG	REGISTER
REINF	REINFORCED, REINFORCING
REQD	REQUIRED
RESIL	RESILIENT
REV	REVISION
RF	RADIOGRAPHY & FLUOROSCOPY
RFO	ROOF OPENING
RH	RIGHT–HAND
RHR	RIGHT–HAND REVERSE
RM	ROOM
RND	ROUND
RO	ROUGH OPENING
RR	RAILROAD
RS	ROOF SUMP
RSF	RESILIENT SHEET FLOORING
RTF	RESILIENT TILE FLOORING
RTNG	RETAINING
RVS	REVERSE
S	SOUTH
SA	SUPPLY AIR
SAB	SOUND ATTENUATION BLANKET
SAF	SPRAY–APPLIED FIREPROOFING
SAN	SANITARY SEWER
SB	SOIL BORING
SC	STAFF CALL
SCHED	SCHEDULE
SE	SOUTHEAST
SECT	SECTION
SECY	SECRETARY
SER	SERVICE
SH	SHOWER
SHT	SHEET
SIM	SIMILAR
SL	SLIDING
SLNT	SEALANT
SP	SHAFT PARTITION
SPEC	SPECIFICATION
SPKR	SPEAKER
SPR	SPRINKLER
SQ	SQUARE
SR	SUPPLY RISER
SRC	SECONDARY ROOF CONDUCTOR
SSK	SERVICE SINK
SSTL	STAINLESS STEEL
ST	STORM
STA	STATION
STD	STANDARD
STIF	STIFFENER
STL	STEEL
STM	STEAM
STOR	STORAGE
STRUCT	STRUCTURAL
SUP	SUPPLY
SUPP	SUPPORT
SUSP	SUSPENDED, SUSPENSION
SW	SOUTHWEST
SW	SWITCH (ELEC
SYM	SYMMETRICAL
SYST	SYSTEM
T	TREAD, THERMOSTAT (MECH
T&B	TOP AND BOTTOM
T&G	TONGUE AND GROOVE
T&R	TREAD AND RISER
TA	TOILET ACCESSORIES
TBD	TACKBOARD
TEL	TELEPHONE
TEMP	TEMPERATURE
TERR	TERRAZZO
THD	THREAD
THK	THICKNESS, THICK
THRESH	THRESHOLD
TLS	TOUCHLESS SENSOR
TOC	TOP OF CONCRETE (ELEVATION)
TOIL	TOILET
TOS	TOP OF STEEL (ELEVATION)
TOT	TOTAL
TR	TOP OF RAIL (ELEVATION)
TRAN	TRANSOM
TV	TELEVISION
TW	TOP OF WALL (ELEVATION)
TYP	TYPICAL
UFD	UNDERFLOOR DUCT
UG	UNDERGROUND
UH	UNIT HEATER
UL	UNDERWRITERS LABORATORIES
UNO	UNLESS NOTED OTHERWISE
UR	URINAL
VAC	VACUUM
VACD	VACUUM DENTAL
VEL	VELOCITY
VENT	VENTILATING, VENTILATION
VERT	VERTICAL, VERTICALLY
VEST	VESTIBULE
VIF	VERIFY IN FIELD
VOL	VOLUME
VP	VISION PANEL
VWC	VINYL WALL COVERING
W	WEST, WIDE, WIDTH, WIDE FLANGE
W/	WITH
W/O	WITHOUT
WAGD	WASTE ANESTHESIA GAS DEVICE
WC	WATER CLOSET
WD	WOOD
WF	WASH FOUNTAIN
WG	WALL GUARD
WH	WALL HYDRANT
WI	WROUGHT IRON
WO	WINDOW OPENING
WP	WEATHERPROOF
WP	WORK POINT
WPFG	WATERPROOFING
WR	WATER RESISTANT
WS	WATERSTOP
WT	WEIGHT
WTG	WAITING
WWF	WELDED WIRE FABRIC
XH	EXTRA HEAVY

INDEX TO DRAWINGS

ARCHITECTURAL SYMBOLS



GENERAL NOTES

1. DIMENSIONS –

   TAKE FIELD MEASUREMENTS TO VERIFY EXISTING CONDITIONS.

   SEE CIVIL / ARCHITECTURAL / STRUCTURAL SHEETS FOR PLAN DIMENSIONS

   RECEIVE CERTIFIED OR ACCEPTED EQUIPMENT DRAWINGS PRIOR TO PROCEEDING WITH AFFECTED WORK.

   REVIEW DIMENSIONS SHOWN ON CONTRACT DRAWINGS, SHOP DRAWINGS, AND SUBMITTALS. REPORT INCONSISTENCIES TO ARCHITECT–ENGINEER AND RECEIVE CLARIFICATION PRIOR TO PROCEEDING.

   VERIFY SIZES OF OPENINGS, CURBS, BASES, RECESSES, ANCHOR BOLT SIZES AND LOCATIONS.

2. SHEET NUMBERS INDICATED AT SECTIONS OR DETAILS ARE FOR CONVENIENCE ONLY AND ARE NOT INTENDED TO NECESSARILY IDENTIFY ALL CONDITIONS WHERE THE SECTION OR DETAIL MAY BE REFERENCED.

REFERENCE DRAWINGS

REV.	DESCRIPTION	DRWN	DSGN	APPD	DATE
0	AS BUILT – BASIN NUMBER AND TITLE BLOCK	L. FROEHLICH	A. BOUSHEE	R. BUSH	5/7/07

FACILITY: WIND TO HYDROGEN SYSTEM

LOCATION/UNIT: MINOT, NORTH DAKOTA

CONTRACT/DESIGNATION:

DESIGN BY: ALBERT KAHN ASSOCIATES
DRAWN BY:
DESIGN CHK:
DRAFT CHK:
APPROVED:
SCALE:

ABBREVIATIONS AND SYMBOLS

BASIN ELECTRIC POWER COOPERATIVE
1717 EAST INTERSTATE AVENUE
BISMARCK, NORTH DAKOTA 58503–0564
PHONE 701–223–0441

VENDOR/ORIGINATED FROM: ALBERT KAHN ASSOCIATES
VENDOR DRAWING NO. G–001 | ORIGINAL REV 5
BASIN DRAWING NO. 0AI–0001 | REV. NO. 0

01/27/04

SECTION 02300 – EARTHWORK

A. UTILIZE SERVICES OF REGISTERED LAND SURVEYOR OR ENGINEER ACCEPTABLE TO OWNER TO ESTABLISH TEMPORARY BENCHMARKS, SURVEY TO LOCATE LINES AND LEVELS, SET GRADE STAKES AND PERFORM INCIDENTAL SURVEYING.
B. PROOF ROLL ENTIRE SITE AFTER SITE HAS BEEN GRUBBED, CLEARED AND LEVELED. IN AREAS YIELDING UNDER ACTION OF PROOF ROLLER, REMOVE UNSTABLE MATERIAL AND FILL WITH ENGINEERED FILL UNLESS DIRECTED OTHERWISE BY ARCHITECT–ENGINEER.
C. GRADE SITE TO ESTABLISH AND MAINTAIN LINES AND FINAL ROUGH GRADES INDICATED ON DRAWINGS. CONSTRUCT ROUGH GRADES REASONABLY SMOOTH AND FREE FROM IRREGULAR SURFACE CHANGES AS ORDINARILY OBTAINABLE FROM BLADE GRADER OR SCRAPER OPERATIONS.
D. CONSTRUCT EARTH SURFACES TO CONTRACT GRADE ELEVATIONS HAVING MAXIMUM DEVIATION OF PLUS 0 AND MINUS 0.1 FOOT FOR CUT AREAS AND PLUS 0.1 FOOT AND MINUS 0 FOOT FOR FILL AREAS.
E. CROWN OR SLOPE COMPACTED SUBGRADE IN CUTS AND FILLS TO FACILITATE DRAINAGE OF SURFACE.
F. CLEAR SUBGRADE AND, PRIOR TO PLACING FILL IN SITE AREAS, WORK TO REMOVE RUTS AND RIDGES, AERATE, ROLL AND COMPACT.
G. AERATE, ROLL AND COMPACT SUBGRADE AFTER COMPLETING EXCAVATION IN CUT AREAS OF SITE AREAS.
H. COMPACT SUBGRADE WITH EQUIPMENT BEST SUITED TO OBTAIN DENSITY OF NOT LESS THAN 95 PERCENT AS DETERMINED BY STANDARD PROCTOR.
I. IF AFTER SUBGRADE PREPARATION IS COMPLETE, UNSTABLE MATERIAL IS FOUND IN WORK AREA, NOTIFY ARCHITECT–ENGINEER AND OBTAIN INSTRUCTIONS BEFORE PROCEEDING WITH WORK.
J. PROVIDE ENGINEERED FILL IN ACCORDANCE WITH ASTM D2487. ENGINEERED FILL SHALL BE FREE FROM DEBRIS, WASTE, FROZEN MATERIALS, ORGANIC AND DELETERIOUS MATERIALS. ORGANIC CONTENT OF EARTH SHALL NOT BE MORE THAN 5 PERCENT AS DETERMINED BY ASTM D2974.
K. PROTECT GRADED AREAS AGAINST EROSION.
L. PLACE NEW FILL OVER EXTRUDED POLYSTYRENE INSULATION SO AS NOT TO DAMAGE INSULATION.
END OF SECTION

SECTION 02821

CHAIN LINK FENCES AND GATES
PART 2 PRODUCTS
1.01 MANUFACTURERS
A. CHAIN LINK FENCES AND GATES:
1. MASTER–HALCO, INC./ ANCHOR FENCE: WWW.FENCEONLINE.COM.
1.02 MATERIALS
A. POSTS, RAILS, AND FRAMES: ASTM F 1083 SCHEDULE 40 HOT–DIPPED GALVANIZED STEEL PIPE, WELDED CONSTRUCTION, MINIMUM YIELD STRENGTH OF 25 KSI (172 MPA).
B. WIRE FABRIC: ASTM A 392 ZINC COATED STEEL CHAIN LINK FABRIC.
C. CONCRETE: TYPE SPECIFIED IN SECTION 03300.
1.03 COMPONENTS
A. LINE POSTS: 2.38 INCH (60 MM) DIAMETER.
B. CORNER AND TERMINAL POSTS: 2.88 INCH (73 MM).
C. GATE POSTS: 2.875 INCH (73 MM) DIAMETER FOR GATES 6 FEET OR LESS, 4 INCH, 101.6 MM FOR GATE LEAFS 6 TO 12 FEET WIDE..
D. TOP, BRACE RAIL AND BOTTOM RAIL: 1.66 INCH (42 MM) DIAMETER, PLAIN END, SLEEVE COUPLED.
E. GATE FRAME: 2.875 INCH (73 MM) DIAMETER FOR GATES 3 TO 6 FEET WIDE AND 4 INCH, 102MM FOR GATE LEAF FRAMES OVER 6 FEET. GATE FRAMES: WELDED FABRICATION. CENTER UPRIGHT REQUIRED ON GATE LEAVES 8 FEET AND WIDER.
F. FABRIC: 2 INCH (51 MM) DIAMOND MESH INTERWOVEN WIRE, 11 GAGE THICK, TOP SELVAGE KNUCKLE END CLOSED, BOTTOM SELVAGE TWISTED TIGHT.
G. TIE WIRE: GALVANIZED STEEL WIRE.
1.04 ACCESSORIES
A. CAPS: CAST STEEL GALVANIZED; SIZED TO POST DIAMETER, SET SCREW RETAINER.
B. FITTINGS: SLEEVES, BANDS, CLIPS, RAIL ENDS, TENSION BARS, TRUSS RODS, FASTENERS AND FITTINGS; STEEL.
C. HARDWARE FOR SINGLE SWINGING GATES: 180 DEGREE HINGES, 2 FOR GATES UP TO 60 INCHES (1525 MM) HIGH, 3 FOR TALLER GATES; FORK LATCH WITH GRAVITY DROP AND PADLOCK HASP; KEEPER TO HOLD GATE IN FULLY OPEN POSITION.
D. HARDWARE FOR DOUBLE SWINGING GATES: 180 DEGREE HINGES, 2 FOR GATES UP TO 60 INCHES (1525 MM) HIGH, 3 FOR TALLER GATES; DROP BOLT ON INACTIVE LEAF ENGAGING SOCKET STOP SET IN CONCRETE, ACTIVE LEAF LATCHED TO INACTIVE LEAF PREVENTING RAISING OF DROP BOLT, PADLOCK HASP; KEEPERS TO HOLD GATE IN FULLY OPEN POSITION.
1.05 FINISHES
A. COMPONENTS (OTHER THAN FABRIC): GALVANIZED IN ACCORDANCE WITH ASTM A 123/A 123M, AT 1.7 OZ/SQ FT (530 G/SQ M).
B. HARDWARE: HOT–DIP GALVANIZED TO WEIGHT REQUIRED BY ASTM A 153/A 153M.
C. ACCESSORIES: SAME FINISH AS FRAMING.
PART 3 EXECUTION
2.01 INSTALLATION
A. INSTALL FRAMEWORK, FABRIC, ACCESSORIES AND GATES IN ACCORDANCE WITH ASTM F 567.
B. PLACE FABRIC ON OUTSIDE OF POSTS AND RAILS.
C. SET INTERMEDIATE, TERMINAL, GATE, AND LINE POSTS PLUMB.
D. BRACE EACH GATE AND CORNER POST TO ADJACENT LINE POST WITH HORIZONTAL CENTER BRACE RAIL AND DIAGONAL TRUSS RODS.
E. PROVIDE TOP RAIL THROUGH LINE POST TOPS AND SPLICE WITH 6 INCH (150 MM) LONG RAIL SLEEVES.
F. INSTALL CENTER BRACE RAIL ON CORNER GATE LEAVES.
G. INSTALL BOTTOM RAIL BETWEEN POSTS WITH FITTINGS AND ACCESSORIES.
H. DO NOT STRETCH FABRIC UNTIL CONCRETE FOUNDATION HAS CURED 28 DAYS.
I. POSITION BOTTOM OF FABRIC 2 INCHES (50 MM) ABOVE FINISHED GRADE.
J. FASTEN FABRIC TO TOP RAIL, LINE POSTS, BRACES, AND BOTTOM TENSION RAIL WITH TIE WIRE AT MAXIMUM 15 INCHES (380 MM) ON CENTERS.
K. ATTACH FABRIC TO END, CORNER, AND GATE POSTS WITH TENSION BARS AND TENSION BAR CLIPS.
L. INSTALL GATE WITH FABRIC TO MATCH FENCE. INSTALL HARDWARE.
M. PROVIDE CONCRETE CENTER DROP TO FOOTING DEPTH AND DROP ROD RETAINERS AT CENTER OF DOUBLE GATE OPENINGS.
END OF SECTION

SECTION 03300 – CAST–IN–PLACE CONCRETE

A. STRUCTURAL DESIGN FOR CONCRETE WORK IS BASED ON THE STRENGTH DESIGN METHOD OF 'BUILDING CODE REQUIREMENTS FOR STRUCTURAL CONCRETE', ACI 318–05.
B. DETAILING OF REINFORCEMENT SHALL BE GOVERNED BY THE 'ACI MANUAL OF STANDARD PRACTICE FOR DETAILING REINFORCED CONCRETE STRUCTURES', ACI 315.
C. CEMENT.
1. PORTLAND CEMENT: ASTM C 150, TYPE I.
D. WATER.
1. CLEAN AND FREE FROM INJURIOUS MATERIALS SUCH AS OIL, ACID, SALT, ALKALI, AND ORGANIC MATTER.
E. AGGREGATE, FINE AND COARSE.
1. GENERAL REQUIREMENTS: ASTM C 33.
2. FINE AGGREGATE: NATURAL SAND.
3. COARSE AGGREGATE: WELL GRADED, MEETING THE REQUIREMENTS OF ASTM C33, SIZE 57.
F. ADMIXTURES
1. AIR–ENTRAINING IN ACCORDANCE WITH ASTM C 260.
G. REINFORCING STEEL SHALL BE DEFORMED STEEL BARS CONFORMING TO ASTM A615 OR A996 WITH A MINIMUM YIELD STRENGTH OF 60,000 PSI.
H. WELDED WIRE REINFORCEMENT
1. IN ACCORDANCE WITH ASTM A 185, MINIMUM YIELD STRENGTH OF 65 KSI.
2. FLAT SHEETS; ROLLED FABRIC NOT ACCEPTABLE.
I. IN ACCORDANCE WITH ACI 301 AND ACI 318, EXCEPT AS MODIFIED BY THESE SPECIFICATIONS.
J. CONCRETE REQUIREMENTS.
1. ENTRAINED AIR FOR SURFACES EXPOSED TO WEATHER: 6 PERCENT, PLUS OR MINUS 1–1/2 PERCENT.
2. FIELD CONTROL SHALL BE BY COMPRESSIVE STRENGTH.
K. CONCRETE MIX DESIGN.
1. ULTIMATE COMPRESSIVE STRENGTH F'C AT 28 DAYS: NOT LESS THAN 4500 PSI.
2. CEMENT CONTENT: NOT LESS THAN 560 POUNDS PER CUBIC YARD.
3. WATER/CEMENT RATIO: NOT MORE THAN 0.44.
4. SLUMP: NOT MORE THAN 3 INCHES.
5. MODULUS OF RUPTURE AT 28 DAYS: NOT LESS THAN 575 PSI.
L. PROTECT ALL CONCRETE FROM FREEZING DURING PLACEMENT AND CURING.
M. BEFORE PLACING CONCRETE COORDINATE WORK WITH OTHER TRADES. ITEMS TO BE COORDINATED ARE, BUT NOT LIMITED TO, OPENINGS, PIPING, CONDUITS AND EMBEDDED ITEMS.
N. CURING.
1. WATER CURE FOR MINIMUM OF 7 DAYS BY COVERING WITH WATER OR OTHER ACCEPTABLE METHOD.
2. CURING COMPOUNDS IN ACCORDANCE WITH ASTM C 309, TYPE 2, WHITE PIGMENT.
END OF SECTION

SECTION 05500

METAL FABRICATIONS
1.01 MATERIALS – STEEL
A. STEEL SECTIONS: ASTM A 36/A 36M.
B. STEEL TUBING: ASTM A 500, GRADE B COLD–FORMED STRUCTURAL TUBING.
C. PLATES: ASTM A 283.
D. PIPE: ASTM A 53/A 53M, GRADE B SCHEDULE 40, BLACK FINISH.
E. BOLTS, NUTS, AND WASHERS: ASTM A 325 (ASTM A 325M), TYPE 1, GALVANIZED TO ASTM A 153/A 153M WHERE CONNECTING GALVANIZED COMPONENTS.
F. WELDING MATERIALS: AWS D1.1; TYPE REQUIRED FOR MATERIALS BEING WELDED.
G. SHOP AND TOUCH–UP PRIMER: SSPC–PAINT 15, COMPLYING WITH VOC LIMITATIONS OF AUTHORITIES HAVING JURISDICTION.
H. TOUCH–UP PRIMER FOR GALVANIZED SURFACES: SSPC–PAINT 20, TYPE I – INORGANIC, COMPLYING WITH VOC LIMITATIONS OF AUTHORITIES HAVING JURISDICTION.
1.02 FABRICATION
A. FIT AND SHOP ASSEMBLE ITEMS IN LARGEST PRACTICAL SECTIONS, FOR DELIVERY TO SITE.
B. FABRICATE ITEMS WITH JOINTS TIGHTLY FITTED AND SECURED.
C. GRIND EXPOSED JOINTS FLUSH AND SMOOTH WITH ADJACENT FINISH SURFACE. MAKE EXPOSED JOINTS BUTT TIGHT, FLUSH, AND HAIRLINE. EASE EXPOSED EDGES TO SMALL UNIFORM RADIUS.
D. SUPPLY COMPONENTS REQUIRED FOR ANCHORAGE OF FABRICATIONS. FABRICATE ANCHORS AND RELATED COMPONENTS OF SAME MATERIAL AND FINISH AS FABRICATION, EXCEPT WHERE SPECIFICALLY NOTED OTHERWISE.
1.03 FABRICATED ITEMS
A. BOLLARDS: STEEL PIPE, CONCRETE FILLED, CROWNED CAP, AS DETAILED; PRIME PAINT FINISH.
1.04 FINISHES – STEEL
A. PRIME PAINTING: ONE COAT.
END OF SECTION

SECTION 09900

PAINTS AND COATINGS
PRODUCTS
1.01 MANUFACTURERS
A. PAINTS:
1. ICI PAINTS NORTH AMERICA: WWW.ICIPAINTSINNA.COM.
2. BENJAMIN MOORE & CO: WWW.BENJAMINMOORE.COM.
3. PPG ARCHITECTURAL FINISHES, INC: WWW.PPGAF.COM.
1.02 PAINTS AND COATINGS – GENERAL
A. PAINTS AND COATINGS: READY MIXED.
B. VOLATILE ORGANIC COMPOUND (VOC) CONTENT:
1. PROVIDE COATINGS THAT COMPLY WITH THE MOST STRINGENT REQUIREMENTS SPECIFIED IN THE FOLLOWING:
a. 40 CFR 59, SUBPART D––NATIONAL VOLATILE ORGANIC COMPOUND EMISSION STANDARDS FOR ARCHITECTURAL COATINGS.
2. DETERMINATION OF VOC CONTENT: TESTING AND CALCULATION IN ACCORDANCE WITH 40 CFR 59, SUBPART D (EPA METHOD 24), EXCLUSIVE OF COLORANTS ADDED TO A TINT BASE AND WATER ADDED AT PROJECT SITE; OR OTHER METHOD ACCEPTABLE TO AUTHORITIES HAVING JURISDICTION.
C. CHEMICAL CONTENT: THE FOLLOWING COMPOUNDS ARE PROHIBITED:
1. AROMATIC COMPOUNDS: IN EXCESS OF 1.0 PERCENT BY WEIGHT OF TOTAL AROMATIC COMPOUNDS (HYDROCARBON COMPOUNDS CONTAINING ONE OR MORE BENZENE RINGS).
2. ACROLEIN, ACRYLONITRILE, ANTIMONY, BENZENE, BUTYL BENZYL PHTHALATE, CADMIUM, DI (2–ETHYLHEXYL) PHTHALATE, DI–N–BUTYL PHTHALATE, DI–N–OCTYL PHTHALATE, 1,2–DICHLOROBENZENE, DIETHYL PHTHALATE, DIMETHYL PHTHALATE, ETHYLBENZENE, FORMALDEHYDE, HEXAVALENT CHROMIUM, ISOPHORONE, LEAD, MERCURY, METHYL ETHYL KETONE, METHYL ISOBUTYL KETONE, METHYLENE CHLORIDE, NAPHTHALENE, TOLUENE (METHYLBENZENE), 1,1,1–TRICHLOROETHANE, VINYL CHLORIDE.
1.03 PAINT SYSTEMS – EXTERIOR
A. PAINT ME–OP–2A – FERROUS METALS, PRIMED, ALKYD, 2 COAT:
1. TOUCH–UP WITH RUST–INHIBITIVE PRIMER RECOMMENDED BY TOP COAT MANUFACTURER.
2. SEMI–GLOSS: TWO COATS OF ALKYD ENAMEL; COLOR AS SELECTED BY OWNER..
EXECUTION
2.01 APPLICATION
A. APPLY PRODUCTS IN ACCORDANCE WITH MANUFACTURER'S INSTRUCTIONS.
B. DO NOT APPLY FINISHES TO SURFACES THAT ARE NOT DRY. ALLOW APPLIED COATS TO DRY BEFORE NEXT COAT IS APPLIED.
C. APPLY EACH COAT TO UNIFORM APPEARANCE. APPLY EACH COAT OF PAINT SLIGHTLY DARKER THAN PRECEDING COAT UNLESS OTHERWISE APPROVED.
END OF SECTION

REV.	DESCRIPTION	DRWN	DSGN	APPD	DATE
0	AS BUILT – BASIN NUMBER AND TITLE BLOCK	L. FROEHLICH	A. BOUSHEE	R. BUSH	5/7/07

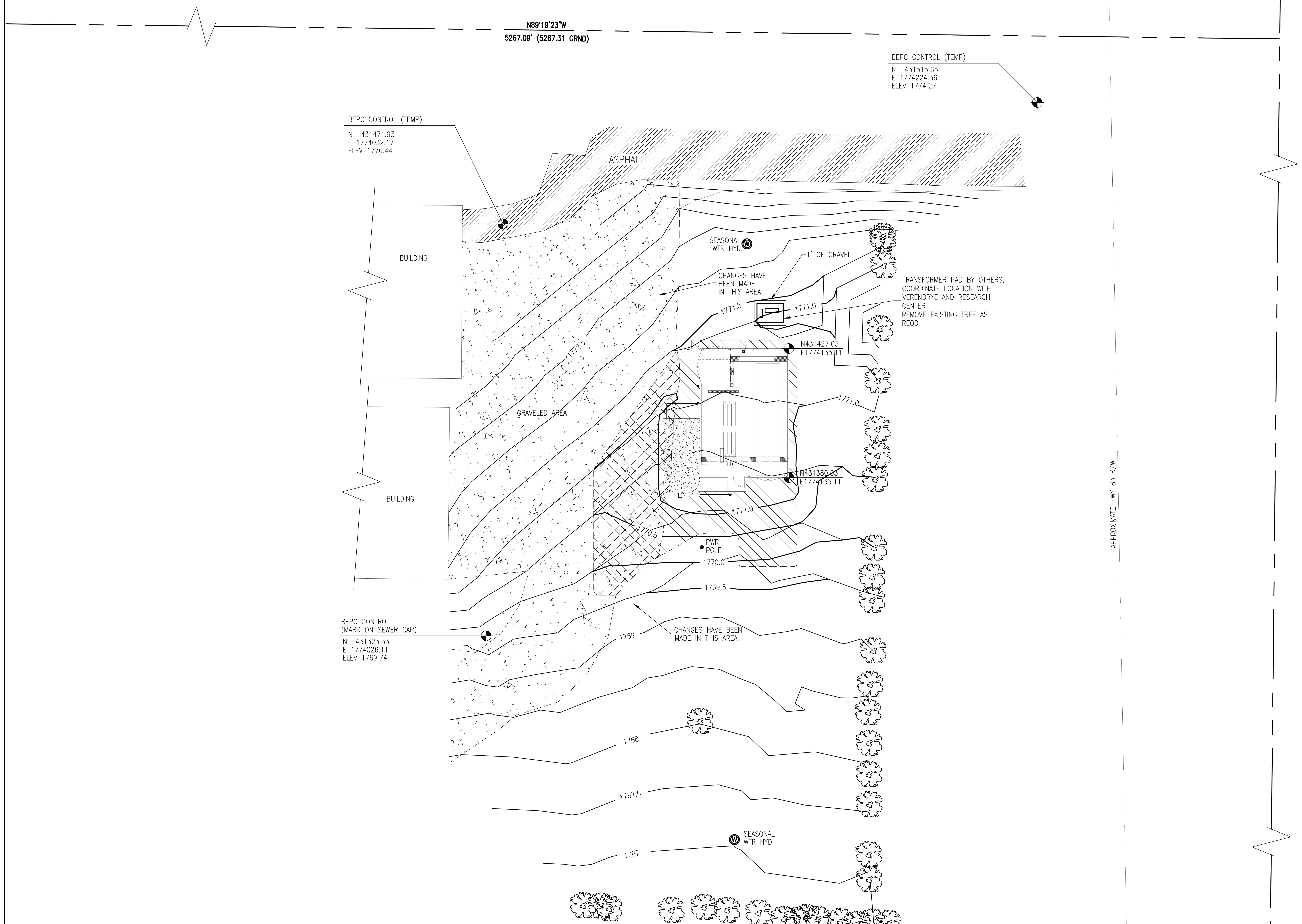
REFERENCE DRAWINGS

FACILITY: WIND TO HYDROGEN SYSTEM
LOCATION/UNIT: MINOT, NORTH DAKOTA
CONTRACT/DESIGNATION:

SPECIFICATIONS

BASIN ELECTRIC POWER COOPERATIVE
1717 EAST INTERSTATE AVENUE
BISMARCK, NORTH DAKOTA 58503–0564
PHONE 701–223–0441

DESIGN BY ALBERT KAHN ASSOCIATES
DRAWN BY
DESIGN CHK.
DRAFT CHK.
APPROVED
SCALE: NONE
VENDOR/ORIGINATED FROM: ALBERT KAHN ASSOCIATES
VENDOR DRAWING NO. G–002 | ORIGINAL REV 5
BASIN DRAWING NO. 0GI–0001 | REV. NO. 0



SITE PLAN

0" 20'-0" 40'-0"
1" = 20'-0"

NORTH

LEGEND:

- PORTION OF EXISTING GRAVELED AREA TO BE REGRADED
- PROVIDE NEW GRAVELED AREA, SEE GRAVEL PAVING DETAIL ON SHEET C-102
- EXISTING GRADE ELEVATIONS
- NEW GRADE ELEVATIONS

NOTES :

1. REFER TO SHEET NO. C-101 FOR GRADING AND FOUNDATION PLAN AT HYDROGEN FUELING STATION.
2. REFER TO ELECTRICAL DRAWINGS FOR NEW ELECTRICAL SITE WORK.
3. TOPOGRAPHIC SURVEY PROVIDED BY BASIN ELECTRIC POWER COOPERATIVE DATED: JUNE 2005.

REV.	DESCRIPTION	DRWN	DSGN	APPD	DATE
0	AS BUILT - BASIN NUMBER AND TITLE BLOCK	L. FROEHLICH	A. BOUSHEE	R. BUSH	5/7/07

REFERENCE DRAWINGS

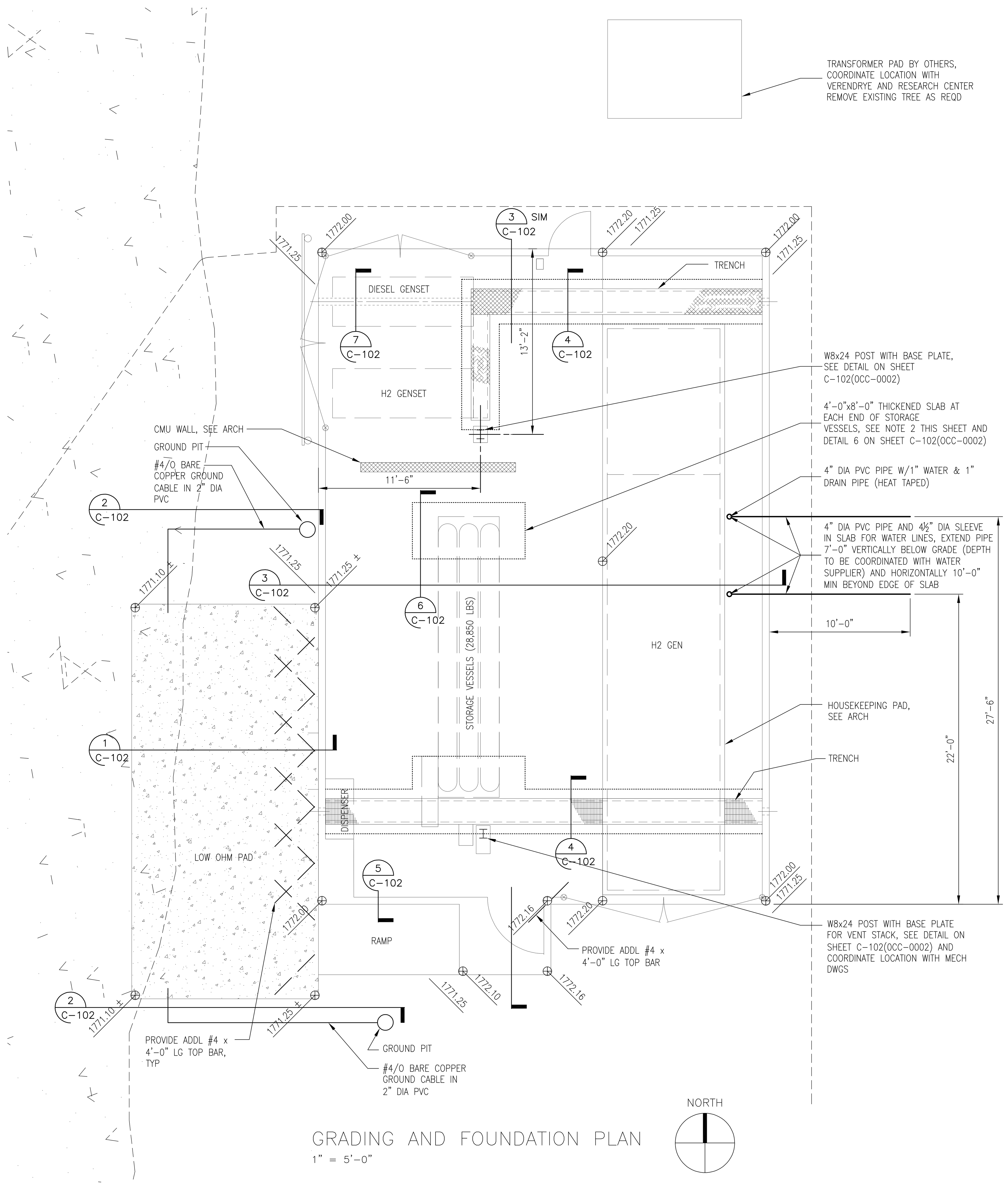
FACILITY: WIND TO HYDROGEN SYSTEM
LOCATION/UNIT: MINOT, NORTH DAKOTA
CONTRACT/DESIGNATION:

SITE PLAN

BASIN ELECTRIC POWER COOPERATIVE
1717 EAST INTERSTATE AVENUE
BISMARCK, NORTH DAKOTA 58503-0564
PHONE 701-223-0441

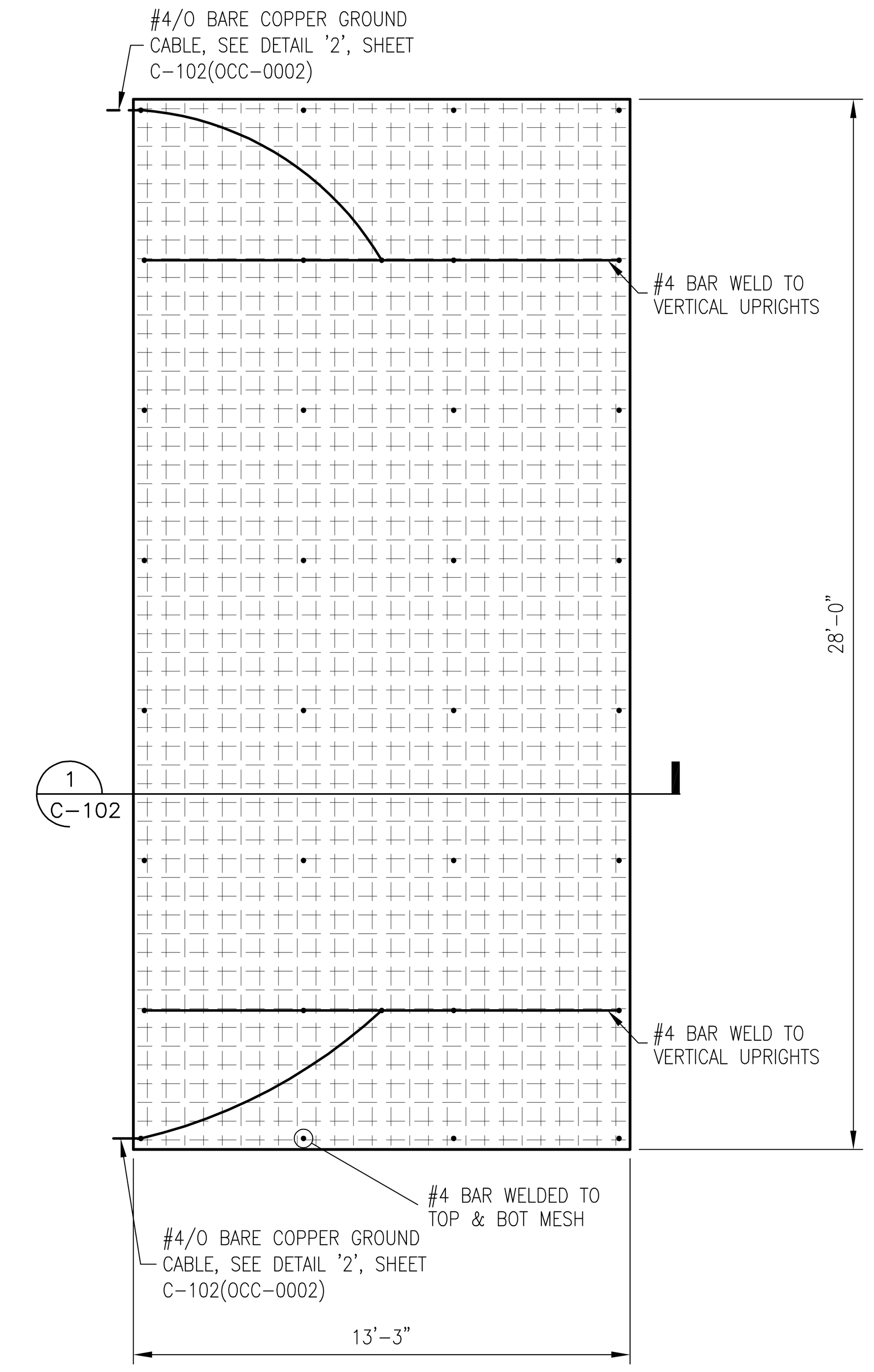
DESIGN BY ALBERT KAHN ASSOCIATES
DRAWN BY
DESIGN CHK.
DRAFT CHK.
APPROVED
SCALE: AS SHOWN
VENDOR/ORIGINATED FROM: ALBERT KAHN ASSOCIATES
VENDOR DRAWING NO. C-100 ORIGINAL REV 5
BASIN DRAWING NO. 0GA-0001 REV. NO. 0

01/27/04



GRADING AND FOUNDATION PLAN

1" = 5'-0"



LOW OHM PAD PLAN

1/4" = 1'-0"

NOTE :

THE RESISTANCE TO GROUND OF THE OVERALL PAD GROUNDING SYSTEM SHALL NOT EXCEED 5 Ohms. THIS VALUE WILL BE DETERMINED BY AN INDEPENDENT TESTING SERVICE ORGANIZATION, UTILIZING THE FALL OF POTENTIAL METHOD. IF THE VALUE IS EXCEEDED, ADDITIONAL GROUND RODS SHALL BE DRIVEN UNTIL THE 5 Ohm VALUE IS MET. CHEMICAL TYPE ELECTRODES WILL BE CONSIDERED IF THE STATED VALUE CAN NOT BE OBTAINED UTILIZING CONVENTIONAL GROUND RODS.

NOTES :

1. REFER TO ELECTRICAL DRAWINGS FOR EQUIPMENT PAD ELECTRICAL GROUNDING REQUIREMENTS.
2. COORDINATE LOCATION OF THICKENED SLAB AND ANCHORAGE OF STORAGE VESSELS WITH EQUIPMENT SUPPLIER.
3. REFER TO ELECTRICAL DRAWINGS FOR NEW ELECTRICAL SITE WORK.
4. ALL TRENCHED CONSTRUCTION UNDER GRAVEL OR UTILITIES SHALL BE BACKFILLED WITH CLASS II SAND OR OTHER APPROVED GRANULAR MATERIAL IN 12" LAYERS AND COMPACTED TO A MINIMUM OF 95% OF ITS MAXIMUM DRY DENSITY.
5. SEE ARCH DRAWINGS FOR ADDITIONAL SLAB DIMENSIONS.

REV.	DESCRIPTION	DRWN	DSGN	APPD	DATE
0	AS BUILT - BASIN NUMBER AND TITLE BLOCK	L. FROEHLICH	A. BOUSHEE	R. BUSH	5/7/07

REFERENCE DRAWINGS

BASIN DRAWING NUMBER

OCC-0002 SECTIONS AND DETAILS

FACILITY: WIND TO HYDROGEN SYSTEM

LOCATION/UNIT: MINOT, NORTH DAKOTA

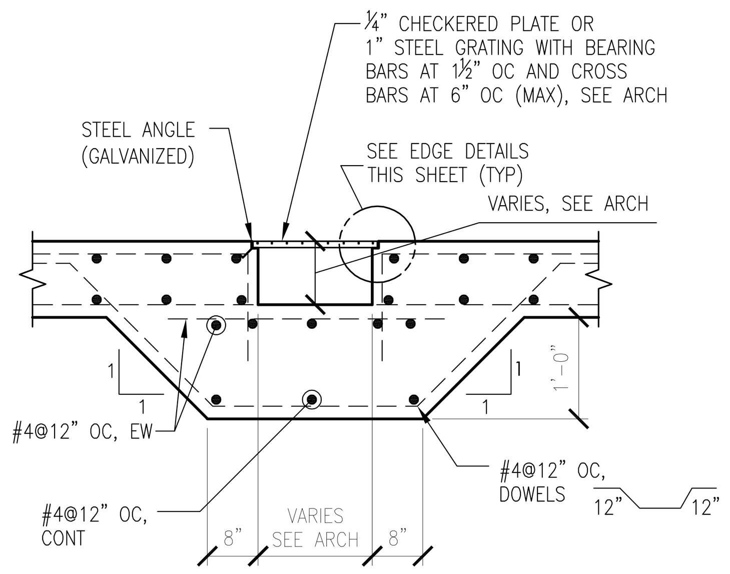
CONTRACT/DESIGNATION:

GRADING AND FOUNDATION PLAN

BASIN ELECTRIC POWER COOPERATIVE
1717 EAST INTERSTATE AVENUE
BISMARCK, NORTH DAKOTA 58503-0564
PHONE 701-223-0441

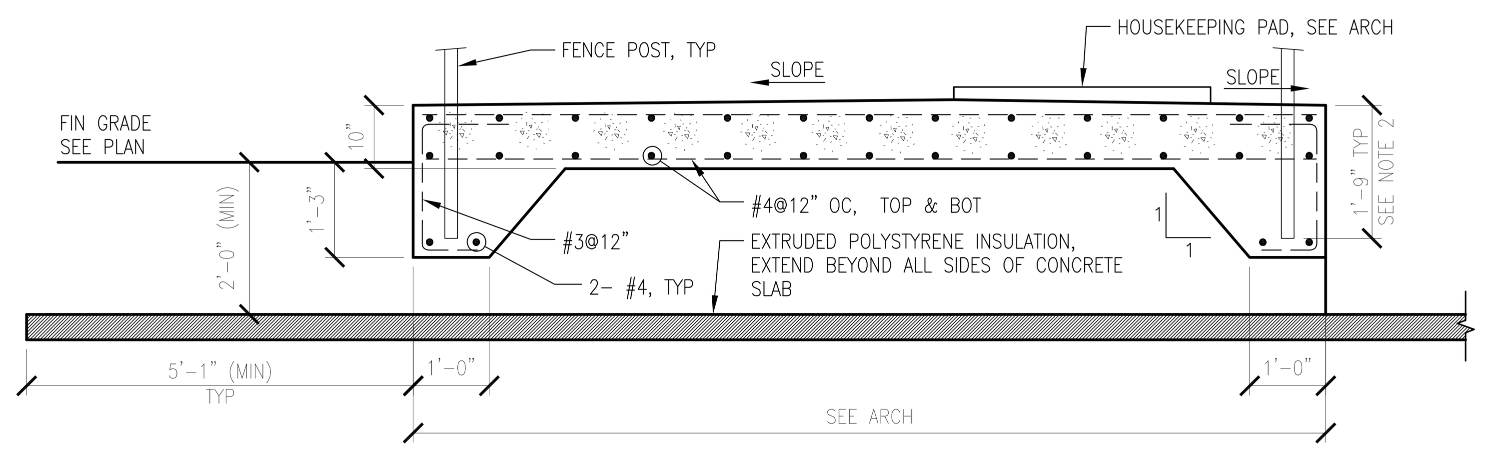
DESIGN BY: ALBERT KAHN ASSOCIATES
DRAWN BY:
DESIGN CHK:
DRAFT CHK:
APPROVED:
SCALE: AS SHOWN
VENDOR/ORIGINATED FROM: ALBERT KAHN ASSOCIATES
VENDOR DRAWING NO.: C-101 — ORIGINAL REV: 5
BASIN DRAWING NO.: OCC-0001 — REV. NO.: 0

01/27/04



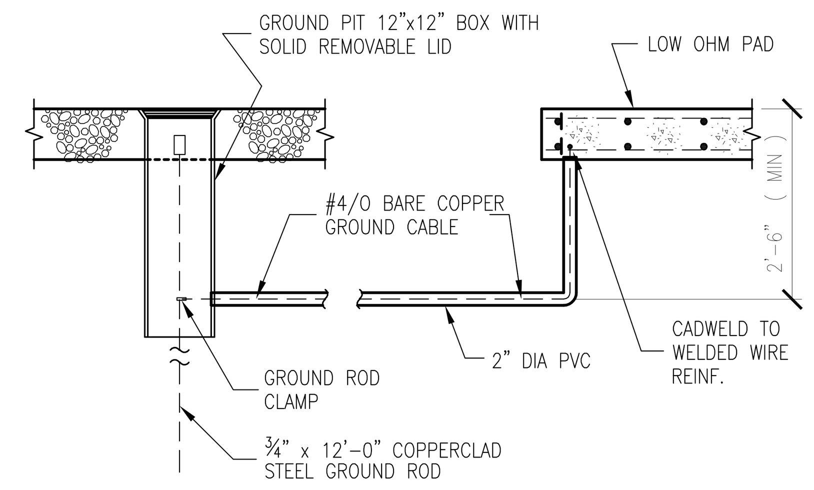
NOTE : STEEL GRATING/CHECKERED PLATE/SHAPE SUPPLIER TO COORDINATE INSTALLATION OF GRATING, PLATE AND SHAPES EMBEDDED IN CONCRETE WITH CONCRETE CONTRACTOR

DETAIL 4 C-101
1/2" = 1'-0"

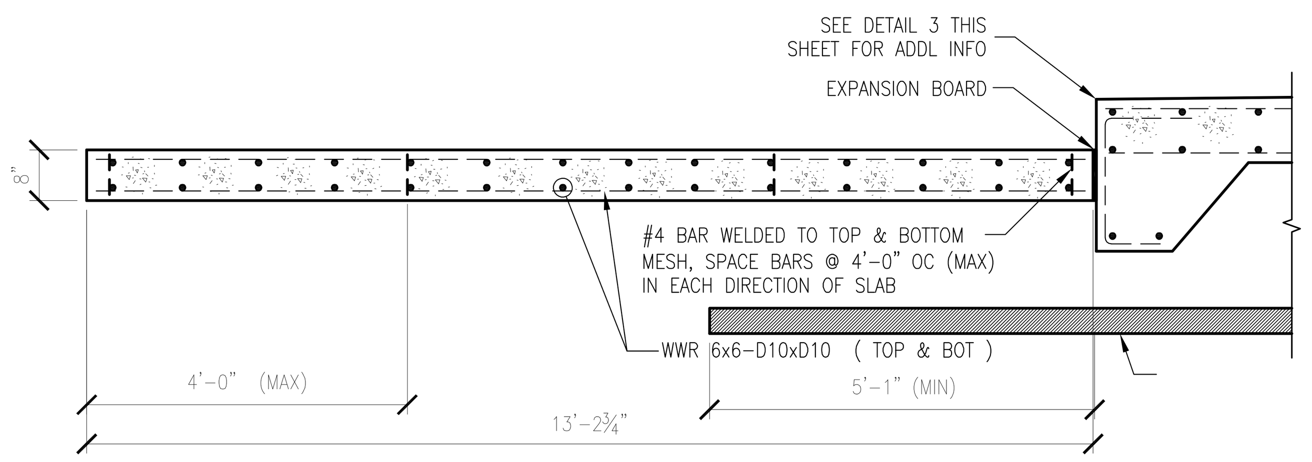


NOTES :
1. REFER TO TYPICAL SECTION AT CONCRETE ON GROUND, THIS SHEET.
2. SEE A-100 FOR FOOTING DETAIL AND LOCATIONS OF LARGE GATE POSTS.

DETAIL 3 C-101
1/2" = 1'-0"

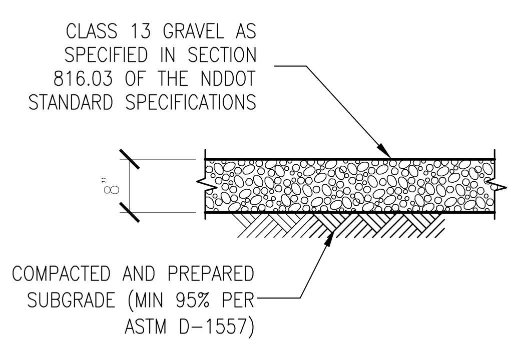


DETAIL 2 C-101
1/2" = 1'-0"



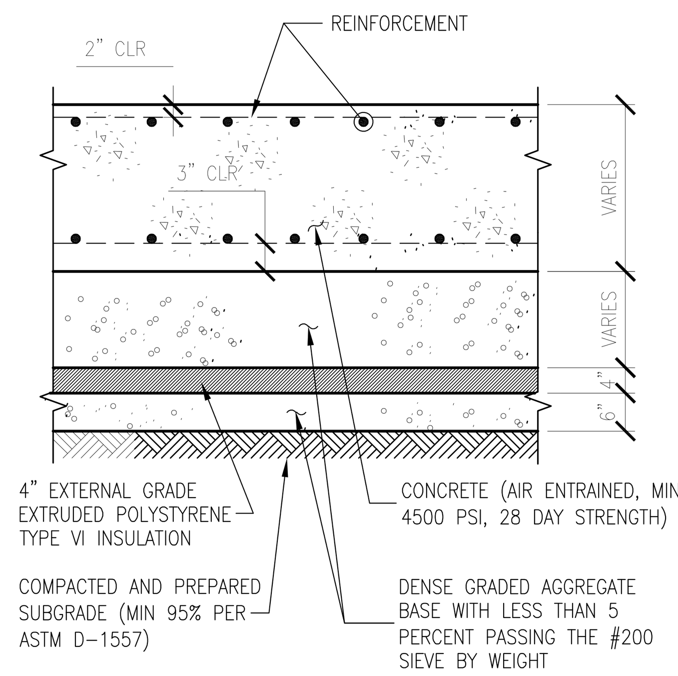
NOTE : REFER TO TYPICAL SECTION AT CONCRETE ON GROUND, THIS SHEET.

DETAIL 1 C-101
1/2" = 1'-0"



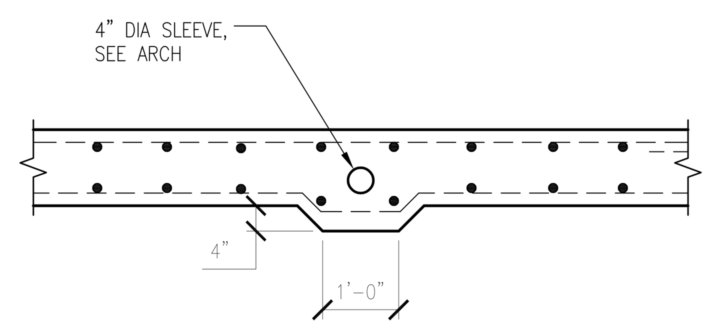
NOTE:
CONSTRUCTION PROCEDURES, METHODS AND EQUIPMENT SHALL CONFORM TO SECTION 302 OF THE NDDOT STANDARD SPECIFICATIONS

GRAVEL PAVING DETAIL



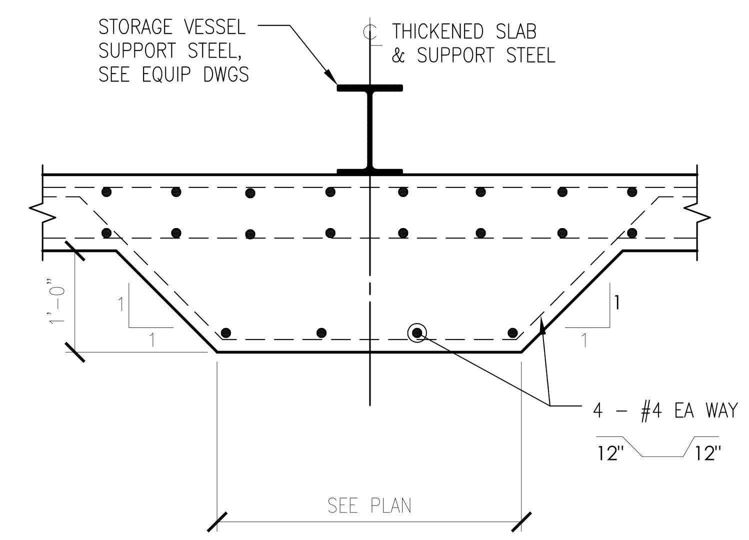
NOTE:
INSULATION AND FILL ABOVE INSULATION SHALL BE OMITTED UNDER LOW OHM PAD EXCEPT FOR 5'-1" EXTENSION BEYOND EDGE OF CONCRETE EQUIPMENT PAD AS INDICATED IN DET 1 ON THIS SHEET

TYPICAL SECTION AT CONCRETE ON GROUND

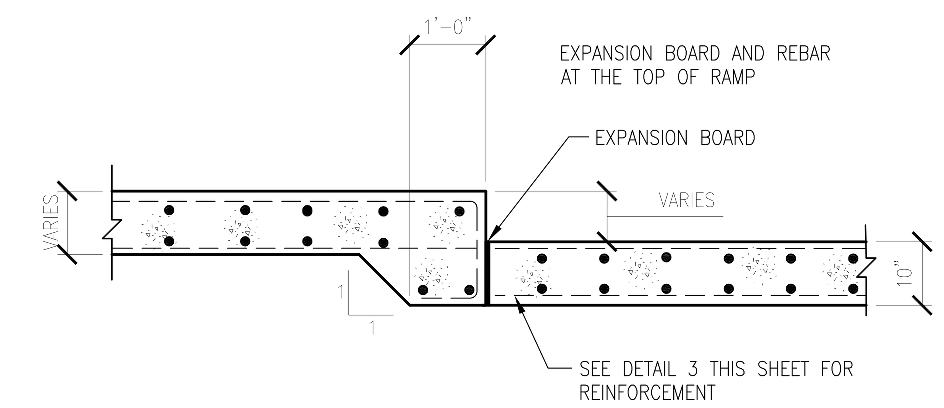


NOTE : REFER TO DETAIL 3 THIS SHEET FOR REINFORCEMENT.

DETAIL 7 C-101
1/2" = 1'-0"

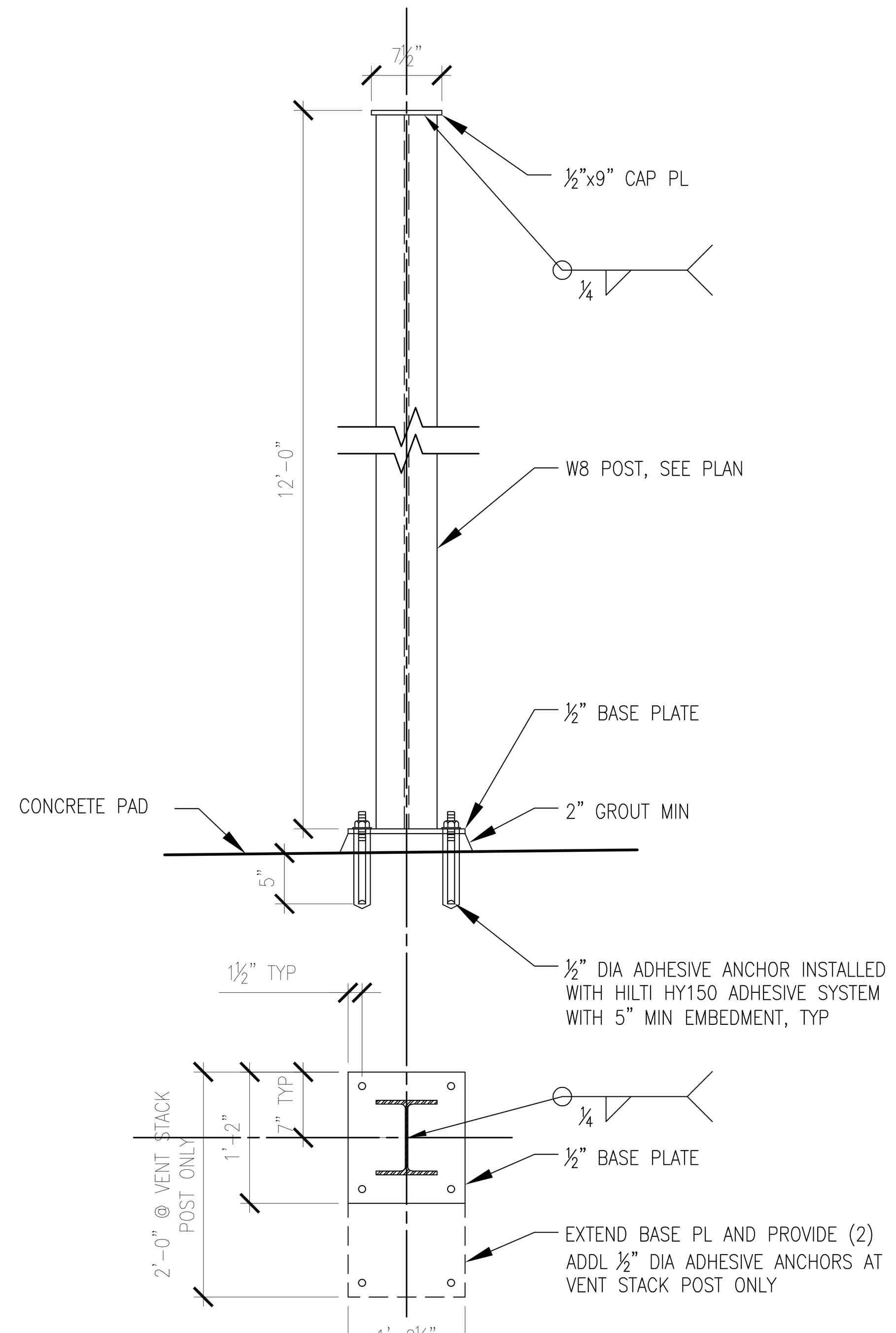


DETAIL 6 C-101
1/2" = 1'-0"



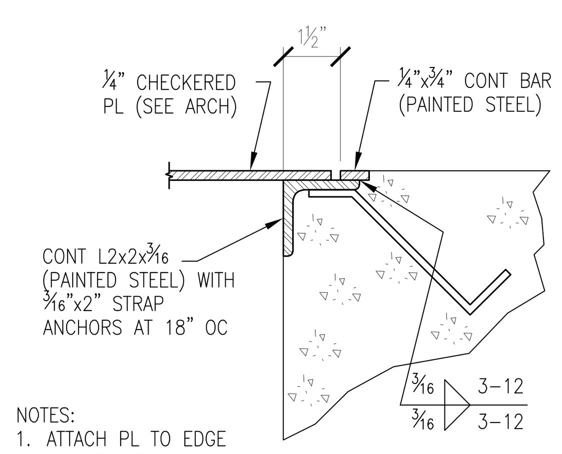
NOTE : REFER TO TYPICAL SECTION AT CONCRETE ON GROUND, THIS SHEET.

