Solar Powered Hydrogen Generating Facility and Hydrogen Powered Vehicle Fleet

Technical Progress Report for the period
January 1, 1995–March 31, 1995

James J. Provenzano
Managing Director

Clean Air Now
Project Office
1222 Lincoln Boulevard
Santa Monica, CA 90401

April, 1995

PREPARED FOR THE UNITED STATES
DEPARTMENT OF ENERGY

Under Contract No. DE-FC36-94GO10039

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Technical Progress Report #3

1. INSTRUMENT NO.: DE-FC36-94GO10039

2. PROJECT TITLE: Solar Powered Hydrogen Generating Facility And Hydrogen Powered Vehicle Fleet

3. REPORTING PERIOD: January 1, 1995 through March 31, 1995

4. NAME AND ADDRESS: Clean Air Now
   Project Office
   1222 Lincoln Boulevard
   Santa Monica, CA 90401
   (310) 394-1214

5. PROJECT START DATE: August 11, 1994

6. COMPLETION DATE: September 10, 1995
DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.
7. APPROACH CHANGES:

1. (Clarification of item 7.2 of Technical Progress Report #2): By isolating the entire hydrogen generation system from the electrical grid we avoided the need for a rectifier and interface electrical equipment. These savings were applied to the added cost of the addition of the high pressure receiver (5,000 psi.), off-grid batteries, and two inverters to run the AC compressor and to control the current. Isolating the system from the grid has caused The Electrolyser Corporation to incur additional costs that they are willing to absorb.

8. PERFORMANCE VARIANCES, ACCOMPLISHMENTS, OR PROBLEMS:

1. The Project proceeded generally according to schedule, with most of the activity directed at the procurement of materials, initiation of equipment fabrication by the subcontractors, discussion and direction of sub-tasks in partners' scope of work, and the development of educational materials.

2. The first vehicle retrofit was completed in March 1995 on schedule, and prepared for delivery to DOE's/Rocketdyne's Energy Technology Engineering Center (ETEC) for Safety Analysis.

3. An overall systems design and integration review was held on February 15 with all the Project's partners. The Electrolyser Corp. (TEC) gave a presentation on the electrolysis sub-system and received approval to proceed with the final drawings to be submitted to Clean Air Now. The truck's fuel and filling systems were updated with minor changes (See item 11-1). Safety analysis was reviewed. Representatives from Xerox were present to concur with the design and safety activities. Xerox, supporting our earlier decision, presented a strong view that deionized water is appropriate for our electrolysis installation (vs. RO). Before going for permits Xerox will go through its internal plan check procedures in early 2nd quarter. From this meeting work statements were “firmed up”.

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4. Engineering drawings and specifications (See item 11-2) were received from TEC and a review by the Project Manager and Project Engineer was completed. After changes were made the package was forwarded to the install contractor Matrix Construction and Engineering for use in obtaining Xerox' approval and city permits. The expected completion date of installation still remains August 31, 1995.

5. Discussions continued with the University of California Riverside's College of Engineering - Center for Environmental Research and Technologies (CE-CERT) and ETEC regarding the hydrogen truck's engine performance testing, emissions testing, and safety analysis of all Project systems. Final definition of the Safety Analysis of the truck and systems was reached. ETEC's Test Plan, Safety Analysis Review, and Final Report on the 1st truck will be included in the 2nd quarter progress report(See item 11-3). This work will be performed under a CRADA between ETEC and Clean Air Now, outside TRP funding, and applied towards co-funding. CE-CERT is working on control house design and instrumentation.

6. Managing Director James Provenzano, formerly of Xerox, presented a paper on the Project at the National Hydrogen Association Annual Meeting and Technology Conference, March 7-9, 1995, in Washington, D.C. The corporate perspective was addressed on the impetus to participate in a non-core business project such as this. This is the largest hydrogen demonstration project currently in progress in the country and as such received much interest. The paper will be included with next quarters report.

7. CAN's Executive Director Paul Staples and Project Engineer Dr. Paul Scott of Touchstone Technology visited Solar Engineering Applications Corporation (SEA) in Santa Clara, CA in March to discuss the progress of the photovoltaic array. No delays were determined at that meeting.

8. Clean Air Now showcased its first Xerox Maintenance hydrogen powered truck at the 1995 U.S. DOE Clean Air Road Rally on March 30 and April 1, 1995 at the Los Angeles Zoo. The truck and some of the Project partners were exposed to the press and other interested parties. Due to the lack of safety analysis at that time the truck was a static display. The DOE's Assistant Secretary for Energy Efficiency and Renewable Energy Christine Ervin viewed the truck and discussed its unique aspects with Clean Air Now personnel (See item 11-8).
9. OPEN ITEMS:

1. Remaining required cofunding documentation is included with this report (See items 11-4-6).

10. STATUS ASSESSMENT AND FORECAST:

1. As stated above, the installation of all the capital equipment is planned to be completed on schedule. Due to the limited time between install completion (Aug. 31, 1995) and Project completion (Sept. 10, 1995) it is anticipated that we will need to ask for an extension of the Final Technical Report filing date, in order to provide time to obtain sufficient project data. Taking ETEC’s schedule under consideration, December 1995 is a more realistic target date for Final Technical Report submission. ETEC has agreed to a Nov. 1, 1995 submittal date for their final documents. This will be discussed further in the coming months.

2. It is anticipated that ETEC’s scope of work will have to be adjusted in order for Clean Air Now to contract with UCR to perform the vehicles’ performance evaluation and emissions testing. This is due to ETEC’s contractual procedural constraints and lack of necessary on-site equipment to complete such tasks. This will be discussed more fully in the next report.
11. DESCRIPTION OF ATTACHMENTS:

2. TEC’s and SEA’s Draft Specifications for Construction at Site for <Project>.
3. ETEC’s schedule for Truck Testing and Safety Analysis.
4. SEA Corporation’s co-fund documentation.
5. The Electrolyser Corporation’s co-fund documentation.
6. The City of West Hollywood’s co-fund documentation.
7. Letter of interest from Cabazon Tribe to further develop the hydrogen infrastructure in California with Clean Air Now.
8. Follow-up letter to DOE Assistant Secretary Christine Ervin post Los Angeles DOE Clean Air Road Rally.
11. Project Contact List as of 4/1/95. (This list excludes the US DOE & South Coast Air Quality Management District contacts.)

12. SIGNATURE OF RECIPIENT AND DATE:

[Signature]
5/16/95

13. SIGNATURE OF DOE REVIEWING REPRESENTATIVE AND DATE:
E.C.M. SEQUENCING
START-UP:
1. IGN. SW. --- ON
2. ENGINE CRANKING (~5 SECONDS APPX.)
3. IGN. SYSTEM --- ON (CRANKING)
4. FUEL --- ON TILL START

E.C.M. SEQUENCING
SHUT-DOWN
1. IGN. SW. --- OFF
2. FUEL --- OFF
3. ENGINE SPEED < 100 RPM
4. IGN. SYSTEM --- OFF

COMPONENT SPEC.
1. CHEM-TECH (25XO8490) (ZERO FLOW IN CLOSED POS)
2. NUPRO B-4P547
3. WHITEY SS0856
4. NUPRO SS2061 DOUBLE CHECK
5. STANDARD CGA-58 Connector
6. TECSON 22-1323-205 REGULATOR (125PSI MAX/DUT)
7. CCI CONTROLS 7707 H2 DETECTOR
8. ADVANCED FUEL COMPONENTS MODEL 121 SOLENOID VALVE
9. NORGREN 1/2-300-120 REGULATOR (400 PSI MAX) BZWATOMATIC SPOR-006-3400-312 DOME LOADER
10. COMDYNE 0570020 AF TANK (300 CUFT, VOL)
11. ALUM/FRPGLASS200 PSI RATED ON/20
12. II. KLINCK 80PSI SERIES SWITCH 2500PSI BURST
U.L. RECOGNIZED FILE SA995 CSA CERTIFIED FILE L7462

TOLERANCES:
1/4 ± .010
1/8 ± .005
1/16 ± .005
1/32 ± .005

ADVANCED MACHINING
DYNAMICS
FUEL SYSTEM SCHEMATIC

OPTIONAL SOLENOID OPERATED EMERGENCY FUEL CUT-OFF SYSTEM

CONTROL LOGIC
EMERGENCY SHUT-OFF VALVE
LOGIC

IGN. SW. PR. SW. OPER.
ON OFF X X
EM. VALVE X X

ADVANCED MACHINING
DYNAMICS
FUEL SYSTEM SCHEMATIC

FIGURE 1.
Fuel System Schematic

No: 019-TH-0001
Date: 04/17/99
Page: 12
Draft Specification for Construction at Site for Xero/CAN!
Solar Hydrogen Demonstration in El Segundo CA
(Date: March 21, 1995)

This document outlines construction work to be performed at Xerox El Segundo to install a 50 kW UNICELL-CLUSTER™ Hydrogen gas generator and high pressure storage system for the Xero/CAN Solar Hydrogen demonstration.

