Summary of Approach/Rationale

- **Project Goal**

  To develop a heat and power system to supply 3-5 kW of grid quality electric power from kerosene/diesel fuel in remote arctic environments
- **Project Rationale**

  Fuel and maintenance are high in remote areas because of transportation. Combined heat and power maximizes fuel use. Therefore, distributed power approach
- **Technical Approach**

  Centered on PEMFC with fuel processing and power conditioning
- **Project Approach - Team**

  Sandia National Laboratories (SNL), Livermore, CA

  Teledyne Brown Engineering (TBE), Hunt Valley, MD

  Schatz Energy Research Center (SERC)

  Humboldt State University, Arcata, CA

  Hydrogen Burner Technology (HBT), Long Beach, CA

Background SERC

Schatz Energy Research Center (SERC)

- **Working on PEM since 1992**
- **Primary Interest in Renewable Energy**
- **200 w to 9 kW**
- **Stationary Applications**
- **Vehicle Applications**
- **Patented process**

Background HBT

- Experience in hydrocarbon fuel conversion to hydrogen reformate gas through both its 10 year old Phoenix Gas Systems and 2 year old DOE PNGV programs.
- Successful experience with higher hydrocarbon fuel conversion in its patented lower cost straight partial oxidation technology (UOB™).
- Current Commercial Hydrogen Generators - PGS Product Line: 600 SCFH & 4200 SCFH Units:
  - 99.9+% Hydrogen
  - Fuel Flexible
  - <5 PPM CO Levels
  - Skid Mounted Packaging
  - Low Capital Cost

  Other Development Programs

Background TBE

Energy Systems has two product lines, both involving energy conversion and both applicable to this project:

electrolysers and power generators

Electrolysers:

- **Industrial quality to world market**
- **High purity H2/O2**
- **Wide range 1 slm to 800 slm**

  going up to 2000 slm
- **Associated equipment and safety experience**

Small Power Generators:

- **Reliable Prime power for remote locations, worldwide**
- **Thermoelectric, various heat sources**
- **2.5 kW long-lived gas-fueled generator**
- **Other conversion technologies**

Results

- **Phase 1 started July 1998.**
- **In September, SERC delivered a 3kW fuel cell stack to SNL for testing on hydrogen.**
- **SERC assisted SNL/ UAF with test bench setup**
- **SNL/UAF set up test benches and tested SERC 3kw stack (Test results published)**
- **TBE delivered a Model HM50 Hydrogen Generator to SNL (Modified for UAF but not yet installed at UAF)**
- **HBT developed a scaled-down version of partial oxidation type fuel processor and designed it for kerosene/diesel (Delivered on 3/31/99, not yet tested at SNL)**

Fuel Cell Results

Test Results at SERC

- **3kW at over 75 amps (250 mA/cm^2), steady performance**
- **stable 3.15 kW at an average 700 mV/cell, for a stack efficiency of 56% (LHV).**
- **To all appearances, this test could have continued indefinitely**

Test Results at SNL

- **Open circuit voltage efficiency: 75%**
- **At load voltage efficiency: 58%**
- **Net electrical efficiency (LHV): 48%**
- **Net electrical efficiency (HHV): 41%**

