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Environmental Assessment of the 40-Kilowatt Fuel Cell System Field Test Operation

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Prepared for
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Lewis Research Center
Under Purchase Order C-42701-D

for
U.S. DEPARTMENT OF ENERGY
Fossil Energy
Office of Coal Utilization and Extraction

Department of Energy

FINDING OF NO SIGNIFICANT IMPACT

40 Kilowatt Fuel Cell System Field Test Operation

The Department of Energy has prepared a programmatic environmental assessment (EA) of the proposed 40 kW Fuel Cell System Field Test Operation. Based on the findings of this EA, the Department has determined that the proposed action does not constitute a major Federal action significantly affecting the quality of the human environment within the meaning of the National Environmental Policy Act of 1969 (NEPA) (42 U.S.C. 4321 et seq.). Therefore, no environmental impact statement is required.

The proposed action is the field testing, for a two-year period, of up to forty-eight 40 kW fuel cells in cooperation with local utilities at approximately 25 sites nationwide. Fuel cells convert natural gas to electricity with high efficiency, and the waste heat can be used for onsite needs. Various building types and market segments (including low-rise apartments, office buildings and banks, schools, restaurants and stores, light industries, and nursing homes and hospitals) will be selected for testing, in several configurations, and in a variety of states and geographic regions. The units will be manufactured and shipped to the site, and connected with local gas and electric systems. The modules are of all-weather construction and measure approximately 9 ft x 5 ft x 6 1/2 ft. Units will be installed either indoors, outdoors at ground level, or on the rooftop.

The proposed field test includes:

- Monitoring of energy usage in candidate field test facilities for a one year period.
- Installation of up to forty-eight 40 kW fuel cell power plants and auxiliary energy equipment at approximately 25 test sites nationwide.
- Operation and monitoring of each fuel cell power plant for a one to two year period.
- Removal of most of the fuel cell power plants from the test sites at the conclusion of the field test and restoration of the sites, if necessary.

The National Aeronautics and Space Administration's Lewis Field Research Center (NASA-Lewis) is serving as the Department's lead center for phosphoric acid fuel cell development. The Gas Research Institute is coordinating the activities of the cooperating utilities.

There are no significant impacts associated with the proposed program.

- The air emission rates from individual fuel cell power plants are so low that the emissions will not cause any measurable deterioration of ambient air quality at or near the test sites. Some small improvement may occur if the fuel cells replace conventional heating equipment having higher emission rates or if they displace emissions from central generating stations.

o The power plant generates a sufficient quantity of water to satisfy its requirements during all but the most extreme operating conditions when some makeup water may be required. It is air-cooled and thus will use little or no water and does not require connection to a continuous water supply. During cold weather and transient operating conditions, a small excess of water may be generated that will require discharge to a drain at the site. This discharge water is of high quality and can be safely processed by a municipal water treatment facility.

o When properly sited, the power plant installation is expected to meet all local noise ordinances. The noise level is well within Occupational Safety and Health Administration standards and will meet Environmental Protection Agency goals for protection of hearing and prevention of activity interference if noise attenuating structures are erected. Some activity interference may still occur in areas immediately surrounding the installation.

o Installation of the power plant will have negligible land use or visual impacts. Installation at ground level requires a prepared foundation area of 17 ft x 15 ft. Construction impacts, and impacts on wildlife and vegetation, will be minimal.

o The field testing of fuel cell power plants at on-site locations will not pose any unusual risks to the health and safety of site occupants or utility service personnel. The power plant has been designed according to selected safety codes and standards, is equipped with a built-in safety system and other safety features, and is being evaluated for certification by two nationally recognized testing laboratories. Because natural gas is used for fuel, the risk of an accident cannot be reduced to zero; however, the risk of an accident causing injury or death is extremely low and comparable to that expected from other gas fueled heating and cooling equipment.

o Limited electromagnetic interference testing has not revealed any problems with either radiated or conducted electromagnetic noise from the power plant inverter. Federal Communications Commission regulations prohibit the operation of [illegible] incidental radiation device if it causes harmful radiation. NASA-Lewis is taking the necessary steps to ensure that the power plants will not cause harmful radiation at the field test sites as a result of either radiated or conducted electromagnetic noise.

o No environmental obstacles to future commercial deployment of this technology have been identified. Displacement of conventional power plants by fuel cell power plants would lead to national and local improvements in air quality, water supply and quality, and ambient noise levels. Their higher energy efficiency would translate into substantial energy savings with accompanying economic and national security benefits. With the exception of possible effects on the platinum market, no impacts of unusually large magnitude are expected from the manufacture, transportation, and installation of power plants and components. The national fuel production system and its environmental impacts should not be measurably expanded or altered by fuel cell deployment.

The assessment discusses reasonable alternatives to the proposed testing program, including program strategy alternatives, technology alternatives, and the no action alternative. The assessment also discusses alternatives to possible future commercialization of on-site fuel cell power plants.

Site specific NEPA reviews will be conducted to identify potential site specific impacts.

Single copies of the environmental assessment are available from:

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The Aerospace Corporation
El Sequndo, California

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Cleveland, Ohio 44135
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Office of Coal Utilization and Extraction
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PREFACE

The 40 Kilowatt Fuel Cell System Field Test Operation is being co-sponsored by the United States Department of Energy, Office of Coal Utilization and Extraction, and the Gas Research Institute. The National Aeronautics and Space Administration - Lewis Research Center (NASA-LeRC) has been designated by the Department of Energy to be the Lead Center for phosphoric acid fuel cell development. The field test consists of the installation and operation of up to forty-eight 40 kilowatt phosphoric acid fuel cell power plants and auxiliary energy equipment at approximately 24 test sites nationwide. The test sites will be a variety of residential, commercial, and industrial facilities. Operation and monitoring of each power plant will last for a one to two year period.

An Environmental Assessment is prepared when it is unclear whether a proposed federal action is a major action with a significant effect on the quality of the human environment. The purpose of the Environmental Assessment is to identify and clarify potential alternatives, so that the need for an Environmental Impact Statement can be resolved. This Environmental Assessment is in accordance with the National Environmental Policy Act (NEPA) of 1969, as amended (42 U.S.C. Sec. 4321 et. seq.), the implementing regulations of the Council of Environmental Quality (40 CRF 1500-1508, 43 FR 55978, November 29, 1978), and the Department of Energy final NEPA guidelines (45 FR 20694, March 28, 1980).

ACKNOWLEDGMENTS

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Multiply	By	To Obtain
British thermal units (Btu)	1.0544	Kilojoules (kJ)
British thermal units/square foot (Btu/ft^2)	0.098	Kilojoules/square meter (kJ/m^2)
Cubic feet (ft^3)	0.0283	Cubic meters (m^3)
Degrees Celsius (°C) + 273.15	1	Degrees kelvin (K)
Degrees Fahrenheit (°F) + 459.67	5/9	Degrees kelvin (K)
Feet (ft)	0.3048	Meters (m)
Gallons (gal)	3.7854	Liters (l)
Inches of water (39.2°F)	249.0	Newtons/square meter (N/m^2)
Miles/hour (mph)	0.4470	Meters/second (m/sec)
Pounds (lb)	0.4536	Kilograms (kg)
Pounds/square foot (lb/ft^2)	47.88	Newtons/square meter (N/m^2)
Pounds/square inch (psia)	6894	Newtons/square meter (N/m^2)
Square feet (ft^2)	0.0929	Square meters (m^2)

1. INTRODUCTION

Phosphoric acid fuel cell power plants are a developing technology for the efficient generation of electric power from fossil fuels. Fuel cell power plants offer several advantages vis-a-vis other energy conversion systems which make them attractive not only to the government but also to various elements of the private sector. These advantages include:

- High energy efficiency
- Low atmospheric emissions
- Little or no water use
- Low noise and vibration
- Modular construction with short lead time
- Siting flexibility

Fuel cell technology has now reached a level of maturity where testing under actual service conditions is required. Two such field tests are currently planned. The first field test, which is the subject of this assessment, is a cooperative effort between the Department of Energy (DOE), the Gas Research Institute (GRI), and a number of gas utilities. The power plants to be tested have a rated output of 40 kilowatts and up to 48 of them will be installed at approximately 24 sites dispersed throughout the country. More than 24 sites may be chosen for testing by the completion of site selection activities. The test sites will include residential, commercial, and light industrial applications. The 40 kW Fuel Cell System Field Test Operation is scheduled to begin in late 1982. The second field test involves a 4.8 megawatt power plant located at an electric utility site in New York City. The test is a cooperative undertaking between DOE, the Electric Power Research Institute, and several electric utilities including Consolidated Edison, the host utility. This power plant is currently being installed with operation scheduled to start in late 1981 (Ref. 1). An environmental assessment of this field test has already been prepared (Ref. 2).

The two field tests differ in several important aspects, power plant size being the most obvious. Other major differences include fuel type, internal power plant operating pressure, service requirement, and operating environment. Further, the 40 kW power plants are designed to recover thermal energy produced as a byproduct of the electric generation. This thermal energy can be used for space heating, the generation of domestic hot water, or possibly for air conditioning.

This environmental assessment examines the potential environmental consequences, both adverse and beneficial, of the 40 kW Fuel Cell System Field Test Operation. The assessment is of necessity generic in nature since actual test sites have not yet been selected. In compliance with the National Environmental Policy Act (NEPA) and DOE implementation guidelines, this assessment provides the basis for determining the need for an environmental impact statement. In addition, this assessment provides siting criteria to avoid or minimize negative environmental impacts and standards for determining candidate test sites, if any, for which site specific assessments may be required.

An environmental assessment of the 4.8 MW fuel cell field test (Ref. 2) concluded that the environmental impacts would be insignificant. Based on that assessment, a determination was made that no formal Environmental Impact Statement (EIS) is required for that field test.

1.1 Fuel Cell Technology

Fuel cell power plants convert fossil fuels directly into electric power through an electrochemical process. The most commonly considered fuels at present are natural gas and light petroleum distillates such as naphtha. It is expected that more advanced fuel cells will be designed to operate on heavier fuels including coal derived gases and liquids.

Fuel cell power plants consist of three major subsystems: (1) a fuel reformer that converts the fossil fuel into a fuel rich in molecular hydrogen and low in certain impurities such as carbon monoxide and sulfur oxides, (2) a power section that converts this fuel into direct current electric power, and (3) a power conditioner that converts the direct current power into regulated three-phase alternating current electric power.

The electrical efficiency expected from 40 kW phosphoric acid fuel cells is approximately 38 percent at half to full rated power output. One of the byproducts of the electrochemical reaction in fuel cells is heat. Heat may also be generated within the fuel processor section. Installations that can effectively utilize both the electrical and thermal energy output from fuel cell power plants can increase their total energy efficiency to over 80 percent. In phosphoric acid fuel cell power plants, the recovered thermal energy is in the temperature range of 344 K (160°F) to 408 K (275°F). The thermal energy in this range can be readily used in many types of facilities including multi-family residences, commercial buildings and light industry facilities.

1.2 Background of Fuel Cell Development

Development of phosphoric acid fuel cell power plants for dispersed terrestrial applications was first promoted in 1967 under the TARGET (Team to Advance Research for Gas Energy Transformation) project, originally sponsored by United Technologies Corporation (UTC) and a consortium of gas and gas-electric utilities. The TARGET concept utilized gas (natural or synthetic) as the fuel, converting it into electricity. More than 65 12.5-kilowatt capacity power plants providing this energy output were tested under field conditions in 1971 through 1973. Encouraging results of this test program led to the design and fabrication of a pilot 40 kW fuel cell power plant by UTC under a joint TARGET/UTC program.

In 1977, UTC, with support from the American Gas Association and GRI, contracted with DOE to upgrade and continue the development of the pilot 40 kW power plant to a preprototype configuration suitable for field testing. The modifications included addition of fuel preprocessor components to accommodate pipeline and peak shave gas mixtures, the redesign and repackaging of the heat recovery equipment, and insertion of recent technological innovations which improve durability, producibility, maintainability, and reduce production cost.

The DOE designated NASA-Lewis Research Center to be its Lead Center for phosphoric acid fuel cell development. At present, the phosphoric acid fuel cell program consists of two closely related development efforts: the on-site program and the electric utility program. Four different phosphoric acid fuel cell power plants are in development under NASA-Lewis: two by UTC, another by Westinghouse and Energy Research Corporation, and a fourth by Engelhard Industries. The on-site power plant being developed by UTC, the subject of this assessment, is at the preprototype level of development and is deemed ready for field tests of limited duration. Additional technology development of all these power plants will proceed concurrent with the field tests of UTC units.

In addition to the phosphoric acid fuel cells, several other fuel cell technologies are under development. These include the molten carbonate and solid oxide fuel cells. Development of these technologies lags several years behind the phosphoric acid fuel cell and is aimed for use in large power plants and large industrial applications. Their fuels are expected to be coal-derived synfuels. These alternative technologies have no bearing on the 40 kW fuel cell field test or on this assessment.

1.3 Field Test Program and Objectives

The 40 kW Fuel Cell System Field Test Operation involves approximately two dozen utilities in addition to UTC. It is cofunded by DOE and GRI who are contracting for procurement of the fuel cell power plants, spare parts, engineering support, and training of utility personnel. GRI is also coordinating utility activities associated with on-site operation and business assessments.

Although DOE and GRI have complimentary field test objectives, their specific field test objectives differ. DOE field test objectives strive to define the environmental and fuel use characteristics of on-site phosphoric acid fuel cell power plants. These objectives include accomplishment of the following:

- Evaluation of the fossil fuel conservation potential of fuel cells in light of their high energy efficiency.
- Verification of the low air emission rates of fuel cells and evaluation of the resulting impacts on air pollution reduction.
- Definition of technology development goals.

The primary GRI interest in the field test is the assessment of the commercial potential of on-site phosphoric acid fuel cell power plants. Therefore, the field test objectives of GRI and the gas utilities include accomplishment of the following:

- Establishment that the 40 kW field test power plant operating characteristics are compatible with the needs of the market.
- Evaluation of technology maturity and readiness for widespread applications.

- Exploration and evaluation of regulatory, code, and legal issues.
- Evaluation of the early markets for on-site fuel cell power plants.
- Assessment of installation, operating, and maintenance costs.
- Informing the public of the concept to prepare for a broader acceptance by society.
- Identification of necessary power plant modifications and improvements resulting from field operating experience.

Subject to funding availability, 48 preprototype power plants manufactured by UTC are scheduled for installation at field sites during 1982, 1983, and 1984. Each participating utility will select a number of potential sites from representative early entry markets in its service territory. In preparation for final site selection, it will measure and analyze thermal and electric load data for each site, interview building owners and managers, rank the sites, and submit its recommendations to DOE and GRI for final selection. The utilities will then design and prepare the sites to receive the 40 kW fuel cell power plants, install the equipment, operate the power plants, and analyze the results.

DOE and GRI monitoring of site selection and installation options will ensure that a balanced mix of configurations, applications, and other program variables is selected. The sites will include light industrial, commercial, and residential applications. The actual field tests of the power plants are scheduled to run for at least one year at each selected site. These tests will evaluate the fuel cell energy system under a range of operating conditions and energy demands. At the conclusion of the field test period, the power plants will be removed from the sites and the operational data will be analyzed in preparation for a subsequent commercial feasibility program.

Each participating utility will perform a business assessment in parallel with the other field test activities. The objective of the business assessment activities is for each utility to establish the viability of on-site fuel cell energy service as a business opportunity in its service territory. It is planned that each business assessment include the following major elements: (1) marketing activities, (2) assessment of potential institutional and regulatory legal inducements and constraints, (3) a business venture analysis, and (4) public information activities.

The 40 kW Fuel Cell System Field Test Operation is an important step in the development of on-site phosphoric acid fuel cell power plants for widespread commercial application. The testing and evaluation of these preprototype power plants is expected to provide technical, environmental, economical, and institutional information that will promote the development of improved prototype and commercial power plants by fuel cell manufacturers. For example, UTC commitment to design and construct commercial on-site power plants will be influenced by the results of this field test.

The environmental impacts expected from the widespread commercial application of phosphoric acid fuel cell power plants differ substantially from the environmental impacts expected from this limited field test. Commercialization impacts will be far more numerous with increased magnitude and complexity. The dynamic nature of fuel cell technology development injects considerable uncertainty into the forecast of these impacts. The environmental impacts of commercialization will be the subject of a separate assessment that will evaluate them in much greater detail than does this assessment.

1.4 Assessment Scope and Content

This assessment presents an analysis and evaluation of the expected environmental and safety impacts resulting from the 40 kW Fuel Cell System Field Test Operation, and examines the installation, operation, and decommissioning phases of the program. The assessment will focus on local impacts in and around the test sites since environmental impacts of a national scale are not anticipated to result from this limited field test. The fact that the numerous and varied field test sites have yet to be selected necessitates that this assessment be limited to a generic treatment of impacts where site-specific knowledge is required and unavailable. Although the scope of this assessment is limited to environmental impacts directly attributable to field test activities, summary treatment is provided of anticipated environmental impacts resulting from the future widespread deployment of commercial on-site phosphoric acid fuel cell power plants.

It should be noted that this assessment is based on the field test plans as described by the DOE/GRI Project Agreement of July 1981 (Ref. 3) and the more detailed Project Plan of November 1981 (Ref. 4). These documents detail various aspects of the field test including scope, management structure and procedures, cost sharing, and insurance requirements. These plans may change prior to the start of the field test due to budget adjustments.

Contained herein are descriptions of the proposed action (Section 2); the existing environment (Section 3); probable environmental impacts (Section 4); risk of credible accidents from the proposed action (Section 5); consistency and compliance of the proposed action with federal, state, and local policies and regulations (Section 6); alternatives to the proposed action (Section 7); and environmental guidance and criteria for power plant siting (Section 8).

The environmental assessment was prepared by The Aerospace Corporation as one task of its support contract to NASA-Lewis Research Center under Order No. C-42701-D.

References

1. National Aeronautics and Space Administration (NASA)-Lewis Research Center, The Electric Utility Phosphoric Acid Fuel Cell Program, October 1980.

2. Department of Energy (DOE), Environmental Assessment - 4.8 MWe Fuel Cell Demonstration Plant, DOE/EA-0009, January 1978.

3. Gas Research Institute and Department of Energy, "Project Agreement - 40 kW Phosphoric Acid Fuel Cell Field Test," July 1981.

4. Field Test Steering Committee, "40 kW Phosphoric Acid Fuel Cell Field Test Project Plan," November 1981.

2. DESCRIPTION OF THE PROPOSED ACTION

Phosphoric acid fuel cell power plants are highly efficient power generators with the capability of providing both electrical and thermal energy from hydrogen-rich fuels. The 40 kW Fuel Cell System Field Test Operation will test the performance of from 20 to 48 of the 40 kW fuel cell power plants in a variety of on-site commercial, residential, and light industrial markets. The power plants will be sited in combination with heat pumps or other auxiliary energy equipment to form on-site integrated energy systems. The actual test period at each site will last for one year but will be preceded by a variety of site monitoring and installation procedures. At the conclusion of the test period, most of the power plants will be removed from the sites. Approximately 24 gas, electric, and gas/electric utilities are currently participating in the field test and each will oversee the installation and operation of either one or two fuel cell power plants.

This section provides a comprehensive discussion of field test activities, participants, scheduling, and costs. This is followed by a description of on-site phosphoric acid fuel cell power plants including a detailed description of the field test 40 kW fuel cell power plant developed by United Technologies Corporation (UTC). The section concludes with a discussion of on-site energy system configurations and operating strategies.

2.1 Field Test Operation

The field test operation actually consists of four separate but interrelated activities that follow one after the other: (1) site characterization and selection; (2) site design, preparation, and power plant installation; (3) field test operation and data acquisition; and (4) site decommissioning and restoration. In addition, business assessments will be conducted by the individual participating utilities. During the site characterization activity, a large number of potential sites for power plant installation will be evaluated using established siting criteria. Sites judged as being particularly suitable will be instrumented to monitor their thermal and electrical use characteristics. Based on the results of the site characterizations, with due consideration given to field test objectives, approximately 24 sites will be selected for power plant installation. The sites will then be prepared to receive the power plants, and all interfaces will be connected once the power plants are delivered. During the actual operation of the power plants, a data acquisition system will continuously monitor and record the performance of each power plant at each site. Since the power plant is designed to operate automatically, an operator will usually not be present to monitor performance. At the conclusion of the field test operation, most of the power plants will be removed from the test sites and the sites will be restored to their original pretest condition. A few of the power plants may continue operation at the sites past the conclusion of the field test. Some auxiliary energy equipment may also be left at the sites. The following is a description of field test participants, site selection criteria, and field test activities, schedule, and costs. A discussion of actions related to this field test concludes this section.

2.1.1 Field Test Participants

The five primary participants in the field test operation are the NASA-Lewis Research Center, the Department of Energy (DOE), the Gas Research Institute (GRI), United Technologies Corporation (UTC), and approximately 24 gas, electric, and gas/electric utilities and military bases. As a field center for DOE, NASA-Lewis Research Center is contracting for procurement of the fuel cell power plants, spare parts, engineering support, and training of utility personnel. GRI is coordinating the activities of the individual utilities including the effort associated with site selection and on-site operation, as well as the business assessment to be developed by each utility.

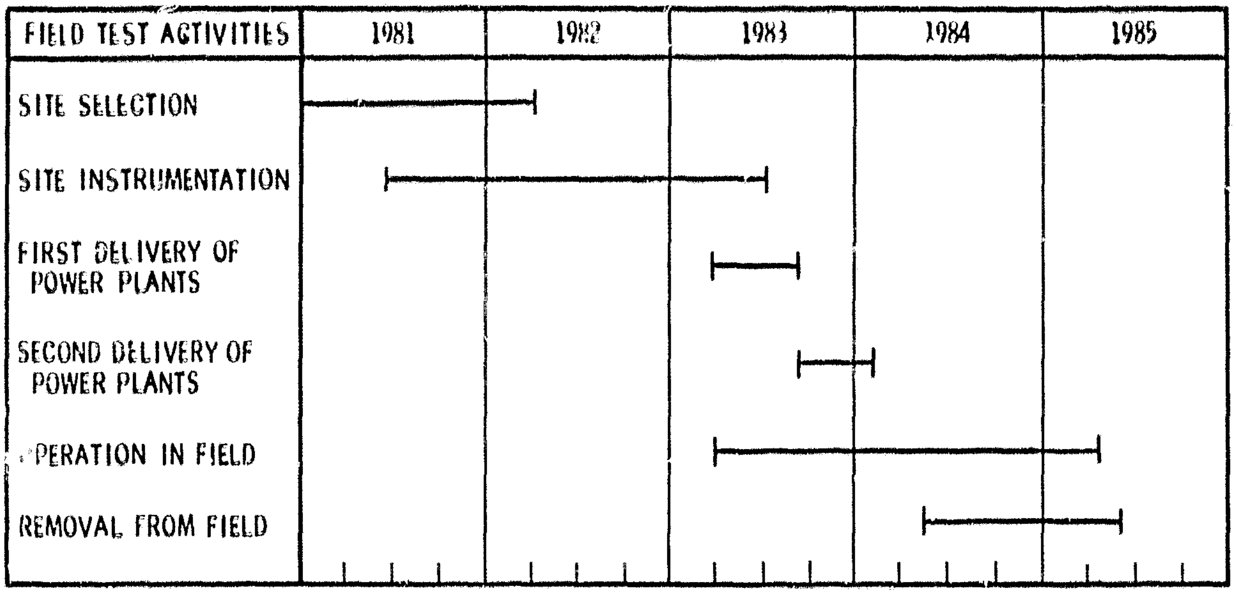
UTC is the designer and manufacturer of the field test power plant. It has conducted design and performance tests on a pilot power plant and a preprototype model to advance the power plant's reliability, safety, and environmental and power system compatibility. It will fabricate the field test power plants and spare parts during two production runs incorporating appropriate design changes as production proceeds. UTC will also provide consultation to GRI and the utilities during site selection and furnish manuals, training, and field support.

Each participating utility will purchase data acquisition systems for the field test. The utilities will use the siting criteria to select a large number of candidate siting locations, will choose a handful of sites from the candidate list for instrumentation, will conduct the instrumentation procedures to monitor site energy characteristics, and will submit the results to DOE and GRI. Each utility will have the responsibility for making all necessary contractual arrangements with site owners and operators. The names and locations of the utilities participating in the field test as of November 1981 are provided in Appendix A. A number of utilities, and hence test sites, may be added to this group by the end of site selection activities. The number of test sites cannot exceed the number of power plants available for testing, however.

2.1.2 Field Test Schedule

The field test operation is tentatively scheduled to extend through the end of 1984. As of November 1981, each utility is in a particular stage of site selection. Some have selected their sites for instrumentation and are ordering the data acquisition systems while others are still evaluating their preliminary list of candidate sites. Sites selected for instrumentation will be monitored for a minimum of one year. Delivery of the power plants from UTC's first production run will occur between April 1983 and September 1983. Delivery of the power plants from the second production run will occur between September 1983 and January 1984. Power plants will begin on-site operation as soon as they are delivered and installed. Test operation will be continued for approximately one year after initial startup. Depending on their delivery date and time required for installation, power plants will begin operating in the field sometime between May 1983 and early 1984. The field test will conclude in early 1985 when the last power plants are removed from the field sites and the sites restored to their original condition. Figure 2-1 shows the expected schedule for the field test.

Figure 2-1. Schedule of Activities for the 40 kW Fuel Cell Power Plant Field Test



2.1.3 Resources and Manpower Requirements

The total cost of the field test for fiscal years 1980-1984 is estimated to be $52 million. Power plant procurement and field test support are being cofunded by DOE ($14 million) and GRI ($29 million). Site preparation, power plant operation and maintenance, and data acquisition and analysis will be funded by the participating utilities ($10 million). Each utility will also have to provide an expected 3-5 manyears of internal manpower. The DOE and GRI cost figures include their internal manpower costs.

2.1.4 Site Selection Criteria

The Ad Hoc Fuel Cell Planning Committee has developed the following criteria for GRI to guide site selection and power plant allocation (Ref. 1):

- All market segments should be tested. Various building types in each market segment should be tested to cover the range of electrical and thermal loads, installation requirements, and fuel conservation impact. Specific market segments to be considered are:
  - Low-rise apartments - 25 to 50 units
  - Office buildings and banks - less than 1485 m^2 (16,000 ft^2)
  - Hospitals - less than 100 beds

  - Nursing homes - 50-80 beds
  - Laundries
  - Schools - less than 4645 m^2 (50,000 ft^2)
  - Hotels and motels - less than 80 rooms
  - Restaurants - 50-100 sit-down meals
  - Stores - less than 2323 m^2 (25,000 ft^2)
  - Light industries
  - Groupings of single family homes
  - Refrigerated warehouses - 4645-7432 m^2 (50,000-80,000 ft^2)
  - Health spas - less than 2323 m^2 (25,000 ft^2)

- Variations in fuel cell system configurations should be tested. Examples are:

  - Electric power production with heat recovery
  - Electric power production with heat recovery integrated with heat pumps
  - Electric power production with special electrical provisions
  - Electrical grid connection
  - Electrical grid isolation

- Testing should be conducted in as many states as possible and in the geographic regions providing a good representation of the economic, climate, legal, and regulatory conditions to be encountered.

DOE will superimpose its own criteria on these GRI criteria. The DOE criteria are currently under development and will concern evaluation of the field test's contribution to fuel conservation and to the national interest in general.

2.1.5 Site Selection Activities

Each utility will locate 30 to 60 potential fuel cell test sites from the range of early market candidates. The candidate sites may be new or retrofit applications. Once the 30 to 60 candidate buildings have been identified, they must be investigated to confirm their viability and to determine owner/operator/occupant willingness to participate in the test program. Based on these considerations and others, each utility, with the assistance of GRI and DOE, will select 3 to 10 building sites for further evaluation. This evaluation will consist of a one-year instrumentation program using standardized data acquisition systems and sensors to monitor building load factors and thermal energy consumption. Installation of the data acquisition system may require minor site alterations and will probably require the shutdown of the site's energy system for several hours. A coordinating contractor and UTC will analyze the instrumentation data for all sites and will prepare an assessment of the compatibility of the various sites with a fuel cell power plant.

Following all of these considerations and analyses, the program manager for each utility will rank the sites that have been instrumented in the order that will best meet the primary objectives of the utility, taking into account the objectives and requirements of the field test. The ranking will include a recommended fuel cell energy configuration for each site. Based upon this ranking, a final test site selection will be made by GRI and DOE. Each participating utility company will receive at least one power plant. Some participants may not have their first priority sites selection so that the necessary total program mix of sites can be achieved.

2.1.6 Power Plant Installation Activities

Power plants will be delivered to the building sites selected for participation in the field test operation. Delivery will likely be via truck with use of forklifts, cranes, and other equipment to move and install the power plants at the sites. The power plants will be installed in one of three locations at the sites: (1) indoors, (2) outdoors at ground level, or (3) rooftop. The power plant's dimensions allow it to be moved through standard sized double doors and thus major interior alterations to accommodate indoor siting should not be necessary. Power plants installed outdoors at ground level must have a cleared, level pad and will rest on a supporting base (e.g., railroad ties).

Service people with special fuel cell training will be in charge of installing, starting, operating, and decommissioning the power plants. Because the fuel cell power plant installation (one or two power plants) will be a temporary, one-year addition to the site's energy system, all existing energy equipment at the site will remain in place. Heat pumps and other auxiliary energy equipment may be installed at some sites in conjunction with power plant installation. Interfacing the power plant with the site's energy system will require the installation of various pipes and wires. These interface lines will likely be buried at outdoor ground-level installations. Minor site alterations may be necessary to accommodate the routing of interface lines through the site (e.g., drill holes through walls). The site's energy system will have to be shut down for a period lasting from several hours to a day in length so that the actual hookup of the power plant to the energy system can occur. Installation will be completed with the placement of fencing, vegetation or other security, noise attenuation, or aesthetic structures.

2.1.7 Power Plant Operation Activities

The performance of the power plant installations will be monitored during their entire operation at the field test sites. Recording cassettes in the data acquisition systems will store data collected by the system. These cassettes will be replaced at two week intervals. Scheduled maintenance and unscheduled repair work will be performed by fuel cell trained service people. Since the sites will retain the connection to their pretest energy sources during the field test, shutdowns of the power plant installations due to overload or failure will not adversely affect the energy supply to the sites.

2.1.8 Power Plant Decommissioning Activities

At the conclusion of the test program, most of the power plants will be removed from the building sites and returned to the manufacturer for further testing and analyses. Fuel cell trained service personnel will perform all necessary decommissioning activities to ensure that power plant removal can be conducted in a safe manner. Forklifts, cranes and other equipment will be used to load the power plants onto trucks for transport back to the manufacturer. All interface equipment will be removed from the sites and the sites' pretest energy systems will resume their normal operation. Heat pumps and other auxiliary items may be left in place at the sites for continued use by site occupants. Efforts will be made to restore the sites to as close to their pretest condition as possible.

2.1.9 Business Assessment Activities

Business assessments by each participating utility will examine and define the potential business scenarios for commercial on-site fuel cell energy service and will assess their meaning to each utility. Business assessments will be performed in parallel with the other field test activities. The utility's business assessment together with field testing experience will be the basis for the decision to proceed to initial commercial on-site fuel cell energy service as a new business option.

The planned business assessment procedure includes the following major elements: (1) marketing activities, (2) assessment of potential institutional and regulatory legal inducements and constraints, (3) a business venture analysis, and (4) public information activities. The marketing activities will define technical and economic characteristics of on-site fuel cell markets, assess the probable penetration of these markets, and forecast the number of probable installations. The institutional, legal, and regulatory investigations will identify, assess, and resolve potential inducements or constraints on the on-site fuel cell energy service offering. The business venture analysis will define potential business modes and organizational structures in which to pursue the previously identified markets. This venture analysis and the assessment of potential institutional, economic, and legal inducements and constraints are the major inputs for the business assessment. The public information activities will attempt to develop the on-site fuel cell market to the point where customers and other decision makers understand the concept, react favorably to it, and are ready to accept the energy service offering.

2.1.10 Other Activities Relevant to the Field Test

Two other fuel cell field test programs have results that are relevant to the environmental assessment of the field test described in this document. One of these programs field tested a smaller fuel cell power plant at on-site locations during the early 1970's while the second is currently under way and will test a large centralized fuel cell power plant in New York City.

During 1971 through 1973, the TARGET group, consisting of 22 gas utilities with no government involvement, field tested 12.5 kW phosphoric acid fuel cell power plants. These UTC-manufactured units were operated nationwide at 35 sites in 17 states, Canada, and Japan. One to three power plants operated at each site. The total operating time was 205,000 hours and the longest installation test lasted 7700 hours. The goal of this previous field test was to investigate technical, business, marketing, and institutional aspects of fuel cell electric service. The 12.5 kW power plants were early fuel cell technology with an electric generating efficiency of only 28 percent and no heat recovery. They met all local siting regulations and experienced no accidents or safety problems. The 40 kW power plants to be tested in the current field test feature numerous improvements including an expanded fuel use capability, heat recovery, grid-connect capability, all weather operation, and improved operation and durability. The 40 kW power plant does, however, contain components that differ from those in the 12.5 kW power plant, and many of these new components have not been fully tested.

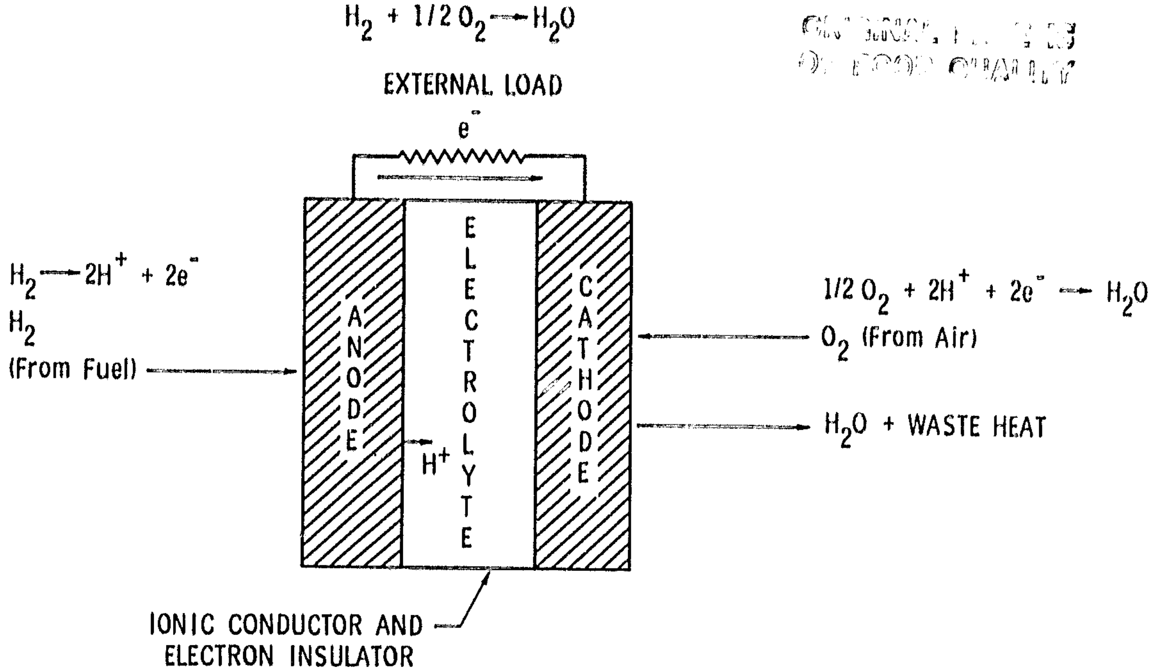
The fuel cell program in New York City has constructed and will operate a 4.8 MW phosphoric acid fuel cell power plant at lower Manhattan. This large, centralized power plant (120 times larger than the 40 kW fuel cell) will use naphtha as the primary fuel and will include storage of a large quantity of naphtha at the site. It is a pressurized unit without heat recovery. An environmental assessment of this program was prepared by DOE in January 1978 (Ref. 2). The primary environmental concern of this test program is related to the safety aspects of naphtha storage. The 40 kW power plant will not store fuel on-site, but its on-site location may present other environmental concerns.

2.2 Fuel Cell Power Plant Principles

Fuel cells are electrochemical energy conversion devices that can continuously transform the chemical energy of a fuel and oxidant into electrical energy by an isothermal process involving an essentially invariant electrode-electrolyte system. Unlike a battery, a fuel cell does not run down or require recharging; it will operate as long as both fuel and oxidant are supplied to the electrodes and an adequate level of electrolyte is maintained. The electrodes act as catalytic reaction sites where the electrochemical transformation of the fuel and oxidants occurs, producing direct current (dc) electricity. Because the fuel cell is able to achieve a direct conversion of the fuel's chemical energy into electrical energy, rather than employing an intermediate heat engine, the Carnot cycle dependence of efficiency on the difference in temperatures does not apply. The fuel cell can therefore yield a high fuel to dc power conversion efficiency. Conventional energy conversion devices, on the other hand, operate in an indirect manner by using an intermediate heat engine. Chemical energy is first converted to heat in high-temperature combustion reactions. This heat produces mechanical work and then is converted to electrical energy using a rotating electrical generator.

As illustrated in Figure 2-2, a fuel cell consists of two electrodes -- a positive electrode, the cathode, and a negative one, the anode -- separated by an electrolyte, which transmits ions, but not electrons. A fuel containing hydrogen is supplied to the anode and air (oxygen) is supplied to the cathode. A catalyst on the porous anode facilitates the hydrogen molecules (H_2) in the fuel to dissociate into hydrogen ions (H^+) and electrons. In an acidic electrolyte, the hydrogen ions migrate through the electrolyte to the cathode, where they react with oxygen to form water (H_2O). The oxidative half-reaction at the anode yields electrons that flow from the anode to the cathode through an external circuit when the electrodes are connected by a conductor. Heat is a by-product of this process.

Figure 2-2. Components and Chemical Reactions of a Fuel Cell

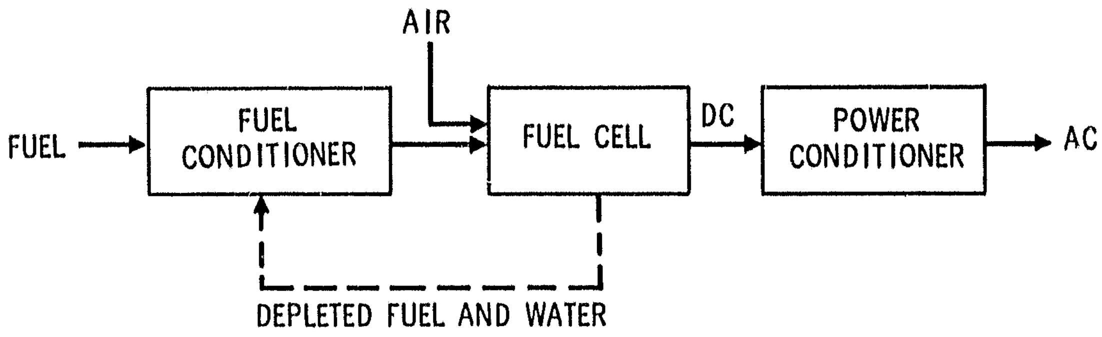


A single fuel cell produces 0.5-1.0 volt dc at a current that is proportional to the cell area. Individual cells are connected in series, as in a lead acid battery, so a fuel cell stack can be constructed with an output voltage compatible with the application.

Fuel cell systems are currently under development by UTC, Westinghouse/Energy Research Corporation, and Engelhard Industries. The technology has many generic features shared by all three development programs: use is made of a concentrated phosphoric acid electrolyte operating at temperatures of up to 478 K (400°F) at pressures ranging from atmospheric to about 3.4×10^5 N/m^2 (50 psia); the electrolyte is contained within a silicon carbide matrix sandwiched between graphite electrodes; platinum electrocatalysts in the form of highly dispersed crystallites are supported by a carbon substrate on the electrodes; total cell catalyst loading is less than 1 mg of platinum/cm^2 of electrode geometric area; and cell cooling is accomplished by use of a liquid or gas. If a liquid coolant is used, it passes through the fuel cell stack in isolated tubes and is either heated to an elevated liquid temperature or to a phase change. Gas coolant, usually air, may or may not be confined to isolated tubes when passing through the fuel cell stack.

The complete fuel cell system consists of three basic subsystems which when integrated compose the power plant unit. These three subsystems, which are common to all three development programs, are: (1) the fuel processor for converting primary fuels such as natural gas and naphtha into hydrogen-rich gas; (2) the power section consisting of the stack of fuel cells containing planar electrodes and an electrolyte holding matrix as sandwiched sheets, housed in plate and frame filter-press assemblies; and (3) a power conditioner for converting the dc electrical output to alternating current (ac) at a suitable voltage. The interrelationship of the three basic power plant subsystems is shown in Figure 2-3. The fuel processor consists of a steam reformer, shift converter, and sulfur remover. This subsystem reduces the carbon monoxide and virtually eliminates sulfur compounds from the fuel gas because they are poisonous to the fuel cell stack catalysts. The reformer burner operates at a relatively low temperature so that little thermal NO_x is produced.

Figure 2-3. Basic Power Plant Subsystems



2.3 Description of UTC 40-kW Fuel Cell Power Plant

The phosphoric acid fuel cell power plant to be evaluated during the 40 kW Fuel Cell System Field Test Operation is a preprototype design that has been developed and manufactured by United Technologies Corporation of South Windsor, Connecticut. Two versions of the power plant will actually be tested. The following is a physical and operational description of the first version of this power plant. Because development activities are continuing, this description should not be considered as absolutely final. The second version will be an improved preprototype, and its development will be based on the performance of the first version and improvements provided by parallel development programs. Only minor design changes are anticipated, however. The power plant description provided herein is based on information from two UTC documents: (1) On-Site 40-Kilowatt Fuel Cell Power Plant Model Specification (Ref. 3), and (2) On-Site 40-Kilowatt Fuel Cell Power Plant Verification Test Plan (Ref. 4).