The work description is broken down into tasks. For each task the principle performer(s) of the work and principle material supplier(s) are identified. The following short forms have are used to refer to the different performers: TEC-The Electrolyser Corporation, UCR-University of California Riverside, XerodCAN-Xerox Clean Air Now! Project Team, SEA-Solar Engineering Applications Corporation, and Contractor-Matrix Engineering.

Ref. Drawings
EXISTING SITE LAYOUT (TEC DWG: 2076-D-016)
PROPOSED SITE LAYOUT (TEC DWG: 2076-D-017/8)
OUTLINE & MOUNTING LAYOUT, GEN IV (SEA DWG: 10446)
BUS BAR MOUNTING GEN IV (SEA DWG: 10450)

are attached.

Work Description

Task 1 General Site Construction:

Sub-Task 1.1: Removal of Existing Perimeter Fence

- Work to be performed by Contractor
- Material to be supplied by Contractor

Referring to the Existing Site Layout the fence enclosing the existing fuelling station will be partially removed along the northeast boundary and entirely removed along the south east boundary. Fencing materials will be saved to be used in building the new perimeter fence.

Sub-Task 1.2: Installation of New Perimeter Fence

- Work to be performed by Contractor
- Materials to be supplied by Contractor

Referring to the Proposed Site Layout a new fence will be erected of the same type and height as the old fence. The new fence will run along the north boundary, east boundary and along the south boundary to where it joins the existing fence. The fence will be of the same height (8') and fabric (chain link) as the existing fence using the same type of line
posts (2 7/8”). The fence will include a 12’ sliding gate close to the north-east corner of the site as indicated on the Proposed Site Layout.

**Sub-Task 1.3: Installation of Operator’s Cabana**

- Work to be performed by UCR/TEC and portable structure supplier
- Materials to be supplied by UCR/TEC and portable structure supplier

TEC/UCR will arrange the construction and delivery of a portable structure which will be the filling station office and which will house the process monitoring computer. The building, to be supplied locally, will be located as indicated in the Proposed Site Layout, and will be similar to that shown in the attached component data. The building will be of wood frame construction, Pentagon shaped, 8’ per side, with overhang (16”), and will have windows on four sides. The structure will be delivered pre-wired with lights, flooring and ready to furnish. No foundation will be required. The need for air conditioning/heating systems in the building will be investigated by UCR.

**Sub-Task 1.4: Electrical Power & Telephone Line to Operator’s Cabana**

- Work to be performed by Xerox/CAN
- Materials to be supplied by Xerox/CAN

Power (120V/30 amps) and a telephone line will be supplied to the main junction box at the cabana.

**Sub-Task 1.5: Installation of Feedwater Treatment Station**

- Work to be performed by UCR/TEC and water chemical supply company.
- Materials to be supplied by UCR/TEC

TEC/UCR will arrange the supply and installation of the Feedwater Treatment Station from a local water chemical supplier. The Feedwater Treatment Station will be located directly behind the Operator’s Cabana and will consist of a deionizer bed, and electrically driven circulation pump. The water treatment equipment must be accessible to outside personnel who will be contracted to maintain the equipment, regenerate de-ionizer beds etc. An enclosure for the water treatment equipment will be supplied by TEC.

**Sub-Task 1.6: Water Supply to Feedwater Treatment Station**

- Work to be performed by Xerox/CAN
- Materials to be supplied by Xerox/CAN
Xerox/CAN! will supply water to the Feedwater Treatment Station (min line flow rate 20 litre/h).

**Sub-Task 1.7: Installation of "New Jersey" Pylons**

- Work to be performed by Contractor
- Materials to be supplied by Contractor

Removable post barricades similar to the type used to protect the storage area will be erected, at positions indicated in the Proposed Site Layout, protecting the high pressure gas line and blocking vehicle access to the Electrolysis Module. The separation distance between pylons will be the same as pylons surrounding the existing gas storage (approx. 4 1/2').

**Task 2: Installation of Photovoltaic Power System**

The total number of panels to be supplied by SEA will depend on results of future performance tests. The number of panels may vary between 37 and 40. The position of the three additional panels are identified by dotted outline in the Proposed Site Layout. The panels will be configured in two groups. A group of 6-8 panels will be pre-configured to supply high voltage, 180 V DC, to power the compressor motor and associated controls. A group of Low Voltage, GEN IV, PV panels will supply power to the electrolysis cell bank. The low-voltage panels will occupy the areas east and north of the electrolysis house.

**Sub-Task 2.1: Installation of PV Panel Frames**

- Work to be performed by Contractor
- Materials to be supplied by SEA.

The PV modules sit in PV panel frames. The assembly of the PV panel frame is shown in SEA Drawing: OUTLINE AND BUS BAR MOUNTING GEN IV. The PV panel frames will be positioned as shown in the Proposed Site Layout, in rows, 20' apart. The panels will be bolted to 3' screw anchors, detail given in attached component data sheets. The anchors must be installed by the contractor before July 15. After the anchors are installed the PV panel frames can be bolted to the anchors. The contractor will install frames. Information on screw anchors is provided in attached component data. PV panel frames and anchors will be supplied by SEA.

**Sub-Task 2.2: Installation of Low Voltage Bus Bar**

- Work to be performed by Contractor
The low voltage bus bar connects the low voltage PV modules to the electrolysis cell bank bus bar. The main bus bar runs are showed in the Proposed Site Layout. The bus bar will be supported on Unistrut Post Bases (Type P 2073 A) as outlined in Support Detail-1. Further information on Unistrut post bases are given in the attached component data. Main bus bar runs will be coated in "shrink-wrap". The installation of the bus bar to the panel will be as shown in BUS BAR MOUNTING GEN IV. All bus bar runs will be installed by the Contractor before the PV modules are connected to the bus bar.

Sub-Task 2.3: Installation of High Voltage Cable

- Work to be performed by Contractor
- Materials to be supplied by SEA Corp.

The high voltage cable connects the high voltage panels to the electrical control room of the Electrolysis Module. The cable will run inside a conduit supported by Unistrut Post Bases (Type P 2072A) as outlined in Support Detail-3 and to be supplied by TEC. The conduit will run between the two panel rows. The bases will be mounted 5 feet apart. The post bases will be installed by the Contractor. The cable will be grounded to the high pressure gas line which in turn is connected to the common ground (Praxair) at the gas storage site.

Sub-Task 2.4: Electrical Connection of Low Voltage Bus Bar to Electrolysis Cell Bank

- Work to be performed by TEC
- Materials to be supplied by TEC.

The low voltage bus bar will be connected to the electrolysis cell bank by TEC.

Sub-Task 2.5: Electrical Connection of High Voltage Cable to Compressor Power System

- Work to be performed by Contractor
- Materials to be supplied by SEA

The high voltage cable will be connected to the PV modules using the connector supplied by SEA. The cable will run in conduit in between the panels where connections from each panel (#4 wire) will be pulled into the main cable.
Sub-Task 2.5: Installation of PV Modules

- Work to be performed by Contractor
- Materials to be supplied by SEA

Details of the mounting of bus bar on the PV panel frames is outlined in SEA drawing BUS BAR MOUNTING GEN IV. SEA will install modules and will make electrical connections between modules and bus bars.