DETAIL 5 C-101
1/2" = 1'-0"



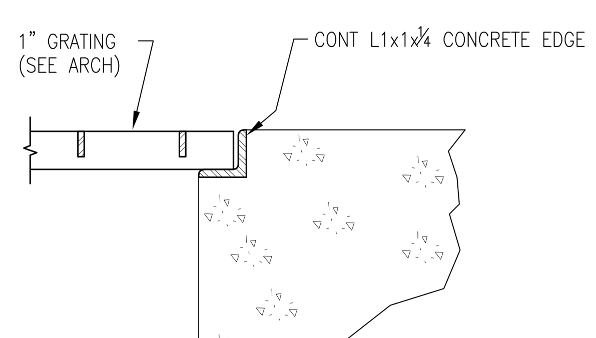
NOTES:
1. ALL STEEL SHALL BE PAINTED BLACK
2. POST SHALL BE A992 MATERIAL
3. PLATES SHALL BE A36 MATERIAL

TYPICAL POST DETAIL



NOTES:
1. ATTACH PL TO EDGE ANGLE WITH COUNTERSUNK SCREWS
2. ALL STEEL SHALL BE A36

EDGE DETAIL – CHECKERED PLATE
3" = 1'-0"



NOTE:
ALL STEEL SHALL BE A36

EDGE DETAIL – GRATING
3" = 1'-0"

REV.	DESCRIPTION	DRWN	DSGN	APPD	DATE
0	AS BUILT – BASIN NUMBER AND TITLE BLOCK	L. FROEHLICH	A. BOUSHEE	R. BUSH	5/7/07

REFERENCE DRAWINGS
BASIN DRAWING NUMBER
OCC-0001 GRADING AND FOUNDATION PLAN

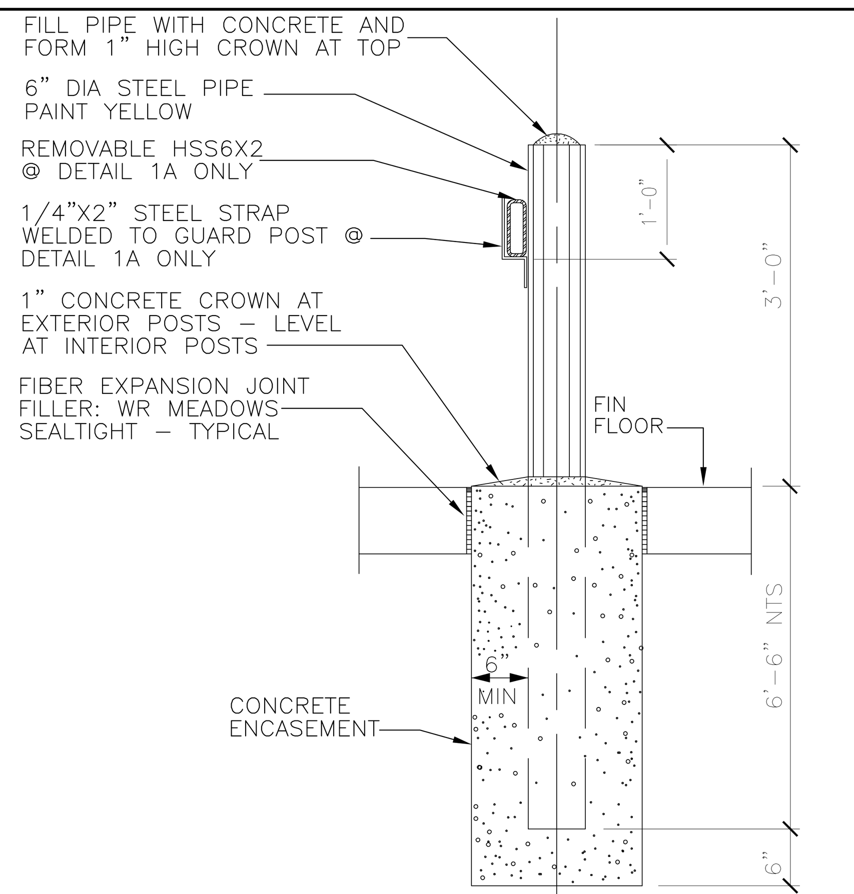
FACILITY: WIND TO HYDROGEN SYSTEM
LOCATION/UNIT: MINOT, NORTH DAKOTA
CONTRACT/DESIGNATION:

SECTIONS AND DETAILS

BASIN ELECTRIC POWER COOPERATIVE
1717 EAST INTERSTATE AVENUE
BISMARCK, NORTH DAKOTA 58503-0564
PHONE 701-223-0441

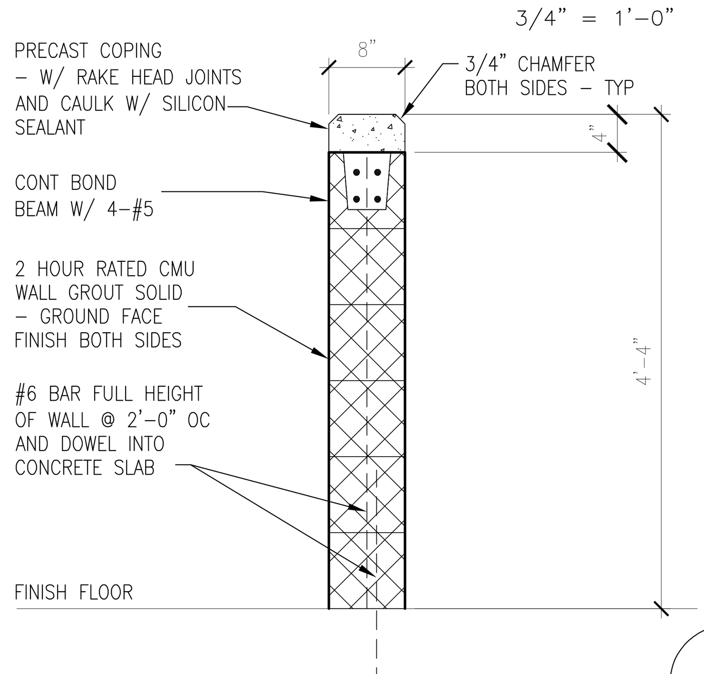
DESIGN BY: ALBERT KAHN ASSOCIATES
DRAWN BY:
DESIGN CHK:
DRAFT CHK:
APPROVED:
SCALE: AS SHOWN
VENDOR/ORIGINATED FROM: ALBERT KAHN ASSOCIATES
VENDOR DRAWING NO. C-102 — ORIGINAL REV 5
BASIN DRAWING NO. OCC-0002 — REV. NO. 0

01/27/04



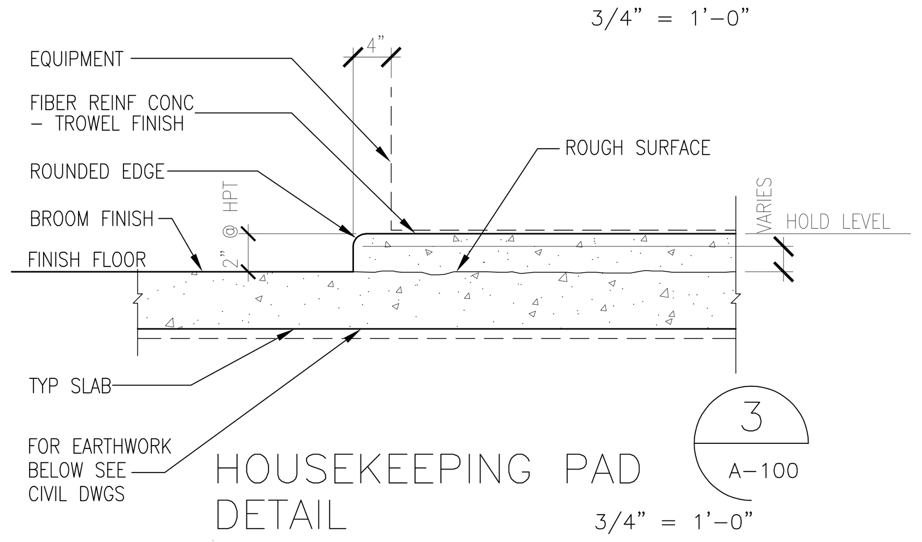
6" PIPE GUARD POST 1 A-100 1A A-100

3/4" = 1'-0"



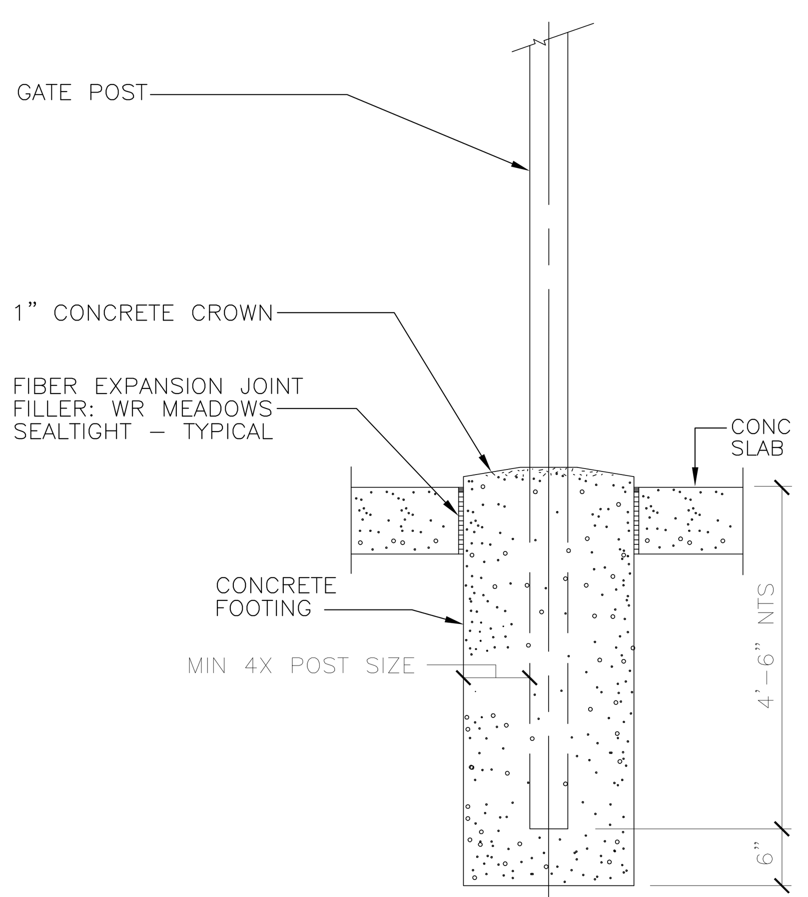
2 A-100

3/4" = 1'-0"



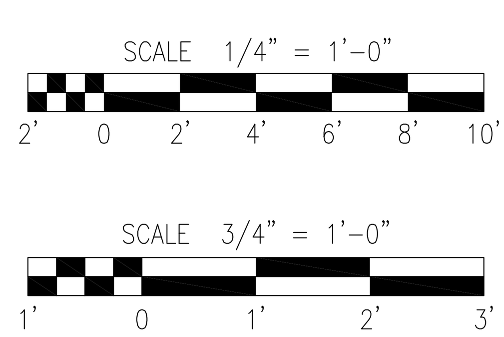
HOUSEKEEPING PAD DETAIL 3 A-100

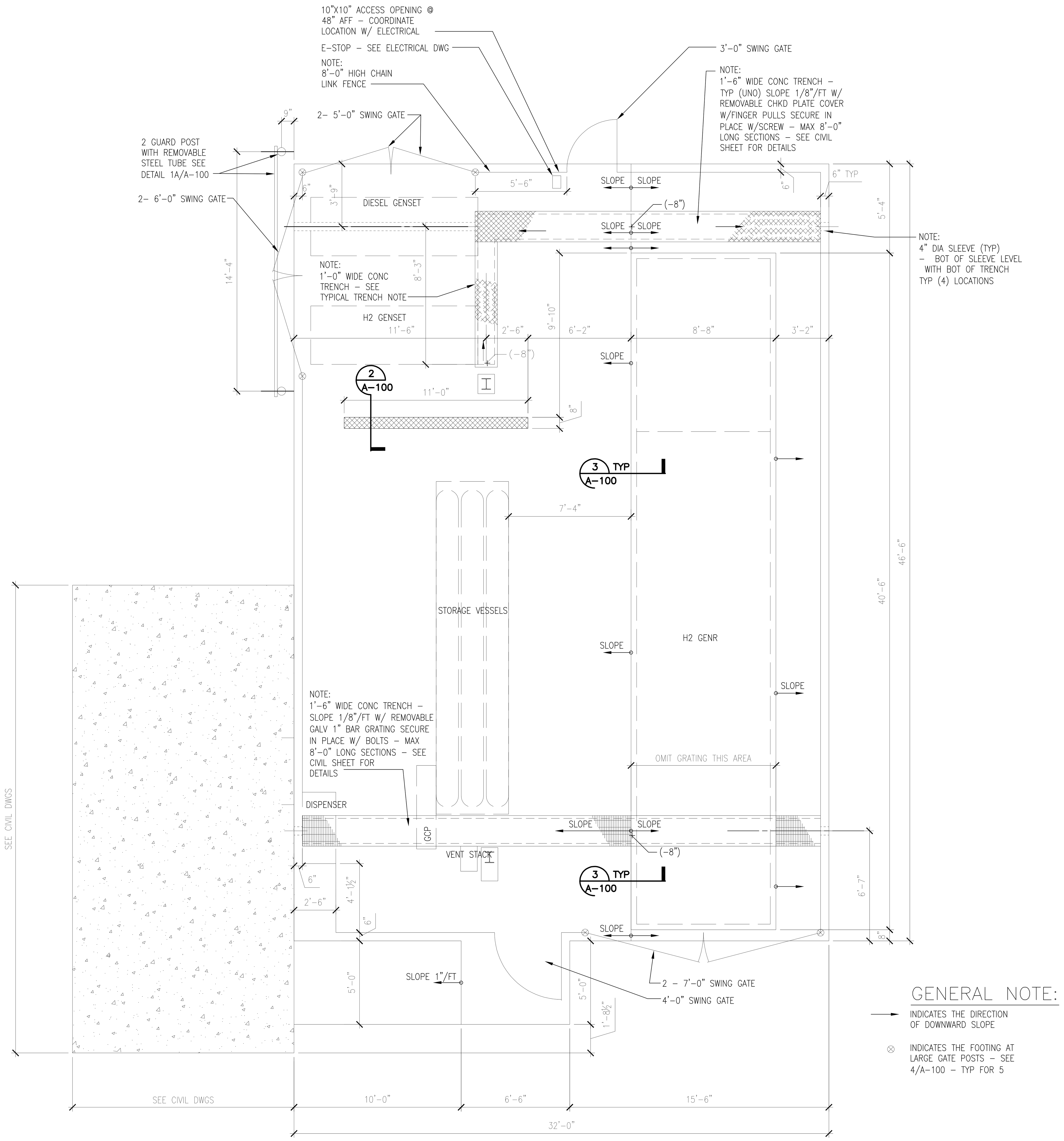
3/4" = 1'-0"



GATE POST 4 A-100

3/4" = 1'-0"





HYDROGEN FUELING STATION PLAN

1/4" = 1'-0"

NORTH

GENERAL NOTE:

→ INDICATES THE DIRECTION OF DOWNWARD SLOPE

⊗ INDICATES THE FOOTING AT LARGE GATE POSTS – SEE 4/A-100 – TYP FOR 5

REV.	DESCRIPTION	DRWN	DSGN	APPD	DATE
0	AS BUILT – BASIN NUMBER AND TITLE BLOCK	L. FROEHLICH	A. BOUSHEE	R. BUSH	5/7/07

REFERENCE DRAWINGS

FACILITY: WIND TO HYDROGEN SYSTEM

LOCATION/UNIT: MINOT, NORTH DAKOTA

CONTRACT/DESIGNATION:

FLOOR PLAN AND DETAILS

BASIN ELECTRIC POWER COOPERATIVE
1717 EAST INTERSTATE AVENUE
BISMARCK, NORTH DAKOTA 58503-0564
PHONE 701-223-0441

DESIGN BY ALBERT KAHN ASSOCIATES

DRAWN BY:

DESIGN CHK:

DRAFT CHK:

APPROVED:

SCALE: AS SHOWN

VENDOR/ORIGINATED FROM: ALBERT KAHN ASSOCIATES

VENDOR DRAWING NO. A-100 ORIGINAL REV 5

BASIN DRAWING NO. 0AA-0001 REV. NO. 0

01/27/04

SPECIFICATIONS

1.0 STATEMENT OF WORK

1. COORDINATE THE DELIVERY OF THE EQUIPMENT SUPPLIED BY THE OWNER WITH THE OWNER AND OTHER TRADES. OWNER SUPPLIED EQUIPMENT INCLUDES:
   .1 HYDROGENICS HYSTAT-A-30 FUEL GENERATOR
   .2 HYDROGENICS STORAGE MODULE
   .3 HYDROGENICS GAS CONTROL PANEL
   .4 HYDROGENICS FUEL DISPENSER
   .5 HYDROGENICS STORAGE VENT STACK
   .6 50 KW DIESEL FUELED GENERATOR
   .7 60 KW HYDROGEN FUELED GENERATOR
   .8 'K' OR 'T' SIZE NITROGEN CYLINDER
   .9 NITROGEN PRESSURE REGULATOR SET c/w FLEXIBLE HOSE
   .10 DETRONICS OR EQUIVALENT GAS AND FLAME DETECTION SYSTEM
2. COORDINATE THE MECHANICAL WORK WITH OTHER TRADES FOR ORDERLY AND EFFICIENT INSTALLATION OF ALL EQUIPMENT IN THE CAST-IN-PLACE TRENCHES.
3. INSTALL THE HYDROGENICS VENT STACKS AS PER THE DRAWINGS.
   .1 STORAGE VENT STACK
   .2 PROCESS HYDROGEN VENT STACK
   .3 PROCESS OXYGEN VENT STACK
4. FABRICATE AND INSTALL:
   .1 THE STATION VENT STACK MAST AS PER THE DRAWINGS.
   .2 THE STATION VENT STACK RISERS AS PER THE DRAWINGS.
   .3 THE GAS AND FLAME DETECTION SYSTEM MAST AS PER THE DRAWINGS.
5. SUPPLY AND INSTALL HYDROGEN VENT TUBING AS PER THE DRAWINGS:
   .1 FROM THE FUEL GENERATOR TO THE STATION VENT STACK (2 LINES).
   .2 FROM THE DISPENSER TO THE STATION VENT STACK.
6. SUPPLY AND INSTALL THE HYDROGEN SUPPLY TUBING AND VALVES AS PER THE DRAWINGS:
   .1 FROM THE FUEL GENERATOR TO THE GAS CONTROL PANEL.
   .2 FROM THE GAS CONTROL PANEL TO THE STORAGE MODULE, HIGH, MEDIUM AND LOW BANKS.
   .3 FROM THE GAS CONTROL PANEL TO THE DISPENSER .
   .4 FROM THE GAS CONTROL PANEL TO THE HYDROGEN FUELED GENERATOR.
7. SUPPLY AND INSTALL INSTRUMENT AIR TUBING AND VALVES AS PER THE DRAWINGS:
   .1 FROM THE FUEL GENERATOR TO THE GAS CONTROL PANEL.
   .2 FROM THE GAS CONTROL PANEL TO THE DISPENSER.
8. INSTALL NITROGEN COMPONENTS AS PER THE DRAWINGS:
   .1 REGULATOR SET ON THE STATION VENT STACK.
   .2 'K' CYLINDER AT THE STATION VENT STACK.
9. SUPPLY AND INSTALL PURGE TUBING FROM THE NITROGEN PRESSURE REGULATOR SET TO THE FUEL GENERATOR.
10. SUPPLY AND INSTALL PERMANENT LABELS ON EACH PROCESS GAS LINE TO IDENTIFY PROCESS GAS AND DIRECTION OF FLOW AS PER CODES AND STANDARDS.
11. SUPPLY AND INSTALL SIGNAGE IN THE SIZES AND QUANTITIES SHOWN. SIGNS TO BE FABRICATED FROM DIE-BOND LAMINATED MATERIAL. SIGN DESIGNS WILL BE SUPPLIED TO THE CONTRACTOR IN ELECTRONIC FORMAT BY OWNER. SIGN LOCATIONS WILL BE PROVIDED TO THE CONTRACTOR AT A LATER DATE.
12. CONDUCT CLEANING/PRESSURE/LEAK/ACCEPTANCE TEST OF THE HYDROGEN SUPPLY SYSTEM AS PER DIVISION 15, SECTION 15950.
13. STARTUP AND COMMISSION THE HYDROGEN, INSTRUMENT AIR, NITROGEN SUPPLY SYSTEM AS PER THE SPECIFICATIONS. COORDINATE THIS TASK WITH OTHER TRADES AND HYDROGENICS FORCES.
14. PARTICIPATE IN SITE ACCEPTANCE TEST (SAT). SAT PROCEDURE WILL BE PUBLISHED AT A LATER DATE. CONTRACTOR SHALL PROVIDE THE SERVICES OF ONE TECHNICIAN FOR FOUR (4) DAYS TO ASSIST THE OWNER WITH THE SAT.
15. PROVIDE ASBUILTS, SHOP DRAWINGS, OEM BULLETINS AS SPECIFIED.
16. PROVIDE ONE YEAR WARRANTY ON MATERIALS AND WORKMANSHIP.

2.0 GENERAL DRAWING NOTES

1. ANY DEVIATION FROM THE DESIGN COVERED SHALL BE APPROVED BY THE ENGINEER.
2. UNLESS SPECIFIED OTHERWISE THESE NOTES APPLY TO AL DRAWINGS IN THE MECHANICAL DIVISION.
3. APPLICABLE DESIGN CODES, LATEST EDITION, LATEST ADDENDA:
   .1 ASME B31.3 PROCESS PIPING
   .2 NFPA 52 VEHICULAR FUEL SYSTEM CODE
   .3 NFPA 55 STANDARD FOR THE USE, STORAGE, AND HANDLING OF COMPRESSED GASES AND CRYOGENIC FLUIDS IN PORTABLE AND STATIONARY CONTAINERS, CYLINDERS AND TANKS.
   .4 NFPA 70 NATIONAL ELECTRIC CODE
4. ALL FITTINGS SHALL BE RATED BY THE MANUFACTURER FOR THE DESIGN PRESSURE AND TEMPERATURES GIVEN IN THE RELEVANT SPECIFICATION. THE INSTALLER IS RESPONSIBLE TO ENSURE THIS REQUIREMENT IS SATISFIED.
5. ALL PIPE FITTINGS SHALL BE INSTRUMENT QUALITY SWAGELOK (OR APPROVED EQUIVALENT). MATERIAL FOR THESE FITTINGS SHALL BE STAINLESS STEEL FOR TEMPERATURE SERVICE -40°C TO +93°C (-40°F TO +200°F).
6. ALL TUBE FITTINGS SHALL BE SWAGELOK (OR APPROVED EQUIVALENT). TUBE FITTING MATERIAL TO BE 316LSS WHEN USED WITH 316LSS TUBE
7. SEE DRAWING M-401 FOR TRENCH DETAILS.
8. ALL BELOW GRADE PIPE SHALL BE WELDED.
9. ALL ABOVE GRADE PIPING SIZES GREATER THAN NPS 2 SHALL BE WELDED. SIZES NPS 2 AND SMALLER MAY BE THREADED OR WELDED.
10. ALL BELOW GRADE TUBE SHALL BE WELDED.
11. ALL ABOVE GRADE TUBING, ALL SIZES, MAY BE WELDED OR CONNECTED WITH FERRULED FITTINGS, SWAGELOK OR APPROVED EQUIVALENT.
12. ALL WELDED PIPING AND TUBING SHALL BE SOCKET WELDED OR BUTT WELDED IN ACCORDANCE WITH THE REQUIREMENTS OF ASME B31.3 CHAPTER IX.
13. ALL BUTT WELDMENTS SHALL UNDERGO 100% RADIOGRAPHIC EXAMINATION PER ASME B31.3 (OR APPROVED ALTERNATIVE).
14. ALL SOCKET WELDMENTS SHALL UNDERGO 100% LIQUID DYE PENETRANT EXAMINATION.
15. ALL ASTM A269 TUBING SHALL BE THE BRIGHT ANNEALED GRADE.
16. TEST PRESSURE AS PERCENTAGE OF DESIGN PRESSURE IS 110%. DESIGN PRESSURE SHALL BE THE SETTING OF THE MECHANICAL REFLIEF VALVE(S) IN THAT PORTION OF THE SYSTEM.
17. NORMAL PRESSURE: 1.0132 BAR. NORMAL TEMPERATURE: 15°C.
18. ALL PIPING AND TUBING SHALL BE CLEANED AND PNEUMATIC TESTED IN ACCORDANCE WITH ASME B31.3 (OR APPROVED ALTERNATIVE). AS FOLLOWS:

DIVISION 15 SECTION 15950

1.0 GENERAL

1.1 WORK INCLUDED

1. THIS DOCUMENT OUTLINES THE PNEUMATIC PRESSURE PIPING TESTING PROCEDURE FOR THE INTERCONNECTING PIPING AND TUBING. ALL VENDOR SUPPLIED EQUIPMENT SHALL BE TESTED AND APPROVED BY THE VENDOR'S PRIOR TO SHIPMENT, ACCORDING TO ANSI / ASME B31-3 AND SHALL NOT BE THE RESPONSIBILITY OF THE CONTRACTOR.

   NO LEAKS SHALL BE REPAIRED UNDER PRESSURE

   NO LEAKS ARE ACCEPTABLE
2. UPON COMPLETION OF THE INSTALLATION AND INTERCONNECTIONS OF THE EQUIPMENT THAT COMPRISE THIS STATION, THE CONTRACTOR SHALL VISUALLY INSPECT THE SITE TO ENSURE THAT IT IS CLEAN AND READY FOR THE PRESSURE TEST. THE PRESSURE TEST SHALL BE CONDUCTED IN ACCORDANCE WITH ANSI / ASME B31.3.
3. THE INTERNAL GAS-WETTED SURFACES OF THE PIPING SYSTEM AND COMPONENTS SHOULD BE CLEANED TO REMOVE ANY CONTAMINANTS THAT COULD COMPROMISE THE PERFORMANCE OF FUEL CELLS, GAS TIRBINES, OR OTHER APPLICATONS EQUIPMENT. CLEANING THE SYSTEM PIPING AND COMPONENETS TO AN OXYGEN CLEAN LEVEL IS ACCEPTABLE.
   APPLICABLE STANDARDS INCLUDE:

   COMPRESSED GAS ASSOCIATION PAMPHLET G-4.1, "CLEANING EQUIPMENT FOR OXYGEN SERVICE".

   ASTM PAMPHLET G23, "PRACTICE FOR CLEANING METHODS FOR MATERIAL AND EQUIPMENT USED IN OXYGEN ENRICHED ENVIRONMENTS".
4. DURING FABRICATION AND ASSEMBLY OF THE SYSTEM ALL COMPONENTS, PIPING EXTERIORS AND APPURTENANCES SHALL BE CLEANED TO REMOVE FOREIGN MATERIALS, CORROSION PRODUCTS, AND MILL SCALE. AFTER CLEANING, OPEN ENDS OF PIPING AND VESSELS SHALL BE SUITABLY CAPPED OR PLUGGED TO PREVENT CONTAMINATION.

2.0 PRODUCTS

2.1 LIST OF TEST EQUIPMENT AND MATERIALS

LIST OF TEST EQUIPMENT

1. CERTIFIED ACCURATE GAUGES C/W 3-WAY VALVES
2. TEST GAS INJECTION VALVES AND TUBING PLUG FITTINGS.
3. HYDROGEN LEAK DETECTOR: H2 ELECTRONIC DETECTOR BACHARACH LEAKATOR 10 OR APPROVED EQUIVALENT
4. HELIUM LEAK DETECTOR: ION SCIENCE GASCHECK 3000 OR APPROVED EQUIVALENT

2.2 LIST OF TEST CONSUMABLES

1. HELIUM (QUANTITY DEPENDING ON SYSTEM CAPACITY AND AMOUNT OF LEAK REPAIR REQUIRED).
2. PROCESS GAS AT MAXIMUM AVAILABLE PRESSURE AT 99.95 % PURITY (QUANTITY DEPENDING ON SYSTEM CAPACITY AND AMOUNT OF LEAK REPAIR REQUIRED).
3. NUPRO "SNOOP" OR APPROVED EQUIVALENT LEAK DETECTION SOLUTION
4. MAXPRO OR EQUIVALENT AIR-DRIVE BOOSTER COMPRESSOR TO BOOST TEST GASES TO TEST PRESSURES.
5. PORTABLE AIR COMPRESSOR OF SUITABLE CAPACITY FOR THE OPERATION OF THE MAXPRO OR EQUIVALENT BOOSTER COMPRESSOR

3.0 EXECUTION

3.1 WATER LINES / CHILLED WATER LINES

1. ALL WATER LINES SHALL BE TESTED WITH AIR TO 1.1 TIMES THE MAXIMUM OPERATING PRESSURE (MOP) (THE TEST PRESSURE) FOR A MINIMUM OF 30 MINUTES. THE CONTRACTOR WILL CHANGE THE SYSTEM TO THE TEST PRESSURE AND WILL INSPECT THE SYSTEM TO IDENTIFY ANY LEAKS. TESTING OF ANY LEAKS. TESTING OF THE JOINTS SHALL BE WITH A SUITABLE LEAK-DETECTION SOLUTION AS APPROVED BY THE ENGINEER. THE CONTRACTOR SHALL THEN RELIEVE THE PRESSURE IN THE SYSTEM AND REPAIR ANY LEAKS. THE CONTRACTOR SHALL REPEAT THIS PROCEDURE UNTIL THE SYSTEM WILL HOLD THE TEST PRESSURE FOR 30 MINUTES.

3.2 COMPRESSED AIR LINES

1. ALL COMPRESSED AIR LINES SHALL BE TESTED WITH AIR TO 1.1 TIMES THE MAXIMUM OPERATIN PRESSURE (MOP) (THE TEST PRESSURE) FOR A MINIMUM OF 30 MINUTES. THE CONTRACTOR WILL INTRODUCE 25 PSIG PRESSURE TO THE SYSTEM AND TEST FOR LEAKS. THE CONTRACTOR WILL THEN GRADUALLY INCREASE THE PRESSURE IN THE SYSTEM UNTIL A PRESSURE OF 120 PSIG IS REACHED. THE CONTRACTOR WILL INSPECT THE SYSTEM TO IDENTIFY ANY LEAKS. TESTING OF THE JOINTS SHALL BE WITH A SUITABLE LEAK-DETECTION IDENTIFY ANY LEAKS. TESTING OF THE JOINTS SHALL BE WITH A SUITABLE LEAK-DETECTION SOLUTION AS APPROVED BY THE ENGINEER. THE CONTRACTOR SHALL THEN RELIEVE THE PRESSURE IN THE SYSTEM AND REPAIR ANY LEAKS. THE CONTRACTOR SHALL REPEAT THIS PROCEDURE UNTIL THE SYSTEM WILL HOLD THE TEST PRESSURE FOR 30 MINUTES.

3.3 PROCESS GAS LINES

3.3.1 INTRODUCTION

1. THE MAXIMUM OPERATING PRESSURE (MOP) IS THE STEADY STATE GAUGE PRESSURE AT WHICH THE SEGMENT OF THE SYSTEM NORMALLY OPERATES.
2. THE SET PRESSURE IS DEFINED AS THE SET POINT OF THE PRESSURE RELIEF VALVES THAT ARE CONNECTED TO THE SEGMENT OF PIPE TO BE TESTED. THE SET PRESSURE IS THE MOP X 1.10.
3. ALL PROCESS GAS "WETTED" EQUIPMENT, COMPONENTS AND TUBING SHALL BE SUBJECTED TO A PRESSURE TEST, LEAK TEST AND ACCEPTANCE TEST, AS DEFINED BELOW. PRESSURE TEST SHALL BE CONDUCTED AT 1.1 TIMES THE SET PRESSURE WITH HELIUM. LEAK TEST SHALL BE CONDUCTED AT THE MAXIMUM OPERATING PRESSURE WITH HELIUM. ACCEPTANCE TEST SHALL BE CONDUCTED AT THE MAXIMUM OPERATING PRESSURE PRESSURE WITH HYDROGEN.

3.3.2 PROCEDURE

1. THE CONTRACTOR SHALL ENSURE THAT THE ENGINEER, A REPRESENTATIVE FROM BASIN ELECTRIC AND A QUALIFIED REPRESENTATIVE FROM THE AHJ, ARE PRESENT PRIOR TO CONDUCTING ANY TESTING. ATTENDANCE BY THE AHJ IS AT THE AHJ'S DISCRETION.
2. TEST SEGMENTS THAT ARE EXEMPT FROM THE PRESSURE TEST WILL BE ISOLATED BY CLOSING MANUAL ISOLATION VALVES OR DISCONNECTING AND PLUGGING THE TUBING WITH AN APPROVED PLUG FITTING.

   FOR THE PORTION OF THE SYSTEM SUBJECTED TO THE HIGHEST MOP, THE CONTRACTOR SHALL: CLOSE THE VALVES AS SHOWN ON THE TEST PLAN SCHEMATICS WHICH WILL BE PROVIDED BY THE ENGINEER, OR AS DIRECTED BY THE ENGINEER DURING THE TEST.
3. THE CONTRACTOR SHALL USE THE INJECTION POINT FOR THE TEST GAS AS SHOWN ON THE TEST PLAN SCHEMATICS, OR AS DIRECTED BY THE ENGINEER DURING THE TEST.
4. THE CONTRACTOR SHALL USE THE TEST PRESSURE GAUGE AS THE CERTIFIED GAUGE TO CONDUCT THE PRESSURE TEST FOR THIS PORTION OF THE SYSTEM. THE CONTRACTOR SHALL VENT THE SYSTEM WHEN REQUIRED AS SHOWN ON THE TEST PLAN SCHEMATIC, OR AS DIRECTED BY THE ENGINEER DURING THE TEST.
5. THE CONTRACTOR SHALL ATTACH THE "TEST GAS" CYLINDER(S) AT THE INJECTION POINT.
6. THE CONTRACTOR SHALL THEN PROCEED WITH THE PRELIMINARY LEAK TEST. THE PRELIMINARY LEAK TEST SHALL BE CONDUCTED USING HELIUM AS THE TEST GAS. THE CONTRACTOR WILL CHARGE THE SYSTEM TO A PRESSURE OF 25 PSIG AND WILL INSPECT THE SYSTEM TO IDENTIFY ANY SIGNIFICANT LEAKS. IF NECESSARY, THE CONTRACTOR WILL ACHIEVE THE TEST PRESSURE BY THE USE OF A PNEUMATIC PUMP APPROVED BY THE ENGINEER. TESTING OF THE JOINTS SHALL BE WITHA SUITABLE LEAK-DETECTION SOLUTION AS APPROVED BY THE ENGINEER. THE CONTRACTOR SHALL THEN RELIEVE THE PRESSURE IN THE SYSTEM AND REPAIR ANY LEAKS. THE CONTRACTOR SHALL REPEAT THIS PROCEDURE UNTIL THE SYSTEM WILL HOLD 25 PSIG FOR 5 MINUTES.
7. UPON SUCCESSFUL COMPLETION OF THE PRELIMINARY LEAK TEST, THE CONTRACTOR SHALL THEN PROCEED WITH THE PRESSURE TEST. THE PRESSURE TEST SHALL BE CONDUCTED USING HELIUM AS THE TEST GAS. THE CONTRACTOR WILL CHARGE THE SYSTEM TO THE TEST PRESSURE. THIS PRESSURE WILL BE ACHIEVED GRADUALLY IN INCREMENTS COMMENCING WITH 25 PSIG FOR THE FIRST PLATEAU AND THEN IN INCREMENTS EQUAL TO 10% OF THE TEST PRESSURE OR 100 PSIGINCREMENT, WHICHEVER IS GREATER. IF NECESSARY, THE CONTRACTOR WILL ACHIEVE THE TESTPRESSURE BY THE USE OF A PNEUMATIC PUMP APPROVED BY THE ENGINEER. THE CONTRACTOR WILL INSPECT THE SYSTEM TO IDENTIFY ANY LEAKS. TESTING OF THE JOINTS SHALL BE WITH A SUITABLE LEAK-DETECTION SOLUTION AND HELIUM LEAK DETECTION INSTRUMENT AS APPROVED BY THE ENGINEER. THE CONTRACTOR WILL THEN RELIEVE THE PRESSURE FROM THE SYSTEM AND REPAIR ANY LEAKS. THE CONTRACTOR SHALL REPEAT THIS PROCEDURE UNTIL THE SYSTEM WILL HOLD THE TEST PRESSURE FOR 30 MINUTES. AT THE CONCLUSION OF THE 30 MINUTE TEST, THE CONTRACT SHALL RELIEVE THE PRESSURE IN THIS PORTION OF THE SYSTEM.
8. REPEAT STEPS 1 THROUGH 7 FOR THE PROCESS GAS LINES WHICH OPERATE AT LOWER MOP'S. THE TEST PRESSURE SHALL BE AS INDICATED.
9. UPON SUCCESSFUL COMPLETION OF ALL THE PRESSURE TESTS, THE CONTRACTOR SHALL RELIEVE THE PRESSURE FROM THE SYSTEM, RECONNECT ALL TUBING AND RE-INSTALL THE PRDS. THE CONTRACTOR SHALL THEN PURGE THE SYSTEM 4 TIMES WITH HELIUM AT A PRESSURE OF 480 KPAG (70PSIG) TO SCAVENGE ANY OXYGEN IN THE SYSTEM SUCH THAT THE RESIDUAL OXYGEN REMAINING IN THE SYSTEM IS LESS THAN OR EQUAL TO 0.1% OXYGEN BY VOLUME. AFTER THE FOURTH PURGE THE CONTRACTOR SHALL CHARGE THE SYSTEM TO 1 BARG (15 PSIG) WITH HELIUM.
10. UPON SUCCESSFUL COMPLETION OF THE OXYGEN PURGING OF THE SYSTEM, THE CONTRACTOR SHALL THEN PROCEED WITH THE LEAK TEST. THE LEAK TEST WILL BE CONDUCTED AT THE MOP. THE LEAK TEST SHALL BE CONDUCTED USING HELIUM. AT THE START OF THE LEAK TEST, THE SYSTEM WILL BE PRESSURIZED TO NOMINALLY 1 BARG (15 PSIG) WITH HELIUM. THE CONTRACTOR WILL THEN CHARGE THE SYSTEM WITH HELIUM TO THE MOP. IF NECESSARY, THE CONTRACTOR WILL ACHIEVE THE TEST PRESSURE BY THE USE OF A PNEUMATIC PUMP APPROVED BY THE ENGINEER. THIS PRESSURE WILL BE ACHIEVED GRADUALLY IN INCREMENTS EQUAL TO 10% OF THE MOP OR 100 PSIG INCREMENTS, WHICHEVER IS GREATER. THE CONTRACTOR WILL THEN INSPECT THE SYSTEM TO IDENTIFY ANY LEAKS. TESTING OF THE JOINTS SHALL BE WITH A SUITABLE LEAK-DETECTION SOLUTION AS APPROVED BY THE ENGINEER AND HELIUM LEAK DETECTION INSTRUMENT AS APPROVED BY THE ENGINEER. THE CONTRACTOR WILL THEN RELIEVE THE PRESSURE FROM THE SYSTEM AND REPAIR ANY LEAKS. THE CONTRACTOR SHALL REPEAT THIS PROCEDURE UNTIL THE SYSTEM WILL HOLD THE MOP FOR 5 MINUTES.
11. UPON SUCCESSFUL COMPLETION OF THE LEAK TEST, THE CONTRACTOR SHALL RELIEVE THE PRESSURE FROM THE SYSTEM. THE CONTRACTOR SHALL THEN PURGE THE SYSTEM 4 TIMES WITH HYDROGEN AT A PRESSURE OF 480 KPAG (70 PSIG) TO SCAVENGE ANY HELIUM IN THE SYSTEM SUCH THAT THE RESIDUAL HELIUM REMAINING IN THE SYSTEM IS LESS THAN OR EQUAL TO 0.1% HELIUM BY VOLUME PRIOR TO HIGH PRESSURE PROCESS GAS BEING INTRODUCED.
12. UPON SUCCESSFUL COMPLETION OF THE HELIUM PURGING, THE CONTRACTOR SHALL REDUCE THE SYSTEM PRESSURE TO 1 PSIG AND PROCEED WITH THE ACCEPTANCE TEST. THE ACCEPTANCE TEST SHALL BE CONDUCTED USING HYDROGEN AS THE TEST GAS. THE CONTRACTOR SHALL COMPLETE THE CHARGING OF THE SYSTEM TO THE MOP WITH PROCESS GAS. THIS PRESSURE WILL BE ACHIEVED GRADUALLY IN 10% INCREMENTS TO THE MOP OR 100 PSIG INCREMENTS, WHICHEVER IS GREATER. THE CONTRACTOR WILL THEN INSPECT THE SYSTEM TO IDENTIFY ANY LEAKS. TESTING OF THE JOINTS SHALL BE WITH A SUITABLE LEAK-DETECTION SOLUTION AND ELECTRONIC EQUIPMENT DESIGNED FOR LEAK DETECTION OF PROCESS GAS AS APPROVED BY THE ENGINEER. THE CONTRACTOR SHALL THEN RELIEVE THE PRESSURE IN THE SYSTEM AND REPAIR ANY LEAKS. THE CONTRACTOR SHALL REPEAT THIS PROCEDURE UNTIL THE SYSTEM WILL HOLD THE MOP FOR 30 MINUTES.
13. UPON SUCCESSFUL COMPLETION OF THE ACCEPTANCE TEST, THE CONTRACTOR SHALL RETURN ALL VALVES IN THE "SYSTEM" TO THEIR NORMAL POSITION AND RETURN THE SYSTEM TO ITS NORMAL OPERATING CONDITIONS AND LEAVE THE SYSTEM FILLED WITH HYDROGEN AT THE INDICATED MOP'S UNLESS INSTRUCTED OTHERWISE BY THE ENGINEER.
14. THE CONTRACTOR WILL PROVIDE ALL "TEST GAS", AN APPROVED LEAK-DETECTION SOLUTION, THE ELECTRONIC GAS-DETECTION EQUIPMENT, ANY EQUIPMENT NECESSARY TO BOOST THE SYSTEM PRESSURE TO THE REQUIRED TEST PRESSURE AND ALL GAUGES NECESSARY FOR THE EXECUTION OF THIS PROCEDURE. THE CONTRACTOR SHALL PROVIDE APPROPRIATE PERSONNEL TO CONDUCT THE TEST AND UNDERTAKE REPAIRS UNDER THE ENGINEER'S SUPERVISION.

VALVES
GATE VALVE
NORMALLY CLOSED VALVE
NORMALLY OPEN VALVE
BALL VALVE
GLOBE VALVE
NEEDLE VALVE
THREE-WAY VALVE
DIAPHRAM VALVE
CHECK VALVE
BUTTERFLY VALVE
CONTROL VALVE
SAFETY VALVE
SOLENOID VALVE
MOTORIZED VALVE
PNEUMATIC VALVE
EXCESS FLOW VALVE
STRAINER
MOTOR
PUMP
COMPRESSOR
ELECTRIC GENERATOR
INTERNAL COMBUSTION ENGINE
FLOW INDICATOR
FIXED ORIFICE / FLOW RESTRICTOR
FLEXIBLE JOINT
COALESCING FILTER
DESICCANT FILTER
CARTRIDGE FILTER

DESIGNATORS	
	DRAIN
D	OPEN DRAIN
C	CHEMICAL SEWER
S	SEWER
	ELECTRICAL INTERLOCK
A	ANNUNCIATOR ALARM POINT
XX m3/hr	FLOW RATE
Vxxx	VALVE DESIGNATION
NO.	DEVICE DESIGNATION
TP XXX	TERMINATION POINT
XX 123	INSTRUMENT DESIGNATION (LOCAL)
XX 123	INSTRUMENT DESIGNATION (REMOTE)
VO	VENT OUT
	REVISION INDICATOR
S.P.	SAMPLE POINT
S.P.	SAMPLE POINT WITH VALVE
N.C.	NORMALLY CLOSED
N.O.	NORMALLY OPEN
F/O	FAIL OPEN
F.C.	FAIL CLOSED
	BULKHEAD FIITNG IF LOCATED AT A CABINET WALL CHANGE OF TUBE SIZE OTHERWISE
	DIELECTRIC FLANGE & UNION

ELECTRICAL
THREE PHASE LINE-380V
SINGLE PHASE LINE-380V
SINGLE PHASE LINE-220V
RJ-45 CAT.5 ETHERNET CABLE
RJ-11 TWISTED PAIR ANALOG CABLE
4 WIRE SHEILDED BELDEN TYPE COMMUNICATION CABLE
FUSIBLE UNIT
DISCONNECT SWITCH
CIRCUIT BREAKER
EMERGENCY SHUT DOWN (LOCALIZED) (ESD)
EMERGENCY STOP (FULL FACILITY) (ESTOP)
KWH METER WITH KWH, MAX. POWER VA, KVAR RECORDING (PM)
ALARM HORN
ALARM STROBE LIGHT
HYDROGEN FLAME SENSOR
COMBUSTIBLE GAS SENSOR (GS)

INSTRUMENTATION DESCRIPTION	
CE	CONDUCTIVITY ELEMENT
CV	CHECK VALVE
DPS	DIFFERENTIAL PRESSURE SWITCH
DPT	DIFFERENTIAL PRESSURE TRANSDUCER
FE	FLOW ELEMENT
FSL	FLOW SWITCH LOW
FT	FLOW TRANSMITTER
HAE	HYDROGEN ANALYSER ELEMENT
HE	HYDROGEN ELEMENT
LD	LIQUID LEAK DETECTOR
LSH	LEVEL SWITCH HIGH
LSHH	LEVEL SWITCH HIGH-HIGH
LSL	LEVEL SWITCH LOW
LSLL	LEVEL SWITCH LOW-LOW
LS	LEVEL SWITCH
LTS	LIMIT TILT SWITCH
NRV	NON RETURN VALVE
OAE	OXYGEN ANALYSER ELEMENT
PCV	PRESSURE CONTROL VALVE
PD	PRESSURE DAMPENER
PG	PRESSURE GAUGE
PI	PRESSURE INDICATOR
PRV	PRESSURE RELIEF VALVE
PSL	LOW PRESSURE SWITCH
PT	PRESSURE TRANSDUCER
PV	PNEUMATIC VALVE
LI	LEVEL GLASS
SV	SOLENOID VALVE
TE	TEMPERATURE ELEMENT
TI	TEMPERATURE INDICATOR
TSH	TEMPERATURE SWITCH HIGH
TT	TEMPERATURE TRANSMITER
V	VALVE
XV	PILOTED VALVE
ZS	LIMIT SWITCH
MI	DEW POINT ANALYSER
MT	DEW POINT TRANSDUCER
OT	OXYGEN PPM TRANSDUCER
OZ	OXYGEN PPM ANALYSER

REFERENCE DRAWINGS

REV.	DESCRIPTION	DRWN	DSGN	APPD	DATE
0	AS BUILT - BASIN NUMBER AND TITLE BLOCK	L. FROEHLICH	A. BOUSHEE	R. BUSH	5/7/07

FACILITY: WIND TO HYDROGEN SYSTEM

LOCATION/UNIT: MINOT, NORTH DAKOTA

CONTRACT/DESIGNATION:

MECHANICAL SPECIFICATIONS

BASIN ELECTRIC POWER COOPERATIVE
1717 EAST INTERSTATE AVENUE
BISMARCK, NORTH DAKOTA 58503-0564
PHONE 701-223-0441

DESIGN BY ALBERT KAHN ASSOCIATES
DRAWN BY
DESIGN CHK
DRAFT CHK
APPROVED
SCALE: NONE
VENDOR/ORIGINATED FROM: ALBERT KAHN ASSOCIATES
VENDOR DRAWING NO. M-100 | ORIGINAL REV 5
BASIN DRAWING NO. OMI-0001 | REV. NO. 0

01/27/04

Station Alarm Beacon sign (30" × 30")

BASIN ELECTRIC POWER COOPERATIVE

STATION ALARM BEACON

Horn	Light	Status	Vehicle Operator Response
OFF	OFF	All systems normal.	OK to Refuel
ON	Flashing	Equipment problem. Flame detected or ESTOP has been actuated; all systems defaulting to safe status	Not OK to Refuel. Exit the area until Station Operator authorizes re-entry to the Fueling Station.
OFF	Flashing	ESTOP actuation acknowledged; all systems defaulted to safe condition; corrective actions in progress	Not OK to Refuel. Exit the area until Station Operator authorizes re-entry to the Fueling Station.

Annotations: green (first row OFF/OFF), red (second row ON/Flashing), yellow (third row OFF/Flashing).

NOTE: An alarm signal does not automatically indicate an emergency situation. Follow the instructions as stated in the applicable Response column.

TO REPORT AN INCIDENT AT THIS STATION
CALL ?????????? AND PROVIDE THIS FACILITY CODE ??????????

Stay Calm. Use your judgement and common sense.

red (number only)
red (number only)

COUNT: 1
(1 AT DISPENSER)
1/2" BLACK (RED, YELLOW AND GREEN as noted) LETTERS
WHITE BACKGROUND

Instructions sign (24" × 18")

INSTRUCTIONS

THIS DISPENSER IS CALIBRATED TO DELIVER 5,000 PSIG (350 BAR) SETTLED PRESSURE @ 59°F IN THE VEHICLE TANK. INDICATED GAUGE FILL PRESSURE MAY BE HIGHER.

1. TURN OFF IGNITION.
2. INITIATE REFUELLING AT THE DISPENSER.
3. CONNECT THE GROUNDING CABLE AND COMMUNICATION CABLE (IF EQUIPPED).
4. CONNECT FUELING HOSE TO THE VEHICLE.
5. FUELLING BEGINS AUTOMATICALLY (HISSING SOUND).
6. FUELLING IS COMPLETE WHEN THE METER STOPS INDEXING.
7. DISCONNECT THE FUELLING HOSE AND REPLACE IN THE DISPENSER HOLSTER.
8. DISCONNECT THE GROUNDING CABLE, COMMUNICATION CABLE (IF EQUIPPED) AND RETRACT.
9. COMPLETE REFUELLING AT DISPENSER.

NEED HELP? CALL SECURITY ??????????
AND PROVIDE THIS FACILITY CODE: ?????????

red (numbers only)

COUNT: 1
(1 AT DISPENSER)
1/2" BLACK AND RED LETTERS
WHITE BACKGROUND

Incident sign (12" × 12")

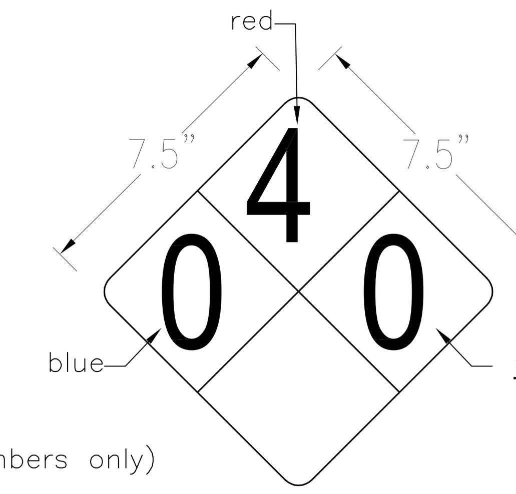
BASIN ELECTRIC POWER COOPERATIVE

TO REPORT AN INCIDENT AT THIS STATION
CALL ???????????
AND PROVIDE THIS FACILITY CODE:
?????????

red (numbers only)

COUNT: 2
(1 ON EACH WALK-IN GATE)
3/4" BLACK & RED LETTERS
WHITE BACKGROUND

Hazard diamond (7.5" × 7.5")



COUNT: 4
(1 ON EACH BOUNDARY FENCE)
3" RED, YELLOW AND BLUE LETTERS
WHITE BACKGROUND

Gas & flame detection sign (6" × 6")

GAS & FLAME DETECTION SYSTEM
MUST BE INSPECTED AND RECALIBRATED BY:
YYYY/MM/DD

COUNT: 2
(1 ON CONTROL PANEL, 1 ON DISPENSER)
½ AND ⅜" RED LETTERS
WHITE BACKGROUND

Authorized personnel sign (24" × 18")

AUTHORIZED PERSONNEL ONLY

HYDROGEN
FLAMMABLE GAS

NO SMOKING OR
OPEN FLAMES

NO PARKING

COUNT: 4
(1 ON EACH BOUNDARY FENCE)
1" RED LETTERS
WHITE BACKGROUND
NFPA 52 SEC. 6.4.3.11
NFPA 50A 2-5

Warning sign (18" × 18")

WARNING!

HYDROGEN
FLAMMABLE GAS

NO SMOKING OR OPEN FLAMES

NO CELL PHONES

TURN IGNITION OFF
DURING FUELLING

HYDROGEN DOES NOT HAVE
A DISTINCTIVE ODOR

COUNT:1
(1 AT DISPENSER)
3/4" RED LETTERS
WHITE BACKGROUND
NFPA 52 SEC. 6.14.10

Emergency stop sign (12" × 6")

EMERGENCY
STOP
BUTTON

COUNT: 1
(1 AT E-STOP POST)
1" RED LETTERS
WHITE BACKGROUND

Emergency shutdown sign (12" × 6")

EMERGENCY
SHUTDOWN
BUTTON

COUNT: 3
(2 AT FUEL GENERATOR, 1 AT DISPENSER)
1" RED LETTERS
WHITE BACKGROUND

SCALE 3" = 1'-0"
0 3" 6" 9" 1'

Title block

REFERENCE DRAWINGS

REV.	DESCRIPTION	DRWN	DSGN	APPD	DATE
0	AS BUILT – BASIN NUMBER AND TITLE BLOCK	L. FROEHLICH	A. BOUSHEE	R. BUSH	5/7/07

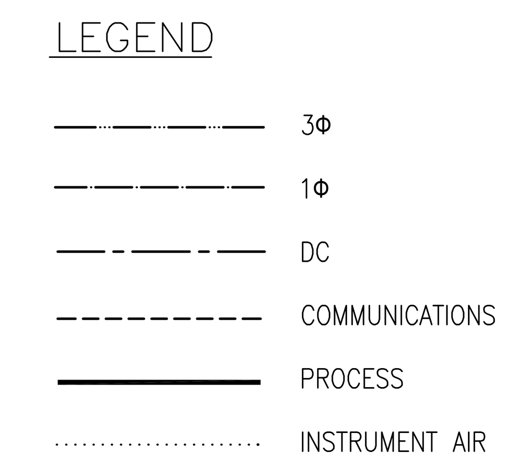
FACILITY: WIND TO HYDROGEN SYSTEM
LOCATION/UNIT: MINOT, NORTH DAKOTA
CONTRACT/DESIGNATION:

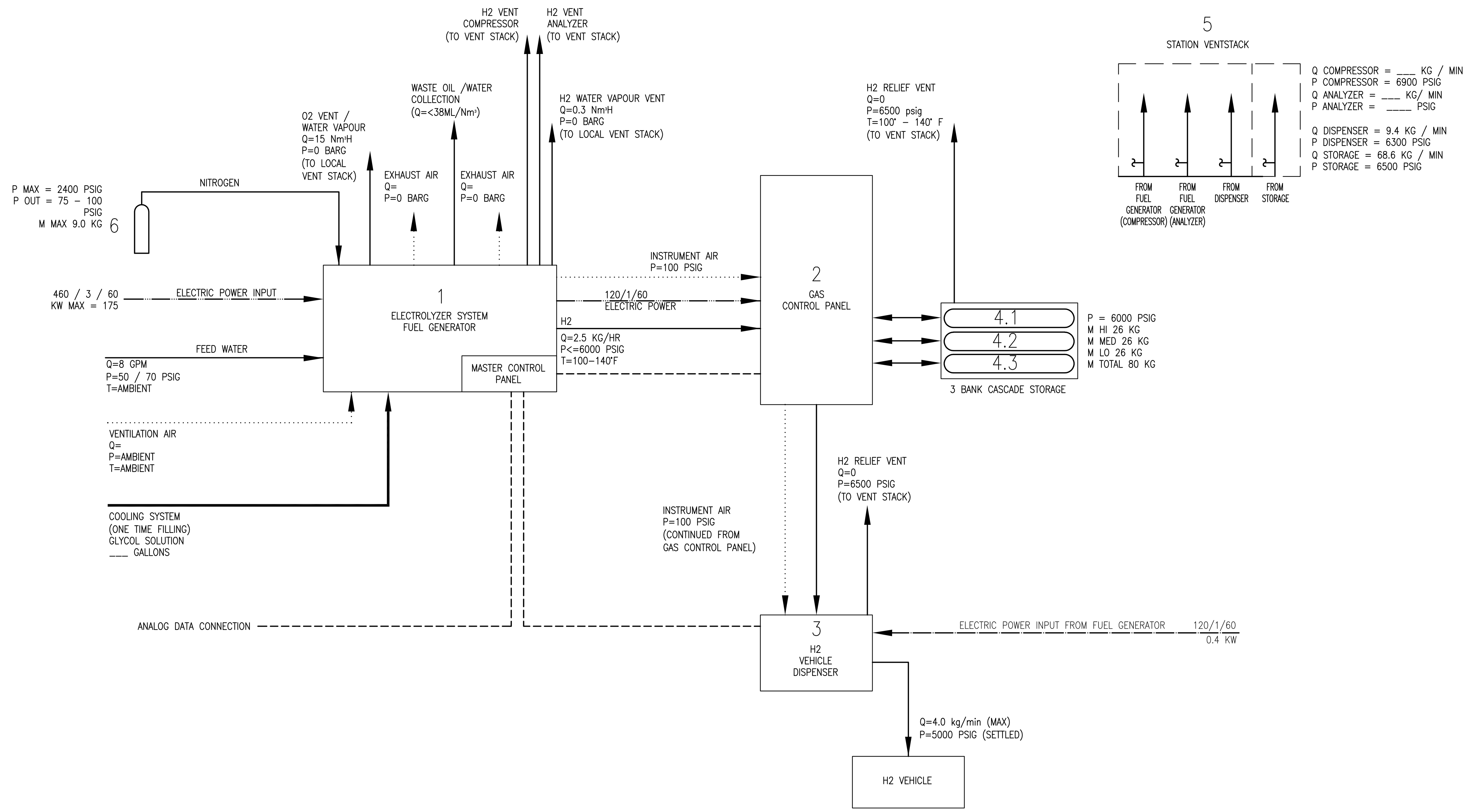
SIGNS

BASIN ELECTRIC POWER COOPERATIVE
1717 EAST INTERSTATE AVENUE
BISMARCK, NORTH DAKOTA 58503-0564
PHONE 701-223-0441

DESIGN BY: ALBERT KAHN ASSOCIATES
DRAWN BY:
DESIGN CHK:
DRAFT CHK:
APPROVED:
SCALE: AS SHOWN
VENDOR/ORIGINATED FROM: ALBERT KAHN ASSOCIATES
VENDOR DRAWING NO.: M-101
ORIGINAL REV: 5
BASIN DRAWING NO.: OMI-0002
REV. NO.: 0

01/27/04





REV.	DESCRIPTION	DRWN	DSGN	APPD	DATE
0	AS BUILT – BASIN NUMBER AND TITLE BLOCK	L. FROEHLICH	A. BOUSHEE	R. BUSH	5/7/07

REFERENCE DRAWINGS

FACILITY: WIND TO HYDROGEN SYSTEM

LOCATION/UNIT: MINOT, NORTH DAKOTA

CONTRACT/DESIGNATION:

PROCESS FLOW DIAGRAM

BASIN ELECTRIC POWER COOPERATIVE
1717 EAST INTERSTATE AVENUE
BISMARCK, NORTH DAKOTA 58503–0564
PHONE 701–223–0441

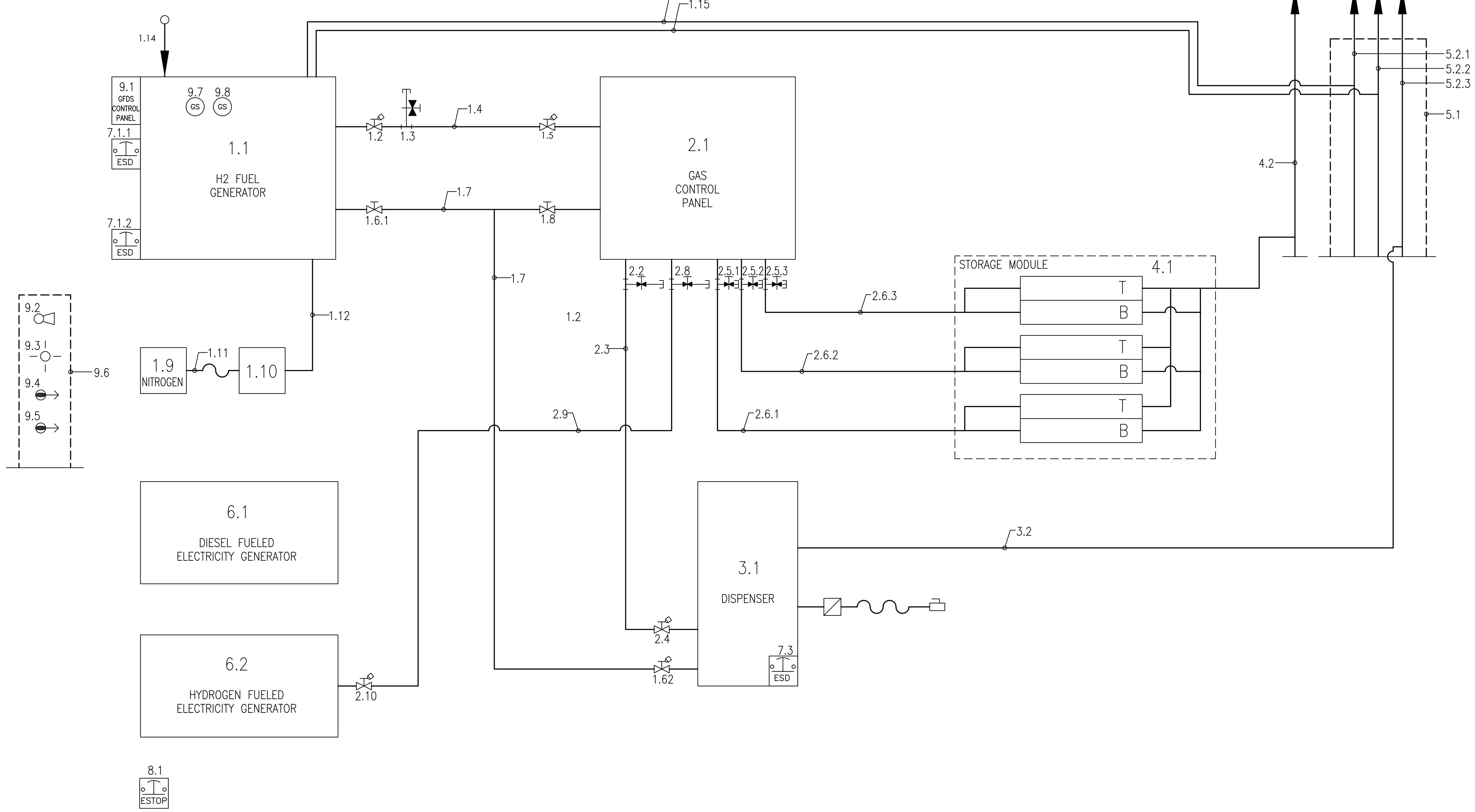
DESIGN BY ALBERT KAHN ASSOCIATES
DRAWN BY
DESIGN CHK.
DRAFT CHK.
APPROVED

SCALE: NONE

VENDOR/ORIGINATED FROM: ALBERT KAHN ASSOCIATES

VENDOR DRAWING NO. M–200 | ORIGINAL REV 5

BASIN DRAWING NO. OMF–0001 | REV. NO. 0



NOTE:
FOR A DETAILED PROCESS AND INTIGRATION DIAGRAM OF THE FUEL GENERATOR, GAS CONTROL PANEL, DISPENSER AND STORAGE MODULE SEE HYDROGENICS DRAWINGS.

REV.	DESCRIPTION	DRWN	DSGN	APPD	DATE
0	AS BUILT – BASIN NUMBER AND TITLE BLOCK	L. FROEHLICH	A. BOUSHEE	R. BUSH	5/7/07

REFERENCE DRAWINGS

FACILITY: WIND TO HYDROGEN SYSTEM
LOCATION/UNIT: MINOT, NORTH DAKOTA
CONTRACT/DESIGNATION:

PROCESS AND INTEGRATION DIAGRAM

BASIN ELECTRIC POWER COOPERATIVE
1717 EAST INTERSTATE AVENUE
BISMARCK, NORTH DAKOTA 58503–0564
PHONE 701–223–0441

DESIGN BY ALBERT KAHN ASSOCIATES
DRAWN BY
DESIGN CHK.
DRAFT CHK.
APPROVED
SCALE: NONE
VENDOR/ORIGINATED FROM: ALBERT KAHN ASSOCIATES
VENDOR DRAWING NO. M–300 ORIGINAL REV 5
BASIN DRAWING NO. OMF–0002 REV. NO. 0

ID No.	ITEM NAME	QTY.	DESCRIPTION	EQUIPMENT VENDOR SPECIFICATIONS	FUNCTION	SET POINT OR RANGE	SCOPE
1.1	FUEL GENERATOR	1	HYDROGENICS MODEL HySTAT A-30 ELECTROLYZER	BY HYDROGENICS	GENERATES HIGH PURITY HYDROGEN WHICH IS COMPRESSED TO THE STATION WORKING PRESSURE WITH AN INTEGRATED COMPRESSION MODULE	Pmax = 6000 psig Qmax = 2.5 kg/hr	OSOI
1.2	VALVE, ISOLATION	1	MANUAL ISOLATION VALVE, 2 WAY, c/w LOCKING KIT	SWAGELOK, 80 SERIES, 3/8 INCH	SHUTS OFF THE FLOW OF HYDROGEN FROM THE FUEL GENERATOR TO THE BALANCE OF PLANT	Pmax = 6000 psig NO	CSCI
1.3	TEST PORT	1	'T' FITTING c/w NEEDLE VALVE AND CAP	SWAGELOK, HN SERIES, 316 SS, 1/4 INCH	ACCESS PORT FOR CONNECTION OF PRESSURE TESTING APPARATUS	Pmax = 6000 psig NC	CSCI
1.4	TUBE, SUPPLY	20 ft±	316 L STAINLESS STEEL TUBE	SWAGELOK, 3/8 INCH OD x 0.083 INCH WALL THICKNESS ASTM A269	DELIVERS HYDROGEN FROM THE FUEL GENERATOR TO THE GAS CONTROL PANEL (GCP)	Pmax = 6000 psig Qmax = 2.5 kg/hr	CSCI
1.5	VALVE, ISOLATION		MANUAL ISOLATION VALVE, 2 WAY, c/w LOCKING KIT	SWAGELOK, 80 SERIES, 3/8 INCH	SHUTS OFF THE FLOW OF HYDROGEN FROM THE FUEL GENERATOR AT THE GCP	Pmax = 6000 psig Qmax = 2.5 kg/hr NO	CSCI
1.6.1 to 1.6.3	VALVE, ISOLATION	3	MANUAL ISOLATION VALVE, 2 WAY	SWAGELOK, 60 SERIES, BRASS, 1/2 INCH	SHUTS OFF FLOW OF INSTRUMENT AIR AT THE FUEL GENERATOR, DISPENSER, AND THE GAS CONTROL PANEL	Pmax = 100 psig Qmax =	CSCI NO
1.7	TUBE, SUPPLY	35 ft±	GALVANIZED PIPE	GALVANIZED PIPE, 1/2 INCH ID	DELIVERS INSTRUMENT AIR TO THE GCP AND DISPENSER	Pmax = 100 psig Qmax =	CSCI
1.8	NOT USED						
1.9	CYLINDER, NITROGEN	1	'T' SIZE NITROGEN BOTTLE	BY CUSTOMER	NITROGEN SUPPLY FOR THE FUEL GENERATOR	Pmax = 2400 psig Mmax = 9 kg	OSCI
1.10	VALVE, PRESSURE CONTROL	1	NITROGEN PRESSURE CONTROL VALVE c/w GAUGES (PCV)	BY CUSTOMER	CONTROLS THE PRESSURE OF THE NITROGEN SUPPLY TO THE FUEL GENERATOR	Pin/max = 2400 psig Pout = 75 psig	OSCI
1.11	HOSE, SUPPLY	1	FLEXIBLE HOSE TO CONNECT THE NITROGEN CYLINDER TO THE PCV	BY CUSTOMER	FLEXIBLE HOSE FOR CONNECTING THE N2 CYLINDER TO THE PCV	Pmax = 2400 psig	OSCI
1.12	TUBE, SUPPLY	1	316 L STAINLESS STEEL TUBE	SWAGELOK, 3/8" INCH OD x 0.083 INCH WALL THICKNESS ASTM A269	DELIVERS NITROGEN TO THE FUEL GENERATOR	Pmax = 75 psig	CSCI
1.13	TUBE, VENT	25 ft±	316 L STAINLESS STEEL TUBE	SWAGELOK, 3/4" INCH OD x 0.065 INCH WALL THICKNESS ASTM A269	DELIVERS HYDROGEN VENT GASES FROM THE FUEL GENERATOR TO THE VENT STACK	Pmax = 6900 psig Qmax = (tbd)	CSCI
1.14	PIPE, SUPPLY	6 ft±	BY OWNER	BY OWNER	DELIVERS POTABLE WATER FROM THE OWNER'S SUPPLY STUB TO THE FUEL GENERATOR	Pmax = 60 psig Qmax = 8 gpm	OSOI
1.15	TUBE, VENT	25 ft±	316L STAINLESS STEEL	SWAGELOK 1/2" INCH OD x 0.049 INCH WALL THICKNESS ASTM A269	DELIVERS HYDROGEN VENT GASES FROM THE FUEL GENERATOR TO THE VENT STACK	Pmax = ______psig Qmax =	CSCI
2.1	PANEL, GAS CONTROL	1	HYDROGENICS GAS CONTROL PANEL	BY HYDROGENICS	RECEIVES HYDROGEN FROM THE FUEL GENERATOR AND CONTROLS THE FLOW TO / FROM STORAGE, TO THE DISPENSER AND TO THE ELECTRICITY GENERATOR	Pin/max = 6000 psig Pout/max = 6000 psig	OSCI
2.2	TEST PORT	1	'T' FITTING c/w NEEDLE VALVE AND CAP	SWAGELOK, HN SERIES, 316 SS, 1/4 INCH	ACCESS PART FOR CONNECTION OF PRESSURE TESTING APPARATUS	Pmax = 6000 psig NC	CSCI
2.3	TUBE, SUPPLY	15 ft±	316 L STAINLESS STEEL TUBE	SWAGELOK, 3/8 INCH OD x 0.083 INCH WALL THICKNESS ASTM A269	DELIVERS HYDROGEN FROM THE GCP TO THE DISPENSER	Pmax = 6000 psig Qmax = 4.0 kg/min	CSCI CSCI
2.4	VALVE, ISOLATION	1	MANUAL ISOLATION VALVE, 2 WAY, c/w LOCKING KIT	SWAGELOK, 80 SERIES, 3/8 INCH	SHUTS OFF THE FLOW OF HYDROGEN FROM THE GCP AT THE DISPENSER	Pmax = 6000 psig NO	CSCI
2.5.1 to 2.5.3	TEST PORT	3	'T' FITTING c/w NEEDLE VALVE AND CAP	SWAGELOK, HN SERIES, 316 SS, 1/4 INCH	ACCESS PART FOR CONNECTION OF PRESSURE TESTING APPARATUS	Pmax = 6000 psig NC	CSCI
2.6.1 to 2.6.3	TUBE, SUPPLY	25 ft±	316 L STAINLESS STEEL TUBE	SWAGELOK, 3/8 INCH OD x 0.083 INCH WALL THICKNESS ASTM A269	DELIVERS HYDROGEN TO / FROM THE GCP AND THE 3 BANK CASCADE STORAGE	Pmax = 6000 psig Qmax = 4.0 kg/hr	CSCI
2.7	NOT USED						
2.8	TEST PORT	1	'T' FITTING c/w NEEDLE VALVE AND CAP	SWAGELOK, HN SERIES, 316 SS, 1/4 INCH	ACCESS PART FOR CONNECTION OF PRESSURE TESTING APPARATUS	P = 150 psig NC	CSCI
2.9	TUBE, SUPPLY	20 ft±	316 L STAINLESS STEEL TUBE	SWAGELOK, 1/2 INCH OD x 0.049 INCH WALL THICKNESS ASTM A269	DELIVERS HYDROGEN FROM THE GCP TO THE ELECTRICITY GENERATOR	P = 80 psig Qmax = 2.5 kg/hr	CSCI
2.10	VALVE, ISOLATION	1	MANUAL ISOLATION VALVE, 2 WAY, c/w LOCKING KIT	SWAGELOK, 60 SERIES, 1/2 INCH	SHUTS OFF THE FLOW OF HYDROGEN FROM THE GCP TO THE ELECTRICITY GENERATOR	P = 80 psig Qmax = 37 scfm (5.27 kg/hr)	NO CSCI
2.11	TUBE, VENT	10 ft±	316 L STAINLESS STEEL TUBE	SWAGELOK 3/4 INCH OD x 0.065 INCH WALL THICKNESS ASTM A269	DELIVERS HYDROGEN VENT GASES FROM THE GAS CONTROL PANEL TO THE VENT STACK	Pmax = _____psig Qmax =	FUTURE
2.12	INLET, PORT	1	BULKHEAD FITTING	BY HYDROGENICS	CAPPED FITTING FOR FUTURE CONNECTION OF TUBE TRAILER TRANSFER HOSE	P = (tbd) Q = (tbd)	OSOI
3.1	DISPENSER	1	HYDROGENICS FUEL DISPENSER	BY HYDROGENICS	SINGLE HOSE DISPENSER TO PROVIDE 5000 psig (350 barg) SETTLED VEHICLE FILLS, c/w BREAKAWAY COUPLER AND SAE NOZZLE	Pmax = 6000 psig Psettled = 5000 psig Qmax = 4.0 kg/min	OSCI
3.2	TUBE, VENT	15 ft±	316 L STAINLESS STEEL TUBE	SWAGELOK, 1 INCH OD x 0.083 INCH WALL THICKNESS ASTM A269	DELIVERS HYDROGEN VENT GASES FROM THE DISPENSER TO THE VENT STACK	Pmax = 6300 psig Qmax = 9.4 kg/min	CSCI
4.1	STORAGE MODULE	1	CP INDUSTRIES ASME STEEL CYLINDERS, 6 @16 IN OD x 19' 6" L	BY HYDROGENICS	HYDROGEN STORAGE ASSEMBLY IN 3 BANK CASCADE CONFIGURATION c/w PRESSURE RELIEF VALVES AND DEDICATED VENT STACK	Pmax = 6000 psig Mmax = 80 kg	OSCI
4.2	STACK, VENT	1	DEDICATED STORAGE VENT STACK	BY HYDROGENICS	DELIVERS FUGITIVE EMISSIONS FROM THE HYDROGEN STORAGE CYLINDERS TO A LOCATION THAT IS AWAY FROM EQUIPMENT AND PERSONNEL	Pmax = 6667 psig Qmax = 68.58 kg/min	OSCI
5.1	MAST, VENT STACK	1	STRUCTURAL STEEL MAST	CUSTOM DESIGN FOR BEPC AS PER AKA DRAWINGS	SUPPORTS VENT STACK RISERS AND SELF CLOSING RAINCAP	N/A	CSCI
5.2.1	RISERS, VENT STACK	1	316 L STAINLESS STEEL TUBE AND FITTINGS	SWAGELOK, 1INCH OD x 0.083 INCH WALL THICKNESS ASTM A269	DELIVERS FUGITIVE EMISSIONS FROM THE FUEL GENERATOR TO A LOCATION THAT IS AWAY FROM EQUIPMENT AND PERSONNEL	Pmax = 6900 psig Qmax = _____kg/min	CSCI
5.2.2	RISERS, VENT STACK	1	316 L STAINLESS STEEL TUBE AND FITTINGS	SWAGELOK, 1/2 INCH OD x 0.049 INCH WALL THICKNESS ASTM A269	DELIVERS FUGITIVE EMISSIONS FROM THE FUEL GENERATOR TO A LOCATION THAT IS AWAY FROM EQUIPMENT AND PERSONNEL	Pmax = _____psig Qmax = _____kg/min	CSCI
5.2.3	RISERS, VENT STACK	1	316 L STAINLESS STEEL TUBE AND FITTINGS	SWAGELOK, 1 1/4 INCH OD x 0.109 INCH WALL THICKNESS ASTM A269	DELIVERS FUGITIVE EMISSIONS FROM THE DISPENSER TO A LOCATION THAT IS AWAY FROM EQUIPMENT AND PERSONNEL	Pmax = 6300 psig Qmax = 9.4 kg/min	CSCI
6.1	GENERATOR	1	STATIONARY ELECTRICITY GENERATOR	BY OWNER DIESEL FUELED	STANDBY ELECTRICAL GENERATOR TO PROVIDE POWER TO THE STATION WHEN POWER IS NOT AVAILABLE FROM THE GRID	480/3/60 50 KW	OSOI
6.2	GENERATOR	1	STATIONARY ELECTRICITY GENERATOR	BY OWNER HYDROGEN GAS FUELED	STANDBY ELECTRICAL GENERATOR TO DEMONSTRATE WIND TO ELECTRICITY TO HYDROGEN TO ELECTRICITY ENERGY CYCLE	480/3/60 60 KW	OSOI
7.1.1 to 7.1.2	ESD	2	EMERGENCY SHUT DOWN BUTTON	BY HYDROGENICS	EMERGENCY LOCALIZED SHUTDOWN OF THE ELECTROLYZER; OTHER STATION OPERATIONS ARE NOT INTERRUPTED	N/C MANUAL RESET	OSOI
7.2	ESD	1	EMERGENCY SHUT DOWN BUTTON	BY HYDROGENICS	EMERGENCY LOCALIZED SHUTDOWN OF THE DISPENSER; OTHER STATION OPERATIONS ARE NOT INTERRUPTED	N/C MANUAL RESET	OSOI
8.1	E-STOP	1	EMERGENCY STOP BUTTON	BY ELECTRICAL DIVISION	EMERGENCY FULL FACILITY SHUTDOWN; ALL EQUIPMENT AND SYSTEMS STOP AND FAIL SAFE	N/C MANUAL RESET	N/A
9.1	PANEL, EMERGENCY ALARM	1	GAS AND FLAME DETECTION SYSTEM CONTROL PANEL c/w UPS BATTERY PACK	TBD	MICROPROCESSOR BASED MODULE THAT PERFORMS ALL OF THE CONTROL AND COMMUNICATIONS FUNCTIONS FOR THE GAS AND FLAME DETECTION SENSORS	–	OSOI
9.2	ALARM, AUDIBLE	1	ALARM HORN	MEDC EExd, DB3	PROVIDES AUDIBLE SIGNAL THAT A GAS LEAK OR FLAME HAS BEEN DETECTED	ON IF ANY SENSOR IS ON; OFF WHEN ALL SENSORS ARE OFF, WHEN E-STOP IS RESET OR WHEN ACKNOWLEDGED	OSOI
9.3	ALARM, VISUAL	1	ALARM STROBE LIGHT	FEDERAL SIGNAL STROBE, 225XT	PROVIDES VISIBLE SIGNAL THAT A GAS LEAK OR FLAME HAS BEEN DETECTED	ON IF ANY SENSOR IS ON OR IF THE E-STOP IS ACTUATED OFF WHEN ALL SENSORS ARE OFF OR WHEN THE E-STOP IS RESET	OSOI
9.4 to 9.5	SENSOR, FLAME	2	HYDROGEN FLAME SENSOR	DETECTOR ELECTRONICS X3302	FLAME SENSOR, CALIBRATED TO DETECT FLAMES FROM A HYDROGEN FIRE	–	OSOI
9.6	MAST, GFDS	1	STRUCTURAL STEEL MAST	CUSTOM DESIGN FOR BEPC AS PER AKA DRAWINGS	SUPPORTS GAS AND FLAME DETECTION EQUIPMENT	–	CSCI
9.7 to 9.8	SENSOR, GAS	2	COMBUSTIBLE GAS SENSOR	DETECTOR ELECTRONICS CGS SERIES	GAS SENSOR, DETECTS HYDROGEN VAPOURS	TBD	OSOI