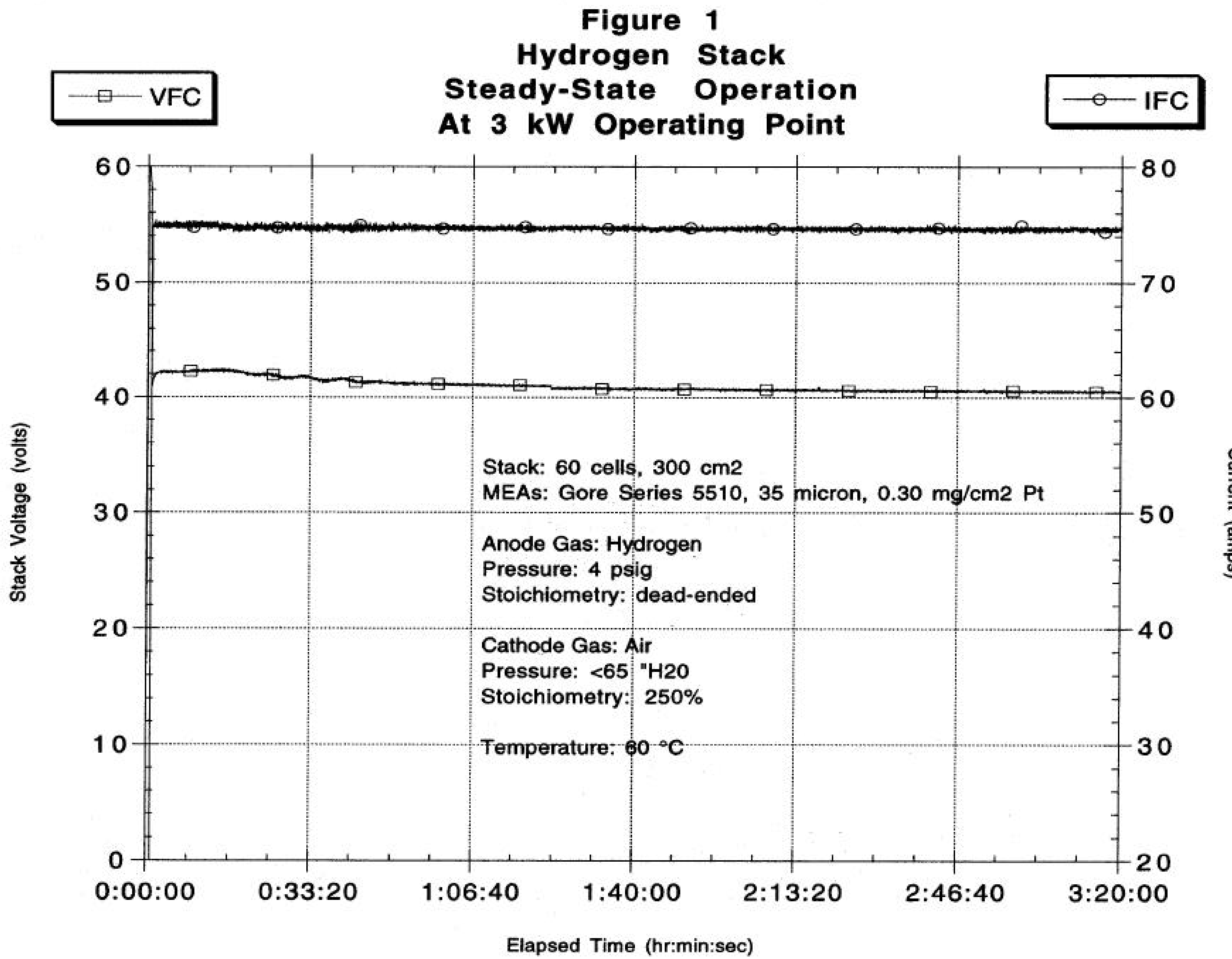
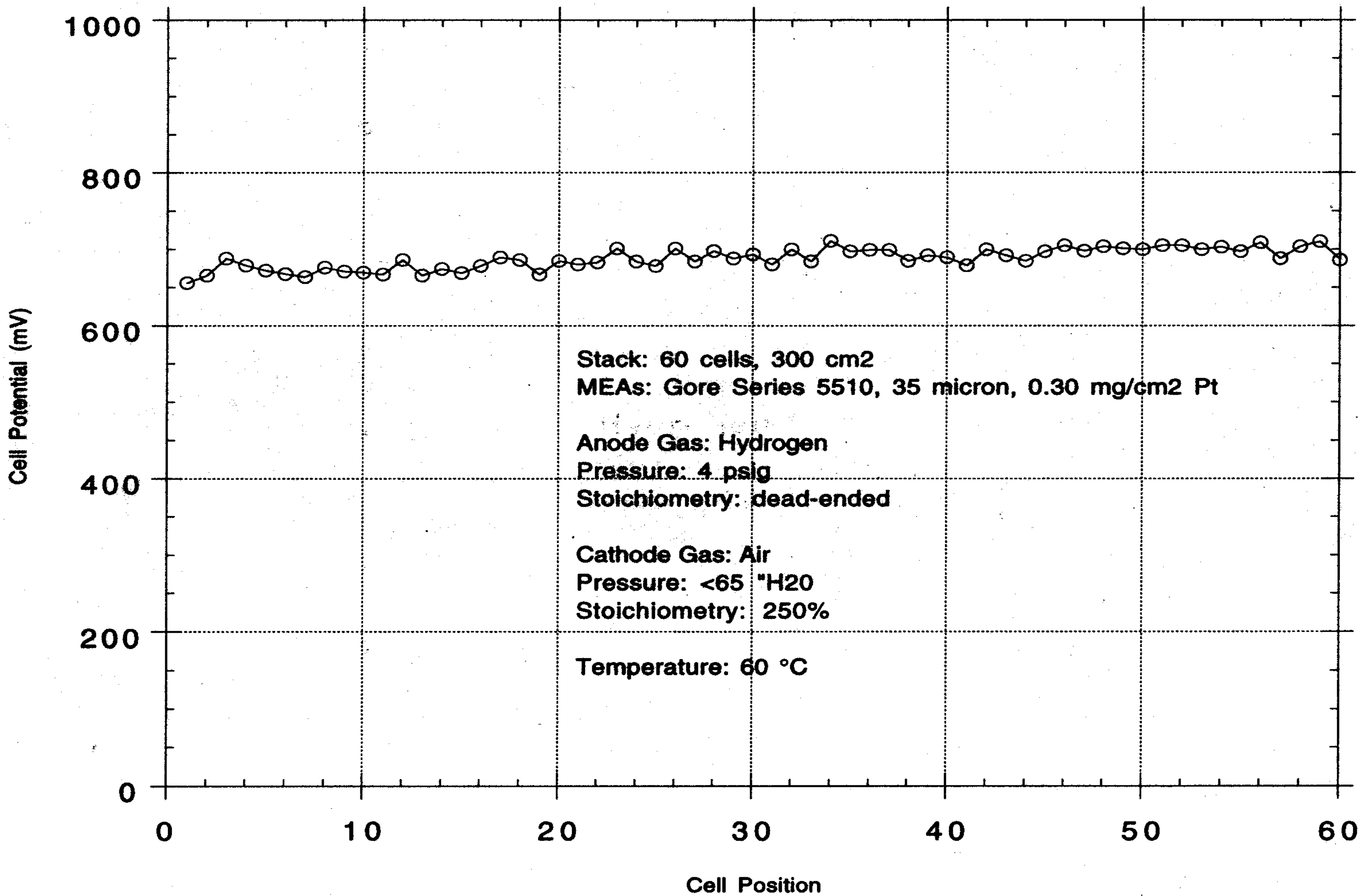