Task 3: Installation of UNICELL-CLUSTER™ Electrolysis Module

The electrolysis cell bank, compressor, associated power system and controls will be packaged in a single container 40' long by 8' wide by 8' high and will be delivered to the site on a flat bed trailer. The Electrolysis Module will be equipped with lifting lugs. The estimated weight of the unit is 32,000 lb.

Sub-Task 3.1: Foundation and Erection of Electrolysis Module

- Work to be performed by Contractor
- Materials to be supplied by SEA

The unit will be installed on a concrete pad 41' x 9' x 12" and will be anchored at 4 points.

Sub-Task 3.2: Feedwater Piping from Operator Cabana to Electrolysis Module

- Work to be performed by Contractor
- Materials to be supplied by SEA

Feedwater will be piped from the feed water treatment station to the Electrolysis Module following the route shown in the Proposed Site Layout. The pipe will be constructed of PVC or equivalent and will travel underground from the Feed Water Treatment Station behind the Operator's Cabana to the edge of the PV field. From the edge of the PV field the water line will be supported by the posts (Support Detail-3) carrying the high voltage line and data link line to the Electrolysis Module.

Sub-Task 3.3: Data link line between Operator Cabana and Electrolysis Module

- Work to be performed by Contractor
- RS-485 cable to be supplied by TEC/ Cable supports to be supplied by TEC

The data link line will be strapped to the same support posts that carry the feedwater
piping. The cable will be supported on post bases (Unistrut P 2072 A) positioned with five foot separation. See Support Detail-3. The bases will be bolted into the pavement according to the pattern shown in the Unistrut product description in the attached component data.

Sub-Task 3.4: Installation of Piping Run from Electrolysis Module to High Pressure Gas Drier and Storage

- Work to be performed by Contractor
- Materials to be supplied by Contractor

Piping from the discharge of the compressor will run with the main bus and will be attached to the same supporting posts (Support Detail-1). The piping will run north to the last row of PV panels. From there it will run with the instrumentation cable to the high pressure drier. Pipe connections to the compressor will be threaded stainless steel pipe unions supplied by TEC; socket welded to the pipe. All piping will be welded 1/2 " Schedule 80 stainless steel pipe tested for an operating pressure of 5000 psi.

Task 4: Installation of High Pressure Gas Drier and Storage System

The drier unit will be a single tower desiccant bed unit built into a skid along with a junction box for accepting the instrumentation cable and for power distribution to the instrumentation. There will be two pressure transducers on the gas storage and a dew-point meter at the gas drier. The pressure vessel will be 1 ft in diameter and approximately ten feet high. The gas drier will be located in between the existing low pressure storage and the high pressure storage supplied by TEC. The gas drier and storage will have been pressure tested prior to shipment to site. Test documentation will be delivered with equipment.

Sub-Task 4.1: Installation of the Gas Drier

- Work to be performed by Contractor
- Materials to be supplied by TEC.

The gas drier skid will be located on a concrete pad on the inlet to the gas storage vessels between the existing low pressure storage and the high pressure storage supplied by TEC. The skid will be mounted on four anchors (1" studs) and will have a footprint approximately 4'x4'.

Sub-Task 4.2: Piping Connections to Gas Drier

- Work to be performed by Contractor
Materials to be supplied by SEA

The inlet to the drier will be connected to the pipe from the Electrolysis Module. The outlet pipe will be connected to the adjacent high pressure gas storage. Both connections will use socket welded stainless steel unions rated for 5000 psi operating pressure.

Sub-Task 4.3: Instrumentation Cable to Gas Drier

- Work to be performed by Xerox/CAN
- Cable to be supplied by TEC/ All other materials to be supplied by Contractor

Power to instrumentation will come from the electrolysis module through an instrumentation cable to be supplied by TEC. The instrumentation cable will run along the bus bar supports through the middle of the array and then along the piping run behind the last row of PV panels. With the high pressure piping it will travel underground to the high pressure gas drier and storage unit.

Sub-Task 4.4: Installation of High Pressure Gas Storage

- Work to be performed by Contractor
- Materials to be supplied by TEC

The two high pressure vessels will be packaged as a standard ASME unit (see attached data sheets) measuring approximately 30' long, 4' wide and 2' high. It will be mounted on two concrete pads to be poured by the Contractor. The unit will weigh approximately 13000 lb. The assembly will be bolted to two floating concrete pads by 1" studs/four anchors per I-beam (total of 8 for whole assembly). The exact mounting pattern will be supplied later. The unit will be delivered to site pre-piped with priority fill manifold.

Task 5: Modifications to Dispenser

The filling station operator will have the option to select between the existing low pressure storage or the high pressure storage by turning two three-way valves at a piping junction to be located at the point which the pipe goes into the ground to travel to the dispensing island.

The high pressure gas storage system will be operated as a cascaded system. When filling a vehicle from the high pressure gas storage the operator will turn a three-way valve at the dispenser to draw from the low pressure receiver first and then from the high pressure receiver.
Sub-Task 5.1:  Piping Connection to Dispenser

- Work to be performed by Contractor
- Flow control components to be supplied by TEC. Piping to be supplied by Contractor

The high pressure storage vessels will have separate outlet pipes which will run from the south end of the pressure vessels, above ground, along the base of the existing low pressure storage. The gas lines will be connected to the two existing lines which run from the two banks of low pressure receivers to the dispenser. (photo of location attached) A three way valve on each line will switch between the high pressure vessels and the existing low pressure storage. A non-return valve will be installed on each supply line (four non-return valves in total)

Sub-Task 5.2:  Modification to Dispenser Controls:

- Work to be performed by Contractor
- Flow control components to be supplied by TEC/piping to be supplied by Contractor

Modifications to dispenser will include the following:

i) Installation of higher rated (6,000 psi) "fire-valves" at the shut-off as shown in photographs and in the Detail P&I D Modification to Dispenser.
ii) Installation of three way valve at T junction, where two lines are joined before split to nozzles.
iii) Installation of regulator on down leg of piping before split to nozzles (photo of location attached).
iv) Installation of strainer upstream of regulator.

All changes to piping to be welded Schedule 80 stainless steel to socket fittings tested for operating pressure of 5000 psi.

Work Schedule:

A schedule by Tasks is shown in the attached Gant Chart: "Proposed Schedule for Site Construction for Xerox/CAN! Solar Hydrogen Demonstration Project" The firm dates are:

- May 15: Early date for start of construction
- July 15: Complete installation of PV panel screw anchors
- Aug 1: Electrolysis Module Delivery to site
- Aug 15: Finish site construction
- Aug 31: Complete plant commissioning
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<td>1.2: Installation of New Perimeter Fence</td>
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<td>1.2. Installation of Operator's Cabana</td>
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<td>1.4. Electrical Power Supply to Operator's Cabana</td>
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<td>1.6. Installation of Feedwater Treatment Station</td>
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<td>1.6. Water Supply to Feedwater Treatment Station</td>
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<td>1.7. Installation of &quot;New Jersey&quot; Pythons</td>
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<td>2.1. Installation of PV Panel Frames</td>
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<td>2.2. Installation of Low Voltage Bus Bar</td>
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<td>2.3. Installation of High Voltage Cables</td>
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<td>2.4. Electrical Connection of Bus Bar to Electrolyte Cell Bank</td>
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<td>2.6. Electrical Connection of High Voltage Cable Compressor Power System</td>
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<td>2.9. Installation of PV Modules</td>
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<td>3.1. Foundation and Erection of Electrolyte Module</td>
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<td>15</td>
<td>3.2. Feedwater Piping From Operator Cabana to Electrolyte Module</td>
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<td>3.3. Data Link Between Operator Cabana and Electrolyte Module</td>
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<td>3.4. Installation of Piping Run From Electrolyte Module to High Pressure Gas Drier and Storage</td>
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<td>4.1. Installation of the Gas Drier</td>
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<td>4.2. Piping Connections to Gas Drier</td>
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<td>4.3. Instrumentation Cable to Gas Drier</td>
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<td>4.4. Installation of High Pressure Gas Storage</td>
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<td>5.2. Modification to Dispenser Controls</td>
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<td>Plant Commissioning</td>
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<td>Dismantle Electrolyte Module</td>
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<td>Dismantle of High Pressure Gas Storage</td>
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The Electrolyzer Corporation