CSCI = CONTRACTOR SUPPLY
CONTRACTOR INSTALL
OSCI = OWNER SUPPLY
CONTRACTOR INSTALL
OSOI = OWNER SUPPLY
OWNER INSTALL

REV.	DESCRIPTION	DRWN	DSGN	APPD	DATE
0	AS BUILT – BASIN NUMBER AND TITLE BLOCK	L. FROEHLICH	A. BOUSHEE	R. BUSH	5/14/07

REFERENCE DRAWINGS

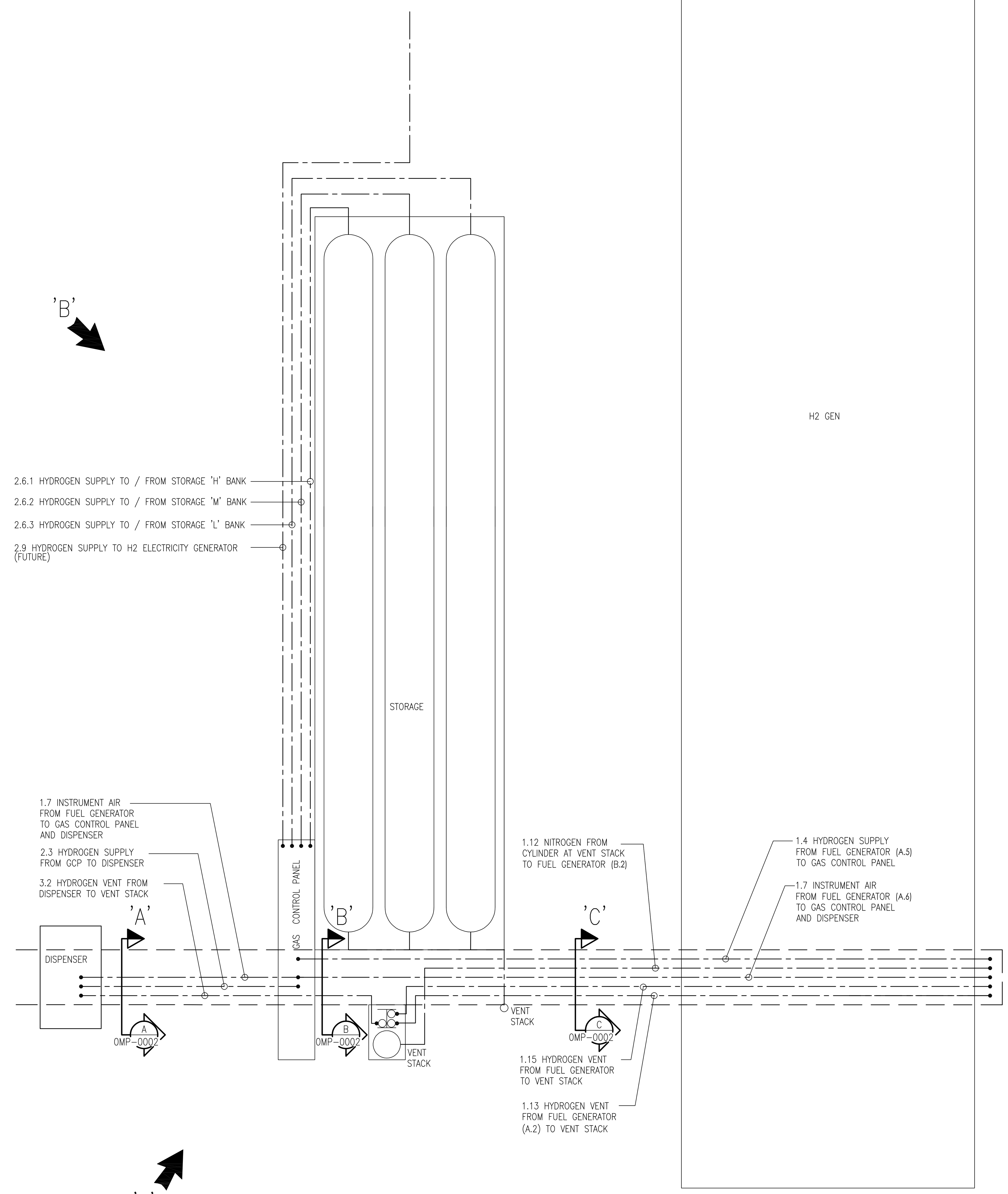
FACILITY: WIND TO HYDROGEN SYSTEM
LOCATION/UNIT: MINOT, NORTH DAKOTA
CONTRACT/DESIGNATION:

PROCESS AND INTEGRATION DIAGRAM SCHEDULE

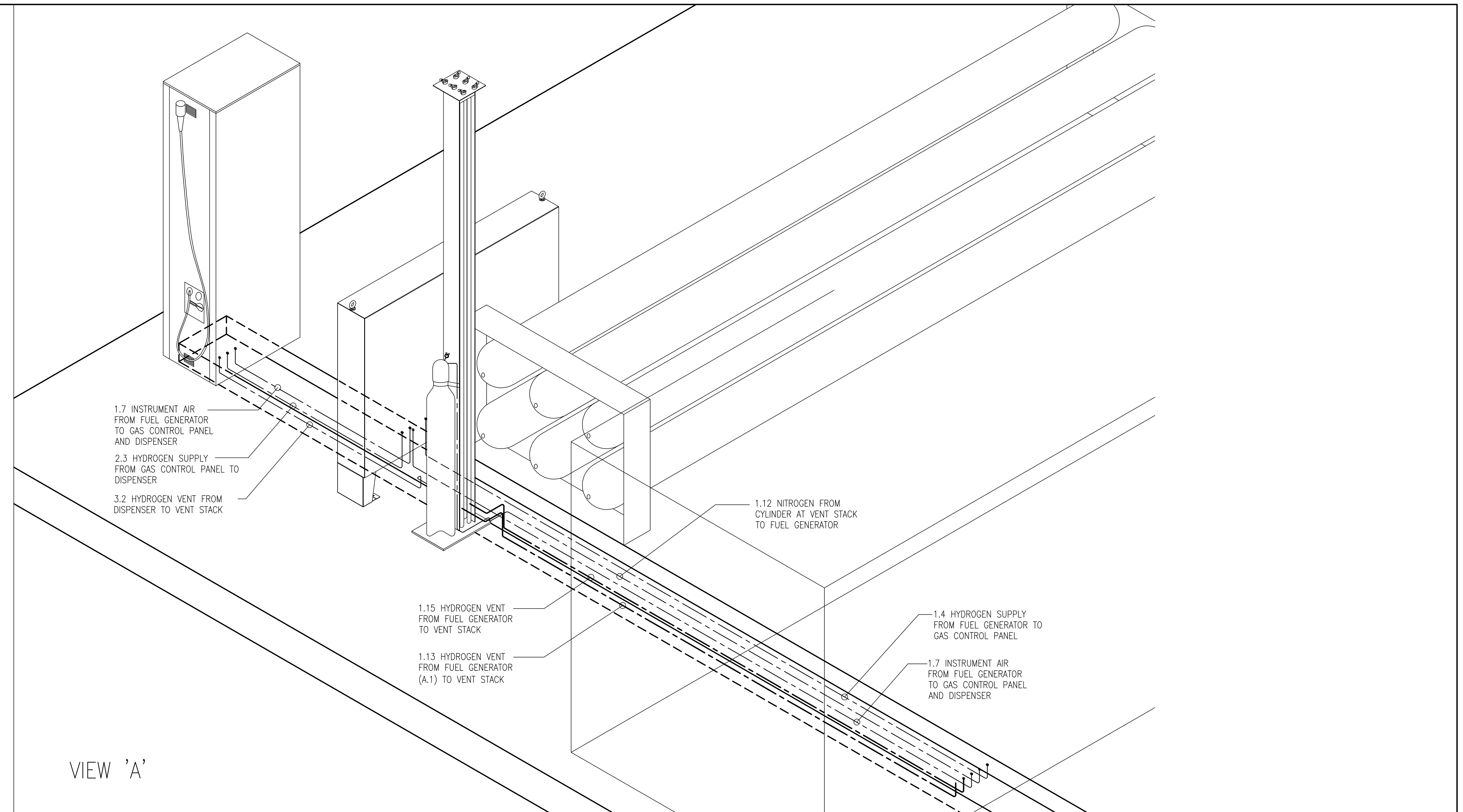
BASIN ELECTRIC POWER COOPERATIVE
1717 EAST INTERSTATE AVENUE
BISMARCK, NORTH DAKOTA 58503-0564
PHONE 701-223-0441

DESIGN BY ALBERT KAHN ASSOCIATES
DRAWN BY
DESIGN CHK.
DRAFT CHK.
APPROVED
SCALE: NONE
VENDOR/ORIGINATED FROM: ALBERT KAHN ASSOCIATES
VENDOR DRAWING NO. M-301 ORIGINAL REV 5
BASIN DRAWING NO. 0MF-0003 REV. NO. 0

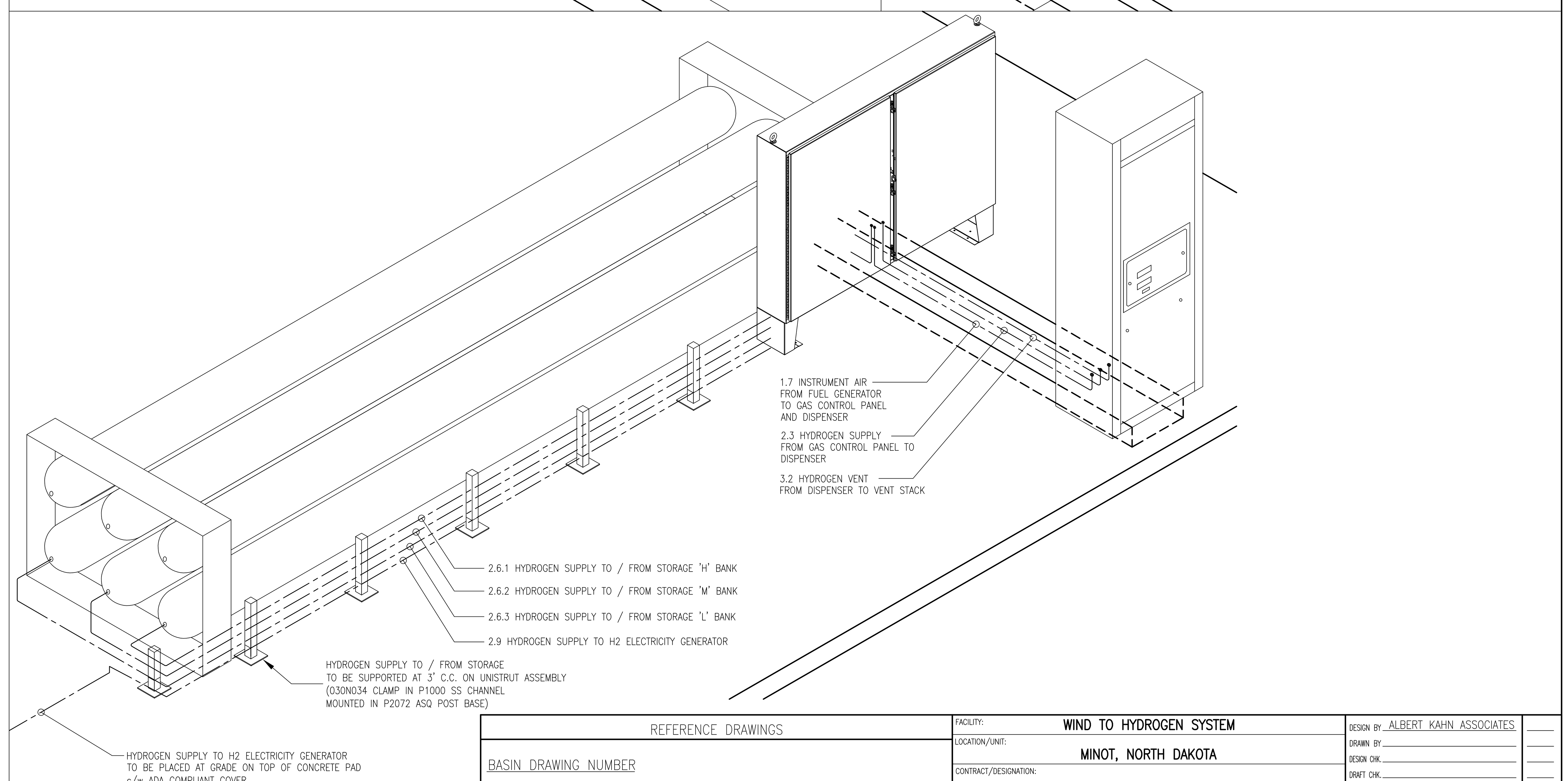
FOR PIPE AND TUBING SPECIFICATIONS SEE DRAWING NO. M-301 BASIN DWG. NO. 0MF-0003



PLAN VIEW



VIEW 'A'



VIEW 'B'

REFERENCE DRAWINGS

BASIN DRAWING NUMBER

0MP-0002 MECHANICAL UTILITIES DETAILS

REV.	DESCRIPTION	DRWN	DSGN	APPD	DATE
0	AS BUILT - BASIN NUMBER AND TITLE BLOCK	L. FROEHLICH	A. BOUSHEE	R. BUSH	5/7/07

FACILITY: WIND TO HYDROGEN SYSTEM

LOCATION/UNIT: MINOT, NORTH DAKOTA

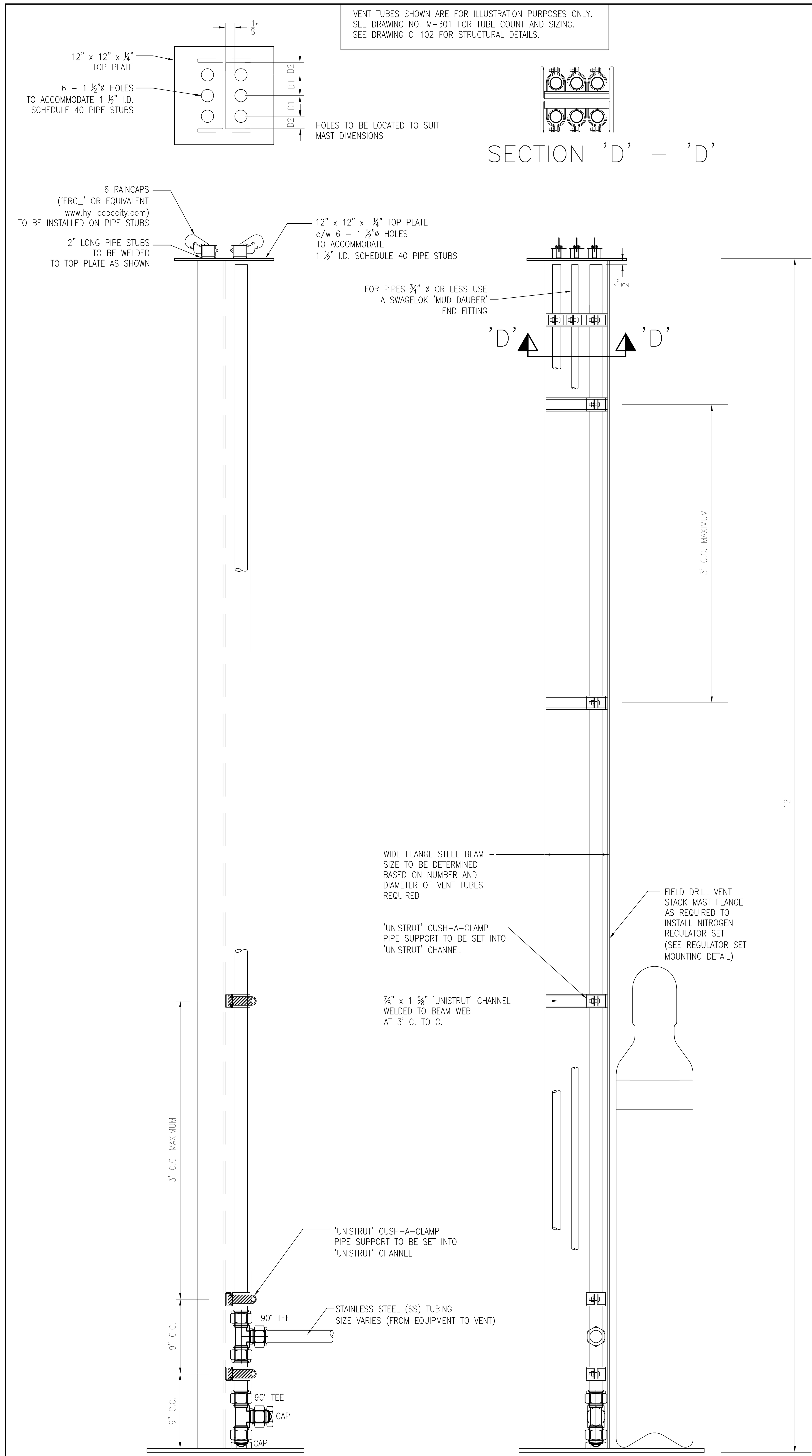
CONTRACT/DESIGNATION:

MECHANICAL UTILITIES TRENCH LAYOUT

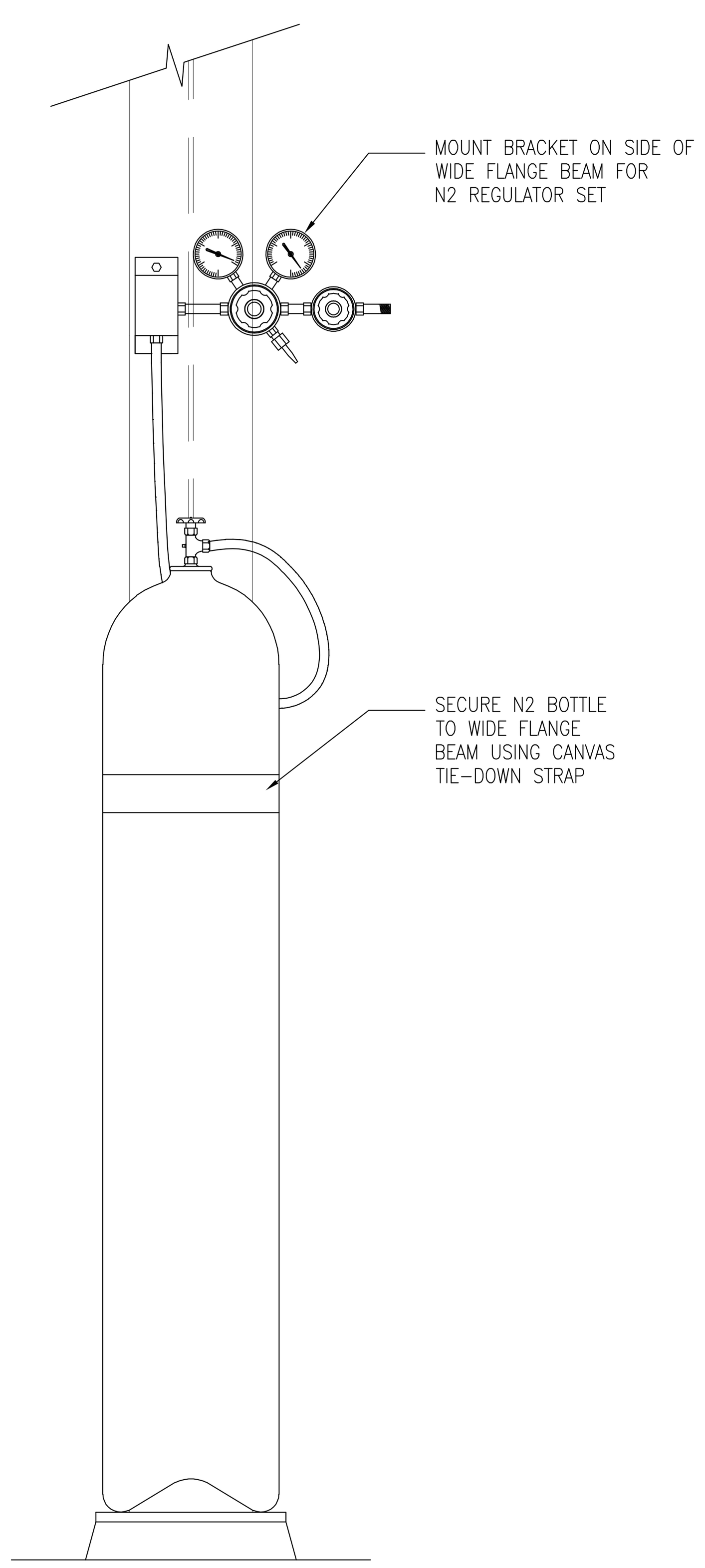
BASIN ELECTRIC POWER COOPERATIVE
1717 EAST INTERSTATE AVENUE
BISMARCK, NORTH DAKOTA 58503-0564
PHONE 701-223-0441

DESIGN BY: ALBERT KAHN ASSOCIATES
DRAWN BY:
DESIGN CHK.
DRAFT CHK.
APPROVED:
SCALE: NONE
VENDOR/ORIGINATED FROM: ALBERT KAHN ASSOCIATES
VENDOR DRAWING NO. M-400 ORIGINAL REV 5
BASIN DRAWING NO. 0MP-0001 REV. NO. 0

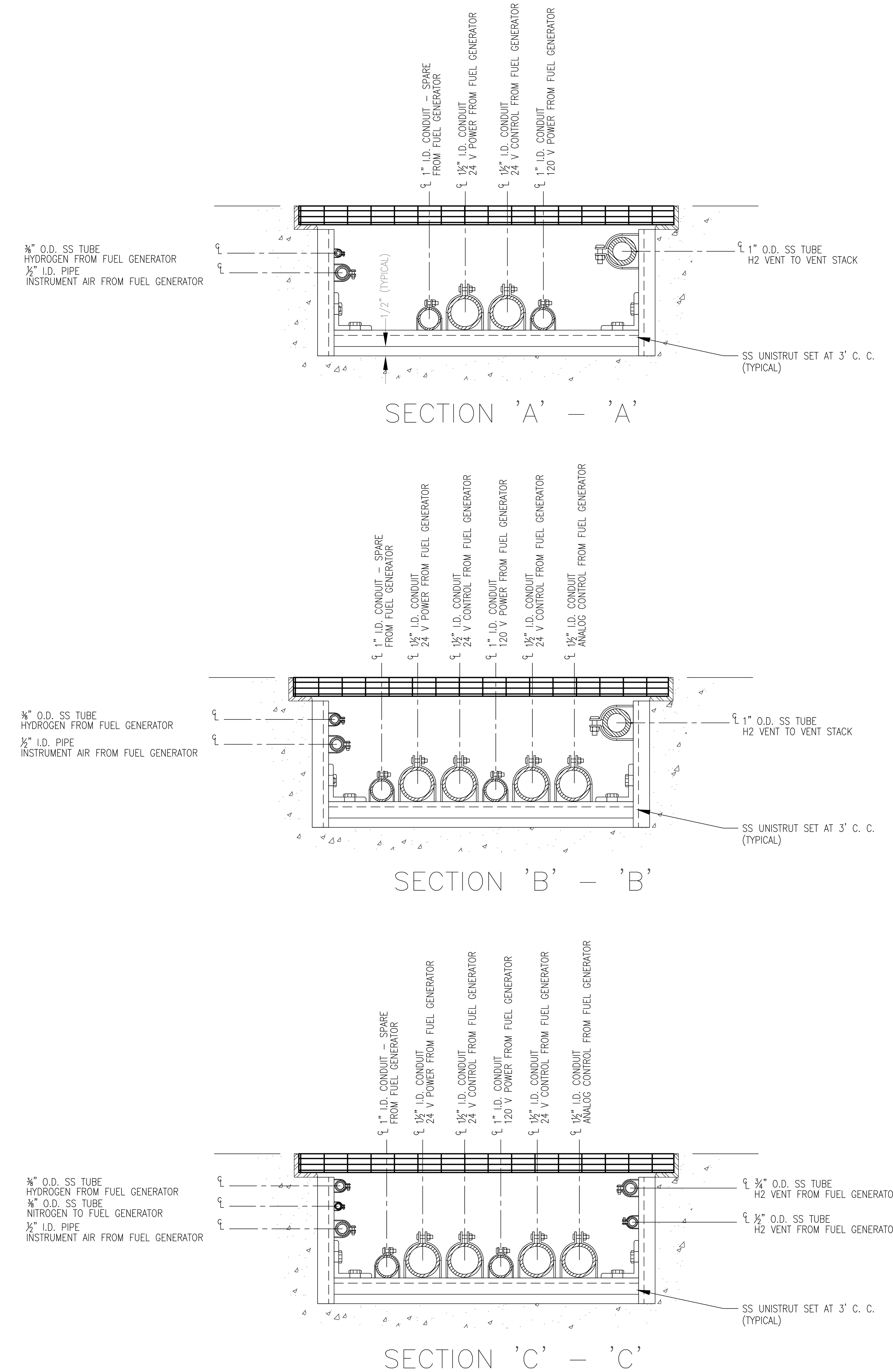
01/27/04



STATION VENT STACK DETAILS



N2 BOTTLE / REGULATOR MOUNTING DETAILS



TRENCH DETAILS

SEE DWG. NO. M-400(BASIN DWG. OMP-0001) FOR SECTION LOCATIONS

REV.	DESCRIPTION	DRWN	DSGN	APPD	DATE
0	AS BUILT – BASIN NUMBER AND TITLE BLOCK	L. FROEHLICH	A. BOUSHEE	R. BUSH	5/7/07

REFERENCE DRAWINGS

BASIN DRAWING NUMBER

OMP-0001 MECHANICAL UTILITIES TRENCH LAYOUT

FACILITY: WIND TO HYDROGEN SYSTEM

LOCATION/UNIT: MINOT, NORTH DAKOTA

CONTRACT/DESIGNATION:

MECHANICAL UTILITIES DETAILS

BASIN ELECTRIC POWER COOPERATIVE
1717 EAST INTERSTATE AVENUE
BISMARCK, NORTH DAKOTA 58503-0564
PHONE 701-223-0441

DESIGN BY ALBERT KAHN ASSOCIATES
DRAWN BY
DESIGN CHK.
DRAFT CHK.
APPROVED

SCALE: NONE

VENDOR/ORIGINATED FROM: ALBERT KAHN ASSOCIATES

VENDOR DRAWING NO. M-401 | ORIGINAL REV 5

BASIN DRAWING NO. OMP-0002 | REV. NO. 0

01/27/04

H2 COMPRESSION – PHYSICAL SETBACKS

ID	D	CODE	DESCRIPTION
D1	10	NFPA 52: 9.3.1.3.1	(i) FROM THE NEAREST IMPORTANT BUILDING
D2	10	NFPA 52: 9.3.1.3.1	(ii) FROM THE LINE OF ADJOINING PROPERTY THAT CAN BE BUILT UPON
D3	10	NFPA 52: 9.3.1.3.1	(iii) FROM ANY SOURCE OF IGNITION
D4	10	NFPA 52: 9.3.1.3.2	FROM THE NEAREST PUBLIC STREET OR SIDEWALK LINE
D5	50	NFPA 52: 9.3.1.3.3	FROM THE NEAREST RAIL OF ANY RAIL ROAD MAIN TRACK

H2 ANCILLARY (GENERATION/GAS CONTROL PANEL/EMERGENCY DUMP PANEL) – PHYSICAL SETBACKS

ID	D	CODE	DESCRIPTION
D6	10	NFPA 52: 9.3.1.3.1	(i) FROM THE NEAREST IMPORTANT BUILDING
D7	10	NFPA 52: 9.3.1.3.1	(ii) FROM THE LINE OF ADJOINING PROPERTY THAT CAN BE BUILT UPON
D8	10	NFPA 52: 9.3.1.3.1	(iii) FROM ANY SOURCE OF IGNITION
D9	10	NFPA 52: 9.3.1.3.2	FROM THE NEAREST PUBLIC STREET OR SIDEWALK LINE
D10	50	NFPA 52: 9.3.1.3.3	FROM THE NEAREST RAIL OF ANY RAIL ROAD MAIN TRACK

H2 DISPENSING EQUIPMENT – PHYSICAL SETBACKS

ID	D	CODE	DESCRIPTION
D11	10	NFPA 52: 9.3.1.3.1	(i) FROM THE NEAREST IMPORTANT BUILDING
D12	10	NFPA 52: 9.3.1.3.1	(ii) FROM THE LINE OF ADJOINING PROPERTY THAT CAN BE BUILT UPON
D13	10	NFPA 52: 9.3.1.3.1	(iii) FROM ANY SOURCE OF IGNITION
D14	10	NFPA 52: 9.3.1.3.2	FROM THE NEAREST PUBLIC STREET OR SIDEWALK LINE
D15	50	NFPA 52: 9.3.1.3.3	FROM THE NEAREST RAIL OF ANY RAIL ROAD MAIN TRACK

H2 POINT OF TRANSFER – PHYSICAL SETBACKS

ID	D	CODE	DESCRIPTION
D16	0	NFPA 52: 9.3.1.3.7	FROM BUILDINGS CONSTRUCTED OF MATERIALS WITH FIRE RESISTANCE => 2 HOURS
D17	3	NFPA 52: 9.3.1.3.8	FROM STORAGE
D18	10	NFPA 52: 9.3.1.3.6	(i) FROM BUILDINGS CONSTRUCTED OF MATERIALS WITH FIRE RESISTANCE < 2HOURS
D19	10	NFPA 52: 9.3.1.3.6	FROM A STREET OR PUBLIC SIDEWALK
D20	10	NFPA 52: 9.3.2.4	(ii) FROM ANY BUILDING OPENING

DISTRIBUTOR'S TRANSFER PANEL / GASEOUS H2 STORAGE> 15,000 scf – PHYSICAL SETBACKS

ID	D	CODE	DESCRIPTION
D21	3	NFPA 52:9.3.1.3.9	VALVES AND FITTINGS OF MULTIPLE GROUPS OF CONTAINERS FROM ANY OBSTRUCTION
D22	3	NFPA 52:9.3.1.3.8	FROM POINT OF TRANSFER
D23	5*	NFPA 55: 10.3.2.2.1 (1)(A) 1.	FROM A SPRINKLERED BUILDING WITH WALLS CONSTRUCTED OF NON–COMBUSTIBLE OR LIMITED COMBUSTIBLE MATERIAL
D24	5*	NFPA 55: 10.3.2.2.1 (1)(A) 1.	FROM AN UNSPRINKLERED BUILDING HAVING NON–COMBUSTIBLE CONTENTS AND WALLS CONSTRUCTED OF NON–COMBUSTIBLE OR LIMITED COMBUSTIBLE MATERIAL
D25	5*	NFPA 55: 10.3.2.2.1 (1)(A) 2. (b)	FROM AN UNSPRINKLERED BUILDING WITH COMBUSTIBLE CONTENTS AND WITH WALLS OF FIRE RESISTANCE => 2 HOURS
D26	5*	NFPA 55: 10.3.2.2.1 (14)	FROM THE LINE OF ADJOINING PROPERTY THAT IS ABLE TO BE BUILT UPON
D27	5	NFPA 55: 10.3.2.2.1 (15) (B)	HORIZONTAL DISTANCE FROM THE VERTICAL PLANE BELOW THE NEAREST OVERHEAD ELECTRIC WIRE OTHER THAN AN ELECTRIC TROLLEY, TRAIN OR BUS LINE
D28	10	NFPA 52: 9.3.1.3.1	FROM THE NEAREST IMPORTANT BUILDING
D29	10	NFPA 52: 9.3.1.3.1	FROM THE LINE OF ADJOINING PROPERTY THAT CAN BE BUILT UPON
D30	10	NFPA 52: 9.3.1.3.1	FROM ANY SOURCE OF IGNITION
D31	10	NFPA 52: 9.3.1.3.2	FROM THE NEAREST PUBLIC STREET OR SIDEWALK LINE
D32	10	NFPA 52: 9.3.1.3.4	FROM READILY IGNITABLE MATERIAL
D33	10	NFPA 55: 10.3.2.2.1 (2) (A)	FROM WALL OPENINGS NOT ABOVE ANY PART OF A SYSTEM
D34	10*	NFPA 55: 10.3.2.2.1 (4) (A)	FROM AN UNDERGROUND TANK, 0–1000 GALLONS CONTAINING ANY CLASSES OF FLAMMABLE OR COMBUSTIBLE LIQUIDS
D35	15	NFPA 55: 10.3.2.2.1 (13)	(i)FROM PUBLIC SIDEWALKS
D36	15	NFPA 55: 10.3.2.2.1(13)	(ii)FROM PARKED VEHICLES
D37	15	NFPA 55: 10.3.2.2.1 (15) (C)	FROM OVERHEAD PIPING CONTAINING OTHER HAZARDOUS MATERIALS
D38	20	NFPA 52: 9.3.1.3.5	FROM ABOVE GROUND TANKS CONTAINING FLAMMABLE OR COMBUSTIBLE LIQUIDS
D39	20*	NFPA 55: 10.3.2.2.1 (5) (A)	FROM ANY UNDERGROUND STORAGE TANKS, >1000 GALLONS CONTAINING ANY CLASS OF FLAMMABLE OR COMBUSTIBLE LIQUID
D40	25*	NFPA 55: 10.3.2.2.1 (1) (A) 2 (a)	FROM AN UNSPRINKLERED BUILDING WITH COMBUSTIBLE CONTENTS AND WITH WALLS OF FIRE RESISTANCE < 2 HOURS
D41	25	NFPA 55: 10.3.2.2.1 (2) (B)	FROM WALL OPENINGS ABOVE ANY PART OF THE SYSTEM
D42	25*	NFPA 55: 10.3.2.2.1 (3) (A)	FROM AN ABOVE GROUND TANKS 0–1000 GALLONS CONTAINING ANY CLASS OF FLAMMABLE OR COMBUSTIBLE LIQUID
D43	25*	NFPA 55: 10.3.2.2.1 (4) (B) NFPA 55: 10.3.2.2.1 (5) (B)	FROM THE VENT OR FILL OPENING OF ANY TANK CONTAINING ANY CLASS OF FLAMMABLE OR COMBUSTIBLE LIQUID
D44	25*	NFPA 55: 10.3.2.2.1 (6) (A)	FROM FLAMMABLE GAS STORAGE OTHER THAN H2, 0–15000 scf
D45	25*	NFPA 55: 10.3.2.2.1 (9)	FROM SLOW BURNING SOLIDS
D46	25*	NFPA 55: 10.3.2.2.1 (10)	FROM OPEN FLAMES AND WELDING
D47	25*	NFPA 55: 9.3.2 (12) (iv)	FROM BULK LIQUID OXYGEN STORAGE IF GAS H2 STORAGE IS =< 25000 scf
D48	50	NFPA 52: 9.3.1.3.3	FROM THE NEAREST TRACK OF ANY RAIL ROAD MAIN TRACK
D49	50*	NFPA 55: 10.3.2.2.1 (1) (B)	FROM A BUILDING WITH WALLS CONSTRUCTED OF OTHER THAN NON–COMBUSTIBLE OR LIMITED COMBUSTIBLE MATERIAL
D50	50*	NFPA 55: 10.3.2.2.1 (3) (B)	FROM AN ABOVE GROUND TANK, >1000 GALLONS CONTAINING ANY CLASS OF FLAMMABLE OR COMBUSTIBLE LIQUID
D51	50*	NFPA 55: 10.3.2.2.1 (6) (B)	FROM FLAMMABLE GAS STORAGE OTHER THAN H2, >15000 scf
D52	50*	NFPA 55: 10.3.2.2.1 (8)	FROM FAST BURNING SOLIDS
D53	50	NFPA 55: 10.3.2.2.1 (11)	(i) FROM AIR COMPRESSOR INTAKES
D54	50	NFPA 55: 10.3.2.2.1 (11)	(ii) FROM HVAC INLETS
D55	50	NFPA 55: 10.3.2.2.1 (12)	FROM PLACES OF PUBLIC ASSEMBLY
D56	50	NFPA 55: 10.3.2.2.1 (15) (A)	FROM HORIZONTAL DISTANCE FROM THE VERTICAL PLANE BELOW THE NEAREST OVERHEAD WIRE OF AN ELECTRIC TROLLEY, TRAIN OR BUS LINE
D57	50*	NFPA 55: 9.3.2 (12) (v)	FROM BULK LIQUID OXYGEN STORAGE IF GAS SYSTEM IS >25000 scf

DISTRIBUTOR'S TRANSFER PANEL / LIQUID H2 STORAGE =<3500 GALLONS – PHYSICAL SETBACKS

ID	D	CODE	DESCRIPTION
D58	5	NFPA 55: 11.3.1.2 (1) (b)	FROM THE VERTICAL PLANE BELOW THE NEAREST OVERHEAD ELECTRIC WIRE
D59	5	NFPA 55: 11.3.2.2.1 (a) (1)	(i) FROM UNSPRINKLERED BUILDINGS WITH WALLS CONSTRUCTED OF NON–COMBUSTIBLE OR LIMITED COMBUSTIBLE MATERIAL
D60	5	NFPA 55: 11.3.2.2.1 (a) (1)	(ii) FROM UNSPRINKLERED BUILDINGS HAVING NON–COMBUSTIBLE CONTENTS AND WITH WALLS CONSTRUCTED OF NON–COMBUSTIBLE OR LIMITED COMBUSTIBLE MATERIALS
D61	5	NFPA 55: 11.3.2.2.1 (a) (2) (b)	FROM AN UNSPRINKLERED BUILDING WITH COMBUSTIBLE CONTENTS AND WITH WALLS CONSTRUCTED OF NON–COMBUSTIBLE OR LIMITED COMBUSTIBLE MATERIALS WITH FIRE RESISTANCE RATING => 3 HOURS
D62	5	NFPA 55: 11.3.2.2.5	FROM ANOTHER STATIONARY LIQUIFIED HYDROGEN CONTAINER
D63	5	NFPA 55: 11.3.2.2.12	FROM INLETS TO UNDGROUND SEWERS
D64	25**	NFPA 55: 11.3.2.2.1 (a) (2) (a)	FROM AN UNSPRINKLERED BUILDING WITH COMBUSTIBLE CONTENTS WITH WALLS CONTRCUTED OF NON–COMBUSTIBLE OR LIMITED COMBUSTIBLE MATERIALS WITH FIRE RESISTANCE RATING OF <3 HOURS
D65	25	NFPA 55: 11.3.2.2.2 (b)	FROM INOPERABLE WALL OPENINGS
D66	25**	NFPA 55: 11.3.2.2.11	(i) FROM PUBLIC WAYS
D67	25**	NFPA 55: 11.3.2.2.11	(ii) FROM RAIL ROADS
D68	25**	NFPA 55: 11.3.2.2.11	(iii) FROM PROPERTY LINES
D69	50	NFPA 55: 11.3.1.2 (1) (a)	FROM THE VERTICAL PLANE BELOW THE NEAREST OVERHEAD WIREOF AN ELECTRIC TROLLEY, TRAIN OR BUS LINE
D70	50**	NFPA 55: 11.3.2.2.1 (a) (2) (c) (1)	FROM AN SPRINKLERED BUILDING WITH WALLS CONSTRUCTED OF COMBUSTIBLE MATERIALS
D71	50**	NFPA 55: 11.3.2.2.1 (a) (2) (c) (2)	FROM AN UNSPRINKLERED BUILDING WITH WALLS CONSTRUCTED OF COMBUSTIBLE MATERIALS
D72	50**	NFPA 55: 11.3.2.2.4	(i) FROM ABOVE GROUND TANKS CONTAINING ALL CLASSES OF FLAMMABLE AND COMBUSTIBLE LIQUIDS (ii) FROM THE VENT OPENING AND FILL OPENING OF BELOW GROUND TANKS CONTAINING ALL CLASSES OF FLAMMABLE AND COMBUSTIBLE LIQUIDS"
D73	50**	NFPA 55: 11.3.2.2.6	FROM FLAMMABLE GAS STORAGE OTHER THAN HYDROGEN
D74	50**	NFPA 55: 11.3.2.2.8	FROM COMBUSTIBLE SOLIDS
D75	50	NFPA 55: 11.3.2.2.9	FROM OPEN FLAMES AND WELDING
D76	75	NFPA 55: 11.3.2.2.2 (a)	FROM OPERABLE WALL OPENINGS
D77	75	NFPA 55: 11.3.2.2.3	(i) FROM AIR COMPRESSOR INTAKES (ii) FROM HVAC EQUIPMENT INLETS"
D78	75**	NFPA 55: 11.3.2.2.7	(i) FROM LIQUID OXYGEN STORAGE (ii) FROM OXIDIZERS STORAGE"
D79	75	NFPA 55: 9.3.2 (12)	FROM BULK LIQUID OXYGEN STORAGE
D80	75	NFPA 55: 11.3.2.2.10	FROM PLACES OF PUBLIC ASSEMBLY
D81	TBD	NFPA 55: 11.3.1.2 (2)	FROM PIPING CONTAINING OTHER HAZARDOUS MATERIALS

DISTRIBUTOR'S TRANSFER PANEL / LIQUID H2 STORAGE 3501 to 15000 GALLONS – PHYSICAL SETBACKS

ID	D	CODE	DESCRIPTION
D82	5	NFPA 55: 11.3.1.2 (1) (b)	FROM THE VERTICAL PLANE OF THE NEAREST OVERHEAD ELECTRICAL WIRE,EXCEPT AN ELECTRIC TROLLEY, TRAIN OR BUSLINE
D83	5	NFPA 55: 11.3.2.2.1 (a) (1)	(i) FROM SRINKLERED BUILDING WITH WALLS CONSTRUCTED OF NON–COMBUSTIBLE OR LIMITED COMBUSTIBLE MATERIAL
D84	5	NFPA 55: 11.3.2.2.1 (a) (1)	(ii) FROM UNSPRINKLERED BUILDINGS HAVING NON–COMBUSTIBLE CONTENTS AND WITH WALLS CONSTRUCTED OF NON–COMBUSTIBLE OR LIMITED COMBUSTIBLE MATERIALS
D85	5	NFPA 55: 11.3.2.2.1 (a) (2) (b)	FROM AN UNSPRINKLERED BUILDING WITH COMBUSTIBLE CONTENTS AND WITH WALLS CONTRUCTED OF NON–COMBUSTIBLE OR LIMITED COMBUSTIBLE MATERIALS WITH FIRE RESISTANCE RATING => 3 HOURS
D86	5	NFPA 55: 11.3.2.2.5	FROM ANOTHER STATIONARY LIQUIFIED HYDROGEN CONTAINER
D87	5	NFPA 55: 11.3.2.2.12	FROM INLETS TO UNDGROUND SEWERS
D88	50**	NFPA 55: 11.3.2.2.1 (a) (2) (a)	FROM AN UNSPRINKLERED BUILDING WITH COMBUSTIBLE CONTENTS WITH WALLS CONTRUCTED OF NON–COMBUSTIBLE OR LIMITED COMBUSTIBLE MATERIALS WITH FIRE RESISTANCE RATING OF <3 HOURS
D89	50	NFPA 55: 11.3.2.2.2 (b)	FROM INOPERABLE WALL OPENINGS
D90	50**	NFPA 55: 11.3.2.2.11	(i) FROM PUBLIC WAYS
D91	50**	NFPA 55: 11.3.2.2.11	(ii) FROM RAIL ROADS
D92	50**	NFPA 55: 11.3.2.2.11	(iii) FROM PROPERTY LINES
D93	50	NFPA 55: 11.3.1.2 (1) (b)	FROM THE VERTICAL PLANE BELOW THE NEAREST OVERHEAD WIRE OF AN ELECTRIC TROLLEY, TRAIN OR BUS LINE
D94	50**	NFPA 55: 11.3.2.2.1 (a) (2) (c)	(i) FROM A SPRINKLERED BUILDING WITH WALLS CONSTRUCTED OF COMBUSTIBLE MATERIAL
D95	75**	NFPA 55: 11.3.2.2.1 (a) (2) (c) (2)	(ii) FROM AN UNSPRINKLERED BUILDING WITH WALLS CONSTRUCTED OF COMBUSTIBLE MATERIALS
D96	75**	NFPA 55: 11.3.2.2.4	(i) FROM ABOVE GROUND TANKS CONTAINING ALL CLASSES OF FLAMMABLE AND COMBUSTIBLE LIQUIDS (ii) FROM THE VENT OPENING AND FILL OPENING OF BELOW GROUND TANKS CONTAINING ALL CLASSES OF FLAMMABLE AND COMBUSTIBLE LIQUIDS"
D97	75**	NFPA 55: 11.3.2.2.6	FROM FLAMMABLE GAS STORAGE OTHER THAN HYDROGEN
D98	75**	NFPA 55: 11.3.2.2.8	FROM COMBUSTIBLE SOLIDS
D99	50	NFPA 55: 11.3.2.2.9	FROM OPEN FLAMES AND WELDING
D100	75	NFPA 55: 11.3.2.2.2 (a)	FROM OPERABLE WALL OPENINGS
D101	75	NFPA 55: 11.3.2.2.3	(i) FROM AIR COMPRESSOR INTAKES (ii) FROM HVAC EQUIPMENT INLETS
D102	75**	NFPA 55: 11.3.2.2.7	(i) FROM LIQUID OXYGEN STORAGE (ii) FROM OXIDIZERS STORAGE"
D103	75	NFPA 55: 9.3.2 (12)	FROM BULK LIQUID OXYGEN STORAGE
D104	75	NFPA 55: 11.3.2.2.10	FROM PLACES OF PUBLIC ASSEMBLY
D105	TBD	NFPA 55: 11.3.1.2 (2)	FROM OVERHEAD PIPING CONTAINING OTHER HAZARDOUS MATERIALS

DISTRIBUTOR'S TRANSFER PANEL / LIQUID H2 STORAGE =<15000 GALLONS – PHYSICAL SETBACKS

ID	D	CODE	DESCRIPTION
D106	5	NFPA 55: 11.3.1.2 (1) (b)	FROM THE VERTICAL PLANE BELOW THE NEAREST OVERHEAD WIRE OF AN ELECTRIC TROLLEY, TRAIN OR BUS LINE
D107	5	NFPA 55: 11.3.2.2.1 (a) (1)	(i) FROM A SPRINKLERED BUILDING WITH WALLS CONSTRUCTED OF NON–COMBUSTIBLE OR LIMITED COMBUSTIBLE MATERIAL
D108	5	NFPA 55: 11.3.2.2.1 (a) (1)	(ii) FROM AN UNSPRINKLERED BUILDING HAVING NON–COMBUSTIBLE CONTENTS AND WALLS CONSTRUCTED OF NON–COMBUSTIBLE OR LIMITED COMBUSTIBLE MATERIAL
D109	5	NFPA 55: 11.3.2.2.1 (a) (2) (b)	FROM AN UNSPRINKLERED BUILDING WITH COMBUSTIBLE CONTENTS AND WITH WALLS CONTRUCTED OF NON–COMBUSTIBLE OR LIMITED COMBUSTIBLE MATERIALS WITH FIRE RESISTANCE RATING => 3 HOURS
D110	5	NFPA 55: 11.3.2.2.5	FROM ANOTHER STATIONARY LIQUIFIED HYDROGEN CONTAINER
D111	5	NFPA 55: 11.3.2.2.12	FROM INLETS TO UNDGROUND SEWERS
D112	75**	NFPA 55: 11.3.2.2.1 (a) (2) (a)	FROM AN UNSPRINKLERED BUILDING WITH COMBUSTIBLE CONTENTS WITH WALLS CONTRCUTED OF NON–COMBUSTIBLE OR LIMITED COMBUSTIBLE MATERIALS WITH FIRE RESISTANCE RATING OF <3 HOURS
D113	50	NFPA 55: 11.3.2.2.2 (b)	FROM INOPERABLE WALL OPENINGS
D114	75**	NFPA 55: 11.3.2.2.11	(i) FROM PUBLIC WAYS
D115	75**	NFPA 55: 11.3.2.2.11	(ii) FROM RAIL ROADS
D116	75**	NFPA 55: 11.3.2.2.11	(iii) FROM PROPERTY LINES
D117	50	NFPA 55: 11.3.1.2 (1) (a)	FROM THE VERTICAL PLANE BELOW THE NEAREST OVERHEAD WIRE OF AN ELECTRIC TROLLEY, TRAIN OR BUS LINE
D118	50**	NFPA 55: 11.3.2.2.1 (a) (2) (c) (1)	(i) FROM A SPRINKLERED BUILDING WITH WALLS CONSTRUCTED OF COMBUSTIBLE MATERIAL
D119	50**	NFPA 55: 11.3.2.2.1 (a) (2) (c) (1)	(i) FROM A SPRINKLERED BUILDING WITH WALLS CONSTRUCTED OF COMBUSTIBLE MATERIAL
D120	100**	NFPA 55: 11.3.2.2.1 (a) (2) (c) (2)	FROM AN UNSPRINKLERED BUILDING WITH WALLS CONSTRUCTED OF COMBUSTIBLE MATERIALS
D121	100**	NFPA 55: 11.3.2.2.4	(i) FROM ABOVE GROUND TANKS CONTAINING ALL CLASSES OF FLAMMABLE AND COMBUSTIBLE LIQUIDS (ii) FROM THE VENT OPENING AND FILL OPENING OF BELOW GROUND TANKS CONTAINING ALL CLASSES OF FLAMMABLE AND COMBUSTIBLE LIQUIDS"
D122	75**	NFPA 55: 11.3.2.2.6	FROM FLAMMABLE GAS STORAGE OTHER THAN HYDROGEN
D123	100**	NFPA 55: 11.3.2.2.8	FROM COMBUSTIBLE SOLIDS
D124	50	NFPA 55: 11.3.2.2.9	FROM OPEN FLAMES AND WELDING
D125	75	NFPA 55: 11.3.2.2.2 (a)	FROM OPERABLE WALL OPENINGS
D126	75	NFPA 55: 11.3.2.2.3	(i) FROM AIR COMPRESSOR INTAKES (ii) FROM HVAC EQUIPMENT INLETS
D127	75**	NFPA 55: 11.3.2.2.7	(i) FROM LIQUID OXYGEN STORAGE (ii) FROM OXIDIZERS STORAGE
D128	75	NFPA 55: 9.3.2 (12)	FROM BULK LIQUID OXYGEN STORAGE
D129	75	NFPA 55: 11.3.2.2.10	FROM PLACES OF PUBLIC ASSEMBLY
D130	TBD	NFPA 55: 11.3.1.2 (2)	FROM OVERHEAD PIPING CONTAINING OTHER HAZARDOUS MATERIALS

H2 COMPRESSION – ELECTRICALLY CLASSIFIED AREA

ID	D	ZONE / DIVISION	CODE	DESCRIPTION
D131	15	2	NFPA 52: 9.3.3.9.2	FROM THE EQUIPMENT

H2 ANCILLARY (GENERATION/GAS CONTROL PANEL/EMERGENCY DUMP PANEL) – ELECTRICALLY CLASSIFIED AREA

ID	D	ZONE / DIVISION	CODE	DESCRIPTION
D132	15	2	NFPA 52: 9.3.3.9.2	FROM ANCILLIARY EQUIPMENT (SUBJECT TO DE–CLASSIFICATION BY THE MANUFACTURER)

H2 DISPENSING EQUIPMENT – ELECTRICALLY CLASSIFIED AREA

ID	D	ZONE / DIVISION	CODE	DESCRIPTION
D133	ALL	1	NFPA 52: 9.3.3.9.3	OUTDOOR DISPENSING EQUIPMENT ENCLOSURE INTERIOR UP TO SUPPORT MECHANISM OR CONNECTION TO THE GROUND
D134	5	2	NFPA 52: 9.3.3.9.4	OUTDOOR DISPENSING EQUIPMENT EXTERIOR
D135	ALL	1	NFPA 52: 9.3.3.9.5	INDOOR DISPENSING EQUIPMENT ENCLOSURE INTERIOR UP TO SUPPORT MECHANISM OR CONNECTION TO THE GROUND
D136	ALL	2	NFPA 52: 9.3.3.9.6	INDOOR DISPENSING EQUIPMENT ENCLOSURE EXTERIOR SURROUNDING ROOM WITH ADEQUATE VENT

H2 RELIEF VENT OPENINGS – ELECTRICALLY CLASSIFIED AREA

ID	D	ZONE / DIVISION	CODE	DESCRIPTION
D137	5	1	NFPA 52: 9.3.3.9.7	FROM THE OPENING
D138	15	2	NFPA 52: 9.3.3.9.8	FROM THE OPENING
D139	15	1	NFPA 52: 9.3.3.9.9	WITHIN 15 DEGREES OF THE LINE OF THE DISCHARGE OF THE OPENING

DISTRIBUTOR'S TRANSFER PANEL

ID	D	ZONE / DIVISION	CODE	DESCRIPTION
D140	15	2	NFPA 55: 10.4.3.5	IN ACCORDANCE WITH NFPA 70, TABLE 11.2.6 AND ARTICLE 501

GASEOUS H2 STORAGE – ELECTRICALLY CLASSIFIED AREA

ID	D	ZONE / DIVISION	CODE	DESCRIPTION
D141	0	2	NFPA 52: 9.3.3.9.1	AROUND CONTAINERS IF THE PRV's AND PRD's ARE PIPED AND VENTED AS PER NFPA 52 CHAPTER 5

LIQUID H2 – ELECTRICALLY CLASSIFIED AREA

ID	D	ZONE / DIVISION	CODE	DESCRIPTION
D142	3	1	NFPA 55: 11.2.6	(ii) AROUND THE DELIVERY CONNECTION POINT
D143	25	2	NFPA 55: 11.2.6	(iii) AROUND THE DELIVERY CONNECTION POINT
D144	TBD	1	NFPA 55: 11.2.6	IN ACCORDANCE WITH NFPA 70, TABLE 11.2.6 AND ARTICLE 501
D145	TBD	2	NFPA 55: 11.2.6	IN ACCORDANCE WITH NFPA 70, TABLE 11.2.6 AND ARTICLE 501

* SPECIFIED DISTANCE CAN BE ELIMINATED BY LOCATING A 2HR RATED FIRE BARRIER BETWEEN SYSTEM AND LISTED DEVICE
** SPECIFIED DISTANCE CAN BE REDUCED BY 2/3 FOR INSULATED PORTIONS OF THE SYSTEM

ID – REFERENCE IDENTIFIER
D – REQUIRED DISTANCE

DISTRIBUTOR'S TRANSFER PANEL:
AN ENCLOSED CABINET OR OPEN AIR RACK SUPPLIED BY THE INDUSTRIAL GAS DISTRIBUTOR AND CONTAINING DEVICES, INSTRUMENTS AND VALVES WHERE THE CUSTODY OF THE FUEL IS TRANSFERRED FROM THE DISTRIBUTOR TO THE CUSTOMER.

GAS CONTROL PANEL:
AN ENCLOSED CABINET OR OPEN AIR RACK CONTAINING DEVICES, INSTRUMENTS AND VALVES, OTHER THAN THE DISTRIBUTOR'S TRANSFER PANEL.