2.3.1 Physical and Functional Description

The 40-kW fuel cell power plant, as pictured in Figure 2-4, is an on-site energy device which simultaneously generates ac electric power and recoverable thermal energy. It uses pipeline gas (including peak shaved gas) for fuel and phosphoric acid for the fuel cell electrolyte. The power plant is provided with an all-weather cabinet for ease of siting. Cabinet dimensions are 2.74m x 1.57m x 1.98m (108 in. x 62 in. x 78 in.). The dry weight of the power plant is approximately 3175 kg (7000 pounds) and its volume is $8.52 m^3$ ($302 ft^3$). The 40-kW fuel cell power plant consists of four major subsystems and their associated controls:

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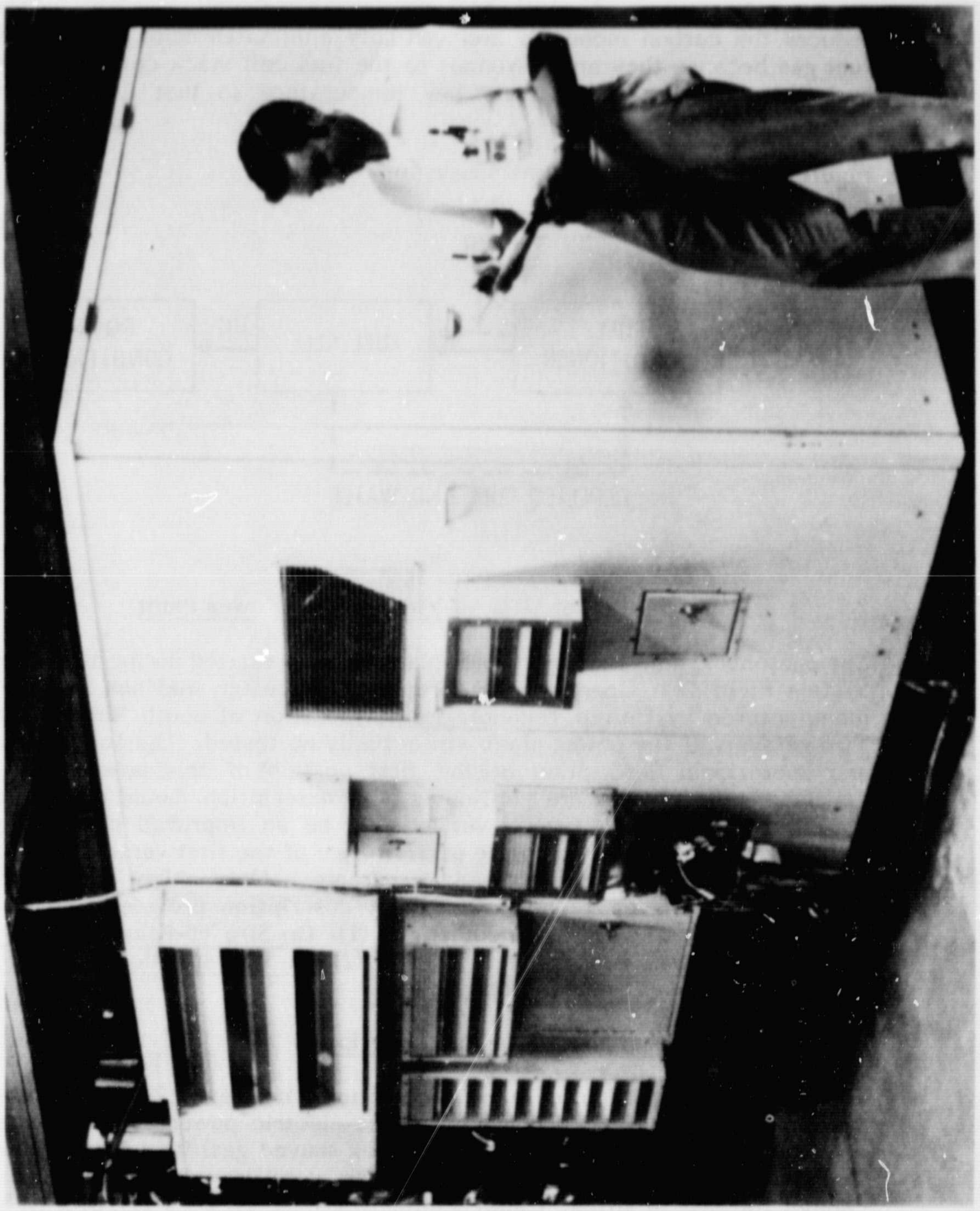


Figure 2-4. The UTC 40 kW Fuel Cell Power Plant Enclosed in Its All-Weather Cabinet.
All exposed wiring will be enclosed when the power plant is sited for Field Testing.

- Fuel processor (including preprocessor)
- Power section (fuel cell stack)
- Thermal management system (including heat recovery)
- Power conditioner

The following is a brief description of each of these major subsystems. Figure 2-5 has been provided as an aid to understanding the functioning and interrelationships of the subsystems. It is a detailed schematic of the power plant that shows all major components and process flows of air, fuel, steam, water, and exhaust.

2.3.1.1 Fuel Processor

The fuel processor subsystem (left side of Figure 2-5) produces a hydrogen-rich gas of a purity suitable for fuel cell use. The platinum catalysts in the anode structure and fuel processor subsystem, and the nickel catalysts in the fuel processor subsystem, are sensitive to fuel impurities, particularly sulfur compounds and to a lesser extent carbon monoxide. The concentrations of these impurities is therefore reduced prior to contact of the fuel stream with the platinum and nickel catalysts. Low concentrations of sulfur can result in deleterious impact on catalyst performance and therefore overall power plant performance. The power plant's fuel specifications encompass virtually all normal gas compositions anticipated. Tables 2-1 and 2-2 display the range of acceptable gas mixtures.

In a steady state operation, fuel enters the fuel preprocessor subsystem (preoxidizer and hydrodesulfurizer) where it is mixed with a portion of hydrogen-rich gas that has already been processed. This mixture of fuel and hydrogen-rich gas flows through the preoxidizer, where oxygen is removed if it is present, as in a peak-shaved fuel for example. The fuel stream then enters the hydrodesulfurizer where sulfur compounds are converted to H_2S which is subsequently absorbed by the zinc oxide scrubber. The desulfurized fuel passes through a hydrogenator where propylene is converted to propane.

After mixing with steam, the fuel enters the fuel processing subsystem (reformer and shift converter) where the fuel and steam are catalytically converted into a hydrogen-rich gas. Hydrocarbons in the fuel are reformed to produce H_2, CO, and CO_2, and the CO is subsequently shifted to produce still more H_2 and CO_2. Methane reformers operate endothermically with exit fuel and exhaust gas temperatures of about 617 K (650°F). The process fuel stream exits the exothermic shift converter at 506 K (450°F). The hydrogen-rich gas from the fuel processor subsystem is cooled, filtered, and flows to the power section.

The depleted fuel leaves the power section and flows to the reformer burner where the remaining fuel is burned with air from the process air system to produce the thermal energy required for the steam reforming process. Reformer burner exhaust combines with depleted air from the power section and flows to the heat exchangers to be cooled for heat and water recovery. The water subsequently is used for fuel processing needs.

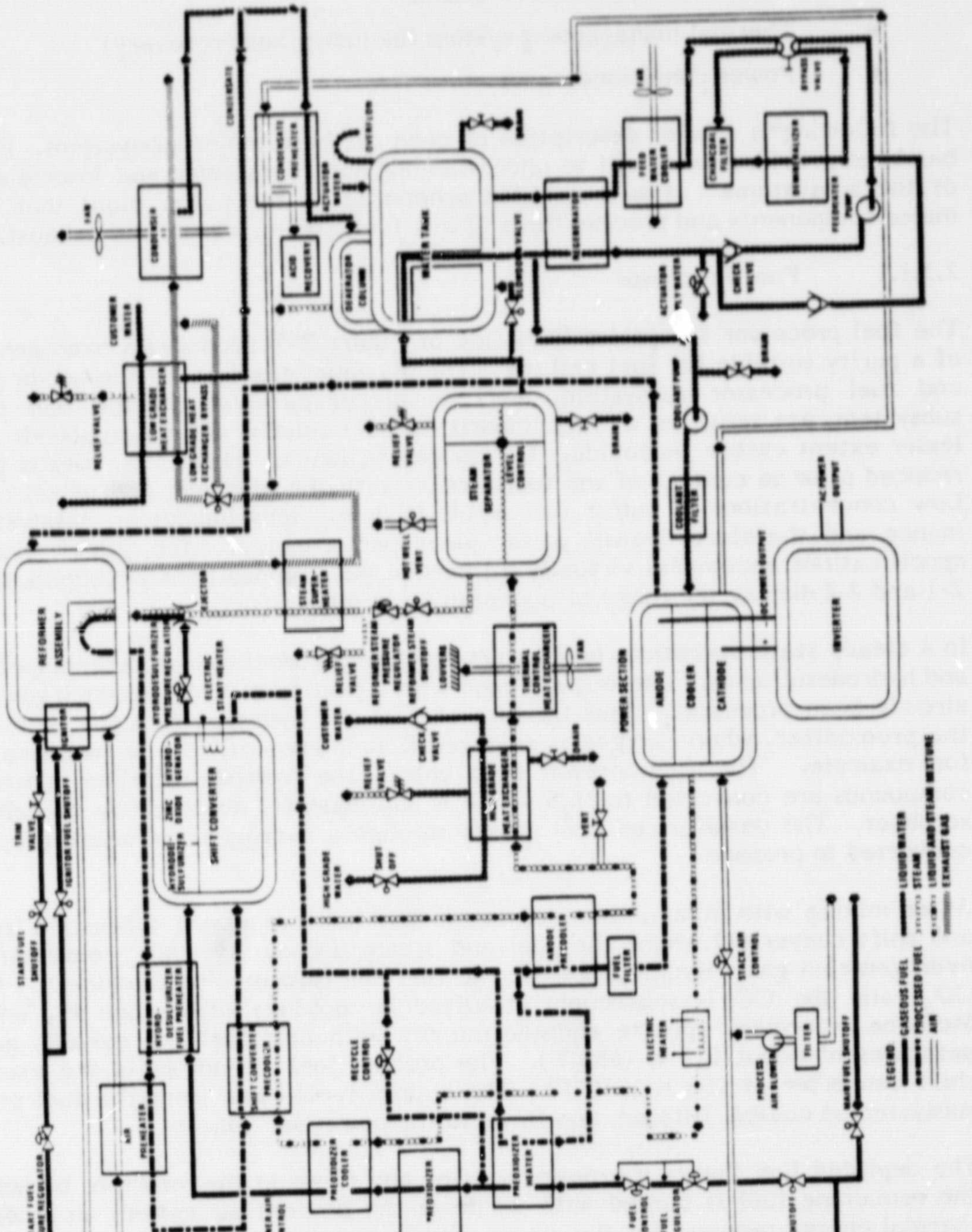


Figure 2-5. Detailed Power Plant Schematic (Ref. 3)

Table 2-1. Pipeline Gas Specification (Ref. 3)

Component	Maximum Allowable Volume (%)
Methane	100.0
Ethane	10.0
Propane	5.0
Butanes	1.25
Pentanes, Hexanes	0.5
CO_2	3.0
O_2	2.5
N_2 (Continuous)	15.0
Total Sulfur	30.0 ppm (volume)
Thiophane Sulfur	10.0 ppm (volume)
NH_3	1.0 ppm (volume)
Chlorine	0.05 ppm (weight)

Table 2-2. Peak Shaved Gas Specification (Ref. 3)

Component	Allowable Max. Volume in Total Gas Mix (%)
Natural Gas	45.0 (minimum)
Peak Shave Gas Mix	55.0
Liquified Petroleum (L.P.) Gas	36.0
Air	23.5
Propylene	3.6 (10.0 in L.P. Gas)
Total Sulfur	30.0 ppm (volume)
Thiophane Sulfur	10.0 ppm (volume)
NH_3	1.0 ppm (volume)
Chlorine	0.05 ppm (weight)

2.3.1.2 Power Section

The power section (lower center of Figure 2-5) is constructed of 270 individual phosphoric acid fuel cells. Each cell consists of an electrolyte holding matrix (silicon carbide) sandwiched between graphite-Teflon electrodes. Separator plates prevent mass transfer from one cell to the next. Copper tubing with an exterior coat of perfluoroalkoxy (PFA) passes through the stack between every six cells to allow the passage of cooling water. The cells electrochemically consume hydrogen from the hydrogen-rich gas and oxygen from the process air system as they produce direct current electricity. Steam is produced as a by-product of the electrochemical process and flows from the exit side of the cathodes to condensers. Gases exiting the anodes and cathodes are at a temperature of 464 K (375°F).

2.3.1.3 Thermal Management Subsystem

The thermal management subsystem (right side of Figure 2-5) controls the power section temperature and provides relatively high grade thermal energy by circulating water through the power section. A total of 284 liters of water (75 gallons) is contained in the subsystem. Heat generated in the process of producing power is removed from the power section by changing the circulating water into a two phase mixture of steam and water. The two phase mixture flows through a high grade heat exchanger where water from an external customer loop may be heated to a maximum temperature of 408 K (275°F). After passing through an air cooled thermal control heat exchanger, the steam-water mixture is directed to a steam separator vessel where steam is separated for use in the fuel processing subsystem. The remaining water is recycled through the coolant loop where it is demineralized and filtered prior to re-entering the power section. Water flowing into the power section must be extremely pure so that it will poorly conduct electricity. The delivery of hot water from the high grade system is controlled by the power plant, and heat will only be delivered when excess is available from the cooling system.

The power plant also has the capability of transferring by-product heat from the exhausts of both the reformer burner and the cathode of the fuel cells to a second customer water loop by means of a low grade heat exchanger. The quantity of heat available is a function of output power. If this low grade heat is not required by the customer, an air-cooled heat exchanger will automatically provide sufficient cooling for power plant operation. Water vapor in the exhaust flow is condensed in the low grade and air-cooled heat exchangers and used for power plant cooling and fuel processing. The minute quantities of phosphoric acid that normally leave the fuel cells with the exhaust gas flow (1 ppm) condense out of the exhaust flow at a higher temperature than the water vapor and thus can be isolated from the recovered water and stored. Approximately 0.5 liter of acid is recovered and stored per year of operation. Acid that is not condensed out of the flow at that point is condensed out with the water, but analysis of the water in the coolant system indicates that its pH is in a neutral range of 6-7. The fuel cell stack is designed with an acid reserve to last for 40,000 hours of operation under normal operating conditions. The power plant provides sufficient water recovery to permit operation under normal load requirements and ambient conditions and thus requires no external water supply beyond initial tank fill. During round the clock, full load operation above an ambient temperature of 308 K (95°F), some make-up water will be required. These prolonged ambient temperatures are not expected to be encountered during the field test. Any excess water in the coolant system is discharged to an external drain.

2.3.1.4 Power Conditioner

Direct current power from the power section (bottom center of Figure 2-5) is fed to the power conditioner subsystem where an inverter assembly converts the unregulated dc output into voltage regulated, current limited ac power. The inverter is a three-phase solid-state device which provides a regulated ac voltage at a nominal level of 120/208 volts. Single phase, 120 volt ac is provided through use of a neutral forming autotransformer. A portion of this power is supplied to the power plant controller making the power plant electrically self-sufficient once startup is completed. The inverter provides a fault clearing capability and uninterruptible power source to maintain operation of critical power plant components during fault clearing periods of up to five seconds. The inverter also provides various ac voltages and a power section output dc current for use by the controller. The field test power plant is designed for the very fast load response required for isolated operation. It is capable of responding to load changes within two cycles, or in less than 1/30 of a second. A summary of the electrical performance characteristics is presented in Table 2-3.

Table 2-3. Electrical Characteristics (Ref. 3)

Output Power Form	4 wire, 3 phase
Frequency	60 Hertz
Frequency Stability	± 0.0002 percent per year
Voltage	120/208 Volts ac
Voltage Regulation	± 5 percent with up to 30 percent load unbalance under steady state conditions
Voltage Recovery	Within 2 cycles
Phase Separation	$120^\circ \pm 5^\circ$ electrical
Current Limit	Up to 300 amps RMS for line-to-line short circuits and 450 amps RMS for line to neutral short circuits
Maximum Duration of Current Limit	5 seconds
Total Harmonic Distortion	≤ 8 percent for isolated operation ≤ 4 percent for grid-connected operation
Electromagnetic Noise	Shall not degrade performance of conventional electrical equipment located farther than 10 ft from the power plant.

2.3.1.5 Additional Features of the Power Plant

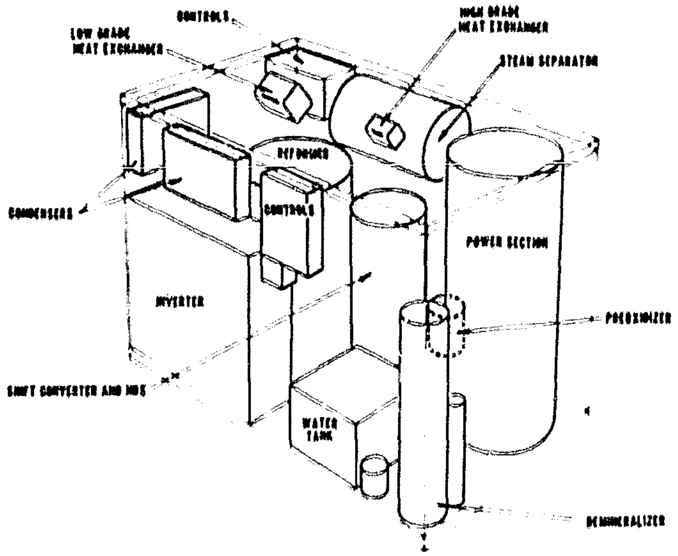
The power plant controller is a programmed microcomputer which provides the control intelligence for the three basic power plant operations: start, run, and shutdown. A master control unit (not included within the individual power plant unit) is used to synchronize and control power plants connected together in multi-unit installations. The master control unit provides for equal load sharing among the individual units. A maximum of six power plant units may be operated in parallel with the present master control unit design. Shutdown of any one power plant in a multiple installation will not interfere with the operation of other parallel units.

The power plant controller unit includes automatic sensing for equipment protection and automatic shutdown in the event of critical out-of-limits component operation. Provision for manual shutdown of the power plant is also provided. During both automatic and manual shutdown, fuel flow stops within ten seconds of shutdown initiation.

The heat input required for power plant startup is supplied to the power section through electric resistance heaters in the thermal management subsystem and to the fuel processor subsystem through a burner in the reformer. Electrical energy required for power plant startup is provided by an external source. A portion of the startup power is provided by a separate dc power supply.

The reformer, shift converter, and steam separator operate at relatively high temperatures and are isolated in a separate compartment within the power plant away from the power section, inverter, controls, water tank, and water purification system. This compartment is well insulated to limit heat transfer. The approximate operating temperatures for the high temperature components are: reformer 644 K (700°F), shift converter 561 K (550°F), and steam separator 455 K (360°F). The lower temperature components operate at temperatures below 422 K (300°F) although the power section operating temperature is in the range of 464 K (375°F). A view of the relative location of these components within the power plant cabinet can be seen in the cutaway illustration in Figure 2-6.

Figure 2-6. Major Component Location (Ref. 3)



2.3.2 Materials of Construction

The power plant is constructed primarily of metal, carbon, plastic, and fiberglass. Assorted catalysts within the power plant facilitate chemical reactions, and various chemical compounds purify fuel and water flows. Phosphoric acid is used as the fuel cell electrolyte.

The power section consists of a single stack made up of 270 individual fuel cells. The stack matrix is silicon carbide. The cell electrodes are constructed of graphite fibers and amorphous graphite, held together with Teflon (a polytetrafluoroethylene plastic), with a small amount of platinum catalyst. Platinum loading is 0.75 mg/cm^2 of electrode surface for a total of about 400g platinum in the entire stack. The matrix and electrodes of the fuel cell stack are saturated with about 63 liters (16.6 gallons) of 99+ percent phosphoric acid (H_3PO_4). Manifolds which conduct the reactants to and from the fuel cells are located on the four sides of the fuel cell stack and are coated with plastic.

The power section cooling system and heat recovery system contain approximately 550m (1800 ft) of copper tubing having a 4.76mm outside diameter (3/16 in.). The exterior surface is coated with a perfluoroalkoxy plastic (PFA). There are 14 individual heat exchange functions in the power plant. The heat exchangers are constructed of copper-nickel alloys and stainless steel. The condensate preheater will probably be constructed of plastic or a plastic-coated metal. The demineralizer, water tank, demister, and various tubing of the cooling and water purification system are made of plastic. The demineralizer contains ion exchange resins and is constructed of DMN 424 A/B plastic. The water tank is constructed of an acetal copolymer (Celcon).

The reformer, shift converter, and other fuel processing components are constructed of carbon steel and stainless steel. Platinum and nickel catalysts are present in the fuel processing system. The hydrodesulfurizer catalyst (nickel-molybdenum on aluminum oxide support) is pyrophoric, and the shift converter catalyst (copper on zinc oxide support) is somewhat pyrophoric. Zinc oxide is used to scrub sulfur compounds from the fuel stream. The inverter is of a solid state design and is primarily metallic. It contains mineral oil for insulation and plastic sheeting.

The power plant pumps, fans, electric heaters, and blowers are constructed primarily of carbon steel. These components are accompanied by electrical wiring. The plastic electrical insulation is made of nylon FEP and cross-linked polyethylene THNN. Tie wraps and clamps are made of nylon. The base, frame, and shell of the power plant are constructed of carbon steel. The external metal shell is covered with a rust-resistant paint. The power plant's thermal insulation is made of fiberglass (Ref. 5).

2.3.3 Interfaces With Site

Interface connections between the power plant and the site are classified in three categories: (1) electrical, (2) gases and liquids requiring transport plumbing, and (3) gases not requiring transport plumbing. Electrical interfaces between the power plant and the site consist of the output power and control wiring, power from the electrical bus for startup, and grounding connections. In addition, a separate dc power supply unit is required for power plant startup. Field test power plants will have an instrumentation interface connector for internal power plant instrumentation. Characteristics of the electrical interfaces are summarized in Table 2-4.

Liquid and gas interfaces requiring transport plumbing include the gas fuel line, heat recovery connections, and a water drain line. The location of these interfaces on the power plant cabinet is shown in Figure 2-7, and the interface characteristics are summarized in Table 2-5. The fuel line can deliver pipeline gas to the power plant at a maximum rate of 0.28 m^3 /min (10 cfm). The fuel system can tolerate fuel pressures ranging from 1.0×10^3 N/m^2 to 3.5×10^3 N/m^2 (4 to 14 in. of water). A manual fuel shutoff valve will be situated in the fuel line. The heat recovery connections consist of inlet and outlet plumbing for both the high-grade and low-grade heat recovery systems. Both systems transport water into the power plant at 300 K (80°F) or higher and out of the plant at 344 K (160°F), although output temperatures of up to 408 K (275°F) are permissible in the high-grade system. The flow rate for the customer high-grade system is 454 to 1816 liters/hr (120 to 480 gal/hr) with pressure up to 1.14×10^6 N/m^2 (165 psia). The customer low-grade heat recovery system moves water through the power plant at the rate of 568 to 1892 liters/hr (150 to 500 gal/hr) with a maximum pressure of 1.03×10^6 N/m^2 (150 psia). The heat recovery plumbing will be covered with fiberglass insulation or equivalent material. Internal power plant drains have been connected into one line to simplify

Table 2-4. Electrical Interfaces (Ref. 3)

	INTERFACE	FROM SUPPLIER	TO/SUPPLIER	DESCRIPTION	POWER FORM	NO. OF WIRES
1	OUTPUT POWER	POWER PLANT PSD	OUTPUT BREAKER/ CUSTOMER	POWER PLANT ELECTRICAL OUTPUT	120/208 VAC 60 HZ 3 PHASE 40 KW @ 0.85 PF	4
2	OUTPUT BREAKER CONTROL	POWER PLANT/ PSD	OUTPUT BREAKER/ CUSTOMER	SIGNAL FROM POWER PLANT TO CONTROL OUTPUT BREAKER	120 VAC 60 HZ 1 PHASE	2
3	MASTER CONTROL	POWER PLANT/PSD	MASTER CONTROL UNIT/PSD	CONTROL FOR PARALLEL OPERATION OF POWER PLANTS	≤ 120 VAC, 60 HZ 1 PHASE	20 COND. CABLE
4	CURRENT TRANSFORMER OUTPUT	CURRENT TRANSFORMER IN OUTPUT BREAKER ENCLOSURE/CUST	MASTER CONTROL UNIT/PSD	SIGNAL FROM INDIVIDUAL POWER PLANTS USED TO REGULATE LOAD SHARING IN MULTIPLE POWER PLANTS	≤ 24 VAC 60 HZ	2
5	MASTER CONTROL	SYSTEM LOAD BUS/CUSTOMER	MASTER CONTROL UNIT/PSD	SIGNAL FROM LOAD BUS TO MASTER CONTROL	120/208 VAC 60 HZ 3 PHASE	4
6	START-UP POWER, DC	DC POWER SUPPLY/CUSTOMER	POWER PLANT/PSD	INPUT POWER TO OPERATE POWER PLANT LOGIC AND UPS DURING START-UP	270 VDC 750W (FLOATING)	2
7	START-UP POWER, DC	POWER PLANT/ PSD	DC POWER SUPPLY/CUSTOMER	POWER TO OPERATE DC POWER SUPPLY DURING START-UP	120 VAC 60 HZ 1 PHASE 750W	2
8	START-UP POWER, AC	POWER PLANT CONTROL BREAKER PANEL/CUSTOMER	POWER PLANT/PSD	INPUT POWER TO OPERATE POWER PLANT COMPONENTS AND HEATERS	120/208 VAC, * 60 HZ, 21 KW 3 PHASE	4
9	START-UP POWER, AC	SYSTEM LOAD BUS/ CUSTOMER	POWER PLANT CONTROL BREAKER PANEL/CUSTOMER	POWER TO OPERATE POWER PLANT COMPONENTS AND DC LOGIC	120/208 VAC 60 HZ 3 PHASE 21 KW	4
10	ALTERNATE AC POWER	UTILITY LINE/ CUSTOMER	TRANSFER SWITCH/ CUSTOMER	POWER TO START POWER PLANT AND ALTERNATE SOURCE	120/208 VAC 60 HZ 3 PHASE	4
11	OUTPUT POWER	OUTPUT BREAKER/ CUSTOMER	TRANSFER SWITCH CUSTOMER	POWER PLANT ELECTRICAL OUTPUT	120/208 VAC 60 HZ 3 PHASE 40-KW @ 0.85 PF/ POWER PLANT	4
12	SYSTEM LOAD	TRANSFER SWITCH/ CUSTOMER	SYSTEM LOAD BUS/CUSTOMER	POWER DISTRIBUTION	120/208 VAC 60 HZ 3 PHASE	4
13	INSTRUMENTA-TION	POWER PLANT/ PSD	DATA ACQUISITION SYSTEM/CUSTOMER	INTERNAL POWER PLANT INSTRUMENTATION	0-10 Vdc	57 COND. CABLE

*While shutdown, approximately 1-kW is used to maintain the power section at 100°F.

Figure 2-7. Location of Liquid and Gas Interfaces Requiring Transport Plumbing (Ref. 3)

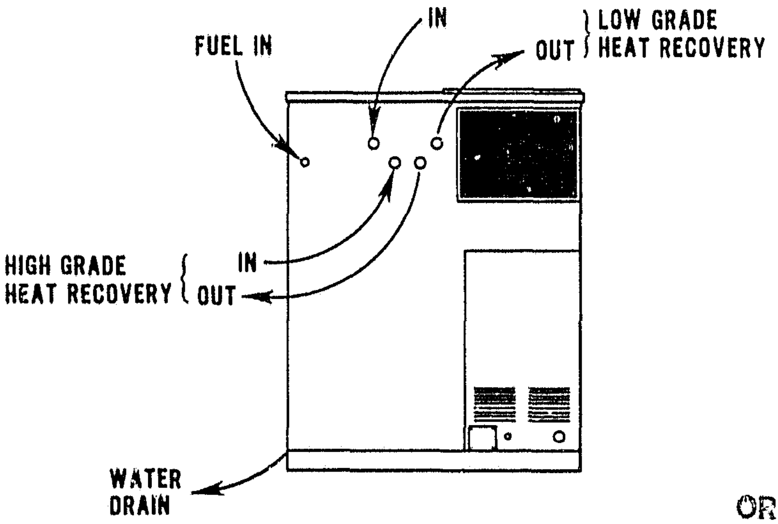


Table 2-5. Gas and Liquid Interfaces Requiring Transport Plumbing (Ref. 3)

Interface	Fluid	Flow Rate m^3/hr (gal/hr)	Pressure N/m^2	Temperature K (°F)	Comments
Fuel	Pipeline Gas	16.99 (10 ft^3/min)	1.0-3.5x10^3 (4-14 in. H_2O)	284-306 (50-90)	Includes Peak Shaving Mixtures
High Grade (In)	Water	0.45 (120)	1.14x10^6 (165 psia)	300 (80)	Output Temperatures
Heat Recovery (Out)	Water	0.45 (120)	1.14x10^6 (165 psia)	344 (160)	up to 408 K (275°F) are permissable
Low Grade (In)	Water	0.57 (150)	1.03x10^6 (150 psia)	300 (80)	
Heat Recovery (Out)	Water	0.57 (150)	1.03x10^6 (150 psia)	344 (160)	
Drains					
Coolant Loop	Water				Shipping & Storage Drain Only
Separator	Water				Shipping & Storage Drain & Blowdown
Water Tank Overflow	Water	0.038 (10)	Ambient	344 (160) Max	
Water Tank/Fill	Water				Shipping & Storage Drain Only

the water drain interface. This drain will connect to a site drain and will dispose of a maximum of 38 liters/hr (10 gal/hr) of surplus water at a maximum temperature of 344 K (160°F) and ambient pressure.

Gas interfaces not requiring plumbing include the power plant air inlets, exhausts, and vents. The location of these interface ducts on the power plant cabinet is shown in Figure 2-8, and the interface characteristics are summarized in Table 2-6. Air inlets provide the power plant needs for process air, condenser cooling, thermal control heat exchanger cooling, water cooler cooling, and inverter cooling. The total maximum air requirement is 173 m^3/min (6100 ft^3/min). Power plant exhausts consist of process exhausts and cooling exhausts. The total maximum exhaust flow is 235 m^3/min (8350 ft^3/min) with a maximum mixed exhaust temperature of 361 K (190°F). The volumes of air and exhaust flows are dependent on the levels of power output and customer use of recovered heat. Power plants installed indoors will require a hood and flue for venting of power plant exhausts. Provided the flue is sized to accommodate the flow of exhaust products by natural convection, the hood need not be designed for forced convection. Vents on the power plant cabinet allow cooling air to be discharged. Steam is discharged during the maintenance and startup procedures and intermittently through pressure relief valves during periods of overpressure.

2.3.4 Operating Characteristics

The on-site power plant is designed for a nominal net ac electrical output of 40 kilowatts. The normal power range is zero to 40-kW with a transient overload capability to 56-kW for a maximum of five seconds under balanced load conditions. The electrical efficiency design goal is 40 percent of the fuel lower heating value at half power and full rated power. The field test power plants are expected to operate in the efficiency range of 37 to 40 percent from half to full rated power. As shown in Figure 2-9, the recovery of by-product heat results in a high total fuel utilization of up to 80 percent at full rated power.

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Figure 2-8. Location of Gas Interfaces Not Requiring Transport Plumbing (Ref. 3)

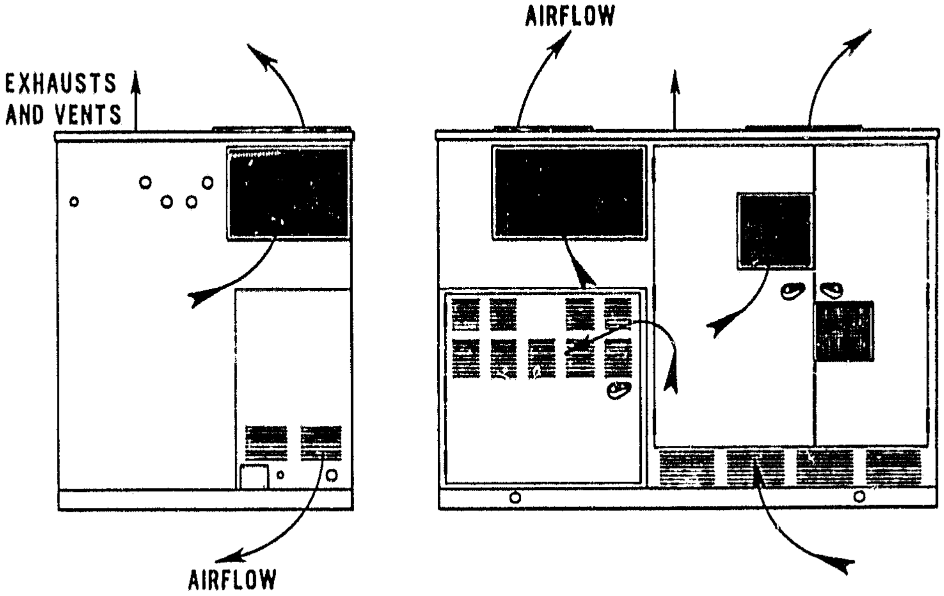


Table 2-6. Gas Interfaces Not Requiring Transport Plumbing (Ref. 3)

Interface	Fluid	Maximum Flow Rate m^3/min (ft^3/min)	Pressure	Temperature K (^oF)	Comments
Air Inlets					
Process Air	Air	5.66 (200)	Ambient	242-317 (-25-120)	
Condenser Cooling	Air	98.52 (3480)	Ambient	242-317	Total Flow
Thermal Control Heat					Requirement
Exchanger Cooling	Air	39.63 (1400)	Ambient	242-317	is
Water Cooler Cooling	Air	6.23 (220)	Ambient	242-317	172.69 m^3/min
Inverter Cooling	Air	22.65 (800)	Ambient	242-317	(6100 ft^3/min)
Exhausts*					
Process Exhaust & Condenser Cooling	Air/CO_2/N_2	127.40 (4500)	Ambient	344 (160)	Maximum Mixed
Thermal Control Heat					Exhaust
Exchanger Cooling	Air	76.44 (2700)	Ambient	428 (310)	Temperature
Water Cooler Cooling	Air	7.08 (250)	Ambient	328 (130)	= 361 K (190°F)
Inverter Cooling	Air	25.48 (900)	Ambient	328 (130)	
Vents					
Coolant Loop Bleed	Air	--	--	--	For Filling Only
Separator Vent	Air	--	--	--	For Startup Only
Separator Safety Relief	Steam	--	--	--	Overpressure Relief
High Grade Heat					
Exchanger Relief	Steam	--	--	--	Overpressure Relief
Superheater Safety Relief	Steam	--	--	--	Overpressure Relief
Low Grade Heat					
Exchanger Relief	Steam	--	--	--	Overpressure Relief

*Flows and temperatures listed are not coincident.

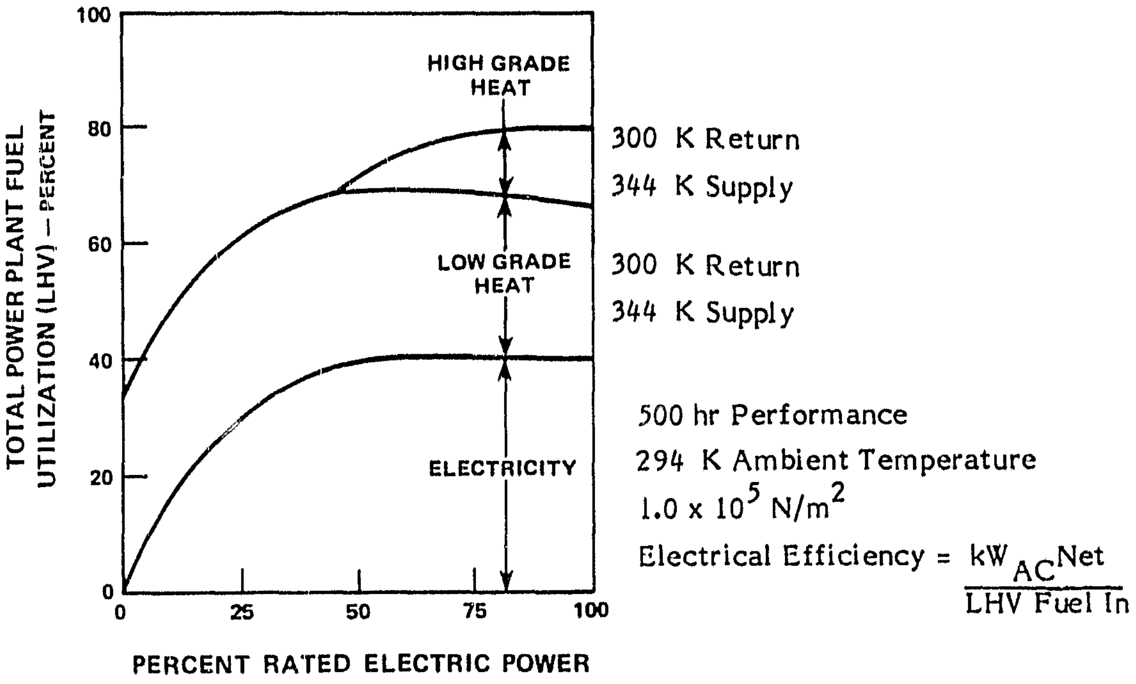
The power plant will provide rated power and five seconds of overload or current limit operation within an ambient temperature range of 242 K to 317 K (-25°F to 110°F). In ambient temperatures between 317 K and 322 K (120°F), the power plant will continue to supply rated power but will have limitations in overload and current limit capacity. The power plant is designed to withstand the environmental conditions specified in Table 2-7. It is capable of operating at altitudes up to 1830m (6000 ft) with some limitation of transient overload capability.

Table 2-7. 40 kW On-Site Power Plant Weather Specifications (Ref. 3)

Ambient Temperature	242 to 322 K (-25 to +120°F)
Wind (Side Wall)	36m/sec (80 mph)
Snow or Ice Roof Load	1915 N/m^2 (40 lb/ft^2)
Solar Radiation	29 kJ/m^2/hr (300 Btu/ft^2/hr)

Electrical power is delivered as 3 phase, 60 Hz alternating current at 120/208 volts. Frequency stability is ± 0.0002 percent per year. Steady state output of any phase is 120 volts ± 5 percent from minimum to rated power output conditions, including load unbalance conditions between phase of up to 30 percent. Inverter design provides voltage recovery within two cycles following either a balanced or unbalanced step change in load. Total harmonic distortion of any phase will not exceed 15 percent for any load up to the peak power condition and is, in fact, less than the distortion present in utility grade power.

Figure 2-9. Total Power Plant Fuel Utilization (Ref. 3)



The inverter incorporates a rapid action current limit feature to allow the output current to reach the zero voltage fault clearing value without exceeding the inverter power handling capacity. Under fault conditions, the inverter provides up to 300 amps RMS for line-to-line short circuits and 450 amps RMS for line-to-neutral short circuits. Maximum duration of the current limit is five seconds within an ambient temperature range of 242 to 316 K (-25 to 110°F). The inverter will supply steady state loads up to rated capacity in ambient temperature up to 322 K (120°F). Full transient overload and current limit capabilities are reduced at this temperature to approximately two seconds duration. Full overload or current limit operation in excess of this period may cause a fuse to open resulting in an automatic power plant shutdown. The same basic inverter design will be used in all power plants regardless of whether they are connected to or isolated from the utility grid. Grid connected inverters will have some additional equipment to facilitate the interface, however.

The inverter is designed to conform to FCC regulations and under normal operating conditions it will not produce electromagnetic interference of sufficient magnitude to cause degraded performance of any electrical equipment being powered by it or being operated farther than 3 meters (10 ft) from the power plant.

2.3.5 Heat Recovery Characteristics

The power plant can transfer by-product heat from the exhaust gases and cooling system to customer water loops via low-grade and high-grade heat exchangers. The quantity of heat delivered is primarily a function of output power but also depends on ambient temperature, altitude, and duration of power plant operation. The customer can take as much heat from the low grade heat system as is available but can only take heat from the high grade heat system when an excess is available since the power plant requires a portion of the high grade heat for its own operation. The customer is not required to recover all or any portion of the thermal energy since the air-cooled system is capable of removing any thermal energy not utilized by the customer.

At 50 percent of rated power, approximately 60,000 kJ/hr (57,000 Btu/hr) are available from the low-grade exchanger, and 0-10,000 kJ/hr (0-9500 Btu/hr) are available from the high-grade exchanger. At 100 percent of rated power, heat availability increases to 100,000-120,000 kJ/hr and 30,000-80,000 kJ/hr for the low-grade and high-grade heat exchangers respectively. These thermal energy ranges are maximum values and the actual thermal availability may be less depending on the inlet and exit temperatures of the customer flow loops. Figures 2-10 and 2-11 illustrate the variability of heat recovery with changing operating conditions. The temperature and altitude variables in these figures are operational extremes. The time variable represents total hours of power plant operation.

2.3.6 Air Emissions Characteristics

Air pollutants from the 40 kW fuel cell power plant originate from two sources: the reformer assembly burner and the cathode side of the fuel cell stack. Sulfur emissions from the burner are significantly reduced by pretreating the fuel before it enters the fuel cell stack and is subsequently ignited in the burner. Since the platinum catalysts in the fuel cells can not tolerate sulfur compounds, most of the sulfur is removed from the fuel prior to reforming. Any halogens and sulfur that happen to pass through the fuel cleanup system are emitted in the exhaust; however, emission tests have proven sulfur emission levels to be extremely low.

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Figure 2-10. Low Grade Heat Availability (Ref. 3)

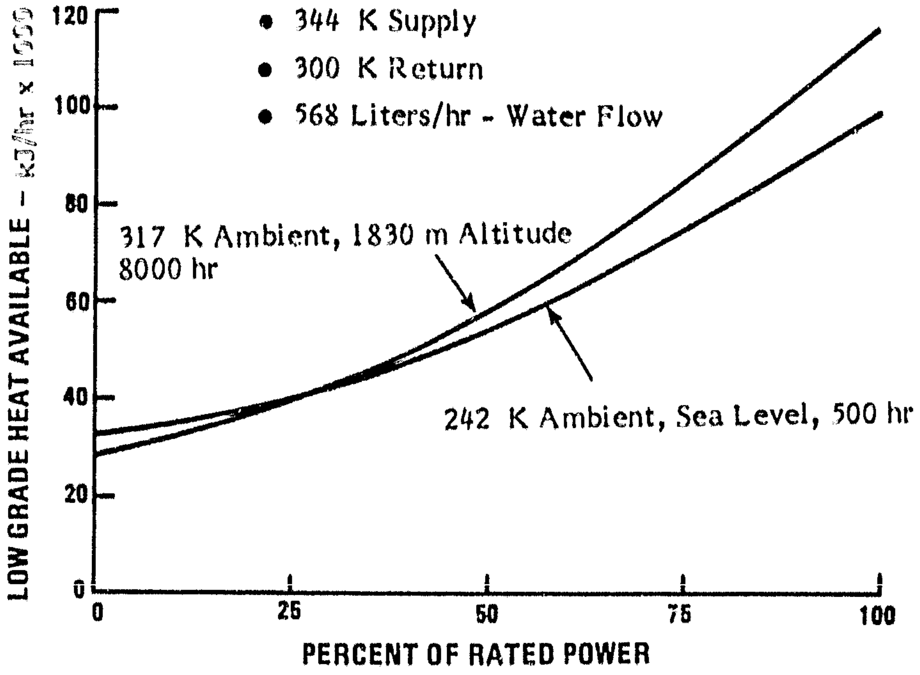
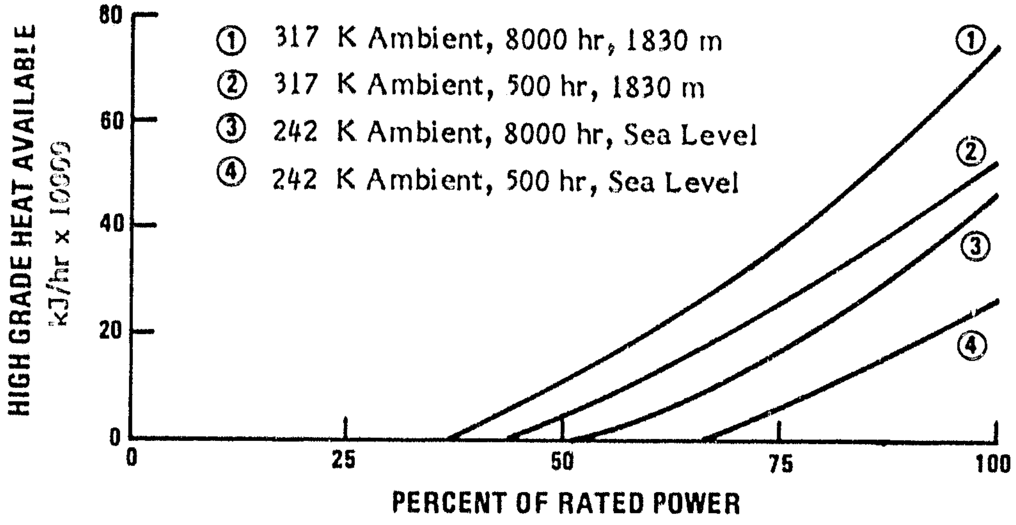


Figure 2-11. High Grade Heat Availability (Ref. 3)



When hydrogen-rich fuel from the reformer is fed to the anode, approximately 80 percent of the hydrogen is consumed while the remaining hydrogen and residual hydrocarbon fuel components flow to the reformer burner to supply heat energy for the reforming process. Under normal operating conditions, the burner fuel is converted almost exclusively to CO_2 and water vapor. The reformer burner temperature is low enough so that little thermal NO_x is produced. NO_x will be present in the emissions, however, as a result of bound nitrogen in the fuel.

