Attachment A

Hydrogen Compatibility Study Team Report and Supporting Documents

A-1 Hydrogen Compatibility Study Team Report

A-2 Natural Gas (LNG)-Hydrogen Refueling Station Site Compatibility Review – Mr. Gary Pope

A-3 Natural Gas Refueling Infrastructure Hydrogen Compatibility Review of Proposed CNG Fueling Facilities in SCAQMD Territory – Mr. Herbert Burnett

A-4 Spreadsheet: Project-by-Project Description

A-5 Estimate of Electrolytic Hydrogen Cost – Dr. Peter Lehman

A-6 Compressor Survey Report – Mr. Herbert Burnett

A-7 Schematic Diagram, AQMD Vehicle H2 Layout – Mr. Polo del Toro

A-8 Schematic Diagram, CNG Station Configuration – Mr. Herbert Burnett

A-9 Schematic Diagram, LNG/LCNG Station Configuration - Mr. Herbert Burnett

A-10 Air Products And Chemicals, Inc. Bulk Hydrogen Site Evaluation Documents – Mr. Mark Pedersen

Hydrogen Compatibility Study Team Report

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Status Report
For
Hydrogen Study Team

SCAQMD

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Section 1 - Objective

On July 20, 2001 the Board directed the staff to conduct a field evaluation and assessment of possible enhancements that could enable natural gas (NG) fueling stations to be compatible for future hydrogen refueling. The staff assembled a team of experts asking that they visit each of the awardees sites and make a determination as to the extent these natural gas fueling stations could be made hydrogen compatible.

A preliminary report was presented to the Technology Committee on July 27th with the Team's findings. The following report was prepared and will be presented at the Board Meeting on August 17th, 2001.

The team defined "hydrogen compatible" in the context of a natural gas refueling system for vehicles. A hydrogen compatible system would use the most suitable equipment, controls and dispensers at this date that could be employed for delivering both hydrogen and natural gas at current design volumes, pressures and purities in an economic and operationally safe manner. Equipment material selection, design pressures, cooling and control systems would all have to be designed to accommodate both fuels. The plans should recognize that 1) the design of H2 systems will change over time and 2) H2 and CNG systems could be completely separate. Foresight into future codes, spacing set-backs, the effect of equipment degradation on hydrogen fuel quality and site operation characteristics will all have an effect on the design of a compatible system.

The Study Team developed criteria based on site specifics; including space considerations, accessibility, fueling scenarios, types of vehicles, codes and standards, operations, maintenance and current project status. After completing the evaluations, a listing of possible modifications was made for each site which would hopefully minimize future possible expenses to add hydrogen fueling to the NG Station.

Section 2 - Site-by-Site Review

Each of the site visits conducted by the team members was documented and appears in the Appendix. In each case, with the exception of those sites using Fuel Maker technology, a determination was made regarding what if any site or equipment modifications could be made. (In the two sites using a Fuel Maker, these sites did not require an extensive infrastructure – so there are no recommended utility modifications. In addition, Fuel Maker does not currently offer a H2 compatible unit.) The sites were inspected, all available equipment specifications, drawings, plot plans and Piping and Instrument Diagrams were reviewed, and estimates of hydrogen siting nuances were made.

Also appearing in the Appendix are two different pictures of fueling station scenarios. The first picture, "CNG STATION CONFIGURATION" provides the reader with the basic equipment components and fuel flow of a CNG fueling station. The second picture, "LNG/LCNG STATION CONFIGURATION" provides the reader with a basic equipment components and fuel flow of a LNG or LCNG fueling station.

Section 3 - Background & Analysis

a) Team Rationale for Adopting H2 System Components

When looking at the CNG sites we asked the following questions in this order;

- Is there sufficient room to install additional equipment and does the schedule allow making design changes?
- What potential modifications can be made now at each site to minimize additional costs at later date without sacrificing safety?
- What is the impact of these changes to both project cost and schedule? Are the estimated costs within reason for the expected benefits?

b) Prioritizing Potential Sites

After reviewing the sites and discussing the proposed equipment, we assessed which sites could potentially be used for H2 fueling at a later date. There were three main reasons why some of the sites where eliminated. These were 1) LNG based systems were eliminated due to the cost and complexity of converting to H2, 2) project schedule was too tight, and 3) space constraints would not allow future installation of H2 supply equipment. Not only does any new equipment (such as hydrogen generation or storage) need to be considered, but there needs to be sufficient room for maintenance for the new and existing equipment. An open area is greatly preferred to allow for natural ventilation in the event of any leaks.

c) Other points to consider:

<u>Natural Gas Supply Systems</u>

Of the twenty (20) installations we reviewed, there were three basic types of natural gas fueling stations. Each site fell into one of the groups below;

- Small fueling appliance (Fuel Maker)
  2 sites or 10% of the group
- LNG Storage and Supply System
  Hauled in product. This included a cryogenic storage tank and cryogenic liquid pump. 9 sites or 45% of the group
- CNG Compressor
  Using NG from pipeline – 9 sites or 45% of the group

Potential Types of Hydrogen Supply

There are two means for hydrogen supply, onsite generation or hauled in product. Onsite generation includes reforming and electrolysis. Hauled in hydrogen can be delivered either as a gas or a liquid. Gaseous hydrogen can be delivered by tube trailer and either dropped off or used to fill storage tubes at the site. Hauled in liquid is delivered and stored in a cryogenic storage tank. (Another option is by H2 pipeline but this is currently not available for any of the sites considered.)

If early hydrogen usage is expected to be from a small number of vehicles, then the volume of hydrogen usage will be low and potentially required on a sporadic basis. Because of this, it is unlikely that very early hydrogen supply can be sourced economically from a hydrocarbon based onsite generator, whose performance is dependent on continuous operation, or on a liquid hydrogen supply source which needs sufficient usage to prevent product boil-off. Delivered hydrogen in the form of compressed gas or onsite electrolytic production of hydrogen would be the most likely choices for the early stages of this scenario. These two options have several trade-offs. The delivered hydrogen requires onsite storage with appropriate set-backs. However, since a large quantity of product is available, this option allows the most cost efficient trade-off of compression and high pressure storage to accommodate the fill. For onsite electrolysis, both the capacity selected and utility costs will need to be evaluated. (Refer to the Appendix for an estimated cost of hydrogen fuel production using electrolysis.) It is unlikely to be economical to size the generator to achieve production directly for fast fill. Therefore, a larger capacity of high pressure storage will be required thus generating the same footprint storage issue required for delivered hydrogen. If the most economical long term hydrogen supply is going to be an onsite hydrocarbon based generator or liquid, then a temporary delivered hydrogen scenario may prove to be a lower cost option than electrolysis.

If the early hydrogen usage is for several buses that will be put into routine service, then the most economical hydrogen supply mode could be to start with liquid or onsite hydrocarbon based generator.

Site Assessment Based On Delivered Gaseous Hydrogen

If you consider that a likely option is delivered gaseous hydrogen by Tube Trailer, there needs to be sufficient space for this equipment. The equipment must also be installed to meet the current code requirements for exposure distances.

(1) Size of Equipment

The approximate dimensions for a large GH2 tube trailer are 8'-5" wide and 40' long. (Approximately 60' long if you include the cab.) This is the typical means to supply gaseous hydrogen. The trailer can be used to "bump" or fill fixed storage tubes onsite or for larger volumes, the trailer can be left onsite instead. They are built in accordance with the DOT and typically hold over 100,000 SCF. (Smaller tube trailers may also be available.)

The approximate dimensions for a generic three pack of high pressure gaseous storage vessels are roughly 3' x 25' when mounted on their side, or 7' x 25' when mounted flat. These are coded pressure vessels and are built in accordance with ASME/ANSI section 8. Depending on the pressure and quantity the volume of gas will change. These tubes can be stacked on top of each other when installed flat or horizontally (7' wide).

Note – the dimensions above do NOT include clearance around equipment for maintenance.

(2) Safety

The most important thing to consider with any project is the safe operation of the system and the safety of the operators. There are issues that will need to be addressed and reviewed at a later date if these sites are used for hydrogen fueling in the future. At the present time, it is critical that any proposed changes to the NG stations for hydrogen compatibility do not impact the safety of the currently proposed NG systems.

(3) Codes & Standards

While there are many codes and standards pertaining to NG fueling stations, they do not exist at the current time for hydrogen fueling stations. There are however numerous codes and standards which are used today to site a gaseous hydrogen system at a consumer site. The most widely used code today is currently the National Fire Protection Association (NFPA) 50A – Standard for Gaseous Hydrogen Systems at Consumer Sites, 1999 Edition. A brief summary chart for siting a bulk gaseous system (in excess of 15,000 SCF of onsite storage) is included in the Appendix. Additional information can also be found in both the Uniform Fire Code (UFC) 1997 edition as well as the California Fire Code (CFC) 1998 edition. There is also another Standard used for installing a liquid hydrogen system, NFPA 50B – Standard for Liquefied Hydrogen Systems at Consumer Sites, 1999

Edition. A summary chart is also included in the Appendix as well for this.

Refer to the Appendix for a detailed list of applicable codes for NG vehicles and fueling stations along with detailed information concerning California codes and regulations for H2.

d) Site and Equipment Summary

Each site was visited by at least one team member. A spreadsheet was developed listing the key issues such as available space, supply equipment, etc. (Refer to the Appendix) The table listed the major capital equipment which was planned to be installed. (It is important to note that with some sites we did not know for certain what equipment was going to be installed. Some of the sites had not completed their designs and one site was still uncertain about whether they were going with CNG or LNG.)

Below is a list of the major NG equipment being proposed at the sites along with a brief outline of issues that need to be addressed for hydrogen service.

LNG Cryogenic Storage Tank

You could purchase a cryogenic storage tank to hold either LNG or LHy but there would be increased costs. The proposed LNG tanks are very large, much larger than what would probably be required for early stage H2 station(s) when there would be very few H_2 vehicles. There would be considerable hydrogen venting with an oversized liquid storage tank. In addition the tank design would have to include/address the following items;

- The inner vessel would have to change from 9Ni to Stainless steel resulting in additional cost.
- Modify vacuum jacketed (VJ) fill piping to allow LHy fill connections.
- Modify VJ piping for pump liquid supply and vapor return lines (if using LHy pump) to accept LHy bayonets.
- Misc. piping, vent stack changes, component changes.
- Other issues would also include NFPA and CCR Title 08 for siting LHy, electrical classification in the area, etc.

LNG High Pressure Reciprocating Pump

It may be possible to convert these pumps at a later date to liquid hydrogen (LHy) if liquid hydrogen was the source. This will depend on the manufacturer and model of the LNG pump selected. Hydrogen is more difficult to pump than LNG due to its fluid properties and will require a vacuum jacketed piping manifold.

CNG Compressor
If a CNG compressor were to be used in H2 service, it would have to be specified for this before the compressor was purchased. (A more detailed review is included in the next section 4.b.). Some of the issues with using the same compressor in both NG and H2 are;

- More complicated controls for switching between supply source and storage.
- Need to address purity and purging issues when switching from NG to H2. Would require adding oil removal filters, etc. (Note - This would be required if the end use application is Fuel Cell vehicles. If it is H2/CNG blends in IC engines this would not be an issue.)
- May end up requiring another H2 compressor (in series) to boost the pressure unless higher pressure compressor was specified. Current CNG compressors are probably much larger than what would be required for early stage H2 fueling station.
- Design changes would require the manufacturer to address the possibility of higher temperatures with H2 (increased cooling), higher horsepower for CNG (larger motor), safety relief valve sizing, valve dynamics, etc.

Equipment Controls (Tank, Pump, Compressors)
Typical CNG equipment has a hazardous area electrical rating of Class I, Div. 1 or 2, Group C and D. Hydrogen service requires Group B rated components. The system controls (switches, panels, etc.) would need to be designed initially with Group B compatibility in order to switch easily to hydrogen in the future.

CNG High Pressure Gas Storage Vessels
CNG vessels are typically rated at 5500 psig, implying a maximum working pressure of about 5000 psig. They can be converted to H2 service, but they will not be capable of completely filling 5000 psig vehicles. Fills of about 75% are likely. To use the same vessels, a station would need to be completely H2 or CNG not both at the same time. Also, future conversion of the tubes from CNG to H2 would likely require extensive cleaning to remove oil. It would not be economical to use the storage vessels for dual service since large losses would result when converting back and forth.

Dispenser
There are a number of issues in the design of a single dispenser to deliver CNG and/or H2. Full function H2 dispensers are not commonly available as

off-the-shelf items at this time. The following design issues would have to be addressed;

- H2 dispenser would require a different fill hose and nozzle.
- Different electrical classification (Group B instead of Group D).
- Different flow meter.
- Higher delivery pressures with H2
- Possible code conflicts

e) Technical Feasibility for H2 Compressor

When we looked at the major equipment currently planned for the NG stations, the CNG Compressor appeared to be the most likely component which potentially could be operated using both gases. The high cost of compression equipment makes it appealing to consider dual use. A listing of various operating scenarios was put together to help define the main issues as listed below. We assumed a timeframe of within 10 years for our discussion. In addition, a generic survey was created (see Appendix) and sent to both CNG and H2 compressor manufacturers (see Compressor Vendor List in Appendix). Results from this survey are summarized and included in the Appendix as well. In general we found that many compressor manufacturers are capable of producing units that are compatible for both H2 and NG at about a 10 - 15% cost premium. An additional 10 – 15% on average premium was also required for increasing the discharge pressure of the compressor (from 4500 psi to 6000 psi).

Scenario # 1 - If the compressor was used for both CNG & H2 service

PROS

- Lower capital by buying only one compressor and having only one foundation/pad and utilities (disconnect, breaker, etc.).
- Save space with only one compressor.
- Save money – operating and maintenance will be lower for only one compressor for preventive maintenance, spare parts, etc.
- No harm by ordering H2 compatible Compressor (other than possible cost increase).

CONS

- If H2 is not added to the site, a premium may have been paid for the compressor. This may require a larger motor, increased cooling, electrical issues (Group B instead of Group D), safety relief valve sizing, etc.
- H2 vehicles are being developed for higher pressures (5000 psi vs. 3600 psi for CNG) onboard storage. This would potentially require either: (1) a second compressor in series, which would add system controls and complexity or (2) a higher discharge compressor purchased initially and thus higher costs.

- There is an inherent risk, although manageable, in a dual system that a contaminant from the natural gas could get into the hydrogen product and cause failure to the fuel cell. One solution would be to design and install an automated system that addresses the purging and purity requirements. This can be done with controls, filters, etc., but will result in a more complicated controls system with slightly higher maintenance costs (switching valves, etc.). (We are currently unable to list any installations doing this at this time. Also, this item would not apply if it were H2/CNG blends for IC engines.)
- If the initial hydrogen usage was small (a few light duty vehicles), it is highly probable that the compressor will be oversized for the needed capacity. The source of hydrogen, particularly if it is being produced on site, needs to be considered since it may not match the duty of the compressor either. However, a large compressor would enable direct filling of the vehicle without the need for high pressure storage vessels. At the least, the storage volume would be reduced.

Scenario # 2 - Compressor converted to only H2 at a later date
(Assumes that CNG system is no longer needed.)

PROS

- Save money not having to buy a new H2 compressor later. Also applies to foundation/pad/utilities if the machine stays in the same location.
- Compressor could be relocated if necessary.
- No harm by ordering H2 compatible Compressor (other than possible cost increase).

CONS

- Seems unlikely that CNG fleets would go away in 10 years since funding is typically for at least 12 years.
- Pay a premium for H2 compressor.
- If you assume the first H2 fueling stations would be small initially, then CNG compressors may be oversized. Future source of hydrogen will be key to determining compressor size.
- H2 PEMFC vehicles seem to be moving to higher pressures. 5000 psi vs. 3600 psi for CNG. Possibly 10,000 psig in the next 3-5 years.

Comments

- We estimated that 40% of the sites (8 total) would require purchasing a new CNG compressor. Each site is different (equipment layout and type). Of these 8 sites, 4 were eliminated from further consideration due to current tight schedules or limited

availability of real estate at the sites, and two others were eliminated due to the size or type of compressor being installed. This left a total of 2 sites where a H2 compatible compressor could be specified.

- Actual volumes, pressure and type of hydrogen source (onsite generation vs hauled in product) are not confirmed. Since the source of H2 and volume of on-site storage (if required) is not known, it is tough to commit to siting.
- Hydrogen usage for fuel cell vehicles will require higher purity gas than hydrogen combustion engines.
- Compressor vendors were asked this question – "Can your standard CNG machine support a blend of up to 30% H2 without requiring any modifications or does the machine need to be built for H2 service?" Most all vendors indicated that modifications would be required.
- High volume accounts (over 3MM SCF/month) that use hauled in liquid hydrogen would probably use a liquid pump (no compressor).

Section 4 - Recommendations

The Natural Gas/Hydrogen Compatibility Study Team finds that:

1) The use of hydrogen fuel in motor vehicles has several advantages including:
   a) reduced emissions when used with internal combustion engine vehicles.
   b) zero emissions when used with fuel cell vehicles.
   c) increased security of fuel supply since hydrogen can be made from natural gas or renewable sources.

2) Because of the advantages listed in 1) above, the team recommends that NG fueling stations that are being designed and built within the South Coast Air Basin incorporate upgrades and/or retrofits where practical so that they are compatible with the possibility of adding hydrogen dispensing capability in the future.

3) The Study Group recommends that five natural gas fueling stations that are being designed and built within the South Coast Air Basin incorporate upgrades and/or retrofits (detailed below) so that they are compatible with the possibility of adding hydrogen dispensing capability in the future. An estimated cost for these upgrades is provided on the Project by Project Description spreadsheet in the Appendix.

   These four sites (in no particular) order are:
   + PFC/Admin. Services Co-Op in Gardena
   + City of Placentia in Placentia
   + Valley Vista in City of Industry
   + PFC/Waste Mgmt of Inland Empire at I-215 and CA-60
   + Pinnacle/Ware Disposal Company

   The recommendations for these sites are as follows:

   - Make the following generic provisions:

     a.) Electrical Upgrades; Additional power capacity (breaker, feed wire, etc.) 480 VAC, 100 amp and underground spare conduits.

     b.) Mechanical Upgrades; underground high pressure piping that is hydrogen compatible, running parallel to the installed gas service line, additional fuel island dispenser stub-ups in the eventuality of being used at the site. If hydrogen is not used, the additional pipe and stub-up can be used for an additional natural gas dispenser.

c.) The site owner should be encouraged to set aside additional real estate for future hydrogen equipment and fueling dispensers.

d.) Fire protection and gas detection site plan consider H2 fuel and be signed by a registered California engineer with expertise in this field.

- AQMD should provide consulting resources to assist those NG fueling stations that are desirous of upgrading their systems to be hydrogen compatible.

- A hydrogen compatible compressor should be considered but is not strongly recommended at two of the sites; PFC/Admin. Services Co-Op in Gardena and City of Placentia in Placentia. Initially, the H2-CNG compressor could be used for building natural gas load, with hydrogen gas being provided by a tube trailer. As the load for both natural gas and hydrogen fuel increases, a new, larger CNG compressor could be installed and the original H2-CNG compressor could be used exclusively for hydrogen service. At this point the hydrogen tube trailer could be replaced with a permanent hydrogen fuel source (electrolytic, fossil fuel reformer or bulk liquid tank). The estimated cost for these upgrades is also provided on the Project by Project Description spreadsheet in the Appendix.

- The Study Team does not recommend the modification of CNG dispensers to dispense hydrogen or that hydrogen compatible dispensers be purchased at this time.

One final comment – While the sites above may appear to be suitable for hydrogen fueling stations in the future, the team recommends that prior to any funding, that the site owner provide review documents that indicate a general acceptance. The following groups would all have to be consulted prior to the installation of a hydrogen fueling station; A&E, fire protection/gas detection compliance, Federal, State, OSHA, County and local agency regulations. The site owner would also need to identify and meet any of the safety concerns of the local citizens prior to the actual installation of a hydrogen fueling station.

SECTION 5 – APPENDIX

A-2

Natural Gas (LNG)-Hydrogen Refueling Station Site Compatibility Review

Gary Pope USA Pro

Natural Gas (LNG)-Hydrogen Refuelling Station

Site Compatibility Review

Gary Pope

USA PRO & ASSOCIATES

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FUNDING REVIEW OF LIQUEFIED NATURAL GAS REFUELING STATIONS TO DETERMINE THE SUITABILITY FOR FUTURE HYDROGEN AUTOMOTIVE APPLICATIONS

FIELD INSPECTION AND DATA ACQUISITION

1. **Interview Site Owner/Operator—Determine feasibility of hydrogen use**

2. **Inspect the Site—Review current facility/operation, provide photos**

3. **Review all available drawings; plot plans and P&ID materials.**

4. **Review proposal/application for: site equipment compatibility and operational long-term availability.**

5. **Define the most suitable equipment that could be employed at this date and the estimated cost. Determine equipment compatibility—note strategies to be employed to facilitate a future hydrogen refueling station.**

6. **Determine hydrogen specific siting nuances**

7. **Provide estimate of additional cost to facilitate the future installation of a hydrogen refueling facility at each site**

Potential Hydrogen Sites Assigned for Inspection and Review

1. City of Long Beach, Long Beach, CA
2. Foothill Transit, Pomona, CA
3. Omnitrans, San Bernardino, CA
4. Omnitrans, Montclair, CA
5. PFC/Poma Distributing, Rialto, CA
6. Santa Monica Big Blue Bus, Santa Monica, CA
7. Taormina Industries, Anaheim, CA
8. County Sanitation District of LA County, Puente Hills, CA
9. Riverside Waste Management, Riverside, CA

Long Beach CNG/LNG Public Refueling Site, Long Beach, CA

1. **Interview site owner/operator—determine feasibility of hydrogen use.**

The Long Beach Fleet Manger, Mr. Dennis Hill, is very proactive with the heavy-duty alternate fuel fleet that is being operated in Long Beach. He has been a leader in the quest for new engine(s), chassis, and fuel combinations that will meet the needs of the city of Long Beach fleet.

The current CNG refueling site is located on Temple Ave adjacent to the 405 Freeway in Long Beach, California. This CNG refueling station is currently one of the largest in the California and could be considered as one of the best-run public refueling stations in the nation.

The current site is being upgraded to add liquefied natural gas (LNG) and will use the LNG as a source for all of the CNG refueling operations. The location and the abilities of the owner/operator would make this an ideal site for hydrogen dispensing in the future.

2. Inspect the site.

The site was inspected and the location of the hydrogen dispenser could be accommodated by replacing one of the current stand-alone dispensers. This dispenser is located at the front of the building. Current CNG piping may well be suitable for this application.

3. Review all available drawings; plot plans and P&ID materials.

The drawings, finalized plot plans, and P&ID are currently in progress. We have included a most recent plot plan of the new LNG and LNG-CNG facility. There appears to be adequate space to facilitate a hydrogen cryogenic tank and equipment for this application.

4. Review proposal application for equipment compatibility.

The proposal application indicates that the site is a multi-purpose public alternate fuel refueling station. The cryogenic pumps, vaporizers, and piping could be purchased with hydrogen compatibility included in the specification. It is doubtful that one of the cryogenic pumps or other equipment would be pulled from daily operation to accommodate the use of hydrogen in the future. The following are the potential equipment combinations that may be suitable for the sites:

A. High-pressure gaseous trailer, compressor, etc.
B. Hydrogen reformer installation
C. Cryogenic tank, cryogenic pump, vaporiser, etc.
D. Cryogenic tank, compressor, vaporiser, etc.

5. Define the most suitable equipment that could be employed at this date and the estimated cost. Determine equipment compatibility—note strategies to be employed.

The current equipment purchased with this funding would not normally be suitable for hydrogen use. All of the cryogenic equipment will be in operation during the life of the LNG installation. However, the following items could be considered as a means of facilitating the installation of a future hydrogen cryogenic system:

A. All permitting (Title 08, OSHA, etc.), would include the future use of hydrogen as an automotive fuel.
B. The registered engineer who provides the methane detection—fire protection studies would add the hydrogen component to his work.
C. A pad for the small cryogenic tank could be poured.
D. Piping from the hydrogen pad could be installed and stubbed for later use.

E. The electrical could be expanded to include the hydrogen equipment power requirements.
F. Modification of engineering plans.

6. Determine hydrogen siting nuances.

A. The siting is exceptionally well positioned for an automotive hydrogen public refueling site.
B. Due to the multi-fuel public use of the station, it would be recommended to provide a HAZOPS review of the site that included the hydrogen component.

7. Provide estimate of additional cost to accommodate the future installation of a hydrogen refueling facility at this site.

A.	All permitting (Title 08, OSHA, etc., would include the future use of hydrogen as an automotive fuel	$20,000
B.	The registered engineer who provides the methane detection—fire protection studies would add the hydrogen component to his work	20,000
C.	Provide pad for the small cryogenic tank could be poured. Review of site and pad for additional space to accommodate cryogenic tank, pumps, etc.	5,000
D.	Piping from the hydrogen pad could be installed and stubbed for later use	
E.	Modification of engineering and site plans	10,000
F.	Modify electrical 1. Additional power panel - distribution 2. Additional electrical for panels and dispenser to be stubbed off for the future installation 3. Additional power for lighting 4. Trench and engineering work for electrical	10,000
	Total amount of estimated change order items	$65,000

Recommendation: This site is the most qualified for future installation of a hydrogen refueling station. This site currently is servicing a large variety of public domain customers with compressed natural gas and in the near future will add liquefied natural gas refueling. This location is just off the 405 Freeway and provides easy access to multiple refueling pumps. This site is without question the most advanced public refueling site in Southern California for public access.

If the future were to include a stand-alone hydrogen refueling installation, it would be highly recommended to consider the Long Beach public refueling site.

Foothill Transit—Refueling site, Pomona, CA

1. Interview site owner/operator—determine feasibility of hydrogen use.

The Foothill Pomona bus refueling site is currently operating with diesel only. Recently the transit determined that it would begin a transition to compressed natural

gas (CNG) for all of their bus fleet. The initial order of buses is scheduled to be operating in the first quarter of 2002. Within the next several years, the transit will have approximately 139 CNG buses at this location.

Foothill Transit's proposed CNG refueling site has yet to determine the source of natural gas fuel: pipeline or liquefied natural gas (LNG). The options are spelled out in the current RFP and upon review of the equipment suppliers bid documents, the transit will decide which type of fuel they will utilize.

The current site has business offices, a bus washing operation, a full maintenance garage, and diesel refueling. Parking for the buses is extremely limited and any outside refueling equipment will represent an engineering and permitting challenge.

2. Inspect the site.

The site was reviewed and the location of a cryogenic hydrogen dispenser could be accommodated, if the transit decided to provide public access to any portion of the property. The logical choice for a public access refueling station does not fall within the scope of the compressed natural gas refueling station plans for either pipeline or liquefied natural gas as a source of CNG.

3. Review all available drawings; plot plans and P&ID materials.

The drawing's finalized plot plans and P&ID information will not be available until the job is bid and a contractor is selected.

4. Review proposal application for equipment compatibility.

The proposal application indicates that the site could be public alternate fuel refueling station. Our assessment of the current site and general operations indicates that a stand-alone public refueling station would be the most likely scenario. All of the necessary equipment could be purchased at the time of a hydrogen installation. It is doubtful that one of the proposed cryogenic pumps or CNG compressors would be pulled from daily operation to accommodate the use of hydrogen in the future. The following are the potential equipment combinations that may be suitable for the sites:

A. High pressures gaseous trailer, compressor, etc.
B. Hydrogen reformer installation
C. Cryogenic tank, cryogenic pump, vaporiser, etc.
D. Cryogenic tank, compressor, vaporiser, etc.

5. Define the most suitable equipment that could be employed at this date and the estimated cost. Determine equipment compatibility—note strategies to be employed.

None of the current equipment purchased with SCAQMD funding would normally be suitable for hydrogen use. All of the cryogenic equipment will be in operation during the life of the LNG-CNG installation. However, the following items could be considered as a means of facilitating the installation of a future hydrogen cryogenic system:

A. All permitting (Title 08, OSHA, etc.) would include the future use of hydrogen as an automotive fuel.
B. The registered engineer who provides the methane detection—fire protection studies would add the hydrogen component to his work.
C. A pad for the small cryogenic tank or compressor could be designated.
D. Piping from the hydrogen pad could be installed and stubbed for later us.
E. The electrical could be expanded to include the hydrogen equipment power requirements.
F. Modification of engineering plans and review of siting issues.

6. Determine hydrogen siting nuances.

A. The proposed public refueling station siting is suitable for automotive natural gas and hydrogen refueling site.
B. Due to the multi-fuel, transit and public use of the location, it would be recommended to provide a HAZOPS review of the site that included the hydrogen component.

7. Provide estimate of additional cost to accommodate the future installation of a hydrogen refueling facility at this site.

A.	Current permitting (Title 08, OSHA, etc.) would include the future use of hydrogen as an automotive fuel	$ 20,000
B.	The registered engineer who provides the methane detection —fire protection studies would add the hydrogen component to his work.	20,000
C.	A pad for the small cryogenic tank or trailer could be poured. Review of site and pad for additional space to accommodate cryogenic tank, pumps, high-pressure equipment, etc.	5,000
D.	Modification of engineering and site plans	10,000
E.	Modify electrical	15,000
	1. Additional power panel - distribution	
	2. Additional electrical for panels and dispenser to be stubbed off for the future installation	
	3. Additional power for lighting	
	4. Trench and engineering work for electrical	
Total amount of estimated change order items		$70,000

Recommendation: This site is not well suited for an investment of the funds for a hydrogen refueling station. The transit has not chosen the fuel source or provided for the public access that would be necessary for a hydrogen installation. The financial estimate cannot be accurately determined at this time and does not represent an in-depth analysis of the financial commitment necessary for the project.

Omnitrans, San Bernardino, CA

1. Interview site owner/operator - determine feasibility of hydrogen use.

The Omnitrans San Bernardino site is currently operating a compressed natural refueling station at this location. Omnitrans is installing liquefied natural gas (LNG-CNG) refueling station at this location in the near future.

The location is an industrial transit operation and the new equipment is being located in a remote section of the operation. This location would not facilitate the installation of additional equipment and it would be a challenge to incorporate the permitting into the present day plan.

2. Inspect the site—review current facility/operation—provide photos.

The site was inspected and the location of a public refueling station would be a considerable burden to the general operation and layout of the facility.

3. Review all available drawings; plot plans and P&ID materials.

The drawings, finalized plot plans, and P&ID are currently being developed by the contractor who was awarded the LNG refueling station contract. At this time, the drawings are not available.

4. Review proposal/application for: site equipment compatibility and operational long-term availability.

The LNG cryogenic vessels have been ordered and will not facilitate cryogenic hydrogen. The lead-time and the change order cost would add an unreasonable amount of money and delay to the project. Because of the additional demands, it would be considered inadvisable to provide for a hydrogen upgrade.

5. Define the most suitable equipment that could be employed at this date and the estimated cost. Determine equipment compatibility—note strategies to be employed to facilitate a future hydrogen refueling station.

Due to the accelerated timeline for completion of the current LNG-CNG project and the significant cost of a change order, it would not be advisable to consider additional hydrogen components.

6. Determine hydrogen specific siting nuances.

All of the HAZOPS, fire protection-methane detection, site engineering, etc. would have to be restarted. The project timeline prevents this from being a consideration.

7. Provide estimate of additional cost to facilitate the future installation of a hydrogen refueling facility at each site.

This dollar costs would be significant and could easily exceed $100,000

Omnitrans, Montclair, CA

1. Interview site owner/operator—determine feasibility of hydrogen use.

The Omnitrans Montclair site is not currently operating a compressed natural refueling station at this location. Omnitrans is installing liquefied natural gas (LNG-CNG) refueling station at this location and should be operational in the near future.

The location is an industrial transit operation and it would not facilitate the installation of additional equipment at this time. Furthermore, it would be a challenge to incorporate the permitting for a hydrogen unit within the present day plan.

2. Inspect the site—review current facility/operation—provide photos.

The site was reviewed and the location of a public refueling station would be of a considerable burden to the general operation and layout of the facility.

3. Review all available drawings; plot plans and P&ID materials.

The drawings, finalized plot plans and P&ID are currently being developed by the contractor who was awarded the LNG refueling station contract. At this time, the drawings are not available.

4. Review proposal/application for: site equipment compatibility and operational long-term availability.

The LNG cryogenic vessels have been ordered and will not facilitate cryogenic hydrogen. The lead-time and the change order cost would add an unreasonable amount of money and delay to the project.

5. Define the most suitable equipment that could be employed at this date and the estimated cost. Determine equipment compatibility—note strategies to be employed to facilitate a future hydrogen refueling station.

Due to the accelerated timeline for completion of the current LNG-CNG project and the significant cost of a change order, it would not be advisable to consider additional hydrogen components.

6. Determine hydrogen specific siting nuances.

The timeline for completion prevents a hydrogen review from being a consideration. All of the HAZOPS, fire protection-methane detection, site engineering, etc., would have to be restarted.

7. Provide estimate of additional cost to facilitate the future installation of a hydrogen refueling facility at each site.

The dollar costs would be significant and could easily exceed $ 80,000.

PFC/Poma Distributing, Rialto, CA

1. Interview site owner/operator - determine feasibility of hydrogen use.

The site was reviewed and the use of hydrogen may well be a consideration for the future. This location is currently a (diesel) public refueling station and is located within a short distance from a major freeway. Furthermore, no contracts have been awarded for the site, the permits have not been established and potentially the timeline would not be a major hurdle.

2. Inspect the site—review current facility/operation—provide photos.

The site was inspected for a potential location of a hydrogen dispenser and storage units. Although the site has limited space it would appear that there may well be room for a small cylinder operation, Furthermore, the potential of utilizing the adjoining vacate lot may well be a viable consideration should this become an important hub for hydrogen users.

3. Review all available drawings; plot plans, and P&ID materials.

The drawings for the site were not available. The inspections team did review the site considerations for a cryogenic 16,000-gallon LNG vessel.

4. Review proposal/application for: site equipment compatibility and operational long-term availability.

The site is in the early stages and the plan has not been presented to various suppliers and permitting agencies. This would be one of the better opportunities for a stand-alone hydrogen refueling station.

5. Define the most suitable equipment that could be employed at this date and the estimated cost. Determine equipment compatibility—note strategies to be employed to facilitate a future hydrogen refueling station.

The cryogenic equipment could be ordered to be hydrogen compatible. This would incur a significant additional cost to the present day project. Additional considerations would provide for a change in the final schedule and various permitting challenges.

6. Determine hydrogen specific siting nuances.

Beyond changing the specification for the cryogenic equipment to be hydrogen compatible, the single item that would provide the greatest impact would be upgrading the electrical to meet the demands of future hydrogen equipment. Gas Detection, Fire Protection, and a HAZOPS would also be a viable consideration.

7. Provide an estimate of additional cost to facilitate the future installation of a hydrogen refueling facility at each site.

The costs associated with: trenching, electrical upgrades, island stub-off, permitting, gas detection, and potentially a HAZOPS is estimated at $30,000.

Santa Monica Big Blue Bus, Santa Monica, CA

1. Interview sites owner/operator - determine feasibility of hydrogen use.

The Santa Monica Big Blue Bus has sent out an RFP for a LNG bus refueling facility and a public LNG-CNG refueling station. This project includes new shop and bus wash/inspection buildings. The final proposals are in the review process and they should have a selection before their board by the end of August 2001.

The integration of a hydrogen station within the scope of this project will require a complete A&E review.

2. Inspect the site— review current facility/operation—proved photos.

The site was reviewed and the potential locations available are limited by the size of the property and major site permitting considerations. The current cryogenic equipment will not be suitable for the hydrogen application. The CNG components could provide for an integrated hydrogen approach if the project A&E review could be facilitated prior to the ground breaking.

3. Review all available drawings; plot plans and P&ID materials.

The site drawings were reviewed and are available from Santa Monica Big Blue Bus upon request.

4. Review proposal/application for: site equipment compatibility and operational long-term availability.

The long-term availability of hydrogen for this site can be established through a feasibility review effort by the A&E firms. This would also require that the permitting, fire protection—gas detection and an additional HAZOPS be included with the new scope.

5. Define the most suitable equipment that could be employed at this date and the estimated cost. Determine equipment compatibility—note strategies to be employed to facilitate a future hydrogen refueling station.

The complexity of the project, high demands regarding the timelines, and review processes may well limit the ability to provide an upgrade of any of the equipment to be installed. The cryogenic equipment could be upgraded for hydrogen use, however, due to the size of each vessel (30,000 gallons) and other specialized pumps and vaporizers, these items would have to be reviewed within the next several weeks.

6. Determine hydrogen specific siting nuances.

Due to the size of the project, these are too numerous to detail within this document.

7. Provide estimate of additional cost to facilitate the future installation of a hydrogen refueling facility at each site.

The costs would be significant and could exceed $100,000.

Taormina Industries, Anaheim, CA

1. Interview site owner/operator - determine feasibility of hydrogen use.

Taormina Industries is a current user of LNG fuel for their refuse trucks. The location has a temporary LNG tank onsite and the proposed new equipment is an upgrade to their operation. The site is divided into two distinct sections: the front of the building has a large public diesel and gasoline-refueling facility, the rear of the site has the LNG refueling station. The plans for the new LNG site were not available and the project has not been sent out for bid to the equipment suppliers.

2. Inspect the site—review current facility/operation—provide photos.

The current site and location of the LNG vessel was inspected and it is very apparent that they probably will not be using the present location in the future. A hydrogen tank would not easily fit this location due to the proximity of industrial buildings and the general traffic flow of the refuse trucks.

3. Review all available drawings; plot plans and P&ID materials.

There are no available drawings for this site.

4. Review proposal/application for: site equipment compatibility and operational long-term availability.

The compatibility of the LNG cryogenic equipment is questionable due to sizable increase in the cost of a hydrogen use verses the liquefied natural gas vessel. The refueling location has not been determined at this time and hydrogen would have a costly impact on the site if it were added to the present day plan.

5. **Define the most suitable equipment that could be employed at this date and the estimated cost. Determine equipment compatibility—note strategies to be employed to facilitate a future hydrogen refueling station.**

The future of this site for hydrogen would be to provide a stand-alone hydrogen refueling station at the front of the building. All of the hydrogen equipment and related services facilities would be designed at the time of the installation.

6. **Determine hydrogen specific siting nuances.**

The installation of a hydrogen refueling station at this location would require all of the engineering, permitting, HAZOPS, etc., of a new refueling station.

7. **Provide estimate of additional cost to facilitate the future installation of a hydrogen refueling facility at each site.**

If the location of the new LNG facility were placed within an acceptable permitting location, the cost of facilitating a hydrogen installation would be within the $ 30,000 range. This would provide for permitting, electrical, trenching, piping, gas detection, and engineering for the future upgrade.

LA County Sanitation District—Puente Hills, CA (Landfill)

1. **Interview sites owner/operator - determine feasibility of hydrogen use.**

The proposed site is raw land at this time and does not have any facilities developed for a LNG refueling station. The general plan is in the development stages and the hydrogen location potential could be incorporated within the general plan.

2. **Inspect the site—review current facility/operation—provide photos.**

The site is yet to be developed for this project.

3. **Review all available drawings; plot plans and P&ID materials.**

The LNG refueling site topographic outline is available from the owner of the landfill. There are no specific drawings for the refueling station at this time.

4. **Review proposal/application for: site equipment compatibility and operational long-term availability.**

The compatibility of the site is yet to be determined due to the industrial location and heavy duty fleet demands of the LNG refueling station. The LNG refueling station will be used by heavy-duty class eight trucks. Because of the location and the high volume of large trucks, the facility would have to incorporate safety considerations for automobiles.