REV.	DESCRIPTION	DRWN	DSGN	APPD	DATE
0	AS BUILT – BASIN NUMBER AND TITLE BLOCK	L. FROEHLICH	A. BOUSHEE	R. BUSH	5/7/07

REFERENCE DRAWINGS

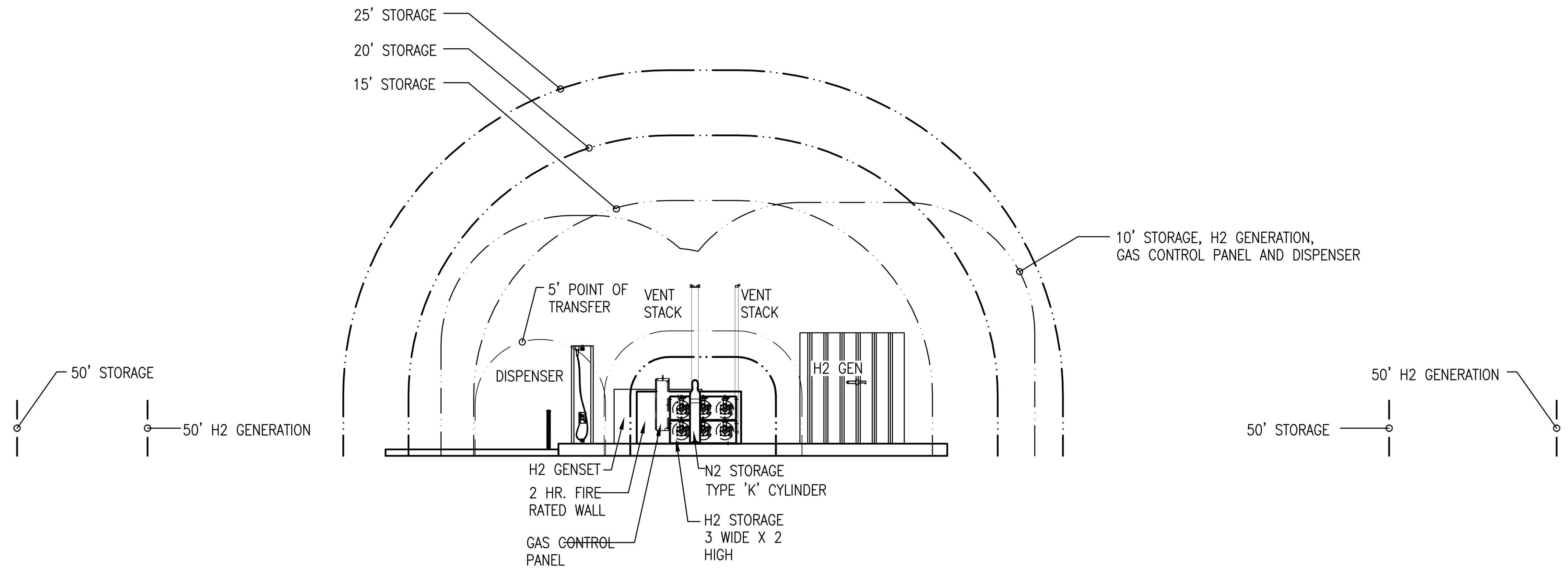
FACILITY: WIND TO HYDROGEN SYSTEM
LOCATION/UNIT: MINOT, NORTH DAKOTA
CONTRACT/DESIGNATION:

CLASSIFIED ZONES AND PHYSICAL SETBACKS GENERAL NOTES

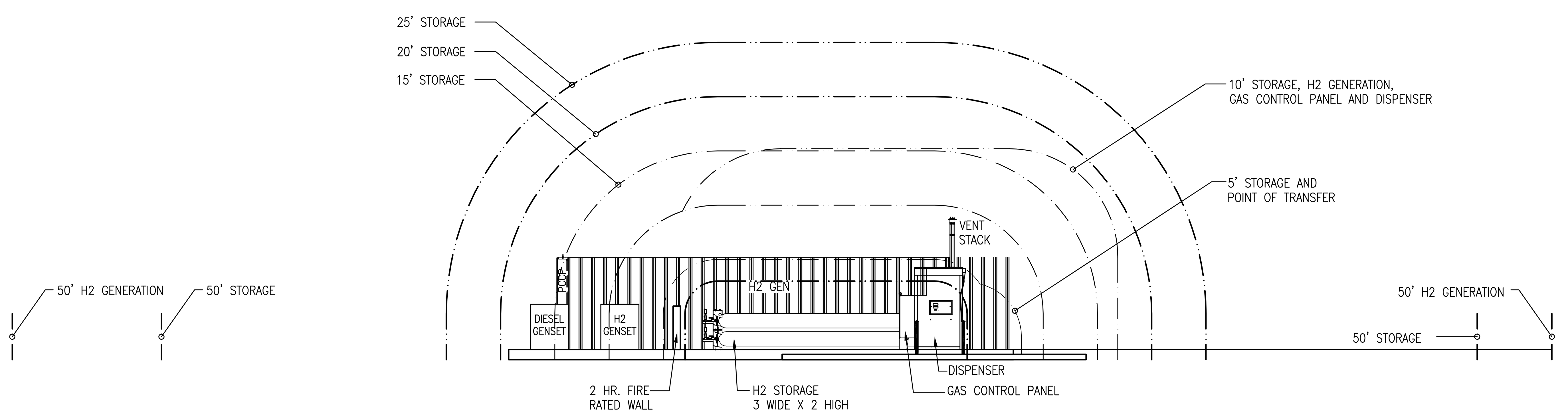
BASIN ELECTRIC POWER COOPERATIVE
1717 EAST INTERSTATE AVENUE
BISMARCK, NORTH DAKOTA 58503-0564
PHONE 701-223-0441

DESIGN BY: ALBERT KAHN ASSOCIATES
DRAWN BY:
DESIGN CHK:
DRAFT CHK:
APPROVED:
SCALE: NONE
VENDOR/ORIGINATED FROM: ALBERT KAHN ASSOCIATES
VENDOR DRAWING NO.: M-500 ORIGINAL REV: 5
BASIN DRAWING NO.: 0GI-0002 REV. NO.: 0

01/27/04



SOUTH ELEVATION



WEST ELEVATION

REV.	DESCRIPTION	DRWN	DSGN	APPD	DATE
0	AS BUILT – BASIN NUMBER AND TITLE BLOCK	L. FROEHLICH	A. BOUSHEE	R. BUSH	5/7/07

REFERENCE DRAWINGS

FACILITY: WIND TO HYDROGEN SYSTEM

LOCATION/UNIT: MINOT, NORTH DAKOTA

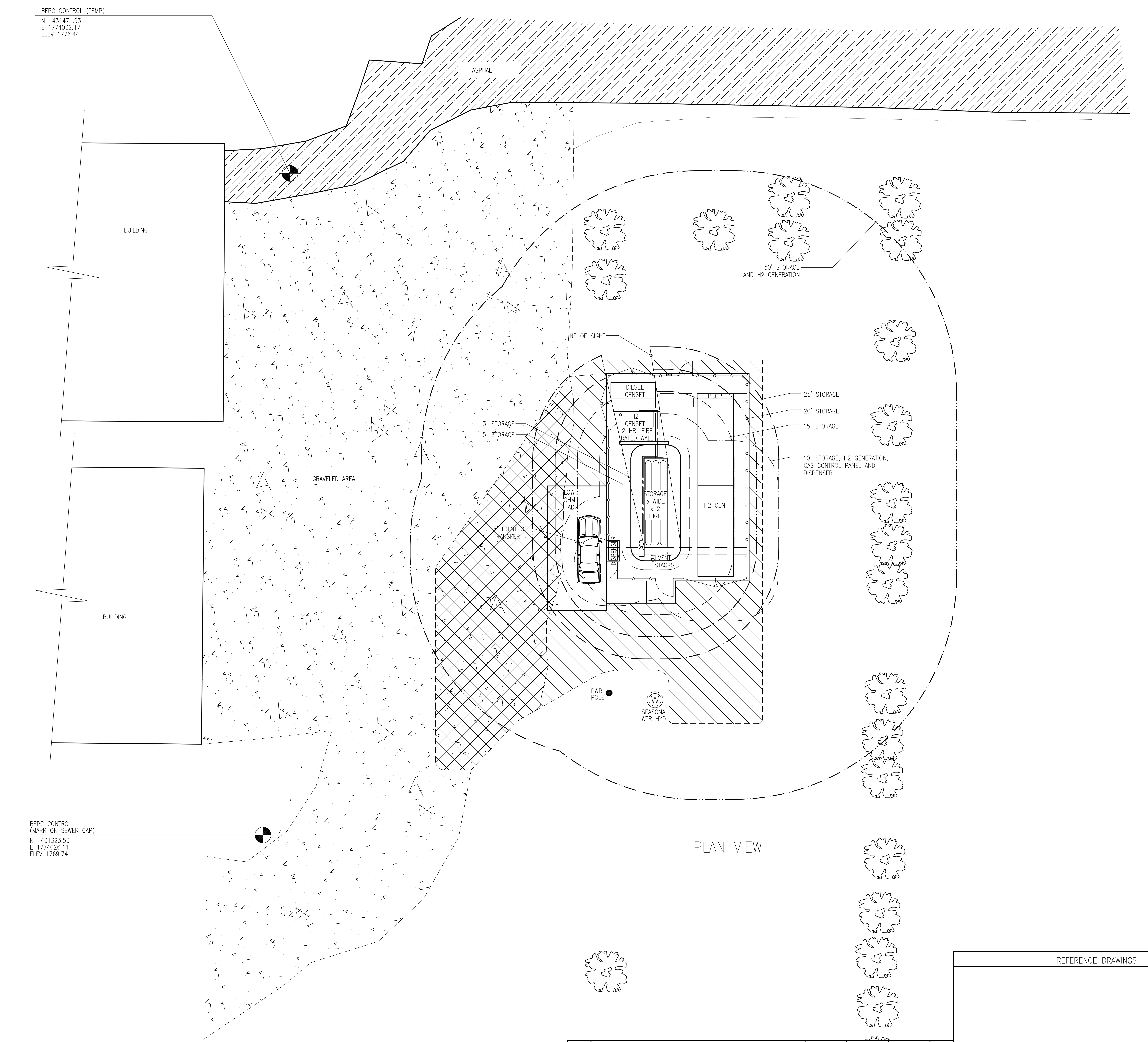
CONTRACT/DESIGNATION:

PHYSICAL SETBACKS ELEVATIONS

BASIN ELECTRIC POWER COOPERATIVE
1717 EAST INTERSTATE AVENUE
BISMARCK, NORTH DAKOTA 58503-0564
PHONE 701-223-0441

DESIGN BY: ALBERT KAHN ASSOCIATES
DRAWN BY:
DESIGN CHK:
DRAFT CHK:
APPROVED:
SCALE: NONE
VENDOR/ORIGINATED FROM: ALBERT KAHN ASSOCIATES
VENDOR DRAWING NO.: M-502 | ORIGINAL REV: 5
BASIN DRAWING NO.: 0AI-0002 | REV. NO.: 0

01/27/04



REV.	DESCRIPTION	DRWN	DSGN	APPD	DATE
0	AS BUILT – BASIN NUMBER AND TITLE BLOCK	L. FROEHLICH	A. BOUSHEE	R. BUSH	5/7/07

REFERENCE DRAWINGS

FACILITY: WIND TO HYDROGEN SYSTEM

LOCATION/UNIT: MINOT, NORTH DAKOTA

CONTRACT/DESIGNATION:

PHYSICAL SETBACKS PLAN

BASIN ELECTRIC POWER COOPERATIVE
1717 EAST INTERSTATE AVENUE
BISMARCK, NORTH DAKOTA 58503–0564
PHONE 701–223–0441

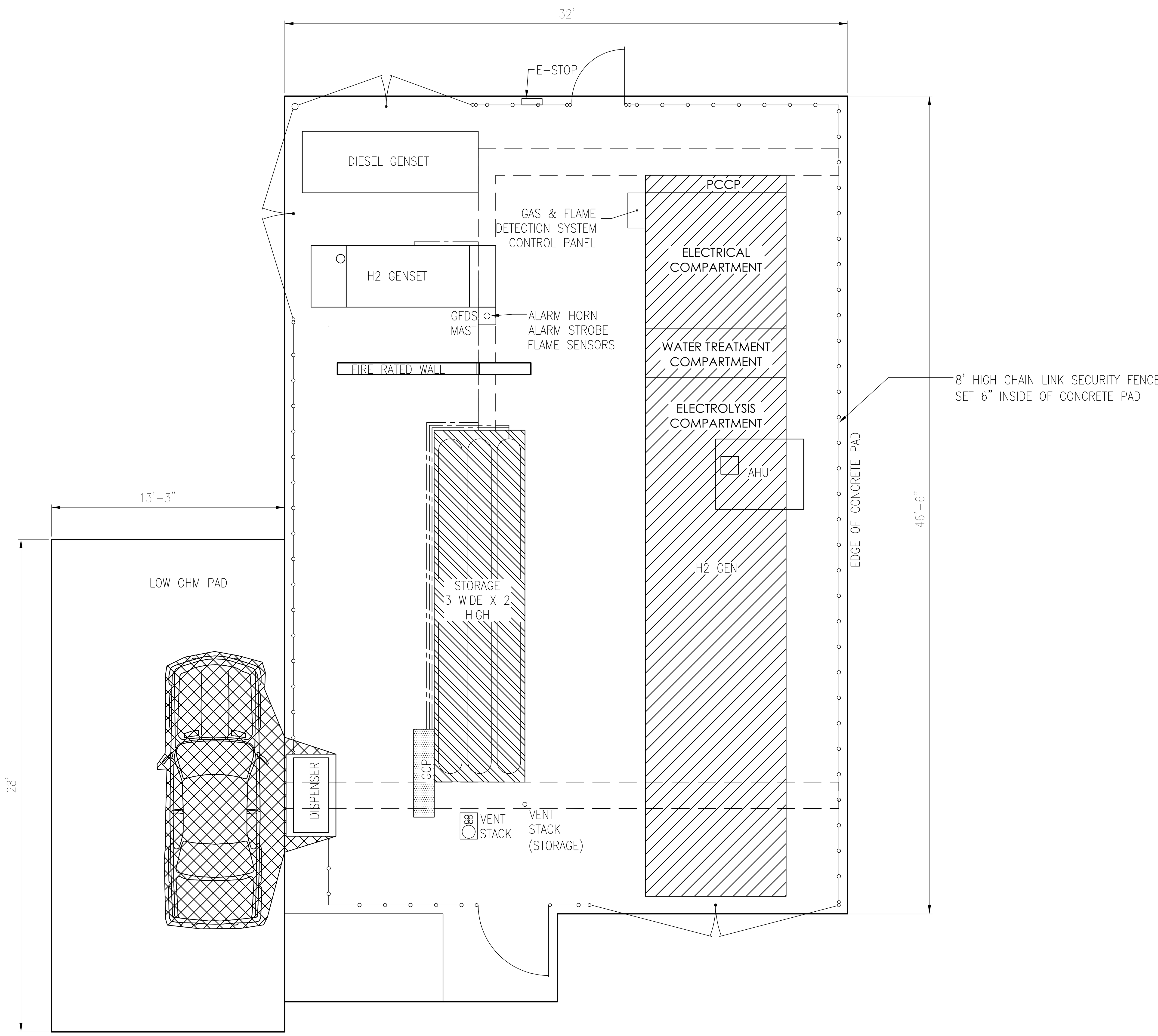
DESIGN BY ALBERT KAHN ASSOCIATES
DRAWN BY
DESIGN CHK.
DRAFT CHK.
APPROVED

SCALE: NONE

VENDOR/ORIGINATED FROM: ALBERT KAHN ASSOCIATES

VENDOR DRAWING NO. M–503 — ORIGINAL REV 5

BASIN DRAWING NO. 0AI–0003 — REV. NO. 0



LEGEND:

- FUEL GENERATOR
- FUEL STORAGE
- GAS CONTROL PANEL
- FUEL DISPENSER

NOTES:

1. GFDS EQUIPMENT LOCATIONS ARE PRELIMINARY. FINAL LOCATIONS TO BE SET BY DESIGN-BUILD CONTRACTOR AS APPROVED BY LOCAL AHJ.
2. DISPENSER INTERIOR, GAS CONTROL PANEL INTERIOR AND FUEL GENERATOR ELECTROLYSIS COMPARTMENT ARE FACTORY EQUIPPED WITH GAS DETECTION SYSTEM.

REV.	DESCRIPTION	DRWN	DSGN	APPD	DATE
0	AS BUILT - BASIN NUMBER AND TITLE BLOCK	L. FROEHLICH	A. BOUSHEE	R. BUSH	5/7/07

REFERENCE DRAWINGS

FACILITY: WIND TO HYDROGEN SYSTEM

LOCATION/UNIT: MINOT, NORTH DAKOTA

CONTRACT/DESIGNATION:

GAS AND FLAME DETECTION COVERAGE REQUIREMENTS

BASIN ELECTRIC POWER COOPERATIVE
1717 EAST INTERSTATE AVENUE
BISMARCK, NORTH DAKOTA 58503-0564
PHONE 701-223-0441

DESIGN BY: ALBERT KAHN ASSOCIATES
DRAWN BY:
DESIGN CHK:
DRAFT CHK:
APPROVED:
SCALE: NONE
VENDOR/ORIGINATED FROM: ALBERT KAHN ASSOCIATES
VENDOR DRAWING NO.: M-600
ORIGINAL REV: 5
BASIN DRAWING NO.: 0GI-0003
REV. NO.: 0

01/27/04

DIVISION 16 – ELECTRICAL

SECTION 16050 – BASIC ELECTRICAL MATERIALS AND METHODS
PART 1 GENERAL
1.01 RELATED SECTIONS
1.02 REFERENCES

A. NECA 1 – STANDARD PRACTICES FOR GOOD WORKMANSHIP IN ELECTRICAL CONTRACTING; 2000.
B. NECA 101 – STANDARD FOR INSTALLING STEEL CONDUITS (RIGID, IMC, EMT); 2001.
C. NFPA 70 – NATIONAL ELECTRICAL CODE 2002.
UL 360 – LIQUID-TIGHT FLEXIBLE STEEL CONDUITS; 1992.
D. UL (ECMD) – ELECTRICAL CONSTRUCTION MATERIALS DIRECTORY;
E. CURRENT EDITION.

PART 2 PRODUCTS
2.01 MATERIALS

A. CONDUIT AND FITTINGS.
- FITTINGS SHALL BE U.L. LISTED, CONSTRUCTED OF FORMED MATERIAL, ELECTRICALLY CONDUCTIVE OF THE SAME SIZE AND FINISH AS THE CONDUIT ON WHICH INSTALLED.
- CONDUIT ONE INCH AND LARGER IN SIZE SHALL BE PROVIDED WITH A GROUNDING AND INSULATED BUSHING SIMILAR AND EQUAL TO O.Z. ELECTRICAL PRODUCTS COMPANY'S TYPE "BL". INSULATED BUSHINGS AND DOUBLE LOCKNUTS (THAT IS, ONE INSIDE AND ONE OUTSIDE) SHALL BE PROVIDED AT JUNCTION BOXES, OUTLET BOXES, PULL BOXES AND CABINET ENTRANCES.
- PROVIDE U.L. SEAL-OFF FITTINGS FOR CONDUITS DUE TO HIGH OR LOW TEMPERATURE PLACES SUCH AS WALK-IN COOLERS AND FOR HAZARDOUS APPLICATIONS SUCH AS GASOLINE PUMPS, PAINT STORAGE, PAINT SPRAY BOOTH, STORM WATER OR SEWAGE WATER LIFT STATIONS. FILL SEAL OFF AS RECOMMENDED BY CROUSE HINDS CO. FOR EXPLOSION-PROOF APPLICATIONS.
- BONDED GALVANIZED EXPANSION JOINTS SHALL PROVIDE FOR MINIMUM OF 4 INCH MOVEMENT AND SHALL HAVE A TINNED COPPER FLEXIBLE BRAIDED JUMPER AROUND THE JOINT, O.Z. TYPE EX OR TX AS REQUIRED, WITH TYPE BJ JUMPER.
- CONDUIT PENETRATIONS THROUGH FLOORS (NOT SLAB ON GRADE AND FOUNDATION WALLS) AND FIREWALLS SHALL BE SLEEVED USING GRC AND SEALED WITH A U.L. APPROVED/LISTED MATERIAL GIVING A MINIMUM FIRE RATING OF 2 HOURS.
- PROVIDE O.Z. ELECTRICAL PRODUCTS COMPANY'S TYPE "DUX" DUCT WATERSTOP SEALING COMPOUND FOR ALL SERVICE ENTRANCE AND ANY OTHER FEEDER CONDUITS TO PREVENT WATER TO DRAIN INTO ELECTRICAL EQUIPMENT SPACE.

1. RIGID STEEL CONDUIT, ELBOWS AND COUPLINGS.
a. ZINC COATED STEEL IN ACCORDANCE WITH ANSI C80.1.
b. ACCEPTABLE MANUFACTURERS.
1) GRINNELL.
2) LTV.
3) TRIANGLE PWC, INCORPORATED.
4) WHEATLAND TUBE COMPANY, INCORPORATED.
c. FITTINGS.
1) CAST OR MALLEABLE IRON BODIES.
2) CADMIUM OR ZINC PLATED.
3) TAPER THREADS, SCREW ATTACHED COVER PLATES, AND GASKETS WHEN LOCATED IN DAMP, WET OR INDUSTRIAL AREAS.
4) ACCEPTABLE MANUFACTURERS.
(a) APPLETON ELECTRIC COMPANY.
(b) CROUSE-HINDS COMPANY.
(c) PYLE-NATIONAL.
(d) O-Z/GEDNEY COMPANY.
d. EXPANSION FITTINGS.
1) CAST OR MALLEABLE IRON BODIES.
2) THREADED END CAPS FOR RECEIVING FIXED AND MOVEABLE CONDUITS.
3) METALLIC PRESSURE PACKING AND COPPER BONDING JUMPER ASSEMBLY.
4) MOVEMENT OF CONDUIT, MINIMUM OF 4 INCHES.
5) ACCEPTABLE MANUFACTURERS.
(a) TYPE XJ BY APPLETON ELECTRIC COMPANY.
(b) TYPE XJ BY CROUSE-HINDS COMPANY.
(c) TYPE AX BY O-Z/GEDNEY COMPANY.
(d) TYPE AF BY SPRING CITY.
e. LOCKNUTS, MALLEABLE IRON OR STEEL, ZINC OR CADMIUM PLATED.
1) BUSHING FOR ONE INCH AND SMALLER CONDUIT.
(a) INSULATING PLASTIC.
(b) NONBURNABLE, THERMOSETTING PHENOLIC, IN ACCORDANCE WITH UL REQUIREMENTS.
(c) DO NOT INCLUDE NONRIGID PLASTIC BUSHINGS.
2) BUSHINGS FOR 1-1/4 INCH AND LARGER CONDUIT.
(a) MALLEABLE IRON OR STEEL, ZINC OR CADMIUM PLATED.
(b) INSULATING INSERT OR THERMOSETTING PLASTIC, AS SPECIFIED FOR SMALLER CONDUIT BUSHINGS, MOLDED LOCKED INTO BUSHING RING.

2. LIQUIDTIGHT FLEXIBLE STEEL CONDUIT.
a. IN ACCORDANCE WITH UL 360.
b. PVC JACKET.
c. ACCEPTABLE MANUFACTURERS.
1) ALFLEX.
2) ANAMET.
3) CARLON.
4) O-Z/GEDNEY COMPANY, FLEXI-GARD.
d. FITTINGS.
1) DESIGNED TO MAINTAIN LIQUIDTIGHT FEATURE OF INSTALLATION.
2) ACCEPTABLE MANUFACTURERS.
(a) ST SERIES BY APPLETON ELECTRIC COMPANY.
(b) CROUSE-HINDS COMPANY.
(c) THOMAS AND BETTS STEELCITY.

3. EXPLOSION PROOF FLEXIBLE METAL CONDUIT.
a. APPROVED FOR USE IN CLASS 1, GROUP A, B, C AND D AREAS AND NOT REQUIRING BONDING JUMPER.
b. ACCEPTABLE MANUFACTURERS.
1) TYPE EX BY APPLETON ELECTRIC COMPANY.
2) TYPE EC BY CROUSE-HINDS COMPANY ANAMET.
3) PYLE-O-FLEX BY PYLE-NATIONAL.

4. SEAL FITTINGS FOR SEALING CONDUITS, HAZARDOUS AREAS.
a. UL LISTED FOR USE IN CLASS 1, GROUP B OR D AREAS.
b. TYPE EYS FOR USE IN VERTICAL RUNS ONLY.
c. ACCEPTABLE MANUFACTURERS.
1) APPLETON ELECTRIC COMPANY.
2) CROUSE-HINDS COMPANY.
3) STEEL ELECTRIC.

B. PULL AND JUNCTION BOXES.
1. GALVANIZED, CAST, OR MALLEABLE IRON.
2. THREADED HUBS AND THREADED COVERS.
3. APPROVED FOR USE IN CLASS I, GROUP A, B, C OR D AREAS AS APPLICABLE.
4. SIZED IN ACCORDANCE WITH NFPA 70 REQUIREMENTS FOR WIRING SPACE.
5. ACCEPTABLE MANUFACTURERS.
a.) APPLETON ELECTRIC COMPANY.
b.) CROUSE-HINDS COMPANY
c.) PYLE-NATIONAL.

PART 3 EXECUTION
3.01 INSTALLATION
A. CONDUIT SYSTEM.
1. RIGID STEEL CONDUIT.
a. IN MOST AREAS, UNLESS OTHERWISE INDICATED IN CONTRACT DOCUMENTS.
2. LIQUIDTIGHT FLEXIBLE METAL CONDUIT, INSTEAD OF NONJACKETED FLEXIBLE METAL CONDUIT.
a. IN DAMP OR WET LOCATIONS AND FOR FINAL CONNECTIONS TO ALL MOTORS.
3. IN ACCORDANCE WITH NFPA 70. CONDUIT SIZES, IN ACCORDANCE WITH NFPA 70 UNLESS ANOTHER CONDUIT SIZE IS ESTABLISHED BY CONTRACT DOCUMENTS.
4. MINIMUM SIZE, 3/4 INCH.
5. CONCEAL CONDUIT IN OFFICE AND SIMILAR FINISHED AREAS.
6. DO NOT RUN CONDUIT IN CONCRETE FLOORS UNLESS SPECIFICALLY INDICATED.
7. RUN EXPOSED CONDUIT PARALLEL OR PERPENDICULAR TO WALLS, STRUCTURAL MEMBERS, OR INTERSECTIONS OF VERTICAL PLANES AND CEILINGS.
8. KEEP CONDUIT MINIMUM OF 6 INCHES AWAY FROM PARALLEL RUNS OF HIGH TEMPERATURE SURFACES, E.G., STEAM OR HOT WATER PIPES.
9. DO NOT RUN CONDUIT DIRECTLY UNDER COLD WATER LINES.
10. DO NOT INSTALL CRUSHED OR DEFORMED CONDUITS.
11. REMOVE OBSTRUCTION FROM CONDUIT OR RECONSTRUCT THE CONDUIT SYSTEM WITH CORRESPONDING MATERIALS.
12. DRAW UP ALL CONDUIT JOINTS AS TIGHTLY AS POSSIBLE.
13. CAP EXPOSED EMPTY CONDUITS WHICH DO NOT TERMINATE IN OUTLETS, PANELS AND CABINETS WITH STANDARD GALVANIZED PLUMBER'S PIPE CAPS.
14. PLUG EMPTY CONDUITS WHICH TERMINATE FLUSH WITH FLOORS OR WALLS WITH FLUSH COUPLING AND BRASS PLUG.
15. DO NOT USE BENDS AROUND OUTSIDE CORNERS, USE FITTINGS.
16. BENDS AND OFFSETS.
a. MINIMUM RADIUS OF CURVATURE.
1) 24 INCHES FOR 2 INCH AND 2-1/2 INCH CONDUIT.
2) 36 INCHES FOR 3 INCH AND LARGER CONDUIT.
17. EXCEPT WHERE CONDUIT RUNS ARE SHOWN IN EXACT DETAIL, INSTALL PULL POINTS AT MAXIMUM 200 FOOT INTERVALS IN STRAIGHT RUNS.
18. WHERE BENDS ARE INCLUDED BETWEEN PULL POINTS, REDUCE THIS MAXIMUM PERMISSIBLE 200 FOOT SEPARATION BETWEEN PULL POINTS BY 50 FEET FOR EACH 90 DEGREE BEND AND 25 FEET FOR EACH 45 DEGREE BEND.
19. DO NOT USE RUNNING THREADS ON ANY PART OF CONDUIT SYSTEM.
20. EXPANSION FITTINGS.
a. EXPOSED CONDUIT RUNS OF EXCESSIVE LENGTH, CROSSING BUILDING EXPANSION JOINTS, AND ELSEWHERE AS INDICATED IN CONTRACT DOCUMENTS.
21. DOUBLE LOCKNUTS AND BUSHINGS.
a. RIGID CONDUIT TERMINATION'S INTO THREADLESS OPENINGS.
b. INCREASE LENGTH OF CONDUIT THREADS AT TERMINATION'S SUFFICIENTLY TO ALLOW BUSHING TO BE FULLY SEATED AGAINST END OF CONDUIT.
22. SUPPORTS.
a. DO NOT USE PERFORATED STRAP OR WIRE FOR CONDUIT OR HANGER SUPPORT.
b. SUPPORT EXPOSED CONDUIT, MINIMUM EVERY 8 FEET IF SMALLER THAN 2 INCH, AND EVERY 10 FEET IF 2 INCH AND LARGER, UNLESS OTHERWISE NOTED.
c. DO NOT USE STEEL HANGER WIRE SUPPORT FOR CONDUITS LARGER THAN 3/4 INCH.

B. PULL AND JUNCTION BOXES.
1. HOT-DIPPED GALVANIZED STEEL BOXES: SHEET STEEL WITH WELDED SEAMS. PROVIDE A RIGID ASSEMBLY. CONSTRUCT WITH INTERNAL STRUCTURAL STEEL BRACING. HOT DIP GALVANIZED AFTER FABRICATION. COVER SHALL BE GASKETED.
2. INSTALL BOXES IN WIRING OR RACEWAY SYSTEMS THAT SERVE PULLING OF WIRES AND MAKING SPLICES.
3. SUPPORT BOXES INDEPENDENT OF CONDUIT AND SECURE RIGIDLY IN PLACE.

SECTION 16060 – GROUNDING AND BONDING

PART 1 GENERAL
1.01 REFERENCES
A. NFPA 70 – NATIONAL ELECTRICAL CODE: 2002.
B. UL (ECMD) – ELECTRICAL CONSTRUCTION MATERIALS DIRECTORY; CURRENT EDITION.

PART 2 PRODUCTS
2.01 MATERIALS.
A. GROUNDING CONDUCTORS (WIRE AND CABLE)
1. SYSTEMS
a. GENERAL USE ABOVE GRADE, BARE AND INSULATED.
b. CONDUIT WITH PHASE CONDUCTORS, INSULATED.
c. UNDERGROUND USE, BARE COPPER.
d. GROUND ELECTRODE CONDUCTOR, STRANDED CABLE
e. GROUND BUS; BARE ANNEALED COPPER BARS OF RECTANGULAR CROSS SECTION
f. BRAIDED BONDING JUMPERS; COPPER TAPE, BRAIDED NO.30 GAUGE BARE COPPER WIRE TERMINATED WITH COPPER FERRULES.
g. BONDING STRAP/CONNECTORS; SOFT COPPER
2. WIRE
a. BARE, STRANDED ANNEALED COPPER.
b. INSULATED, STRANDED ANNEALED COPPER.
1) INSULATED WITH HEAT AND MOISTURE RESISTANT POLYVINYL CHLORIDE COMPOUND.
2) MEET UL REQUIREMENTS FOR TYPE THW, 75 DEGREES C.
3) RATED 600 VOLTS.
4) COLOR-CODED, GREEN.
5) ACCEPTABLE MANUFACTURERS.
(a) ANAMET.
(b) GENERAL ELECTRIC.
(c) ROME CABLE CORP.
(d) TRIANGLE WIRE & CABLE.
(e) GROUNDING ELECTRODES
1. GROUND RODS; COPPER-CLAD STEEL WITH HIGH STRENGTH STEEL CORE AND ELECTROLYTIC-GRADE COPPER OUTER SHEATH, MOLTEN WELDED TO CORE – 3/4" x 10' IN SIZE.
2. PLATE ELECTRODES; COPPER PLATES, MINIMUM 0.10 INCH THICK, SIZES AS INDICATED.

GROUNDING CONNECTIONS.
1. TO STRUCTURAL STEEL USED FOR MAIN BUILDING FRAMING OR NEAREST AVAILABLE GROUND BUS.
a. BOLTED LUGS.
1) ACCEPTABLE MANUFACTURERS.
(a) BLACKBURN/HOLUB, DIV. THOMAS & BETTS.
(b) ILSCO.
(c) O-Z/GEDNEY.
2. TO NONPERMANENTLY FIXED EQUIPMENT.
a. LUGS BOLTED TO EQUIPMENT.
1) ACCEPTABLE MANUFACTURERS.
(a) BLACKBURN/HOLUB, DIV. THOMAS & BETTS.
(b) ILSCO.
3. FOR FENCE GROUNDING
a. USE TYPE GD, GL, AND GZ BURNDY GROUND CONNECTOR.

GROUNDING FITTINGS.
1. FOR BONDING A GROUND CONDUCTOR TO OWN CONDUIT.
a. ACCEPTABLE PRODUCTS.
1) TYPE NE BY BURNDY.
2) TYPE BD BY TELEDYNE PENN UNION.
b. EQUIPMENT GROUNDING CONDUCTOR APPLICATION: COMPLY WITH NEC ARTICLE 250 FOR SIZES AND QUANTITIES OF EQUIPMENT GROUNDING CONDUCTORS, EXCEPT WHERE LARGER SIZES OR MORE CONDUCTORS ARE INDICATED.
1) INSTALL SEPARATE INSULATED EQUIPMENT GROUNDING CONDUCTORS WITH CIRCUIT CONDUCTORS FOR THE FOLLOWING IN ADDITION TO THOSE LOCATIONS WHERE REQUIRED BY CODE:
(a) FEEDERS AND BRANCH CIRCUITS, RECEPTACLE CIRCUITS, SINGLE-PHASE MOTOR OR APPLIANCE CIRCUITS AND THREE-PHASE MOTOR OR APPLIANCE BRANCH CIRCUITS.
c. NONMETALLIC RACEWAYS: INSTALL AN INSULATED EQUIPMENT GROUND CONDUCTOR IN NONMETALLIC RACEWAYS UNLESS THEY ARE DESIGNATED FOR TELEPHONE OR DATA CABLES.
d. UNDERGROUND CONDUCTORS: BARE, STRANDED COPPER EXCEPT AS OTHERWISE INDICATED.
e. SIGNAL AND COMMUNICATIONS: FOR TELEPHONE, ALARM AND COMMUNICATION SYSTEMS, PROVIDE A #4 AWG MINIMUM GREEN INSULATED COPPER CONDUCTOR IN RACEWAY FROM THE GROUNDING ELECTRODE SYSTEM TO EACH TERMINAL CABINET OR CENTRAL EQUIPMENT LOCATION.
f. SEPARATELY DERIVED SYSTEMS REQUIRED BY NEC TO BE GROUNDED SHALL BE GROUNDED IN ACCORDANCE WITH NEC PARAGRAPH 250-26.

PART 3 EXECUTION
3.01 INSTALLATION.
A. GENERAL.
1. GROUND ELECTRICAL SYSTEMS AND EQUIPMENT IN ACCORDANCE WITH NEC REQUIREMENTS EXCEPT WHERE THE DRAWINGS OR SPECIFICATIONS EXCEED NEC REQUIREMENTS.
2. BOND GROUND CONDUCTOR TO CONDUIT AT EACH END OF METALLIC CONDUIT USED FOR MECHANICAL PROTECTION OF GROUND CONDUCTOR.
3. MAKE METALLIC RACEWAY FITTINGS AND GROUNDING CLAMP TIGHT TO ENSURE GROUNDING PATH.
4. DO NOT SOLDER GROUNDING CIRCUIT CONNECTIONS.
5. MAINTAIN CONTINUITY OF EQUIPMENT GROUNDING SYSTEM LOCATED IN NONMETALLIC CONDUIT AND DUCTS WITH BAR OR CONDUCTOR INSTALLED AND CONNECTED BY ACCEPTED METHOD TO EQUIPMENT AT BOTH ENDS.
6. MAKE GROUND CONTINUITY POSITIVE THROUGHOUT.
7. GROUND STRUCTURAL STEEL BUILDING FRAMING IN WEB OF COLUMN.
8. GROUND TO NONPERMANENTLY FIXED EQUIPMENT.
a. LUGS BOLTED TO EQUIPMENT.
1. THOROUGHLY CLEAN BONDING SURFACES OF NONCONDUCTING MATERIALS.
2. WHERE BOLTED CONNECTIONS ARE USED, TREAT SURFACES WITH CORROSION INHIBITING COMPOUND.
9. GROUND EACH SECTION OF FENCE, FENCE POST, AND FENCE GATES.
B. GROUND RODS: LOCATE A MINIMUM OF ONE-ROD LENGTH FROM EACH OTHER AND AT LEAST THE SAME DISTANCE FROM ANY OTHER GROUNDING ELECTRODE. INTERCONNECT GROUND RODS WITH BARE CONDUCTORS BURIED AT LEAST 24" BELOW GRADE. CONNECT BARE-CABLE GROUND CONDUCTORS TO GROUND RODS BY MEANS OF EXOTHERMIC WELDS EXCEPT AS OTHERWISE INDICATED. MAKE THESE CONNECTIONS WITHOUT DAMAGING THE COPPER OR EXPOSING THE STEEL. USE 3/4" BY 10' GROUND RODS EXCEPT AS OTHERWISE INDICATED.
C. BRAIDED-TYPE BONDING JUMPERS: INSTALL TO CONNECT GROUND CLAMPS ON WATER METER PIPING TO BYPASS WATER METERS ELECTRICALLY. USE ELSEWHERE FOR FLEXIBLE BONDING AND GROUNDING CONNECTIONS.
D. ROUTE GROUNDING CONDUCTORS ALONG THE SHORTEST AND STRAIGHTEST PATHS WITHOUT OBSTRUCTING ACCESS OR PLACING CONDUCTORS WHERE THEY MAY BE SUBJECTED TO STRAIN, IMPACT, OR DAMAGE, EXCEPT AS INDICATED.
E. BOND INTERIOR METAL PIPING SYSTEMS AND METAL AIR DUCTS TO EQUIPMENT GROUND CONDUCTORS OF PUMPS, FANS, ELECTRIC HEATERS AND AIR CLEANERS SERVING INDIVIDUAL SYSTEMS.
F. TEST WELLS: LOCATE AS INDICATED AND FABRICATE IN ACCORDANCE WITH DETAILS INDICATED.

3.02 CONNECTIONS
A. MAKE CONNECTIONS IN SUCH A MANNER AS TO MINIMIZE POSSIBILITY OF GALVANIC ACTION OR ELECTROLYSIS. SELECT CONNECTORS, CONNECTION HARDWARE, CONDUCTORS AND CONNECTION METHODS SO METALS IN DIRECT CONTACT WILL BE GALVANICALLY COMPATIBLE.
1. USE ELECTROPLATED OR HOT-TIN COATED MATERIALS TO ASSURE HIGH CONDUCTIVITY AND MAKE CONTACT POINTS CLOSER IN ORDER OF GALVANIC SERIES.
2. MAKE CONNECTIONS WITH CLEAN BARE METAL POINTS OF CONTACT.
3. ALUMINUM TO STEEL CONNECTIONS SHALL BE WITH STAINLESS STEEL SEPARATORS AND MECHANICAL CLAMPS.
4. ALUMINUM TO GALVANIZED STEEL CONNECTIONS SHALL BE WITH TIN-PLATED COPPER JUMPERS AND MECHANICAL CLAMPS.
5. COAT AND SEAL CONNECTIONS INVOLVING DISSIMILAR METALS WITH INERT MATERIALS SUCH AS RED LEAD PAINT TO PREVENT FUTURE PENETRATION OF MOISTURE TO CONTACT SURFACES.
6. RESTORE SURFACE FEATURES AT AREAS DISTURBED BY EXCAVATION AND RE-ESTABLISH ORIGINAL GRADES EXCEPT AS OTHERWISE INDICATED.
B. EXOTHERMIC WELD CONNECTIONS: USE OF CONNECTIONS TO STRUCTURAL STEEL AND FOR UNDERGROUND CONNECTIONS EXCEPT THOSE AT TEST WELLS. INSTALL AT CONNECTIONS TO GROUND RODS AND PLATE ELECTRODES. COMPLY WITH MANUFACTURER'S WRITTEN RECOMMENDATION. WELDS THAT ARE PUFFED UP OR THAT CONVEX SURFACES INDICATING IMPROPER CLEANING ARE NOT ACCEPTABLE.
C. TERMINATE INSULATED EQUIPMENT GROUNDING CONDUCTORS FOR FEEDERS AND BRANCH CIRCUITS WITH PRESSURE-TYPE GROUNDING LUGS. WHERE METALLIC RACEWAYS TERMINATE AT METALLIC HOUSINGS WITHOUT MECHANICAL AND ELECTRICAL CONNECTION TO THE HOUSING, TERMINATE EACH CONDUIT WITH A GROUNDING BUSHING. CONNECT GROUNDING BUSHING WITH A BARE GROUNDING CONDUCTOR TO THE GROUND BUS IN THE HOUSING. BOND ELECTRICALLY NONCONTINUOUS CONDUITS AT BOTH ENTRANCES AND EXITS WITH GROUNDING BUSHINGS AND BARE GROUNDING CONDUCTORS.
D. TIGHTEN GROUNDING AND BONDING CONNECTORS AND TERMINALS, INCLUDING SCREWS AND BOLTS, IN ACCORDANCE WITH MANUFACTURER'S PUBLISHED TORQUE TIGHTENING VALUES FOR CONNECTORS AND BOLTS. WHERE MANUFACTURER'S TORQUING REQUIREMENTS ARE NOT INDICATED, TIGHTEN CONNECTIONS TO COMPLY WITH TORQUE TIGHTENING VALUES SPECIFIED IN U.L. 486A AND U.L. 486B.
E. CONNECTIONS AT TEST WELLS: USE COMPRESSION-TYPE CONNECTORS ON CONDUCTORS AND MAKE BOLTED- AND CLAMPED-TYPE CONNECTIONS BETWEEN CONNECTORS AND GROUND RODS.
F. COMPRESSION-TYPE CONNECTIONS: USE HYDRAULIC COMPRESSION TOOLS TO PROVIDE THE CORRECT CIRCUMFERENTIAL PRESSURE FOR COMPRESSION CONNECTORS. USE TOOLS AND DIES RECOMMENDED BY THE MANUFACTURER OF THE CONNECTORS. PROVIDE EMBOSSING DIE CODE OR OTHER STANDARD METHOD TO MAKE ADVISABLE INDICATION THAT A CONNECTOR HAS BEEN ADEQUATELY COMPRESSED ON THE GROUND CONDUCTOR.
G. MOISTURE PROTECTION: WHERE INSULATED GROUND CONDUCTORS ARE CONNECTED TO GROUND RODS OR GROUND BUSES, INSULATE THE ENTIRE AREA OF THE CONNECTION AND SEAL AGAINST MOISTURE PENETRATION OF THE INSULATION AND CABLE.

SECTION 16075 – ELECTRICAL IDENTIFICATION

PART 1 GENERAL
1.01 REFERENCES
A. NFPA 70 – NATIONAL ELECTRICAL CODE:2002.

PART 2 PRODUCTS
2.01 MANUFACTURERS
A. SUBJECT TO COMPLIANCE WITH REQUIREMENTS, PROVIDE PRODUCTS BY ONE OF THE FOLLOWING –
1. BRADY CORPORATION; WWW.BRADYCORP.COM.
2. IDEAL INDUSTRIES, INC.; WWW.IDEALINDUSTRIESINC.COM
3. PANDUIT CORP.; WWW.PANDUIT.COM.
4. THOMAS & BETTS CORPORATION; WWW.TNB.COM.

2.02 MATERIALS
A. RACEWAY AND CABLE LABELS –
1. GENERAL –
a. WHERE MORE THAN ONE TYPE ARE LISTED FOR A SPECIFIED APPLICATION, SELECTION IS INSTALLER'S OPTION, BUT PROVIDE SINGLE TYPE FOR EACH APPLICATION CATEGORY.
b. USE MANUFACTURER'S STANDARD PRODUCTS.
c. COLOR: COMPLY WITH ANSI A13.1 AND NFPA 70.
d. LEGEND: VOLTAGE.
2. ADHESIVE LABELS.
a. PREPRINTED, FLEXIBLE, SELF-ADHESIVE VINYL.
b. LAMINATE OVER LEGEND WITH CLEAR, WEATHER AND CHEMICAL RESISTANT COATING.
3. COLORED PLASTIC SLEEVES.
a. FLEXIBLE, PREPRINTED, COLOR CODED, ACRYLIC BANDS.
b. PRETENSIONED, WRAPAROUND.
c. SIZED TO SUITE DIAMETER OF LINE IT IDENTIFIES.

PART 3 EXECUTION
3.01 INSTALLATION
A. GENERAL
1. INSTALL IDENTIFICATION DEVICES IN ACCORDANCE WITH MANUFACTURER'S WRITTEN INSTRUCTIONS.
2. INSTALL LABELS WHERE INDICATED AND AS REQUIRED BY OSHA AND NFPA 70.
3. INSTALL LABELS AT LOCATIONS FOR BEST CONVENIENCE OF VIEWING WITHOUT INTERFERENCE WITH OPERATION AND MAINTENANCE OF EQUIPMENT.
4. COORDINATE NAMES, ABBREVIATIONS, COLORS, AND OTHER DESIGNATIONS USED FOR ELECTRICAL IDENTIFICATION WITH CORRESPONDING DESIGNATIONS USED IN THE CONTRACT DOCUMENTS OR REQUIRED BY CODES AND STANDARDS.
B. SEQUENCE OF WORK
1. COORDINATE WORK WITH OTHER TRADES.
2. WHERE FIELD APPLIED FINISHES ARE SPECIFIED, APPLY ELECTRICAL IDENTIFICATION AFTER COMPLETION OF FINISHES.
3. FOR WORK IN CONCEALED LOCATIONS, COMPLETE WORK PRIOR TO INSTALLATION OF FINISHES THAT WILL CONCEAL WORK.
C. SELF-ADHESIVE IDENTIFICATION PRODUCTS.
1. CLEAN SURFACES OF DUST, LOOSE MATERIAL, AND OILY FILMS BEFORE APPLYING.
D. CONDUCTOR IDENTIFICATION.
1. CONDUCTOR INSULATION COLOR.
a. COLOR CODE.
1) LINE AND LOAD CIRCUITS, AC OR DC, ABOVE 100 VOLTS: BLACK.
2) AC CONTROL CIRCUITS, 150 VOLTS AND BELOW: RED.
3) DC CONTROL CIRCUITS, 150 VOLTS AND BELOW: BLUE.
4) EQUIPMENT GROUNDING CONDUCTORS (NONCURRENT CARRYING): GREEN WITH OR WITHOUT YELLOW STRIPE.
5) GROUNDED (CURRENT CARRYING) CONDUCTORS NO. 6 AND SMALLER: WHITE.
2. CONDUCTOR PHASE IDENTIFICATION.
a. USE A UNIQUE COLOR SCHEME FOR EACH SYSTEM VOLTAGE.
b. IN THE ABSENCE OF AN EXISTING SITE COLOR SCHEME OR AN OWNER OPTION STANDARD, USE THE FOLLOWING:
1) 480/277 VOLT SYSTEMS.
(a) PHASE A: BROWN.
(b) PHASE B: ORANGE.
(c) PHASE C: YELLOW.
(d) NEUTRAL: GRAY.
(e) GROUND: GREEN
2) 208/120 VOLT SYSTEMS.
(a) PHASE A: BLACK.
(b) PHASE B: RED.
(c) PHASE C: BLUE.
(d) NEUTRAL: WHITE.
(e) GROUND: GREEN.
c. USE COLOR CODING TO IDENTIFY PHASE AND GROUNDED CONDUCTORS AT TERMINALS AND SPLICES.
d. USE A CONSISTENT METHOD THROUGHOUT INSTALLATION.
3. CIRCUIT IDENTIFICATION.
a. USE A CONSISTENT SYSTEM OF TAGS OR ADHESIVE LABELS.
b. IDENTIFY CONDUCTORS AT TERMINATION'S AND SPLICES.
c. PROVIDE CIRCUIT IDENTIFICATION FOR
1) CONDUCTORS TO BE EXTENDED IN THE FUTURE.
(a) INDICATE SOURCE AND CIRCUIT NUMBERS.
2) MULTIPLE POWER/LIGHTING CIRCUITS IN THE SAME ENCLOSURE.
(a) IDENTIFY EACH CONDUCTOR WITH SOURCE, VOLTAGE, CIRCUIT NUMBER, AND PHASE
(b) USE COLOR CODING FOR VOLTAGE AND PHASE INDICATION.
3) MULTIPLE CONTROL/COMMUNICATIONS CIRCUITS IN THE SAME ENCLOSURE.
(a) IDENTIFY EACH CONDUCTOR BY ITS SYSTEM AND CIRCUIT DESIGNATION.
E. POWER CIRCUIT IDENTIFICATION.
1. IDENTIFY CABLES, FEEDER, AND POWER CIRCUITS.
2. LEGEND
a. 1/4 INCH STAMPED OR EMBOSSED CHARACTERS.
b. INDICATE CIRCUIT DESIGNATIONS.

REFERENCE DRAWINGS

BASIN DRAWING NUMBER
OED-0002 ELECTRICAL SPECIFICATIONS

REV.	DESCRIPTION	DRWN	DSGN	APPD	DATE
0	AS BUILT – BASIN NUMBER AND TITLE BLOCK	L. FROEHLICH	A. BOUSHEE	R. BUSH	5/7/07

FACILITY: WIND TO HYDROGEN SYSTEM
LOCATION/UNIT: MINOT, NORTH DAKOTA
CONTRACT/DESIGNATION:

ELECTRICAL SPECIFICATIONS

BASIN ELECTRIC POWER COOPERATIVE
1717 EAST INTERSTATE AVENUE
BISMARCK, NORTH DAKOTA 58503-0564
PHONE 701-223-0441

DESIGN BY: ALBERT KAHN ASSOCIATES
DRAWN BY:
DESIGN CHK:
DRAFT CHK:
APPROVED:
SCALE: NONE
VENDOR/ORIGINATED FROM: ALBERT KAHN ASSOCIATES
VENDOR DRAWING NO. E-001 ORIGINAL REV 5
BASIN DRAWING NO. OED-0001 REV. NO. 0

01/27/04

SECTION 16120 – CONDUCTORS AND CABLES

PART 1 GENERAL
1.01 REFERENCES

A. NFPA 70 – NATIONAL ELECTRICAL CODE;2002.
B. TIA/EIA-568 – COMMERCIAL BUILDING TELECOMMUNICATIONS CABLING STANDARD; B, 2003.
C. UL (ECMD) – ELECTRICAL CONSTRUCTION MATERIALS DIRECTORY; CURRENT EDITION.
D. UL 44 – STANDARD FOR THERMOSET-INSULATED WIRES AND CABLES; 1999.
E. UL 83 – THERMOPLASTIC-INSULATED WIRES AND CABLES; 1998.
F. UL 1569 – METAL-CLAD CABLES; 1999.

1.02 QUALITY ASSURANCE
A. WIRE AND CABLE.
1. LISTED BY UNDERWRITERS LABORATORIES INC. (UL) AND LABELED AS MEETING NATIONAL ELECTRICAL CODE REQUIREMENTS.
2. FURNISH WIRE AND CABLE ON WHICH STANDARD FACTORY TESTS ESTABLISHED BY ASTM, ANSI, ICEA, NEMA, NFPA AND UL HAVE BEEN PERFORMED.

PART 2 PRODUCTS
2.01 MATERIALS

A. WIRE.
1. CHARACTERISTICS.
a. IN ACCORDANCE WITH STANDARD SPECIFICATIONS ESTABLISHED FOR MATERIAL AND CONSTRUCTION BY ASTM, ANSI, ICEA, NEMA, NFPA AND UL WHERE APPLICABLE.
b. CONDUCTORS, ANNEALED COPPER, MINIMUM OF 98 PERCENT CONDUCTIVITY.
c. SINGLE CONDUCTOR UNLESS MULTICONDUCTOR IS INDICATED ON CONTRACT DRAWINGS.
d. CONDUCTOR SIZES IN ACCORDANCE WITH NEC (NFPA 70) REQUIREMENTS, UNLESS OTHERWISE INDICATED IN CONTRACT DOCUMENT, BUT NOT LESS THAN 12 AWG.
e. SOLID OR STRANDED CONDUCTORS FOR 10 AWG AND SMALLER.
f. STRANDED CONDUCTORS FOR 8 AWG AND LARGER.
g. 600 VOLTS.
h. TYPE, NEC (NFPA 70) SPECIFIED.

2. ACCEPTABLE MANUFACTURERS.
a. AMERICAN INSULATED WIRE CORPORATION.
b. AETNA INSULATED WIRE CO, CERROWIRE.
c. THE OKONITE COMPANY.
d. PIRELLI CABLE CORPORATION.
e. SOUTHWIRE COMPANY.

3. LOCATIONS.
a. FOR GENERAL INTERIOR AND EXTERIOR USE.
1) 600 VOLTS.
2) TYPE THHN/THWN-2, RATED 90 DEGREES C IN DRY AND WET LOCATIONS.

B. MULTICONDUCTOR CONTROL CABLE, FOR INSTALLATION IN CONDUIT.
1. SIZE AND NUMBER OF CONDUCTORS, AS INDICATED ON DRAWINGS.
2. CONDUCTORS, 19 STRAND INDIVIDUAL, ANNEALED COPPER.
3. COLOR CODING, IN ACCORDANCE WITH ICEA, METHOD 1, TABLE K1.
4. CABLING, ROUND WITH FILLERS AND BINDER TAPE.
5. JACKET, PVC.
6. 600 VOLTS.
7. INSULATION, RATED 90 DEGREES C.
a. 26 MILS LINEAR POLYETHYLENE AND 4 MILS NYLON, OR 20 MILS HMW POLYETHYLENE AND 10 MILS PVC.
b. ACCEPTABLE PRODUCT.
1) TYPE SDC-90 BY TRIANGLE PWC.
2) OLFEX TRAY II CY BY LAPP SYSTEMS USA.
3) UNITRONIC 300CY BY LAPP SYSTEMS USA.
4) UTP CABLE BY LAPP SYSTEMS USA.

C. CONNECTORS.
1. FOR SPLICING COPPER CONDUCTORS 8 AWG AND SMALLER.
a. SOLDERLESS COMPRESSION TYPE.
b. ACCEPTABLE MANUFACTURERS.
1) AMP PRODUCTS.
2) IDEAL ELECTRIC COMPANY.
3) ILSCO CORPORATION.
4) THOMAS AND BETTS CORPORATION.

2. FOR STRAIGHT SPLICING CONDUCTORS 6 AWG AND LARGER.
a. SOLDERLESS COMPRESSION 2-WAY TYPE.
b. ACCEPTABLE MANUFACTURERS.
1) AMP.
2) BLACKBURN/HOLUB.
3) TYPE YS-L BY BURNDY.
4) IDEAL ELECTRIC COMPANY.
5) ILSCO DIVISION OF BARDES CORPORATION.
6) SERIES 54500 BY THOMAS AND BETTS CORPORATION.

D. LUGS FOR TERMINATING COPPER CONDUCTORS.
1. FOR 8 AWG AND SMALLER.
a. SOLDERLESS TYPE.
b. EQUIPMENT MANUFACTURER'S STANDARD, UNLESS OTHERWISE SPECIFIED.
2. FOR 6 AWG AND LARGER.
a. SOLDERLESS COMPRESSION TYPE.
b. ONE HOLE FOR 6 AWG THROUGH 4/0 AWG INCLUSIVE.
c. 2-HOLE FOR LARGER SIZES.
d. ACCEPTABLE MANUFACTURERS.
1) TYPE YA-L BY BURNDY.
2) ILSCO DIVISION OF BARDES CORPORATION.
3) SERIES 54000 BY THOMAS AND BETTS CORPORATION.
3. FOR CONTROL WIRING.
a. SOLDERLESS COMPRESSION TYPE WITH TINNED RING TONGUE.
b. ACCEPTABLE MANUFACTURERS.
1) HYDENT BY BURNDY.
2) ILSCO DIVISION OF BARDES CORPORATION.
3) STA-KON BY THOMAS AND BETTS CORPORATION.
E. WIRE LABELS FOR IDENTIFICATION OF CONDUCTORS.
1. ACCEPTABLE MANUFACTURERS.
a. AMP PRODUCTS.
b. IDEAL ELECTRIC COMPANY.
c. PANDUIT CORPORATION.
d. RAYCHEM CORPORATION.
e. 3M COMPANY.
F. INSULATING TAPE, FOR GENERAL USE.
1. ACCEPTABLE PRODUCTS.
a. CATALOG NO. 602-35-7010 BY OKONITE.
b. 33 PLUS BY 3M COMPANY.
c. FOR HIGH TEMPERATURE USE, 27 BY 3M COMPANY.
d. SUBSTITUTIONS: SEE SECTION 01600 – PRODUCT REQUIREMENTS.

PART 3 EXECUTION
3.01 INSTALLATION

A. CONVENTIONAL WIRING.
1. INSTALL IN RACEWAY WHERE EXPOSED WIRING IS INDICATED OR SPECIFIED.
2. WIRE ONLY IN COMPLETED RACEWAY SYSTEMS WHEN PROTECTED FROM WEATHER.
3. INSTALL CONDUCTORS CONTINUOUS, WITHOUT SPLICES, BETWEEN EQUIPMENT.
4. WHERE SPLICES ARE REQUIRED, MAKE UP SPLICES IN BOXES.
5. DO NOT USE FITTINGS FOR SPLICES.
6. INSTALL PHASE AND NEUTRAL CONDUCTORS OF EACH BRANCH OR FEEDER CIRCUIT AS INDICATED.
7. TERMINATE CONDUCTORS AT SAME LOCATION, MECHANICALLY AND ELECTRICALLY, AT BOTH ENDS, FOR EQUAL DIVISION OF TOTAL CURRENT BETWEEN CONDUCTORS.
8. INSTALL CONDUCTORS SO BENDING RADIUS OF ANY WIRE OR CABLE IS NOT LESS THAN MINIMUM RECOMMENDED BY ICEA OR MANUFACTURER.
9. CONNECT ALL POWER WIRING TO EQUIPMENT FOR PHASING A-B-C-N LEFT TO RIGHT, TOP TO BOTTOM, AND FRONT TO BACK, WHERE POSSIBLE, AND PERMANENTLY IDENTIFY PHASING ON THE STRUCTURE OR HOUSING ADJACENT TO BUS.
10. PHASE IDENTIFICATION A-B-C IS EQUIVALENT TO TRANSFORMER PHASE IDENTIFICATION X1-X2-X3 AND H1-H2-H3.
11. CONNECT PHASE WIRING TO ALL 3 PHASE RECEPTACLES FOR SAME PHASE ROTATION IN ALL RECEPTACLES WITH INTERCHANGEABLE PLUGS.

B. COLOR CODING AND CONDUCTOR IDENTIFICATION.
1. IDENTIFY INDIVIDUAL FEEDER AND SUBFEEDER CONDUCTORS AS TO PHASE CONNECTION A, B, C, BY MEANS OF WIRE LABELS AT EACH SPLICE AND TERMINATION.
C. SPLICES AND TERMINATIONS.
1. USE LUGS FOR SPECIFIC SIZE AND TYPE OF CONDUCTOR.
2. INDENT COMPRESSION CONNECTORS AND LUGS WITH TOOLS RECOMMENDED BY CONNECTOR OR LUG MANUFACTURER.
3. THOROUGHLY CLEAN WIRE ENDS BEFORE CONNECTORS OR LUGS ARE APPLIED.
4. WHENEVER COPPER LUGS ARE TERMINATED ON ALUMINUM BUS, USE A BELLEVILLE WASHER AND 2 TIN OR CADMIUM PLATED WASHERS, ONE ON EACH SIDE IN COMBINATION WITH ALUMINUM JOINT COMPOUND ON CONTACTING SURFACES.
5. TIGHTEN BOLTS UNTIL BELLEVILLE WASHER IS FLAT.
6. INSULATE BARE SURFACES OF CONDUCTORS WITH 4 LAYERS (HALF LAP IN 2 DIRECTIONS) OF ELECTRICAL INSULATING TAPE.
7. ON LARGER SPLICES AND TERMINALS, BUILD UP CONNECTION WITH ELECTRICAL INSULATING PUTTY BEFORE APPLYING TAPE, TO ELIMINATE SHARP EDGES AND VOIDS.
8. TERMINATE ARMORED CABLES AT EQUIPMENT WITH AN ARMORED CABLE TERMINATOR.
9. TERMINATE CABLE GROUND CONDUCTORS ON EQUIPMENT GROUND BUS.
D. CABLE IDENTIFICATION.
1. IDENTIFY CABLES PER SECTION 16075.

SECTION 16121 – ELECTRIC HEAT TRACING SYSTEMS

1.01 MANUFACTURED UNITS
A. ELECTRIC HEAT TRACING SYSTEMS
1. FURNISH AND INSTALL ELECTRIC HEAT TRACING SYSTEMS, WHERE INDICATED ON DRAWINGS, COMPLETE WITH ELECTRIC HEATING CABLE, COLD LEADS, CONTROL PANEL, JUNCTION BOXES, OUTDOOR THERMOSTAT, LINE THERMOSTATS, INTERCONNECTING WIRING AND CONDUIT, CIRCUIT BREAKER PANELS, AND ALL CONTROL CONTACTORS REQUIRED FOR DISTRIBUTION TO ELECTRIC HEAT TRACING CIRCUITS.

2. ELECTRIC HEATING CABLE
a. FLAT, FLEXIBLE, ELECTRICAL RESISTANCE, HEATER STRIPS WITH ELECTRICALLY CONDUCTIVE CORE MATERIAL BETWEEN 2 COPPER BUS STRIPS, FLEXIBLE, ABRASION RESISTANT, AND ELECTRICALLY INSULATING OUTER SHEATH AND WIRING CONNECTIONS WITH END SEALS.
b. ELECTRICAL CONDUCTIVITY OF CORE MATERIAL SHALL DECREASE WITH INCREASING TEMPERATURE.
c. FURNISH AND INSTALL HEATER STRIPS SUITABLE FOR OPERATION AT MAXIMUM MAINTAINENCE TEMPERATURE OF 120 °F AND MAXIMUM CONTINUOUS EXPOSURE TEMPERATURE OF 185 °F.
d. REFER TO DRAWINGS FOR OPERATING VOLTAGE.
e. ACCEPTABLE MANUFACTURERS:
1.) RAYCHEM: CHEMELEX AUTO-TRACE TYPE BTV
2.) THERMON: TYPE HSX/TSX

3. CONTROLS
a. OUTDOOR THERMOSTAT SET AT 40 °F COMPLETE WITH SENSING BULB AND CAPILLARY TUBING.
b. FURNISH EACH INDIVIDUAL TRACING CIRCUIT WITH PIPE SENSING THERMOSTAT AND CONTROL RELAY.

PART 2 EXECUTION
2.01 INSTALLATION

A. ELECTRIC HEAT TRACING
1. INSTALL ELECTRIC HEAT TRACING CABLE IN ACCORDANCE WITH MANUFACTURER'S INSTRUCTIONS AND ARCHITECT-ENGINEER REVIEWED INSTALLATION DRAWINGS.
2. AT PIPE SUPPORTS, GUIDES AND ANCHORS, ROUTE CABLES TO PREVENT CRUSHING, FRAYING, TEARING, BREAKING OR SHEARING UNDER FORCES AND MOTIONS EXPECTED DURING INSTALLATION AND OPERATION.
3. AT EXPANSION JOINTS, INSTALL ENOUGH SLACK IN CABLE TO COMPENSATE FOR THE MOST EXTREME JOINT ELONGATION EXPECTED.
4. STRAIGHTEN KINKS IN CABLE PRIOR TO INSTALLATION.
5. TAPE CABLE TO ENSURE CONTINUOUS CONTACT BETWEEN CABLE AND PIPE.
6. TERMINATE LEADS IN JUNCTION BOXES. LOCATE AND SEAL JUNCTION BOXES TO PREVENT ENTRY OF MOISTURE. FURNISH ONE JUNCTION BOX FOR EACH PIPING SYSTEM.
7. LIMIT MAXIMUM CABLE CIRCUIT LENGTH SO STARTING INRUSH CURRENT AT 0 °F DOES NOT EXCEED CIRCUIT BREAKER RATING.

SECTION 16500 – TESTING

1. GENERAL
A. THIS DOCUMENT OUTLINES THE TESTING PROCEDURES FOR THE ELECTRICAL SYSTEMS. ALL EQUIPMENT VENDOR SUPPLIED EQUIPMENT SHALL BE TESTED AND APPROVED BY THE EQUIPMENT VENDOR(S) PRIOR TO SHIPMENT AND SHALL NOT BE THE RESPONSIBILITY OF THE CONTRACTOR.
B. ELECTRICAL CONTRACTOR TO HIRE A QUALIFIED TESTING FIRM TO PERFORM TESTING AFTER THE INSTALLATION OF ELECTRICAL EQUIPMENT, DEVICES AND ASSOCIATED WIRE AND CONDUIT IS COMPLETED.

2.0 TEST

THE ELECTRICAL CONTRACTOR SHALL;

1. FOR ALL CIRCUITS ENSURE THAT ALL ELECTRICAL EQUIPMENT, MATERIALS AND SYSTEMS INSTALLED ARE SUBJECTED TO AN INSPECTION AND APPLICABLE TESTS PRIOR TO COMMISSIONING TO ENSURE THAT THE COMPLETE INSTALLATION IS IN ACCORDANCE WITH ALL DRAWINGS AND SPECIFICATIONS.
2. ENSURE THAT THE SYSTEM AND ITS COMPONENT WIRING IS COMPLETE AND CIRCUIT IS PRETESTED PRIOR TO THE INSPECTION AND TEST FOR ACCEPTANCE.
3. CAREFULLY CHECK WIRING FOR EACH SYSTEM AND/OR PART OF A SYSTEM TO ENSURE THAT THE SYSTEM WILL FUNCTION PROPERLY AS INDICATED BY WIRING AND SCHEMATIC DIAGRAMS, DESCRIPTION OF OPERATION, ETC.
4. SUPPLY ALL INSTRUMENTS, METERS AND PERSONNEL REQUIRED FOR TESTS.
5. ENSURE TESTING BE CONDUCTED BY FULLY QUALIFIED PERSONNEL ONLY. TESTS REQUIRING INITIAL POWER ENERGIZATION OF A SYSTEM SHALL NOT BE MADE WITHOUT NOTIFICATION TO THE ENGINEER. TEST, CHECKS AND THE LIKE CARRIED OUT BY OR ON BEHALF OF THE CONTRACTOR SHALL BE DOCUMENTED AND SIGNED OFF AT NO ADDITIONAL COST TO PURCHASER. SUBMIT FIVE COPIES OF THE TEST CERTIFICATES TO THE ENGINEER.
6. FAILURE OR DEFECTS IN WORKMANSHIP REVEALED BY TESTS SHALL BE CORRECTED PROMPTLY AND TESTS RECONDUCTED AT NO EXTRA EXPENSE TO PURCHASER.

2.1 INSULATION RESISTANCE TESTS – 1000 VOLTS AND BELOW
A. TESTS ON CABLE AND WIRE IN THIS VOLTAGE RANGE SHALL BE LIMITED TO INSULATION RESISTANCE MEASUREMENTS USING A MEGGER INSTRUMENT (500V INSTRUMENT FOR CIRCUITS UP TO 350V SYSTEMS; 1000V INSTRUMENT FOR 351-600V SYSTEMS).
B. REPLACE OR REPAIR ALL CIRCUITS WHICH DO NOT MEET MINIMUM REQUIREMENTS SPECIFIED BY THE CABLE OR WIRE MANUFACTURER. INSULATION RESISTANCE OF THE FOLLOWING CIRCUITS SHALL BE MEASURED:
1. POWER CIRCUITS (WITH EQUIPMENT DISCONNECTED): PHASE-TO-PHASE, PHASE-TO-NEUTRAL AND PHASE-TO-GROUND.
2. CONTROL CIRCUITS (WITH EQUIPMENT DISCONNECTED): MEASURE TO GROUND.
3. DO NOT PERFORM MEGGER TESTS ON CONTROL CIRCUITS CONTAINING TRANSISTOR OR SOLID-STATE COMPONENTS.
4. DO NOT PERFORM MEGGER TEST ON INSTRUMENTATION OR THERMOCOUPLE WIRING.
5. WHERE POWER FACTOR CORRECTION EQUIPMENT IS INSTALLED IT MAY BE NECESSARY TO DISCONNECT THE CAPACITORS FROM THE SYSTEM PRIOR TO TESTING TO AVOID OVERVOLTAGE.
6. AT COMPLETION OF TEST, ENSURE ALL EQUIPMENT AND WIRING ARE DISCHARGED TO GROUND POTENTIAL.
7. THE CONTRACTOR SHALL RECORD ALL TEST RESULTS ON ALL CABLES AND WIRES AND SUBMIT RESULTS TO THE ENGINEER.

2.2 CONTINUITY LOOP CHECKS
A. THE CONTRACTOR SHALL:
1. UPON WIRING COMPLETION, CHECK THE CONTINUITY OF THE ENTIRE CIRCUIT FROM FIELD DEVICE TO SOURCE; THE ENGINEER SHALL WITNESS AND APPROVE THIS PROCEDURE.
2. VERIFY THAT ALL WIRE NUMBERS CORRESPOND TO THE RESPECTIVE FIELD DEVICE AND SOURCE TERMINATION'S AS PER DRAWINGS AND/OR SUPPORTING DOCUMENTS.
3. WITH INSTRUMENTATION AND THERMOCOUPLE WIRING, THE CONTRACTOR SHALL CHECK CONTINUITY OF EACH CIRCUIT FROM FIELD DEVICE TO SOURCE USING AN OHMMETER OR A DC BUZZER. MEGGER OR 120 VOLT FILAMENT LAMP TESTING IS NOT ACCEPTABLE.
4. RECORD ALL TEST RESULTS ON ALL CABLES AND WIRES AND SUBMIT TO THE ENGINEER FOR APPROVAL.

2.3 GROUNDING RESISTANCE TESTS
A. THE CONTRACTOR SHALL:
1. TEST THE GROUND SYSTEM EFFICIENCY WITH THE "FALL-OF-POTENTIAL" GROUND RESISTANCE TEST AT EACH GROUND BED. VERIFY THAT THE OHMIC RESISTANCE VALUES ARE ACCEPTABLE AS PER THE GROUNDING INSTALLATION SPECIFICATIONS.
2. NOTIFY ELECTRIC AUTHORITIES THAT THEY MAY BE PRESENT TO WITNESS CONTRACTOR TESTING AND PROVIDE ANY ASSISTANCE REQUIRED BY ELECTRIC AUTHORITY FOR THEIR OWN TESTING PROCEDURES.
3. FIVE (5) TEST COPIES SHALL BE FURNISHED TO THE ENGINEER WITHIN ONE (1) WEEK AFTER TEST.

3.0 VEHICLE FUELING PAD TEST
A. TESTING:
1. PERFORM SURFACE RESISTANCE TESTING IN ACCORDANCE WITH DIN 1081 TEST (DIN = DEUTSCHES INSTITUT FUR NORMUNG)
2. PERFORM SURFACE RESISTANCE TESTING IN ACCORDANCE WITH CAFCP GROUND PATH (NOZZLE TO 1081 PROBE) TEST (CAFCP = CALIFORNIA FUEL CELL PARTNERSHIP).
3. EACH OF THE ABOVE TESTS SHALL RECORD THE MATERIAL, CONDITION OF MATERIAL (DRY, WET, ETC), A RESISTANCE READING AT 10 SECONDS AND A READING AT 15 SECONDS.
4. PERFORM EACH OF THE TESTS INDICATED IN #1 AND #2 AT THE FOLLOWING LOCATIONS:
a. CURB 3' EAST OF DISPENSER HOSE CONNECTION.
b. 6' EAST OF DISPENSER HOSE CONNECTION.
c. 9' EAST OF DISPENSER HOSE CONNECTION.
d. APPROX. 16' EAST AND 6' NORTH OF DISPENSER HOSE CONNECTION.
e. 9' EAST AND 6' NORTH OF DISPENSER HOSE CONNECTION.
5. PERFORM SURFACE RESISTANCE TESTING TO CONFIRM THAT PAD SURFACE TO GROUND RESISTANCE IS EQUAL TO OR LESS THAN 5 OHMS.

B. REPORT:
1. REPORT SHALL INDICATE THE FOLLOWING:
a. TESTING TEAM/OBSERVERS
b. WEATHER CONDITIONS DAY OF TEST
c. EXACT EQUIPMENT USED INCLUDING OPERATING RANGES
d. PICTURES OF TEST CONDITIONS
e. TESTING METHODS
f. TABLES INDICATING TEST RESULTS
g. CONCLUSIONS BASED ON TESTING RESULTS
h. RECOMMENDATIONS BASED ON TESTING RESULTS
2. THE PURPOSE OF THE ABOVE TESTING PROCEDURE IS TO VERIFY THAT THE SUPPLEMENTAL GROUNDING STRAP (PROVIDED BY MANUFACTURER ON DISPENSING EQUIPMENT) IS NOT NECESSARY TO MEET STATIC ELECTRICITY THRESHOLD OF 1 MEGA-OHM OR LESS (IEEE STIPULATES THAT 1 MEGA-OHM OR LESS IS ADEQUATE FOR STATIC GROUNDING). RECOMMENDATIONS SHALL BE INDICATED IN THE EVENT THAT THE SURFACE RESISTANCE EXCEEDS THE 1 MEGA-OHM THRESHOLD.