The oxygen-deficient exhaust stream from the cathode consists primarily of ambient air gases (particularly N_2) and product steam. Very small quantities of phosphoric acid (1 ppm) normally exit the cathode with this exhaust stream. The acid is injurious to downstream heat exchangers and therefore is removed by acid and water vapor condensers. The condensate preheater removes about 90-95 percent of the acid in the exhaust flow and much of the remainder is removed with water vapor as it passes through the condenser. The result is that the quantity of H_3PO_4 in the power plant emissions is substantially less than 0.1 part per million.

United Technologies Corporation has conducted emission tests on a preprototype 40 kW power plant that is very similar to that which will be field tested. These tests were made at three net power levels: 0 kW, 20 kW, and 38½ kW. The tests measured emission rates for NO_x, SO_x, particulates, smoke, and total hydrocarbons (THC); the results of the testing are presented in Table 2-8. The natural gas fuel selected for the tests did not contain air or liquid petroleum gas (LPG) in the total gas mixture because a UTC analysis found that the power plants would only be operated on peak shaved gas for an average of 200 hours per year. Inclusion of these constituents should not have a major impact on air emission rates, however (Ref. 5).

Table 2-8. 40 kW Fuel Cell Power Plant Exhaust Emissions
in kg/GJ Heat Input for Various Net Output Levels
(lbs per million Btu)

	0 kW Net Power	20 kW Net Power	38½ kW Net Power
NO_x	.0027 (.0056)	.00062 (.0013)	.00029 (.00060)
SO_2	.000017 (.000035)	.000015 (.000032)	.000016 (.000034)
Particulates	.00072 (.0015)	.0010 (.0021)	.0000 (.0000)*
Smoke	None	None	None
THC	.021 (.043)	.0031 (.0065)	.0012 (.0025)

*Possible sampling problem

The emission test results were obtained following one hour of continuous operation at each of the three net power levels tested. During unsteady state operating conditions (startup and load response transients), air emissions will probably be higher. Reformer burner temperature may go up during load decreases resulting in a higher NO_x emission.

2.3.7 Noise Characteristics

The power plant has various fans, blowers, pumps, and other mechanical components that produce noise. In testing performed by UTC, the maximum free field noise level at any point measured 4.6m (15 ft) horizontally from the power plant perimeter was found to be 61 dBA at full rated power. This noise level varied little over the output range of the power plant. The primary noise producers are the process air blower and the condenser fan (Ref. 5).

2.4 Power Plant Installation and Operation

This section provides general information regarding power plant transportation, handling, installation, operation, maintenance, and dependability. More detailed information on each of these items will be provided in the Field Test Power Plant Installation, Operation, and Maintenance manuals to be issued by the Gas Research Institute. The duties and activities of all field test participants are described in 2.1.1.

2.4.1 Transportation and Installation

The power plant has been designed for ease of handling and flexibility in mode of transportation. The design includes the capability to withstand reasonable handling loads (3 gs) in both the horizontal and vertical direction, consistent with normal industrial equipment design practice. The power plant base provides the structural means for both lifting and movement. Power plant size and weight permit transportation by either truck, train, ship, or aircraft. The shock and vibration loads (4 gs) assumed in the power plant design are consistent with transportation by air-ride truck. To accommodate shipping by other modes, an external shipping fixture would be required. The power plant may be tipped to 45° during handling and shipping.

The power plant may be installed as a single unit or in multiple units of up to six per master control unit. The design provides a minimum of interfaces with the site, ensuring ease of installation. Sufficient space must be available at the site to allow access to the power plant for maintenance and repair. The power plant should be installed plumb and level. It imposes a floor loading of approximately 7.18×10^3 N/m^2 (150 lb/ft^2) and its size allows it to easily pass through a double doorway of standard dimensions.

2.4.2 Startup, Operation, and Shutdown

The control system on the power plant provides fully automatic operation over the complete power range. During the four hour startup sequence, the control function is semiautomatic and the presence of a service-person is required. Shutdown is manual or automatic. Automatic shutdown is based on monitored power plant out-of-limits conditions. (These are described in the Safety System section, 2.4.3, immediately following.)

Externally supplied electrical power from the electrical bus and a separate dc power supply unit is required during power plant start to provide power for electric heaters, pumps, and control components. Special procedures must be followed during the initial startup.

The power plant responds automatically to changes in load demand by sensing the power being delivered and metering the fuel flow as required. Rated output voltage recovery will take place within two cycles (1/30 second) following a step change in output power. Overloads above the rated 40 kW output power will be maintained for up to five seconds. If this time limit is exceeded, the total load will be disconnected automatically by activation of the output breaker to protect the power plant. The power plant remains operating and loads can be applied after the overload condition is corrected. Manual reset of the power plant following activation of the output breaker is required for the power plant to resume normal operation.

One kW of external power is required to provide for an even cool down of the power section and then to keep the power section at 311 K (100°F). Should a power outage occur during a power plant shutdown and cause the fuel cell stack temperature to drop below 311 K, the phosphoric acid electrolyte could solidify resulting in a possible slight loss of stack performance. About 20 such events can be tolerated before the cell stack would require replacement. In the event shutdown occurs at or below a power plant ambient temperature of 274 K (33°F), all water must be drained from the power plant and the demineralizer and charcoal filter removed and stored. Power plant restart can be initiated at any time after shutdown provided that water and all removed components have been replaced.

2.4.3 Safety System

Included in the power plant controller unit is the automatic safety sensing system for equipment protection and automatic shutdown in the event of critical out-of-limits component operation. The sensing system monitors nine operating parameters using thermoelectric sensors and other equipment. It is designed so that most operational irregularities of an unsafe nature will be detected by one or more of the sensors. The nine parameters subject to continuous monitoring by the system are:

- High TMS Temperature (Steam Separator)
- High Reformer Temperature
- Low Reformer Temperature
- Cabinet Overtemperature (Multiple)
- Preoxidizer Overtemperature
- Loss of Reformer Burner Air
- Inverter Failure Conditions
- Loss of Coolant Flow
- Power Section Ground Fault

When a critical out-of-limits condition is detected, the safety system will automatically initiate the shutdown of the power plant. Provisions for manual shutdown of the power plant are also provided. During both automatic and manual shutdowns, fuel flow stops within ten seconds of shutdown initiation. The unit can be restarted only by trained service personnel following inspection and correction of the irregularity. Shutdown of one unit will not affect the normal operation of other power plant units operating in parallel with it so long as the power overload conditions of these power plants are not exceeded.

UTC has tested both the automatic and manual shutdown procedures and has demonstrated that fuel flow stops within ten seconds after shutdown initiation. The automatic safety system has been tested by creating staged operating irregularities and was found to initiate shutdown according to design. Functional verification of all critical input signals was made electronically. The safety systems of all power plants will be bench-tested by UTC prior to shipment of the power plants to their on site test locations (Ref. 5).

2.4.4 Dependability and Maintenance

The design life goal for the mature, commercial power plant with periodic overhaul and maintenance is twenty years with an operational goal of no more than one unscheduled shutdown per year. However, it is anticipated that the field test power plants will be operated for 8000 hours each and these preprototype power plants may experience unscheduled shutdowns in excess of the above goal.

Two types of scheduled maintenance are required by the power plant: (1) minor component changes or cleaning which can be accomplished with the power plant operating, and (2) annual procedures which require power plant shutdown. The packaging arrangement inside the power plant has been designed to permit efficient and safe maintenance, adjustment, and repair. For every 2000 hours of power plant operation the demineralizer requires changing, while for every 4000 hours of operation, the air filter for the process air blower must be changed and the external condenser surfaces and water cooler must be cleaned. These three operations can be safely conducted during power plant operation. A number of components require checking, cleaning, or changing on an annual basis. Since field test operation is scheduled to last only one year before the power plants are removed from the sites and returned to the manufacturer for examination, these annual maintenance functions will probably not be necessary during on-site operation. The annual maintenance procedure would require an eight hour shutdown of the power plant. Scheduled maintenance items are summarized in Table 2-9.

Table 2-9. Scheduled Maintenance Items (Ref. 3)

	Conducted During Power Plant Operation			Requires Power Plant Shut Down	
	Every 2000 Hours	Every 4000 Hours	Every 8000 Hours	Every 8000 Hours	
Demineralizer	Change				
External Condenser Surfaces and Water Cooler		Clean			
Air Filter for Process Air Blower		Change			
Acid Tank			Change		
Inverter Air Filter				Change	
Safety Valves				Actuate	(local codes apply)
Steam Separator				Internal Inspection	(local codes apply)
High Grade Heat Exchanger				Clean	customer side if necssary
Low Grade Heat Exchanger				Clean	
Water Tank				Clean	
Coolant Filter				Clean	
Charcoal Filter				Change	
Reformer				Check Gaskets, Thermocouples	

2.5 On-Site Energy Systems

An on-site energy system is defined here as a system in which all or part of a building's energy needs are generated on-site. On-site systems can take many forms. The simplest system is one in which the power plant installed on-site is used to generate electric power only. More elaborate versions utilize the rejected heat from the power plant to satisfy, in part at least, the thermal demands of the building such as space heat, domestic hot water, or process needs. A still more elaborate version would allow the use of the power plant reject heat for space cooling via an absorption chiller.

Conceptually, any power plant that is available in the size range required for any specific building is suitable for on-site generation. For residential, commercial, and light industrial applications, a system that is particularly attractive is the fuel cell. The fuel cell power plant is relatively quiet, clean, vibration free, and of modular construction. The modularity enables the achievement of high reliability without excessive redundant capacity. The fuel cell thermal output is of suitable quality for space heating, domestic hot water, and for use by absorption chillers.

The following discussion describes possible configurations and operating strategies for on-site energy systems in general, and then for the field test in particular.

2.5.1 Electric Generation Only

The total electric generating capacity installed on-site can vary from very low to an amount equal to the peak electric demand plus some reserve capacity to meet reliability requirements. In the latter case, the building could sever all ties to the local electric utility and thus operate in a grid-isolated manner. Alternatively, the installed generating capacity could be limited to an amount approximately equal to the peak electric demand with the utility providing backup or standby power in case some or all of the on-site generating capacity is out of service.

If the on-site installed capacity is even less, the local electric utility would need to supply electric power whenever the demand exceeds the on-site installed generating capacity. This situation is illustrated in Figure 2-12. This figure assumes that on-site power generation is limited to what can be used on-site with no power export. Alternatively, the on-site power plant could be operated at full power continuously. This situation is illustrated in Figure 2-13. When the amount of power generated exceeds the amount required, the excess is exported to the utility gird. If the amount needed exceeds the amount generated, the deficiency is purchased from the utility.

If the total installed on-site generating capacity is reduced below the minimum electrical needs of the building, then all of the full load electric output can be utilized on-site. This is illustrated in Figure 2-14. Other operating strategies, not discussed here, are also possible. The output and load curves shown in these figures are representations of a theoretical site situation. Actual load curves for particular building types are illustrated in Section 3. The actual output curves are dependent on the site load and type of operational strategy employed.

In all cases discussed above, the operation and design of the heating or cooling systems are unaffected by the substitution of on-site power generation for power purchased from the utility grid.

Figure 2-12. Possible Electrical Load/Output Relationship During Electrical Load Following Operation

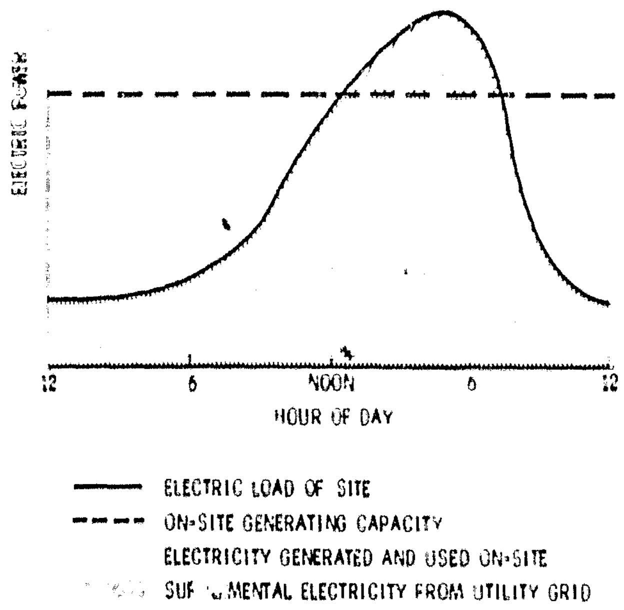


Figure 2-13. Possible Electrical Load/Output Relationship During Continuous Full Power Operation

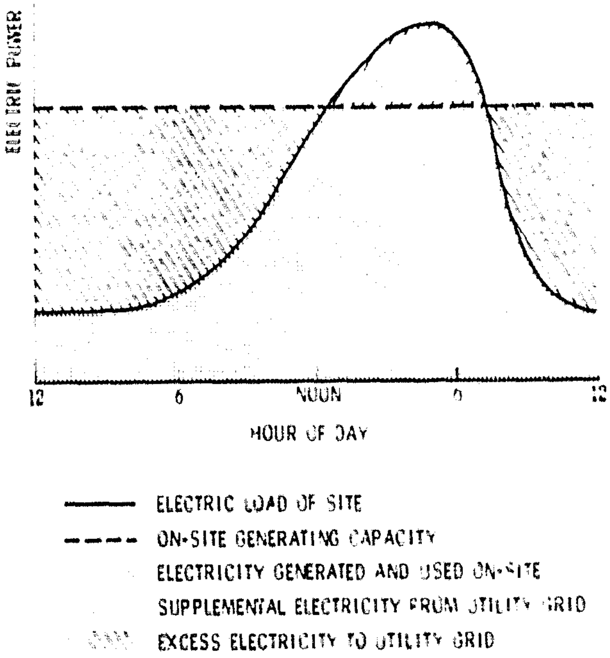
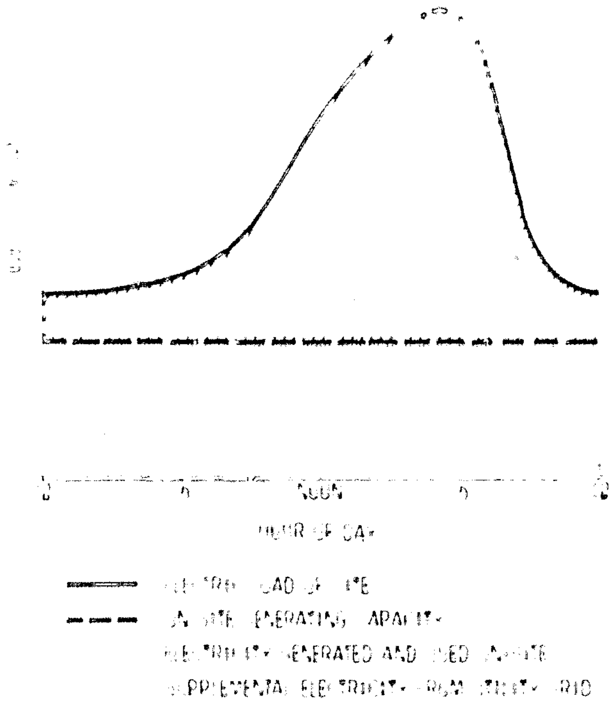


Figure 2-14. Possible Electrical Load/Output Relationship When the On-Site Generating Capacity is Below the Minimum Electrical Load



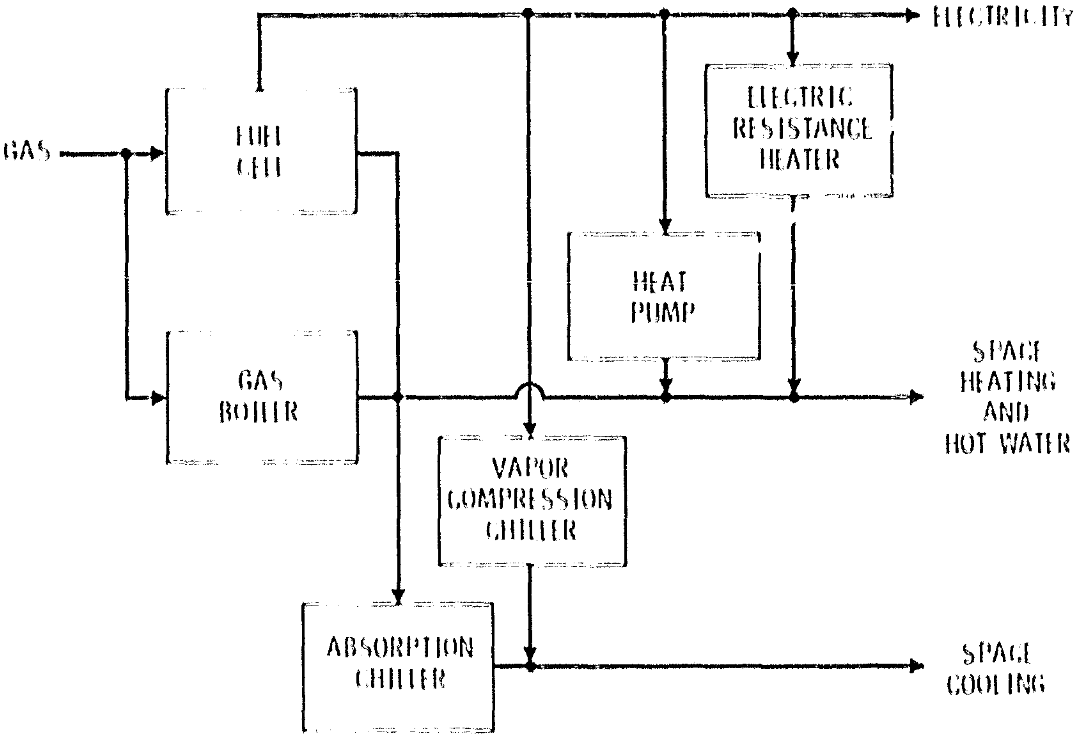
2.5.2 On-Site, Integrated Energy Systems

If the byproduct heat from the on-site electric generation is used to satisfy either heating or cooling demands, then the design and operation of the heating and cooling systems are no longer independent of the electrical design and operation. Such systems are called on-site, integrated energy systems (OS/IES) in this report. The primary advantage of integrated systems is the improvement of overall energy utilization efficiency. Many design configurations are made possible by using a fuel cell power plant in combination with an air conditioner or heat pump, and a gas furnace and heater.

A description of all possible OS/IES configurations is not practicable; however, many of these configurations can be viewed as variations of the generalized OS/IES configuration in Figure 2-15. This system includes a fuel cell, absorption chiller, vapor compression chiller, heat pump, electric resistance heaters, thermal energy storage, and a supplemental boiler. The system may be centralized for application to larger buildings to take advantage of equipment sizes and economies of scale or it may be employed as a dispersed or unitary system in small apartment buildings to take advantage of low-cost, standard equipment and to reduce overhead.

The fuel cell power plant in Figure 2-15 would satisfy all or any part of the building's electrical energy requirements. Building requirements for space heat, hot water, and process steam would be satisfied to the maximum extent possible by the thermal energy available from the fuel cell. When the thermal energy from the fuel cell is less than that required by the building, either the heat pump or the electric resistance heater would be operated to meet the excess load. In a similar manner, the cooling demands of the building would first be met using heat from the fuel cell as input to the absorption chiller. When the available thermal energy is inadequate, or if the capacity of the absorption chiller is exceeded, the electric compression chiller could be operated. Only when the fuel cell power plant's thermal and electrical capacity for heating or cooling is exceeded, would an auxiliary boiler be operated to produce the required thermal energy. Although not shown in Figure 2-15, thermal storage has the potential to improve energy performance by storing energy that otherwise would be rejected as waste. It has a smoothing effect on equipment operation, permitting operation at higher levels during low load periods, while storing the energy for subsequent peak shaving. When thermal storage is used for peak shaving, it permits equipment size reductions which improves part-load efficiencies (Refs. 6 and 7).

Figure 2-15. OS/IES Configuration Showing Various Possible System Components (Ref. 7)



As is the case with on-site systems providing only electricity, the on-site generation capacity of OS/IES can vary from a very small amount to an amount necessary for stand-alone, grid-isolated operation. A variety of operating strategies is available for use with the OS/IES including those previously described for the on-site system restricted to electric generation. In addition, if the OS/IES has a connection to the utility grid, it can operate in a thermal load-following mode. Because one of the major benefits of on-site power plant operation is the recovery and use of thermal energy that is normally wasted by conventional power generating schemes, total fuel energy utilization can be maximized by satisfying all of the site's thermal energy demands with thermal energy from the power plants. Excess electrical production can be exported to the grid and power shortfalls can be alleviated by withdrawing power from the grid. This strategy eliminates the need to waste thermal energy from the power plants as well as the need to use electrical energy to provide space heating and hot water. Implementation of thermal load-following requires a site with a thermal energy demand substantial and constant enough to warrant power plant operation at elevated levels.

2.5.3 Field Test Configurations and Operating Strategies

The field test will not evaluate all possible on-site energy system configurations or operating strategies. Most, if not all, of the test sites will have an OS/IES utilizing byproduct heat from the fuel cell. The number of fuel cell power plants installed at each test location, either one or two, will be such that it can satisfy all or a divisible portion of the electric demand. Since most of the test buildings will have peak electric demands greater than the 40 or 80 kilowatts provided by one or two power plants respectively, most of the power plant installations will likely be sized to provide service to only a portion of the building. The thermal load-following mode of operation will not likely be tested.

The OS/IES configuration at each test location will be heavily dependent on the electrical, heating, and cooling requirements of the location and the energy equipment already installed. The most common configuration to be used during the field test will connect the fuel cell power plant directly to the existing equipment in the test building with little or no additional equipment for heating or cooling. Thermal energy recovered from the fuel cell power plants will be used to preheat the domestic hot water supply. Preheated water can be stored in the hot water heater tank until it is withdrawn and fully heated for use. This form of thermal storage allows recovery of thermal energy from the fuel cell power plants even during times when the demand for thermal energy is low. A source of thermal backup (furnace, heater) will probably be required at all sites to meet space heating and hot water needs not satisfied by the fuel cell power plant. A schematic of the OS/IES anticipated to be most commonly used during the field test is shown in Figure 2-16.

Several of the test locations are tentatively scheduled to include electric heat pumps as part of their OS/IES for heating and cooling purposes. The heat pumps will be installed during fuel cell power plant installation if they are not already operating at the site. As shown in Figure 2-17, the heat pump will supply space heating and cooling while hot water will be supplied by the fuel cell power plant and a backup thermal energy supplier. The power plant and backup may also supplement space heating.

The power plant inverter is designed to give the fuel cell unit the capability of operating as either a stand-alone, grid-isolated electrical generation system, or as a grid-connected system having an interconnection with the grid of an electric utility. Grid-connected units will also operate in the isolated mode after automatically disconnecting from the grid in case of a fault on the grid. The field test will evaluate fuel cell power plant performance for both of these electrical connection arrangements. It is expected that approximately one-third of the power plant installations will be grid-isolated and two-thirds will be grid-connected. Technically, all of the power plants require connection to an external electrical source in order to draw the power required during startup and shutdown. However, power plant installations that are grid-connected will be able to export excess electrical output to the utility grid when output exceeds site demands and withdraw supplemental electrical power when power plant output is less than that required by the site. Should the peak electrical demand of the site exceed the maximum power plant installation output, and supplementary electricity is not available from a utility grid, the installation will automatically shut down in order to protect itself. In the event of a power plant shutdown at a grid-isolated site for this or any other reason, a transfer switch will automatically shift the site load to the site's conventional power system so that site occupants will not be inconvenienced by a power disruption.

Figure 2-16. Basic OS/IES Configuration Proposed for Field Test

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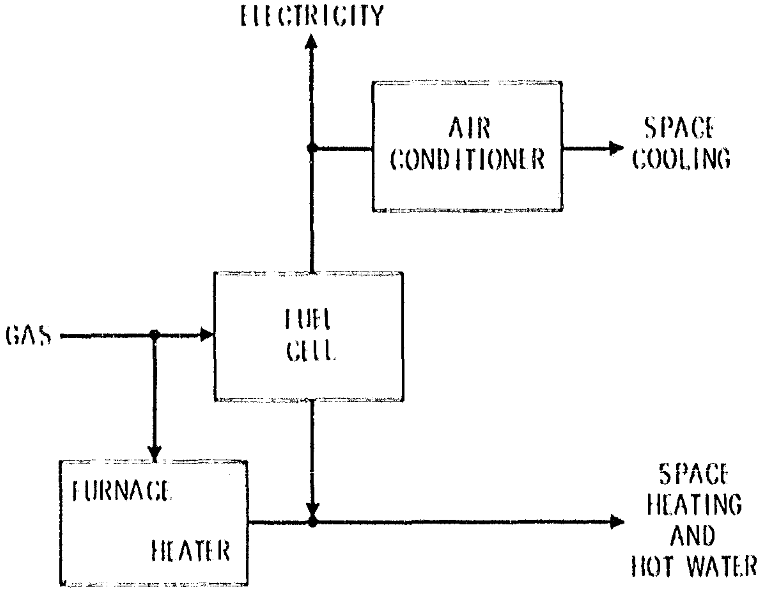
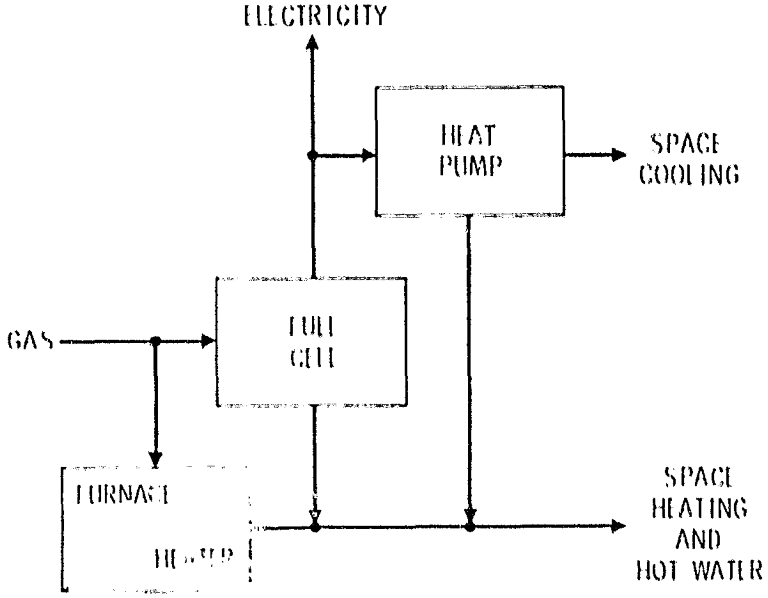


Figure 2-17. OS/IES Configuration (with Heat Pump) Proposed for Field Test



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5. Brown, James D., Program Manager, Fuel Cell Operations, United Technologies Corporation, Personal communication, 1981.
6. MATHTECH, Inc. An Analysis of the Application of Fuel Cells in Dual Energy Use Systems, February 1979.
7. MATHTECH, Inc. Study of Fuel Cell On-Site, Integrated Energy Systems in Residential/Commercial Applications, October 1980.

3. ENVIRONMENTAL SETTING

The utilities participating in the fuel cell field test program are at varying stages of involvement, with preliminary installation sites having been selected by some utilities for data acquisition. The following section describes the water resources, air quality and climatic conditions representative of the areas serviced by the utilities in the program. Reasonable noise standards which should be met by the fuel cell units are indicated. Also included is a discussion of the candidate facility types and their associated energy demand profiles. The types of equipment currently used to satisfy the heating and cooling needs of buildings are identified with their energy efficiencies and environmental impacts.

3.1 National Environment

The sustained environmental improvement effort of the past decade has made significant inroads on identified problems throughout the nation. Environmental problems which persist today are often regional, and most result from excessive demands on resources by the concentrated populations characteristic of urban and suburban areas. These are the areas in which the fuel cell power plants are most likely to be located. Because final sites have not been selected, the following environmental setting analysis is generic in nature, serving to identify areas of environmental concern which may need to be addressed in site specific evaluations.

3.1.1 Participating Utilities

It is highly desirable that tests be conducted in as many states as possible and in geographic regions that provide a good representation of the economic climate, legal, and regulatory conditions to be encountered in a commercial on-site fuel cell business venture. To satisfy this goal, 24 American utilities and two utilities in Japan are expected to participate in the field test program. These American utilities are identified in Appendix A and located on the map in Figure A-1. Japanese utility siting is not addressed in this environmental assessment, however.

3.1.2 Energy Consumption

The candidate facilities represent the residential, commercial and, depending on definition, the industrial sectors. Some light industries may be classified as part of the commercial sector. Of all the energy consumed in the United States, the energy demands of these three broad groupings are about 20 percent, 13 percent and 37 percent, respectively. Of the energy used in commercial buildings during 1975, retail and wholesale structures accounted for 24 percent, while educational buildings used 19 percent, finance and "other" offices used 16 percent, health buildings used 6 percent, hotels and motels used 6 percent, and public administration buildings accounted for 4 percent (Ref. 1).

Tables 3-1 and 3-2 summarize the energy consumed in the United States in 1972 by sector and energy use category. Heating and cooling services include space heating and cooling, water heating, and refrigeration. Other general energy services include

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Table 3-1. Energy Utilization for Heating and Cooling Services, 1972 (EJ)[(a)] (Ref. 2)

	Space Heating			Space Cooling		Water Heating		Refrigeration	
Energy Carrier	Res.	Comm.	Ind.	Res.	Comm.	Res.	Comm.	Res.	Comm.
Electricity[(b)]	0.327	0.097	--	0.257	0.525	0.288	0.012	0.367	0.286
Natural Gas	3.964	2.221	0.130	--	0.169	0.970	0.086	--	--
Petroleum Products	3.376	1.891	0.056	--	--	0.348	0.135	--	--
Coal	0.208	0.117	0.003	--	--	--	--	--	--
Wood	0.448	--	--	--	--	--	--	--	--
Total	8.323	4.328	0.189	0.257	0.694	1.606	0.233	0.367	0.286
Percentage of Total National Energy Consumption	10.8	5.6	0.2	0.3	0.9	2.1	0.3	0.5	0.4

(a) One exajoule (EJ) is 10^{18} joules or 0.9478×10^{15} Btu.

(b) Electricity converted at 3.6 megajoules per kilowatt hour.

Table 3-2. Energy Utilization for Other General Energy Services, 1972 (EJ)[(a)] (Ref. 2)

	Cooking		Drying		Lighting			Electronic Services	Appliance Services
Energy Carrier	R[(c)]	C	R,C	A	R	C,I,A,N,M	S	R,C,I	R,C,A,N,M
Electricity[(b)]	0.129	0.009	0.096	--	0.267	0.574	0.044	0.330	0.227
Natural Gas	0.316	0.156	0.128	--	--	--	--	--	--
Petroleum Products	--	--	--	0.081	--	--	--	--	--
Total	0.610		0.305		0.885			0.330	0.227
Percentage of Total National Energy Consumption	0.8		0.4		1.1			0.4	0.3

(a) One exajoule (EJ) is 10^{18} joules or 0.9478×10^{15} Btu.

(b) Electricity converted at 3.6 megajoules per kilowatt hour.

(c) Key to sector abbreviations: residential (R), commercial (C), industrial (I), agriculture (A), construction (N), mining (M), street lighting (S).

cooking, drying, lighting, electronic services, and appliance services. Although these are primarily residential and commercial energy services, substantial amounts of energy for these purposes are also required in the industrial, agricultural, construction and mining sectors. The percentage of total energy consumed is based on the 1972 United States gross energy consumption of 77.03 EJ* (Ref. 3).

3.1.3 Air Quality

In general, air quality throughout the nation has been improving. Combined data from 25 major metropolitan areas show that the number of unhealthful days declined by 15 percent between 1974 and 1977 while the number of very unhealthful days declined 32 percent (Ref. 4). Air quality is defined as unhealthful when any one of five main air pollutants presently monitored (particulates, carbon monoxide, sulfur dioxide, nitrogen dioxide, and oxidants) exceeds the National Ambient Air Quality Standards (NAAQS).

The Council on Environmental Quality (CEQ) analyzes air quality data by Standard Metropolitan Statistical Area (SMSA) to reflect the level of pollution throughout an urban area as opposed to levels within the central city alone. In all cases, a SMSA overlaps or is included within the areas serviced by the utilities participating in the fuel cell program. Air quality of those SMSAs for which data have been compiled is not assumed to be representative of the air quality which can be expected at a candidate site but rather is useful to indicate the degree to which air pollution should be a concern in the siting of a new project. More accurate air quality information can be obtained at local monitoring stations and will have to be retrieved for site specific evaluations.

Although air pollution, in general, has decreased, it still remains a problem. The most recent data which has been compiled (1977), indicates that New York and Los Angeles still register in the unhealthful range for more than two-thirds of the days of the year. The Environmental Protection Agency has categorized different levels of air pollution in terms of a Pollutant Standard Index (PSI). This health-regulated index is described in Table 3-3. The analysis of various PSI levels experienced by 41 SMSAs suggests that many cities still have significant air pollution problems, particularly involving oxidants and carbon monoxide.

Table 3-4 presents air quality data on several SMSAs which are serviced by utilites in the fuel cell test program. A PSI level is exceeded if any one of the five main pollutants exceeds the values defined in Table 3-3. Some utilities are not represented because of insufficient SMSA related data in their service area. A description of the cities and counties included in each SMSA can be found in the 1972 Department of Commerce publication, Standard Metropolitan Statistical Areas. Variations in weather from year to year can cause great variation in pollution readings, especially for the smaller, and normally less polluted SMSAs. Since data for any single year can not be counted on as being typical, three year data has been presented. Daily values used in the CEQ analysis are based on the worst PSI value in an entire SMSA. Although air quality is representative of the region as a whole, subregions may vary considerably.

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*One exajoule (EJ) is 10^{18} joules or 0.9478×10^{15} Btu.

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Table 3-3. Definition of Pollutant Standard Index (PSI) Values (Ref. 5)

Index value	Air quality level	Pollutant levels					Health effect descriptor	General health effects	Cautionary statements
		TSP (24-hour) μg/m³	SO₂ (24-hour) μg/m³	CO (8-hour) μg/m³	O₃ (1-hour) μg/m³	NO₂ (1-hour) μg/m³			
500	Significant harm	1,000	2,620	57.5	1,200	3,750		Premature death of ill and elderly. Healthy people will experience adverse symptoms that affect their normal activity.	All persons should remain indoors, keeping windows and doors closed. All persons should minimize physical exertion and avoid traffic.
400	Emergency	875	2,100	46.0	1,000	3,000	Hazardous	Premature onset of certain diseases in addition to significant aggravation of symptoms and decreased exercise tolerance in healthy persons.	Elderly and persons with existing diseases should stay indoors and avoid physical exertion. General population should avoid outdoor activity.
300	Warning	825	1,600	34.0	800	2,260	Very unhealthful	Significant aggravation of symptoms and decreased exercise tolerance in persons with heart or lung disease, with widespread symptoms in the healthy population.	Elderly and persons with existing heart or lung disease should stay indoors and reduce physical activity.
200	Alert	375	800	17.0	[2] 400	1,130	Unhealthful	Mild aggravation of symptoms in susceptible persons, with irritation symptoms in the healthy population.	Persons with existing heart or respiratory ailments should reduce physical exertion and outdoor activity.
100	NAAQS	260	365	10.0	160	(1)			
50	50 percent of NAAQS	[3] 75	[3] 80	5.0	80	(1)	Moderate		
0		0	0	0	0	(1)	Good		

[1] No index values reported at concentrations below those specified by alert level criteria.
[2] 400 μg/m³ was used instead of the O_3 alert level of 200 μg/m³.
[3] Annual primary NAAQS.

Table 3-4. Air Quality at Utility Serviced SMSAs (1975-1977) (Ref. 5)

Utility	SMSA Serviced	'Unhealthful,' 'Very unhealthful,' and 'hazardous' (PSI > 100) (Number of Days)		'Very unhealthful' and 'hazardous' (PSI > 200) (Number of Days)	
		3-yr Avg.	Min/Max Annual	3-yr Avg.	Min/Max Annual
Baltimore G&E	Baltimore	60	32-79	12	2-25
Brooklyn Union Gas Consolidated Edison	New York	224	206-268	118	95-142
Dayton Power	Dayton	45	30-63	2	1-4
Memphis Light, Gas & Water	Memphis	28	22-37	2	0-3
Mountain Fuel Resources	Salt Lake City	81	61-110	18	9-25
National Fuel Gas	Buffalo	31	23-40	5	3-8
Northern Illinois Gas	Chicago	124	81-150	21	14-31
Northwest National Gas	Portland	75	70-81	3	2-5
Pacific G&E	San Francisco	30	22-45	1	0-1
San Diego G&E	San Diego	52	38-74	6	4-9
Southern California Gas	Los Angeles	242	206-268	118	95-142

3.1.4 Climate

Air temperatures in the 48 conterminous United States have been reliably observed as cold as 216 K (-70°F) (Rogers Pass, Montana) and as hot as 327 K (129°F) (Death Valley, California) (Ref. 6). More useful statistics can be defined in terms of 100 year recurrence intervals, i.e., a 1 percent probability of occurrence in any given year. As seen from Figures 3-1 and 3-2, coldest and hottest temperatures with 100 yr return periods are no colder than 238 K (-35°C) over about half the country and no hotter than 318 K (45°C) over a different half (Ref. 6).

The annual extreme fastest mile wind speed has been chosen as the best available measure of wind for design purposes. The standard level for measurement is taken to be 9 meters (30 ft) above ground. Figure 3-3 identifies isotachs (lines of equal windspeed) of extreme winds which can be expected in different parts of the country on the average of once every 25 years. This time frame is roughly equivalent to the expected lifetime of a fuel cell plant. Although the maximum speed noted in this figure is 45 m/sec (100 mph), higher windspeeds affecting larger areas can be expected with a decreased chance of occurrence. Windspeeds up to 58 m/sec (130 mph) have been projected to hit some coastal areas with a recurrence level of 100 years based on hurricane records of the last century. It should be noted that the windspeeds recorded will be slightly higher than actual speeds at ground level due to frictional losses of energy.

Figure 3-1. Coldest Temperatures with Annual Probability of 1% or Less, Estimated from Annual Extremes, 1931-1960, at 220 First Order Stations (°C) (Ref. 6)

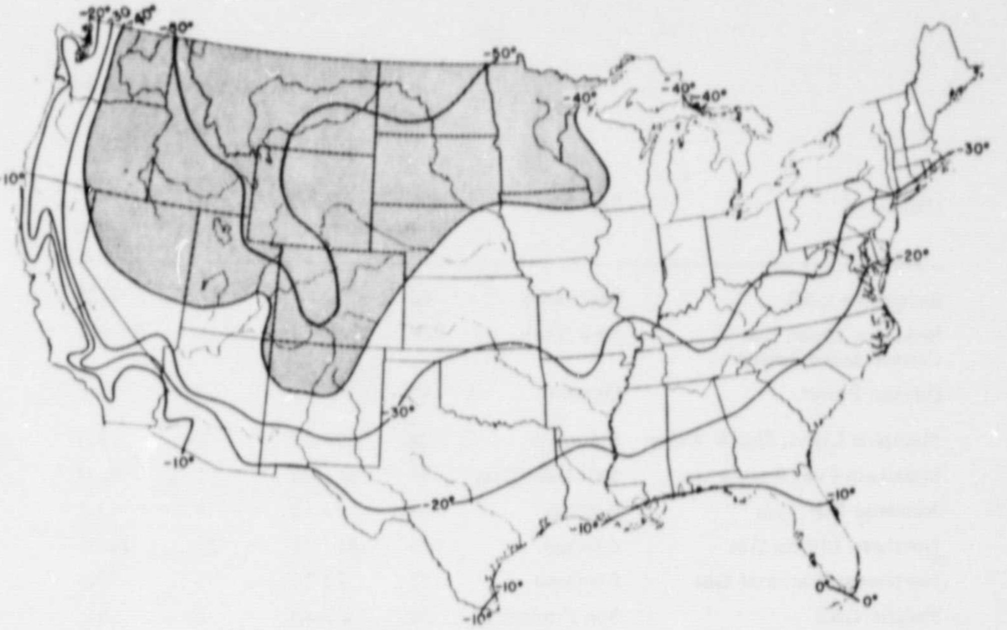


Figure 3-2. Hottest Temperatures with Annual Probability of 1% or Less, Estimated from Annual Extremes, 1931-1960, at 220 First Order Stations (°C) (Ref. 6)

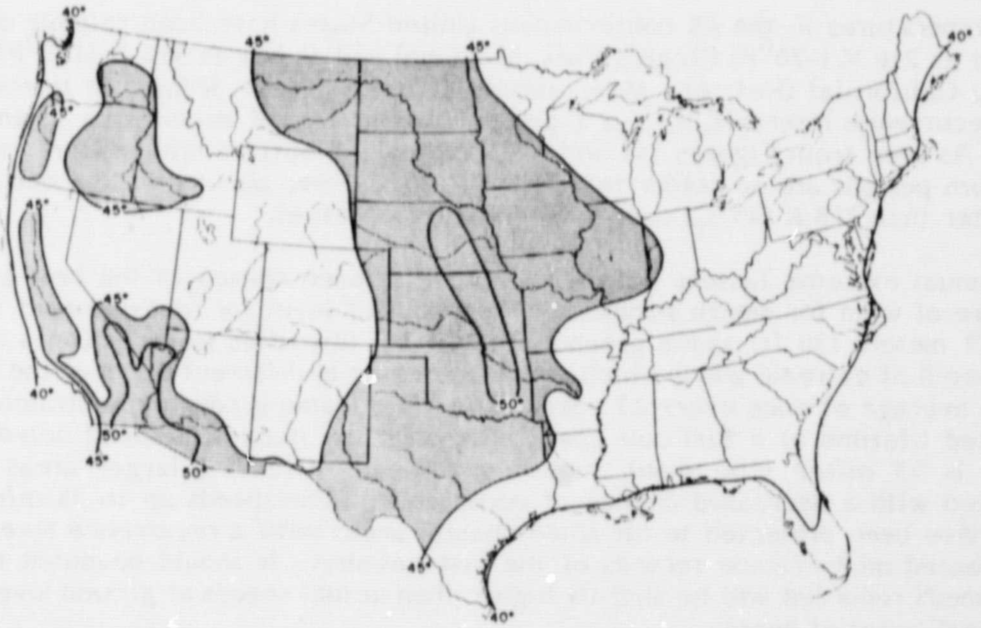
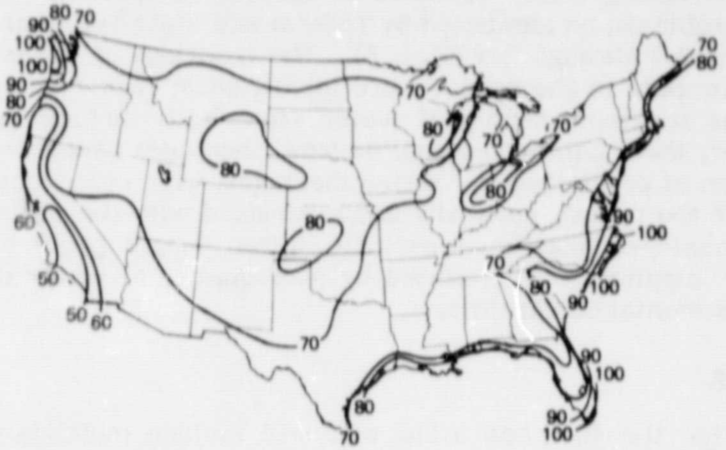


Figure 3-3. Isotach 0.04 Quantiles, in Miles per Hour: Annual Extreme-Mile 9 Meters Above Ground, 25-YR Mean Recurrence Interval (Ref. 7)



These temperature and wind speed data are important to power plant siting because the power plant is designed to provide rated power and 5 seconds of overload or current limit operation within an ambient temperature range of 242 K to 317 K (-25°F to 110°F). In ambients between 317 K and 322 K (120°F), the power plant will continue to supply rated power but will have limitations in overload and current limit capacity. If shutdown occurs at or below an ambient temperature of 274 K (33°F), service procedures are required to prevent the water in the power plant from freezing. The fuel cell power plant design criterion for side wall wind strength is 36 m/sec (80 mph).