Page 1

Commercially Confidential
PROJECT: Wind Load Analysis of Solar Array Panel

CLIENT: SEA Corp.
(408) 986-9231
Neil Kaminar
FAX 986-9233
3500 Thomas Rd. Suite E
Santa Clara, CA 95054

LOCATION: CAN-Xerox Corp.
El Segundo, CA

STRUCTURE: Solar Array Panels on Ground Level in Parking Lot
Assume Ht= 0 ft  Array Ht< 15 ft

PANEL: Specification from Manufacturer.
-Array module = 20'-0" x 9'-0"
-Tilt = 35'
-Array Weight = 250#
-Mounting Grid = 10'-0" x 9'-0"
-Module Width = 10"
-Module Spacing = 20"oc (10" opening between modules)
-Number of Modules per Array = 12

FRAME: Horizontal Supports = 4" Ht x 3" Wth x 20 ga. Tube Steel
-Vertical Supports = 4" Ht x 3" Wth x 20 ga. Tube Steel
-Diagonal Struts = 1.1/2" Diam. x 20 ga. Tube Steel
-The Mounting Foot is 6" long 16 ga. Steel w/ bent flanges to sit on a asphalt surface w/ screw anchors for uplift.

LAT.LOAD: As per 1992 UBC, Chapter 23, PART II—WIND DESIGN
(Pressure coeff. for minor structures)
Exposure = B  Coefficient Ce= 0.62
Wind Speed = 80 MPH  Wind Pressure qs= 12.6 psf
UBC Table 23-H(7) Pressure Coefficient Cq= 1.4
Importance Factor I=1
Design Wind Pressure P=Ce*Cq*qs*I  P= 10.94 psf
## Tributary Vertical Surface Area of Modules

<table>
<thead>
<tr>
<th>Module L=</th>
<th>9 ft</th>
<th>Angle=</th>
<th>35°</th>
<th>Ht=</th>
<th>6.30 ft</th>
</tr>
</thead>
<tbody>
<tr>
<td>Module W=</td>
<td>10 ft</td>
<td>Module Vert. Area=</td>
<td>5.25 ft²</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Module No.</td>
<td>12</td>
<td>Area=</td>
<td>63.02 ft²</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rail Ht=</td>
<td>6 ft</td>
<td>Rail L=</td>
<td>20 ft</td>
<td>Area=</td>
<td>10.00 ft²</td>
</tr>
<tr>
<td>2-Rails +12 Modules = Total Area=</td>
<td>83.02 ft²</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Total Horizontal Fh = P*Area = 908 #/Array

Uplift Fv = Fh*Tanφ = 636 #/Array

## Overturning Moment taken at short strut end of array

- Fh = 908 #
- Fv = 636 #
- Array Wt = -250 #

Total M = 5505 ft#

Struts per Side = 2

Strut Spacing L = 9 ft

Uplift ft = 306 #/Mount

Strut Horizontal Sliding = Fh/4 = 227 #/Mount

## Anchorage of Array Foot to Asphalt Surface

**DIXIE Foundation Anchors**

- 4" Helix Diam., Class 7 Soil, Soil Holding Strength = 1500 #
- Cat.#D-6524 (See Pad Mount Stabilizing Anchor, Cat.#D-6234)

**AB CHANCE Foundation Anchors (Type GP)**

- 4" Helix Diam.
- Cat.#C107-0190

## Capacity of Foundations with Uplift or Tension Forces

(“Foundation Analysis and Design”, Bowles, 3rd Ed., 4-11)

Assume Soil wt= 120 pcf
Friction Angle= 39°

B = 4
D = 36

Limit H/B = 3
Max.H = 12

Tu = π*c*B*H + sf*1.57*wt*B*(2D-H)*H*Ku*tan φ + W

sf = mh/B = 2.05

Ku = tan²(45+20/2) = 2.04
Ku = Kp*Tan(2φ/3) = 0.995
Ku = sqrt(Kp) = 1.43

W = wt*B*2*pi/4*D = 31.42 #

Tu = 1056 #

SF = 2

LDF = 1.33

Ta = 702 # > Uplift

## Bolting of Array to Foundation Leveling Pad

1/4" MB welded to Leveling Pad (4 each leg)

Weld Check

- Fy = 36000 psi
- Fv = 14400 psi
- LDF = 1.33
- Fv = 19152 psi

Weld Th = 0.25

w/ 1/2 weld Stress, Partial insp.)

- Allow.V = 4701 # > OK

Bolt Check

- A = 0.049 in²
- Fc = 28728 psi
- Allow.V = 470 #
- Allow.T = 1410 #

T/Bolt = 76 #

T/All.T+V/All.V = 0.17 *OK

Weld 4-1/4" Threaded studs to Foundation Leveling Pad
Connection for Array Foot to Anchor

- Min. 1/4" Threaded Stud
- Spacing as required for Array Mount
- Anchor Leveling Pad
- See Manufacturers Spec's.

3' = 1'-8"
The Solution

© 1984 Dixie Electrical Mfg. Co., Birmingham, AL
a wholly-owned subsidiary of Aluma-Form, Inc.
1500 Red Hollow Road • P.O. Box 6298 • Birmingham, Alabama 35217 (205) 853-1000

The Anchor

The Advantages

- This system employs inexpensive "no wrench" anchors - no digger truck required.
- Bearing pads are threaded to easily level the slab.
- Can reduce return service or maintenance stops.
- Simplifies excavation and grading.
- Shares equipment load bearing with the soil, reducing compaction requirements.
- Manual installation tool available, see ordering information.

No Wrench Type Pad-Mounted Stabilizing Anchor Ordering Information

<table>
<thead>
<tr>
<th>Catalog Number</th>
<th>Description</th>
<th>Helix Dia.</th>
<th>Approx. Net Unit Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>D-6234</td>
<td>½&quot; Dia. x 36&quot; Long</td>
<td>4&quot;</td>
<td>5½ Lbs.</td>
</tr>
<tr>
<td>CF-33056</td>
<td>Manual Installing Tool (not shown)</td>
<td>—</td>
<td>3 Lbs.</td>
</tr>
</tbody>
</table>
MANUALLY INSTALLED TYPE GP FOUNDATIONS

These anchors are designed for installation using standard hand tools. (i.e., Ratchet Wrench with deep socket).

<table>
<thead>
<tr>
<th>Catalog Number</th>
<th>Description</th>
<th>Suggested Max. Installation Torque</th>
<th>Std. Pkg.</th>
</tr>
</thead>
<tbody>
<tr>
<td>C107-0048</td>
<td>4&quot; Helix, 3/4&quot; x 35&quot; Shaft, includes hex jam nut</td>
<td>350 ft-lb.</td>
<td>1</td>
</tr>
<tr>
<td>C107-0190</td>
<td>4&quot; Helix, 3/4&quot; x 35&quot; Shaft, includes adjustable leveling pad</td>
<td>250 ft-lb.</td>
<td>1</td>
</tr>
<tr>
<td>E107-0188</td>
<td>Leveling Pad Only</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

SQUARE DRIVE TYPE LD FOUNDATIONS

These anchors are designed for installation using power-digging equipment. The 2-inch square head has a tapped 3/4" center hole to permit use of threaded accessories.