REFERENCE DRAWINGS

BASIN DRAWING NUMBER
OED-0001 ELECTRICAL SPECIFICATIONS

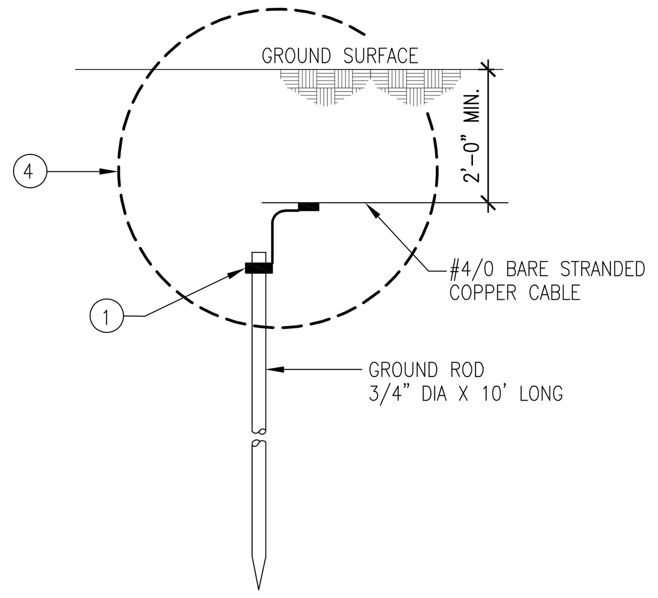
REV.	DESCRIPTION	DRWN	DSGN	APPD	DATE
0	AS BUILT – BASIN NUMBER AND TITLE BLOCK	L. FROEHLICH	A. BOUSHEE	R. BUSH	5/7/07

FACILITY: WIND TO HYDROGEN SYSTEM
LOCATION/UNIT: MINOT, NORTH DAKOTA
CONTRACT/DESIGNATION:

ELECTRICAL SPECIFICATIONS

BASIN ELECTRIC POWER COOPERATIVE
1717 EAST INTERSTATE AVENUE
BISMARCK, NORTH DAKOTA 58503-0564
PHONE 701-223-0441

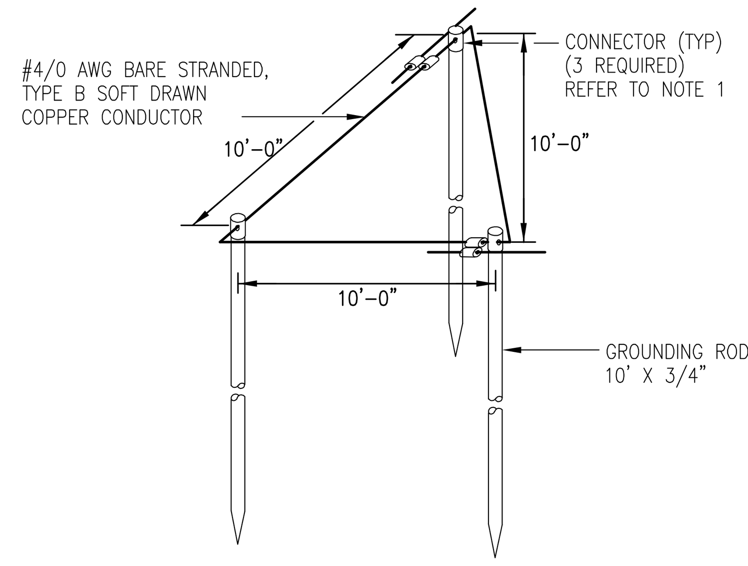
DESIGN BY ALBERT KAHN ASSOCIATES
DRAWN BY
DESIGN CHK.
DRAFT CHK.
APPROVED
SCALE: NONE
VENDOR/ORIGINATED FROM: ALBERT KAHN ASSOCIATES
VENDOR DRAWING NO. E-002 ORIGINAL REV 5
BASIN DRAWING NO. OED-0002 REV. NO. 0



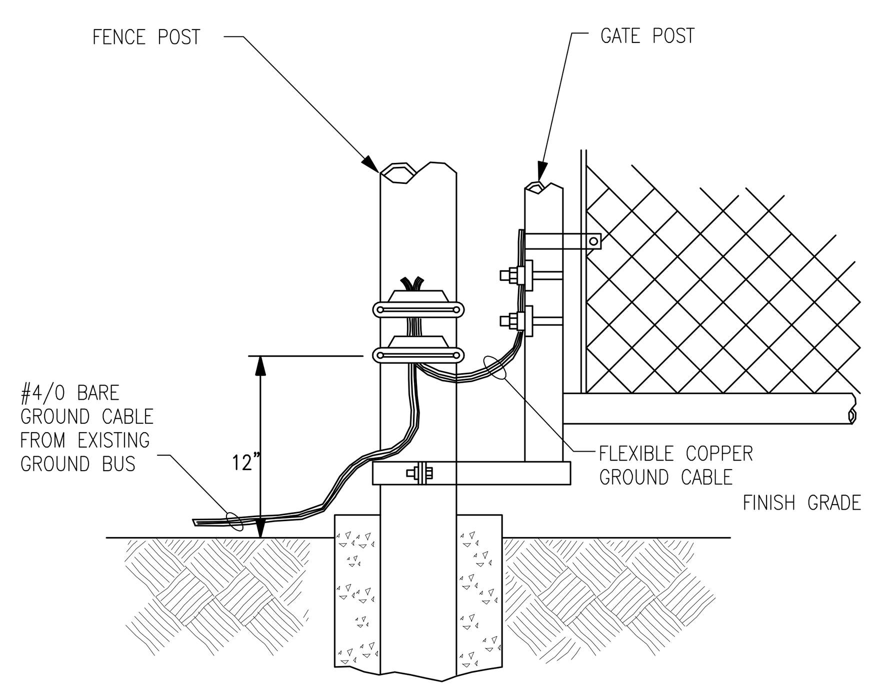
DETAIL #1
GROUNDING ROD INSTALLATION – BURIED TYPE
SCALE = NONE

NOTES:

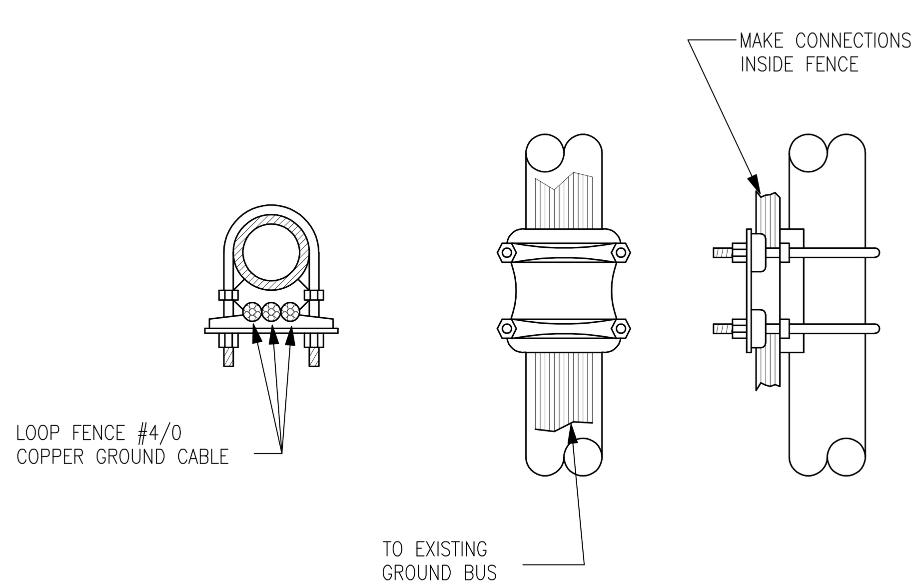
1. – ALL GROUND LOOP CONNECTIONS SHALL BE THERMITE WELD.
2. – TRENCH GRATE SEAT SHALL BE CONTINUOUS AND BONDED TO GROUNDING GRID.
3. – ALL EQUIPMENT SHALL BE BONDED TO GROUNDING GRID.
4. – GROUND TEST WELL FOR TESTING. FURNISH AND INSTALL WELL COVER.



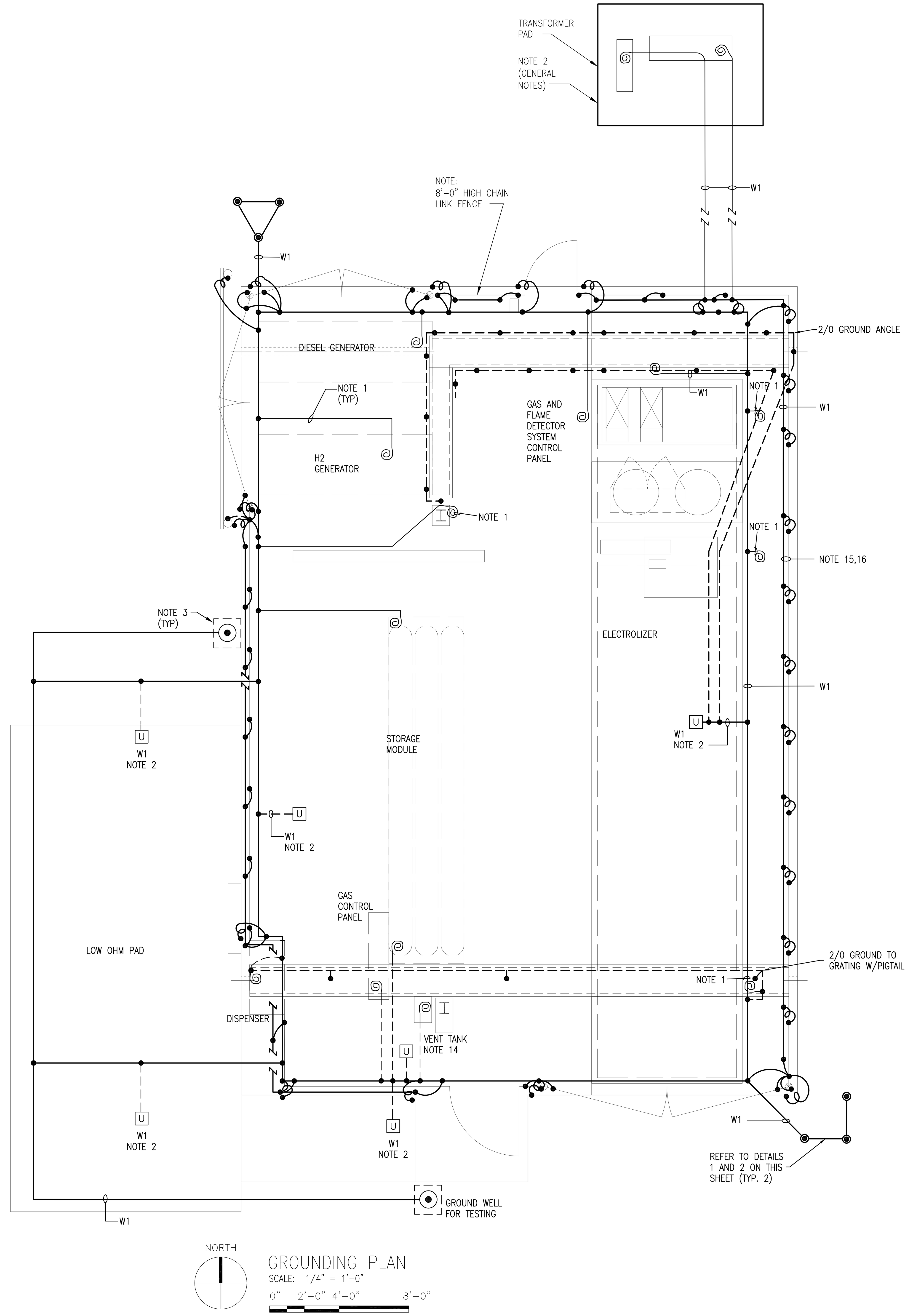
DETAIL #2
CORNER SET GROUNDING ELECTRODES
SCALE = NONE



DETAIL #3
FENCE/GATE POST GROUNDING DETAIL
SCALE = NONE



DETAIL #4
FENCE POST GROUNDING DETAIL
SCALE = NONE



GROUNDING PLAN
SCALE: 1/4" = 1'-0"
0" 2'-0" 4'-0" 8'-0"
1/4" = 1'-0"

SYMBOL LEGEND

- BURIED GROUND CABLE, #4/0 BARE SOFT DRAWN COPPER (BSDC). FOR BURIAL DEPTH 36" MINIMUM FOR MAIN GROUND LOOP AND #2/0 BARE SOFT DRAWN COPPER FOR PIG TAILS.
- #4/0 GROUND ALONG THE FENCE.
- GROUND SPLICE: BELOW GRADE: EXOTHERMIC WELD (CADWELD) OR UL APPROVED COMPRESSION TYPE CONNECTION. ABOVE GRADE: EXOTHERMIC WELD (CADWELD) OR UL APPROVED BOLT TYPE MECHANICAL CONNECTION.
- #2/0 BSDC PIG TAIL FOR FUTURE CONNECTION TO EQUIPMENT. 10' FREE LENGTH ABOVE FINAL GRADE OR TOP OF FINISHED CONCRETE, UNLESS NOTED OTHERWISE.
- GROUND ROD, 3/4" DIA. X 10'-0" LONG, COPPER-CLAD. THE ROD SHALL BE DRIVEN TO A MINIMUM DEPTH OF 10 FEET BELOW GRADE AND CONNECT TO GROUND GRID. IN SANDY OR GRAVELY SOIL DRIVE (2) RODS.
- GROUND TEST WELL.
- U – GROUNDING CONNECTION TO REBAR FOR CONCRETE PAD.
- W1 = #4/0 GROUND BARE COPPER CABLE FOR MAIN GROUND LOOP.
- W2 = #2/0 BARE COPPER IN 1"C RIGID GALVANIZED STEEL CONDUIT FOR EQUIPMENT (PIG TAILS) GROUNDING.
- F – EMERGENCY STOP PULL STATION
- COMBINATION HORN/STROBE FIRE ALARM DEVICE
- STROBE
- X – DETECTOR
  - S – SMOKE DETECTOR (ION OR PHOTO AS SPECIFIED)
  - D – DUCT DETECTOR (ION OR PHOTO AS SPECIFIED)
  - H – HEAT DETECTOR
  - B – BEAM DETECTOR
  - F – FLAME DETECTOR
- 10' PIG TAILS FOR FENCE AND POST GROUNDING ALONG SIDE PAD

GENERAL NOTES

1. ALL WORK SHALL BE PERFORMED ACCORDING TO BASIN ELECTRIC POWER STANDARDS, NATIONAL ELECTRIC CODE AND LOCAL REQUIREMENTS.
2. TRANSFORMER PAD LOCATION IS SHOWN FOR SCHEMATIC PURPOSE ONLY. REFER TO CIVIL SHEET C-100 FOR EXACT LOCATION.

ELECTRICAL GROUNDING NOTES

1. CONTRACTOR TO PROVIDE CONDUIT STUBBED UP FOR GROUNDING PIG TAIL IN 1" CONDUIT. FURNISH AND INSTALL #2/0 PIG TAILS FOR FUTURE CONNECTION TO EQUIPMENT COIL AT LEAST 10'-0" GROUNDING CABLE AT EQUIPMENT END
2. TIE GROUND LOOP TO REBAR USED FOR CONCRETE PAD.
3. GROUND WELL FOR TESTING.
4. GROUNDING SYSTEM MATERIAL INSTALLATION AND TERMINATION LABOR IS THE RESPONSIBILITY OF THE ELECTRICAL CONTRACTOR.
5. GROUNDING CONNECTION: BELOW GRADE: EXOTHERMIC WELD (CADWELD) OR UL APPROVED COMPRESSION TYPE CONNECTION. ABOVE GRADE: EXOTHERMIC WELD (CADWELD) OR UL APPROVED BOLT TYPE MECHANICAL CONNECTION.
6. GROUNDING GRID CONDUCTOR: MINIMUM SIZE #4/0 COPPER. INSTALL THE GROUNDING GRID IN DIRECT CONTACT WITH THE EARTH AT A DEPTH OF NOT LESS THAN 36" BELOW GRADE.
7. FURNISH AND INSTALL GROUNDING FOR POST/BOLLARDS AS SHOWN ON THIS SHEET.
8. CHECK ALL ACCESSIBLE GROUNDING ELECTRODES, USING A GROUND RESISTANCE TESTER. RESISTANCE MUST NOT EXCEED 5 OHMS.
9. GROUND HYDROGEN STORAGE TANKS, TUBES AND VENT STACKS AND OTHER EQUIPMENT AS SUGGESTED BY MANUFACTURER.
10. ALL 10' LONG GROUNDING PIG TAILS PENETRATING CONCRETE SHALL BE COILED AND STACKED, SO AS TO EXIT THE CONCRETE POUR AS NEARLY PERPENDICULAR AS POSSIBLE.
11. FREE LENGTHS OF PIG TAIL PENETRATIONS SHALL BE PROTECTED FROM DAMAGE AND CONTAMINATION BY WET CONCRETE DURING AND AFTER INSTALLATION.
12. GROUND ALL EQUIPMENT USING EXOTHERMIC WELD (CADWELD) CONNECTIONS.
13. COORDINATE WITH EQUIPMENT SUPPLIER FOR EXACT DIMENSIONS.
14. PROVIDE GROUND FOR STORAGE BOTTLES USING THE FLEXIBLE BONDING JUMPERS.
15. FURNISH AND INSTALL #4/0 BARE COPPER GROUND WIRE ALONG THE FULL LENGTH OF FENCE ENCLOSURE AND ATTACH TO FENCE AT 3'-0" INTERVALS. REFER TO GROUND CONNECTION DETAIL FOR FENCE POST AS SHOWN IN DETAIL #3 AND 4.
16. USE BURNDY CONNECTORS OR APPROVED EQUAL TO GROUND FENCE AND FENCE POST.

REV.	DESCRIPTION	DRWN	DSGN	APPD	DATE
0	AS BUILT – BASIN NUMBER AND TITLE BLOCK	L. FROEHLICH	A. BOUSHEE	R. BUSH	5/7/07

REFERENCE DRAWINGS

FACILITY: WIND TO HYDROGEN SYSTEM
LOCATION/UNIT: MINOT, NORTH DAKOTA
CONTRACT/DESIGNATION:

HYDROGEN FUELING SYSTEM
GROUNDING PLAN

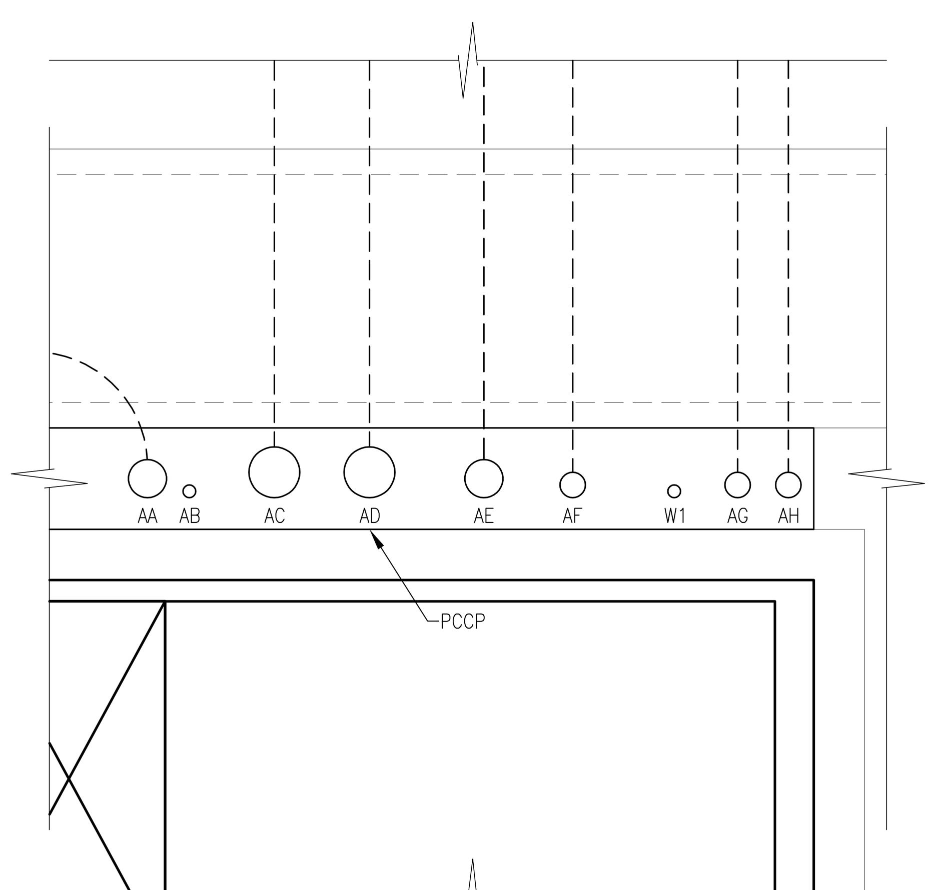
BASIN ELECTRIC POWER COOPERATIVE
1717 EAST INTERSTATE AVENUE
BISMARCK, NORTH DAKOTA 58503-0564
PHONE 701-223-0441

DESIGN BY: ALBERT KAHN ASSOCIATES
DRAWN BY:
DESIGN CHK:
DRAFT CHK:
APPROVED:
SCALE: AS SHOWN
VENDOR/ORIGINATED FROM: ALBERT KAHN ASSOCIATES
VENDOR DRAWING NO.: E-100 | ORIGINAL REV: 0
BASIN DRAWING NO.: 0EG-0001 | REV. NO.: 0

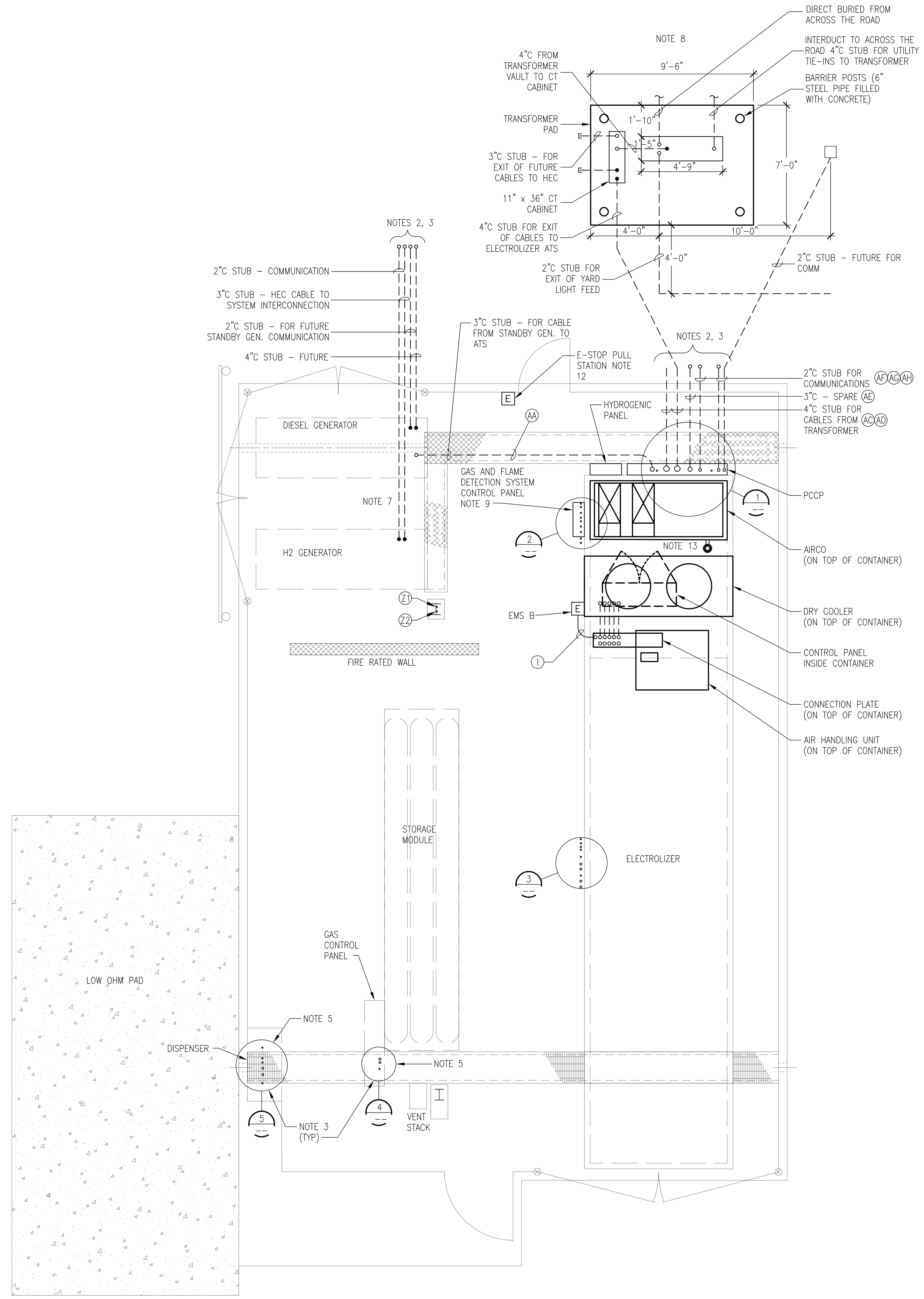
01/27/04

TABLE 1

ID	DESCRIPTION	CONDUIT SIZE AND TYPE	CABLE TYPE
A	24V POWER FROM CSD PANEL	1 1/2" GALV. RMC	W850 (OLFLEX TRAY II CY 3GAWG14)
B	24V POWER FROM CSD PANEL	1 1/2" GALV. RMC	W851 (UNITRONIC 300CY 10GAWG18)
C	120VAC CSD PANEL (2)	1" GALV. RMC	W850 (OLFLEX TRAY II CY 3GAWG14) (2)
D	SPARE FROM CSD PANEL	1" GALV. RMC	(PULL STRING)
E	ETHERNET CABLE	1" GALV. RMC	UTP CABLE (ETHERNET)
F	NOT USED		
G	CONTROL 24V DC FROM CONTROL PANEL	1 1/2" CONDUIT RMC	W860 (UNITRONIC 300CY 10GAWG18)
H	CONTROL ANALOG FROM CONTROL PANEL	1 1/2" CONDUIT RMC	W861 (UNITRONIC 300CY 10GAWG18)
I	EMS-B FROM CONTROL PANEL (2)	1" GALV. RMC	W31 (UNITRONIC 300CY 4GAWG18) (2)
J	AIRCO TO CONTROL PANEL THROUGH CONNECTION PLATE	1 1/2" GALV RMC	W800 (OLFLEX TRAY II CY 4GAWG14
K	AIRCO TO CONTROL PANEL THROUGH CONNECTION PLATE	1 1/2" GALV RMC	W801 (UNITRONIC 300CY 6GAWG18)
L	THERMOSTAT	1 1/2" GALV RMC	W803 (UNITRONIC 300CY 10GAWG18)
M	DRY COOLER (CLC) TO CONTROL PANEL THROUGH CONNECTION PLATE	1 1/2" GALV RMC	W46A (OLFLEX TRAY II CY 4GAWG14)
N	DRY COOLER (CLC) TO CONTROL PANEL THROUGH CONNECTION PLATE	1 1/2" GALV RMC	W46C (OLFLEX TRAY II CY 3GAWG14)
O	DRY COOLER (CLC) TO CONTROL PANEL THROUGH CONNECTION PLATE	1 1/2" GALV RMC	W47A (OLFLEX TRAY II CY 4GAWG14)
P	DRY COOLER (CLC) TO CONTROL PANEL THROUGH CONNECTION PLATE	1 1/2" GALV RMC	W47C (OLFLEX TRAY II CY 3GAWG14)
Q	FAN PROCESS FOR VENTILATION GROUP FROM HVAC UNIT TO CONTROL PANEL	1 1/2" GALV RMC	W160 (OLFLEX TRAY II CY 4GAWG14) (CABLE FURNISHED BY VENDOR)
R	HEATING ELEMENTS FOR VENTILATION GROUP FROM HVAC UNIT TO CONTROL PANEL	1 1/2" GALV RMC	W177 (OLFLEX TRAY II CY 4GAWG6) (CABLE FURNISHED BY VENDOR)
S	HEATING ELEMENTS FOR VENTILATION GROUP FROM HVAC UNIT TO CONTROL PANEL	1 1/2" GALV RMC	W178 (UNITRONIC 300CY 10GAWG18) (CABLE FURNISHED BY VENDOR)
T	FROM HVAC SYSTEM TT TO CONTROL PANEL	1 1/2" GALV RMC	W266 (OLFLEX TRAY II CY 2GAWG14) (CABLE FURNISHED BY VENDOR)
U	FROM HVAC UNIT FOR FLOW AND PRESSURE TO CONTROL PANEL	1 1/2" GALV RMC	W508 (UNITRONIC 300CY 4GAWG18) (CABLE FURNISHED BY VENDOR)
W1	FROM GAS & FLAME DETECTOR CONTROL PANEL TO PCCP GUTTER	1" GALV RMC	
X1	FROM GAS & FLAME DETECTOR CONTROL PANEL TO DESPENSER	1" GALV RMC	
X2	FROM GAS & FLAME DETECTOR CONTROL PANEL TO GAS CONTROL PANEL	1" GALV RMC	
Y1	FROM GAS & FLAME DETECTOR CONTROL PANEL TO RISER	1" GALV RMC	
Y2	FROM GAS & FLAME DETECTOR CONTROL PANEL TO RISER	1" GALV RMC	
Z1	FROM GAS & FLAME DETECTOR CONTROL PANEL TO HORN/STROBE AT I BEAM	1" GALV RMC	
Z2	FROM GAS & FLAME DETECTOR CONTROL PANEL TO HORN/STROBE AT I BEAM	1" GALV RMC	
AA	FROM PCCP GUTTER TO STANDBY GENERATOR	3" GALV RMC	
AB	FROM PCCP GUTTER FOR GROUNDING	1" GALV RMC	
AC	FROM PCCP GUTTER FOR CT/SERVICE NOTES 2 & 3	4" GALV RMC	
AD	FROM PCCP GUTTER SPARE NOTES 2 & 3	4" GALV RMC	
AE	FROM PCCP GUTTER SPARE NOTES 2 & 3	3" GALV RMC	
AF	FROM PCCP GUTTER SPARE NOTES 2 & 3	2" GALV RMC	
AG	FROM PCCP GUTTER FOR COMMUNICATIONS SPARE NOTES 2 & 3	2" GALV RMC	
AH	FROM PCCP GUTTER FOR COMMUNICATIONS PHONE AND DATA	2" GALV RMC	
AJ	FROM GAS & FLAME DETECTOR CONTROL PANEL FOR GROUNDING	1" GALV RMC	



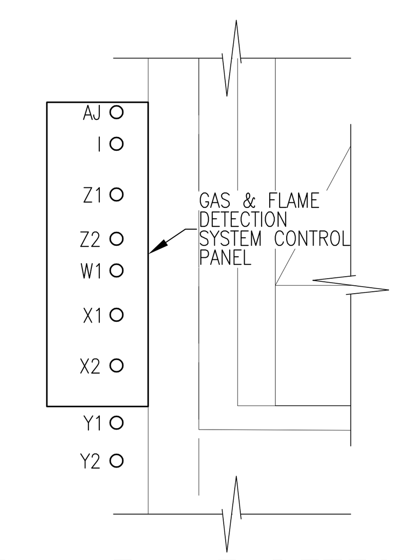
DETAIL 1
1"=1'-0"



POWER PLAN
1/4"=1'-0"

SHEET NOTES

1. CONFORM WITH CODES, REGULATIONS, AND NATIONAL ELECTRICAL CODE (NEC) FOR INSTALLATION OF EQUIPMENT AND DEVICES IN HAZARDOUS LOCATIONS AS INDICATED ON SHEET M-500 AND M-501.
2. CONDUIT STUBS TO BE STUBBED OUT AT LEAST 3' BEYOND THE EDGE OF PAD WITH THE TOP OF THE CONDUIT AT LEAST 36" BELOW GRADE. CAP BOTH ENDS OF CONDUIT TO PREVENT ANY TYPE OF DEBRIS AND DIRT FROM GETTING INSIDE THE CONDUIT STUBS.
3. REFER TO VENDOR (HYDROGENICS) PROVIDED LAYOUT DRAWINGS FOR EXACT LOCATION OF CONDUIT ENTRY AND EXIT LOCATIONS.
4. CONTRACTOR TO FURNISH AND INSTALL CONDUIT BETWEEN AIR HANDLING UNIT, DRY COOLER, AIRCO AND CONTROL PANEL AS MENTIONED IN TABLE 1 ON THIS SHEET. WIRES ARE PROVIDED WITH CONTAINER BY VENDOR AND CONNECTED BY CONTRACTOR.
5. CONTRACTOR TO FURNISH AND INSTALL CONDUIT AND WIRE AS NOTED IN TABLE 1.
6. PROVIDE AND INSTALL ELECTRIC HEAT TRACING FOR RURAL WATER (FEED WATER) LINE, ELECTROLIZER HYDROGEN VENT LINE AND ELECTROLIZER OXYGEN VENT LINE. HEAT TRACING SHALL BE AS SPECIFIED IN SECTION 16121 AND AS LISTED BELOW:
   A. ELECTRIC HEAT TRACE SHALL OPERATE AT 120 VOLTS.
   B. 1-15 AMP AND 2-6 AMP CIRCUIT BREAKERS ARE AVAILABLE IN THE ELECTRICAL CONTROL ROOM. ROUTE ALL CONDUIT TO THESE BREAKERS THROUGH THE CONNECTION PLATE ON THE TOP CONTAINER.
   C. COORDINATE HEAT TRACING ON WATER LINE WITH THE MECHANICAL TRADES.
7. CONTRACTOR TO VERIFY EXACT LOCATION WITH VENDOR PROVIDED DRAWINGS FOR DIESEL AND HYDROGEN GENERATOR.
8. TRANSFORMER PAD LOCATION IS SHOWN FOR SCHEMATIC PURPOSE ONLY. REFER TO CIVIL SHEET C-100 FOR APPROXIMATE LOCATION.
9. FURNISH AND INSTALL 120V POWER SOURCE FOR FLAME DETECTION SYSTEM CONTROL PANEL (FROM CSD PANEL).
10. FURNISH AND INSTALL HORN/STROBE/FLAME DETECTOR ON POST PROVIDED BY ARCHITECTURAL DIVISION. REFER TO ARCHITECTURAL PLANS FOR EXACT LOCATION OF POST.
11. FURNISH WIRING AND CONDUIT FOR GAS DETECTION IN THE CONTROL ROOM OR WATER ROOMS BY SENSORS PROVIDED WITH FLAME DETECTION SYSTEM. A CONTACT CLOSURE FROM THE FLAME DETECTION PANEL WILL SHUTDOWN THE ELECTROLYZER.
12. CONTRACTOR TO FURNISH AND INSTALL EMERGENCY STOP (E-STOP) BUTTON. E-STOP BUTTON WILL CAUSE THE FLAME DETECTION PANEL TO SHUTDOWN THE ELECTROLYZER AND DISPENSER FUNCTIONS.
13. CONTRACTOR TO FIELD LOCATE 120V, 20A, WP, GFI RECEPTACLE. TIE THIS RECEPTACLE INTO THE RECEPTACLE LOCATED IN THE ELECTRICAL CONTROL ROOM ADJACENT TO DOOR. CONTRACTOR TO FIELD LOCATE ALL ASSOCIATED WIRING AND CONDUIT.



GAS & FLAME DETECTION PANEL DETAIL 2
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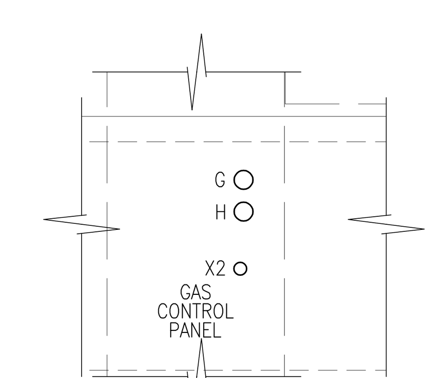
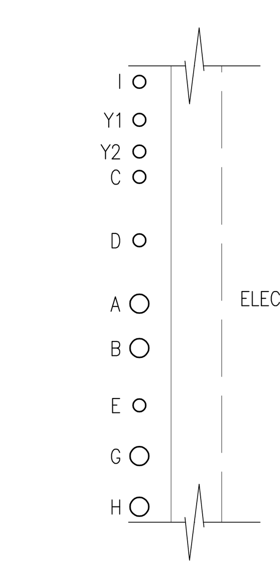


DETAIL 4
1"=1'-0"



RISER DETAIL 3
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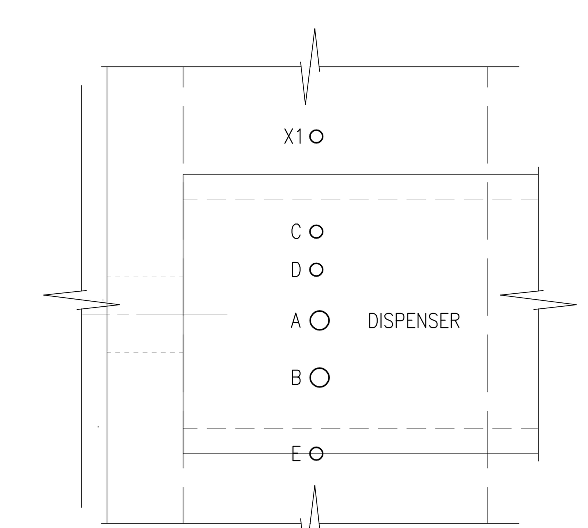

DETAIL 5
1"=1'-0"

REV.	DESCRIPTION	DRWN	DSGN	APPD	DATE
0	AS BUILT - BASIN NUMBER AND TITLE BLOCK	L. FROEHLICH	A. BOUSHEE	R. BUSH	5/7/07

REFERENCE DRAWINGS

FACILITY: WIND TO HYDROGEN SYSTEM
LOCATION/UNIT: MINOT, NORTH DAKOTA
CONTRACT/DESIGNATION:

POWER PLAN

BASIN ELECTRIC POWER COOPERATIVE
1717 EAST INTERSTATE AVENUE
BISMARCK, NORTH DAKOTA 58503-0564
PHONE 701-223-0441

DESIGN BY: ALBERT KAHN ASSOCIATES
DRAWN BY:
DESIGN CHK:
DRAFT CHK:
APPROVED:
SCALE: AS SHOWN
VENDOR/ORIGINATED FROM: ALBERT KAHN ASSOCIATES
VENDOR DRAWING NO.: E-101 — ORIGINAL REV: 5
BASIN DRAWING NO.: 0EA-0001 — REV. NO.: 0

01/27/04

BASIN ELECTRIC
POWER COOPERATIVE

HYDROGEN REFUELING STATION EQUIPMENT

WIND TO HYDROGEN STATION
NORTH DAKOTA RESEARCH CENTER

MINOT, ND

DRAWING INDEX

SHT.NO.	SHEET TITLE
00	COVER/INDEX
01	RISER DIAGRAM
02	FLAME DETECTION COVERAGE AREA
03	DISPENSER AREA DEVICE MOUNTING
04	ELECTRICAL LADDER
05	INSTRUMENTATION WIRING
06	LIGHT–HORN ASSEMBLY
07	ENCLOSURE LAYOUT
08	UPS ENCLOSURE
09	UPS ELECTRICAL LADDER

CORITECH SERVICES

CORITECH JOB# 6033

4716 DELEMERE BLVD
ROYAL OAK, MI 48073
(248-549-3300)
WWW.CORITECH.COM

FOR
CONSTRUCTION
8-17-07

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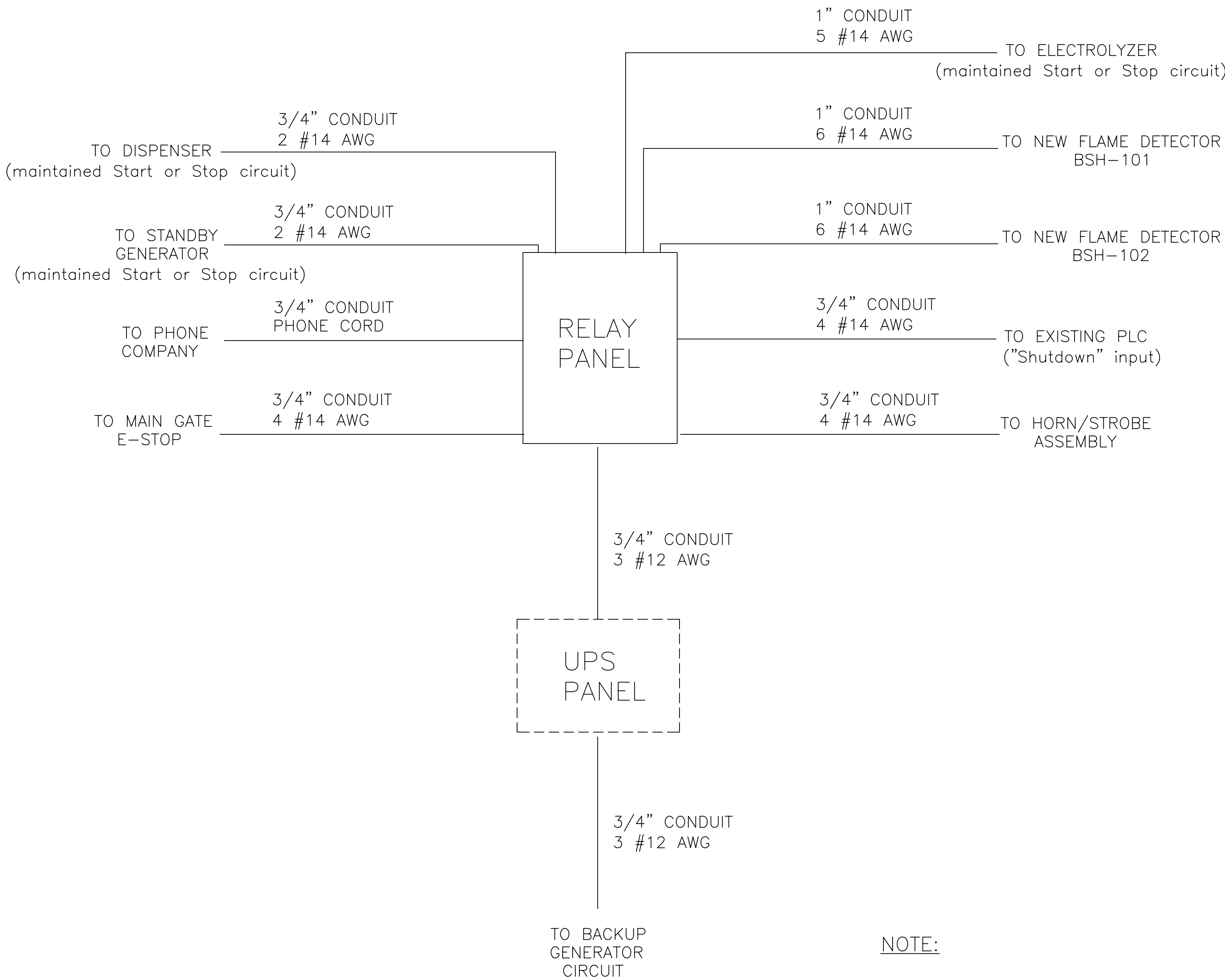
BASIN ELECTRIC—WIND TO HYDROGEN STATION

RISER DIAGRAM



NOTE:

ALL CONDUIT RUNS REQUIRE SEALED FITTINGS AT BOTH ENDS. RELAY PANEL AND FLAME DETECTORS TO BE MOUNTED IN UNCLASSIFIED AREA.

SEALED FITTING POURED FOLLOWING COMMISSIONING.

Trouble

A marshaled trouble signal from the electrolyzer panel (Hydrogenics) or any individual flame detector trouble signal will activate a "Trouble" alert. The relay panel indicating lamp will illuminate and the auto dialer will call out with a trouble call. Basin Electric Power Cooperative and all maintenance entities identified in the call out protocol will be notified via the auto dialer.

Fire Detection

Detection of a hydrogen flame will activate the Fire Alert signal. The relay panel "Fire" indicating lamp will illuminate, the fire strobe will flash, the horn will annunciate, the auto dialer will call out with a Fire Alert. Relay panel output contacts dedicated to shutdown the Electrolyzer system, the Dispenser, and the Standby Generator, will open the individual control circuits. There is at least one spare shutdown contact available for future use. The horn can be reset during alarming, but the strobe will remain on until the alarm has been cleared. Basin Electric Power Cooperative, 911, and all maintenance entities identified in the call out protocol will be notified via the auto dialer.

E-Stop

Depressing the E-Stop button will perform all the functions mentioned in the Fire Detection description above, but only Basin Electric Power Cooperative and all maintenance entities identified in the call out protocol will be notified via the auto dialer. "911" is not called for E-Stop notification.

BASIN ELECTRIC
POWER COOPERATIVE
1717 E.INTERSTATE AVE.
BISMARCK, ND
58503

SEAL/APPROVAL STAMP

FOR
CONSTRUCTION

DATE/REV	DESCRIPTION
07/18/07	FOR REVIEW/APPROVAL
REV. 0	
08/17/07	FOR CONSTRUCTION
REV. 1	

CORITECH SERVICES
4716 DELEMERE BLVD
ROYAL OAK, MI 48073
(248-549-3300)
WWW.CORITECH.COM

PROJECT
WIND TO HYDROGEN STATION AT
ND RESEARCH EXTENSION CENTER
MINOT, ND

DRAWN BY: WD	DATE: 07/18/07
APPROVED BY: JTS	DATE: 07/18/07

ACAD FILE NAME: 6033-R1.dwg

DRAWING TITLE
FLAME DETECTION
ADDITIONS
RISER DIAGRAM

JOB NUMBER	SHEET	SHEETS
6033	1 OF	9

DRAWING NUMBER:	REVISION
6033-001	1

8/16/2007 3:04 PM

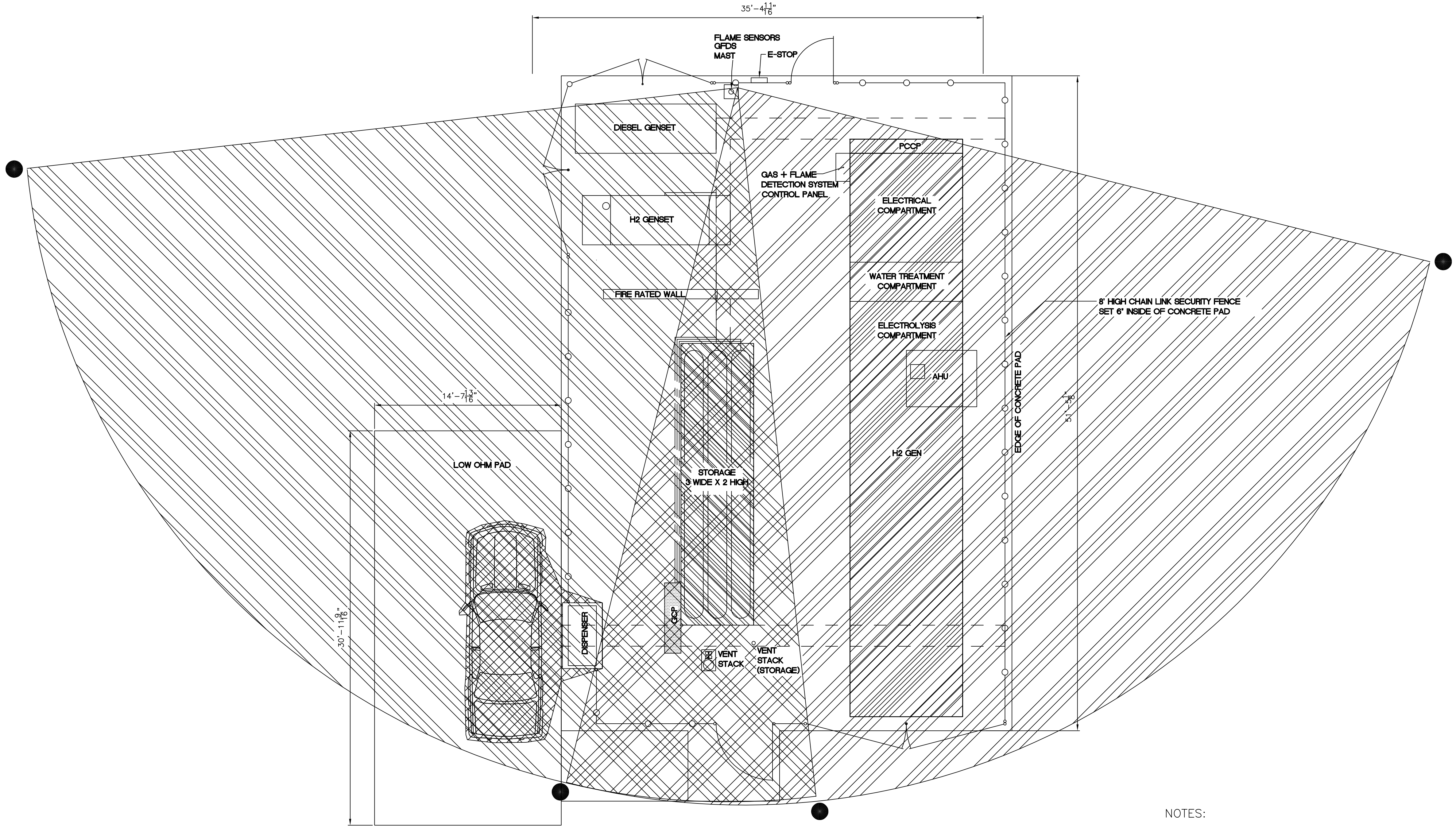
BASIN ELECTRIC–WIND TO HYDROGEN STATION

FLAME DETECTION COVERAGE AREA

FLAME DETECTOR COVERAGE

COVERAGE AREA FLAME DETECTOR

AIMING LOCATIONS



NOTES:

1) FLAME DETECTOR AIMED DOWNWARDS NO LESS THAN 10 DEGREES
2) MOUNT DETECTORS NEAR TOP OF MAST
3) FINAL AIMING OF DETECTORS DURING COMMISSIONING
4) STROBE NOT TO BE MOUNTED IN DIRECT PATH OR PROXIMITY OF FLAME DETECTORS, NO LESS THAN 3' FROM DETECTOR.
5) COMMISSIONING ENGINEER MAY REVISE DETECTOR LOCATIONS FOR FALSE ALARM PREVENTION OR OPTIMUM COVERAGE

BASIN ELECTRIC POWER COOPERATIVE

1717 E.INTERSTATE AVE.
BISMARCK, ND
58503

SEAL/APPROVAL STAMP

FOR
CONSTRUCTION

DATE/REV	DESCRIPTION
07/18/07	FOR REVIEW/APPROVAL
REV. 0	
08/17/07	FOR CONSTRUCTION
REV. 1	

CORITECH SERVICES
4716 DELEMERE BLVD
ROYAL OAK, MI 48073
(248–549–3300)
WWW.CORITECH.COM

PROJECT
WIND TO HYDROGEN STATION AT
ND RESEARCH EXTENSION CENTER
MINOT, ND

DRAWN BY: WD	DATE: 07/18/07
APPROVED BY: JTS	DATE: 07/18/07

ACAD FILE NAME: 6033–R1.dwg

DRAWING TITLE
FLAME DETECTION
ADDITIONS
FLAME DETECTION COVERAGE AREA

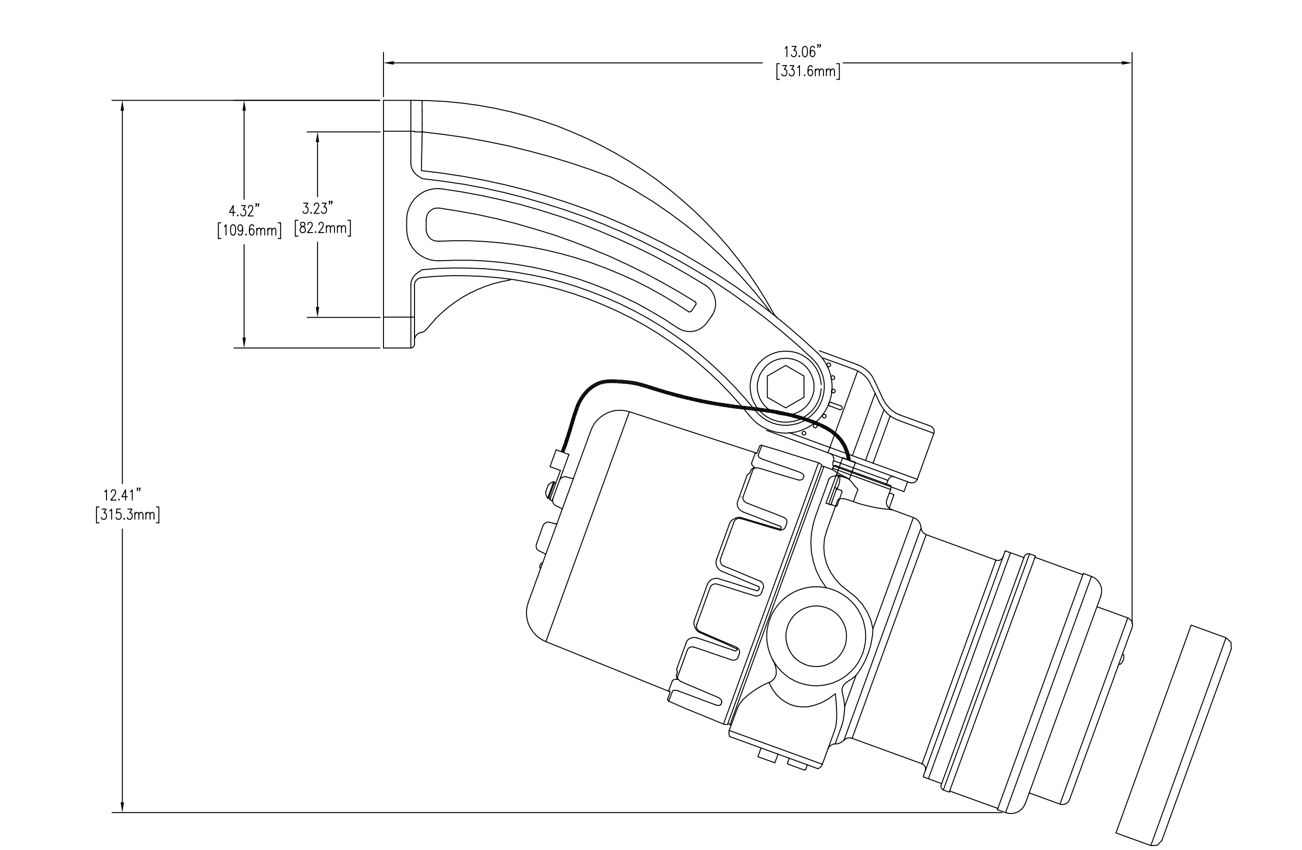
JOB NUMBER	SHEET	SHEETS
6033	2 OF	9

DRAWING NUMBER:	REVISION
6033–002	1

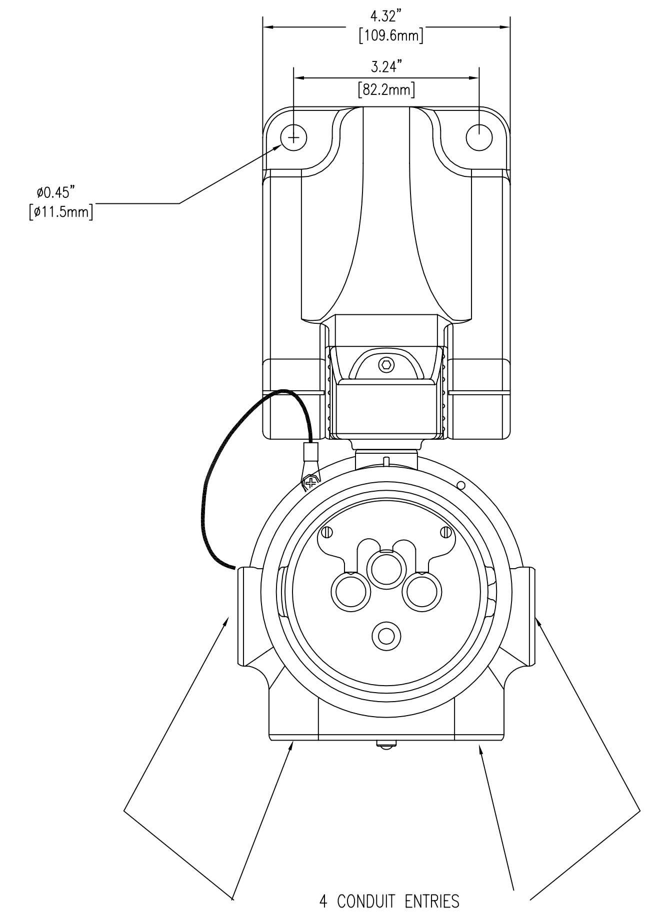
8/16/2007 3:04 PM

BASIN ELECTRIC—WIND TO HYDROGEN STATION

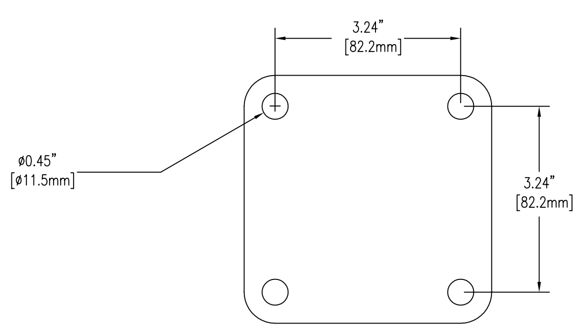
FLAME DETECTOR MOUNTING



REMOVE PROTECTIVE CAP AFTER FINAL INSTALLATION



4 CONDUIT ENTRIES
PLUGS REQUIRED FOR THE UNUSED ENTRIES



Q9033B10002 SWIVEL MOUNTING BRACKET BASE
INSTALLATION DETAIL, DIMS IN INCHES (MILLIMETERS)

FLAME DETECTOR MOUNTING TO MAST

BASIN ELECTRIC
POWER COOPERATIVE
1717 E.INTERSTATE AVE.
BISMARCK, ND
58503

SEAL/APPROVAL STAMP

FOR
CONSTRUCTION

DATE/REV	DESCRIPTION
07/18/07	FOR REVIEW/APPROVAL
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08/17/07	FOR CONSTRUCTION
REV. 1	

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DRAWING TITLE
FLAME DETECTION
ADDITIONS
FLAME DETECTOR MOUNTING

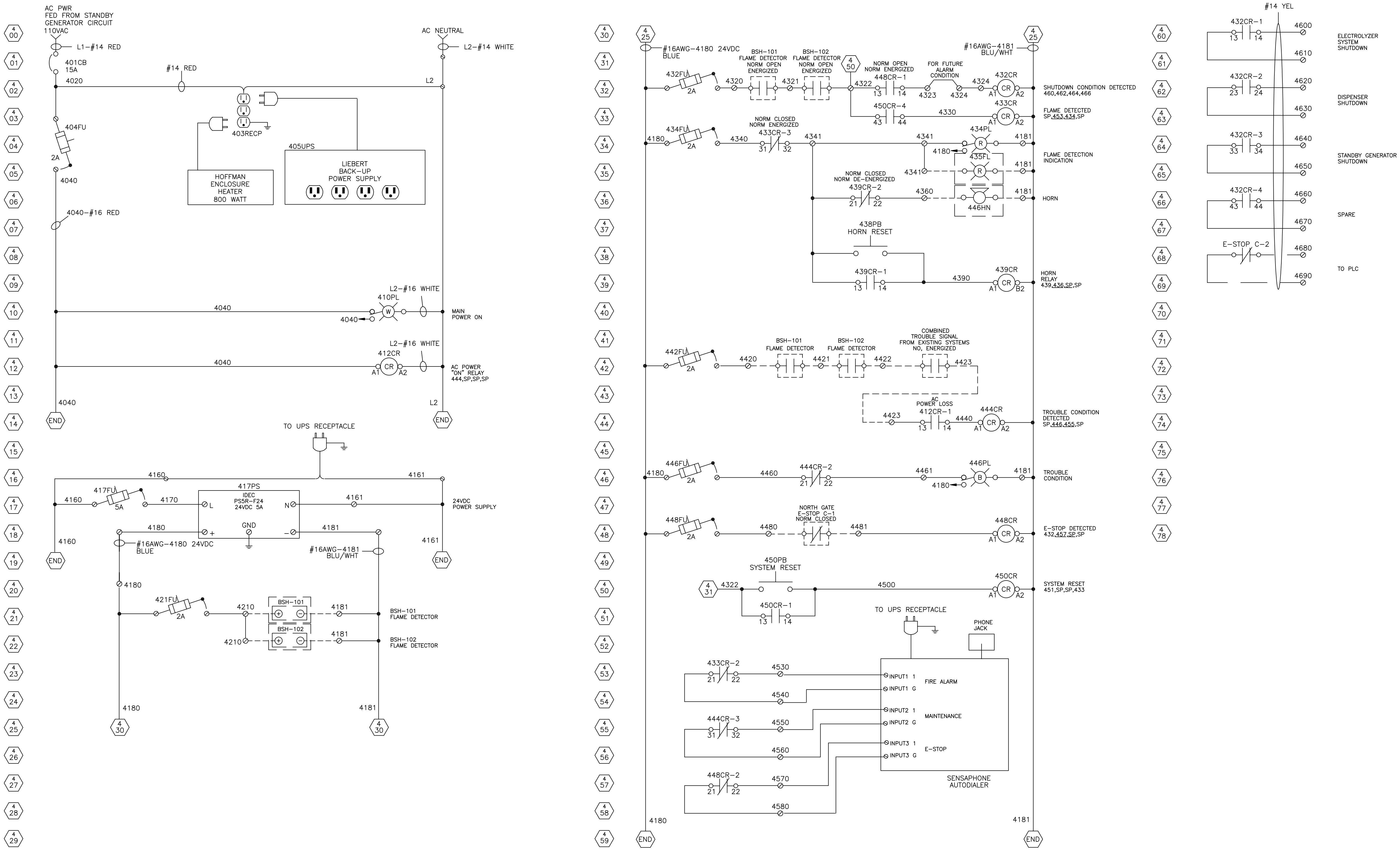
JOB NUMBER	SHEET	SHEETS
6033	3 OF	9

DRAWING NUMBER:	REVISION
6033-003	1

8/16/2007 3:04 PM

BASIN ELECTRIC–WIND TO HYDROGEN STATION

ELECTRICAL LADDER



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DRAWING TITLE
FLAME DETECTION
ADDITIONS
ELECTRICAL LADDER

JOB NUMBER	SHEET	SHEETS
6033	4 OF	9

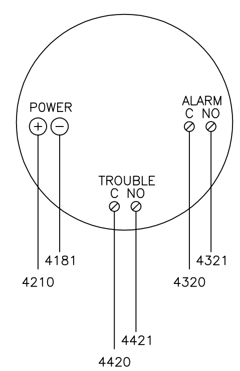
DRAWING NUMBER:	REVISION
6033–004	1

8/16/2007 3:04 PM

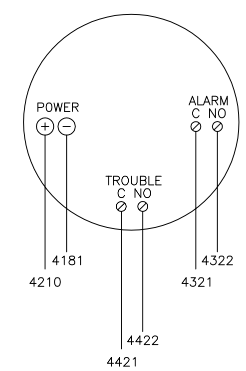
BASIN ELECTRIC—WIND TO HYDROGEN STATION

INSTRUMENTATION WIRING

BSH-101
FLAME DETECTOR
WIRING



BSH-102
FLAME DETECTOR
WIRING



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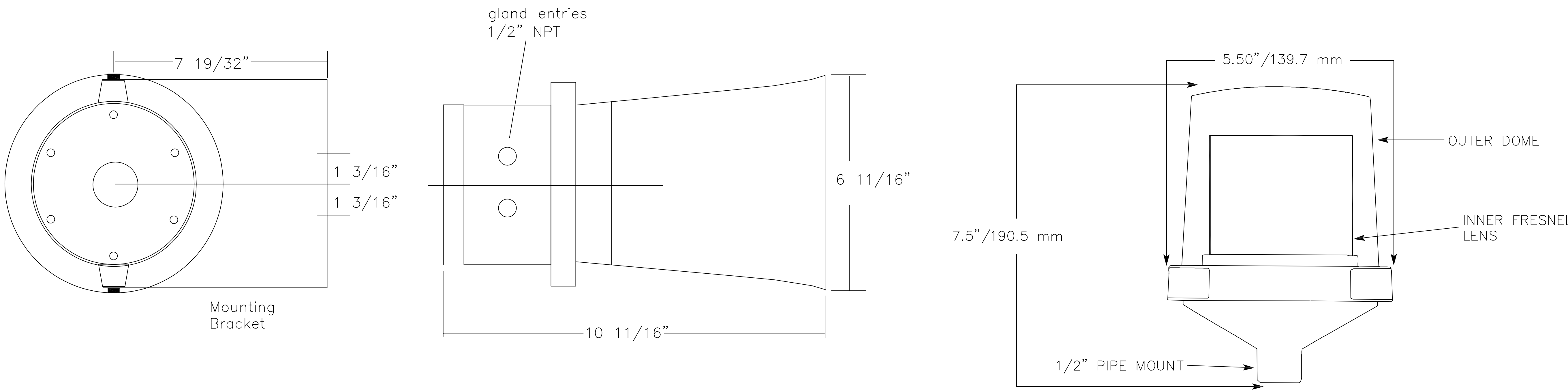
DRAWING TITLE
FLAME DETECTION
ADDITIONS
INSTRUMENTATION WIRING

JOB NUMBER 6033 — SHEET 5 OF SHEETS 9
DRAWING NUMBER: 6033-005 — REVISION 1

8/16/2007 3:04 PM

BASIN ELECTRIC–WIND TO HYDROGEN STATION

LIGHT–HORN ASSEMBLY



NOT TO SCALE

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POWER COOPERATIVE
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REV. 1	