5. **Define the most suitable equipment that could be employed at this date and the estimated cost. Determine equipment compatibility—note strategies to be employed to facilitate a future hydrogen refueling station.**

Because the site is currently, raw undeveloped land it is within the realm of possibility that the design of the station could be reviewed for automotive usage. The equipment compatibility is normally not a consideration due to the large differently between liquefied natural gas vessels and the added cost of a hydrogen vessel.

6. **Determine hydrogen specific siting nuances.**

The site is underdeveloped.

7. **Provide estimate of additional cost to facilitate the future installation of a hydrogen refueling facility at each site.**

If the location of the new LNG facility were place within an acceptable permitting location, the cost of facilitating a hydrogen installation would be within the $30,000 range. This would provide for permitting, electrical, trenching, piping, gas detection, and engineering for the future hydrogen upgrade.

Riverside Waste Management - Riverside, CA

1. **Interview site owner/operator—determine feasibility of hydrogen use.**

The proposed site is raw land at this time and does not have any facilities developed for a LNG refueling station. The general plan has been developed stages and the hydrogen location potential could be incorporated within the general plan.

2. **Inspect the site—review current facility/operation—provide photos.**

The site is yet to be developed for this project. Current operation is on an adjoining piece of property and the refueling is provided by a LNG "wet fueling" operation.

3. **Review all available drawings; plot plans and P&ID materials**.

The drawings were review at the site with Mr. Peter Teng; P.E., and he also provided the team with a copy of the equipment RFP. In order to provide for a hydrogen installation, the A&E components of the new facility would have to be revisited.

4. **Review proposal/application for: site equipment compatibility and operational long-term availability.**

The compatibility of the site is yet to be determined due to the industrial location and demands of the LNG refueling station. The LNG refueling station will be used by the refuse industry heavy-duty class eight trucks. Because of the location and the high volume of large trucks, the facility would have to incorporate safety considerations for automobiles.

5. Define the most suitable equipment that could be employed at this date and the estimated cost. Determine equipment compatibility—note strategies to be employed to facilitate a future hydrogen refueling station.

Because the site is currently raw undeveloped land, it is within the realm of possibility that the design of the station could be reviewed for automobile usage. The equipment compatibility is normally not a consideration due to the large differently cost between liquefied natural gas vessels and the added cost of a hydrogen vessel.

6. Determine hydrogen specific siting nuances.

The site is underdeveloped.

7. Provide estimate of additional cost to facilitate the future installation of a hydrogen refueling facility at each site.

If the location of the new LNG facility were placed within an acceptable location, the cost of facilitating a hydrogen installation would be within the $30,000 range. This would provide for permitting, electrical, trenching, piping, gas detection, and engineering for the future hydrogen upgrade.

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Natural Gas Refueling Infrastructure Hydrogen Compatibility Review of Proposed CNG Fueling Facilities in SCAQMD Territory

Herbert Burnett

Burnet & Burnette

Natural Gas Refueling Infrastructure Hydrogen Compatibility Review of Proposed CNG Fueling Facilities in SCAQMD Territory

IN CONJUNCTION WITH THE HYDROGEN COMPATIBILITY TASK FORCE

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H2 FACILITIES MENU AND SYSTEMS/EQUIPMENT/CONSTRUCTION COMPATIBILITY MENU

1. BULK HYDROGEN FUELING SYSTEM-Portable in gaseous state

   1- Hydril tube assembly 1- Jumbo Tube Trailer 1 Pressure Control manifold
   1 Tube trailer discharge stanchion

2. LIQUID HYDROGEN FUELING SYSTEM- Stationary

   1- Cryogenic storage vessel 1- Ambient Air process vaporizer
   1- Pressure –temperature control manifold

3. HYDROGEN NATURAL GAS REFORMER OR ELECTROLYZER FACILITY

   Onsite H2 processing and dispensing

CNG SITE INSPECTIONS AND SCHEDULE

TOTAL CNG SITES -- (10)

Honda and Sunline are not considered station sites but have existing operating H2 facilities.

Team will not visit FuelMaker sites at Monterey Park and Calstart/Weststart

Report preparation Thursday 7/26 3pm –7pm

All work complete Friday 7/27 -- 5 pm

SITE FIELD TOUR ITINERARY
AND DATA ACQUISITION PROCESS

1. INTERVIEW OWNER AND CONSULTANT COMPANY-ADVISE OBJECTIVE
2. REVIEW DRAWINGS INCLUDING PLOT PLAN AND P&ID
3. INSPECT THE SITE FACILITY PLOT INCLUDING FUEL DEPOT
4. TAKE PERTINENT PICTURES
5. CONSENSUS ON TYPE OF H2 STRATEGY TO EMPLOY- SHORT TERM AND LONG TERM
6. APPLY H2 TEMPLATE AND STRATEGIES TO SITE AND PROJECT
7. DEVELOP A H2 MENU WITH ROM $ AND TIMETABLE
8. CHECK FOR H2 PLAN CONSISTENCY WITH OTHER 19 SITES

SITES WITH FUELMAKERS
CITY OF MONTEREY PARK AND CALSTART/WESTSTART

The award partially covers the cost of installing either Model FM 8 or FM 16 FuelMakers, singular or in parallel filling to 3600 psi.

A. MONTEREY PARK- $59,000 to offset the cost of installing multiple FuelMakers at the City Yard

B. CALSTART/WESTSTART- $10,350 to offset the cost of installing FuelMakers at their facility

C. <u>FUELMAKER HYDROGEN COMPATIBILITY ASSESSMENT</u>

RALPH RACKAM, CHIEF ENGINEER –TORONTO 800 227 6241

1. FM been considering hydrogen feedstock for fm for over 2 years

2. FM not certified by UL/FM for H2, only demo projects now.

3. No H2 standards yet, may have to wait 2+ years

4. FM an only go to 3600 psi fill pressure

5. Several peripheral changes to accommodate H2

   H2 leak detection increased ventilation

   control system and nozzle modifications

6. cost of changes for h2 about 30% of $6000 retail value ~$2000

7. FuelMaker unit now operating on H2 at Honda-Torrance Steve Matheison or Ben Knight 310 781 5825

8. Existing FuelMaker (latest generation) will require major upgrades and system changes to increase fill pressure to 5000 psi. not achievable with the current generation.

9. Met with Ben Knight, Honda R&D Americas VP 7/26. the team toured the hydrogen test facility and reviewed the h2 process plant train. the converted FuelMaker has been successfully operating in a 3600 psi h2 application for several months fueling at the rate of about 1/3 GEG per hour at 2 psi suction pressure. he confirmed the modifications listed by FuelMaker above. because of the sensitive nature of their project he would neither confirm or deny our other key design, operations, and maintenance inquiries or statements.

10. This confirms that a modified current generation FuelMaker will operate successfully in H2 service.

SITE #1
PFC WASTE MANAGEMENT OF INLAND EMPIRE-MORENO VALLEY

$88,000 to offset the cost of purchasing and installing a new CNG fueling system

Existing facility- currently time fill only @ 3600 psi

Existing facility plot is about 40 ft x 40 ft w/ external perimeter wall
1- 400 scfm IMW compressor with enclosure
1- 5000 psi ASME storage vessel
1- ZEBEC suction side dryer
19- time fill nozzles on 4 time fill posts using 2 rows

The proposed funds are for expansion to fast fill-

a. 2 additional ASME vessels for a cascade system fast fill island
b. Fueling island with universal card reader system for fleet access

Hydrogen Compatibility Assessment

1. Install additional underground sleeves and conduits to the proposed external fueling island for future hydrogen service

2. Consider increasing existing and planned electrical power design loads to include hydrogen pump and compressor for either a bulk hydrogen or natural gas reformer hydrogen system

3. Get site owner to commit to an additional 20 ft x 40 ft plot for future hydrogen fueling facility adjacent to existing CNG station

4. Design the proposed external fueling island to accommodate a future hydrogen dispenser

SITE #2
JURUPA UNIFIED SCHOOL DISTRICT-
JURUPA

$125, 000 to offset the cost of purchasing and installing a new 3600 psi CNG fueling system for 34 school buses on time fill and 1 fast fill dispenser at the existing depot fueling island. 5 each 3000 psi buses will fill at the 3000 psi fast fill island

EXISTING FACILITY- Currently under construction with about 15% complete and the compressor already purchased. Estimated completion is 1 September 2001. The existing island is about 200 feet from the future CNG fueling station with 2 unleaded and 1 diesel fueling dispenser.

Facility plot is about 40 ft x 40 ft w/ external perimeter chain link fence
1- 200 scfm Sulzer compressor with enclosure
1- Zebec suction side dryer
34- time fill nozzles on 9 time fill posts using 2 rows. 29 buses for after hours non peak time fueling
1 each 3000 psi single hose fast fill dispenser
Multiforce card reader system for other municipal fleets in the region for day time fueling only

HYDROGEN COMPATIBILITY ASSESSMENT

1. Install additional underground sleeves and conduits to the existing depot fueling island for future hydrogen service

2. Consider increasing existing and planned electrical power design loads to include hydrogen pump and compressor for a bulk hydrogen system-#2

3. Get site owner to commit to an additional 20 ft x 40 ft plot for future hydrogen fueling facility adjacent to existing CNG station

4. Get site owner to commit to removing one of the 2 existing unleaded gasoline dispensers to create a spot under the existing canopy to accommodate a future hydrogen dispenser

SITE #3
PFC - TAXI ADMINISTRATIVE SERVICES CO-OP - GARDENA

$106,450 to PFC to offset the cost of purchasing and installing a new CNG fueling system

No work in progress, design not yet started and application for cup not yet filed. The proposed facility plot is on vacant land adjacent to the cab facility fronting on Rosecrans blvd on about 1 acre (300' by 150'). Existing concrete block perimeter wall.

Proposed facility configuration-

1- 200 scfm IMW compressor with enclosure
3- 5000 psi ASME storage vessels
1- Zebec suction side dryer
drive thru 2 lane fueling island w/ canopy- 2 ea 2 hose dispensers
Dispenser Island with Universal card reader system for all fleets

HYDROGEN COMPATIBILITY ASSESSMENT

1. PFC/*owner cup request to the city of Gardena to include* H2 fueling system.

2. Install additional underground sleeves and conduits to the proposed fueling island for future hydrogen service.

3. Consider increasing planned electrical power design loads to include hydrogen pump and compressor for a bulk hydrogen system -#2.

4. Get site owner to commit to an additional 40 ft x 40 ft plot for future hydrogen fueling facility adjacent to proposed CNG station

5. Design the proposed external fueling island to accommodate a future hydrogen dispenser.

SITE #4
CITY OF BURBANK MUNICIPAL YARD
BURBANK

$230,000 to city to offset the cost of purchasing and installing a new CNG fueling system

No work in progress, preliminary design started with plot plan and flow schematic. application for cup not yet filed. An existing single story brick building on a 125' x 100' plot will be demolished to create the site for the new fueling station. The proposed fueling facility will front on lake blvd. there is an adjacent 75' x 100' landscaped area plot to the north of the proposed CNG station that can be used for a future stand alone bulk hydrogen fueling system- #2

Proposed facility configuration-

1- 400 scfm compressor with enclosure
3- 5000 psi ASME storage vessels
1- Zebec suction side dryer
Drive thru 2 lane fueling island with canopy- 1 ea 2 hose dispenser
Universal card reader system for all fleets

HYDROGEN COMPATIBILITY ASSESSMENT

1. City CUP and CEQA request to include H2 fueling system on the adjacent site

2. Hydrogen fueling dispenser will have its own independent side island separate from CNG fueling due to the congested site conditions

SITE #5
VALLEY VISTA SERVICES -
CITY OF INDUSTRY

$200,000 to offset the cost of purchasing and installing a new CNG fueling system

Planning work just starting. plan to have 15 to 20 CNG trash trucks. preliminary design started with a plot plan that includes gasoline, diesel (both u/g) and CNG on a 1 acre plot fronting on Hatcher Street. application for cup not yet filed. the proposed facility plot is on vacant land.

Proposed facility configuration-

2- 400 scfm compressor with enclosure
3- 5000 psi ASME storage vessels
1- Zebec suction side dryer
Drive thru 2 lane fueling island with canopy- 1 ea 2 hose CNG dispenser and 1 each 2 hose gasoline and diesel dispensers.
Universal card reader system for all fleets

HYDROGEN COMPATIBILITY ASSESSMENT

1. Owner CUP request to the City of Industry to include H2 fueling

2. Install additional underground sleeves and conduits to the proposed fueling island for future hydrogen service

3. Consider increasing planned electrical power design loads to include hydrogen pump and compressor for a bulk hydrogen system -#2

4. Get site owner to commit to an additional 50 ft x 50 ft plot for future bulk hydrogen fueling facility-#2 adjacent to proposed CNG station plot

5. Design the proposed external fueling island to accommodate a future hydrogen dispenser. Will have to be lengthened for this accommodation

SITE #6
FOOTHILL TRANSIT- POMONA YARD
POMONA

$500,000 to foothill transit to offset the cost of purchasing and installing a new CNG fueling system

No field work in progress. performance specs for CNG and LCNG completed. project out to bid for both fueling systems. Application for permits not yet filed. Existing underground conduit bank and high pressure gas line from compressor station to existing internal dispenser island already installed. 25' x 145' fueling station plot already selected. The proposed 50' x 150' external fueling island with 8' block isolation wall will front on First Avenue.

Proposed facility configuration will be either 60,000 gallon LNG/LCNG system or 4500 scfm + CNG compressor system

The external island has been deferred due to the lack of a fuel system decision. There is very limited access for both a bulk hydrogen fueling system #2 and an external fueling island if either CNG or LCNG is installed. Much more detailed research, investigation and study is required.

HYDROGEN COMPATIBILITY ASSESSMENT

1. Have owner commit, if space is available, to implementing h2 at the external island when a decision on the fuel type is made and a second decision is made to install the external island. The external island could be CNG or LNG/LCNG which could impact the potential for adding an H2 dispenser.

SITE #7
CITY OF PLACENTIA- CITY YARD

$200,000 to foothill transit to offset the cost of purchasing and installing a new CNG fueling system.

New station with compressor, dryer and dispenser island with 2- 2 hose CNG dispensers planned for fast filling. Open for external fleet access 24 hours per day.

No work in progress. Preliminary planning in progress with rough plot plan completed. Application for permits not yet filed. CNG station fueling station plot not yet selected.

Proposed CNG facility will be for 13 buses out of a 43 total bus fleet. also 2 CNG street sweepers will be filled from the system. limited plot limit although enough space to install the CNG station and the future H2 station

HYDROGEN COMPATIBILITY ASSESSMENT

1. Install additional underground sleeves and conduits to the proposed fueling island for future hydrogen service

2. Consider increasing planned electrical power design loads to include hydrogen pump and compressor for a bulk hydrogen system -#2

3. Get site owner to commit to an additional 50 ft x 50 ft plot for future bulk hydrogen fueling facility-#2 adjacent to proposed CNG station plot

4. Proposed fueling island to accommodate a future hydrogen dispenser. Will have to be lengthened for this accommodation.

SITE #8
FULLERTON UNIFIED SCHOOL DISTRICT

$137,200 to FUSD to offset the cost of purchasing and installing a new cng fueling system

Preliminary planning in progress. application for permits not yet filed. CNG station fueling station plot not yet selected. Six CNG buses on time fill.

Proposed CNG facility will be for 6 time fill buses out of a 43 total bus fleet. Very tight plot limit with just enough space to install the CNG station

There is not adequate access and space for a bulk hydrogen fueling system #2

HYDROGEN COMPATIBILITY ASSESSMENT

Site is not adequate for H 2 facility

SITE #9
PINNACLE CORP- WARE DISPOSAL

$230,000 to pinnacle Corporation to offset the cost of purchasing and installing a new CNG fueling system

Preliminary planning in progress. No drawings available. Site is roughly 150' frontage by >1000' depth. application for permits not yet filed. CNG station fueling station plot not yet selected.

proposed CNG facility will be for 30 + fast fill trash trucks using a dedicated internal CNG fueling island. A second external fueling island with 24 hour street side access is planned for local fleets. A very tight frontage may restrict installation of a 2 sided heavy duty drive thru external fueling island. There is adequate internal space for a CNG station on the property side opposite to the RR tracks.

There is adequate access and space for a bulk hydrogen fueling system #2.

HYDROGEN COMPATIBILITY ASSESSMENT

1. Install additional underground sleeves and conduits to the external fueling island only for future hydrogen service

2. Consider increasing planned electrical power design loads to include hydrogen pump and compressor for a bulk hydrogen system -#2

3. Get site owner to commit to an additional 50 ft x 50 ft plot for future bulk hydrogen fueling facility-#2 adjacent to proposed CNG station plot

4. Commitment for the external fueling island to accommodate a future hydrogen dispenser.

A-4

Spreadsheet: Project-by-Project Description

Entity	Fuel	Operational Function	Compressor/ Pump	Elec. Req.	Storage Tank	Refueling	Site	Code	Design Engrg.	Owner Receptivity	Project Status	Schedule Impact	Incremental Cost	Comments	Recommended Upgrade / Reason for No Recommended Upgrade
Recommended Upgrade															**Recommended Upgrade**
City of Placentia 401 East Chapman Avenue Placentia, CA	CNG	fast-fill; light-duty vehicles	TBD	TBD	TBD	dedicated CNG	minimal space	TBD	TBD	receptive	early planning stage	none	$80,000	electric panel upgrade, electrical conduit and gas piping, gas detection & fire protection plans, consulting services	upgrade facilities as noted in comments ($30K), optional upgrade to dual use CNG/H2 compressor ($50K)
PFG/Admin. Services Co-Op 2129 Rosecrans Avenue Gardena, CA	CNG	fast-fill; light-duty vehicles	200 scfm; 4-stage	480 v; 3 phase	3 storage vessels	dedicated CNG	adequate	TBD	TBD	receptive	bids received	none	$100,000	electric panel upgrade, electrical conduit and gas piping, gas detection & fire protection plans, consulting services	upgrade facilities as noted in comments ($30K), optional upgrade to dual use CNG/H2 compressor ($70K)
Valley Vista City of Industry, CA	CNG	fast-fill; heavy-duty vehicles and public refueling	CNG compressor	480 v; 3 phase	3-6 storage vessels	dedicated CNG	adequate	TBD	TBD	adequate	early planning stage	none	$35,000	electric panel upgrade, electrical conduit and gas piping, gas detection & fire protection plans, consulting services	upgrade facilities as noted in comments
PFG/Waste Mgmt of Inland Empire I-215 and CA-60 Riverside/West Chatsworth, Inc.	CNG	fast-fill; heavy-duty vehicles	existing	existing	1 existing, adding 2 vessels	dedicated CNG	adequate	TBD	TBD	receptive	bids received	none	$15,000	electric panel upgrade, electrical conduit and gas piping, gas detection & fire protection plans, consulting services	upgrade facilities as noted in comments
1035 East 4th St Santa Ana, CA	CNG	*fast-fill; heavy-duty vehicles*	*400 scfm; 3-stage*	*TBD*	*30,000 scf cascade*	*dedicated CNG*	*plot adequate; external stand minimal space*	*TBD*	*TBD*	*receptive*	*bids received*	none	$25,000	electric panel upgrade, electrical conduit and gas piping, gas detection & fire protection plans, consulting services, H2 compatible compressor	minimal space for public fueling island
No Recommended Upgrade															**Reason for No Recommended Upgrade**
City of Burbank 810 N. Lake Avenue Burbank, CA	CNG	fast-fill; light- & heavy-duty vehicles	400 scfm; 4-stage	480 v; 3 phase	3 storage vessels	dedicated CNG	minimal space	TBD	TBD	receptive	preliminary plans	none	$0	complete stand-alone H2 fueling system required	minimal space
Foothill Transit 200 S. East End Avenue Pomona, CA	CNG	fast-fill; transit buses	TBD	480 v; 3 phase	6 vessels	dedicated CNG	extremely critical	TBD	TBD	uncertain	plans out to bid	extremely tight schedule	unknown	decision delayed until customer makes fuel selection	extremely tight schedule, site specifics undecided
Fullerton Union High School District 1000 S. Lesse St La Habra, CA	CNG	time-fill; buses	TBD	TBD	none	dedicated CNG	unacceptable for H2	TBD	TBD	receptive	early planning stage	none	$0		site unacceptable for H2
Jurupa Unified Schoo District 4740 Pedley Road Riverside, CA	CNG	time-fill; buses; single hose fast-fill dispenser	200 scfm; 4-stage	480 v; 3 phase	none	dedicated CNG	adequate	TBD	N/A	receptive	under construction	extremely tight schedule	$0		unacceptable due to schedule
City of Monterey Park 751 S. Alhambra Avenue Monterey Park, CA	CNG	time-fill; light duty	Fuel Maker system; 4-stage	240 v; 1 phase	none	dedicated CNG	space restrictions	TBD	TBD	receptive	bids received	none	N/A	Fuel Maker unit is R&D demo for H2	Fuel Maker units
Westfleet Company 2181 E. Foothill Blvd. Pasadena, CA	CNG	time-fill; light duty	Fuel Maker system; 4-stage	240 v; 1 phase	none	dedicated CNG	space restrictions	TBD	TBD	receptive	bids received	none	N/A	Fuel Maker unit is R&D demo for H2	Fuel Maker units
Clean Commercial Fueling Inc. 1200 Magnolia Avenue Corona, CA	LCNG	fast-fill; heavy- & light-duty vehicles	TBD	TBD	TBD	dedicated CNG	adequate	TBD	TBD	receptive	preliminary plans	none	$35,000	*electric panel upgrade, electrical conduit and gas* piping, gas detection & fire protection plans, consulting services	*LNG operation - siting and permitting are serious* challenges at this location for future hydrogen use in combination with LNG siting
Gen/Trans 1700 West Fifth St San Bernardino, CA	LCNG	fast-fill; heavy-duty vehicles and public refueling	cryogenic pump	480 v; 3 phase	cryogenic 60,000 gallons	LCNG	adequate	TBD	TBD	receptive	bids received	extremely tight schedule	exceeds $100,000	A&E and permitting considerations	Major industrial site - not conducive to light duty vehicles -Hydrogen releasing equipment would be located so far from refueling island, we present day refueling of light vehicles. Siting and permitting issues
Gen/Trans 4748 Arrow Highway Montclair, CA	LCNG	fast-fill; heavy-duty vehicles and public refueling	cryogenic pump	480 v; 3 phase	cryogenic 20,000 gallons	LCNG	adequate	TBD	TBD	receptive	bids received	extremely tight schedule	$80,000 +	A&E and permitting considerations	Major industrial site - not conducive to light duty vehicles - LNG and hydrogen siting issues
PFG/Ford Distributing Co. Inc 571 W. Stover Avenue Rialto, CA	LCNG	fast-fill; heavy-duty vehicles	cryogenic pump	480 v; 3 phase	cryogenic 18,000 gallons	dedicated CNG	minimal space	TBD	TBD	receptive	plans out to bid	none	$35,000	electric panel upgrade, electrical conduit and gas piping, gas detection & fire protection plans, consulting services	minimal space- Refueling station is located at a major intersection and has major heavy duty traffic
Tiberinus Industries 1134 Blue Gum St Anaheim, CA	LNG	fast-fill; heavy-duty vehicles	cryogenic pump	480 v; 3 phase	cryogenic 18,000 gallons	LNG only	adequate	TBD	TBD	receptive	developing RFP	none	$35,000	electric panel upgrade, electrical conduit and gas piping, gas detection & fire protection plans, consulting services	Major industrial site - not conducive to multi-fuel addition of hydrogen. High concentration of heavy duty vehicles. Permitting a issue
County San Dist. Of LA County Puente Hills Landfill	LNG	fast-fill; heavy-duty vehicles	cryogenic pump	480 v; 3 phase	cryogenic 18,000 gallons	LNG only	adequate	TBD	TBD	receptive	developing RFP	none	$35,000	electric panel upgrade, electrical conduit and gas piping, gas detection & fire protection plans, consulting services	Major industrial site - not conducive to light duty vehicles
Riverside County Waste Management Agua Mansa Road I-10, SH60 and SH91	LNG	fast-fill; heavy-duty vehicles	cryogenic pump	480 v; 3 phase	cryogenic 18,000 gallons	LNG only	adequate	TBD	TBD	receptive	reviewing bids	none	$35,000	electric panel upgrade, electrical conduit and gas piping, gas detection & fire protection plans, consulting services	Major industrial site - not conducive to light duty vehicles- May present major permitting issues
City of Long Beach Gas Utility Yard 2400 East Spring St Long Beach, CA	LNG & LCNG	fast-fill; heavy-duty vehicles and public refueling	cryogenic pump	480 v; 3 phase	cryogenic 30,000 gallons	LNG & CNG	adequate	TBD	TBD	receptive	preliminary plans	none	$50,000	electric panel upgrade, electrical conduit and gas piping, gas detection & fire protection plans, consulting services	Not suitable due to liquefaction facility and multi-fuel permitting considerations
City of Santa Monica Big Blue Bus 1660 7th Street & corner of 9th St/Olympic Santa Monica, CA	LNG & LCNG	fast-fill; heavy-duty vehicles and public refueling	cryogenic pump	480 v; 3 phase	cryogenic 60,000 gallons	LNG & CNG	inadequate	TBD	TBD	receptive	bids received	none	$100,000	A&E for total project considerations are beyond the financial and timeline possibilities of this project review.	Site is under construction & will be fully developed in near term. Not suitable for hydrogen consideration at this time due to effects on all phases of this bus refueling site

A-5

Estimate of Electrolytic Hydrogen Cost

Dr. Peter Lehman Schatz Energy

Estimate of Electrolytic Hydrogen Cost

for the

Natural Gas-Hydrogen Compatibility Study Team

Dr. Peter Lehman
Schatz Energy Research Center
Humboldt State University
Arcata, CA 95521

For this estimate, I used specifications and costs for the Teledyne Energy Systems TITAN EC-750 electrolyzer. This information was provided by Jay Laskin, Manager of Marketing and Sales for TES. The information is as follows:

- Installed cost is $425,000
- H_2 is provided at 110 psig and 99.9998% purity
- Output is 42 Nm^3/hr = 42,000 Nl/hr
- Electricity consumption is 5.6 kWh/Nm^3
- Operation and maintenance (O&M) cost is $5,000/yr
- Module replacement cost is $60,000 and is required every 4 years

To estimate the cost of hydrogen, I'll use life cycle cost analysis. To calculate the net present value of the life cycle cost of this system, I use the following assumptions:

- System life is 20 years
- Net discount rate (investment rate - inflation rate) is 4%
- Electricity cost is $0.10/kWh

The yearly electricity cost is then:

$$\text{Electricity cost} = (42\ Nm^3/hr) \times (24/hrs/day) \times (365\ days/yr) \times (5.6\ kWh/Nm^3) \times (\$0.10/kWh)$$
$$= \$206{,}000/yr$$

The life cycle cost is:

$$LCC = (\text{Capital cost}) + (\text{O\&M costs}) + (\text{Electricity costs}) + (\text{Module replacement costs})$$

The O&M costs and the electricity costs are discounted to present value using the uniform present worth factor of 13.59 for 20 years and a 4% net discount rate. The module replacement costs are discounted using the following single present value factors: 4 years = 0.855; 8 years = 0.731; 12 years = 0.625; and 16 years = 0.534 for a 20 year life and a 4% net discount rate.

The life cycle cost is then:

$$LCC = (\$425,000) + (\$5,000)\cdot(13.59) + (\$206,000)\cdot(13.59) + (\$60,000)\cdot(.855+.731+.625+.534)$$
$$= \$3,457,000$$

Using the lower heating value of H_2 = 242 kJ/mol and the lower heating value of gasoline = 125,000 kJ/gal, the amount of hydrogen produced in 20 years expressed as gallons of gasoline equivalent is:

Total H_2 produced = (42,000 Nl/hr) x (24 hrs/day) x (365 days/yr) x (20 years) x
(1 mol/24.1 Nl) x (242 kJ/mol) x (1 gal gasoline/125,000 kJ)
= 591,000 gal of gasoline equivalent

Thus, the cost of hydrogen over the 20 year life of this system expressed in terms of gallons of gasoline equivalent is:

Cost of H_2 produced = \$3,457,000/591,000 gal of gasoline equivalent = \$5.85/gal

A-6

Compressor Survey Report

Herbert Burnett

Burnet & Burnette

CNG/H2 COMPRESSOR VENDOR SURVEY SUMMARY AND CONCLUSIONS

The following conclusions and summary finding regarding the dual application, mechanical compatibility, operational capability, and comparative costs of CNG and H2 compressors based on the enclosed survey and spreadsheet are noted below:

- 8 of the 15 compressors vendors responded to the survey
- 7 of the 8 compressor vendors manufactured both CNG and H2
- Reciprocating compressors are more frequently used for CNG
- Diaphragm compressors are generally used for H2 with few CNG applications
- Reciprocating compressor cost about 12% to 15% more for H2 than CNG.
- One diaphragm compressor vendor stated no cost difference between H2 and CNG for its mode. This cost appears to be 10% higher than comparable vendor cost for this size.
- Only one reciprocating compressor vendor stated no cost difference for H2 compared to CNG
- None of the 8 vendors have manufactured a compressor for both CNG and H2 operation
- None of the manufacturers recommended switching the same compressor between CNG and H2 for safety, product quality, and operational purposes
- Most of the CNG and H2 vendors use the same specifications for manufacturing
- It cost about 40% to 50% of an existing original compressor cost to convert to H2 in the field
- Lead time for purchase of a CNG compressor & H2 compressor is the same

SCAQMD H2/CNG COMPRESSOR SURVEY SUMMARY

COMPANY	CNG	H2	SURVEY QUESTIONS								
			#1 SIZE,SCFM	#1b COST M +$000	#2 SPECIFICATIONS	#3 NUMBER BUILT-2 YRS	#4 USED FOR BOTH H2 AND CNG	#5 MAX PRESSURE	#6 % INCREASE TO BUILD SAME CNG & H2 UNIT	#7 LEAD TIME	#8 CONVERT EXIST TO H2
SULZER-GREENFIELD	X	X	RECIP 20-400 CNG 20-400 H2 20-400 BOTH	$150M CNG $190M H2 BOTH $190M	CNG- API N/A H2- NFPA 52, ASME, ANSI, NEC	CNG -203 H2- 36	NO	CNG- PER SPEC H2 PER SPEC	20%	H2 -4 WEEKS LONGER	UNKNOWN, DEPENDS ON DESIGN
NORWALK	X	X	RECIP 20-400 CNG 20-400 H2 BOTH-NONE; H2 OK WITH CHANGES	$175/250M CNG $200/275M H2 BOTH $275M	CNG- ASME, NEC NFPA 52 API 1618 API 11P H2-ASME NEC NFPA 53 API 1618	CNG -5 H2- 10/12 OTHERS-6 RELATED GASES	NO	CNG 3600 H2- 5000	$10M	ABOUT SAME	$20-25M
KNOX-WESTERN	X	X	RECIP 20-400 CNG 20-400 H2 BOTH-NONE; H2 OK WITH CHANGES	CNG 200 SCFM- $100/110M; H2 200SCFM-$125/130M	CNG- ASME, NEC NFPA 52 API 1618 API 11P H2-ASME NEC NFPA 53 API 1618	CNG 150-200 H2 10-20	NO	CNG 3600 H2- 2600	$15-20M	4 WEEKS LONGER	$40-50M
PINNACLE	X	X	RECIP 20-400 CNG 20-400 H2 BOTH-NONE; H2 OK WITH CHANGES	NO DATA- $60M BID TO CONVERT SCAQMD DIAMOND CNG STATION	CNG- ASME, NEC NFPA 52 H2- ASME NEC NFPA 53 API	CNG- 10 H2 - 0	NO	CNG 5000 H2- 10,000	NO DATA	NO DATA	60% MORE THAN CNG COMPRESSOR
RIX INDUSTRIES	X	X	RECIP 20-400 CNG 20-400 H2 BOTH-NONE; H2 OK NO CHANGES	CNG 200 SCFM- $1450/155M; H2 200SCFM-$125/130M	CNG- ASME, NEC NFPA 52 API 1618 API 11P H2-ASME NEC API 1618	CNG 145 H2 45	NO	CNG 5,000 H2- 6,000	$10 -15M	ABOUT SAME	$10/15M BUT DEPENDS ON MODEL
PRESSURE PRODUCTS INDUSTRIES		X	DIAPHRAGM; 200-400 SCFM; H2 OK WITHOUT CHANGES	CNG AND H2- $226 M EACH	CNG- API 1618 WITH DEVIATIONS; H2 API 1618 WITH DEVIATIONS	CNG 0 H2 60 OTHER GASES 50+	NO	CNG -AS NEEDED H2 AS NEEDED	0	ABOUT SAME	$0 IF THEIR OWN COMPRESSOR DESIGNED TO API
HOWDEN-BURTON CORBLIN COMPRESSOR	X	X	DIAPHRAGM; 200-400 SCFM; H2 OK WITH CHANGES	NO COST DATA AVAILABLE	CNG- ASME, NEC NFPA 52 API 1618 API 11P, NFPA 53 H2-ASME NEC API 1618	CNG <5 H2 24+	NO	CNG -AS NEEDED H2 AS NEEDED	NO DATA	ABOUT SAME	30% OF COMPRESSOR COST
COMP AIR- UK VENDOR	X	X	RICIP 400 SCFM; H2 WITH CHANGES	CNG $ 211M; H2 $ 226M	NO DATA PROVIDED	NO DATA PROVIDED	NO DATA PROVIDED	CNG-3600; H2- 6000	NO DATA	NO DATA	NO DATA

HFB 6/14/01 H2 COMPATIBILITY

UNIQUE SITUATION

SCAQMD Survey
of Compressors for CNG and Hydrogen Service

All information provided on this form will be kept confidential and will only be used in summary form. Please direct your questions regarding this survey form to Adewale Oshinuga (909 396 2599 or email aoshinuga@aqmd.gov).

Your response is greatly appreciated and is requested within 24 hours of receipt.

QUESTION	RESPONSE
1. What sizes of compressors do you make?	CNG Size 1 :_____Size 2_____ Hydrogen Size 1_____ Size 2_____ Both Hydrogen and CNG Size 1_____ Size 2_____
What type of compressor do you make?	Reciprocating ___ Piston Type____ Diaphragm ___ Centrifugal ____ Other ___
Can a CNG compressor be used in hydrogen service in your compressor?	Yes _____ No_____ Why? _____
2. What is the cost of each compressor listed in #1? Assume inlet pressure is the same.	CNG Size 1 $_____ Size 2$_____ Hydrogen Size 1$_____ Size 2$_____ Both Hydrogen and CNG Size 1 $_____ Size 2 $_____
3. What is the API Specification and other specs that you use to build a hydrogen compressor and a CNG compressor?	CNG Compressor _____ Hydrogen Compressor _____
4. How many hydrogen compressors and how many CNG compressors have you built in the last 2 years?	CNG _____ Hydrogen _____ Other types of compressors_____
5. Do you have a CNG compressor operating in the US that is used for both hydrogen and CNG?	Yes _____ No _____ If yes, where_____
6. If a CNG compressor is used in hydrogen service, what is the maximum discharge pressure that can be delivered?	Pressure in psig on hydrogen_____ Pressure in psig on CNG _____
7. Approximately what is the cost difference in building a hydrogen compressor compared to a CNG compressor for the same frame size and mechanical performance?	Additional Cost: 5000 psi $_____ 6000 psi $ _____ 7000 psi $ _____ 8000 psi $ _____ 9000 psi $ _____ 10,000 psi $ _____
8. What would it cost to convert an existing operating CNG compressor to hydrogen?	First, can it be done. Yes____ No _____ Cost $ _____

Name_____ **Company**_____ **Email or phone number** _____

Date _____

ank you for completing this survey. Please return it by fax to 909 396 3252, or by email to the address above. hfb 8/1/1

SCAQMD Survey of Compressors for CNG and Hydrogen Service

All information provided on this form will be kept confidential and will only be used in summary form. Your response is greatly appreciated and is requested within 24 hours of receipt.

QUESTION	RESPONSE
1. What sizes of compressors do you make?	CNG Size 1: 200 Scfm Size 2: 400 Scfm Hydrogen Size 1: 200 Scfm Size 2: 400 Scfm
	Both Hydrogen and CNG Size 1: None, easily done Size 2: None, easily done
What type of compressor do you make?	Reciprocating X Piston Type____ Diaphragm ___ Centrifugal ____ Other ___
Can a CNG compressor be used in hydrogen service in your compressor?	Yes X, without modification No
2. What would be the approximate cost for the following compressor? Assume inlet pressure is the same.	Size 1: 200 Scfm $145-155,000 Size 2: $165-175,000
	Both Hydrogen and CNG None
3. What is the API Specification and other specs that you use to build a hydrogen compressor and a CNG compressor?	CNG Compressor: ASME, NEC, NFPA52, API618, API 11P
	Hydrogen Compressor: ASME, NEC, API618
4. How many hydrogen compressors and how many CNG compressors have you built in the last 2 years?	CNG 146 Hydrogen 46
	Other types of compressors 200+ in other gases
5. Do you have a CNG compressor operating in the US that is used for both hydrogen and CNG?	Yes _____ No X
	If yes, where_____
6. If a CNG compressor is used in hydrogen service, what is the maximum discharge pressure that can be delivered for the same compressor?	Pressure in psig on hydrogen: 5,000 psi
	Pressure in psig on CNG: 6,000psi
7. Approximately what is the cost difference in building a hydrogen compressor compared to a CNG compressor for the same frame size and mechanical performance?	Additional Cost: 5,000 psi: $10-15,000 6,000 psi: $10-15,000 7,000 psi: No Data
	8,000 psi: No Data 9,000 psi: No Data
8. *What would it cost to convert an existing* operating CNG compressor to hydrogen?	*First, can it be done.* Yes X No _____ Cost $10-15,000 but depends on model

Name: George Wood **Company:** Rix Industries **Email or phone number:** (707) 333-6273

Date: August 7, 2001

Thank you for completing this survey.

SCAQMD Survey
of Compressors for CNG and Hydrogen Service

All information provided on this form will be kept confidential and will only be used in summary form. Your response is greatly appreciated and is requested within 24 hours of receipt.

QUESTION	RESPONSE
1. What sizes of compressors do you make?	CNG Size 1: 200 Scfm Size 2: 400 Scfm Hydrogen Size 1: 200 Scfm Size 2: 400 Scfm
What type of compressor do you make?	Both Hydrogen and CNG Size 1: None Size 2: None Reciprocating X Piston Type____ Diaphragm ___ Centrifugal ____ Other ___
Can a CNG compressor be used in hydrogen service in your compressor?	Yes _X, but internal changes such as valve replacements will be needed No
2. What would be the *approximate cost* for the following compressor? Assume inlet pressure is the same.	Size 1: 200 Scfm $100-110,000 Size 2: $125-130,000 Both Hydrogen and CNG None
3. What is the API Specification and other specs that you use to build a hydrogen compressor and a CNG compressor?	CNG Compressor: ASME, NEC, NFPA52, API618, API 11P Hydrogen Compressor: ASME, NEC, NFPA63, API618
4. How many hydrogen compressors and how *many CNG compressors have you built in the* last 2 years?	CNG 150-200 Hydrogen 10-20 Other types of compressors 200 – Other Gases
5. Do you have a CNG compressor operating in the US that is used for both hydrogen and CNG?	Yes _____ No X If yes, where_____
6. If a CNG compressor is used in hydrogen service, what is the maximum discharge *pressure that can be delivered for the same* compressor?	Pressure in psig on hydrogen: Couple of thousand pounds Pressure in psig on CNG: 3,600 –5,000psi
7. Approximately what is the cost difference in building a hydrogen compressor compared to a CNG compressor for the same frame size and mechanical performance?	Additional Cost: 5,000 psi: 15-20,000 6,000 psi: No Data 7,000 psi: No Data 8,000 psi: No Data 9,000 psi: No Data
8. What would it cost to convert an existing operating CNG compressor to hydrogen?	First, can it be done. Yes__X__ No _____ Cost $40,000-50,000

Name: Robert Yucha Company: Knox-Western Email or phone number: (814) 459-2754 x 243

Date: August 7, 2001

General Statement: A compressor in hydrogen service can be used for Natural Gas by simply replacing gas valves. If the compressor is built for Natural Gas service, It should not be used for Hydrogen without major modifications.

nk you for completing this survey.

