EBH-4

October 7, 1976

REPORT

SPE WATER ELECTROLYSIS TECHNOLOGY DEVELOPMENT FOR LARGE SCALE HYDROGEN PRODUCTION

Contract EY-76-C-02-2675 *000

(Formerly Contract #E(11-1)-2675)

Progress Report No. 4

Reporting Period: June 15, 1976 through September 30, 1976

Prepared for

Energy Research and Development Administration (ERDA)
Division of Conservation and Technology
Washington, D. C. 20545

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Progress Report No. 41.0 INTRODUCTION

1.1 This is the fourth quarterly progress report describing effort in Water Electrolysis Technology Development for Large-Scale Hydrogen Production being performed by the General Electric Company, Direct Energy Conversion Programs (GE/DECP), for the Energy Research and Development Administration (ERDA) under Contract #E(11-1)-2675.

This progress report covers the effort from June 15, 1976 through September 30, 1976.

1.2 Report Format

As agreed at the joint meeting at GE, Wilmington on August 27, 1976, the structure of this report has been modified to provide technical information from all parts of the Bulk Hydrogen Generation program to all customers.

To do this, and satisfy each customer's contractual needs, this and subsequent quarterly reports will be structured as follows:

Cover page and Section 1, Introduction, will contain program and contractual information primarily unique to a specific customer and will be different for each customer.

Section 2, Technical Progress, and Section 3, Plans for Next Quarter, will cover all aspects of the program and will be common to all customers. Sponsorship of the individual tasks will be indicated.

2.0 TECHNICAL PROGRESS

2.1 Summary of Progress

The following is a summary of the technical results of the bulk hydrogen generation technology development effort during the last quarter.

2.1.1 Task 1.1 - Low Cost Current Collector Development (ERDA Sponsored)

- o Porous carbon fiber paper selected as the cathode membrane and electrode assembly support based on over 1200 hrs operational evaluation.
- o Three potential anode supports are under test. All three appear technically satisfactory after 500 to 1200 hours operational evaluation on each.
- o Optimization of molds and molding techniques for a foil backed ribbed carbon collector of bipolar design, including ribbed flow fields, manifolds, ports and sealing surfaces, is in process. Trial samples look good.

2.1.2 Task 1.2 - High Temperature Operation (ERDA Sponsored)

- o Over 2800 hours demonstrated at 300°F on platinum screened cell.
- o Over 2200 hours demonstrated at 300°F on cell with carbon cloth cathode current collector.
- o Updating of high temperature test facilities started.

2.1.3 Task 1.3 - Catalytic Electrode Development (Niagara Mohawk Sponsored)

- o 48 hours screening tests of 56 different anode catalysts have been completed.
- o A 500 hour life test program of twelve anode catalyst types which showed promise on the screening tests has been started.
- o Attempts to stabilize RuO_x for use as an anode catalyst are being pursued.
- o Low loaded cathodes on graphite substrates show performance to

within 25 MV of baseline. Optimization of substrate thickness and fabrication procedures continuing.

- o Twenty five low loaded anodes catalyst/substrate combinations have all shown poor performance stability with time. Investigation of reduced decal loadings is being initiated.

2.1.4 Task 1.4 - Low Cost Polymer Development (Niagara Mohawk Sponsored)

- o Continued development of the grafted TFS membrane has shown greatly improved physical characteristics and encouraging performance for samples in the 25 - 45% graft level range.

2.1.5 Evaluation of H₂ Enrichment on Older Gas Pipelines

- o Test plan has been firmed. Facility preparation has been initiated and the pipe samples have been procured.

2.1.6 Task 1.5 - Cell and SPE Optimization (GE Sponsored)

- o Initial testing of cells with tandem (anion/cation monobed followed by cation only) deionizers show improved voltage invariance.
- o Completed evaluation of a hydraulically loaded cell test fixture which eliminates gaskets and gives uniform cell compression. Hydraulic fixtures are being factored into the low cost current collector and high temperature operation tasks.

2.2 Discussion of Results

2.2.1 Task 1.1 - Low Cost Current Collector Development (ERDA Sponsored)

2.2.1.1 M and E Support

As discussed in the last quarterly report, in order to prevent creep of the M and E into the grooves of a ribbed current collector configuration at 300°F operating temperature, additional support of the M and E across the grooves is required. Support is required on both the anode and cathode sides.

In their most simple form, such support would be thin porous plates between the M and E and the ribbed collector as shown in Figure 1.