<table>
<thead>
<tr>
<th>Catalog Number</th>
<th>Description</th>
<th>Suggested Max. Installation Torque</th>
<th>Std. Pkg.</th>
</tr>
</thead>
<tbody>
<tr>
<td>C107-0054</td>
<td>6&quot; Helix, 1 1/2&quot; x 69&quot; Shaft</td>
<td>1,800 ft-lbs.</td>
<td>1</td>
</tr>
<tr>
<td>C107-0398</td>
<td>6&quot; Helix, 1 1/2&quot; x 93&quot; Shaft</td>
<td>1,800 ft-lbs.</td>
<td>1</td>
</tr>
<tr>
<td>C107-0049</td>
<td>10&quot; Helix, 1 1/2&quot; x 69&quot; Shaft</td>
<td>1,800 ft-lbs.</td>
<td>1</td>
</tr>
<tr>
<td>C107-0050</td>
<td>10&quot; Helix, 1 1/2&quot; x 93&quot; Shaft</td>
<td>1,800 ft-lbs.</td>
<td>1</td>
</tr>
<tr>
<td>C107-0394</td>
<td>8&quot; Helix, 2&quot; x 69&quot; Shaft</td>
<td>4,000 ft-lbs.</td>
<td>1</td>
</tr>
<tr>
<td>C107-0385</td>
<td>10&quot; Helix, 2&quot; x 69&quot; Shaft</td>
<td>4,000 ft-lbs.</td>
<td>1</td>
</tr>
</tbody>
</table>

To install square drive foundation anchors use Catalog No. 639000 wrench adapter, combined with the correct size kelly bar adapter. Complete description of the installation tools can be found in the anchor tools section 4A of the catalog.

ACCESSORIES FOR SQUARE DRIVE

<table>
<thead>
<tr>
<th>Catalog Number</th>
<th>Description</th>
<th>Std. Pkg.</th>
</tr>
</thead>
<tbody>
<tr>
<td>C107-0111</td>
<td>Level Pad</td>
<td>1</td>
</tr>
<tr>
<td>E211-0037</td>
<td>Threaded Stud</td>
<td>20</td>
</tr>
</tbody>
</table>
TO: Charlie Pappas
Electrolyser
416-621-9410
FAX 416-621-9830
FROM: Mark Semekoski
CP Industries, Inc.
412-664-6605
FAX 412-664-6653

PLEASE CALL SENDER AT 412-664-6605 IF COPIES ARE NOT LEGIBLE

REFERENCE: Your RFQ to CPI via Noracor dated 2/27/95.
CPI Inquiry C-23158.

SUBJECT: Quotation

CPI is pleased to offer the following for your compressed hydrogen needs.

ITEM: One (1) 2-vessel ASME assembly mounted horizontally in I-beams 2 wide X 1 high.

Spec: Seamless pressure vessels to ASME UBV Code Section VIII Division 1 Appendix 22 Safety factor 3 to 1 for dry gas non-corrosive service. Design temperature -20F to +200F.

Size: 16" OD X 1.177" minimum wall X 28'10" long.

Volume: 26.6 cu ft per vessel.
53.2 cu ft per assembly.

Design pressure: 5471 psi.
Operating pressure: 4924 psi.

Capacity: 14,700 scf of hydrogen at 4924 psi.

Weight: 13,100 lbs per assembly, estimated.

Other: Each vessel will have 1/2" NPT openings on front and rear plugs. Vessels will be UT inspected and certified for hydrogen service. Assembly will not have shut off valves or safety devices. Entire assembly will be painted with epoxy primer and one coat white high solids urethane enamel.
ASME Standard Unit

**Notes**

1. Design
   ASME S&PV Code, Section VIII, Div. 1, (SF=3).

2. Design temperature
   Minimum Design Metal Temperature (MDMT) to plus 200°F.

3. Service
   Dry gas, non-corrosive.

4. Vessel material
   ASME SA-372, Type IV.

5. Heat treatment
   Tensile strength—105,000 psi min.
   Yield strength—65,000 psi min.

6. Fabrication
   Vessel shall be seamless type with swaged ends.

7. Inspection
   ASME-certified and National Board commissioned. Magnetic particle inspect exterior.

8. Stamping
   In accordance with the ASME Code.

9. Registration
   Register with National Board.

10. Exterior
    Shot-blast and apply one coat zinc chromate primer and one coat enamel.

11. Interior
    Shot-blast free of loose scale and evacuate. Inert to a pressure of 7 to 15 PSIG with dry nitrogen and seal for shipment.

---

**Diagram**

- Front View
- Side View
- Rear safety vent assembly

**Dimensions**

- Diameter thru 8 holes per seam.
- Vessel length.
- Exterior: Shot-blast and apply one coat zinc chromate primer and one coat enamel.
- Interior: Shot-blast free of loose scale and evacuate. Inert to a pressure of 7 to 15 PSIG with dry nitrogen and seal for shipment.
# Xerox/CAN H2 Truck Testing and Safety Analysis

<table>
<thead>
<tr>
<th>ID</th>
<th>Name</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Test Plan</td>
<td>25d</td>
</tr>
<tr>
<td>2</td>
<td>Prepare Draft Test Plan</td>
<td>3w</td>
</tr>
<tr>
<td>3</td>
<td>Safety Review Meeting</td>
<td>0d</td>
</tr>
<tr>
<td>4</td>
<td>Final Test Plan</td>
<td>2w</td>
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<tr>
<td>5</td>
<td>H2 Fueling Setup</td>
<td>4w</td>
</tr>
<tr>
<td>6</td>
<td>Truck Testing</td>
<td>20d</td>
</tr>
<tr>
<td>7</td>
<td>Truck Delivered</td>
<td>0d</td>
</tr>
<tr>
<td>8</td>
<td>Initial Checkout Tests</td>
<td>1w</td>
</tr>
<tr>
<td>9</td>
<td>Safety Testing</td>
<td>1w</td>
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<tr>
<td>10</td>
<td>Service Testing</td>
<td>2w</td>
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<tr>
<td>11</td>
<td>Return Truck</td>
<td>0d</td>
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<tr>
<td>12</td>
<td>Safety Assessment</td>
<td>70d</td>
</tr>
<tr>
<td>13</td>
<td>Obtain Reg.fm Factory Mit</td>
<td>4w</td>
</tr>
<tr>
<td>14</td>
<td>Analyze Test Results</td>
<td>2w</td>
</tr>
<tr>
<td>15</td>
<td>Prepare Final Report</td>
<td>3w</td>
</tr>
</tbody>
</table>

### Project Information
- **Date:** 2/22/95
- **Critical**
- **Noncritical**
- **Progress**
- **Milestone**
- **Summary**
- **Rolled Up**
March 22, 1995

Mr. James J. Provenzano
Clean Air Now
660 Venice Boulevard, #112
Venice, CA 90291

Re: CAN/DOE Contract DE-FC36-94GO10039

Dear James:

SEA Corporation is pleased to be a participant on the solar hydrogen project. Total cost of the photovoltaic energy system is $437,271. Accordingly, SEA has committed the amount of $39,633. The resulting cost to Clean Air Now is $397,638, which will be invoiced monthly.

Each invoice will identify SEA's contribution to assist you in tracking the funding. Please address any technical questions to Neil, any business questions to me.

We look forward to a successful project.

Yours truly,

Janet S. Walde
Director of Business Operations
February 3, 1995

Mr. Paul Staples
Vice President
Clean Air Now!
660 Venice Blvd. #112
Venice, CA
90291
USA

Dear Mr. Staples,

Regarding a breakdown on TEC cost share on services and equipment being supplied to CAN for the Xerox/CAN project in El Segundo (our proposal 1001:103-203), the cost share can be allocated between the UNICELL-CLUSTER™ PV hydrogen generator and the hydrogen vehicle filling station as follows:

Cost-share on UNICELL-CLUSTER™ contributed by TEC: $282,000.00

Cost-share on vehicle filling station consisting of:
- IR&D on Hydrogen Vehicle Filling Stations by CECERT/UCR (University of California Riverside CA) $45,000.00
- Technical assistance in integration of UNICELL-CLUSTER™ with Hydrogen Vehicle Filling Station at Xerox El Segundo $36,000.00

Total Cost-share on Vehicle Filling Station $81,000.00

Total Cost-share on Xerox/CAN Project $363,000.00

Please don't hesitate to call if further detail is required.