SCAQMD Survey
of Compressors for CNG and Hydrogen Service

All information provided on this form will be kept confidential and will only be used in summary form. Your response is greatly appreciated and is requested within 24 hours of receipt.

QUESTION	RESPONSE
1. a. What sizes of compressors do you make?	CNG 20 to 400 SCFM Hydrogen Size 20 to 400 SCFM
35 psig suction, 4500 psig discharge	Both Hydrogen and CNG 20 to 400 SCFM
What type of compressor do you make?	Reciprocating X Piston Type____ Diaphragm ___ Centrifugal ____ Other ___
Can a CNG compressor be used in hydrogen service in your compressor?	Yes _____ No X Why? CNG compressor is not designed for H2
1.b. What would be the approximate cost for the following compressor? Assume 300 scfm, 35 psi inlet and 4500 psi outlet.	CNG $160,000 Hydrogen $180,000
	Both Hydrogen and CNG $180,000
2. What is the API Specification and other specs that you use to build a hydrogen compressor *and a CNG compressor*?	CNG Compressor API does not apply to process compressors
	Hydrogen Compressor NFPA 52, ASME, ANSI, NEC, NEMA, AWS
3. How many hydrogen compressors and how many CNG compressors have you built in the last 2 years?	CNG 203 Hydrogen 36
	Other types of compressors 132
4. Do you have a CNG compressor operating in the US that is used for both hydrogen and CNG?	Yes _____ No X
	If yes, where_____
5. If a CNG compressor is used in hydrogen service, what is the maximum discharge pressure that can be delivered for the same compressor?	Pressure in psig on hydrogen The design pressure
	Pressure in psig on CNG The design pressure
6. *If there is a cost increase* for you to build a hydrogen compressor compared to a CNG compressor (for the same frame size and mechanical performance) what is it?	Please circle one;
	<5% <10% <15% (<20%) <25% or more than 25%
7. Are the lead times the same for H2 and CNG compressors?	YES X NO _____If no what is the difference in lead time 4 weeks
8. What would be the additional cost to increase *the discharge pressure from 4500 psi* (CNG) to each of the following pressures in H2:	5000 psi $ 7%-8% 6000 psi $ 10%-12%
9. What would it cost to convert an existing operating CNG compressor to hydrogen?	First, can it be done. Yes____ No _____ Cost Depends on the design. It may be cost prohibitive.
10. Can your standard CNG compressor be used *(at a later date) in a blend of up to a* maximum of 30% hydrogen?	Yes_____ No X If No why Not? Compressor not suitable for *Hydrogen service.*

Name: Shakeel Ahmed, Company: GreenField Compression Inc. Email or phone number: shakeel.ahmed@fgcomp.com

ate: August 7, 2001

Note: If the compressor is built for Hydrogen service, it can be used for Natural Gas by simply installing Natural Gas valves. If the compressor is built for Natural Gas service, It should not be used for Hydrogen without major modifications.

Thank you for completing this survey.

SCAQMD Survey
of Compressors for CNG and Hydrogen Service

All information provided on this form will be kept confidential and will only be used in summary form. Your response is greatly appreciated and is requested within 24 hours of receipt.

QUESTION	RESPONSE
1. What sizes of compressors do you make?	CNG Size 1: 200 Scfm Size 2: 400 Scfm Hydrogen Size 1: 200 Scfm Size 2: 400 Scfm
What type of compressor do you make?	Both Hydrogen and CNG Size 1: None Size 2: None
Can a CNG compressor be used in hydrogen service in your compressor?	Reciprocating X Piston Type____ Diaphragm ___ Centrifugal ____ Other ___
	Yes X, but internal changes such as valve replacements will be needed No
2. What would be the approximate cost for the following compressor? Assume inlet pressure is the same.	Size 1: 200 Scfm $175-250,000 Size 2: $200-275,000
	Both Hydrogen and CNG None
3. What is the API Specification and other specs that you use to build a hydrogen compressor and a CNG compressor?	CNG Compressor: ASME, NEC, NFPA52, API618, API 11P
	Hydrogen Compressor: ASME, NEC, NFPA63, API618
4. How many hydrogen compressors and how many CNG compressors have you built in the last 2 years?	CNG 5 Hydrogen 10-12
	Other types of compressors 6 – Other Gases
5. Do you have a CNG compressor operating in the US that is used for both hydrogen and CNG?	Yes _____ No X
	If yes, where_____
6. If a CNG compressor is used in hydrogen service, what is the maximum discharge pressure that can be delivered for the same compressor?	Pressure in psig on hydrogen: 5,000 psi
	Pressure in psig on CNG: 3,600 psi and above
7. Approximately what is the cost difference in building a hydrogen compressor compared to a CNG compressor for the same frame size and mechanical performance?	Additional Cost: 5,000 psi: 10,000 6,000 psi: $10,000 7,000 psi: $10,000
	8,000 psi: 10,000 9,000 psi: $10,000
8. What would it cost to convert an existing operating CNG compressor to hydrogen?	First, can it be done. Yes X No _____ Cost $20,000-25,000

Name: Graham Barker **Company:** Norwalk Company, Inc. **Email or phone number:** (203) 838-4766

Date: August 7, 2001

General Statement: A compressor in hydrogen service can be used for Natural Gas by simply replacing gas valves. If the compressor is built for Natural Gas service, It should not be used for Hydrogen without major modifications.

Thank you for completing this survey.

SCAQMD Survey
of Compressors for CNG and Hydrogen Service

All information provided on this form will be kept confidential and will only be used in summary form. Your response is greatly appreciated and is requested within 24 hours of receipt.

QUESTION	RESPONSE
1. What sizes of compressors do you make? What type of compressor do you make? Can a CNG compressor be used in hydrogen service in your compressor?	CNG Size 1: 200 Scfm Size 2: 400 Scfm Hydrogen Size 1: 200 Scfm Size 2: 400 Scfm Both Hydrogen and CNG Size 1: None Size 2: None Reciprocating X Piston Type____ Diaphragm ___ Centrifugal ____ Other ___ Yes X, changes in piping and sequencing valuves No
2. What would be the approximate cost for the following compressor? Assume inlet pressure is the same.	Size 1: 200 Scfm No Data Size 2: No Data Both Hydrogen and CNG None
3. What is the API Specification and other specs that you use to build a hydrogen compressor and a CNG compressor?	CNG Compressor: ASME, NEC, NFPA52 Hydrogen Compressor: ASME, NEC, NFPA 63, API
4. How many hydrogen compressors and how many CNG compressors have you built in the last 2 years?	CNG 12 Hydrogen 0 Other types of compressors -
5. Do you have a CNG compressor operating in the US that is used for both hydrogen and CNG?	Yes _____ No X If yes, where_____
6. If a CNG compressor is used in hydrogen service, what is the maximum discharge pressure that can be delivered for the same compressor?	Pressure in psig on hydrogen: 10,000 psi Pressure in psig on CNG: 5,000psi
7. Approximately what is the cost difference in building a hydrogen compressor compared to a CNG compressor for the same frame size and mechanical performance?	Additional Cost: 5,000 psi: No Data 6,000 psi: No data 7,000 psi: No Data 8,000 psi: No Data 9,000 psi: No Data The Company sells stations rather than individual compressors
8. What would it cost to convert an existing operating CNG compressor to hydrogen?	First, can it be done. Yes X No _____ Cost 50% more than CNG compressor

Name: Drew Diggins **Company:** Pinnacle **Email or phone number:** (915) 686-7002

Date: August 7, 2001

Thank you for completing this survey.

SCAQMD Survey
of Compressors for CNG and Hydrogen Service

All information provided on this form will be kept confidential and will only be used in summary form. Your response is greatly appreciated and is requested within 24 hours of receipt.

QUESTION	RESPONSE
1. What sizes of compressors do you make?	CNG Size 1: 200 Scfm Size 2: 400 Scfm Hydrogen Size 1: 200 Scfm Size 2: 400 Scfm
What type of compressor do you make?	Both Hydrogen and CNG Size 1: No, but could design Size 2: No, but could design
Can a CNG compressor be used in hydrogen service in your compressor?	Reciprocating Piston Type____ Diaphragm _X__ Centrifugal ____ Other ___
	Yes _X, but internal changes such as valves will be needed No
2. What would be the approximate cost for the following compressor? Assume inlet pressure is the same.	Size 1: No Data Size 2: No Data
	Both Hydrogen and CNG
3. What is the API Specification and other specs that you use to build a hydrogen compressor and a CNG compressor?	CNG Compressor: API618, ASME, NEC, NFPA52
	Hydrogen Compressor: API618, ASME, NEC, NFPA63
4. How many hydrogen compressors and how many CNG compressors have you built in the last 2 years?	CNG < 5 Hydrogen 24+
	Other types of compressors 24+ in other gases
5. Do you have a CNG compressor operating in the US that is used for both hydrogen and CNG?	Yes _____ No X
	If yes, where_____
6. If a CNG compressor is used in hydrogen service, what is the maximum discharge pressure that can be delivered for the same compressor?	Pressure in psig on hydrogen: As Needed
	Pressure in psig on CNG: As Needed
7. Approximately what is the cost difference in building a hydrogen compressor compared to a CNG compressor for the same frame size and mechanical performance?	Additional Cost: 5,000 psi: No Data 6,000 psi: No Data 7,000 psi: No Data
	8,000 psi: No Data 9,000 psi: No Data
8. What would it cost to convert an existing operating CNG compressor to hydrogen?	First, can it be done. Yes__X__ No _____ Cost < 30%0

Name: Bob Filosa Company: Howden/Burton Corblin Compressor Email or phone number: (215) 702-7777

Date: August 9, 2001

Thank you for completing this survey.

SCAQMD Survey
of Compressors for CNG and Hydrogen Service

All information provided on this form will be kept confidential and will only be used in summary form. Your response is greatly appreciated and is requested within 24 hours of receipt.

QUESTION	RESPONSE
1. What sizes of compressors do you make?	CNG Size 1: 200 Scfm Size 2: 400 Scfm Hydrogen Size 1: 200 Scfm Size 2: 400 Scfm
What type of compressor do you make?	Both Hydrogen and CNG Size 1: 200 Scfm Size 2: 400 Scfm
Can a CNG compressor be used in hydrogen service in your compressor?	Reciprocating Piston Type____ Diaphragm _X__ Centrifugal ____ Other ___ Yes _X, without modification; use the same o-ring for CNG/Hydrogen No
2. What would be the approximate cost for the following compressor? Assume inlet pressure is the same.	Size 1: $226,000 Size 2: $ 226,000 Both Hydrogen and CNG Same
3. What is the API Specification and other specs that you use to build a hydrogen compressor and a CNG compressor?	CNG Compressor: API618 with some deviation Hydrogen Compressor: API618 with some deviation
4. How many hydrogen compressors and how many CNG compressors have you built in the last 2 years?	CNG 0 Hydrogen 50 Other types of compressors 50+ in other gases
5. Do you have a CNG compressor operating in the US that is used for both hydrogen and CNG?	Yes _____ No X If yes, where_____
6. If a CNG compressor is used in hydrogen service, what is the maximum discharge pressure that can be delivered for the same compressor?	Pressure in psig on hydrogen: As Needed Pressure in psig on CNG: As Needed
7. Approximately what is the cost difference in building a hydrogen compressor compared to a CNG compressor for the same frame size and mechanical performance?	Additional Cost: 5,000 psi: $0 6,000 psi: $0 7,000 psi: 0 8,000 psi: 0 9,000 psi: 0
8. What would it cost to convert an existing operating CNG compressor to hydrogen?	First, can it be done. Yes__X__ No _____ Cost $0

Name: Lee Coleman **Company:** Pressure Product Industries **Email or phone number:** (215) 675-1600

Date: August 8, 2001

Note: The compressors can be used in Division 2 area because of their zero leaking rate.

Thank you for completing this survey.

PINNACLE CNG COMPANY
P.O. Box 2499
Midland, Texas 79702

(915) 686-7002 (Office)
(915) 686-1557 (Fax)

July 19, 2001

Mr. Larry Watkins
Project Manager
21865 East Copley Drive
Diamond Bar, California 91765-4182

Re: Feasibility Study of a Hydrogen Compatible Fast Fill CNG Fueling Station

Dear Mr. Watkins:

As you requested, I have assembled bullet points on the step-by-step process Pinnacle CNG envisions in evaluating the feasibility of making the Diamond Bar fast fill CNG site hydrogen compatible. The proposal assumes that Pinnacle is awarded the bid for the Diamond Bar fast fill CNG station. The feasibility study would include the following steps:

- Set performance specifications for a hydrogen/CNG station
  - Purity of hydrogen to be dispensed (Hythane, 99.99% hydrogen)
  - Pressure for hydrogen dispensing (4,000 PSI)
  - Determine source of hydrogen and delivery pressure
  - Dedicated hydrogen dispenser with special filling profile
  - Automatic hydrogen vehicle performance reporting (MPG, engine hours, range)

- Test hydrogen compressor performance establishing empirical data (Midland, Texas)
  - kW per Hydrogen Gasoline Gallon Equivalent (HGGE)
  - Determination of hydrogen seepage from system (SCF/H)
  - Calibration of hydrogen dispenser Lbs Mass / HGGE
  - Performance curve Hp per SCFM at variable inlet pressures
  - Testing at 4000 PSI is estimated at 200 hours at $350 per hour plus electricity and hydrogen used.

To the extent possible Pinnacle will utilize its existing equipment, however the compressor and cooler materials, flow valves, dispensers, flow lines, operating system computer code and safety relief valves will need to be modified for hydrogen. Pinnacle proposes that SCAQMD pay Pinnacle $139,466 to implement the following necessary modifications:

1. Hydraulic compressor cylinders and heads	$25,000
2. Cooler section materials	36,066
3. Valves	10,400
4. Hydrogen dispenser	27,000
5. Hydrogen flow lines	11,000
6. Computer programming	13,000
7. Labor (manufacturing and installation)	17,000
	$139,466

Pinnacle will contribute a like amount by providing its expertise, use of its test facilities and equipment and the 200 hours of testing (including the electricity and hydrogen). This initial stage of the feasibility study is estimated to take 140 days. If this initial stage is successful, then Pinnacle believes there will need to be additional testing for 800 hours at 4,000 PSI and 1,000 hours at 6,000 PSI. The cost of this additional testing can be better determined at that the conclusion of the initial stage. Pinnacle anticipates that SQACMD and Pinnacle would work jointly to obtain sufficient funding to conduct the two additional stages of testing and to cover the cost of manufacturing the hydrogen compatible CNG equipment. This equipment would be installed at the Diamond Bar fast fill CNG site.

If you have any questions, please do not hesitate to call me. My e-mail address is ddiggins@pinnaclecng.com

Sincerely yours,

Drew Diggins, P.E.
Operations Manager

DD/GDD/ggm

lwatkinsletter.doc

COMP-AIR

GAS REFUELLING PROJECT – GENERAL SPECIFICATION

GAZPACK 70 COMPRESSION MODULE

GENERAL: MACHINE SELECTION & PERFORMANCE EXPECTATION

Machine type	-	"W" configuration, Oil Lubricated, Reciprocating Piston
Cooling	-	Air-cooled via multi-stage air blast heat exchanger
Max intake temperature (norm)	-45°C	
Ambient temperature (norm)	-	-10 to 45°C
Drive method	-	Vee belt drive
Available gas pressure	-	**90 psig (assumed in both CH4 & H2 configurations).**
Module working pressure	-	3600 psig (based on natural gas operation
Module working pressure	-	6000 psig (if configured for H2 operation)
Selected speed	-	1395 rpm est.

Configuration for 3600 psig	-	First stage of compression	-	Qty 1 x 115 mmØ double acting
		Second stage of compression	-	Qty 1 x 80 mmØ single acting
		Third stage of compression	-	Qty 2 x 50 mmØ single acting
		Fourth stage of compression	-	Qty 2 x 28 mmØ single acting
		Cylinder stroke	-	80 mm
Configuration for 6000 psig	-	First stage of compression	-	Qty 1 x 115 mmØ double acting
		Second stage of compression	-	Qty 1 x 80 mmØ single acting
		Third stage of compression	-	Qty 2 x 40 mmØ single acting
		Fourth stage of compression	-	Qty 2 x 22 mmØ single acting
		Cylinder stroke	-	80 mm

A) Estimated capacity (configured for 3600 psig on CNG)	-	420 Scfm
A1)Estimated shaft power at (A)	-	191 hp
B) Estimated capacity (configured for 6000 psig on H2)	-	343 Scfm
B1) Estimated shaft power at (B)'	-	169 hp
C) Estimated capacity (6000 psig build used on 3600 psig CNG)	-	370 Scfm
C1) Estimated shaft power at (C)	-	173 hp
Motor requirement to cater for all scenarios	-	*200 hp (minimum)*

GAS REFUELLING PROJECT – GENERAL SPECIFICATION

COMMERCIAL SECTION

Pricing Table (all pricing is shown in US$)

	Qty	Description	Unit Price	Total Price per station
See ###	1	GazPack 70 Compressor Module (configured 3600 psig)	$ 211505.00	$211505.00
See ***		Motor and drive arrangement (Class 1, Div 1, Group D)	Included in item 1	Included in item 1
		Gas inlet train	Included in item 1	Included in item 1
		Gas recovery system	Included in item 1	Included in item 1
		Gas delivery system	Included in item 1	Included in item 1
		Systems enclosure	Included in item 1	Included in item 1
		Enclosure gas detection	Included in item 1	Included in item 1
		Enclosure lighting	Included in item 1	Included in item 1
		Compressor sump heater	Included in item 1	Included in item 1
See ###		Packaged electrical work (UL Switches/wiring)	Included in item 1	Included in item 1
		Starter control panel (For Safe area)	Included in item 1	Included in item 1
		Testing & Documentation	$ 2,800.00	$ 2,800.00
		TOTAL COST (UK Sterling)		**$ 214,305.00**
Note ***	1	Price ***reduction*** for NON UL electric's (i.e. standard CompAir intrinsically safe equipment + standard wiring	- $ 29,088.00	- $ 29,088.00
Note ###	1	Price ***addition*** if powered electric's/control supplied to Class 1, Div 1, Group B (hydrogen). Uprated (6000 psig) cylinder configuration, cooler & piping system.	+ $15204.00	+ $ 15,204.00

Please Note: At this time, all prices are indicative only and based on our interpretation of the of the system requirements at present. This quotation cannot be assumed to be compliant, in part or in whole with any project specification unless confirmed to that effect in writing. We will be happy to review alternatives of equipment if required in order to offer a total system solution.

Pricing shown at present is NETT, and are for equipment supplied unpacked and Ex Works, UK. Additional costs for equipment supplied FOB UK Port is envisaged to be approximately $ 2,800.00

Terms & Conditions

Subject to contract agreement, this quotation is initially made in accordance with standard conditions of sale. Validity for this initial proposal is 60 days from the date of this quotation.

Despatch Period

The despatch period for the first unit is likely to be approximately 20 - 24 working weeks from our acknowledgement of your official order, satisfactory letter of credit detail and clarification of all necessary technical and commercial details which allows us to commence with uninterrupted manufacture etc, etc.

BURNETT AND AIR PRODUCTS COMPRESSOR VENDORS (in no particular order)

NORWALK- see below
ARIEL- 614 397 0311
HURRICANE- 800 955 4626
GEMINI- 512 289 5454
KNOX WESTERN – see below
TMC- no current number
INGERSOLL-RAND – see below
PINNACLE – 915 686 7002
MAKO – 904 732 2268
PIGNONE – 714 895 7811
SULZER – see below
IMW- 502 584 7766
HASKELL – 818 843 4000
DRESSER-RAND- 607 937 2430
RIX- see below

Henderson Compressors
Shakeel Ahmed @ 972 234 3226, ext 117
Compressor was used at CaFCP and will be used at DOE. 6000 psig capability
909 N. Bowser Rd.
Richardson, TX

CompAir
Have been used in many Stuart applications.
Based in UK, North America located in Ocala FL, (904) 732-2268

Greenfield (Sulzer) Compressors (also associated with Hendersen)
Dave Pearce @ (972) 889-2400 ext 134
Extensive CNG Experience and has said they could do H2 as well.
Same address as Henderson

Pinnacle

Dresser-Rand
Paul Clark Drive
P.O. Box 560
Olean, NY 14760
Phone (716) 375-3000
www.dresser-rand.com

Norwalk Company, Inc.
Box 548, 20 N. Water Street

FuelMaker

TELEFAX to:

AQMD
909 396 3879

Attn: Larry Watkins

Date: August 7, 2001

From: Ralph Rackham

Re: Hydrogen Compression

FuelMaker Corp., Toronto
Tel. No. (416) 674-3034 Ext 221
Fax No. (416) 674-3042

Total Number of Pages 3 Including This Page.

Hi Larry:

The following is a follow-up to our telephone conversation earlier today. To operate one of our VRAs on hydrogen we make the following changes·

- material for the valve springs is changed
- the material for the 4th stage a head is changed (depending on the operating pressure)
- material is changed for the 4th stage piston and cylinder
- the humidity of the hydrogen must be closely controlled
- the burst disc is replaced (depending on the operating pressure)
- hose, nozzle, and breakaway may be modified
- gas detectors are installed within the appliance housing
- control logic is modified to require a gas detection permissive
- positive indication of airflow is required as a permissive

Other considerations.

- Our VRAs are certified for operation on natural gas. In the case of hydrogen there is no such certification so a case-by-case approval is required. In the case of Honda's fast fill hydrogen station in Torrance approval was obtained with the appropriate ventilation, detection, and control logic.
- VRAs are typically designed to be safe enough to permit operation with natural gas by an unskilled and untrained user. This is not the case for hydrogen - special training is required and the installation should be protected against interference by unauthorized personnel. An example of "Special Conditions for Operation. " is attached

FuelMaker Corporation • 6185 Sugar Maple Drive, Westerville, OH 43082-9792 TEL: (614) 794-1993 FAX: (614) 794-1998

August 8, 2001

Mr. Larry Watkins
South Coast AQMD
21865 E. Copley Drive
Diamond Bar, CA 91765-4182

Dear Larry:

Thank your for contacting us and considering FuelMaker equipment for the fast-fill hydrogen refueling station project under consideration at AQMD.

We are pleased to offer you the following cost estimate for a turn-key hydrogen fueling station package per your request. The items listed on the following pages include prices for the following categories: basic equipment, various optional features, design & engineering, installation and commissioning.

Please note that this is only a preliminary cost estimate for budgetary purposes and does not represent an actual quotation. We do however feel comfortable that the figures contained herein are a reasonable calculation of the costs that would be involved and that a formal quotation from FuelMaker, if requested, would be within a variance of +/- 20% of the *total. Please also pay special attention to the parameters and assumptions listed which* provide the basis for our cost estimates.

We look forward to working with you on this project should you decide to move forward and would be happy to supply you with a formal quotation at your request. Please contact me if you should have any questions or need clarification on the enclosed information.

Sincerely,
FuelMaker Corporation

Bruce E. Rayner

Bruce E. Rayner
Vice-President – U.S. Sales

Cc: Ralph Rackham – FuelMaker
Anthony Chan – FuelMaker
Larry Ozier – Gas Equipment Systems

Cost Estimate for FuelMaker Fast-Fill Hydrogen Refueling Station
August 8, 2001

Product/Service	Description	Price
FuelMaker Hydrogen Compression Unit	Modified VRA (not certified) to compress low-pressure hydrogen to 5,000 psi and transfer into storage.	$9,500
FuelMaker Fast-Fill Storage & Dispensing Unit	Self-contained high pressure hydrogen storage and dispensing unit consisting of manual sequencing valve, ESD, sheet-metal enclosure, breakaway, fill hose assembly, gas detector and other needed components determined by FuelMaker to insure a safe and reliable system.	$46,000
Automatic Sequencing and Priority Fill	Optional enhanced fast-fill feature, if desired.	$20,000
Flow measurement with Display	Optional enhanced fast-fill feature to easily identify and record amount of fuel dispensed per vehicle, if desired.	$12,000
Design & Engineering	One-half of the engineering and development costs to design, manufacture and test above system. FuelMaker will absorb the other 50%.	$15,000
Installation, commissioning and freight.	Includes 6'x25' poured concrete pad, six impact-protection bollards, up to 60' trench in earthen soil for low-pressure H2 pipe (incl.) for connection to H2 supply, two low-pressure regulators, and all high-pressure pipe, connections and fittings and applicable signage. Also includes electrical disconnect switch and final electrical connection, and mounting/securing of all related hardware. See following installation assumptions.	$21,500

Assumptions

- AQMD will provide tube trailer as hydrogen source for refueling system. Available pressure at trailer outlet will be 5-10 psi or greater.
- Costs do not include permitting work, fees or other unspecified equipment required for the site & installation to meet local code approval.
- Installation costs assume electrical connection (240-volt, single phase, 20-amp circuit) will be available at the desired location of the FuelMaker compression unit. A 120-volt, single phase, 15-amp circuit will also be required at the Fast-Fill Storage & Dispensing unit. Final installation costs will also depend on characteristics of the selected location.
- This estimate governed by 8/7/01 telefax from FuelMaker's Ralph Rackham to Larry Watkins regarding considerations and special conditions pertaining to hydrogen compression and refueling with the FuelMaker VRA and related equipment.

A-7

Schematic Diagram

AQMD Vehicle H2 Layout

Polo del Toro

Sunline Transit

AQMD Vehicle H2 layout

1) Tube Trailer to fuel vehicle directly to @ 3000 psi via fuel maker storage/dispenser and supply Fuel Makers H2

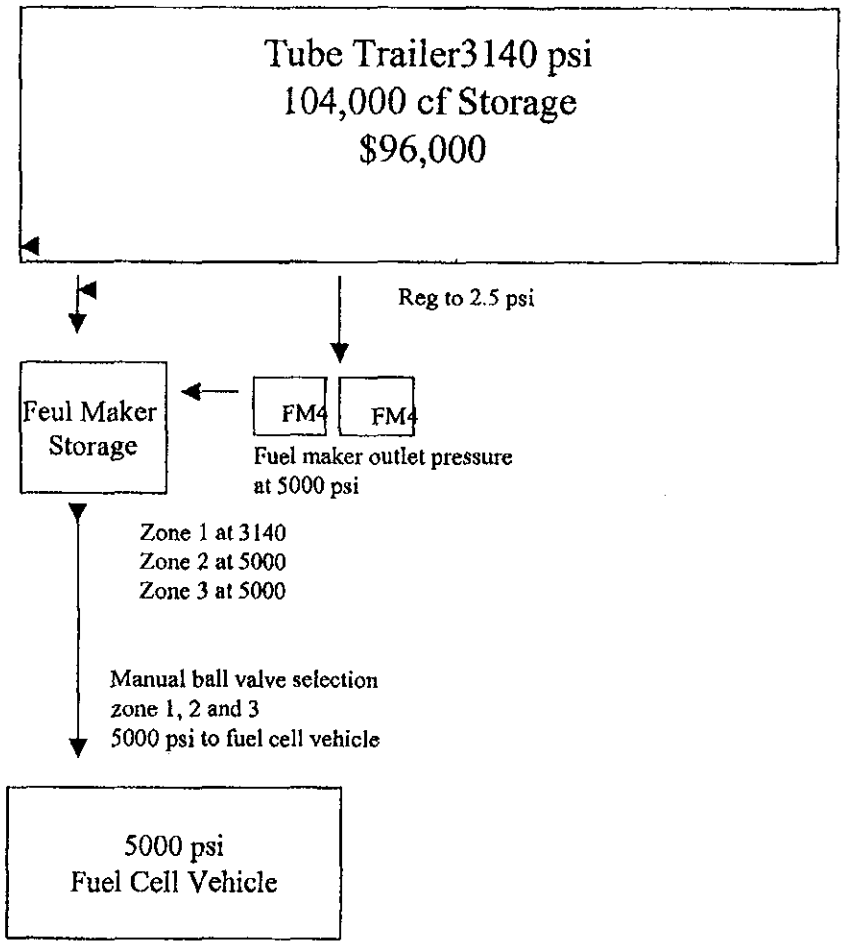
2) Regulate inlet pressure to Fuel Maker to @ 2.5 psi inlet

3) Fuel maker storage at 5000 psi 2 zone@$15,000 to $20,000 5 way ball valve to accept tube trailer as zone 1 zone 2 and 3 relief set to 5500 psi Custom built by fuel maker ?

4) 5000 psi rated fueling hose and nozzle Fuel Maker

5) Optional fuelmaker to decrease storage refueling time of 5000 psi?

6) System can be ordered to auto start But manual fueling must be done to cascade between zones



A-8

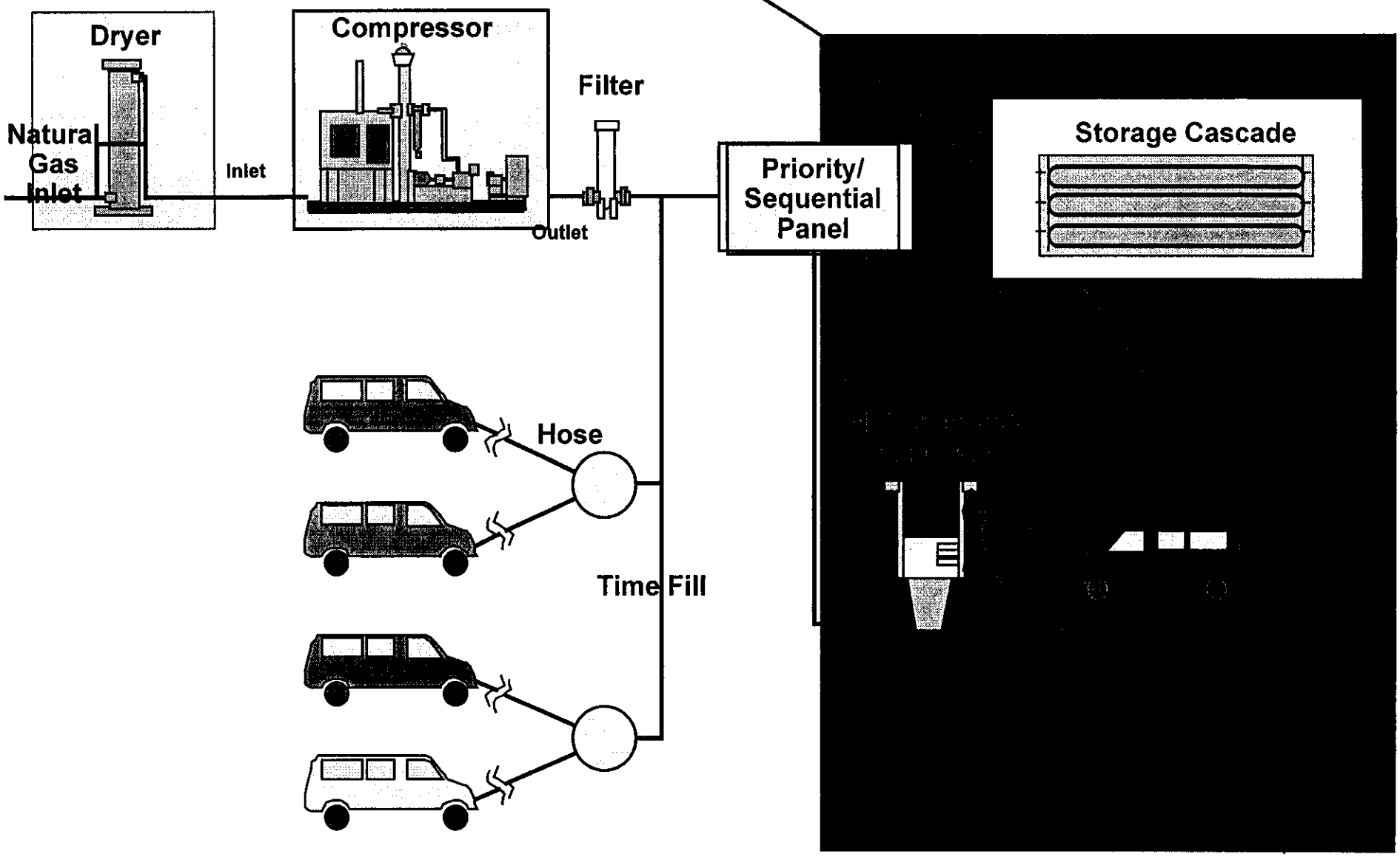
Schematic Diagram

CNG Station Configuration

Herbert Burnett

Burnet & Burnette

CNG STATION CONFIGURATION



A-9

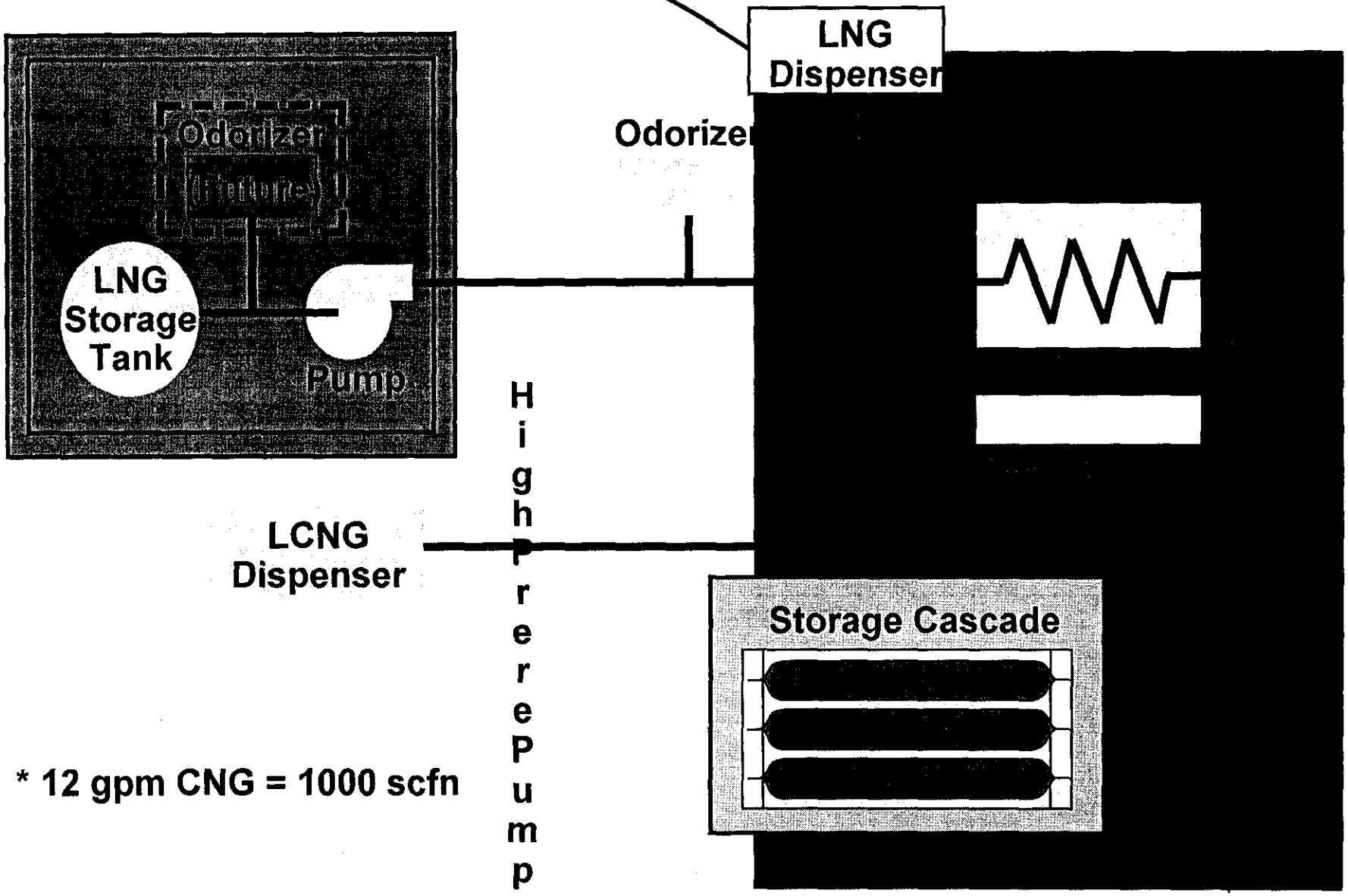
Schematic Diagram

LNG/LCNG Station Configuration

Herbert Burnett

Burnet & Burnette

LNG/LCNG STATION CONFIGURATION



* 12 gpm CNG = 1000 scfn

A-10

Bulk Hydrogen Site Evaluation Documents

Mark Pedersen Air Products and Chemicals, Inc.

Air Products

AIR PRODUCTS AND CHEMICALS (APCI), INC.

BULK HYDROGEN (BHY) SYSTEM INSTALLATION SCOPE OF WORK

Date: _____

Revision: 0

Customer Name: _____ System Location: _____

Product/Purity: / _____ City, State: , _____

A. EQUIPMENT CAPABILITIES

Total Monthly Volume (SCF/Month)				
Product Used As (Gas or Liquid)				
Design Monthly Usage (SCF/Month):				
Design Supply Pressure (psig, +/-10%)				
Design Continuous Flow Rate (SCFH):				
Design Peak Flow Rate (SCFH):				
Duration of Peak Flow Rate (hr)::				
Frequency of Peak Flow Rate (x/day)				
Product Usage Pattern (hr/day, days/wk):	,	,	,	,

Special Capabilities:

B. MAJOR EQUIPMENT DESCRIPTION

1 Hydril Tube Assembly - 3 or 6 pack`

1 Jumbo Tube Trailer

1 Pressure Control Manifold

1 Tube Trailer Discharge Stanchion

1 Telemetry Remote Monitoring System

C. MATERIALS OF CONSTRUCTION

Product Piping: Type K Copper ASTM B88, minimum 35% Cd-free Silver Solder,
Stainless Steel ASTM A269, Type 304 or 316, Schedule 10S, minimum

Process Valves: Brass/Bronze

D. APCI'S BHY SYSTEM INSTALLATION RESPONSIBILITIES

1. Contact customer to discuss scope of work and negotiate installation schedule.
2. Conduct site visit/site evaluation. A technical representative of APCI must approve the installation site prior to the initiation of civil work by the customer.
3. Provide all drawings required for the execution of the site preparation which may include, but is not limited to, site layout and utilities, foundation details, and non-proprietary process flow diagrams.
4. Provide all materials not explicitly highlighted under the customer's scope of work to commission and start-up the BHY supply system in accordance with APCI specifications and standards.
5. Coordinate for the shipment of all major equipment to the customer's installation site.