3.1.5 Water Resources

Fuel cell sites are located in regions of widely varying water supply and quality. The water resources of these regions have been characterized according to their general level of quality and quantity based on data supplied by 21 water resource regions throughout the country. These 21 regions in turn represent 106 subregions which are the basic data collecting units. Subregion data point up problems that are primarily basinwide in nature and thus may not adequately identify specific local or point source problems. Overall, however, data aggregated from the subregions portray both regional and national conditions, and also the wide contrasts in both regional and national water sources and uses.

The Water Resources Council in its Second National Water Assessment has analyzed the water data base in an effort to identify and describe water resource problems in the United States. By establishing a base period, 1975,* and studying future water use and consumption trends, the Council has projected water resource conditions over a 25 year period ending in the year 2000.

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* 1975 is the base year for the Second National Water Assessment data. It represents assumed average conditions at that time rather than actual 1975 data.

Several regions are now, or will soon be, suffering from water resource problems related to the increasing water demands of various competing users. The areal extent of these problems, as identified by federal and state/regional study teams, is mapped in Figures 3-4 through 3-9 (Ref. 8). The locations of some of the utilities scheduled to participate in the program are identified in each map. Nationally, the United States has an ample supply of water from both surface and underground sources. However, there can be regional or local shortages of water because of the uneven distribution of precipitation. Water shortages, which can occur in any season and in any part of the nation, generally are associated with the arid West, but many humid eastern localities also have periodic water supply problems. At times, inadequate water supplies can be caused by poor quality of water or by economic, social, and environmental constraints.

3.1.6 Noise

Siting locations for the fuel cell field test will include multi-family residences, commercial establishments and light industry. Some end users will be more noise intolerant than others, with multi-family residences generally conceded to be the least noise tolerant. Noise restrictions for these residences should meet the most stringent regulations sanctioned by the federal government. The Department of Transportation has established standards to ensure that measures are taken in the overall public interest to achieve highway noise levels that are compatible with different land uses. Although these standards were promulgated for traffic noise control, the numbers established are conservative and are based on criteria which are applicable for any noise source. Noise standards with relation to land use are presented in Table 3-5. As noted in this table, different noise levels are allowed for interior as opposed to exterior locations. This distinction may require outside siting of units at some locations.

The unit fuel cell power plant at 25 kW (net) capacity is designed to operate at 60 dBA at a point measured 4.6 meters (15 ft) horizontally from the power plant perimeter. A sample testing of one such unit measured 61 dBA. A comparison of this sound level with other common ambient noises is seen in Table 3-6.

3.1.7 Land Use and Aesthetics

Because of the large area cumulatively serviced by the participating utilities, the land use patterns at any site which may be selected are impossible to predict. The categories of candidate sites discussed previously indicate that fuel cell units will be located mostly in commercial or residential areas of moderate to heavy population density.

3.2 Local Environment of Candidate Facilities

It is the expressed goal of the program that the candidate facilities be diverse in market segment and building type. The potential field test site is restricted only by the selection guidelines recommended in the project plans and environmental considerations arising from this assessment. Thus, participating utilities are to solicit applications from residential, commercial and light industrial market segments.

Figure 3-4. Inadequate Surface Water Supply and Related Problems (Ref. 8)

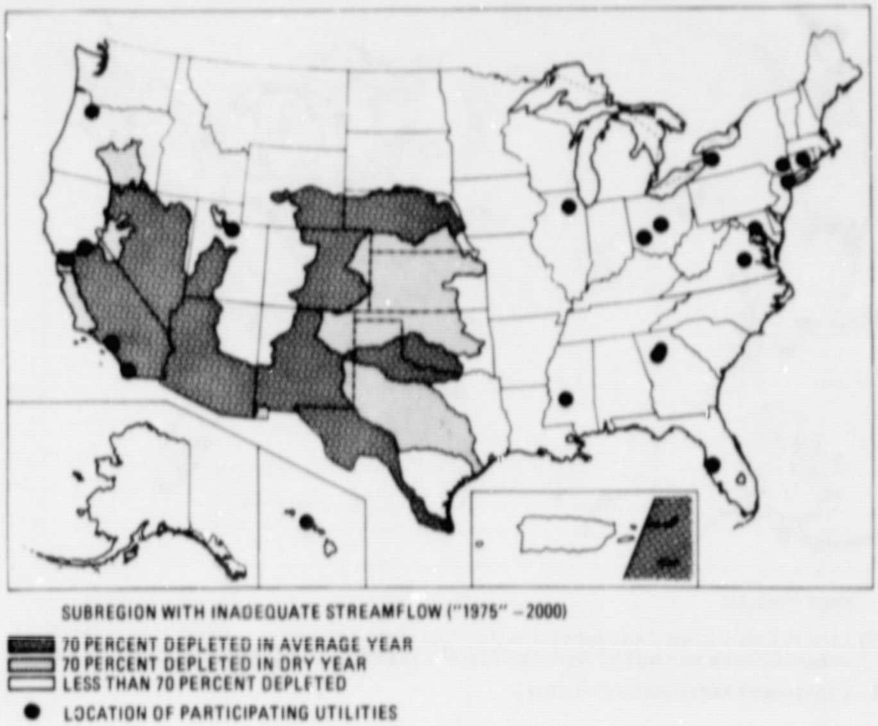

Figure 3-5. Ground Water Overdraft and Related Problems (Ref. 8)

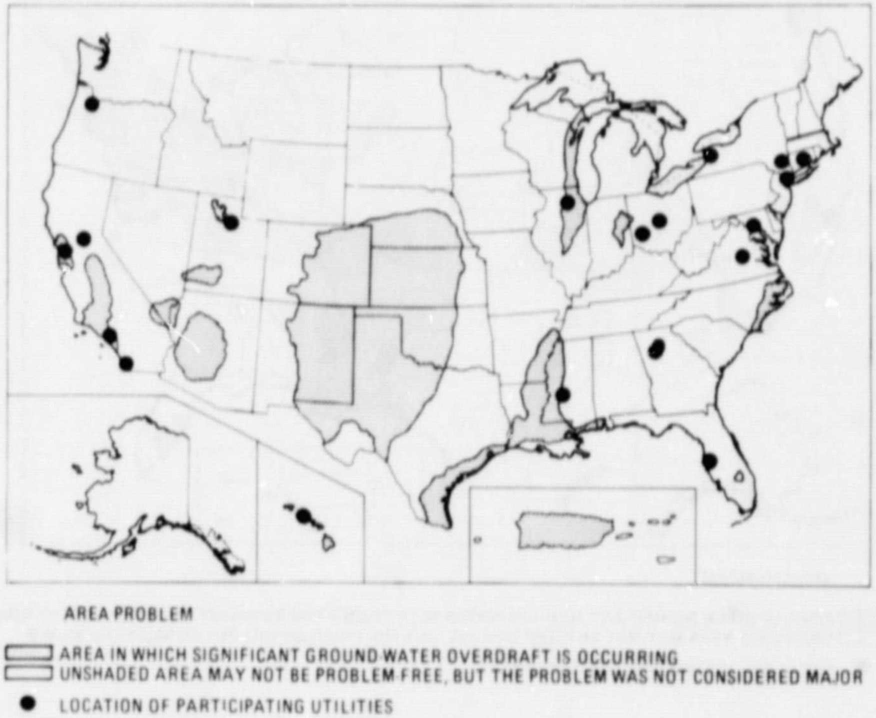

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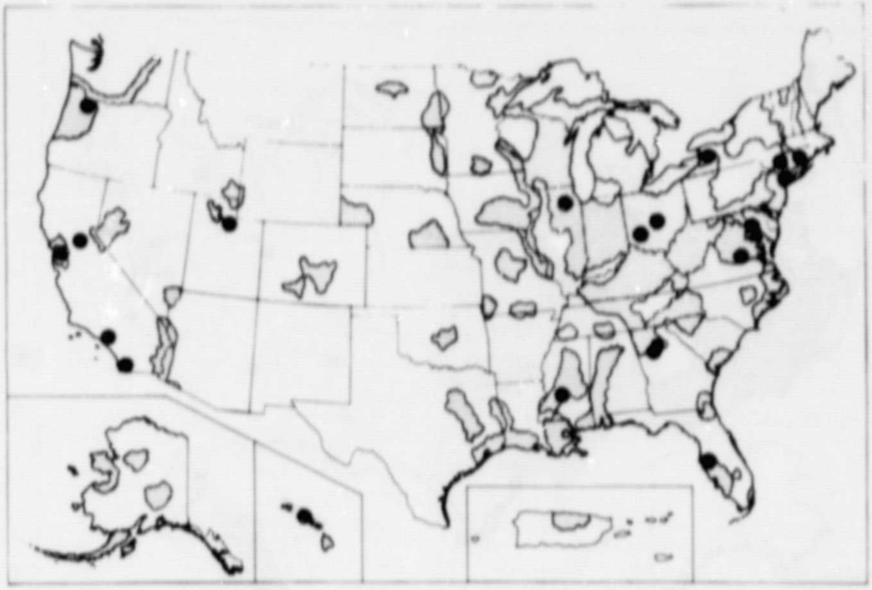
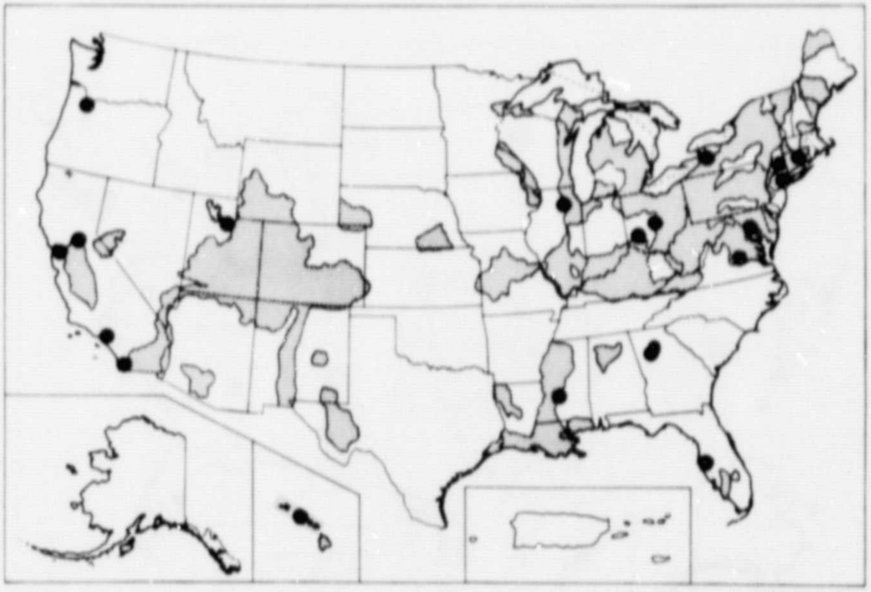
Figure 3-6. Surface Water Pollution Problems from Point Sources (Municipal and Industrial Waste) (Ref. 8)



AREA PROBLEM

▨ AREA IN WHICH SIGNIFICANT SURFACE WATER POLLUTION FROM POINT SOURCES IS OCCURRING
☐ UNSHADED AREA MAY NOT BE PROBLEM-FREE, BUT THE PROBLEM WAS NOT CONSIDERED MAJOR
● LOCATION OF PARTICIPATING UTILITIES

Figure 3-7. Surface Water Pollution Problems from Nonpoint Sources (Ref.8)



AREA PROBLEM

▨ AREA IN WHICH SIGNIFICANT SURFACE WATER POLLUTION FROM NONPOINT SOURCES IS OCCURRING
☐ UNSHADED AREA MAY NOT BE PROBLEM-FREE, BUT THE PROBLEM WAS NOT CONSIDERED MAJOR
● LOCATION OF PARTICIPATING UTILITIES

Figure 3-8. Ground Water Pollution Problems (Ref. 8)

Figure 3-9. Quality of Drinking Water Problems (Ref. 8)

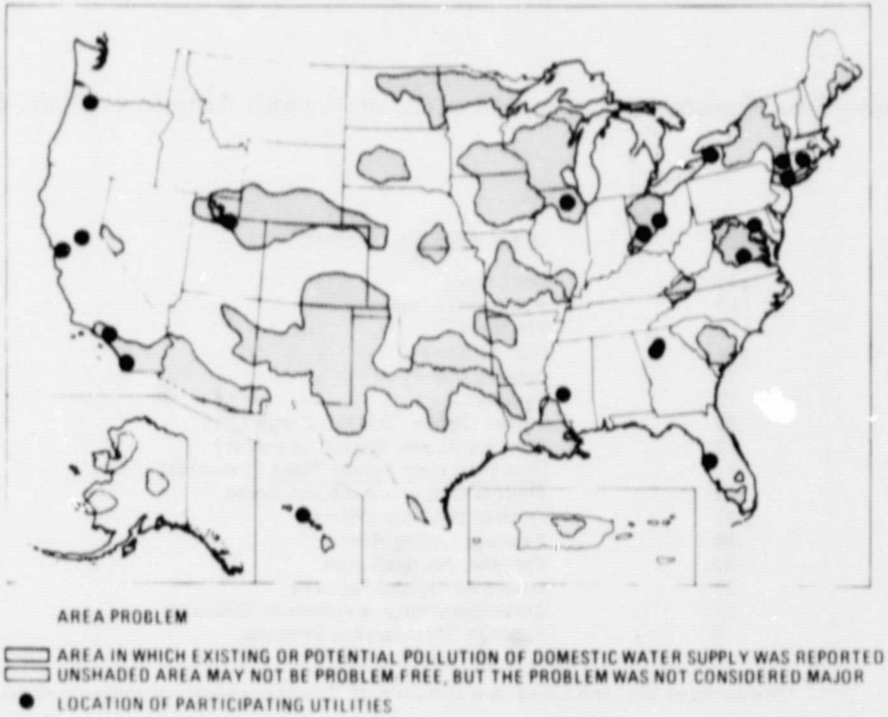


Table 3-5. Department of Transportation, Federal Highway Administration Highway Noise Control Standards and Procedures (Ref. 9)

Land Use	Design Noise Level dBA	Description of Land Use Category
A	60 (Exterior)	Tracts of lands in which serenity and quiet are of extraordinary significance and serve an important public need, and where the preservation of those qualities is essential if the area is to continue to serve its intended purpose. Such areas could include amphitheaters, particular parks or portions of parks, or open spaces which are dedicated or recognized by appropriate local officials for activities requiring special qualities of serenity and quiet.
B	70 (Exterior)	Residences, motels, hotels, public meeting rooms, schools, churches, libraries, hospitals, picnic areas, recreation areas, playgrounds, active sports areas, and parks.
C	75 (Exterior)	Developed lands, properties or activities not included in categories A and B of this subparagraph.
D		For requirements on undeveloped lands, see original document.
E	55 (Interior)	Residences, motels, hotels, public meeting rooms, schools, churches, libraries, hospitals, and auditoriums.

Table 3-6. Comparative Sound Levels of Various Activities (Ref. 10)

dBA	Source or Type of Noise*
130	Jet Engine
115	Riveter (11 meters)
110	Thunder
100	Noisy Factory
95	Subway Car
90	Automobile
80	Street Corner Traffic, Large City
70	Conversational Speech (1 meter)
61	Unit Fuel Cell Power Plant (5 meters)
60	Typical Office - Ambient Noise
50	Private Business Office
40	Average Living Room
30	Theater, No Audience
20	Studio for Sound Pictures
10	Quiet Breathing in Anechoic Chamber
0	Average Threshold of Hearing

*All examples are computed at a distance of 8 meters unless otherwise indicated.

A wide variety of conventional heating and cooling equipment is presently used to service the candidate facilities. Therefore, the fuel cell power plants will be required to interface effectively with several selected energy system configurations while servicing a variety of building activities. One or two units will be installed at each site to ensure that the installation meets the maximum expected electrical load (or some divisible portion); therefore, the size of the candidate facilities will probably have to be limited. Given the above guidelines, the candidate facilities described in Section 2.1.2 have been suggested as appropriate. A description of these building types and the conventional heating and cooling equipment they use is provided in this section.

3.2.1 Energy Use Patterns and Demand Profiles

Energy demands of buildings are dependent upon several factors. These include building size, insulation properties, configuration, and activity; outside climate; and time of day. The preliminary data gathering stage of the fuel cell field test is responsible for identifying buildings which will be most compatible with the fuel cell units after considering these factors. The first consideration is that the facility demand is appropriate for the one or two units which will be installed. This will vary by region and building activity. Secondly, for the efficient operation of the fuel cell, it is necessary that the facility have an appropriate balance in the electric and thermal (heating and cooling) demands so that maximum use is made of the heat energy derived from the fuel cells. Maximum efficiency can be attained when the thermal demand profile over the course of a day is similar to the electric demand profile. This factor is not as important during grid connected operation or when equipment is used for thermal storage.

Energy consumption in office spaces is mainly attributable to space conditioning (heating and cooling), domestic hot water production, lighting, small office equipment and elevators. In general, energy consumption patterns among various office spaces are similar with two important exceptions. The use of electronic data processing equipment adds to the electric load as does the stricter climate control which is required for these machines. Secondly, extended and weekend operation of building systems to provide flexibility for workers can cause large variation among seemingly similar office spaces. Energy use in hotels/motels is comprised of space conditioning, lighting, domestic hot water production, elevators, and a small amount of special equipment such as ice makers or vending machines. Occupied spaces must maintain full comfort climate conditions 24 hours a day, so energy demand closely follows occupancy levels.

With the exception of refrigeration, warehouse energy use is generally low, since lighting is minimal and the interior climate conditions are less stringent. Also, infiltration is minimized by the lack of windows and the fact that the buildings are generally used for storage and there is no frequent opening and closing of doors. The energy use in small stores can vary widely because the category is very broadly defined. The usual uses exist, space conditioning and lighting, but beyond those, the equipment present is too diversified to allow any valid generalization. The energy uses in restaurants include low-level lighting, space conditioning, and significant amounts of energy for food preparation and food storage equipment. Infiltration through door openings and closings, excessive ventilation, and long operating hours are significant factors. Also, in the cooling season, heat gains from high occupancy rates and from cooking equipment place an unusually high load on the cooling system.

The energy required over a 24 hour period, defined as the energy demand profile of a building, will depend upon the function of the building. The data presented in Figures 3-10 through 3-18, which are illustrative of the demand profiles of several building types, have been derived from a collection of energy demand profiles compiled by the Argonne National Laboratory (Ref. 11). Energy demand is broken down into three major categories: electric demand from appliances, heating demand and cooling demand. The thermal energy produced by the fuel cell units may be used to provide heating or cooling. Load factor (LF) shown on these graphs is defined as the ratio of average to peak demand. Because each building category is represented by a myriad of types, and since geographic location strongly influences energy demand profiles for heating and cooling, it is necessary to pick a representative example in each case. With the exception of commercial structures and hospitals, data for representative buildings were obtained in the city of Washington, D.C. The data for commercial buildings were acquired from St. Charles, Maryland, and cities in Ontario, Canada, and data on hospitals came from Chicago.

The profiles portrayed in Figures 3-10 through 3-18 were chosen because they most closely represented the preferred size for candidate facilities. Based on energy use data from sample buildings, computer simulations describing demand profiles for each building type have been constructed. The resultant profiles can be assumed to fairly represent all buildings of similar function.

Energy demands for three residential building types, single family homes, garden apartments and townhouses, are described in Figures 3-10 though 3-12. Mid rise and high rise apartments are not considered because they generally require more energy than can be delivered by one or two fuel cell units. All three graphs show that electrical demands rise above an overnight base beginning at 6:00 a.m. and begin to taper off by 10:00 p.m. During the day, demand peaks in the early morning and post-work evening hours with a smaller peak in the late afternoon. Cooling demands are highest in the late afternoon and early evening, which is compatible with the peaking electrical demands. On the other hand, heating requirements are highest at night and early morning, and are lowest in the late afternoon. This trend is an inverted profile of the electrical demand pattern.

Figure 3-13 represents the composite demand profiles from 25 different commercial buildings in Ontario, Canada, ranging from small industries to service stations and a bowling alley. Commercial demand profiles are highly predictable, and can be expected to maintain a consistent base consumption throughout the year. Schools, commercial buildings and office buildings are similar in that they are utilized during the day and vacated at night. These buildings are also less used on weekends at which time energy demands will differ from those graphed in Figures 3-13 through 3-16. Seasonal occupancy patterns will further add fluctuation to the energy demands of school buildings. The demand profiles for schools and office buildings are similar to residential buildings in that electricity and cooling is required during the day, whereas, heat is required at night. The demand profiles for commercial buildings do not show this pattern, possibly because appliance and heating demands are not separately distinguished. Other data indicate that commercial building heat demands are highest when the fewest number of people are in the building, night temperatures are lower, and few lights are on in the building. Hospitals and motels are in use 24 hours a day and thus have demand profiles similar to residential buildings.

Figure 3-10. Simulated Energy Demand Profiles for a 140m^2/Unit Single Family Residence

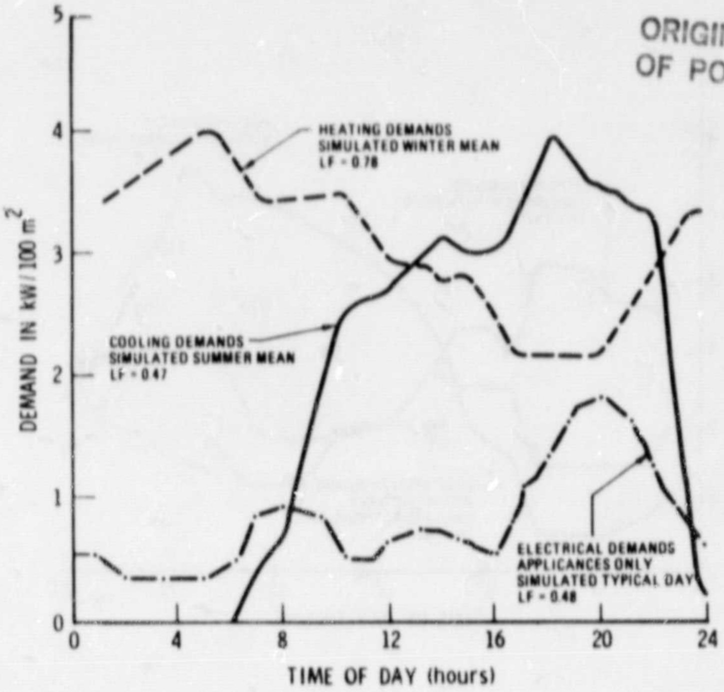


Figure 3-11. Simulated Energy Demand Profiles for a 120m^2/Unit Townhouse with 3.2 Residents/Unit

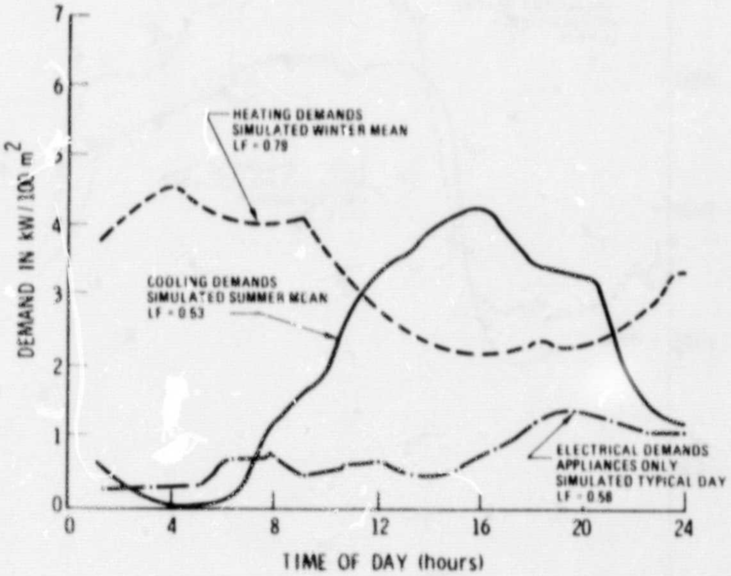


Figure 3-12. Simulated Energy Demand Profiles for a 120m^2/Unit Garden Apartment with 1.8 Residents/Unit

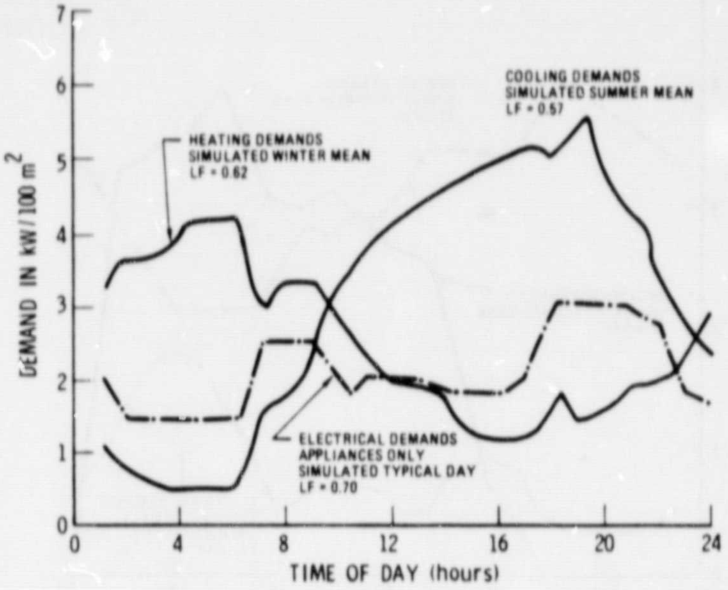


Figure 3-13. Simulated Energy Demand Profiles for a Composite of 25 Different Commercial Buildings

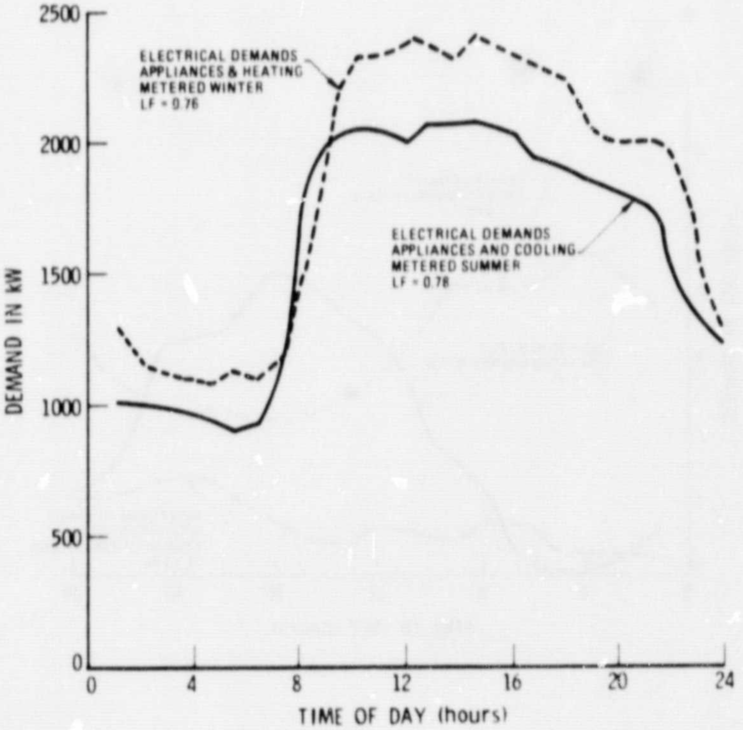


Figure 3-14. Simulated Electrical Demand Profile for Three Selected Building Types

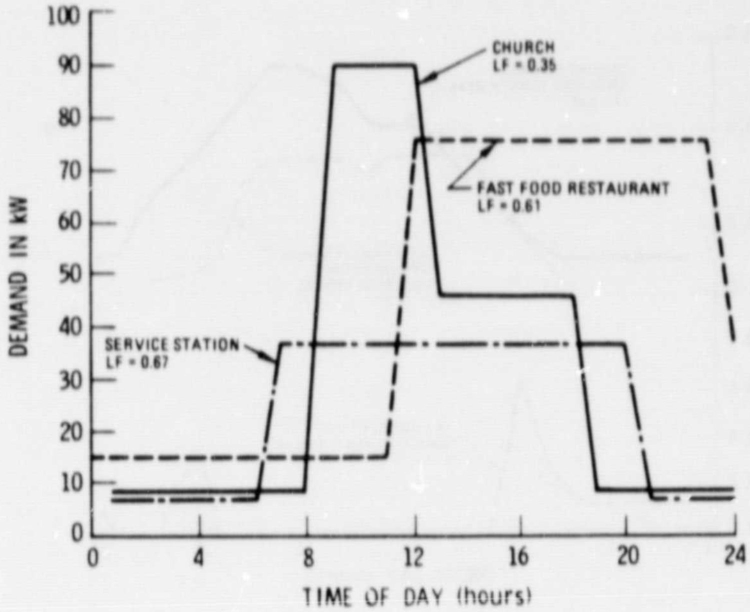


Figure 3-15. Simulated Energy Demand Profiles for a 2000m^2 Elementary School with 360 Students

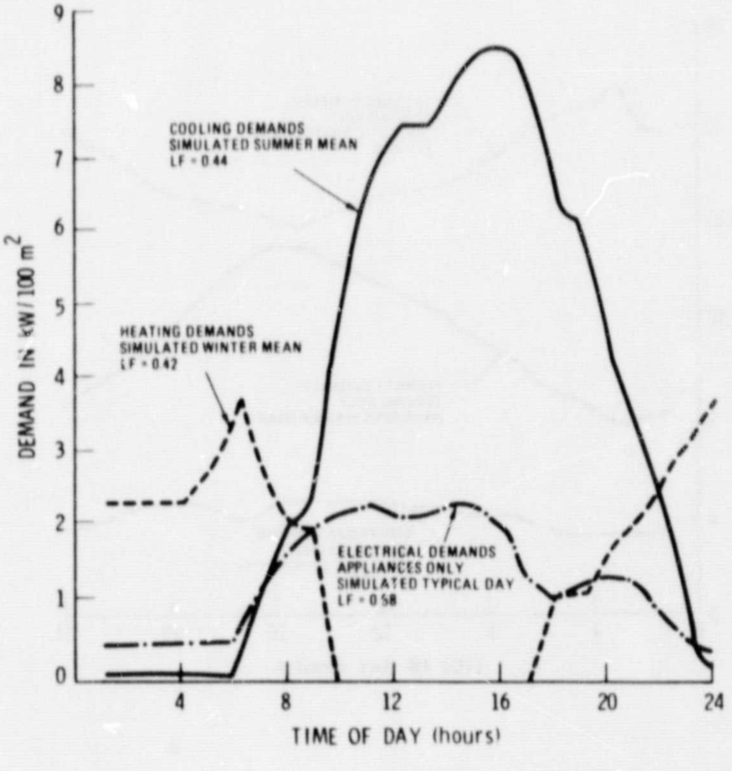


Figure 3-16. Simulated Energy Demand Profiles for a 22,300m^2 Office Building with 1000 Occupants

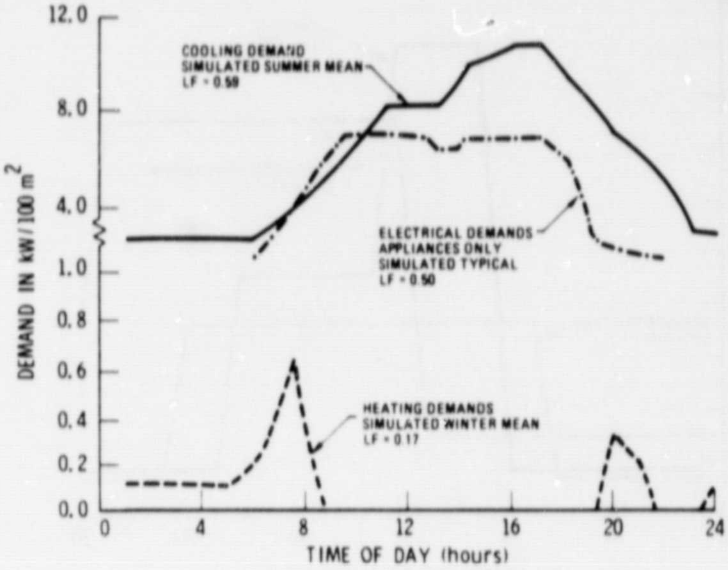


Figure 3-17. Simulated Energy Demand Profiles for a 5,900m^2 Hospital

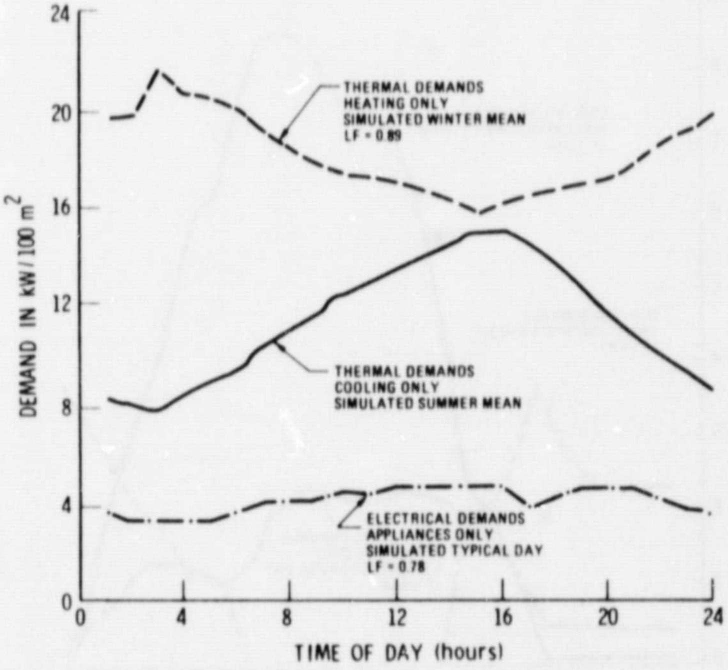
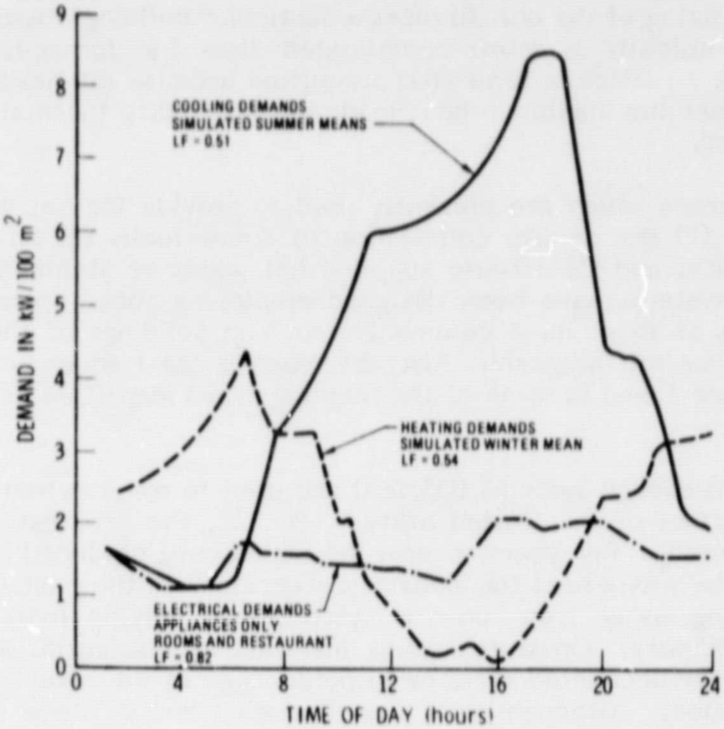


Figure 3-18. Simulated Energy Demand Profiles for a 75 Room 4,600m^2 Motel with 300 Occupants



The fuel cell units have the flexibility to follow either the thermal or electric load of a building. In those cases where the thermal load of a facility can be followed with the excess electricity sold to the utility, i.e., grid connected, efficient fuel cell operation is more easily obtained. However, fuel cell systems which are grid isolated will be less efficient than grid connected systems unless either thermal demand closely follows electric demand, or a thermal storage system is employed. Figures 3-10 through 3-18 indicate that cooling and electric demand profiles display similar peaks for several representative building types. On the other hand, heating and electric demand peaks do not correlate at all. Thus, the operation of grid isolated units will be more efficient during the summer than winter. During the winter, a storage or backup system may be required.

3.2.2 Conventional Heating and Cooling Systems

Central air conditioning systems are widespread in commercial and many residential buildings, although individual room units are often used in the latter. Most systems rely on a mechanical compression cycle utilizing a compressor-condensing unit, a refrigerant circulation system and an air moving device (fan). Another option, absorption chillers, substitute a physiochemical process for the purely mechanical process of the compression cycle. Since waste thermal heat rather than electricity provides the energy source for these space cooling devices, they are ideal for the total energy concept envisioned for the fuel cell program.

Heat pumps operating in reverse can also be used to provide space cooling. Since these devices are designed to function in a moderate climate where the air conditioning load is larger than the space heating load, they are more often found in mid to southern regions. Because heat pumps provide both winter heating and summer cooling, sizing of the unit to meet a particular building's heating and cooling loads most economically is more complicated than for furnace/air conditioner applications. The situation is somewhat simplified because the heat pump need not be designed to meet the maximum heat load; supplementary thermal heating can be used when required.

Three energy sources which are presently used to provide for hot water and space heating include: (1) the on-site combustion of fossil fuels, (2) on-site equipment utilizing electricity, and (3) off-site supplied hot water or steam district heating. Several heating systems have been designed employing these options. Table 3-7 contains a listing of those most commonly found in buildings of the type and size being considered for this program. Also described is the frequency with which the various systems are found in some of the building types identified as potential early market segments.

On-site integrated energy systems (OS/IES) are used to some extent by each of the major market sectors of the United States. By far, the greatest user of OS/IES technology is industry. For years several industries have produced their electricity on-site utilizing the waste heat for industrial processes. In the past, industrial firms have been shifting away from on-site systems and relying increasingly on the electric utility industry. On-site systems installed in residential and commercial buildings have never accounted for a large percentage of the total power generated in the United States. Although some installations were in place as early as the 1920s, the development of on-site energy generation in these market sectors is a relatively recent phenomenon. This picture is rapidly changing, primarily because of the tremendous advances in solar technology for on-site use. There are two basic technologies available for active, on-site solar energy systems--solar thermal systems and photovoltaic arrays. It is possible, though unlikely, that some sites selected for testing may have some form of on-site generating equipment already in place.

3.2.2.1 Energy Efficiency

If used as an OS/IES, the on-site 40-kW fuel cell unit is considerably more energy efficient than the systems being replaced. OS/IES operation is characterized by the use of thermal waste heat from the fuel cell power plant as an energy source for hot water, space heating and cooling, and industrial process heating needs. Fuel cell units have the potential to satisfy these thermal needs in conjunction with the electrical requirements of a facility such that approximately 80 percent of the supply fuel (natural gas) is converted into useful work. In comparison, conventional central power generation results in around a 30 percent overall efficiency. Electrical conversion using steam generators is not as efficient as the direct chemical to electrical conversion of the fuel cell (about 30-35 percent as compared to 40 percent). Furthermore, useful applications of the byproduct thermal energy are effectively prohibited by the high losses associated with thermal energy distribution from these isolated central generators. An additional 3 percent energy penalty is incurred in the transmission and distribution of electrical energy to individual users.

Table 3-7. Frequency of Occurrence of Heating Systems in Selected Building Types (Ref. 14)

System Type	Apartment Buildings		Motels		Nursing Homes		Small Commercial		Fast Food		Industrial (not process)	
	HC	CC	HC	CC	HC	CC	HC	CC	HC	CC	HC	CC
Two pipe fan-coil heating	S	S	C	C	C	C						
Gas or electric furnaces (interior and rooftop)	C	C					C	C	C	C	S	S
Electric baseboard	C	C	S	S	S	C						
Hot water baseboard	C	S	S	S	C	C						
Unit heaters - gas or electric							C	C	C	C	C	C
Unit heaters - steam							S	S			C	S
Unit heaters - hot water							S	S	S	S	C	S
Incremental electric resistance heating and air source heat pump heating	S	C	C	C	S	S						
Incremental electric and water source heat pump heating	R	S	S	S								
Air handling or built-up air conditioning system w/heating coils			C	C	C	C	C	C	C	C	S	S
Radiant panel heating-electric	S	S			S	S						
Radiant panel heating-hot water	S	R			S	R						

Legend:

HC - Heating Climate >5000 degree days
CC - Cooling Climate
C - System Commonly Used
S - System Sometimes Used
R - System Rarely Used
Blank - System Never Used.

Fuel combustion furnaces and hot water heaters generally have a published efficiency greater than 70 percent, although cold starts and poor maintenance will reduce this to as low as 60 percent (Ref. 12). Air conditioners and heat pumps are rated in terms of the coefficient of performance, or COP. The COP is the ratio of heat removed or added from the conditioned space to the heat equivalent of the electricity consumed by the device. The COP varies as a function of ambient temperature and the operating level of the equipment.

For the combined Westinghouse SLO30C condenser and ECO30 evaporator unit (cooling capacity 29,856 kJ/hr, 28,300 Btu/hr), COP values range from 1.58 to 2.25, depending on the external temperature (Ref. 12). Vapor compression and absorption chillers have COPs of about 2.8 and 0.6, respectively, at 3/4 load operation (Ref. 13). Current state of the art heat pumps typically have values in the range of 1.0 to 2.8 as a function of external temperature.

Advanced models can have COPs ranging up to 3.6 for heating although values are somewhat less for cooling. At these higher efficiencies, heat pumps are somewhat more efficient than furnaces and air conditioning systems.

3.2.2.2 Air Emissions

In fuel burning furnaces and water heaters, the combustion takes place within a metal-walled heat exchanger and the circulating air or water passes over the outside surfaces of the heat exchanger. In this way, the heat transfer takes place through the heat exchanger walls and the circulating air does not come in contact with the fuel or products of combustion. The products of combustion are conveyed to the outside atmosphere through a flue or vent for disposal. Generally, there are no air pollution control devices for equipment installed in buildings of the size considered for this program.