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MINOT, ND

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DRAWING TITLE
FLAME DETECTION
ADDITIONS
LIGHT–HORN ASSEMBLY

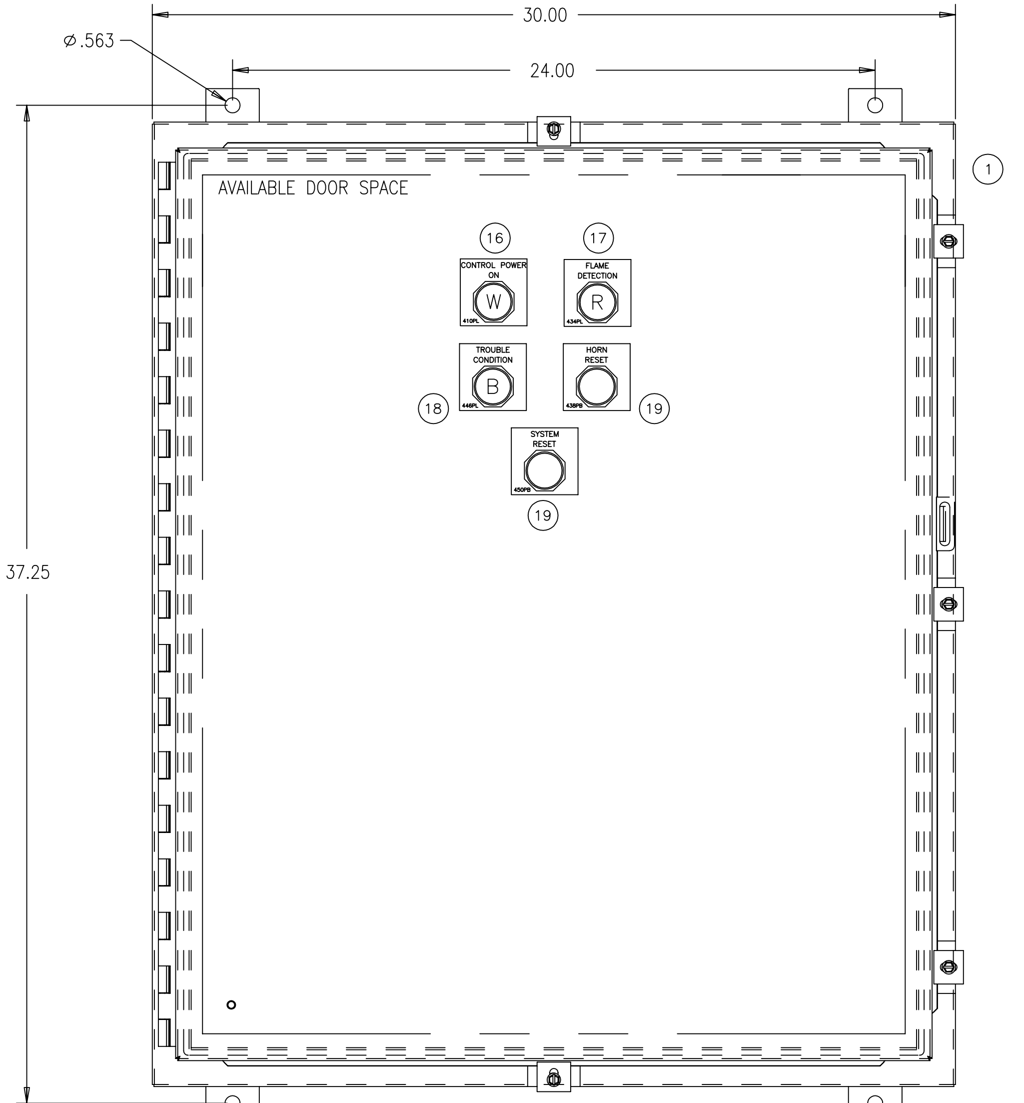
JOB NUMBER	SHEET	SHEETS
6033	6 OF	9

DRAWING NUMBER:	REVISION
6033–006	1

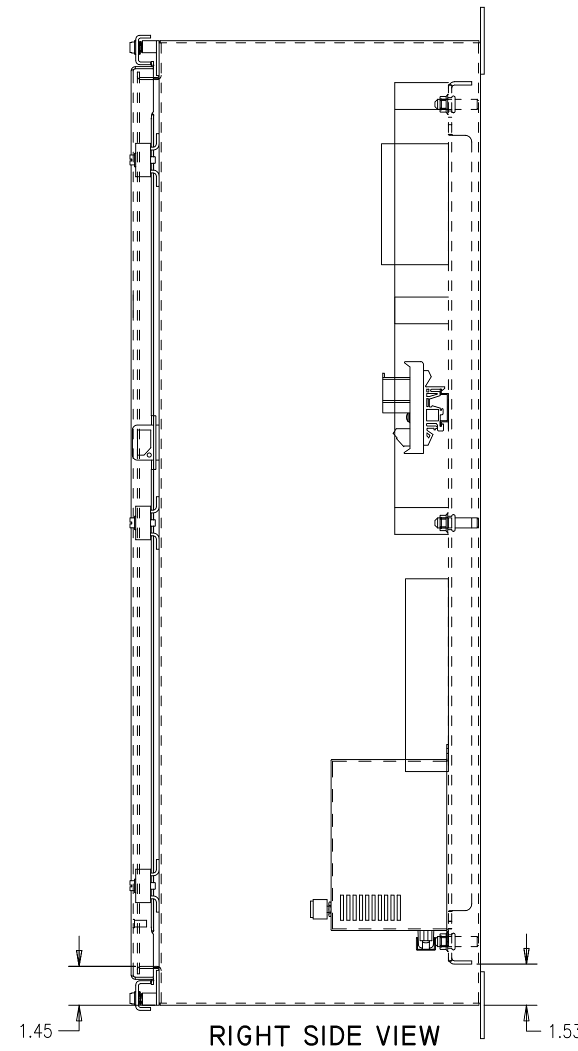
8/16/2007 3:04 PM

BASIN ELECTRIC–WIND TO HYDROGEN STATION

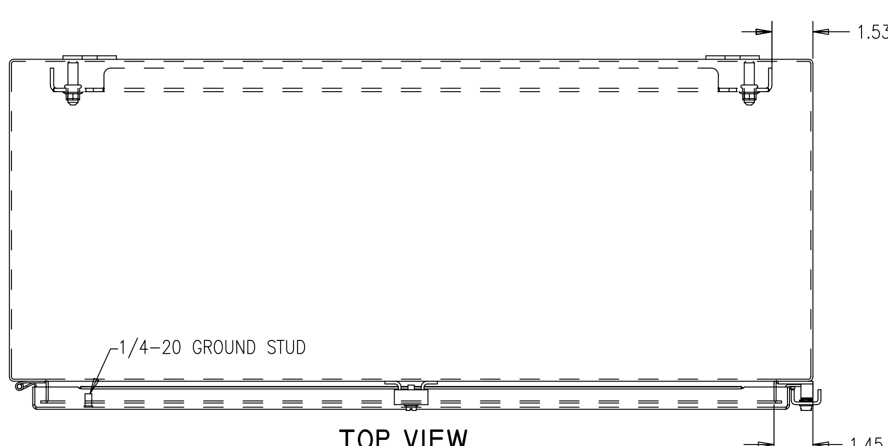
ENCLOSURE LAYOUT



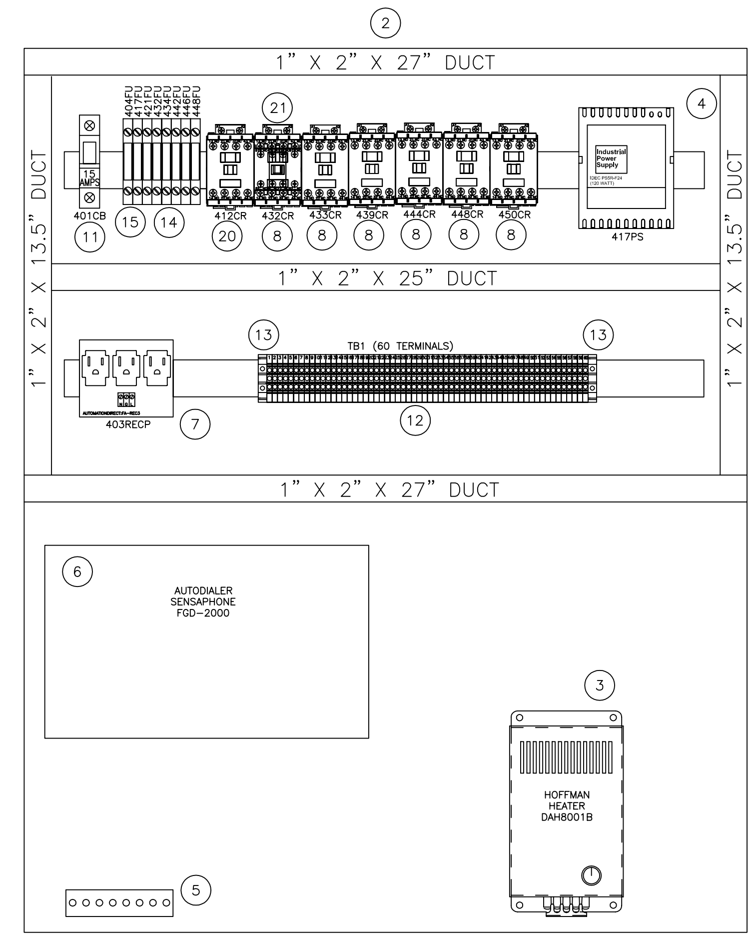
FRONT VIEW



RIGHT SIDE VIEW



TOP VIEW



TB1

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BILL OF MATERIALS

ITEM	QTY	DESCRIPTION	MFG	PART #
1	1	ENCLOSURE 36"H X 30"W X 12"D	SCE	SCE–36H30DLP
2	1	SUB–PANEL 33"H X 27"W	SCE	SCE–36P30
3	1	HEATER	HOFFMAN	DAH8001B
4	1	24VDC POWER SUPPLY	IDEC	PS5R–F24
5	1	GROUND BAR	CORITECH	CUSTOM
6	1	AUTODIALER	SENSAPHONE	FGD–2000
7	1	RECEPTACLE	AUTOMATION DIRECT	FA–REC3
8	5	24VDC RELAY	ALLEN–BRADLEY	700–CF220J
9	–	3A FUSE	FUSETRON	FNA–3
10	–	1 POLE FUSE BLOCK	ALLEN–BRADLEY	1492–CE6
11	1	15A CIRCUIT BREAKER		
12	60	TERMINALS	ALLEN–BRADLEY	1492–W4
13	2	TERMINAL END ANCHOR	ALLEN–BRADLEY	1492–EA35
14	6	SINGLE CIRCUIT FUSE BLOCK	ALLEN–BRADLEY	1492–H4
15	1	SINGLE CIRCUIT FUSE BLOCK	ALLEN–BRADLEY	1492–H5
16	1	PUSH TO TEST PILOT LIGHT	ALLEN BRADLEY	800T–QT10W
17	1	PUSH TO TEST PILOT LIGHT	ALLEN BRADLEY	800T–QT24R
18	1	PUSH TO TEST PILOT LIGHT	ALLEN BRADLEY	800T–QT124B
19	2	PUSHBUTTON	ALLEN BRADLEY	800T–A6D1
20	1	CONTROL RELAY	ALLEN BRADLEY	700–CF220D
21	1	AUXILIARY CONTACT BLOCK, 4NC	ALLEN BRADLEY	100–FA04
22	1	24VDC RELAY	ALLEN BRADLEY	700–CF400E

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DRAWING TITLE
FLAME DETECTION
ADDITIONS
ENCLOSURE LAYOUT

JOB NUMBER	SHEET	SHEETS
6033	7 OF	9

DRAWING NUMBER:	REVISION
6033–007	1

8/16/2007 3:04 PM

FMEA

(Failure Modes and Effects Analysis)
for
Basin Electric Power Cooperative
Wind to Hydrogen
Vehicle Fueling Station
Minot, North Dakota

July 2006
Rev : 0

Kahn

BASIN ELECTRIC
POWER COOPERATIVE

DMA

FMEA Rating Scale Guide

Severity Rating Scale

Rating	*Description*	*Definition*
10	Dangerously high	Failure could injure the customer or an employee
9	Extremely high	Failure would create noncompliance with federal / state / municipal regulations
8	Very high	Failure renders the unit inoperable or unfit for use
7	High	Failure causes a high degree of customer dissatisfaction
6	Moderate	Failure results in a subsystem or partial malfunction of the product
5	Low	Failure creates enough of a performance loss to cause the customer to complain
4	Very low	Failure can be overcome with modification to the customer's process or product, but there is minor performance loss
3	Minor	Failure would create a minor nuisance to the customer, but the customer can overcome it without performance loss.
2	Very minor	Failure may not be readily apparent to the customer, but would have minor effects on the customer.
1	None	Failure would not be noticeable to the customer and would not affect the customer's process or product.

Occurrence Rating Scale

Rating	*Description*	*Potential Failure Rate*
10	Very high: Failure is almost	More than one occurence per day for installed system (Cpk<0.33)
9	inevitable	One occurrence every three to four days for installed systems (Cpk≈0.33)
8	High: Repeated failure	One occurrence per week in installed systems (Cpk≈0.67)
7		One occurrence every month or one occurrence in 100 events (Cpk≈0.83)
6	Moderate: Occasional failure	One occurrence every three months or three occurences in 1,000 events (Cpk≈1/00)
5		One occurrence every six months to one year or one occurrence in 10,000 events (Cpk≈.1.17)
4		One occurrence per year or six occurences in 100,000 events (Cpk≈1.33).
3	Low: Relatively few failures	One occurrence every one to three years or six occurrences in ten million events (Cpk≈1.67).
2		One occurrence every three to five years or 2 occurences in one billion events (Cpk≈2.00).
1	Remote: Failure is unlikely	One occurrence in greater than five years or less than two occurences in one billion events (Cpk>2.00).

FMEA Rating Scale Guide

Detection / Prevention / Control Rating Scale

Rating	*Description*	*Definition*
10	Significant Uncertainty of Hydrogen Station Status	Third Party Notification of Event (Security Personnel / Employee / General Public)
9	Uncertainty of Hydrogen	Manual Inspection with Test Equipment conducted by a Qualified Technician
8	Station Status	Notification by an Hydrogen Station user (Vehicle Operator)
7		Manual Inspection without Test Equipment conducted by a Qualified Technician
6	Likely Awareness	Interpretation of Sensor data at Power / Control / Communication Panel or Data Acquisition Computer
5	of Hydrogen Station Status	Sensor input generates an Hydrogen Station alarm
4	System Response with Likely Awareness	Closed loop control c/w indirect monitoring via Hydrogen Station sensors (mechanical relief valve and pressure sensors)
3	of Hydrogen Station Status	Closed loop control c/w indirect monitoring via Hydrogen Station sensors and Hydrogen Station alarm (mechanical relief valve and pressure sensors that generate a low pressure alarm if valve doesn't re-seat)
2	System Response	Single sensor and / or actuator with direct closed loop control and associated Hydrogen Station alarm
1	with Awareness of Hydrogen Station Status	Redundant sensors and / or actuators with direct closed loop control and associated Hydrogen Station alarm

Rationale for Detection / Prevention / Control Rating Scale

1. All equipment and material is of high quality, compatible with usage in a hydrogen system.
2. All manufacture and field installations will be conducted by certified technicians skilled in working with high-pressure piping and associate electrical and control systems.
3. The Hydrogen Station is designed to safely handle the remedial impact of the events addressed in this FMEA.
4 At start -up, the Hydrogen Station will undergo a rigorous Pneumatic Pressure Test in accordance NFPA 52 and/or ASME B31.3 or the local equivalent.
5. The Hydrogen Station will be maintained according to the prescribed Preventive and Predictive Maintenance Schedule as defined by the Vendor.
6. For maintenance, the section of the Hydrogen Station taken out of service will be subjected to a leak test at working pressure with a suitable leak- detection solution and / or electronic leak-detection instruments when being returned to service.
7. Given the above assumptions, the Detection / Prevention / Control Rating Scale is developed from the perspective of how well the Hydrogen Station detects, prevents, controls, and notifies the Station Operator that an event has occurred. Therefore, redundant sensors or actuators with direct closed loop control and associated Hydrogen Station alarm is a much preferred response than the Station Operator finding out from a Third Party that an event has occurred at the Hydrogen Station.

Scope of Analysis:

The Station FMEA is limited to an analysis of the integrated system and the components used to integrate the primary equipment. It is assumed that the manufacturers of the primary equipment (e.g. the fuel generator, storage module, dispenser, gas and flame detection, etc) have conducted an FMEA for their products and that the products will fail safe. It is further assumed that the product FMEA is available to the Owner of the station upon request.

Item	A) Device Quantity	Part Description	Part Function	Potential Failure Mode	Effect of Failure	B) Severity	Potential Causes of Failure	C) Occurrence	Current Detection / Prevention / Controls	D) Detection / Prevention / Control	Actual Risk Priority Number (AxBxCxD)	Maximum Potential Risk Priority Number (Ax1000)	Recommended Action	Person Responsible - Action Date	Action Results: Actions Taken	SOV	OCC	DET	R.P.N.
1.1	1	generator, fuel	generation of hydrogen by the electrolysis of water process	loss of electric power	*unit cannot generate hydrogen *h20 wetted componenets are vulnerable to freeze damage	8	* loss of electric power from the grid * failure of standby electric generator to start	5	* preventative maintenance of genset * system exercised regularly * system Master Control Panel is able to communicate fault conditions to Owner's central dispatch	5	200	1000							
	1	generator, fuel	generation of hydrogen by the electrolysis of water process	fail safe shutdown by the supervisory control system	*unit cannot generate hydrogen	6	* wear and tear	6	* thoroughly tested during installation * preventative maintenance * installed by a certified installer * system Master Control Panel is able to communicate fault conditions to Owner's central dispatch	5	180	1000							
1.2	1	NO ball valve	isolates flow of hydrogen from the fuel generator to the balance of the plant	leak at packing	* high pressure hydrogen release to outdoors	2	* wear and tear * improper manufacture	1	* thoroughly tested during installation * preventative maintenance * infrequent use * limited h2 flow rate	9	18	1000							
	1	NO ball valve	isolates flow of hydrogen from the fuel generator to the balance of the plant	leak at compression fitting	* high pressure hydrogen release to outdoors	2	* wear and tear * improper assembly	1	* thoroughly tested during installation * preventative maintenance * infrequent use * limited h2 flow rate	9	18	1000							
1.3	1	NC needle valve c/w end plug	vent, injection and sample port in fuel line	leak at packing	high pressure hydrogen release to outdoors	2	* wear and tear * improper manufacture	1	* thoroughly tested during installation * preventative maintenance * infrequent use * limited h2 flow rate * installed by a certified installer	9	18	1000							
	1	NC needle valve c/w end plug	vent, injection and sample port in fuel line	leak at compression fitting	* high pressure hydrogen release to outdoors	2	* wear and tear	1	* thoroughly tested during installation * preventative maintenance * installed by a certified installer * infrequent use * limited h2 flow rate	9	18	1000							
1.4	1	3/8 in, 316 ss seamless tube c/w fittings	delivers h2 at 6000 psig from the fuel generator to the gas control panel	crack, break or loose fitting causing a minor leak	* high pressure hydrogen release to outdoors	2	* vibration, fatigue, fitting leak or failure, earthquake, collision	1	* thoroughly tested during installation * preventative maintenance * installed by a certified installer * limited h2 flow rate	9	18	1000							
	1	3/8 in, 316 ss seamless tube c/w fittings	delivers h2 at 6000 psig from the fuel generator to the gas control panel	crack, break or loose fitting causing a major leak	* high pressure hydrogen release to outdoors	8	* vibration, fatigue, fitting leak or failure, earthquake, collision	1	* thoroughly tested during installation * preventative maintenance * installed by a certified installer * limited h2 flow rate	8	64	1000							
	1	3/8 in, 316 ss seamless tube c/w fittings	delivers h2 at 6000 psig from the fuel generator to the gas control panel	crack, break or loose fitting causing auto-ignition fire	* h2 fire inside the station	10	* vibration, fatigue, fitting leak or failure, earthquake, collision	1	* thoroughly tested during installation * preventative maintenance * installed by a certified installer * limited h2 flow rate * limited h2 inventory * flame detection system shuts down all systems if a flame is detected * flame detection system calls out to fire department	2	20	1000							
1.5	1	NO ball valve	isolates flow of hydrogen from the fuel generator at the gas control panel	leak at packing	* high pressure hydrogen release to outdoors	2	*wear and tear *improper assembly	1	* thoroughly tested during installation * preventative maintenance * infrequent use * limited h2 flow rate	9	18	1000							
	1	NO ball valve	isolates flow of hydrogen from the fuel generator at the gas control panel	leak at compression fitting	* high pressure hydrogen release to outdoors	2	* wear and tear * improper assembly	1	* thoroughly tested during installation * preventative maintenance * installed by a certified installer * infrequent use * limited h2 flow rate	9	18	1000							
1.6	3	NO ball valve	shuts off instrument air for maintenance	leak at packing	* low pressure air leak	2	*wear and tear *improper manufacture	1	* thoroughly tested during installation * preventative maintenance * infrequent use * limited air flow rate	9	54	3000							
	3	NO ball valve	shuts off instrument air for maintenance	leak at compression fitting	* low pressure air leak	2	*wear and tear *improper assembly	1	* thoroughly tested during installation * preventative maintenance * installed by a certified installer * infrequent use * limited air flow rate	9	54	3000							

Item	A) Device Quantity	Part Description	Part Function	Potential Failure Mode	Effect of Failure	B) Severity	Potential Causes of Failure	C) Occurrence	Current Detection / Prevention / Controls	D) Detection / Prevention / Control	Actual Risk Priority Number (AxBxCxD)	Maximum Potential Risk Priority Number (Ax1000)	Recommended Action	Person Responsible - Action Date	Action Results				
															Actions Taken	SOV	OCC	DET	R.P.N.
1.7	2	pipe, air	delivers instrument air from the fuel generator to other devices	crack, break or loose fitting causing a minor leak	* low pressure air leak	2	* vibration, fatigue, fitting leak or failure, earthquake, collision	1	* thoroughly tested during installation * preventative maintenance * installed by a certified installer * limited air flow rate	9	36	2000							
	2	pipe, air	delivers instrument air from the fuel generator to other devices	crack, break or loose fitting causing a major leak	* low pressure air leak	6	* vibration, fatigue, fitting leak or failure, earthquake, collision	1	* thoroughly tested during installation * preventative maintenance * installed by a certified installer * limited air flow rate	7	84	2000							
1.8		not used									0	0							
1.9	1	cylinder, nitrogen	supply of inert gas for fuel generator operations	no nitrogen in the cylinder	* unit cannot generate hydrogen	6	* operator error	3	* preventative maintenance * infrequent use	7	126	1000							
	1	cylinder, nitrogen	supply of inert gas for fuel generator operations	no nitrogen in the cylinder	* unit cannot generate hydrogen	6	* leak in gas train	2	* thoroughly tested during installation * preventative maintenance * installed by a certified installer * infrequent use	9	108	1000							
1.10	1	valve, pressure control	regulates the pressure of the n2 supply to the fuel generator	fails open	* allows n2 above set pressure to flow to the fuel generator	8	* failure of valve	1	* robust equipment designed exclusively for this purpose * preventative maintenance * system Master Control Panel is able to communicate fault conditions to Owner's central dispatch	6	48	1000							
	1	valve, pressure control	regulates the pressure of the n2 supply to the fuel generator	fails closed	* unit cannot generate hydrogen	6	* failure of valve	1	* robust equipment designed exclusively for this purpose * preventative maintenance * system Master Control Panel is able to communicate fault conditions to Owner's central dispatch	6	36	1000							
1.11	1	hose, supply	connects n2 cylinder to the n2 pcv	crack, break or loose fitting causing a minor leak	* loss of n2	6	* wear and tear * improper assembly	1	* thoroughly tested during installation * preventative maintenance * installed by a certified installer * robust equipment designed exclusively for this purpose	9	54	1000							
	1	hose, supply	connects n2 cylinder to the n2 pcv	crack, break or loose fitting causing a major leak	* loss of n2	6	* wear and tear	1	* thoroughly tested during installation * preventative maintenance * installed by a certified installer * robust equipment designed exclusively for this purpose	7	42	1000							
1.12	1	tube, supply	delivers n2 from n2 cylinder to the fuel generator	crack, break or loose fitting causing a minor leak	* loss of n2	6	* wear and tear * improper assembly	1	* thoroughly tested during installation * preventative maintenance * installed by a certified installer * robust equipment designed exclusively for this purpose	9	54	1000							
	1	tube, supply	connects n2 cylinder to the n2 pcv	crack, break or loose fitting causing a major leak	* loss of n2	6	* wear and tear	1	* thoroughly tested during installation * preventative maintenance * installed by a certified installer * robust equipment designed exclusively for this purpose	7	42	1000							
1.13	1	3/4 in, 316 SS seamless tube c/w fittings	delivers vented h2 to the vent stack	crack, break or loose fitting causing a minor leak	* high pressure hydrogen release to outdoors	1	*improper assembly * vibration, fatigue, fitting leak or failure, earthquake, collision	1	* preventative maintenance * installed by a certified installer * infrequent use * limited h2 flow rate * limited h2 inventory	9	9	1000							
	1	3/4 in, 316 SS seamless tube c/w fittings	delivers vented h2 to the vent stack	crack, break or loose fitting causing a major leak	* high pressure hydrogen release to outdoors	2	* improper assembly * vibration, fatigue, fitting leak or failure, earthquake, collision	1	* preventative maintenance * installed by a certified installer * infrequent use * limited h2 flow rate * limited h2 inventory	9	18	1000							

Item	A) Device Quantity	Part Description	Part Function	Potential Failure Mode	Effect of Failure	B) Severity	Potential Causes of Failure	C) Occurrence	Current Detection / Prevention / Controls	D) Detection / Prevention / Control	Actual Risk Priority Number (AxBxCxD)	Maximum Potential Risk Priority Number (Ax1000)	Recommended Action	Person Responsible - Action Date	Action Results: Actions Taken	SOV	OCC	DET	R.P.N.
1.14	1	pipe, water	delivers potable water to the fuel generator	crack, break or loose fitting causing a minor leak	* water loss in summer * freeze damage in winter	2	* vibration, fatigue, fitting leak or failure, earthquake, collision	1	* thoroughly tested during installation * preventative maintenance * installed by a certified installer	7	14	1000							
	1	pipe, water	delivers potable water to the fuel generator	crack, break or loose fitting causing a major leak	* unit cannot generate hydrogen * freeze damage in winter	6	* vibration, fatigue, fitting leak or failure, earthquake, collision	1	* thoroughly tested during installation * preventative maintenance * installed by a certified installer	5	30	1000							
	1	pipe, water	delivers potable water to the fuel generator	water in pipe freezes	* unit cannot generate hydrogen * freeze damage in winter	6	* loss of electric power from the grid * failure of standby electric generator to start * overloaded circuit breaker	5	* thoroughly tested during installation * preventative maintenance * installed by a certified installer	5	150	1000							
1.15	1	1/2 in, 316 SS seamless tube c/w fittings	delivers vented h2 to the vent stack	crack, break or loose fitting causing a minor leak	* high pressure hydrogen release to outdoors	1	* improper assembly * vibration, fatigue, fitting leak or failure, earthquake, collision	1	* preventative maintenance * installed by a certified installer * infrequent use * limited h2 flow rate * limited h2 inventory	9	9	1000							
	1	1/2 in, 316 SS seamless tube c/w fittings	delivers vented h2 to the vent stack	crack, break or loose fitting causing a major leak	* high pressure hydrogen release to outdoors	2	* improper assembly * vibration, fatigue, fitting leak or failure, earthquake, collision	1	* preventative maintenance * installed by a certified installer * infrequent use * limited h2 flow rate * limited h2 inventory	9	18	1000							
2.1	1	gas control panel	controls the flow of high pressure hydrogen to / from all equipment	crack, break or loose fitting causing a minor leak	* hydrogen release to gcp cabinet	2	* wear and tear * vibration, fatigue, fitting leak or failure, earthquake, collision	3	* thoroughly tested during manufacture * thoroughly tested during installation * preventative maintenance * installed by a certified installer	5	30	1000							
	1	gas control panel	controls the flow of high pressure hydrogen to / from all equipment	crack, break or loose fitting causing a major leak	* hydrogen release to gcp cabinet	6	* wear and tear * vibration, fatigue, fitting leak or failure, earthquake, collision	2	* thoroughly tested during manufacture * thoroughly tested during installation * preventative maintenance * installed by a certified installer * gas detection system causes fail safe shutdown * system Master Control Panel is able to communicate fault conditions to Owner's central dispatch	5	60	1000							
	1	gas control panel	controls the flow of high pressure hydrogen to / from all equipment	crack, break or loose fitting causing auto-ignition fire	* h2 fire inside the station	10	* failure of valve	1	* throughly tested during manufacture * thoroughly tested during installation * preventative maintenance * installed by a certified installer * flame detection system shuts down all systems if a flame is detected * flame detection system calls out to fire department * system Master Control Panel is able to communicate fault conditions to Owner's central dispatch	5	50	1000							
	1	gas control panel	controls the flow of high pressure hydrogen to / from all equipment	fails open	* allows hydrogen to flow to storage or dispenser	10	* wear and tear * vibration, fatigue, fitting leak or failure, earthquake, collision	1	* robust equipment designed exclusively for this purpose * thoroughly tested during manufacture * thoroughly tested during installation * preventative maintenance * installed by a certified installer * fails safe in closed position	6	60	1000							
	1	gas control panel	controls the flow of high pressure hydrogen to / from all equipment	fails closed	* prevents flow of hydrogen to storage, dispenser	8	* failure of valve * loss of instrument air * loss of control signal * wear and tear	3	* robust equipment designed exclusively for this purpose * thoroughly tested during manufacture * thoroughly tested during installation * preventative maintenance * installed by a certified installer * fails safe in closed position	6	144	1000							

Item	A) Device Quantity	Part Description	Part Function	Potential Failure Mode	Effect of Failure	B) Severity	Potential Causes of Failure	C) Occurrence	Current Detection / Prevention / Controls	D) Detection / Prevention / Control	Actual Risk Priority Number (AxBxCxD)	Maximum Potential Risk Priority Number (Ax1000)	Recommended Action	Person Responsible - Action Date	Action Results: Actions Taken	SOV	OCC	DET	R.P.N.
2.2	1	NC needle valve c/w end plug	vent, injection and sample port in fuel line	leak at packing	* high pressure hydrogen release to outdoors	2	* wear and tear * improper manufacture	1	* thoroughly tested during installation * preventative maintenance * infrequent use * limited h2 flow rate	9	18	1000							
	1	NC needle valve c/w end plug	vent, injection and sample port in fuel line	leak at compression fitting	* high pressure hydrogen release to outdoors	2	* wear and tear	1	* thoroughly tested during installation * preventative maintenance * installed by a certified installer * infrequent use * limited h2 flow rate	9	18	1000							
2.3	1	3/8 in, 316 ss seamless tube c/w fittings	delivers h2 at 6000 psig from the gas control panel to the dispenser	crack, break or loose fitting causing a minor leak	* high pressure hydrogen release to outdoors	2	* vibration, fatigue, fitting leak or failure, earthquake, collision	1	* thoroughly tested during installation * preventative maintenance * installed by a certified installer * hydrogen rises and disperses rapidly in case of leak * nearby electrical equipment is Class 1 Div. 2 rated	9	18	1000							
	1	3/8 in, 316 ss seamless tube c/w fittings	delivers h2 at 6000 psig from the gas control panel to the dispenser	crack, break or loose fitting causing a major leak	* high pressure hydrogen release to outdoors	8	* vibration, fatigue, fitting leak or failure, earthquake, collision	1	* thoroughly tested during installation * preventative maintenance * installed by a certified installer * hydrogen rises and disperses rapidly in case of leak * nearby electrical equipment is Class 1 Div. 2 rated	8	64	1000							
	1	3/8 in, 316 ss seamless tube c/w fittings	delivers h2 at 6000 psig from the gas control panel to the dispenser	crack, break or loose fitting causing auto-ignition fire	* h2 fire inside the station	10	* vibration, fatigue, fitting leak or failure, earthquake, collision	1	* thoroughly tested during installation * preventative maintenance * installed by a certified installer * flame detection system shuts down all systems if a flame is detected * flame detection system calls out to fire department	2	20	1000							
2.4	1	NO ball valve	isolates flow of hydrogen from the gas control panel to the dispenser	leak at packing	* high pressure hydrogen release to outdoors	2	*wear and tear *improper manufacture	1	* thoroughly tested during installation * preventative maintenance * infrequent use	9	18	1000							
	1	NO ball valve	isolates flow of hydrogen from the gas control panel to the dispenser	leak at compression fitting	* high pressure hydrogen release to outdoors	2	* wear and tear * improper assembly	1	* thoroughly tested during installation * preventative maintenance * installed by a certified installer * infrequent use	9	18	1000							
2.5.1 to 2.5.3	3	NC needle valve c/w end plug	vent, injection and sample port in fuel line	leak at packing	* high pressure hydrogen release to outdoors	2	* wear and tear * improper manufacture	1	* thoroughly tested during installation * preventative maintenance * infrequent use * limited h2 flow rate	9	54	3000							
	3	NC needle valve c/w end plug	vent, injection and sample port in fuel line	leak at compression fitting	* high pressure hydrogen release to outdoors	2	* wear and tear	1	* thoroughly tested during installation * preventative maintenance * installed by a certified installer * infrequent use * limited h2 flow rate	9	54	3000							
2.6.1 to 2.6.3	3	3/8 in, 316 ss seamless tube c/w fittings	delivers h2 to / from the gcp and the storage cylinders	crack, break or loose fitting causing a minor leak	* high pressure hydrogen release to outdoors	2	* vibration, fatigue, fitting leak or failure, earthquake, collision	1	* thoroughly tested during installation * preventative maintenance * installed by a certified installer * hydrogen rises and disperses rapidly in case of leak	9	54	3000							
	3	3/8 in, 316 ss seamless tube c/w fittings	delivers h2 to / from the gcp and the storage cylinders	crack, break or loose fitting causing a major leak	* high pressure hydrogen release to outdoors	8	* vibration, fatigue, fitting leak or failure, earthquake, collision	1	* thoroughly tested during installation * preventative maintenance * installed by a certified installer * hydrogen rises and disperses rapidly in case of leak	8	192	3000	Confirm that Hydrogenics has an algorithm in the PLC that indicates a trouble condition if there is a pressure drop at each storage PT, if there is no "consumption activity occurring						
	3	3/8 in, 316 ss seamless tube c/w fittings	delivers h2 to / from the gcp and the storage cylinders	crack, break or loose fitting causing auto-ignition fire	* h2 fire inside the station	10	* vibration, fatigue, fitting leak or failure, earthquake, collision	1	* thoroughly tested during installation * preventative maintenance * installed by a certified installer * flame detection system shuts down all systems if a flame is detected * flame detection system calls out to fire department	2	60	3000							

Item	A) Device Quantity	Part Description	Part Function	Potential Failure Mode	Effect of Failure	B) Severity	Potential Causes of Failure	C) Occurrence	Current Detection / Prevention / Controls	D) Detection / Prevention / Control	Actual Risk Priority Number (AxBxCxD)	Maximum Potential Risk Priority Number (Ax1000)	Recommended Action	Person Responsible - Action Date	Action Results: Actions Taken	Action Results: SOV	Action Results: OCC	Action Results: DET	Action Results: R.P.N.
2.7		not used									0	0							
2.8	1	NC needle valve c/w end plug	vent, injection and sample port in fuel line	leak at packing	* high pressure hydrogen release to outdoors	2	* wear and tear * improper manufacture	1	* thoroughly tested during installation * preventative maintenance * infrequent use * limited h2 flow rate	9	18	1000							
	1	NC needle valve c/w end plug	vent, injection and sample port in fuel line	leak at compression fitting	* high pressure hydrogen release to outdoors	2	* wear and tear * improper assembly	1	* thoroughly tested during installation * preventative maintenance * installed by a certified installer * infrequent use * limited h2 flow rate	9	18	1000							
2.9	1	3/8 in, 316 ss seamless tube c/w fittings	delivers h2 from the gcp and the electricity generator	crack, break or loose fitting causing a minor leak	* high pressure hydrogen release to outdoors	2	* vibration, fatigue, fitting leak or failure, earthquake, collision	1	* thoroughly tested during installation * preventative maintenance * installed by a certified installer * limited h2 flow rate	9	18	1000							
	1	3/8 in, 316 ss seamless tube c/w fittings	delivers h2 from the gcp and the electricity generator	crack, break or loose fitting causing a major leak	* high pressure hydrogen release to outdoors	8	* vibration, fatigue, fitting leak or failure, earthquake, collision	1	* thoroughly tested during installation * preventative maintenance * installed by a certified installer * limited h2 flow rate	8	64	1000							
	1	3/8 in, 316 ss seamless tube c/w fittings	delivers h2 from the gcp and the electricity generator	crack, break or loose fitting causing auto-ignition fire	* h2 fire inside the station	10	* vibration, fatigue, fitting leak or failure, earthquake, collision	1	* thoroughly tested during installation * preventative maintenance * installed by a certified installer * limited h2 flow rate * flame detection system shuts down all systems if a flame is detected * flame detection system calls out to fire department	2	20	1000							
2.10	1	3/8 in, 316 ss seamless tube c/w fittings	isolates flow of hydrogen from the gcp to the electricity generator	crack, break or loose fitting causing a minor leak	* high pressure hydrogen release to outdoors	2	* vibration, fatigue, fitting leak or failure, earthquake, collision	1	* thoroughly tested during installation * preventative maintenance * installed by a certified installer * limited h2 flow rate	9	18	1000							
	1	3/8 in, 316 ss seamless tube c/w fittings	isolates flow of hydrogen from the gcp to the electricity generator	crack, break or loose fitting causing a major leak	* high pressure hydrogen release to outdoors	8	* vibration, fatigue, fitting leak or failure, earthquake, collision	1	* thoroughly tested during installation * preventative maintenance * installed by a certified installer * limited h2 flow rate	8	64	1000							
	1	3/8 in, 316 ss seamless tube c/w fittings	isolates flow of hydrogen from the gcp to the electricity generator	crack, break or loose fitting causing auto-ignition fire	* h2 fire inside the station	10	* vibration, fatigue, fitting leak or failure, earthquake, collision	1	* thoroughly tested during installation * preventative maintenance * installed by a certified installer * limited h2 flow rate * flame detection system shuts down all systems if a flame is detected * flame detection system calls out to fire department	2	20	1000							
2.11		not used									0	0							
2.12	1	plug fitting	isolates compressor inlet	crack, break or loose fitting causing a minor leak	* high pressure hydrogen release to outdoors	2	* vibration, fatigue, fitting leak or failure, earthquake, collision	1	* thoroughly tested during installation * preventative maintenance * installed by a certified installer * limited h2 flow rate	9	18	1000							
	1	plug fitting	isolates compressor inlet	crack, break or loose fitting causing a major leak	* high pressure hydrogen release to outdoors	8	* vibration, fatigue, fitting leak or failure, earthquake, collision	1	* thoroughly tested during installation * preventative maintenance * installed by a certified installer * limited h2 flow rate	9	72	1000							
3.1	1	dispenser	provides 350 bar (settled) fueling of dual fuel (gas / h2) vehicles	unit will not flow fuel	* vehicles cannot run on hydrogen	5	* wear and tear * loss of electric power * failure of standby generator to start	5	* pm of genset * system exercised regularly * preventative maintenance * thoroughly tested during installation * robust equipment designed exclusively for this purpose * thoroughly tested during manufacture	8	200	1000							
	1	dispenser	provides 350 bar (settled) fueling of dual fuel (gas / h2) vehicles	unit continues to flow fuel to a full cylinder	* vehicle cylinder is overfilled	9	* wear and tear * improper manufacture * improper assembly	1	* thoroughly tested during installation * thoroughly tested during manufacture * preventative maintenance * installed by a certified installer * robust equipment disigned exclusively for this purpose * fails safe in closed position * attended fueling with trained vehicle operators	8	72	1000							

Item	A) Device Quantity	Part Description	Part Function	Potential Failure Mode	Effect of Failure	B) Severity	Potential Causes of Failure	C) Occurrence	Current Detection / Prevention / Controls	D) Detection / Prevention / Control	Actual Risk Priority Number (AxBxCxD)	Maximum Potential Risk Priority Number (Ax1000)	Recommended Action	Person Responsible - Action Date	Action Results: Actions Taken	Action Results: SOV	Action Results: OCC	Action Results: DET	Action Results: R.P.N.
3.2	1	1 in, 316 SS seamless tube c/w fittings	delivers vented h2 to the vent stack	crack, break or loose fitting causing a minor leak	* high pressure hydrogen release to outdoors	1	*improper assembly * vibration, fatigue, fitting leak or failure, earthquake, collision	1	* preventative maintenance * installed by a certified installer * infrequent use * limited h2 flow rate	9	9	1000							
	1	1 in, 316 SS seamless tube c/w fittings	delivers vented h2 to the vent stack	crack, break or loose fitting causing a major leak	* high pressure hydrogen release to outdoors	2	* improper assembly * vibration, fatigue, fitting leak or failure, earthquake, collision	1	* preventative maintenance * installed by a certified installer * infrequent use * limited h2 flow rate	9	18	1000							
4.1	3	storage module	high pressure storage of fuel	crack, break or loose fitting causing a minor leak	* high pressure hydrogen release to outdoors	2	* vibration, fatigue, fitting leak or failure, earthquake, collision	1	* thoroughly tested during installation * preventative maintenance * installed by a certified installer * hydrogen rises and disperses rapidly in case of leak	9	54	3000							
	3	storage module	high pressure storage of fuel	crack, break or loose fitting causing a major leak	* high pressure hydrogen release to outdoors	8	* vibration, fatigue, fitting leak or failure, earthquake, collision	1	* thoroughly tested during installation * preventative maintenance * installed by a certified installer * hydrogen rises and disperses rapidly in case of leak	8	192	3000	Confirm that Hydrogenics has an algorithm in the PLC that indicates a trouble condition if there is a pressure drop at each storage PT, if there is no "consumption activity occurring						
	3	storage module	high pressure storage of fuel	crack, break or loose fitting causing auto-ignition fire	* h2 fire inside the station	10	* vibration, fatigue, fitting leak or failure, earthquake, collision	1	* thoroughly tested during installation * preventative maintenance * installed by a certified installer * flame detection system shuts down all systems if a flame is detected * pressure relief values present over-pressure condition * flame detection system calls out to fire department	2	60	3000							
4.2	1	3 in ID steel pipe	Directs all vented h2 to a point 12 ft above the equipment pad	stack clogs or seals-off	* main vent stack is rendered inoperable	10	* debris * ice	1	* preventative maintenance - regular vent line check	7	70	1000	Confirm that the Hydrogenics vent stack has a primary and secondary vent outlet						
	1	3 in ID steel pipe	Directs all vented h2 to a point 12 ft above the equipment pad	stack fails structurally	* main vent stack is crimped and directs flow non-vertically	8	* wind loading * earthquake * structural fatigue	1	* preventative maintenance * nearby area is an electrically classified area * regardless of vent orientation h2 will rise	7	56	1000							
	1	3 in ID steel pipe	Directs all vented h2 to a point 12 ft above the equipment pad	stack fails structurally	* main vent stack is severed releasing h2 in the station enclosure	9	* wind loading * earthquake * structural fatigue	1	* preventative maintenance * entire storage area is an electrically classified area * storage structure designed to safely vent H2 to atmosphere * storage system designed to handle an auto-ignition fire via integrated PRD's	7	63	1000							
	1	3 in ID steel pipe	Directs all vented h2 to a point 12 ft above the equipment pad	stack fails structurally	* main vent stack is completely crimped and seals-off vent	10	* wind loading * earthquake * structural fatigue	1	* preventative maintenance	7	70	1000							
5.1	1	8 x 6 H-beam c/w base plate and top vents	supports riser pipes	structural failure	* risers are crimped and direct the flow non-vertically	8	* wind / ice loading * earthquake * structural fatigue	1	* robust equipment designed exclusively for this purpose * regardless of vent orientation h2 will rise and disperse rapidly	7	56	1000							
	1	8 x 6 H-beam c/w base plate and top vents	supports riser pipes	structural failure	* risers are crimped and sealed off	10	* wind / ice loading * earthquake * structural fatigue	1	* robust equipment designed exclusively for this purpose	7	70	1000							
5.2.1 to 5.2.3	3	various OD 316 SS seamless tube c/w fittings	directs all vented h2 to a point 12 ft above the equipment pad	riser clogs or seals off	* vented h2 cannot be released to outdoors	10	* debris * ice	1	* preventative maintenance * secondary vent path	7	210	3000							
6.1	1	diesel fueled generator c/w transfer switch	backup electricity supply to h2 station	will not start or stops running	* loss of backup electrical power	8	multiple	5	* preventative maintenance * infrequent use * system Master Control Panel is able to communicate fault conditions to Owner's central dispatch	6	240	1000							
	1	transfer switch to service back-up power circuits	automatically switches from purchased power to ICE / Gen Set upon purchased power failure or manual demonstration mode	fails open	* ICE / Gen Sets cannot service back-up circuits OR demonstration cannot proceed	8	* failure of transfer switch	1	* robust equipment designed exclusively for this purpose * preventative maintenance * system exercised regularly * alarms when transfer not completed**	3	24	1000	** confirm this is true						

															Action Results				
Item	**A) Device Quantity**	**Part Description**	**Part Function**	**Potential Failure Mode**	**Effect of Failure**	**B) Severity**	**Potential Causes of Failure**	**C) Occurrence**	**Current Detection / Prevention / Controls**	**D) Detection / Prevention / Control**	**Actual Risk Priority Number (AxBxCxD)**	**Maximum Potential Risk Priority Number (Ax1000)**	**Recommended Action**	**Person Responsible - Action Date**	**Actions Taken**	**SOV**	**OCC**	**DET**	**R.P.N.**
6.2	1	hydrogen fueled generator	demonstrates hydrogen as electric storage medium	will not start or stops running	* loss of power backfeed to the grid	2	multiple	5	* preventative maintenance * infrequent use	7	70	1000							
7.1.1 to 7.3	3	manually actuated, latched button	emergency shutdown of individual pieces of equipment	fails open	* cannot shutdown equipment	5	* loss of electrical supply * failure of device	2	* preventive maintenance * device on UPS * separate circuit from Master Controller * multiple ESD locations * manual ESD by-pass by shutting down equipment separately	5	150	3000							
	3	manually actuated, latched button	emergency shutdown of individual pieces of equipment	fails closed	* shuts down equipment inadvertently	8	* failure of device	1	* preventive maintenance	2	48	3000							
8.1	1	manually actuated, latched button	emergency shutdown of individual pieces of equipment	fails open	* cannot shutdown equipment	5	* loss of electrical supply * failure of device	2	* preventive maintenance * device on UPS * separate circuit from Master Controller * multiple ESD locations * manual ESD by-pass by shutting down equipment separately	5	50	1000							
	1	manually actuated, latched button	emergency stop of all station operations	fails closed	* shuts down equipment inadvertently * false alarm to Fire Department	8	* failure of device	1	* preventive maintenance	2	16	1000							
9.1	1	emergency alarm panel c/w UPS	controls gas and flame detection system and Hydrogenics trouble alarm	fails off or locked up	* cannot monitor or react to sensed events	10	* loss of electricity supply * equipment failure	2	* continuously self monitors and alarms on failure * equipped with UPS * preventative maintenance	2	40	1000							
	1	emergency alarm panel c/w UPS	controls gas and flame detection system and Hydrogenics trouble alarm	UPS fails off	* cannot work if main and standby power is OFF	9	* batteries discharged * equipment failure	1	* preventative maintenance * infrequent use	7	63	1000							
9.2 to 9.3	2	alarm annunciators	gives visual & audible indication of alarm conditions	fails open	* does not alarm when required	1	* loss of electrical supply * failure of device	1	* preventative maintenance * device on UPS * separate circuit from Master Controller * multiple alarm beacons	7	14	2000							
	2	alarm annunciators		fails closed	* false alarm to fire department	1	* failure of device	1	* preventative maintenance	6	12	2000							
9.4 to 9.5	2	flame sensors	continuously monitors field of view for hydrogen flames	"0" current reading	* cannot sense and react to hydrogen flame	8	* loss of electricity * loss of control circuit sensor failure	2	* preventative maintenance * robust equipment designed exclusively for this purpose * continuously self monitors and alarms on system or device failure * double redundant backup power supply	2	64	2000							
9.6	1	8 x 6 H-beam c/w base plate	supports gas and flame detection system alarm annunciators	structural failure	* alarms may be damaged	8	* wind / ice loading * earthquake * structural failure	1	* robust equipment designed exclusively for this purpose	7	56	1000							
9.7 to 9.8	2	gas sensors	continuously monitors HYSTAT 30 compartments for h2	"0" current reading	* cannot sense and react to hydrogen vapors in the air	8	* loss of electricity * loss of control circuit * sensor failure	2	* preventative maintenance * robust equipment designed exclusively for this purpose * continuously self monitors and alarms on system or device failure * double redundant backup power supply	2	64	2000							

SUB-TOTAL ACTUAL RPN	SUB-TOTAL MAXUMUM RPN
4949	117000

FMEA Risk Priority Number (RPN) Summary

	Actual RPN	Maximum Potential RPN
Vehicle Fueling Station	**4949**	**117000**
RPN Quotient	**0.04230**	

BASIN ELECTRIC
POWER COOPERATIVE

DRAFT

Hazard Identification & Risk Assessment (HIRA)

Revision 0

Hydrogen Fuelling Station

for

Basin Electric Power Cooperative

Minot, North Dakota

May 2006

Kahn
ALBERT KAHN ASSOCIATES, INC.
PLANNING, DESIGN AND MANAGEMENT
Albert Kahn Building
7430 Second Ave.
Detroit, Michigan

DMA

Basin Electric Power Cooperative (BEPC)
Hazard Identification and Risk Assessment(HIRA)
Revision 0

Introduction

The primary focus of this analysis is on the Hydrogen Fuelling Station (H2 Station) and risks associated with Hydrogen (H2). General risks from ancillary equipment (eg. diesel generator) were included in this HIRA but not necessarily in sufficient detail since detailed design documentation or safety analysis was not available to the HIRA team.

Preliminary consideration of the interfaces with the H2 Station Construction as well as BEPC Operation and Maintenance were also included in the scope of the analysis.

Definitions

HIRA is a semi-quantitative risk analysis. It is intended to be a preliminary screening process to determine priorities and identify risks worthy of more detailed quantitative risk analysis. By definition, Risk = Probability X Consequence. Suggested estimators for Probability and Consequence used were based on U.S. Military specification 882 on Risk Assessment and shown in Figure 1.

Figure 1A: Probability

DESCRIPTION (events over a lifetime)	LEVEL
Frequent $P > 10^{-1}$, continuous	A
Probable $P > 10^{-2}$, regular	B
Occasional $P > 10^{-3}$, several	C
Remote $P > 10^{-6}$, few	D
Improbable $P < 10^{-6}$, one	E

Figure 1B: Consequence

DESCRIPTION	CATEGORY
Catastrophic (Death, $1M loss, major spill, etc.)	1
Critical (Serious injury, >$200K loss, etc.)	2
Marginal (Lost time injury, >$10k loss, etc.)	3
Negligible (Minor injury, >$2k loss, etc.)	4

The definitions in Figure 1 are guidelines and should be modified over time to best fit company experience. If in doubt, be conservative and rank either probability or consequence at a higher level or category pending more detailed analysis.

The multiplication of Probability X Consequence yields a matrix of risk scores shown in Figure 2.

Figure 2: Risk Assessment Value

Severity ***Frequency***	**1 - Catastrophic**	**2 - Critical**	**3 - Marginal**	**4 - Negligible**
A - Frequent	1A Unacceptable	2A Unacceptable	3A Unacceptable	4A Acceptable*
B - Probable	1B Unacceptable	2B Unacceptable	3B Undesirable	4B Acceptable*
C - Occasional	1C Unacceptable	2C Undesirable	3C Undesirable	4C Acceptable
D - Remote	1D Undesirable	2D Undesirable	3D Acceptable*	4D Acceptable
E - Improbable	1E Acceptable*	2E Acceptable*	3E Acceptable*	4E Acceptable

The matrix in Figure 2 implies that certain level of organizational authority shall be consulted and certain types of risk controls or mitigations shall be considered:

- Red Zone risks must be referred to senior management and require a design solution if possible since design is the most effective risk control (eg. fail-safe shutdown). Work must stop for any Red Zone risk until mitigations are in place.

- Yellow Zone risks must be referred to middle management and a design solution is preferred but if not practical a safety device may be substituted (eg. automated warnings). Yellow Zone risks should be the subject of more frequent and intense monitoring and audit, primarily because of the potential consequence of failure.

- Green Zone risks must be referred to front line supervision and administrative controls can be used (eg. procedures or training). Green Zone risks marked* should be reviewed periodically to ensure the quality of risk controls is being maintained, to prevent loss from either probability or consequence.

The acceptability of the risk scores in Figure 2 are based on the Probability and Consequence of an event after the risk controls have been considered.

For example, the results can be summarized in the worksheet shown in Figure 3.

Hazard ID (Energy)	Existing Controls (Barriers)	Risk Estimate (P X C)	Risk Assessment Matrix	Action/Comments
Construction "Dig-in" to: -H2 Piping -H2 Cable	-Work Plan -drawings -depth / fill -warning tape -concrete -operator skill	Remote X Catastrophic	1D = Undesirable or Yellow Zone	Additional controls: -Dig permit -Locate proc. Risk reduced to: 1E = Acceptable* or Green Zone
Etc.				

The purpose of the exercise is not simply to classify risk but instead to identify priorities and additional controls for continuous improvement in risk reduction where feasible.

Analysis Method

Some risks may be identified more than once in a HIRA and there may be overlap with other safety analysis techniques (eg. FMEA). Our philosophy is that it is better to look at a risk more than once than to overlook it.

The HIRA is intended to be a dynamic document. Priority risks will be updated as site projects progress. Revisions to date:

- R0 = Draft Review of Preliminary Design by DMA

HIRA Results

The results are presented in a series of charts at the end of this report. Items noted in blue require further clarification and discussion to properly assess risk.

Conclusions

Priority Risks

1. No Red Zone risks were identified.

2. Yellow Zone risks identified in the Charts include the following scenarios:
    - D1.1 H2 leak or fire in Electrical / PLC / Compressed Air Room
    - D1.2 H2 leak or fire in Water Treatment / Chiller Room
    - D7. BEPC General Station and Site Hazards

3. Several Green Zone risks were judged to be acceptable based on certain assumptions listed under Actions / Comments in the Charts. Continuous improvement ideas for further risk reduction and follow up were also listed.

4. It was not possible at this time to determine the risks for BEPC beyond the Design phase, however, several suggestions have been offered to reduce the risk during the Construction, Commissioning, Operations and Maintenance phases of this project.

Priority Actions

All risks should be monitored and reassessed as the project progresses. Priority risks will be the subject of more frequent monitoring and audit

Specific actions:

Design Team

□ Review NFPA 55 requirement for setback from storage to building intake and exhausts. Consider the addition of gas detection and process shutdown.

Client

□ BEPC to develop H2 Station Emergency Plan and integrate with existing System Operating Center (SOC) plans.

□ BEPC to coordinate alarm communication protocol with local Fire Department.

□ BEPC to arrange Department of energy (DOE) H2 emergency responder training for local Fire Department.

Hazard ID (Energy)	Risk Controls (Barriers)	Risk Estimate (Prob. X Cons.)	Risk Assessment Matrix Value	Actions / Comments
Safety by Design • Design is the most effective risk control so the focus of the analysis at this stage was primarily on the inherent hardware risks presented by the design concept since it is intended to be a remotely controlled station linked to a BEPC System Operations Center. The training and experience of people and the availability of work procedures were also considered as these risk controls also affect the integrity of the hardware. • The focus of this HIRA is on the integration of various modules into the overall site design and not on the specific risks within the Hydrogenics designed modules since these are manufactured to meet code.				
D1. Electrolyser • Self-contained modular Design by Hydrogenics includes separate "rooms" housed in a shipping container. Features include general ventilation air and roof exhaust, glycol cooling system, waste oil/water collection system, O2 roof vent, H2 vent to station stack, emergency shutdown (ESD) and other safety features.				
D1.1 H2 leak or fire in Electrical / PLC / Compressed Air Room	-Not electrically classified but outside classification zone (see M-501) -Roof perforated for 50% as per Hydrogenics drawing 1023797	Remote X Catastrophic -leak into intake and gas pocket	1D = Undesirable	-Review NFPA 55 re setback from storage to intake and exhausts -Addition of gas detection and process shutdown = 1E = Acceptable
D1.2 H2 leak or fire in Water Treatment / Chiller Room	-Not electrically classified but outside classification zone (see M-501) -Gas tight seal to prevent penetration from adjacent Electrolysis Room	Remote X Catastrophic -failure of gas tight seal or leak into intake	1D = Undesirable	-Review NFPA 55 re setback from storage to intake and exhausts -Addition of gas detection and process shutdown = 1E = Acceptable
D1.3 H2 leak or fire in Electrolysis Room	-Partially within classification zone -Class 1, Division 2 rated equipment -H2 gas detection interlocked to ventilation and process shutdown.	Improbable X Catastrophic	1E = Acceptable	
D1.4 H2 leak or fire associated with equipment on top of container	-Not electrically classified but outside classification zone (see M-501) -outdoor, so dispersion is most likely	Improbable X Catastrophic	1E = Acceptable	

Hazard ID (Energy)	Risk Controls (Barriers)	Risk Estimate (Prob. X Cons.)	Risk Assessment Matrix Value	Actions / Comments
D2. Gas Control Panel • Self-contained modular Design by Hydrogenics includes internal piping and assorted devices, instruments and valves (DIV's).				
D2.1 H2 piping leak or fire at panel	-stainless piping steel piping and Swagelok (or equivalent) fittings -Panel within classification zone -Class 1, Division 2 rated equipment -gas detector in panel interlocked to shut down H2 supply -outdoor, so dispersion is most likely	Improbable X Catastrophic	1E = Acceptable	
D3. H2 Vehicle Dispenser • Self-contained modular Design by Hydrogenics breakaway hose, vibration/knock-down sensor, emergency shut down (ESD) and other safety features.				
D3.1 H2 piping leak or fire at dispenser	-stainless piping steel piping and Swagelok (or equivalent) fittings -Dispenser within classification zone -Class 1, Division 2 rated equipment -gas detector in panel interlocked to shut down H2 supply -outdoor, so dispersion is most likely	Improbable X Catastrophic	1E = Acceptable	
D4. H2 Storage • Self-contained modular Design by Hydrogenics including pressure relief valves and dedicated vent stack.				
D4.1 H2 leak or fire in piping to / from storage	-worst case scenario for a leak due to available volume (80 kg) and maximum pressure (6000 psig) -stainless piping steel piping and Swagelok (or equivalent) fittings -majority of connections at north end of storage outside classified zone -2 hour fire rated wall to maintain separation from liquid diesel fuel -outdoor, so dispersion is most likely	Improbable X Catastrophic	1E = Acceptable	-Review design of vent stack cap for possibility of blockage. (See D5.1 for comparison) -Review need for an excess flow valve to minimize potential release

Hazard ID (Energy)	Risk Controls (Barriers)	Risk Estimate (Prob. X Cons.)	Risk Assessment Matrix Value	Actions / Comments
D5. Station Vent Stack • Custom design for site				
D5.1 Inoperability of vent stack due to blockage	-stainless piping steel piping and Swagelok (or equivalent) fittings -self-sealing top venting cap design with side venting in case of ice/snow and bird screening	Improbable X Catastrophic	1E = Acceptable	-Confirm cap design.
D6. Auxiliary Equipment and Grounding • Custom design for site				
D6.1 H2 leak or fire in vicinity of Diesel Generator or diesel fire	-located outside classified zone (see M501) -outdoor, so dispersion likely -generator not required to be classified (NFPA37) -2 hour fire rated wall to maintain separation from liquid diesel fuel	Improbable X Critical	2E = Acceptable	
D6.2 H2 Generator (future option)	-To be determined			
D6.3 Grounding problems lead to static discharge	-continuous station ground mat -bonding lugs on all major equipment -CAD weld ground connections -low ohm concrete pad for vehicle users	Improbable X Catastrophic	1E = Acceptable	
D7. BEPC General Station and Site Hazards	-Site is setback from road to the north and highway to east -Pipe guard posts are present on the west and south sides to protect storage and dispenser from vehicles in parking lot -Security included chain link fence and dusk to dawn lighting	Remote X Critical -given the listed risk controls, a catastrophic station design failure, security,	2D = Undesirable	-Station is designed to be operated unmanned with safety features for vehicle users ☐ BEPC to develop H2 Station Emergency Plan and integrate with existing SOC plans

Hazard ID (Energy)	Risk Controls (Barriers)	Risk Estimate (Prob. X Cons.)	Risk Assessment Matrix Value	Actions / Comments
	-Station Flame and Gas Detection System as per NFPA52:2006 will alarm and automatically shut down station -E-Stop located inside north walk-in gate and reachable from outside through hand hole in fence -E-Stop produces visual and audible alarm with acknowledge button, e-stops can only be reset locally by BEPC -Site alarms are will be monitored remotely by BEPC SOC -H2 Station meets all code setback and electrically classified zone requirements -Closest buildings are part of a University Research Facility, other public exposure is minimal.	traffic or public emergency is unlikely		☐ BEPC to coordinate alarm communication protocol with local Fire Department ☐ BEPC to arrange DOE H2 emergency responder training for local Fire Department -Completion of actions listed above = 2E = Acceptable

Hazard ID (Energy)	Risk Controls (Barriers)	Risk Estimate (Prob. X Cons.)	Risk Assessment Matrix Value	Actions / Comments
Safety in Construction and Commissioning • Focus of this stage of the analysis is a review of the risks associated with ongoing major construction and commissioning activities and the interface with site operations or vice versa. Changing conditions can introduce new risks and good work planning and coordination is a necessary control.				
C1. Construction of H2 Station • H2 risks at this stage should be minimal for BEPC since it is a green field site.				
C1.1 General construction risks	-Risks of excavation, hot work, construction traffic or public traffic will not be compounded since there will be no H2 on site until the commissioning phase	Not applicable		☐ BEPC should develop a Project Safety Plan to coordinate the site work of Hydrogenics and the various construction trades
C2. Commissioning of H2 Station Phase 2 • H2 risks at this stage will increase for BEPC as H2 is introduced to the site for commissioning purposes.				
C2.1 General commissioning risks	-work scheduling will become a more critical issue as H2 is required on site for testing and start up purposes (eg. pressure testing of piping)	To be determined		☐ As part of the Project Safety Plan, BEPC should integrate the H2 risks associated with start up and testing of equipment and systems ☐ BEPC should also develop a Station Acceptance Test to prove the design functions as intended, especially critical safety systems and features

<table>
<tr><th>Hazard ID
(Energy)</th><th>Risk Controls
(Barriers)</th><th>Risk Estimate
(Prob. X Cons.)</th><th>Risk Assessment Matrix Value</th><th>Actions / Comments</th></tr>
<tr><td colspan="5">Safety in Operations and Maintenance
• Focus of this stage of the analysis is on the risks to people who operate, inspect and maintain the hardware as well as the general public. (Vehicle operations and maintenance is beyond the scope of this analysis but must be considered by owners.)</td></tr>
<tr><td colspan="5">O1. Station Operations
• Station designed to run unattended.</td></tr>
<tr><td>O1.1 Routine risks to vehicle users and general public</td><td>-training to be provided to all users including refueling, emergency shutdown and other safety features … possible station emergency stop if any abnormal event is detected
-security card access and code required for refueling
-minimal exposure of general public to station risks</td><td>To be determined</td><td></td><td>☐ BEPC to provide the necessary training to all vehicle users</td></tr>
<tr><td>O1.2 Emergency risks</td><td>-H2 Station specific emergency response plan to be developed
-training to be provided to employees and external emergency response people as noted in D7</td><td>To be determined</td><td></td><td>☐ BEPC to develop and integrate emergency plans

☐ BEPC to provide training</td></tr>
<tr><td colspan="5">O2. Station Maintenance
• Maintenance should be no more complicated for an experienced technician than any gas system.</td></tr>
<tr><td>O2.1 Inspection and Maintenance risks</td><td>-H2 maintenance work should be considered high risk and requires:
• written work plans, procedures and permits (lockout, hot work)
• non-sparking tools, H2 gas detector, etc.
• Entry Protocol (open all gates, use corn broom to detect invisible H2 fire, etc.)</td><td>To be determined</td><td></td><td>☐ BEPC to develop H2 Station inspection / maintenance plans and procedures

☐ BEPC to provide H2 hazard specific training to operations and maintenance employees or contractors</td></tr>
</table>

Hazard ID (Energy)	Risk Controls (Barriers)	Risk Estimate (Prob. X Cons.)	Risk Assessment Matrix Value	Actions / Comments
Safety in Decommissioning and Disposal • No significant risks identified at this time for this stage of the life cycle.				

APPENDIX C

HIGH-PRESSURE TESTING AND CERTIFICATION REPORT

APPENDIX C

HIGH-PRESSURE TESTING AND CERTIFICATION REPORT

EPC Pressure Testing Documentation

Engineering
Procurement &
Construction, LLC
Energy Independence through Hydrogen and Fuel Cells
12211 W Alameda Parkway, Suite 105
Lakewood, CO 80228
720 974 1709
www.epc4h2.com

July 17, 2007

Basin Electric Power Cooperative
1717 East Interstate Avenue
Bismarck, ND 58503-0564

Attn.: Mr. Randy Bush

Dear Randy,

Attached is our report for the high pressure testing of the hydrogen lines at the Minot Hydrogen system. It includes the revised procedure which we agreed upon on Tuesday before beginning the work, and each of the individual test packages for the lines tested. I have also included copies of my daily reports for you reference and files. Finally, I have enclosed the invoice for our services. Please call me if you have any questions or concerns or require additional submittals.

I greatly appreciate the opportunity to participate on your project and hope that we can be of further assistance in upcoming phases of the work. Is was especially good to meet you and Brad face to face and I hope we can get together again in the near future.

Best regards,

John Cornish, PE
President

The Contract scope of testing was reviewed after inspecting the physical system. The Test Procedure was modified as shown below (changes in blue and underlined) and agreed upon between EPC, Randy Bush and Brad Stevens as reasonable, appropriate and sufficient to demonstrate and insure the integrity of the piping system. By virtue of performing this procedure, EPC assures Basin Electric Power Cooperative that the system complies with ANSI B31.3 and is safe for operation.

Testing Procedure:

3.3 PROCESS GAS LINES

3.3.1 INTRODUCTION

.1 The maximum operating pressure (mop) is the steady state gauge pressure at which the segment of the system normally operates.

.2 The set pressure is defined as the set point of the pressure relief valves that are connected to the segment of pipe to be tested. The set pressure is the mop x 1.10.

.3 All process gas "wetted" equipment, components and tubing shall be subjected to a pressure test, leak test and acceptance test, as defined below. Pressure test shall be conducted at 1.1 times the set pressure with helium. Leak test shall be conducted at the maximum operating pressure with helium. Acceptance test shall be conducted at the maximum operating pressure with hydrogen.

Testing pressure clarification 3.3.1.3:

- ***Pressure relief valve blinded the required pressure is required to be at 1.1 times the maximum operating pressure - none***
- ***Pressure relief valves unblinded for the acceptance testing should be done at maximum operating pressure. - none***

3.3.2 PROCEDURE

.1 The Company shall ensure that either Owner's representative or a qualified representative from the authority having jurisdiction are present prior to conducting any testing. Attendance by the other entities of authority is at their discretion. (Brad or Randy)

.2 Test segments that are exempt from the pressure test will be isolated by closing manual isolation valves or disconnecting and plugging the tubing with an approved plug fitting. Limits of test were the ICS installed piping. Hydrogenics equipment and piping was not tested.

For the portion of the system subjected to the highest mop, the Company shall close the valves as shown on the test plan schematics which will be provided by the engineer, or as directed by the engineer during the test. All sections tested at 6600 psi.

.3 The Company shall use the injection point for the test gas as shown on the test plan schematics, or as directed by the engineer during the test. Test ports were adequately located for helium injection on all five test packages.

.4 The Company shall use the test pressure gauge as the certified gauge to conduct the pressure test for this portion of the system. The Company shall vent the system when required as shown on the test plan schematic, or as directed by the engineer during the test.

.5 The Company shall attach the "test gas" cylinder(s) at the injection point.