6. Schedule and coordinate an APCI approved crane and rigging contractor to off load all major equipment at the customer's installation site. Schedule and coordinate an APCI approved mechanical contractor to assist the APCI on-site representative in the BHY system installation.
7. Perform all possible shop prefabrication of BHY system pipeline components and cleaning of all BHY system components prior to arrival on-site at the customer's facility.
8. Provide all labor and materials not highlighted in the customer's scope of work to commission and start-up the BHY supply system. This will include the following:
   a. Prepare the installation site and coordinate safety training with external APCI contractors. Control access to the installation area and inspect the crane prior to initiating the BHY system installation.
   b. Rig, set, level, and anchor all major equipment.
   c. Install piping, piping supports, tube decals, valve tags, piping labels and all other minor equipment required to commission the BHY supply system
   d. Conduct an Operational Readiness Inspection (ORI) of the gaseous supply system.
   e. Pressure test/Leak test BHY system field installed piping.
   f. Fill and commission the BHY supply system immediately following the installation of the supply equipment.
9. Provide supply system description and safety orientation to the customer's operating personnel.
10. Provide labor and material required to perform routine maintenance and repair of the APCI-owned portions of the hydrogen supply system in accordance with APCI standard operating procedures.
11. Arrange for temporary supply to maintain customer piping distribution line supply pressure.

E. CUSTOMER'S BHY SYSTEM INSTALLATION RESPONSIBILITIES

1. CIVIL
   a. Provide a suitable site that meets all of the requirements of NFPA 50A (latest edition). A technical representative of APCI must inspect and approve the installation site prior to the initiation of any civil work by the customer.
   b. Provide adequate tanker access to and from the installation site (Combined Tractor and Trailer Length: 68' max.). With an inside turn radius of 50', a 90 degree turn requires a minimum road width of 25' and a 180 degree turn requires a minimum road width of 31'.Notify Air Products of any delivery restrictions or delivery windows.
   c. Provide a designated drop area that allows for a safe staging area to perform the change out of the single bay tube trailer installation. This staging area must be approved by a technical representative of APCI. The designated drop area must be able to accommodate two tube trailers positioned side by side (24' x 68' required) and enable the trailers' landing gear to rest on ground with adequate load bearing capacity. Preferred landing gear zone is reinforced concrete (3' x 24' x 8" thick). Acceptable alternate is a steel plate for each trailer (2 required - 3' x 8' x ¾" thick).
   d. Provide a hydril tube or tube trailer foundation and equipment pad as per specifications supplied by APCI. APCI requires a minimum of two weeks cure time on all foundation pours. Equipment cannot be set on foundations with cure times less than two weeks without prior approval by the responsible APCI Engineer.
   e. Provide a standard 6' chain link fence with a swing delivery gate, personnel gate and protective posts (crash bollards), as required, to protect the system from vehicular traffic. Reference the APCI supplied drawings for the specific type of delivery gate.
   f. Provide a soil analysis of the tank installation site in order to determine the existing underlying soil conditions used for the foundation design. The analysis must include documentation regarding environmental evaluation of the site, soil samples, site preparation, and investigation report. If this documentation is current and available, no additional soil testing is required.
2. ELECTRICAL
   a. Provide explosion proof electrical equipment, where required, within 15' of any portion of the fenced boundary of the BHY system. Reference the National Electric Code (NEC), latest revision, per Class 1, Group B, Division II,

locations. Electrical equipment installed within 3' of any portion of the fenced boundary of the BHY system must comply with Class 1, Group B, Division I criteria of the NEC, latest edition.

b. Provide dedicated 120 VAC, 20 amp, single phase, 60 Hz electrical service to a stub up location at least 15' from any portion of the fenced boundary of the BHY installation. Air Products will advise of final location. Install the electrical service per the National Electric Code, latest edition. The power should be available the date of the supply system installation.

c. Provide a dedicated, voice quality, analog phone line to a stub up location at least 15' from any portion of the fenced boundary of the BHY installation. Air Products will advise of final location. Install the phone service per the appropriate codes. The phone line must be able to transmit and receive calls 24 hours per day without the use of a manual switchboard. The phone should be activated the date of the supply system installation.

d. Provide adequate lighting for the installation area for night deliveries and system maintenance.

e. Provide a 2 conductor cable from the telemetry unit to the APCI supplied Rosemount transmitter located at the front of the BHY equipment. Air Products will advise of final location. Encase the cable in conduit and install the proper seal-offs and breathers per the applicable electrical code.

f. Provide a 2/0 ground wire between the telemetry unit and the BHY equipment, per the applicable electrical code.

g. Enable APCI to ground the BHY system. Provide ¾" diameter x 6' long ground rods - ITT Weaver Type WB 3/4. Test using a megger ground tester. Resistance must not exceed 5 ohms.

3. MECHANICAL
   a. Install the piping distribution line to the edge of the auxiliary equipment foundation as shown on the APCI supplied drawings (i.e., stubbed approximately 18" above ground level and 1' from the corner of this foundation). The desired end connection is a FNPT bronze adapter. Communicate a different choice of end connection to an APCI Construction representative at least one week prior to APCI's on-site date.

   b. Ensure that the maximum allowable working pressure of the hydrogen piping distribution line and its components is greater than 2640 psig. If not, provide a safety relief valve set at the maximum allowable working pressure of the lowest rated component in the piping distribution line. Size the safety relief valve for the maximum flow capacity of the system. All safety relief valves must vent out of doors to a safe location elevated 7', minimum, above grade.

   c. Provide a 1" block and tie-in valve assembly downstream of all the APCI BHY supply equipment. The material specification is available from APCI upon request.

4. GENERAL
   a. Provide all required state and local installation and operating permits.

   b. Keep area clean and free of all debris and weeds.

   c. Prohibit the storage of oil, grease, lubricants or any flammable or combustible material on or within the equipment area.

   d. Provide tube pressure readings, as required, to the APCI point of contact. Notify Air Products if customer's consumption or usage pattern changes temporarily or permanently from normal, i.e., plant shutdown, addition of a new shift, addition of new process equipment.

   e. Provide site specific safety training for APCI personnel and contractors in accordance with OSHA guidelines.

   f. Prevent any customer employee or third party not properly trained in the operation of the supply system from altering, repairing, adjusting or tampering with the supply equipment.

   g. Reset any equipment after power failures, where applicable (i.e. circuit breakers for telemetry, pumps, etc.)

   h. If any customer scope items are not completed prior to the agreed upon installation date and APCI needs to make a return visit(s) to complete the installation, the customer agrees to reimburse APCI, at APCI's standard service rates prevailing when such services are rendered, for additional expenses incurred due to the return visit(s).

   i. Any special site conditions or requirements not specifically listed in this document will be a change in original scope. These include, but are not limited to, building or zoning codes and restrictions, height, noise, or delivery restrictions, corrosive atmospheres, special materials of construction, emergency shutoff requirements, special

instrumentation or control, sampling or analytical services, painting or color specifications, reserve supply requirements, details of existing concrete foundations, temporary supply requirements, requirements for excess flow or earthquake valves, soil bearing capacity, special design requirements, requirements for union labor, special cleaning requirements, special piping codes such as ANSI, special installation or maintenance procedures, or special site restrictions.

F. SCHEDULE

Equipment lead time after receipt of order:	8 weeks
APCI BHY supply system on-stream after customer's completed scope:	28 days
On-site time required to set, pipe and commission supply system:	X days

Submitted By:

Air Products and Chemicals, Inc. Date

Regional Engineer

,

Accepted By:

Customer Date

Title

GASEOUS HYDROGEN SITE EVALUATION, In Excess of 15,000 SCF Capacity

Air Products

DATE	CUSTOMER	LOCATION
		,
DISTRICT		SUBMITTED BY:

SITE EVALUATION SECTION		Enter below, the shortest distance between the exposure and ***the nearest point of the hydrogen system***	
NFPA 50A (1994 edition) Type of Outdoor Exposure Evaluation Criteria		Min. Distance to Exposure (ft)	Evaluation
1. Buildings or Structure	(a) Wall(s) adjacent to system constructed of noncombustible or limited-combustible materials		
	(1) Sprinklered building or structure, or contents noncombustible.	5	
	(2) Unsprinklered building or structure with combustible contents		
	(A) Adjacent wall(s) with fire-resistance rating less than 2 hours.	25[1]	
	(B) Adjacent wall(s) with fire-resistance rating of 2 hours or greater.	5	
	(b) Wall(s) adjacent to system constructed of other than noncombustible or limited-combustible materials.	50[1]	
2. Wall Openings	(a) Not above any part of a system	10	
	(b) Above any part of a system	25	
3. Flammable & Combustible Liquid Storage Aboveground	(a) Class IIIB Combustible Liquids	15[1]	
	(b) 1000 gallons or less of all others	25[1]	
	(c) 1001 gallons or more of all others	50[1]	
4. Flammable & Combustible Liquid Storage Belowground - less than 1000 gallons	(a) Tank	10[1]	
	(b) Vent or fill opening of tank	25[1]	
5. Flammable & Combustible Liquid Storage Belowground - 1001 gallons or more	(a) Tank	20[1]	
	(b) Vent or fill opening of tank	25[1]	
6. Flammable gas storage (other than hydrogen), either high or low pressure	(a) 0-15,000 SCF capacity	25[1]	
	(b) In excess of 15,000 SCF capacity	50[1]	
7. Oxygen storage - 20,000 SCF or more		50[1]	
8. Fast-burning Solids - ordinary lumber, paper, excelsior		50[1]	
9. Slow-burning Combustibles - coal, heavy lumber		25[1]	
10. Open Flames or Welding		25[1]	
11. Air compressor intakes or inlets to ventilating or air-conditioning equipment		50	
12. Places of public assembly		50	
13. Public sidewalks and parked vehicles		15	
14. Line of adjoining property that may be built upon		5	
15. Weeds, dry bush, vegetation		15'	
16. Overhead power lines		15	

Notes:

1. The distances may be reduced by up to 2/3 of the distance shown if a protective structure, such as a fire wall having a minimum fire resistance of 2 hours, is installed between the hydrogen system and the exposure. The protective structure must interrupt the line of sight between the system and the exposure. The protective structure, in lieu of distance, protects ***uninsulated*** portions of the container, supports, controls, piping, etc. from external fire. Definition: Class IIIB Combustible Liquid - closed cup flash point = 200° F or higher

Forward to Project Engineer:	Approval:	Date

Note: The distance criteria recommended by NFPA have been adopted by OSHA- reference OSHA Subpart H-Hazardous Materials (29 CFR 1910.103)

AIR PRODUCTS AND CHEMICALS (APCI), INC.
LIQUID HYDROGEN (LHY) SYSTEM INSTALLATION SCOPE OF WORK

Date: _____
Revision: 0

Customer Name: _____ System Location: _____
Product/Purity: / City, State: ,

A. EQUIPMENT CAPABILITIES

Total Monthly Volume (SCF/Month)				
Product Used As (Gas or Liquid)				
Design Monthly Usage (SCF/Month):				
Design Supply Pressure (psig, +/-10%)				
Design Continuous Flow Rate (SCFH):				
Design Peak Flow Rate (SCFH):				
Duration of Peak Flow Rate (hr)::				
Frequency of Peak Flow Rate (x/day)				
Product Usage Pattern (hr/day, days/wk):	,	,	,	,

Special Capabilities:

B. MAJOR EQUIPMENT DESCRIPTION

1 Cryogenic Storage Vessel
Quantity Ambient Air Process Vaporizer(s)
Quantity Ambient Air Economizer Vaporizer(s)
1 Pressure-Temperature Control Manifold
1 Tank Telemetry Remote Monitoring System

C. MATERIALS OF CONSTRUCTION

Product Piping: Type K Copper, minimum 35% Cd-free Silver Solder
Process Valves: Brass/Bronze

D. APCI'S LHY SYSTEM INSTALLATION RESPONSIBILITIES

1. Contact customer to discuss scope of work and negotiate installation schedule.
2. Conduct site visit/site evaluation. A technical representative of APCI must approve the installation site prior to the initiation of civil work by the customer.
3. Provide all drawings required for the execution of the site preparation which may include, but is not limited to, site layout and utilities, foundation details, and non-proprietary process flow diagrams.
4. Provide all materials not explicitly highlighted under the customer's scope of work to commission and start-up the LHY supply system in accordance with APCI specifications and standards.

5. Coordinate for the shipment of all major equipment to the customer's installation site.
6. Schedule and coordinate an APCI approved crane/rigging contractor to off load all major equipment at the customer's site. Schedule and coordinate an APCI approved mechanical contractor to assist the on-site APCI contact with the installation.
7. Perform all possible shop prefabrication of LHY system pipeline components and cleaning of all LHY system components prior to arrival on-site at the customer's facility.
8. Provide all labor and materials not highlighted in the customer's scope of work to commission and start-up the LHY supply system. This will include the following:
   a. Prepare the installation site and coordinate safety training with external APCI contractors. Control access to the installation area and inspect the crane prior to initiating the LHY system installation.
   b. Rig, set, level, and anchor all major equipment.
   c. Install piping, piping supports, tank decals, valve tags, piping labels and all other minor equipment required to commission the LHY supply system.
   d. Install and secure the vent stack with guy wires or support angles. The vent stack should terminate 25' above grade on horizontal tanks and approximately 10' above the tanks on vertical tanks (25' minimum).
   e. Ground the tank and the major auxiliary equipment.
   f. Conduct an Operational Readiness Inspection (ORI) of the liquid supply system.
   g. Pressure test/Leak test LHY system field installed piping.
   h. Cool down and first fill the cryogenic storage vessel immediately following the installation of the supply equipment.
   i. Initiate hydrogen supply by commissioning the LHY supply system following the first fill of the storage vessel.
9. Provide system review and safety orientation to the customer's operating personnel.
10. Provide labor and material required to perform routine maintenance and repair of the APCI-owned portions of the hydrogen supply system in accordance with APCI standard operating procedures.
11. Arrange for temporary supply to maintain customer piping distribution line supply pressure.

E. CUSTOMER'S LHY SYSTEM INSTALLATION RESPONSIBILITIES

1. CIVIL
   a. Provide a suitable site that meets all of the requirements of NFPA 50B, latest edition. A technical representative of APCI must inspect and approve the installation site prior to the initiation of any civil work by the customer.
   b. Provide adequate tanker access to and from the installation site (Combined Tractor and Trailer Length: 68' max.). With an inside turn radius of 50', a 90 degree turn requires a minimum road width of 25' and a 180 degree turn requires a minimum road width of 31'.Notify Air Products of any delivery restrictions or delivery windows.
   c. Yard surface where the product delivery trailer will off load should be level or slope no more than 1.5 - 2.0%, so that product will move towards the back of the trailer.
   d. Provide a tank foundation and equipment foundation as per specifications supplied by APCI. APCI requires a minimum of two weeks cure time on all foundation pours. Equipment cannot be set on foundations with cure times less than two weeks without prior approval by the responsible APCI Engineer.
   e. Provide a non-combustible surface in areas that will be under any delivery piping of the LHY trailer during deliveries. APCI will provide drawings showing location of these noncombustible area.
   f. Provide a standard 6' chain link fence with a sliding delivery gate, personnel gate and protective posts (crash bollards) around the perimeter of the supply system. Reference the APCI supplied drawings for the specific type of delivery gate. This will protect the supply system from vehicular traffic.

g. Provide a steel plate, per ASTM A-36, 1" thick to span the length and width of one of the tank piers. Lubricate the exposed surface with Dow Corning's "Molykote G" paste, or equivalent.

h. Provide a soil analysis of the tank installation site in order to determine the existing underlying soil conditions used for the foundation design. The analysis must include documentation regarding environmental evaluation of the site, soil samples, site preparation, and investigation report. If this documentation is current and available, no additional soil testing is required.

2. ELECTRICAL

a. Provide explosion proof electrical equipment, where required, within 25' of any portion of the fenced boundary of the LHY system. Reference the National Electric Code (NEC), latest revision, per Class 1, Group B, Division II, locations. Electrical equipment within 3' of any portion of the fenced boundary of the LHY system should comply to Class 1, Group B, Division I criteria of the NEC, latest edition.

b. Provide 480 VAC, 3 phase, 60 cycle, 30 amp electrical service to the point of termination on the APCI supplied electrical disconnect (for use during deliveries). The APCI supplied drawings detail the location of the disconnect. Reference the NEC, latest revision, per Class 1, Group B, Division II, locations. The power should be available the date of the supply system installation.

c. Provide dedicated 120 VAC, 20 amp, single phase, 60 Hz electrical service to a stub up location at least 25' from any portion of the fenced boundary of the LHY installation. APCI will advise of final location. Install the electrical service per the National Electric Code, latest edition. The power should be available the date of the supply system installation.

d. Provide a dedicated, voice quality, analog phone line to a stub up location at least 25' from any portion of the fenced boundary of the LHY installation. APCI will advise of final location. Install the phone service per the appropriate codes. The phone line must be able to transmit and receive calls 24 hours per day without the use of a manual switchboard. The phone should be activated the date of the supply system installation.

e. Provide a 4 conductor cable from the telemetry unit to the front of the APCI supplied Rosemount transmitters, located at the front of the LHY tank. APCI will advise of final location. Encase the cable in conduit and install the proper seal-offs and breathers per the applicable electrical code.

f. Provide a 2/0 ground wire between the telemetry unit and the LHY tank, per the applicable electrical code. APCI will advise of final location.

g. Provide adequate lighting for the installation area for night deliveries and system maintenance.

h. Provide a grounding system with a maximum resistivity of 25 ohms. A minimum of (2) connection points should be provided for grounding Air Products equipment. The grounding system should be installed per the National Electric Code (NEC) Article 250, latest revision. Provide connections to ¾" x 10' long 'Copperweld' ground rods. Test using a megger ground tester. Resistance must not exceed 25 ohms

i. Provide a 4 conductor cable from the telemetry unit, installed at the front of the LIN tank, to the APCI supplied Rosemount transmitters, installed at the front of the LHY tank. APCI to advise of final location. Encase the cable in conduit and install the proper seal-offs and breathers per the applicable electrical code.

j. Provide a #12 ground wire between the telemetry unit, installed at the front of the LIN tank, and the LHY tank, per the applicable electrical code. APCI to advise of final location.

3. MECHANICAL

a. Install the piping distribution line to the edge of the auxiliary equipment foundation as shown on the APCI supplied drawings (i.e., stubbed approximately 18" above ground level and 1' from the corner of this foundation). The desired end connection is a FNPT bronze adapter. Communicate a different choice of end connection to an APCI Construction representative at least one week prior to APCI's on-site date.

b. Provide a source of nitrogen or dry instrument air (40 psig) to the front of the LHY tank. APCI will advise of the final location. Design a break point in this supply line at personnel access height to a stub up location located 25', minimum, from any portion of the fenced LHY supply system. Again, APCI will advise of final location. The

nitrogen or dry instrument air will operate the LHY tank's fire control valves and the LHY system's emergency shut off valve.

c. Ensure that the maximum allowable working pressure of the hydrogen piping distribution line and its components is greater than 165 psig. If not, provide a safety relief valve set at the maximum allowable working pressure of the lowest rated component in the piping distribution line. Size the safety relief valve for the maximum flow capacity of the system. All safety relief valve must vent out of doors to a safe location elevated 7', minimum, above grade.

d. Provide a 1" block and tie-in valve assembly downstream of all the APCI LHY supply equipment. The material specification is available from APCI upon request.

e. Provide a source of water within 100 feet of the system, for maintenance and cleaning. Utility flow and pressure are acceptable.

f. Provide 60 psig nitrogen or dry instrument air in the vicinity of the LHY installation for use on the APCI supplied vaporizer switching system. APCI will advise of final location.

g. Provide 3/8" stainless steel tubing from the liquid nitrogen (LIN) system's pressure - temperature control manifold to a the front of the LHY tank. APCI will advise of final location. Design a break point in this supply line at personnel access height to a stub up location located 25', minimum, from any portion of the fenced LHY supply system. Again, APCI will advise of final location. Encase the tubing in conduit and install per the applicable electrical code.

4. GENERAL

a. Provide all required state and local installation and operating permits.

b. Keep area clean and free of all debris and weeds.

c. Prohibit the storage of oil, grease, lubricants or any flammable or combustible material on or within the equipment area.

d. Provide tank readings, as required, to the APCI point of contact. Notify Air Products if customer's consumption or usage pattern changes temporarily or permanently from normal, i.e., plant shutdown, addition of a new shift, addition of new process equipment.

e. Provide site specific safety training for APCI personnel and contractors in accordance with OSHA guidelines.

f. Prevent any customer employee or third party not properly trained in the operation of the supply system from altering, repairing, adjusting or tampering with the supply equipment.

g. Reset any equipment after power failures, where applicable (i.e. circuit breakers for telemetry, pumps, etc.)

h. If any customer scope items are not completed prior to the agreed upon installation date and APCI needs to make a return visit(s) to complete the installation, the customer agrees to reimburse APCI, at APCI's standard service rates prevailing when such services are rendered, for additional expenses incurred due to the return visit(s).

i. Any special site conditions or requirements not specifically listed in this document will be a change in original scope. These include, but are not limited to, building or zoning codes and restrictions, height, noise, or delivery restrictions, corrosive atmospheres, special materials of construction, emergency shutoff requirements, special instrumentation or control, sampling or analytical services, painting or color specifications, reserve supply requirements, details of existing concrete foundations, temporary supply requirements, requirements for excess flow or earthquake valves, soil bearing capacity, special design requirements, requirements for union labor, special cleaning requirements, special piping codes such as ANSI, special installation or maintenance procedures, or special site restrictions.

F. SCHEDULE

Equipment lead time after receipt of order:	8 weeks
APCI LHY supply system on-stream after customer's completed scope:	28 days
On-site time required to set, pipe and commission supply system:	X days

Submitted By:

Air Products and Chemicals, Inc. Date

Project Engineer

,

Accepted By:

Customer Date

Title

LIQUID HYDROGEN SITE EVALUATION

AIR PRODUCTS

DATE	CUSTOMER	LOCATION		
DISTRICT	TANK SIZE	PROPOSED (NEW)	PROPOSED (CHANGEOUT)	EXISTING
SUBMITTED BY:	CONTRACT/INSTALLATION DATE	APPROVED BY:		APPROVAL DATE

SITE EVALUATION SECTION

Enter below, the shortest measured distance between the exposure listed and the nearest point of the hydrogen installation (tank, vaporizers, piping, control station), and the unloading connection on delivery equipment.

NFPA #50B 1989 EDITION) EVALUATION CRITERIA	AIR PRODUCTS EVALUATION CRITERIA	MINIMUM DISTANCE (FEET) FROM SYSTEMS TO EXPOSURE			EVALUATION
TYPE OF EXPOSURE		LIQUEFIED HYDROGEN STORAGE (CAPACITY IN GALLONS)			
		39.63-3,500	3,501-15,000	15,001-75,000	
1. Building/Structure					
(a) Wall(s) adjacent to system constructed of noncombustible or limited combustible materials.	See Exhibit G[5], noncombustible, sprinklered building with noncombustible contents				
(1) Sprinklered building/structure or unsprinklered building/structure having noncombustible contents.		5[1,3]	5[1,3]	5[1,3]	
(2) Unsprinklered building/structure with combustible contents. Adjacent wall(s) with fire-resistance rating less than 3 hours[2]	See Exhibit G[5], noncombusti-ble, unsprinklered with combustible contents	25	50	75	
Adjacent wall(s) with fire-resistance rating of 3 hours or greater[2]	See Exhibit G[5], fire resistive building	5	5	5	
(b) Wall(s) adjacent to system constructed of combustible materials	See Exhibit G[5], combustible building				
(1) Sprinklered building/structure		50	50	50	
(2) Unsprinklered building/structure		50	75	100	
2. Wall Openings					
(a) Openable		75	75	75	
(b) Unopenable		25	50	50	
3. Air Compressor Intakes, Inlets for Air Conditioning or Ventilating Equipment		75	75	75	
4. All Classes of Flammable and Combustible Liquids (Aboveground and Vent or Fill Openings if Below Ground) Exception: Distances may be reduced to 15 ft. for Class IIIB combustible liquids		50	75	100	
5. Between Stationary Liquefied Hydrogen Containers	Air Products policy is 25 feet between tanks over 15,000 gallon capacity	5	5	5	
6. Flammable Gas Storage (other than hydrogen)		50	75	75	
7. Liquid Oxygen Storage and other Oxidizers		75	75	75	
8. Combustible Solids		50	75	100	
9. Open Flames, and Welding		50	50	50	
10. Places of Public Assembly		75	75	75	
11. Public Ways, Railroads, and Property Lines		25[6]	50[6]	75	
12. Protective Structures		5[3]	5[3]	5[3]	
13. Ordinary Electricals		25	25	25	

LIQUID HYDROGEN SITE EVALUATION

AIR PRODUCTS

NOTE 1: Portions of wall less than 10 feet (measured horizontally) from any part of a system shall have a fire resistance rating of at least 1/2 hour. NOTE 2: Exclusive of windows and doors. NOTE 3: Where protective structures are provided, ventilation and confinement of product shall be considered. The 5-foot distance in Nos. 1 and 12 facilitates maintenance and enhances ventilation. NOTE 4: The distance in Nos. 1, 4, 6, 7, 8 and 11 may be reduced where protective structures have a minimum fire resistance rating of two hours interrupt the line of sight between uninsulated portions of the liquefied hydrogen storage system and the exposure. (See definition of Outdoor Location.) NOTE 5: See DOM Volume 8, Section 2.3.1. NOTE 6: Minimum 75 feet is required for exposures to a third party. Distance may be reduced to 50 feet minimum if a 2-hour firewall is installed.	For general use, parked cars – a. From fill connection - 25 feet b. From any part of the system - 25 feet or firewall. Large parking lots may require up to 50 feet Air Products policy permits a reduction by 2/3 when fire walls are provided, unless specified otherwise by the local authority.

LIQUID HYDROGEN SITE EVALUATION

AIR PRODUCTS

NFPA # 50B (1989 EDITION) EVALUATION CRITERIA	AIR PRODUCTS EVALUATION CRITERIA	EVALUATION
A. Outdoor Location. Outside any building or structure and not enclosed by more than two walls. This includes locations under a roof, weather shelter or canopy height are provided with vent space between the walls and the vented roof, weather shelter or canopy.		
B. The storage containers shall be located so that they are readily accessible to mobile supply equipment at ground level and to authorized personnel.	Plant roads - distance to plant roads must be controlled during unloading operations by barricading to exclude all traffic within 25' of the fill connection and tanker unloading connection.	
C. The containers shall not be located beneath electric power lines or where exposed by their failure.	System, including liquid tanker for filling, must be 15 feet to the side of overhead power lines.	
D. The containers shall not be located close to piping containing flammable liquids, or other flammable gases, or oxidizing materials.	25 feet from continuous (welded or brazed) pipeline. 50 feet from mechanical (threaded flanged) joints in pipeline.	
E. Systems near aboveground flammable liquid storage or liquid oxygen storage shall be located on ground higher than the flammable liquid storage or liquid oxygen storage except when dikes, diversion curbs, grading, or separating solid walls are used to prevent accumulation of liquids within 50 feet of the liquid hydrogen system.		
F. Storage sites shall be fenced and posted to prevent entrance by unauthorized personnel. Sites shall also be placarded as follows: "LIQUID HYDROGEN - WARNING - FLAMMABLE. NO SMOKING - NO OPEN FLAME. EXTREMELY COLD LIQUID AND GAS. MAY CAUSE SEVERE FROSTBITE. USE IN ACCORDANCE WITH AIR PRODUCTS' MATERIAL SAFETY DATA SHEET."	A personnel gate must be located at the rear of the installation for use in an emergency.	
G. Electrical wiring and equipment located beyond 3 feet but within 25 feet of a point where connections are regularly made and disconnected or within 25 feet of a liquid hydrogen storage container, shall be in accordance with Article 501 of the National Electrical Code, NFPA No. 70, for Class 1, Division 2, Group B locations.		
H. Roadways and yard surfaces located below liquefied hydrogen piping, from which liquid air may drip, shall be constructed on noncombustible materials.	Concrete or gravel required under fill connection and tanker PB coil.	
I. Air Products requires 25 feet from inlets to underground sewers (NFPA minimum 5 feet). Distance may be reduced depending on firewalls and location to possible spill points. Drawings must include location of underground sewer openings.		

ADDITIONAL CRITERIA:

1. The location of the unloading connection on the delivery trailer must be considered when establishing distances (NFPA requirement).
2. Gases SHE will consider trailer vent locations when evaluating the site (non-NFPA requirement).
3. The responsible Distribution Terminal Manager is to be advised of the proposed installation and must approve for safe access.

COMMENTS

Note: The distance criteria recommended by NFPA have been adopted by OSHA- reference OSHA Subpart H-Hazardous Materials (29 CFR 1910.103)

Attachment B

Expert Panel Review/Comments

	Name	Association
B-1	Dr. Sigmund Gronich	Department of Energy Hydrogen Program
B-2	Dr. Marshall Miller	University of California, Davis Institute of Transportation Studies
B-3	Alan Niedzwiecki	IMPO Technologies, Inc.
B-4	Dr. Venki Raman	Air Products and Chemicals, Inc.
B-5	Dr. Sandy Thomas	H_2Gen Innovations, Inc.

COMMENTS BY DR. SIGMUND GRONICH

Thank you for providing me the ability to comment on the results of the Hydrogen Study Team Evaluation. There is general merit to consider the conversion of compressors that were being considered for natural gas systems to be hydrogen compatible. As the study points out, it is better to start with the needs of the hydrogen requirement to define the compressor than the reverse process. This would imply that there would be some significant design work required to achieve the goals of the program.

Secondly, the report covers the more complicated control systems, the need to purify and switch from natural gas to hydrogen and back, and the need for perhaps a booster compressor. These issues can have significant ramifications to the cost of the projects, Also, the compressor size for the natural gas application appears larger than the ultimate hydrogen system that would be needed for the early phase of introducing hydrogen vehicles.

There is a need for research and development of hydrogen compressors. In addition to mechanical/electrical systems, there is a possibility of developing thermo-compression systems. Over the next three years, the Hydrogen Program will be investigating advanced compressor systems for use at fueling stations of both mechanical and thermo-compression systems.

The purpose of the proposal addresses the "chicken-egg" issue. By providing this dual capability, it would provide a capability to encourage bus and vehicle manufacturers to produce hydrogen vehicles. But there is an issue associated as to where the best location for these vehicles might be. They will be for the service of fleet vehicles or buses, but it is not clear that the locations selected were the most conducive to the potential customers. An alternative approach might be to consider existing hydrogen fueling stations such as SunLine Transit Agency and the possible LAX hydrogen station being considered. Perhaps two of the lower cost options being considered here can be combined with those possibilities. In that manner it would support both the ability to introduce new technology compressors and evaluate the natural gas/hydrogen compatibility approach. Gardena and Placentia should be evaluated as to their merit for inducing fleet vehicle and bus operations. Because this is the most critical issue. There has to be a demand or an anticipation of a possible encouragement to bring demand to the area to warrant the investment in hydrogen infrastructure systems.

In summary, it is a viable approach that must be reviewed carefully in the ability of the approach to encourage the deployment of hydrogen vehicles and determine the cost/benefit of this approach to other priorities in the development of hydrogen compressors.

COMMENTS BY DR. MARSHALL MILLER

Comments on Hydrogen Compatibility Issues in CNG Fueling Stations

Fuel cell vehicles will be commercialized during the next 5-10 years. While the first vehicles will be used at fleet stations and can be fueled at a single fleet location, developing a hydrogen infrastructure will be critical to the introduction of light duty fuel cell vehicles for the general public. Although commercial fuel cell vehicles may be several years away, a hydrogen infrastructure will take some time to develop properly. It is not too soon to begin working toward this goal. I support a strong hydrogen program and funding for hydrogen fueling stations. There are two reasons, however, why I do not believe it is wise to give extra funding to CNG stations to make their compressors more hydrogen compatible.

First, I believe it is unlikely that a given CNG station would benefit from extra funds for hydrogen compatibility. Once a CNG station is built, there are 4 future scenarios - the station never uses hydrogen, the station converts to hydrogen and never dispenses CNG after the conversion, the station dispenses both CNG and hydrogen from different compressors, and the station dispenses both CNG and hydrogen from the same compressor. The first scenario would clearly be a waste of money since the addition funds yield no benefit. The second scenario is very unlikely - CNG will not be phased out that quickly. Since a second compressor will be purchased in the third scenario, the optimal situation would be to optimize both compressors to the particular gas they would dispense rather than make one compatible for both fuels. The only situation where compatibility would be a benefit is the fourth situation. It is not clear how many stations could easily use only one compressor in their daily operation. I suspect that the vast majority would not operate in this manner.

Second, there are many unknowns involved in this analysis. The design of some stations is not fixed, the probability that a particular site will eventually use hydrogen is not known, the ability of stations to use one compressor for both hydrogen and CNG is problematic, and there are still questions about the exact cost of these upgrades.

While funding for compressor compatibility is unwise, there may be reasons to fund inexpensive compatibility upgrades such as the electrical and mechanical upgrades suggested in the report. The costs would be small ($17,500 in many cases), and the savings would be significant. They should not be completed for every CNG station since the majority of these will probably not use hydrogen in the short to mid-term. Some stations should be identified as likely hydrogen candidates, and funding for those upgrades could be awarded to those sites.

I would suggest the following steps for the board.

1) Allocate funding to study the practicality of compressors that dispense both CNG and hydrogen. The funding should better determine the cost premium for the compressor, under what conditions a station could operate dispensing both CNG and hydrogen from a single compressor (size and type of fleet), and proper methods for switching from one gas to the other. This situation might be very useful for transit stations operating CNG and hydrogen/natural gas mixture buses.

2) Do not allocate funds for compressor compatibility upgrades at specific stations.

3) Allocate funding to identify specific sites for future hydrogen stations. These sites may or may not have CNG fueling now. The site selections should be based both on the site qualifications (as studied in the report) and on the expected vehicles refueling there. Some sites are unlikely to operate fuel cell or CNG/hydrogen mixture vehicles. The selection should include issues such as whether the site is close to a hydrogen pipeline, the willingness of the site operators to embrace the new technology, and how the location would affect the overall regional infrastructure.

4) If a site is selected as a good candidate for future hydrogen use, money should be allocated for electrical and mechanical compatibility upgrades if the timing is right (before construction).

5) Allocate funds for the construction of hydrogen fueling stations. These stations specified in number 3 above could be prioritized and funded in that order.

Bio:

Marshall Miller is the Director of the Hydrogen Bus Technology Validation Program which will run hydrogen/natural gas mixture buses in Davis, CA. He runs the Hybrid Vehicle Propulsion Systems Laboratory at the University of California, Davis.

Alan Niedzwiecki
Executive Director, Business Development Advanced
IMPO Technologies, Inc.

General

Under "Objective," it is stated that the "...Study Team developed criteria...."

You may wish to provide a list or identify the Study Team of experts.

What are the criteria for the parameters listed?

A better or clearer definition of purpose and "hydrogen compatibility" would be helpful:

Specifically, is the purpose to be able to refuel CNG and hydrogen vehicles at the same time; or allow switching completely to hydrogen when there is sufficient demand; or .....?

With respect to hydrogen compatibility, there did not appear to be much detail on the potential impact of hydrogen impurities. At this point, our understanding of current fuel cell vehicle technology is, essentially, that completely oil-free compressors will be required in the "near-term." How is that requirement being addressed, especially in terms of compressor selection? My understanding is that OEM fuel cell vehicles have zero tolerance for impurities.

Also, what is the expectation of these "hydrogen compatible" CNG fueling stations in terms of operating life? Are they envisioned to be a "stop gap" for the early years/small volumes of hydrogen vehicles or something longer term?

Can you provide more rationale.....Further to expectations and purpose, what is the AQMD's expected timing and numbers of hydrogen vehicles to be introduced in Southern California to justify increasing costs of L/CNG stations needed today?

Technical

In the absence of the appendices and further technical details, I have the following questions/comments:

Did the Study Team review materials compatibility with hydrogen, more specifically, the materials selection differences between a CNG and an H2 compression station relative to the potentially corrosive nature of hydrogen in moist environments? I refer to the effects of hydrogen on piston, rings, compression chambers, sequencing and priority panels, storage, piping, valving, etc. Dry hydrogen does not appear to be a problem, but in the presence of moisture, (e.g.: condensation) the potential exists for rapid deterioration and component failure.

OEM produced direct hydrogen fuel cell vehicles already require 5000 psi storage even in current prototype versions, with storage up to 10,000 psi coming sooner rather than later (prototypes within 1-2 years).

That being the case, what pressure rating(s) are being assumed for the "hydrogen compatible" compressors?

The California Fuel Cell Partnership site has 2 dispensers (3,600 and 5,000 psi) for compressed hydrogen to avoid the risk of mis-fueling (especially over-pressurization). How many dispensers are planned (e.g. 1 for CNG @ 3600 psi and 2-3 for hydrogen @ 3,600 - 10,000 psi) in the context of siting requirements?

What are the cost differentials for the electrical system ratings (Group B, C, and D)? It would be useful to have all the differential costs broken out to determine which "hydrogen compatible" components are most easily justified.

I hope you will find my comments useful and I want you to know that we at QUANTUM are very supportive of the great work you are doing at the AQMD. Should you have any questions or require any additional information, please feel free to contact me at (949) 399-4552.

COMMENTS BY DR. VENKI RAMAN

I fully support the AQMD's effort to investigate current options to prepare for a future hydrogen fueling infrastructure by "piggy-backing" on to currently planned investments to install CNG fuel stations.

The "Team Rationale" in paragraph a) under the Background and Analysis section is sound. An acceptable response to those three questions should lead one to conclude that "preinvestment" in certain equipment to make the station hydrogen compatible now is a prudent investment.

The Study Team recommendations contained on the last page are on the mark. Clearly the cost implications will be a major determinant in the final decision at any one of the four sites currently considered feasible.

In closing I applaud the effort put into this by the Study Team. These sorts of innovative approaches to infrastructure development will help move forward the future hydrogen fuel network that will be e key to clean air and sustainable energy.

Venki Raman

Comments on the "Status Report on Hydrogen Study Team Evaluation"

By C. E. (Sandy) Thomas, Ph.D., President
H_2Gen Innovations, Inc.
Arlington, Virginia

1.0 Summary of Recommendations

While we strongly support the introduction of hydrogen fueling stations for fuel cell vehicles, we are concerned that developing and installing large-scale compressors capable of compressing both natural gas and hydrogen may not be the most cost-effective approach to expediting hydrogen fueling systems in the district. In all likelihood, these dual-use compressors would never be used for a hydrogen fueling system. Instead, we recommend that the funds allocated for the compressor upgrades be used to purchase complete, integrated hydrogen fueling systems to support 100 FCVs including a natural gas reformer, a small hydrogen compressor, storage tanks and a hydrogen dispenser.

2.0 Company Background

H_2Gen Innovations, Inc.[1] and our parent company Directed Technologies, Inc. are strong advocates of moving quickly to direct hydrogen fuel cell vehicles for the transportation sector. We have previously shown that direct hydrogen FCVs will be less costly and reduce environmental impacts more than either methanol- or gasoline-powered FCVs[2]. Our assessment of hydrogen fuel costs for the DOE and the Ford Motor Company indicated that hydrogen could be provided at the local fueling station at a cost per mile in a FCV equal to or less than the cost per mile of wholesale gasoline in a conventional car, provided that the hydrogen was generated on-site by reforming natural gas[3]. In our most recent annual report under contract to the Hydrogen Program Office of the U.S. Department of Energy, we project that the total societal cost of providing such a distributed hydrogen fueling infrastructure could be as much as 50% less than the current societal cost of maintaining the existing crude oil/gasoline infrastructure. In fact, by moving from a crude oil/gasoline fuel supply to a natural gas/hydrogen fuel supply, society could save over $30 billion per year in annual transportation infrastructure costs[4].

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[1] H_2Gen Innovations, Inc, a venture of Directed Technologies, Inc., was founded in February 2001 exclusively to mass-produce low-cost hydrogen fueling systems for fuel cell vehicles and stationary fuel cell systems.

[2] C.E. Thomas, B. D. James, F. D. Lomax, Jr., and I. F. Kuhn, Jr., "Fuel options for fuel cell vehicle: hydrogen, methanol or gasoline?", *Int. J. of Hydrogen Energy*, 25 (2000) 551-567.