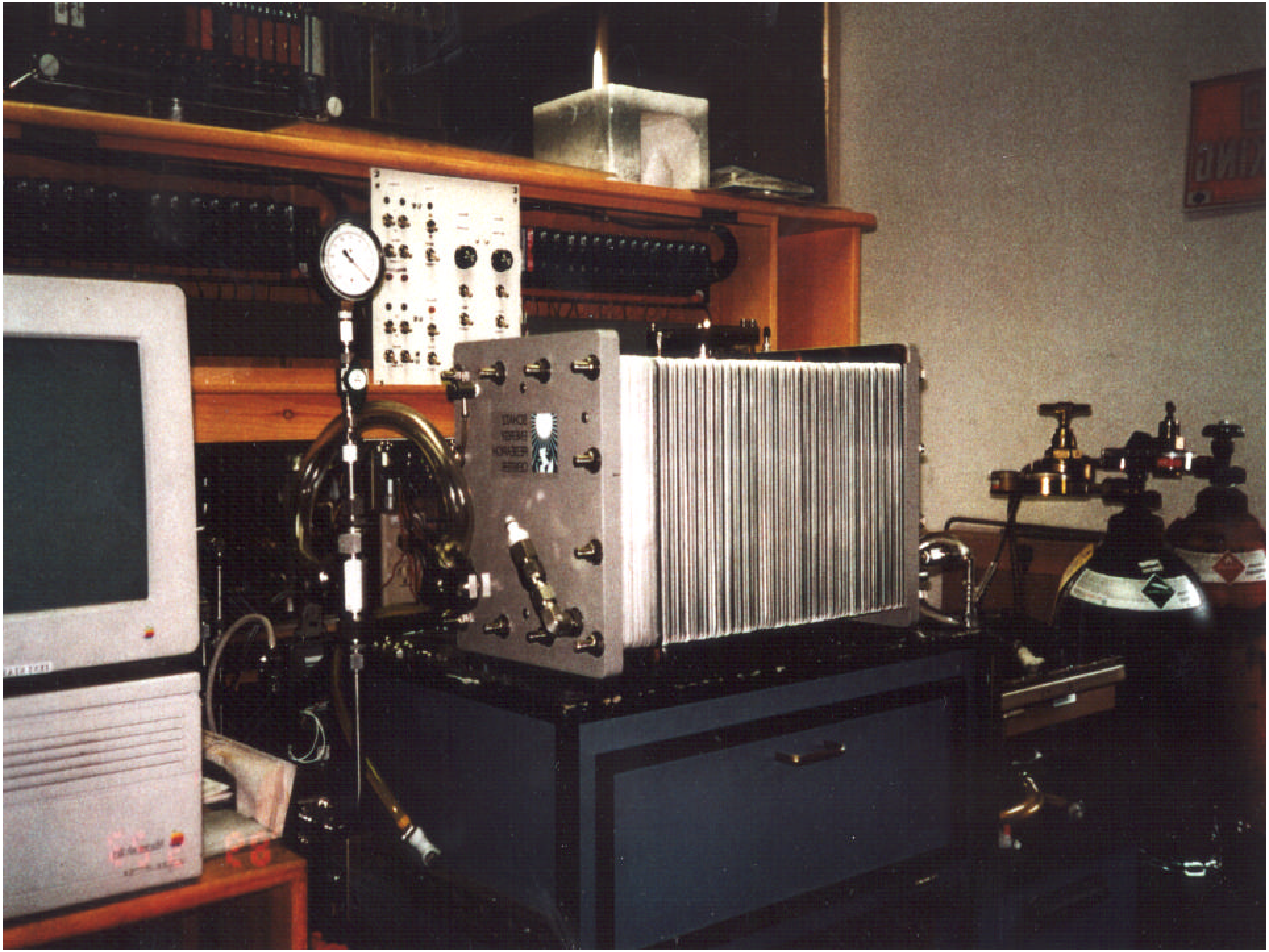