Figure 1. Test Set-Up - Gas Pipe Testing

2.2.1.1.1 Cathode (Hydrogen Side) Support

The use of carbon fiber paper as the cathode M and E support continues to look fully satisfactory. It has been utilized in conjunction with machined or molded grooved carbon cathode collectors as the "standard" cathode collector configuration in all recent carbon collector testing and has demonstrated over 1200 hours life to date. (The test is still in process.)

In view of this, evaluation of alternate cathode M and E support schemes such as molded porous carbon plates has been discontinued, and until a disadvantage becomes apparent, carbon fiber paper will be utilized as the cathode M and E support.

2.2.1.1.2 Anode (Oxygen Side) Support

Three candidates for the anode M and E support have been initially identified and are currently being evaluated. The results to date of comparative operational tests are shown in Figure 2. All show promise on the basis of support and performance.

A porous tantalum plate (.007 in. thick, 60% porosity with platinum plating) is being evaluated in cell #HT59B utilizing the new hydraulically loaded test fixture (ref. para. 2.2.5.2). It has accumulated over 700 hours to date, and since installation of an improved deionizer (ref. para. 2.2.5.1) has shown good performance stability.

A single layer of 6/0 titanium screen is used as the anode M and E support in cell #HT58. It has accumulated over 1200 hours to date and again, since installation of an improved deionizer, has shown good performance stability. Its slightly higher voltage level is attributable to residual contamination picked up during the 500 hours prior to the deionizer replacement.

A perforated titanium foil (1 mil thick with 3.5 mil holes on 7 mil centers) is the anode support in cell #HT63 and has accumulated about 500 hours to date. This cell has had the tandem deionizer installed since the start of test and is also showing good performance stability.

All of the above cells have carbon fiber paper as the cathode support.

If all three cells continue to give satisfactory support and performance indications, the decision as to which to utilize in future scale up will depend on cost and size availability. Information is currently being requested from vendors to assess these factors.

Figure 2. Comparative Performance - Anode Support Evaluation

2.2.1.2 Bipolar Plate Development

A major step in the development of a low cost carbon collector is the design and test of a molded carbon collector of bipolar design in lab sized cells.

The design for a 3 X 3" bipolar collector including ribbed flow fields, internal manifolds, entrance and exit parts, and gasketless sealing surfaces has been completed. This design is illustrated in Figure 3.

Trial foil backed carbon collectors have been molded. Present emphasis is on development of foil forming, release of parts, and sealing surfaces.

2.2.2 High Temperature Operation (ERDA Sponsored)

2.2.2.1 Life Testing

The 3000°F life testing of a cell containing woven carbon cloth as the cathode current collector and niobium screen as the anode current collector was terminated after 2200 hours. It was found that gasket deterioration in the port areas had led to some O₂ to H₂ side leakage.

This test showed:

- A. the compatability of carbon with the cell cathode environment over long periods of time and,
- B. the tendency of silicone rubber gaskets to deteriorate at high temperatures.

In the low cost current collector under development the membrane seals directly to the current collector, thus eliminating the need for rubber gaskets.

The 3000°F life testing of a cell containing platinum screens as the cathode current collector and niobium screens as the anode current collector was terminated after 2800 hours due to gasket deterioration. A plot of its performance vs. time is shown in Figure 4.

At the 2500 hour point, an experimental cation only deionizer was installed in an attempt to reduce the 40 μ V/hour voltage increase rate that had been experienced up to that time. With the "cation only" deionizer, however, the voltage increased rapidly. The test was terminated at the 2800 hour point and the membrane removed for analysis as part of the improved deionization task. (See para. 2.2.6.1.)

Figure 3. Bipolar Collector Configuration

Figure 4. Cell HT-35 1000 ASF Performance at 300 F

This test again, (1) stressed the need for improved deionization to achieve invariant performance over long operational periods, and (2) stressed the need for a gasketless collector design.

2.2.2.2 Test Facility Modification

In view of the pronounced effect of ionic contamination on all performance at high current densities and high temperatures, and the need for improved cell compression via the newly designed hydraulically loaded test fixtures, it is imperative that the test facilities be up-graded to

- o eliminate potentially contaminating materials from the system,
- o improve the water quality monitoring both out of the deionizer and out of the cell itself,
- o adapt to the hydraulically loaded fixture,

and in order to improve the reliability of the test station, to

- o convert to electrical heating of the inlet water and cell end plates,
- o incorporate on-line resistant measurement equipment,
- o provide each station with independent electrical feed.