The fuel used in this equipment may be either natural gas or a liquid fuel, generally #2 fuel oil. In either case, the combustion products are similar. The amounts of pollutants produced will vary depending on the temperature and completeness of combustion, but as a rule, only minor amounts of hydrocarbons and carbon monoxide will be produced. If a unit is operated improperly or not maintained, however, the resulting concentrations of these pollutants may increase by several orders of magnitude. This is most likely to be the case with small, often unattended units. The operation of a fuel-fired furnace and water heater in a building of the same size considered for this program will require a gross heat input rate of approximately 305,950 kJ/hr (290,000 Btu/hr) on a typical winter day (Ref. 15). Of this fuel supply, approximately 85 percent, or 260,060 KJ/hr, will be consumed in providing space heating (Ref. 2). Based on emission factors for natural gas and fuel oil combustion in domestic furnaces, the air pollutants emitted for a typical winter day from these systems are estimated in Table 3-8. Flue gas cleaning equipment has not been utilized to control emissions from the combustion equipment.

3.2.2.3 Noise Emissions

Sound rating, testing, and standard setting for heating and air conditioning equipment is provided by several professional organizations, three of which are the American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. (ASHRAE), the Air Moving and Conditioning Association (AMCA), and the Air

Table 3-8. Air Pollutant Emissions from a Domestic Natural Gas or Fuel Oil Furnace With a Gross Heat Input Rate of 260,000 kJ/hr (246,500 Btu/hr) (Ref. 16)

Pollutant	Emissions (kg/Typical Winter Day) Natural Gas	Fuel Oil
Particulates	0.012-0.039	0.049
Sulfur oxides (SO_2)	0.002	2.556S*
Carbon monoxide	0.051	0.102
Hydrocarbons (as CH_4)	0.020	0.018
Nitrogen oxides (NO_2)	0.206	0.371

*S is the fraction, by weight, of sulfur in the oil.

Conditioning and Refrigeration Institute (ARI). ARI has developed standards to provide the industry and the public with a procedure for rating and evaluating the sound power level of outdoor unitary air conditioning equipment (Ref. 17). Equipment certified by an independent laboratory under contract to ARI is assigned a Standard Sound Rating Number (SRN).

Sound control measures for heat ventilation and air conditioning equipment is usually included in the planning of a building for economical reasons. Although fan noises can be very loud at the source, proper engineering measures attenuate noise levels in occupied areas to acceptable levels. For central air cooling and heating equipment, silencers and appropriate duct sizing and lining reduce the sound levels of inhabited rooms to design levels of between 30 and 55 dBA. Correctly sized air outlets reduce the air velocity to minimize noise output. Sound radiated from well-designed and maintained equipment is typically steady and broad band in character making this noise less obtrusive than impulsive or pure tone sounds. Barrier walls may be erected, if necessary, to mitigate the high noise levels emitted from air conditioners located outdoors.

Room air conditioners, on the other hand, produce a sound level well above recommended levels for residences; and noise is recognized as a serious consumer objection. Since these units usually have provision for operation at reduced speed and noise level at low load, the owner has some control over the noise and is more tolerant.

3.2.2.4 Safety

The American National Standards Institute (ANSI) provides the recognized mechanism in the United States for establishing consensus product safety standards. Under the auspices of this organization, standards for heating and cooling equipment have been developed by the cooperative efforts of commerce and industry, standards developing organizations, public, and consumer interests.

The Consumer Product Safety Commission maintains a record of accidents resulting from the operation of various types of heating and cooling equipment. Data from this organization is provided in Table 3-9 for furnaces, water heaters, air conditioners, and heat pumps. The data describe accidents which have been reported by a small sample of hospital emergency rooms. As such, only those accidents of sufficient severity to require emergency medical treatment are represented. From this sampling of reported cases, the Commission statistically predicts the number of similar accidents which have occurred throughout the nation.

Table 3-9. Accidents Resulting from the Operation of Heating and Cooling Equipment in the United States, 1979-1980 (Ref. 18)

	Number of Accidents			
Equipment	1979		1980(a)	
Furnaces				
Coal	143	(2)(b)	0	(0)
Electric (excluding floor furnace)	33	(1)	0	(0)
Oil (excluding floor furnace)	516	(9)	451	(5)
Gas (excluding floor furnace)	1866	(29)	2406	(29)
Floor Furnaces	646	(25)	980	(19)
Not Specified(c)	4571	(93)	4348	(63)
Total	7775	(159)	8185	(116)
Water Heaters				
Electric	0	(0)	121	(1)
Gas	952	(27)	1579	(18)
Other	123	(4)	129	(2)
Not Specified	2230	(51)	3723	(48)
Total	3305	(82)	5552	(69)
Air Conditioners				
Electric	1127	(12)	971	(16)
Gas	0	(0)	0	(0)
Other	814	(13)	291	(5)
Not Specified	6479	(145)	5368	(72)
Total	8420	(170)	6630	(93)
Heat Pumps	39	(1)	0	(0)

(a) The survey sample was smaller in 1980 than 1979.

(b) The numbers in parentheses are the actual number of accidents reported in the surveyed sample. The adjacent data are national estimates statistically derived from these samples.

(c) The specific type of heating or cooling equipment was not recorded by the hospital emergency room and may include any of the preceding categories.

3.3 Economic and Legal Environment for Commercialization

Phosphoric acid fuel cell power plants are being developed and field tested for on-site multi-kilowatt and dispersed utility multi-megawatt applications. Large central fuel cell power plants may also become a reality in the future. During the past several years, studies have attempted to forecast the level of market penetration for both on-site and utility fuel cells that would result from commercialization. Taken as a whole, these studies have predicted total fuel cell penetration by 2000 that range from a high of 400,000 MW to a low of 180,000 MW. The on-site share of this penetration is estimated to be approximately 10,000 to 25,000 MW (Refs. 21-24). These levels greatly exceed the less than two megawatts of generating capacity to be installed during the 40 kW field test.

Although the field test is a major step towards commercialization of phosphoric acid fuel cell power plants, it by no means assures eventual widespread commercialization. The road to commercialization is strewn with factors of economic and legal uncertainty that could retard or halt fuel cell application. Fuel cell power plants will have to compete with conventional generators (diesels, turbines, etc.) in addition to new technology generators (photovoltaics, etc.) for a share of the electrical generation market. Capital, operating, and fuel costs of fuel cells and their competitors, as well as their performance characteristics, will likely decide the success or failure of fuel cell penetration into this market. Legal factors may also have a bearing on fuel cell commercialization. These factors may include regulatory restrictions on fuel use, fuel cell ownership, utility control of on-site generators, and various environmental quality parameters. The 40 kW field test will address many of these factors; however, their final resolution may not occur until the late 1980s or 1990s.

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4. POTENTIAL ENVIRONMENTAL IMPACTS

This section discusses and evaluates potential environmental impacts arising from the field test of the 40 kW fuel cell power plants. It is divided into two subsections: (1) the local impacts of fuel cell power plant installation, operation, and decommissioning, and (2) the cumulative and long term impacts of the entire field test operation. It concludes with a summary of field test impacts.

4.1 Impacts of Installation, Operation, and Decommissioning

Potential environmental impacts of the field test operation can be conveniently classified as resulting from any one of three activities: power plant installation, power plant operation, or power plant decommissioning. A review of the field test procedures, fuel cell power plant technology, and probable siting locations revealed environmental parameters that may be impacted to some degree during each of these three field test activities. Based on the same review, field activities were determined to have negligible impact on a variety of other environmental parameters. Figure 4-1 identifies the environmental parameters discussed and evaluated in this section for each field test activity (shaded). The parameters determined as not being impacted are also identified (unshaded). The business assessment activities were judged to cause no environmental impacts and are not discussed in this section.

The following is a discussion and evaluation of the environmental parameters potentially affected by field test activities. The impact evaluation concludes with a justification explaining why the remaining parameters would not be impacted by the field test.

4.1.1 Power Plant Installation

Prior to delivery of the power plants, each candidate site will be evaluated during a one-year instrumentation program using standard data acquisition systems and sensors to monitor building load factors and thermal energy consumption. The installation of the data acquisition system may require minor site alterations and will probably require the shutdown of the site energy system for several hours.

Delivery of power plants to building sites selected for participation in the field test will likely be by truck. Forklifts, cranes, and other equipment will be used to move and install the power plants at the sites. The power plants will be installed in one of three locations at the sites: (1) indoors, (2) outdoors at ground level, or (3) on rooftops. The power plant dimensions allow it to be moved through standard sized double doors and thus major interior alterations to accommodate indoor siting should not be necessary. Power plants installed outdoors at ground level must have a cleared, level pad and will rest on a supporting base (e.g., railroad ties).

Professional service people with special fuel cell training will be in charge of installing, starting, and decommissioning the power plants. Because the fuel cell power plant installation (one or two power plants) will be a temporary, one or two year addition to the site energy system, all existing energy equipment at the site will remain in place. Heat pumps and other auxiliary energy equipment may be

Figure 4-1. Environmental Parameters Considered in This Assessment (Parameters evaluated are shaded and those deemed unaffected and not evaluated are unshaded.)

	FIELD TEST ACTIVITY		
	SITE SELECTION AND INSTALLATION	POWER PLANT OPERATION	DECOMMISSIONING AND REMOVAL
AIR QUALITY	▨	▨	▨
CLIMATE			
CULTURE			
ELECTROMAGNETIC INTERFERENCE		▨	
GEOLOGY			
HEALTH & SAFETY	▨	▨	▨
LAND USE & AESTHETICS	▨	▨	▨
NOISE	▨	▨	▨
SOCIOECONOMICS			
SOILS			
TOPOGRAPHY			
VEGETATION	▨	▨	▨
VOLTAGE FLICKER		▨	
WATER QUALITY & SUPPLY	▨	▨	▨
WILDLIFE	▨	▨	▨

installed at some sites in conjunction with power plant installation. Interfacing the power plant with the site energy system will require the installation of various pipes and wires. These interface lines will either run above ground or be buried at outdoor ground-level installations. Minor site alterations may be necessary to accommodate the routing of interface lines through the site (e.g., drill holes through walls). Roof mounted power plants may require that additional structural support be added to the roof area. All or part of the site's gas, electric and water systems will have to be shut down for several hours so that the actual hookup of the power plant to these systems can occur. Installation at outdoor sites will be completed with the placement of fencing, vegetation or other security, noise attenuation, or aesthetic structures.

4.1.1.1 Air Quality

Transportation of the power plants to the test sites will likely be by truck. Other equipment may be used at the site to unload and position the power plants (e.g., cranes, forklifts). The operation of motorized equipment for transport will result in the emission of engine exhaust along the route of transit and at the installation site. Emission rates will vary with truck size, speed, and other operation variables. Diesel and gasoline engine operation for several hours at the site will also cause emission of air pollutants. However, because the power plant is relatively small and light, only one truck trip will be required for delivery and large equipment should not be needed to move it about the site. All emissions will add to the ambient concentrations of air pollutants in the immediate vicinity of equipment operation and may cause short term annoyance to people in the area. These emissions should disperse rapidly, however, and result in only extremely minute and undetectable increases in the ambient concentrations of air pollutants in the entire air basin. Existing levels of regional ambient air quality for selected test sites is provided in Section 3.

Power plants installed at outdoor, ground-level locations may require a minor ground excavation during preparation of the foundation pad. Fugitive dust may be generated during this construction activity; however, because of the small foundation area required by the power plant (5.2m x 4.5m or 17.0 ft x 14.7 ft) and the short period of exposure until the excavation is covered with gravel or other supporting material, the dust generated should be minimal and of very minor significance.

It is expected that some number of visitors will frequent the power plant installation to view its operation. This visitation rate will vary from one site to another and it is conceivable that one or more sites may require construction of additional parking areas. Construction of parking areas will be accompanied by emissions from heavy equipment and generation of fugitive dust. The quantity of emissions and dust caused by construction will vary according to parking area sizes; however, the duration should be short term and the magnitude of impact relatively minor.

4.1.1.2 Water Supply and Quality

Site monitoring and installation activities will have little or no impact on the water supply and quality at the test sites or in the watersheds in which the test sites are located. Water supply to all or a portion of each test site may be interrupted for a short period to facilitate connection of the water system to the power plant thermal energy recovery system and other auxiliary energy equipment. Outdoor construction activities may result in storm water runoff having higher concentrations of suspended solids and turbidity because of erosion of soil disturbed during construction. The magnitude of the sediment load in the runoff will depend on the level of outdoor construction required, but will be no greater than that expected for construction activities of a similar size.

4.1.1.3 Noise

Noise is any unwanted, undesired, or valueless sound. Depending on exposure, noise levels, and noise frequencies, it can cause physiological and psychological damage to human beings and can have an adverse effect on activities such as work, recreation, sleep, communication, and rest. Noise is measured in terms of decibels (dB)--a reference quantity for sound intensity. The decibel is actually a logarithm of a ratio of two values of sound intensity. Sound intensity levels in terms of decibels can be arranged into sound scales with the zero decibel level representative of the threshold of human hearing. On the logarithmic decibel scale, every 10 dB increase represents a tenfold increase in physical intensity and approximately a doubling in loudness as perceived by people. The intensity level of a sound wave in a free field (uninterrupted space for transmission) decreases at a rate of 6 dB per doubling of distance from the source. Barriers to sound transmission result in reflection or reverberation in sound pressure level. There are several weighted sound scales in use but the one most closely corresponding to the sensitivities of the human ear is the A scale. The decibel units on this scale are abbreviated dBA.

The principal noise impact from power plant installation activities will be from the operation of heavy equipment. Trucks are expected to transport the power plants from the manufacturer to the field test sites. Noise from trucks and other heavy equipment is considered a nuisance as well as disruptive. The noise levels produced by a truck increase with vehicle and engine speed and also depend upon variables such as road surface, axle loading, tread design, and wear conditions. The sound level at 15m (49 ft) from a truck traveling 58 km/hr (36 mph) is about 88 dBA. This sound level increases to upwards of 96 dBA at speeds greater than 58 km/hr. Changes in operational variables can result in variations in noise level of up to 20 dB at constant vehicle speed (Ref. 1). People located along the transportation route will be subjected to these sound levels during a brief exposure period but no significant impact is expected. Truck noise at the test site may be prolonged for several hours as the power plants and other energy system components are delivered; however, other than causing some temporary annoyances, the short duration should result in no significant impact.

Operation of equipment at the site during site preparation and power plant positioning will produce intermittent noise lasting from one to several days. The duration will depend on the amount of site preparation required and the location of the installation at the site. Sound levels from cranes, forklifts, backhoes, or other types of equipment will be comparable to that produced by diesel trucks but will be intermittent in nature. The impact of these sounds on site occupants will vary according to ambient sound levels (refer to Section 3 for typical ambient sound levels), but at all sites this impact should be minimal because of the short exposure time.

In order to install the data acquisition systems in candidate buildings, and later the power plant interfaces in field test buildings, minor modifications may be necessary to the building interiors. These modifications may include additional passageways for electrical wiring and plumbing and additional structural support to roof areas carrying power plants. Use of power equipment to make these modifications will create unwanted sound in and around the site for a short period. Although this noise may be a short term nuisance to site occupants, it should not cause any impacts of measurable concern.

4.1.1.4 Land Use and Visual Aesthetics

Monitoring and installation activities will not impact land usage at the test sites; however, some temporary interference with normal site activities may occur. Monitoring of the candidate sites with data acquisition systems may temporarily interfere with the normal use of the sites because of the necessity of interrupting the power supply to the sites for several hours to allow installation of the monitoring systems. The level of disruption will vary according to site type, but it is possible that installation and removal of the monitoring systems may be timed to cause the least possible disruption. Site activity will also be disrupted during power plant installation because of the need to interrupt power and water supplies to the site to accommodate connection of power plant interfaces. The interruption should not last longer than one day.

Each power plant to be installed at the test site will require a level space having areal dimensions of 5.2m x 4.5m. This space will be required indoors, on the roof, or outdoors at ground level. The pre-installation use of this space will have to be forfeited in order to make room for the power plant.

During the actual installation of the power plants, normal activities may be interreupted for several days by the presence of heavy equipment and service people. If additional parking or other construction activity is also required, additional disruption of the normal use of the site can be expected for a limited period.

Visual aesthetics at and around the site may be temporarily degraded by minor construction activities and the presence of trucks and other equipment. The degree of degradation will vary according to the existing environment at each site; however, because the entire installation operation should not require longer than several days, the overall impact should be very minor in all cases.

4.1.1.5 Wildlife

The impacts that monitoring and installation activities will have on wildlife will depend largely on the type of habitat and kinds of species present at or near the test sites. Since the majority of test sites will be in urban and suburban localities in close proximity to existing buildings and auxiliary structures, it is expected that critical habitats and the presence of sensitive species will occur only rarely, if at all, near the test sites. Species that normally inhabit urban and suburban areas are generally unaffected by the types of short term manmade disruptions expected during monitoring and installation, such as noise, vibration, and visual intrusions. A small number of animals will be displaced if their habitat is altered during construction of power plant foundations, parking areas, and other structures required by the field test.

4.1.1.6 Vegetation

Installation of the power plants at some outdoor locations may require the removal of vegetation during site preparation. Construction of parking areas and other field test related structures may also require removal of vegetation. Heavy equipment operated at the test sites may trample vegetation. None of these potential impacts will be minor at most test sites since power plants will be installed in close proximity to existing structures and mitigating actions may be taken during installation to avoid damage to vegetation that is particularly valued by site occupants and wildlife.

4.1.1.7 Health and Safety

The primary health and safety impact during site selection and installation is related to the operation of heavy equipment in transporting the power plant and preparing the site. Trucks are a safety hazard due mainly to their size and weight. They are more damaging when they collide with another vehicle or person than the standard automobile. Although the chances are remote, the potential exists for an accident involving trucks transporting the power plants to the site or heavy equipment operating at the site. Such an accident could result in death or injury to people along the delivery route or at the test site.

Installation of the power plants will necessitate connection to the site's electricity and natural gas systems. Grid-connected power plants will require installation of an interface with the utility grid system. The maximum line voltage of the electrical connections will be 120/208 volts. The pressure of the gas system will be relatively low at 1.0-3.5 x 10^3 N/sq. m (4-14 in. of water). These tasks will be performed by trained personnel and all necessary safety precautions will be taken. Therefore, accidents arising from the interfacing of the power plant with the site energy systems and the utility grid system are extremely unlikely.

During the site selection monitoring of the candidate site energy systems and the connection of the power plant to these systems, the site's electrical power and natural gas supplies will be interrupted for a period of from several hours to a full day. Adequate notice of the interruption should be given to site occupants so that safety problems can be avoided. Backup or emergency energy systems may be employed at locations when a power disruption could cause potentially serious health and safety problems. Need for these systems will be determined locally.

The field test operation, including the site selection and instrumentation activities, is subject to the requirements of two Department of Energy Orders (5480.1 and 5481.1) addressing health and safety issues. These requirements apply to all direct DOE operations and all contractor operations where DOE has control over environmental protection, safety, and health protection. A description of the two relevant DOE Orders is provided in Section 6.

4.1.2 Power Plant Operation

Each power plant installation will be operated for a one or two year period. Since the power plants are designed for automatic operation, an operator will usually not be present to monitor performance. Scheduled and unscheduled maintenance will be performed by fuel cell trained service people. Since the test sites will retain the connection to their pretest energy sources during the field test, shutdowns of the power plant installations due to overload or failure will not adversely affect the energy supply to the sites. Grid-isolated power plants will have a transfer switch that will automatically shift the site load to the pretest system. Grid-connected power plants will rely on their connection to the grid to meet site demands in case of a shutdown. Visitors are expected at the test sites to view power plant operations. The visitation rate will vary according to site accessibility and public interest in the area.

4.1.2.1 Air Quality

The types and quantities of air pollutants emitted by the 40 kW fuel cell power plant during normal, steady-state operation are described in Section 2.3.6. The emission rates are this low because the power plant burns natural gas for fuel, processes the gas before combustion to remove sulfur, and operates at a low enough temperature to limit formation of thermally produced NO_x. These rates are many times less than the emission rates allowed by federal standards for large fossil-fueled generating stations. They also compare very favorably to the emission rates for conventional domestic gas heating equipment. These emissions rates are for operation under steady state conditions. Although emission measurements have not been taken for non-steady state conditions (startup and load response transients), it is likely that emission rates will be somewhat higher. Fuel for startup bypasses the fuel processing subsystem and the emissions will consequently have a higher concentration of SO_2. The fuel heat rate will vary during load response transients thereby causing the emission rate to vary. During all non-steady state conditions, clean burning natural gas is used for fuel and thus emissions will remain relatively low. The frequency of non-steady state operating conditions will vary with application but should remain a minor part of total power plant operation.

In order to estimate the daily 24 hour air pollution load emitted by the 40 kW power plant, a heat rate of 10,547 kJ/kW-hr (10,000 Btu/kW-hr) is assumed for power plant operation (actual heat rate is less). Operation of the power plant for 24 hours at 40 kW (full power output) produces 960 kW hours of electricity with an input heat of 10,125 MJ (9,600,000 Btu). Based on this heat input value, the 24 hour emission quantities expected from a single power plant and an installation consisting of two power plants operating in parallel are those given in Table 4-1.

Table 4-1. Twenty-Four Hour Total Air Emissions from Fuel Cell Power Plant Installations in Kilograms (pounds)

	One Power Plant	Two Power Plants
NO_x	0.0026 (0.0058)	0.0052 (0.012)
SO_2	0.00015 (0.00033)	0.00030 (0.00066)
Particulates	0.0091 (0.020)	0.018 (0.040)
Smoke	none	none
Total HC	0.011 (0.024)	0.022 (0.048)

As discussed in Section 2.3.6, very small quantities of phosphoric acid (1 ppm) normally exit the cathode with the exhausted air flow. The vast majority of this acid emission is removed by the power plant acid recovery system. Most of the acid that escapes this recovery (less than 0.1 ppm) is removed from the exhaust flow during the recovery of water vapor in the condensers. The concentration of phosphoric acid that remains in the cathode exhaust flow is therefore substantially less than 0.1 ppm. Once this flow is diluted by combination with the burner exhaust flow, the concentration of phosphoric acid has been calculated by UTC to be below detectable levels. Phosphoric acid is not considered to be a particularly toxic chemical and OSHA regulations prescribe a safe time-weighted air exposure limit of 1 mg/m^3 (0.2 ppm). This is a much higher air concentration than that emitted by the power plant.

The rate of air pollutants emitted by a fossil-fuel powered generating station is dependent on the type of fuel burned and emission control equipment used. In any case, these generating stations must meet federal air emission standards. Although the emissions from the generating stations may, in some instances, be below the standards, these standards can be used for comparative purposes. The federal emission standards for gas, oil, and coal-fueled generating stations are given in Table 4-2 accompanied by the emission rates for the fuel cell power plant at half rated power. The emission rates at half rated power are used for comparison since they are greater than the emission rates at full rated power. The emission rates for zero, half, and full power are given in Section 2.3.6. The emission rates of the fuel cell power plant seem to be less than the emission rates for central fossil-fuel power generating plants regardless of their fuel type.

Table 4-2. Air Emission Rates for the 40 kW Fuel Cell Power Plant and Fossil-Fuel Powered Generating Stations in kg/GJ (lb/million Btu)

	Fuel Cell	Federal Standards		
	(Half Rated Power)	Gas-Fired	Oil-Fired	Coal-Fired
NO_x	.00062 (.0013)	.096 (.2)	.14 (.3)	.33 (.7)
SO_2	.000015 (.000032)	No Standard	.38 (.8)	.57 (1.2)
Particulates	.0010 (.0021)	.048 (.1)	.048 (.1)	.048 (.1)
Smoke	None	20% Opacity	20% Opacity	20% Opacity
THC	.0031 (.0065)	No Standard	No Standard	No Standard

The emission rates of the 40 kW fuel cell power plant also compare very favorably with the emission rates of a domestic gas furnace. When operating at full rated power, the power plant is capable of providing about 150,000 kJ/hr (142,300 Btu/hr) of thermal energy. Table 4-3 shows the emission rates of the power plant at full rated power accompanied by the emission rates of a domestic gas furnace supplying 150,000 kJ/hr of thermal energy. At full rated power, the power plant has lower, or equivalent, emission rates than the gas furnace for the four emission constituents listed in Table 4-3.

Table 4-3. Air Emission Rates for the 40 kW Fuel Cell Power Plant and a Domestic Gas Furnace While Supplying 150,000 kJ/hr of Thermal Energy (Ref. 2)

Pollutant	Emissions in grams/hr (lb/hr) Power Plant	Gas Furnace
NO_x	0.10 (0.00020)	8.6 (0.018)
SO_2	0.006 (0.000013)	.064 (0.00014)
Particulates	0.38 (0.00084)	1.1 (0.0024)
THC	0.46 (0.0010)	0.86 (0.0018)

The very low emission rates of the 40 kW power plant will have only a marginal effect on the ambient concentrations of air pollutants in the near vicinity of the power plant and will cause no adverse health effects or property damage. If the power plant electrical and thermal outputs are replacing a gas or oil furnace at the site then air emissions from the site could actually be less. Replacement of electric heating units or placement of the power plant at a new site will slightly increase air emissions from the site. In either case, the difference is negligible from the point of affecting health or property. Power plants sited indoors will have hoods and flues to supply fresh air and ventilate all exhausts to the outside and thus preserve indoor air quality.

The movement of visitors to and from the test sites will increase the emission of automobile exhausts in the vicinity of the sites. The additional volume of traffic resulting from visitation to the test sites will of course vary from site to site, but in all cases is not expected to be great enough to cause a significant increase in the ambient concentrations of CO, NO_x, or hydrocarbons outside of the immediate test site area. At the test sites themselves, these automobile emissions may result in a temporary increase in ambient concentrations, but not of a sufficient magnitude to cause health or property damage.

4.1.2.2. Water Supply and Quality

A number of the 40 kW fuel cell power plants will be sited during the field test in areas of the country having water supply and quality problems (refer to Section 3.1.5). However, the fuel cell power plant differs fundamentally in its water supply and discharge characteristics from conventional electric generating sources because of the water producing nature of the fuel cell itself.

The air-cooled 40 kW fuel cell power plant does not require attachment to an external water supply to fulfill its process water and cooling needs. The electrochemical reactions within the fuel cell stack produce a sufficient quantity of water to compensate for steam consumption in the fuel reformer and water vapor loss via the exhaust stream. This self-sufficiency is made possible by the recovery of a portion of the byproduct water from the fuel cell exhaust stream and reformer exhaust flow. Power plant condensers feed the recovered water back to the water tank and purification unit where it is again available to meet cooling and fuel processing needs.

Upon installation, the power plant cooling system is filled with deionized water. Deionized water is used because the cooling water and process water must have low conductivity and be very clean. The recovered water vapor is fed through a charcoal filter and the ion exchangers in the demineralizer to remove impurities and is then available to supplement the coolant water. The coolant water can also be periodically blown down through the purification system. Overall, the power plant water purification system maintains the coolant and process water at a very high level of quality.

During certain operating conditions, the power plant will produce more water than it can consume in the reforming process and lose in the exhaust stream. This is especially the case during transients and cold weather. Excess water is collected in the water tank of the coolant system until tank capacity is reached. At tank capacity, additional excess water is removed from the power plant via an overflow drain to a water drain at the site. The maximum flow rate of the overflow is estimated to be 37.9 liters (10 gallons) per hour. The excess water has a maximum temperature of 344K (160^{o}F) and a 6-7 pH range. This water is condensate from the low grade heat exchanger and condensers. It is discharged prior to passage through the purification unit. In spite of this, the quality of the water is expected to be totally acceptable for discharge since its sources are the relatively clean exhaust flows and its transport is through the corrosion resistant recovery system. Quantitative water quality data is not available. Other drains from the coolant system will also connect with the site drain. These drains can be used to drain the system during maintenance. The water occasionally discharged from these drains will also be of a relatively high quality.

In comparison, conventional central generating stations have major water requirements for waste heat dissipation. The amount of water required depends on the cooling system used; much greater amounts of water are required for once-through cooling systems than for a closed-cycle system which employs cooling towers operating as a closed loop. Table 4-4 gives the estimated water requirements for a coal-fired power plant. The throughput water is that which is taken into the cooling system. Most of this water is discharged back to the source. The throughput water is recycled in the systems using cooling ponds or wet cooling towers, and once the pond or tower is filled with water, continued withdrawal from the external water source will comprise approximately 10 percent of the figures shown in Table 4-4.

Table 4-4. Estimated Water Requirements for a Coal-Fired Power Plant (Ref. 3)

	Water Requirements (liters/kW-hr)	
Cooling System	Throughput	Consumptive Use
Once-Through	1150	0.95
Cooling Ponds	150	0.95
Wet Cooling Towers	150	2.8

The consumptive use is that portion of the water taken into the system which is lost to evaporation and seepage.

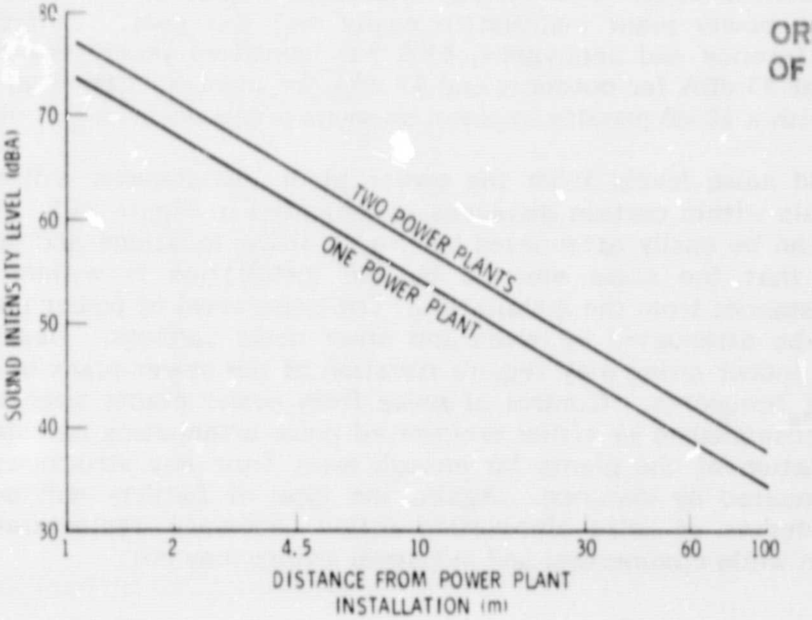
The withdrawal of water from a natural source for throughput cooling adds to the competing uses of water resources. Impingement, entrainment, chlorination and heating can affect aquatic life as it is drawn through the cooling system. The discharge of thermal waste and small concentrations of chlorine and toxic metals into the receiving water body compounds the burden already carried by that aquatic system.

In summary, once the closed coolant system is filled with deionized water, the fuel cell power plant does not require that water be supplied to it for cooling, processing, or any other purpose. It is totally water self sufficient, except during very unusual operating conditions (refer to Section 2.3.1.3), and thus will have no detrimental impacts on local water supplies. The small quantity of overflow coolant water that flows from the plant can be safely discharged into the local sewer system and will have no significant impacts on the operation of the local wastewater treatment facility. It has significant water use and discharge advantages over conventional central generating stations.

4.1.2.3 Noise

The power plant free field noise level at the 4.6m (15 ft) perimeter was measured at 61 dBA at full power operation. The noise level was found to vary little over the output range of the power plant. Based on the 61 dBA reading for one power plant, an installation of two power plants will produce a free field noise level 64 dBA at 4.6m. Figure 4-2 illustrates the change in free field noise as a function of distance from the power plant installation. The noise produced is in the middle to lower frequency ranges.

Figure 4-2. Free Field Sound Pressure Levels for Installations of One and Two Power Plants as a Function of Distance from the Installation



The impact of the power plant noise on the surrounding environment should be evaluated with respect to existing ambient noise levels, local noise ordinances, and federal and state noise guidelines. All the noises generated in an area constitute the area's ambient noise level. As substantiated by Tables 3-5 and 3-6, these levels are generally higher in industrial and commercial environments and lower in residential environments. The power plant is more likely to increase the ambient noise level in residential zones; however, the degree of adverse impact will be determined by the exact level of existing ambient noise, the siting location of the power plant, and any noise attenuating barriers surrounding the power plant. The free field noise level at 4.6m from an installation of two power plants was calculated to be 64 dBA. For comparative purposes, the sound level from a normal conversation at 1m or from an air conditioning unit at 1m is 70 dBA.

Local ordinances specify the allowable noise levels in a given region. Noise level criteria are usually set for residential, commercial, retail, and industrial zones. Many localities also differentiate between daytime and nighttime noise levels. Typical local noise ordinances range from 75 dBA for heavy industrial areas in the daytime (65 dBA at nighttime) to 55 dBA for suburban residential areas in the daytime (45 dBA at night). These are ambient neighborhood noise limits and do not apply to noise levels immediately adjacent to the noise emitter. Proper siting and noise attenuating measures should allow the power plant installations to comply with all local ambient noise ordinances in most, if not all, zones.

The power plant noise levels are well below the OSHA noise exposure limit of 90 dBA for an eight-hour day established to protect worker hearing (refer to Section 6.2.4). The EPA has identified noise levels which, if not exceeded, should protect against some of the worst effects of noise (Ref. 4). These levels include a margin of safety and were derived without considering the technical or economic feasibility of achieving them. They should be viewed as long range environmental goals rather than EPA-recommended regulatory requirements. To protect against hearing loss, EPA identified a 24 hour average (Leq) exposure of 70 dBA or less. Leq is an energy average of sound levels and is not the same as an arithmetic average because peak sound levels contain much more energy than less intense levels. Beyond its 4.6m perimeter, the power plant installation easily met this goal. To protect against activity interference and annoyance, EPA has identified yearly day-night average values (Ldn) of 55 dBA for outdoors and 45 dBA for indoors. Ldn is an Leq for a 24 hour period with a 10 dB penalty imposed on sound levels occurring at night.

The free field noise levels from the power plant installations will exceed these suggested goals within certain distances as indicated in Figure 4-2. The free field noise levels can be easily attenuated by proper siting locations and noise barriers, however, so that the noise emitted by the installation is within the goals at reasonable distances from the installation. The noise level of power plants installed indoors may be attenuated by walls and other noise barriers. Depending on the facility type, indoor siting may require isolation of the power plant in a room away from building occupants. Control of noise from power plants sited outdoors may have to be accomplished by either erection of noise attenuating barriers around the plants or location of the plants far enough away from any structures so that the noise is attenuated by distance. Again, the type of facility will determine the method and degree of noise elimination action necessary--residential sitings may require action while commercial and industrial sitings may not.

A second source of noise during power plant operation in the field may come from visitors moving through the site. Noise from automobiles and buses arriving and departing, and persons moving through the site, will differ from the power plant noise in that it will be intermittent and relatively infrequent. At some test sites, these noise sources may cause some temporary annoyances, but they should have no health or welfare effects.

In comparison, fossil-fuel powered generating stations contain many sources of noise production. Forced-draft fans, boiler feed pumps, and turbine-generators contribute large amounts of noise to the station's sound levels. These levels often approach or exceed the OSHA standards and EPA recommendations for protection of human health and welfare. Although more people will be exposed to noise from many dispersed on-site fuel cell power plants than from one central generating station, this noise is much less intense and therefore less hazardous.

The possible impacts of power plant noise on wildlife at or near the test sites is discussed in Section 4.1.2.5.

4.1.2.4 Land Use and Visual Aesthetics

The 40 kW fuel cell power plant has the form of a large rectangular box with dimensions of 2.74m x 1.57m x 1.95m (108 in. x 62 in. x 78 in.). One or two of these units will be sited at each test location accompanied by smaller auxiliary elements of the on-site integrated energy system (e.g., heat pump, hot water heat exchanger, piping). The power plants can be sited indoors, outdoors at ground level, or rooftop, with the exact location at each site determined by site characteristics. Because the test sites will retain connection to their pretest energy systems as a backup, power plant shutdown will not affect normal functions at the sites.

The areas immediately adjacent to the power plant may be unusable for certain activities requiring a low ambient noise level (e.g., sleeping, resting, study) but other than this, power plants sited at indoor or rooftop locations will not have a significant land use impact since they will be confined within or atop existing structures and will not alter the general use of these structures. Most of the auxiliary equipment accompanying indoor or rooftop units will likewise be located indoors or on the roof.

Power plants sited outdoors will at most have a very minor land use impact and then only during the one year field test. Each of these units will be sited on a level pad of ground having areal dimensions of 5.2m x 4.5m (17.0 ft x 14.7 ft) to allow for adequate space for ventilation and maintenance access. These pads will probably be covered by a layer of gravel with the power plant resting on two or more supporting railroad ties or equivalent size supports. When allowed by local codes, the outdoor locations may be surrounded by a fence for security and/or noise attenuation. Multiple units operated in parallel will require a proportionately greater area for siting. The gas line, water lines, drain line, and electricity input and output lines will run above or below ground between the power plant and the site facility. Some auxiliary equipment, in particular the heat pumps, may also be sited outdoors and adjacent to the facility.

Depending on the exact location, power plants sited outdoors or rooftop may have a minor impact on visual aesthetics, particularly in residential areas. This visual intrusion, however, will be similar to that expected from a roof-mounted air conditioning unit of a similar size or a small backyard utility building. In addition, the power plant cabinet will be a neutral color to reduce visual intrusion. Shrubs or other decorative items may be used to upgrade the appearance of outdoor units.

The water vapor in the power plant air exhaust stream may cause formation of a fog plume during certain operating and weather conditions. This water vapor is often diluted by mixing with the condenser cooling air prior to emission. The volume of cooling air and hence the dilution factor varies according to ambient temperature and the need for recovered water. At full rated output, the exhaust stream dewpoint varies from 262 K (-11°C) (high cooling air flow) to 270 K (-3°C) (low cooling air flow). At half rated power, the dewpoint with a low cooling air flow is 262 K (-11°C). During low ambient temperatures or periods of low-grade heat extraction, the condenser fan is turned off and the cooling air flow is not available for dilution. This causes the dewpoint of the exhaust stream to be substantially higher; up to a maximum of 314 K (41°C).

If the temperature of the exhaust plume is at or below the dewpoint, fogging will occur. The size of the fog plume will depend on the volume of the exhaust flow, the ambient humidity, and the local air turbulance. If the condenser fan is not operating, a fog plume can be expected most of the time from outdoor power plants. If the fan is operating, the dewpoint of the combined exhaust flow drops substantially and outdoor power plants will cause a fog plume only during cold weather. Power plants sited indoors will have their water vapor exhaust diluted by all of the cooling air flows as they pass up the flue. The occurrence of fog plumes from indoor power plants is thus much less likely. The fog plumes could degrade visual aesthetics in the immediate vicinity of the power plant. This will probably be more of an annoyance at residential sites, and possibly commercial sites, than at industrial sites.

Land use and visual aesthetics may be affected by the movement through the test sites of visitors viewing power plant operation. Parking areas will be required by these visitors, and if existing parking facilities are inadequate, new areas will have to be constructed resulting in forfeiture of pretest land use. Depending upon the volume of site visitors, visual aesthetics may be slightly degraded by the movement of people through the site and the presence of more automobiles, buses, parking areas, and other field test related structures.

The 40 kW fuel cell power plant requires a floor space of 23.4 square meters (5.2m x 4.5m) for the foundation and adequate access. A typical 100 MW(e) coal-fired power plant requires about 2.9×10^5 square meters of land for all of its on-site facilities (Ref. 3). This is an equivalent of 116 square meters of land use for each 40 kilowatts of generating capacity. This is nearly five times the land required by the fuel cell power plant to provide the same generating capacity. Of course the fuel cell power plants will be sited in urban and suburban areas where their noise may limit the use of lands immediately adjacent to them; but on the other hand, power plants sited at indoor and rooftop locations may not require any forfeiture of existing land use whatsoever. Central generating stations will also limit the ways in which lands adjacent to them may be used because of noise and odor problems.

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4.1.2.5 Wildlife

It is unlikely that the operation of the power plants at the test sites will have any significant impacts on wildlife at or near the sites. The bottom of the power plant is sealed to prevent entry of small animals and thus avoid injury to them and to the power plant itself. The one facet of power plant operation having possible wildlife impact, however, is the noise emissions of the power plant.

Studies have shown that animal response to noise is a function of the frequency spectrum, intensity, duration, and pattern of exposure. Responses to noise range from interference with behavioral patterns to disruption of auditory apparatus (Ref. 3). Most of these animal studies have investigated the effects of high levels of sound during acute, short term exposures much in excess of the free field noise levels expected at more than several meters from the power plant. While behavioral and physiological changes have been noted by these studies, the effects of exposures to low intensity sound levels like those expected in the vicinity of the power plant have not been evaluated. Thus the possibility cannot be eliminated that wildlife around the power plant may suffer subtle physiological or behavioral stresses.

The degree of impact that power plant noise might have on wildlife will largely depend on the species present at or near the sites, as well as the pretest ambient noise levels of the sites. Since the majority of test sites will be in urban and suburban localities, species that are sensitive to manmade intrusions should occur only rarely, if at all, near the test sites. In many instances, the power plant noise is not expected to significantly increase ambient noise levels at sites and therefore only wildlife that is extremely close to the power plant will be impacted.

The attraction of visitors to the test sites by power plant operation will result in increased noise and physical intrusion that could have a minor impact on wildlife. The species present at most sites should be easily able to adjust to these increases in manmade disturbances, however.

4.1.2.6 Vegetation

Vegetation located within several meters of the power plant, or overhanging the power plant, may be adversely affected by thermal exhausts. The maximum temperature of the mixed power plant exhaust is 361 K (190°F). This heat may result in the death of some plants. Vegetation around the power plant may also be trampled by visitors to the test sites. Neither of these impacts to site vegetation is considered important and both may be controlled by proper siting of the power plant installation and management of visitor activities.

4.1.2.7 Health and Safety

The power plant is designed and constructed to ensure a reasonably high level of health and safety for both the general public living and working in its vicinity, and service personnel performing maintenance duties. The operation of the power plants during the field test is subject to the requirements of Department of Energy Orders addressing health and safety concerns. These requirements apply to all direct DOE operations and all contractor operations where DOE has control over environmental protection, health, and safety protection. These two DOE Orders are described in Section 6.2.7. When sited outdoors, the power plant should be located such that it does not create a hazard by impairing visibility on adjacent streets, alleys, or other types of thoroughfares. The fog plume emitted by the power plant during cold or humid weather could impair visibility, and the size and direction of this plume should be considered during site selection. Increased pedestrian and motorized vehicle traffic around and through the test sites caused by visitors to the fuel cell installation may increase the risk of traffic accidents and injuries.

The unit has been design according to selected safety codes and standards, is equipped with a built-in safety system to monitor performance and initiate shutdown in case of operating irregularities, and is being evaluated for certification by two nationally recognized testing laboratories. These and other health and safety issues are discussed below. The risk and possible consequences of credible accidents involving the power plant are investigated in Section 5.

Safety Codes

The following codes and standards have been selected by UTC as applicable, and both their letter and spirit have been included in the 40 kW power plant design criteria:

- National Electrical Code, 1978
- ASME Boiler and Pressure Vessel Code, 1977
- ANSI B31 Code for Pressure Piping, 1977
- UL 795 Commercial-Industrial Gas Heating Equipment
- ANSI Z 21.47 - 1978 (AGA) Gas-Fired Central Furnaces

The National Electrical Code is sponsored by the National Fire Protection Association under the American National Standards Institute (ANSI). Its purpose is the practical safeguarding of persons and property from hazards arising from the use of electricity. Compliance will result in an installation essentially free from electrical hazard. Included among the code's standards for electrical materials and methods, are standards covering all factors which contribute to the practical safeguarding of persons using or likely to come in contact with the fuel cell equipment. Standards require adequate space for ventilation and maintenance access as well as adequate illumination for working. Guidelines specify avoidance of dangerous contact with dampness, wetness, corrosive fumes, liquids or vapors, and excessive temperatures.