.6 For each line segment to be tested, connect purge air to inlet of test port. Fully disconnect both ends of segment to be tested. Disconnect and cap tubing so as to avoid sending potential contaminants into valves or sensing devices. Cap or plug one end of the segment and leave the other end open and unrestricted to atmosphere. Cover this opened end lightly with clean white toweling to catch and observe the presence of any foreign material which may come from the tubing during the purge. Open purge valve to tubing segment for several seconds to allow approximately 100 psi dry, bottled, compressed air to blow freely through tubing, exiting through the clean towel. Continue purge until all foreign material is purged from tubing. If it is determined that foreign material cannot be satisfactorily purged with this method, tubing should be appropriately cleaned in place or replaced as needed, to remove the foreign material and retested. Reconnect or plug this end of the tubing segment and repeat the procedure for the other end of the segment being tested. Reconnect each end to the system or leave plugged, as required, in preparation for pressure and leak testing.

.7 The Company shall then proceed with the preliminary leak test. The preliminary leak test shall be conducted using helium as the test gas. The Company shall charge the system to a pressure of 25 psig and will inspect the system to identify any significant leaks. If necessary, the Company shall achieve the test pressure by the use of a pneumatic pump approved by the engineer. Testing of the joints shall be with a suitable leak-detection solution as approved by the engineer. The Company shall then relieve the pressure in the system and repair any leaks. The Company shall repeat this procedure until the system will hold 25 psig for 5 minutes.

.8 Upon successful completion of the preliminary leak test, the Company shall then proceed with the pressure test. The pressure test as outlined here shall also serve as the MOP leak test. The pressure test shall be conducted using helium as the test gas. The Company shall charge the system to the test pressure. This pressure will be achieved gradually in increments commencing with 25 psig for the first plateau and then in increments equal to 10% of the test pressure or 100 psig increment, whichever is greater. If necessary, the Company shall achieve the test pressure by the use of a pneumatic pump approved by the engineer. The Company shall inspect the system to identify any leaks. Testing of the joints shall be with a suitable leak-detection solution and helium leak detection instrument as approved by the engineer. The Company shall then relieve the pressure from the system and repair any leaks. The Company shall repeat this procedure until the system will hold the test pressure for 30 minutes. At the conclusion of the 30 minute test, the contract shall relieve the pressure in this portion of the system.

.9 Repeat steps 1 through 7 for the process gas lines which operate at lower mop's. the test pressure shall be as indicated. None

Oxygen cleaning step 3.3.2.9:
Oxygen cleaning step is not necessary and could be replaced with an air cleaning step or air blow cleaning at 150 psi. The oxygen will be bottled air to further reduce the potential of introducing moisture into the piping. Section 3.3.6 added

.10 Upon successful completion of all the pressure tests, the Company shall relieve the pressure from the system, reconnect all tubing and re-install the prds. Balance of section deleted.

.11 deleted
.12 deleted
.13 deleted
.14 deleted

.15 The Company shall provide all "test gas", an approved leak-detection solution, the electronic gas-detection equipment, any equipment necessary to boost the system pressure to the required test pressure and all gauges necessary for the execution of this procedure. The Company shall provide appropriate personnel to conduct the test and undertake repairs under the engineer's supervision

7-30-5

EPC

DAILY FIELD REPORT

JOB NAME	Basin Electric	DATE	7/3/07
PROJECT		REPORT NO.	1
JOB NO.		SHEET	1 OF 1
LOCATION	MINOT / EERC	WEATHER	FAIR
CLIENT		TEMP	90 AT 3 AM (PM)

WORK IN PROGRESS OR COMPLETE (INCLUDING SUBCONTRACTORS):

Arrived on site @ 7:20 Met Al & Mike & Began setting up pump. Helium & air delivered ~ 11:00. Revised procedure & met with Randy Bush & Brad Sturns who reviewed & approved. Performed air blow into clean white cloth of each of the 5 systems. All 5 were witnessed by Client as clean. Hooked up pump & air to begin testing system #1. At ~ 3:00 pm, ready to pressurize & found cone on HP pipe missing. Called around for 2 hours - no luck. Arranged [?] to Fedex for 7/5 delivery

CONTRACTOR EQUIPMENT	QUANTITY	CONTRACTOR WORK FORCE	QUANTITY
ICS		2	
EPC		2.	

VERBAL DISCUSSIONS/INSTRUCTIONS

Found cone at hotel and replanned to start next AM.
Brad off on 4th

REQUEST FOR PROJECT ACTION

VISITORS

Praxair delivered 2 cylinders He + 1 cyl. air.

ACCIDENTS REPORTED TODAY 0
ACCIDENTS TO DATE 0
EPC REPRESENTATIVE [signature]
CLIENT REPRESENTATIVE

6:30 - 5:30

EPC

DAILY FIELD REPORT

JOB NAME	Basin Electric	DATE	7/4/07
PROJECT		REPORT NO.	2
JOB NO.		SHEET	1 OF 1
LOCATION	Minot / EERC	WEATHER	Hot
CLIENT		TEMP	90 AT 3 AM/PM (PM circled)

WORK IN PROGRESS OR COMPLETE (INCLUDING SUBCONTRACTORS):

Arrived @ 7:00 AM. Installed one and tested systems per procedure. Got to last one (system 5) and couldn't find leak. Gave up at 5 & went back to hotel. Found leaks @ the tank inlet & replaced small spool & fitting into valve. Still small leaks @ 4:00 GasCheck went dark!! Replaced batteries - no fix.
No free or electrical work today (Holiday).

CONTRACTOR EQUIPMENT	QUANTITY	CONTRACTOR WORK FORCE	QUANTITY
ICS			2
EPC		Booster Pump	2

VERBAL DISCUSSIONS/INSTRUCTIONS

JP from Hydrogenics arrived late. Said they were waiting for official direction on what to do to start up.
Randy left & Mark to be in tomorrow from Basin

REQUEST FOR PROJECT ACTION

VISITORS

ACCIDENTS REPORTED TODAY 0
ACCIDENTS TO DATE 0
EPC REPRESENTATIVE [signature]
CLIENT REPRESENTATIVE

6:30 - 9:30 AM

EPC

DAILY FIELD REPORT

JOB NAME	Basin Electric	DATE	7/5/07
PROJECT		REPORT NO.	3
JOB NO.		SHEET	1 OF 1
LOCATION	Unit 1 EERC	WEATHER	Rain during night
CLIENT		TEMP	AT AM/PM

WORK IN PROGRESS OR COMPLETE (INCLUDING SUBCONTRACTORS):

Pumped system 5 to 6000 psi & immediately found small leak at EPC coupling on test port. Depressurized, tightened fitting & repressurized at about 7:30. Mark arrived from Basin a little after 8:00 and observed recorded pressure. We let it sit for another half hour then signed it off. We then unblanked the line & connected it to the tank isolation valve which we thought was leaking. Pressurized to 6600 and pressure held solid for 25 minutes. Depressurized. Packed up & left the site at 9:30 AM.

CONTRACTOR EQUIPMENT	QUANTITY	CONTRACTOR WORK FORCE	QUANTITY
ECS	2		
EPC	2		
Hydrogenics	1		

VERBAL DISCUSSIONS/INSTRUCTIONS

REQUEST FOR PROJECT ACTION

VISITORS

ACCIDENTS REPORTED TODAY
ACCIDENTS TO DATE
EPC REPRESENTATIVE [signature]
CLIENT REPRESENTATIVE

Engineering
Procurement &
Construction, LLC
Energy Independence through Hydrogen and Fuel Cells
12211 W Alameda Parkway, Suite 105
Lakewood, CO 80228
720 974 1709
www.epc4h2.com

July 17, 2007

High Pressure Test Report
Cover Sheet

The project was in Minot, ND for Basin Electric Power Cooperative at the NDSU NCERC location. EPC used an air powered booster pump to apply high pressures to each of 5 test packages, described below and on the test package drawings attached. All high pressure tubing was successfully tested to 6600 psi per the attached procedure. Pressure test forms for each test are also attached.

Material Data
All tubing was 3/8 OD 316 SS, 0.065 wall. Per Swagelok Tube Fitters Manual, 1998 edition, and based on ANSI B31.3, pg 9-6, this tube is designed for a working pressure of up to 6500 psig. Male fittings are rated for 7800 psi and female fittings for 5300 psi (pg 9-10) with a 3.75:1 design factor. All of these are suitable for testing at 6600 psi and operation at the intended design working pressure of 6000 psi.
All tubing, fittings and valves are by Swagelok, except as noted. No material certification or mill test data were available for inclusion with this test documentation.
Supports (Swagelok clamps) were inspected for safe location to minimize whip if a failure should occur and the nominal spacing of 36 inches was prudent.

Legend (on isometric drawings)
Valve type 1:
3/8" Locking
Swagelok
SS-83KS6-LH
Seat PCTFE
6000 PSI @ 100F

Valve type 2:
¼"
Swagelok
6S3NBS4
6000 PSI @ 100F

Valve type 3:
Butech
K106-LT-7-22-HLD
HT#A16155 316 CW
MAWP 10,000 PSI @ 72F

EPC

Flushing & Hydrotest Record

Project: Basin Electric
Date: 7/2/07
System PRESSURE TEST SYSTEM 1

Description of piping system, pipe class or materials of construction, location of blinds, extent of test and other pertinent information (include sketch showing joints, low point drain and high point vents, blinds, etc.):

See attached dwg & ISO.

Started pressure test at 7:50. Raised pressure in ~660 psi increments to full bottle pressure of 2200 psi. Started pump and continued in 660 psi increments. 6600 psi @ 8:22. Pressure gage conn. leaked. Repaired, Reestablished pressure @ 8:46. Test complete 9:16 AM 7/4/07.

Air Blow @ 125 psi for 10 seconds - 2 times. CJG
Air Blow completed: 1:45 PM 7/3/07 CJG - EPC
MMW - BEPC

System walkthrough complete (initials of inspector):

- Hangers installed: ✓
- Springs cold set: ✓ N/A
- Relief valves gagged: ✓ N/A
- Instruments isolated: ✓ N/A
- Pumps/equipment isolated: ✓ N/A
- Insulation removed to expose joints: ✓ N/A

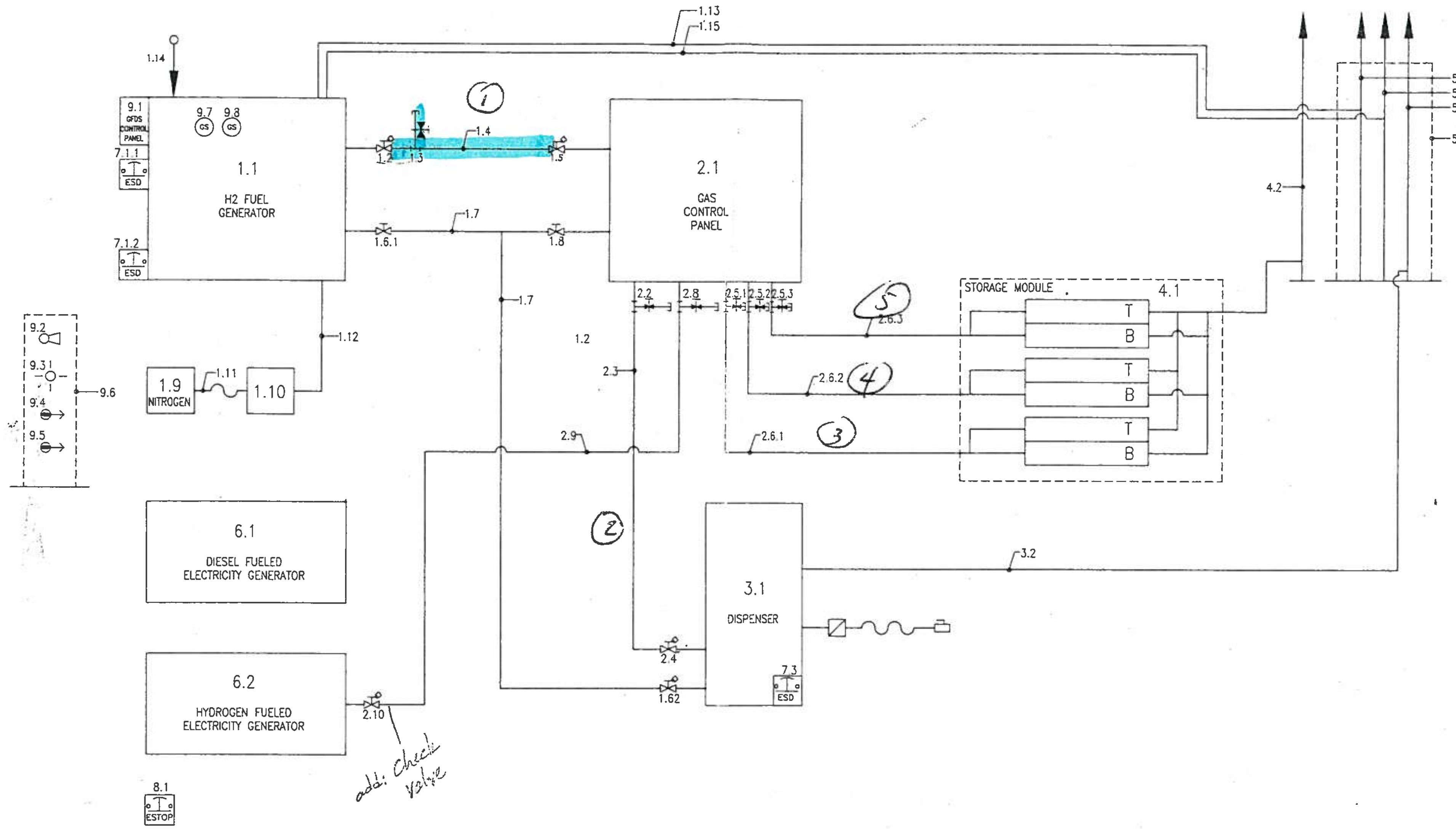
Maximum operating pressure: 6000 Test pressure: 6750 psi
Description of how pressures were determined: 1.1 x MOP

Time test began: 8:46 7/4/07 Time test ended 9:17.

Corrective measures needed, if any: None

System flushing/restoration procedure Left @ 50 psi helium & capped
Reconnected Hydrogenics tubing in gas cabinet
Performed by: John Cornish
Witnessed by: Randall G Busk (RGB)

Test Package # 1



NOTE:
FOR A DETAILED PROCESS AND INTEGRATION DIAGRAM OF THE FUEL GENERATOR, GAS CONTROL PANEL, DISPENSER AND STORAGE MODULE SEE HYDROGENICS DRAWINGS.

REV	DESCRIPTION	DRWN	DSGN	APPD	DATE
0	AS BUILT - BASIN NUMBER AND TITLE BLOCK	L. FROEHLICH	A. BOUSHEE	R. BUSH	5/7/07

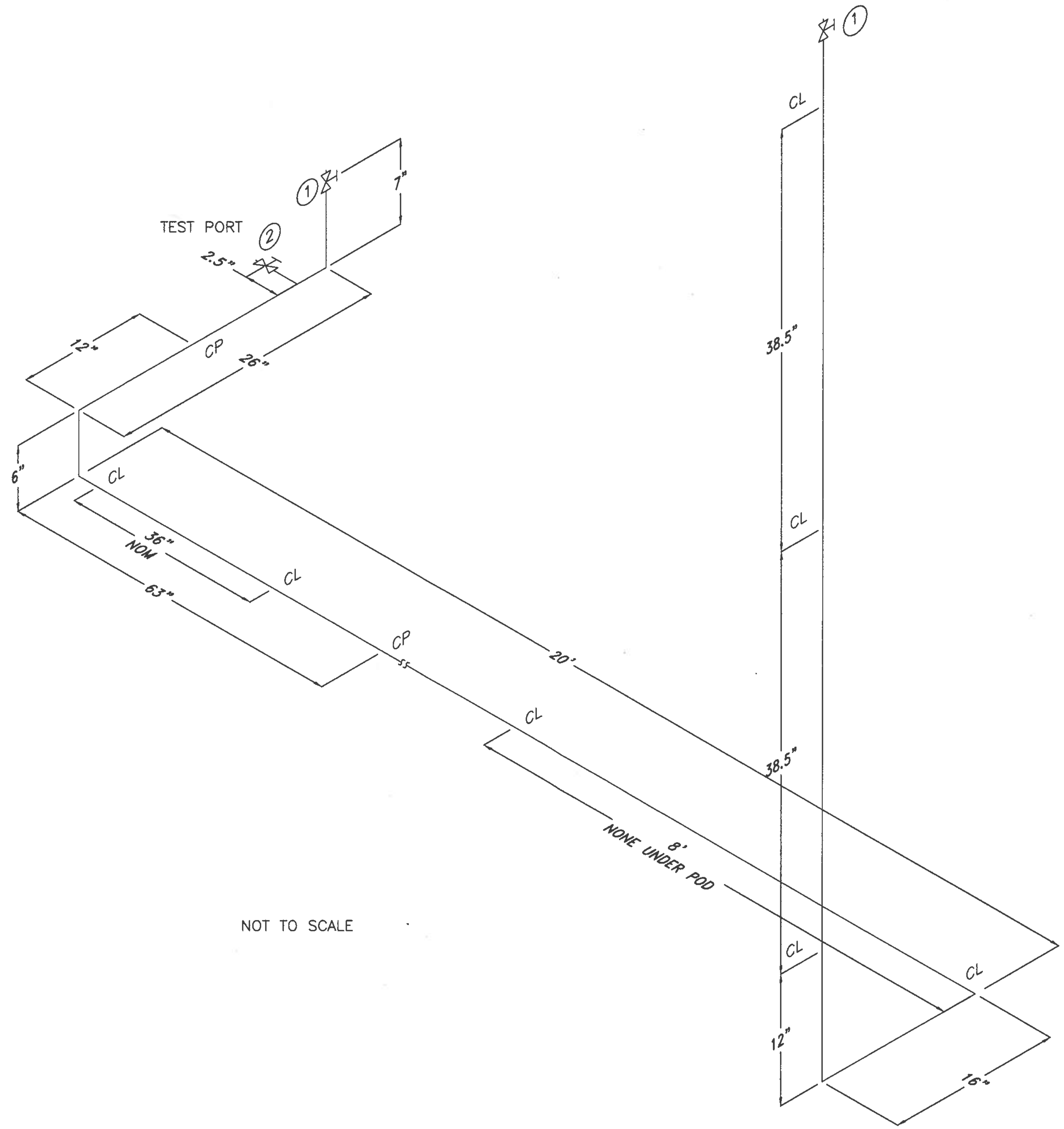
REFERENCE DRAWINGS

FACILITY: WIND TO HYDROGEN SYSTEM
LOCATION/UNIT: MINOT, NORTH DAKOTA
CONTRACT/DESIGNATION:

PROCESS AND INTEGRATION DIAGRAM

BASIN ELECTRIC POWER COOPERATIVE
1717 EAST INTERSTATE AVENUE
BISMARCK, NORTH DAKOTA 58503-0564
PHONE 701-223-0441

DESIGN BY ALBERT KAHN ASSOCIATES
DRAWN BY
DESIGN CHK.
DRFT CHK.
APPROVED
SCALE NONE
VENDOR/ORIGINATED FROM: ALBERT KAHN ASSOCIATES
VENDOR DRAWING NO. M-300 ORIGINAL REV 5
BASIN DRAWING NO. OMF-0002 REV. NO. 0



LEGEND

CL CLAMP
CP COUPLING
BHC BULKHEAD CONNECTOR
(X) VALUE TYPE (SEE COVER SHEET)

NOT TO SCALE

NO.	DATE	REVISION	DESIGNED BY	DRAWN BY	CHECKED BY	ENGINEER STAMP
0	7/7/07	H2 COMPRESSOR TO CONTROL PANEL LINE		RAY	AJC	

Engineering
Procurement &
Construction, LLC
6221 Chimney Rock Trail
Morrison CO 80465
303-697-8268
www.epc4h2.com

BASIN ELECTRIC

HYDROGEN DISPENSING STATION

LINE 1.4 ISOMETRIC

DWG NO. TEST PACKAGE 1 REV. 0

EPC

Flushing & Hydrotest Record

Project: Basin Electric
Date: 7/4/07
System Pressure Test System 2

Description of piping system, pipe class or materials of construction, location of blinds, extent of test and other pertinent information (include sketch showing joints, low point drain and high point vents, blinds, etc.):

Air blow @ 125 psi for 10 seconds - twice
Air blow complete 1:55 7/3/07 [illegible] EPC (RGB)

System walkthrough complete (initials of inspector):
- Hangers installed: ✓
- Springs cold set: N/A
- Relief valves gagged: N/A
- Instruments isolated: N/A
- Pumps/equipment isolated: N/A
- Insulation removed to expose joints: N/A

Maximum operating pressure: 6000 psi   Test pressure: 6600
Description of how pressures were determined: 1.1 x MOP

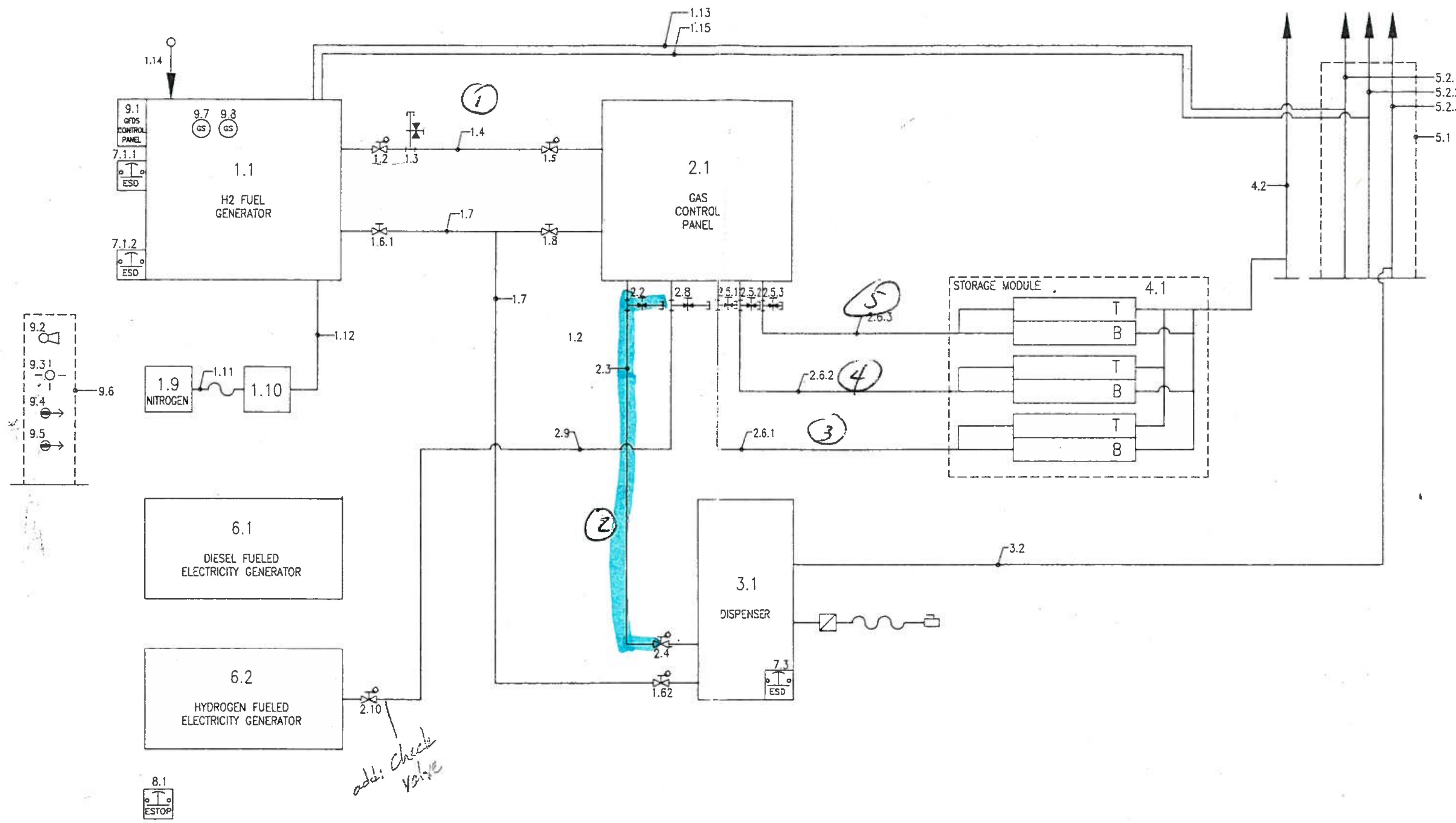
Time test began: 10:00 - 6600 7/4/07   Time test ended 10:30

Corrective measures needed, if any:
~~[illegible]~~ Tightened 150.0 [illegible] in dispenser during prelim-test

System flushing/restoration procedure
Reconnected tubing in Hydrogenics gas cabinet.

Performed by: John Cornwell
Witnessed by: Randall G Bush (RGB)

Test Purge #2



NOTE:
FOR A DETAILED PROCESS AND INTIGRATION DIAGRAM OF THE FUEL GENERATOR, GAS CONTROL PANEL, DISPENSER AND STORAGE MODULE SEE HYDROGENICS DRAWINGS.

REFERENCE DRAWINGS

REV.	DESCRIPTION	DRWN	DSGN	APPD	DATE
0	AS BUILT – BASIN NUMBER AND TITLE BLOCK	L. FROEHLICH	A. BOUSHEE	R. BUSH	5/7/07

FACILITY: WIND TO HYDROGEN SYSTEM
LOCATION/UNIT: MINOT, NORTH DAKOTA
CONTRACT/DESIGNATION:

PROCESS
AND
INTEGRATION DIAGRAM

BASIN ELECTRIC POWER COOPERATIVE
1717 EAST INTERSTATE AVENUE
BISMARCK, NORTH DAKOTA 58503-0564
PHONE 701-223-0441

DESIGN BY ALBERT KAHN ASSOCIATES
DRAWN BY
DESIGN CHK.
DRAFT CHK.
APPROVED
SCALE: NONE
VENDOR/ORIGINATED FROM: ALBERT KAHN ASSOCIATES
VENDOR DRAWING NO. M-300
ORIGINAL REV 5
BASIN DRAWING NO. OMF-0002
REV. NO 0

EPC

Flushing & Hydrotest Record

Project: Basin Electric
Date: 7/3/07
System Pressure Test System 3

Description of piping system, pipe class or materials of construction, location of blinds, extent of test and other pertinent information (include sketch showing joints, low point drain and high point vents, blinds, etc.):

See attached dwg & iso.

Air blow @ 125 psi for 10 seconds - twice.
Air Blow Completed: 2:00 PM 7/3/07 [illegible] - EPC
RGB

System walkthrough complete (initials of inspector):

- Hangers installed: ~~[illegible]~~ ✓
- Springs cold set: N/A
- Relief valves gagged: N/A
- Instruments isolated: N/A
- Pumps/equipment isolated: N/A
- Insulation removed to expose joints: N/A

Maximum operating pressure: 6000 psi Test pressure:
Description of how pressures were determined: from eng. dwgs 1.1 x MOP

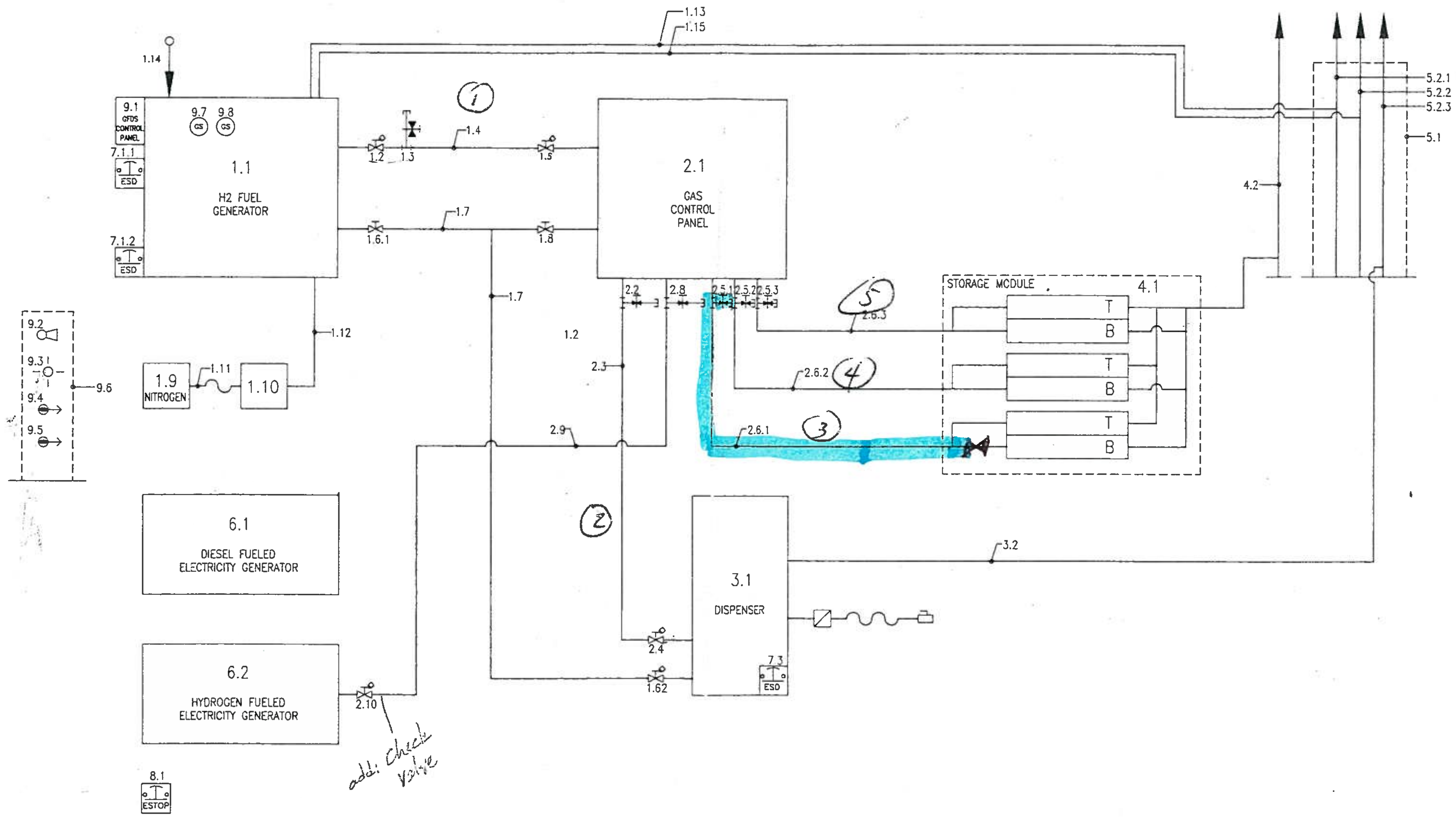
Time test began: 7/4/07. ~~11:17~~ AM 12:11 Time test ended 12:46

Corrective measures needed, if any:
At 3000 psi, ferrule on back side of test port required tightening - fixed before going to full pressure. After 1/2 hour P = 6580. No leaks found @ 10⁵ ppm so started retest. Typical gauge. 6630 (a little white between needle & 6600)

System flushing/restoration procedure
Reconnected Hydrogenics tubing in gas cabinet.

Performed by: John Coensis
Witnessed by: Randall G Bush (RGB)

Test Package #3



NOTE:
FOR A DETAILED PROCESS AND INTIGRATION DIAGRAM OF THE FUEL GENERATOR, GAS CONTROL PANEL, DISPENSER AND STORAGE MODULE SEE HYDROGENICS DRAWINGS.

REV	DESCRIPTION	DRWN	DSGN	APPD	DATE
0	AS BUILT – BASIN NUMBER AND TITLE BLOCK	L. FROEHLICH	A. BOUSHEE	R. BUSH	5/7/07

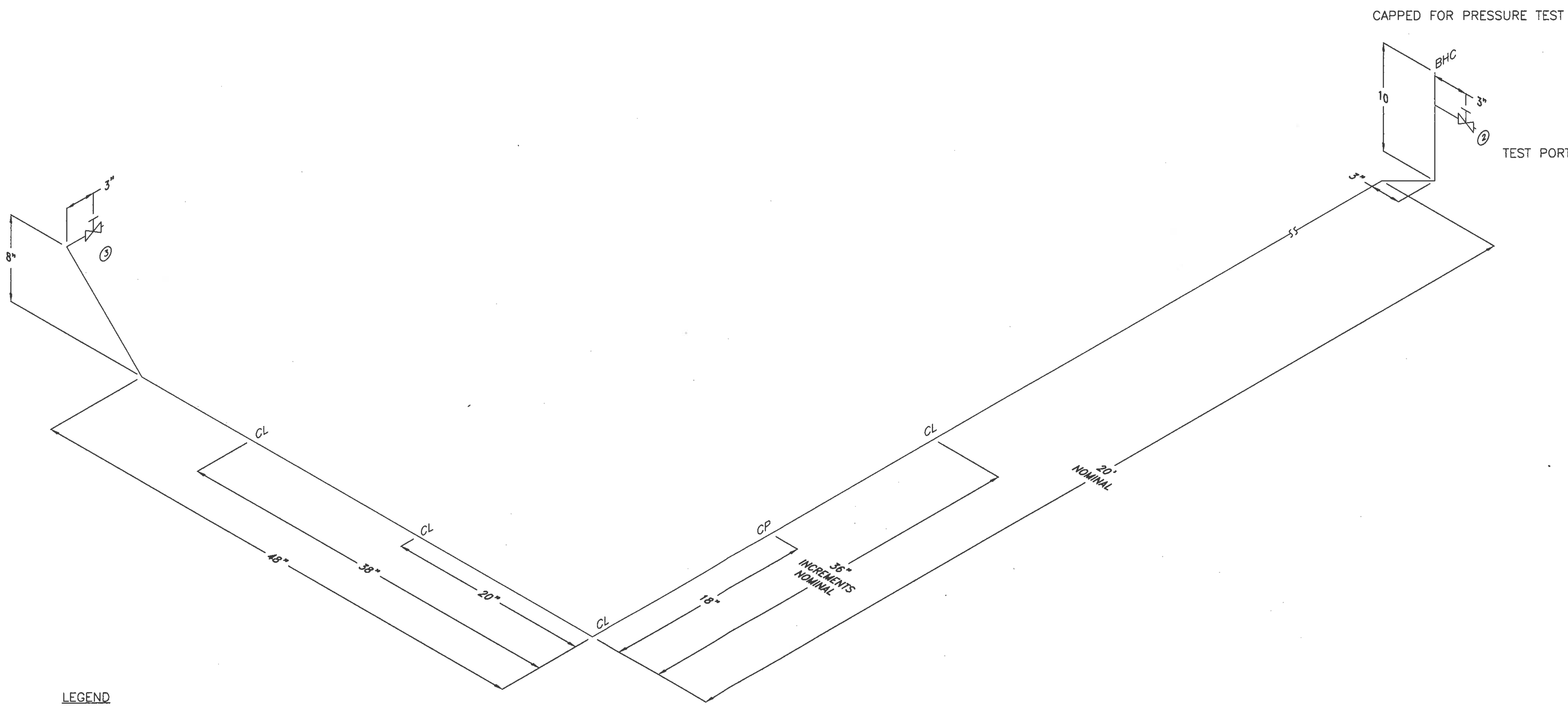
REFERENCE DRAWINGS

FACILITY: WIND TO HYDROGEN SYSTEM
LOCATION/UNIT: MINOT, NORTH DAKOTA
CONTRACT/DESIGNATION:

PROCESS
AND
INTEGRATION DIAGRAM

BASIN ELECTRIC POWER COOPERATIVE
1717 EAST INTERSTATE AVENUE
BISMARCK, NORTH DAKOTA 58503-0564
PHONE 701-223-0441

DESGN BY: ALBERT KAHN ASSOCIATES
DRAWN BY:
DESGN CHK:
DRFT CHK:
APPROVED:
SCALE: NONE
VENDOR/ORIGINATED FROM: ALBERT KAHN ASSOCIATES
VENDOR DRAWING NO.: M-300
ORIGINAL REV: 5
BASIN DRAWING NO.: OMF-0002
REV NO.: 0



LEGEND

CL CLAMP
CP COUPLING
BHC BULKHEAD CONNECTOR
(X) VALVE TYPE (SEE COVER SHEET)

NOT TO SCALE

NO.	DATE	REVISION	DESIGNED BY	DRAWN BY	CHECKED BY
0	7/7/07	CONTROL PANEL TO H2 STORAGE LINE		RAY	AJC

ENGINEER STAMP

Engineering Procurement & Construction, LLC
6221 Chimney Rock Trail
Morrison CO 80465
303-697-9266
www.epc4h2.com

BASIN ELECTRIC
HYDROGEN DISPENSING STATION
LINE 2.6.1 ISOMETRIC
DWG NO. TEST PACKAGE 3 REV. 0

EPC

Flushing & Hydrotest Record

Project: Basin Electric
Date: 7/3/07
System Pressure Test System 4

Description of piping system, pipe class or materials of construction, location of blinds, extent of test and other pertinent information (include sketch showing joints, low point drain and high point vents, blinds, etc.):

Air Blow performed at 125 psi for 10 seconds - twice
Air Blow Completed: 2:05PM. [illegible] RCB

System walkthrough complete (initials of inspector):

- Hangers installed: ✓
- Springs cold set: N/A
- Relief valves gagged: N/A
- Instruments isolated: N/A
- Pumps/equipment isolated: N/A
- Insulation removed to expose joints: N/A

Maximum operating pressure: 6000 psi. Test pressure: 6650 (just below center)
Description of how pressures were determined: 1.1 MOP

Time test began: 1:20 PM Time test ended

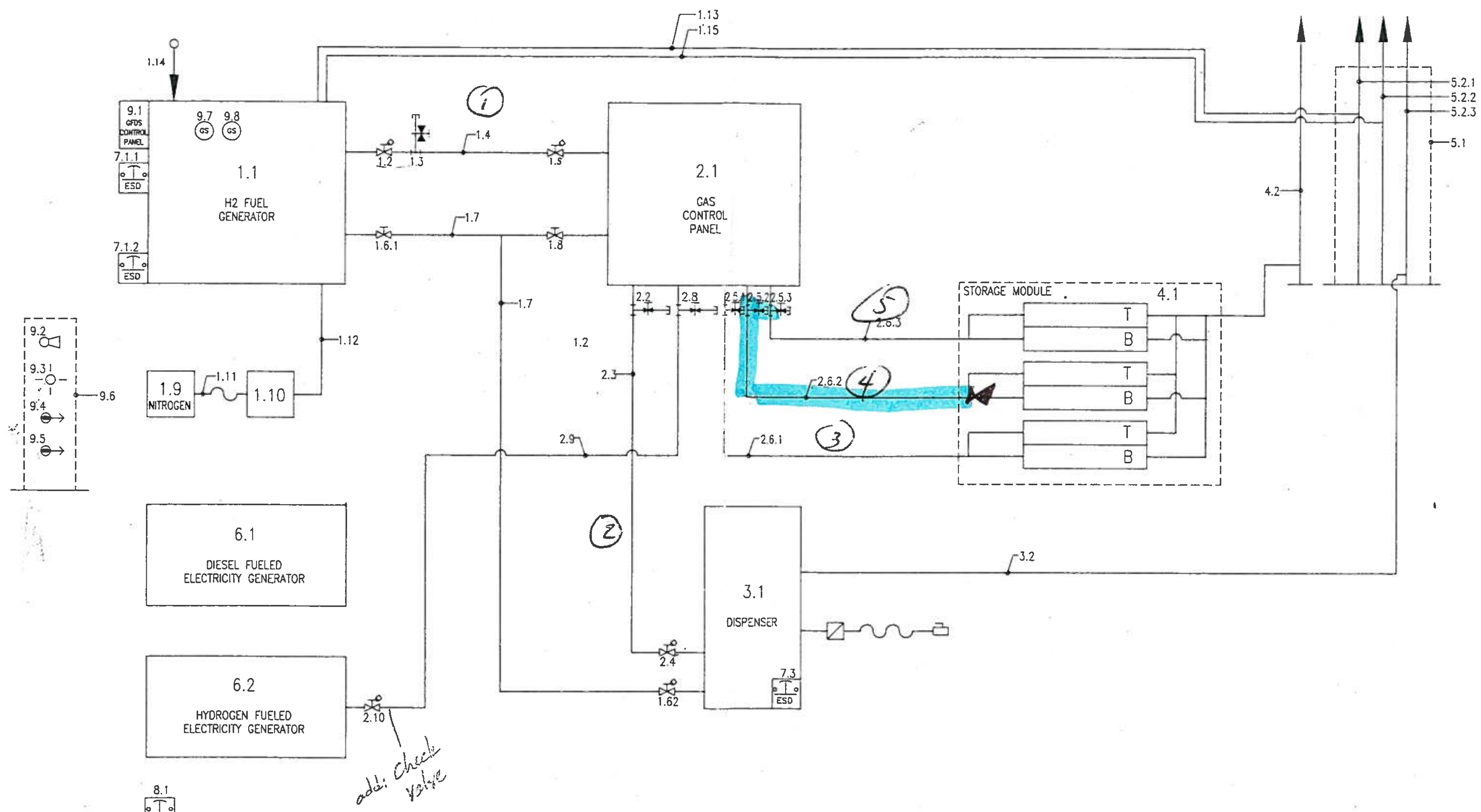
Corrective measures needed, if any:

NONE

System flushing/restoration procedure reconnected Hydrogenics tubing in gas cabinet

Performed by: John Cornish.
Witnessed by: Randall G Bost RGB

Test Package # 4



NOTE:
FOR A DETAILED PROCESS AND INTEGRATION DIAGRAM OF THE FUEL GENERATOR, GAS CONTROL PANEL, DISPENSER AND STORAGE MODULE SEE HYDROGENICS DRAWINGS.

REV.	DESCRIPTION	DRWN	DSGN	APPD	DATE
0	AS BUILT - BASIN NUMBER AND TITLE BLOCK	L. FROEHLICH	A. BOUSHEE	R. BUSH	5/7/07

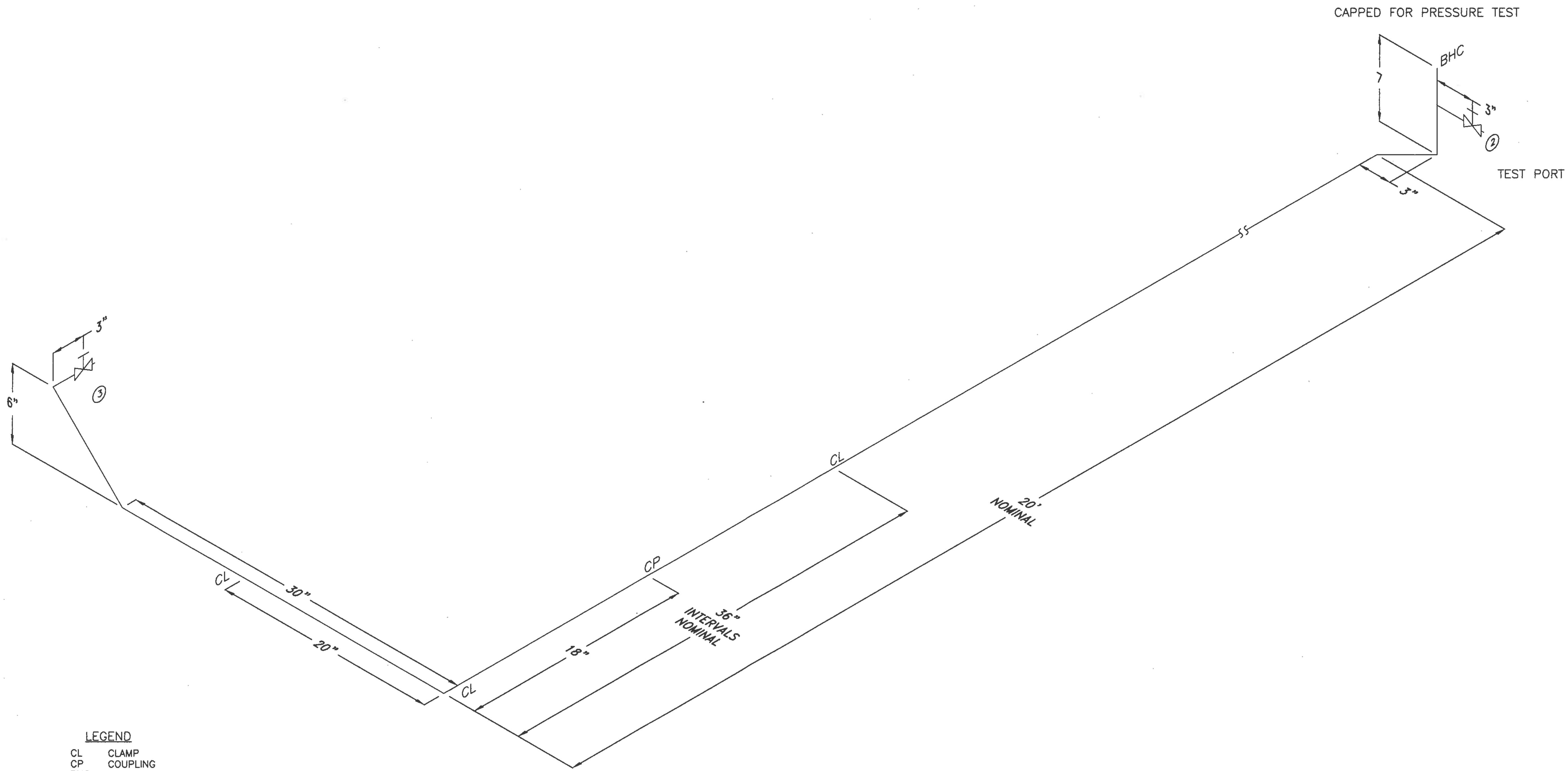
REFERENCE DRAWINGS

FACILITY: WIND TO HYDROGEN SYSTEM
LOCATION/UNIT: MINOT, NORTH DAKOTA
CONTRACT/DESIGNATION:

PROCESS
AND
INTEGRATION DIAGRAM

BASIN ELECTRIC POWER COOPERATIVE
1717 EAST INTERSTATE AVENUE
BISMARCK, NORTH DAKOTA 58503-0564
PHONE 701-223-0441

DESIGN BY ALBERT KAHN ASSOCIATES
DRAWN BY
DESIGN CHK.
DRFT CHK.
APPROVED
SCALE: NONE
VENDOR/ORIGINATED FROM: ALBERT KAHN ASSOCIATES
VENDOR DRAWING NO. M-300
ORIGINAL REV 5
BASIN DRAWING NO. OMF-0002
REV. NO. 0



LEGEND

CL CLAMP
CP COUPLING
BHC BULKHEAD CONNECTOR
(X) VALVE TYPE (SEE COVER SHEET)

NOT TO SCALE

NO.	DATE	REVISION	DESIGNED BY	DRAWN BY	CHECKED BY
0	7/7/07	CONTROL PANEL TO H2 STORAGE LINE		RAY	AJC

ENGINEER STAMP

Engineering Procurement & Construction, LLC
6321 Chimney Rock Trail
Morrison CO 80465
303-697-9288
www.epc4h2.com

BASIN ELECTRIC
HYDROGEN DISPENSING STATION
LINE 2.6.2 ISOMETRIC
DWG NO. TEST PACKAGE 4 REV. 0

EPC

Flushing & Hydrotest Record

Project: Basin Electric
Date: 7/5/07
System Pressure Test System 5-

Description of piping system, pipe class or materials of construction, location of blinds, extent of test and other pertinent information (include sketch showing joints, low point drain and high point vents, blinds, etc.):

This form documents retesting on 7/5/07.

System walkthrough complete (initials of inspector):
Hangers installed: ✓
Springs cold set: N/A
Relief valves gagged: N/A
Instruments isolated: N/A
Pumps/equipment isolated: N/A
Insulation removed to expose joints: N/A

T = 65°F

Maximum operating pressure: 6000 Test pressure: 6630 (white between needle & 6600)
Description of how pressures were determined: 1.1x mop

Time test began: 7:08 AM 7/5/07 Time test ended 7:56 white still showing

Corrective measures needed, if any: Reconnected under gas cabinet

System flushing/restoration procedure

Performed by: John Oenish
Witnessed by: Mark McWinn (MMW) BEPC

EPC

Flushing & Hydrotest Record

Project: Basin Electric
Date: 7/3/07
System Pressure Test System 5

Description of piping system, pipe class or materials of construction, location of blinds, extent of test and other pertinent information (include sketch showing joints, low point drain and high point vents, blinds, etc.):
See attached iso & dwg.

Air Blow at 125 psi for 10 seconds - twice
Air Blow Completed: 2:08 PM 7/3/07 [initials] EPC (RGB)

System walkthrough complete (initials of inspector):
- Hangers installed: ✓
- Springs cold set: N/A
- Relief valves gagged: N/A
- Instruments isolated: N/A
- Pumps/equipment isolated: N/A
- Insulation removed to expose joints: N/A

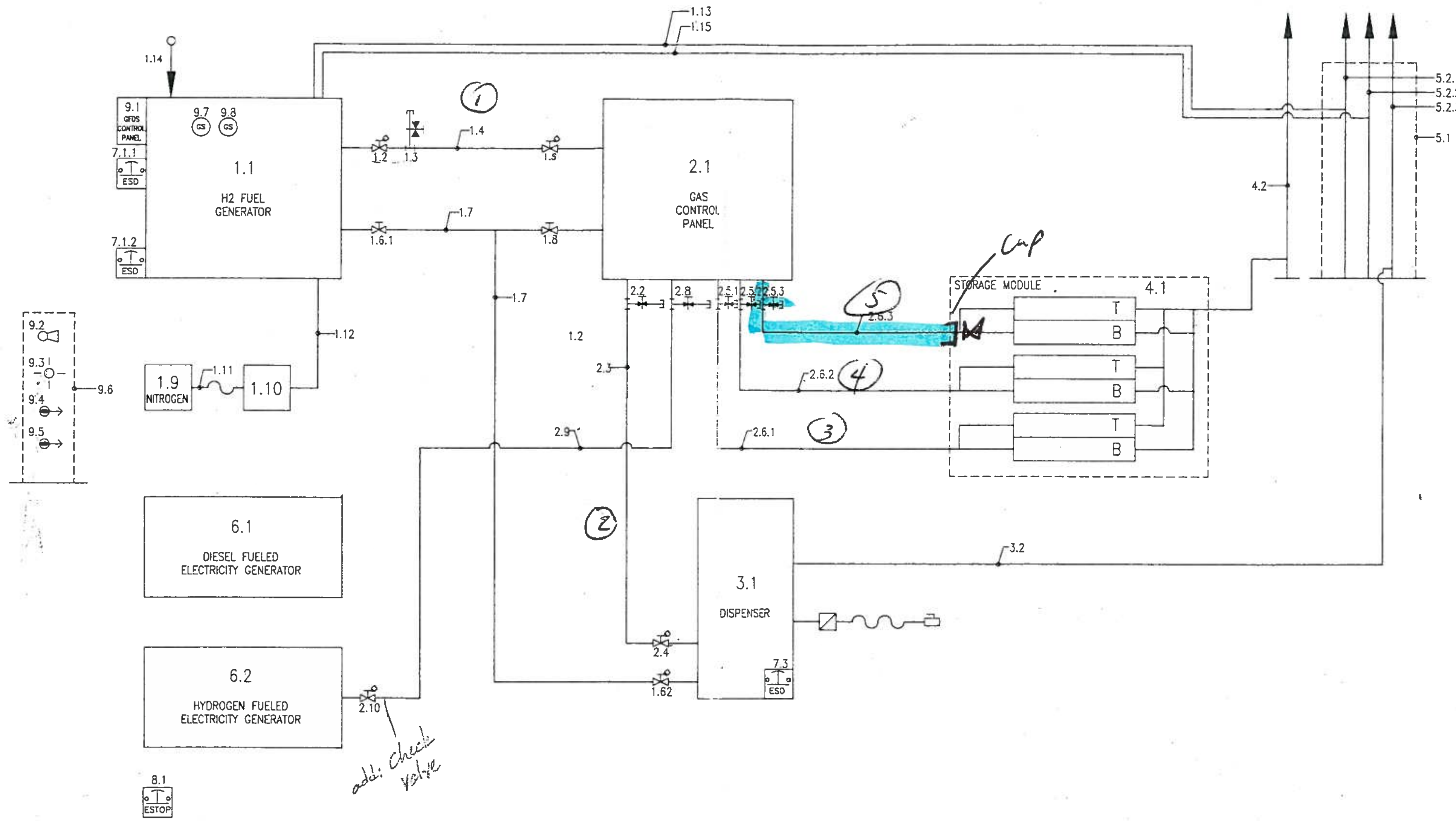
Maximum operating pressure: 6000 psi. Test pressure:
Description of how pressures were determined: 1.1 x MOP.

Time test began: ~~2:28 just in middle of 6600.~~ Time test ended
7/4/07. ~~3:38 just at 6600.~~

Corrective measures needed, if any:
Fitting at Tank valve had slow leak & had to be replaced. Twice!

System flushing/restoration procedure
Reconnected Hydrogenics tubing in gas cabinet
Performed by: John Cornish
Witnessed by:

Test Package # 5



NOTE:
FOR A DETAILED PROCESS AND INTEGRATION DIAGRAM OF THE FUEL GENERATOR, GAS CONTROL PANEL, DISPENSER AND STORAGE MODULE SEE HYDROGENICS DRAWINGS.

REFERENCE DRAWINGS

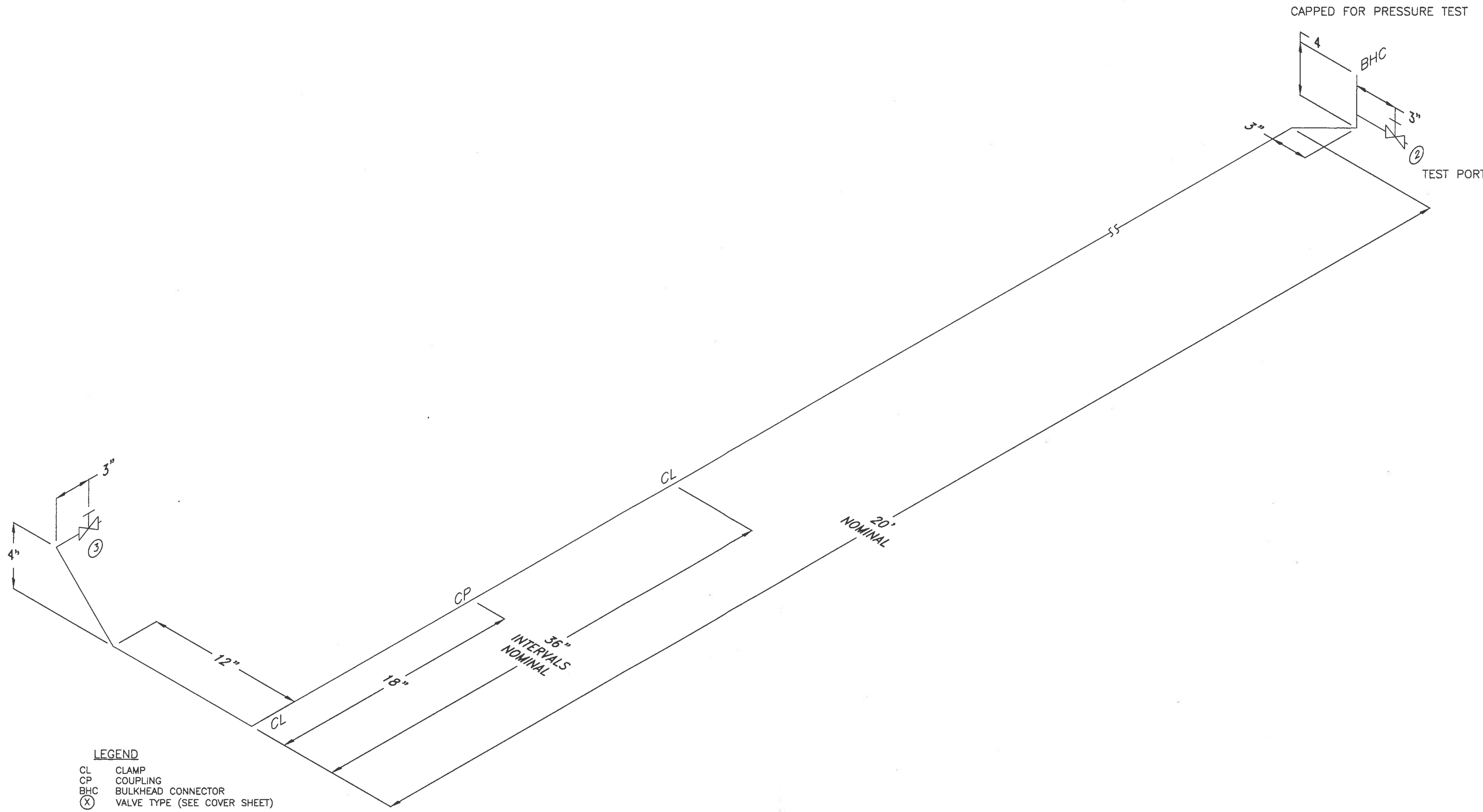
REV.	DESCRIPTION	DRWN	DSGN	APPD	DATE
0	AS BUILT – BASIN NUMBER AND TITLE BLOCK	L. FROEHLICH	A. BOUSHEE	R. BUSH	5/7/07

FACILITY: WIND TO HYDROGEN SYSTEM
LOCATION/UNIT: MINOT, NORTH DAKOTA
CONTRACT/DESIGNATION:

PROCESS
AND
INTEGRATION DIAGRAM

BASIN ELECTRIC
POWER COOPERATIVE
1717 EAST INTERSTATE AVENUE
BISMARCK, NORTH DAKOTA 58503-0564
PHONE 701-223-0441

DESIGN BY: ALBERT KAHN ASSOCIATES
DRAWN BY:
DESIGN CHK.
DRAFT CHK.
APPROVED
SCALE: NONE
VENDOR/ORIGINATED FROM: ALBERT KAHN ASSOCIATES
VENDOR DRAWING NO. M-300 ORIGINAL REV 5
BASIN DRAWING NO. OMF-0002 REV NO. 0



LEGEND

CL CLAMP
CP COUPLING
BHC BULKHEAD CONNECTOR
(X) VALVE TYPE (SEE COVER SHEET)

NOT TO SCALE

NO.	DATE	REVISION	DESIGNED BY	DRAWN BY	CHECKED BY
0	7/7/07	CONTROL PANEL TO H2 STORAGE LINE		RAY	AJC

ENGINEER STAMP

Engineering Procurement & Construction, LLC
6221 Chimney Rock Trail
Morrison CO 80465
303-697-9268
www.epc4h2.com

BASIN ELECTRIC

HYDROGEN DISPENSING STATION

LINE 2.6.3 ISOMETRIC

DWG NO. TEST PACKAGE 5 REV. 0

APPENDIX D

NATIONALLY RECOGNIZED TESTING LABORATORY CERTIFICATION REPORT

APPENDIX D

NATIONALLY RECOGNIZED RESTING LABORATORY CERTIFICATION REPORT

QPS Final Certification Documentation

A SCC Accredited Certification, Testing & Inspection Body

Customer File No: **QEFC 35100**	Report No: **QEFC 35100 - 8**	Issue Date: October 09, 2007
Issued By (QPS): Rafael Colón	Approved By (QPS): Jim Morrison, C.E.T, C.E.I. (reviewed for ordinary locations)	
Approved By (SGS): Jim Morrison, C.E.T, C.E.I		
Customer Name: Hydrogenics Corporation	Address: 5985 McLaughlin Road, Mississauga, ON	
Contents: Certificate of Conformity; Report: Pages 1 to 22; Photographs: Pages 15 & 16; Attachments: None		

PRODUCT LABELLED

1) Hydrogen Hystat-A System gas generator and compressor manufactured by Hydrogenics
   Model Number: 1000D/30/454
   Serial Number: P06081-001
   Power Supply: 480 Vac, 3 Ph, 60 Hz, 175W
   Ambient Temperature - 40°C + 40°C (-40°F to +104°F)
   Hydrogen Production Rate: 17.6 cfm (30N m^3/h)
   Hydrogen Discharge Pressure: 6600 psi (454 bar-g)
   Oxygen Production Rate: 8.8 cfm (15 N m^3/h)
   Oxygen Discharge Pressure: 145 psig (10 bar-g)
   Water Inlet Flow Rate : 20 gph (100 l/h)
   Water Inlet Max Pressure: 43.5 psig (3bar-g)
   Hazardous location rating: Electrical Room & Water Room: Non Hazardous,
   Process Room: Class I Div 2, Group B, T1
2) Power Rack, (Rectifier)
   Model Number: 100D/30/454
   Serial Number: P06081-002
   Power Supply: Input 480, 3 ph, 60 Hz, 400A, 35 KA
   Output Cell stack 1: 200 Vdc, 440 Amps
3) Control Panel (main electrical cabinet)
   Model Number: 100D/30/454
   Serial Number: P06081-003
   Power Supply: 480 Vac, 3 ph, 60 Hz, 125 A, 35 KA

4) Compressor Panel (main electrical cabinet)
   Model Number: 100D/30/454
   Serial Number: P06081-004
   Power Supply: 480 Vac, 3 ph, 60 Hz, 20 HP

MANUFACTURER

Hydrogenics Corporation
5985 McLaughlin Road,
Mississauga, Ontario, L5R 1B8

LOCATION OF INSPECTION

Same as above

APPLICABLE STANDARDS

The labelled product was certified to the following standards/codes:

- UL 913: UL Standard for Intrinsically Safe Apparatus and Associated Apparatus for Use in Class I, II and III, Division I, Hazardous (Classified) Location- 7th Edition.
- UL 1604: UL Standard for Electrical Equipment For Use in Class I and II Division 2, and Class III Hazardous (Classified) Locations. Third Edition;
- UL508: Standard for Industrial Control Equipment. (17th Edition, 2005 ANSI adopted)
- UL 508A: Standard for Industrial Control Panels 1st Edition
- NFPA 70 National Electrical Code 2005 Edition, Article 500, Hazardous (Classified) Locations, Classes I, II, III Division 1 and 2.

LABEL LOG

Field Certification Serial Number		Equipment Serial Number
Label No:	**S 10065**	Hystat-A System Serial Number: P06081-001
Label No:	**S 10066**	Control Panel, Serial Number: P06081-003
Label No:	**QSF 10004**	Power Rack, Serial Number: P06081-002
Label No:	**QSF 10002**	Compressor Panel, Serial Number: P06081-004

MODIFICATIONS REQUIRED

Upon examination of the subject product on location, the modifications listed below were required by QPS to bring the product into compliance with the applicable standard(s) and have been incorporated into the labelled product.

- Drain Vessel in the generation area shall be marked with type of liquid & quantity.
Corrected, label verified in place: "condensate collection tank, capacity 650 Liters".

- Drainage and cable entrance of main electrical cabinet in water supply room: There is a probability of liquid from the pump unit or at any other point in the room flood the electrical cabinet in the water supply room. The cables are entering to cabinet at the floor level allowing liquid not trapped by the drain reach the internals of the electrical cabinet. See Article 501.15 (f) (1), NEC 70.
Corrected, ¾ x ¾ angles welded rear to the electrical at the floor level.

- Assembly techniques of components in the hazardous area. Solenoid valves need to be mechanically secured and mounted in position that will prevent them being exposed to mechanical damage.
Corrected

- Openings in walls: Openings in walls for cables and conduits between hazardous and non-hazardous areas shall be adequately sealed.
Correct: Cables passing through listed UL cable glands specific for multi passage cables.

- Explosion proof enclosure of the heater in the classified hazardous area is not sealed protected.
Corrected, air heater is UL listed 317H, Class I Group B, C and D. Seal was verified in place at this time.

- Intrinsically safe conductors in the hazardous areas have several contact points with other non intrinsically safe circuits along the raceway and also verified in the main electrical cabinet.
Corrected: IS circuits were separated, and rearranged in the race way. All verified in accordance with the code.

- The intrinsically safe circuits are not mechanically separated in the raceway and are not identified.
Corrected: labels in place identifying IS circuits.

- IS barriers Tag numbers 855A2, 855A5, 855A8 and 856A2, are barriers without function in the installation and shall be removed of the electrical cabinet.
Corrected: barriers removed.

- Bare live parts of all electrical parts in the Power Rack, (rectifier) is to be guarded so adequate provision is made for the safety of persons and protection of mechanical equipments.
Corrected: Bare live parts of Power Rack were covered and protected against tools or personnel access.

- Bare live parts of stacks 1 and 2 are to be guarded so adequate provision is made for the safety of persons and protection of mechanical equipments.
Corrected: Stacks properly covered and protected against tools or personnel access.

- Intrinsically safe grounding and bounding equipment: It is recommended to review bounding and grounding of shielded wiring in junction boxes. For intrinsically safe and non incendive wires, shield shall be grounded in the non-hazardous area at one point only.
Corrected: IS wires, shield grounded in the electrical cabinet, non hazardous section, electrical installation reviewed.

- Equipment located in hazardous area shall be marked its designated area: three heaters modules in the hazardous area do not contain hazardous markings for Class I Div 2 and Temperature code. In addition these heaters do not bear approval markings for USA or Canada.
Corrected: Heaters verified **c CSA us** ***approved, maximum temperature also indicated in the name plate.***

- HySTAT-A System shall be provided with a nameplate of a permanent nature and of corrosion resistive material, which is to be located on the outside of the Marine Container enclosure by the main disconnect power at the entrance.
Corrected: name plate verified in place.

- HySTAT-A System shall be provided with disconnecting means which shall be suitably rated for the application and which shall be installed in accordance with NEC 66.6.1/2/3 (a)(b)(c).
Corrected: disconnect switch provided, it is a Cutler Hammer heavy duty safety switch, 480 Vac.

-HySTAT –A System Disconnecting means shall be marked with the ON and OFF positions.
Corrected: Markings provided with the panel manufacturer.

- The following or equivalent caution markings shall be applied on the disconnect switch outside of the HySTAT-A System, Main Control Panel and Power Rack- by the main nameplate: CAUTION - HIGH VOLTAGE 480V
Corrected

- Main electrical cabinet (control panel) shall be provided with a nameplate of a permanent nature and of corrosion resistive material, which is to be located on the outside of the enclosure.
Corrected: name plate verified in place.

- Main electrical Cabinet shall be provided with disconnecting means which shall be suitably rated for the application and which shall be installed in accordance with NEC 66.6.1/2/3 (a)(b)(c).
Corrected: Disconnect switch provided, Cutler Hammer heavy duty safety switch, 480 Vac. (pull handle and disconnect switch at the door removed)

- The following or equivalent caution markings shall be applied on the Main electrical Cabinet nameplate: DISCONNECT 30Q1 SWITCH BEFORE OPENING
Corrected, warning label verified in place.

- Compressor Control Panel shall be provided with a nameplate of a permanent nature and of corrosion resistive material, which is to be located on the outside of the enclosure.
Corrected: name plate verified in place.

- Compressor Control Panel shall be provided with disconnecting means which shall be suitably rated for the application and which shall be installed in accordance with NEC 66.6.1/2/3 (a)(b)(c).
Corrected: Disconnect switch provided, Cutler Hammer heavy duty safety switch, 480 Vac.

- In the utility room, metering pump and centrifugal pumps 740M2 ,740M5 752M7 and 753M2 shall be provided with disconnecting means which shall be suitably rated for the application and which shall be installed in accordance with NEC 66.6.1/2/3 (a)(b)(c).
Corrected: Disconnect switch provided, it is a Cutler Hammer heavy duty safety switch, 480 Vac. Also all disconnects were verified with proper Tag number identifying pumps and caution marling 40 Volts.