Under this task during the last quarter, the necessary modifications were designed and modifications of one of the five high-temperature test stands was initiated and is about 75% complete.

It is planned to continue up-grading of the test stands program funding levels permit.

2.2.3 Catalytic Electrode Development (Niagara Mohawk Sponsored)

2.2.3.1 Alternative Catalyst Systems

Synthesis of Candidate Catalysts

During this quarter, an additional 16 ruthenium oxide anode catalyst samples were prepared with variations in methods, binders and process treatments aimed at obtaining a stable RuO_x anode electrode. This brings the total number of anode catalyst samples synthesized to date to 56.

Evaluation of Candidate Catalysts * (See Footnote)

Cells made from the 16 additional RuO_x samples were all subjected to 48 hours of operational screening tests. The results of this testing are shown in Figure 6, along with the initial two RuO_x samples tested during the last quarter.

It can be seen that all the ruthenium oxide anode catalyst cells showed initial performance superior to E50 but exhibited rapid performance deterioration with time. Stabilization of the ruthenium oxide catalyst by baking at temperatures of 500° and 600°C showed some promise based on the 48 hour testing (see Figure 5, cells 85, 103, 104), but during continued testing (shown in Figure 6) performance deteriorated in the 50 to 75 hour range. A ruthenium oxide sample baked at an intermediate temperature of 550°C is currently in process.

Life Testing

After consideration of the 48 hour screening data obtained last quarter (shown in Figure 7) the following cells were selected for 500 hour test evaluation.

<u>Cell</u>	<u>Anode</u>	<u>Cathode</u>
NM-02	Pt/Ru/Hf	Std. Pt.
NM-03	Pt/Ru/Zr	Std. Pt.
NM-05	Pt/Ru/Ta	Std. Pt.
NM-14	Ru/Ir/Hf	Std. Pt.
NM-15	Ru/Ir/Zr	Std. Pt.
NM-17	Ru/Ir/Ta	Std. Pt.
NM-18	Ru/Ir/W	Std. Pt.
NM-32	Ir/Nb	Std. Pt.
NM-35	Ir/Ti	Std. Pt.
NM-50	Pt/Ru	Std. Pt.
NM-69	Pt/Ru	Pd
NM-70	Ru/Ir	Std. Pt.

The first four cells evaluated for 500 hour performance were a baseline cell, NM-50 (Pt/Ru anode), NM-69 (Pt/Ru anode with palladium cathode) and NM-70 (Ru/Ir anode). Cell potential versus time for these cells is plotted in Figure 8.

Both cells NM-50 and NM-70 had stable performance to 500 hours with NM-50 ending up 6 MV better than baseline and NM-70 20 MV worse than baseline. The performance decay of cell NM-69 may have been due to the palladium cathode electrode. Work on palladium catalyst as a replacement for platinum in the cathode electrode has been temporarily discontinued.

* Note: Pt-Ir and Pt-Ru are catalyst systems developed by the General Electric Company, on it's own funds, prior to the award of these contracts.

Comparative Performance - RuOx Anode Catalyst
 Relative to E50 Baseline @ 1000 ASF @ 180°F

Figure 5.

Figure 6. Life Test of RuOx Cells

Comparative 500 Hour Life Tests - Binary Anode Catalyst

Figure 8.

The second group of cells operated for 500 hours was the Pt/Ru/transition metal group. Cell voltage of NM-02, 03 and 05 is plotted versus hours of operation in Figure 9. All three cells proved to be less stable with time than the baseline cell. It should be mentioned here that these three cells were the same cells that were operated for the 48 hour screening test. Each cell was then disassembled and stored prior to being reassembled into hardware for the 500 hour stability test. Whether or not this had any effect on the stability performance has not been determined as yet. One or more of these cells may be prepared as new cells and retested for 500 hours to see if disassembly and storage was a factor in the stability test.

A third set of cells is now being tested for 500 hour stability. Cells NM 14-1 (Ru/Ir/Hf) and NM 15-1 (Ru/Ir/Zr) and another baseline cell have given very stable performance for 200 hours. All three of these cells are new cells and not the same cells which were performance tested during the 48 hour screening survey. Figure 10 shows a plot of cell voltage versus hours of operation for these cells.