[3] C. E. Thomas, I. F. Kuhn, Jr., B. D. James, F. D. Lomax, Jr., and G. N. Baum, "Affordable hydrogen supply pathways for fuel cell vehicles," *Int. J. of Hydrogen Energy*, Vol. 23, pp. 507-516, 1998.

[4] C. E. Thomas, J. P. Reardon, F. D. Lomax, Jr., J. Pinyan and I. F. Kuhn, Jr., *Distributed Hydrogen Fueling System Analysis*, prepared for the Hydrogen Program Office, U. S. Department of Energy under Grant No. DE-FG01-99EE35099, October 2000.

3.0 AQMD Proposal

We applaud the visionary support provided by the South Coast Air Quality Management District over the years for alternative fuels including fuel cells and hydrogen. Your early support for fuel cells is much appreciated by the community. We also applaud the intent of the current proposal to make CNG fueling stations compatible with hydrogen. Adding hydrogen pipes and electrical capacity in trenches along with the new natural gas lines from the compressor to the dispensing station seems cost effective for those fueling sites that are likely to add hydrogen capability in the future.

3.1 Dual-Use Compressors

However, we have serious reservations about the cost-effectiveness of the proposed plan to make NG compressors compatible with hydrogen. From a technical standpoint, we have no doubt that companies can build compressors to handle both hydrogen and natural gas. The study team's estimate of 25% added cost for such compatibility may be reasonable, but extra time to design, test and modify truly compatible compressors may be excessive. It would seem prudent to allow at least one to two year's of testing time after the prototype compressors were designed and built to make sure that these dual-capable compressors have the required operational and lifetime characteristics.

Our greatest concern is not technical, however, but operational and therefore financial. We believe that the probability may be low that a large, hydrogen-capable natural gas compressor would ever be used economically for a hydrogen dispensing station. In fact the study team seems to have accepted this premise, since they recommend that the dual-use compressors should only be used for natural gas initially, and then should later be switched to exclusive hydrogen use. This recommendation makes sense, given the assumption that dual-use compressors will be designed, tested, and purchased. As noted in the study, there are two possible scenarios: simultaneous natural gas/hydrogen compressor use, or sequential use.

3.1.1 Simultaneous Compressor Use

We do not consider simultaneous natural gas and hydrogen compressor use feasible for FCVs for the following reasons:

1. The natural gas compressors listed in the study (200 to 400 scfm) are much too large for likely initial hydrogen fueling systems for passenger vehicles. For example, a hydrogen on-site production system suitable for fueling 100 FCVs or two FC buses would have an average production rate of about 15 scfm or 13 to 26 times smaller than the natural gas compressors suggested for conversion by the study team. A small hydrogen compressor filling cascade storage tanks is the most economical route for inexpensive compressed hydrogen delivery.

2. The NG pressures of 3,600 psi are much lower than that needed for onboard hydrogen tanks. The study team suggests 6,000 psi for 5,000-psi tanks, but in reality the economic optimum pressure is closer to 7,000 to 8,000 psi for 5,000-psi car tanks. Even at 7,000 psi, the cascade tank farm utilization is barely above 50%. Since these tanks are very expensive, it is less costly in many circumstances to increase the compressor pressure by adding another stage, if necessary, rather than adding more storage tanks.
3. The mercaptan odorants and other sulfur compounds in natural gas would contaminate fuel cells. Mercaptan is known to be a strong adsorbent, frequently requiring hours of purging to remove the odorants from pipes, valves and compressor cylinder walls. Thus hydrogen could not be compressed immediately after natural gas use. It is doubtful that a compressor could be used to fill a natural gas vehicle and later to fill a FCV with hydrogen within a reasonable period of time the same day.

Simultaneous use is obviously feasible for internal combustion engine vehicles (ICEVs), as has already been demonstrated for vehicles using hythane. However, we do not believe that hydrogen burned in conventional ICEs offers significant societal advantage over natural gas in ICEs to warrant converting natural gas to hydrogen.

3.1.2 Sequential Natural Gas/Hydrogen Use

The recommendation of the study group to restrict the dual use compressors to natural gas initially, followed later by exclusive hydrogen use makes more sense than simultaneous use. This approach avoids the sulfur/Mercaptan contamination issue, but does not avoid the mismatch in flow rates and pressures. Hence our judgment that these dual-use compressors might never be used for a practical hydrogen fueling system.

3.2 Alternative Recommendation: Purchase Complete Hydrogen Fueling Systems

As an alternative to designing, building, testing and installing dual-use compressors, we recommend that the AQMD fund the purchase of complete hydrogen fueling systems. In the early days of direct hydrogen FCVs, there will be relatively small numbers of FCVs in any fleet or neighborhood. We estimate that the incremental cost of developing large-scale compressors to be compatible with both natural gas and hydrogen may be sufficient to purchase a complete hydrogen fueling system to support 100 FCVs or two direct hydrogen FC buses. These fueling systems would include a natural gas reformer to produce the hydrogen on-site, a gas clean-up system, a small hydrogen compressor, storage tanks, control and safety systems, and a hydrogen dispenser to fill the FCV car tanks at 5,000 psi. We estimate that such a system would cost $200,000 to $275,000 in moderate production volumes, which is comparable to the incremental costs for making the large natural gas compressors compatible with hydrogen.

The study team is recommending the investment of $600,000 for the four stations they deemed suitable for conversion to hydrogen. We suggest that this money might be sufficient to purchase two to three complete hydrogen fueling systems, once these systems are fully developed. These hydrogen fueling appliances may be available in two to three years, based on current development schedules. In our judgment, the SCAQMD and the citizens of California would be better served by waiting two to three years if necessary to install two to three fully functioning hydrogen fueling systems for $600,000, rather than to invest that same money now to convert large scale natural gas compressors to hydrogen compatibility, on the outside chance that these oversize, under-pressurized compressor systems might prove useful to some as yet undefined hydrogen fueling system 10 to 12 years from now.

Attachment C

Other Information Received from Various Sources

Correspondence on
Hydrogen Compatibility Issue

#	Correspondent	Company	Business
01	Frank Finn, Dr.	FIBA Technologies	H2 & CNG storage systems
02	Ian Patterson	Fueling Technologies, Inc.	H2 & CNG dispensers
03	John Coursen	SCI Tanks	H2 & CNG on-board tanks
04	Ian Patterson	Fueling Technologies, Inc.	H2 & CNG compressors
05	Aaron Rachlin	DCH	H2 & CNG diaphragm compressors
06	David Savidge	Rix Industries	Manufacturers of CNG & H2 compressors
07	Drew Diggins	Pinnacle CNG	Manufacturers of CNG compressors
08	Roger Conyers/Chris Morgan	CPI Tanks	H2 & CNG land-based storage tanks
09	Greg Vlasek	Pinnacle CNG Company	CNG compressor systems
10	Paul Staples	HyGen Industries	H2 energy developers
11	Anupom Ganguli	AQMD	List of contacts made
12	Shakeel Ahmed	Greenfield Compression	NG compressor manufacturer
13	Fredinand Panik	Calif. Fuel Cell Partnership	Alternative fuel collaborative
14	Cynthia Verdugo-Peralta Amendment #38	Governing Board Member	
15	Shakeel Ahmed/Venki Raman	Air Products & Chemicals	Alternative fuel provider
16	Andrew Littlefair	Pickens Fuel Corp.	Alternative fuel provider

E-MAIL

March 8, 2001

ATTN: Mr. Ranji George

Rgeorge@aqmd.gov

SUBJECT: Response to Survey – NGV Refueling Station for Hydrogen

REF.: Your e-mail dated 27 February 2001

Dear Mr. George:

In response to your survey, FIBA Technologies, Inc. is pleased to submit this letter to inform you that FIBA agrees with the members of the AQMD Governing Board in that we also strongly recommend that any project to build NGV refueling stations must consider the future use of hydrogen as an alternative fuel.

FIBA has been engaged in the activities of the compressed gas industry since 1958 and we have been building hydrogen (and CNG) storage systems for nearly 25 years. We have become the leader in the compressed gas, specialty gas and alternative fuel industries, and all of the major industrial gas suppliers call FIBA when challenging, special services and product safety and purity applications are required for their business development. FIBA is an active member of the Compressed Gas Association (CGA) and other organizations and we participate in the writing of CGA pamphlets that are referred to by regulatory agencies and users of compressed gases. Our many years of experience give us the credentials needed to make the right decisions about what products are most suitable for a particular application.

The following is offered to specifically address the points of your e-mail. Note that your e-mail had two (2) items identified as b. I will refer to those as b1 and b2:

a.) We estimate that 99% of the components selected for a CNG fueling station are also suitable for hydrogen applications. The important differences are the areas of dispensers and electrical codes. A system built to the safety codes required for hydrogen (including setbacks) will be satisfactory for a CNG system. But, electrical codes have some important differences in that the hydrogen codes are more stringent than CNG codes. Dispensers for hydrogen are not nearly as advanced as those available for the CNG systems. There just hasn't been the demand for the components required to fuel automobiles with hydrogen gas. This is an area that requires more R&D. Piping used for CNG applications is exactly the same as that suitable for hydrogen. The same applies to dryers, storage and compressors, *provided that the proper compressor is selected.* It is critical that a suitable compressor is chosen for a system that will pump either CNG or hydrogen (refer to section c).

b1.) Compressed gas cylinders have been storing and transporting hydrogen gas since the late 1800's and, surprisingly, little has changed with regards to the cylinder designs! But, the design and engineering staffs at FIBA Technologies, Inc. have sought out manufacturers that can provide the largest payloads and highest pressures, and we have taken advantage of the volume and pressure by developing cascade controls and pressure-reducing stations that use multiple, manifold zones to pressure-transfer hydrogen gas in sequenced stages. We combine the gas storage with a diaphragm compressor for ultra high purity (no oils are introduced to the gas stream) and peak performance at minimal cost. Additionally, we use state-of-the-art system components, including compression systems built with a programmable logic controller.

The key vendors in the hydrogen marketplace are the major industrial gas suppliers, such as BOC Gases, Air Products & Chemicals, Praxair, Air Liquide, Messer and Airgas. FIBA supplies to all of them and we are considered by each to be a preferred supplier. For pressure vessels we offer new and reconditioned DOT and ASME tubes supplied by three (3) different vendors. For compressors, we offer PDC diaphragm machines when a daughter station is being built and Norwalk compressors when the mother station is being built. Both of these companies are well aware of the unique design considerations of hydrogen gas. In fact, many of the other compressor companies that supply machines for CNG applications will decline to bid on a hydrogen system, due to their inexperience with the product and concerns about leakage or breakdown of the machine's components (explained below in section c).

b2.) Selection of the proper compressor and the proper combination of DOT and ASME storage can achieve minimal incremental cost. Over many years we have packaged hydrogen systems using a half-dozen manufacturer brands and we have learned from our experience what the advantages and disadvantages are of each design. By knowing the strengths and weaknesses of each compressor make we are able to professionally advise our customers as to what application they are best suited for. In the case of AQMD, incremental costs will be minimized if a compressor suitable for *both* CNG and hydrogen is chosen.

Costs can also be minimized if the gas storage consists of the proper mix of mobile, DOT tube trailers and stationary, ASME pressure vessels. When comparing the same gas storage capacity, DOT tube trailers represent a twenty-percent (20%) savings over ASME tubes. Furthermore, the DOT trailers allow the operators of a refueling station to either: a] offer excess product to gas users (at times when the station has a surplus of CNG or hydrogen volume – at start-up for example) or, b] haul in back-up gas at times when there is a shortage of gas at the station (for instance, when the station's equipment is down for maintenance). Tube trailers are also an item that is easily leased. By leasing the trailers, AQMD can save substantial investment capital.

c.) We believe that the compressor is the heart of any fueling system and the models offered by FIBA are the finest in the industry for CNG and hydrogen applications. Our diaphragm compressor line is economically priced and designed for efficient, low maintenance operation at daughter stations by allowing high suction and discharge pressures and low electricity usage. The 2,000-psig suction pressure capabilities of FIBA compressors allow a reduction in the quantity of on-site storage needed at fueling stations (in the form of expensive, ASME tubes) by taking advantage of the stored energy produced by the mother station compressor. (Unlike reciprocating compressors, the diaphragm compressor doesn't require the suction pressure to be dropped down to between 5 and 40 psig only to be brought back up again.) Additionally, FIBA offers 2-stage models that can be used to supercharge the CNG or hydrogen gas up to 4,000 or 6,000 psig when desirable. Great care must be taken when selecting a compressor for hydrogen applications due to the unique properties of the gas. In converted air machines that are not designed for light gases, such as hydrogen and helium, users will experience hazardous (and expensive) leaks at the crankcase seals and shafts. Additionally, bearing components in reciprocating machines (not pertinent to diaphragm compressors) have been prone to breakdown when used in hydrogen service.

d.) FIBA would very much like to participate in discussions relating to AQMD's development of CNG and hydrogen refueling stations! We have a great knowledge base about what works and what doesn't work and we offer quality products and services for the applications. The attached photos illustrate a few of our most interesting projects. One shows a CNG tube trailer with a compressor built on-board (mounted underneath the tube bundle). The motor of this trailer's compressor is powered by the CNG that is carried within the trailer's tubes! Another illustrates a tube trailer with a compressor positioned within the rear control cabinet. The smaller piece of equipment is a compressor built within a small trailer that can be towed by a pick-up truck. Contained within the cabinet of this tag-along trailer is all the necessary electrical and cascade filling controls for remote compression applications.

In summary, Mr. George, FIBA has developed products and services that support productivity, economy and, most importantly, safety. We are always interested in partnering with companies promoting hydrogen as an alternative fuel and spearheading the necessary research and development. As the industry develops, FIBA expects to be instrumental in designing fast fill stations throughout the United States and abroad.

Our equipment is exceptional for either CNG or hydrogen fueling. In addition to compressors, our products include mobile and stationary gas storage equipment (e.g. ASME receiver assemblies, tube trailers, and skid containers), and cascade and pressure regulator controls and dispensers. Our designs are based upon our experience and our many years of membership in, or dealings with, such organizations as the CGA, National Fire Protection Association (NFPA), U.S. Department of Transportation (DOT), American Society of Mechanical Engineers (ASME), International Oxygen Manufacturers Association (IOMA), National Hydrogen Association (NHA), Natural Gas Vehicle Coalition and the National Welding Supply Association (NWSA).

Mr. George, I trust that this letter addresses the issues of your survey in a satisfactory manner. If additional information about the products and service of our company is desired, please do not hesitate to call this office toll-free at 1-800-343-3460 or view our web site at www.fibatech.com. We look forward to being of service to AQMD and its customers!

Sincerely yours,

Frank H. Finn, Sr.

Frank H. Finn, Sr.
Chief Executive Officer
FIBA Technologies, Inc.

cc: Christopher R. Adams
Assistant Vice President
FIBA Technologies, Inc.

Fueling Technologies Inc.

South Coast Air Quality Management District,
21865 E. Copley Drive,
Diamond Bar, CA
91765-4182

June 22, 2001

Attention: Mr. Ranji S. George

Subject: Hydrogen Compatible CNG Systems

Dear Sir:

Thank you for your recent email regarding the capability of installation of CNG equipment that can be further upgraded to fueling hydrogen powered vehicles. Fueling Technologies, Inc. has experience in this area both with our own internal personnel and with strategic relationships with compressor manufacturers. We also work closely with contractors who have the personnel and necessary licensing to install and service the equipment throughout California and most other states.

Major differences between CNG and hydrogen are summarized in the following table:

	CNG	Hydrogen	Implications
Electrical rating	Group D	Group B	Electrical components must have Group B rating; some CNG equipment does not have Group B components as standard.
Maximum Working Pressures	3,600 psi	6,250 psi	Hydrogen is to be filled to 5,000 psi settled pressure; in order to adequately fill a vehicle to 5,000 psi the system must be capable of handling 6,250 psi.
Material Composition Limitations	Aluminum	Special coated aluminum required	Hydrogen can embrittle certain materials, such as aluminum or titanium. Aluminum is used with a special protective coating.
Gas supply	Limited by capacity of natural gas supply lines	Limited by hydrogen generation supply capability	Limited hydrogen generation capacity can reduce capacity of hydrogen compressor system and therefore the number of vehicles that can be fueled. One alternative to overcome this problem is to have a buffer supply of hydrogen available on site, either with a trailer or stationary storage.

The following address the major fueling system components:

Dispenser:

CNG Dispenser General Specifications:

Maximum Working Pressure:	5,000 psi
Maximum Flow Capacity:	130 pounds/minute
Electrical Components:	Class 1, Group D, Division 1, Explosion Proof
Code Compliance:	National Electric Code
Electrical Requirements:	110V 60 Hz
Dimensions (W X D X H):	33" X 22" X 92"
Operating Temperature:	-40° F To +160° F
Vehicle Filling Pressure:	3,000 psi

Fueling Technologies, Inc., 131 Citation Drive, Unit 23, Concord, ON, Canada L4K 2R3
Telephone: (905) 669-0158 *Fax: (905) 669-7561* *Email ian@fuelingtech.com*

Nozzle connection:	Standard NGV1
Vehicle fueling control:	Internal to dispenser with no wired connection to vehicles.

Hydrogen Dispenser General Specifications:

Maximum Working Pressure:	7,000psi
Meter Maximum Flow Rate:	130lbs/minute
Electrical Components:	Class 1, Group B, C, D, Division1 and Division 2 (with air purge enclosure)
Code Compliance:	National Electric Code
Electrical Requirements:	110V 60 Hz
Dimensions (W*D*H):	33" x 22" x 92"
Operating temperature ranges:	-40 ° F to +160°F
Nozzle connection:	California Fuel Cell Partnership standard interface for 5,000 psi. See Note 1 below
Vehicle fueling control:	Internal to dispenser with no wired connection to vehicles with optional vehicle connections. See Note 2 Below.

Note 1:

The California Fuel Cell Partnership (CaFCP) has provision for two filling pressures, 3,600 psi and 5,000 psi. The difference in the equipment required is the fueling nozzle and the control software. FTI manufactures two dispenser configurations to meet the CaFCP pressures, one that can fill two vehicles simultaneously at to two different pressures. The other dispenser system can fill only one vehicle at a time to either pressure.

Note 2:

The specification for communications between a hydrogen dispenser and a hydrogen vehicle is under development by the CaFCP. FTI is involved with the committee developing this interface. FTI hydrogen dispensers meet the current communications and protocol specifications and can be upgraded to meet future requirements. FTI CNG dispensers are equipped with the same basic electronics for either CNG or hydrogen. Without the communications link to the vehicles the only difference between CNG and hydrogen is software. The communications link can be retrofitted without any electronics changes.

Major Differences between Standard FTI dual hose CNG dispenser and an FTI CNG dispenser with hydrogen compatibility:

1. Control valves to accommodate 7,000 psi hydrogen instead of 5,000 psi CNG valves.
2. Provision for air purge enclosure for meters (NOTE: The meters are expected to receive Group B certification by January 2002, which would negate the requirement for an air purge, therefore the dispenser would be provided with the air purge capability if there is a requirement to deliver hydrogen before the approval is required).
3. Software change in control system to accommodate hydrogen instead of CNG.
4. Increase wall thickness of tubing.

Priority Sequencing Panel:

Major Differences between standard FTI Priority/Sequencing Panel for CNG and a Priority/Sequencing Panel for Hydrogen:

1. Control valves to accommodate 7,000 psi hydrogen instead of 5,000 psi CNG valves.
2. Increase wall thickness of tubing.

Compressor:

FTI does not manufacture compressors, however we work with many compressor companies. CompAir is one of those companies. Based in England, CompAir manufacture, commission and support more high pressure air and gas compressors than any other company in the world. They have been building high pressure compressors for more than 100 years. A CompAir compressor is installed in the Stuart Energy hydrogen system located at Palm Springs, CA.

CompAir have technical services and engineering capability based in the United States and Canada to support its equipment in California. Frontline support for any California sites would also be provided by AES Environmental based in Van Nuys, CA.

CompAir offers a range of compressors that are interchangeable with CNG and hydrogen. Compressor capacities range from those suitable for small, time fill fleet applications to high capacity bus fueling operations.

The major differences between CNG and hydrogen compressors are summarized in the following table:

Component	CNG	Hydrogen	Comments
Pistons	Aluminum Pistons	Special coating on aluminum pistons	Coated pistons provide 100% hydrogen compatibility and are 100% suitable for CNG service.
Valves	Advanced, concentric inlet and outlet valves specific for high pressure gas applications	Low lift valves are installed	Low lift valves are required for hydrogen operation. These can be installed at the time of manufacture or can be easily retrofitted on site. NOTE: Valve replacement is a routine maintenance item; low lift valves can be installed as part of future maintenance. Low lift valves are also fully compatible with CNG.
Oil Carry Over	Oil carryover is limited by compressor design and after filters. Oil carry over increases maintenance on vehicles	Oil carryover is prevented by coalescing and charcoal filters.	Oil is removed from the gas stream in both CNG and hydrogen. Many CNG compressors have major oil carryover problems that cannot be removed by filtration. This is damaging in CNG and is fatal to fuel cells. CompAir's compressor design minimizes oil carryover. Oil carryover is eliminated by utilizing coalescing filters, charcoal filters immediately after compressor. FTI dispensers have full coalescing filters to remove any trace amounts of oil. It is recommended that filter maintenance frequency be increased to virtually eliminate the possibility of any oil carryover.

Storage:

CNG storage is typically used as 3,600, 4,000 or 4,500 psi. Hydrogen storage is available at 6,900 psi. The hydrogen storage is fully compatible with CNG.

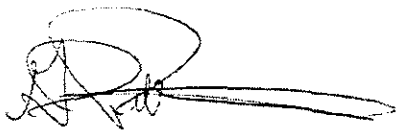
Summary:

It is feasible and practical to construct CNG facilities that could be upgraded to hydrogen in the future. We recommend that an evaluation of the feasibility be based on key points such as filling pressures for hydrogen, timeline for requirement for hydrogen fuel and the interim requirements to develop a hydrogen infrastructure to support a limited number of hydrogen vehicles from CNG/hydrogen sites. We believe that a hybrid solution is possible to provide hydrogen fueling infrastructure at CNG sites. The scope of such an option would have to be defined, but we believe it can be accomplished.

We would welcome the opportunity to present solutions to you. We have specifications for two sites: 1) AQMD Facilities in Diamond Bar and 2) Foothills Transit. We are preparing alternative proposals for both of these facilities that would offer Hydrogen compatible equipment for CNG. These proposals will be sent to you early next week.

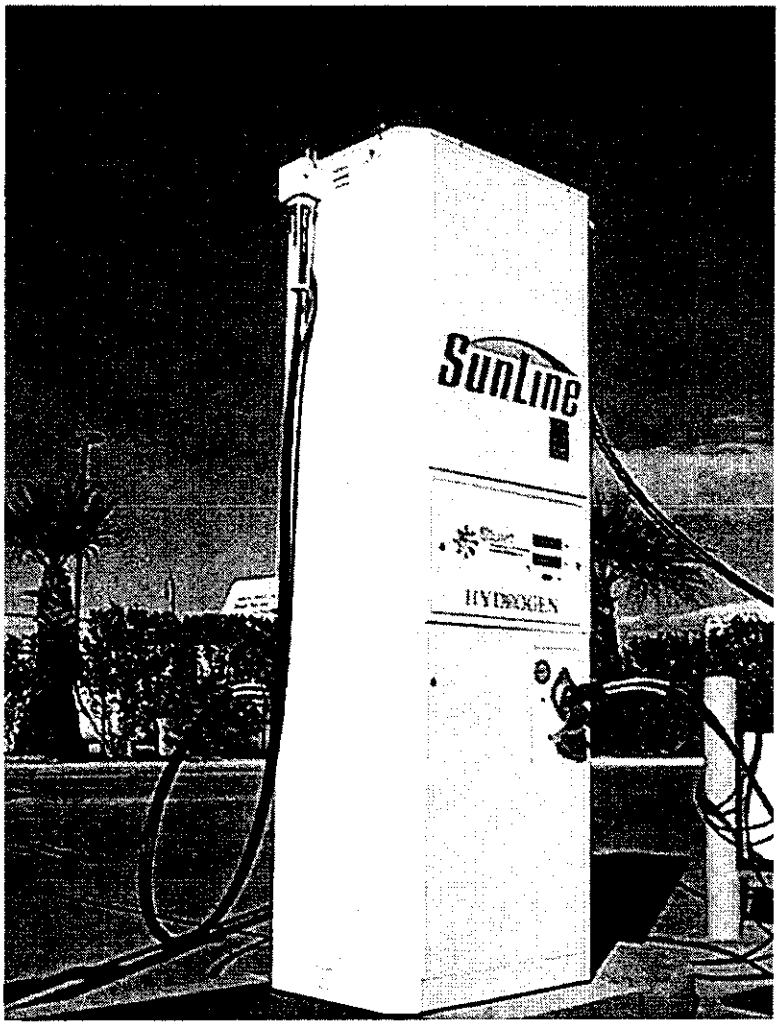
We are looking forward to working with you.

Yours very truly,
Fueling Technologies, Inc.



Ian Patterson, P.Eng., President.

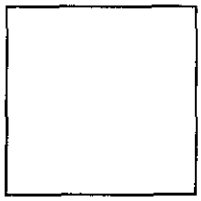
HYDROGEN SYSTEMS



Fueling Technologies, Inc., 131 Citation Drive, Unit 23, Concord, ON, Canada L4K 2R3
Telephone: (905) 669-0158 *Fax: (905) 669-7561* *Email fuelingtech@fuelingtech.com*

Fueling Technologies, Inc. - Company Introduction

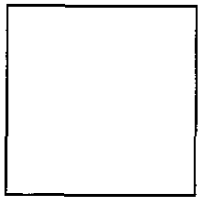
Fueling Technologies Inc. (FTI) is a manufacturer of dispensers for fueling vehicles powered by clean alternative fuels such as CNG, LPG and Hydrogen (for fuel cell powered vehicles). The Company has spent over 8 years developing its products and channels of distribution throughout the world.



Fueling Technologies Inc. Toronto Facilities

With offices in Toronto, Canada; Evesham, UK; and joint venture offices in Beijing, China; Shenzhen, China; Bangkok, Thailand; Karachi, Pakistan and Mumbai, India; FTI is positioned to market, install and support its products on a worldwide basis.

Hydrogen Dispenser



General Specifications

Maximum Working Pressure:	5000 PSI
Meter Maximum Flow Rate:	22.7 Kg./minute
Electrical Components:	Class 1, Group B, C, D, Division 1 and Division 2 (with air purge enclosure) or to CENELEC Zone 1 & Zone 2 as required
Electrical Requirements:	110V 60 Hz or 240V 50 Hz
Dimensions (W* D* H):	860 mm x 560 mm x 2100 mm, Weight: (Single hose approx. 430 Lb.)
Operating temperature range:	-40^0 C To $+60^0$ C

Standard Equipment

- High profile gasoline type dispenser cabinet, with high hose outlet
- Electrical components are approved for Class 1, Group B, C, D, Division 1, Hazardous Locations
- NEMA4 air purged enclosure integrated to dispenser cabinet for Division 2 components (external air supply required)
- Nozzle holster with storage receptacle for Sherex hydrogen nozzle
- 3/8 " stainless piping and fittings on pressure lines
- Inlet valves and sequencing inlet valves are pneumatically operated ball valves (external air supply required).
- Ball valves are three-piece assemblies for convenient maintenance.
- Ball valves are operated with low-pressure air or nitrogen.
- Internal vent line for actuator exhaust combined with nozzle vent line. This line is piped to base of dispenser for connection to vent line away from dispenser.
- Mass flow meter with internal transmitter in air purged enclosure, certified for Division 2.
- Electronic computer for sale, volume with 1 " high, price per unit display is 0.7" high. All displays are back lit display
- Twin Line delivery hose
- Breakaway system with release cage for pressure line on hose.
- Nozzle price is not included in the price of the dispenser.
- Large capacity filters on inlet line, with coalescing element to remove oil, water and particulate.

Priority/Sequencing Panel:

The purpose of the Priority/Sequencing Panel is to direct the flow from the compressor to each of three storage banks. Banks are filled in priority with the number 3 bank being filled first, then the #2 bank and finally the #1 bank. In this way the #3 bank is maintained at the highest pressure to ensure that sufficient storage is available to complete a vehicle fill.

Typical Priority/Sequencing Panel for CNG

Hydrogen model is similar in configuration

The priority valves are spring loaded and have an adjustable opening pressure.

The sequencing valves control the flow from storage to the dispenser. These valves are pneumatically operated (external air supply is required) and are controlled by the Dispenser Control System. The DCS selects the bank that will supply the dispenser with hydrogen. The selection criteria is based on flow rate and is fully programmable in the DCS.

The system also includes the capability to supply hydrogen directly from the compressor to the dispenser automatically if the storage pressure is too low.

The discharge from the sequencing valves is manifolded into a single supply line to the dispenser. The pressure in this line is regulated from 6,000 psi to 5,000 psi.

All components are installed in a NEMA4 weather resistant enclosure which can be wall mounted on any vertical surface. The system includes bulkhead fittings through the enclosure for connections to compressor, storage and dispenser supply lines. Four liquid filled pressure gauges are installed on the enclosure (one for each storage bank and one for compressor inlet). Pressure gauges are visible from outside the enclosure.

General Specifications

Maximum Working Pressure:	415 bar (6,000 psi)
Pressure Regulation:	350 bar (5,000 psi)
Maximum Flow Rate:	500 M^3 / hour
Electrical Components:	Class 1, Group B, C, D, Division 1 and Division 2 (with air purge enclosure) or to CENELEC Zone 1 & Zone 2 as required
Number of Lines:	One inlet, 3 outlets to storage and one outlets to dispenser (for single hose dispensers only) with a direct fill from compressor
Operating Temperature:	-40 ^{O} C to 60 ^{O} C
Dimensions:	600 x 609 x 203 mm
Mounting / Enclosure:	Wall mounted fully enclosed NEMA 4
Connection Size:	3/8" tube end
Tubing size:	All flow tubing is 3/8" seamless stainless steel
Pressure Gauges:	Liquid filled pressure gauges for each bank and compressor inlet

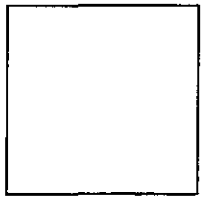
Slow Fill Hydrogen System

The slow fill system is comprised of two major components

1. Fueling stand with delivery hose and nozzles.
2. Dispenser control system (DCS) to control filling pressure of vehicles to a temperature compensated pressure.

One DCS can control any number of fueling stands.

Fueling Stand



Bus Slow Fill Fueling Stand (CNG)

General Specifications

Maximum Working Pressure:	5000 PSI
Meter Maximum Flow Rate:	22.7 Kg./minute
Electrical Components:	No electrical components on fueling stands
Dimensions (W* D* H):	24 mm x 24 mm x 2100 mm, Weight: (Single hose approx. 110 Lb.)
Operating temperature range:	-40^0C To $+60^0$C

Standard Equipment

- Steel tubing 24 mm square tube with integral hose outlet module located at top of stand.
- Steel baseplate with provision for 4 anchor bolts
- Isolation ball valve to start or stop flow
- Breakaway coupling (¼") with tripod release tripod
- Internal tubing ¼" with ¼" tubing connection at base of fueling stand.
- Single line delivery hose (3/8" pressure line), rated at 5,000 psi maximum working pressure.
- Nozzle storage receptacle
- Internal vent line for nozzle vent line. This line is piped to base of dispenser for connection to vent line away from dispenser. Optional vent to atmosphere configuration available.

Dispenser Control System for Slow Filling Systems

This system is a standalone electronic module that controls the filling pressure for slow fill hydrogen facilities. It fills a vehicle to a temperature compensated pressure based on the ambient temperature during fueling. Pressure inputs are located in the hydrogen line adjacent to the DCS module.

General Specifications

Maximum Working Pressure:	Pressure transducer - 5000 PSI
Electrical Components:	Class 1, Group B, C, D, Division 1 or to CENELEC Zone 1 as required
Electrical Requirements:	110V 60 Hz or 240V 50 Hz
Operating temperature range:	-40^0C To $+60^0$C

Standard Equipment

- Dispenser Control System circuit board
- Explosion proof enclosure suitable for hazardous locations.
- Pressure transducer supplied loose. Includes intrinsically safe barrier to rate the pressure transducer as intrinsically safe.
- Start button on face of explosion proof enclosure to start fueling operation.
- Mounting hardware for installation of enclosure on vertical surface.

Ranji George

From: Coursen, John [JCoursen@Harsco.com]
Sent: Monday, July 02, 2001 9:07 AM
To: 'Ranji George'
Cc: Williams, Robert
Subject: RE: Storage Tanks

Dear Ranji:

As we discussed, the bulk storage tanks you require must be built and certified to the ASME pressure vessel code. Our sister Taylor -Wharton companies are more active with this type of product, and I have contacted Mr. Randy Bunning to assist you. I will call tomorrow to discuss this with you, and I have also given Mr. Bunning your phone number.

John Coursen

-----Original Message-----
From: Coursen, John
Sent: Friday, June 29, 2001 2:03 PM
To: 'Ranji George'
Cc: Schaffer, Randolph; Williams, Robert
Subject: RE: H2 Tanks

Dear Ranji:

I have also spoken with Randy regarding the questions you presented. The issues you want to discuss involve many different departments within SCI and our parent company Harsco. I am certian that we can help you with this fuel station project, but we believe that the best way to serve you would be through communications with myself. In this manner, I can help you with many of your questions, and quickly find the best person to address more specialized topics.

I look forward to working with you.

John Coursen

-----Original Message-----
From: Ranji George [mailto:RGeorge@aqmd.gov]
Sent: Friday, June 29, 2001 1:20 PM
To: 'Coursen, John'
Subject: RE: H2 Tanks

Mr. Coursen
Thank you for your reply. I am in touch with Mr. Randi Schaeffar as well. He said he will coordinate the pricing information with your division. I will be faxing more specific information to Mr. Schaeffar soon. Please keep in touch.

-----Original Message-----
From: Coursen, John [mailto:JCoursen@Harsco.com]
Sent: Friday, June 29, 2001 7:10 AM
To: 'rgeorge@aqmd.gov'
Subject: H2 Tanks

Dear Mr. George:

Bob Williams informed me that you have questions regarding hydrogen tanks.
How can we help?

John Coursen
Structural Composites Industries
Product Line Manager - Composite Fuel Tanks
909 444 2503

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Ranji George

From: Ian Patterson [ian@fuelingtech.com]
Sent: Monday, July 02, 2001 11:46 AM
To: Ranji George (E-mail)
Subject: CompAir Compressor Reference List

Q010674a.CNG.REF.doc

Q010674a.HYDROGEN.HPREF.doc

Dear Sir

Please find a copy of two reference lists from CompAir Compressors for CNG and Hydrogen.