The pressurized cooling system is designed according to the Boiler and Pressure Vessel Code. This code establishes rules of safety governing the design, fabrication, and inspection during the construction of pressure vessels. Because of the tremendous variety of pressure vessels, the rules are flexible and can be satisfied if sufficient margins of safety are demonstrated. The objective of the rules is to afford reasonably certain protection of life and property and to provide a margin for deterioration in services so as to give a reasonably long and safe period of usefulness.

The Code for Pressure Piping has been applied to both the fuel processing system and the cooling system. The code regulations govern: materials and equipment; welding; piping system components and fabrication details; design, installation, and testing; operating and maintenance procedures; and corrosion control. The ASME recognizes that there are varying degrees of criticality involved in pipeline usage depending on the degree of danger posed by a potential accident. Because of the difficulty in quantifying various degrees of danger, the code does not differentiate between the design, fabrication, and erection requirements for critical and non-critical piping systems. The standards are thus conservative in their protection and a designer is encouraged to specify more rigid requirements if justified. The pipelines associated with the fuel cell system do not transport materials considered critically dangerous, however. The steam separator vessel in the power plant cooling system must meet the requirements of Section 8 of the code, and 24 state governments will require the vessel to carry the ASME stamp.

Both the Commercial-Industrial Gas Heating Equipment Code and the Gas-Fired Central Furnaces Code address the design and safety of the power plant reformer burner system. These codes ensure that the design, materials, construction, and installation of the burner system are adequate to safeguard persons and property from potential hazards arising from burner operation. Specific sections of these codes address the protection of equipment users and service personnel. The ANSI Z 21 Committee is in the process of broadening its scope to include standards specifically for electric generating appliances that use gas. When new standards are issued, the fuel cell manufacturer will make any necessary modifications to ensure that the design, materials, and construction of the field test power plants meet all requirements.

UTC has conducted structural analyses and design reviews during the design phase to verify that the design of all power plant components is in compliance with the above codes and standards. This was followed by the inspection and testing of the actual components to further verify their compliance.

Safety System

Included in the power plant controller unit is the automatic safety sensing system for equipment protection and automatic shutdown in the event of critical out-of-limits component operation. It is designed to detect operational irregularities of an unsafe nature and halt the flow of fuel to the power plant should an unsafe condition arise. UTC has conducted tests on the system to ensure that it functions according to design. A description of this safety system is provided in Section 2.4.3.

The detection of operating irregularities by this system will eliminate the great majority of sources for possible power plant accidents and safety hazards. Credible accident scenarios not totally eliminated by this system are discussed in Section 5.

Safety Certification

Two nationally recognized testing laboratories, Underwriters' Laboratories (UL) and the American Gas Association (AGA), are participating in the safety design of the 40 kW fuel cell power plants. UL develops safety specifications for electrical and other types of devices and will certify an electrical device if it meets all of UL's safety specifications and testing requirements. AGA develops safety specifications for gas appliances and will likewise certify a gas appliance if it meets all AGA requirements. Both UL and AGA have been involved in the design of the 40 kW fuel cell power plant beginning with the initial design phase.

UL has reviewed the design and construction of the power plant and has recommended safety tests that UTC should perform on the power plant. UTC has already performed many of the UL-recommended safety tests. UL does not certify demonstration products and, because it does not consider the production of 48 field test power plants to constitute a full production run, a formal certification from UL will not be issued. In lieu of formal certification, UL is preparing an engineering report that will (1) document the safety tests observed by UL; (2) state that although the power plants are not certified, they do meet specific UL established criteria; and (3) identify areas requiring further UL investigation.

AGA has also reviewed the design and construction of the power plant units. Because existing codes do not directly address fuel cell equipment, AGA has selected the most applicable sections of the existing codes and, using them as a basis, has prepared draft specifications for the fuel cell power plant. The sections of existing code selected by AGA closely agree with the previously mentioned safety codes upon which UTC based the design of the power plant. UTC will make the required modifications in the design and construction of the field test power plant to bring it into line with the AGA draft specifications. A formal certification from AGA will probably not be issued, however, since AGA normally does not certify demonstration products.

Safety Features

The power plant is designed with a number of safety features that will minimize any potential hazard it may present to persons working or playing in its vicinity. The power plant has no moving components exterior of its cabinet that could cause injury to nearby persons. Special tools are required to open the cabinet and thus the chance entry of unauthorized persons into the cabinet is extremely unlikely. All air and exhaust vents are screened to prevent the entry of hands, arms, and other large objects into the cabinet interior. The bottom of the power plant is sealed to keep out rodents and other creatures that could possibly impair power plant operation. Fences may be installed to limit access to the power plant area. The components that operate at the highest temperatures (converter, reformer, and steam separator) are in a well insulated section of the power plant. The insulation ensures that the temperature of the exterior surface of the cabinet will remain below those temperatures capable of causing heat injury when contacted.

The power plant uses the inverter cooling air flow to maintain a positive air pressure inside the cabinet. This air pressure will flush any natural gas or fumes out of the cabinet and so prevent the accumulation of a dangerous quantity of these gases inside the power plant. Power plants installed indoors will be equipped with an exhaust hood and flue that will capture all exhaust emissions and cooling air streams, as well as any fugitive gases or fumes, and transport them to the exterior of the building. The exhaust hood and flue should be designed so that they will not impose a back pressure on the power plant. The operation of the exhaust hood will ensure that persons in an interior location with the power plant will not be exposed to ambient concentrations of power plant exhausts, gases, or fumes that could pose a hazard to their health.

The power plant is designed for easy and safe access during maintenance. Some maintenance procedures can be safely performed while the power plant is operating. The major annual maintenance requires that the power plant be shut down, however, and thus any safety risk to service personnel is minimized. The inverter's capacitors are designed so that, following power plant shutdown, they will not hold a charge that could cause injury to service personnel.

The working environment surrounding the power plant is regulated by health and safety standards promulgated by the Federal Occupational Safety and Health Administration (OSHA). The goal of OSHA standards is the protection of the worker in the workplace and these standards address many facets of the work environment including exposure to noise, radiation, air contaminants, and toxic substances. OSHA standards also set forth requirements for adequate safety equipment, safety color codes for marking physical hazards, and accident prevention signs and tags.

DOE safety and health orders require strict adherence to all applicable OSHA standards during all phases of the field test operation, including installation, operation, and decommissioning of the power plants, to ensure the highest level of safety and health for maintenance personnel and other workers in the power plant vicinity.

Safety Hazard of Grid Connected Operation

The power plant inverter is designed to avoid creation of a potential safety hazard to utility electricians working on the line. These electricians, even when following operating procedures, may be working on high voltage lines which are not absolutely grounded. With several power conditioning units, such as the power plant inverter, operational on the low voltage side of the line, the potential exists to back feed electrical power into the high voltage line thus creating a safety hazard.

The power plant inverter avoids this hazard by monitoring utility grid activity during grid-connected operation. Failure of the grid for more than 30 seconds will cause the power plant to disconnect from the grid and go into isolated operation. While disconnected, the inverter sends signals into the grid system to alert the utility of the disconnection. The power plant must be manually reconnected once grid power is restored. Manual reconnection eliminates the possibility of an inadvertent automatic reconnection caused by equipment failure. In order to ensure the safety of electricians working on utility lines connected to the field test power plants, special precautions should be taken by the utilities to inform the electricians of the hazards and safety features.

4.1.2.8 Electromagnetic Interference

Electromagnetic interference (EMI) is an undesirable effect of unwanted electromagnetic signals (noise) upon a radio communications system or other electronic system manifested by degradation, misrepresentation, or loss of information which could be extracted in the absence of this noise. Electromagnetic noise is produced by many types of communication and electronic devices, and can be radiated through the air or conducted along the electrical supply line. The 40 kW fuel cell power plant inverter is capable of producing both radiated and conducted electromagnetic noise. This noise in turn has the potential of causing EMI in radios, televisions, and other communication devices expected to be found at or near the field test sites. However, the power plant inverter is being designed to minimize both radiated and conducted EMI-producing noise. Prior to operation at the field test sites, the power plants must conform with all Federal Communications Commission (FCC) regulations restricting the production of harmful EMI in radio communication devices.

The model specifications for the 40 kW fuel cell power plant state that, under normal operating conditions, the inverter system will not produce EMI of sufficient magnitude to cause degraded performance of any electrical equipment being powered from it, or electrical equipment being operated farther than three meters (10 feet) from the power plant. The model specifications also state that the inverter will conform to all FCC regulations. As detailed in Section 6 of this assessment, these regulations prohibit the operation of an incidental radiation device from causing harmful interference. Harmful interference is defined as any emission, radiation, or induction which endangers the functioning of a radio navigation service or of other safety services, or seriously degrades, obstructs, or repeatedly interrupts radio communication service. The power plant inverter is an incidental radiation device because it radiates radio frequency energy during the course of its operation although it is not intentionally designed to generate radio frequency energy.

During the verification testing of power plant performance, UTC conducted some initial testing for EMI by utilizing a standard UHF/VHF television receiver powered by the power plant. The television was operated at a distance of three meters from the power plant during a complete range of power plant output levels. Under the limited test conditions, the performance of the television was at no time degraded by radiated or conducted electromagnetic noise from the power plant.

Experience with photovoltaic inverters has indicated that radiated electromagnetic noise in the VHF television frequencies is substantially less than radiated noise in lower frequencies including the AM radio frequencies (Ref. 5). NASA-Lewis Research Center testing on a photovoltaic inverter resulted in no interference for television and FM radio reception, but interference (buzzing) in the AM radio band was encountered (Ref. 6). Complete testing of the 40 kW fuel cell power plant inverter by UTC has not been conducted for the television and radio bands. However, NASA-Lewis is taking steps to ensure that all necessary EMI testing is conducted to guarantee, as much as possible, that the power plants will be in full compliance with FCC regulations at all test sites. If further testing uncovers EMI problems, NASA-Lewis will insist that the problems are corrected before delivery of the power plants to the test sites.

The power plant is equipped with an EMI filter that is shielded by a heavy steel enclosure. This filter is designed to remove conducted electromagnetic noise from the power supply as it leaves the power plant. Without such a filter, conducted noise could degrade the performance of electrical devices. In cases where the power plant is connected to the utility grid, conducted noise could potentially interfere with utility signals on the power distribution lines. NASA-Lewis will take the necessary actions to ensure that the EMI filter eliminates a sufficient level of the power plant's conducted noise to avoid problems in the local distribution system and electrical equipment powered by the system.

In summary, the limited EMI testing that has been performed thus far has revealed no problems with either radiated or conducted electromagnetic noise from the power plant inverter. More complete testing of photovoltaic inverters has shown that radiated noise is greater in frequency bands lower than the FM radio band and may cause interference in these bands. NASA-Lewis is taking the necessary steps to reasonably ensure that the power plants will not cause harmful interference at the field test sites as a result of either radiated or conducted electromagnetic noise.

4.1.2.9 Voltage Flicker

The operation of the fuel cell power plants will not result in the occurrence of voltage flicker effects at the test sites above the level of pretest effects. The voltage characteristics of fuel cell power plant supplied electricity and utility supplied electricity are basically the same. Equipment that induces voltage flicker on utility systems will induce flicker on the fuel cell system and should be avoided. Equipment that is so sensitive to flicker that it requires special isolation from the conventional utility distribution system will probably require isolation from the fuel cell power system. The electrical characteristics of power plant output power, including voltage regulation, are described in 2.3.1.4.

As used widely throughout the electric utility industry, the term flicker means any perceptible sudden fluctuation in electrical lighting intensity occurring more frequently than once a day. These fluctuations in lighting intensity are caused by sudden fluctuation in voltage. Due to the historical association with their effect on lighting, the sudden voltage fluctuations have come to be commonly termed voltage flicker. This association has carried over even when discussing effects on other electrical devices where light variations do not apply. Voltage flicker is caused by the switching of high power industrial appliances such as large motors, arc furnaces, seam welders, reciprocating compressors, and of domestic appliances such as dish washers, washing machines, refrigerators, and electrical heating installations. The switching induces voltage transients in the local electrical distribution system that can affect the performance of other electrical devices on the local distribution system. Large industrial equipment frequently requires a separate power supply to eliminate its flicker induced effects on other equipment. The magnitude and frequency of induced voltage flicker is determined by the electrical characteristics of the inducing device and the power distribution system. The consumer perception of the voltage flicker is determined by the sensitivity to flicker of affected electrical devices as reflected by performance changes.

Voltage flicker has long been a subject of concern to electric utilities. In providing electric service to a device which has large, sudden variations in electrical demand, one of the considerations facing the utility is the prevention of unacceptable voltage flicker on the supplying system. Most utilities have guidelines that restrict service to devices that would create objectionable performances in the devices of neighboring consumers. These guidelines are based on tolerable lighting flicker curves that give the maximum tolerable voltage change per frequency of voltage flicker (Ref. 7).

In large measure, the magnitude of voltage flicker presently permitted on a system is tied to the quality of service that consumers from that system have come to expect. For example, every customer on an electrical system which traditionally has limited voltage fluctuations to five percent has accommodated his operation to satisfactorily operate on that supplied voltage. Since it is generally impractical for a utility to supply the quality of service required by equipment that is very sensitive to voltage flicker, many different methods have been employed to ensure the standard of voltage control required. The most elaborate of these methods is the uninterruptable power supply (UPS) system. Improvements in UPS systems have made it possible to eliminate even the most minor disturbance from the power supply. The replacement of the utility supplied voltage with the voltage supplied by the 40 kW fuel cell power plant will have little effect on the quality of service provided so long as the magnitude and frequency of voltage flicker permitted on the service line is not increased above the tolerable limit. Only minor changes in voltage flicker are expected to occur because the characteristics of the voltages from the utility and fuel cell power plant are basically the same and the mere substitution of one for another will have little effect.

4.1.2.10 Energy Efficiency

As illustrated in Figure 2-9, the field test power plants are expected to operate in the electric generating efficiency range of 37 to 40 percent from half to full rated power. The recovery of byproduct heat results in a high total fuel utilization of up to 80 percent at full rated power. This compares to electric generating efficiencies of 30 to 35 percent for central fossil-fuel and nuclear electric generating stations that lose approximately 10 percent of the electrical output during transmission and typically have no heat recovery.

The on-site integrated energy system utilizing the 40 kW fuel cell power plant compares very favorably with traditional on-site energy systems in terms of energy efficiency. A simulation study by UTC (Ref. 8) demonstrated that energy systems using on-site fuel cell power plants are more energy efficient than traditional energy systems. The UTC on-site energy system comparison was based on the operational demonstration of a 40 kW preprototype fuel cell power plant. An on-site energy system using this power plant was compared with a traditional on-site energy system using external supplies of gas and electricity. The three systems are shown schematically in Figure 4-3. The energy resources required by each system in providing the useful energy needs of a 16-unit apartment complex on a representative winter day were calculated and are displayed in Table 4-5. The apartment complex required a total of 348,150 kJ/hr in useful energy. The gas and/or electrical supplies (metered energy) required by each system to provide this useful energy level are also shown in Table 4-5. Assuming that 10,550 kJ (10,000 Btu) are consumed in the generation and transmission of a kilowatt-hr of electricity from a typical fossil-fuel fired generating plant, the total energy resource required to provide the useful energy for the apartment complex if 506,400 kJ/hr for the traditional system, 780,700 kJ/hr for the all electric system, and 337,600 kJ/hr for the on-site fuel cell power plant system.

The UTC energy analysis for the three systems was extended to obtain the annual energy resource requirement data displayed in Table 4-6. The 16-unit apartment complex was assumed to be located in an area of the country having an annual temperature measurement of 6000 heating and cooling degree-days for the purpose of the annual analysis. This degree-day level corresponds to a number of U.S. cities

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Figure 4-3. Schematics of Three On-Site Energy Systems Compared in UTC Energy Analysis (Ref. 8)

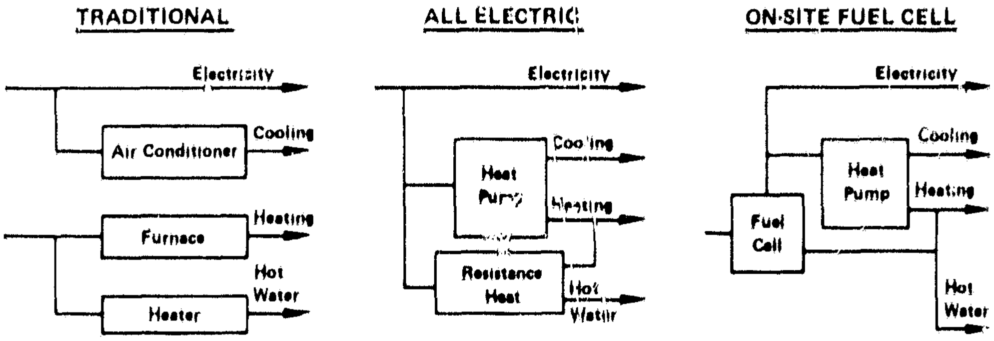

Table 4-5. Comparative Energy Resource Requirements for Three On-Site Energy Systems (Energy Use Per Hour) (Ref. 8)

	Traditional	All Electric	On-Site Fuel Cell
Useful Energy			
Total - kJ	348,150	348,150	348,150
Btu	330,000	330,000	330,000
Metered Energy			
Fuel - kJ	400,900	-	337,600
Btu	380,000	-	320,000
Electricity - kW-hr	10.0	74.0	-
Energy Resources Required			
Total - kJ	506,400	780,700	337,600
Btu	480,000	740,000	320,000

Table 4-6. Annual Energy Consumption Analysis for Three On-Site Energy Systems at 6000 Degree-Days Location (Ref. 8)

	Traditional	All Electric	On-Site Fuel Cell
Metered Energy			
Fuel - Million kJ	2584	-	2163
Million Btu	2450	-	2050
Electricity - kW-hr	120,000	448,000	-
Energy Resources Required			
Total - Million kJ	3850	4726	2163
Million Btu	3650	4480	2050
Resource Utilization Efficiency - Percent	53	43	94

including Chicago, Cleveland, Detroit, Hartford, Omaha, and Salt Lake City. Table 4-6 shows that the annual energy consumption of the on-site fuel cell system (2163 million kJ) in fulfilling the thermal and electrical energy needs of the apartment complex is substantially less than either the traditional system (3850 million kJ) or the all electric system (4726 million kJ). Of particular interest is the fact that the on-site fuel cell system can provide all of the thermal and electrical energy needs for the apartment complex while consuming less metered gas (2163 million kJ) than the traditional gas/electric system consumes while meeting only the thermal energy needs of the site (2548 million kJ).

The energy efficiency percentages presented in Table 4-6 were calculated by summing the efficiencies of the components of each system, including the efficiency of a fossil-fuel fired generating plant in providing electricity to the traditional and all-electric systems. The energy efficiency percentages clearly indicate the superiority of the on-site fuel cell system in conserving energy resources when compared with the two traditional heating and cooling systems.

4.1.3 Power Plant Decommissioning

At the conclusion of the field test, the power plants will be removed from building sites and returned to the manufacturer. Fuel cell trained service personnel will perform all necessary decommissioning activities to ensure that power plant removal can be conducted in a safe manner. Forklifts, cranes and other equipment will be used to load the power plants onto trucks for transport back to the manufacturer. All interface equipment will be removed from the sites, and the pretest energy systems will resume their normal operation. Heat pumps and other auxiliary items installed for the field test may be left in place at the sites for continued use by site occupants. Efforts will be made to restore the sites to as close to their pretest condition as possible. The power plants at several field test locations may be left in place past the conclusion of the one-year field test for extended testing and use by site occupants.

4.1.3.1 Air Quality

Removal of the power plants from the test sites will likely require the use of motorized equipment such as cranes, forklifts, and trucks. The impact on air quality resulting from the use of this equipment will be very similar to the impact expected from the use of the same type of equipment during installation procedures (refer to 4.1.1.1). Air emissions from the equipment may cause a possible short term annoyance to people at the test site, but should disperse rapidly resulting in no detectable increases in the ambient concentrations of air pollutants in the entire basin.

Restoration of power plant pads, parking areas, and other field test facilities, may generate a minor quantity of fugitive dust at the test sites. This dust may remain a minor problem until the ground areas are relandscaped.

4.1.3.2 Water Supply and Quality

Power plant decommissioning activities will have little or no impact on the water supply and quality at the test sites or in the watersheds in which the test sites are located. Water supply to the test sites may be interrupted for several hours to facilitate disconnection of the water system from the power plant thermal energy recovery system and other auxiliary energy equipment. The drainage and discharge of the coolant water will not impact the local wastewater treatment system. Outdoor removal and restoration activities may result in storm water runoff having high concentrations of suspended solids and turbidity because of erosion of disturbed soil. The magnitude of the sediment load in the runoff will depend on the level of soil disturbance, but will be no greater than that expected for construction activities of a similar size.

4.1.3.3 Noise

The principal noise impact from power plant decommissioning activities will be from the operation of heavy equipment. Trucks are expected to transport the power plants from the test sites to the manufacturer, and other heavy equipment may be used to transport the power plants and other auxiliary energy equipment about the test sites. The expected impacts of these activities will be similar to the noise impacts expected of installation activities (refer to 4.1.1.3). The impact of on-site occupants and persons along the transit route will vary according to ambient sound levels, but in all cases, noise impact should be minimal because of the short exposure time.

Use of power equipment around the site to restore building modifications necessitated by installation will create unwanted sound in and around the site for a short period. Although this noise may be a short term nuisance to site occupants, it should not cause any serious or permanent impacts.

4.1.3.4 Land Use and Visual Aesthetics

Removal of the power plants may temporarily interfere with normal activities at the test sites because of the presence of heavy equipment and service people, and the need for a short interruption of power and water supplies (refer to 4.1.1.4). If additional parking areas or other auxiliary field test structure are to be restored to their pretest condition, disruption of the normal use of the site can be expected for a longer period, depending on the extent of restoration effort required.

Visual aesthetics at and around the site may be temporarily degraded by removal and restoration activities and the presence of trucks and other equipment. The degree of degradation will vary according to the existing environment at each site; however, because the entire removal and restoration operation should not require longer than several days, the overall impact should be very minor in all cases.

4.1.3.5 Wildlife

The impacts of decommissioning activities on wildlife will be very similar to the impacts of installation (refer to 4.1.1.5). A small number of animals may benefit from the restoration of habitat that was lost during installation of power plant foundations, parking areas, and other structures required by the field test.

4.1.3.6 Vegetation

Operation of heavy equipment at the test sites during power plant removal may result in trampling and other physical damage to site vegetation. Mitigating actions may be taken during decommissioning activities to avoid damage to vegetation.

Most of the vegetation removed during power plant installation could be restored following power plant removal from the sites, if desirable. None of these impacts to local vegetation will be of concern at most test sites.

4.1.3.7 Health and Safety

The impacts on health and safety of power plant decommissioning and removal are basically the same as the impacts expected from power plant delivery and installation and are subject to the same DOE Orders (refer to 4.1.1.7). Operation of heavy equipment at the site and along the route of removal is the primary safety concern; however, disconnection of the power plant interfaces and interruption of power to the test site are also health and safety concerns.

4.1.4 Non-Impacted Parameters

As illustrated in Figure 4-1, the review of the field test procedures, fuel cell power plant technology, and probable siting locations indicated that the field test operation will have no significant impact on a variety of other parameters including:

- Climate
- Culture
- Geology
- Socioeconomics
- Soils
- Topography

Although the fuel cell power plant emits carbon dioxide, particulates, water vapor, and other emissions capable of effecting small changes in a region's climate when present in abnormal concentrations, the quantities of these constituents emitted by the power plant are so small as to have no possible effect on climate. The actual total emission into the atmosphere may actually be reduced because the power plants will offset larger quantities of emissions from conventional power plants and heating equipment for comparative levels of generated power and heat. But whether slightly elevated or reduced, the change in atmospheric concentrations of climate-affecting constituents caused by the field test is negligible.

It is conceivable that widespread operation of on-site fuel cell power plants could hasten a shift toward decentralized, alternative energy technology, and thus have a possible effect on the attitude of American culture toward energy production and use. The proposed field test operation will test preprototype technology at approximately 24 locations, and thus it is highly unlikely that any such cultural shifts will result from the field test alone. A more plausible cultural effect of the field test could result from testing at or near historical landmarks or acheological sites. Although not specifically excluded by the site selection criteria, it is highly unlikely that any field testing will be conducted at or near recognized historical landmarks because of the additional delays involved in complying with local, state, and federal regulations that address historical preservation.

The geological and topographical characteristics of the test sites will not be affected by the field test. Although minor excavations may be required at some sites for power plant foundations and other structures, the geologic structure and topographical features of the site and surrounding area will not be modified in the least by the field test.

Socioeconomic impacts of the field test, excluding the effects of government and utility financial support, will be small but beneficial. Owners of test site facilities will receive an economic gain during the one year test because they will receive the benefits of increased energy efficiency in the form of lower gas and electricity bills. This economic gain, while important to site owners, is small and dispersed when viewed from the national perspective and is considered minor.

As mentioned previously under the discussions of air and water qualities, a small amount of soil may be eroded from the site during installation and decommissioning activities. Although this soil loss could result in local impacts to air and water quality, the loss in terms of soil preservation would be so minute as to preclude a further consideration of its effects at the test sites.

4.2 Impacts of Power Plant Production

The environmental impacts associated with the production of 48 field test fuel cell power plants are judged to be relatively minor because of the following factors: (1) production is limited to 48 power plants, (2) production will take place in existing facilities, (3) production will occur only during a two year period, (4) minor amounts of platinum and other materials will be used, and (5) many commercial components manufactured by other existing facilities will be used for power plant assembly. The only noteworthy environmental impacts which would be expected from the limited production activities involve worker health issues and small volumes of air emissions and wastewater effluents. The production of power plant components will require the processing of metallic, plastic, and chemical raw materials that may result in the emission of hazardous particulates, vapors, and gases. The use of proper ventilation, vapor recovery, and personal protection required by government regulation will minimize employee exposure to these emissions. The small volumes of air emissions and wastewater resulting from the limited production activities should be easily controlled by on-site equipment and should not impact the local environment surrounding the production facility.

4.3 Cumulative and Long Term Impacts

The field test operation will not result in any significant incremental increase in environmental impacts at the test sites when added to other past, present, or reasonably foreseeable future actions. This fact stems from three reasons: (1) each power plant installation will cause only minor or insignificant impacts, (2) the field test is a unique operation and is not accompanied by other pasts, present, or future actions at the sites, and (3) the actual field test will last only one or two years. It is conceivable that an unrelated development activity at or near a test site during the field test period may add impacts with those resulting from the field test. Such a situation would have to be examined on a site specific basis but, in any case, the impacts would be cumulative only during the one year test period.

The majority of the power plants will be removed and the test sites restored at the conclusion of the field test, and thus no long term environmental impacts are expected. The only conceivable long term impact might be in the form of injuries to service personnel and site occupants in the unlikely event of an accident during any of the three field test program phases. The risks of such accidents are discussed in Section 5.

4.4 Projected Impacts of Fuel Cell Commercialization

The 40 kW Fuel Cell System Field Test Operation is a step towards the commercial introduction of on-site fuel cell power plants for residential, commercial, and light industrial use. Since a single sized fuel cell unit (i.e., the 40 kW fuel cell) cannot adequately meet the needs of a diverse market demand, research documents point out the need for developing a family of fuel cell power plants sized from 40 kW to 2 MW. The production and nationwide deployment of large numbers of these systems will have important environmental repercussions. Environmental impacts will result from four main aspects of fuel cell commercialization: (1) power plant manufacture, including raw materials acquisition and processing, construction and operation of primary production facilities, and operation of secondary (parts) production facilities; (2) power plant transportation, site preparation and installation; (3) power plant operation; and (4) fuel production, transport, distribution, and storage. As discussed in Section 3.2.2, fuel cell systems will have to compete with other energy technologies for a share in the on-site energy market. The true environmental costs or benefits to society resulting from the commercialization of on-site fuel cell systems are defined by the difference between using this or some other technology for given applications.

The environmental impacts resulting from the manufacture of fuel cell power plants are expected to be typical of the manufacturing and construction industries as a whole. It appears that for all power plant materials but platinum, the net changes in material quantities required for fuel cell manufacture are, at most, small percentages of total projected production volumes. Therefore, only negligible environmental and supply market impacts will be caused by added production of these materials. Reliance on platinum as a catalyst could seriously strain the national and world platinum markets. The platinum catalyst is recovered and reused, however. Construction of fuel cell manufacturing facilities will produce the types of temporary impacts expected from the construction of any large manufacturing facility. Typical impacts include dust, noise, water runoff, erosion, traffic, and general aesthetic disruption. The only noteworthy environmental impacts arising from the operation of primary and secondary production facilities are air emissions and possibly wastewater effluents. These would occur during the processing and storage of metals, plastics, and other power plant production materials. Some worker health impacts may result from exposure to metallic and synthetic materials and their particulates, fumes, and gases.

The activities associated with power plant transportation, site preparation, and power plant installation are temporary at each site and are not expected to produce any major environmental impacts. The power plants and components will likely be transported by trucks on public highways and streets. The principal impact of concern regarding transport is the safety hazard posed by truck operation. The power plants are not a particularly hazardous cargo since they will not contain fuel during transport and any phosphoric acid present will be absorbed within the cell matrix and unavailable for spillage. Construction work will occur at both on-site and utility sites; however, site preparation and installation for on-site units will not require any major construction while these activities at utility sites do not represent particularly large construction efforts. Typical, but temporary, construction impacts will result from these activities.

The cumulative environmental impacts resulting from the operation of several thousand megawatts of fuel cell power plant installed capacity will undoubtedly be substantial. Because of their comparatively low fuel requirements and environmental emissions, the operation of fuel cell power plants results in much fewer environmental impacts than similarly sized conventional energy systems. Consequently, a high level of displacement of these conventional technologies by fuel cells will lead to corresponding environmental improvements at the national and local level. In particular, major improvements should result in air quality, water supply and quality, and ambient noise levels. The high conversion efficiency of fuel cell systems will additionally translate into substantial energy savings with accompanying economic and national security benefits. Energy, land, and other resources will be conserved by a reduction in need for additional long distance power transmission facilities. The operational hazards of fuel cell power plants should not be greater than that of conventional energy technologies.

Fuel cell power plant commercialization requires a fuel system for producing and delivering liquid and gaseous fuels. Fuel extraction and processing typically have major environmental consequences. The national fuel production scenario and its resulting impacts should not be measurably expanded or altered by fuel cell deployment, however, since fuel cells should be able to utilize nearly all fuel types and fuel cell deployment will replace the fuel demand of displaced power plants rather than creating additional demand. Since fuel cells are more energy efficient than most competing technologies, overall fuel production impacts may lessen as a result of fuel cell commercialization. A need may arise for expansion of some types of refining facilities. The nature of the fuel transport, distribution, and storage system will be determined largely by the types of fuels handled and the size of the power plants served. Development of this system will produce construction impacts and the movement of fuels through populated areas will expose the public to the health and safety hazards imposed by toxic, explosive, and flammable fuels.

4.5 Summary of Impacts

No serious environmental impacts were found during the evaluation of proposed field test activities. By the time the fuel cell power plant is fully tested and ready for delivery to the test sites, it should be virtually environmentally benign and only cause minor or very insignificant impacts if properly sited. A summary of impacts to specific environmental parameters is provided in Section 8.1. Comparisons with conventional energy equipment and systems demonstrate that the fuel cell power plant and integrated fuel cell energy systems are superior in terms of overall energy efficiency and low environmental impacts. The risks and possible consequences of credible accidents involving the power plant are discussed in Section 5.

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5. RISK OF CREDIBLE ACCIDENTS

This section considers the risks and consequences of credible accidents involving the 40 kW fuel cell power plant. The evaluation is limited to accidents creating possible hazards to human health and safety. It is further limited to accidents that might realistically be expected to occur as a result of plausible power plant malfunctions. The section is divided into three parts discussing: (1) safety features of the power plant, (2) credible accident scenarios, and (3) possible consequences of such accidents. Gas leakage, explosion, and fire related consequences are discussed. Several of the accident scenarios admittedly push the plausibility factor to an extreme for the sake of completeness. A complete discussion of health and safety issues associated with power plant operation is provided in 4.1.2.7.

The risk evaluation is based on a UTC study, entitled "Failure Mode and Effect Analysis" (Ref. 1), which examined each individual component of the power plant to determine its rate of failure and the possible consequences of such a failure.

5.1 Features of the Fuel Cell Safety System

The power plant controller includes automatic sensing for equipment protection and automatic shutdown in the event of critical out-of-limits component operation. This sensing system minimizes the potential hazard to personnel or equipment in the event of a single component failure. A certain amount of built-in redundancy also reduces the risk associated with component failure. Although the safety features incorporated into the fuel cell power plant design are comprehensive, the required use of natural gas with its associated hazards are such that the risk of an accident cannot be reduced to zero.

There are no gas detectors or audible alarms in the unit despite the fact that system or component malfunctions can potentially result in a gas buildup in the fuel cell cabinet. Fuel leaks can result from a failure in the fuel processing section, the fuel cell power stack, or at any point in the fuel transport system. Depending on the failure point, the fuel may be odorized natural gas or an odorless, hydrogen enriched gas. The use of the hydrogen enriched gas by the power plant is not particularly hazardous because: (1) the hydrogen is not present as a pure gas but only as the hydrogen enriched gas mixture containing carbon monoxide, carbon dioxide, hydrocarbons, and other constituents, and (2) a relatively small volume of the hydrogen enriched gas is present within the power plant since the gas is not stored but flows directly from the shift converter to the fuel cell stack where it is consumed.

Three safety features will reduce the chance of a critical gas buildup in the event of a leak. The first is the automatic shutdown system designed to activate when a fuel loss is detected. Although this system will not detect minor leaks, larger fuel leaks will result in the following sequence of events: fuel escaping from the system will lower the fuel flow and reduce the output voltage which, in turn, will be sensed by a microcomputer in the control center, activating the fuel shutoff valve. If the control system malfunctions or if the leak is small, the failure may go undetected. In this case, the second and third safety features will minimize the hazard: The cabinet is sectioned to isolate any escaped gas from an ignition source (i.e., electric spark, reformer burner), and the cabinet is continuously ventilated by a forced air flow that cools the inverter. For units located indoors, the gas flushed out of the cabinet is exhausted to the outdoors through an exhaust hood and flue. The development of an explosive concentration of gas in the cabinet is thus unlikely.

Natural gas usage has been an important energy supply in our country for many years, during which time continually improved methods for its safe distribution and use have evolved. The codes and regulations which govern natural gas utilization are extensive. These codes have been considered in the design of the UTC 40 kW fuel cell power plant as outlined previously in Section 4.1.2.7. Fuel cell units provide additional gas utilization safety features which are not present in the equipment they replace. By virtue of the additional features, they may be considered safer than current building-sited gas distribution and utilization equipment.

5.2 Credible Accident Scenarios

The UTC "Failure Mode and Effect Analysis" study examined the failure rates of power plant subsystem components. By weighting these rates with hazard values determined by the extent to which a failure could potentially affect the system or environment (i.e., human hazard, loss of power plant availability, reduced efficiency or reliability, nuisance, or no effect), the degree of hazard associated with each failure type was derived. Components whose failure would have an impact on safety were assigned the highest hazard value.

Only those system malfunctions which could result in a human hazard, as opposed to system down time or reduced efficiency, were selected from the study for consideration by this assessment. UTC identified 24 components whose malfunction could create a situation where the safety system would have to intervene to avert a possible human hazard. The combined failure rate for 18 of these components was calculated to be equivalent to approximately 12 failures for every million hours operating time. Failure rates for the remaining six components were not calculated by UTC, but by adding an uncertainty factor into the failure rates of comparable equipment in the power plant, each of these six components can be assumed to fail at the rate of one time for every million hours operating time. The 24 components are thus estimated to have a combined failure rate of 18 failures for every million hours operating time. Over the 384,000 hour operating life of the field test program, considering a maximum of 48 units in the test, this failure rate translates to an expected 6.9 failures which could pose a human hazard in the event of a concurrent safety system failure. Fewer units tested would reduce the operating time and the number of expected failures.

Of the 24 components whose failure could create a human hazard, 23 are associated with the fuel processing, fuel cell power stack, and fuel distribution systems. Their failure could result in gas leakage and a subsequent buildup of combustible gas in the power plant cabinet. Approximately 17 such failures are calculated to occur in these 23 components for every million hours of power plant operating time. If the gas leak is undetected by the safety system and shutdown does not take place, the gases would be flushed to the exterior by the internal ventilation system. The other component identified by the UTC study is located in the microcomputer section of the control system, and its failure could result in the loss of automatic shutdown capability. Such a loss would nullify the primary safety system and could allow the power plant to continue operation even during hazardous out-of-bounds conditions. This component has been calculated to fail approximately one time for every million hours of operating time.

The failure rates of components give probability to a scenario of events which could result in an accident endangering people. Although this probability is undefined, it is much less than the probability of individual component failures would indicate. This is because the built-in, overlapping safety features of the system are such that simultaneous malfunctions of several components, including components of the safety features, would be necessary before an endangering accident would be possible. These failure rates do not account for failures caused by vandalism, or natural hazards; nor do they account for failures induced by improper operation, faulty maintenance or other human errors. The safe design of the power plant and the training of operators and service personnel will minimize these sources of failure. In general, the following credible accident scenarios have been identified:

- Plugging of the exhaust hood and flue at an indoor site, resulting in the concentration of hazardous power plant exhausts in the enclosed indoor area;

- A power plant gas leak accompanied by failure of the exhaust hood at an indoor site, resulting in a concentration of raw or processed gas in the enclosed indoor area capable of causing an explosion or death/injury by asphyxiation;

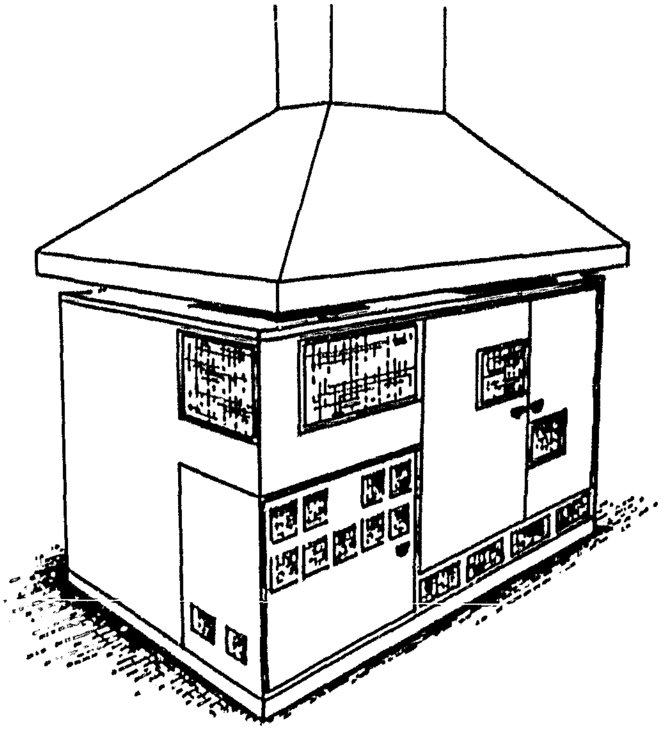
- A power plant gas leak accompanied by failures of the internal ventilation system and safety system, resulting in a combustible mixture of raw or processed gas within the power plant cabinet capable of ignition and explosion by an internal ignition source; and

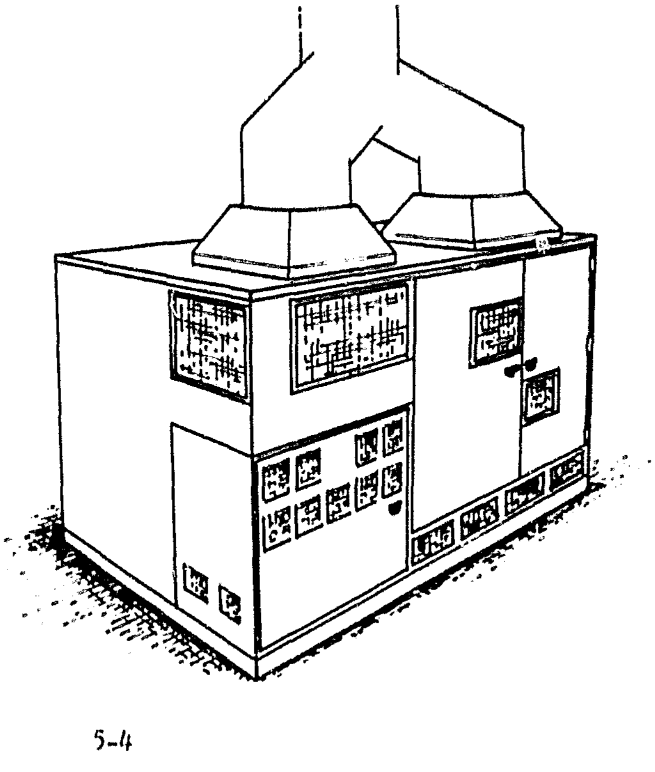
- An electrical short circuit or other internal malfunction capable of decomposing and/or igniting combustible plastics and other materials within the power plant, resulting in a fire.

Current plans call for using an air exhaust hood and flue to remove power plant exhausts and cooling air from indoor sites. The hoods will be situated just above the power plants and will extend out beyond the power plant perimeter. An alternative exhaust removal method being considered for use during the field test is the connection of exhaust flues directly to the power plant vents. Both systems are shown in Figure 5-1 and each has safety advantages and disadvantages. An exhaust hood will collect and remove all exhausts, escaped gases, smoke, and fumes originating within the power plant regardless of where they exit the power plant cabinet but would allow exhausts to escape from the hood should a flue blockage occur. A direct-connected exhaust flue system will not remove emissions from all possible exit locations but will not allow exhausts to escape the system in the event of a flue blockage.

Failure of an exhaust hood accompanied by continued power plant operation could allow exhausts and gas, if a gas leak is present, to concentrate in an enclosed indoor area. Although the exhaust rates are very low, continued operation would

Figure 5-1. Two Exhaust Systems for Removing Power Plant Air Emissions From Indoor Sites. (The exhaust hood system (upper figure) and the flue system (lower figure).)





eventually result in the creation of an indoor atmosphere hazardous to human health. Should gas escaping from either exhaust removal system build to a combustible concentration, an external ignition source could conceivably cause an explosion. At outdoor locations, escaped gas should disperse rapidly and should not be a health or safety problem. Indoor locations housing power plants will receive a continuous supply of air for process and cooling needs.

According to tests by UTC, a major gas leak will cause a voltage drop in power plant output. This voltage drop will be sensed by the safety system which will initiate a power plant shutdown while the interior ventilation flushes the escaped gas out of the cabinet. If the leak is not large enough to cause a voltage drop and thus goes undetected, a shutdown will not occur but the escaped gas will still be flushed. Thus failures in the automatic shutdown and/or ventilation system would be a prerequisite for any credible accident scenario involving the buildup of a combustible gas mixture in the cabinet. The venting of the power plant cabinet is provided by five fans that cool the inverter. The failure of a single fan during high power output will cause the inverter temperature to increase and force a shutdown by the safety system. Failure of more than one fan may be required to cause an over-temperature shutdown during low power output. Between the time of fan failure and power plant shutdown, the remaining fans will continue operation and should provide a sufficient air flow to vent the cabinet. Thus in order for a combustible mixture to build in the cabinet, more than one inverter fan would have to malfunction simultaneously and the gas leakage rate would have to be substantial enough to create the mixture prior to power plant shutdown. The likelihood of such a series of events occurring is extremely remote.