2.2.3.2 Reduced Catalyst Loading

The approach to this task has been to deposit a thin layer of active catalyst on a conductive decal substrate. The substrate must be resistant to the environment of its particular electrode (oxidation resistant on the anode and resistant to reduction on the cathode). See Figure 11 for a diagram of the cell cross section.

Evaluation of Substrate Materials

A total of 40 low loaded electrodes have been evaluated to date. Fifteen of these were low loaded cathodes and 25 were low loaded anodes.

Cathode

The results of the 48 hour screening tests on the 15 low loaded cathode cells are shown in Figure 12. Graphite shows promise as a substrate for the cathode electrode. Of the 15 low loaded cathodes; five contained Poco graphite with platinum concentrations of .02 to .25 gm/Ft². Performance of these five varied only 25 to 65 MV from baseline (see Figure 12).

Two other graphite materials and one carbon sample were evaluated with results not quite as good as Poco graphite.

Variations in processing have shown that pressing of the decal before sputtering with platinum enhances cell performance.

Figure 10. Comparative 500 Hour Life Test - Ternary Anode Catalysts

REDUCED CATALYST LOADING

APPROACH

Cathode		Anode	
<u>Substrate</u>	<u>Catalyst</u>	<u>Substrate</u>	<u>Catalyst</u>
Carbon/Graphite	Platinum	Transition Metal Silicides	E50
Transition/Metal Silicides		Transition Metal Borides	Ir
		Transition Metal Powders	Ru
			Pt Alloys of Ru

Figure 11.

Figure 12.

Sputtering atmosphere (gas present in bell jar prior to evacuation for sputtering) has an effect on cathode performance. The preferred ranking of sputtering atmosphere is:

air > helium > argon >>> nitrogen

Optimization of the sputtered graphite cathode is proceeding. The approach now being followed to reduce the electrode resistance is:

- A. fabricate thinner Poco graphite substrated,
- B. sputter the Poco graphite material with platinum prior to decal fabrication followed by the standard surface sputter. Either one of these procedures, or both, may lower cathode electrode resistance.

One 500 hour stability test has been completed (NM 46-1) and a second test is in process (NM 109) on low loaded cathodes. A plot of cell voltage versus hours operated is shown in Figure 13. Cell NM 46-1 was not as stable as the base-line cell during the 500 hour test. Whether this is a characteristic of low loaded cathode cells or only of one sample has yet to be determined.

Anode

The results of the 48 hour screening tests of the 25 low loaded anodes is shown in Figure 14.

None of the special substrates evaluated to date have performed well. Transition metals, transition metal borides and transition metal silicides have given high impedance decals while carbon/graphite and ruthenium sponge substrates were unable to withstand the anodic environment.

In order to evaluate sputtering techniques for the anode electrode, platinum decals were used as the anode substrate. Platinum decals were evaluated after sputtering with iridium and platinum - 10 ruthenium. The substrate decals were sputtered in atmospheres of air, helium, nitrogen and argon. Another variable evaluated was sputtering the platinum decal in the pressed and unpressed condition.

Results of these evaluations have shown that three cells had promising initial performance (NM-88, NM-92 and NM-106). These cells were pressed platinum substrates sputtered with iridium to .025 to .05 gm/Ft². Two cells were sputtered in air and the third in argon. Performance of all three cells decayed rapidly with time. To date, we have not had performance stability with sputtered anodes through the 48 hour screening test.

Figure 13. Comparative Life Test - Low Loaded Cathode

Figure 14. Comparative Performance of Low Loaded Anode Electrode

Efforts will be made to determine the lower limit of E50 catalyst loading which will assure stable baseline performance using our current decal fabrication techniques with and without platinum as a catalyst substrate.

2.2.4 Low Cost Polymer Development (Niagara Mohawk Sponsored)

The purpose of this task is to define, evaluate and optimize alternate membranes to duPont's Nafion[®] which offer potential for lower cost.

2.2.4.1 Evaluation of Sample Membranes

Six sample membranes have been received from Radiation Application Industries (RAI) for evaluation. The table below describes some of the physical characteristics of the samples.

TABLE I

<u>Sample</u>	<u>Baseline</u>	<u>Graft Level (TFS)</u>	<u>Physical Strength</u>
103	FEP	80%	Poor
104	FEP	80%	Poor
105	FEP	36%	Poor
107-1	FEP	26%	Poor
107-2	ACLAR	26%	Very Poor
109-1	FEP	35.9%	Excellent

Five of these samples have been operationally evaluated.