Best regards

Matthew Fairlie
Director of Technology, Energy Projects
David Hare  
Environmental Services and Operations Manager  
8611 Santa Monica Blvd.  
West Hollywood, CA 90069  

April 20, 1995  

Paul Staples  
Project Manager  
Clean Air Now  
660 Venice Blvd. #112  
Venice, CA 90291  

RE: FUNDING SUPPORT  

Dear Mr. Staples:  

As per our last meeting, I am forwarding to you a listing of the City’s intent to participate in the development of a hydrogen powered vehicle fleet. To date, the City has budgeted almost $9,000 for the purchase and retrofit of a Ford Ranger Pickup Truck. I have received and reviewed the specifications for the vehicle and the City is currently in the process of purchasing a vehicle which meets the stated specifications.  

I will keep you informed of our progress in locating and purchasing a vehicle. I look forward to our next meeting and the further development of this project.  

Sincerely,  

[Signature]  

David Hare  
Manager, Environmental Services and Operations
March 7, 1995

Robert M. Zweig, MD
Chairman, Board of Directors
Clean Air Now
1222 Lincoln Blvd.
Santa Monica, CA 90401

Re: Development of hydrogen generation and fueling facility

Dear Dr. Zweig:

In furtherance of our meeting on March 3, 1995, I want to communicate to you that the Cabazon Tribe has a strong interest in further exploring the mutual benefits of co-developing a hydrogen generating and fueling facility in the Coachella Valley with your group.

We view the development of clean renewable energy sources is a paramount issue for southern California. I look forward to touring your facility at UCR in the near future.

Please contact me when you return from Washington.

Sincerely,

Michael Derry
Planner, Cabazon Band of Mission Indians

MRD/lcw
April 11, 1995

Ms. Christine Ervin
Assistant Secretary for Energy
Efficiency and Renewable Energy
U.S. Department of Energy
1000 Independence Ave., S.W.
Room 6C-106
Washington, D.C. 20585

Dear Ms. Ervin:

In follow-up to your request on March 31 at the road rally in Los Angeles, I’m enclosing a copy of the hydrogen article featured on the March 19 cover of the Los Angeles Times Magazine. I think you will find it very interesting and worthwhile.

Thank you for visiting our hydrogen powered truck and discussing the Clean Air Now/Xerox Solar Hydrogen Vehicle Project. It was a pleasure talking with you once again; it is heartening to listen to someone who cares about the environment and future generations and is in a position to influence people, policy and politicians.

Ms. Ervin, we greatly appreciate you talking with Representative Walker and Senator Harkin regarding hydrogen technology funding. As you know, the United States must increase its commitment to the advancement of the hydrogen economy if we are to maintain our global competitiveness and protect our environment for the long term.

Sincerely,

James J. Provenzano
Managing Director

ervin.doc

cc: Lucito B. Cataquiz - U.S. Department of Energy
     Bill Ives - U.S. Department of Energy
The Last Best Hope of Earth?

Trapped in This Water Is the Simplest Element of Them All—Hydrogen. Can It Solve All Our Complex Problems? Take a Trip to the Loneliest Frontier of Energy Research.

By Alan Weisman
Interstate 70 enters Golden, Colo., and begins to curl through the foothills of the Rockies. There it bisects an unassuming clump of brick buildings—the National Renewable Energy Laboratory. Among the government’s national laboratories, NREL is modest, operating on a fraction of the billions commanded by atomic research giants like Sandia, Los Alamos and Lawrence Livermore. Inside, there are no monstrous particle accelerators; experiments here are more likely to proceed in test-tube racks, bell jars and small glass beakers, like the one John Turner is filling with a clear solution of water and household lye.

Turner, a chemist with a graying blond beard and gold-rimmed glasses, sticks a narrow glass slide, coated on one end with a black, mica-like substance, into the lye solution. The humming lab ventilators mask the sound of the vehicles whizzing by on the nearby interstate, but Turner has spent most of his career here, and during those years he’s always had those cars in mind. As he aims a pencil-thin beam from a high-intensity lamp at the flask, he puts it this way: “Suppose someone announced he intended to ship millions of gallons of a carcinogenic, explosive fluid that emits toxic fumes through our downtown and then store it underground in our neighborhoods. People would rise up in anger, right?”

Wrong. Just outside on I-70, cars are spraying residues of that very poison all over the mountains. After 11 decades of tinkering, their internal combustion engines are miracles of technology with hundreds of moving parts. Yet various laws of physics still limit their ability to extract energy from petroleum. Nearly three-fourths of its potential simply radiates away or pours, partly combusted, out the tailpipe, rising in geologic layers of brown muck until the Rockies themselves dwindle to ghostly smudges.

John Turner is among a cadre of scientists trying to suppress what he regards as humanity’s most pervasive, and self-inflicted, epidemic. In a little more than a
Researcher John Turner separates water into hydrogen and oxygen at the National Renewable Energy Laboratory near Denver.
Hydrogen derived from solar energy emits no noxious fumes

Since even before the moon shots, all U.S. astronauts’ heat, electricity and drinking water have been derived from hydrogen and solar power. While the space program is the first step toward realizing these scientists’ dream: to switch the planet from an economy fueled with dirty coal and petroleum to one run on clean hydrogen.

The idea of something so ubiquitous—hydrogen—is the most abundant element, comprising three-fourths of the mass of the universe—replacing diminishing fossil fuels seems the stuff of fiction. Once, in fact, it was: In 1870, Jules Verne’s “Mysterious Island” described a world that would one day derive its energy from hydrogen.

Back then, Verne didn’t realize that this source of energy was also virtually pollution-free. The cycle is so elegant it seems nearly miraculous: Separating water into its two constituent gases, hydrogen and oxygen. Burn the hydrogen for fuel, and it re-couples with oxygen to form water again. No nasty particulates, no insidious carbon monoxide, no eye-stinging Ozone or sulfur dioxide (at high temperatures, however, small, controllable amounts of nitrous oxides can form when hydrogen is burned in the presence of air).

Mainly, though, hydrogen’s exhaust is plain water vapor—which can then be recaptured and neatly converted again to hydrogen.

According to Bill Hoagland, founder of NREL’s hydrogen program, it would take less than a gallon of water to get the same range from hydrogen that cars currently get from a gallon of gasoline. Because hydrogen can be made anywhere, it’s told repeatedly, there would be no more dependency on imported oil. No more OPEC. Maybe no more global warming, either, because it emits no greenhouse gases. As for hydrogen’s unfortunate association with bombs and blimps, like the ill-fated Hindenburg, Hoagland reminds me that fossil fuels also readily explode, and studies rate hydrogen safer because it’s nontoxic and dissipates quickly.

It seems like the perfect fuel. Yet, these scientists insist, it’s been under-researched, under-funded and virtually ignored in Detroit, which perseveres in its allegiance to petroleum, and in Washington, which persists in keeping the lid shut on the Persian Gulf.

So why aren’t we leaping at this chance to end pollution, energy wars and economic bondage to a few privileged locations that float atop the earth’s ebbing supplies of oil? Much of it comes down to money and the seemingly incontestable reign of the petroleum industry. Unlike natural gas, to which hydrogen is often compared, you can’t dig a hole and find it. To tap hydrogen’s energy, you have to expend energy because it’s always combined with something else. Having to un-combine it makes it more expensive, at least in the near term, than crude petroleum products, including natural gas. And no alternative-energy constituency has the clout to buck powerful fossil-fuel lobbies and find a way to pay for retrofitting the world for a brand-new technology.

Currently, the U.S. Department of Energy allot hydrogen about one-nineth of what it spends on continuing petroleum research. (And two-thirds of DOE’s budget doesn’t go for energy at all, but for nuclear weapons research and cleanup.) Nor has the public thus far demonstrated much interest in trading the ease of dirty energy, available at the turn of an ignition key or of a light switch, for a major commitment to something cleaner and renewable. Yet hydrogen’s time has come. The Japan-U.S. Hydrogen Energy Conference is convinced that hydrogen’s time must come. Fossil fuels will become expensive again; even today, their true price isn’t revealed at the gas pump, where the numbers don’t include the cost of pollution and the expense of protecting our interests in the Middle East.

Other countries are less reluctant about hydrogen than the United States. Two years ago, Japan, an island nation frightened by the prospect of rising seas if the ice caps start to melt, unveiled a multibillion-dollar 28-year program to form a global hydrogen system. The Japanese are talking power plants, cars, buses, planes, ships and rockets, all over the world, all fueled with renewable hydrogen.