Should a gas leak develop and both the ventilation and automatic shutdown systems fail, a combustible gas mixture could concentrate in the cabinet before the inverter overheats and the power plant is manually shut down. Achievement of a combustible gas mixture will depend on several power plant variables including the size of the leak, the section of the fuel system from which the leak occurs (and therefore the nature of the gas), and the internal cabinet dimensions where the gas is concentrating. Ignition could be provided by an electrical short circuit or spark. The risk of such an accident situation actually occurring is even more remote since it would require simultaneous failures in three separate power plant systems. The chain of events leading to a gas related accident are described in Figure 5-2. The "detection and manual shutdown" option of Figure 5-2 refers to a chance detection of escaped gas or other irregularity by someone in the vicinity of the power plant who can call for help or manually initiate shutdown without assistance. Since the power plant is designed for automatic operation, an operator will usually not be present to detect operating irregularities. If the power plant is sited in a boiler room where an operator is normally on duty, this operator may be able to detect an obvious irregularity.

Credible fire accidents can result from short circuits and other malfunctions in the power plant electrical system. Tests using Underwriters' Laboratories prescribed methods have demonstrated that many of the power plant's plastics (Teflon, PFA, and polyethylene) are resistant to ignition, and if ignited, will not support combustion for more than 25 seconds. Celcon will ignite if contacted by a very hot wire, and will support combustion; however, it is very resistant to ignition via high electrical current arcing (Ref. 2). Other power plant plastics may or may not be capable of ignition and unsupported combustion. Malfunctions in the inverter

Figure 5-2. Gas Related Credible Accident Chain of Events

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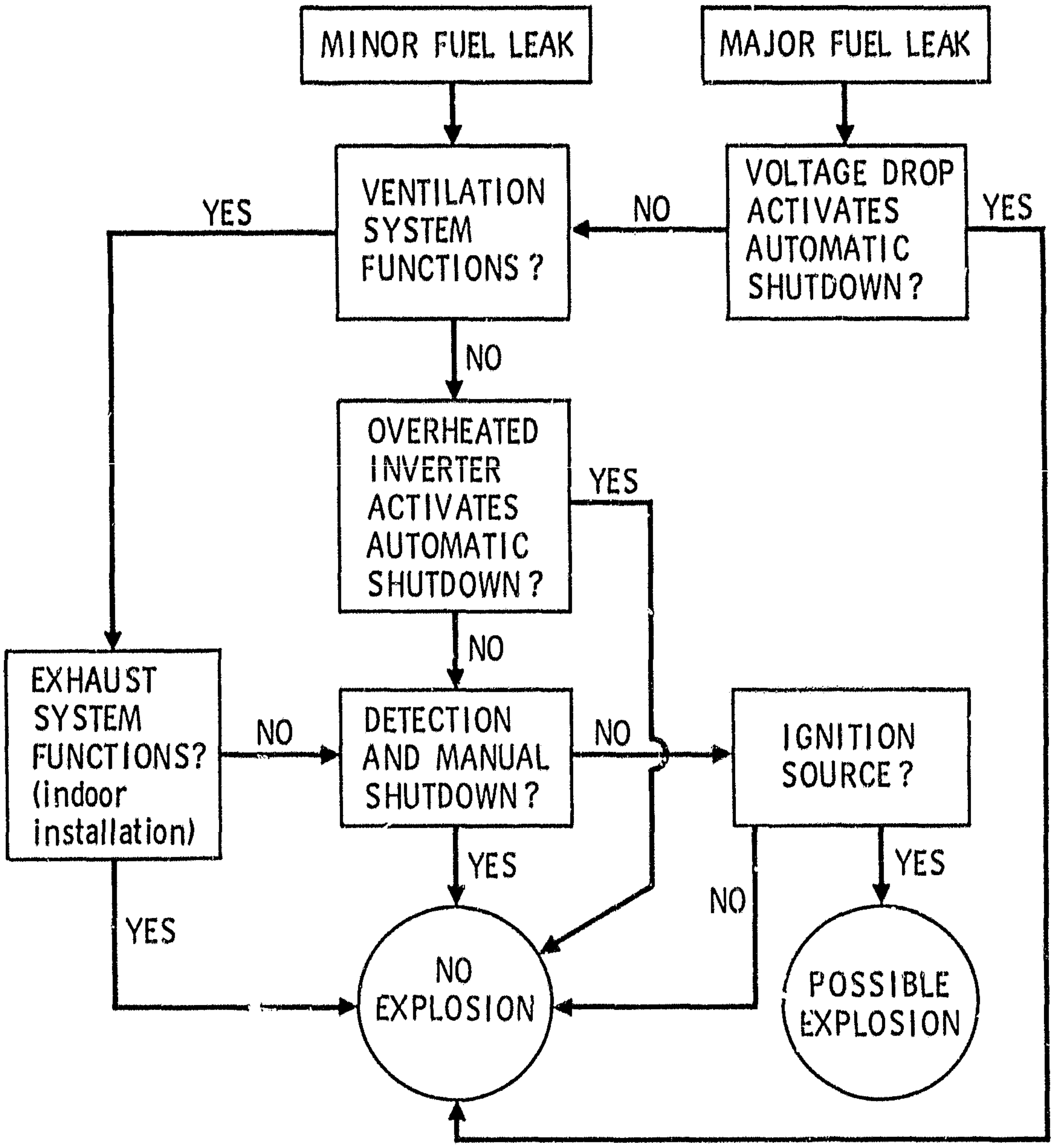

transformer could cause overheating and a possible fire hazard. Shorted capacitors could explode and cause minor damage. The debris from an explosion could cause other short circuits and fire hazards. Short circuits are also possible anywhere in the electrical system. However, compliance with UL standards and recommendations will help ensure a high degree of electrical safety.

It is informative to review the accident injuries caused by the operation of conventional on-site heating and cooling equipment. Table 3-9 provides statistically derived national estimates of injuries requiring emergency room treatment that were caused by this equipment. During 1980, an estimated 20,367 injuries were inflicted nationwide by furnaces, water heaters, air conditioners, and heat pumps. Lack of fuel cell injury rate data makes a direct comparison of conventional versus fuel cell safety hazards impossible; however, it is evident that the operation of conventional heating and cooling equipment is a major cause of serious injuries. Operation of on-site fuel cell power plants will replace the operation of some conventional equipment and, depending on the fuel cell injury rate, will result in either an increase or reduction in the rate of injuries inflicted by on-site heating and cooling equipment.

5.3 Possible Consequences of a Credible Accident

A power plant malfunction that results in an explosion or fire could have serious health and safety consequences for people at the affected test site. The magnitude of health and safety consequence would be determined in large part by the occupancy characteristics of the various candidate building types. Figure 5-3 indicates occupancy characteristics of building types that might be expected to elevate the risks of injury or death from an explosion or fire.

Buildings that are open to the general public will be host to people not familiar with emergency procedures and escape routes. This could make these people more susceptible to injury or death during an accident episode than full time occupants having a greater knowledge of procedures and the building layout. Sites that have a higher percentage of young, elderly, ill, or disabled people than found in the general population may have worse accident consequences because of the impaired ability of these groups to escape. Sites that are occupied 24 hours per day, or for other extended periods, increase the chances of an accident occurring at a time when people are present. Sleeping occupants in buildings with sleeping quarters will be more susceptible to death or injury because of their impaired ability to recognize and react to danger. The hazards to human health and safety resulting from gas and exhaust leaks, explosion, and fire are detailed below.

5.3.1 Gas and Exhaust Leakage

The leakage of gas from the power plant cabinet or associated piping into an enclosed area poses a serious health and safety danger because of the risk of asphyxiation and explosion. Asphyxiation is caused by a lack of oxygen. The risk of asphyxiation is greater than that expected from a common natural gas leak because some of the leaking gas may be deodorized processed gas and thereby undetectable by scent. A major gas leak, accompanied by inadequate exhaust ventilation, could fill an enclosed area with a potentially lethal and explosive concentration of gas. The risk of asphyxiation and explosion will depend on the nature of the enclosure and existence of neighboring ignition sources. The consequences of an explosion are discussed in the following section.

Figure 5-3. Occupancy Characteristics of Candidate Building Types for the Fuel Cell Field Test Operation

CANDIDATE TEST SITES	OCCUPANCY CHARACTERISTICS					
	GENERAL PUBLIC	CHILDREN	ELDERLY	ILL OR DISABLED	SLEEPING	24 HOUR
APARTMENTS		X	X	X	X	X
BANKS AND OFFICE BUILDINGS	X					
HEALTH SPAS	X					
HOSPITALS	X			X	X	X
HOTELS AND MOTELS	X				X	X
LAUNDRIES	X					
LIGHT INDUSTRIES						
NURSING HOMES			X	X	X	X
RESTAURANTS	X					
SCHOOLS		X				
STORES	X					
SINGLE FAMILY HOMES		X	X	X	X	X
WAREHOUSES						

Inadequate exhaust ventilation accompanied by continued power plant operation could concentrate exhaust gases in an indoor area. Although the power plant operates on clean burning natural gas and has low emission rates, exposure to concentrated exhaust gases could result in illness or death from asphyxiation or carbon monoxide poisoning. Carbon monoxide poisoning is caused by the buildup of carboxyhemoglobin in the blood supply caused by the inhalation of carbon monoxide. Carboxyhemoglobin restricts the oxygen carrying ability of the blood, and elevated concentrations can result in death.

5.3.2 Explosions

The damage inflicted to the power plant, and the people and property in its vicinity, during an explosion will depend on a number of factors including: (1) the volume and concentration of escaped gas, (2) the ability of the power plant cabinet to contain the explosion, (3) the location of the power plant at the test site, and (4) the proximity of people to the power plant at the moment of an explosion. In the event of an explosion, possible injuries could be inflicted by the resulting shock wave, discharged projectiles, steam and hot water, and phosphoric acid.

An internal gas leak that is undetected either because of its small size or a failure of the safety system could create an explosive mixture of gas inside the power plant when accompanied by a failure in the ventilation system. The extent and concentration of the escaped gas could be quite large before it is detected or an explosion results. The power plant cabinet may contain small explosions but could not be expected to contain the larger explosions that could potentially occur. In the event of an explosion, the shock wave and projectiles could injure people in the vicinity of the power plant. Extensive damage to test site facilities may also occur depending on the location of the power plant at the site and the nature of the site.

The power plant contains hot water and steam used in the fuel reforming process and fuel cell cooling. The steam separator vessel contains a reservoir of hot water at 403 K (267°F) and the water tank holds water at 373 K (212°F). Large quantities of steam are not present. An explosion could eject steam and splatter hot water onto nearby persons that could result in scalding of exposed body areas.

Most of the phosphoric acid in the power plant is absorbed in the matrix and electrodes of the fuel cell stack. The only reservoir of liquid acid in the power plant is the small acid recovery vessel. This vessel is emptied during the annual maintenance procedures and should contain no more than approximately one half liter of phosphoric acid at any time. An explosion could rupture this vessel and splatter nearby persons with acid. Disintegration of part of the fuel cell stack in an explosion could cause the ejection of phosphoric acid impregnated projectiles.

Phosphoric acid is a tribasic acid of moderate strength. It is considered a moderate toxic hazard when inhaled, ingested, or applied to the eyes or skin. A moderate toxic hazard may produce both irreversible and reversible changes, but is not severe enough to cause death or permanent injury (Ref. 3). Testing has not shown it to be carcinogenic, mutagenic, or teratogenic. It can be an irritant when inhaled or applied to the eyes or skin in sufficient quantities. Inhalation of a concentration of 100 mg/m^3 has produced irritation in the respiratory tracts of humans. Experimentation with rabbits has produced severe irritation within 72 hours after a 119 mg dose in one eye and within 24 hours after a 595 mg dose to one sq in. of skin (Ref. 4). Should phosphoric acid contact the skin or eyes of persons during an explosion episode, it should cause no lasting health effects if removed promptly and the affected area is treated. The acid in the fuel cell stack is a greater potential hazard than the acid in the acid recovery vessel because of its elevated temperature. This acid is absorbed within the stack matrix and electrodes, however, and should not be readily available for human contact during or following an explosion. Inhalation of phosphoric acid vapor near the scene of an explosion should not present health hazards because of the large concentration required to produce even minor irritation effects and the small volume of phosphoric acid available for vaporization.

In summary, the primary dangers to health and safety during a power plant explosion will be from the shock wave and projectiles. Serious injury, and possibly death, could be the consequence of a major explosion. The hazards of splattered hot water and phosphoric acid are not nearly as grave. Some injuries due to scalding may occur from contact with hot water, but the phosphoric acid should be only a minor hazard if exposure to it is treated promptly.

5.3.3 Fire

Death and injury due to fire is a complex event resulting from many contributing factors. The major factors are generally agreed to be: (1) oxygen deficiency, (2) poisoning from carbon monoxide, (3) heat destruction of tissues and thermal shock, (4) irritation of the respiratory tract by various gases and aerosols, (5) development of fear leading to panic, and (6) prevented escape due to smoke-reduced visibility. Although unlikely, it is conceivable that an internal failure could result in an explosion and fire within the power plant cabinet. The risk of such an accident is examined in 5.2. A fire could spread to structures at the test site, especially if the power plant is sited indoors or rooftop, and result in property damage and conceivably death and injury to occupants and firefighters.

Some components of the 40 kW fuel cell power plant are constructed of combustible materials. These combustibles include plastics, paint, and insulating oil. When combusted or heated to extreme temperatures, these materials are capable of producing toxic gases and particulates. A fire within the power plant cabinet, whether originating in the power plant or spreading to the power plant from an external source, could cause combustion and decomposition of power plant components that would release oxidated combustion products and pyrolysis products. Pyrolysis degradation products are not fully oxidized and present a potential health hazard even more serious than that presented by oxidized combustion products when present at equal concentrations.

In a fire situation, an internal cabinet temperature of 775 K (960°F) or more is possible. Under these conditions, all or most of the structural plastics will decompose by pyrolysis, if not by combustion, and will evolve pyrolysis and/or combustion products. At an outdoor or rooftop location, these gases and particulates will vent to the atmosphere and should not cause a serious health threat. However, at an indoor location, these products could concentrate in an enclosed space and subject building occupants and firefighters to the hazards of smoke poisoning, carbon monoxide poisoning, and asphyxiation. Smoke poisoning is defined as an inhalation injury without significant surface burns. It is primarily a chemical injury to the tracheobronchial tree and lung parenchyma due to the thermal decomposition products from any material.

Plastics compose the majority of combustibles in the power plant as a number of different plastics are used as construction materials. Hazards from the combustion and thermal decomposition of plastics are variable and depend on the particular plastic involved, the temperature of combustion or decomposition, and the humidity of the atmosphere. In general, these hazards include evolution of combustible and noncombustible gases, and smoke and particulate formation.

The oxidized combustion products released from the plastic components of the power plant by flaming combustion will consist primarily of carbon monoxide, carbon dioxide, water vapor, and nitrogen oxides. The amount of carbon monoxide produced will vary with conditions of combustion and the plastic's thermal stability, but in numerous combustion tests on a variety of plastics, carbon monoxide was found to be the primary toxic product of combustion. Exposure of laboratory rats to carbon monoxide concentrations of 2000-6000 ppm for 30 min. resulted in 50 percent mortality. Large scale combustion tests on a variety of plastics have shown that these lethal carbon monoxide concentrations may be equaled or exceeded during real fire situations at indoor locations (Ref. 5). It can be reasonably surmised that the carbon monoxide, particulates, and other products of combustion emanating from the power plant during a fire will present a potentially lethal hazard to any persons remaining in an enclosed space where high concentrations of these constituents are present.

The high heat of combustion can cause neighboring plastics that are not involved in the fire to degrade thermally by pyrolysis. The nature of these products depend not only on the chemical composition of the intact polymer but also on the conditions under which it is decomposed. Quite often they are monomers or other unoxidized toxic organic subunits of the plastic polymer. Depending on their proximity to the combustion flames and the abundance of oxygen in the surrounding atmosphere, some portion of these products will probably be oxidized to carbon monoxide and other combustion products.

A group of plastics that has been used extensively in the construction of the power plant is the fluorocarbon polymers. Teflon (polytetrafluoroethylene) is a basic construction material of the fuel cell stack itself and is also present in heat exchangers and tubing. PFA (perfluoroalkoxyl) coats the tubes that cool the fuel cell stack. FEP (fluorinated ethylene-propylene) is used as an additive to nylon for electrical insulation. Studies on the pyrolysis products of fluorocarbon polymers (Ref. 6) indicate that at temperatures that only produce softening or melting of the polymer (725-825 K or 870-1150°F), the monomer (tetrafluoroethylene) of Teflon and PFA tends to be the principal pyrolysis product. It may in turn emit highly toxic fumes of fluorides (Ref. 3). This is the case for Teflon up to a temperature of about 775 K (960°F). At the same time, perfluoropropene, other perfluoro compounds containing four or five carbon atoms, and a particulate, waxy fume are generated. For Teflon, the principal pyrolysis product within the range of temperatures from 775 to 1075 K (960 to 1500°F) becomes carbonyl fluoride. This compound is a powerful irritant but hydrolyzes readily to hydrogen fluoride and carbon dioxide upon contact with moisture. These two compounds are substantially less harmful. At temperatures above 1075 K (1500°F), the principal pyrolysis products of Teflon are tetrafluoromethane, hydrofluoric acid, and carbon dioxide. If pyrolysis occurs in the presence of glass, (fiberglass is present as insulation in the power plant), silicon tetrafluoride may be formed by reaction between the silicon in the glass and hydrofluoric acid. Teflon produces other pyrolysis products whose toxicities are unknown. These products include: octafluorocyclobutane, perfluoroisobutylene, hexafluoropropylene, and a mixture of perfluoroolefins.

The pyrolysis products of fluorocarbon polymers other than Teflon have not been as extensively studied. It has been suggested that the pyrolysis of FEP produces hexafluoropropylene among other products. It is known that PFA pyrolyses into its monomer (tetrafluoroethylene) at a melting temperature of 725 K (870°F). Cross-linked polyethylene THNN is used in the power plant for electrical insulation. Polyethylene is the simplest member of a large group of thermoplastic resins. Its pyrolysis products include formaldehyde and acrolein (Ref. 7). Tie wraps and clamps in the power plant are constructed of nylon. Nylon is a polyamide, and, similar to other nitrogen containing polymers, it pyrolyzes to give hydrogen cyanide and ammonia in small quantities (Ref. 8). It appears as though hydrogen cyanide is not produced by nylon below a temperature of 675 K (780°F).

When oxygen is present during the pyrolysis of plastic materials, carbon dioxide, carbon monoxide, and water are formed in addition to the pyrolysis products. The composition of these oxidative thermal degradation products is very sensitive to ambient conditions, and, if an ample supply of oxygen is available, the chief products will be carbon dioxide and water. In an oxygen deficient environment, on the other hand, pyrolysis products will predominate. If elements other than carbon and hydrogen are present, other oxygenated products will be produced. Thus, carbonyl fluoride is formed from Teflon and nitromethane is produced from nylon when their polymers are thermally degraded in air (Ref. 8).

There have been a number of animal studies completed for Teflon (polytetrafluoroethylene), as well as other fluorinated polymers, at temperatures where significant thermal decomposition occurs. The consistent findings among these studies included: (1) a dramatic increase in the weight loss of the polymers and toxicity as they temperature increased above 775 K (960°F), and (2) the high prevalence of pulmonary damage including hemorrhage and edema (Ref. 9).

Human exposures to the thermal decomposition products of fluorinated polymers have resulted in a physiological response termed polymer fume fever. The first symptom noted following exposure is a sense of discomfort in the chest. A dry cough may or may not develop. Systemic symptoms appear after a few hours with a gradual increase in temperature and pulse rate, followed in most cases by an episode of chills and sweating. Muscle and joint pains have been reported as well as headaches, nausea, weakness, and shortness of breath. Recovery from these accidental exposures generally takes place fairly rapidly and is usually complete within two days (Ref. 7).

Many of the thermal degradation products of Teflon, including hydrogen fluoride, carbonyl fluoride, and octafluorisobutylene, are known to have deleterious effects on the respiratory tract in concentrations of several hundred ppm (Ref. 8). The National Institute of Occupational Safety and Health (NIOSH) has not recommended a standard for a safe exposure concentration to decomposition products of fluorocarbon polymers because of insufficient information. However DuPont, the manufacturer of Teflon, has recommended that a ventilation rate that limits concentration of fluorocarbon polymer decomposition products to a level of one ppm should offer an adequate safeguard (Ref. 6). In the unlikely event of a fire, the concentration of decomposition products inside the cabinet and adjacent to the cabinet in an enclosed area could exceed several hundred ppm and thereby result in exposure of occupants, service people, and firefighters to hazardous conditions.

Other power plant materials, besides the plastics, may also evolve dangerous products when subjected to heat. Phosphoric acid emits toxic fumes of oxides of phosphorus during thermal decomposition. The fiberglass insulation within the power plant could melt at high temperatures and evolve small quantities of silicon oxide vapor. The binder used in the insulation could also emit toxic products. Approximately 400g of platinum are present as catalysts in the fuel cell stack,and nickel is used as a catalyst in the fuel processing system. Zinc oxide is used to absorb sulfur compounds from the fuel flow. When heated to extreme temperatures, all three of these metals emit toxic fumes that are capable of causing a condition known as metal fume fever. Symptoms of this condition include irritation of the upper respiratory tract, coughing, nausea, and headache. However, all three metals have melting points in excess of 1725 K (2645°F) and thus should not evolve fumes in most fire situations. The zinc sulfide and sulfate formed during sulfur removal could evolve oxides of sulfur if heated to decomposition or hydrogen sulfide if exposed to moisture. Mineral oil acts as an insulator in the inverter assembly. It is a slight fire hazard when exposed to heat or flame (Ref. 3).

Table 5-1 lists a number of product gases of power plant materials accompanied by time weighted average (TWA) threshold limit values and inhalation hazard rating (IHR) values. The TWA value is a time weighted average concentration for a normal 8-hour workday or 40-hour workweek, to which nearly all workers may be repeatedly exposed without adverse effect. These values are based on various government criteria (Ref. 10). The extent to which these limit values will be exceeded during an accident will depend on the level of power plant involvement and the nature of the surrounding environment.

Table 5-1. Time Weighted Averages (TWA) and Inhalation Hazard Rating (IHR) Values for Selected Combustion and Pyrolysis Products (Refs. 3 and 10)

Parent Material	Product Gas	TWA	IHR*
Plastics	Carbon Dioxide	5000 ppm	Slight
	Carbon Monoxide	100 ppm	High
	Nitrogen Oxides	5 ppm	High
Teflon	Carbonyl Fluoride	5 ppm	High
	Hydrofluoric Acid	-	High
	Tetrafluoromethane	-	Moderate
Polyethylene	Acrolein	0.1 ppm	High
	Formaldehyde	2 ppm	High
Nylon	Ammonia	25 ppm	High
	Hydrogen Cyanide	10 ppm	High
	Nitromethane	100 ppm	High
Phosphoric Acid	Phosphoric Acid & Oxides	1 mg/m^3	Moderate
Nickel	Nickel Fume	1 mg/m^3	-
Platinum	Platinum Fume	0.002 mg/m^3	-
Zinc Oxide	Zinc Oxide Fume	5 mg/m^3	-

*Slight: Causes readily reversible changes which disappear after end of exposure.
Moderate: May involve both irreversible and reversible changes, but not severe enough to cause death or permanent injury.
High: May cause death or permanent injury after very short exposures to small quantities.

In summary, the power plant's combustible components, primarily the plastics, will produce a variety of combustion and pyrolysis gases in a fire situation. The nature of these gases will depend on the fire conditions, but many will be toxic, and if concentrated in an enclosed space, may be lethal. Carbon monoxide is apparently the prime toxicant of concern because of its high production rates. Hydrogen cyanide and other highly toxic gases may be produced, but in lesser quantities. The toxic gases, smoke, and heat from a power plant fire could create a dangerous environment, especially in indoor areas, that could cause serious injury or death to site occupants, power plant service people, or emergency response personnel.

The consequences of a power plant fire should be put into perspective, however, by comparing them to the consequences expected from any structure fire. Plastics have assumed a very important place in modern society and are practically ubiquitous, being found in the home and industry, and as components of many commonplace items. Any fire in a building will likely involve some amount of plastic material. Many types of plastics are highly flammable, in contrast to most of the plastics used in the power plant, and can spread a fire rapidly while releasing hazardous fumes. The thermal degradation of natural materials can also cause smoke poisoning and other injuries, and indeed such natural materials as wool, felt, leather, and wood are known to evolve deleterious products (Ref. 9). Therefore, while a power plant fire may create a hazardous environment within its vicinity, the level of hazard should be comparable to that arising out of common structure fires.

5.4 Accident Risk of Commercial Fuel Cell System

The probabilities and consequences of accidents resulting from the operation of a large scale commercial fuel cell system (numerous on-site and dispersed power plants) are difficult to assess because of limited information regarding system characteristics. The accident risk related to the operation of preprototype UTC fuel cell power plants has been described by this section. The operational risks of a multi-megawatt utility fuel cell power plant differ considerably from the risks of on-site fuel cell power plants because of different operational and exposure parameters. The hazards imposed by power plant manufacture, transportation, installation and fuel delivery will increase the cumulative accident risk in the system by an as yet unknown factor. It can be said, however, that the cumulative accident risk of a commercial system will be proportional to the total numbers of on-site and utility fuel cell power plants in the field. Furthermore, the risk will decrease as fuel cell operational experience increases and fuel cell technology continues to develop and improve.

5.5 Summary of Risk

The placement of 40 kW fuel cell power plants at residential, commercial, and light industrial locations will contribute to the possibility of an on-site explosion or fire. The power plant design, construction, materials, and safety system ensure that this risk is extremely low. If the power plant is replacing conventional heating and cooling equipment at the test sites, the overall risk of an accident may actually be less since conventional equipment is itself a major cause of death and injury nationwide. Should the power plant become involved in a fire, whether from an internal or external source, the power plant plastics will evolve gases and fumes that could create a dangerous safety hazard if confined in an enclosed environment. It should be noted, however, that all construction materials in the power plant will conform to the requirements of all applicable national standards for gas and electrical equipment. The power plant plastics are commonly found in residential, commercial and industrial environments as a wide variety of useful items, including electrical and piping components.

Power plant accidents may arise from gas leakage, internal malfunctions resulting in ignition of power plant combustibles, or exhaust hood failure. The power plant is designed and constructed to minimize these hazards. The participation of the American Gas Association and Underwriters' Laboratories will ensure compliance with all applicable and supplementary safety codes.

In the event of an internal gas leak, the ventilation system will flush the escaped gas to the exterior of the cabinet and the safety system may initiate a power plant shutdown. Approximately 17 gas leak failures are estimated to occur during every million hours of operating time. The risk of an explosion due to gas leakage is thought to be extremely remote, however, because of the redundant power plant safety features. Many of the plastics used in the power plant are difficult to ignite and will not support combustion. This will limit the risks of fires starting within the power plant cabinet.

In the unlikely event of an accident, the environment surrounding the power plant may become very hazardous. This is especially true at indoor locations where gases, fumes, and smoke can concentrate. An explosion's shock wave and projectiles could cause injury to site occupants. The gases, fumes, and smoke from leaks and fires could cause injury or death due to asphyxiation, smoke poisoning, or carbon monoxide poisoning. Test sites housing children; the elderly, ill, or disabled; or sleeping occupants may be more susceptible to accident consequences because of the impaired ability of these groups to escape from a major accident episode.

The accident risk of a large scale commercial fuel cell system will naturally be higher than the risk imposed by this field test because of the greater number of fuel cell power plants in the field. Although this risk is currently unquantifiable, it will be proportional to power plant numbers and will decline as operational experience increases and fuel cell technology continues to develop and improve.

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6. GOVERNMENT POLICIES AND REGULATIONS

A variety of federal, state, and local policies and regulations apply to the 40 kW fuel cell field test. For the most part, these regulations have been promulgated to achieve the goals established by energy and environmental legislation during the past decade. This section provides a discussion of the applicable energy and environmental management policies and regulations. It also evaluates the policy consistency and regulatory compliance of on-site fuel cell power plant siting and operation. Federal legislation discussed in this section includes:

- National Energy Act
- Federal Nonnuclear Energy Research and Development Act
- Clean Air Act
- Federal Water Pollution Control and Clean Water Acts
- Marine Protection, Research, and Sanctuaries Act
- Endangered Species Preservation Act
- Wild and Scenic Rivers Act
- Coastal Zone Management Act
- National Historic Preservation Act
- Noise Control and Quiet Communities Acts
- Occupational Safety and Health Act
- Toxic Substances Control Act
- Resource Conservation and Recovery Act
- Communications Act

6.1 Energy Legislation

Energy legislation in this country since 1973 has been directed toward decreasing national dependence on foreign energy supplies through conservation measures, development of renewable and synthetic fuel technologies, and increased domestic production of conventional resources. The on-site 40 kW fuel cell power plant is recognized as a valuable asset for achieving this objective. These small power systems promote energy conservation by the efficient use of fossil fuel supplies, deriving up to twice the amount of useful work per unit of energy when compared to conventional systems. Their flexibility, small size and reliability make them especially effective for satisfying intermediate and peak load requirements. As a consequence of these potential benefits, energy legislation has directly or indirectly encouraged fuel cell technology development through program funding, research and the selective exemption from regulatory requirements.

6.1.1 National Energy Act

Provisions of the National Energy Act (NEA) of 1978 are designed to reduce United States oil import needs by the year 1985, increase the use of fuels other than oil and gas, and increase energy efficiency. The NEA is composed of five separate pieces of legislation:

- The Public Utilities Regulatory Policies Act (PL 95-617), which provides methods for encouraging public utility rate structure revisions to move energy pricing to reflect actual costs.
- The Energy Tax Act (PL 95-618), which contains a range of tax credits for conservation and solar energy as well as other tax measures designed to reduce the nation's dependence on imported oil.
- The National Energy Conservation Policy Act (PL 95-619), which established a variety of regulatory, grant and loan programs to enhance conservation.
- The Powerplant and Industrial Fuel Use Act (PL 95-620), which is designed to increase the use of coal.
- The Natural Gas Policy Act (PL 95-621), which essentially decontrols the price of new natural gas and establishes other measures designed in part to encourage production of natural gas.

The National Energy Conservation Policy Act requires utilities to develop energy conservation programs for residential and commercial buildings. These programs are to identify and promote appropriate energy conservation measures. Included among residential energy conservation measures are devices associated with load management techniques that reduce the maximum kilowatt demand on an electric utility. The 40 kW fuel cell power plant can be considered a load management device since it is located on-site and can reduce peak demand by satisfying the site demand and supplying electricity into the utility grid. Commercial energy conservation measures specified by the Act include cogeneration systems which produce electricity as well as steam or other forms of thermal or mechanical energy. The fuel cell power plant is a cogeneration device and thus should qualify as such a measure even though it may not be operated as a cogenerator at all test sites. Therefore, promotion of the development and use of on-site fuel cell power plants by utilities is consistent with the objectives of the Act.

The National Energy Act directly affects the use of natural gas in several important ways. First, under the Powerplant and Industrial Fuel Use Act, natural gas may not be used as a primary energy source in new electric generating plants, unless DOE specifically grants an exemption for its use. The law states that most uses of natural gas to fuel power plants must be phased out by 1990. These restrictions apply only to very large power plants with fuel heat input rates of 105 million kJ (100 million Btu) per hour or greater. Since the 40 kW fuel cell power plant uses natural gas at a maximum rate of 655,000 kJ (621,000 Btu) per hour, it is exempt from these restrictions.

Second, the Energy Tax Act is intended to discourage industrial use of natural gas by restricting both investment tax credits and accelerated depreciation. Because the 40 kW fuel cell power plants will be field tested primarily at residential and commercial sites and many may be owned by the government rather than private industry, use of natural gas will not be discouraged in the majority of cases by these tax disincentives.

And third, the Natural Gas Policy Act ended the 25-year old federal regulatory regime that distinguished between intrastate and interstate gas and controlled the prices of the latter. Price controls will be lifted by category of use, with price increases to residential and commercial customers lagging behind the increases to industrial users. The cost of the natural gas used by the fuel cell power plant will rise as a result of this legislation, but because the power plants will be sited at residential and commercial test sites, they will benefit from the slower price increases. Even if fuel cell units were to be installed at industrial sites, as cogenerators they would be exempt from the incremental prices passed on to industrial users.

The Public Utilities Regulatory Policies Act of 1978 addresses the topic of rate design standards for utilities. This Act proposes that utilities structure their retail rates in a way that would encourage conservation of energy, efficient use of facilities and resources, and equitable rates to electric consumers. Cogeneration and small power production facilities are encouraged by Federal Energy Regulatory Commission rules which exempt them from certain state and federal regulations pertaining to electric utility rates. The fuel cell units, as small power producers or cogenerators, qualify for these exemptions.

6.1.2 Federal Nonnuclear Energy Research and Development Act

The Federal Nonnuclear Energy Research and Development Act of 1974 (PL 93-577) established a national program for research, development, and demonstration of potentially beneficial energy sources and utilization technologies. Energy conservation, meaning both improvement in the efficiency of energy production and use, and reduction in energy waste, is a primary consideration in program implementation. Included among the specific program elements is the commercial demonstration of fuel cells for central station electric power generation. While the research, development, and demonstration of on-site fuel cell power plants is not specifically mentioned in the text of the Act, these activities are consistent with the Act's purpose and objectives because of the beneficial energy and environmental attributes of fuel cell technology.

The federal government is authorized by the Act to provide assistance for or participation in demonstration projects, including field demonstrations of prototype energy utilization applications. It may also enter into cooperative agreements with non-federal entities to demonstrate the technical feasibility and economic potential of prototype energy technologies. DOE and NASA-Lewis Research Center participation in the 40 kW fuel cell field test operation is consistent with both this authorization and the policy and objectives of the Act.

6.2 Environmental Legislation

Environmental impacts associated with individual fuel cell power plants, as well as the field test operation as a whole, are minor in scope and magnitude. With proper implementation, the fuel cell field test should have no difficulty complying with all federal, state, and local regulations, addressing air emissions, water use and discharge, noise, and health and safety. Several pieces of legislation, especially those concerned with siting and land use, will probably not apply to field test activities since it is unlikely that any attempt will be made to site units in sensitive areas (i.e., critical habitats for endangered species, wild and scenic river protected areas, historical landmarks, state and national parks, etc.) at this stage of on-site fuel cell development. If such a site is eventually proposed, a fuel cell power plant must comply with the more stringent land management practices enforced in these areas.

In many instances, the development and testing of fuel cell power plants assists environmental protection objectives by providing an alternative to environmentally disruptive conventional central power generation facilities. As environmental legislation becomes more coordinated with energy policy, activities which promote the continued development of fuel cell technologies will likely be favored by regulations in both fields.

6.2.1 Air Quality Management

The provisions of the Clean Air Act of 1963 (PL 88-206), as amended to the present, encourage cooperative activities and uniform legislation by state and local governments for the prevention and control of air pollution. While the Clean Air Act directs EPA to set ambient air quality standards and to establish emission limitations for new pollutant sources, the task of developing strategies for attaining the ambient air quality standards is given to the states. Accordingly, states are required to have State Implementation Plans that spell out in specific detail how federal ambient air quality goals will be met.

Each state is required as a part of their State Implementation Plan to have a permit program governing new stationary sources of pollutants. New sources located in an area that meets national ambient air quality standards (NAAQS) are regulated by the prevention of significant deterioration (PSD) program which limits the cumulative amount of pollutants that can be added to the area by new sources. The PSD program does not apply to power plants, however, if their heat input is less than 250 million Btu per hour. If the new source is located in an area that does not meet all NAAQS requirements (non-attainment areas), the emission offset program applies. This program prohibits new major emission sources unless an equivalent amount of emissions from existing sources can be reduced. In addition, the new source must use control technology that will result in the lowest achievable emission rate (LAER).

In general, the PSD and emission offset programs apply only to new sources of pollution which are expected to interfere with the attainment or maintenance of national standards. The likelihood that there will be such interference will vary with local conditions, such as current air quality, meteorology, topography, and growth rates. For this reason, it is not practicable to establish definitive nationally applicable criteria as to the types or sizes of such facilities which should be reviewed. Therefore, the determination whether an air emission permit is required for the operation of a single or double fuel cell unit will be an individual and subjective decision by the regional air quality management district which has jurisdiction. Emissions from the 40 kW fuel cell power plants are so small that it is unlikely that they would be considered a significant pollution source in any locality. The South Coast Air Quality Management District (SCAQMD) in Southern California, with perhaps the most stringent emission and siting regulations in the country, has indicated that a permit would not be required for a double unit installation (Ref. 1).

The Clean Air Act requires the Administrator of the EPA to publish (and periodically revise) federal standards of performance for emissions from new sources. These standards are defined for the stationary source categories which the Administrator determines cause or contribute significantly to air pollution. Because federal coverage is limited to major new sources, fuel cell power systems are not included in any of the categories. Federal new source performance standards have been defined for three types of fossil-fuel fired steam generating units having heat inputs of more than 73 megawatts (250 million Btu per hour). These standards, shown in Table 6-1, are not applicable to the much smaller, non-steam fuel cell power plants. Nonetheless, they are the federal performance standards most closely related to the operation of the 40 kW fuel cell power plants and thus may be utilized for comparison. As seen from this table, typical pollutants from the 40 kW fuel cell power plant are much less than the federal standards for the cleanest central electric generating station.

Table 6-1. Federal Standards for Central Electric Generating Stations (kg/GJ)

		Electric Generation System Type		
Pollutant	Fuel Cell Unit Emission (Half Rated Power)	Gas-Fired	Oil-Fired	Coal-Fired
NO_x	0.00062	0.096	0.14	0.30
SO_2	0.00015	*	0.38	0.57
Particulates	0.0010	0.048	0.048	0.04
Smoke	None	20% Opacity	20% Opacity	20% Opacity
Total Hydrocarbons	0.021	*	*	*

*No Standard

6.2.2 Water Quality Management

The goal of the Federal Water Pollution Control Act (FWPCA) of 1972 (PL 92-500) is to restore and maintain the chemical, physical and biological integrity of the nation's waters. In order to achieve this goal, the following objectives and policies were set:

- Discharge of pollutants into the navigable waters be eliminated by 1985.
- Wherever attainable, an interim goal of water quality which provides for the protection and propagation of fish, shellfish, and wildlife and provides for recreation in and on the water be achieved by July 1, 1983.
- Discharge of toxic pollutants in toxic amounts be prohibited.
- Federal financial assistance be provided to construct publicly owned waste treatment works.

- Areawide waste treatment management planning processes be developed and implemented to assure adequate control of sources of pollutants in each state.

- A major research and demonstration effort be made to develop technology necessary to eliminate the discharge of pollutants into the navigable waters, waters of the contiguous zone, and the oceans.

This legislation has been modified by the Clean Water Act of 1977 (PL 95-217) which rolled back the cleanup deadlines, began identifying toxic pollutants, and established three categories of pollutant discharges.

The section of the Clean Water Act relevant to the fuel cell field test addresses effluent limitations for point sources which discharge process wastewater pollutants into a publicly owned treatment works. Currently, local interim water quality standards apply to the discharge of wastewaters into treatment systems and storm drains. These will be replaced in 1983 when EPA promulgates stricter national standards. The present local standards for such water quality parameters as pH, temperature, trace metals, cyanide, oil and grease are primarily designed to protect the treatment system, and ultimately the recipient water body, from industrial discharges. Such discharges must be in compliance with any applicable pretreatment requirements specified in a discharge permit.

Water condensed from the power section and reformer exhausts of the on-site fuel cell power plants is recovered and used to satisfy the fuel processing steam requirements of the units. To maximize system efficiency, this water must necessarily be of high quality, a condition maintained by the water purification system. Under normal load requirements and ambient conditions, a sufficient amount of water is produced to satisfy the requirements of the power plant. However, transient overloads and cold weather produce more water than is required and the excess water is discharged to a drain. Due to the quality requirements of the power plant, this discharge water will be exceptionally pure and should easily meet required local discharge standards. Dilution with the normal discharges of the building will substantially reduce the high temperature (344 K/160°F) of the power plant overflow water prior to entering the local treatment system.

Compliance with discharge standards however, does not exempt the fuel cell units from the permitting process. The decision to issue a discharge permit is made on a case by case basis by the local sanitation district with reference to water emissions data for typical industrial processes. In the absence of appropriate data, as is the case with fuel cells, discharge into local treatment systems or storm drains will generally require a permit unless the water is of equal or better quality than typical residential sewage (Ref. 2). Fuel cell unit discharge water quality easily meets this requirement; therefore a discharge permit should not be necessary.

Every industrial facility that discharges wastes directly into a water body must have a permit under the National Pollutant Discharge Elimination System (NPDES). These permits, issued either by EPA or by states with EPA-approved programs for administering the system, specify discharge limitations for specific pollutants. Permits issued to sewage treatment plants under NPDES require that pretreatment programs be enforced. Because the fuel cell does not discharge waste directly into a body of water, it does not require an NPDES permit. Similarly, a permit will not be required under the Marine Protection, Research and Sanctuaries Act of 1973 (PL 92-522) (The Ocean Dumping Act) which regulates the dumping of materials in marine environments.

6.2.3 Federal Land and Water Use Policies

Depending upon the site selected for any given power plant, Federal land and water use regulations could impose restrictions upon power plant installation and operation. As part of their site-selection activities, the participating utilities will determine whether or not the sites are subject to such regulations.

Under the Endangered Species Preservation Act of 1966 (PL 89-669), as amended in 1969 and 1973, the Secretary of the Interior is authorized to acquire lands in order to conserve, protect, restore and propagate species of fish and wildlife that are threatened with extinction. If a site is located on property acquired for the conservation of fish and wildlife, it will be necessary to consult with the United States Fish and Wildlife Service, and appropriate state agencies to determine if installation of a fuel cell power plant will be allowed.

Under the Wild and Scenic Rivers Act of 1968 (PL 90-542), certain rivers are designated to have their natural environmental qualities preserved. The Act provides for the protection of the environmental qualities of both the water and the land area adjacent to the river, the boundaries of which are specified. A stream classification system, providing for three river categories was designed to regulate the degree and intensity of shoreline development. While both residential and public service facilities may be developed in two of the river categories, such development is subject to approval of the management agency of the particular river involved. The management plans govern improvements to existing buildings and structures as well as new construction projects. Land management regulations pertaining to aesthetics may require agency approval for the outdoor or rooftop installation of a fuel cell power plant.

The Coastal Zone Management Act of 1972 (PL 92-583) requires state and local authorities to establish management programs, subject to federal approval, for environmentally sensitive coastal areas. Coastal zone siting of a power plant will require compliance with any guidelines established by the management programs for the specific area involved.

The National Historic Preservation Act of 1966 (PL 89-665) authorizes the Secretary of the Interior to maintain the National Register of historic landmarks. In addition to individual buildings and sites, the National Register includes some historic regions in their entirety. If a fuel cell power plant installed under this program could potentially impact a property listed in the National Register, or eligible for such listing, the Department of Energy must be advised, and must consult with the State Historic Preservation Officer to determine whether the action will have an effect upon the historical, architectural, archeological, or cultural characteristics of the property that qualified it to meet National Register criteria.