Performance after 48 hours is plotted in Figure 15. The 500 hour stability test data is plotted in Figure 16.

One sample (107-2) was removed from test after failure during the heat-up to 180°F. The physical strength of this sample was so poor that the failure came as no surprise.

A second sample (104) decayed rapidly during the 48 hour screening test and was removed from further testing after 48 hours.

The four remaining sample membranes performed well during the initial 48 hour screening and were continued on test for the 500 hour stability evaluation. One of the samples (103) began a rapid rate of performance decay after 115 hours and testing of this sample was terminated after 307 hours.

Two samples appeared to achieve stable performance after 400 hours of testing. One sample (105) was 10 MV from baseline performance and the other

Figure 15. Membrane Survey. - 48 Hour Performance - 180°F

Figure 16. Comparative Life Test - RAI (TFS) vs. Nafion (R)

50 MV at the end of 500 hours operation.

The final, and most promising sample (109-1) has been on test 100 hours with a lower rate of decay than any of the previous samples.

2.2.5 Evaluation of the Effect of Hydrogen Enrichment on Older Gas Pipeline (Niagara Mohawk Sponsored)

The test approach for this evaluation has been agreed upon with Niagara Mohawk. A test plan, which may change slightly based on the actual pipes received, is attached as Appendix A.

Preparation of the test facility has started and the pipe samples are in transit.

2.2.6 Cell and SPE Optimization (GE Sponsored)

Under this task effort is being continued cell performance invariance via two main thrusts; improved deionization and improved cell compression techniques.

2.2.6.1 Improved Deionization

The water pretreatment or deionizer has been modified in the form of a "tandem" bed. The deionizer consists of a monobed followed by a cation bed. The monobed consists of strong cation resin in the H^+ form mixed with strong anion resin in the OH^- form. The monobed removes ionic (and some organic) impurities, producing water quality of about 16 meg-ohm-cm. The cation bed just downstream acts as a mechanical and chemical trap to absorb degradation products from anion beads which may escape the main monobed. In some cases cells have been poisoned by anion beads escaping from the main deionizer bed. Since anion beads produce measurable amines when they are not in contact with cation beads, the amine enters the cell where it neutralizes the active membrane protons. This is avoided by placing a small amount of cation beads at the discharge of the bed.

These improved tandem deionizers have been installed in the three low cost current collector cells currently on test with significant improvement in performance invariance (see para. 2.2.1.1.2).

2.2.6.2 Improved Cell Compression Techniques

A hydraulically loaded test fixture has been designed and fabricated and is functioning very well. The improvements brought about by this new hardware are:

1. Elimination of rubber gaskets and instead the use of a membrane-to-metal seal. Creep, leakage and gasket degradation have thus been eliminated.
2. A uniform and controllable contact between M and E and current collector, avoiding loss of contact pressure with time.

One of the low cost current collector cells is presently on life test at 180°F, 1000 ASF in the new hardware (ref. para. 2.2.1.1.2 and Figure 2).

3.0 PLANS FOR THE NEXT QUARTER

Task 1.1 - Low Cost Current Collector (ERDA Sponsored)

- o Continue to operationally evaluate anode support configurations and select best approach for initial 2.5 Ft² cell design.
- o Complete development of a molded bipolar current collector for evaluation with lab sized cells early in 1977.

Task 1.2 - High Temperature Operation (ERDA Sponsored)

- o Complete modification of the high temperature test stands.
- o Resume 300°F evaluation of carbon collector cells.

Task 1.3 - Catalytic Electrode Development (NMPC Sponsored)

- o Continue efforts to stabilize RuO_x as an anode catalyst.
- o Continue 500 hour test of promising alternative anode catalysts.
- o Continue to optimize carbon substrates for low loaded cathodes.
- o Evaluate low loaded decal anode electrodes.

Task 1.4 - Low Cost Polymer Development (NMPC Sponsored)

- o Evaluate recent grafted TFS polymer samples and specify, manufacture and test of four more samples.

Gas Pipeline Test (Niagara Mohawk Sponsored)

- o Receive pipe
- o Complete test facility
- o Initiate testing

Task 1.5 - Cell and SPE Development (GE Sponsored)

- o Increase effort towards definition of improved deionization techniques.

APPENDIX A

Test Plan for

Evaluation of the Effect of Hydrogen Enrichment on Older Gas Pipeline

Purpose:

The purpose of these tests is to evaluate the effects of exposing older gas pipelines to selected hydrogen/methane gas mixtures for an extended period of time.