And there’s a recent surprise announcement by Daimler-Benz, the parent company of Mercedes-Benz, that has excited many people here: The German auto maker claims it has cleared the major obstacles to producing the first commercially viable hydrogen-powered automobile. Unless Mercedes is just trying to spook the competition, hydrogen’s prospects have suddenly improved faster than anyone dared hope. The Mercedes in question runs on a fuel cell, a refillable device that, like a battery, chemically converts fuel directly to electricity without having to burn it. Fuel cells can function on methanol or natural gas, but with hydrogen, they’re up to three times more efficient than conventional engines.

The most advanced models, including the one Daimler-Benz uses, come from the Vancouver-based Ballard Power Systems Inc., which designed fuel cells for the Canadian defense department, using technology NASA developed for the Gemini mission and then shelved. Originally large, bulky affairs of stackable metal plates separated by membranes resembling plastic wrap, Ballard’s fuel cells are now small enough to fit inside a minivan class. “When we start producing them in volume,” says Ballard co-founder Keith Prater, a former University of Texas chemist, “the price will shrink, too.”

SURROUNDED BY CONFERENCE DOORS PROMOTING THE LATEST IN photovoltaics, fuel cells and electrolyzers—devices that separate water into oxygen and hydrogen—I ask Princeton physicist Joan M. Ogden if the United States is letting the future slip away to foreign competitors. She tells me of a recent, unreleased General Motors study admitting that non-polluting fuel cells could be mass-produced for the same cost as a conventional engine. “Actually, they should cost less, because they have no moving parts,” she says. “They’ll also last longer and be cheaper to maintain.”

But while Mercedes, BMW and Mazda race to bring a hydrogen car to market, U.S. auto makers, by comparison, don’t seem very interested.

A few years ago, Ogden quit Princeton’s glamorous fusion energy program to engage in relatively impoverished research in renewable hydrogen. “Fusion will take decades,” she told aghast colleagues. “I want results in my lifetime.” Soon after, she co-authored a book that proposed making hydrogen by splitting water with electricity from solar photovoltaic (PV) cells. (In this process, as electricity made from sunlight passes through a pair of electrodes immersed in water, hydrogen bubbles collect around one pole and oxygen around another.) Although PV is still expensive, Ogden argued that mass production and technological improvements would lower costs until they intersect with rising oil prices. The book has been alternately praised and scorned, the latter because of a map showing how much of the United States would have to be covered by photovoltaics to produce sufficient hydrogen to meet the total U.S. annual energy needs. The area is designated by a circle that reaches from Alaska up to the Mexican border. Ogden says she didn’t try to guess the value of all that real estate miss the point, she insists. No one ever suggested putting all the PV in the same place.
zone-depleting gases. Think of it: clean air all over L.A.

"Obviously, deserts are ideal, because they get the most sun, and minimal rainfall is enough to make plenty of hydrogen. But I did a little calculation once. Let's say 2,000 people who work at Princeton drive there every day. If I wanted to run their cars on hydrogen, how much roof space would I need to cover with PV to make enough hydrogen fuel for them? I figured that by putting panels on fewer than half the university rooftops, even with New Jersey's humble sunshine levels, we could convert all those cars to hydrogen. Think if we did that all over the country.

That same afternoon, Peter Lemman, an environmental engineer from Humboldt State University in Northern California, tells me what it would take to do the same for the 9 million cars in the Los Angeles Basin: "An area about 940 square miles. About two-thirds the size, say, of Edwards Air Force Base."

Cover Edwards Air Force Base with shiny photovoltaic panels?

"Sure. It would mean a fairly dramatic reorientation of priorities, and a huge expenditure, probably like building the interstate highway system. That took $100 billion and 34 years. But we did it because as a society we decided it was important. Wouldn't you think that eliminating all smog might be important?"

All week, people here have been repeating a mantra of massive American investments in the future that paid off, like the Marshall Plan, the interstate highway system and—especially during a pilgrimage to the old Apollo launch pad—President Kennedy's decision to put men on the moon. Although these ventures involved enormous expense, they were embraced by the public because of visionary, daring leadership, but they also coincided, rather than conflicted, with powerful interests. A commitment to transform America's energy infrastructure to accommodate clean hydrogen would, I suspect, evoke awesome resistance from the petroleum and auto industries. And decisions these days seem dictated more by the global marketplace than by the foresight of leaders.

Yet the one vision these scientists from Argentina, Egypt, Russia, Germany and Japan tell me may save civilization from choking on its own exhaust emanates from California. They refer specifically, and reverently, to mandates by the California Air Resources Board and the South Coast Air Quality Management District, which require that zero-emission vehicles (ZEVs) constitute 2% of all cars sold in the state by 1998 and 10% by 2003.

The allure of these requirements is the fact that, with one out of 18 Americans living in the L.A. Basin alone, whoever can first manufacture a viable car that meets this standard will get rich. Everybody assures me that batteries aren't going to do it; the acceleration is rotten, the range is too short, and they must be recharged by plugging into dirty power plants that only shift the pollution elsewhere. The assumption here is that the only way to build a real ZEV is by using a hydrogen fuel cell, and California's regulations will help force that technology into existence. The air quality district's chief scientist, Alan Lloyd, who's speaking at the conference, agrees.

Lloyd's problem, though, is that he is not exactly considered a prophet in his own land. Rather than instilling native pride, California's world champion air-quality laws, which some believe have wrecked the state's economy, have barely survived legislative plots to scuttle them.

And despite the vaunted environmental pedigree of Vice President Al Gore, the Clinton Administration hasn't been much help either. While a few projects like experimental wind farms have been encouraged, federal efforts have focused more on improving energy efficiency than on developing new sources. Most frustrating to Alan Lloyd is a multimillion-dollar Administration program called PNGV the Partnership for a New Generation of Vehicles, whose goal is to deliver a prototype car that gets triple today's expected gas mileage—about 80 miles per gallon—by the year 2004. "Which means that after 10 years, they will develop a vehicle that will be illegal in California because it's too dirty," he says, glaring heavenward. "That's unacceptable. A new-generation vehicle should be fuel-efficient and clean. Leadership should come from the White House, but their agenda is being driven more from Detroit."

Other energy advocates claim the technology for an 80-m.p.g. vehicle already exists, but the Administration has simply caved in to the Big Three auto makers and the oil industry. But since I haven't seen filling stations dispensing hydrogen on American street corners, I ask Lloyd if a fuel-cell vehicle designed to run on the stuff is really practical.

In the interim, there are lots of ways to make hydrogen besides solar energy, Lloyd explains. Using steam, it can be derived from natural gas or even mixed with it—known as town gas, that was what America once burned for light and cooking. Hydrogen improves the potency and lowers the emissions of natural gas, and with some modification it might even be shipped through natural gas pipelines. At some point in the future, a similar alarm was once sounded by buggy-whip manufacturers.

The real obstacle, Lloyd says, is America's current lust to pawn the future for the sake of profits today. "While Detroit hires 100 attorneys to defeat every new emissions standard we establish, Japan assigns 1,000 engineers to meet the challenge."

Maintaining energy's status quo might make some sense, or at least some money, for purveyors of petroleum and internal-combustion engines. But the conference's keynote speaker assures us that the decision won't really be theirs. University of Colorado physicist emeritus Albert A. Bartlett says he knows little about hydrogen but something about basic arithmetic. He's particularly drawn to calculating the time it takes for things to double. This is pertinent, he says, to consumption of fossil fuels, because it allows the petroleum and coal industries to deceive the world about how long those resources will actually last.

To illustrate what he means, he proposes that we imagine a species of bacteria that reproduces by dividing in two. Those two become four; the four become eight, and so forth. "Let's say we place one bacterium in a bottle at 11 a.m., and at noon we observe the bottle to be full. At what point was it half full?" The answer, it turns out, is 11:59 a.m.

"Now, if you were a bacterium in that bottle, at what point would you realize you were running out of space? At 11:56 a.m., when the bottle is only 1/32 full, and 97% is open space, yearning for development?"