Ian Patterson, President
Fueling Technologies, Inc.
131 Citation Drive, Unit 23,
Concord, ON
Canada
L4K 2R3
Tel: 905-669-0158 X 222
Fax: 905-669-7561

CUSTOMER REFERENCE LIST

HYDROGEN COMPRESSORS

HIGH PRESSURE – NOMINAL 80 to 350 BARG

MODEL	CUSTOMER	COUNTRY
5336	British Tar Products	UK
5336	Electrolyser Corporation, Canada	World Wide
5415	Electrolyser Corporation, Canada	World Wide
5417	Electrolyser Corporation, Canada	World Wide
5436	Electrolyser Corporation, Canada	World Wide
5436	Mettur Chemicals	India
5415	Acme (Formerly Gujarat)	India
5415	CCM	Malaysia
5415	Larson & Toubro	India
5336	Karnataka Oxygen	India
5415	Asiatic Oxygen	India
5415	Polimex Cekop	Poland
5415	Electricity Supply Commission	South Africa
5336	Hindustan Organic Co	India
5436	ICI Asean	Malasia
5415	Rajdheni Gases	India
5415	Tuticoran Power Station	India
5415	Emirates Industrial Gases	Dubai
5415	Northern Ireland Electricity	UK
5436	Southern Petrochemical Ind Corp	India
5415	Jordan Engineering	UK
5436	Brilliant Investments	India
5415	Johnson Matthey	Thailand
5417	Johnson Matthey	Thailand
5415	Nuclear Power (Sizewell "B")	UK
5336	Epic Oil	South Africa
5415	Tisco GmbH	Germany

CUSTOMER REFERENCE LIST

HYDROGEN COMPRESSORS

HIGH PRESSURE – NOMINAL 80 to 350 BARG

MODEL	CUSTOMER	COUNTRY
5336	CompAir SA Pty Ltd	South Africa
5415	CompAir SA Pty Ltd	South Africa
5417	CompAir SA Pty Ltd	South Africa
5417	Saudi Industrial Gases	Saudi Arabia
5417	Acme Manufacturing	India
5417	National Thermal Power	India
5436	Ago Fano SA	Columbia
5470	CompAir France	France
5417	India Meteorological	India
5407	*Hitachi Zosen Corp*	*Saudi Arabia*
5417	National Thermal Power Corporation	India
5407	Mahindra & Mahindra Ltd	India
5409	Stuart Energy Systems	Worldwide
5417	Stuart Energy Systems	Worldwide
5436	Stuart Energy Systems	Worldwide

REFERENCE LIST

COMPAIR UK LTD - IPSWICH - CNG COMPRESSORS

YEAR	MODEL	NO OFF	CUSTOMER	COUNTRY
1980	5436	1	WAVERLY DRY PRODUCTS	NEW ZEALAND
1981	5436	1	JOHN WHITING MOTORS	NEW ZEALAND
	5436	2	DUAL FUELS	NEW ZEALAND
1982	5436	9	DUAL FUELS	NEW ZEALAND
	5415	1	COMPAIR IPSWICH	UK
	5436	1	WAIKARAKA MOTORS	NEW ZEALAND
1983	5436	10	DUAL FUELS	NEW ZEALAND
	5415	2	DUAL FUELS	NEW ZEALAND
	5436	2	BP GAS	NEW ZEALAND
	5436	1	WHITE SERVICE STATION	NEW ZEALAND
	5436	1	OXTON MOTORS	NEW ZEALAND
	5436	1	WESTEND AUTOS	NEW ZEALAND
	5436	1	JOHN WHITING MOTORS	NEW ZEALAND
	5415	1	AUTO FUELS	NEW ZEALAND
	5436	2	AUTO FUELS	NEW ZEALAND
	5436	1	WAIRAU ENERGY	NEW ZEALAND
1984	5436	1	MIAMI INTERNATIONAL AIRPORT	USA
	5436	1	PEPSI COLA, MIAMI	USA
	5415	1	HEJLEMANN HOLDINGS	NEW ZEALAND
	5436	2	DUAL FUELS	NEW ZEALAND
	5406	2	DAVID GORDON	NEW ZEALAND
	5436	1	WARKWORTH	NEW ZEALAND

REFERENCE LIST

COMPAIR UK LTD - IPSWICH - CNG COMPRESSORS

YEAR	MODEL	NO OFF	CUSTOMER	COUNTRY
1984	5436	1	PERCY MOTORS	NEW ZEALAND
	5436	4	SHELL OIL NZ	NEW ZEALAND
	5436	1	KRIKS BUSH MOTORS	NEW ZEALAND
	5436	1	SENIOR HOLDINGS	NEW ZEALAND
	5436	1	B P GAS	NEW ZEALAND
	5436	1	AFPB	NEW ZEALAND
	5415	1	AUTO FUELS	NEW ZEALAND
	5415	2	AUCKLAND CITY COUNCIL	NEW ZEALAND
	5436	1	NZ POST OFFICE	NEW ZEALAND
	5436	1	MARAC FINANCE	NEW ZEALAND
	5436	1	BADER ST SERVICE STATION	NEW ZEALAND
	5436	1	SUPREME SERVICE STATION	NEW ZEALAND
	5415	1	TERRY GRUEBNER MOTORS	NEW ZEALAND
1985	5415	1	NORTH MIAMI CITY	USA
	5436	1	COLORADO STATE	USA
	5406	2	D GORDON LTD	NEW ZEALAND
	5415	1	MANGAPAPA SERVICE STATION	NEW ZEALAND
	5415	1	STAR SERVICE STATION	NEW ZEALAND
	5436	6	SHELL OIL NZ	NEW ZEALAND
	5436	1	COMPAC INDUSTRIES	NEW ZEALAND
	5415	1	NZ POST OFFICE	NEW ZEALAND
	5436	4	DAVID GORDON LTD	NEW ZEALAND
	5436	1	LAKE ROAD SERVICE STATION	NEW ZEALAND

REFERENCE LIST

COMPAIR UK LTD - IPSWICH - CNG COMPRESSORS

YEAR	MODEL	NO OFF	CUSTOMER	COUNTRY
1985	5436	1	WESTEND AUTO'S	NEW ZEALAND
	5436	2	B P GAS	NEW ZEALAND
	5436	1	ABBOTTS WAY SERVICE STATION	NEW ZEALAND
	5436	1	DOUBLE SS SERVICE STATION	NEW ZEALAND
	5436	1	DON EMERY MOTORS	NEW ZEALAND
	5436	1	TE RAPA MOTORS	NEW ZEALAND
	5436	1	PROJECT TECHNOLOGY	NEW ZEALAND
1986	5436	6	B P GAS	NEW ZEALAND
	5436	1	MOTOR CENTRE	NEW ZEALAND
	5436	1	BILL ROAN MOTORS	NEW ZEALAND
	5436	2	WAHAROA SERVICE STATION	NEW ZEALAND
	5436	1	ST JOHNS SERVICE STATION	NEW ZEALAND
	5436	2	TOWN CENTRE MOTORS	NEW ZEALAND
	5436	2	KENT STREET MOTORS	NEW ZEALAND
	5436	1	TAG CORPORATION	NEW ZEALAND
	5436	2	DAVIE MOTORS	NEW ZEALAND
	5415	1	PENROSE SERVICE STATION	NEW ZEALAND
	5436	1	GREENS SERVICE STATION	NEW ZEALAND
	5436	1	WINDSOR PARK	NEW ZEALAND
	5436	1	WELLSFORD ENERGY CENTRE	NEW ZEALAND
	5436	1	SHELL OIL NZ	NEW ZEALAND
	5436	1	WELGAS HOLDINGS LTD	NEW ZEALAND
	5436	1	GLENPARK MOTORS	NEW ZEALAND

REFERENCE LIST

COMPAIR UK LTD - IPSWICH - CNG COMPRESSORS

YEAR	MODEL	NO OFF	CUSTOMER	COUNTRY
1986	5436	1	GLENFIELD MOTOR CENTRE	NEW ZEALAND
	5436	1	MILLS SERVICE STATION	NEW ZEALAND
1987	5406	4	OIL & NATURAL GAS CORPORATION	INDIA
	5415	1	B P GAS	NEW ZEALAND
	5436	2	DAVID GRACE MOTORS	NEW ZEALAND
	5436	1	B P GAS	NEW ZEALAND
	5436	1	D GORDON LTD	NEW ZEALAND
1988	5409	1	ENERCOL ENERGY SYSTEMS	UK
	5436	2	GAS AND FUELS CORPORATION	AUSTRALIA
1989	5408	1	GAZ DE FRANCE	FRANCE
	5436	2	GAS AND FUELS CORPORATION	AUSTRALIA
1991	5415	2	GAZ DE FRANCE	FRANCE
	5436	4	GAS AND FUELS CORPORATION	AUSTRALIA
	5408	1	GAS AND FUELS CORPORATION	AUSTRALIA
1992	5436	4	GOTEBORG ENERGI/VATTENFALL	SWEDEN
	5415	1	UNITED TURBINE	SWEDEN
	5436	1	CHERRY CREEK SCHOOLS, COLORADO	USA
	5415	1	AIRBORNE EXPRESS	USA
	5415	1	PEOPLES GAS	USA
	5405	2	NATIONAL ENERGY	USA
	5406	2	NATIONAL ENERGY	USA
1993	5436	1	BRITISH GAS	UK

REFERENCE LIST

COMPAIR UK LTD - IPSWICH - CNG COMPRESSORS

YEAR	MODEL	NO OFF	CUSTOMER	COUNTRY
	5417	1	BRITISH GAS	UK
	5415	2	PEOPLES GAS	USA
	5406	2	MAKO	USA
	5406	2	CENTRAL HUDSON UTILITY CO	USA
1993	5408	1	GAS & FUELS CORP	AUSTRALIA
	5404	1	MARINTEK	NORWAY
	5408	18	NATIONAL ENERGY	USA
	5405	2	NATIONAL ENERGY	USA
	5415	1	MARROW & HOLMAN	USA
DAUGHTER STATION		12	GAS AUTHORITY OF INDIA	INDIA
1994	5415	1	SOUTHERN CALIFORNIA GAS COMPANY	USA
	5415	1	WHIRLPOOL CORPORATION	USA
	5436	2	ATM MITRANS	CUBA
	5436	1	CURT NYBERG/GOTEBORG ENERGI	SWEDEN
	5450	1	MAKO	USA
	5450	1	COMPAIR NEW ZEALAND	CHINA
	5436	4	R.P.G.C.	BANGLADESH
	5415	1	A.E.C.	SOUTH AFRICA
	5436	1	CURT NYBERG	SWEDEN
	5450	1	KARAMAY OIL	BANGLADESH
	5450	1	TOHO GAS/JAPAN STEEL WORKS	JAPAN
	5436	4	RPGCL (PETRONABGLA)	BANGLADESH
	5450	1	XINJIANG PETROLEUM CORP	CHINA
	5415	1	WHIRLPOOL CORP	USA

REFERENCE LIST

COMPAIR UK LTD - IPSWICH - CNG COMPRESSORS

YEAR	MODEL	NO OFF	CUSTOMER	COUNTRY
1995	5409	1	EASTERN NATURAL GAS	UK
	5436	1	GOTENBURG ENERGI	SWEDEN
	5436	2	MINISTRY OF TRANSPORT	CUBA
1996	GAZPACK70	1	BUSINESS GAS/SOUTHAMPTON CITY BUS	UK
	GAZPACK50	4	PETRONAS	MALAYSIA
	GAZPACK5	1	BRITISH GAS/CAMBUS	UK
	5409	4	KRAUS	CANADA
	5417	1	IMW-ATLAS	USA
	GAZPACK36	1	BP	UK
1997	GAZPACK5	1	COSWORTH ENGINEERING	UK
	GAZPACK5	1	GAS CONTAINER SERVICES	UK
	GAZPACK5	1	BRITISH GAS - BOURNEMOUTH	UK
	GAZPACK5	1	BRITISH GAS - GKN	UK
	GAZPACK5	1	BRITISH GAS - PERTH	UK
	GAZPACK5	1	BRITISH GAS - SUTTON	UK
	GAZPACK9	1	BRITISH GAS - NORTHAMPTON	UK
	GAZPACK9	1	CHARLES DE GAULLE AIRPORT	FRANCE
	GAZPACK36	1	BRITISH GAS - WALSALL	UK
	GAZPACK17	1	BRITISH GAS - MERTON	UK
1998	GAZPACK7	2	BRITISH GAS	UK
	GAZPACK50	1	BRITISH GAS - SUTTON	UK
	GAZPACK9	1	COMPAIR LUCHARD	FRANCE
	GAZPACK5	1	BRITISH GAS - BIRMINGHAM	UK
	GAZPACK 50	2	COMPAIR FRANCE - MEAUX	FRANCE

REFERENCE LIST

COMPAIR UK LTD - IPSWICH - CNG COMPRESSORS

YEAR	MODEL	NO OFF	CUSTOMER	COUNTRY
1999	5409 CNG	4	COMPAIR MAKO	USA
	5436 CNG	6	COMPAIR AUSTRALASIA	PAKISTAN
	GAZPACK 50	2	COMPAIR FRANCE - MONTBELIARD	FRANCE
	GAZPACK 50	2	COMPAIR FRANCE – BORDEAUX	FRANCE
	GAZPACK 70	2	COMPAIR FRANCE – NANCY	FRANCE
	GAZPACK 7	1	COMPAIR IBERICA	SPAIN
	GAZPACK 50	2	COMPAIR AUSTRALASIA	CHINA
	GAZPACK 7	1	TICKFORDS	UK
2000	GAZPACK 36	1	GULSHAN SERVICE STATION	PAKISTAN
	GAZPACK 7	1	GAS CONTAINER SERVICES	TUNISIA
	GAZPACK 50	2	COMPAIR AUSTRALIA	CHINA
	5409 CNG	1	COMPAIR MAKO	USA
	GAZPACK 50	3	COMPAIR FRANCE	FRANCE
	GAZPACK 37	2	CALTEX OIL (PAKISTAN) LTD	PAKISTAN
	GAZPACK 37	5	CHEPSTOW SHIPPING CO (EXPORT)	PAKISTAN
	5409 CNG	2	COMPAIR AUSTRALIA	AUSTRALIA
	GAZPACK 50	4	COMPAIR AUSTRALIA	CHINA
	GAZPACK 37	2	COMPAIR AUSTRALIA	AUSTRALIA
	GAZPACK 36	1	CURT NYBERG AB	SWEDEN
	GAZPACK 70	1	COMPAIR FAR EAST	KOREA
	5470	1	SWIRE ENGINEERING	CHINA
	GAZPACK 70	2	COMPAIR FRANCE	FRANCE
	GAZPACK 70	4	COMPAIR AUSTRALIA	AUSTRALIA

REFERENCE LIST

COMPAIR UK LTD - IPSWICH - CNG COMPRESSORS

YEAR	MODEL	NO OFF	CUSTOMER	COUNTRY
2000	GAZPACK 37	5	CHEPSTOW SHIPPING CO (EXPORT)	PAKISTAN
	GAZPACK 70	2	PILSUNG ENGINEERING	KOREA
	GAZPACK 37	1	COMPAIR AUSTRALIA	AUSTRALIA
	GAZPACK 7	2	GAS CONTAINER SERVICES	UK
2001	GAZPACK 50	2	COMPAIR FRANCE S.A.	FRANCE
	5409 CNG	3	COMPAIR DLT GMBH	GERMANY
	5407 CNG	2	COMPAIR DLT GMBH	GERMANY
	GAZPACK 37	4	COMPAIR AUSTRALASIA	AUSTRALIA

Ranji George

From: Aaron S. Rachlin [arachlin@dcht.com]
ent: Tuesday, July 03, 2001 4:54 PM
o: Ranji George
Subject: PDC Diaphragm Compressors that can be used for both CNG and Hydrogen

Diaphragm Compressors.htm

91326A.dwg

Hello Ranji,

I wanted to touch bases with you regarding the email you sent last Thursday regarding Minimizing Fuel Cell Infrastructure Costs: H2 and CNG compatibility. In addition to contacting our colleagues at Norsk-Hydro regarding the compatibility of the Hofer Diaphragm Compressor to this dual fuel task, I have also contacted PDC Machines, Inc., out of Warminster, Pennsylvania, who I also understand makes a very high quality diaphragm compressor that can, I have confirmed, be used in the scenario outlined below (for both CNG and hydrogen gas) compression and dispensing. The contact I spoke with at PDC is named Steve Cohen, and Mr. Cohen's phone number is (410) 357-8387, fax number is (410) 357-8261, and he can be reached via email at stevchen@bcpl.net.

Mr. Cohen informed me that his PDC diaphragm compressors can handle both CNG and compressed hydrogen gas, provided that there are no condensables and no moisture in either of the gas streams (I believe this issue can be alleviated through the use of an appropriate gas dryer, as well as nitrogen purging between usage of CNG toward hydrogen). He also mentioned that all applicable safety codes and standards could be met (I believe he mentioned the Class I, Divisions I & II classifications for Hazardous Gases in an Atmosphere, and in case of Malfunctioning equipment) and were all adhered to by PDC compressors.

short, Ranji, he was only able to briefly review the appended documents regarding the actual proposed CNG refueling stations, but he was confident that at least their compressors could handle the job for both gases.

Please feel free to contact Mr. Cohen directly, and I hope this information is somewhat helpful to you. Also, as stated above, I will pass along any feedback I receive from Norsk Hydro on this as I soon as I receive it from them.

Best,

Aaron

P.S. - Ranji, I'm not sure if you have AutoCAD on your computer, but if you do, attached please find the safety zone diagram we just received from Norsk indicating the setbacks around the electrolyzer hydrogen plant and refueling station. Don't worry if you can't open the attachment because by the end of the week we will be sending you the same diagram along with a drawing of the Preliminary layout for H2 filling station, as well as its Utility Requirements, all in Hard Copy format.

-----Original Message-----
From: Ranji George [mailto:RGeorge@aqmd.gov]
nt: Thursday, June 28, 2001 5:58 PM
ject: Minimizing Fuel Cell Infrastructure Costs: H2 and CNG compatibility
gent)

DAVID SAVIDGE,
RIXX INDUSTRIES
BENICIA, CA.

RE: COMPATIBLE COMPRESSORS
60 SCFM 4VX and the 300 SCFM 2JJS.

SUMMARY

OIL FREE COMPRESSORS

- WITH 40 PSIG INLET PRES/SURE (3 month maintenance); OUTLET 4500 PSIG WITH 60 SCFM
  Base Price: $60 - $65,000
  Compatible H2/CNG price : $75,000.

- With 40 psig inlet, 300 scfm outlet at 4500 psig
  - $150,000 base price
  - $160,000 compatible price.

-----Original Message-----
From: David Savidge
Sent: Friday, July 06, 2001 4:17 PM
To: RGeorge@aqmd.gov
Subject: RE: CNG/H2 Compressors

Hi Ranji,

A compressor built for H2 will work fine on CNG. Even better, as you and I have discussed. And even if you do have a problem it will be in the piston rings or the valves, both of which are easy to change out.

You may want to talk with George about a service program under which we guarantee the machine's performance after switching over to H2, even if it is five years later.

As far as having built dual-use compressors, it turns out that we have. The H2 compressors that Chevron in Richmond have were run on nitrogen prior to going to H2. There were no problems. And we have built systems that run on both oxygen and nitrogen. But never CNG and H2. The ironic part of our discussions is that CNG is one of the easiest gases to deal with--easy to compress (low heat), easy to seal, forgiving on compressor wear parts.

Hello Ranji,

We have no doubts that our hydrogen compressors will work very well on CNG. In fact, we expect them to work better on CNG. If you would like to talk with our Chief Engineer, John Below, I can arrange that.

We have a CNG package at our plant here that maybe we could use for an H2 test, if that would help make our case.

I have attached users list and references for some of our H2 users. And here is a CNG user you could talk with:

San Antonio River Walk 210-207-7862 Richard Hurd
4 x 4VX4BG-23.3 units, installed 9-95

Let me know what other information you need.

Cheers,

The differential for this hybrid H2/CNG compressor is about $10-15K. As far as pricing for subsequent units goes, we can do the second system, provided it is exactly the same as the first, for about $60,000. If five are ordered at once, after the first system is designed and built, then the price comes down below $55,000 each.

We would offer our standard 18/12 warranty on these packages--18 months from shipment or 12 months of operation, whichever occurs

first. Preventive maintenance contracts can be discussed, but we do not have a set price for these.

Let me know what other information you need. Thanks for your interest. Yours Truly,

Dave

Dear Ranji,

We have made oil-free compressors for both CNG and H2 applications and we can provide a single compressor that can do both. The hydrogen application requires that we look very carefully at our seals and at out materials. However, once selections have been made, they can be applied in a CNG situation as well.

Changing from CNG to hydrogen would require no changes in the compressor, but we would recommend a nitrogen purge prior to switching over.

The compressor below is one that we have sold extensively into the CNG market. We have also applied this frame at pressures up to 6,000 psig, oil-free. This is a four-stage, air-cooled, oil-free machine that we have provided to Praxair, BOC, Air Products, Air Liquide and others for a variety of heavy-duty industrial applications.

We have manufactured many hydrogen compressors for clients such as Praxair, Chevron, and Texaco, among others. We have not done any hydrogen fueling stations yet, but we believe that we are close to getting our first, of what will be many, we hope.

Reference: Q01-0659

Inlet Pressure: 40 psig
Inlet Temperature: 90F
Flow: 60 SCFM
Discharge Pressure: 5-6,000 psig

Compressor: RIX 4VX4BG-17.5

Stages: 4
Cooling: Air, forced
Power: 40 BHP
Speed: 780 RPM (belt drive)

Dimensions: 4'W x 6'L x 5"H (approx.)
Weight: 2,000 lbs. (approx.)

Price: US$70,000 FOB Benicia, CA

Delivery: 4-5 Months

Accessories: Motor (Explosion-Proof) & belt drive; intercoolers and aftercooler, cooling fan and directional air shrouds (motor XP); relief valves (stainless steel internals) for each stage; inlet pressure switch; regulating discharge pressure switch (6,000 to 4,500 psig); oil pressure switch; discharge temperature switch; pressure gauges; inlet filter (y-strainer); discharge check valve (SS). Terminal box mounted on skid (Nema 7). Full testing at operating flow and pressure. Programmable logic controller (RIX standard). On-off lights.

Not included: Variable flow valve, vent unloader valve; vent silencer; motor starters.

Let me know what else you need, and good luck!

Yours Truly,

Dave Savidge

David Savidge, RIX industries, June 29, 2001.

The differential for this hybrid H2/CNG compressor is about $10-15K. As far as pricing for subsequent units goes, we can do the second system, provided it is exactly the same as the first, for about $60,000. If five are ordered at once, after the first system is designed and built, then the price comes down below $55,000 each.

We would offer our standard 18/12 warranty on these packages--18 months from shipment or 12 months of operation, whichever occurs first. Preventive maintenance contracts can be discussed, but we do not have a set price for these.

Let me know what other information you need. Thanks for your interest.

Yours Truly,

RIX INDUSTRIES REFERENCE LIST

Hydrogen

Safety-Kleen:
Contact: Rob Litavecz, Maintenance Supervisor. Ph: (219) 397-1131 #6142
Compressors: Seven 2JS/2JJS hydrogen compressors
Location: East Chicago, Ill.
Notes: Outdoor service, 24 hr

Safety-Kleen: Dale MacIntyre, Engineering Dept, Breslau, Ontario. They have seven 2JS/2JJS hydrogen compressors operating in East Chicago, Ill.
Phone: (519) 648-2291; Fax: (519) 648-3317

Chevron Research: Curt Mauroner, Engineering Dept, Richmond, CA. Chevron has two model 3KX3BG-8.5 units. They are 3 stage and pump dry hydrogen from 50 to 4,000 psig.
Phone: (510) 242-3416; Fax: (510) 242-2995

Chevron Research in Richmond, CA. owns two RIX 3KX units which pump dry hydrogen from 50 to 3,200 psig. For information call Curt Mauroner, Engineering Dept. @ (510) 242-3416.

The unit has run over 7000 hours @ 3200 PSI on a single set of piston rings.

Martin Lane of **Texaco Research**, Texas. Texaco has ten (10) Rix model 3K3G-20 3,000 psi hydrogen compressors. Phone (409) 982-8211??????; Fax (409) 982-8207

Mohawk Oil: Colin Hay (604) 929-1281 Model 1K1G

Natural Gas

Caltex Petroleum: reference is Mr. Robin Edinboro, Purchasing Dept, Caltex Services, Texas. Mr. Edinboro was involved with the purchase of 30 natural gas compressors in the early 1980's (all 3600 psi).
Phone: (972) 830-3651, Fax: (972) 830-1056

(1)

RIX INDUSTRIES

User List

Hydrogen Compressors (partial)

CUSTOMER	MODEL	INLET PSIG	DISCH PSIG	HP
Breslube Ltd	1KX1BG-47.5	620	690	30
Breslube Ltd	1KX1BG-47.5	620	690	30
Crawford & Russell / Phillips Petroleum	1KX1BG-3.7	370	820	10
Glyco Inc	1KX1BG-16.7	330	355	10
Howe-Baker / Phillips Petroleum	1KX1G-28	610	740	30
Howe-Baker / Phillips Petroleum	1KX1G-28	610	740	30
Howe-Baker / Phillips Petroleum	1KX1G-12.3	180	735	20
Howe-Baker / Phillips Petroleum	1KX1G-22	666	800	20
Howe-Baker / Hyundai, Daesan, Korea	1KX1BG-1.9	510	1150	7.5
Tulsa Pro Quip / Phillips Petroleum	1KX1G-16	650	735	15
Tulsa Pro Quip / Phillips Petroleum	1KX1G-28	610	730	30
Tulsa Pro Quip / Phillips Petroleum	1KX1G-28	610	730	30
Breslube/SafetyKleen	2JJS2G-98	70	1000	150
Breslube/SafetyKleen	2JJS2G-98	70	1000	100
Breslube/SafetyKleen	2JS1G-68	800	900	100
Breslube/SafetyKleen	2JS1G-68	800	900	100
Breslube/SafetyKleen	2JS1G-55	800	900	60
Breslube/SafetyKleen	2JJS1G-82	600	900	150
Breslube/SafetyKleen	2JJS1G-82	600	900	200
Breslube/SafetyKleen	2JJS1G-82	600	900	200
Union Carbide	2JS3BG-195	15	315	75
Praxair, Inc.	2JS2BG-15	80	3000	60
Praxair, Inc.	2JS2BG-15	80	3000	60
Praxair, Inc.	2JS2BG-15	80	3000	60
Praxair, Inc.	2JS2BG-15	80	3000	60
Praxair, Inc.	2JS2BG-15	80	3000	60
Praxair, Inc.	2JS2BG-15	80	3000	60
Praxair, Inc.	2JS2BG-15	80	3000	60
Praxair, Inc.	2KX2BG-11	80	2400	30
Hydro-Chem	2KX2BG-37	200	1165	30
Republic, Guatemala	2K2G-44	0	412	20
Chevron Research	3KX3G-8.5	50	4000	15
Chevron Research	3KX3G-8.5	50	4000	15
Texaco Research	3K3G-20	5	3000	15
Texaco Research	3K3G-20	5	3000	15
Praxair, Inc.	3K3BG-9.3	80	3000	30
Praxair, Inc.	3K3BG-9.3	80	3000	30
Praxair, Inc.	3K3BG-9.3	80	3000	30
Praxair, Inc.	3K3BG-9.3	80	3000	30
Praxair, Inc.	3K3BG-9.3	80	3000	30
Praxair, Inc.	3KX3BG-17	80	2000	30

RIX Industries
6460 Hollis Street
Oakland, CA 94608
(510) 658-5275 (510) 428-9102 fax

Note: Model numbers containing a "B" have oil-free compression

4/98

RIX Industries
6460 Hollis Street
Oakland, CA 94608
(510) 658-5275 (510) 428-9102 fax

DREW DIGGINS
PAT OKERMAN
PINNACLE COMPRESSORS
MIDLAND TEXAS

-----Original Message-----

I could build 4 compressor per month but only install 2 compressors per month, 9 months would equal 18 compressors.

Nitrogen Purge for 16 seconds would deliver 99.9976% pure hydrogen.

From: Drew Diggins
Sent: Friday, July 06, 2001
To: Ranji George
Subject: RE: Compatible CNG and H2 equipment

Dear Mr. George,
Pinnacle CNG's 5" HIC (Hydraulic Intensifier Compressor) is available in both a 5,000 and 10,000 PSI discharge models. The materials used in the high pressure compression chambers is a low yield, ductile material which would be compatible for hydrogen compression. The current CNG rod and piston seal material used is also compatible for hydrogen compression. Pinnacle's hydraulic intensifier provides "Oil Free" compression. Pinnacle has designed its hydraulic intensifier so that it can compress CNG as well as hydrogen with a minimum amount of purge required. If changed from CNG to hydrogen compression "on the fly" the discharged hydrogen would be at 99.97% purity in 12 seconds.

Pinnacle CNG could demonstrate hydrogen/CNG compatible compression technology with a change order for the SCAQMD Diamond Bar CNG project that Pinnacle is the low bid. Pinnacle has the ability to test its complete compressor assembly in its Midland, TX test bay both with hydrogen and CNG. Please let me know your next step in moving this project forward.

Drew Diggins P.E.
Operations Manager
Pinnacle CNG Company

Ranji,
The option for compression at $530,000 would provide the "performance" i.e. capacity and quality, of the SCAQMD bid specifications but would change the equipment specified and allow Pinnacle to utilize its patented compression process lowering the installed cost to your referenced $530K. Additional savings would be realized by the SCAQMD through lower energy requirements, 12.6% minimum for the life of the equipment, 10 Years. If the stations were Utilized by SCAQMD at 50% capacity this could provide a savings greater than the initial installed cost $530,000 over the ten Year life! It would pay for its self!

I will reserve comments on the Hydrogen project until I have finished my material modifications and priced the changes.
Drew Diggins

July 10, 2001

Ranji S. George
AQMD, TAO
21865 E. Copley Drive
Diamond Bar, CA 91765
Phone: 909-396-3255
Fax: 909-396-3252

Subject: ASME Seamless Pressure Vessel Quotation – Hydrogen/CNG Projects

Reference: CPI Quote C-27453

Dear Mr. George,

In response to your request for quotation for the above subject, we are pleased to provide you with the following proposal.

1. **Pricing**
   1.1. Total "lump sum" price for Item 1 is $48,088.00.
   FOB Clearfield, UT; No freight allowed.

2. **Scope**

   2.1. To provide shop supplies, material, and labor for the fabrication of CP Industries supplied material for the following vessels:

Item	Qty	Description	Unit Price
1.0	(4)	ASME Seamless Pressure Vessels 16" Dia.x 28'-0" Long Water Volume: 25.88 ft 8,333 scf/vessel of hydrogen gas @ 6,000 psig WP Design Pressure: 6,900 MAWP @ 3:1 SF Corrosion Allowance: None Minimum Wall Thickness: 1.263" Ultimate Tensile Strength: 135, 000 psi Max. Service: Compressed Hydrogen/CNG Gas Temp. Rating: -20° F to 200° F Material: SA-372-J-CL70 STD Finish / Paint (White 3 to 5 mills DFT) Standard Saddle Rack Supports No Valves	$14,000.00

Item

2.0 Our proposal includes the following items:

2.1 Material to ASME specifications
2.2 ASME Sect. VIII Construction and Registration with the National Board.

3 **Terms and Conditions**

3.1 Our price is subject to acceptance within 30 days of the date or this proposal.
3.2 Price is firm through delivery.
3.3 Payment terms are net 30 days from date of invoice, based upon credit approval.
3.4 Price excludes any taxes (State, Local, or Federal), which may be imposed or applicable.
3.5 Material is subject to prior sale, which can affect lead-time of shipment and price.
3.6 Prices quoted are based on the quantity specified in Item 1.
3.7 See General Terms and Conditions attached.

4 **Shipment Schedule**

4.1 Shipment schedule to be determined upon placement of purchase order.
4.2 The estimated total shipping weight is

We appreciate the opportunity of quoting on your requirements and we look forward to serving you. Should you have any questions and/or comments concerning our proposal, please do not hesitate to contact us.

Best Regards

Roger E. Conyers
CP Industries
Executive Vice President

cc: file

cpi CP Industries (A Division of Remion Industries, Inc.) **Utah Plant**

851 South Freeport Ind. Parkway, Suite 3, Clearfield, UT 84015 Phone (801) 773-2575 Fax (801) 773-2980

August 6, 2001

Ranji S. George
AQMD, TAO
21865 E. Copley Drive
Diamond Bar, CA 91765
Phone: (909) 396-3255
FAX: (909) 396-3252

Subject: ASME Seamless Pressure Vessel Quotation-"33,000 scf CNG Storage" Project

Reference: CP Industries Quote No. C27503

Dear Mr. George:

In response to your request for quotation for the above subject, we are pleased to provide you with the following proposal:

1.0 **Pricing**

1.1 Total "lump sum" price is $48,228.00.
FOB Clearfield, UT; No freight allowed.

2.0 **Scope**

2.1 To provide shop supplies, material, and labor for shop fabrication of CP Industries supplied material for the following vessels:

Item	Qty	Description	Price/3-pack
1.	(1)	(3-pack) Assembly of ASME Seamless Pressure Vessels 20" Dia. x 22'- 0" Long Water Volume = 33.3 ft^3/vessel 33,798 scf/3-pack of CNG @ 4,500 psig WP Design Pressure = 5,500 MAWP @ 3:1 SF Corrosion Allowance = NONE Minimum Wall = 1.280" Service = Dry Compressed Natural Gas (CNG) Temp. Rating = (-20° F to 200° F) Material = SA-372-J-CL70, (135,000 psi max. UTS.) STD Saddle Racks, Seizmic Zone 4 Rated, Stacked (1-Wide x 3-High) STD Paint: White Enamel (3 to 5 mils DFT.) STD Valve Set (Isolation, Service, PRV and Drain Valves)	$48,228.00

2.2 Our proposal includes the following items:

2.2.1 Material to ASME specifications.
2.2.2 ASME Sect. VIII Construction and Registration with the National Board.
2.2.3 Valves will be shipped loose and will require onsite installation onto the vessels by the "Buyer".

3.0 **Terms and Conditions**

3.1 Our price is subject to acceptance within 30 days of the date of this proposal.
3.2 Price is firm through delivery.
3.3 Payment terms are net 30 days from date of invoice, based upon credit approval.
3.4 Our price excludes any taxes (State, Local, or Federal) which may be imposed or applicable.
3.5 Material is subject to prior sale, which can affect lead time of shipment and price.
3.6 Prices quoted are based on the quantity specified above.
3.7 See General Terms and Conditions attached.

3.8 Our proposal includes the following items:

4.0 **Shipment Schedule**

4.1 Shipment schedule to be determined upon receipt of purchase order.
4.2 The estimated total shipping weight is 21,300 lbs.

We appreciate the opportunity of quoting on your requirements and we look forward to serving you. Should you have any questions and/or comments concerning our proposal, please do not hesitate to contact us.

Best regards,

Chris Morgan
Chris Morgan
Engineer/Estimator

cc: Roger Conyers

Ranji S. George, AQMD, TAO
Quote No.: C-27503
August 6, 2001

Series "CP-I"

CONDITIONS

1. **PAYMENTS:** Payments shall be made at par in legal tender of the United States of America. Buyer shall make such arrangements for payment as Seller shall from time to time reasonably require and Seller may suspend production, shipment or delivery until such arrangements are made. In the event Buyer fails to make payment in full within the time period set forth on the invoice or within the time period expressly agreed upon in writing by the parties, such failure to pay on time constitutes a material breach of contract by Buyer permitting Seller to suspend production, shipment or delivery under this or any other contract between Buyer and Seller and Buyer shall pay to seller interest on the unpaid amount at the maximum rate permitted by law or the Prime Rate in effect by Morgan Guaranty Trust Company on the first of the month for each month plus 3.5 %, whichever is less, and Seller shall have, in addition, all other remedies permitted to Seller by law, equity and this contract. If Seller has to take legal action to collect any amount due hereunder, Buyer shall pay all court costs plus reasonable attorney's fees incurred by Seller in bringing such legal action.
2. **TAXES:** To the extent legally permissible, all present and future taxes imposed by any Federal, state, foreign or local authority which Seller may be required to pay or collect, upon or with reference to the sale, purchase, transportation, delivery, storage, use or consumption of goods or services, including taxes upon or measured by the receipts therefrom (except net income and equity franchise taxes), shall be for account of Buyer.
3. **TITLE; INCIDENTAL TRANSPORTATION AND STORAGE CHARGES:** Unless otherwise agreed, title to goods and risk of loss shall pass to Buyer upon tender of delivery at the F.O.B. point specified. Any charges at destination for spotting, switching, handling charge for goods left in Seller's possession after notification to Buyer that the goods are available to ship.
4. **TIME OF SHIPMENT AND SHIPPING:** Time is not of the essence hereunder. Each shipment is to be considered a separate sale. Seller reserves the right to ship all or any part of the goods from any shipping point of CP INDUSTRIES, Inc. other than the shipping point or points specified herein.
5. **SPECIFICATION VARIATIONS:** Except in the particulars specified by Buyer and expressly agreed to in writing signed by Seller, the goods furnished hereunder shall be produced in accordance with Seller's standard practices. All goods, however, including those produced to meet an exact specification, shall be subject to Seller's mill tolerances and variations consistent with good mill practice in respect to dimension, weight, straightness, section, composition and mechanical or physical properties, and to normal variations in surface and internal conditions and in quality; to deviations from tolerances and variations consistent with practical testing and inspection methods; and to regular mill practice on over and under shipments.
6. **INSPECTION:** Where mill inspection is made by Buyer, Buyer's inspector shall be deemed the agent of Buyer with authority to waive specified tests and details of test procedure and to accept goods as conforming to this contract with respect to all characteristics of such goods for which such inspection is made.
7. **FORCE MAJEURE; ALLOCATION OF PRODUCTION:** In the event either party's performance hereunder is delayed or made impossible, or commercially impracticable due to causes such as fire, explosion, strike or other difference with workers, shortage of energy sources, facility, material or labor, delay in or lack of transportation, temporary or permanent plant shutdown, breakdown or accident, compliance with or other action taken to carry out the intent or purpose of any law, regulation, or other requirement of any governmental authority, or any cause beyond that party's reasonable control, that party shall have such additional time within which to perform this contract as may be reasonably necessary under the circumstances. However, the obligation of Buyer to pay for goods delivered is never suspended. In addition, if due to force majeure or any other cause, Seller is unable to produce sufficient goods to meet all demands from customers and internal uses, Seller shall have the right to allocate production amount to its customers and plants in any manner which Seller may determine to be equitable.
8. **PATENT INDEMNITY:** Seller shall indemnify Buyer (a) for all direct and actual damages recovered from Buyer by a third party in a legal action for infringement of a U.S. patent claim covering goods furnished hereunder, on condition that Buyer promptly notifies Seller of the alleged infringement, affords Seller the opportunity to assume defense thereof, and cooperates with Seller in defense of the action and in any feasible mitigation of damages; and (b) for Buyer's directly and reasonably incurred expenses in defending such legal action if, after such notice and opportunity given by Buyer, Seller elects not to assume such defense, provided that such election by Seller shall not otherwise affect Buyer's aforesaid obligations. In like manner, Buyer shall indemnify Seller, and Seller's indemnity of Buyer hereunder shall not apply, with respect to a claim arising out of Seller's compliance with special designs or specifications furnished by Buyer, now or hereafter forming a part of this contract, or with other written instructions given by Buyer for the purpose of directing the manner in which Seller shall perform this contract. In no event shall a party hereto have any liability hereunder for indirect or consequential losses or damages suffered, or other expenses incurred, by the other party hereto or any third party by reason of any patent infringement claim.
9. **WARRANTY; DISCLAIMERS:** SELLER WARRANTS THAT THE GOODS FURNISHED HEREUNDER WILL BE PRODUCED AND TESTED IN ACCORDANCE WITH THE SPECIFICATIONS SET FORTH ON THE FACE HEREOF. HOWEVER, NO WARRANTY OF FITNESS FOR ANY PARTICULAR PURPOSE NOR ANY OTHER REPRESENTATION OR WARRANTY, WHETHER EXPRESS OR IMPLIED, IS MADE RESPECTING SAID GOODS, OR THE PRODUCTION THEREOF AND THERE ARE NO WARRANTIES WHICH EXTEND BEYOND THE DESCRIPTION ON THE FACE HEREOF.
10. **LIMITATION OF REMEDIES:** Seller will replace, at the delivery point specified herein, any goods furnished hereunder that are found to be defective or otherwise fail to conform to any warranty or this contract, or, at Seller's option, Seller will repay the price paid for such goods, plus any transportation charges paid by Buyer in addition to such price. Claims must be made promptly following delivery of the goods to Buyer and Seller must be given a reasonable opportunity to investigate and cure any nonconformance. Buyer's exclusive remedies with respect to any goods furnished by Seller hereunder that are found to be defective or otherwise not in conformity with any warranty or this contract shall be limited exclusively to the right to replacement thereof or to repayment of the price, as above provided. Seller's liability for any other breach of this contract shall be limited to the difference between the delivered price of the goods covered hereby and the market price of such goods at Buyer's destination at the time of such breach. IN NO EVENT SHALL SELLER BE LIABLE FOR PERSONAL INJURY, PROPERTY DAMAGE, LOSS OF PROFIT, DELAY, OR ANY INCIDENTAL OR CONSEQUENTIAL, DAMAGES WHETHER ARISING FROM CONTRACT, BREACH OF CONTRACT, TORT, SELLER'S NEGLIGENCE, STRICT LIABILITY, OR ANY EXPRESS OR IMPLIED WARRANTY, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED WARRANTIES OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE.
11. **EXCLUSIVE TERMS AND CONDITIONS; ACCEPTANCE; MODIFICATION:** No terms or conditions other than those stated herein and no agreement or understanding, oral or written, in any way purporting to modify these terms and conditions shall be binding on Seller unless hereafter made in writing, specifically stating that it is a modification of these terms and conditions, and signed by Seller's authorized representative. If these conditions and this form constitute Seller's acceptance of Buyer's order, then this acceptance is expressly made

CONDITIONS (Continued)

conditional on Buyer's assent to these conditions as the only conditions for this sale. Acceptance of the products sold hereunder by Buyer shall constitute assent to these conditions and Seller hereby objects to and rejects any and all additional or different terms proposed by Buyer, whether contained in Buyer's purchase order or shipping release forms, or elsewhere. All proposals, negotiations and representations, if any, made prior and with reference hereto are merged herein.

12. **CONDITIONS INCORPORATED BY REFERENCE:** Any clause required to be included in a contract of this type by any applicable law or administrative regulation having the effect of law shall be deemed to be incorporated herein.
13. **WAIVER:** Waiver by Seller or Buyer of any breach of these provisions shall not be construed as a waiver of any other breach.
14. **ASSIGNMENT:** Neither party may assign its rights or obligations hereunder without the prior written consent of the other party.
15. **TITLES:** The titles used in these Conditions are for convenience of reference only and are not to be considered in interpreting the substance of the condition.

PINNACLE CNG COMPANY

P. O. Box 2499
Midland, Texas USA 79702
Office: (915) 686-7002
Fax: (915) 686-1557

Gregory E. Vlasek
Regional Manager of Government Relations, Sales Representative

July 25, 2001

Hon. Hal Bernson, Chair
South Coast AQMD Governing Board
Technology Committee
21865 East Copley Drive
Diamond Bar, CA 91765 **via FAX: (213) 473-6925, (909) 396-3317**

Dear Chairman Bernson:

RE: CNG-Hydrogen Compatible Technology Evaluation

Pinnacle CNG Company was pleased to testify at last Friday's Board hearing to introduce our company and patented CNG compression technology. We very much appreciate the Board's award of a District CNG infrastructure grant to Pinnacle for construction of our first CNG station within the South Coast Air Basin at Ware Disposal Co. in Santa Ana. We are also pleased to be anticipating staff's confirmation of our company's low bid on the new District headquarters CNG fueling station as also being the conforming low bid.

It was clear to us from last Friday's proceeding that the Governing Board is very committed in its desire for natural gas vehicle technologies to provide a planned and economical transition to hydrogen technologies. Pinnacle did not testify on this subject. However, developing commercial gas compression technology is Pinnacle's core business, and we are well positioned to assist SCAQMD with demonstration of a commercial hydrogen-compatible fueling system *within the next six months*.