Samples:

The following samples will be supplied by Niagara Mohawk for evaluation.

Sample No.	Dia.	Length	Metal	Special Features	Normal Max. Working Pressure
1.	14"	4 Ft.	Steel	New, without girth weld, for Ref.	250 psig
2.	14"	4 Ft.	Steel	Old, with old girth weld, for Ref.	250 psig
3.	14"	4 Ft.	Steel	Old, with old girth weld, for evaluation	250 psig
4.	14"	4 Ft.	Steel	Old, made up weld, for evaluation	250 psig
5.	14"	4 Ft.	Steel	Old, made up weld, for evaluation	250 psig
6.	14"	4 Ft.	Steel	Old, with made up weld for evaluation	250 psig
7.	12"	4 Ft.	C.I.	Old, for ref.	25 psig
8.	12"	4 Ft.	C.I.	Old, with mechanical coupling and mechanical joint, for evaluation	25 psig
9.	8"	4 Ft.	C.I.	Old with mechanical coupling and cement joint, for evaluation	0.25 psig
10.	4"	4 Ft.	C.I.	Same as sample 9 for ref.	0.25 psig
11.	1/2"	4 Ft.	Plastic	New, for diffusion evaluation	25 psig

Test Method

Initial Inspection of Samples

Each metal pipe section will undergo the following incoming inspection procedures:

1. Cleaning
2. X ray girth welds (90° intervals)
3. Dimensional check including variation in wall thickness and dimensions of possible existing pits.
4. Weight and density of each section.
5. Non-destructive testing by FPT (florescent penetrant test) or by ultra-sonic testing to determine profile of existing microscopic cracks.

Sample Preparation

After initial inspection, a 6" sample of each metal pipe will be cut off for future metalurgical evaluation. Appropriate test fittings will be installed in the end caps and welded to the samples, by certified gas line welders, to form pressure vessels. Each test section will be pressure tested at proof pressure and helium leak tested at rated pressure. All welds will conform to API 1104 and will be 100% inspected.

Baseline Testing

Samples 1, 2, 7 and 10 will be instrumented with strain gages and hydrostatically burst tested to establish the burst characteristics typical of pipe before any exposure to hydrogen. Four strain gage pairs (capable of measuring 20% elongation) will be mounted on each pipe in the region of maximum stress (approximately 1.25 in. from the end cap welds). The strain will be recorded as each test section is hydraulically loaded slowly to its burst pressure.

Hydrogen Enrichment Evaluation

The remaining samples of metal pipe (samples 3, 4, 5, 6, 8 and 9) will be installed in the pipe test enclosure and connected to the pressurization, control and monitoring set up shown in Figure 1.

The samples will be exposed to H₂ enriched methane in accordance with the following:

<u>Sample No.</u>	<u>Pressure</u>	<u>Concentration</u>	<u>Exposure Time</u>
3	250 psig	10% H ₂ /90% CH ₄	1 Month
4	250 psig	10% H ₂ /90% CH ₄	TBD
5	250 psig	Variable from 10% to 100% Hydrogen (Schedule TBD)	1 Month
6	250 psig	Variable from 10% to 100% Hydrogen (Schedule TBD)	TBD
8	25 psig	10% H ₂ /90% CH ₄	1 Month
9	0.25	10% H ₂ /90% CH ₄	1 Month

The test sections will be charged from a common gas manifold. Nitrogen will be used for an initial purging and evacuation of the test sections to exclude oxygen. A thermal conductivity gas detector will be used to monitor the percent hydrogen in methane. Gas samples will be taken at intervals for gas chromatograph analysis. Gas pressure and percent hydrogen will be recorded at suitable time intervals to insure the quality of the test conditions.

Post Exposure Testing

After exposure of one month, samples 3, 5, 8 and 9 will be hydrostatically burst tested in the same manner as the baseline samples 1, 2, 7 and 10 and strain gage and burst pressure data compared to assess the effect of the exposure.

Based on this comparison, the exposure time of the remaining samples 4 and 6 will be determined.

Diffusion Testing of Plastic Pipe

The plastic pipe (sample #11) will be subjected to 25 psi of 10% H₂/90% CH₄ and diffusion characteristics determined by long term pressure decay measurements.

Report

The results of this testing will be compiled in a report subsequent to completion of the testing.