6.2.4 Noise

The Noise Control Act of 1972 (PL 92-574) directs EPA "to promote an environment for all Americans free from noise that jeopardizes their health or welfare." Under the Act, EPA is required to regulate new products that are "major sources of noise" and to establish noise labeling requirements for noisy products as well as for products designed to reduce noise. At this time, standards have been established regulating railroads, motor carriers engaged in interstate commerce, construction equipment, and transportation equipment. In view of the high noise levels which characterize these sources, it is apparent that the intent of the legislation was not to regulate the more moderate noise emissions from such sources as the fuel cell power plant.

In 1978 the Noise Control Act was modified by the Quiet Communities Act (PL 95-609), the purpose of which was to encourage the development of noise control programs on the community and state level. Local ordinances specify the allowable noise levels in a given region. Noise level criteria are usually set for residential, commercial, retail, and industrial zones. Many localities also differentiate between day time and night time noise levels. Typical local noise ordinances range from 75 dBA for heavy industrial areas in the day time (65 dBA at night time) to 55 dBA for suburban residential areas in the day time (45 dBA at night). Proper siting and noise attenuating measures should allow the power plants to comply with all local noise ordinances in most, if not all, regions.

Occupational Safety and Health Administration (OSHA) noise regulations will apply to those fuel cell units which are placed in a working environment. Standards promulgated by this agency under the Occupational Safety and Health Act of 1970 (PL 91-596) are outlined in Table 6-2. The power plant noise levels are well below the OSHA noise exposure limit of 90 dBA for an eight-hour day established to protect worker hearing. Under authority of the Noise Control Act, EPA recommended that OSHA adopt a more stringent standard of 85 dBA for 8-hour noise exposures. Should this standard be adopted, the power plant noise levels will still satisfy OSHA regulations.

Table 6-2. Department of Labor, Occupational Noise Exposure Standards (Ref. 3)

Permissible Noise Exposures

Duration Per Day (Hrs)	Sound Level dBA
8	90
6	92
4	95
3	97
2	100
1-½	102
1	105
½	110
¼ or less	115

EPA has also identified noise levels which if not exceeded should protect against some of the worst effects of noise. These levels include a margin of safety and were derived without considering the technical or economic feasibility of achieving them. They should be viewed as long range environmental goals rather than EPA-recommended regulatory goals. To protect against hearing loss, EPA identified a 24-hour average exposure of 70 dBA or less. At its 4.6m (15 ft) perimeter, the power plant noise level of 61 dBA easily meets this goal. To protect against activity interference and annoyance, EPA has identified yearly average values of 55 dBA for outdoors and 45 dBA for indoors. The power plant noise levels will exceed these goals; however, the noise levels can be easily attenuated by proper siting or shielding.

6.2.5 Toxic Substances

The philosophy of the 1976 Toxic Substances Control Act (TSCA) (PL 94-469) is that chemicals should not enter the marketplace and be dispersed into the environment without adequate testing, and that the effects of existing chemicals should be reviewed so that unreasonable risks to human health or the environment may be removed. TSCA requires EPA to publish an inventory of existing chemical substances, and to require industry to develop data on the health and environmental effects of the chemicals they manufacture. The only substance in this inventory applicable to the 40 kW fuel cell power plant is phosphoric acid. Phosphoric acid is on the chemical inventory published by EPA in May 1979, and also appears in the 1978 Registry of Toxic Effects of Chemical Substances (RTECS).

The RTECS entry for phosphoric acid indicates that an OSHA air contaminant standard exists limiting the concentration of acid in the air to no more than 1 mg/m^3 (0.2 ppm). This limit is a time weighted average rather than a ceiling value. The concentration of the phosphoric acid vapors emitted from the power plant will be substantially less than 0.1 ppm (see Section 2.3.6). Since this concentration will be quickly diluted to insignificant levels upon venting from the fuel cell unit, phosphoric acid vapor emissions will easily conform with RTECS standards.

6.2.6 Resource Conservation

The Resource Conservation and Recovery Act of 1976 (PL 94-580) encourages the practice of recovering energy and other resources from discarded materials by providing both technical and financial assistance for the development of management plans and facilities for resource recovery. Present plans call for recovering platinum and other materials from the 40 kW fuel cell stacks after they are removed from service.

6.2.7 DOE Safety and Health Orders

The field test operation is subject to the requirements of two Department of Energy Orders addressing safety and health concerns. These requirements apply to all DOE operations and all contractor operations where DOE has control over environmental protection, safety, and health protection.

The Environmental Protection, Safety, and Health Protection Program established by DOE Order 5480.1 assures the protection of the environment, the safety and health of the public, and the safeguarding of government property. It guarantees the provision of safe and healthful workplaces and conditions of employment for all DOE employees and contractors. Typical activities and functions related to this program include: environmental protection, occupational safety, fire protection, industrial hygiene, health physics, occupational medicine, and process and facilities safety. DOE line organizations and DOE contractors have the responsibility for implementing the program. This responsibility includes program implementation, execution, and assurance that all DOE and federal environmental protection, safety, and health protection policies, regulations, and requirements are adhered to continuously and vigorously in DOE operations.

DOE Order 5481.1 established the Safety Analysis and Review System. This system consists of uniform requirements for the preparation and review of safety analyses for DOE operations and required the identification of hazards, their elimination or control, assessment of the risks, and documented management authorization of operations. It is the DOE policy to assure that operations are conducted in a manner that will limit risks to the health and safety of the public and employees, and adequately protect property and the environment. This assurance is provided, in part, by the preparation and review of safety analyses for DOE operations. The basic responsibility for implementation of this policy lies with the DOE line program organization responsible for the operation. UTC has completed a Failure Mode and Effect Analysis for the on-site 40 kW fuel cell power plant and has made the analysis available to DOE (Ref. 4). The analysis, which addresses the safety and risk questions of the power plant, is further discussed in Section 5.

6.3 Other Regulations

Other regulations governing the fuel cell program are primarily associated with building codes, construction standards, and local zoning laws designed to segregate land uses and minimize activity conflicts. Due to the small degree of environmental impacts associated with the fuel cell power plants and the flexibility of program site selection, there is expected to be little difficulty in complying with these regulations. During the site selection process, provisions will be made by individual utilities to satisfy all regulatory requirements. The remainder of this section discusses the applicability of Federal Communication Commission regulations to the field test, and DOE's responsibility to ensure that departmental activities do not cause significant environmental impacts in foreign nations.

6.3.1 Local Codes

Article 10 of the proposed agreement between the Gas Research Institute (GRI) and each participating utility (Company) addresses the topic of permits, licenses and approvals and states that:

> "Company shall be responsible for the acquisition of applicable permits, licenses, approvals, and other enabling documents from the appropriate governmental agencies for siting and operation of each power plant installation. GRI shall provide Company with any information it may have, or have access to, to assist Company in obtaining such permits, licenses, approvals, and documents."

Each participating utility will thus accept the responsibility of ensuring compliance with all applicable local codes and regulations pertaining to the siting, installation, operation, and maintenance of the on-site fuel cell power plants in their service area. Such local regulations include zoning, building, fire, electrical, pressure vessel, plumbing, noise, and installation codes. Additionally, some local codes may require that certain types of hardware be installed by licensed tradespeople, and that certain components be certified by AGA or UL.

The utilities are approaching the on-site fuel cell power plant in much the same manner that they would approach any other energy system; that is, they intend to comply fully with all applicable statutes. They will comply, to the maximum extent possible, with all applicable codes and regulations pertaining to on-site activities during the field test (Ref. 5).

6.3.2 Federal Communications Commission

In accordance with Section 301 of the Communications Act of 1934, as amended, the Federal Communications Commission (FCC) prohibits the operation of an incidental radiation device that causes harmful interference. Harmful radiation is defined as any emission, radiation, or induction which endangers the functioning of a radio navigation service or other safety service, or seriously degrades, obstructs, or repeatedly interrupts a radio communication service. An incidental radiation device is any device that radiates radio frequency energy during the course of its operation although not intentionally designed to do so. In the event that harmful interference is caused, the operator of the device must take prompt action to eliminate the harmful interferences.

The 40 kW fuel cell power plant is considered an incidental radiation device because the inverter is a source of emitted and conducted radio frequency radiation. The power plant has been equipped with EMI filters to remove conducted radiation at the source. Initial testing by UTC has not indicated the production of harmful interference and NASA-Lewis is taking steps to ensure that all necessary EMI testing is conducted to guarantee, as much as possible, that the power plants will be in full compliance with FCC regulations at all test sites. If further testing uncovers EMI problems, NASA-Lewis will insist that the problems are corrected before delivery of the power plants to the test sites.

6.3.3 DOE International Responsibilities

Executive Order 12114 was issued on January 4, 1979 in order to further the purposes of the National Environmental Policy Act (NEPA) with respect to the environment outside the United States, its territories and possessions. The Order requires that Federal agencies conduct environmental review procedures for major actions significantly affecting the environment of the global commons or any foreign nation which may or may not be involved in the action. Actions not having a significant effect on the environment outside the United States, as determined by the responsible agency, are specifically exempted. If so required, environmental review activities may entail generic, programmatic or specific environmental impact statements; bilateral or multilateral environmental studies; or concise reviews of the environmental issues involved, including environmental assessments, summary environmental analyses or other appropriate documents.

DOE recently adopted final implementing guidelines for Executive Order 12114, in large measure reiterating the provisions of this Presidential document (46 FR 1007, January 5, 1981). These guidelines supplement the procedures set forth in DOE's final guidelines for compliance with NEPA, published in March 28, 1980 (45 FR 20694). Since the fuel cell field test will involve the testing of 2-4 units in Japan (in Tokyo and Osaka), DOE is required to evaluate the significance of the environmental impacts of overseas testing with respect to the new departmental guidelines. In light of the minimal environmental impacts anticipated from the field test, participation by the Japanese utilities will unlikely necessitate any environmental documentation other than that required for the field test as a whole.

6.4 Conclusion

Based on this review, it appears that the field test activities will not be in conflict with any of the legislation or regulations considered. Care should be exercised however, if test sites are located in areas of special air quality classification, sensitive habitat for endangered fish and wildlife, or historical interest; or if power plant overflow water is discharged without treatment into natural water bodies. Under these conditions, special permitting procedures may apply. These siting considerations are further addressed in Section 8.3.

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7. ALTERNATIVES TO THE PROPOSED ACTION

The 40 kW fuel cell field test is an integral part of the program to develop and evaluate on-site fuel cell power systems. The testing strategies and fuel cell hardware developed for the field test have been designed to achieve established program objectives in an economical and timely manner. Through a detailed planning process, the following alternatives to the field test operation have previously been addressed and rejected. These alternatives were generally considered to represent less desirable options from the standpoint of fulfilling the energy efficiency and environmental quality objectives of DOE and the commercialization objectives of GRI. Furthermore, as discussed in the following sections, any reduction in the anticipated environmental impacts resulting from alternative actions would be minor. The alternative to the field test which have been considered within this section are broadly defined as follows:

- Program Strategy Alternatives
- Technology Alternatives
- No Action Alternative

Also discussed are alternatives to fuel cell commercialization.

7.1 Program Strategy Alternatives

The field test operation could conceivably be restructured through alternative testing strategies. Such alternatives include testing more or less units, installing more than two units per building, choosing different applications (e.g., industrial or single family home installations), testing the units in a laboratory setting, or testing a central power system concept rather than dispersed generation. As discussed below, these options have been either rejected or are currently being addressed in other projects, such as the 4.8 MW central power generation test program described in Section 2.1.9. The chosen testing strategy is a reconciliation of program goals and economic constraints which have been defined by energy and environmental considerations and business risk factors associated with the development of a fuel cell market. In general, various siting strategy alternatives will neither significantly increase nor decrease the environmental impacts associated with this program; therefore, changes in the program strategy are considered unnecessary.

A test program consisting of approximately 48 fuel cell units was defined to secure sufficient data to evaluate fuel cell unit operations under a variety of conditions. This number of units is required to test a representative sample of building types, market segments, and system configurations in a variety of geographic regions. Increasing the number of units and test sites for the program would proportionately increase the attendant environmental impacts. The additional capital outlay and economic risks were not considered commensurate with the potential program gains which could be realized by a larger fuel test program. Although proportionately fewer environmental impacts would result from a scaled down program, these impacts have been determined to be minor by this assessment. At the same time, a reduction in scale would be adverse to realization of the wide market sampling goal.

No more than two units will be tested at any one location since double unit configurations are deemed sufficient to test the functioning of fuel cell units in parallel. An alternative decision to test three or more units at one site would increase the environmental impacts associated with installation, operation, and decommissioning activities at the affected test sites. Without significantly adding to the quality of the evaluation, it would also either increase the cost of the field test by requiring the production of additional units, or reduce the number of the test sites and thereby the variability of the field test.

For the field test, the market segments have been limited to the residential and commercial/light industrial sectors since these contain particularly attractive candidates for initial commercialization and are suitable for testing energy use and environmental characteristics. Alternatives in the industrial and single family home sectors were not considered. Industrial buildings were rejected because the ability to determine user requirements quantitatively is limited. Siting in industrial areas, however, would be compatible with the existing land use thereby minimizing the environmental conflicts which may arise as a result of the field test. Single family homes were not included because of the unfavorable economics associated with meeting their characteristically high ratio of peak to average electric demand. Single family homes also have electrical demand peaks that fall substantially short of 40 kilowatts. The testing of these alternative market segments would expose different populations to the impacts associated with fuel cell operation. In general, fewer people would be impacted with the installation of units in single family home areas; however, the field test would not be as fruitful in terms of data acquisition.

Testing the fuel cell power plants in a laboratory setting would facilitate greater performance monitoring and limit public exposure, but it would fail to meet many of the field test objectives. Unanticipated operating and environmental impact conditions, as well as regulatory requirements, would not as likely be determined in the laboratory as at actual test sites in the field. The experience and comments of customers serviced by the fuel cell units during the field test would also be lost by implementation of a laboratory testing scheme.

Dispersed small-scale fuel cell power plants are particularly attractive for use in heavily populated environments where sites suitable for the construction of conventional centralized plants have become unavailable. Initially, they are expected to find significant application as dispersed on-site generators in replacing obsolete fossil generators in urban areas, in providing power to areas where transmission corridors are unavailable, and in small rural and municipal utilities. Research is also being directed toward the development of centrally generated power from fuel cells but this approach largely negates a major advantage of on-site fuel cell applications, e.g. the recovery and use of waste thermal energy. By using thermal waste heat for space heating and cooling, hot water or industrial processes, fuel cell efficiency can be increased to as much as 80 percent. Environmental impacts associated with central power generation are generally reduced in geographical area but increased in magnitude. Because the expressed goal of the program is to test dispersed generation systems, and realizing that concurrent research is being conducted for a 4.8 MW fuel cell assembly to test the central power generation capabilities of fuel cells, the program alternative of central power generation is essentially a no action proposal.

7.2 Technology Alternatives

A number of fuel cell technologies are available for development into power plant systems. Phosphoric acid fuel cell units such as those being used for this field test program have been under intensive development by UTC and other groups for a number of years. Aside from the large investment in time and money which has already been committed and the more advanced state of development, there are several characteristics of the 40 kW phosphoric acid fuel cell unit which make it the desirable alternative for this field test.

One technology alternative would consist of changing the power output size of the fuel cell unit. The decision to construct 40 kW units was based on marketing studies which demonstrated that this was a good size to cover as much of the market as possible with first generation models. The 40 kW unit allows for flexibility in meeting diverse load demands, and multiple installations increase reliability over single larger units. A 12.5 kW size unit, which was tested during the TARGET program, was determined to be too small for many commercial applications. Environmental impacts associated with larger fuel cell units increase proportionately but within the small-scale, dispersed generation parameters of this test, these impacts are expected to remain minimal.

Other fuel cell technologies currently under study in major development programs include molten carbonate, solid oxide, and to a lesser extent, alkaline and ion-exchange membrane fuel cells. The first two systems in particular are viewed as the technologies of the future, potentially surpassing the performance of phosphoric acid fuel cell units. It is hoped that these alternative technologies will continue to develop so that their unique benefits can eventually be realized in future power plant installations.

All fuel cell technologies in general share several characteristics which minimize their environmental impacts compared with conventional energy technologies. They have low air pollutant emission rates, discharge small amounts of relatively pure water, require small amounts of supply water, and provide a quiet and clean source of energy. The environmental impacts which could be expected to arise from the demonstration of advanced fuel cell technologies (molten carbonate, solid oxide, etc.) similar in size to the 40 kW phosphoric acid units are not clearly defined. However, the immature developmental state and greater technological complexity of these advanced fuel cell systems suggest that their environmental impacts would exceed those of the phosphoric acid fuel cell units under the conditions of the field test. In any case, they are considered more applicable to large central applications and thus do not meet the objectives of this field test.

Because molten carbonate fuel cells operate at comparatively high temperatures, they are prone to corrosion and leakage problems as well as electrode decomposition and electrolyte instability. Solid oxide fuel cell technology is even less developed and, like molten carbonate, is expected to find future applications in large, coal-fueled, central station power plants. Alkaline fuel cells have reached an advanced state of development for aerospace applications where high efficiency is a premium. They are less suitable for terrestrial applications because of their inability to function for any length of time with CO or CO_2 in the fuel stream. Thus, they have been eliminated as a possible technology alternative for this field test. Ion-exchange membrane fuel cells are still at a relatively early stage of development and are not presently a viable technology alternative.

Because of their comparatively advanced stage of development, phosphoric acid fuel cells offer several advantages for use in the field test program. Units operated during the 12.5 kW TARGET program provided reliable service for over 200,000 hours of testing time. Because phosphoric acid units operate at lower temperatures with less hazardous substances, accidents are expected to be fewer and potentially less dangerous than those associated with alternative fuel cell systems. This lower hazard potential reduces the expected environmental impacts. In addition, the tolerance of phosphoric acid fuel cell units to sulfur impurities in the fuel gas is greater than the molten carbonate fuel cell. And, unlike alkaline cells, fossil fuels can be used. The use of natural gas as a fuel allows phosphoric acid systems to be easily integrated into the existing energy infrastructure, while at the same time maintaining access to future energy supplies, including synthetic and liquefied natural gas (SNG and LNG). These advantages support the choice of the natural gas/phosphoric acid fuel cell technology over other current alternatives for the proposed action.

7.3 No Action Alternative

A no action decision would avoid all environmental impacts, positive or negative, associated with the fuel cell field test operation. These impacts have been determined to be minimal by this assessment. This alternative would also inhibit the development of an energy technology which has the potential of providing far-reaching societal benefits if and when it achieves widespread application. Fuel cell power plants have a higher energy conversion efficiency than traditional power supply systems, thereby conserving natural resources and reducing national dependence on imported oil. From an environmental standpoint, fuel cells are quiet, consume little or no water, and have very few emissions, mostly carbon dioxide and water. A no action decision would discourage research in this important energy area. This may indirectly increase long term environmental impacts through the continuance of our present dependence on more environmentally damaging energy technologies.

7.4 Alternatives to Fuel Cell Commercialization

The field test is a step toward the eventual commercialization and widespread deployment of on-site fuel cell power plants. Previous market penetration studies for on-site fuel cell power plants have estimated total penetration of from several thousand megawatts to tens of thousands of megawatts in generating capacity by the year 2000 (Refs. 1-4). Considering that the installation of 25 40-kW power plants is required for each megawatt of generating capacity, these market penetration projections suggest that hundreds of thousands of on-site fuel cell power plants may be deployed within the next two decades. Alternatives to this massive commercial deployment can be classified into three main groups: (1) continuation of conventional electrical service from a utility grid; (2) development of increased on-site generating capacity by deploying large numbers of conventional generators such as diesel engines or modern reciprocating engines designed for use in total energy systems; and (3) development of increased on-site generating capacity by deploying large numbers of new technology generators such as photovoltaic systems.

Continued reliance on conventional grid-supplied electrical power as an alternative to on-site fuel cell power plants implies a continued reliance on large, centralized oil- and gas-fueled power plants since these power plants are the most logical candidates for displacement by fuel cell commercialization. Deployment of on-site fuel cell power plants will certainly not approach eliminating the need for these large power plants, but it may permit early retirement of the most inefficient ones and postponement of the construction of additional ones. As described throughout Section 4, on-site fuel cell power plants have numerous environmental advantages over large oil and gas plants. They are more energy efficient over a wide range of output loads and permit thermal energy recovery which further boosts their efficiency. They emit substantially less air pollutants per power output, have little or no water requirements, require little space, and are generally quiet, odor free, and visually unobtrusive. Their use may also displace the air emissions of furnaces and other conventional on-site energy equipment. The environmental benefits that will accrue from on-site fuel cell power plant deployment vis-a-vis conventional electrical service are substantial enough to overshadow reliance on conventional electrical service as a preferred alternative.

Diesel, gasoline, and gas fueled reciprocating engine generators are currently used at many locations for primary or backup power supply. Although these generators can be equipped for thermal energy recovery, they do not have the overall energy efficiency and generating flexibility that are characteristic of fuel cell power plants. In addition, they have higher air emissions, are noisier, and have limited fuel use capability. A massive deployment of these types of conventional on-site generators in residential, commercial, and industrial locations will not produce fuel savings and will substantially increase air quality and noise impacts at the sites. Deployment of these types of generators is therefore not considered a valid alternative to deployment of on-site fuel cell power plants.

Small reciprocating engine generators are being developed for on-site use. They will be designed to operate on a variety of fuel types and can be equipped for thermal energy recovery. Their energy efficiency will be equivalent to that of fuel cell power plants but they probably will not have the same generating flexibility and may produce more air emissions, noise, and vibration. These types of generators appear to have a promising future for small on-site applications and their commercialization may be a viable alternative to some commercial applications of fuel cell power plants (Ref. 5).

Energy technology research and development is proceeding on several types of alternative on-site electrical generating devices in addition to fuel cells. For example, photovoltaic systems convert sunlight directly into electricity and may one day be used as on-site sources of electrical power. They will not be available for widespread applications, however, until less costly production methods are developed and hence photovoltaic systems are not currently an alternative to fuel cell power plants. In spite of these alternative systems, the unique operational and environmental characteristics of fuel cell power plants justify continued development efforts toward their commercialization.

The 40 kW fuel cell field test does not commit the government, fuel cell manufacturers, or participating utilities to this commercialization, but is rather a step to assess the commercial option.

7.5 Summary of Alternatives

Parameters have been defined for the construction and operation of on-site phosphoric acid fuel cell power plants which will most efficiently determine the commercial viability and environmental impacts of these energy systems. Alternatives to this proposed action which have been identified include program strategy alternatives, technology alternatives, and a no action alternative. Some program alternatives, such as testing fewer units, testing in a lab setting, or testing in industrial and rural market sectors, would reduce or mitigate the already minimal impacts of the fuel cell field test. At the same time, these alternatives would negatively affect program goals to a degree disproportionate to any benefits which may be accrued.

Technology alternatives are currently impractical or undesirable due mainly to the immature stage of development of non-phosphoric acid fuel cell technologies. Although molten carbonate and solid oxide fuel cells show great promise for the future, they are presently unacceptable for consideration in commercial markets. The no action alternative is not only unjustified in light of the determinations of this assessment, but inaction may be linked to long term negative environmental impacts by serving to inhibit the development of this potentially beneficial energy technology.

References

1. Burns and McDonnell Engineering Company, An Assessment of the Fuel Cell's Role in Small Utilities, February 1978, EPRI EM-696.

2. Energy Research and Development Administration, National Benefits Associated with Commercial Application of Fuel Cell Power Plants, February 1976, ERDA 76-54.

3. Mathtech, Inc. Venture Analysis Case Study for On-Site Fuel Cell Energy Systems, July 1978.

4. Sanghvi, A.P., "Framework for Evaluating the Socioeconomic Impacts of Commercializing New Energy Technologies with an Application to the On-Site Fuel Cell Energy System," Energy, Vol. 5 pp 1231-44, 1980.

5. National Geographic Society, Energy: A National Geographic Special Report, page 55, February 1981.

8. SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

The foregoing environmental assessment of the preprototype 40 kW fuel cell field test has analyzed the installation, operation, and decommissioning of up to 48 fuel cell power plants. This section summarizes the impacts expected during the field test, develops conclusions concerning their severity, and offers recommended environmental guidelines for use during site selection and installation activities.

8.1 Impact Summary

The field test will operate a relatively small number of preprototype power plants for a limited one-year period. Because of the small size of these power plants, their high energy efficiency, and their benign environmental characteristics, the overall environmental impact, from a national perspective, is expected to be very small. Local impacts have also been judged to be minor except at test sites with unusual characteristics. These types of sites should be avoided during the field test.

The impacts associated with certain of the environmental parameters considered in this assessment are summarized below.

- Air Quality - The air emission rates from individual fuel cell power plants are so low that the emissions will not cause any measurable deterioration of ambient air quality at or near the test sites. Some small improvement may occur if the fuel cells replace conventional heating equipment having higher emission rates or if they displace emissions from central generating stations. Likewise, the air emissions from equipment used to transport and position the power plants, or to construction field test related structures, will have a negligible impact on ambient air quality. Fugitive dust from site construction activities should be minor and of short duration in most instances and have little or no impact.

- Water Supply and Quality - The power plant generates a sufficient quantity of water to satisfy its requirements during all but the most extreme operating conditions when some makeup water may be required. It is air-cooled and thus will use little or no water and does not require connection to a continuous water supply. During cold weather and transient operating conditions, a small excess of water may be generated that will require discharge to a drain at the site. This discharge water is of high quality and can be safely processed by a municipal water treatment facility. A negligible amount of water may be conserved at central generating stations because of slightly reduced power output. Installation and decommissioning of the power plant will require temporary disruptions in the water supply to the test sites. Outdoor construction activities may result in storm water runoff having higher than normal concentrations of suspended solids and turbidity for a short period.

- Noise - When properly sited, the power plant installation should be able to meet all local noise ordinances. The noise level is well within OSHA standards and will meet EPA goals for protection of hearing and prevention of activity interference if noise attenuating structures are erected. Some activity interference may still occur in areas immediately surrounding the installation.

Noise from heavy equipment used to install and remove the power plants and from visitors passing through the test sites will be intermittent and, while possibly causing some temporary annoyances, should have no health or welfare effects.

- Land Use and Aesthetics - The power plant requires only a small foundation area measuring 5.2m x 4.5m (17.0 ft x 14.7 ft). Operation of the power plants will not alter the activities at the candidate sites. Construction of auxiliary field test structures (e.g., additional parking areas), if required, will result in some forfeiture of current land use. The visual intrusion caused by the power plant will be similar to that expected from a roof-mounted air conditioning unit of a similar size or a small backyard utility building and is not considered a major impact. The fog plume emanating from the power plant during cold or humid weather may cause some minor visual degradation. The operation of heavy equipment during installation and decommissioning and the movement of visitors through the sites during power plant operation may cause some minor intermittent interference with normal facility use and general site aesthetics.

- Wildlife - Wildlife will not be significantly impacted by the field test since only a small area of land will be affected at each site and the power plant noise is not loud enough to interfere with communication or behavioral patterns except at extremely close range. Wildlife species inhabiting the urban and suburban environments of most test sites are generally acclimated to manmade disturbances and more sensitive species should occur only rarely, if at all. The power plant is sealed to prevent entry of small animals.

- Vegetation - Although some vegetation may be removed or trampled during site preparation and power plant installation, these impacts will be very local and insignificant. Vegetation adjacent to the power plant may be adversely affected by thermal exhausts. Site restoration activities will replace damaged vegetation.

- Health and Safety - The field testing of fuel cell power plants at on-site locations will not pose any unusual risks to the health and safety of site occupants or utility service personnel. The power plant has been designed according to selected safety codes and standards, is equipped with a built-in safety system and other safety features, and is being evaluated for certification by two nationally recognized testing laboratories. Because natural gas is used for fuel, the risk of an accident cannot be reduced to zero; however, the risk of an accident causing injury or death is extremely low and comparable to that expected from other gas fueled heating and cooling equipment. An accident involving gas leakage, explosion, or fire would endanger people in the vicinity of the power plant, particularly where plants are sited indoors. The entire field test operation is subject to all applicable DOE, OSHA, and other governmental health and safety regulations.

- Electromagnetic Interference (EMI) - Limited EMI testing has not revealed any problems with either radiated or conducted electromagnetic noise from the power plant inverter. Federal Communications Commission regulations prohibit the operation of an incidental radiation device if it causes harmful radiation. NASA-Lewis is taking the necessary steps to ensure that the power plants will not cause harmful radiation at the field test sites as a result of either radiated or conducted electromagnetic noise.

- Voltage Flicker - The operation of the fuel cell power plants will not result in the occurrence of voltage flicker at the test sites above the level of pretest flicker. The voltage characteristics of fuel cell power plant supplied electricity and utility supplied electricity are basically the same. Equipment that induces voltage flicker on utility systems will induce flicker on the fuel cell system and should be avoided. Equipment that is so sensitive to flicker that it requires special isolation from the conventional utility distribution system will probably require isolation from the fuel cell power system.

Although not extensively considered by the scope of this assessment, the commercial production and nationwide deployment of large numbers of fuel cell power plants will have important environmental repercussions. Displacement of conventional power plants by fuel cell power plants will lead to national and local improvements in air quality, water supply and quality, and ambient noise levels. Their higher energy efficiency will translate into substantial energy savings with accompanying economic and national security benefits. With the exception of possible effects on the platinum market, no impacts of unusually large magnitude are expected from the manufacture, transportation, and installation of power plants and components. The national fuel production system and its environmental impacts should not be measurably expanded or altered by fuel cell deployment. Fuel delivery will require creation of a delivery infrastructure and may increase public exposure to dangerous fuels because of the transport, unloading and storage of a variety of possible fuels in urban and suburban areas.

8.2 Assessment Conclusions

The 40 kW fuel cell power plant is quiet, nearly vibration free, has low air emission rates, and does not require connection to a water supply. It is constructed according to all relevant safety standards and has numerous built-in safety features. The environmental assessment of the proposed field test indicates that with proper siting the installation, operation, and decommission activities connected with the field test should have no major impacts on environmental quality or health and safety during normal power plant operation.

Since the scope and length of the field test is limited. and it is not accompanied by other actions at the test sites, no cumulative or long term impacts are expected exclusive of those caused by accidents. The risk of fatality or injury-causing accidents has been judged to be extremely remote. The risk can be further reduced by the installation of additional safety equipment. The field test will not result in any irreversible or irretrievable commitment of resources, other than financial resources, manpower, and power plant materials, since the power plants can be removed and the test sites restored at any time during the field test. No significant secondary construction or growth impacts are expected.

8.3 Recommended Guidelines for Site Selection

Preliminary plans are to install the fuel cell power plants in a variety of locations for this field test: (1) outside at ground level, (2) rooftop, and (3) indoors. At each test site, one particular installation location may have environmental and health/safety advantages over the others. For example, although the power plants will be constructed according to applicable codes and safety tested, for some test sites it may be prudent to install the preprototype units at outdoor ground level locations where the consequences of an accident, should one occur, are likely to be less severe. On the other hand, rooftop or indoor locations may be preferred at test sites when control of access to the power plant is a prime concern. Indoor sites may also be preferred for lessening aesthetic, noise, and fog plume impacts. Each test site should be evaluated to determine the siting location that minimizes impacts to safety, health, and the environment.

The low level of environmental impacts and health/safety risk produced by field testing the preprototype units may be further lowered by selecting certain types of test facilities. Test facilities not housing children, the elderly, or the infirm may be more desirable for initial field testing because of a lesser potential for safety impacts should a power plant accident occur. In addition, aesthetic, noise, and fog plume impacts may be more acceptable at some facilities than at others. For example, what little adverse impact is produced by the fuel cell power plant may be more acceptable at light industrial sites or certain commercial sites than at residential, hospital, or nursing home sites. While no candidate sites should be eliminated solely on the basis of environmental or health/safety impacts, extra care should be exercised when siting at facilities having special occupancy characteristics.

Fuel cell power plants appear to be ideally suited for areas of the country experiencing air quality or water supply problems. It would be worthwhile to site some of the power plants in these areas so that the effect of any unique operating variables on power plant performance can be evaluated.

A site selection guide has been compiled to assist utilities in selecting candidate sites which are most appropriate for meeting the field test objectives (Ref. 1). It is recommended that DOE and GRI require concurrent attention to the following environmental guidelines in order to ensure that these objectives are achieved with a minimum of environmental disruption. Environmental conditions which may be unique to individual test sites are discussed in these guidelines. Flexibility in site selection will allow utilities to avoid sites which increase environmental conflicts; thus, it is recommended that units not be installed at locations which are environmentally sensitive or which require major secondary construction. In general, noncompliance with one, or even a few of the guidelines should not result in the need for a site specific environmental assessment. However, unusual siting conditions or requirements may result in the need for additional permits and supporting environmental data.

8.3.1 Sites Recommended for Exclusion

Test sites having the following characteristics are recommended for exclusion from the field test because of their increased potential for causing adverse environmental and safety impacts. Achievement of field test objectives will not be retarded by avoidance of sites with these characteristics.

- Sites that discharge the wastewater from the power plant directly into natural waterways without prior treatment should be avoided. Only sites that can discharge the wastewater into a wastewater treatment system should be considered appropriate for the field test. This will free the utility from responsibilities involving the NPDES permitting process.

- A significant portion of national lands are managed by federal, state and local agencies to preserve wildlife habitats, areas of unique or unusual beauty, and recreational areas. Land management programs protect national and state parks, coastal zones, wetlands, wild and scenic rivers, and critical habitats for endangered species. Activities involving new construction or modification of existing buildings in such areas are strictly regulated and may require a separate environmental review. Since siting in protected areas is not important for the goals of this field test, these areas should be identified by the utility and rejected as inappropriate candidate sites.

- A National Register of historic properties is maintained by the Secretary of the Interior. Since the inclusion of these buildings and sites in the program is not necessary to achieve the objectives of the field test, fuel cell power plant sites which would negatively affect such properties should not be considered under this program.

- Major secondary construction includes activities not directly required for fuel cell unit installation, such as the construction of visitor facilities or major building modifications required to accommodate auxiliary equipment. Sites should be selected to avoid the necessity of this additional activity, but where this is not possible, efforts should be made to minimize the additional environmental impacts. This can be accomplished by environmentally sound construction procedures and attention to health and safety regulations and building codes.

- The quality of natural gas supplies at each site should be ascertained to ensure that power plant fuel specifications will be met. The power plants require pipeline or peak shaved gas delivered at a pressure of 4 to 14 inches of water. Quality criteria for both pipeline and peak shaved gas are defined by UTC (Ref. 2). Sites with gas supplies not meeting these criteria should be eliminated from field test consideration.

8.3.2 Recommended Communication with Regulatory Authorities

Communication with a variety of federal, state, and local regulatory authorities is recommended in order to obtain site information and ascertain permit requirements.

- Based on established siting requirements, it is highly probable that some of the fuel cell power plants will be located in areas of poor air quality which have been designated "non-attainment areas" by the EPA. Although the siting of new sources of pollution in such areas is strictly regulated by the governing regional air quality management district, the low air pollutant emissions from the fuel cell units will probably exempt them from any permitting requirements. Nevertheless, the local air quality management board should be consulted by the utility prior to installation of the fuel cell unit.

- Although the relatively pure quality of the discharged water will probably exempt the fuel cell units from any permits required by a wastewater treatment facility, permission to use a treatment system should be obtained from the local sanitation district.

- Local regulations pertaining to noise should be identified by the utility for each test site.

- Land use management authorities should be consulted to determine land use restrictions at or adjacent to candidate field test sites. While it is unlikely that fuel cell activities will affect endangered species, it is the responsibility of the Department of Energy to be aware of any sensitive or endangered wildlife or vegetation in the area and provide mitigation measures for their protection as necessary.

- As discussed in this document, it is the responsibility of the participating utility to comply with all local codes governing the installation and operation of the power plant at each individual site. These include, but are not limited to, construction permits, zoning laws, noise regulations, aesthetic requirements, solar rights, health and safety regulations, and any obligations arising from the use of local utilities and services.

8.3.3 Recommended Actions

The following actions are recommended at selected field test sites in order to minimize certain environmental impacts and safety hazards.

- Power plant installation should take advantage of existing noise attenuating structures or locations, i.e., isolated areas, existing walls, or rooftop locations. To minimize conflicts, special consideration should be given to noise-sensitive activities at or adjacent to the site, such as those expected at hospitals, libraries, schools or sleeping quarters. The necessity of constructing noise attenuation barriers will have to be ascertained for each siting situation.

- Gas and smoke detectors should be installed at indoor power plant locations to provide adequate warning of unsafe conditions.

- The exhaust hood and flue should be designed so that there is no back pressure on the power plant.

- Special provisions for site selection, access restriction, and evacuation may be desirable for test sites occupied by groups more prone to accident consequences, such as children, or the sick, disabled, or elderly.

- Installations at outdoor ground-level sites should be situated such that they and their fog plumes do not impair the visibility of traffic on adjacent streets, alleys, and other accessways.

- Equipment that is sensitive to the harmonic content of the incoming power should be carefully monitored to determine if additional filtering is required to maintain acceptable performance.

- Power plant installation and decommissioning procedures should be timed to minimize the disruption of test site activities, and occupants should be notified in advance of any possible disruptions.

- If desirable, the test sites should be restored to their original pretest condition.

- Utility personnel should be informed of the safety features and potential hazards of fuel cell power plants operating in a grid-connected manner.

- Precautions should be taken to ensure that test facilities can provide adequate structural support for the fuel cell power plants, particularly at rooftop locations.

These environmental guidelines have been compiled to assist utilities in selecting test sites in a manner which minimizes environmental conflicts. For the relatively few test sites required, compliance with these guidelines should not be difficult. Any unusual characteristics of a specific site should be evaluated by the utility in light of the goals of the program and with concern for any additional environmental impacts.

References

1. Gas Research Institute. Site Selection Guide for the 40 kW Fuel Cell Operational Feasibility Program, March 1980.

2. United Technologies Corporation, Power Systems Division. On-Site 40-Kilowatt Fuel Cell Power Plant Model Specification, September 1979.

APPENDIX A

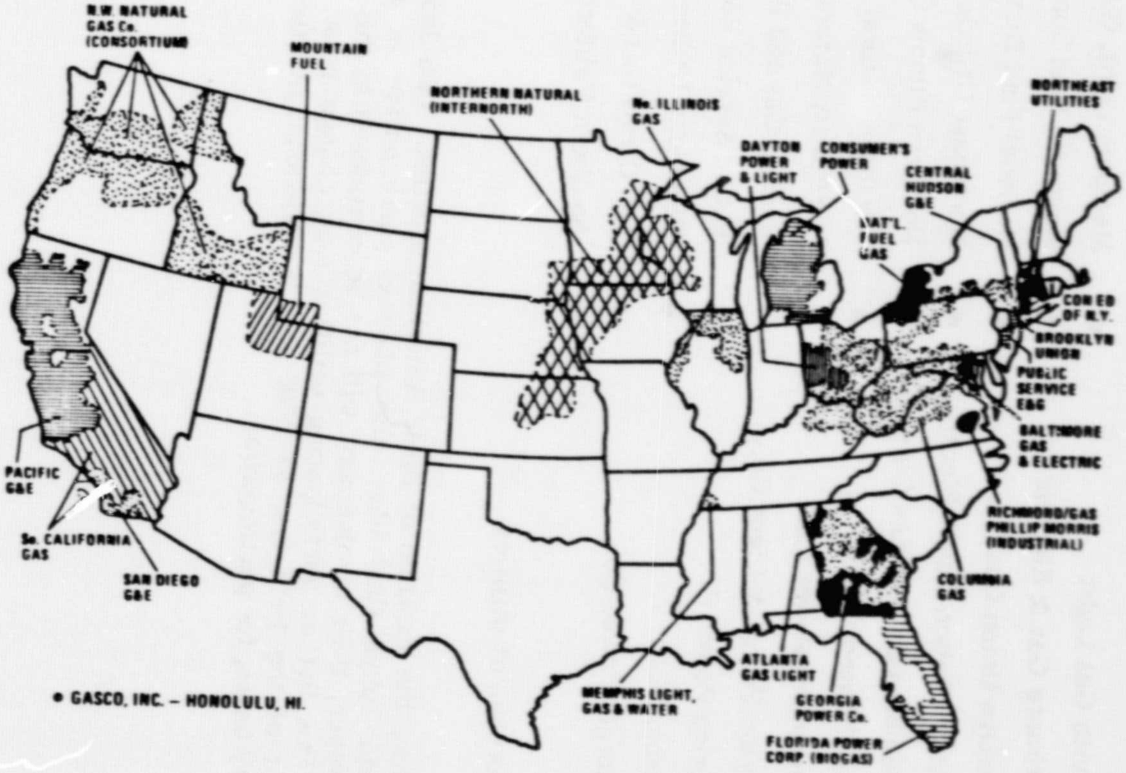
As of November 1981, the following utilities were either actively involved, or had scheduled involvement, in the site selection activities of the 40 kW fuel cell field test:

- Atlanta Gas Light
- Baltimore Gas & Electric
- Brooklyn Union Gas Co.
- Central Hudson Gas & Electric
- Columbia Gas Services Corp.
- Consolidated Edison
- Consumers Power Co.
- Dayton Power & Light Co.
- Florida Power Co.
- Gasco, Inc.
- Georgia Power Co.
- Memphis Light, Gas & Water
- Mountain Fuel Supply Co.
- National Fuel Distribution Co.
- Northeast Utilities
- Northern Illinois Gas Co.
- Northern Natural Gas Co.
- Northwest Natural Gas Co.*
- Pacific Gas and Electric Co.
- Public Service E&G*
- Richmond Utilites/Phillip Morris
- San Diego Gas & Electric
- Southern California Gas Co.

* Leading consortium of utilities

Figure A-1 shows the location of these American utilities. Two Japanese utilities (Osaka Gas and Tokyo Gas) have also planned participation in the field test operation; however, their involvement will not be considered in this environmental assessment. This list of participating utilities may change prior to the actual commencement of the field test as DOE selects additional utilities, and possibly several military bases, for participation.

Figure A-2. Location of American Utilities Participating in the Field Test



GLOSSARY

AGA	American Gas Association
AMCA	Air Moving and Conditioning Association
ANSI	American National Standards Institute
ARI	Air Conditioning and Refrigeration Institute
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
ASME	American Society of Mechanical Engineers
CEQ	Council on Environmental Quality
COP	coefficient of performance
DOE	Department of Energy
EMI	electromagnetic interference
EIS	Environmental Impact Statement
EPA	Environmental Protection Agency
FCC	Federal Communications Commission
FEP	fluorinated ethylene-propylene
FWPCA	Federal Water Pollution Control Act
GRI	Gas Research Institute
IHR	inhalation hazard rating
LAER	lowest achievable emission rate
LF	load factor
LHV	lower heating value
LPG	liquid petroleum gas
NAAQS	National Ambient Air Quality Standards
NASA	National Aeronautics and Space Administration
NEPA	National Environmental Policy Act
NIOSH	National Institute of Occupational Safety and Health
NPDES	National Pollutant Discharge Elimination System
OSHA	Occupational Safety and Health Administration
OS/IES	on-site/integrated energy system

PFA	perfluoroalkoxy
PSD	prevention of significant deterioration
PSI	pollutant standard index
RMS	root mean square
RTECS	Registry of Toxic Effects of Chemical Substances
SCAQMD	South Coast Air Quality Management District
SMSA	Standard Metropolitan Statistical Area
SRN	sound rating number
TARGET	Team to Advance Research for Gas Energy Transformation
THC	total hydrocarbons
TMS	thermal management system
TSCA	Toxic Substances Control Act
TWA	time weighted average
UL	Underwriters' Laboratories
UPS	uninterruptable power supply
UTC	United Technologies Corporation