At staff's request, Pinnacle has furnished a written proposal to demonstrate a commercial hydrogen-compatible compression and dispensing system, at a cost not significantly higher than today's standard CNG systems. Mr. Larry Watkins is the program supervisor evaluating our proposal. Additionally, we have arranged for our chief engineer and operations manager, Mr. Drew Diggins, to attend this

California Office:
6945 Fair Oaks Boulevard Suite 6
Carmichael, California USA 95608-3362
Telephone: (916) 482-2004
Fax: (916) 482-2036

Friday's Technology Committee meeting. Mr. Diggins will be prepared to make a brief presentation and answer any questions on the hydrogen compression technology that Pinnacle is ready to demonstrate.

Pinnacle CNG has established a well-deserved reputation in the CNG industry for innovative engineering, efficiency, reliability and customer service. We are enthusiastic about working with the SCAQMD Governing Board to bring our decades of gas compression engineering experience into the service of clean air in southern California.

The enclosed information packet will help acquaint you with Pinnacle and our role in the fuel compression industry.

Very truly yours,

Greg Vlasek

Cc: Technology Committee Members:
Vice Chair Norma J. Glover
Mr. Jon D. Mikels
Mr. Leonard Paulitz
Dr. S. Roy Wilson

Governing Board Members:
Mr. Michael D. Antonovich
Dr. William A. Burke
Mrs. Jane W. Carney
Mrs. Beatrice J. S. Lapisto-Kirtley
Mr. Ronald O. Loveridge
Mr. James W. Silva
Mrs. Cynthia Verdugo-Peralta

Dr. Chung Liu
Larry Watkins

HyGen Industries, LLC

ALTERNATIVE ENERGY DEVELOPERS

Dear Ms. Verdugo-Peralta,

I am sending you this fax to confirm that Rich Capua, Owner of Matrix Engineers and Contractors, supported your efforts at the last SCAQMD Board meeting on July 20th, to require all new CNG fueling systems funded by the district to be hydrogen compatible, and objected to the staffs statement that there are no codes and standards for hydrogen fueling systems in place.

Matrix has over 30 years experience in installing industrial gas systems, especially hydrogen systems, and at that meeting referred to current standards and codes that go beyond natural gas systems standards and codes. At the tech meeting on July 27th Mr. Capua came prepared with approved blueprints for a system he is currently installing, and was prepared to show these blueprints to the committee and discuss the process. However, because the meeting started late and the public discussion on the issue came much later than expected, Mr. Capua had to leave for a previous engagement with the customer he was willing to discuss and was not able to present his materials to the committee. I would highly recommend that the SCAQMD Board require that the committee invite Mr. Capua to sit on the committee as a bona-fide expert in hydrogen systems installations and codes & standards, since that is the case. I have discussed the issue with him and he has expressed a willingness to do so. You will not find a more qualified expert in the field. He has actually put systems in and on the ground, and has done more systems than anyone in the field that I know of. His customer base includes Praxair, Air Products, Rocketdyne, Xerox, Clean Air Now, and NASA among others. The Clean Air Now Hydrogen Facility at Xerox operated safely and efficiently for 5 years without one problem with any of the installation that Matrix conducted.

Please feel free to contact Mr. Capua at 800-369-5757. I am sure you will find him receptive to your invitation.

Also, I would be glad to offer HyGen's expertise as hydrogen energy developers to advise the committee on project development and deployment. I am fairly confident I can get an expert from United Technologies to offer their expertise on hydrogen generation, and transmission. I am also confident we can get an expert from NASA and or Los Alamos to also advise the committee/board on hydrogen codes/standards and handling.

Please feel free to call me at my new number at 310-574-6110 to discuss the possibilities.

Sincerely,

Paul Staples, Chairman & CEO

PS. Did you get my info on Sulzer Compressor Manufacturers that I emailed you before the tech meeting. I ran across them in my research to find a company that can supply a compressor that works with both hydrogen and natural gas. They are just one of several we are considering. HyGen has formed a partnership with the City of Santa Monica to do such a project at their natural gas vehicle fueling facility. Let me know if you received it the email. We have been having problems with our ISP's of late in delivering emails. Probably one of those viruses hit their systems. Although everything seems to be back to normal now. If you did not receive it, I will forward it to you again.

PH: 310-574-6110
4085 GLENCOE AVE. #112
e-mail: h24u@hygen.com
FAX: 310-574-9919
MARINA DEL REY, CA. 90292

Dory Kilgour

From: Anupom Ganguli
Sent: Wednesday, August 08, 2001 10:00 AM
To: Dory Kilgour
Subject: FW: Natural Gas - Hydrogen Refueling

F.Y.I.
-----Original Message-----
From: Anupom Ganguli
Sent: Thursday, July 19, 2001 5:27 PM
To: Chung Liu
Subject: Natural Gas - Hydrogen Refueling

I have talked with a number of people over the past 2-3 weeks regarding the issue of whether a natural gas refueling station can be converted in future to H2 refueling station, and the technical feasibility and costs of such modifications. A list of these people and a summary of these discussions can be found below.

Contacts Made:

Karen Campbell, Air Products (Presentation)
Steven Lelewer, Hydrogen Burner Technology (At Ca FCP Mtg)
Jim Heffel, Univ. of Calif, Riverside, CERT (At BMW Reception)
Jim Ohi, National Renewable Energy Lab. (At BMW Reception)
David Savidge, RIXX Industries (Telephone)
Andy Abele, Quantum Industries (Telephone)
Drew Diggins, Pinnacle CNG Systems (Presentation)
Catherine Lentz (At Ca FCP Mtg)

Summary of Information:

H2 Refueling Stations erected to date, cost about $1 million or more. The Ca FCP station costs more and the Las Vegas station funded by DOE costs much more. Natural Gas reforming is one of at least 3 common paths to commercial H2 fuel, including water electrolysis, and liquid H2 storage (with methanol reforming as another option).

The 2 AQMD H2 station awards would likely be both electrolyzers with total station costs of about $ 1 million each.

Major costs for H2 stations from CNG include reformer, compressor, dispenser, and storage. The last three can also be used for CNG service, IN THEORY. In practice, several issues need to be investigated and demonstrated, such as impurities and sulfur removal from natural gas, higher pressure seals and materials (H2 is needed at 6000 psig for FCVs while CNG pressure is lower), contamination, material compatibility, and perhaps most importantly H2 codes and standards compliance. This development can be done, at certain cost, and with additional time. However, such dual capability or dual service experience is missing at this time: NO ONE HAS BUILT AND OPERATED A CNG/H2 SYSTEM THAT WILL MEET THE NEEDS OF CNG VEHICLES AND FUEL CELL VEHICLES YET. THEREFORE, IT IS NOT DEMONSTRATED FOR COMMERCIAL USAGE YET.

Note that several vendors claim to supply H2 compatible components at 10-25 percent increased cost. These have not been demonstrated, and are not integrated into a package that can work practically, in response to specified fuel specs. But there is no THEORETICAL REASON why they cannot be integrated in future, although the cost is expected to be much higher. It is also important to note that further R&D and competing electrolyzer technology can lower the CNG-H2 system costs in future, so that the current designs are no longer economic. One of the remaining "wild cards" mentioned by several people is compliance with fire and safety codes which would be acceptable by local city officals - and which are in various stages of development.

Recommendation:

It appears that a demonstration program may be appropriate to build and test such a Dual Capable System to further assess the technical and cost issues, and smooth the way for commercialization. Such conversion projects are specifically mentioned in the TAO Plan 2001 Update, Project CFM 4-2, for potential funding.

Chung Liu

From: Shakeel Ahmed [Shakeel.Ahmed@GFComp.com]
Sent: Thursday, August 09, 2001 11:31 AM
To: Cynthia Verdugo-Peralta
Cc: Ronald Loveridge; Jane Carney; 'h24u@hygen.com'
Subject: Hydrogen & Natural Gas Compressors

H2&NG Compressor Survey.doc

It is my understanding that you are interested in utilizing a single compressor for the compression of Hydrogen and Natural Gas, please see the following.

GreenField Compression Inc. Division of Sulzer Burckhardt, designs, manufactures and packages compressors for various gases and applications. Sulzer has been in the compressor business for over 150 years. Sulzer has built over 23,000 high pressure compressors and over 1,300 NGV fueling stations.

Compressors for Hydrogen service is one of Sulzer specialties. A compressor built for Hydrogen service can also be used for the compression of Natural Gas.

When gas service is changed from Hydrogen to Natural Gas or vice versa, the system has to be purged of the old gas. This can be accomplished manually initially and after the control have been developed, will be done automatically.

The budget price of our Model C4T compressor for Natural Gas with 40 psig suction pressure and 4500 psig discharge pressure with a flow rate of 350 SCFM is $160,000. The same compressor for Hydrogen service has a budget price of $180,000.

I have also attached a copy of the survey regarding this issue.

Please call if you have any questions.

Sincerely,

Shakeel Ahmed
Applications Engineer
<<H2&NG Compressor Survey.doc>>

RECEIVED

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SCAQMD
EXECUTIVE OFFICE

July 17, 2001

The Honorable Bill Burke
Chairman, SCAQMD Governing Board
1110 W. Ohio Ave., Suite 100
Los Angeles, CA 90025

Dear Bill:

I am writing this letter to support the Amendment, proposed by Board Member Cynthia Verdugo-Peralta, to Agenda Item #38 "Award Multiple Contracts for Natural Gas Refueling Station Infrastructure." The Amendment is a creative solution to a complex issue, providing a fueling infrastructure for hydrogen powered vehicles.

The members of the California Fuel Cell Partnership (CaFCP) are beginning to strategically consider a possible pilot phase demonstration of fuel cell vehicles. The phase may begin as soon as calendar year 2003. Ideal locations for this demonstration would be in a dense urban area that can support these vehicles and the needed infrastructure. We recognize the need for clean fuels and zero emission vehicles in the South Coast Air Basin. Not only is the area a prime area from an ecological standpoint but also from a financial and technological point of view. The LA area has many fleets of all types that could utilize fuel cell vehicles. Once the population in the area becomes accustomed to the vehicles and comfortable with the hydrogen fuel then the area will likely be a prime location to introduce the vehicles into the private consumer market. The area is also a good place to begin commercialization because several of our automotive manufacturing members have already established facilities. Introduction of a new technology is a high-risk venture for private industry. Responsive State and Local government are important to minimize financial risk to whatever degree is possible.

The installation of an alternative fuel infrastructure can be a daunting task for fuel suppliers. The risk of stranded capital is an unattractive possibility. Government support will be desirable in order to minimize this risk and to push the infrastructure and the vehicles it will fuel closer to commercialization. Please seriously consider this cost-effective proposal that Ms. Verdugo-Peralta has wisely offered as an Amendment.

Best regards,

Ferdinand Panik
Chairman, California Fuel Cell Partnership

Motion by Cynthia Verdugo-Peralta on Agenda Item 38

AWARD MULTIPLE CONTRACTS FOR CNG REFUELING STATIONS MAKING THEM COMPATIBLE FOR A HYDROGEN INFRASTRUCTURE

MOTION

I make the following motion to set the foundation to:

- Attract Fuel Cell Vehicles to South Coast Basin
- Promote ongoing FCV technology development
- Provide Infrastructure for three fuels instead of one
- Minimize Stranded Investment in CNG refueling
- Leverage small investment to install multiple refueling stations
- Substantially reduce infrastructure costs by reducing equipment duplication
- Reduce Land use by avoiding separate refueling infrastructures for each fuel type
- Substantially reduce Tail Pipe Emissions through Hythane & FC Vehicles
- Raise public and fleet awareness of FCVs

I move that the Board direct the Executive Officer to:

(1) Utilize $1.5 million currently identified in TAO's work plan for hydrogen refueling infrastructure (#CFM 4-2) to offset any potential incremental costs to make the proposed CNG refueling stations compatible with Hydrogen, in order to refuel and transition into future vehicles powered by CNG/H2 Blends and Hydrogen Fuel Cell Vehicles.

(2) Execute contract with Air Products, or an equally qualified vendor to assess the cost, best site candidates, feasibility, space requirements; codes and standards and other issues associated with implementing this motion to ensure the construction of CNG refueling stations, which will be compatible with Hydrogen refueling. The total contract cost is not to exceed $50,000 with funding from the Clean Fuels Fund.

(3) Report back to the Governing Board at the August board meeting with findings of this study and recommendations for potential upgrades to the CNG refueling sites identified for Hydrogen compatibility, including targeted supplement grants for to assist with the incremental costs and to follow on an expedited schedule prior to construction of the stations.

(4) Based on the findings of the contractor, the Governing Board will fund the recommended sites identified for this project, until the set aside funds are exhausted.

(5) Approve the staff recommendation for funding of the **5 CNG and 3 LNG** refueling sites proposed by staff; which addresses equipment not relevant to this motion.

(6) Execute contract with Professor Marshall Miller, U.C. Davis, and Dr. Sandy Thomas of DT Technology to provide ongoing consulting services regarding development and implementation of Hydrogen Refueling Infrastructure in the South Coast Basin, in an amount not to exceed $30,000 each.

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S. Roy Wilson, Ed.D.
Supervisor, Fourth District
County of Riverside

Julia Verdugo-Peralta
Governor's Appointee

July 15, 2001

The Honorable Norma Glover
Councilmember, City of Newport Beach
450 Santa Ana Ave.
Newport Beach, CA 92663

Dear Norma:

I am writing to seek your support for an amendment to agenda item #38, which I will be putting forth at the upcoming Governing Board meeting on Friday, July 20, 2001. As you may know, agenda item #38 is to "Award Multiple Contracts for Natural Gas Refueling Station Infrastructure." I am asking that we utilize $1.5 Milllion from TAO funds and draw down from these funds until the funds are exhausted, to make as many of the CNG refueling stations compatible with Hydrogen.

The purpose of my amendment is to:

- **Attract Fuel Cell Vehicles (FCV) to South Coast Basin**
  By building a CNG/Hydrogen compatible refueling station infrastructure we will attract the vehicle manufacturers to our Basin sooner. It will also take away the "chicken and egg" argument regarding which needs to come first, the vehicles, or the infrastructure.
- **Promote ongoing FCV technology development**
  With an infrastructure in place it will encourage and speed up the technology development of CNG/H2 Blend and Fuel Cell powered vehicles.
- **Provide Infrastructure for three fuels instead of one**
  We could get three fuels in our basin for very near the price of one. By ensuring that these CNG Refueling stations are built to be compatible for Hydrogen we can have CNG, CNG/H2 (Hythane, which reduces the emissions in CNG), and pure Hydrogen.
- **Minimize Stranded Investment of a CNG Refueling Station**
  When hydrogen powered vehicles arrive in large numbers, the proposed CNG facilities may become obsolete and we will have to start all over again with a new infrastructure. This amendment would allay those fears. By building a CNG refueling station compatible with Hydrogen, the stations could initially be used for CNG vehicles, then in a few years CNG and CNG/H2 blends (Hythane), and a few years later CNG, CNG/H2, and pure H2. Finally, pure H2 for FCV's. This amendment can introduce all 3 transitions much more smoothly and less costly. In addition Government investments in the CNG infrastructure would not go wasted.

- **Leverage small investment to install multiple refueling stations**
  By spending a little more money now, we can save a large amount of money later, by not building separate infrastructures and therefore leveraging the initial investment for the incremental costs. One of the lowest quotes we received for a CNG refueling station was from Pinnacle at $703K per station. Their engineer, Drew Diggins, he has stated that to build a separate Hydrogen refueling station it would cost approximately $750K, **per station**. Ian Patterson from FTI (Fueling Technologies Inc.), they produce the dispensers, stated that it would be approximately 10% more to make the dispensers compatible for Hydrogen. I am also enclosing a quote staff received from CompAire, a company from England who builds the compressors, which states that they can produce a compatible compressor for approximately $15,000 more than the single fuel CNG compressor. We have received information that they have built approximately 300 CNG stations and they are the supplier to Stuart Energy.
- **Substantially reduce infrastructure costs by reducing equipment duplication**
  Most of the same companies who provide the components for a CNG refueling station can also provide them for a CNG/H2 compatible system, substantially reducing the cost.
- **Reduce Land use by avoiding separate refueling infrastructures for each fuel type**
  By building compatible refueling stations we reduce the amount of valuable land required for the refueling infrastructure, than if we build separate infrastructures for each fuel type.
- **Substantially reduce Tail Pipe Emissions through Hythane & FC Vehicles**
  The whole purpose of promoting clean alternative fueled vehicles is to reduce the amount of toxic emissions in our basin. By building an infrastructure, which can support 3 fuels instead of just 1, we are ensuring that vehicle emissions will be reduced.
- **Raise public and fleet awareness of FCVs**
  By approving this amendment, we will draw worldwide attention to the idea of clean alternative fueled vehicles becoming a reality. We will bring CNG, CNG/H2 (Hythane) and Hydrogen Fuel Cell powered vehicles into the mainstream.

California Fuel Cell Partnership members have described Hydrogen as the "Blue Ribbon" fuel, which brings the most environmental benefit. Members of our own Clean Fuels Advisory Group stated the following at their January meeting: ***Dr. Vernon Roan, University of Florida, "...fuel cells are the "bright star" for future possibilities. Infrastructure activities need to be addressed, as the auto manufacturers have already committed to fuel cells and fuel cell vehicles will be on the road soon. If fuel cells are to receive public acceptance, it is the infrastructure that will determine this. There is a need to facilitate public acceptance, therefore, and more effort needs to be put into preparing for the arrival of fuel cell vehicles so that they are accepted by the public and are, therefore, a success." Brian Runkel, California Environmental Business Council, echoed the importance of a fuel cell infrastructure. He suggested focusing on where the program can have the greatest impact within the next five years, indicating the AQMD could play a major role in pushing fuel cell technology.***

I regret that I was not able to meet with each of you individually, as I will be in Sacramento at the California Fuel Cell Partnership Steering Committee meeting from Monday through Wednesday. If you have any questions, you can reach me at (714) 777-7729, or you can call my Board Assistant, Rhonda Reyes at (626) 712-3861 and she will forward the message to me. All I have left to say is, let's not miss this "golden opportunity."

Sincerely,

Cynthia Verdugo-Peralta

Cynthia Verdugo-Peralta
Governor's Appointee

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July 15, 2001

The Honorable Jon Mikels
Supervisor, County of San Bernardino
8303 Haven Ave.
Rancho Cucamonga, CA 91730

Dear Jon :

I am writing to seek your support for an amendment to agenda item #38, which I will be putting forth at the upcoming Governing Board meeting on Friday, July 20, 2001. As you may know, agenda item #38 is to "Award Multiple Contracts for Natural Gas Refueling Station Infrastructure." I am asking that we utilize $1.5 Milllion from TAO funds and draw down from these funds until the funds are exhausted, to make as many of the CNG refueling stations compatible with Hydrogen.

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- **Promote ongoing FCV technology development**
  With an infrastructure in place it will encourage and speed up the technology development of CNG/H2 Blend and Fuel Cell powered vehicles.
- ***Provide Infrastructure for three fuels instead of one***
  We could get three fuels in our basin for very near the price of one. By ensuring that these CNG Refueling stations are built to be compatible for Hydrogen we can have CNG, CNG/H2 (Hythane, which reduces the emissions in CNG), and pure Hydrogen.
- **Minimize Stranded Investment of a CNG Refueling Station**
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County of Riverside

Cynthia Verdugo-Peralta
Governor's Appointee

July 15, 2001

The Honorable Roy Wilson
Supervisor, County of Riverside
Larson Justice Center
Indio, CA 92201

Dear Roy:

I am writing to seek your support for an amendment to agenda item #38, which I will be putting forth at the upcoming Governing Board meeting on Friday, July 20, 2001. As you may know, agenda item #38 is to "Award Multiple Contracts for Natural Gas Refueling Station Infrastructure." I am asking that we utilize $1.5 Milllion from TAO funds and draw down from these funds until the funds are exhausted, to make as many of the CNG refueling stations compatible with Hydrogen.

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...hia Verdugo-Peralta
...nor's Appointee

July 15, 2001

The Honorable Hal Bernson
Councilmember, City of Los Angeles
Los Angeles City Hall-East
Los Angeles, CA 90012-4878

Dear Hal:

I am writing to seek your support for an amendment to agenda item #38, which I will be putting forth at the upcoming Governing Board meeting on Friday, July 20, 2001. As you may know, agenda item #38 is to "Award Multiple Contracts for Natural Gas Refueling Station Infrastructure." I am asking that we utilize $1.5 Milllion from TAO funds and draw down from these funds until the funds are exhausted, to make as many of the CNG refueling stations compatible with Hydrogen.

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Cynthia Verdugo-Peralta
Governor's Appointee

July 15, 2001

Jim Silva
Supervisor, County of Orange
10 Civic Center Plaza - 5th Floor
Santa Ana, CA 92701-4061

Dear Jim:

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Supervisor, Fourth District
County of Riverside

Jane Carney Verdugo-Peralta
Governor's Appointee

July 15, 2001

The Honorable Mike Antonovich
Supervisor, County of L.A.
869 Hall of Administration
Los Angeles, CA 90012

Dear Mike :

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South Coast
Air Quality Management District
21865 E. Copley Drive, Diamond Bar, CA 91765-4182
(909) 396-2000 • http://www.aqmd.gov

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S. Roy Wilson, Ed.D.
Supervisor, Fourth District
County of Riverside

Cynthia Verdugo-Peralta
Governor's Appointee

July 15, 2001

The Honorable Bill Burke
Chairman, SCAQMD Governing Board
11110 W. Ohio Ave., Suite 100
Los Angeles, CA 90025

Dear Bill:

I am writing to seek your support for an amendment to agenda item #38, which I will be putting forth at the upcoming Governing Board meeting on Friday, July 20, 2001. As you may know, agenda item #38 is to "Award Multiple Contracts for Natural Gas Refueling Station Infrastructure." I am asking that we utilize $1.5 Milllion from TAO funds and draw down from these funds until the funds are exhausted, to make as many of the CNG refueling stations compatible with Hydrogen.

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- **Attract Fuel Cell Vehicles (FCV) to South Coast Basin**
  By building a CNG/Hydrogen compatible refueling station infrastructure we will attract the vehicle manufacturers to our Basin sooner. It will also take away the "chicken and egg" argument regarding which needs to come first, the vehicles, or the infrastructure.
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July 15, 2001

The Honorable Bea LaPisto-Kirtley
Councilmember, City of Bradbury
600 Winston Ave.
Bradbury , CA 91010

Dear Bea :

I am writing to seek your support for an amendment to agenda item #38, which I will be putting forth at the upcoming Governing Board meeting on Friday, July 20, 2001. As you may know, agenda item #38 is to "Award Multiple Contracts for Natural Gas Refueling Station Infrastructure." I am asking that we utilize $1.5 Milllion from TAO funds and draw down from these funds until the funds are exhausted, to make as many of the CNG refueling stations compatible with Hydrogen.

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Cynthia Verdugo-Peralta
Governor's Appointee

July 15, 2001

The Honorable Leonard Paulitz
Mayor Pro-Tem, City of Montclair
5111 Benito St.
Montclair, CA 91763

Dear Leonard :

I am writing to seek your support for an amendment to agenda item #38, which I will be putting forth at the upcoming Governing Board meeting on Friday, July 20, 2001. As you may know, agenda item #38 is to "Award Multiple Contracts for Natural Gas Refueling Station Infrastructure." I am asking that we utilize $1.5 Milllion from TAO funds and draw down from these funds until the funds are exhausted, to make as many of the CNG refueling stations compatible with Hydrogen.

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Cynthia Verdugo-Peralta
Governor's Appointee

July 15, 2001

The Honorable Ron Loveridge
Mayor, City of Riverside
3900 Main St.
Riverside, CA 92501

Dear Ron:

I am writing to seek your support for an amendment to agenda item #38, which I will be putting forth at the upcoming Governing Board meeting on Friday, July 20, 2001. As you may know, agenda item #38 is to "Award Multiple Contracts for Natural Gas Refueling Station Infrastructure." I am asking that we utilize $1.5 Million from TAO funds and draw down from these funds until the funds are exhausted, to make as many of the CNG refueling stations compatible with Hydrogen.

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Governor's Appointee

July 15, 2001

The Honorable Jane Carney
, Carney & Delany, LLP
3801 University Ave., #750
Riverside, CA 92506

Dear Jane :

I am writing to seek your support for an amendment to agenda item #38, which I will be putting forth at the upcoming Governing Board meeting on Friday, July 20, 2001. As you may know, agenda item #38 is to "Award Multiple Contracts for Natural Gas Refueling Station Infrastructure." I am asking that we utilize $1.5 Milllion from TAO funds and draw down from these funds until the funds are exhausted, to make as many of the CNG refueling stations compatible with Hydrogen.

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COMP-AIR

GAS REFUELLING PROJECT – GENERAL SPECIFICATION

GAZPACK 70 COMPRESSION MODULE

GENERAL: MACHINE SELECTION & PERFORMANCE EXPECTATION

Machine type	-	"W" configuration, Oil Lubricated, Reciprocating Piston
Cooling	-	Air-cooled via multi-stage air blast heat exchanger
Max intake temperature (norm)	-45°C	
Ambient temperature (norm)	-	-10 to 45°C
Drive method	-	Vee belt drive.
Available gas pressure	-	**90 psig (assumed in both CH4 & H2 configurations).**
Module working pressure	-	3600 psig (based on natural gas operation
Module working pressure	-	6000 psig (if configured for H2 operation)
Selected speed	-	1395 rpm est.

Configuration for 3600 psig	-	First stage of compression	-	Qty 1 x 115 mmØ double acting
		Second stage of compression	-	Qty 1 x 80 mmØ single acting
		Third stage of compression	-	Qty 2 x 50 mmØ single acting
		Fourth stage of compression	-	Qty 2 x 28 mmØ single acting
		Cylinder stroke	-	80 mm
Configuration for 6000 psig	-	First stage of compression	-	Qty 1 x 115 mmØ double acting
		Second stage of compression	-	Qty 1 x 80 mmØ single acting
		Third stage of compression	-	Qty 2 x 40 mmØ single acting
		Fourth stage of compression	-	Qty 2 x 22 mmØ single acting
		Cylinder stroke	-	80 mm

A) Estimated capacity (configured for 3600 psig on CNG)	-	420 Scfm
A1) Estimated shaft power at (A)	-	191 hp
B) Estimated capacity (configured for 6000 psig on H2)	-	343 Scfm
B1) Estimated shaft power at (B)	-	169 hp
C) Estimated capacity (6000 psig build used on 3600 psig CNG)	-	370 Scfm
C1) Estimated shaft power at (C)	-	173 hp
Motor requirement to cater for all scenarios	-	200 hp (minimum)

GAS REFUELLING PROJECT – GENERAL SPECIFICATION

COMMERCIAL SECTION

Pricing Table (all pricing is shown in US$)

	Qty	Description	Unit Price	Total Price per station
See ###	1	GazPack 70 Compressor Module (configured 3600 psig)	$ 211505.00	$211505.00
See ***		Motor and drive arrangement (Class 1, Div 1, Group D)	Included in item 1	Included in item 1
		Gas inlet train	Included in item 1	Included in item 1
		Gas recovery system	Included in item 1	Included in item 1
		Gas delivery system	Included in item 1	Included in item 1
		Systems enclosure	Included in item 1	Included in item 1
		Enclosure gas detection	Included in item 1	Included in item 1
		Enclosure lighting	Included in item 1	Included in item 1
		Compressor sump heater	Included in item 1	Included in item 1
See ###		Packaged electrical work (UL Switches/wiring)	Included in item 1	Included in item 1
		Starter control panel (For Safe area)	Included in item 1	Included in item 1
		Testing & Documentation	$ 2,800.00	$ 2,800.00
		TOTAL COST (UK Sterling)		**$ 214,305.00**
Note ***	1	Price ***reduction*** for NON UL electric's (i.e. standard CompAir intrinsically safe equipment + standard wiring	- $ 29,088.00	- $ 29,088.00
Note ###	1	Price ***addition*** if powered electric's/control supplied to Class 1, Div 1, Group B (hydrogen). Uprated (6000 psig) cylinder configuration, cooler & piping system.	+ $15204.00	+ $ 15,204.00

Please Note: At this time, all prices are indicative only and based on our interpretation of the of the system requirements at present. This quotation cannot be assumed to be compliant, in part or in whole with any project specification unless confirmed to that effect in writing. We will be happy to review alternatives of equipment if required in order to offer a total system solution.

Pricing shown at present is NETT, and are for equipment supplied unpacked and Ex Works, UK. Additional costs for equipment supplied FOB UK Port is envisaged to be approximately $ 2,800.00

Terms & Conditions

Subject to contract agreement, this quotation is initially made in accordance with standard conditions of sale. Validity for this initial proposal is 60 days from the date of this quotation.

Despatch Period

The despatch period for the first unit is likely to be approximately 20 - 24 working weeks from our acknowledgement of your official order, satisfactory letter of credit detail and clarification of all necessary technical and commercial details which allows us to commence with uninterrupted manufacture etc, etc.

GreenField

GreenField Compression,Inc.
909 North Bowser Road
Richardson, TX 75081
972-234-3226

Date July 26, 2001

To VPC Energy

Telephone
Telefax 714-693-7863

From Shakeel Ahmed
Telephone 972-234-3226 ext.117
Telefax 972-234-4829
E-Mail shakeel.ahmed@gfcomp.com

Copy

Pages (including this one)-1

URGENT

Re Hydrogen/Natural Gas Compressor

This is to inform you that GreenField Compression can offre a single compressor for the compression of Hydrogen and Natural Gas.

GreenField Compression Inc. Division of Sulzer Burckhardt, designs, manufactures and packages compressors for various gases and applications. Sulzer has been in the compressor business for over 150 years. Sulzer has built over 23,000 high pressure compressors and over 1,300 NGV fueling stations.

Compressors for Hydrogen service is one of Sulzer specialties. A compressor built for Hydrogen service can also be used for the compression of Natural Gas.

When gas service is changed from Hydrogen to Natural Gas or vice versa, the system has to be purged of the old gas. This can be accomplished manually initially and after the control have been developed, will be done automatically.

The budget price of our Model C4T compressor for Natural Gas with 40 psig suction pressure and 4500 psig discharge pressure with a flow rate of 350 SCFM is $160,000. The same compressor for Hydrogen service has a budget price of $176,000.

Please call if you have any questions.

Sincerely,

Shakeel Ahmed
Applications Engineer

Air Products and Chemicals, Inc.
7201 Hamilton Boulevard
Allentown, PA 18195-1501
Telephone (610) 481-4911

30 July 2001

Ms. Cynthia Peralta
Board Member
South Coast Air Quality Management District
California

Dear Cynthia:

I believe that the budget value of the Air Products/DOE project in Las Vegas, NV is being misinterpreted as somehow representing the cost to build a hydrogen fuel station. I would like to correct this misconception and explain what this budget covers.

The program budget of $10.8 million represents a 6 year project to develop, design, construct, and operate a natural gas-based on-site H_2 generation system, a 50 kW hydrogen PEM fuel cell, a fuel station that includes blending of natural gas and hydrogen, and dispense three fuels CNG, NG/H_2 blende, and pure H_2. The budget also covers operating costs for a 3-year period. While the actual cost breakdown of the budget is proprietary, please be advised that the bulk of the costs go towards development of the H_2 generator, the development and construction of a 50 kW H_2 fuel cell power plant, and development of blending systems for the CNG and H_2. It is totally inaccurate to equate these costs to the cost of a hydrogen fuel station.

The following are some approximate indicative costs for H_2 fuel stations:

1. A H_2 fuel station with a nominal capacity of 2,000 - 3,000 SCFH (this will fill 2-3 buses or service about 150-200 cars) will cost about $0.5 million.

2. A larger fleet-type liquid H_2 based fuel station to fill 50 buses per day -- consuming 1,000,000 SCFD H_2, would cost about $1.0 million.

I hope this explains the costs for H_2 fuel stations. If you have any questions on this please feel free to call me at 610-481-8336.

Sincerely,

Venki Raman

Venki Raman

VR:dj

PICKENS FUEL CORP.

3030 Old Ranch Parkway
Suite 280
Seal Beach, California 90740
562/493.2804 fax: 562/493.4532
888/PFC.NGVS

Andrew J. Littlefair
President

Dr. Barry Wallerstein
Executive Officer
South Coast Air Quality Management District
21865 East Copley Drive
Diamond Bar, CA 91765-4182

Dear Dr. Wallerstein,

It is my understanding that discussions are taking place among the Governing Board members to allocate SCAQMD TAO funds to make Compressed Natural Gas (CNG) stations hydrogen compatible. I am told that this is to begin the process of developing future infrastructure for Fuel Cell Vehicles (FCVs). Let me first state that PFCe-Fuels considers FCVs the next generation of clean fuel vehicles that will eventually replace the vehicles we drive today, including Natural Gas Vehicles (NGVs). Natural gas will play an important part of future clean air vehicle development and use, and as such, it can be one of the primary sources of the hydrogen needed by FCVs. PFCe-Fuels looks at NGVs as a bridge to FCVs, one that will ensure that our industry will thrive for decades to come.

While I believe that a future capital investment that would make CNG stations hydrogen compatible will be needed, I believe that a number of first steps must be taken before monies are allocated for equipment and for these to be properly installed. A number of PFCe-Fuels staff members have a background in the industrial gas industry, having worked for BOC Gases and installed hydrogen systems. They agree that in the future, it makes sense for hydrogen compatible CNG facilities; however, they do not agree that now is the time and have a number of questions which are as follows:

1) **To date FCVs are more of an experimental vehicle than fleet or consumer vehicles and are not made in mass quantities. As such, there are no standards for these vehicles to design a station around. For instance, we do not know what the storage pressure, storage location, or fill procedure that will be necessary. How can a CNG station be made hydrogen compatible without this information?**

2) **We are not aware of any NFPA, UFC, or OSHA codes in existence that covers the unattended dispensing of hydrogen as a vehicle fuel. How can a station be designed to be hydrogen compatible without applicable codes being discussed or in place?**

3) **Natural gas compressors and hydrogen compressors are not the same due to the molecular size of the gases being compressed. There is a possibility that future FCVs will store CNG on board and reformulate it to**

hydrogen for use by the fuel cell. It is assumed that the goal would be to make current CNG facilities capable of fueling FCVs. As FCV technology is still early in the development stages as a commercial vehicle with no industry standards, how can a station be designed to fuel vehicles when the type of fuel has not been specified?

4) **Many stationary fuel cells today operate on hydrogen produced from natural gas that has passed through a reformer. If this becomes the prevailing technology for FCVs, i.e. reformers on board, then the CNG stations in operation today and in the future will be capable of fueling FCVs. Why then is there a need to produce hydrogen at a fueling site and store it?**

As the South Coast region begins to convert from vehicles operated on petroleum fuels to those operated on alternative fuels, investment in infrastructure must take precedence in order to ensure these environmentally sound vehicles can operate as efficiently as possible. Today, vehicles operated on alternative fuels such as Compressed Natural Gas (CNG) offer great promise in improving our regional air quality and meeting the needs of the user. In the decades to come, CNG vehicles will gradually give way to cleaner Fuel Cell vehicles operated on hydrogen produced from water or natural gas. Fuel Cell vehicles offer the potential to virtually eliminate the harmful tailpipe emissions that result from today's automobiles. However, at best, Fuel Cell vehicles, operating on hydrogen, are at least 10 to 15 years away from being a practical alternative to fleet operators and consumers.

The current investment in CNG infrastructure will provide a vital bridge to the next generation of cleaner vehicles. This investment will last well into our foreseeable future, as Compressed Natural Gas can be a primary source of hydrogen for Fuel Cell vehicles. This means that today's investment in CNG is actually an investment in next generation vehicles. To date, only one public access station that dispenses hydrogen exists in California. This station, operated by SunLine Transit Agency, has shown great promise, however, its' reliability and capacity are limited. Before investing large amounts of resources in hydrogen facilities, it would be prudent of the SCAQMD to formulate a "blue print" for Fuel Cell vehicle infrastructure that can result from today's investment in CNG infrastructure. It is therefore proposed that the SCAQMD designate $200,000 of TAO monies towards an engineering and planning study to be conducted by SunLine Transit Agency and the College of the Desert. The goal of this study is to develop the recommended approach and practices to successfully develop future Fuel Cell infrastructure. This study will focus not only on new Fuel Cell infrastructure but also on the conversion of existing CNG infrastructure to service the next generation of clean air vehicles.

Dr. Wallerstein, I believe that providing funding that helps to guide the industry in one direction and develops a best practices approach would be better use of the TAO monies at this time, especially in light of the implementation of the 1190 rules. If you have any questions regarding this matter, please call me at (562) 493-2804. Thank you.

Sincerely,

Andrew J. Littlefair
President
PFCe-Fuels

Attachment D

Codes and Regulations Review

D-1 Best Industiral Practices Involoving CNG, CHG and CNG/CHG Blends as Automotive Fuels – Center For Hydrogen Safety

D-2 California Codes and Regulations for Automotive Hydrogen – Mr. Gary Pope

D-3 Codes, Standards and Advisories Applicable to Natural Gas Vehicles – Mr. Gary Pope

BEST INDUSTRIAL PRACTICES

INVOLVING

CNG, CHG AND CNG/CHG BLENDS

AS AUTOMOTIVE FUELS

A TOPICAL DISCUSSION

By:

66 Cedar Street, Suite 301
Newington, CT 06111-2646

Authored By:
Addison Bain, Ph.D.
Senior Principal Engineer

August 13, 2001

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PREFACE (About the Author)

The Author uses his background experience base as the principal source of information resulting from his association with NASA's hydrogen, systems design, operations and maintenance activities since 1961. During the early years of the Apollo Program one had to develop hydrogen specific equipment specifications and procedures without the benefit of published standards. As one example, the Author with the assistance of the US Steel Company and the Interstate Commerce Commission developed the 3AAX specification, allowing the construction and use of hydrogen over the road tube trailers to transport hydrogen above the conventional, and limiting pressure ratings. Special permits were necessary to transport liquid hydrogen, but with industry, DOT and NASA efforts specifications were eventually developed to overcome the need for the application and long approval process for permitting.

As a team member in the development of the first edition of the NASA Hydrogen Safety Handbook, as a founding member of the International Hydrogen Energy Association, National Hydrogen Association, ISO/TC 197 Hydrogen Technologies, and as a team member in the development of the Sourcebook for Hydrogen Applications, several ISO standards on hydrogen, preparation of the Canadian Hydrogen Plan, the WE-NET safety group, the Author extracts from this database.

The Author was project manager in implementing the 35-mile, 600 PSIG, natural gas mainline to and throughout the Kennedy Space Center (KSC) and the Cape Canaveral Air Force Station, with a distribution network serving over 30 use points. He was responsible for designing and managing the largest federal compressed natural gas (CNG) fueling station and implemented other federal and public CNG stations.

The Author was the NASA project manager overseeing the CNG/compressed hydrogen gas (CHG) automotive research project performed at the Florida Solar Energy Center (FSEC). He continues to participate in the efforts of alternative fuels implementation for the DOE Space Coast Clean Cities program as chairman and serves as the USA representative for the Economic Commission for Europe hydrogen ad hoc group. He is the chairman of the FSEC Policy Advisory Board, past member of the DOE Hydrogen Technical Advisory Panel, and a team member of the Hydrogen Plan for Florida project. He serves as a team member of the BMW liquid hydrogen automotive fleet project.

PURPOSE

In view of recent issues regarding codes and standards primarily for hydrogen automotive fueling stations, the Author was called upon to provide his views and opinions. The use of natural gas and the blends with hydrogen are a part of the issue. The approach the author takes is to review a variety of issues in a topical discussion manner to share his associated experiences and observations to illustrate the complexity of the development and the publishing of appropriate documentation and more importantly their application and limits.