- All 3 phase in the block distribution of control panels, and cable entrance of power rack shall have the input terminals identified with: L1 L2 L3
Corrected, L1 L2 and L3 verified in place.

- Provide updated complete electrical schematics wiring diagram
Corrected, Drawings Revision 8 provided.

- Each heater shall be provided with the following or equivalent caution markings - adjacent to the space heater: CAUTION – HOT SURFACE
Corrected

- The safety interlock key at the door of the power rack panel is verified non operational, there is no safety and the key is not cutting power when door is open. The latch of the sensor was verified positioned in the sensor and shall riveted in place at the door.
Corrected

- Battery terminals, connectors and wiring in the electrical control panel shall have the polarity identified. In addition batteries shall be guarded so adequate provision is made for the safety of persons and protection of tools.
Corrected

- The following labels shall be placed in the batteries section
- "Caution risk of explosion if battery is replaced by an in corrected type"
- "Dispose of Batteries in accordance with local regulations"
- Caution –Battey Circuits Live When Main D/C Off – 240 VA
- The following marking:

All markings and labels verified in place, Corrected

-Receptacle in the electrical control cabinet, to be marked with maximum amperage allowed and the following marking: " Isolated Power"
Corrected, now indicating 12 Amps maximum

- Switches in the utility room shall have metal covers for the application.
Corrected, plastic covers removed

- The following marking shall appear on Hystat-A disconnect means, Control Panel, disconnect means of Control Panel tag 30Q1, Power Rack, Compressor Panel, disconnect means of Compressor Panel and all disconnecting means located in the water supply room.

Corrected, verified in all panels and disconnect means listed above.

- Junction box of the compressor in the hazardous area shall Door panel be bonded to the chassis ground and the conductor shall be green colour & sized no. 14 awg min. The connections shall terminate on separate no. 6 bolt, starlockwasher & nut assembly. Both ends of the bonding conductor shall terminate in ring connectors.
Corrected, Bonding and grounding issues, all verified in the final inspection, all verified corrected.

MARKINGS

Markings on the Equipment: The labelled product is plainly marked in a permanent manner in a place where the details are readily visible after installation with the following:

1) Markings <u>Hystat-A system</u>

a) On the exterior of Hystat-A system

Hydrogen Hystat-A System gas generator and compressor manufactured by Hydrogenics
Model Number: 1000D/30/454
Serial Number: P06081-001
Power Supply: 480 Vac, 3 Ph, 60 Hz, 175W
Hazardous location rating: Electrical Room: Non Hazardous,
Water Room: Non Hazardous
Process Room: Class I Div 2, Group B, T1
Outdoor use, 3R
Ambient Temperature - 40°C + 40°C (-40°F to +104°F)
Power Supply: Input
480 V, 3 hp, 60 Hz, 400 A, 35 K SCC
Largest Motor: 480 V, 20 HP, 3 ph, 60 hz,
Outputs
Dispenser
120 Vac, 1 ph, 60 Hz, 175 W
24V dc, 6 Amps,
Heat Trace:
120 Vac, 1 ph, 60 Hz, 360 W, 3 circuits.

Hydrogen Production Rate: 17.6 cfm (30N m^3/h)
Hydrogen Discharge Pressure: 6600 psi (454 bar-g)
Oxygen Production Rate: 8.8 cfm (15 N m^3/h)
Oxygen Discharge Pressure: 145 psig (10 bar-g)
Water Inlet Flow Rate: 20 gph (100 l/h)
Water Inlet Max Pressure: 43.5 psig (3bar-g)

The QPS/SGS label applied to the name plate.

2) Warning/Caution Notices Hystat-A system

a) On the Hystat-A System name plate

- Install in a Non Hazardous Area
- Refer to Control Drawing P06081 before servicing the equipment
- Intrinsically Safe Device [ia]
- Do not service this equipment unless area is know to be non-hazardous
- See maintenance manual for instructions before servicing this equipment.

b) Warning Labels to be placed at the doors of the process area

CAUTION High Pressure Gas System
Class I, Div 2, Group B, T1

c) Warning Label to be placed on the main disconnect switch of Hystat-A system

HYSTAT SYSTEM MAIN DISCONNECT
480 VOLTS

2) Markings of Control Panel

2a) On the exterior of Control Panel

Model Number: 100D/30/454
Serial Number: P06081-003
Power Supply: 480 Vac, 3 ph, 60 Hz, 125 A, 35 KA
Ambient Temperature - 40°C + 40°C (-40°F to +104°F)

Power Supply:
Input:
480 V, 3 hp, 60 Hz, 125 A, 35 K SCC
Largest Motor: 480 V, 20 HP, 3 ph, 60 hz
Outpus:
Heating Doxo:
120V, 1 Ph, 60 Hz, 1.2 kW
Heating Drier A:
120V, 1 Ph, 60 Hz, 1.2 kW
Heating Drier B:
120V, 1 Ph, 60 Hz, 1.2 kW
RO pressure Pump:
115V, 1 Ph, 60 Hz, 1HP
RO anti-scalent Pump
115V, 1 HP, 60 Hz, 0.8A
CLC Heating Blower 1:
120 V, 1 ph, 60 Hz, 0.11 kW
CLC Heating Blower 2:
120 V, 1 ph, 60 Hz, 0.11 kW
Air Compressor Drier:
120V, 1 Ph, 60 Hz, 0.15A
Air compressor:
480V, 3 HP, 60 Hz, 0.9A

Chiller:
480V, 3 HP, 60 Hz, 7.2A
H2 Compressor:
480V 3 ph, 60 Hz, 3.4A
Ex heating 1:
480V, 3 Ph, 60 Hz, 3.2 kW
Heating EPS:
480V, 3 ph, 60 Hz, 1.7 kW
Heating Utility:
480V, 3 ph, 60 Hz, 1.7 kW
AHU Fan:
480V, 3 ph, 60 Hz, 0.75 HP
AHU heating:
480V, 3 ph, 60 Hz, 24 kW
Dispenser;
120 Vac, 1 ph, 60 Hz, 175 W / 24 Vdc, 10 Amps
Heat Trace:
120 Vac, 1 Ph, 60 Hz, 360W, 3 circuits
Closed loop blower 2:
480V, 3 ph, 60 Hz, 2.15 HP
Regulator pump electrolyte cooling:
480V, 3 ph, 60 Hz, 2.7 A
Closed loop cooling pump:
480V, 3 ph, 60 Hz, 1.5 HP

The QPS/SGS label applied to the name plate.

2b) Warning/Caution Notices Control Panel

- Install in a Non Hazardous Area
- Refer to Control Drawing P06081 before servicing the equipment
- Intrinsically Safe Device [ia]
- Do not service this equipment unless area is know to be non-hazardous
- See maintenance manual for instructions before servicing this equipment.

- WARNING: Substitution of components May Impair intrinsic Safety
- The following label

- DISCONNECT 30Q1 SWITCH BEFORE OPENING
- 480 VOLTS
- The following marking shall be added inside the panel near to where the fuses are located: "Caution – Replace Fuses with Same Type & Rating".

2c) On the <u>disconnect switch Tag No 30Q1</u> (disconnecting means of Control Panel)

- 480 VOLTS
- The following label

2d) on the <u>interior of Control Panel, battery section</u>

- Caution risk of explosion if battery is replaced by an in corrected type
- Dispose of Batteries in accordance with local regulations
- Caution –Battery Circuits Live When Main D/C Off – 240 VA
- The following marking:

2e) On the interior of Control Panel,

All grounding terminals shall be identified with the words "G", "GR" or the international ground symbol (IEC Symbol 5019). [Ref: NEC Article 250.126]
Alternatively, the ground point may be marked "G", "GR", "GRD", "GND", "GRND" "GROUND" "GROUNDING" or use IEC 5019. [Ref: Para. 40.1.5 – UL 508]
Also, a green colored terminal screw with hexagonal head, terminal or pressure wire connector may be used. [Ref: Para. 40.1.5 – UL 508]
Ref: (USA) UL 508 – 40.1.5/UL 508A – 54.5/NEC Article 250.126 NFPA 79 – 8.2.1.2.4

3) Markings <u>Compressor Panel</u>

3a) On the exterior of Control Panel

Model Number: 100D/30/454

Serial Number: P06081-004
Ambient Temperature 10°C to 40°C (50°F to 104°F)
Power Supply:

Input:
480 V, 3 ph, 60 Hz, 35A, SCC 35 kA
Largest Motor:
480 V ac, 20 HP, 3 ph, 60 Hz
Output:
Compressor Heater:
120 V ac, 3 Ph, 60 Hz, 500 W
Compressor motor:
480 Vac, 3 Ph, 60 Hz, 20 HP

The QPS/SGS label applied to the name plate.

3b) Warning/Caution Notices on the external of the Compressor Panel

- See maintenance manual, schematic dwg d-10360-4 for instructions before servicing this equipment.
- The following label

- 480 VOLTS

3c) on the disconnect switch of Compressor Panel

- 480 VOLTS
- The following label

3d) on the <u>interior of Compressor Panel</u>

- Grounding symbol as per IEC 60417 -5019 ⏚ or "GND" or "GD"
- The following marking shall be added inside the panel near to where the fuses are located: "Caution – Replace Fuses with Same Type & Rating".

<u>CONDITIONS OF ACCEPTABILITY/CERTIFICATION</u>

Parts not covered in this report

- Hydrogen storage system, Diesel Generator system and auxiliary services, Field installation of Gas Control Panels and Dispenser interconnecting the Hystat-A module at site in Minot, ND, USA.

- Pressure piping parts and systems under the Technical Standards ands Safety Act, Boilers and Pressure Vessels Regulation is not part of the examination covered by QPS Field Evaluation Services Inc.

General

- The field certified and labeled product has been altered to include the required modifications outlined above.
- The approved construction of the labelled product is as described below in this report.
- Certification is voided if the labeled product has been modified or changed by the manufacturer or end user after labeling, unless the changes have been reviewed and approved in writing by QPS. Verbal approval is not permitted.
- Certification covers only safety from electric shock and fire/explosion hazards, and applies only to the construction elements described in this report.
- QPS did not evaluate the suitability of the use of equipment involving toxic or corrosive gases; steam locations defined as hazardous locations by the National Electrical Code.

DESCRIPTION OF LABELED PRODUCT

The Hystat-A, model Number: 1000D/30/454 is a water electrolysis based product that generates high-purity hydrogen for use in fuelling applications of high pressure storage vessels and/or vehicle fuelling applications.

All modules of Hystat-A are constructed in the internals of a metal shipping container with dimensions approximately 8 Ft (2.4 m) W x 8 Ft (2.4 m) D x 40 Ft (12.2m) L.

The container is segregated in three sections as it follows:

1) EPS room containing the main electrical panel, power rack panel, auxiliary air compressor and control panel, and also the control panel of main compressor in the hazardous area,
2) Water supply room and filtration system,
3) Hydrogen generation room also containing, purification process and gas compression module,

The EPS room and Water supply room are non classified hazardous area and,

System Characteristics of the Control, Generator and Compressor module.

Control module: The control module of the Hystat- A is mounted in the main electrical cabinet in the EPS room. The panel is assembled in a heavy steel frame enclosure, NEMA 3R, with dimensions approximately of 1.64 Ft (0,5 m) W x 1.14 Ft (0,35 m) D x 2.2 Ft (0,7m) L.

Generator module: The generator module contains the two electrolysis cell stacks, gas analysis panel, the electrolyte cooler, gas separator, gas cooler and heating system. The stack is covered and protected against access to components under voltage.

Compressor module: The compressor module is mounted is sequence of the generation and gas separator, close to the forced ventilation system. The room has two electrical motors; the electrical motor of the compressor and also the motor of the ventilation system. The electrical motor with maximum power ratings is the electrical motor of compressor, 20 PH and thermal analysis indicates motor with the hottest temperature classification, T2B (260ºC).

Capacity: The entire system has a generation capacity of 17 cubic feet per minute (30 cubic meters per hour), maximum operational compression is 6600 psi.

Hydrogen Leak Detector System: Two gas detectors manufactured by Zellweger Analytics transmitter model 2110B are used to verify major Hydrogen leaks. One is installed above of the gas compressor module and the second is mounted above the stacks. At 10 % of Hydrogen's Lower Explosive Limit (LEL = 4% H2 in air), the detector activates the ventilation supply system (CFM 2600 capacity) and also shut down the unit at a 25% of LEL.

Electrical Protection

As described in this report, the construction of these units provides the degree of protection against electrical shock, fire and injury required for hazardous (classified) locations.

Area Classification

The system investigated meets the area classification **Class I Division 2,** as per requirements presented in the document: dwg DEI-0001, Basin Electric Power Cooperative Rev 1

Hazardous Locations Wiring

- Wiring connections for intrinsically safe circuits were verified adequately separated from nonintrisically safe circuits.

- Intrinsically safe and non intrinsically safe terminals are separated by use of mechanical barrier in the electrical cabinet.

- The conductors of the intrinsically circuits are placed in raceway and were found in compliance with wiring techniques for intrinsically safe circuits, are identified and also separated from other system or wiring methods.

- Intrinsically safe circuits and wiring were verified designed for the application and were verified in accordance with the design.

Grounding/Bonding:

- All grounding and bonding size of conductors were verified in accordance with the required standards.

- All grounding terminals were verified identified. The terminals shall be identified with the words "G", "GR" or the international ground symbol (IEC Symbol 5019). [Ref: NEC Article 250.126] Alternatively, the ground point may be marked "G", "GR", "GRD", "GND", "GRND" "GROUND" "GROUNDING" or use IEC 5019. [Ref: Para. 40.1.5 – UL 508] Also, a green colored terminal screw with hexagonal head, terminal or pressure wire connector may be used. [Ref: Para. 40.1.5 – UL 508]
Ref: (USA) UL 508 – 40.1.5/UL 508A – 54.5/NEC Article 250.126 NFPA 79 – 8.2.1.2.4

Protective Earthing Method: A green or green/yellow insulated 18 AWG conductor is connected to the protective earth terminal of the power entry module of Hystat Control Panel, by an insulated crimp-type quick connect terminal. The opposite end of the conductor is terminated with a crimp-type, closed-loop connector and secured to the chassis by a plated steel threaded stud, min size No 6 or M4, with a lock washer or star washer and nut.

Bonding Details

- All modules; Electrical Cabinet, Power Rack, Gas Generation System, Hydrogen Purification & Compression System modules, were verified in compliance with the applicable standards and code.

- Enclosures of Control Panel and Power Rack are bonded to the chassis ground connection by masking paint and use of star washers to ensure good metal to metal contact between surfaces.

- When required, paint was masked, star washers, or other positive means were provided to ensure good metal to metal contact between surfaces.

- Fixed equipments mounted in the Hystat - A unit such as the compressor skid, stacks and gas vessels are mounted on the metal frame and exposed non-current-carrying metal parts, including frames, metal exteriors of motors, lighting fixtures, cabinets, were verified properly bonded.

- All bonding connections are looped to the normal grounding wire in the power entrance/feed.

- Isolated sections of metal raceway were verified to be bonded to ground by connections to other grounded raceways or frames.

- The bonding conductors run with a circuit conductor and are provided with individual covering in green color or a green / yellow combination.

- Interconnecting Cables: All interconnecting cables are Certified/Recognized cable having min 0.8mm wire insulation with min 0.8 mm insulation jacket.

- Internal Wiring: All internal wiring is certified and is reliably routed and secured away from sharp edges having a radius less than 1.5 mm. Additional insulation was provided where wiring passes over sharp edges and through holes. Primary and Extra Low Voltage wires are routed and secured away from each other.

T-Code Review and Evaluation

The Hystat-A system are Class I hazardous locations, and the units shall not be installed in an area where vapors or gases are present to have an ignition temperature less than the maximum external temperature found of each equipment.

Generator unit: All components and electrical equipment were verified as analysis revealed that the high surface temperatures found was 445°C. The Hystat-A is awarded T1, based on the surface temperature of heaters located in the generation and compressor area.

Environmental Ratings

The environmental rating of the Hystat-A system was found to be NEMA 3R.

Critical Components:

See "Table of Critical Components" below

Bill of Material

The bill of materials and supported documents provided by the manufacturer are available at QPS under file No QFC 35100-8

Drawings & Supported documents:

- Area Classification Drawing No OEL-001 Rev 1, July 11, 2007, Albert Kahn Associates
- DWG No/project Number P06081, Electrical Diagrams, April 04, 2006, Revision 08, 170 pages
- DWG No S100252-112, Rev 0, Name plate Hydrogenics, Control Panel
- DWG No S100252-113, Rev 0, Name plate Hydrogenics, Power Rack
- DWG No S100252-114, Rev 0, Name plate Hydrogenics, Compressor Panel
- DWG No S100252-115, Rev 0, Name plate Hydrogenics, Hystat-A System
- P&D H2 Process part Hystat-A 10000/30/10, 8 pages
- Intrinsic safety data table P06081, Rev 0
- BOM document No P06081 Control Panel/compressor panel/power Rack BOM, 7 pages
- Basin Electric Power Cooperative Hystat –A Manual S100252
- Basin Electric Power Cooperative Hystat –A Model 4LX-123080 Diaphragm Compressor System
- Electrical Components – Control Panel, Volume 1
- Electrical Components – Power Rack Volume 2
- Electrical Components – Container Volume 3

Tests

The following tests were performed to the Hystat-A unit.

STD	INFORMATION	VERDICT		
CLAUSE NO.		Pass	Fail	N/A
UL 508 Cl. 49.1.2	**Dielectric Voltage Withstand Test**			
	1- H2 Compressor, schematics 770; 1,960 KV/60 sec	X		
	2- Closing Loop Cooling Pump , schematics 752; 1,960 KV/60 sec	X		
	3-Closing Loop Cooling Pump outside, schematics 750 & 751; 1,960 KV/60 sec	X		
	4- H2 Chiller Schematics 760; 1,960 KV/60 sec	X		
	5- Drier Heater, 1,240 KV, 60 sec	X		
	6- Ventilation Group; 1,960 KV/60 sec	X		
	7- Container Heating; 1,960 KV/60 sec	X		
	8- Control Panel, 120 Vac Power Distribution 1,240 KV /60 sec	X		

	9- Control Panel 480 Vac Power Distribution, 1,960 KV/60 sec	X		

TEST EQUIPMENT INFORMATION

Inst. ID No.	Instrument Type	Test Number	Range	Last Cal. Date	Next Cal. Date
Quad Tech Inc USA	Dielectric Strength tester model Sentry plus serial number 71411	1 – 9	As indicated above Vac	April 23, 2007	April 23, 2008

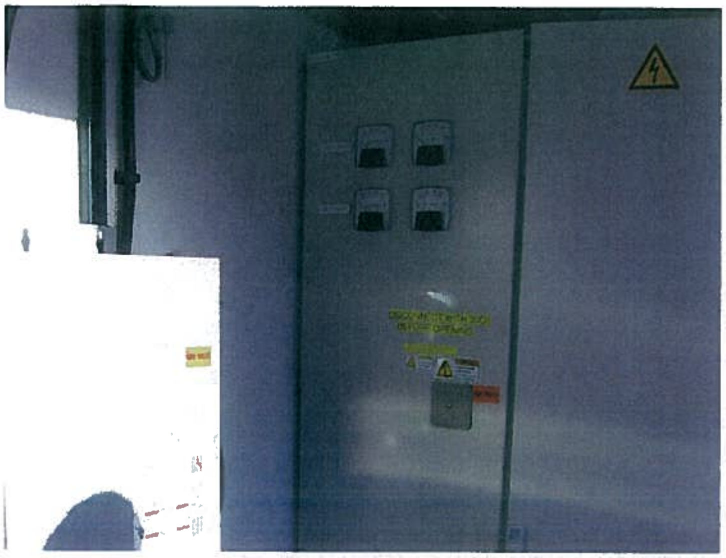
Note: No additional tests were deemed necessary due to all components being approved and being used within intended application.

Photographs

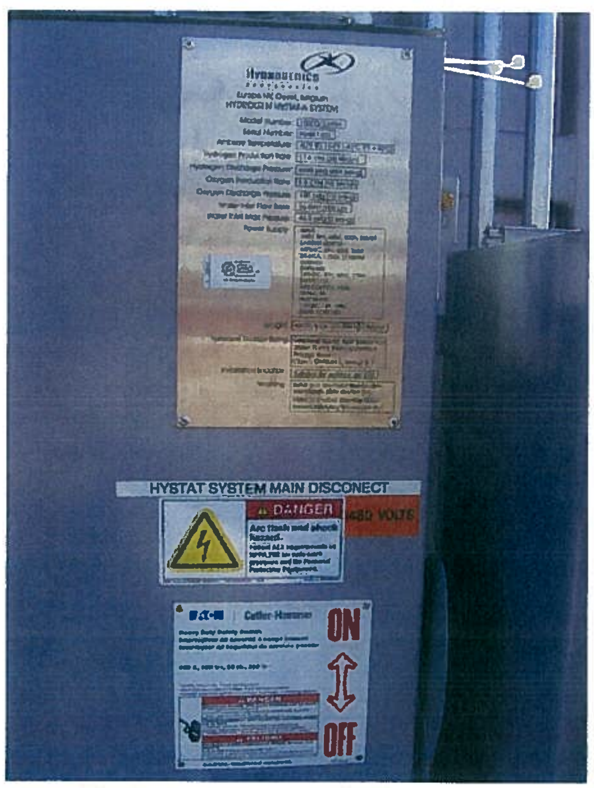
1) Hystat-A unit in the field.

2) View of Class I Div 2 area; compressor skid, gas sensor at the ceiling, and forced ventilation.

3) Control Panel of Hystat-A and disconnect Switch 30Q1 on the left.



4) Name plate of Hystat-A unit



Pages 17–21 are intentionally left out because of confidentiality reasons.

APPENDIX E

CHRONOLOGICAL SUMMARY OF HYDROGEN PRODUCTION

APPENDIX E

CHRONOLOGICAL SUMMARY OF HYDROGEN PRODUCTION

Hydrogen Production Data

Date	Hydrogen Production Cell Stack 1 (liters)	Cell Stack 2 (liters)	Daily Total (liters)	Cumulative Total (liters)	Daily Total (kg)	Cumulative Total (kg)	Wilton Wind Farm Electrical Output (kW)
1-Feb-08	0	0	0	0	0.00	0.0	
2-Feb-08	0	0	0	0	0.00	0.0	
3-Feb-08	0	0	0	0	0.00	0.0	
4-Feb-08	0	0	0	0	0.00	0.0	
5-Feb-08	0	0	0	0	0.00	0.0	
6-Feb-08	0	0	0	0	0.00	0.0	
7-Feb-08	0	0	0	0	0.00	0.0	
8-Feb-08	0	0	0	0	0.00	0.0	
9-Feb-08	0	0	0	0	0.00	0.0	
10-Feb-08	0	0	0	0	0.00	0.0	
11-Feb-08	0	0	0	0	0.00	0.0	
12-Feb-08	25,426	25,200	50,626	50,626	4.52	4.5	
13-Feb-08	25,873	24,384	50,257	100,883	4.49	9.0	
14-Feb-08	43,300	42,741	86,041	186,924	7.68	16.7	
15-Feb-08	0	0	0	186,924	0.00	16.7	
16-Feb-08	0	0	0	186,924	0.00	16.7	
17-Feb-08	0	0	0	186,924	0.00	16.7	
18-Feb-08	0	0	0	186,924	0.00	16.7	
19-Feb-08	0	0	0	186,924	0.00	16.7	
20-Feb-08	0	0	0	186,924	0.00	16.7	
21-Feb-08	0	0	0	186,924	0.00	16.7	
22-Feb-08	0	0	0	186,924	0.00	16.7	
23-Feb-08	0	0	0	186,924	0.00	16.7	
24-Feb-08	0	0	0	186,924	0.00	16.7	
25-Feb-08	0	0	0	186,924	0.00	16.7	
26-Feb-08	0	0	0	186,924	0.00	16.7	
27-Feb-08	0	0	0	186,924	0.00	16.7	
28-Feb-08	0	0	0	186,924	0.00	16.7	
29-Feb-08	0	0	0	186,924	0.00	16.7	
1-Mar-08	0	0	0	186,924	0.00	16.7	
2-Mar-08	0	0	0	186,924	0.00	16.7	
3-Mar-08	0	0	0	186,924	0.00	16.7	
4-Mar-08	0	0	0	186,924	0.00	16.7	
5-Mar-08	0	0	0	186,924	0.00	16.7	

Date	Hydrogen Production Cell Stack 1 (liters)	Cell Stack 2 (liters)	Daily Total (liters)	Cumulative Total (liters)	Daily Total (kg)	Cumulative Total (kg)	Wilton Wind Farm Electrical Output (kW)
6-Mar-08	0	0	0	186,924	0.00	16.7	
7-Mar-08	0	0	0	186,924	0.00	16.7	
8-Mar-08	0	0	0	186,924	0.00	16.7	
9-Mar-08	0	0	0	186,924	0.00	16.7	
10-Mar-08	0	0	0	186,924	0.00	16.7	
11-Mar-08	0	0	0	186,924	0.00	16.7	
12-Mar-08	1,020	996	2,016	188,940	0.18	16.9	
13-Mar-08	0	0	0	188,940	0.00	16.9	
14-Mar-08	0	0	0	188,940	0.00	16.9	
15-Mar-08	0	0	0	188,940	0.00	16.9	
16-Mar-08	0	0	0	188,940	0.00	16.9	
17-Mar-08	0	0	0	188,940	0.00	16.9	
18-Mar-08	0	0	0	188,940	0.00	16.9	
19-Mar-08	0	0	0	188,940	0.00	16.9	
20-Mar-08	0	0	0	188,940	0.00	16.9	
21-Mar-08	0	0	0	188,940	0.00	16.9	
22-Mar-08	0	0	0	188,940	0.00	16.9	
23-Mar-08	0	0	0	188,940	0.00	16.9	
24-Mar-08	0	0	0	188,940	0.00	16.9	
25-Mar-08	0	0	0	188,940	0.00	16.9	
26-Mar-08	0	0	0	188,940	0.00	16.9	
27-Mar-08	0	0	0	188,940	0.00	16.9	
28-Mar-08	0	0	0	188,940	0.00	16.9	
29-Mar-08	0	0	0	188,940	0.00	16.9	
30-Mar-08	0	0	0	188,940	0.00	16.9	
31-Mar-08	0	0	0	188,940	0.00	16.9	
1-Apr-08	0	0	0	188,940	0.00	16.9	
2-Apr-08	73,569	68,315	141,884	330,824	12.67	29.5	
3-Apr-08	111,171	101,560	212,731	543,555	18.99	48.5	
4-Apr-08	57,468	57,373	114,841	658,396	10.25	58.8	
5-Apr-08	104,243	102,005	206,248	864,644	18.42	77.2	
6-Apr-08	323,882	322,590	646,472	1,511,116	57.72	134.9	
7-Apr-08	158,614	158,687	317,301	1,828,417	28.33	163.3	
8-Apr-08	94,654	98,232	192,886	2,021,303	17.22	180.5	

Date	Hydrogen Production Cell Stack 1 (liters)	Cell Stack 2 (liters)	Daily Total (liters)	Cumulative Total (liters)	Daily Total (kg)	Cumulative Total (kg)	Wilton Wind Farm Electrical Output (kW)
9-Apr-08	240,861	240,512	481,373	2,502,676	42.98	223.5	
10-Apr-08	52,589	50,986	103,575	2,606,251	9.25	232.7	
11-Apr-08	0	0	0	2,606,251	0.00	232.7	
12-Apr-08	9,763	9,404	19,167	2,625,418	1.71	234.4	
13-Apr-08	0	0	0	2,625,418	0.00	234.4	
14-Apr-08	526	526	1,052	2,626,470	0.09	234.5	
15-Apr-08	112,417	109,296	221,713	2,848,183	19.80	254.3	
16-Apr-08	53,102	46,022	99,124	2,947,307	8.85	263.2	
17-Apr-08	0	0	0	2,947,307	0.00	263.2	
18-Apr-08	0	0	0	2,947,307	0.00	263.2	
19-Apr-08	0	0	0	2,947,307	0.00	263.2	
20-Apr-08	0	0	0	2,947,307	0.00	263.2	
21-Apr-08	148,080	148,013	296,093	3,243,400	26.44	289.6	
22-Apr-08	268,128	267,754	535,882	3,779,282	47.85	337.4	
23-Apr-08	206,156	206,092	412,248	4,191,530	36.81	374.2	
24-Apr-08	167,321	167,474	334,795	4,526,325	29.89	404.1	
25-Apr-08	158,057	158,106	316,163	4,842,488	28.23	432.4	
26-Apr-08	158,216	158,275	316,491	5,158,979	28.26	460.6	
27-Apr-08	157,740	157,743	315,483	5,474,462	28.17	488.8	
28-Apr-08	156,990	157,095	314,085	5,788,547	28.04	516.8	
29-Apr-08	157,170	157,259	314,429	6,102,976	28.07	544.9	
30-Apr-08	157,380	157,557	314,937	6,417,913	28.12	573.0	
1-May-08	166,340	166,415	332,755	6,750,668	29.71	602.7	
2-May-08	124,026	180,200	304,226	7,054,894	27.16	629.9	
3-May-08	0	0	0	7,054,894	0.00	629.9	
4-May-08	0	0	0	7,054,894	0.00	629.9	
5-May-08	0	0	0	7,054,894	0.00	629.9	
6-May-08	0	0	0	7,054,894	0.00	629.9	
7-May-08	0	0	0	7,054,894	0.00	629.9	
8-May-08	0	0	0	7,054,894	0.00	629.9	
9-May-08	0	0	0	7,054,894	0.00	629.9	
10-May-08	0	0	0	7,054,894	0.00	629.9	
11-May-08	0	0	0	7,054,894	0.00	629.9	
12-May-08	0	0	0	7,054,894	0.00	629.9	

Date	Hydrogen Production Cell Stack 1 (liters)	Cell Stack 2 (liters)	Daily Total (liters)	Cumulative Total (liters)	Daily Total (kg)	Cumulative Total (kg)	Wilton Wind Farm Electrical Output (kW)
13-May-08	0	0	0	7,054,894	0.00	629.9	
14-May-08	0	0	0	7,054,894	0.00	629.9	
15-May-08	0	0	0	7,054,894	0.00	629.9	
16-May-08	0	0	0	7,054,894	0.00	629.9	
17-May-08	0	0	0	7,054,894	0.00	629.9	
18-May-08	0	0	0	7,054,894	0.00	629.9	
19-May-08	9,439	9,448	18,887	7,073,781	1.69	631.6	
20-May-08	0	0	0	7,073,781	0.00	631.6	
21-May-08	0	0	0	7,073,781	0.00	631.6	
22-May-08	0	0	0	7,073,781	0.00	631.6	
23-May-08	0	0	0	7,073,781	0.00	631.6	
24-May-08	0	0	0	7,073,781	0.00	631.6	
25-May-08	0	0	0	7,073,781	0.00	631.6	
26-May-08	0	0	0	7,073,781	0.00	631.6	
27-May-08	0	0	0	7,073,781	0.00	631.6	
28-May-08	138,435	154,792	293,227	7,367,008	26.18	657.8	
29-May-08	157,164	157,061	314,225	7,681,233	28.06	685.8	
30-May-08	167,049	167,134	334,183	8,015,416	29.84	715.7	
31-May-08	156,926	157,412	314,338	8,329,754	28.07	743.7	
1-Jun-08	164,219	164,488	328,707	8,658,461	29.35	773.1	
2-Jun-08	191,088	191,119	382,207	9,040,668	34.13	807.2	
3-Jun-08	170,567	170,412	340,979	9,381,647	30.44	837.6	
4-Jun-08	113,955	113,849	227,804	9,609,451	20.34	858.0	
5-Jun-08	59,630	59,679	119,309	9,728,760	10.65	868.6	
6-Jun-08	156,878	156,947	313,825	10,042,585	28.02	896.7	
7-Jun-08	157,005	157,533	314,538	10,357,123	28.08	924.7	
8-Jun-08	157,913	158,037	315,950	10,673,073	28.21	953.0	
9-Jun-08	105,083	105,095	210,178	10,883,251	18.77	971.7	
10-Jun-08	90,336	90,290	180,626	11,063,877	16.13	987.8	
11-Jun-08	145,256	145,203	290,459	11,354,336	25.93	1,013.8	
12-Jun-08	10,841	10,819	21,660	11,375,996	1.93	1,015.7	
13-Jun-08	177,159	177,228	354,387	11,730,383	31.64	1,047.4	
14-Jun-08	45,083	45,095	90,178	11,820,561	8.05	1,055.4	
15-Jun-08	0	0	0	11,820,561	0.00	1,055.4	

Date	Hydrogen Production Cell Stack 1 (liters)	Cell Stack 2 (liters)	Daily Total (liters)	Cumulative Total (liters)	Daily Total (kg)	Cumulative Total (kg)	Wilton Wind Farm Electrical Output (kW)
16-Jun-08	18,161	17,938	36,099	11,856,660	3.22	1,058.6	
17-Jun-08	20,585	20,587	41,172	11,897,832	3.68	1,062.3	
18-Jun-08	145,529	145,450	290,979	12,188,811	25.98	1,088.3	
19-Jun-08	28,990	29,019	58,009	12,246,820	5.18	1,093.5	
20-Jun-08	55,380	55,511	110,891	12,357,711	9.90	1,103.4	
21-Jun-08	0	0	0	12,357,711	0.00	1,103.4	
22-Jun-08	0	0	0	12,357,711	0.00	1,103.4	
23-Jun-08	0	0	0	12,357,711	0.00	1,103.4	
24-Jun-08	68,497	68,496	136,993	12,494,704	12.23	1,115.6	
25-Jun-08	282,002	281,768	563,770	13,058,474	50.34	1,165.9	
26-Jun-08	74,491	74,504	148,995	13,207,469	13.30	1,179.2	
27-Jun-08	140,074	140,004	280,078	13,487,547	25.01	1,204.2	
28-Jun-08	0	0	0	13,487,547	0.00	1,204.2	
29-Jun-08	0	0	0	13,487,547	0.00	1,204.2	
30-Jun-08	40,079	40,074	80,153	13,567,700	7.16	1,211.4	
1-Jul-08	125,802	125,761	251,563	13,819,263	22.46	1,233.9	
2-Jul-08	0	0	0	13,819,263	0.00	1,233.9	
3-Jul-08	26,538	26,538	53,076	13,872,339	4.74	1,238.6	
4-Jul-08	0	0	0	13,872,339	0.00	1,238.6	
5-Jul-08	0	0	0	13,872,339	0.00	1,238.6	
6-Jul-08	0	0	0	13,872,339	0.00	1,238.6	
7-Jul-08	0	0	0	13,872,339	0.00	1,238.6	
8-Jul-08	30,740	30,700	61,440	13,933,779	5.49	1,244.1	
9-Jul-08	0	0	0	13,933,779	0.00	1,244.1	
10-Jul-08	147	147	294	13,934,073	0.03	1,244.1	
11-Jul-08	32,009	32,003	64,012	13,998,085	5.72	1,249.8	
12-Jul-08	0	0	0	13,998,085	0.00	1,249.8	
13-Jul-08	0	0	0	13,998,085	0.00	1,249.8	
14-Jul-08	0	0	0	13,998,085	0.00	1,249.8	
15-Jul-08	45,286	45,292	90,578	14,088,663	8.09	1,257.9	
16-Jul-08	53,023	53,010	106,033	14,194,696	9.47	1,267.4	
17-Jul-08	0	0	0	14,194,696	0.00	1,267.4	
18-Jul-08	68,957	69,028	137,985	14,332,681	12.32	1,279.7	
19-Jul-08	107,359	107,294	214,653	14,547,334	19.17	1,298.9	

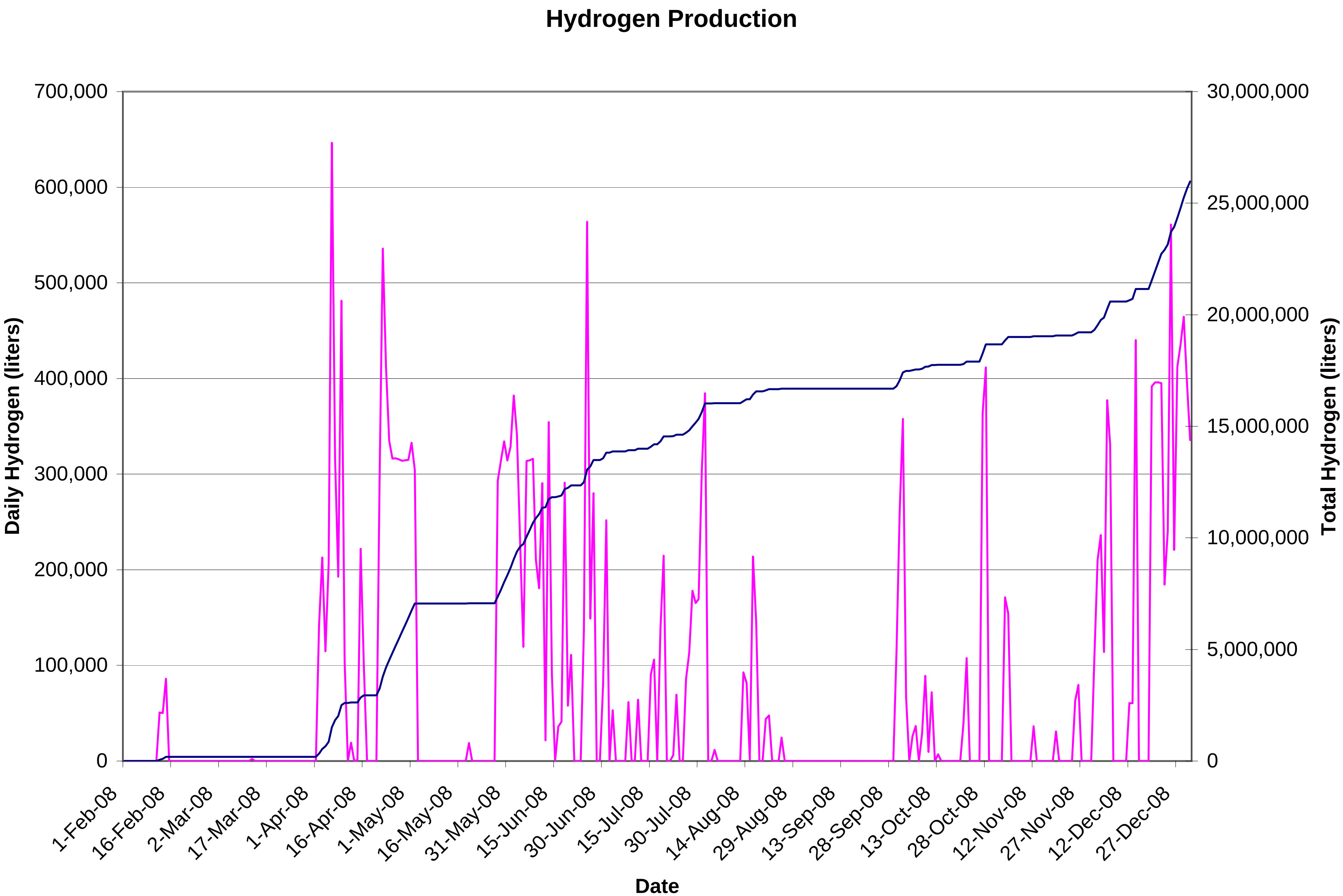
Date	Hydrogen Production Cell Stack 1 (liters)	Cell Stack 2 (liters)	Daily Total (liters)	Cumulative Total (liters)	Daily Total (kg)	Cumulative Total (kg)	Wilton Wind Farm Electrical Output (kW)
20-Jul-08	0	0	0	14,547,334	0.00	1,298.9	
21-Jul-08	0	0	0	14,547,334	0.00	1,298.9	
22-Jul-08	3,127	3,126	6,253	14,553,587	0.56	1,299.4	
23-Jul-08	34,601	34,552	69,153	14,622,740	6.17	1,305.6	
24-Jul-08	0	0	0	14,622,740	0.00	1,305.6	
25-Jul-08	0	0	0	14,622,740	0.00	1,305.6	
26-Jul-08	42,957	42,961	85,918	14,708,658	7.67	1,313.3	
27-Jul-08	18,169	95,288	113,457	14,822,115	10.13	1,323.4	
28-Jul-08	89,080	89,047	178,127	15,000,242	15.90	1,339.3	
29-Jul-08	82,595	82,609	165,204	15,165,446	14.75	1,354.1	
30-Jul-08	84,726	84,724	169,450	15,334,896	15.13	1,369.2	
31-Jul-08	151,703	151,593	303,296	15,638,192	27.08	1,396.3	
1-Aug-08	192,273	192,239	384,512	16,022,704	34.33	1,430.6	
2-Aug-08	0	0	0	16,022,704	0.00	1,430.6	
3-Aug-08	0	0	0	16,022,704	0.00	1,430.6	
4-Aug-08	5,876	5,718	11,594	16,034,298	1.04	1,431.6	
5-Aug-08	0	0	0	16,034,298	0.00	1,431.6	
6-Aug-08	0	0	0	16,034,298	0.00	1,431.6	
7-Aug-08	0	0	0	16,034,298	0.00	1,431.6	
8-Aug-08	0	0	0	16,034,298	0.00	1,431.6	
9-Aug-08	0	0	0	16,034,298	0.00	1,431.6	
10-Aug-08	0	0	0	16,034,298	0.00	1,431.6	
11-Aug-08	0	0	0	16,034,298	0.00	1,431.6	
12-Aug-08	0	0	0	16,034,298	0.00	1,431.6	
13-Aug-08	46,284	46,282	92,566	16,126,864	8.26	1,439.9	
14-Aug-08	40,666	40,847	81,513	16,208,377	7.28	1,447.2	
15-Aug-08	824	829	1,653	16,210,030	0.15	1,447.3	
16-Aug-08	106,749	107,056	213,805	16,423,835	19.09	1,466.4	
17-Aug-08	72,401	72,370	144,771	16,568,606	12.93	1,479.3	
18-Aug-08	0	0	0	16,568,606	0.00	1,479.3	
19-Aug-08	0	0	0	16,568,606	0.00	1,479.3	
20-Aug-08	22,030	21,969	43,999	16,612,605	3.93	1,483.3	
21-Aug-08	23,869	23,854	47,723	16,660,328	4.26	1,487.5	
22-Aug-08	0	0	0	16,660,328	0.00	1,487.5	

Date	Hydrogen Production Cell Stack 1 (liters)	Cell Stack 2 (liters)	Daily Total (liters)	Cumulative Total (liters)	Daily Total (kg)	Cumulative Total (kg)	Wilton Wind Farm Electrical Output (kW)
23-Aug-08	0	0	0	16,660,328	0.00	1,487.5	
24-Aug-08	0	0	0	16,660,328	0.00	1,487.5	
25-Aug-08	12,190	12,149	24,339	16,684,667	2.17	1,489.7	
26-Aug-08	0	0	0	16,684,667	0.00	1,489.7	
27-Aug-08	0	0	0	16,684,667	0.00	1,489.7	
28-Aug-08	0	0	0	16,684,667	0.00	1,489.7	
29-Aug-08	0	0	0	16,684,667	0.00	1,489.7	
30-Aug-08	0	0	0	16,684,667	0.00	1,489.7	
31-Aug-08	0	0	0	16,684,667	0.00	1,489.7	
1-Sep-08	0	0	0	16,684,667	0.00	1,489.7	
2-Sep-08	0	0	0	16,684,667	0.00	1,489.7	
3-Sep-08	0	0	0	16,684,667	0.00	1,489.7	
4-Sep-08	0	0	0	16,684,667	0.00	1,489.7	
5-Sep-08	0	0	0	16,684,667	0.00	1,489.7	
6-Sep-08	0	0	0	16,684,667	0.00	1,489.7	
7-Sep-08	0	0	0	16,684,667	0.00	1,489.7	
8-Sep-08	0	0	0	16,684,667	0.00	1,489.7	
9-Sep-08	0	0	0	16,684,667	0.00	1,489.7	
10-Sep-08	0	0	0	16,684,667	0.00	1,489.7	
11-Sep-08	0	0	0	16,684,667	0.00	1,489.7	
12-Sep-08	0	0	0	16,684,667	0.00	1,489.7	
13-Sep-08	0	0	0	16,684,667	0.00	1,489.7	
14-Sep-08	0	0	0	16,684,667	0.00	1,489.7	
15-Sep-08	0	0	0	16,684,667	0.00	1,489.7	
16-Sep-08	0	0	0	16,684,667	0.00	1,489.7	
17-Sep-08	0	0	0	16,684,667	0.00	1,489.7	
18-Sep-08	0	0	0	16,684,667	0.00	1,489.7	
19-Sep-08	0	0	0	16,684,667	0.00	1,489.7	
20-Sep-08	0	0	0	16,684,667	0.00	1,489.7	
21-Sep-08	0	0	0	16,684,667	0.00	1,489.7	
22-Sep-08	0	0	0	16,684,667	0.00	1,489.7	
23-Sep-08	0	0	0	16,684,667	0.00	1,489.7	
24-Sep-08	0	0	0	16,684,667	0.00	1,489.7	
25-Sep-08	0	0	0	16,684,667	0.00	1,489.7	

Date	Hydrogen Production Cell Stack 1 (liters)	Cell Stack 2 (liters)	Daily Total (liters)	Cumulative Total (liters)	Daily Total (kg)	Cumulative Total (kg)	Wilton Wind Farm Electrical Output (kW)
26-Sep-08	0	0	0	16,684,667	0.00	1,489.7	
27-Sep-08	0	0	0	16,684,667	0.00	1,489.7	
28-Sep-08	0	0	0	16,684,667	0.00	1,489.7	
29-Sep-08	0	0	0	16,684,667	0.00	1,489.7	
30-Sep-08	57,172	57,211	114,383	16,799,050	10.21	1,499.9	
1-Oct-08	130,724	130,817	261,541	17,060,591	23.35	1,523.3	
2-Oct-08	179,127	178,504	357,631	17,418,222	31.93	1,555.2	
3-Oct-08	33,414	33,274	66,688	17,484,910	5.95	1,561.2	
4-Oct-08	0	0	0	17,484,910	0.00	1,561.2	
5-Oct-08	13,003	12,964	25,967	17,510,877	2.32	1,563.5	
6-Oct-08	18,271	18,280	36,551	17,547,428	3.26	1,566.7	
7-Oct-08	0	0	0	17,547,428	0.00	1,566.7	
8-Oct-08	14,579	14,584	29,163	17,576,591	2.60	1,569.3	
9-Oct-08	44,573	44,592	89,165	17,665,756	7.96	1,577.3	
10-Oct-08	4,709	4,709	9,418	17,675,174	0.84	1,578.1	
11-Oct-08	35,955	35,964	71,919	17,747,093	6.42	1,584.6	
12-Oct-08	0	0	0	17,747,093	0.00	1,584.6	
13-Oct-08	3,481	3,482	6,963	17,754,056	0.62	1,585.2	
14-Oct-08	0	0	0	17,754,056	0.00	1,585.2	
15-Oct-08	0	0	0	17,754,056	0.00	1,585.2	
16-Oct-08	0	0	0	17,754,056	0.00	1,585.2	
17-Oct-08	0	0	0	17,754,056	0.00	1,585.2	
18-Oct-08	0	0	0	17,754,056	0.00	1,585.2	
19-Oct-08	0	0	0	17,754,056	0.00	1,585.2	
20-Oct-08	0	0	0	17,754,056	0.00	1,585.2	
21-Oct-08	19,673	19,483	39,156	17,793,212	3.50	1,588.7	
22-Oct-08	53,808	53,658	107,466	17,900,678	9.60	1,598.3	
23-Oct-08	0	0	0	17,900,678	0.00	1,598.3	
24-Oct-08	0	0	0	17,900,678	0.00	1,598.3	
25-Oct-08	0	0	0	17,900,678	0.00	1,598.3	
26-Oct-08	0	0	0	17,900,678	0.00	1,598.3	
27-Oct-08	183,281	180,710	363,991	18,264,669	32.50	1,630.8	
28-Oct-08	208,544	202,899	411,443	18,676,112	36.74	1,667.5	
29-Oct-08	0	0	0	18,676,112	0.00	1,667.5	

Date	Hydrogen Production Cell Stack 1 (liters)	Cell Stack 2 (liters)	Daily Total (liters)	Cumulative Total (liters)	Daily Total (kg)	Cumulative Total (kg)	Wilton Wind Farm Electrical Output (kW)
30-Oct-08	0	0	0	18,676,112	0.00	1,667.5	
31-Oct-08	0	0	0	18,676,112	0.00	1,667.5	
1-Nov-08	0	0	0	18,676,112	0.00	1,667.5	
2-Nov-08	0	0	0	18,676,112	0.00	1,667.5	
3-Nov-08	85,666	85,571	171,237	18,847,349	15.29	1,682.8	
4-Nov-08	77,075	76,966	154,041	19,001,390	13.75	1,696.6	
5-Nov-08	0	0	0	19,001,390	0.00	1,696.6	
6-Nov-08	0	0	0	19,001,390	0.00	1,696.6	
7-Nov-08	0	0	0	19,001,390	0.00	1,696.6	
8-Nov-08	0	0	0	19,001,390	0.00	1,696.6	
9-Nov-08	0	0	0	19,001,390	0.00	1,696.6	
10-Nov-08	0	0	0	19,001,390	0.00	1,696.6	
11-Nov-08	0	0	0	19,001,390	0.00	1,696.6	
12-Nov-08	18,214	17,980	36,194	19,037,584	3.23	1,699.8	
13-Nov-08	0	0	0	19,037,584	0.00	1,699.8	
14-Nov-08	0	0	0	19,037,584	0.00	1,699.8	
15-Nov-08	0	0	0	19,037,584	0.00	1,699.8	
16-Nov-08	0	0	0	19,037,584	0.00	1,699.8	
17-Nov-08	0	0	0	19,037,584	0.00	1,699.8	
18-Nov-08	0	0	0	19,037,584	0.00	1,699.8	
19-Nov-08	15,477	15,278	30,755	19,068,339	2.75	1,702.5	
20-Nov-08	0	0	0	19,068,339	0.00	1,702.5	
21-Nov-08	0	0	0	19,068,339	0.00	1,702.5	
22-Nov-08	0	0	0	19,068,339	0.00	1,702.5	
23-Nov-08	0	0	0	19,068,339	0.00	1,702.5	
24-Nov-08	0	0	0	19,068,339	0.00	1,702.5	
25-Nov-08	31,729	31,440	63,169	19,131,508	5.64	1,708.2	
26-Nov-08	39,864	39,707	79,571	19,211,079	7.10	1,715.3	
27-Nov-08	0	0	0	19,211,079	0.00	1,715.3	
28-Nov-08	0	0	0	19,211,079	0.00	1,715.3	
29-Nov-08	0	0	0	19,211,079	0.00	1,715.3	
30-Nov-08	0	0	0	19,211,079	0.00	1,715.3	
1-Dec-08	56,411	52,279	108,690	19,319,769	9.70	1,725.0	
2-Dec-08	105,781	104,553	210,334	19,530,103	18.78	1,743.8	

Date	Hydrogen Production Cell Stack 1 (liters)	Cell Stack 2 (liters)	Daily Total (liters)	Cumulative Total (liters)	Daily Total (kg)	Cumulative Total (kg)	Wilton Wind Farm Electrical Output (kW)
3-Dec-08	120,182	116,006	236,188	19,766,291	21.09	1,764.8	
4-Dec-08	57,086	56,925	114,011	19,880,302	10.18	1,775.0	
5-Dec-08	195,561	181,686	377,247	20,257,549	33.68	1,808.7	991,020
6-Dec-08	167,152	163,566	330,718	20,588,267	29.53	1,838.2	512,484
7-Dec-08	0	0	0	20,588,267	0.00	1,838.2	417,924
8-Dec-08	0	0	0	20,588,267	0.00	1,838.2	635,616
9-Dec-08	0	0	0	20,588,267	0.00	1,838.2	153,816
10-Dec-08	0	0	0	20,588,267	0.00	1,838.2	814,692
11-Dec-08	0	0	0	20,588,267	0.00	1,838.2	456,648
12-Dec-08	30,476	29,929	60,405	20,648,672	5.39	1,843.6	483,600
13-Dec-08	30,476	29,929	60,405	20,709,077	5.39	1,849.0	918,288
14-Dec-08	220,265	219,779	440,044	21,149,121	39.29	1,888.3	913,368
15-Dec-08	0	0	0	21,149,121	0.00	1,888.3	503,604
16-Dec-08	0	0	0	21,149,121	0.00	1,888.3	280,608
17-Dec-08	0	0	0	21,149,121	0.00	1,888.3	470,040
18-Dec-08	0	0	0	21,149,121	0.00	1,888.3	516,792
19-Dec-08	195,815	195,937	391,752	21,540,873	34.98	1,923.3	279,504
20-Dec-08	197,948	197,922	395,870	21,936,743	35.35	1,958.6	1,015,536
21-Dec-08	198,128	197,907	396,035	22,332,778	35.36	1,994.0	810,072
22-Dec-08	197,522	197,562	395,084	22,727,862	35.28	2,029.3	712,128
23-Dec-08	92,242	92,267	184,509	22,912,371	16.47	2,045.7	468,576
24-Dec-08	120,344	120,316	240,660	23,153,031	21.49	2,067.2	638,904
25-Dec-08	280,732	280,308	561,040	23,714,071	50.09	2,117.3	842,952
26-Dec-08	110,361	110,379	220,740	23,934,811	19.71	2,137.0	274,632
27-Dec-08	206,134	206,179	412,313	24,347,124	36.81	2,173.9	589,956
28-Dec-08	217,652	217,673	435,325	24,782,449	38.87	2,212.7	619,896
29-Dec-08	232,269	232,286	464,555	25,247,004	41.48	2,254.2	646,584
30-Dec-08	198,156	198,216	396,372	25,643,376	35.39	2,289.6	531,912
31-Dec-08	167,828	167,863	335,691	25,979,067	29.97	2,319.6	



Hydrogen Production
Daily Hydrogen (liters)
700,000
600,000
500,000
400,000
300,000
200,000
100,000
0
Total Hydrogen (liters)
30,000,000
25,000,000
20,000,000
15,000,000
10,000,000
5,000,000
0
1-Feb-08
16-Feb-08
2-Mar-08
17-Mar-08
1-Apr-08
16-Apr-08
1-May-08
16-May-08
31-May-08
15-Jun-08
30-Jun-08
15-Jul-08
30-Jul-08
14-Aug-08
29-Aug-08
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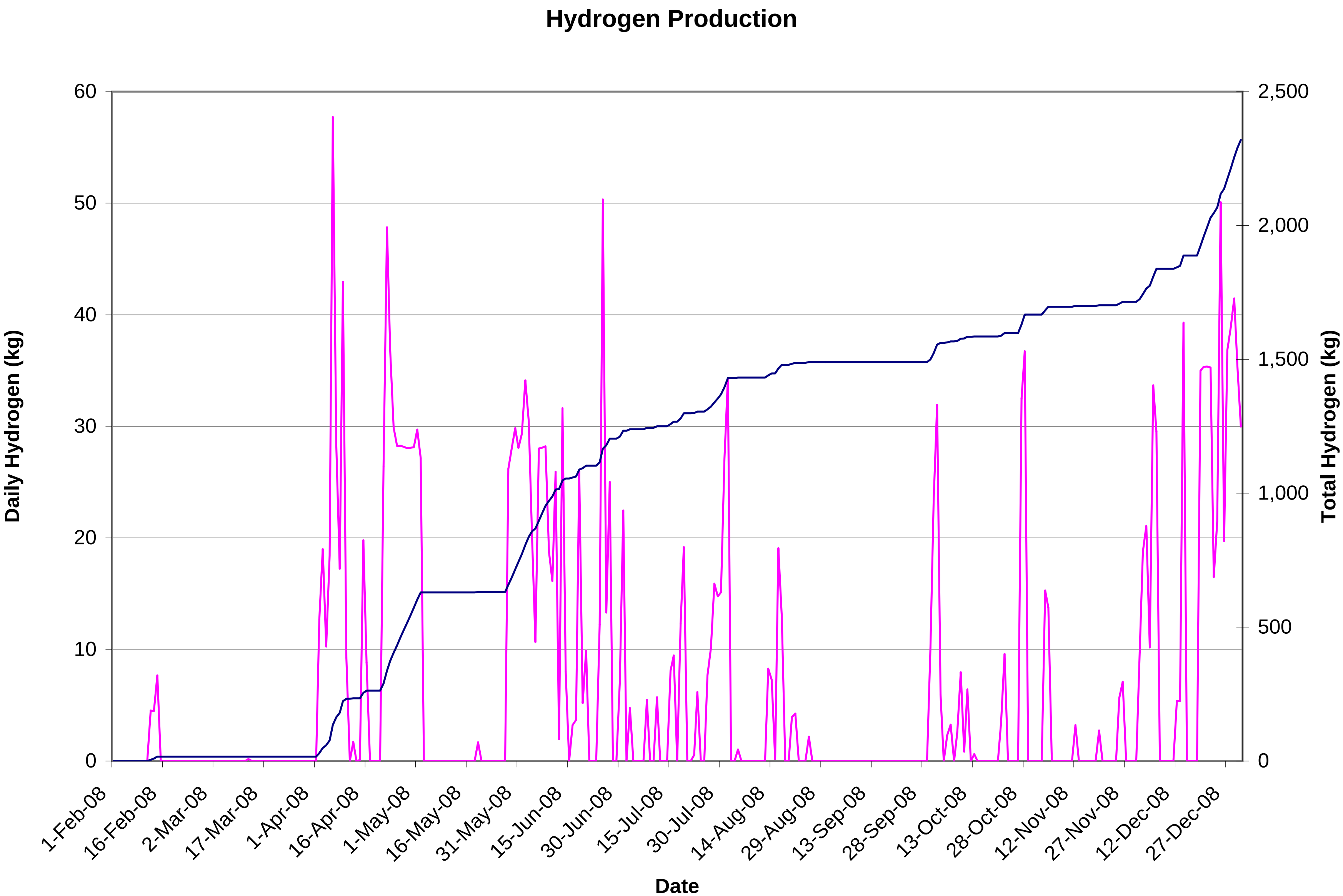
12-Dec-08
27-Dec-08
Date


Hydrogen Production
Daily Hydrogen (kg)
Total Hydrogen (kg)
Date
0
10
20
30
40
50
60
0
500
1,000
1,500
2,000
2,500
1-Feb-08
16-Feb-08
2-Mar-08
17-Mar-08
1-Apr-08
16-Apr-08
1-May-08
16-May-08
31-May-08
15-Jun-08
30-Jun-08
15-Jul-08
30-Jul-08
14-Aug-08
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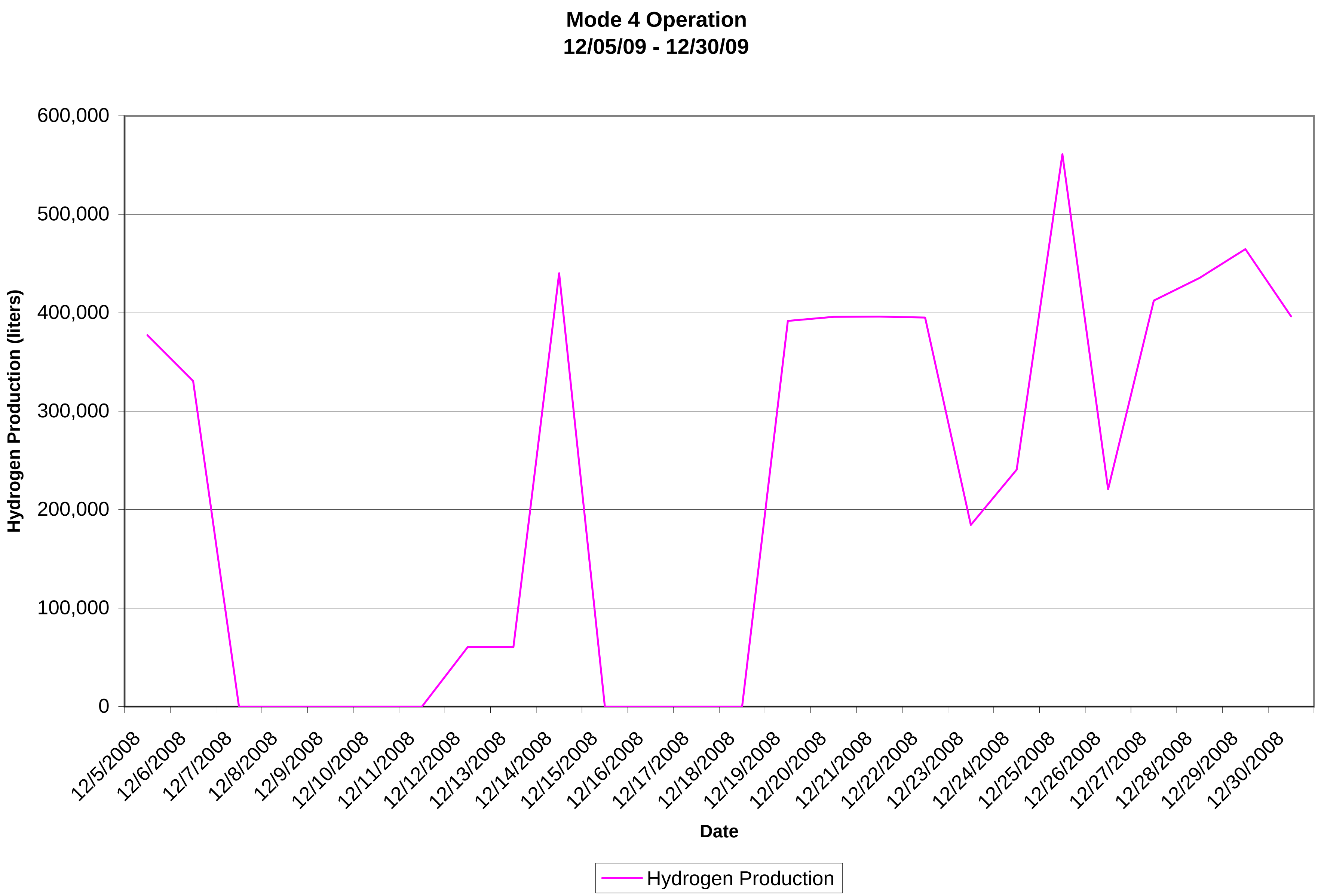
12-Dec-08
27-Dec-08


Mode 4 Operation
12/05/09 - 12/30/09
600,000
500,000
400,000
300,000
200,000
100,000
0
Hydrogen Production (liters)
12/5/2008
12/6/2008
12/7/2008
12/8/2008
12/9/2008
12/10/2008
12/11/2008
12/12/2008
12/13/2008
12/14/2008
12/15/2008
12/16/2008
12/17/2008
12/18/2008
12/19/2008
12/20/2008
12/21/2008
12/22/2008
12/23/2008
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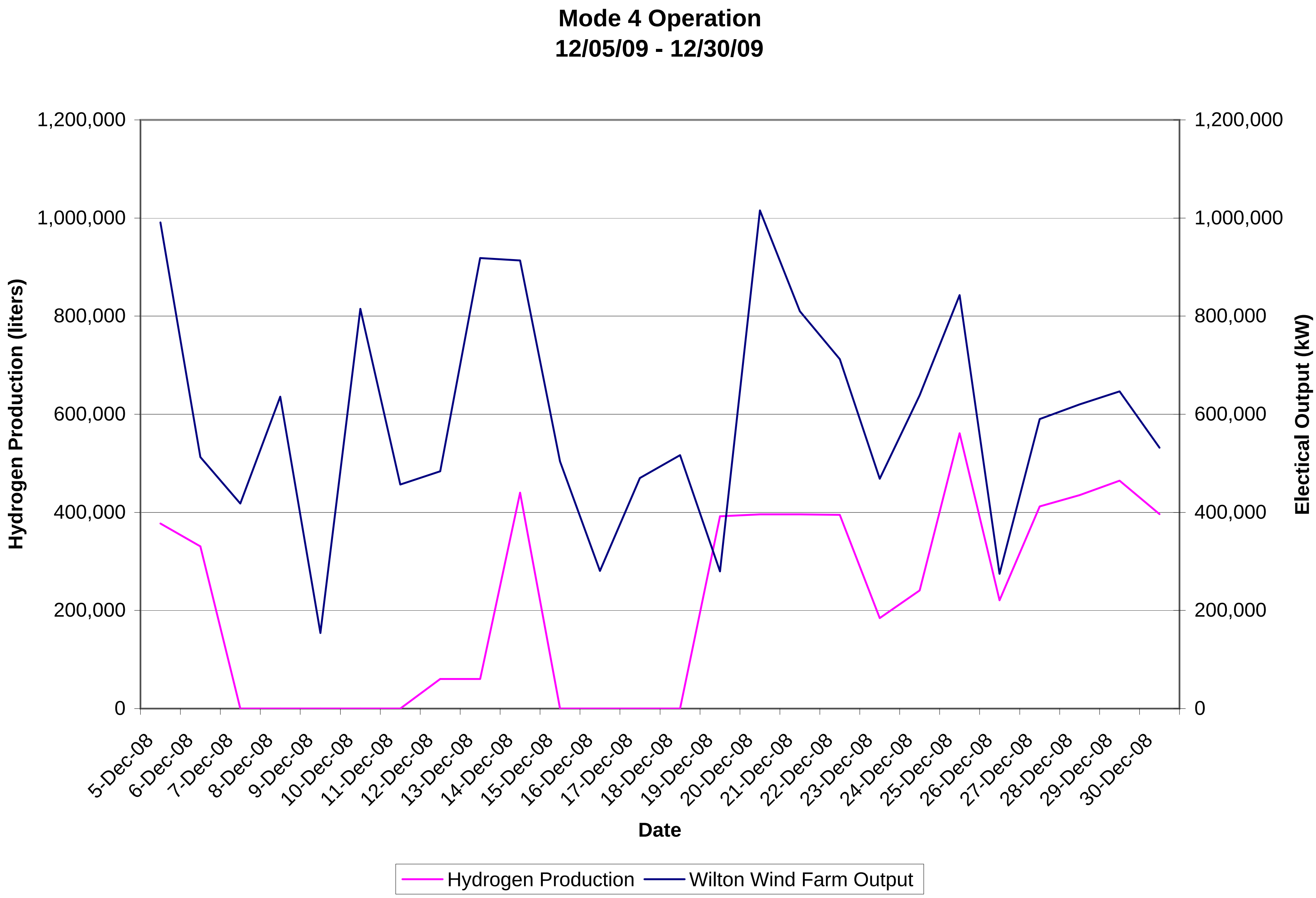
12/29/2008
12/30/2008
Date
Hydrogen Production


Mode 4 Operation
12/05/09 - 12/30/09
Hydrogen Production (liters)
Electical Output (kW)
1,200,000
1,000,000
800,000
600,000
400,000
200,000
0
5-Dec-08
6-Dec-08
7-Dec-08
8-Dec-08
9-Dec-08
10-Dec-08
11-Dec-08
12-Dec-08
13-Dec-08
14-Dec-08
15-Dec-08
16-Dec-08
17-Dec-08
18-Dec-08
19-Dec-08
20-Dec-08
21-Dec-08
22-Dec-08
23-Dec-08
24-Dec-08
25-Dec-08
26-Dec-08
27-Dec-08
28-Dec-08
29-Dec-08
30-Dec-08
Date
Hydrogen Production
Wilton Wind Farm Output