Figure 1
Hydrogen Stack
Steady-State Operation
At 3 kW Operating Point
VFC
IFC
Stack Voltage (volts)
Current (amps)
0
10
20
30
40
50
60
20
30
40
50
60
70
80
0:00:00
0:33:20
1:06:40
1:40:00
2:13:20
2:46:40
3:20:00
Elapsed Time (hr:min:sec)
Stack: 60 cells, 300 cm2
MEAs: Gore Series 5510, 35 micron, 0.30 mg/cm2 Pt
Anode Gas: Hydrogen
Pressure: 4 psig
Stoichiometry: dead-ended
Cathode Gas: Air
Pressure: <65 "H20
Stoichiometry: 250%
Temperature: 60 °C

Figure 2
Hydrogen Stack
Cell-Cell Variation
At 3 kW Operating Point





HM Series Hydrogen Generator

For on-site generation of high purity hydrogen capacities of 2.8 to 11.2 Nm^3/h for industrial uses

* Convenient and Cost Saving
* Microprocessor-Controlled
* Designed for Reliability and Safety
* Wide Range of Applications
* Customized Options Available
* Easy Installation
* Compressors Can Be Eliminated

Fuel Reformer

Plans for Future Work

Phase 2 (Feb - Dec 1999)

Continue efforts of Phase 1 so subsystems can be run as a breadboard system.

- **Build second fuel cell stack and ancillary components**
- **Develop a control system for the fuel cell subsystem**
- **Integrate the fuel cell subsystem with controller**
- **Integrate fuel cell subsystem with power handling components**
- **Develop power handling algorithms, integrate into controller**
- **Test Phase 1 fuel processor**
- **Retrofit reformer with latest advanced catalyst from HBT’s ongoing development**
- **Build enhanced fuel processor**
- **Integrate fuel processor into the system**

Plans for Future Work

Phase 3 (Jan - Dec 2000)

Systems will be fully integrated, packaged, automated, and complete, ready for operational testing in Alaska.

- **Analyze results from Phase 2 testing**
- **Upgrade where necessary**
- **Integrate heat transfer subsystems**
- **Package configuration**
- **Integrate control systems into an overall control package**
- **Develop top level control algorithms for the heat and power system**
- **Instrument for testing**
- **Test**

Status of Economic Evaluation / System Analyses

<u>Total fuel costs depend on:</u>

- **Overall system efficiency**
  (combining heat and power >90%)
- **Electrical generation efficiency**
  fuel cell stack demonstrated 56%
  fuel cell subsystem demonstrated 48%
  reformer efficiency not yet tested
  reformer power demand not yet finalized
- **Power conditioning efficiency ~90%**

<u>Maintenance costs not known yet</u>

<u>Equipment costs</u>

Production costs large uncertainty:

- **Useful life not yet proven**
- **Commercial forces**

Goals and Basis for Goals

Project Goals

- **To develop a heat and power system to supply 3-5 kW of grid quality electric power from kerosene/diesel fuel in remote arctic environments**
- **Centered on PEMFC with fuel processing and power conditioning**
- **Demonstrate the usefulness of such a system**

Basis for Goals

- **A system which produces power and whose waste heat is useful in home heating enables more efficient use of fuel in the region**
- **Support the development of products and infrastructure based on hydrogen utilization**

Major Barriers to Meeting Goals

Potential Barriers to Project Goals

- **Performance of the fuel reformer**
- **Longevity of the fuel reformer**
- **Longevity of the fuel cell stack**

General Barriers

- **Development Cost**
- **Time to demonstrate that the technical barriers are overcome**