INTRODUCTION

For decades CNG has been used extensively as an automotive fuel in many countries. Only in the past decade has CNG been recognized as a significant alternative vehicle fuel in the U.S. Hydrogen as a potential automotive fuel has been recognized for some time. The various forms of hydrogen, namely liquid and gaseous, is the subject of many current automotive fuel projects. This paper will limit the hydrogen discussion primarily to compressed hydrogen gas.

The long term concern for a viable natural gas supply, the increased attention to a cleaner exhaust from the internal combustion engine has lead many researchers to consider blending the two gases CNG and CHG in various ratios to meet certain objectives.

SCOPE and PROBLEM STATEMENT

This paper, oriented primarily to safety related topics, will examine the use of CNG, CHG and the blending of the two products for use in automotive applications.

Department of Transportation (DOT) regulations, National Fire Protection Association (NFPA) guidelines, Compressed Gas Association (CGA) standards and specifications and a variety of related documents constitute the principal source of accepted practices in the use of natural gas and hydrogen. In the case of CNG, there are specific standards in place. Likewise there are specific standards that can be applied to CHG applications, with minimal alteration. In the case of CNG and CHG blends, standards are yet to be published. The DOT does recognize the mixture of natural gas and hydrogen for transport.

There are efforts underway in the U.S. by the National Hydrogen Association (NHA) to host sessions in the preparation of codes and standards for hydrogen, and the natural gas-hydrogen blend for automotive applications. A similar effort is also underway under the auspices of the ISO/TC 197 Hydrogen Technologies working groups (with associated ISO liaisons), the International Code Council (ICC) ad hoc for hydrogen (AHC) and the European Integrated Hydrogen Project ad hoc group.

The problem being dealt with is that there currently are vehicles "on the road" around the world employing these fuels using a variety of attendant fuel dispensers and "stations". Fuels are being implemented without the companion codes and standards, a concern obviously more to the non-technical community, and rightly so. However, history tells us that technical evolution and introduction of new hardware applications go hand in hand with the development of the "required" documentation.

Some standards development is incident driven calling on the related experts to address the specific issue. The recent CNG incidents, for example, caused the need to revisit longstanding "established and approved" codes and standards.

CODES, STANDARDS AND BEST INDUSTRIAL PRACTICES

History of Hydrogen Energy

Shortly after the International Association for Hydrogen Energy (IAHE) was established in 1974 it was recognized that 1) it would take some time before appropriate implementing elements would see the need for hydrogen codes and standards, as the "hydrogen economy" was a vision way into the future and 2) when the industry did finally see the need their development would be behind the power curve for new hydrogen technologies.

It was not until June 1990 that the first effort to instill a movement for hydrogen standardization and guideline development was formalized. This resulted in the formation of ISO/TC 197 Hydrogen Energy Technologies. The initial 35 delegates from a number of nations worked to scope out the task at hand and identified some 30 other ISO organizations that would constitute potential liaisons with TC 197.

At about the same time the National Hydrogen Association (NHA) was formed in the U.S. The organization struggled for years building its membership, recognition and government financial support. Today the NHA is the foremost organization in the world to effectively coordinate, track and influence national and international endeavors in codes and standards development.

Today's Situation

The NHA is supporting the WG 3 Refueling Station and WG 5 Safe Self-Service Refueling activity. The NHA is coordinating with SAE relative to vehicle/refueling station interface standards. In 1997 the NHA using NFPA 52 (CNG standard for fuel systems) as a guideline provided a marked up version for CHG and CNG/CNG for the NFPA. No action has resulted as of this date.

ISO/TC 197 continues to work CNG and CNG/CHG related standards for fueling stations and filling connections.

The ICC established an ad hoc group to develop a hydrogen standard covering service stations and other topics. Blends are not considered.

The Working Party on Pollution and Energy (GRPE) of the World Forum for Harmonization of Vehicle Regulation (WP29) of the United Nations Economic Commission for Europe (ECE) has instituted the European Integrated Hydrogen Project (EIHP). During Phase 1 draft regulations were developed addressing vehicle onboard storage systems for liquid and gaseous hydrogen. During Phase 2 (year 2001) two working groups will be addressing Refueling Stations (WP2) and Refueling Interface (WP3) for hydrogen systems.

Other Activities

Standards work is going on for related fields such as fuel cells, metal hydrides and portable generators using hydrogen, thus complicating the coordination of interface requirements. Hydrogen fueled appliances such as water heaters, stoves, lighting fixtures and such are being offered for the public market.

The Blind Leading the Blind

In all due respects for the National Institute for Science and Technology (NIST) but adding insult to injury is their report of last fall, "Refueling Automobiles with Hydrogen". It is good analysis on the topic of electrostatic electricity and its implication for refueling automobiles with gaseous hydrogen. However, the parties preparing the report were way off base with the real world in the actual process of filling a vehicle. They propose a design criteria that is absurd. This serves as an example of how to mislead the "newcomer" hydrogen systems designer.

Best Industrial Practices

Prudent engineering design and sound judgment in operational and maintenance activities go with out saying. Codes and standards have their place. They however, have to be supplemented with related handbooks, vendor data sheets, industry standard procedure instructions, studies and reports. The draftsman and design engineer need a library of documentation to achieve their goals. No standards exist for the preparation of appropriate testing, checkout, operating and maintenance procedures and instructions.

The author has experienced and observed more mishaps in the field because of procedural problems than with system designs or "code compliance". Thus this paper is titled, "Best Industrial Practices", because a "Codes and Standards" title would simply represent a subset to the overall issue at hand.

SYSTEMS ENGINEERING

Materials Compatibility

Perhaps one of the most important design aspects for hydrogen and hydrogen rich mixtures is the topic of materials compatibility.

Metallic and non-metallic materials in use today for natural gas and hydrogen systems are much the same. The most concern is in the case of the metals used. Cast iron is prohibited for CNG as well as CHG. Seamless copper, aluminum alloy and selected steel tubing/piping are permitted. The fuel gas code prohibits the use of aluminum alloy pipe for exterior locations or underground applications. This is due to concerns with external corrosion.

It is widely recognized that compressed hydrogen and hydrogen bearing gases can have embrittling effect on metallic materials especially steels. The foremost concern is the ultimate tensile strength of the steel assuming chemical composition is within prescribed limits. Of the three types of hydrogen embrittlement, the hydrogen environment (H-E) mechanism is the most important for pipelines/vessels at ambient temperatures. The H-E mechanism is accelerated in the case of very high tensile steels.

The DOT does not permit the use of the cylinder specification designated as 3T (vs. 3AX, 3AAX) for hydrogen because of the high tensile parameter. Limits of water/hydrogen sulfide are also placed on methane for use in compressed gas cylinders, due to possible internal stress corrosion.

The fuel gas code lists coke oven gas as one of the fuel gases falling under the code. The coke oven gas primary constituents are hydrogen at 53.2% and methane at 26.7%. No restrictions or separate provisions are identified in the code pertaining to this mixture even in view of the "high" hydrogen content.

Studies concerning the use of the natural gas transmission network for hydrogen service raised concern over embrittlement. The concern is certainly valid for pipe installed before say the 1940's. Improvements in steel making with low sulfur and chrome-moly addition should make the pipe acceptable for hydrogen service. The author was in charge of the propellants and gases function at KSC for a number of years. Standard carbon steel cylinders have been in hydrogen service at 2,000 psi for decades. However a rule was implemented to not place any cylinder in hydrogen service if it was manufactured prior to 1940 as a "safe guard".

Various remedies for embrittlement have been proposed. One is to add small percentages of additives, such as oxygen, sulfur dioxide, ethane, etc. These "additives" constitute typical contaminates in natural gas, thus it seems that a percentage of natural gas would mitigate the possible embrittlement. The author in 1961 was part of a team investigating this problem. It was found that a trace amount of oxygen did mitigate the embrittlement. At the time materials were being selected for 10,000 psi hydrogen service. In practice, very high tensile steel should not be used in either methane or hydrogen service.

A high-pressure vessel (6,000 psi) in hydrogen service ruptured at a NASA facility in the beginning of the Apollo program. It was fabricated using a new steel designated as T-1, supposedly suitable for hydrogen service. Hydrogen embrittlement of the primary metal was first blamed and all such vessels were taken out of service. It was later found that the problem was in the weld zone, due to carbide precipitation weaking the vessel wall.

In 1964 the author experienced a pressure gage rupture during pumping operations. The 400-series steel bourdon tube had failed. Laboratory analysis revealed that stress

corrosion induced by the sea-side atmosphere was the problem. Never the less only gages with monel or beryllium-copper bourdon tubes were used after the incident. Also for gages used in high-pressure, "blow-out" backs with the safety front design were implemented. 300-series stainless steel can be used if precision gage accuracy is not an issue.

This discussion on materials compatibility serves to demonstrate the need for experience in the field to find its way into the designer's hands. Clearly, preconceived standards would not have identified the problems. Fortunately the information is getting published in such references as the *"Sourcebook"*.

Systems Design

The intent of this paper is to bring out the complications with the existing standards, those under development, and the gaps between them and reality and not provide any sort of design guideline. The designer is faced with many questions during the designing process in which there is a judgment call. The following examples illustrate the point.

What should the spacing be for pipeline supports.
Are filters required and where.
What type of valve should be used, needle, ball, gate.
Are valves, gages and controls located convenient for the operator.
Is the mechanical/electrical system compatible with the attendant structural and architectural design.
Is the system fail safe.

Level of detail is another consideration. Can the control panel be fabricated from a one line schematic? The author has had control panels made from basic schematics that the fabricator, without specific direction, took into consideration the aspects of human engineering (operations/maintenance/calibration/cleaning/testing), conditions of the local environment and ease of installation. On the other hand the author has prepared very detailed control panel drawings for rocket launch sites. This type of design had to allow for rocket exhaust overpressure, acoustical vibration and related special conditions.

OPERATIONAL CONSIDERATIONS

Even with the best design packages the engineer must work closely with the field. Checking to see that the techs did not reverse the installation of a check valve or use adapters to make the "job easier". A certain amount of quality control is always warranted. The author encountered a situation where valves were installed that were of the correct material. But what got by the receiving inspection was that the supplier provided valve connectors of material not compatible with the hydrogen system.

The issue of system cleanliness and contamination control is not very well addressed in the current or even proposed standards. This is a serious oversight.

A DISCUSSION OF CNG/CHG BLENDS

General

In order to assess the safety aspects of the CNG/CHG blends it is necessary to examine the individual gas properties and how they compare. The issues to address are the classical concerns for flammable gases, namely; leakage, detection, flammability and ignition sources. The term methane is used interchangeably with natural gas.

Leakage

Hydrogen has a diffusion coefficient of almost four times that of methane (natural gas), thus one may conclude it would be significantly more prone to leak from a small opening. Due to the excellent work by Dr. Mike Swain (University of Miami), it has been shown that the flow rate would be on the order of one-half of the four to one rate expected. Thus the actual flow rate for hydrogen is about twice that of methane. This of course varies with the system pressure (laminar vs. turbulent conditions).

As the percentage of hydrogen in the blend increases naturally the volume of hydrogen relative to the amount of methane released increases proportionally under a leakage situation. However another important factor comes in to play. The methane has a higher energy density, about three and a half times that of hydrogen. However under identical leak geometries it has been shown that the comparative energy release is much less, on the order of 1.2 to 2.7 times that of hydrogen. Thus there is a compensation factor with these two properties. In other words, the introduction of hydrogen in a natural gas blend does not significantly increase the overall "danger" of a leak as one might at first suspect.

Another property comparison of importance is the gas sonic velocity encountered for larger leaks. Sonic velocity for hydrogen being three times that of methane would indicate any stored hydrogen would escape proportionally faster. However, hydrogen is almost eight times more buoyant and will disperse almost four times more rapidly than methane. Methane again has the higher total energy on a volume comparison basis. Thus the introduction of hydrogen in a natural gas blend should not increase the energy release risk at the lower end of the hydrogen ratio spectrum.

Considering the above factors the leakage concern should not be dramatically different at any point within the CNG/CHG ratio spectrum (less than 50% of hydrogen, an arbitrary value by the author). The contributing safety asset of the one product appears to reasonably counter the safety liability of the other product in this context.

Detection

One method of gas detection is the practice of odorization. Gas odorization received attention in Europe about 1880 in connection with the use of water gas that is toxic, in view of its high percentage of carbon monoxide. In the U.S. it was not until the 1930's that odorization started to become the "warning agent" practice for fuel gases. Using an odorant implies that everyone can sense it which is impossible. A certain percentage of the population cannot detect the level of odorant used today because of either the lack of sense of smell or other factors such as age, colds, allergies and certain diseases. In practice the problem with odorants is the fact it only indicates that maybe a problem exists. It does not quantify or readily locate the leak. The propensity of the ethyl mercaptan to absorb on surfaces, and the extremely low concentration for "normal" olfactory detection leads to further problems.

It is interesting to note that the Code of Federal Regulations (CFR) qualifies the use of an odorant in a number of locations. For example paragraph 173.301 states for LP gas that odorization is not required if harmful in the use or further processing, or will serve no useful purpose as a warning agent. Paragraph 192.625 excludes the odorant for natural gas if it makes the end product unfit for the purpose for which it was intended. Also if the combustible gas is hydrogen intended for use as a feedstock in a manufacturing process an odorant is not required.

This is not to say odorants are a bad thing. Odorization may still have its place in certain end use applications. For pure hydrogen there has been much research and development for hydrogen specific detectors. In the past there were many shortcomings with the common catalytically combustion based detectors. Today however, much progress has been made using a unique palladium nickel alloy as the heart of the sensor. These new designs can offer accurate partial pressure measurements from 10 ppm to 100% hydrogen. Thus a sensor system can be designed to offer a quantifiable "situational awareness" of overall system status.

In the case of CNG/CHG blends there should be the characteristic contribution of the odorized natural gas, for "detection", assuming the natural gas is from a distribution utility. The assurance of detection in closed environments and the need for emergency action may require assessment for the need of specific sensors. This is possibly true for a fueling station and the attendant fuel storage areas.

Implementation of any of the detection methods is a judgment call. The author would recommend that for hydrogen concentrations over 50% that the designer consider the employment of a hydrogen specific sensor system.

Flammability / Ignition Energy

There is a significant difference in the flammability limits (range) for hydrogen vs. natural gas. The lower limit for each is about the same. For hydrogen the upper limit is five times that of natural gas, which is probably one of the two properties (the other minimum ignition energy), which leads to it being characterized as a "dangerous fuel".

In practice the lower flammability limit is of more concern. Since the fuel concentration in air builds up from zero in most incidents, the lean limit is the most important to consider. In practice it has been found that the textbook values of "4 to 5" percent are not realistic (too low) but the designer and operator should use conservative values.

Typically the ignition energy of hydrogen is quoted as being a factor of ten below that for natural gas or even gasoline. The problem is the "quoter" fails to qualify that the low ignition energy is at a stoichiometric mix of about 25 to 30% hydrogen in air. Actually the ignition energy at the lean limit, the area of concern, is the same for hydrogen as it is for methane. At the lean limit the ignition energy is less than 10 mj. Most all ignition sources, including the static electricity from the human body, exceeds this value. Thus the "danger" is similar for most automotive fuels.

DOT Labeling / Containerization

The Department of Transportation (DOT) regulates the transport of CNG and CHG and specifies requirements for such items as labeling and containerization.

DOT regulations (49CFR part 178) call out specification 3AX and 3AAX for containers used for either hydrogen or methane. There is no restriction on using any blends.

DOT regulations (49CFR part 173) addresses labeling for hydrogen, methane and blends of both gases. In each case, the typical red flammable gas label applies. For CNG the orange identification label is UN1971. For CHG the label number is UN1049. For a mixture the label number is UN2034. There are no restrictions or separation of requirements for differing ratios of CNG/CHG. It is noted that the labeling pertains to bulk shipments of the product, but this is indicative of the fact DOT recognizes each of the compressed gases and their blends.

Codes and Standards

Clearly adequate codes and standards exist for automotive CNG fuel. These include NFPA 54, National Fuel Gas Code; NFPA 52, CNG Vehicular Fuel Systems; and SAE J1616, Fuel Composition for NGV's. There are also NGV specifications for connectors and cylinders.

ISO standards also exist for natural gas (CNG) containers and systems.

Although there are a number of standards and guides for hydrogen (NFPA 50A and B, CGA G-5, etc) none exist yet for automotive applications.

There is a significant movement to address vehicular requirements and fueling facilities for not only hydrogen but blends with natural gas as well. The approach is to use existing CNG documents and develop parallel documents for hydrogen and hydrogen blends. The current approach is to assume "pure" hydrogen in the development of the standards including the hydrogen blends.

The pure hydrogen approach philosophy is for the most part acceptable since the requirements for natural gas are similar. However there are a few areas that require discrimination. One would be the ground to vehicle connector. This seems reasonable for a distinction between pure hydrogen and natural gas including the blends. Another pertains to materials compatibility. For the most part materials commonly used in either a pure natural gas or pure hydrogen environment are typically the same. The concern is similar, in that, for natural gas is the potential for stress corrosion with high water and sulfur content and environmental embrittlement for hydrogen. Thus prudent selection of materials is important for both products. The one discriminator of significance is the electrical code.

NFPA 70, the National Electrical Code, divides Class I hazardous locations (flammable gases or liquids) into four groups, in descending order of "hazard". Hydrogen is in Group B and natural gas and gasoline are in Group D (least (?) dangerous). This leads to electrical equipment within a certain distance (15 feet) of a hydrogen system to be designed with explosion proof enclosures (an expensive additive). The classification was put into place in 1937 (ironically at the time when the Hindenburg fire took place). The reason for a special classification for hydrogen appears to be a function of the flammability limit and the quenching gap.

The quenching gap for hydrogen is 0.06 cm and for methane 0.2 cm. Does this mean a gap of 0.13 for say a 50/50 mixture of hydrogen and natural gas? Also does partial pressures come into play? From experience it seems that hydrogen significantly "contaminated" by natural gas would alter its properties proportionally. One might argue that at lower percentages of hydrogen the Group D classification is certainly appropriate.

The author recommends that the industry challenge the Group B classification for hydrogen and support a program to evaluate "the problem" in a modern scientific manner.

A DISCUSSION OF CNG-CHG SYSTEM CROSS UTILIZATION

The concept of using existing natural gas systems for hydrogen has been the basis of study since 1974. Pipeline materials and system components, particularly compressors are areas of most concern.

There is also the concept of using systems interchangeably. Conceivably the system could be designed for the worst case (hydrogen) initially. Aside from the differences in cost there are some fundamental operational considerations that should be of concern.

Clearly a fail-safe design is mandatory at the "front" end of the system and at the "receiver" location to ensure that cross contamination or misuse of product does not occur.

RELATED ISSUES

Public Perception

Mention hydrogen and most people, including the officials that oversee code compliance, think of the negative aspects instilled by the so-called hydrogen bomb and the Hindenburg disaster. Clearly the hydrogen bomb connection can be refuted easily and perhaps with the research by the author, the implications of the Hindenburg fire can be diminished.

Jurisdictional Authority

Guides such as CGA and NFPA are generally for reference for use by the authority having jurisdiction. Until standards are issued for CNG/CHG these authorities must use the judgment of experts in the field. For example, for hydrogen fueling station design one can take the NFPA 52 and very easily "adapt" it. The success to implementing any new hydrogen system project is the early involvement of local authorities. This should always be mandatory.

Teaming Approach

One cannot over emphasize the need for using a teaming approach from the time of concept to final project implementation. A constant throughout the process is to address the potential hazards, from design to final systems checkout.

CONCLUDING REMARKS

Whenever engineers confront new technical challenges, they must rely upon their best judgment adopting from possibly related codes and standards. This must be flavored with the knowledge available from other sources. New technology innovation would be stifled if the time consuming and evolving consensus-building process were always employed to write a specific standard before implementing a new technology or application.

Since there is no one recipe for design, hydrogen systems and components are of that ilk. People from many disciplines are working worldwide to write, discuss and even

debate the pros and cons of the elements that would forge prudent codes, standards and practices. The fact that significant liability issues exist if the proposed and excepted standards are met but loss of life or property results is a sobering reminder of the importance for adequate due diligence.

The approach that the author used in designing systems, writing specifications and developing operating, maintenance and test procedures for hydrogen systems was to take the existing related (vessels, piping, components) specifications and adapt to hydrogen specific properties. Many times procedures (prior to final approval) had to be validated in the field under actual operating conditions and documentation changes made during the process. The designer, engineer, quality control and safety representatives were present.

Today there is a mountain of information that deals with hydrogen. Most in draft form but it represents the latest input from experts from around the world. There is simply no reason not to use this "database" for the interim in developing the necessary designs. Employing prudent engineering is the key to this process and involvement with experts especially the product suppliers is important.

If hydrogen technology progress is to be made then all parties involved must subscribe to this approach.

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5. NFPA 52, *Standard for Compressed Natural Gas,* 1995 edition.

6. NFPA 50A, *Standard for Gaseous Hydrogen Systems,* 1994 edition.

7. NFPA 70, *National Electrical Code.*

8. SAE J 1616, *Fuel Composition for Natural Gas Vehicles.*

9. CGA G-5 series hydrogen standards.

10. DOT Regulations, 49 CFR paragraph 173, 178 and 192.

11. ISO 14687;1999 *Hydrogen fuel – product specification.*

12. ISO/WD 15916 *Basic considerations for the safety of hydrogen systems.*

13. ISO/WI 15866 *Gaseous hydrogen blends and hydrogen fuel – service stations.*

14. ISO/WI 15869 *Gaseous hydrogen blends and hydrogen – land vehicle tanks.*

15. ISO/WI 17268 *Gaseous hydrogen – land vehicle filling connectors.*

16. ISO TC58/WG7 *Draft standard, Selecting metallic materials resistant to hydrogen embrittlement.*

California Codes and Regulations for Automotive Hydrogen

Background

The use of hydrogen as an automotive fuel is in the earliest stages of automotive design and engineering. The building of the vehicle has been the first consideration, and as in the case of natural gas, it has been assumed that providing automotive refueling stations, implementation of regulations, infrastructure and public acceptance would follow in the short term. There should be a considerably shorter path to acceptance and implementation, if one can review and capitalize on the natural gas experience.

The increased interest in the use of hydrogen as an automotive fuel can be related to the early considerations of using both forms of natural gas as an automotive fuel: Liquefied natural gas and compressed natural gas (CNG). However, the comparison of these two very distinct paths has some very challenging differences as we relate the fuel to the natural gas experience:

The use of hydrogen in the compressed state will bear witness to the same considerations as CNG. The following are some basic considerations:

Compressed Hydrogen

1. Hydrogen gas presents a very different set of fire safety challenges
2. The pressure of the onboard fuel tanks is substantially above the 3600 psi range for natural gas. Hydrogen is 5,000 or more
3. New refueling connectors must be designed and tested
4. The onboard CNG tanks are not acceptable for this application and a new breed of tanks will have to be produced
5. PRD valves and other tank system considerations will have to be engineered
6. Failure Modes Effects Analysis will need to be done for fuel systems
7. Valves and regulators, etc will have to be designed for the automotive applications
8. A consideration for some applications for an odorant will be necessary
9. A consideration for proper marking for the fuel and an indicator of hydrogen and other fuel combinations such as: hythane

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Cryogenic Hydrogen

1. The cryogenic temperatures are much colder. This will have an effect on the materials, gaskets and other working materials
2. The temperatures will have direct effect on the type of cryogenic tanks and pressures that will be acceptable.
3. The ability to use saturated fuel may be in question as well as the end use pressures
4. The safety criteria for the automotive application will have to be reviewed
5. The refueling station will have an entirely new set of criteria

The considerations for commercial implementation is often over looked in the quest for on-road automobile demonstrations and testing. The ability of an automotive manufacturer to build a vehicle for demonstration purposes is far easier than the implementation of production sites, refueling stations and the general safety considerations for every day use of the refueling sites and vehicles. Of even greater importance is the ability to permit and install refueling stations as well as provide maintenance and use of a public garage. The natural gas experience should prove to everyone that the implementation of a new automotive fuel must begin with the simultaneous development of: the vehicle(s), code revisions and acceptance, acceptance of local regulations for the use of the fuel.

The path for hydrogen implementation is comparable with that of natural gas with one very basic exception. This exception is a major consideration, as the early stages of natural gas vehicle and refueling station development was sponsored throughout the nation by the gas companies and their presence as a local utility. The advancement of hydrogen does not appear to have this type of sponsorship and massive universal support as a commercially viable fuel.

Hydrogen Documentation

1. Compressed Gas Association CGA P-12-1993 Safe Handling of Cryogenic Liquids
2. NFPA 50B Standard for Liquefied Hydrogen Systems at Consumer Sites - 1999
3. NFPA 50A Standard for Gaseous Hydrogen Systems at Consumer Sites - 1999
4. NASA Glenn Safety Manuel, Chapter 6 - Hydrogen, Revision Date 06/99
5. NSS 1740.12, Safety Standard for Explosive, Propellants, and Pyrotechnics, 1993
6. NSS 1740.11, Safety Standard for Fire Protection, Aug 1993
7. NSS 1740.15 , Safety Standard for Oxygen and Oxygen Systems -Jan 1996
8. NSS 1740.16, Safety Standard for Hydrogen and Hydrogen Systems, Feb 1997
9. DOD 6055.9-std, DOD Ammunition and Explosives Safety Standards, July 1999
10. 29 CFR 1910.103 Hydrogen

NSS = NASA Directive
DOD = Department of Defense
CFR = Code of Federal Regulations

The items listed one through ten are just a sampling of the considerations that one will have to review in order to move the use of hydrogen forward. Although several of the above mentioned standards appear to have no bearing on the automotive applications - DOD 6055.9 std, DOD ammunition and explosives safety standards, one should understand that in the formulation of any new application where the public safety is involved, you will have to review every known regulation, code, technical paper possible in order to resolve any potential dangerous situations.

A further consideration is the demand for each of the agencies to thoroughly review all of the documents that will contribute to the process for new California hydrogen vehicle and refueling station regulations. In the review of the documents, often nuances do not meet with the current regulations within the State. It cannot be more deeply emphasized that not only are the NFPA and other documents not adopted codes and regulations, but in many cases they are not adopted from city to city at the Fire Marshall level.

The public safety is held in the highest respect for these regulations and beyond the mere word within the document, there are numerous acceptable practices that find there way into later editions of the documents. One should keep in mind that both agencies are also responsible for inspect within their individual jurisdiction: California Highway Patrol - all licensed vehicles and the California Pressure Vessel Code - OSHA -Title 08 inspects pressure vessels sites as well as all unlicensed vehicles.

California Codes - Regulations and Recommended Practices

The implementation of hydrogen does not currently have regulations, recommended practices and various agency reviews for general use and safe applications. The automotive applications are not directly considered, and the documents are pointed toward stationary applications. Furthermore, unlike natural gas, which is used in a large number of households throughout the United States, hydrogen will not be grandfathered into the social system without a considerable amount of effort.

One of the best comparisons is to review the progress of LNG and CNG regulations for vehicles and refueling stations as a predictor of the future use of hydrogen. The list on the last pages of this document "Code Standards and Advisories Applicable to Natural Gas Vehicles" is representative of the contributing agencies that have had input into the California regulations: California Code of Regulations- Title 08 and the California Highway Patrol - Title 13 for natural gas vehicle and refueling stations.

The code and regulation considerations for hydrogen automotive fuel will be considerable, when one reviews the following partial list for natural gas applications:

NFPA	52	Compressed natural gas for vehicular fuel systems
NFPA	57	Liquefied natural gas vehicular fuel system code
NFPA	88A	Standard for parking garages
NFPA	88B	Standard for Repair garages
NFPA	59A	Standard for the production, storage and handling of LNG
SAE	1616	Recommended Practice for compressed natural gas vehicles
SAE	J2343	Recommended practice for LNG powered H.D. trucks
SAE	J2406	Recommended practice for fuel systems - gas and liquid

Federal Transit Authority Guidelines
Uniform Fire Code
International Fire Code

ANSI — Natural Gas Vehicle standards for:
- Fueling connection devices
- Vehicle fuel containers
- Components for gas powered vehicles
- Dispensing Systems
- Hoses for dispensing systems
- Breakaway devices for hoses and systems
- Manually operated valves for dispensing systems
- Requirements for relief devices - fuel containers

49 CFR — Regulations for:
- Fuel Container Integrity
- Fuel System integrity of gas vehicles
- All fuel systems

California Pressure Vessel Code - Title 13 -	Regulations for onsite production, refueling stations and non-licensed vehicles
California Highway Patrol Title 08	Regulations for all motor vehicles

It should be noted that currently the California Pressure Vessel Code and the California Highway Patrol do not have any regulations for hydrogen-powered vehicles or the use of commercial hydrogen refueling stations. These codes and standards will have to be developed prior to the move from the demonstration phase to commercial applications. Furthermore, there are no building codes, fire codes, etc. within California that the local city, county inspectors can use for acceptance of a hydrogen refueling station or garage.

The above-mentioned codes, standards and regulations for natural gas potentially could run a parallel path for the use of hydrogen as an automotive fuel. It should be understood that within many of the above mentioned regulations and codes, there has been a considerable amount of time and effort spent on the use of Failure Modes and Effects Analysis (FMEA) for the systems and components.

The FMEA process can be best understood by example of the Society of Automotive Engineers SAE J2343 recommended practice committee work and the document that was adopted by the California Highway Patrol as a Title 13 regulation. This document took two years of work by a SAE committee made up of all of the truck and automotive manufacturers (OEM), the American Trucking Association and experts in the field. Included in this work was the FMEA, which was engineered by an outside firm. The total estimated cost for this effort was $ 500,000, which includes the time of the participants, the cost of the FMEA and the leadership personnel. However, more importantly, it is the mere fact that the OEM has had the interest to send their top engineering staff personnel to the meetings and contribute to the process. This is a key element in the process as the SAE documents are one of the few that will be adopted by agencies such as the California Highway Patrol and the California Pressure Vessel Code - OSHA.

The essence of the future use of hydrogen as an automotive fuel is that the process could utilize many of the current standards and regulations as a "bench mark" for separate hydrogen automotive applications. The key to the process is to start with the early development of the vehicles and refueling stations that are demonstrations and make sure that they follow any current codes and are thoroughly researched for future commercial applications. The failure to do so leads one to believe that the demonstration will be acceptable for future implementation of both the vehicle and the refueling station. Nothing could be further from the truth.

The years of work for the acceptance of natural gas as a vehicle fuel should prove to everyone that the process is one of public review and comment. The overwhelming benefits of the use of natural gas as a commercially viable automotive fuel, which has had considerable amount of support from all sectors, is still a work in process.

The process for building the vehicles is well structured and the OEM companies have a vast amount of engineering and financial resources. The industry has not moved forward as rapidly as expected, partially due to the inability to install refueling stations. The acceptance of new codes and standards in California, which is a leader in the development of new fuels, has been burdened by the lack of proper guidance, engineering review and communications with public officials. This is still a burden to the installation of compressed natural gas and liquid natural gas refueling stations, small-scale liquefier and large production plants.

The natural gas experience should clearly point out that for the long-term success of any new fuel, such as hydrogen, it will take considerable time, leadership and experience in order to bring the new fuel into the commercial market. Until the regulations are in place, each location will be a site-specific set of circumstances. In the case of Title 08 for dispensing facilities, they will probably follow the natural gas requirements that all dispensing facilities must be certified as meeting these orders by California Registered Engineer(s) competent in the design, fabrication, and construction of LNG/CNG containers, cryogenic equipment, piping systems, fire protection equipment, gas detection and other components of the facility.

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Codes, Standards and Advisories Applicable to Natural Gas Vehicles

(This list is not all-inclusive)

Document	Applicability	Comments
NFPA 52 – Compressed Natural Gas Vehicular Fuel Systems Code – 1998	CNG vehicles (incl. marine) and fueling facilities,	Probably single best source of guidance for CNG vehicles and fueling facilities.
NFPA 57 – Liquefied Natural Gas Vehicular Fuel System Code - 1999	LNG and LNG to CNG vehicles (incl. marine) and fueling facilities	
NFPA 88B – Standard for Repair Garages - 1997	All garages used for major repair and maintenance of motorized vehicles	Has some specific requirements for garages working with NGVs, such as ventilation, electrical requirements near the ceiling, temperature of exposed surfaces on heaters.
NFPA 88A – Standard for Parking Structures – 1998	Open, enclosed, basement and underground parking structures	No special requirements for NGVs other than reference to NFPA 52 and 57
NFPA 30A – Code for Motor Fuel Dispensing Facilities and Repair Garages	Applies to facilities dispensing both gaseous and liquid fuels at the same facility	Includes requirements of 88B.
NFPA 59A – Standard for the Production, Storage, and Handling of Liquefied Natural Gas - 1996	Site selection, design, construction, and fire protection for LNG facilities.	
SAE J1616 – Recommended Practice for Compressed Natural Gas Vehicle Fuel	CNG	Recommendations on vehicular fuel composition.
SAE J2323 – Recommended Practices for LNG Powered Heavy Duty Trucks	LNG	Primarily heavy truck recommendations but some maintenance facility equipment and procedures.
Design Guidelines for Bus Transit Systems Using Liquefied Natural Gas (LNG) as an Alternative Fuel (3/97)	Transit Facilities but useful reference for other fleets	FTA Report - Not only references required codes (e.g., NFPA) but also suggests additional precautions and provides general information.

Document	Applicability	Comments
Design Guidelines for Bus Transit Systems Using Compressed Natural Gas as an Alternative Fuel (6/96)	ditto	ditto
Compressed Natural Gas Safety in Transit Operations (10/95)	ditto	ditto
Liquefied Natural Gas Safety in Transit Operations (3/96)	ditto	ditto
Uniform Fire Code - 1997	"The most widely adopted model building code in the United States"	May be the fire code used in your area. Check with local fire marshal
International Fire Code - 2000	New fire code introduced this year.	Check with local fire marshal on applicability
CSA B108-99 Annex – Indoor Refueling of Natural Gas Vehicles	Canadian Std. Fueling facilities w/ a building that has primary functions other than fueling. Does not cover public stations.	Proposed Annex currently (1/00) undergoing balloting
ANSI NGV1-1994 (with 1997 and 1998 addenda) – Compressed Natural Gas Vehicle Fueling Connection Devices	CNG vehicular fueling connection devices	Assures standardized nozzles and receptacles
ANSI NGV2-2000 – Basic Requirements for Compressed Natural Gas Vehicle Fuel Containers	CNG fuel containers	Container requirements in addition to FMVSS 304.
ANSI NGV3.1-1995 – Fuel System Components for Natural Gas Powered Vehicles	Fuel system components for NGVs (excludes LNG components upstream of vaporizer)	Primarily for converted vehicles.
ANSI NGV4.1-1999 – NGV Dispensing Systems	CNG vehicular fuel dispensing systems	
ANSI NGV4.2-1999 – Hoses for Natural Gas Vehicles and Dispensing Systems	CNG dispenser and vehicular hose assemblies	
ANSI NGV4.4-1999 – Breakaway Devices for Natural Gas Dispensing Hoses and Systems	CNG dispenser shear valves and fueling hose emergency breakaway shutoff devices	

Document	Applicability	Comments
ANSI NGV4.6—1999 – Manually Operated Valves for Natural Gas Dispensing Systems	Manually operated CNG valves, excluding cylinder shut-off valves	
ANSI PRD1-1998 (with 1999 addendum) – Basic Requirements for Pressure Relief Devices for Natural Gas Vehicle Fuel Containers	Pressure Relief Devices for CNG Fuel Containers	
CGA C-6.4-1998 – Methods for External Visual Inspection of Natural Gas Vehicle Fuel Containers and Their Installations	CNG vehicular fuel containers	Referenced in ANSI NGV2
49 CFR 571.304, FMVSS 304 – Compressed Natural Gas Fuel Container Integrity	CNG motor vehicle fuel containers	DOT Federal Motor Vehicle Safety Standard for CNG motor vehicles.
49 CFR 571.303, FMVSS 303 – Fuel System Integrity of Compressed Natural Gas Vehicles	CNG vehicles ≤10,000 lbs. GVWR and school buses	DOT Federal Motor Vehicle Safety Standard for crash test of light duty vehicle and school bus CNG fuel systems.
49 CFR 393.65, FMCSR – All Fuel Systems	Commercial vehicles in interstate commerce	DOT Federal Motor Carrier Safety Regulations
CA Code of Regulations, Title 13, Div 2, Ch 4, Article 2	Fuel systems using LNG in 15 CCR 935, CNG in 13 CCR 934	CA requirements
TX Administrative Code, Title 16, Part 1, Ch 13	CNG regulations in Subchapter E, LNG regulations in Subchapter M	TX requirements

National Fire Protection Association (NFPA) documents – contact NFPA at 1-800-344-3555 or *http://catalog.nfpa.org*

Society of Automotive Engineers (SAE) documents – contact SAE at 774-726-0790 or www.sae.org/products

Federal Transit Administration (FTA) documents – contact William Hathaway at 617-494-2081 or the National Technical Information Service at 703-605-6050 or www.ntis.gov

Uniform Fire Code – Contact Western Fire Chiefs Association/Uniform Fire Code Association at 760-723-6911 or www.wfca.com/ufca or buy from a bookstore, such as Amazon.Com

International Fire Code – Contact International Codes Council at 703-931-4533 or www.intlcode.org

Canadian Standards Association (CSA) documents – Contact CSA at 1-800-463-6727 or www.csa.ca

ANSI NGV documents – Contact Kelly Batte at Natural Gas Vehicle Coalition at 703-527-3022 or kbatte@ngvc.org

Compressed Gas Association (CGA) documents – Contact CGA at 703-412-0900 or www.cganet.com

Code of Federal Regulations (CFR) – Can be obtained on the web at www.access.gpo.gov

California Code of Regulations (CCR) – Can be obtained on the web at http://ccr.oal.ca.gov

Texas Administrative Code – Can be obtained on the web at http://info.sos.state.tx.us:80/pub/plsql/readtac$ext.ViewTAC

American Society of Mechanical Engineers (ASME)

International Standards Organization (ISO)

International Codes Council (ICC)

International Society for Measurement and Control (ISA)

Hydrogen Specific - Not specific to automotive applications

- SME B31.3, Process Piping
- ASME BPVC, Boiler and pressure Vessel Code
- CGA G-5.3-1997, Commodity Specification for Hydrogen
- CGA G-5.4-1992, Standard for Hydrogen Piping Systems at Customer Locations
- CGA G-5.5-1996, Hydrogen Vent Systems

- CGA G-5-1991, Hydrogen
- NFPA 69, Standard on Explosion Prevention Systems
- NFPA 325, Guide to Fire Hazard Properties of Flammable Liquids and Gases
- NFPA 50A, Std. for Gaseous Hydrogen Systems at Consumer Sites
- NFPA 50B, Std. for Liquefied Hydrogen Systems at Consumer Sites
- 29CFR1910.103, Hydrogen Fuel - Product Specification (Similar to NFPA 50A)
- ANSI/UL 2279, Elect. Equip. for Use in Class I, Zone 0, 1, and 2 Hazardous Locations
- ANSI/UL 913, Intrinsically Safe Apparatus
- ANSI/ISA RP 12.6, Installation of Intrinsically Safe Systems for Hazardous Locations
- ANSI/ISA S 12.16.01, Electrical Apparatus for Use in Class I, Zone 1 Hazardous Locations
- NFPA 496, Standard for Purged and Pressurized Enclosures for Electrical Equipment
- NFPA 497, Classification of Liquids, Gases, and Vapors for Electrical Equipment in Hazardous Locations
- NFPA 70 –1999, National Electric Code

Codes, Stds List[2].doc