Everyone giggles. "Now suppose, with a minute to spare, the bacteria discover three new bottles to inhabit. They sigh with relief: They have three
times more bottles than had ever been known, quadrupling their space res- 
source. Surely this makes them self-sufficient in space. Right?"

Except, of course, it doesn't. Bartlett's point is that in exactly two more
minutes, all four bottles will be full. Likewise, when President Jimmy Carter
noted that in each of three previous decades the world had burned more
fuel than had been consumed previously in all of history, it meant that fuel
consumption was doubling every decade. That rate slowed temporarily
with the energy crisis, but now, with world population rising and today's
breakneck industrialization in the Third World, the exponential gobbling
of limited resources is again accelerating.

"It's seriously misleading when we hear, for
example, that at current levels of output and

proposed cuts in funding provided by the Matsunaga Act.

In Washington, Harkin's hydrogen consultant, Sandy Thomas, shows me
a chart of the Department of Energy's budget. Out of $18.6 billion, $10 bil-
lion goes for nuclear-weapons research and cleanup. "That's even though
we aren't building nuclear weapons anymore. It's an upper-middle-class
welfare program for nuclear scientists. Then there's nearly $1 billion for
fossil fuels, even though they're running out; $500 million for atomic fis-
sion, though we've stopped building nuclear reactors, and nearly half a
billion for fusion at the energy Sciences office of which even its most optimistic
proponents admit it at least 40 years away."

"And for hydrogen research? I ask.

"Ten million."

**Hydrogen is already on the road, powering some Vancouver buses**

I gape. "I know," he says.

"We've argued for shifting even $100 million out of
DOE's nuclear-weapons fund. But those decisions
are made at the top. It's hard to reach Harkin's or O'Leary's
ear on this one."

At a White House conference
on environmental technology in December,
chaired by Gore, Energy Secretary O'Leary admits to me that in the wake
of a new Republican Congress that threatens to cut not just budgets but
the entire DOE, she questions the wisdom of bankrolling fusion. On hydrogen
however, she doesn't yield. "I'm not an apostle for traditional energy. But
my strong opinion is that hydrogen isn't there yet. We have to deliver non
mature technologies to market first. Excepting fusion, I think our invest-
ments fairly represent the energy marketplace for the near and mid-term."

At the conference, Gore, five Cabinet officers and President Clinton's sci-
cence adviser meet with 1,400 industrialists, entrepreneurs and environ-
mental representatives to discuss how the U.S. can prosper in the growing
international market for clean, green technology. There are seminars on
environmental export financing and transitions to industrial ecology—
barely any mention of energy, except for a small workshop on fuel cells and
another on transportation technologies.

In the latter, I join a study group chaired by Ford's representative for the
Partnership for a New Generation of Vehicles. Among the points we've
asked to consider are the prospects for introducing alternative fuels like
hydrogen to diesel cars. Shortly after their inauguration, he pre-

sent ed the new Administration with a $400-page proposal for a sustainable
energy future based on hydrogen. It showed how, by using solar photovoltaic
electricity to split water, hydrogen actually becomes a way to store the power
of the sun, because it can be burned at night or shipped to cold climates
where solar energy is scarce. It explained that the cheapest way to produce
hydrogen could be through "electro-farming"; using marginal land to grow
grasses and crops like switch

**SO HOW WOULD YOU GET PEOPLE TO BUY THIS THING?** I YELL TO
Thomas Klaiber; but he doesn't hear me, because a low-slung, Class C rat-
ing series model and a black, V-12 600LSi, roar past us at that instant, on
on either side. We're on the Mercedes-Benz test track in Stuttgart, Ger-
many. Klaiber, a mechanical engineer, is head of the Daimler-Benz hydrc

gen fuel cell group; the van he's driving is the hydrogen-powered vehicle
that prompted Mercedes' grand announcement.

If this is really the future we're driving into, at a top cruising speed of 5
miles per hour, it's a little like riding the tortoise while being passed by
leaps and bounds of fast cars. He didn't get that fact told the President. He should have been more imaginative. When we negotiated the
banked curves and climb steep little hills that suddenly appear in the mic-
dle of the straightways. Yet the van itself feels surprisingly normal. And
the surrounding internal combustion thunder, the most noticeable differ-
ence is how quietly it runs. The fuel cell itself makes no sound. There's onl
the hum of an air compressor.

Some significant technological challenges remain unmet, however. Much e

**Continued on Page 4**
Hydrogen

Continued from Page 22

The cargo area is filled with fiberglass pressure tanks. Although hydrogen has up to three times the efficiency of gasoline, its lightness gives it such low density that even when compressed, its storage requires at least four times the space of a conventional gas tank. This is fine for the fuel-cell buses that Ballard Power Systems is operating successfully in Vancouver, because there's plenty of room on their roofs to store hydrogen. To partly alleviate this problem for passenger cars, Daimler-Benz plans to shrink the fuel cell to one-fourth its current size, even as it increases horsepower.

"The alternative is we store the hydrogen in metal hydrides," Klaiber says, referring to a process in which certain metals absorb hydrogen like a sponge, then release it when heated. "They're fine for commuter cars; citizens tested the space little.

Plucking strokes his mustache. "We'll have to find a way to make clean cars fascinating," he says. "Like selling people on sales tax.

"It's not an altogether encouraging analogy, especially in the context. Germany, world leader in hydrogen research investment—about $12 million a year since the late 1970s until it was blindered by the expense of renumeration—is hardly the renewable-energy economy I imagined. An official from the state of Bavaria's electric utility, which has the world's biggest hydrogen pilot facility, admits there are no plans to scale up to a full-sized working plant. So what will they do in 30 years, when Bavaria's aging nuclear plants must be phased out and fossil fuels are expected to be scarce?

"I can't answer that question. Nobody can. Nobody gives a damn about the future."

Back in my own country, I share this story with Michael Heben, a lanky young material scientist at the National Renewable Energy Laboratory in Golden, Colorado. Heben, a lanky young mate¬rials scientist at the National Renewable Energy Laboratory in Golden, Colorado, is "the love Americans have for running the planet freely in their own cars. Hydrogen will make that possible when the present technology gets too dirty to extend into the future."

"It has introduced legislation calling for a quadrupling of research funds for hydrogen over the next three years. Part of the money will be matched by nonfederal sources and part expropriated from technologies Walker believes are either futile or outdated.

"We have little play for industries that resist change, including auto makers. If Edison were to invent the light bulb today, the headlines would read, '200,000 candle makers lose their jobs.' We've been through this before, like when cars put blacksmiths out of business. It's wrenching, but overall our national competitiveness gets stronger. The same thing will happen in energy. The people themselves will demand it."

He pauses to gaze at a plaque naming him the latest recipient of the National Hydrogen Ass'n's Spark M. Matsunaga Award. "Driving on the interstate, I watch them stringing fiber-optic cable up the median strip for the Internet. The government talks about the Internet but can't come up with a structure. Meanwhile, it's happening because people want it. When they realize they need clean hydrogen, somebody will find a way to supply that, too."
### Financial Status Report

**Department of Energy**

**Recipient Organization**

**Project/Grant Period (See Instructions)**

**FROM** (Month, day, year) **TO** (Month, day, year)

**January 1, 1995** **March 31, 1995**

**Final Report**

**Basis**

**Cash**

**ACCRUAL**

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#### Certification

I certify to the best of my knowledge and belief that this report is correct and complete and that all outlays and unliquidated obligations are for the purposes set forth in the award documents.

**Signature of Authorized Certifying Official**

James J. Provenzano

**Secretary/Project Manager**

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**Indirect Expense**

**A. Type of Rate**

- [ ] Provisional
- [ ] Predetermined
- [ ] Final
- [ ] Fixed

**B. Rate**

**C. Base**

**D. Total Amount**

**E. Federal Share**

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**Remarks:** Attach any explanations deemed necessary or information required by Federal sponsoring agency in compliance with governing regulations.

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**Standard Form 269 (7-76)**

Prescribed by Office of Management and Budget

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